Water Quality and Streamflow Monitoring of San Francisquito and Los Trancos Creeks at Piers Lane, Water Year 2002, Long-term Monitoring and Assessment Program

San Mateo and Santa Clara Counties, California

Prepared for:

Stanford University, Utilities Division

Prepared by:

Jonathan Owens

Chris White

Bonnie Mallory

Barry Hecht

Balance Hydrologics, Inc.

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A report prepared for:

Stanford University
Utilities Division, FACOPS
327 Bonair Siding, 2nd Floor
Stanford, CA 94305-7270
Attn: Marty LaPorte
(650) 725-7864

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Balance Project Assignment 201082

Original Signed

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Jonathan Owens
Hydrologist

Original Signed

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Chris White
Water Quality Specialist

Original Signed

____

Bonnie Mallory
Hydrologist

Original Signed

____

Barry Hecht, CEG, CHg
Hydrologist / Geomorphologist

Balance Hydrologics, Inc.
841 Folger Ave
Berkeley, CA 94710-2800
510-704-1000
office@balancehydro.com

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EXECUTIVE SUMMARY

This report presents the results of surface water monitoring in the San Francisquito Creek watershed by Balance Hydrologics, Inc. (“Balance”), on behalf of the Utilities Division of Stanford University (“Stanford”). Stanford is a cooperator in the San Francisquito Creek Watershed Council, which is managing the Long-Term Monitoring and Assessment Plan (LTMAP), originally created by a subcommittee of the San Francisquito Creek Coordinated Resource Management and Planning (CRMP) Steering Committee. The LTMAP was established primarily to monitor and assess current (i.e., baseline) conditions, analyses of trends, and evaluation of watershed management. All three LTMAP monitoring stations currently in operation are in the lower San Francisquito Creek watershed. Addition of one or more stations at upstream locations is currently being explored. Expanding the monitoring network to include stations higher in the watershed would provide greater understanding of longitudinal and temporal variation in water quality and stream flow conditions.

To assist the LTMAP in one of its objectives, Balance was asked to collect surface water data for use in describing constituents which might adversely affect water quality in the watershed, under a full range of storm runoff and low-flow conditions, in major part as they affect the full range of steelhead life stages. We are also evaluating contaminants present in San Francisquito and Los Trancos Creeks to prioritize them for more detailed study in future years, describing when they are present or absent and the relationship to flow, and assessing the amount of bedload and suspended sediment being transported by the two streams, as compared to upstream locations also monitored during water year 2002 for other projects.

The San Francisquito Creek watershed is located on the San Francisco Peninsula, and includes the northwestern portion of Santa Clara County and the southeastern portion of San Mateo County (Figure 1). In their downstream reaches, San Francisquito Creek and Los Trancos Creek form the boundary between the two counties. The watershed encompasses approximately 45 square miles, of which about 39 square miles lies upstream from the Piers Lane stations, and includes a wide diversity of urbanized, rural and natural habitats.

The City of Palo Alto contracted with Larry Walker Associates to install three LTMAP monitoring stations in fall 2001. Balance initiated operation of two of the newly-installed stations during water year 2002:

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

City of Palo Alto staff are operating the third station, on San Francisquito Creek at Newell Road, a short distance upstream of Highway 101 and near the head of tidewater.

During the initial year of operation, we established procedures to coordinate with laboratory staff, measured stream flows, and collected water-quality samples on several occasions. The stations are equipped to continuously monitor water levels, rainfall, water temperature, specific conductance, dissolved oxygen, and pH. Manual measurements of specific conductance, temperature, water level and flow were made at regular intervals to calibrate the electronic record. This report summarizes the first year's findings. Measurement and observations continue during water year 2003.

Drawing on prior work, and in coordination with other work in the watershed, we sampled both streams for organophosphate pesticides on one occasion, and for nutrients and trace metals on one or two dates in mid-winter. Organophosphate pesticide concentrations were non-detectable. Nitrogen was detected in the nitrate form but not as ammonia, and phosphate was also detected. Both nitrate and phosphate concentrations were at levels typical of local streams. Concentrations of total and dissolved aluminum, copper, lead, nickel, selenium, and zinc but not silver were detected above analytical reporting limits. However, levels of all of these constituents were well below aquatic acute and chronic toxicity objectives set by the U.S. EPA or the San Francisco Bay Regional Water Quality Control Board Basin Plan (1995).

Specific conductance values were abnormally high in Los Trancos Creek during the summer. During other seasons, specific conductance in both creeks varied in a predictable manner inversely with discharge, depending on the amount of rainfall received. Daily mean water temperatures at all sampling stations were regularly below 21°C. However, maximum temperatures were occasionally above 22°C in San Francisquito Creek, reflecting less-than-optimum temperature conditions for steelhead habitat. Peak temperatures were higher in San Francisquito Creek than in Los Trancos Creek.

Only a limited number of samples with appreciable suspended sediment were collected, and these were consistent with prior observations elsewhere in the watershed.

1. INTRODUCTION

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 Creek Watershed Management Council. The goals of the LTMAP are to provide a comprehensive framework for organizing and coordinating monitoring and assessment activities with the San Francisquito watershed.

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

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

2. when the contaminants are present, and the relationship between the presence, absence or concentration of contaminants and flow; and

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

The two LTMAP stations monitored for Stanford are located on Piers Lane, a short distance downstream (north) of Interstate 280, in Menlo Park and Palo Alto. Both stations were installed in fall 2001 by staff of Kinnetic Laboratories, Inc. (Santa Cruz) and Larry Walker Associates (Davis) under contract to the City of Palo Alto. Balance initiated operation of the newly-installed stations during water year 2002[1] and collected a limited number of samples during the first year of operation. The San Francisquito Creek at Piers Lane station is equipped with a tipping-bucket rain gauge. Both stations are equipped to continuously monitor water level, water temperature, specific conductance (a proxy for salinity), dissolved oxygen, and pH. Manual measurements of specific

[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 2002 (WY2002) began on Oct. 1, 2001 and concluded on September 30, 2002.

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

City of Palo Alto staff are operating the third station in the LTMAP network, which is located on San Francisquito Creek at Newell Road, a short distance upstream of Highway 101 and near the head of tidewater. All three LTMAP monitoring stations currently in operation are in the lower San Francisquito Creek watershed. Addition of one or more stations at upstream locations is currently being explored. Expanding the monitoring network to include stations higher in the San Francisquito Creek watershed would provide greater understanding of longitudinal variation in water quality and stream flows and more fully represent conditions throughout the watershed.

