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City of Santa Cruz
Alternative Water Supply Study

EXECUTIVE SUMMARY

November 2000

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CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY STUDY

EXECUTIVE SUMMARY

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OVERVIEW

In the past the City has managed to provide water to its service area by combination of prudent supply source management, efficient operation, and conservation efforts of consumers. In recent years, however, it has become increasingly difficult to meet the water demand, particularly in drought conditions. As the City continues to develop, the demand for water will exceed the amount of supply available from the existing sources, even in non-drought years. Additional water supply sources are needed to maintain service to customers.

Integrated Water Plan

It is the City's intent to develop an overall water supply strategy which includes not only new water sources, but also strategies to reduce demand. The overall water supply strategy — the Integrated Water Plan (IWP)— will begin with confirmation and agreement on the future water demands and the safe yield of the supply system. These two elements establish the basis for the plan. When completed, the IWP will include three elements:

- Reduced demand by conservation in all years.
- Reduced demand by usage curtailment in drought years.
- New sources of supply.

The IWP will compare and contrast new water supply alternatives to various growth and conservation/curtailment concepts. The objective of the IWP is to establish an overall water supply strategy which combines new water supplies and demand reduction strategies.

Alternative Water Supply Study

The objective of this study is to identify water supply alternatives to meet the City's current and future water supply needs. The water supply alternatives evaluated in this study include groundwater and surface water.

This study considers alternatives for new supply only; alternatives for conservation and curtailment are being studied separately by the City and are not described or considered in this document.

AVAILABLE WATER SUPPLY

The City's existing water supply system was analyzed to establish the amount of supply available. The analysis included:

- A review of historic rainfall and surface water hydrology data.
- An estimate of the available supply from the City's surface and groundwater sources.
- An evaluation of the monthly and seasonal supply conditions.

The available supply was compared to expected demands to quantify supply deficits during short-term, critical dry periods. Hydrologic conditions that occurred during 1976-77 were used to simulate expected conditions during a critical dry period. This period was selected because it represents an extreme drought condition from the past that will likely occur again in the future. It is during drought conditions that the City's existing supply is – and will continue to be – most vulnerable.

Analysis Summary

The principal findings of the water supply evaluation are as follows:

- **Projected Demands Exceed the Available Supply.** The amount of supply that can be produced from the City's sources is limited, and is strongly linked to precipitation and runoff. During drought conditions the demand far exceeds available supply. Even if precipitation is average or above average, and if conservation programs are implemented and successful, it is likely that the City will begin to face regular peak season supply shortfalls as demands increase in the future.
- **Storage Capacity is Very Limited.** The City's only surface water storage reservoir, Loch Lomond, is undersized. For example, if a prolonged drought similar to the 1976-77 hydrologic period were to occur under the current demand conditions, the estimated supply contribution from the reservoir is approximately 790 MG. The projected demand during the two-year period is approximately 9000 MG, so the reservoir would contribute only about 9 percent of the demand.
- **Prolonged Drought Conditions are Critical.** Lacking the capability to store large volumes of water the City needs new sustainable water supplies. This is because during drought conditions there is a limited amount of "flowing" supply in the City's surface water sources. If drought conditions persist for two or more years, the effect is even more pronounced, particularly during the high-demand summer months. Table ES.1 shows the projected shortfalls during the critical dry period.

Table ES.1 Estimated Monthly and Seasonal Deficits During the Critical Drought Year[1,2] Alternative Water Supply Study City of Santa Cruz

Deficit Condition	Current Demand	2020 Demand	Buildout Demand
Maximum Monthly Deficit[3]	285	395	440
Maximum Seasonal Deficit[4]	1,245	1,800	2,070
Maximum Annual Deficit	1,400	2,125	2,490
Total Drought Deficit[5]	2,605	3,970	4,760
Total Drought Duration[6]	30 months	30 months	31 months

Notes:

(1) Deficits are calculated during the second year of the critical two-year drought period unless otherwise specified. Deficits are calculated based on projected demand, with no adjustment for potential demand reduction by usage curtailment programs.
(2) All values in million gallons (MG) unless otherwise specified.
(3) Maximum month deficit occurs in July of the second drought year.
(4) Maximum seasonal deficit calculated by summing monthly deficits during May through October.
(5) Total drought deficit calculated by summing monthly deficits for the entire drought duration.
(6) Total drought duration includes months in which supply deficits are projected to occur, both before and after the start of the calendar two-year drought period. Deficits are estimated by comparison of projected demand vs. expected available supply (yield). For buildout, demand conditions projected drought duration increases by one month due to additional projected shortfalls in the months preceding the two-year calendar drought period.

WATER SUPPLY ALTERNATIVES

Ten potential water supply alternatives were identified for evaluation:

- Brackish groundwater supply from wells in the San Lorenzo River Alluvial Plain near the mouth of the river.

- Fresh groundwater supply from wells in the San Lorenzo Alluvial Plain.

- Maximized use of existing sources and storage in Loch Lomond Reservoir. This alternative includes increased capture and/or storage of surface water from existing north coast and San Lorenzo River supplies, in conjunction with optimized use of existing diversions.

- Groundwater supply near the Wilder Ranch gravel quarry.

- Sea water desalination.
- Conjunctive use with Soquel Creek Water District.
- Groundwater supply from the Purisima Aquifer near the Beltz wells.
- Groundwater supply from the Santa Margarita Aquifer.
- Wastewater reclamation.
- Reservoir storage in the Olympia Quarry.

Alternative Screening

A basic premise of water supply planning is that reliable and sustainable sources of supply are preferable, and are generally considered to be more viable. For example, a supply alternative may produce water during the first drought year, but not the second or subsequent years. In this example the viability (benefit)of the supply alternative is diminished compared to other alternatives that can provide supply in the second drought year when projected shortfalls are most critical. Viability of supply is particularly important for water supply systems like the City's because drought conditions can significantly impact the amount of available supply and reliability of its sources.

A corollary premise of supply planning is that it must be feasible to implement a supply alternative. For example, it may be difficult to implement a supply alternative due to high cost, environmental constraints, or other public acceptance issues, even if the alternative is demonstrated to be reliable and have ample supply.

With these two basic premises in mind, a screening evaluation was completed for each of the ten supply alternatives. Table ES.2 summarizes the results of the evaluation. As shown in the table, of the ten alternatives considered, five are considered to be potentially viable. The five alternatives are represented on Figure ES.1.

Engineering Evaluation Summary

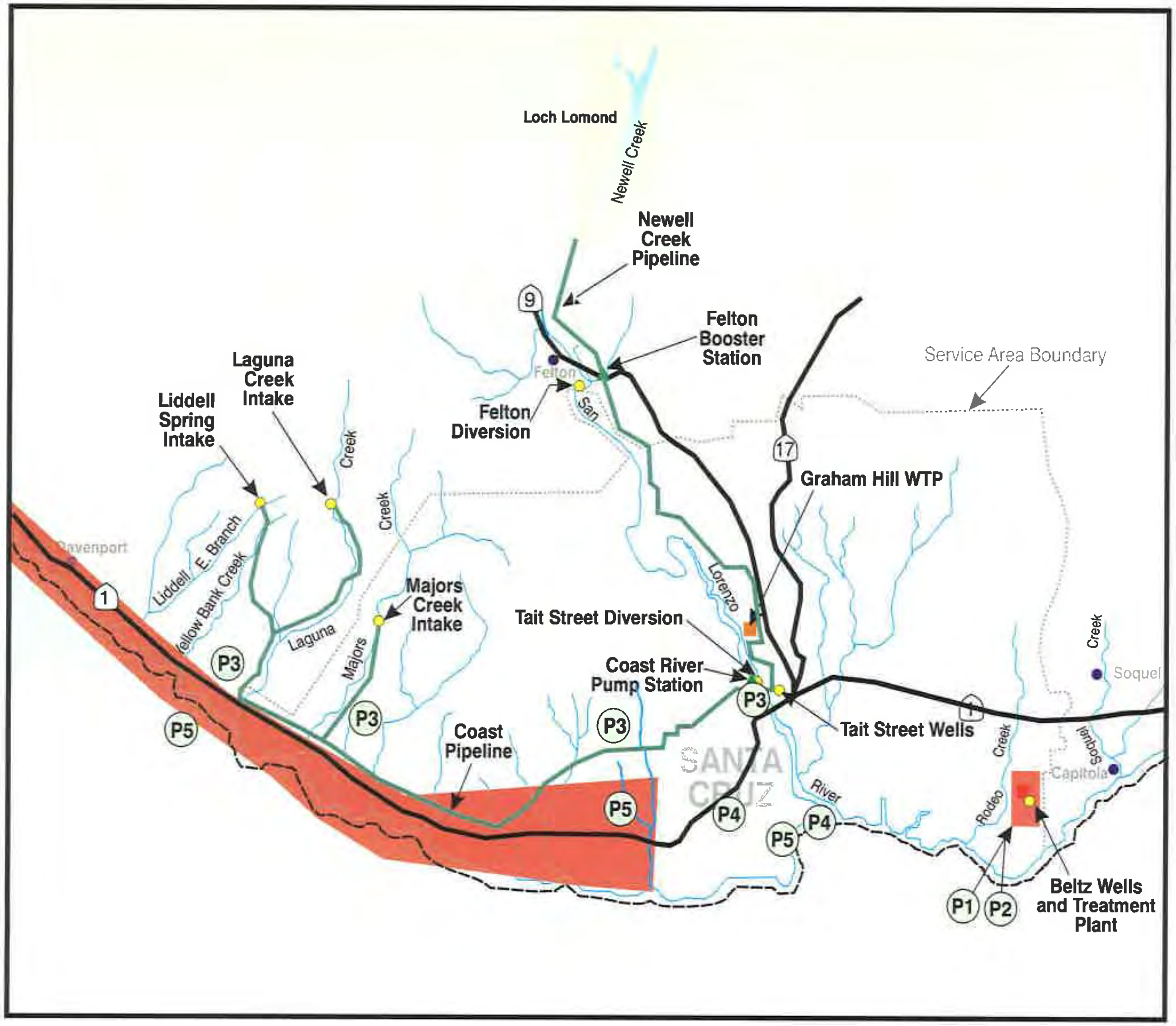
A conceptual level engineering analysis was completed for each of the five potentially viable alternatives in order to identify infrastructure requirements, costs, and associated implementation issues. Table ES.3 presents a summary comparison of the project alternatives.

As shown in the table each alternative has benefits and drawbacks relative to project cost, availability and reliability of supply, and ease of implementation. These elements will provide the basis for a comprehensive ranking and prioritization of supply strategies as the City implements the IWP.

Table ES.2 Preliminary Screening of Supply Alternatives
Alternative Water Supply Study
City of Santa Cruz

Alternative	Preliminary Screening[1]	Comment	Considered for Further Evaluation?
Groundwater from Santa Margarita Aquifer near Wilder Ranch	Viability is Questionable	• Existing users present institutional constraints • Quantity limited; uncertain reliability during drought • Supply not reliable or sustainable during drought	Yes [3]
Fresh Groundwater from the San Lorenzo Alluvium	Not Viable	• Quantity limited • Conflict with water rights at Tait Street • Supply not reliable or sustainable during drought	No
Brackish Groundwater from the San Lorenzo Alluvium	Not Viable	• Fatal flaw conflict with existing water rights	No
Groundwater Supply from Purisma Aquifer near Beltz/ Live Oak Area	Viability is Questionable	• Existing users present institutional constraints • Quantity uncertain • Supply not reliable or sustainable during drought	Yes [2]
Groundwater Supply from Santa Margarita Aquifer Near Beltz/Live Oak Area	Viability is Questionable	• Quantity uncertain • Supply not reliable or sustainable during drought	Yes [2]
Conjunctive use with Soquel Creek Water District	Not Viable	• Fatal flaw water rights constraint • Limited available surface water supplies	No
Maximized Use of Existing sources and storage in Loch Lomond Reservoir	Potentially Viable	• Benefit in drought and non-drought years • Improves system reliability and operation	Yes
Desalination	Potentially Viable	• Reliable and sustainable supply • Improved redundancy of supply	Yes
Wastewater Reclamation	Potentially Viable	• Net supply gain may be limited and cost high	Yes
Reservoir Storage in Olympia Quarry	Not Viable	• Numerous technical and institution issues to overcome	No

Notes:
(1) Preliminary "fatal flaw" screening based on ability of supply source to provide reliable and sustainable supply during drought. Includes also consideration of implementation issues (e.g., potential conflicts with existing water rights, potential conflicts with existing users (for groundwater), etc.)
(2) Based on discussion of alternatives with Santa Cruz City Council, March 15, 2000. Several groundwater alternatives that are considered to be of questionable viability based on preliminary screening have been included for further evaluation because groundwater supply may be more feasible if combined with other supply or demand offset strategies; to be determined as part of the City's proposed Integrated Water Plan.
(3) Due to limited supply and potential conflicts with existing users, this supply alternative is considered to be most viable only if an alternative supply can be provided to existing agricultural users (i.e., reclaimed water for irrigation in exchange for City's use of groundwater; see discussion under Project P5).



Locations of Water Supply Alternatives[1]

- (P1) Groundwater Supply
  - Purisima Aquifer Near Beltz/Live Oak
- (P2) Groundwater Supply
  - Santa Margarita Aquifer Near Beltz/Live Oak
- (P3) Optimized Use of Existing Sources
- (P4) Desalination
- (P5) Reclamation

(1) Locations are representative only. Exact locations of project components have not been established.

(2) Projects P3, P4, and P5 include multiple components.

Shaded area indicates general region/area of application for project alternative.

Figure ES-1
WATER SUPPLY ALTERNATIVES
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

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Table ES.3 Project Alternative Summary
Alternative Water Supply Study
City of Santa Cruz

Alterna-tive Number	Project Alternative	General Design Assumptions	Infrastructure Assumptions	Est. New Supply (MG)	Total Estimated Project Cost ($Million)	Amortized Capital Cost ($/MG)	Annual O&M Cost ($/MG)	Total Annualized Cost ($/MG)	Summary of Issues
P1	Groundwater supply from Purisima Aquifer near Beltz/Live Oak	• New wells at existing Beltz Well Site Nos. 1 and 4. • 50 to160 MG/yr each from shallow and deep zones	• 1 to 3 new wells at 200 to 400 feet deep. • 1,500 feet 6-inch pipe (raw water to treatment) • 3,300 feet 8-inch pipe (raw water to treatment) • 7,200 feet 12- to 16-inch pipe (distribution system) • Treatment capacity upgrades at 1 mgd for iron and manganese removal	100[(1)]	8.3	8,500	1,800	10,300	• Limited supply • Reliability of ground-water is questionable • Potential conflict with existing users
P2	Groundwater supply from Santa Margarita Aquifer near Beltz/Live Oak	• New wells at existing Beltz Well Site Nos. 1 and 4	• 1 to 3 new wells at 800 to 1,000 feet deep • Treatment for iron and manganese and distribution system upgrades[(2)]	100	1.0	1,100	300	1,400	• Limited supply • Reliability of ground-water is questionable.
P3	Maximized use of existing sources and storage in Loch Lomond Reservoir	• North Coast supply system upgrades for 20 cfs (12 mgd).	• 77,400 feet of 14-to 36-inch pipe (new North Coast supply pipeline) • Increased capacity of coast/river pump station from 20 to 30 cfs • 5,500 feet of 18-inch pipeline (pump station to Graham Hill WTP) • Pressure filtration at pump station at 30 cfs	600 [(3)]	38.9	6,600[(3)]	500[(3)]	7,100	• Improved operation and reliability but additional supply not sufficient to meet needs • Rigorous and lengthy permitting and environmental impact evaluation process
P4	Desalination	• Unlimited supply available. • Facilities located north/northwest end of City near industrial park. • Use abandoned wastewater outfall for new intake. • Brine disposal in existing wastewater outfall.	• Upgrades to abandoned WW outfall for new intake • New intake pumps • 10,000 feet 36-inch pipe (raw water to treatment) • 16,500 feet 24-inch pipe (treatment water to system) • 10,000 feet 36-inch pipe (brine to WW outfall) • RO treatment facilities[(5)] • Ancillary support systems for RO[(5)]	1.5 to 6[(6)]	18 - 42.1[(7)]	2,000 - 3,300[(7)]	2,300 - 3,100[(7)]	4,300 - 6,400[(7)]	• Rigorous and lengthy permitting and environmental impact evaluation process • Site for treatment facility not confirmed

Table ES.3 Project Alternative Summary (Continued)
Alternative Water Supply Study
City of Santa Cruz

Alternative Number	Project Alternative	General Design Assumptions	Infrastructure Assumptions	Est. New Supply (MG)	Total Estimated Project Cost ($Million)	Amortized Capital Cost ($/MG)	Annual O&M Cost ($/MG)	Total Annualized Cost ($/MG)	Summary of Issues
P5A and P5B	Reclamation In-City and North Coast	• 170 to 230 MG/yr demand offset for in-city application(4) • 500 to 700 MG/yr available supply for North Coast agriculture application(4)	• New filtration and disinfection facilities at 10 mgd • 45,000 feet 18-inch pipe to North Coast farms • 20,000 feet 4-inch pipe to UCSC. • 60,000 feet of 4-to 12-inch pipe to other in-city users • Pump station at 10 mgd, hp varies depending on delivery destination	170 to 230 (in-city) 500 to 700 (Coast Ag)(4)	49.9	5,500	900	6,400	• Water exchange with farmers is most viable project; would need contractual entitlements to groundwater • Site for treatment facility not confirmed
P5B	Reclamation North Coast Only	• 500 to 700 MG/yr available supply for North Coast agriculture application(4)	• New filtration and disinfection facilities at 7 mgd • 45,000 feet 18-inch pipe to North Coast farms • Pump station at 7 mgd, hp varies depending on delivery destination	500 to 700 (Coast Ag)(4)	28.4	4,100	700	4,800	• Water exchange with farmers is most viable project; would need contractual entitlements to groundwater • Site for treatment facility not confirmed

Notes:
(1) Assumes recent estimates of Purisima Aquifer yield are accurate and that water is available even though there are areas of localized low water levels. Estimate also assumes that existing users will not significantly increase pumpage in future from upper zone, and that lower zone can sustain production.
(2) Treatment and distribution system upgrades constructed as part of P1 would be sufficient for the required capacity increase from P2.
(3) Supply available depends on hydrologic conditions; 150 MG/yr in normal years and 600 MG/yr in drought years. Cost estimates assume that upgraded system would provide approximately 600 MG/yr during drought.
(4) In-city applications for outdoor irrigation of parks, school yards, UCSC, golf courses. North Coast application only viable if irrigators agree to groundwater exchange (i.e., groundwater from Santa Margarita Aquifer along North Coast).
(5) RO treatment system includes pretreatment and RO membranes. Ancillary facilities include building, yard piping, chemical systems, pumps, etc.,
(6) The amount of supply provided by desalination would depend on several factors, including supply available from other sources and demand offsets from conservation and curtailment. A range of 1.5 to 6 mgd was assumed in order to bracket a range of expected costs.
(7) Capital cost range for 1.5 to 6 mgd, respectively. Unit capital and unit O&M costs ($/MG) for 6 mgd to 1.5 mgd, respectively (i.e., unit costs are lower for higher capacity facilities).

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City of Santa Cruz

Preliminary Investigation of
Water Supply Alternatives

TECHNICAL MEMORANDUM NO.1
PROJECT CONCEPT DEVELOPMENT

March 1998

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CITY OF SANTA CRUZ
PRELIMINARY INVESTIGATION OF WATER SUPPLY ALTERNATIVES

TECHNICAL MEMORANDUM NO. 1
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INTRODUCTION

The City of Santa Cruz derives its water supply primarily from surface water sources. As such, the City's water supply is linked to runoff generated by rainfall. In "normal" years (i.e., years of average or above average rainfall) the yield from the surface water sources is sufficient to meet water demands of the City. This is due in large part to the fact that rainfall replenishes storage in Loch Lomond Reservoir. However, the storage volume in Loch Lomond is relatively under-sized compared to the City's service area demands. Consequently, in dry or drought years the yield from the surface sources is decreased, and the water available to replenish the storage in Loch Lomond is reduced.

Historically, the City has managed to meet demands even in drought years with a combination of prudent management of its sources, efficient operation of the supply system, and the conservation efforts of its consumers. However, the City's current demand exceeds the estimated available yield from its sources during drought conditions. In the future it will be increasingly difficult to meet additional demands during drought conditions. Additional water supply sources are needed to maintain service to customers during dry or drought years.

This study will complete a comprehensive analysis of alternatives to meet the current and future water supply needs of the City. The emphasis of this study is to identify operational strategies to enhance the yield from the City's existing sources and identify additional sources that can reliably supplement the City's water supply during prolonged drought conditions. This technical memorandum (TM) will present the preliminary alternatives identified for study. The preliminary analysis in this document will form the basis for more detailed analysis of alternatives to be completed in subsequent TMs.

BACKGROUND

The City has previously conducted two water supply studies:

- City of Santa Cruz Water Department Water Master Plan, Leedshill-Herkenhoff, Inc., April 1989.
- City of Santa Cruz Water Supply Alternatives Study, Camp Dresser & McKee Inc., January 1994.

The focus of each study was to identify how the City could meet its demands during the most severe hydrologic period (i.e., drought conditions). The Master Plan (1989) identified potential alternatives for further study based on the critical drought period which occurred in 1976-77. The

Alternatives Study (1994) investigated numerous water supply alternatives to meet the City's needs based on the critical 1976-77 drought and the longer 1987-91 drought conditions.

Based on findings of the Alternatives Study (1994), in May 1995 the City began preliminary engineering studies to investigate the recommended most feasible alternative, a new water supply from new brackish coastal groundwater wells located north of the City. In May 1997 the City Council elected to discontinue the preliminary engineering studies for the coastal brackish well project. The City is now initiating this study to identify other new alternative water supply sources/projects that are viable.

Six potential water supply alternatives have been identified for study:

- Brackish groundwater supply (located in proximity to the mouth of the San Lorenzo River).
- Fresh groundwater supply from wells located in the San Lorenzo Alluvial Plain.
- Maximized use of existing sources and storage in Loch Lomond Reservoir. This alternative includes increased capture and/or storage of surface water from existing north coast and San Lorenzo River supplies, in conjunction with optimized use of existing diversions. Four variations of alternative surface water supplies have been identified for consideration:
  - Increased capture and pretreatment of north coastal supplies in lieu of treatment of Newell Creek and San Lorenzo River water.
  - Increased capture of north coastal supplies for diversion to storage in Loch Lomond Reservoir.
  - Increased capture and pretreatment of San Lorenzo River water.
  - Increased capture of San Lorenzo River water with diversion to storage in Loch Lomond Reservoir.
- Groundwater recharge/extraction near the Wilder Ranch gravel quarry.
- Sea water desalination.
- Conjunctive use with Soquel Creek Water District.

The purpose of this TM is to identify project elements and concepts for each of six alternatives. The alternatives will be reviewed with the City and with the public before more detailed evaluation. Some of the alternatives may be eliminated from further study or modified based on available technical information or project feasibility. In addition, other alternatives may be substituted or added based on information gathered during the course of this evaluation.

WATER DEMANDS

The City is currently updating the future water demand projections. Preliminary demand estimates range from 5,050 million gallons per year (MG/yr) to 6,024 MG/yr for 2005 and 2020, respectively (Maddaus, et. al., 1997). This study will consider supply alternatives to meet a range of demand scenarios, as identified from Maddaus, et.al. Demand scenarios will be adjusted to account for conservation measures as follows:

(Note: Subsequent to completion of this document the future demand projections were modified; TM2 - Water Supply).

- Permanent water conservation to reflect building code requirements for new construction (e.g., low flow residential plumbing devices).
- Long term adjustment to reflect implementation of permanent, proactive conservation programs by the City (e.g., rebate programs for retrofit installation of low flow plumbing devices in existing buildings or homes). Long term conservation adjustments are being evaluated and developed by the City in a separate study (Barakat, et.al. 1998).
- Drought demand reduction from water use restrictions during peak summertime demand periods.

SUMMARY OF EXISTING SYSTEM

The City obtains water from several ground and surface water sources, as shown schematically in Figure 1.1. For ease of understanding the complex water supply system, the sources are grouped as follows:

- **North Coast.** This system is comprised of surface water diversions from three coastal streams (Reggiardo Creek, Laguna Creek, and Majors Creek) and one natural spring (Liddell Spring) located approximately six to eight miles northwest of Santa Cruz. Water from these diversions flows by gravity through the Coast Pipeline to the Coast Pump Station. The water is pumped from the Coast Pump Station for treatment at the Graham Hill Water Treatment Plant (GHWTP).
- **San Lorenzo River.** This system is comprised of two surface water diversions: one is located near the community of Felton (Felton Diversion) and the second is near Tait Street in Santa Cruz (Tait Street Diversion). Three shallow groundwater wells located adjacent to the river at Tait Street are included in this system. Water from the Tait Street Diversion and wells is pumped to the GHWTP for treatment. Water from the Felton Diversion is pumped through the Newell Creek Pipeline to Loch Lomond Reservoir.
- **Newell Creek/Loch Lomond Reservoir.** Loch Lomond is the only major reservoir in the San Lorenzo River watershed. It receives water from Newell Creek and Felton Diversion

Source	Period	Maximum Diversion Rate (cfs)	Fish Flow Require-ments (cfs)	Annual Diversion Limit (MG/year)
North Coast[1]	Year-round	No limit	None	None
San Lorenzo River				
Tait Street Diversion and Wells	Year-round	12.2	None	None[3]
Felton Diversion to Loch Lomond Reservoir	September	7.8	10	977
	October	20.0	25	
	November-May	20.0	20	
	June-August	--[2]	--	
Loch Lomond Reservoir on Newell Creek				
Collection	September-June	No limit	--	1,825
Withdrawal	Year-round	--	1	1042

(1) Water rights for City of Santa Cruz North Coast Sources are pre-1914 rights with all downstream rights purchased by City; therefore, City may divert up to the full natural flow of each stream.

(2) Not specified for indicated time period.

(3) Although there is no prescribed annual diversion limit, the actual available diversion is constrained to approximately 1,600-2,200 MG/year due to seasonal low flows and high turbidity.

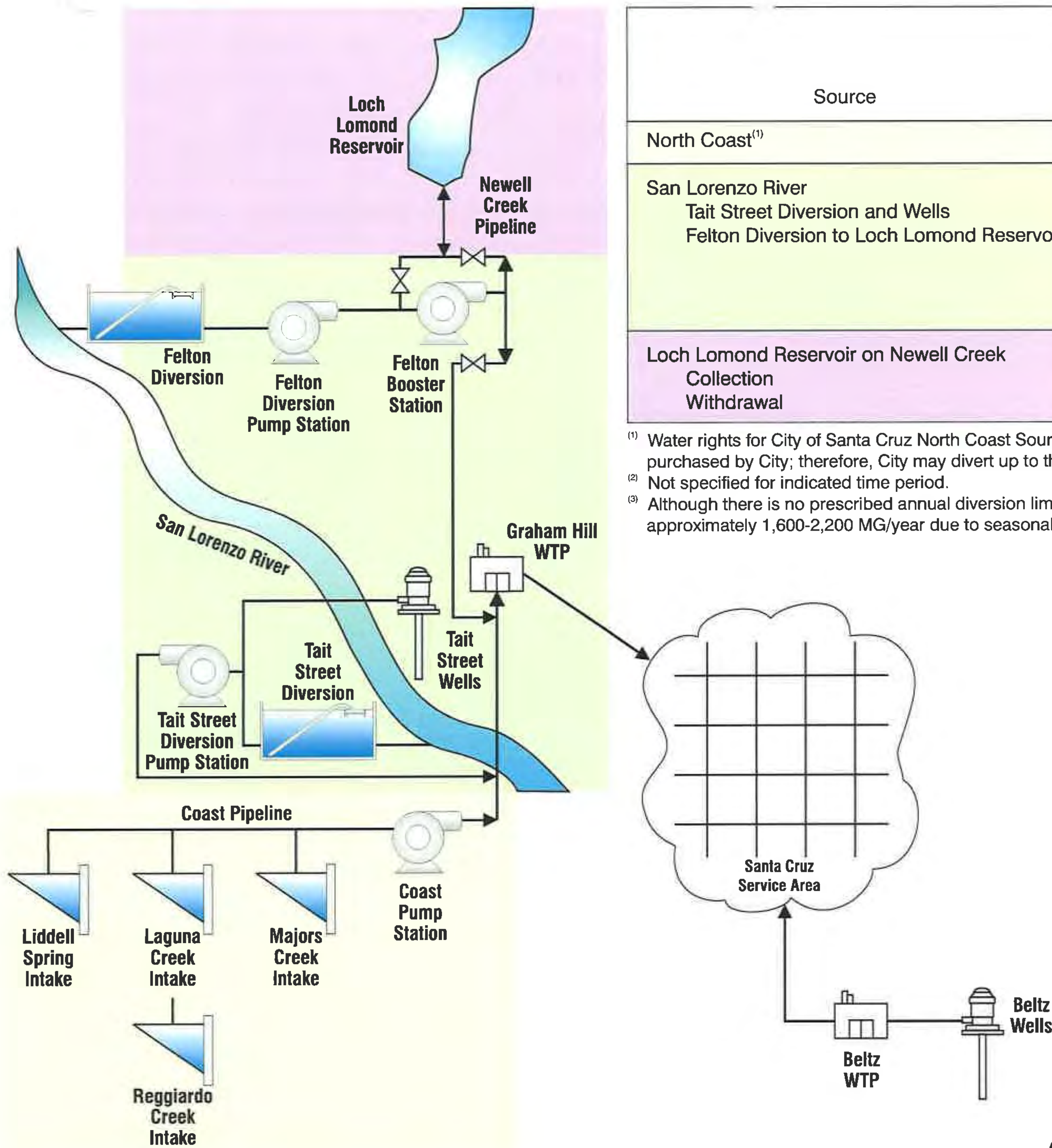

Figure 1.1
SANTA CRUZ
WATER SUPPLY SYSTEM
CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY PROJECT

SC1000RF3.CDR

on the San Lorenzo River. The reservoir has a total storage capacity of 2,810 MG and a useable volume of approximately 2,600 MG. The unusable volume includes water below the lowest outlet and water reserved by agreement for the San Lorenzo Valley Water District.

- **Beltz Wells.** This system includes four groundwater wells. Water from the wells is treated at the source to remove iron and manganese prior to delivery to the distribution system.

With the exception of the Beltz Wells, each source has associated water rights which prescribe diversion limits and use restrictions. The allowable seasonal and annual diversion limits and use restrictions are summarized on Figure 1.1. In addition to the limits and restrictions, the water rights dictate that the water from the Felton Diversion on the San Lorenzo River must be diverted to Loch Lomond Reservoir. The water rights associated with the other sources specify use within the City's Service Area Boundary only.

SAFE YIELD

Each of the City's supply sources has a theoretical "safe yield". The annual safe yield is the amount of water that can be reliably provided in one year during the most severe drought conditions. Previous reports have estimated the safe yield of the City's supply system for two drought conditions: the short-term (2 year) critically dry period of 1976 and 1977 and the extended dry period (5 years) of 1987 through 1991. The range of safe yield from these studies is approximately 3,500 to 3,900 MG/yr for the short-term and long-term drought periods, respectively. These yield estimates are based on review of historical precipitation records and stream flow data, are adjusted to reflect operational characteristics of the supply system (i.e., pumping capacity or treatment limitations, hydraulic constraints, etc.) and seasonal use limitations as prescribed by water rights.

The range of estimates illustrates that drought conditions can impact safe yield differently depending on the severity and duration. The measurable impact of drought conditions on the City's water supply is a function of the type of source (i.e., ground or surface water). The City's sources can be broadly categorized based on expected performance during a drought:

- **Minimal Impact: Beltz Wells.** Groundwater sources typically are minimally affected by drought, particularly if the drought is of short duration. This is because underground storage has less direct correlation to rainfall/runoff compared to surface sources. There is no indication that the yield of the wells was significantly diminished for either the critical 1976-77 or the prolonged 1987-91 droughts.

- **Variable Impact: Loch Lomond Reservoir.** Loch Lomond is intended primarily for storage. During the high demand periods in the summer the reservoir storage is used to supplement the available supply from other sources. During fall, winter and spring -- when demands are reduced -- it is preferable to use water from the reservoir only if it is full or nearly full, and if rainfall during these months has been "normal." Operation of the reservoir in this manner preserves the storage so that it can be used to supplement the other sources during periods of high demand or drought. The amount of storage depletion that actually occurs during periods of high demand or drought -- as the stored water is used to help meet system demands -- is variable, and depends on the available yield from the City's other sources.

- **Extreme Impact: San Lorenzo River, North Coast Diversions, and Newell Creek.** The yield from these surface water sources is directly linked to rainfall and runoff, and therefore is significantly impacted by the severity and duration of a drought. A drought impacts a surfacewater supply in two ways: 1) by reducing the rainfall that enters the water supply directly as runoff, and; 2) by diminishing the subsurface groundwater inflow (baseflow) which contributes to the source throughout the year.

This study will model the expected drought performance of the system (i.e., the expected safe yield). Yield estimates will be developed based on analysis of historical hydrologic conditions, taking into account seasonal variations in supply and system operational characteristics. The projected future water supply shortfall will be derived from comparison of the yield estimates to the projected demand, (Maddaus, et.al., 1998). Projected demand estimates will be adjusted to account for permanent and drought demand conservation and use restrictions as discussed in Section 3.

WATER SUPPLY ALTERNATIVES

The six water supply alternatives to be considered in this study were outlined in Section 2. These alternatives were developed jointly with City staff with consideration of information and findings of the previous studies. Each of six alternatives is described in the following paragraphs. The discussion includes:

- Brief summary of the alternative.
- Factors that may influence the implementation and/or feasibility.
- Conceptual infrastructure improvements required to develop the supply.

Environmental and Regulatory Considerations

Each of the water supply alternatives under study will include new facilities and infrastructure (e.g., pipelines, pump stations, etc.). A primary emphasis of this study is to identify environmental, regulatory, and permit issues related to implementation of the water supply facilities and infrastructure associated with the alternatives.

Potential environmental issues can be broadly summarized as follows:

- Need to maintain reasonable in stream flows to protect fisheries, riparian habitat, and/or public trust values.

- Need to avoid or mitigate potential impact to sensitive species or their habitat.
- Need to avoid or mitigate potential impact to cultural resources.
- Need to negate the potential for growth inducement.

The potential for growth inducement related to the supplemental water supplies will be addressed as part of this study. Recognizing the need to negate potential growth inducement, the alternatives will provide a supplemental water supply only as necessary to meet current and projected future supply deficits during drought conditions.

Regulatory and permit requirements associated with facilities construction and operation can be broadly summarized as follows:

- **Section 404 Permit under the Federal Clean Water Act.** Section 404 of the federal Clean Water Act requires the U.S. Army Corps of Engineers (Corps) to regulate discharges of dredged or fill material in waters of the United States, including wetlands. Discharges of dredged or fill material, including placement of structures, into waters of the United States, generally require a permit from the Corps. The Corps may either issue individual permits on a case-by-case basis or general permits on a program level. Nationwide permits are a type of general permit that are issued for particular fill activities.

- **Federal and State Endangered Species Acts.** Section 9 of the federal Endangered Species Act (ESA) prohibits the "taking" of species listed by the U.S. Fish and Wildlife Service (USFWS) as threatened or endangered. As defined in the ESA, "taking" means: ". . to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct." The term "take" would also apply to the disruption of habitat considered critical to protected species. In recognition that "take" cannot always be avoided, Sections 7 and 10(a) of the ESA include provisions for takes that are incidental to otherwise lawful activities.

  The state ESA prohibits the taking, importation, or sale of state-listed species. The state ESA requires state lead agencies, as defined by the California Environmental Quality Act, to consult with the California Department of Fish and Game (DFG) on projects with potential impacts on state-listed species. Section 2081 of the California Fish and Game Code authorizes DFG to issue permits or enter into memoranda of understanding for takes of state-listed species under certain circumstances.

- **Section 402 National Pollution Discharge Elimination System (NPDES) Permit.** The federal Clean Water Act authorizes states to issue NPDES permits for discharges to surface waters, excluding those regulated by the Corps under Section 404. If a facility or activity will discharge waste (including stormwater runoff for certain industrial or construction activities) to surface water, an NPDES permit must be obtained from the Regional Water Quality Control Board. An NPDES permit would be required for brine discharge or for construction involving more than 5 acres. In addition, any discharge of brine into the Monterey Bay National Marine Sanctuary would require review of permit conditions by the National Oceanic and Atmospheric Administration.

- **Air Districts Authority to Construct and Permit to Operate.** Pursuant to the federal Clean Air Act, air districts issue permits to ensure that emissions (including fugitive dust emissions) from temporary or mobile facilities or equipment, or facilities and equipment considered a stationary source (e.g., building, structure, installation) do not interfere with the attainment and maintenance of ambient air quality standards.

- **Streambed Alteration Agreement under Sections 1600-1607 of California Fish and Game Code.** Sections 1601-1607 of the Fish and Game Code require a streambed alteration agreement from DFG for any activity that might substantially divert or obstruct the natural flow or substantially change the bed, channel, or bank of any river, stream, or lake, or for the use of any material from the streambed. In practice, DFG defines its jurisdictional authority to the top of the stream or lake bank, to the outer edge of the riparian vegetation, or to the 100-year floodplain. Jurisdictional boundaries may encompass an area greater than under Section 404.

- **Coastal Development Permit.** Santa Cruz County has a state-certified local coastal program (LCP) which is administered by the County Planning Department pursuant to the California Coastal Act. The LCP governs decisions regarding the short- and long-term conservation, development, and use of coastal resources. Alternatives with activities occurring in the coastal zone would require a coastal development permit.

- **Encroachment Permits.** Encroachment permits or easements may be required from the California Department of Transportation, the California Department of Parks and Recreation, the County, the City, and/or railroad companies, if an alternative affects areas within lands or rights-of way of these respective jurisdictions. Permits are issued to ensure that the proposed encroachment is compatible with and protects the primary use of the land or right-of-way and is properly designed for safety.

These environmental and regulatory issues are common to each alternative but may only be relevant for a specific site. It is possible that some of these issues may represent "fatal flaws" for one or more of the alternatives; however, the details of the alternatives have not been sufficiently examined at this time to make a determination of impact to overall feasibility. Specific issues related to each individual alternative will be discussed in detail under subsequent tasks after site locations are established.

The remainder of discussion in this TM addresses only general environmental issues related to potential for fishery, habitat, or cultural resources.

ALTERNATIVE 1 - BRACKISH GROUNDWATER SUPPLY (MOUTH OF SAN LORENZO RIVER)

River bed alluvium aquifers are typically comprised of coarse grain deposits that readily transmit water. Thus, production of water from an alluvial aquifer can be sustained at relatively high rates. The City's Tait Street Wells are an example of a shallow groundwater supply from a river bed alluvial aquifer.

New brackish shallow groundwater wells could be located in the vicinity of the mouth of the San Lorenzo River (i.e., along the final half mile of the river course, downstream from the Tait Street Diversion and within the river bed alluvium).

Influencing Factors

The potential for developing a brackish groundwater source in the vicinity of the mouth of the San Lorenzo River will be influenced by two primary considerations:

- **Quality.** Groundwater sources developed near the river mouth would require treatment to remove saline/brackish constituents. Shallow groundwater in the alluvial plain may also contain iron and manganese minerals, which can impact the efficiency of desalination treatment processes (i.e., reverse osmosis).

- **Quantity.** The production of brackish from the alluvial aquifer near the mouth of the river can be best determined with test wells. The San Lorenzo River has, over time, scoured and redeposited alluvial material along its course. The effect of this recurring action is to create discontinuity within the coarse grained alluvium, effectively segmenting the aquifer. This may limit opportunity for brackish groundwater production of significant and/or sustainable yield. In other words, alluvial aquifers have the potential to support significant short term well production but may provide limited sustained yield if the alluvium is segmented.

Conceptual Infrastructure Improvements

The conceptual infrastructure improvements associated with a new shallow groundwater supply from the mouth of the San Lorenzo River may include:

- **New production wells.** Depending on location new wells could either be Ranney-type collectors or wells similar to those at Tait Street.

- **New treatment facilities.** Treatment for brackish water would require a new desalination facility (e.g., membrane treatment by reverse osmosis).

- **Water Distribution Pump Station.** A new pump station would be required to deliver water to the distribution system.

- **Water Distribution Piping.** New piping would be required to deliver the treated water to the City's distribution system.

Potential Advantages

- **Location.** New facilities would be located in relatively close proximity (i.e., less than two miles) to the existing distribution system.
- **Reliability.** The impacts of drought on a brackish groundwater supply is somewhat attenuated compared to surface water sources.
- **Environmental.** Brackish groundwater production from the alluvial aquifer reduces the potential for impact to fisheries compared to direct diversion of surface flows.

Potential Constraints

- **Quality.** There is a small chance that salt water intrusion may be increased by prolonged pumping during drought conditions. This could potentially affect the quality of water produced by the Tait Street Wells, particularly during drought conditions when there is reduced underflow in the San Lorenzo River. Ground water modeling would be required to further evaluate this issue.
- **Water Rights.** Brackish shallow groundwater will likely be hydraulically linked to the San Lorenzo River. Accordingly, use of wells may require a permit with seasonal/annual use restrictions (similar to permit requirements for the Tait Street Diversion).
- **Quantity.** The ultimate yield is highly dependent on installing the well(s) in a productive alluvial aquifer seam. Test wells are needed to confirm optimum locations and the yield of the alluvial aquifer.
- **Cost.** The cost of desalination treatment is high.
- **Environmental.** Groundwater pumping could result in impacts to riparian habitat and other vegetation from the lowering of groundwater levels, or by introduction of more saline water in the shallow aquifer. Fishery resources could be affected by potential reduced flows in the San Lorenzo River, if shallow groundwater is hydraulically linked to the river. Construction of wells, a new pump station, treatment facility (if desalination is required for brackish water), and pipelines could result in possible impacts to sensitive species or their habitat and cultural resources. If desalination is necessary, methods to reduce impacts from the discharge of concentrated brine into the Monterey Bay National Marine Sanctuary would need to be implemented. Additionally, the construction and operation of the required conceptual infrastructure improvements may result in compliance with regulatory and permit requirements discussed above.

ALTERNATIVE 2 - FRESH GROUNDWATER SUPPLY (SAN LORENZO ALLUVIAL PLAIN)

This alternative is similar to Alternative 1 except that wells would be installed further upstream from the ocean to produce fresh groundwater rather than brackish water, and also to minimize the potential for water quality impacts from the ocean due to prolonged pumping.

Influencing Factors

The potential for developing a new groundwater source is influenced primarily by the hydrogeologic conditions of the alluvial plain. The river has realigned over the years (due in part to development in the City near the mouth of the river) and the configuration of the aquifer associated with the current river alignment is not fully known. Previous investigations indicate the best potential to produce groundwater is the in the vicinity of the existing Tait Street Wells. Away from this immediate vicinity, for example near the downtown area, the alluvium tends to narrow and hydrogeologic conditions become more unfavorable (i.e., more fine grained deposits of lower yield, low recharge potential, etc.)

Groundwater in and around the downtown area is relatively shallow depending on seasonal rainfall and tidal influences. However, there is sufficient geologic evidence to support that soil matrix away from the river is not a continuous alluvium. It is unlikely that this shallow groundwater source would provide a reliable, sustainable source of supply, particularly during a drought. The potential to develop a new groundwater source away from the immediate river alluvium is not considered viable.

Maximizing the production from the existing groundwater source in the river alluvium (e.g., near Tait Street) is considered to be potentially viable. However, there is a potential limitation associated with this alternative. Shallow groundwater within the immediate alluvial plain is hydraulically linked to the river. Operation of any new wells would likely be limited by the existing instantaneous/annual use restrictions that have been permitted for the lower San Lorenzo River, as described in Figure 1.1.

Conceptual Infrastructure Improvements

The conceptual infrastructure improvements associated with a new groundwater supply within the San Lorenzo River alluvial plain will include:

- **New Production Wells.** New wells would be Ranney-type collectors or similar to the Tait Street wells.
- **Raw Water Transmission Piping.** Depending on water quality, hydraulics and other system operating considerations, piping could be routed to the Coast Pump Station or routed directly to GHWTP.

- **Raw Water Pumps.** Depending on hydraulic, raw water piping, and other system operating considerations, increased pumping capacity could be provided at the Coast Pump Station. Alternatively, a new pumping facility could be constructed.

The water quality associated with this alternative is assumed to be similar to that of the Tait Street Wells and will require treatment prior to distribution. Treatment could be accomplished at the wells, or at GHWTP (as is done with the Tait wells).

Potential Advantages

- **Location.** New facilities would be located in relative close proximity to the existing raw water transmission system and water treatment facilities (i.e., within one to two miles).

- **Quality.** The alluvial aquifer will provided some natural filtration. The groundwater will not be impacted by seasonal variations in turbidity typical of the surface sources and would not have seasonal use constraints due to sediments.

- **Cost.** Shallow groundwater production and treatment is a relatively inexpensive. Also, the close proximity to the existing transmission system and treatment facilities may result in lower capital costs compared to other alternatives.

- **Reliability.** Reliability is increased by installation of new groundwater wells that provide a supply that is not subject to water quality use constraints, as is the case with river diversions. The impacts of drought on groundwater supplies may be attenuated compared to surface water sources, particularly if the water can be diverted for storage in Loch Lomond.

- **Environmental.** Groundwater production from the alluvial aquifer reduces the potential for impact to fisheries compared to direct diversion of surface flow.

Potential Constraints

- **Water Rights.** Shallow groundwater within the alluvial plain may be hydraulically linked to the river (even if the wells are not located adjacent to the river). Accordingly, use of wells may require a permit with seasonal/annual use restrictions (similar to permit requirements for the Tait Street Wells).

- **Quantity.** The ultimate yield is highly dependent on installing the wells in sand seams that are connected to the river. Test wells are needed to confirm optimum locations and the yield of the alluvial aquifer. The potential impacts of new well production on the production capacity of the Tait wells would also need to be evaluated.

- **Local Impact.** Installation of new facilities increases the potential for local impact and/or conflict with development in the area. At minimum, the location of new wells would need to be coordinated with adjacent land use.

- **Environmental.** The potential environmental constraints of this alternative are the same as those identified for Alternative 1.

ALTERNATIVE 3 - MAXIMIZE THE USE OF EXISTING SOURCES AND STORAGE IN LOCH LOMOND RESERVOIR

The overall objective of this study is to identify water supply alternatives that can meet the City's current and projected future demands during periods of drought. In meeting this objective, a primary emphasis is to evaluate water supply alternatives that will enable the City to maximize the yield of its existing sources by more efficient use. In so doing, the City will be better able to maximize the storage in Loch Lomond Reservoir throughout the year.

Loch Lomond is the City's only significant source of storage, and therefore its primary drought reserve. The City's operating objective is to limit the use of the reservoir whenever feasible, thereby keeping it full as much of the year as possible. The net effect is to conserve the stored water so that it is available to supplement the yield from other sources during high demand and drought conditions. In order to preserve the storage the City has established a use priority for water supply sources:

- North Coast.
- Beltz wells.
- San Lorenzo River.
- Loch Lomond.

Despite the need to preserve storage there are occasional deviations from the use priority. This is because the current operation strategy also attempts to balance source water quality and operating costs with system demands.

The goal of this alternative is to build on the City's existing operational philosophy and find additional ways to use the City's existing sources — particularly the surface sources — more effectively and increase the overall yield from the system. Options include increased capture and/or storage of surface water from existing north coast and San Lorenzo River supplies, alone or in conjunction with optimized seasonal use of existing diversions. Four variations for use of surface water supplies have been identified for consideration:

- Increased capture and pretreatment of north coastal supplies in lieu of treatment of Newell Creek and San Lorenzo River water.
- Increased capture of north coastal supplies for diversion to storage in Loch Lomond Reservoir.
- Increased capture and pretreatment of San Lorenzo River water.

- Increased capture of San Lorenzo River water with diversion to storage in Loch Lomond Reservoir.

Each of these variations have the potential to increase the yield of the supply system. In addition, all of these variations are consistent with the City's current operational philosophy because they have the potential to either minimize use of Loch Lomond, or increase its storage volume throughout the year via increased diversion for storage.

Influencing Factors

The amount of additional yield that can be developed from these alternative variations is directly linked to the City's ability to use and/or store more surface water when it is most plentiful, in the fall and winter months when rainfall and runoff is highest. The need to capture water during these months presents two influencing factors:

- Demand from system customers in the fall, winter, and spring months is relatively low in comparison to the amount of water which could potentially be diverted during these months, when streamflows are highest. Because system demand is low there is limited potential to significantly increase the yield from the sources by simply diverting "excess" flows and using the water to help meet system demand.

- The storage capacity in Loch Lomond Reservoir is typically replenished by rainfall and runoff in the fall and winter. As the reservoir fills during these months the amount of "excess" storage capacity is reduced. Thus, there is limited potential to increase yield from the surface water sources by diverting excess runoff and storing the water in Loch Lomond.

  Even if storage in Loch Lomond is maximized during high runoff periods, the City will still need additional water supply alternatives during periods of drought. If the reservoir was full at the start of a drought period the amount of storage in Loch Lomond is still not sufficient to meet the projected long term system demands. This coupled with the fact that the yield from the City's existing sources is naturally diminished during drought indicates that additional water storage alternatives would be needed to help meet the City's supply needs during drought. Several possible ground water storage alternatives are discussed later in this section. Ground water storage alternatives could be developed in conjunction with increased diversion of the surface sources.

Increasing diversions from the surface sources during winter months also presents water quality issues. Currently, much of the available supply is not diverted for use due to poor water quality (i.e., high turbidity which makes the water more difficult to treat) The poor water quality also impacts the operation of system facilities. The impacts of water quality on system operation can be summarized as follows:

- **North Coast System.** High turbidity impacts the ability to transport the raw water to the treatment plant due to sand which settles in the pipeline. Fine sand associated with the turbidity also increases wear on the Coast pumps.

- **San Lorenzo (Tait Street).** Sand from the river diversion has historically been a problem this facility. Pumps at the Coast Pump Station require frequent routine maintenance.

A third factor influencing the feasibility of this alternative is the hydraulic constraint within the existing Coast Pipeline. Water from the North Coast sources is delivered to the City by gravity. Lidell Spring, Laguna Creek, and Majors Creek are capable of supplying approximately 2.6, 7.0, and 4.4 cfs, respectively, if they are operated separately. However, when the sources are operated simultaneously, the combined capacity is approximately 9.4 cfs. The 9.4 cfs capacity represents the maximum flow available under the available gravity head, even though the sum of the individual source capacities is approximately 14.0 cfs. The reduction in capacity is due to increased headloss in the pipeline. Also, when Lidell Spring and Laguna Creek are operating near or at capacity production from Majors Creek is not possible due to hydraulic restrictions under the available gravity head. This hydraulic restriction effectively limits the ability to divert and capture of water from Majors Creek, increasing the City's reliance on other supplies.

Conceptual Infrastructure Improvements

The conceptual infrastructure improvements associated with increasing the usage of the existing supplies may include:

- **Upgrades to the North Coastal Diversion.** Upgrades may include a new pump station at Majors Creek (to provide increased capacity from the diversion, which is currently limited due to hydraulic constraints under gravity flow), or modifications to diversion structures at Laguna or Lidell to increase diversion capacity.

- **Upgrades to the Coast Pipeline System.** Much of the pipeline system from the diversion structures and Coast pipeline is over fifty years old and in poor repair. In addition, several reaches of pipelines from the diversion structure are exposed and vulnerable to landslides, thereby impacting reliability of this system.

- **Upgrades to the Coast Pump Station and Tait Well.** The wells and pump station are also old and in poor repair and in need of upgrades to increase operating efficiency and capacity. Currently the total supply from the North Coast and Tait Street Diversions is limited by the Coast Pump Station and discharge pipeline capacity.

- **Upgrades to the Newell Creek Pipeline.** The Newell Creek Pipeline is the sole way to transport water to and from Loch Lomond Reservoir. Water cannot be diverted at Felton for delivery to the reservoir when the reservoir storage is being used to supplement supply (or vice versa). This not only limits operational flexibility, but occasionally also results in lost diversion capacity from the river. For example, under some conditions operators prefer to use the water from Loch Lomond because it is of better quality than the river supply. In so doing, however, diversions from the river are discontinued, thereby losing potential to increase storage in the reservoir. In addition, flow from the diversion through the Newell Creek Pipeline is limited by the pressure rating of the pipe.

Both of these constraints effectively limit the ability to optimize the diversion entitlement from the San Lorenzo River at Felton.

- **Variable Speed Drives at the Felton Diversion and Booster Pump and Tait Street Pump Stations.** Variable speed drives at these pump stations would allow operators to optimize the diversion to match system demand conditions, and may also increase capture during low flow conditions in the river. A project to improve reliability and flexibility of the Felton Booster Station was previously studied by the City and variable speed drives were included in the recommended project.

- **New Treatment Facilities.** If additional water from the surface sources is to be captured and used, new treatment facilities may be required to maximize the use of high turbidity sources during the winter. Treatment upgrades could be implemented at the GHWTP, or at an alternative locations (e.g., Coast Pump Station). The new treatment facilities would primarily be focused on sedimentation/clarification of the surface supplies to protect pumps, improve treatability, and/or to make the water suitable for groundwater storage options (if determined feasible).

- **Upgrades to the Beltz Wells.** Three of the four Beltz wells are old and in poor repair, due in part to damage from the 1989 earthquake. The City is currently replacing two of the wells damaged during the 1989 earthquake and the other wells must be upgraded to restore capacity and allow increased usage throughout the year. Increased usage of these wells would further reduce the need to rely on Loch Lomond storage for supplemental supply.

Potential Advantages

- **Location.** Many of the proposed upgrades would be completed at or near the City's existing facilities.

- **Reliability.** Upgrading the existing facilities, and constructing additional new treatment and/or transmission facilities would allow optimum use of existing sources and would increase the reliability and operational flexibility of the water supply system.

Potential Constraints

- **Quality.** Treatment upgrades for the high turbidity water may be substantial, and may be needed at multiple locations (e.g., treatment for both the coastal supplies and the river supply).

- **Quantity.** The amount of excess flows from the surface sources that are not currently being captured represent a significant portion of City's long term supply needs. The potential to increase the available yield from the City's existing surface water sources depends strongly on the ability to use and/or store water which is not currently being captured. If the City is to significantly increase the yield from the surface water sources by increasing diversions under this alternative suitable groundwater recharge/storage alternatives will likely be required.

- **Costs.** Costs of treatment and capacity upgrades for existing and new facilities may be significant.

- **Water Rights.** This alternative targets increased usage of the City's surface water sources. The water rights for these sources prescribe specific use designations: diversion for direct use (North Coast), or diversion for storage (Felton). These use designations may conflict with the seasonal operation strategies. For example, it may be beneficial to divert flows from North Coast streams during the winter months for groundwater storage or to Loch Lomond, rather than direct use. To do this may require a change in the water rights permit conditions.

- **Environmental.** Changes in the place of use (including storage through groundwater recharge) could result in potential limitations on diversion of surface flow in order to maintain instream flows for protection of fisheries, riparian habitat, and/or public trust values. Increased surface flow diversion, construction of a pump station and treatment facility, and upgrades to the pipelines, pump stations, and the Beltz Wells could result in possible impacts to sensitive species or their habitat (such as the California red-legged frog) and cultural resources. Additionally, the construction and operation of the required conceptual infrastructure improvements may result in compliance with some or all regulatory and permit requirements discussed above.

ALTERNATIVE 4 - GROUNDWATER RECHARGE AND EXTRACTION NEAR WILDER RANCH GRAVEL QUARRY

During years of normal or above normal rainfall there is a significant volume of runoff in the City's surface water sources that is not diverted for use or storage. Previous studies have not identified a new surface water storage reservoir that is feasible at this time; however, it may be possible to store the water underground. Under this alternative, surface water would be recharged at or near the Wilder Ranch gravel quarry operation.

Historical records indicate that wells constructed in the Santa Margarita Formation bedrock aquifer and located in the Wilder Ranch area are typically capable of producing between 200 and 700 gpm. Thus, a recharge/extraction operation could potentially increase the City's yield by several hundred million gallons per year, depending on the number of wells and the degree to which sustainable yield of the aquifer can effectively be augmented by recharge from other sources, such as the North Coast supplies.

Influencing Factors

The primary factors that will influence the feasibility of this alternative are as follows:

- **Aquifer Characteristics.** The Wilder Ranch area has been actively mined for sand and gravel for approximately 30 years. The same geologic properties that support the sand and gravel mining also make the aquifer potentially viable as a groundwater source. The characteristics of the aquifer that promote reasonable production rates are:

  - Lower degree of cementation within the sediment.
  - Concentration of coarser-grained sand deposits.
  - Thicker formation cross section.

  Data from published reports also indicate that the percolation capacity of the soil in this area would support a moderately high rate of recharge, up to 30 gpd/sq.ft. However, recent reports indicate that groundwater levels in the area are relatively shallow, approximately 10 feet below the surface in some areas of low surface topography. Recharge of groundwater in this area (e.g., by surface spreading in existing quarry pits) would create a localized groundwater mound. Groundwater mounding could result in groundwater levels that would rise above the creek bed elevation in the Sandy Flat Gulch Creek, such that some of the groundwater would be lost as runoff. In addition, groundwater mounding in the area could constrain the existing gravel and sand mining operations.

- **Aquifer Yield.** Historical groundwater records indicate that the Santa Margarita aquifer down slope from the Wilder Ranch area has been in a state of overdraft for many years. This overdraft condition has created aquifer storage space that could potentially be "filled" by artificial recharge (assuming the recharge operation could be accomplished without creating a localized groundwater mound, or without resulting in losses to surface runoff, as noted above).

  The amount of increased yield that could be provided by a recharge operation (either via surface spreading or direct injection) is uncertain. Although wells in the area have demonstrated production capability of 200 to 700 gpm, there is ample evidence from historical agricultural use to suggest that extended pumping under constant demand will exceed the available recharge in this area. Artificial recharge would help to offset the impacts of pumping. However, there is no guarantee that water recharged for storage would be available for later use unless certain pumping/use restrictions on the aquifer can be implemented.

- **Water Quality.** Runoff water available for diversion and storage typically contains a high concentration of fine grained sands and silts. Treatment to remove these fined grained particles would likely be required prior to recharge. If the particles are not removed they will tend to settle and/or bind together (either on the bottom of a surface spreading basin or in the well screen of an injection well) and could significantly impact the rate of recharge. If finished water from the GHWTP is used for recharge water quality will not be a significant constraint.

Conceptual Infrastructure Improvements

The conceptual improvements associated with increasing the capture along the existing supplies may include:

- **New Pump Station.** A new pump station may be required to deliver water to the recharge area from a location along the Coast pipeline. The pump station would divert flow during periods of excess runoff and/or low system demand to either surface spreading areas or injection wells.

- **New Pipelines.** Additional pipelines would be required between the Coast pipeline and the recharge area. It is likely that a minimum of two pipelines would be installed for system reliability and redundancy and to allow water to be injected and withdrawn simultaneously.

- **New Wells.** Extraction wells would be required to obtain groundwater from the new supply. Recharge wells may also be required if surface spreading areas is not deemed to be feasible.

- **New Treatment Facilities.** Recharge water would be from excess North Coast or San Lorenzo River supplies. Treatment facilities will require sedimentation and chlorination equipment. Disinfection is prudent to prevent bacterial growth in the recharge facilities.

Potential Advantages

- **Location.** Many of the proposed upgrades would be in proximity to North Coast raw water supply pipeline.

- **Quantity.** The north coastal system appears to have the most "excess" water. In addition, the aquifer appears to have the characteristics that would allow injection and extraction.

Potential Constraints

- **Quality.** Treatment upgrades for the high turbidity water may be substantial. The potential exists for salt water intrusion if extraction produces an overdraft condition in the aquifer.

- **Quantity.** The hydrogeology (aquifer space, percolation rates, etc.) must be developed for the aquifer. As mentioned above, the availability of water during drought years and potential for water losses due to the mounding effects of recharge must be quantified before the actual yield can be established.

- **Local Impact.** The feasibility of this alternative depends on the availability of land for the surface spreading areas and the wells. The project will also require cooperation between governmental agencies (State Parks, Department of Fish and Wildlife, etc.) and private industries.

- **Water Rights.** This alternative targets increased usage of the City's surface water sources. The water rights for these sources prescribe specific use designations (e.g., diversion for direct use (North Coast), or diversion for storage (Felton), etc.) which may conflict with the seasonal operation strategies. For example, it may be beneficial to divert flows from North Coast streams during the winter months for groundwater storage, rather than direct use. To do this would require a change in the water rights permit conditions.

- **Environmental.** Construction of the new pump station, pipelines, wells, and treatment facilities could result in possible impacts to sensitive species or their habitat (such as the California red-legged frog) and cultural resources. Additionally, the construction and operation of the required conceptual infrastructure improvements may result in compliance obligations with some or all regulatory and permit requirements discussed above. For example, special operating requirements and/or permit provisions may be required to recharge ground water with chlorinated water.

ALTERNATIVE 5 - SEA WATER DESALINATION

Desalination of sea water to produce potable water is feasible but expensive alternative.

Conceptual Infrastructure Improvements

The conceptual improvements associated with a desalination treatment facility will include:

- **New Pump Stations.** A new submersible pump system would be required to deliver water from the intake structure to the treatment facility. A second pump station would be required to increase the pressure prior to the reverse osmosis treatment system

- **New Pipelines.** The City has two existing ocean outfalls: an abandoned outfall that is approximately 3,500 feet long and an new outfall that is approximately 8,000 feet long. A recent project in Santa Barbara included retrofit and use of the abandoned outfall as the intake for the desalination plant, and use of the existing wastewater outfall as the discharge for the brine. This approach reduced the disruptive work in the ocean. For Santa Cruz pipelines would be required to connect the abandoned wastewater ocean outfall with the desalination plant and to connect the brine reject discharge with the existing ocean outfall. The abandoned ocean outfall would require relining.

- **New Intake Structure.** The end of the abandoned ocean outfall will be replaced with an intake structure that screens larger objects from entering the intake and reduces the impact on the surrounding aquatic environment.

- **Power Supply.** The new treatment plant would likely require a new electrical supply to provide high voltage power for the reverse osmosis system.

- **New Treatment Facilities.** Treatment facilities would require conventional treatment for solids (e.g., pressure or membrane filtration) as well as the reverse osmosis treatment system.

Potential Advantages

- **Location.** The City owns property near the wastewater treatment plant. Depending on the size it may be possible to locate a desalination facility near the wastwater plant. This would reduce the amount of new piping to the ocean outfalls and to the distribution system.

- **Quantity.** The amount of water available is unlimited. However to negate the potential for growth inducement the actual quantity developed would be limited to match supplemental drought supply needs.

- **Environmental.** Use of desalted ocean water would reduce the potential need for increased surface water diversions from the City's existing sources. If desalination is implemented in lieu of increased surface diversion there will be a corresponding reduction in the potential for impact to fisheries or riparian habitat.

Potential Constraints

- **Local Impact.** The feasibility of this alternative depends, in part, on the availability of land for the new pump station and treatment plant, and the potential impacts to surrounding landholders.

- **Costs.** Capital and operating costs of desalination treatment are significantly higher than the cost of conventional treatment. The high cost of operation may be partially offset by relatively infrequent and limited operating cycles during drought conditions.

- **Environmental.** Construction of treatment facilities, intake facilities and associated pipelines and pump stations could result in impacts to sensitive species or habitats, as well as cultural resources. Mitigation strategies will need to be identified as necessary to prevent impact. Monitoring of the ocean outfall will be required to assure that the discharge will not have an impact on the marine environment.

ALTERNATIVE 6 - CONJUNCTIVE USE WITH SOQUEL CREEK WATER DISTRICT

The proximity of the City's water system to the Soquel Creek Water District (District) enhances the potential for sharing resources. The District currently derives its supply solely from groundwater. This groundwater supply has been stressed due to increased demands within the District, and reportedly is near the point of overdraft. Limited use of the wells by the District during winter periods -- when supply could be augmented by the City -- should reduce the stress on the aquifer and enhance natural recharge. For example, under the City's current winter demand conditions, the City may have excess water supply and treatment capacity which could be provided to the

District. The water could be used to supplement the District's groundwater supply so that year round demands on the groundwater supply could be reduced. Depending on the seasonal demands of the City and the District, it may also be possible to recharge excess surface water supplies in the District's aquifer for later withdrawal during drought (i.e., conjunctive use). .

Under the above scenario, the District would provide groundwater to the City during drought conditions, in exchange for the City providing surface water during non-drought years.

Conceptual Infrastructure Improvements

The conceptual improvements associated with this alternative will include:

- **New Pipelines and Pump Stations.** New pipelines and pump stations would be required to deliver water to the Soquel distribution system. An additional pump station may be required for aquifer recharge.

- **New Wells.** New wells may be required to meet drought condition demands for both systems. New injection wells may be required to recharge the aquifer during off-peak seasons.

- **New Treatment Facilities.** Treatment facilities may be required for the groundwater.

Potential Advantages

- **Quality.** The Purisima aquifer which supplies both Soquel Creek Water District's well and the City's Beltz Wells has reportedly been stressed for many years and has the potential for salt water intrusion. This option would reduce the use of the aquifer and even provide for aquifer recharge.

- **Location.** The two systems are relatively close to each other.

- **Reliability.** Interconnection would provide each system with a backup for emergency conditions.

- **Quantity.** Santa Cruz has the capacity to supplement Soquel demands during winter and spring seasons.

Potential Constraints

- **Quality.** Supplemental supply from the City will not be sufficient to offset the District's needs throughout the entire year. To meet its demand the District will continue pumping from its existing ground water supply. This increased pumping from the Purisima formation within the District may increase the potential for salt water intrusion.

- **Quantity.** The Purisima geologic formation is the same formation used by the Beltz wells. Increased pumping during a drought may impact the performance of the Beltz wells. In addition, the District and/or City would need to closely monitor the pumping operation and groundwater storage in the aquifer if groundwater is to be supplied to the City during drought by an exchange agreement.

- **Local Impact.** The feasibility of this alternative depends in part on the availability of land and easements for the required infrastructure.

- **Water Rights.** This alternative targets increased usage of the City's surface water sources, and would also divert water from the City's service area. The water rights for the surface sources prescribe specific use designations (e.g., diversion for direct use (North Coast), or diversion for storage (Felton), etc.) which may conflict with the seasonal operation strategies, or use outside the City service area. This alternative would require a change in the water right permit conditions.

- **Costs.** Capital costs will include new pump stations, wells and pipeline.

- **Institutional.** An agreement would need to be reached between the City and the District that would provide sufficient assurances of water supply to each party during drought conditions. Cost sharing of facility construction and operation would also need to be resolved in the agreement.

- **Environmental.** Construction of pump stations, pipelines, wells, and treatment facilities could result in possible impacts to sensitive species or their habitat and cultural resources. Additionally, the construction and operation of the required conceptual infrastructure improvements may result in compliance with some or all regulatory and permit requirements discussed above.

ADDITIONAL POTENTIAL OPTIONS

This TM describes project concepts for six water supply alternatives that have been identified as potentially viable. These project concepts were developed jointly by City staff and Carollo Engineers to serve as the basis for the scope of work for this project. As indicated earlier in this memorandum, City staff and Carollo recognized that additional potentially viable project concepts could be identified during the course of the project.

Additional alternatives that have been identified during the course of preparing this TM are:

- **Recharge and Extraction at Beltz Wells.** Preliminary review of the geologic information indicates that Purisima aquifer underlying the Beltz Wells may be suitable for recharge and extraction.

- **Wells at Felton Diversion.** Preliminary review of the geologic information near the Felton Diversion indicates that an alluvial aquifer may be available for installation of wells similar to those at Tait Street. The water quality from the wells would be higher than that from the river and may allow the City to pump the water directly to treatment, a condition that could be incorporated into the new water rights. This option may also reduce the potential environmental impacts associated with a direct river diversion.

- **Purchase Agricultural Wells and Deliver Raw Water from the North Coast Supplies.** Farmers along the north coast currently derive their supply primarily from groundwater. In normal years, it may be possible for the City to provide some (or all) of the agricultural demand by supplying surface water from the North Coast diversions. In exchange, farmers would reduce (or eliminate) pumping so the groundwater would be available for drought supply. During drought water supply for agricultural use would be curtailed and growers would be compensated for lost revenue. The avoided cost of developing a new supply could potentially offset the cost of paying farmers for lost revenue.

These project concepts are considered to have equal merit to the six alternatives previously discussed. These concepts will be reviewed an evaluated in greater detail as the study progresses. The results of the project concept development will be presented at the initial public scoping workshop.

PROJECT SCHEDULE

The six alternatives described above are summarized in Table 1.1. The project goal is to evaluate these alternatives and develop one feasible project that will meet the City's supply requirements. The remaining steps in the evaluation are summarized below.

- **Scoping Workshop with Public.** A scoping workshop will be held to present conceptual water supply alternatives to the general public and other groups that may have special interest in the project alternatives. The meeting will be used to identify potential institutional constraints, technical issues, and environmental issues to be addressed as part of initial screening of alternatives and to solicit comments and ideas. Following the scoping meeting the consultant team will meet with staff and a Water Commission subcommittee, as applicable, to review input received at the public scoping meeting. Alternatives will be refined as needed to reflect public and City input. Alternatives will be subjected to preliminary screening based on judgement and reconnaissance level analysis. Additional alternatives may be selected for further study.

- **Data Acquisition and Field Work.** Background data and technical information to support the project alternatives will be established through field investigations. Tasks will include developing more detailed hydrologic information as necessary to support surface water project concepts and obtaining specific hydrogeologic information as necessary to support the groundwater project alternatives.

- **Identify Implementation Criteria**. Implementation criteria will identify and describe non-economic criteria which could influence the overall feasibility of the project alternatives. Non-economic criteria to be investigated include water rights, water flow requirements for fisheries, environmental and associated permitting requirements, and other factors related to institutional constraints and/or public perception.

- **Initial Screening of Alternatives.** The purpose of this task is to complete an initial screening of alternatives, so that a list of most feasible and/or preferred alternatives can be developed. The screening will be based on the information compiled from the activities listed above. The list of most feasible and/or preferred alternatives may need to be refined into one or more combinations to meet the City's overall water supply needs. The goal is to obtain an additional water supply to meet the demands during a critical dry period.

- **Refine Conceptual Alternatives.** The final task is to develop conceptual engineering schemes for each of the feasible project alternatives. Engineering concepts will be developed to a level of detail sufficient to develop the overall feasibility of the alternatives. This evaluation will include costs and will also address operational, institutional, and environmental constraints. It is assumed that a single water supply alternative will not meet the City's overall water supply needs, and that several permutations and combinations of project alternatives will need to be evaluated as part of this task. Evaluation criteria will be developed and projects will be ranked to establish a single most preferred alternative project (or combination of projects as necessary to meet the projected demands). Public input will be solicited on the final recommendation.

Table 1.1 Summary of Potential Supply/Storage Alternative
Alternative Water Supply Project
City of Santa Cruz

Alternative	Pros	Cons
1. Brackish groundwater supply mouth of San Lorenzo River.	• Close to distribution system. • Environmentally superior to surface diversion.	• Cost of brackish water treatment. • Quantity uncertain. • Potential to promote sea water intrusion.
2. Fresh groundwater supply (San Lorenzo Alluvial Plan).	• Close to distribution system. • Low cost (if no treatment is required). • Water quality (low turbidity). • Environmentally superior to surface diversion. • Improved system reliability.	• Potential to promote sea water intrusion with increase pumping. • Quantity uncertain. • Potential conflict with existing diversion limits at Tait Street.

Table 1.1 Summary of Potential Supply/Storage Alternative
Alternative Water Supply Project
City of Santa Cruz

Alternative	Pros	Cons
3. Maximize use of existing sources and storage in Loch Lomond Reservoir.	• Optimized use of existing facilities and supply sources. • Improved system reliability.	• Cost for facility improvements including treatment for high turbidity. • Additional storage likely required to optimize use of sources. • Water Rights may need to be modified.
4. Groundwater recharge and extraction at Wilder Ranch.	• Close proximity to existing North Coast Pipeline. • Optimized use of existing supply in winter months.	• Additional yield uncertain may only be minimal gain. • Treatment required prior to storage. • Water Rights may need to be modified.
5. Ocean desalinization.	• Ample supply.	• Cost of facilities and operation. • Potential environmental impact with brine discharge.
6. Conjunctive use with Soquel Creek Water District.	• Supply available. • Positive public perception.	• Interagency issues must be resolved. • Need to develop hydrogeology. • Cost of new infrastructure. • Water rights will need to be modified.

GLOSSARY OF TERMS

Alluvium	Material (clay, silts, sand gravel) deposited by a river either along the river bed or at the mouth of the river.
Conjunctive Use	Sharing water resources between suppliers to maximize the water available during drought conditions.
Desalination	Removal of minerals, primarily salt, from sea water.
Infrastructure	Manmade improvements and equipment associate with a system. Typically referred to as capital improvements.
MG/yr	Million gallons per year. Unit of measure for water demand and use.
Runoff	Rainfall that reaches a surfaces water such as a river or reservoir infrastructure.
Yield	Water supply collected from a source within a given time frame, such as a year.

City of Santa Cruz
Preliminary Investigation of Water
Water Supply Alternatives

TECHNICAL MEMORANDUM NO. 2
WATER SUPPLY

Carollo Engineers, P.C.
in Association with
Linsley, Kraeger Associates

February 1999

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CITY OF SANTA CRUZ
PRELIMINARY INVESTIGATION OF WATER SUPPLY ALTERNATIVES

TECHNICAL MEMORANDUM NO. 2
WATER SUPPLY

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INTRODUCTION

Previous studies of the City of Santa Cruz water supply have concluded that the there is not enough water to meet the long term needs of the City, particularly under drought conditions. This document updates the previous studies and estimates the available water supply from the City's existing sources during drought conditions.

The water supply estimates developed in this document will be used to assess the limitations of the existing supply system. The findings and conclusions will serve as the basis for an evaluation of water supply alternatives, to be completed separately as part of the overall scope of work for this project.

SCOPE

The scope of work for this evaluation includes:

- A review of historic rainfall and surface water hydrology data.
- An estimate of the available supply from the City's surface and ground water sources.
- An evaluation of the monthly and seasonal supply conditions.

The information from this evaluation is to be used to quantify the available water supply for short-term, critical dry periods, and the corresponding supply deficit during these same periods. This is a primary objective of this study.

SUMMARY OF EXISTING SYSTEM

The City obtains water from several ground and surface water sources, as shown in Figure 2.1. For ease of understanding the complex water supply system, the sources are grouped as follows:

- **North Coast.** This system is comprised of surface water diversions from three coastal streams (Reggiardo Creek, Laguna Creek, and Majors Creek) and one natural spring (Liddell Spring) located approximately six to eight miles northwest of Santa Cruz. Water from these diversions flows by gravity through the Coast Pipeline to the Coast Pump Station. The water is pumped from the Coast Pump Station for treatment at the Graham Hill Water Treatment Plant (GHWTP).
- **San Lorenzo River.** This system is comprised of two surface water diversions: one is located near the community of Felton (Felton Diversion) and the second is near Tait Street

Source	Period	Maximum Diversion Rate (cfs)	Fish Flow Require-ments (cfs)	Annual Diversion Limit (MG/year)
North Coast[1]	Year-round	No limit	None	None
San Lorenzo River				
Tait Street Diversion and Wells	Year-round	12.2	None	None[3]
Felton Diversion to Loch Lomond Reservoir	September	7.8	10 }	977
	October	20.0	25 }	
	November-May	20.0	20 }	
	June-August	--[2]	--	
Loch Lomond Reservoir on Newell Creek				
Collection	September-June	No limit	--	1,825
Withdrawal	Year-round	--	1	1042

(1) Water rights for City of Santa Cruz North Coast Sources are pre-1914 rights with all downstream rights purchased by City; therefore, City may divert up to the full natural flow of each stream.

(2) Not specified for indicated time period.

(3) Although there is no prescribed annual diversion limit, the actual available diversion is constrained to approximately 1,600-2,200 MG/year due to seasonal low flows and high turbidity.

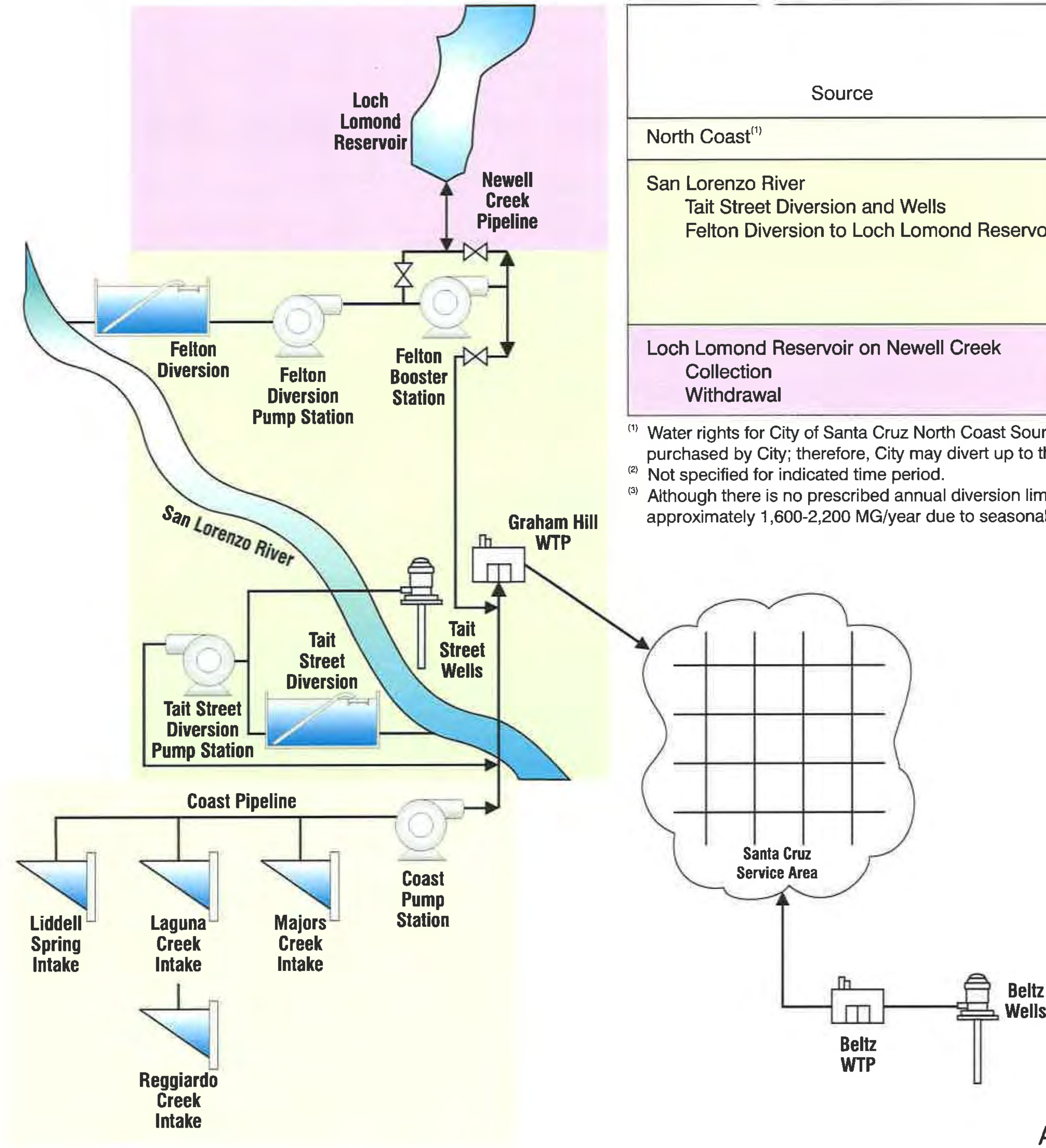


Figure 2.1
SANTA CRUZ WATER SUPPLY SYSTEM
CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY PROJECT

SC1000RF2 CDR

in Santa Cruz (Tait Street Diversion). Three shallow groundwater wells located adjacent to the river at Tait Street are included in this system. Water from the Tait Street Diversion and wells is pumped to the GHWTP for treatment. Water from the Felton Diversion is pumped through the Newell Creek Pipeline to Loch Lomond Reservoir.

- **Newell Creek/Loch Lomond Reservoir.** Loch Lomond is the only major reservoir in the San Lorenzo River watershed. It receives water from Newell Creek and Felton Diversion on the San Lorenzo River. The reservoir has a total storage capacity of 2,810 million gallons (MG) and a useable volume of 2,600 MG. The unusable volume includes water below the lowest outlet and water reserved for use by the San Lorenzo Valley Water District under agreement with the City.

- **Beltz Wells.** This system includes four groundwater wells (two new wells and two existing, operational wells). Water from the wells is treated at the source to remove iron and manganese prior to delivery to the distribution system.

With the exception of the Beltz Wells, each source has associated water rights. These water rights describe annual and seasonal diversion limits, and also designate the type and place of use (e.g., diversion to storage in Loch Lomond Reservoir, direct diversion for use within the City, etc.). The allowable seasonal and annual diversion limits and use restrictions are summarized on Table 2.1. The City's existing water rights dictate that the water from the Felton Diversion on the San Lorenzo River must be diverted to storage in Loch Lomond Reservoir. The water rights for the San Lorenzo River at Tait Street and Newell Creek at Loch Lomond specify use within the City's Service Area Boundary only.

AVAILABLE WATER SUPPLY

Available water supply is described as "yield", which is defined as the amount of water that can be supplied in a specified time interval. Each of the City's supply sources has a theoretical "safe yield", which is typically defined as the amount of water that is generated in one year by the combination of rainfall, runoff and storage during critical drought conditions. As determined by classical hydrology methods the safe yield is estimated by a straight calculation of rainfall, runoff, and storage during the critical drought period.

Although each of the City's supply sources has a theoretical safe yield, the amount of water actually available for supply is *less* than would be derived from a hydrologic calculation. This is because the City has various operational constraints that limit its ability to capture, store, and use all of the water that is generated by rainfall and runoff. These operational constraints include the seasonal and annual diversion limits prescribed by the water rights for its surface water sources, and infrastructure constraints that limit the amount of water that can be captured, stored, and/or delivered for treatment and use.

Table 2.1 Seasonal and Annual Diversion Limits and Use Restrictions During the Critical Drought Year[1] Alternative Water Supply Study City of Santa Cruz

Source	Period	Maximum Diversion Rate (cfs)	Fish Flow Requirements (cfs)	Annual Diversion Limit (MG/year)
North Coast(1)	Year-Round	No Limit	None	None
San Lorenzo River				
Tait Street Diversion and Wells	Year-Round	12.2	None	None[3]
Felton Diversion to Loch Lomond Reservoir	September	7.8	10	
	October	20.0	25	977
	November-May	20.0	20	
	June-August	–[2]	–	
Loch Lomond Reservoir on Newell Creek				
Collection	September-June	No Limit	–	1,825[4]
Withdrawal	Year-round	–	1	1,042

(1) Water rights for City of Santa Cruz North Coast Sources are pre-1914 rights with all downstream rights purchased by City; therefore, City may divert up to the full natural flow of each stream.
(2) Not specified for indicated time period.
(3) Although there is no prescribed annual diversion limit, the actual available diversion is constrained to approximately 1,600-2,200 MG/year due to seasonal low flows and high turbidity.
(4) Annual collection limit includes diversion under the Newell Creek water right only. Diversions from San Lorenzo River at Felton are not included in this total.

For the purposes of this study the term *operational yield* — the yield based on the limiting conditions of the supply system, including its operational constraints — will be used to describe the estimated water supply available during drought conditions.

Procedure for Determining Operational Yield

Water supply estimates for this study are developed with a hydrologic/operational model of the City's supply system (Linsley, Kraeger Associates, 1998). The model incorporates the historic hydrology for the City's surface sources from 1935-95, and also incorporates specific operational characteristics of the supply system identified by City staff. These operational characteristics include pumping capacity or treatment limitations, pipeline hydraulic constraints, storage limitations, and seasonal use limitations prescribed by water rights.

As noted above, the operational characteristics of the City's system determine the amount of water that is *actually available* for supply. To calculate the amount of supply available the following approach was incorporated in the model:

- Historical streamflow (runoff) was compiled to develop the available daily flows at the point of diversion for the north coastal sources, San Lorenzo River, and Newell Creek. Streamflow data for ungauged periods or stream reaches were adjusted using statistical techniques by comparison to known rainfall and/or runoff quantities.

- Operational constraints are applied to the flows at the point of diversion to determine the *available* water supply. Daily available supply is equal to the minimum controlling parameter:

    - Streamflow (less any requirements for in-stream release).

    - Water right diversion rate.

    - Hydraulic capacity of diversion structures and/or transmission pipelines.

    - No flow (during periods of high turbidity).

The operational model calculates the available supply in monthly increments based on a summation of the daily data. Daily data are used to eliminate the possibility for inaccurate estimation of available supply which could otherwise occur if only monthly data were used. For example, two months may have the same monthly stream flow totals but may have very different daily distributions (e.g., the stream flow may occur over just a few days due to a large rainfall event rather than a smaller volume over the entire month).

Based on discussions with City staff, the model assumes a specific priority of use for each source of supply, as follows: north coast, San Lorenzo River at Tait Street, Beltz wells, and Loch Lomond. This order of priority is derived to maximize the use of the City's free flowing surface sources (before the water reaches the ocean), and also to use the stored groundwater and surface water sources only as necessary, thereby reserving as much of the stored water for supply during drought.

A more detailed explanation of the model input parameters, including the various operational constraints and seasonal use limitations is included in Appendix A.

Supply from Loch Lomond Reservoir

The City has two stored water sources: groundwater in the Beltz well field and surface water in Loch Lomond reservoir. Of these two sources, Loch Lomond provides the largest amount of storage and use capacity. To maximize the City's available supply from the reservoir in drought conditions it is preferable to reserve storage in the reservoir to the greatest extent possible in non-drought years. Accordingly, the operations model assumes that Loch Lomond is used for supply only if the available supply from other sources is not sufficient to meet demand for any given day, or if there are operational constraints such as water rights or treatment limitations due to high turbidity that preclude the use of the other sources.

The model also assumes that some reserve storage, or "carryover" storage, will remain in the reservoir at the end of the drought period. Prudent water supply planning dictates that carryover storage be provided as a factor of safety in the event that future drought conditions are worse than shown by the historical record, either longer in duration or of more severe intensity. Prudent operation of a water supply system also dictates that some storage be reserved in the event that other sources are out of service due to maintenance or unforseen circumstances such as flood or earthquake. Based on discussions with City staff, the reserve storage has been set as 1,100 MG. This includes 1,000 MG of usable storage plus approximately 100 MG of dead storage in the reservoir. (Note: The reserve storage does not include storage required to maintain the minimum stream flow downstream of the reservoir (fish habitat maintenance flow) or storage allotted to San Lorenzo Valley Water District; see discussion under Operational Yield, below).

Drought Analysis

Based on review of the available historical precipitation record from 1935 to present, the City has experienced two types of droughts in the past: the short duration, one or two year critical drought (e.g., 1961, 1976-77), and longer duration droughts of more moderate severity (e.g., 1987-92). Of these two drought conditions, the short-term critical drought of 1976-77 represents the most severe conditions with respect to the City's estimated operational yield. The drought analysis for this study is based on the critical two year drought observed in 1976-77. For the drought analysis, we have assumed that the hydrologic conditions preceding and following the drought would be the same as occurred in 1975 and 1978, respectively.

Reservoir Storage Depletion

Even if the supply from other sources is maximized, the high demands in the summer months require that some of the storage in Loch Lomond be used. Most often, the amount of supply withdrawn from the reservoir is replenished the following winter. During drought conditions, however, the reservoir storage is not fully replenished, so it is important to establish how the available supply will be utilized during the drought.

To maximize the supply available from Loch Lomond during the assumed two year drought condition the operational model incorporates a reservoir release rule curve. This rule curve distributes the available supply from the reservoir over the two year drought period. During a short-term two year drought the reservoir release rule curve, if used as predicted by the model, would prevent over-use of the supply in the first drought year so that some stored water would be available for supply in the second year. For this study the reservoir release rule curve assumes a storage depletion at a constant, fixed amount during the drought period. In estimating the fixed withdrawal from the reservoir, the following baseline parameters were developed:

- Full storage in Loch Lomond in May of the year preceding the drought, approximately 2,800 MG (based on review of the rainfall and runoff from 1975, the year preceding the critical drought).

- Normal demands from May-March of the first drought year.

- Carryover storage in Loch Lomond at end of two year drought 1,100 MG.

Using these parameters, the fixed withdrawal rate is calculated as follows:

Fixed monthly withdrawal =

(Start Level April $_{\text{first year of drought}}$) MG $_{\text{start}}$-1,100 MG $_{\text{end}}$)/___ months = ___ MG/month.

In the equation the starting reservoir level -- April of the first year of the drought -- is different for each demand condition. This is because the amount of reservoir storage used to meet demands in the year preceding the drought will increase as demands increase in the future. The equation is based on the premise that a constant supply from the reservoir will continue until the minimum pool elevation reaches 1,100 MG, at which time it is assumed that no additional supply is available. Thus, for the two year drought period, the fixed monthly withdrawal calculated from the equation would be different for each demand condition. The following example illustrates:

- **Current Demand Conditions.** The starting reservoir volume in April for the current demand condition is approximately 2,135 MG. Assuming a 21 month drought duration (i.e., 24 months less January, February, and March of the first drought year) the fixed monthly storage depletion is calculated as:

  (2,135 MG - 1,100 MG) / 21 months = 49 MG/month

- **Build-out Demand Conditions.** For the build-out demand condition the starting reservoir level is approximately 1,750 MG. The fixed monthly storage depletion is calculated as:

  (1,750 MG - 1,100 MG) / 21 months = 30 MG/month

A primary objective of the modeling effort was maximize the use of the storage during the drought under all demand scenarios (i.e., maximize the time period before the minimum pool elevation of 1,100 MG is reached), using a single value for the constant storage depletion that could reasonably be applied to each demand scenario. This is preferable because it makes comparison of the estimated yield and/or deficits between demand scenarios simpler and more consistent. However, as shown in the example above, there is considerable difference in the storage depletion values calculated for each demand condition. We also note that the illustrative calculations above are simplified examples of the reservoir storage depletion operation, and do not account for other gains and losses such as evaporation, fish releases, and inflow, which the model otherwise includes. When these other factors are included in the model analysis, the available monthly storage depletion actually available for each demand condition is less. Considering all these factors, and based on model results from several iterative analyses in which the drought duration (i.e., number of months of drought in the equation above) was varied for each demand condition, a fixed monthly storage depletion of approximately 35 MG/month was determined to be a reasonable value for all demand conditions.

We emphasize that, for each demand condition, a constant supply of 35 MG/month will not be available in each month throughout the entire duration of the drought. For example, the iterative analysis showed that as demands increase in the future the target carryover storage of 1,100 MG could be reached as early as May of the second year of the drought (see Appendix A for the buildout demand condition). Our review of the model results also shows that assuming a lesser storage depletion (e.g., 25 MG/month) would extend the supply availability beyond May, but this is of little impact in reducing the overall maximum monthly deficits which occur later in the summer. In short, as the drought progresses through the summer months of the second year, the supply available from the reservoir is of very limited benefit in meeting the overall system demands (this is discussed further below). We also emphasize that the calculated fixed storage depletion rate is not sufficient to meet the supply needs during drought conditions. To meet the projected deficit during drought, the City will need additional supply, alone or in combination with conservation and/or rationing.

Operational Yield

A recent study estimates the City's future demand at 5,154 MG/yr and 5,490 MG/yr for 2020 and buildout, respectively (Maddaus, 1998) . The year during which build-out demand will occur is not certain, but for the purposes of this study is assumed as 2050. The estimated operational yield for these future demand conditions presented in Table 2.2.

To assist with interpretation of information in the table, relevant information for each of the line items are summarized as follows:

1. **Demand.** Line 1 presents the estimated demand for three different case conditions. The demand estimates are adjusted to reflect the expected demand reduction from naturally occurring conservation such as household plumbing retrofits (ref. Maddaus, 1998). The demand estimates are not adjusted to reflect possible usage curtailment during the drought.

2. **Loch Lomond (LL) Storage Volume in May of the Year Preceding the Drought.** The storage in May of the year preceding the drought is an important parameter in calculating the operational yield during the drought because some of the available storage volume will be used to meet demands during the high water use summer months, just prior to the beginning of the drought period. As the storage is depleted to meet these demands there will be less storage available in the reservoir at the beginning of the drought.

Table 2.2	Estimated Operational Yield During the Critical Drought Year[1,2] Alternative Water Supply Study City of Santa Cruz		
Supply Source	**Current Demand**	**2020 Demand**	**Buildout Demand**
Yield Calculation Parameters			
1. Demand (MG/yr)	4,497	5,154	5,490
2. LL Storage May of Year Preceding Drought	2,810	2,810	2,810
3. LL Storage Jan. 1 First Year of Drought	2,135	1,890	1,835
4. LL Storage Jan. 1 Second Year of Drought	1,625	1,305	1,200
5. LL Storage Dec. 31 Second Year of Drought	1,265	1,110	1,095
River /Groundwater			
6. North Coast	545	545	545
7. San Lorenzo River	1,975[3]	2,035[3]	2,045[3]
8. Beltz Wells	285[4]	325[4]	345[4]
Subtotal River/Groundwater Supply	2,805	2,905	2,935
Loch Lomond			
9. Inflow			
a. Felton	100[5]	85[5]	115[5]
b. Newell Creek	195	195	195
Subtotal Inflow	295	280	310
10. Storage Depletion	360[6]	195[6]	105[6]
11. Other Gains/Losses			
a. Rainfall/Evap	(20)	(10)	(10)
b. Reservoir Release[7]	(340)[7]	(340)[7]	(340)[7]
Subtotal Gains/Losses	(360)	(350)	(350)
Subtotal Loch Lomond Supply	295	125	65
12. **Total Yield**	3,100	3,030	3,000
13. **Total Deficit**	1,400	2,125	2,490

Table 2.2	Estimated Operational Yield (Continued) During the Critical Drought Year[1,2] City of Santa Cruz			
	Supply Source	**Current Demand**	**2020 Demand**	**Buildout Demand**
14.	**Peak Monthly Deficit**	285 (9.2 MGD)[8]	395 (12.8 MGD)[8]	430 (13.9 MGD)[8]
15.	**Peak Monthly Shortfall (% of demand not met)**[9]	56%	68%	71%

(1) Yield from sources calculated from available supply during the second year of the two drought period.
(2) All values in million gallons (MG) unless otherwise specified.
(3) Actual production estimated by model varies due to assumed priority of use for City sources and varying seasonal demands in winter for current, 2020, and 2050 conditions.
(4) Beltz well production assumed as 1.0 mgd maximum capacity per City staff. Actual production estimated by model varies due to assumed priority of use for City sources and varying seasonal demands in winter for current, 2020, and 2050 conditions.
(5) Available inflow from Felton estimated by model varies due to assumed model criteria for diversion, including available flow in river, concurrent use of transmission pipeline for supply, and reservoir storage level.
(6) Storage depletion calculated by subtracting ending reservoir volume from starting reservoir volume.
(7) Releases from the reservoir include1 cfs for maintenance of in-stream fishery habitat and 0.46 cfs assumed to approximate use of annual supply allocation for San Lorenzo Valley Water District.
(8) Supply capacity needed to offset peak monthly deficit, not including demand reduction from new conversation programs that may be implemented by the City, or usage curtailment during drought.
(9) Percent of demand not met does not include demand reduction from new conversation programs that may be implemented by the City, or usage curtailment during drought.

Based on historical rainfall and streamflow data for Newell Creek, the model predicts that the reservoir will be at full capacity, approximately 2,800 MG, in May of the year preceding the drought.

3. **LL Storage Volume on January 1 of the First Year of the Drought.** During the summer months of the year preceding the drought, and the fall months at the beginning of the drought, there is very little inflow to the reservoir. Line 3 of the table identifies how much storage is expected to be available for supply at the start of the drought, assuming normal demand on the reservoir during the preceding months. This starting storage volume is used to estimate how much supply will be *available* during the entire two year drought. The amount of storage available decreases with increasing demand (i.e., current demand vs. estimated buildout demand).

   As shown in the table, the amount of storage at the beginning of the drought ranges from 2,135 MG to 1,835 MG for the current and buildout demand conditions, respectively. These estimated storage volumes represent approximately 75 to 65 percent of maximum reservoir capacity, for the current and buildout demand conditions, respectively. However, it is important to note that 1,100 MG of the storage volume is reserved as carryover storage. An additional amount must be allocated for fish habitat bypass (approximately 240 MG) and storage rights for the San Lorenzo Valley Water District (SLVWD) (approximately 105 MG). Therefore, the actual amount *available* for supply during the two year drought period is reduced by approximately 1,445 MG, ranging from 790 MG to 490 MG for the two demand conditions. These storage volumes represent only about 9 percent and 4 percent of the total demand during the drought for the two demand conditions.

4. **LL Storage Volume on January 1 of the Second Year of the Drought.** Line 4 of the table is included to illustrate how much reservoir storage will remain at the beginning of the second year of the drought. As discussed above, the model calculates the storage volume by assuming a fixed withdrawal rate of approximately 35 MG/month, and also accounts for other gains (rainfall and streamflow) and losses (evaporation, fish flow release) during the first drought year.

   As shown in the table, the amount of storage remaining in the reservoir after the first year of the drought ranges from approximately 1,625 MG to 1,200 MG for the current and buildout conditions, respectively. Accounting for the target carryover storage of 1,100 MG and the 345 MG of fish bypass and SLVWD water storage requirements, the amount of storage available for supply is approximately 280 MG and 0 MG (-145 MG) for the two demand conditions, respectively.

5. **LL Storage Volume at the End of the Drought.** Line 5 of the table illustrates the remaining storage volume at the end of the drought. As shown in the table, the amount of storage remaining at the end of the drought meets or exceeds the 1,100 MG carryover storage target. This is due to rainfall which occurs at the very end of the drought in December of the second calendar year. However, the model predicts that the storage volume in the reservoir does drop to the 1,100 MG storage level — and in fact drops below this value for a short time — in the summer months of the second year of the drought (see Appendix A model outputs).

6. **North Coast Supply.** The north coast system is comprised of three surface diversions, Lidell Spring, Laguna Creek (with contribution from Riggiardo Creek), and Majors Creek. Line 6 of the model shows the estimated total available supply from the three sources. The available supply is calculated based on the estimated available flow at each point of diversion, less operational constraints and/or hydraulic restrictions in the transmission pipeline. For example, staff have observed that the north coastal sources are too turbid to treat during rainy days, so the model assumes no diversions on these days. Likewise, the available diversions are limited to a maximum capacity of 9.1 cfs due to hydraulic limitations in the transmission pipeline (see Appendix A for a more detailed discussion of operational and hydraulic constraints).

