Water Quality and Streamflow Monitoring of San Francisquito and Los Trancos Creeks at Piers Lane, and Bear Creek at Sand Hill Road, Water Year 2004, 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 2004 stream gaging and water quality sampling conducted as part of a long-term, water-quality sampling program sponsored by Stanford University and the City of Palo Alto. Water year 2004 was the third year of monitoring at the Los Trancos Creek and San Francisquito Creek stations at Piers Lane, and the first year of monitoring at the Bear Creek at Sand Hill Road site. Measurements and observations continue during water year 2005.

Since fall 2001, Balance Hydrologics, Inc. has operated two automated water-quality sampling stations on San Francisquito Creek and Los Trancos Creek just above their confluence. As in previous years, 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. Four sets on each stream were collected using time-paced composite samples. The entire fifth set, and all samples for particular constituents (e.g., mercury), were collected as grab samples. Suspended-sediment samples were collected during and between storms and used to estimate annual suspended-sediment yields.

In fall 2003, Kinnetic Labs (Santa Cruz) installed another automated sampling station, located on Bear Creek at Sand Hill Road, along the northern border of the Jasper Ridge Biological Preserve. The station, which is also operated by Balance Hydrologics, is configured similarly to the other stations with a datalogger, several probes, and a programmable pumping unit. Due to delays in setting-up the station, only three sets of time-paced composite water-quality samples were collected during water year 2004. However, a complete record of stream flows was developed, manual water-quality measurements were made throughout the season, and suspended-sediment samples were collected during and between storms.

Water temperatures in San Francisquito Creek exceeded optimal levels on most days from late June through early August. Water temperatures in Los Trancos Creek were cooler than in San Francisquito Creek during the dry season but still exceeded optimal levels in late July. Suspended-sediment concentrations were similar to expected values.

None of the samples contained detectable levels of diazinon or chlorpyrifos. Metals (aluminum, copper, lead, mercury, nickel, selenium, silver and zinc) were often detected but not at abnormal levels. Total mercury concentrations in samples from one storm event on each creek exceeded the Regional Board chronic toxicity objective. Dissolved concentrations of all metals (including mercury) were well below levels of regulatory concern.

Ammonia-nitrogen concentrations equaled or exceeded the detection limit on three occasions in Bear Creek and twice on Los Trancos Creek. At assumed levels of pH and temperature, the estimated concentration of un-ionized ammonia in wet-season samples from these two streams were well below the Regional Board chronic (annual median) toxicity value. However, the un-ionized ammonia concentration in the dry-season sample from Los Trancos Creek slightly exceeded the regulatory threshold. Nitrate-nitrogen was detected at moderate levels in all samples from all three streams, with the lowest concentrations typically observed in samples from Bear Creek. Levels were typical of those observed in other local streams.

1. 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, analyze trends, and evaluate watershed management. Three LTMAP monitoring stations in the lower San Francisquito Creek watershed have been monitored since fall 2001 (water year 2002[1]); monitoring a fourth station higher in the watershed began in fall 2003. Stanford and the San Francisquito Watershed Council have explored addition of one or more stations even 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.

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 two Piers Lane stations, and includes a wide diversity of urbanized, rural and natural habitats. The 11.7-square mile Bear Creek sub-watershed encompasses the northwestern headwaters of San Francisquito Creek, covering approximately 25 percent of its watershed. Los Trancos Creek has a sub-watershed area of 7.8 square miles.

The first three LTMAP automated sampling stations were installed in fall 2001. City of Palo Alto staff are operating the lowermost station on San Francisquito Creek at Newell Road, a short distance upstream of Highway 101 and near the head of tidewater.

[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 2004 (WY2004) began on Oct. 1, 2003 and concluded on September 30, 2004.

Balance staff are operating the other two stations, on San Francisquito Creek and Los Trancos Creek at Piers Lane, a short distance downstream (north) of Interstate 280 and immediately upstream of the confluence of the two creeks. A fourth LTMAP station was installed on Bear Creek at Sand Hill Road (BCSH) in fall 2003. This station, which is also operated by Balance, is about 2.5 miles upstream from Piers Lane and receives flows from about one-half of the San Francisquito Creek watershed.

Data and findings from the initial two years of monitoring the Piers Lane stations are presented in the prior annual monitoring reports (Owens and others, 2003; Owens and others, 2004). To better integrate findings from the three stations currently monitored by Balance staff, this report summarizes the third year's findings from the two Piers Lane stations, as well as the results from the initial year of monitoring the Bear Creek at Sand Hill Road station. Measurement and observations will continue during water year 2005 (WY2005).

2. 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 adversely affect water quality in the watershed, under storm runoff and low-flow conditions, in major part as they affect the full 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 Creek, Los Trancos Creek and Bear Creek, 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 suspended sediment and bedload being transported by the three streams and compare them to results from other locations in the watershed also monitored during water year 2004 for other projects.

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

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

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
- 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 listed above can also have chronic or acute toxicity.

The quantity of baseflow is also an important factor in maintaining habitat quality. Too little water in the creeks during the spring and summer can impede out-migration of year-old fish and affect summer survival of newly hatched “young-of-the-year”. Insufficient baseflow also magnifies the effects of introduced pollutants by reducing the amount of dilution available to decrease pollutant concentrations.

2.2 Related Water Quality Studies in the Watershed

We know of only one recent sub-watershed-scale investigation of water quality. 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 a draft report summarizing data from all three years of monitoring was recently submitted for preliminary review. Both 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 Bear Creek Sub-watershed Station

The Bear Creek at Sand Hill Road station (designated as BCSH) is located on the northern border of the Jasper Ridge Biological Preserve (Figure 1), approximately 2.5 miles upstream of the San Francisquito Creek at Piers Lane station. Balance has periodically monitored streamflow and water quality constituents at this site, which receives flows from almost one-half of the San Francisquito Creek watershed above Piers Lane, since the spring of 1997. Prior to the current study, the most complete sets of data were compiled during water years 2000 to 2002, when this station was one of eight stations in the watershed regularly monitored on behalf of the San Francisquito Watershed Council (see Section 2.2 above). Balance continued to operate the gaging station during water year 2003 but only minimal water quality measurements were made that year.

Through the combined efforts of Stanford Management Co., Stanford Linear Accelerator Center, and the Jasper Ridge Biological Preserve, this location recently became the fourth station in the LTMAP monitoring network. In fall 2003 (WY2004), Kinnetic Laboratories, Inc. (Santa Cruz) installed new monitoring equipment on the left bank of Bear Creek, about 200 feet downstream from Sand Hill Road and only a short distance from the previous gaging location. The station is equipped with a tipping-bucket rain gauge, a streamside staff plate, a datalogger and automated sampler pumping unit housed within an enclosure, and several water-quality probes. Water level, water temperature, specific conductance (an index of salinity), dissolved oxygen, and pH are continuously monitored. Water levels are measured using a pressure transducer, rather than a bridge-mounted sonar transponder, as at the two Piers Lane stations described below. Manual measurements of water levels at a staff plate, stream flow and water quality parameters are made at regular intervals to calibrate the electronic record. The station is connected to a land-line telephone so that real-time data can be monitored over the Internet. The automated sampler is designed to collect aliquots over a specified period into a composite sample bottle. Following sampled events, sub-samples of the mixed composite sample are poured into prepared sample bottles for laboratory analysis of individual constituents.

While most of the equipment at the Bear Creek at Sand Hill Road station was installed in early November 2003, the probes were not calibrated until late in the month and the first set of composite samples was collected in late December. Due to the delay in commencing operations and the water year 2004 rainfall pattern, composite water quality sampling during the first year of operation was limited to two sets of wet-season samples and one set of dry-season samples. Monitoring during water year 2005 is proceeding as originally envisioned.

3.2 Piers Lane Stations

The other two LTMAP stations discussed in this report are located on Los Trancos Creek and San Francisquito Creek, just upstream from their confluence, where Piers Lane crosses both creeks (Figure 1). The stations are within 100 yards of each other and only a short distance downstream (north) of Interstate 280. The stations were installed in fall 2001 by staff of Kinnetic Laboratories, Inc. and Larry Walker Associates (Davis) under contract to the City of Palo Alto. The station on San Francisquito Creek is equipped with a tipping-bucket rain gauge. Water levels are measured by an ultrasonic sonar transponder mounted on the bridge above the creek at each site. Otherwise, each station is equipped with the same instrumentation described above for the Bear Creek station and is monitored using the same protocols. Both stations are currently powered by batteries. Cell phone telemetry was attempted but found to drain 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 but is reportedly not feasible at this time.

Balance initiated operation of the newly-installed Piers Lane stations, designated as San Francisquito Creek at Piers Lane (SFPL) and Los Trancos Creek at Piers Lane (LTPL), at the start of water year 2002. For a number of reasons detailed in the first-year monitoring report (Owens and others, 2003), only a limited number of samples were collected during the first year of operation. Monitoring during water years 2003 and 2004 more closely followed the envisioned sampling sequence.

3.2 Other Stations in the Watershed

As part of a series of cooperating projects, Balance also monitored a number of locations in the San Francisquito Creek watershed upstream of Piers Lane during water year 2004. The main focus was on 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 verify the gaging data and 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 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.

3.2.2 Searsville Sub-watershed stations

Balance operated gages at Searsville Dam and upstream from the dam on Corte Madera Creek at Westridge Drive during water year 2004. Data collection from the Searsville sub-watershed stations focuses on sediment transport. Searsville and Corte Madera Creek flow data were considered in this report where such comparisons were useful.

3.2.3 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 Piers Lane. This station was originally established in 1931 and has maintained a continuous record of flow since 1954. USGS staff regularly collected suspended-sediment (but not bedload sediment) data at this station from the mid-1960s to early 1970s (Brown and Jackson, 1973).

4. HYDROLOGIC SUMMARY, WATER YEAR 2004

Observations and measurements from our water year 2004 site visits are documented in Table 1 (Bear Creek), Table 2 (Los Trancos Creek) and Table 3 (San Francisquito Creek). Annual hydrologic summaries for each of the three creeks are presented in Forms 1 to 3. Table 4 is a hydrologic summary for all three creeks over the period of record, which for Bear Creek, includes gaging results from the earlier three-year water quality study (water years 2000 to 2002).

Daily flow hydrographs are plotted together in Figure 2 and for individual creeks in Figures 3 to 5. Figure 6 shows the unit flow hydrograph for each of the three creeks. "Unit flow", calculated by dividing the mean daily flow by the watershed area, allows comparison of the response to rainfall among different watersheds. In general, the magnitude of streamflow is governed by the size of the watershed, so that a larger watershed produces higher flows. However, differences among streams in wet- and dry-season baseflows also reflect variations in the geology, topography and management of diversions within their watersheds.

4.1 Narrative Summary

Baseflows in the streams were low in October 2003, the beginning of water year 2004. Light rains commenced during early November, as shown in Figure 7, where the cumulative rainfall record from the Bear Creek at Sand Hill Road rain gage is plotted together with the WY2004 streamflow record. In contrast to water year 2003, many of the early rain events this year were small and of similar size making it difficult to define a distinct "first-flush" [3] in water year 2004. Heavy rains occurred from late November through the start of January 2004 (Figure 7). The highest water levels and flow rates on Bear Creek (Figure 3) and San Francisquito Creek (Figure 4) occurred on Jan. 1, 2004, with calculated peak flow rates of 1190 cubic feet per second (cfs) and 1474 cfs, respectively. The rest of January was comparatively dry, then a series of spring storms produced moderate peaks on February 2, 18 and 25. The highest water levels and flow

[3] "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. Note that the first flush from impermeable surfaces, such as roads and roofs, often occurs earlier in the season than the first flush from open space lands, which must first become saturated.

rates on Los Trancos Creek (Figure 5) occurred on Feb. 25, 2004 (581 cfs), slightly exceeding the calculated peak flow rate of 560 cfs on January 1, 2004. March was generally clear and signaled the beginning of the spring flow recession which continued into the summer with only a few minor rains.

4.2 Precipitation

The water year 2004 rainfall record from the Piers Lane tipping-bucket rain gauge is incomplete because rodents severed the cable and the equipment was not repaired until after the wet season had ended. Based on the tipping-bucket rain gauge records from the Bear Creek at Sand Hill Road station and the Jasper Ridge Biological Preserve[4], water year 2004 rainfall of 20.5 inches was approximately 83 percent of the long-term mean annual precipitation of about 26 inches for the station location (Rantz, 1971)[5]. The monthly pattern shows that precipitation in December 2003 and February 2004 was well above average, while rainfall from October and November 2003, and from January and March through May 2004 was below average.

Rainfall records for two index precipitation stations in this region, Mount Hamilton and the San Francisco Airport, were obtained from the California Data Exchange Center (CDEC). These data show that water year 2004 rainfall at Mount Hamilton was also below-normal at 93 percent of the long-term average values, while rainfall at the San Francisco Airport was equal to the long-term average.

4.3 Return Period of Peak Flows

Even though we do not have a sufficient period of record to calculate the return period of peak flows at the stations that we monitor, we can evaluate the peak flows at the USGS gaging station on San Francisquito Creek (ID number 11164500). The peak flow for the year at that station was 1,980 cfs on January 1, 2004, which corresponds to a 2.3-year return period, based on the annual-peak series.

4.4 Unexplained Flow Surges

During summer of water year 2002, we observed and recorded abnormal flow peaks and higher than expected specific conductance (a measure of salinity) values on Los Trancos

[4] October 2003 rainfall data from the Jasper Ridge Biological Preserve recording rain gauge was used in this evaluation because the rain gauge at the Bear Creek at Sand Hill Road station was installed on October 31, 2003.
[5] Long-term mean annual precipitation at Piers Lane is approximately 18.5 inches (Rantz, 1971).

Creek more than a mile upstream from Piers Lane. We did not observe or record any similar, obviously-abnormal flow peaks on Los Trancos Creek during water years 2003 or 2004, or on San Francisquito Creek in water year 2003.

This year, we noted an abnormal spike at the Bear Creek at Sand Hill Road station on July 26 and 27, 2004 (Figures 3 and 13). Upon further scrutiny of our data, it appears that a significant volume of warmer, fresher water was discharged into Bear Creek. Over a three-hour period, flow increased from 0.10 to 0.55 cfs. Water temperature rose from 17.5˚C to 23.3˚C, significantly more than the usual diurnal range of about 2˚C. Specific conductance decreased from 480 µs to 420 µs. Flow, temperature and specific conductance gradually returned to their pre-spike values over the next day. The spike in flow and temperature was less distinct but still clearly discernible in the record for San Francisquito Creek further downstream on the same evening (Figure 4).

4.5 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.

4.5.1 Developing a record of water levels

The monitoring equipment at the Bear Creek at Sand Hill Road station includes two pressure transducers, which measure water levels in the creek at 15-minute intervals, and a Campbell Scientific CR10X datalogger to record the water-level data. The two stations at Piers Lane are equipped with ultrasonic sonar transponders connected to an American Sigma 950 flow meter and datalogger. Field measurements and observations at each station are used to calibrate the electronic record. Observations during site visits include: water level (or gage height) at the staff plate, high water marks, the presence of twig and leaf dams which may temporarily raise or lower water levels, signs of sedimentation or scour, and the specific conductance and temperature of the water (Tables 1 to 3).

During this year, as is typically done, we applied multiple stage shifts to the electronic water-level record to account for intermittent sedimentation, leaf dams and algae growth that affect the water-level elevation at the monitoring locations. We found that observed high-water marks corresponded well (usually within 0.2 to 0.3 feet) with the recorded water-level peaks, providing additional confidence in the stage record. As a check on the data, we also compared the Bear Creek record to the records from Corte Madera Creek and Searsville Dam. Because the timing and general magnitude of flow peaks at these stations were in agreement, we conclude that the monitoring equipment was working properly.

4.5.2 Computing flows

Based on our periodic site visits, staff plate readings, and flow measurements (Tables 1 to 3), we create an empirical stage-to-discharge relationship ("stage-discharge rating curve") for each gage. This rating curve is then applied to the electronic record of water levels measured by the pressure transducers (at BCSH) and sonar transponders (at SFPL and LTPL).

At low flows, the sonar transponder values have a large amount of variation, up to about 0.3 feet per day. We consider most of this variation to be "noise" in the instrument reading that does not reflect actual changes in water-levels, although a lower-amplitude (0.02-foot) diurnal pattern of water-level change is typically observed during low-flow periods. The flow record becomes particularly "noisy" at the 15-minute level of detail, which is why we present the data in daily form. Mean daily stream flow values appear to be fairly accurate because daily averaging removes most of the noise. Upon request, the more detailed, 15-minute record can be made available for specific periods of interest.

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 manual measurements at the peak flow levels. Peak-flow estimates for this study are based on extension of the stage-discharge curve from our highest measured flow to the peak water level recorded by the automated monitoring equipment.

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. Because the Bear Creek at Sand Hill Road gage is also part of the LTMAP study, the same protocols were used there as at the Piers Lane stations and results are comparable. Interested readers are referred to the water quality monitoring plan 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 in October. The LTMAP 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:

Field Measurements

- streamflow (cubic feet per second, or cfs)
- specific conductance (µs @ 25°C)
- water temperature (°C)
- dissolved oxygen (mg/L)
- pH
- qualitative remarks, for example, odors, color, clarity, (if noticeable), and anomalies

<u>Laboratory Analyses</u>

- metals (aluminum, copper, lead, mercury, nickel, selenium, silver and zinc)
- organophosphate pesticides (diazinon and chlorpyrifos)
- nitrate-nitrogen and ammonia-nitrogen
- total phosphorus
- total hardness (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 the initial year of monitoring at the Bear Creek at Sand Hill Road station, we were unable to complete the following items as they were initially outlined in the project proposal:

- All three sets of composite water-quality samples were collected as time-paced samples, rather than flow-paced samples. We plan to continue using either time-paced or flow-paced sample collection as appropriate during water year 2005.
- One of the two pressure transducers began producing a wildly fluctuating signal in May 2004, after having performed well since installation at the beginning of the water year. The pressure transducer was subsequently repaired in October 2004. Because only one of the two transducers malfunctioned, it did not affect our ability to produce a flow record.
- The dissolved oxygen probe needs to be cleaned regularly to maintain functioning. This task has now been integrated into the equipment maintenance schedule and the quality of the instream data has improved markedly since September 2004.

During the third year of monitoring Los Trancos Creek and San Francisquito Creek at Piers Lane, we were unable to complete the following items as they were initially outlined in the project proposal:

- Four of the five sets of composite water-quality samples were collected as time-paced samples, rather than flow-paced samples. Grab samples were collected for the Dec. 6 to 7, 2003 event on San Francisquito Creek, when it was discovered that equipment tubing had become detached during the storm (see Appendix C).

Grab samples were also collected during the Sept. 7, 2004 sampling of Los Trancos Creek when a tube clamp failed. As a result of these malfunctions, we began taping the tubing to the sample bottle and this problem has not recurred. 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. We plan to continue using either time-paced or flow-paced sample collection as appropriate during water year 2005.

- Due to failure of a computer hard drive following downloading, the flow record from the San Francisquito Creek and Los Trancos Creek at Piers Lane stations is missing for the period November 20 to December 5, 2003. A low battery at the San Francisquito Creek station also caused the loss of the flow record for the period between March 26 and May 25, 2004. We created synthetic records for the missing intervals at both sites based on our gaging at upstream stations on Los Trancos Creek (at Arastradero Road), Searsville Dam, and Bear Creek at Sand Hill Road, and verified it by comparison to manual measurements and to the record at the USGS gage one-half mile downstream on San Francisquito Creek.

- Due to low battery voltage, the San Francisquito Creek datalogger did not record data from March 26 to May 25, 2004. The flow record was reconstructed from Balance's records at Searsville Dam and Bear Creek at Sand Hill Road.

- Prior to the start of water year 2004, we cleaned the tipping-bucket rain gauge at the San Francisquito Creek station and verified that it was calibrated properly. However, the rain gauge worked only intermittently during the subsequent wet season. Further investigation in summer 2004 revealed rodent damage to the cables. The cables were then replaced and the rain gage has operated well thereafter.

- The automated sampler pump at the San Francisquito Creek station stopped working on February 18, 2004. With the assistance of staff from Kinnetic Laboratories, the problem was found to be a blown fuse, which was replaced in summer 2004. The pump is now operating well and we have a stock of spare fuses in case this problem recurs.

- The probes installed to continuously monitor specific conductance, dissolved oxygen and pH have worked only intermittently or not at all since the stations were installed. These probes require frequent maintenance to maintain operation, even during baseflow (non-storm) periods, and foul even more rapidly when flows are high. As the existing probes are unreliable, we made manual measurements of specific conductance on most site visits in water year 2004. Dissolved oxygen was measured regularly with a hand-held meter. pH was measured occasionally using a hand-held meter and/or pH paper test strips. Until the probes are replaced with lower-maintenance, higher-reliability models, the record for these three parameters will consist solely of manual measurements.

We have addressed a number of the maintenance-related issues presented above through development of checklists for staff to use in the field to confirm equipment functioning (e.g., batteries, cables, hard drives, fuses). Recommendations for improving the monitoring program during water year 2005 and subsequent years are presented briefly in Chapter 7 below.

6. RESULTS AND DISCUSSION OF WATER QUALITY SAMPLING

This chapter includes a discussion of findings by individual constituent or constituent group. Results of manual measurements of specific conductance, temperature, pH, and dissolved oxygen are included in Tables 1 to 3. The specific dates when composite and/or grab water quality samples were collected, the laboratory reporting limits[6], and the analytical results are presented in Table 5 (Bear Creek at Sand Hill Road) and Table 6 (San Francisquito Creek and Los Trancos Creek at Piers Lane). Results of suspended-sediment sampling during and between storms, used to estimate annual suspended-sediment yields, are presented in Table 8 (Bear Creek at Sand Hill Road) and Table 9 (San Francisquito Creek and Los Trancos Creek at Piers Lane). All laboratory reports are collected in Appendix A (Piers Lane stations) and Appendix B (Bear Creek). Detailed hydrographs showing the timing of sample collection for various constituents during each of the water-quality sampling visits are graphically presented in Appendix C.

During the third year of operating the two Piers Lane stations, we collected time-paced composite water-quality samples on five occasions: wet season samples were collected on: Nov. 6 to 8, 2003; Nov. 29 to 30, 2003; Dec. 6 to 7, 2003; and Dec. 29 to 30, 2003. The dry-season baseflow sample was collected on Sept. 7 to 8, 2004.

Due to delays in installing and setting-up the monitoring equipment, and the above average rainfall in December 2004, composite water quality sampling during the first year of operating the Bear Creek at Sand Hill Road station was limited to two sets of wet-season samples and one set of dry-season samples. We collected time-paced composite water-quality samples on Dec. 29 to 30, 2003 and Feb. 1 to 2, 2004. The dry-season baseflow sample was collected on Sept. 7 to 8, 2004.

6.1 Water Quality Objectives

The San Francisco Bay office (Region 2) of the Regional Board regulates water quality in the Bay area in accordance with the Water Quality Control Plan or 'Basin Plan' (RWQCB, 1995). The Basin Plan includes both numeric and narrative water quality objectives against which the LTMAP monitoring results in Tables 5 and 6 are evaluated. The water quality objectives for trace metals in the 1995 Basin Plan, for the South Bay below the Dumbarton Bridge and tributary streams which discharge into this portion of the Bay, were previously written as total recoverable concentrations, rather than the more bioavailable dissolved concentrations of the metals, because they were established in 1986 preceding the U.S. EPA directive on aquatic life criteria for metals. Furthermore, the U.S. EPA ambient water quality criteria for many metals have been updated since 1986 to incorporate more recent toxicity data and/or revisions to how the criteria were calculated.

To address these inconsistencies, the U.S. EPA criteria promulgated by the California Toxics Rule (CTR) included changes to the water quality objectives for arsenic, cadmium, chromium, copper (fresh water only), lead, nickel, silver and zinc. The updated water quality objectives were adopted by the Regional Board in 2004, approved by the U.S. EPA (Region 9) on January 5, 2005[7], and are now included in the Basin Plan. Tables 5 and 6 have been modified from previous years to incorporate the new water quality objectives for dissolved trace metal constituents into the Basin Plan objectives rather than showing them on separate lines. We note that the existing Basin Plan objective for mercury was retained pending development of new water quality objectives for this constituent, which will likely be based on fish tissue concentrations.

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 μs (all values are normalized to 25°C). The lowest levels occur during storms, when flows are diluted with rain and fresh runoff.

During water year 2004, specific conductance ranged from about 150 to 1200 μs in Bear Creek (Table 1; Figure 9)[8], from about 300 to 1600 μs in Los Trancos Creek (Table 2), and

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[6] Laboratory reporting limits varied due to the methods used and the amount of sample dilution required.
[7] The Basin Plan amendment was previously approved by the State Water Resources Control Board on July 22, 2004, and by the California Office of Administrative Law on October 4, 2004.
[8] The upstream station on Bear Creek was intermittently monitored during the year prior to installation of the new LTMAP gage and the specific conductance probe was partially-clogged with sediment. A different specific conductance probe, recently-calibrated, was installed on Nov. 25, 2003 as part of the new station approximately 40 feet downstream from the old gage.

from about 320 to 1400 µs in San Francisquito Creek (Table 3). Specific conductance was typically lowest in Bear Creek and highest in Los Trancos Creek. In Los Trancos Creek, specific conductance levels were generally higher during the WY2004 wet season than in previous years (Figure 8), while values during late-season baseflow periods were higher this year than in WY2003 but similar to those observed in WY2002. This difference may be due to greater late-season recharge during the wet spring of water year 2003. Specific conductance levels in San Francisquito Creek followed the same pattern in water year 2004 as in previous years (Figure 10), with higher specific conductance at low flows, and lower levels during storm events.

6.3 Nitrogen

As noted above, nitrogen has been identified as one of the potential pollutants affecting steelhead fisheries habitat in the San Francisquito Creek watershed, with possible sources including horse stables, fertilizers, yard waste, and failing on-site septic systems. The most readily accessible forms of nitrogen in stream systems are typically nitrate (NO_3^-) and ammonia (NH_3), although relatively large amounts of nitrogen can be stored in both living and dead biomass (i.e., leaf litter). Ammonia is the form produced during decomposition of organic matter and is common in fertilizers. When mixed with water, the majority of ammonia quickly reacts to form the relatively harmless ammonium ion (NH_4^+) which, due to its positive charge, is rapidly taken up by plants or microbially converted to nitrate. However, a small amount remains as un-ionized ammonia, which is toxic to fish and aquatic invertebrates. The concentration of un-ionized ammonia increases with increased pH and water temperature. Nitrate, in contrast, persists much longer in the environment and is more mobile in soil.

6.3.1 Ammonia-nitrogen

Ammonia-nitrogen concentrations[9] in San Francisquito Creek were below the detection limit (0.2 mg/L) on all dates sampled in water year 2004 (Table 6). During the wet season, the ammonia concentration of samples collected from Bear Creek on December 29, 2003, during the rising limb of the largest storm of the season, and February 2, 2004 were equal to the detection limit. The ammonia concentration of the samples collected from Los Trancos Creek on December 29, 2003 (0.39 mg/L) exceeded the detection limit.

[9] 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.

Assuming a worst-case pH value of of 8.0[10] and a water temperature of 11˚C (see Table 2), un-ionized ammonia in Los Trancos Creek would be about 2.0 percent (Goldman and Horne, 1983: p. 127) of the total ammonia concentration, or 0.008 mg/L. While the Regional Board has not established a specific acute toxicity objective for ammonia, the concentration in Los Trancos Creek is well below the 0.025 mg/L threshold for chronic (annual median) exposure to un-ionized ammonia cited in the Basin Plan (RWQCB, 1995). Un-ionized ammonia concentrations in Bear Creek on both dates sampled would be even lower.

The ammonia concentration of dry-season samples collected from two of the three streams on Sept. 8, 2004 exceeded the detection limit. Based on a pH value of 8.2 and a water temperature of 22.4˚C in Los Trancos Creek (Table 6), un-ionized ammonia would be about 6.8 percent of the total ammonia concentration of 0.60 mg/L, or about 0.041 mg/L, exceeding the Basin Plan threshold for chronic exposure. Due to the lower values for pH (7.8) and water temperature (18.4˚C) in Bear Creek on the same date (Table 5), un-ionized ammonia would be only about 2.1 percent of the total ammonia concentration of 0.22 mg/L, or about 0.005 mg/L, well below the regulatory threshold.

6.3.2 Nitrate-nitrogen

Nitrification is the process whereby ammonia-nitrogen (NH_3) is microbially converted to nitrite (NO_2^-), and then nitrate ($NO_3^{-)}$. The intermediate step occurs rapidly, so nitrite-nitrogen concentrations are usually very low or undetectable. Samples collected for nitrate analysis are preserved on ice and must be analyzed within 48 hours. However, timely delivery and processing of nitrate samples collected late in the work week and over weekends is problematic because laboratories are closed on weekends. To address this constraint, some of the water year 2004 samples were collected in acidified bottles, extending the hold time to 28 days, and submitted to the laboratory for "nitrite plus nitrate" analysis. The two analyses are listed separately in Tables 5 and 6 but, for practical purposes, virtually all of the nitrogen under the "nitrite plus nitrate" column is nitrate-nitrogen.

Nitrate-nitrogen concentrations were above the detection limit in all three creeks on all sampling dates in water year 2004 and followed a similar pattern. Nitrate concentrations ranged from 0.1 to 1.0 mg/L in Bear Creek, from 0.8 to 4.0 mg/L in Los

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[10] No pH measurements were made at the time the Dec. 29 sample were collected, however, pH in Los Trancos Creek ranged from 7.5 to 8.0 when measured during other storm events (see Table 6).

Trancos Creek, and from 0.8 to 3.9 mg/L in San Francisquito Creek. The pattern of small storms early in the wet season made distinguishing a first-flush event more difficult this year than in WY2003. However, nitrate concentrations of 3.0 to 4.0 mg/L in samples collected from Los Trancos Creek and San Francisquito Creek during two November 2003 storms, early in the water year 2004 wet season, were similar to concentrations measured in the first-flush storm of November 2002 (WY2003). Nitrate concentrations in samples from these two streams collected during the Dec. 6 to 7, 2003 storm event[11] were lower (0.8 to 1.1 mg/L) and more similar to baseflow values from June 2003 than to measurements from later in the WY2003 wet season. Samples from the Dec. 29, 2003 event, the fourth and final set of water year 2004 wet-season samples and the only major storm sampled this year, had nitrate values of 1.1 to 2.0 mg/L, equal to or lower than values measured in Los Trancos Creek and San Francisquito Creek on Dec. 13 to 15, 2002 (WY2003) during a storm of similar magnitude.

The December 29, 2003 event was also the first water quality sampling event at the Bear Creek at Sand Hill Road station. The duplicate composite samples submitted to the laboratory had nitrate concentrations of 1.0 and 1.1 mg/L, at the low end of the range of values from samples collected downstream on San Francisquito Creek during the same storm. The February 2, 2004 storm was the second wet-season sampling event at the Bear Creek station. The nitrate concentration of the composite sample was only 0.4 mg/L, lower than that of any wet-season sample collected from Los Trancos Creek or San Francisquito Creek since the monitoring program began in winter 2001.

Dry-season composite samples collected September 7 to 8, 2004 from Los Trancos Creek and San Francisquito Creek had nitrate-nitrogen concentrations of 2.6 mg/L and 1.8 mg/L, respectively. These values are less than one-half the concentrations of dry-season samples collected from these two streams in late August 2003, although much higher than the 0.43 mg/L in the single sample collected from Los Trancos Creek on September 19, 2002[12]. The nitrate concentration of the September 7 to 8, 2004 sample from Bear Creek was at the detection limit (0.1 mg/L), much lower than in samples from Los Trancos Creek and San Francisquito Creek.

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[11] Due to sampler malfunction, the samples from San Francisquito Creek were collected as grab samples on Dec. 7 during the falling limb of the hydrograph, while samples from Los Trancos Creek were composite samples collected during the storm period.
[12] The Sept. 2002 sample was collected to investigate a high-salinity, abnormal flow peak on Los Trancos Creek and not as part of the regular LTMAP sampling program.

Wet-season nitrate-nitrogen concentrations are generally expected to be highest during first-flush events early in the season, when sufficient runoff is present to flush accumulated nitrate into the stream but flows are below the threshold where nitrate concentrations become highly diluted by fresh runoff. Nitrate concentrations in samples collected during the two November 2003 storms were moderately-elevated (3.0 to 4.0 mg/L) but below current levels of concern (Tables 5 and 6). We note that the U.S. EPA has recommended a threshold of about 0.5 mg/L *total* nitrogen for ambient waters in sub-ecoregion 6, which includes a wide range of stream types in a diversity of settings from San Diego to northern California (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 Bear Creek at Sand Hill Road station ranged from 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 storms, similar to levels observed during late-winter sampling in San Francisquito and Los Trancos Creeks during water year 2002. Concentrations during dry-season baseflow periods ranged from 0.14 to 0.63 mg/L, similar to the September 2004 measurement in Bear Creek at Sand Hill Road this year but much lower than values observed in Los Trancos Creek and San Francisquito Creek.

6.4 Organophosphate Pesticides

San Francisquito Creek is listed by the State Water Quality Control Board as being impaired by the common organophosphate pesticide, diazinon. As of December 31, 2004, the U.S. EPA banned sales of diazinon-containing outdoor, non-agricultural products in the United States in order to eliminate all residential uses of the insecticide. In the Bay Area, the Regional Board recently proposed a total maximum daily load (TMDL) that addresses diazinon (Johnson, 2004) in an effort to reduce pesticide-related toxicity in urban creeks. The TMDL process calls for development of numeric targets that translate the current Basin Plan's narrative toxicity objective[13]. Therefore, the Regional Board recently proposed diazinon concentration targets of 0.05 µg/L (four-day average) and 0.08 µg/L (one-hour average), not to be exceeded more than once every

[13] Waters should remain free of toxics at concentrations lethal to or adversely impacting aquatic organisms (RWQCB, 1995).

three years[14]. These objectives were originally identified by the California Department of Fish and Game and are consistent with the federal antidegradation policy promulgated in the Code of Federal Regulations (Title 40, §131.12).

