San Mateo County Mid-Coast Aquifers:

Literature and Data Review

Prepared for:

San Mateo County
Board of Supervisors

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1. SUMMARY

- The San Mateo County Board of Supervisors seeks to identify where and how much water may be safely taken from the ground, from Half Moon Bay north to Devils Slide, without posing significant risks during an extended drought to community health or environmental resources and values. This Phase I report identifies information sources, ground-water units and their boundaries. Phase II will analyze the data and develop alternatives and recommendations, with Phase III assessing their environmental effects under the California Environmental Quality Act (CEQA).

- In general terms, the region is characterized by coastal plains and narrow mountain valleys, underlain by loose, unconsolidated alluvial and coastal-terrace deposits formed largely from or filled with coarse- and medium-grained sand eroded from the granitic rocks of Montara Mountain. In most cases, wells draw water of low mineral content with relative ease from these valley (alluvial) aquifers and portions of the coastal plain composed primarily of weathered granitic materials.

- Lower and more variable yields are measured from wells developed in granitic bedrock, or in the consolidated gray siltstones and sandstones mapped primarily as Purisima formation. Wells in both types of bedrock can often yield sufficient water for individual homes, and in some areas can produce sufficient water for community supply. Ground water is generally of good quality, with mineral content typically lower than that found south of Highway 92 on the south coast of San Mateo County. Water drawn from the Purisima siltstones and sandstones generally contains the highest mineral content, which sometimes exceeds the maximum concentrations recommended for domestic water supply.

- To delineate the mid-coast aquifers, we employed a broad-reaching watershed approach that recognizes the close connection between the valley aquifers and the coastal plan, and the implied need to manage them conjunctively. In general, sub-basin boundaries followed the topographic catchment area for each valley-aquifer, extending to the top of the watershed divide; then catchments were grouped based on the associated coastal plain aquifer, which was delineated based on recognized or discernible ground-water divides and the nature of the aquifer materials. Four sub-basin groupings of valley and coastal-plain aquifers were identified:

  a) Martini Creek south to Dean Creek, which includes Montara Creek;

b) San Vicente south to Denniston Creek, including the airport aquifer;

c) El Granada area; and

d) Arroyo de en Medio south to Frenchmans Creek.

- Basic data describing aquifer properties are generally limited in the study area, mostly coming from driller's well logs, which vary widely in quality of data. Well logs describe how the well is constructed, the yield of the well and water-level drawdown when initially tested, in addition to descriptions of the geologic materials encountered during drilling. Additional data have been developed from only several dozen wells. Perhaps more than in other coastal basins with long records of aquifer response, greater efforts to collect and archive wells logs with consistent and more descriptive information on aquifer properties are warranted.

- Well logs include short-duration (1-2 hour) drawdown information, generally collected following completion of the well, as part of the well development (clarification) process. Existing tests are often too brief to reasonably characterize the properties of the aquifer and performance of the well. In many parts of the Mid-Coast, longer-duration tests and consistent methodologies can provide data significantly more useful in assessing whether a well can sustain supply during multi-year droughts. Some of the most useful information was found in hydrologic studies either for a specific mid-coast basin or specific project in the study area.

- The County is potentially interested in assessing with a reasonable level of assurance the performance of a well drilled at any specific location or the long-term capacity of an aquifer from which it draws water to provide domestic water supplies during drought periods. Subsequent phases of the investigation are intended to provide information and guidance for these issues. Given that the aquifer properties and the data used to evaluate aquifers vary widely across the region, and recent demand for domestic wells in close proximity to each other in an urbanized setting near the coast, the County might consider additional steps to assure that wells meet high standards for quantity, quality and long-term reliability, pending a more complete assessment of groundwater supplies and conditions in Phase II.

2. INTRODUCTION

The San Mateo County Board of Supervisors seeks to identify the ground-water yield that may be safely taken from the 'Mid-Coast' aquifers, and estimate the number of residential wells that they will be able to permit without posing significant risks to community health or environmental resources and values. County staff has requested a multi-phased technical report that may be used at the basin / watershed planning level, including aquifer management alternatives, and leading directly to evaluation of effects of ground-water development on public health and natural resources. This approach would lead to expedited and smoother permitting, address issues linked to discretionary actions of County staff, and have tangible benefits and cost savings in longer-term monitoring programs if linked to a specific mitigation through the California Environmental Quality Act (CEQA).

The 'San Mateo County Mid-Coast' is loosely referred to as the stretch of coast along Highway 1 from northern Half Moon Bay to Devils Slide. Domestic water is supplied to the southern part of the region by Coastside County Water District (CCWD), providing services from Half Moon Bay to Princeton, and by investor-owned Citizens Utility Company of California (CUCC) on the north, servicing Montara and Moss Beach, in addition to private wells scattered through both service areas and outlying districts. With the exception of CCWD, which meets much of its demand through long-term contractual agreements with San Francisco Public Utilities Commission (PUC), the source of domestic water is from local surface and ground water resources. The carrying capacity of the local resources may be defined as the population that can be sustained using conservation measures during an extended drought without undue stress to valued natural resources.

County staff anticipates the ground-water investigation to progress through three phases:

- Identification of information sources, and the ground-water units and their boundaries,
- Hydrogeologic analysis and hydrologic investigation,
- Environmental assessment under the California Environmental Quality Act.

Staff requested that Balance Hydrologics assist with developing a scope for and conducting the first phase. This report summarizes our results.

After analyzing the available data, we divided the Mid-Coast into four sub-basins for further analysis (Figure 1), based on (a) recognized or discernible ground-water divides, (b) the nature of the aquifer materials; (c) aquifer behavior and extent of flow across aquifer units, (d) units organized as best feasible by watershed so that both surface and ground water can be considered conjunctively, and (e) traditionally-recognized units where consistent with the above.

Earlier studies generally defined a specific Mid-Coast aquifer of concern by the discrete physical boundaries of the aquifer(s) where known high-yielding wells were located or principal storage found. Local examples include the Airport Aquifer or El Granada Terrace Aquifer. We have chosen to take a broader-reaching watershed approach and include the entire ground-water shed in the sub-basin boundary, extending to the top of the bedrock watershed divide, and including 'pocket' aquifers[1] scattered through the valleys and foothills of Montara Mountain. We believe that this approach provides a more complete evaluation of the local water resources, at a manageable scale, recognizing the intrinsic linkage between surface flows and ground water in this landscape of small, sandy valleys and plains. Where appropriate, specific studies may divide (and have divided) the sub-basins into smaller sub-units.

The Mid-Coast study area grades almost imperceptibly into the Pilarcitos[2] watershed and ground-water basins to the south. Water management within the Frenchmans sub-basin will affect Pilarcitos, and vice versa. Additionally, several investigations wholly or largely within the Pilarcitos basin are applicable or of direct value to the Mid-Coast investigation. As one example, data collected within the Pilarcitos watershed are some of the most useful information available for the runoff properties of the granitic watersheds of Montara Mountain. We have included data and references from the Pilarcitos basin where these are likely to be of particular

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[1] We use the term 'pocket' aquifer as a mountain watershed hydrogeologic system comprising weathered bedrock (soil), colluvial (up-slope) wedges, alluvial (valley-bottom) deposits, and underlying fractured bedrock. On the Mid-Coast, pocket aquifers are composed of coarse-grained decomposed granitic rocks overlying deeply-fractured Montara Mountain granitics. These unconfined aquifers have enhanced recharge attributes that manifest in less runoff with a markedly less 'flashy' hydrograph (Owens, Porras, and Hecht, 2001). Some of the highest yielding wells are found in pocket aquifers. Leaving the mountain valley, pocket aquifers generally connect to a broader aquifer downstream, comprising alluvial fan deposits and marine terraces, which have generally been the focus of previous study.

[2] Pilarcitos Creek has a much larger watershed than the Mid-Coast sub-basins to the north (27 mi^2, as compared to 20 mi^2 for the combined sub-basins illustrated in Figure 1). Pilarcitos Creek drains a wider variety of bedrock, hydrogeologic and geomorphic conditions, as is more highly managed, serving as a water source for the San Francisco Water Department as well as a principal source for CCWD. Because of these clear differences and distinctive water-resource development, Pilarcitos Creek was not included in the Mid-Coast basin study area; however, data and reports applicable to the Mid-Coast sub-basins were summarized in Table 3.

value to the Mid-Coast analysis, or in linking management alternatives in the two watersheds. Similarly, information from watersheds further to the south, or to the north and east, has been included in this report where we deem it pertinent to the Mid-Coast.

We reviewed 27 reports and summarized the hydrologic and hydrogeologic information in three multi-paged tables (Tables 1, 2 and 3). Table 1 summarizes information reported on the Martini Creek, Montara Creek and Dean Creek group of sub-basins; Table 2 summarizes the San Vicente Creek, Denniston Creek and Pillar Point graben group of sub-basins; and Table 3 summarizes information on the El Granada, Arroyo de en Medio, and Frenchmans Creek sub-basins, as well as selected reports on the Pilarcitos Creek watershed, which are pertinent to managing basins to the north. We consider these three tables the core of our report, and show which reports provide unique data, where historic data are summarized, what analyses have been conducted and for what conclusions.

We envision the outline of the phase 2 report to include a detailed discussion of each group of sub-basins, as delineated in Figure 1. In the classic ground-water basin style, this would include a discussion on: a) ground-water occurrence, b) aquifer properties, c) ground-water movement and recharge, d) ground-water quality, and e) historic and current ground-water use. We have initiated this discussion in Section 3.

Specific information on hydrogeologic properties, such as transmissivity and storage coefficient, is summarized in Table 4 by sub-basin and source. Latitude was taken in this table, where specific sub-basin data gaps exist, to infer values based on adjacent basin values. We stress the preliminary nature of estimates in Table 4, which are subject to revision. This information is discussed in Section 4. In general, few extended aquifer tests have been conducted (mostly in the Pilarcitos Creek watershed), and summaries of specific capacity of wells by aquifer is limited. These are areas for further investigation.

Sources of rainfall and streamflow records are summarized in Tables 5 and 6. With the exception of recently collected (unpublished) data on San Vicente and Denniston Creeks, streamflow records exist only for watersheds beyond the Mid-Coast study area, and no specific relations are yet defined for the geographically-distinct watersheds of the Mid-Coast.

Initial discussions with the County highlighted five reports of interest:

1. Montara water supply investigation for Montara Sanitary District (California DWR, 1999);

2. Preliminary feasibility assessment of ground water in the Martini Creek, McNee Ranch and Upper Montara Creek Area, interim status report (Balance Hydrologics, 1999);

3. Draft Montara - Moss Beach Water Well EIR (Hecht and others, 1989: ‘Kleinfelder 2’);

4. El Granada ground-water investigation report (Laduzinsky and others, 1988: ‘Kleinfelder 1’);

5. Half Moon Bay / Pillar Point Marsh ground-water basin study (Luhdorff & Scalmanini Consulting Engineers, and Earth Sciences Associates, 1992, 1991, 1987).

Detailed summaries of these reports are featured in Appendix A.

3. REGIONAL HYDROGEOLOGY AND AQUIFER BOUNDARIES

Principal geologic information may be readily, but not exclusively, found on four maps, and supporting materials and references:

- Preliminary geologic map of San Mateo County, California (Brabb and Pampeyan, 1972);
- Geologic map of San Mateo County, California (Brabb and Pampeyan, 1983);
- Geologic map of the Montara Mountain and San Mateo 7-1/2' quadrangles, San Mateo, County, California (Pampeyan, 1994);
- Preliminary maps of quaternary deposits and liquefaction susceptibility, nine-county San Francisco Bay Region, California: a digital database (Knudsen et al., 2000).

Mid-Coast ground water generally moves through a reasonably complex coastal aquifer system composed of four distinct aquifer units: heavily-fractured Cretaceous granitic rocks of the Montara Mountain batholith that forms the basement bedrock; overlying weakly to moderately consolidated sandstone and siltstone of the Pliocene-aged Purisima Formation; Quaternary marine terrace deposits of various ages, and Holocene coarse-grained alluvium and colluvium.

Figure 1 shows mapped unconsolidated deposits (after Brabb and Pampeyan, 1983) and the sub-basin boundaries we suggest for use in the Mid-Coast. We illustrated deposits with high permeabilities (e.g., alluvium, inner fan and coarse-grained deposits) with shades of yellow, and low permeabilites (eg. marine terraces, outer fan and fine-grained deposits) with shades of brown. Surficial bedrock is not differentiated in Figure 1 but may be interpreted within the Mid-Coast Basin study area by the brown-green shaded relief base; it is generally fractured-granitic rock with minor exposures of Purisima formation in the Pillar Point area. Limited exposures of Lompico Sandstone and Monterey Shale outcrop in the lower Frenchmans Creek sub-basin. Granitic and Purisima bedrock also underlies the unconsolidated deposits. Storage in the bedrock aquifers is similar in magnitude to the storage in the terrace and alluvial aquifers, but dispersed across discrete fractures in an order-of-magnitude larger basin volume (Table 4).

The terraces and alluvial deposits form the principal aquifers of the region, and have been the principal focus of municipal well development. Permeability, particularly in alluvium, and storage per unit surface area are both higher in unconsolidated deposits than in granitic or

Purisima bedrock (Table 4). Extending along nearly every creek on the Mid-Coast, coarse-grained alluvial deposits up to a depth of 75 feet are mapped. Feeding into these stream-worked deposits, colluvial wedges are mapped up to a depth of 20 feet (Pampeyan, 1994). These Holocene deposits all overlie deeply-fractured granitic bedrock and provide permeable ground-water storage, ground-water drains, as well as an effective avenue for deep percolation to the granitic bedrock aquifers. Some of the highest yielding wells are found in these pocket aquifers, penetrating both the valley alluvium and the underlying fractured granite. Weathered granitic bedrock often extends to the catchment divide and provides area for both runoff and bedrock-aquifer recharge.

Emerging from the mountains, Mid-Coast streams feed broader aquifers in alluvial fan and stream deposits, where the majority of wells are concentrated. Aquifers found in these unconsolidated material are not exclusively unconfined, as one might reason. Aquifer tests in the Pilarcitos Creek and Frenchmans Creek area show confined (or possibly semi-confined) hydrogeologic conditions (Geoconsultants, 1989), ostensibly related to finer-grained lenses or members within these deposits. The current stream course and recent alluvium reportedly overlie the confined aquifer at the Balboa well field at the mouth of Pilarcitos Creek (Luhdorff & Scalmanini Consulting Engineers, 2000). Confining conditions were also observed from aquifer tests in the San Vicente / Denniston Creek sub-basin (S=0.001), and artesian conditions were found beneath the confining organic-rich (marsh?) deposits, as well (Luhdorff & Scalmanini Consulting Engineers and Earth Sciences Associates, 1991). Near El Granda, these broad alluvial aquifers have been observed to convey fresh water about 900 feet off shore (San Mateo County Harbor District, 1972).