7. **San Lorenzo River Supply.** Line 7 of the table shows the estimated available supply from the San Lorenzo River at Tait Street, including the direct surface diversion and the shallow wells. Like the north coast supply, the available supply is calculated based on the estimated available flow and well production less operational constraints (turbidity restrictions and water rights limitations) and pump and pipeline capacity restrictions (see Appendix A).

   The table shows a slight increase in the yield contribution from this source as demand increases toward build-out conditions. This is due to a steady increase in demands during the winter months - when water is most available - which in turn translates into a slight increase in use of this source.

8. **Beltz Well Supply.** Based on discussions with City staff, the estimated maximum sustainable production (i.e., all day, every day) from the Beltz wells is approximately 1 million gallons per day (mgd), or 365 MG/yr. As shown in the table, the estimated contribution to yield from the Beltz wells is less than 365 MG/yr, and varies for each of the three demand conditions.

   The yield contribution is less than the assumed maximum because the model predicts that the wells will not be used to the full 1 mgd capacity during the winter months, when system demands are reduced. During the winter there are many days when the system demands can be met from the north coast and San Lorenzo supplies only, which are assumed to be used first in the model's order of use priority. During the summer months the model predicts that the wells will be used to the full capacity of approximately 30 MG/month.

   The yield contribution varies (increases) between the three demand conditions because increased future demands will correspondingly increase winter time use of the wells.

9. **Loch Lomond Inflow.** Inflow to Loch Lomond comes from two sources: Newell Creek and water diverted (pumped) from the San Lorenzo River at Felton.

   As shown in line 9a of the table, the estimated contribution from Felton is variable. This is because the diversions from Felton are controlled by three variables: available flow in the river, reservoir storage level, and demand from Loch Lomond, according to the following logic:

   Criterion 1: If flow in the river exceeds the minimum fish flow requirement, the model assumes a diversion is possible and proceeds to check the storage level in Loch Lomond.

   Criterion 2: The model assumes that diversions are only possible if the reservoir level is at or below specified seasonal levels (see Appendix A for a complete description of the levels). For example, the model assumes no diversion during the winter months if the reservoir is full or nearly full because of the high probability that the reservoir will fill on its own, and that water pumped would be spilled shortly after pumping.

Criterion 3: If criteria 1 and 2 are met, the model checks, on a daily basis, whether the reservoir is being used for supply. If the reservoir is being used the model assumes no diversion. This is because the connecting pipeline between Felton and the reservoir serves the dual purpose of a transmission main to the City's water treatment facility, so simultaneous use for reservoir filling and withdrawal for supply is not possible.

In the second year of the drought much of the water diverted from Felton occurs in December, at which time the historical hydrology shows the drought ends (see Appendix A). During this time both criteria 1 and 2 are satisfied for all demand scenarios, however criterion 3 is not.

The fact that the model predicts increase diversion from Felton for the buildout demand scenario is directly attributable to criterion 3. For the buildout demand scenario, the reservoir levels are below the minimum carryover storage requirement of 1,100 MG in the month of December. Accordingly, the model assumes that the reservoir cannot be used for supply (withdrawal) during this month, so the model assumes the pipeline is available for filling and calculates increased diversion from Felton based on criteria 1 and 2.

The yield contribution from the Newell Creek inflow (line 9b) is a direct function of the historical hydrology, and is constant for each demand scenario.

10. **Storage Depletion.** The yield contribution from reservoir storage is calculated by subtracting the ending reservoir volume from the beginning reservoir volume. As shown in the table the storage available for supply decreases with increasing system demand. This is a result of increased demands on the reservoir in the year preceding the drought, which directly impact the amount of storage available at the start of, and during the drought (see discussion item 3 above).

11. **Other Gains and Losses.** Gains to the reservoir storage include rainfall which falls directly on the surface area of the reservoir. Losses include evaporation and releases from the reservoir, including the maintenance flow for in-stream fishery habitat and an assumed annual supply allocation for the San Lorenzo Valley Water District. The District has a contractual entitlement to approximately 102 MG/yr of supply from the reservoir, which for the purposes of this study is assumed to be used by them during the drought.

The model predicts that there will be no gains to the reservoir during the drought. The net evaporation loss is less for the 2020 and build-out demand scenarios because the average reservoir volume is less than the current demand condition, thereby reducing the amount of surface area available for evaporation.

12. **Total Yield.** The total operational yield is calculated as the sum of the river and groundwater sources plus the contribution from Loch Lomond Reservoir. As shown in the table, the estimated operational yield ranges between approximately 3,100 and 3,000 MG, for the build-out and current conditions, respectively. After consideration of the model input parameters,

assumptions, and level of accuracy of the yield estimate, an operational yield of 3,000 MG is considered a representative estimate for the range of current and future demand conditions.

As discussed above, this analysis assumes the critical drought conditions would be similar to the two year drought of 1976-77. Line 12 presents the estimated operational yield for the critical year (second year of the drought) only.

13. **Projected Deficit.** The estimated projected deficit is calculated as the difference between the demand and the estimated supply. Line 13 presents the projected deficit for the critical year only, which ranges from approximately 1,400 MG to 2,500 MG for the current and buildout demand conditions, respectively. These projected deficits represent approximately 30 percent and 45 percent of the total estimated demand for the two demand conditions. The cumulative deficit for the entire drought duration, and associated peak seasonal deficits are discussed further below.

14. **Maximum Monthly Deficit.** Demand for water does not occur "on average" during the year; demand varies seasonally, and increases significantly in the summer months. The maximum monthly deficit, which is predicted to occur in July of the second drought year, has been included in the table to show that the City will be faced with significant shortfalls in the summer months. The monthly shortfalls are over two times what would be predicted by simply averaging the estimated annual deficit over twelve month. For example, for the current demand condition the peak monthly shortfall will be approximately 2.45 times higher than would be estimated by averaging the annual deficit (285 MG vs. 115 MG). It is also important to note that although the peak monthly deficit is predicted to occur in July, the estimated deficits in June and August are nearly as high.

    This finding is significant because it illustrates that the City will need new, sustainable, supplies of considerable capacity to meet the projected seasonal demands.

15. **Peak Monthly Shortfall.** As noted in Table 2.2, the calculation of peak monthly deficit does not account for possible demand reductions due to ongoing conservation programs or usage curtailment that would be implemented during a drought. It is reasonable to expect that the combination of conservation and usage curtailment could achieve 15 to 20 percent demand reduction, thereby lowering the projected monthly shortfall. However, even with a significant reduction of demand from conservation and curtailment, the peak monthly shortfall could be as high as 35 to 50 percent of the monthly demand for current and build-out demand conditions, respectively.

Differences in the Operational Yield Estimates

The critical year operational yield varies between 3,000 MG and 3,100 because of the different demands used for the calculation. The varying demand has the following impacts on the calculation of operational yield:

- **Beltz Well and San Lorenzo River Supply.** As noted above, the operational model assumes a specific priority of use for the City's sources. During the summer months all sources will be utilized to their fullest capacity. However, during the winter months there are several days when the demand is low enough, and the supply available from the North Coast and San Lorenzo River is high enough, that the Beltz wells and the San Lorenzo River are not used to their full capacity.

  As demands increase in the future the winter use from the wells and the river will increase. Table 2.2 shows the resulting increase in supply over time for these sources.

- **Loch Lomond Supply.** The equation for fixed withdrawal from the reservoir shows that the amount of supply available from the reservoir depends on the reservoir storage volume at the start of the drought, which in turn is directly linked to the demand in the previous year. As demands increase in the future, the amount of storage in the reservoir at the beginning of the drought will correspondingly decrease. This will decrease the amount of storage available for supply during the drought. Table 2.2 shows the resulting decrease in storage depletion from current to 2050 conditions.

Comparison to Previous Studies

Previous studies have estimated the yield of the City's supply system for the short-term critically dry period of 1976 and 1977. The range of yield from these studies is approximately 3,500 to 3,750 MG/yr for the short-term drought period (CDM, 1994; Leedshill Herkenhoff Inc., 1989). These yield estimates are based on review of historical precipitation records and stream flow data, and are adjusted to reflect similar (or same) operational characteristics of the supply system (i.e., pumping capacity or treatment limitations, hydraulic constraints, storage limitations, etc.), and seasonal use limitations prescribed by water rights.

Comparing the previous results to those calculated for this study it is apparent that the yield estimates vary by approximately 500 to 750 MG. Upon review of the calculations, the differences are accounted for as follows:

- **Contribution from North Coast Supply.** For this study the contribution from the north coast sources is based on actual production records during the 1976-77 drought. Actual production records are used in lieu of model values because comparison of the two data sets showed an apparent bias in the model which slightly underestimated the available supply from the north coast.

  The 1989 study used estimated available stream flow values for the 1976-77 period rather than actual production values, as were used for this study. The supply estimated in the 1989 study for the north coast sources increased the estimated yield during the drought by approximately 180 MG (725 MG vs 545 MG).

  The 1994 study estimated the yield from the City's sources by taking the average available supply during the two year drought period, as calculated from the City's historical production records. In so doing the estimated supply from the north coast sources increased the estimated yield during the drought by approximately 75 MG compared to the estimate for the second year only, as was done for this study (620 MG vs. 545 MG).

- **Contribution from San Lorenzo River.** For this study the available supply was calculated by estimating the daily flow at the diversion, less reductions in flow due to turbidity constraints, water rights constraints, and/or hydraulic capacity limitations. The turbidity constraint used for this study was based on discussions with City staff and was adjusted to more accurately reflect current operating limitations during rainy days.

  The 1994 used similar approach and had similar results. The 1989 study also used a similar approach, but differed in the application of the turbidity constraint. Due to the difference in the turbidity constraint the supply estimated in the 1989 study increased the estimated yield by approximately 155 MG (2,200 MG vs 2,045 MG).

- **Contribution from Loch Lomond.** The assumed contribution from Loch Lomond used for this study was based on a rigorous iterative evaluation of supply and demand before and during the drought. The supply available from the reservoir was determined based on daily comparisons of demand and inflows, gains, and losses from the reservoir. Actual historical reservoir storage levels during 1976-77 were not used as the basis for estimating the available supply because the result would have been an underestimation of supply. This is because the reservoir storage level was down at the start of the of the 1976-77 drought due to prolonged maintenance at the Tait Street pump station prior to the start of the drought, which resulted in increased withdrawals from the reservoir.

  The 1989 study estimated the second year drought contribution from Loch Lomond at approximately 570 MG. This available supply was determined based on an assumed ending reservoir storage volume of approximately 670 MG, which compares to the assumed 1,100 MG carryover storage used in this study. The resulting increase in supply from the reservoir is approximately 430 MG (assuming similar reservoir storage levels at the start of the drought of approximately 1835 MG).

  The 1994 study estimated the supply from Loch Lomond by taking the average available supply during the two year drought period, similar to the approach used in this study. However, the 1994 study estimated the total available supply from the reservoir at approximately 480 MG during the second year of the drought compared to approximately 65 MG estimated for this study of (assuming similar reservoir storage levels at the start of the drought of approximately 1,835 MG). After detailed review and comparison of the assumed inflows, gains, and losses in the reservoir, the difference of approximately 415 MG can be accounted for as follows:

  - The 1994 study assumes a 1,000 MG carryover storage, but does not account for storage allocated for use by the San Lorenzo Valley Water District. This storage volume is an annual allotment and has been assumed in this study to be used by the District in each of the two drought years, resulting in 200 MG of additional withdrawal (release) from the reservoir during the two year drought period. Thus, the 1994 estimates an additional 100 MG of the supply available from the reservoir during the second year of the drought compared to this study.

- The 1994 study assumes that the ending reservoir storage volume will be 1000 MG, and calculates the available storage depletion from the reservoir as approximately 420 MG (1835 MG $_{start}$ - 1000 MG $_{end}$)/2 years = +/- 420 MG/year). This storage volume was calculated, but not actually modeled on a daily time step as was done in this study. As discussed above, this study assumes a fixed withdrawal from the reservoir only until the minimum carryover storage volume of 1,100 MG is reached (1,000 MG useable storage plus 100 MG dead storage).

  Referring to Table 2.2, the buildout demand conditions result in a reservoir storage level at the start of the drought of 1835 MG, the same as assumed in the 1994 study. For these conditions, the model predicts that the 1,100 MG minimum pool elevation will occur in May of the second year of the drought, and no further withdrawals for supply will be made. Because the model assumes no additional withdrawals starting in May, the total estimated storage depletion during the second year of the drought is approximately 315 MG less than is calculated using the 1994 study approach (420 MG vs. 105 MG).

The preceding discussion highlights the differences between the yield estimates, and explains why the previous studies reached different conclusions. For the 1989 study the total difference between the three surface sources resulted in an increase in the yield calculation of approximately 765 MG (180 MG + 155 MG + 430 MG = 765 MG). For the 1994 study, the total of the difference resulted in an increase of approximately 480 MG (75 MG + 415 MG = 480 MG).

Clearly, the estimated yield from the previous studies is higher than the operational yield estimated by model. However, we believe that the yield estimated by the operational model is more representative of the actual supply conditions than the previous studies. There are two factors to support this conclusion:

- **Daily Time Step.** The model has been developed to evaluate the supply and demand conditions on a daily time interval. The daily time interval provides the most refined data set, and therefore the most accurate method to evaluate the supply availability as it would *actually* occur during specific seasonal demand conditions. The previous studies estimated the *average* supply availability during the two year drought period, which as shown above, could lead to overestimation of the available supply. An example of how daily information is more beneficial than assumed average conditions is demonstrated by the comparing the differences in estimated supply availability from Loch Lomond as calculated by this study versus the 1994 study.

- **Updated Operational Criteria.** The model has been developed to incorporate the most up-to-date operational criteria and constraints, and therefore provides the most accurate simulation of the City's actual operation. An example of how the updated operational information changed the yield calculation from the previous studies is again demonstrated by comparing the differences in estimated supply availability from Loch Lomond. Our evaluation assumed a reasonable carryover storage volume of 1,100 MG versus 530 MG carryover storage (of which only 330 MG would be useable storage) assumed in the 1989 study, a difference of 470 MG. Similar differences, although less pronounced, occurred between this study and the 1994 study.

Monthly and Seasonal Supply

One of the primary benefits of the daily time step is that it provides an accurate estimation of supply and deficit conditions as demand varies by season. For example, daily information can easily be translated into monthly or quarterly data by summation. Previous studies estimated the average deficit conditions over the two year drought, but did not define the deficits during the peak summer demand season. Although this type of average data is useful to broadly define the supply shortfall over a long period of time, it is not sufficient to adequately characterize how the shortfall will actually impact the City's water supply operation.

Review of the monthly data developed for this study shows that the deficit accumulates primarily during the peak demand months of May through October. This result is expected, but is also uniquely different than information developed from previous studies. The data shows that the City will face very high monthly deficits during this six month period, much higher than would be predicted by averaging the total projected deficit over twelve months.

Table 2.2 presented the estimated supply deficit for the most critical year (second calendar year) of the two year drought. The second year was depicted because the deficits will be most pronounced during this period due to the fact that available supply decreases as the drought duration progresses. This second calendar year period is also convenient for evaluating supply and deficit conditions because it ends at the same time as 1976-77 dry period ended. However, we note that the model output shows that similar deficits will occur during the first year of the drought. In fact, the model predicts that deficits will actually begin to occur several months prior to the two year calendar period start date and will also extend beyond the two year calendar period. Simply stated, the drought could actually impact the City's operation for as long as 31 months, not just the 24 month calendar period as was estimated by previous studies.

Table 2.3 presents a summary of the monthly, seasonal, and total deficits for each of the three demand conditions. The table outlines new information developed in this study as a result of data evaluation in daily time steps converted to monthly outputs. The most significant finding of this evaluation is that the City will face an estimated maximum monthly shortfall ranging from approximately 300 to 450 MG. Lacking the capability to store large volumes of water, the City would need new sustainable water supplies capable of producing approximately 9.0 to 14.0 mgd.

This is an increase of supply of approximately 5 to 10 mgd compared to estimates developed previously.

Water Supply in Non-Drought Years

The preceding analysis focused on supply and deficit conditions during drought years. However, as noted earlier in this document this study modeled supply and demand conditions for the historical hydrologic period from 1935-95. This modeling allows examination of current and future supply conditions in non-drought years.

Table 2.3 Estimated Monthly and Seasonal Deficits During the Critical Drought Year[1,2] Alternative Water Supply Study City of Santa Cruz

Deficit Condition	Current Demand	2020 Demand	Buildout Demand
Maximum Monthly Deficit[3]	285 (9.2 MGD)	395 (12.8 MGD)	430 (13.9 MGD)
Maximum Seasonal Deficit[4]	1,245	1,800	2,070
Maximum Annual Deficit	1,035	2,125	2,490
Total Drought Deficit[5]	2,605	3,970	4,760
Total Drought Duration[6]	30 months	30 months	31 months

Notes:
(1) Deficits are calculated during the second year of the critical two drought period unless otherwise specified.
(2) All values in million gallons (MG) unless otherwise specified.
(3) Maximum month deficit occurs in July of the second drought year.
(4) Maximum seasonal deficit calculated by summing monthly deficits during May - October.
(5) Total drought deficit calculated by summing monthly deficits for the entire drought duration.
(6) Total drought duration by included months of deficit before and after the start of the calendar two year drought period, as represented by historical hydrology.

Figures 2.2 through 2.4 show the operational yield for the City's existing supply system for each of the three demand scenarios. As shown in the graphs, supply shortfalls to occur much more regularly in the future, and will not be isolated to severe drought periods only (assuming future hydrologic patterns will be similar to historic conditions observed from 1935-95). For example, Figure 2.2 shows that the City could face shortfalls in nearly one out of every two years. Figure 2.3 shows that by 2020 the City could face supply shortfalls three out of every four years. Figure 2.4 shows that supply shortfalls would occur essentially every year under the assumed build-out demand conditions.

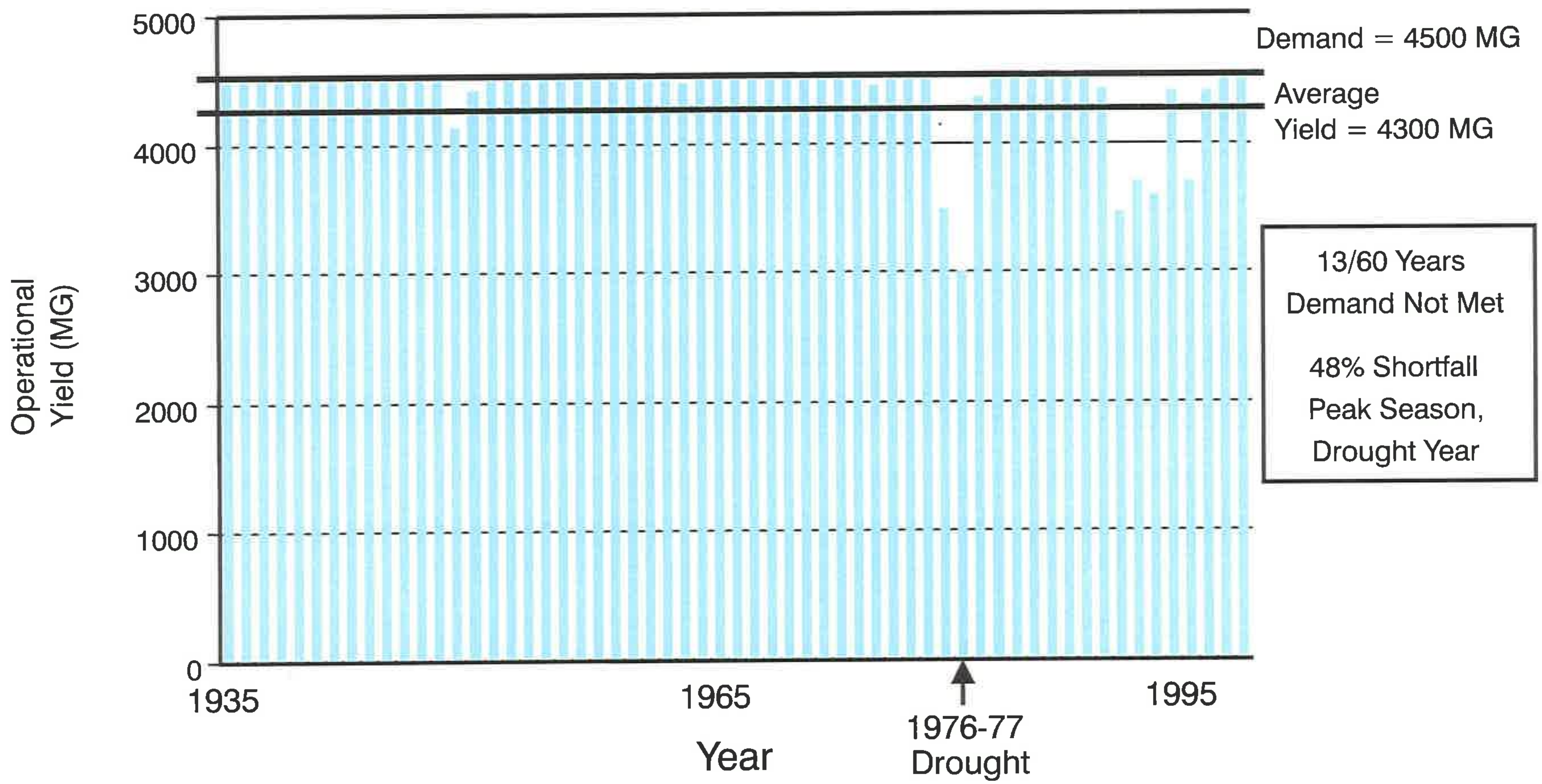
FINDINGS AND CONCLUSIONS

Significant findings and conclusions of our analysis are as follows:

- **Storage Capacity is Very Limited.** The available storage in Loch Lomond is undersized for the projected future supply needs. In drought years, the storage available for supply is only on the order of 9 percent (best case) to 0 percent (worst case) of the estimated demands.

- **New Water Supply Sources are Needed.** Lacking significant water storage capacity, new water supply sources must be developed. The preceding analysis is based on projected water demands that have not been adjusted to reflect the City's ongoing water conservation programs, or water usage curtailment that could be implemented in a severe drought. It is possible that the combination of conservation and curtailment could reduce the demands - and the resulting deficits - by 15 to 20 percent. However, even if these or more rigorous conservation and usage curtailment targets are achieved, the City still faces significant projected deficits, and will need new sources capable of producing up to 11.5 mgd of additional supply during peak demand conditions.

- **Future Supply Deficits Occur in Non-Drought Years.** The evaluation of future supply and demand conditions showed that deficits will occur with increased frequency, and will not be limited only to severe drought years. We emphasize that *the range of estimated monthly shortfalls varies depending on the hydrologic conditions, and in many cases would be small enough to be overcome by implementation of conservation and/or curtailment, provided that such measures are implemented - and are successful - every year.* New water supply strategies which integrate conservation, usage curtailment, and new water supplies will need to be developed.

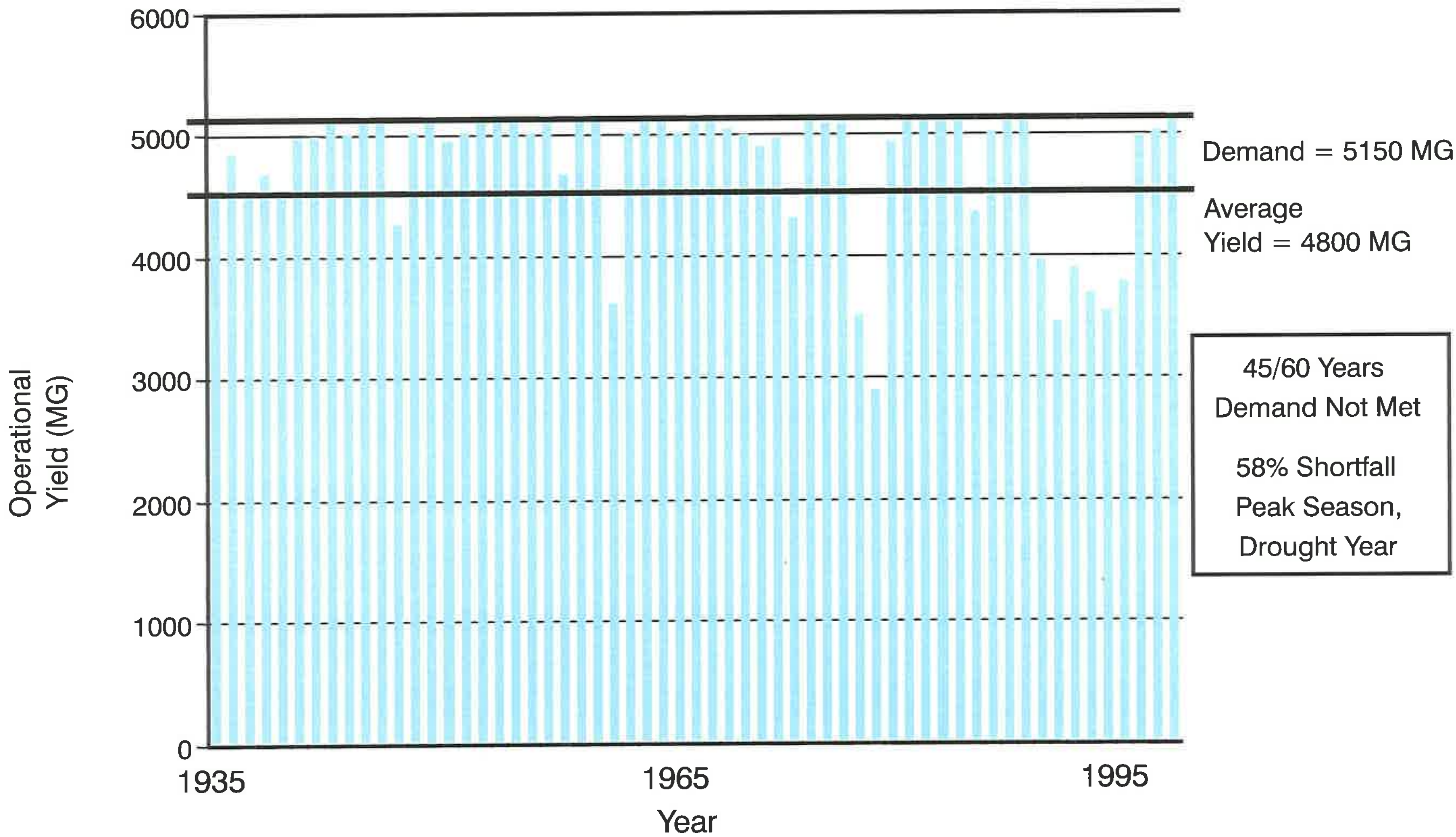


(1) Graph shows operational yield calculated based on historical hydrology from 1935-1995 for current demand conditions.

(2) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(3) Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 2.2
HISTORICAL HYDROLOGY VS 2000 DEMAND[1, 2, 3]
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY



(1) Graph shows operational yield calculated based on historical hydrology from 1935-1995 for current demand.

(2) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(3) Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 2.3
HISTORICAL HYDROLOGY VS 2020 DEMAND[1, 2, 3]
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY

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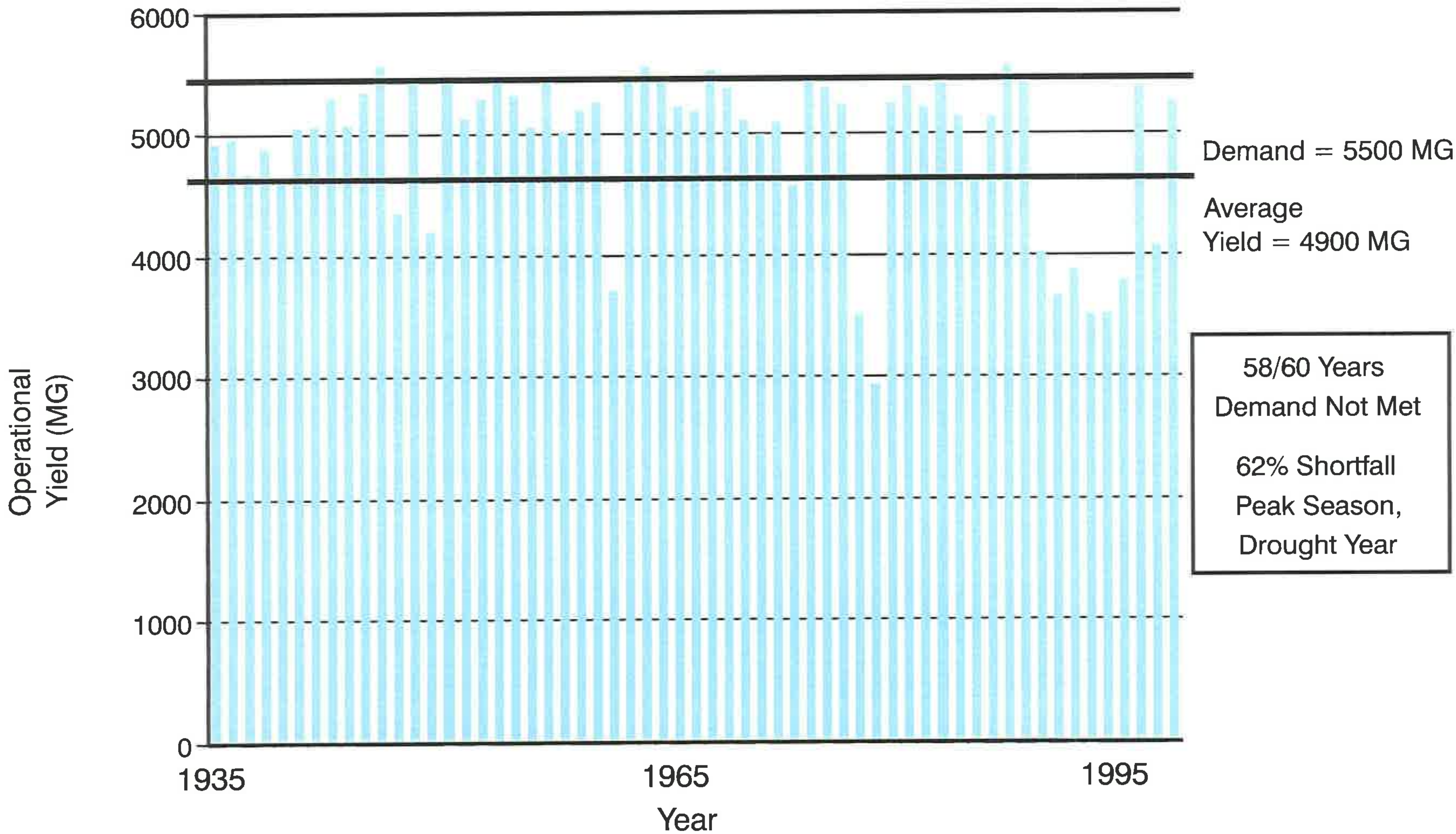


(1) Graph shows operational yield calculated based on historical hydrology from 1935-1995 for current demand.

(2) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(3) Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 2.4
HISTORICAL HYDROLOGY VS BUILDOUT (1, 2, 3)
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY

APPENDIX A - OPERATIONAL MODEL OUTPUT

Model Assumptions
Summary of Model Output
- Demand at 4,497 MG
- Demand at 5,154 MG
- Demand at 5,490 MG

Complete Model Output
- Demand at 4,497 MG
- Demand at 5,154 MG
- Demand at 5,490 MG

December 30, 1998

Operation model of Santa Cruz City Water System, Present Conditions

A daily computer model has been constructed to simulate the operation of the individual components of the City's water system. The components of the Santa Cruz Water system are: the north coast diversions, Tait St. surface and well diversion, the Felton diversion of San Lorenzo river flow into Loch Lomond reservoir, the Beltz well field and the operation of Loch Lomond reservoir to deliver water to the Graham Hill water treatment plant. Each component has physical characteristics that are represented in the model. The period of daily model simulation is from October 1, 1935 to September 30, 1996. The purpose of modeling this extended period is to evaluate the impact of critical drought operation decisions on normal to below normal water supply years. Similarly, system operation in normal years will determine the reservoir volume at the beginning of extreme drought periods.

I. Daily Stream Flow and Demand records.

Daily flow records have been developed for key input points in the system. The points are:

I.1 Liddell Spring inflow
I.2 Laguna and Riggiardo Creeks inflow
I.3 Majors Creek inflow
I.4 Newell Creek reservoir inflow
I.5 Flow on the San Lorenzo River at Big Trees,
(a) with historic felton diversion added
(b) with Newell Creek inflow subtracted, before Oct. 1960
I.6 Flow on the San Lorenzo River at Big Trees, modified by LH Table E-21 " Losses between Big Trees gauge and Tait Street Diversion"
I.7 A daily demand pattern was developed from the January to December 1994 period. The data total demand for the year was divided into each day. This produced a fraction for each day of the year. Multipling the data by the desired annual demand purduces the daily demand values. The monthly values were multiplied by a fraction to match the monthly distribution used in the Maddaus study on demand. For the purposes of system evaluation two demands are evaluated: the current demand, 4497 mg/yr and estimated buildout demand of 5490 mg/yr.

II. Model Operation

The simulation of the system proceeds each day through the physical components of the City's network in this order:

II.1 Liddell Spring. All flow from 0.0 cfs to 2.6 cfs(1167 gpm) will be diverted to the north Coast pipeline. Maximum capacity 2.6 cfs(1167 gpm). The diversion is turned out if rain occurrs on that day and is not turned in until the second dry day.

II.2 Laguna and Riggiardo Creeks. All flow from 0.0 to 6.6 cfs (2962 gpm) will be diverted to the north coast pipe line. Maximum capacity is 6.6 cfs(2962 gpm). The diversion is turned out if rain of greater than 1 inch occurrs on any day and is turned in the next day.

II.3 Majors Creek. Because Majors Creek is at a lower elevation than Laguna or Liddell, flow from Majors does not enter the north coast pipe line until the flow in Laguna is below 4.12 cfs (1850 gpm). Jim Bently observed that when Laguna is 1500 gpm, Majors is about 300 gpm and when Laguna is 1000 gpm Majors contributes about 700 gpm. This relationship has been represented in the model. The range of possible flow from Majors is from 0.0 to 1.56 cfs(700 gpm). The diversion is turned out if rain occurrs on that day and is not turned in until the second dry day.

For November to May:

San Lorenzo flow cfs	Diversion pumps cfs	gpm
0.0	0.0	0.0
27.40	0.0	0.0
27.41	4.40	1975
28.97	4.40	1975
28.98	5.97	2680
30.35	5.97	2680
30.36	7.35	3299
31.47	7.35	3299
31.48	8.47	3801
32.69	8.47	3801
32.70	9.69	4359
33.25	9.69	4349
33.26	10.25	4600
33.90	10.25	4600
33.91	10.90	4892
34.81	10.90	4892
34.82	11.81	5300
35.59	11.81	5300
35.60	12.59	5650
36.81	12.59	5650
36.82	13.81	6198
100000	13.81	6198

II.6.b Loch Lomond reservoir is below
6138 AF (2,000 MG) for September, October and November
6445 AF (2,100 MG) for December and January
7058 AF (2,300 MG) for February
7673 AF (2,500 MG) for March
8287 AF (2,700 MG) for April
8593 AF (2,800 MG) for May
These are operation rules are intended to prevent the water diversion from Felton to Loch Lomond if there is possibility that the reservoir would spill later in the year. This is an economic consideration.

II.6.c Flow on the San Lorenzo is above 13 cfs in September or 28 cfs in October or 23 cfs in November through May

II.6.d Water is not being diverted from Loch Lomond Reseroivr to the Graham Hill water treatment plant

II.6.e The flow of the San Lorenzo at Felton is not above 1,000 cfs

II.6.f No water is diverted from Felton until the stream flow has exceeded 100 cfs on two separate days. This condition must be met each year after September 1st.

II.6.g Water right: the maximum amount of water diverted from Felton to Loch Lomond Reservoir is 3000 acre-ft in any year. For this analysis the year is assumed to be January 1 to December 31.

II.6.h The flow at Big Trees on the San Lorenzo is reduced by channel lossed, LH table E-21, to estimate the flow reaching Tait St.

II.7 The remaining residual demand (from II.5 above) is met by the surface diversion at Tait St. maximum capacity 11.2 cfs (5,027 gpm). If the rainfall is greater that 0.5 inches in the day and the stream flow at Tait St. is above 450 cfs, the surface diversion is canceled do to excess turbidity. This leaves a residual demand. Three pumps are used:

San Lorenzo cfs	diversion cfs (gpm)
0.0	0.0 0
5.12	0.0 0
5.13	5.12 (2300)
10.24	5.12 (2300)
10.25	10.24 (4600)
11.19	10.24 (4600)
11.20	11.19 (5022)
100000	11.20 (5027)

II.8 The remaining residual demand (from II.7 above) is met by the wells at Tait St., maximum capacity 1.9 cfs(853 gpm). If the Tait St. wells can not meet this demand another residual demand is created. If however the flow in III. and IV. are greaterh than 12.2 cfs (5475 gpm), the 1.9 cfs (853 gpm) is reduced to meet the water right of 12.2 cfs. (5475 gpm).

II.9 The three diversions are North Coast, Tait St.- surface and Tait St.- well are added together. If greater than 20 cfs (8976 gpm), pipe line capacity to the Graham Hill treatment plant, they are reduced to 20 cfs(8976 gpm). If above 20 cfs (8976 gpm) the demand met from the flow above 20 cfs is added back into the residual demand.

II.10 The residual demand (from II.8 above) is met by the Beltz wells. Maximum capacity 1.55 cfs(694 gpm or 1 MGD). If the Beltz wells can not meet the remaining demand, the remaining residual demand is carried forward. The beltz wells go directly to the treatment plant and do not effect the capacity of the Tait St. system.

II.11 The residual demand (from II.10 above) is met by Loch Lomond reservoir. If water is required from Loch Lomond on the same day a diversion from Felton has occurred, the Felton diversion is canceled and the pipeline is used only to transfer water from the reservoir to the Graham Hill water treatment plant. The minimum reservoir volume is 3,379.6 acre-ft or 1100 MG. This mimimum reservoir volume consists of 100 MG for reservoir dead storage not available for use and a critical reservoir reserve storage of 1000 MG. The total amount of water diverted from Loch Lomond reservoir in any year is 3200 acre-ft (1042.6 MG). Of this amount the San Lorenzo Valley Water District will take 102.1 mg/yr (313.4 acre-ft/yr), the remaining amount 940.5 mg (2886.6 acre-ft/yr) is the maximum available to the City. For this evaluation the year is assumed to be from January 1 to December 31.

The maximum storage in Loch Lomond reservoir is 8624 acre-ft. This is a water right limit. Any flow above this volume is spilled down Newell Creek to the San Lorenzo River. A 1 cfs fish flow is released each day from Loch Lomond reservoir. The 313.4 acre-ft/yr to be taken by the San Lorenzo Valley Water District is assumed to be a uniform withdrawal of 0.43 cfs/day over the year. No drought restrictions were placed on this withdrawal. The maximum diversion to storage in Loch Lomond reservoir is 5600 acre-ft per season of diversion, September 1 to July 1.

II.12 However water diverted to Loch Lomond from Felton is water diverted to stoarge. The water from Felton in Loch Lomond can not be used for 30 days from the last Felton diversion. This water is not included in the 940.5 MG (II.11 above)limit. (3200 af/yr less 313.4 af/yr for San Lorenzo Valley Water District)

III. Simulation output.

The simulation of the water supply provides a monthly summary at key points in the system. Daily flow values to understand specific operations can also be developed for the entire period of record, October 1, 1936 to September 30, 1996. A summary of the output is provided for three demand levels: current demand 4497 mg/yr, year 2020 demand 5154 mg and year 2050 demand 5490 mg/yr. A example of the output is provided for the drought period 1976 to 1977. The location of the flows are shown on the attached drawing of the Santa Cruz Water Supply System.

The data series are identified by index names:

Index Name

- Flw66: the total demand not met for the total system
- Flw54: the component of demand met from the North Coast
- Flw56: the water diverted from Felton diversion
- Flw58: the component of demand met from Tait St., Surface
- Flw61: the component of demand met from Tait St., Wells
- Flw63: the component of demand met from Beltz wells
- Flw65: the component of demand met from Loch Lomond Res.
- Res80: Loch Lomond reservoir storage, million gallons
- Flw67: Loch Lomond reservoir spill down stream.

II.4 The sum of three north coast sources is reduced by the maximum capacity of the north coast pipe line, 9.1 cfs (4084 gpm).

II.5 For each day of the simulation there is a daily demand. The North Coast flows are used to meet this demand. Any demand not met by the North Coast sources is carried forwarded to the next source of supply. This leaves a residual demand yet to be met.

II.6 The flow on the San Lorenzo at Felton is diverted to Loch Lomond if:

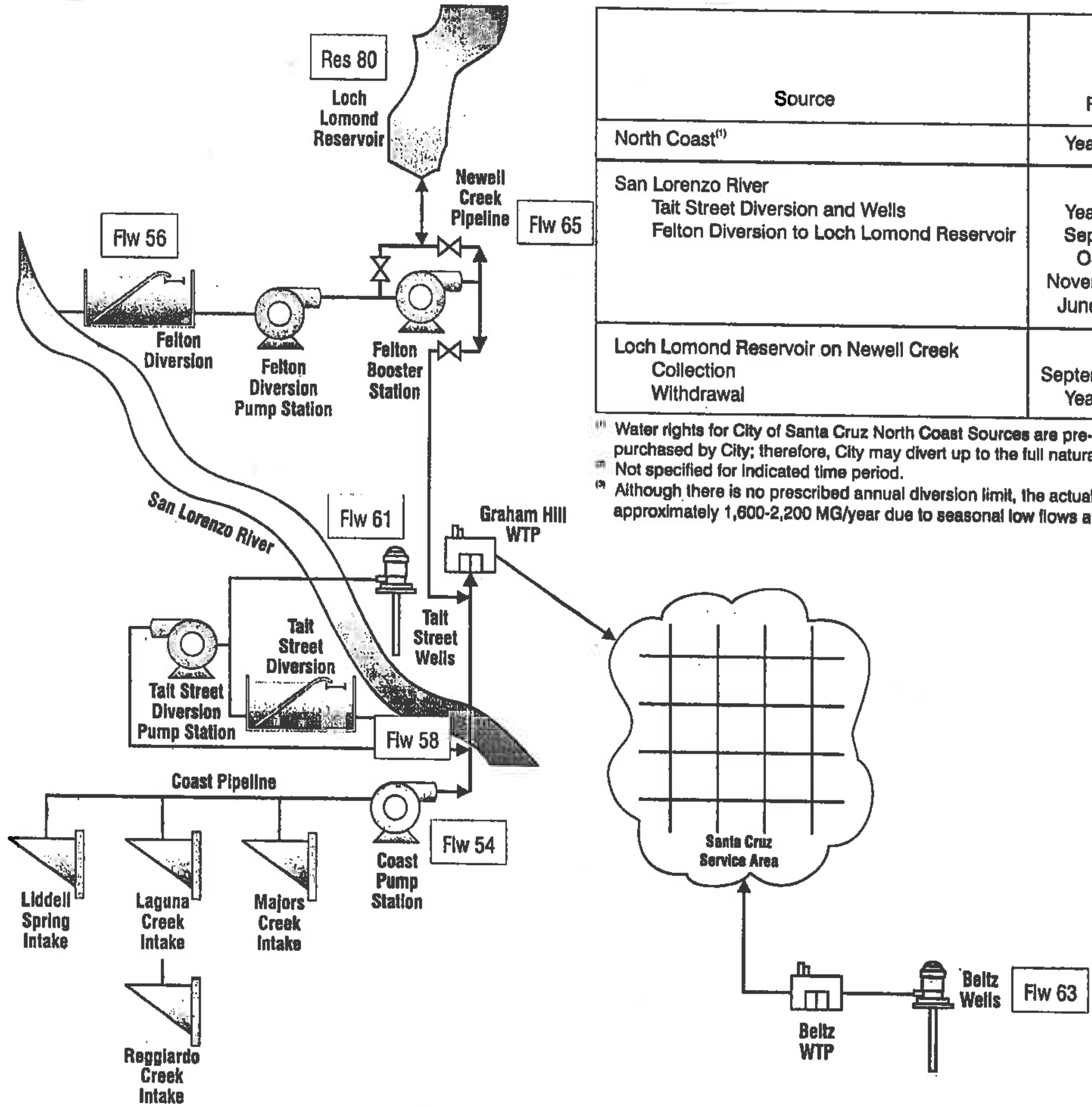
II.6.a The date is between September and May, following the diversion table:

For September:

San Lorenzo flow cfs	Diversion pumps cfs	gpm
0.0	0.0	0.0
17.40	0.0	0.0
17.41	4.40	1975
18.97	4.40	1975
18.98	5.97	2680
20.35	5.97	2680
20.36	7.35	3299
21.47	7.35	3299
21.48	7.80	3801
100000	7.80	3801

For October:

San Lorenzo flow cfs	Diversion pumps cfs	gpm
0.0	0.0	0.0
32.40	0.0	0.0
32.41	4.40	1975
33.97	4.40	1975
33.98	5.97	2680
35.35	5.97	2680
35.36	7.35	3299
36.47	7.35	3299
36.48	8.47	3801
37.69	8.47	3801
37.70	9.69	4359
38.25	9.69	4349
38.26	10.25	4600
38.90	10.25	4600
38.91	10.90	4892
39.81	10.90	4892
39.82	11.81	5300
40.59	11.81	5300
40.60	12.59	5650
41.81	12.59	5650
41.82	13.81	6198
100000	13.81	6198



Source	Period	Maximum Diversion Rate (cfs)	Fish Flow Require-ments (cfs)	Annual Diversion Limit (MG/year)
North Coast[1]	Year-round	No limit	None	None
San Lorenzo River				
Tait Street Diversion and Wells	Year-round	12.2	None	None[3]
Felton Diversion to Loch Lomond Reservoir	September	7.8	10 }	977
	October	20.0	25 }	
	November-May	20.0	20 }	
	June-August	--[2]	--	
Loch Lomond Reservoir on Newell Creek				
Collection	September-June	No limit	--	1,825
Withdrawal	Year-round	--	1	1042

(1) Water rights for City of Santa Cruz North Coast Sources are pre-1914 rights with all downstream rights purchased by City; therefore, City may divert up to the full natural flow of each stream.
(2) Not specified for indicated time period.
(3) Although there is no prescribed annual diversion limit, the actual available diversion is constrained to approximately 1,600-2,200 MG/year due to seasonal low flows and high turbidity.

Figure 1
SANTA CRUZ
WATER SUPPLY SYSTEM
CITY OF SANTA CRUZ

SC00F1.CDR

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The following data series are output from the simulation model with a current demand of 4,497 Million Gallons/year

INDEX NAME: flw66
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1948	0	0	0	48.2	14.1	34.8	69.6	76.4	84.8	8.54	6.67	21.2	364.26
1949	15.1	1.88	58.3	0	0	0	0	0	0	0	0	0	75.28
1961	0	0	0	0	0	0	0	0	0	0	41.4	0	41.37
1972	0	0	0	0	0	0	0	0	0	38.4	14.6	0	52.98
1976	0	0	0	15.3	43.1	159	237	224	190	89.1	42.5	15.2	1014.76
1977	9.33	5.95	14.3	25.2	119	223	283	273	223	122	62.7	36.1	1397.50
1978	58.6	41.6	39.3	0	0	0	0	0	0	0	0	0	139.53
1987	0	0	0	0	0	0	0	0	0	0	23.6	59.2	82.87
1988	0	0	0	20.8	75.6	130	229	223	172	98.1	62.4	26.1	1037.05
1989	5.07	5.22	47.4	14.3	30.0	114	212	153	137	61.6	6.58	0	786.44
1990	16.0	15.8	4.53	8.95	78.8	107	135	180	179	102	67.9	16.5	911.00
1991	0	20.0	80.4	0	0	0	0	0	0	0	0	0	100.40
1992	0	0	0	0.44	34.9	117	131	190	162	66.4	40.8	37.3	779.95
1993	73.6	43.3	5.88	0	0	0	0	0	0	0	0	0	122.84
Aver.Mo.	3.01	2.27	4.24	2.26	6.71	14.98	22.00	22.36	19.45	9.94	6.26	3.59	

Annual Average: 117.05

INDEX NAME: flw54
COMMENT: North.Coast.component.of.Demand

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw56
COMMENT: Water.diverted.to.Loch.Lomond.reservor

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1976	0	0	53.7	11.0	0	0	0	0	0	0	0	0	64.69
1977	20.7	0	24.9	0	0	0	0	0	0	0	0	53.6	99.14
Aver.Mo.	6.90	.00	26.20	3.66	.00	.00	.00	.00	.00	.00	.00	17.85	

Annual Average: 54.61

INDEX NAME: flw58
COMMENT: Tait.st.amount.diverted.to.meet.demand

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	177	113	128	182	222	217	224	217	217	202	208	199	2306.67
1976	205	191	196	210	224	168	103	125	107	128	157	183	1997.15
1977	197	184	199	202	180	110	101	102	99.9	106	130	146	1756.63
Aver.Mo.	192.95	162.96	174.52	197.86	208.63	165.17	142.55	148.01	141.39	145.03	164.91	176.17	

Annual Average: 2020.15

INDEX NAME: flw61
COMMENT: Amount.of.demand.met.by.Tait.st.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	5.96	7.25	6.97	7.61	15.7	19.4	20.0	20.6	19.4	20.0	12.5	7.09	162.47
1976	4.24	10.4	8.17	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.6	9.09	246.69
1977	8.82	4.88	10.6	12.3	20.8	34.3	12.8	7.91	20.9	32.7	28.7	23.7	218.33
Aver.Mo.	6.34	7.52	8.59	13.29	18.23	24.79	23.63	20.42	24.44	28.38	20.26	13.29	

Annual Average: 209.17

INDEX NAME: flw63
COMMENT: Amount.of.demand.met.by.beltz.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	3.15	9.49	12.7	6.69	20.3	30.0	31.0	31.0	30.0	23.3	12.8	8.03	218.50
1976	0.88	12.2	4.86	27.2	29.8	30.0	31.0	31.0	30.0	30.7	-26.6	16.8	270.95
1977	5.32	5.55	11.3	28.8	31.0	30.0	31.0	31.0	30.0	31.0	25.9	24.2	285.13
Aver.Mo.	3.12	9.08	9.62	20.92	27.03	30.00	31.00	31.00	30.00	28.33	21.76	16.34	

Annual Average: 258.19

INDEX NAME: flw65
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	11.9	60.3	75.0	16.3	13.1	87.7	147	142	81.8	60.9	13.6	3.64	712.83
1976	0	7.89	12.9	22.1	32.1	34.5	35.6	35.6	34.5	33.9	25.0	8.99	283.19
1977	2.36	2.68	8.88	23.7	35.6	34.5	35.6	35.6	34.5	35.6	27.0	18.1	294.31
Aver.Mo.	4.76	23.63	32.26	20.71	26.96	52.24	72.60	71.12	50.25	43.47	21.86	10.26	

Annual Average: 430.11

INDEX NAME: res80
COMMENT: Loch.Lomond.Reservoir.Storage

Million Gallons

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2417	2786	2815	2811	2805	2711	2532	2354	2239	2187	2155	2135
1976	2117	2106	2135	2109	2040	1965	1883	1814	1751	1684	1641	1625
1977	1643	1625	1636	1582	1520	1449	1372	1295	1234	1169	1144	1267

INDEX NAME: flw67
COMMENT: Loch.Lomond.spilled.flow

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	681	194	64.8	27.8	28.7	28.7	27.8	28.7	27.8	28.7	1192.59
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	245.99	83.33	40.75	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 623.13

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The following data series are output from the simulation model with a 2020 year demand of 5154 mg/year.

INDEX NAME: flw66
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1937	0	0	0	0	0	0	0	0	103	67.2	57.2	49.3	277.07
1938	0	0	0	0	0	0	0	7.04	155	66.1	29.9	4.12	262.31
1939	0	0	0	0	0	0	0	0	151	125	67.6	27.8	370.97
1940	0	0	0	0	0	0	0	0	103	74.5	35.2	97.0	309.26
1941	0	0	0	0	0	0	0	139	142	63.3	35.6	59.8	439.60
1942	0	0	0	0	0	0	0	0	21.4	72.4	50.5	21.5	165.72
1943	0	0	0	0	0	0	0	0	7.92	69.1	33.9	27.0	137.89
1945	0	0	0	0	0	0	0	0	0	0	0	63.6	63.57
1948	0	0	0	65.4	48.7	99.3	143	149	150	45.6	25.8	27.8	754.81
1949	20.5	3.10	78.1	0	0	0	0	0	0	0	0	0	101.67
1951	0	0	0	0	0	0	0	0	0	20.3	73.3	90.4	184.05
1952	0	0	0	0	0	0	0	0	0	0	43.9	68.9	112.81
1953	0	0	0	0	0	0	0	0	0	0	4.81	9.31	14.12
1955	0	0	0	0	0	0	0	0	0	0	0	53.4	53.40
1956	0	0	0	0	0	0	0	0	0	87.6	23.6	6.52	117.78
1958	0	0	0	0	0	0	0	0	130	63.8	38.9	16.4	248.74
1959	0	0	0	0	0	0	0	0	0	23.2	31.4	15.3	69.91
1961	0	0	0	9.98	74.0	166	287	293	256	160	124	14.8	1385.12
1962	8.49	78.9	35.9	0	0	0	0	0	0	0	0	0	123.38
1964	0	0	0	0	0	0	0	0	0	0	0	24.3	24.26
1965	0	0	0	0	0	0	0	0	0	0	65.2	47.3	112.45
1966	0	0	0	0	0	0	0	0	0	0	4.33	45.9	50.23
1968	0	0	0	0	0	0	0	0	0	0	23.5	52.5	75.92
1969	0	0	0	0	0	0	0	0	0	3.80	34.7	69.9	108.37
1970	0	0	0	0	0	0	0	0	0	2.36	106	71.4	180.02
1971	0	0	0	0	0	0	0	0	0	17.6	69.4	63.1	150.08
1972	0	0	0	0	0	0	0	97.1	303	138	32.2	0	570.54
1974	0	0	0	0	0	0	0	0	0	0	41.0	28.1	69.10
1975	0	0	0	0	0	0	0	0	0	82.1	39.0	16.2	137.30
1976	0	0	0	51.8	101	228	311	296	255	142	79.0	28.4	1492.14
1977	12.0	9.70	26.4	64.0	181	309	393	381	322	212	132	83.2	2125.78
1978	78.7	55.8	53.7	0	0	0	0	0	0	0	0	0	188.17
1979	0	0	0	0	0	0	0	0	0	0	0.33	47.9	48.20
1980	0	0	0	0	0	0	0	0	0	0	22.1	20.5	42.57
1982	0	0	0	0	0	0	0	0	0	0	21.5	37.2	58.67
1983	0	0	0	0	0	0	0	115	157	48.1	78.0	90.6	488.73
1984	0	0	0	0	0	0	0	0	0	0	92.2	15.6	107.80
1987	0	0	0	35.0	91.2	166	224	295	249	136	55.1	64.0	1316.10
1988	26.3	0	0.32	45.4	135	199	303	295	238	152	95.7	35.8	1526.24
1989	7.13	6.94	63.6	48.5	83.9	184	286	225	203	107	18.8	1.11	1234.33
1990	22.4	19.7	5.68	37.1	136	176	209	252	244	156	109	51.3	1418.78
1991	21.5	37.0	106	28.9	108	172	275	290	247	160	63.6	81.8	1590.86
1992	13.6	85.1	19.4	19.2	91.6	186	205	262	228	119	85.3	53.8	1368.20
1993	96.8	61.0	10.2	0	0	0	0	0	0	0	0	0	167.97
1994	0	0	0	0	0	0	0	0	0	67.5	51.3	0.03	118.78
Aver.Mo.	5.12	5.95	6.65	6.75	17.53	31.43	43.94	51.62	61.07	41.37	33.25	28.04	

Annual Average: 332.73

INDEX NAME: flw54
COMMENT: Demand met from North Coast Sources

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw56
COMMENT: Water.diverted.to.Loch.Lomond.reservor

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	0	17.9	0	0	0	0	0	0	0	0	0	0	17.85
1976	0	0	41.9	0	0	0	0	0	0	0	0	0	41.94
1977	0	0	7.04	0	0	0	0	0	0	0	0	80.3	87.37
Aver.Mo.	.00	5.95	16.33	.00	.00	.00	.00	.00	.00	.00	.00	26.78	

Annual Average: 49.05

INDEX NAME: flw58
COMMENT: Tait.st.amount.diverted.to.meet.demand, Surface diversion

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	201	130	141	195	224	217	224	217	217	203	215	218	2403.60
1976	222	200	209	210	224	168	103	125	107	128	158	186	2039.89
1977	210	195	209	202	180	110	101	102	99.9	106	131	147	1791.69
Aver.Mo.	211.16	175.16	186.28	202.30	209.43	165.17	142.55	148.01	141.39	145.39	168.00	183.57	

Annual Average: 2078.39

INDEX NAME: flw61
COMMENT: Amount.of.demand.met.by.Tait.st.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	10.9	9.50	11.9	18.7	19.7	19.4	20.0	20.6	19.4	21.4	17.0	11.9	200.58
1976	14.3	16.3	16.6	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.9	10.2	272.43
1977	16.0	13.2	16.7	12.3	20.8	34.3	12.8	7.91	20.9	32.7	29.7	25.2	242.46
Aver.Mo.	13.73	13.00	15.08	16.99	19.56	24.79	23.63	20.42	24.44	28.86	22.21	15.77	

Annual Average: 238.49

INDEX NAME: flw63
COMMENT: Amount.of.demand.met.by.beltz.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	10.2	13.8	18.2	20.5	29.3	30.0	31.0	31.0	30.0	29.9	22.4	14.1	280.46
1976	11.5	18.6	17.6	30.0	31.0	30.0	31.0	31.0	30.0	31.0	29.4	28.1	319.20
1977	17.9	15.6	20.2	30.0	31.0	30.0	31.0	31.0	30.0	31.0	28.7	29.3	325.67
Aver.Mo.	13.18	16.00	18.65	26.83	30.45	30.00	31.00	31.00	30.00	30.64	26.84	23.86	

Annual Average: 308.44

INDEX NAME: flw65
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	16.9	73.6	94.1	30.6	60.6	157	220	214	147	23.9	0	0	1038.71
1976	2.75	25.1	21.8	33.1	35.1	34.5	35.6	35.6	34.5	35.5	31.8	22.3	347.69
1977	8.32	6.99	14.6	34.1	35.6	18.4	0	0	0	0	0	5.48	123.55
Aver.Mo.	9.33	35.22	43.50	32.59	43.79	70.04	85.34	83.31	60.54	19.82	10.59	9.25	

Annual Average: 503.32

INDEX NAME: res80
COMMENT: Loch.Lomond.Reservoir.Storage

Million gallons

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2177	2547	2815	2811	2785	2622	2370	2120	1942	1926	1907	1891
1976	1871	1842	1851	1804	1734	1661	1582	1514	1452	1386	1336	1306
1977	1296	1275	1261	1199	1137	1084	1045	1006	981	952	952	1112

INDEX NAME: flw67
COMMENT: Loch.Lomond.spilled.flow

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	422	180	37.0	27.8	28.7	28.7	27.8	28.7	27.8	28.7	891.69
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	159.68	78.62	31.46	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 522.83

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The following data series are output from the simulation model with a 2050 year demand of 5490 mg/year.

INDEX NAME: flw66
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1937	0	0	0	0	0	0	0	142	182	95.0	76.9	54.4	549.76
1938	0	0	0	0	0	0	0	206	189	91.7	42.9	6.08	534.90
1939	0	0	0	0	0	0	0	102	285	152	89.6	43.5	671.65
1940	0	0	0	0	0	0	0	132	194	101	53.5	108	588.08
1941	0	0	0	0	0	0	137	209	175	90.0	49.9	66.8	727.79
1942	0	0	0	0	0	0	0	59.9	177	99.3	61.9	24.1	422.47
1943	0	0	0	0	0	0	0	34.9	185	96.8	53.3	37.5	407.18
1944	0	0	0	0	0	0	0	0	37.1	116	65.2	13.4	231.97
1945	0	0	0	0	0	0	0	0	18.4	140	50.7	96.1	304.77
1946	0	0	0	0	0	0	0	0	0	83.8	78.1	18.9	180.81
1948	0	0	0	79.1	74.7	135	181	186	184	71.8	43.1	33.7	987.50
1949	24.0	3.73	88.2	0	0	0	0	0	0	0	0	0	115.91
1952	0	0	0	0	0	0	0	0	88.0	93.7	73.9	75.1	330.63
1953	0	0	0	0	0	0	0	0	74.6	97.8	76.9	16.5	265.70
1954	0	0	0	0	0	0	0	0	0	35.9	79.2	46.7	161.75
1955	0	0	0	0	0	0	0	0	0	13.2	82.3	152	248.03
1956	0	0	0	0	0	0	0	31.8	186	127	39.9	12.2	397.28
1957	0	0	0	0	0	0	0	0	0	6.34	47.5	44.7	98.55
1958	0	0	0	0	0	0	0	77.4	192	90.8	58.4	26.1	445.12
1959	0	0	0	0	0	0	0	0	163	82.0	51.1	26.0	322.28
1960	0	0	0	0	0	0	0	0	2.62	138	118	15.4	274.33
1961	0	0	0	20.0	104	201	325	330	289	188	146	19.1	1623.27
1962	10.9	87.5	40.6	0	0	0	0	0	0	0	0	0	139.05
1963	0	0	0	0	0	0	0	0	0	0	14.0	0	14.00
1964	0	0	0	0	0	0	0	0	0	23.9	57.3	64.7	145.96
1965	0	0	0	0	0	0	0	0	61.7	91.8	95.1	53.7	302.24
1966	0	0	0	0	0	0	0	0	0	115	119	49.8	283.75
1967	0	0	0	0	0	0	0	0	0	0	21.2	23.5	44.70
1968	0	0	0	0	0	0	0	0	0	28.6	91.0	62.1	181.77
1969	0	0	0	0	0	0	0	0	162	92.4	53.7	78.9	387.32
1970	0	0	0	0	0	0	0	0	156	97.9	126	79.7	460.15
1971	0	0	0	0	0	0	0	0	139	116	91.6	77.0	424.24
1972	0	0	0	62.4	135	237	351	351	302	131	90.6	11.6	1670.57
1973	89.6	115	52.1	0	0	0	0	0	0	0	0	0	256.63
1974	0	0	0	0	0	0	0	0	0	39.2	69.2	35.8	144.19
1975	0	0	0	0	0	0	0	0	88.8	133	57.4	26.3	305.56
1976	0	0	0	76.1	132	264	349	333	288	169	101	40.7	1753.59
1977	15.5	13.8	34.7	107	249	363	431	418	356	240	155	108	2489.04
1978	88.9	63.1	61.0	0	0	0	0	0	0	0	59.9	9.88	282.80
1979	0	0	0	0	0	0	0	0	0	66.3	67.8	57.0	191.05
1980	0	0	0	0	0	0	0	0	124	95.5	56.3	29.5	304.91
1981	0	0	0	0	0	0	0	0	0	53.9	95.0	49.7	198.54
1982	0	0	0	0	0	0	0	0	148	88.1	72.7	41.4	349.75
1983	0	0	0	0	0	0	108	212	190	73.9	91.2	101	775.83
1984	0	0	0	0	0	0	0	0	90.3	118	123	18.8	350.07
1986	0	0	0	0	0	0	0	0	0	79.3	58.3	28.9	166.60
1987	0	0	0	59.4	122	202	262	332	283	164	75.7	79.6	1579.08
1988	34.5	1.27	1.69	66.2	167	235	341	332	271	205	148	61.4	1864.44
1989	14.5	13.9	77.5	73.2	114	219	355	298	270	170	35.6	7.36	1649.05
1990	27.2	23.0	8.85	60.8	167	212	268	325	312	220	167	88.7	1878.96
1991	40.9	51.0	128	50.4	140	208	313	327	280	208	120	136	2001.80
1992	42.2	109	30.5	38.0	122	222	243	299	261	147	129	74.0	1716.28
1993	109	70.0	12.3	0	0	0	0	0	0	0	0	0	191.04
1994	0	0	0	34.2	101	176	254	300	269	130	87.7	26.7	1377.83
1995	153	1.76	112	0	0	0	0	0	0	0	0	0	266.67
Aver.Mo.	10.82	9.21	10.79	12.11	27.13	44.53	65.28	83.92	111.23	85.13	66.15	40.97	

Annual Average: 567.29

INDEX NAME: flw54
COMMENT: Demand met from North Coast sources

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw56
COMMENT: Water.diverted.to.Loch.Lomond.reservor

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	8.93	26.8	17.9	0	0	0	0	0	0	0	0	0	53.55
1976	0	0	27.5	0	0	0	0	0	0	0	0	0	27.54
1977	0	0	0	0	0	0	0	0	0	0	0	116	116.03
Aver.Mo.	2.98	8.93	15.13	.00	.00	.00	.00	.00	.00	.00	.00	38.68	

Annual Average: 65.70

INDEX NAME: flw58
COMMENT: Tait.st.amount.diverted.to.meet.demand, Surface diversion

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	207	136	143	195	224	217	224	217	217	203	216	222	2422.20
1976	224	201	210	210	224	168	103	125	107	128	158	186	2043.26
1977	210	195	210	202	180	110	101	102	99.9	106	131	147	1793.22
Aver.Mo.	213.64	177.38	187.65	202.40	209.43	165.17	142.55	148.01	141.39	145.39	168.39	184.85	

Annual Average: 2086.23

INDEX NAME: flw61
COMMENT: Amount.of.demand.met.by.Tait.st.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	15.4	12.4	14.5	21.0	20.0	19.4	20.0	20.6	19.4	21.8	18.2	16.0	218.66
1976	18.5	17.8	20.2	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.9	10.3	281.88
1977	19.1	15.0	19.4	12.3	20.8	34.3	12.8	7.91	20.9	32.7	30.3	25.2	250.72
Aver.Mo.	17.68	15.04	18.05	17.75	19.67	24.79	23.63	20.42	24.44	28.98	22.79	17.18	

Annual Average: 250.42

INDEX NAME: flw63
COMMENT: Amount.of.demand.met.by.beltz.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	14.9	15.9	23.0	27.4	30.6	30.0	31.0	31.0	30.0	30.4	25.7	17.5	307.44
1976	20.0	24.0	23.1	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	29.9	341.05
1977	24.7	23.2	24.4	30.0	31.0	30.0	31.0	31.0	30.0	31.0	29.0	30.6	345.91
Aver.Mo.	19.87	21.04	23.50	29.15	30.86	30.00	31.00	31.00	30.00	30.79	28.24	26.01	

Annual Average: 331.47

INDEX NAME: flw65
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.8	82.3	106	47.8	90.9	193	258	251	91.7	0	0	0	1143.93
1976	9.61	36.8	33.5	34.5	35.6	34.5	35.6	35.6	34.5	35.6	33.0	29.3	388.26
1977	15.7	11.9	20.2	17.2	0	0	0	0	0	0	0	1.15	66.24
Aver.Mo.	16.05	43.67	53.31	33.17	42.19	75.76	97.93	95.62	42.08	11.88	11.00	10.15	

Annual Average: 532.81

INDEX NAME: res80
COMMENT: Loch.Lomond.Reservoir.Storage

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2104	2474	2815	2810	2760	2562	2272	1986	1864	1872	1853	1837
1976	1810	1769	1753	1704	1635	1564	1486	1418	1356	1290	1239	1201
1977	1184	1158	1131	1086	1061	1026	988	950	924	895	896	1096

INDEX NAME: flw67
COMMENT: Loch.Lomond.spilled.flow

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	354	164	30.3	27.8	28.7	28.7	27.8	28.7	27.8	28.7	801.15
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	137.14	73.20	29.24	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 492.65

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The following data series are output from the simulation model with
a current demand of 4,497 Million Gallons/year

INDEX NAME: flw66
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1948	0	0	0	48.2	14.1	34.8	69.6	76.4	84.8	8.54	6.67	21.2	364.26
1949	15.1	1.88	58.3	0	0	0	0	0	0	0	0	0	75.28
1961	0	0	0	0	0	0	0	0	0	0	41.4	0	41.37
1972	0	0	0	0	0	0	0	0	0	38.4	14.6	0	52.98
1976	0	0	0	15.3	43.1	159	237	224	190	89.1	42.5	15.2	1014.76
1977	9.33	5.95	14.3	25.2	119	223	283	273	223	122	62.7	36.1	1397.50
1978	58.6	41.6	39.3	0	0	0	0	0	0	0	0	0	139.53
1987	0	0	0	0	0	0	0	0	0	0	23.6	59.2	82.87
1988	0	0	0	20.8	75.6	130	229	223	172	98.1	62.4	26.1	1037.05
1989	5.07	5.22	47.4	14.3	30.0	114	212	153	137	61.6	6.58	0	786.44
1990	16.0	15.8	4.53	8.95	78.8	107	135	180	179	102	67.9	16.5	911.00
1991	0	20.0	80.4	0	0	0	0	0	0	0	0	0	100.40
1992	0	0	0	0.44	34.9	117	131	190	162	66.4	40.8	37.3	779.95
1993	73.6	43.3	5.88	0	0	0	0	0	0	0	0	0	122.84
Aver.Mo.	3.01	2.27	4.24	2.26	6.71	14.98	22.00	22.36	19.45	9.94	6.26	3.59	

Annual Average: 117.05

INDEX NAME: flw54
COMMENT: North.Coast.component.of.Demand

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw56
COMMENT: Water.diverted.to.Loch.Lomond.reservor

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1976	0	0	53.7	11.0	0	0	0	0	0	0	0	0	64.69
1977	20.7	0	24.9	0	0	0	0	0	0	0	0	53.6	99.14
Aver.Mo.	6.90	.00	26.20	3.66	.00	.00	.00	.00	.00	.00	.00	17.85	

Annual Average: 54.61

INDEX NAME: flw58
COMMENT: Tait.st.amount.diverted.to.meet.demand

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	177	113	128	182	222	217	224	217	217	202	208	199	2306.67
1976	205	191	196	210	224	168	103	125	107	128	157	183	1997.15
1977	197	184	199	202	180	110	101	102	99.9	106	130	146	1756.63
Aver.Mo.	192.95	162.96	174.52	197.86	208.63	165.17	142.55	148.01	141.39	145.03	164.91	176.17	

Annual Average: 2020.15

INDEX NAME: flw61
COMMENT: Amount.of.demand.met.by.Tait.st.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	5.96	7.25	6.97	7.61	15.7	19.4	20.0	20.6	19.4	20.0	12.5	7.09	162.47
1976	4.24	10.4	8.17	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.6	9.09	246.69
1977	8.82	4.88	10.6	12.3	20.8	34.3	12.8	7.91	20.9	32.7	28.7	23.7	218.33
Aver.Mo.	6.34	7.52	8.59	13.29	18.23	24.79	23.63	20.42	24.44	28.38	20.26	13.29	

Annual Average: 209.17

INDEX NAME: flw63
COMMENT: Amount.of.demand.met.by.beltz.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	3.15	9.49	12.7	6.69	20.3	30.0	31.0	31.0	30.0	23.3	12.8	8.03	218.50
1976	0.88	12.2	4.86	27.2	29.8	30.0	31.0	31.0	30.0	30.7	-26.6	16.8	270.95
1977	5.32	5.55	11.3	28.8	31.0	30.0	31.0	31.0	30.0	31.0	25.9	24.2	285.13
Aver.Mo.	3.12	9.08	9.62	20.92	27.03	30.00	31.00	31.00	30.00	28.33	21.76	16.34	

Annual Average: 258.19

INDEX NAME: flw65
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	11.9	60.3	75.0	16.3	13.1	87.7	147	142	81.8	60.9	13.6	3.64	712.83
1976	0	7.89	12.9	22.1	32.1	34.5	35.6	35.6	34.5	33.9	25.0	8.99	283.19
1977	2.36	2.68	8.88	23.7	35.6	34.5	35.6	35.6	34.5	35.6	27.0	18.1	294.31
Aver.Mo.	4.76	23.63	32.26	20.71	26.96	52.24	72.60	71.12	50.25	43.47	21.86	10.26	

Annual Average: 430.11

INDEX NAME: res80
COMMENT: Loch.Lomond.Reservoir.Storage

Million Gallons

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2417	2786	2815	2811	2805	2711	2532	2354	2239	2187	2155	2135
1976	2117	2106	2135	2109	2040	1965	1883	1814	1751	1684	1641	1625
1977	1643	1625	1636	1582	1520	1449	1372	1295	1234	1169	1144	1267

INDEX NAME: flw67
COMMENT: Loch.Lomond.spilled.flow

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	681	194	64.8	27.8	28.7	28.7	27.8	28.7	27.8	28.7	1192.59
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	245.99	83.33	40.75	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 623.13

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The following data series are output from the simulation model with
a 2020 year demand of 5154 mg/year.

INDEX NAME: flw66
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1937	0	0	0	0	0	0	0	0	103	67.2	57.2	49.3	277.07
1938	0	0	0	0	0	0	0	7.04	155	66.1	29.9	4.12	262.31
1939	0	0	0	0	0	0	0	0	151	125	67.6	27.8	370.97
1940	0	0	0	0	0	0	0	0	103	74.5	35.2	97.0	309.26
1941	0	0	0	0	0	0	0	139	142	63.3	35.6	59.8	439.60
1942	0	0	0	0	0	0	0	0	21.4	72.4	50.5	21.5	165.72
1943	0	0	0	0	0	0	0	0	7.92	69.1	33.9	27.0	137.89
1945	0	0	0	0	0	0	0	0	0	0	0	63.6	63.57
1948	0	0	0	65.4	48.7	99.3	143	149	150	45.6	25.8	27.8	754.81
1949	20.5	3.10	78.1	0	0	0	0	0	0	0	0	0	101.67
1951	0	0	0	0	0	0	0	0	0	20.3	73.3	90.4	184.05
1952	0	0	0	0	0	0	0	0	0	0	43.9	68.9	112.81
1953	0	0	0	0	0	0	0	0	0	0	4.81	9.31	14.12
1955	0	0	0	0	0	0	0	0	0	0	0	53.4	53.40
1956	0	0	0	0	0	0	0	0	0	87.6	23.6	6.52	117.78
1958	0	0	0	0	0	0	0	0	130	63.8	38.9	16.4	248.74
1959	0	0	0	0	0	0	0	0	0	23.2	31.4	15.3	69.91
1961	0	0	0	9.98	74.0	166	287	293	256	160	124	14.8	1385.12
1962	8.49	78.9	35.9	0	0	0	0	0	0	0	0	0	123.38
1964	0	0	0	0	0	0	0	0	0	0	0	24.3	24.26
1965	0	0	0	0	0	0	0	0	0	0	65.2	47.3	112.45
1966	0	0	0	0	0	0	0	0	0	0	4.33	45.9	50.23
1968	0	0	0	0	0	0	0	0	0	0	23.5	52.5	75.92
1969	0	0	0	0	0	0	0	0	0	3.80	34.7	69.9	108.37
1970	0	0	0	0	0	0	0	0	0	2.36	106	71.4	180.02
1971	0	0	0	0	0	0	0	0	0	17.6	69.4	63.1	150.08
1972	0	0	0	0	0	0	0	97.1	303	138	32.2	0	570.54
1974	0	0	0	0	0	0	0	0	0	0	41.0	28.1	69.10
1975	0	0	0	0	0	0	0	0	0	82.1	39.0	16.2	137.30
1976	0	0	0	51.8	101	228	311	296	255	142	79.0	28.4	1492.14
1977	12.0	9.70	26.4	64.0	181	309	393	381	322	212	132	83.2	2125.78
1978	78.7	55.8	53.7	0	0	0	0	0	0	0	0	0	188.17
1979	0	0	0	0	0	0	0	0	0	0	0.33	47.9	48.20
1980	0	0	0	0	0	0	0	0	0	0	22.1	20.5	42.57
1982	0	0	0	0	0	0	0	0	0	0	21.5	37.2	58.67
1983	0	0	0	0	0	0	0	115	157	48.1	78.0	90.6	488.73
1984	0	0	0	0	0	0	0	0	0	0	92.2	15.6	107.80
1987	0	0	0	35.0	91.2	166	224	295	249	136	55.1	64.0	1316.10
1988	26.3	0	0.32	45.4	135	199	303	295	238	152	95.7	35.8	1526.24
1989	7.13	6.94	63.6	48.5	83.9	184	286	225	203	107	18.8	1.11	1234.33
1990	22.4	19.7	5.68	37.1	136	176	209	252	244	156	109	51.3	1418.78
1991	21.5	37.0	106	28.9	108	172	275	290	247	160	63.6	81.8	1590.86
1992	13.6	85.1	19.4	19.2	91.6	186	205	262	228	119	85.3	53.8	1368.20
1993	96.8	61.0	10.2	0	0	0	0	0	0	0	0	0	167.97
1994	0	0	0	0	0	0	0	0	0	67.5	51.3	0.03	118.78
Aver.Mo.	5.12	5.95	6.65	6.75	17.53	31.43	43.94	51.62	61.07	41.37	33.25	28.04	

Annual Average: 332.73

INDEX NAME: flw54
COMMENT: Demand met from North Coast Sources

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw56
COMMENT: Water.diverted.to.Loch.Lomond.reservor

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	0	17.9	0	0	0	0	0	0	0	0	0	0	17.85
1976	0	0	41.9	0	0	0	0	0	0	0	0	0	41.94
1977	0	0	7.04	0	0	0	0	0	0	0	0	80.3	87.37
Aver.Mo.	.00	5.95	16.33	.00	.00	.00	.00	.00	.00	.00	.00	26.78	

Annual Average: 49.05

INDEX NAME: flw58
COMMENT: Tait.st.amount.diverted.to.meet.demand, Surface diversion

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	201	130	141	195	224	217	224	217	217	203	215	218	2403.60
1976	222	200	209	210	224	168	103	125	107	128	158	186	2039.89
1977	210	195	209	202	180	110	101	102	99.9	106	131	147	1791.69
Aver.Mo.	211.16	175.16	186.28	202.30	209.43	165.17	142.55	148.01	141.39	145.39	168.00	183.57	

Annual Average: 2078.39

INDEX NAME: flw61
COMMENT: Amount.of.demand.met.by.Tait.st.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	10.9	9.50	11.9	18.7	19.7	19.4	20.0	20.6	19.4	21.4	17.0	11.9	200.58
1976	14.3	16.3	16.6	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.9	10.2	272.43
1977	16.0	13.2	16.7	12.3	20.8	34.3	12.8	7.91	20.9	32.7	29.7	25.2	242.46
Aver.Mo.	13.73	13.00	15.08	16.99	19.56	24.79	23.63	20.42	24.44	28.86	22.21	15.77	

Annual Average: 238.49

INDEX NAME: flw63
COMMENT: Amount.of.demand.met.by.beltz.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	10.2	13.8	18.2	20.5	29.3	30.0	31.0	31.0	30.0	29.9	22.4	14.1	280.46
1976	11.5	18.6	17.6	30.0	31.0	30.0	31.0	31.0	30.0	31.0	29.4	28.1	319.20
1977	17.9	15.6	20.2	30.0	31.0	30.0	31.0	31.0	30.0	31.0	28.7	29.3	325.67
Aver.Mo.	13.18	16.00	18.65	26.83	30.45	30.00	31.00	31.00	30.00	30.64	26.84	23.86	

Annual Average: 308.44

INDEX NAME: flw65
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	16.9	73.6	94.1	30.6	60.6	157	220	214	147	23.9	0	0	1038.71
1976	2.75	25.1	21.8	33.1	35.1	34.5	35.6	35.6	34.5	35.5	31.8	22.3	347.69
1977	8.32	6.99	14.6	34.1	35.6	18.4	0	0	0	0	0	5.48	123.55
Aver.Mo.	9.33	35.22	43.50	32.59	43.79	70.04	85.34	83.31	60.54	19.82	10.59	9.25	

Annual Average: 503.32

INDEX NAME: res80
COMMENT: Loch.Lomond.Reservoir.Storage

Million gallons

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2177	2547	2815	2811	2785	2622	2370	2120	1942	1926	1907	1891
1976	1871	1842	1851	1804	1734	1661	1582	1514	1452	1386	1336	1306
1977	1296	1275	1261	1199	1137	1084	1045	1006	981	952	952	1112

INDEX NAME: flw67
COMMENT: Loch.Lomond.spilled.flow

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	422	180	37.0	27.8	28.7	28.7	27.8	28.7	27.8	28.7	891.69
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	159.68	78.62	31.46	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 522.83

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The following data series are output from the simulation model with a 2050 year demand of 5490 mg/year.

INDEX NAME: flw66
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1937	0	0	0	0	0	0	0	142	182	95.0	76.9	54.4	549.76
1938	0	0	0	0	0	0	0	206	189	91.7	42.9	6.08	534.90
1939	0	0	0	0	0	0	0	102	285	152	89.6	43.5	671.65
1940	0	0	0	0	0	0	0	132	194	101	53.5	108	588.08
1941	0	0	0	0	0	0	137	209	175	90.0	49.9	66.8	727.79
1942	0	0	0	0	0	0	0	59.9	177	99.3	61.9	24.1	422.47
1943	0	0	0	0	0	0	0	34.9	185	96.8	53.3	37.5	407.18
1944	0	0	0	0	0	0	0	0	37.1	116	65.2	13.4	231.97
1945	0	0	0	0	0	0	0	0	18.4	140	50.7	96.1	304.77
1946	0	0	0	0	0	0	0	0	0	83.8	78.1	18.9	180.81
1948	0	0	0	79.1	74.7	135	181	186	184	71.8	43.1	33.7	987.50
1949	24.0	3.73	88.2	0	0	0	0	0	0	0	0	0	115.91
1952	0	0	0	0	0	0	0	0	88.0	93.7	73.9	75.1	330.63
1953	0	0	0	0	0	0	0	0	74.6	97.8	76.9	16.5	265.70
1954	0	0	0	0	0	0	0	0	0	35.9	79.2	46.7	161.75
1955	0	0	0	0	0	0	0	0	0	13.2	82.3	152	248.03
1956	0	0	0	0	0	0	0	31.8	186	127	39.9	12.2	397.28
1957	0	0	0	0	0	0	0	0	0	6.34	47.5	44.7	98.55
1958	0	0	0	0	0	0	0	77.4	192	90.8	58.4	26.1	445.12
1959	0	0	0	0	0	0	0	0	163	82.0	51.1	26.0	322.28
1960	0	0	0	0	0	0	0	0	2.62	138	118	15.4	274.33
1961	0	0	0	20.0	104	201	325	330	289	188	146	19.1	1623.27
1962	10.9	87.5	40.6	0	0	0	0	0	0	0	0	0	139.05
1963	0	0	0	0	0	0	0	0	0	0	14.0	0	14.00
1964	0	0	0	0	0	0	0	0	0	23.9	57.3	64.7	145.96
1965	0	0	0	0	0	0	0	0	61.7	91.8	95.1	53.7	302.24
1966	0	0	0	0	0	0	0	0	0	115	119	49.8	283.75
1967	0	0	0	0	0	0	0	0	0	0	21.2	23.5	44.70
1968	0	0	0	0	0	0	0	0	0	28.6	91.0	62.1	181.77
1969	0	0	0	0	0	0	0	0	162	92.4	53.7	78.9	387.32
1970	0	0	0	0	0	0	0	0	156	97.9	126	79.7	460.15
1971	0	0	0	0	0	0	0	0	139	116	91.6	77.0	424.24
1972	0	0	0	62.4	135	237	351	351	302	131	90.6	11.6	1670.57
1973	89.6	115	52.1	0	0	0	0	0	0	0	0	0	256.63
1974	0	0	0	0	0	0	0	0	0	39.2	69.2	35.8	144.19
1975	0	0	0	0	0	0	0	0	88.8	133	57.4	26.3	305.56
1976	0	0	0	76.1	132	264	349	333	288	169	101	40.7	1753.59
1977	15.5	13.8	34.7	107	249	363	431	418	356	240	155	108	2489.04
1978	88.9	63.1	61.0	0	0	0	0	0	0	0	59.9	9.88	282.80
1979	0	0	0	0	0	0	0	0	0	66.3	67.8	57.0	191.05
1980	0	0	0	0	0	0	0	0	124	95.5	56.3	29.5	304.91
1981	0	0	0	0	0	0	0	0	0	53.9	95.0	49.7	198.54
1982	0	0	0	0	0	0	0	0	148	88.1	72.7	41.4	349.75
1983	0	0	0	0	0	0	108	212	190	73.9	91.2	101	775.83
1984	0	0	0	0	0	0	0	0	90.3	118	123	18.8	350.07
1986	0	0	0	0	0	0	0	0	0	79.3	58.3	28.9	166.60
1987	0	0	0	59.4	122	202	262	332	283	164	75.7	79.6	1579.08
1988	34.5	1.27	1.69	66.2	167	235	341	332	271	205	148	61.4	1864.44
1989	14.5	13.9	77.5	73.2	114	219	355	298	270	170	35.6	7.36	1649.05
1990	27.2	23.0	8.85	60.8	167	212	268	325	312	220	167	88.7	1878.96
1991	40.9	51.0	128	50.4	140	208	313	327	280	208	120	136	2001.80
1992	42.2	109	30.5	38.0	122	222	243	299	261	147	129	74.0	1716.28
1993	109	70.0	12.3	0	0	0	0	0	0	0	0	0	191.04
1994	0	0	0	34.2	101	176	254	300	269	130	87.7	26.7	1377.83
1995	153	1.76	112	0	0	0	0	0	0	0	0	0	266.67
Aver.Mo.	10.82	9.21	10.79	12.11	27.13	44.53	65.28	83.92	111.23	85.13	66.15	40.97	

Annual Average: 567.29

INDEX NAME: flw54
COMMENT: Demand met from North Coast sources

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw56
COMMENT: Water.diverted.to.Loch.Lomond.reservor

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	8.93	26.8	17.9	0	0	0	0	0	0	0	0	0	53.55
1976	0	0	27.5	0	0	0	0	0	0	0	0	0	27.54
1977	0	0	0	0	0	0	0	0	0	0	0	116	116.03
Aver.Mo.	2.98	8.93	15.13	.00	.00	.00	.00	.00	.00	.00	.00	38.68	

Annual Average: 65.70

INDEX NAME: flw58
COMMENT: Tait.st.amount.diverted.to.meet.demand, Surface diversion

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	207	136	143	195	224	217	224	217	217	203	216	222	2422.20
1976	224	201	210	210	224	168	103	125	107	128	158	186	2043.26
1977	210	195	210	202	180	110	101	102	99.9	106	131	147	1793.22
Aver.Mo.	213.64	177.38	187.65	202.40	209.43	165.17	142.55	148.01	141.39	145.39	168.39	184.85	

Annual Average: 2086.23

INDEX NAME: flw61
COMMENT: Amount.of.demand.met.by.Tait.st.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	15.4	12.4	14.5	21.0	20.0	19.4	20.0	20.6	19.4	21.8	18.2	16.0	218.66
1976	18.5	17.8	20.2	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.9	10.3	281.88
1977	19.1	15.0	19.4	12.3	20.8	34.3	12.8	7.91	20.9	32.7	30.3	25.2	250.72
Aver.Mo.	17.68	15.04	18.05	17.75	19.67	24.79	23.63	20.42	24.44	28.98	22.79	17.18	

Annual Average: 250.42

INDEX NAME: flw63
COMMENT: Amount.of.demand.met.by.beltz.wells

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	14.9	15.9	23.0	27.4	30.6	30.0	31.0	31.0	30.0	30.4	25.7	17.5	307.44
1976	20.0	24.0	23.1	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	29.9	341.05
1977	24.7	23.2	24.4	30.0	31.0	30.0	31.0	31.0	30.0	31.0	29.0	30.6	345.91
Aver.Mo.	19.87	21.04	23.50	29.15	30.86	30.00	31.00	31.00	30.00	30.79	28.24	26.01	

Annual Average: 331.47

INDEX NAME: flw65
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.8	82.3	106	47.8	90.9	193	258	251	91.7	0	0	0	1143.93
1976	9.61	36.8	33.5	34.5	35.6	34.5	35.6	35.6	34.5	35.6	33.0	29.3	388.26
1977	15.7	11.9	20.2	17.2	0	0	0	0	0	0	0	1.15	66.24
Aver.Mo.	16.05	43.67	53.31	33.17	42.19	75.76	97.93	95.62	42.08	11.88	11.00	10.15	

Annual Average: 532.81

INDEX NAME: res80
COMMENT: Loch.Lomond.Reservoir.Storage

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2104	2474	2815	2810	2760	2562	2272	1986	1864	1872	1853	1837
1976	1810	1769	1753	1704	1635	1564	1486	1418	1356	1290	1239	1201
1977	1184	1158	1131	1086	1061	1026	988	950	924	895	896	1096

INDEX NAME: flw67
COMMENT: Loch.Lomond.spilled.flow

Million Gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	354	164	30.3	27.8	28.7	28.7	27.8	28.7	27.8	28.7	801.15
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	137.14	73.20	29.24	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 492.65

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Current demand 4497 mg/yr

INDEX NAME: flw65
STATION NAME: LL.Demand
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1936	0	0	0	0	0	0	0	0	0	67.3	16.2	30.0	113.45
1937	24.0	101	134	0	14.1	82.7	101	106	83.0	21.0	29.2	40.0	737.28
1938	55.1	113	114	12.7	12.3	68.4	107	110	89.8	29.3	17.1	2.60	730.94
1939	29.1	10.8	28.2	0.34	44.6	111	204	221	186	70.4	33.1	13.2	952.07
1940	91.0	85.2	63.6	21.1	21.0	68.8	110	113	94.7	28.8	11.9	75.8	784.86
1941	91.0	106	86.5	120	37.5	60.1	94.2	99.8	76.6	22.5	16.0	48.7	858.71
1942	69.2	45.7	33.4	57.2	23.6	59.3	95.8	101	78.6	27.9	36.8	16.6	645.07
1943	87.7	22.6	49.4	8.46	12.3	79.2	110	110	85.9	22.7	9.03	17.6	615.20
1944	27.9	64.6	15.7	17.9	29.9	75.6	110	109	85.2	43.7	34.2	9.38	622.84
1945	2.53	61.9	39.7	3.15	31.3	74.3	108	109	85.6	65.5	19.6	68.4	669.56
1946	9.80	14.3	17.9	0.48	33.3	88.2	119	120	102	31.1	35.4	14.3	585.23
1947	9.37	13.0	32.9	0.69	37.3	108	124	183	198	96.5	13.8	16.1	832.03
1948	2.45	9.60	29.7	10.3	14.1	30.2	35.6	35.6	34.5	20.5	10.9	5.22	238.75
1949	4.60	1.15	17.2	0	28.6	90.4	128	133	105	37.7	21.1	19.4	586.82
1950	52.2	25.9	11.8	13.0	27.4	94.1	124	136	121	63.6	94.1	33.2	796.60
1951	38.1	3.49	22.9	9.03	32.1	88.4	117	124	97.2	50.5	41.0	74.3	697.23
1952	126	23.5	70.4	4.79	12.8	86.3	98.4	104	85.6	20.2	33.3	57.0	722.11
1953	46.6	0	16.1	19.0	16.1	77.3	108	114	83.1	23.4	28.1	4.93	536.67
1954	25.2	32.8	44.5	21.2	12.5	75.6	105	114	87.7	21.5	41.0	32.8	614.20
1955	40.4	10.2	3.14	30.7	13.8	73.7	109	110	87.7	21.1	32.5	107	639.09
1956	128	40.1	0	25.5	25.3	71.1	116	109	87.6	48.9	5.12	4.64	661.18
1957	17.4	40.6	6.64	20.1	41.0	60.4	94.9	101	77.3	12.1	4.38	26.4	502.45
1958	43.4	125	90.3	87.3	15.3	71.7	109	108	93.5	16.7	11.1	7.35	778.72
1959	36.0	51.0	0	8.06	28.4	94.4	123	124	101	11.0	5.30	5.69	587.73
1960	46.4	32.8	5.61	8.51	27.4	84.6	136	174	158	56.5	59.7	7.11	795.94
1961	12.8	2.00	17.2	7.41	50.2	131	249	257	225	142	70.9	14.3	1177.71
1962	7.90	77.1	34.8	0	19.1	98.7	123	164	119	55.9	3.32	14.4	717.47
1963	22.0	43.3	30.4	91.1	14.6	61.0	99.1	103	89.4	38.6	63.3	0	655.87
1964	25.4	0	7.49	3.46	53.7	111	129	203	124	66.3	51.9	85.8	860.37
1965	50.6	4.62	8.54	58.2	11.8	79.1	111	116	86.4	17.3	50.9	37.3	631.20
1966	17.0	18.1	0	7.41	42.3	110	142	194	172	97.5	74.2	38.2	913.05
1967	61.2	6.95	65.1	139	13.2	78.4	83.8	94.3	72.9	9.32	27.7	13.3	664.71
1968	26.9	16.8	26.1	9.51	29.6	82.8	115	132	105	34.7	39.2	39.3	656.90
1969	92.0	135	28.1	19.9	14.0	85.2	116	117	93.4	21.7	10.6	55.5	787.61
1970	121	14.3	27.9	0	11.8	65.5	114	114	85.4	21.9	73.6	55.6	705.00
1971	4.94	0	19.4	9.05	29.5	92.8	124	141	126	37.2	34.7	43.3	662.20
1972	15.5	6.98	0.67	29.8	77.9	166	275	277	238	47.5	58.0	9.42	1202.29
1973	76.7	97.3	42.2	0	11.8	64.2	108	111	91.8	47.2	76.2	29.2	756.26
1974	46.5	9.51	66.1	45.5	11.8	62.5	90.4	91.5	75.3	41.6	16.8	20.6	578.07
1975	11.9	60.3	75.0	16.3	13.1	87.7	147	142	81.8	60.9	13.6	3.64	712.83
1976	0	7.89	12.9	22.1	32.1	34.5	35.6	35.6	34.5	33.9	25.0	8.99	283.19
1977	2.36	2.68	8.88	23.7	35.6	34.5	35.6	35.6	34.5	35.6	27.0	18.1	294.31
1978	17.2	12.6	12.6	37.6	11.8	67.2	105	108	91.2	14.2	27.5	5.14	510.14
1979	46.0	55.8	25.6	9.86	14.0	77.6	116	110	98.2	48.6	24.2	36.4	662.60
1980	61.3	84.9	14.6	13.9	21.2	86.1	119	110	86.7	20.9	6.49	13.6	637.92
1981	37.8	7.60	28.9	0	36.5	91.5	145	201	180	71.6	43.4	29.9	873.45
1982	52.3	30.5	74.7	124	11.8	67.5	101	110	98.1	22.8	43.5	29.0	764.91
1983	63.4	116	127	66.8	47.0	58.8	95.1	102	91.3	8.99	57.1	70.1	903.77
1984	0	6.66	13.2	0	27.3	96.6	124	124	108	41.0	67.9	11.1	619.22
1985	7.02	14.1	16.3	3.32	39.8	115	142	149	139	83.0	50.1	14.4	772.06
1986	32.5	76.6	73.3	0	15.1	84.0	118	119	116	20.6	8.48	6.40	669.24
1987	16.0	30.6	24.8	20.9	65.5	131	186	259	219	117	20.9	0	1090.17
1988	24.4	0	0.02	14.4	33.6	34.5	35.6	35.6	34.5	35.6	23.0	6.76	278.08
1989	1.26	1.15	12.4	19.4	28.3	34.5	35.6	35.6	34.5	27.8	6.30	0.14	237.07
1990	4.76	3.45	1.15	15.4	31.2	34.5	35.6	35.6	34.5	35.6	29.1	17.7	278.78
1991	1.08	4.60	18.8	19.0	82.6	137	237	254	216	141	51.7	75.8	1238.17
1992	11.6	82.2	16.2	9.21	31.0	34.5	35.6	35.6	34.5	33.9	32.2	12.6	369.19
1993	19.5	14.9	3.45	10.7	36.4	79.0	106	108	95.2	33.4	24.0	22.3	553.37
1994	10.4	31.5	4.01	16.7	45.7	105	178	227	205	84.0	57.4	18.1	982.08
1995	130	1.14	95.1	29.0	24.6	61.7	88.3	97.5	74.7	11.8	4.07	18.7	636.80
Aver.Mo.	37.24	35.19	32.77	23.20	27.79	78.57	113.15	123.60	103.19	43.19	32.56	26.88	

Annual Average: 677.35

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INDEX NAME: flw66
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Demand.Remaining
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1936 JANUARY
ENDS DATE: 1995 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1948	0	0	0	48.2	14.1	34.8	69.6	76.4	84.8	8.54	6.67	21.2	364.26
1949	15.1	1.88	58.3	0	0	0	0	0	0	0	0	0	75.28
1961	0	0	0	0	0	0	0	0	0	0	41.4	0	41.37
1972	0	0	0	0	0	0	0	0	0	38.4	14.6	0	52.98
1976	0	0	0	15.3	43.1	159	237	224	190	89.1	42.5	15.2	1014.76
1977	9.33	5.95	14.3	25.2	119	223	283	273	223	122	62.7	36.1	1397.50
1978	58.6	41.6	39.3	0	0	0	0	0	0	0	0	0	139.53
1987	0	0	0	0	0	0	0	0	0	0	23.6	59.2	82.87
1988	0	0	0	20.8	75.6	130	229	223	172	98.1	62.4	26.1	1037.05
1989	5.07	5.22	47.4	14.3	30.0	114	212	153	137	61.6	6.58	0	786.44
1990	16.0	15.8	4.53	8.95	78.8	107	135	180	179	102	67.9	16.5	911.00
1991	0	20.0	80.4	0	0	0	0	0	0	0	0	0	100.40
1992	0	0	0	0.44	34.9	117	131	190	162	66.4	40.8	37.3	779.95
1993	73.6	43.3	5.88	0	0	0	0	0	0	0	0	0	122.84
Aver.Mo.	2.96	2.23	4.17	2.22	6.60	14.73	21.63	21.98	19.13	9.77	6.15	3.53	

Annual Average: 115.10

INDEX NAME: flw50
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Liddell
COMMENT: Outflow.from.Liddell.Spring
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	37.0	20.2	13.4	23.5	47.0	47.0	48.7	48.7	50.4	30.2	35.3	35.3	436.88
1976	36.2	17.7	30.0	16.2	42.8	35.4	37.9	28.2	30.8	36.7	28.6	29.9	370.38
1977	30.2	25.0	21.7	27.6	21.2	28.8	25.3	29.3	23.4	26.7	23.4	12.4	294.96
Aver.Mo.	34.49	20.96	21.69	22.42	37.04	37.08	37.31	35.41	34.87	31.22	29.10	25.84	

Annual Average: 367.41

INDEX NAME: flw51
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Laguna
COMMENT: outflow.from.Laguna.and.Riggiardo.Creeks
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	24.0	30.5	49.4	108	109	56.8	7.23	11.4	25.8	21.2	22.7	17.5	484.27
1976	13.3	11.8	17.3	16.8	11.2	10.2	3.06	5.10	7.14	6.12	6.90	6.68	115.60
1977	8.99	9.29	9.99	10.3	6.19	1.55	4.13	2.06	1.99	6.19	5.98	13.5	80.17
Aver.Mo.	15.41	17.21	25.58	45.15	42.27	22.84	4.80	6.17	11.64	11.18	11.86	12.57	