Concentrations of diazinon, and another common organophosphate pesticide, chlorpyrifos, were below the detection limit in all three streams on all dates sampled in water year 2004 (Tables 5 and 6). Neither pesticide was detected in samples from Los Trancos Creek and San Francisquito Creek in water years 2002 and 2003[15]. 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 Metals

Composite water quality samples collected from the three streams during water year 2004 were analyzed for total and dissolved concentrations of eight metals commonly associated with urban and suburban development in the San Francisquito Creek watershed: aluminum, copper, lead, mercury, nickel, selenium, silver, and zinc. Most metals were detected in either the dissolved or solid form in all three streams on every sampling date (Tables 5 and 6). The exceptions were: mercury (not sampled in Los Trancos Creek or San Francisquito Creek on November 6, 2003, or in Bear Creek on December 29, 2003 and September 8, 2004); lead (not detected in Los Trancos Creek on November 6, 2003 and November 29, 2003, or in San Francisquito Creek on November 29, 2003); and silver (detected only once, in the total recoverable form, on Los Trancos Creek during the Dec. 29, 2003 storm event).

Speciation is the term used to describe partitioning of the total load of a particular metal between the dissolved and particulate forms. Metals in the dissolved form are considered more readily available to aquatic organisms and therefore potentially more deleterious. As a result, the U.S. EPA recently developed specific criteria for the

[14] The proposed numerical standard is intended to apply only to the Clean Water Act Section 303(d) listing process methodology and does not revise water quality objectives. To place a water segment on the 303(d) list there must be at least 3 exceedances in a sample size of 10 to 11. To delist a water segment there can be no more than 1 exceedance in a sample size of 38 to 51. For further information, see the Draft Water Quality Control Policy included as an appendix to the Draft Functional Equivalent Document (State Water Resources Control Board, 2003).

[15] Samples collected for the Bear Creek water-quality study, and for the LTMAP study during water year 2002 and most of water year 2003, were analyzed for organophosphate pesticide content using a methodology with a detection limit of 0.5 ug/L. A more sensitive methodology, with a detection limit of 0.05 ug/L, was used beginning with the June 26, 2003 sampling.

dissolved form of selected trace metals. These criteria are hardness-dependent, since calcium and magnesium (the primary components of hardness[16]) act to buffer metal toxicity. The criteria were adopted in California through the California Toxics Rule (CTR) and have been incorporated into Basin Plan documents by the nine Regional Boards. The proportion of the metal present in the dissolved form is dependent on the pH of the water, the chemical properties of the specific metal, and the nature of the suspended solids that are present (Sansalone and Buchberger, 1997a and 1997b):

- At typical San Francisquito watershed baseflow pH levels of 7.5 to 8.0 (Tables 1 to 3), metals are generally more likely to adsorb onto particles, while lower pH levels during storm events favor the dissolved form (Paulson and Amy, 1993).

- Copper and lead are more likely to form complexes with sediments in the system and thus have a greater particulate fraction, whereas the majority of the total cadmium and zinc is often in the dissolved phase (Characklis and Wiesner, 1997; Flores-Rodriguez and others, 1994).

- Higher suspended sediment or turbidity concentrations will increase the particulate metal fraction due to the greater number of sites available for adsorption. It is important to note that many metals have been shown to be associated with the smallest of the suspended particles (Dempsey and others, 1993; Sansalone and Buchberger, 1997a).

As noted above, metals have been found to be less toxic to aquatic organisms when ambient hardness levels are higher. In general, hardness is lowest in Bear Creek and slightly higher in Los Trancos Creek than in San Francisquito Creek. During the water year 2004 wet season, hardness levels in the three streams ranged from 101 to 239 mg/L as $CaCO_3$ (Tables 5 and 6). For Los Trancos Creek and San Francisquito Creek, these values were similar to those observed during WY2003 and lower than values from WY2002. Hardness generally decreased as streamflow increased, reflecting reduced contributions of ground water relative to surface runoff during storms. Unfortunately, due to a miscommunication, Regional Water Quality Control Plant laboratory did not analyze total hardness concentrations in composite samples from the December 29, 2003 event, the only storm this year where all three streams were sampled.

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

The highest hardness values measured in Los Trancos Creek (820 mg/L) and San Francisquito Creek (500 mg/L) during water year 2004 were in the dry-season samples collected September 7 to 8, 2004. Dry-season measurements in both streams in WY2003, and in San Francisquito Creek in WY2002, were similarly elevated as compared to wet-season samples. We note that the upper limit of hardness used by the Regional Board to assess the effects of metal concentrations is usually 400 mg/L. At the hardness levels typically observed in Los Trancos Creek and San Francisquito Creek during the dry season ($\geq$250 mg/L as $CaCO_3$), the potential toxicity of trace metal ions is low.

Hardness in Bear Creek was slightly lower (170 mg/L as $CaCO_3$) in the sample collected September 8, 2004 than in the sample from February 2, 2004 (239 mg/L as $CaCO_3$). For comparison, hardness was measured at 120 and 140 mg/L as $CaCO_3$ in October and November 2001 at the Bear Creek at Sand Hill Road station. Hardness measured at stations higher in the Bear Creek watershed during the same period ranged from 92 to 370 mg/L as $CaCO_3$. Based upon these measurements, the regulatory values included for comparison in Tables 5 and 6 are calculated for the range of 100 to 500 mg/L as $CaCO_3$. Table 7 presents water quality objectives at hardnesses of 100 to 500 mg/L as $CaCO_3$ for the five hardness-dependent trace metals sampled as part of the LTMAP program.

6.5.1 Aluminum

In Los Trancos Creek and San Francisquito Creek, *total aluminum* concentrations were at least one order of magnitude higher in composite samples from the December 29, 2003 samples than in samples from the three earlier sampling events (Table 6). Samples collected in Bear Creek on December 29, 2003 and February 2, 2004 (Table 5) had similarly elevated total aluminum concentrations. This is not unexpected since aluminum is a naturally occurring component of the silts and clays that largely comprise suspended sediment, and stream flows and suspended sediment concentrations were highest on these dates during the two largest storms of water year 2004. In addition, the acid digestion performed for total metal analysis typically releases a much larger amount of the mineral than is naturally present in the stream. Thus, the contrast with *dissolved aluminum* concentrations, which tended to be lowest in all three streams during the largest storms and below the detection limits during the dry-season. 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 earlier Bear Creek study.

6.5.2 Copper

Total copper concentrations were highest in composite samples collected from all three streams during the December 29, 2003 storm (Tables 5 and 6), although concentrations in Los Trancos Creek and San Francisquito Creek were lower than those measured in the first-flush storm sampled in November 2002 (WY2003). Total copper concentrations in all three streams were lowest in the dry-season samples collected September 7 to 8, 2004 and similar to values measured in Los Trancos Creek and San Francisquito Creek during the WY2003 dry-season sampling.

Concentrations of *dissolved copper* in wet-season samples from the three streams ranged from 1.9 to 7.7 ug/L during water year 2004, similar to the range of wet-season dissolved copper concentrations measured at the Sand Hill Road station during the earlier Bear Creek study (1.8 μg/L to 9.9 μg/L). For the December 29, 2003 event where all three streams were sampled, the dissolved copper concentration in Bear Creek was higher than in Los Trancos Creek or San Francisquito Creek. However, the dry-season sample from Bear Creek collected on September 7 to 8, 2004 had a lower dissolved copper concentration than samples from the other two streams, where concentrations were similar to values measured during the August 2003 (WY2003) dry-season sampling. Dissolved copper concentrations in all samples collected during water year 2004 were below the acute and chronic toxicity objectives for dissolved copper established by the Regional Board (Table 7). Sources of copper in the watershed include dust from vehicle brake pads, automotive fluids, wash waters and architectural building materials.

6.5.3 Lead

Total lead concentrations in water year 2004 samples ranged from nondetectable to 16 μg/L (Tables 5 and 6), lower than values measured in Los Trancos Creek and San Francisquito Creek during the WY2003 wet season. The same trend was apparent in all three streams: total lead concentrations were highest (and similar) in samples collected during the December 29, 2003 storm event, and concentrations were low or nondetectable in dry-season samples collected September 7 to 8, 2004.

As observed in WY2003, concentrations of *dissolved lead* were below the detection limit in 4 of 5 (including the duplicate sample) water year 2004 samples from San Francisquito Creek. Dissolved lead was nondetectable in all five samples from Los Trancos Creek this year, and in all three samples from Bear Creek. The sole detection, a concentration of 0.6 µg/L in one of the two samples from San Francisquito Creek on December 7, 2003, was well below the acute and chronic toxicity objectives for dissolved lead established by the Regional Board.

The predominant source of lead in the watershed 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 earlier 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.

Total mercury concentrations in samples from San Francisquito Creek ranged from 0.0026 to 0.13 µg/L during water year 2004, while total mercury concentrations in samples from Los Trancos Creek ranged from 0.0016 to 0.27 µg/L (Table 6). Trends were the same in both streams and similar to values measured in WY2003. The highest total mercury concentrations measured in these two streams this year were in samples from the major December 29, 2003 storm event, when levels in both streams exceeded the Regional Board chronic (annual median) standard of 0.025 µg/L. This storm appeared to function as a first-flush event for unpaved portions of the watershed, producing total mercury concentrations similar to those of the more clearly-defined first-flush storm of November 2002. Bear Creek was not sampled for mercury during the December 29, 2003 storm (Table 5). However, the total mercury concentration of the sample collected during the large storm of February 2, 2004 (0.11 µg/L) was similar to values measured in the other two streams on December 29, 2003 and also exceeded the Regional Board chronic standard. Total mercury concentrations in all other samples from the three creeks were well below the regulatory standard.

Total mercury concentrations were low in dry-season samples collected from Los Trancos Creek and San Francisquito Creek on September 7 to 8, 2004 but nondetectable in late-August 2003 (WY2003) dry-season samples. Mercury was not analyzed in dry-season samples collected from Bear Creek this year.

Dissolved mercury concentrations in samples from Los Trancos Creek and San Francisquito Creek ranged from 0.0007 to 0.0039 µg/L during water year 2004, similar to values measured in WY2003. As observed for total mercury, the highest concentrations in these two streams were found in samples collected during the December 29, 2003 storm event. The dissolved mercury concentration of the sample collected from Bear Creek during the February 2, 2004 storm event was 0.0022 mg/L, similar to values in the other two streams during the December storm. The lowest dissolved mercury concentrations, from dry-season sampling of Los Trancos Creek and San Francisquito Creek, were similar to levels in dry-season samples collected from these streams in late-August 2003 (WY2003). Dissolved mercury concentrations in all water year 2004 samples were well below the regulatory standard.

6.5.5 Nickel

Total nickel concentrations in samples from Los Trancos Creek and San Francisquito Creek ranged from 3.7 to 54 µg/L in water year 2004 (Table 6) and were generally similar to values measured in WY2003. As observed for lead, total nickel concentrations in both streams were highest during the large storm of December 29, 2003, and lower in samples collected earlier and later in the season during periods of lower flows. Total nickel concentrations in Bear Creek (Table 5) were similarly elevated (32 µg/L) in the sample collected during the large February 2, 2004 storm event.

Dissolved nickel concentrations ranged from 2.9 to 5.0 µg/L in Los Trancos Creek and San Francisquito Creek during water year 2004 and were also generally similar to values measured in WY2003. Concentrations in Bear Creek ranged from 3.6 to 4.1 µg/L. Wet-season samples from San Francisquito Creek had slightly higher dissolved nickel concentrations than samples from Los Trancos Creek on all four dates sampled. However, the dry-season sample collected from Los Trancos Creek on September 7 to 8, 2004 had a higher dissolved nickel concentration than the sample collected from San

Francisquito Creek on the same date. Variation in dissolved nickel concentrations across sampling dates in all three streams was less than for other trace metals, such as copper or zinc. Concentrations were similar in both streams for all events and similar to levels measured during water year 2003 and 2002. All values were far below acute and chronic toxicity objectives for dissolved nickel established by the Regional Board.

6.5.6 Selenium

In water year 2004, *total selenium* concentrations ranged from 0.1 to 0.6 μg/L in Bear Creek, from 0.2 to 0.9 μg/L in Los Trancos Creek, and from 0.2 to 0.4 μg/L in San Francisquito Creek (Tables 5 and 6). The highest concentrations in all three streams were measured in samples collected during the large storm of December 29, 2003. In WY2003, the highest total selenium concentrations in Los Trancos Creek and San Francisquito Creek were also measured during the major mid-December 2002 storm, although concentrations were more than twice as high as levels measured this year (WY2004). Total selenium concentrations in other water year 2004 wet-season samples from these two streams were lower and in the same range as late-winter samples collected in water years 2003 and 2002. The dry season sample collected from Los Trancos Creek on September 7 to 8, 2004 had a total selenium concentration of 0.4 μg/L, equivalent to the sample collected on December 29, 2003. The dry-season sample from San Francisquito Creek had a similar total selenium concentration (0.3 μg/L) as the late winter samples, while the concentration of the dry-season sample from Bear Creek was even lower (0.1 μg/L). All concentrations were far below the U.S EPA (National Toxic Rule) aquatic acute toxicity objective of 20 μg/L and the chronic toxicity objective of 5 μg/L.

Concentrations of *dissolved selenium* in the three streams ranged from nondetectable to 0.4 μg/L in water year 2004 and followed a similar trend. As observed for total selenium concentrations, dissolved selenium concentrations in the three streams were similar to values measured in late winter storms on Los Trancos Creek and San Francisquito Creek during water years 2003 and 2002. All values were far below acute and chronic toxicity objectives for dissolved selenium established by the U.S EPA. 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.

6.5.7 Silver

The sole detection for silver in water year 2004 was a *total silver* concentration of 0.3 µg/L in the sample collected from Los Trancos Creek during the storm of December 29, 2003 (Table 6). This concentration was well below the aquatic instantaneous maximum value for dissolved silver established by the Regional Board; no acute or chronic toxicity standards have been established for silver at this time. All other samples from the three streams were below the detection limit for both total silver and *dissolved silver*.

For comparison, silver was detected once in Los Trancos Creek and once in San Francisquito Creek in WY2003, also at concentrations of 0.3 µg/L. In WY2002, concentrations of silver in samples from both streams were below the 0.2 µg/L detection limit during each of the two wet-season events sampled.

6.5.8 Zinc

Zinc tends to be substantially more abundant and more soluble than other trace metals. In general, as with other metals, one would expect higher *total zinc* concentrations at high flows, when streams are transporting elevated loads of suspended sediment. This was the pattern observed in water year 2004, when total zinc concentrations in the three streams ranged from 7.0 to 100.0 µg/L, with the highest total zinc concentrations measured when streamflows were highest, during the storm of December 29, 2003 (Tables 5 and 6). Similarly, the highest total zinc concentrations in Los Trancos Creek and San Francisquito Creek in WY2003 were also measured during the major mid-December 2002 storm. WY2004 dry-season samples collected from the three streams on September 7 to 8, 2004 had total zinc concentrations of 7.0 to 8.0 µg/L, in contrast to nondetectable total zinc concentrations in WY2003 dry-season samples from Los Trancos Creek and San Francisquito Creek.

In water year 2004, *dissolved zinc* concentrations ranged from 6.0 to 41.0 µg/L , with the highest levels in all three streams observed in samples collected during the December 29, 2003 storm. Dry-season samples collected on September 7 to 8, 2003 from Los Trancos Creek and San Francisquito Creek had nondetectable dissolved zinc concentrations, while the sample from Bear Creek measured 6.0 µg/L. Dissolved zinc concentrations in all samples were well below the regulatory standard.

In both WY2004 and WY2003, dissolved zinc concentrations generally increased with increasing streamflows. Concentrations were highest when sampled during major storms, lower during smaller events, and low or nondetectable in dry-season samples. Zinc is much more soluble than the other trace metals sampled, which may explain part of the difference in response. Both local geologic formations[17] and anthropogenic sources, such as road runoff and galvanized architectural materials (e.g., roofs, fencing, gutters), likely contribute to observed dissolved zinc levels.

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 are considered to provide adequate habitat, and values chronically above 25˚C are likely not viable for the local steelhead population.

Balance staff made numerous manual measurements of water temperature in the three streams and, at each station, one or two instream probes continuously recorded water temperatures. Manual temperature readings measured during site visits followed the same seasonal pattern and values recorded by the instream probes (Figures 11 to 13). Water temperatures were within the acceptable range for steelhead habitat during most of the water year 2004 season. As observed in the two previous years (WY2003 and WY2002), water temperatures in San Francisquito Creek (Figure 11) appeared to be slightly cooler than in Los Trancos Creek (Figure 12) during the wet season, and slightly warmer during the dry season. Water temperatures in Bear Creek during the wet season were slightly cooler than in San Francisquito Creek (Figure 13), and markedly cooler than in Los Trancos Creek. During the dry season, temperatures in Bear Creek were cooler than in Los Trancos Creek, and much cooler than in San Francisquito Creek.

Maximum daily temperatures in San Francisquito Creek periodically exceeded the 21˚C threshold from mid-June through early August 2004 (Figure 11). Maximum daily temperatures in Los Trancos Creek exceeded the threshold in late July 2004 and approached the threshold during several other periods from mid- to late-summer

[17] 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 sub-watersheds (Balance Hydrologics, 1996). Both formations are also known geologic sources of phosphate.

(Figure 12). In contrast, water temperatures in Bear Creek only exceeded the 21˚C threshold on one occasion, on July 26 to 27, when warmer, fresher water from an unknown source was discharged into the stream (see Section 4.4).

6.7 pH

As stated above in Section 5.3, the pH probes at the Los Trancos Creek and San Francisquito Creek stations were essentially non-functional in water year 2004, so this parameter was measured periodically using hand-held meters and paper test strips. Based on limited sampling, pH varied between 7.7 and 8.5 in Los Trancos Creek (Table 2, Figure 14), and between 7.3 and 8.5 in San Francisquito Creek (Table 3, Figure 15), similar to pH measurements during WY2003. Values of pH were typically slightly higher in Los Trancos Creek than in San Francisquito Creek for both dry- and wet-season measurements.

The pH probe at the Bear Creek at Sand Hill Road station appeared to function moderately well during most of the water year 2004 season (Figure 16), although we only have a few manual measurements with which to compare the record (Table 1), particularly during the wet season. More manual measurements will be required in WY2005 to better calibrate the electronic record from the instream probe. Based on the values measured this year, pH in Bear Creek varied between 6.8 and 7.4 during water year 2004 and was generally lower than at the San Francisquito Creek and Los Trancos Creek stations further downstream. 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.

6.8 Dissolved Oxygen

As stated above in Section 5.3, the dissolved oxygen probes at the Los Trancos Creek and Bear Creek stations were essentially non-functional in water year 2004. The dissolved oxygen probe at the San Francisquito Creek station functioned poorly, although measurements made during the low-flow period were generally consistent with values measured using a hand-held meter. Based on manual measurements during water year 2004, dissolved oxygen concentrations varied between 58 and 98 percent of saturation in Bear Creek (Table 1, Figure 17) and between 75 and 105 percent of saturation in Los Trancos Creek (Table 2, Figure 18). Dissolved oxygen concentrations in San Francisquito Creek (Table 3, Figure 19) varied between 39 and 97 percent of saturation, with even lower values suggested by the electronic record. Concentrations were typically highest in Los Trancos Creek, as observed in WY2003, and higher in Bear Creek than in San Francisquito Creek. Dissolved oxygen concentrations decreased in all three streams during summer months, when water temperatures are high, streamflow is low, and there is little turbulence. Concentrations in San Francisquito Creek decreased even further during the early fall, when dead leaves blown into the creek have begun to rot but have not yet been flushed downstream by high flows from winter storms.

As noted in our WY2003 report (Owens and others, 2004), manual measurements of dissolved oxygen can vary considerably depending upon where in the creek the probe is placed, with values ranging from about 15 to 60 percent saturation at locations as little as one foot apart. This situation is particularly common in the fall, when the streams are full of dead leaves. Based on our monitoring data to date, we expect dissolved oxygen concentrations in the creeks to range from 10 to 14 mg/L (90 to 100 percent saturation) during the winter and especially at high flows, when turbulence and cold ambient water temperatures promote oxygen saturation. Dissolved oxygen concentrations become more limiting for fish as streamflows decrease and temperatures rise in spring and summer, with the lowest concentrations occurring in the fall, at the start of the next water year but before rains raise water levels and flush leaves from the creeks.

6.9 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 human-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. Suspended sediment is supported by the turbulence of the water and is transported at a velocity approaching the mean velocity of flow. In the San Francisquito Creek watershed, as elsewhere in the Santa Cruz Mountains, suspended sediment consists primarily of fine sands, silts, and clays. 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. At the Piers Lane sites and in the Bear Creek watershed, bedload consists primarily of coarse sands and gravels, but will also include cobbles at extreme high flows. Total sediment discharge is the sum of bedload-sediment and suspended-sediment discharges.

6.9.1 Suspended sediment

Suspended-sediment samples were collected from all three 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 grab samples were analyzed by Soil Control Laboratories of Watsonville, California, a state-certified laboratory. Composite samples were analyzed at the Regional Water Quality Control Plant in Palo Alto. Results are shown in Tables 5 and 6 under the heading "Total Suspended Solids". No suspended-sediment samples were collected when stream waters were visibly clear. 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 limit of 5.0 mg/L.

By multiplying the reported suspended-sediment concentrations by the streamflow at the time the sample was taken, concentrations (mg/L) were converted into an instantaneous suspended-sediment "load" (tons/day), as shown in Tables 8 and 9. We then plotted sediment load as a function of streamflow to create suspended-sediment rating curves describing the general trend of the data points for each creek (Figures 20 and 21). We also applied the suspended-sediment rating curves to the records of streamflow (at 15-minute intervals) to calculate a total annual suspended-sediment load for each creek (Forms 4 to 6). Interpretation of suspended-sediment rates and total loads is discussed in Section 6.9.3 below.

6.9.2 Bedload sediment

The *Draft Surface Water Quality Monitoring Plan 2001/02* (LWA, 2001) does not include consideration or protocols for measurements of bedload-sediment transport. At all three LTMAP gaging stations discussed in this report, the threshold for significant bedload transport occurs at flow depths and velocities that border on being too deep to sample safely by wading. However, through the close of water year 2004, we have occasionally been successful in measuring bedload transport at the Bear Creek station, but not at the Piers Lane sites. A greater emphasis on collecting bedload sediment transport data may develop as the LTMAP matures.

Although we have only a limited number of bedload-sediment measurements on Bear Creek, as compared to the number of suspended-sediment samples, we have used data from sampling prior to initiation of the LTMAP program to construct a bedload rating curve for this station (Figure 20). Bedload samples are converted to a discharge rate (in units of tons per day) and then plotted as a function of flow. As expected, sediment discharge increases as flow increases. We also applied the bedload rating curve to the record of streamflow (at 15-minute intervals) to calculate an annual bedload total (Form 4 and Table 4). Interpretation of bedload-sediment rates and total loads for Bear Creek is discussed in Section 6.9.3 below.

6.9.3 Sediment discussion

Similar to last year (Owens and others, 2004: Figure 13), suspended sediment loads (as a function of flow) and total sediment loads at the two Piers Lane stations were similar in water year 2004 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). Comparison of the suspended-sediment rating curve for the Bear Creek station (Figure 20) with the rating curves for the Los Trancos Creek and San Francisquito Creek at Piers lane stations (Figure 21) shows that both Bear Creek and Los Trancos Creek generally carry higher suspended-sediment loads *at a given flow* than San Francisquito Creek. Higher rates of transport in tributary streams is a typical condition and nearly universal throughout the Bay Area (c.f., Hecht, 1983), since tributary watersheds tend to be steeper and more subject to erosion due to higher flow velocities. In addition, suspended-sediment concentrations in San Francisquito Creek are diluted by outflows from Searsville Lake, which traps a large proportion of the sediment load from tributary streams higher in the watershed. We compared the sediment rating curve for Bear Creek to rating curves of other creeks that we monitor in the watershed and found that sediment-discharge rates (as a function of flow) for Bear Creek are lower than rates for Corte Madera or Los Trancos Creeks.

It is important to note that storm flow in San Francisquito Creek is typically twice as high as flow in Bear Creek[18], and usually three to five times greater than flow in Los Trancos Creek (Figure 2), so San Francisquito Creek still transports more sediment. This is evident in the annual sediment summaries (Forms 4 to 6), which show that the calculated total suspended-sediment load in San Francisquito Creek was about 6,900 tons in water year 2004, compared to about 5,600 tons in Bear Creek and 3,000 tons in Los Trancos Creek. Differences are even greater during an above-average rainfall year, such as water year 2003, when the calculated total suspended-sediment load in San Francisquito Creek was about 55,000 tons, compared to about 7,000 tons in Los Trancos Creek.

Sediment measurements at each of the stations also shows a strong dependence on flow at the time of the measurement; when flow is higher, the creeks carry more sediment. Therefore, sediment totals for each stream also vary from year to year depending on the overall wetness of the year and the size of the largest flood peak (Table 4). This concept of "episodicity" is useful for interpreting the sediment measurements within the context of the inter-annual variability in climate conditions. Rather than trying to calculate an *average* sediment discharge per year, we acknowledge that there will be large year-to-year variability in sediment discharge. For example, on Bear Creek, where we have the longest record and have sampled both bedload sediment and suspended sediment, the sediment totals for water year 2000 are much higher than for water years 2001, 2002, and 2004 combined (Table 4). We attribute these higher totals to the higher peak flows and

[18] The relationship between flow at the Bear Creek at Sand Hill Road station and flow at San Francisquito Creek at Piers Lane varies seasonally with the amount of outflow from Searsville Lake. Typically, differences in flow between the two sites are smaller at the start of the wet season, when the water level in the lake is below the spillway. Later in the wet season, differences are greater once the lake begins to spill freely.

larger total volume of flow in water year 2000, rather than to any specific activities (or lack of activity) by inhabitants of the watershed.

6.9.4 Assessing bias of automated suspended-sediment sampling

The standard method for sampling suspended sediment is to use an isokinetic sampler to collect a depth- and width-integrated sample (Porterfield, 1972; Edwards and Glysson, 1999). Depth integration is important because the concentration of suspended sediment increases from the stream surface downwards to the bed. We typically use a DH-48 hand-held sampler to collect equal-transit-rate[19] sub-samples at multiple verticals across the width of the creek. We wanted to assess the degree of bias associated with using an automated sampler to collect suspended sediment samples, because the automated sampler does not have an isokinetic intake, draws the sample from a fixed point, and creates a composite sample from which a sub-sample is decanted and analyzed. However, by subsampling from the stream at regular intervals (time-paced sampling) or from pre-set volumes of flow (flow-paced sampling), the automated sampler can theoretically produce a more accurate representation of suspended sediment transport during the entire course of a particular storm event than is possible from one or two manually-collected grab samples.

The initial tests[20] reported below were conducted in the early afternoon of February 18, 2004. Stream flow in Bear Creek, which had peaked at 499 cfs at about 5 AM that morning, had decreased to approximately 185 cfs in early afternoon and was falling slowly while we collected the set of samples for this test. The four types of samples used in this analysis are:

- "composite" - We pumped about 8 liters of creek water into a bucket using the ISCO sampler; the sample was then swirled and mixed and a sub-sample was decanted into a bottle.

- "direct pump" – We used the ISCO sampler to pump water directly from the creek into a bottle.

- "at intake" – We plunged a DH-48 hand-held sampler from the surface to the approximate location of the sampler intake near the streambed and held it

[19] Equal-transit-rate (ETR) means that the sampler is lowered and raised at a constant rate at a particular vertical point on a transect across the width of the creek, then moved to the next point where the process is repeated.
[20] We intend to conduct at least two more tests of a similar nature before drawing any firm conclusions.

there for about 15 seconds, then quickly raised it out of the water and poured the sample into a bottle.

- "depth-integrated" – We used the DH-48 to collect depth-integrated sub-samples at three verticals across about half the width of the creek; the sample was then poured from the DH-48 into a bottle.

The samples were collected in the order listed above, and all within a time span of ten minutes. The sample bottles used were identical 500-milliliter polyethylene bottles. All samples were sent to the same analytical laboratory (Soil Control Lab) and analyzed using identical methods. The results, detailed in Table 9 and discussed below, are consistent with our understanding of the limitations of different methods for sampling suspended sediment. For each type of sample, we present the suspended sediment concentration reported by the laboratory and the resulting suspended-sediment load for a 24-hour period.

- "composite" = 276 mg/l = 135 tons/day – This is the lowest value and probably reflects settling-out of the heaviest particles during the interval between completion of mixing and decanting the sub-sample from the composite vessel into the sample bottle.

- "direct pump" = 350 mg/l = 171 tons/day – This is the highest value and probably reflects the high sediment concentrations near the bottom of the water column, where the intake is located. The shape of the intake port and the resulting intake velocities could also be influencing the results.

- "at intake" = 331 mg/l = 161 tons/day – This value is relatively high but slightly lower than the value from the "direct pump" test, perhaps due to an influx of water as the DH-48 sampler was being lowered and raised through the water column above the intake location.

- "depth-integrated" = 308 mg/l = 150 tons/day – Because this sample was manually collected using standard methods, it is the standard for comparison of the other types of samples collected.

Based on the results of this initial test, the sub-sample from the composite bottle under-represented suspended-sediment concentrations in the creek by about 9 percent, as compared to the depth-integrated sample, even though the sample collected through the automated sampler over-represented suspended-sediment concentrations by about 14 percent. While it appears that the two effects partially offset each other in this first test, additional test results will give us more confidence in our interpretation. Furthermore, we expect the results of the sampling techniques to differ depending on the flow level at which the test is conducted, since the relative fractions of the different sediment size classes mobilized will differ with stream flow.

7. FUTURE MONITORING AND RECOMMENDATIONS

The following recommendations are based on our experience and observations since inception of monitoring:

1. Greater familiarity with the equipment and the local hydrologic conditions at the two Piers Lane monitoring sites allowed us to improve our sampling methods and achieve more complete sampling coverage. We also initiated operation of the newly-installed station at Bear Creek at Sand Hill Road this year and took a limited number of samples. Monitoring in water year 2005 is proceeding in closer accordance to the 2001 monitoring plan.

2. We used time-paced sampling to collect most of the composite water quality samples this year. Flow-paced sampling of low flows during the wet season (e.g., small first-flush storms) is impractical at the Piers Lane stations due to the "noise" inherent in the transponder signal. In addition, the stream bed at the Los Trancos Creek station periodically experiences aggradation or degradation, complicating programming for flow-paced sampling. Finally and most importantly, despite using numerous sources of weather data, we have found it extremely difficult to predict the length and intensity of storm events in the San Francisquito Creek watershed setting. Under these conditions, it is more practical to program the monitoring equipment to collect time-paced samples, than to guess the volume and pattern of rainfall which, if wrong, would result in partial- or over-sampling of runoff. However, we will continue our attempts to perform flow-paced sampling in water year 2005, particularly for larger storms.

3. We plan to sample water quality at all three sites on 5 occasions in water year 2005, as occurred at the Piers Lane stations in water years 2003 and 2004. Our focus will continue to be on monitoring: "first-flush" storms in late fall and early winter; 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; and a spring storm, once trees have begun to leaf-out, temperatures have risen and use of fertilizers and pesticides on landscaping has resumed. We will also perform one non-storm (baseflow) sampling in late summer, when salinities, temperatures and nitrogen concentrations may be elevated.

4. The specific conductance, dissolved oxygen and pH probes at both Piers Lane stations continue to be fouled or non-functional. The different brand of specific conductance probe installed at the station on Bear Creek at Sand Hill Road worked better, as did the dissolved oxygen probe, when they were regularly cleaned. Automated collection of specific conductance data is particularly important in detecting transient changes in salinity related to unauthorized discharges or diversions. Automated collection of pH and dissolved oxygen data is particularly important in summer when elevated water temperatures can impair fish habitat. The automated pH and dissolved oxygen probes 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. Thus, we recommend that replacement specific conductance probes be installed at the two Piers Lane monitoring stations if sufficient budget becomes available. We also increased the frequency of manual pH measurements beginning in June 2004. 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 2005.

5. We would like to perform additional investigations of the bias in suspended-sediment sampling due to the use of an automated, composite sampler. If time and conditions allow, we want to repeat the experiment described in Section 6.9.4 above at higher and lower flows to see if the results are similar to those from the initial test.

6. The monitoring records clearly show the effects of diversions and discharges during the summer months on stream flows and salinities. Should the program decide that further assessment would be useful, we can explore alternative sampling schemes to assess changes in water quality associated with these alterations in flows.

7. The three original LTMAP monitoring stations are all located in the lower San Francisquito Creek watershed; monitoring at a fourth station upstream on Bear Creek at Sand Hill Road began in winter 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 would 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 2004 were below average. Based on USGS data for San Francisquito Creek, the peak flows for the year were about a 2.3-year recurrence-interval flood.

2. We successfully collected composite samples using time-paced sampling on four occasions from each of the two Piers Lane stations, and on three occasions from the Bear Creek at Sand Hill Road station in water year 2004. The December 29, 2003 storm event and the September 2004 dry-season baseflows were sampled at all three stations.

