KLEINFELDER

EL GRANADA GROUND WATER INVESTIGATION REPORT

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1 SUMMARY

Aquifer Geometry and Boundaries

The El Granada area is underlain by two distinct aquifer systems. The principal water-bearing zone consists of unconsolidated deposits of sand, silt, and clay that comprise the Half Moon Bay Terrace. Water for residential use is also produced from two bedrock formations underlying the terrace. The main bedrock aquifer is composed of granitic rocks of the Montara Mountain Batholith which is overlain along the coast by shale and sandstone of the Purisima Formation. These formations are considered as a single bedrock system in this report. Wells completed in the bedrock aquifer are typically of low yield, but may vary depending on favorable fracture patterns in the rock. Yields of wells completed in the terrace aquifer are typically 20 times higher than yields for wells completed in the bedrock aquifer for a given drawdown (lowering of water level in the well due to pumping). Exchange of water between the terrace and bedrock aquifers is thought to be quite limited.

The terrace aquifer reaches a maximum thickness of about 80 to 90 feet along Highway 1 and thins abruptly along a bedrock escarpment near the base of the hills to the northeast. The terrace aquifer is bounded by the stream deposits of Arroyo de en Medio on the southeast, and those of Denniston Creek on the northwest, although the latter boundary is less well-defined. The terrace aquifer has an average saturated thickness of about 50 feet.

Water-Bearing Properties

The potential volumes of water in storage estimated in this report suggest that the amount of water available within the El Granada terrace aquifer is large relative to present estimated pumpage. However, the limited available data indicate a wide potential variability in the water-bearing properties of the aquifer at any specific location, indicating a potential risk for some areas of high density well clusters during critical drought periods. In addition, declining water levels during drought years may result in short-term water quality degradation for individual home owners.

Using estimated values of specific yield and water level fluctuations for varying hydrologic conditions, the volumes of water in storage for normal, dry, and critical drought conditions are estimated to be 470, 400, and 195 to 325 million gallons (1450, 1250, and 600 to 1000 acre-feet) respectively, for the terrace aquifer. Ground-water storage in the granitic bedrock is estimated to be approximately 80 to 260 million gallons (250 to 800 acre-feet), although this value is less well known. Storage within the Purisima Formation is not known, but is probably small relative to the other values. We also feel that a potentially significant amount of the water produced from many bedrock wells may be provided by vertical flow through the gravel pack from the terrace aquifer. Thus, while many of the wells in the El Granada area are completed at least partly within bedrock aquifer, the water-bearing properties of this zone are poorly understood.

Ground-water outflow beneath Highway 1 is estimated to be 145 million gallons (445 acre-feet) for average rainfall years. Dry year and critical drought year outflows are estimated to be 125 and 100 million gallons (383 and 311 acre-feet), respectively. Assuming 40 percent of the estimated outflow may be available for withdrawal without producing undesirable effects, we estimate a working safe yield of approximately 58 million gallons (178 acre-feet) for years of normal rainfall years, 50 and 40 million gallons (153 and 124 acre-feet) for dry and critical drought years, respectively. These estimated safe yields are considered to be in addition to present withdrawals. The estimates of storage, outflow and hence, safe yield, are based on reasonable hydrogeologic assumptions and limited available observations of aquifer response. Additionally, geologic properties vary considerably laterally and with depth. Hence, actual storage and safe yield may vary by a factor of two or more from our estimates, especially for specific subareas of El Granada.

Water-level records from monitoring wells located to the north and south of El Granada indicate average seasonal water-level fluctuations of 4 to 10 feet during average rainfall years. Water-level declines of 14 to 29 feet have been recorded during dry and critically-dry years in a monitoring well just west of the Half Moon Bay Airport. However, water levels recovered to a nearly-constant winter maximum during subsequent normal or above-average rainfall years. This, coupled with an estimated outflow through the terrace beneath Highway 1 of 445, 383, and 311 acre-feet per year for normal, dry, and critical drought years, respectively, suggests only a minimal potential for sea-water intrusion in the El Granada area, given present recharge and pumping patterns.

The available data indicate generally fair water quality within El Granada, although treatment is commonly required for iron and manganese. Elevated concentrations of nitrates have been reported in several wells, suggesting a potential for water-quality to fall to unacceptable levels during periods of significant water-level decline. The source of the nitrate is not presently known, but may include deep percolation from sewers, agricultural applications, septic-system effluent, or decaying organic matter naturally found in the terrace deposits.

The distribution of chloride concentrations in existing wells do not indicate intrusion of seawater in the El Granada area. However, unexpectedly high (200 mg/l) chloride concentrations are reported for several wells completed in the granitic bedrock. The source of the chloride is unclear, but could be related to sampling errors or possible emanations from deeper geologic structures. As with the nitrate, chloride concentrations could increase during extended drought cycles, if the latter is in fact the case.

The water-quality maps prepared for this report suggest that significant recharge may occur from a stock pond located in the canyon above Vallejo Avenue. Estimates of recharge based on standard infiltration rates and Darcian flow suggest that approximately 52 million gallons (160 ac.ft./yr) may be added to the aquifer system during average years. Although additional investigation is warranted, the preliminary recharge estimates indicate that infiltration ponds of this nature could provide significant additional recharge for long-term ground-water basin management.

Potential Directions For Management

The preliminary hydrogeologic analysis suggests that the potential volumes of water in storage are large compared to present withdrawals. As such, potential directions for management of the ground-water resource can be divided into three levels of involvement: Passive, active, and intensive, as outlined in Figure 1.

Passive Management would continue the present system of permitting and installing wells, documenting problems that may occur, and re-assessing basin management annually to decide upon a number of permits to issue for the following year. This plan might also incorporate some limited re-sampling of wells and limited water-level measurements.

The Active Management program would be designed to establish observed patterns of ground water response to varying rainfall, allowing more precise identification of potential problem areas associated with clustered wells or geologic constraints. This approach is intended to address unresolved questions regarding the occurrence and movement of ground water in El Granada, and provide a basis for management decisions in specific subareas of the basin.

An Intensive Management program could be designed to allow further development of the ground water resource. Recharge to the aquifer might be enhanced by a managed recharge program of infiltration ponds or galleries, and might also include community wells discharging to the existing and planned distribution systems.

Mgmt Level	Additional Work	Purpose	Probable Costs
Passive	- Limited resampling of wells reporting elevated levels of chloride, nitrates, or specific conductance - Limited water-level monitoring - Initiate coordination with GSD to locate potential septic systems and possible sewer-line leaks - Implement limited quality control program for water-quality analyses	To continue present system of permitting wells and documenting problems that may occur. Reassess basin management annually, and decide upon a number of permits to issue for the year.	Approximately, 1-3 weeks of County Staff time annually
Active	- Install monitoring well systems - Expand water-quality analyses - Require bi-yearly analysis of wells - Require extended aquifer tests in high-density well areas	To establish historical pattern of ground water response to varying climatic conditions or ground water pumping. Better identify potential problem areas related to clustered wells or geologic constraints. Better define recharge and movement of ground water.	County Staff Time: 2-3 weeks one-time expenditure 1-2 weeks per year Outside Engineering Services: $8,000-12,000 one-time expenditure some applicant or owner costs
Intensive	- Include "Active Management" tasks (above) - Installation of community wells - Managed recharge program (infiltration ponds/galleries)	To manage recharge of aquifer for continued water supply. To develop water supply and distribution system in controlled setting.	Capital projects funded by perceived return on investment, or improved reliability of supply

Figure 1.
Summary of Alternative Aquifer Management Approaches, El Granada Area, San Mateo County

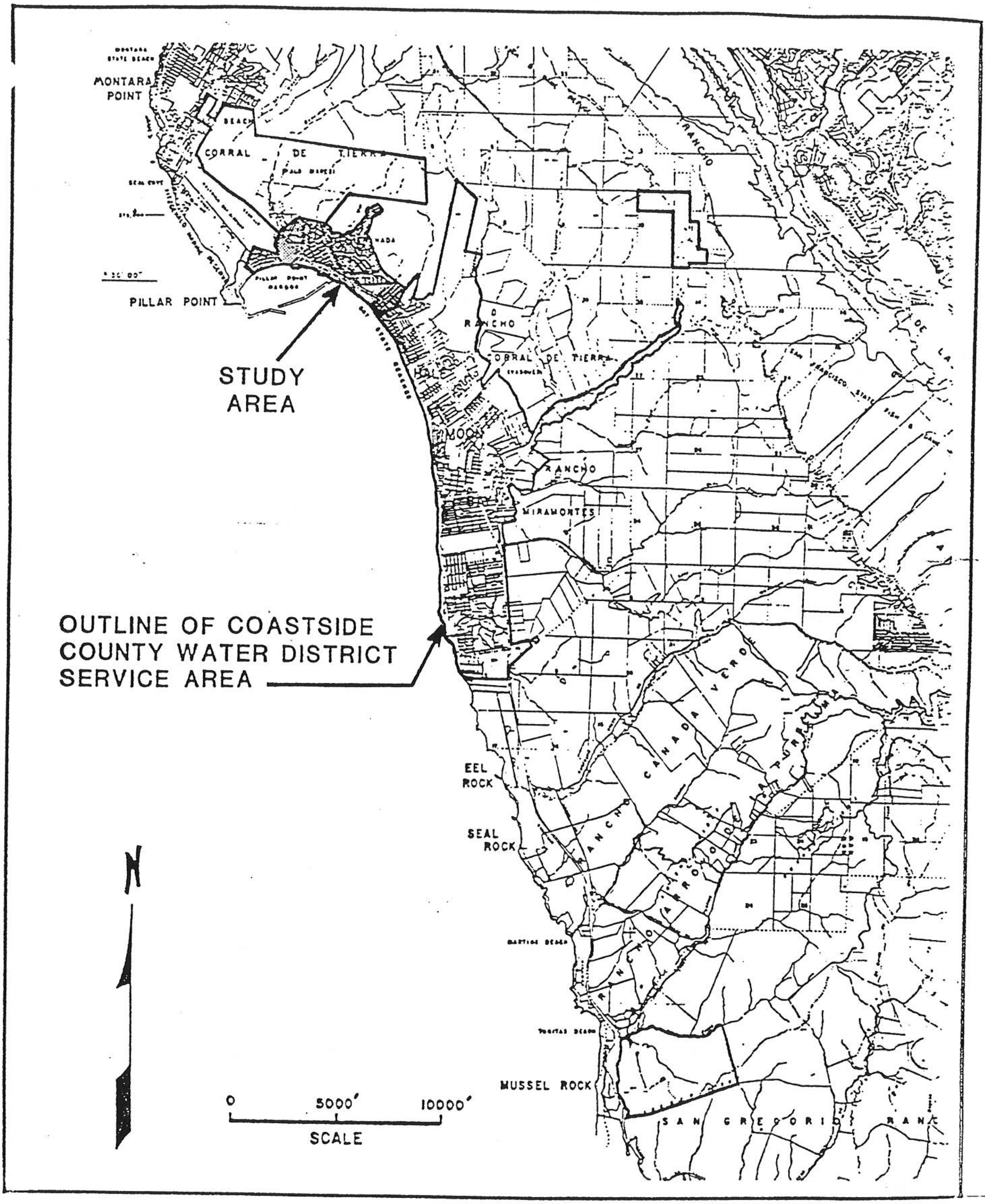


Figure 2. Study Area Location Map

2 INTRODUCTION

This report presents a reconnaissance description of the local ground-water resources in the El Granada area and discusses factors affecting their recharge, discharge, annual and seasonal fluctuations, and water quality. A map of the study area is presented on Figure 2.

Uncertainty exists over the adequacy of ground water supplies in the El Granada area to serve the growing number of residences relying on individual wells. This concern is derived in part from a lack of historical data on ground water conditions in this area. The ability of the ground water system to sustain yields during drought periods is sensitive to the available ground water storage and the balance of ground water inflows and outflows.

This study was authorized by the County of San Mateo. It builds upon a growing framework of previous hydrogeologic investigations in the region. The study draws heavily on the existing information collected by San Mateo County Environmental Health staff. These data include, among other elements, lithologic logs, well-construction details, and key water-quality data for many existing wells in the area, Previous investigations in the region include work by Earth Science Associates (ESA) (1986), ESA with Luhdorff and Scalmanini (1987), Geoconsultants (1987 a,b), and other unpublished reports.

Municipal water supplies in the coastal terrace area of San Mateo County are currently considered insufficient to serve projected growth. Coastside County Water District obtains an average of 1.4 million gallons per day (mgd) from surface water diversions to meet the demands of about 3800 connections in the City of Half Moon Bay and the unincorporated areas of El Granada, Princeton, and Miramar. As stated in the 1986 San Mateo County General Plan, the safe yield of these sources are thought to fall short of the district's average consumption rate. To the immediate northwest, Citizens Utilities supplies an average of about 0.3 mgd to roughly 1400 connections in the communities of Moss Beach and Montara; this water is obtained solely from shallow ground water sources reported to be producing near their limit. Attempts to develop ground water from deeper zones beneath the Citizen Utilities service area have thus far been unsuccessful.

Faced with a local moratorium on water-service connections, new residential development in the El Granada area has relied solely on individual domestic water wells since 1985. These wells are characteristically shallow and of low yield. At present, permits for more than 250 domestic water wells have been issued, and about 125 wells have been completed.

Potentially-significant ground water management concerns in the El Granada area during dry periods include:

1. Diminishing yields or drying up of wells in the areas where yields decrease more rapidly with depth, or in individual wells constructed with inadequate aquifer penetration.
2. Yields which diminish disproportionately in areas of densely-clustered wells.
3. Increasing concentrations of nitrates and related constituents in a few localized areas within El Granada, possibly associated with leakage from sewer system.
4. Inducing inflow from the alluvium of Denniston Creek, possibly with perceptible effects on water levels in the Denniston Creek alluvium and in the adjacent Half Moon Bay Airport aquifer.

The technical approach used in this study involves assembling existing data, followed by organization into three separate, largely-independent lines of evidence:

1. Developing a hydraulic analysis of available ground-water storage, occurrence, and movement (aquifer mechanics approach).
2. Estimating a balance of ground water inflows and outflows within the El Granada area (dynamic hydrology approach).
3. Exploring recharge and movement by interpreting spatial variations in ground-water quality.

The following chapters of this preliminary report will follow this general format. Each section includes a discussion of information used and the analyses performed. Suggestions for additional work are outlined in Chapter 7.

Generally, our suggestions are presented in two tiers of optional basin management strategies:

1. Short-term management investigations, which are directed toward decisions required prior to connection to the CCWD system.
2. Long-term management investigations; information to be used primarily for long-term dependence on individual well supplies.

Acknowledgments

Previous work in the area and the observations of interested individuals were essential in developing the technical approach and findings presented in this preliminary report. Many individuals provided access to unpublished data or were available for informative discussions. As such, we would like to express our appreciation to a few of the many people who graciously provided the information used in preparing this report.

Existing well data and water-quality analyses for the El Granada area and other information were compiled by Leonard Chew and Richard Wilson of the San Mateo County Office of Environmental Health, who also provided numerous other helpful data, often on short notice, and Bill Rozar of the County Planning Department. Information on water use and regional service connections were provided by Bill Heaslet, Hank Sciaroni, Viola Schuetrum, George Zinckgraf, Ed Fonseca, Kamil Azoury, and Dave Mier. In addition, valuable information on the local area was provided by Kenneth Lajoie of the USGS, Carl Hauge of the DWR, and Phillip Flint.

3 AQUIFER ANALYSIS

3.1 INTRODUCTION AND INFORMATION USED

Unconsolidated marine terrace deposits, and weathered granite and sedimentary rocks comprise the El Granada area's two principal hydrogeologic units. A geologic map of the site is shown on Plate 2. The quartz diorite basement rock is extensively overlain by a thin cover of alluvium and associated sandy-loam soils. Small, narrow valleys cut into the basement rock contain stringers of alluvium that broaden seaward, interfingering with the terrace deposits; the main local aquifer. The terrace ranges between 1500 and 3000 feet in width. It includes an older inland unit and a younger coastal unit, which are considered jointly for the purposes of this report.

Available information in the files of several San Mateo County agencies, the Department of Water Resources, U.S. Geological Survey, Citizens Utilities, and the Coastside Water District were reviewed and assimilated onto a common base to evaluate the extent, thickness, and properties of the significant hydrogeologic units. Specific items addressed in this portion of the study include:

1. The degree to which the terrace and underlying weathered bedrock are hydraulically interconnected into a single system.
2. The upgradient and lateral extent of the El Granada hydrologic unit.
3. The estimated volume of ground water in storage.
4. Estimated rate of ground water flow through the system.

Table A1 in Appendix I lists well locations and construction details for approximately 120 wells used to describe the boundaries and properties of the El Granada hydrologic system. Well locations are presented graphically on Plate 3.

3.2 OCCURRENCE AND MOVEMENT OF GROUND WATER

3.2.1 Aquifer Geometry, Boundaries, and Properties

The El Granada area is underlain by two distinct aquifer systems defined on the basis of general lithology and water-bearing properties. The principal aquifer consists of unconsolidated deposits of sand, silt and clay that comprise the Half Moon Bay Terrace. Included within this system are the surficial deposits of alluvial materials located along stream valleys margins. This aquifer system is referred to throughout this report as the terrace aquifer.

The unconsolidated deposits forming the terrace aquifer unconformably overlie sandstone and siltstone of the Purisima Formation and granitic rocks (primarily quartz diorite) of the Montara Mountain batholith. While a significant number of domestic wells in El Granada draw water from these bedrock zones, the recorded drilling logs do not contain sufficient detail to provide more than a general indication of the bedrock zone from which a particular well draws. Furthermore, no consistent differences in water quality or specific capacity are noted between wells that might reasonably be expected to be completed in the Purisima Formation versus the granitic rocks. Thus, the bedrock aquifer designations presented in Table A3B (Appendix I) are chosen on the basis of reasonable geologic assumptions, and these two geologic units are collectively referred to as the bedrock aquifer throughout this report.

The distinction of the terrace and bedrock aquifers is primarily based on their respective ability to transmit water. Average specific capacities for wells completed (perforated) within the terrace aquifer are approximately 20 times higher than for wells completed within the bedrock aquifer (Tables A2A, A2B Appendix I). Based on both hydraulic and water-quality data (see below), exchange of water between the bedrock and terrace is normally quite limited.

Lateral boundaries for the El Granada Terrace aquifer are defined by a variety of indicators including geologic structure, ground water flow direction, and reported water quality, that when combined indicate distinct recharge basins. The southeastern boundary has been placed in the vicinity of Arroyo de en Medio just southeast of El Granada and the northwestern boundary is defined along Denniston Creek and through the northern portion of Princeton by the Sea. However, because of limitations in the available data, these boundaries cannot be strictly defined at present.

The terrace aquifer thins sharply along a bedrock escarpment on the northeast as shown on the geologic cross sections (Plates 4,5, and 6). It extends southwestward beneath Half Moon Bay. As indicated on Plate 14, an anomalous bedrock high is located in the northwest portion of El Granada. The terrace materials appear to be considerably thinner in this area (Plate 6, cross section C-C') resulting in a subarea of the aquifer subject to potentially greater risks in declining water level years (an area roughly bounded by Alcatraz, Escondita, and Almeria Avenues, Assessors Parcel blocks 047-052, to 055, and 074 to 077).

The water-bearing properties of an aquifer can be described by a series of coefficients, including transmissivity, specific yield, and specific capacity of wells, among others. Transmissivity is a measure of the rate at which water will flow through a unit width of an aquifer under a unit water-level gradient. In this report, transmissivity is measured in gallons per day per one foot aquifer width, or gallons per day per foot (gpd/ft). The amount of water released from a unit volume of aquifer materials when drained by gravity is called the specific yield. The specific capacity of a well is defined as the yield in gallons per minute per foot of drawdown (lowering of the water, level in the well due to pumping) and is expressed as gallons per minute per foot of drawdown (gpm/ftdd).

Water-bearing properties of the El Granada aquifers have been evaluated from information regarding individual wells available from the County of San Mateo files, and from previously-published reports. Data on specific capacities for wells in the El Granada area are available from County records; however, only very limited aquifer testing has been recorded. Values for transmissivity, specific yields, and response of water levels to variable rainfall are estimated or computed using reasonable hydrogeologic assumptions, consistent with observed conditions.

Results from limited-duration (four to six hour) aquifer tests from 44 wells completed in the terrace aquifer indicate an average specific capacity of approximately 0.93 gallons per minute per foot of drawdown (gpm/ftdd). Specific capacities in individual wells range from 0.5 to 2.86 gpm/ftdd. Specific yield of the terrace aquifer is estimated at 0.08, based on detailed logs of geotechnical and other engineering-related borings (Lowney-Kaldveer, 1974: Wells, 1975) and on interpretation of well driller's logs in the County files.