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Annual Average: 226.68

INDEX NAME: flw52
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Majors
COMMENT: outflow.from.Majors.Creek
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.2	12.1	5.84	0	0	17.5	27.6	23.1	22.7	14.6	16.8	15.2	177.65
1976	22.0	11.1	21.4	16.7	23.6	18.4	19.8	12.5	15.0	15.2	14.9	16.8	207.43
1977	19.3	15.2	15.1	14.4	11.6	12.9	12.5	12.9	13.9	11.6	18.3	12.1	169.73
Aver.Mo.	21.14	12.79	14.13	10.36	11.74	16.27	19.94	16.19	17.20	13.78	16.69	14.71	

Annual Average: 184.94

INDEX NAME: flw53
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: North.Coast
COMMENT: Combined.North.Coast.flows.reduced.to.capacity.of.pipeline,cap.9.1.cfs
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw54
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: NC.demand
COMMENT: North.Coast.component.of.Demand
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw55
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: NC.Remaining
COMMENT: Remaining.demand.after.demand.met.by.north.coast
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

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STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	198	190	222	212	269	354	422	411	348	306	247	218	3397.96
1976	210	222	222	294	348	412	445	448	394	314	271	233	3812.74
1977	223	204	244	292	386	432	464	450	408	327	274	248	3951.91
Aver.Mo.	210.27	205.17	229.75	266.22	334.22	399.41	443.39	436.30	383.47	315.64	263.86	233.17	

Annual Average: 3720.87

INDEX NAME: flw56
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Felton.Div
COMMENT: Water.diverted.to.Loch.Lomond.reservor
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1976	0	0	53.7	11.0	0	0	0	0	0	0	0	0	64.69
1977	20.7	0	24.9	0	0	0	0	0	0	0	0	53.6	99.14
Aver.Mo.	6.90	.00	26.20	3.66	.00	.00	.00	.00	.00	.00	.00	17.85	

Annual Average: 54.61

INDEX NAME: flw57
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.div.suf
COMMENT: Tait.st.surface.diversions.amount.available
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	210	138	145	195	224	217	224	217	217	203	217	224	2432.05
1976	224	201	210	210	224	168	103	125	107	128	158	186	2044.08
1977	210	195	210	202	180	110	101	102	99.9	106	131	147	1793.22
Aver.Mo.	214.73	178.13	188.19	202.40	209.43	165.17	142.55	148.01	141.39	145.39	168.62	185.78	

Annual Average: 2089.79

INDEX NAME: flw58
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.div.dem
COMMENT: Tait.st.amount.diverted.to.meet.demand
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	177	113	128	182	222	217	224	217	217	202	208	199	2306.67
1976	205	191	196	210	224	168	103	125	107	128	157	183	1997.15
1977	197	184	199	202	180	110	101	102	99.9	106	130	146	1756.63
Aver.Mo.	192.95	162.96	174.52	197.86	208.63	165.17	142.55	148.01	141.39	145.03	164.91	176.17	

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Annual Average: 2020.15

INDEX NAME: flw59
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.remaining
COMMENT: Amount.of.demand.remaining.after.surface.diversion.at.tait.st.
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	21.0	77.1	94.6	30.4	46.8	137	198	194	131	104	38.9	18.8	1091.29
1976	5.12	30.5	26.0	84.6	123	244	342	323	287	186	114	50.1	1815.59
1977	25.8	19.1	45.1	90.1	207	322	363	348	308	221	144	102	2195.28
Aver.Mo.	17.33	42.21	55.23	68.36	125.58	234.24	300.83	288.29	242.08	170.61	98.95	56.99	

Annual Average: 1700.72

INDEX NAME: flw60
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.Wells
COMMENT: Amounts.available.for.diversion.from.Tait.st.wells,1.9cfs
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	38.1	28.2	28.2	36.8	38.1	36.8	38.1	38.1	36.8	38.1	36.8	38.1	432.23
1976	38.1	33.9	38.1	36.8	30.1	21.1	38.1	34.0	34.2	33.8	22.2	10.9	371.38
1977	29.2	21.4	31.9	16.9	22.6	34.5	12.8	7.91	21.5	32.7	33.5	32.2	297.01
Aver.Mo.	35.12	27.84	32.75	30.19	30.26	30.82	29.64	26.67	30.84	34.85	30.83	27.06	

Annual Average: 366.87

INDEX NAME: flw61
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.Wells
COMMENT: Amount.of.demand.met.by.Tait.st.wells
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	5.96	7.25	6.97	7.61	15.7	19.4	20.0	20.6	19.4	20.0	12.5	7.09	162.47
1976	4.24	10.4	8.17	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.6	9.09	246.69
1977	8.82	4.88	10.6	12.3	20.8	34.3	12.8	7.91	20.9	32.7	28.7	23.7	218.33
Aver.Mo.	6.34	7.52	8.59	13.29	18.23	24.79	23.63	20.42	24.44	28.38	20.26	13.29	

Annual Average: 209.17

INDEX NAME: flw62
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.well
COMMENT: Amount.of.demand.remaining.after.tait.st.wells.
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

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STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	15.1	69.8	87.6	23.0	33.4	118	178	173	112	84.2	26.5	11.7	931.33
1976	0.88	20.1	17.8	64.6	105	223	304	291	254	154	94.1	41.0	1568.89
1977	17.0	14.2	34.5	77.8	186	288	350	340	287	189	116	78.4	1976.94
Aver.Mo.	10.99	34.69	46.64	55.13	108.13	209.45	277.20	267.87	217.64	142.24	78.70	43.71	

Annual Average: 1492.39

INDEX NAME: flw63
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Beltz.demand
COMMENT: Amount.of.demand.met.by.beltz.wells
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	3.15	9.49	12.7	6.69	20.3	30.0	31.0	31.0	30.0	23.3	12.8	8.03	218.50
1976	0.88	12.2	4.86	27.2	29.8	30.0	31.0	31.0	30.0	30.7	26.6	16.8	270.95
1977	5.32	5.55	11.3	28.8	31.0	30.0	31.0	31.0	30.0	31.0	25.9	24.2	285.13
Aver.Mo.	3.12	9.08	9.62	20.92	27.03	30.00	31.00	31.00	30.00	28.33	21.76	16.34	

Annual Average: 258.19

INDEX NAME: flw64
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Beltz.demand
COMMENT: Beltz.demand.remaining.to.be.met
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	11.9	60.3	75.0	16.3	13.1	87.7	147	142	81.8	60.9	13.6	3.64	712.83
1976	0	7.89	12.9	37.4	75.2	193	273	260	224	123	67.5	24.2	1297.95
1977	11.7	8.63	23.2	48.9	155	258	319	309	257	158	89.7	54.2	1691.81
Aver.Mo.	7.87	25.61	37.02	34.21	81.10	179.45	246.20	236.87	187.64	113.90	56.94	27.37	

Annual Average: 1234.20

INDEX NAME: flw65
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: LL.Demand
COMMENT: Demand.met.by.Loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	11.9	60.3	75.0	16.3	13.1	87.7	147	142	81.8	60.9	13.6	3.64	712.83
1976	0	7.89	12.9	22.1	32.1	34.5	35.6	35.6	34.5	33.9	25.0	8.99	283.19
1977	2.36	2.68	8.88	23.7	35.6	34.5	35.6	35.6	34.5	35.6	27.0	18.1	294.31
Aver.Mo.	4.76	23.63	32.26	20.71	26.96	52.24	72.60	71.12	50.25	43.47	21.86	10.26	

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Annual Average: 430.11

INDEX NAME: flw66
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Demand.Remaining
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1976	0	0	0	15.3	43.1	159	237	224	190	89.1	42.5	15.2	1014.76
1977	9.33	5.95	14.3	25.2	119	223	283	273	223	122	62.7	36.1	1397.50

Aver.Mo. 1.98 13.50 127.22 165.75 70.43 17.11
3.11 4.76 54.14 173.61 137.39 35.08

Annual Average: 804.09

INDEX NAME: res80
DATA TYPE: volume
UNITS: ENGLISH
STATION NAME: LL.Reservoir
COMMENT: Loch.Lomond.Reservoir.Storage
RECORD SPAN: 1936 TO 1996
Multiplier: .326 .326 .326 .326 .326 .326
.326 .326 .326 .326 .326 .326 .326
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2417	2786	2815	2811	2805	2711	2532	2354	2239	2187	2155	2135
1976	2117	2106	2135	2109	2040	1965	1883	1814	1751	1684	1641	1625
1977	1643	1625	1636	1582	1520	1449	1372	1295	1234	1169	1144	1267

INDEX NAME: res80
DATA TYPE: volume
UNITS: ENGLISH
STATION NAME: LL.Reservoir
COMMENT: Loch.Lomond.Reservoir.Storage
RECORD SPAN: 1936 TO 1996
Multiplier: 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	570	577	577	577	577	575	572	569	566	565	565	564
1976	564	564	564	564	562	561	559	557	556	554	553	553
1977	553	553	553	551	550	548	545	543	541	539	538	542

INDEX NAME: flw67
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: ll.spill
COMMENT: Loch.Lomond.spilled.flow
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	681	194	64.8	27.8	28.7	28.7	27.8	28.7	27.8	28.7	1192.59
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94

Aver.Mo. 26.23 83.33 27.78 28.70 28.70 28.70

28.70 245.99 40.75 28.70 27.78 27.78

Annual Average: 623.13

INDEX NAME: flw68
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Felton.div
COMMENT: Component.of.Loch.lomond.met.from.felton.Div.-water.right.a1
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1976	0	0	0	3.63	20.0	34.5	6.53	0	0	0	0	0	64.69
1977	0	2.68	2.39	15.7	24.8	0	0	0	0	0	0	0	45.59
Aver.Mo.	.00	.89	.80	6.44	14.96	11.50	2.18	.00	.00	.00	.00	.00	

Annual Average: 36.76

INDEX NAME: flw69
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: newell.Cr
COMMENT: component.of.loch.lomond.met.from.Newell.Cr.water.right-B
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	11.9	60.3	75.0	16.3	13.1	87.7	147	142	81.8	60.9	13.6	3.64	712.83
1976	0	7.89	12.9	18.5	12.1	0	29.1	35.6	34.5	33.9	25.0	8.99	218.50
1977	2.36	0	6.50	8.05	10.8	34.5	35.6	35.6	34.5	35.6	27.0	18.1	248.73
Aver.Mo.	4.76	22.73	31.47	14.28	12.00	40.74	70.42	71.12	50.25	43.47	21.86	10.26	

Annual Average: 393.35

INDEX NAME: flw70
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Water.R.A2
COMMENT: Water.from.Newell.Creek.under.Felton.diversion.rules
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Aver.Mo.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	

Annual Average: .00

JOB COMPLETED

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2020 demand

5154 mg/yr

INDEX NAME: flw65
STATION NAME: LL.Demand
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1936	0	0	0	0	0	0	0	0	0	121	51.4	45.1	217.35
1937	30.0	135	177	4.28	62.2	152	175	179	45.0	0	0	0	958.39
1938	71.4	144	150	20.8	60.5	137	181	175	0	0	0	0	940.54
1939	37.4	14.7	38.8	11.4	99.5	180	278	293	100	0	0	0	1053.94
1940	114	110	81.7	36.7	69.7	138	184	185	57.6	0	0	0	976.24
1941	123	136	112	156	84.8	129	168	33.1	0	0	0	0	940.54
1942	92.3	61.0	41.8	77.9	74.1	128	170	173	123	0	0	0	940.54
1943	112	29.1	65.2	15.2	60.5	148	184	182	143	0	0	0	940.54
1944	38.3	81.0	20.6	29.6	77.9	144	184	181	151	89.4	52.6	12.0	1061.31
1945	3.85	79.9	50.8	8.54	81.4	143	182	182	151	113	37.7	22.6	1055.27
1946	12.3	19.6	24.8	6.77	83.4	158	193	192	167	81.2	59.5	17.0	1014.31
1947	12.4	16.9	39.6	8.32	92.0	178	198	255	263	149	44.1	22.8	1278.70
1948	5.05	13.5	39.2	17.8	28.9	34.5	35.6	35.6	34.5	33.6	25.0	10.7	313.91
1949	5.84	1.15	17.2	3.98	83.0	160	202	206	170	88.9	56.1	33.7	1028.00
1950	64.0	32.3	14.8	20.5	78.0	164	198	208	186	117	130	53.2	1265.64
1951	47.9	5.90	30.8	20.5	83.7	158	191	196	163	80.5	0	0	976.24
1952	161	33.8	91.1	11.7	60.2	156	172	176	151	66.6	13.0	0	1092.26
1953	61.3	0	21.4	31.0	66.9	147	182	186	148	70.7	52.7	0	967.31
1954	33.4	40.8	54.4	32.1	60.5	144	179	186	153	68.5	62.9	42.0	1057.34
1955	50.1	12.9	4.55	46.5	62.0	143	183	182	153	69.2	61.6	82.3	1050.10
1956	168	52.4	0	36.5	73.7	140	190	182	153	11.6	0	0	1005.95
1957	21.5	50.1	9.51	33.0	96.8	129	169	173	143	56.7	28.6	36.2	946.64
1958	53.7	159	115	114	65.3	141	183	180	29.2	0	0	0	1038.71
1959	42.4	64.1	0	14.3	82.1	164	197	196	166	32.1	0	0	958.39
1960	57.8	39.2	8.33	17.7	79.8	154	209	246	223	110	96.2	10.5	1252.38
1961	18.9	3.21	22.9	13.6	33.8	34.5	35.6	35.6	34.5	35.6	31.7	7.98	308.11
1962	6.51	15.4	8.05	5.04	70.0	168	197	236	185	82.5	8.53	17.2	999.04
1963	25.8	56.1	38.7	114	65.9	130	173	175	155	78.4	81.7	0	1093.83
1964	33.1	0	11.4	18.1	112	180	202	275	189	120	85.1	83.3	1310.11
1965	64.3	7.19	10.1	77.7	59.1	149	185	188	152	64.7	11.6	0	967.31
1966	23.3	22.0	0	19.9	101	180	216	266	237	151	108	0	1323.94
1967	75.8	10.7	80.2	174	61.5	147	158	167	138	53.3	55.8	18.4	1139.38
1968	33.3	20.7	31.5	15.3	81.8	152	189	204	170	83.7	46.9	0	1029.00
1969	115	170	41.3	29.5	61.5	155	190	189	159	61.7	0	0	1171.30
1970	152	19.6	35.6	7.97	59.1	134	188	186	151	68.5	0	0	1002.01
1971	7.56	0	23.6	18.7	80.9	162	198	214	191	71.6	0	0	967.31
1972	19.8	12.1	5.19	70.3	138	236	349	252	0	0	62.4	13.0	1158.36
1973	95.9	125	57.9	4.28	59.1	133	182	183	157	95.1	98.9	37.4	1229.28
1974	59.9	12.2	82.9	64.3	61.4	131	164	164	141	88.7	7.19	0	976.37
1975	16.9	73.6	94.1	30.6	60.6	157	220	214	147	23.9	0	0	1038.71
1976	2.75	25.1	21.8	33.1	35.1	34.5	35.6	35.6	34.5	35.5	31.8	22.3	347.69
1977	8.32	6.99	14.6	34.1	35.6	18.4	0	0	0	0	0	5.48	123.55
1978	17.2	12.6	12.6	54.2	59.1	136	179	180	157	59.9	55.6	6.51	929.54
1979	56.7	69.5	31.4	21.4	62.2	147	190	183	164	98.1	48.0	0	1070.23
1980	75.3	104	18.6	23.5	71.3	156	192	182	152	68.4	13.6	0	1056.56
1981	52.3	11.6	39.8	7.04	91.7	161	219	273	245	126	73.8	41.7	1342.39
1982	71.8	41.1	94.3	159	59.1	136	174	182	163	61.6	38.1	0	1181.51
1983	78.0	151	169	89.9	96.0	128	169	59.3	0	0	0	0	940.54
1984	0	10.5	17.4	6.82	81.8	166	198	196	173	90.9	9.04	0	949.46
1985	8.39	16.7	21.6	17.2	96.9	184	216	221	204	137	89.3	20.7	1232.74
1986	41.6	96.9	93.6	6.13	62.8	153	192	191	181	68.2	37.6	18.0	1141.97
1987	31.5	43.6	55.0	32.9	34.7	34.5	35.6	35.6	34.5	35.6	30.5	27.3	431.53
1988	16.7	3.79	3.24	28.7	35.6	34.5	35.6	35.6	34.5	35.6	29.4	18.5	311.95
1989	14.6	10.7	25.0	33.3	34.0	34.5	35.6	35.6	34.5	35.6	22.9	11.0	327.30
1990	9.29	6.60	8.83	32.5	34.7	34.5	35.6	35.6	34.5	35.6	33.9	17.1	318.72
1991	0	0	28.4	29.6	35.1	34.5	35.6	35.6	34.5	35.6	32.4	34.4	335.75
1992	16.9	27.0	19.9	26.0	34.7	34.5	35.6	35.6	34.5	35.6	34.5	25.0	359.97
1993	19.5	14.9	3.45	18.5	88.9	149	180	181	161	82.6	55.5	30.8	983.91
1994	14.9	38.1	6.24	38.8	104	174	252	299	270	70.3	45.3	31.5	1344.65
1995	165	2.31	121	44.6	72.0	130	162	170	140	55.3	26.3	24.1	1112.70
Aver.Mo.	47.79	42.88	42.62	36.26	68.31	129.95	163.48	164.97	125.52	60.07	34.61	15.00	

Annual Average: 931.45

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INDEX NAME: flw66
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Demand.Remaining
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1936 JANUARY
ENDS DATE: 1995 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1937	0	0	0	0	0	0	0	0	103	67.2	57.2	49.3	277.07
1938	0	0	0	0	0	0	0	7.04	155	66.1	29.9	4.12	262.31
1939	0	0	0	0	0	0	0	0	151	125	67.6	27.8	370.97
1940	0	0	0	0	0	0	0	0	103	74.5	35.2	97.0	309.26
1941	0	0	0	0	0	0	0	139	142	63.3	35.6	59.8	439.60
1942	0	0	0	0	0	0	0	0	21.4	72.4	50.5	21.5	165.72
1943	0	0	0	0	0	0	0	0	7.92	69.1	33.9	27.0	137.89
1945	0	0	0	0	0	0	0	0	0	0	0	63.6	63.57
1948	0	0	0	65.4	48.7	99.3	143	149	150	45.6	25.8	27.8	754.81
1949	20.5	3.10	78.1	0	0	0	0	0	0	0	0	0	101.67
1951	0	0	0	0	0	0	0	0	0	20.3	73.3	90.4	184.05
1952	0	0	0	0	0	0	0	0	0	0	43.9	68.9	112.81
1953	0	0	0	0	0	0	0	0	0	0	4.81	9.31	14.12
1955	0	0	0	0	0	0	0	0	0	0	0	53.4	53.40
1956	0	0	0	0	0	0	0	0	0	87.6	23.6	6.52	117.78
1958	0	0	0	0	0	0	0	0	130	63.8	38.9	16.4	248.74
1959	0	0	0	0	0	0	0	0	0	23.2	31.4	15.3	69.91
1961	0	0	0	9.98	74.0	166	287	293	256	160	124	14.8	1385.12
1962	8.49	78.9	35.9	0	0	0	0	0	0	0	0	0	123.38
1964	0	0	0	0	0	0	0	0	0	0	0	24.3	24.26
1965	0	0	0	0	0	0	0	0	0	0	65.2	47.3	112.45
1966	0	0	0	0	0	0	0	0	0	0	4.33	45.9	50.23
1968	0	0	0	0	0	0	0	0	0	0	23.5	52.5	75.92
1969	0	0	0	0	0	0	0	0	0	3.80	34.7	69.9	108.37
1970	0	0	0	0	0	0	0	0	0	2.36	106	71.4	180.02
1971	0	0	0	0	0	0	0	0	0	17.6	69.4	63.1	150.08
1972	0	0	0	0	0	0	0	97.1	303	138	32.2	0	570.54
1974	0	0	0	0	0	0	0	0	0	0	41.0	28.1	69.10
1975	0	0	0	0	0	0	0	0	0	82.1	39.0	16.2	137.30
1976	0	0	0	51.8	101	228	311	296	255	142	79.0	28.4	1492.14
1977	12.0	9.70	26.4	64.0	181	309	393	381	322	212	132	83.2	2125.78
1978	78.7	55.8	53.7	0	0	0	0	0	0	0	0	0	188.17
1979	0	0	0	0	0	0	0	0	0	0	0.33	47.9	48.20
1980	0	0	0	0	0	0	0	0	0	0	22.1	20.5	42.57
1982	0	0	0	0	0	0	0	0	0	0	21.5	37.2	58.67
1983	0	0	0	0	0	0	0	115	157	48.1	78.0	90.6	488.73
1984	0	0	0	0	0	0	0	0	0	0	92.2	15.6	107.80
1987	0	0	0	35.0	91.2	166	224	295	249	136	55.1	64.0	1316.10
1988	26.3	0	0.32	45.4	135	199	303	295	238	152	95.7	35.8	1526.24
1989	7.13	6.94	63.6	48.5	83.9	184	286	225	203	107	18.8	1.11	1234.33
1990	22.4	19.7	5.68	37.1	136	176	209	252	244	156	109	51.3	1418.78
1991	21.5	37.0	106	28.9	108	172	275	290	247	160	63.6	81.8	1590.86
1992	13.6	85.1	19.4	19.2	91.6	186	205	262	228	119	85.3	53.8	1368.20
1993	96.8	61.0	10.2	0	0	0	0	0	0	0	0	0	167.97
1994	0	0	0	0	0	0	0	0	0	67.5	51.3	0.03	118.78
Aver.Mo.	5.12	5.95	6.65	6.75	17.53	31.43	43.94	51.62	61.07	41.37	33.25	28.04	

Annual Average: 332.73

INDEX NAME: flw50
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Liddell
COMMENT: Outflow.from.Liddell.Spring
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year

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1975	37.0	20.2	13.4	23.5	47.0	47.0	48.7	48.7	50.4	30.2	35.3	35.3	436.88
1976	36.2	17.7	30.0	16.2	42.8	35.4	37.9	28.2	30.8	36.7	28.6	29.9	370.38
1977	30.2	25.0	21.7	27.6	21.2	28.8	25.3	29.3	23.4	26.7	23.4	12.4	294.96

Aver.Mo. 20.96 22.42 37.08 35.41 31.22 25.84
34.49 21.69 37.04 37.31 34.87 29.10

Annual Average: 367.41

INDEX NAME: flw51
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Laguna
COMMENT: outflow.from.Laguna.and.Riggiardo.Creeks
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	24.0	30.5	49.4	108	109	56.8	7.23	11.4	25.8	21.2	22.7	17.5	484.27
1976	13.3	11.8	17.3	16.8	11.2	10.2	3.06	5.10	7.14	6.12	6.90	6.68	115.60
1977	8.99	9.29	9.99	10.3	6.19	1.55	4.13	2.06	1.99	6.19	5.98	13.5	80.17

Aver.Mo. 17.21 45.15 22.84 6.17 11.18 12.57
15.41 25.58 42.27 4.80 11.64 11.86

Annual Average: 226.68

INDEX NAME: flw52
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Majors
COMMENT: outflow.from.Majors.Creek
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.2	12.1	5.84	0	0	17.5	27.6	23.1	22.7	14.6	16.8	15.2	177.65
1976	22.0	11.1	21.4	16.7	23.6	18.4	19.8	12.5	15.0	15.2	14.9	16.8	207.43
1977	19.3	15.2	15.1	14.4	11.6	12.9	12.5	12.9	13.9	11.6	18.3	12.1	169.73

Aver.Mo. 12.79 10.36 16.27 16.19 13.78 14.71
21.14 14.13 11.74 19.94 17.20 16.69

Annual Average: 184.94

INDEX NAME: flw53
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: North.Coast
COMMENT: Combined.North.Coast.flows.reduced.to.capacity.of.pipeline,cap.9.1.cfs
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85

Aver.Mo. 50.95 77.93 76.19 57.77 56.18 53.12
71.03 61.39 91.04 62.05 63.71 57.65

Annual Average: 779.02

INDEX NAME: flw54

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DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: NC.demand
COMMENT: North.Coast.component.of.Demand
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw55
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: NC.Remaining
COMMENT: Remaining.demand.after.demand.met.by.north.coast
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	239	227	265	263	331	424	496	483	414	360	294	260	4055.20
1976	251	260	265	345	410	481	519	520	460	368	318	275	4471.35
1977	264	241	287	342	448	502	537	522	473	382	321	290	4609.15
Aver.Mo.	251.39	242.61	272.30	316.52	396.37	468.93	517.26	508.51	448.83	369.99	310.85	275.01	

Annual Average: 4378.56

INDEX NAME: flw56
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Felton.Div
COMMENT: Water.diverted.to.Loch.Lomond.reservor
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	0	17.9	0	0	0	0	0	0	0	0	0	0	17.85
1976	0	0	41.9	0	0	0	0	0	0	0	0	0	41.94
1977	0	0	7.04	0	0	0	0	0	0	0	0	80.3	87.37
Aver.Mo.	.00	5.95	16.33	.00	.00	.00	.00	.00	.00	.00	.00	26.78	

Annual Average: 49.05

INDEX NAME: flw57
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.div.suf
COMMENT: Tait.st.surface.diversions.amount.available
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	210	138	145	195	224	217	224	217	217	203	217	224	2432.05
1976	224	201	210	210	224	168	103	125	107	128	158	186	2044.08
1977	210	195	210	202	180	110	101	102	99.9	106	131	147	1793.22
Aver.Mo.	214.73	178.13	188.19	202.40	209.43	165.17	142.55	148.01	141.39	145.39	168.62	185.78	

Annual Average: 2089.79

INDEX NAME: flw58
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.div.dem
COMMENT: Tait.st.amount.diverted.to.meet.demand
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	201	130	141	195	224	217	224	217	217	203	215	218	2403.60
1976	222	200	209	210	224	168	103	125	107	128	158	186	2039.89
1977	210	195	209	202	180	110	101	102	99.9	106	131	147	1791.69
Aver.Mo.	211.16	175.16	186.28	202.30	209.43	165.17	142.55	148.01	141.39	145.39	168.00	183.57	

Annual Average: 2078.39

INDEX NAME: flw59
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.remaining
COMMENT: Amount.of.demand.remaining.after.surface.diversion.at.tait.st.
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	38.0	96.9	124	67.4	107	207	271	266	197	157	78.4	42.2	1651.60
1976	28.5	59.9	56.0	135	185	313	416	396	353	241	160	89.0	2431.46
1977	54.2	45.5	77.9	140	269	391	437	420	373	276	190	143	2817.46
Aver.Mo.	40.23	67.45	86.03	114.21	186.95	303.76	374.71	360.50	307.44	224.60	142.86	91.45	

Annual Average: 2300.17

INDEX NAME: flw60
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.Wells
COMMENT: Amounts.available.for.diversion.from.Tait.st.wells,1.9cfs
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	38.1	28.2	28.2	36.8	38.1	36.8	38.1	38.1	36.8	38.1	36.8	38.1	432.23
1976	38.1	33.9	38.1	36.8	30.1	21.1	38.1	34.0	34.2	33.8	22.2	10.9	371.38
1977	29.2	21.4	31.9	16.9	22.6	34.5	12.8	7.91	21.5	32.7	33.5	32.2	297.01
Aver.Mo.	35.12	27.84	32.75	30.19	30.26	30.82	29.64	26.67	30.84	34.85	30.83	27.06	

Annual Average: 366.87

INDEX NAME: flw61
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.Wells
COMMENT: Amount.of.demand.met.by.Tait.st.wells
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	10.9	9.50	11.9	18.7	19.7	19.4	20.0	20.6	19.4	21.4	17.0	11.9	200.58
1976	14.3	16.3	16.6	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.9	10.2	272.43
1977	16.0	13.2	16.7	12.3	20.8	34.3	12.8	7.91	20.9	32.7	29.7	25.2	242.46
Aver.Mo.	13.73	13.00	15.08	16.99	19.56	24.79	23.63	20.42	24.44	28.86	22.21	15.77	

Annual Average: 238.49

INDEX NAME: flw62
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.well
COMMENT: Amount.of.demand.remaining.after.tait.st.wells.
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	27.1	87.4	112	51.0	90.0	187	251	245	177	136	61.4	30.3	1456.47
1976	14.2	43.6	39.4	115	167	293	378	363	319	208	140	78.8	2159.03
1977	38.2	32.3	61.2	128	248	357	424	412	352	243	160	118	2575.01
Aver.Mo.	26.50	54.45	70.94	98.01	168.42	278.97	351.08	340.08	283.00	195.74	120.65	75.68	

Annual Average: 2063.50

INDEX NAME: flw63
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Beltz.demand
COMMENT: Amount.of.demand.met.by.beltz.wells
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	10.2	13.8	18.2	20.5	29.3	30.0	31.0	31.0	30.0	29.9	22.4	14.1	280.46
1976	11.5	18.6	17.6	30.0	31.0	30.0	31.0	31.0	30.0	31.0	29.4	28.1	319.20
1977	17.9	15.6	20.2	30.0	31.0	30.0	31.0	31.0	30.0	31.0	28.7	29.3	325.67
Aver.Mo.	13.18	16.00	18.65	26.83	30.45	30.00	31.00	31.00	30.00	30.64	26.84	23.86	

Annual Average: 308.44

INDEX NAME: flw64
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Beltz.demand
COMMENT: Beltz.demand.remaining.to.be.met
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY

ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	16.9	73.6	94.1	30.6	60.6	157	220	214	147	106	39.0	16.2	1176.01
1976	2.75	25.1	21.8	84.9	136	263	347	332	289	177	111	50.6	1839.83
1977	20.3	16.7	41.0	98.1	217	327	393	381	322	212	132	88.6	2249.34
Aver.No.	13.32	38.45	52.30	71.18	137.97	248.97	320.08	309.08	253.00	165.09	93.80	51.82	

Annual Average: 1755.06

INDEX NAME: flw65
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: LL.Demand
COMMENT: Demand.met.by.Loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	16.9	73.6	94.1	30.6	60.6	157	220	214	147	23.9	0	0	1038.71
1976	2.75	25.1	21.8	33.1	35.1	34.5	35.6	35.6	34.5	35.5	31.8	22.3	347.69
1977	8.32	6.99	14.6	34.1	35.6	18.4	0	0	0	0	0	5.48	123.55
Aver.No.	9.33	35.22	43.50	32.59	43.79	70.04	85.34	83.31	60.54	19.82	10.59	9.25	

Annual Average: 503.32

INDEX NAME: flw66
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Demand.Remaining
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	0	0	0	0	0	0	0	0	0	82.1	39.0	16.2	137.30
1976	0	0	0	51.8	101	228	311	296	255	142	79.0	28.4	1492.14
1977	12.0	9.70	26.4	64.0	181	309	393	381	322	212	132	83.2	2125.78
Aver.No.	4.00	3.23	8.80	38.59	94.17	178.92	234.74	225.77	192.46	145.27	83.21	42.57	

Annual Average: 1251.74

INDEX NAME: res80
DATA TYPE: volume
UNITS: ENGLISH
STATION NAME: LL.Reservoir
COMMENT: Loch.Lomond.Reservoir.Storage
RECORD SPAN: 1936 TO 1996
Multiplier: .326 .326 .326 .326 .326 .326
.326 .326 .326 .326 .326 .326 .326
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2177	2547	2815	2811	2785	2622	2370	2120	1942	1926	1907	1891
1976	1871	1842	1851	1804	1734	1661	1582	1514	1452	1386	1336	1306
1977	1296	1275	1261	1199	1137	1084	1045	1006	981	952	952	1112

INDEX NAME: res80
DATA TYPE: volume
UNITS: ENGLISH
STATION NAME: LL.Reservoir

COMMENT: Loch.Lomond.Reservoir.Storage
RECORD SPAN: 1936 TO 1996
Multiplier: 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	565	572	577	577	577	574	569	564	560	560	559	559
1976	558	558	558	557	555	553	551	550	548	546	544	543
1977	543	542	542	540	538	536	535	534	533	531	531	537

INDEX NAME: flw67
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: ll.spill
COMMENT: Loch.Lomond.spilled.flow
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	422	180	37.0	27.8	28.7	28.7	27.8	28.7	27.8	28.7	891.69
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	159.68	78.62	31.46	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 522.83

INDEX NAME: flw68
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Felton.div
COMMENT: Component.of.Loch.lomond.met.from.felton.Div.-water.right.a1
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	8.19	21.7	68.3	0	0	0	0	0	0	0	0	0	98.18
1976	0	0	0	25.1	16.9	0	0	0	0	0	0	0	41.94
1977	0	0	0	7.04	0	0	0	0	0	0	0	5.48	12.53
Aver.Mo.	2.73	7.22	22.78	10.70	5.62	.00	.00	.00	.00	.00	.00	1.83	

Annual Average: 50.88

INDEX NAME: flw69
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: newell.Cr
COMMENT: component.of.loch.lomond.met.from.Newell.Cr.water.right-B
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	8.71	51.9	25.7	30.6	60.6	157	220	214	147	23.9	0	0	940.54
1976	2.75	25.1	21.8	8.05	18.2	34.5	35.6	35.6	34.5	35.5	31.8	22.3	305.76
1977	8.32	6.99	14.6	27.1	35.6	18.4	0	0	0	0	0	0	111.03
Aver.Mo.	6.60	28.00	20.72	21.89	38.17	70.04	85.34	83.31	60.54	19.82	10.59	7.42	

15/11

Annual Average: 452.44

INDEX NAME: flw70
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Water.R.A2
COMMENT: Water.from.Newell.Creek.under.Felton.diversion.rules
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Aver.Mo.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	

Annual Average: .00

JOB COMPLETED

17/22

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2050 demand.
5490 mg/...

INDEX NAME: flw65
COMMENT: Demand.met.by.Loch.Lomond.reservoir

Million gallons/month

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1936	0	0	0	0	0	0	0	0	0	149	74.0	59.3	281.96
1937	35.0	151	198	15.9	92.2	187	213	74.0	0	0	0	0	967.31
1938	80.3	160	169	35.1	91.0	173	219	13.2	0	0	0	0	940.54
1939	42.0	16.6	44.2	23.7	130	216	316	229	0	0	0	0	1016.94
1940	126	123	91.0	51.5	99.6	173	222	90.3	0	0	0	0	976.24
1941	139	151	124	178	115	164	69.0	0	0	0	0	0	940.54
1942	104	68.8	46.0	95.5	105	164	207	150	0	0	0	0	940.54
1943	125	32.4	73.2	29.1	90.6	184	222	184	0	0	0	0	940.54
1944	44.9	89.4	23.2	42.7	108	180	222	218	147	0	0	0	1074.41
1945	4.52	89.1	56.4	19.6	111	179	220	218	166	0	0	0	1063.91
1946	13.6	22.3	28.4	19.0	113	193	230	229	201	24.6	0	0	1074.41
1947	15.2	19.2	43.1	20.4	123	213	236	292	296	177	65.4	33.1	1533.32
1948	10.2	17.2	45.4	21.0	33.0	34.5	35.6	35.6	34.5	34.5	29.6	16.2	347.50
1949	7.14	1.15	17.2	14.0	114	195	240	242	204	116	78.4	46.1	1275.93
1950	72.1	35.5	16.3	34.5	108	199	236	245	220	145	148	63.4	1522.87
1951	52.9	7.13	34.9	32.9	114	193	228	233	196	128	94.2	98.6	1413.51
1952	179	39.0	102	25.5	90.1	191	210	213	96.3	0	0	0	1145.81
1953	68.8	0	24.1	45.1	96.8	182	220	223	107	0	0	0	967.31
1954	39.1	44.8	59.4	45.3	91.0	180	217	223	186	59.7	0	0	1145.81
1955	55.1	14.3	5.27	58.6	92.5	178	221	219	186	83.1	0	0	1113.36
1956	188	58.7	0	51.4	104	175	227	187	0	0	0	0	991.86
1957	25.8	55.0	11.0	46.2	127	165	207	210	176	77.4	0	0	1100.40
1958	58.9	176	127	135	95.3	176	221	139	0	0	0	0	1127.96
1959	45.6	70.9	0	25.8	112	199	235	233	36.3	0	0	0	958.39
1960	64.6	42.4	9.72	31.7	110	190	247	283	254	0	0	0	1231.97
1961	27.2	4.40	26.1	20.3	34.5	34.5	35.6	35.6	34.5	35.6	33.1	14.5	335.98
1962	13.3	16.6	8.05	16.1	10.0	204	235	273	218	103	18.3	19.4	1224.07
1963	27.8	62.7	43.0	131	96.4	165	211	212	188	105	80.0	0	1322.63
1964	38.2	0	14.1	33.1	144	216	240	312	223	123	49.6	59.3	1452.54
1965	71.2	8.51	10.9	95.4	89.1	184	222	225	124	0	0	0	1029.79
1966	26.5	24.0	0	37.4	132	215	254	303	271	64.3	13.6	0	1340.21
1967	83.3	12.7	87.9	196	91.7	183	195	203	172	80.9	53.0	0	1358.84
1968	36.7	22.6	34.2	26.4	112	188	227	241	204	82.2	0	0	1173.34
1969	127	189	48.0	43.1	91.5	190	228	226	29.9	0	0	0	1171.30
1970	168	22.3	39.5	19.6	89.1	170	226	223	28.1	0	0	0	985.16
1971	8.90	0	26.3	33.3	112	198	236	250	85.1	0	0	0	949.46
1972	24.2	17.1	15.1	32.7	35.5	34.5	35.6	35.6	34.5	34.9	19.2	4.04	323.00
1973	16.1	24.1	13.8	15.7	89.1	168	220	220	191	122	113	41.6	1234.95
1974	66.8	13.5	91.4	80.5	91.4	167	202	201	174	76.6	0	0	1163.66
1975	22.8	82.3	106	47.8	90.9	193	258	251	91.7	0	0	0	1143.93
1976	9.61	36.8	33.5	34.5	35.6	34.5	35.6	35.6	34.5	35.6	33.0	29.3	388.26
1977	15.7	11.9	20.2	17.2	0	0	0	0	0	0	0	1.15	66.24
1978	17.2	12.6	12.6	71.4	89.1	171	217	217	190	86.9	14.8	0	1100.04
1979	62.5	76.5	34.3	34.7	92.7	182	228	220	197	58.9	0	0	1186.26
1980	82.4	114	20.6	35.8	102	191	230	219	61.9	0	0	0	1056.56
1981	61.6	13.6	45.3	18.8	122	197	257	310	279	99.8	0	0	1403.43
1982	81.8	46.6	104	181	89.1	172	212	219	49.3	0	0	0	1154.74
1983	85.5	170	191	106	127	163	98.8	0	0	0	0	0	940.54
1984	0	12.4	19.5	18.9	112	202	236	233	116	0	0	0	949.46
1985	9.82	18.6	24.4	30.1	128	220	253	258	237	165	112	30.1	1486.62
1986	46.8	107	104	17.1	92.7	189	229	228	214	15.9	0	0	1244.47
1987	46.6	58.0	75.3	34.2	35.6	34.5	35.6	35.6	34.5	35.6	33.3	32.0	490.88
1988	25.3	12.8	10.5	32.9	35.6	34.5	35.6	35.6	34.5	10.3	0	9.20	277.01
1989	24.1	13.3	31.3	34.2	35.2	34.5	4.60	0	0	0	27.2	19.0	223.48
1990	15.1	9.29	21.9	34.5	35.6	34.5	13.8	0	0	0	0	0	164.64
1991	0	0	27.4	33.1	35.6	34.5	35.6	35.6	34.5	14.9	0	1.15	252.56
1992	6.84	22.4	26.2	32.1	35.6	34.5	35.6	35.6	34.5	35.6	14.9	24.0	338.06
1993	19.5	14.9	3.45	30.3	119	184	218	218	194	110	76.3	39.5	1225.81
1994	22.5	41.4	8.29	26.0	34.5	34.5	35.6	35.6	34.5	35.6	31.9	19.7	360.10
1995	30.5	1.15	21.8	59.9	102	166	200	207	173	82.1	44.5	30.7	1119.11
Aver.Mo.	50.31	46.29	45.83	46.80	88.73	151.79	179.28	168.98	108.21	43.46	20.97	11.52	

Annual Average: 962.18

INDEX NAME: flw66
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Demand.Remaining
COMMENT: Total.Demand.not.met.from.loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1936 JANUARY
ENDS DATE: 1995 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1937	0	0	0	0	0	0	0	142	182	95.0	76.9	54.4	549.76
1938	0	0	0	0	0	0	0	206	189	91.7	42.9	6.08	534.90
1939	0	0	0	0	0	0	0	102	285	152	89.6	43.5	671.65
1940	0	0	0	0	0	0	0	132	194	101	53.5	108	588.08
1941	0	0	0	0	0	0	137	209	175	90.0	49.9	66.8	727.79
1942	0	0	0	0	0	0	0	59.9	177	99.3	61.9	24.1	422.47
1943	0	0	0	0	0	0	0	34.9	185	96.8	53.3	37.5	407.18
1944	0	0	0	0	0	0	0	0	37.1	116	65.2	13.4	231.97
1945	0	0	0	0	0	0	0	0	18.4	140	50.7	96.1	304.77
1946	0	0	0	0	0	0	0	0	0	83.8	78.1	18.9	180.81
1948	0	0	0	79.1	74.7	135	181	186	184	71.8	43.1	33.7	987.50
1949	24.0	3.73	88.2	0	0	0	0	0	0	0	0	0	115.91
1952	0	0	0	0	0	0	0	0	88.0	93.7	73.9	75.1	330.63
1953	0	0	0	0	0	0	0	0	74.6	97.8	76.9	16.5	265.70
1954	0	0	0	0	0	0	0	0	0	35.9	79.2	46.7	161.75
1955	0	0	0	0	0	0	0	0	0	13.2	82.3	152	248.03
1956	0	0	0	0	0	0	0	31.8	186	127	39.9	12.2	397.28
1957	0	0	0	0	0	0	0	0	0	6.34	47.5	44.7	98.55
1958	0	0	0	0	0	0	0	77.4	192	90.8	58.4	26.1	445.12
1959	0	0	0	0	0	0	0	0	163	82.0	51.1	26.0	322.28
1960	0	0	0	0	0	0	0	0	2.62	138	118	15.4	274.33
1961	0	0	0	20.0	104	201	325	330	289	188	146	19.1	1623.27
1962	10.9	87.5	40.6	0	0	0	0	0	0	0	0	0	139.05
1963	0	0	0	0	0	0	0	0	0	0	14.0	0	14.00
1964	0	0	0	0	0	0	0	0	0	23.9	57.3	64.7	145.96
1965	0	0	0	0	0	0	0	0	61.7	91.8	95.1	53.7	302.24
1966	0	0	0	0	0	0	0	0	0	115	119	49.8	283.75
1967	0	0	0	0	0	0	0	0	0	0	21.2	23.5	44.70
1968	0	0	0	0	0	0	0	0	0	28.6	91.0	62.1	181.77
1969	0	0	0	0	0	0	0	0	162	92.4	53.7	78.9	387.32
1970	0	0	0	0	0	0	0	0	156	97.9	126	79.7	460.15
1971	0	0	0	0	0	0	0	0	139	116	91.6	77.0	424.24
1972	0	0	0	62.4	135	237	351	351	302	131	90.6	11.6	1670.57
1973	89.6	115	52.1	0	0	0	0	0	0	0	0	0	256.63
1974	0	0	0	0	0	0	0	0	0	39.2	69.2	35.8	144.19
1975	0	0	0	0	0	0	0	0	88.8	133	57.4	26.3	305.56
1976	0	0	0	76.1	132	264	349	333	288	169	101	40.7	1753.59
1977	15.5	13.8	34.7	107	249	363	431	418	356	240	155	108	2489.04
1978	88.9	63.1	61.0	0	0	0	0	0	0	0	59.9	9.88	282.80
1979	0	0	0	0	0	0	0	0	0	66.3	67.8	57.0	191.05
1980	0	0	0	0	0	0	0	0	124	95.5	56.3	29.5	304.91
1981	0	0	0	0	0	0	0	0	0	53.9	95.0	49.7	198.54
1982	0	0	0	0	0	0	0	0	148	88.1	72.7	41.4	349.75
1983	0	0	0	0	0	0	108	212	190	73.9	91.2	101	775.83
1984	0	0	0	0	0	0	0	0	90.3	118	123	18.8	350.07
1986	0	0	0	0	0	0	0	0	0	79.3	58.3	28.9	166.60
1987	0	0	0	59.4	122	202	262	332	283	164	75.7	79.6	1579.08
1988	34.5	1.27	1.69	66.2	167	235	341	332	271	205	148	61.4	1864.44
1989	14,5	13.9	77.5	73.2	114	219	355	298	270	170	35.6	7.36	1649.05
1990	27.2	23.0	8.85	60.8	167	212	268	325	312	220	167	88.7	1878.96
1991	40.9	51.0	128	50.4	140	208	313	327	280	208	120	136	2001.80
1992	42.2	109	30.5	38.0	122	222	243	299	261	147	129	74.0	1716.28
1993	109	70.0	12.3	0	0	0	0	0	0	0	0	0	191.04
1994	0	0	0	34.2	101	176	254	300	269	130	87.7	26.7	1377.83
1995	153	1.76	112	0	0	0	0	0	0	0	0	0	266.67
Aver.Mo.	10.82	9.21	10.79	12.11	27.13	44.53	65.28	83.92	111.23	85.13	66.15	40.97	

Annual Average: 567.29

INDEX NAME: flw50
DATA TYPE: flow
UNITS: ENGLISH

STATION NAME: Liddell
COMMENT: Outflow.from.Liddell.Spring
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	37.0	20.2	13.4	23.5	47.0	47.0	48.7	48.7	50.4	30.2	35.3	35.3	436.88
1976	36.2	17.7	30.0	16.2	42.8	35.4	37.9	28.2	30.8	36.7	28.6	29.9	370.38
1977	30.2	25.0	21.7	27.6	21.2	28.8	25.3	29.3	23.4	26.7	23.4	12.4	294.96
Aver.Mo.	34.49	20.96	21.69	22.42	37.04	37.08	37.31	35.41	34.87	31.22	29.10	25.84	

Annual Average: 367.41

INDEX NAME: flw51
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Laguna
COMMENT: outflow.from.Laguna.and.Riggiardo.Creeks
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	24.0	30.5	49.4	108	109	56.8	7.23	11.4	25.8	21.2	22.7	17.5	484.27
1976	13.3	11.8	17.3	16.8	11.2	10.2	3.06	5.10	7.14	6.12	6.90	6.68	115.60
1977	8.99	9.29	9.99	10.3	6.19	1.55	4.13	2.06	1.99	6.19	5.98	13.5	80.17
Aver.Mo.	15.41	17.21	25.58	45.15	42.27	22.84	4.80	6.17	11.64	11.18	11.86	12.57	

Annual Average: 226.68

INDEX NAME: flw52
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Majors
COMMENT: outflow.from.Majors.Creek
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.2	12.1	5.84	0	0	17.5	27.6	23.1	22.7	14.6	16.8	15.2	177.65
1976	22.0	11.1	21.4	16.7	23.6	18.4	19.8	12.5	15.0	15.2	14.9	16.8	207.43
1977	19.3	15.2	15.1	14.4	11.6	12.9	12.5	12.9	13.9	11.6	18.3	12.1	169.73
Aver.Mo.	21.14	12.79	14.13	10.36	11.74	16.27	19.94	16.19	17.20	13.78	16.69	14.71	

Annual Average: 184.94

INDEX NAME: flw53
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: North.Coast
COMMENT: Combined.North.Coast.flows.reduced.to.capacity.of.pipeline,cap.9.1.cfs
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year

20/5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw54
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: NC.demand
COMMENT: North.Coast.component.of.Demand
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	83.1	62.8	68.7	132	156	121	83.5	83.2	98.9	66.1	74.8	68.1	1098.80
1976	71.5	40.6	68.7	49.7	77.7	64.0	60.8	45.8	52.9	58.0	50.4	53.3	693.41
1977	58.5	49.5	46.8	52.2	39.0	43.2	41.9	44.3	39.4	44.5	47.7	38.0	544.85
Aver.Mo.	71.03	50.95	61.39	77.93	91.04	76.19	62.05	57.77	63.71	56.18	57.65	53.12	

Annual Average: 779.02

INDEX NAME: flw55
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: NC.Remaining
COMMENT: Remaining.demand.after.demand.met.by.north.coast
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	260	246	287	288	363	459	534	520	447	388	318	281	4391.19
1976	272	280	287	371	442	517	556	557	493	396	342	296	4808.04
1977	285	259	309	368	480	537	575	559	507	409	345	312	4945.14
Aver.Mo.	272.41	261.74	294.06	342.23	428.15	504.46	555.03	545.42	482.24	397.77	334.88	296.40	

Annual Average: 4714.79

INDEX NAME: flw56
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Felton.Div
COMMENT: Water.diverted.to.Loch.Lomond.reservor
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	8.93	26.8	17.9	0	0	0	0	0	0	0	0	0	53.55
1976	0	0	27.5	0	0	0	0	0	0	0	0	0	27.54
1977	0	0	0	0	0	0	0	0	0	0	0	116	116.03
Aver.Mo.	2.98	8.93	15.13	.00	.00	.00	.00	.00	.00	.00	.00	38.68	

Annual Average: 65.70

INDEX NAME: flw57
DATA TYPE: flow

UNITS: ENGLISH
STATION NAME: Tait.div.suf
COMMENT: Tait.st.surface.diversions.amount.available
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	210	138	145	195	224	217	224	217	217	203	217	224	2432.05
1976	224	201	210	210	224	168	103	125	107	128	158	186	2044.08
1977	210	195	210	202	180	110	101	102	99.9	106	131	147	1793.22

Aver.Mo. 178.13 202.40 165.17 148.01 145.39 185.78
214.73 188.19 209.43 142.55 141.39 168.62

Annual Average: 2089.79

INDEX NAME: flw58
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.div.dem
COMMENT: Tait.st.amount.diverted.to.meet.demand
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	207	136	143	195	224	217	224	217	217	203	216	222	2422.20
1976	224	201	210	210	224	168	103	125	107	128	158	186	2043.26
1977	210	195	210	202	180	110	101	102	99.9	106	131	147	1793.22

Aver.Mo. 177.38 202.40 165.17 148.01 145.39 184.85
213.64 187.65 209.43 142.55 141.39 168.39

Annual Average: 2086.23

INDEX NAME: flw59
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.remaining
COMMENT: Amount.of.demand.remaining.after.surface.diversion.at.tait.st.
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	53.2	111	144	92.8	138	242	309	303	230	185	101	59.9	1968.99
1976	48.1	78.6	76.8	161	217	349	454	432	386	268	184	110	2764.78
1977	75.0	64.0	98.8	166	301	427	475	457	407	304	214	165	3151.91

Aver.Mo. 84.36 139.84 339.29 397.41 252.38 111.55
58.77 106.41 218.72 412.47 340.85 166.49

Annual Average: 2628.56

INDEX NAME: flw60
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.Wells
COMMENT: Amounts.available.for.diversion.from.Tait.st.wells,1.9cfs
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year

1975	38.1	28.2	28.2	36.8	38.1	36.8	38.1	38.1	36.8	38.1	36.8	38.1	432.23
1976	38.1	33.9	38.1	36.8	30.1	21.1	38.1	34.0	34.2	33.8	22.2	10.9	371.38
1977	29.2	21.4	31.9	16.9	22.6	34.5	12.8	7.91	21.5	32.7	33.5	32.2	297.01

Aver.Mo. 27.84 30.19 30.82 26.67 34.85 27.06
35.12 32.75 30.26 29.64 30.84 30.83

Annual Average: 366.87

INDEX NAME: flw61
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.Wells
COMMENT: Amount.of.demand.met.by.Tait.st.wells
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	15.4	12.4	14.5	21.0	20.0	19.4	20.0	20.6	19.4	21.8	18.2	16.0	218.66
1976	18.5	17.8	20.2	20.0	18.2	20.7	38.1	32.7	33.1	32.5	19.9	10.3	281.88
1977	19.1	15.0	19.4	12.3	20.8	34.3	12.8	7.91	20.9	32.7	30.3	25.2	250.72

Aver.Mo. 15.04 17.75 24.79 20.42 28.98 17.18
17.68 18.05 19.67 23.63 24.44 22.79

Annual Average: 250.42

INDEX NAME: flw62
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Tait.well
COMMENT: Amount.of.demand.remaining.after.tait.st.wells.
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	37.7	98.2	129	75.2	122	223	289	282	211	163	83.1	43.9	1756.93
1976	29.7	60.8	56.6	141	199	328	416	400	353	236	164	99.9	2482.90
1977	55.9	49.0	79.3	154	280	393	462	449	386	271	184	139	2901.19

Aver.Mo. 69.32 123.21 314.50 377.00 223.40 94.38
41.09 88.36 200.11 388.84 316.41 143.70

Annual Average: 2380.34

INDEX NAME: flw63
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Beltz.demand
COMMENT: Amount.of.demand.met.by.beltz.wells
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	14.9	15.9	23.0	27.4	30.6	30.0	31.0	31.0	30.0	30.4	25.7	17.5	307.44
1976	20.0	24.0	23.1	30.0	31.0	30.0	31.0	31.0	30.0	31.0	30.0	29.9	341.05
1977	24.7	23.2	24.4	30.0	31.0	30.0	31.0	31.0	30.0	31.0	29.0	30.6	345.91

Aver.Mo. 21.04 29.15 30.00 31.00 30.79 26.01
19.87 23.50 30.86 31.00 30.00 28.24

Annual Average: 331.47

INDEX NAME: flw64

DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Beltz.demand
COMMENT: Beltz.demand.remaining.to.be.met
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.8	82.3	106	47.8	90.9	193	258	251	181	133	57.4	26.3	1449.49
1976	9.61	36.8	33.5	111	168	298	385	369	323	205	134	70.0	2141.85
1977	31.2	25.8	54.9	124	249	363	431	418	356	240	155	109	2555.28

Aver.Mo. 48.28 94.06 284.50 346.00 192.62 68.37
21.22 64.87 169.25 357.84 286.41 115.45

Annual Average: 2048.87

INDEX NAME: flw65
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: LL.Demand
COMMENT: Demand.met.by.Loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.8	82.3	106	47.8	90.9	193	258	251	91.7	0	0	0	1143.93
1976	9.61	36.8	33.5	34.5	35.6	34.5	35.6	35.6	34.5	35.6	33.0	29.3	388.26
1977	15.7	11.9	20.2	17.2	0	0	0	0	0	0	0	1.15	66.24

Aver.Mo. 43.67 33.17 75.76 95.62 11.88 10.15
16.05 53.31 42.19 97.93 42.08 11.00

Annual Average: 532.81

INDEX NAME: flw66
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Demand.Remaining
COMMENT: Total.Demand.not.met.from.Loch.Lomond.reservoir
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	0	0	0	0	0	0	0	0	88.8	133	57.4	26.3	305.56
1976	0	0	0	76.1	132	264	349	333	288	169	101	40.7	1753.59
1977	15.5	13.8	34.7	107	249	363	431	418	356	240	155	108	2489.04

> 4340/2 ≈ 2170 MG/YR AVG

Aver.Mo. 4.61 60.89 208.75 250.38 180.74 58.21
5.17 11.55 127.06 259.91 244.33 104.45

Annual Average: 1516.06

INDEX NAME: res80
DATA TYPE: volume
UNITS: ENGLISH
STATION NAME: LL.Reservoir
COMMENT: Loch.Lomond.Reservoir.Storage
RECORD SPAN: 1936 TO 1996
Multiplier: .326 .326 .326 .326 .326 .326
.326 .326 .326 .326 .326 .326 .326
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	2104	2474	2815	2810	2760	2562	2272	1986	1864	1872	1853	1837
1976	1810	1769	1753	1704	1635	1564	1486	1418	1356	1290	1239	1201
1977	1184	1158	1131	1086	1061	1026	988	950	924	895	896	1096

INDEX NAME: res80
DATA TYPE: volume
UNITS: ENGLISH
STATION NAME: LL.Reservoir
COMMENT: Loch.Lomond.Reservoir.Storage
RECORD SPAN: 1936 TO 1996
Multiplier: 1.000 1.000 1.000 1.000 1.000 1.000
1.000 1.000 1.000 1.000 1.000 1.000 1.000
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	564	571	577	577	576	573	567	561	558	558	558	558
1976	557	556	556	555	553	551	549	547	545	543	541	540
1977	540	539	538	536	536	534	533	531	530	529	529	537

INDEX NAME: flw67
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: ll.spill
COMMENT: Loch.Lomond.spilled.flow
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	28.7	25.9	354	164	30.3	27.8	28.7	28.7	27.8	28.7	27.8	28.7	801.15
1976	28.7	26.8	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	338.86
1977	28.7	25.9	28.7	27.8	28.7	27.8	28.7	28.7	27.8	28.7	27.8	28.7	337.94
Aver.Mo.	28.70	26.23	137.14	73.20	29.24	27.78	28.70	28.70	27.78	28.70	27.78	28.70	

Annual Average: 492.65

INDEX NAME: flw68
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Felton.div
COMMENT: Component.of.Loch.lomond.met.from.felton.Div.-water.right.a1
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	0	0	0	47.2	90.9	65.2	0	0	0	0	0	0	203.39
1976	0	0	0	26.4	1.09	0	0	0	0	0	0	0	27.54
1977	0	0	0	0	0	0	0	0	0	0	0	1.15	1.15
Aver.Mo.	.00	.00	.00	24.56	30.68	21.74	.00	.00	.00	.00	.00	.38	

Annual Average: 77.36

INDEX NAME: flw69
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: newell.Cr
COMMENT: component.of.loch.lomond.met.from.Newell.Cr.water.right-B
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

25/c

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
1975	22.8	82.3	106	0.55	0	128	258	251	91.7	0	0	0	940.54
1976	9.61	36.8	33.5	8.05	34.5	34.5	35.6	35.6	34.5	35.6	33.0	29.3	360.72
1977	15.7	11.9	20.2	17.2	0	0	0	0	0	0	0	0	65.09
Aver.Mo.	16.05	43.67	53.31	8.61	11.52	54.02	97.93	95.62	42.08	11.88	11.00	9.77	

Annual Average: 455.45

INDEX NAME: flw70
DATA TYPE: flow
UNITS: ENGLISH
STATION NAME: Water.R.A2
COMMENT: Water.from.Newell.Creek.under.Felton.diversion.rules
RECORD SPAN: 1936 TO 1996
Multiplier: .646 .646 .646 .646 .646 .646
.646 .646 .646 .646 .646 .646 .646
Total Multiplier: 1.00000

STARTS DATE: 1975 JANUARY
ENDS DATE: 1977 DECEMBER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Year
Aver.Mo.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	

Annual Average: .00

JOB COMPLETED

26/5

City of Santa Cruz
Preliminary Investigation of Water
Supply Alternatives

TECHNICAL MEMORANDUM NO. 3
GROUNDWATER SUPPLY

Carollo Engineers, P.C.
in Association with Fugro West, Inc.

November 1999

2700 YGNACIO VALLEY ROAD, SUITE 300 • WALNUT CREEK, CALIFORNIA 94598 • (925) 932-1710 • FAX (925) 930-0208

CITY OF SANTA CRUZ
PRELIMINARY INVESTIGATION OF WATER SUPPLY ALTERNATIVES

TECHNICAL MEMORANDUM NO. 3
GROUNDWATER SUPPLY

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GROUNDWATER SUPPLY

The City of Santa Cruz obtains most of its domestic water supply from surface water sources. Groundwater is also used for a small portion of the supply. These two sources are not sufficient to meet the City's water supply needs (see TM 2 - Water Supply, Carollo/Kraeger, 1999). New water supplies must be developed to offset the expected shortfalls. One alternative for additional supply is groundwater.

One objective of this water supply study is to determine whether groundwater is a viable source of supply. This document discusses the potential use of groundwater.

GROUNDWATER SUPPLY ALTERNATIVES

Previous water supply studies have concluded that the local coastal aquifers cannot provide a reliable supply of groundwater to meet the total projected shortfalls. However, as part of this study four local aquifer areas were identified as having the potential to supply some of the projected shortfall, either alone or in combination. The four local aquifer areas studied are:

- Santa Margarita Aquifer near Wilder Ranch.
- San Lorenzo Alluvial Aquifer near the Mouth of the San Lorenzo River.
- Santa Margarita Aquifer near Downtown/Eastside Santa Cruz.
- Purisima Aquifer near the Beltz Well Field.

These alternatives were evaluated to determine the potential for significant yield based on a review of available published geologic and hydrogeologic information (Carollo/Fugro West, Inc. 1999). A summary of the evaluation findings for the four groundwater sources is presented in Appendix B.

Available Groundwater Supply

Yield. The annual or safe yield of an aquifer is defined as the amount of water that can be supplied from the source in a year. As determined by classical hydrogeologic methods, the yield is estimated with consideration of the soil characteristics in the water bearing strata (e.g., sand or clay), the size of the water bearing strata, amount of recharge to the strata, etc.

Considering these elements, each of the four groundwater alternatives were evaluated to determine the potential for significant yield. The evaluation was based on a review of available published geologic and hydrogeologic information; no field work was conducted to supplement this evaluation. In general, our evaluation confirms the findings of several previous investigations, and we conclude that the local coastal aquifers do hold limited amounts of groundwater.

Based on interpretation of existing data and engineering judgement, the estimated maximum groundwater supply potential from all sources combined is approximately 850 MG/yr. It is important to distinguish, however, that the amount actually available for supply on a reliable basis (i.e., during drought conditions) is expected to be significantly less, in the range of 0 to 300 MG/yr.

Limiting Conditions. A groundwater source may be demonstrated capable of a specific yield, but may not be a viable domestic water supply source for other reasons. For example, the aquifer may not be large enough to provide significant storage/supply capacity to sustain prolonged use, or geologic conditions within the aquifer may limit the rate/capacity of natural recharge such that groundwater supply during drought is reduced. Even if a source is determined to be of suitable capacity and reliability there may be other technical factors (e.g., degradation of ground water quality over time due to prolonged pumping) or institutional factors (e.g., other competing interests) that may effectively limit its availability.

Considering the estimated maximum yield from the four groundwater sources alone it appears that the sources could provide considerable additional supply. However, closer examination of the potential limiting conditions during drought indicates that this is not the case. Although the sources can be expected to produce some additional supply during the first year of the drought, the reliability and sustainability of the sources during the second (or subsequent) drought years is questionable. As noted above, the reliable supply from all sources combined during a prolonged drought may range from 0 to 300 MG/yr.

The conditions which limit the supply during drought are as follows:

- **Limited Natural Recharge During Drought.** In severe drought conditions there is very little precipitation, and therefore very little water available for natural recharge of the aquifers by infiltration. This is of particular concern for the aquifers evaluated in this study because, typical of many coastal aquifers, they do not have large storage capacity, so regular recharge would be required to sustain the supply during prolonged droughts. Moreover, the aquifers evaluated in this study are "confined" — the water bearing strata lies between layers of nonwater bearing strata of limited or low permeability — so the rate/capacity of recharge is comparatively low; recharge for aquifers of this type occurs slowly over periods of regular precipitation and infiltration which are not typical of a drought. Figure 3.1 illustrates this concept.

- **Competing Interests.** The two biggest aquifers evaluated for this study, the Santa Margarita aquifer near Wilder Ranch and the Purisima aquifer, have existing users. The competing interests for the supply is of particular concern, particularly during the summer months of a drought when supply would be needed most by the existing users. The available (reliable) yield during a prolonged drought is also uncertain because the yield from the aquifers will likely decrease as other users increase their reliance on this supply. Because of these competing interests there may be no appreciable supply that could be delivered to the City in a drought.

Artificial recharge of the groundwater sources — to improve reliability/sustainability during the drought — was considered but is not viable for the following reasons:

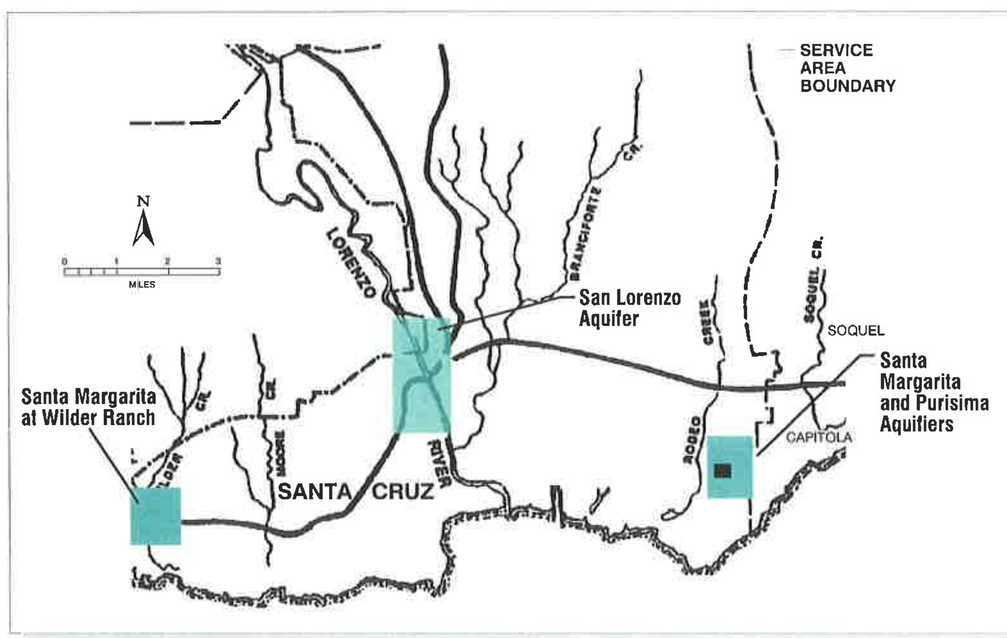
- **No Surplus Surface Water Supply for Recharge.** Review of historical hydrologic data indicates that it is reasonable to expect some precipitation in the winter months, even in a prolonged drought. However, based our evaluation of the estimated production from the City's existing sources during drought there is no "surplus" supply that could be used for recharge of groundwater sources. This is particularly true in the future as more of the available surface water will be used to offset the increased demand.

- **Water Rights Constraint.** Even if surface water is available the City's water rights have limiting conditions that do not allow the use of the existing surface sources for groundwater recharge. To use the water for groundwater recharge would require a change of the existing water rights (change from diversion for direct use to diversion for storage). A water right change of this type is not viable, and effectively precludes all conjunctive use alternatives with surface water and groundwater.

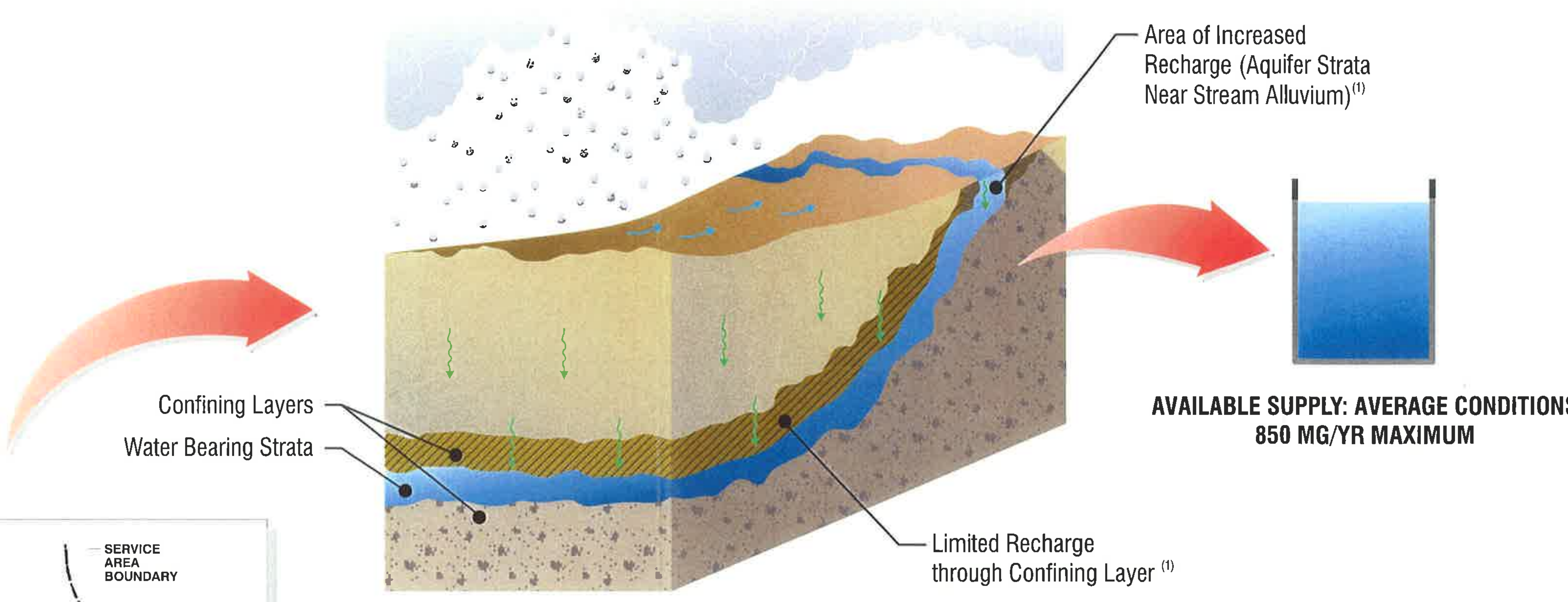
- **Groundwater Recharge with Reclaimed Wastewater is Not Viable.** Groundwater recharge with reclaimed wastewater is practiced by several water utilities in California. However, for the City's particular application there are numerous issues that could effectively limit its viability:

    - **Limited Additional Supply.** Current state guidelines for use of reclaimed wastewater for groundwater recharge stipulate that no more than 50 percent of the water extracted from a wastewater recharge project be reclaimed wastewater (ref. personal communication with B. Hultquist, member DHS Groundwater Reclamation Advisory Committee, and Title 22 CCR, Division 4, Chapter 3 - Environmental Health, Draft Criteria for Groundwater Recharge with Reclaimed Wastewater, 1994).

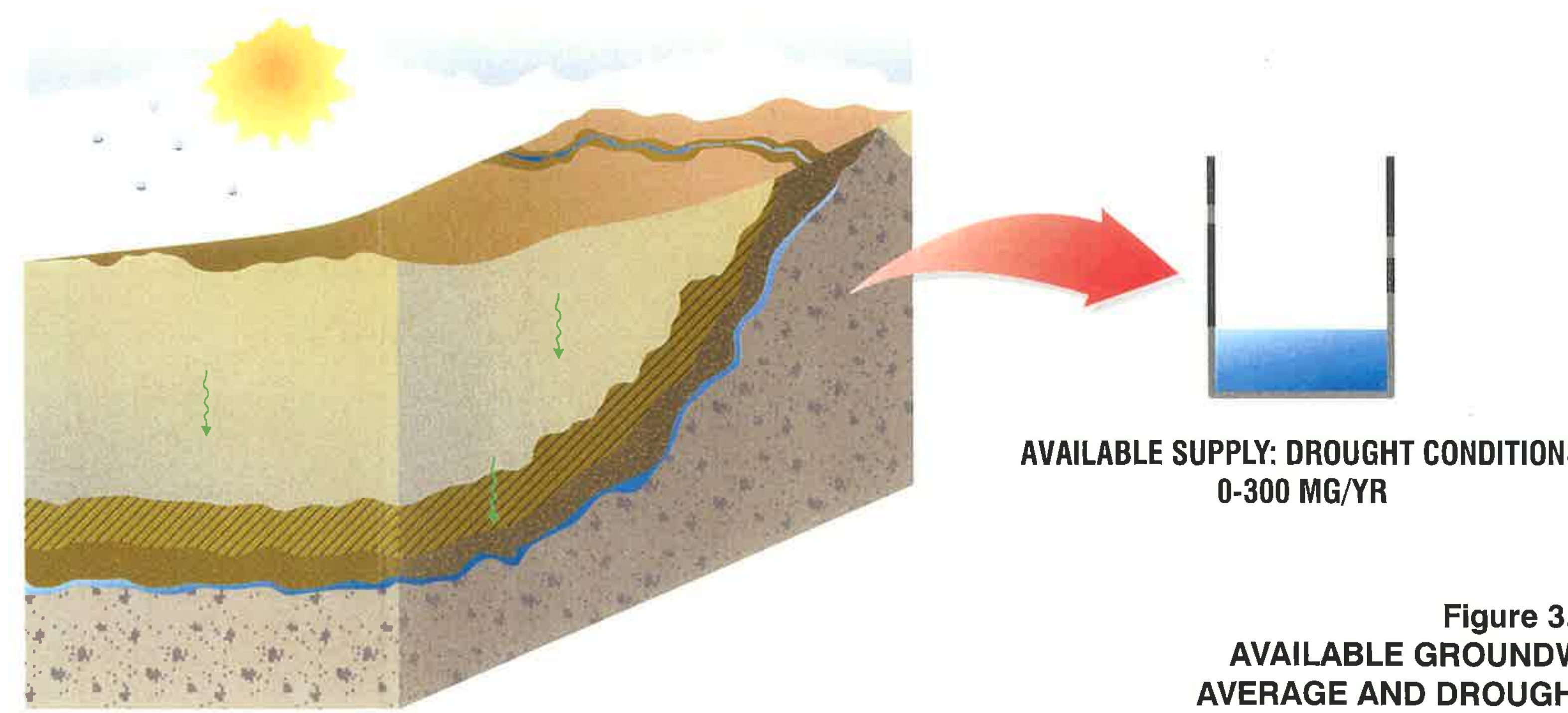
      As noted above, during prolonged drought conditions there will be limited natural recharge to the aquifers that would be available to blend with



Possible Groundwater Sources for Santa Cruz



RECHARGE IN AVERAGE CONDITIONS



RECHARGE IN DROUGHT CONDITIONS

Notes:
1) Available supply depends on seasonal precipitation, geologic conditions (e.g., high recharge in stream alluvium, reduced recharge through containing layers, etc), and localized pumping.

Figure 3.1
AVAILABLE GROUNDWATER SUPPLY: AVERAGE AND DROUGHT CONDITIONS (1)
CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY PROJECT

sc400rl3.cdr

reclaimed wastewater. The amount of groundwater available for blending would range between 0 MG/yr (worst case) and 300 MG/yr (best case with all four sources). The amount of groundwater actually available for blending would likely be 100 MG/yr or less. This is because the two groundwater sources with the most potential for significant natural recharge during a drought, the Santa Margarita aquifer near Wilder Ranch and the Purisima aquifer, both have existing users. Implementation of a reclaimed wastewater recharge project into basins with existing users is difficult, and may not be feasible due to potential impacts on existing users (see also discussion under Implementation Issues below).

Even in a favorable scenario with 100 MG/yr available for blending with reclaimed wastewater, the total volume of ground water available for drought supply is low, on the order 200 MG.

- **Supply Availability During Peak Season is Questionable.** Current state guidelines for groundwater recharge also require that reclaimed water for potable reuse must remain in the ground for a minimum of 6 months, and up to 12 months depending on the level of treatment and the method of recharge surface spreading or direct injection.

Based on conceptual evaluation of recharge options, surface spreading is not considered feasible due to geologic constraints in the four source aquifers. Accordingly, recharge would need to be accomplished via direct injection. For direct injection the minimum detention time requirement is 12 months. This is a significant consideration because it effectively limits how/when the recharged groundwater could be used. In the assumed two-year drought scenario the groundwater supply would likely not be available during the peak season shortfall of the second drought year. Figure 3.2 illustrates the constraint on use:

*During the first drought year the available groundwater supply would be utilized in the summer to meet peak demands.

*During fall/early winter of the first drought year the aquifer recharges and water would be available for blending (Note: the example assumes that some precipitation in the fall would occur and provide modest recharge, but this may not occur during a severe drought).

*During the winter months of the second drought year the aquifer would be artificially recharged with reclaimed wastewater. As shown in the figure, the recharge process could take 6 to 8 months to complete, so the recharge operation would end at the beginning of the summer season at the earliest.

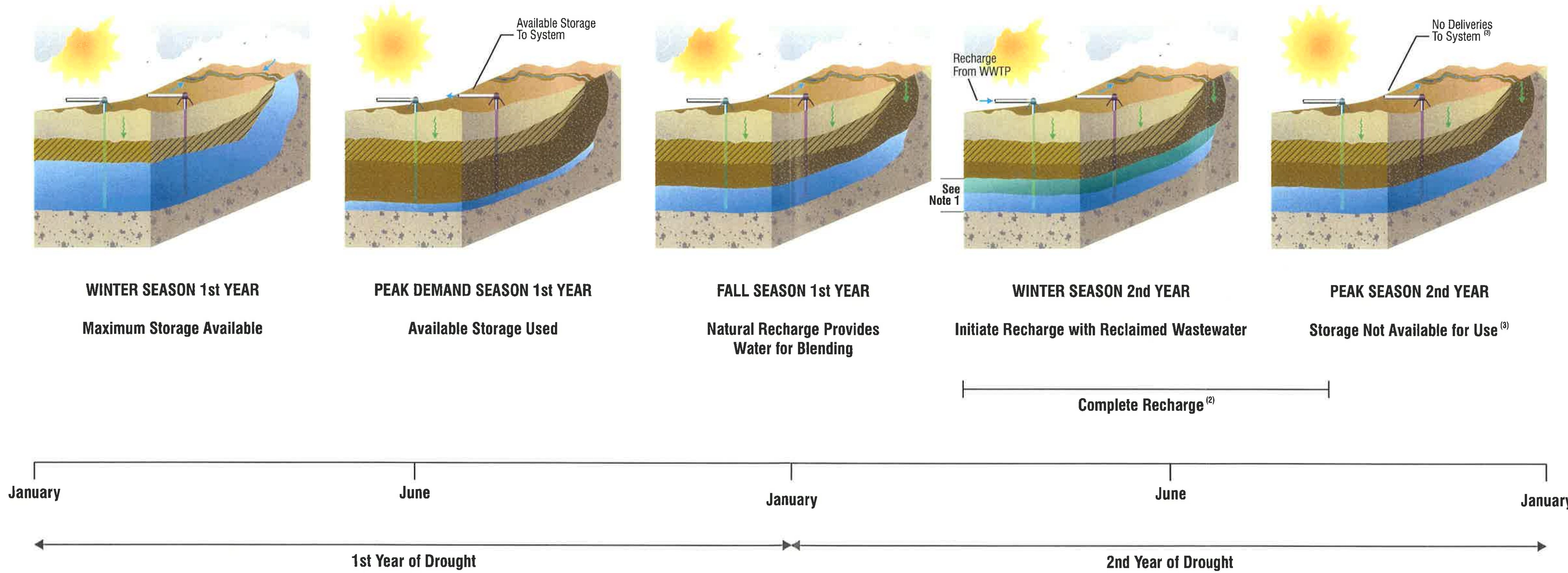
*After completion of recharge the groundwater must remain for 12 months before it is extracted. With this time requirement, the groundwater would not be available for use in the second drought year, when it is needed most.

Implementation Issues. Although simple in concept there are many issues that must be addressed to take a waste water reclamation project from concept to viable water supply. The two most likely implementation issues for the City are cost and political/public acceptance.

Current state guidelines require that reclaimed water to be used for ground water recharge must meet all drinking water standards. To meet this criterion the wastewater must receive filtration treatment and organic chemical removal by reverse osmosis membranes (ref. personal communication with B. Hultquist, member DHS Groundwater Reclamation Advisory Committee). The City's existing wastewater treatment facility currently does not provide either filtration or reverse osmosis treatment, so new facilities would need to be constructed to provide the additional treatment. In addition, a new, separate distribution system would need to be installed to deliver the water to the recharge sites, and new wells would need to be constructed for both injection and extraction of the reclaimed water (different wells must be used for injection and extraction). New infrastructure of this type is very costly and will result in a relatively high unit cost for the water (i.e., $/MG of new supply). Although cost is not necessarily a fatal flaw, it is an important consideration for supply alternatives that are considered to have relatively low reliability and low volume of additional supply.

Even if the costs for recharge with reclaimed wastewater compare favorably to other alternatives, these projects can be difficult to implement. State regulatory officials at the Department of Health Services and the Water Resources Control Board are currently reevaluating the existing guidelines for recharge to determine whether additional treatment and/or other criteria are needed to ensure protection of public health and the groundwater quality. If additional treatment requirements are established there will be additional costs for implementation.

Perhaps most significant, public opposition is common even with high levels of treatment prior to recharge. For example, the implementation of two recent wastewater reclamation projects in the state was postponed



LEGEND

- Recharge Well
- Supply Well
- Reclaimed Wastewater
- Groundwater

Notes:
1) Reclaimed wastewater is injected and blended with groundwater to achieve a maximum 50/50 blend in the aquifer.
2) Time estimated to complete recharge with reclaimed wastewater is 6-8 months.
3) Water extracted from the supply well must be shown to have detention time of 12 months prior to extraction.

Figure 3.2
RECHARGE WITH RECLAIMED WASTEWATER OPERATIONAL SCENARIO DURING DROUGHT
CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY PROJECT

sc400rf2.cdr

indefinitely due to public concerns, *after the technical merits of the projects had been reviewed and approved by regulatory agencies*. The impact of public acceptance is very important for the City because two of the potential groundwater source alternatives considered for recharge, the Santa Margarita aquifer near Wilder Ranch and the Purisima, currently have existing users. It is uncertain whether a viable project concept could be developed with these users. This is particularly so for the Soquel Creek Water District due to potential impacts to their supply source, the Purisima aquifer, because it is their sole source of supply.

When combined we believe these implementation issues present too many uncertainties for groundwater recharge with reclaimed wastewater to be viable, particularly for the relatively small amount of additional reliable supply that would be provided. We do believe, however, that wastewater reclamation for irrigation supply may have merit (see Wastewater Reclamation below).

Conclusion. Our findings are similar to previous groundwater evaluations of the area. Groundwater is potentially available but in limited quantity. None of the groundwater sources evaluated can provide a significant portion of the projected shortfall during a drought, and it is not likely that all four alternatives could be implemented (see also discussion in Appendix B). Most importantly, none of the sources are considered reliable or sustainable during prolonged usage in a drought. This is particularly significant because lacking reliability of groundwater supply, the City would still need to provide other additional sources to provide supply in the second (or subsequent) year of a drought.

We believe the combination of constraints significantly limits the viability of groundwater as a drought supply alternative for the City. We do not recommend that this alternative be pursued further for drought supply.

It is possible that groundwater could be used as a nondrought year supply "building block." However, it is important to note that within Santa Cruz County and elsewhere along the coast there are several examples to illustrate that coastal groundwater supplies provide marginal long-term reliability. If the City was faced with no other options there would be increased benefit of developing groundwater for nondrought supply. The City does have other options, particularly since a new drought supply alternative must be implemented. The new supply can serve both drought and nondrought years, so there appears to be little need or benefit for developing additional groundwater supply.

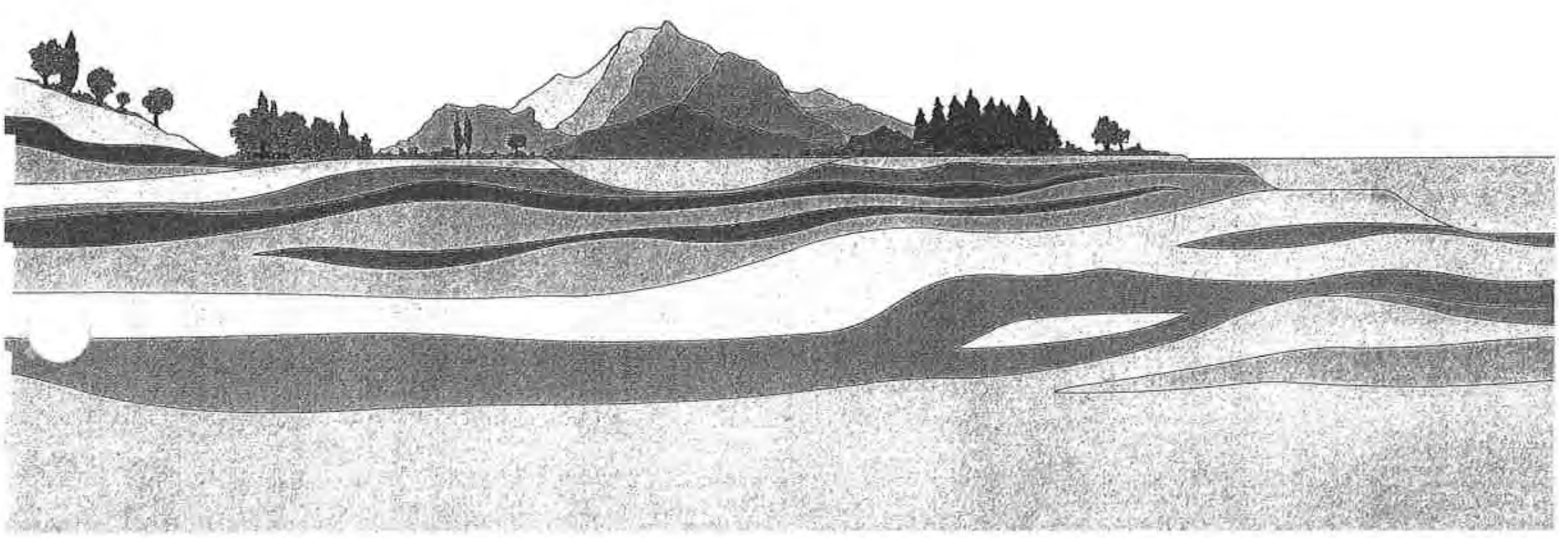
APPENDIX A - STUDY OF GROUNDWATER SUPPLY ALTERNATIVES

FUGRO WEST, INC.

PRELIMINARY HYDROGEOLOGIC STUDY OF GROUNDWATER SUPPLY ALTERNATIVES SANTA CRUZ, CALIFORNIA

Prepared for:
CITY OF SANTA CRUZ
ON BEHALF OF CAROLLO ENGINEERS

June 1999



FUGRO WEST, INC.

5855 Olivas Park Drive
Ventura, CA 93003-7672
Tel: (805) 650-7000
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June 15, 1999
Project No. 97-71-1221

Carollo Engineers
2700 Ygnacio Valley, Suite 300
Walnut Creek, California 94598

Attention: Mr. Ken Wilkins
Associate Engineer

Subject: *Preliminary Hydrogeologic Study of Groundwater Supply Alternatives, Santa Cruz, California*, Dated June 1999.

Dear Mr. Wilkins:

Submitted herein is a final of the subject report prepared as part of the City of Santa Cruz Preliminary Investigation of Water Supply Alternatives. This report presents the findings, conclusions, and recommendations of the Phase 1–Water Supply Alternatives Analysis, Task 3.2 Geologic Review, which utilizes existing hydrogeologic data. As part of this study, we have summarized the potential for future development of four groundwater resource alternatives. These four alternatives include: a) Wilder Ranch Area Groundwater Alternative, b) Downtown and Eastside Santa Margarita Aquifer Groundwater Alternative, c) Purisima Formation Groundwater and Beltz Well Field Optimization Alternative, and d) San Lorenzo River Alluvial Aquifer Groundwater Alternative. These alternatives have been prioritized for the purpose of guiding future exploration efforts that will provide further data to assess the feasibility of developing additional groundwater supply.

Please call if you have any questions.

Sincerely,

FUGRO WEST, INC.

Curtis H. Hopkins, C.Hg. 114
Senior Hydrogeologist

Copies Submitted: (6)

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INTRODUCTION

This report summarizes the findings, conclusions, and recommendations developed from a hydrogeologic study conducted by Fugro as part of the comprehensive water supply alternative study being conducted by Carollo Engineers (Carollo) for the City of Santa Cruz Water Department (City). Current City water demand projections indicate municipal water supply shortfalls will occur with increasing frequency in the future, and are expected to be significant during extended droughts or severe dry periods. These projections are substantiated by past water supply shortages endured by the City. The purpose of this study is to provide a preliminary assessment of the potential to develop additional groundwater supply alternatives to augment the existing municipal water supply. The project study area includes the City and coastal areas proximate to the City's water service area. The study area is shown on Plate 1 - Study Area Location Map.

The scope of work for this phase of the study was developed through discussions with Carollo (the project team leader and design engineers) and City Water Department staff, and includes the following:

- Review existing information on hydrogeologic conditions from previously completed supply alternative studies (CDM, 1994; Leedshill, 1989) as related to specific project alternatives.
- Develop project concepts by identifying project elements/concepts for two groundwater project alternatives related to preliminary siting and estimated yield, and assist with preliminary screening of alternatives to identify obvious environmental constraints and issues.
- Prepare discussion to be included in Technical Memorandum No. 1 based on existing information of siting and hydrogeologic yield issues and constraints for the two groundwater alternatives.
- Attend public workshop and provide technical support related to groundwater alternatives.
- Review input received at the public scoping workshop and assist with screening and refinement of alternatives based on judgement and reconnaissance-level analysis.
- Provide detailed hydrogeologic review of existing information that is pertinent to preliminary assessment of proposed groundwater alternatives and prepare this report presenting the findings.

BACKGROUND

Past water resource studies conducted by the City have included assessments of groundwater resource availability and preliminary evaluations of conjunctive use water supply projects with adjacent water districts including the Soquel Creek Water District (SQCWD) to the east, and Scotts Valley Water District (SVWD) to the north. These studies have estimated available groundwater supplies and identified potential limitations on additional development of groundwater resources in this coastal bedrock terrain. Significant variations in the materials that comprise the local bedrock geology and local geologic/geomorphic structures affect groundwater movement and availability. The primary limitations include limited natural recharge to the coastal aquifer systems and the threat of water quality degradation due to seawater intrusion.

This study area (see Plate 1) includes a section of the Santa Cruz County coastline that lies between the SQCWD service boundary to the east of the City, and Baldwin Creek to the northwest of the City. The general locations of the four primary groundwater resource alternatives summarized in this report also are indicated on Plate 1. The groundwater supply alternatives include:

1. Wilder Ranch Area Groundwater Alternative.
2. Downtown and Eastside Santa Margarita Aquifer Groundwater Alternative.
3. Purisima Formation Groundwater and Beltz Well Field Optimization Alternative.
4. San Lorenzo River Alluvial Aquifer Groundwater Alternative.

These alternatives have been selected for initial evaluation because of their inferred potential to provide a considerable annual supply of groundwater (greater than 300 million gallons per year (MGY)), or provide an opportunity for artificial recharge, storage, and subsequent production of groundwater.

GROUNDWATER ALTERNATIVES EVALUATION

WILDER RANCH AREA GROUNDWATER ALTERNATIVE

Hydrogeology

The Santa Margarita sandstone aquifer, which lies beneath the terraced coastline north of the City limits, has been utilized for over 50 years to provide groundwater as a water supply for agricultural irrigation. The bedrock aquifer system in the Wilder Ranch State Park (Wilder Ranch) area has been evaluated by a number of water resources studies over the last 30 years. Dozens of water wells have historically been drilled between the City limits and the Baldwin Creek area, which reportedly provide operational production capacities between 50 gallons per minute (gpm) and 700 gpm. The quality of groundwater produced from these wells ranges from fair to poor (800 to 1,400 mg/l [milligrams per liter] total dissolved solids [TDS] concentration).

The Santa Margarita Sandstone is the main aquifer zone along this section of the coastline. The Lompico Sandstone and the granitic and marble basement rock have been reported to provide groundwater at rates high enough to support single-family residential well demands (5 to 50 gpm). Along this section of coastline, the Lompico Formation is not believed to be present, and the crystalline basement rock, which underlies the Santa Margarita Formation, is primarily separated from it by the Monterey Shale Formation. The Santa Margarita Sandstone is overlain by the Santa Cruz Mudstone. Where the water table rises above the formation contact, the bedrock aquifer is confined. Recent studies have indicated that the Santa Cruz Mudstone is an effective aquitard and has abated the encroachment of seawater during the conditions of recent overdraft. Plate 2 - Hydrogeologic Cross-Section Location Map, Sections A-A', B-B', and C-C', provides the location of the cross sections included on Plates 3, 4, and 5 – Hydrogeologic Cross-Sections A-A', B-B', and C-C', respectively.

The Santa Margarita aquifer in this area supports a wide range of well production rates that may be, in part, due to the adequacy of the well design and the construction methods used. However, these well data have been used in past water resource studies to estimate aquifer transmissivity values. Estimates using these limited data result in aquifer transmissivity values that vary laterally along the coast, and range between 5,000 gallons per day per foot (gpd/ft) and 50,000 gpd/ft. These estimated values are partially supported by a few aquifer tests where production rates and water level drawdown were monitored during pumping, and used to calculate aquifer parameters.

Water quality and groundwater production variations are typical in coastal bedrock aquifers where lateral changes occur in the formation grain size and the degree of cementation between the sand and gravel grains. These physical changes in the aquifer materials affect the primary porosity and, consequently, the hydraulic transmission characteristics of the aquifer. Lateral variations in groundwater quality and production can be more pronounced where a bedrock aquifer system contains semi-planar fracture sets or shear zones, which provide a highly permeable secondary porosity. In aquifer systems where fracture systems provide preferential flow paths for groundwater movement, the success of a water well installation may be governed by its location relative to a more permeable fracture zone. The primary and secondary porosity of a bedrock aquifer directly controls its production characteristics, recharge potential, and storage capacity. This appears to be the condition of the Santa Margarita Sandstone in the Wilder area as evidenced by the documentation provided by available well construction records.

Water Balance and Availability

The Santa Margarita Sandstone aquifer system located between the San Lorenzo River and Baldwin Creek receives recharge from several sources. Recharge is provided by infiltration of rainfall on the formation outcrop areas, induced infiltration from coastal streams, and inflow from underlying bedrock. The combined annual recharge from these sources has been estimated by past studies to average in the range from 7,600 acre feet per year (AFY) (ESA, 1979) to 2,840 AFY (Johnson, 1984). The estimated groundwater production for agricultural uses varies from 3,500 AFY (ESA, 1979) to 1,200 AFY (Johnson, 1984).

The exact amount of groundwater production in the Wilder Ranch area is difficult to calculate for several reasons. These reasons include: a) typically well discharges are not metered in this area, b) surface water is used when it is available (and not documented) and, c) the demand varies from one year to the next. However, the method of estimation applied during a study conducted for the County of Santa Cruz (Johnson, 1984) is considered to provide a level of accuracy sufficient for this study. The method used by that study estimated the area of the Santa Margarita outcrop that could receive recharge (approximately 1,400 acres) and estimated that, out of the average annual precipitation of 32 inches, the amount of recharge to this area is 12 inches per year. Additional recharge was estimated at up to 700 AFY from subsurface bedrock inflows. The total recharge to the Santa Margarita Formation in the Wilder Ranch area was estimated by that study to be on the order of approximately 2,100 AFY.

The estimated average groundwater production in the Wilder Ranch area for agricultural irrigation is approximately 1,200 AFY (Johnson, 1984). Additional groundwater losses were estimated at about 900 AFY as outflow from the aquifer offshore. In concept, the difference between total aquifer recharge and the existing groundwater demands is the additional annual supply of groundwater available for further development. From the results of that study, about 900 AFY are available for future development in the Wilder Ranch area of the coastline. Groundwater availability has been estimated by other studies to range between 2,000 and 4,500 AFY (Luhdhorff & Scalmanini [L&S], 1984a). It should be noted that resource evaluation errors could occur if localized well data are inappropriately applied to a broad aquifer assessment where significant lateral changes in aquifer properties affect its storage and recharge capacities.

For this study we have used a more conservative estimate of recharge from the average annual rainfall (25 percent or 8 inches per year) because of the steep topography in the outcrop areas, and a slightly reduced estimate of inflow from the underlying bedrock (600 AFY). From these values we calculate the perennial yield of the Santa Margarita aquifer at approximately 1,530 AFY. Based on seasonal groundwater production estimates of 1,200 AFY for agricultural uses and Santa Cruz County (County) water level monitoring records, we believe that a perennial yield on the order up 1,500 AFY is more accurate for the Wilder Ranch area.

County data indicate that pumping patterns in the Wilder Ranch area have lowered water levels and created a pumping trough that is roughly parallel with the coastline (see Plate 2). Seasonally, this depression is well below mean sea level (MSL) (i.e., an elevation of -100 feet). This pumping trough reportedly extends parallel to the coast from the western boundary of the City up to approximately Wilder Creek. The declining water levels suggest that groundwater extractions are locally exceeding the ability of the aquifer to recharge and transmit water to the location of primary production. Toward the end of the irrigation season, water quality degradation reportedly results in groundwater with higher TDS and elevated levels of chloride. This moderate seasonal fluctuation (or gradual decline) of water quality results in an annual use of approximately 250 AFY of the City water supply for irrigation during the late summer months (communication with City staff, 1998).

The current decline (or maintained depression) in groundwater levels indicates that the overlying use exceeds local recharge. If pumping were more evenly distributed along the coastline westerly toward Baldwin Creek, the annual production of up to 1,500 AFY may be sustainable for the current land uses while minimizing the possible impacts created by over pumping. In contrast with past resource assessments, this estimate of additional sustainable yield (300 AFY) does not indicate that significant additional Wilder Ranch area groundwater is available to supply the City.

Artificial Recharge

Additional groundwater supplies from the North Coast Santa Margarita aquifer system appear limited for existing uses as well as future municipal use. However, if the City were able to artificially enhance recharge (through spreading or direct injection) and/or offset historical pumping by providing another source of irrigation water to replace existing groundwater use (i.e., raw surface water diversions or tertiary treated reclaimed water, etc.), then groundwater could be stored and made available for municipal use. Water supply options historically considered for this purpose have included artificial groundwater recharge using the mined portion of the Wilder Quarry as a location for spreading basins. For the purpose of evaluating this option, this study assumes that a water supply is readily available for recharge from north coast streams, San Lorenzo River diversions, or reclaimed water.

Groundwater recharge using surface ponds will require both an adequate sustainable infiltration rate and available storage space in the underlying aquifer. Available field data are limited; however, infiltration testing (ESA, 1971) cited in a United States Geologic Survey (USGS) study (Akers and Jackson, 1977) suggests that the exposed formation at the Wilder Quarry provides an infiltration rate of approximately 30 gpd/ft^2 (0.001 centimeter per second). This value is representative of a silty sand or very fine-grained sand material and is believed to be a reasonable estimate for the Santa Margarita materials exposed in the quarry. Using the proposed extent of the mined quarry area, we have assumed 5 acres of land can potentially be developed as recharge ponds. If recharge spreading could be conducted annually over a 5-month period, 6.5 million gallons per day (MGD) or 980 million gallons per year (MGY) of artificial recharge could theoretically be provided. An estimate of the required storage space sufficient for 980 mg of groundwater can be calculated if we assume an average effective porosity for the sandstone formation of 15 percent. If we assume pumping were concentrated to within one-half-mile on both sides of the quarry location, then over an area roughly 3,000 feet by 5,000 feet would need to be dewatered an average depth of 58 feet to create space for 980 mg of storage. To create a pumping trough of this size would require a substantial number of wells and would significantly increase the risk of seawater intrusion or other water quality degradation. Creating this magnitude of storage in this coastal bedrock aquifer is not considered feasible. A project considering up to one-third of this amount may feasible, but would need to contend with the conditions discussed below.