3. Most of the 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, more frequent cleaning may improve functioning, 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, and maximum temperatures in Los Trancos Creek exceeded the threshold in late July. 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. Temperatures in Bear Creek were intermediate between the two Piers Lane stations during the wet season, and cooler than in Los Trancos Creek and San Francisquito Creek during the dry season.

5. Organophosphate pesticide concentrations were below detectable limits in all three streams on all dates sampled. Given the small number of total samplings to-date, further sampling should be performed before concluding when or if these pesticides are present or absent in the two streams.

6. Ammonia-nitrogen concentrations equaled or exceeded the detection limit on three occasions in Bear Creek and twice on Los Trancos Creek. At assumed levels of pH and temperature, the estimated concentration of un-ionized ammonia in wet-season samples from these two streams were well below the Regional Board chronic (annual median) toxicity value. However, the un-ionized ammonia concentration in the dry-season sample from Los Trancos Creek slightly exceeded the regulatory threshold. Nitrate-nitrogen was detected at moderate levels in all samples from all three streams, with the lowest concentrations typically observed in samples from Bear Creek. Levels were typical of those observed in other local streams.

7. Almost all of the metals sampled (aluminum, copper, lead, mercury, nickel, selenium, silver and zinc) were detected in either the dissolved or total recoverable form in all three streams on each sampling date this year. Yet except for the samples collected during the largest event sampled on each stream, when total mercury concentrations exceeded the chronic toxicity objective set by the Regional Board, concentrations of all total and dissolved metals were well below levels of regulatory concern in all samples analyzed in water year 2004.

8. Fluctuations in flow and specific conductance during baseflow periods were most noticeable at the Bear Creek station but propagated downstream to San Francisquito Creek at Piers Lane. Upstream diversions and other flow alterations may significantly impact summer baseflows and, therefore, fish and aquatic habitat. Besides the volumetric changes to flow, water quality may also be altered by the apparent additions to creek flow.

9. Sufficient suspended-sediment samples were collected from all three streams during high and intermediate flow conditions to estimate suspended-sediment transport totals for water year 2004. We did not make estimates of bedload sediment transport at the Piers Lane stations. However, collection of bedload samples from Bear Creek during water year 2004, when combined with results from previous years, allowed calculation of a bedload-sediment total for this station. These estimates and qualitative observations at all three stations indicate that conditions were typical of creeks in the San Francisquito watershed.

10. We conducted a preliminary test of the autosampler to evaluate sampling bias during suspended-sediment sampling. We found that the fixed intake tends to over-represent sediment concentrations at high flows, while the process of sub-sampling from the composite vessel tends to under-represent sediment concentrations. Although these effects partially-offset each other, the end result is that composite sampling tends to under-represent the actual suspended sediment concentration in the stream.

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.

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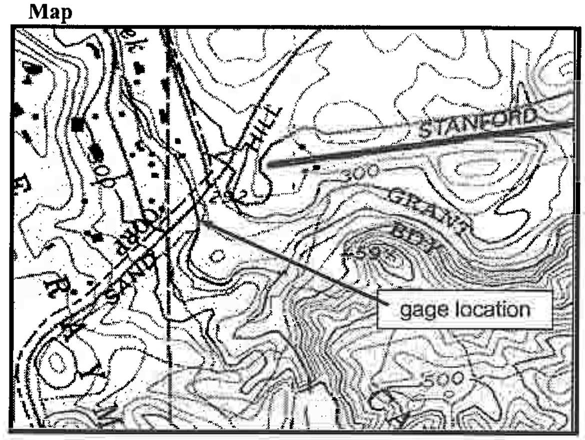
FORMS

Water Year:	**2004**
Stream:	Bear Creek
Station:	at Sand Hill Road
County:	San Mateo County, CA

Form 1. Annual Hydrologic Record

Map



Station Location / Watershed Descriptors

Latitude: 37 24' 40", Longitude: 122 14' 28" Jasper Ridge Biological Preserve, Stanford, CA. Gage is installed on left bank, about 200 feet downstream from Sand Hill Rd. Staff-plate pool is eroded into hard sandstone; underflow is thought to be minimal. Land use includes forested open space, and suburban uses in valleys. Drainage area above gage is 11.7 sq. miles.

Mean Annual Flow

Mean annual flow (MAF) for 2004 is 5.87 cfs.
MAF for WY 2002 was 5.12 cfs, for WY 2001 was 3.71 cfs, and for WY 2000 was 10.65 cfs.

Peak Flows

Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)	Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)
12/14/03	5:00	2.88	100	2/2/04	11:30	3.12	152
12/24/03	11:00	2.32	58	2/16/04	17:45	2.05	38
12/29/03	17:30	5.39	591	2/18/04	5:00	5.96	744
1/1/04	**12:15**	**7.28**	**1186**	2/25/04	12:45	6.04	766
				3/25/04	18:30	2.18	47

Peak for Period of Record (Oct. 1999 to Sept. 2004): 2050 cfs on Feb. 13, 2000.

Period of Record

Staff plate installed 5/12/97. New datalogger and probes installed Nov. 2003. Flow, sediment transport, water quality, and specific conductance measured periodically. Gaging sponsored by Jasper Ridge Biological Preserve.

WY 2004 Daily Mean Flow (cubic feet per second)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1	0.19	0.22	0.23	4.69	1.45	24.56	1.03	0.77	0.36	0.19	0.20	0.24
2	0.23	0.17	0.54	282.50	1.48	24.47	1.08	0.75	0.31	0.10	0.12	0.28
3	0.25	0.26	0.65	54.13	33.53	20.58	1.08	0.79	0.25	0.08	0.10	0.29
4	0.24	0.21	0.17	18.84	34.64	16.30	1.19	0.76	0.22	0.04	0.12	0.32
5	0.28	0.16	0.12	5.74	19.87	14.29	1.16	0.70	0.22	0.13	0.11	0.30
6	0.26	0.24	0.61	3.87	11.26	12.42	1.13	0.70	0.20	0.23	0.09	0.37
7	0.21	0.39	3.15	3.41	7.34	10.97	1.14	0.67	0.17	0.17	0.10	0.30
8	0.16	1.41	1.77	2.57	5.29	10.06	1.12	0.71	0.14	0.12	0.17	0.27
9	0.17	0.80	0.38	1.83	3.96	9.29	1.09	0.64	0.16	0.06	0.27	0.27
10	0.18	0.19	0.60	2.03	3.52	8.47	1.07	0.62	0.17	0.04	0.09	0.23
11	0.15	0.13	5.12	2.29	2.71	7.70	0.99	0.59	0.19	0.01	0.01	0.29
12	0.11	0.08	2.72	1.76	2.23	7.11	0.99	0.59	0.22	0.08	0.02	0.36
13	0.19	0.07	0.49	1.63	2.79	6.64	0.97	0.62	0.19	0.14	0.20	0.38
14	0.15	0.06	0.50	1.69	2.68	6.18	0.96	0.53	0.19	0.16	0.13	0.35
15	0.12	0.14	11.27	1.67	2.46	5.73	0.98	0.53	0.21	0.13	0.08	0.40
16	0.13	0.15	0.84	1.69	2.24	5.33	1.01	0.52	0.20	0.09	0.12	0.28
17	0.12	0.07	0.55	1.64	13.23	5.02	1.04	0.55	0.14	0.11	0.14	0.30
18	0.17	0.07	0.47	1.58	112.12	4.78	1.04	0.58	0.13	0.10	0.09	0.29
19	0.24	0.08	0.44	1.48	280.28	4.62	1.01	0.51	0.26	0.12	0.03	0.28
20	0.32	0.09	1.10	1.41	44.81	4.36	1.06	0.46	0.29	0.10	0.01	0.35
21	0.29	0.11	0.87	1.46	29.01	4.28	1.39	0.46	0.20	0.16	0.04	0.34
22	0.25	0.10	0.75	1.43	21.34	4.08	1.08	0.45	0.13	0.14	0.05	0.21
23	0.20	0.10	0.57	1.42	19.93	3.93	1.00	0.48	0.12	0.12	0.12	0.12
24	0.18	0.10	0.61	1.43	15.00	2.90	0.95	0.51	0.12	0.12	0.09	0.03
25	0.21	0.13	12.80	1.96	16.26	2.30	0.94	0.49	0.10	0.10	0.06	0.02
26	0.18	0.14	9.53	1.53	233.83	6.54	1.01	0.47	0.09	0.12	0.14	0.01
27	0.14	0.12	1.95	1.48	102.72	2.64	0.94	0.44	0.18	0.26	0.24	0.03
28	0.12	0.11	0.89	1.74	54.46	1.21	0.88	0.51	0.32	0.11	0.28	0.02
29	0.09	0.11	0.74	1.62	33.52	1.16	0.80	0.47	0.30	0.08	0.24	0.11
30	0.10	0.14	176.66	1.47		1.11	0.81	0.47	0.23	0.06	0.30	0.08
31	0.18		61.66	1.50		0.94		0.37		0.46	0.27	
MEAN	0.19	0.20	9.64	13.34	38.41	7.74	1.03	0.57	0.20	0.13	0.13	0.24
MAX. DAY	0.32	1.41	176.66	282.50	280.28	24.56	1.39	0.79	0.36	0.46	0.30	0.40
MIN. DAY	0.09	0.06	0.12	1.41	1.45	0.94	0.80	0.37	0.09	0.01	0.01	0.01
cfs days	5.8	6.1	298.7	413.5	1114.0	240.0	30.9	17.7	6.0	3.9	4.0	7.1
ac-ft	11.5	12.2	592.6	820.1	2209.5	476.0	61.4	35.1	11.9	7.8	8.0	14.1

Monitor's Comments

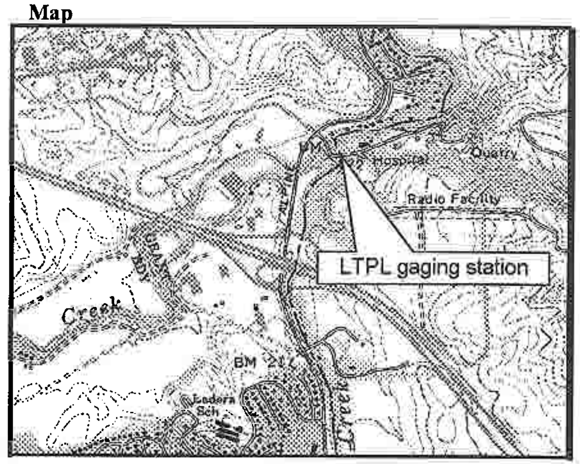
1. We collected a continuous water-level record for the water year, except for a small data gap on parts of 6/9 and 6/10/2004.
2. Diversions upstream of the gaging location affect flow in the creek. Also, a small amount of water intermittantly flows into the creek from a ditch on the northwest side of Sand Hill Road (upstream of the gaging station).
3. Multiple stage shifts were applied to the rating equation. Stage shifts adjust for local scour and fill in addition to water-level changes due to algae growth or dams caused by dropped leaf accumulation.
4. Access to gage kindly provided by the Jasper Ridge Biological Preserve, Stanford University.
5. Daily values with more than 2 to 3 significant figures result from electronic calculations. No additional precision is implied.

Water Year 2004 Totals:		
Mean annual flow	**5.87**	(cfs)
Max. daily flow	**282**	(cfs)
Min. daily flow	**0.01**	(cfs)
Annual total	**2148**	(cfs-days)
Annual total	**4260**	(ac-ft)

Water Year:	2004	
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 2004 was 2.03 cfs.
MAF for WY2003 was 2.63 cfs.

Peak Flows

Date	Time[2] (24-hr)	Gage Ht. (feet)	Discharge (cfs)	Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)
11/8/03	21:00	1.97	16	2/2/04	13:30	2.514	67
12/10/03	0:30	1.94	15	2/17/04	22:30	3.013	122
12/14/03	6:00	1.92	15	**2/25/04**	**11:00**	**5.47**	**582**
12/29/03	18:00	4.92	419	2/26/04	1:00	3.93	266
1/1/04	12:00	5.46	563	3/25/04	21:15	1.57	9.2

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 quaility samples have been made since Feburary 2002. Gaging sponsored by Stanford University Utilities Division.

WY 2004 Daily Mean Flow (cubic feet per second)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1	0.11	0.10	0.52	113.79	1.01	4.43	0.64	0.38	0.40	0.31	0.08	0.04
2	0.11	0.10	0.34	9.30	16.25	3.22	0.64	0.37	0.39	0.26	0.08	0.04
3	0.11	0.09	0.27	2.90	6.73	2.99	0.53	0.34	0.39	0.24	0.08	0.04
4	0.11	0.10	0.31	2.51	4.07	2.73	0.48	0.35	0.39	0.22	0.08	0.03
5	0.11	0.11	0.45	1.13	4.03	2.38	0.54	0.34	0.40	0.27	0.07	0.04
6	0.11	0.12	1.02	1.34	3.75	2.22	0.50	0.39	0.39	0.23	0.07	0.03
7	0.12	0.28	1.06	1.39	2.97	2.03	0.43	0.41	0.40	0.20	0.07	0.03
8	0.12	2.20	0.31	1.15	1.62	1.96	0.40	0.41	0.38	0.21	0.07	0.03
9	0.12	1.62	0.64	1.13	1.48	1.99	0.47	0.42	0.43	0.18	0.06	0.03
10	0.12	0.46	3.06	0.79	1.52	1.81	0.43	0.44	0.45	0.18	0.07	0.03
11	0.11	0.29	1.30	0.59	1.69	1.58	0.33	0.43	0.42	0.17	0.07	0.03
12	0.11	0.24	0.38	0.59	1.94	1.64	0.33	0.44	0.42	0.17	0.06	0.03
13	0.11	0.20	0.38	0.58	2.60	1.51	0.34	0.37	0.40	0.16	0.06	0.02
14	0.12	0.28	3.52	0.54	2.43	1.46	0.33	0.32	0.44	0.15	0.06	0.02
15	0.11	0.72	0.37	0.56	2.34	1.50	0.35	0.36	0.37	0.12	0.06	0.02
16	0.11	0.33	0.31	0.57	3.20	1.43	0.37	0.40	0.35	0.12	0.06	0.02
17	0.12	0.26	0.28	0.53	14.31	1.46	0.36	0.41	0.40	0.11	0.06	0.02
18	0.12	0.25	0.27	0.50	28.00	1.47	0.39	0.46	0.40	0.11	0.05	0.03
19	0.11	0.26	0.73	0.51	5.05	1.35	0.41	0.45	0.33	0.10	0.05	0.03
20	0.10	0.27	0.66	0.59	4.62	1.40	0.43	0.53	0.36	0.09	0.05	0.03
21	0.10	0.30	1.15	0.64	4.12	1.51	0.39	0.61	0.37	0.10	0.05	0.03
22	0.11	0.33	0.39	0.67	4.39	1.14	0.35	0.58	0.28	0.08	0.05	0.02
23	0.10	0.29	0.46	0.68	3.70	0.86	0.32	0.51	0.28	0.08	0.05	0.02
24	0.10	0.26	1.84	2.03	4.20	0.86	0.30	0.53	0.22	0.07	0.05	0.02
25	0.09	0.25	2.34	0.82	135.76	2.98	0.27	0.47	0.21	0.07	0.05	0.02
26	0.09	0.23	0.42	1.02	73.11	1.71	0.26	0.47	0.18	0.07	0.04	0.02
27	0.09	0.23	0.27	1.48	12.46	1.17	0.26	0.45	0.19	0.05	0.04	0.02
28	0.08	0.24	0.28	1.42	6.88	0.86	0.25	0.49	0.19	0.05	0.05	0.02
29	0.10	0.24	77.06	1.24	5.75	0.65	0.28	0.43	0.20	0.06	0.04	0.02
30	0.13	0.35	18.81	1.03		0.68	0.26	0.43	0.23	0.07	0.04	0.02
31	0.27		1.29	0.90		0.54		0.41		0.07	0.04	
MEAN	0.11	0.37	3.89	4.93	12.41	1.73	0.39	0.43	0.34	0.14	0.06	0.03
MAX. DAY	0.27	2.20	77.06	113.79	135.76	4.43	0.64	0.61	0.45	0.31	0.08	0.04
MIN. DAY	0.08	0.09	0.27	0.50	1.01	0.54	0.25	0.32	0.18	0.05	0.04	0.02
cfs days	3.5	11.0	120.5	152.9	360.0	53.5	11.6	13.4	10.3	4.4	1.9	0.8
ac-ft	7.0	21.8	239.0	303.3	714.0	106.1	23.1	26.6	20.3	8.7	3.7	1.6

Monitor's Comments

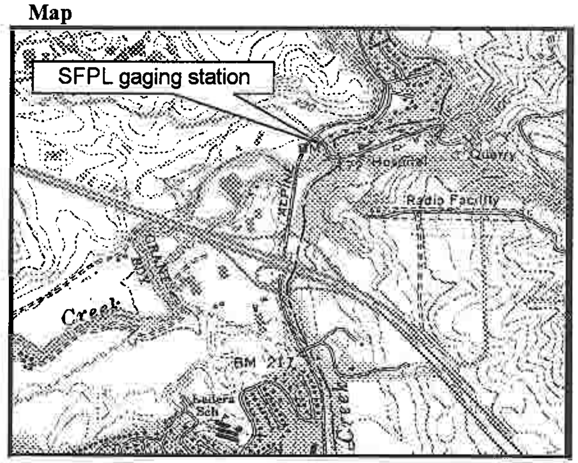
1. We collected a continuous record for the entire water year, except for Nov. 20 to Dec. 5. Data spliced in with data from Balance's upstream Los Trancos data, that was scaled to match.
2. Multiple stage shifts were applied to the rating equation; stage shifts adjust for local scour or fill and leaf 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 2004 Totals:		
Mean annual flow	**2.03**	(cfs)
Max. daily flow	**136**	(cfs)
Min. daily flow	**0.02**	(cfs)
Annual total	**744**	(cfs-days)
Annual total	**1475**	(ac-ft)

Water Year:	2004	
Stream:	San Francisquito Creek	
Station:	Piers Lane	**SFPL**
County:	San Mateo County, CA	

Form 3. 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 2004 was 11.02 cfs.
MAF for WY2003 was 15.40 cfs

Peak Flows

Date	Time[2] (24-hr)	Gage Ht. (feet)	Discharge (cfs)	Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)
12/14/03	7:30	4.92	70	2/2/04	13:30	5.70	192
12/24/03	14:30	4.70	52	2/18/04	5:45	8.26	934
12/29/03	18:15	7.72	746	2/25/04	14:15	9.13	1260
1/1/04	**13:15**	**9.67**	**1474**	3/25/04	20:15	4.70	52

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 2004 Daily Mean Flow (cubic feet per second)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1	0.35	0.28	0.77	447.57	4.25	44.56	4.21	1.51	0.55	0.43	0.31	0.27
2	0.37	0.31	0.88	114.72	71.77	39.46	4.07	1.50	0.51	0.37	0.28	0.27
3	0.39	0.34	0.40	39.98	72.91	31.67	3.98	1.44	0.46	0.32	0.23	0.25
4	0.41	0.34	0.35	20.61	40.41	27.78	3.94	1.32	0.43	0.30	0.20	0.24
5	0.40	0.35	0.82	14.76	25.41	24.79	3.89	1.20	0.45	0.29	0.16	0.28
6	0.37	0.32	2.66	12.29	19.17	22.12	3.91	1.13	0.44	0.31	0.16	0.30
7	0.40	0.78	6.11	10.12	14.85	20.36	4.07	1.10	0.43	0.36	0.16	0.27
8	0.37	2.88	0.77	7.70	11.53	19.00	4.21	1.05	0.42	0.34	0.15	0.21
9	0.33	3.69	1.09	7.02	9.84	17.81	4.07	1.07	0.42	0.30	0.14	0.19
10	0.30	0.68	10.14	8.11	8.37	16.39	4.07	0.98	0.45	0.27	0.19	0.21
11	0.30	0.38	5.64	6.33	6.65	14.80	4.50	0.96	0.43	0.25	0.20	0.22
12	0.31	0.35	1.11	5.57	7.32	13.70	4.11	1.01	0.45	0.23	0.17	0.25
13	0.26	0.32	0.87	5.32	7.20	12.64	3.96	0.89	0.46	0.22	0.16	0.27
14	0.28	0.37	13.97	5.09	6.42	11.59	4.10	0.86	0.46	0.23	0.14	0.26
15	0.30	0.51	1.56	5.38	6.13	10.85	3.84	0.83	0.43	0.21	0.14	0.32
16	0.32	0.41	0.77	4.94	19.55	10.09	3.78	0.83	0.45	0.24	0.14	0.22
17	0.31	0.40	0.61	4.47	104.40	9.48	3.25	0.86	0.41	0.21	0.15	0.24
18	0.32	0.33	0.56	4.19	425.81	9.10	3.25	0.81	0.38	0.18	0.15	0.23
19	0.30	0.32	1.28	4.21	70.99	8.33	3.03	0.77	0.37	0.17	0.15	0.26
20	0.28	0.34	2.29	4.97	42.66	7.97	3.18	0.76	0.44	0.15	0.16	0.28
21	0.28	0.34	1.37	4.17	32.73	7.84	2.90	0.78	0.45	0.17	0.16	0.28
22	0.32	0.33	0.77	3.74	31.40	7.67	2.62	0.86	0.38	0.17	0.17	0.24
23	0.29	0.33	0.77	3.65	24.50	6.29	2.58	0.92	0.36	0.17	0.17	0.20
24	0.27	0.33	11.91	6.93	25.46	5.78	2.55	0.84	0.35	0.16	0.16	0.18
25	0.26	0.36	14.09	4.63	452.98	13.59	2.61	0.79	0.34	0.17	0.15	0.16
26	0.25	0.35	3.27	4.04	304.64	15.47	2.24	0.77	0.31	0.15	0.15	0.15
27	0.23	0.34	1.05	4.53	130.20	6.60	2.00	0.75	0.30	0.16	0.12	0.15
28	0.23	0.34	0.78	5.42	69.18	5.91	1.83	0.81	0.43	0.24	0.14	0.15
29	0.26	0.37	230.23	4.65	48.00	5.47	1.65	0.69	0.50	0.19	0.13	0.16
30	0.27	0.46	167.08	4.53		4.78	1.55	0.63	0.43	0.17	0.20	0.15
31	0.61		26.02	4.27		4.70		0.59		0.40	0.28	
MEAN	0.32	0.57	16.45	25.29	72.23	14.73	3.33	0.94	0.42	0.24	0.17	0.23
MAX. DAY	0.61	3.69	230.23	447.57	452.98	44.56	4.50	1.51	0.55	0.43	0.31	0.32
MIN. DAY	0.23	0.28	0.35	3.65	4.25	4.70	1.55	0.59	0.30	0.15	0.12	0.15
cfs days	10.0	17.2	510.0	783.9	2094.8	456.6	99.9	29.3	12.7	7.5	5.4	6.9
ac-ft	19.8	34.2	1011.6	1554.9	4154.9	905.6	198.2	58.1	25.2	14.9	10.7	13.6

Monitor's Comments

1. We collected a continuous record for the entire water year, except for Nov. 20 to Dec.5 and Mar. 26 to May 25.
2. Missing portions of the record were calculated based on summing flow measured at Searsville Dam and Bear Creek at Sand Hill Road (other Balance stream gaging sites).
3. Multiple stage shifts were applied to the rating equation; stage shifts adjust for local scour or fill.
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 2004 Totals:		
Mean annual flow	**11.02**	(cfs)
Max. daily flow	**453**	(cfs)
Min. daily flow	**0.12**	(cfs)
Annual total	**4034**	(cfs-days)
Annual total	**8002**	(ac-ft)

 841 Folger Ave, Berkeley, CA 94710 (510) 407-1000; fax: (510) 407-1001

Form 4. Annual Sediment-Discharge Record, Bear Creek at Sand Hill Road, water year 2004

Water Year:	**2004**
Stream:	Bear Creek **BCSH**
Station:	at Sand Hill Road
County:	San Mateo County, CA

Total annual sediment discharge (suspended- plus bedload-sediment discharge)
WY 2004: 6,179 *tons*

WY 2004 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	2152.0	0.1	6.3	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	23.9	17.2	4.6	0.0	0.0	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	4.4	11.1	3.1	0.0	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.6	4.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.3	1.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.7	0.2	0.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.1	0.1	0.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	
8	0.0	0.2	0.0	0.1	0.3	1.2	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.0	0.0	0.0	0.1	0.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.8	0.1	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.3	0.1	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.1	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.1	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	
14	0.0	0.0	4.0	0.1	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.1	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	
16	0.0	0.0	0.0	0.1	2.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	0.0	0.1	481.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	0.0	0.1	1092.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	0.1	0.1	17.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.0	0.1	8.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	0.0	0.1	4.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	0.1	4.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.1	2.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	3.8	0.1	3.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	1.7	0.1	1063.2	1.5	0.0	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.1	0.1	70.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	0.1	23.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	0.0	0.1	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	519.0	0.1	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	46.8	0.1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	**Qss**
31	0.0		0.4	0.1		0.0		0.0		0.0	0.0		**Annual**
TOTAL	0	0	578	2183	2829	33	1	0	0	0	0	0	**5,624**
Max.day	0	0	519	2152	1092	6	0	0	0	0	0	0	**2,152**

WY 2004 Daily Bedload-Sediment Discharge *(tons)*

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	
1	0.0	0.0	0.0	177.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	3.1	2.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.4	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
8	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
14	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
16	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	0.0	0.0	51.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	0.0	0.0	116.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	0.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	0.1	0.0	107.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.0	0.0	11.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	63.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	7.6	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	**Qbed**
31	0.0		0.0	0.0		0.0		0.0		0.0	0.0		**Annual**
TOTAL	0	0	72	181	300	3	0	0	0	0	0	0	**555**
Max.day	0	0	63	177	116	1	0	0	0	0	0	0	**177**

Daily values are based on calculations of sediment discharge at 15-minute intervals.
Multiple sediment-discharge rating curves were used for different periods of the year and ranges of flow.
Daily values with more than 2 to 3 significant figures result from electronic calculations. No additional precision is implied.

Form 5. Annual Sediment-Discharge Record, Los Trancos Creek at Piers Lane, water year 2004

Water Year: 2004
Stream: Los Trancos
Station: at Piers Lane — **LTPL**
County: San Mateo County, CA

WY 2004 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	894.4	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	2.7	17.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.2	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.1	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
8	0.0	0.5	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
14	0.0	0.0	0.7	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
16	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	0.0	0.0	28.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	0.0	0.0	40.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	0.1	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	0.2	0.0	1249.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.0	0.0	331.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	0.1	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	0.0	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	380.1	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	27.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	**Qss**
31	0.0		0.0	0.0		0.0		0.0		0.0	0.0		**Annual**
TOTAL	0.0	0.7	409.0	898.2	1679.0	3.2	0.1	0.2	0.1	0.0	0.0	0.0	2,991
Max.day	0.0	0.5	380.1	894.4	1249.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1,249

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.

Form 6. Annual Sediment-Discharge Record, San Francisquito Creek at Piers Lane, water year 2004

Water Year:	2004	
Stream:	San Francisquito Creek	
Station:	at Piers Lane	**SFPL**
County:	San Mateo County, CA	

WY 2004 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	1888.6	0.1	10.0	0.1	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	75.6	45.6	7.9	0.1	0.0	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	8.6	27.0	5.0	0.1	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	2.2	8.4	3.9	0.1	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	1.1	3.3	3.1	0.1	0.0	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.1	0.8	1.8	2.5	0.1	0.0	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.4	0.5	1.1	2.1	0.1	0.0	0.0	0.0	0.0	0.0	
8	0.0	0.2	0.0	0.3	0.7	1.8	0.1	0.0	0.0	0.0	0.0	0.0	
9	0.0	0.1	0.0	0.2	0.5	1.6	0.1	0.0	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.8	0.3	0.4	1.4	0.1	0.0	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.3	0.2	0.2	1.1	0.1	0.0	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.2	0.3	1.0	0.1	0.0	0.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.1	0.3	0.8	0.1	0.0	0.0	0.0	0.0	0.0	
14	0.0	0.0	2.0	0.1	0.2	0.7	0.1	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.1	0.2	0.6	0.1	0.0	0.0	0.0	0.0	0.0	
16	0.0	0.0	0.0	0.1	2.3	0.5	0.1	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	0.0	0.1	232.4	0.5	0.1	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	0.0	0.1	1164.9	0.4	0.1	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	0.0	0.1	27.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.0	0.1	9.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	0.0	0.1	5.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	0.1	5.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.1	3.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	1.6	0.3	3.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	1.2	0.1	1889.7	1.9	0.0	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.1	0.1	518.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	0.1	87.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	0.0	0.1	24.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	564.4	0.1	11.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	228.4	0.1		0.1	0.0	0.0	0.0	0.0	0.0	0.0	Qss
31	0.0		3.6	0.1		0.1		0.0		0.0	0.0		Annual
TOTAL	0.0	0.3	802.9	1980.7	4073.9	50.6	1.8	0.1	0.0	0.0	0.0	0.0	6,910
Max.day	0.0	0.2	564.4	1888.6	1889.7	10.0	0.1	0.0	0.0	0.0	0.0	0.0	1,890

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, Bear Creek at Sand Hill Road, water year 2004

Site Conditions				Streamflow				Water Quality Observations							High-Water Marks		Remarks
Date/Time	Observer	Stage	Hydrograph	Measured Discharge	Estimated Discharge	Instrument Used	Estimated Accuracy	Water Temperature	Field Specific Conductance	Adjusted Specific Conductance	pH	Dissolved Oxygen	Dissolved Oxygen	Additional sampling?	Estimated stage at staff plate	Inferred dates?	
(mm/dd/yr)		(feet)	R/F/S/B)	(cfs)	(cfs)	(AA/PY)	(e/g/f/p)	(oC)	(µmhos/cm)	(at 25 oC)	(pH)	(mg/L)	(% sat.)	(Qbed, etc.)	(feet)	(mm/dd/yr)	
8/21/03 14:57	bkh	1.01	B	0.05	...	PY	f	18.5	576	662	...			...	...	...	flow is clear with leaves covering the bed, staff plate leans ~5 degrees, collected data
10/2/03 12:00	jo	1.035	B	...	0.2	visual	p	14.3	630	806	...	5.8	58%	...	...	...	water clear, collected data
11/4/03 14:19	jo	1.09	B, D	...	0.2	visual	p	10.7	590	831	...	...	...	...	...	...	new WQ station has been installed; water clear, algae and fine sediment on bed, collected data
11/25/03 13:00	jo	1.07	B, D	0.13	...	PY	f	7.4	550	847	...			...	1.4	11/8/03?	worked with KK to calibrate new station, set clock, download data
12/24/03 7:16	jo	1.24	R	...	1.1	visual	p	10.1	550	787	...	10.1	91%	Qss	2.2	last week	Qss at 7:25; water just a little turbid, rain starting to intensify, other HWM = 2.9
12/28/03 19:56	jo	1.155	B	...	0.5	visual	p	...	...	...	...	...	...	...	...	...	no new HWMs; water clear and flowing lazily; many 1" fish in creek; set up sampler for upcoming storm, time paced
12/29/03 14:45	cw	4.55	R	...	...	...	...	10.7	130	183	...	...	...	WQ grabs, Qss	at HWM for season		mid-storm grab samples for WQ; Qss at 14:30
12/30/03 21:30	cw	...	F	...	...	...	...	9.8	336	485	...	...	...	WQ	...	...	retrieve composite sample and distributed to individual bottles, GH not visible in darkness
1/1/04 14:25	cw, jg	5.55	F	670	...	float	p	10.6	106	150	...	...	...	Qss	7.5	1/1/2004	water high; Qss at 13:50; float test at 14:13
1/13/04 12:22	jo	1.195	B	1.70	...	PY	g	10.0	580	833	6.8	10.4	92%	Qss	7.4, 2.9	1/1/04, 1/2/04	gravel bars have been reworked by high flows; water slightly turbid; pH (strip); photos taken; data download
2/1/04 20:33	jo	1.17	B	...	...	...	...	9	550	811	...	...	...	...	...	...	water clear, sampler set to start @ 22:00
2/2/04 11:35	jg, cw	3.11	R	...	...	...	...	9.9	242	348	...	11.1	98%	WQ grabs, Qss	...	...	collected grab samples for WQ; flow too fast and deep for bedload measurement
2/2/04 18:05	jg, cw	2.06	F	...	...	...	...	...	...	...	...	...	...	...	...	...	turned off sampler, total sample volume = 17 liters
2/16/04 11:37	jo	1.57	R	...	6	visual	p	10.8	469	659	...	...	...	Qss	...	...	Qbed measured to be almost zero, water somewhat turbid
2/18/04 11:12	jo	3.65	F	...	212	visual	p	11.1	141	197	...	...	...	Qss, Qbed	6.4	2/18/04	multiple Qss samples taken to test automated sampler; rain overnight and this AM; Qbed sample may not have represented all of active bed
3/2/04 16:35	jg	1.79	F, B	18.24	...	AA	g	10.9	330	462	...	...	...	...	4.1	2/26/04	water clear; download lower datalogger
3/4/04 17:20	jo	1.675	B	...	14.4	visual	p	11	373	521	...	...	...	Qss, Qbed	...	...	water slightly turbid (~1.5-foot visibility); no bedload moving, download upper datalogger
4/23/04 13:00	jg	1.155	B	0.94	...	PY	g	12.8	542	722	...	...	...	...	...	...	new algae on bed and vegetation on banks; instream apparatus = bio. expt.?
5/25/04 12:55	jo	1.095	B	0.50	0.4	PY	g	...	575	748	...	...	...	...	...	...	water clear until ducks swam by, increasing turbidity; many small 1-inch fish in pool; water temperature = 13.7 deg.C from datalogger, but manual temperature probe was not working
6/1/04 11:20	jo	1.072	B	...	...	...	...	15.6	600	742	7.5-7.6	8.0	83%	...	...	...	pH strip; many small fish in pool; decreased clarity in the pools
6/23/04 18:10	jo	1.00	B	0.10	...	PY	f	17.8	670	783	7.4-7.5	6.5	68%	...	...	...	pH strip; gate closed; water clear; many fish in pool
6/29/04 15:05	jo, jg	1.055	B	...	0.4	visual	p	17.8	599	700	7.9	7.2	75%	...	...	...	D.O. varied with location-- at riffle = 9.35 mg/l and 99.4% @ 18.1 C
7/28/04 11:40	bkh	1.027	B	0.15	...	PY	g	18.1	387	449	7.6	6.4	67%	...	...	...	used two pH meters and strips; water murky
8/26/04 11:05	jo, gg	1.085	B	0.27	...	PY	g,f	17.4	617	729	7.7	6.4	65%	...	...	...	used two pH meters and strips; water clear; fresh tracks of vehicle driving across creek
9/7/04 14:50	jo	1.09	B	...	...	...	...	19.5	491	550	7.9	8.0	86%	...	...	...	hot weather; many fish in pools; set up equipment to start collecting a composite sample
9/8/04 14:50	cw	1.09	B	...	0.06	...	...	18.4	471	542	7.8	6.4	68%	WQ grab	...	...	used two pH meters and strips; water clear; collected 27-hour sample
10/5/04 11:11	jg	1.065	B	0.13	...	PY	g	14.3	530	678	7.8	7.3	72%	...	...	...	leaves on cobble bars above water line; smell of dead animal

