Water Quality and Streamflow Monitoring of San Francisquito and Los Trancos Creeks at Piers Lane, Water Year 2003, Long-term Monitoring and Assessment Program

San Mateo and Santa Clara Counties, California

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SUMMARY

San Francisquito Creek is currently listed by the California State Water Quality Control Board as being impaired by sediment and by the organophosphate pesticide, diazinon. Water quality in the creek is of particular concern because the creek is habitat for steelhead trout, a federally-listed threatened species. This study reports results of water year 2003 stream gaging and water quality sampling, the second year of a long-term, water-quality sampling program sponsored by the Stanford University Utilities Division.

Balance Hydrologics, Inc. operated two automated water-quality sampling stations on San Francisquito Creek and Los Trancos Creek just above their confluence. The electronic records were combined with manual measurements to create flow records for each stream. Measurements of temperature, specific conductance, dissolved oxygen and pH were made manually. Five sets of comprehensive water-quality samples were collected throughout the water year using flow-paced or time-paced composite samples; some grab samples were also collected. Suspended-sediment samples were collected during and between storms and used to estimate annual suspended-sediment yields.

We collected continuous water-level and temperature data for the entire year. Water temperatures in San Francisquito Creek were above optimal levels during a short portion of the summer. Suspended-sediment concentrations were similar to expected values. None of the samples contained detectable levels of diazinon or chlorpyrifos. Trace metals (aluminum, copper, lead, mercury, nickel, selenium, silver and zinc) were often detected, but not at abnormal levels. Total recoverable metals concentrations occasionally exceeded Regional Board or U.S. EPA acute and/or chronic toxicity levels but dissolved metals concentrations were well below levels of regulatory concern. Ammonia was only detected on one occasion and the level of un-ionized ammonia in San Francisquito Creek appeared to slightly exceed the Regional Board chronic (annual median) toxicity value, while the concentration in Los Trancos Creek was slightly below the regulatory threshold. Nitrate-nitrogen concentrations were moderate and typical of levels observed in other local streams.

1.0 INTRODUCTION

This report presents the results of surface water monitoring in the San Francisquito Creek watershed by Balance Hydrologics, Inc. ("Balance"), on behalf of the Stanford University Utilities Division ("Stanford"). Stanford is a participant in the San Francisquito Watershed Council, which is managing the Long-Term Monitoring and Assessment Plan (LTMAP), originally created by a subcommittee of the San Francisquito Creek Coordinated Resource Management and Planning (CRMP) Steering Committee. The LTMAP was established primarily to monitor and assess current (i.e., baseline) conditions, analyses of trends, and evaluation of watershed management. Three LTMAP monitoring stations in the lower San Francisquito Creek watershed have been monitored since fall 2001. In fall 2003, monitoring commenced at a fourth station upstream on Bear Creek at Sand Hill Road. Stanford and the San Francisquito Watershed Council have explored addition of one or more stations further upstream if funding could be secured. Expanding the monitoring network to include stations higher in the watershed would provide greater understanding of longitudinal and temporal variation in water quality and stream flow conditions.

To assist the LTMAP in one of its objectives, Balance was asked to collect surface water data for use in describing constituents which might adversely affect water quality in the watershed, under a full range of storm runoff and low-flow conditions, in major part as they affect the full range of steelhead life stages. We are also evaluating contaminants present in San Francisquito and Los Trancos Creeks to prioritize them for more detailed study in future years, describing when they are present or absent and the relationship to flow, and assessing the amount of bedload and suspended sediment being transported by the two streams, as compared to upstream locations also monitored during water year 2003 for other projects.

The San Francisquito Creek watershed is located on the San Francisco Peninsula, and includes the northwestern portion of Santa Clara County and the southeastern portion of San Mateo County (Figure 1). In their downstream reaches, San Francisquito Creek and Los Trancos Creek form the boundary between the two counties. The watershed encompasses approximately 45 square miles, of which about 37 square miles lies upstream from the Piers Lane stations, and includes a wide diversity of urbanized, rural and natural habitats.

The City of Palo Alto contracted with Larry Walker Associates to install three LTMAP monitoring stations in fall 2001. City of Palo Alto staff are operating the lowermost station on San Francisquito Creek at Newell Road. Balance initiated operation of the two other newly-installed stations during water year 2002, and continued operation during water year 2003:

- San Francisquito Creek at Piers Lane (SFPL), immediately upstream of the confluence with Los Trancos Creek; and
- Los Trancos Creek at Piers Lane (LTPL), immediately upstream of the confluence with San Francisquito Creek.

Balance staff also began monitoring an upstream station on Bear Creek at Sand Hill Road in fall 2003.

During this second year of operation, we collected water-quality samples on five occasions from the Piers Lane stations. The stations are equipped to continuously monitor water levels, rainfall, water temperature, specific conductance, dissolved oxygen, and pH. Manual measurements of specific conductance, temperature, water level and flow were made at regular intervals to calibrate the electronic record. This report summarizes the second year's findings. Measurement and observations continue during water year 2004.

2.0 BACKGROUND

Surface-water monitoring for this project is being implemented to assess known and potential pollutant concentrations as part of the Long-Term Monitoring and Assessment Plan (LTMAP). The LTMAP was created by a subcommittee of the San Francisquito Creek Coordinated Resource Management and Planning (CRMP) Steering Committee and is now managed by the San Francisquito Watershed Council. The goals of the LTMAP are to provide a comprehensive framework for organizing and coordinating monitoring and assessment activities in the San Francisquito Creek watershed.

As part of the LTMAP, surface water data is being collected for use in describing constituents which might impact water quality in the watershed, under storm runoff and low-flow conditions, and under a broad range of steelhead life stages. To assist the LTMAP in one of its objectives, Balance was asked to:

1. identify which contaminants or sets of contaminants are present in San Francisquito and Los Trancos Creeks, and to prioritize analytes for more detailed study in future years;

2. assess if a relationship exists between the presence, absence or concentration of contaminants and flow; and

3. evaluate the amount of bedload and suspended sediment being transported by the two streams and compare it to upstream locations also monitored during water year 2002 for other projects.

The two LTMAP stations discussed in this report are located on Piers Lane, a short distance downstream (north) of Interstate 280, in Menlo Park and Palo Alto. Both stations were installed in fall 2001 by staff of Kinnetic Laboratories, Inc. (Santa Cruz) and Larry Walker Associates (Davis) under contract to the City of Palo Alto. Balance initiated operation of the newly-installed stations during water year 2002[1]. Only a limited number of samples could be collected during the first year of operation; monitoring during water year 2003 more closely followed the envisioned sampling sequence. The San Francisquito Creek at Piers Lane station is equipped with a tipping-bucket rain gauge. Both stations are equipped to continuously monitor water level,

[1] Most hydrologic and geomorphic monitoring occurs for a period defined as a water year, which begins on October 1 and ends on September 30 of the named year. For example, water year 2003 (WY2003) began on Oct. 1, 2002 and concluded on September 30, 2003.

water temperature, specific conductance (an index of salinity), dissolved oxygen, and pH. Manual measurements of specific conductance, water temperature and flow were made at regular intervals to calibrate the electronic record. The stations are powered by batteries and the current cell phone telemetry drains the batteries too quickly to make the data available in real-time. Connection to AC power or a land-line telephone would decrease obstacles to real-time data availability.

City of Palo Alto staff operate a third station in the LTMAP network, located on San Francisquito Creek at Newell Road, a short distance upstream of Highway 101 and near the head of tidewater. A fourth station installed higher in the watershed, upstream on Bear Creek at Sand Hill Road, became operational in fall 2003.

2.1 Local influences on water quality

Restoration of habitat for steelhead -- a federally-listed threatened species greatly valued by the watershed community at large – in the San Francisquito Creek drainage has been the focus of substantial efforts over the past ten years. Technical professionals and knowledgeable residents with experience in these streams suspect that water quality may be a significant constraint to the size and robustness of the steelhead population in San Francisquito Creek and its tributaries. Steelhead are anadromous[2] fish which spawn and rear throughout the free-flowing headwaters of the San Francisquito Creek watershed. Water-quality impairment may likely affect other sensitive local species or possibly other beneficial uses as well.

The principal sources of potential concern include:

- Horses and perhaps other livestock, particularly those boarded on land adjacent to the stream channels of San Francisquito Creek and its tributaries and/or using the stream or riparian buffer areas;
- Septic systems;
- Urban runoff, including road and highway surface runoff, which may contribute nutrients and other constituents, such as heavy metals;
- Pulses of water observed and documented in the streams at low flow, which may originate from human-managed sources, perhaps from flushing of swimming pools and other chlorinated ponds; and

[2] Migrates to the ocean as a juvenile and returns to fresh water to spawn.

- Common garden, orchard and lawn chemicals (i.e., fertilizers, pesticides).

Urban runoff and animal wastes from horses and other domesticated species, when washed into the creeks of the watershed, may be acutely toxic to steelhead and other fish or aquatic species. Chronic toxicity and/or indirect effects of these loadings may also counteract sustained regional efforts to improve and restore populations of steelhead. Each of the other sources can also have chronic or acute toxicity as well.

2.2 Related water-quality studies in the watershed

Only one subwatershed-scale investigation of water quality has recently been underway. As part of a grant from the Packard Foundation, the San Francisquito Watershed Council asked Balance to conduct a three-year water quality study in the Bear Creek portion of the larger watershed during water years 2000 through 2002. Balance has reported the results of the initial year of monitoring (Owens and others, 2001) and data from subsequent years are currently being evaluated. Published and unpublished data from the Bear Creek study are used in this report as a basis for comparison. The Bear Creek watershed encompasses the northwestern headwaters of San Francisquito Creek, as shown in Figure 1. Thus, water-quality problems in the Bear Creek watershed directly affect nearly all other spawning and rearing areas in the San Francisquito Creek watershed. Conversely, measures which control causes of toxicity to fish in the Bear Creek system will benefit nearly the entire local steelhead population, as well as other species in the San Francisquito Creek watershed. Knowledge of natural and anthropogenic factors affecting water quality in Bear Creek can help in planning and assessing water quality elsewhere in the watershed.

3. STATION LOCATIONS

3.1 Piers Lane Stations

The two stations that Balance monitored for this study are located within 100 yards of each other, just upstream of the confluence of San Francisquito and Los Trancos Creeks, where Piers Lane crosses both creeks (Figure 1). We have designated the two stations as San Francisquito Creek at Piers Lane (SFPL) and Los Trancos Creek at Piers Lane (LTPL). Each station is equipped with a datalogger and an automated sampler within an enclosure, several water-quality probes, and a streamside staff plate. Water levels are measured by a sonar transponder mounted on the bridge above the creek at each site. The probes include:

- a specific conductance probe;
- a dissolved oxygen probe; and
- a pH sensor.

Both the specific conductance and dissolved oxygen probes also measure water temperatures. The San Francisquito station includes a tipping-bucket recording rain gauge.

3.2 Other Stations Within the Watershed

As part of a series of cooperating projects, Balance also monitored a number of locations upstream of Piers Lane during water year 2003. The main focus was monitoring streamflow and sediment discharge. Data from some of these other stations are used in this report for comparison to the data collected at the Piers Lane stations. Comparison of flow records among stations helps to provide a check on the gaging data and also helps us to describe and document differences in hydrologic responses to rainfall. These differences are proving larger than expected, such as very low baseflows on West Union Creek or flashy storm peaks on Dry Creek, and may prove in and of themselves to be of significance to stream management, including steelhead restoration. Selected stations are described below.

3.2.1 Bear Creek subwatershed stations

Balance operated a gaging station on Bear Creek at Sand Hill Road during water year 2003 but only minimal water-quality measurements were made this year. This station was one of eight stations in the watershed (Figure 1) that were regularly monitored during water years 2000 to 2002 on behalf of the San Francisquito Watershed Council, as part of the 3-year Packard Foundation study discussed above in Section 2.2. The Bear Creek at Sand Hill Road station is the closest station to the Piers Lane sites, only about 2.5 miles upstream. Approximately one-half of the San Francisquito Creek watershed above the SFPL site lies upstream of the Sand Hill Road station.

The Bear Creek at Sand Hill Road station became the fourth station in the LTMAP monitoring network in fall 2003 (WY2004) when a datalogger and automated water quality sampler were installed through the combined efforts of Stanford Management Co., Stanford Linear Accelerator Center, and the Jasper Ridge Biological Preserve. Regular monitoring at this station commenced again in water year 2004.

3.2.2 Los Trancos Creek at Arastradero Road

Balance operates another station on Los Trancos Creek about 1.8 miles upstream of Piers Lane on behalf of Stanford University Utilities Division. This upstream station has been in operation since November 1994.

3.2.3 Searsville Sub-Watershed Stations

Balance operated gages at Searsville Dam and on Corte Madera Creek at Westridge Drive during water year 2003. Data collection from the Searsville sub-watershed stations focuses on sediment transport. Searsville and Corte Madera flow data were considered in this report where such comparisons were useful.

3.2.4 U.S. Geological Survey Station on San Francisquito Creek

USGS stream gage #1164500 (San Francisquito Creek at Stanford University) is located approximately 0.5-miles downstream from the two Piers Lane stations. This station was originally established in 1931, and has maintained a continuous record of flow since 1954. Suspended-sediment data (but not bedload sediment) were collected by USGS during the mid-1960s through early 1970s (Brown and Jackson, 1973), but the agency has not regularly collected subsequent data.

4. HYDROLOGIC SUMMARY, WATER YEAR 2003

Observations and measurements from our water year 2003 site visits are documented in Table 1 (San Francisquito Creek) and Table 2 (Los Trancos Creek). Daily flow hydrographs for the two streams are plotted in Figures 2 through 5.

Baseflows were low at the beginning of the water year in early October 2002. After a brief rise following the first seasonal storm on November 7, flows remained below one cubic feet per second (cfs) until mid-December, when a series of storms produced the highest water levels and flow rates of the water year. This occurred on December 16, 2002, with a calculated peak flow rate of about 2,700 cfs on San Francisquito Creek and a peak flow of about 1,000 cfs on Los Trancos Creek. The peak water level at the USGS gage downstream on December 16 approximately equalled a 5- to 7-year flood event. The remainder of the winter was mostly dry and punctuated by small-to-moderate rainfall events. However, a series of spring storms produced moderate peaks on March 15, April 13, and April 28, 2003. The last significant rainfall of the water year 2003 season occurred in early May.

4.1 Precipitation

The rainfall record is plotted alongside the flow hydrographs in Figures 4 and 5. The tipping-bucket rain gauge at Piers Lane recorded a total of 26.82 inches for the season. This value is approximately 145 percent of the long-term mean annual precipitation of approximately 18.5 inches for the station location (Rantz, 1971). The California Data Exchange Center (CDEC) shows that water year 2003 rainfall for two index precipitation stations in this region, Mount Hamilton and the San Francisco Airport, was also above-normal at 117 to 120 percent of long-term average values. The monthly pattern shows that precipitation in December, April, and May was well above average, while rainfall in January, February, and March was below average.

4.2 Unexplained Flow Surges

During summer of water year 2002, we observed and recorded abnormal flow peaks on Los Trancos Creek more than a mile upstream from Piers Lane. Flows entering the stream from a tributary upstream were muddy and substantially more saline than the ambient creek water. Specific conductance (a measure of salinity) downstream in Los Trancos Creek at Piers Lane was also higher than expected on the same date.

We did not observe or record any similar, obviously-abnormal flow peaks this year (water year 2003) and specific conductance values measured during late-season, low-flow periods in Los Trancos Creek were lower than those observed the previous year (Figure 7).

In past years (but not in water year 2003), we have also noted small flow peaks that occur during non-storm periods and which do not show the characteristic shape of a runoff response to rainfall. It is possible that similar flow surges occurred without detection during this water year. We have hypothesized that these flow surges resulted from human activity in the watershed upstream of our gage location but have not identified a cause or located a source. The flow surges that we have observed probably do not have a large effect on total flow for the year but they do appear to substantially affect the salinity of the creek, particularly during the dry season when flows are low. We do not know what other constituents may be elevated during such peaks. These sudden pulses, although small, could also disturb aquatic biota and adversely affect in-stream conditions during low-flow periods.

4.3 Creating a Record of Streamflow

We develop a record of streamflow in two steps. First, a record of water levels is compiled from the recorded electronic data and calibrated with field observations. Flow rates are then computed from the water levels using empirical equations developed specifically for each site from field measurements.

4.3.1 Developing a record of water levels

Each of the two stations is equipped with an ultrasonic sonar transponder connected to an American Sigma 950 flow meter. The equipment measures and records the water level in the creek at 15-minute intervals. We found that observed high-water marks corresponded well with the recorded peaks. This year, the equipment did not record any false peaks, so we had no need to filter them out in the data analysis process[3], as we did in the previous year. At low flows, the sonar transponder values have a large amount of variation, up to about 0.3 feet per day. We believe that most of this variation is "noise" in the instrument reading and does not reflect actual changes in water-levels,

[3] False peaks have a shape that was different from actual peaks and were substantially higher than concurrent high-water marks observed on the streambanks.

although creek levels usually do have a lower-amplitude (0.02-foot) diurnal pattern during low-flow periods.

4.3.2 Computing flows

Based on our periodic site visits, staff plate readings, and flow measurements (Tables 1 and 2), we create an empirical stage-to-discharge relationship ("stage-discharge rating curve") for each gage. This rating curve is then applied to the datalogger and sonar-transponder record of water levels. During this year, as is typically done, we applied multiple stage shifts to account for changes in algal growth, sedimentation, and leaf dams in the channel downstream of the gages that affected the water-level elevation at the monitoring locations. Due to the noise in the stage data, the flow record also becomes "noisy" at the 15-minute level of detail. However, mean daily values appear to be fairly accurate because the daily averaging removes most of the noise.

As with all other gaging of natural streams, some uncertainty remains (especially at high and low flows) in spite of efforts to be as precise as possible. We do not have measurements for each year at the peak flow levels; our peak-flow estimates for this study are based on: 1) extension of the stage-discharge curve from our highest measured flow to the peak water level recorded by the monitoring equipment (one of several accepted methods), 2) float-test velocities, and 3) by correlation to the downstream USGS gage (which has an established rating curve).

5. WATER QUALITY SAMPLING APPROACH

Larry Walker Associates developed the water quality monitoring plan for the two LTMAP stations at Piers Lane while under contract to the City of Palo Alto (LWA, 2001). Their *Draft Surface Water Quality Monitoring Plan 2001/02*, available from the City of Palo Alto, provides a complete description of the methods and protocols used in this study. Interested readers are referred to that document for additional detail.

5.1 Timing of Sampling Visits

The hydrologic conditions during which a sample is taken is an important factor. For example, sampling baseflow in April can be expected to provide very different results from sampling a "first-flush" event[4] in October. The Piers Lane monitoring program is designed to measure field parameters on each sampling visit. Samples for ammonia, nitrate, mercury, total and dissolved metals, and organophosphate pesticide analyses are collected during storm or baseflow sampling on alternate visits, approximately five times annually. Sediment sampling occurs from fall through spring, when flows are sufficiently elevated to transport sediment, but not in summer.

5.2 Field Measurements and Laboratory Analyses

The focus of the study is on characterizing water quality in the two streams during both baseflow and storm periods, particularly with regard to those constituents potentially affecting fisheries and aquatic habitat conditions. Thus, the sampling plan includes a broad range of chemical constituents, and both total and dissolved constituent analyses:

<u>Field Measurements</u>

- streamflow (cubic feet per second, or cfs)
- specific conductance (umhos/cm @ 25°C)
- water temperature (°C)
- dissolved oxygen (mg/L)

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[4] "First-flush" refers to a storm event that is strong enough to produce runoff and which occurs after a period of weeks or months of dry weather. The term is typically applied to the first major storm event of the wet-season but it may also be used to describe any significant storm occurring after a prolonged dry period. Since first-flush storms mobilize accumulated sediment, litter, nutrients and other pollutants, the resultant runoff often contains higher concentrations of these constituents than are observed in runoff from subsequent storms.

- pH
- qualitative remarks, for example, odors, color, clarity, (if noticeable), and anomalies

Laboratory Analyses

- trace metals (aluminum, copper, lead, mercury, nickel, selenium, silver and zinc)
- organophosphate pesticides (diazinon and chlorpyrifos)
- nitrate-nitrogen and ammonia nitrogen
- phosphorus
- total hardness (also needed to interpret metal toxicity)
- total suspended solids

5.3 Exceptions and Deviations from Proposed Methods

Deviations almost inevitably occur in hydrologic studies, usually at very high or low flows, such as the responses necessary when a tree falls or other changes in the channel at the sampling location are encountered. During this second year of monitoring, we were unable to complete the following items as they were initially outlined in the project proposal:

- Some of the composite samples were collected as time-paced samples and some were collected as flow-paced samples (see Appendix B). During low flows, flow-paced sampling is unreliable due to the large daily fluctuations in the sonar transponder readings, so we programmed the sampler to take time-paced samples. During higher flows, we employed flow-paced sampling. We plan to continue using either time-paced or flow-paced sample collection as appropriate during water year 2004.

- The specific conductance probes appear to have not worked properly from the inception of monitoring and repeated attempts to calibrate the probes have been unsuccessful. As the existing probes are unreliable, we will continue to make manual measurements of specific conductance on most site visits in water year 2004.

- Similarly, both the dissolved oxygen and pH probes have worked only intermittently since the station was installed. The probes require frequent maintenance to maintain operation, even during baseflow (non-storm) periods, and foul even more rapidly when flows are high. Dissolved oxygen was measured occasially during water year 2003 with a hand-held meter; pH was measured occasionally using pH paper test strips and a hand-held meter. We are using manual pH and dissolved oxygen meters to sample stream flows in water year 2004. Given the unreliability of the two installed probes, the record for these two parameters will consist solely of manual measurements.

Recommendations for improving the monitoring program during water year 2004 and subsequent years are presented briefly in Section 7 below.

6. RESULTS AND DISCUSSION OF WATER QUALITY SAMPLING

This chapter includes a discussion of findings by individual constituent or constituent group. The dates when water quality samples were collected, the reporting limits, and the analytical results are presented in Table 3. All laboratory reports are collected in Appendix A. Detailed hydrographs showing the timing of sample collection for various constituents during each of the five water-quality sampling visits are graphically presented in Appendix B. Geologic influences which appropriately should be considered in interpretations are summarized in Appendix C.

6.1 Regulatory Standards and Objectives

Table 3 includes three sets of values for comparison with the WY2003 water-quality sampling results. The U.S. EPA criteria promulgated by the California Toxics Rule (CTR) currently apply throughout the region *except* for the South Bay below the Dumbarton Bridge and tributary streams which discharge into this portion of the Bay. In the South Bay, San Francisco Bay Regional Water Quality Control Board water quality objectives, established in the 1995 Basin Plan, still apply. However, the Regional Board has proposed a Basin Plan amendment, currently undergoing environmental review, that updates the water quality objectives for seven pollutants [arsenic, cadmium, chromium (VI), copper, lead, silver, and zinc] to be consistent with the U.S. EPA criteria. In particular, the Basin Plan objectives are currently expressed as total recoverable, rather than the more bioavailable dissolved concentrations, because they were established in 1986, preceding the U.S. EPA directive on aquatic life criteria for metals. The more protective Basin Plan objective for mercury, as well as existing objectives for nickel and PAHs, will be retained.

6.2 Specific Conductance

Specific conductance, a widely used index for salinity or total dissolved solids (TDS), was measured in the field and recorded at field temperatures, then later converted to an equivalent value at 25°C according to the accepted relationship between specific conductance and temperature. The expected range of specific conductance in the San Francisquito Creek Watershed is from about 100 to 1500 µmhos/cm, normalized to 25°C.

The lowest levels occur during storms, when flows are diluted with rain and fresh runoff.

In general, specific conductance levels at both stations followed the expected pattern, with higher specific conductance (higher salinity) at low flows, and lower levels occurring during storm events (Figures 6 and 7; Tables 1 and 2). This pattern can best be discerned from our manual measurements, as the automated specific conductance probes seem to have barely worked, if at all. Specific conductance during baseflow periods was higher in Los Trancos Creek than in San Francisquito Creek, as was observed in water year 2002. However, dry-season specific conductances in Los Trancos Creek were lower this year than during water year 2002 (Figure 7). This may be due to slightly higher baseflows or less influx of high-salinity waters from unknown sources.

6.3 Nitrogen

Ammonia-nitrogen concentrations[5] in streams are generally low because ammonia is rapidly taken up by plants or microbially converted to nitrate nitrogen. The un-ionized ammonia fraction, which is toxic to fish and aquatic invertebrates, increases with increased pH and water temperature. Samples collected on November 7, 2002, immediately preceding the first-flush storm of water year 2003, were the only samples where ammonia-nitrogen concentrations were above the detection limit (Table 3). Assuming a pH of 8.0[6] and water temperature of 15 ˚C (see Figures 10 and 11), un-ionized ammonia would be about 2.65 percent (Goldman and Horne, 1983: p. 127) of the total ammonia-nitrogen concentrations of 1.2 mg/L in San Francisquito Creek and 0.79 mg/L in Los Trancos Creek. The Regional Board has not established a specific acute toxicity objective for ammonia but the resulting un-ionized ammonia concentration of 0.032 mg/L in San Francisquito Creek would exceed the 0.025 mg/L threshold for chronic (annual median) exposure to un-ionized ammonia cited in the Basin Plan (RWQCB, 1995). In Los Trancos Creek, the un-ionized ammonia concentration of 0.021 mg/L would be slightly below the chronic toxicity objective.

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[5] Nitrate and ammonia concentrations are reported herein as mg/L nitrate-nitrogen. One mg/L nitrate-nitrogen is equivalent to 4.4 mg/L of nitrate, and one mg/L of ammonia-nitrogen is equivalent to 1.2 mg/L of ammonia.

[6] No pH measurement was made at the time the Nov. 7 sample was collected, however, pH in both streams was about 8.0 when measured during other baseflow periods (see Figures 10 and 11).

We note that the U.S. EPA has recommended updated maximum (acute) and continuous (chronic) water quality criteria for total ammonia. These revised criteria are currently being considered for adoption by the Regional Water Quality Control Board, Los Angeles office (Region 4). At a pH of 8.0 and water temperature of 15 ˚C, the continuous concentration criteria is 2.32 mg/L total ammonia when fish early life stages are present and 2.36 mg/L when fish early life stages are absent. At the same pH value[7], the maximum concentration of total ammonia is 5.62 mg/L when salmonids are present and 8.41 mg/L when salmonids are absent. Total ammonia concentrations observed in San Francisquito and Los Trancos Creeks in November 2002 were well below these regulatory thresholds.