1.1 Local influences on water quality

Restoration of habitat for steelhead -- a 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. Water-quality impairment would 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, an anadromous fish[2] which spawns and rears throughout the headwaters of the San Francisquito Creek watershed, and is federally-listed as a Threatened species.

1.2 Related water-quality studies in the watershed

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

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

2. STATION LOCATIONS

2.1 Piers Lane Stations

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

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

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

2.2 Other Stations Within the Watershed

As part of a series of cooperating projects, Balance also monitored a number of locations upstream of Piers Lane during water year 2002. At some of these stations we monitored water quality, while at other stations the main focus was monitoring streamflow and sediment discharge. Data from some of these other stations are used in this report for comparison to the data collected at the Piers Lane stations. Comparison of flow records among stations helps to provide a check on the gaging data and also helps us to describe and document differences in hydrologic responses to rainfall. These differences are proving larger than expected and may prove in and of themselves to be of significance to stream management, including steelhead restoration. Selected stations are described below.

2.2.1 Bear Creek Sub-Watershed Stations

During water year 2002, Balance also operated three continuous-record stations and five additional partial-record stations within the Bear Creek watershed. These stations were monitored on behalf of the San Francisquito Watershed Council as part of a 3-year water-quality study. Figure 1 shows the location of the eight sampling stations within the watershed. The closest Bear Creek station is at Sand Hill Road, about 2.5 miles upstream from Piers Lane. Approximately one-half of the San Francisquito Creek watershed upstream of the SFPL site lies upstream of the San Hill Road location.

2.2.2 Los Trancos Creek at Arastradero Road

Balance operates another station on Los Trancos Creek about 1.5 miles upstream of Piers Lane on behalf of Stanford University Utilities Divisions. This upstream station has been in operation since November 1994.

2.2.3 Searsville Sub-Watershed Stations

Balance operated gages at Searsville Dam and on Corte Madera Creek at Westridge Drive during water year 2002. Data collection from the Searsville sub-watershed stations focuses on sediment transport. Searsville and Corte Madera flow data were considered in this report where comparison was useful.

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

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

3. HYDROLOGIC SUMMARY, WATER YEAR 2002

Observations and measurements from site visits are documented in Table 1. Flow hydrographs are plotted in Figures 2 through 5.

The water year began with low baseflows in early October 2001. Light rains occurred during October and November, and heavy rains from late November into the very beginning of January 2002. The highest water levels and flow rates occurred on December 2, 2001, with a calculated peak flow rate of 830 cubic feet per second (cfs) on San Francisquito Creek and a peak flow of 480 cfs for Los Trancos Creek. The rest of the winter was mainly dry, punctuated by a few small rainfall events. The last rain was in mid-May, followed by gradual recession of flows to spring and summer baseflow levels.

3.1 Precipitation

Daily stage hydrographs and the rainfall record are plotted in Figures 6 and 7. The tipping-bucket rain gauge at Piers Lane recorded a total of 17.42 inches for the season. Although the station did not record daily data for a portion of the spring, it did appear to record the total that fell during that period. The mean annual precipitation for the station location is approximately 18.5 inches per year (Rantz, 1971). Most precipitation stations for this region, listed by the California Data Exchange Center (CDEC), show water year 2002 as receiving approximately 93 to 106 percent of average rainfall. During water year 2001, rainfall at the same group of stations ranged from 80 to 90 percent of average rainfall. These reported totals are consistent with total flows that we measured at stations throughout this and adjoining watersheds, which indicate that water year 2002 was locally slightly wetter than water year 2001.

3.2 Unexplained Flow Surges

On July 16, 2002, during the dry season of water year 2002, we observed and recorded abnormal flow peaks more than a mile upstream from Piers Lane. Some of these flow surges contributed fine sediment to the creek and increased flow by about 0.25 cfs. The flow was entering from a west-side tributary to Los Trancos Creek at Arastradero Road. It consisted of water that was muddy and substantially more saline than the ambient creek water. Specific conductance (a measure of salinity) downstream in Los Trancos Creek at Piers Lane was also higher than expected on the same date. From the monitoring record, it appears that additional flow surges probably occurred in August as well. Specific conductance measurements at Piers Lane indicate that Los Trancos Creek transported slightly-elevated dissolved solids ("salinity") starting in mid-July and continuing through the end of the water year. To provide additional information regarding the nature and potential source of the discharges, we collected a sample on September 19, 2002 and had it analyzed for general minerals. The results of that analysis are shown in Table 4.

In past years, we have also noticed small flow peaks that occur during non-storm periods and do not show the characteristic shape of a runoff response to rainfall. We have hypothesized that these flow surges resulted from human activity in the watershed upstream of our gage location but have not identified a cause or located a source. The flow surges that we have observed probably do not have a large effect on total flow for the year but they do persist and appear to substantially affect the salinity of the creek, particularly during the dry season when flows are low. These sudden pulses, although small, may also disturb aquatic biota and adversely affect in-stream conditions during low-flow periods.

3.3 Creating a Record of Streamflow

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

3.3.1 Developing a record of water levels

Each of the two stations is equipped with an ultrasonic sonar transponder connected to an American Sigma 950 flow meter. The equipment measures and records the water level in the creek at 15-minute intervals. We found that observed high-water marks corresponded well with the recorded peaks, as shown by the plotted high-water marks and other stage observations in Figures 8 and 9. The equipment occasionally recorded false peaks which we filtered-out in the data analysis process[3]. At low flows, the sonar transponder values have a large amount of variation, up to about 0.3 feet per day

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

(Figures 8 and 9). We believe that most of this variation is “noise” in the instrument reading and does not reflect actual changes in water-levels, although creek levels usually do have a lower-amplitude diurnal pattern during low-flow periods.

3.3.2 Computing flows

Based on our periodic site visits, staff plate readings, and flow measurements (Table 1), we create an empirical stage-to-discharge relationship (“stage-discharge rating curve”) for each gage. This rating curve is then applied to the datalogger and sonar-transponder record of water levels. During this year, as is typically done, we applied multiple stage shifts to account for changes in algal growth, sedimentation, and leaf dams in the channel downstream of the gages that affect the water-level elevation at the monitoring locations. Due to the noise in the stage data, the flow record also becomes “noisy” at the 15-minute level of detail (see Figures 4 and 5). However, mean daily values appear to be fairly accurate because the daily averaging removes most of the noise.

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

4. 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, which provides a complete description of the methods and protocols used in this study. Interested readers are referred to that document for additional detail.

4.1 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 Piers Lane monitoring program is designed to measure field parameters on each sampling visit. Samples for ammonia, nitrate, mercury, total and dissolved metals, and organophosphate pesticide analyses are collected during storm or baseflow sampling on alternate visits, approximately six times annually. Sediment sampling will occur from fall through spring, when flows are sufficient, but not in summer.