Notes:

Observer Key: cw = Chris White; jo= Jonathan Owens; bjm= Bonnie Mallory; bkh= Brian Hastings; sb = Scott Brown; jg = John Gartner; gg = Greg Guensch
Stage: Water level observed at outside staff plate
Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or diversion underway (D)
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 (V).
Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) estimated percent accuracy given
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 = water quality suite; other symbols as appropriate

Table 2. Station observer log, Los Trancos Creek at Piers Lane, water year 2004

Site Conditions				Streamflow				Water Quality Observations							High-Water Marks		Remarks
Date/Time	Observer(s)	Stage (staff plate)	Hydrograph	Measured Discharge	Estimated Discharge	Instrument Used	Estimated Accuracy	Water Temperature	Specific Conductance at field temp.	Specific Conductance at 25C	pH	Dissolved Oxygen	Dissolved Oxygen	Additional sampling?	Estimated stage at staff plate	Inferred dates?	
(mm/dd/yr)		(feet)	(R/F/S/B)	(cfs)	(cfs)	(AA/PY)	(e/g/f/p)	(°C)	(μmhos/cm)	(at 25 °C)	(pH)	(mg/L)	(% sat.)	(Qbed, etc.)	(feet)	(mm/dd/yr)	
10/2/03 16:10	jo	1.05	B	0.11	...	PY	g	16.0	1290	1579	8.5	10.6	108%	...	...	...	pH w/ strip, water clear, leaf dams?, download data
11/6/03 14:20	cw	0.93	B	...	2.7 - 4	visual	p	12.8	1188	1582	...	...	...	...	...	...	water clear, sampler started
11/8/03 13:47	cw	1.065	F	...	4	visual	p	13.8	1077	1397	...	10.12	98%	WQ	...	...	sampler turned off @ 14:07, D.O. @ 13:47 was 9.61 mg/L and 94 %
11/20/03 12:50	jo	1.09	B	0.263	...	PY	g	12.3	1060	1431	7.7	10.58	99%	WQ	~1.6	11/8/03	water very clear, minimal leaf dams, few leaves in water, algae on gravel bed, download data
11/25/03 14:45	jo	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	cleaned rain gage
11/28/03 17:23	jo, sp	1.085	B	...	...	...	...	10.8	1020	1433	...	10.17	93%	...	...	...	water very clear, set to sample starting at 23:45 (500 ml each hour, 39X)
11/30/03 16:15	cw	1.19	B	...	...	...	...	11.6	882	1213	...	...	...	WQ	...	...	water clear
11/30/03 18:05	cw	1.17	B,R	...	...	...	...	11.8	923	1262	...	9.26	86	WQ	...	...	sampled WQ @ 1615
12/5/03 12:07	jo, bjm	1.155	F, B	...	0.35	visual	p	12.8	918	1223	7.5-8.0	10.06	95%	...	...	...	pH w/ strips, water clear, set sampler to start at 3:00am (500 ml each hour, 36X)
12/7/03 12:44	jo, bjm	1.25	F	...	0.55	visual	p	13.0	810	1073	7.7	9.68	93%	Qss, WQ	1.45	12/6/03	water clear, pH w/ meter, composite and grab samples collected 14:00
12/24/03 1:08	jo	1.16	B	...	0.55	visual	p	12.3	...	...	...	...	...	...	2.1	...	sampler set up for flow pacing, add'l remarks in field notes
12/24/03 10:20	jo	1.36	R	...	1.5	visual	p	12.3	910	1228	...	9.23	87%	..	2.16	...	water too clear for Qss
12/28/03 20:20	jo	1.105	B	...	0.7	visual	p	...	...	...	...	...	...	...	...	...	set up samplers to begin at 2:00 12/29 (36 500-ml aliquots at 30-min intervals), water very clear
12/29/03 13:00	cw	3.15	R	...	...	...	...	10.9	238	333	...	...	...	Qss, WQ	3.15	...	mid-storm grab samples
12/30/03 21:00	cw	1.37	F	...	...	...	...	10.2	686	980	...	...	...	WQ	...	...	pick up composite samples
1/1/04 16:00	cw, jg	3.073	F	75	...	float	f	10.5	208	295		...	...	Qss	3.07	1/1/04	storm earlier in day, not raining at time of visit, very turbid flow
1/13/04 17:05	jo	1.08	B	...	1.1	visual	p	11.0	1110	1551	...	9.45	87%	...	5.3	1/1/04	water very clear, upper staff reinstalled, bed seems to have scoured
1/21/04 13:36	jo	1.1	R	0.583	...	AA	g	9.8	970	1400		10.5	93%	...	...	...	water very clear, free of sed. on bed on top of sand, gr + cobbles
2/2/04 15:40	jg, cw	2.04	F	23	...	float	f	11.5	...	...		10.67	99%	Qss	...	...	no SC (meter broken), water temperature from DO meter
2/16/04 10:20	jo	1.385	F	...	2	visual	p	11.3	758	1051	...	...	...	Qss	...	...	water slightly turbid, no bedload moving, showers this AM
2/18/04 13:23	jo	1.51	F	...	3	visual	p	...	...	...	...	...	...	...	...	...	download data, no bedload moving, Qsc efficiency test
3/4/04 14:38	jo	1.248	B	2.84	2 to 3	AA	g	11.2	720	1001	...	11.02	102%		...	...	water very clear, NOAA walks creek today, fresh rockfall d/s of bridge
4/23/04 19:30	jg	0.95	B	0.031	0.3 - 0.4	PY	g	14.9	1029	1296	...	...	...	...	...	...	no bedload, water clear
5/25/04 18:00	jo	1.04	B	0.396	...	PY	g/f	16.0	925	1133	...	...	...	...	...	...	water clear, water on rocks, bank collapse
6/1/04 10:15	jo	1.05	B	...	...	...	...	14.7	910	1153	7.9	10	100%	...	...	...	pH with strip, water clear, several 2-3" fish in staff pool
6/29/04 10:10	jo, jg	0.91	B	0.183	...	PY	g/f	16.2	1182	1440	7.9	8.5	87%	...	...	...	download data, no bedload moving, some small leaf dams, 2" fish, some algae
7/28/04 17:00	bkh	0.83	B	0.05	...	PY	g, f	21.1	1474	1589	7.9	6.7	75%	...	...	...	stage = 0.93 prior to breaking leaf dam, water clear
8/26/04 15:25	jo, gg	0.80	B	0.048	0.04	PY	g	19.4	1515	1702	8.0	7.5	82%	...	...	...	water clear; pH with multiple meters
9/3/04 10:45	jo	0.81	B	...	...	...	...	15.6	1482	1833	...	7.5	76%	...	...	...	water clear; dead rat in staff pool
9/7/04 12:15	jo	0.80	B	...	0.03	visual	p	18.0	1586	1845	8.1	8.3	88%	...	...	...	hot day; programmed sampler to collect 24-hour sample
9/8/04 17:30	cw	0.78	B	...	0.03	visual	p	22.4	1694	1771	8.2	6.5	75%	WQ	...	...	hose not feeding sample to bottle; collected all grab samples instead
10/5/04 15:40	jg	0.84	B	0.017	...	PY	f	16.5	1676	2026	8.1	6.8	71%	...	...	...	small leaf dam downstream of staff plate

Observer Key: cw = Chris White; jo= Jonathan Owens; sp = Stacey Porter; bjm= Bonnie Mallory; bkh= Brian Hastings; jg = John Gartner; gg = Greg Guensch

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

Table 3. Station observer log, San Francisquito Creek at Piers Lane, water year 2004

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. (µmhos/cm)	Specific Conductance at 25C (us@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)	
10/2/03 15:52	jo	3.31	B	0.29	...	PY	f	15.8	1130	1391	8.2	6.2	62%	...	...	...	pH (meter), greenish tint to water, many 3" fish in pool, download data
11/6/03 15:25	cw, bjm	3.30	B	...	0.1	...	p	11.3	1018	1411	...	...	...	...	...	...	water clear, set up samplers to begin at 19:00 (500mL each hr, 40x)
11/8/03 15:00	cw	3.35	B	...	...	...	...	13.2	983	1295	...	6.28	67%	WQ	...	...	water clear
11/20/03 13:10	jo	3.36	B	0.314	...	PY	f/p	11.8	940	1286	7.4	6.7	60%	WQ	...	...	water clear, rotting grey leaves amongst rocks, 3-4" fish in pool
11/25/03 14:45	jo	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	cleaned out rain gauge, only very little debris in rain gauge
11/28/03 17:37	jo, sp	3.38	B	...	...	...	...	9.3	810	1185	...	7.25	65%	...	...	...	creek smells of rotting leaves, set sampler to start at 23:45 (500ml each hour, 39X); dark, tough to see gage height on staff plate
11/30/03 16:35	cw	3.50	B	...	...	...	...	10.3	858	1222	...	5.65	51%	WQ	...	...	water clear, so no Tss sample; turned off sampler at 16:50
12/5/03 12:45	jo, bjm	3.52	F, B	...	0.4 - 0.5	visual	p	11.6	800	1100	7.5-8.0	8.4	78%	Qss	...	...	pH w/ strips, water cloudy in pool and smelly; programmed to start sampling 3:00 AM Dec.6
12/7/03 13:15	jo, bjm	3.73	F	...	1.5	visual	p	12.2	570	771	8.5	8.93	85%	Qss, WQ	4.2	12/6/03	pH w/ meter, collected all WQ samples as grabs, water murky and dark gray
12/24/03 1:57	jo	3.54	B	...	...	...	...	...	...	...	...	...	...	...	...	...	sampler set up for flow pacing, water clear in riffle but murky in pool, data collected, see notebook for add'l remarks
12/24/03 10:05	jo	3.82	R	...	...	...	...	11.0	750	1048	...	8.7	79%	Qss	...	...	raining, water slightly turbid, Qss at 10:27
12/28/03 20:45	jo	3.52	B	...	...	...	...	...	...	...	...	...	...	...	...	...	previous composite discarded; set up samplers to begin at 2:00 12/29 (36, 500-ml aliquots at 30-min intervals), water turbid 1-foot visibility
12/29/03 13:15	cw	6.20	R	...	...	...	...	10.2	248	354	...	...	...	many WQ	...	...	mid-storm grab samples, site visit from 1255-1415, stage 9" > hose clamp, stage 6.40-6.50 @ 14:00
12/30/03 22:05	cw	4.63	F	...	...	...	...	9.6	377	547	...	...	...	composites	...	...	pick up composite samples, water turbid
1/1/04 15:40	cw, jg	7.70	F	...	...	...	...	10.3	229	326	...	...	...	Qss	9.2-9.2	1/1/04	storm earlier in day, not raining at time of visit, very turbid flow
1/13/04 17:24	jo	3.75	B	...	4	visual	p	10.2	600	857	...	9.55	86%	Qss	9.9	1/1/04	water turbid, much woody debris on top of brush on far bank of creek, download data
1/21/04 13:00	jo	3.70	R	3.68	...	AA	f	8.5	530	792	...	10.2	89%	...	...	...	water slightly turbid, buds on trees
2/2/04 15:40	jg,cw	5.40	F	...	...	...	...	10.1	...	...	...	10.45	93%	Qss	...	...	no SC (meter broken), water temperature from DO meter; stage reading +/- 0.05 feet
2/16/04 10:37	jo	4.13	R	...	10	visual	p	10.5	609	863	...	...	...	Qss	...	...	water slightly turbid; sampled bedload but caught only organic debris
2/18/04 14:28	jo	6.35	B	...	...	...	...	...	...	...	...	...	...	Qss	...	...	Qss testing
3/4/04 14:00	jo	4.32	B	29.7	...	AA	f	10.7	500	704	...	10.6	97%	Qss	9.25	2/25/04	water turbid, visibility ~8 ft, downloaded data
4/23/04 18:20	jg	3.62	B	2.42	~1.5	PY	f	15.3	725	904	...	...	...	...	...	...	water clear, no bedload transport
5/25/04 17:32	jo	3.40	B	0.77	...	PY	f	17.3	970	1149	...	...	...	...	...	...	SC meter temperature spiking, poison oak at stairs and enclosure
6/1/04 10:32	jo	3.37	B	...	...	...	...	15.9	970	1191	7.7	6.36	64%	...	...	...	pH with strip, water clear in riffle but slightly turbid in pool
6/29/04 11:45	jo, jg	3.35	B	0.445	...	PY	f	17.7	1093	1281	7.7	5.94	63%	...	9.4	2/25/04	download data, water slightly cloudy in pool, clear in riffle, some algae and silt on rocks, 1" fish
7/28/04 18:00	bkh	3.29	B	0.17	...	PY	f	20.4	1283	1406	8.1	3.53	39%	...	...	...	two pH meters used plus strips, water clear
8/26/04 16:00	jo, gg	3.27	B	0.155	...	PY	f	19.2	1220	1377	7.7	6.5	71%	...	...	...	two pH meters used plus strips; water clear in rifle; brown algae most places, but bright green algae and tint in staff pool
9/3/04 10:54	jo	3.33	B	...	...	...	...	16.7	1160	1395	...	4.4	46%	...	...	...	diagnosed and fixed equipment problems with KK
9/7/04 12:32	jo	3.33	B	...	0.15	visual	p	17.9	1132	1320	8.0	5.3	56%	...	...	...	hot weather; programmed sampler to collect 24-hour sample
9/8/04 18:40	cw	3.30		...	...	...	...	19.3	1130	1273	8.1	4.7	49%	WQ	...	...	grab samples for Hg, NH3, 18:55; decanted composite samples 19:05-19:30
10/5/04 16:32	jg	3.27	B	0.121	...	float	p	15.1	1107	1387	7.3	5.4	54%	...	...	...	difficult to measure flow through rocks

Observer Key: cw = Chris White; jo= Jonathan Owens; sp = Stacey Porter; bjm= Bonnie Mallory; bkh= Brian Hastings; jg = John Gartner; gg = Greg Guensch

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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

Table 4. Hydrologic summary for the period of record, Bear Creek at Sand Hill Road, Los Trancos and San Francisquito Creeks at Piers Lane

Water Year [1]	Annual Flow [4]				Sediment Discharge [4]				Peak Flow		
	Mean Annual Flow	Maximum Daily Flow	Minimum Daily Flow	Total Flow Volume	Suspended Sediment	% suspended	Bedload Sediment	% bedload	Peak Flow	Peak Stage [5]	Date Time
	(cfs)	*(cfs)*	*(cfs)*	*(ac-ft)*	*(tons)*		*(tons)*		*(cfs)*	*(ft)*	*(24-hr)*
Bear Creek at Sand Hill Road [2, 6]											
2000	10.65	683.6	0.01	7728	24,426	93%	1,778	7%	2050	8.81	2/13/2000 20:45
2001	3.71	112.6	0.01	2689	681	87%	98	13%	353	4.26	1/25/2001 16:45
2002	5.12	188.9	0.01	3704	1,681	91%	171	9%	733	5.78	12/2/2001 7:45
2003	...	...	...	...	...	...	...	...	...	...	...
2004	5.87	282.5	0.01	4260	5624	91%	555	9%	1186	7.28	1/1/2004 12:15
Los Trancos Creek at Piers Lane [3, 7]											
2003	2.67	123	0.01	1,934	2,494	...	...	...	649	7.58	12/16/02 6:30
2004	2.70	136	0.00	1,461	2,991	...	...	...	582	5.47	2/25/2004 11:00
San Francisquito Creek at Piers Lane [3, 7]											
2003	15.40	782	0.09	11,146	10,097	...	...	...	2,706	12.46	12/16/02 6:30
2004	11.02	453	0.12	8,002	6,910	...	...	...	1,474	9.67	1/1/04 13:15

Notes:

General: Values displaying more than 2 or 3 significant figures are the result of electronic calculations; no additional precision is implied.

1) Hydrologic monitoring is conducted by "water years", rather than calendar years, to encompass whole rainfall seasons. Water year 2004 (WY2004) extends from October 1, 2003 through September 30, 2004 and corresponds to the water year used by most federal agencies.

2) The period of record for this station is October 12, 1999 to Sept. 30, 2004. Balance collected some data during water year 2003 but that record has not been compiled.

3) The period of record for these stations is October 2002 to Sept. 30, 2004; the partial record from the initial season (WY2002) of monitoring is not shown.

4) Daily flow values were computed from instantaneous flow calculated at 15-minute intervals. Sediment discharge values were totalled from calculations at 15-minute intervals

5) Stage is the staff plate reading; the staff plate is set at an arbitrary datum and does not represent the absolute depth of water in the creek.

6) Year-long sediment discharge totals have not been calculated prior to WY2000, even though occasional sediment-transport measurements were performed.

7) Sediment totals for water year 2003 were recalculated by applying the sediment rating curves from water year 2004, which were revised after analysis of the WY2004 data.

Table 5. Summary of water quality for Bear Creek at Sand Hill Road, water year 2004.

Field observations [1]							*Nutrients* [2]				*Pesticides*		*Others* [3]		
Date and Time	Observer	Gage Height	Hydrograph	Discharge	Water Temperature	Specific conductance	**Ammonia-N**	**Nitrate-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 [5]						**12/29/2003**	0.2		0.5	0.02	0.05	0.05	5.0		
						2/2/2004	0.2		0.1	0.02	0.05	0.05	5.0		1.0
						9/7-8/2004	0.2		0.1	0.02	0.05	0.05			
Bear Creek at Sand Hill Road															
12/29/03 composite	cw	comp.	**R, P, F**	**128**					1.1, 1.0	1.65	ND	ND	420, 400	290	
12/29/2003 14:35	cw	4.53	R, F	258	10.7	183	0.2				ns	ns	450	313	
2/2/04 composite	cw, jg	comp.	**R, P, F**	**23**					0.4	1.12	ND	ND	100		239
2/2/2004 11:20	cw, jg	3.08	R	114	9.5	348	0.2				ns	ns	444, 643	120, 198	
9/7-8/2004	jo, cw	comp.	**B**	**0.28**					0.1	0.245	ND	ND			170
9/8/2004 21:05	cw	1.09	B	0.06	18.4	539	0.22								
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

12/29/2003 composite (starting 12/29/03 2:00; 36 500-ml samples every 30 minutes; until 12/29/03 19:30)
2/2/2004 composite (starting 2/1/04 22:00; 36 500-ml samples every 30 minutes; until 2/2/04 15:30)
9/8/2004 composite (starting 9/7/04 15:30; 36 500-ml samples every 45 minutes; until 9/8/04 18:30)

Table 5. Summary of water quality for Bear Creek at Sand Hill Road, water year 2004 (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]	**12/29/2003**	1000	10	1.2	0.6	0.8	0.4	...	...	1.2	0.6	0.1	0.1	0.2	0.2	10.0	5.0
	2/2/2004	500	10	0.6	0.6	0.4	0.4	0.05	0.0005	0.6	0.6	0.1	0.1	0.2	0.2	5.0	5.0
	9/7-8/2004	10	10	0.6	0.6	0.4	0.4	...	...	0.6	0.6	0.1	0.1	0.2	0.2	5.0	5.0
Bear Creek at Sand Hill Road																	
12/29/03 composite	**128**	9,000	60	33	5.6	15	ND	ns	ns	32	4.1	0.6	0.2	ND	ND	79	41
2/2/2004 composite	**23**	3,100	20	10.9	4.8	5.1	ND	ns	ns	12	3.9	0.3	ND	ND	ND	32	21
2/2/2004 11:20	114							0.11	0.0022								
9/7-8/2004	**0.28**	20	ND	1.2	1.2	ND	ND			3.2	3.6	0.1	0.1	ND	ND	8.0	6.0
9/8/2004 18:50	0.12							ns	ns								
SF Bay RWQCB (1995)--Aquatic acute toxicity: 1-hour average [11]		None		None	13.4 - 61.2	None	64.6 - 352.5	2.4	2.4	None	468.2 - 1827.2	20	20	None	3.4 - 55.0	None	118.1 - 462.0
SF Bay RWQCB (1995)-- Aquatic chronic toxicity: 4-day average [11]		None		None	9.0 - 35.4	None	2.5 - 13.7	0.025	0.025	None	52.0 - 202.9	5	5	(instantaneous maximum; no acute or chronic toxicity		None	117.2 - 458.2

12/29/2003 composite (starting 12/29/03 2:00; 36 500-ml samples every 30 minutes; until 12/29/03 19:30)
2/2/2004 composite (starting 2/1/04 22:00; 36 500-ml samples every 30 minutes; until 2/2/04 15:30)
9/8/2004 composite (starting 9/7/04 15:30; 36 500-ml samples every 45 minutes; until 9/8/04 18:30)

Table 5. Summary of water quality for Bear Creek at Sand Hill Road, water year 2004 (continued).

Notes: **ND = not detected** **ns = not sampled,**

1) Observer Key: cw is Chris White; jo is Jonathan Owens; sp is Stacey Porter, bjm is Bonnie Mallory
Hydrograph: R=Rising; P=Peak; 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 (H2SO4) 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.
Suspended sediment analyses by Soil Control Lab (Watsonville, CA) with detection limit of 5.0 mg/L, except some 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 (HNO3). 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 analyses performed by Caltest (Napa).
All other laboratory analyses including suspended sediment (composite samples only) performed by the City of Palo Alto RWQCP.
6) Reporting limits for total aluminum vary with sample concentration, due to the dilution used to bring the sample into analytical range.
Thus, the reporting limit may vary slightly among samples collected at different sites on the same day.
7) Un-ionized ammonia concentrations chronically in excess of 0.025 mg/L (annual median value) can be toxic (RWQCB, 1995).
The fraction of total ammonia that is in the toxic, un-ionized form increases with increases in pH and temperature. Mean daily temperatures in Bear Creek varied from about 6.6 to 20.1°C, and pH measurements ranged from 6.8 to 7.4 during the WY2004 monitoring period.
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) Selected trace metals objectives are hardness-dependent (RWQCB, 1995). The range shown is for hardness of 100 to 500 mg/L as $CaCO_3$.
The California Toxics Rule, recently (2004) adopted by the Regional Board, approved by the U.S. EPA and incorporated into the Basin Plan establishes aquatic acute and chronic toxicity objectives for dissolved concentrations of metals, based on hardness. The objectives are calculated based on the following equations:

Dissolved Copper, 1-hour average = (e{0.9422 [ln(hardness)] - 1.700}) x (0.960)
Dissolved Copper, 4-day average = (e{0.8545 [ln(hardness)] - 1.702}) x (0.960)

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]})

Dissolved Nickel, 1-hour average = (e{0.8460 [ln(hardness)] + 2.255 }) x (0.998)
Dissolved Nickel, 4-day average = (e{0.8460 [ln(hardness)] + 0.0584}) x (0.997)

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

Dissolved Zinc, 1-hour average = (e{0.8473 [ln(hardness)] + 0.884 }) x (0.986)
Dissolved Zinc, 4-day average = (e{0.8473 [ln(hardness)] + 0.884}) x (0.978)

Table 6. Summary of water quality at San Francisquito and Los Trancos Creeks at Piers Lane, water year 2004.

Field observations [1]							*Nutrients* [2]				*Pesticides*		*Others* [3]		
Date and Time	Observer	Gage Height	Hydrograph	Discharge	Water Temperature	Specific conductance	Ammonia-N	Nitrate-N	Nitrate + Nitrite-N	Phosphate-P	Chlorpyrifos	Diazinon	Total Suspended Solids	Turbidity	Hardness
		(feet)	*(R,P,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: [5]						**11/6-8/2003**	0.2		0.5	0.02	0.5	0.6			1.0
						11/29-30/2003	0.2	0.1	0.5	0.02	0.5	0.6			1.0
						12/6-7/2003	0.2	0.1		0.02	0.05	0.05	0.5		1.0
						12/29/2003	0.2	0.2; 0.5(LT;dups.)		0.02	0.05	0.05	0.5		1.0
						9/7-8/2004	0.2		0.1	0.02	0.05	0.05			
San Francisquito Creek at Piers Lane															
11/6-8/2003	cw	comp.	**R,F**	**0.67**					3.3				...	...	204
11/8/2003 15:15	cw	3.35	B	0.34	13.2	1295	ND			0.43	ND	ND	...	...	
11/29-30/2003	jo, sp	comp.	**B,R**	**2.43**				3.9	3.0	0.22	ND	ND	...	...	208
11/30/2003 16:30	cw	3.50	R	0.43	10.3	1222	ND						...	...	
12/6-12/7/2003	***all samples for this date are grab samples on 12/7/03 due to sampler malfunction***														
12/7/2003 13:30	jo, bjm	3.73	F	2.54	12.2	771	ND	1.0		0.43	ND	ND		...	104
12/7/2003 13:30	jo, bjm	3.73	F	2.54	12.2	771	ND	0.8		0.40	ns	ns	84	32	101
12/29/2003	jo,cw	comp.	**R,P**	**229**					1.1	1.13	ND	ND	340, 377	230	na
12/29/2003 13:20	cw	6.20	R	265	10.2	354	ND		2.0				710	380	
9/7-8/2004	jo, cw	comp.	**B**						1.8	0.215	ND	ND			500
9/8/2004 19:05	cw	3.30	B	0.12	19.3	1269	ND								
Los Trancos Creek at Piers Lane															
11/6-8/2003	cw	comp.	**R,F**	**0.23**					3.0	0.35	ND	ND	...	...	210
11/8/2003 16:15	cw	1.05	B	0.12	13.8	1397	ND						...	...	
11/29-30/2003	jo, sp	comp.	**B,R**	**0.27**				4.0	3.0	0.22	ND	ND	...	...	226
11/30/2003 16:15	cw	1.19	R	0.45	11.6	1213	ND						...	...	
12/6-12/7/2003	jo, bjm	comp.	**R,F**	**1.70**				1.1		0.46	ND	ND	9	...	184
12/7/2003 14:08	jo, bjm	1.22	F	0.83	13.0	1073	ND						27.5	1.5	
12/29/2003	jo, cw	comp.	**R,P**	**67.4**					2	1.72	ND	ND	527, 510	320	na
12/29/03 13:05,13:55	cw	3.15	R	36.50	10.9	333	0.39		1.3				1530	480	
9/7-8/2004	***all samples for this sampling are grab samples on 9/8/2004 due to sampler malfunction***														
9/8/2004 17:35-17:50	cw	0.78	B	0.28	22.4	1782	0.60		2.6	0.15	ND	ND			
SF Bay RWQCB (1995)--Aquatic acute toxicity: 1-hour average							---[7]	---[8]	---[8]	---[8]	---[9]	---[9]	---[10]	---[10]	None
SF Bay RWQCB (1995)--Aquatic chronic toxicity: 4-day average							---[7]	---[8]	---[8]	---[8]	---[9]	---[9]	---[10]	---[10]	None

Table 6. Summary of water quality at San Francisquito and Los Trancos Creeks at Piers Lane in Water Year 2004 (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, 6]	**11/6-8/2003**	100	100	0.6	0.6	0.4	0.4	ns	ns	0.6	0.6	0.1	0.1	0.2	0.2	5.0	5.0
	11/29-30/2003	100	100	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
	12/6-12/7/2003	100	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
	12/29/2003	1-2,000	10	1.2	0.6	0.8	0.4	0.05	0.0005	1.2	0.6	0.1	0.1	0.2	0.2	10.0	5.0
	9/7-8/2004	20	10-20	0.6	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
San Francisquito Creek at Piers Lane																	
11/6-8/2003	**0.67**			8.7	3.9	0.5	ND			4.9	4.2	0.3	0.2	ND	ND	18.0	13.0
11/8/2003 15:15	0.34	400	ND					ns	ns								
11/29-30/2003	**2.43**	ND	ND	7.1	2.4	ND	ND			3.7	4.1	0.2	0.2	ND	ND	8.0	15.0
11/30/2003 16:30	0.43							0.0026	0.0012								
12/6-7/2003	***all samples for this sampling are grab samples on 12/7/03 due to sampler malfunction***																
12/7/2003 13:30	2.54	700	190	9.8	7.7	1.5	0.6	0.0060	0.0022	10.0	4.7	0.2	0.3	ND	ND	19.0	7.0
12/7/2003 13:30	2.54	600	170	12.2	4.9	1.6	ND	0.0068	0.0019	12.0	5.0	0.2	0.3	ND	ND	18.0	ND
12/29/2003	**229**	8,000	40	49.0	4.4	12.0	ND			32.0	4.3	0.4	0.2	ND	ND	76.0	32.0
12/29/2003 13:20	265							0.1300	0.0028								
9/7-8/2004		30	ND	2.4	1.4	0.6	ND			6.0	4.3	0.4	0.4	ND	ND	7.0	ND
9/8/2004 18:50	0.12							0.0030	0.0007								
Los Trancos Creek at Piers Lane																	
11/6-8/2003	**0.23**	ND	ND	6.8	3.2	ND	ND			7.0	3.5	0.2	0.2	ND	ND	11.0	7.0
11/8/2003 16:15	0.12							ns	ns								
11/29-30/2003	**0.27**	ND	ND	8.4	1.9	ND	ND			8.0	3.0	0.3	0.2	ND	ND	10.0	18.0
11/30/2003 16:15	0.45							0.0016	0.0012								
12/6-7/2003	**1.70**	160	20	4.8	3.3	0.5	ND			3.6	2.9	0.3	0.3	ND	ND	9.0	ND
12/7/2003 2:08	0.83							0.0024	0.0016								
12/29/2003	**67.4**	12,000	10	42.0	3.8	16.0	ND			54.0	3.9	0.9	0.3	0.3	ND	100.0	28.0
12/29/2003 13:05,13:55								0.2700	0.0039								
9/7-8/2004	***all samples for this sampling are grab samples on 12/7/03 due to sampler malfunction***																
9/8/2004 13:05,13:55		ND	ND	3.7	1.8	ND	ND	0.0064	0.0010	4.8	4.9	0.3	0.3	ND	ND	8	ND
SF Bay RWQCB (1995)--Aquatic acute toxicity: 1-hour average [11]		None		None	13.4 - 61.2	None	64.6 - 352.5	2.4	2.4	None	468.2 - 1827.2	20	20	None	3.4 - 55.0	None	118.1 - 462.0
SF Bay RWQCB (1995)-- Aquatic chronic toxicity: 4-day average [11]		None		None	9.0 - 35.4	None	2.5 - 13.7	0.025	0.025	None	52.0 - 202.9	5	5	(instantaneous maximum; no acute or chronic toxicity		None	117.2 - 458.2

Table 6. Summary of water quality at San Francisquito and Los Trancos Creeks at Piers Lane, water year 2004 (continued).

Notes: ND = not detected ns = not sampled, na = not analyzed

1) Observer Key: cw is Chris White; jo is Jonathan Owens; sp is Stacey Porter, bjm is Bonnie Mallory
Hydrograph: R=Rising; P=Peak; 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 (H2SO4) 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.
Suspended sediment analyses by Soil Control Lab (Watsonville, CA) with detection limit of 5.0 mg/L, except some 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 (HNO3). 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 analyses performed by Caltest (Napa).
All other laboratory analyses including suspended sediment (composite samples only) performed by the City of Palo Alto RWQCP.
6) Reporting limits for total aluminum vary with sample concentration, due to the dilution used to bring the sample into analytical range.
Thus, the reporting limit may vary slightly among samples collected at different sites on the same day.
7) Un-ionized ammonia concentrations chronically in excess of 0.025 mg/L (annual median value) can be toxic (RWQCB, 1995).
The fraction of total ammonia that is in the toxic, un-ionized form increases with increases in pH and temperature. Mean daily temperatures varied from about 6.4 to 20.4°C in San Francisquito Creek and from about 7.6 to 20.0°C in Los Trancos Creek during the WY2004 monitoring period. pH measurements ranged from 7.3 to 8.5 in San Francisquito Creek and from 7.7 to 8.5 in Los Trancos Creek during water year 2004.
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) Selected trace metals objectives are hardness-dependent (RWQCB, 1995). The range shown is for hardness of 100 to 500 mg/L as $CaCO_3$.
The California Toxics Rule, recently (2004) adopted by the Regional Board, approved by the U.S. EPA and incorporated into the Basin Plan establishes aquatic acute and chronic toxicity objectives for dissolved concentrations of metals, based on hardness. The objectives are calculated based on the following equations:

Dissolved Copper, 1-hour average = (e{0.9422 [ln(hardness)] - 1.700}) x (0.960)
Dissolved Copper, 4-day average = (e{0.8545 [ln(hardness)] - 1.702}) x (0.960)

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]})

Dissolved Nickel, 1-hour average = (e{0.8460 [ln(hardness)] + 2.255 }) x (0.998)
Dissolved Nickel, 4-day average = (e{0.8460 [ln(hardness)] + 0.0584}) x (0.997)

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

Dissolved Zinc, 1-hour average = (e{0.8473 [ln(hardness)] + 0.884 }) x (0.986)
Dissolved Zinc, 4-day average = (e{0.8473 [ln(hardness)] + 0.884}) x (0.978)

Table 7. Water quality objectives for dissolved trace metals concentrations at hardnesses typically observed in the San Francisquito Creek watershed.