Estimates of transmissivity may be developed through theoretical and empirical relationships between specific capacity or specific yield and transmissivity that have been used by the California Department of Water Resources (1974, 1975). Using these relationships and the values of specific capacity and specific yield previously discussed estimated transmissivity for the terrace aquifer ranged from 850 to 4800 gpd/ft, with an average of about 1700 gpd/ft. This value represents an average transmissivity consistent with that expected within the fine-grained silty sands of the terrace aquifer.

To our knowledge, only two extended aquifer tests have been conducted in the terrace aquifer. Multiple-well aquifer tests described by King (1986, 1987) resulted in reported calculated values of transmissivity of 4,114 and 840 gallons per day per foot (gpd/ft) for wells in Assessors Parcel Blocks 046-042 and 047-293, respectively. It should be noted that these data were not critically reviewed for this report. The results fall within the range of values estimated empirically from an independent database and agree favorably as a conservative average of the empirically derived values of transmissivity. Overall, these estimations indicate that significant variations in water-bearing properties may exist within the terrace aquifer probably related to lateral changes in stratigraphy. For example, data from available well logs indicate that the upper portions of the terrace aquifer in the southeastern portion of El Granada contains more clay than a similar section in the northwestern areas.

Specific capacities of 59 wells completed in the bedrock aquifers average approximately 0.06 gpm/ftdd, with individual well values ranging from 0.003 to 0.13 gpm/ftdd. A few wells are apparently located within favorable fracture zones and have specific capacities on the order of 0.5 to 1.2 gpd/ftdd. Specific yield of the bedrock aquifer is estimated to be 0.01 or less. Transmissivity of the bedrock aquifer is unknown and cannot be readily estimated by empirical relationships, but is thought to be low, perhaps on the order of a few hundred gpd/ft or less. Approximately 25 wells in the El Granada area have perforated intervals extending through both aquifer systems, resulting in observed specific capacities intermediate between the average terrace and bedrock aquifer values.

3.2.2 Ground-Water Occurrence and Storage

Water-level contour maps (Plates 7 and 8) were prepared for spring and fall seasons using well data from San Mateo County files (data only available for 1985 to Spring 1987). Well-head elevations for well locations plotted on the topographic base maps were estimated from property sketches provided on the well applications, or estimated where these were absent based on reasonable assumptions regarding likely drilling locations on the property. Elevations of static water levels relative to mean sea level were calculated using drillers logs and records of water depth at the start of the short-duration aquifer tests required by the County. In comparing the maps of spring and fall water levels, it appears that little or no difference was discernible in the

El Granada area, as measured since 1985. In contrast, hydrographs from monitoring wells in the Denniston Creek area and water level records from monitoring wells at Moss Beach indicate seasonal water level fluctuations of 5 to 15 feet are commonly recorded within the coastal terrace aquifer (Earth Science Associates, 1987; Kleinfelder & Associates, 1986). The apparent absence of marked seasonal fluctuations at El Granada suggests that either 1) the aquifer exists in a steady-state condition, i.e., aquifer storage is at capacity and all additional input is lost through outflow, or 2) the estimations of land surface elevations of the wells results in a margin of error sufficient to obscure the normal seasonal variation in water level. More precise data from a monitoring program in which well-head elevations are established by survey may be needed to resolve this question.

The ground-water level maps indicate a hydraulic gradient of approximately 0.05 (equivalent to a 5% slope) extending from the highland areas of El Granada to about 1000 feet from Half Moon Bay where the gradient diminishes to approximately 0.028. Data for this latter area are limited. Overall hydraulic gradient is approximately 0.036, a value which is used in most subsequent water-balance computations.

Ground-water storage (Table 1) is estimated using well log data from 49 wells completed in the terrace aquifer, and more detailed geotechnical borings completed in the area. Most of the drillers logs were found to be imprecise with regard to lithologic descriptions of the terrace materials; however, careful comparisons of these logs with detailed geotechnical borings and field observations of the terrace stratigraphy at Half Moon Bay allow reasonable interpretation of the terrace stratigraphy as depicted on the geologic cross-sections (Plates 4,5,6). An average specific yield of 0.08 is estimated for the terrace aquifer using empirical specific yield values of 0.01 for clay, 0.05 for clayey sand and silt and 0.15 for fine sand presented by the California Department of Water Resources (1975).

The effective storage area of the terrace aquifer covers an area of approximately 365 acres. The aquifer varies in thickness from about 50 to 80 feet thick and has an effective thickness of approximately 65 feet. Well-log data indicate an average saturated thickness of about 50 feet. Thus, present storage in the terrace aquifer is the product of estimated specific yield, saturated thickness and area, or 0.08 x 50 x 365 = 1460 acre feet (a.f.), or 475 million gallons (mg). If only the terrace above sea level is considered (mean saturated thickness of approximately 30 feet) aquifer storage is estimated at 285 mg (876 a.f.).

Ground-water storage in the bedrock aquifers and related alluvial valleys is more difficult to quantify. First, the available well logs do not include sufficient detail to effectively discriminate between the Purisima Formation and the granitic rocks, and second, saturated thickness of the usable water-bearing zone cannot be accurately estimated. However, assuming a saturated thickness of 200 feet, a specific yield of 0.003 to 0.01 and an area of 400 acres results in estimated storage of 81 to 260 mg (250 to 800 a.f.) for the bedrock aquifers. This storage is conservatively excluded from subsequent calculation of water use due to the extreme uncertainties in estimating actual water production potential. Well-construction practices in El Granada normally include a twenty-foot sanitary seal with a gravel pack extending from the sanitary seal to the base of the well. Thus, even though a well may be perforated within the bedrock, vertical migration through the gravel pack from the terrace aquifer may represent a significant contribution to the yields of one or two gallons per minute associated with most bedrock wells. It should also be noted that the quality of water in the Purisima Formation may or may not be suited for domestic use; it is not considered in the above estimates.

Ground water flow through the system is estimated using the Darcian flow equation Q=TIL, where T=transmissivity, I = hydraulic gradient, and L= length of cross section. For normal rainfall years, outflow through the system is estimated at 1700 x 0.036 x 6500 = 397,800 gpd, or 445 acre feet per year (af/yr). Estimates of outflow for dry and very dry years are based on an assumed reduction in transmissivity equivalent to the estimated percent loss in aquifer saturated thickness outlined on Table 1. For example, the estimated decline in saturated thickness during a dry year such as 1981 is seven feet, or 14 percent of the total saturated thickness. Correspondingly, the estimated transmissivity is reduced by 14 percent in calculating the estimated dry year outflows, and 30 percent for very dry year (1977) outflows. Estimated outflow from the terrace aquifer is then 145 mg/yr (445 af/yr) for normal years, 125 mg/yr (383 af/yr) for dry years, and 100 mg/yr (311 af/yr) for very dry years. However, these estimates are not narrowly bounded, and could misrepresent actual variations in storage and outflow by a factor of two or perhaps more.

3.2.3 Water-Level Fluctuations

There are currently no systematic long-term water-level records available for wells within the El Granada terrace aquifer. However, hydrographs from monitoring wells located in other portions of the Half Moon Bay Terrace indicate that substantial water-level fluctuations can occur in response to short and long term climatic variations. As shown in Table 2, recent seasonal variations of 5 to 10 feet are common in monitoring wells located both to the north and south of

El Granada. These records include wells monitored in the coastal terrace aquifer in Moss Beach by Kleinfelder (1986), wells in the Denniston Creek area monitored by Coastside Water District, and wells near the Half Moon Bay Airport and the City of Half Moon Bay monitored by the California Department of Water Resources (unpublished data provided by C. Hauge, 1987).

Water levels recorded for dry years indicate a potential water level decline of 10 to 15 feet, and water-level reductions of up to 29 feet were recorded during the 1976-77 water year in DWR monitoring well 5S/6W-10J1 located near Airport Street, just west of Half Moon Bay Airport. However, a significant feature of the well hydrographs reported by ESA (1987) and the DWR for areas both north and south of El Granada is the apparent recharge of the aquifer systems to a nearly-constant winter maximum during normal or above average rainfall years. Thus, while significant lowering of water levels is recorded during severe drought conditions, water levels appear to recover to normal levels during normal rainfall years.

3.2.4 Discussion

The preceeding estimates of ground water storage and outflow are based on estimated values of specific yield, transmissivity, and water-level fluctuations for years of varying rainfall. While the estimates are based on reasonable hydrogeologic assumptions, a specific range of values has not been defined for the aquifer systems in the El Granada area. In particular, the absence of water-level records during periods of above or below average rainfall presents a serious limitation in evaluating the ability of the aquifer system to supply residential demand during extended drought cycles.

The estimated outflow and potential volumes of water in storage presented in this report suggest that the amount of water available within the El Granada terrace aquifer is large relative to present estimated pumpage of 16 to 21 million gallons (50 to 65 a.f.) per year. Assuming 40 percent of the estimated outflow to be available for domestic use without producing undesirable effects results in an estimated safe yield of 58, 50, and 40 million gallons (178, 153, and 124 a.f.) for normal, dry, and very dry years, respectively. If the resultant estimates were off by a factor of 2, an estimated 20 million gallons (62 a.f.) would be available for pumping during very dry years. The safe yield of coastal terrace aquifers is commonly estimated to be 30 to 50 percent of estimated outflows. At El Granada, the terrace aquifer has a large discharge boundary with Half Moon Bay and the heavily pumped Denniston Creek alluvium. Thus, the 40 percent value used in this report seems appropriate given our current state of knowledge of the aquifer system. It should be noted that dry years may occur consecutively and droughts of this sort may be the primary concern in terrace aquifers such as El Granada's. These questions are further discussed in the next chapter.

Further, this type of analysis does not address localized effects of clustered wells and potential over-pumping within select subareas of the basin, or potential degradation of water quality in response to declining water levels. Other uncertainties in the available data include defining the northwestern boundary of the aquifer system and evaluating the potential effect of significant ground-water withdrawal in the northwestern portion of the aquifer on the Denniston Creek area and the Half Moon Bay Airport aquifer system.

TABLE 1

TERRACE AQUIFER
ESTIMATED VOLUME OF WATER IN STORAGE AND SAFE YIELD
NORMAL, DRY, AND VERY DRY YEARS

Water Year	Estimated Saturated Thickness (feet)(1)	Estimated Specific Yield(2)	Effective Terrace Area (acres)	Estimated Storage (acre-feet)	Estimated Outflow (acre-feet)	Estimated Safe Yield (acre-feet)(3)
Normal (mean)	50	0.08	365	1460	445	178
Dry (1981)	43	0.08	365	1255	383	153
Very Dry (1977)	21 to 35	0.08	365	613 to 1022	311	124

(1) Water level changes based on hydrographs from Coastside Water District monitoring well.

(2) Assumes an average specific yield throughout entire aquifer.

(3) Assumes 40% of estimated outflow available for pumping without producing undesirable effects.
One acre foot equals approximately 0.326 million gallons.

TABLE 2

REGIONAL WATER-LEVEL FLUCTUATIONS

Well Location or Designation	Recent Seasonal Fluctuations(feet)	Dry Year (1980-81) Decline (feet)	Very Dry Year (1976-1977) Decline (feet)
Moss Beach (1)	4 to 8	--	--
Denniston Creek(2) CCWD M-1	5 to 8	10	17
HMB Airport(3) 5S/6W-10J1	7 to 10	14	29
Frenchmans Creek(3) 5S/5W-20E1	5 to 16	11	--

(1) Data from Kleinfelder (1986)
(2) Data from Coastside County Water District
(3) Data from California Department of Water Resources (Hauge,1987)

4 WATER BALANCE

A comparison can be made between the volume of water entering storage each year and the volume of outflows and pumpage during the same period. The results, known as a water budget or hydrologic balance, indicate whether the annual demands are equal to or exceed the long-term supply. When applied to dry and critical drought conditions, extreme demand effects can be estimated.

Water storage in the El Granada area is almost entirely below ground. The terrace aquifer is the principal reservoir of usable ground water. For the purpose of this analysis, all water inflows to and outflows from the terrace aquifer ~~are~~ balanced. The volume of water entering the terrace aquifer is compared to the volume of withdrawals and outflows. The difference, the change in the stored volume of ground, water represents the net surplus or overdraft. A schematic of the inflows and outflows are illustrated in Figure 3.

Water balances have been computed for three types of years--typical or normal rainfall, dry (about 75 percent of mean annual rainfall, such as occurred in 1981), and critically dry (about 55 percent of mean annual rainfall, as reported during 1976 and 1977). The effects of water-management practices for each of these types of years may be estimated from the water balance. An assessment of the consequences of any particular sequence of normal, dry, and drought years may be developed from the results. For purposes of illustration, water years 1981 and 1977 are taken to be dry and critically dry years, respectively; climatic and hydrologic data from these years have been used in the water balance, where appropriate. Because data collected during extreme conditions, such as 1977, may be atypical, estimates have also been developed using data for 1976, another critically dry year.

The water budget is based on the water year, which begins October 1 and ends September 30 of the named year. Water year 1981, for example, began on October 1, 1980, and ended on the following September 30, 1981. The water year is used in all computations of this chapter.

WATER BUDGET SCHEMATIC
USING MEAN ANNUAL VALUES
EL GRANADA, CALIFORNIA

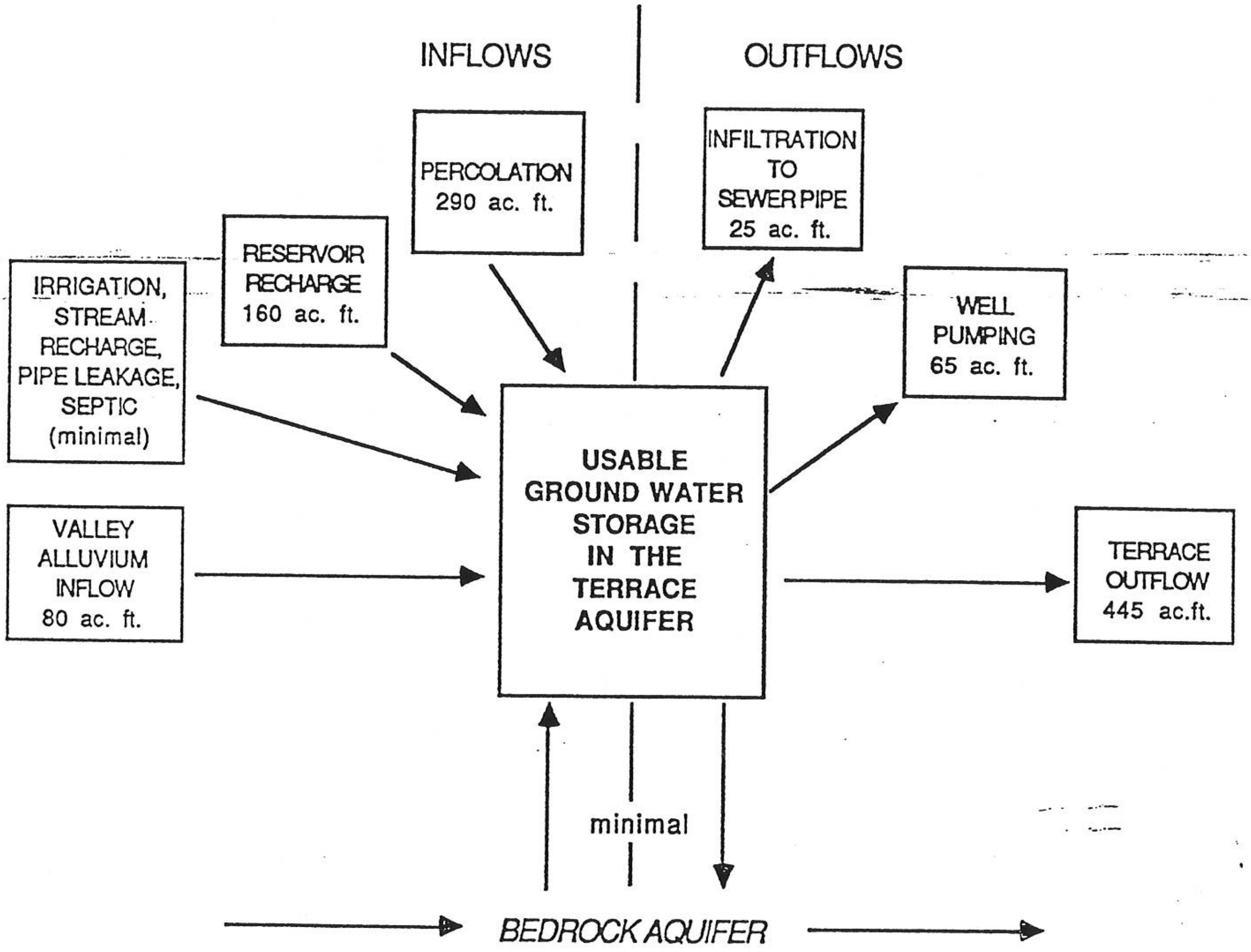


FIGURE 3. WATER BUDGET SCHEMATIC

A valid water budget includes consideration of a large number of inflows and outflows that are small relative to the issues being considered. In this water budget, components of less than 20 to 25 acre-feet per year are considered to be below the level of sensitivity. These are discussed, but are not included in the computations.

4.1 INFLOWS

Principal inflow components -- percolation, recharge, and valley alluvial ground water -- contribute an annual average 530 acre-feet of water to the terrace aquifer. Percolation which fundamentally consists of precipitation less surface runoff and evapotranspiration is a basin wide input. The terrace catchment area of 613 acres is envisioned to include the effective terrace area (365 acres), plus areas immediately above the terraces which drain directly to the terrace, rather than to the coastal valleys. Water infiltrating though the soils reaches the terrace aquifer primarily during the winter months, at which time soil moisture storage is at a maximum. Surface recharge, on the other hand, contributes to ground water storage during the majority of the year, with elevated rates during winter and spring months. Water infiltrating through reservoir bottoms and stream beds constitute this component. Additionally, water flowing though valley alluvium contribute to the terrace aquifer throughout the year, with accelerated flows during winter and spring months.

4.1.1 Percolation to Ground Water

Precipitation in the El Granada area is formally measured by three agencies. The County of San Mateo maintains five stations, of which three are in the El Granada area: 1) Scarper Peak, 2) Princeton, and 3) El Granada. The San Francisco Water Department measures rainfall at Pilarcitos Reservoir and at several locations in the upper watershed. In addition, the National Oceanic and Atmospheric Administration (NOAA) maintains a climatological station at the Half Moon Bay Airport.

We adopted the thirty-five year NOAA precipitation record (1951-85) as the basic data from which to calculate annual precipitation of the terrace and the upper watersheds. Fourteen years of this record (1940-54) was correlated to the precipitation record at Pilarcitos Reservoir to develop an extended mean annual precipitation record at Half Moon Bay, 1864 to 1954 (U.C. Agricultural Extension, 1956). More recently, a climatological summary was developed by NOAA for the period 1951 to 1980. For the purposes of this hydrologic balance, a summary of monthly mean precipitation for the period 1951 to 1985 was used. Utilizing available precipitation records and published isohyetal maps (Rantz, 1974; Soil Conservation Service 1961) a mean basin precipitation for the El Granada area of 37 inches was estimated, which agrees with previously-published figure for the area (U.C. Agricultural Extension, 1956). The thirty-five year NOAA record of precipitation at Half Moon Bay was used in the calculation of percolation. This station recorded an average mean annual precipitation of 25.22 inches for the 1951 to 1985 period.

A substantial quantity of precipitation leaves the watershed as runoff. Estimates are principally based on slope, soil type, and cover. A hydrologic report for the Colma Creek basin (Knott, 1973) documents runoff for the years 1964-1971, during urban development. Results show the runoff to rainfall ratio increasing from 0.25 to 0.43 during the eight-year period of study. Land use at the end of the study was 54% urbanized, 43% open space, and 3% agriculture. Applying these findings and the soil survey runoff descriptors (SCS, 1961) to site topographic conditions, 40 percent of the seasonal rainfall is thought to leave the terrace as runoff. Upper watershed runoff is expected to be slightly less. Runoff coefficients for the two drainages, Purisima Creek and Pilarcitos Creek, nearest in proximity to the streams above El Granada has been gaged to be about 27 percent of the estimated mean annual rainfall.