Data available for this evaluation suggest that the infiltration rate at the quarry would be adequate to recharge a substantial volume of water into the aquifer system. However, other hydrogeologic conditions, including available storage space and groundwater movement through the aquifer, must be favorable for this conceptual project to be technically feasible. Past hydrogeologic investigations conducted to permit continued quarry operations provide limited data for this assessment. These data indicate that groundwater levels beneath the quarry in April 1992 were at an elevation of 45 feet above MSL (Haro, Kasunich and Associates, Inc., 1992), about 25 to 30 feet below ground surface in the central quarry area. This level is consistent with May 1991 measurements taken in Sandy Flat Gulch along the west side of the quarry where groundwater was found within 10 feet of the ground surface (Dewitt, 1992). The high water levels in the vicinity of the quarry suggest there is little storage space in the aquifer at the present time to place additional water. Because groundwater mounding occurs around an aquifer recharge source, a significant portion of the recharged water could be lost to streams adjacent the quarry as rising groundwater contributes to stream flows.

The difference in water levels between the quarry site (approximately 45 feet above MSL) and the pumping trough (approximately 100 feet below MSL) indicate that lateral movement of groundwater is restricted between these two areas. Restrictions on flow from the point of recharge to the point of available storage would ultimately limit the operation of a centralized aquifer recharge project. To use the proposed quarry for recharge, water wells would need to be located closer to the quarry and distributed in a manner to maximize the advantage of favorable aquifer properties.

Another approach to artificial recharge is through the use of injection wells. Although direct injection can typically be more costly than surface spreading operations, the advantages include a distribution of recharge across the area of available storage. This allows direct placement where the groundwater levels are the lowest (areas of greatest available storage space) and where aquifer flow properties are most favorable. Seasonal artificial recharge (which would likely require the use of multiple injection wells) is believed capable of increasing the annual water supply of this aquifer by up to another 325 MGY. This estimate is based on the assumption that exercising the water levels between documented historic low levels (below sea level) and historic high levels in the area of the pumping trough can accomplish this amount of aquifer storage.

Alternative Irrigation Supply

Another approach to optimizing the use of groundwater resources in the Wilder Ranch area is to provide an alternate supply of subpotable water (reclaimed water or excess surface diversions) to all agricultural irrigation uses in the Wilder Ranch area. This could eliminate the current primary use of groundwater, estimated at approximately 390 MGY, and make that groundwater available for a potable raw water supply. The combined total of natural and artificial recharge is estimated to provide an annual yield of up to approximately 800 MGY from the Wilder Ranch area Santa Margarita Formation between Baldwin Creek and the City. The water supply would likely have a varying water quality that would range in TDS concentration from 500 to 1,500 mg/l. This estimate of groundwater availability includes the provision that an alternative water supply can be made available to replace the current agricultural groundwater uses.

Environmental Constraints

Potential environmental impacts from overproduction of groundwater from this aquifer would include declining water levels, potential for seawater intrusion, and general water quality degradation from brackish water-bearing zones. The current pumping depression has not yet resulted in documented seawater intrusion. This fact suggests that an effective confining layer of Santa Cruz Mudstone beneath the ocean protects the aquifer. To the north around Davenport, the Santa Cruz Mudstone rapidly thickens offshore, and is assumed to do the same in the Wilder area. In effect, past production has demonstrated that at least temporary overdraft can be tolerated by the aquifer system. However, current agricultural uses depend on City water deliveries in the late summer season because the low water levels induce groundwater quality degradation. Groundwater becomes brackish as a result of increasing chloride and TDS concentrations that are believed to result from groundwater leakage from overlying and underlying finer-grained (more mineralized) formations.

Groundwater production in the North Coast/Wilder Ranch area has the potential to be impacted by contaminant migration associated with present and future municipal landfill operations (see Plate 1). We are not aware of any significant groundwater contamination resulting from the existing landfill operations. However, there is always a risk that down gradient water quality (toward the coast) could be impacted. A detailed analysis of the level of risk was not performed as part of this study.

Additional Data Needs

If the City decides to pursue this groundwater alternative, additional information will be needed to further assess the technical feasibility of this project alternative. That information should include: a) identification of a source water supply for north coast agriculture, b) identification of a source water supply for groundwater injection, and c) a more accurate estimate of current annual groundwater production. Additional technical work should include drilling test wells in areas of uncertain groundwater conditions and/or using existing wells located along the existing City pipeline alignment to conduct aquifer tests (including injection testing). In addition, testing of recharge and production capacities should be conducted at the Wilder Quarry if the surface water spreading option is given further consideration as a project component.

As part of additional efforts, the City should explore the institutional mechanisms available for management of groundwater resources (i.e., AB 3030). Use of the aquifer system would need to be managed for the benefit of all users. Groundwater management would address many of the technical concerns and likely include establishing groundwater-pumping allocations, well discharge metering, annual reporting procedures, groundwater credits, and/or potential physical solutions.

DOWNTOWN AND EASTSIDE SANTA MARGARITA AQUIFER GROUNDWATER ALTERNATIVE

Hydrogeology

The occurrence of the Santa Margarita Formation beneath the central and eastern portions of the City's water service district has been discussed in a number of past studies. Investigations providing data that indicate the Santa Margarita Sandstone extends from outcrop locations north of the City and is likely present at depths beneath the City include:

- Testhole drilling in 1957 at 41st Avenue and Cory Street (Brown & Caldwell [B&C], 1963).
- Testhole drilling in 1957 at Arana Creek and Brookwood Drive (B&C, 1963).
- Testhole drilling in 1957 at 41st Avenue and Capitola Road (B&C, 1963).
- Testhole drilling in 1957 at Harvey West Stadium (B&C, 1963).
- A study on stratigraphy, paleontology, and geology (Clark, 1981).
- A study on paleocurrent structures in the Santa Margarita Sandstone (Phillips, 1981).
- A study on the history of the Ben Lomond Fault zone (Stanley and McCaffrey, 1983).
- Testhole drilling on Thurber Lane (L&S, 1988).
- Testhole drilling at DeLaveaga tank site (L&S, 1988).

Subsurface geologic interpretations of the Santa Margarita Sandstone using these data are provided at the locations shown on Plate 6 - Hydrogeologic Cross-Section Location Map, Sections D-D', E-E', F-F', and G-G', and Plate 10 - Hydrogeologic Cross-Section Location Map, Sections H-H', I-I'. The subsurface projections constructed along these lines are provided as Plates 7, 8, and 9 - Hydrogeologic Cross-Sections D-D', E-E', F-F' and G-G', respectively, and Plate 11 - Hydrogeologic Cross-Sections H-H' and I-I'. Plates 7 and 8 provide an interpretation of the geologic units that are believed present below the central portion of the City (along the San Lorenzo River). These sections were constructed using the interpretation of data from a surface geophysical study (Stanley and McCaffrey, 1983) and show the Santa Margarita Sandstone locally having a thickness of up to several hundred feet along the down-dropped side of the inferred normal faults. Plate 11 shows geologic interpretations of subsurface conditions under the eastern Santa Cruz area in the vicinity of the City Beltz Well field. These interpretations are derived primarily from test hole data and show the Santa Margarita Sandstone to be substantially thinner in this area. Plate 10 shows the location of these previous test hole investigations along with other well locations. Because available data indicate the formation thickness, burial depths, and possibly formation materials are significantly different between the downtown and eastside areas, we will discuss each area of the Santa Margarita aquifer separately.

Downtown Santa Margarita Formation. A surface geophysical investigation conducted in 1983 concluded that gravity anomalies in the vicinity of the City indicate an offset occurs in the crystalline basement rock about 1 mile west of the San Lorenzo River (Stanley and McCaffrey, 1983). This geologic feature was interpreted as an extension of the Ben Lomond fault. The study suggests that:

> *"... geology and gravity data show that a 10 to 12 million year-old nonconformity between Cretaceous granitic basement and the overlying Santa Margarita Sandstone is offset vertically about 200 meters by the fault." "Most of the displacement on the Ben Lomond fault probably took place during deposition of the Santa Margarita Sandstone in the middle to late Miocene (9 to 12 million years ago) because isopachs of this sandstone are generally parallel to the fault and the sandstone thickens dramatically near the fault"* (Stanley and McCaffrey, 1983).

To our knowledge, no test holes have been drilled to any significant depth in this portion of the City, and no data are available that could be useful in assessing bedrock lithology to the east of this fault zone.

Although the Santa Margarita Formation is inferred to be thicker east of the fault, the aquifer yield characteristics and groundwater quality are unknown. Because of these unknown conditions, and because the City obtained poor results from a test hole drilled approximately 2 miles to the west, this potential aquifer zone was not recommended to the City for further investigation (Weber, 1989).

A sedimentary facies study on the depositional environment of the Santa Margarita sands that were found in outcrops around the City was conducted in 1981. From these exposures, the study concluded that between the City and the Wilder area the Santa Margarita Formation is characterized by a bioturbated facies. This biofacies is typically associated with finer-grained sedimentary deposits that contain a higher clay content (Phillips, 1981). The study, however, indicates that toward the east end of the City's service district, paleocurrent structures observed in formation outcrops suggest coarser-grained deposits (better aquifer materials) may be present.

Eastside Santa Margarita Formation. In 1957, the City drilled four test holes to evaluate local groundwater conditions. Two of the test holes were surveyed using the electrical resistivity logging technique. Below is the reported description of the materials and a qualitative interpretation of the geophysical log of Test Hole No. 1, which was located at 41st Avenue and Cory Street.

> "*The log shows the presence of a 90-ft thick stratum of sand at the bottom of the hole. The Schlumberger electrical log implies that permeability in this stratum is substantially greater than in overlying Purisima black sand. Yield of this deep aquifer cannot be estimated because its source of recharge is not known*" (B&C, 1963).

Test Hole No. 2 was located at 41st Avenue and Capitola Road and the following was reported on its findings.

> "*A hard granitic formation, overlain with 60 ft of decomposed granite, was found at a depth of 802 ft. Results of Schlumberger tests indicate relatively high permeabilities in Purisima sands to a depth of 270 ft, in the sandy shale between depths of 677 and 690 ft, and in decomposed granite sands at the bottom of the hole*" (B&C, 1963).

These two test holes reportedly encountered granitic sands ranging from 60 to 90 feet thick, and which may comprise a productive aquifer zone. Test wells were not constructed at either of these sites.

The 1963 account of the hydrogeologic conditions found beneath the location of Test Hole Nos. 3 and 4 was consistent with the findings of subsequent demonstration studies. Test Hole No. 3 was drilled in Harvey West Stadium to a depth of 193 feet. The well log shows the subsurface materials to include clay, tight-white sand, limestone, and granite. Because none of these formations were inferred capable of yielding significant amounts of water, no additional exploratory work was done at that time (B&C, 1963). Test Hole No. 4 was drilled near Arana Creek on the north side of Brookwood Drive. The well log indicates the presence of several thin strata of sand. Drilling was reportedly stopped at a depth of 220 feet, where very hard, decomposed granitic formation was encountered. These accounts of hydrogeologic conditions were later substantiated. The City drilled the Harvey West test wells (at a location comparable to Test Hole No. 3) and produced 35 gpm to 50 gpm (B&C, 1984). The City subsequently drilled the DeLaveaga Tank site (comparable to Test Hole No. 4) (L&S, 1988) and decided not to complete the hole as a well.

The Thurber Lane test holes drilled by the City approximately 4,000 feet north of Highway 1 adjacent Rodeo Creek Gulch again indicate *"a thin section, approximately 26 feet in thickness, of coarser grained, lighter colored sand was encountered; it has physical characteristics similar to Santa Margarita sandstone, which has not been commonly encountered or reported below the Purisima in the eastern Santa Cruz Soquel-Aptos area. However, similar material has recently been encountered and completed in a production well in the Soquel area by the Soquel Creek Water District"* (L&S, 1988).

The City has not yet redrilled or tested the sites where the inferred Santa Margarita sandstone appears to provide substantially better aquifer characteristics (the sites of Test Hole Nos. 1 and 2 drilled in 1957). This is likely because of the cost of drilling the greater depths down to the reported Santa Margarita Formation, and the adequacy of other City water supplies. Geologic projections using the formation depths identified in the two test holes that were drilled along 41st Avenue suggest that the granitic sands (believed to be the Santa Margarita Formation) would be located between depths of 800 feet and 1,000 feet at the existing City Beltz well sites. This could prove to be a productive aquifer zone if the hydrogeologic descriptions interpreted from correlation of the drill cuttings and the test hole electric log data are accurate and the permeability of this stratum is either comparable or greater than the overlying Purisima black sands.

Water Balance and Availability

Possible recharge mechanisms include: a) infiltration of direct precipitation on the formation outcrops, b) streambed infiltration beneath the San Lorenzo River, c) streambed infiltration from coastal streams east of the San Lorenzo River, d) downward leakage from the overlying Purisima Formation, and e) inflow from underlying crystalline bedrock. The fracture system of the Ben Lomond fault zone also could provide a pathway for groundwater flow and allow recharge that is more regionally derived from the inland portion of the watershed. Previous studies indicated that the relationship of the granitic basement rock, Santa Margarita Formation, and Purisima Formation is largely unclear in portions of the eastern Santa Cruz/Live Oak area (L&S, 1984a). Little additional data have been generated since this study, and the amount of natural recharge to the Santa Margarita Formation in both the downtown and eastside areas is unknown.

Eastside Santa Margarita Formation. Available data indicate that a granitic sand layer, speculated to be the Santa Margarita Formation, increases in reported thickness from 26 feet up to 90 feet southward toward Monterey Bay. For the purpose of assessing the potential amount of groundwater in storage, we have assumed that the formation has an average thickness of 50 feet in the area between Highway 1 and the shoreline and between Capitola and the San

Lorenzo River, and has an effective porosity of 15 percent. These aquifer values yield an approximate formation storage volume within the defined area of 30,000 acre-feet.

Aquifer yield can be assessed using the qualitative comparison of these aquifer materials (B&C, 1963) with the overlying Purisima aquifer zones. Recent pump test data indicate that the Purisima aquifer zones present in this area have transmissivity values between 40,000 and 45,000 gpd/ft (Fugro, 1998). Using the assumed average aquifer thickness of 50 feet, we can estimate a formation transmissivity of 20,000 gpd/ft (or more). Given the available drawdown of several hundred feet and this estimated formation transmissivity value, wells completed in this area could be anticipated to yield on the order of 1,000 gpm or more. At this rate, four to five wells could provide 5 to 7 MGD. However, there are no data available at this time to indicate that the aquifer would naturally recharge at this rate.

Because specific recharge mechanisms have not been assessed, an estimate of sustainable yield was not provided by previous studies. However, based on conditions of aquifer confinement and limited aquifer outcrop areas near the coast (i.e., beneath the San Lorenzo River to the north of the City), sustainable yield is assumed by this study to be relatively low (in the range of 300 AFY to 900 AFY). A study of the Santa Margarita Formation conducted for the Association of Monterey Bay Area Governments (AMBAG) provides a geologic interpretation that projects a continuous section of Santa Margarita sandstone from the Bean Creek area to some point off shore, (Watkins-Johnson Environmental, Inc., 1993). In land recharge to this formation could potentially provide a greater amount of groundwater recharge to this coastal sandstone aquifer than has been estimated by this study. However, we assume that most inland recharge to this formation is either extracted by inland wells or released back to surface drainage channels at points lower in the watershed to become part of the San Lorenzo River baseflow.

The lack of natural recharge would have little affect on artificial recharge alternatives that could be considered if this aquifer has adequate production characteristics. It also should be noted that no data are available to indicate specific groundwater quality within this zone. There is only an implied level of acceptability evidenced by SQCWD having completed a well in what is believed to be a comparable zone in the Soquel-Aptos area (L&S, 1988), and because poor water quality characteristics were not identified by the electric log interpretation (B&C, 1963). It is reasonable to assume that water produced from this zone would require some type of treatment (i.e., iron and manganese, etc.).

Downtown Santa Margarita Formation. Available data indicate that the Santa Margarita Formation may approach a thickness of several hundred feet beneath the downtown area along the San Lorenzo River (Stanley and McCaffrey, 1983). The previously estimated volume of groundwater in storage for the Santa Margarita Sandstone would increase based on these conditions. However, if the effective porosity decreased proportionally as a result of finer-grained materials, the amount of groundwater in storage would effectively remain the same.

Absent additional data, we will use the previous gross estimate for the coastal area beneath the City water service area of 30,000 acre-feet.

Well yields in this area cannot be accurately estimated without field data. However, if the aquifer were to provide a transmissivity of 10,000 gpd/ft, wells would be anticipated to yield approximately 5 gpm/ft of drawdown. With 100 feet of available drawdown, a well would produce 500 gpm. Based on data available from City test wells drilled to the west of town and in the Harvey West Park area, we estimate that wells will likely produce in the range of 200 to 500 gpm. Aquifer recharge is believed to be from infiltration beneath the San Lorenzo River. Because little data are available, we assumed that recharge is relatively low and a component of the gross aquifer recharge estimate provided in the discussion of the eastside Santa Margarita Formation (300 AFY to 900 AFY). Water quality is assumed to be fair (TDS below 1,000 mg/l), but treatment may be necessary for select chemical constituents (i.e., iron and manganese).

Artificial Recharge

The well yields and annual yield of the Santa Margarita Formation cannot be estimated with any degree of certainty until exploration and testing has been conducted. Preliminary data indicate that if natural recharge were not available to this zone, artificial recharge though direct injection could provide groundwater storage. Confined aquifer conditions, aquifer thickness, and the electrical resistivity signature suggest that this zone may be suitable for direct injection as well as production. If the estimated production properties of this zone are close to actual conditions, we can estimate that an annual storage and recovery program could be developed that would be capable of cycling in the range of 325 to 650 MGY.

Environmental Constraints

Environmental impacts associated with production of groundwater from this formation are believed to be minimal. Because of the depth of burial, the formation is not likely in direct connection with the ocean until substantial distances offshore. This condition minimizes the potential for seawater intrusion. Because there is little (if any) current demand on groundwater from this aquifer zone, impacts to existing uses would be insignificant.

Additional Data Needs

Future work to define the potential of this aquifer should include drilling a test hole and completing a test well to allow groundwater production testing and water quality analyses for direct assessment of this inferred groundwater resource. If favorable results are obtained from groundwater production testing, injection testing should be conducted using the same wells to provide preliminary data on the feasibility of a long-term or seasonal injection and storage project. A source of injection supply and the time of availability will need to be identified to further assess artificial recharge options.

PURISIMA FORMATION GROUNDWATER AND BELTZ WELL FIELD OPTIMIZATION ALTERNATIVE

Hydrogeology

The Purisima Formation is a multi-layered confined to leaky-confined aquifer system. The primary aquifer units are comprised primarily of interbedded fine- to medium-grained sandstone layers that vary from weakly to highly cemented. These marine sands are interbedded with sandy silt and sandy clay that serve as confining layers. The entire aquifer system has been estimated by previous studies to contain over 1,000,000 acre-feet (325 billion gallons) of groundwater in storage. Most of this groundwater is contained in aquifer materials located below sea level.

Aquifer delineation adopted by previous studies (using the lettering system to identify individual zones) indicates the City's Beltz wells are completed in the lower Purisima aquifer units designated as the A and AA zones (L&S, 1996). Hydrogeologic cross-sections H-H' and I-I' (see Plate 11) provide an interpretation of the subsurface materials present under the Beltz well field. The Beltz well field has been a vital component of the City's water supply system since its acquisition from the Beltz Water Company. Current water supply projections include the Beltz wells as a constant component of the City's water supply, yielding 700 gpm or 345 MGY.

Water Balance and Availability

The Purisima aquifer system has been the subject of numerous water supply studies over the last 30 years and was first characterized by the USGS in 1968 (Hickey, 1968). The next major hydrogeologic study was performed also by the USGS and presented the conclusion that the groundwater system was subject to a condition of overdraft and seawater intrusion (Muir, 1980). This conclusion later became the center of much controversy and prompted numerous studies of basinwide conditions. Muir provided estimates of groundwater availability by correlating approximations of the total annual production with observations of water level changes in wells. Using two methods of approximation, the study summarized the potential yield of the Purisima Formation to be on the order of 4,100 AFY to 4,400 AFY.

Subsequent studies also have provided estimates of groundwater availability. Below is a listing of investigations that considered aquifer supply and demand issues and provided estimates of annual aquifer yields:

- (Hickey, 1968). This study estimated 7,000 AFY and 3,000 AFY of groundwater is available from the Purisima B and C subunits, respectively, providing a total of 10,000 AFY of perennial yield.

- (Muir, 1980). This study estimated the potential yield of groundwater from the Purisima Formation is about 4,400 AFY.
- (Thorup, 1981). This investigation estimated that groundwater availability was in the range of 10,200 AFY to 11,400 AFY, and suggested that a value of 8,000 AFY be considered as a reasonable average for a perennial yield.

In 1981, the SQCWD conducted a study to gain a better understanding of the actual perennial or sustainable yield formerly defined by the above wide range of estimates (L&S, 1981). This study suggested that groundwater management in the Soquel-Aptos area be interactive and respond to basin water level reactions to pumping. The study concluded that groundwater management should not be reduced to simple management by numbers (i.e., by defining basin yield as an absolute number and limiting pumpage to that value). The study further stated that although the potential for seawater intrusion is present in any coastal basin, the characteristics of the Soquel-Aptos area preclude the possibility of sudden and significant quality changes. Accordingly, the report concluded that management actions should be based on continued monitoring and interpretation of the basin reaction to groundwater pumping and that plans for both surface and groundwater development should continually evolve as part of those management actions (L&S, 1981). It should be noted that a perennial yield value was not estimated as part of that study, and that the SQCWD subsequently began management of the basin with this recommended strategy.

In 1984, a groundwater study was conducted for the City of Santa Cruz to evaluate the groundwater development potential in the eastern Santa Cruz and Live Oak areas. A summary of the study findings included the conclusion that the Purisima Formation is neither in a state of overdraft nor is it experiencing saltwater intrusion. The report concluded that approximately 9,000 AFY of subsurface outflow (not captured by extraction wells) was estimated to be discharging through the entire Purisima Formation to Monterey Bay. It was furthermore suggested that some of that discharge, which is essentially equivalent to developable additional yield, would appear to be potentially developable by the City in the northeastern Santa Cruz/Live Oak area (L&S, 1984a).

In the following year, L&S prepared a groundwater resource management report for the SQCWD. The report reclassifies the Purisima Formation into seven stratigraphic subunits consisting of AA, A, B, C, D, E, and F, and states that each is confined by claystone or siltstone layers. The Purisima Formation was estimated to contain 1,375,000 acre-feet of groundwater in storage. The report states that there had been no change in groundwater storage beneath the SQCWD between 1983 and 1984 (L&S, 1985). In addition, the Purisima Formation yield was summarized based on observations that reportedly indicated groundwater flow was occurring offshore beneath the coastline. The report concluded that the Purisima Formation was capable of sustaining an annual yield on the order of 12,000 to 13,000 acre-feet, and that it remained noteworthy that the yield of the Purisima Formation appeared to greatly exceed the pumpage at that time (L&S, 1985).

Aquifers beneath the Soquel-Aptos area continue to be evaluated. It is our understanding that a comprehensive groundwater model is being constructed for resource management purposes. The groundwater resources of the Soquel-Aptos area are being managed under an AB3030 Groundwater Management Plan developed for the SQCWD and the Central Water District (L&S, 1996). As stated in the management plan, the SQCWD had already effectively implemented a groundwater management program, which is consistent with the opportunities provided by AB3030 to address concerns about overdraft and seawater intrusion. The groundwater management plan was referred to as a formalization of the SQCWD's ongoing management in the Soquel-Aptos area (L&S, 1996). The management plan concluded that on a long-term basis there has not been a widespread steady decline in groundwater levels throughout the Soquel-Aptos area. The study presented the conclusion that a depression of coastal groundwater levels had developed in one or more Purisima aquifer subunits in the central portion of SQCWD. It also found that a recovery of coastal groundwater levels to well-above sea level was occurring in all Purisima subunits in the western portion of the District (L&S, 1996). The western portion of the SQCWD is adjacent the area of the City's Beltz well field. The recovery of water levels has, in part, resulted from reduced pumping by the City in recent years during reconstruction of the Beltz treatment plant and water wells. The City's new wells have the ability to extract 1,500 gpm and fully utilize the treatment plant capacity. Historical data indicate that the aquifer system in this area has not been regularly pumped by this well field for more than approximately 260 MGY (800 AFY). The reasons for relatively low use in the past have included the need to construct additional water quality treatment facilities, operational constraints of the old wells, and the past adequacy of other City water supplies. A basin response to the City's projected groundwater use and the proposed SQCWD plans to take more water from this area will regulate the amount of additional groundwater that is available for future production.

During the course of this study, the SQCWD completed a survey tabulating groundwater extraction from both private and municipal wells in the Soquel-Aptos area. The results of that survey indicate that about 2,235 MGY of groundwater is extracted annually from Purisima aquifer zones. Although this amount may be significantly below the historical estimates of the perennial basin yield of 2,600 and 4,235 MGY (8,000 to 13,000 AFY), it may be at or approaching the effective perennial yield. The effective perennial yield is considered to be the amount of groundwater that can effectively be captured through conventional (cost effective) methods without inducing adverse basin conditions. Explanations for the difference between the calculated and apparently developable perennial yield values of the Purisima aquifer include the physical (practical) limitations on capture of subsurface flow and/or the potential that perennial basin yields have been overestimated. The developable yield estimate being considered by the SQCWD for groundwater management purposes is 2,900 MGY (SQCWD communication, 1998). The difference between the estimated current annual use and this estimate of developable groundwater indicates that over 600 MGY is potentially available for future development without creating adverse impacts.

Beltz Well Field Improvements

Additional groundwater development in the vicinity of the Beltz well field along the City's water service district boundary (coincident with 41st Avenue) appears to have merit. This is supported by the hydrogeologic data review conducted as part of this study along with conclusions provided by previous studies conducted for the City and the SQCWD since the early 1980s. Assuming past aquifer yield studies are accurate and that additional treatment plant capacity can be provided, the City could possibly produce more water from the Purisima aquifer along this section of the coastline. Well yield capabilities suggest that the City could produce an additional 650 MGY. However, recent concerns raised by Santa Cruz County focus on the question of whether natural aquifer recharge can sustain the current or additional localized demand.

Additional production from the Purisima aquifer could be accomplished by refurbishing or replacing the Beltz wells at the existing well locations, and/or adding one or two new well sites along the City's eastern water service area boundary (adjacent 41st Avenue). Additional yield may also be obtainable from deeper fine-grained sand units beneath the Beltz well field (between the depths of 200 feet and 500 feet). A finer gravel pack and well screen design would likely be required. However, given the available drawdown, properly designed wells could be expected to produce upwards of 300 gpm to 500 gpm from this deeper zone. This could increase the overall yield from the Beltz area and possibly raise annual production by another 165 MGY to 325 MGY.

In summary, the Beltz well field (if expanded and refurbished) appears capable of producing up to an additional 650 MGY. Basin analyses provided by previous investigators (with the exception of Muir) suggest that additional yield can be obtained from this area of the basin. However, recent concerns suggest that natural aquifer recharge may not be capable of supporting additional demand from the primary aquifer zones that have historically been used. This suggests also that additional supply may only be available from deeper zones that have had little or no historical demand. For these reasons, additional groundwater supply from the Purisima aquifer in the area of the Beltz well field is estimated to be limited to about 325 MGY. Private wells in the County area along with the SQCWD will most likely develop the remaining available groundwater supply.

Artificial Recharge

Artificial recharge could also increase the annual yield obtained from the Purisima aquifer system. Injection of water into the aquifer zones in the Beltz well field or along the shoreline just west of Capitola (adjacent the Beltz well field) would increase water levels in the zones produced by the City during times of injection. Injection could assist in the abatement of seawater intrusion while optimizing the yield of this system. Preliminary calculations suggest that annual injection of up to 650 MGY is feasible.

Environmental Constraints

Environmental impacts associated with overdraft of this groundwater supply include well interference between City wells, private wells, and SQCWD wells. The SQCWD has been constructing new water wells along the City's eastern water service district boundary. However, we believe it is feasible to locate additional City wells such that mutual drawdown interference could be managed to a tolerable level (i.e. 20 to 30 feet).

Aquifer properties that have been calculated from data provided by production testing at the newly completed Roland Avenue Well and the 30th Avenue Well suggest that the Purisima aquifer zones lying between 100 and 200 feet in depth are a leaky confined system. Should the City or SQCWD elect to increase extractions in this area, additional monitoring wells should be considered to observe and regulate water levels along the shoreline. This will be necessary to provide adequate observation of groundwater conditions and allow assessments of the potential to cause saltwater intrusion. In addition, strategically placed wells could provide an early warning system if water quality degradation was induced by existing or additional basin extractions.

Additional Data Needs

Additional work to further evaluate this alternative should include rehabilitating or reconstructing the existing City wells and conducting subsequent aquifer testing. This would provide additional production data to calculate and refine aquifer parameters and, at the same time, provide the City with more efficient and reliable backup wells. These data should be used in a comprehensive model of the basin to simulate long-term effects of additional groundwater demands in this area. The City should further investigate coastal conditions at key locations where seawater intrusion is most likely to occur (i.e., Schwan Lagoon, Corcoran Lagoon, Moran Lake, and along Opal Cliffs). A better understanding of aquifer conditions will allow formulation of better managerial strategies and optimization of yield from the Beltz well field. Although no data are available to assess groundwater quality of the Purisima aquifer zones west or southwest of the Beltz well field, historical pumping has not reportedly induced seawater intrusion in this area. Bedding plane projections obtained from the Beltz wells indicate that the main productions zones used by the City likely outcrop along the shoreline between Soquel Point and the Santa Cruz Harbor. This condition suggests that if groundwater levels in this area fall below sea level there is a high risk of seawater intrusion. Increases in pumping by the City or SQCWD would increase this risk. The risk however, could be managed with additional coastal monitoring wells to provide zone specific observations.

Artificial recharge could be used to expand the amount of groundwater available for annual production. Recharge water sources will need to be identified and additional studies conducted to determine if the source water and groundwater are compatible. Although the current water system modeling being conducted by the City does not consider a groundwater recharge option, the existing City wells could be utilized for trial injection testing if seasonal injection and subsequent extraction in the Beltz well field appears advantageous. This would provide data to allow an assessment of the technical feasibility of this alternative and develop preliminary design requirements and costs for project alternatives comparison.

SAN LORENZO RIVER ALLUVIAL AQUIFER GROUNDWATER ALTERNATIVE

Hydrogeology

The San Lorenzo River alluvial groundwater basin has been divided by previous studies into an upstream and a downstream subbasin. These subbasins are delineated by the bedrock ridge trending east/west in the vicinity of Water Street (B&C, 1984). This separation appears to be based primarily on land surface features where the basin narrows. Available data of the subsurface geology indicates that the alluvial aquifer is hydraulically continuous. Historical data have been supplemented by the recent San Lorenzo River Flood Control Project assessment conducted by the U.S. Army Corps of Engineers (1995) of the geologic materials that lie beneath the flood control levees which contain the active river channel. This assessment was conducted from the Highway 1 Bridge crossing downstream to the Southern Pacific Railroad Bridge that crosses the mouth of the river at the shoreline. This study used cone penetrometer and testhole boring methods to generate geologic data for geotechnical design considerations. These data indicate there is laterally discontinuous layering of the alluvial materials deposited by the river (lenticular deposits) and suggest that roughly 40 percent of the alluvial material beneath this reach of the active channel are comprised of fine-grained silt and clay.

Investigative studies conducted for the seismic retrofit analysis of the Water Street and Soquel Avenue Bridge sites provide additional geotechnical data. Data from these studies were used to construct geologic cross sections of the alluvial aquifer at these river crossings. The locations of the sections are shown on Plate 6 and the sections are provided on Plate 9 – Hydrogeologic Cross-Sections F-F' and G-G'. These data indicate that the deepest section of alluvial material at these two locations is about 90 feet below MSL and occurs at the Soquel Avenue Bridge. The Water Street Bridge data indicate alluvium thickens from east to west from depths of 45 to 65 feet below MSL and suggests that the active river channel at this location does not overly the deepest portion of the basin (see Plate 9). Although the shallow alluvium is reported to range in depth down to approximately 90 feet below MSL, the average saturated thickness for the entire area that is covered with alluvium is considerably less and provides a relatively small groundwater storage capacity. The total groundwater storage capacity of the basin is estimated by this study to be around 2,000 acre-feet (650 MG), with around 90 percent of the groundwater stored below MSL. This indicates that aquifer storage reduction greater than 65 MG during a dry period could result in basin levels below MSL. Because of this condition would promote seawater intrusion, groundwater production would need to be located immediately adjacent the river and limited seasonally where induced recharge from the river would equal extractions and minimize storage depletion.

The river channel base elevation at the Soquel Avenue Bridge crossing was reported at mean sea level at the time of that study. This crossing is about 4,300 feet below the Highway 1 bridge. At the Highway 1 bridge, the river bed elevation is approximately 10 feet above MSL. Because of the low topographic profile of the river channel, high tidal surges can cause saltwater to move rapidly up river. Use of this aquifer system along the river for a freshwater supply is therefore limited to the upper reaches (i.e., towards the Highway1 Bridge crossing) where, because of the location, the water table depression caused by pumping has a reduced potential to induce saltwater flow into the aquifer system.

Water Balance and Availability

Over the past 20 years, the City has conducted several studies to assess the potential of using the San Lorenzo River alluvial aquifer system to expand their water supplies. The list of studies includes:

- (Earth Science Associates, 1979). This study considered the production of groundwater west of the San Lorenzo River in the area of Neary Lagoon.
- (Ranney, 1981). This study investigated the potential for construction of a radial collector well to increase extractions at the location of the existing Tait wells.
- (B&C, 1984). This study evaluated the potential to use the area south of Harvey West Industrial Park and along the San Lorenzo River for an artificial groundwater recharge project using river water diversions as the supply, percolation ponds for infiltration recharge, and alluvial wells for groundwater recovery.
- (L&S, 1990). This study reviewed previous studies and identified the Tait well field as an area that has the potential for an additional alluvial water well.

The common conclusion reached by these studies is that there is a potential to increase alluvial groundwater production, but well location must be selective (targeting coarse-grained deposits in deeper alluvial sections).

Conjunctive use of this aquifer was assessed and determined not to be feasible based primarily on low well yields at two locations selected for test well construction (B&C, 1984). The study considered surface water spreading alternatives with a plan to recharge up to 5,000 AFY (1,644 MGY) through infiltration into the alluvial groundwater system and, subsequently or simultaneously, extract the groundwater using conventional wells. However, the study appears to have overestimated the amount of available aquifer storage and ignored the heterogeneous nature of materials in an alluvial aquifer system, which can affect the formation's ability to transmit water.

Groundwater production in the vicinity of the Tait Street diversion structure is considered to be part of the surface water diversion project. Consequently, well discharges at this location are governed by surface water diversion limitations. The annual surface water allocation can reportedly be supplied through surface diversions; thus, groundwater produced at the Tait Street well field is a direct substitute, not a supplemental supply. Groundwater production from the San Lorenzo River alluvial aquifer would appear beneficial only if production downstream of the Tait Street diversion structure were not restricted by the existing diversion water rights limitations. For the purpose of this study, it is assumed that groundwater production south of Highway 1 would be permitted.

The production of groundwater from the lower portion of the alluvial basin, however, creates an increased risk of seawater intrusion. Substantial extractions would necessarily be restricted to the winter season when substantial river flows can prevent tidal surges from pushing seawater significant distances up the river channel. In addition, groundwater production would need to be restricted to the wet season when the affects of groundwater withdrawal cause insignificant losses to the winter flood flows in the river and are compatible with environmental goals for the San Lorenzo River. Although there are some potential benefits to developing this supply of groundwater, the physical and regulatory mechanisms to allow this will need to be tested and developed. In addition, this supply is available at a time when the City has ample surface water supplies and limited available surface storage. Groundwater production during the winter season could include treatment and distribution for use as a groundwater recharge supply in areas where storage is available in either the Santa Margarita or Purisima Formations.

If the City considers water supply options that include desalination of brackish or saline water, the San Lorenzo River alluvial aquifer appears to be capable of providing a saline groundwater supply. The production capacity along the lower river reach (below the Water Street Bridge) is estimated at 3 to 5 MGD (2,000 to 4,000 gpm) and would be obtainable through a series of wells or subsurface infiltration gallery. There are no production data available to allow further refinement of this estimate. However, it is believed that seawater infiltration would be rapidly induced by groundwater production within the tidal prism of the San Lorenzo River. Unlike the goal of producing fresh water from this shallow aquifer, saltwater production would not require maintaining aquifer levels above sea level. The filtration properties of the alluvial aquifer can likely provide a water supply with relatively low turbidity and minimize the pre-filtration process prior to salt removal.

Artificial Recharge

Artificial recharge of this groundwater system is not feasible due to its linear configuration, shallow depth, low elevation, and proximity to the coastline. The unconfined and unconsolidated nature of the river alluvium could subject overlying uses to conditions that cause local structural impacts if the basin were dewatered or overfilled. These conditions include raising the groundwater level near the ground surface (resulting in nuisance water and liquefaction issues) and then subsequently locally depressing the water level in the basin (resulting in potential subsidence issues).

Environmental Constraints

Environmental impacts associated with groundwater production along the downtown reach of the San Lorenzo River include the potential to diminish surface flows in the river during the summer and early fall. Regulating extraction rates in accordance to river stages can likely mitigate this impact. Depressing groundwater levels in the lower reaches of the river will likely result in saltwater intrusion. If a freshwater supply is desired, an adequate setback from the coastline and the operation of extraction facilities at optimal rates will be required.

Improper facilities location, design, or operation could result in significant lowering of the water table and could create the potential for localized land surface subsidence. The subsidence potential should be assessed and, if necessary, mitigated through prudent design and operation of the groundwater extraction system. This means that if fine-grained materials in the area of the proposed extractions are locally susceptible to consolidation and underlie/support adjacent structures, the design and operation of extraction facilities should prevent excessive drawdown.

The City's downtown area has historically supported a variety of municipal and industrial uses. Groundwater contamination resulting from these past land uses may be an obstacle to the use of this water supply alternative. Potential contamination sources include leaky underground storage tanks used to store solvents or fuels.

Additional Data Needs

Additional work that is required to develop a fresh alluvial groundwater supply will include aquifer testing along the river levees below Highway 1 and above Soquel Avenue. This work should include the construction and testing of shallow production wells along this reach of the river. Test data collection should include well production versus distance-drawdown of groundwater levels, and water quality data. Observations of river conditions should include documentation of saltwater inflow frequencies and distances up river, and a river stage analysis that would allow an estimation of the seasonal period during which groundwater could be produced.

Because of the typically loose, unconsolidated nature of materials found in shallow alluvial deposits, a preliminary assessment should be conducted of the potential for groundwater drawdown to cause land surface subsidence. The potential production from this aquifer is the highest in the winter when hydrologic conditions (high river stages) minimize the potential for upstream seawater incursions that result from tidal surges. During the winter season, the City water system has the least demand, and Loch Lomond Reservoir approaches being full or spilling; thus, the City will need to assess system storage and use limitations prior to considering further development of this supply.

SUMMARY OF EVALUATION FINDINGS

The groundwater resources in the coastal area around the City have been explored and largely characterized by past studies. These resources are believed capable of providing additional water supply within the constraints of site-specific groundwater quality and sustainable yield issues. Table 1 – Summary of Groundwater Alternatives, provides a listing of the individual projects considered in this report and the corresponding potential water supply projections. Along with the potential to increase the native groundwater production capacity of the City water supply, the addition of an artificial recharge component could allow full utilization of coastal aquifers in areas where yield is acceptable and storage space is available (or can be made available through temporary overdraft). Supplemental recharge could provide a mitigation measure (i.e., an injection barrier, etc.) to help control potential water quality impacts that can be induced during maximum development of available groundwater supply.

Table 1. Summary of Groundwater Alternatives

Groundwater Alternative Description	Estimated Existing Production (AFY)/(MGY)	Additional Groundwater Available (AFY)/(MGY)	Aquifer Storage and Recovery Potential (AFY)/(MGY)	Potential Groundwater Supply Development by City (AFY)/(MGY)
Wilder Ranch Area, Santa Margarita Aquifer	(1,200)/(390)[1]	(300)/(100)[2]	(1,000)/(325)[3]	(1,300)/(425)
Downtown and Eastside Santa Margarita Aquifer	(0)/(0)	(300)/(100)[4]	(1,000)/(325)[5]	(1,300)/(425)[6]
Beltz Well Field Purisima Aquifer	(800)/(260)[7]	(1000)/(325)[8]	(2,000)/(650)[9]	(3,000)/(975)[10]
San Lorenzo Alluvium	(500)/(165)[11]	(1000)/(325)[12]	(0)/(0)	(1000)/(325)

[1] – Reference (Johnson, 1984)
[2] – Assumes a more even redistribution of pumping between Santa Cruz and Baldwin Creek
[3] – Assumes groundwater recharge distributed across pumping trough using injection wells
[4] – Assumes moderate leakage from overlying or underlying formations and/or minor stream bed infiltration
[5] – Assumes average thickness and reasonable transmissivity based on existing geophysical logs
[6] - Combines previous two assumptions
[7] – Based on engineering water supply projections
[8] – Reference (L&S, 1984b, 1985, and 1996), Based on assumption past water supply projections were accurate, well field can be expanded to the northeast, and groundwater system can sustain production
[9] – Assumes source water is available for injection and existing City wells or new well locations can be used
[10] – Assumes both well field expansion and seasonal/annual recharge program can be implemented
[11] – Represents Tait well use that is included in current annual diversion limitations
[12] – Assumes groundwater production downstream and/or from Tait wells during the winter so that production can be considered by regulators as groundwater not surface water diversion

The overall project feasibility of each one of the defined alternatives will rely on the ability to successfully develop the essential components, which include: a) groundwater monitoring programs, b) water supplies for artificial recharge and/or replacement of existing groundwater uses, c) modification of current City water supply operational strategies, d) sufficient definition of existing conditions for optimal planning and design, and e) regulatory and public acceptance. Field exploration will be necessary to provide hydrogeologic information to support or refute the inferences and assumptions used in this study that are based on available data. The additional definition of existing conditions will be required to generate reliability in the conceptual engineering of project components. Groundwater modeling should be conducted also for long-range planning of resource availability and to allow simulation of potential impacts of the alternatives being considered. Modeling should incorporate information that is developed from site-specific field investigations and aquifer testing. Modeling will provide long-term simulation of basin water level responses to production, and an understanding of the sensitivity to water balance components.

PRIORITY OF IMPLEMENTATION

In this section we have prioritized the groundwater project alternatives to assist in the sequential development of pertinent data. The data would be used to review the validity of many hydrogeologic assumptions made for preliminary evaluation of these resources. Priority was established based on available data, the apparent reliability of the water supply alternative, the apparent economics of obtaining the supply, and the apparent ease of implementation. Costs to conduct additional field investigations and construct wells to develop these groundwater alternatives are included in Appendix A - Cost Considerations.

The Beltz well field is currently in operation as one of the City's reliable water supplies. Increasing the capacity and reliability of this supply appears to be the easiest and quickest alternative to implement. Test holes have been drilled in the Beltz area and provide initial data from which preliminary design and project costs can be provided. Because of these conditions, we believe optimization of the Beltz well field operations should be the first alternative considered for additional study to develop data and allow a more detailed assessment of the alternative water supply feasibility. This will not only provide additional groundwater resources, but it will improve the reliability of the exiting well field. During the process of well field improvement, groundwater injection and recovery potentials can be defined. Environmental and political obstacles are currently perceived to be minimal for the implementation of testing for this project alternative. The primary obstacle to additional supply development will be the actual amount of annual recharge received by the Purisima Formation. This issue, combined with the existing competing interests, lowers the overall rating of this alternative. As part of additional study, the injection and storage potential of this aquifer should be evaluated. A source of water for injection also will need to be identified for this aspect of the groundwater alternative to be considered feasible.

The location of existing Beltz well sites in the eastern Santa Cruz area could readily allow test hole completion for an assessment of the underlying Santa Margarita Formation. Historical studies and field investigations support the apparent potential of this supply. This groundwater supply alternative offers unique opportunities if favorable water quality and production characteristics are available. The supply is virtually unutilized and would appear to provide the opportunity for both groundwater production and groundwater injection/storage. Like the Purisima Formation alternative, this alternative appears to present fewer environmental and political obstacles to the implementation of testing this groundwater resource. It is likely that data for this alternative can be developed at the same time additional data for the Beltz alternatives are being generated. Drilling a deep test hole at one of the Beltz well sites in which data could be acquired for the Santa Margarita and Purisima aquifers could do this. Well design data could be developed for both formations, and the deep test hole used for a Santa Margarita test well. From those data, a shallower well completion to test production of the 200- to 300-foot zone could be designed and completed. This would save time and mobilization costs. For these reasons, we have identified this alternative as the next groundwater option that should be considered for additional study.

The third alternative to explore should be the potential to produce groundwater from the San Lorenzo River alluvium. The development of this alternative appears beneficial for many reasons. One reason is that the alluvial basin is relatively unused and has relatively little demand (i.e., few competing interests). The production of groundwater from this aquifer during a time of significant runoff could provide an opportunity to induce infiltration of river water that would otherwise be lost as runoff. It may allow seasonal operation of the alluvial basin at a time that minimizes seawater intrusion. Restrictions on this alternative include that groundwater may only be produced during a time when system demand is low and system storage (i.e., Loch Lomond Reservoir) will likely be limited. If production of groundwater is tied to the limitations imposed on the Tait surface water diversion structure, no additional supply is gained. The potential of this supply appears to lie in the ability to produce it when it is available and store it in a place other than Loch Lomond. Storage of this supply in the Santa Margarita or Purisima Formation aquifers could provide additional water for use on a seasonal basis or during an extended drought. This groundwater supply could also provide the opportunity for conjunctive use with adjacent water districts (i.e., SQCWD). If additional storage capacity or new diversion/ groundwater production rights can not be secured this alternative is fatally flawed and the only potential use for this aquifer would be as a near shore saline groundwater supply.

The last alternative we recommend studying at this time is the development of additional groundwater from, and the seasonal recharge in, the Wilder Area Santa Margarita Sandstone. The groundwater resources of this area are currently being used or are in the process of being developed to the fullest potential by the overlying land users. For the City to be able to use the Wilder Ranch area aquifer system, an alternative water supply would need to be provided to offset current and future groundwater use. If this is not possible, then significant conjunctive use agreements would be required to allow recharge and storage of groundwater by the City, and prevent the risk of existing users pumping out the City's supply. These complications, combined with the facts that the landowner is a State agency, the land is leased to private agricultural enterprises, and the area is outside the City limits, make this alternative an apparently more complicated supply to pursue. Should an alternative water supply be identified and contacts with landowners and operators provide a more favorable indication of the willingness to cooperate, then the City would want to conduct further study to provide more information on alternative development and economic feasibility.

CONCLUSIONS AND RECOMMENDATIONS

The findings of this study indicate that, before any of the groundwater alternatives that are being evaluated can be selected for implementation, the City will need to consider: a) economic feasibility, b) social and regulatory acceptance, c) potential joint agency participation, d) environmental impacts, and e) operation and maintenance considerations. The conclusions and recommendations resulting from this study take into account as many of these issues as possible given the preliminary nature of the overall supply alternatives study.

Based on the study findings, we have developed the following conclusions:

GENERAL CONCLUSIONS

1. Groundwater resources in and around the City's water service area are available to be developed as an additional supply. However, the exact amount of additional groundwater that is available cannot be precisely estimated from existing data. Current estimates of groundwater availability indicate that development of native groundwater supplies in and around the City will not satisfy the projected shortage during a drought.
2. Development of additional groundwater supplies may require adjustments to the current City water supply management strategy.
3. Development of additional groundwater supplies may require negotiations with regulatory agencies to optimize water resource use strategies and minimize environmental impacts.
4. Aquifers beneath and adjacent the City's water service district appear to offer the potential for seasonal and, perhaps, long-term injection and storage of water.
5. Groundwater demand is increasing within the County area surrounding the City's water service district.
6. Saltwater intrusion is a definite threat to water quality in the San Lorenzo alluvial basin, is a likely threat to water quality in the Purisima aquifers, and a potential but unlikely threat to the deeper Santa Margarita aquifer.

7. Prudent well location, design, and construction will be required in order for any of the groundwater alternatives to be successful.

8. A well siting study should be conducted for any groundwater alternative that is further considered for a supply. The well siting study should identify property ownership, permit issues, and optimal locations for conveyance systems vs. aquifer considerations, and should prioritize the potential sites.

PURISIMA FORMATION AQUIFERS

1. The Purisima Formation is the most productive aquifer system in the vicinity of the City. However, it is not clear how much additional water will be available on an annual basis. It is technically feasible to increase well field production. However, the availability of groundwater on a long-term basis will depend on the actual amount of annual recharge received by the aquifer and the City's ability to effectively develop and manage the supply without causing adverse impacts.

2. Redistribution and/or extension of the Beltz well field along 41st Avenue will minimize localized impacts (excessive drawdown) and optimize groundwater capture. Improvements to the existing well field along with a few new wells is estimated to permit the production of up to 325 MGY in addition to the current 260 MGY supply projection.

3. A deeper finer-grained aquifer zone (between 200 and 300 feet at the Roland Avenue Well site) appears available for additional production at moderate rates (200 gpm to 500 gpm) given the available drawdown and formation grain size. This zone is estimated to provide up to 325 MGY of additional capacity to that being produced from the shallower, more permeable zone.

4. Artificial aquifer recharge could be conducted in this area if a suitable recharge water supply and operational strategy can be developed. The seasonal recharge potential of the Purisima aquifer system in this area is estimated up to 650 MGY.

5. Increased definition and monitoring of hydrogeologic conditions in specific coastal areas that present a greater risk of water quality degradation would be prudent basin management.

DOWNTOWN AND EASTSIDE SANTA MARGARITA FORMATION

1. Available data suggest that the Santa Margarita Formation may be present and sufficiently permeable and thick to provide a potentially viable aquifer in the downtown and eastern water service areas. However, no water quality data or aquifer production data are available at this time.

2. The inferred conditions, if accurate, could provide either a beneficial groundwater supply or an aquifer zone for underground storage of surplus water when surface storage is not available.

3. There is little or no demand on this zone (low potential for impact on adjacent users), and the depth of burial provides a natural protection from saltwater intrusion.

4. Preliminary estimates indicate up to 290 MGY may be available as a groundwater supply, or the zone may be capable of seasonally storing up to 325 MGY.

SAN LORENZO ALLUVIAL BASIN

1. Groundwater production from the San Lorenzo River alluvial basin (in the reach below Highway 1) has the potential to induce seawater intrusion into the aquifer. Groundwater extractions along the river channel will likely increase infiltration from the river and decrease surface flow. This may only be tolerable during the winter (4 to 6 months a year) given wildlife and fishery considerations.

2. Preliminary estimates indicate that an additional 325 AFY may be obtainable from this source of groundwater.

3. Production below Soquel Avenue Bridge would most certainly induce saltwater infiltration and could potentially provide a brackish groundwater supply.

WILDER RANCH AREA, SANTA MARGARITA AQUIFER GROUNDWATER

1. The current estimate of available groundwater for additional development in the Wilder Ranch is approximately 100 MGY.

2. Although quarry pit infiltration rates appear to be adequate from available data, groundwater recharge that is proposed at the Wilder Quarry might be problematic because of existing hydrogeologic conditions. These conditions include: a) high groundwater levels (no available storage space) in the area of the quarry, b) relatively slow movement from the point of recharge (Wilder Quarry) to the existing pumping trough (area of available storage space), c) mounding around the recharge area could emerge as rising groundwater and be lost as surface flow, and d) natural groundwater recharge does not appear adequate for overlying uses. Unless the City develops an agreement with overlying users, existing wells could produce a substantial portion of the water placed in the aquifer for storage.

3. The primary use of groundwater in the Wilder Ranch area is for subpotable irrigation demands. If a lower quality water supply could be developed that was adequate to replace the groundwater use, groundwater basin management would be easier and the perennial yield of the basin would be available to the City.

4. The area of the proposed project is outside of the City limits and on lands owned by the State.

Based on these conclusions, we recommend that the City consider field exploration of these alternatives in an order where the Purisima Formation and Downtown/Eastside Santa Margarita Formation are explored first and simultaneously. We recommend that the exploration program be developed in a sequential manner to allow avoidance of unnecessary work and maximize data collection. We recommend that this work be conducted on a schedule that coordinates with the progression of project team engineering and environmental work tasks.

We also recommend that the City consider exploring the potential to negotiate groundwater production constraints along the San Lorenzo River and link groundwater production to river flows. This would allow use of this supply during a time that impacts are believed to be minimal.

CLOSURE

This report has been prepared for the exclusive use of the City of Santa Cruz and its agents for specific application to assessing the preliminary feasibility of developing groundwater supply alternatives to augment the City's municipal water supply system. The findings, conclusions, and recommendations presented herein were prepared in accordance with generally accepted hydrogeologic resource planning and engineering practices. No other warranty, express or implied, is made.

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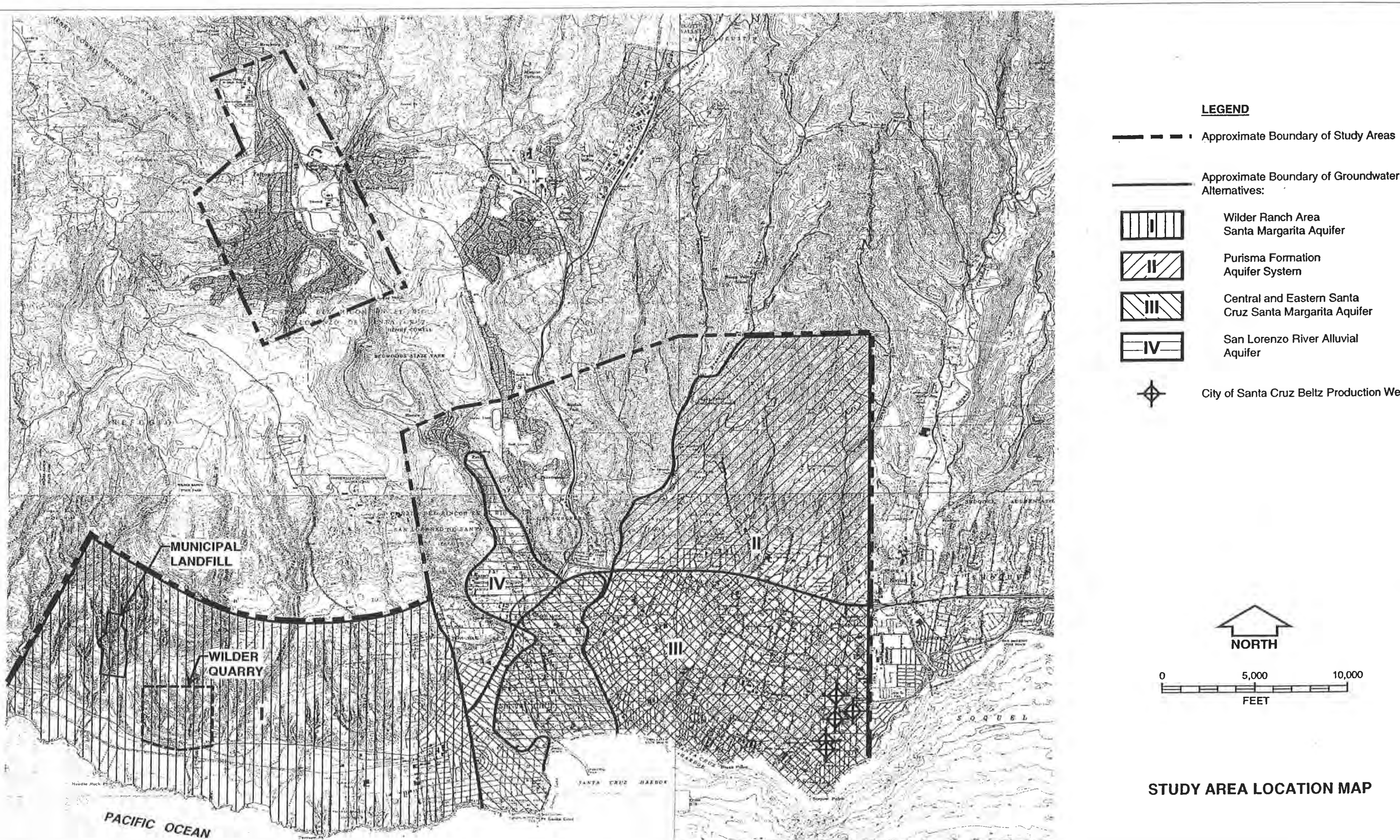
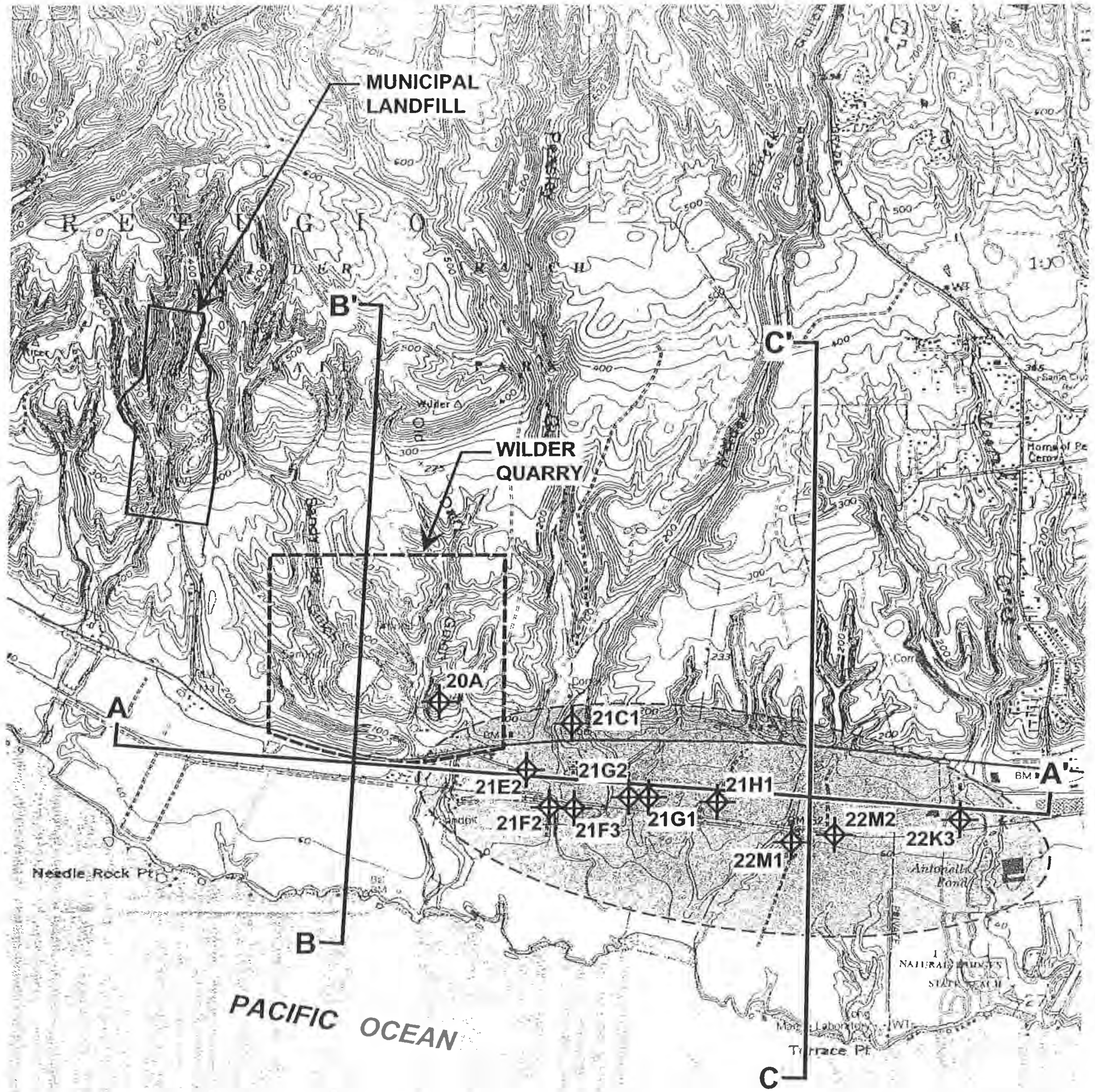
PLATES

FUGRO



STUDY AREA LOCATION MAP

PLATE 1



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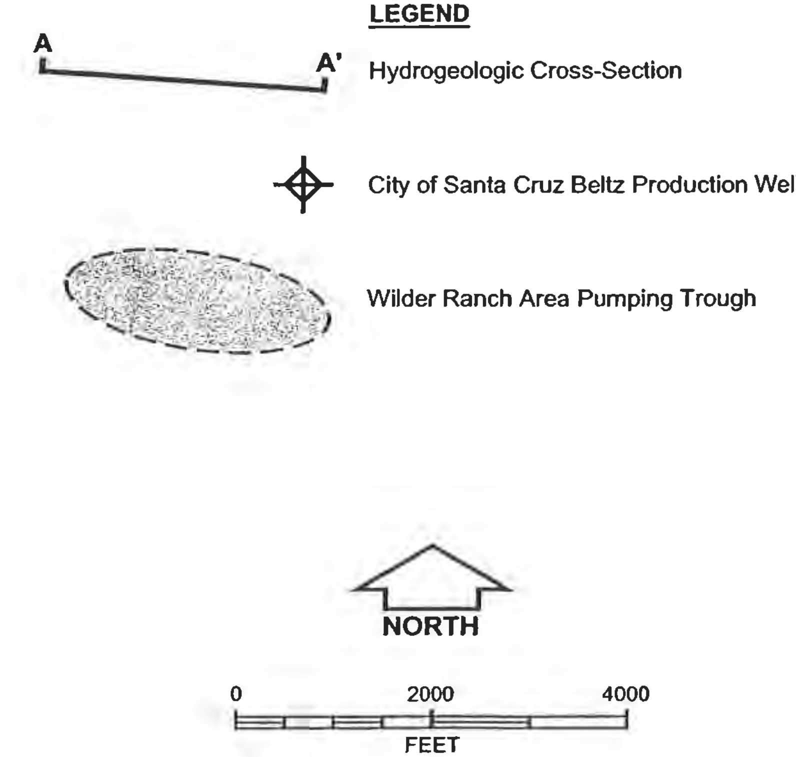
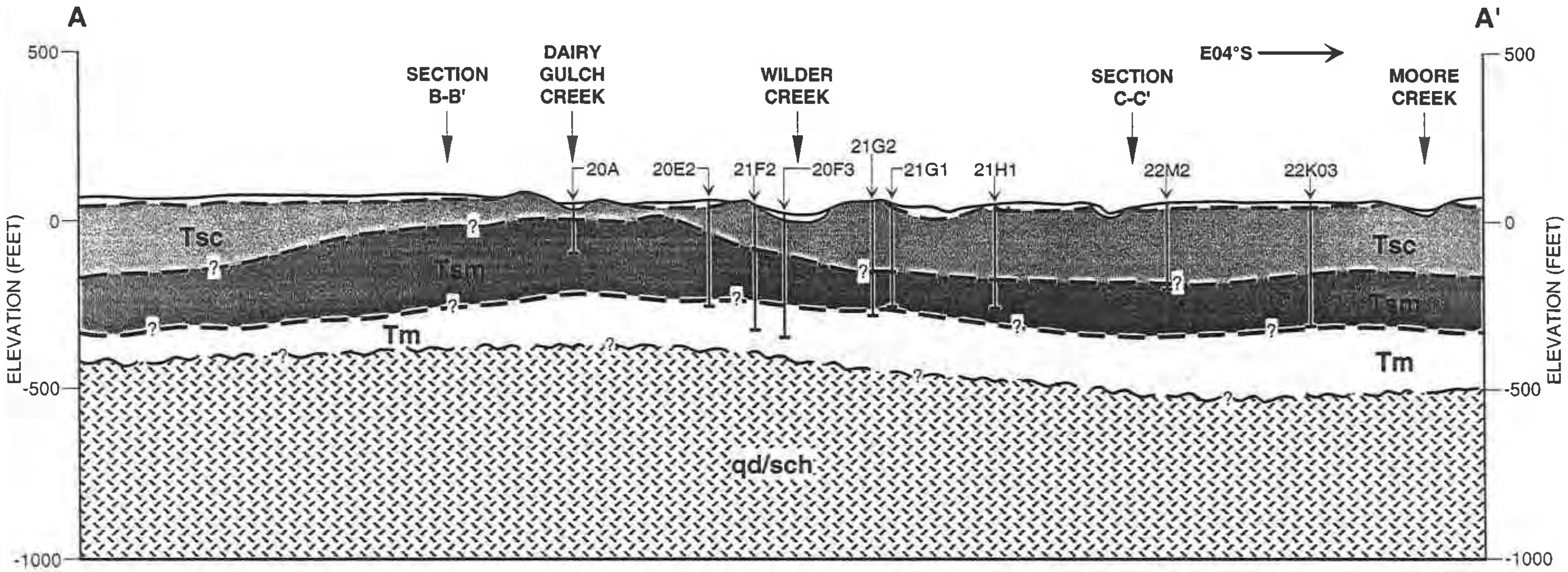


HYDROGEOLOGIC CROSS-SECTION LOCATION MAP
SECTIONS A-A', B-B', AND C-C'



Geology interpreted from Bore Hole Data and Clark (1981).

EXPLANATION

Contact

Unconformity

Qal — **Alluvium (Holocene)**— unconsolidated gravel, sand, and silt

Qm — **Marine terrace deposits (Pleistocene)**— unconsolidated moderate yellowish-brown fine sand and granular gravel

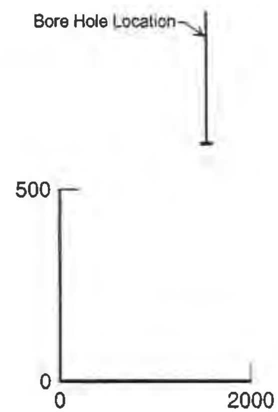
Tsc — **Santa Cruz Mudstone (upper Miocene)**— medium- to thick-bedded and faintly laminated olive-gray to pale yellowish-brown blocky siliceous mudstone and nodular sandy siltstone

Tsm — **Santa Margarita Sandstone (upper Miocene)**— very thick-bedded to massive light olive-gray to white medium- to fine-grained calcareous arkosic sandstone, locally bituminous

Tm — **Monterey Formation (middle Miocene)**— medium to thick-bedded and and laminated olive-gray to light gray subsiliceous organic mudstone and sandy siltstone. Includes few thick dolomite interbeds

qd — **Quartz diorite (upper Cretaceous)**— crystalline plutonic basement rock

sch — **Pelitic schist and quartzite (Mesozoic/Paleozoic)**— metasedimentary basement rock



Horizontal and Vertical
Scales in Feet
Vertical Exaggeration = 4x

PLATE 3

HYDROGEOLOGIC CROSS-SECTION A-A'

June 1999
Project No. 97-71-1221

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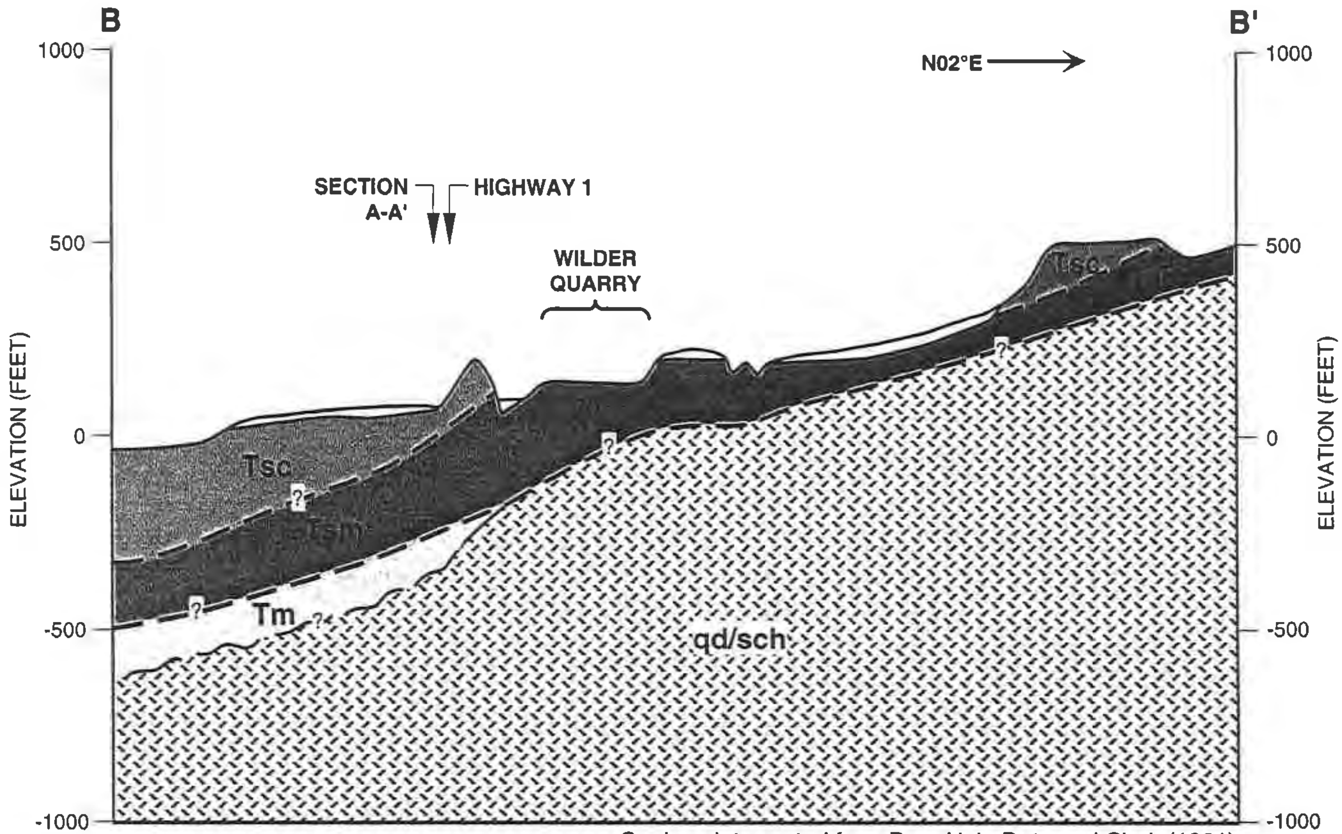


Geology interpreted from Bore Hole Data and Clark (1981).

EXPLANATION

Contact

Unconformity

Qal — **Alluvium (Holocene)**— unconsolidated gravel, sand, and silt

Qm — **Marine terrace deposits (Pleistocene)**— unconsolidated moderate yellowish-brown fine sand and granular gravel

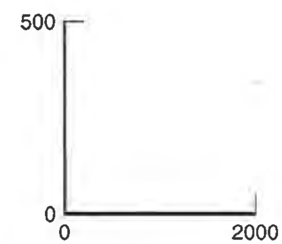
Tsc — **Santa Cruz Mudstone (upper Miocene)**— medium- to thick-bedded and faintly laminated olive-gray to pale yellowish-brown blocky siliceous mudstone and nodular sandy siltstone

Tsm — **Santa Margarita Sandstone (upper Miocene)**— very thick-bedded to massive light olive-gray to white medium- to fine-grained calcareous arkosic sandstone, locally bituminous

Tm — **Monterey Formation (middle Miocene)**— medium to thick-bedded and and laminated olive-gray to light gray subsiliceous organic mudstone and sandy siltstone. Includes few thick dolomite interbeds

qd — **Quartz diorite (upper Cretaceous)**— crystalline plutonic basement rock

sch — **Pelitic schist and quartzite (Mesozoic/Paleozoic)**— metasedimentary basement rock



Horizontal and Vertical Scales in Feet
Vertical Exaggeration = 4x

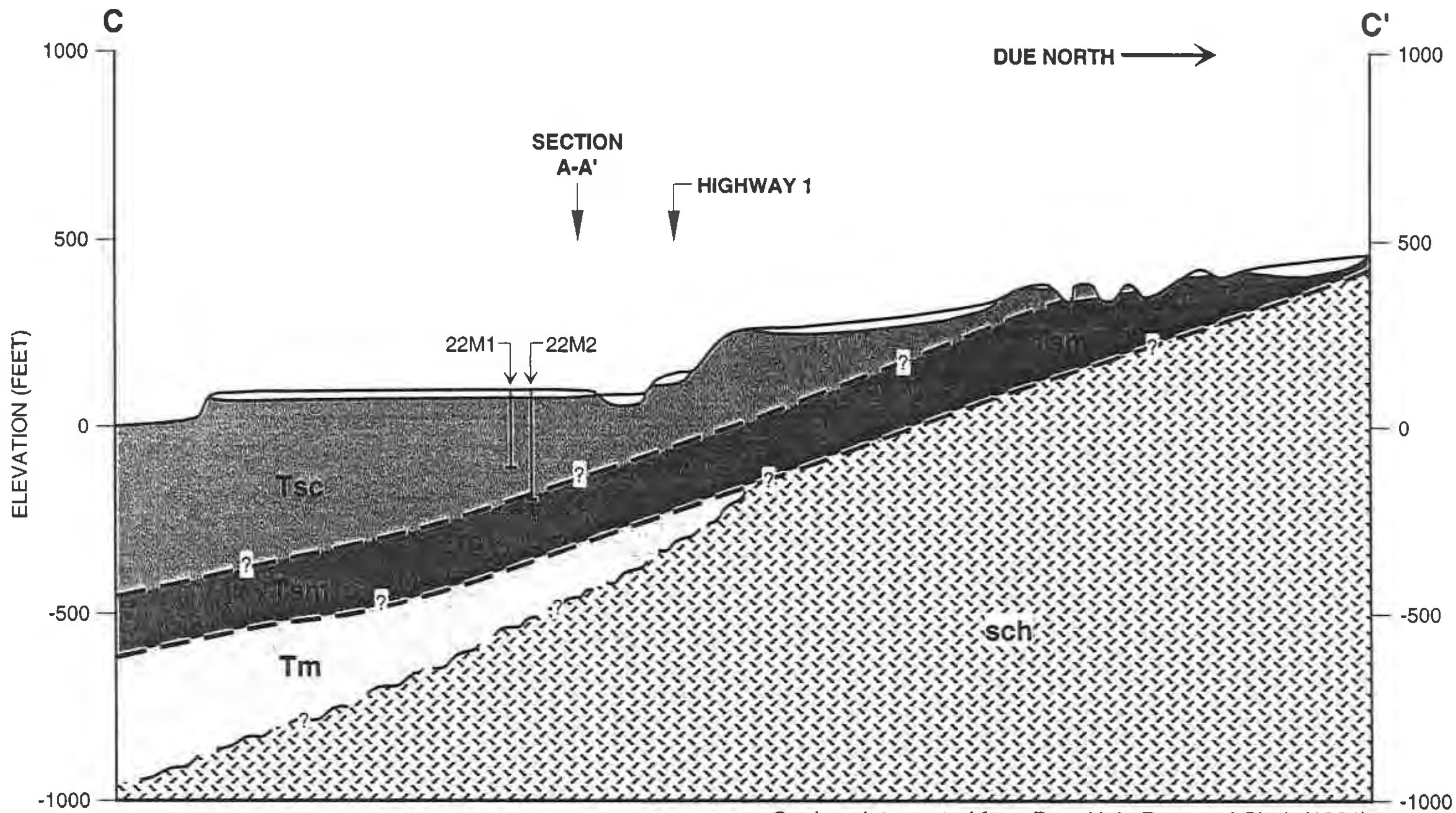
HYDROGEOLOGIC CROSS-SECTION B-B'

PLATE 4

June 1999
Project No. 97-71-1221

FUGRO

June 1999
Project No. 97-71-1221



Geology interpreted from Bore Hole Data and Clark (1981).

EXPLANATION

Contact

Unconformity

Qal	**Alluvium (Holocene)**— unconsolidated gravel, sand, and silt
Qm	**Marine terrace deposits (Pleistocene)**— unconsolidated moderate yellowish-brown fine sand and granular gravel
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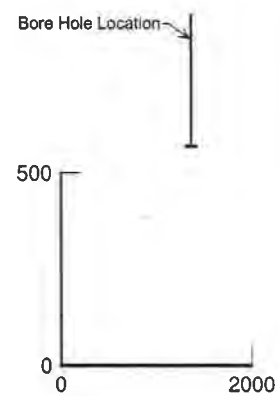
sch	**Pelitic schist and quartzite (Mesozoic/Paleozoic)**— metasedimentary basement rock

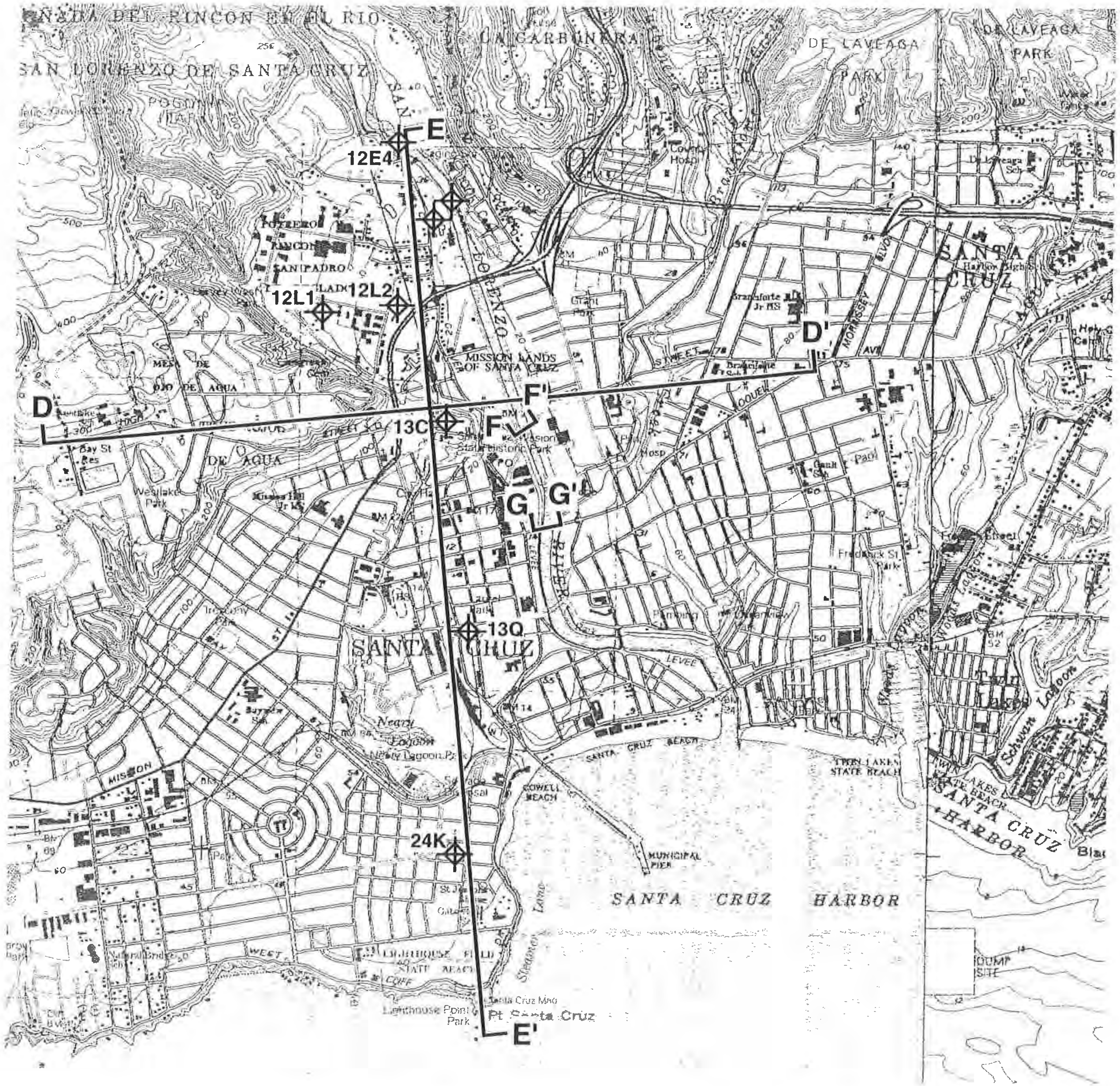


Horizontal and Vertical
Scales in Feet
Vertical Exaggeration = 4x

HYDROGEOLOGIC CROSS-SECTION C-C'

PLATE 5

FUGRO



LEGEND

D — D' Hydrogeologic Cross-Section

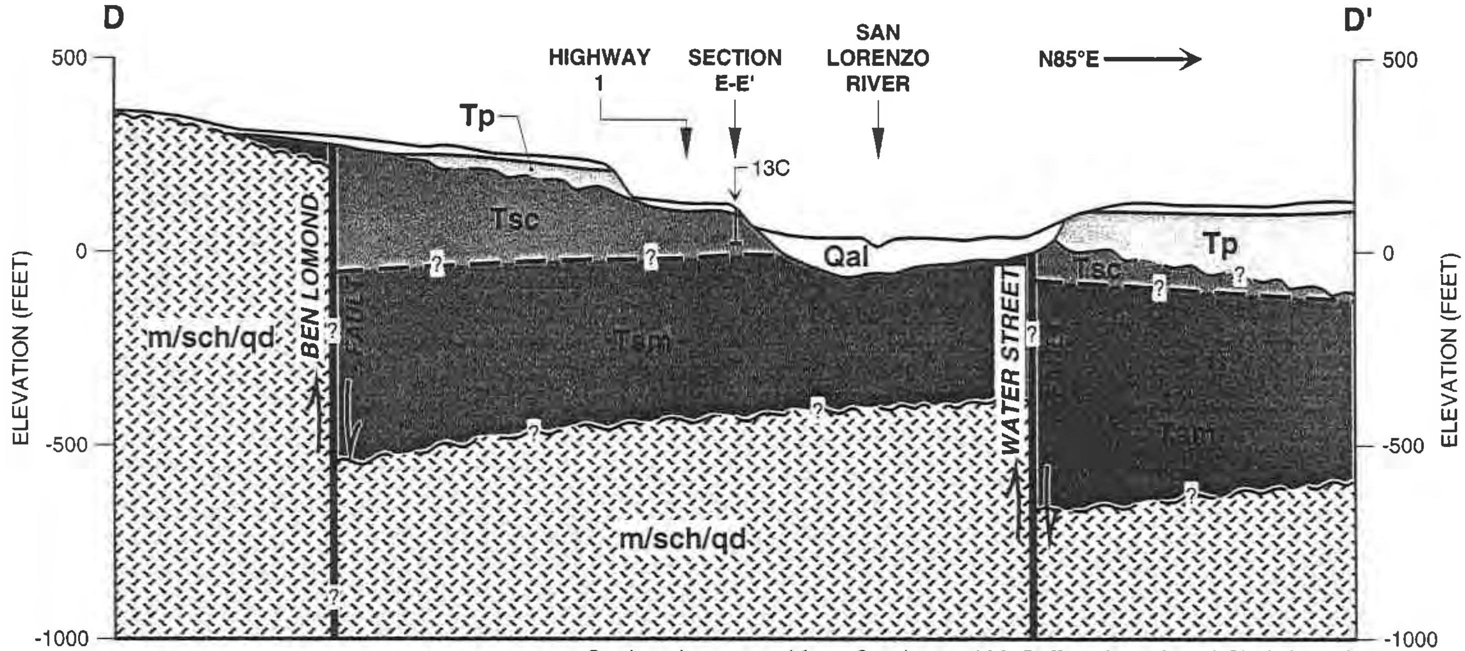
City of Santa Cruz Beltz Production Well

NORTH

0 2000 4000
FEET

HYDROGEOLOGIC CROSS-SECTION LOCATION MAP SECTIONS D-D', E-E', F-F', AND G-G'

9771\1221...sf.p4



Geology interpreted from Stanley and McCaffrey (1983) and Clark (1981).

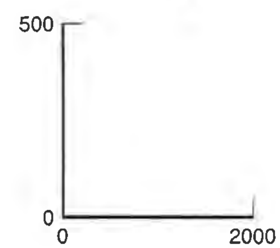
EXPLANATION

Contact

Unconformity

Qal	**Alluvium (Holocene)**— unconsolidated gravel, sand, and silt
Qm	**Marine terrace deposits (Pleistocene)**— unconsolidated moderate yellowish-brown fine sand and granular gravel
Tp	**Purisima Formation (upper Miocene and Pliocene)**— very thick bedded yellowish-gray tuffaceous and diatomaceous siltstone with thick interbeds of bluish-gray semifriable fine-grained andesitic sandstone
Tsc	**Santa Cruz Mudstone (upper Miocene)**— medium- to thick-bedded and faintly laminated olive-gray to pale yellowish-brown blocky siliceous mudstone and nodular sandy siltstone
Tsm	**Santa Margarita Sandstone (upper Miocene)**— very thick-bedded to massive light olive-gray to white medium- to fine-grained calcareous arkosic sandstone, locally bituminous
qd	**Quartz diorite (upper Cretaceous)**— crystalline plutonic basement rock
sch	**Pelitic schist and quartzite (Mesozoic/Paleozoic)**— metasedimentary basement rock
m	**Marble (Mesozoic/Paleozoic)**— metamorphic basement rock locally contains interbedded schist and calc-silicate rock

Bore Hole Location



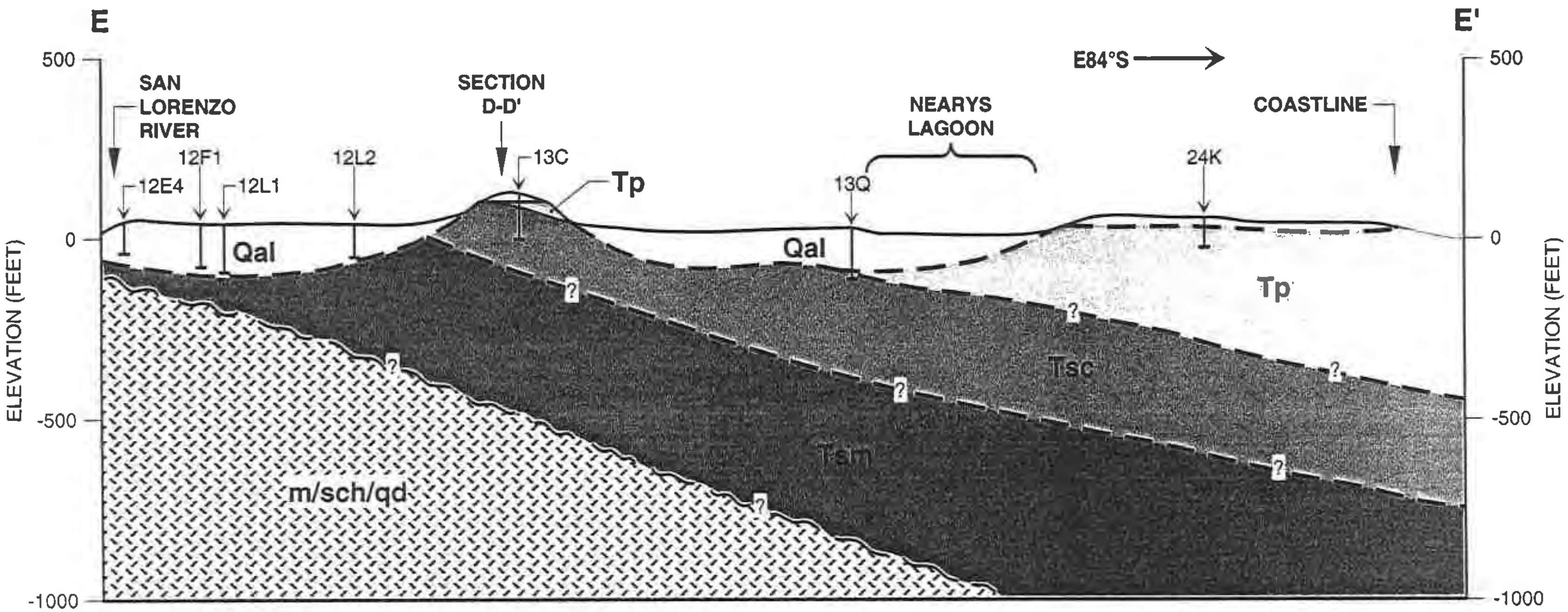
Horizontal and Vertical Scales in Feet
Vertical Exaggeration = 4x

HYDROGEOLOGIC CROSS-SECTION D-D'

PLATE 7

June 1999
Project No. 97-71-1221

FUGRO



Geology interpreted from Bore Hole Data, Stanley and McCaffrey (1983), and Clark (1981).

EXPLANATION

Contact

Unconformity

Qal	**Alluvium (Holocene)**— unconsolidated gravel, sand, and silt
Qm	**Marine terrace deposits (Pleistocene)**— unconsolidated moderate yellowish-brown fine sand and granular gravel
Tp	**Purisima Formation (upper Miocene and Pliocene)**— very thick bedded yellowish-gray tuffaceous and diatomaceous siltstone with thick interbeds of bluish-gray semifriable fine-grained andesitic sandstone
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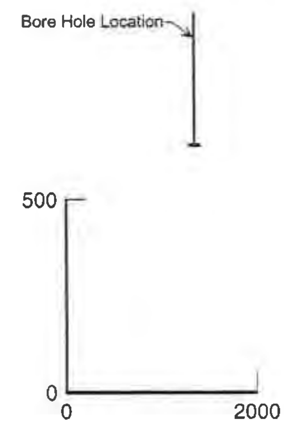


Horizontal and Vertical Scales in Feet
Vertical Exaggeration = 4x

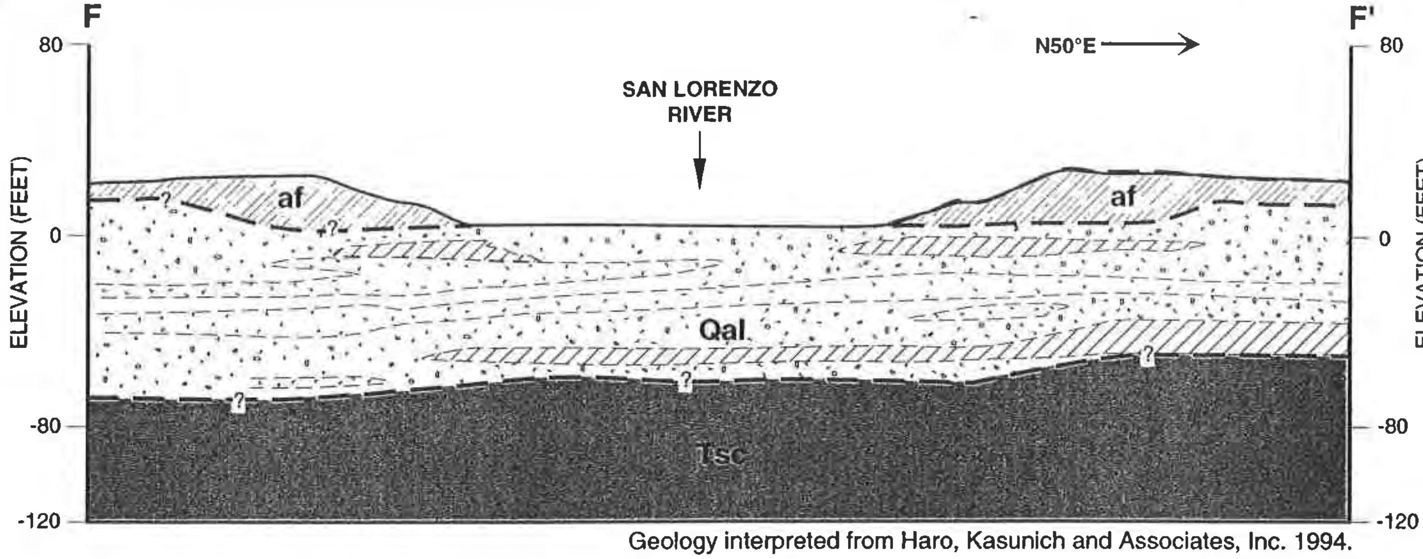
June 1999
Project No. 97-71-1221

FUGRO

PLATE 8

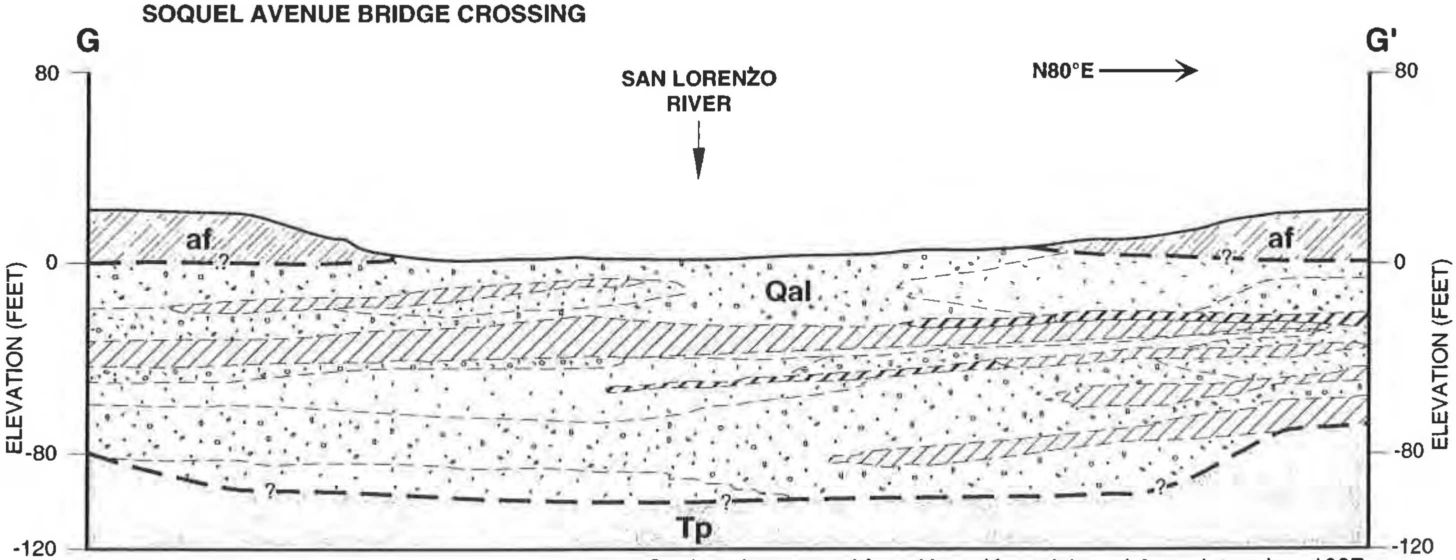
HYDROGEOLOGIC CROSS-SECTION E-E'

WATER STREET BRIDGE CROSSING



Geology interpreted from Haro, Kasunich and Associates, Inc. 1994.

SOQUEL AVENUE BRIDGE CROSSING



Geology interpreted from Haro, Kasunich and Associates, Inc. 1997.