Nitrate-nitrogen concentrations were above the detection limit in both streams on all five sampling dates in water year 2003 and followed a similar pattern. Nitrate-nitrogen concentrations ranged from 0.8 to 5.5 mg/L in San Francisquito Creek, and from 1.6 to 5.7 mg/L in Los Trancos Creek, as compared to a range of 0.43 to 1.8 mg/L for the two mid-winter baseflow samplings in water year 2002. Concentrations are generally expected to be highest during intermediate flows, when sufficient runoff is present to flush nitrate into the stream but flows are below the threshold where nitrate concentrations become highly diluted by fresh runoff. While nitrate concentrations were highest in samples collected in November 2002 and August 2003, when stream flows were lowest (Table 3), the lowest concentrations in both streams were measured in samples collected in late June 2003, when flows were only marginally higher. These results suggest that during non-storm periods, the source(s) and sink)s) of nitrate are not constant and can vary considerably. Similar seasonal variability is reported for other streams in the region.

Nitrate-nitrogen concentrations in the flow-paced samples collected during the mid-December 2002 and late-February 2003 storms were moderately-elevated (2.0 to 3.1 mg/L) but well below current levels of concern (Table 3). We note that the U.S. EPA has recommended a threshold of about 0.5 mg/L *total* nitrogen for potential adoption in 2004 (U.S. EPA, 2000). The *Pajaro River Watershed Water Quality Management Plan* (Applied Science and Engineering, 1999) reported that nitrate-nitrogen concentrations of 0.05 to 2.0 mg/L would be expected in "uncompromised" streams draining the Santa Cruz Mountains. For comparison, nitrate-nitrogen concentrations at the closest Bear Creek station, at Sand Hill Road about 2.5 miles upstream from Piers Lane, ranged from

[7] The U.S. EPA maximum value is not temperature-dependent but depends on pH and fish species present.

0.16 to 2.50 mg/L during a 3-year study encompassing water years 2000 through 2002 (Balance Hydrologics, unpublished data). Concentrations were typically between 0.6 and 1.0 mg/L during winter baseflow periods, similar to levels observed during mid-winter baseflow sampling in San Francisquito and Los Trancos Creeks during water year 2002.

6.4 Pesticides

San Francisquito Creek is listed by the State Water Quality Control Board as being impaired by the common organophosphate pesticide, diazinon. Concentrations of diazinon, and another common organophosphate pesticide, chlorpyrifos, were below the detection limit on all five dates sampled (Table 3). For comparison, during the Bear Creek water-quality study, diazinon was detected only once in three years, at 15.3 ug/L in October 2000, and chlorpyrifos was never detected in any sample.

6.5 Trace Metals

Samples collected in November and December 2002, and in February, June and August 2003, were analyzed for a suite of total and/or dissolved concentrations of trace metals commonly associated with urban and suburban development in the San Francisquito Creek watershed: aluminum, copper, lead, mercury, nickel, selenium, silver, and zinc. All metals were detected in either the dissolved or solid form in both streams on one or more sampling dates.

Dissolved metals concentrations are of greatest potential concern, since this form is most bio-available to aquatic organisms. The water quality objectives for metals are hardness-dependent, since calcium and magnesium (the primary components of hardness[8]) act to buffer metals toxicity. We note that the upper limit of hardness used by the Regional Board to assess the effects of metal concentrations is typically 400 mg/L. At the hardness levels observed in San Francisquito Creek and Los Trancos Creek in water year 2003 (150 to 550 mg/L as $CaCO_3$), the potential toxicity of trace metal ions is low. In Table 3, the regulatory values included for comparison are calculated for the range of 250 to 500 mg/L as $CaCO_3$.

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[8] The convention is to express total hardness in terms of an equivalent concentration of calcium carbonate ($CaCO_3$).

6.5.1 Aluminum

In both streams, total aluminum concentrations were higher in composite samples from the November 2002 first-flush sample, and in the samples from subsequent storms (Table 3), than in the two samples from summer baseflows. This is not unexpected since aluminum is a naturally occurring component of the silts and clays that largely comprise suspended sediment, and the acid digestion for total metal analyses typically releases a much larger amount of the mineral than is naturally present in the stream. Accordingly, dissolved aluminum concentrations in the November and December 2002 samples were two orders of magnitude lower than the total aluminum concentrations, and nondetectable in the samples from the February 2003 storm and in dry-season sampling. Concentrations of aluminum in both forms were similar to published values for aluminum concentrations in surface waters in natural streams of the United States (Hem, 1985), which include contributions from urban sources. Aluminum concentrations were not analyzed in the Bear Creek study.

6.5.2 Copper

Total copper concentrations were 74 µg/L in first-flush samples from both creeks during the November 2002 storm (Table 3). This value was the highest concentration observed in San Francisquito Creek during water year 2003; however, the total copper concentration was even higher (82 µg/L) in the sample collected from Los Trancos Creek during the December 2002 storm. On both dates, values in both stream samples exceeded the aquatic acute and chronic (4-day average) toxicity objectives for total copper established by the Regional Board and the U.S. EPA. Total copper concentrations for the subsequent wet-season sample in February 2003 were much lower, while concentrations in the two dry-season samples ranged from 1.6 to 2.2 µg/L, similar to winter baseflow values from water year 2002[9], and well below regulatory standards.

Concentrations of dissolved copper in both streams ranged from 1.6 to 17.0 ug/L, with the highest values observed in samples from the November 2002 storm, and the lowest values from dry-season sampling in August 2003. In all cases, dissolved copper concentrations were well below the acute and chronic toxicity objectives for dissolved copper established by the Regional Board and the U.S. EPA (Table 3). For comparison,

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[9] The similarity between the WY2003 dry-season samples and the WY2002 winter baseflow samples is that these samples were collected during non-storm periods. No conclusion regarding trends in wet- or dry-season metals concentrations in these two streams is intended.

in the Bear Creek study, concentrations of dissolved copper at the Sand Hill Road station ranged from 1.8 μg/L to 9.9 μg/L during the wet season.

6.5.3 Lead

Total lead concentrations ranged from nondetectable to 30 μg/L in samples from Los Trancos Creek in water year 2003, and slightly lower (nondetectable to 17 μg/L) in samples from San Francisquito Creek (Table 3) but the same trend was apparent in both streams. Lead concentrations were slightly higher in samples collected during the December 2002 storm than in first-flush samples collected the previous month. Concentrations measured during both events exceeded the aquatic chronic toxicity objective but not the acute toxicity objective established by the Regional Board and the U.S. EPA. Lead concentrations were low or nondetectable in samples collected during the February 2003 storm and the two dry-season sampling events, and well below regulatory objectives.

Concentrations of dissolved lead were below the detection limit in 4 of 5 samples from San Francisquito Creek, and in 3 of 5 samples from Los Trancos Creek. Where detected, concentrations were between 0.5 and 1.6 μg/L, well below the Regional Board and the U.S. EPA standards. The predominant source of lead is probably residues from leaded gasoline, bound to organic matter or soil near roads and highways, and transported in urban runoff. For comparison, in the Bear Creek study, concentrations of dissolved lead ranged from 2.6 to 8.4 μg/L in wet-season storm samples from stations in the Dry Creek watershed, which receives runoff from Highway 280. Lead concentrations were nondetectable in samples from stations in other watersheds monitored during the same study. Lead is rarely reported from streams or wells in the region where human influences are minimal, and does not seem to have a significant or discernible geologic source, although likely present in trace quantities.

6.5.4 Mercury

Mercury is of increasing concern locally, as studies document remobilization of mercury from sediments deposited in San Francisco Bay during the hydraulic gold-mining era, and bioconcentration in fish and waterfowl once inorganic mercury is biomethylated by microbes.

Water year 2002 samples from the Piers Lane sites were not analyzed for mercury. In addition, the grab and composite samples from the first two storms of water year 2003 were mistakenly submitted to the laboratory with a request for low-level mercury analysis (reporting limit of 0.05 to 0.10 μg/L), rather than the trace-level analysis (reporting limit of 0.0005 μg/L) specified in the monitoring plan (LWA, 2001). Subsequent samples collected in February, June and August 2003 and analyzed at the lower detection limit produced detectable concentrations of both total and dissolved mercury. Thus, it is likely that the samples from the November and December 2002 storms, where mercury was reported as nondetectable, would also have shown detections if trace-level analysis had been undertaken.

Total mercury concentrations in samples from San Francisquito Creek ranged from 0.0009 to 0.06 μg/L during water year 2003, while total mercury concentrations in samples from Los Trancos Creek ranged from 0.0010 to 0.021 μg/L. Concentrations were typically slightly higher in Los Trancos Creek, although trends were the same in both streams, with the highest concentrations measured in samples collected just before and during the first-flush storm of November 2002 (Table 3). Concentrations of dissolved mercury, while below the (elevated) detection limit in the November and December 2002 storms, ranged from 0.0010 to 0.0019 μg/L in San Francisquito Creek, and from 0.0010 to 0.0048 μg/L in Los Trancos Creek. Levels of total mercury in the November 2002 samples from both creeks exceeded the Regional Board standard of 0.025 μg/L; total and dissolved mercury concentrations in all other samples were well below the regulatory standard. Mercury concentrations were not analyzed in the Bear Creek study.

6.5.4 Nickel

Total nickel concentrations ranged from 3.7 to 38 μg/L in San Francisquito Creek, and from 3.5 to 117 μg/L in Los Trancos Creek during water year 2003 (Table 3). As observed for lead, total nickel concentrations in both streams were higher during the second storm of water year 2003 than during the November 2002 first-flush event. The lowest values observed, during the two dry-season sampling events[10], were similar to winter baseflow values measured in spring 2002. All concentrations were far below the aquatic acute and chronic toxicity objectives established by the Regional Board and the U.S. EPA.

[10] Due to a miscommunication, Regional Water Quality Control Plant laboratory staff did not analyze nickel concentrations in samples collected February 24-25, 2003.

Dissolved nickel concentrations, which ranged from 3.1 to 10 μg/L, were similar in both streams for all events and similar to levels measured during water year 2002. In contrast to levels of total nickel, concentrations of dissolved nickel were highest during the first-flush event of November 2002. The lowest values were measured in samples collected during the dry season. Again, all values were far below acute and chronic toxicity objectives established by the Regional Board and the U.S. EPA.

6.5.6 Selenium

Total selenium concentrations ranged from 0.3 to 1.3 μg/L in San Francisquito Creek, and from 0.2 to 2.1 μg/L in Los Trancos Creek, during the four water year 2003 events where samples were analyzed for this constituent (Table 3) [11]. Concentrations were highest in the December 2002 event, the major storm of the water year 2003 wet season. Samples from Los Trancos Creek had slightly higher total selenium concentrations for both the November and December 2002 storm samples than samples from San Francisquito Creek. Selenium concentrations in subsequent wet- and dry-season samples were lower and similar in both streams, and in the same range as wet-weather baseflow samples collected in water year 2002.

Concentrations of dissolved selenium in both streams ranged from nondetectable to 0.3 μg/L, only slightly above the detection limit of 0.1 μg/L, and followed a similar trend. As observed for total selenium concentrations, dissolved selenium concentrations were similar to values measured in winter baseflows during water year 2002.

Selenium concentrations were not analyzed in the Bear Creek study but these concentrations are within the background range expected for this element, which is present in rocks throughout the watershed. All values were well below the U.S EPA aquatic acute toxicity objective of 20 μg/L and the chronic toxicity objective of 5 μg/L.

6.5.7 Silver

Concentrations of silver were below the detection limit in winter baseflow samples from water year 2002 and was only detected once in each stream during water year 2003 (Table 3). The total silver concentration was 0.3 μg/L in the Los Trancos Creek composite sample from the December 2002 storm. In San Francisquito Creek, the dissolved silver concentration was 0.3 μg/L during the August 2003 dry-season

[11] Due to a miscommunication, Regional Water Quality Control Plant laboratory staff did not analyze selenium concentrations in samples collected August 19-20, 2003.

sampling. All other samples from both creeks were below the detection limit for silver. Concentrations of total and dissolved silver were well below the aquatic instantaneous maximum value established by the U.S. EPA; no acute or chronic toxicity standards have been established for silver at this time.

6.5.8 Zinc

Zinc tends to be substantially more abundant and more soluble than other trace metals. In general, as with specific conductance and other trace metals, one would expect higher zinc concentrations at low flows, when streams are fed primarily by mineral-enriched ground water, if zinc contributions were of geologic origin[12]. However, if concentrations increase as flow increases (as happened with the small data set from water year 2002), then the predominant source may include runoff from roads, roofs, galvanized fencing, and other human influences.

In water year 2003, total zinc concentrations ranged from nondetectable to 110 μg/L in San Francisquito Creek, and from nondetectable to 180 μg/L in Los Trancos Creek, and followed the same trend in both streams (Table 3). Total zinc concentrations were higher in Los Trancos Creek than in San Francisquito Creek on all dates where levels were above the detection limit. Samples from the November 2002 first-flush event had the highest concentrations, however, concentrations were only slightly lower in the subsequent storm the following month (December 2002). Concentrations measured during both events exceeded the aquatic acute and chronic toxicity objectives established by the Regional Board but were well below the acute and chronic toxicity objectives established by the U.S. EPA. Zinc concentrations were much lower in samples collected during the February 2003 storm, similar to levels observed during water year 2002 wet-season baseflow sampling, and well below regulatory standards. During the dry season, total zinc concentrations in both streams were below the detection limit.

Dissolved zinc concentrations ranged from 9.0 to 25 μg/L in San Francisquito Creek, and from 7.0 to 40 μg/L in Los Trancos Creek. Concentrations were highest in Los Trancos Creek on all dates except the August 2003 sampling. In contrast to results for total zinc concentrations, levels of dissolved zinc were slightly higher in samples collected during

[12] Elsewhere in the Santa Cruz Mountains, zinc and cadmium are reported in elevated concentrations in both waters and sediment emanating from portions of the Monterey formation and the lower Purisima formation (c.f., Rickers and others, 2001; also, see Majmundar, 1980). Both units outcrop in portions of the San Francisquito and Los Trancos subwatersheds (Balance Hydrologics, 1996). Both formations are also known geologic sources of phosphate.

the December 2002 storm than in the November first-flush event. All analytical results for dissolved zinc were well below the aquatic acute and chronic toxicity objectives established by the Regional Board and the U.S. EPA.

For comparison, in our previous work on Bear Creek, the Sand Hill Road station regularly had the highest concentrations of dissolved zinc of all stations in the watershed, with wet-season concentrations ranging from non-detectable to 85 μg/L on April 6, 2000.

6.6 Temperature

Temperature strongly affects steelhead habitat. Although steelhead can withstand high water temperatures of 29˚C for a short period of time, and 25˚C for longer periods, they have progressively-increasing difficulty extracting dissolved oxygen from water at temperatures above 21˚C (Lang and others, 1998) and require a larger food source to sustain their elevated metabolism (Smith, pers. comm.). Therefore, water temperatures of 21˚C and below may be considered to provide adequate habitat, and values chronically above 25˚C even for short periods are likely not viable for the local steelhead population.

Balance staff made numerous manual measurements of water temperature and two probes continuously recorded water temperatures at each site (Figures 8 and 9). The majority of temperatures were within the acceptable range. Water temperatures appeared to be slightly cooler in San Francisquito Creek than in Los Trancos Creek during the wet season, and slightly higher during the dry season. From late June through early August 2003, maximum daily temperatures in San Francisquito Creek but not Los Trancos Creek regularly exceeded the 21˚C threshold. The maximum water temperature recorded at the SFPL station was 23.1°C on July 18 and 22, 2003. The maximum water temperature recorded at the LTPL station was 21.9°C on July 21, 2003. Manual temperature readings measured during site visits followed the same seasonal pattern and values matched temperatures recorded by the two probes (Figures 8 and 9).

6.7 Dissolved Oxygen and pH

As stated above in Section 5.3, the pH and dissolved oxygen (DO) probes were essentially non-functional in WY2003, so these parameters were measured periodically using hand-held meters and paper test strips (Tables 1 and 2, Figures 10 and 11). Based on limited sampling during WY2003, pH varied between 6.8 and 8.2 in San Francisquito

Creek, and between 7.7 and 8.5 in Los Trancos Creek. We note that fisheries biologists familiar with the northern Santa Cruz Mountains and San Francisco Peninsula streams have found that pH is very rarely a limiting factor in regards to steelhead habitat, so long as there is flow moving from pool to pool.

DO values in San Francisquito Creek varied from about 60 to 125 percent of saturation, based on limited sampling during WY2003. DO values in Los Trancos Creek were less variable, ranging from about 95 to 110 percent of saturation. We have found that manual DO values can vary considerably depending upon where in the creek the probe is placed. We have noted values ranging from about 15 to 60 percent saturation within about one foot distance; this situation seems to be more common in the fall, when dead leaves blown into the creeks have begun to rot but have not yet been flushed downstream by high flows from winter storms. During the winter and especially at high flows, when turbulence and cold ambient water temperatures promote oxygen saturation, we expect dissolved oxygen concentrations in the creeks to range from 10 to 14 mg/L (90 to 100 percent saturation).

6.8 Suspended Sediment

San Francisquito Creek is listed by the State Water Resources Control Board as impaired due to sediment loading. All creeks carry some sediment; problems can arise when creeks carry too much sediment. Biologically, too much fine sediment can reduce oxygen circulation to buried eggs, abrade fish gills, fill hiding and resting niches and impede post-storm feeding. Too much coarse sediment affects bed conditions in a number of ways that can constrain steelhead habitat, including filling pools and undercut banks, creating 'soft' beds that are prone to scour, and forming mid-channel bars that divert flows into the banks, inducing bank erosion. Excess sediment can also settle-out at low-gradient locations, reducing pool depths and decreasing the flood capacity of the channel.

Monitoring sediment concentrations and rates of sediment transport is important as a way of evaluating the amount of sediment being carried by the creek, to assess the mobility of spawning gravels and document changes that may signal improving or worsening conditions. Previous Balance reports have documented rates of sediment transported in various watersheds upstream from Piers Lane (Balance Hydrologics, 1996; Owens and others, 2001; Owens and Hecht, 2002), as well as the role of Searsville

Lake in trapping sediment and the contributions from different geologic formations. In this watershed, we have observed a number of sources, both natural (e.g., bank failure, landslides) and human-caused or -exacerbated (e.g., failure of culvert outfalls, construction erosion control measures, bank protection). Detailing these sources, however, is beyond the scope of this report.

Following convention, we distinguish two types of sediment in transport, each of which is measured during storms using specific types of samplers and sampling methods. Bedload sediment is supported by the bed of the stream; it rolls and saltates along the bed, commonly within the lowermost 3 inches of the water column. Movement can be either continuous or intermittent, but is generally much slower than the mean velocity of the stream. Bedload at the Piers Lane sites consists primarily of coarse sands and gravels, but at high flows can also include cobble-sized material. We have not yet measured bedload transport at the Piers Lane sites but these measurements can be done as the LTMAP matures.

Suspended sediment is supported by the turbulence of the water and is transported at a velocity approaching the mean velocity of flow. At Piers Lane, as elsewhere in the Santa Cruz Mountains, suspended sediment consists primarily of fine sands, silts, and clays. Total sediment discharge is the sum of bedload-sediment and suspended-sediment discharges. Suspended-sediment samples were collected from both stations throughout the water year at various dates and levels of flow (Table 4) using standard methods and equipment adopted by the Federal Interagency Sedimentation Program (FISP; see Hecht, 1983). All samples were analyzed by Soil Control Laboratories of Watsonville, California, a state-certified laboratory. Results are shown in Table 3 under "TSS". In Table 4, the reported concentrations (in units of milligrams per liter) were converted into an instantaneous "load" (in units of tons per day) by applying the streamflow at the time the sample was taken.

We then constructed suspended-sediment rating curves for each creek by plotting sediment load as a function of streamflow (Figure 12). Comparison of the data points in Figure 12 shows that Los Trancos Creek generally carries a higher suspended-sediment load *at a given flow* than San Francisquito Creek. However, it is important to note that flow in San Francisquito Creek is usually three to five times greater than flow in Los Trancos Creek, so San Francisquito Creek still transports more sediment. This is evident in the annual sediment summaries (Forms 3 and 4): the calculated total sediment load in San Francisquito Creek was about 55,000 tons in water year 2003, compared to about

7,000 tons in Los Trancos Creek. Higher rates of transport in a tributary is a usual condition, and nearly universal in the Bay Area (c.f., Hecht, 1983)

Figure 13 shows that suspended sediment loads as a function of flow, and total sediment loads for water year 2003, were similar to USGS sediment transport data collected at the downstream gage on San Francisquito Creek during the late 1960s and early 1970s (Brown and Jackson, 1973).

No suspended-sediment samples were collected when stream waters were clear, as was the case on most visits from spring through early fall 2003. From past experience, we have found that samples collected when the streams are clear produce no useful information because they test below the analytical reporting limits of 5.0 mg/L.

7. FUTURE MONITORING AND RECOMMENDATIONS

We believe that the sampling performed this year was useful and informative and achieved the second-year objectives of the long-term study. As compared to our work during the initial year, we were able to improve our sampling methods and achieve more complete sampling coverage due to greater familiarity with the equipment and the local hydrologic conditions at the two monitoring sites.

We plan to continue to perform a mixture of time- and flow-paced composite sampling in water year 2004. For very low flows (small first-flush storms) the noise inherent in the transponder signal will likely preclude the accurate readings necessary to employ flow-paced sampling. Thus, we plan to perform time-paced composite sampling for those storms. However, flow-paced sampling will typically be used for larger storms.

As in water year 2003, we plan to sample water quality on 5 occasions in water year 2004. Our focus will continue to be on monitoring "first-flush" storms in late fall and early winter, and larger less-frequent mid-winter storms, which result in the highest concentrations and/or largest loads of total and dissolved metals and other sediment-related constituents. We will also perform one or two non-storm (baseflow) samplings in the late spring and summer months, when salinities, temperatures and nitrogen concentrations may be elevated.

The specific conductance, dissolved oxygen and pH probes at both stations continue to be fouled or non-functional. We have installed a different brand of specific conductance probe at other locations, including the station on Bear Creek at Sand Hill Road, with good results. Automated collection of specific conductance data is particularly important in detecting transient changes in salinity related to unauthorized discharges or diversions. Thus, we recommend that replacement probes be installed at the two Piers Lane monitoring stations if sufficient budget becomes available. The automated pH and dissolved oxygen probes at these sites require visits at intervals of about two weeks to clean the probes, clear fouling and maintain functioning, a frequency that clearly exceeds the envisioned budget for this study. While the LTMAP team reviews the need for automated data collection of these parameters, we plan to continue making manual pH and dissolved oxygen measurements to measure stream conditions during water year 2004.

Finally, the three original LTMAP monitoring stations are all located in the lower San Francisquito Creek watershed. A fourth station was recently installed upstream on Bear Creek at Sand Hill Road and monitoring commenced in fall 2003. Stanford and the San Francisquito Watershed Council have explored addition of one or more stations further upstream if funding could be secured. Extending the monitoring network higher in the watershed should provide greater understanding of longitudinal variation in water quality and stream flows and more fully represent conditions throughout the watershed. Because conditions change more rapidly in headwater streams, monitoring further upstream improves our understanding of temporal variations in addition to advanced warning of pulses or other anomalous loads which may be moving downstream.

8. CONCLUSIONS

1. Rainfall and streamflow totals for water year 2003 were above average. Based on data from other locations in the watershed, the peak flow for the year was about a 5- to 7-year recurrence-interval flood.

2. We successfully collected composite samples on five occasions throughout the year using a combination of flow-paced and time-paced sampling.

3. Most water-quality probes attached to the dataloggers worked poorly or not at all under the sediment-laden conditions prevailing in the San Francisquito Creek watershed. Different brands of probes might work better, or the method of mounting them may need to be adjusted to prevent fouling and burial by sediment.

4. Mean daily water temperatures at the two sampling stations were regularly below 21°C, although maximum temperatures in San Francisquito Creek regularly exceeded the 21°C threshold from late June through early August. Temperatures in San Francisquito Creek appeared to be slightly cooler than in Los Trancos Creek during the wet season, and slightly warmer during the dry season.

5. Organophosphate pesticide concentrations were below detectable limits on all five dates sampled, including the distinct first-flush event in November 2002. Given the small number of total sampling dates (five this year, two last year), further sampling should be performed before concluding when or if these pesticides are present or absent in the two streams.

6. Ammonia-nitrogen was detected only during the first-flush storm in November 2002. At assumed levels of pH and temperature, the estimated concentration of un-ionized ammonia in San Francisquito Creek appeared to slightly exceed the Regional Board chronic (annual median) toxicity value, while the concentration in Los Trancos Creek was slightly below the regulatory threshold. Nitrate-nitrogen was detected at moderate levels in all samples, with the highest and lowest concentrations observed when streamflows were lowest. Levels were typical of those observed in other local streams.

7. All trace metals sampled (aluminum, copper, lead, mercury, nickel, selenium, silver and zinc) were detected in either the dissolved or total recoverable form at least once in each stream. Levels of these constituents tended to be highest during the first or second storm of the season, and lowest in samples collected during the dry season. Concentrations of total copper, total lead, total mercury and total zinc exceeded the aquatic acute and/or chronic toxicity objectives set by the U.S. EPA and the San Francisco Bay Regional Water Quality Control Board on one or more occasions. Concentrations of dissolved constituents were always well below levels of regulatory concern.

8. Sufficient suspended-sediment samples were collected from the two streams to calculate estimates of sediment transport totals for water year 2003. These estimates and qualitative observations indicate that conditions were typical of creeks in the San Francisquito watershed.

9. The addition of an LTMAP monitoring station in the upper watershed (Bear Creek at Sand Hill Road) for water year 2004 contributes substantially to the value of this study, and should provide a more comprehensive and representative understanding of hydrologic and water quality conditions throughout the entire watershed.