Marine terraces may be found adjacent and subjacent to the alluvial fan deposits, or isolated up-slope. Well logs reviewed for the Montara-Moss Beach and El Granada areas suggest unconfined conditions in the shallow aquifers of terrace deposits (Laduzinsky and others, 1988; Hecht and others, 1989; Balance Hydrologics, 1999). In the Montara – Moss Beach area they generally show one-third the yield and twice the salinity as the alluvial aquifers (Woyshner and Hecht, 1999).

4. GROUND-WATER OCCURRENCE BY SUB-BASIN

4.1 Aquifers of Martini Creek, Montara Creek, Dean Creek Sub-Basins

The northern portion of the Mid-Coast Aquifers study area comprises the watersheds of Montara Creek, Martini Creek, the unnamed creek between the two, and Dean Creek. Sandy pocket (or 'shoestring') alluvial aquifers extend along the creeks. Montara Creek is the largest, with a 1.25 square-mile contributing watershed, followed by Martini Creek, which has a 0.95 square-mile watershed that recharges the alluvial and bedrock aquifers (Figure 1). About 1,500 acre feet of storage was estimated for the Montara Creek sub-basin (Hecht and others, 1989, Table 5), and about 1,000 acre feet of storage was estimated above the CUCC Wagner #3 well near cross-streets Drake and Alta Vista (Table 2, Woyshner and Hecht, 1999). About 940 acre feet for the Martini sub-basin, above the stream crossing about 1,500 feet upstream of Hwy 1 (Table 2, Woyshner and Hecht, 1999). Other minor pocket aquifers evaluated were located between Martini and Montara Creeks, as well as Green Valley, north of Martini Creek (Woyshner and Hecht, 1999). Dean Creek has not been evaluated.

The coastal streams have dissected a well-preserved stair-stepping sequence of marine terraces, on which the communities of Montara and Moss Beach have been settled. Four distinct Quarternary terraces have been mapped (Knudsen and others, 2000; Brabb and Pampeyan, 1972), overlying Purisima and granitic bedrock units. At the mouth of Martini Creek, roughly 60 acres of coarse-grained alluvial fan and stream deposits[3] have been mapped adjacent to approximately 110 acres of marine terrace; about 500 acre feet of storage (excluding underlying fractured bedrock) was estimated for this unincorporated area north of Montara (sub-units D and E in Woyshner and Hecht, 1999). South of this area, the Montara Terrace has about 530 acre feet of storage and the Moss Beach Terrace has about 700 acre feet of storage (Hecht and others, 1989). The hilly area between the two terraces comprises Upper Moss Beach, which consists of a surficial cover of marine terrace deposits (perhaps 40 feet thick) underlain by fractured, granitic bedrock, and Montara Heights, which is primarily fractured, granitic bedrock. Ground-water storage for these sub-units was estimated at 210 and 330 acre feet, respectively (Hecht and others, 1989).

[3] The alluvial deposits at the mouth of Martini Creek are similarly mapped as those below San Vicente and Denniston Creeks in the Pillar Point graben but an order of magnitude smaller area (see the corresponding section for comparative details of this aquifer).

Of the sub-units evaluated, the marine terraces and underlying fractured bedrock provide about 2,270 acre feet of storage, while pocket aquifers provide about 2,440 acre feet of storage. In an independent accounting of storage for the grouped sub-basins (Table 4), we estimate a preliminary total of 4,400 acre feet of storage.[4]

4.2 Aquifers of the San Vicente Creek, Denniston Creek, Pillar Point Graben Sub-Basins

The dominant aquifer on the Mid-Coast is the coarse-grained unconsolidated deposits of the Pillar Point graben, commonly called the 'Airport Aquifer'. Down-faulted along the Seal-Cove fault[5] on the west and Denniston fault on the east, the basin has accumulated coarse-grained alluvial fan and stream deposits that are primarily decomposed granite from Montara Mountian, deposited by San Vicente Creek on the north and Denniston Creek on the south. Weathered and fractured Purisima and granitic bedrock lies beneath the unconsolidated deposits, augmenting the ground-water supplies within the sandy, basin-fill sediments. Extending headward along both creeks, as with nearly all of the creeks on the Mid-Coast, are coarse-grained alluvial aquifers and underlying fractured granitic bedrock aquifers.

Regionally, the graben has the coarsest and deepest deposits of the Mid-Coast (Fio and Leighton, 1995). Previous ground-water investigations have focused on the Denniston Creek portion of the sub-basin, where domestic water production wells are concentrated, and where concerns of overdrafting and detrimental impacts to the Pillar Point Marsh have been raised. San Vicente Creek and its alluvium at the north end of the graben, however, should logically be included in a comprehensive evaluation of the basin, particularly as reservoirs fed from San Vicente Creek recharge to the graben sediments.

Total basin storage capacity was estimated for the airport aquifer from specific yields based on grain-size analyses (Lowney-Kaldveer Associates, 1974): Denniston Creek subarea was estimated at 1,800 acre feet, San Vicente Creek subarea, at 995 acre feet, and the airport subarea, at 4,630 acre feet. Capacity to sea-water elevation is about two-thirds of total, or about 5,000

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[4] Estimates in Table 4 are preliminary and subject to revision.

[5] Dividing the La Honda and Pigeon Point blocks, the Seal Cove - San Gregorio fault is recognized as a major structural feature. The Seal Cove fault extends northward from Moss Beach and connects with the San Andreas fault near Bolinas Lagoon in Marin County; southward from Pillar Point, it crosses Half Moon Bay to the mouth of San Gregorio Creek, where it becomes the San Gregorio fault, which extends to Ano Nuevo and across Monterey Bay to the west of the Monterey Peninsula, where it is called the Pallo Colorado fault southward from Garrapata Creek.

acre feet. Earth Science Associates and Luhdorff & Scalmanini (1987) suggested that if two-thirds of the storage were used, then it might cause water-level declines below sea level in some areas. In an independent accounting of storage (Table 4), we estimate a preliminary total of 2,900 acre feet of storage in unconsolidated material, which includes pocket aquifers, and 3,300 acre feet in fractured bedrock.

4.3 Aquifers of the El Granada Sub-Basin

South of Denniston Creek, the landscape is dominated by a resistant knob of Montara Mountain, which rises steeply above El Granada to elevations exceeding 1,200 feet. Denniston Creek drains the northwest slopes of the knob, and Frenchmans Creek drains the eastern slopes. Two minor creeks drain the southwest slopes; Arroyo de en Medio flows through Miramar, and an unnamed creek flows through El Granada, each depositing coarse-grained alluvial fan deposits on the subjacent marine terraces. Much of El Granada was settled on a marine terrace (mapped as Terrace 2) and fine-grained alluvial fan deposits, located between the creeks. As in the Montara – Moss Beach area, many domestic wells draw water from the terrace aquifer, which were critically evaluated for hydrogeologic performance in the El Granada Ground Water Investigation in the 'Kleinfelder 1' report (Laduzinsky and others, 1988). We retained the El Granada sub-basin boundary used in this prior report, but extended it to the top of the watershed and south along the divide with Arroyo de en Medio.

The effective storage area of the terrace aquifer, as defined in the 'Kleinfelder 1' report, covers an area of about 365 acres. The aquifer varies in thickness from about 50 to 80 feet thick, and has an average thickness of about 65 feet. Well-log data from 49 wells indicated an average saturated thickness of about 50 feet. Based on a specific yield of 0.08, they estimated storage at 1,260 acre feet. If only the terrace above sea level is considered (mean saturated thickness of about 30 feet) aquifer storage was estimated at 880 acre feet. We estimate a preliminary total of 1,200 acre feet of storage in unconsolidated material, which includes pocket aquifers, and 1,000 acre feet in fractured bedrock (Table 4).

4.4 Aquifers of the Frenchmans Creek, Arroyo de en Medio Sub-basins

Bedrock geology changes south of El Granada, where we have grouped Frenchmans Creek and Arroyo de en Medio sub-basins. Miocene-aged sedimentary units of the Santa Cruz Mountains outcrop here and presumably underlie the alluvial fan deposits at the mouth of Frenchmans Creek, and possibly lower Arroyo de en Medio as well. Similar to other streams on the Mid-Coast, Frenchmans Creek and Arroyo de en Medio flow off Montara Mountain, where coarse-grained (decomposed granite) alluvial aquifers overlie heavily-fractured granitic bedrock aquifers. This pocket aquifer system feeds downstream alluvial fan deposits on the coastal plain. The alluvial fans fine outward and exhibit confined-aquifer conditions but are also readily responsive to recharge by rain (Geoconsultants, 1989). Confined-aquifer conditions have also been observed in aquifer tests to the south in the Pilarcitos Creek aquifer. Marine terraces are not well preserved in this sub-basin, as they are in El Granada and the Montara – Moss Beach areas.

Culturally, the northern fringes of Half Moon Bay extend into Frenchmans Creek and Arroyo de en Medio. CCWD services this area, as well as El Granada, with water from the San Francisco Water Department (Pilarcitos Lake and Crystal Springs Reservoir) and Pilarcitos Well Field. CCWD also operates the Denniston surface water and well field project for its northern service area. Hydrologic and hydrogeologic data are available for these areas that may be applicable to the Mid-Coast from El Granada north to Martini Creek. For these reason we have reviewed selected reports on these areas, as well as pertinent information from the Pilarcitos basin. We propose the southern boundary of the Mid-Coast aquifers study area to coincide with the southern limit of the Frenchmans watershed and the northern boundary of the Pilarcitos basin (Figure 1). In Table 4 we have worked up preliminary estimates of aquifer storage, to be further revised.

5. PERTINENT DATA SOURCES AND RELEVANT DATA GAPS

Important properties of aquifers include transmissivity and hydraulic conductivity (or more informally, 'permeability'), the capacity for storage (or 'storativity'), and factors limiting yield during seasonal and drought cycles. We have summarized in Table 4 much of the available information describing aquifer properties from the reviewed reports. The table is a preliminary trial for quantifying aquifer storage by sub-basin and source, and merits revision in later phases of the Mid-Coast investigation. In general, ground-water storage has been estimated based on grain-size distributions (taken from the well log), and in part water-balance analyses. In Table 4, storage was calculated from surface area and inferred depth of a deposit, summer water levels during normal years, and estimated storage coefficient. Unconsolidated materials were distinguished by high and low permeability. Granitic colluvium, alluvium, younger inner fan, and coarse-grained fan deposits were considered to be highly permeable; marine terraces, outer fans, and fine-grained basinal alluvium between the fans were classed as having lower permeabilities. Heavily-weathered, fractured bedrock aquifers were assessed in Table 4, but not deeply fractured bedrock. Storage in unconsolidated aquifers were estimated to total 15,000 acre-feet beneath 5.8 square miles, and in fractured-bedrock, about 9,000 acre-feet within 14 square miles. In general, each 10-foot change in ground-water elevation the unconsolidated material yields one acre-foot of water per acre, and in fractured-bedrock, yields 0.1 acre feet of water per acre. Ground-water levels in unconsolidated material generally fluctuate seasonally about 5 feet during normal years, 10 feet during dry years, and 20 feet during droughts.

Limited data were available to estimate permeability. Hydrogeologic properties for aquifers have mostly been estimated by evaluating drillers well logs. In addition to the geologic log and well construction specifications, well logs include short-duration (1-2 hour) drawdown information that are generally collected following completion of the well as part of the well development (clarification) process. Specific capacity (Cs) of a well is the yield (gpm) per foot of drawdown, as taken from the well log. Transmissivity (T) has been estimated based on Cs (DWR Bulletin No. 118-2, 1974), and hydraulic conductivity (K), from T divided by the thickness of the aquifer (b), also estimated from the well log. Few aquifer tests[6] have been conducted or are available. In fractured bedrock, permeability was estimated with a method

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[6] A more rigorous method for estimating aquifer permeability generally involves monitoring drawdown during an 'aquifer test', a long-duration (8, 12, 24 or 72 hour) pumping and recovery test. Generally conducted for production wells, an aquifer test should ideally also result in an estimate of storage coefficient as well as permeability, provided observations are made in a suitably-located observation well.

developed by Bedinger and others (1986), which was used in the Montara – Moss Beach Water Well Draft EIR (Hecht and others, 1989).

Permeability also varied widely across the basin. Primarily based on aquifer test data, we grouped bulk permeability in Table 4 for the three types of aquifers: a) unconsolidated material with high-ranging permeability (about $K=10^{-2}$ cm / s and T=10,000 gpd / ft); b) unconsolidated material with low-ranging permeability (about $K=10^{-3}$ cm / s and T=1000 gpd / ft); and c) bedrock (about $K=10^{-4}$ cm / s, T=100 gpd / ft). Permeability data for the Montara / Moss Beach and El Granada areas that were estimated from well log information (specific capacity) show undifferentiated lower levels of permeability.

6. CLOSURE

We have conducted a comprehensive literature review of surface- and ground-water related studies, published papers and available data that provide relevant information bearing on the issue of safe yield of the Mid-Coast aquifers. A summary of the reports and available data are included within this report in the attached tables. We recognize the Mid-Coast aquifers as a complex hydrogeologic system with intrinsic linkage between surface flows and ground water in a landscape of coastal plains and small, sandy valleys, principally composed of decomposed Montara Mountain granitics. We have identified three distinct but interconnected aquifer types:

- Alluvium and colluvial wedges of the mountain valleys, and contiguous course-grained alluvium and fan deposits on the coastal plain, forming highly-permeable aquifers that are the principal ground-water resource for the Mid-Coast;

- Lower-permeable aquifers of finer-grained outer alluvial fans and marine terraces subjacent to coarse-grained deposits on the coastal plain (or similar remnants found upslope), from which scattered domestic wells commonly draw ground water;

- Bedrock aquifers, primarily composed of Montara Mountain granitics, demonstrating large, enhanced recharge areas, and permeability dispersed across discrete fractures that may augment ground water supplying specific wells that penetrate or extend beyond overlying unconsolidated deposits.

We have proposed a study area (Figure 1) and have grouped like sub-basins based on (a) recognized or discernible ground-water divides, (b) the nature of the aquifer materials; (c) aquifer behavior and extent of flow across aquifer units, (d) units organized as best feasible by watershed so that both surface and ground water can be considered conjunctively, and (e) traditionally-recognized units where consistent with the above. While estimating storage by sub-basin group and ground-water source (Table 4), we identified data gaps from which to conduct further study. Data describing aquifer properties are limited in the study area. Basic hydrologic data – such as rainfall and streamflow – are also limited in the study area, and have been summarized in Tables 5 and 6.