EXPLANATION

Contact

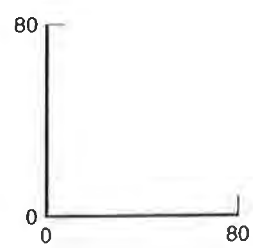
af — **Artificial Fill**

Qal — **Alluvium (Holocene)**— unconsolidated gravel, sand, and silt

- **Silt and Clay**
- **Sand**
- **Silt and Silty Sand**
- **Gravelly Sand**

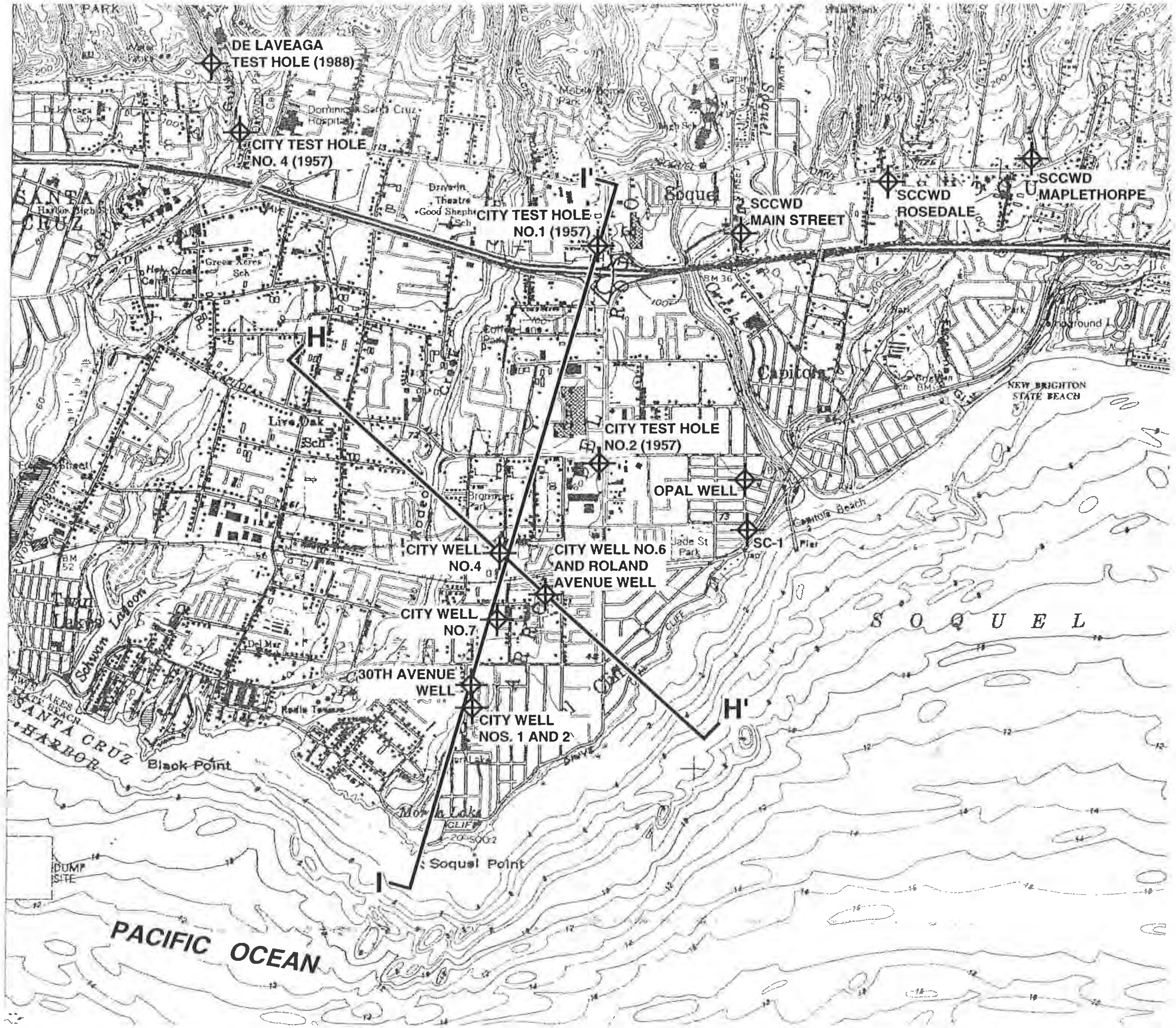
Tp — **Purisima Formation (upper Miocene and Pliocene)**— very thick bedded yellowish-gray tuffaceous and diatomaceous siltstone with thick interbeds of bluish-gray semifriable fine-grained andesitic sandstone

Tsc — **Santa Cruz Mudstone (upper Miocene)**— medium- to thick-bedded and faintly laminated olive-gray to pale yellowish-brown blocky siliceous mudstone and nodular sandy siltstone



Horizontal and Vertical Scales in Feet

HYDROGEOLOGIC CROSS-SECTIONS F-F' AND G-G'



LEGEND

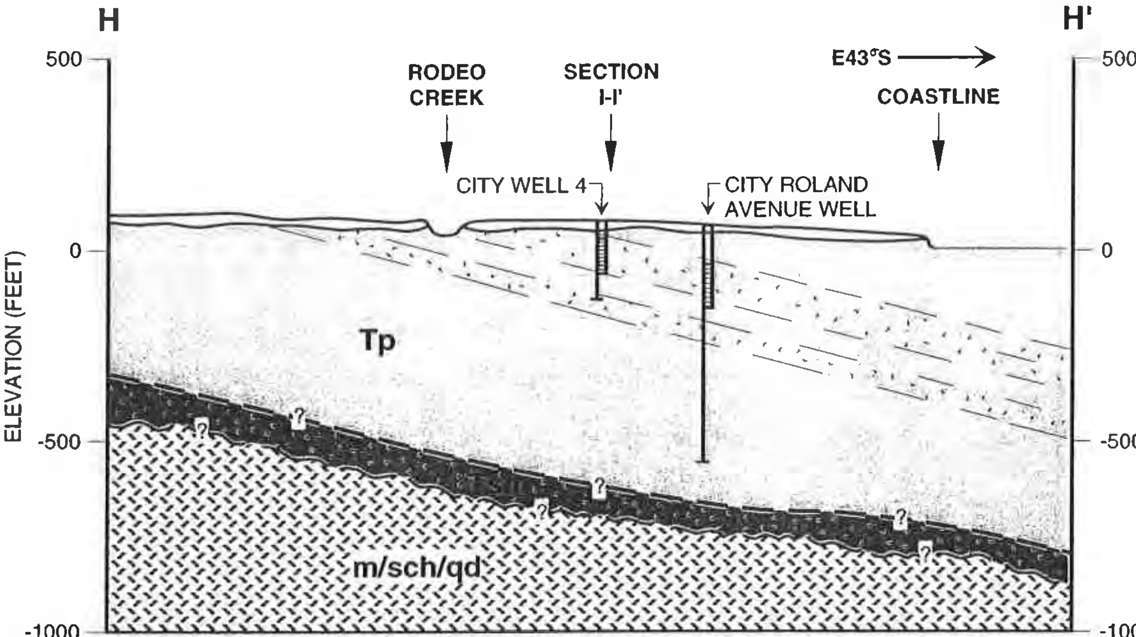
H — H' Hydrogeologic Cross-Section

City of Santa Cruz Beltz Production Well

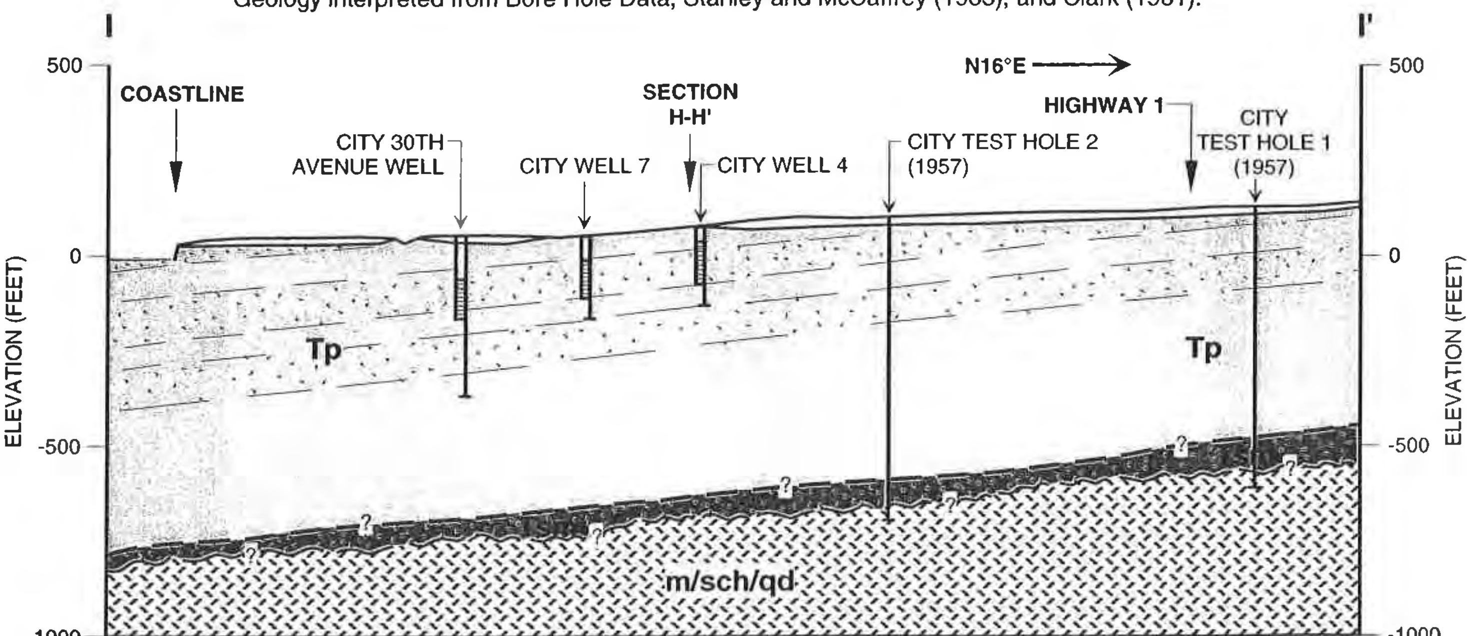
NORTH

0 2000 4000
FEET

HYDROGEOLOGIC CROSS-SECTION LOCATION MAP SECTIONS H-H' AND I-I'



Geology interpreted from Bore Hole Data, Stanley and McCaffrey (1983), and Clark (1981).



Geology interpreted from Bore Hole Data, Stanley and McCaffrey (1983), and Clark (1981).

EXPLANATION

Contact — Unconformity

Constructed Well (Screen Interval) — Bore Hole Location

Qm — **Marine terrace deposits (Pleistocene)**— unconsolidated moderate yellowish-brown fine sand and granular gravel

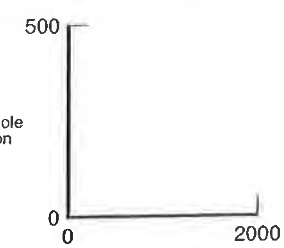
Tp — **Purisima Formation (upper Miocene and Pliocene)**— very thick bedded yellowish-gray tuffaceous and diatomaceous siltstone with thick interbeds of bluish-gray semifriable fine-grained andesitic sandstone

Tsm — **Santa Margarita Sandstone (upper Miocene)**— very thick-bedded to massive light olive-gray to white medium- to fine-grained calcareous arkosic sandstone, locally bituminous

qd — **Quartz diorite (upper Cretaceous)**— crystalline plutonic basement rock

sch — **Pelitic schist and quartzite (Mesozoic/Paleozoic)**— metasedimentary basement rock

m — **Marble (Mesozoic/Paleozoic)**— metamorphic basement rock locally contains interbedded schist andcalc-silicate rock calc-silicate rock



Horizontal and Vertical Scales in Feet
Vertical Exaggeration = 4x

HYDROGEOLOGIC CROSS-SECTIONS H-H' AND I-I'

PLATE 11

APPENDIX A
COST CONSIDERATIONS

APPENDIX A
COST CONSIDERATIONS

The groundwater alternatives reviewed by this study rely on inferences or assumptions that will require additional work (field verification of data) prior to further assessment with groundwater modeling or preliminary design engineering. The approximate cost to provide these supplemental data have been separated by alternative, and have been approximated based on our knowledge of local conditions, drilling contractor costs, and past experience with projects in and around developed commercial and residential communities including the County of Santa Cruz. Table A1–Summary of Field Investigation Costs for Groundwater Alternatives, provides a listing of the projected costs based on available information and the preliminary development of the work tasks that are described in the following sections.

Table A1. Summary of Field Investigation Costs for Groundwater Alternatives

Groundwater Alternative Description	Drilling, Well Construction, Materials, and Aquifer Testing	Aquifer Tests and Water Quality Sample Analysis	Groundwater Modeling, Construction Management, and Report Preparation	Total Cost of Project Alternative Assessment*
Wilder Ranch Area, Santa Margarita Aquifer	$600,000	$100,000	$60,000	$760,000
Downtown and Eastside Santa Margarita Aquifer	$280,000	$50,000	$60,000	$390,000
Beltz Well Field Purisima Aquifer	$250,000	$60,000	$85,000 [1]	$395,000
San Lorenzo Alluvium	$185,000	$45,000	$55,000	$285,000

* - Alternative costs assume City or project team provides CEQA environmental documentation if required.
[1] - Cost does not include groundwater modeling

WILDER RANCH AREA GROUNDWATER RECHARGE PROJECT

The technical feasibility of developing the Wilder Ranch area groundwater alternative can be further assessed if we substantiate existing data. The proposed project consists of several technical components that are essential to the success of the alternative. These components include: a) further identification of the Santa Margarita Formation aquifer conditions, b) assessing the potential to distribute production of groundwater more evenly along the coastline, c) assessing both the natural and proposed artificial recharge to the aquifer system to verify the true potential of this alternative, and d) identifying potential replacement irrigation water supplies for farming. Artificial recharge alternatives include surface water spreading at the Wilder Quarry and direct injection using water wells. Conceptual approaches to generating these data are presented below along with estimated costs to conduct the work.

Natural recharge to the aquifer system controls the amount of water available from this alternative without artificial enhancement. A detailed interview of groundwater users (well operators) in the proposed project area could assist in refining the estimate of the average annual recharge of groundwater. Information that should be compiled for further resource assessment includes electrical meter readings and well-pump performance curves along with any other records on well production tests. These types of data will allow another approximation of groundwater production to verify quantities previously estimated. This effort will require cooperation from individual well owners because utility records are typically considered to be private and confidential. This task will require identifying all the production wells within the area of interest and contacting the well owners/operators to discuss the merits of cooperating with the City on this resource assessment. There are up to 30 wells estimated to be available to provide production information in the area between the City and Baldwin Creek. This approach is anticipated to be labor intensive. The level of effort believed necessary to provide the resource evaluation is estimated to require a budget of $20,000.

Optimizing production of groundwater from the coastal bedrock aquifer system will require distribution of pumping proportionally along the coastline. This will allow greater utilization of natural groundwater recharge to the Santa Margarita aquifer and/or allow the creation of storage space for artificial groundwater recharge alternatives. This assessment may be able to utilize existing active or inactive wells. However, for budgetary estimates, we have assumed that construction of four new wells will be required to substantiate assumptions and identify existing groundwater conditions. The well locations would be situated adjacent Highway 1 and distributed at representative locations identified from existing data. Each well would be drilled to depths of up to 600 feet, developed, and pumped to provide production test data for aquifer analysis and samples for water quality testing. Additional testing could include direct injection of potable water to assess artificial recharge capabilities in this area. This effort would provide information for preliminary engineering design considerations and generate data to further assess resource use alternatives. Preliminary well designs, contractor procurement, well construction and testing, and project management and report preparation work is estimated to cost $500,000. This estimate does not include land acquisition costs to obtain easements for drilling and testing, or environmental documentation.

Recharge options, including use of the Wilder Quarry, will need to use hydrogeologic data specific to the quarry location. This will require surface and subsurface materials testing to refine groundwater recharge and production estimates for this alternative. We estimate testing can be conducted utilizing a sealed double-ring infiltrometer or other similar infiltration test method to generate additional recharge data for portions of the quarry that may be suitable for the proposed alternative. In addition, subsurface exploration will be required to determine if aquifer properties change within the Santa Margarita Formation at depth or lateral distances. Test wells drilled to depths of up to 200 feet are believed necessary. For the purpose of estimating the cost of resource assessment, we have assumed that three wells will be necessary.

The cost to provide the surface material testing, test well construction, aquifer testing, and project management and reporting is $240,000.

Permanent project costs will likely include a series of aquifer storage and recovery wells constructed along the alignment of the City water line just north or south of State Highway 1. Historical well performance variations in the Santa Margarita aquifer suggest a permanent well field will likely require 8 to 12 wells for injection and extraction operations. The well field is estimated to accommodate a preliminary scenario for extraction of up to 2,500 AFY over an 8-month period (2,400 gpm) and injection of 1,000 AFY over a 4-month period (1,900 gpm). This scenario assumes natural recharge will provide 1,500 AFY. The cost to construct 12 wells and provide wellhead improvements, including well pumps, motors, and controls (excluding wellhead treatment), is estimated to be $1,690,000. This cost does not include water treatment, pipelines, land acquisition costs, environmental documentation, or an imported irrigation supply to replace existing groundwater use.

DOWNTOWN AND EASTSIDE SANTA MARGARITA FORMATION WATER WELL PROJECT

The assessment of this alternative is anticipated to require construction of two test wells and one observation well. Tentatively, one test well and one observation well would be located in the vicinity of the Beltz well field (perhaps at an existing site). The other test hole/test well would be located within the eastern City limits west of the San Lorenzo River. Based on the findings at these two locations, additional drilling could include a test hole within the downtown area to determine the properties of the inferred thicker section of the Santa Margarita Formation. The drilling and construction program is anticipated to be a routine data collection program that will include aquifer production and water quality testing. Additional testing could include direct injection of potable water to generate artificial recharge data. For purposes of this estimate, we have assumed well depths up to 1,000 feet below ground surface. The estimated cost to drill three test holes and complete two test wells to this depth is $280,000. Additional costs will include work to provide aquifer testing, project management, modeling, and report preparation and are estimated at $110,000.

Should this alternative prove to be a beneficial alternative, project development costs will likely include the installation of up to five wells to depths of up to 1,000 feet. The construction and instrumentation of each well with pumps, motors, and electrical controls is estimated at approximately $175,000. Cumulative well construction and instrumentation costs are estimated at $875,000. This cost does not include land acquisition, environmental documentation, pipelines or treatment plant considerations. It is likely that a couple of these wells could be drilled at Beltz Well locations and not require the purchase of additional property.

PURISIMA FORMATION PRODUCTION AND BELTZ WELL FIELD OPTIMIZATION PROJECT

The Purisima Formation is currently under investigation as part of the Soquel Creek Water District (SQCWD), Central Water District (CWD), and City AB3030 groundwater management plan. It is our understanding that the entire groundwater system within the groundwater management agency, which includes all Purisima aquifer zones and the Aromas sand aquifer, is being modeled as part of that study. The groundwater model may be useful to the City if it can be obtained in a useable format (non-proprietary) that will allow the City to run various injection/extraction scenarios and simulate long-term water level responses.

Currently, there is a groundwater monitoring system established to the south/southeast along the coastline. The City should review the adequacy of this monitoring network in relation to the Beltz well field. There are limited exposures of the underlying geology along this section of coastline and, as a consequence, limited structural control is provided. Review of aquifer geometry data indicates the potential for the basal Purisima aquifer zones to approach the ground surface near coastal erosion features. If this condition exists, it could increase the risk of saltwater intrusion at or near the location of the overlying lagoons. We believe that the City should consider expanding the existing monitoring program and drill test holes to further define the shallow geology in the vicinity of these coastal features. Based on the findings of these borings, the City should consider installing observation wells to monitor water quality and water level variations at these locations. Borehole depths will likely be less than 100 feet. At this time, three locations appear to be adequate to provide the additional hydrogeologic data that would be useful in evaluating whether the existing coastal groundwater monitoring network provides sufficient protection for the Beltz well field. The total costs to provide the exploration efforts outlined above to establish groundwater monitoring points are estimated at $55,000.

The City's Beltz well field currently produces from a coarse sand and gravel zone of the Purisima Formation located between depths of 100 and 200 feet at most of the existing well locations. A finer-grained aquifer zone, which lies between the depths of 200 and 300 feet, has been identified in test holes drilled by the City and is believed to be unutilized in this area. This zone offers a potential to increase local production from the Purisima Formation. Existing data indicate that a well design that incorporates a finer gravel pack and smaller screen openings than have been conventionally used in this area will be required to produce from this zone. Given the amount of available drawdown, this aquifer zone shows the potential to provide production at a beneficial rate. This potential should be explored by constructing a test well and small-diameter observation well to demonstrate available production, obtain aquifer parameters for groundwater modeling, and provide groundwater samples for water quality analysis. The estimated costs to construct the observation well and test well at one of the existing City well sites, provide aquifer and water quality testing, project management, and report preparation is $110,000.

The City's ability to produce additional water from the Beltz well field will, in part, be dependent on the ability to disperse pumping over a larger area. This will minimize mutual drawdown interference affects between wells and help prevent development of a localized pumping depression. We recommend that the City review well efficiency data and, if necessary, conduct well efficiency testing to allow an assessment of current system capacities and the need to replace or rehabilitate the older Beltz wells. In addition, we recommend that the City identify sites and consider drilling up to two test wells along 41st Avenue to allow testing of available aquifer zones and provide data for engineering design of additional production wells. Data generated from this work will be useful in refining estimates of aquifer yields and the potential for groundwater storage operations. The cost estimated to review existing facility conditions and summarize well field improvements is $20,000. The cost to construct and test two exploration wells that are completed along 41st Avenue to depths of up to 300 feet is estimated at $210,000. This cost does not include site acquisition or environmental documentation work tasks.

Current data indicate that full development of the water supply in the Live Oak area of the City's water service district could require four additional wells constructed in the fine sand aquifer (200 to 300 feet deep) and another two wells constructed along 41st Avenue. The cost to construct and complete six additional well facilities is estimated at approximately $1,200,000. This cost estimate only includes construction of a new well, installation of a permanent well pump and controls, and minor site improvements (access and fencing, etc.). This estimate does not include land acquisition cost for two or three new well sites, treatment plant construction or expansion, or pipelines constructed to connect the new wells to the treatment plant. This cost estimate does not consider operation and maintenance costs over the lifetime of the wells. This cost is included in Table A2-Estimated Costs for Implementation of Groundwater Alternatives, for comparison with the cost of other project alternatives to construct groundwater extraction facilities.

City well performance records indicate that full utilization of existing wells in conjunction with new wells will require reconstruction or rehabilitation of the older wells. For the purpose of this cost assessment, we have assumed full replacement of existing wells at the present locations. The cost to reconstruct three new wells at the sites of Beltz Well Nos. 1 and 2, 4, and 7 is estimated to cost $400,000. Total well construction costs for upgrade and expansion of the Beltz well field is on the order of $1,600,000. These costs include design and construction of dual-purpose wells that will be suitable for use as aquifer injection and extraction wells.

SAN LORENZO RIVER ALLUVIAL AQUIFER WELLS PROJECT

Geologic conditions indicated by borehole data and cone penetrometer data appear capable of providing sustainable yields of up to 500 gpm to a properly designed and constructed conventional well installation. Field investigations for this alternative would require installation of shallow wells to test the production characteristics of the aquifer along the section of river that is apparently favorable for seasonal production. Three test wells would be constructed and would consist of shallow 8-inch-diameter PVC plastic well casing and screen, and be set to depths of up to 100 feet. Additionally, 2-inch-diameter observation wells would be required to measure water level drawdown along the river (toward the ocean) and away from the river into the downtown area. These data would allow a preliminary assessment of seawater intrusion and subsidence potentials. The cost to provide the complete well construction and testing program with water quality testing, groundwater modeling, and subsidence analysis is approximately $285,000.

Permanent installations for this alternative will likely include groundwater produced along the San Lorenzo River from a series of wells (i.e., five wells producing 400 gpm) or an infiltration gallery or horizontal wells capable of producing up to 2,000 gpm. This would allow the production of up to 1,000 AFY during a 4-month period when the river stage would permit this amount of extraction and still maintain adequate flow to abate seawater incursions up the river. The cost to construct and equip five wells to depths of up to 100 feet is estimated at $550,000.

Table A2. Estimated Costs for Implementation of Groundwater Alternatives

Groundwater Alternative Description	Well Construction and Permanent Pump Costs[1,2]	Additional Groundwater Available (MGY)	Injection and Recovery Well Costs[2]	Additional Groundwater Available (MGY)
Wilder Ranch Area, Santa Margarita Aquifer	500,000	100	1,690,000	425
Downtown and Eastside Santa Margarita Aquifer	500,000	100	850,000	425
Beltz Well Field Purisima Aquifer	1,600,000	325	1,600,000	975
San Lorenzo Alluvium	550,000	325	0	325

1 Preliminary costs to be refined by field investigation work
2 Cost only includes well construction and pump and electrical controls. Treatment and pipeline needs are not included

APPENDIX B - GROUNDWATER SUPPLY SCREENING

APPENDIX B - GROUNDWATER SUPPLY SCREENING

This document presents a summary of the findings from the evaluation of groundwater supply alternatives for the City of Santa Cruz Alternative Water Supply Project. Included is a description of the of the alternatives studied, and the findings of a preliminary screening evaluation for each alternative.

GROUNDWATER ALTERNATIVES

Previous water supply studies have concluded that the local coastal aquifers cannot provide a reliable supply of groundwater to meet the projected shortfalls. However, as part of this study four local aquifer areas were identified as having the potential to supply some of the projected shortfall, either alone or in combination. The four areas are:

1. Santa Margarita Aquifer near Wilder Ranch

2. San Lorenzo Alluvial Aquifer near the Mouth of the San Lorenzo River

3. Santa Margarita Aquifer near Downtown/Eastside Santa Cruz

4. Purisima Aquifer near the Beltz Well Field

These alternatives were evaluated to determine the potential for significant yield based on a review of available published geologic and hydrogeologic information. A more complete discussion of of the site specific geology and hydrogeology is included in TM 3 - Groundwater Supply (Carollo/Fugro West, Inc. 1999).

Santa Margarita Aquifer Near Wilder Ranch

Based on a comparison of the estimated yield and the estimated current production we believe that the groundwater in the Santa Margarita aquifer near the Wilder Ranch is currently being used to its fullest potential — and is perhaps being seasonally overdrafted — by the overlying agricultural land users. Although the source does have appreciable yield, there does not appear to be any "excess" yield that could be used for domestic supply.

Further potential constraints on this alternative include:

1. **Implementation Constraints.** If this source was to be used, the City would need to offset the current groundwater use (i.e., provide supplemental supply to the agricultural users), or implement an artificial recharge project in the area.

   Artificial recharge does not appear to be technically prudent, particularly by surface spreading at the quarry area. High groundwater in the quarry area would limit the effectiveness of recharge, and it is expected that much of water recharged would be lost as surface outflow. There is a more promising location for recharge in the area currently pumped by agricultural users (i.e., the area of localized groundwater depression). However, although it may be technically feasible to recharge in this area, it would be very difficult to preclude the existing overlying land users from using the recharged water unless very rigorous contractual entitlements were established. The competing interest for this supply source is of particular concern during the summer months or during drought when demand on the groundwater is highest, at which time the City would most need the supply.

Perhaps most important, the City's water rights for the north coastal streams — the most likely source of water for recharge — do not provide for diversion to storage. Use of water from the streams for artificial recharge of the groundwater would be considered diversion to storage (i.e., groundwater storage). Based on preliminary review of the water rights it does not appear feasible to modify the current rights to include diversion to storage.

2. **Marginal to Poor Quality.** The quality of the groundwater in the area is marginal to poor, due in part to its proximity to the coast. Agricultural users in the area have found that water quality may differ seasonally; quality worsens during the summer months after pumping. During the typical summer pumping season there is limited natural recharge and greater influence from the brackish interface along the coast. The variable quality makes this supply questionable, particularly during a prolonged drought when the influence from the brackish water along the coast would be even greater.

Conclusion. We believe that the combination of constraints significantly limits the viability of this alternative. Even if a surface water source could be made available for recharge — which is essentially a non-starter given the existing surface water rights constraints — the ability to control use of the supply is questionable because of the numerous competing interests for groundwater in the area. On this basis, we consider the alternative to be fatally flawed.

We do not recommend that this alternative be pursued further by the City.

San Lorenzo Alluvial Aquifer - Fresh Water

The alluvial aquifer is a potential source of supply because of its inherent link to the river. This linkage, however, represents a primary constraint for this alternative. Water rights on the river are currently fully appropriated, making it very difficult (if not impossible) to secure a new water right to pump groundwater from the river alluvium.

In concept it may be possible that pumping from the alluvium would be permitted during the winter or spring high flows, at which time there would be "excess" groundwater underflow that would otherwise flow to the ocean. Under these specific conditions it could be reasoned that additional pumping would result in no appreciable impact to the river, its habitat, or the existing users. We estimate that up to 300 MG could be pumped during a high runoff year. However, because the water would be utilized during the high runoff conditions — when demand is low and water is available from other, existing sources — there would be limited benefit of direct use of the supply. To take full advantage of the additional supply it would need to be stored; Loch Lomond does not have excess storage capacity so any water pumped would have to be stored elsewhere.

One possible option would be to store the pumped groundwater in another larger groundwater basin (i.e., use the water is as a source of supply for artificial recharge elsewhere). However, it is important to note that additional supply from this source could be reliably obtained only in non-drought years or during the first year of the projected two-year drought conditions; during the second year of the drought (or subsequent years if the drought persisted) flows in the river would be zero or near zero in the area of the alluvium, so there would be no "excess" supply to pump and store elsewhere. Considering these issues, we do not believe that pumping this source for use as a recharge supply elsewhere would significantly improve the reliability or sustainability of the City's supply during the drought periods, when it is needed most. The quality of this supply also is uncertain, although it is of somewhat lesser concern than its reliability. Prolonged pumping — even during periods of high runoff — increase the potential for sea water intrusion.

Conclusion. Of the constraints identified above, we consider the water rights constraint to be of primary concern. Even if the water right issue could be overcome, the lack of reliability and sustainability during the drought makes this a questionable alternative, and an unlikely candidate for a supply building block.

Based on the water rights constraint and the limited supply availability during drought we consider this alternative to be fatally flawed. We do not recommend that this alternative be pursued further by the City.

San Lorenzo Aquifer - Brackish Supply

The amount of brackish water supply available from the alluvium depends in part on the available fresh groundwater underflow. The amount of groundwater in the alluvium is linked to river flow, which will vary depending on rainfall and runoff. As noted above this linkage is a primary constraint for this alternative.

As with the fresh groundwater alternative there is a slight possibility that pumping brackish supply from the alluvium could be permitted during the winter or spring high flows, at which time there would be "excess" flows that would otherwise flow to the ocean. However, the potential seasonal pumping constraints raise questions regarding the reliability or sustainability of the supply during the drought periods when it is needed most. The quality of this supply also is uncertain because prolonged pumping increases the potential for sea water intrusion, which could transition the quality to be more like seawater than a brackish supply.

Conclusion. For similar reasons as the fresh water alternative, we believe that this supply has limited benefit during the drought periods. We do not recommend that the brackish water alternative from the alluvium be pursued further.

Wells located at the mouth of the river targeting seawater for desalination may have merit. Pumping for seawater rather than brackish supply would impart no appreciable impact to the river, and would not be subject to the constraints associated with the river and fresh water underflow. This concept is discussed further in "Desalination" below.

Santa Margarita Aquifer - Eastside

This alternative offers the advantage that it could be developed at relatively short time frame compared to other supply alternatives and at relatively low cost because the target area of the Santa Margarita aquifer is located on the eastside of the City near the existing Beltz well field. There are currently no know users of the aquifer in this location; this aquifer lies well beneath the Purisima formation, which is comparatively shallow and therefore is much easier to access for the area users, including private well owners. By constructing a new well at one of the City's existing Beltz well sites (or rehabilitating an existing well) this alternative could be implemented with relatively few institutional issues.

The estimated average additional supply from this alternative is up to 100 million gallons per year (MG/yr) unless the supply can be augmented via artificial recharge. This additional supply is relatively insignificant compared to the City's overall supply needs and we do not consider this source to be a viable long-term drought supply alternative. Even with recharge, the reliability and sustainability of this source are uncertain for reasons similar to those noted above.

Conclusion. Based on the limited supply from this source we do not recommend that this alternative be pursued further by the City at this time. This alternative does have limited potential as a supply building block, and could be considered in the future if other more viable supply alternatives cannot be implemented.

Purisima Aquifer - Beltz Wells

The Purisima formation has historically been the most productive of the coastal aquifers in and around the eastern portion of the City. Because of its productivity, there are many competing interests for supply from this aquifer, including Soquel Creek Water District, the City, and numerous private well owners.

Recent estimates indicate that current pumpage is below the natural recharge potential by approximately 700 MG/yr (Soquel Creek Water District communication, 1998). However, studies of this aquifer system have shown that the current level of pumpage has resulted in a decrease in basin water levels and some localized overdraft of the basin in the Soquel-Aptos area. The localized overdrafting indicates that the natural recharge potential may be overestimated, or that there are physical limitations within the aquifer that effectively limit the available production capacity to a value well below the estimated natural recharge (e.g., multiple zones within the aquifer with only limited connection between them). Even if the physical limitations can be overcome (e.g., wells installed in multiple zones) there may also be technical and economic factors that limit the amount of water that can be produced. For example, even if numerous smaller capacity wells are installed there may be localized drawdown or well interference that would effectively limit production capacity from a given area of the aquifer. The costs for numerous wells and associated treatment facilities would be high.

Even if the technical issues can be addressed, we believe that the availability of this supply on a long term-basis is uncertain, and is particularly uncertain during drought conditions when other users will increase their reliance on this supply. Further increases in pumpage from this aquifer in areas near the shoreline also have the potential to increase seawater intrusion, potentially causing water quality to degrade.

Like the other alternatives, the reliability and sustainability of this source during droughts is questionable and unproven. Because there are numerous competing interests for this supply there are also political and institutional issues associated with implementation of this alternative. We do not believe that any projects targeting increased production in/around the Beltz area would be a viable long-term supply alternative given the current state of decreased water levels in the aquifer, and potential impacts to other users if pumpage from the aquifer is increased.

Conclusion. Based on the numerous technical constraints and other institutional issues we believe that this alternative has several potential fatal flaws, and is not viable. We do not recommend that it be pursued further by the City.

Conjunctive Use with Soquel Creek Water District. Under this alternative the City would supply water to the District in normal or above average rainfall years, and in exchange, the District would provide groundwater during times of drought. The water supplied by the City could be used for groundwater recharge or used directly by the District to meet demands (thereby decreasing usage of the aquifer in non-drought years so that the storage/yield could be maximized for supply in drought).

As noted above, the recent estimates of pumpage versus yield in the Purisima aquifer indicate that current pumpage is below the natural recharge potential, yet there are localized areas of overdraft. This indicates that the estimated natural recharge capacity may be too high. Based on our review of the geologic characteristics of the aquifer, it is technically possible to augment the yield via artificial recharge. However, even though the concept is technically possible we believe that conjunctive use with Soquel Creek Water District is fatally flawed for three reasons:

1. **Water Rights.** Recharge in Soquel would require a water right change for the type of use (change from diversion for use to diversion for storage), and the point of use

(Soquel Creek Water District is outside the City's designated service area). As discussed above, this does not appear to be viable.

2. **Water Supply for Recharge.** Even if the water rights issue could be resolved, based on our evaluation of the City's existing sources there does not appear enough "surplus" supply that could be used for recharge or supply in Soquel, particularly in the future as demands increase.

3. **Conjunctive Use Supply Constraint.** The availability of groundwater supply on a long-term basis is uncertain, and is particularly uncertain during prolonged drought conditions when the aquifer will be stressed as other users increase their reliance on this supply. It would be difficult to quantify a "guaranteed" supply that could be delivered to the City in a drought.

For these reasons, we do not recommend that this alternative be pursued further by the City.

carollo engineers

City of Santa Cruz
Preliminary Investigation of Water
Supply Alternatives

TECHNICAL MEMORANDUM NO. 4
ALTERNATIVE SCREENING

September 2000

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CITY OF SANTA CRUZ
PRELIMINARY INVESTIGATION OF WATER
SUPPLY ALTERNATIVES

TECHNICAL MEMORANDUM NO. 4
ALTERNATIVE SCREENING

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ALTERNATIVE SCREENING

This technical memorandum (TM) presents a description of the of the alternatives studied, and the findings of a preliminary screening evaluation for each water supply alternative. The preliminary screening evaluation in this document will be the basis for more detailed analysis of viable alternatives to be completed in a subsequent phase of this project.

SUMMARY

The objective of this study is to identify water supply alternatives to meet the City's current and future water supply needs.

This objective is based on two fundamental concepts:

- The City obtains essentially all of its water supply from surface water sources. The amount of water produced from these sources varies each year, depending on precipitation and runoff. During years of below normal precipitation or prolonged drought conditions — such as occurred most recently from 1987 to 1992 — the amount of supply produced from the sources is significantly reduced. During these conditions the City's demand for water exceeds the available supply, so the City must deplete its only available storage, Loch Lomond Reservoir.

- The City's General Plan provides for the limited but continued development and growth of the City. As the City continues to develop customer demand for water will exceed the amount of supply available from the existing sources, even in nondrought years.

To meet its water supply needs the City has identified a strategy to integrate three elements:

- Reduced demand by conservation in all years.

- Reduced demand by usage curtailment in drought years.

- New water sources.

This study considers alternatives for new supply only; alternatives for conservation and curtailment are being studied separately by the City and are not described or considered in this document. The water supply alternatives evaluated in this study include groundwater and surface water. Both fresh and brackish supplies are considered. The amount of supply available from each source alternative is quantified to determine its potential for use. The relative supply contribution of a single source alone, and in combination with other sources, is evaluated to identify how sources could be best grouped for a new reliable supply.

Each source is evaluated to determine its ability to supply water during a critical two- year drought period. The critical two-year drought period is selected as the basis of the evaluation because drought conditions will occur in the future, much as they have in the past, and it is during the drought conditions that the City's existing supply is (and will continue to be) most vulnerable. Other nondrought conditions were also evaluated as a basis of comparison to the drought conditions.

Findings and Conclusions

The engineering analysis completed for this study has resulted in three principal findings:

- **Projected Demands Exceed the Available Supply.** The amount of supply that can be produced from the City's sources is limited, and is strongly linked to precipitation and runoff. During drought conditions, demand far exceeds available supply. Unless programs for substantial and regular demand reduction by conservation and/or curtailment can be successfully implemented, the City will begin to face supply shortfalls as demands increase in the future, even in nondrought years.

- **Prolonged Drought Conditions are Critical.** During drought conditions there is a limited amount of "flowing" supply in the City's surface water sources. If drought conditions persist for two or more years the effect is even more pronounced, particularly during the high demand summer months. Lacking the capability to store large volumes of water the City will need new sustainable water supplies.

- **Storage Capacity is Very Limited.** The City's only surface water storage reservoir, Loch Lomond, is undersized. In drought years the lack of inflow to the reservoir significantly limits the amount of water available as supply for the City.

From these findings there are three primary conclusions:

- **New Water Supply Sources are Needed.** The City is committed to combining three elements-conservation, curtailment and new supplies-to meet its future demands. Each element is important; however, the results of the supply evaluation indicate that the City's water supply strategy must emphasize new water sources. This is because even the most aggressive and successful programs for demand reduction by conservation and/or usage curtailment will not likely be enough to offset the City's demand for water.

  The water supply analysis is based on projected water demands. (ref. Maddaus, 1999). The water demand projections were not adjusted to reflect possible usage curtailment strategies that could be implemented in a severe drought. Such strategies could reduce the demands and the resulting deficits in nondrought years, but will have only limited effect in a severe drought. For example, experience of other California utilities with established (and drought tested) conservation and curtailment programs indicates that it is reasonable to expect that such programs can achieve sustained demand reduction during prolonged droughts in the range of 15 to 25 percent. A sustained demand reduction in this range will not be enough to offset drought supply deficits for the City.

- **Sustained Production is Needed for a Prolonged Drought.** Historical records show that the City has faced droughts ranging from two to five years over the last 60 years. Prolonged droughts of similar duration in the future are inevitable.

  To be viable, sources of supply must be able to produce over the course of one or more years of drought, and they must produce during the summer months. Some of the alternatives evaluated are not recommended for further consideration at this time because they do not provide reliable supply over the projected two-year duration of the drought. For example, if a source is capable of reliable supply over the first but not the second drought year, its benefit as a supply "building block" is significantly diminished compared to other alternatives that can provide supply in the second drought year when projected shortfalls are most critical. Alternatives that can serve as reliable building blocks are preferred, and should be prioritized for further study.

- **Additional Storage is Needed.** Demand for water increases in the summer, and it is during the summer months of a prolonged drought that "flowing" supplies are even more diminished. The lack of "flowing" supply in the surface water sources during drought dictates that the source of the new supply must have a storage component.

  There are three types of storage available to the City:

  - Groundwater aquifer(s).
  - Surface water impoundment(s).
  - Ocean (i.e., seawater as a source of supply via desalination).

These three fundamental conclusions are significant because they form the basis for screening criteria against which all supply alternatives must be evaluated. These criteria were applied to the potential groundwater and surface water alternatives, and the following conclusions were developed:

- **Groundwater is Not a Viable Supply Alternative.** Similar to surface sources, coastal groundwater supplies are also affected during drought conditions, particularly during prolonged droughts. Most coastal aquifers are relatively small. Lacking a source of regular recharge — such as naturally occurring infiltration by precipitation, or artificial recharge from an alternative source — the storage is not readily replenished and the aquifers cannot sustain prolonged pumping.

  Several potential groundwater sources were considered, but none are considered viable. There are two primary reasons:

  - The sources provide limited storage and are not expected to provide sufficient reliable supply (i.e., sustained production in the second or subsequent years of a prolonged critical drought).

  - Artificial recharge from an alternative source (e.g., surface water or reclaimed wastewater) is not feasible due to technical constraints and/or implementation issues.

- **Desalination is a Viable Supply Alternative.** Desalination of sea water provides ample, sustainable supply with the necessary storage.

- **Reclamation and Optimized Use of Existing Source are Potentially Viable Supply Alternatives.** Each of these alternatives can provide supplemental supply. However, the relative contribution of these sources is far below the City's projected needs. For these alternatives to be viable, they must be used in combination with other supply alternatives such as desalination.

  It seems feasible that these two alternatives could be used as elements of the City's future water supply system. However, additional work is necessary to determine whether these alternatives should be implemented in conjunction with another project. For example, the cost of these projects must be compared to the incremental cost of obtaining a like amount of supply from another viable supply alternative such as desalination. Other potential benefits of these alternatives, such as improving the reliability of the existing sources by, and the environmental benefits of, reclamation, must also be considered.

- **Surface Water Storage is a Potentially Viable Alternative.** As noted above, one of the fundamental criteria for new water supply projects is ability to provide storage. For this study surface water storage in the Olympia gravel quarry was considered.

  Although feasible, there appear to be numerous issues that could preclude implementation of the quarry alternative. To date, no permit has been filed to complete the additional mining necessary for increased storage in the quarry. Also, no formal plans have been identified to describe who would participate in the project (i.e., City only or multi-agency project with San Lorenzo Valley Water District, Scotts Valley Water District, etc.), and/or how the additional supply would be allocated.

Additional work is necessary to determine if the quarry alternative or other storage alternatives should be considered. Previous water supply studies have identified several surface water storage projects that could help offset the City's water supply needs; however, these projects were determined to have several limiting constraints to implementation.

Recommendations

The screening analysis of water supply alternatives identified three potentially viable alternatives:

- Desalination.
- Optimized Use of Existing Surface Sources.
- Wastewater Reclamation.

We recommend that the engineering concepts for these alternatives be further refined so that the benefits, drawbacks, and estimated costs can be compared and contrasted. We also recommend that each project be evaluated with respect to potential environmental impact in order to better understand and quantify potential implementation constraints.

AVAILABLE WATER SUPPLY

An evaluation of the City's water supply was previously completed as part of this project (TM No. 2 Water Supply, Carollo/Linsley Kraeger Associates, 1999). The scope of work for the evaluation included:

- A review of historic rainfall and surface water hydrology data.
- An estimate of the available supply from the City's surface and groundwater sources.
- An evaluation of the monthly and seasonal supply conditions.

The information from the evaluation was used to quantify the available water supply for short-term, critical dry periods, and the corresponding supply deficit during these same periods. The evaluation also documented the available supply and corresponding deficit conditions during nondrought years.

Summary of Analysis

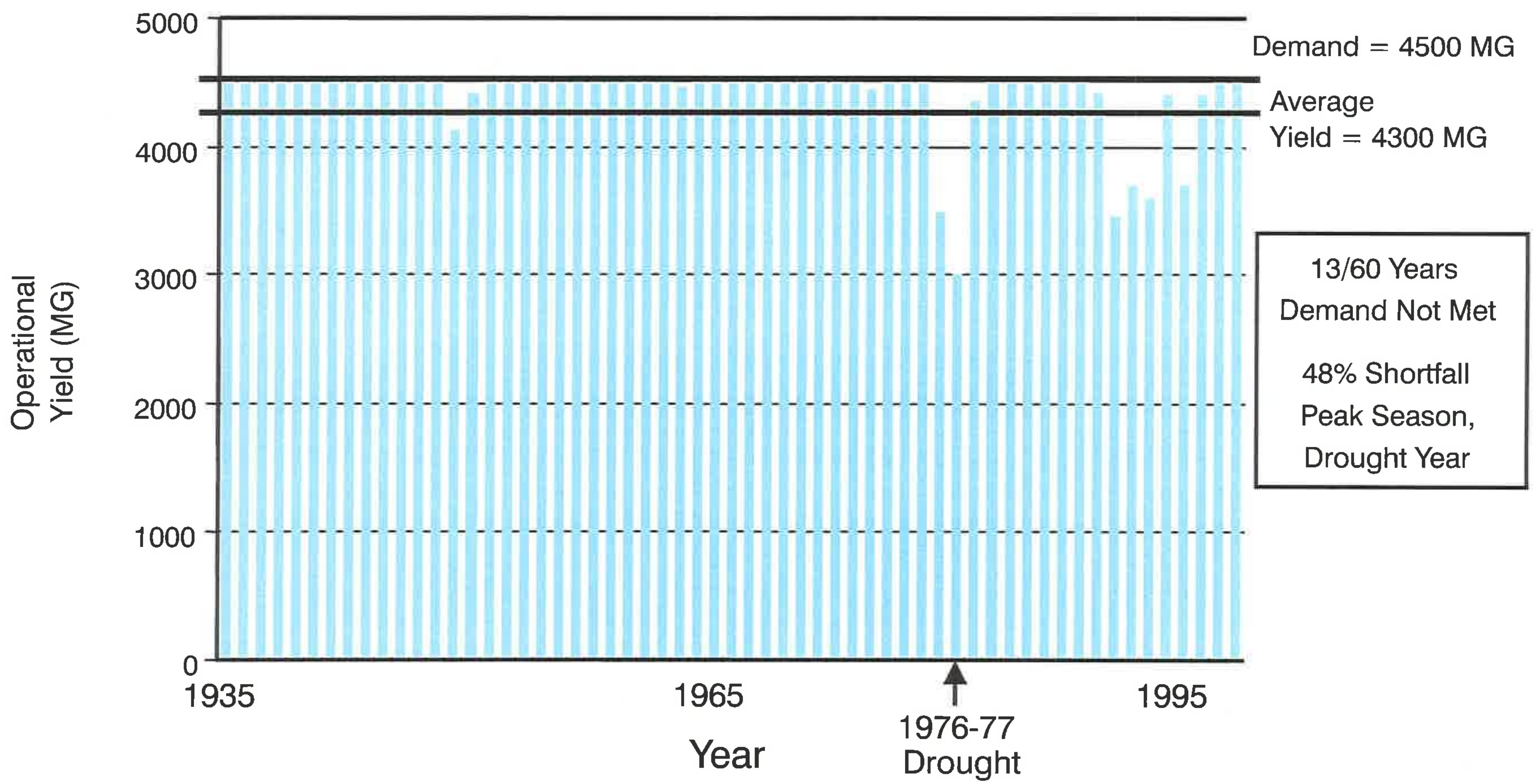
Average and Drought Year Shortfalls

The analysis showed that supply shortfalls will occur much more regularly in the future, and will not be isolated to severe drought periods only (see Appendix A for a summary description of water supply modeling results).

Figure 4.1 illustrates the range of available supply (yield) based on historical hydrologic conditions and estimated demand conditions in 2000. The figure illustrates that if historical hydrologic patterns were repeated, in most years the City will be able to meet its projected year 2000 demands. However, the City's existing water supply system could not meet the year 2000 demand in as many as 13 years out of the 60-year period. Figures 4.2 and 4.3 show similar evaluations for the 2020 and buildout demand conditions; shortages could occur in as many as 45 and 58 years of the 60-year period for the two conditions, respectively.

(Note: The frequency and magnitude of shortage will depend, in part, on the level and success of conservation and curtailment. The demand projections shown in Figures 4.1 through 4.3 are adjusted to reflect the expected benefit of naturally occurring conservation, such as will occur as the result of plumbing retrofits to meet new code requirements, landscape irrigation audits, etc. The demand projections have not been adjusted for usage curtailment that would likely occur during a drought, or for other new conservation programs that may be implemented by the City (e.g., conservation kits, rebates for low water use washing machines, etc. [see also Santa Cruz Water Conservation Plan, Fiske and Associates, February 2000]).

For drought conditions, the estimated shortfall is even more pronounced. Based on review of the available historical precipitation record from 1935 to present, the City has experienced two types of droughts in the recent past: the short duration, one or two-year critical drought (e.g., 1961, 1976 to 1977), and longer duration droughts of more moderate severity (e.g., 1987 through 1992). Of these two drought conditions, the short-term critical drought of 1976 to 1977 represents the most severe conditions, so the analysis for this study is based on the short-term drought. (Note: The 1976 to 1977 drought was identified as the critical drought during the period of record for which accurate historical precipitation and stream flow data were available. The period of record evaluated only includes approximately 60 years of data, which is a very limited data set relative to geologic time. It is a certainty that the City will face droughts of equal severity, and perhaps more severe, in the future. A relevant example is the drought which occurred in 1928 through 1931 (not



(1) Graph shows operational yield calculated based on historical hydrology from 1935-1995 for current demand conditions.

(2) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(3) Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 4.1
HISTORICAL HYDROLOGY VS 2000 DEMAND(1, 2, 3)
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY

(1) Graph shows operational yield calculated based on historical hydrology from 1935-1995 for current demand.

(2) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(3) Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 4.2
HISTORICAL HYDROLOGY VS 2000 DEMAND(1, 2, 3)
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY

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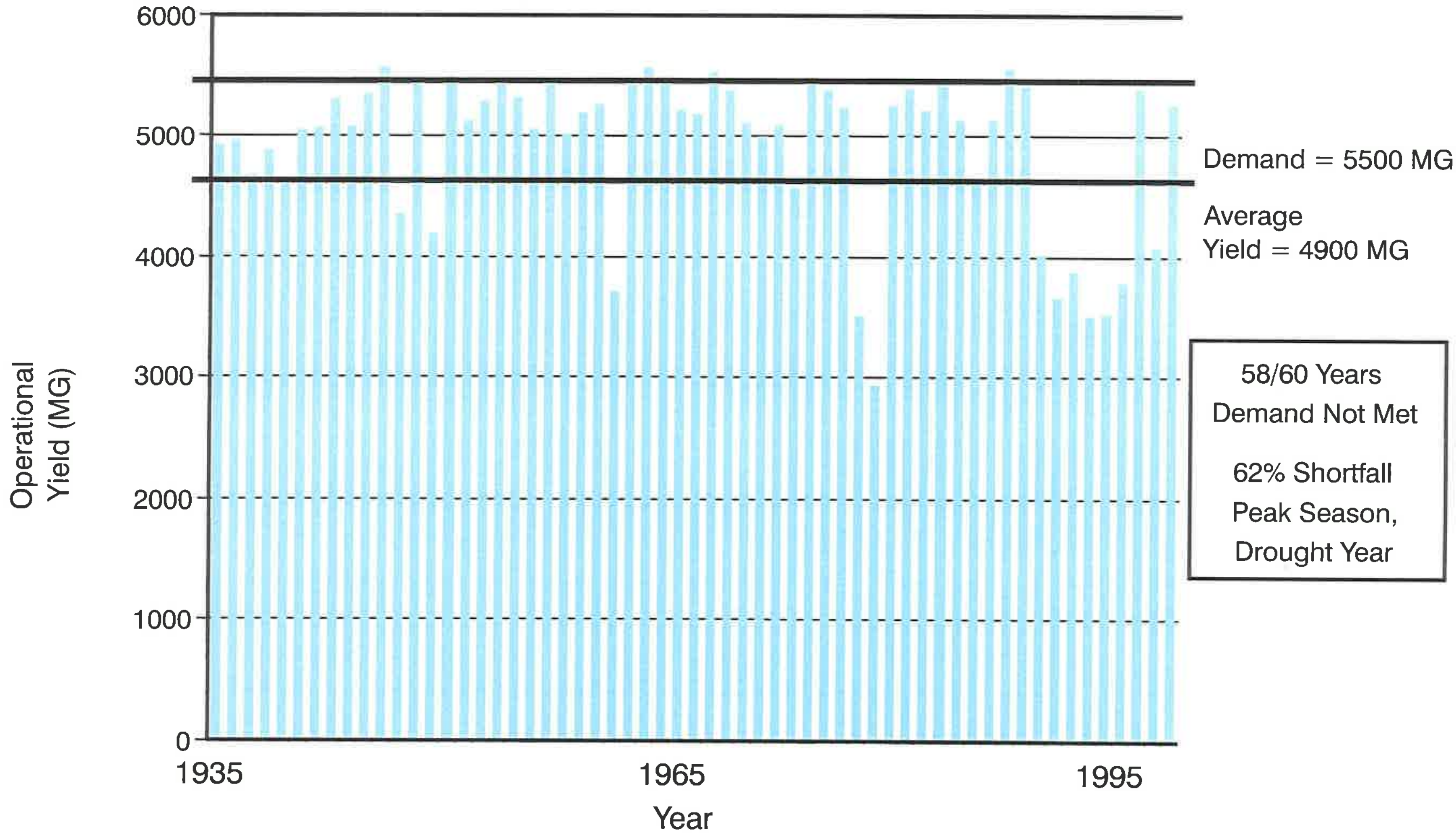


(1) Graph shows operational yield calculated based on historical hydrology from 1935-1995 for current demand.

(2) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(3) Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 4.3
HISTORICAL HYDROLOGY VS BUILDOUT [1, 2, 3]
CITY OF SANTA CRUZ ALTERNATIVE WATER SUPPLY STUDY

included in this evaluation) which, based on available data from other areas of the state, was equally severe and of longer duration than the 1976 to 1977 drought).

Monthly and Seasonal Supply

For the drought analysis, the hydrologic conditions preceding and following the drought were assumed to be the same as occurred in 1975 and 1978, respectively. Figure 4.1 illustrates that the estimated supply yield during a two-year critical drought is only about 75 percent of the cumulative year 2000 demand. However, it is important to distinguish that much of the cumulative water demand accrues in the high-demand summer months (e.g., May through October). Review of the monthly data developed for this study shows that the supply shortfalls during these months are significant.

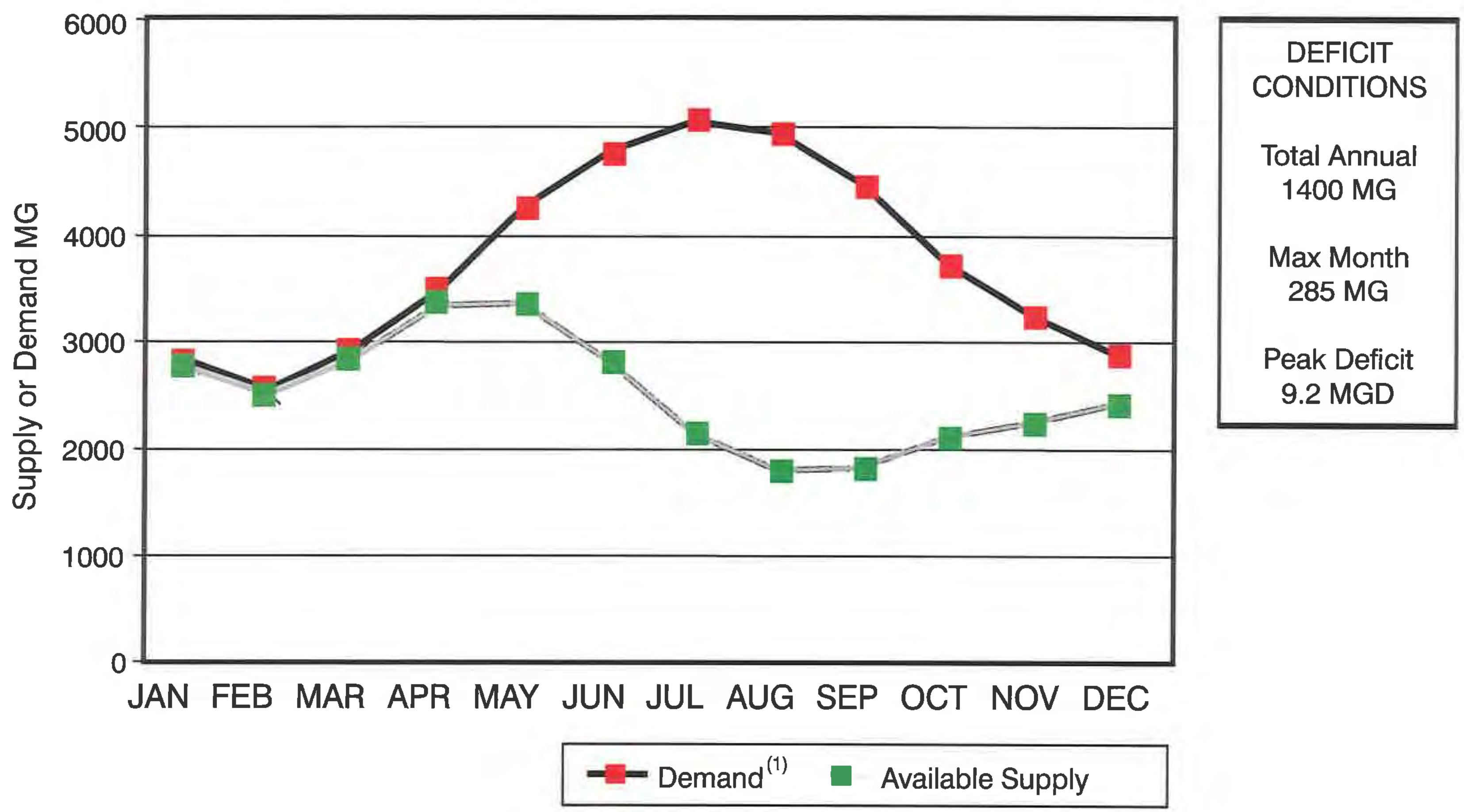
Figures 4.1 through 4.3 show that the estimated peak season shortfall during a drought could range from as much as 48 to 62 percent during the peak period for the three demand periods. This result is expected because summer demands increase significantly compared to the winter months, and as noted above, these peak season demands account for much of the total annual demand. Figures 4.4 through 4.6 illustrate the impact of seasonal peak demands for the 2000, 2020 and buildout demand conditions. Table 4.1 presents a summary of the monthly, seasonal, and total deficits for each of the three demand conditions.

Findings

The principal findings of the water supply evaluation are as follows:

- **Projected Demands Exceed the Available Supply.** The amount of supply available that can be produced from the City's sources is limited, and is strongly linked to precipitation and runoff. During drought conditions demand far exceeds available supply. Even if precipitation is average or above average, and if conservation programs are implemented and successful, it is likely that the City will begin to face regular peak season supply shortfalls as demands increase in the future.

- **Prolonged Drought Conditions are Critical.** During drought conditions there is a limited amount of "flowing" supply in the City's surface water sources. If drought conditions persist for two or more years, the effect is even more pronounced, particularly during the high-demand summer months. Lacking the capability to store large volumes of water, the City would need new sustainable water supplies.



(1) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(2) Deficit conditions are projected worst case. Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from conservation or usage curtailment.

Figure 4.4
DROUGHT CONDITIONS
VS. PROJECTED MONTHLY DEMAND 2000 [1, 2]
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY

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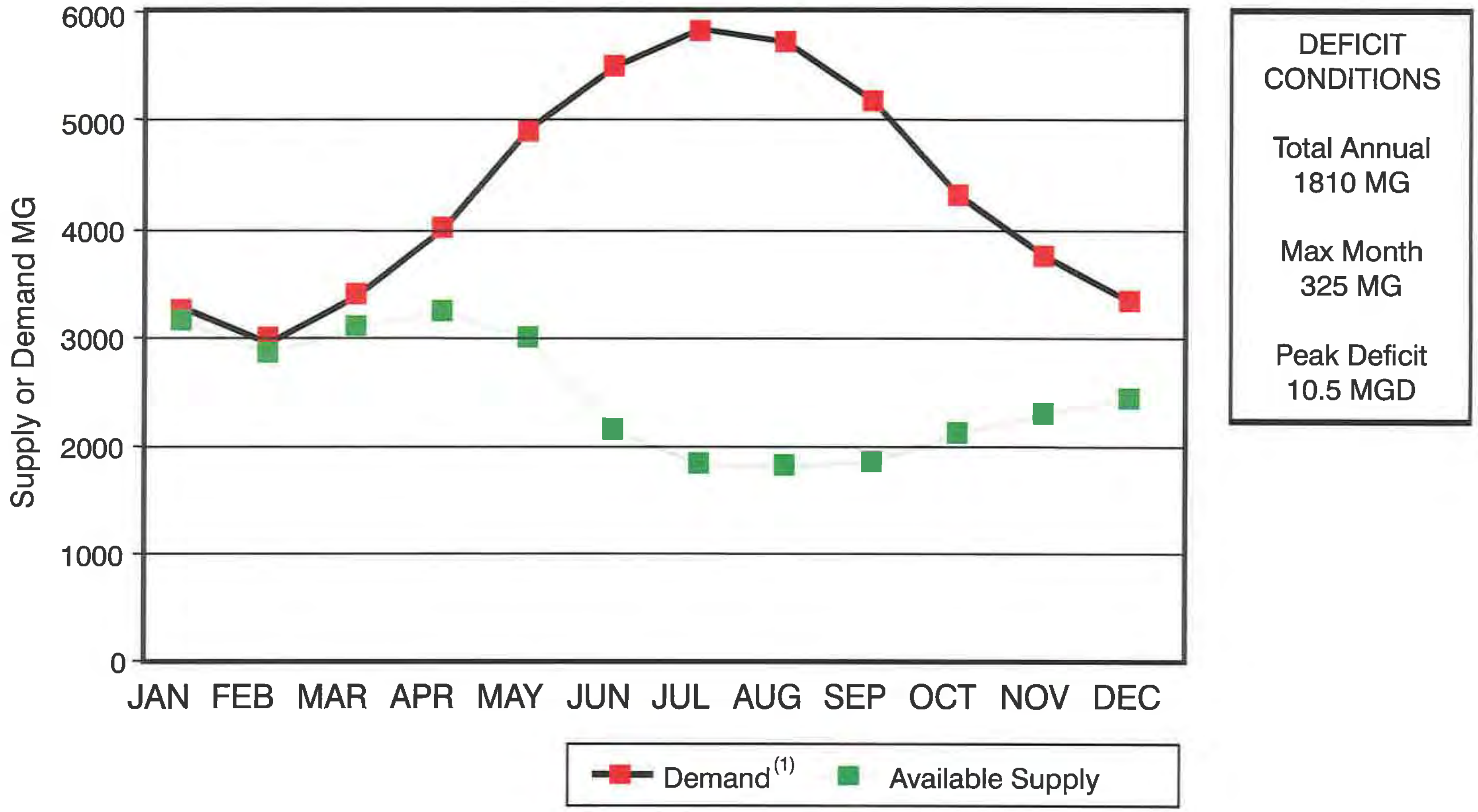

(1) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(2) Deficit conditions are projected worst case. Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 4.5
DROUGHT CONDITIONS
VS. PROJECTED MONTHLY DEMAND 2020[1, 2]
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY

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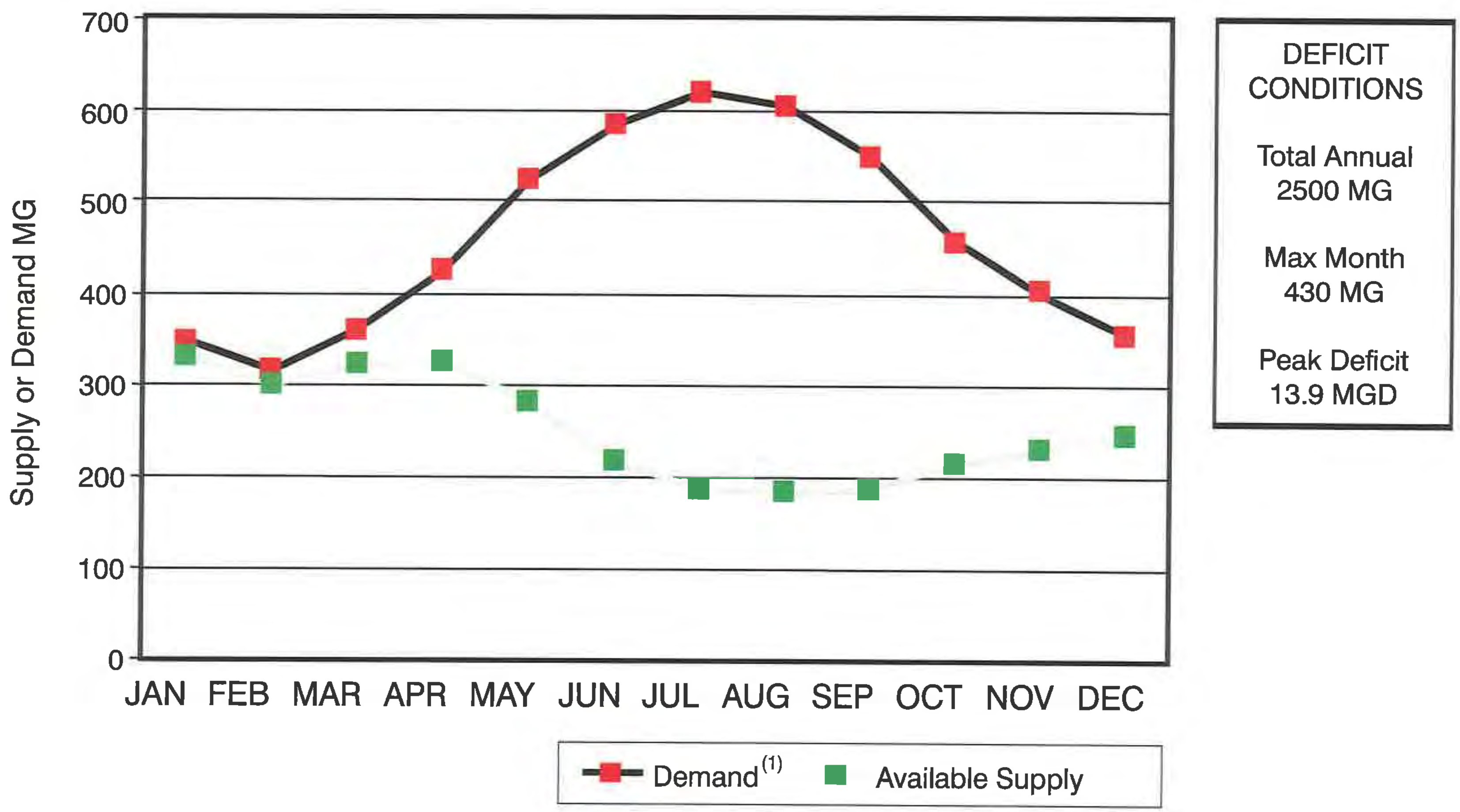

(1) Demand projection includes adjustment for naturally occurring conservation (e.g., plumbing retrofits, landscape irrigation retrofits, etc.) (ref. City of Santa Cruz Water Demand Investigation, Maddaus, 1998)

(2) Deficit conditions are projected worst case. Demand projections used to calculate deficits are not adjusted to reflect potential demand reduction from usage curtailment.

Figure 4.6
DROUGHT CONDITIONS
VS. PROJECTED MONTHLY DEMAND BUILDOUT [1, 2]
CITY OF SANTA CRUZ ALTERNATIVE
WATER SUPPLY STUDY

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**Table 4.1 Estimated Monthly and Seasonal Deficits During the Critical Drought Year[1,2]
Alternative Water Supply Study
City of Santa Cruz**

Deficit Condition	Current Demand	2020 Demand	Buildout Demand
Maximum Monthly Deficit[3]	285	395	440
Maximum Seasonal Deficit[4]	1,245	1,800	2,070
Maximum Annual Deficit	1,400	2,125	2,490
Total Drought Deficit[5]	2,605	3,970	4,760
Total Drought Duration[6]	30 months	30 months	31 months

Notes:
(1) Deficits are calculated during the second year of the critical two-year drought period unless otherwise specified. Deficits are calculated based on projected demand, with no adjustment for potential demand reduction by usage curtailment programs.
(2) All values in million gallons (MG) unless otherwise specified.
(3) Maximum month deficit occurs in July of the second drought year.
(4) Maximum seasonal deficit calculated by summing monthly deficits during May through October.
(5) Total drought deficit calculated by summing monthly deficits for the entire drought duration.
(6) Total drought duration includes months of deficit before and after the start of the calendar two-year drought period, as represented by comparison of projected demand vs. yield based on historical hydrology. For buildout, demand conditions projected drought duration increases by one month due to additional projected shortfalls in the months preceding the two-year calendar drought period.

- **Storage Capacity is Very Limited.** The City's only surface water storage reservoir, Loch Lomond, is undersized. For example, in a prolonged drought similar to the 1976 to 1977 hydrologic period, the reservoir could supply only about 5 percent of the City's current demand during the two-year drought (i.e., the reservoir would only supply approximately 475 MG of the projected 9000 MG demand during the two-year period; see Appendix A).

Conclusions

There are three ways that the City can offset the projected supply deficits:

- Implement conservation programs to reduce overall demand.
- Implement curtailment programs to reduce overall demand.
- Develop new water sources.

The City is committed to develop a water supply strategy - an Integrated Water Plan (IWP) - that will incorporate each of these three elements. Each element of the IWP is expected to contribute to the overall water supply needs. The final contribution of each element will be determined after evaluation of curtailment strategies, conservation program alternatives, and new water supplies. In developing the IWP each of the three elements will be evaluated to determine the relative advantages, disadvantages, and costs for implementation. (Note: The final IWP is to be completed as a separate effort by the City at the completion of this and an ongoing study to evaluate conservation alternatives).

Each element is important, however, from the findings of this water supply evaluation there are three primary conclusions regarding the City's future water supply needs:

- **New Water Supply Sources are Needed.** Lacking water storage capacity, new water supply sources must be developed, even if conservation and curtailment programs are implemented.

  The water supply analysis is based on projected water demands that were not adjusted to reflect the City's ongoing water conservation programs, or water usage curtailment that could be implemented in a severe drought. It is possible that the combination of conservation and curtailment strategies implemented by the City could reduce the demands and the resulting deficits. For example, the City may achieve demand reduction in the range of 15 to 25 percent during drought, similar to several California utilities with well-established conservation/curtailment programs. However, *even if these or more rigorous conservation and usage curtailment targets are achieved, the City will still face significant seasonal deficits during a drought, both now and in the future.*

- **Sustained Production is Needed for a Prolonged Drought.** Historical records show that the City has faced droughts ranging from two to five years over the last 60 years. Prolonged droughts of similar duration in the future are inevitable.

  To be viable, sources of supply must be able to produce over one or more years of drought, and they must produce during the summer months. Demand for water increases in the summer, and it is during the summer months of a prolonged drought that "flowing" supplies are even more diminished.

- **Additional Storage is Needed.** The lack of "flowing" supply in the surface water sources during drought dictates that the supply sources must have a storage component. Storage will enable demands be met in the absence of a reliable "flowing" surface supply.

WATER SUPPLY ALTERNATIVES

The City has previously conducted two water supply evaluations, each focusing on how the City could meet its demands during the most severe drought conditions. The Master Plan (1989) identified potential alternatives for further study based on the critical drought period which occurred in 1976 to 1977. The Alternatives Study (1994) investigated numerous water supply alternatives to meet the City's needs based on the critical 1976 to 1977 drought and the longer 1987 through 1991 drought conditions. The alternatives studied in the 1994 study included brackish and fresh groundwater and new surface water supply reservoirs.

Based on findings of the Alternatives Study (1994), in May 1995 the City began preliminary engineering studies to investigate the recommended most feasible alternative, a new water supply from brackish groundwater wells located along the coast north of the City. In May 1997 the City Council determined the coastal brackish well project was not viable and elected to discontinue the preliminary engineering studies.

Current Study

For this study, six potential water supply alternatives were originally identified for evaluation:

- Brackish groundwater supply from wells in the San Lorenzo River Alluvial Plain near the mouth of the river.
- Fresh groundwater supply from wells in the San Lorenzo Alluvial Plain.
- Maximized use of existing sources and storage in Loch Lomond Reservoir. This alternative includes increased capture and/or storage of surface water from existing north coast and San Lorenzo River supplies, in conjunction with optimized use of existing diversions.
- Groundwater supply near the Wilder Ranch gravel quarry.
- Sea water desalination.
- Conjunctive use with Soquel Creek Water District.

During the course of work four other project alternatives have been identified as potentially viable:

- Groundwater supply from the Purisima Aquifer near the Beltz wells.
- Groundwater supply from the Santa Margarita Aquifer.
- Wastewater reclamation.

- Reservoir storage in the Olympia Quarry.

At the outset of this study a primary goal was to identify multiple alternative supply sources that could used to supplement the City's existing system. This goal was established because it is inherently advantageous to develop a water supply system that has multiple sources (i.e., multiple supply "building blocks"). This is particularly true where drought conditions can significantly impact the reliability of one or more sources. To be reliable, a source must be capable of meeting at least some demand as the drought progresses, and in particular during the second (or subsequent) years. Bearing this in mind, the potential supply alternatives were evaluated (screened) with respect to three criteria:

- Amount of supply available.
- Expected reliability/sustainability during a drought.
- Ease of implementation.

Each of the alternatives is briefly summarized below. Also included are constraints and/or "fatal flaws" to the alternatives that have been identified during preliminary evaluation.

Some of the alternatives are not recommended for further study because they are not considered to be viable due to technical and/or other factors. Likewise, some alternatives are not recommended for further consideration at this time because they do not provide reliable supply over the projected two-year duration of the drought. For example, if a source is capable of reliable supply over the first but not the second drought year, its benefit as a supply "building block" is significantly diminished compared to other alternatives that can provide supply in the second drought year, when projected shortfalls are most critical. Alternatives that can serve as reliable building blocks are preferred, and should be prioritized for further study.

Groundwater Supply Alternatives

Previous water supply studies have concluded that the local coastal aquifers cannot provide a reliable supply of groundwater to meet the total projected shortfalls. However, as part of this study four local aquifer areas were identified as having the potential to supply some of the projected shortfall, either alone or in combination. The four local aquifer areas studied are:

- Santa Margarita Aquifer near Wilder Ranch.
- San Lorenzo Alluvial Aquifer near the Mouth of the San Lorenzo River.
- Santa Margarita Aquifer near Downtown/Eastside Santa Cruz.
- Purisima Aquifer near the Beltz Well Field.

These alternatives were evaluated to determine the potential for significant yield based on a review of available published geologic and hydrogeologic information (Carollo/Fugro West, Inc. 1999). A summary of the evaluation findings for the four groundwater sources is presented in Appendix B.

Available Groundwater Supply

Yield. The annual or safe yield of an aquifer is defined as the amount of water that can be supplied from the source in a year. As determined by classical hydrogeologic methods, the yield is estimated with consideration of the soil characteristics in the water bearing strata (e.g., sand or clay), the size of the water bearing strata, amount of recharge to the strata, etc.

Considering these elements, each of the four groundwater alternatives were evaluated to determine the potential for significant yield. The evaluation was based on a review of available published geologic and hydrogeologic information; no field work was conducted to supplement this evaluation. In general, our evaluation confirms the findings of several previous investigations, and we conclude that the local coastal aquifers do hold limited amounts of groundwater.

Based on interpretation of existing data and engineering judgement, the estimated <u>maximum</u> groundwater supply potential from all sources combined is approximately 850 MG/yr. It is important to distinguish, however, that the amount actually available for supply on a reliable basis (i.e., during drought conditions) is expected to be significantly less, in the range of 0 to 300 MG/yr.

Limiting Conditions. A groundwater source may be demonstrated capable of a specific yield, but may not be a viable domestic water supply source for other reasons. For example, the aquifer may not be large enough to provide significant storage/supply capacity to sustain prolonged use, or geologic conditions within the aquifer may limit the rate/capacity of natural recharge such that groundwater supply during drought is reduced. Even if a source is determined to be of suitable capacity and reliability there may be other technical factors (e.g., degradation of ground water quality over time due to prolonged pumping) or institutional factors (e.g., other competing interests) that may effectively limit its availability.

Considering the estimated maximum yield from the four groundwater sources alone it appears that the sources could provide considerable additional supply. However, closer examination of the potential limiting conditions during drought indicates that this is not the case. Although the sources can be expected to produce some additional supply during the first year of the drought, the reliability and sustainability of the sources during the second (or subsequent) drought years is questionable. As noted above, the reliable supply from all sources combined during a prolonged drought may range from 0 to 300 MG/yr.

The conditions which limit the supply during drought are as follows:

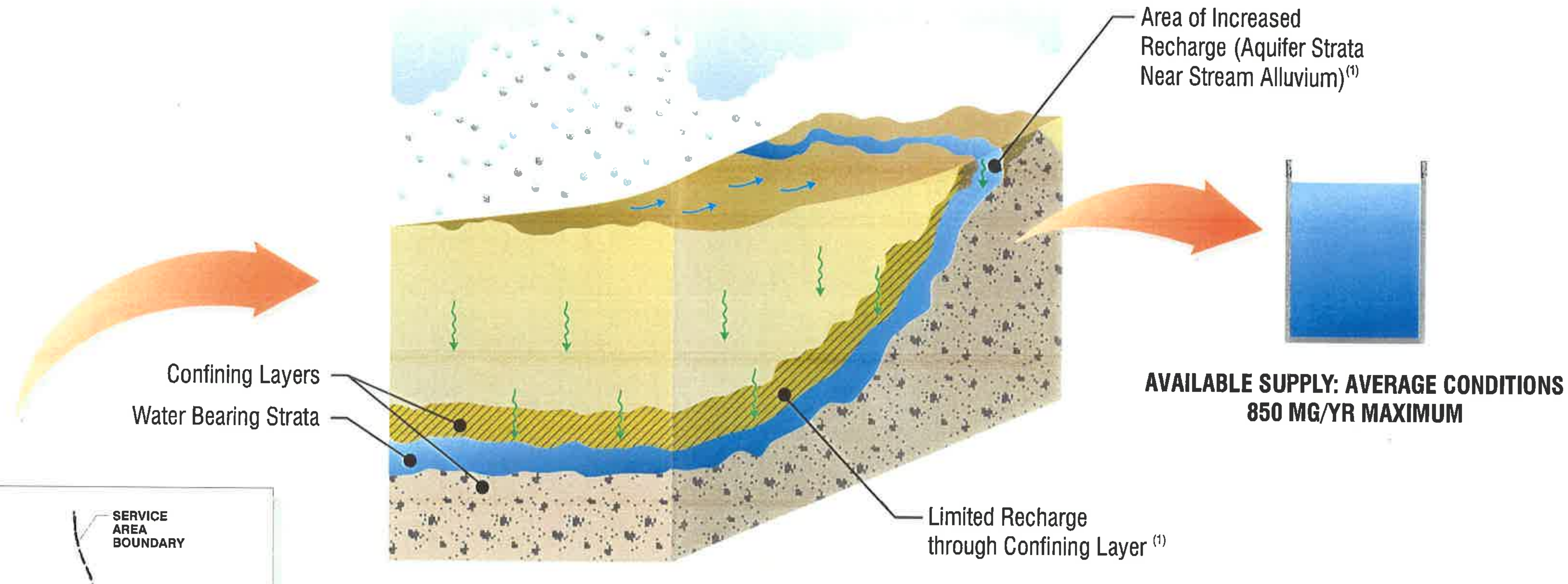
- **Limited Natural Recharge During Drought.** In severe drought conditions there is very little precipitation, and therefore very little water available for natural recharge of the aquifers by infiltration. This is of particular concern for the aquifers evaluated in this study because, typical of many coastal aquifers, they do not have large storage capacity, so regular recharge would be required to sustain the supply during prolonged droughts. Moreover, the aquifers evaluated in this study are "confined" — the water bearing strata lies between layers of nonwater bearing strata of limited or low permeability — so the rate/capacity of recharge is comparatively low; recharge for aquifers of this type occurs slowly over periods of regular precipitation and infiltration which are not typical of a drought. Figure 4.7 illustrates this concept.

- **Competing Interests.** The two biggest aquifers evaluated for this study, the Santa Margarita aquifer near Wilder Ranch and the Purisima aquifer, have existing users. The competing interests for the supply is of particular concern, particularly during the summer months of a drought when supply would be needed most by the existing users. The available (reliable) yield during a prolonged drought is also uncertain because the yield from the aquifers will likely decrease as other users increase their reliance on this supply. Because of these competing interests there may be no appreciable supply that could be delivered to the City in a drought.

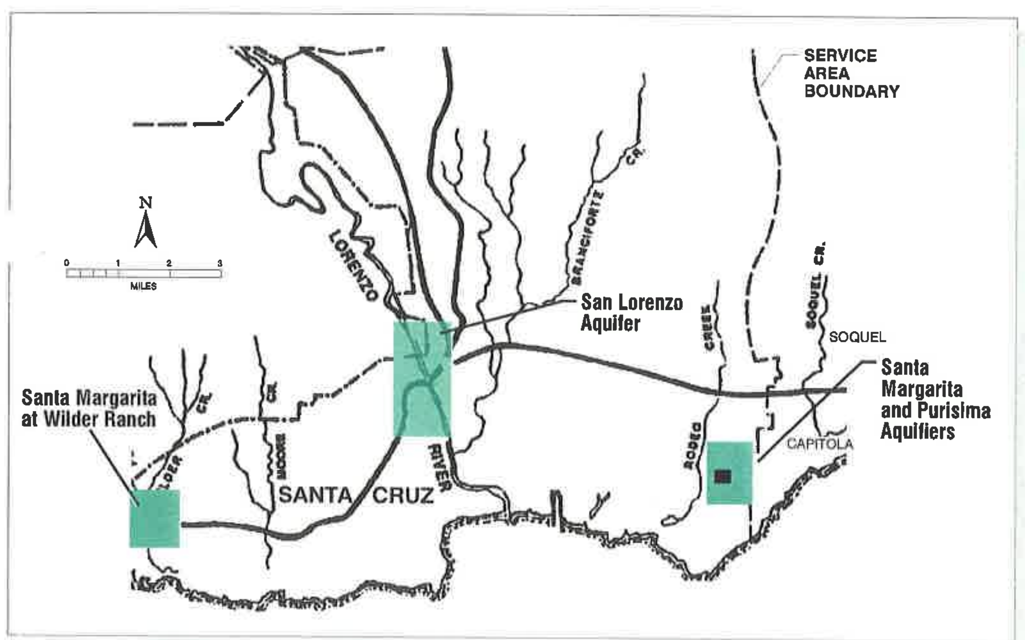
Artificial recharge of the groundwater sources — to improve reliability/sustainability during the drought — was considered but is not viable for the following reasons:

- **No Surplus Surface Water Supply for Recharge.** Review of historical hydrologic data indicates that it is reasonable to expect some precipitation in the winter months, even in a prolonged drought. However, based our evaluation of the estimated production from the City's existing sources during drought there is no "surplus" supply that could be used for recharge of groundwater sources. This is particularly true in the future as more of the available surface water will be used to offset the increased demand.

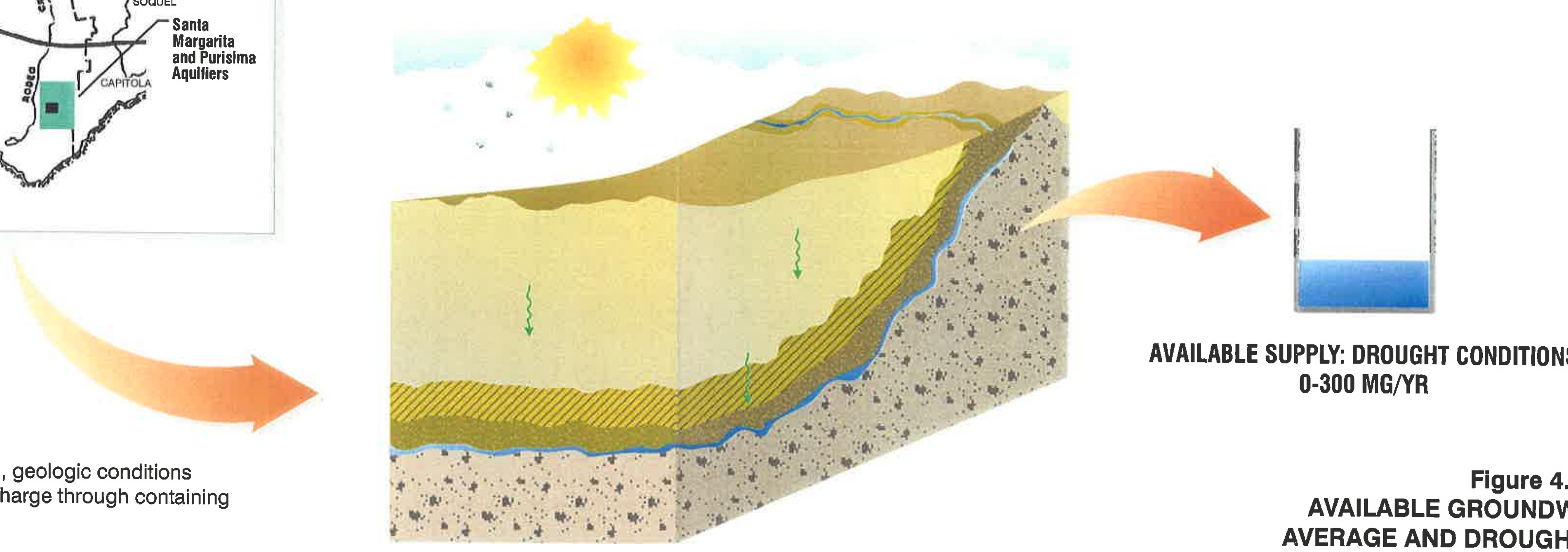
- **Water Rights Constraint.** Even if surface water is available the City's water rights have limiting conditions that do not allow the use of the existing surface sources for groundwater recharge. To use the water for groundwater recharge would require a



RECHARGE IN AVERAGE CONDITIONS



Possible Groundwater Sources for Santa Cruz



RECHARGE IN DROUGHT CONDITIONS

Notes:
1) Available supply depends on seasonal precipitation, geologic conditions (e.g., high recharge in stream alluvium, reduced recharge through containing layers, etc), and localized pumping.

Figure 4.7
AVAILABLE GROUNDWATER SUPPLY: AVERAGE AND DROUGHT CONDITIONS (1)
CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY PROJECT

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change of the existing water rights (change from diversion for direct use to diversion for storage). A water right change of this type is not viable, and effectively precludes all conjunctive use alternatives with surface water and groundwater.

- **Groundwater Recharge with Reclaimed Wastewater is Not Viable.** Groundwater recharge with reclaimed wastewater is practiced by several water utilities in California. However, for the City's particular application there are numerous issues that could effectively limit its viability:

  - **Limited Additional Supply.** Current state guidelines for use of reclaimed wastewater for groundwater recharge stipulate that no more than 50 percent of the water extracted from a wastewater recharge project be reclaimed wastewater (ref. personal communication with B. Hultquist, member DHS Groundwater Reclamation Advisory Committee, and Title 22 CCR, Division 4, Chapter 3 - Environmental Health, Draft Criteria for Groundwater Recharge with Reclaimed Wastewater, 1994).

    As noted above, during prolonged drought conditions there will be limited natural recharge to the aquifers that would be available to blend with reclaimed wastewater. The amount of groundwater available for blending would range between 0 MG/yr (worst case) and 300 MG/yr (best case with all four sources). The amount of groundwater actually available for blending would likely be 100 MG/yr or less. This is because the two groundwater sources with the most potential for significant natural recharge during a drought, the Santa Margarita aquifer near Wilder Ranch and the Purisima aquifer, both have existing users. Implementation of a reclaimed wastewater recharge project into basins with existing users is difficult, and may not be feasible due to potential impacts on existing users (see also discussion under Implementation Issues below).

    Even in a favorable scenario with 100 MG/yr available for blending with reclaimed wastewater, the total volume of ground water available for drought supply is low, on the order 200 MG.

  - **Supply Availability During Peak Season is Questionable.** Current state guidelines for groundwater recharge also require that reclaimed water for potable reuse must remain in the ground for a minimum of 6 months, and up to 12 months depending on the level of treatment and the method of recharge surface spreading or direct injection.

    Based on conceptual evaluation of recharge options, surface spreading is not considered feasible due to geologic constraints in the four source aquifers. Accordingly, recharge would need to be accomplished via direct injection. For direct injection the minimum detention time requirement is 12 months. This is a significant consideration because it effectively limits how/when the recharged groundwater could be used. In the assumed two-year drought scenario the groundwater supply would likely not be available during the peak season shortfall of the second drought year. Figure 4.8 illustrates the constraint on use:

* During the first drought year the available groundwater supply would be utilized in the summer to meet peak demands.

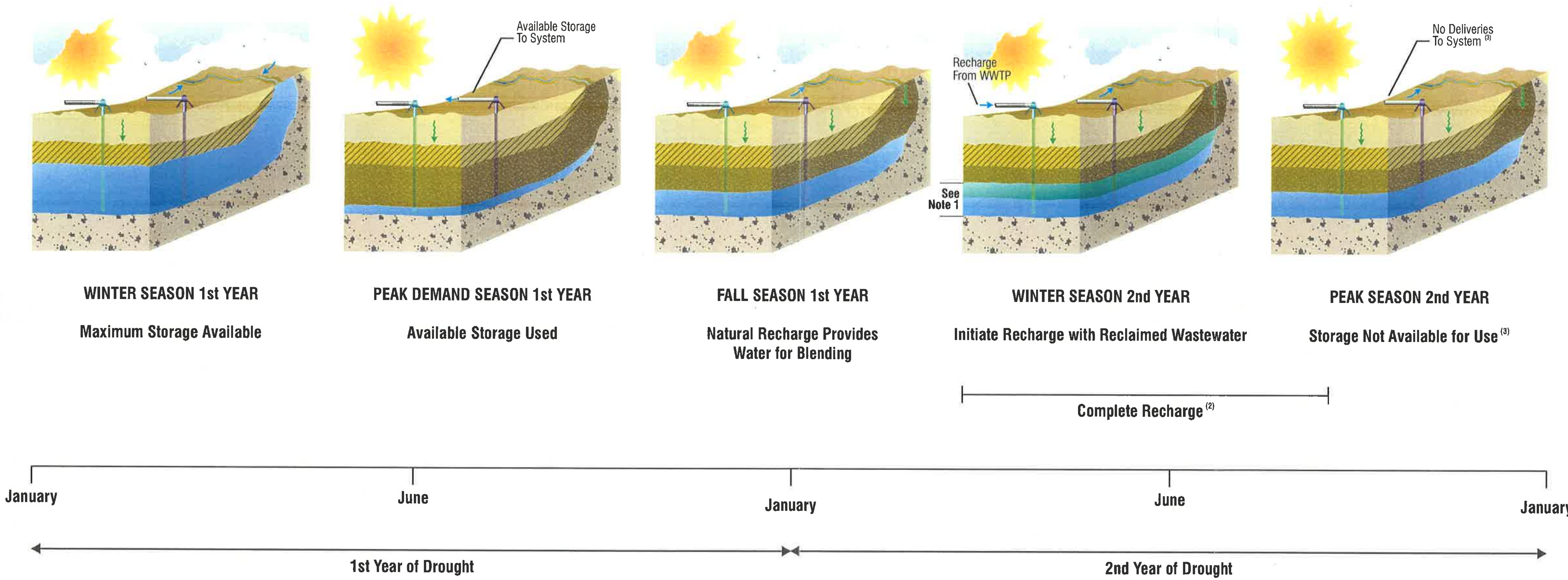
* During fall/early winter of the first drought year the aquifer recharges and water would be available for blending (Note: the example assumes that some precipitation in the fall would occur and provide modest recharge, but this may not occur during a severe drought).

* During the winter months of the second drought year the aquifer would be artificially recharged with reclaimed wastewater. As shown in the figure, the recharge process could take 6 to 8 months to complete, so the recharge operation would end at the beginning of the summer season at the earliest.

* After completion of recharge the groundwater must remain for 12 months before it is extracted. With this time requirement, the groundwater would not be available for use in the second drought year, when it is needed most.

- **Implementation Issues.** Although simple in concept there are many issues that must be addressed to take a waste water reclamation project from concept to viable water supply. The two most likely implementation issues for the City are cost and political/public acceptance.

Current state guidelines require that reclaimed water to be used for ground water recharge must meet all drinking water standards. To meet this criterion the wastewater must receive filtration treatment and organic chemical removal by reverse osmosis membranes (ref. personal communication with B. Hultquist, member DHS Groundwater Reclamation Advisory Committee). The City's existing wastewater treatment facility currently does not provide either filtration or reverse osmosis treatment, so new facilities would need to be constructed to provide the additional



LEGEND

- Recharge Well
- Supply Well
- Reclaimed Wastewater
- Groundwater

Notes:
1) Reclaimed wastewater is injected and blended with groundwater to achieve a maximum 50/50 blend in the aquifer.
2) Time estimated to complete recharge with reclaimed wastewater is 6-8 months.
3) Water extracted from the supply well must be shown to have detention time of 12 months prior to extraction.

Figure 4.8
RECHARGE WITH RECLAIMED WASTEWATER OPERATIONAL SCENARIO DURING DROUGHT
CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY PROJECT

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treatment. In addition, a new, separate distribution system would need to be installed to deliver the water to the recharge sites, and new wells would need to be constructed for both injection and extraction of the reclaimed water (different wells must be used for injection and extraction). New infrastructure of this type is very costly and will result in a relatively high unit cost for the water (i.e., $/MG of new supply). Although cost is not necessarily a fatal flaw, it is an important consideration for supply alternatives that are considered to have relatively low reliability and low volume of additional supply.

Even if the costs for recharge with reclaimed wastewater compare favorably to other alternatives, these projects can be difficult to implement. State regulatory officials at the Department of Health Services and the Water Resources Control Board are currently reevaluating the existing guidelines for recharge to determine whether additional treatment and/or other criteria are needed to ensure protection of public health and the groundwater quality. If additional treatment requirements are established there will be additional costs for implementation.

Perhaps most significant, public opposition is common even with high levels of treatment prior to recharge. For example, the implementation of two recent wastewater reclamation projects in the state was postponed indefinitely due to public concerns, *after the technical merits of the projects had been reviewed and approved by regulatory agencies*. The impact of public acceptance is very important for the City because two of the potential groundwater source alternatives considered for recharge, the Santa Margarita aquifer near Wilder Ranch and the Purisima, currently have existing users. It is uncertain whether a viable project concept could be developed with these users. This is particularly so for the Soquel Creek Water District due to potential impacts to their supply source, the Purisima aquifer, because it is their sole source of supply.

When combined we believe these implementation issues present too many uncertainties for groundwater recharge with reclaimed wastewater to be viable, particularly for the relatively small amount of additional reliable supply that would be provided. We do believe, however, that wastewater reclamation for irrigation supply may have merit (see Wastewater Reclamation below).

Conclusion. Our findings are similar to previous groundwater evaluations of the area. Groundwater is potentially available but in limited quantity. None of the groundwater sources evaluated can provide a significant portion of the projected shortfall during a drought, and it is not likely that all four alternatives could be implemented (see also discussion in Appendix B). Most importantly, none of the sources are considered reliable or sustainable during prolonged usage in a drought. This is particularly significant because lacking reliability of groundwater supply, the City would still need to provide other additional sources to provide supply in the second (or subsequent) year of a drought.

We believe the combination of constraints significantly limits the viability of groundwater as a drought supply alternative for the City. We do not recommend that this alternative be pursued further for drought supply.

It is possible that groundwater could be used as a nondrought year supply "building block." However, it is important to note that within Santa Cruz County and elsewhere along the coast there are several examples to illustrate that coastal groundwater supplies provide marginal long-term reliability. If the City was faced with no other options there would be increased benefit of developing groundwater for nondrought supply. The City does have other options, particularly since a new drought supply alternative must be implemented. The new supply can serve both drought and nondrought years, so there appears to be little need or benefit for developing additional groundwater supply.

Surface Water Supply Alternatives

Maximize the Use of Existing Sources and Storage in Loch Lomond Reservoir

The emphasis of this alternative is to optimize the use of existing surface sources, including increased capture and/or storage of surface water from existing north coast and San Lorenzo River supplies, alone or in conjunction with optimized seasonal use of existing diversions.

The amount of additional yield that can be developed from optimized use of the existing sources is a strong function of the City's ability to use and/or store surface water when it is most plentiful -- in the fall and winter months when rainfall and runoff is highest. Although seemingly simple in concept, there are two limiting constraints that make it difficult to use and/or store the water:

- **Reduced Demand.** System demand in the fall, winter, and early spring months is relatively low. Because system demand is low there is limited potential to significantly increase the yield from the sources by simply diverting "excess" flows and using the water to help meet system demand.

- **Limited Storage.** If the water is not used to meet system demands, it must be stored for later use. Currently, the City's only option for storage is Loch Lomond Reservoir.

Based on our evaluation using simulated rainfall and runoff conditions typical of the fall and winter months, we have determined that in most years there is sufficient inflow to fill the reservoir. Thus, there is no benefit to divert "excess" flows to storage in most years because the storage gain in the reservoir would be temporary, only to be lost as spill later in the season.

In addition to these two constraints, water quality during the winter months is sometimes poor (i.e., high turbidity), particularly immediately after rainfall when runoff is high. The high turbidity makes the water more difficult to treat, and also impacts the operation of system facilities such as the Coast pumps. Due to the poor water quality much of the available "excess" supply during high runoff is not diverted.

It is also important to note that even if high flows are available for diversion and of suitable quality, there are hydraulic constraints in the existing infrastructure that limit the amount of water that can be currently be diverted from the sources. For example, the delivery capacity of the Coast pipeline is currently limited by the available gravity head from the sources. This gravity flow capacity is often less than the amount flowing in the North Coast sources that could otherwise be diverted. Options to mitigate the capacity and treatability constraints are discussed in the following section.

Options to Maximize Use of Winter Flows. During the high-runoff events when water quality is poor the City must often use water from Loch Lomond for supply. The reservoir water is generally much easier to treat during these periods because the quality is not subject to rapid changes like the stream sources (i.e., high turbidity due to silt in the runoff). Although easier to treat, use of the reservoir supply early in the year can create a supply constraint later in the summer when it is needed most. This is because the City has a maximum withdrawal limit from the reservoir in each calendar year under its water right, so it is not always beneficial to draw against the maximum limit early in the year. As demands increase in the future it will be even more important to preserve storage in Loch Lomond so that more of the supply is available to help offset summer demands, when available supply from the "free flowing" streams is decreased.

To determine how the existing stream sources could be optimized — thereby maximizing the storage and usage allocation in Loch Lomond — the following scenarios were modeled:

- No. 1 - Turbidity Restrictions on North Coast Supply Lifted.
- No. 2 - Flow Restrictions on North Coast Supply Lifted.
- No. 3 - Flow and Turbidity Restrictions on Tait Street Supply Lifted.
- No. 4 - New Pipe between Felton and Loch Lomond.

- No. 5 - Felton Turbidity Lifted.

Each upgrade scenario was modeled as a single element (i.e., No. 1 alone, No. 2 alone, etc.), and also in the full matrix of combinations (i.e., No. 1 and No. 2; No. 1, No. 2, and No. 3, etc.) to determine the range of expected supply increase. Observations from the model runs are as follows:

- **Drought Years.** Under drought conditions none of the five scenarios alone are expected to significantly increase yield. Each scenario is projected to provide 150 MG/yr or less; however, if all the scenarios were implemented together the combined additional supply would be approximately 600 MG/yr on average during a two-year drought.

  Much of the potential additional supply results from the diversion of high turbidity flows from the surface sources. The historical hydrologic record indicates that even in droughts there is limited rainfall. But due to the sporadic, flashy nature of the rainfall the resulting runoff is of poor (e.g., new pretreatment for coastal streams, hydraulic upgrades, etc.) quality and not used for supply. With the modifications to the existing system it would be possible to divert from the sources during the flashy runoff periods in the winter months of a drought, thereby reserving storage in Loch Lomond.

  Other observations from the model runs are:

  - Approximately 55 percent of the projected additional supply from all scenarios combined is from modifications for Scenario Nos. 1 through 3.
  - The ability to direct divert at Felton, as modeled by addition of a second pipe between Felton and Loch Lomond, could provide substantial benefit, increasing the available supply by as much as 200 MG/yr on average.
  - Having the ability to divert water at Felton during high turbidity events could also be of substantial benefit, increasing the available supply by as much as 200 to 250 MG/yr.

  It is important to note that although the model scenarios indicate additional supply is potentially available, the City will still face significant shortfalls in the summer months of a prolonged drought. Perhaps most important, none of the possible scenarios for optimized use of the existing sources will be of much benefit during the high-demand months of the second year of a critical two-year drought, such as the drought of 1976 to 1977. For example, with modifications for scenarios Nos. 1 through 4 in place, the projected maximum-month deficit in the second year of the drought would only be reduced by about 50 MG, so the City would still face a shortfall during the maximum month of approximately 370 MG for the buildout demand conditions. This example is significant because it demonstrates that even with upgrades to the existing supply system, the City will still need a strategy — combining new supply with conservation and curtailment — to help offset demands.