From fall 2001 through mid-winter 2002, full operation of the two stations was delayed due to missing equipment, documentation, and software, and delays in contracting and coordinating with labs. Once these issues were resolved, the stations became operable and have remained so through the present date.

4.2 Field Measurements and Laboratory Analyses

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

<u>Field Measurements</u>

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

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

<u>Laboratory Analyses</u>

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

4.3 Exceptions and Deviations from Proposed Methods

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

- We inadvertently disabled the two dataloggers[4] during spring 2002 as we were first becoming familiar with instrument operation and attempting to reprogram sampling parameters based on our initial flow measurements. We made manual measurements during this interval but were unable to collect data from the electronic probes.

- For the same reasons noted above (Section 4.1), during this initial season of a projected long-term study, we did not sample for water-quality parameters until the spring baseflow period. Water year 2002 water quality samples were collected as grab samples, or depth-integrated samples (ammonia and suspended sediment) using a manual DH-48 sampler, a water quality sampler developed and approved by the Federal Interagency Sedimentation Program, rather than as flow-paced composite samples. We have since modified the automated collection program and completed both flow-paced and time-paced sample collection during water year 2003.

- The specific conductance probes appear to have not worked properly from the inception of monitoring and repeated attempts to calibrate the probes were unsuccessful. The patterns of variation in specific conductances seem realistic during portions of the monitoring period, when compared to the manual measurements

[4] The datalogger on San Francisquito Creek was inoperable from March 7 to June 20, 2002. The datalogger on Los Trancos Creek was inoperable from Feb. 28 to April 11, 2002.

made on most site visits but the magnitudes of the values are not credible. As the existing probes are unreliable, we will continue to make manual measurements of specific conductance on most site visits in water year 2003.

- Similarly, both the dissolved oxygen and pH probes have worked only intermittently since the station was installed. The probes require frequent maintenance to maintain operation, even during baseflow (non-storm) periods, and foul even more rapidly when flows are high. Thus, dissolved oxygen was not measured during water year 2002, and pH was only measured sporadically using pH paper test strips. We are using manual pH and dissolved oxygen meters to sample stream flows in water year 2003. Given the unreliability of the two probes, the manual measurements will comprise the record for these parameters.

Recommendations for improving the monitoring program during water year 2003 and subsequent years are presented briefly in Section 6 below.

5. RESULTS AND DISCUSSION OF WATER QUALITY SAMPLING

This chapter includes a discussion of findings by individual constituent or constituent group. The dates when water quality samples were collected, the reporting limits, and the analytical results are presented in Table 3. Analytical results from the September 19, 2002 sample, collected to evaluate sources of atypically elevated levels of specific conductance in Los Trancos Creek (see Section 3.2), are tabulated separately in Table 4 due to the increased number of constituents. All laboratory reports are collected in Appendix A.

5.1 Regulatory Standards and Objectives

Table 3 includes three sets of values for comparison with the WY2002 water-quality sampling results. The U.S. EPA criteria promulgated by the California Toxics Rule (CTR) apply throughout the region except for the South Bay below the Dumbarton Bridge, and tributary streams which discharge into this portion of the Bay. In the South Bay, San Francisco Bay Regional Water Quality Control Board water quality objectives, established in the 1995 Basin Plan, still apply. However, the Regional Board has proposed a Basin Plan amendment for consideration in June 2003 that updates the water quality objectives for seven pollutants [arsenic, cadmium, chromium (VI), copper, lead, silver, and zinc] to be consistent with the U.S. EPA criteria (Wil Bruhns, RWQCB, pers. comm). The more protective Basin Plan objective for mercury, as well as existing objectives for nickel and PAHs, will be retained. In addition, we have also included the California Department of Health Services drinking water standards in Table 3, since they are likely familiar to many readers. However, we note that the focus of this study is on the health of aquatic habitat in the two creeks, and not use for domestic supply.

5.2 Specific Conductance

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

In general, specific conductance levels at both stations follow an expected pattern, with higher specific conductance (higher salinity) at low flows, and lower levels occurring during storm events (Figures 14 and 15, and Tables 1 and 2). This pattern can best be discerned from our manual measurements, as the automated specific conductance probes seem to have barely worked, if at all. As discussed in Section 3.2, the unexpectedly high specific conductance in Los Trancos Creek during the summer months (Figure 15) deviates from the pattern of expected values. The cause may be influxes from some human, animal or natural influence. Analysis of a water-quality sample collected during this period, on September 19, 2002 (see Table 4), confirmed the high specific conductance but did not point directly to an obvious source.

5.3 Nitrogen

In general, nitrate-nitrogen concentrations[5] are expected to be highest during intermediate flows, when sufficient runoff is present to flush nitrate into the stream, but flows are below the threshold where nitrate concentrations become highly diluted by fresh runoff. The three samples analyzed did contain moderate concentrations of nitrate-nitrogen, ranging from 0.43 to 1.8 mg/L. These values are slightly elevated but well below current levels of concern (Table 3), although much lower thresholds of about 0.5 mg/L *total* nitrogen are being recommended by the EPA for potential adoption in 2004 (U.S. EPA, 2000). The *Pajaro River Watershed Water Quality Management Plan* (Applied Science and Engineering, 1999) reported that nitrate-nitrogen concentrations of 0.05 to 2.0 mg/L would be expected in "uncompromised" streams draining the Santa Cruz Mountains. For comparison, nitrate-nitrogen concentrations at the closest Bear Creek station, at Sand Hill Road about 2.5 miles upstream from Piers Lane, ranged from 0.16 to 2.50 mg/L during a 3-year study encompassing water years 2000 through 2002. Concentrations were typically between 0.6 and 1.0 mg/l during winter baseflow periods (Balance Hydrologics, unpublished data).

Ammonia-nitrogen concentrations in both creeks were below the detection limit on the two dates sampled this year (Table 3).

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

5.4 Pesticides

Concentrations of the common organophosphate pesticides chlorpyrifos and diazinon were below the detection limit for both constituents on the two dates sampled (Table 3). San Francisquito Creek is listed as impaired by diazinon. For comparison, during the Bear Creek water-quality study, chlorpyrifos was never detected in any sample and diazinon was detected only once in three years, at 0.02 mg/L in October 2000.

5.5 Trace Metals

Samples collected on February 28 and March 7, 2002 were analyzed for a suite of total and/or dissolved concentrations of metals commonly associated with urban and suburban development in the San Francisquito Creek watershed: aluminum, copper, lead, nickel, selenium, silver, and zinc. Analytical results for silver were below the detection limit in samples from both creeks. However, all other metals were detected in both the dissolved and solid form (Table 3) on one or both dates.