9. LIMITATIONS

Analyses and information included in this report are intended for use at the watershed scale and for the planning and long-term monitoring purposes described above. Analyses of channels and other water bodies, rocks, earth properties, topography and/or environmental processes are generalized to be useful at the scale of a watershed, both spatially and temporally. Information and interpretations presented in this report should not be applied to specific projects or sites without the expressed written permission of the authors, nor should they be used beyond the particular area to which we have applied them. Balance Hydrologics, Inc. should be consulted prior to applying the contents of this report to evaluating water supply or any out-of-stream uses not specifically cited in this report.

Readers who have additional pertinent information, who observed changed conditions, or who may note material errors should contact us with their findings at the earliest possible date, so that timely changes may be made.

10. ACKNOWLEDGEMENTS

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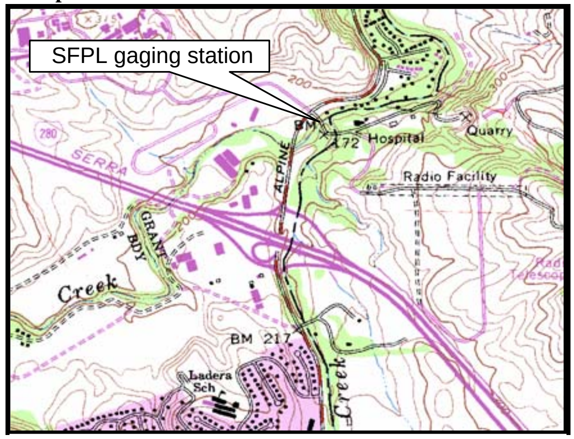
FORMS

Water Year:	2003	
Stream:	San Francisquito Creek	
Station:	Piers Lane	**SFPL**
County:	San Mateo County, CA	

Form 1. Annual Hydrologic Record

Map



Station Location / Watershed Descriptors

Latitude: 37° 24' 48" N, Longitude: 122° 11' 29" W in San Mateo County, CA. The gaging station is located directly under Piers Lane bridge at San Francisquito Creek, immediately upstream of its confluence with Los Trancos Creek. Land use includes open space, low-density residential, and some commercial uses. The watershed area above gaging station = 29.9 square miles.

Mean Annual Flow

Mean annual flow (MAF) for WY 2003 is 15.40 cubic feet per second (cfs)

Peak Flows

Date	Time[2] (24-hr)	Gage Ht. (feet)	Discharge (cfs)	Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)
11/8/02	9:45	6.36	328	2/16/03	3:15	5.90	219
12/14/02	18:30	7.56	708	2/25/03	5:15	4.93	66
12/16/02	**6:30**	**12.46**	**2706**	3/15/03	7:00	5.62	165
12/19/02	16:30	8.09	856	4/4/03	8:00	4.75	54
12/28/02	20:00	7.16	550	4/13/03	8:45	6.93	467
12/31/02	3:30	7.12	538	4/28/03	2:30	5.04	75
1/10/03	0:15	4.83	60	5/3/03	17:00	4.85	53

The peak for the period of record (October 2002 to September 2003) was 2706 cfs, on 12/16/02.

Period of Record

Equipment installed October 2001. Periodic site visits to measure flow, make observations, and collect water quality samples have been made since Feburary 2002. Gaging sponsored by Stanford University Utilities Division.

WY 2003 Daily Mean Flow (cubic feet per second)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1	0.29	0.10	0.24	59.75	6.37	11.85	5.37	20.10	2.03	0.40	0.49	0.30
2	0.28	0.12	0.25	37.17	5.69	10.66	7.63	22.99	1.77	0.34	0.47	0.30
3	0.27	0.11	0.26	25.55	4.19	12.57	9.75	38.04	1.40	0.35	0.45	0.29
4	0.27	0.09	0.27	21.30	5.43	11.55	23.67	30.14	1.43	0.34	0.44	0.29
5	0.26	0.11	0.28	18.92	5.13	9.91	11.83	21.24	1.43	0.35	0.44	0.28
6	0.24	0.15	0.33	16.28	4.70	7.86	7.01	18.21	1.59	0.34	0.44	0.28
7	0.21	3.25	0.36	13.79	4.56	7.33	7.32	14.74	1.41	0.38	0.40	0.30
8	0.21	68.50	0.36	12.24	4.40	7.04	7.17	13.42	1.36	0.40	0.41	0.27
9	0.25	3.07	0.77	17.22	4.05	7.00	6.61	12.66	1.55	0.37	0.38	0.32
10	0.25	0.89	0.92	39.39	3.88	7.11	6.53	9.42	1.33	0.38	0.39	0.32
11	0.22	0.65	0.56	24.96	3.93	8.72	6.54	8.63	1.30	0.38	0.37	0.29
12	0.21	0.38	0.46	20.25	7.56	8.56	73.05	7.46	1.29	0.40	0.36	0.29
13	0.21	0.27	138.87	17.75	7.86	9.34	222.93	6.54	1.29	0.40	0.36	0.29
14	0.18	0.22	327.55	14.63	6.09	11.22	53.48	5.96	1.10	0.44	0.38	0.30
15	0.20	0.21	142.52	11.46	7.98	66.50	32.66	5.66	1.00	0.39	0.35	0.30
16	0.19	0.22	782.44	10.02	87.37	28.77	25.47	5.31	0.98	0.37	0.36	0.29
17	0.15	0.19	150.67	9.08	22.99	20.02	22.36	5.05	0.79	0.39	0.35	0.29
18	0.18	0.18	47.79	8.93	14.34	14.03	19.27	5.19	0.84	0.38	0.34	0.29
19	0.17	0.21	260.31	10.48	12.51	9.93	15.94	4.27	0.70	0.36	0.35	0.30
20	0.18	0.21	304.94	10.31	10.36	8.72	14.67	3.97	0.61	0.37	0.34	0.29
21	0.16	0.23	123.07	13.50	9.01	8.28	15.15	4.01	0.60	0.37	0.37	0.26
22	0.17	0.24	47.30	12.31	8.02	7.46	15.63	3.43	0.54	0.41	0.38	0.23
23	0.18	0.24	28.25	11.99	7.76	7.71	13.27	3.46	0.56	0.40	0.35	0.26
24	0.18	0.23	20.58	11.23	13.95	7.91	26.17	3.48	0.49	0.43	0.36	0.26
25	0.16	0.24	16.03	10.19	45.26	6.08	28.39	3.95	0.41	0.41	0.33	0.27
26	0.16	0.23	13.96	9.19	22.44	5.68	27.54	3.51	0.38	0.42	0.31	0.27
27	0.13	0.21	11.88	8.06	20.43	5.21	21.58	3.12	0.35	0.41	0.31	0.29
28	0.09	0.22	164.17	7.91	15.01	6.12	51.44	2.74	0.33	0.40	0.32	0.31
29	0.10	0.22	237.32	6.93		4.50	38.85	2.63	0.33	0.41	0.33	0.32
30	0.11	0.26	58.81	6.77		6.05	24.59	2.28	0.36	0.46	0.32	0.32
31	0.11		226.38	6.59		7.40		2.10		0.51	0.31	
MEAN	0.19	2.72	100.25	16.26	13.26	11.33	28.06	9.47	0.99	0.39	0.37	0.29
MAX. DAY	0.29	68.50	782.44	59.75	87.37	66.50	222.93	38.04	2.03	0.51	0.49	0.32
MIN. DAY	0.09	0.09	0.24	6.59	3.88	4.50	5.37	2.10	0.33	0.34	0.31	0.23
cfs days	5.9	81.5	3107.9	504.2	371.3	351.1	841.9	293.7	29.6	12.2	11.6	8.7
ac-ft	11.8	161.6	6164.5	1000.0	736.4	696.4	1669.9	582.5	58.6	24.1	22.9	17.2

Monitor's Comments

1. We collected a continuous record for the entire water year.
2. Multiple stage shifts were applied to the rating equation; stage shifts adjust for local scour or fill and leaf debris build-up.
3. The upper portion of the rating curve is based on several high-flow estimates.
4. Daily values with more than 2 to 3 significant figures result from electronic calculations; no additional precision is implied.
5. Flow is regulated by multiple diversions and an upstream lake (Searsville Lake).

Water Year 2003 Totals:		
Mean annual flov	**15.40**	(cfs)
Max. daily flow	**782**	(cfs)
Min. daily flow	**0.09**	(cfs)
Annual tota	**5619**	(cfs-days)
Annual tota	**11146**	(ac-ft)

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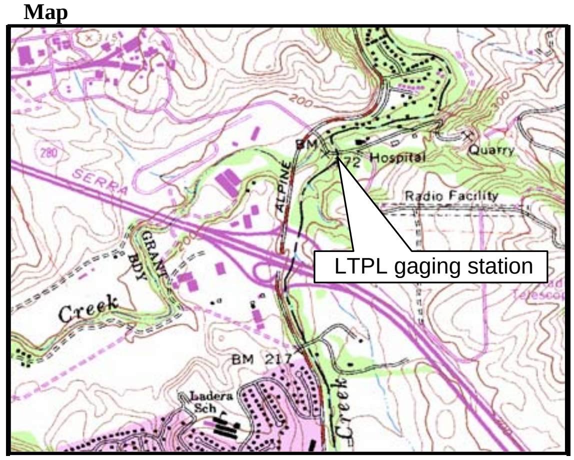
Water Year:	2003	
Stream:	Los Trancos Creek	
Station:	Piers Lane	**LTPL**
County:	San Mateo County, CA	

Form 2. Annual Hydrologic Record

Map



Station Location / Watershed Descriptors

Latitude: 37° 24' 48" N, Longitude: 122° 11' 29" W, in San Mateo County, CA. The gaging station is located under Piers Lane bridge at Los Trancos Creek. Land use includes open space, sports fields, small commercial areas, and low-density residential. There is a water diversion about 1.8 miles upstream. Los Trancos Creek watershed area above gaging station = 7.8 square miles .

Mean Annual Flow

Mean annual flow (MAF) for WY 2003 is 2.67 cubic feet per second (cfs)

Peak Flows

Date	Time[2] (24-hr)	Gage Ht. (feet)	Discharge (cfs)	Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)
11/8/02	10:15	4.36	155	2/16/03	2:00	3	65
12/14/02	16:45	4.83	229	2/25/03	1:45	2.4	33
12/16/02	**6:30**	**7.58**	**649**	3/15/03	7:00	2.75	54
12/19/02	16:15	5.93	309	4/13/03	7:15	4.05	145
12/28/02	18:00	5.60	250	4/28/03	9:15	2.17	19
12/31/02	2:30	6.78	416	5/3/03	9:45	1.85	8.9
1/10/03	0:30	1.88	10.2				

The peak for the period of record (October 2002 to September 2003) was 649 cfs, on 12/16/02.

Period of Record

Equipment installed October 2001. Periodic site visits to measure flow, make observations, and collect water quality samples have been made since Feburary 2002. Gaging sponsored by Stanford University Utilities Division.

WY 2003 Daily Mean Flow (cubic feet per second)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1	0.03	0.02	0.42	3.37	0.93	1.18	0.88	5.31	0.75	0.26	0.21	0.20
2	0.03	0.02	0.42	1.91	0.88	1.12	1.33	5.67	0.72	0.24	0.20	0.18
3	0.02	0.02	0.40	2.40	0.84	1.69	1.18	6.13	0.73	0.23	0.20	0.18
4	0.02	0.02	0.38	3.72	0.85	1.49	2.62	4.51	0.74	0.23	0.19	0.16
5	0.02	0.02	0.38	3.39	0.91	1.26	0.74	3.84	0.67	0.20	0.21	0.16
6	0.02	0.02	0.47	3.02	1.22	1.18	1.25	3.65	0.64	0.22	0.31	0.17
7	0.02	0.50	0.39	2.84	1.12	1.07	1.51	3.32	0.66	0.22	0.33	0.16
8	0.02	33.72	0.33	2.78	1.07	0.97	1.20	3.60	0.69	0.23	0.29	0.14
9	0.02	1.32	0.54	3.50	1.02	0.88	0.95	2.96	0.69	0.21	0.27	0.19
10	0.02	0.93	0.46	4.97	1.08	0.97	0.91	2.94	0.71	0.20	0.27	0.17
11	0.02	0.52	0.36	3.13	1.17	0.92	0.79	2.75	0.82	0.22	0.28	0.15
12	0.02	0.47	0.38	2.98	2.19	1.23	18.93	2.72	0.68	0.22	0.28	0.12
13	0.02	0.50	20.41	2.82	1.21	1.04	36.78	2.54	0.65	0.20	0.28	0.14
14	0.02	0.42	53.58	2.74	1.23	1.79	10.84	2.32	0.58	0.19	0.26	0.13
15	0.02	0.42	14.09	2.45	2.12	9.09	6.91	2.14	0.56	0.17	0.25	0.13
16	0.02	0.51	123.17	2.37	14.13	1.19	6.18	1.98	0.50	0.17	0.24	0.13
17	0.01	0.47	16.55	2.19	1.69	1.01	5.13	1.89	0.44	0.16	0.27	0.13
18	0.01	0.43	10.58	2.23	0.97	0.83	4.02	1.87	0.48	0.14	0.27	0.12
19	0.01	0.42	59.64	2.19	1.44	0.83	3.07	1.78	0.47	0.13	0.27	0.12
20	0.01	0.49	27.78	2.32	1.63	1.01	3.01	1.71	0.44	0.14	0.49	0.11
21	0.02	0.45	9.16	2.52	1.44	0.87	2.42	1.47	0.47	0.14	0.32	0.10
22	0.02	0.44	2.21	1.45	1.34	0.85	1.34	1.18	0.42	0.15	0.29	0.09
23	0.02	0.45	1.33	0.52	1.21	0.90	2.19	1.12	0.56	0.16	0.27	0.11
24	0.02	0.37	1.10	0.77	3.95	0.64	1.69	1.06	0.41	0.19	0.25	0.10
25	0.02	0.47	0.96	0.88	8.54	0.72	2.53	1.11	0.31	0.17	0.22	0.11
26	0.02	0.48	0.97	1.15	1.63	0.97	3.61	1.19	0.27	0.20	0.19	0.11
27	0.02	0.45	0.90	1.08	2.53	0.81	3.43	1.13	0.22	0.24	0.26	0.13
28	0.02	0.46	53.33	0.94	1.36	0.81	13.92	1.01	0.20	0.36	0.19	0.12
29	0.02	0.46	38.96	0.91		0.76	9.51	0.79	0.21	0.32	0.18	0.11
30	0.01	0.50	7.44	1.08		0.79	6.38	0.86	0.24	0.22	0.19	0.11
31	0.02		47.74	1.07		0.84		0.83		0.23	0.18	
MEAN	0.02	1.53	15.96	2.25	2.13	1.28	5.17	2.43	0.53	0.20	0.26	0.14
MAX. DAY	0.03	33.72	123.17	4.97	14.13	9.09	36.78	6.13	0.82	0.36	0.49	0.20
MIN. DAY	0.01	0.02	0.33	0.52	0.84	0.64	0.74	0.79	0.20	0.13	0.18	0.09
cfs days	0.6	45.8	494.8	69.7	59.7	39.7	155.2	75.4	15.9	6.3	7.9	4.1
ac-ft	1.1	90.8	981.5	138.3	118.4	78.7	307.9	149.5	31.6	12.6	15.7	8.1

Monitor's Comments

1. We collected a continuous record for the entire water year.
2. Multiple stage shifts were applied to the rating equation; stage shifts adjust for local scour or fill and leaf debris build-up
3. The upper portion of the rating curve is based on several high-flow estimates.
4. Daily values with more than 2 to 3 significant figures result from electronic calculations; no additional precision is implied.
5. Stanford operates a surface water diversion and fish ladder, about 1.8 miles upstream of this station, which may divert water out of Los Trancos Creek from December 1 to April 30.

Water Year 2003 Totals:		
Mean annual flow	**2.67**	(cfs)
Max. daily flow	**123**	(cfs)
Min. daily flow	**0.01**	(cfs)
Annual total	**975**	(cfs-days)
Annual total	**1934**	(ac-ft)

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Form 3. Annual Sediment-Discharge Record

Water Year:	2003	
Stream:	San Francisquito Creek	
Station:	at Piers Lane	**SFPL**
County:	San Mateo County, CA	

WY 2003 Daily Suspended-Sediment Discharge *(tons)*

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	
1	0.0	0.0	0.0	13.7	0.0	0.2	0.0	0.7	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	3.6	0.0	0.1	0.1	1.1	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	1.3	0.0	0.2	0.1	4.2	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.8	0.0	0.2	1.6	2.1	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.6	0.0	0.1	0.2	0.8	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	
8	0.0	101.9	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	
9	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.0	1.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.7	0.1	0.1	82.3	0.1	0.0	0.0	0.0	0.0	
13	0.0	0.0	622.7	0.5	0.1	0.1	694.9	0.0	0.0	0.0	0.0	0.0	
14	0.0	0.0	1999.0	0.3	0.0	0.2	10.8	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	278.8	0.1	0.2	30.5	2.5	0.0	0.0	0.0	0.0	0.0	
16	0.0	0.0	46316.4	0.1	67.0	1.8	1.3	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	191.3	0.1	1.0	0.7	0.9	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	7.7	0.1	0.3	0.3	0.6	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	2643.8	0.1	0.2	0.1	0.4	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	1122.0	0.1	0.1	0.1	0.3	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	110.6	0.2	0.1	0.1	0.3	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	7.2	0.2	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	1.7	0.2	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	0.7	0.1	0.7	0.1	1.8	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	0.4	0.1	6.9	0.0	1.8	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.2	0.1	0.9	0.0	1.6	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.2	0.1	0.7	0.0	0.8	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	985.8	0.1	0.3	0.0	9.2	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	800.1	0.0		0.0	4.2	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	13.3	0.0		0.0	1.2	0.0	0.0	0.0	0.0	0.0	**Qss**
31	0.0		872.1	0.0		0.0		0.0		0.0	0.0		**Annual**
TOTAL	0.0	101.9	55973.9	30.7	78.9	35.2	817.6	10.7	0.0	0.0	0.0	0.0	**57,049**
Max.day	0.0	101.9	46316.4	13.7	67.0	30.5	694.9	4.2	0.0	0.0	0.0	0.0	**46,316**

WY 2003 Daily Bedload-Sediment Discharge *(tons)*

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	
1													
2													
3													
4													
5	Daily Bedload Discharge was not measured or calculated												
6													
7													
8													
9													
10	Daily Bedload Discharge was not measured or calculated												
11													
12													
13													
14													
15	Daily Bedload Discharge was not measured or calculated												
16													
17													
18													
19													
20	Daily Bedload Discharge was not measured or calculated												
21													
22													
23													
24													
25	Daily Bedload Discharge was not measured or calculated												
26													
27													
28													
29													
30													**Qss**
31	Daily Bedload Discharge was not measured or calculated												**Annual**
TOTAL	...	...	...	...	...	...	...	...	...	...	...	...	**...**
Max.day	...	...	...	...	...	...	...	...	...	...	...	...	**...**

Daily values are based on calculations of sediment discharge at 15-minute intervals.
Daily values with more than 2 significant figures result from electronic calculations. No additional precision is implied.

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Form 4. Annual Sediment-Discharge Record

Water Year: 2003
Stream: Los Trancos
Station: at Piers Lane **LTPL**
County: San Mateo County, CA

WY 2003 Daily Suspended-Sediment Discharge *(tons)*

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	
1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	
8	0.0	68.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	
9	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.1	0.1	0.0	11.5	0.1	0.0	0.0	0.0	0.0	
13	0.0	0.0	21.9	0.1	0.0	0.0	33.8	0.1	0.0	0.0	0.0	0.0	
14	0.0	0.0	106.7	0.1	0.0	0.1	1.5	0.1	0.0	0.0	0.0	0.0	
15	0.0	0.0	10.2	0.1	0.2	3.6	0.6	0.1	0.0	0.0	0.0	0.0	
16	0.0	0.0	883.9	0.1	5.9	0.0	0.5	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	3.9	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	1.4	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	191.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	28.4	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	1.6	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	0.0	0.0	1.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	143.6	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	42.3	0.0		0.0	1.2	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	0.7	0.0		0.0	0.5	0.0	0.0	0.0	0.0	0.0	**Qss**
31	0.0		165.3	0.0		0.0		0.0		0.0	0.0		**Annual**
TOTAL	0.0	68.3	1601.4	2.3	8.8	3.9	53.7	2.9	0.1	0.0	0.0	0.0	**1,741**
Max.day	0.0	68.2	883.9	0.3	5.9	3.6	33.8	0.5	0.0	0.0	0.0	0.0	**884**

WY 2003 Daily Bedload-Sediment Discharge *(tons)*

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	
1													
2													
3													
4													
5	Daily Bedload Discharge was not measured or calculated												
6													
7													
8													
9													
10	Daily Bedload Discharge was not measured or calculated												
11													
12													
13													
14													
15	Daily Bedload Discharge was not measured or calculated												
16													
17													
18													
19													
20	Daily Bedload Discharge was not measured or calculated												
21													
22													
23													
24													
25	Daily Bedload Discharge was not measured or calculated												
26													
27													
28													
29													
30													**Qss**
31	Daily Bedload Discharge was not measured or calculated												**Annual**
TOTAL	...	...	...	...	...	...	...	...	...	...	...	...	**...**
Max.day	...	...	...	...	...	...	...	...	...	...	...	...	**...**

Daily values are based on calculations of sediment discharge at 15-minute intervals.
Daily values with more than 2 significant figures result from electronic calculations. No additional precision is implied.

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TABLES

Table 1. Station observer log: San Francisquito Creek at Piers Lane, water year 2003

Site Conditions				Streamflow				Water Quality Observations							High-Water Marks		Remarks
Date/Time (mm/dd/yr)	Observer(s)	Stage (staff plate) (feet)	Hydrograph (R/F/S/B)	Measured Discharge (cfs)	Estimated Discharge (cfs)	Instrument Used (AA/PY)	Estimated Accuracy (e/g/f/p)	Water Temperature (°C)	Specific Conductance at field temp. (umhos/cm)	Specific Conductance at 25C (at 25 °C)	pH (pH)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat.)	Additional sampling? (Qbed, etc.)	Estimated stage at staff plate (feet)	Inferred dates? (mm/dd/yr)	
San Francisquito Creek at Piers Lane																	
9/19/02 9:10	jo, cw, bjm	3.29	B	0.28	...	PY	f	15.6	1080	1336	...	...	...	...	...	...	pH (strip); slightly turbid; fish, crayfish, and hummingbirds;
10/16/02 10:55	jo, cw	3.25	B	0.28	...	PY	p	12.6	1100	1473	6.8	...	...	...	...	...	water mostly clear; crayfishing lines and trash
11/7/02 9:00	cw, bjm	3.38	F	...	0.33	vis. est.	p	12.0	1085	1476	...	...	...	NH3, Hg	~3.6	11/7/02	first flush; started composite (timed--500ml/hr) sample at ~11:00
11/8/02 10:40	cw, sb	3.75	F	1.79	...	AA	f	14.2	574	737	...	...	...	Qss, WQ, NH3, Hg	6.25	11/8/02	collect 48-hour composite sample; high-flow channel to left pooled but not flowing now; water turbid
12/13/02 10:45	jo, smc	4.43	R	...	...	...	...	...	...	...	...	...	...	...	...	...	raining moderately; started composite (flow paced) sampling ~10:30
12/13/02 11:41	jo, smc	4.58	R	...	...	...	...	11.8	610	834	...	...	...	...	...	...	water rising
12/14/02 11:30	er, cw	5.53	F	...	180	float	p	13.0	415	550	...	...	...	Qss, NH3	~7.25	12/13/02	Q est. assumes 2-foot depth at this stage.
12/14/02 16:20	er, cw	~6.0	F	...	...	...	...	13.2	630	830	...	...	...	Qss	...	...	dim light--difficult to see staff plate
12/15/02 13:55	cw	5.05	F	...	...	...	...	13.0	480	636	...	...	...	Qss, WQ, NH3	7.22	12/14/02	collect composite sample at 15:00
12/19/02 14:10	gp, ch	6.20	R	...	...	...	...	9.0	123	181	...	...	...	Qss	...	...	limited field notes; flow/stage too high to measure
1/16/03 14:00	jo, bkh	3.93	B	11.47	...	AA	f	10.5	570	807	...	...	...	Qss	7.75	12/19/02	water fairly turbid, greenish brown color
2/5/03 16:30	jo	3.78	B	6.80	...	AA	p	9.5	600	873	...	...	...	...	...	...	rocks slippery w/ algae; water clearer than normal, velocity at 0.4 depth seemed low due to turbulence on cobbles
2/19/03 16:04	jo	4.00	F	...	8	vis. est.	p	10.9	600	841	7.5	...	...	Qss	...	...	pH (strip); water turbid
2/23/03 16:27	jo	3.81	B	...	6	vis. est.	p	11.1	670	934	...	...	...	...	...	...	water turbid; female mallard squawking in creek; set-up composite sampler (flow pacing at 1 aliquot/250,000 cfs) with time delay to start at 23:45; local resident concerned re WQ (esp. Dustak spill);
2/25/03 16:55	er	4.43	?	...	...	...	...	11.9	503	686	...	...	...	Qss, WQ, NH3, Hg	...	...	collect composite sample at 17:17
3/15/03 11:47	gp, bjm	5.16	F	...	108	float	p	14.5	478	609	...	9.7	...	Qss	...	...	rain overnight; water too fast to wade for bedload (none visibly moving)
3/25/03 15:16	bkh	3.77	B	4.82	...	PY	p/f	14.0	691	891	...	10.9	...	...	...	...	Use of std. meter would have been more appropriate.
4/23/03 17:15	jo	3.97	B, F	10.46	...	AA	f	14.2	620	796	7.7	...	...	...	~12.0	12/16/02	pH (strip); water green & turbid; mallards; mosquitos biting
5/21/03 13:36	jo	3.82	B	...	7	vis. est.	p	17.2	740	879	...	8.7	83%	...	...	...	water mostly clear; kingfisher w/prey; filamentous green algae in riffle
5/22/03 15:50	bkh, ch	3.76	B	4.01	...	PY	g	19.1	747	845	...	...	...	...	...	...	evidence of pooling under bridge in high flow channel from most recent storm (April events); abundant trout visible in stream.
6/25/03 10:45	bjm	3.44	B	0.47	...	PY	g	16.9	850	1029	...	...	...	...	...	...	started composite (timed - 500 ml/hr) sampling at ~10:55; water clear but tinted brown; many mosquitoes;
6/26/03 10:09	bjm	3.43	B	...	...	...	...	17.9	865	1009	8.1	4.7	...	WQ, NH3, Hg	...	...	pH (meter); collect composite sample ~10:30; water clear
7/23/03 16:58	jo	3.32	B	0.43	...	PY	f	22.0	1110	1171	7.9	10.8	123%	...	...	...	pH = (strip); many fish <1 inch long; water looks clear in riffle but greenish-yellow in pool
8/19/03 16:55	jo	3.32	B	0.34	...	PY	f	20.0	1190	1317	8.1	8.8	100%	...	...	...	pH (meter); water clear no Qss;
8/20/03 15:07	bjm	3.33	B	...	...	...	...	18.4	1113	1282	...	...	...	WQ, Hg, NH3	...	...	very little composite sample, fixed hose connection; sample collected 16:00; all are grab samples
10/2/2003 15:52	jo	3.31	B	0.29	...	PY	f	15.8	1130	1390.7	8.2	6.2	62%	...	...	...	pH (meter); greenish tint to water; many 3" fish in pool