We envision the next phase of the Mid-Coast ground-water study may include the following components:

- Monitoring system planning, installation and data collection:
    - Several dozen wells, distributed amongst Mid-Coast study area, for aquifer testing and ongoing monitoring;
    - Water quality sampling for general minerals at key wells;
    - Streamflow and rainfall monitoring network of strategically-placed stations across the study area to optimize use of data for inter-basin correlation.
- Initial analysis and synthesis:
    - Water balances that estimate safe yield for each sub-basin;
    - Assessment of storage for each sub-basin that specifically addresses ground-water availability during extended drought periods;
    - Assess feasibility of recharge and conjunctive use, at preliminary level;
    - Identify surface sources suited to recharge ground water;
    - Identify areas where the aquifers are recharged by rainfall and those where the aquifers are recharged mainly by streams;
    - Identify areas where water quality is impaired, and how it affects aquifer development;
    - Relate rainfall to (a) onset of observed recharge, (b) development of saturated soils in the watershed;
    - Describe aquifer properties, using driller's logs, permit tests, and aquifer response.

- Reporting and community review:
  - Public outreach to convey results via newspapers;
  - Program brochure and website;
  - Public meeting.

6.1 Limitations

This report was prepared in general accordance with the accepted standard of practice in surface-water and ground-water hydrology existing in Northern California for projects of similar scale at the time the investigations were performed. No other warranties, expressed or implied, are made.

As is customary, we note that readers should recognize that interpretation and evaluation of subsurface conditions and physical factors affecting the hydrologic context of any site is a difficult and inexact art. Judgments leading to conclusions and recommendations are generally and customarily made with an incomplete knowledge of the conditions present. More extensive or extended studies, including additional and more complete aquifer tests, can reduce the inherent uncertainties associated with such studies. We note, in particular, that many factors affect local and regional ground-water levels. If the client wishes to further reduce the uncertainty beyond the level associated with this study, Balance should be notified for additional consultation.

Standard environmental information – such as rainfall, topographic and geologic mapping – have been used in summarized analyses and approaches without verification or modification, in conformance with local custom. Much subsurface information are reported on driller's logs and are variable in data quality and accuracy; we have made no attempt to verify interpretations made by authors of the literature reviewed. New information or changes in regulatory guidances could influence recommendations, perhaps fundamentally. As updated information becomes available, the interpretations and recommendations contained in this report may warrant change. To aid in revisions, we ask that readers or reviewers advise us of new plans, conditions, or data of which they are aware.

Concepts, findings and interpretations contained in this report are intended for the exclusive use of San Mateo County, under the conditions presently prevailing except where noted otherwise. Their use beyond the boundaries of the site could lead to environmental or structural damage, and/or to noncompliance with water-quality policies, regulations or permits.

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Table 1. Hydrologic and hydrogeologic information in selected reports, Martini, Montara, Dean Creeks, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Hydrogeologic analysis and sustainable yield of the Montara - Moss Beach ground-water basin.	Hedlund, C.L.	2002, pending Master's thesis	1) Seasonal ground-water elevations for 34 wells, January, August, October, and November 2001	1) Citizens Utilities annual water production: 1997-2000	1) Marine terraces show large variability of depth to ground water.
			2) Water quality samples for 29 wells, analyzed for general minerals, voc's, and total coliforms, Summer 2001	2) Initial aquifer delineation by Kleinfelder & Associates (1989)	2) Ground-water elevations measured near fault traces show large fluctuation, often independent of precipitation pattern.
			3) Geographic coordinates and ground elevations (asl) for all study wells	3) Well logs for Montara and Moss Beach, San Mateo County Environmental Health Services Division	3) Elevated chloride concentrations observed throughout the basin, both east and west of Highway 1.
			4) Formatted spatial data for study area in GIS format	4) Monthly precipitation record at Half Moon Bay Airport	4) Highest levels for nitrate found in the alluvial fan of San Vicente Creek
				5) Water quality results for Montara and Moss Beach, San Mateo County Environmental Health Services Division	5) Several wells in area are known to be contaminated with petroleum products, both naturally occurring and introduced.
Montara district water system master plan update	Citizens Utilities Company of California	2000	1) Monthly production summary for CUCC wells for 1999 (Appendix A).	1) Water sources previously considered: 1996 water system master plan update (CUCC); 1999 Montara water supply study for Montara Sanitary District (DWR); 1999 Preliminary feasibility assessment of ground-water in Martini Cr, McNee Ranch and Upper Montara area (Balance Hydrologics).	1) Evaluation of water source alternatives: ground water; surface water, water transfers and wheeling; desalination; recycled water; water conservation; dewatering Devil's Slide.
			2) Water quality data from CUCC production wells 1993-2000 (Appendix C).	2) Existing water supplies and demands, and treated water storage. Existing wells and surface water treatment plant have total production of 402 gpm. Average day demand in 1999 for Montara District was 262 gpm.	2) Local ground water and surface water sources are the best supplement source alternatives. Suggested wells could supply an additional estimated 143 ac-ft/yr
			3) List of private wells in Montara and Moss Beach area (Appendix E).	3) Historical Water Use in the Montara District. The estimated per capita water use is 60 gpd.	3) Review of system improvements and capital improvement program.

Table 1. Hydrologic and hydrogeologic information in selected reports, Martini, Montara, Dean Creeks, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Montara Water Supply for Montara Sanitary District	Department of Water Resources	June 1999	1) Stream flow measurements and water quality (Title 22) samples taken on January 28, 1998, Martini Creek, San Vicente Creek, and Denniston Creek	1) Regional geology. Unconsolidated material average 75 ft in Montara, 60 ft in El Granada and Princeton, and 75 ft beneath the Hal Moon Bay airport. Montara Mountain granitic rock commonly fractured to 100 ft.	1) Estimated costs for additional ground-water supply projects on McNee Ranch (Martini Cr) and in Wagner Valley (Montara Cr).
				2) DWR well records. Depth and yield histogram summary for 45 wells in Montara area (16.5 gpm and 205 ft averages) and 38 wells in Denniston sub-basin (44 gpm and 88 ft average).	2) An additional 23 ac-ft/yr can be extracted from Denniston upon approval of a monitoring program. Additional data may support a development permit for additional extraction.
				3) Groundwater extraction. In Montara area, 150 ac-ft/yr by CUCC and 60 ac-ft/yr by private uses. In Denniston sub-basin, CCC limited to 436 ac-ft/yr.	3) Conjunctive use alternatives limited.
				4) Long-term monitoring of depth to ground-water in CUCC wells; limited conclusions.	4) Contractual agreements include new contract and water marketing (transfers).
				5) Summary of water rights for diversion and storage.	5) Other projects include water recycling, water conservation, desalination, dewater Devil's Slide.
				6) Surface water, water quality summary	
Preliminary feasibility assessment of ground water in the Martini Creek, McNee Ranch and Upper Montara	Woyshner, M.W., Hecht, B. (Balance Hydrologics)	March 1999	none	1) 76 wells inventoried: drillers logs, pump-test reports, and water quality analyses summarized.	1) Statistical summary of well performance and salinity by sub-area: Upper Montara Terrace, Lower Montara Terrace, Upper Montara Cr, Montara Heights, and SW of Alamo St.
				2) Rainfall, runoff and evapotranspiration data summarized.	2) Ranking of wells by decreasing performance and salinity.
				3) Summary of water rights applications.	3) Comprehensive hydrologic budgets developed to estimate ground-water recharge during normal, dry and drought years.
				4) Color IR aerial photographs interpreted for seeps, springs and structural lineations.	4) Gross transmissivity of marine terraces and fractured granite estimated at 2400 gpd/ft from steady-state ground-water shed recharge.
					5) Estimated ground-water storage.
					6) Summary of water resources and uses.

Table 1. Hydrologic and hydrogeologic information in selected reports, Martini, Montara, Dean Creeks, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
					7) Estimated ground-water level deline in the terrace and alluvium between 10 an 20 feet for dry and critically dry years.
					8) Criteria and maps presented to guide selection of new well locations.
Draft Montara - Moss Beach Water Well EIR	Kleinfelder, Balance Hydrologics, Reid and Assoc., Renshaw, D.	1989	none	1) Environmental setting: climate, physiography, geology, geomorphology, hydrology, water quality, soils, erosion, sedimentation, and biology, as well as communities, growth, traffic and circulation.	1) Comprehensive water budget conducted for 5 sub-units: Montara terrace, Montara heights, Montara Creek, Moss Beach/Upper Moss Beach, and Upper Seal Cove terrace.
				2) Construction and performance summary of 31 wells. Estimated ranges of hydrogeologic properties of water-bearing units: granitic bedrock, Purisima bedrock, marine terrace and valley alluvium.	2) Totaling all sub-units, estimated normal year storage 3332 ac-ft and ground-water outflow 428; dry year storage 2971 ac-ft and outflow 317 ac-ft; critically dry year storage 2380 ac-ft and outflow 252 ac-ft.
				3) Granitic bedrock: Sy=0.01, Cs= 0.0079-2.88 gpm/ft, T=100-450 gpd/ft, b=250 ft, K=10-4 cm/s.	3) Effects of proposed ground water pumpage on storage and outflow by hydrologic sub-unit, and potential mitigation measures.
				4) Purisima bedrock: Sy=0.01, Cs= 0.002-0.06 gpm/ft, T=100 gpd/ft, b=250 ft, K=10-5 cm/s.	
				5) Marine terrace Sy=0.08, Cs= 0.5-4.0 gpm/ft, T=1800 gpd/ft, b=60 ft, K=10-3 cm/s.	
				6) Valley alluvium: Sy=0.1, Cs= 0.5-4.0 gpm/ft, T=1800 gpd/ft, b=60 ft, K=10-3 cm/s.	
				7) Reported water quality for wells.	
Montara - Moss Beach water system, report of technical evaluation and	Henry Hyde Associates	1986	none	CUCC records	1) Evaluation of existing CUCC facilities.
					2) Appraisal value of existing facilities.
					3) Financial plan.
					4) Annexation considerations.

Table 1. Hydrologic and hydrogeologic information in selected reports, Martini, Montara, Dean Creeks, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Evaluation of ground-water development potential, Montara service area	Luhdorff & Scalmanini	1982	none	1) Review of existing geologic information. Summary of CUCC well tests: capacity, static water levels, pumping levels, total dynamic head, pumping efficiency, and specific capacity	1) Evaluation of pumping interference after 7 days of pumping at 100 gpm using Airport aquifer (10,000 gpd/ft) and Portola aquifer transmissivities (4000 gpd/ft).
					2) Most significant ground water supplies are from alluvium and terraces cut into bedrock
					3) Proposed well locations: in Martini Creek, at existing dam site; on the floor of Wagner Valley, north of existing wells; two on San Vicente Creek; and two on Denniston Creek, above the dam and within the foothill terrace
Water supply expansion alternatives analysis	EIP Associates	1981	none	1) Water production and consumption 1975-1980	1) Total safe yield from Pilarcitos and Denniston = 1380 ac-ft (450 mg)
				2) Current water supply capabilities: safe and normal yields	2) Total normal yield from Pilarcitos and Denniston = 2700 ac-ft (879 mg)
				3) Estimated CCWD water supply requirements	

Table 2. Hydrologic and hydrogeologic information in selected reports, San Vicente Creek, Denniston Creek, and Pillar Point Graben, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Streamflow report for Denniston and San Vicente Creeks.	Coastside County Water District Staff	pending	1) Periodic stage and streamflow measurements in Denniston Creek above Denniston Reservoir, below Denniston Reservoir, and at Princeton, 1996-2001 2) Denniston Reservoir diversions, 1996-2001 3) Periodic stage and streamflow measurements in San Vicente Creek, 1998-2001	none	none
Stream gaging and ground-water modeling, Half Moon Bay airport aquifer, correspondence, preliminary analyses and raw data only (no report issued).	Hydrofocus	May 1998 through December 2000	1) Continuous stream-gaging on San Vicente and Denniston Creeks, August 1998 through October 1999; monthly streamflow measurements at gage and several points downstream, including Hwy 1 and mouth; spot measurements on Martini Creek. 2) Ground-water elevation measurements every four hours in two monitoring wells, July 1999 through July 2000. Monthly measurements at 5 monitoring wells. 3) Video logs of four 6-inch diameter wells proposed for production and used for monitoring; two of the wells show iron precipitation but no clogging. 4) Results of October 7, 1998 Martini Creek water quality sample tested for Title 22.	1) Review of Coastal Commission records on Citizens Utility wells #3 and #4 in the airport aquifer.	1) Hydrologic analysis of 50 homes on 220 acres of agricultural land, Cowell-Torello property. Existing agricultural use is about 480 ac-ft/yr, and proposed project use is estimated at 400 ac-ft/yr, below the maximum allowed rate of 431 ac-ft/yr. 2) San Vicente Creek provides sufficient flow for the proposed project; ground-water pumping would be required during drought years. 3) Ground-water flow modeling using 1990 drought conditions estimates no significant impacts to the Pillar Point Marsh, relative to existing conditions. 4) Preliminary water budget calculations show little surplus water in the San Vicente and Denniston watersheds. 5) Little to no recharge was observed through creek bed following 1998 record wet year, contrary to LSCE/ESA observations during drought.
Montara Water Supply for Montara Sanitary District	Department of Water Resources	June 1999	See hydrologic and hydrogeologic information for Martini, Montara, Dean Creeks (Table1), which included information on Denniston sub-basin.		