Dissolved metals concentrations are of greatest potential concern, since this form is most bio-available to aquatic organisms. The water quality objectives for metals are hardness-dependent, since calcium and magnesium (the components of hardness) act to buffer metals toxicity. We note that the upper limit of hardness used by the Regional Board to assess the effects of metal concentrations is typically 400 mg/l. At the hardness levels observed in San Francisquito Creek and Los Trancos Creek in winter 2002 (250 to 500 mg/L as $CaCO_3$), the potential toxicity of trace metal ions is low.

5.5.1 Aluminum

Elevated total aluminum concentrations at SFPL and LTPL (Table 3) are not unexpected, particularly in the higher flow samples, because aluminum is a naturally occurring component of silts and clays that are commonly present as suspended sediment, and acid digestion for total metal analyses typically release a much larger amount of the mineral than is naturally present in the stream. Dissolved aluminum concentrations are much lower and similar to published values for aluminum concentrations in surface waters in natural streams of the United States (Hem, 1985), which include contributions from urban sources. Aluminum concentrations were not analyzed in the Bear Creek study.

5.5.2 Copper

The highest copper concentrations observed were in a sample collected at SFPL on March 7, 2002 during rising flow (Table 3). The total copper concentration in the sample was 9.1 micrograms per liter (µg/L) and the dissolved copper concentration was 5.6 µg/L. At a hardness concentration of 250 mg/L, these values are well below the aquatic acute and chronic toxicity objectives established by the U.S. EPA and the Regional Board (Table 3). In the Bear Creek study, concentrations of dissolved copper at the Sand Hill Road station ranged from 1.8 µg/L to 9.9 µg/L during the wet season.

5.5.3 Lead

Lead was not detected in water samples from either monitoring station on February 28 (Table 3) but was detected in samples from both stations on March 7, 2002 at values similar to or lower than wet-season concentrations observed in the Bear Creek study during the three previous years. The total lead concentration was higher at SFPL than at LTPL (2.9µg/L vs. 0.6 µg/L), as was the dissolved lead concentration (0.6 µg/L vs. 0.4 µg/L) but values from both streams were well below the aquatic acute toxicity objectives established by the U.S. EPA (262 µg/L) and the Regional Board (172.3 µg/L), as calculated for a hardness of 250 mg/L (Table 3). Concentrations were also well below chronic toxicity objectives set forth by the U.S. EPA (6.7 µg/L) and the Regional Board (10.2 µg/L) for the same hardness value.

The predominant source of lead is probably residues from leaded gasoline, bound to organic matter or soil near roads and highways, and transported in urban runoff. In the Bear Creek study, lead concentrations at stations in the Dry Creek watershed, which receives runoff from Highway 280, ranged from 2.6 to 8.4 µg/L during the wet season. 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.

5.5.4 Selenium

Selenium was detected in water samples from both monitoring stations on Feb. 28 and March 7, 2002 (Table 3). Selenium concentrations were only slightly above the detection limit of 0.1 µg/L in all samples. The highest value was 0.5 µg/L for total selenium in LTPL on Feb. 28. Dissolved selenium concentrations ranged from 0.1 to 0.3 µg/L in

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

5.5.5 Zinc

Zinc tends to be substantially more abundant and more soluble than other trace metals, and was detected on both sampling dates at the two monitoring stations (Table 3). In general, as with specific conductance and other trace metals, one would expect higher zinc concentrations at low flows, when streams are fed primarily by mineral-enriched ground water, if zinc contributions were of geologic origin.[6]. However, if concentrations increase as flow increases (as happens with our small data set here), then the predominant source may include runoff from roads, roofs, galvanized fencing, and other human influences. All analytical results for both total and dissolved zinc were well below the aquatic acute and chronic toxicity objectives established by the U.S. EPA and the Regional Board.

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

5.6 Temperature

Temperature strongly affects steelhead habitat. Although steelhead can withstand high water temperatures of 29°C for a short period of time, and 25°C for longer periods, they have progressively-increasing difficulty extracting dissolved oxygen from water at temperatures above 21°C (Lang and others, 1998) and require a larger food source to sustain their elevated metabolism (Smith, pers. comm.). Therefore, water temperatures of 21°C and below may be considered as adequate habitat, and values chronically above 25°C even for short periods are likely not viable for the local steelhead population. While Balance staff can discuss factors affecting temperature and can report assessments in streams of similar size and influences, criteria for and evaluation of temperature for

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

steelhead habitat management in San Francisquito Creek should be made by senior biologists familiar with the stream and by agencies charged with managing such habitat.

We made numerous manual measurements of water temperature and have records of water temperature from two probes at each site (see Figures 10 through 13). Maximum daily temperatures are slightly higher in San Francisquito Creek. The maximum recorded temperature at SFPL station was 23.0°C on July 19, 2002, and for LTPL was 21.4°C the same day. Temperature readings collected during site visits follow the same seasonal pattern, with the highest field measurement of 22.0°C found in SFPL on July 1, 2002.

5.7 Suspended Sediment

Suspended sediment samples were collected from both stations on March 7, 2002 during a rising hydrograph, but still at relatively low flow. The results of the analysis are shown in Tables 1 and 2 under “TSS”. Stream waters were clear on most visits and, from past experience, we have found that samples collected under these conditions test below the analytical reporting limits of 5.0 mg/L. Thus, we can draw no conclusions based on our limited sampling this year but note that conditions seemed to be typical of creeks in the San Francisquito watershed.

5.8 Dissolved Oxygen and pH

As stated above in Section 4.3, the pH and dissolved oxygen probes were non-functional in WY2002. No dissolved oxygen measurements were made and pH was measured intermittently using paper test strips (see Figures 16 and 17). We note that fisheries biologists familiar with the northern Santa Cruz Mountains and San Francisco Peninsula streams have found that pH and DO are very rarely a limiting factor in regards to steelhead habitat, so long as there is flow moving from pool to pool. Furthermore, DO is often highly variable along the length of a stream and, in summer, over the course of a day. During the winter and especially at high flows, when turbulence and cold ambient water temperatures promote oxygen saturation, we expect dissolved oxygen concentrations in the creek to range from 10 to 14 mg/L.

5.9 Other Water Quality Issues

According to the Palo Alto Daily News (O'Shea, 2002), on April 13, 2002, a contractor allowed approximately 200 to 300 gallons of Dustac, a dust-minimizing agent, to run off the Ford Field parking lot into Los Trancos Creek. The spill occurred between Arastradero Road and Piers Lane. It is suspected that the spill caused oxygen depletion resulting in a fish kill, including a number of juvenile steelhead trout. We had inadvertently disabled the datalogger during this period, so we have no data related to the spill.