- **Average Precipitation Years.** Under average (normal) rainfall conditions none of the five scenarios are expected to significantly increase yield. Each scenario is projected to provide 70 MG/yr or less of additional supply. This result is expected because in most years the limitation is not total supply volume available, but rather the lack of storage capacity to maximize the use of winter flows for later use in the higher demand summer months when the "flowing" supplies are reduced.

  If all the scenarios were implemented together the combined additional supply would be approximately 200 MG/yr, on average. Although the gain of supply is less than 5 percent of the projected demand, these upgrades would improve the reliability and flexibility of the system (i.e., ability to divert and treat from all sources without capacity or water quality constraints), which is a significant operational benefit.

Conclusions. The significant findings and conclusions regarding maximized use to the existing supplies are as follows:

- Modification of the City's water supply infrastructure can increase the overall supply in both average and drought years. The improvements that would provide the most significant benefit are hydraulic capacity upgrades on the North Coast supply, and pretreatment facilities to allow diversion and use of higher turbidity water from the North Coast, Felton, and Tait Street supplies.
- Even with all of the hydraulic and pretreatment upgrades, the City will face a significant maximum-month shortfall during the second year of a critical two-year drought ranging from approximately 360 to 400 MG.

We recommend that this alternative be considered further for three reasons:

- The potential supply available during a drought is sufficient to help offset some of the projected shortfall.
- The infrastructure improvements would provide water supply "building blocks" and would improve the overall system operation and reliability in both non-drought and drought years.
- Based on our preliminary analysis of water rights and other factors related to implementation there are no apparent limiting constraints or "fatal flaws" associated

with this alternative. Additional work is needed to identify potential environmental mitigation measures that will be required as part of construction of new infrastructure facilities.

The conceptual infrastructure improvements associated with increasing the usage of the existing supplies include:

- **Upgrades to the North Coastal Diversion.** Upgrades may include a diversion structure or pump station at Majors Creek (to provide increased capacity from the diversion, which is currently limited due to hydraulic constraints under gravity flow), and/or modifications to diversion structures at Laguna or Lidell to increase diversion capacity.

- **Upgrades to the Coast Pipeline System.** The pipeline is not sized to maximize the diversion capacity of the coastal sources. Much of the pipeline system from the diversion structures and Coast pipeline is over fifty years old and in poor repair. In addition, several reaches of pipelines from the diversion structure are exposed and vulnerable to landslides, thereby impacting reliability of this system.

- **Upgrades to the Coast Pump Station and Tait Well.** The wells and pump station are also old and in poor repair and in need of upgrades to increase operating efficiency and capacity. Currently the total supply from the North Coast and Tait Street Diversions is limited by the Coast Pump Station and discharge pipeline capacity.

- **Variable Speed Drives at the Felton Diversion and Booster Pump and Tait Street Pump Stations.** Variable speed drives at these pump stations would allow operators to optimize the diversion to match system demand conditions and also increase capture during low-flow conditions in the river.

- **New Treatment Facilities.** If additional water from the surface sources is to be captured and used, new treatment facilities may be required to maximize the use of high-turbidity sources during the winter. Treatment upgrades could be implemented at the Coast Pump Station or at an alternative location (to be determined). The new treatment facilities would primarily be focused on sedimentation/clarification of the surface supplies to protect pumps and/or to improve treatability.

Desalination

Desalination of sea water or brackish groundwater to produce potable water has always been a feasible but costly alternative. The installation of reverse osmosis facilities in the coastal communities of Pacifica and Santa Barbara and planned installation in Cambria underscores that desalination facilities can be implemented with due consideration of technical, institutional, and environmental issues. Additional work will be needed to identify potential environmental mitigation measures that would be required as part of construction of new infrastructure facilities.

The conceptual improvements associated with a desalination treatment facility would include:

- **New Intake.** A new intake system, either a direct ocean intake or well-type system would be required. For example, brackish wells located at the mouth of the San Lorenzo River could supply some (or all) of the needed capacity.

- **New Pipelines.** The City has two existing ocean outfalls: an abandoned outfall that is approximately 3,500 feet long and an new outfall that is approximately 8,000 feet long. It is possible that a desalination project could include retrofit and use of the abandoned outfall as the intake for the desalination plant, and use of the existing wastewater outfall as the discharge for the brine. This approach reduced the disruptive work in the ocean. Pipelines would also be required to connect the abandoned wastewater ocean outfall with the desalination plant, to connect the brine reject discharge with the existing ocean outfall, and to connect the plant with the City's potable water distribution system.

- **Power Supply.** The new treatment plant would likely require a new electrical supply to provide high-voltage power for the reverse osmosis system.

- **New Treatment Facilities.** Treatment facilities would include solids removal if a direct ocean intake is used (e.g., granular media or membrane filtration) as well as the reverse osmosis treatment system.

As discussed above, neither the groundwater or optimized use of existing sources can meet the supply shortfalls. Given the City's need to develop a reliable and sustainable supply source of high capacity we believe that desalination represents the most viable of the City's alternatives. Although desalination will clearly be a relatively high cost alternative due to the necessary infrastructure and operating costs, based on our preliminary analysis there are no apparent limiting technical constraints or "fatal flaws" associated with this alternative.

We recommend that this alternative be pursued further by the City.

Wastewater Reclamation

The City's wastewater treatment plant produces water that is suitable for some agricultural applications (indirect irrigation of nontable crops), and for limited public access irrigation. The level of treatment currently provided is not sufficient for the water to be suitable for general irrigation use on playgrounds, parks, school yards, etc.

Under this supply concept, reclaimed water would be used only for irrigation to reduce the demand on the potable supply system. The use of the supply would occur primarily during the high-demand summer months because there is limited irrigation demand in the fall and winter months. Potential users of the reclaimed supply include parks, school yards, cemeteries, golf courses and other large irrigation customers such as UCSC. As discussed earlier in this document, groundwater recharge with reclaimed wastewater is not considered to be viable. Likewise, reclamation for direct potable use is not considered viable at this time. Although reclamation for potable consumption is technically feasible, there are numerous regulatory and public acceptance issues that would effectively prevent its implementation.

Based on our experience with other reclamation projects the irrigation supply must have no restrictions on use to be viable. Per the state's regulatory requirements (Title 22, Division 4, Chapter 3 Reclamation Criteria) such "unrestricted use" of reclaimed water requires additional treatment to that currently provided. The current treatment facilities provide "secondary" treatment (sedimentation and disinfection) whereas unrestricted use would require "tertiary" treatment (secondary treatment plus filtration and additional disinfection). New filters and modifications to the disinfection system would be required to upgrade treatment for unrestricted use applications.

The City has very little useable land at the existing wastewater treatment plant to accommodate the new treatment facilities. If implemented, the facilities would most likely have to be located elsewhere in the City at "satellite" treatment plants (e.g., a small capacity satellite treatment plant could be located in proximity to a user such as a golf course or cemetery). The City also has no infrastructure to support separate distribution of the reclaimed water to irrigation customers. Distribution infrastructure would include a new pump station, distribution piping, and new meter connections for each reclaimed water customer.

Environmental Benefits and Constraints

By definition reclaimed water has been made suitable for a controlled beneficial use that would not otherwise occur. This transformation of the water to a useable product results in two obvious environmental benefits:

- There is no "waste disposal" of the valuable water resource.
- Reuse of the water could potentially lessen the need to rely on existing supplies or the need to develop alternative water resources.

Another primary benefit of wastewater reclamation is that there are relatively few environmental impacts. Environmental impacts most often associated with wastewater reclamation include:

- **Public Health.** Reclaimed water has been used throughout the United States for irrigation of school yards, parks, ball fields, etc. In California, public health is protected when reclaimed water is treated and used pursuant to the California regulatory requirements. Under these rules the City would be charged with regular monitoring of the treatment process to ensure compliance with treatment requirements.

- **Degradation of Underlying Groundwater.** For the City and surrounding area the potential impacts to groundwater resources are not significant. The reclaimed water would be applied at modest rates typical of landscape irrigation and in a relatively dispersed areal distribution. Both of these factors would effectively minimize the impacts to underlying groundwater.

Implementation and Overall Viability

Santa Cruz is a community that is strongly committed to preserving the environment. The community also has a desire to manage the use of natural resources wisely. Reclamation can meet both of these objectives, and therefore has a high bias for implementation.

Although there is a bias to implement, our experience has shown that the overall viability of reclamation projects is strongly influenced by two factors:

- **Cost.** Based on a cursory evaluation of several of the City's large irrigation users (i.e., cemetery, golf courses, schools, etc), we noted that the possible application locations are generally quite dispersed throughout the City, and in some cases far removed from the wastewater treatment plant. The dispersed nature of the potential users means that long distribution piping runs would be required, which would contribute significantly to the costs for this alternative. Because of the large infrastructure requirements (treatment system upgrades and distribution piping), and operation and maintenance costs (additional treatment and pumping cost for delivery to the system), reclaimed water for direct irrigation is typically a relatively expensive alternative.

- **Net Gain of Supply.** A detailed inventory of potential users has not yet been completed, but we believe there are several potential users that could use reclaimed water. It is important to note, however, that all of the large potential users may not be amenable to the use of reclaimed water. For example, although application on golf courses is a seemingly logical option, it sometimes cannot be implemented because the high salt content of the wastewater is not compatible with the turf.

  It is also important to consider that in periods of prolonged drought the City will likely implement usage restrictions and/or curtailment policies that target outdoor irrigation as part of the overall IRP. Thus, application of reclaimed water for irrigation may be of limited net gain to the overall water supply because it serves only to replace/offset a limited demand.

Conclusion

Based on our experience with reclamation in other similar conditions, we believe that wastewater reclamation will have limited additional supply benefit and high costs. Both of these factors have the potential to limit the viability of this alternative. However, at this point in the evaluation we do not have enough information to accurately compare the benefits, drawbacks, and relative costs of reclamation against other supply alternatives. We therefore recommend that reclamation be carried as a supply alternative so that these comparisons can be made.

Additional work to be completed for this alternative includes:

- Comprehensive evaluation of potential customers and expected demand offset. This evaluation would include evaluation of irrigation users in the City and outside the City (i.e., irrigation supply for the north coast farmers), as well as potential application for some industrial users.
- Evaluation of limiting constraints for use of the reclaimed water (i.e., salt tolerance on turf, location of new treatment facilities, etc.).
- Evaluation of infrastructure requirements, including treatment upgrades and distribution system needs.

Reservoir Storage in the Olympia Quarry

As noted previously, the City's existing supply system is constrained by the relatively small amount of storage provided in Loch Lomond Reservoir, the City's only storage facility. The project concept for reservoir storage in the Olympia Quarry near Felton could provide additional storage, thus making it a potentially attractive alternative supply project.

The project alternative is based on a proposal from the gravel quarry operators under which the mining operation would extend below the existing groundwater table. At the completion of the mining a small lake would be created with a water surface in connection with the groundwater surface elevation of the surrounding aquifer at approximately 365 feet MSL (Weber, Hayes and Associates, 1999). This corresponds to a lake volume of approximately 160 to 190 MG depending on the final excavated volume from the quarry. The lake is proposed to be contained primarily by the walls of the quarry excavation rather than a structural dam (Weber, Hayes and Associates, 1999). However, there is potential to increase the storage volume by construction of a dam (Note: previous studies conducted by the City evaluated options to raise the dam on Loch Lomond between 4 to 14 feet for an estimated increase in supply of 260 to 1000 MG).

At this time the project alternative is highly conceptual. Issues to be addressed at this point include:

- **County Permit Approval.** At this time the quarry operators have not submitted a permit application to extend the mining operation. If the permit is not filed, or alternatively is not approved by the County, there can be no project.

  There is no confirmation that the quarry operators will be granted the required conditional use permit to extend their current mining operation. The Santa Cruz Mining Ordinance requires all mining operations be confined to no lower than 20 feet above the underlying groundwater elevation unless it is determined (by the Planning Commission) that mining operation near or below the water table will benefit the recharge of the aquifer. Work completed to date by the quarry operators indicates that the mining operation will have no deleterious impacts to the aquifer, but has also not demonstrated a benefit.

  One possible way to demonstrate a benefit would be to create new water storage for potable supply. However, use of the quarry site for a water storage reservoir would likely require that the volume be significantly increased over the proposed 160 MG. This would require construction of a dam, which in turn would require that numerous technical and institutional issues be addressed.

- **Available Water Supply.** Even with construction of a dam to increase the available storage, there are currently no estimates of the volume of water that could be used for potable supply. And although the quarry operators have approached the City regarding possible interest in the project, it is likely that any project to provide additional surface water storage would involve other parties such as the San Lorenzo Valley Water District and Scotts Valley Water District. This being the case, the City would likely receive only a portion of the total available supply.

Conclusion

Even if the use permit is granted — which is questionable at this time — there are numerous technical and institutional issues that would need to be further investigated to assess the viability of this project.

Based on existing information we believe that this project would be very difficult to implement. We recommend that this alternative only be pursued if the City confirms with the County that the use permit will be extended to allow additional mining. If this occurs, we recommend the following course of action, to be completed in phases:

- **Evaluation of Water Rights.** Given the complex nature of water supply and associated water rights on the local streams it is necessary to confirm that there is a source(s) of water that could be used to fill the potential reservoir after the quarry operation has stopped. A reconnaissance level evaluation of water rights on Zayante Creek indicates that this source could potentially be used to fill the reservoir. This source is a likely candidate for supply to the new reservoir because of the potential ability to divert water under existing rights and because of its proximity to the quarry location. Additional investigation of the water rights on the creek would help to identify whether the limitations on the rights could be addressed; the rights are currently designated for storage only and for an alternate point of use designation.

- **Geologic Evaluation.** Available information (CH2MHill, 1999) indicates that there are several faults that could impact the location and/or construction of a dam at the quarry site. There is also some question of the suitability of the site geology for a water storage impoundment. Accordingly, this evaluation would include the following elements:

  - Desktop evaluation of the local site conditions and areal geology and local hydrogeology and groundwater supply.

  - Review of areal faults and seismic setting and field reconnaissance and mapping of the quarry and reservoir area and potential dam foundation and abutments.

  - Analysis of the suitability of the site materials for water storage and potential seepage, need for engineered liner to reduce seepage, and potential impacts to area groundwater and slope stability.

  - Evaluation of alternatives to maximize storage in the quarry, including conceptual design criteria for the dam spillway and inlet/outlet facilities, and foundation and material requirements and static/seismic loadings.

  - Evaluation of construction concepts and potential constructability and/or environmental constraints.

  - Preparation of a conceptual level cost estimate for construction of water storage reservoir.

Pending the outcome of these two elements, additional work would need to be completed to refine the alternative. This would likely include the following:

- **Water Supply Evaluation.** This work would include modeling of water availability from local surface supplies including Zayante Creek at a minimum, and possibly others (to be determined later). The modeling work would be used to estimate expected annual available supply and supply availability during drought, similar to the evaluation completed for the Alternative Water Supply study.

This work would also include evaluation of water supply needs for other agencies which may participate in this project (i.e., San Lorenzo Valley Water District, Scotts Valley Water District, etc.). This element is necessary to identify how much of the additional storage would be available to the City.

- **Infrastructure Assessment.** The quarry would be an "off-stream" storage facility and would require new infrastructure to deliver water to and from the site. This evaluation would include a review of topographic information to assess delivery system hydraulics, and the possible need for new infrastructure at the supply source(s) (e.g., diversion structures, pump stations) and at intermediate points along the transmission piping.

Pending successful completion of all of the above, we believe that the last element of the investigation would include an environmental review, similar to the review proposed in the ongoing study.

SUMMARY

A primary goal of this study is to identify multiple alternative supply sources that could be used to supplement the City's existing system. This goal was established because it is inherently advantageous to develop a water supply system that has multiple sources (i.e., multiple supply "building blocks"). This is particularly true for water supply systems like the City's, where drought conditions can significantly impact the reliability of one or more sources. To be reliable a source must be capable of meeting at least some demand as the drought progresses, and in particular during the second (or subsequent) years. Bearing this in mind, the potential supply alternatives were evaluated (screened) with respect to three criteria:

- Amount of supply available.
- Expected reliability/sustainability during a drought.
- Ease of implementation.

Ten possible water supply projects have been evaluated to determine their potential to provide additional water supply. Of these ten, only two are considered viable supply alternatives at this time, Optimized Existing Supply and Desalination. Two additional alternatives are potentially viable, Storage in Olympia Quarry and Wastewater Reclamation, but additional work is necessary to more thoroughly define the potential benefits and limiting constraints.

The groundwater supply alternatives are not recommended for further study because they are not considered to be viable due to technical and/or other factors, or because they do not provide reliable supply over the projected two year duration of the drought. Although a few of the groundwater alternatives may provide some supply in the first year of a drought, alternatives that can serve as reliable building blocks are preferred and should be prioritized for further study.

Table 4.2 summarizes the findings.

Table 4.2 Supply Alternative Summary
Alternative Water Supply Study
City of Santa Cruz

Alternative	Recommend Further Evaluation	Comment
Groundwater from Santa Margarita Aquifer near Wilder Ranch	No	• Existing users present institutional constraints • Quantity uncertain • Supply not reliable or sustainable during drought
Fresh Groundwater from the San Lorenzo Alluvium	No	• Quantity limited • Potential conflict with existing water rights at Tait Street • Supply not reliable or sustainable during drought
Brackish Groundwater from the San Lorenzo Alluvium	No	• Quantity uncertain • Potential conflict with existing water rights at Tait Street • Supply not reliable or sustainable during drought
Groundwater Supply from Purisma Aquifer near Beltz Wells	No	• Existing users present institutional constraints • Quantity uncertain • Supply not reliable or sustainable during drought
Groundwater Supply from Santa Margarita Aquifer New Beltz	No	• Quantity uncertain • Supply not reliable or sustainable during drought
Conjunctive Use with Soquel Creek Water District	No	• Water rights constraint • Quantity uncertain • Supply not reliable or sustainable during drought
Maximize Use of Existing Sources and Storage in Loch Lomond Reservoir	Yes	• Benefit in drought and nondrought years • Improves system reliability and operation
Desalination	Yes	• Reliable and sustainable supply of needed capacity
Wastewater Reclamation	Yes	• Net supply gain may be limited and cost high; additional work required to quantify these elements
Reservoir Storage in Olympia Quarry	No	• Numerous technical and institution issues to be addressed

Next Steps

The next steps in the evaluation are summarized below:

- **Scoping Workshop with City Council and Public.** A scoping workshop will be held to present viable water supply alternatives to the City Council, general public and other groups that may have special interest in the project alternatives. The meeting will be used to identify potential institutional constraints, technical issues, and environmental issues to be addressed as part of subsequent evaluation of alternatives, and to solicit comments and ideas.

  As part of the scoping workshop, the potential for a region-wide water supply project should be considered. The City is not unique in its need to develop additional water supplies. The neighboring water utilities of Soquel Creek, Scotts Valley, and San Lorenzo Valley have similar water supply needs. Given the nature and scope of the a new water supply project for the City, there is potential to develop the project as a regional facility, and with such a transition the utilities could benefit from improved supply capacity and reliability at shared costs. Given the potential benefits of a regional facility, we recommend that this concept be explored further with Council and the neighboring utilities.

  Following the scoping meeting, the consultant team will meet with staff and a Water Commission subcommittee, as applicable, to review input received at the public scoping meeting. Alternatives will be refined as needed to reflect public and City input.

- **Refine Conceptual Alternatives.** The final task is to develop conceptual engineering schemes for each of the feasible project alternatives. Engineering concepts will be developed to a level of detail sufficient to develop the overall feasibility of the alternatives. This evaluation will include costs and will also address operational, institutional, and environmental constraints. It is assumed that a single water supply alternative will not meet the City's overall water supply needs, and that several permutations and combinations of project alternatives will need to be evaluated as part of this task. Evaluation criteria will be developed and projects will be ranked to establish a single most preferred alternative project (or combination of projects as necessary to meet the projected demands). Public input will be solicited on the final recommendation.

carollo engineers

City of Santa Cruz
Alternative Water Supply Study

TECHNICAL MEMORANDUM NO. 5
WATER SUPPLY ALTERNATIVES

November 2000

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CITY OF SANTA CRUZ
ALTERNATIVE WATER SUPPLY STUDY

TECHNICAL MEMORANDUM NO. 5
WATER SUPPLY ALTERNATIVES

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WATER SUPPLY ALTERNATIVES

The objective of this study is to identify water supply alternatives to meet the current and future water supply needs for the City of Santa Cruz. This objective is based on two fundamental concepts:

- The City obtains essentially all of its water supply from rivers and creeks. The amount of water produced from these sources varies each year, depending on precipitation and runoff. During years of below-normal precipitation or prolonged drought conditions — such as occurred most recently from 1987-92 — the amount of supply produced from the sources is significantly reduced. During these conditions the City's demand for water exceeds the available supply, so the City must deplete its only available storage, Loch Lomond Reservoir.

- The City's General Plan provides for limited development and growth of the City. As the City continues to develop, customer demand for water will exceed the amount of supply available from the existing sources, *even in non-drought years.*

Other documents completed as part of this study identify the key conclusions regarding the City's current and future water supply, and establish the most viable water supply alternatives (ref. TM 2 - Water Supply and TM 4 - Alternative Screening). This technical memorandum presents the essential findings and recommendations for the City's Alternative Water Supply Project. Included is a description of water supply alternatives and a summary of the key technical and non-technical issues for each alternative.

INTEGRATED WATER PLAN

It is the City's intent to develop an overall water supply strategy which includes not only new water sources, but also strategies to reduce demand. The overall water supply strategy — the Integrated Water Plan (IWP)— will begin with confirmation and agreement on the future water demands and safe yield of the supply system. These elements establish the basis of the plan. When completed, the IWP will include three elements:

- Reduced demand by conservation in all years.

- Reduced demand by usage curtailment in drought years.

- New sources of supply.

The IWP will compare and contrast new water supply alternatives to various growth and conservation/curtailment strategies to establish a most effective/preferred supply and demand combination. When completed, the IWP will identify a new water supply strategy to meet both current and future needs.

This project considers alternatives for new supply only. Alternatives for conservation and curtailment are being studied separately by the City, but are not described or considered in this document.

PROJECT CONCEPT DEVELOPMENT

A primary goal of this project is to identify multiple supply alternatives that could used to augment the City's existing water supply system. This goal was established because it is inherently advantageous to develop a water supply system that has multiple sources. This is particularly important for the City, because its water supply system is extremely vulnerable to shortfalls during drought conditions. For example, if a severe drought were to occur in within the next one to two years (i.e., in the year 2001-02) the City could face shortfalls of 1400 million gallons or more, or roughly 30 percent of the projected annual demand. In the future, shortfalls could be as much as 2,100 to 2,500 MG/yr in 2020 and 2050, respectively (see also TM No. 2 - Water Supply, Carollo/Linsley-Kraeger Associates, 1999).

(Note: The range of projected shortfalls referenced above is based on projected demands. The projected demands include adjustments to reflect modest conservation, but do not include adjustments for usage curtailment that are likely to be implemented by the City during severe drought conditions (ref. City of Santa Cruz Water Demands, Maddaus,1998). The range of projected shortfalls will need to be refined as part of the IWP to reflect potential demand offsets from new conservation and usage curtailment strategies.)

Preliminary Screening

A preliminary screening of potentially viable water supply alternatives was previously completed as part of this project (ref. TM No. 4 - Alternative Screening, Carollo, September 2000). The preliminary screening evaluation included groundwater and surface water alternatives. Both fresh and saline supplies were considered as follows:

- Groundwater supply from the Santa Margarita Aquifer near the Wilder Ranch gravel quarry.
- Fresh groundwater supply from wells in the San Lorenzo Alluvial Plain.
- Brackish groundwater supply from wells in the San Lorenzo River Alluvial Plain near the mouth of the river.
- Groundwater supply from the Santa Margarita Aquifer near the Beltz Well Field.
- Conjunctive use with Soquel Creek Water District.

- Groundwater supply from the Purisima Aquifer near the Beltz wells.

- Maximized use of existing sources and storage in Loch Lomond Reservoir. This alternative includes increased capture and/or storage of surface water from existing north coast and San Lorenzo River supplies, in conjunction with optimized use of existing diversions.

- Sea water desalination.

- Wastewater reclamation.

- Reservoir storage in the Olympia Quarry.

The preliminary screening evaluation of each supply alternative focused on its ability to supply water during a critical two-year drought period. The critical two-year drought period was selected as the basis of the evaluation because drought conditions will occur in the future, much as they have in the past, and it is during the drought conditions that the City's existing supply is (and will continue to be) most vulnerable (ref. TM No. 2 Water Supply, Carollo/Linsley-Kraeger Associates, 1999).

A general premise of the preliminary screening – and water supply planning in general is that reliable and sustainable sources of supply are preferable, and are generally considered to be more viable. For example, a source may provide reliable supply over the first drought year, but not the second or subsequent years. In this example the benefit/viability of the source is significantly diminished compared to other alternatives that can provide supply in the second drought year when projected shortfalls are most critical.

As shown in Table 5.1, the preliminary screening determined that the City's most viable new water supply alternatives are:

- Maximized use of existing sources and storage in Loch Lomond Reservoir.

- Sea water desalination.

- Wastewater reclamation.

Although several groundwater alternatives were considered, the preliminary screening showed that these sources are not likely to provide reliable supply during a prolonged drought. For this reason the viability of these alternatives is questionable. However, despite their questionable viability it was determined that it may be premature to exclude some of these alternatives from further consideration, particularly considering the City's proposed approach to combine multiple supply and/or demand offset alternatives via the the Integrated Water Plan, as discussed above (ref. Meeting with City Council, March 15, 2000).

POTENTIAL SUPPLY ALTERNATIVES

This section presents a summary description of each potential water supply alternative. The following information is included:

- Project Description
- Estimated Incremental Yield
- Engineering Evaluation
- Implementation Analysis
- Summary of Significant Issues

Table 5.2 presents a summary of each project alternative. Figure 5.1 illustrates the general location of the project alternatives.

Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)

Project Description

This project would develop groundwater supply from the Purisima aquifer in the Beltz/Live Oak area along the City's eastern service area border near Capitola. The groundwater would be used primarily during drought periods, but could also be used during other years to help sustain storage in Loch Lomond Reservoir.

Estimated Incremental Yield

The estimated additional supply from this project is up to 320 million gallons per year (MG/yr). The available supply is estimated from potential contributions from two water bearing zones in the Purisima aquifer near the Beltz/Live Oak area, an upper zone consisting of primarily medium to coarse grained sands and a lower zone consisting of more fine grained sands. Each zone is estimated to contribute approximately 50 percent (up to about 160 MG each) of the total estimated available supply (ref. Appendix B of TM 3 - Groundwater Supply, Carollo in Association with Fugro West, November 1999).

(Note: The hydrogeology of the Purisima aquifer varies depending on location, and includes seven water bearing/stratigraphic "subunits" at varying depths below ground surface, depending on aerial location of the aquifer. The reference to "upper" and "lower" zones is a generalized description of the aquifer characteristics/statigraphy near the

Tab. .1 Preliminary Screening of Supply Alternatives
Alternative Water Supply Study
City of Santa Cruz

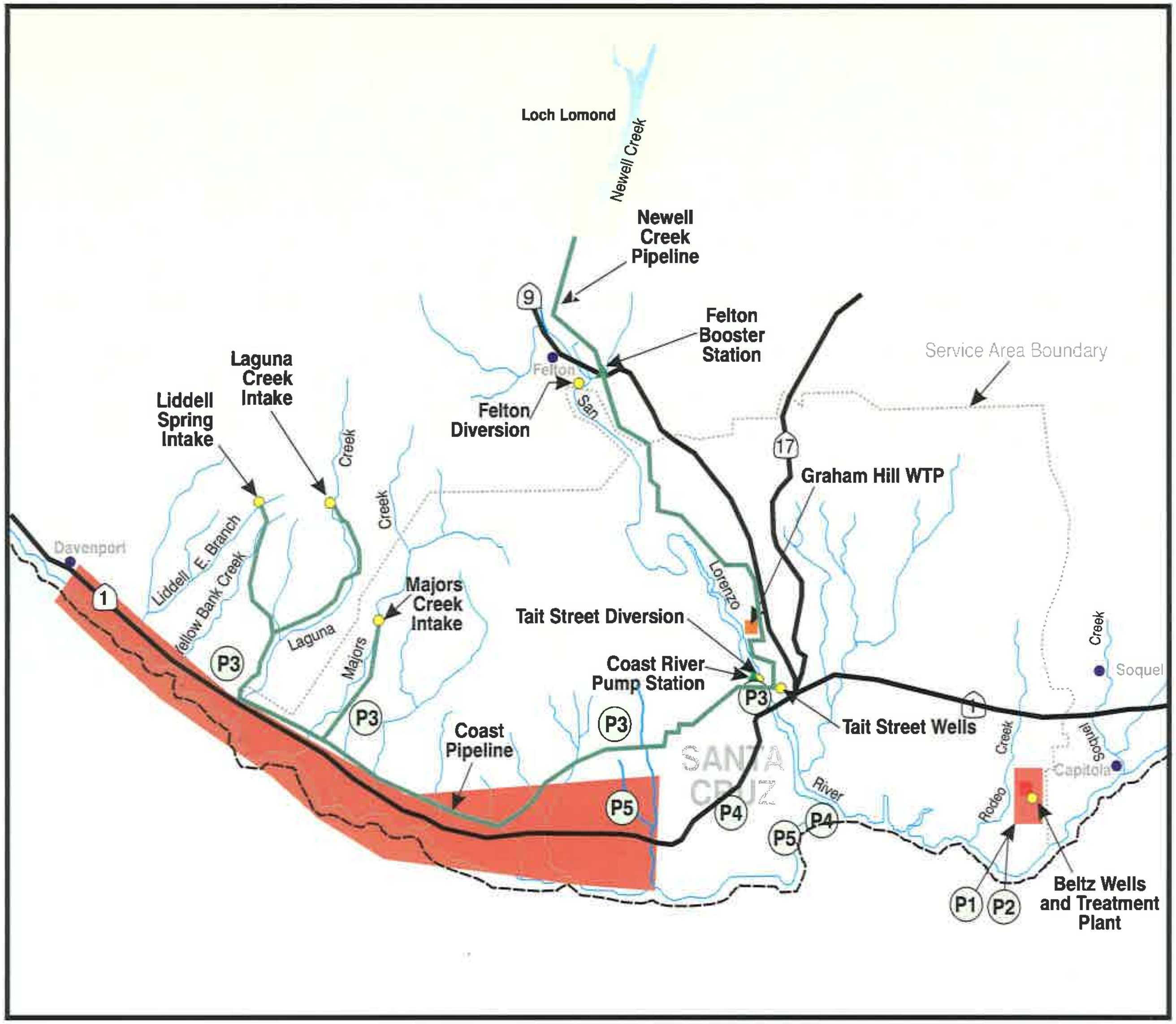
Alternative	Preliminary Screening[(1)]	Comment	Considered for Further Evaluation?
Groundwater from Santa Margarita Aquifer near Wilder Ranch	Viability is Questionable	• Existing users present institutional constraints • Quantity limited; uncertain reliability during drought • Supply not reliable or sustainable during drought	Yes [(3)]
Fresh Groundwater from the San Lorenzo Alluvium	Not Viable	• Quantity limited • Conflict with water rights at Tait Street • Supply not reliable or sustainable during drought	No
Brackish Groundwater from the San Lorenzo Alluvium	Not Viable	• Fatal flaw conflict with existing water rights	No
Groundwater Supply from Purisma Aquifer near Beltz/ Live Oak Area	Viability is Questionable	• Existing users present institutional constraints • Quantity uncertain • Supply not reliable or sustainable during drought	Yes [(2)]
Groundwater Supply from Santa Margarita Aquifer Near Beltz/Live Oak Area	Viability is Questionable	• Quantity uncertain • Supply not reliable or sustainable during drought	Yes [(2)]
Conjunctive use with Soquel Creek Water District	Not Viable	• Fatal flaw water rights constraint • Limited available surface water supplies	No
Maximized Use of Existing sources and storage in Loch Lomond Reservoir	Potentially Viable	• Benefit in drought and non-drought years • Improves system reliability and operation	Yes
Desalination	Potentially Viable	• Reliable and sustainable supply • Improved redundancy of supply	Yes
Wastewater Reclamation	Potentially Viable	• Net supply gain may be limited and cost high	Yes
Reservoir Storage in Olympia Quarry	Not Viable	• Numerous technical and institution issues to overcome	No

Notes:
(1) Preliminary "fatal flaw" screening based on ability of supply source to provide reliable and sustainable supply during drought. Includes also consideration of implementation issues (e.g., potential conflicts with existing water rights, potential conflicts with existing users (for groundwater), etc.)
(2) Based on discussion of alternatives with Santa Cruz City Council, March 15, 2000. Several groundwater alternatives that are considered to be of questionable viability based on preliminary screening have been included for further evaluation because groundwater supply may be more feasible if combined with other supply or demand offset strategies; to be determined as part of the City's proposed Integrated Water Plan.
(3) Due to limited supply and potential conflicts with existing users, this supply alternative is considered to be most viable only if an alternative supply can be provided to existing agricultural users (i.e., reclaimed water for irrigation in exchange for City's use of groundwater; see discussion under Project P5).

Table **Project Concept Summary**
Alternative Water Supply Study
City of Santa Cruz

Alternative Number	Project Alternative	General Design Assumptions	Infrastructure Assumptions
P1	Groundwater supply from Purisima Aquifer near Beltz/Live Oak	• Up to 320 MG/yr available supply[1] (160 MG/yr each from shallow and deep zones) • New wells at existing Beltz Well Site Nos. 1 and 4.	• 1 to 3 new wells at 200 to 400 feet deep. • 1,500 feet 6-inch pipe (raw water to treatment). • 3,300 feet 8-inch pipe (raw water to treatment). • 7,200 feet 12- to 16-inch pipe (distribution system). • Treatment capacity upgrades at 1 mgd for iron and manganese removal.
P2	Groundwater supply from Santa Margarita Aquifer near Beltz/Live Oak	• Up to 100 MG/yr available supply • New wells at existing Beltz Well Site Nos. 1 and 4	• 1 to 3 new wells at 800 to 1,000 feet deep. • Treatment for iron and manganese and distribution system upgrades[2].
P3	Maximized use of existing sources and storage in Loch Lomond Reservoir	• 150 to 600 MG/yr available supply[3] • North Coast supply system upgrades for 20 cfs (12 mgd).	• 77,400 feet of 14-to 36-inch pipe (new North Coast supply pipeline). • Increased capacity of coast/river pump station from 20 to 30 cfs. • 5,500 feet of 18-inch pipeline (pump station to Graham Hill WTP). • Pressure filtration at pump station at 30 cfs.
P4	Desalination	• Unlimited supply available. • Facilities located north/northwest end of City near industrial park. • Use abandoned wastewater outfall for new intake. • Brine disposal in existing wastewater outfall.	• Upgrades to abandoned wastewater outfall for new intake. • New intake pumps. • 10,000 feet 36-inch pipe (raw water to treatment). • 16,500 feet 24-inch pipe (treatment water to system). • 10,000 feet 36-inch pipe (brine to wastewater outfall). • RO treatment facilities[4]. • Ancillary support systems for RO[4].
P5	Reclamation	• 170 to 230 MG/yr demand offset for in-city application[5].	• New filtration and disinfection facilities at 10 mgd. • 32,000 feet 12-inch pipe to North Coast farms. • 20,000 feet 4-inch pipe to UCSC. • 60,000 feet of 4-to 12-inch pipe to other in-city users. • Pump station at 10 mgd, hp varies depending on delivery destination.
		• 500 to 700 MG/yr available supply if reclaimed water exchanged for North Coastal groundwater[5].	• 1 to 3 new wells at 200 to 400 feet deep • 3,500 feet 8-inch pipe

Notes:
(1) Assumes recent estimates of Purisima Aquifer yield are accurate and that increased pumping will not worsen localized low water levels or induce seawater intrusion. Estimate also assumes that existing users will not significantly increase pumpage in future from upper zone, and that lower zone can sustain production.
(2) Treatment and distribution system upgrades constructed as part of P1 would be sufficient for the required capacity increase from P2.
(3) Supply available depends on hydrologic conditions; 150 MG/yr in normal years and 600 MG/yr in drought years.
(4) RO treatment system includes pretreatment and RO membranes. Ancillary facilities included building, yard piping, chemical systems, pumps, etc.
(5) In-city applications for outdoor irrigation of parks, school yards, UCSC, golf courses. North Coast application only viable if irrigators agree to use reclaimed water instead of groundwater.



Locations of Water Supply Alternatives[1]

- (P1) Groundwater Supply - Purisima Aquifer Near Beltz/Live Oak
- (P2) Groundwater Supply - Santa Margarita Aquifer Near Beltz/Live Oak
- (P3) Optimized Use of Existing Sources
- (P4) Desalination
- (P5) Reclamation

(1) Locations are representative only. Exact locations of project components have not been established.

(2) Projects P3, P4, and P5 include multiple components.

Shaded area indicates general region/area of application for project alternative.

Figure 5.1
WATER SUPPLY ALTERNATIVES
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

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Beltz/Live Oak area, and specifically references the AA and A subunits. The reference to the "upper" and "lower" zones is intended for ease of reference in this document only; more detailed information is included of Appendix B, TM 3, November 1999).

Limitations on Estimated Yield. The Purisima aquifer is currently used as a source of domestic supply by the City, Soquel Creek Water District (Soquel Creek WD), and numerous private well owners. Accordingly, the available yield from this source as a supplemental domestic supply source depends on the amount pumped by the City and other users. The current level of pumpage has resulted in a decrease in basin water levels in the central portion of the basin near the Soquel-Aptos area. The decreased water levels indicates that the current level of pumpage is near (or above) the natural recharge potential of the aquifer, or that there are physical limitations within the aquifer that effectively limit the available production capacity to a value well below the estimated natural recharge (e.g., multiple zones/subunits within the aquifer with only limited connection between them). Even if the physical limitations can be overcome (e.g., wells installed in multiple zones) there may also be factors that effectively limit the amount of water that can be produced. Most notably, increased pumping has the potential to further lower water levels in some areas of the aquifer such that there is increased potential for seawater intrusion. Recent documentation developed by Soquel Creek WD indicates that the current total pumpage from the aquifer already causes undesirable coastal water level effects, so increased pumping may worsen these effects (ref. "...Estimated Practical Developable Groundwater Yield of Soquel-Aptos Area, Soquel Creek WD in association with Ludhorff and Scalmanini and Concur, 1998).

In the Beltz/Live Oak area the pumpage is known to occur primarily in the hydrogeologic subunits nearest to ground surface. This is significant because the additional pumping from these shallower subunits (i.e., the "upper zone") has potential to lower water levels and increase the likelihood of seawater intrusion. There is no known pumpage from the "lower" zone of the Purisima aquifer in the Beltz/Live Oak area. Historically, the upper zone in this area has produced sufficient supply to meet the demands, so deeper wells have not been completed. Also, the lower zone is known to contain more fine grained soils which will likely result in lower well efficiencies, greater drawdown within the wells, and increased pumping cost (ref. communication with Fugro West, October 1999).

It is also important to note that Soquel Creek WD is likely to continue to develop the groundwater supply to meet its system demand, at least until an alternative supply source can be developed (the water district currently relies on the Purisima groundwater for approximately 60 percent of its supply, but is considering other alternative sources). Considering the potential limitations on the yield from the aquifer and the potential for some increased pumping, the reliable/sustainable production capacity of the aquifer may actually be less than the estimated maximum of 320 MG/yr. During limited recharge and/or increase usage conditions which will occur during a sustained drought, the estimated reliable/sustainable production capacity from this groundwater source is estimated to be less, on the order of 100 MG/yr (ref. TM 3 - Groundwater Supply, Carollo in association with Fugro West, November 1999).

Engineering Evaluation

Facilities Requirements. Figure 5.2 illustrates the facility requirements to develop this groundwater supply. The facilities include:

- **New Well(s).** The wells would be operated during the high-demand months. Assuming production rates typical of other domestic supply wells (approximately 0.5 to 1.0 mgd), 1 to 3 new wells would need to be constructed; 1 well for the shallow zone and 1-2 wells for the deep zone. The depth of the wells would likely range from 200-400 feet.

- **Distribution Piping.** As shown schematically in Figure 5.2, new piping would be required to deliver the pumped groundwater to the existing Beltz treatment facilities. For this study the new wells are assumed to be constructed at either of the City's existing well sites 1 and 4 (based on preliminary evaluation by Fugro West, 1999). New piping from these sites to the treatment facilities would include approximately 1,500 feet of 6-inch diameter (site 4 to treatment) and 3,300 feet of 8-inch diameter (site 1 to treatment).

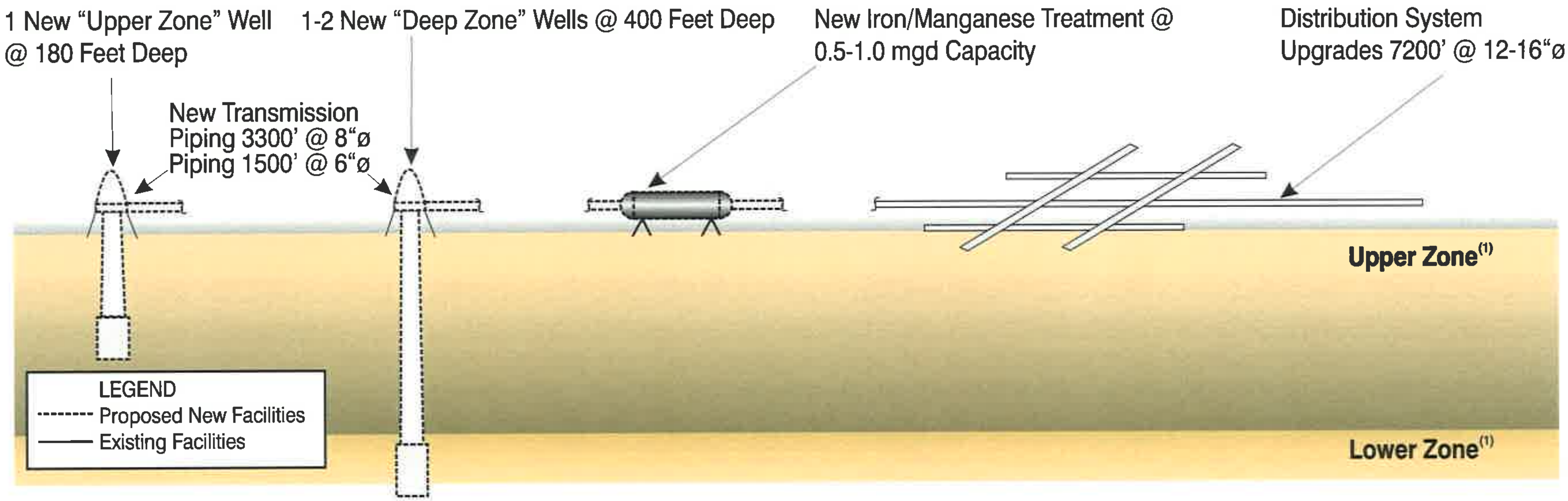
  Distribution system in the immediate vicinity of the treatment facilities would also need to be upgraded to provide increased hydraulic capacity. The finished water distribution capacity would be sized to deliver up to 3.5 mgd. This would require approximately 7,200 feet of 12- to 16-inch piping to replace the existing 8-inch pipe which is undersized.

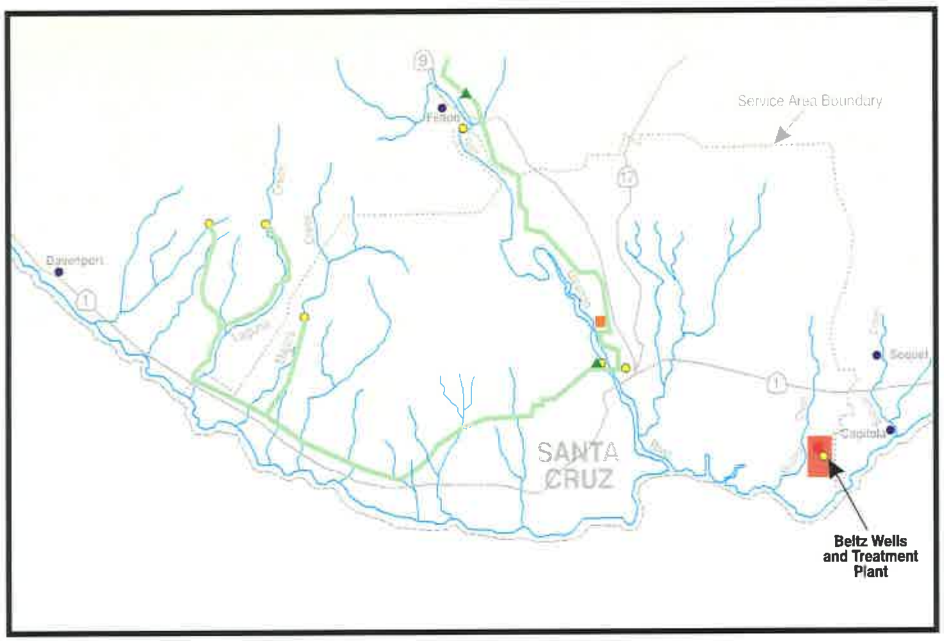
- **Treatment Facilities.** The groundwater in the Purisima aquifer can be generally categorized as fair to good, but it does contain levels of iron and manganese which require filtration treatment. The project concept would upgrade the existing Beltz treatment facilities to provide filtration treatment capacity of 3.5 mgd (i.e., new filtration vessel, miscellaneous piping and chemical feed upgrades).

Cost Estimate. The estimated costs for Project P1 are shown in Table 5.3. A more detailed breakdown of the costs is presented in Appendix A.

Implementation Assessment

For this project the City would be upgrading existing facilities (new supply wells and distribution infrastructure), so there are no apparent significant engineering constructability issues. Similarly, there are no significant environmental issues related to construction of the new facilities. Other issues related to implementation of this project are as follows:





Potential Area for Groundwater Supply Project P1 (1)

Shaded area indicates general region/area of application for project alternative.

NOTES

(1) The hydrogeology of the Purisima Aquifer includes multiple water bearing/stratigraphic subunits. The reference to "upper and lower zones" is a generalized description of the aquifer characteristics/stratigraphy near the Beltz/Live Oak area.

Figure 5.2
FACILITY REQUIREMENTS FOR PROJECT P1
GROUNDWATER SUPPLY FROM
PURISIMA AQUIFER IN BELTZ/LIVE OAK AREA
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

Table 5.3 Conceptual Costs for Project P1 - Groundwater Supply from the Purisima Aquifer Near the Beltz/Live Oak Area Alternative Water Supply Project City of Santa Cruz					
Alternative Description	**Supply Available (MG/yr)(1)**	**Estimated Project Costs ($Million)**	**Amortized Project Costs ($/MG)**	**Estimated Operating Costs ($/MG)**	**Total Estimated Costs ($/MG)**
Groundwater from Purisima Aquifer Near Beltz/Live Oak Area	100	8.3	8,500	1,800	10,300

Notes:
(1) Assumes estimated lowest production from upper and lower zones. Lowest production used as the basis for cost due to uncertainty of supply availability during drought (ref. consensus decision of City Water Commission, August 2000) .

Competing Interest for Supply. As discussed above, the Purisima aquifer is currently used as a source of domestic supply by the City, SCWD, and private well owners. With increased pumping by the City and/or SCWD there is increased potential for localized drawdown (best case), or seawater intrusion (worst case). In a recent communication to the City, Soquel Creek WD expressed concern regarding the City's potential increased pumping from the aquifer with this alternative, noting in particular that increased pumping could lead to seawater intrusion in the central portion of the basin (ref. communication from Soquel Creek to the City, July 2000). Given the concern regarding the effects of additional pumping, the viability of this alternative is somewhat questionable.

The increased potential for lower groundwater levels and seawater intrusion notwithstanding, there are other potential issues related to use of this supply source. The water produced from this source would primarily be used during the summer months of a drought when supply would be needed most by the existing users. Increased usage by the City during drought periods could also impact supply availability to existing users. Equally important, the available (reliable) yield during a prolonged drought is uncertain because the yield will likely decrease as other users increase their reliance on this supply. Because of these competing interests there may be very little additional supply that could be delivered to the City in a drought.

Summary of Issues

Significant issues related to implementation and viability that have been identified for this project are:

- The amount of additional supply available from the Purisima aquifer is unknown. Recent evaluations of the aquifer indicate that the demands on the source are near or above the sustainable production capacity.

Although the groundwater basin is not adjudicated, the fact that other users currently rely on the basin as a primary source of supply may limit the City's ability to pursue increased pumping. The City may need to pursue agreements with the other users to establish how the resource will be used and managed.

(Note: Soquel Creek WD has developed a Groundwater Management Plan for the Purisima aquifer in the Soquel-Aptos area. Any plans to increase usage from the aquifer should be coordinated with the district for continuity with resource management strategies that are already outlined in the plan.)

- The available supply from the source depends on seasonal pumping and recharge. During drought conditions of two or more years, the available additional (new) supply from the source is expected to decrease. The limited reliability and sustainability of this source during drought significantly reduces its viability as a new water supply alternative.

Groundwater from Santa Margarita Aquifer Near Beltz/Live Oak Area (P2)

Project Description

This project would develop groundwater supply from potential water bearing strata below the Purisima aquifer in the Beltz/Live Oak area along the City's eastern border near Capitola. The groundwater would be used primarily during drought periods, but could also be used during other years to help sustain storage in Loch Lomond Reservoir.

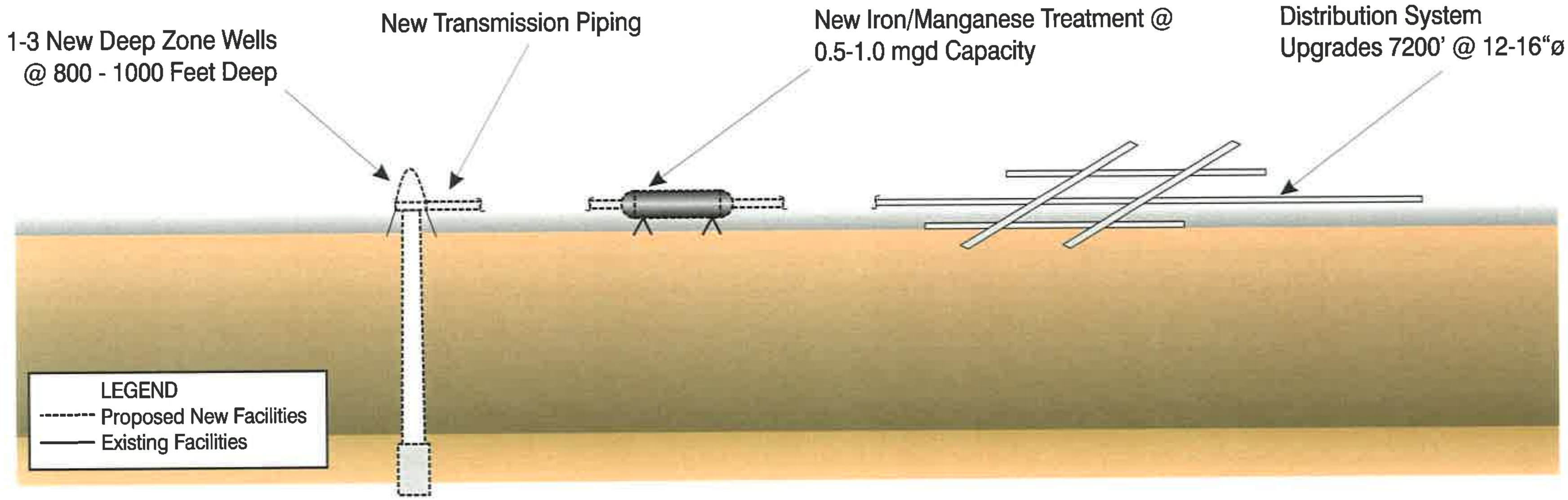
Estimated Incremental Yield

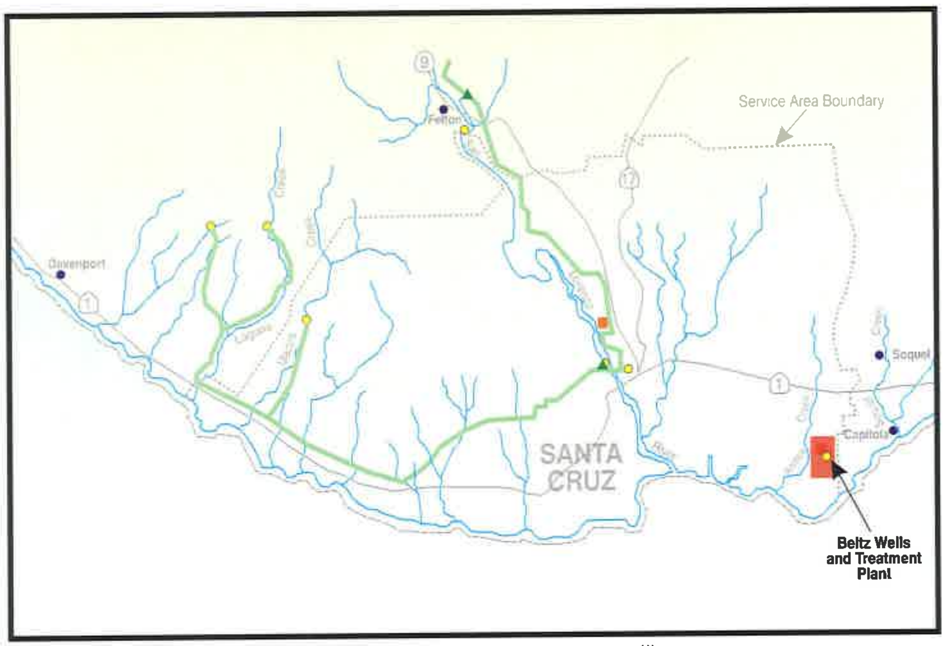
The estimated additional supply from this project is <u>up to</u> 100 MG/yr. The available supply is estimated from contributions from a potential water bearing strata approximately 800 to 1,000 feet below ground surface, near the Beltz/Live Oak area. The strata has been identified as having coarse grained material with similar characteristics to that of the Santa Margarita aquifer. Based on interpretation of other geologic/hydrogeologic information it is possible that the Santa Margarita aquifer could extend to the eastern area of the City, although this is not confirmed (the Santa Margarita aquifer is known to lie primarily north of the City).

Engineering Evaluation

Facilities Requirements. Figure 5.3 illustrates the facility requirements to develop this groundwater supply. The facilities include:

- **New Well(s).** Assuming production rates typical of other domestic supply wells (approximately 0.5 to 1.0 mgd) and assuming operation during the high-demand months, 1 to 3 new wells would need to be constructed. The depth of the wells would likely range from 800-1,000 feet. Wells would be located at the City's existing Beltz area well sites.





Potential Area for Groundwater Supply Project P2 [1]

Shaded area indicates general region/area of application for project alternative.

Notes:

1) New transmission distribution piping and treatment upgrades may be completed as part of project P1 (see discussion in text).

Figure 5.3
FACILITY REQUIREMENTS FOR PROJECT P2
GROUNDWATER SUPPLY FROM
THE SANTA MARGARITA AQUIFER
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

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(Note: The coarse grained material with similar characteristics to the Santa Margarita aquifer lies below the Purisima aquifer in the Beltz/Live Oak area. Wells completed for this alternative could be screened at different depth intervals to target production from both the Purisima aquifer (Project P1) and lower water bearing strata below).

- **Distribution Piping.** As described for project alternative P1, new piping would be required to deliver the pumped groundwater to the existing Beltz treatment facilities. For this study the new wells are assumed to be constructed at either of the City's existing well sites 1 and 4 (based on preliminary evaluation by Fugro West, 1999).

- **Treatment Facilities.** The quality of the groundwater is unknown. Given the depth below ground surface of the formation, the recharge mechanisms are difficult to predict. Flushing of the aquifer may be slow and dissolved mineral concentrations could build up over time. If the source requires iron and manganese treatment similar to that required for the Purisima aquifer, the treatment could be accomplished at the City's Beltz facility.

  It is also possible that connate/brackish fluids could be present. For example, some wells completed in the Santa Margarita aquifer along the North Coast produce water with elevated levels of dissolved salts. Treatment to reduce dissolved salts, if present, would include blending and/or demineralization via membrane processes.

Cost Estimate. The estimated costs for Project P2 are shown in Table 5.4.

Implementation Analysis

No significant engineering or constructability issues are apparent for the addition of new supply wells and distribution infrastructure. Similarly, there are no significant environmental issues related to construction of the new facilities. Other issues related to implementation of this project are as follows:

Competing Interest for Supply. Recent communications from Soquel Creek Water District indicate that the district does have a well which is screened in the Santa Margarita formation. The exact amount of supply produced from the formation is not known (the well is also screened to produce from subunits of the Purisima); however, it is not likely that pumpage from this source by the City would impact supply availability to SCWD. Also, as noted above for the Purisima aquifer the available (reliable) yield during a prolonged drought is uncertain, particularly if SCWD increases its reliance on this supply. Because of these competing interests the amount of additional supply in the Beltz area that could be delivered to the City in a drought is unknown.

Table 5.4 Conceptual Costs for Project P2 - Groundwater Supply from the Santa Margarita Aquifer Near the Beltz/Live Oak Area
Alternative Water Supply Project
City of Santa Cruz

Alternative Description	Supply Available (MG/yr)[1]	Estimated Project Costs ($Million)	Amortized Project Costs ($/MG)[2]	Estimated Operating Costs ($/MG)	Total Estimated Costs ($/MG)
Groundwater from Santa Margarita Aquifer Near Beltz/ Live Oak Area	100	1.0	1,100	300	1,400

Notes:
(1) Maximum additional supply available, assuming the aquifer extends to eastern most boundary of the City's service area, near the Beltz/Live Oak area.
(2) Project cost estimate assumes that new wells used in P1 would be extended below Purisima aquifer to Santa Margarita aquifer. Costs for required infrastructure and treatment (if necessary) included in cost estimate for project P1.

Summary of Issues

Significant issues related to implementation and viability that have been identified for this project are:

- There are limited data to confirm that the Santa Margarita aquifer extends to the eastern boundary of the City service area. Similarly, there are limited data to assess the potential production capacity. The quality of the water is unknown.

  If the City pursues this alternative, additional field testing will be required to more accurately quantify the potential for supply.

- If the supply is available, the City would need to determine the impacts, if any, related to competing interests for the supply.

Maximized Use of Existing Sources and Storage in Loch Lomond Reservoir (P3)

Project Description

This project would include facility improvements to optimize the use of existing surface sources, including increased capture and use of surface water from existing North Coast streams and San Lorenzo River supplies, alone or in conjunction with optimized seasonal use of existing diversions. The primary objective of this alternative is to better utilize the City's "flowing" surface water sources during the winter months so that storage in Loch Lomond Reservoir can be utilized primarily during the high-demand summer months when it is needed most. The additional supply would be used in all years.

Estimated Incremental Yield

The estimated incremental yield from optimized use of the existing sources ranges from approximately 150 to 600 MG/yr, depending on the hydrologic conditions (drought or non-drought year), and the type of facility upgrade (treatment facility upgrade, pipeline capacity increase, etc).

Engineering Evaluation

The amount of additional supply that can be developed from optimized use of the existing sources is a strong function of the City's ability to use (or store) the stream and river sources in the fall and winter months when rainfall and runoff is highest. Although seemingly simple in concept, there are two limiting constraints that make it difficult to do this:

- **Limited Storage.** If water is diverted but not used to meet system demands it must be stored for later use. The City's only option for storage is Loch Lomond Reservoir. Historical hydrologic data shows that there is sufficient inflow to fill the reservoir in most years. Thus, there is no benefit to divert "excess" flows to storage in most years because the storage gain in the reservoir would be temporary, only to be lost as spill later in the season.

- **Low Demand When Water is Most Available.** Lacking storage, the only way to make better use of the existing supply is to use more of the water when runoff is highest. However, demand for water is relatively low in the fall, winter, and early spring months so there is limited potential to use of the supply when it is most available.

In addition to these two constraints, water quality during the winter months is sometimes poor (i.e., high turbidity), particularly immediately after rainfall when runoff is high. The high turbidity makes the water more difficult to treat, and also impacts the operation of system pumping facilities. Due to the poor water quality much of the available supply during high runoff is not diverted.

Even if high flows are available for diversion and of suitable quality, hydraulic constraints in the existing infrastructure limit the amount of water that can currently be diverted from the sources. For example, in the winter and spring months there is water flowing in the North Coast sources that cannot be diverted due to pipeline capacity limitations.

Facilities Requirements. Optimized use of the existing sources could include one or more of the following facility upgrades:

- Provide treatment to mitigate turbidity restrictions on the North Coast supply.

- Upgrade the capacity of the North Coast pipeline to mitigate existing hydraulic constraints.

- Provide treatment and/or facility upgrades to mitigate turbidity restrictions on San Lorenzo River at Tait Street (e.g., new shallow groundwater wells in lieu of direct surface diversion).

- Upgrade the capacity of the Coast pump station and transmission pipeline to the treatment plant to mitigate existing hydraulic constraints.

- Upgrade the hydraulic capacity of the Felton/Loch Lomond supply system.

Each upgrade element was evaluated to determine the range of expected supply increase. The full matrix of combinations was also evaluated to determine the range of expected supply increase that could be provide by mixing/matching the upgrade alternatives. Observations from the evaluation are as follows:

- Under drought conditions none of the five scenarios alone are expected to significantly increase available supply. Each scenario is projected to provide 150 MG/yr or less; however, if all the scenarios were implemented together the combined additional supply would be approximately 600 MG/yr on average during a two-year drought.

- Under average (normal) rainfall conditions none of the five scenarios are expected to significantly increase available supply. Each scenario is projected to provide 70 MG/yr or less of additional supply. If all the scenarios were implemented together the combined additional supply would be approximately 200 MG/yr, on average.

  (Note: The fact that the estimated average yield increase is projected to be <u>less</u> in normal years than in drought years is expected. In most years the limitation is not total supply volume available, but rather the lack of demand and storage capacity to maximize the use of winter flows. Thus, the effect of the improvements is most pronounced during drought, because the City would have improved capability to capture and use the limited available flow in the surface streams).

- Approximately 80 percent of additional supply results from the ability to divert high turbidity flows from the surface sources and improvements to the North Coast pipeline and pump station.

Facility Sizing. The best way to maximize supply from the existing sources is to upgrade the North Coast system and the San Lorenzo River diversion at Tait Street. The conceptual infrastructure improvements include:

- **Upgrades to the North Coast Supply System.** As shown on Figure 5.1, the North Coast supply system provides surface water via diversion from Lidell Spring, Laguna/Reggiardo Creek, and Majors Creek. Water diverted from these sources flows by gravity to the Coast pump station, from which it is pumped to the GHWTP. If the sources are operated together the existing system has a maximum capacity of approximately 9.1 cfs (about 6 mgd) due to hydraulic limitations in the existing pipelines under gravity flow. The 9.1 cfs capacity represents the maximum flow by gravity, but is important to note that the sum of diversion capacity from the three sources is approximately 14.0 cfs (about 8.5 mgd). As noted above, the amount of water flowing in the sources is often well in excess of the existing diversion capacity, with each source capable of producing up to 6-10 cfs (about 3.5 to 6.5 mgd) during the winter and early spring months of December through April (total available from all sources is approximately 15-25 cfs (about 10 to 16 mgd)).

  Because the North Coast supplies can provide substantial flow during many months of the year, it is highly desirable to capture and use as much of the flow as possible. In particular, it is desirable to capture the flow during the winter and early spring when the flows in the creeks are highest. During these months it is possible that the creeks could supply most (or all) of the City's demands, thereby lessening the need to rely on other sources. Based on an analysis of historical and projected future demands in the fall, winter and spring months (when flow is most plentiful in the Coast sources), the City will need a total supply of approximately 250-400 MG/month (about 8 to 13 mgd), or up to 20 cfs. Accordingly, upgrades to the North Coast pipeline system were targeted to provide up to 20 cfs (about 13 mgd).

  (Note: During the late spring and summer months of May through September the flow in the coastal sources decreases, and is typically in the range of 5-10 cfs (about 3 to 6.5 mgd). During this time period, less flow would be diverted from the coast sources so there would be "excess" capacity available to accommodate flow from groundwater sources along the North Coast (Project P5), if the project is implemented. The additional flow from groundwater sources, if implemented, is expected to range from approximately 4 to 6 cfs; see discussion under P5 below).

  To meet this target capacity the recommended upgrades are as follows:

  - Approximately 36,100 feet of 36-inch pipeline between the Coast Pump Station and the Majors "Y" to replace the existing pipe which varies from 20 to 24 inches.

  - Approximately 14,400 feet of 24-inch pipeline from the Majors "Y" to the Lidell "Y" replace the existing 16-inch pipeline.

- Approximately 11,400 feet of 20-inch pipeline from the Majors "Y" to the Majors diversion structure to replace the existing pipeline which varies from 10 to 16 inches.
- Approximately 5,000 feet of 14-inch pipeline from Lidell "Y" to the Lidell diversion structure to replace the existing 10-inch pipeline.
- Approximately 12,500 feet of 16-inch pipeline from the Laguna "Y" to the Laguna diversion structure to replace the existing 14-inch pipeline.

Figure 5.4 shows the recommended pipeline upgrades.

Several variations of upgrade alternatives were evaluated to determine the recommended upgrades. For example, the evaluation included options to replace various sections of pipe that are known to be hydraulic bottlenecks (in lieu of completely new pipeline reaches), and also included a review of possible pumping alternatives rather than a pipeline capacity increase by gravity flow. The evaluation determined that alternatives to replace various sections of pipe and/or provide increased capacity via pumping were not viable for the following reasons:

The North Coast supply pipelines are old, and in fair to poor condition. Several reaches of the pipelines are exposed and vulnerable to landslides, thereby impacting reliability of this system. With the exception of small sections of pipe that have been repaired in the last 10 years, the newest sections of pipe are over 20 years old. Most of the pipelines have been in service 50 years or more. The expected useful life of pipeline infrastructure is approximately 50 years.

Given the age, condition, and vulnerability of the pipeline, and the City's need to maintain reliable supply from the North Coast supply system, there is ample rationale to initiate replacement of the supply pipelines in total, rather than upgrade portions of the pipeline to alleviate hydraulic bottlenecks. In addition, there is no apparent cost advantage for upgrading the pipeline in pieces rather than in total, particularly since most of the pipeline segments will need to be replaced within the foreseeable future. For example, installation of a new parallel line between the Coast Pump Station and the Majors "Y" was considered because this reach of pipeline is the one of the main hydraulic constraints and is also the longest (most costly) segment to replace. The parallel line was sized for approximately 11 cfs (20 cfs total target capacity less approximately 9 cfs capacity in the existing line). However, comparison of costs for a parallel and new full-capacity pipeline showed that the parallel line would result in a cost savings of only 10 to 15 percent. This cost savings is not considered to be sufficient to warrant a parallel line, particularly since the existing 70-year-old line will need to be replaced in the near future anyway.

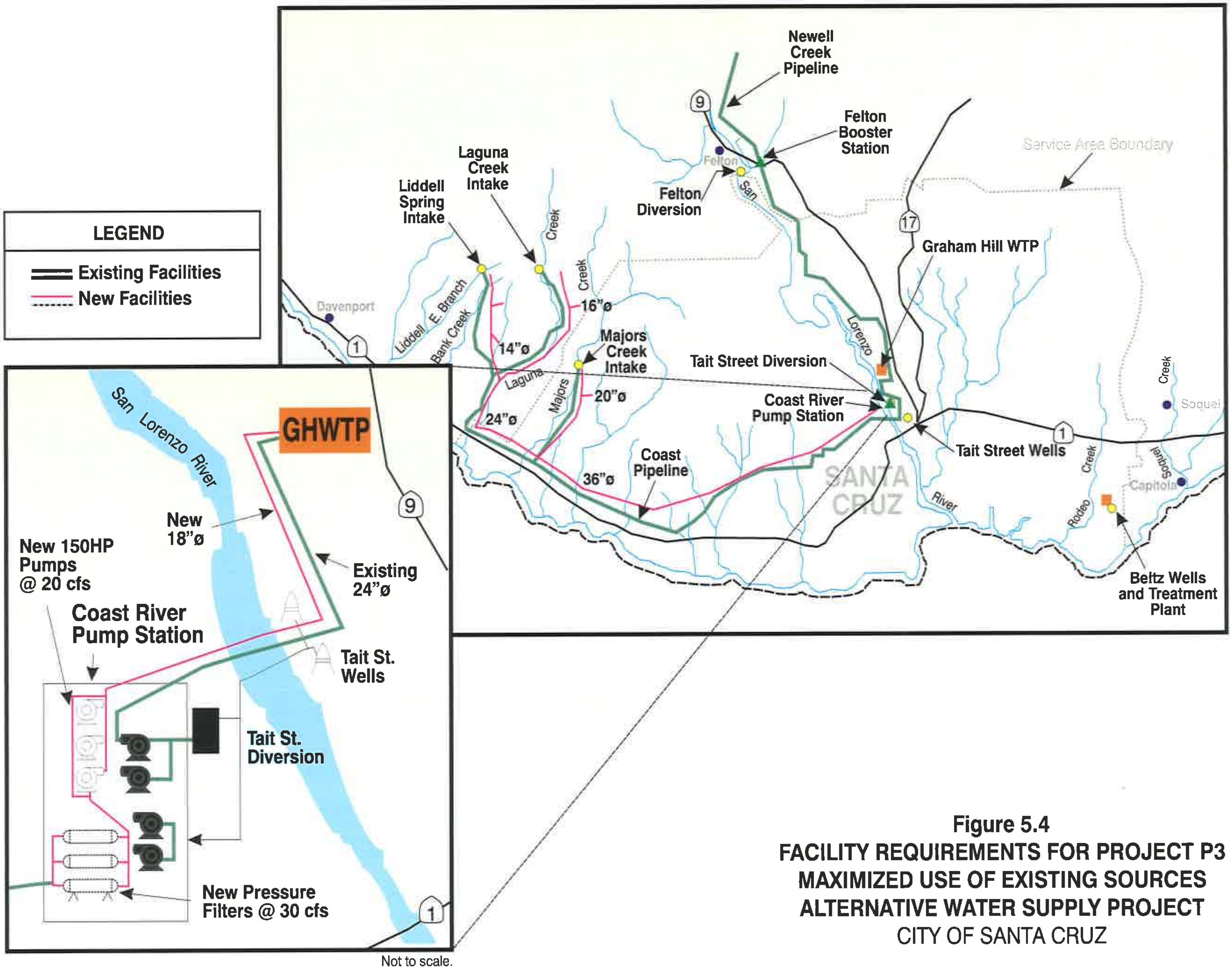

Figure 5.4
FACILITY REQUIREMENTS FOR PROJECT P3
MAXIMIZED USE OF EXISTING SOURCES
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

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Pumping from the Majors Creek source was considered as an alternative to a new pipeline between the Majors diversion structure and the main Coast pipeline. Pumping was considered because flow from the diversion is limited by available gravity head; the available static pressure head from Majors is too low to overcome the pressure in the main pipeline when water is diverted from the other sources, so little or no flow can be delivered from Majors during many months of the year.

Pumping was discounted for two reasons. First, installation of new pumps would require increased operating pressure above the reported 150 psi pressure capacity rating of most of the older sections of the existing piping (see note below). Second, there was no apparent cost advantage for installation of a new pump station at the facility. Costs for the new pump station in the remote location at the diversion structure would be high due to the need for new high voltage electrical service, construction of new access road, etc.

(Note: The constraint on pumping due to pressure capacity rating would be alleviated if a new pipeline is constructed between the Coast Pump Station and the Majors "Y". However, there still is no apparent advantage of pumping compared to a new pipeline with respect to cost, particularly considering that a new pump station would require annual operating costs (i.e., power, maintenance, etc.) compared to flow by gravity in a new pipeline.)

- **Upgrades at the Coast/San Lorenzo River Pump Station.** As shown on Figure 5.4, the Coast Pipeline terminates at the Coast Pump Station, which is located adjacent to the San Lorenzo River near Tait Street. The site also includes the diversion structure for the river, the "River" Pumps, and the "Well" Pumps. The three sets of pumps discharge to a common transmission pipeline which delivers water to the GHWTP. The existing transmission line varies from 20 to 24 inches in diameter. The current capacity of the pumps/pipeline is approximately 20 cfs (about 13 mgd). Future demands in the late spring and summer months are projected to range between 300 to 600 MG/month (10 to 20 mgd), or about 15 to 30 cfs.

  It is desirable to upgrade the pumping and pipeline facilities to supply as much of the projected demand as possible (i.e., maximize use of water flowing in the creeks and river when it is available and reduce reliance on Loch Lomond Reservoir). Based on analysis of historical hydrology during the late spring and early summer months, the <u>combined</u> flow from both the North Coast and the San Lorenzo River sources can exceed 20 cfs in some years. As noted above, additional supply from coastal groundwater sources in the range of 4-6 cfs may also be available if project P5 is implemented. Thus, comparing the expected range of monthly demands to the range of expected runoff/stream flow, there will be conditions under which the combined flow from all sources could provide most (or all) of the demands, particularly in the winter and spring months. Accordingly, the pipeline and pumping facility upgrades were targeted to provide up to a maximum of 30 cfs in order to have capacity to meet the uppermost range of future demand.

To meet this target capacity the recommended upgrades are as follows:

- Approximately 5,500 feet of 18-inch pipeline between the pump station and GHWTP, to be placed in parallel to the existing pipe which varies from 20 to 24 inches.

- Replace the existing Coast Pumps with three new 150 hp units with a combined capacity of up to 20 cfs (Note: the existing River pumps can provide the remaining 10 cfs of pumping capacity, for a total of 30 cfs).

Pretreatment. In addition to the capacity upgrades, new clarification treatment is recommended. The clarification treatment would allow use of high-turbidity winter and spring flows that are typically not diverted in order to protect pumps, and/or because the water is otherwise difficult to treat at the GHWTP. The recommended treatment system upgrades are:

- Pressure filtration vessels with a capacity of up to 30 cfs.

The pressure filters would be used as "roughing filters" in order to provide removal of the raw water turbidity, much the same as would be provided by a sedimentation unit process. The system would be designed to treat flows from both the North Coast and the San Lorenzo River. Pressure filters are recommended based on evaluation of several types of turbidity removal systems including both conventional and high-rate sedimentation clarifiers. Although there are many types of systems that could provide the desired turbidity removal, filtration was determined to best meet the needs for the given site constraints (the existing pump station site area is constrained due to proximity to the river), and with consideration of costs and ease of operation. Of primary consideration was the ability to operate the roughing filters under pressure so that there would be less re-pumping of the water delivered to GHWTP. Eliminating repumping is of particular advantage for the North Coast sources, which currently have to be repumped to increase the pressure by only about 40 psi, compared to the river system which must be pumped to approximately 150 psi prior to delivery to the GHWTP.

Figure 5.4 shows the recommended upgrades.

Several variations of upgrade alternatives were evaluated to determine the recommended upgrades. For example, the evaluation included options to replace/upsize the existing 24-inch line between the pump station and treatment plant (in lieu of the recommended new parallel 18-inch pipeline). New shallow wells to replace the existing Tait Street wells located adjacent to the river were also considered in lieu of pressure filtration pretreatment. The evaluation determined that these options were not viable for the following reasons:

- Costs to upsize the existing 24-inch pipeline to a 30-inch line to accommodate the capacity increase are estimated to be approximately twice the costs for an 18-inch pipeline. Also, per discussions with City staff, the pipeline is in good repair and does not appear to be in need of immediate replacement (the pipeline is approximately 40 years old but has no history of leaks and shows no signs of corrosion or interior blockage due to mineral deposits).

  Installation of a new parallel pipeline also provides an additional benefit of improved reliability and redundancy. This is an important consideration given the City's high reliance on the water supply from the Coast/River pump station.

  (Note: The new pipeline was sized at 18-inches to provide the required capacity at low cost. If a new pipeline is to be installed, there may be a benefit to sizing the pipe at 24-inches. A 24-inch pipe would provide equivalent capacity to the existing pipeline, and therefore would provide full redundancy. It is recommended that a more detailed evaluation of pipeline costs and associated operational issues regarding required capacity and redundancy be evaluated further as part of the design effort for the new pipeline, if implemented).

- Increased capacity via increase pumping cannot be implemented due to pressure constraints on the existing pipe. The existing pipe has a pressure rating of approximately 150 psi, of which approximately 80 and 20 percent is used up by static head and friction head, respectively. Thus, there is no "excess" pressure capacity for additional friction losses that would occur due to increased flow in the pipeline.

  Variable speed drives on the river pumps were also considered as a possible alternative to improve operation and increase supply (ref. TM 4 - Alternative Screening). In some cases, variable speed drives on pumps may also be advantageous because the pumping rate can match the river flow rate, even at the lowest flow rates in the river. However, based on evaluation of flow conditions in the river, it was determined that variable speed drives would not have any measurable supply increase over the current pumps/pumping operation.

- New wells near the Tait Street crossing would effectively serve the same purpose as pretreatment because groundwater is not subjected to high turbidity events like the stream sources. However, even if new wells are constructed the production capacity of the well sources would be limited to approximately 12 cfs due to water rights constraints. This is because the wells are hydraulically linked to the river and therefore subject to the same water rights as a direct diversion of surface water from the river. Additional pretreatment capacity of approximately 18-20 cfs would still be needed for the North Coast supply. There is no apparent cost advantage for construction of wells and associated new transmission piping from the wells to the pump station compared to providing additional incremental filtration pretreatment capacity of approximately 10-12 cfs.

- Alternative locations for the recommended treatment facilities are not considered viable. Locations considered include along the North Coast and at the GHWTP. These locations were not considered to have any advantages compared to the Coast/San Lorenzo Pump Station location.

- **Upgrades at the Felton Diversion and Loch Lomond Supply System.** The Felton Diversion and Loch Lomond supply system consists of Loch Lomond Reservoir, the Newell Creek Pipeline (between the reservoir and GHWTP), the Felton Diversion Pump Station (FDPS), and the Felton Booster Station (FBS). The system is operated in one of two modes. In the first mode, water is diverted from the San Lorenzo River and pumped up to Loch Lomond. In the second mode, water flows from the reservoir to GHWTP. Operation in both modes cannot occur simultaneously. For both operating modes there are limitations which restrict the amount of flow that can be delivered. The limitations are a combination of pumping capacity (at both the diversion station and the booster station) and pipeline pressure ratings.

  Three possible alternatives were considered to maximize the conveyance capacity to and from Loch Lomond:

  - Increase the pumping capacity at the FDPS and FBS.
  - Add variable speed drives at the FDPS to enable diversion/pumping from the river even at very low flow rates.
  - Add treatment to allow diversion of high-turbidity flows.

Based on a model analysis of system operation and review of historical hydrology, none of these alternatives is considered to have potential to increase the available supply. For example, model results showed that increasing the pumping capacity from the diversion structure and/or adding variable speed pumps would not result in a measurable change in the supply from the current operation. There are two reasons for this. First, in most years there is ample supply in Newell Creek to fill (or nearly fill) Loch Lomond without any supplemental diversions from the river. Conversely, in drought years there is very little water to divert, so having increased capacity is of little benefit. Second, the model showed that increased pumping capacity provides for a quicker end result, but does not increase supply (i.e., there is no change in the end result compared to pumping at a lesser rate over a longer period of time). For similar reasons, the model results showed that having treatment so that turbid water could be diverted to storage in Loch Lomond is also of no measurable benefit. Turbid river flow correlates with substantial rainfall/runoff in the entire watershed, so during these periods inflow to Loch Lomond from Newell Creek is also high.

It is important to note that if the pumping modifications were shown to be of benefit, the Newell Creek Pipeline and associated booster station transmission pipelines would also need to be upgraded. This is because the existing pipelines have pressure limitations that effectively preclude significant increases in flow. If pumping modifications were implemented to increase flows, the operating pressure in the pipe would exceed the pressure rating of the pipelines. This limitation could be corrected by construction of a new pipeline; however, the Newell Creek Pipeline traverses remote and environmentally sensitive areas, so construction to upgrade the pipeline would be costly and subject to considerable environmental mitigation. Both of these factors would make upgrades difficult to implement.

None of the three alternatives for the Felton Diversion and Loch Lomond supply system have significant potential to increase supply. On this basis it would appear that upgrades are of minimal benefit, and may not be warranted. However, because the Felton/Loch Lomond facilities are critical elements of the City's supply system, there is ample rationale to provide as many upgrades as possible to the facilities. At a minimum, minor upgrades to the FDPS and the FBS, including a new pipeline between the FDPS and the FBS and increased pumping capacity at the FBS should be pursued by the City. These upgrades would improve operational flexibility and reliability (ref. Felton Booster Station Preliminary Design Report, Carollo 1991). Other upgrades, including a new supply pipeline between FDPS and the reservoir, would significantly enhance system reliability.

(Note: This study is intended to define alternatives to provide additional water supply. Because the upgrades to the Felton Diversion/Loch Lomond system would provide reliability and redundancy but would not provide significant additional supply, they are not considered further in this document. However, it is recommended that these upgrades be considered for implementation as part of the City's overall infrastructure maintenance/upgrade program.)

Costs. Estimated costs for Project P3 are shown in Table 5.5. The costs were calculated based on upgrades required to provide the maximum incremental supply available, 600 MG/yr. The cost assumes that all the required new facilities would be implemented

Table 5.5 Conceptual Costs for Project P3 - Maximize Existing Sources Alternative Water Supply Project City of Santa Cruz					
Alternative Description	**Supply Available (MG/yr)**	**Estimated Project Costs ($Million)**	**Amortized Project Costs ($/MG)**	**Estimated Operating Costs ($/MG)**	**Total Estimated Costs ($/MG)**
Maximum Incremental Supply from Upgrades	600 (1)	38.9	6,600	500	7,100

Notes:
(1) Maximum additional supply available from North Coast and San Lorenzo River during drought conditions.

together, rather than phased or incremental upgrades at the various facilities. This determination is supported by an engineering evaluation of various combinations of upgrades which demonstrated that there is limited benefit of completing the upgrades in incrementally (i.e., upgrading pumping capacity but not upgrading pipeline capacity).

It is also important to note that facility upgrades to the City's existing system would serve two purposes. First, the upgrades would provide increased capacity to deliver up to 600 MG/yr of additional supply during drought. Second, the upgrades would provide additional reliability and redundancy for the City's system, which will improve the City's ability to meet demands under all conditions. Many of the proposed upgrades would replace existing facilities that are old and/or in need of repair, and which will otherwise need to be replaced at some point in the future. This is also an added benefit, beyond that which is shown by the benefit of incremental supply only. These points are noted because the added benefit of improved reliability equates to a value or "worth" beyond the incremental supply that is provided by the upgrades. Taken as a whole, it can be reasoned that the value of these added benefits effectively reduces the unit cost of the upgrades ($/MG), particularly considering that the upgrades would be used all year every year, not just in a drought.

Implementation Analysis

No significant engineering or constructability issues are apparent for the proposed upgrades to the existing system, although a more detailed preliminary design analysis will be needed to determine the best way to locate/upgrade the Coast/River pump station. Under this project the City would be upgrading facilities to better utilize water supplies under its existing water rights, so there are no foreseeable issues related to competing interests.

The infrastructure upgrades include installation of new pipelines for the North Coast system, which will require construction in/through environmentally sensitive areas. Based on preliminary environmental assessment, there are potential impacts to sensitive species and habitat related to construction of the new facilities; however, none of the potential impacts are thought to be significant. Where minor impacts are possible there appear to be reasonable mitigation strategies that could be implemented. For example, where new coast pipelines would involve construction in existing creeks, the construction could be sequenced to occur during "dry" months to avoid potential impacts on fishery habitat (see also Appendix B for additional details). The diversion of additional water from the north coastal sources also has a slight potential to impact fishery habitat. However, most of the increases in diversion would occur during high-runoff months when the fishery habitat is less vulnerable, so that the potential for impact would be minimal or less than significant.

Due to construction in environmentally sensitive areas, numerous permits would be required. The permitting effort, and the associated preparation of the environmental impact assessment/documentation, would require coordination with multiple agencies. There are no apparent permitting "fatal flaws;" however, the process would likely take a minimum of 15-18 months to complete.

Summary of Issues

Significant issues related to implementation and viability that have been identified for this project are:

- The upgrades will provide additional supply during drought and nondrought years, and will also improve operational reliability and flexibility. However, even with the additional supply the City will still face shortfalls.

- The permitting effort, and the associated preparation of the environmental impact assessment/documentation, will be a lengthy process and will need to be considered when developing the project completion schedule, if this project is implemented.

Desalination (P4)

Project Description

This project would include construction of new seawater desalination facilities including intake facilities, conveyance system, treatment plant and brine disposal system. It is assumed that this project would be used primarily in drought years, although the facility could also be used in nondrought years.

Estimated Incremental Yield

Desalination facilities would provide the City with an unlimited, sustainable and reliable water supply. It is the only supply alternative that could fully meet the City's projected shortfall. The sizing/capacity of desalination facilities would depend on contributions from other water supply alternatives and/or conservation and curtailment strategies implemented as part of the City's Integrated Water Plan (IWP).

Facilities Requirements

The proposed facilities for this alternative are shown in Figure 5.5. The facilities include:

- **Conveyance System.** The conveyance system includes three new pipelines and associated pumping facilities for raw water delivery, treated water delivery, and brine disposal. New pipelines and pumping facilities would be for raw and treated water delivery. Brine disposal would be provided via the City's existing wastewater outfall (i.e., co-mingle the brine with the wastewater).

- **Treatment System.** The treatment plant consists of the desalination process equipment and ancillary support systems, including the following:

  - Microfiltration (MF) Pretreatment
  - Ultraviolet (UV) Disinfection
  - Chemical Pretreatment
  - Reverse Osmosis (RO) Units
  - Chemical Post-treatment
  - Building

Engineering Evaluation

Facility Siting. Three key criteria were considered to identify potential sites for the treatment plant:

- Proximity to intake facilities/brine disposal point.

- Proximity to Bay Street Reservoir for distribution system storage.

- Land requirement of 2 to 2.5 acres for the treatment plant.

These key criteria were used to provide an initial screening of areas in and around the City. The initial screening determined that there are no areas to the east and southeast of the City suitable for the treatment plant. The primary reason is distance from critical facilities (i.e., proximity to the intake structure, ocean outfall for brine disposal, and treated water storage in Bay Street Reservoir), and the lack of available land area with surrounding use that is generally compatible with a treatment facility.

Figure 5.6 shows the approximate location of four potential sites that were identified to the west/northwest of the City. The four site areas are:

- **Wilder Ranch Area.** Gravel quarry operations currently occupy land near Wilder Ranch approximately 1 mile north of the City along Highway 1. The site area was considered because of the potential availability of land in areas where gravel mining operations have been completed. As part of the required reclamation of the

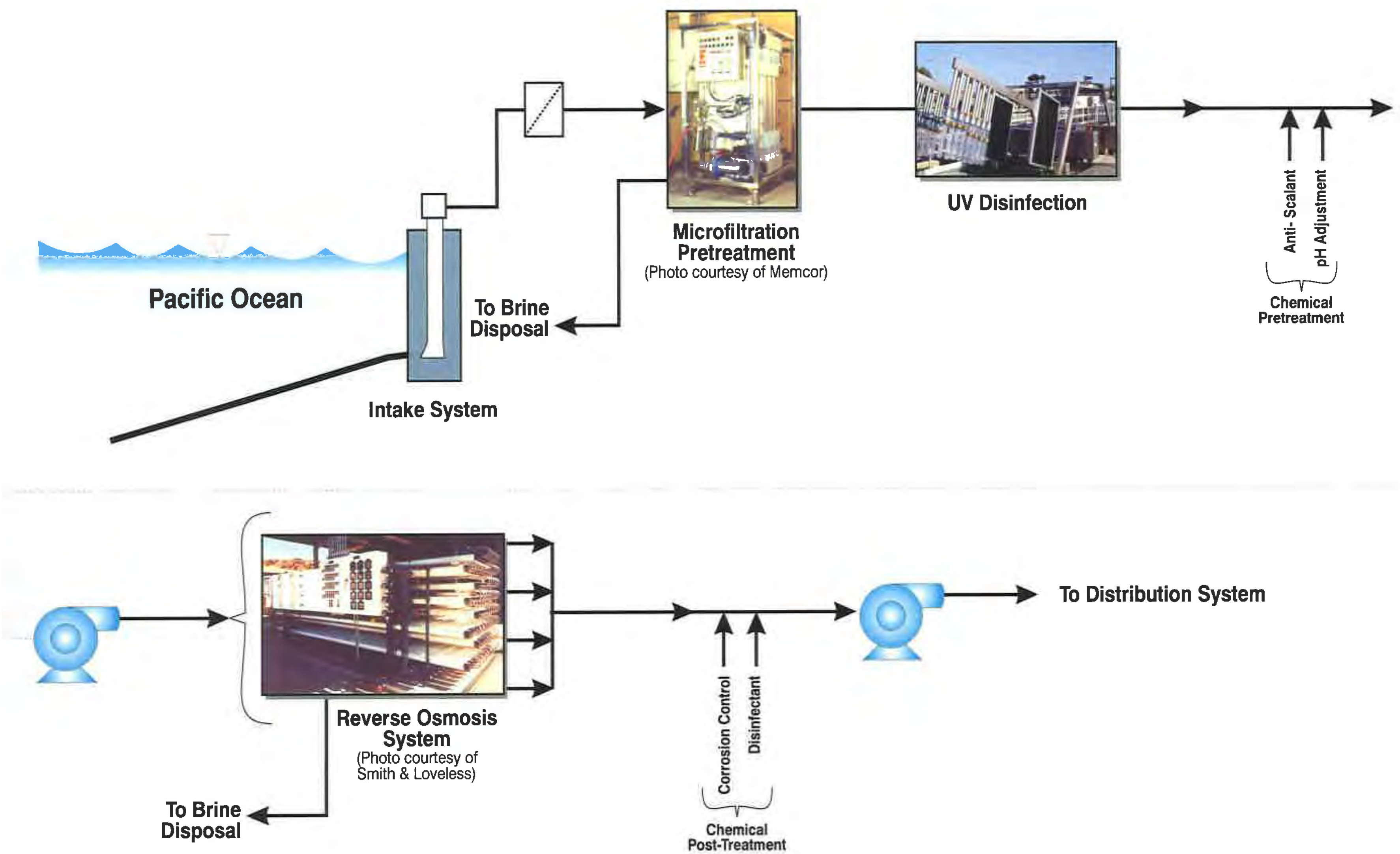

Figure 5.5
DESALINATION FACILITIES SCHEMATIC FOR PROJECT P4
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

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Figure 5.6
POTENTIAL DESALINATION TREATMENT PLANT SITES FOR PROJECT P4
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

LEGEND

● Potential Treatment Plant Site

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land area at the completion of the mining a small area could be could be restored and used to site a treatment facility.

- **Terrace Point.** The University of California at Santa Cruz (UCSC) currently owns land at Terrace Point, much of which remains undeveloped. The site was considered because there is undeveloped land, and because the site is relatively close to the critical facilities. In addition, UCSC has an agreement with the City that it will assist with water system infrastructure upgrades that are (will be) necessary to support increasing demands as the campus population grows. One way that UCSC could provide assistance to the City is to make land available for new facilities.

- **UCSC Campus.** The UCSC campus has substantial undeveloped land area. Although this land area is designated for use as open space, the site was considered because it is one of only a few areas where there is undeveloped land, and also for reasons noted above regarding University assistance with infrastructure upgrades.

- **City Industrial Park.** There currently is undeveloped land in the City's industrial park along the City's northwestern boundary. The site was considered because there is undeveloped land, and because the site is relatively close to the critical facilities.

Of these four sites, only the industrial park and Terrace Point sites are considered to be potentially viable. For both the quarry and the UCSC campus sites there would be significant piping and pumping requirements for raw water, finished water, and brine lines compared to the other alternatives. The piping and pumping are considered to be "fatal flaws" because of the significant increase to capital and operating costs compared to the other two sites. Accordingly, the project concept assumes that the desalination treatment facilities would be sited at either Terrace Point or the City Industrial Park.

Facility Sizing. The desalination treatment systems could be sized for all or part of the City's projected demand shortfall. Factors that would influence the sizing of the facility include the variability in the City's future demand (depends on future growth), the amount of supply provided by other alternatives, and the amount of demand reduction resulting from conservation and curtailment. Considering these factors, a range of 3 to 14 mgd was used as the basis for sizing the facility sizing. The desalination treatment processes were sized assuming a minimum plant capacity of 3 mgd, with potential for expansion in increments of 3 mgd. This is considered a reasonable basis for sizing the treatment processes because desalination systems are typically designed with expandable modular-type units.

Assumptions for sizing the conveyance systems are slightly different. For seawater desalination, 50 to 60 percent of the raw water is rejected as brine so conveyance facilities must be sized for approximately 2 to 2.5 times the treated water supply demand. Unlike the treatment facilities, it is not practical to expand pipeline capacity in a modular fashion as demands increase. Therefore, for this planning level analysis the conveyance facilities were sized assuming a minimum treated water demand of 9 mgd to account for possible future capacity needs.

For these assumed raw water and finished water capacity ranges, the conceptual infrastructure requirements include:

- **Intake Facilities.** There are two alternatives for intake facilities, beach wells and direct ocean intake.

  Beach well intake systems are often preferred because they provide natural pretreatment necessary to protect the RO membranes. However, preliminary review of the coastal geology indicated no suitable sites for beach wells at the required capacity. Although there are some potential sites (i.e., the mouth of the San Lorenzo River and other similar creek mouth beach areas along the coast north of the City, and the Santa Cruz beach near the boardwalk) none appear to be viable. The beach areas at the near the river/creek discharges to the ocean are not sufficient to support multiple wells that would be required for supply. Near the boardwalk there is substantial beach area, but this location is not considered preferable/feasible for two primary reasons. First, there is a suitable alternative with the direct ocean intake that could be constructed with less impact (i.e., no impact to the beach area and associated public access). Second, the California Coastal Commission recently adopted guidelines for all types of beach construction which are sufficiently stringent that it would be difficult to comply with the requirements for a project that would include construction of multiple wells. To construct wells on the beach without impact as prescribed by the guidelines — as would be required in construction/use permits — would result in onerous/costly construction techniques and substantial mitigation. There would also likely be considerable public concern/opposition to construction on the beach, even if construction impacts could be minimized and access could be maintained.

  The second alternative is a direct ocean intake through the City's abandoned wastewater outfall. The abandoned outfall extends approximately 2300 feet into the Pacific Ocean and has a final depth of 40 feet below mean sea level. With some modification the abandoned outfall line is believed to be suitable for an intake facility (see discussion below in Engineering Evaluation).

  Conversion of the existing ocean outfall to an intake facility will requires the following modifications:

  - Screen
  - Submersible, variable speed pumps
  - Lining of the pipe

- **Raw Water Conveyance.** The size of the raw water conveyance pipe will be 30-36 inches in diameter. The length of the pipeline will vary depending on final location, and would be approximately 5,000 feet and 10,000 feet for the Industrial Park and Terrace Point sites, respectively. A minimum of two 5 mgd pumps at 200 hp each would be required for a minimum treated water capacity of 3 mgd. Additional pumps could be added if additional capacity is needed.

  (Note: For a treated water capacity of 3 mgd, pumps would not need to be sized for 5 mgd and 200 hp. However, pumps of 5 mgd capacity each are assumed for this conceptual level analysis because they would be suitable for expansion, if additional capacity was desired at a later date. Sizing in this manner is slightly conservative with respect to cost estimating.)

- **Treatment System and Support Systems.** As noted above, it is assumed that the treatment system would be sized for a minimum capacity of 3 mgd, and capacity expansions would be accomplished in a modular fashion.

- **Finished Water Conveyance.** The finished water conveyance would be provided by approximately 16,500 feet of 24-inch pipeline. Pumping would be provided by 3 mgd pumps at 100 hp each.

- **Brine Disposal.** Under normal operation, reject brine from the RO units will pass first through an energy recovery turbine (which provides supplemental power to minimize the raw input power required for the high pressure pumps) and then to the brine outfall pipeline. Two alternatives for the brine disposal were considered:

  - **Beach Well Discharge.** Beach well discharge would be located along the coast line and allow for disposal of brine water. Beach wells are often preferred because they provide a nonpoint source discharge and ocean construction is not required. However, as discussed for the intake facilities, the California Coastal Commission recently adopted stringent guidelines for beach construction. Beach well discharge is not considered preferable due to the construction requirements, and also because the City can utilize the existing wastewater ocean outfall.

  - **Connection to the Wastewater Ocean Outfall.** The capacity of the ocean outfall is approximately 31 mgd at mean tide level and 20 mgd at extreme high water. Average dry weather flow (ADWF) from the wastewater treatment plant is approximately 18 mgd. It is expected that the desalination facility would operate primarily during the high-demand summer months when wastewater flows are lowest. Based on comparison of ADWF and a range of brine discharges ranging from 3 to 12 mgd (expected worst case) there is sufficient capacity in the outfall.

Although the ocean outfall is technically a point source discharge, the potential impacts are mitigated due to the fact that the brine will mix with the wastewater treatment plant effluent, thereby diluting the TDS concentration of the brine and increasing the salinity of the wastewater effluent. This has a beneficial effect on the "Zone of Initial Dilution" and creates a discharge more similar to natural seawater.

Brine would be conveyed to the existing ocean outfall via a 30-inch diameter pipe. The length of the pipeline will vary depending on final location, and would be approximately 5,000 feet and 10,000 feet for the Industrial Park and Terrace Point sites, respectively.

- **Power Supply.** Seawater desalination requires approximately one megawatt of power per mgd of treatment plant finished water production. This is equivalent to 18 to 20 kilowatt hours per 1,000 gallons of water produced.

  Although this is a large power requirement, preliminary review of power availability confirmed that there is a power substation near the industrial park area that could provide the necessary power. However, in order to provide power to the treatment plant from the substation a new high voltage (21kV) line would need to be installed and connected to a transformer on the treatment plant site. The new transformer would in turn deliver 480-volt power to the treatment plant.

  Two alternatives to conventional power supplies were also considered, photovoltaic and fuel cells. Currently photovoltaic energy sources (solar collectors and energy converters) are only suitable for low-voltage power demands and end-users that do not require a continuous supply of power (i.e., users that can tolerate some reduction in available power for extended periods such as home water heaters, solar powered lights, etc.). Fuel cells combine hydrogen (from methanol, natural gas or petroleum) and oxygen (from air) without combustion to form power, water, heat and carbon dioxide; however, the largest fuel cell power plant presently in operation is 250 kilowatts, far below that required for a desalination facility. In addition, capital costs for both alternatives are still prohibitively expensive at $2-4 million per mgd of treatment plant finished water production. It is possible that alternative energy sources may be developed to the point where they can produce larger quantities of power at lower costs, but this change does not appear to be forthcoming in the foreseeable future. Accordingly, the project concept for the desalination facilities assumes that power would be provided by conventional sources.