Table 2. Hydrologic and hydrogeologic information in selected reports, San Vicente Creek, Denniston Creek, and Pillar Point Graben, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Condition Compliance for Permit A-3-SMC-86-155 CUCC	California Coastal Commission	March 5, 1993	1) Comments to LSCE/ESA basin study, including those by DWR (Exhibit E) that were requested by Coastal Commission.	1) Related large wells: 2 wells serving Farallon Vista (1988); 3 wells serving El Granada Mobile Home Trailer Park (1985); four agricultural wells east of Hwy 1 (1991).	1) Findings and declarations (section III) include comments to the LSCE/ESA basin study.
				2) Summary of LSCE/ESA basin study (section II).	2) Total production from all wells in basin is limited to 481 ac-ft/yr; no more than 45 ac-ft/yr of additional extraction.
Half Moon Bay/ Pillar Point Marsh ground-water basin study: phase I, phase II and supplemental data	Luhdorff & Scalmanini Consulting Engineers, and Earth Sciences Associates	June 1992; September 1991; June 1987	1) Water-level elevations in 26 wells and interpolated contours in Half Moon Bay Airport/ Pillar Point Marsh Basin, 1987 to 1992; water levels lower during drought and recover with near-normal rainfall.	1) Aquifer characteristics from well logs: a) geologic cross sections show 70-foot thick unconsolidated sands and silty sands overlying weakly-consolidated Purisima Formation; b) southerly gw flow, artesian at marsh; c) transmissivity (poor data).	1) Accounting of hydrogeologic conditions during 1987 to 1992 drought, during which water years 1987 and 1990 were the two driest years and 1989 and 1992 were just below normal.
			2) 8-hour to 24-hour duration, constant-rate aquifer tests to estimate basin transmissivity (5200 gpd/ft) and storativity (0.001); data not included.	2) Water-level elevation in DWR monitoring well (5S/6W-10J1), 1953 to 1991. Water-level elevations in CCWD monitoring wells, 1976 to 1986.	2) Ground-water elevations along the coast persisted above sea-level during the drought, despite pumping depressions around production wells.
			3) Surface flow measurements on Denniston Creek to estimate ground-water recharge through stream-bed (29 ac ft per day).	3) Specific conductance and chloride concentrations of ground water, 1953 to 1991	3) Rapid rises in water levels following periods of substantial rainfall suggest that the basin recharges relatively quickly, and that water-level elevations in the basin are largely related to recharge conditions.
			4) Vertical gradients below Pillar Point Marsh from nested piezometers, 1989 to 1992; consistently artesian throughout drought.	4) Annual ground-water extraction from Half Moon Bay airport aquifer by CCWD and CUCC, 1976 to 1991; increasing from 250 ac-ft in 1976 to 430 ac-ft in 1988 and then lowering to 340 ac-ft in 1991.	4) Developed ground-water budget for years 1987 to 1990; estimated 'safe yield' averaged 480 to 520 ac-ft/yr, exceeding 1987-90 pumping estimate from all sources of 436 ac-ft/yr by 45 to 87 ac-ft/yr.
				5) Surface-water diversions from Denniston Creek, 1975 to 1985.	5) Biological monitoring and assessment concluded no significant premature or unseasonal plant stress in the wetland communities (Questa Engineering Corp.).
				6) Annual precipitation at Half Moon Bay, 1950 to 1991.	6) Specific conductance and chloride ion concentrations has remained stable since the 1950's.
					7) Monitoring and adaptive-management recommended.

Table 2. Hydrologic and hydrogeologic information in selected reports, San Vicente Creek, Denniston Creek, and Pillar Point Graben, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Draft Montara - Moss Beach Water Well EIR	Kleinfelder, Balance Hydrologics, Reid and Assoc., Renshaw, D.	1989	See hydrologic and hydrogeologic information for Martini, Montara, Dean Creeks (Table1), which included information on Denniston sub-basin.		
Water supply and ground-water conditions, Farallon Vista Project	Luhdorff & Scalmanini Consulting Engineers	October 1987	none	1) Refers to LSCE/ESA phase I report (June 1987).	1) Development adds 40 ac-ft/yr demand to ground-water resource, about 10% of basin-wide demand, falling within staged increase concept. Two wells permitted in 1988. 2) Distance-drawdown relationship if well pumped at 25 gpm.
Environmental Monitoring of the Pillar Point Marsh, part I baseline data; part II progress report	Flint, P.S.	March 1978; February 1977	1) Marsh water level in 30 shallow bore holes (24 to 60 inches deep). 2) Monitoring health status of marsh vegetation.	1) Review of hydrologic and pumping records. Seven Denniston wells commenced operation in 1976 and the Torres well in 1977. 2) Monitoring well records from recently established monitoring wells (M1 to M7).	1) Condition of marsh following 1976 to 1977 drought was good; only surrounding terrestrial zones showed pronounced impact from drought. 2) No observed impact to marsh from ground-water pumping.
Ground-water investigation, Denniston Creek vicinity	Lowney-Kaldveer Associates	April 1974	1) Subsurface investigation. Eleven bore holes, ranging in depths from 35 to 140 feet, were drilled, sampled and logged; monitoring wells installed. Geologic cross sections interpolated. 2) Aquifer test conducted on CCWD well #3 at 15,000 gpd/ft. 3) Ground-water contour map showing a 0.01 southward gradient.	1) Review of available hydrologic and water quality records.	1) Specific yields estimated from grain-size class analysis and bore-hole logs: Denniston Creek subarea 0.13 and San Vicente/ Airport subarea 0.11. 2) Total basin storage capacity estimated from specific yields: Denniston Creek subarea 1800 af; San Vicente Creek subarea 995 af; Airport subarea 4630 af. Capacity to sea-water elevation is 2/3 of total. 3) Average annual hydrologic balance of inflows and outflows of surface and ground water. Critiqued by LSCE/ESA in phase I. 4) Concluded an additional 400 ac-ft/yr of pumping with limited impacts to storage and flow gradient; pumping upwards of 800 ac-ft/yr are likely feasible with adaptive-management monitoring.

Table 3. Hydrologic and hydrogeologic information in selected reports, El Granada, Frenchmans Creek and Pilarcitos Creek, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Streamflow and basic water-quality at selected sites within the Pilarcitos Creek watershed, WY1998-WY2000; Sediment-transport reconnaissance of the Pilarcitos Creek watershed.	Owens, J., Porras, G., and Hecht, B. (Balance Hydrologics)	2001	1) Daily streamflow, specific conductance and sediment transport data for Apanolio Creek and other Pilarcitos tributaries during water year 2000.	1) Summary of water year 1998 and 1999 data.	1) Runoff per unit area from granitic watersheds is much less than from watersheds underlain by Purisima and other sedimentary formations.
				2) Notes that the USGS gage was severely impacted by sediment and rating-curve shifts, so in recent years it may not be usable for water balance calculations.	2) Recharge and water quality are much higher on granitic watersheds.
					3) Sediment transport rates in Pilarcitos Cr and its northern tribs are elevated relative to other studies in the region.
Draft evaluation of existing water distribution system, Coastside County Water District.	Water Resources Associates	June 2001	none	1) Summarizes the development of a 'WaterCAD' model (Haestad Methods, Inc) that simulates the infrastructure of the Coastside County Water District. It evaluates the ability of the system to provide for existing customers, as well as additional single-family residential customers.	1) Evaluation of existing system: a) 2% do not meet pressure criterion on max day (3,130 gpm on May 19, 1997); b) less than 1% of the pipes have velocities greater than 5 fps (10-inch mains); c) 24% do not meet pressure criterion and 10% of the pipes have velocities greater than 5 fps (8 and 12 inch mains) at peak hour (? gpm at 9 am on June 14, 2000); d) 59 fire hydrants do not meet the max day fire flow criteria of 1,000 gpm at 20 psi; e) 40 fire hydrants do not meet the average day fire flow criteria of 1,000 gpm at 20 psi; f) existing storage is 8,050,000 gallons (24.7 acre-feet) exceeds the 6,600,000 gallons per day requirement.
					2) Evaluation of additional single-family residential customers: a) normal yield may provide for and increase of 399 single-family residential customers (totaling 4,351), and not adding additional limits to peak production capacity; b) If the district planned for normal yield, 33 percent reduction would be required to reduce demand to safe yield during a drought; c) peak-hour pressure criterion failures will increase marginally.

Table 3. Hydrologic and hydrogeologic information in selected reports, El Granada, Frenchmans Creek and Pilarcitos Creek, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Coastside County Water District Supply Evaluation, Calendar Year 2000 Report	Coastside County Water District Staff	February 2001	none	1) Monthly production of water supply sources	1) Water year 2000 system usage was 779 mg (2390 ac-ft) for 239 connections
				2) Annual water sales by user categories	2) Projected production requirements for 2001 was 811 mg (2490 ac-ft).
				3) Estimated production capability	3) Capability of untreated transmission pipelines and treatment plants is 5.32 mgd (3694 gpm)
				4) Estimated unmetered water usage during 2000	4) Capacity of Pilarcitos Lake is 1,889 gpm
				5) Potential new water service connections during 2001	
				6) Comparison of water production and sales	
				7) Number of active connections	
				8) Annual comparison of average daily residential water usage	
				9) Peak daily demand periods	
				10)Transmission capability during peak demand periods 2000	
Investigation and response to water right complaint, Ocean Colony Partners' Balboa Well Field	Luhdorff & Scalmanini Consulting Engineers	February 9, 2000	1) 8-hour constant-rate aquifer test conducted at 66 gpm from well nearest Pilarcitos Creek. Aquifer parameters calculated at 3 observation wells; transmisivity (T) = 9,400 gpd/ft; hydraulic conductivity (K) = 1.5e-2 cm/s; storativity (S) = 0.001; depth to Purisima bedrock about 60 ft; alluvial thickness (b) about 30 ft.	1) Well logs of production wells used to develop geologic cross-sections, suggesting confined conditions to the aquifer.	1) Hydrogeologic evidence at the Balboa well field indicate a shallow, confined aquifer that is effectively independent of Pilarcitos Creek and its underflow.
			2) Long-term monitoring of well-field pumping and stream stage during baseflow 1999, showing independence.	2) Surface- and ground-water quality data reviewed, 1987-1996.	2) Notable differences between surface and ground water quality, and no evidence of long-term degradation of ground-water quality by seawater intrusion.
			3) Specific conductance monitored during aquifer test, surface and ground water similar; end-of-test sample analyzed for general minerals.		

Table 3. Hydrologic and hydrogeologic information in selected reports, El Granada, Frenchmans Creek and Pilarcitos Creek, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Phase II of Lower Pilarcitos Creek ground-water investigation, Half Moon By, CA	Nelson, E.A.	1998	1) Drilling permits, logs, Title 22 chemical analyses, pumping rate and drawdown of 5 production wells. Data note: We estimate mean values for aquifer parameters using drawdown and pumping rate totals for 12-hour tests: transmisivity (T) = 12,000 gpd/ft; hydraulic conductivity (K) = 2e-2 cm/s; depth to Purisima bedrock about 84 ft; alluvial thickness (b) about 27 ft.		1) Well production ranged from 120 to 200+ gpm, totaling 840 gpm. Rule-of-thumb long-term production is 420 to 630 gpm.
					2) Cone of depression of each well was estimated at 1000 ft, causing significant drawdown in surrounding wells.
					3) Hydrogeologic analyses not conducted on 12-hour aquifer test data.
					4) Ground-water quality is suitable for public use after treatment for hardness, iron and manganese (typical).
Pilarcitos Creek alternative point of CCWD diversion study	Feeney, M. (Balance Hydrologics), Forgensen, P. (Schaaf & Wheeler), and Leidy, R. (EIP Assoc.)	1996 draft	none	1) Aquifer testing of CCWD Pilarcitos Well Field d/s of Stone Dam. Values of specific capacity (Cs=14.6), transmissivity (T=125,000 gpd/ft) and hydraulic conductivity (K=1.6e-1 cm/s) summarized for 7 shallow production well penetrating coarse alluvium and fan. Depth to granite bedrock about 42 ft; alluvial thickness (b) about 36 ft.	1) Ground-water flow modeling corroborate District's observations that the well field is adequate for recapture of diversions released to the creek.
				2) Summary of upper Pilarcitos basin hydrology, CCWD supply operations, and fisheries condition.	2) Increased instream flows of 5000 ft reach above the well field is expected to enhance steelhead production.
Annual report 1988-1989 ground-water resources, Half Moon Bay, CA	Geoconsultants	July 1989	1) Monthly water-level elevation monitored in 25 wells.	1) 328 wells inventoried: drillers logs, pump-test reports, and water quality analyses summarized.	1) Winter and summer ground-water contour maps.
			2) Specific conductance monitored in 25 wells in January and June.		2) Winter water levels during 1989 fell about 5 feet as compared to 1988, summer to summer water levels recovered 2 feet.
			3) Aquifer tests conducted in the Miramar area (Arroyo de en Medio and Frenchmans Creek): 24 hrs @ 23 gpm, T=4,450 gpd/ft, S=0.0004 (responsive to rain); Balboa Well Field (Pilarcitos Creek west) 24 hrs @ 150 gpm, T=29,750 gpd/ft, S=0.0018; and Highlands area (Pilarcitos Creek east), 70 hrs @ 23 gpm, T=3,500 gpd/ft, S=0.00063		3) Estimates of aquifer storage: Arroyo de en Medio, A=132 ac, b=19 ft, Sy=0.13, S=326 ac-ft; Frenchman's Creek, 320 ac, b=22 ft, Sy=0.16, S=1126 ac-ft; other basins include Pilarcitos Cr and Canada Verde, totaling 11,500 ac-ft.
					4) Ground-water quality fair with no discernible degradation observed. Majority of high Cl concentrations from wells penetrating Purisima.

Table 3. Hydrologic and hydrogeologic information in selected reports, El Granada, Frenchmans Creek and Pilarcitos Creek, San Mateo County, California.

Title of report	Author(s)	Year of publication	Data generated by author(s)	Historic data summarized	Hydrogeologic analyses and principal conclusions
Potential hydrologic impact of Marchant Resort Hotel, Half Moon Bay, CA	Oliver, J.M., and Hecht, B. (Balance Hydrologics)	May 1989	none	1) Drillers logs, electric logs, Title 22 chemical analyses, and 24-hr aquifer test results from 2 wells.	1) Based on 24-hour pump tests at 5 gpm, specific capacity (Cs) of the shallow wells are 0.1 and 0.5 gpm/ft. (est. T=500 gpd/ft)
				2) Water demand estimates, and storage and treatment designs based on 70% occupancy.	2) Ground-water quality is suitable for public use after treatment for hardness, iron and manganese (typical).
				3) Report of fresh water in borings for breakwater.	3) Impact to Denniston Creek (2500 ft away) and aquifer unlikely.
El Granada ground-water investigation report.	Laduzinsky, D., Hecht, B., Woyshner, M.W. (Kleinfelder, Inc.)	April 1988	none	1) Wells inventoried and summarized in appendices: drillers logs, pump-test reports, and water quality analyses.	1) Yield per foot of drawdown (Cs) is 20 times greater in the terrace than in bedrock, exchange is limited.
				2) Transmisivity (T) of the terrace aquifer was estimated at 1700 gpd/ft from specific capacity of 44 wells (Cs=0.93 gpm/ft). Hydraulic conductivity (K) averages 1.6e-3 cm/s.	2) Relative to amount extracted, total ground-water storage in terrace aquifer is large but declining water levels and quality are an issue where wells are clustered, particularly during droughts.
				3) Terrace aquifer saturated thickness averages about 50 ft, and has an area of about 365 acres; resulting storage is 1460 ac ft using an estimated specific yield of 0.08.	3) Data indicate fair water quality, Fe and Mn treatment required, some elevated nitrate and Cl levels, and no seawater intrusion. Elevated Cl along fault traces. Specific conductance averaged 590 umhos/cm in terrace and 830 in bedrock, all ranging of 300 to 1400.
				4) Specific capacity of 59 wells in bedrock generally ranged 0.003 to 0.13 gpm/ft, with few wells in favorable fracture densities that ranged 0.5 to 1.2 gpm/ft. Specific yield was estimated at 0.003 to 0.01, and storage 250 to 600 ac-ft.	4) Based on ground-water flow estimates and observed post-drought water-level rise in monitoring wells, potential seawater intrusion is minimal in the El Granada area at recharge and pumping patterns present at the time of the report.
				5 During dry years (1981) estimated terrace storage is 1260 ac-ft; in 1977 (extreme drought conditions) storage was estimated at 610 to 1020 ac-ft.	5) Geologic map and cross sections presented; ground-water level, chloride, nitrate and specific conductance contour maps developed.
				6) Seasonal water-level fluctuation averaged 4-10 ft; drought year decline was 14-29 ft, but readily recovers with normal rainfall.	6) Recharge potential is high.
				7) Review of historical records and a comprehensive hydrologic budget developed for the terrace aquifer.	7) Passive, active and intensive basin management programs proposed.