Trace Metal	Water Quality Objectives [1]	Ambient Total Hardness Levels [2] (mg/L as $CaCO_3$)				
		100	200	300	400	500
Copper	CMC (1-hour average)	13.4	25.8	37.8	49.6	61.2
Copper	CCC (4-day average)	9.0	16.2	22.9	29.3	35.4
Lead	CMC (1-hour average)	64.6	136.1	208.6	280.8	352.5
Lead	CCC (4-day average)	2.5	5.3	8.1	10.9	13.7
Nickel	CMC (1-hour average)	468.2	841.7	1186.1	1512.9	1827.2
Nickel	CCC (4-day average)	52.0	93.5	131.7	168.0	202.9
Silver	Instantaneous Maximum	3.4	11.4	22.8	37.4	55.0
Zinc	CMC (1-hour average)	118.1	212.5	299.7	382.4	462.0
Zinc	CCC (4-day average)	117.2	210.8	297.2	379.3	458.2

Notes:

1. Water quality objectives adopted by the Regional Water Quality Control Board, Region 2 (San Francisco Bay), then approved by the State Water Resources Control Board on July 22, 2004 and by the California Office of Administrative Law on October 4, 2004. The criteria maximum concentration (CMC) is equivalent to the prior aquatic "acute" toxicity objective, while the criteria continuous concentration (CCC) is equivalent to the prior aquatic "chronic" toxicity objective.
2. Since calcium and magnesium are the primary components of hardness, the convention is to express total hardness in terms of an equivalent concentration of calcium carbonate ($CaCO_3$).

Table 8. Measurements and calculation of sediment transport, Bear Creek at Sand Hill Road, water year 2004

	Field Observations [1]					*Bedload Sampling Details*						*Sediment Transport*				
Sample Date:Time	Observer(s)	Stage	Stream Condition	Streamflow Discharge	Streamflow Value Source	Active Bed Width	Sampler Width	No. of Verts.	Time/Vert.	Total Time	Sample Dry Weight	Bedload Discharge	Bedload Discharge	Suspended Sediment Concentration	Suspended Sediment Discharge	Turbidity
		(ft)	*R,F,B,U*	*(cfs)*	*M,R,E*	*(ft)*	*(ft)*		*(sec)*	*(sec)*	*(gm)*	*(lb/sec)*	*(tons/day)*	*(mg/l)*	*(tons/day)*	*(ntu)*
Bear Creek at Sand Hill Road																
12/24/03 7:25	jo	1.24	R	0.80	R									28.2	0.06	10
12/29/03 14:30	cw	4.53	R,F	379	R									450	460	280
12/29/03 comp	auto	composite sample		**196**										420	**222**	290
1/1/04 14:00	cw, jg	5.76	F	680	R									1520	2,788	700
1/13/04 11:30	jo	1.20	B	1.7	M									14	0.06	5.5
2/2/04 11:05	cw, jg	2.90	R	110	R									444	132	340
2/2/04 11:45	cw, jg	3.07	R	145	R									643	251	660
2/2/04 comp	auto	composite sample		**29**										100	**7.9**	
2/2/04 18:00	cw, jg	2.09	F	41	R									220	24	170
2/16/04 11:30	jo	1.57	R	11	R	5	0.25	2	60	120	**10**	0.004	0.15	19	0.56	18
2/18/04 10:23	jo	3.86	F	263	R									370	262	280
2/18/04 10:50	jo	3.76	F	246	R	test: composite sample from about 8 liters								276	**183**	260
2/18/04 10:53	jo	3.75	F	244	R	test: direct from pump into sample bottle								350	230	280
2/18/04 10:55	jo	3.74	F	243	R	test: sampled in creek at intake location								331	217	260
2/18/04 10:56	jo	3.74	F	242	R	test: depth- and width-integrated sample in creek								308	201	270
2/18/04 11:07	jo	3.69	F	236	R	15	0.25	3	20	60	35.6	0.078	3.30	...	...	...

Notes and explanations

1) Observer Key: jo= Jonathan Owens; cw= Chris White ; jg = John Gartner   Stream Condition: R = rising, F = falling, B = baseflow, U = uncertain
Streamflow discharge is the measured or estimated instantaneous flow at the time that sediment was sampled. The value is usually taken from the datalogger record and typically differs from the mean flow for the day. **Bold** flow values indicate average flow during the period of composite sampling.
Streamflow Value Source: M = measured; R = rating curve; E = estimated; Streamflow for composite samples is mean flow for the sampling period.

2) Active Bed Width is estimated by the field observer as the width through which significant amounts of bedload are being transported.
Sampler Width and Type: 0.25 = 3-inch Helley Smith; 0.50 = 6-inch Helley Smith

3) Values for sediment discharge showing more than two to three digits are the result of calculations; increased precision is not implied.
Bedload Discharge (lbs/sec) = [active bed width (ft) * sample dry weight (gm) * 0.002205 (lbs)]/ [sampler width (ft) * sampling time (sec)]
Bedload Discharge (tons/day) = [active bed width (ft) * sample dry weight (gm) * 86,400 (sec)]/ [sampler width (ft) * sampling time (sec) * 907,200 (gm)]
The detection limit for suspended sediment is 5 mg/L ; values shown as <5 indicate that the sample was below the detection limit.
If the creek is visibly clear, then suspended sediment samples are not collected because concentrations would likely be below the detection limit.

Table 9. Measurements and calculation of suspended sediment transport in San Francisquito Creek and Los Trancos Creek at Piers Lane, water year 2004

	Field observations [1]				*Suspended sediment* [2]		
Date and Time	Observer(s)	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							
12/7/03 13:15	jo, bjm	3.73	F	2.7	9	0.06	...
12/7/03 13:15	jo, bjm	3.73	F	5.1	84	1.2	32
12/24/03 10:30	jo	3.81	R	7.5	39.5	0.79	33
12/29/03 13:15	cw	6.20	R	283	710	542	380
12/29/03 2:00-20:00	auto	comp.	R	**229**	377	233	230
12/29/03 2:00-20:00	auto	comp.	R	**229**	340	210	...
1/1/04 16:00	cw, jg	7.91	F	810	1020	2228	510
1/13/04 17:30	jo	3.75	B	4.9	24	0.31	17
2/2/04 15:45	cw, jg	5.40	F	128	277	96	330
2/16/04 10:31	jo	4.13	R	21	19	1.1	10
2/18/04 14:19	jo	6.30	F	309	301	251	290
2/18/04 14:22	jo	6.30	F	309	430	358	300
2/18/04 14:27	jo	6.30	F	310	293	245	290
2/18/04 14:28	jo	6.30	F	310	280	234	300
3/5/04 14:32	jo	4.32	B	29.7	15	1.2	15
Los Trancos Creek at Piers Lane							
12/6/-12/7/03 comp	auto	comp.	R, F	**1.70**			
12/7/03 14:35	jo, bjm	1.24	F	1	27.5	0.06	1.5
12/29/03 13:00	cw	2.36	R	39.2	1530	162	480
12/29/03 2:00-20:00	auto	comp.	R, F	**67.4**	527	96	320
12/29/03 2:00-20:00	auto	comp.	R, F	**67.4**	510	93	...
1/1/04 16:00	cw, jg	3.07	F	87.7	820	194	550
2/2/04 15:40	cw, jg	2.01	F	26.0	234	16	320
2/16/04 10:22	jo	1.39	R,F?	4.78	4.3	0.06	2.6
2/18/04 13:38	jo	1.49	F	5.71	60	0.92	92
2/18/04 13:40	jo	1.49	F	5.71	40	0.62	80
2/18/04 13:42	jo	1.49	F	5.71	36	0.55	82
2/18/04 13:43	jo	1.49	F	5.71	39	0.60	83

Notes:

1) Observer Key: jo= Jonathan Owens; bjm= Bonnie Mallory; cw= Chris White ; jg = John Gartner
Stream Condition: R = rising, F = falling, B = baseflow, U = uncertain
Streamflow discharge is the measured or estimated instantaneous flow at the time that sediment was sampled. The value is usually taken from the datalogger record and typically differs from the mean flow for the day.
Bold flow values indicate average flow during the period of composite sampling

2) Values for sediment discharge showing more than two to three digits 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.
If the creek is visibly clear, then suspended sediment samples are not collected because concentrations would be below the detection limit.

FIGURES

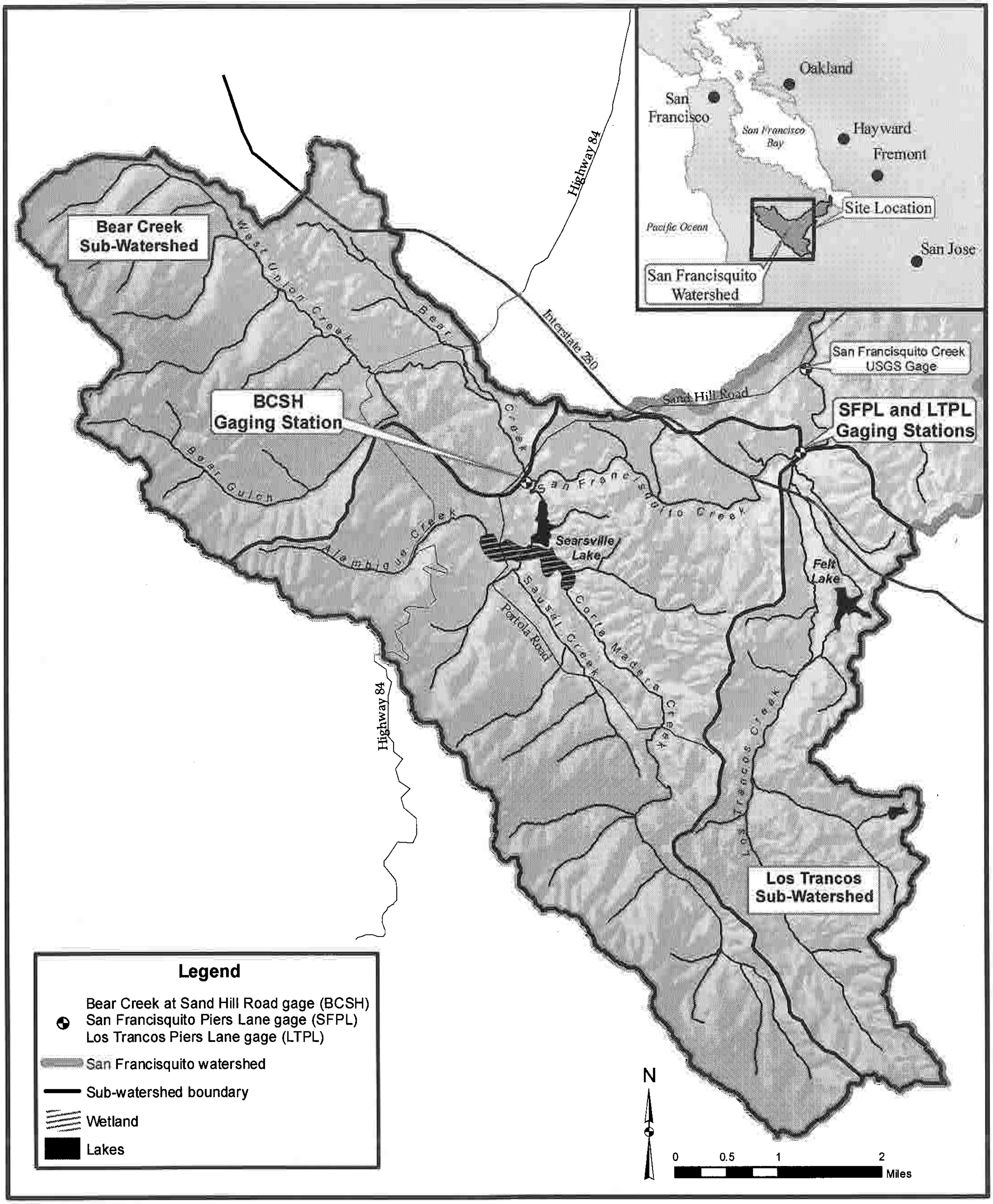

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Figure 1. Site location and San Francisquito watershed map
The Piers Lane stations are located just above the confluence of San Francisquito and Los Trancos Creeks. The Bear Creek station is located downstream of Sand Hill Road.

W:\Projects\202018\202018_Figure1.mxd

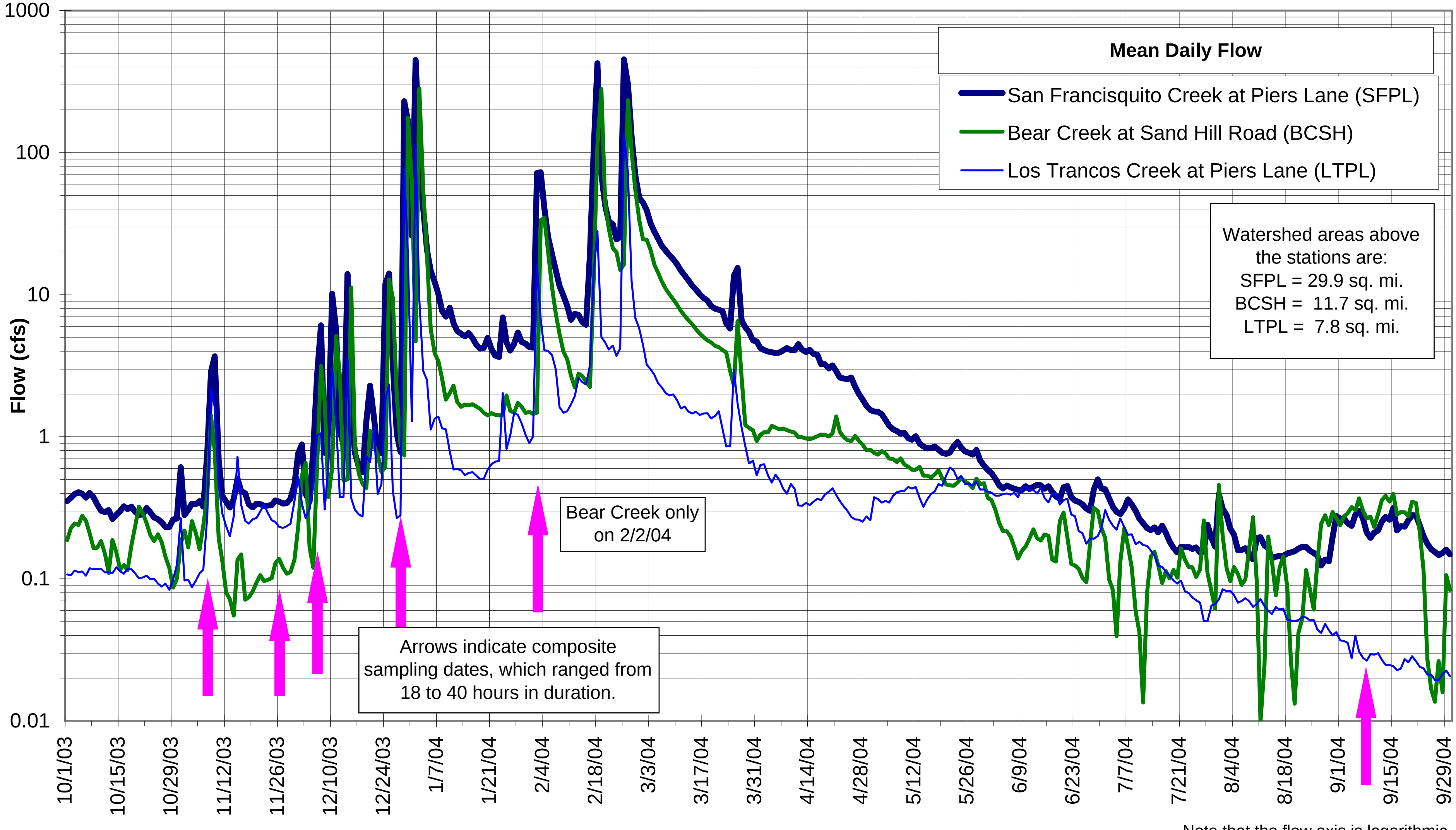

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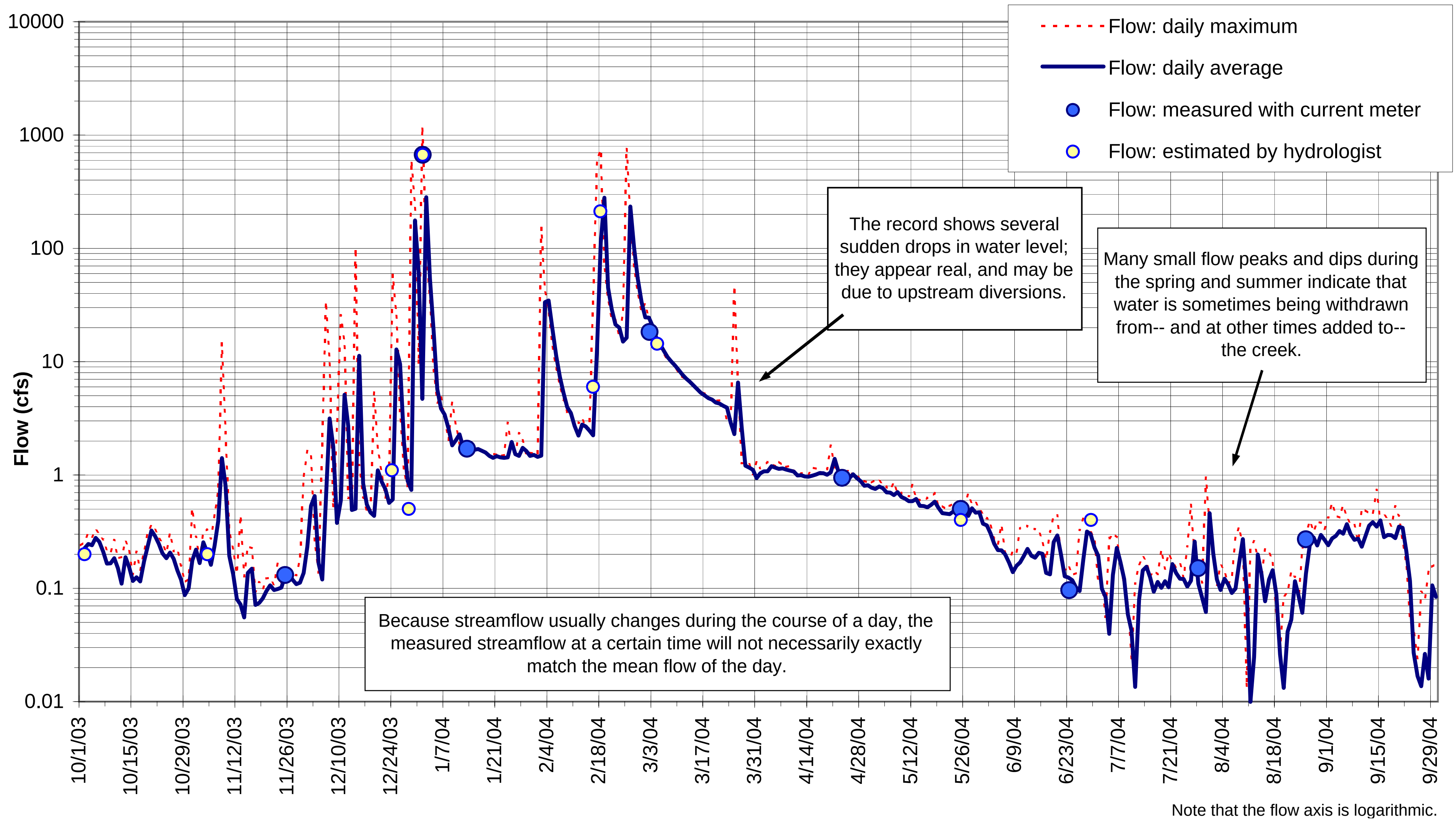
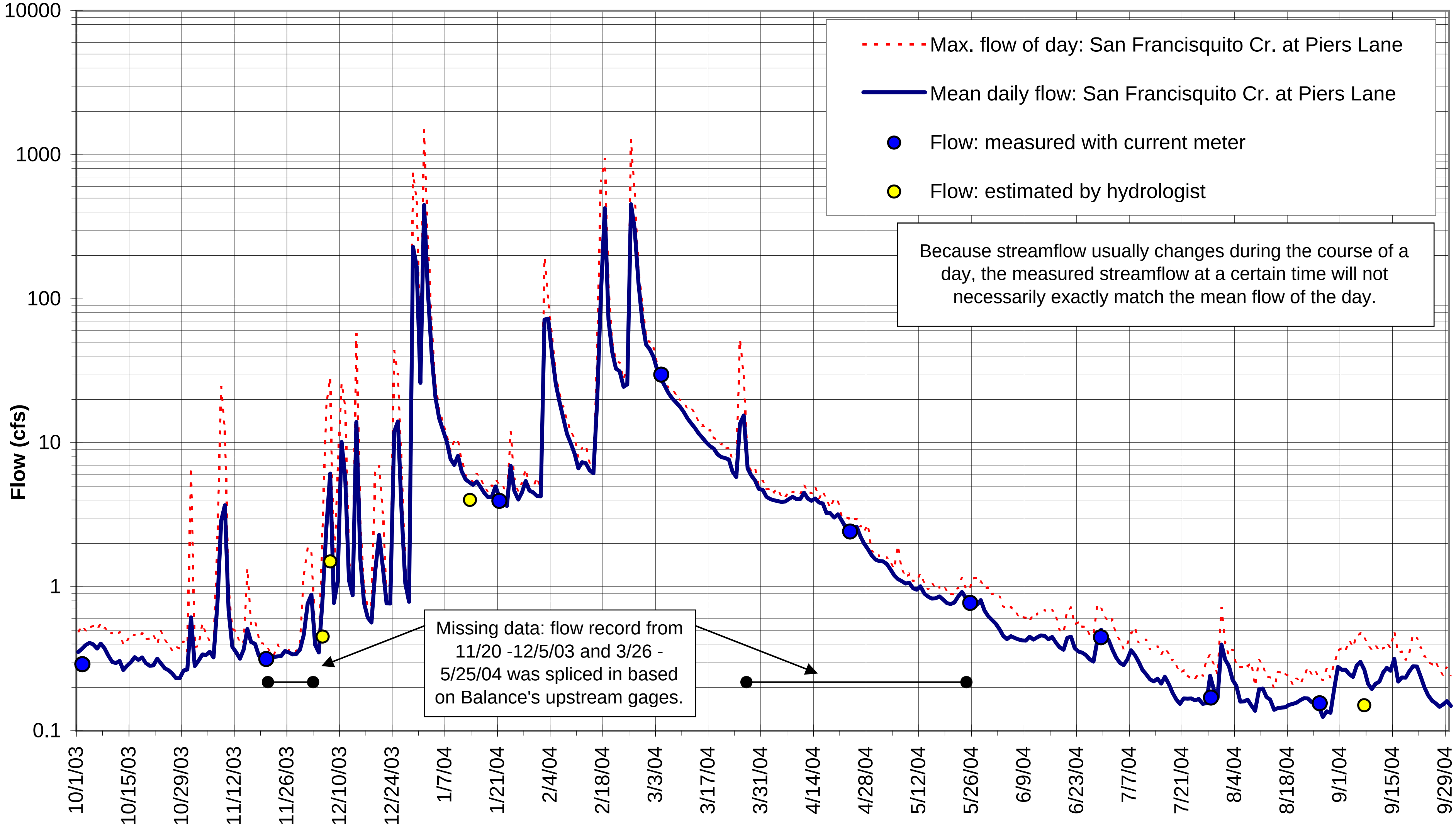
Figure 2. Daily flow hydrographs for San Francisquito, Los Trancos and Bear Creeks, water year 2004. Flow in San Francisquito Creek is generally greater than flow in Bear Creek or Los Trancos Creek, as one would expect from its larger drainage area. The first composite sampling on Bear Creek was December 29, 2003.



Balance Hydrologics, Inc.

Figure 3. Daily flow hydrograph for Bear Creek at Sand Hill Road, water year 2004. Some flow regulation occurs upstream of this station. The peak flow of approximately 1190 cfs was recorded on January 1, 2004 at 12:15 PM. The same storm produced the peak flow of the year on San Francisquito Creek, but not on Los Trancos Creek. A flow of 0.01 cfs approximates our detection limit; flow below that level can be considered almost zero flow.



Note that the flow axis is logarithmic.

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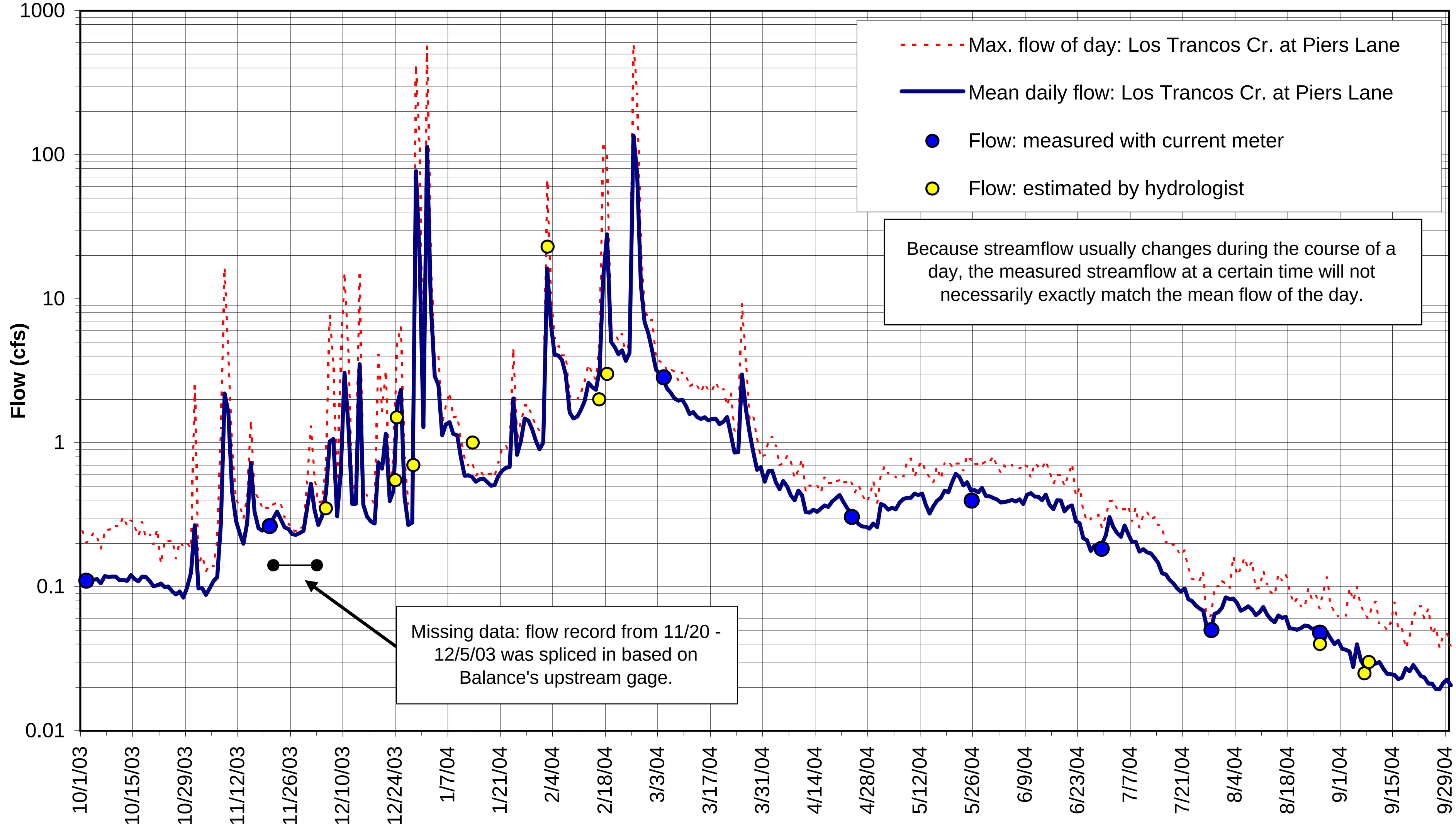
Figure 4. Daily flow hydrograph for San Francisquito Creek at Piers Lane, water year 2004. The peak flow of approximately 1,470 cfs was recorded on January 1, 2004 at 1:15 PM, a different storm than the one which produced the peak flow for Los Trancos Creek.



Note that the flow axis is logarithmic.

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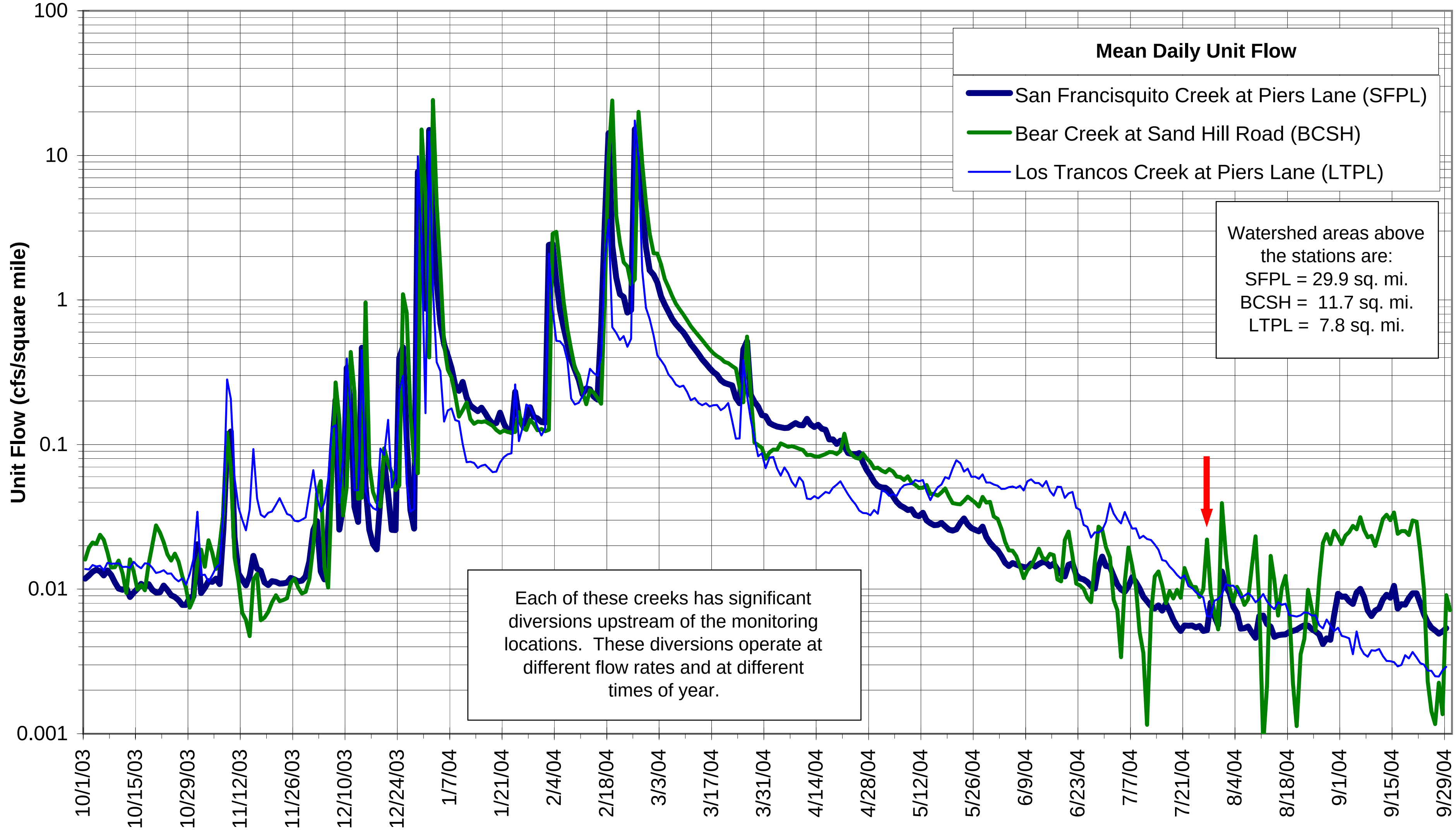
Figure 5. Daily flow hydrograph for Los Trancos Creek at Piers Lane, water year 2004. The peak flow of approximately 580 cfs was recorded on February 25, 2004 at 11:00 AM, a different storm than the one which produced the peak flow on San Francisquito Creek.



Note that the flow axis is logarithmic.

Balance Hydrologics, Inc.

Figure 6. Unit flow hydrographs for San Francisquito, Los Trancos and Bear Creeks, water year 2004. 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 most cases, this lower flow is probably due to diversions, but is also influenced by geology and topography.