An average runoff year, however, does not directly correspond with an average rainfall year. The first seven to nine inches of seasonal rainfall is typically absorbed by dry vegetation, duff and soils surfaces. When surface conditions become saturated, significant runoff begins. Therefore, for an average rainfall year, runoff is expected to be less than average (Appendix 2). Runoff during normal, dry, and very dry years is estimated to be 75% of mean annual runoff for normal rainfall years, 50% of mean annual runoff for dry rainfall years, and 15% of mean annual runoff for drought years such as 1976 and 1977.

Water that infiltrates into the soil is available for evapotranspiration or enters soil moisture storage. Soil moisture storage is the moisture retained in the soil after a given amount of water loss or gain has occurred, and evapotranspiration represents water loss by vegetation transpiration and soil evaporation. The amount of storage fundamentally depends on soil type, soil structure, soil depth, vegetation types, and climate. Once soil moisture storage reaches its maximum, any excess infiltration becomes percolation.

Potential evapotranspiration (PET), evapotranspiration from 4 to 7 inch tall uncut pasture measured in lysimeters under optimal conditions (i.e., maximum soil moisture), is available for the Half Moon Bay area (U.C. Cooperative Extension). PET peaks during the summer months, at which time solar radiation is at its maximum. At that time, field soil moisture storage is decreasing. As soil moisture storage is depleted, the rate of evapotranspiration decreases below its potential rate, thereby resulting in a value less than the corresponding PET value. This value is the actual evapotranspiration (AET) and represents the actual amount of water loss by evapotranspiration. AET used in the development of the water balance was computed using a method developed by Thornthwaite and Mather (Appendix 2), assisted by soil survey descriptors for moisture holding capacities (SCS, 1961).

4.1.2 Inflow from Valley Alluvium

Ground water entering the terrace aquifer from the valley floors to the north and eastmay be estimated with a Darcian calculation. Ground-water inflow from the valleys at Montecito Avenue and Santa Maria Avenue is calculated to be approximately 5 to 10 and 50 to 100 acre feet per year, respectively. Estimates by comparison with computed average surface runoff (200 and 225 acre feet respectively) appear to be hydrologically reasonable. Because the valley at Vallejo Street contains a reservoir, inflow was treated as reservoir recharge (Section 4.1.3). Recharge from the colluvial slopes immediately above the terrace is assumed to be minimal in comparison.

4.1.3 Reservoir Recharge

Water-quality data (see Chapter 4) originally suggested that the reservoir in the valley above Vallejo Street may be an important source of sustained recharge. In most years, the reservoir is reported to be full in spring, gradually declining over the course of the summer. The capacity of the facility is large relative to the runoff from most winter storms, and a relatively high proportion of the annual runoff may be retained. Channel development downstream of the reservoir is quite limited. Three independent calculations were made to assess the probable magnitude of recharge to the terrace deposits from this reservoir:

1. Assuming typical vertical permeabilities of 0.0001 to 0.00001 cm/sec for lake-bottom sediments, a range of possible recharge values was computed to be 50 to 500 acre feet per year.
2. Darcian flow through the alluvial valley-floor sediments was calculated to be 50 to 100 acre feet per year using hydraulic conductivity values based on observed specific capacities for the terrace aquifer nearby. As the alluvial sediments in this narrow valley may well contain coarser, gravelly and more permeable horizons, a more reasonable estimate of flow from the alluvial sediments to the terrace deposits is 50 to 200 acre feet per year.

3. Watershed runoff is sufficient in most years to sustain this amount of recharge. Mean annual runoff is estimated to be 280 to 360 acre feet per year, assuming runoff coefficients of 0.27 to 0.35 for this steep tributary valley.

Evapotranspirative losses from the pond and marshy-ground surface is estimated to be 10 to 15 acre feet per year, (Blayney, in California State Water Resources Board, 1953) or below the level of sensitivity utilized in the water balance.

4.1.4 Other Inflows

Possible inflows to the aquifer (inputs to the water balance) that were both difficult to quantify and expected to be small in volume were regarded conservatively. Rather than adding estimates of these types of inputs to the water balance and thereby potentially over-estimating the quantity of water available in the aquifer, we chose to exclude such inputs from the water balance. These potential inputs and the basis for their exclusion are identified below.

Three larger valleys open onto the terrace. The drainage at Montecito Street contains an intermittent stream which, when flowing, is channeled onto a curbed road at Balboa Avenue and enters a storm sewer. In addition, a drainage at Santa Maria Avenue also contains an intermittent stream which enters a storm sewer at Kathryn Avenue. A small quantity of this flow may infiltrate through the surface of unpaved roads. Flow through alluvium where the canyons merges with the terrace is treated as valley alluvium inflow (Section 3.1.2).

Estimated runoff from these drainages, using mean annual precipitation of 37 inches and a runoff factor of 0.27 (consistent with other watersheds in the Half Moon Bay region for which good hydrologic records are available), was 200 and 225 acre-feet per year, respectively. These values exclude infiltration above urban areas. Assuming as much as 5 percent of this runoff infiltrates to the aquifer, the quantity input would remain less than the level of resolution of inputs used for this water balance (25 acre-feet per year). In addition, the route along which this water flows is relatively impermeable. Therefore, infiltration from both drainages were excluded as an input to the water balance and runoff is assumed to flow to the ocean.

The largest valley through which ground water may recharge the terrace deposits begins near the upper end of Vallejo Street. This valley holds the stock pond which serves as the source of the recharge described in Section 3.1.3, above. Recharge of the alluvium both upstream from and below the stock pond may occur, but is not separately quantified.

Leakage from sewer pipes was also excluded as a potential input to the water balance, despite indications of possible sewer leaks. Since sewer lines are not pressurized, we expect that the quantity of water potentially input to the aquifers at any one location is relatively small.

Water which may enter the aquifer through septic tanks and leach fields was excluded from the water balance. Few septic tanks are thought to exist in El Granada. Sewer connection records suggest fewer than 20 septic systems exist in the study area, which would contribute a quantity of water to aquifer recharge far less than the level of resolution of the water balance. It is hoped that this can be confirmed in connection with any subsequent analysis of potential septic tank influence on ground-water quality.

Input to the water balance from irrigation in the study area were assumed to be negligible, based on the general absence of water-intensive landscaping and limited agricultural areas within El Granada.

Dry wells, which in some similar areas of California are used for storm drainage, are not known to exist in the study area, and are therefore excluded from consideration as an input to the water balance.

4.2 OUTFLOWS

Outflow and withdrawals form the terrace aquifer are divided into three components -- infiltration to sewer pipes, well pumping, and terrace outflow to the ocean. As stated in Section 3.2.2, 445 acre feet per year (145 mg/yr) is expected to leave the terrace aquifer as outflow. This quantity constitutes the majority of water leaving the system. Withdrawals from the terrace aquifer are principally from well pumping and infiltration to sewer pipes. Together, outflow and withdrawals remove an estimated average of 535 acre feet per year (175 mg/yr) from usable ground water storage.

4.2.1 Infiltration to Sewer Pipe

During the rainy season, sewage volume entering the Sewer Authority Mid-Coast (SAM) sewage treatment plant from the Granada Sewer District (GSD) increased substantially from the average dry weather flow. This reflects the fact that seepage through cracks and holes in sewer pipes, unauthorized storm drainage connections, and manholes, export water from the study area which might otherwise have infiltrated to the water table and served to recharge the aquifer. Although a large portion of this exported water enters storm drains, the precise proportion cannot be accurately determined with available data. In keeping with the conservative approach of the water balance, we assume that water exported from study area sewers in excess of average dry weather flows is water that would have recharged the aquifer, and is therefore shown as an output in the water balance.

The quantity of storm runoff and sewer infiltration exported by the sewer system was estimated by subtracting daily average dry weather flow from the daily average wet weather flow for each month, and then multiplying this average daily flow by the number of days in the month in question. Summarizing these flows over the wet season provided an estimate of the annual total. This annual volume was then related to precipitation in the four years for which the sewage records were available (1983-1987). Based on a 1986 GSD engineering analysis of sewer infiltration/inflow, the proportion of sewer export attributable to the study area was estimated. This was possible because the engineering analysis evaluated four sub-areas in the GSD, two of which coincided with our study area. These two sub-areas contributed 37 percent of total infiltration/inflow (sewer export) from the GSD. In the water balance for a year of normal rainfall, an estimated 25 acre-feet was exported through sewers. This estimate was based on measured sewer discharge and an engineering study of infiltration/inflow (Carroll/Resources Engineering and Management, 1986). This volume is at the level of resolution used in the water balance; in drier years of the analysis, it is below the threshold. These outputs from the water balance, although small, were included in the water balance because the data on which they were based are substantiable.

4.2.2 Ground-Water Pumpage

4.2.2.1 Methods of Estimation

On an annualized basis, well production in the water balance is computed based on an average of 271 gallons per day per well, the average reported for residential water connections in the CCWD. This value falls within the range of about 90 to 120 gallons per day per capita (gpcd) typically reported from coastal-terrace communities in Central California. A growing body of evidence suggests that actual water use in El Granada homes served by wells may be lower than 271 gpd. Hence, we present this portion of the water budget in a form allowing for ready re-calculation of ground-water pumpage if these initial local patterns are confirmed by future meter readings.

San Mateo County has issued well permits and required meters on wells in El Granada since 1985. Approximately 120 wells have been installed. Approximately 36 acre-feet per year may be pumped from these new wells, based on CCWD mean residential usage.

Records for wells installed prior to 1985 were unavailable. Consequently, estimated total ground-water pumpage was derived indirectly by two different methods. One method was to estimate the number of CCWD service connections and the number of GSD sewer connections in the study area, and to assume the difference between the two represents the number of wells. The second method was to estimate the volume of total ground-water pumpage from measurements of sewage outflow from the study area, less water purchased from CCWD in the study area and adjusted for an estimated volume of purchased water not entering the sewer system. For both methods, only residential sewer and water connections and volumes were considered because the only wells known in the area serve individual homes.

Estimated residential water connections, sewer connections, water sales volume, and sewage production volume are summarized in Table 3. Of a total of 1664 sewer connections in the GSD, approximately 1182 were residential sewer connections within the study area. This estimate should be regarded as accurate because it was based on detailed review of the latest available GSD billing records. A value of 956 CCWD residential connections in the study area was based on an CCWD staff estimate that 35 percent of CCWD's total of 4047 connections water sales were in the El Granada-Princeton-Miramar area. About 1365 residential connections were therefore estimated to be in the El Granada-Princeton-Miramar area which was nearly equivalent to the GSD service area. The number of connections in the study area was estimated as 70 percent of the total for El Granada-Princeton-Miramar. A possible range of the number of connections on the study area was calculated by assuming 65 percent and 75 percent as low and high range values, respectively. These proportions, 65 percent to 75 percent, were based on the proportions of developed land in the study area relative to developed land in the GSD and the proportion of sewer connections in the study area relative to the total number of connections in the GSD service area. Thus, the possible number of residential water connections in the study area ranges from 887 to 1,024, with a most-likely value of 956.

Total sewage volume produced by residences in the study area was estimated from the number of connections, 1182, and the average daily sewage production per residential connection of 221 gallons. This sewage production figure was used in the San Mateo County Local Coastal Plan to estimate demand for sewage treatment capacity. Thus, residential sewage volume generated daily in the study area was estimated as 0.26 million gallons. Total water volume purchased by residential consumers in the study areas was estimated from the possible range of connections and the average daily residential purchase in the CCWD in 1985, 271 gallons. The resulting range of purchased water volume was 0.241-0.278 mgd per day, with 0.259 mgd serving as the best estimate.

4.2.2.2 Estimated Annual Pumpage

Ground-water pumpage based on the estimated number of wells (Table 4), ranged from 48 to 88 acre-feet per year, with a best estimate of 69 acre-feet (22.5 million gallons). These estimates were based on 158 to 295 wells (best estimate of 226 wells), and average daily production of 271 gallons per well.

Estimated ground water pumpage based on the difference between sewage volumes and purchased water volumes (Table 3), ranged from 44 to 76 acre feet per year, with a best estimate of 61 acre-feet per year. This estimate assumed that 20 percent of purchased water did not enter sewers, that is, was used outdoors or otherwise consumed. Modifying this assumption by increasing the percentage purchased but not entering sewers would increase the estimated ground water pumpage. The estimated volume of ground water pumpage by the two methods are in reasonable agreement; averaging the two best estimates together yields and annual ground water pumpage from both older and newer domestic wells of 65 acre-feet.

4.3 DISCUSSION

A preliminary hydrologic budget for the El Granada terrace aquifer was developed for normal, dry, and critical drought years (Table 5). Several components to the budget, as previously stated, are based on limited data and/or derived by theoretical calculations. Other components, however, are based on measurements or well-controlled estimates, and provide a solid foundation upon which to assess the water balance.

A hydrologic budget for a normal year is indicative of long-term trends in water storage within the terrace aquifer. A positive balance indicates surplus and a negative balance indicates overdraft. Because inflows and outflows for normal conditions balance to zero, the terrace aquifer is assumed to recharge in most years, with minor fluctuations expected. That is, overdraft may occur during drought years and surplus during wet periods, but long-term storage remains steady.

TABLE 3
ESTIMATED GROUND WATER PUMPAGE

	Number of Residential Connections		Residential Volume (mgd)	
	Estimated Average	Possible Range	Estimated Average	Possible Range
Sewage(1)				
El Granada Sanitary District	1664(2)	NA	0.360(3)	NA
Study Area	1182(2)	NA	0.261(3)	NA
Water Sales(4)				
El Granada-Princeton	1365(5)	NA	0.370(6)	NA
Study Area(7)	956	887 - 1024	0.259	0.241 - 0.278

1. Data from Sewer Authority Mid-Coast and Granada Sanitary District.
2. Based on Granada Sanitary District Sewer Charges, July 1987.
3. Based on number of connections and average daily discharge of 221 gallons of sewage per residence per day. Demand for sewage treatment from Local Coastal Plan.
4. Data from Coastside County Water District.
5. 35% of Water District sales to residential consumers are in the Granada-Princeton-Miramar area (CCWD)
6. Based on average residential consumption of 271 gallons per day.
7. Estimated average based on 70% contribution of study area to El Granada-Princeton-Miramar water sales; low and high range values based on 65% and 75% contribution, respectively. The study area has 71% of the total number of residential connections in the Granada Sanitary District. Water connections presumably have a similar distribution.

TABLE 4
ESTIMATED GROUND WATER PUMPAGE
NUMBER OF WELLS AND GROUND WATER WITHDRAWLS ESTIMATED AS DIFFERENCE BETWEEN RESIDENTIAL SEWER AND WATER CONNECTIONS, STUDY AREA(1)

	Estimated Average	Possible Range
Number of Wells(2)	226	158-295
Total (mgd) (3)	0.061	0.043-0.080
Total (Acre-Feet/Yr)(3)	69	48-88

GROUND WATER WITHDRAWALS ESTIMATED AS DIFFERENCE BETWEEN VOLUME OF SEWAGE AND VOLUME OF WATER SALES, STUDY AREA RESIDENTIAL USE(4)

	Estimated Average	Possible Range
Sewage Volume	0.261	NA
Purchased Water(14) Entering Sewer System (mgd)(5)	0.207	0.193 - 0.222
Ground Water Withdrawn (mgd)(6)	0.054	0.039 - 0.068
Ground Water Withdrawn (Acre Feet/Year)	61	44 - 76
Number of Wells (7)	199	144 - 251

1. Assumes that sewer connections in excess of water connections are representative of the number of wells in the study area.
2. Study area residential sewer connections minus study area estimated residential water connections.
3. Based on estimated number of wells and 271 gallons per day per well (CCWD average consumption per residence).
4. Assumes that water discharged to sewers in excess of purchased water represents the volume of water withdrawn through domestic wells.
5. Assumes that 20 percent of volume purchased does not enter sewers.
6. Difference between sewage volume per day and purchased water entering sewer system per day.
7. Estimated average ground water withdrawn per day divided by average residential water consumption (271) gallons per day).

The hydrologic budget, however, is more appropriately utilized as an indication of extreme conditions. When the water balance for normal conditions are validated, an estimation of the amount of ground water in reserve during dry and wet periods can be calculated. For the purposes of this analysis, dry year (i.e., 1981) and drought (i.e., 1976 and 1977) conditions were examined (Table 6). Results indicate 140 acre-foot overdraft during a dry year and 210 to 300 acre-foot overdraft during a critical dry year. This corresponds to a 5 to 10 foot average drawdown for the terrace aquifer during a dry year and a 10 to 20 foot drawdown during a critically dry year. For a two year drought similar to 1976-77, a 500 acre foot overdraft with 17 to 34 feet of drawdown can be expected by the end of the drought. However, because the water balance for normal conditions is zero, a rapid recovery of water levels during wet years can be expected. The observed response to climatic variations in Half Moon Bay terrace monitoring wells supports this interpretation (Section 2.2.3).

4.4 INFORMATION USED

Available data on water sales and sewage production in El Granada were used to estimate ground water withdrawals from the aquifer and export of runoff and infiltrating ground water by sewer pipes.

Water sales data were provided by the Coastside County Water District (CCWD). Records of water sales and service connections are not kept specifically for El Granada by CCWD, however, annual reports on water production and sales within the CCWD were available. Data for sales volume and residential service connections from the 1985 CCWD annual report ("Water Supply Evaluation"), together with CCWD staff estimates of the El Granada-Princeton-Miramar region's proportion of water sales in the District were the basis of estimated water sales and service connections on the study area.

Data on sewage production and sewer connections in the study area were provided by the Granada Sanitary District (GSD) and the Sewer Authority Mid-coast (SAM). The number of GSD sewer connections in the study area was derived directly from GSD billing records. The number of sewer connections combined with the average volume of sewage produced per connection, provided an estimate of average sewage volume produced in the study area.

SAM records of sewage produced by the GSD, (average daily volumes by month from November 1983 to July 1987), together with annual precipitation data for the region, provided the basis for estimating the volume of runoff and infiltrating ground water exported form the GSD by sewer pipes. An analysis of infiltration and inflow performed by GSD engineers provided an estimate of the proportion of the GSD's total sewer infiltration and inflow contributed from the study area.

San Mateo County well permits from 1985 to 1987 provided a minimum estimate of the number of wells in the study area; however, other means were used to estimate ground-water withdrawals and the potential number of existing wells. A minimum estimate of withdrawals from ground water would tend to underestimate outputs from the water balance.

The calculation of terrace infiltration was based on rainfall data collected at Half Moon Bay by the National Oceanic and Atmospheric Administration. Runoff coefficient estimations were guided by a study in Colma Creek basin (Knott, 1973), soil survey descriptors (SCS, 1961), and USGS streamflow data from the coastal San Mateo and Santa Cruz counties. Potential evapotranspiration (PET) data was measured in the Half Moon Bay area by the U. C. Cooperative Extension. A method of computing actual evapotranspiration, developed by Thornthwaite and Mather, was used in accordance with runoff coefficients and PET.

Darcy's relation for flow through porous media was used to calculate inflows from valley alluvium. Infiltration rates of .0001 and .00001 cm/sec guided reservoir recharge estimates. And, evaporation measurements are published in the California State Water Resources Board Bulletin No. 5.

TABLE 5
Preliminary Hydrologic Budget for the El Granada Terrace Aquifer
"Normal", "Dry", and "Critical Drought" Years

Type of Year Year Chosen As Representative	Normal Year (Mean) ac. ft.	Dry Year Water Year 1981 ac. ft.	Critical Drought Years Water Year 1976 ac.ft.	 Water Year 1977 ac. ft.	Remarks
<u>Inflows</u>					
Precipitation	1290	983	752	746	NOAA data at Half Moon Bay, 35 yr. period of record
Inflow from alluvial and granitic areas north of terrace	80	40	12	12	Theoretical calculation, Darcian flow
Pond recharge	160	80	24	24	10^{-5} to 10^{-4} cm/sec. infiltration; Darcian flow
Other inflows (2)	t	t	t	t	
SUBTOTAL	1530	1103	788	780	
<u>Outflows</u>					
Actual evapotranspiration	614	518	534	610	PET; U.C. Cooperative Extention at Half Moon Bay AET; The water balance, Thornthwaite and Mather
Runoff(1)	387	258	77	77	40% of ppt; Colma Creek Basin, Knott 1973; 54% urban
Infiltration to sewer	25	18	14	14	Sewer Authority Midcoast monitoring records
Well pumpage (3)	65	65	65	65	Estimate based on GSD and CCWD billing records
Pond evaporation	t	t	t	t	58 inches/yr., SWRB Bulletin No. 5
Terrace ground water outflow at Hwy 1	445	383	311	311	Theoretical calculation, Darcian flow
SUBTOTAL	1536	1242	1001	1077	
BALANCE (inflows-outflows)	0	-140	-210	-300	Recorded as two significant digits
Equivalent Drop in Water Level (4)	0	5-10 feet	7-14 feet	10-20 feet	

footnotes: t - trace amounts which are difficult to accurately quantify, assumed less than 25 ac. ft.