Cost Estimate. The estimated costs for Project P4 are shown in Table 5.6. As shown in the table, the total annual costs have been calculated for two case conditions, 3 mgd and 6 mgd. Treatment facilities sized within this range would provide additional supply to cover a wide range of potential supply deficits during a drought for the current and future demand conditions.

Table 5.6 Conceptual Costs for Project P4 - Desalination Alternative Water Supply Project City of Santa Cruz					
Alternative Description	**Supply Available (MG/yr)⁾**	**Estimated Project Costs ($Million)**	**Amortized Project Costs ($/MG)**	**Estimated Operating Costs ($/MG)**	**Total Estimated Costs ($/MG)**
Desalination (3 mgd capacity)	1,095	31.9	3,000	2,300	5,300
Desalination (6 mgd capacity)	2,190	42.1	2,000	2,300	4,300

The 3 and 6 mgd case conditions were examined because the desalination facilities could be sized to meet a range possible projected supply shortfalls. As noted previously, there are several factors that would influence sizing of desalination facilities, including the amount of supply provided by other alternatives, the amount of demand reduction by conservation and curtailment, and future growth. Based on an evaluation of estimated future growth projections and available supply, it does not appear likely that desalination facilities, if implemented, would be sized for a capacity less than 3 mgd, even if the City implements aggressive conservation and usage curtailment programs. However, if future growth is less than projected, the capacity of a desalination facility could be reduced. Table 5.7 illustrates the estimated costs for a reduced capacity facility.

Table 5.7 Conceptual Costs for Reduced Capacity Desalination Facility Alternative Water Supply Project City of Santa Cruz					
Alternative Description	**Supply Available (MG/yr)⁾**	**Estimated Project Costs ($Million)**	**Amortized Project Costs ($/MG)**	**Estimated Operating Costs ($/MG)**	**Total Estimated Costs ($/MG)**
Desalination (1.5 mgd capacity)	550	18	3,300	3,100	6,400
Desalination (0.75 mgd capacity)	275	13.1	5,100	3,700	8,800

It is also important to note that desalination facilities, if implemented, could provide supply for both the City and other users. For example, the City and neighboring Soquel Creek Water District share a common need to develop alternative water supplies. The City's emphasis is more on drought supply whereas the District's emphasis is more on an alternative "every day" supply so that groundwater pumpage can be reduced. Although the supply needs of the City and District are somewhat different, they may be complimentary with respect to sizing and operation of desalination facilities. In concept the facilities could be operated to supply water to the District during normal rainfall years, and to the City during drought years. For example, a desalination sized at 3 mgd could be operated to provide a portion of the District's daily needs in average rainfall years, thereby reducing pumpage from the groundwater. During a drought, the facility would provide a portion of the City's daily needs, but would provide little or no water to the District because they could meet demands with increased groundwater pumping. Sizing and operating the facility in this way – as a regional supply rather than a City-only supply – provides opportunity for efficient operation and cost sharing.

Implementation Analysis

The installation of seawater desalination facilities in coastal communities such as Pacifica and Santa Barbara and planned installation in Cambria underscores that such facilities can be implemented with due consideration of technical, environmental, and institutional issues.

For Santa Cruz, the on-land facilities associated with a desalination system (i.e., pipelines, pump stations, and treatment systems) do not present any unusual engineering or constructability constraints. However, although feasible, the rehabilitation of the abandoned ocean outfall for a new intake will require thorough engineering and difficult construction.

A desalination treatment system and associated infrastructure is also somewhat different from other alternatives relative to potential environmental impact because it requires substantial new construction, rather than other alternatives which include comparatively modest upgrades to existing facilities only. Based on preliminary environmental review, there do not appear to be any significant environmental issues. For example, there are potential biological constraints at the Terrace Point Site. But given the large size of the site there opportunity to locate the treatment facilities to avoid any special-status species or wetlands issues, and otherwise mitigate any potential impacts to a less-than-significant level (see also Appendix B). Irrespective of the site location, there is substantial construction in potentially environmentally sensitive areas, including the ocean, so numerous permits would be required. The permitting effort, and the associated preparation of the environmental impact assessment/ documentation, would require coordination with multiple agencies. Table 5.8 summarizes other potential environmental issues.

The primary institutional challenge for a desalination system is siting of the treatment facilities. Although land is potentially available at the Industrial Park and Terrace Point sites, considerable additional work is needed to confirm a site location and secure the land. Before land can be secured, environmental documentation for the project must be certified.

If the project is pursued there may be other institutional issues related to development of the project as regional supply. Given the nature and scope of a potential water desalination water supply project there is potential to implement the project as a regional facility, particularly because a regional facility would provide an opportunity for cost sharing.

Table 5.8 Summary of Environmental Issues for Desalination Alternative Water Supply Project City of Santa Cruz			
Issue	**Impact at City Industrial Park Site[(1)]**	**Impact at Terrace Point Site[(1)]**	**Comments**
Construction Related Impacts	Minor	Minor-Moderate	• Visitor uses may be sensitive at Terrace Point Site
Compatibility with Adjacent Land Uses	Minor	Minor-Moderate	• Terrace Point site aesthetics would need to be compatible with potential residential uses
Visual Impacts	Minor	Minor-Moderate	• Terrace Point site aesthetics would need to be compatible with potential residential uses
Potential for Cultural Resources	Minor-Moderate	Minor	• Excavation activities could uncover cultural, archaeological, historical or paleontological resources
Potential for Public Controversy	Minor	Moderate	• General Plan requires a specific plan for Terrace Point prior to development • Desalination facility would be located within area designated for "coastal-dependent" uses
Potential to Disrupt Traffic From Pipeline	Major	Major	• Potential disruption of traffic on Mission Boulevard and Bay Avenue during construction
Growth Inducement	Major	Major	• Size to accommodate growth consistent with the City's General Plan • Growth inducement is a potential impact of any project increasing water supplies • Potential impact may be mitigated if used as a regional supply project, serving the City only in drought conditions and other users in non-drought years
Energy Usage	Major	Major	• Significant energy requirements Coastal Act requires minimizing energy consumption
(1) Minor/Major/Moderate represents the anticipated severity of the issue and is based on the City of Santa Cruz Water Supply Alternatives Environmental and Regulatory Constraints Analysis (Jones & Stokes, February 2000; see Appendix B).			

Summary of Issues

Significant issues related to implementation and viability that have been identified for this project are:

- Due to the nature of construction of facilities in the ocean, and planned discharge of brine into the ocean, there will be considerable coordination requirements with multiple agencies to complete the necessary environmental review and documentation. This process would likely take 18-24 months to complete, and could delay implementation of the project.

- Facility siting alternatives have been identified through initial screening. Additional work is needed to confirm a site location and secure the land. Final site selection would need to be determined based on feasibility of acquisition. Before land can secured, environmental documentation and certification of the project concept must be completed.

- Sizing of the facility is critical to development of expected costs for construction and operation. Facility sizing would need to be confirmed and coordinated with planned conservation/curtailment efforts, and/or with planned development of alternate sources of supply. Similarly, the potential for use of the facility for regional supply to other agencies would need to be considered.

- The planned use of the abandoned outfall as a new intake structure and use of the existing wastewater outfall for brine disposal are based on conceptual engineering review of these facilities, including hydraulic capacity, age/condition, and ability to construct required modifications. Additional engineering at the preliminary design level will be required to more completely describe the engineering details for use of these facilities.

Wastewater Reclamation (P5)

Project Description

This project would include facility improvements for use of reclaimed wastewater for some outside irrigation applications. There are two project concepts for this alternative:

- Use reclaimed water to offset demands on the potable supply system by providing a new, replacement supply for irrigation applications in the City service area (hereafter P5A).

- Provide reclaimed water to North Coast farms in exchange for City use of groundwater supplies in the Santa Margarita aquifer along the North Coast (hereafter P5B).

The additional supply would be used in all years, drought and nondrought. It is assumed that the supply would be utilized primarily during the high-demand summer months because this is the only period during which there is substantial irrigation demand.

Estimated Incremental Yield

In-City Applications (P5A). The demand offset (or incremental supply) from the use of reclaimed water varies depending on the application. For example, the use of reclaimed water for irrigation accounts within the City will provide a demand offset, but the amount of demand offset will vary depending on the assumed distribution infrastructure (irrigation accounts are widespread throughout the City, so the demand offset is highly dependent on new infrastructure to deliver the water). Considering the variables and influencing factors for applications in the City, the estimated potential demand offset ranges from approximately 170 to 230 MG/yr for current and expected buildout demand conditions, respectively (see Engineering Evaluation below for assumptions).

Agricultural Application (P5B). The use of reclaimed water for the North Coast farmers is somewhat different because the project concept assumes the reclaimed water would be used for irrigation in lieu of groundwater. The yield from the groundwater supply is a function of hydrology/hydrogeology and is not dependent on infrastructure. The estimated available yield from the Santa Margarita aquifer along the coast ranges from 500 to 700 MG/yr.

Engineering Evaluation

The project concept assumes reclaimed water for outdoor irrigation only. Potential users of the reclaimed supply include parks, school yards, cemeteries, golf courses and other large irrigation customers such as UCSC (all current City accounts) and farmers north of the City.

Other project concepts were evaluated as follows.

- **Reclaimed Water for Groundwater Recharge.** Groundwater recharge with reclaimed wastewater is practiced in California. However, for the City's application there are numerous technical and implementation issues that render this project concept nonviable (ref. TM 4-Project Alternative Screening).
- **Reclamation for Direct Reuse.** Although reclamation for direct reuse (potable consumption) is technically feasible, there are numerous regulatory and public acceptance issues that would effectively prevent its implementation. Accordingly, reclamation for direct potable use is not considered viable at this time.
- **Reclaimed Supply from Scotts Valley.** The City of Scotts Valley has recently upgraded its wastewater treatment facilities to provide treatment necessary for reclamation. Distribution infrastructure is also in place (a pipeline down Graham Hill Road) that would provide for delivery of reclaimed water to potential users (e.g., Pasatiempo golf course and the cemetery near the intersection of Graham Hill Road and Ocean Street extension). However, based on discussions with Scotts Valley staff, there is already enough customer demand for reclaimed water to match the available treatment capacity, so there is no available supply or capacity that could be used by the City. Accordingly, the use of reclaimed supply from Scotts Valley is not considered viable.

Facility Requirements. The City's wastewater treatment plant produces water that is suitable for some agricultural applications (indirect irrigation of nontable crops), and for limited public access irrigation. The level of treatment currently provided is not sufficient for the water to be suitable for general irrigation use on playgrounds, parks, school yards, etc. Based on experience with other reclamation projects in the state, the reclaimed supply must have no restrictions on use to be viable. Per the state's regulatory requirements

(Title 22, Division 4, Chapter 3 Reclamation Criteria) such "unrestricted use" of reclaimed water requires additional treatment to that currently provided. The current treatment facilities provide "secondary" treatment (sedimentation, aeration/clarification, and disinfection) whereas unrestricted use would require "tertiary" treatment (secondary treatment plus filtration and additional disinfection). New filters and modifications to the disinfection system would be required to upgrade treatment for unrestricted use applications.

The project concept for use of reclamation for both P5A and P5B is based on construction of new tertiary treatment systems at the City's existing wastewater treatment plant. It is important to note, however, that the City has very little useable land at the existing wastewater treatment plant to accommodate the new treatment facilities, and the land that is available may be needed for future upgrades (other than tertiary treatment). The area around the site is being utilized so it would likely be difficult to acquire adjacent land required for tertiary treatment facilities. The City also has no infrastructure to support separate distribution of the reclaimed water to irrigation customers. Distribution infrastructure would include new pump stations, distribution piping, and new meter connections for each reclaimed water customer.

It is possible that treatment facilities could be located elsewhere in the City at "satellite" treatment plants (e.g., small capacity satellite treatment plants could be located in proximity to a large capacity user such as a golf course, cemetery, or north coast farmers). However, based on cursory review of land use in proximity to the potential users, there do not appear to be sites that are clearly preferable/viable for satellite treatment plants. Possible locations for a satellite treatment facility include the City's industrial park (in the northwest area of the City near Delaware and Swift streets) or the UCSC campus (the campus has large areas of open space land that could potentially be used). A site near the City's industrial park has the advantage that it is near the City's existing wastewater outfall so it would be possible to route a portion of the secondary treated flow to the new facilities. Also, the site is located on the northern portion of the City, closest to the North Coast farmers. The UCSC campus site has the advantage that there is unoccupied land, and it is in close proximity to the campus, which could account for 20 to 30 percent of the reclaimed water demand. Of these two sites, neither is "ideal." Pumping would be required to route the reclaimed water to and from the sites which would increase operating costs, particularly for the UCSC site where the elevation difference between the wastewater treatment plant and any potential site would be several hundred feet. In addition, neither potential site area has a land use designation for the proposed use.

Figure 5.7 shows the potential users and associated infrastructure requirements for the in-City facilities.

Figure 5.8 shows facility requirements for reclamation along the North Coast.

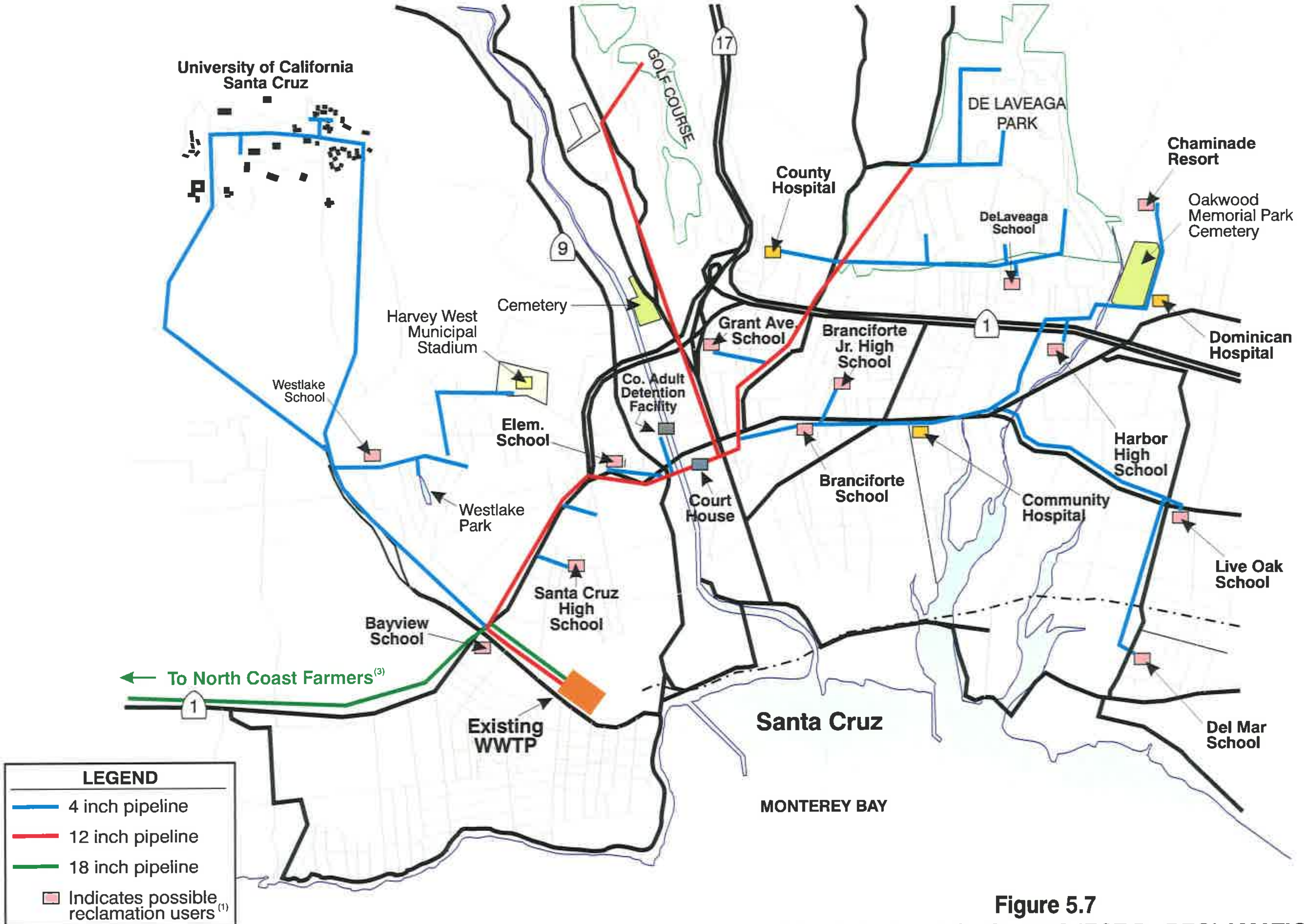

Figure 5.7
IN CITY FACILITIES FOR PROJECT P5 RECLAMATION
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

NOTES: 1) Potential Reclamation users identified based on coarse screening of large outdoor water users, and does not represent list of all potential users.

2) Pipeline sizes based on requirements for potential users in proximity to pipeline route.

3) See Figure 5.8

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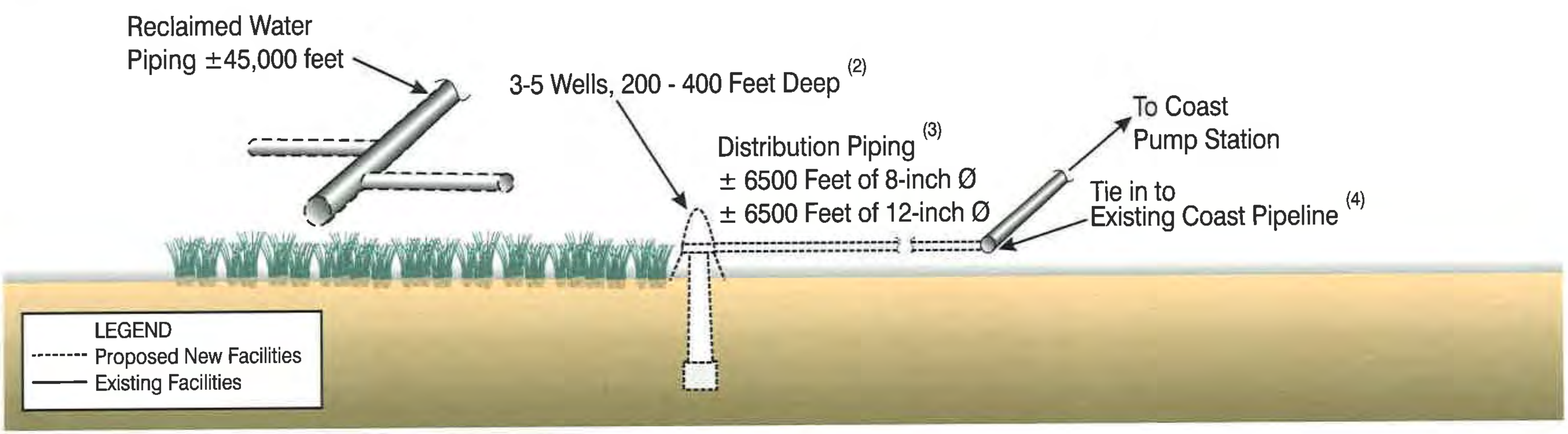

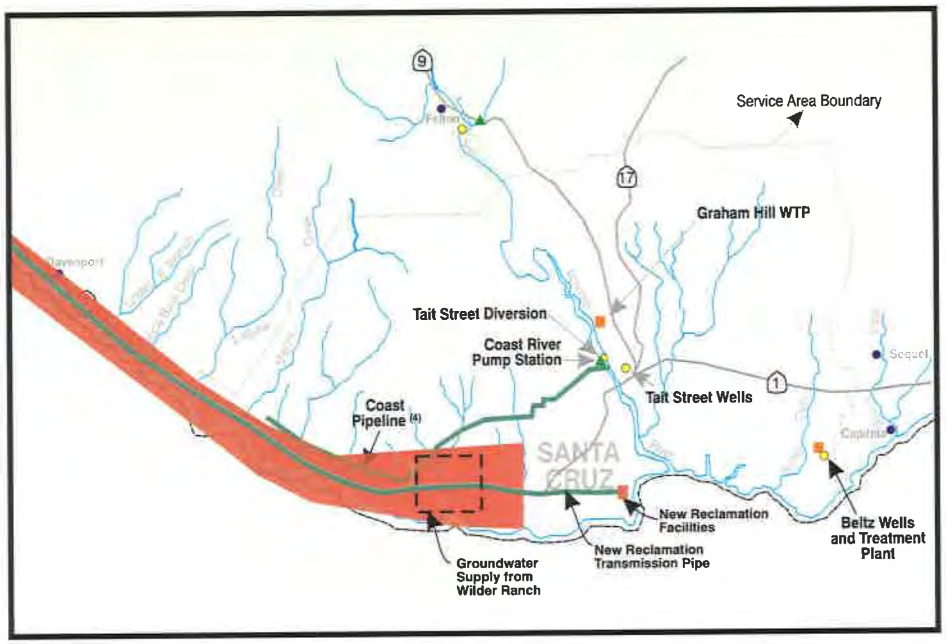

Potential Area for Reclamation/Groundwater Exchange Supply Project P5B (1)

NOTES

(1) The highlighted area represents the general location of reclamation along the coast.

(2) The depth of the wells may vary depending on location drilled because of varying surface features and depth to the aquifer along the coast.

(3) Assumes approximately one half mile piping at each of five well sites.

(4) The existing pipeline has hydraulic capacity limitations. Upgrades completed as part of project P3 would provide the needed capacity.

Shaded area indicates general region/area of application for project alternative.

Figure 5.8
FACILITY REQUIREMENTS FOR PROJECT P5B
RECLAMATION FOR
NORTH COAST AGRICULTURE
ALTERNATIVE WATER SUPPLY PROJECT
CITY OF SANTA CRUZ

Facility Sizing. As noted above, the amount of demand offset that can be achieved with reclamation inside the City is a strong function of ability to deliver water to potential users. Due to the fact that users are dispersed throughout the City there is a practical limit to amount of distribution infrastructure that could be cost effectively constructed. Accordingly, the project concept assumes that 50 percent of the estimated irrigation demand within the City service area could/would be served by a reclamation project. This equates to approximately 170 to 230 MG/yr for current and expected buildout demand conditions, respectively.

Reclamation potential for farms along the North Coast assumes that seasonal irrigation needs are approximately 600 to 900 MG/yr. This range assumes approximately 2000-3,000 acres of irrigable acreage in any given year, of which up to 70 percent would be irrigated with reclaimed water (the remainder is assumed to be irrigated with surface water diversions, based on similar current and historical operations). The irrigation requirements are assumed to vary between 0.75 and 1 foot of applied water per acre of land.

Treatment facility upgrades would need to be sized to accommodate peak month demands during the summer months. The peak month demands are estimated to range from 65 to 90 MG for the "in-City" users and 200-300 MG for the North Coast farmers. Accordingly, the average flow during the peak month would range from approximately 7 to 10 mgd. Based on these potential irrigation demands, the conceptual facility requirements are as follows:

- **Treatment Facility Upgrades.** Facilities to provide tertiary treatment would include filtration and disinfection. The filtration process could be accomplished by granular media gravity filters (e.g., sand and/or anthracite) or membranes. Disinfection could be provided by either ultraviolet irradiation or chlorination with sodium hypochlorite. Associated chemical feed and storage equipment for chemical systems (i.e., coagulant/filtration aid chemicals, sodium hypochlorite, etc.) may also be needed depending on type of filtration.

- **Distribution System Infrastructure.** Distribution system infrastructure would include pumps and distribution piping as follows:

    - <u>In-City Accounts (P5A).</u> The remainder of the in-city accounts such as cemeteries, golf courses, parks, schools, etc., would all be served by a main distribution system. A minimum of approximately 20,000 feet of 12-inch pipe and 40,000 feet of 4-inch pipe would be required.

    - <u>UCSC (P5A).</u> It is assumed that the distribution facilities to the UCSC campus would include a dedicated feed and pumping system. This assumption is made for two reasons. First, the campus is essentially an isolated user, and does have enough demand potential to warrant a dedicated line (0.5 to 1 mgd). Second, the campus demand is located several hundred feet above most of the rest of the potential users in the system, so dedicated pumps would be required to meet the pumping requirements.

A minimum of approximately 20,000 feet of 4-inch piping would be required for distribution. Pumping would be accomplished by 2-150 hp pumps, each with a capacity of 0.5 mgd.

- North Coast Farmers (P5B). It is assumed that the City would provide a main distribution pipeline to the farmers, from which water would be delivered through various "turnouts." It is assumed that the pipeline would generally follow the Highway 1 alignment, and that the distribution piping to the various farms would be provided by the farmers (i.e., the City would provide the main supply, but the farmers would be responsible for delivery downstream of the connection, similar to application for domestic and irrigation accounts).

  A minimum of approximately 45,000 feet of 18-inch piping would be required for the main distribution header to the farms. Pumping would be accomplished by 3-150 hp pumps, each with a capacity of 3.5 mgd (2 duty and 1 standby).

(Note: For the conceptual project it has been assumed that the treatment would be provided at/near the existing WWTP (not at satellite facilities). If satellite treatment facilities were used the infrastructure requirements would be slightly different, depending on the location of the satellite facility. The infrastructure requirements would include pumps and piping to deliver the secondary treated wastewater to the satellite plants, and piping to end users.)

Costs. Two cost estimates were prepared for this supply alternative. The first cost estimate assumes reclamation for in-city and North Coast farmers (Projects P5A and P5B). The second cost estimate assumes reclamation for North Coast farmers only (Project P5B). Project P5A was not estimated separately due to the high cost of treatment and distribution facilities for a relatively limited supply. The estimated costs are shown in Table 5.9.

Implementation Analysis

The facility upgrades required for reclamation can be grouped into two categories, treatment systems and distribution infrastructure. There are no significant engineering issues for either category; both the treatment systems and the required infrastructure are typical of other water/wastewater facilities. Similarly, there are no apparent construction issues that would represent a "fatal flaw" for the project. However, both systems do present some constructability challenges. For example, there is no clearly viable site location for the treatment facilities. And although the construction of the required pumping

Table 5.9 Conceptual Costs for Wastewater Reclamation
Alternative Water Supply Project
City of Santa Cruz

Alternative Description	Supply Available (MG/yr)	Estimated Project Costs ($Million)(1)	Amortized Project Costs ($/MG)	Estimated Operating Costs ($/MG)	Total Estimated Costs ($/MG)
Combined Project - Reclamation for In-City and North Coast Farmers (Project P5A and P5B)	925	49.9	5,500	900	6,400
Reclamation for North Coast Farmers Only (Project P5B)	700	28.0	4,100	700	4,800

Notes:
(1) Includes costs for reclamation facilities, distribution/transmission facilities, and new wells and associated pipelines to connect to the North Coast pipeline.

and piping infrastructure is simple in concept, experience has demonstrated that routing and installation of new piping in existing streets can be difficult due to conflicts with existing water, sewer, electrical, and communication utilities.

Similarly, there are no apparent environmental or implementation issues that would present a "fatal flaw" for this project concept. By definition, reclaimed water has been made suitable for a controlled beneficial use that would not otherwise occur. This transformation of the water to a useable product results in two obvious environmental benefits:

- There is no "waste disposal" of the valuable water resource.
- Reuse of the water could potentially lessen the need to rely on existing supplies or the need to develop alternative water resources.

Even with a strong bias to implement the project there are several implementation issues that would need to be resolved:

- **Confirm Municipal Usage.** The City would need to confirm that some of the larger potential users such as the UCSC campus, cemeteries and golf courses would be amenable to the use of reclaimed water. For example, golf turf grasses are often not tolerant of salt loads typical of reclaimed wastewater; however, based on review of the application rates and salt content it does not appear that the turf would be impacted if reclaimed water was used.

- **Confirm North Coast Usage.** For application on the North Coast, the City would also need to confirm that the farmers would be amenable to use of the reclaimed water. There are several local examples of reclamation along the coast and Salinas Valley, so there would not appear to be a significant implementation issues. Also, based on preliminary discussions with several North Coast farmers, there appears to be considerable interest for the use of reclaimed water.

  It is important to note that the farmers' interest in the supply will be strongly linked to its cost. The farmers' cost for pumped groundwater typically ranges around $60-80/AF (about $200-250/MG). Compared to the amortized capital and operating costs for reclamation and groundwater facilities, it is estimated that the City's costs for this project would be approximately $1400/AF.

- **Confirm Groundwater Usage Entitlements on the North Coast.** For reclamation to be viable on the North Coast, the City must have guarantees that the groundwater would be available in exchange for the reclaimed supply. To accomplish this the City would need to develop rigorous contractual agreements with the farmers, and perhaps pursue adjudication of the basin in the area. There is no reason that such agreements/entitlements could not be developed, but to do so may take some time and may have associated scheduled implications. Although the agreements/entitlements could be developed in parallel to other project elements (e.g., EIR documentation, facility engineering, permitting), it would be preferable to have such agreements in place prior to pursuing/developing the project.

In addition to these issues, this project will require a coordinated permitting and environmental impact documentation/assessment among multiple agencies, particularly if the project includes construction along the North Coast (as discussed for Project P3).

Lastly, it is important to consider that the benefit of reclaimed water is most pronounced when it equates to a demand offset (i.e., use of reclaimed water for outdoor irrigation offsets the demand for potable supply that would otherwise be used for outdoor irrigation). During periods of prolonged drought the benefit of reclaimed water for demand offset is reduced. This is because during a drought the City will likely implement usage restrictions and/or curtailment policies that target outdoor irrigation. Such usage restrictions inherently reduce demand, so the net benefit of demand offset from reclamation is also reduced.

Summary of Issues

Significant issues related to implementation and viability of this project are:

- Of the two project alternatives for reclamation, only exchange of reclaimed water for groundwater will provide additional supply. If the City pursues this alternative, rigorous contractual agreements/entitlements for use and control of the groundwater must be secured

- Additional work would need to be completed to confirm a viable site location for treatment facilities.

SUMMARY

As noted at the beginning of this document, it is the City's intent to develop an overall water supply strategy which includes not only new water sources, but also strategies to reduce demand. When completed, water supply strategy — the Integrated Water Plan — will integrate four elements:

- Potential action by City Council to modify growth and development plans so as to reduce future water demand.
- Reduced demand by conservation in all years.
- Reduced demand by usage curtailment in drought years.
- New water sources.

The IWP will provide a detailed analysis of all the water supply alternatives/strategies, so that each can be ranked and prioritized to determine a preferred approach to provide supply building blocks for the City. Because the City will complete an analysis of alternatives during the IWP, a detailed ranking and prioritization of supply alternatives is not included in this document.

Table 5.10 presents a summary comparison of the project alternatives.

Table 5.10 Conceptual Project Alternative Summary
Alternative Water Supply Study
City of Santa Cruz

Alternative Number	Project Alternative	General Design Assumptions	Infrastructure Assumptions	Est. New Supply (MG)	Total Estimated Project Cost ($Million)	Amortized Capital Cost ($/MG)	Annual O&M Cost ($/MG)	Total Annualized Cost ($/MG)	Summary of Issues
P1	Groundwater supply from Purisima Aquifer near Beltz/Live Oak	• New wells at existing Beltz Well Site Nos. 1 and 4. • 50 to160 MG/yr each from shallow and deep zones	• 1 to 3 new wells at 200 to 400 feet deep. • 1,500 feet 6-inch pipe (raw water to treatment) • 3,300 feet 8-inch pipe (raw water to treatment) • 7,200 feet 12- to 16-inch pipe (distribution system) • Treatment capacity upgrades at 1 mgd for iron and manganese removal	100(1)	8.3	8,500	1,800	10,300	• Limited supply • Reliability of ground-water is questionable • Potential conflict with existing users
P2	Groundwater supply from Santa Margarita Aquifer near Beltz/Live Oak	• New wells at existing Beltz Well Site Nos. 1 and 4	• 1 to 3 new wells at 800 to 1,000 feet deep • Treatment for iron and manganese and distribution system upgrades(2)	100	1.0	1,100	300	1,400	• Limited supply • Reliability of ground-water is questionable.
P3	Maximized use of existing sources and storage in Loch Lomond Reservoir	• North Coast supply system upgrades for 20 cfs (12 mgd).	• 77,400 feet of 14-to 36-inch pipe (new North Coast supply pipeline) • Increased capacity of coast/river pump station from 20 to 30 cfs • 5,500 feet of 18-inch pipeline (pump station to Graham Hill WTP) • Pressure filtration at pump station at 30 cfs	600 (3)	38.9	6,600(3)	500(3)	7,100	• Improved operation and reliability but additional supply not sufficient to meet needs • Rigorous and lengthy permitting and environmental impact evaluation process
P4	Desalination	• Unlimited supply available. • Facilities located north/northwest end of City near industrial park. • Use abandoned wastewater outfall for new intake. • Brine disposal in existing wastewater outfall.	• Upgrades to abandoned WW outfall for new intake • New intake pumps • 10,000 feet 36-inch pipe (raw water to treatment) • 16,500 feet 24-inch pipe (treatment water to system) • 10,000 feet 36-inch pipe (brine to WW outfall) • RO treatment facilities(5) • Ancillary support systems for RO(5)	1.5 to 6(6)	18 - 42.1(7)	2,000 - 3,300(7)	2,300 - 3,100(7)	4,300 - 6,400(7)	• Rigorous and lengthy permitting and environmental impact evaluation process • Site for treatment facility not confirmed

Table 5.10 Conceptual Project Alternative Summary (Continued)
Alternative Water Supply Study
City of Santa Cruz

Alterna-tive Number	Project Alternative	General Design Assumptions	Infrastructure Assumptions	Est. New Supply (MG)	Total Estimated Project Cost ($Million)	Amortized Capital Cost ($/MG)	Annual O&M Cost ($/MG)	Total Annualized Cost ($/MG)	Summary of Issues
P5A and P5B	Reclamation In-City and North Coast	• 170 to 230 MG/yr demand offset for in-city application(4) • 500 to 700 MG/yr available supply for North Coast agriculture application(4)	• New filtration and disinfection facilities at 10 mgd • 45,000 feet 18-inch pipe to North Coast farms • 20,000 feet 4-inch pipe to UCSC. • 60,000 feet of 4-to 12-inch pipe to other in-city users • Pump station at 10 mgd, hp varies depending on delivery destination	170 to 230 (in-city) 500 to 700 (Coast Ag)(4)	49.9	5,500	900	6,400	• Water exchange with farmers is most viable project; would need contractual entitlements to groundwater • Site for treatment facility not confirmed
P5B	Reclamation North Coast Only	• 500 to 700 MG/yr available supply for North Coast agriculture application(4)	• New filtration and disinfection facilities at 7 mgd • 45,000 feet 18-inch pipe to North Coast farms • Pump station at 7 mgd, hp varies depending on delivery destination	500 to 700 (Coast Ag)(4)	28.4	4,100	700	4,800	• Water exchange with farmers is most viable project; would need contractual entitlements to groundwater • Site for treatment facility not confirmed

Notes:

(1) Assumes recent estimates of Purisima Aquifer yield are accurate and that water is available even though there are areas of localized low water levels. Estimate also assumes that existing users will not significantly increase pumpage in future from upper zone, and that lower zone can sustain production.
(2) Treatment and distribution system upgrades constructed as part of P1 would be sufficient for the required capacity increase from P2.
(3) Supply available depends on hydrologic conditions; 150 MG/yr in normal years and 600 MG/yr in drought years. Cost estimates assume that upgraded system would provide approximately 600 MG/yr during drought.
(4) In-city applications for outdoor irrigation of parks, school yards, UCSC, golf courses. North Coast application only viable if irrigators agree to groundwater exchange (i.e., groundwater from Santa Margarita Aquifer along North Coast).
(5) RO treatment system includes pretreatment and RO membranes. Ancillary facilities include building, yard piping, chemical systems, pumps, etc.,
(6) The amount of supply provided by desalination would depend on several factors, including supply available from other sources and demand offsets from conservation and curtailment. A range of 1.5 to 6 mgd was assumed in order to bracket a range of expected costs.
(7) Capital cost range for 1.5 to 6 mgd, respectively. Unit capital and unit O&M costs ($/MG) for 6 mgd to 1.5 mgd, respectively (i.e., unit costs are lower for higher capacity facilities).

GLOSSARY OF TERMS

- aquifer — A water-bearing strata below ground surface.
- cfs — Flow rate of water in cubic feet per second.
- drawdown — A term referencing use of groundwater in which the pumpage of groundwater causes localized lowering/deepening of the groundwater level.
- head — A term referencing the available energy to provide flow or water, or available energy (i.e., pressure) in a pipeline.
- mgd — Flow rate of water in million gallons per day.
- overdraft — A term referencing use of groundwater supply in which the amount of pumpage from an aquifer exceeds the recharge capacity.
- yield — A term used in reference to amount of reliable and sustainable water supply from a given source, typically for the period of one year.

  As determined by classical hydrogeologic methods, groundwater yield is estimated with consideration of the soil characteristics in the water-bearing strata (e.g., sand or clay), the size of the water-bearing strata, amount of recharge to the strata, etc. For surface water yield is determined with consideration of rainfall, infiltration/runoff, available storage, etc.

APPENDIX A - COST ESTIMATES

SANTA CRUZ ALTERNATIVE WATER SUPPLY PROJECT

PROJECT COST SUMMARY

PROJECT ALTERNATIVE	AVAILABLE SUPPLY MG	CAPITAL COST	AMMORTIZED CAPITAL $/MG-YR	O&M COST $/YR	UNIT O&M $/MG-YR	TOTAL UNIT COST $/MG-YR
P1 - GW from Purisima @ Beltz	100	$ 8,324,000	$ 8,500	$ 182,900	$ 1,800	$ 10,300
P2 - GW from SntaMrg @Beltz	100	$ 1,031,000	$ 1,100	$ 31,800	$ 300	$ 1,400
P3 - Opt. Exist. Sources						
600 MG	600	$ 38,907,000	$ 6,600	$ 318,700	$ 500	$ 7,100
P4 - Desalination						
1.5 mgd	548	$ 17,995,000	$ 3,300	$ 1,692,163	$ 3,100	$ 6,400
3 mgd	1,095	$ 31,783,000	$ 3,000	$ 2,565,525	$ 2,300	$ 5,300
6 mgd	2,190	$ 42,075,000	$ 2,000	$ 4,968,181	$ 2,300	$ 4,300
P5 Reclamation						
P5A and P5B - NC&City	925	$ 49,883,000	$ 5,500	$ 819,825	$ 900	$ 6,400
P5B - NC Only	700	$ 28,074,000	$ 4,100	$ 479,875	$ 700	$ 4,800

Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Cost Summary - 100 MG Annual Supply

Item	Cost
Construction of Wells	$625,000
Transmission Piping	$355,000
Treatment Facilities	$3,125,000
Distribution Piping	$940,000
Subtotal	**$5,045,000**
Estimating Allowance (25%)	$1,261,250
Construction Contingency (20%)	$1,009,000
Engineering, Legal and Administrative Allowance (20%)	$1,009,000
Total Capital Cost	**$8,324,000**
Amortization for 20 years at 8%	$848,000
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$8,480
O&M Costs	$134,400
Power Costs ($)	$48,500
Unit Production O&M Cost ($/MG)	$1,800
Total Annual Cost ($/MG)	$10,300

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
New Wells - 100 MG Annual Supply

Item		Cost
Construction of Wells		$500,000
Pumps		
Miscellaneous Equipment		
	Subtotal	**$500,000**
Electrical and Instrumentation (25%)		$125,000
	Subtotal	**$625,000**
Estimating Allowance (25%)		$156,250
Construction Contingency (20%)		$125,000
Engineering, Legal and Administrative Allowance (20%)		$125,000
	Total Capital Cost	**$1,031,250**
Amortization for 20 years at 8%		$105,036
Daily Production (mgd)		6
Total Annual Production (MG)		100
Unit Production Capital Cost ($/MG)		$1,050
O&M Costs (2% of Total Capital Cost)		$20,625
Power Costs ($)		$48,500
Unit Production O&M Cost ($/MG)		$690
	Total Annual Cost ($/MG)	$1,740

Notes
1) Cost assumes one well at 200 feet @ $150,000 and one well at 200-400 feet @ $250,000

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Distribution Piping - 100 MG Annual Supply

Item	Cost
Pipeline - Finished to System (12 inch)	$240,000
Pipeline - Finished to System (14 inch)	$380,000
Pipeline - Finished to System (16 inch)	$320,000
Subtotal	**$940,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$940,000**
Estimating Allowance (25%)	$235,000
Construction Contingency (20%)	$188,000
Engineering, Legal and Administrative Allowance (20%)	$188,000
Total Capital Cost	**$1,551,000**
Amortization for 20 years at 8%	$157,970
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$1,600
O&M Costs (.5% of Total Capital Cost)	$7,755
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$80
Total Annual Cost ($/MG)	$1,680

Notes

1) Piping assumes upgrades from existing well sites 4 and 1.
2) Piping from site 4 at 1500 feet of 6 inch diameter;piping from site 1 at 3300 feet of 8 inch diameter
3) Miscellaneous distribution system upgrades around Beltz treatment plant for increased capacity into system; 2000 feet of 16 inch diameter 2700 feet of 14 inch diameter and 2500 feet of 12 inch diameter
4) Pipe costs at $10/dia-inch/ft for installation in existing streets.

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Transmission Piping - 100 MG Annual Supply

Item	Cost
Pipeline - Raw Water (6 inch)	$90,000
Pipeline - Raw Water (8 inch)	$265,000
Subtotal	**$355,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$355,000**
Estimating Allowance (25%)	$88,750
Construction Contingency (20%)	$71,000
Engineering, Legal and Administrative Allowance (20%)	$71,000
Total Capital Cost	**$585,750**
Amortization for 20 years at 8%	$59,700
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$600
O&M Costs (0.5% of Total Capital Cost)	$2,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$30
Total Annual Cost ($/MG)	$630

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Treatment Facilities - 100 MG Annual Supply

Item		Cost
Filtration Vessel and Ancillary Support Facilities		$2,500,000
	Subtotal	**$2,500,000**
Electrical and Instrumentation (25%)		$625,000
	Subtotal	**$3,125,000**
Estimating Allowance (25%)		$781,250
Construction Contingency (20%)		$625,000
Engineering, Legal and Administrative Allowance (20%)		$625,000
	Total Capital Cost	**$5,156,250**
Amortization for 20 years at 8%		$525,178
Daily Production (mgd)		2
Total Annual Production (MG)		100
Unit Production Capital Cost ($/MG)		$5,250
O&M Costs (2% of Total Capital Cost)		$103,125
Power Costs ($)		$0
Unit Production O&M Cost ($/MG)		$1,030
	Total Annual Cost ($/MG)	$6,280

Notes

1) Cost for new treatment facilities assumes upgrade to pressure filtration at 3.5 mgd capacity.
2) Power costs included in power cost for wells; assumes wells provide operating pressure for treatment system

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Cost Summary - 320 MG Annual Supply

Item	Cost
Construction of Wells	$625,000
Transmission Piping	$355,000
Treatment Facilities	$3,125,000
Distribution Piping	$940,000
Subtotal	**$5,045,000**
Estimating Allowance (25%)	$1,261,250
Construction Contingency (20%)	$1,009,000
Engineering, Legal and Administrative Allowance (20%)	$1,009,000
Total Capital Cost	**$8,324,000**
Amortization for 20 years at 8%	$848,000
Total Annual Production (MG)	320
Unit Production Capital Cost ($/MG)	$2,650
O&M Costs	$134,400
Power Costs ($)	$48,500
Unit Production O&M Cost ($/MG)	$600
Total Annual Cost ($/MG)	$3,300

Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
New Wells - 320 MG Annual Supply

Item	Cost
Construction of Wells	$500,000
Pumps	
Miscellaneous Equipment	
Subtotal	**$500,000**
Electrical and Instrumentation (25%)	$125,000
Subtotal	**$625,000**
Estimating Allowance (25%)	$156,250
Construction Contingency (20%)	$125,000
Engineering, Legal and Administrative Allowance (20%)	$125,000
Total Capital Cost	**$1,031,250**
Amortization for 20 years at 8%	$105,036
Daily Production (mgd)	6
Total Annual Production (MG)	320
Unit Production Capital Cost ($/MG)	$330
O&M Costs (2% of Total Capital Cost)	$20,625
Power Costs ($)	$48,500
Unit Production O&M Cost ($/MG)	$220
Total Annual Cost ($/MG)	$550

Notes
1) Cost assumes one well at 200 feet @ $150,000 and one well at 200-400 feet @ $250,000

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Distribution Piping - 320 MG Annual Supply

Item	Cost
Pipeline - Finished to System (12 inch)	$240,000
Pipeline - Finished to System (14 inch)	$380,000
Pipeline - Finished to System (16 inch)	$320,000
Subtotal	**$940,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$940,000**
Estimating Allowance (25%)	$235,000
Construction Contingency (20%)	$188,000
Engineering, Legal and Administrative Allowance (20%)	$188,000
Total Capital Cost	**$1,551,000**
Amortization for 20 years at 8%	$157,970
Total Annual Production (MG)	320
Unit Production Capital Cost ($/MG)	$500
O&M Costs (.5% of Total Capital Cost)	$7,755
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$20
Total Annual Cost ($/MG)	$520

Notes

1) Piping assumes upgrades from existing well sites 4 and 1.
2) Piping from site 4 at 1500 feet of 6 inch diameter;piping from site 1 at 3300 feet of 8 inch diameter
3) Miscellaneous distribution system upgrades around Beltz treatment plant for increased capacity into system; 2000 feet of 16 inch diameter 2700 feet of 14 inch diameter and 2500 feet of 12 inch diameter
4) Pipe costs at $10/dia-inch/ft for installation in existing streets.

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Transmission Piping - 320 MG Annual Supply

Item	Cost
Pipeline - Raw Water (6 inch)	$90,000
Pipeline - Raw Water (8 inch)	$265,000
Subtotal	**$355,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$355,000**
Estimating Allowance (25%)	$88,750
Construction Contingency (20%)	$71,000
Engineering, Legal and Administrative Allowance (20%)	$71,000
Total Capital Cost	**$585,750**
Amortization for 20 years at 8%	$59,700
Total Annual Production (MG)	320
Unit Production Capital Cost ($/MG)	$190
O&M Costs (0.5% of Total Capital Cost)	$2,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$10
Total Annual Cost ($/MG)	$200

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Groundwater from Purisima Aquifer Near Beltz/Live Oak Area (P1)
Treatment Facilities - 320 MG Annual Supply

Item	Cost
Filtration Vessel and Ancillary Support Facilities	$2,500,000
Subtotal	**$2,500,000**
Electrical and Instrumentation (25%)	$625,000
Subtotal	**$3,125,000**
Estimating Allowance (25%)	$781,250
Construction Contingency (20%)	$625,000
Engineering, Legal and Administrative Allowance (20%)	$625,000
Total Capital Cost	**$5,156,250**
Amortization for 20 years at 8%	$525,178
Daily Production (mgd)	2
Total Annual Production (MG)	320
Unit Production Capital Cost ($/MG)	$1,640
O&M Costs (2% of Total Capital Cost)	$103,125
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$320
Total Annual Cost ($/MG)	$1,960

Notes

1) Cost for new treatment facilities assumes upgrade to pressure filtration at 3.5 mgd capacity.
2) Power costs included in power cost for wells; assumes wells provide operating pressure for treatment system

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Groundwater from Santa Margarita Aquifer Near Beltz/Live Oak Area (P2)
Cost Summary

Item	Cost
Construction of Wells	$625,000
Transmission Piping	$0
Treatment Facilities	$0
Distribution Piping	$0
Subtotal	**$625,000**
Estimating Allowance (25%)	$156,250
Construction Contingency (20%)	$125,000
Engineering, Legal and Administrative Allowance (20%)	$125,000
Total Capital Cost	**$1,031,000**
Amortization for 20 years at 8%	$105,000
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$1,050
O&M Costs	$10,300
Power Costs ($)	$21,500
Unit Production O&M Cost ($/MG)	$300
Total Annual Cost ($/MG)	$1,400

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Groundwater from Santa Margarita Aquifer Near Beltz/Live Oak Area (P2)
New Wells

Item	Cost
Construction of Wells	$250,000
Subtotal	**$250,000**
Electrical and Instrumentation (25%)	$62,500
Subtotal	**$312,500**
Estimating Allowance (25%)	$78,125
Construction Contingency (20%)	$62,500
Engineering, Legal and Administrative Allowance (20%)	$62,500
Total Capital Cost	**$515,625**
Amortization for 20 years at 8%	$52,518
Daily Production (mgd)	
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$525
O&M Costs (2% of Total Capital Cost)	$10,313
Power Costs ($)	$22,000
Unit Production O&M Cost ($/MG)	$320.00
Total Annual Cost ($/MG)	$850

Notes

1) Assumes wells would be constructed at existing well sites 4 and 1.
2) Well cost assumes extention of 2 wells from project P1 (i.e., use the same casing) but extend to depth of 1000 feet at additional cost of $250,000/well

Groundwater from Santa Margarita Aquifer Near Beltz/Live Oak Area (P2)
Distribution Piping

Item	Cost
Pipeline - Finished to System (12 inch)	$0
Pipeline - Finished to System (14 inch)	$0
Pipeline - Finished to System (16 inch)	$0
Subtotal	**$0**
Electrical and Instrumentation (0%)	$0
Subtotal	**$0**
Estimating Allowance (25%)	$0
Construction Contingency (20%)	$0
Engineering, Legal and Administrative Allowance (20%)	$0
Total Capital Cost	**$0**
Amortization for 20 years at 8%	$0
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$0
O&M Costs (0.5% of Total Capital Cost)	$0
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$0
Total Annual Cost ($/MG)	$0

1) Assumes piping upgrades from existing well sites 4 and 1 for project P1 would be used at no additional cost.

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Groundwater from Santa Margarita Aquifer Near Beltz/Live Oak Area (P2)
Transmission Piping

Item	Cost
Pipeline - Raw Water (6 inch)	$0
Pipeline - Raw Water (8 inch)	$0
Subtotal	**$0**
Electrical and Instrumentation (0%)	$0
Subtotal	**$0**
Estimating Contingency (25%)	$0
Construction Contingency (20%)	$0
Engineering, Legal and Administrative Contingency (20%)	$0
Total Capital Cost	**$0**
Amortization for 20 years at 8%	$0
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$0
O&M Costs (0.5% of Total Capital Cost)	$0
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$0
Total Annual Cost ($/MG)	$0

Groundwater from Santa Margarita Aquifer Near Beltz/Live Oak Area (P2)
Treatment Facilities

Item	Cost
Filtration Vessel and Ancillary Support Facilities	$0
Subtotal	**$0**
Electrical and Instrumentation (25%)	$0
Subtotal	**$0**
Estimating Allowance (25%)	$0
Construction Contingency (20%)	$0
Engineering, Legal and Administrative Allowance (20%)	$0
Total Capital Cost	**$0**
Amortization for 20 years at 8%	$0
Daily Production (mgd)	6
Total Annual Production (MG)	100
Unit Production Capital Cost ($/MG)	$0
O&M Costs (2% of Total Capital Cost)	$0
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$0
Total Annual Cost ($/MG)	$0

Notes

1) Assumes upgrades at Beltz WTP for project P1 would be used at no additional cost.

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Maximized Use of Existing Sources and Storage In Loch Lomond Reservoir (P3)
Cost Summary (600 MG Incremental Supply)

Item	Cost
North Coast Upgrades	$19,580,000
Coast/San Lorenzo River PS Upgrades	$4,000,000
Subtotal	**$23,580,000**
Estimating Allowance (25%)	$5,895,000
Construction Contingency (20%)	$4,716,000
Engineering, Legal and Administrative Allowance (20%)	$4,716,000
Total Capital Cost	**$38,907,000**
Amortization for 20 years at 8%	$3,963,000
Total Annual Production (MG)	600
Unit Production Capital Cost ($/MG)	$6,600
O&M Costs	$293,500
Power Costs ($)	$25,200
Unit Production O&M Cost ($/MG)	$500
Total Annual Cost ($/MG)	$7,100

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Maximized Use of Existing Sources and Storage In Loch Lomond Reservoir (P3)
North Coast Supply System (600 MG Incremental Supply)

Item	Cost
Pipeline - Majors "Y" to Coast Pump Station (36 inch)	$10,500,000
Pipeline - Lidell "Y" to Majors "Y" (24 inch)	$2,800,000
Pipeline - Majors Diversion Structure to Majors "Y" (20 inch)	$1,800,000
Pipeline - Lidell Diversion Structure to Lidell "Y" (14 inch)	$1,100,000
Pipeline - Laguna Diversion Structure to Laguna "Y" (16 inch)	$1,600,000
Subtotal	**$17,800,000**
Electrical and Instrumentation (10%)	$1,780,000
Subtotal	**$19,580,000**
Estimating Allowance (25%)	$4,895,000
Construction Contingency (20%)	$3,916,000
Engineering, Legal and Administrative Allowance (20%)	$3,916,000
Total Capital Cost	**$32,307,000**
Amortization for 20 years at 8%	$3,290,555
Total Annual Production (MG)	600
Unit Production Capital Cost ($/MG)	$5,500
O&M Costs (0.5% of Total Capital Cost)	$161,500
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$300
Total Annual Cost ($/MG)	$5,800

Notes

1) Cost for piping assumes capacity from each source upt to 8-10 cfs; capacity lower reach of line at 20 cfs.
2) Cost for pipe assumed as $8/dia-inch/foot for installation in open area.
3) Unit production cost assumes that once upgraded system would produce incremental supply of up to 600 MG during drought
4) Electrical/Instrumentation at 10 percent allowance for SCADA upgrades, if needed.

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Maximized Use of Existing Sources and Storage In Loch Lomond Reservoir (P3)
Coast/San Lorenzo River Pump Station (600 MG Incremental Supply)

Item		Cost
Pipeline - Coast Pump Station to GHWTP (18 inch)		$1,000,000
Coast Pumps		$450,000
Pressure Filtration Vessels		$1,750,000
	Subtotal	**$3,200,000**
Electrical and Instrumentation (25%)		$800,000
	Subtotal	**$4,000,000**
Estimating Allowance (25%)		$1,000,000
Construction Contingency (20%)		$800,000
Engineering, Legal and Administrative Allowance (20%)		$800,000
	Total Capital Cost	**$6,600,000**
Amortization for 20 years at 8%		$672,228
Total Annual Production (MG)		600
Unit Production Capital Cost ($/MG)		$1,100
O&M Costs (2% of Total Capital Cost)		$132,000
Power Costs ($)		$25,200
Unit Production O&M Cost ($/MG)		$1,300
	Total Annual Cost ($/MG)	$2,400

Notes

1) Cost for piping assumes 5500 ft 18 inch at $8/dia-inch/ft plus allowance for river crossing
1) Cost for pump station assumes 3 10cfs pumps at 150 hp and allowances for ancilliary piping and building upgrades
2) Cost for filtration vessels includes 30 cfs capacity, misc. site upgrades, and ancilliary piping and support systems.

Maximized Use of Existing Sources and Storage In Loch Lomond Reservoir (P3)
Felton Diversion and Loch Lomond Supply System (600 MG Incremental Supply)

Item		Cost
	Subtotal	**$0**
Electrical and Instrumentation (0%)		$0
	Subtotal	**$0**
Estimating Allowance (25%)		$0
Construction Contingency (20%)		$0
Engineering, Legal and Administrative Allowance (20%)		$0
	Total Capital Cost	**$0**
Amortization for 20 years at 8%		$0
Daily Production (mgd)		0
Total Annual Production (MG)		0
Unit Production Capital Cost ($/MG)		#DIV/0!
O&M Costs (2% of Total Capital Cost)		$0
Power Costs ($)		$0
Unit Production O&M Cost ($/MG)		#DIV/0!
	Total Annual Cost ($/MG)	#DIV/0!

Desalination Facilities - 0.75mgd (P4)
Cost Summary

Item	Cost
Intake Facilities	$311,250
Conveyance System	$3,400,000
Treatment Facilities	$4,612,500
Subtotal	**$8,323,750**
Estimating Allowance (25%)	$2,080,938
Construction Contingency (20%)	$1,664,750
Engineering, Legal and Administrative Allowance (20%)	$1,664,750
Total Capital Cost	**$13,734,000**
Amortization for 20 years at 8%	$1,399,000
Total Annual Production (MG)	274
Unit Production Capital Cost ($/MG)	$5,100
O&M Costs (2% of Total Capital Cost)	$822,513
Power Costs ($)	$203,800
Unit Production O&M Cost ($/MG)	$3,700
Total Annual Cost ($/MG)	$8,800

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Desalination Facilities - 0.75mgd (P4)
Intake Facilities

Item	Cost
Outfall Modifications (Screen and Lining)	$58,000
Tunnel Gate Structure Modifications	$38,000
Pump Station	$96,000
Raw Water Pumps	$38,000
Miscellaneous Equipment	$19,000
Subtotal	**$249,000**
Electrical and Instrumentation (25%)	$62,250
Subtotal	**$311,250**
Estimating Allowance (25%)	$77,813
Construction Contingency (20%)	$62,250
Engineering, Legal and Administrative Allowance (20%)	$62,250
Total Capital Cost	**$513,563**
Amortization for 20 years at 8%	$52,308
Daily Production (mgd)	0.75
Total Annual Production (MG)	273.75
Unit Production Capital Cost ($/MG)	$190
O&M Costs (2% of Total Capital Cost)	$10,300
Power Costs ($)	$20,000
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$290

Notes:

1) O&M assumes routine maintenance for pumps, intake screens, etc.

Desalination Facilities - 0.75mgd (P4)
Conveyance System

Item	Cost
Raw Water Pipe	$800,000
Finished Water Pipe	$2,000,000
Brine Disposal Pipe	$600,000
Subtotal	**$3,400,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$3,400,000**
Estimating Allowance (25%)	$850,000
Construction Contingency (20%)	$680,000
Engineering, Legal and Administrative Allowance (20%)	$680,000
Total Capital Cost	**$5,610,000**
Amortization for 20 years at 8%	$571,394
Daily Production (mgd)	0.75
Total Annual Production (MG)	273.75
Unit Production Capital Cost ($/MG)	$2,087
O&M Costs (0.5% of Total Capital Cost)	$28,050
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$102
Total Annual Cost ($/MG)	$2,190

Notes:

1) O&M assumes minimal routine maintenance for conveyance pipelines.

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Desalination Facilities - 0.75mgd (P4)
MF Pretreatment

Item	Cost	
Preliminary Screens (200 micron strainer)	$20,000	
Microfiltration Units	$400,000	
Backwash System (Pumps, Valving and Storage Tanks)	$20,000	
Chemical Cleaning System (Pumps, Valving and Storage Tanks)	$60,000	
Miscellaneous Equipment	$20,000	
Subtotal	**$520,000**	
Electrical and Instrumentation (25%)	$130,000	
Subtotal	**$650,000**	
Estimating Allowance (25%)	$162,500	
Construction Contingency (20%)	$130,000	
Engineering, Legal and Administrative Allowance (20%)	$130,000	
Total Capital Cost	**$1,072,500**	
Amortization for 20 years at 8%	$109,200	
Daily Production (mgd)	0.75	
Total Annual Production (MG)	273.75	
Unit Production Capital Cost ($/MG)	$400	
O&M Costs (10% of Total Capital Cost)	$107,250	
Power Costs ($)	$0	<= Included in Intake Facility Costs
Unit Production O&M Cost ($/MG)	$392	
Total Annual Cost ($/MG)	$792	

Notes:

1) O&M assumes routine maintenance MF pretreatment (cleaning) plus allowance for annual membrane replacement.

Desalination Facilities -0.75mgd (P4)
UV Disinfection

Item	Cost	
UV Units	$400,000	
Miscellaneous Equipment (Piping and Valving)	$200,000	
Subtotal	**$600,000**	
Electrical and Instrumentation (25%)	$150,000	
Subtotal	**$750,000**	
Estimating Allowance (25%)	$187,500	
Construction Contingency (20%)	$150,000	
Engineering, Legal and Administrative Allowance (20%)	$150,000	
Total Capital Cost	**$1,237,500**	
Amortization for 20 years at 8%	$126,043	
Daily Production (mgd)	0.75	
Total Annual Production (MG)	273.75	
Unit Production Capital Cost ($/MG)	$460	
O&M Costs (1% of Total Capital Cost)	$12,375	
Power Costs ($)	$17,800	<=65$/MG
Unit Production O&M Cost ($/MG)	$100	
Total Annual Cost ($/MG)	$560	

Notes:

1) O&M assumes routine maintenance UV units (cleaning) plus allowance for annual lamp replacement.

Desalination Facilities -0.75mgd (P4)
Chemical Pretreatment

Item	Cost
Anti-scalant Metering Pumps	$10,000
Anti-scalant Storage Tanks	$10,000
Anti-scalant Piping and Valves	$10,000
pH Adjustment Metering Pumps	$10,000
pH Adjustment Storage Tanks	$10,000
pH Adjustment Piping and Valves	$10,000
Subtotal	**$60,000**
Electrical and Instrumentation (25%)	$15,000
Subtotal	**$75,000**
Estimating Allowance (25%)	$18,750
Construction Contingency (20%)	$15,000
Engineering, Legal and Administrative Allowance (20%)	$15,000
Total Capital Cost	**$123,750**
Amortization for 20 years at 8%	$12,600
Daily Production (mgd)	0.75
Total Annual Production (MG)	273.75
Unit Production Capital Cost ($/MG)	$50
O&M Costs (25% of Total Capital Cost)	$30,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$150

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

Desalination Facilities - 0.75mgd (P4)
RO System

Item	Cost
High Pressure Pumps	$200,000
Energy Recovery Turbines	$200,000
RO Units	$1,000,000
Membrane Cleaning Skid	$200,000
Miscellaneous Equipment (Piping and Valves)	$200,000
Subtotal	**$1,800,000**
Electrical and Instrumentation (25%)	$450,000
Subtotal	**$2,250,000**
Estimating Allowance (25%)	$562,500
Construction Contingency (20%)	$450,000
Engineering, Legal and Administrative Allowance (20%)	$450,000
Total Capital Cost	**$3,712,500**
Amortization for 20 years at 8%	$378,128
Daily Production (mgd)	0.75
Total Annual Production (MG)	273.75
Unit Production Capital Cost ($/MG)	$1,381
O&M Costs (15% of Total Capital Cost)	$556,875
Power Costs ($)	$3,800
Unit Production O&M Cost ($/MG)	$7,101
Total Annual Cost ($/MG)	$8,482

Notes:

1) O&M assumes routine maintenance for RO membranes (cleaning) plus allowance for annual membrane replacement.

Desalination Facilities - 0.75mgd (P4)
Chemical Post-Treatment

Item	Cost
Corrosion Control Metering Pumps	$10,000
Corrosion Control Storage Tanks	$20,000
Corrosion Control Piping and Valves	$20,000
Disinfectant Metering Pumps	$10,000
Disinfectant Storage Tanks	$20,000
Disinfectant Piping and Valves	$20,000
Subtotal	**$100,000**
Electrical and Instrumentation (25%)	$25,000
Subtotal	**$125,000**
Estimating Allowance (25%)	$31,250
Construction Contingency (20%)	$25,000
Engineering, Legal and Administrative Allowance (20%)	$25,000
Total Capital Cost	**$206,250**
Amortization for 20 years at 8%	$21,000
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$20
O&M Costs (25% of Total Capital Cost)	$51,600
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$0
Total Annual Cost ($/MG)	$20

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

Desalination Facilities - 0.75mgd (P4)
Ancillary Support Facilites

Item	Cost
Purchase Land (Allowance)	$60,000
Brine Pump Station	$40,000
Brine Pumps	$30,000
Finished Water Pumps	$130,000
Carbon Dioxide Storage Tank	$40,000
Carbon Dioxide Evaporation and Feed System	$40,000
Operations Building	$270,000
Subtotal	**$610,000**
Electrical and Instrumentation (25%)	$152,500
Subtotal	**$762,500**
Estimating Allowance (25%)	$190,625
Construction Contingency (20%)	$152,500
Engineering, Legal and Administrative Allowance (20%)	$152,500
Total Capital Cost	**$1,258,125**
Amortization for 20 years at 8%	$128,100
Daily Production (mgd)	0.75
Total Annual Production (MG)	273.75
Unit Production Capital Cost ($/MG)	$500
O&M Costs (2% of Total Capital Cost)	$25,163
Power Costs ($)	$300
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$600

Notes:

1) O&M assumes routine maintenance for pumps and other facilities.

Desalination Facilities - 1.5mgd (P4)
Cost Summary

Item	Cost
Intake Facilities	$493,750
Conveyance System	$3,400,000
Treatment Facilities	$7,012,500
Subtotal	**$10,906,250**
Estimating Allowance (25%)	$2,726,563
Construction Contingency (20%)	$2,181,250
Engineering, Legal and Administrative Allowance (20%)	$2,181,250
Total Capital Cost	**$17,995,000**
Amortization for 20 years at 8%	$1,833,000
Total Annual Production (MG)	548
Unit Production Capital Cost ($/MG)	$3,300
O&M Costs (2% of Total Capital Cost)	$1,271,563
Power Costs ($)	$420,600
Unit Production O&M Cost ($/MG)	$3,100
Total Annual Cost ($/MG)	$6,400

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Desalination Facilities -1.5mgd (P4)
Intake Facilities

Item	Cost
Outfall Modifications (Screen and Lining)	$91,000
Tunnel Gate Structure Modifications	$61,000
Pump Station	$152,000
Raw Water Pumps	$61,000
Miscellaneous Equipment	$30,000
Subtotal	**$395,000**
Electrical and Instrumentation (25%)	$98,750
Subtotal	**$493,750**
Estimating Allowance (25%)	$123,438
Construction Contingency (20%)	$98,750
Engineering, Legal and Administrative Allowance (20%)	$98,750
Total Capital Cost	**$814,688**
Amortization for 20 years at 8%	$82,978
Daily Production (mgd)	1.5
Total Annual Production (MG)	547.5
Unit Production Capital Cost ($/MG)	$150
O&M Costs (2% of Total Capital Cost)	$16,300
Power Costs ($)	$44,000
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$250

Notes:

1) O&M assumes routine maintenance for pumps, intake screens, etc.

Desalination Facilities - 1.5mgd (P4)
Conveyance System

Item	Cost
Raw Water Pipe	$800,000
Finished Water Pipe	$2,000,000
Brine Disposal Pipe	$600,000
Subtotal	**$3,400,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$3,400,000**
Estimating Allowance (25%)	$850,000
Construction Contingency (20%)	$680,000
Engineering, Legal and Administrative Allowance (20%)	$680,000
Total Capital Cost	**$5,610,000**
Amortization for 20 years at 8%	$571,394
Daily Production (mgd)	1.5
Total Annual Production (MG)	547.5
Unit Production Capital Cost ($/MG)	$1,044
O&M Costs (0.5% of Total Capital Cost)	$28,050
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$51
Total Annual Cost ($/MG)	$1,095

Notes:

1) O&M assumes minimal routine maintenance for conveyance pipelines.

Desalination Facilities - 1.5mgd (P4)
MF Pretreatment

Item	Cost	
Preliminary Screens (200 micron strainer)	$30,000	
Microfiltration Units	$600,000	
Backwash System (Pumps, Valving and Storage Tanks)	$30,000	
Chemical Cleaning System (Pumps, Valving and Storage Tanks)	$90,000	
Miscellaneous Equipment	$30,000	
Subtotal	**$780,000**	
Electrical and Instrumentation (25%)	$195,000	
Subtotal	**$975,000**	
Estimating Allowance (25%)	$243,750	
Construction Contingency (20%)	$195,000	
Engineering, Legal and Administrative Allowance (20%)	$195,000	
Total Capital Cost	**$1,608,750**	
Amortization for 20 years at 8%	$163,900	
Daily Production (mgd)	1.5	
Total Annual Production (MG)	547.5	
Unit Production Capital Cost ($/MG)	$300	
O&M Costs (10% of Total Capital Cost)	$160,875	
Power Costs ($)	$0	<= Included in Intake Facility Costs
Unit Production O&M Cost ($/MG)	$294	
Total Annual Cost ($/MG)	$594	

Notes:

1) O&M assumes routine maintenance MF pretreatment (cleaning) plus allowance for annual membrane replacement.

Desalination Facilities -1.5mgd (P4)
UV Disinfection

Item	Cost	
UV Units	$600,000	
Miscellaneous Equipment (Piping and Valving)	$200,000	
Subtotal	**$800,000**	
Electrical and Instrumentation (25%)	$200,000	
Subtotal	**$1,000,000**	
Estimating Allowance (25%)	$250,000	
Construction Contingency (20%)	$200,000	
Engineering, Legal and Administrative Allowance (20%)	$200,000	
Total Capital Cost	**$1,650,000**	
Amortization for 20 years at 8%	$168,057	
Daily Production (mgd)	1.5	
Total Annual Production (MG)	547.5	
Unit Production Capital Cost ($/MG)	$307	
O&M Costs (1% of Total Capital Cost)	$16,500	
Power Costs ($)	$35,600	<=65$/MG
Unit Production O&M Cost ($/MG)	$100	
Total Annual Cost ($/MG)	$407	

Notes:

1) O&M assumes routine maintenance UV units (cleaning) plus allowance for annual lamp replacement.

Desalination Facilities -1.5mgd (P4)
Chemical Pretreatment

Item	Cost
Anti-scalant Metering Pumps	$20,000
Anti-scalant Storage Tanks	$20,000
Anti-scalant Piping and Valves	$20,000
pH Adjustment Metering Pumps	$20,000
pH Adjustment Storage Tanks	$20,000
pH Adjustment Piping and Valves	$20,000
Subtotal	**$120,000**
Electrical and Instrumentation (25%)	$30,000
Subtotal	**$150,000**
Estimating Allowance (25%)	$37,500
Construction Contingency (20%)	$30,000
Engineering, Legal and Administrative Allowance (20%)	$30,000
Total Capital Cost	**$247,500**
Amortization for 20 years at 8%	$25,200
Daily Production (mgd)	1.5
Total Annual Production (MG)	547.5
Unit Production Capital Cost ($/MG)	$50
O&M Costs (25% of Total Capital Cost)	$61,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$150

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

Desalination Facilities - 1.5mgd (P4)
RO System

Item	Cost
High Pressure Pumps	$300,000
Energy Recovery Turbines	$300,000
RO Units	$1,500,000
Membrane Cleaning Skid	$400,000
Miscellaneous Equipment (Piping and Valves)	$300,000
Subtotal	**$2,800,000**
Electrical and Instrumentation (25%)	$700,000
Subtotal	**$3,500,000**
Estimating Allowance (25%)	$875,000
Construction Contingency (20%)	$700,000
Engineering, Legal and Administrative Allowance (20%)	$700,000
Total Capital Cost	**$5,775,000**
Amortization for 20 years at 8%	$588,199
Daily Production (mgd)	1.5
Total Annual Production (MG)	547.5
Unit Production Capital Cost ($/MG)	$1,074
O&M Costs (15% of Total Capital Cost)	$866,250
Power Costs ($)	$3,800
Unit Production O&M Cost ($/MG)	$4,116
Total Annual Cost ($/MG)	$5,190

Notes:

1) O&M assumes routine maintenance for RO membranes (cleaning) plus allowance for annual membrane replacement.

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Desalination Facilities - 1.5mgd (P4)
Chemical Post-Treatment

Item	Cost
Corrosion Control Metering Pumps	$20,000
Corrosion Control Storage Tanks	$30,000
Corrosion Control Piping and Valves	$30,000
Disinfectant Metering Pumps	$20,000
Disinfectant Storage Tanks	$30,000
Disinfectant Piping and Valves	$30,000
Subtotal	**$160,000**
Electrical and Instrumentation (25%)	$40,000
Subtotal	**$200,000**
Estimating Allowance (25%)	$50,000
Construction Contingency (20%)	$40,000
Engineering, Legal and Administrative Allowance (20%)	$40,000
Total Capital Cost	**$330,000**
Amortization for 20 years at 8%	$33,600
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$30
O&M Costs (25% of Total Capital Cost)	$82,500
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$130

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

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Desalination Facilities - 1.5mgd (P4)
Ancillary Support Facilites

Item	Cost
Purchase Land (Allowance)	$90,000
Brine Pump Station	$60,000
Brine Pumps	$50,000
Finished Water Pumps	$200,000
Carbon Dioxide Storage Tank	$60,000
Carbon Dioxide Evaporation and Feed System	$60,000
Operations Building	$430,000
Subtotal	**$950,000**
Electrical and Instrumentation (25%)	$237,500
Subtotal	**$1,187,500**
Estimating Allowance (25%)	$296,875
Construction Contingency (20%)	$237,500
Engineering, Legal and Administrative Allowance (20%)	$237,500
Total Capital Cost	**$1,959,375**
Amortization for 20 years at 8%	$199,600
Daily Production (mgd)	1.5
Total Annual Production (MG)	547.5
Unit Production Capital Cost ($/MG)	$400
O&M Costs (2% of Total Capital Cost)	$39,188
Power Costs ($)	$300
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$500

Notes:

1) O&M assumes routine maintenance for pumps and other facilities.

Desalination Facilities - 3mgd (P4)
Cost Summary

Item	Cost
Intake Facilities	$812,500
Conveyance System	$7,000,000
Treatment Facilities	$11,450,000
Subtotal	**$19,262,500**
Estimating Allowance (25%)	$4,815,625
Construction Contingency (20%)	$3,852,500
Engineering, Legal and Administrative Allowance (20%)	$3,852,500
Total Capital Cost	**$31,783,000**
Amortization for 20 years at 8%	$3,237,000
Total Annual Production (MG)	1,095
Unit Production Capital Cost ($/MG)	$3,000
O&M Costs (2% of Total Capital Cost)	$1,648,325
Power Costs ($)	$917,200
Unit Production O&M Cost ($/MG)	$2,300
Total Annual Cost ($/MG)	$5,300

Desalination Facilities - 3mgd (P4)
Intake Facilities

Item	Cost
Outfall Modifications (Screen and Lining)	$150,000
Tunnel Gate Structure Modifications	$100,000
Pump Station	$250,000
Raw Water Pumps	$100,000
Miscellaneous Equipment	$50,000
Subtotal	**$650,000**
Electrical and Instrumentation (25%)	$162,500
Subtotal	**$812,500**
Estimating Allowance (25%)	$203,125
Construction Contingency (20%)	$162,500
Engineering, Legal and Administrative Allowance (20%)	$162,500
Total Capital Cost	**$1,340,625**
Amortization for 20 years at 8%	$136,546
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$120
O&M Costs (2% of Total Capital Cost)	$26,800
Power Costs ($)	$83,000
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$220

Notes:

1) O&M assumes routine maintenance for pumps, intake screens, etc.

Desalination Facilities - 3mgd (P4)
Conveyance System

Item	Cost
Raw Water Pipe	$1,500,000
Finished Water Pipe	$4,000,000
Brine Disposal Pipe	$1,500,000
Subtotal	**$7,000,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$7,000,000**
Estimating Allowance (25%)	$1,750,000
Construction Contingency (20%)	$1,400,000
Engineering, Legal and Administrative Allowance (20%)	$1,400,000
Total Capital Cost	**$11,550,000**
Amortization for 20 years at 8%	$1,176,399
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$1,074
O&M Costs (0.5% of Total Capital Cost)	$57,750
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$53
Total Annual Cost ($/MG)	$1,127

Notes:

1) O&M assumes minimal routine maintenance for conveyance pipelines.

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Desalination Facilities - 3mgd (P4)
MF Pretreatment

Item	Cost	
Preliminary Screens (200 micron strainer)	$50,000	
Microfiltration Units	$1,000,000	
Backwash System (Pumps, Valving and Storage Tanks)	$50,000	
Chemical Cleaning System (Pumps, Valving and Storage Tanks)	$150,000	
Miscellaneous Equipment	$50,000	
Subtotal	**$1,300,000**	
Electrical and Instrumentation (25%)	$325,000	
Subtotal	**$1,625,000**	
Estimating Allowance (25%)	$406,250	
Construction Contingency (20%)	$325,000	
Engineering, Legal and Administrative Allowance (20%)	$325,000	
Total Capital Cost	**$2,681,250**	
Amortization for 20 years at 8%	$273,100	
Daily Production (mgd)	3	
Total Annual Production (MG)	1095	
Unit Production Capital Cost ($/MG)	$200	
O&M Costs (10% of Total Capital Cost)	$268,125	
Power Costs ($)	$0	<= Included in Intake Facility Costs
Unit Production O&M Cost ($/MG)	$245	
Total Annual Cost ($/MG)	$445	

Notes:

1) O&M assumes routine maintenance MF pretreatment (cleaning) plus allowance for annual membrane replacement.

Desalination Facilities - 3mgd (P4)
UV Disinfection

Item	Cost	
UV Units	$1,000,000	
Miscellaneous Equipment (Piping and Valving)	$200,000	
Subtotal	**$1,200,000**	
Electrical and Instrumentation (25%)	$300,000	
Subtotal	**$1,500,000**	
Estimating Allowance (25%)	$375,000	
Construction Contingency (20%)	$300,000	
Engineering, Legal and Administrative Allowance (20%)	$300,000	
Total Capital Cost	**$2,475,000**	
Amortization for 20 years at 8%	$252,085	
Daily Production (mgd)	3	
Total Annual Production (MG)	1095	
Unit Production Capital Cost ($/MG)	$230	
O&M Costs (1% of Total Capital Cost)	$24,750	
Power Costs ($)	$71,200	<=65$/MG
Unit Production O&M Cost ($/MG)	$100	
Total Annual Cost ($/MG)	$330	

Notes:

1) O&M assumes routine maintenance UV units (cleaning) plus allowance for annual lamp replacement.

Desalination Facilities - 3mgd (P4)
Chemical Pretreatment

Item	Cost
Anti-scalant Metering Pumps	$25,000
Anti-scalant Storage Tanks	$50,000
Anti-scalant Piping and Valves	$50,000
pH Adjustment Metering Pumps	$25,000
pH Adjustment Storage Tanks	$50,000
pH Adjustment Piping and Valves	$50,000
Subtotal	**$250,000**
Electrical and Instrumentation (25%)	$62,500
Subtotal	**$312,500**
Estimating Allowance (25%)	$78,125
Construction Contingency (20%)	$62,500
Engineering, Legal and Administrative Allowance (20%)	$62,500
Total Capital Cost	**$515,625**
Amortization for 20 years at 8%	$52,500
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$50
O&M Costs (25% of Total Capital Cost)	$128,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$150

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

Desalination Facilities - 3mgd (P4)
RO System

Item	Cost
High Pressure Pumps	$500,000
Energy Recovery Turbines	$500,000
RO Units	$2,500,000
Membrane Cleaning Skid	$600,000
Miscellaneous Equipment (Piping and Valves)	$500,000
Subtotal	**$4,600,000**
Electrical and Instrumentation (25%)	$1,150,000
Subtotal	**$5,750,000**
Estimating Allowance (25%)	$1,437,500
Construction Contingency (20%)	$1,150,000
Engineering, Legal and Administrative Allowance (20%)	$1,150,000
Total Capital Cost	**$9,487,500**
Amortization for 20 years at 8%	$966,327
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$882
O&M Costs (10% of Total Capital Cost)	$948,750
Power Costs ($)	$3,800
Unit Production O&M Cost ($/MG)	$2,133
Total Annual Cost ($/MG)	$3,016

Notes:

1) O&M assumes routine maintenance for RO membranes (cleaning) plus allowance for annual membrane replacement.

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Desalination Facilities - 3mgd (P4)
Chemical Post-Treatment

Item	Cost
Corrosion Control Metering Pumps	$25,000
Corrosion Control Storage Tanks	$50,000
Corrosion Control Piping and Valves	$50,000
Disinfectant Metering Pumps	$25,000
Disinfectant Storage Tanks	$50,000
Disinfectant Piping and Valves	$50,000
Subtotal	**$250,000**
Electrical and Instrumentation (25%)	$62,500
Subtotal	**$312,500**
Estimating Allowance (25%)	$78,125
Construction Contingency (20%)	$62,500
Engineering, Legal and Administrative Allowance (20%)	$62,500
Total Capital Cost	**$515,625**
Amortization for 20 years at 8%	$52,500
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$50
O&M Costs (25% of Total Capital Cost)	$128,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$150

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

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Desalination Facilities - 3mgd (P4)
Ancillary Support Facilites

Item	Cost
Purchase Land (Allowance)	$150,000
Brine Pump Station	$100,000
Brine Pumps	$75,000
Finished Water Pumps	$335,000
Carbon Dioxide Storage Tank	$100,000
Carbon Dioxide Evaporation and Feed System	$100,000
Operations Building	$700,000
Subtotal	**$1,560,000**
Electrical and Instrumentation (25%)	$390,000
Subtotal	**$1,950,000**
Estimating Allowance (25%)	$487,500
Construction Contingency (20%)	$390,000
Engineering, Legal and Administrative Allowance (20%)	$390,000
Total Capital Cost	**$3,217,500**
Amortization for 20 years at 8%	$327,700
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$300
O&M Costs (2% of Total Capital Cost)	$64,350
Power Costs ($)	$300
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$400

Notes:

1) O&M assumes routine maintenance for pumps and other facilities.

Desalination Facilities - 6mgd (P4)
Cost Summary

Item	Cost
Intake Facilities	$812,500
Conveyance System	$7,000,000
Treatment Facilities	$17,700,000
Subtotal	**$25,512,500**
Estimating Allowance (25%)	$6,378,125
Construction Contingency (20%)	$5,102,500
Engineering, Legal and Administrative Allowance (20%)	$5,102,500
Total Capital Cost	**$42,096,000**
Amortization for 20 years at 8%	$4,288,000
Total Annual Production (MG)	2,190
Unit Production Capital Cost ($/MG)	$2,000
O&M Costs (2% of Total Capital Cost)	$3,277,700
Power Costs ($)	$1,745,400
Unit Production O&M Cost ($/MG)	$2,300
Total Annual Cost ($/MG)	$4,300

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Desalination Facilities - 6mgd (P4)
Intake Facilities

Item	Cost
Outfall Modifications (Screen and Lining)	$150,000
Tunnel Gate Structure Modifications	$100,000
Pump Station	$250,000
Raw Water Pumps	$100,000
Miscellaneous Equipment	$50,000
Subtotal	**$650,000**
Electrical and Instrumentation (25%)	$162,500
Subtotal	**$812,500**
Estimating Allowance (25%)	$203,125
Construction Contingency (20%)	$162,500
Engineering, Legal and Administrative Allowance (20%)	$162,500
Total Capital Cost	**$1,340,625**
Amortization for 20 years at 8%	$136,546
Daily Production (mgd)	6
Total Annual Production (MG)	2190
Unit Production Capital Cost ($/MG)	$60
O&M Costs (2% of Total Capital Cost)	$26,800
Power Costs ($)	$163,000
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$160

Notes:

1) O&M assumes routine maintenance for pumps, intake screens, etc.

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Desalination Facilities - 6mgd (P4)
Conveyance System

Item	Cost
Raw Water Pipe	$1,500,000
Finished Water Pipe	$4,000,000
Brine Disposal Pipe	$1,500,000
Subtotal	**$7,000,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$7,000,000**
Estimating Allowance (25%)	$1,750,000
Construction Contingency (20%)	$1,400,000
Engineering, Legal and Administrative Allowance (20%)	$1,400,000
Total Capital Cost	**$11,550,000**
Amortization for 20 years at 8%	$1,176,399
Daily Production (mgd)	6
Total Annual Production (MG)	2190
Unit Production Capital Cost ($/MG)	$537
O&M Costs (0.5% of Total Capital Cost)	$57,750
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$26
Total Annual Cost ($/MG)	$564

Notes:

1) O&M assumes minimal routine maintenance for conveyance pipelines.

Desalination Facilities - 6mgd (P4)
MF Pretreatment

Item	Cost	
Preliminary Screens (200 micron strainer)	$50,000	
Microfiltration Units	$2,000,000	
Backwash System (Pumps, Valving and Storage Tanks)	$50,000	
Chemical Cleaning System (Pumps, Valving and Storage Tanks)	$150,000	
Miscellaneous Equipment	$50,000	
Subtotal	**$2,300,000**	
Electrical and Instrumentation (25%)	$575,000	
Subtotal	**$2,875,000**	
Estimating Allowance (25%)	$718,750	
Construction Contingency (20%)	$575,000	
Engineering, Legal and Administrative Allowance (20%)	$575,000	
Total Capital Cost	**$4,743,750**	
Amortization for 20 years at 8%	$483,200	
Daily Production (mgd)	6	
Total Annual Production (MG)	2190	
Unit Production Capital Cost ($/MG)	$200	
O&M Costs (10% of Total Capital Cost)	$474,375	
Power Costs ($)	$0	<= Included in Intake Facility Costs
Unit Production O&M Cost ($/MG)	$217	
Total Annual Cost ($/MG)	$417	

Notes:

1) O&M assumes routine maintenance MF pretreatment (cleaning) plus allowance for annual membrane replacement.

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Desalination Facilities - 6mgd (P4)
UV Disinfection

Item	Cost	
UV Units	$2,000,000	
Miscellaneous Equipment (Piping and Valving)	$200,000	
Subtotal	**$2,200,000**	
Electrical and Instrumentation (25%)	$550,000	
Subtotal	**$2,750,000**	
Estimating Allowance (25%)	$687,500	
Construction Contingency (20%)	$550,000	
Engineering, Legal and Administrative Allowance (20%)	$550,000	
Total Capital Cost	**$4,537,500**	
Amortization for 20 years at 8%	$462,157	
Daily Production (mgd)	6	
Total Annual Production (MG)	2190	
Unit Production Capital Cost ($/MG)	$211	
O&M Costs (1% of Total Capital Cost)	$45,375	
Power Costs ($)	$142,400	<=65$/MG
Unit Production O&M Cost ($/MG)	$100	
Total Annual Cost ($/MG)	$311	

Notes:

1) O&M assumes routine maintenance UV units (cleaning) plus allowance for annual lamp replacement.

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Desalination Facilities - 6mgd (P4)
Chemical Pretreatment

Item	Cost
Anti-scalant Metering Pumps	$25,000
Anti-scalant Storage Tanks	$50,000
Anti-scalant Piping and Valves	$50,000
pH Adjustment Metering Pumps	$25,000
pH Adjustment Storage Tanks	$50,000
pH Adjustment Piping and Valves	$50,000
Subtotal	**$250,000**
Electrical and Instrumentation (25%)	$62,500
Subtotal	**$312,500**
Estimating Allowance (25%)	$78,125
Construction Contingency (20%)	$62,500
Engineering, Legal and Administrative Allowance (20%)	$62,500
Total Capital Cost	**$515,625**
Amortization for 20 years at 8%	$52,500
Daily Production (mgd)	6
Total Annual Production (MG)	2190
Unit Production Capital Cost ($/MG)	$20
O&M Costs (25% of Total Capital Cost)	$128,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$120

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

Desalination Facilities - 6mgd (P4)
RO System

Item	Cost
High Pressure Pumps	$1,000,000
Energy Recovery Turbines	$500,000
RO Units	$5,000,000
Membrane Cleaning Skid	$600,000
Miscellaneous Equipment (Piping and Valves)	$500,000
Subtotal	**$7,600,000**
Electrical and Instrumentation (25%)	$1,900,000
Subtotal	**$9,500,000**
Estimating Allowance (25%)	$2,375,000
Construction Contingency (20%)	$1,900,000
Engineering, Legal and Administrative Allowance (20%)	$1,900,000
Total Capital Cost	**$15,675,000**
Amortization for 20 years at 8%	$1,596,541
Daily Production (mgd)	6
Total Annual Production (MG)	2190
Unit Production Capital Cost ($/MG)	$729
O&M Costs (15% of Total Capital Cost)	$2,351,250
Power Costs ($)	$3,800
Unit Production O&M Cost ($/MG)	$1,707
Total Annual Cost ($/MG)	$2,436

Notes:

1) O&M assumes routine maintenance for RO membranes (cleaning) plus allowance for annual membrane replacement.

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Desalination Facilities - 6mgd (P4)
Chemical Post-Treatment

Item	Cost
Corrosion Control Metering Pumps	$25,000
Corrosion Control Storage Tanks	$50,000
Corrosion Control Piping and Valves	$50,000
Disinfectant Metering Pumps	$25,000
Disinfectant Storage Tanks	$50,000
Disinfectant Piping and Valves	$50,000
Subtotal	**$250,000**
Electrical and Instrumentation (25%)	$62,500
Subtotal	**$312,500**
Estimating Allowance (25%)	$78,125
Construction Contingency (20%)	$62,500
Engineering, Legal and Administrative Allowance (20%)	$62,500
Total Capital Cost	**$515,625**
Amortization for 20 years at 8%	$52,500
Daily Production (mgd)	3
Total Annual Production (MG)	1095
Unit Production Capital Cost ($/MG)	$50
O&M Costs (25% of Total Capital Cost)	$128,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$150

Notes:

1) O&M assumes routine maintenance for chem systems plus allowance for annual cost of chemicals.

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Desalination Facilities - 6mgd (P4)
Ancillary Support Facilites

Item	Cost
Purchase Land (Allowance)	$150,000
Brine Pump Station	$100,000
Brine Pumps	$75,000
Finished Water Pumps	$335,000
Carbon Dioxide Storage Tank	$100,000
Carbon Dioxide Evaporation and Feed System	$100,000
Operations Building	$700,000
Subtotal	**$1,560,000**
Electrical and Instrumentation (25%)	$390,000
Subtotal	**$1,950,000**
Estimating Allowance (25%)	$487,500
Construction Contingency (20%)	$390,000
Engineering, Legal and Administrative Allowance (20%)	$390,000
Total Capital Cost	**$3,217,500**
Amortization for 20 years at 8%	$327,700
Daily Production (mgd)	6
Total Annual Production (MG)	2190
Unit Production Capital Cost ($/MG)	$100
O&M Costs (2% of Total Capital Cost)	$64,350
Power Costs ($)	$300
Unit Production O&M Cost ($/MG)	$0
Total Annual Cost ($/MG)	$100

Notes:

1) O&M assumes routine maintenance for pumps and other facilities.

Wastewater Reclamation - North Coast and In-City Municipal (P5A)
Cost Summary

Item	Cost
Treatment Facilities	$15,937,700
Distribution PS and Piping	$10,520,000
Storage Reservoir	$2,167,000
New Wells	$1,607,500
Subtotal	**$30,232,200**
Estimating Allowance (25%)	$7,558,050
Construction Contingency (20%)	$6,046,440
Engineering, Legal and Administrative Allowance (20%)	$6,046,440
Total Capital Cost	**$49,883,000**
Amortization for 20 years at 8%	$5,081,000
Total Annual Production (MG)	925
Unit Production Capital Cost ($/MG)	$5,500
O&M Costs	$646,025
Power Costs ($)	$173,800
Unit Production O&M Cost ($/MG)	$900
Total Annual Cost ($/MG)	$6,400

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Wastewater Reclamation - North Coast and In-City Municipal (P5A)
Treatment Facilities

Item		Cost
Filtration and Ancillary Facilities		$5,250,000
Chemical Feed Storage		$150
Disinfection		$7,500,000
	Subtotal	**$12,750,150**
Electrical and Instrumentation (25%)		$3,187,500
	Subtotal	**$15,937,700**
Estimating Allowance (25%)		$3,984,425
Construction Contingency (20%)		$3,187,540
Engineering, Legal and Administrative Contingency (20%)		$3,187,540
	Total Capital Cost	**$26,297,205**
Amortization for 20 years at 8%		$2,678,400
Daily Production (mgd)		8.5
Total Annual Production (MG)		925
Unit Production Capital Cost ($/MG)		$2,900
O&M Costs (2% of Total Capital Cost)		$525,900
Power Costs ($)		$3,000
Unit Production O&M Cost ($/MG)		$600
	Total Annual Cost ($/MG)	$3,500

Notes:

1) Filtration cost estimate assumes gravity media filtration plus allowance for associated piping and valving
2) Disinfection estimate allowance for chlorine or UV disinfection system

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Wastewater Reclamation - North Coast and In-City Municipal (P5A)
Distribution Pump Station

Item	Cost
North Coast Pumps	$300,000
Municipal Pumps	$200,000
Subtotal	**$500,000**
Electrical and Instrumentation (25%)	$125,000
Subtotal	**$625,000**
Estimating Allowance (25%)	$156,250
Construction Contingency (20%)	$125,000
Engineering, Legal and Administrative Contingency (20%)	$125,000
Total Capital Cost	**$1,031,250**
Amortization for 20 years at 8%	$105,036
Daily Production (mgd)	8.5
Total Annual Production (MG)	925
Unit Production Capital Cost ($/MG)	$100
O&M Costs (2% of Total Capital Cost)	$20,625
Power Costs ($)	$ 62,600
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$200

Notes

1) North Coast pumps assume 3 at 3.5 mgd at 300 hp each
2) Municipal pumps assume 2 at 0.5 mgd at 100 hp for UCSC and 3 for other city applications at 1 mgd each, 150 hp

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Wastewater Reclamation - North Coast and In-City Municipal (P5A)
Reservoir

Item	Cost
Reservoir	$1,970,000
Subtotal	**$1,970,000**
Electrical and Instrumentation (10%)	$197,000
Subtotal	**$2,167,000**
Estimating Allowance (25%)	$541,750
Construction Contingency (20%)	$433,400
Engineering, Legal and Administrative Contingency (20%)	$433,400
Total Capital Cost	**$3,575,550**
Amortization for 20 years at 8%	$364,179
Daily Production (mgd)	8.5
Total Annual Production (MG)	925
Unit Production Capital Cost ($/MG)	$400
O&M Costs (0.5% of Total Capital Cost)	$17,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$20
Total Annual Cost ($/MG)	$420

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Wastewater Reclamation - North Coast and In-City Municipal (P5A) Distribution System

Item	Cost
Pipeline - UCSC (4 inch)	$800,000
Pipeline - Golf Course (12 inch)	$2,400,000
Pipeline - Municipal (4 inch)	$1,600,000
Pipeline - North Coast (18 inch)	$4,700,000
Service Connection Allowance (5%)	$395,000
Subtotal	**$9,895,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$9,895,000**
Estimating Allowance (25%)	$2,473,750
Construction Contingency (20%)	$1,979,000
Engineering, Legal and Administrative Contingency (20%)	$1,979,000
Total Capital Cost	**$16,326,750**
Amortization for 20 years at 8%	$1,662,924
Daily Production (mgd)	8.5
Total Annual Production (MG)	925
Unit Production Capital Cost ($/MG)	$1,800
O&M Costs (0.5% of Total Capital Cost)	$81,600
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$1,900

Notes

1) In city piping assumes 60K feet of 4 inch and 20K feet 12 inch at $10/dia-inch/ft for installation in existing streets
2) Coast pipe assumes 32,000 feet at $8/dia-inch/ft for installation in open terrain

Wastewater Reclamation - North Coast Only (P5B)
Cost Summary

Item	Cost
Treatment Facilities	$11,875,000
Distribution PS and Piping	$1,365,000
Storage Reservoir	$2,167,000
New Wells	$1,607,500
Subtotal	**$17,014,500**
Estimating Allowance (25%)	$4,253,625
Construction Contingency (20%)	$3,402,900
Engineering, Legal and Administrative Allowance (20%)	$3,402,900
Total Capital Cost	**$28,074,000**
Amortization for 20 years at 8%	$2,859,000
Total Annual Production (MG)	700
Unit Production Capital Cost ($/MG)	$4,100
O&M Costs	$453,175
Power Costs ($)	$26,700
Unit Production O&M Cost ($/MG)	$700
Total Annual Cost ($/MG)	$4,800

Wastewater Reclamation - North Coast Only (P5B)
Treatment Facilities

Item	Cost
Filtration/Flocculation	$3,750,000
Chemical Feed Storage	$150,000
Disinfection	$5,600,000
Subtotal	**$9,500,000**
Electrical and Instrumentation (25%)	$2,375,000
Subtotal	**$11,875,000**
Estimating Allowance (25%)	$2,968,750
Construction Contingency (20%)	$2,375,000
Engineering, Legal and Administrative Contingency (20%)	$2,375,000
Total Capital Cost	**$19,593,750**
Amortization for 20 years at 8%	$1,995,700
Daily Production (mgd)	7
Total Annual Production (MG)	700
Unit Production Capital Cost ($/MG)	$2,900
O&M Costs (2% of Total Capital Cost)	$391,875
Power Costs ($)	$2,300
Unit Production O&M Cost ($/MG)	$600
Total Annual Cost ($/MG)	$3,500

Wastewater Reclamation - North Coast Only (P5B)
Distribution Pump Station

Item	Cost
North Coast Pumps	$300,000
Subtotal	**$300,000**
Electrical and Instrumentation (25%)	$75,000
Subtotal	**$375,000**
Estimating Allowance (25%)	$93,750
Construction Contingency (20%)	$75,000
Engineering, Legal and Administrative Contingency (20%)	$75,000
Total Capital Cost	**$618,750**
Amortization for 20 years at 8%	$63,021
Daily Production (mgd)	7
Total Annual Production (MG)	700
Unit Production Capital Cost ($/MG)	$90
O&M Costs (.5% of Total Capital Cost)	$30,900
Power Costs ($)	$43,400
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$190

Notes

1) North Coast pumps assume 3 at 3.5 mgd at 300 hp each

Wastewater Reclamation - North Coast Only (P5B)
Reservoir

Item	Cost
Reservoir	$1,970,000
Subtotal	**$1,970,000**
Electrical and Instrumentation (10%)	$197,000
Subtotal	**$2,167,000**
Estimating Allowance (25%)	$541,750
Construction Contingency (20%)	$433,400
Engineering, Legal and Administrative Contingency (20%)	$433,400
Total Capital Cost	**$3,575,550**
Amortization for 20 years at 8%	$364,179
Daily Production (mgd)	7
Total Annual Production (MG)	700
Unit Production Capital Cost ($/MG)	$520
O&M Costs (0.5% of Total Capital Cost)	$17,900
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$30
Total Annual Cost ($/MG)	$550

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Wastewater Reclamation - North Coast Only (P5B)
Distribution System

Item	Cost
Pipeline - North Coast (18 inch)	$6,500,000
Service Connection Allowance (5%)	$325,000
Subtotal	**$6,825,000**
Electrical and Instrumentation (0%)	$0
Subtotal	**$6,825,000**
Estimating Allowance (25%)	$1,706,250
Construction Contingency (20%)	$1,365,000
Engineering, Legal and Administrative Contingency (20%)	$1,365,000
Total Capital Cost	**$11,261,250**
Amortization for 20 years at 8%	$1,146,989
Daily Production (mgd)	7
Total Annual Production (MG)	700
Unit Production Capital Cost ($/MG)	$1,600
O&M Costs (0.5% of Total Capital Cost)	$56,300
Power Costs ($)	$0
Unit Production O&M Cost ($/MG)	$100
Total Annual Cost ($/MG)	$1,700

Notes

1) Pipeline assumes 32K feet at $8/dia-inch/ft.

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APPENDIX B - PRELIMINARY ENVIRONMENTAL ASSESSMENT

Final

City of Santa Cruz
Water Supply Alternatives
Environmental and Regulatory
Constraints Analysis

Prepared for:

Carollo Engineers
Walnut Creek, CA

Prepared by:

Jones & Stokes
Sacramento, CA

Jones & Stokes

August 2000

Final

City of Santa Cruz Water Supply Alternatives Environmental and Regulatory Constraints Analysis

Prepared for:

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Walnut Creek, CA 94598
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Jones & Stokes

August 2000

This document should be cited as:

Jones & Stokes. 2000. City of Santa Cruz water supply alternatives environmental and regulatory constraints analysis. Final. August. (J&S 97-322.) Sacramento, CA. Prepared for Carollo Engineers, Walnut Creek, CA.