Stage: Water level observed at outside staff plate
Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or uncertain (U).
Instrument: If measured, typically made using a standard (AA) or pygmy (PY) bucket-wheel ("Price-type") current meter. If estimated, from rating curve (R) or visual (vis. est.).
Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) = +/- > 9%
High-water mark (HWM): Measured or estimated at location of the staff plate
Specific conductance: Measured in micromhos/cm in field; then adjusted to 25degC by equation (1.8813774452 - [0.050433063928 * field temp] + [0.00058561144042 * field temp^2]) * Field specific conductance
Additional Sampling: Qbed = Bedload, Qss = Suspended sediment, Nutr = nutrients; other symbols as appropriate

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Table 2. Station observer log: Los Trancos Creek at Piers Lane, water year 2003

Site Conditions				Streamflow				Water Quality Observations							High-Water Marks		Remarks
Date/Time (mm/dd/yr)	Observer(s)	Stage (staff plate) (feet)	Hydrograph (R/F/S/B)	Measured Discharge (cfs)	Estimated Discharge (cfs)	Instrument Used (AA/PY)	Estimated Accuracy (e/g/f/p)	Water Temperature (°C)	Specific Conductance at field temp. (umhos/cm)	Specific Conductance at 25C (at 25 °C)	pH (pH)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat.)	Additional sampling? (Qbed, etc.)	Estimated stage at staff plate (feet)	Inferred dates? (mm/dd/yr)	
Los Trancos Creek at Piers Lane																	
9/19/02 8:40	jo, cw, bjm	1.27	B	0.033	...	PY	f	14.8	1600	2021	...	...	...	WQ	...	...	SC msmt. high?; much silt on bed stirred by walking; many leaf dams;
10/16/02 10:30	jo, cw	1.24	B	0.024	...	PY	f	12.0	830	1129	7.8	...	...	...	...	...	pH (strip); leaf/stick dam re-forming d/s staff; sparrows bathing
11/7/02 8:46	cw, bjm	1.35	F	...	...	...	...	14.2	860	1104	...	...	...	NH3, Hg	...	...	first flush; started composite (timed - 500 ml/hr) sampling at ~11:15
11/9/02 9:40	cw, sb	1.54	F	1.23	...	PY	g/f	13.9	776	1004	...	...	...	Qss, WQ, NH3, Hg	3.84	11/8/02	collect composite sample; water very clear
12/13/02 10:02	jo, smc	1.59	R	...	1.85	vis. est.	p	...	...	...	...	...	...	...	...	...	started composite (flow paced) sampling at ~ 11:30
12/13/02 11:30	jo, smc	1.69	R	...	...	...	...	12.9	610	810	...	...	...	...	...	...	additional stage reading to show rising water
12/14/02 10:50	er, cw	1.75	F	...	6.66	float	p	13.6	580	756	...	...	...	Qss, NH3	...	...	hydrograph falling from overnight, more rain today
12/14/02 16:15	er, cw	...	R	...	...	...	...	13.0	460	609	...	...	...	Qss	...	...	hydrograph rising; gage height not noted; limited notes in file
12/15/02 13:30	cw	1.40	F	...	...	...	...	12.5	710	953	...	...	...	Qss, WQ, NH3	~4.9	12/14/02	collect composite sample at 14:15
12/19/02 10:05	gp, ch	2.39	R	...	...	...	...	10.0	850	1220	...	...	...	...	...	...	water rising quickly; wse=0.39'> base of upper staff plate (missing)
1/16/03 13:30	jo, bkh	1.47	B	2.42	...	AA	g	11.2	770	1070	...	...	...	...	...	...	the bed has changed substantially; looked downstream for staff plate
2/5/03 17:00	jo	1.30	B	0.64	...	AA	g	10.2	830	1185	...	...	...	...	7.5	12/16/03	water clear; bed reworked by high flows -- many boulders now visible (net scour) and vegetation cleared-out
2/19/03 16:00	jo	1.36	F	...	2.5	vis. est.	p	11.8	960	1313	7.7	...	...	...	...	...	pH (strip); SC msmt. high?; water very clear;
2/23/03 16:20	jo	1.29	B	...	1.25	vis. est.	p	11.8	880	1204	...	...	...	...	...	...	water very clear; 2-3" fish; set-up composite sampler (flow pacing at 1 aliquot/30,000 cfs) with time delay to start at 23:4
2/25/03 15:29	er	1.49	F	...	...	...	...	13.0	625	828	...	...	...	Qss, WQ, NH3, Hg	...	...	collect composite sample at 16:33
3/15/03 11:14	gp, bjm	1.56	F	...	4.4	float	p	13.5	374	489	...	10.0	96%	Qss	2.46	3/15/03	no bedload moving; rain overnight
3/25/03 16:30	bkh	1.27	B	0.67	...	PY	g	13.2	950	1252	...	8.6	...	...	4.4	3/20/03	DO = 8.3 - 8.9 mg/L (range over a 15-minute period, meter unstable)
4/23/03 15:55	jo	1.48	F, B	2.59	...	AA	f	12.8	730	972	7.9	...	...	...	~7	12/16/02	pH (strip); water very clear; 2-inch fish under staff plate overhang
5/21/03 13:19	jo	1.39	B	...	2	vis. est.	p	15.5	730	905	...	10.1	102%	...	...	...	water clear; people drinking/smoking under bridge
5/22/03 15:19	bkh, ch	1.37	B	1.45	...	PY	g	17.1	760	905	...	...	...	...	...	...	sunny and clear
6/25/03 9:07	bjm	1.24	B	0.45	...	PY	g	14.9	897	1130	...	...	...	...	...	...	observed several 4" fish; started composite (timed - 500 ml/hr) sampling at ~10:40
6/26/03 12:00	bjm	...	B	...	...	...	...	16.7	949	1141	8.1	9.2	...	WQ, NH3, Hg ...	...	...	gage height not noted; water clear; collect composite sample ~10:00
7/23/03 17:18	jo	1.03	B	0.12	...	PY	g	20.2	1290	1421	7.9	9.2	103%	...	...	...	pH (strip); water clear; many brown eucalyptus leaves in stream and on banks
8/19/03 16:30	jo	1.15	B	0.26	...	PY	g	19.1	1150	1302	8.3	8.9	96%	...	...	...	pH (meter); water clear; leaf dams d/s of staff, 2" fish
8/20/2003 14:55	bjm	1.19	B	...	0.5	vis. est.	f	19.1	1066	1206	...	...	...	WQ, Hg, NH3	...	...	samples collected at 15:00
10/2/2003 16:10	jo	1.05	B	0.11	...	PY	g	16.0	1290	1579.4	8.5	10.6	108%	...	...	...	pH = 8.5 (strip); water clear, leaf dams?

Observer Key: cw = Chris White; jo= Jonathan Owens; gp= Gustavo Porras; smc = Shawn Chartrand; bjm= Bonnie Mallory; er= Eric Reidner; eb= Ed Ballman; bkh= Brian Hastings; ch= Charlotte Hedlund; sb = Scott Brown

Stage: Water level observed at outside staff plate

Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or uncertain (U).

Instrument: If measured, typically made using a standard (AA) or pygmy (PY) bucket-wheel ("Price-type") current meter. If estimated, from rating curve (R) or visual (vis. est.).

Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) = +/- > 9%

High-water mark (HWM): Measured or estimated at location of the staff plate

Specific conductance: Measured in micromhos/cm in field; then adjusted to 25degC by equation (1.8813774452 - [0.050433063928 * field temp] + [0.00058561144042 * field temp^2]) * Field specific conductance

Additional Sampling: Qbed = Bedload, Qss = Suspended sediment, WQ = collection via automated sampler, DO = Dissolved oxygen msmt., pH = pH msmt., NH3 = ammonia (grab) sample, Hg = mercury (grab) sample

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Table 3. Summary of water quality at San Francisquito and Los Trancos Creeks at Piers Lane in Water Year 2003.

Field observations [1]							*Nutrients* [2]				*Pesticides*		*Others* [3]		
Date and Time	Observer	Gage Height	Hydrograph	Discharge	Water Temperature	Specific conductance	Ammonia-N	Nitrate-N	Nitrite-N	Phosphate-P	Chlorpyrifos	Diazinon	Total Suspended Solids	Turbidity	Hardness
		(feet)	*(R,F,B,U)*	*(cfs)*	*(°C)*	*(µhos/cm @ 25°C)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(ug/L)*	*(ug/L)*	*(mg/L)*	*(NTU)*	*(mg/L)*
Analytical detection limits: [4]						**11/7/2002**	0.2						5.0		
						11/9/2002		0.5	0.06	0.1	1.0	1.2	5.0		1.0
						12/13/2002	0.2	0.1	0.03	0.1	1.0	1.2	5.0		1.0
						12/14/2002	0.2								
						2/25/2003	0.2	0.1	0.03	0.1	0.5	0.6	*0.5*		1.0
						6/26/2003	0.2	0.1		0.02	0.05	0.05			1.0
						8/20/2003	0.2	0.1		0.02	0.05	0.05	*0.5*		1.0
San Francisquito Creek at Piers Lane															
11/7/2002 12:15	cw, bjm	3.38	F	*0.33*	12.0	1476	1.2								
11/7-9/2002								4.3	0.08	1.88	ND	ND			304
11/9/2002 10:10	cw, sb	3.75	F	1.79	14.2	737							52	51	
11/9/2002 12:55	cw, sb	--	--	--	--	--	ND								
12/13-15/2002								3.1	ND	3.98	ND	ND			157
12/14/2002 11:30	er, cw	5.53	F	*180*	13.0	550	ND						66	68	
12/15/2002 14:05	cw	5.05	F	*74.7*	13.0	636	ND						120	160	
2/24-25/2003								2.6	0.04	0.57	ND	ND	35		292
2/25/2003 17:45	er	4.43	F	--	11.9	686	ND						21	16	
6/25-26/2003				*0.47*				0.8		0.18	ND	ND			450
6/26/2003 10:00	bjm, cw	3.43	B		17.9	1009	ND								
8/19-20/2003 all samples for this date are grab samples on 8/20/03 due to sampler malfunction															
8/20/2003 15:10	bjm	3.33	B	*0.34*	18.4	1282	ND	5.5		0.22	ND	ND	2.8		524
Los Trancos Creek at Piers Lane															
11/7/2002 12:30	cw, bjm	1.35	F	--	14.2	1104	0.79								378
11/7-9/2002								3.7	ND	2.31	ND	ND			
11/9/2002 9:15	cw, sb	1.54	F	1.23	13.9	1004							7	7.4	
11/9/2002 13:00	cw, sb	--	--	--	--	--	ND								
12/13-15/2002								2.0	ND	7.05	ND	ND			244
12/14/2002 10:55	er, cw	1.75	F	--	13.6	756	ND						12	25	
12/15/2002 13:40	cw	1.4	F	--	12.5	710	ND						14	21	
2/24-25/2003								2.7	ND	4.9	ND	ND	*120*		252
2/25/2003 16:45	er	1.49	F	--	13.0	828	ND						12	13	
6/25-26/2003				*0.45*				1.6		0.18	ND	ND			541
6/26/2003 9:45	bjm, cw		B		16.7	1141	ND								
8/19-20/2003				*0.26*				5.7		0.22	ND	ND	*1.5*		553
8/20/2003 15:00	bjm	1.19	B	--	19.1	1206									
SF Bay RWQCB (1995)--Aquatic acute toxicity: 1-hour average							--[7]	--[8]	--[8]	--[8]	--[9]	--[9]	--[10]	--[10]	None
SF Bay RWQCB (1995)--Chronic acute toxicity: 4-day average							--[7]	--[8]	--[8]	--[8]	--[9]	--[9]	--[10]	--[10]	None
California Toxics Rule (U.S. EPA)--Aquatic acute toxicity: 1-hour average							--[11]	None	None	None	None	None	None	None	None
California Toxics Rule (U.S. EPA)--Chronic acute toxicity: 4-day average							--[11]	None	None	None	None	None	None	None	None

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Table 3. Summary of water quality at San Francisquito and Los Trancos Creeks at Piers Lane in Water Year 2003 (continued).

Field observations [1]		*Trace Metals* [4]															
Date and Time	Discharge	Aluminum (total)	Aluminum (dissolved)	Copper (total)	Copper (dissolved)	Lead (total)	Lead (dissolved)	Mercury (total)	Mercury (dissolved)	Nickel (total)	Nickel (dissolved)	Selenium (total)	Selenium (dissolved)	Silver (total)	Silver (dissolved)	Zinc (total)	Zinc (dissolved)
	(cfs)	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*	*(ug/L)*
Analytical detection limits: [5]	**11/7/2002**							0.05	0.05								
	11/9/2002	—[6]	100	0.6	0.6	0.4	0.4'	0.06	0.06	0.6	0.6	0.1	0.1	0.2	0.2	5.0	5.0
	12/13/2002	100	100	0.6	0.6	0.4	0.4		0.10	0.6	0.6	0.1	0.1	0.2	0.2	5.0	5.0
	12/14/2002																
	2/25/2003	100	100	0.6	0.6	0.4	0.4	0.0005	0.0005			0.1	0.1	0.2	0.2	5.0	5.0
	6/26/2003	10	20	0.6	0.6	0.4	0.4	0.0005	0.0005	0.6	0.6	0.1	0.1	0.2	0.2	5.0	5.0
	8/20/2003	20	10	0.6	0.6	0.4	0.4	0.0005	0.0005	0.6	0.6			0.2	0.2	5.0	5.0
San Francisquito Creek at Piers Lane																	
11/7/2002 12:15 **11/7-9/2002** 11/9/2002 10:10 11/9/2002 12:55	*0.33* 1.79 —	5,000	100	74	17	13	0.6	0.06 *ND*	ns *ND*	30	9.0	0.6	0.3	ND	ND	110	21
12/13-15/2002 12/14/2002 11:30 12/15/2002 14:05	 *180* *74.7*	12,000	100	44	5.2	17	ND	ns	*ND*	38	5.0	1.3	0.2	ND	ND	88	25
2/24-25/2003 2/25/2003 17:45	 —	1600	ND	11.6	5.3	2.6	ND	 0.0059	 0.0019	ns	ns	0.3	0.2	ND	ND	19	22
6/25-26/2003 6/26/2003 10:00	*0.47*	60 **all samples for this date are grab samples on 8/20/03 due to sampler malfunction**	ND	2.2	2.4	ND	ND	 0.0018	 0.0010	3.7	3.5	0.3	0.2	ND	ND	ND	12
8/19-20/2003 8/20/2003 15:10	 *0.34*	40	ND	1.7	1.7	ND	ND	0.0009	0.0010	4.4	4.3	ns	ns	ND	0.3	ND	9
Los Trancos Creek at Piers Lane																	
11/7/2002 12:30 **11/7-9/2002** 11/9/2002 9:15 11/9/2002 13:00	-- 1.23 —	17,000	100	74	10	26	1.2	0.21 *0.20*	ND *ND*	66	10.0	1.9	0.3	ND	ND	180	29
12/13-15/2002 12/14/2002 10:55 12/15/2002 13:40	 -- —	33,000	100	82	3.7	30	ND	*ns*	*ND*	117	6.0	2.1	0.2	0.3	ND	170	40
2/24-25/2003 2/25/2003 16:45	 —	3500	ND	13.7	6.8	4.6	0.5	 0.0099	 0.0048	ns	ns	0.2	0.2	ND	ND	24	34
6/25-26/2003 6/26/2003 9:45	*0.45*	90	ND	2.1	2.7	1.2	ND	 0.0010	 0.0010	3.8	3.1	0.2	ND	ND	ND	ND	15
8/19-20/2003 8/20/2003 15:00	*0.26* —	30	ND	1.6	1.6	ND	ND	 0.0010	 0.0010	3.5	3.5	ns	ns	ND	ND	ND	7.0
SF Bay RWQCB (1995)--Aquatic acute toxicity: 1-hour average		None		42.0 - 80.8	(use total recoverable values)	262.1 - 633.5	(use total recoverable values)	2.4	2.4	3079.0 - 5534.1	(use total recoverable values)	None		None		45.5 - 81.9	(use total recoverable values)
SF Bay RWQCB (1995)--Chronic acute toxicity: 4-day average		None		25.9 - 46.8		10.2 - 24.7		0.025	0.025	342.3 - 615.3		None		None		50.2 - 90.4	
CTR (U.S. EPA)--Aquatic acute toxicity: 1-hour average [12]		None		33.2 - 63.8	31.9 - 61.2	262.1 - 633.5	172.3 - 352.5	None		1018.6 - 1830.9	1016.5 - 1827.2	20	20	19.6 - 64.7	16.7 - 55.0	260.4 - 468.5	256.8 - 462.0
CTR (U.S. EPA)--Chronic acute toxicity: 4-day average [12]		None		20.4 - 36.9	19.6 - 35.4	10.2 - 24.7	6.7 - 13.7	None		113.2 - 203.6	112.9 - 202.9	5	5	(only instantaneous maximum; no acute or chronic toxicity level established only)		260.4 - 468.5	254.7 - 458.2

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Table 3. Summary of water quality at San Francisquito and Los Trancos Creeks at Piers Lane in Water Year 2003 (continued).

Notes: ND = not detected ns = not sampled,

1) Observer Key: cw is Chris White; sb is Scott Brown, bm is Bonnie Mallory, er is Eric Riedner
   Hydrograph: R=Rising; F=Falling; B=Baseflow; U=Uncertain Discharge: estimates are in italics
   All specific conductance and temperature measurements were made in the field.
2) Ammonia and phosphate samples were preserved upon collection with sulfuric acid (H_2SO_4) to pH<2. Nitrate samples were iced but not preserved if analysis could occur within 48 hours; otherwise, nitrate samples were also preserved with sulfuric acid.
3) TSS detection limit is dependent on sample volume; 5 mg/L is the detection limit for a 500 ml sample.
   All suspended sediment analyses by Soil Control Lab (Watsonville, CA) with Detection Limit of 5.0 mg/L,
   except for 2/24-25/2003 and 8/19-20/2003 composite analyses, performed by RWQCP lab with Detection Limit of 0.5 mg/L.
4) Total recoverable metals samples were preserved (unfiltered) upon collection with nitric acid (HNO_3).
   Dissolved metals samples were filtered in the laboratory, then preserved with nitric acid.
5) Limits vary with analytical method, laboratory, quality control measures, and amount of sample dilution.
   Aluminum, nitrate, organophosphate pesticide and mercury (except 11/7-9/2002 and 12/13-15/2002 composite) analyses performed by Caltest (Napa).
   All other laboratory analyses performed by the City of Palo Alto RWQCP.
6) Reporting limits for total aluminum in 11/9/2002 samples were 500 ug/L for San Francisquito Creek, and 2000 ug/L for Los Trancos Creek.
7) Un-ionized ammonia concentrations chronically in excess of 0.025 mg/L (annual median value) can be toxic (RWQCB, 1995).
   The proportion of total ammonia in the un-ionized form increases as a function of pH and temperature.
8) Biostimulatory constituents should not be present in amounts that stimulate excessive aquatic growth (RWQCB, 1995).
9) Waters should remain free of toxics at concentrations lethal to or adversely impacting aquatic organisms (RWQCB, 1995).
10) Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses (RWQCB, 1995).
11) The fraction of total ammonia that is in the toxic, un-ionized form rises with increases in pH and temperature. Mean daily temperatures in San Francisquito and Los Trancos Creeks varied from about 6.5 to 21°C, and pH varied from 6.8 to 8.5 during the WY2003 monitoring period.
12) Metals objectives are hardness-dependent (RWQCB, 1995). The range shown is for hardness of 250 to 500 mg/L as $CaCO_3$.

Total Recoverable Copper, 1-hour average = (e{0.9422 [ln(hardness)] - 1.700})
Dissolved Copper, 1-hour average = (e{0.9422 [ln(hardness)] - 1.700}) x (0.960)

Total Recoverable Copper, 4-day average = (e{0.8545 [ln(hardness)] - 1.702})
Dissolved Copper, 4-day average = (e{0.8545 [ln(hardness)] - 1.702}) x (0.960)

Total Recoverable Lead, 1-hour average = (e{1.273[ln(hardness)] - 1.460})
Total Recoverable Lead, 4-day average = (e{1.273[ln(hardness)] - 4.705})
Dissolved Lead, 1-hour average = (e{1.273[ln(hardness)] - 1.460}) x (1.46203 - {[ln(hardness)] x [0.145712]})
Dissolved Lead, 4-day average = (e{1.273[ln(hardness)] - 4.705}) x (1.46203 - {[ln(hardness)] x [0.145712]})

Total Recoverable Nickel, 1-hour average = (e{0.8460 [ln(hardness)] + 2.255 })
Dissolved Nickel, 1-hour average = (e{0.8460 [ln(hardness)] + 2.255 }) x (0.998)

Total Recoverable Nickel, 4-day average = (e{0.8460 [ln(hardness)] + 0.0584})
Dissolved Nickel, 4-day average = (e{0.8460 [ln(hardness)] + 0.0584}) x (0.997)

Total Recoverable Silver, instantaneous maximum = (e{1.72 [ln(hardness)] - 6.52})
Dissolved Silver, instantaneous maximum = (e{1.72 [ln(hardness)] - 6.52}) x (0.85)

Total Recoverable Zinc, 1-hour average = (e{0.8473 [ln(hardness)] + 0.884 })
Dissolved Zinc, 1-hour average = (e{0.8473 [ln(hardness)] + 0.884 }) x (0.986)

Total Recoverable Zinc, 4-day average = (e{0.8473 [ln(hardness)] + 0.884})
Dissolved Zinc, 4-day average = (e{0.8473 [ln(hardness)] + 0.884}) x (0.978)

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Table 4. Measurements of suspended sediment: San Francisquito and Los Trancos Creeks at Piers Lane, water years 2002 and 2003

Field observations					*Suspended sediment*		
Date and Time	Observer	Stage	Stream Condition	Discharge	Total Suspended Solids	Suspended Sediment discharge	Turbidity
		(feet)	*(R, F, B)*	*(cfs)*	*(mg/L)*	*(tons/day)*	*(NTU)*
San Francisquito Creek at Piers Lane							
3/7/02 16:00	jo, cw	4.53	R	40	65	7.0	na
11/9/02 10:10	sb, cw	3.75	F	2.5	52	0.35	51
12/14/02 11:30	cw, er	5.53	F	160	66	28	68
12/14/02 16:15	cw, er	6.24	R	324	450	393	280
12/15/02 14:05	cw	4.97	F	71.0	120	23	160
12/19/02 14:30	gp, ch	6.45	R	350	3500	3304	830
1/16/03 15:00	jo,bkh	3.89	B	10.0	< 5	< 0.15	5.5
2/19/03 16:30	jo	3.95	F, B	9.8	5	0.13	7.4
2/25/03 17:45	er	4.46	F	33.8	21	1.9	16
3/15/03 11:40	gp, bjm	5.20	F	99.0	180	48	110
Los Trancos Creek at Piers Lane							
3/7/02 16:00	jo, cw	1.71	R	3	9.5	0.08	na
11/9/02 9:15	sb, cw	1.57	F	1.40	7	0.03	7.4
12/14/02 10:55	er, cw	1.74	F	6.66	12	0.22	25
12/14/02 16:25	er, cw	4.63	R	340	2300	2109	750
12/15/02 13:40	cw	1.29	R	1.20	14	0.05	21
2/25/03 16:45	er	1.48	F	3.50	12	0.11	13
3/15/03 10:55	gp, bjm	1.58	F	3.90	220	2.31	230

Notes:

Observer Key: jo= Jonathan Owens; gp= Gustavo Porras; bjm= Bonnie Mallory; cw= Chris White ; sb= Scott Brown; ch = Charlotte Hedlund; er = Eric Reidner; bkh = Brian Hastings

Entries from 3/7/02 are from water year 2002, but are presented here, because they were not presented in last year's report.

Streamflow discharge is the measured or estimated instantaneous flow when sediment was sampled, usually from the datalogger record, and usually differs from the mean flow for the day.

Stream Condition: R = rising, F = falling, B = baseflow, U = uncertain

Values for sediment discharge having more than two to three digits displayed are the result of calculations; increased precision is not implied.

The detection limit for suspended sediment is 5 mg/L, values shown as <5 indicate that the sample was below the detection limit.

During site visits when the creek water is clear, suspended-sediment samples are not normally taken because the sample is expected to be below the detection limit.