(1) Mean runoff is based on 40% of mean precipitation within developed areas of El Granada. Adjustment to correct the variability of flow during normal, dry, and very dry years (Appendix A): normal rainfall, 75% of mean annual runoff; dry rainfall, 50% of mean annual runoff; very dry year, 15% of mean annual runoff.

(2) Other inflows include: stream recharge within terrace area, irrigation, water main leakage, and septic system effluent.

(3) May be slightly greater than actually occurs in El Granada, based on limited water-meter data to date.

(4) Year-to-year change in expected water levels based on balance and estimated specific yield of the uppermost terrace sediments (0.04-0.08).

TABLE 6

Normal, Dry, and Critically Dry Water Year Characteristics

Type of Year	Range of Precipitation	Representative Year
Normal	80-100%	Annual Mean
Dry	60-80% of Mean Annual	1981
Critically Dry	<60% of Mean Annual	1976 1977

5 WATER QUALITY

5.1 PURPOSE

Analysis of water quality is of primary importance in coastal-terrace aquifer systems from four perspectives:

1. The public health must be protected by observing water-quality standards
2. As water levels fall in an overdrafted or depleted aquifer, concentrations of constituents of concern often rise, resulting in dual limitations for ground-water use
3. Long-term trends in key water-quality constituents are essential to responsible aquifer management
4. Differences in water quality within an aquifer often describe the sources and movement of ground water

All four objectives are considered in the discussion contained in this chapter. Emphasis is placed on the first and last, as these are of particular importance, given the interim timeframe projected for aquifer management in El Granada. The data describing water-quality variations within the terrace aquifer are especially instructive regarding the sources and magnitude of recharge of the terrace aquifer system.

5.2 ANALYSES AVAILABLE

Domestic water wells within the El Granada area are routinely tested for iron, manganese, chloride, nitrate and specific conductance prior to final certification by the San Mateo County Department of Health Services. For this investigation, water-quality data from approximately 100 domestic wells (Table A3A and A3B) were used as a basis for mapping concentrations of chloride, nitrate, and specific conductance (Plates 9, 10, 11). While it is not uncommon for wells in the El Granada area to contain high levels of iron or manganese, these data are intended more for the use of individual wells owners than for aquifer management; they were not closely examined for this report. Factors affecting the distribution of specific conductance, chloride, and nitrate are of regional significance, and are discussed in the following sections.

5.2.1 Specific Conductance

Specific conductance, also known as conductivity, is a measure of a fluid's ability to transmit an electrical current. This ability in water is closely related to the concentrations of salts and other dissolved solids in the water. Pure water has a very low specific conductance; as ionic concentrations increase, specific conductance also increases, generally in a linear manner for the moderate levels observed in the El Granada area. Specific conductance is measured in micromhos per centimeter at 25°C. The recommended maximum for specific conductance in public water supplies is 900 umhos/cm, although higher levels are allowed.

Representative values of specific conductance in water sources near El Granada are shown in Table 7. No analyses of ground waters are available for El Granada which describe the composition of the major ions contributing to the conductivity of the water. Table 8 presents general mineral analyses from streams and wells adjacent to the study area. It may be noted that the concentrations in surface waters are normally substantially lower than in ground water. Analyses of ground water presented in these tables were chosen to represent periods of high and low water levels, including the above-average rainfall period of the mid-1970's and the critical drought of 1976 and 1977. Little variation in either the concentrations or relative composition of ground waters was observed in the two adjacent terrace wells. The constancy of ground-water quality in the terrace aquifer is an attribute enhancing the value of the water resource.

Average reported specific conductance of waters in approximately 100 wells in El Granada is about 700 umhos/cm. Values for wells completed in the terrace aquifer range from 300 to 1400, with an average of 590 umhos/cm. Values for wells completed in the bedrock aquifer vary within a similar range but average about 830 umhos/cm. The higher average specific conductance for the bedrock units is not fully understood but is not unusual for coastal systems.

Relatively small differences, however, are noted in the reported specific conductance of adjacent wells completed in different aquifers. Well construction practices in El Granada may promote exchange of waters between geologic units, due both to the large drawdowns (and related high driving hydraulic heads between aquifers) and to the custom of gravel-packing the entire well bore beneath the sanitary seal (generally extending 20 feet below ground level).

The primary features of the specific conductance map (Plate 11) are a series of north-south oriented highs and lows crossing Highway 1, and a major plume-shaped area below the central drainage channel. These features appear to correspond to apparent patterns of recharge emanating from the three drainages entering the terrace from the upland areas.

5.2.2 Chloride

Reported chloride concentrations range from approximately 60 milligrams per liter (mg/l) near Arroyo de en Medio to over 200 mg/l in isolated wells in the upland areas of El Granada (Plate 9). Wells completed in the terrace aquifer average approximately 100 mg/l chloride, whereas wells completed in the bedrock aquifers average about 140 mg/l. Some of the elevated chloride concentration in the bedrock aquifer may be attributed to connate waters within the Purisima Formation (waters with a long residence time in the ground). However, some of the highest values (200 mg/l) are recorded for wells completed within the granitic bedrock in the upland areas, where low chloride values would normally be expected. For example, reported chloride concentrations in similar granitic rocks in coastal Santa Cruz County were in the range of 10 to 25 mg/l. Concentrations of 10 to 50 mg/l are observed in wells completed in granitic rocks along Highway 1 in Monterey County. Two groups of sources for the unusually high chloride levels may be postulated:

1. Sampling or analytical errors, such as taking water samples shortly following chlorination of the well by the driller
2. Geologic sources, including possible emanations from deeper structures.

If the second were true, the geologic contribution would likely be fairly constant over time; during sustained droughts or periods of overdraft, chloride concentrations in wells along the upper edge of the terrace would likely increase, and may surpass the recommended long-term limit of 250 mg/l, or the temporary threshold of 500 mg/l. It is also possible that elevated concentrations of other constituents often associated with deeper geologic waters (such as sodium, boron, arsenic, or fluoride) may be present, although the values reported in nearby wells monitored by DWR (Table 8) are typical for coastal terrace environments.

If the first case were true, changes in sampling would produce more accurate and usable data. It may also lead to anomalous nitrate concentrations, as free chlorine is a major interference in most methods of nitrate determination. Questions might also be raised regarding the representativeness of samples collected for bacterial analysis, if these were taken from the well shortly after chlorination.

5.2.3 Nitrates

All of the wells reviewed during this investigation were found to meet California primary water-quality standards for nitrate, although several were retested by County staff after initial analyses indicated the presence of excess nitrate. The nitrate concentration contour map (Plate 10) reveals several distinct areas of elevated nitrate levels. Concentrations of up to 40 mg/l are reported for wells in Assessors Parcel Blocks 047-041, 042, 043, 047-106, 047-203, 047-273, and 048-045. The nitrates may result from several possible sources, including residences having septic tanks, sewer-line leaks, low lying areas containing abundant organic material within the terrace deposits, and agricultural sources.

The nitrates in the area of Parcel Blocks 047-041, 042, 043 (an area bounded by Alcatraz, Peralta, Presidio Avenues, and Highway 1) may result in part from organic material within the terrace deposit as this area has historically been marshy and wet (Chew, 1987, personal communication). The well in Parcel Block 048-045 (at Miramar Drive and Purisima Way) is located downstream from an active agricultural operation and may contain leached nitrates from fertilization. However, the remaining areas (Balboa at Coronado, Escalona between Paloma and Carmel, and Palma between Isabella and Santa Maria) may be more related to broken sewer lines or old septic systems. Excessive nitrate concentrations may present a significant health risk to infants.

One of the most significant features of the nitrate map (Plate 10) is the plume-shaped body of low-nitrate waters emanating from the central drainage channel at the head of Vallejo Street. This feature provides compelling evidence for recharge to the terrace from the drainage channel. This recharge appears to be related to the stock pond located upstream from the terrace, suggesting that significant recharge by infiltration from the pond occurs.

TABLE 7
Ranges of Selected Water-Quality Parameters from Varying Geologic Sources, El Granada and Vicinity

Water Source	Geologic Source	Period and Type of Record	Range of Analytical Values Specific Conductance (umhos/cm)	Range of Analytical Values Chloride (mg/l)	Source of Data
I. Surface Waters					
Denniston Creek	Montara Mountain granitic rocks	Monthly: 1963-1964 (Dry Year) a/	257-300	--	DWR Bull. No. 138
		1987 CCWD Analysis a/	190	24	Dave Mier, CCWD
		1982 CCWD Analysis c/	220	37	Leonard Chew, SMCHD
San Vicente Creek (Montara)	Montara Mountain granitic rocks	1987 CCWD Analysis a/	260	4.3	As above
Pilarcitos Reservoir	1. Montara Mountain granitic rocks 2. Tertiary sedimentary rocks 3. Franciscan Assemblage	SFWD Analyses for 1980 b/ SFWD Analyses for 1981 a/ SFWD Analyses for 1983 c/ SFWD Analyses for 1986 b/	161 178 161 181	23 21 17 18.1	Matt Nonan, SFWD
Purisima Creek	Teritiary sedimentary rocks (Purisima Fm.)	Monthly: 1963-1964 a/	619-668	--	DWR Bull No. 138
San Gregorio Creek	Tertiary sedimentary rocks	As Abovea/	748-1010	--	As above

a/ Below-normal rainfall
b/ Mean or above mean annual rainfall
c/ Substantially above mean rainfall

TABLE 8

Mineral Analyses of Natural Waters
El Granada Area and Representative Comparisons

Water Source No. Name of Designation	Geologic Source	Sampling Data b/ Date	Sampled	Analyzed by	pHc/	Specc/ Cond.	Analytical Results b/ Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	NO_3	F	B	Si	TDS
I. Surface Water Denniston Cr. at CCWD Diversion	Montara Mt. Granitic Rocks	1982	CCWD	--	7.8	220	20	0.73	170	--	73	--	9	37	<0.44	0.26	--	--	220
II. Ground Waters State Well 5S/6W-11B1 (Ag Well NE of Hwy 1)	Terrace Deposits	8/74d/	DWR	DWR	6.7	640	38	20	46	0.6	104	0	56	84	6.7	--	0.00	--	376
		6/76e/	DWR	DWR	6.5	567	--	--	59	--	111	--	--	110	--	--	--	--	--
5S/6W-14D1 (Princeton Well)	Terrace Deposits	6/75d/	DWR	DWR	72	675	35	22	55	2.1	187	0	2	105	0.3	--	0.10	--	373
		7/77e/	DWR	DWR	7.1	639	--	--	56	--	185	--	--	111	--	--	--	--	--

a/ All analyses in milligrams per liter (mg/l), except for pH (standard units) and specific conductance (umhos/cm at 25°C)
b/ Agency codes: CCWD: Coastside County Water District DWR: California Department of Water Resources
c/ Field values
d/ 1974 and 1975 are years of above-average and average rainfall
e/ 1976 and 1977 are years of critical drought

6 CONCLUSIONS

The potential volumes of water in storage estimated in this report suggest that the amount of water available within the El Granada terrace aquifer is large relative to present estimated pumpage. Using estimated values of specific yield and water level fluctuations for varying hydrologic conditions, the volumes of water in storage for normal, dry, and critical drought conditions are estimated to be 470, 400, and 195 to 325 million gallons (1450, 1250, and 600 to 1000 acre-feet), respectively, for the terrace aquifer. Ground water storage in the granitic bedrock is estimated to be approximately 80 to 260 million gallons (250 to 800 acre-feet), although this value is less well defined. Based on potential water quality problems and poorly-defined extent, storage within the Purisima Formation has been excluded from these discussion. We also feel that a potentially significant amount of the water produced from many bedrock wells may be provided by vertical flow through the gravel pack from the terrace aquifer. Thus, while many of the wells in the El Granada area are completed at least partly within bedrock aquifers, the water-bearing properties of these zones are poorly understood.

Ground water flow through the terrace aquifer (beneath Highway 1) is estimated about 145 million gallons (450 acre feet) per year for normal years, 120 mg (383 acre feet) for dry years, and 100 mg (311 acre feet) for very dry years, based on reasonable hydrogeologic calculations. Actual values of transmissivity, specific yield, and water-level response are not well constrained, and the estimated volumes of ground water storage and outflow could, in specific subareas, be in error by a factor of two or more. For example, available well-driller's logs suggest the presence of a larger percentage of fine-grained materials (clay) within the upper portions of the terrace aquifer in the southeastern portion of El Granada (see Geologic Cross-Section A-A', Plate 4) suggesting this area may be more adversely affected by declining water levels under extreme drought conditions. Similarly, the relatively thin terrace aquifer section beneath the area bounded by Alcatraz, Escondita, and Almeria Avenues, represents a potential drought year high-risk area for wells completed in this portion of the terrace (all existing wells in this area are completed in the bedrock aquifer).

Neither regular water-level measurements nor continuous water-level monitoring have been conducted in El Granada. Hydrographs from monitoring wells located in other portions of the Half Moon Bay Terrace (Earth Science Associates, 1987, Hauge, 1987) indicate seasonal water-level fluctuations of 5 to 10 feet during average years with apparent recharge to a nearly-constant winter maximum during normal or above-average rainfall years.

The hydrographs also indicate a potential lowering of water levels of 17 to 29 feet during critical drought years, as occurred in 1976 and 1977. As an independent line of evidence, a potential drought year water-level decline of 10 to 20 feet, and extended drought condition decline of 17 to 34 feet, are predicted in the preliminary hydrologic budget for the terrace aquifer presented in this report. The preliminary analysis suggests that a potential 20 to 30 foot drop in water levels would not result in a significant potential for sea water intrusion.

The available data indicate generally fair water quality within El Granada although treatment is commonly required due to relatively high concentrations of iron and manganese. Several wells show elevated concentrations of nitrates, suggesting a potential for water-quality to fall to unacceptable levels during periods of significant water-level decline. The source of the nitrate is not presently known, but may include deep percolation from sewers, agricultural applications, septic-system effluent or decaying organic matter naturally found in the terrace deposits.

Anomalously high (greater than 200 mg/l) chloride concentrations are reported for several wells completed in the granitic bedrock. The source of the chloride is unclear, but could be related to sampling errors or possible emanations from deeper geologic structures. As with the nitrate, chloride concentrations could increase during extended drought cycles, if the latter is in fact the case.

The water quality maps prepared for this report suggest that significant recharge to the ground water system may occur from the stock pond located in the canyon above Vallejo Avenue. Estimates of recharge based on standard infiltration rates and Darcian flow suggest that approximately 160 ac.ft./yr may be added to the aquifer system during average years. Although additional investigation is warranted, the preliminary recharge estimates indicate that infiltration ponds of this nature may provide significant inputs for long-term ground water basin management.

Perspectives on risks and alternatives for appropriate management are discussed in the next chapter.

7 ASSESSMENT OF RISKS AND SUGGESTED DIRECTIONS FOR MANAGEMENT OF GROUND WATERS

A major objective of this investigation is identifying the risk involved in developing ground water for individual residences pending completion of the imported water source. In this chapter, the problems likely to be encountered and the manner in which they may be approached are discussed. Several suggested management strategies are advanced conceptually; any specific management plan or implementation appears both premature and beyond the scope of this investigation.

7.1 GENERAL APPROACH: RELATION OF RISKS AND WATER-LEVEL DECLINE

The risks inherent in extensive ground-water development by individual wells in El Granada increase both in magnitude and complexity as water levels decline.

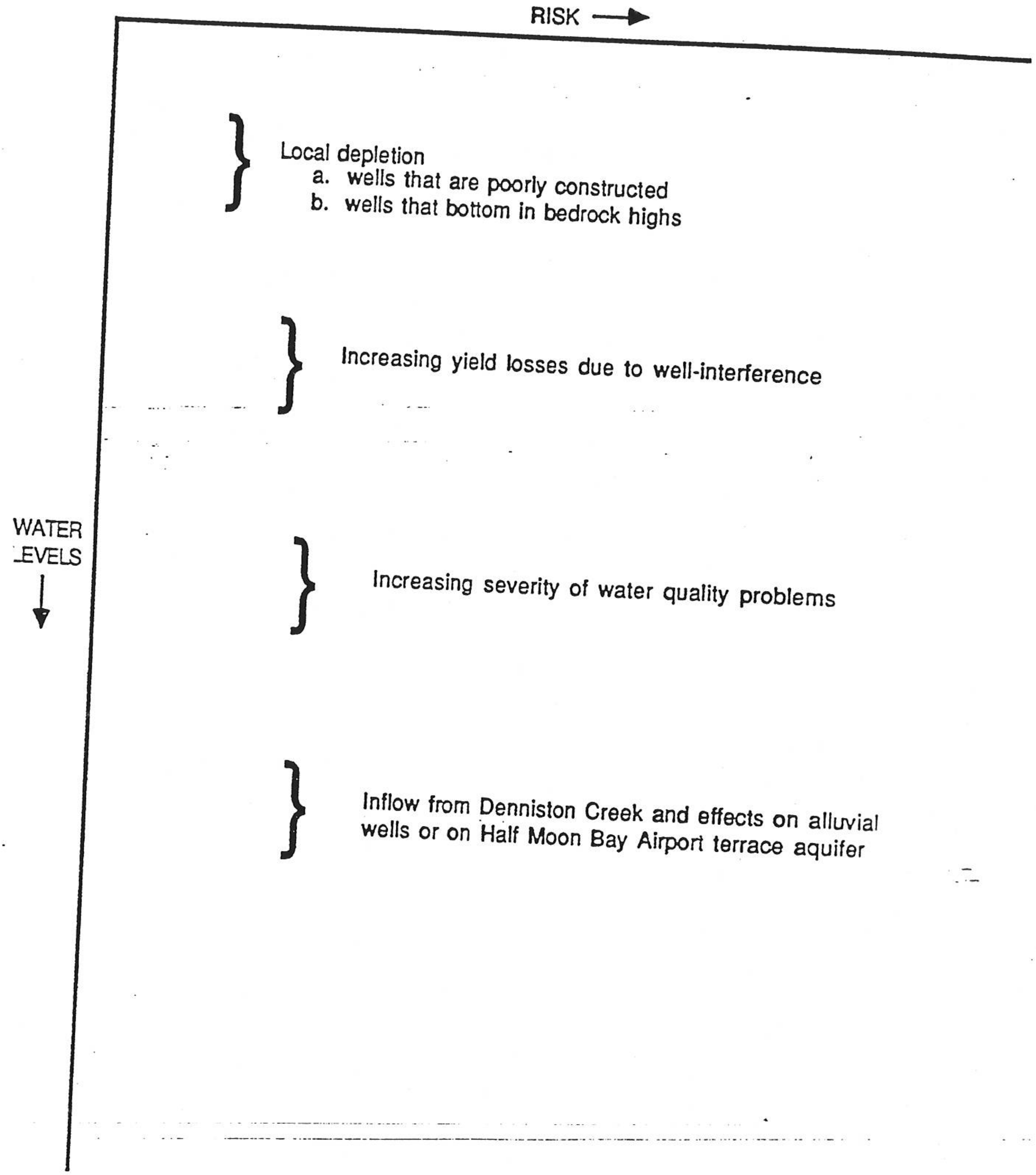
Based on the water-balance analysis, a decline of 15 to 25 feet in mean terrace-aquifer water levels might be expected during a particularly-severe two-year drought, such as occurred in 1976 and 1977. The observed decline in CCWD well M1 -- about 17 feet -- is consistent with the estimated values. The 1976 and 1977 drought provides a reasonable context for assessing probable effects on individual well owners. Other sequences of dry years might be postulated and the effects projected once records are available of actual water-level response during dry periods.

7.2 PROBLEMS LIKELY TO OCCUR AS WATER LEVELS DECLINE

Problems likely to be reported in the terrace aquifer as water levels fall are shown schematically in Figure 4. Each type of problem can occur at a broad range of water-level declines. The focus of this discussion is, however, oriented toward the threshold at which a problem extends beyond a few isolated cases, becoming a community health concern.

FIGURE 4.

SCHEMATIC ILLUSTRATION OF INCREASING RISKS WITH DECLINING WATER TABLE, EL GRANADA AREA, SAN MATEO COUNTY



7.2.1 Local Depletion

The initial effects of falling water levels may be diminished yields and longer duration of pumping, particularly in wells of subnormal construction or maintenance. Wear-and-tear on the pumps and the wells may be initially expected, resulting in increased "down time" for repairs, especially in wells with small-diameter bores, such as is common El Granada. Eventually, yields in the wells diminish to inadequate amounts as water levels decline. Affected individuals must locate alternative sources of supply.