Table 4. Hydrogeologic characteristics by sub-basin group and ground-water source, San Mateo County mid-coast.

Basin atribute	Martini Cr, Montara Cr, Dean Cr	San Vicente Cr, Dennistion Cr, Pillar Point Graben	El Granada,	Frenchman's Cr Arroyo de en Medio	Total
Sub-basin area, mi^2	4.18	7.38	2.39	6.28	20.2
Unconsolidated material with high ranging permeability (colluvium, alluvium, younger inner fan, and coarse-grained fan deposits)					
Surface area, mi^2	0.86	1.32	0.31	0.86	3.35
Surface area, acres	550	845	201	553	2150
Average depth of sediment, ft	50 to 70 [b]; 52 [g]; 75 [i]	70 [c]; 75 [i]	65 [e]	84 [k]; 60 [l]	--
Average volume of sediment, ac-ft	30,000	59,000	22,000	40,000	151,000
Average depth to water, ft	20 [g]	40 [c]			--
Average thickness of aquifer above sea level (b), ft	32 [g]	30 [c]	30 [e]	22 [f]; 27 [k]; 30 [l]	--
Estimated storage coefficient (S)	0.1 (valley alluvium) [b]	0.1 (valley alluvium) [b]; 0.00021 to 0.0075 [c]	0.08 [e]	0.1 (valley alluvium) [b]; 0.0004 [f1]; 0.0018 [f2]; 0.001 [l]	--
Estimated storage in aquifer, ac-ft	1700	2500 (@Sy=0.1)	480	1660 (@Sy=0.1)	6660
Estimated specific capacity (Cs) gpm/ft	0.1-2.9 [a]; 0.5-4.0 [b]		0.93 [e]		--
Estimated transmissivity (T) gpd/ft	1200 [a]; 1800 [b]	5200 [c]; 15,000 [d]	1700 [e]	4450 [f1]; 9400 [l]; 12,000 [k]; 29,750 [f2]	--
Estimated hydraulic conductivity (K) cm/s	$6x10^{-4}$ [a]; 10^{-3} [b]	$4x10^{-3}$ [c]; $2x10^{-2}$ [d]	$1.6x10^{-3}$ [e]	$2x10^{-2}$ [k]; $1.5x10^{-2}$ [l]	--
Unconsolidated material with low ranging permeability (marine terraces, younger outer fan, and fine-grained alluvium)					
Surface area, mi^2	0.67	0.94	0.47	0.38	2.46
Surface area, acres	429	602	301	245	1576
Average depth of sediment, ft	50-70 [b]; 146 [g]	65 [e]	65 [e]	84 [k]; 60 [l]	--
Average volume of sediment, ac-ft	62,000 [g]	39,000	27,000	13,000	79000
Average depth to water, ft	35 [g]				--
Average thickness of aquifer above sea level (b), ft	30 [e]	30 [e]	30 [e]	22 [f]; 27 [k]; 30 [l]	--
Estimated storage coefficient (S)	0.08 [b]	0.08 [e]	0.08 [e]	0.08 [e]	--
Estimated storage in aquifer, ac-ft	1000	1400	720	515	8700
Estimated specific capacity (Cs) gpm/ft	0.02-0.83 [a]; 0.5-4.0 [b]		0.93 [e]	0.1, 0.5 [m]	--
Estimated transmissivity (T) gpd/ft	420 [a]; 1800 [b]	200	1700 [e]	1700 [e]	--
Estimated hydraulic conductivity (K) cm/s	$2x10^{-4}$ [a]; 10^{-3} [b]	$2x10^{-4}$ [a]	$1.6x10^{-3}$ [e]	$1.6x10^{-3}$ [e]	--

Table 4. Hydrogeologic characteristics by sub-basin group and ground-water source, San Mateo County mid-coast.

Basin atribute	Martini Cr, Montara Cr, Dean Cr	San Vicente Cr, Dennistion Cr, Pillar Point Graben	El Granada,	Frenchman's Cr Arroyo de en Medio	Total
Surface bedrock					
Type	Granitic	Granitic	Granitic	Granitic (minor Tm&Tlo)	Granitic
Surface area, mi^2	2.65	5.12	1.61	5.04	14.42
Surface area, acres	1696	3277	1030	3226	9229
Average depth of weathered fractures [h], ft	200-300 [b]	200-300 [b]	200-300 [b]	200-300 [b]	--
Average depth to water, ft	70 [g]	70 [g]	70 [g]	70 [g]	--
Average thickness of aquifer above sea level (b), ft	100 [i]	100 [i]	100 [i]	100 [i]	--
Estimated storage coefficient (S)	0.01 [b]	0.01 [b]	0.001-0.01 [e]	0.001-0.01 [e]	--
Estimated storage in aquifer, ac-ft	1700	3300	1000	3200	9200
Estimated specific capacity (Cs) gpm/ft	0.008-2.9 [b]	0.008-2.9 [b]	0.003-0.01 [e]	0.003-0.01 [e]	--
Estimated transmissivity (T) gpd/ft	100-450 [b]	100-450 [b]	100-450 [b]	100-450 [b]	--
Estimated hydraulic conductivity (K) cm/s	10^{-4} [b]	10^{-4} [b]	10^{-4} [b]	10^{-4} [b]	--

Notes:

a) Summary of 76 well logs by sub-unit, includes both unconsolicated material and fractured bedrock [Woyshner, M.R., Hecht, B., 1999 (Balance Hydrologics)].
b) Estimates based on 31 wells logs and other regional information (Kleinfelder, Balance Hydrologics, Reid & Assoc., Renshaw, D., 1989)
c) Several 8 to 24-hour aquifer tests reported (Luhdorff and Scalmanini Consulting Engineers, and Earth Sciences Associates, 1992, 1991, 1987).
d) Aquifer test conducted on CCWD well #3, poorly reported (Lowney-Kaldveer Assoc., 1974).
e) Based on a review of 49 logs of wells in terrace and 59 logs of wells in bedrock [Laduzinsky, D., Hecht, B., Woyshner, M.W., 1988 (Kleinfelder)].
f) Aquifer tests: (1) 23 hrs @ 23 gpm (responsive to rain) in the Miramar area (Geoconsultants 1989); (2) 24 hrs @ 150 gpm at the Balboa Well field.
g) Summary of 34 wells logs (Hedlund, C., Master's Thesis, 2002 Pending).
h) Based on depths indicated in well logs.
i) Review of well records by Kleinfelder (1988) and DWR (1999) show highly weathered joints and fractures up to 100 ft depth.
j) Estimated by Lowney-Kaldveer Associates (1974); capacity to sea level is 2/3 of total.
k) Estemated from 12-hr aquifer tests conducted in lower Pilarcitos Cr area (Nelson, 1998).
l) Constant-rate well test, 8-hours @ 66 gpm (Luhdoff & Scalmanini Consulting Engineers 2000).

Table 5. Streamflow records for San Mateo County Mid-Coast and coastal basins to the south.

Station Name	Station ID	Latitude	Longitude	Drainage Area (mi ^{2})	Record Start	Record End	Record Period (years)	Observer [c]	Remarks
Martini Cr. and Montara Cr. Sub-Basin									
Martini Cr	--	--	--	--	--	--	--	DWR, Balance, Hydrofocus	Instantaneous measurements and water quality samples
Montara Cr	--	--	--	--	--	--	--	DWR, Balance, Hydrofocus	Instantaneous measurements and water quality samples
San Vicente Cr. and Denniston Cr. Sub-Basin									
San Vicente Cr	--	N37:31:21	W122:30:30		Jun 1998	2000	2	CCWD	Daily staff plate measurements at storm drain pipe
San Vicente Cr	--	--	--	--	8/1/98	10/31/99	1	Hydrofocus	Daily mean flow
San Vicente Cr	--	--	--	--	--	--	--	DWR, Balance, Hydrofocus	Instantaneous measurements and water quality samples
Denniston Cr	--	--	--	--	8/1/98	10/31/99	1	Hydrofocus	Daily mean flow
Denniston Cr	--	--	--	--	--	--	--	DWR, Balance, Hydrofocus	Instantaneous measurements and water quality samples
Denniston Cr above Reservoir	--	N37:31:21	W122:29:17	2.9	Feb 1996	2000	4	CCWD	Daily staff plate measurements at Parshall flume (low flows), weir (intermediate flows), and storm drain (high flows)
Denniston Cr below Reservoir	--	N37:31:11	W122:29:20	3.0	Feb 1996	2000	4	CCWD	Daily staff plate measurements at 2 rectangular weirs
Denniston Reservoir diversions	--	N37:31:11	W122:29:20	--	Feb 1996	2000	4	CCWD	Flows metered at 2 pipes
Denniston Cr at Princeton	--	N37:31:12	W122:29:12	3.3	Feb 1996	2000	4	CCWD	Daily staff plate measurements at storm drain pipe
El Granada, Arroyo de en Medio, and Frenchmans Cr									
No records									
Pilarcitos Creek									
Pilarcitos Cr below Stone Dam near Hillsborough	11162620	N37:31:29	W122:23:54	6.5	10/1/97	9/30/00 [a]	3	USGS	Daily mean flow; peak flow 1998-2000; real-time site.
Pilarcitos Creek at Sare residence	--	N37:29:27	W122:23:13	3.9 [b]	12/17/97	10/1/00	3	Balance	Daily mean flow.
Apanolio Creek near Gossett residence	--	N37:30:08	W122:24:58	1.2	12/10/97	10/1/00	3	Balance	Daily mean flow.
Apanolio Creek above HWY 92	--	N37:28:44	W122:24:49	2.1	7/1/99	11/23/99	< 1	Balance	Low-flow monitoring station
Mills Creek at Higgins Road bridge	--	N37:26:46	W122:24:04	3.8	12/4/97	10/1/00	3	Balance	Daily mean flow
Arroyo Leon above Mills Cr.	--	N37:26:46	W122:24:04		12/4/97	10/1/00	3	Balance	Synthetic record correlated to Mills Cr based on instantaneous measurements.
Arroyo Leon at Miramontes Street	--	N37:27:43	W122:25:31	7.4	6/22/98	11/25/98	< 1	Balance	Low-flow monitoring station
Pilarcitos Cc at Half Moon Bay	11162630	N37:28:00	W122:25:59	27.1	7/1/66	9/30/00 [a]	32	USGS	Daily mean flow; water quality; peak flow 1967-2000; real-time
South of Pilarcitos Creek									
Purisima Cr near Half Moon Bay	11162600	N37:26:06	W122:22:23	4.8	10/1/58	10/3/69	12	USGS	Daily mean flow.
San Gregorio Cr at San Gregorio	11162570	N37:19:33	W122:23:08	50.9	10/1/69	9/30/94	25	USGS	Daily mean flow; peak flow 1970-1997; water quality 1967-
Pescadero Cr near Pescadero	11162500	N37:15:39	W122:19:40	45.9	4/14/51	9/30/00 [a]	47	USGS	Daily mean flow; real time site.
Butano Cr near Pescadero	11162540	N37:14:01	W122:21:56	18.3	7/1/62	10/7/74	14	USGS	Daily mean flow.

Notes:

a) Recent data found on the USGS web site, water.usgs.gov

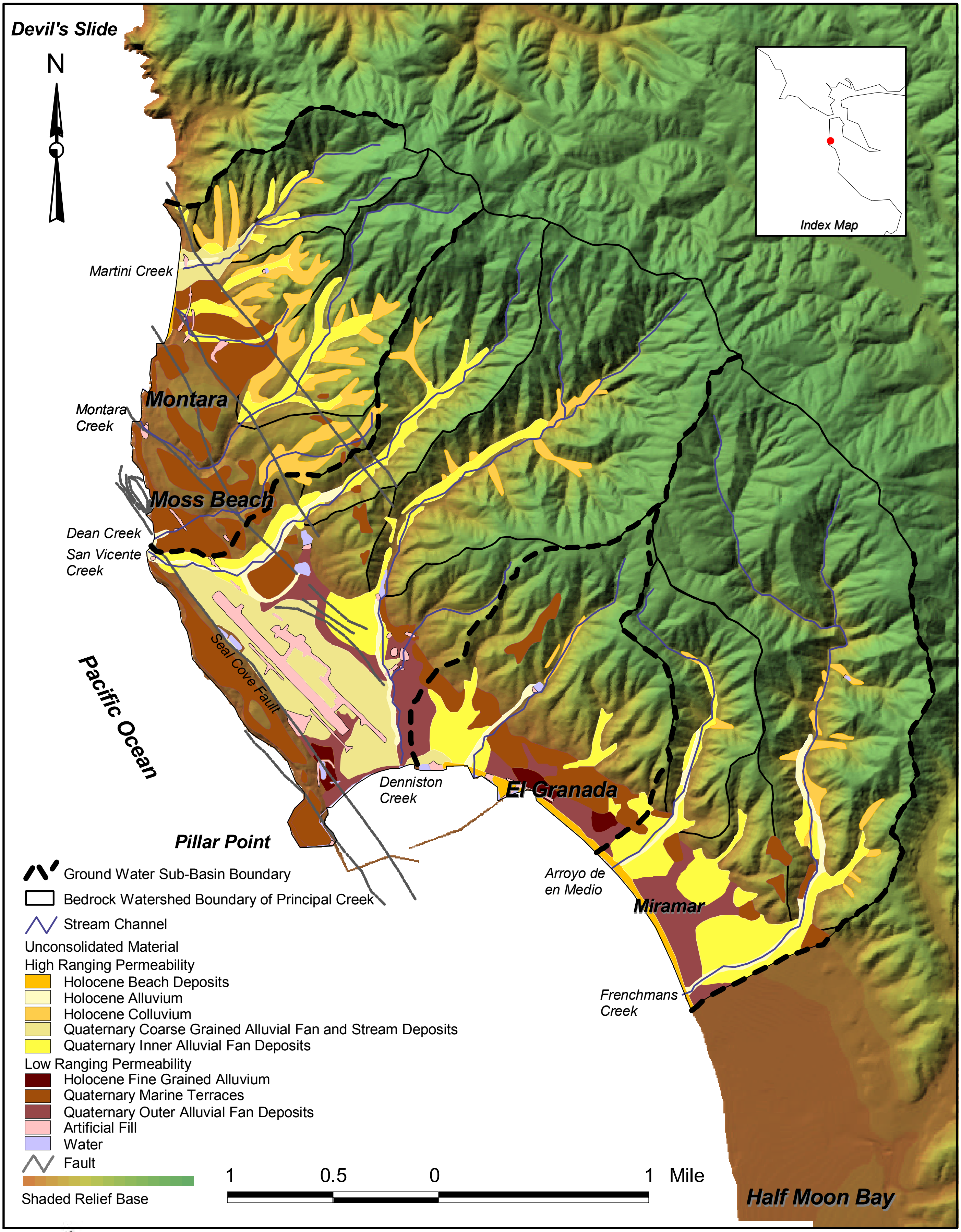
b) Unregulated drainage area upstream of gage is 3.9 square miles, total drainage area including dams and lake is 10.2 square miles.

c) USGS = United States Geological Service; CCWD = Coastside County Water District; Balance = Balance Hydrologics, Inc.; Hydrofocus = Hydrofocus, Inc.; DWR = California Department of Water Resources.