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FIGURES

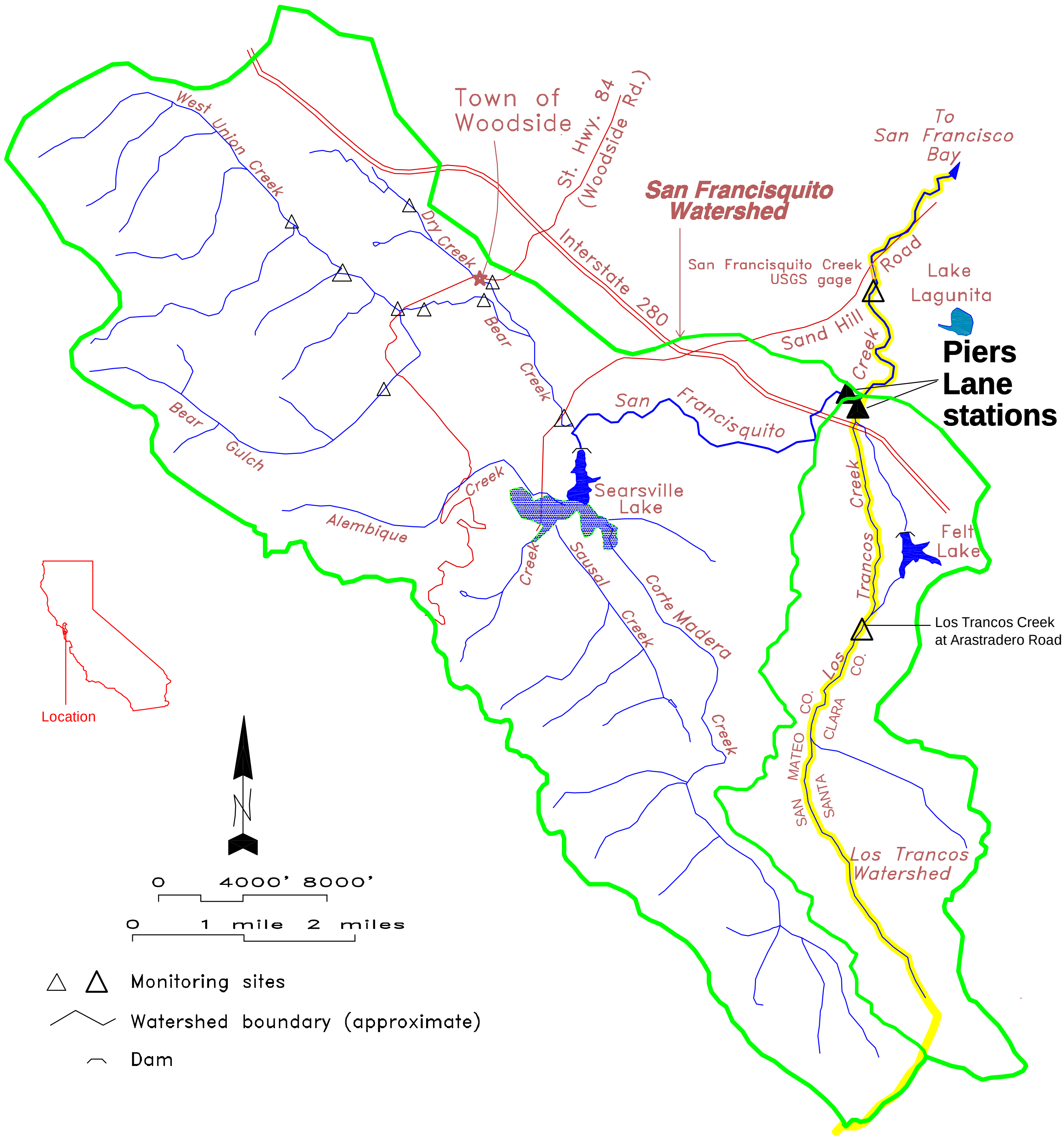

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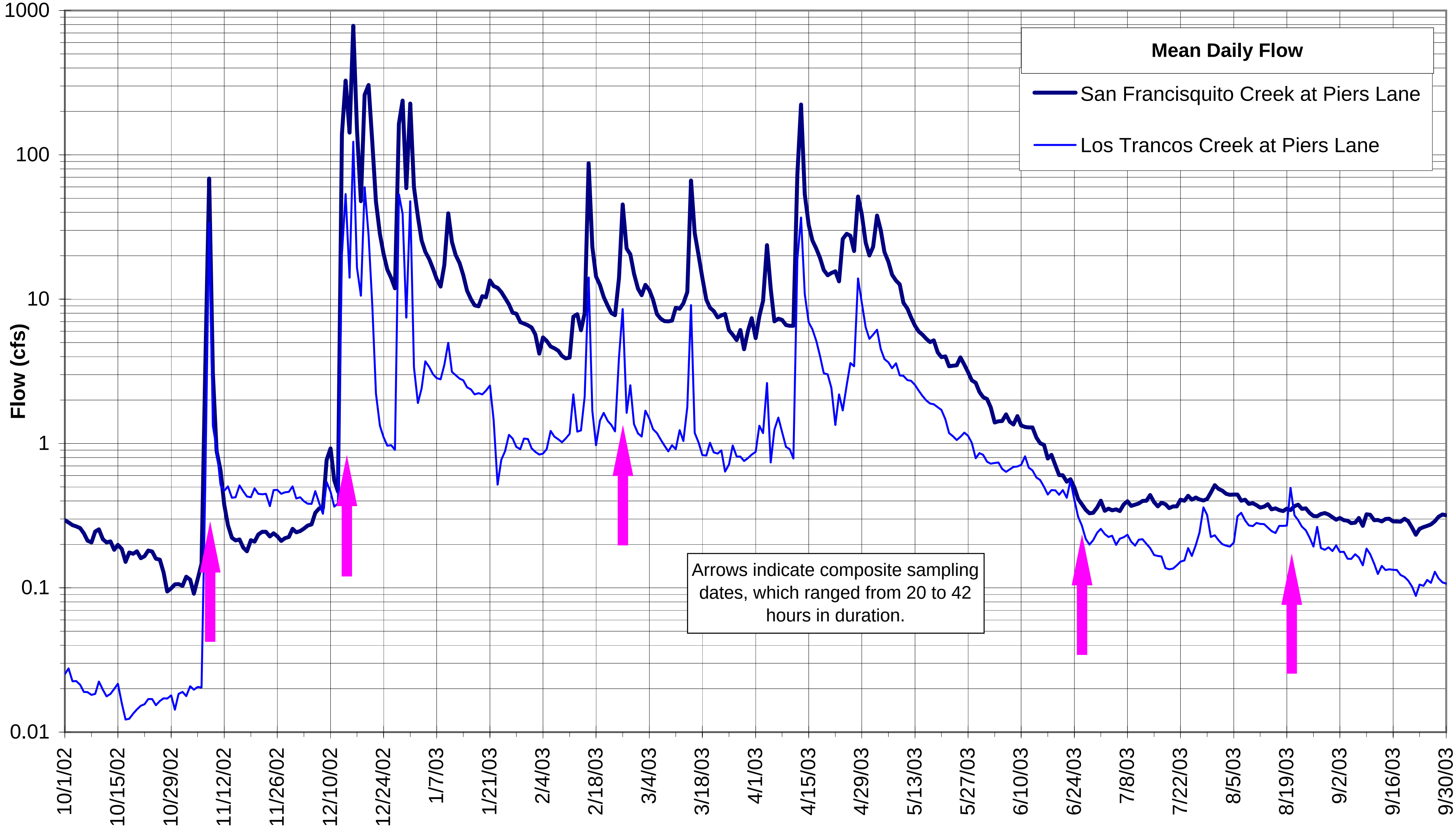
Figure 1. Site location and watershed map.

The Piers Lane stations are located just above the confluence of San Francisquito and Los Trancos Creeks. Stations shown in the Bear Creek portion of the watershed were monitored by Balance Hydrologics during water years 2000-2002, as part of the Watershed Council's Packard Grant, and are discussed in this report.



Note that the flow axis is logarithmic.

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Figure 2. Daily flow hydrographs for San Francisquito and Los Trancos Creeks at Piers Lane, water year 2003. Flow in San Francisquito Creek is generally greater than flow in Los Trancos Creek, as one would expect by its larger drainage area.

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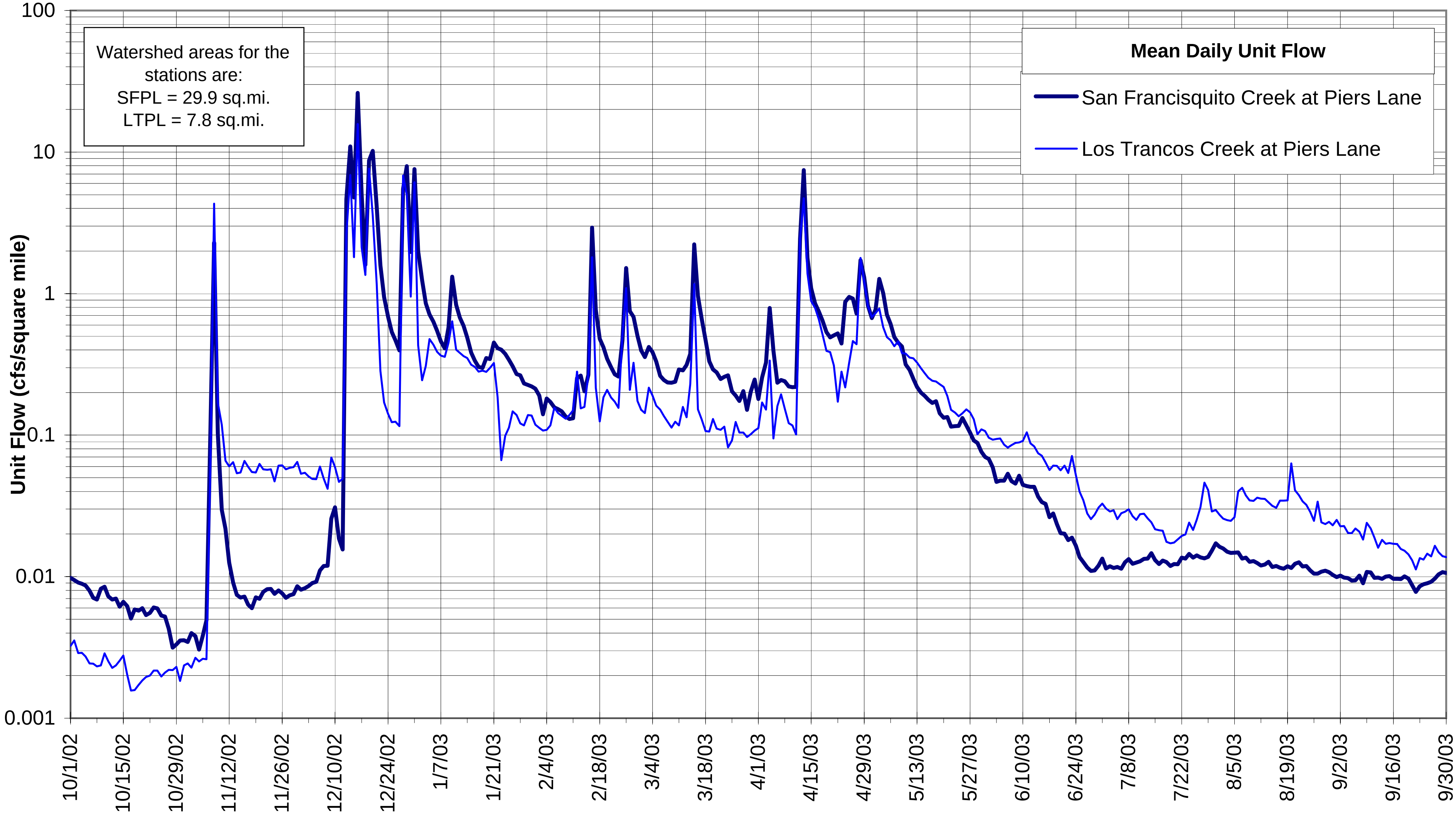

Note that the flow axis is logarithmic.

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Figure 3. Unit flow hydrographs for San Francisquito and Los Trancos Creeks at Piers Lane, water year 2003. Unit flow is calculated by normalizing flow by watershed area. On a unit-flow basis, wet-season baseflow is lower in Los Trancos Creek and summer baseflow is lower in San Francisquito Creek. In both cases, this lower flow is probably due to diversions, but is also influenced by geology and topography.

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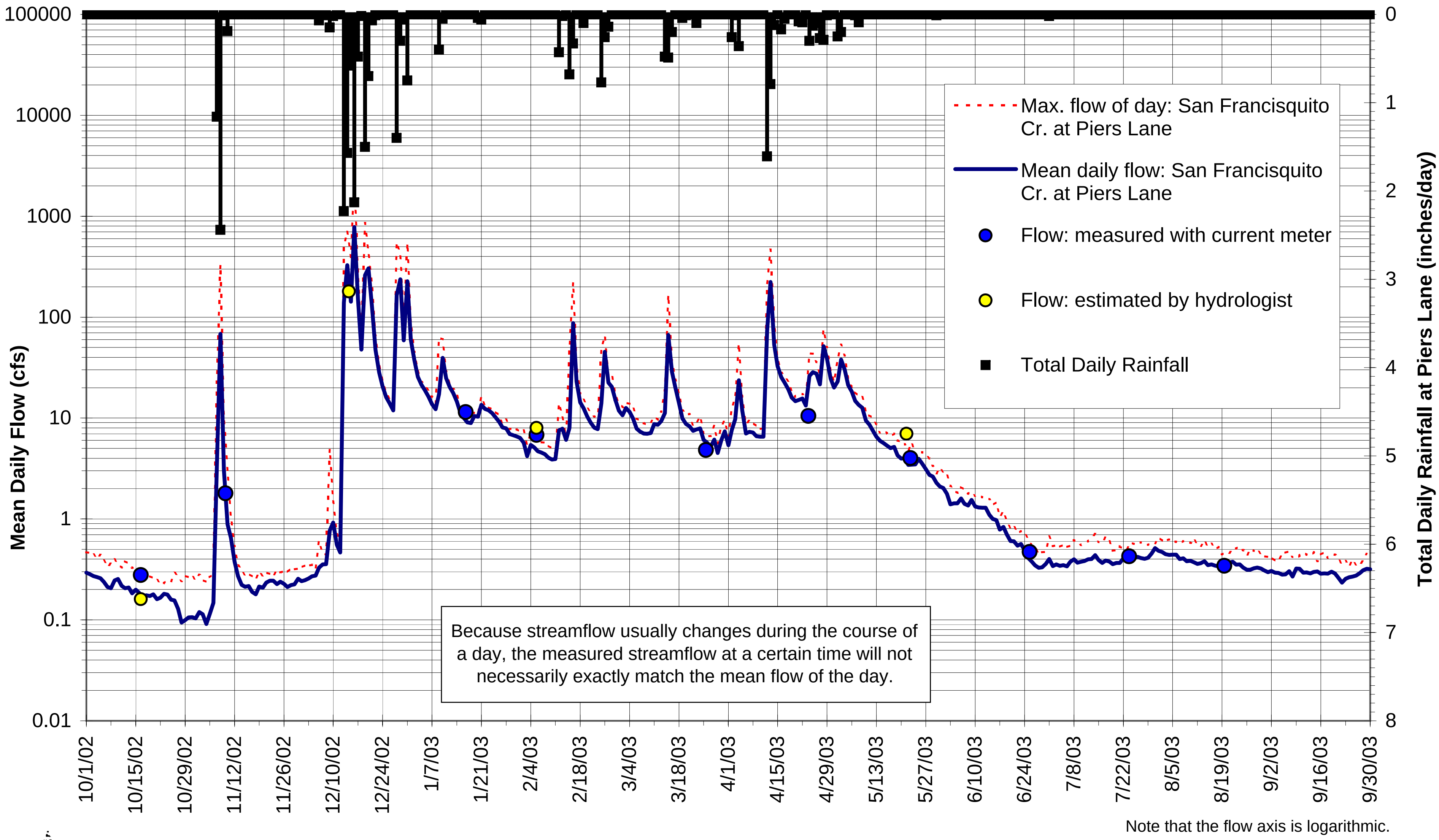

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Figure 4. Daily flow hydrograph and rainfall: San Francisquito Creek at Piers Lane, water year 2003. A peak flow of approximately 2,700 cfs was recorded on December 16, 2002 at 6:30 AM, and is associated with a 4-day cumulative rainfall total of 6.51 inches recorded at Piers Lane rain gauge. Annual precipitation for the water year totalled 25.67 inches.

Piers Lane_2003_DAILY_SUM.xls, Flow SF

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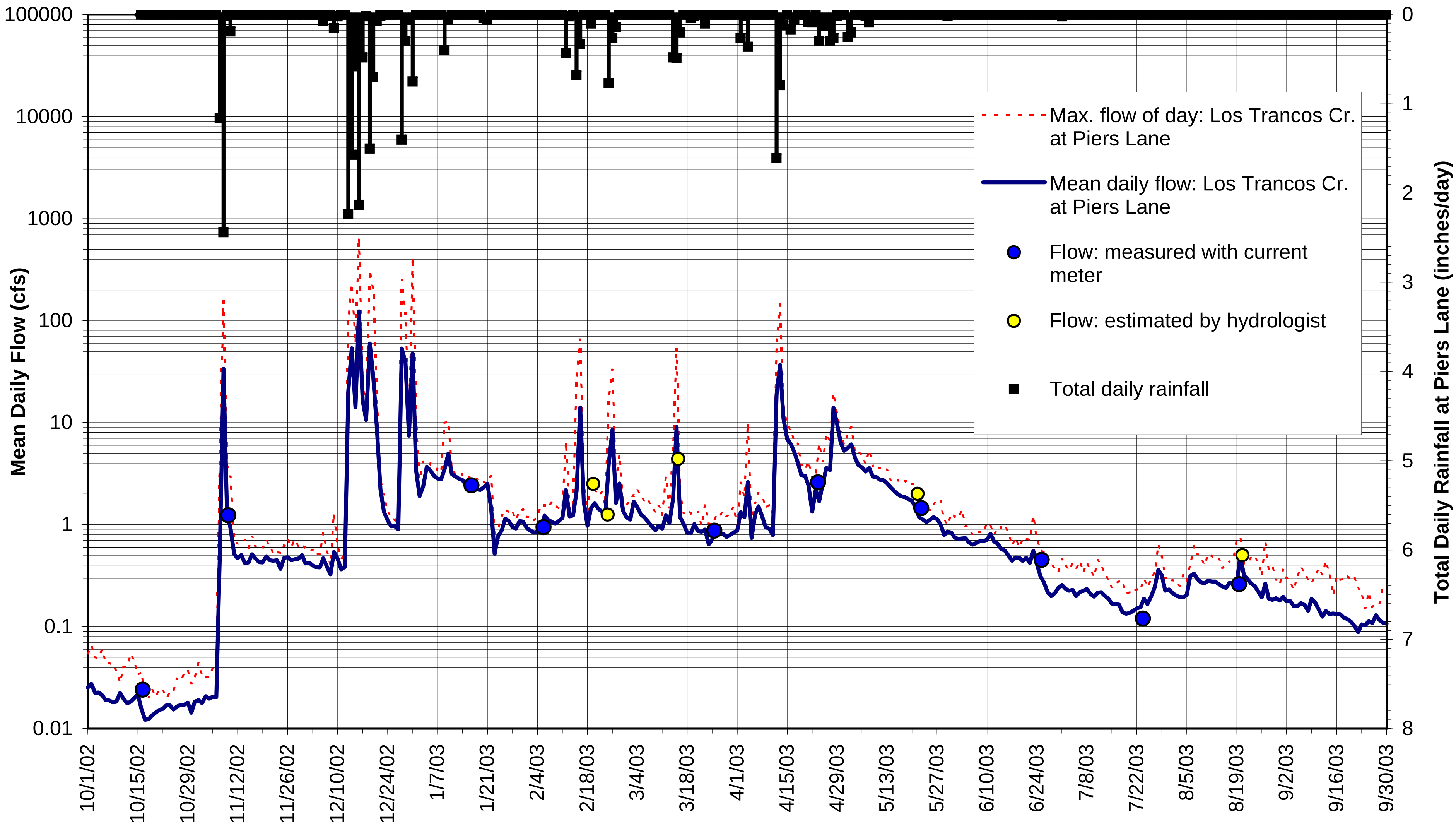

Note that the flow axis is logarithmic.

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Figure 5. Daily flow hydrograph and rainfall: Los Trancos Creek at Piers Lane , water year 2003. The water year 2003 peak flow of about 1,000 cfs occurred December 16, 2002, at 6:30 AM. This peak flow is associated with a 4-day cumulative rainfall total of 6.51 inches. Annual precipitation for the water year totalled 25.67 inches.

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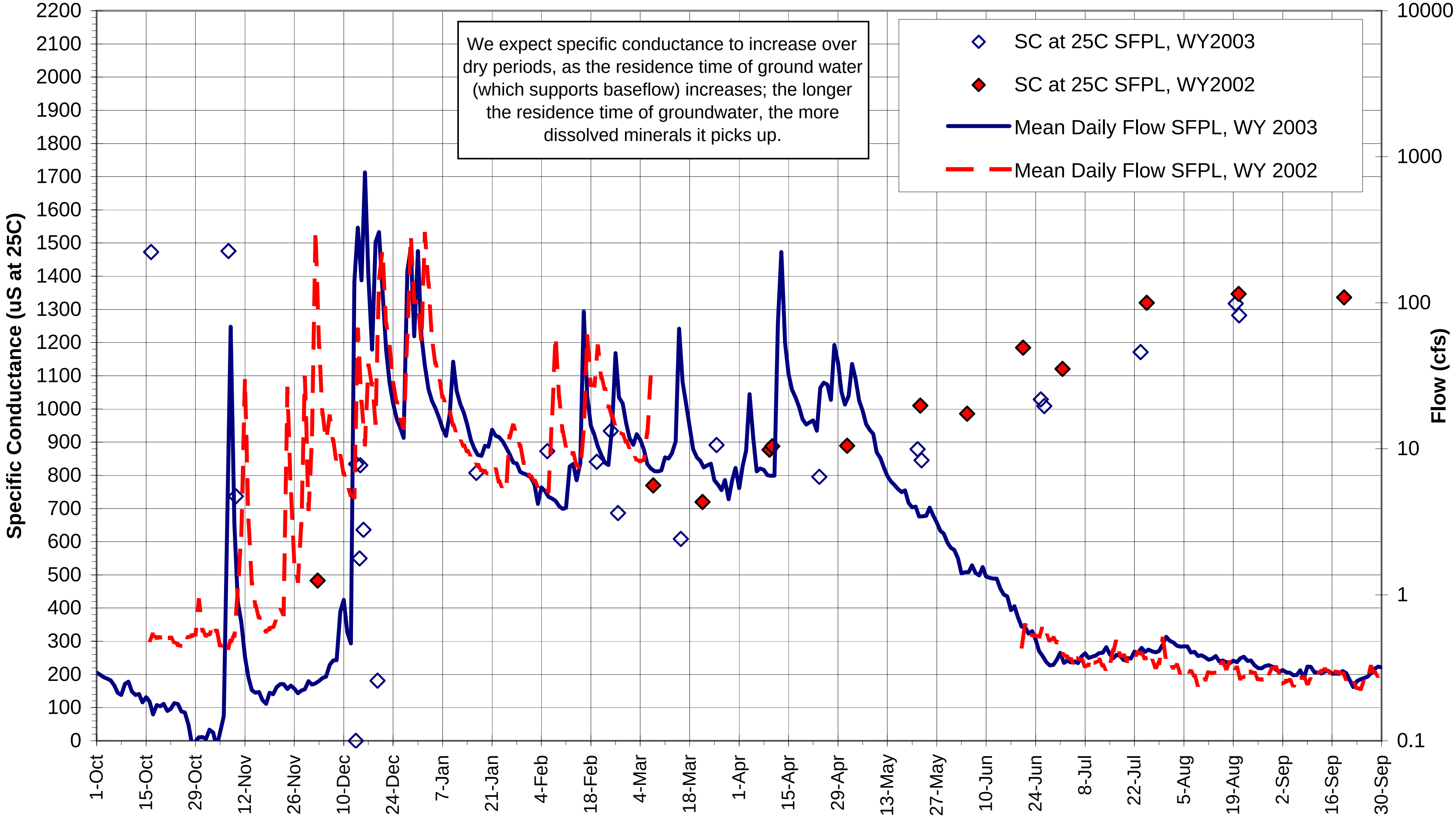

Note that the flow axis is logarithmic.

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Figure 6. Specific conductance measurements: San Francisquito Creek at Piers Lane, water years 2002 and 2003. Flow records are plotted here for reference. Specific conductivity measurements are similar from water year 2003 to water year 2002.

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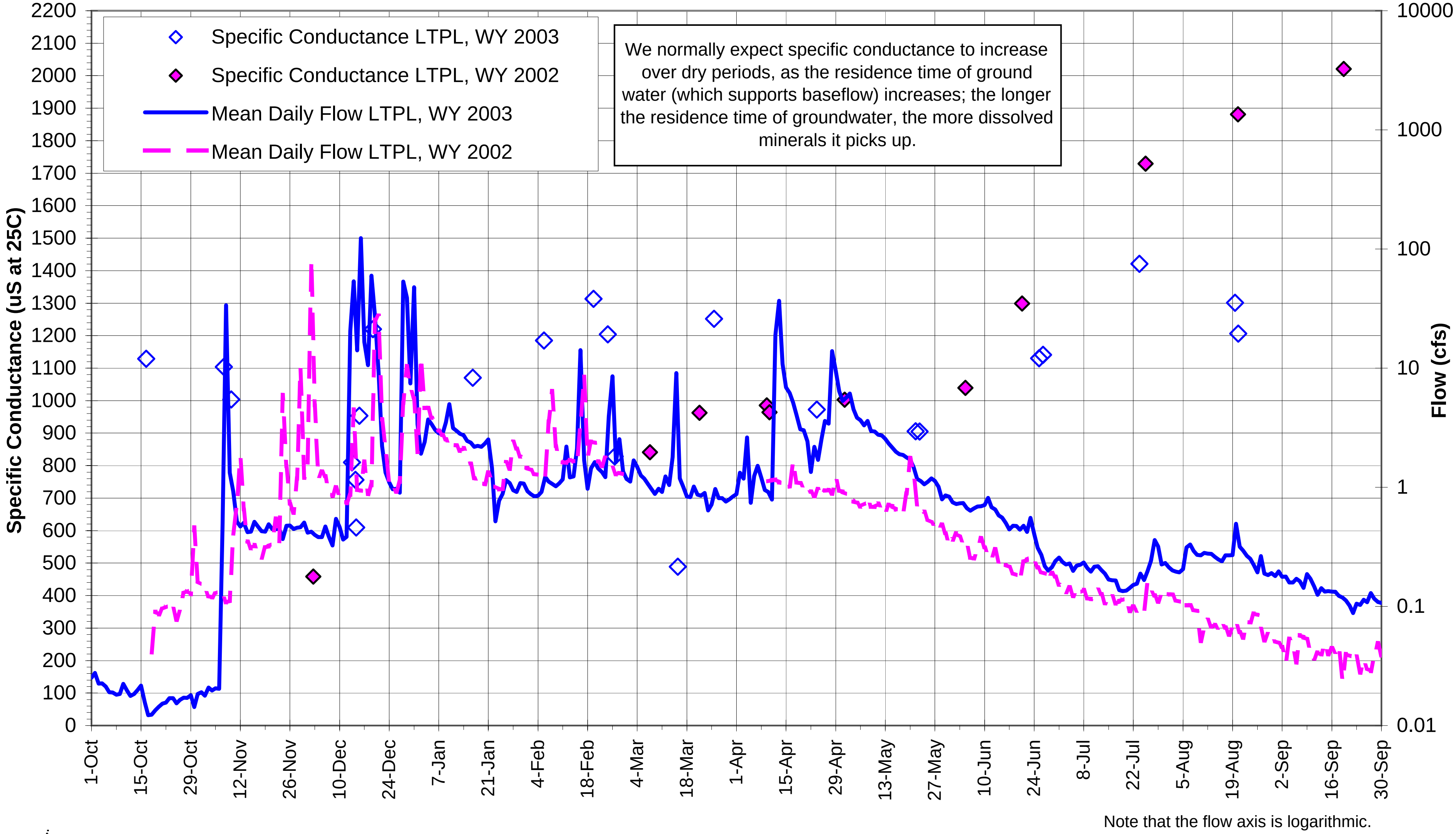

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Figure 7. Specific conductance measurements: Los Trancos Creek at Piers Lane, water years 2002 and 2003. Specific conductivity measurements are lower during the dry season of WY2003 than WY2002, but are higher during the wet season. This may be due to the slightly higher baseflow recorded during water year 2003 or fewer high-salinity additions to the creek. Flow records are plotted here for reference.