A similar progression is expected in some wells within areas of bedrock, or elevated bedrock benches beneath the terrace deposits, such as occurs in the northwestern portion of the study area. Wells which provide ample supply in normal years may yield much lower amounts when water levels fall below the upper zones of more-permeable terrace sediments, and the full demand requirements must be sustained from the bedrock units. A few wells currently have been drilled in such areas since the drought of 1976 and 1977, although we know of no wells which were operative during the drought in these parts of El Granada.

Based on the limited available data, it is likely that local well depletion will extend beyond a few isolated cases when static water levels fall about 15 to 20 feet below normal levels.

7.2.2 Diminished Yields Due to Interference Between Wells

Interference between pumping wells increases as water levels decline, especially in areas such as El Granada, where aquifer hydraulic conductivities (or transmissivities) typically decrease with depth. Additionally, pumps are often operated longer, resulting in larger and more sustained pumping cones.

The degree of additional drawdown related to interference between wells increases as transmissivities decrease. Transmissivities may be most usefully understood in this context as the product of the saturated aquifer thickness and the mean hydraulic conductivity ("permeability") of the aquifer in the saturated zone. The distance between wells, the rate of pumpage, and the degree of local hydraulic confinement (usually expressed as the storage, or storativity coefficient) also affect appreciably the amount of additional drawdown induced by interference between wells. Wells spaced 50 feet apart may exert supplemental interference drawdowns of about 10 to 15 feet in typical terrace-deposit sediments, and 35 to 50 feet or more in fractured granitic materials. During droughts, the effect of interference may be somewhat

greater, due to reduced saturated thickness. Measures which diminish the additional drawdown related to interference increase the reliability of yield during prolonged dry periods. Among such potential measures are reduced pumpage, increased minimum spacing between individual wells, increased mean spacing between domestic wells, and staggered hours of well operations.

Further discussion of the relationships among well spacing, induced drawdown, and aquifer properties is presented in Appendix 3.

7.2.3 Increasing Severity of Water-Quality Constraints.

Originally, water-quality was not considered a limiting factor in El Granada, other than the possibility of intruding sea water. Interpretation of the data collected for the County indicates that at least two more-localized constraints may affect a number of wells considerably earlier than any expression of sea water intrusion might be expected:

1. Elevated nitrates are reported from a number of wells throughout the study area. In at least three cases, reported values are just below maximum concentration levels. If the sources of these nitrates are either large or continuing, nitrate levels in the affected wells and their neighbors might be expected to increase, perhaps sharply. Much of the increase is likely to occur when the water table declines to a level approaching the upper perforation in the well, as nitrates in this type of area tend to be highest in the upper part of the water body, nearest their source at the land surface. Many wells in El Granada have perforations beginning a relatively short distance beneath the normal summer water level. Where substantial nitrates occur in the ground water, increases to levels above drinking-water limits might be expected with water-level declines of 10 to 30 feet.

2. Elevated levels of chloride (generally 200 to 250 mg/l) are reported in a number of wells, most commonly along the upper edge of the terrace deposits. The cause of the these reported values may be either non-representative sampling and analytical practices, or deeper geologic emanations (See Chapter 5). If the latter is true, chloride values would be expected to increase during periods of sustained drought as less recharge is available to dilute the deeper waters. Increases above the secondary-standard maximum of 250 mg/l, or possibly the short-term maximum of 500 mg/l, might occur.

Measures which may be taken to control or minimize the related risks include:

1. Obtaining more information on the distribution of these constituents by continuing the County's practice of requiring analyses as a condition of the well permit.

2. Ascertaining whether the nitrate in wells with elevated concentrations may be due to leakage from sewers or septic system effluent by field-testing for the presence of surfactants (MBAS), and then encouraging location of the source and its repair. Tests for nitrate and other sewer-borne constituents might be conducted following repair or removal of the source.

3. Wells with high nitrogen levels attributable to agricultural sources may be protected in part by encouraging changes in fertilization or irrigation practices; the necessary information is available from the Farm Advisor's Office or the Regional Water Quality Control Board.

4. Sources for the elevated chloride levels can be explored, first by retesting selected wells. If the chloride proves to be of geologic origin, the County may wish to establish a baseline set of values for specific conductance in a number of wells reporting high chloride concentrations, and monitor these changes annually, late in summer or early in fall. Additionally, individuals may be encouraged to test their wells, perhaps more than once, during periods of sustained drought.

7.2.4 Inflow from Denniston Creek and Potential Effects on Areas to the West

The relation between water levels in the western part of the El Granada terrace aquifer and those in the alluvium of Denniston Creek is poorly defined at present. Improved definition would provide useful perspective on two potential ground water problems:

1. Flow from El Granada to the Denniston Creek alluvial aquifer might be induced if sufficient production well pumpage from the alluvium were to be developed; effects on the water balance of El Granada could prove to be large.

2. Excessive decline of water levels in El Granada relative to those in the alluvium could potentially induce flow into El Granada, at some (undetermined) decline in water levels, resulting in water level declines within the southern Airport aquifer and perhaps in Pillar Point Marsh.

Information to assess these questions does not presently exist. It might be gained by a number of means, of which the simplest may be establishing a line of wells from western El Granada to the marsh which might be used to monitor for water level and specific conductance. Interbasin flow depends on the difference in <u>relative</u> water levels, and not their actual values. It is likely that substantial relative differences in water level would develop for an extended period only in the course of water-level declines larger than those discussed above; however, the present regime appears sensitive to any significant changes in water withdrawals and use in the three systems.

7.3 GENERAL MANAGEMENT CONCEPTS APPLICABLE TO EL GRANADA

Risk may also be better assessed and minimized through sound water-management practices. General management options can be divided into three levels of involvement, depending primarily on projected demands on the aquifer system.

The results of this investigation suggest that the El Granada ground water system could support additional wells over the short-term without developing significant problems relating to water availability or quality except during extended drought cycles when water-level declines and/or water-quality constraints will gradually affect an increasing number of wells as the drought persists over a period of years. Thus if the basin is viewed as a short-term supply to be heavily developed only until additional connections to the CCWD system are provided, passive observation and data collection might provide a suitable management approach. A passive management program would consist of the following:

1. Continue present system of permitting and installing wells; documenting any problems that arise related to yield or water quality constraints.
2. Resampling wells reporting elevated concentrations of nitrate, chloride, or specific conductance: Require expanded analysis for wells reporting elevated concentrations of nitrates to determine nitrate source.
3. Recording semi-annual water-level measurements in a few selected wells to establish a record of water-level response.
4. Initiate coordination with GSD to investigate possible sewer line leaks or presence of septic systems.
5. Reassess basin management yearly to decide upon a number of permits to issue for the following year.

The passive management program may also be a suitable approach even if demand on the aquifer system is expected to increase over the long-term.

Alternatively, long-term dependence and development of the aquifer might be more appropriately managed through an active program of data collection and monitoring. An active management program would be designed to establish historical patterns of ground water response to varying climatic conditions and to better identify potential problem areas associated with clustered wells or geologic constraints. In short, the program is designed to address unresolved questions regarding the occurrence and movement of ground water in El Granada, and provide a basis for management decisions in specific subareas of the basin. An active management program would include selected passive management items listed above and would additionally include the following tasks:

OBJECTIVE: Establish an observed record of water-level response to varying rainfall patterns and better define recharge and movement of ground-water.

1. Initiate a monitoring well system along each of the three geologic cross-sections lines shown on Plate 2. Existing residential wells could be used if local residents were willing to participate in the program.
2. Install two continuous water-level recorders in the central portion of the basin (general vicinity of Valencia and Vallejo Avenue, and Vallejo Avenue above San Juan). These records would be used to monitor potential recharge of the terrace aquifer from stream valley runoff.

OBJECTIVE: Better define the northwestern boundary of the El Granada aquifer system and assess potential impact of ground water withdrawal on the Denniston Creek alluvial aquifer system.

3. Conduct quarterly water-level monitoring of the CCWD monitoring wells in the Denniston Creek area.
4. Analyze chloride, nitrate, and specific conductance levels in water samples from CCWD monitoring wells M-1,2,4, and 7.

OBJECTIVE: To assess long-term water-quality trends and identify potential high-risk subareas.

5. Require bi-yearly chemical analysis of wells.
6. Select a series of wells in both the terrace and bedrock aquifers for yearly chloride analysis to assess sea water intrusion potential.
7. Require extended aquifer tests in high-density well areas.
8. Reassess basin management annually.

In addition, locally-recharged and intensively developed ground water bodies such as the terrace aquifer are unusually sensitive to possible contamination. Efforts to minimize the risk of introducing deleterious compounds into the aquifer are likely to be particularly worthwhile in light of the number of individuals potentially-affected and the relatively long anticipated duration of natural flushing. Informal community attention may be an appropriate level of action.

A third, more intensive level of management could be implemented to manage recharge of the aquifer and develop a water supply and distribution in a controlled setting. It may be that the yield of the aquifer or the quality of the water may be enhanced to a moderate degree through a program of managed recharge. The benefits and effectiveness of such a program would be most evident during drier-than-normal years. Recharge augmentation would warrant consideration only if long-term use and protection of the aquifer system were sought. Considerably more hydrogeologic data would be needed prior to development of a responsible recharge-management effort. Such a program would be aimed toward obtaining additional water supplies, which might be harvested with a series of community wells.

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APPENDIX 1

TABLE A1
WELL LOCATION AND CONSTRUCTION

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval(b) (ft)	Sanitary Seal (ft)	Aquifer (c)
047-013-070	15	60				T
047-022-040	18	40				T
047-023-330	17	40				T
047-032-030	8	80	5	20 - 80	20	T
047-041-080	35	75	6	35 - 55	20	T
047-041-100	35	50	5	20 - 50	20	T
047-042-010	35	100	5	20 - 80	20	T
047-042-050	35	75	5	30 - 60	20	T
047-043-050	37	60	5	22 - 60	20	T
047-043-070	37	60	6	23 - 60	20	T
047-043-210	38	75	6	20 - 60	20	T
047-045-110	42	93		30 - 93	20	T/BR
047-045-120	44	95	5	55 - 95	20	T/BR
047-046-120	53	83	6	40 - 83	20	T
047-048-110	38	60	5	30 - 60	20	T
047-055-160	120	180	5	80 - 180	20	BR
047-074-260	78	120	6.5	60 - 120		BR
047-074-270	80	229	5	120 - 229	30	BR

(a) From 1:4800 San Mateo County topographic map, based on either an indicated or an assumed location within parcel.

(b) Uppermost and lowermost perforations only; blank screen may occur within interval.

(c) Aquifer designations, T = Terrace Aquifer, BR = Bedrock Aquifers; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A1
WELL LOCATION AND CONSTRUCTION
(continued)

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval (b) (ft)	Sanitary Seal (ft)	Aquifer (c)
047-074-310	80	240	5	120 - 240	30	BR
047-075-230	90	150	5	50 - 150	20	BR
047-075-210	140	220	5	60 - 220	20	BR
047-075-200	180	250	5	25 - 250	20	BR
047-075-160	120	400	4	120 - 400	20	BR
047-075-150	130	180	4	140 - 180	50	BR
047-075-040	100	246	8	120 - 246	30	BR
047-076-090	115					BR
047-077-010	150	305	5	65 - 305	25	BR
047-077-070	160	275	5	75 - 275	35	BR
047-091-010	48	80	5	30 - 80	30	T
047-091-060	45	100	5	20 - 100	20	T/BR
047-092-190	48	65	5	40 - 65	20	T
047-094-170	60	80	6	40 - 80	20	T
047-095-150	60	95	5	50 - 95	30	T/BR
047-101-150	100	220	4	60 - 220	20	BR
047-102-200	90	140	5	40 - 140	20	T/BR
047-104-100	88	80	5	20 - 80	20	T

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Aquifer designations, T = Terrace Aquifer, BR = Bedrock Aquifer; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A1
WELL LOCATION AND CONSTRUCTION
(continued)

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval (b) (ft)	Sanitary Seal (ft).	Aquifer (c)
047-104-230	91	100	5	30 - 100	20	T
047-105-220	115	260	5	100 - 260	30	BR
047-106-020	125	120	4.5	60 - 120	20	BR
047-106-120	115	200	5	80 - 200	30	BR
047-107-070	115	85	5	30 - 80	30	T
047-112-190	185	205	5	65 - 205	20	BR
047-112-090	155	320	5	60 - 320		BR
047-121-030	50	75	6	35 - 75	20	T
047-121-050	50	80	6	40 - 80	20	T
047-121-080	55	78	6	40 - 78	20	T
047-121-070	55	80	6	40 - 80	20	T
047-122-120	58	80	5	40 - 80	20	T
047-122-020	60	80	5	40 - 80	35	T
047-122-100	65	100	5	60 - 100	22	T/BR
047-124-080	45	60	6	40 - 60	20	T
047-126-130	85	118	5	40 - 118	25	T/BR
047-127-090	75	180	5	80 - 180	30	BR
047-127-110	75	100	5	40 - 100	20	T/BR

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.

(b) Uppermost and lowermost perforations only; blank screen may occur within interval.

(c) Aquifer Designations, T = Terrace Aquifer, BR = Bedrock Aquifer; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A1
WELL LOCATION AND CONSTRUCTION
(continued)

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval (b) (ft)	Sanitary Seal (ft)	Aquifer (c)
047-104-230	91	100	5	30 - 100	20	T
047-105-220	115	260	5	100 - 260	30	BR
047-106-020	125	120	4.5	60 - 120	20	BR
047-106-120	115	200	5	80 - 200	30	BR
047-107-070	115	85	5	30 - 80	30	T
047-112-190	185	205	5	65 - 205	20	BR
047-112-090	155	320	5	60 - 320		BR
047-121-030	50	75	6	35 - 75	20	T
047-121-050	50	80	6	40 - 80	20	T
047-121-080	55	78	6	40 - 78	20	T
047-121-070	55	80	6	40 - 80	20	T
047-122-120	58	80	5	40 - 80	20	T
047-122-020	60	80	5	40 - 80	35	T
047-122-100	65	100	5	60 - 100	22	T/BR
047-124-080	45	60	6	40 - 60	20	T
047-126-130	85	118	5	40 - 118	25	T/BR
047-127-090	75	180	5	80 - 180	30	BR
047-127-110	75	100	5	40 - 100	20	T/BR

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Aquifer Designations, T = Terrace Aquifer, BR = Bedrock Aquifer; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A1
WELL LOCATION AND CONSTRUCTION
(continued)

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval (b) (ft)	Sanitary Seal (ft)	Aquifer (c)
047-131-040	105	60	5	20 - 60	20	T
047-132-110	100	60	5	20 - 60	20	T
047-133-140	125	75	5	45 - 75	20	T
047-133-130	125	68	5	38 - 68	25	T
047-133-160	125	45	5	25 - 45	20	T
047-133-210	115	80	5	40 - 80	30	T
047-134-160	125	160	5	80 - 160	20	BR
047-134-050	130	190	5	80 - 190	20	BR
047-134-040	135	140	5	80 - 140	20	BR
047-135-100	120	200	5	40 - 200	20	BR
047-135-060	120	200		100 - 200	20	BR
047-141-180	250	180	5	100 - 180	25	BR
047-141-040	260	200	5	100 - 200	20	BR
047-181-500	430	500	6	220 - 500	20	BR
047-192-070	200	275	5	40 - 275	20	T/BR
047-202-100	60	120	5	60 - 120	20	T/BR
047-203-040	50	125			20	T/BR
047-207-210	50	245	5	60 - 245	20	BR

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.

(b) Uppermost and lowermost perforations only; blank screen may occur within interval.

(c) Terrace designations, T = Terrace Aquifer, BR = Bedrock Aquifer; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A1
WELL LOCATION AND CONSTRUCTION
(continued)

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval (b) (ft)	Sanitary Seal (ft)	Aquifer (c)
047-209-210	78	80	5	40 - 80	20	T
047-209-160	85	75	5	30 - 75	20	T
047-209-020	85	80	5	50 - 80	25	T
047-209-200	75	280	4	120 - 280	20	BR
047-211-020	75	200	5	40 - 200	25	BR
047-211-080	98	105	5	20 - 60	20	T
047-211-090	90	105	5	40 - 80	20	T
047-212-040	80	140	5	20 - 140	20	BR
047-215-100	120	140		20-140	20	BR
047-215-240	120	275	5	40 - 275	20	BR
047-216-270	100	120	6	40 - 120	20	T/BR
047-216-200	110	220			30	BR
047-222-400	150	240	5	100 - 240	20	BR
047-223-140	185	390	6	135 - 390	32	BR
047-232-020	35	140	5	35 - 140	23	T/BR
047-233-140	45	63				T
047-233-190	45	80				T
047-241-040	110	300				BR

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Aquifer designations, T = Terrace Aquifer, BR = Bedrock Aquifer; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A1
WELL LOCATION AND CONSTRUCTION
(continued)

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval (b) (ft)	Sanitary Seal (ft)	Aquifer (c)
047-241-160	100	87	5	30 - 87	20	BR
047-244-220	200	230	6.5	90 - 220	20	BR
047-244-040	200	270	5	200 - 250	20	BR
047-244-040	200	220	5	60 - 220	20	BR
047-272-130	60	160	5		25	T/BR
047-272-050	55	80	6	40 - 80	20	T
047-273-340	75	140	6	40 - 140	20	T/BR
047-273-070	65	95	6	50 - 95	20	T/BR
047-273-020	65	140	6	40 - 140	20	T/BR
047-273-070	65	80	6	20 - 80	20	T/BR
047-273-350	75	125	5	50 - 125	25	T/BR
047-273-090	70	377				T/BR
047-273-110	70					
047-274-310	80	170	8	80 - 170	22	BR
047-274-010	85	180	6	60 - 180	20	BR
047-286-170	85	460	4	60 - 460	25	BR
047-292-100	70	146			30	T/BR
047-293-031		90	6	50 - 90	30	T/BR

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.

(b) Uppermost and lowermost perforations only; blank screen may occur within interval.

(c) Terrace designations, T = Terrace Aquifer, BR = Bedrock Aquifer; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A1
WELL LOCATION AND CONSTRUCTION
(end)

Location	Elevation	Construction				
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Total Depth (ft)	Casing Diam. (in)	Perforated Interval (b) (ft)	Sanitary Seal (ft)	Aquifer (c)
048-013-370	25	80		40 - 80	35	T
048-034-010	35	80	5	40 - 80	33	T
048-042-110	55	75	5		20	T
048-045-030	75	120	6	40 - 120	20	T/BR
048-047-040	90	95	6	40 - 95	20	T/BR
048-052-070		70	5	20 - 70	20	T
048-055-020	65	80	5	40 - 80	20	T
048-055-010	65	80	5	40 - 80	20	T
048-062-030	75	80	6		20	T
048-063-200	95	80	5	40 - 80		T

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Terrace designations, T = Terrace Aquifer, BR = Bedrock Aquifer; the differentiation of the bedrock aquifers, to the extent feasible from available data, is given in Table A3B.

TABLE A2A
TERRACE AQUIFER
REPORTED WATER LEVEL AND WELL PERFORMANCE

Location	Elevation				Construction	
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Date	Water Level (ft)	Total Depth (ft)	Perforated(b) Interval (ft)	Specific(c) Capacity (gpm/ftdd)
047-013-070	15		12	60		
047-022-040	18		12	40		
047-023-330	17		8	40		1.25
047-032-030	8	7/85	20	80	20 - 80	0.75
047-041-080	35	5/86	9	75	35 - 55	1.18
047-041-100	35	6/86	10	50	20 - 50	
047-042-010	35	6/87	6	100	20 - 80	1.15
047-042-050	35	5/87	9			
047-043-050	37	4/87		60	22 - 60	
047-043-070	37	4/86		60	23 - 60	1.07
047-043-210	38	9/86	23	75	20 - 60	0.4
047-045-110	42	5/86	30	93	30 - 93	1.17
047-045-120	44	6/86	20	95	55 - 95	1.5
047-046-120	53	3/86	25	83	40 - 83	0.43
047-048-110	38	4/87	16	60	30 - 60	1.0
047-091-010	48	12/86	32	80		1.0
047-092-190	48	5/86	30	65	40 - 65	1.6
047-094-170	60	11/85	65	80	40 - 80	0.12
047-095-150	60	7/85	38	95	50 - 90	0.37

(a) From 1:4800 San Mateo County topographic map, based on indicated or assumed location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Gallons per minute per foot of drawdown, as observed at the end of well test required by San Mateo County since 1985.