Table 6. Rainfall records for San Mateo County Mid-Coast and regional coastal basins.

Station Name	Station ID	Latitude	Longitude	Elevation (ft)	Record Start	Record End	Record Period (years)	Observer	Remarks
Regional basins north of Martini Creek									
Pacifica 4 SSE	046599	N37:35:30	W122:28:18	475	11/1/83	Present	18	NCDC [b]	
Martini Cr. and Montara Cr. Sub-Basin									
No records									
San Vicente Cr. and Denniston Cr. Sub-Basin									
Pillar Point	093222	N37:30:00	W122:30:00	130	2/1/73	Present	28	NCDC [b]	Marine Reporting Station (MARS)
Half Moon Bay Airport					1994	Present	7	Half Moon Bay Airport	
El Granada, Arroyo de en Medio, and Frenchmans Cr.									
No records									
Pilarcitos Creek									
Pilarcitos Dam	PLD	N37:32:53	W122:25:19	700	4/19/99	11/7/00	2	City of San Francisco	data accessible on CDEC [a]
Half Moon Bay	043714	N37:27:57	W122:26:44	16	7/1/48	4/25/84	36	NCDC [b]	
Regional basins south of Pilarcitos Creek									
La Honda	044660	N37:19:00	W122:16:00	751	1/7/50	9/30/77	28	NCDC [b]	San Gregorio watershed
San Gregorio 2 SE	047807	N37:18:13	W122:21:42	275	6/1/54	12/31/98	45	NCDC [b]	

Notes:
a) California Deptartment of Water Resources, California Data Exchange Center, http://cdec.water.ca.gov/
b) National Climatic Data Center, http://lwf.ncdc.noaa.gov/



Balance Hydrologics, Inc.

Figure 1. Mid-Coast Aquifers, San Mateo County
Study area sub-basin boundaries showing principal ground-water divides of unconsolidated materials and contributing watersheds.
Sources: (1) Geologic Map of San Mateo County, CA, Brabb & Pampeyan, 1983.
(2) Digital Elevation Model, USGS, for shaded relief base.

APPENDIX A1

MONTARA WATER SUPPLY STUDY FOR MONTARA SANITARY DISTRICT, SAN MATEO COUNTY, CALIFORNIA

(CALIFORNIA DEPARTMENT OF WATER RESOURCES, JUNE 1999)

This study was a cooperative effort between DWR and the Montara Sanitation District (MSD), and equally funded, in an effort to examine technically feasible options for improving water supply reliability within Montara and Moss Beach.

The report "Water System Master Plan Update for the Montara District" by CUCC in 1996 estimated the current shortage by comparing maximum day demand against the system's reliable capacity of 310 gallons per minute (gpm) per connection. The maximum daily demand was 471 gpm per connection, therefore the current system shortage was estimated at 161 gpm. Desalination was eliminated as an option to increase current supplies to the system mainly due to costs. The final suggestion was that Citizens Utilities plan on rehabilitating two existing wells in the Montara area and one at the Half Moon Bay airport. This 1996 study estimates the current system water use to be 511 acre-feet per year, based on a population of 5,705 and a per capita use of 80 gpm. Ground-water development and negotiation of a water transfer are the most favorable options to sustaining the system.

Hydrogeology

- DWR recognized four main water bearing units within the Montara-Moss Beach area.
    - Montara granodiorite (Cretaceous)
    - Purisima formation (Pliocene)
    - Marine terrace deposits (Pleistocene)
    - Coarse-grained alluvium and colluvium
- Average depth for wells in Montara area basin is 209 feet; in the Denniston sub-basin it is 88 feet

- Average yield for wells in the Montara area is 16.5 gpm; in the Denniston sub-basin it is 44 gpm

- Average annual ground-water extraction from the Montara area by CUCC from 1988 to 1995 was 150 acre-feet per year.

- Extraction records for private domestic wells are needed (CUCC had offered to volunteer their employees to do this…)

- Earth Science Associates and Luhdorff & Scalmanini estimated the Denniston sub-basin usable ground-water storage at 1,300 acre-feet. Also estimated the safe-yield between 481 and 523 acre-feet per year.

- Ground-water extraction from the Dennsiton sub-basin between 1987 and 1996 averaged 361.87 acre-feet per year. This decade constitutes a reasonable spectrum of wet and dry years.

Surface Water

- There are four main surface water features within the basin: Martini Creek, Montara Creek, San Vicente Creek, and Denniston Creek.

- The State has filed two applications to divert up to 1.05 cfs from Martini Creek for irrigation of McNee Ranch State Park.

- Diversion from Montara Creek is limited to 0.446 cfs. This is stored in 100,000 and 432,000 gallon storage tanks on Alta Vista.

- CCWD has a permit to divert up to 2 cfs from San Vicente Creek since 1984.

Ground-water Alternatives

- Conjunctive use is recommended

- Increase extraction – CUCC can extract up to 205 acre-feet per year from Denniston SB

- There is a 459 acre-feet per year limitation from the DSB
- Current total extraction is 436 acre-feet per year
- Proposed well sites are for McNee Ranch are near Martini Creek and the Wagner Valley area in the Montara Creek basin. Could offer a conservation addition of 80 acre-feet per year from McNee Ranch.
- An estimated 400 acre-feet of ground water is in storage.
- Estimated costs for ground-water supply from McNee Ranch total $220,378 with an additional annual fee of $33,818.
- Estimated costs for ground-water supply from Wagner well total $115,631 with an additional annual fee of $18,585.

Contractual Agreements/Other Agreements

- New contract will be needed to import purchased water. (Raker Act limits sale of waters likely to be available to MSD to public agencies, not private water companies)
- Water marketing
- State water project transfer
- Central valley project transfer
- Tuolumne basin transfer
- Water recycling
- Water conservation
- Desalination
- Dewater Devils Slide; use water for domestic supply

APPENDIX A2

PRELIMINARY FEASIBILITY OF GROUND-WATER IN THE MARTINI CREEK, MCNEE RANCH AND UPPER MONTARA CREEK AREA

INTERIM STATUS REPORT

(MARK WOYSHNER, AND BARRY HECHT, MARCH 1999)

This 1999 report is a preliminary feasibility assessment by Balance Hydrologics, Inc., to increase water supplies available to the Montara area by exploring ground-water options in the McNee Ranch, Martini Creek, adjacent unnamed basins, and the Montara Creek aquifer areas. It also serves to guide where drilling for ground water in the areas might best occur, as well as determine its compatibility with other water uses that already exist in the basin.

Information Gathered

- Well logs for the Montara Area, Appendix B
- Meterological data, Appendix D
- Relevant reports, Appendix E

Water Balance

- Steady state analysis shows means of 630 acre-feet per year and 758 acre-feet per year runoff.
- 700 acre-feet per year should be available, on average, for water supply
- Domestic use for the year 2030 is predicted to be 645 acre-feet

Well Locations

- In order to supply 645 acre-feet per year for 2030 demand, a pumping rate of 400 gallons per minute would need to be sustained around the clock.
- This rate could be met with 10 wells that pump 40 gpm.
- The highest producing wells appear to be located in alluvial gravels and along fractures, or where conductive materials overlap.
- New wells should also be implemented near areas of natural springs and seeps.

Summary of Water Resources in Montara and Martini Creek Area

- Annual recharge in a normal year (steady-state) is 635 acre-feet or 393 gpm. In as dry year such as 1981 (about 70 percent of rainfall and about 50 percent of runoff), recharge is 425 acre-feet per year or 263 gpm. For a critically dry year (such as 1977), it would be 28 acre-feet per year or 17 gpm.
- Annual runoff in a normal year (steady-state) is 758 acre-feet or 470 gpm. In as dry year like 1981 it is 505 acre-feet per year or 313 gpm. For a critically dry year like 1977, annual runoff might be 152 acre-feet per year or 94 gpm.
- Average estimated storage is 4,135 acre-feet per year. For the terrace and valley alluvium it is 2484 acre-feet, and the upland slopes are 1651 acre-feet.
- Domestic use determined by CUCC in 1995 for 5,705 people at 80 gpcd (gallons per capita-day) was 511 acre-feet. Projected use in 2030 for 7,194 people at 80 gpcd is 645 acre-feet. This represents a shortfall of 134 acre-feet based on current supplies.
- CUCC extracts about 460 gpm (or about 740 acre-feet per year, if pumped continuously) from Airport and Montara Creek production wells.
- Ground-water storage for the watershed subarea of Martini and Montara Creeks is 4,135 acre-feet, based on a total acreage of 1606 acres.

APPENDIX A3

DRAFT MONTARA - MOSS BEACH WATER WELL EIR

(KLEINFELDER, BALANCE HYDROLOGICS,
THOMAS REID & ASSOC., RENSHAW, D., 1989)

This EIR describes and assesses the effects of developing 58 new wells dispersed throughout Montara and Moss Beach in terms of hydrology, biology, community services, traffic and other elements of the environment.

Suggests systematic initial monitoring of ground-water levels in as many of the wells as possible.

Conformance with Policies, Plans, and Regulations

- Well permitting helps control the rate of growth in these two communities.
- The wells are being considered because there is not enough water available form the Citizens Utilities.
- Parcels 5,000 square feet or more in size that do not require a variance for development are exempt from the Coastal Development Permit requirement.
- About half of the parcels are exempt from the CDP.
- LCP limits growth throughout the Mid-Coast to 125 building permits annually.
- LCP Policies 1.18 - location of new development, 1.19 - definition of infill, 1.22 - timing of new development in the mid-coast, 2.25 - mid-coast water supply phase 1 capacity limits: capacity not to exceed 2 million gallons per day average dry-weather flow.
- LCP Policies 1.25 – rural watershed monitoring program, 2.32 – ground-water proposal, 5.21 – water supply, 5.26 – small water impoundments, 5.28 – monitoring of wells, 7.10 – performance standards in riparian corridors, 10.1 – coordinate planning, 10.2 – safeguarding water supplies, 10.3 – water conservation, 10.4 – development of water supplies, 10.8 – water systems for coastal areas, 10.9 – potential water sources, 10.10 – water supplies in

urban areas, 10.15 – water supplies in rural areas, 10.16 – new water systems, 10.17 – improving existing water systems, 10.19 – domestic water supply, 10.20 – well location and construction, 10.18 – aquifer studies and management.

Solid Waste

- Landfill materials are controlled by BFI and allocated to either Ox Mountain or Hillside Landfills.
- Max capacity was expected to be reached at BFI's Ox Mountain Landfill in 1990, an expansion project into Apanolio Canyon is expected to add 80 years.

Wastewater Treatment

- Montara Sanitary District (MSD), which is a member of the Sewer Authority MidCoast (SAM). – allocated 20% of treatment capacity
- City of Half Moon Bay – allocated 50% of treatment capacity
- Granada Sanitary District (GSD) – allocated 30% of treatment capacity
- Total capacity of SAM is 2 million gallons per day
- MSD must reserve 36,368 gallons per day of wastewater treatment capacity for priority land uses.

Climate and Physiography

- Mediterranean, 90% of precipitation as rain, 10% as fog drip
- Mean annual precipitation at HMB is approximately 25.5 in.
- Monthly temperature means range from 50°F to 59°F

- Marine terraces and coastal valleys extend between ocean and crest of Montara Mountain, approx. 2 miles to the east and up to 2500 feet in elevation.
- Terraces dissected by stream, small watersheds, changing at roughly 300 feet in elevation to broad, flat bottomed and steep-walled valleys.
- Up to 100 feet of sediment in these canyons.

Geology

- Primary units:
  - Cretaceous Montara Quartz Diorite
  - Pliocene Purisima Formation
  - Pleistocene Marine Terrace Deposits
  - Holocene Alluvial / Colluvial Deposits

Hydrology and Water Quality

- Water is available from 4 distinct units:
  - Granitic bedrock
  - Sedimentary bedrock of Purisima
  - Marine terrace deposits
  - Valley-fill alluvium

Estimated Hydrogeologic Properties for Each Aquifer

Granitic Bedrock:

- Specific Yield = 0.01, Hydraulic Cond. (gpd / ft^2) = 0.005-1.5, Transmissivity (gpd / ft) = <100-450, Sp. Capacity of Wells (gpm / ftdd) = 0.0079-2.88
- Transmissivity was estimated in two ways: the first uses empirical relationships between specific capacity of specific yield and transmissivity by CADWR and the second uses estimates of hydraulic conductivity in granitic and metamorphic bedrock developed by Bedinger and others (1986).
- Estimated thickness of saturated granitics is assumed to be 300 feet.

Purisima Formation:

- Specific Yield = 0.01, Hydraulic Cond. (gpd / ft^2) = 0.005-0.33, Transmissivity (gpd / ft) = <100-100, Specific Capacity of Wells (gpm / ftdd) = 0.002-0.06
- Presently, no wells are known to draw solely from the Purisima.

Marine Terrace Deposits:

- Specific Yield = 0.08, Hydraulic Cond. (gpd / ft^2) = 10-100, Transmissivity (gpd / ft) = 450-4000, Sp. Capacity of Wells (gpm / ftdd) = 0.5-4.0
- Wells completed in this aquifer are generally 50 to 70 feet deep.
- Transmissivity is estimated at 1800 gpd / ft.

Valley Fill Alluvium:

- Specific Yield = 0.10, Hydraulic Cond. (gpd / ft^2) = 10-100, Transmissivity (gpd / ft) = 450-10,000, Sp. Capacity of Wells (gpm / ftdd) = 0.5-4.0

- Significant deposits are located in the Upper Montara Creek (Wagner Valley), along San Vicente Creek, and north of Kanoff Avenue.