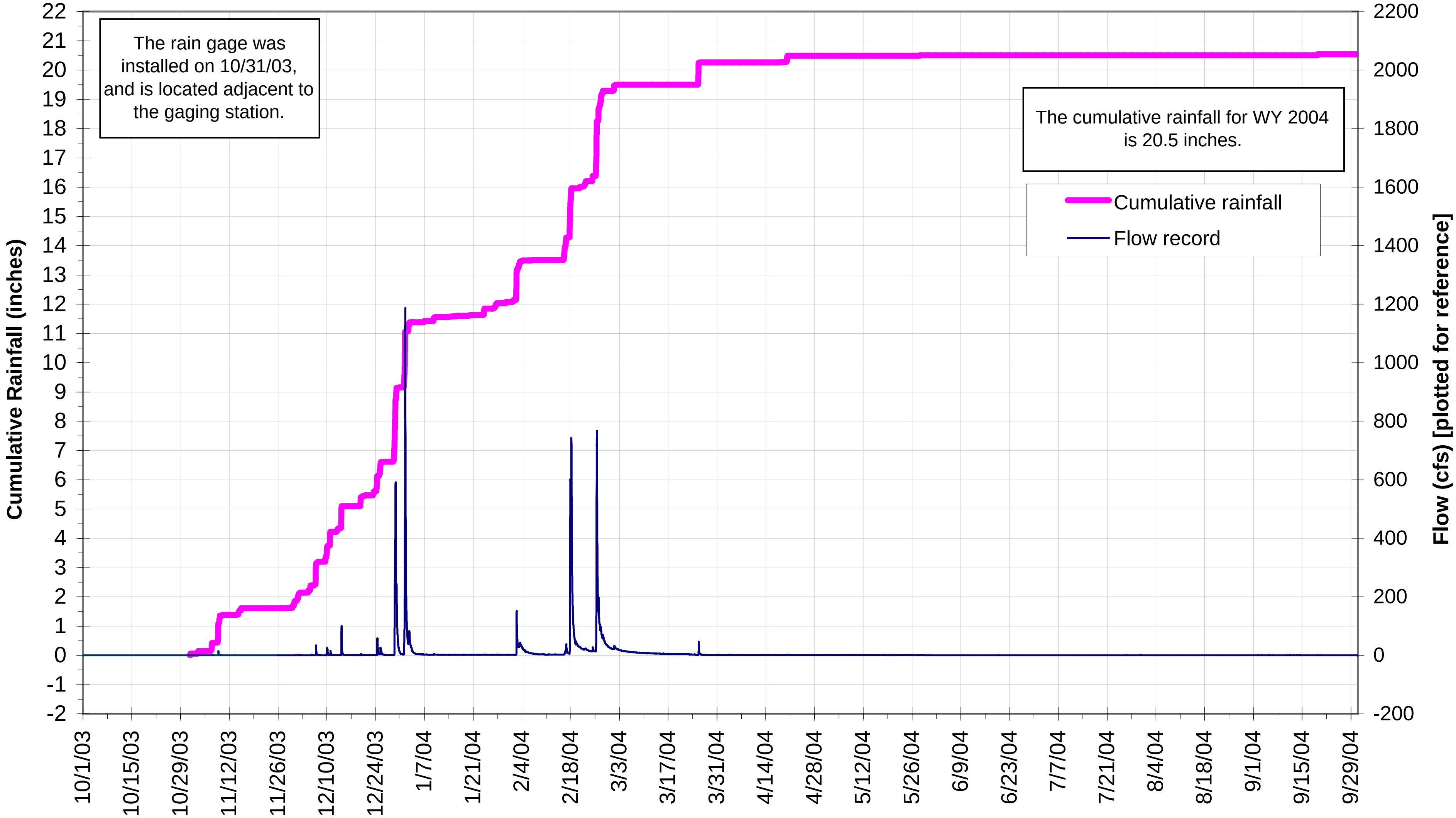


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Figure 7. Cumulative precipitation record, Bear Creek at Sand Hill Road, water year 2004. The long-term mean annual precipitation is approximately 26 inches per year, compared to approximately 20.5 inches of rainfall received during water year 2004.

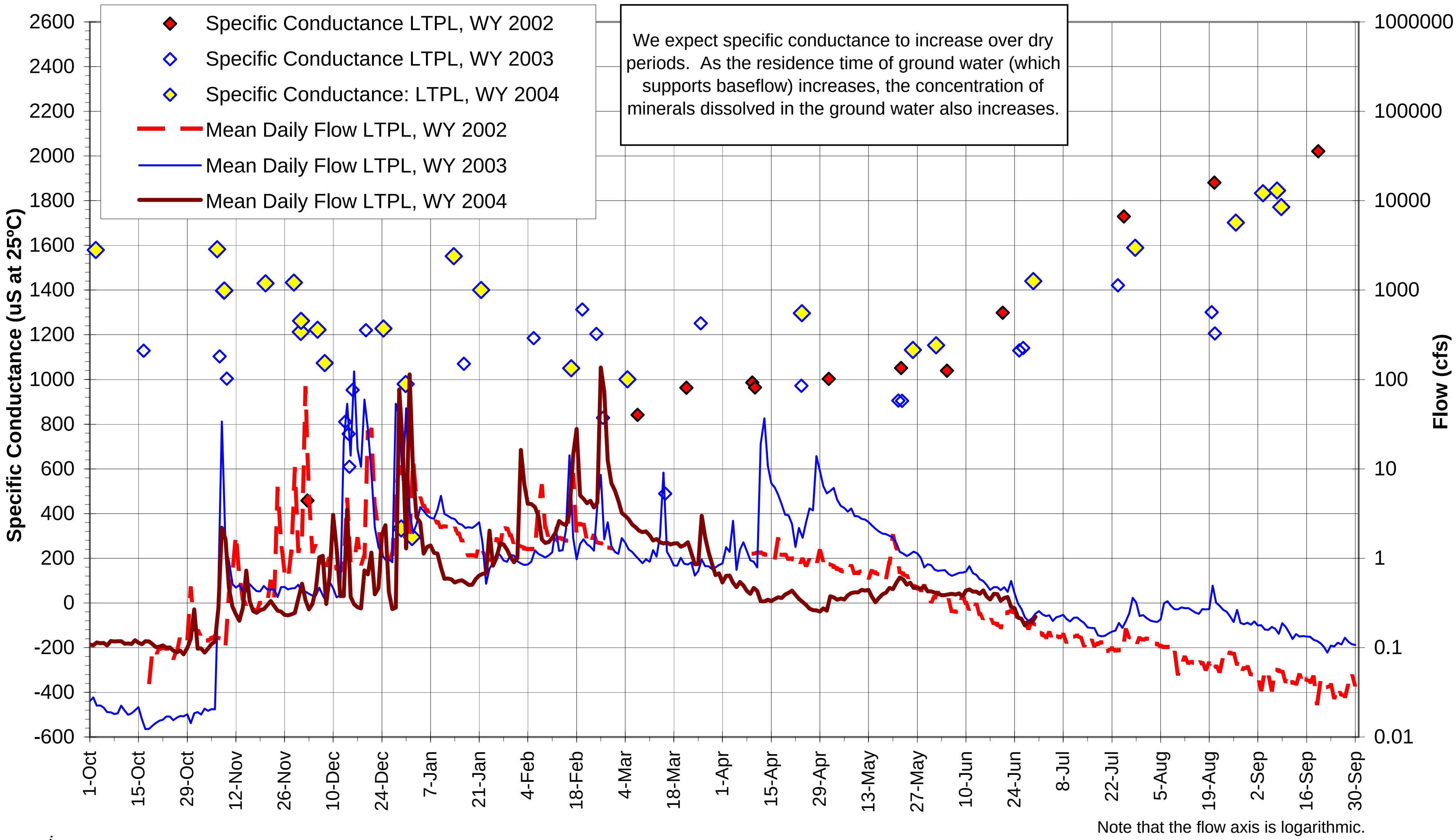

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Figure 8. Specific conductance measurements, Los Trancos Creek at Piers Lane, water years 2002 to 2004. Specific conductance measurements during water year 2004 are higher in Los Trancos Creek than in San Francisquito or Bear Creek. This difference between creeks may be due to geologic influences or human causes.

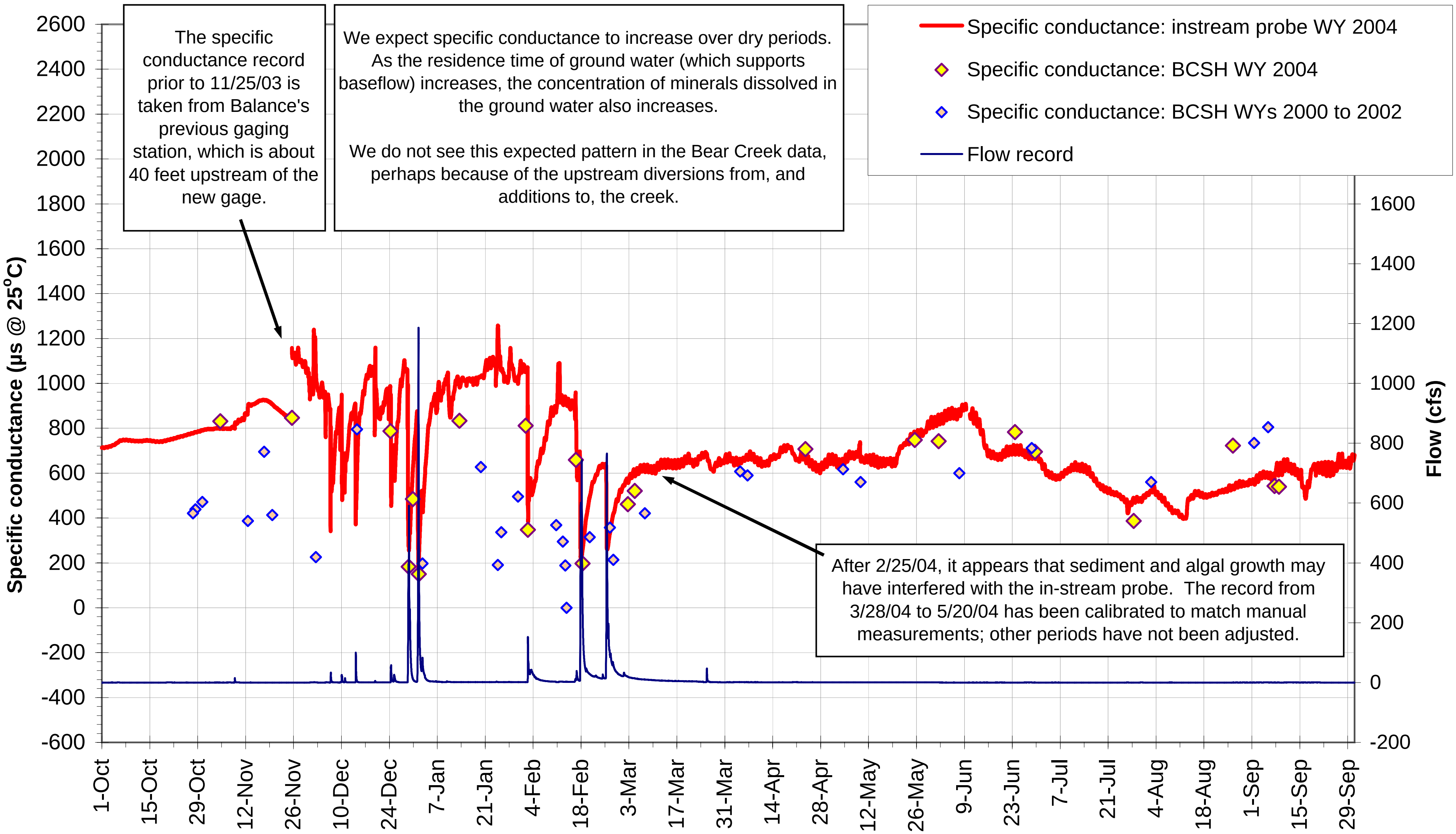

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Figure 9. Specific conductance measurements, Bear Creek at Sand Hill Road, water year 2004. Specific conductance is an index for the amount of dissolved ions in the water. Specific conductance decreases during storms because rainfall contains fewer dissolved ions than ground water, which has more contact with weathered rocks and soil.

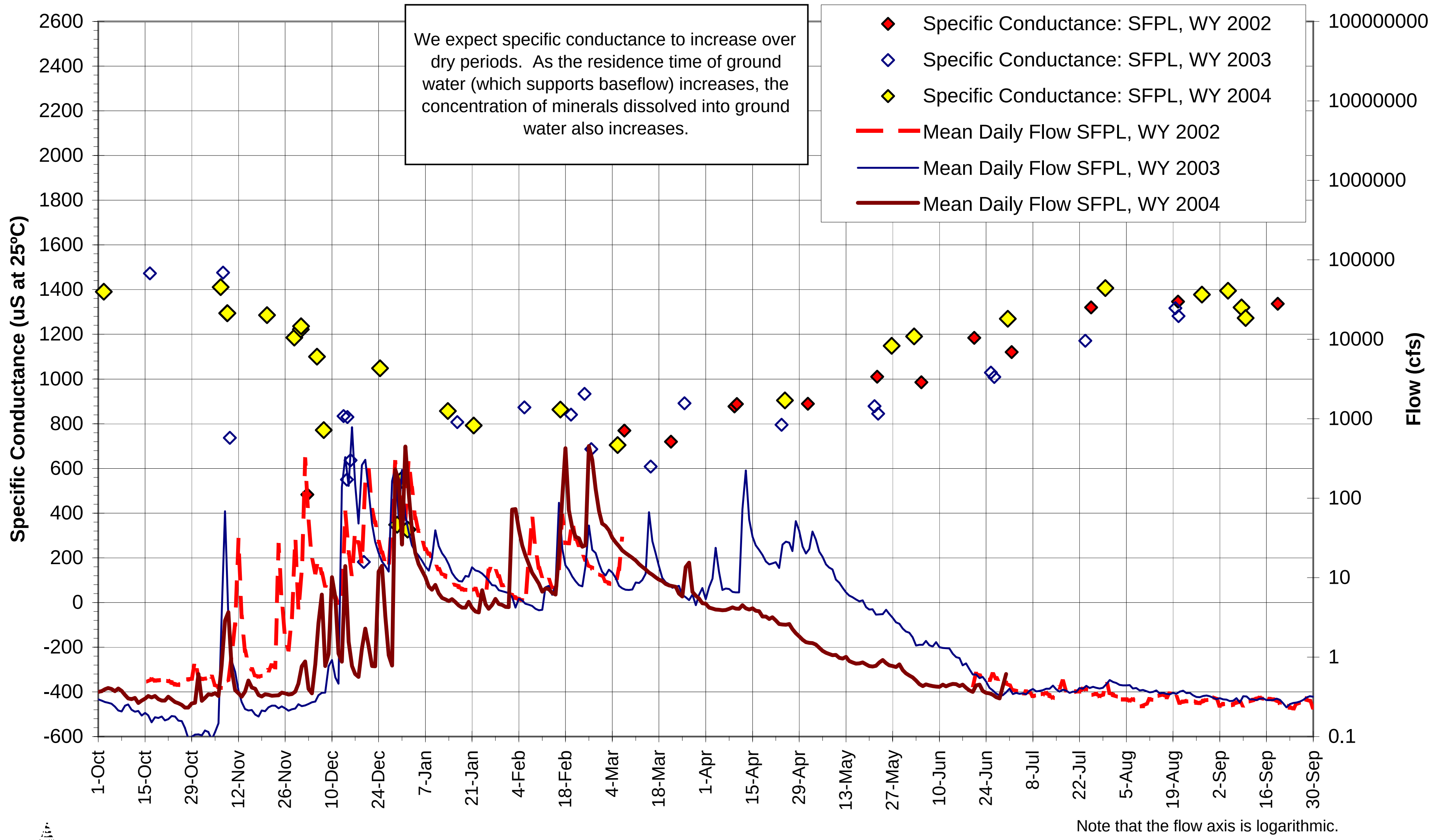

Figure 10. Specific conductance measurements, San Francisquito Creek at Piers Lane, water years 2002 to 2004. Flow records are plotted for reference. Specific conductance measurements are generally similar for all three years.

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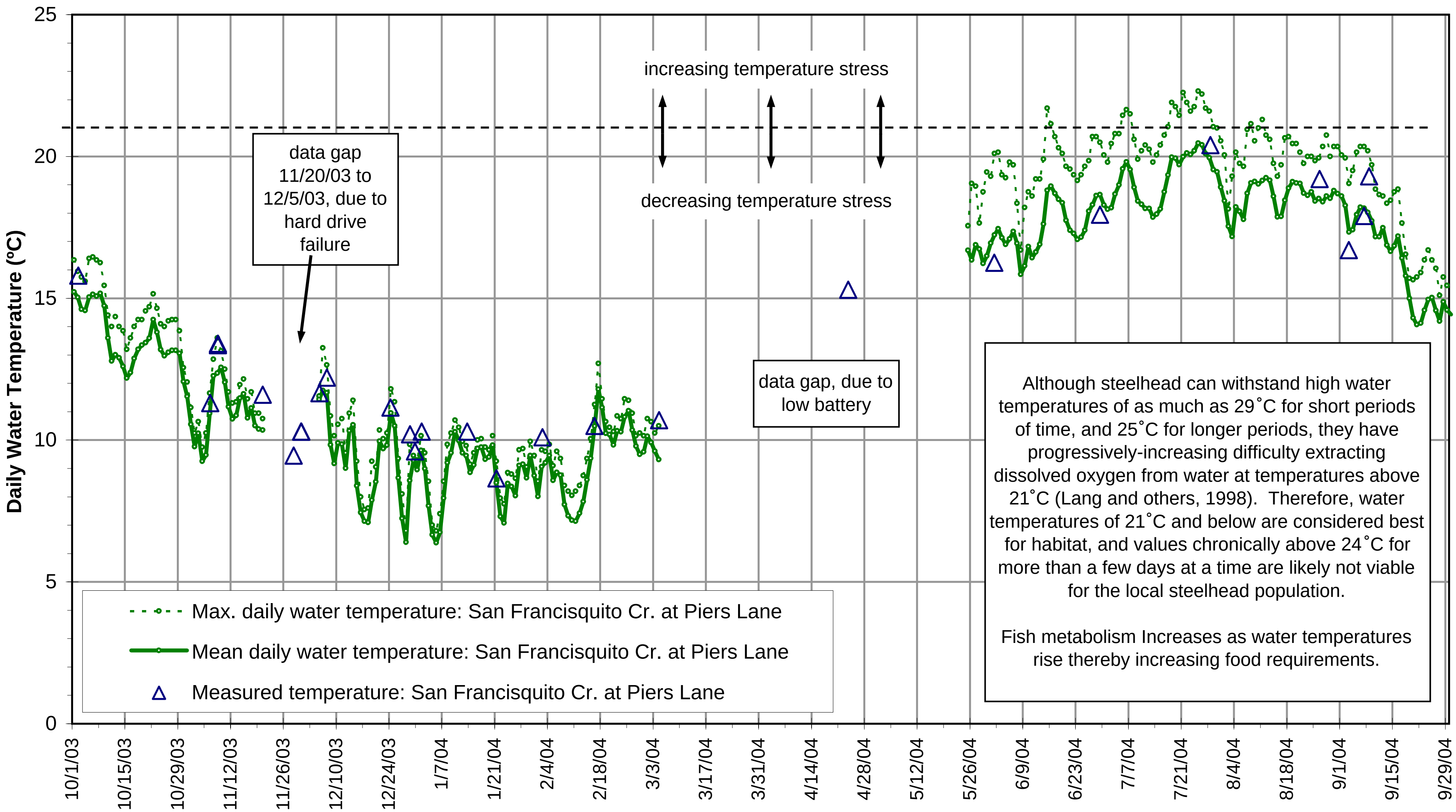
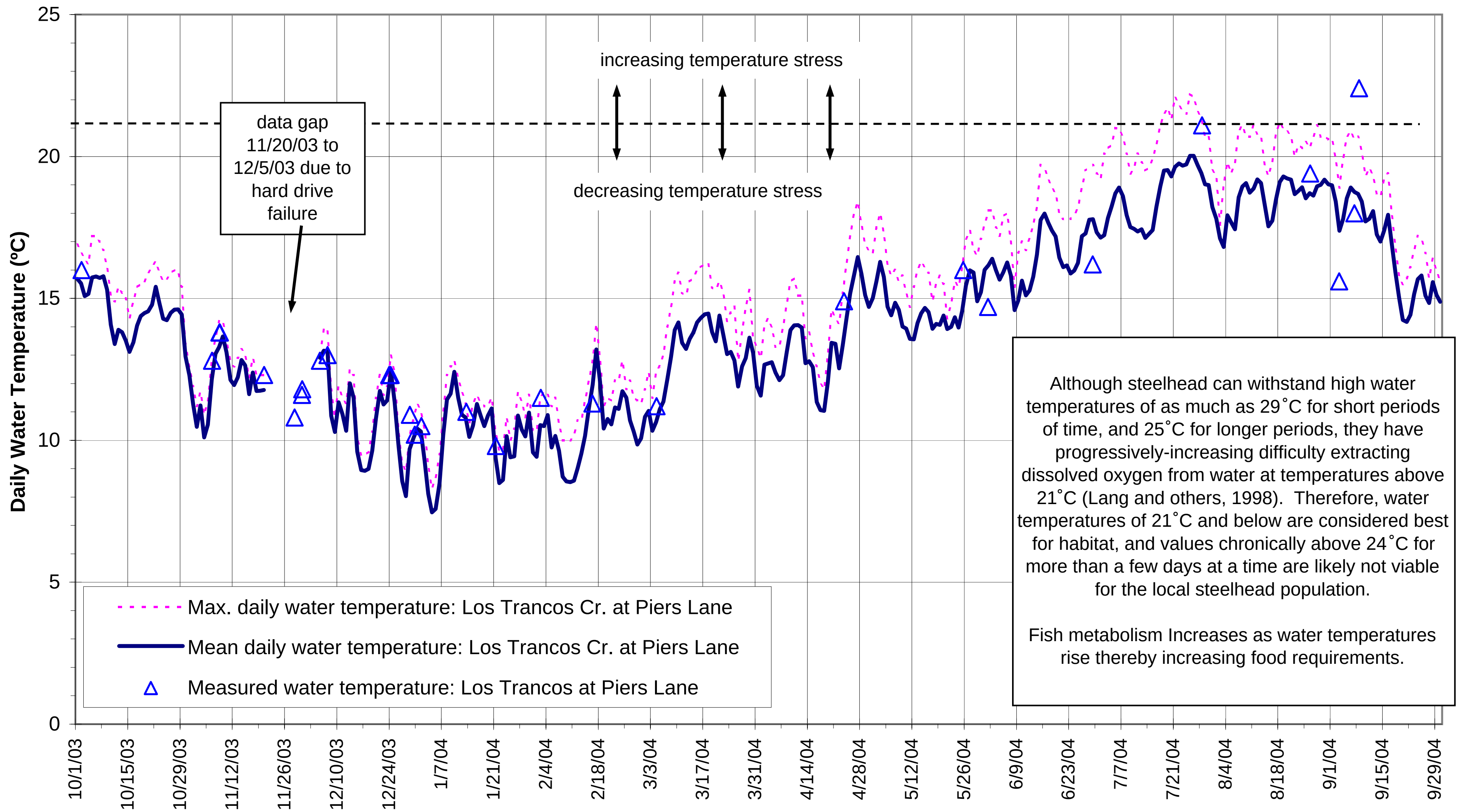


Balance Hydrologics, Inc.

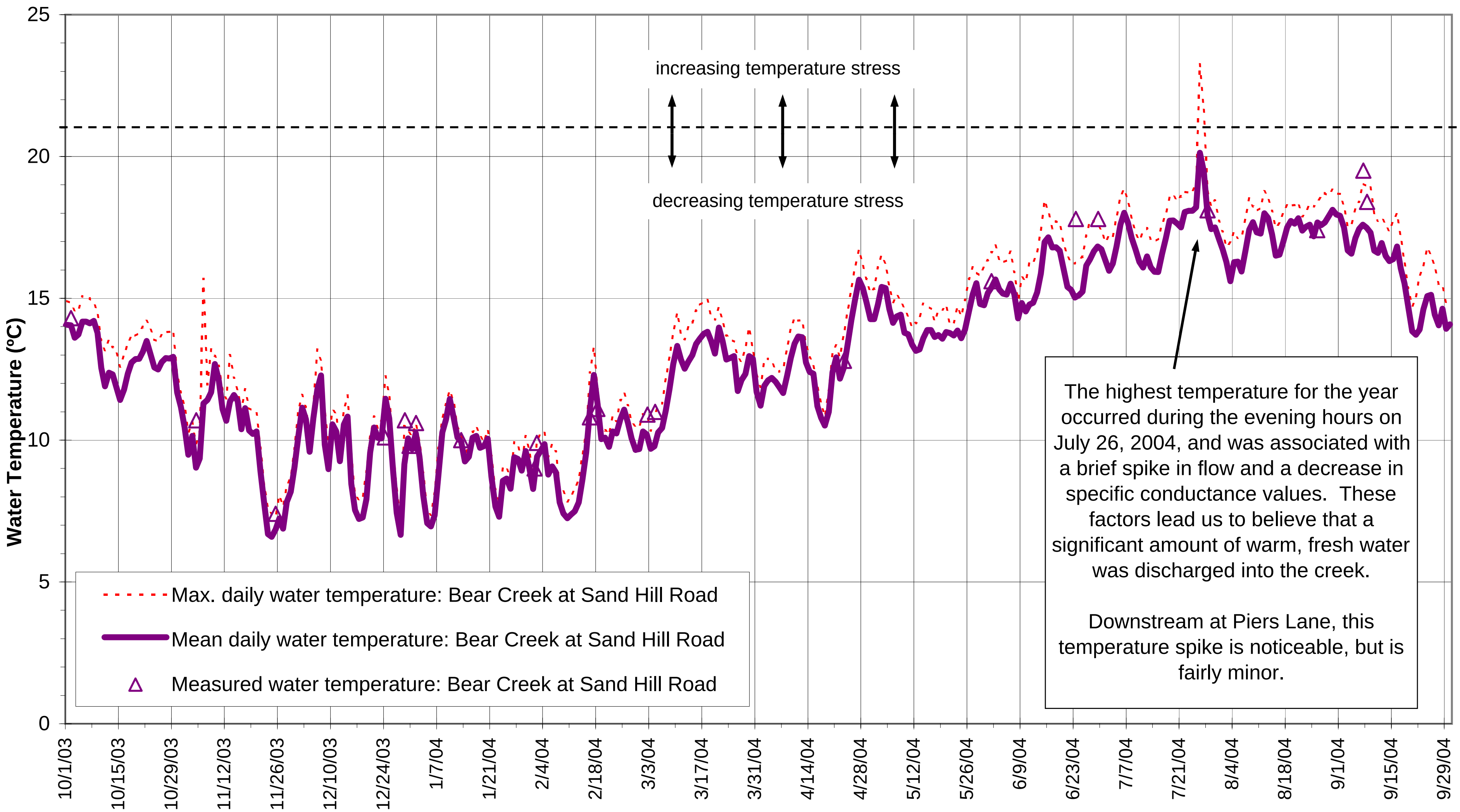
Figure 11. Daily water temperature record for San Francisquito Creek at Piers Lane, water year 2004. Temperature patterns are similar at the San Francisquito Creek and Los Trancos Creek stations. Water temperatures seem to be slightly cooler in San Francisquito Creek than in Los Trancos Creek during the winter months and warmer during the summer.



Balance Hydrologics, Inc.

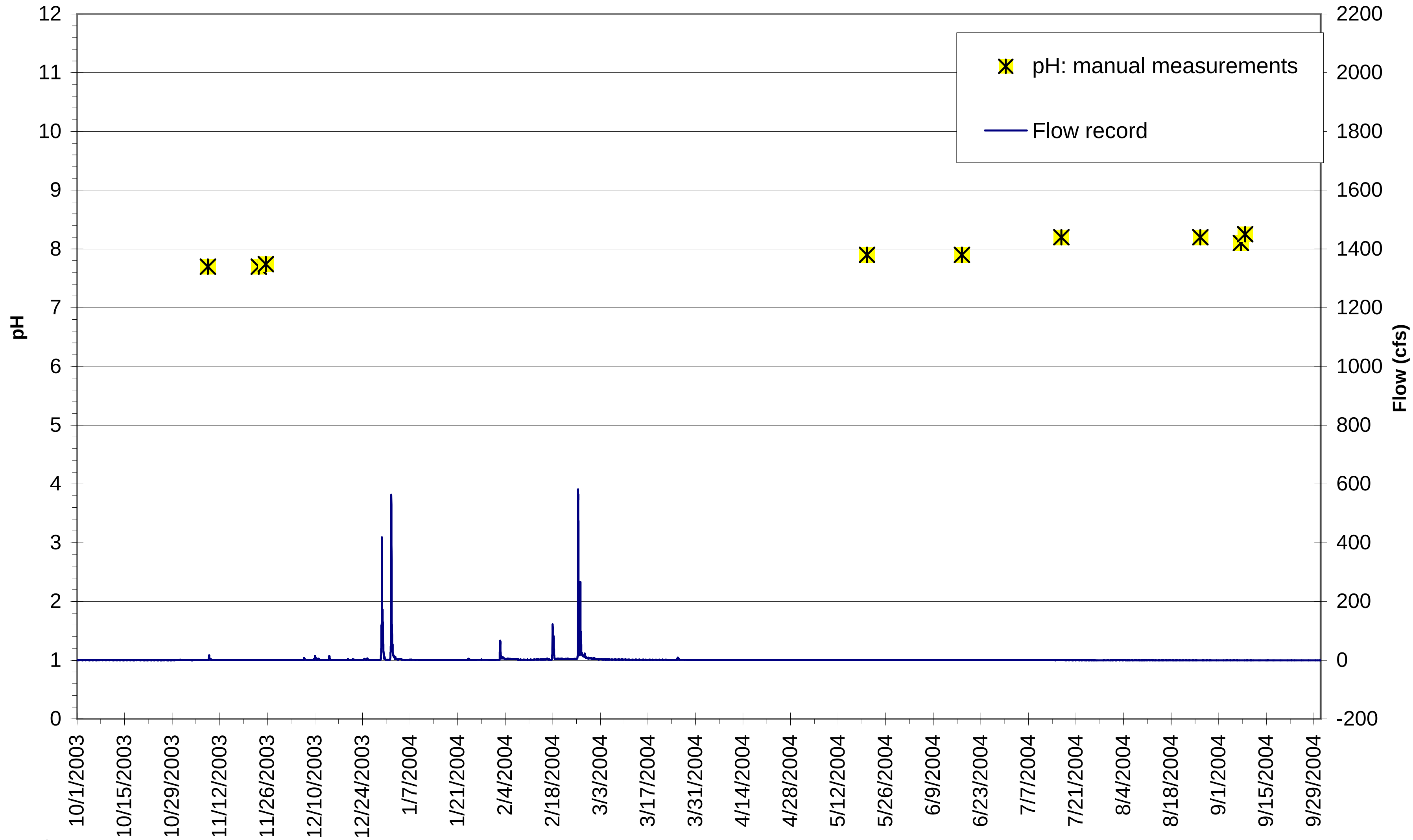
Figure 12. Daily water temperature record for Los Trancos Creek at Piers Lane, water year 2004. Temperature patterns are similar at the San Francisquito Creek and Los Trancos Creek stations. Water temperature seems to be slightly warmer in Los Trancos Creek than in San Francisquito Creek during winter months and cooler during the summer.

Piers Lane_2004_DAILY_SUM.xls



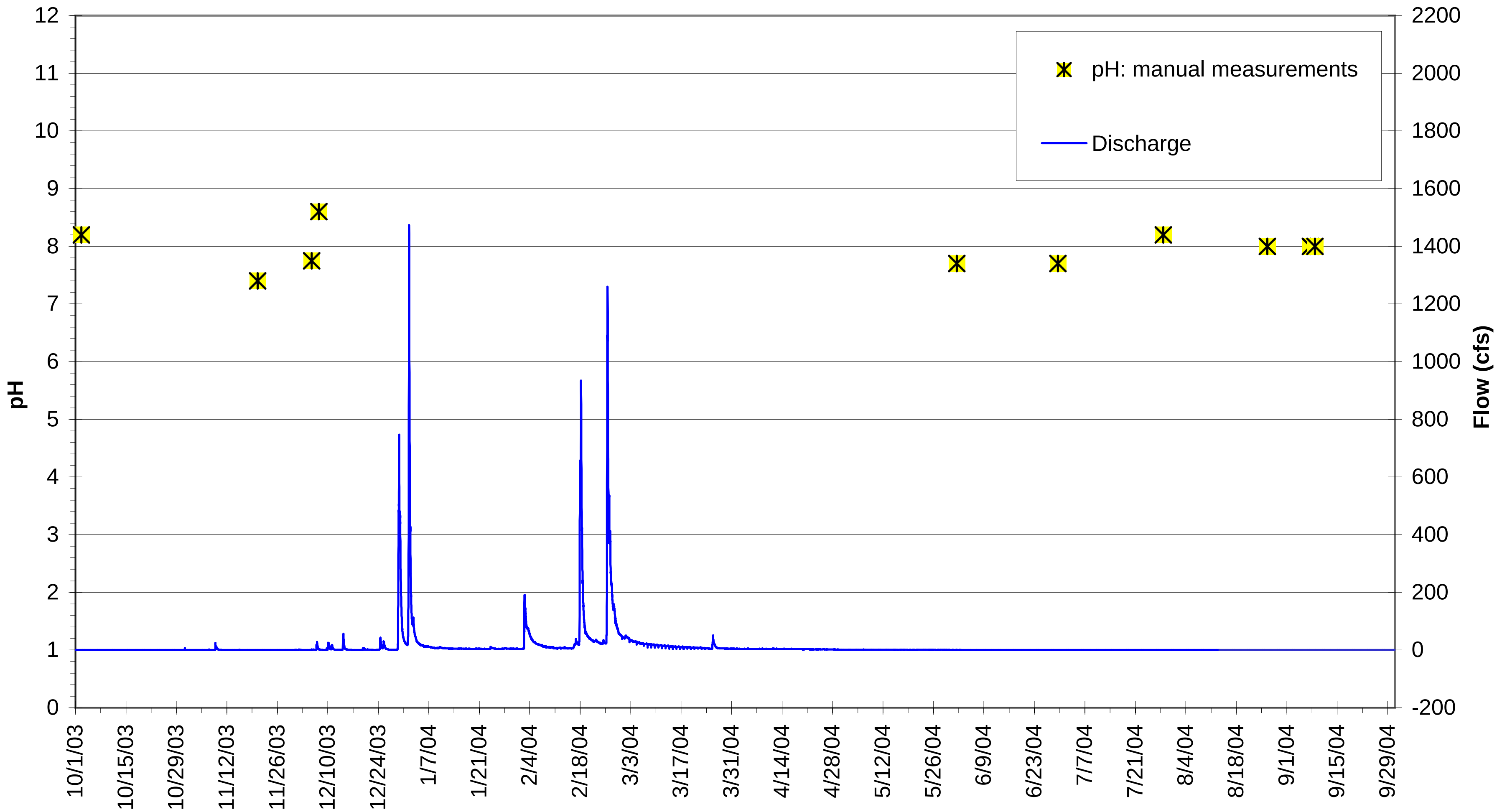
Balance Hydrologics, Inc.