TABLE A2A
TERRACE AQUIFER
REPORTED WATER LEVEL AND WELL PERFORMANCE
(continued)

Location	Elevation				Construction	
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Date	Water Level (ft)	Total Depth (ft)	Perforated(b) Interval (ft)	Specific(c) Capacity (gpm/ftdd)
047-104-100	88	9/86	13	80	20 - 80	0.57
047-104-230	91	1/87	13	100	30 - 100	0.86
047-107-070	115	4/86	28	80	30 - 80	0.14
047-121-030	50	2/86	28	75	35 - 75	1.5
047-121-050	50	2/86	32	80	40 - 80	1.22
047-121-080	55	4/86	38	78	40 - 78	2.86
047-121-070	55	4/86	36	80	40 - 80	0.67
047-122-120	58	4/87	34	80	40 - 80	0.52
047-122-020	60	5/87	30	90	40 - 80	0.50
047-124-080	45	4/86	21	60	40 - 60	0.58
047-131-040	105	1/87	15	60	20 - 60	0.24
047-132-110	100	5/87	25	80	20 - 60	0.12
047-133-140	125	6/86	22	75	45 - 75	1.15
047-133-130	125	2/87	10	68	38 - 68	0.53
047-133-160	125	11/85	10	80	25 - 45	0.75
047-133-210	115	2/87	15	80	40 - 80	0.35
047-209-210	78	1/87	18	80	40 - 80	0.40
047-209-160	85	4/87	22	75	30 - 75	1.3
047-209-020	85	3/87	19	80	50 - 80	0.90
047-211-080	75	4/87	23	105	20 - 60	1.0

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Gallons per minute per foot of drawdown, as observed at the end of well test required by San Mateo County since 1985.

TABLE A2A
TERRACE AQUIFER
REPORTED WATER LEVEL AND WELL PERFORMANCE
(end)

Location	Elevation				Construction	
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Date	Water Level (ft)	Total Depth (ft)	Perforated(b) Interval (ft)	Specific(c) Capacity (gpm/ftdd)
047-211-090	90	4/87	6	105	40 - 80	0.25
047-233-140	45	10/86	9	63		0.12
047-233-190	45	10/86	6	80		0.075
047-272-050	55	4/86	15	80	10 - 80	43
048-013-370	25		16	80		0.31
048-034-010	35	1/87	28	80	40 - 80	1.25
048-042-110	55	5/87		75		1.59
048-045-030	75	9/86	40	120	40 - 120	1.6
048-052-070	--	4/87		70	20 - 70	1.1
048-055-020	65	4/87	23	85	40 - 80	1.1
048-055-010	65	4/87	20	86	40 - 80	0.90
048-062-030	75	4/86		100		
048-063-200	95	9/86	42	80	40 - 80	1.0
048-085-030	--	8/86	37	80	40 - 80	1.67

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Gallons per minute per foot of drawdown, as observed at the end of well test required by San Mateo County since 1985.

TABLE A2B
BEDROCK AQUIFER
REPORTED WATER LEVEL AND WELL PERFORMANCE

Location	Elevation				Construction	
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Date	Water Level (ft)	Total Depth (ft)	Perforated(b) Interval (ft)	Specific(c) Capacity (gpm/ftdd)
047-055-160	120	3/87	45	180	80 - 180	0.03
047-074-260	78	9/86	31	120	60 - 120	
047-074-270	80	4/86	29	229	120 - 229	0.13
047-074-310	80	7/86	30	240	120 - 240	0.04
047-075-230	90	1/87	37	150	50 - 150	0.06
047-075-210	140	3/87	45	220	60 - 220	
047-075-200	180	4/87	44	250	25 - 250	0.008
047-075-160	120	10/85	32	400	120 - 400	0.026
047-075-150	130	5/86	38	180	140 - 180	
047-075-040	100	8/86	10	240	120 - 240	0.08
047-076-090	115	4/87	51	250		0.028
047-077-010	150	5/87	50	305	65 - 305	0.024
047-077-070	160	7/87	70	275	75 - 275	0.021
047-101-150	100	6/86	10	220	60 - 220	0.040
047-102-200	90	10/85	17	140	40 - 140	0.030
047-105-220	115	5/87	10	260	100 - 260	0.052
047-106-020	125	12/86	18	120	60 - 120	0.012
047-106-120	115	12/86	5	200	80 - 200	0.022

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Gallons per minute per foot of drawdown, as observed at the end of well test required by San Mateo County since 1985.

TABLE A2B
BEDROCK AQUIFER
REPORTED WATER LEVEL AND WELL PERFORMANCE
(continued)

Location	Elevation				Construction	
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Date	Water Level (ft)	Total Depth (ft)	Perforated(b) Interval (ft)	Specific(c) Capacity (gpm/ftdd)
047-112-140	185	2/87	32	205	55 - 205	0.015
047-112-090	155	2/87	21	320	80 - 320	0.041
047-122-100	65	3/86	22	100	60 - 100	0.28
047-127-090	75	3/87	10	180	80 - 180	0.30
047-127-110	75	4/87	30	100	40 - 100	0.14
047-134-160	125	6/86	27	160	80 - 160	0.83
047-134-050	130	6/86	25	190	80 - 190	1.19
047-134-040	135	6/86	45	140	80 - 140	0.098
047-135-100	120	11/85	32	200	40 - 200	0.033
047-135-060	120	7/86	32	200	100 - 200	0.045
047-141-180	250	12/86	81	180	100 - 180	0.21
047-141-040	260	3/87	105	200	100 - 200	0.041
047-181-500	430	5/86	160	500	220 - 500	0.023
047-192-070	200	7/86	18	275	40 - 275	0.036
047-203-040	50	1/87	27	125		0.09
047-207-210	50	12/86	5	300	60 - 245	0.006
047-209-200	75	7/86	17	300	120 - 280	0.02
047-211-020	75	3/87	66	200	40 - 200	0.12
047-215-100	120	4/87	12	140	20 - 140	0.020

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Gallons per minute per foot of drawdown, as observed at the end of well test required by San Mateo County since 1985.

TABLE A2B
BEDROCK AQUIFER
REPORTED WATER LEVEL AND WELL PERFORMANCE
(end)

Location	Elevation				Construction	
Well Location (APN)	Estimated(a) Land-Surface Datum (ft)	Date	Water Level (ft)	Total Depth (ft)	Perforated(b) Interval (ft)	Specific(c) Capacity (gpm/ftdd)
047-215-240	120	6/86	24	275	40 - 275	0.010
047-216-270	100	11/86	17	120	40 - 120	0.82
047-216-190	--	10/86	32	222		0.038
047-222-400	150	10/85	49	240	100 - 240	0.035
047-223-140	185	3/86	65	395	135-390	0.06
047-232-020	35	2/87	3	140	35 - 140	0.067
047-241-040	110	4/87	6	300		0.015
047-244-220	200	10/86	30	230	90 - 220	0.008
047-244-040	200	3/87	38	240	60 - 220	0.018
047-244-040	200	4/87	36	270	200 - 250	0.006
047-273-340	75	11/85	32	140	40 - 140	0.031
047-273-070	65	3/85	30	95	50 - 95	0.064
047-273-020	65	11/85	15	140	40 - 140	0.029
047-273-350	75	6/86	24	125	50 - 125	0.067
047-273-090	70	10/86	37	377		0.003
047-273-110	70	8/86	40	300		0.003
047-274-310	80	8/86	20	120	80 - 120	0.039
047-274-010	85	4/86	14	200	60 - 180	0.064
047-286-170	85	11/85	18	460	60 - 460	0.006
047-292-100	70	9/86	38	146		0.073
047-293-031	--	7/85	50	90	50 - 90	0.41

(a) From 1:4800 San Mateo County topographic map, based on location within parcel.
(b) Uppermost and lowermost perforations only; blank screen may occur within interval.
(c) Gallons per minute per foot of drawdown, as observed at the end of well test required by San Mateo County since 1985.

TABLE A3A
WATER QUALITY IN TERRACE AQUIFER

Location	Construction				Results					
Well Location	Total Depth (ft)	Perforated(a) Interval (ft)	Sanitary Seal (ft)	Static Water Level (ft)	Iron (mg/l)	Manganese (mg/l)	Chloride (mg/l)	Nitrate (c) as NO3 (mg/l)	Spec. Cond. (umhos)
047-013-079	60			12	0.4	.32	120	5.7	590
047-022-040	40			12					
047-023-330	40			8					
047-032-03/04	80	20 - 80	20	20	4.3	.27	92	<.5	550
047-041-080	75	35 - 55	20	9	.12	<.02	102	44	678
047-041-100	50	20 - 50	20	10	.25	.05	110	36	580
047-042-010	100	20 - 80	20	6	.5	.12	150	1	420
047-042-050			20	9	1.9	.1	125	12	620
047-043-050	60	22 - 60	20		.1	.05	108	2	770
047-043-070	60	23 - 60	20						
047-043-210	75	20 - 60	20	23	0.6	.003	118	51/2R	1430
047-045-110	93	30 - 93	20	30	0.2	.03	110	45	950
047-045-120	95	55 - 95	20	20	.63	.11	150	3.7	900
047-046-120	83	40 - 83	20	25	.05	.02	88	35	617
047-048-110	60	30 - 60	20	16	.11	.016	67	11	510
047-091-010	80			32	2.2	.21	170	30	1100
047-092-190	65	40 - 65	20	30	.75	.03	76	25	370
047-094-170	80	40 - 80	20	65	.05	.32	112	<1	590
047-095-150	95	50 - 90	30	38	.01	<.02	124	22.5	352

(a) Uppermost and lowermost perforations only.

(b) Laboratory value unless otherwise indicated; field values are followed by (f).

(c) Notation - 51/2R indicates initial result of 51 mg/l and subsequent retest result of 2 mg/l.

TABLE A3A
WATER QUALITY IN TERRACE AQUIFER
(continued)

Location	Construction				Results				
Well Location	Total Depth (ft)	Perforated(a) Interval (ft)	Sanitary Seal (ft)	Static Water Level (ft)	Iron (mg/l)	Manganese (mg/l)	Chloride (mg/l)	Nitrate as NO3 (mg/l)	Spec. Cond. (umhos)
047-104-100	80	20 - 80	20	13	1.0	.36	80	1.5	480
047-104-230	100	30 - 100	20	13	.33	.36	75	1.0	610
047-121-030	75	35 - 75	20	28					
047-121-050	80	40 - 80	20	32	.05	.025	64	17.5	380
047-121-080	78	40 - 78	20	38	1.25	0.1	74	8	430
047-121-070	80	40 - 80	20	36	1.5	.16	74	4	410
047-122-120	80	40 - 80	20	30	0.1	.02	75	1	540
047-122-020	80	40 - 80	35						
047-124-080	60	40 - 60	20	21	0.2	.02	150	12	980
047-131-040	60	20 - 60	20	15	1.6	.77	70	1.5	365
047-132-110	80	20 - 60	20	25	.5	.03	140	17	
047-133-040	75	45 - 75		22	2	.75	150	.5	740
047-209-210	80	40 - 80	20	18	.05	.01	110	18	525
047-209-160	75	30 - 75	20	22	.20	.02	110	17	700
047-209-020	80	50 - 80	25	19	.20	.02	130	24	860
047-211-080	105	20 - 60		23	.05	.03	136	9	550
047-233-140	63		20	9	1.7	.28	112	12	160
047-233-180	80		20	6	3.7	.25	138	4	590
047-372-050	80	40 - 80	20	15	1.6	.5	124	1	550

(a) Uppermost and lowermost perforations only.
(b) Laboratory value unless otherwise indicated; field values are followed by (f).

TABLE A3A
WATER QUALITY IN TERRACE AQUIFER
(end)

Location	Construction				Results					
Well Location	Total Depth (ft)	Perforated(a) Interval (ft)	Sanitary Seal (ft)	Static Water Level (ft)	Iron (mg/l)	Manganese (mg/l)	Chloride (mg/l)	Nitrate(c) as NO3 (mg/l)	Spec. Cond. (umhos)
048-013-370	80		20	16	.27	.58	72	2.8	650
048-034-010	80	40 - 80	20	28	3.0	.45	70	21	420
048-042-110	75		20		.12	.18	64		500
048-048-030	120	40 - 120	20	40	.1	.01	60	100/41R	380
048-052-070	70	20 - 70	20		1.6	.15	69	15	370
048-055-020	85	40 - 80	20	23	1.2	0.2	42	1	700
048-055-010	80	40 - 80	20	20	.05	.05	52	6	320
048-062-030	100				.5	.25	66	23	430
048-063-200	80	40 - 80	20	42	5	.35	90	1	520
048-085-030	80	40 - 80	20	27	.13	.02	69		620
048-133-130	68	38 - 68	25	10	1.9	.62	130	1	840
048-133-160	80	25 - 45	20	10					
048-133-210	80	40 - 80	30	15					

(a) Uppermost and lowermost perforations only.
(b) Laboratory value unless otherwise indicated; field values are followed by (f).
(c) Notation 100/41R indicates initial result of 100 mg/l and subsequent retest result of 41 mg/l.

TABLE A3B
WATER QUALITY IN BEDROCK AQUIFER

Location		Construction				Results				
Well Location	Aquifer(d)	Total Depth (ft)	Perforated(a) Interval (ft)	Sanitary Seal (ft)	Static Water Level (ft)	Iron (mg/l)	Manganese (mg/l)	Chloride (mg/l)	Nitrate(c) as NO3 (mg/l)	Spec. Cond. (umhos)
047-055-160	G	180	80 - 180	20	45	1.8	.13	152	4	
047-074-260	G	120	60 - 120	20	31	.5	.02	180	9.5	640
047-074-270	G	229	120 - 229	30	29	17	.34	102	2.1	700
047-074-310	G	240	120 - 240	30	30	1.8	.06	150	2.9	900
047-075-230	G	150	50 - 150	20	37	.08	.13	141	1	790
047-075-210	G	220	60 - 220	20	45	.37	.04	137	9	755
047-075-200	G	250	25 - 250	20	44	.37	.04	137	9	755
047-075-160	G	400	120 - 400	20	32	.05	.1	102	3	800
047-075-150	G	180	140 - 180	50	38	.25	.13	140	1	445
047-075-040	G	240	120 - 240	30	10	0.1	.02	110	11	410
047-076-090	G	250								
047-077-010	G	305	65 - 305	25	154	.77	.07	140	1	630
047-077-070	G	275	75 - 275	35	70	1.4	.02	180	1.9	900
047-101-150	G	220	60 - 220	20	16	.65	.03	138	1	500
047-102-200	G	140	40 - 140	20	17	1.2	.09	100	1.7	600
047-105-220	G	260	100 - 260	30	10	.55	.03	170	21	760
047-106-020	G	120	60 - 120	20	18	.25	.06	138	42	735
047-106-120	G	200	80 - 200	30	5	.28	.02	190	11	790

(a) Uppermost and lowermost perforations only.

(b) Laboratory value unless otherwise indicated; field values are followed by (f).

(c) Notation 46/37R indicates initial result of 46 mg/l and subsequent retest result of 37 mg/l.

(d) Aquifer designations: G = Granitic Rocks, P = Purisima Formation, P/G = Purisima or Granite.

TABLE A3B
WATER QUALITY IN BEDROCK AQUIFER
(continued)

Location	Construction					Results				
Well Location	Aquifer(d)	Total Depth (ft)	Perforated(a) Interval (ft)	Sanitary Seal (ft)	Static Water Level (ft)	Iron (mg/l)	Manganese (mg/l)	Chloride (mg/l)	Nitrate(c) as NO3 (mg/l)	Spec. Cond. (umhos)
047-112-140	G	205	55 - 205	20	32	.25	.04	115	5	680
047-112-090	G	320	80 - 320		21	.1	.02	37	2.1	360
047-122-100	P	100	60 - 100	22		.2	.02	110	20	350
047-126-130	P	118	40 - 118	25	60	1.0	.04	170	5.5	1200
047-127-110	P	110	40 - 110	20	30	.07	.03	198	.9	676
047-134-160	G	160	80 - 160		27	.32	1.0	150	1.2	810
047-134-050	G	140	80 - 140	20	25	.43	.48	110	.5	790
047-134-040	G	140	80 - 140	20	45	.21	1.5	200	.5	970
047-135-100	G	200	40 - 200	20	32	1.4	.17	180	.95	780
047-135-060	G	200	100 - 200	20	32	1.0	.16	205	2	485
047-141-180	G	180	100 - 180	25	81	.12	.06	149	1	860
047-141-040	G	200	100 - 200	20	105	.32	.06	138	1	820
047-181-500	G	500	220 - 500	770	160	0.3	0.2	130	1	560
047-192-070	G	275	40 - 275	20	18	9.75	0.65	220	1	990
047-202-100	P	120	60 - 120	20						
047-203-040	P	125		20	27	0.2	.01	138	46/37R	385
047-207-210	P/G	300	60 - 245	20	5	2	.41	178	11	870
047-209-200	P/G	300	120 - 280	20	17	.57	.16	176	1	350
047-211-020	P/G	200	40 - 200	25	60	13	.35	100	3.7	750

(a) Uppermost and lowermost perforations only.
(b) Laboratory value unless otherwise indicated; field values are followed by (f).
(c) Notation 46/37R indicates initial result of 46 mg/l and subsequent retest result of 37 mg/l.
(d) Aquifer designations, G = Granitic rocks, P = Purisima Formation, P/G = Purisima or Granite

TABLE A3B
WATER QUALITY IN BEDROCK AQUIFER
(continued)

Location		Construction				Results					
Well Location	Aquifer(d)	Total Depth (ft)	Perforated(a) Interval (ft)	Sanitary Seal (ft)	Static Water Level (ft)	Iron (mg/l)	Manganese (mg/l)	Chloride (mg/l)	Nitrate (c) as NO3 (mg/l)	Spec. Cond. (umhos)
047-211-090	P/G	105	40 - 80	20	6	.05	.06	113	5	450
047-215-100	G	140	20 - 140	20	12	1.2	.22	178	1	
047-215-240	G	275	40 - 275	20	24	2.8	.12	210	1	800
047-216-270	G	120	40 - 120	20	17	0.1	.01	165	16	1090
047-216-190	G	222		20	32	.2	.02	210	4.6	1100
047-222-400	G	240	100 - 240	20	49	6.3	.18	186	4.4	540
047-223-140	G	395	135 - 390	32	65	2	.12	136	1	424
047-232-020	P	140	35 - 140	23	3	1.9	.44	150	.5	1000
047-241-040	G	300			6	3.35	0.7	130	2	350
047-244-220	G	230	90 - 220	20	30	0.5	.16	86	1	415
047-244-040	G	270	200 - 250	20	36					
047-244-040	G	240	60 - 220	20	38					
047-273-340	P/G	140	40 - 140	20	32	.05	.16	116	1	750
047-273-070	P/G	95	50 - 95	20	30	.25	.2	114	1.5	602
047-273-020	P/G	140	40 - 140	20	15	.05	.15	174	37.5	840
047-273-350	P/G	125	50 - 125	25	24	.18	.22	120	22	1000
047-273-090	P/G	377		20	37	0.8	.06	116	25	540
047-273-110	P/G					1.2	0.2	108	30	590

(a) Uppermost and lowermost perforations only.
(b) Laboratory value unless otherwise indicated; field values are followed by (f).
(c) Notation 46/37R indicates initial result of 46 mg/l and subsequent retest result of 37 mg/l.
(d) Aquifer designations, G = Granitic Rocks, P = Purisima Formation, P/G = Purisima or Granite.

TABLE A3B
WATER QUALITY IN BEDROCK AQUIFER
(end)

Location		Construction				Results				
Well Location	Aquifer(d)	Total Depth (ft)	Perforated(a) Interval (ft)	Sanitary Seal (ft)	Static Water Level (ft)	Iron (mg/l)	Manganese (mg/l)	Chloride (mg/l)	Nitrate(c) as NO3 (mg/l)	Spec. Cond. (umhos)
047-274-310	G	120	80 - 120	20	20	.35	.15	90	1	1300
047-274-010	G	200	60 - 180	20	14	0.1	.45	148	1	760
047-286-170	P/G	460	60 - 460	20	18	.05	.32	136	1	480
047-292-100	P/G	146		30	38	.17	.02	150	21	1000
047-293-031	G	90	50 - 90	30	50	.05	.16	50	12	246

(a) Uppermost and lowermost perforations only.
(b) Laboratory value unless otherwise indicated; field values are followed by (f).
(c) Notation 46/37R indicates inital result of 46 mg/l and subsequent retest result of 37 mg/l.
(d) Aquifer designations, G = Granitic Rocks, P = Purisima Formation, P/G = Purisima or Granite.