6. FUTURE MONITORING AND RECOMMENDATIONS

We believe that the sampling performed during this past year was a useful and comprehensive start for the first year of a long-term study. We intend to improve our sampling methods and achieve more complete sampling coverage in the coming year (water year 2003), based on what we have learned in water year 2002.

One goal of the monitoring plan is to perform flow-paced, composite sampling. The samples from water year 2002 were either grab samples or manually-collected, depth-integrated samples. We now have enough information about the watershed response to rainfall and have developed adequate rating curves to program the automated sampler to perform flow-paced composite sampling. For very low flows (small first-flush storms) the noise inherent in the transponder signal may still preclude accurate readings; for those storms, we plan to perform time-paced composite sampling.

For the second year of monitoring, we are planning 6 sampling dates; one focus will be on "first-flush" storms, including late-fall and early-winter storms. These moderate size storms incrementally move more and more constituents from the watershed into the creek with each successively larger storm. We also intend to perform non-storm samplings in the spring and summer.

The specific conductance, dissolved oxygen and pH probes at both stations continue to be fouled or to become impacted by sediment. When cleared, the specific conductance, and dissolved oxygen probes function well, typically for 5 to 10 days before the situation recurs. We have used a different brand of specific conductance probe in the Bear Creek study with good results and installation of replacements at the Piers Lane monitoring stations may be required if automated data collection remains a priority. High probe-maintenance requirements at these sites may also preclude use of automated pH and dissolved oxygen probes. While these issues are being reviewed, we plan to use manual pH and dissolved oxygen meters to sample stream flows during water year 2003.

Biologic criteria for summer water temperatures in the two streams, as they affect steelhead and other aquatic habitat, should be established for local conditions, such that future observations of temperature can be placed into an ecological context.

Finally, the three LTMAP monitoring stations currently in operation are all located in the lower San Francisquito Creek watershed. Addition of one or more stations at upstream locations, such as at Sand Hill Road, is currently being explored. 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.

7. CONCLUSIONS

1. Rainfall and streamflow totals for water year 2002 approached average conditions. The peak flow for the year was about a 1.5 to 2-year recurrence-interval flood, based on data from other locations in the watershed.

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

3. Except for a few days during the summer, water temperatures at the two sampling stations were regularly below 21°C. Temperatures were slightly higher in San Francisquito Creek.

4. Organophosphate pesticide concentrations were below detectable limits on the two dates sampled. Given the limited sampling this year, further sampling at the Piers Lane stations, with emphasis on the fall first-flush storms, is needed to better establish when or if these pesticides are present in the two streams.

5. Nitrogen was detected only as nitrate in both creeks, at levels typical of those observed in other local streams.

6. The concentration of silver was nondetectable but the other trace metals sampled (aluminum, copper, lead, nickel selenium and zinc) were present at levels exceeding analytical reporting limits. However, concentrations of these constituents were similar to those observed during the recent three-year study of the Bear Creek watershed upstream, and well below the aquatic acute and chronic toxicity levels set by the U.S. EPA and the San Francisco Bay Regional Water Quality Control Board in the Basin Plan (1995).

7. Insufficient suspended-sediment samples were collected from the two streams to draw conclusions regarding sediment transport in water year 2002. Observations indicate that conditions were typical of creeks in the San Francisquito watershed.

8. As discussed in Section 6, based on first-year monitoring results, we have made adjustments to the sampling and analysis plan to allow for more reliable and complete data collection in future years of this project.

9. All three existing LTMAP monitoring stations currently in operation are located in the lower San Francisquito Creek watershed. Further consideration should be given to expanding the nascent monitoring network to include stations in the upper watershed. Addition of one or more stations at upstream locations would provide a more comprehensive and representative understanding of hydrologic and water quality conditions throughout the entire watershed.

8. 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.

9. ACKNOWLEDGEMENTS

We believe that this is an important study and would like to thank those individuals and groups whose contributions to the planning and implementation of the LTMAP program and this multi-component study have been invaluable, including: Geoff Brosseau (BASMAA), Phil Bobel (City of Palo Alto WWTP), and Marty Laporte (Stanford University).

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TABLES

Table 1. Station observer log for San Francisquito Creek at Piers Lane, water year 2002

Site Conditions [1]				*Streamflow* [2]				*Water Quality Observations* [3]				*High-Water Marks* [4]		*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 *(oC)*	Specific Conductance at field temp. *(µmhos/cm)*	Specific Conductance at 25C *(at 25°C)*	Additional sampling? *'Qbed, etc.)*	Estimated stage at staff plate *(feet)*	Inferred dates? *(mm/dd/yr)*	
San Francisquito Creek at Piers Lane														
10/30/01 13:00	jo, cw													initial orientation visit; first-flush runoff occurred this morning
12/2/01 15:07	gp, bjm	…	R	…	80	V	p	11.7	352	483	…		12/2/2001	couldn't read staff plate due to angle; flow is 5 to10 times greater than in Los Trancos Creek
2/12/02 7:52	jo	3.87	B	…	5	V	p	…	…	…	…	…	…	stage observed from top of bridge with binoculars
2/28/02 10:35	jo, cw, sb	3.95	B	11.83	…	AA	f	…	…	…	WQ	…	…	water slightly turbid; met with M. LaPorte and R. Medina; a few pockets of sand behind very slippery rocks
3/7/02 15:30	jo, cw	4.55	R, F	…	40	V	p	12.3	570	769	WQ Qss	…	…	SC at 10:25 AM, WQ at 15:30 PM, pH=7.0; water rising w/ increasing turbidity up until sampling time
3/21/02 14:25	jo, er	3.98	B	…	15	V	p	12.3	533	719	…	…	…	brought in recharged batteries
4/9/02 15:00	jo	3.82	B	6.78	…	AA	f	15.1	700	877	…	7.8	12/2/2001	sprinkles this morning; updated rating curve in flowmeter
4/10/02 8:48	jo	3.82	B	…	…	…	…	14.1	690	888	…	…	…	water slightly cloudy; added equipment manuals to site
5/1/02 14:10	er, sb	3.68	B	3.91	…	PY	g	12.6	664	889	…	…	…	partly cloudy day
5/22/02 8:55	jo	3.72	F	4.91	…	PY	f	9.8	700	1010	…	…	…	slight turbidity; found two wires with chicken bones near staff plate (used to catch crayfish?)
6/4/02 13:54	jo	3.45	B	…	2	V	p	18.6	860	985	…	…	…	water slightly cloudy; many 1" to 3" fish in pool, and many crayfish
6/20/02 10:50	jo	3.32	B	…	0.9	V	p	16.9	990	1184	…	…	…	slightly cloudy water; brushed off probes
7/1/02 15:15	smc, ch	3.30	B	0.55	…	PY	g, f	22.0	1062	1121	…	…	…	flow measured ~75 feet upstream of bridge
7/25/02 11:25	jo	3.31	B	0.46	…	PY	f	16.6	1095	1320	…	…	…	many bay leaves in water
8/20/02 12:30	jo	3.29	B	0.30	…	PY	f	16.0	1100	1347	…	…	…	slight turbidity (maybe from the ducks upstream); leaves amongst the rocks on the bed
9/19/02 9:10	jo, cw, bjm	3.29	B	0.28	…	PY	f	15.6	1080	1336	…	…	…	saw fish, crayfish, and hummingbirds; slight turbidity
10/16/02 10:55	jo, cw	3.25	B	0.28	…	PY	p	12.6	1100	1473	…	…	…	water mostly clear; more fishing lines (crayfish?) and trash