Figure 13. Daily water temperature record for Bear Creek at Sand Hill Road, water year 2004. Generally, water temperatures were well within the healthy range for steelhead, except for one episode of possible discharge into the creek in July. The temperature in Bear Creek is usually cooler than San Francisquito or Los Trancos Creeks during the warm periods of the water year.



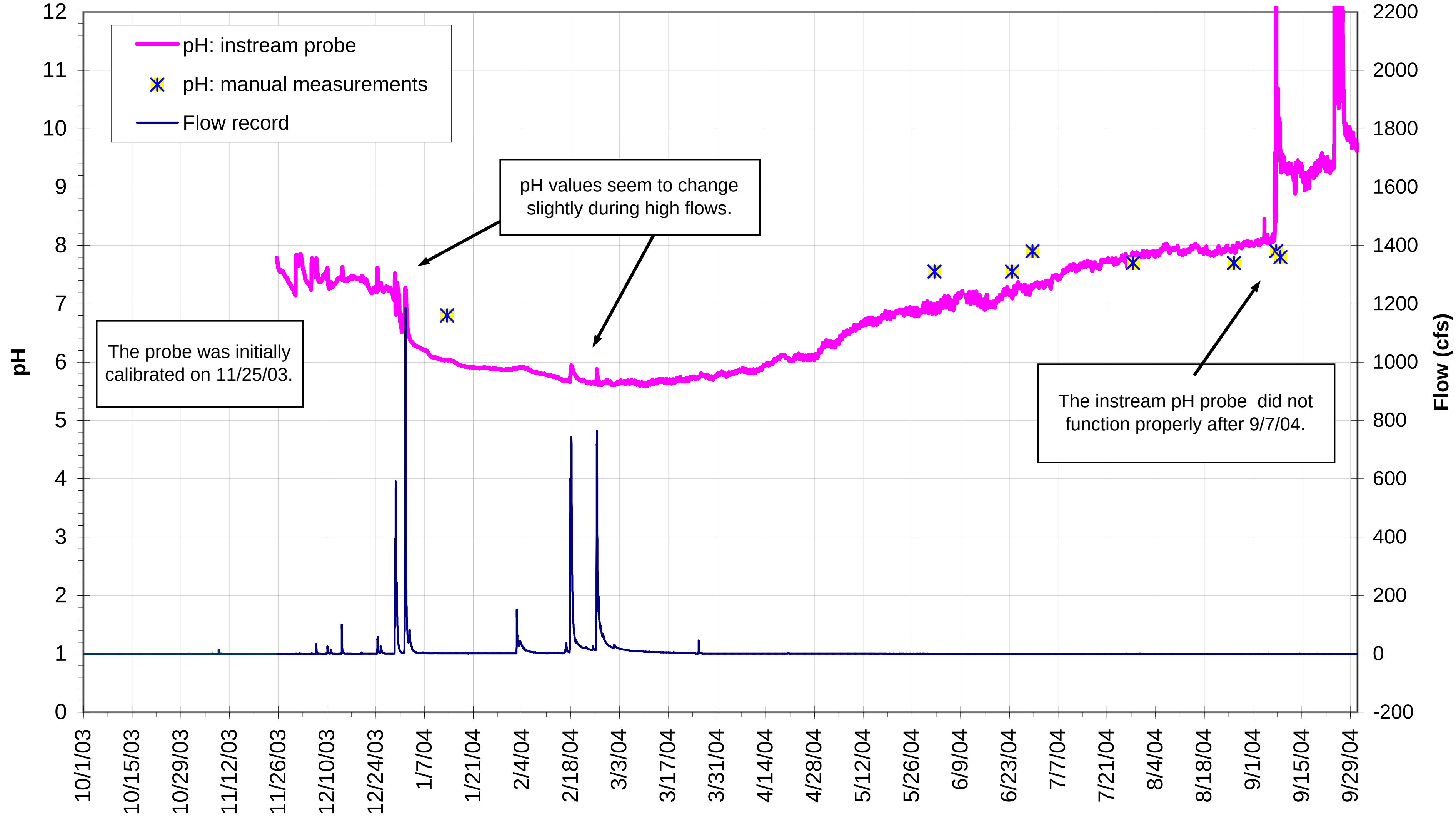
Balance Hydrologics, Inc.

Figure 14. pH record for Los Trancos Creek at Piers Lane, water year 2004.
Only manual measurements are shown because the in-stream probe did not function properly.



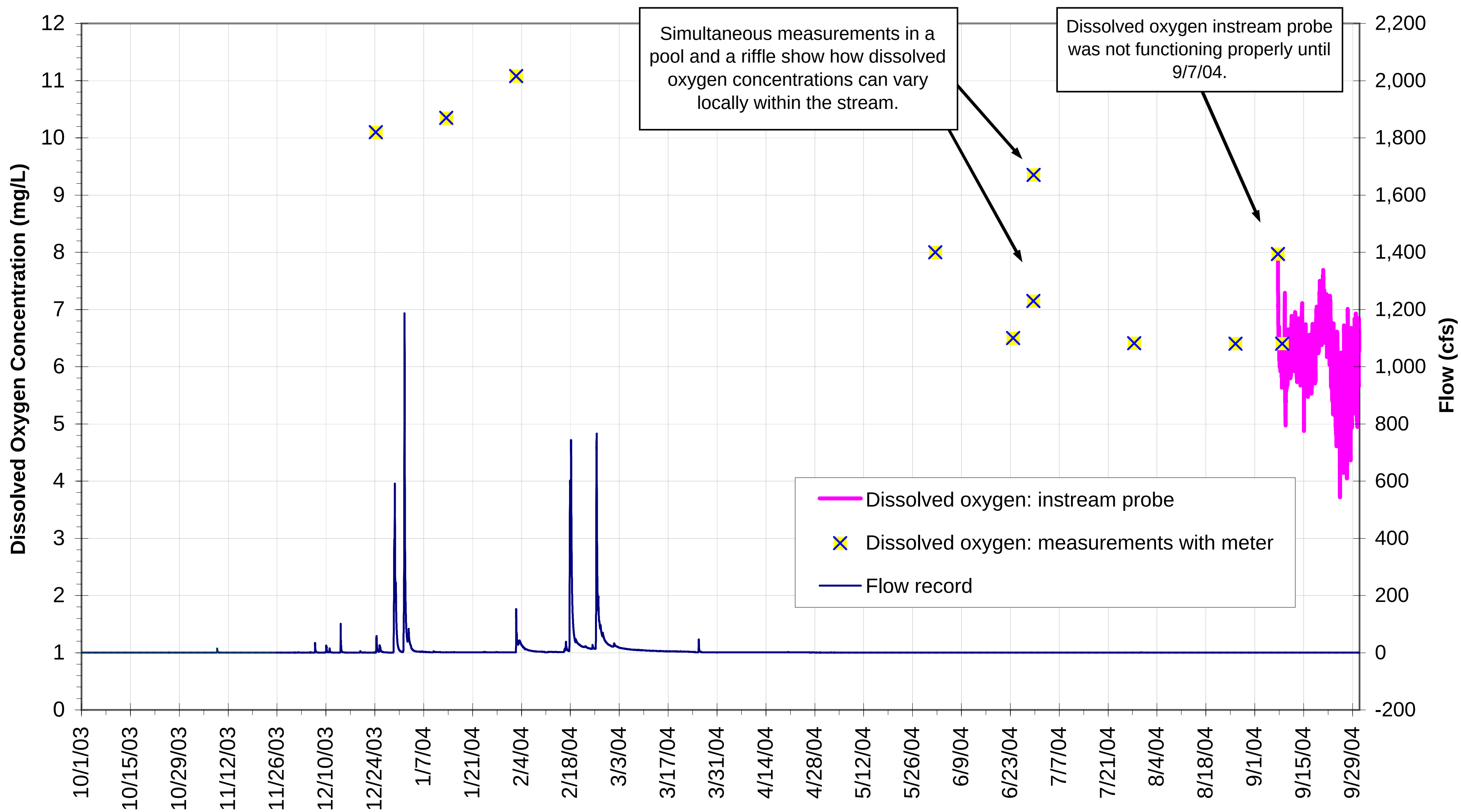
Balance Hydrologics, Inc.

Figure 15. pH record for San Francisquito Creek at Piers Lane, water year 2004.
Only manual measurements are shown because the in-stream probe did not function properly.



Balance Hydrologics, Inc.

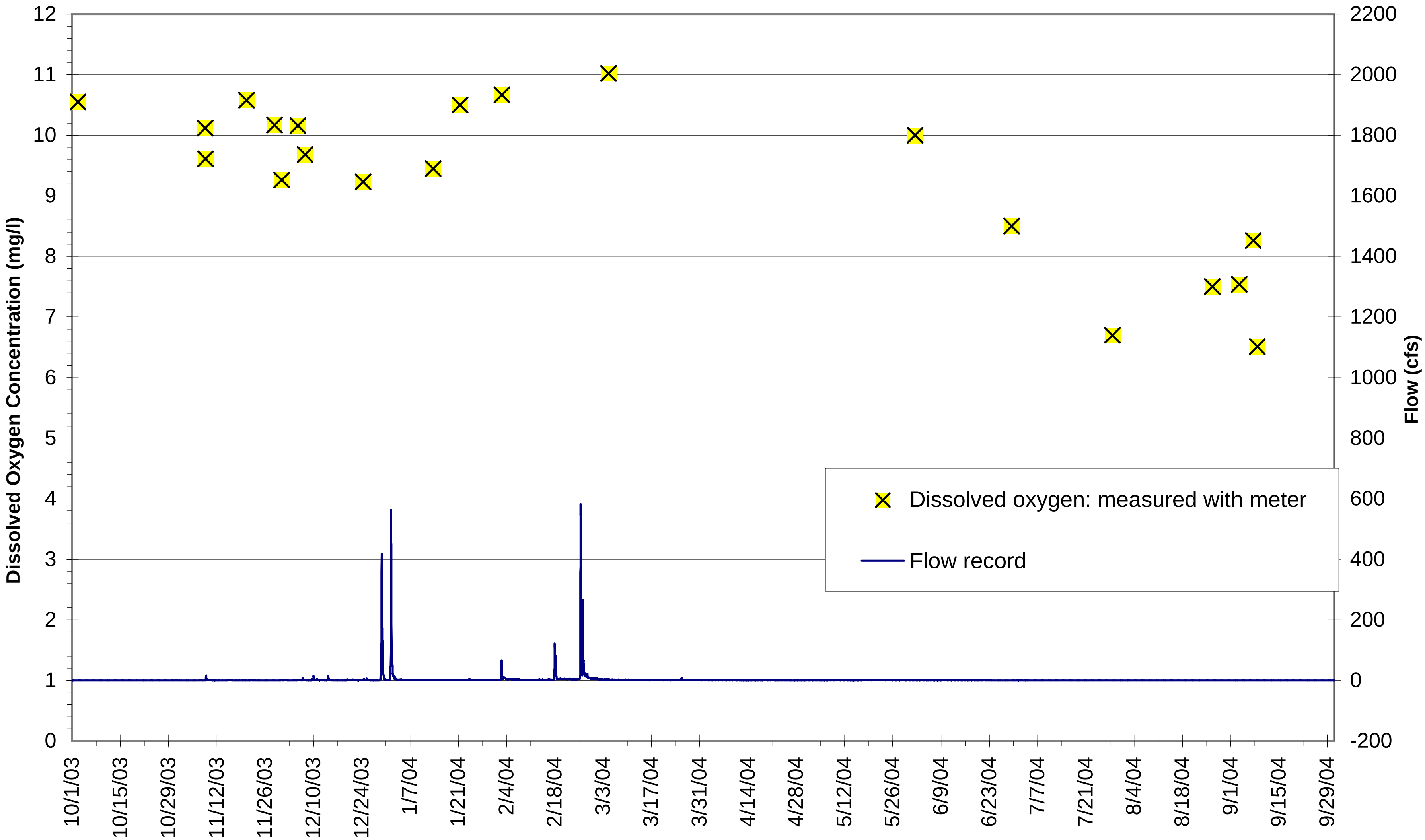
Figure 16. pH record for Bear Creek at Sand Hill Road, water year 2004. The record from the instream probe does not seem to be reliable, based on the unlikely low values during February and March. Manual measurements with a handheld meter and/or pH strips are more reliable and are useful for checking the electronic record.



Balance Hydrologics, Inc.

Figure 17. Dissolved oxygen concentrations in Bear Creek at Sand Hill Road, water year 2004. Only a portion of the electronic record for the instream probe is shown. The instream probe needs to be cleaned regularly, and thus did not function well until the end of the water year. Field measurements with a dissolved oxygen meter are the main source of record for the year.

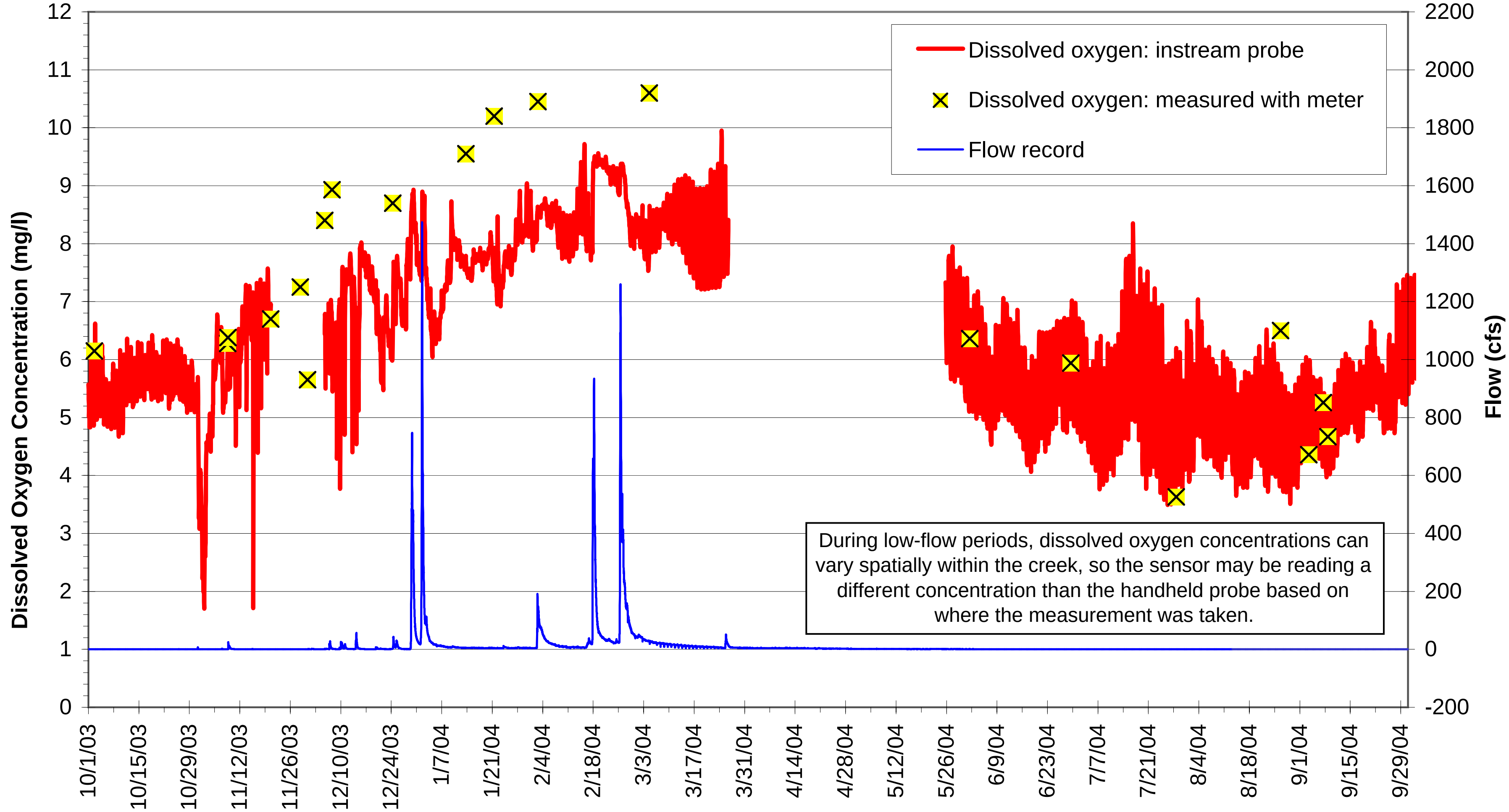
WY2004_BearCr_new_new.xls, DO



Balance Hydrologics, Inc.

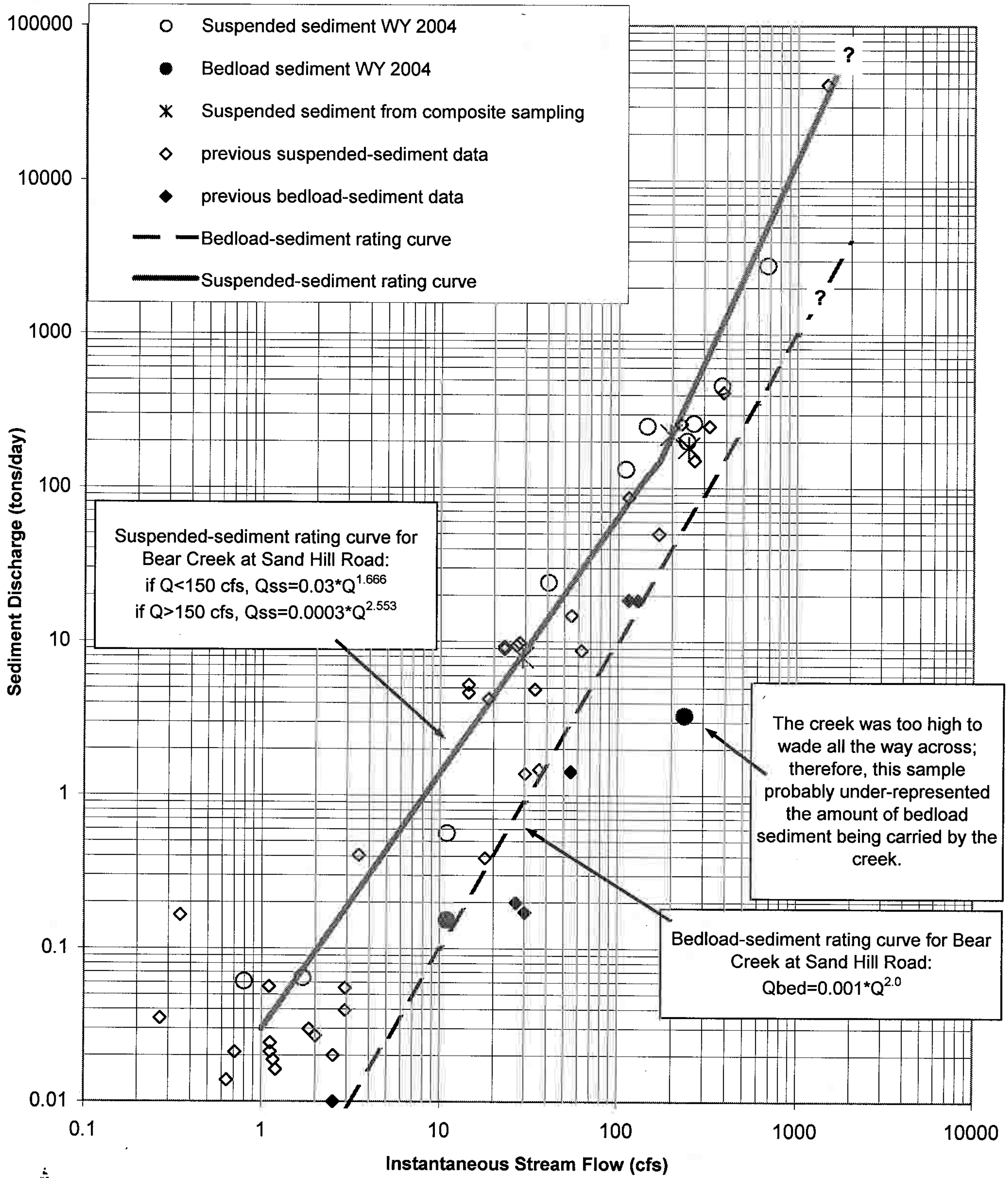
Figure 18. Dissolved oxygen concentrations in Los Trancos Creek at Piers Lane, water year 2004. Only manual measurements are shown because the instream did not function properly. Dissolved oxygen concentrations are lower during late summer and early fall when water temperatures are higher, stream turbulence is lower, and more decomposing leaves are in the creek.

WY04_LTPL15min.xls, hour DO



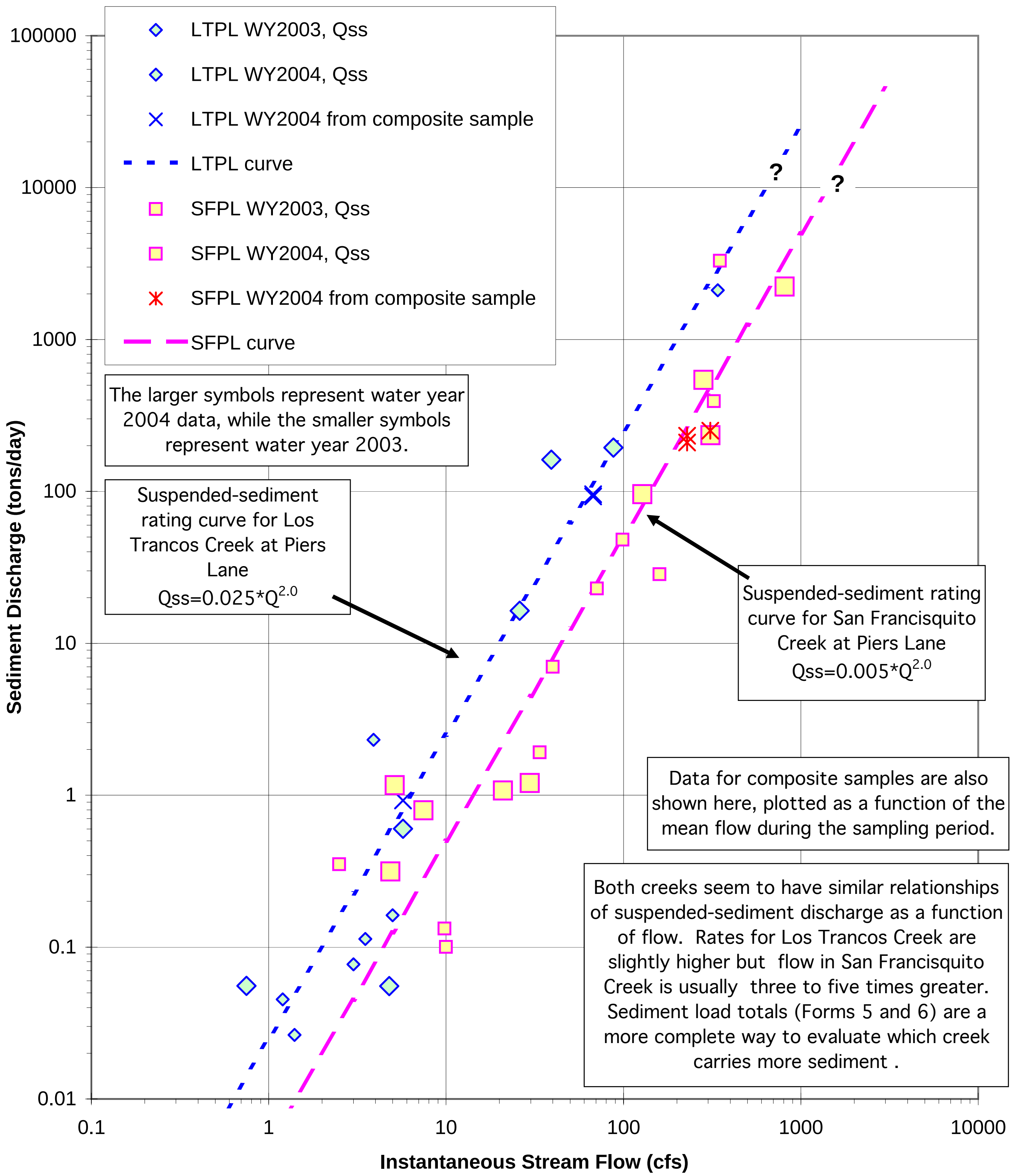
Balance Hydrologics, Inc.

Figure 19. Dissolved oxygen concentrations in San Francisquito Creek at Piers Lane, water year 2004. Dissolved oxygen values recorded by the in-stream probe seem to match measured values fairly well, except during winter, when high saturation is typical. Dissolved oxygen concentrations are lower during late summer and early fall when water temperatures are higher, stream turbulence is lower, and more decomposing leaves are in the creek.



Balance Hydrologics, Inc.

Figure 20. Sediment measurements and rating curves for Bear Creek at Sand Hill Road, water years 1998-2004. Measurements from water year 2004 are similar to those from previous years.



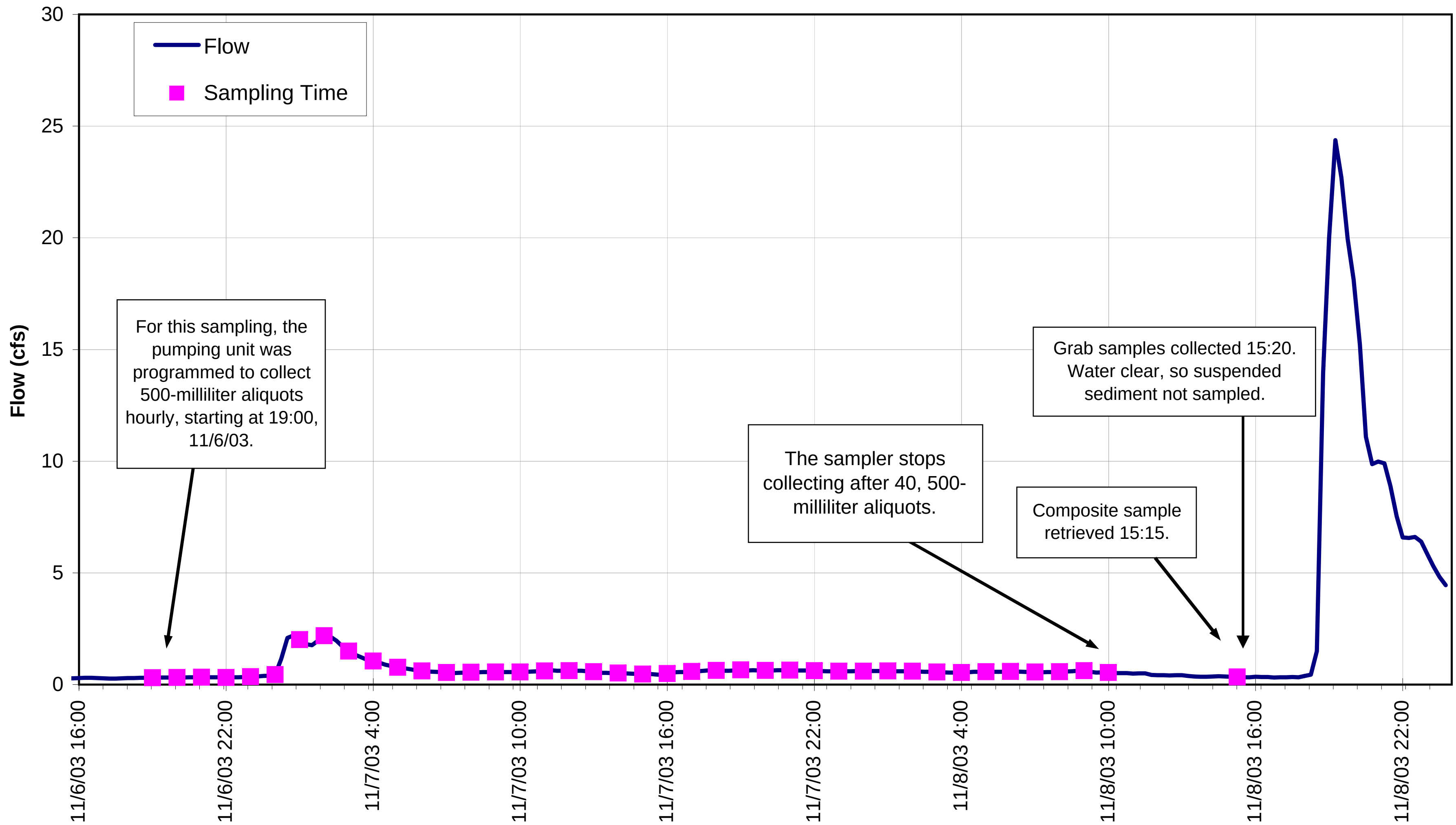
Balance Hydrologics, Inc.

Figure 21. Suspended-sediment measurements and rating curves for the Piers Lane stations. The rating curves have been revised since water year 2003 based on the addition of water year 2004 data points (larger symbols).