APPENDIX 2

TABLE A2-1
Calculated Mean Actual Evapotranspirtion for the El Granada Terrace

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Precipitation	1.63	3.02	4.43	5.32	3.69	3.50	2.06	0.58	0.25	0.12	0.21	0.41	25.22
Runoff (40% x 75% = 30%)	0.49	0.91	1.33	1.60	1.11	1.05	0.62	0.17	0.08	0.04	0.06	0.12	7.58
Infiltration (ppt-runoff)	1.14	2.11	3.10	3.72	2.58	2.45	1.44	0.41	0.18	0.08	0.15	0.29	17.65
PET	2.81	1.30	0.98	1.46	1.65	2.44	2.95	3.61	4.25	4.27	4.15	3.54	33.41
I-PET	-1.67	0.81	2.12	2.26	0.93	0.01	-1.51	-3.20	-4.08	-4.19	-4.00	-3.25	
ΣNeg(I-PET)	-21.90	-1.69	0	0	0	0	-1.51	-4.71	-8.79	-12.98	-16.98	-20.23	
Soil Moisture Storage (ST)1)	0	0.81	2.0	2.0	2.0	2.0	0.88	0.17	0	0	0	0	
ΔST	0	+0.81	+1.19	0	0	0	-1.12	-0.71	-0.17	0	0	0	
AET	1.14	1.30	0.98	1.46	1.65	2.44	2.56	1.12	0.35	0.08	0.15	0.29	13.52

1) Available water capacity = 0.13 inches/inch of soil (SCS, 1980); assumed 15 inches average root zone profile.

NOTE: All values recorded in inches

TABLE A2-2
Bases For Estimating Runoff Coefficients For Normal, Dry and Critical Drought Years for Normal, Dry, and Critical Drought Years

Stream	General Rock Type	Period of Record	Mean Annual Runoff (ac.ft/yr.)	Normal Rainfall 1975 Runoff (ac. ft/yr.)	Normal Rainfall 1975 % M.A.R.	Dry Rainfall 1981 Runoff (ac. ft/yr.)	Dry Rainfall 1981 % M.A.R.	Very Dry Rainfall 1977 Runoff (ac. ft/yr.)	Very Dry Rainfall 1977 % M.A.R.
San Lorenzo R. at Bigtrees	Mixed lithology, incl. much weathered crystalline rock and Santa Margarita sandstone	1936-1984	101400	82000	81	39000	38	10000	10
Pescadero Cr.	Weathered indurated Sandstones	1951-1984	32800	26000	79	9640	29	1250	4
Scott Cr. near Davenport	Primarily fractured granitics and extensive alluvial storage	1937, 1939-41, 1999-73 Data synthesized from gauged record	23850	19490	82	7990	36	1660	7
San Vicente Cr. near Davenport	Weathered granitic rock and minor cavernous limestone	1969-1984	7030	4860	69	2200	31	602	9
Pilarcitos Cr. at Half Moon Bay	Moderately to well consolidated sandstone, appreciable alluvial storage	1966-1984	12320	6500	53	2580	21	372	3
San Gregorio Cr. at San Gregorio	Moderately consolidated sandstones minor volcanics and alluvium	1969-1984	32170	19020	59	9250	29	840	3
Laguna Cr. near Davenport	Moderately consolidated sandstone	1970-1976 Data for 1977, 1981 synthesized from gauged record	3640	2750	76	1370	38	340	9
Majors Cr. near Santa Cruz	Moderately consolidated sandstone	1970-1976 Data for 1977, 1981 synthesized from gauged record	3070	2420	79	1420	46	580	19

APPENDIX 3

APPENDIX 3

TASK REPORT
WATER WELL ORDINANCE (03101) REVIEW

1 INTRODUCTION

The San Mateo County Board of Supervisors passed and adopted Ordinance No. 03101 on April 14, 1987. The ordinance regulates the siting, permitting, construction, and operation of wells serving between one and four domestic connections. It also establishes standards for who may construct (or modify or abandon) wells, minimum acceptable yields and water quality, and monitoring and reporting by well operators. The ordinance revised earlier County regulations in light of new State well-construction standards, contractor-licensing requirements, increased community concern for the protection of the quality and yields of well waters, and growing awareness of the diversity of ground-water environments within San Mateo County.

As part of the larger hydrogeologic investigation of El Granada, we were asked to perform a general review of the water-well ordinance. The scope was to emphasize the hydrogeologic and soils criteria utilized in the ordinance, although comments on regulatory, administrative, or procedural matters were to be welcomed. County staff also asked that our review be based in part on our concurrent analysis of ground water conditions in El Granada, but also be conducted in light of the broader hydrogeologic environments found in the Santa Cruz Mountains and Coastside portions of the County.

Our review is not intended to be comprehensive in nature, nor to address the form or enforceability of the ordinance.

2 LOCATION OF WATER WELLS

Section 4712 of the ordinance specifies the distances which wells shall be set back from properties lines and from sources of potential contamination:

From another well	50 feet
From any septic tank	50 feet
From a septic tank leach field	100 feet
From a seepage pit	100 feet
From a sewer line or lateral	50 feet
From a property line (sewered area)	5 feet
From a property line (unsewered area)	50 feet
From an exterior wall of a buildings foundation	5 feet
From a boundary line of any easement dedicated to or reserved for sanitary sewers or wastewater facilities as shown on a map approved by a sanitary district and placed on file by that district with the County Environmental Health Division	50 feet

Minimum setbacks from septic systems, seepage pits, sewer lines or laterals, and related sources are in accord with those specified by the State as published by the California Department of Water Resources in Bulletin 74 and successor guidelines. State standards also provide for variations from these minimum setbacks, based on the judgement and approval of the enforcing agency. The County may wish to consider in some cases an alternate criterion of a 50 foot setback from the sewer line, rather than from the boundary line of the public easement. Easements may sometimes include an entire roadway, or may otherwise impose an illogical or undue burden on an applicant. Future alterations within the easement should be considered prior to granting a variance.

Certain other coastal counties require setbacks of 150 feet from seepage pits. We suggest that San Mateo County consider the longer setback from all onsite waste-disposal systems not providing significant leaching through the biologically active upper 5 feet of soil in areas where:

1. fractures provide an appreciable portion of the total hydraulic conductivity ("permeability")
2. sandy soils occur, and restrictive continuous clay horizons are absent between the leaching zone and the normal position of the water table
3. high-permeability sand and gravel zones, of alluvial or marine origin, are thought to be present
4. large fluctuations in water level are typical, such that direct contact between the effluent from a seepage pit or similar facility and the water table is expected to occur for at least some time during a majority of years.

It may be useful to note that sampling conducted by our staff (Johnson and others, 1983) in Santa Cruz County showed that conventional septic systems provided significantly greater nitrate and bacterial removal in local sandy soils than did seepage pits or other onsite disposal systems which discharged leachate below the biologically active soil zone in sandy areas.

Setbacks of 5 feet from building or property lines is a widespread and recommended standard. Many or most counties in California require a minimum of 5 feet in their well-construction ordinances. Ready access to wells is a sound practice; in our opinion, it merits application in all seismically-active areas, where rapid repair of many well seals, casings, pumps or other elements of the well system may be needed after an earthquake. Placing wells in closer proximity to structures (or beneath them as is sometimes suggested) also discourages maintenance of the well, and may eventually prevent its proper abandonment. Wells which are not readily visible may also not be considered when neighboring owners are siting wells, or when well canvasses are conducted during public-health emergencies.

Setbacks of 50 feet from other wells are recommended, to avoid excessive interferences between wells. In much of the El Granada area and other areas of the County underlain by coastal-terrace aquifers, saturated thickness of the primary aquifer is typically 30 to 50 feet; this may decline to 15 to 25 feet during droughts or prolonged periods of subnormal recharge. Expected interferences in terrace or alluvial aquifers in excess of 10 to 15 feet should be avoided in areas such as El Granada, so that a minimum of 10 to 15 feet of saturated thickness remains to supply the well. Assumed in this criterion is well construction which incorporates pumping levels substantially below the base of the terrace aquifer system; if pumps are placed at or above the level of the top of the bedrock, even lesser drawdown interferences would be tolerated. Very large drawdowns might be expected in the weathered bedrock if wells are spaced any closer than 50 to 100 feet apart. Further discussion is provided in Section 4.

3 WATER-TESTING VALIDATION

We suggest that a limited and appropriate quality-control program be considered by the County to establish whether samples for chemical analysis are being:

1. Collected in a standard, consistent manner, and at an appropriate time during a pump test
2. Properly identified and labelled in the field, and that the same sample number is being carried through the laboratory analysis, to avoid inadvertent confusion of samples from multiple wells
3. Properly preserved and transported to the laboratories within required holding times
4. Analyzed by the laboratories within the holding times required for the analytical methods being used.

The intent of such a program is to control the quality of sampling and analysis at a level consistent with the needs of individual or group water-supply systems. More intensive quality-assurance procedures should, of course, be used at sites where the presence of toxic substances is suspected or where greater resolution is needed.

The quality-control program for the domestic well system should best be written by County staff, who will administer it. It may be helpful for some of the following approaches or elements to be included in such a program:

1. The field measurement of specific conductance might be noted by the sanitarian along with the sample number on the bottle and later compared with the value reported by the laboratory as a means of identifying any samples which may have been accidentally switched in transit or in the laboratory.

   County field staff may wish to monitor some or all pump tests with a specific conductance meter. Samples collected by the owner or driller to certify the well should not be taken until the specific conductance of water produced from a well or from a tap has held constant for several minutes. This is a useful field indication that the water being produced may be representative of the water in the aquifer, and that the analysis will be meaningful.

2. In limited cases, we suggest that County staff collect a separate sample for independent analysis at the same time that the driller or owner collects the sample required by the well permit application. Collection of a sample 'split' need be done for only a small fraction of the total number of samples, perhaps five percent. The practice should be done randomly.

3. As a condition of accepting a particular analysis, the County may wish to require that the laboratories report the date and time the sample was received, the date of analysis, and the date of the written report to the owner or agent. Many of the local laboratories already follow this recommended practice, which describes whether samples are analyzed within the required holding times.

4. The County may wish to require that a certain number of owners (perhaps 10%) submit samples to two separate laboratories for analysis of some or all of the required constituents. 'Replicate' sampling should be restricted to a relatively small proportion of all wells, perhaps 10 percent, possibly chosen on the basis of application number.

5. Other measures as deemed appropriate by the County staff.

Some additional costs may be incurred by the County and by individual owners. We believe that the additional costs are likely to be quite small relative to those of administering other provisions of the ordinance. Probable benefits to the public are considered large in relation to the costs involved.

4 ANALYSIS OF INTER-WELL DISTANCES WHICH MAY BE APPROPRIATE FOR PREVAILING CONDITIONS IN COASTAL SAN.MATEL COUNTY

One of the siting criteria in the County's water-well ordinance is a distance of 50 feet from other known wells. To test the reasonableness of this criterion, we simulated water-level response with varying well spacing under conditions which appear representative of those in coastal San Mateo County.

A model based on the Theis analysis was selected for this purpose. This type of model is general, versatile, and adaptable to both confined and unconfined conditions. Models using this solution are among the most commonly-used for analysis of small- or moderate-sized aquifer systems for general basin-planning purposes.

The model was applied to a square array of 25 wells in the center of a typical coastal San Mateo County aquifer, with no other pumping demands or recharge. This configuration approximates a neighborhood cluster of wells under summer conditions, isolated from any other major pumpage such as agricultural or large community wells.

We used the model to assess the drawdown which may be expected in the center of this array. Entering the analysis, the maximum range of tolerable or prudent drawdown after a summer of pumping was established at 10 to 15 feet. The basis for this range is that saturated thicknesses of coastal aquifers are typically 30 to 60 feet, and were observed to decline approximately 15 to 25 feet during the 1976-77 drought. Any more than 10 to 15 feet of sustained drawdown, we believe, would de-water a significant number of wells under conditions approaching those of the design drought.

The assumptions used in applying the model, and the parameters and bases used in the simulation, are summarized in Table 1. We assessed ultimate sustained drawdown varying three parameters: Well spacing, transmissivity, and storativity. In all runs, wells were pumped at an average rate of 0.8 gallons per minute, corresponding to an assumed actual water-use pattern of four hours of pumping at the rate specified in the ordinance (2.5 gpm), followed by eight hours of non-operation. Total daily production from each well is 1200 gallons, several times greater than the mean household use; an assumption which offsets other factors which would lead to underestimated drawdown, such as the constant-head boundary (implying an infinite supply of water in the aquifer), the discounting of other pumping of the aquifer, possible export of pumped water from the allowable cluster of wells, or the effects of mutual interference by several wells pumping simultaneously. No recharge from percolation, streams, or septic systems was incorporated in the calculations.

Aquifer parameters were chosen to correspond to the values estimated for the terrace and bedrock aquifers in El Granada. A mean transmissivity of 1700 gallons per day per foot of terrace aquifer was bracketed by values roughly half and twice as large (850, 3500 gpd/ft). A reasonable range of 50 to 400 gpd/ft was used for the bedrock aquifer. A wide range of storativity values was used. The larger value of 0.08 corresponds to our estimate of specific yield in the saturated portions of the terrace aquifer, and might be observed under completely unconfined conditions. The smaller value of 0.00017 is based on our calculations of the lowest storativity value which may be computed from the limited existing aquifer tests in the area (ESRI, 1985), and corresponds to storativity values commonly reported under fully-confined conditions. The two extremes produce drawdowns which differ by about a factor of 2.

Results of the simulation are presented in Table 2. After 150 days of pumping, representing a typical summer, drawdown in terrace aquifers with transmissivities of one-half of the mean value approached or exceeded the limiting range of acceptable water-level depression, at well spacings of 50 feet. In realistic terms, this suggests that perhaps 5 to 10 percent of the terrace aquifer wells would be effectively non-producing at the end of a dry-period summer. This may represent the upper limit of risk acceptable to the County. Larger distances between wells would provide a higher level of yield reliability.

It should be noted that the value of sustained drawdown is considerably more sensitive to aquifer transmissivity than to other factors considered, such as yield, storativity, or well spacing. Other demands on the aquifer, assumed not to exist in our simulations, are likely to be of intermediate importance where they occur. Sound, reliable data on aquifer transmissivity should be sought if local variations from the County-wide regulations are to be considered.

TABLE 1 MODEL ASSUMPTIONS

I. Aquifer Conditions

Initial saturated thickness:	50 feet
Transmissivities	
Terrace deposits (range)	850 gallons per day per foot 1700 3500
Crystalline bedrock (range)	50 gallons per day per foot 400
Storativity factor	0.0017 (low) 0.080 (high)
Extent	infinite
Evapotranspirative losses	nil
Recharge from percolation or streams	nil
Recharge from or discharge to lower aquifer	nil
Hydraulic gradient	0.036 ft/ft (seaward)
Condition	full range of confined to unconfined

II. Well and Operating Conditions

Well condition	excellent
Well performance	completely efficient (no head losses at or in well)
Well spacing (range)	25 feet 50 100
Well depth	at least to base of terrace aquifer, plus sufficient depth for pump and for sand accumulation
Pumping rate	0.8 gallons per minute(a)
Pumping duration	150 days, beginning in May
Pumping array:	5 wells x 5 wells all pumping at uniform rate except for center well
Location of measurement	center well (non-pumping)

III. Assumptions Inherent in This Model

Homogeneous aquifer within saturated zone

Conservation of mass

Porous-medium conditions within reasonable range of Darcian flow

Isotropic aquifer

Constant head boundary at some large distance from the pumping array

Impermeable lower boundary

(a) Mean value, assuming pumping pattern of 4 hours on, 8 hours off, at 2.5 gpm.

TABLE 2. RESULTS OF DRAWDOWN SIMULATIONS, COASTAL SAN MATEO COUNTY CONDITIONS

I. End-of-Summer Sustained Drawdown for Mean Terrace-Aquifer Transmissivity, Varying Storativity and Well Spacings

Simulated Sustained Drawdown (ft)
(Transmissivity = 1700 gpd/ft)

Storativity	Well Spacing		
	25 ft	50ft	100ft
0.00017	17.06	15.25	13.45
0.08	8.74	6.96	5.19

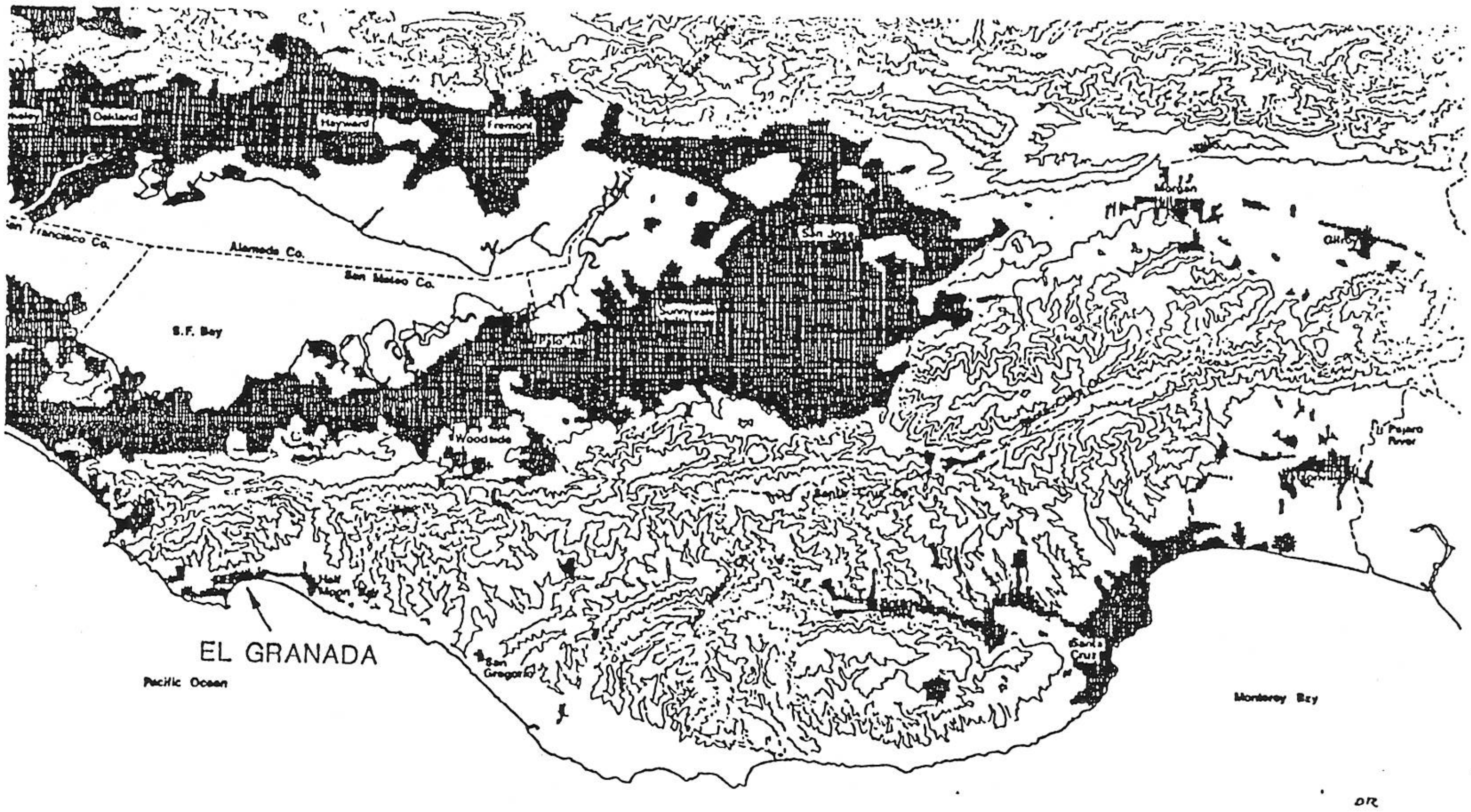
II. End-of-Summer Sustained Drawdown For 50-Foot Spacing Varying Transmissivity and Storativity

Simulated Sustained Drawdown (ft)

Transmissivity (gpd/ft)	S = 0.00017	S = 0.08
850	28.62	12.06
3500	7.88	3.85
400	56.50	23.91
50	356.70	83.15