Notes:

1. Observer Key: jo= Jonathan Owens; cw= Chris White; gp= Gustavo Porras; bjm= Bonnie Mallory; er= Eric Riedner; sb= Scott Brown.
   Stage: Water level observed at outside staff plate
   Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or uncertain (U).
2. 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).
   When flows exceed levels safe for wading, "float" measurements are made timing the passage of twigs or other organic debris through a 20-foot reach of stream.
   Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) estimated percent accuracy $\leq$ 10%, or as shown
3. Specific conductance (SC): Measured in micromhos/cm in field; then adjusted to 25°C by equation:
   (1.8813774452 - [0.050433063928 * field temp] + [0.00058561144042 * field temp^2]) * Field specific conductance
4. High-water mark (HWM): Measured or estimated at location of the staff plate
   Additional Sampling: Qbed = Bedload, Qss = Suspended sediment, Nutr = nutrients; WQ = full suite of constituents sampled, other symbols as appropriate

Table 2. Station observer log for Los Trancos Creek at Piers Lane, water year 2002

Site Conditions [1]				*Streamflow* [2]				*Water Quality Observations* [3]				*High-Water Marks* [4]		*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	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°C)*	*(Qbed, etc.)*	*(feet)*	*(mm/dd/yr)*	
Los Trancos Creek at Piers Lane														
10/30/01 13:00	jo, cw													initial orientation visit, first flush this morning
12/2/01 14:56	gp, bjm	2.00	R	12.7	…	float	p	11.9	336	458	…	4.85	12/2/2001	debris on staff; reading taken after debris removed
2/12/02 7:56	jo	1.50	B	…	1.2	V	p	…	…	…	…	…	…	brown algae on bed material, maybe some sand moved recently; water completely clear
2/28/02 13:00	jo, cw, sb	1.48	B	1.12	…	AA	g	…	…	…	WQ	…	…	met with M. LaPorte and R. Medina; water very clear; sampler intake buried in several inches of sand
3/7/02 14:00	jo, cw	1.67	R	…	3	V	p	12.1	620	841	WQ, Qss	…	…	SC at 10:25 AM, WQ at 14:00 PM, pH=7.5; cold front moved in with light rain ending, air temperature dropping, water clear
3/21/02 14:14	jo, er	1.49	B	…	1	V	p	12.7	721	963	…	…	…	brought in recharged batteries
4/9/02 13:12	jo	1.50	B	…	1.5	V	p	13.8	760	986	…	…	…	water very clear; updated rating curve in flow meter
4/10/02 8:23	jo	1.50	B	…	…	…	…	13.1	730	964	…	…	…	water very clear; added equipment manuals to site
5/1/02 13:30	er, sb	1.46	B	0.74	…	PY	g	11.8	733	1003	…	3.96	unknown	eucalyptus limb across creek, but not in water
5/22/01 8:25	jo	1.43	F	0.79	…	PY	f	10.9	750	1051	…	…	…	water clear; algae on bed; showers two days ago
6/4/02 13:46	jo	1.36	B	…	0.5	guess	p	11.8	760	1040	…	…	…	water very clear; many 1" and 2" fish in the creek
6/20/02 14:35	jo	1.35	B	1.410	…	PY	g, f	14.5	1020	1299	…	…	…	water clear, brown algae on bed, leaf dam d/s of staff, excavated and brushed off probes
7/25/02 10:45	jo	1.33	B	0.105	…	PY	g	15.1	1380	1730	…	…	…	leaf dam downstream of staff; water clear; brown algae on rocks; high SC probably from upstream
8/20/02 12:10	jo	1.31	B	0.063	…	PY	f	15.2	1505	1881	…	…	…	stick and leaf dam downstream of staff; fair number of small fish
9/19/02 8:40	jo, cw, bjm	1.27	B	0.033	…	PY	f	14.8	1600	2021	WQ	…	…	much silt on bed stirred by walking; many leaf dams; SC high
10/16/02 10:30	jo, cw	1.24	B	0.024	…	PY	f	12.0	830	1129	…	…	…	leaf and stick dam reforming downstream of staff; sparrows bathing

Notes:

1. Observer Key: jo= Jonathan Owens; cw= Chris White; gp= Gustavo Porras; bjm= Bonnie Mallory; er= Eric Riedner; sb= Scott Brown.
   Stage: Water level observed at outside staff plate
   Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or uncertain (U).
2. 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).
   When flows exceed levels safe for wading, "float" measurements are made timing the passage of twigs or other organic debris through a 20-foot reach of stream.
   Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) estimated percent accuracy $\leq$ 10%, or as shown
3. Specific conductance (SC): Measured in micromhos/cm in field; then adjusted to 25°C by equation:
   (1.8813774452 - [0.050433063928 * field temp] + [0.00058561144042 * field temp^2]) * Field specific conductance
4. High-water mark (HWM): Measured or estimated at location of the staff plate
   Additional Sampling: Qbed = Bedload, Qss = Suspended sediment, Nutr = nutrients; WQ = full suite of constituents sampled, other symbols as appropriate

Table 3. Summary of water quality at San Francisquito and Los Trancos Creeks at Piers Lane (February 28, 2002 to September 30, 2002).