APPENDICES

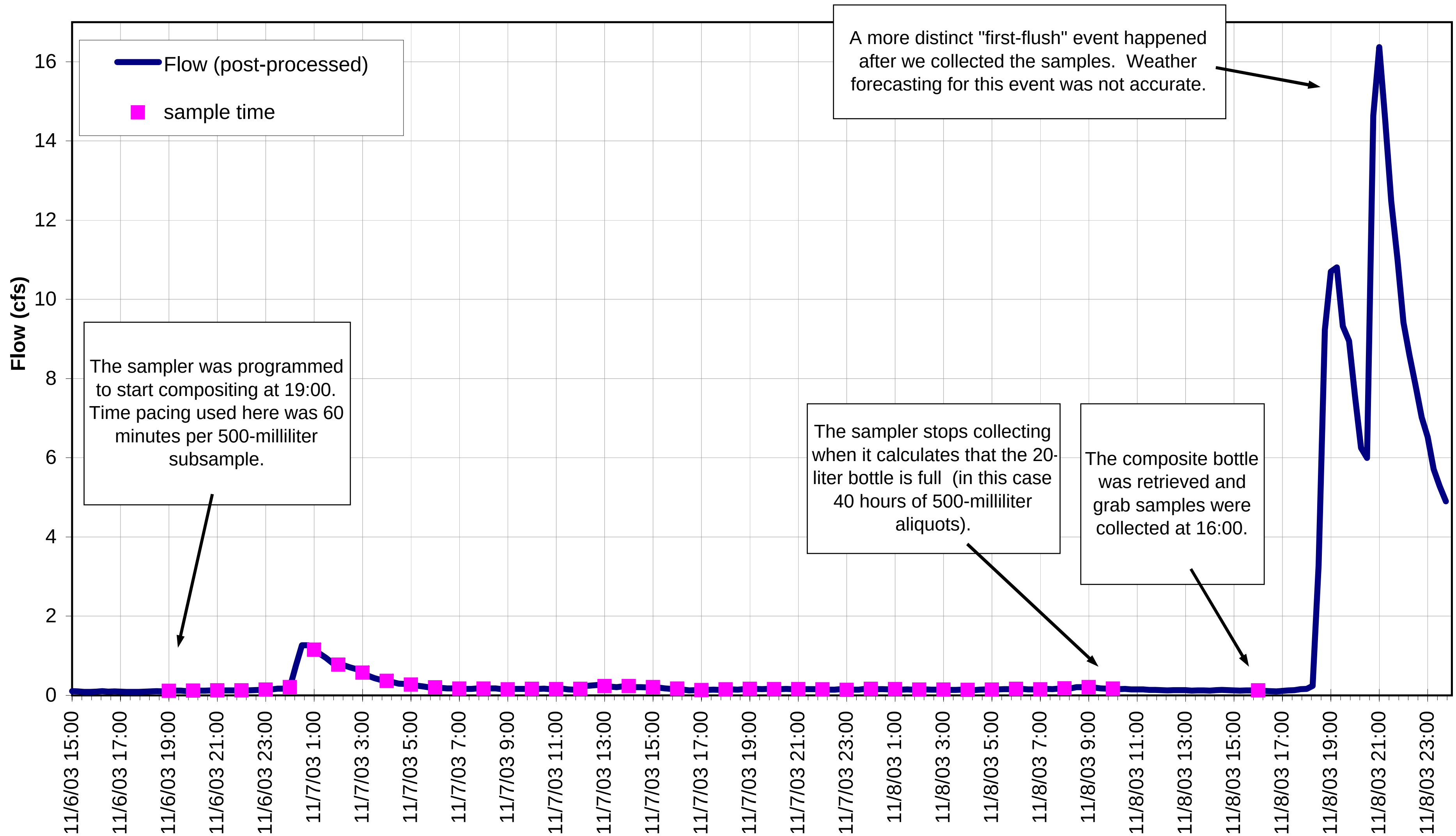
APPENDIX C

Detailed hydrographs of wet-season periods during which composite samples were collected



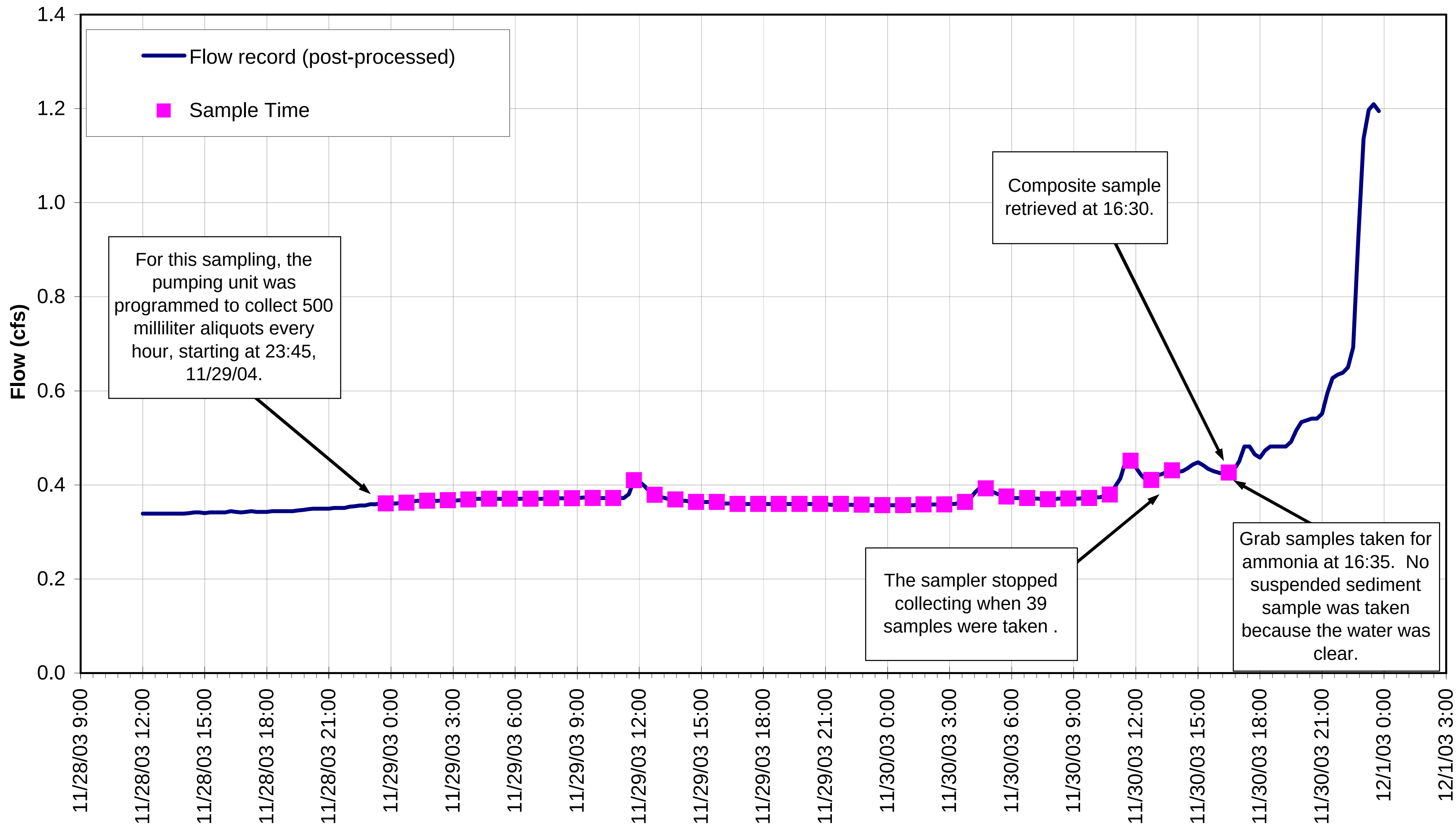
Balance Hydrologics, Inc.

Figure C1. Water-quality sampling detailed hydrograph, November 6 to 8, 2003, San Francisquito Creek at Piers Lane. This sampling was intended to capture the first-flush flows and was time paced. Peak rainfall arrived later than forecast causing us to collect a very small first flush before the onset of a larger and more distinct event.



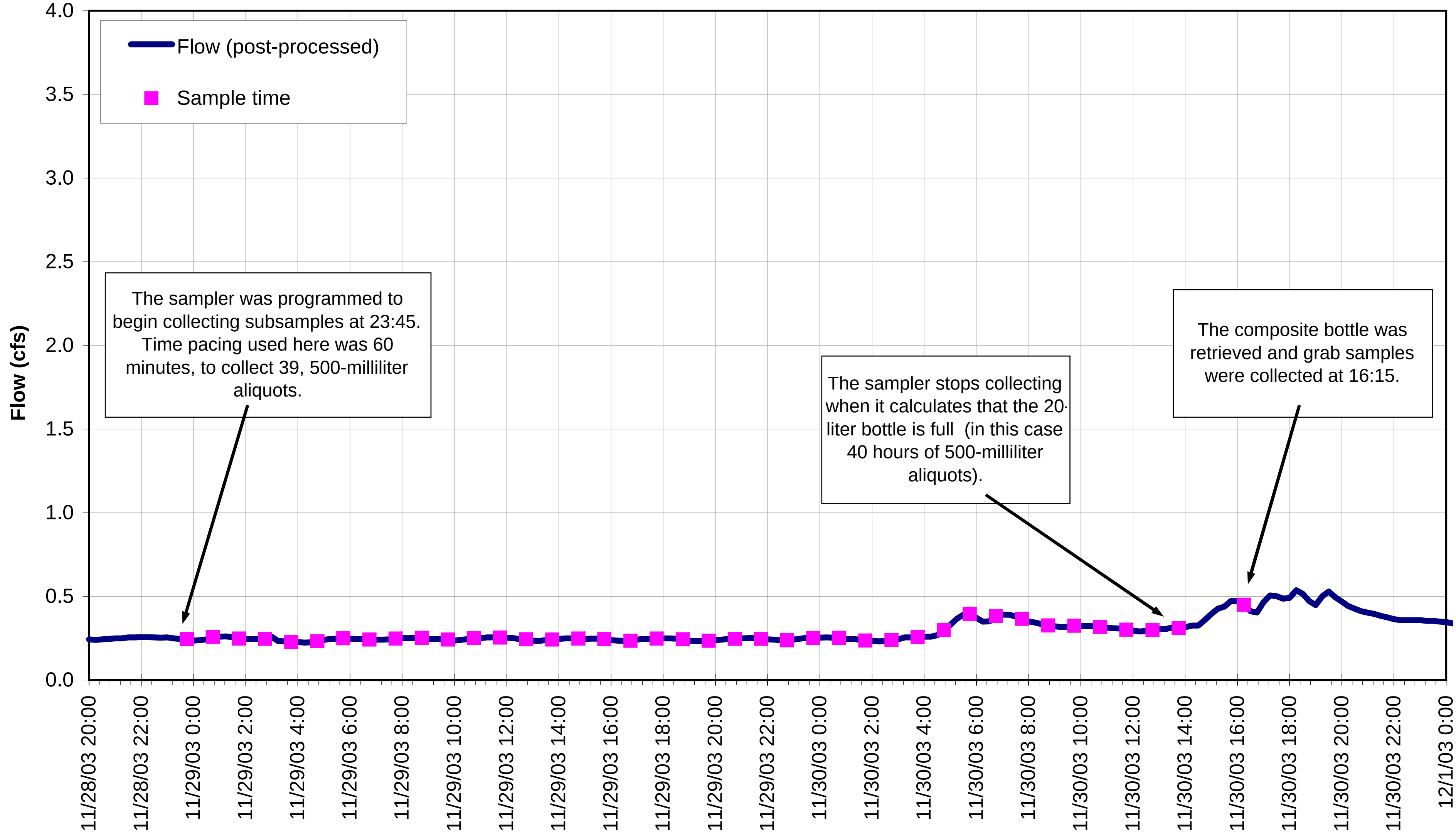
Balance Hydrologics, Inc.

Figure C2. Water-quality sampling detailed hydrograph, Nov. 6 to 8, 2003, Los Trancos Creek at Piers Lane. This sampling was intended to capture the first-flush flows and was time paced. Peak rainfall arrived later than originally forecast causing us to collect a very small first flush before the onset of a larger and more distinct event.



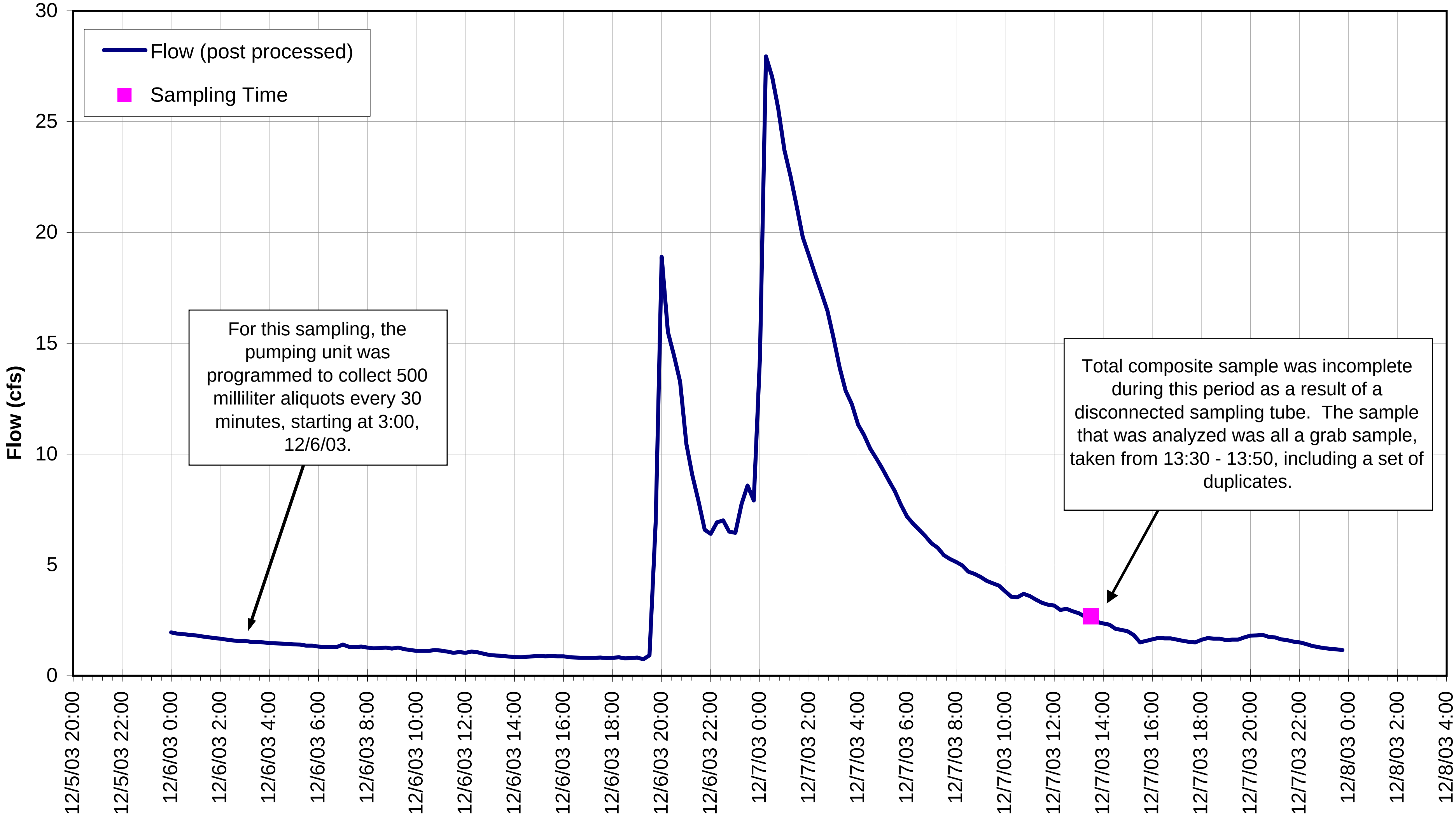
Balance Hydrologics, Inc.

Figure C3. Water-quality sampling detailed hydrograph, November 29 to 30, 2003, San Francisquito Creek at Piers Lane. This sampling was a second attempt to capture first-flush flows and was time-paced. The rainfall was lighter than predicted by the forecast and sampling was not as successful as we had intended.



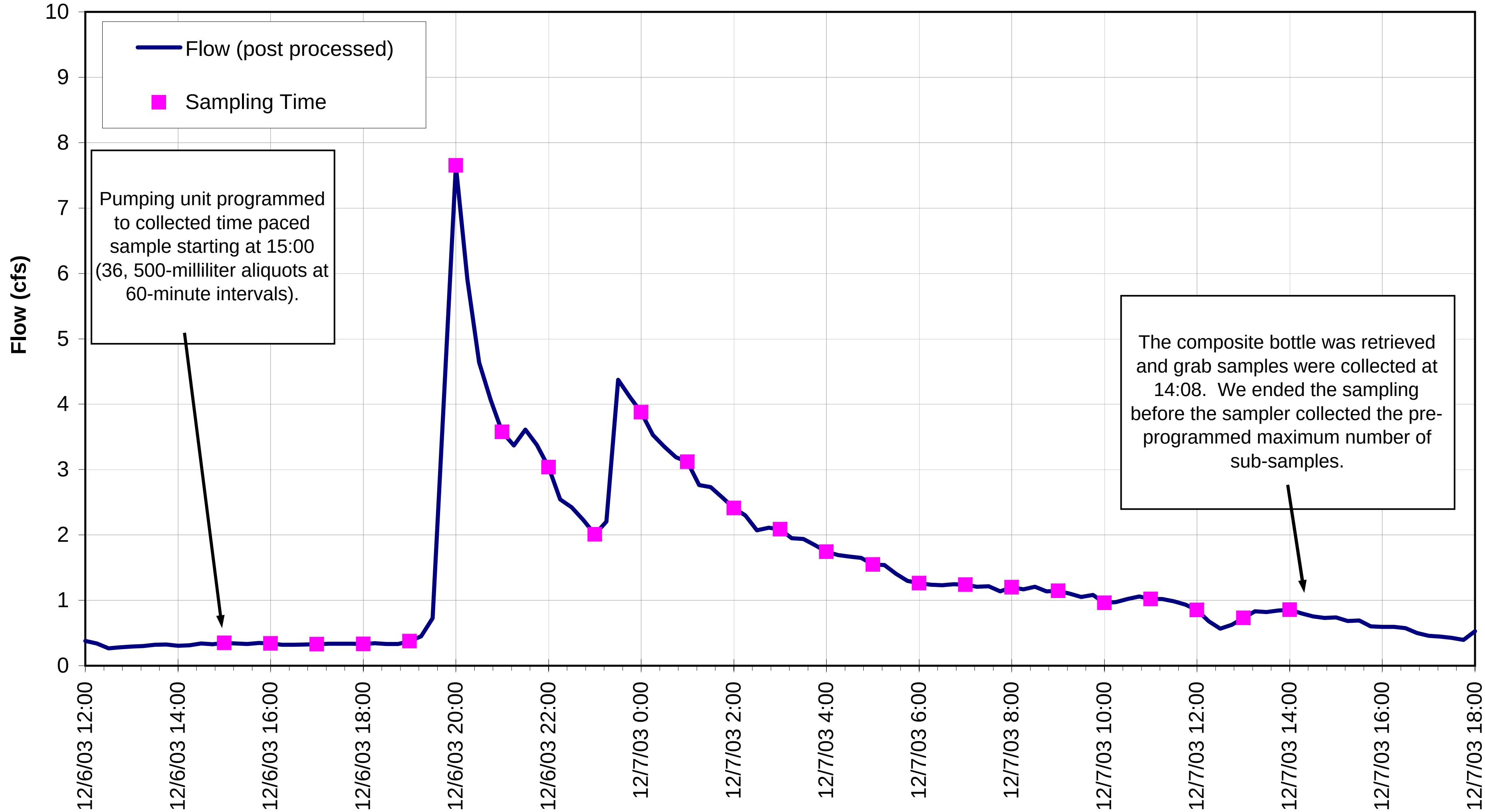
Balance Hydrologics, Inc.

Figure C4. Water-quality sampling detailed hydrograph, Nov. 29 to 30, 2003, Los Trancos Creek at Piers Lane. This sampling was a second attempt to capture first-flush flows and was time-paced. The rainfall was lighter than predicted by the forecast and sampling was not as successful as we had intended.



Balance Hydrologics, Inc.

Figure C5. Water-quality sampling detailed hydrograph, December 6 to 7, 2003, San Francisquito Creek at Piers Lane. This sampling was a third attempt to capture first-flush flows and was time-paced. Our sampling program was well-timed for this storm but the sampler tubing became detached early in the event and insufficient sample was collected for analysis. Instead, we collected a grab sample the following day and submitted it for analysis.



Balance Hydrologics, Inc.

Figure C6. Water-quality sampling detailed hydrograph, December 6 to 7, 2003, Los Trancos Creek at Piers Lane. This sampling was a third attempt to capture first-flush flows and was time-paced.

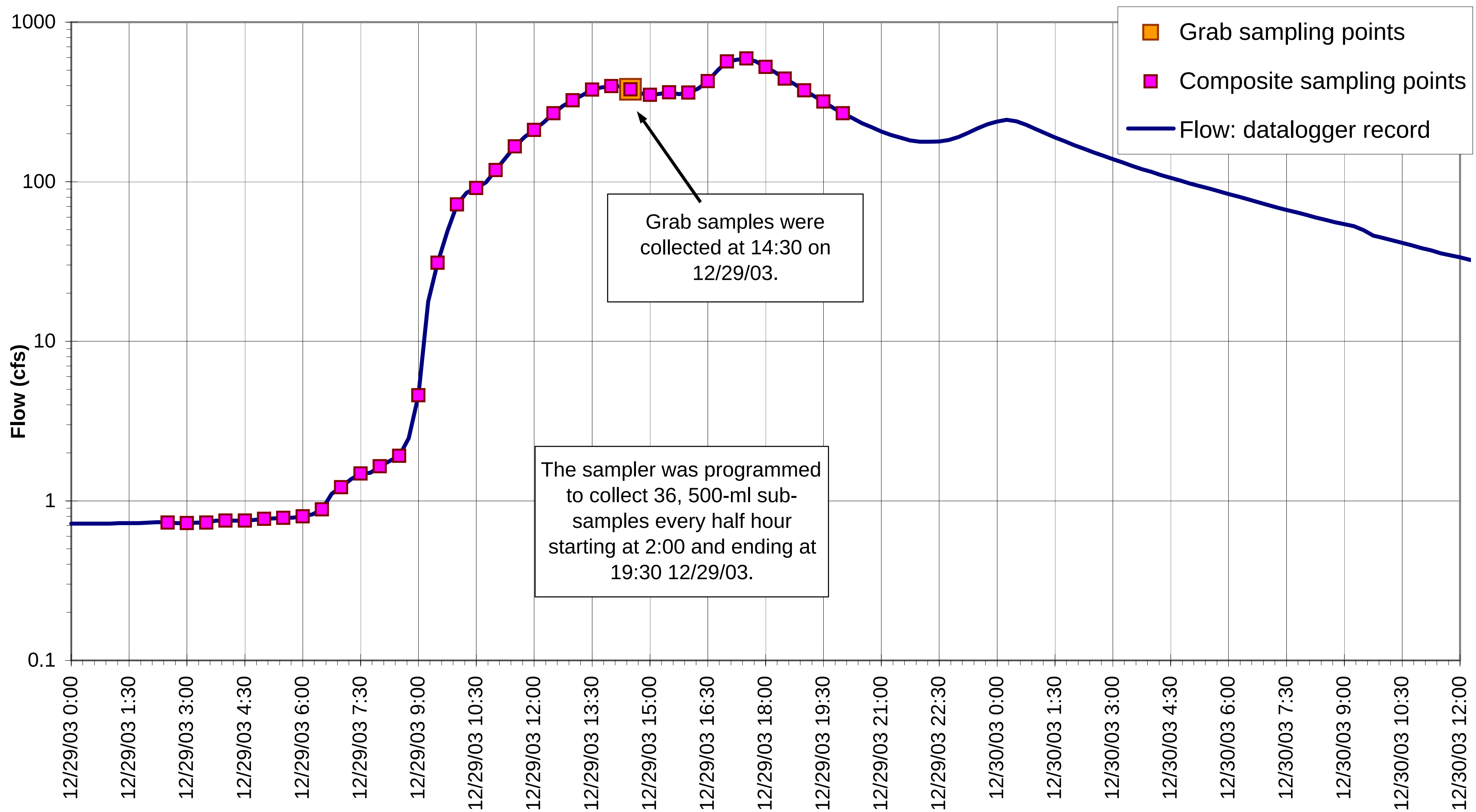


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Figure C7. Water-quality sampling detailed hydrograph, December 29, 2003, Bear Creek at Sand Hill Road. This sampling was intended to capture runoff from a large winter storm. The sampling was time-paced.

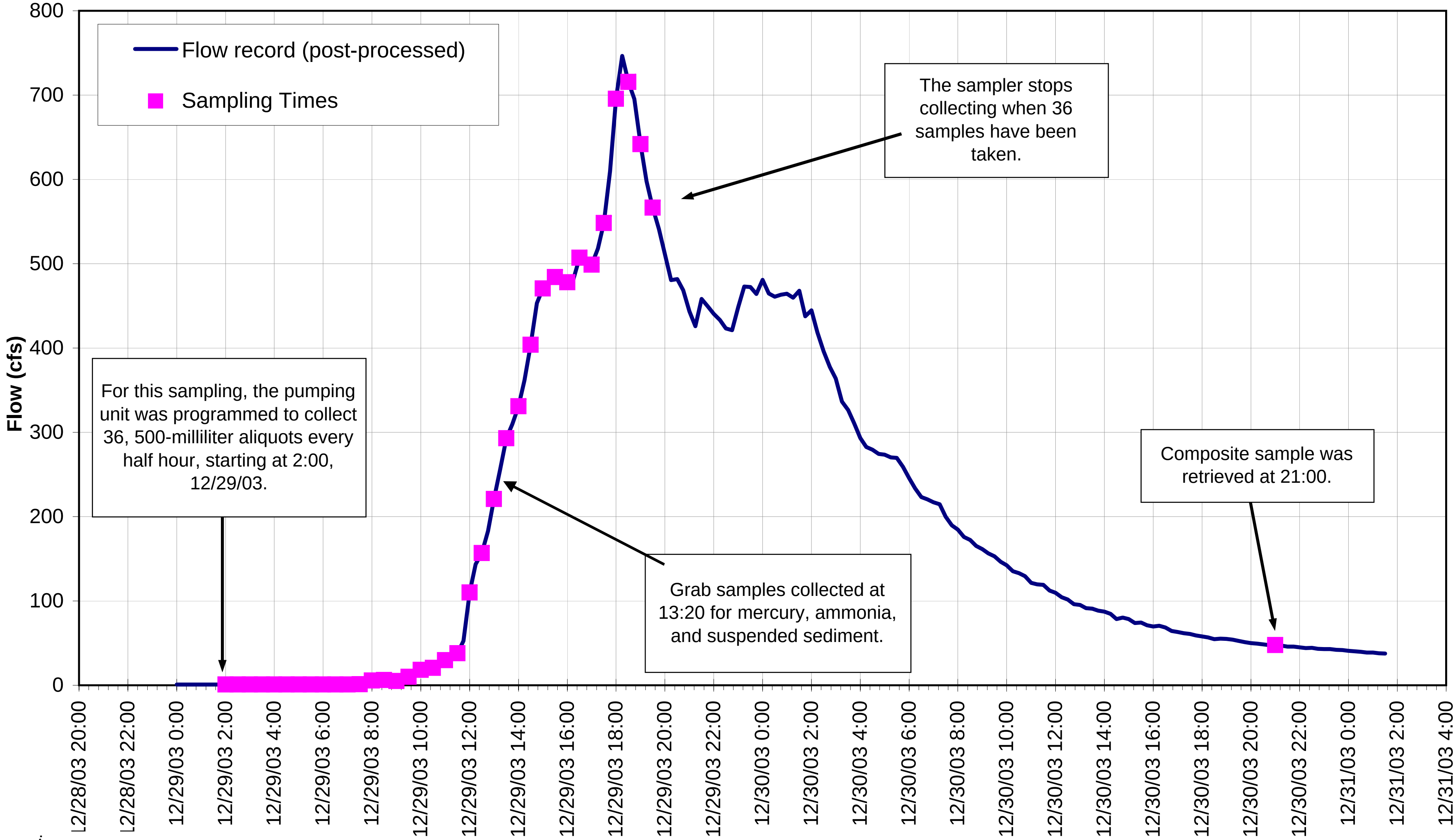

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Figure C8. Water-quality sampling detailed hydrograph, December 29, 2003, San Francisquito Creek at Piers Lane. This was a large and distinct winter event. The time-paced sampling pattern shown here collected many of the sub-sample aliquots before the flow peak. We collected grab samples mid-storm on December 29 during a period of high flow.

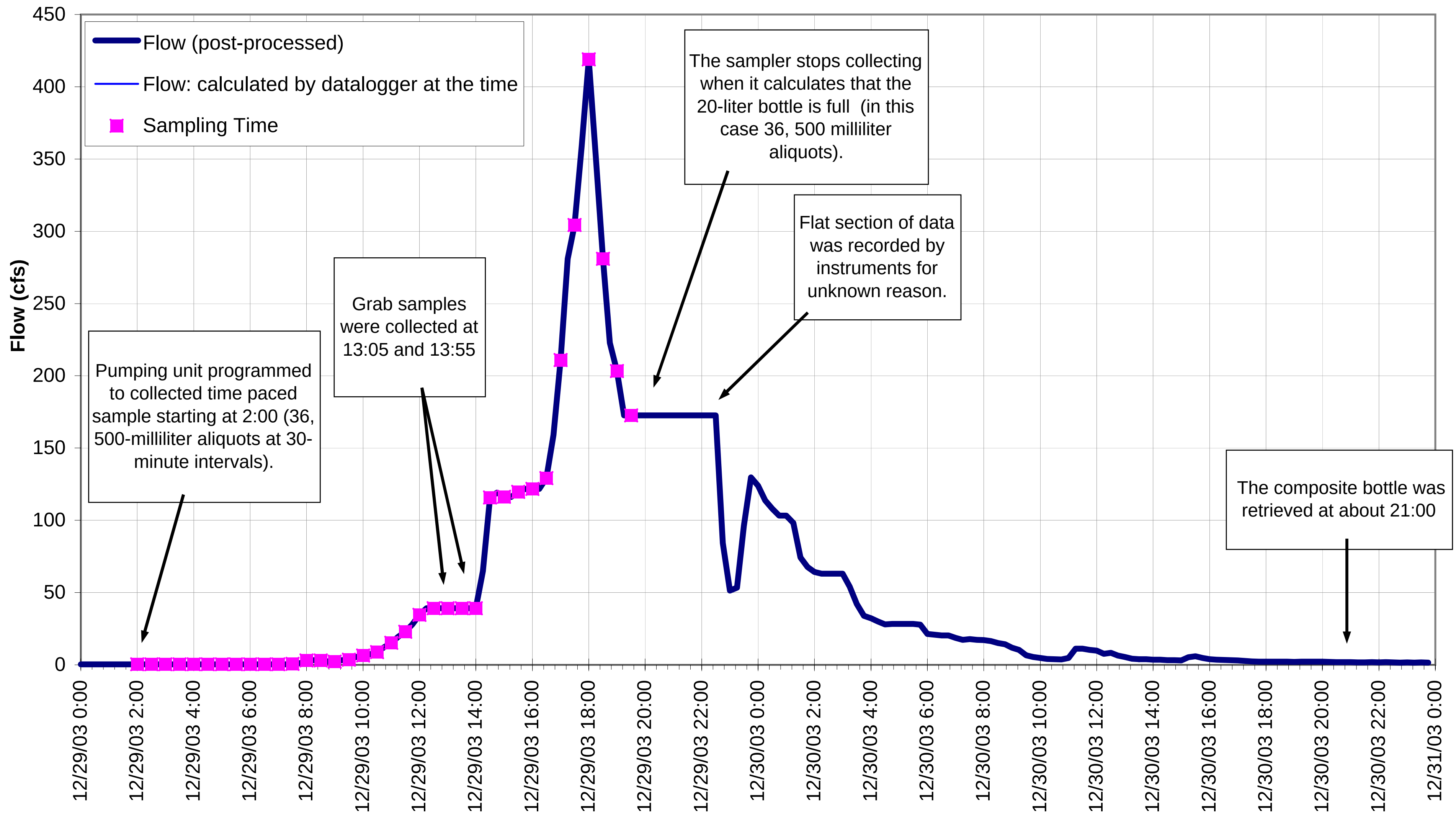

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Figure C9. Water-quality sampling detailed hydrograph, December 29, 2003, Los Trancos Creek at Piers Lane. This was a large and distinct winter event. The time-paced sampling pattern shown here collected many of the sub-sample aliquots before the flow peak. We collected grab samples mid-storm on December 29 during a period of high flow.

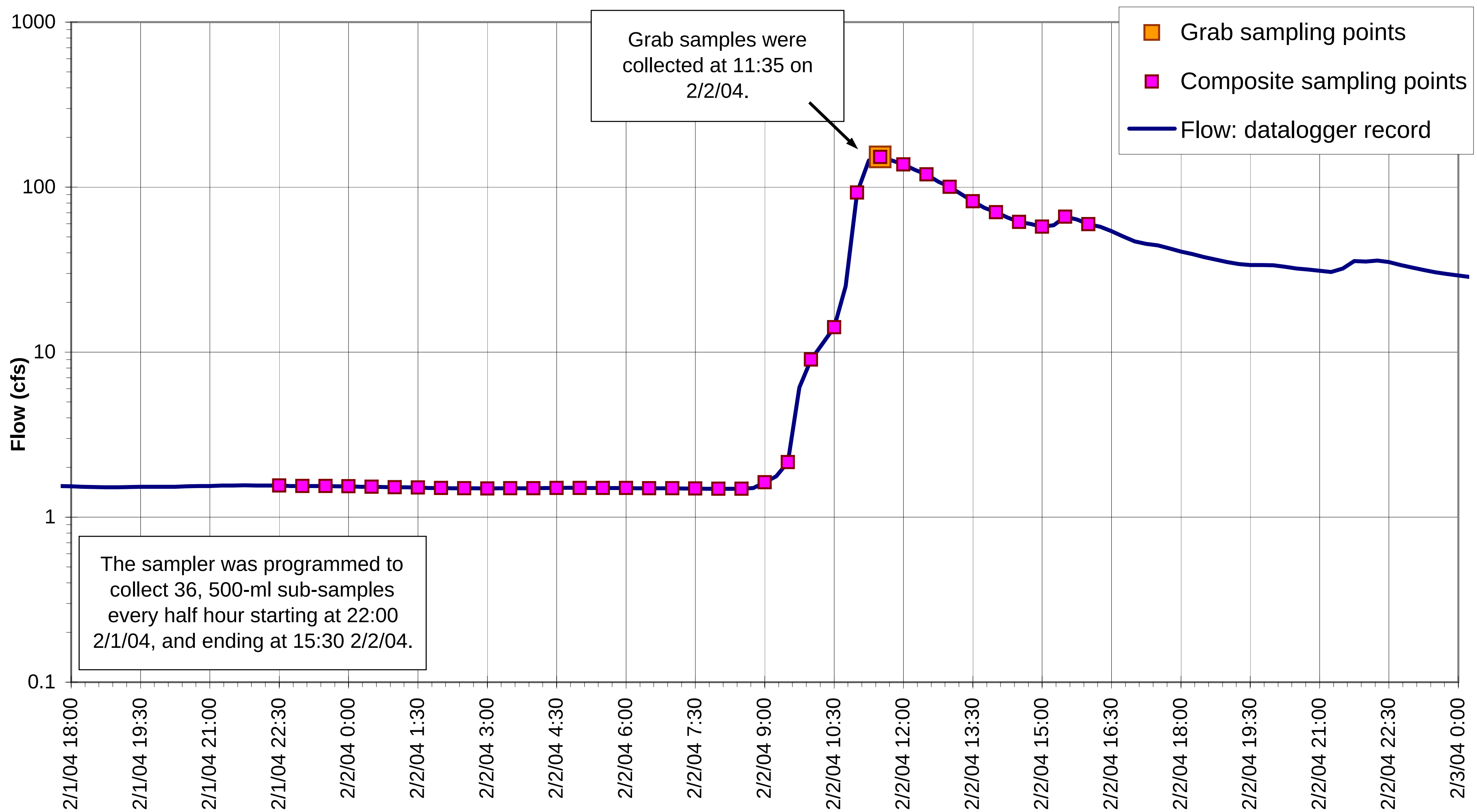

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Figure C10. Water-quality sampling detailed hydrograph, February 2, 2004, Bear Creek at Sand Hill Road. This sampling was intended to capture runoff from a large winter storm. The sampling was time-paced and grab samples were collected at the flow peak.