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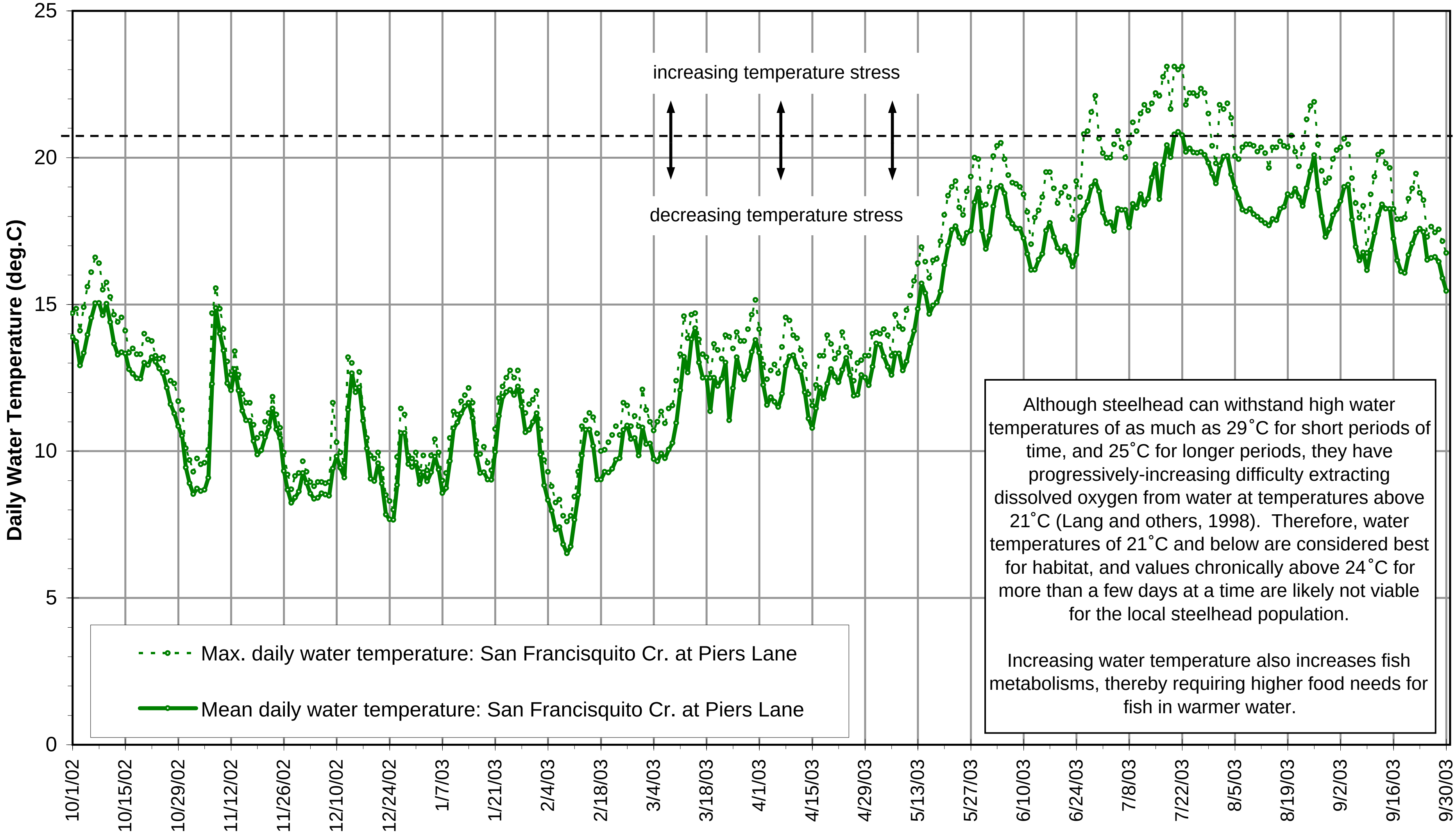

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Figure 8. Daily water temperature record at San Francisquito Creek at Piers Lane, water year 2003. Temperature patterns are similar at the San Francisquito and Los Trancos Creeks locations. Water temperature seems to be slightly cooler in San Francisquito Creek during the winter and then warmer during the summer.

Piers Lane_2003_DAILY_SUM.xls, Temp SF

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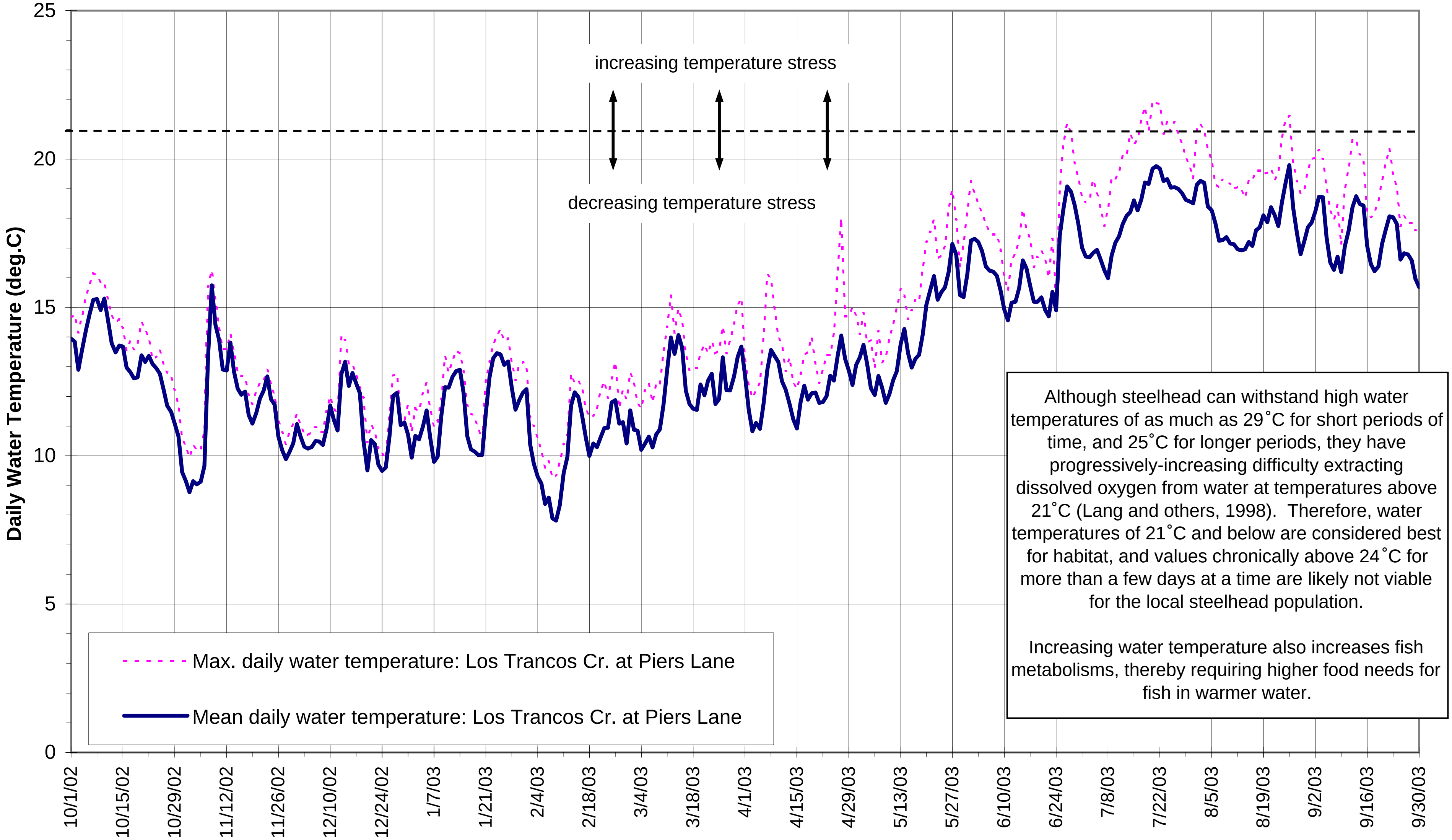

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Figure 9. Daily water temperature record: Los Trancos Creek at Piers Lane, water year 2003. Temperature patterns are similar at the San Francisquito and Los Trancos Creeks locations. Water temperature seems to be slightly cooler in San Francisquito Creek during the winter and then warmer during the summer.

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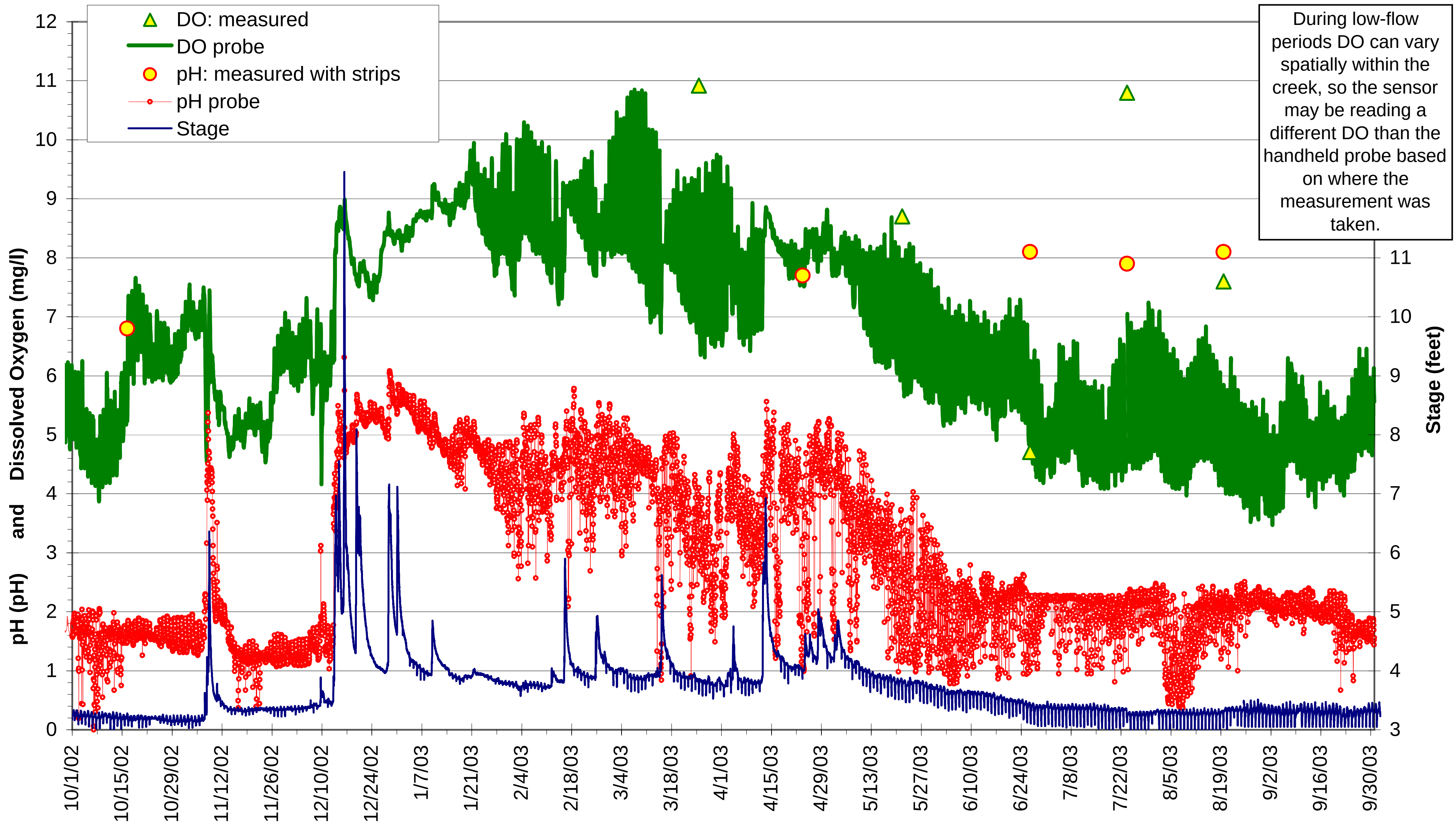

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Figure 10. Hourly dissolved oxygen and pH records: San Francisquito Creek at Piers Lane. The dissolved oxygen (DO) values recorded by the probe are within a realistic range, but don't match measured values, showing low DO during the summer and fall until rains wash dead leaves out of the creek. The pH probe does not match measured values, which seem to consistent throught the year around pH 7.8 to 8.1; we assume that the pH probe is not operating correctly.

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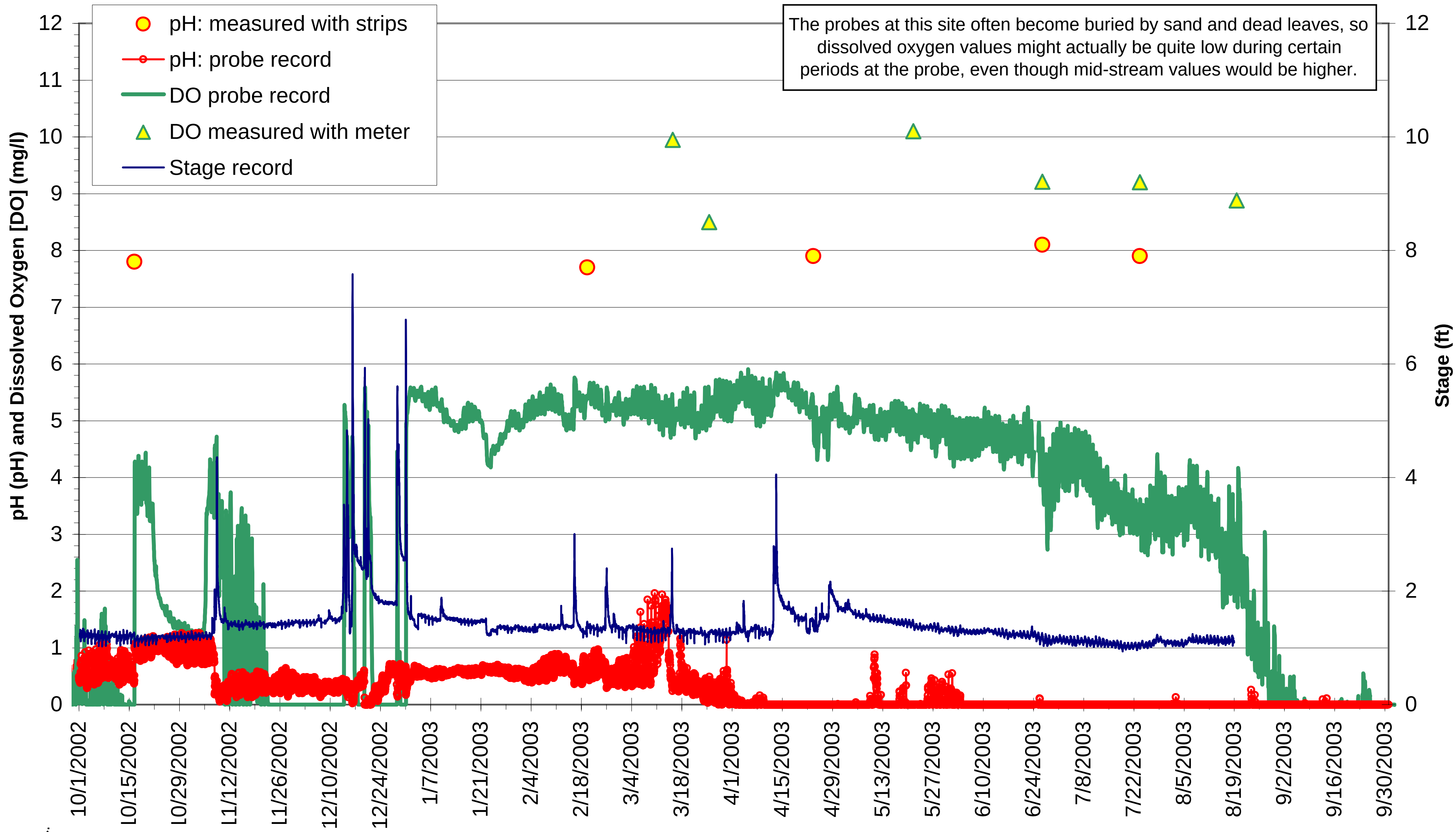

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Figure 11. Hourly dissolved oxygen and pH records: Los Trancos Creek at Piers Lane. Neither probe seems to give realistic values compared to the manual measurements. Dissolved oxygen (DO) measurements yield results that are almost always close to 100% saturation in Los Trancos Creek. The measured pH values are consistently in the range of 7.7 to 8.1; the pH probe appears to not work.

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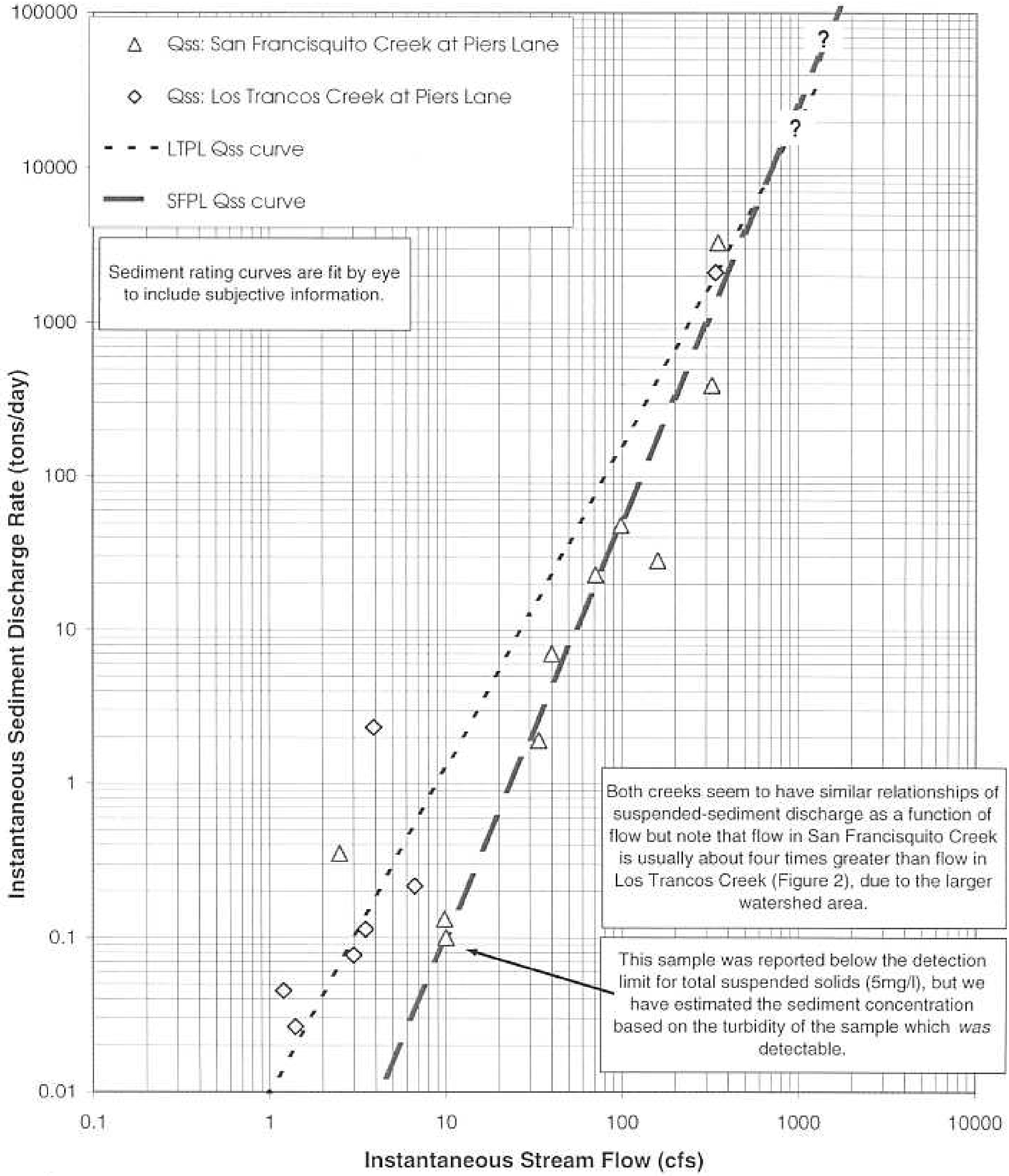

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Figure 12. Suspended-sediment discharge measurements and rating curves: San Francisquito and Los Trancos Creeks at Piers Lane, water year 2003.

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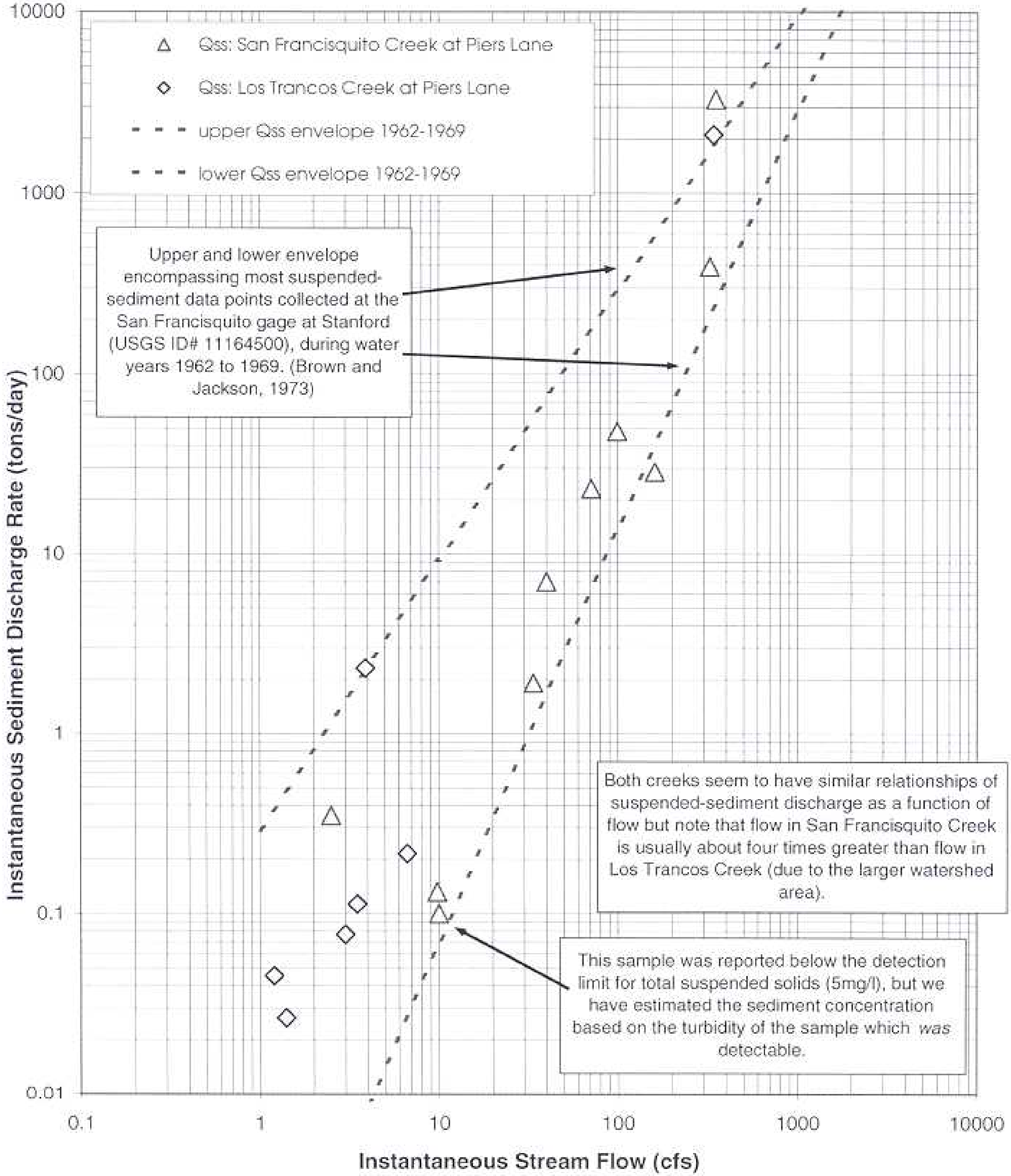

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Figure 13. Comparison of suspended-sediment discharge to 1962-1969 data. The modern data fall within the same range as the 1960s data, when Highway 280 and the Stanford Linear Accelerator Center (SLAC) were under construction.