Table of Contents

List of Tables and Figures

Section 1. Introduction

This analysis identifies anticipated environmental and regulatory issues or impacts associated with water supply alternatives for the City of Santa Cruz. Potential water supply alternatives include:

- upgrading of existing sources,
- desalination,
- wastewater reclamation, and
- surface water storage in Olympia Quarry.

Potential mitigation measures or further studies that may be required also are identified in this analysis. The analysis is based on information provided by Carollo Engineers and a reconnaissance field survey conducted January 18-19, 2000. Although the level of detail in this analysis is similar to a California Environmental Quality Act (CEQA) document, it is important to note that this is not a CEQA document given the reconnaissance nature of this effort. After an alternative is selected, further environmental analysis would be required to comply with CEQA.

This constraints analysis evaluated issues of land use and biological resource:

- Land use matters addressed in this analysis include potential land use conflicts, traffic/access issues, visual impacts, and consistency with relevant policies in the city and county general plans and local coastal programs. All existing facilities that may be upgraded and most of the other alternatives are within the California Coastal Zone. Additional permitting requirements also are identified in this section.

- Biological resource issues addressed in this analysis include a general discussion of the special-status species that may be in the project area and any major impacts to these resources that could potentially occur from implementing the alternatives. A general discussion of permit and consultation requirements for biological resources also is included.

METHODOLOGY AND ASSUMPTIONS

This section provides an overview of the areas that were evaluated during the field reconnaissance and identifies assumptions used in this analysis..

Existing Sources

North Coast Pipeline

A reconnaissance survey was conducted on portions of the pipeline that could be accessed by vehicle (Figure 1). The three pipelines that connect to the North Coast Pipeline (Laguna Creek, Liddell Creek, and Majors Creek) were difficult to access and were not surveyed on foot. This analysis assumes that portions or the entire pipeline would be replaced near the existing pipeline (adjacent to, or in the same location).

Coast Pump Station

A reconnaissance survey was conducted at the Coast Pump Station (Figure 1). Our analysis assumes that upgrades at the pump station could occur within the pump house located on disturbed paved area or at the water intake on the riverbank.

Felton Diversion Station

A reconnaissance surveys was conducted at the Felton Diversion Pump Station (Figure 2). Our analysis assumes that upgrades would likely involve replacing pump station equipment to increase capacity or efficiency. It is also possible that changes could occur at the intake facility to increase diversion capacity.

Desalination

Four possible desalination sites were surveyed during the field reconnaissance:

- Wilder Ranch Sand Quarry (Figures 1 and 3),
- West Santa Cruz (Industrial Area) (Figure 4),
- U.C. Santa Cruz (Figure 5), and
- Terrace Point (Figure 4).

A field reconnaissance was conducted for the existing ocean outfall and likely intake location, pipeline alignment to the possible desalination sites, (Figures 2, 3, and 4) and the potential brackish groundwater intake at the mouth of the San Lorenzo River (Figures 3, 4, and 5).

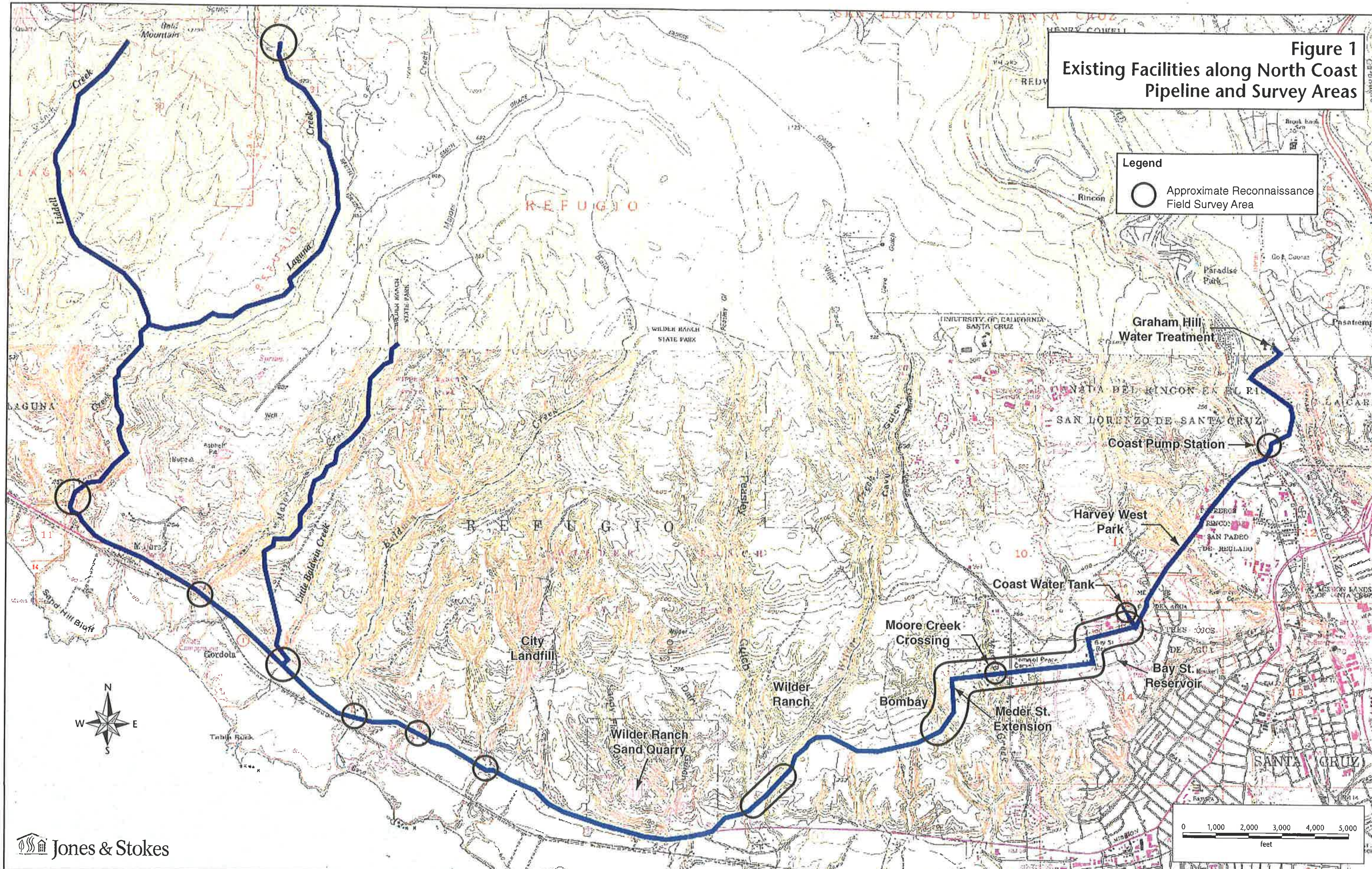
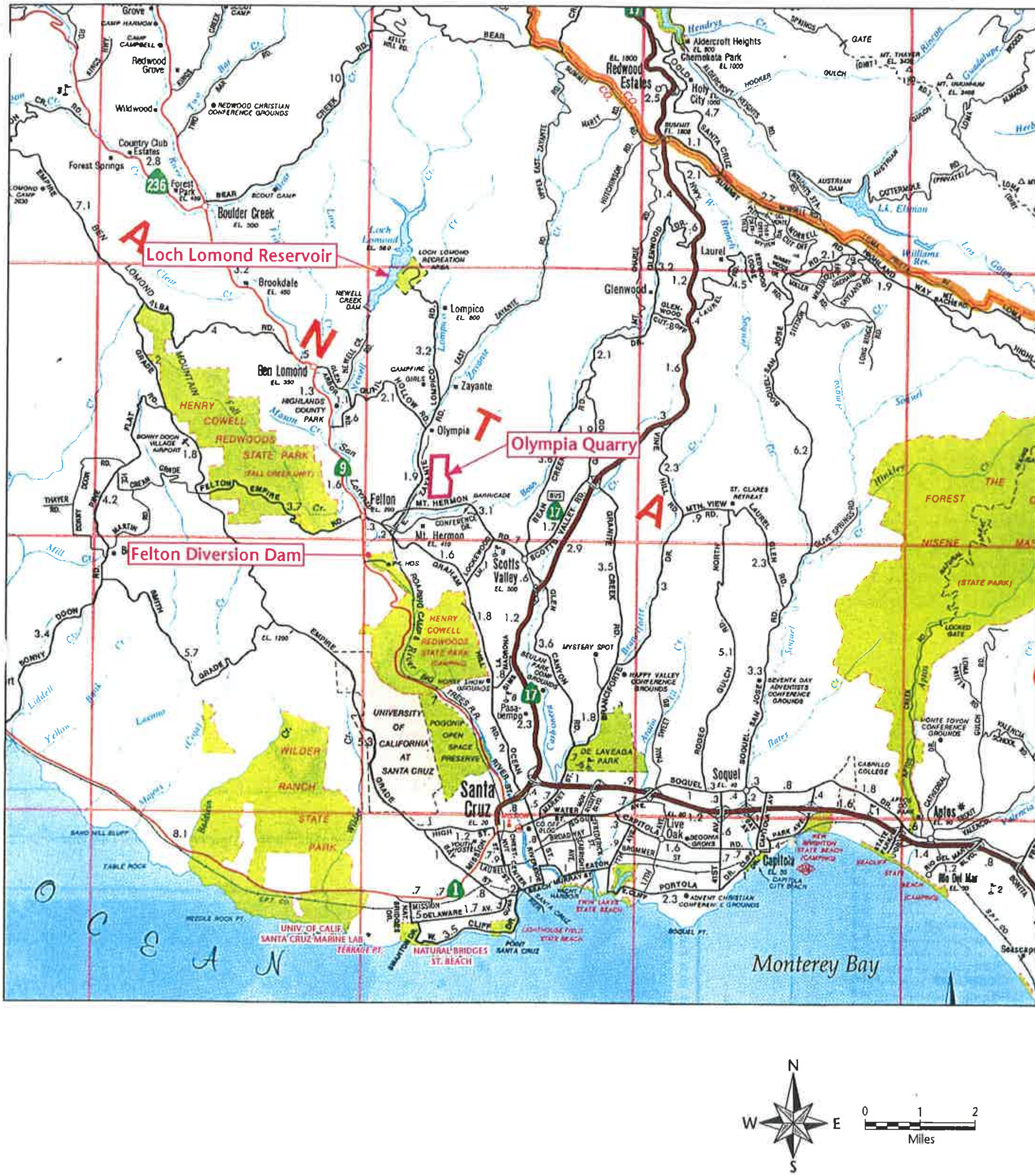
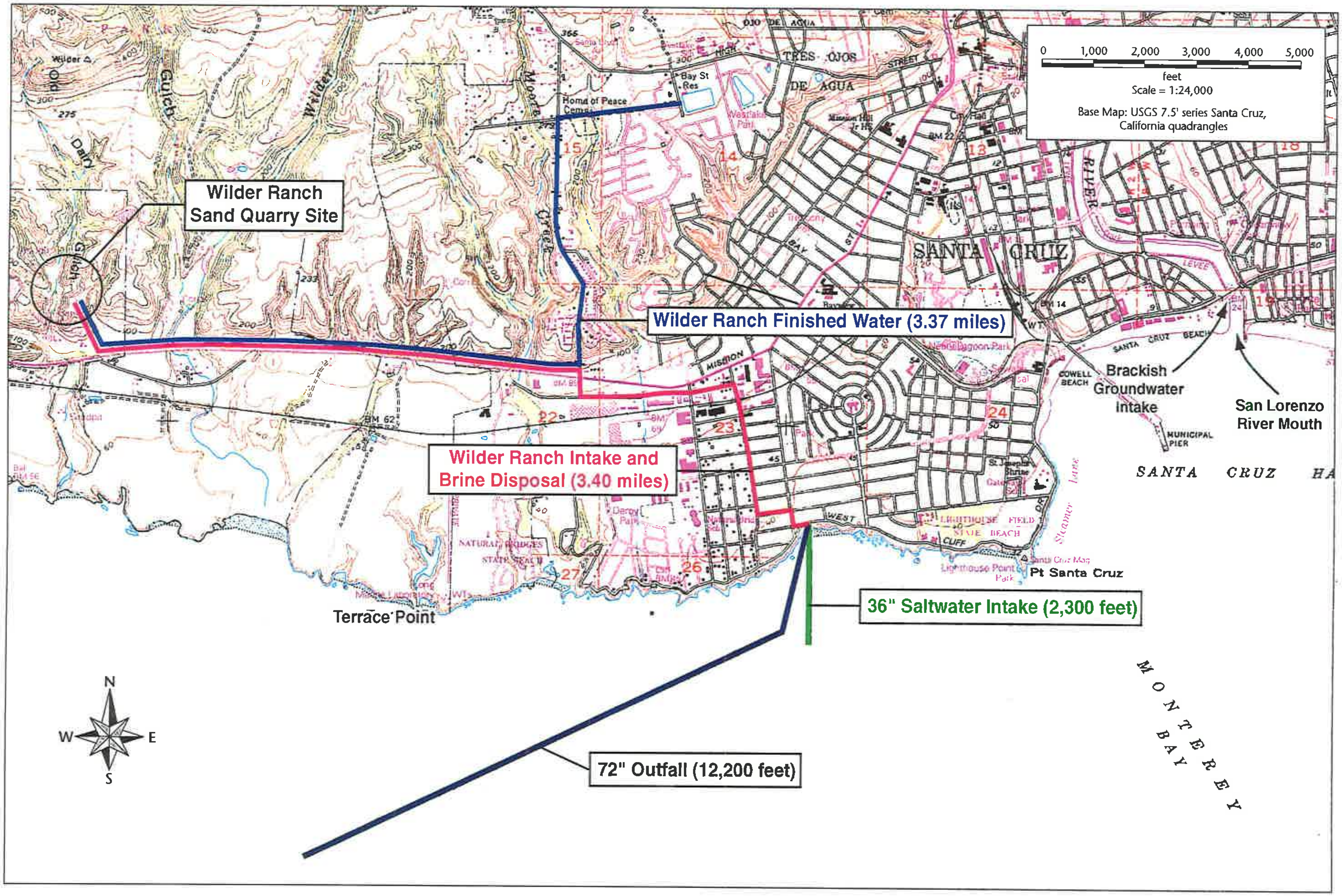


Figure 1
Existing Facilities along North Coast Pipeline and Survey Areas



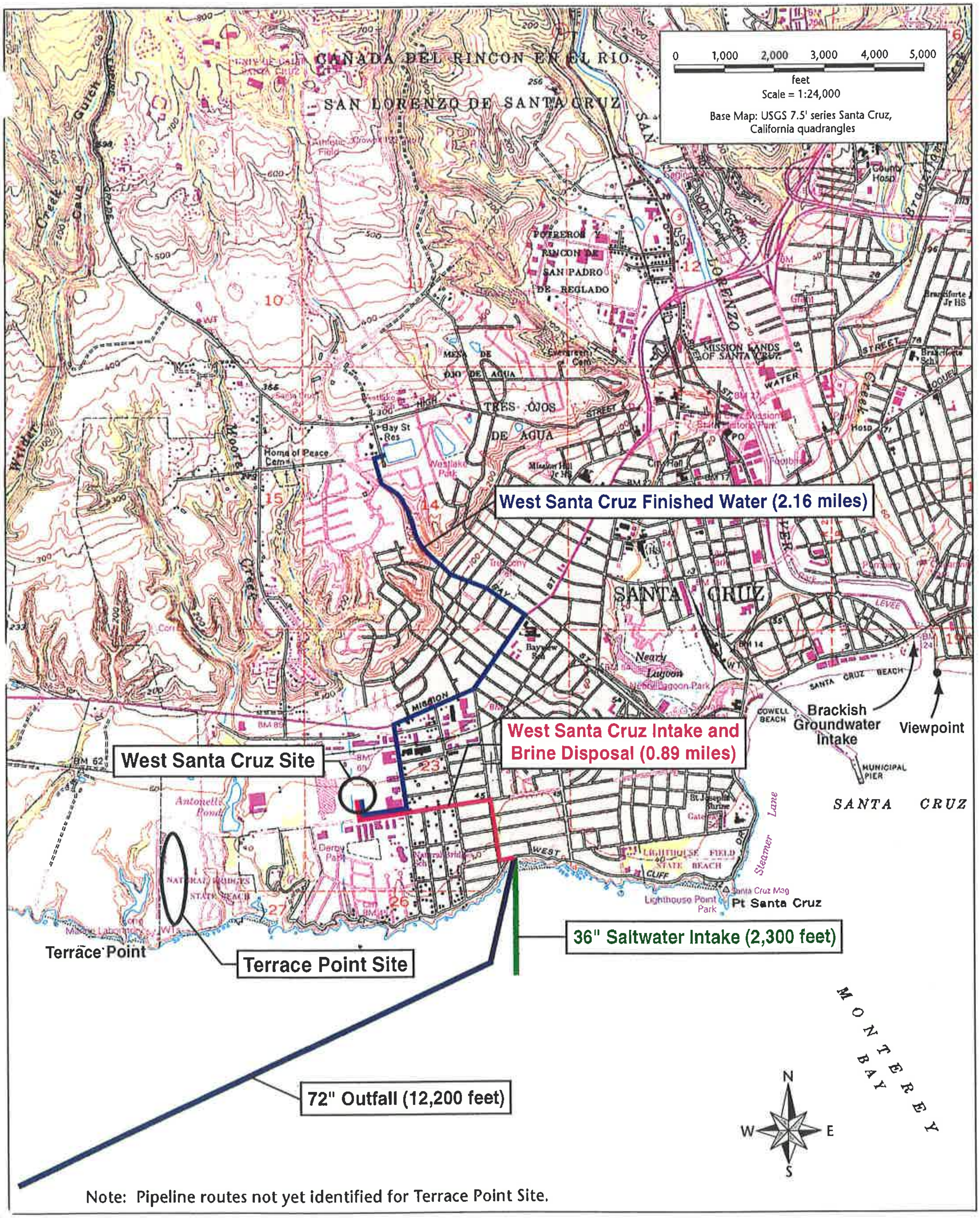
Jones & Stokes

Figure 2
Existing Facilities - Felton Diversion Station, Loch Lomond Reservoir, Olympia Quarry



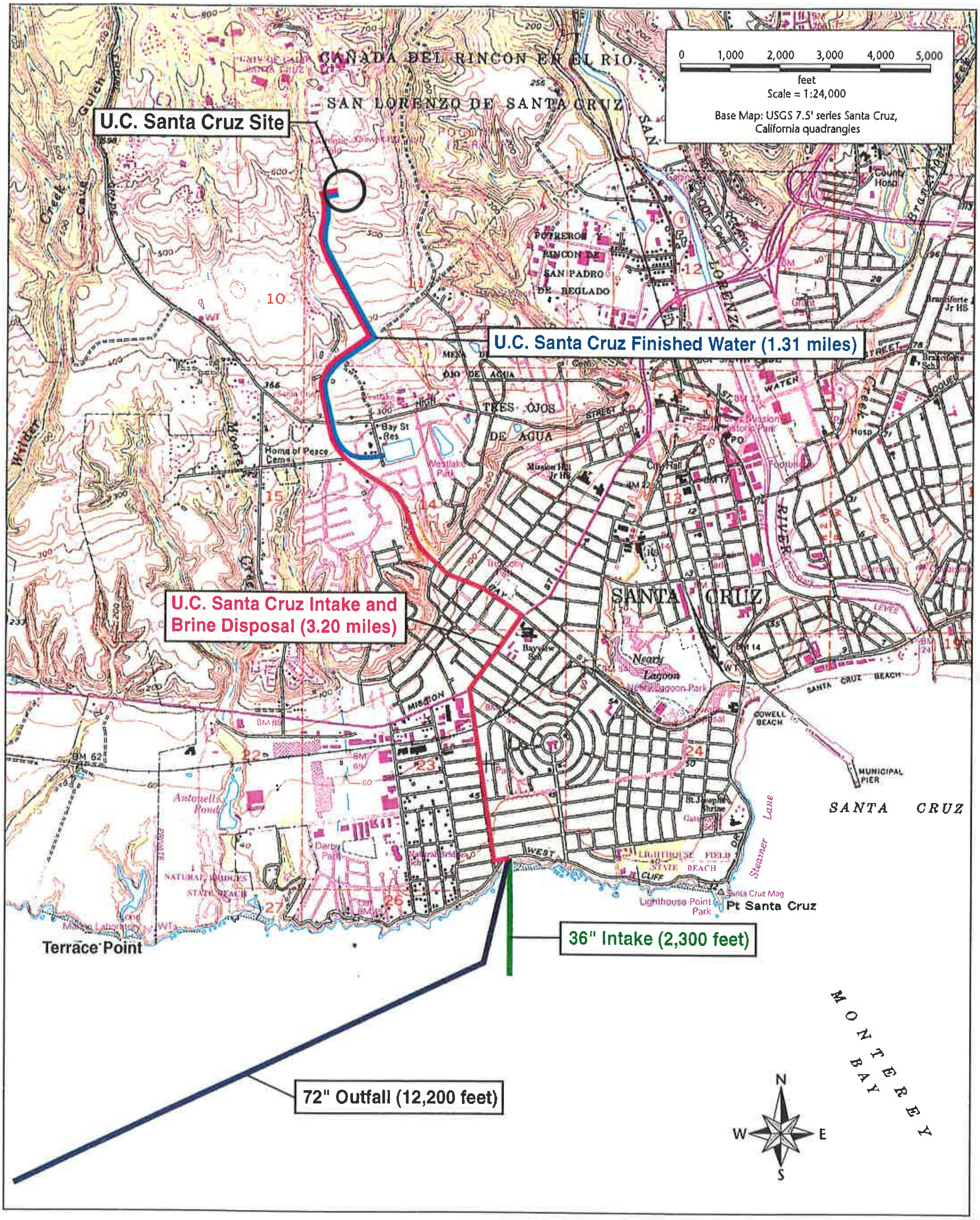
Jones & Stokes

Figure 3
Wilder Ranch Sand Quarry Desalination Site



Jones & Stokes

Figure 4
West Santa Cruz and Terrace Point Desalination Sites



Jones & Stokes

Figure 5
U.C. Santa Cruz Desalination Site

Wastewater Reclamation

Under this concept, wastewater is reclaimed and used for irrigation to reduce the demand on the potable water supply system. The approach used for this analysis is to generally describe the potential impacts if pipelines were installed in existing roadways and the other facilities were constructed in areas already disturbed (no potential pipeline routes were evaluated during the field reconnaissance) to convey reclaimed wastewater.

Surface Water Storage in Olympia Quarry

A reconnaissance survey was conducted for a portion of the Olympia Quarry mine site (Figure 2). This environmental analysis assumes a dam would be constructed and water would be diverted from Zayante Creek. The analysis focuses on regulatory and permit requirements, land use issues, and biological resources.

Section 2. Land Use Issues

UPGRADE EXISTING SOURCES

North Coast Pipeline

Upgrading the existing pipeline would involve construction activities and ground disturbance within the 8- to 10-foot right-of-way (ROW) surrounding the pipeline to replace or upgrade sections of the pipeline. The pipeline extends above ground and underground through developed and undeveloped areas, and along or beneath roadways.

Undeveloped Areas

These areas include the three "feeder" lines extending downhill along Liddell Creek, Laguna Creek, and Majors Creek. These lines feed into the primary North Coast Pipeline along Highway 1 (Figure 1) are located in undeveloped areas. One region is mountainous land in unincorporated Santa Cruz County. The other undeveloped site is between Highway 1 and Meder Street, where the pipeline extends northeast from Highway 1 and through Wilder Ranch State Park, the privately owned Younger Field property outside city limits, and the city-owned 246-acre Bombay property inside city limits.

Most concerns regarding the undeveloped areas pertain to biological resources, including creeks and wooded areas. The following land use discussion focuses on land use conflicts, traffic, and access issues.

Access. Land uses in undeveloped areas include some cattle grazing and range land, undeveloped and state park open space, agricultural fields, and farm worker and rural residential housing. Portions of the pipeline are adjacent to existing structures and access roads. Although the city maintains an approximately 8-foot ROW along the pipeline, construction activities could disturb structures or block access to these areas. Mitigation could include notifying property owners or tenants of construction date, time, and duration. Additional coordination may be necessary if construction activities directly disturb or remove an existing structure or block an access road.

Inadvertent Release of Grazing Animals. Construction activities through grazing and rangelands could result in conflict with cattle and horses that might be frightened by construction equipment or leave the rangeland when access gates are opened. Potential mitigation includes coordinating with each property owner or ranch manager, and ensuring all access gates remain closed.

Disruption to Agricultural Fields. Construction activities through agricultural fields could disrupt agricultural activities and cultivation of crops. Agriculture and coastal-dependent industry are first priority land uses in the coastal zone (county general plan/local coastal plan [LCP] policy 2.22.1). The pipeline typically runs along the edge of the agricultural land but at times extends into the area being cultivated (Werner pers. comm.). Measures to reduce this impact could include limiting construction activities through agricultural lands to the post-harvest fallow period.

Limited Access on Wilder Ranch State Park. Construction activities through Wilder Ranch State Park could have a minor effect on park users. At the Wilder Ranch State Park entrance, the pipeline extends through open space, crosses beneath approximately two dirt trails used by hikers and mountain bikers, through a corner of a horse corral, and continues through open space (including Wilder Creek and swamp area before continuing up the hill). Construction near the trails could interfere with public and employee access to the 4,505-acre state park. If safe detours around the construction area cannot be provided, then the area may be temporarily closed during construction. Potential mitigation could include coordinating construction activities on state park land with park employees, conducting construction activities in heavily used areas of the park during weekdays, and installing appropriate signage at the construction site or park entrance if access is temporarily closed.

Disruption to Nearby Utility Lines. In addition to the North Coast pipeline, which carries sewage to the Coast pump station, there are other underground pipelines in the Highway 1 area. A freshwater line and a leachate line extend along the south side of Highway 1. These parallel lines are 10 feet apart (Chang pers. comm.). The leachate line carries contaminated water from the city's landfill to the sewer collection system in Mission Boulevard (Highway 1). This impact could be avoided by reviewing maps of existing area utilities and coordinating with utility providers, if necessary, to avoid disruption to other nearby utility lines.

Cultural Resources. Ground-disturbing construction activities could affect unknown cultural resources. The likelihood that cultural resources would be discovered is low because ground disturbance would be within the existing pipeline ROW. However, some pipeline sections were installed more than 50 years ago – such as one main line segment installed in 1931 – and there could be undiscovered cultural resources present. Cultural resource surveys would need to be conducted before construction activities could take place.

Roadways

Much of the pipeline extends below or adjacent to roadways. Approximately 1.5 miles of pipeline extends beneath city surface streets from the Meder Street extension to High Street (Figure 1); approximately 4 miles of pipeline runs along Highway 1 from Laguna Creek on the west to the Wilder Ranch State Park entrance on the east. Potential conflicts with existing Highway 1 land uses are discussed in the "Undeveloped Areas" section above. Possible roadway-related conflicts include the following.

Disruption to Highway 1 Traffic. Portions of this segment are within the California Department of Transportation (Caltrans) ROW and would require approval by and coordination with Caltrans to ensure construction activities do not interfere with highway traffic and safety. Other portions of the Highway 1 segment outside the Caltrans ROW are not likely to interfere with highway traffic and safety.

Inaccessibility to Meder Street Rural Residential Area. The pipeline runs below paved surface streets beneath the Meder Street extension and Meder Street, through a rural residential area and across Moore Creek (Figure 1). Meder Street and the Meder Street extension are very narrow in this area (a one-lane roadway), particularly at the creek crossing. Construction activities on these streets would block the roadway and eliminate the only access for homes in this neighborhood. The City expects to complete 300-foot segments within 1 work day (Chang pers. comm.). Potential mitigation could include notifying residents (with flyers and road signage) at least 1 week before and again 24 hours prior to construction date, limiting construction activities to within the standard work day (9 a.m. to 4 p.m.), and providing mid-day access. This is a time during the day (such as a construction lunch break) when residents, including school age children, can access their homes.

Limited Roadway Access Associated with Construction Equipment in Suburban Surface Streets. After the pipeline crosses Moore Creek, it continues beneath Meder Street past the Temple Bethel Jewish Cemetery and University Terrace Park, beneath Cardiff Court and Cardiff Place past the Bay Street Reservoir, and beneath High Street to the Coast water tank at 870 High Street (Figure 1). Because roadways in this area are wider, and construction activities would not block entire streets. Activities may result in traffic detours and delays, safety concerns associated with construction equipment in the roadway, and possible blocked driveways. These impacts would be temporary and short-term. Access can be maintained with a slight detour or parking further away. Mitigation to reduce this impact could include implementing standard safety procedures for roadway construction (construction cones and signage) and limiting construction to within the workday window. Furthermore, residents whose driveways may be blocked should be notified of construction date and times.

Increased Noise, Dust, and Air Emissions from Construction Activities. The adjacent residences, as well as parks and businesses, are considered sensitive receptors that could be affected by these construction-related effects. The City's general plan/LCP states that construction activities should be managed to minimize overall noise impacts (Environmental Quality Element Policy 6.1.2). Mitigation measures could be similar to those described above for the impacts related to roadways.

City-Developed Area

The final segment of the pipeline, between the Coast water tank at 870 High Street and the Coast Pump Station at the San Lorenzo River, crosses beneath urban development, including a residential area, city park, and industrial land. In addition to air quality and noise impacts similar to those discussed above in the "Undeveloped Areas" section, construction of the final pipeline segment could result in property disturbances to developed residential and industrial areas.

Construction activities in the City-developed area could result in disturbance to private property with homes, landscaping (trees), businesses, or other development. Mitigation for this impact could include coordinating with property owners regarding exact location of pipeline, potential property damage, date and time of construction, implementation of safety measures, and compensation for property disruption or loss if appropriate. Furthermore, if tree removal is required, the City Parks and Recreation Department should be consulted regarding the Heritage Tree Ordinance (City of Santa Cruz Municipal Code 9.56.050).

Construction activities could also result in impacts at the Harvey West Park recreation area, including disturbing of the rose garden, steep tree-covered open space, and possibly other areas in the park. If construction activities require substantial vegetation removal, the City should consider creating a pedestrian stairway from the adjacent residential area on top to Harvey West Park facilities below. This would be consistent with the City's general plan/LCP policy to improve access from existing residential developments to Harvey West Park (Parks and Recreation Element Policy 1.2.17). This impact's potential mitigation includes coordinating construction activities with the City Parks and Recreation Department to minimize vegetation removal and ensure erosion control practices.

Relevant Plans and Policies

The entire North Coast Pipeline is within the Coastal Zone (Werner pers. comm.). The pipeline extends through undeveloped, unincorporated county land and through roadways and developed city areas. The project's consistency with the Santa Cruz County General Plan/LCP and the City of Santa Cruz General Plan/LCP are described below.

Santa Cruz County General Plan/Local Coastal Program. Upgrades to the North Coast Pipeline would be consistent with the general plan/LCP designations or relevant policies (Santa Cruz County 1994). The pipeline extends through the Bonny Doon Planning Area beneath land designated Agriculture, Existing Parks and Recreation, and Mountain Residential. Mountain Residential represents the Wilder Ranch Sand Quarry, and the pipeline merely extends through the southeastern corner of this area (Figure 1).

Table 1 includes a description of the relevant general plan designations and a list of relevant policies. Specifically, upgrades to the existing North Coast Pipeline would be in compliance with policies to improve the system and service (Policy 7.18a. Domestic Water Service and Policy 7.18.4 Improvement of Water Systems).

City of Santa Cruz General Plan/Local Coastal Program. Upgrades to the North Coast Pipeline would be consistent with the general plan/LCP designations or relevant policies (City of Santa Cruz 1994). The pipeline extends through undeveloped land (designated Agriculture/Grazing), then beneath roadways passing through residential areas (Very Low and Low density) including Moore Creek (Natural Area). When the pipeline leaves the roadway and extends northeast of High Street, it extends through residential properties (Low Medium density), Harvey West Park (Parks),

Table 1. Relevant Policies and Designations from the 1994
Santa Cruz County General Plan and Local Coastal Plan

Adopted May 24, 1994. Effective date December 19, 1994.

Land Use Designations

Commercial Agricultural Land (Objective 5.13): To maintain for exclusive agricultural use those lands identified on the County Agricultural Resources Map as best suited to the commercial production of food, fiber and ornamental crops and livestock and to prevent conversion of commercial agricultural land to non-agricultural uses; to recognize that agriculture is a priority land use and to resolve policy conflicts in favor of preserving and promoting agriculture on designated commercial agricultural lands.

Existing Park, Recreation and Open Space Designation (Policy 7.1.1): Designate on the general plan and local coastal program land uses and facilities maps those areas existing as, or suitable for, Parks, Recreation and Open Space uses.

Proposed Park Overlay Designation (Policy 7.1.2): Designate specific parcels proposed to be acquired in whole or part for future public park sites on the general plan and local coastal program land use maps for each Planning Area.

Mountain Residential (Objective 2.4): To provide for very low density residential development (10-40 net developable acres per dwelling unit) in areas which are unsuited to more intensive development.

Quarry (Objective 2.19b): To allow orderly economic extraction of mineral resources with conditions to require minimal adverse impacts on environmental and scenic resources and surrounding residential uses.

Policies

Land Use

Policy 2.19.1 (LCP) Siting of Heavy Industries and Quarries. Any change in use or major expansion shall be subject to full environmental and economic analysis and review by the County for the adequacy and appropriateness of the site for the proposed use, and shall be subject to a general plan amendment.

Policy 2.19.2 (LCP) Operation of Existing Quarries. Allow continued operation of existing quarries and allow expansion within areas designated as Mineral Resources, including those located in the Coastal Zone, where impacts of environmental and scenic resources and surrounding residential uses can be mitigated. Require that all mining operations maintain and implement County-approved reclamation plan as required under the California Surface Mining and Reclamation Act (SMARA), and ensure that the rehabilitation and future uses of depleted quarry sites are in accordance with conservation and open space values.

Policy 2.19.6 (LCP) Bonny Doon and North Coast. No new, substantially expanded, or different heavy industrial uses shall be permitted in the Bonny Doon or North Coast Planning Areas. As the existing heavy industrial uses are discontinued, development shall be permitted for uses and intensities consistent with the land use designation on surrounding properties.

Policy 2.19.8 San Lorenzo Valley. Ensure that any industrial development does not adversely impact the water supply watershed in the San Lorenzo Valley. Utilize the Commercial Development permit and environmental review processes to evaluate potential impacts, including drainage and runoff, and require needed mitigation measures as conditions of approval.

Policy 2.21.2 Location of Public Facility/Institutional Land Uses. Allow public facility uses in all urban residential land use designation and zoning districts, as well as limited public facility uses in commercial designations and districts as regulated in Volume II of the County Code.

Policy 2.21.4 Location of Public Utility Transmission Facilities. Public utility transmission and distribution facilities shall be allowed in all land use districts, provided that the routes or site plans of all proposed gas and electric transmission lines shall be submitted to the Planning Department.

Coastal Dependent Development

Policy 2.22.1 (LCP) Priority of Uses within the Coastal Zone. Maintain a hierarchy of land use priorities within the Coastal Zone. First: Agriculture and coastal-dependent industry. Second: Recreation including public parks, visitor-serving commercial uses, and coastal recreation facilities. Third: Private residential, general industrial, and general commercial uses.

Conservation and Open Space

Policy 5.13.10 (LCP) Water and Sewer Lines in the Coastal Zone. Prohibit the placement of water or sewer lines on commercial agricultural lands in the coastal Zone. Allow exceptions to this policy only under the following circumstances and require safeguards (see 5.13.11) to be adopted which ensure that such facilities will not result in the conversion of commercial agricultural lands to non-agricultural uses:

a) Allow water transmission lines from the North Coast to the City of Santa Cruz and allow service lines to be placed on commercial agricultural lands for the purpose of irrigation and related agricultural uses....

Policy 5.13.11 (LCP) Protection for Water and Sewer Lines. For the purposes of Policy 5.13.10, safeguards shall include, but not be limited to:

a) prohibiting hookups to trunk lines through commercial agricultural lands, and

b) prohibiting the levying of assessment fees against commercial agricultural land for the construction of sewer transmission lines running through them.

Policy 5.16.11 (LCP). Quarry Operations to be Consistent with General Plan Policies. Require any future quarry expansion not already authorized under a Mining Approval to be consistent with all General Plan and LCP Land Use Plan policies, including resource protection policies.

Policy 5.16.12 (LCP). Resource Based Industry Within Coast Zone. Require an LCP amendment for any new resource based industry within the Coastal Zone on land which is not designated for such use. Require that the following findings be met as conditions:

a) The site is adequate and appropriate for the proposed use;

b) The project is compatible with available service infrastructure, surrounding uses, and the existing local economy; and

c) The development is consistent with applicable LCP resource protection policies.

Public Facilities

Policy 7.8.4 (LCP). Recommended Acquisitions. Recommend, encourage, and support each of the following State Park acquisitions:

...(f) Wilder Ranch: Support proposed state plans for the expansion of Wilder Ranch State Park. Consider a reclamation plan for Wilder Quarry which provides for a recreational vehicle park/campground in conjunction with Wilder Ranch State Park.

Objective 7.18a. (LCP) Domestic Water Service. To ensure a dependable supply of high quality domestic water to meet the needs of communities that obtain water service from municipal water systems, County water districts, and small water systems.

Policy 7.18.4. (LCP) Improvement of Water Systems. Support water system improvement programs for storage, treatment and distribution facilities to meet necessary water supply and fire suppression requirements.

Policy 7.18.7. (LCP) Water Reuse. Encourage reuse and recycling of water where feasible and where reuse will not have a negative impact on public health or the environment, including the use of greywater systems, and recycling of irrigation water for irrigation purposes as acceptable to Environmental Health Services, State Department of Health Services, and Regional Water Quality Control Board.

Program d. Participate in the development of surface and groundwater management programs to ensure availability of an adequate quantity and quality of domestic water supplies for urban and suburban areas.

Program j. Review and evaluate proposals by water agencies to develop supplemental sources of water supply (such as wastewater reclamation, water conservation, north coast groundwater, or surface water development) to reverse overdraft, seawater intrusion and other basin problems wherever they are occurring. Development and use of these sources must be consistent with General Plan and LCP Land Use Plan resource protection and development policies.

Objective 7.22 (LCP) Wastewater Reclamation and Energy Conservation. To maximize the energy efficiency and potential for energy conversion and resource recovery of sewage treatment in Santa Cruz County.

Policy 7.22.1. Wastewater Reclamation and Reuse Projects. Promote the reclamation and reuse of energy, water and nutrients in wastewater management.

Policy 7.22.2 Wastewater Reclamation for Agricultural Use. Support the concept of building and upgrading sewage treatment facilities capable of producing reusable water and the transporting of wastewater south for reclamation and agricultural use.

Note: Land use designations and policies relevant to all alternatives have been included in this section.

LCP = Local Coastal Program policy.

and industry (Industrial). Before reaching the Coast pump station, the pipeline passes through a strip of Natural Area, Low Density Residential, and Community Facility.

Table 2 includes a description of the general plan designations and a list of relevant policies. Specifically, upgrades to the existing North Coast Pipeline would be in compliance with policy to enhance the distribution system by continuing to maintain and upgrade the water lines, pumping stations, and storage tanks as necessary (Community Facilities Element Policy 6.5).

Several policies are applicable to construction activities, including minimizing overall noise impacts (Environmental Quality Element Policies 6.1.2 and 6.6) and coordinating road projects to minimize disruption (Land Use and Circulation Policy 5.11).

Coast Pump Station

The Coast Pump Station is located on the west bank of the San Lorenzo River at 1214 Highway 9, just inside the city limits (Figure 1). The pump station is located between the SCMD's bus barn and industrial storage. No land use impacts would occur at the Coast Pump Station because all upgrades would be onsite in areas already disturbed and would not affect other land uses or traffic circulation. All work would be temporary and short-term, and would not change any existing views of or from the facility.

Relevant Plans and Policies

The pump station is within the city limits on lands designated Industrial or Community Facility, outside the Coastal Zone. Upgrades at this facility would be consistent with land use designation or relevant policies from the general plan/LCP (City of Santa Cruz 1994).

Table 2 includes a description of the city's general plan designations and a list of relevant policies. Specifically, upgrades to the Coast Pump Station would be in compliance with policy to enhance the distribution system by continuing to maintain and upgrade the water lines, pumping stations, and storage tanks as necessary (Community Facilities Element Policy 6.5).

Other Regulatory Requirements

If the City proposes to increase the diversion capacity at the Coast Pump Station, the City would be required to request a change in its existing water right permit from the State Water Resources Control Board (SWRCB). Changes in water rights would require a completed CEQA analysis to determine the potential impacts from increased diversions, including a water availability analysis.

Felton Diversion Station

The Felton Diversion Station is located on the west bank of the San Lorenzo River on unincorporated land just south of the community of Felton (Figure 2). No land use impacts would occur at the Felton Diversion Station because all upgrades would be onsite in areas already disturbed (paved or existing structures and facilities) and would not affect other land uses or traffic circulation. All work would be temporary and short-term, and would not change existing views of or from the facility.

Relevant Plans and Policies

The Felton Diversion Station is city-owned property on unincorporated county land, outside the Coastal Zone. The diversion station is within the County's San Lorenzo Planning Area on lands designated Existing Parks and Recreation or designated Mountain Residential. Upgrades at this facility would be consistent with land use designation or relevant policies from the general plan/LCP (Santa Cruz County 1994). Table 1 includes a description of the county's general plan designations and a list of relevant policies. Upgrades to the Coast Pump Station would be in compliance with the policy to enhance the distribution system by continuing to maintain and upgrade the water lines, pumping stations, and storage tanks as necessary (Community Facilities Element Policy 6.5).

Other Regulatory Requirements

As described above under the Coast Pump Station, if the City proposes to increase the amount of water diverted from the San Lorenzo River, a change in the City's water right permit from the SWRCB would be required.

DESALINATION

The following potential impacts could occur at all four desalination alternative sites, regardless of the specific location. Minor differences among the sites are described within the text and shown in Table 3. Additional issues specific to an alternative site are discussed after the common impacts.

Construction-Related Noise, Dust, Traffic, and Air Emissions

Construction-related impacts include increased noise, dust, air emissions, and traffic from construction activities and vehicles. These impacts would occur at all four sites, but would be

Table 2. Relevant Policies and Designations from the 1994
City of Santa Cruz General Plan and
Local Coastal Program 1990-2005

Volume I of III: General Plan Elements and Local Coastal Program Summary.
Adopted October 27, 1992. Last amended October 25, 1994.

Land Use Designations

Agriculture/Grazing. Include land that is used for production of food and fiber. This designation is limited to grazing land on the western edge of the City and grasslands of UCSC (including the U.C. Santa Cruz desalination site). Small-scale agricultural uses also exist in Golf Club Drive, Harvey West area.

Residential (Very Low, Low, and Low Medium density of dwelling units).

Very-Low (.1 to 1 dwelling unit per acre densities) is used in rural transition areas and where environmental constraints are high.

Low (1.1 to 10 units per acre densities) is typical of single-family housing areas.

Low-Medium, Medium, and High (10.1 to 55 units per acre densities) typically multi-family residential areas.

Natural Area (Moore Creek and near Golf Club Drive). Land that, for reasons of vegetation and wildlife habitat protection, aesthetic and recreational purposes, and safety should remain in an undeveloped state. Allowable uses such as recreational uses, educational uses, and public facility uses relating to the natural area are dependent upon the environmental sensitivity of each area. As such, the allowable types and intensities of uses must be evaluated and determined on a case-by-case basis, ensuring consistency with the Environmental Quality policies of the city's general plan.

Parks (Harvey West). Park land designations include neighborhood, community and regional park lands used for passive and/or active recreational uses by residents and visitors.

General Industrial. Identifies lands that will be used for industrial development while allowing for protection of the environment and nearby land uses from possible hazards, noise and other disturbances.

Community Facility. Identify existing and potential community facilities to acknowledge their locations and to ensure that suitable area will be set aside to accommodate the need for these facilities, including schools, government offices, post offices, sewer and water facilities, the Civic Auditorium, and the landfill.

Coastal-Dependent. Lands along or near the coastline that will be utilized for coastal-dependent. The Coastal-Dependent/Related Zone District (CD/R) includes the following permitted and conditional uses within the Terrace Point Specific Plan (Principal Permitted Uses 24-10.1380) (Pepper 1996).

A. Aquatic animal holding pens and facilities such as water tanks.

B. Aquaculture and mariculture facilities.

C. Aquariums, coastal- and marine-related, and natural history museums, visitor and/or education centers.

D. Bus/shuttle stops and shelters.

E. Communication, transmitting, reception or relay facilities.

F. Offices, laboratories, and industries that require or benefit from proximity to, or that serve and enhance coastal dependent uses.

G. Marine, meteorologic, wetland, oceanographic, environmental, coastal, ecological, and other related education, research and development offices, laboratories, and industries.

H. Organic farming and farming research facilities.

I. Parking facilities, outdoor storage facilities, and corporation yards related to a permitted use.

J. Rental housing related to the research area and located in conformance with the Specific Plan.

K. Seawater intake, outfall, storage, and pumping stations.

L. Veterinarian facilities.

M. Visitor serving facilities including an inn and restaurant only when located conformance with the Terrace Point Specific Plan.

Policies

Environmental Quality Element

Policy 2.1 (LCP). Meet or exceed State Water Resources Control Board standards for discharge of sewage and storm waters to the Monterey Bay.

Policy 2.3.1 (LCP). Design and site development to minimize lot coverage and impervious surfaces.

Policy 3.1.2 (LCP). Prohibit grading and earth disturbance during wet winter months and ensure that any grading or stockpiles are stabilized and revegetated (or covered) before winter months.

Policy 4.1.5 (LCP). Protect the quality of water discharged into the Bay and prohibit dumping of materials into the Monterey Bay (see Policy 2.1).

Policy 6.1.2. Ensure that construction activities are managed to minimize overall noise impacts.

Policy 6.6. Consider an ordinance regulating the level of daytime and night time intense and intrusive short-duration noise from the operation of machinery and outdoor equipment (leaf blowers) in residential areas.

Community Design Element

Policy 1.3.1 (LCP). Support the preservation of open space character and County land use designations of Gray Whale Ranch and agricultural lands west of the City's boundaries and east of Wilder Ranch.

Policy 2.1.3 (LCP). Protect the Monterey Bay National Marine Sanctuary and the shoreline and views to and along the ocean, recognizing their value as natural and recreational resources.

Policy 2.2.1 (LCP). Develop siting, scale, landscaping and other design guidelines to protect visually sensitive areas and ensure that development is compatible with the character of the area. Areas to be protected include: open space land uses, foothills, bluffs, scenic coastal areas...and San Lorenzo River.

Policy 3.3. Encourage UCSC to maintain the visual quality and character of the campus by siting and designing buildings that blend with the natural landscape and maintain the natural skyline as seen from the city.

Policy 3.5.5. Maintain the visual prominence of important City landmarks and destinations (such as the Boardwalk) as viewed from major circulation routes and public viewpoints.

Policy 6.1.1 (LCP). Protect Heritage Trees and Shrubs by reviewing all construction plans to determine their impacts on Heritage Trees or Shrubs; provide technical information to assist owners in maintaining Heritage Trees and Shrubs on private property. (The City has a Heritage Tree Ordinance.)

Land Use Element

Balanced Community

Policy 1.6 (LCP). Minimize, when practical, obstruction of important views and viewsheds by new development. In the Coastal Zone, development shall be sited and designed to and along the ocean, and in scenic coastal areas, to minimize the alteration of natural land forms, be visually compatible with the character of surrounding areas, and restore visual quality in visually degraded areas.

Residential, Commercial and Industrial Lands

Policy 2.2.4 (LCP). Require a specific plan for the 60-acre Terrace Point property before development occurs (also includes guidance for specific plan development).

Policy 2.8. Maintain industrial lands in their industrial designations to provide a location for development of uses benefitting from industrial park setting.

Open-Space Lands

Policy 3.3 (LCP). Require development adjacent to natural areas and agricultural/grazing lands to be compatible with the adjacent territories in terms of land use, visual transition and siting.

Policy 3.5.1 (LCP). Protect coastal bluffs and beaches from intrusion by non-recreational structures and incompatible uses and along the shoreline.

Policy 3.5.2 (LCP). Require new development and public works projects to provide public access from the nearest public roadway to the shoreline and along the coast.

Concurrency

Policy 4.4 (LCP). Public works projects (including water facilities) in any area within the City (including the Coastal Zone) will be subject to the same land use policies as private development.

Land Use and Circulation

Policy 5.11. Ensure that road projects are coordinated with sewer, water and other utility work to minimize disruption of newly paved or resurfaced streets, develop consistency with City projects and minimize community disruption.

Community Facilities and Services Element

Policy 2.2.1 (LCP). Designate land adjacent to the Long Marine Lab in coastal-dependent uses to allow for related marine research and facility expansion.

Goal CF 6: Supply the water needs of the City's projected 2005 population through water conservation, and then through augmentation of the City's water supply only if necessary. Also ensure water quality and enhance the water distribution system.

Policy 6.3. Consider augmenting the City's water supply with full consideration of cost/yield analyses, quality and environmental impacts.

Policy 6.3.1. Continue preliminary engineering and environmental review of water supply alternative projects in Table CF-5 and consider implementation of selected alternatives. (Table CF-5 on page 313 of the City's General Plan Volume I includes: upgrading existing supply system; increasing capacity of Felton Diversion or reducing operation at Felton Diversion, North Coast pump stations; wastewater reclamation; direct diversion on Zayante Creek, and a desalination plant.)

Policy 6.5 (LCP). Enhance the distribution system by maintaining and upgrading the water lines, pumping stations, and storage tanks as necessary to meet required delivery pressures and fire flow requirements.

Policy 7.3.1 (LCP). Develop and implement wastewater reclamation activities (including the encouragement of private onsite wastewater reclamation) for irrigation and other uses to help conserve the City's water supply.

Parks and Recreation Element

Policy 1.2.17. Improve access (pedestrian, bicycle, automobile) from existing and proposed residential developments to Harvey West Park and Pogonip.

Policy 1.7.6 (LCP). Develop and implement an integrated design, land use plan for West Cliff and East Cliff Drives. Develop design criteria for shoreline structures (minimize amount of material and coverage; emphasize use of non-glare, non-reflective, natural or natural appearing materials).

Cultural Resources Element

Policy 1.3.1 (LCP). Upon discovery of an archaeological or paleontological resource, work must halt on a project. A mitigation plan must be developed that determines the extent and value of the site and its proper disposition, prior to resumption of the project.

Policy 1.3.2 (LCP). Require an archaeological observer on or in the vicinity of known sites for projects involving alterations, reconstruction or a new impact via earth-moving activities. For projects on or in the vicinity of known burial or most-sacred sites, require a Native American observer during earth-moving activities.

Safety Element

Policy 1.2.3 (LCP). Revetments, breakwaters and other construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or protect existing structures or public beaches in danger from erosion.

Volume II of III: Area and Specific Plan Summaries.
Adopted October 27, 1992. Last amended October 25, 1994.

Moore Creek Corridor Access and Management Plan Summary

Policy 1.4.2 (LCP). Require that all exposed slopes be revegetated immediately upon cessation of grading activities through installation of permanent vegetation in conjunction with hydroseeding and other temporary erosion control measures.

Policy 1.4.3 (LCP). Limit vegetation removal to that amount necessary to complete approved construction projects. Any vegetation removed shall be replaced or replanted to ensure slope stability, limit soil erosion potential and significantly reduce offsite sedimentation.

Policy 1.4.5 (LCP). Limit all earth-moving activities between December 1 and March 1. In addition, grading activities shall not begin after September 1 unless grading and plantings can be completed by December 1.

San Lorenzo River Enhancement and Design Plan Summaries

Policy 3.9. Phase and implement improvements to The River Mouth Section of the San Lorenzo River.

Policy 4.3. Provide more opportunities to experience the river at close range and get to the water's edge. (a fountain/water play area at the river mouth, p 109.)

Note: Land use designations and policies relevant to all alternatives have been included in this section.

Table 3. Impact Comparison of Desalination Alternatives

	Wilder Ranch Sand Quarry	West Santa Cruz	UC Santa Cruz	Terrace Point
Construction-Related Impacts[1]	Minor	Minor	Minor	Minor-Moderate
Compatibility with adjacent land uses	Minor[3]	Minor	Moderate	Minor-Moderate
Visual Impacts (views and light & glare)	Minor	Minor	Moderate	Minor-Moderate
Potential for cultural resources	Minor	Minor-Moderate	Minor-Moderate	Minor
Potential for public controversy	Minor	Minor	Moderate	Moderate
Potential to disrupt traffic from pipeline[2]	Minor	Major	Major	Major
Current general plan land use designation	Mountain Residential (with Quarry and Park overlays)	Industrial	Natural Area	Exclusive Agricultural/ Industrial[5]
Consistency with relevant plans and policies	Inconsistent	Consistent	Potentially Inconsistent	Consistent
Proximity to saltwater intake:[4] Ocean saltwater Brackish ground	4 miles 6 miles	<1 mile 2-3 miles	3-4 miles 4 miles	2 miles 3-4 miles
Ownership	Granite Rock	City	U.C. Santa Cruz	U.C. Santa Cruz

Note: Minor/Moderate/Major represents the anticipated severity of the impact and corresponds with text discussion. Impacts that were the same for all alternatives have not been included on this comparison chart, but include: potential for growth inducement and energy requirement for facility operation.

Table 3. Continued

[1] Effects of construction-related noise, dust, air emissions, and traffic on adjacent land uses.

[2] This impact specifically addresses the potential for disruption of traffic circulation/flows on high volume roadways, such as Mission Boulevard and Bay Avenue, due to pipeline construction associated with the desalination plant. Impacts to high volume roadways would be the same under both intake/outfall scenarios.

[3] Minor with existing adjacent uses. There is potential incompatibility with future planned parks and recreation uses on the site.

[4] Distance between the desalination plant and the intake are approximate. The greater the distance, the greater the impacts associated with installing the pipelines and potentially with maintenance.

[5] The City's general plan policy (Community Facilities 2.2.1) designates land adjacent to Long Marine Laboratory for "coastal-dependent" uses.

greater if the construction activities occurred adjacent to sensitive receptors such as residences, parks, and visitor-serving uses.

Potential measures to mitigate construction-related impacts include:

- managing construction activities to minimize overall noise impacts (in compliance with Environmental Quality Element Policy 6.1.2);
- notifying adjacent businesses and facilities of construction dates and times;
- implementing standard construction practices for ensuring air quality compliance, dust suppression, reduced noise, and safety;
- spraying water on exposed dirt to minimize dust; placing appropriate construction signage to ensure safety; and keeping construction vehicles and equipment off the roadway during peak traffic periods; and
- prohibiting grading and earth disturbance during wet winter months and ensure that any grading or stockpiles are stabilized and revegetated (or covered) before winter months (in compliance with Environmental Quality Element Policy 3.1.2).

Wilder Ranch Sand Quarry

The impacts would be minimal at this site because it is surrounded by quarry activities, there are no sensitive adjacent land uses, and the construction activities are compatible with operation of the quarry.

West Santa Cruz and University of California, Santa Cruz Sites

Construction impacts would also be minor at these sites because there are no sensitive adjacent land uses. At the West Santa Cruz site, the area is an industrial/business park, and the land uses are dispersed and should provide sufficient noise insulation. At the University of California, Santa Cruz (UCSC) site, construction traffic on the two-lane Hagar Street could cause some delays, but the impact is considered minor because it is temporary.

Terrace Point Site

The nearby mobile home residents at this location are of a sufficient distance that the impacts would be minor. The adjacent California Department of Fish and Game (CDFG) Wildlife Rescue facility, Longs Marine Laboratory, and visitor serving uses could be sensitive to construction-related noise and dust.

Operations-Related Noise and Air Quality Concerns

In general, desalination facility air emissions consist only of discharges of nitrogen and oxygen from distillation plants that use dearation processes to reduce corrosion, discharge of the air ejector system (for thermal plants), or discharge of the degassifier (for Reverse Osmosis plants). The primary noise source would be pumps (similar to the constant humming at a water or wastewater treatment plant). The pumps would be located in the facility. Measures to minimize or avoid this impact would be based on air pollution control district (APCD) policies. Standard noise reduction measures would be included in the facility's design to reduce operation-related noise levels.

Growth Inducement

As with any project to increase water supplies, a desalination facility at any location could result in growth inducement. According to the State CEQA Guidelines (Section 15126[g]), projects are considered growth-inducing if they remove obstacles to growth, such as expanding a wastewater treatment plant's capacity or providing additional water supplies. To minimize this potential impact (although it would be considered "significant and unavoidable" based on CEQA guidelines), the desalination facility could be sized to accommodate growth consistent with the general plan projections.

Cultural Resources

Because all four sites are undeveloped, it is possible that excavation activities could uncover cultural, archaeological, historical, or paleontological resources. None of the sites are within the City's Sensitive Archaeological and Paleontological Areas map or within an historic district (City of Santa Cruz 1994). At the Wilder Ranch Sand Quarry site, the likelihood that such resources would be uncovered is very low because of the disturbed nature of the site. At the Terrace Point site, literature and field surveys conducted in 1987 and 1993 determined there are no archaeological remains or paleontological resources on the site (Pepper 1996).

If cultural resources are identified or a Section 404 of the Clean Water Act (CWA) Permit is required, compliance with Section 106 of the National Historic Preservation Act (NHPA) would be required (Section 404 of the CWA mandates that compliance with NHPA Section 106 be demonstrated.) Cultural resource surveys of the desalination alternative site would also need to be conducted before CEQA compliance can occur.

Energy Usage

At any location, a desalination facility would require substantial additional energy for operation. Specific energy requirements would not be addressed in future environmental documentation. Project power requirements would need to be compared to energy surpluses from locally available power sources.

Furthermore, Section 30253(4) of the Coastal Act requires that new development minimize energy consumption. Therefore, the Coastal Commission will review desalination facility proposals to determine if a project incorporates means to conserve energy or reduce energy use.

Utilities and Public Services

Operation of a desalination facility would require utilities and public services (such as water supply, wastewater, solid waste, police and fire) at the site. It is anticipated that public services could be extended to the various locations. The Wilder Ranch Sand Quarry site may require slightly greater extension of services because of its more remote location. Utility providers should be contacted to determine service requirements and extension capabilities.

Light and Glare

The desalination facility could include exterior lighting, which could create nighttime light and glare. At the Wilder Ranch Sand Quarry site, this would be most noticeable from Highway 1. At the West Santa Cruz site, the adjacent industry has similar lighting and therefore the lighting would blend with the surrounding area. It would be noticeable at the UCSC site because it is on a hillside visible from the lower campus area, although lights already exist at the adjacent parking lot to the north. At the Terrace Point site, lights would be noticeable from the nearby mobile home park to the east and to the west. To reduce these impacts, the height of exterior lighting could be minimized and lighting should be directed downward.

General Plan Policies

Constructing a desalination facility is consistent with Community Facilities and Services Element Goal CF 6 and Policy 6.3.1, which support augmenting the City's water supply and evaluating desalination (Table 2).

General Plan Land Use Designations and Zoning Amendments

A General Plan land use designation (and zoning amendment) to Community Facilities (Public Facility) would likely be required for all four sites, even if the desalination facility is a compatible or consistent use with the existing designation. A LCP amendment would be required for all sites except UCSC, which is outside the Coastal Zone. The General Plan land use designation and LCP must be amended (these amendments should be included in the EIR prepared for the selected project).

Wilder Ranch Sand Quarry Site

Existing and Planned Land Uses

The site considered for a desalination facility is labeled a "sensitive area" at the quarry and may be designated a "habitat conservation area" in a recent Habitat Conservation Plan approved by the U.S. Fish and Wildlife Service (USFWS) for Granite Rock. The small hill is covered with grassland and shrubs. There are ponds and riparian habitat adjacent to the north, and a private residence and agricultural area to the south. Refer to the "Biological Resources" discussion in Section 3.

Other places in the quarry could be considered for the desalination facility. The area with the least potential for impacts appears to be the old mining area at the north end of the site. This area is covered with grassland and has been disturbed from previous mining activities. The plateau north of the habitat conservation area is heavily disturbed from use as a clay settling pond. This site could have unstable soils, and the uphill location would require additional pumping.

Potential future land uses at the quarry include recreation. Future expansion of Wilder Ranch is being considered for this area as part of the quarry reclamation plan. These issues are addressed under "Relevant Plans and Policies," below.

Visual Quality

It is unlikely the desalination facility would be visible from this portion of Highway 1, which is eligible for scenic highway designation (Albright pers. comm.), because the topography and existing trees near the highway would block views. Further analysis would be required to determine if a desalination facility would be visible from parts of Wilder Ranch State Park. The existing topography suggests a low chance of visibility from public view points. Depending on the visibility of the project site, the facility would need to be designed to blend in with the site's existing visual character (for example, the outside of the facility would be similar to existing surrounding colors).

Relevant Plans and Policies

Wilder Ranch Sand Quarry is outside the city limits and is listed in the County's Bonny Doon Plan Area as Mountain Residential with a Quarry overlay designation, and a Proposed Parks and Recreation overlay designation (Jones & Stokes Associates 1996). Table 1 includes a description of this designation and lists relevant County general plan/LCP and policies. Although the desalination facility would be in compliance with Policy 7.18.4 Improvement of the Water Systems, there are conflicts with Policy 7.8.4 Recommended Acquisitions, and planned future use of the site.

Potential Conflict with Future Expansion of Wilder Ranch State Park

The 1994 county general plan/LCP includes a policy supporting future State Park acquisition of the quarry:

> Public Facilities Policy 7.8.4 (LCP). Recommended Acquisitions. Recommend, encourage, and support the following State Park acquisitions…(f) Wilder Ranch: Support proposed state plans for the expansion of Wilder Ranch State Park. Consider a reclamation plan for Wilder Quarry, which provides for a recreational vehicle park/campground in conjunction with Wilder Ranch State Park.

Since the general plan was approved, the reclamation plan for the quarry has been modified to remove the campground and restore the land to native grassland and riparian habitat. Future land uses would be open space and recreational. Granite Rock modified the reclamation plan (and Condition 11 of the quarry's existing use permit) to specify open space and recreational uses as the end use. According to the county general plan/LCP, first-priority use in the coastal zone is agriculture and coastal-dependent industry. Second-priority uses include public parks and coastal recreation facilities (Policy 2.22.1).

A desalination facility would not be compatible with riparian habitat restoration plans at the same site or on the plateau site to the north. The possibility of siting the facility on the plateau to the north should be explored because it may not interfere with the new riparian habitat restoration plans. The revised reclamation plan shows coastal scrub in this area. However, because it is identified as Clay Settling Pond No. 3, soils stability may be an issue (Jones & Stokes Associates 1996).

West Santa Cruz Site (Industrial Area)

Compatibility with Adjacent Land Uses

A desalination facility is a coastal-dependent industrial use that could be considered compatible with existing and future industrial uses in this area. The city does not own this property.

Potential Alteration to Existing Site Features

A man-made drainage ditch and a large tree are located on the site. The drainage may need to be re-routed. The tree must be evaluated to see if it meets the requirements of a heritage tree. The general plan requires all construction plans be reviewed to determine potential impacts on Heritage Trees. A trees is designated "heritage" if it has a diameter of more than 14 inches, or the tree being considered is unusually beautiful or distinctive, or old or rare.

Visual Quality

The desalination facility is not likely to be visible from this portion of Highway 1 because of trees and intermittent buildings that block the view. The site is not visible from Natural Bridges State Park or other parks or view points. Local views of the site would change, but the use is consistent with planned industrial use of the project site. The desalination facility should be designed to blend with adjacent buildings in the area.

Relevant Plans and Policies

Locating a desalination facility at the West Santa Cruz site would be consistent with land use designation and relevant policies from the City general plan/LCP (City of Santa Cruz 1994). Table 2 includes a description of the City's general plan designations and a list of relevant policies. Siting the facility in the Natural Bridges industrial area would maintain industrial lands in industrial designations (Industrial Lands Policy 2.8) and provide development in an industrial infill and intensification area (Map L-4) and redevelopment area (Map L-5).

University of California, Santa Cruz Site

Potential Incompatibility with Existing Recreation and Grazing

Construction of a desalination facility would remove part of the UCSC land used for grazing and passive recreation activities. Although the facility would not result in a direct conflict with adjacent passive recreation and grazing activities, it could be considered an incompatible use. The general plan requires development adjacent to natural areas and agriculture/grazing lands to be compatible with the adjacent lands in terms of land use, visual transition, and siting. Refer to the "Visual Quality" discussion below. The area's natural character is somewhat altered by the parking area to the north.

Visual Quality

Construction of a desalination facility in this location would change the area's character, views of the region particularly from down slope, and views from the parking lot uphill from the site. This area is undeveloped open space. If this site is selected, the desalination facility should be designed to blend with the adjacent features in the project area.

Relevant Plans and Policies

The UCSC site is on undeveloped grassland that is part of a larger area designated Natural Area in the City's general plan and in the UCSC's long-range development plan, but the zoning is Public Facility. Table 2 includes a description of the City's general plan designations and a list of relevant policies. Siting a desalination facility at this site may be inconsistent with general plan policies encouraging UCSC to maintain the visual quality and character of the campus (Community Design Element Policy 3.3, City of Santa Cruz 1994). This issue is addressed in the previous impact discussion, "Visual Quality."

Potential Inconsistency with "Natural Area" Designation

According to the City's general plan, Natural Area designations include land that should remain undeveloped, for reasons of vegetation and wildlife habitat protection, aesthetic and recreational purposes, and safety. However, allowable uses could include educational uses and public facility uses relating to the natural area, depending on the environmental sensitivity of each area as determined case-by-case. If this alternative location is selected, the City and UCSC planning departments should be contacted to determine if the desalination facility could be considered compatible with the Natural Area and if there is an opportunity to add an educational component to the facility.

Terrace Point Site

Terrace Point is a 60-acre site on the coast owned by the University of California (UC) within the city limits. The site is next to the U.C. Long Marine Laboratory and CDFG Marine Wildlife Veterinary Care and Research Center. The City's general plan/LCP states that a specific plan is required for Terrace Point before development occurs (Land Use Element Policy 2.2.4). This policy includes a specific land use mix of residential, open space, and 25 acres for coastal-dependent use.

A specific plan was prepared by a private developer and submitted to the City in 1995. After several modifications, the City prepared alternatives to the plan, which went through City Council hearings in 1998 and 1999. However, the plan has not been approved, and the LCP still needs to be certified by the California Coastal Commission. In spring 1999, the 60-acre area was purchased by the University of California, which is preparing its own specific plan.

The zoning designation for Terrace Point is General Industrial in the northern portion and Exclusive Agriculture in the southern part, because a specific plan has not been approved. The approved and certified 1994 general plan states the City's intention for this 60-acre area to be a specific plan area with housing, open space, and coastal-dependent uses compatible with the U.C. Long Marine Laboratory (see Table 2, Land Use Element Policy 2.2.4). This remains the intention (Rebagliati pers. comm.). Therefore, this land use analysis is based on the planned land uses indicated in the City's 1994 general plan/LCP.

Most of the area is still undeveloped open space. Wetlands and wildlife habitat in the northern portion will likely remain undeveloped. The Seymour Marine Discovery Center, which includes a visitor center, was recently constructed at the southern end of the site, and the National Oceanic and Atmospheric Administration (NOAA) office research building is being constructed to the north of the Seymour Center. Residential uses are desirable on the eastern portion of the site, closest to the existing DeAnza Mobile Home Park. Coastal-dependent uses are favored on the west side near the existing Long Marine Lab and CDFG wildlife center. (Rebagliati pers. comm.)

For the purposes of this analysis, it is assumed the desalination site would be located within a 25-acre area designated for coastal-dependent use on the western part of the area, near Long Marine Laboratory, CDFG wildlife rescue center, and NOAA. Other specific plan uses would include housing and open space.

Potential Incompatibility with Existing and Planned Land Uses

A desalination facility would be compatible with other coastal-dependent uses in the specific plan area, such as the NOAA facility, and the adjacent UC Long Marine Laboratory. Both uses also require saltwater intake and outfall facilities for marine research and educational uses. The desalination facility would also be compatible with the Seymour Center in the specific plan area, and the adjacent CDFG wildlife rescue center. Other planned uses in the specific plan area are residential and open space.

Although a desalination facility would not be incompatible with residential uses, it may not be desirable for aesthetic reasons. This possible impact could be mitigated with a landscape buffer and perhaps some of the planned open space between the desalination facility and residences, and by ensuring the facility is not unattractive and industrial-looking. This would be in compliance with Community Design Element Policy 2.2.1, which states the building location, scale, landscaping and other design features should be compatible with the area's character.

A desalination facility would be compatible with residential land uses further east, particularly if the specific plan housing is located in-between. It would also be compatible with agricultural land further west, particularly since the facility would not be sensitive to agricultural practices involving fertilizers and pesticides, and creating dust. The desalination facility would be a good buffer between the agricultural land to the west and residential land to the east.

Visual Quality

The site is not conspicuous from Highway 1 (which is eligible for scenic highway designation) due to high embankments, trees, and intermittent buildings near the highway. Views from the Natural Bridges State Park overlook include some seawater tanks and some Long Marine Laboratory roofs, but the views are dominated by the closest mobile home park residents. The site is not visible from the picnic and beach areas of the park because it is screened by the bluff edge and mobile home units.

Views of the site from within and adjacent to the specific plan area will change from undeveloped open space as the specific plan develops. Residents at the adjacent mobile home park to the east would be most sensitive to the change in open space views and character of the site. However, other site development has begun with construction of Seymour Marine Discovery Center and the NOAA facility. City general plan/LCP policy states that the siting, scale, landscaping and other design guidelines should be used to ensure development is compatible with the area's character (Community Design Element Policy 2.2.1).

Relevant Plans and Policies

Refer to the background discussion under "Terrace Point" above. The site is within city limits and subject to the City general plan/LCP. Table 2 includes a description of the city's general plan designations and a list of relevant policies.

General Plan Zoning Designation

The zoning designation is still General Industrial in the northern portion and Exclusive Agriculture in the southern part because a specific plan has not been approved. The approved and certified 1994 general plan clearly states the City's intention for this 60-acre area to be a specific plan area with housing, open space, and coastal-dependent uses compatible with the U.C. Long Marine Laboratory. This has been confirmed by the City Planning Department (Rebagliati pers. comm.). The desalination facility would be consistent with the coastal-dependent designation.

Consistency with General Plan Policy Requiring a Specific Plan

Land Use Element Policy 2.2.4 (LCP) states that a specific plan for the 60-acre Terrace Point property is required before development occurs. The City and UCSC are developing specific plans on separate tracks. The general plan policy also provides directives for the specific plan, including reserving approximately 25 acres for coastal-dependent and coastal-related uses adjacent to Long Marine Laboratory, and requiring use intensities be limited to 20 employees. A desalination facility is a coastal-dependent use that would require 10-15 employees. Other development consistent with the general plan directives, such as the Seymour Marine Discovery Center and the NOAA facility, has been constructed without an approved specific plan.

Intake/Outfall Scenarios

Ocean Intake/Brackish Groundwater Intake

Noise, Dust, and Air Emissions in Local Area from Construction Activities. Construction equipment and activities would increase noise, dust, and air emissions. The adjacent residences, as well as parks and businesses, are considered sensitive receptors that could be affected by these construction-related effects. The City's general plan/LCP states that construction activities should be managed to minimize overall noise impacts (Environmental Quality Element Policy 6.1.2). Construction activities during the week could be limited to within regular business hours (such as 9 a.m. to 4 p.m.) to minimize this impact. Adjacent residents and businesses also should be notified of construction dates and times. Furthermore, standard construction practices should be implemented minimize air quality emissions (such as spraying water on exposed dirt areas to minimize dust).

Temporary Disruption to Traffic on High-Volume Roadways. Installing pipeline(s) for the West Santa Cruz Site, UCSC Site, and Terrace Point facility alternatives would require construction in Mission Boulevard (Highway 1) and Bay Avenue, which both experience heavy traffic, especially during peak traffic hours. Construction activities would block and disrupt traffic flow on these streets. To minimize this impact the following measures could be implemented:

- Coordinate with Caltrans regarding any work on Mission Boulevard (Highway 1).
- Coordinate construction with other road projects to minimize disruption (Land Use Element Policy 5.11).
- Limit construction activities to non-peak hours.
- Implement standard safety procedures for roadway construction (such as construction cones and signage).

Limited Roadway Access. Construction activities would result in construction equipment on surface roadways, possibly creating safety concerns and limited access on the streets and into driveways. Blocking a driveway or street segment is not considered a major impact because it would be temporary, short-term, and access can be maintained with a slight detour. Implementing standard safety procedures for roadway construction (such as construction cones and signage), limiting construction to within typical business hours (such as 9 a.m. to 4 p.m.), and notifying residents that their driveways may be blocked during construction could minimize this impact.

Limited Beach Access on West Cliff Drive/Almar Avenue Stairway to the Beach. This beach access could be temporarily blocked or closed during construction activities near the existing intake/outfall pipelines. Signage at top of stairway indicating date and time stairway access will be closed and location of the closest alternative access could minimize this potential impact.

Potential Disruption of Traffic on Highway 1 and Western Avenue from Wilder Ranch Desalination Facility Alternative. Installing pipeline for the Wilder Ranch alternative requires construction on the north side of Highway 1 and up Western Avenue, which both experience moderate traffic. The pipelines along Highway 1 would not occur within the roadway and would not likely interfere with traffic. If this alternative is selected, the City should coordinate with Caltrans to ensure traffic on the highway is not affected by construction activities.

Continued Cliff Erosion along West Cliff Drive. Cliff erosion will continue around the existing intake/outfall lines entering Monterey Bay from West Cliff Drive. The West Cliff Drive area is subject to intense wave activity, and the erosion rate is approximately 4 inches per year (City of Santa Cruz 1994, map S-1). The pipelines are protected in a cement vault extending outward from the cliff.

Ocean Water Intake

Because there is an existing facility and because pipeline construction and ground disturbance would occur in existing roadways, land use conflicts would be limited to the temporary construction impacts listed above. The proposed intake pipeline was abandoned in 1988, and it is possible the existing pipeline may not be adequate or meet Monterey Bay National Marine Sanctuary (MBNMS) standards. MBNMS staff should be coordinated with early to determine the adequacy of existing pipelines.

Brackish Groundwater Intake

The new brackish water intake system would involve constructing wells and pumps at the San Lorenzo River mouth. A new pipeline would be connected to the wells and would extend below roadways to the new desalination facility. In addition to the impacts identified above for both intake scenarios, the brackish groundwater intake would result in the impacts described below.

Disruption to Public Use of Beach during Construction. Depending on where structures are located and season, construction activities could be disruptive to public use of the beach from increased noise, drifting sand, and safety concerns associated with heavy equipment use. These effects would be temporary and short-term, and are not anticipated to substantially affect tourism. To minimize this impact, construction could be limited to weekdays outside the summer tourist season.

Potential Land Use Conflict. Specific well sites and pump sites have not been identified at this time. Locating the structures adjacent to the Santa Cruz Beach and Boardwalk could be considered a land use conflict because this area is heavily used by the public. Additionally, there could be land use conflicts if the pipeline disturbs an existing or planned land use as it extends to the roadway. The City has several improvement projects planned for the river mouth, including providing more opportunities for people to access the water's edge (San Lorenzo River Enhancement and Design Plan Policies 3.9 and 4.3). This impact could be minimized by locating the wells and pump stations away from areas of heavy public usage or planned riverfront uses, and selecting a cover for the wells that blends with the natural surroundings.

Visual Quality. The San Lorenzo River mouth is part of the area's overall view and character, with the railroad trestle extending overhead and the Santa Cruz Beach and Boardwalk's roller coaster always in the background. This view can be seen from San Lorenzo Boulevard as it turns into East Cliff Drive, the pedestrian walkway on the railroad trestle overhead, and from San Lorenzo Point. San Lorenzo Point is a long, narrow promontory projecting into Monterey Bay, located at the end of East Cliff Drive to the east of the mouth of the San Lorenzo River (Figure 3). The State-owned point provides opportunities for ocean viewing and walking. Although the structures would not be large, they would protrude from the sand or riverbank and alter the natural appearance of the river mouth. This impact could be minimized by locating the wells and pump stations away from areas of heavy public usage or planned riverfront uses and selecting a cover for the wells that blends with the natural surroundings.

Relevant Plans and Policies. The following City general plan/LCP policies are relevant to installation of brackish groundwater intake facilities (well and pump structures) that would be located in the San Lorenzo River mouth (City of Santa Cruz 1994):

- Inconsistent with policy to protect coastal bluffs and beaches from intrusion by non-recreational structures and incompatible uses and along the shoreline (Land Use Element Policy 3.5.1).

- Consistent with City's general plan/LCP policy to permit construction that alters natural shoreline processes when required to serve coastal-dependent uses or protect existing structures or public beaches in danger from erosion. A desalination facility is a coastal-dependent use (Safety Element Policy 1.2.3).

- The City's general plan/LCP includes The San Lorenzo River Enhancement and Design Plan. Land Use Policy 3.9 from this plan includes several planned improvements to the San Lorenzo River mouth (City of Santa Cruz 1994). Installing a brackish groundwater intake system in the river mouth area should be coordinated to ensure the well and pump structures do not conflict with the planned improvements.

WASTEWATER RECLAMATION

This analysis assumes all distribution pipes would be installed in existing roadways and all new facilities would be in already-disturbed areas. Therefore, land use impacts would be relatively minor. The main issues are temporary and short-term traffic disruption, noise, and other construction-related impacts. Further analysis will be required once the facility sites, irrigation sites, and pipeline distribution system are determined.

Potential impacts associated with installing the pipeline beneath roadways would be similar to impacts described for pipeline repairs under "Upgrade Existing Utilities," above. Other potential impacts listed below (without discussion) are similar to impacts already addressed above:

- limited roadway access associated with construction equipment in suburban surface streets;
- increased noise, dust, and air emissions in local area from construction activities;
- temporary disruption to traffic on high-volume roadways;
- potential land use conflict between new facilities and existing uses;
- new source light and glare;
- potential to induce population growth; and
- potential visual effects from tertiary treatment facilities.

Filtration units can be tall towers, which could be visible from Highway 1 or hinder views. Facility design techniques could minimize aesthetic impacts, include placing filtration unit in a vault partially underground, painting facilities the same color as surroundings, and planting vegetation and trees to screen facilities.

Relevant Plans and Policies

Developing wastewater reclamation facilities would be in compliance with the City's general plan/LCP policy to develop and implement wastewater reclamation activities for irrigation and other uses to help conserve the City's water supply (Community Facility and Services Element Policy 7.3.1).

The County's general plan/LCP also includes several policies supporting wastewater reclamation listed in Table 1 (Public Facilities Policies 7.18.7, 7.22.1, and 7.22.2).

SURFACE WATER STORAGE IN OLYMPIA QUARRY

Air Emissions, Dust, Noise, and Traffic

These construction activities have the potential to affect the immediate residential community within 500 feet of the site. These effects are similar to those of current quarry operation and would be expected to occur if the reclamation plan is implemented. Measures to mitigate these impacts would be similar to those described above under the general desalination discussion.

Growth Inducement

Implementation of this alternative would result in growth-inducing impacts.

Visual Quality

The quarry is heavily disturbed and the visual quality and character can be described as very low. It is a huge pit devoid of vegetation. The approved reclamation plan for the quarry calls for revegetation of all exposed slopes. Changing the planned land use to a reservoir would change the site's finished appearance. The slopes would still be revegetated, but most of the canyon bottom would be a larger water reservoir. Depending on the design and success of revegetation, the change in view could be considered a positive change in the site's view and character.

Potential Public Controversy

Diverting water from Zayante Creek and creating a new reservoir would be considered a controversial project. This impact could be reduced with a public involvement program.

Relevant Plans and Policies

Olympia Quarry is located on unincorporated land west of Scotts Valley in the County's San Lorenzo Planning Area. The County general plan/LCP land use designation is Mountain Residential, with a Quarry overlay (CH2M Hill 1999). Table 1 includes a description of this designation and lists relevant general plan/LCP and policies. Revising the reclamation plan to change the finished use to a surface water storage reservoir would be consistent with the following relevant general plan/LCP policies described in Table 1:

- Policy 2.19.2 Operation of Existing Quarries, which allows continued operation and expansion within areas designated Mineral Resources.
- Policy 2.19.8 San Lorenzo Valley, ensures that any industrial development does not adversely impact the water supply watershed in the San Lorenzo Valley.
- Policy 5.16.11. Quarry Operations to be Consistent with General Plan Policies, including resource protection policies.

Section 3. Biological Resources and Permitting

UPGRADE EXISTING SOURCES

North Coast Pipeline

The North Coast pipeline traverses a large variety of habitats that include undisturbed redwood forest, highly disturbed agricultural areas, and urban areas. No biological impacts are expected within the urban areas of Santa Cruz. Several special-status species or sensitive habitats occur or may occur along the pipeline route outside of urban areas. Impacts to biological resources here can be separated into those associated with stream crossings and those in upland habitat (such as outside streams). These potential impacts are discussed based on which regulatory agency will have jurisdiction over the project.

Streams and Stream Crossings

Along Highway 1 and within the City of Santa Cruz, the pipeline crosses at least nine major drainages, including (from west to east) Baldwin Creek, Lombardi Creek, Peasley Creek, Wilder Creek, and Moore Creek. Other drainages crossed have no names. The pipeline is found within Laguna and Majors Creeks and crosses these creeks many times. Because the pipeline was not visited along Majors or Laguna Creek (except at the pipeline intake at Laguna Dam), a complete analysis of the potential biological impacts along these creeks cannot be made at this time. Additional information regarding potential impacts resulting from upgrading these existing sources can be provided if future field reconnaissances are conducted.

Regulatory agencies that may require permits for impacts to biological and hydrologic resources in the creeks include:

- U.S. Army Corps of Engineers (USACE),
- U.S. Fish and Wildlife Service (USFWS),
- National Marine Fisheries Service,
- California Department of Fish and Game (CDFG), and
- California Regional Water Quality Control Board (RWQCB).

Waters of the United States. Upgrading existing pipelines will likely require permits from the USACE under Section 404 of the federal CWA for impacts to wetlands. Section 404 of the CWA regulates the deposit of dredge or fill material into water of the United States, including wetlands. The Section 404 program is governed by the regulatory branch of the USACE. The two types of permits issued by the USACE under Section 404 are Nationwide Permits and Individual Permits.

If impacts to wetlands are relatively small and a project falls into a specific category of uses already permitted, project proponents may apply for a Nationwide Permit. Nationwide Permits are easier to obtain than Individual Permits they typically require fewer mitigation measures and much less processing time. The proposed upgrade of the North Coast Pipeline may qualify for Nationwide Permit 12 for utility line activities. An Individual Permit may be required for upgrades to sections of the pipeline that are within or parallel to creekbeds such as Majors Creek or Laguna Creek.

Endangered Species. Construction of segments of a new pipeline through any creeks in the project area could have adverse effects on endangered species, specifically the federally threatened California red-legged frog. Red-legged frogs are found along the north coast in ponds in and away from streams. There are also documented records of this species in Moore Creek and Laguna Creek (Bulger 1997; NDDB 2000). If impacts could occur in or near streams, surveys should be conducted to federal protocol to determine if this species is present along the corridors and where suitable habitat exists.

If the project might adversely affect the California red-legged frog, the City Water Department must consult with the USFWS, Ventura Field Office. To minimize impacts to this species, project construction should occur during the dry season when red-legged frogs are less likely to be found in streams or ponds. In streams where frogs occur, the City should consider boring under the stream to avoid any impacts to this species. Boring under the stream would also reduce the number of permits required from other regulatory agencies such as the CDFG, as described below.

If the project has the potential to "take" the California red-legged frog (as defined by the Endangered Species Act), and a Section 404 permit is required, the City should urge the USACE to take jurisdiction for compliance with the Endangered Species Act. Federal agencies comply with the Act under Section 7, while a local jurisdiction such as the City Water Department comply with the Act under Section 10(a). Compliance under Section 7 is typically much simpler than compliance under Section 10(a): Section 7 requires an incidental take statement with mitigation measures; Section 10 requires an incidental take permit and a Habitat Conservation Plan (HCP). The only other federally listed species known to occur in the creeks in the project area are three fish species, described below.

Fisheries. The federally listed steelhead trout (threatened), coho salmon (threatened), and tidewater goby (endangered) may occur in the project area. There are recent records of steelhead trout in Majors Creek from the mouth to at least 0.5 mile upstream (NDDB 2000). There is also a record of steelhead from Laguna Creek in 1994 from the mouth of the creek to 3.2 km upstream. Although there are no recent records of coho salmon in Santa Cruz County northwest of the San Lorenzo River, this species may occur in the project area. There are records of tidewater goby from Laguna, Baldwin, Wilder, and Moore Creeks. Tidewater gobies are typically restricted to brackish lagoons at the mouth of rivers. The National Marine Fisheries Service (NMFS) has jurisdiction over project in which federally listed fish may be affected. Because of the potential impacts to these species, consultation with NMFS would be required.

If construction is proposed in Majors or Laguna creeks, the project could have significant adverse impacts on steelhead trout. To avoid such impacts, the pipeline should be rerouted into upland habitat or bored under the creek. Construction of a new pipeline in the watershed of all three species could indirectly affect these species through increased erosion and siltation in the creeks downstream. Mitigation measures could be developed to minimize erosion and indirect impacts to fisheries downstream. These measures could include:

- construction during the dry season,
- construction of sediment traps in the creek downstream of construction sites, and
- boring the pipeline under the creek.

Riparian Habitat. Stream or Lakebed Alteration Agreement is required by the CDFG for alteration of the bed or bank of a stream or its associated riparian vegetation under Section 1601 of the state Fish and Game Code. This agreement is commonly known as a "1601 agreement". The CDFG would have jurisdiction over the project within the streambed and the adjacent riparian habitat. Recently, for linear projects similar to the one proposed, the CDFG has required separate applications and agreements for each perennial drainage crossed. CDFG typically requires mitigation for impacts to streams and adjacent riparian habitat. The City's existing right-of-way easement to clear vegetation for maintenance should reduce or eliminate the CDFG's ability to require mitigation for impacts to riparian habitat.

Due to the number of perennial streams crossed, mitigation for impacts to these streams could be cumulatively considerable. To minimize the need for mitigation, it is recommended that the City consider boring under the major perennial streams. Although a 1601 agreement would likely still be required, mitigation would be substantially reduced if the pipeline was routed under the stream and not through it or over it.

Other Clean Water Act compliance. The City will also be required to comply with Sections 401 and 402 of the CWA. Although not related directly to biological resources, compliance with Section 401 is required for a Section 404 permit to be valid. To comply with Section 401, the City would apply for a Water Quality Certification or waiver from the Central Coast RWQCB. In addition, Section 402 of the CWA requires a Construction Storm Water Permit for construction activities that disturb five or more acres. Preparation of a Storm Water Pollution Prevent Plan (SWPPP) is also required.

Pipeline in Upland Habitat

The pipeline crosses several types of upland habitat, including non-native grassland, agricultural fields, oak woodland, mixed evergreen forest, and redwood forest. The pipeline may also cross native grassland. Oak woodland, redwood forest, and native grassland are considered sensitive by the CDFG. Substantial impacts to these communities could be significant under CEQA.

Furthermore, these habitats may contain special-status plant species. Springtime botanical surveys should be conducted in the pipeline ROW to map vegetation types and populations of special-status plants. If the location of sensitive botanical resources are known, the project can be designed to avoid impacts to these resources.

Special-status wildlife may also be present in the native habitats along the pipeline route. Species that may occur include the peregrine falcon, northern harrier, burrowing owl, black swift, southwestern pond turtle, and California red-legged frog. There would be less-than-significant impacts to foraging habitat for many of these species because the impacts are temporary and widely dispersed along the pipeline corridor. However, impacts to nesting habitat (such as burrowing owls or black swift) could be significant under CEQA. A wildlife survey is recommended to determine the presence of special-status wildlife or their habitat.

Permitting Summary

There do not appear to be any "fatal flaws" (for biological resources) from upgrading the pipeline in creeks or in upland habitat. However, the complexity of the permitting process (number of permits required, number of agencies to consult with for permits) will generally increase with the following factors:

- increased length of the pipeline to be replaced,
- increased number of stream crossings,
- increased proportion of the project along Majors and Laguna Creeks (as in, more of the project within creeks as opposed to upland habitats), and
- increased proportion of the pipeline outside of the current ROW.

To reduce environmental impacts, streamline the permit process, and simplify environmental compliance, the City should consider minimizing these factors whenever possible, if they are compatible with the project goals.

Coast Pump Station

The Coast Pump Station is found on a small, mostly paved lot. Unpaved land in the lot supports exotic weedy and ornamental plants such as English ivy. A few native plants such as coast live oak have been planted as part of the landscaping. Due to the high degree of disturbance on the site, any modifications to the pumps in the facility would not impact on biological resources.

Modifications to the intake structure in the San Lorenzo River will require consultation with the NMFS due to the presence of federally threatened steelhead trout and chinook salmon. Any new intake structure should be designed with fish screens to minimize adverse effects to these species. (Refer to the regulatory discussion above under North Coast Pipeline for information on permits related to fisheries).

Felton Diversion Station

Similar to the Coast Pump Station, the Felton Diversion Station occurs on paved land with no native vegetation. Any modification to the station in the paved area would not impact biological resources. Modifications to the intake structure in the San Lorenzo River will require consultation with the NMFS due to the presence of federally threatened steelhead trout and chinook salmon. Any new intake structure should be designed with fish screens to minimize adverse effects to these species.

DESALINATION

Wilder Ranch Sand Quarry Site

The Wilder Ranch Sand Quarry site may present substantial biological constraints for siting a desalination plant. The Wilder Ranch Sand Quarry is subject to the permit conditions of a recently approved HCP for the California red-legged frog. The HCP and its implementing agreement was approved by the USFWS as a condition of the incidental take permit issued to Granite Rock Company under Section 10(a) of the Endangered Species Act. The proposed site for a desalination plant is on a plateau that may be partly or wholly within an area designated by the HCP (and the permit) as a conservation area for the frog. Siting a desalination plant in or adjacent to this conservation area will likely be considered inconsistent with the conditions of this incidental take permit.

In addition, the site is subject to the conditions of the reclamation plan. Siting a desalination plant at this location would likely require modification of this reclamation plan. If this site is considered further, Granite Rock's 10(a) permit and reclamation plan should be evaluated carefully to determine if they conflict with the proposed project.

There appear to be no other biological constraints on the site except for the California red-legged frog. The proposed site is located on a small plateau that is composed primarily of grasslands, coastal scrub, and several artificial ponds. Because of their highly artificial nature (they are erosion-control structures for previously mined areas), these ponds would not be considered jurisdictional wetlands. Shrubs and trees were recently planted at the site, presumably as part of the its reclamation plan. Many of seedlings are caged to prevent browsing by deer and rabbits.

According to surveys conducted on the property for special-status plants and wildlife (Habitat Restoration Group 1996, Jones & Stokes Associates 1994), the only special-status plant or animal on the property was the California red-legged frog. Although unlikely, it is possible that in the time since the surveys were conducted, special-status species have colonized the area, and some habitats may now support these plants and wildlife. If this site is considered further, repeat biological surveys may be required to determine whether special-status species or their habitats occur in the area.

West Santa Cruz Site (Industrial Area)

This site presents few, if any, biological constraints for development of a desalination plant. The site supports disturbed (ruderal) vegetation dominated by non-native plants. A deep artificial drainage traverses the site. Because the site is highly disturbed and because it is surrounded by urban development, it provides poor-quality habitat for wildlife, none of which are likely to have special-status. The artificial drainage would not qualify as a jurisdictional wetland. However, seasonal wetlands may occur on the site, so a wetland delineation is recommended to determine their extent and quality. Due to the area's large size, it should be easy to site the plant to avoid any wetlands that may occur.

University of California, Santa Cruz Site

The proposed site on the UCSC campus is in a large area of open grassland. The site is grazed and is composed mostly of non-native plants. Sensitive birds may forage on the grasslands on campus, including the burrowing owl, golden eagle, Cooper's hawk, peregrine falcon, and northern harrier (University of California Santa Cruz 1992, 1998). In 1989, burrowing owls inhabited the area proposed for the desalination plant (University of California Santa Cruz 1989). This species may still exist in a breeding or non-breeding colony. Mitigation measures may be required to offset impacts to foraging raptors from loss of habitat. These measures could include protection or restoration of native grassland habitat elsewhere. The site may also be used for dispersal by the California red-legged frog, which occurs in the southern corner of campus. Impacts to this species could be avoided by restricting construction to the dry season and by erecting fencing around the construction site to prevent dispersing frogs from entering Numerous small patches of native grassland on the site may contain several very rare special-status plants. These species include Santa Cruz clover (*Trifolium buckwestiorum*), Santa Cruz tarplant (*Holocarpha macrodenia*), and San Francisco popcorn flower (*Plagiobothrys diffusus*) (California Department of Fish and Game 2000). Because of their extreme rarity, all impacts to these species should be avoided. If this site is considered further, additional biological resource surveys would need to be conducted.

Terrace Point Site

The Terrace Point property has two potential biological constraints to siting a desalination plant: the presence of federally threatened California red-legged frogs and jurisdictional wetlands. A local biologist conducting surveys for a previous development proposal found juvenile California red-legged frogs temporarily occupying ponds on the north edge of the site (Mori 1997). Based on surveys of this species and its habitat along the north coast, local biologists believe red-legged frogs disperse across the northern portion of the site in winter while moving between sites to the west and Antonelli Pond to the east (Bulger 1997). The only other special-status species on site were northern harriers and peregrine falcons (The Habitat Restoration Group 1994). Both species used the site for foraging only (not nesting). A small desalination plant in this location would likely have less-than-significant impacts on these two species.

According to a wetland delineation conducted in 1997, the site's 4 acres of jurisdictional wetlands are mostly north of Delaware Avenue (John Gilchrist and Associates 1997). Because the overall site is large (approximately 50 acres), the plant could easily be sited to avoid these wetlands. The 1997 wetland delineation expires on June 20, 2000. If this site is considered further, another wetland delineation should be performed wherever the plant could be located. It is likely that such a delineation would find a different amount of wetlands on the site (there were 11.7 acres of jurisdictional wetlands on the site in 1993, compared to 4 in 1997). It is recommended that the plant be considered in the southern portion of the site only to avoid impacts on wetlands and potential impacts on the California red-legged frog.

Intake/Outfall Scenarios

Ocean Intake

Operation of the proposed intake pipe (the abandoned ocean outfall) as part of a desalination plant could have adverse impacts on biological resources in the MBNMS. Direct impacts at the intake structure would depend on the type of intake structure and screens, and the rate of seawater intake. Marine organisms could be impinged on (collide with intake screen) or entrained in (taken into the plant with feedwater) the intake structure (Pantell 1993). Impacts to marine organisms would vary by season. Impacts would likely be greater during the summer because the desalination plant would operate at greater capacity (and intake rates would be higher), and because populations and diversity of marine organisms would probably be greater in the spring and summer.

Brackish Groundwater Intake

If the desalination plant relied on intake from brackish groundwater wells near the mouth of the San Lorenzo River, there would be no adverse impacts on marine organisms. Wells would draw water from brackish underground aquifers and would not affect near-shore marine organisms.

Ocean Outfall

The proposed (and existing) ocean outfall is within the MBNMS, which is a federally protected marine area offshore of California's central coast. Changes in seawater chemistry near the outfall structure could directly or indirectly affect marine organisms. The type and degree of impact would depend on various factors, including the amount and timing of brine released, its salinity, temperature, and concentration of other compounds such as heavy metals. Some sessile marine organisms near the outfall could be killed from sudden exposure to higher salinity or temperature. Prolonged exposure to such changes could cause a shift in the marine community around the outfall.

Many of the potential impacts to marine resources from the outfall structure could be avoided or minimized if the concentrated brine was mixed with fresh or brackish water prior to discharge into the ocean. Based on information from Carollo Engineers, it is assumed that a brine/wastewater effluent mixture would be discharged to the ocean. Therefore, as indicated by Carollo Engineers, the salinity of the brine/wastewater mixture would be between 20 and 33 parts per thousand (ppt) of salt (seawater has a typical salinity of 33 ppt of salt). The salinity of the mixture would likely be lowest during the wet winter months. Discharge from the outfall of water with salinity of 20 ppt may still adversely impact marine organisms that are adapted to water with a near-constant salinity of 33 ppt. These potential impacts would have to be evaluated further once the duration and amount of discharge of 20 ppt water was determined. Furthermore, the addition of saline water to the currently discharged effluent could result in a beneficial impact to marine organisms (the discharged water would be saline compared to what is currently discharged). This potential beneficial impact should be evaluated further if desalination is selected.

WASTEWATER RECLAMATION

Specific biological resource surveys are needed to determine potential impacts and mitigation measures. In general, if construction occurs in already-disturbed areas, minor impacts (if any) would occur.

SURFACE WATER STORAGE IN OLYMPIA QUARRY

As described in the preliminary CEQA Initial Study checklist for the quarry's amended permit (Santa Cruz County 1999), many special-status species and sensitive plant communities occur within the quarry's property boundaries. Federally listed species include the Mt. Hermon June beetle, Zayante band-winged grasshopper, Ben Lomond wallflower, and Ben Lomond spineflower. The federally listed California red-legged frog may occur on the site.. Sensitive plant communities that occur on the property include freshwater wetland, coastal riparian forest, and sand parkland.

The Initial Study states that all habitat for special-status species would be avoided if the site was used as a water storage reservoir. However, if this alternative is selected, further biological surveys are needed to determine if special-status species would be affected. The Initial Study also recommends surveys be conducted for the California red-legged frog to determine its status on the site. If red-legged frogs are located on the proposed site, an incidental take permit could be required (which would require consulting with the USFWS).

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PERSONAL COMMUNICATIONS

Albright, Greg. Project manager. Office of State Landscape Architecture for the California Department of Transportation. January 27, 2000 - telephone conversation.

Chang, Chris. Associate engineer. City of Santa Cruz Water Department, Santa Cruz, CA. January 18, 2000 - meeting; January 31, 2000 - telephone conversation.

Rebagliati, Julianna. Associate planner. City of Santa Cruz Planning Department, Santa Cruz, CA. January 31, 2000 - meeting; February 1 and February 2, 2000 - telephone conversations.

Werner, Andy. Landscape gardner. City of Santa Cruz Public Works Department, Santa Cruz, CA. January 18, 2000 - meeting; January 26 and January 27, 2000 - telephone conversations.

Wolfman, Steve. Associate engineer. City of Santa Cruz Public Works Department, Santa Cruz, CA. February 1, 2000 - telephone conversation.