See Table 1 for assumption and bases of simulations

PLATES

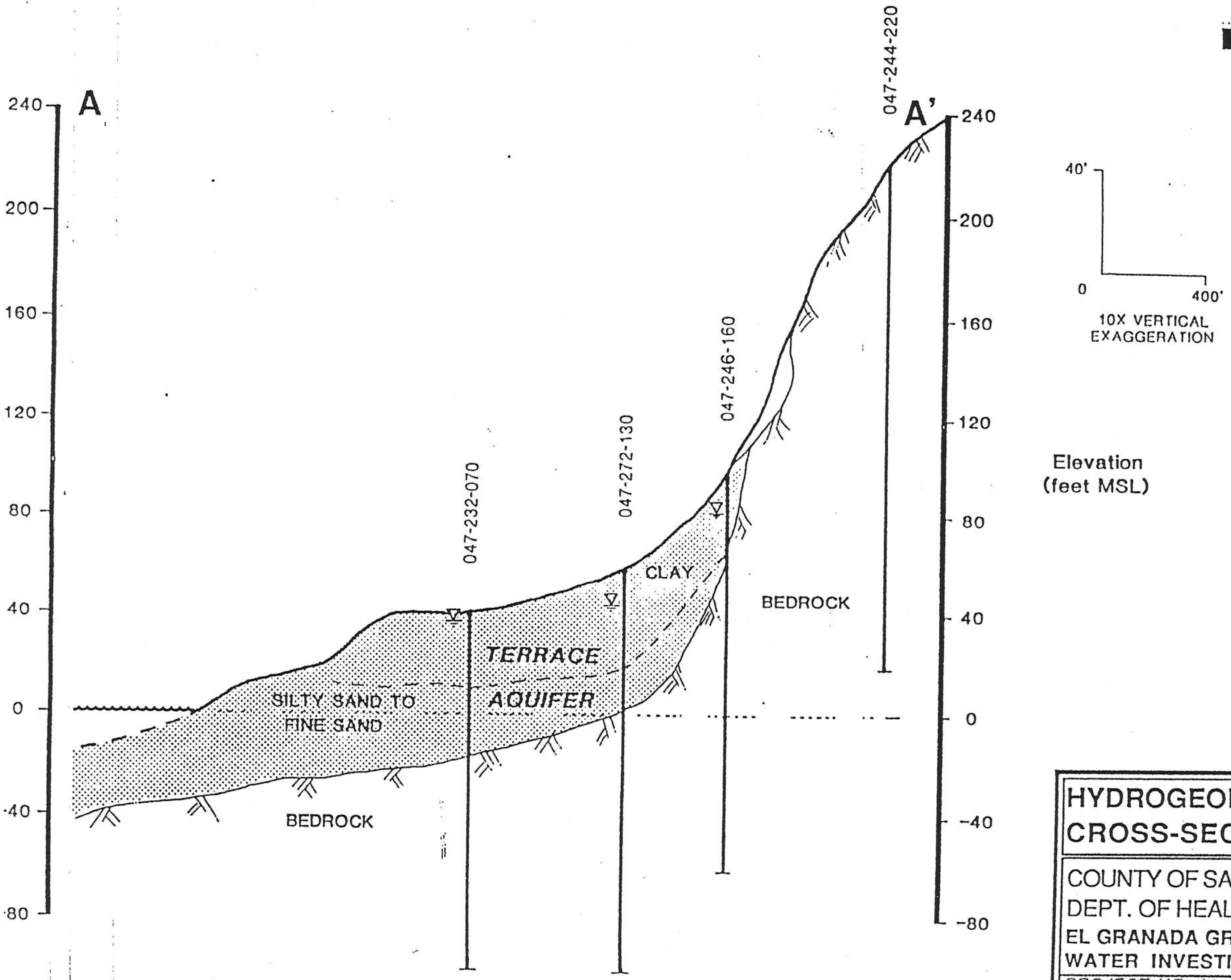


Source: Hecht and Rusmore, 1973;
Original base: Patri et al., 1970.

Revisions from aerial photographs
and topographic maps (1:125,000)
published by ABAG, and reconnaissance.

LOCATION OF EL GRANADA AREA	COUNTY OF SAN MATEO DEPT. OF HEALTH SERVICES EL GRANADA GROUND WATER INVESTIGATION PROJECT NO. 10-1730-01	PLATE 1

KLEINFELDER

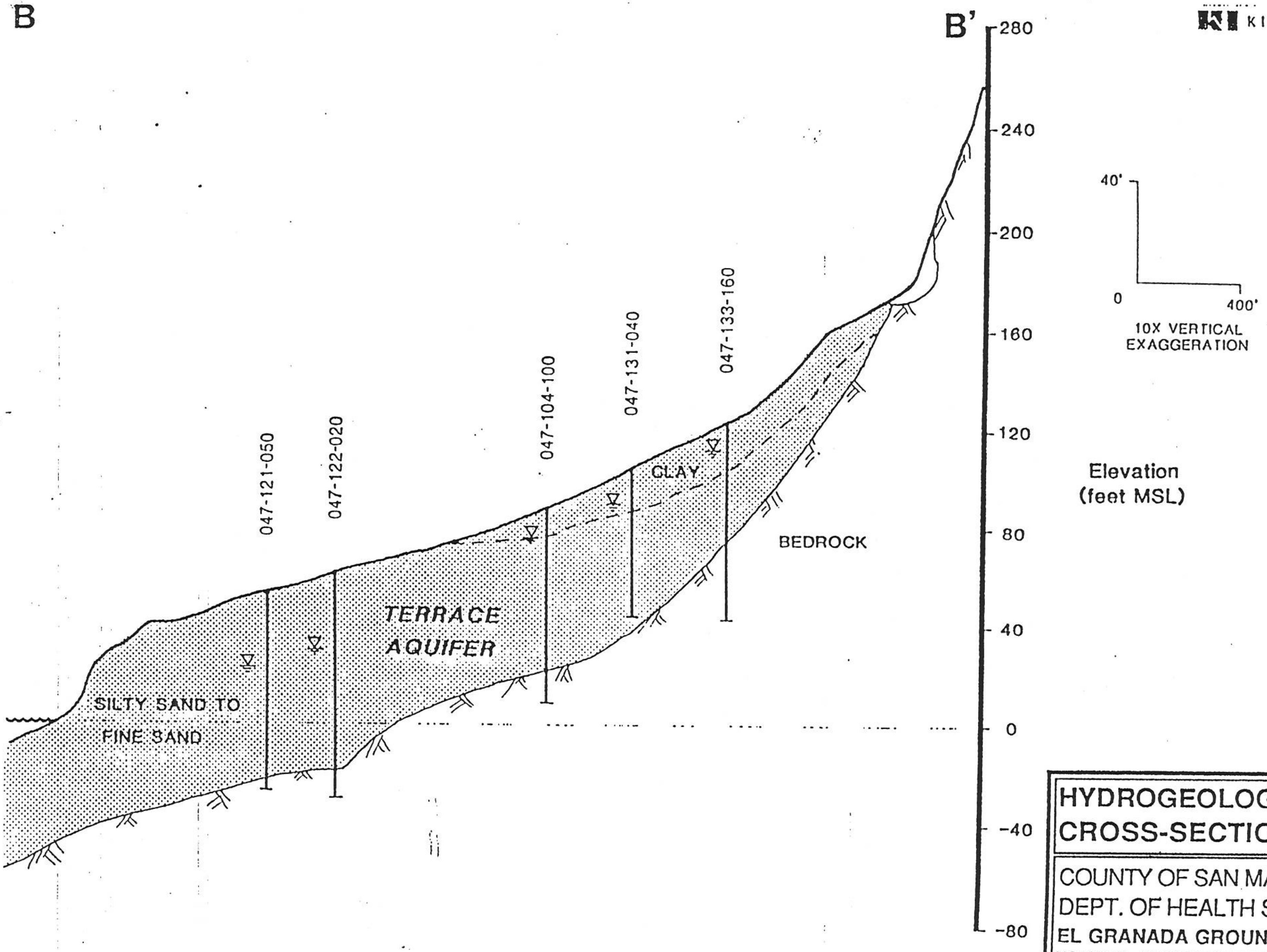


HYDROGEOLOGIC CROSS-SECTION A-A'

COUNTY OF SAN MATEO
DEPT. OF HEALTH SERVICES
EL GRANADA GROUND
WATER INVESTIGATION
PROJECT NO. 10-1730-01

PLATE
4

KLEINFELDER

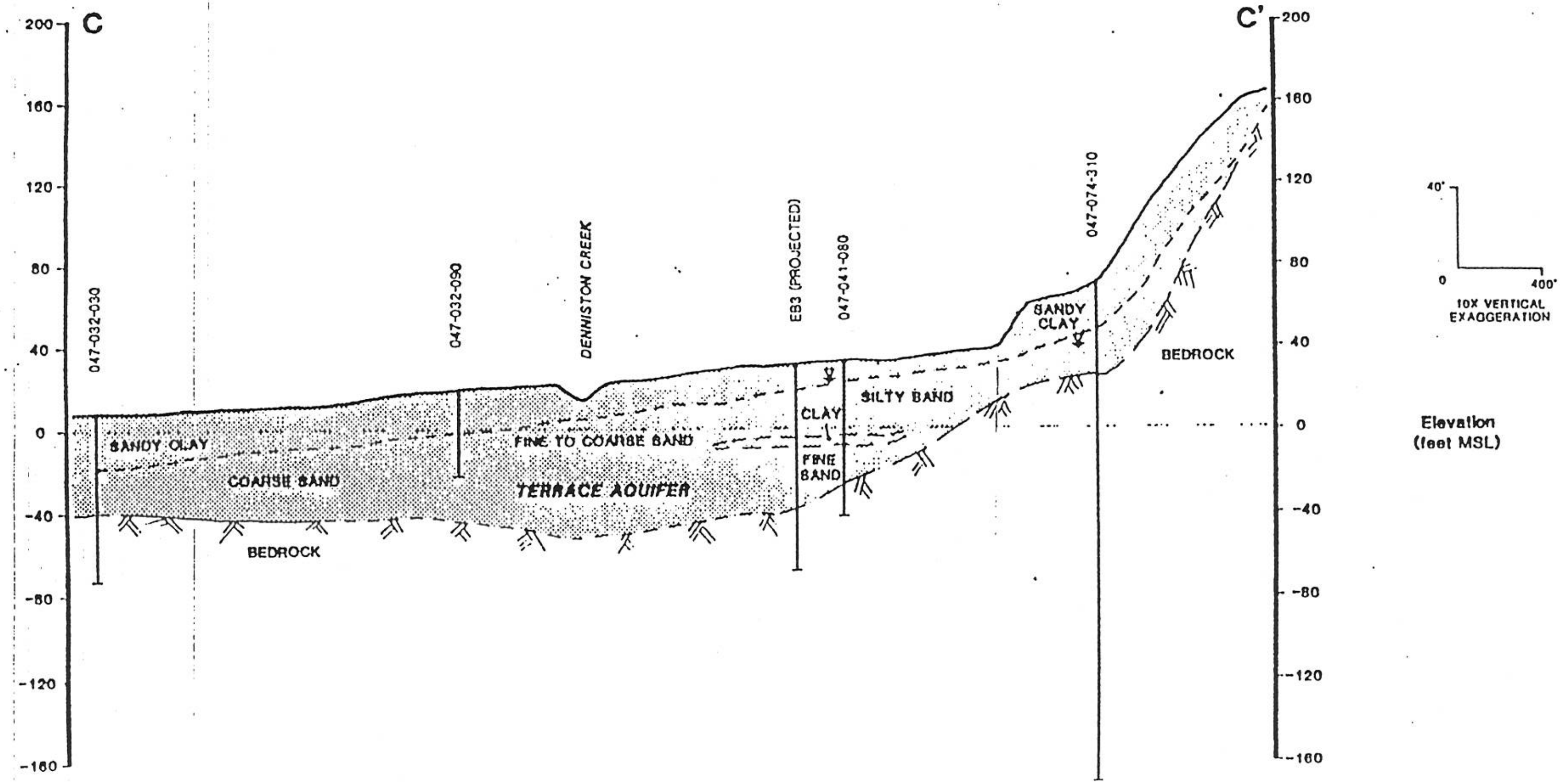


HYDROGEOLOGIC CROSS-SECTION B-B'

COUNTY OF SAN MATEO
DEPT. OF HEALTH SERVICES
EL GRANADA GROUND
WATER INVESTIGATION
PROJECT NO. 10-1730-01

PLATE
5

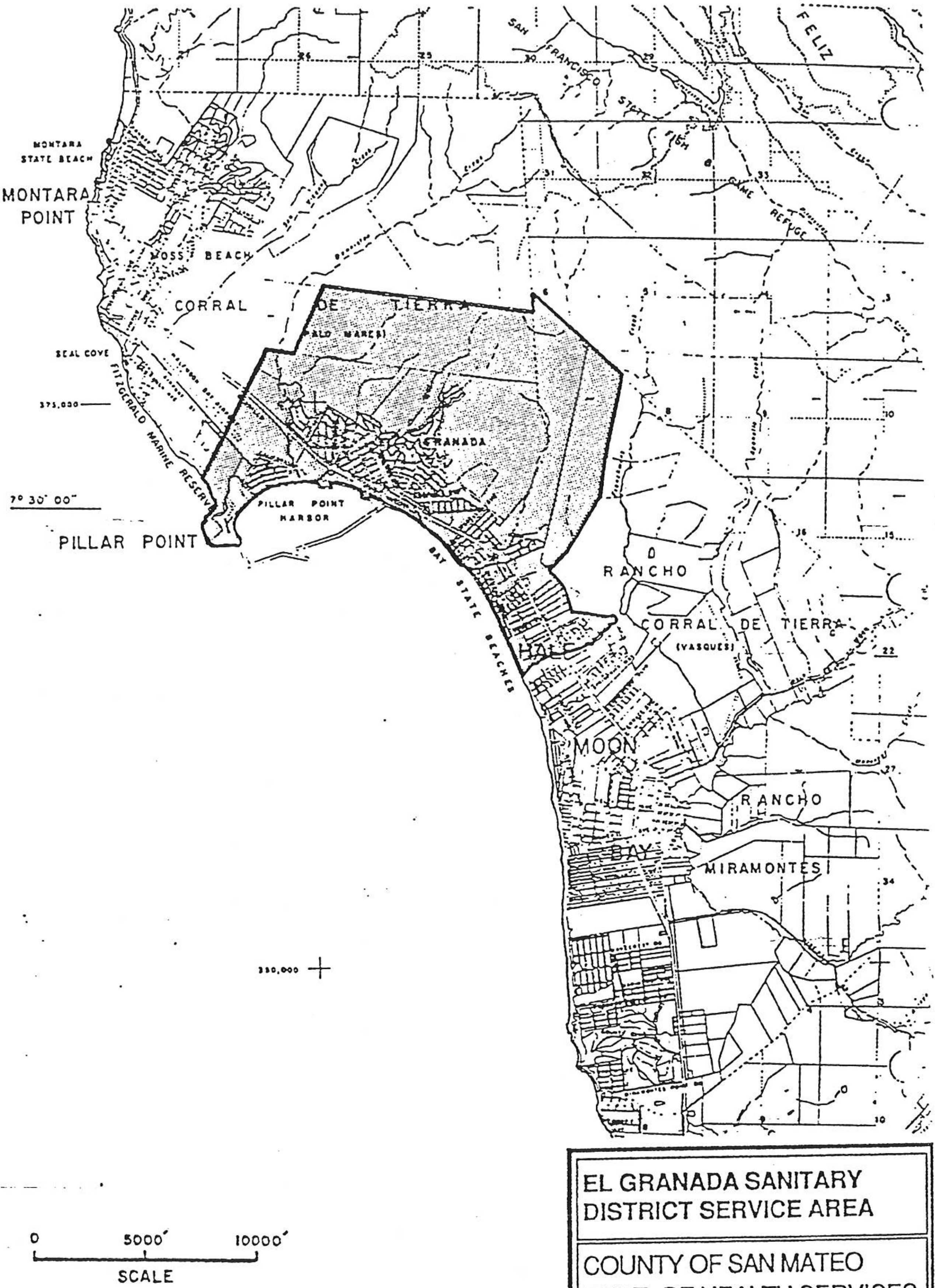
KLEINFELDER



HYDROGEOLOGIC CROSS-SECTION C-C'

COUNTY OF SAN MATEO
DEPT. OF HEALTH SERVICES
EL GRANADA GROUND WATER INVESTIGATION
PROJECT NO. 10-1730-01

PLATE 6

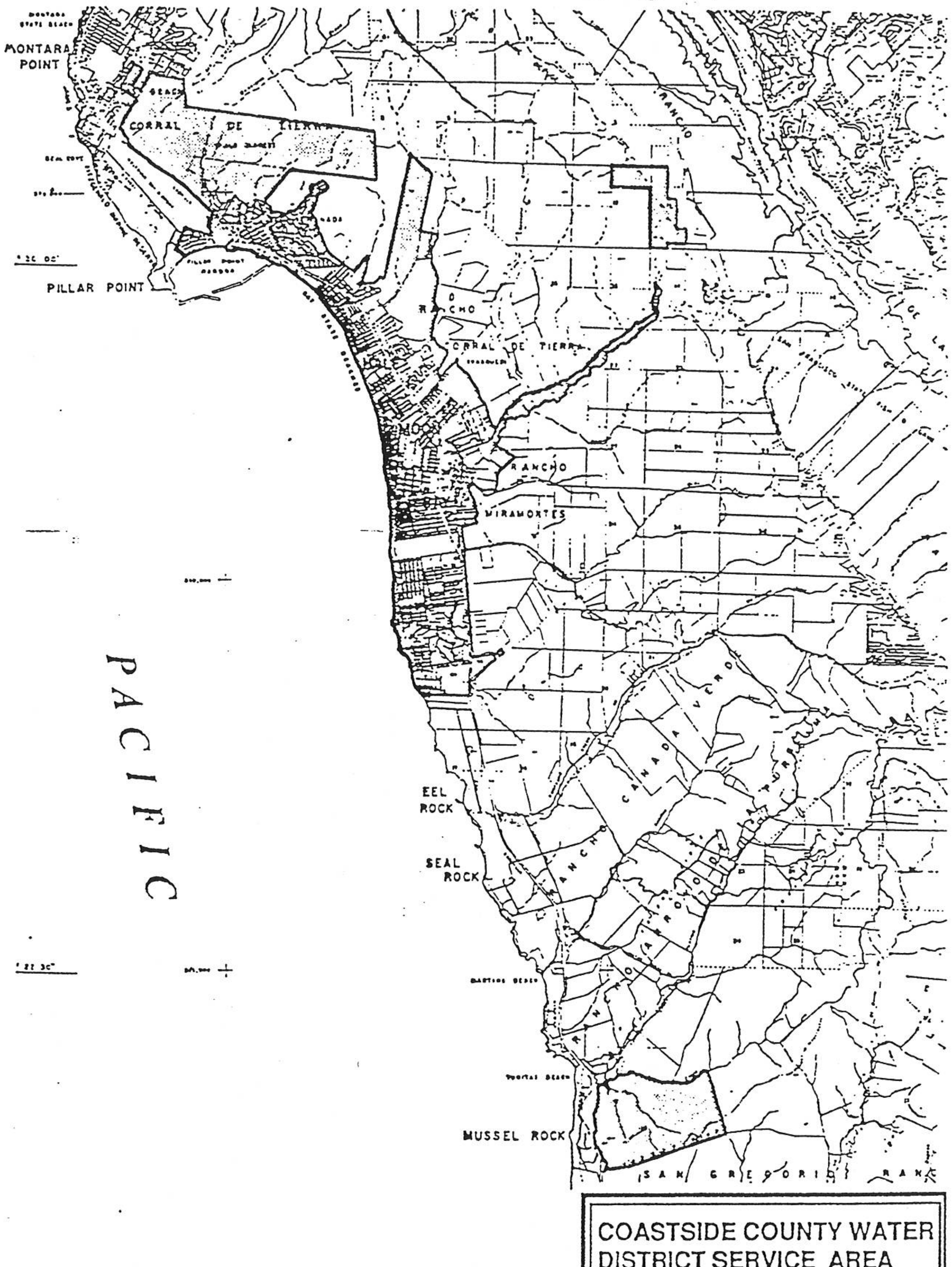


SOURCE: SAN MATEO COUNTY
LOCAL AGENCY FORMATION COMMISSION

EL GRANADA SANITARY
DISTRICT SERVICE AREA

COUNTY OF SAN MATEO
DEPT. OF HEALTH SERVICES
EL GRANADA GROUND
WATER INVESTIGATION
PROJECT NO. 10-1730-01

PLATE
12



0 5000′ 10000′

SCALE

SOURCE: SAN MATEO COUNTY

COASTSIDE COUNTY WATER DISTRICT SERVICE AREA

COUNTY OF SAN MATEO
DEPT. OF HEALTH SERVICES

EL GRANADA GROUND WATER INVESTIGATION

PROJECT NO. 10-1730-01

PLATE 13