Basin Sub-Units

Montara Terrace:

- Approx. 165 acres and roughly bounded by Acacia Street, 6th Street, Farallone Avenue, and the unnamed stream north of Kanoff Avenue in Montara.
- Approx. 80% of the wells drilled in this area are completed in marine terrace deposits.
- Ground-water level declines are estimated at 15 to 30 feet for dry or very dry years, respectively.
- Estimated ground-water storage for normal, dry, and very dry years is 528, 396, and 132 to 330 acre-feet.
- No data describing seasonal or year to year fluctuations in water levels are known.

Montara Heights:

- This area incorporates the upper areas of Montara Creek, 6th Street, and Farallone Avenue.
- Wells completed in this area draw only from granitics.
- Estimated volume of water in storage for this area is estimated at 330 acre-feet

Upper Montara Creek:

- Approx. 385 acres in the upland areas of Montara with portions of Montara Creek basin and alluvial deposits of Wagner Valley.
- Alluvium depth is estimated to be 50 to 70 feet thick.

- Water is produced from granitics.
- Wagner Valley may serve as a recharge area.
- CUCC has four production wells in this area.
- Area has an estimated storage of 1500, 1320, and 1120 acre-feet for normal, dry, and very dry conditions.

Upper Moss Beach:

- Portions of Moss Beach between Stetson Street and Montara Creek (70 acres)
- Estimated volume of water in storage is 210 acre-feet

Moss Beach Terrace

- Area occupies 195 acres in Moss Beach south of Stetson Avenue to Orval Avenue in Seal Cove.
- Main aquifer composed of 50 to 70 feet of marine terrace deposits.
- Estimated volume of water ground-water storage is 700, 546, and 234 to 468 acre-feet for normal, dry, and very dry years.
- Estimated outflows to the ocean are 134, 94, and 40 to 80 acre-feet for normal, dry, and very dry years.

Upper Seal Cove

- 40-acre block uplifted along the Seal Cove fault zone.
- Ground-water storage is estimated at 35, 9 and 1 to 2 acre-feet for a normal, dry, and very dry years.

- Estimated outflow of ground water is 13, 5, and <1 acre-feet for normal, dry, and very dry years.

Ground-water Budget by Aquifer Sub-Unit

Estimates and Assumptions:

- All watersheds have an annual mean runoff rate of 0.27 inches.
- Estimated runoff during average years is adjusted by a multiplier of 0.75, dry years by 0.5, and very dry years by 0.15.
- Infiltration rate is 0.00001 cubic feet per second per square foot.

Montara Terrace:

Inflows

- Direct infilitration from precip = 89 ac-ft (normal), 41 ac-ft (dry), and 4 ac-ft (very dry)
- Infiltration from roadsides = 23 ac-ft (normal), 16 ac-ft (dry), 5 ac-ft (very dry)
- Ground-water inflow from Montara Heights = 22 ac-ft (normal), 14 ac-ft (dry), 3 ac-ft (very dry)

Outflows

- Ground-water outflow from seacliff = 140 ac-ft (normal), 105 (dry), and 35-88 (very dry)
- Surplus / Deficit = -27 ac-ft (dry), -20 to –73 (very dry)
- Runoff from direct precip = 138 ac-ft (normal), 107 (dry), and 89 (very dry)
- Channelized runoff = 8 ac-ft (normal), 2 (ac-ft (dry), and 0 ac-ft (very dry)

Montara Heights:

Inflows

- Direct infiltration from precip = < 1 ac-ft (normal), < 1 ac-ft (dry), and <1 ac-ft (very dry)
- Throughflow in decomposing granite = 8 ac-ft (normal), 7 ac-ft (dry), 6 ac-ft (very dry)

Outflows

- Outflows from DG = 8 ac-ft (normal), 7 ac-ft (dry), and 6 ac-ft (very dry)
- Surplus / Deficit = 0 for all year types

Upper Montara Creek:

Inflows

- Direct infiltration from precipitation = 117 ac-ft (normal), 78 ac-ft (dry), 47 ac-ft (very dry)
- Infiltration from east and southeast tributary watersheds = 166 ac-ft (normal), 85 ac-ft (dry), and 20 ac-ft (very dry)
- Infiltration from channel of Montara Creek = 88 ac-ft (normal), 88 ac-ft (dry), and 21 ac-ft (very dry)
- Seepage from DG = 87 ac-ft (normal), 68 ac-ft (dry), and 50 ac-ft (very dry)

Outflows

- Montara springs diversion = 89 ac-ft (normal), 34 ac-ft (dry), and 29 ac-ft (very dry)
- Wagner #3 well = 115 ac-ft (normal), 112 ac-ft (dry), and 104 ac-ft (very dry)
- Drake well = 44 ac-ft (normal), 34 ac-ft (dry), and 37 ac-ft (very dry)???
- Portola #3 and # 4 wells = 50 ac-ft (normal), and 92 ac-ft (dry)

- Park Well = 5 ac-ft (normal), and 8 ac-ft (very dry)
- Surplus / Deficit = 32 ac-ft (normal), -50 ac-ft (dry), and –110 ac-ft (very dry)
- Runoff from valley alluvium = 19 ac-ft (normal), 15 ac-ft (dry), and 11 ac-ft (very dry)
- Runoff from non-channelized watersheds = 18 ac-ft (normal), 9 ac-ft (dry), and 2 ac-ft (very dry)
- Runoff from channelized watershed = 86 ac-ft (normal), 1 ac-ft (dry), and 0 ac-ft (very dry)

Moss Beach Terrace and Upper Moss Beach

Inflows

- Direct infiltration from precip = 144 ac-ft (normal), 66 ac-ft (dry), and 7 ac-ft (very dry)
- Recharge from channelized flow, Dean Creek = 22 ac-ft (normal), 14 ac-ft (dry), and 5 ac-ft (very dry)
- Recharge from upper Dean Creek Alluvium = 6 ac-ft (normal), 6 ac-ft (dry), and 6 ac-ft (very dry)
- Recharge from channelized flow, San Vicente Creek = 66 ac-ft (normal), 66 ac-ft (dry), and 33 ac-ft (very dry)
- Surplus / Deficit = 104 ac-ft (normal), 58 ac-ft (dry), and 9 to –29 ac-ft (very dry)

Outflows

- Terrace ground-water outflow at seacliff = 134 ac-ft (normal(, 94 ac-ft (dry), and 40-80 ac-ft (very dry)
- Direct runoff from direct precip = 203 ac-ft (normal), 156 ac-ft (dry), and 120 ac-ft (very dry)
- Channelized runoff, Dean Creek = 64 ac-ft (normal), 30 ac-ft (dry), and 5 ac-ft (very dry)

- Throughflow in upper Moss Beach bedrock = 8 ac-ft (normal), 7 ac-ft (dry), and 6 ac-ft (very dry)
- Outflows from upper Moss Beach bedrock aquifer = 8 ac-ft (normal), 7 ac-ft (dry), and 6 ac-ft (very dry)
- No surplus or deficit

Upper Seal Cove Terrace

Inflows

- Direct infiltration from precip = 14 ac-ft (normal), 5 ac-ft (dry), and 2 ac-ft (very dry)

Outflows

- Ground-water outflow at seacliff = 13 ac-ft (normal), 5 ac-ft (dry), and 2 ac-ft (very dry)
- Surplus/Deficit = 1 ac-ft (normal), 0 for remainder.

Water Quality

- Prior to final certification, wells must be tested for iron, manganese, chloride, nitrate, and specific conductance.
- State water quality limits for iron and manganese in drinking water are set at 0.3 and 0.05 mg/L.
- Approximately 1/3 of the existing wells with water quality results exceed drinking water standards and require treatment.
- Chloride concentrations are generally low to moderate, levels range from 45 mg/L in uplands to 150 mg/L in terrace areas.
- Long term limits on chloride are 250 mg/L.

- Chloride concentrations can be a result of ground-water depletion, overdraft, or upwelling of deeper waters within fracture and fault zones.
- Seawater is not considered to be significant in terms of water quality!
- Water quality standards for nitrate (as NO_3) are set at 45 mg/L, above this level can have toxic results.
- Nitrate levels range from 0 mg/L to 26 mg/L as nitrate NO3
- Recommended maximum for specific conductance (SC) at 25° C is 900 umhos/cm.
- Reported SC values range from 250 umhos/cm to 1700 umhos/cm.

Soils, Erosion, and Sedimentation

- Most soils are derived from granitic parent material
- All soils have a large sand component, low organic content, and low to moderate moisture-holding capacity.

Biology

- Wetland area likely to have most conflicts with development is the Pillar Point Marsh.
- Most of the present day vegetation represents the cultural history and the current level of human activity, introduced annual grasses.
- Coastside now dominated by eucalyptus, Monterey cypress, and Monterey pine.

Habitat Types

- Riparian (dependent on nearby surface water feature) – Arroyo Willow, Coulter's Willow, Red Alder, Flowering Current, Stinging Nettle, Poison Oak, Creek Dogwood. German Ivy has become invasive.

- Coastal Grassland – *Danthonia californica*, *Stipa pulchra*, Blue-Eyed Grass, beach strawberry, pacifica grindelia, checkerbloom, California Poppy, Prostrate coyote brush, hairy cat's ear, narrow-leafed plantain, wild radish, pampas grass, and introduced wild oats, ripgut broom, Italian ryegrass, soft chess. Also common are *Juncus effusus* and bog rush, coyote brush, coffeeberry, and yellow bush lupine.
- Wetland
- Aquatic
- Ruderal (rubbish loving) – Mediterranean annual grasses, wild radish, sow thistle, ice plant, sweet alyssum, German ivy, Pittosporum, and tree mallow
- Residential
- Eucalyptus Stands
- Conifer Stand – Monterey pine, Monterey cypress
- Developed and / or landscaped

Plant and Animal Species of Concern

- San Bruno Eflin Butterfly
- Mission Blue Butterfly
- San Francisco Garter Snake
- Brown Pelican
- American Peregrine Falcon
- Hyla Regilla (tree frog)
- Rana Aurora (red-legged frog)
- Montara Manzanita (Arctostaphylos montaraensis)

- San Francisco Owl's Clover (Orthocarpus floribundus)
- White-Rayed Pentachaeta (Pentachaeta Bellidiflora)
- San Francisco Campion (Silene verecunda verecunda)
- Salt Marsh Yellowthroat (Geothlypis trichas sinuosa)
- San Francisco Gumplant (grindelia maritima)
- Hickman's cinquefoil (Potentilla hickmanii)
- Monarch Butterfly

Impacts of the Proposed Project

- 58 parcels with connections will increase the demand on ground water by 17.5 acre-feet per year, based on a usage of 0.302 acre-feet per year per parcel (or 270 gpd per unit).
- This additional demand is equal to 0.5% of the available ground water in storage during normal years,
- Ground-water outflow demands by 58 parcels will be equal to 4.7% of the estimated annual outflow during normal years. During dry and critically dry years it will be 7 and 11 percent.
- Pumpage is expected to decrease amount of water available to riparian habitats by less than 5%.
- Impacts on baseflow are small?
- Effects of pumping on ground-water quality are expected to be minimal
- Effects of septic system usage are expected to be significant
- Potential damage to riparian habitats during drilling and construction.
- Increased runoff and erosion due to clearing of riparian habitats.

- Drawdown will lessen available amount of ground water to riparians.
- Removal of native bunch grasses.
- Destruction of California strawberry plants.
- Depletion of resident and migratory birds.
- Diminished wildlife habitats.
- Destruction of wetland areas and habitats.
- Increased sediment discharge into streams, degrading water quality and increasing turbidity.
- Erosion of stream banks
- Depletion of surface flows due to ground-water withdrawal.
- Destruction of SF gumplant and Hickman's cinquefoil.
- Destruction of SF garter snake habitat

Alternatives to the Proposed Project

- Defer aquifer development by individuals – until water becomes available from the water district
- Develop additional ground-water sources either within or beyond rural-urban boundaries – ground water exploration by Citizens in the airport area
- Concerted water harvesting on agricultural or open space parcels adjoining the communities, watershed management – focus water development outside of the communities. Largest area of potential recharge is the floor of San Vicente Creek, east of Moss Beach.

Recommended Strategies and Practices

- Information most needed is:
    - ground-water levels as they vary seasonally and from yea or year in the six sub-units
    - ground-water quality
    - health and sensitive habitats
    - aquatic habitat
    - special-status and SF Garter
- Bimonthly monitoring of water levels throughout the area for a period of two years.
- Water level recorders installed in each of the three major hydrogeologic units:
    - terrace deposits
    - crystalline bedrock
    - lower Wagner valley alluvium
- 8 to 10 of the chosen wells should be monitored bimonthly beyond the two-year study effort.
- Potential biomonitoring stations in Montara:
    - seeps and springs in the grasslands north of North Montara Creek
    - small wetland area on North Montara Creek at Highway 1
    - small wetland between Cedar and Elm Streets
    - riparian strip along Montara Creek, in the immediate vicinity of the existing CUCC wells,
    - seep in grassland just north and west of major bend in Montara Creek

- riparian strip along the lower 4000 feet of Montara Creek
- along the beachfront cliffs where water-bearing strata intersect

- Potential biomonitoring stations in Moss Beach:
  - vernal wetland / seep in Koeleria grassland
  - cliff front seeps, where vegetated and accessible
  - *Juncus*seep areas in Seal Cove
- A basic inventory of fin fish and other aquatic organisms should be made
- Survey Seal Cove area for SF Garter snake use.
- An area-wide survey for SF Gumplant.
- An area wide survey for Hickman's cinquefoil, believed to have been extirpated by beach cliff erosion and development.
- Site specific surveys for California strawberry.

APPENDIX A4

EL GRANADA GROUND WATER INVESTIGATION

(KLEINFELDER, 1988)

This report was produced by Dennis Laduzinsky, Barry Hecht, and Mark Woyshner of Kleinfelder in April of 1988. The main purpose of this investigation is to present a more detailed description of the local ground-water resources in the El Granada and consider factors affecting their recharge, discharge, annual and seasonal fluctuations, and water quality. The need for such an investigation originated from the reality that municipal water supplies in the coastal terrace area of San Mateo County are considered insufficient to serve projected growth rates.

Significant ground water management concerns for the El Granada area during dry periods:

- Diminishing yields or drying up of wells in areas where ground-water levels decrease rapidly
- Unexpected yield losses in areas of clustered wells.
- Increasing levels of nitrates and related constituents in localized areas.
- Inducing inflow from Denniston Creek alluvium leading to perceptible effects on water levels.

The basin management strategies presented in this report are of two formats, short-term and long-term.

Aquifer Analysis

Unconsolidated marine terrace deposits and weathered granitic bedrock and sedimentary rock comprise El Granada's two principal hydrogeologic units. The quartz diorite basement rock is extensively overlain by a thin covering of alluvium and associated sandy-loam soils. Narrow valleys contain this alluvium interfingering with the main local terrace aquifer deposits. The terrace deposits range between 1500 and 3000 feet in width, including an older inland unit and a younger coastal unit.

- There are two distinct aquifer units underlying the El Granada area based on lithology and hydraulic properties.