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APPENDICES

APPENDIX A

Laboratory results and chain of custody forms

APPENDIX B

Detailed hydrographs of periods when composite samples were collected

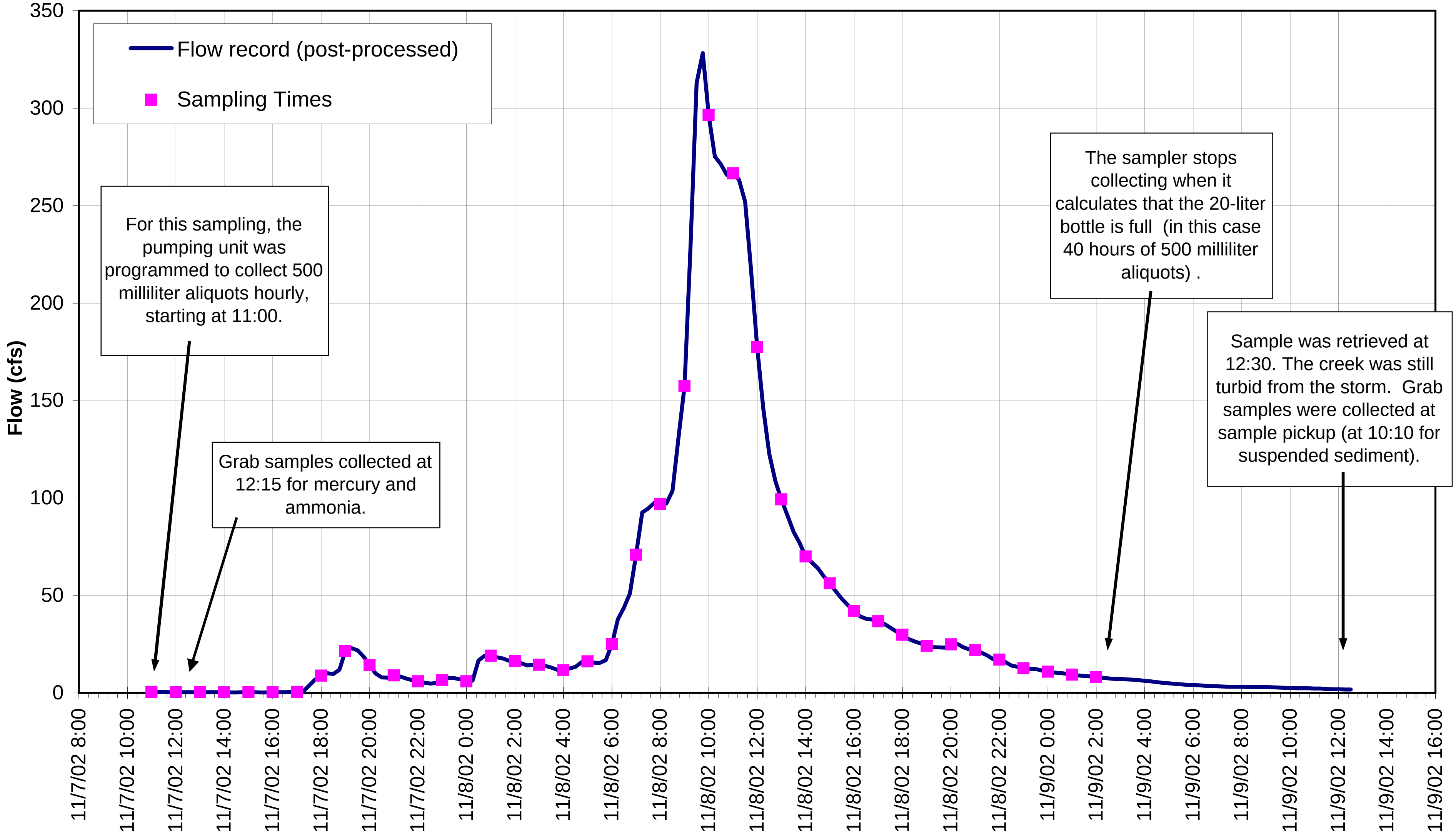

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Figure B1. Water-quality sampling detailed hydrograph, November 7-9, 2002: San Francisquito Creek at Piers Lane. This was a large and distinct "first flush" event. Time-paced sampling shown here collects most of the sub-sample aliquots before and after the flow peak.

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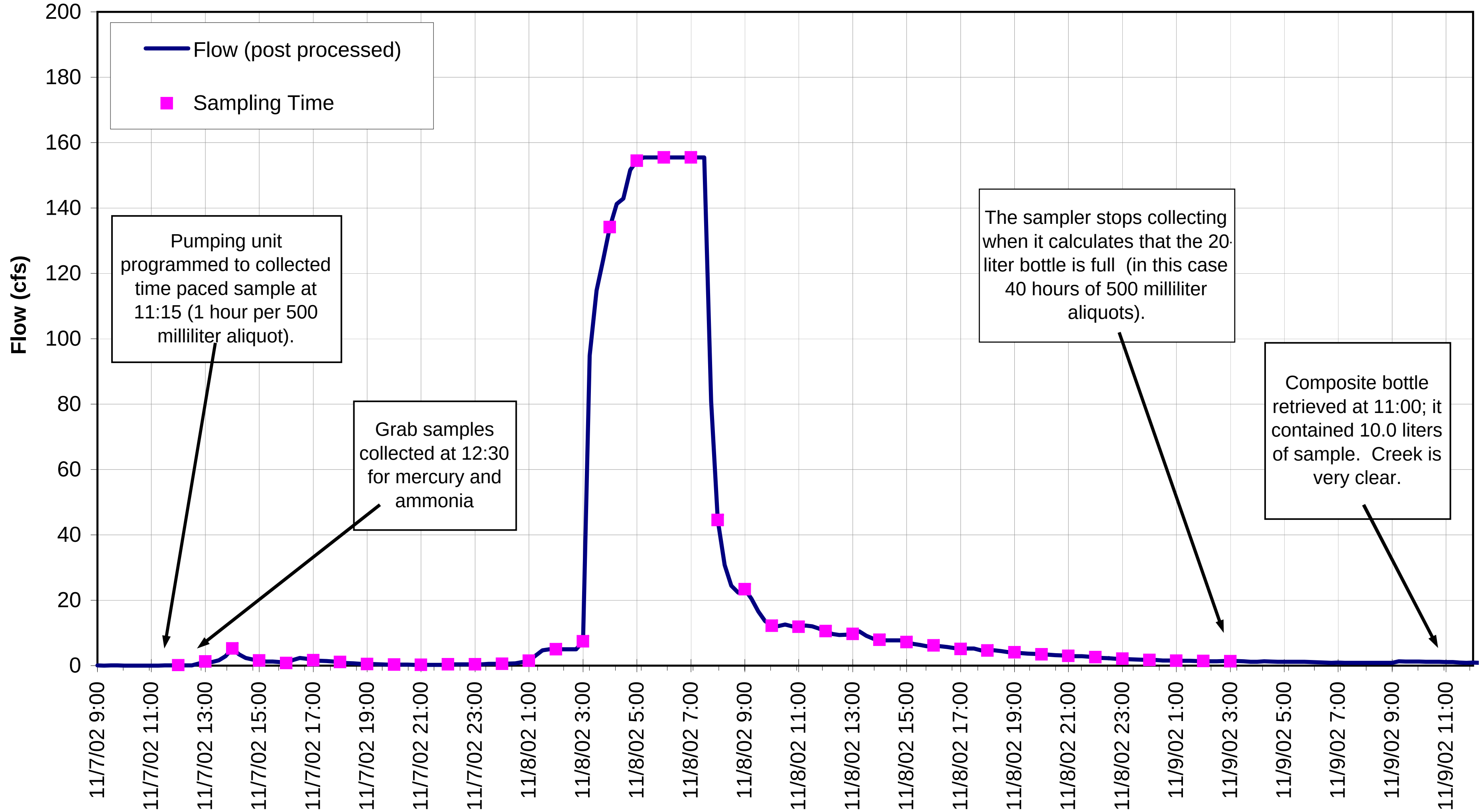

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Figure B2. Water-quality sampling detailed hydrograph, November 7-9, 2003: Los Trancos Creek at Piers Lane. This event was the "first-flush" of water year 2003, and was time paced.

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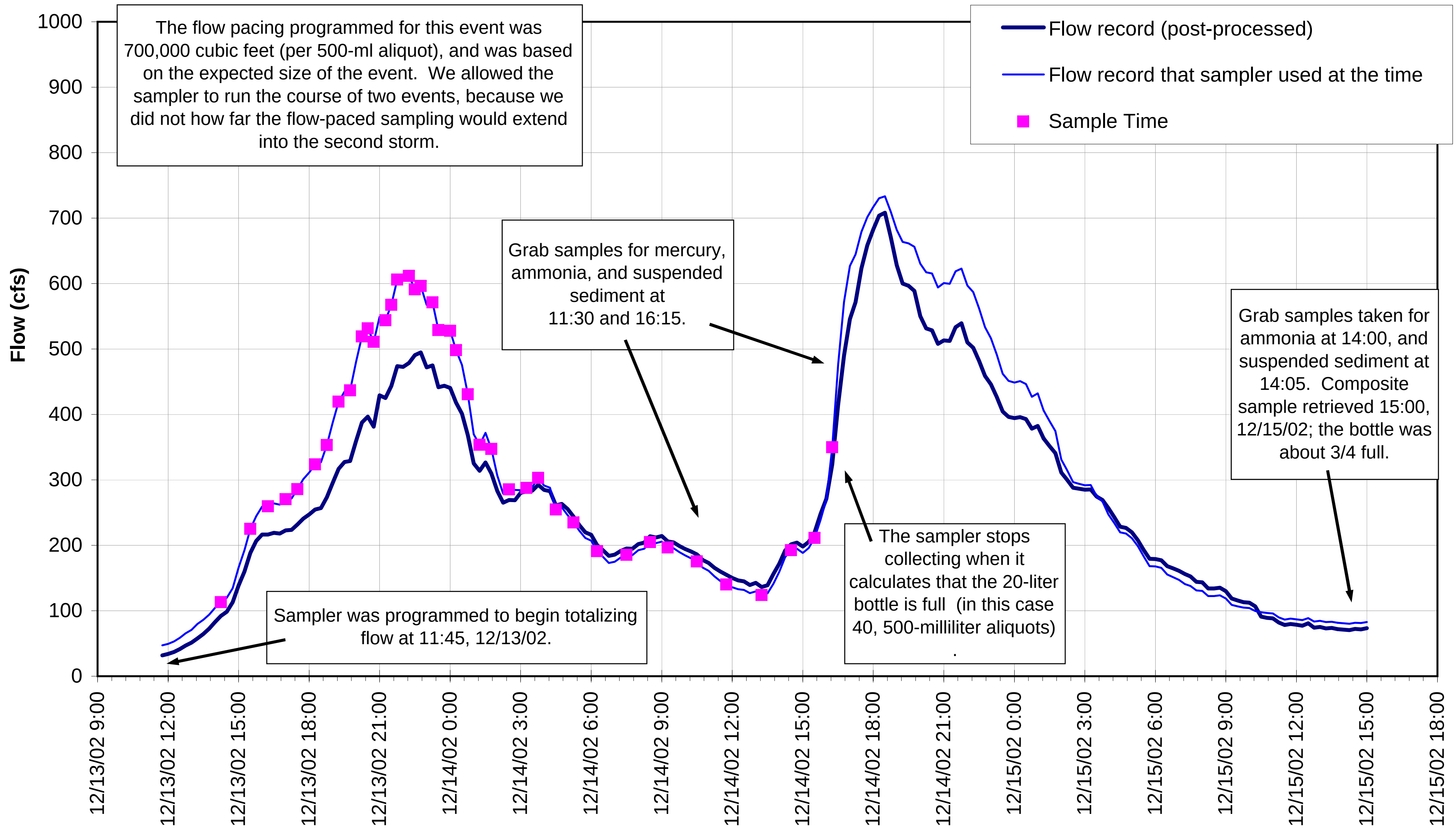

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Figure B3. Water-quality sampling detailed hydrograph, December 13-15, 2002: San Francisquito Creek at Piers Lane. This plot illustrates the portion of the hydrograph that was sampled during this specific event, as well as the effect that flow-paced sampling has on sample timing, which is to take more sub-sample aliquots during the flow peak.

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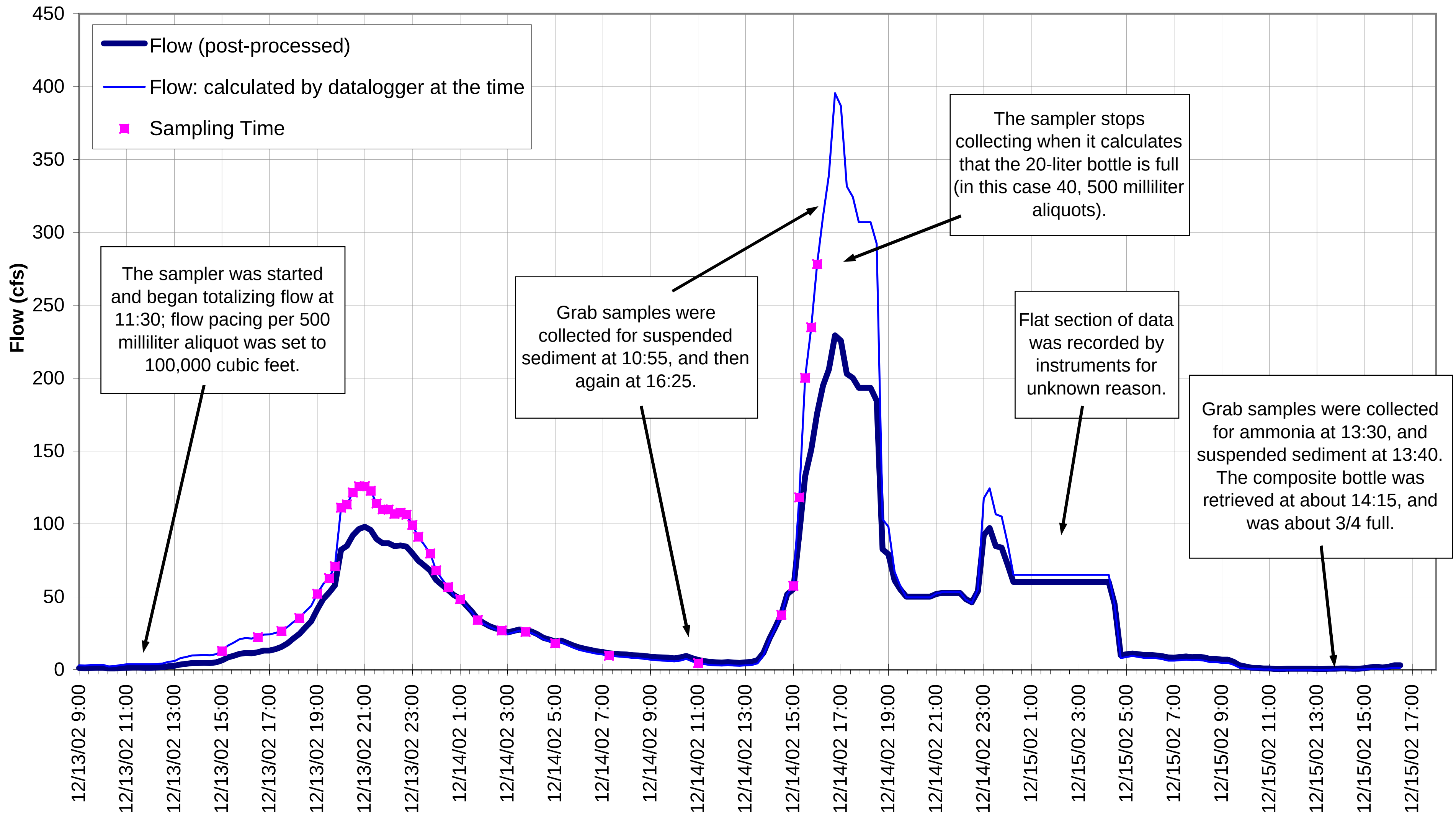

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Figure B4. Water-quality sampling detailed hydrograph, December 13-15, 2002: Los Trancos Creek at Piers Lane. Mid-storm site visits were made 12/14/02 at 10:55 and 16:25 to collect grab samples during a period of high flow. This plot illustrates when the flow-paced sub-samples were collected throughout the event. The final composite sample was an average of all of these sampling points.

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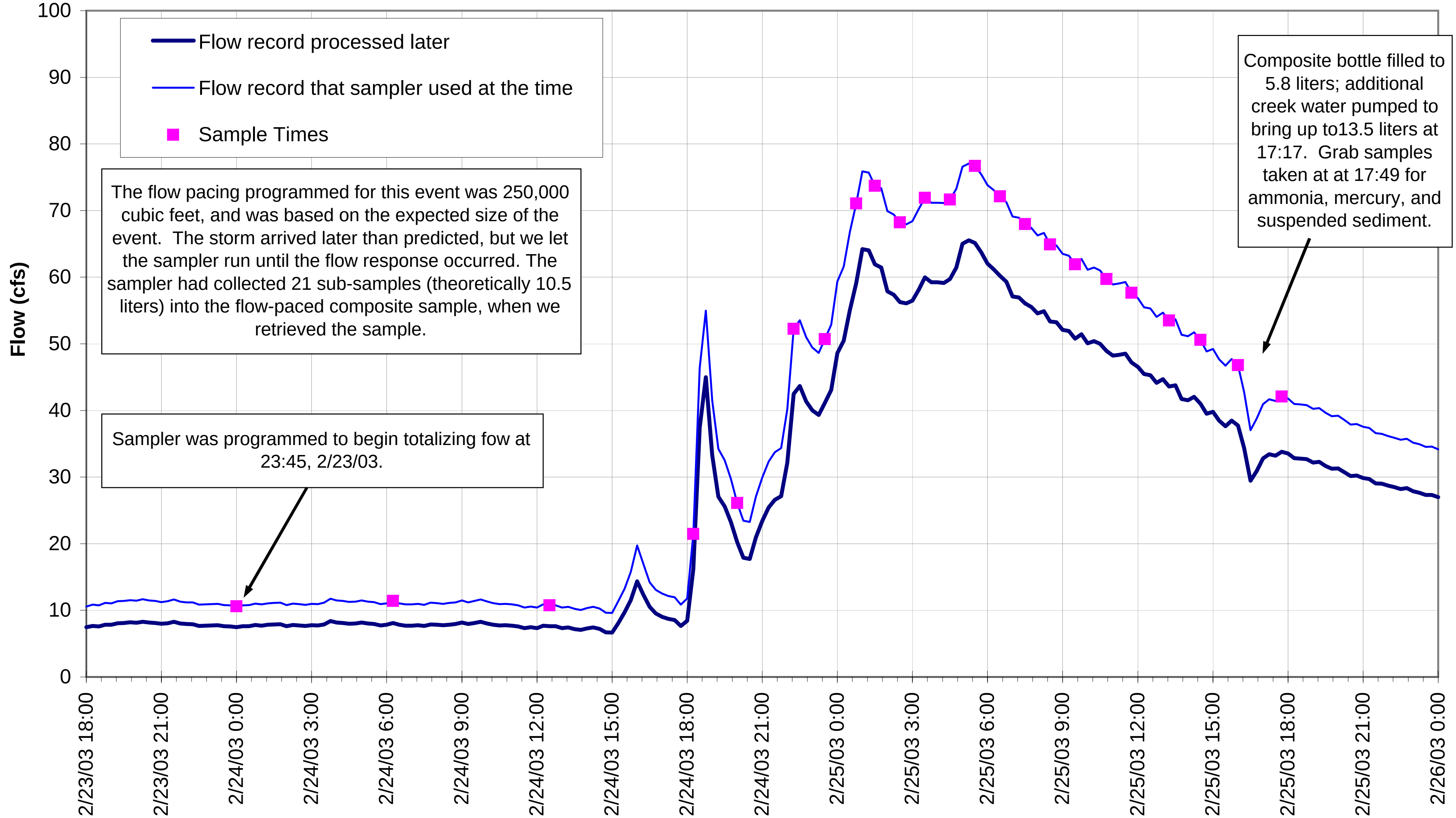

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Figure B5. **Water-quality sampling detailed hydrograph, February 24-25, 2003: San Francisquito Creek at Piers Lane.** This plot illustrates the portion of the hydrograph that was sampled during this specific event, as well as the effect that flow-paced sampling has on sample timing.

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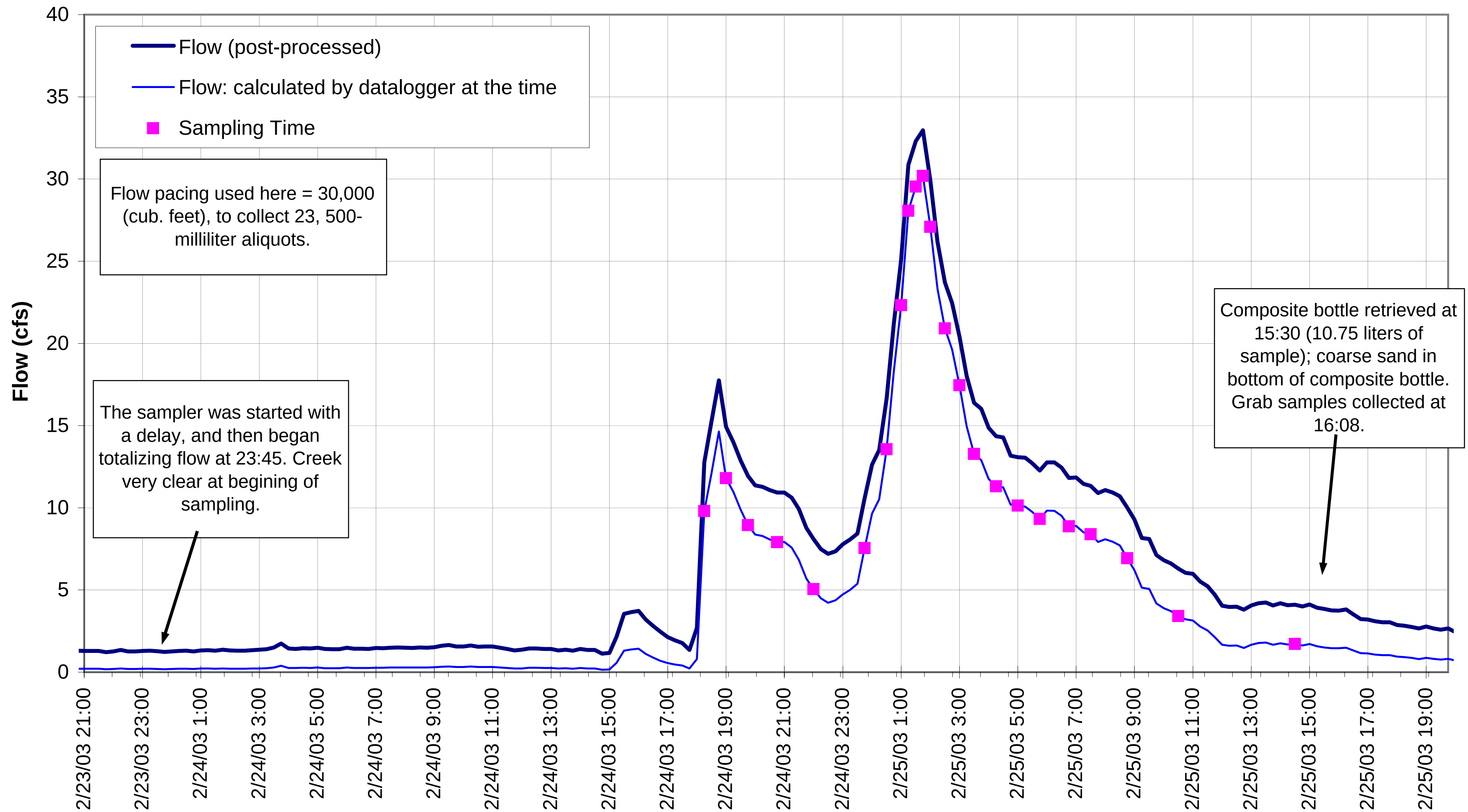

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Figure B6. Water-quality sampling detailed hydrograph, February 24-25, 2003: Los Trancos Creek at Piers Lane. This sampling was intended to be characteristic of mid-winter flows, and was flow paced.

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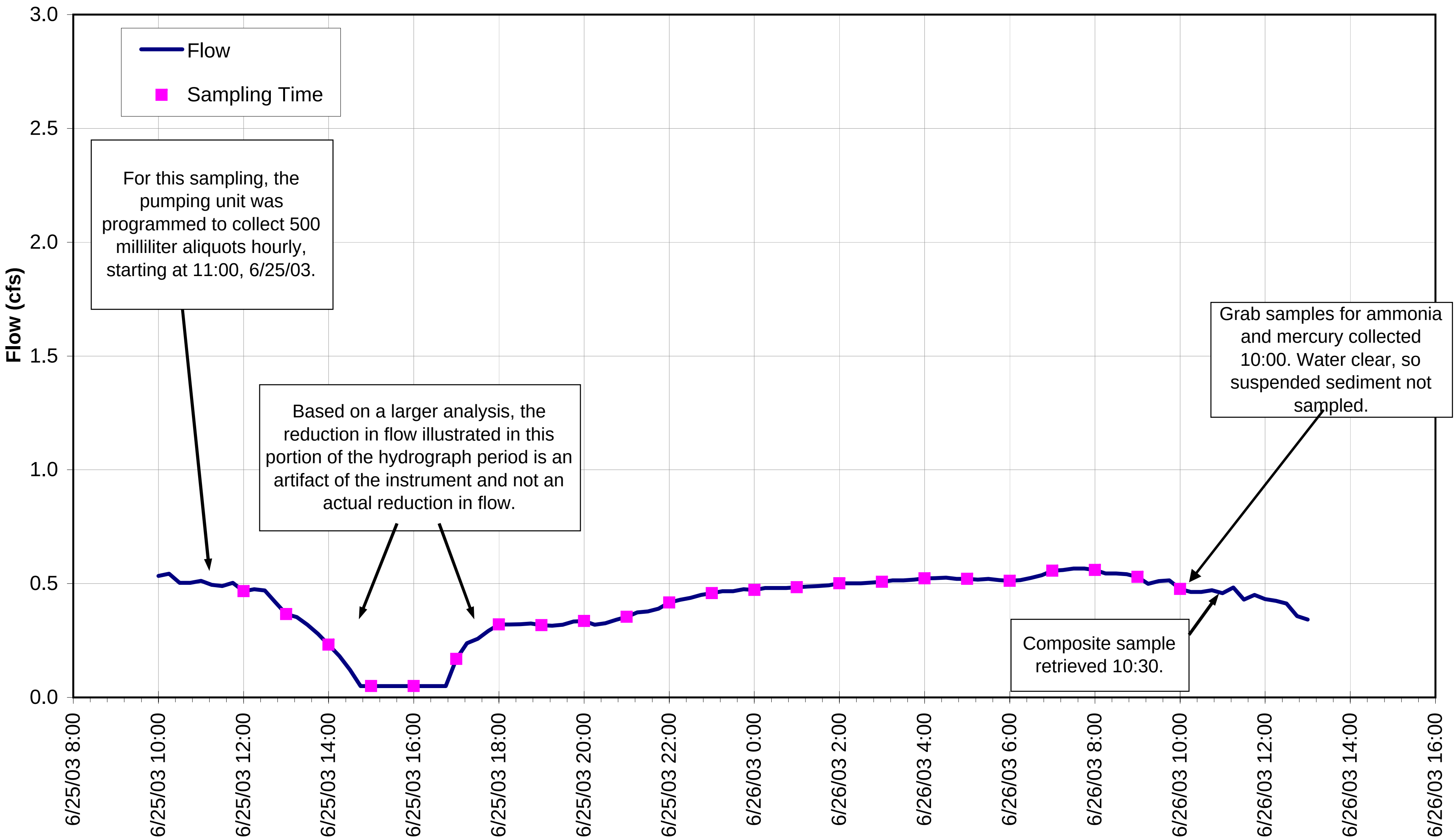

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Figure B7. Water-quality sampling detailed hydrograph, June 25-26, 2003: San Francisquito Creek at Piers Lane. This sampling was intended to characterize late-spring/early-summer baseflow, and was time-paced.