Field observations [1]							*Nutrients* [2]			*Pesticides*		*Trace Metals* [3]														*Others* [4]		
Date and Time	Observer	Gage Height	Hydrograph	Discharge	Water Temperature	Specific conductance	**Ammonia-N**	**Nitrate-N**	**Phosphate-P**	**Chlorpyrifos**	**Diazinon**	**Aluminum (total)**	**Aluminum (dissolved)**	**Copper (total)**	**Copper (dissolved)**	**Lead (total)**	**Lead (dissolved)**	**Nickel (total)**	**Nickel (dissolved)**	**Selenium (total)**	**Selenium (dissolved)**	**Silver (total)**	**Silver (dissolved)**	**Zinc (total)**	**Zinc (dissolved)**	**Total Suspended Solids**	**Turbidity**	**Hardness**
		(feet)	*(R,F,B,U)*	*(cfs)*	*(°C)*	*(µhos/cm @ 25°C)*	*(mg/L)*	*(mg/L)*	*(mg/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)*	*(ug/L)*	*(mg/L)*	*(NTU)*	*(mg/L)*
Analytical detection limits: [5]						**2/28/2002**	0.2	ns	0.1	ns	ns	ns	ns	0.6	0.6	0.4	0.4	1.0	1.0	0.1	0.1	0.2	0.2	1.0	1.0	ns	ns	1.0
						3/7/2002	0.2	0.1	0.1	0.5	0.6	50	20	0.6	0.6	0.4	0.4	1.0	1.0	0.1	0.1	0.2	0.2	1.0	1.0	0.5	ns	1.0
						9/19/2002	ns	0.1	ns	ns	ns	ns	ns	0.01	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.02	ns	ns	ns	3.3
San Francisquito Creek at Piers Lane [6]																												
2/28/2002 12:00	jo, cw, sb	3.95	B	11.83	ns	ns	ND	ns	0.4	ns	ns	ns	ns	ns	1.9	ns	ND	ns	3.0	ns	0.2	ns	ND	ns	6.0	ns	ns	289
2/28/2002 12:00	jo, cw, sb	3.95	B	11.83	ns	ns	ND	ns	0.4	ns	ns	ns	ns	ns	1.3	ns	ND	ns	3.0	ns	0.2	ns	ND	ns	2.3	ns	ns	281
3/7/2002 15:35	jo, cw	4.55	R,F	40	12.3	769	ND	1.2	1.1	ND	ND	2000	180	9.1	5.6	2.9	0.6	10	5.0	0.3	0.2	ND	ND	27.0	9.0	65.0	ns	ns
Los Trancos Creek at Piers Lane [6, 7]																												
2/28/2002 13:50	jo, cw, sb	1.48	B	1.12	ns	ns	ND	ns	0.46	ns	ns	ns	ns	2.1	1.7	ND	ND	4.0	3.0	ND	0.1	ND	ND	4.6	2.1	ns	ns	459
2/28/2002 13:50	jo, cw, sb	1.48	B	1.12	ns	ns	ns	ns	ns	ns	ns	ns	ns	2.9	ns	ND	ns	3.0	ns	0.5	ns	ND	ns	3.3	ns	ns	ns	ns
3/7/2002 13:50	jo, cw	1.67	R	3	12.1	841	ND	1.8	0.67	ND	ND	230	30	3.0	3.0	0.7	ND	4.0	3.0	0.2	0.3	ND	ND	10.0	7.0	ns	ns	355
3/7/2002 16:00	jo, cw	4.55	R	40+	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	9.5	ns	ns
9/19/2002 16:00	jo, cw, bm	1.22	B	0.033	14.9	1909	ns	0.43	ns	ns	ns	ns	ns	ND	ns	ns	ns	ns	ns	ns	ns	ns	ns	ND	ns	ns	ns	830
SF Bay RWQCB (1995)--Aquatic acute toxicity: 1-hour average							---[8]	---[9]	---[9]	---[10]	---[10]	None		42.0 - 80.8		262.1 - 633.5		3079.0 - 5534.1		None		19.6 - 64.7 [14]		45.5 - 81.9		---[11]	---[11]	None
SF Bay RWQCB (1995)--Chronic acute toxicity: 4-day average							---[8]	---[9]	---[9]	---[10]	---[10]	None		25.9 - 46.8		10.2 - 24.7		342.3 - 615.3		None		None		50.2 - 90.4		---[11]	---[11]	None
California Toxics Rule (U.S. EPA)--Aquatic acute toxicity: 1-hour average [12]							---[13]	None	None	None	None	None		31.9 - 61.2		172.3 - 352.5		1016.5 - 1827.2		20	20	16.7 - -55.0 [14]		256.8 - 462.0		None	None	None
California Toxics Rule (U.S. EPA)--Chronic acute toxicity: 4-day average [12]							---[13]	None	None	None	None	None		19.6 - 35.4		6.7 - 13.7		112.9 - 202.9		5	5	None		254.7 - 458.2		None	None	None
California Drinking Water Standards (MCL)--***for reference only***							None	10,000	None	None	None	1000	1000	1300	1300	15	15	100	100	10	10	50	50	5000	5000	None	5.0	None

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

1) Observer Key: jo is Jonathan Owens; cw is Chris White; sb is Scott Brown, bm is Bonnie Mallory
   Hydrograph: R=Rising; F=Falling; B=Baseflow; U=Uncertain
   All specific conductance and temperature measurements were made in the field.
2) Ammonia samples were preserved upon collection with sulfuric acid (H_2SO_4) to pH<2.
3) Dissolved metals samples were filtered in the field and preserved with nitric acid (HNO_3).
4) TSS detection limit is dependent on sample volume, 5 mg/L is the detection limit for a 500 ml sample.
5) Limits vary with analytical method, laboratory, quality control measures, and amount of sample dilution.
   Aluminum, mercury, nitrate and pesticides analyses performed by Caltest (Napa);
   all other laboratory analyses performed by the City of Palo Alto WWTP.
6) Duplicate samples were collected at both stations on 2/28/02.
7) Sample collected due to anomalous specific conductance readings (general minerals analysis in Table 4).
8) Un-ionized ammonia concentrations in excess of 0.025 mg/L can be toxic (RWQCB, 1995).
   The proportion of total ammonia in the un-ionized form is a function of pH and temperature.
9) Biostimulatory constituents should not be present in amounts that stimulate excessive aquatic growth (RWQCB, 1995).
10) Waters should remain free of toxics at concentrations lethal to or adversely impacting aquatic organisms (RWQCB, 1995).
11) Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses (RWQCB, 1995).
12) Metals objectives are hardness-dependent (RWQCB, 1995), range shown is for hardness of 250 to 500 mg/L as $CaCO_3$.
    Copper, 1-hour average = (e{0.9422 [ln(hardness)] - 1.700}) x (0.960)
    Copper, 4-day average = (e{0.8545 [ln(hardness)] - 1.702}) x (0.960)
    Lead, 1-hour average = (e{1.273[ln(hardness)] - 1.460}) x (1.46203 - {[ln(hardness)] x [0.145712]})
    Lead, 4-day average = (e{1.273[ln(hardness)] - 4.705}) x (1.46203 - {[ln(hardness)] x [0.145712]})
    Nickel, 1-hour average = (e{0.8460 [ln(hardness)] + 2.255 }) x (0.998)
    Nickel, 4-day average = (e{0.8460 [ln(hardness)] + 0.0584}) x (0.997)
    Zinc, 1-hour average = (e{0.8473 [ln(hardness)] + 0.884 }) x (0.986)
    Zinc, 4-day average = (e{0.8473 [ln(hardness)] + 0.884}) x (0.978)
13) Per RWCB (1995), ammonia, 1-hour average, salmonids present = $(0.275/1 + 10^{7.204\text{-pH}}) + (39.0/1 + 10^{\text{pH-}7.204})$
    Ammonia, 30-day average, fish early life stages present = $(0.0577/1 + 10^{7.688\text{-pH}}) + (2.487/1 + 10^{\text{pH-}7.688})$
14) Per RWCB (1995),silver, instantaneous maximum = (e{1.72 [ln(hardness)] - 6.52}) x (0.85)