- The main aquifer consists of unconsolidated deposits of sand, silt, and clay that comprises the Half Moon Bay Terrace, and is referred to as the terrace aquifer. Included in this aquifer system are the alluvial deposits located along stream valley margins. These terrace deposits unconformably overlie sandstone and siltstone of the Purisima bedrock formation and granitic bedrock from the Montara pluton.

- These aquifer designations have been made primarily on reasonable geologic assumptions since the recorded well logs provide insufficient detail as the depth to bedrock.

- Average specific capacities for wells completed within the terrace aquifer is approximately 20 times higher than those completed in the bedrock.

- Based on hydraulic and water quality data, exchange of water between the terrace aquifer and the bedrock aquifer is limited.

- The boundaries of the El Granada Terrace are Arroyo de en Medio Creek to the south and Denniston Creek to the north. Both are recharge boundaries.

- Results from four to six hour aquifer tests from 44 wells completed in the terrace aquifer indicates an average specific capacity of approximately 0.93 gpm/ftdd, specific capacities of 0.5 to 2.86 gpm/ftdd, and a specific yield of 0.08. Transmissivity was estimated at 850 to 4800 gpd/ft, with an average of 1700 gpd/ft.

- Specific capacities of 59 wells completed in the bedrock aquifers average 0.06 gpm/ftdd.

- Seasonal water level fluctuations of 5 to 15 feet are common for the area within the terrace aquifer.

- The hydraulic gradient between 0.05 and 0.028 with an overall gradient of 0.036.

- The effective storage area of the terrace aquifer is approximately 365 acres and varies in thickness from 50 to 80 feet.

- Well logs indicate an average saturated thickness area of 1460 acre-feet or 475 million gallons, considering terrace deposits both above and below sea level.

- Estimated specific yield of the bedrock aquifers ranges from 0.003 to 0.01 and an estimated storage of 81 to 260 mg.

- Estimated ground-water flow throughout the system during a normal year is estimated 445 acre-feet per year.

- Estimated outflow from the terrace is 445 af/yr for normal years, 383 af/yr for dry years, and 311 af/yr for critically dry years.

- Present estimated pumpage from storage is 16 to 21 million gallons per year (or about 50 to 65 acre-feet per year.

Water Balance

- Inflows to the aquifer system considered are percolation, recharge, and valley alluvium ground water for a total of 530 ac-ft of water to the terrace.

- Annual precipitation recorded at Half Moon Bay Airport for the period 1951 to 1985 was 25.22 inches.

- 40% of seasonal rainfall is thought to leave the terrace as runoff.

- Recharge rates range from 50 to 500 acre-feet per year.

- Mean annual runoff is estimated to be 280 to 360 acre-feet per year.

- Outflow and withdrawals from the system are infiltration to sewer pipes, well pumping, and terrace outflow to the ocean.

- Outflow from the terrace is estimated at 445 acre-feet per year.

- Outflow and withdrawals total 535 acre-feet per year.

- Outflow from sewer pipes is estimated at 25 acre-feet per year.

- Average water use in El Granada is 271 gpd.
- Ground water pumpage is estimated at 69 acre-feet per year.

Water Quality

- Water quality data was collected from 100 domestic wells to map concentrations of chloride, nitrate, and specific conductance.
- Average reported specific conductance for terrace wells ranges from 300 to 1400 with an average of 580 umhos/cm.
- Average reported specific conductance for bedrock wells averages about 830 umhos/cm.
- Chloride levels for terrace wells averages 100 mg/L, and bedrock wells average 140 mg/L.
- Nitrate concentrations reach as much as 40 mg/L in areas.

APPENDIX A5

HALF MOON BAY / PILLAR POINT MARSH GROUND-WATER BASIN STUDY: PHASE I, PHASE II AND SUPPLEMENTAL DATA

(LUHDORFF & SCALMANINI CONSULTING ENGINEERS,
AND EARTH SCIENCES ASSOCIATES, 1992, 1991, 1987).

Luhdorff & Scalmanini Consulting Engineers (LSCE), and Earth Sciences Associates (ESA) teamed to produce three reports for Coastside County Water District (CCWD) and Citizens Utility Company of California (CUCC) on the Half Moon Bay / Pillar Point Marsh ground-water basin. Completion of the study was a condition by the California Coastal Commission prior to CUCC's development of two new production wells (Permit No. CDP 85-59, Condition No. 7). The purpose of the study was to estimate 'safe yield' of the basin, which was defined as the gross yield (or the amount of water removed) that maintains ground-water levels sufficiently high as to restrict seawater intrusion and sustain the Pillar Point marsh without adverse health impacts (LCP Section 7.20.b), as well as other dependent sensitive and riparian habitats (LCP Section 2.32.c).

The study area was defined as the coastal plain between Moss Beach and Princeton, also called the Denniston Creek Sub-basin in previous studies. Its ground water is often referred to as the 'airport aquifer', because the Half Moon Bay airport occupies a large portion of the basin. The northern boundary of the basin was defined as the low topographic divide with the San Vicente Creek basin, and along the topographic inflection at the base of the mountain. The eastern boundary basin was defined as a no-flow line[7] east of Denniston Creek and west of the town of El Granada. The Seal Cove fault borders it on the southwest and west, and Half Moon Bay is on the south. Pillar Point Marsh occupies a few acres between Princeton and Pillar Point, at the extreme southern tip of the basin. Denniston Creek crosses the plain near the eastern edge of the basin.

The phase I study (June 1987) reviewed and evaluated existing data in order to establish appropriate methodology for defining safe yield of the basin, to be carried our during phase II. It summarized available ground-water, surface-water and precipitation data. It compared

[7] The eastern boundary of the basin has no firm physical meaning other than a ground-water flow line, parallel to the creek, perpendicular to hydraulic head contours, and indicating negligible ground-water flow in the east-west direction.

annual rainfall totals and ground-water elevations[8] going back to early 1950's, and concluded that ground-water levels had remained essentially constant with no apparent long-term changes in water levels or ground-water storage, while during the latter half of this period, ground-water extraction (by CCWD and CUCC) had increased from about 250 acre-feet per year in 1976 to a maximum of 430 acre-feet per year in 1988, and then lowering to 340 acre-feet per year in 1991 at the depth of the 1987-1992 drought. Seasonally, ground-water levels lower during summer recover in the winter, except during temporary periods of drought. Ground-water quality, particularly specific conductance and chloride ion concentrations, has remained stable since initial measurements during the 1950's.

The phase I report found that the basin could support additional pumpage without affecting the Pillar Point Marsh and identified a preliminary range of 'safe yield' values from about 650 to 1300 acre-feet per year. It also proposed that new well development be staged and combined with close monitoring of ground water responses to increased pumping. The first stage of development would be restricted to approximately 15 acre-feet per year of additional pumpage.

The phase I report recommended monitoring and analysis in phase II, including a continuation of current water-level and water-quality monitoring, as well as the following components:

1. Completion of multiple well pumping tests to gain additional data on aquifer transmissivities and storage coefficients;

2. Installation of continuous water-level recorders in observation wells, prior to nearby well testing, to monitor barometric and tidal effects;

3. Development of ground-water level contour maps to estimate storage changes;

4. Establishment of a monitoring program (nested piezometers) to evaluate ground-water conditions in Pillar Point Marsh;

5. Survey Denniston Creek to locate stream-gaging sites to define stream losses as ground-water recharge. No other objective for gaging was identified.

[8] Of approximately 90 well logs located within and adjacent to the study area, a total of 10 wells have been monitored for various periods of time. Water level in well 5S/6W-10J1 (north of the marsh and west of the airport) has been monitored by the Department of Water Resources (DWR) during spring and fall of most years since 1953. While this is a useful boundary for hydrogeologic analysis, its position does shift frequently and over some distance.

The phase II report (September 1991) reviewed the available data presented in phase I, expanded on the hydrogeologic conditions, and included a biological assessment as well as a ground-water basin yield and management plan. Monitoring during water years 1990 and 1991 were particularly instructive as they were the depths of the 1987 to 1992 drought (1989 and 1992 being just below normal). Vertical hydraulic head gradients taken at the Pillar Point Marsh piezometer nest showed upward gradients throughout the drought, indicating that the marsh continued to function as a ground-water discharge area. Ground-water contour maps illustrated above sea level elevations along the coast during the drought, despite pumping depressions around the production wells along Dennistion Creek.

Supplemental monitoring data through April 1992 were presented in a follow-up report (June 1992). Rapid rises in water levels following periods of substantial rainfall suggest that the Denniston Creek Basin recharges relatively quickly, and that water-level elevations in the basin are largely related to recharge conditions.

On March 16, 1998, Denniston Creek was observed[9] flowing into the basin but was dry at its mouth; ground-water recharge was measure at 29 acre-feet per day with more than half occurring downstream of HWY 1, near Princeton. It was estimated that over 2000 acre-feet of basin recharge comes from Denniston Creek during the winter and early spring when flows and aquifer storage is available. Other noteworthy sources of recharge are other drainages to the northeast and southwest, San Vicente Creek, over-irrigated brussel sprout fields, and airport runoff ponds.

Aquifer transmissivity estimates from 8 to 24 hour aquifer tests ranged from 600 to 825 ft^2 per day, and averaged 700 ft^2 per day. Storativity estimates ranged from 0.00021 to 0.0075 with an average of 0.001. Using these values, developed ground-water contour maps, and basin geometry, subsurface inflow and outflow were estimated. Ground-water pumping was estimated from municipal records. Based on a ground-water budget developed for the basin for average conditions, annual pumping (or ‘safe yield’) is 480 to 520 acre-feet per year, an increase of 45 to 87 acre-feet as compared to 1987 to 1990 average. Ongoing monitoring and analysis of ground-water conditions were recommended.

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[9] Stream gaging and ground-water modeling of Half Moon Bay airport aquifer by Hydrofocus, (1998 through 2000 correspondence; preliminary analyses and raw data only; no report issued).

APPENDIX A6

EVALUATION OF GROUND-WATER DEVELOPMENT POTENTIAL,

MONTARA WATER SERVICE AREA

(LUHDORFF & SCALMANINI CONSULTING ENGINEERS, AUGUST 1982)

Geologic Reconnaissance

- Montara service area needs to expand supplies by 0.2 mgd (150 gpm).
- 1956 estimates were that the alluvial deposits would yield a minimum of 740 acre-feet per year, operated conjunctively, expected to supply for 4700 connections (pop. of 14,000).
- In 1971, no developable ground-water sources at either the McNee property or the Torres property.
- Suggestions by Applied Geological Engineering in 1975 and 1976:
  - no further drilling in HMB area.
  - 200 ft well in fractured granite at intersection of Highway 1 and San Vicente Creek.
  - 100-200 ft well in fractured granite and alluvium on north side of Wagner Valley floor.
  - 200 ft well in fractured granite at Drake and Riviera Streets.
  - 200 ft well into alluvium and granite south of Martini Creek at existing dam site.
- Most significant supplies are obtained from alluvium deposited in valleys or on terraces cut into granite.
- Largest drainage basin is Denniston Creek.
- Alluvial plain above the reservoir appears to be most desirable area for supplies.
- Also desirable is the alluvial plain of the upper part of San Vicente Creek

- Potential for development in the alluvial materials on the Wagner Valley floor and Martini Creek.
- Nest best step would be to improve engineering of existing wells and/or construction of new wells located more towards the center of alluvial plains.
- Majority of wells are high in iron and manganese.
- In the 1976-78 drought, some wells experienced salt water intrusion.

Aquifer and Well Charactersictics

- The four Portola wells have pump test data developed by Citizens – summarized in Table 1.
- Aquifer transmissivities in Montara range from 10,000 gpd/ft in the airport area wells to 4,000 gpd/ft near the Portola well. These values are low and indicate low permeability and limited thickness of the Montara area aquifers.
- Most wells have lost efficiency since construction most likely due to incrustation of the intake structure (pump?).
- The best available plant efficiency is 50%. ??
- There appears to be a significant seasonal variation in static water levels in the Portola area.

Summary and Recommendations

- There is potential for additional ground-water development.
- The best aquifers for potential development are the alluvial deposits in the areas of Martini, Montara, San Vicente, and Denniston Creeks.
- Additional wells could be constructed near existing wells or multiple wells can be constructed in new locations to maximize the yield from a given aquifer without significant mutual pumping interference or seawater intrusion.

- Test holes should be drilled at six sites: one in Martini Creek, adjacent to the existing dam; one on the floor of Wagner Valley, north of the existing well; two on San Vicente Creek, in the wide section of the creek above the foothills and one within the broad terrace below the foothills; two on Denniston Creek, one in the wide section of the creek above the dam and one within the broad terrace below the foothills.

- All test hole should be approximately 200 feet deep.

- Each test hole should be completed into a 2 inch monitoring well.

Table A-1 Summary of Pump Tests of Municipal Supply Wells, Citizens Utilities Service Area

Well	Date	Capacity (gpm)	Static Water Level (ft)	Drawdown (ft)	Pumping Water Level (ft)	Total Dynamic Head (ft)	Overall Pumping Plant Efficiency (%)	Specific Capacity (gpm/ft)	Horse-power (hp)
S. Airport	Dec-81	81	38.2	20.7	58.9	195	27	3.9	10
	Sep-81	79	48	15	63	218	30	5.1	10
	Apr-81	63	39	10	49	200	22	6.6	10
	Jul-79	75	49.5	10	59.5	205	34	7.1	10
N. Airport	Dec-81	58	36	39.3	75.3	211.6	27	1.4	15
	Sep-81	60	58	22	80	223	29	2.7	15
	Apr-80	101	31	19	50	200	44	5.3	15
	Jul-79	73	46	24	70	213	27	3.1	15
Drake	Sep-81	18	99	32	131	393	16	0.5	10
	Apr-81	25	80	32	112	373	19	0.7	10
	Jan-80	44	78	15	93	363	30	2.8	10
	Jul-79	31	89	42	131	396	25	0.7	10
Wagner #3	Sep-81	69	77	28	105	423	40	2.4	20
	Mar-51	78	65	24	89	345	37	3.2	20
	Jan-80	85	42	24	66	431	49	3.4	20
	Jul-79	85	67	34	101	410	45	2.5	20
Park	Sep-81	15	12.3	5.4	17.7	368	32	2.7	3
	Mar-81	20	25	6	31	377	43	3.3	3
	Jan-80	17	2.5	37.5	40	385	39	0.4	3
Portola #1	Sep-81	2			197	724	7		5
Portola #2	Sep-81	11	151	4.9	155.9	822	30	2.2	5
	Mar-81	20	10	12.5	22.5	579	55	0.7	5
Portola #3	Sep-81	61	160	53	213	532	40	1.1	15
	Mar-81	44			88.5	693	40		15
Portola #4	Sep-81	48				392			15
	Apr-81	63	47			466			15