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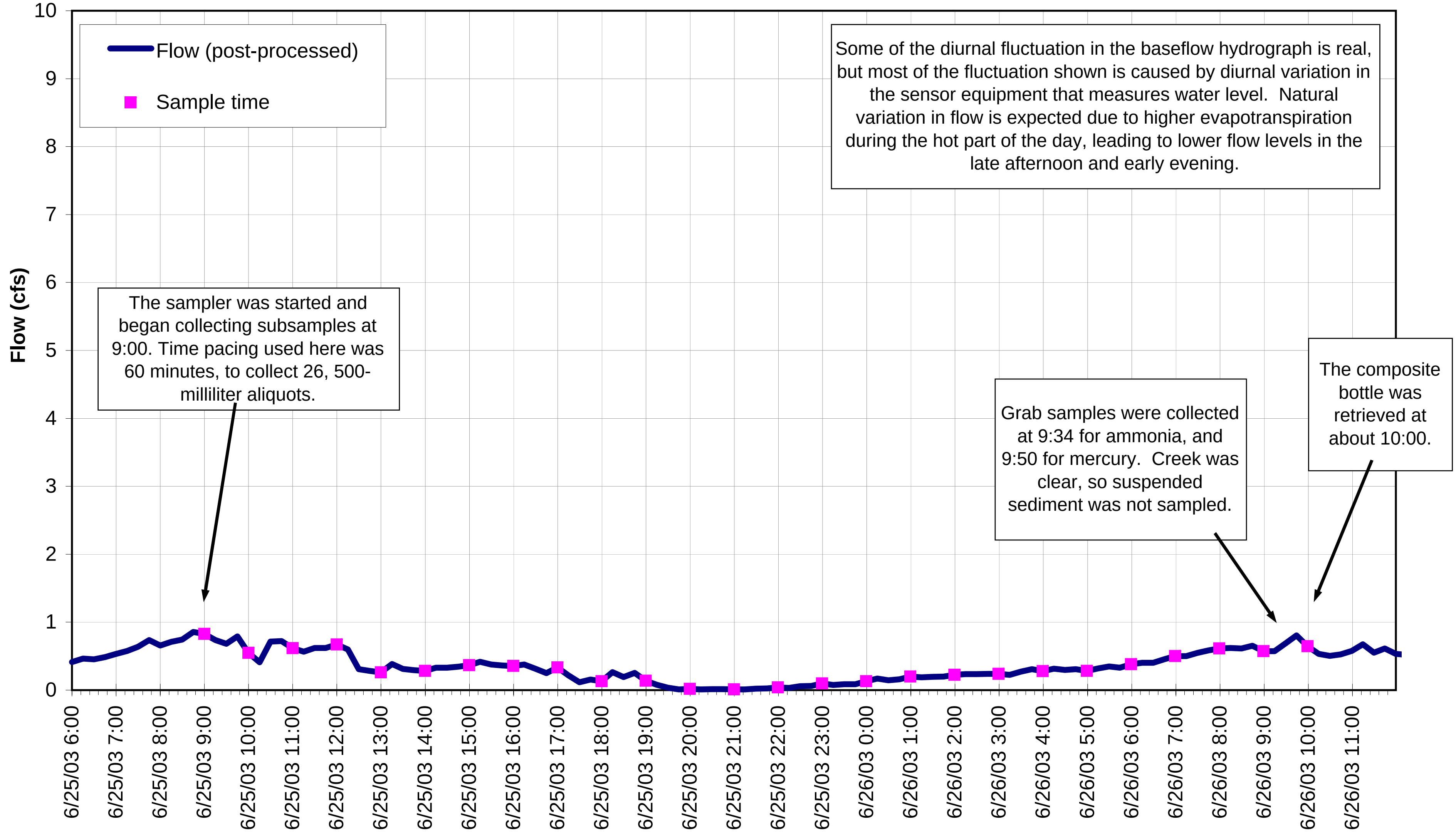

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Figure B8. Water-quality sampling detailed hydrograph, June 25-26, 2003: Los Trancos Creek at Piers Lane. This sampling was intended to characterize late-spring/ early-summer baseflow, and was time-paced.

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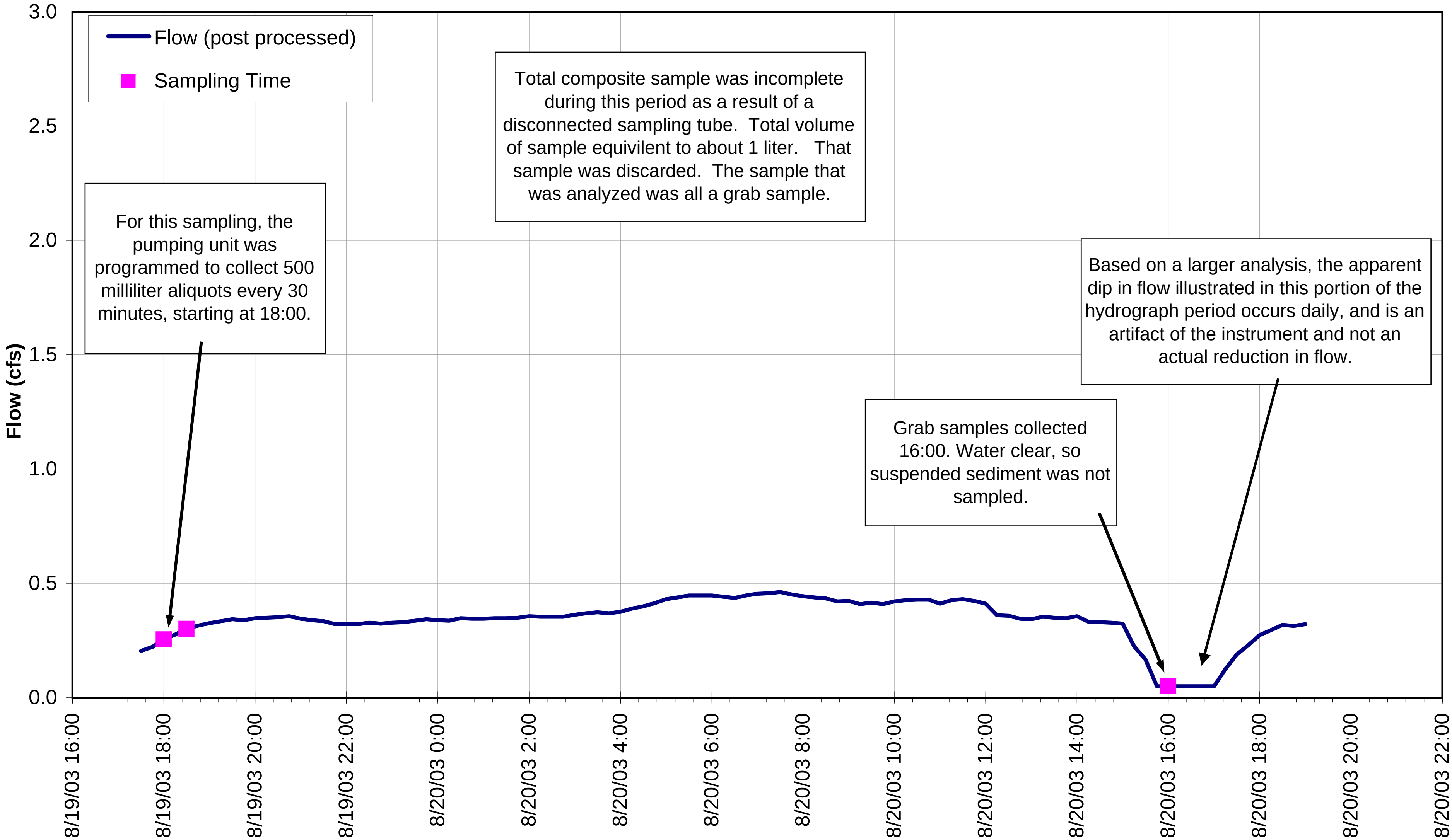

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Figure B9. Water-quality sampling detailed hydrograph, August 19-20, 2003: San Francisquito Creek at Piers Lane. This sampling was intended to characterize late-summer baseflow, and was time paced.

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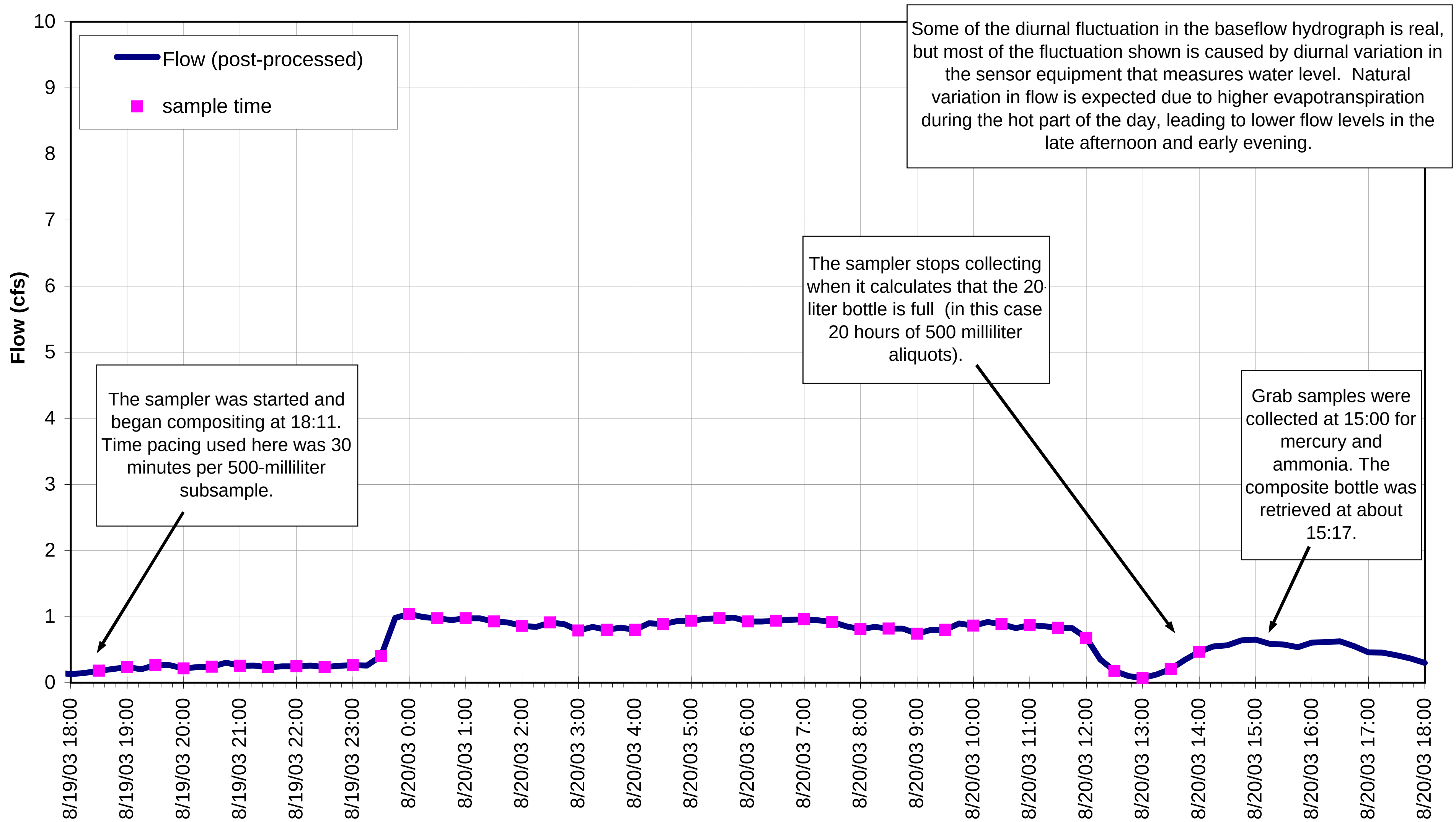

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Figure B10. Water-quality sampling detailed hydrograph, August 19-20, 2003: Los Trancos Creek at Piers Lane. This sampling was intended to characterize late-summer baseflow, and was time paced.

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APPENDIX C

Geologic units with known elevated concentrations of trace elements

Memo

To: Marty Laporte
From: Barry Hecht
Subject: Geologic units with known elevated concentrations of trace elements
Date: February 17, 2004

You have asked for our thoughts on naturally-elevated occurrences of metals in the San Francisquito watershed. This information can be used to evaluate possible sources of rare or occasional 'spikes' of individual trace-element concentrations, and help to distinguish them from trace elements that might be associated with urban, light-industrial or highway runoff. It can also be applied to provide a firmer geologic basis for identifying 'background' conditions, such that data from other watersheds with other influences will not be erroneously applied to the San Francisquito basin, and will help in interpreting water-quality results wherein occasional high values may derive from natural sources.

The emphasis in this memo is on possible trace element contributions from naturally-occurring sources, and in identifying those formations that are known to have some elevation of concentrations in the region. Readers should bear in mind that:

- Not all horizons or outcrops will have elevated concentrations.
- Not all elevated concentrations have a geologic source.

This memo is intended as an overview. To meet your objectives, we have cataloged reports of elevated trace-element concentrations by formation from the regional geologic or water-quality literature without quantification. Further information is available from the cited literature, among other sources. We note that quantitative data are sparse, if they exist at all.

Sources of Information

Two very different classes of information are used in this discussion. First, we have canvassed the regional literature seeking information on which elements may prove elevated given the geologic units that are mapped within the San Francisquito watershed. This is a more complex task than it might sound, since the watershed includes two tectonic plates with sharply different geologic histories and geochemical influences. Additionally, recent advances in understanding of the local tectonics have clarified that the edges of both plates are themselves complex, with significant vertical and horizontal offsets. Many different formations can occur at relatively shallow depths within the watershed, or may prove to be sources of one or more of the Tertiary sediments which outcrop in the watershed. Accordingly, we have drawn upon the geologic literature for some distance north and south of basin, ranging roughly from Chittenden and Pacheco Passes northward to approximately Bolinas, and extending on either side of the fault.

Second, we have reviewed literature from the watershed, including extensive recent background characterization of the SLAC grounds (Erler & Kalinoski, 2003). Additional information is available from prior water-quality sampling (both by Balance and by USGS) and from isolated reports describing individual sites or geologic units.

Regional literature describing elevated naturally-occurring concentrations

Trace metals have been *occasionally* reported in locally-elevated concentrations from a number of the geologic units mapped within the San Francisquito watershed (c.f., Pampeyan, 1993; Page, 1997; Coleman, 1998). Mapped units meriting consideration are described below from oldest to youngest:

- Franciscan volcanic rocks: Outcropping widely in Jasper Ridge and the Westridge areas, these greenstones -- metamorphosed sea-floor basalts -- are a type of rock known to contain elevated naturally-occurring concentrations of many metals elsewhere in the world. In central coastal California, these volcanics are thought to be a contributing source to the mercury-rich deposits of New Almaden, and to scattered mapped copper and silver 'prospects' from Bolinas Ridge southward. The Portola and Ormondale mine shafts on Jasper Ridge explored possible ore bodies within the greenstones, and Regnery (1991: pp. 72 and 93) reports traces of gold, zinc, lead, copper, and iron were identified in early Stanford studies. Soils derived from these rocks tend to be only slightly elevated in trace elements.

- Serpentinites: Serpentines outcrop in the San Francisquito watershed mainly in a limited area along the crest of Jasper Ridge. Chromium, nickel, vanadium, manganese and other heavy metals are often present in serpentinites or ultramafic rocks throughout the state, and in derived soils and alluvium (c.f., Kruckeberg, 1984). Mercury and arsenic are sometimes found in association with serpentinites, most frequently in the adjoining sandstones.

- Franciscan limestones and marbles: Carbonate lenses abound in the Franciscan greenstones of San Mateo and Santa Clara Counties. A necklace of such lenses extends from the Calera quarry in Pacifica through the large unit mined along Permanente Creek. Detrital marble gravel and cobbles are found extensively in the Santa Clara formation within the San Francisquito watershed. To the best of our knowledge, trace elements have not been reported in elevated or problematic concentrations in these units, unlike in similar geologic settings elsewhere in the world.

- Butano/San Lorenzo formations: The Butano formation, which underlies much of the summit ridge from the Portola Valley city hall northward, is largely detrital material, including turbidites and sandstones, with no known naturally-occurring elevated concentrations. The conformable San Lorenzo formation, which underlies much of the top half of the summit ridge south of central Portola Valley includes both mudstone ('Rices') and black shale ('Two Bar') members. Either, but probably the latter, is likely to be the probable source of very occasional elevated concentrations of uranium, vanadium, cadmium, and phosphate reported from upper Soquel Creek or other sampling stations between the summit and the Zayante/Ben Lomond faults.

- Vaqueros/Lambert formations: These units occur throughout the core of the Santa Cruz Mountains, outcropping locally in the headwaters of Sausal and Corte Madera Creeks. Few trace metals are known from the Vaqueros sandstones; the conformable Lambert shales are known to be phosphatic (c.f., Dickert, 1966), and could contain higher trace-element concentrations as occurs in the Monterey formation, but little pertinent information is yet reported.

- Mindego and Page Mill basalts and related dikes and sills: Primarily submarine basalts of varying ages and compositions, but probably containing elevated concentrations of iron, manganese, and many other trace metals typically rich in basalts, including copper.

- Whiskey Hill formation: We know of no elevated concentrations reported from this unit, which includes claystones and mudstones, which can contain higher levels of trace metals.

- Monterey mudstones and shales: Monterey formation sediments outcrop along the lower half of the summit ridge between central Portola Valley and Dennis Martin Creek. Elsewhere throughout central coastal California, many but probably not most of the beds in this formation contain elevated levels of naturally-occurring cadmium (Majmundar, 1980) and phosphorus (Dickert, 1966). Majmundar reports slightly elevated concentrations of zinc and copper, but little lead, is associated with the cadmium. The elevated levels of cadmium and phosphate continue northward into the central Santa Cruz Mountains (c.f., Hecht and Golling, 1982). On several occasions, agencies responsible for water quality and habitat protection have conducted searches for a cadmium source in the San Lorenzo River and adjoining watersheds, not having been apprised of the elevated naturally-occurring concentrations and the higher-than-normal background levels.

- Mio-Pliocene volcanics: Eruptive rocks of intermediate (mainly dacitic) composition are found on the eastern side of the Santa Clara Valley. In northeastern San Benito County and adjoining parts of Santa Clara County, where they are known as the Quien Sabe volcanics, they contain elevated levels of tin, mercury, antimony, copper and arsenic (Drinkwater and others, 1992; Ludington and others, 1987). Related volcanism may have been partially the source of the mercury at New Almaden. These volcanics are not known to extend into the San Francisquito watershed. Their mineralogies and trace-element concentrations are quite distinct from the local basalts of various ages found within the watershed.

- Purisima formation: Underlying the lower half of the summit ridge south of central Portola Valley, the Purisima sediments are soft, rapidly eroding, and are the source of much of the sediment in Corte Madera Creek being deposited in Searsville Lake. Much of the sand and silt forming this unit originated from erosion of predominantly andesitic volcanic rocks in the proto Sierra Nevada. The Purisima seems to contain detrital minerals that contain elevated levels of trace elements. In Santa Cruz County, sand originating mainly from erosion of the Purisima formation was mined as a source of titanium and ballast metals during World War II (c.f., Esmaili and Hecht, 1978). Iron and manganese are often extremely abundant in waters from this formation, and occasional elevated levels of chromium, vanadium, copper, zinc, and titanium are reported from wells or springs developed in this unit. The Purisima is one possible source of tiny amounts of placer platinum reported from San Mateo County beaches (Luepke and Maher, 1991). Further south in the Santa Clara Valley, the formation contains significantly-elevated concentrations of boron and arsenic, and occasionally barium, but this suite of metals seldom is found north of Gilroy (c.f., Esmaili and Hecht, 1978).

SLAC literature describing elevated naturally-occurring concentrations

The Stanford Linear Accelerator Center (SLAC) has recently completed an assessment of background trace-metal concentrations in soils and rock (Erler & Kalinoski, 2003). The study included analysis of 30 samples each from areas mapped as Whiskey Hill, Ladera and Santa Clara formations. All three units are a mixture of sandstones and finer sediments. The samples were deemed to be random and representative, rather than chosen to identify maximum or characteristic metals suites; hence, the SLAC results differ fundamentally from those discussed above.

The SLAC investigation was intended to be quantitative, with a statistically significant number of samples. It affords an opportunity to compare results with those collected in other regions or formations (see Table 16). Accordingly, considerable care was employed in identifying and drilling sites likely to be without contamination or geochemical influence by humans. Samples were drawn by adaptation of conventional geotechnical methods (sleeveless split-spoon sampling) from various depths within 10 feet of the ground surface. Samples were screened to remove all gravels or coarser material (>2.0 mm), and homogenized by hand. As a further experiment, the laboratory analyzed both pulverized and as-received samples, detecting little difference. For the Ladera and Santa Clara formation, soils and rock yielded somewhat different results; Whiskey Hill rock and soils showed little difference. No ground-water, soil-water or runoff samples were collected or analyzed.

Results indicate a range of trace-element values with relatively narrow ranges, and ranges which generally fell within those previously reported for central coastal California. Differences are greater between the soil and coherent rock zones than between formations. The largest spans (expressed as coefficients of variation) were commonly but not always those for elements which tend to be concentrated detritally (or ‘placered’), such as cadmium, chromium, nickel, and mercury; this suggests that physical sorting processes may have a relatively large effect. Further placering of sand grains in streams could result in further concentration of metals in stream sediments, were these to be analyzed. Constituents that tended to be geochemically sorted had the highest variation in the Whiskey Hill formation.

Implications

With a large number and an atypically varied set of geologic sources for naturally occurring trace elements, many potential contributing factors can affect the total or soluble concentrations of these ‘metals’. It is useful to discuss some of the primary influences. Among related implications is that the sources and concentrations of these elements will change over time in several predictable ways, but it may not always be possible to track, ‘explain’ and manage occasional departures from normal concentrations.

All of the trace elements reported from the San Francisquito watershed are found and transported primarily in particulate form. Trace element concentrations in waters and stream sediments can diminish if rates of erosion were to be lowered. Reduction in sediment production and transport will result in a decrease in the **total volume** of trace elements available to the biological network in San Francisquito Creek and the adjoining corridor. Similarly, a reduction in sediment delivery to the waterways will result in diminished **concentrations** of trace metals in the creek, because finer sediment – which may contain greater and more biologically available concentrations of these ‘metals’ – will be disproportionately winnowed and transported out of the system.

At times, sediment yields and bed sedimentation in San Francisquito Creek increase suddenly and markedly, usually associated with episodic events such as major storms, landslides, large wildfires, or earthquakes. Sometimes, the increases may be related directly or indirectly to land uses and related management practices. Greater volumes, concentrations, and bioavailability of trace metals may be expected under such conditions, and the connection between increased trace-element loads and sediment production or bed sedimentation should be kept in mind. Such epicycles are integral to present-day functioning of the San Francisquito watershed. Periods of increased exposure to trace elements should be expected, gradually diminishing to chronic background levels.

Solubility and bioavailability of trace elements can also be influenced by other excursions from the range of conditions considered normal or within the watershed norms. As examples, the pH of rainfall in this watershed is thought to range from about 4.5 to 5.5. Atmospheric or human disturbance can cause pH in rain or storm runoff to fall below 4.5. Similarly, following a watershed fire, the pH of streams and reservoirs downstream can increase by 1 to 1.5 units. These excursions beyond typical natural envelopes can lead to rapid changes in trace-element bioavailability. Aluminum, for example, becomes much more soluble when pH falls below 4.5 or increases above 9. Sudden spikes in detectable concentrations of this light metal may be attributable to such pH excursions, perhaps compounded by the greater availability of organic material (humic 'acids') or basic ash, both of which also affect pH values.

Drought can not only reduce bank strength, but oxygen can reach clays that are kept saturated and in reduced form below the typical water table. The cycle of oxidation followed by solution or reduction can mobilize trace-element ions usually bound to sediments. San Francisquito Creek and its tributaries have extensive areas in which recent clay-rich sediments may oxidize after desiccation, as well as exposures of shales and other formations which may also yield higher concentrations of 'metals' during the latter stages of droughts, or in the seasons immediately following.

Conclusions

1. Elevated concentrations of individual trace metals are reported from one or more geologic units which outcrop within the watershed. It is important to know these influences, such that occasional high concentrations can be suitably interpreted.

2. Several volcanic units are composed of basalts of varying ages which are likely to be preferentially enriched in most metals; of these, only the Franciscan greenstones (or slightly metamorphosed basalts) are spatially extensive.

3. Some elements have common geologic sources throughout coastal central California; others differ markedly from one end of Santa Clara County to the other.

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