Table 4. General minerals analysis for September 19, 2002 sampling, Los Trancos Creek at Piers Lane.

	General							*Cations*					*Anions*			*Trace Metals*		
Date and Time	**Hardness**	**pH**	**Alkalinity, Bicarbonate**	**Alkalinity, Carbonate**	**Alkalinity, Hydroxide**	**Specific conductance**	**Total dissolved solids**	**Calcium**	**Magnesium**	**Manganese**	**Potassium**	**Sodium**	**Chloride**	**Nitrate-N**	**Sulfate**	**Copper**	**Iron**	**Zinc**
Analytical	*(mg/L)*		*(mg/L)*	*(mg/L)*	*(mg/L)*	*cm @ 25°C)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
Detection Limit:	3.3	1.0	1.0	1.0	1.0	1.0	10	0.5	0.5	0.01	0.5	0.5	2.0	0.5	5.0	0.01	0.1	0.02
Los Trancos Creek at Piers Lane																		
9/19/2002 16:00	830	8.0	360	ND	ND	1920	1450	130	120	0.011	1.3	91	190	0.4	500	ND	ND	ND

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

1) Because the Palo Alto WWTP and Caltest laboratories are closed on weekends, this sample was analyzed by Curtis & Tompkins, Ltd. (Berkeley) to ensure that the short (48-hour) holding time for nitrate-nitrogen analysis would be met.

FIGURES

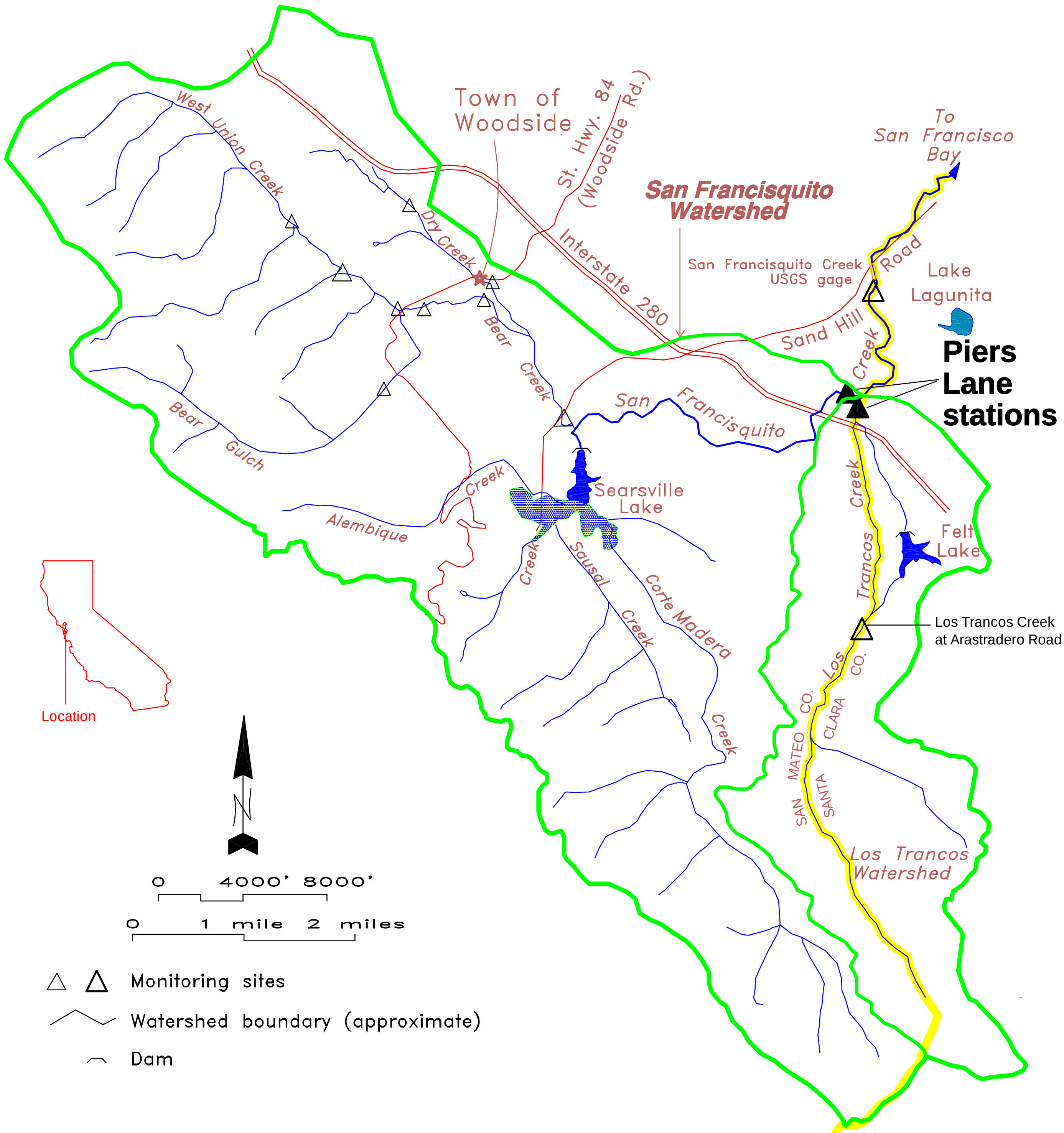

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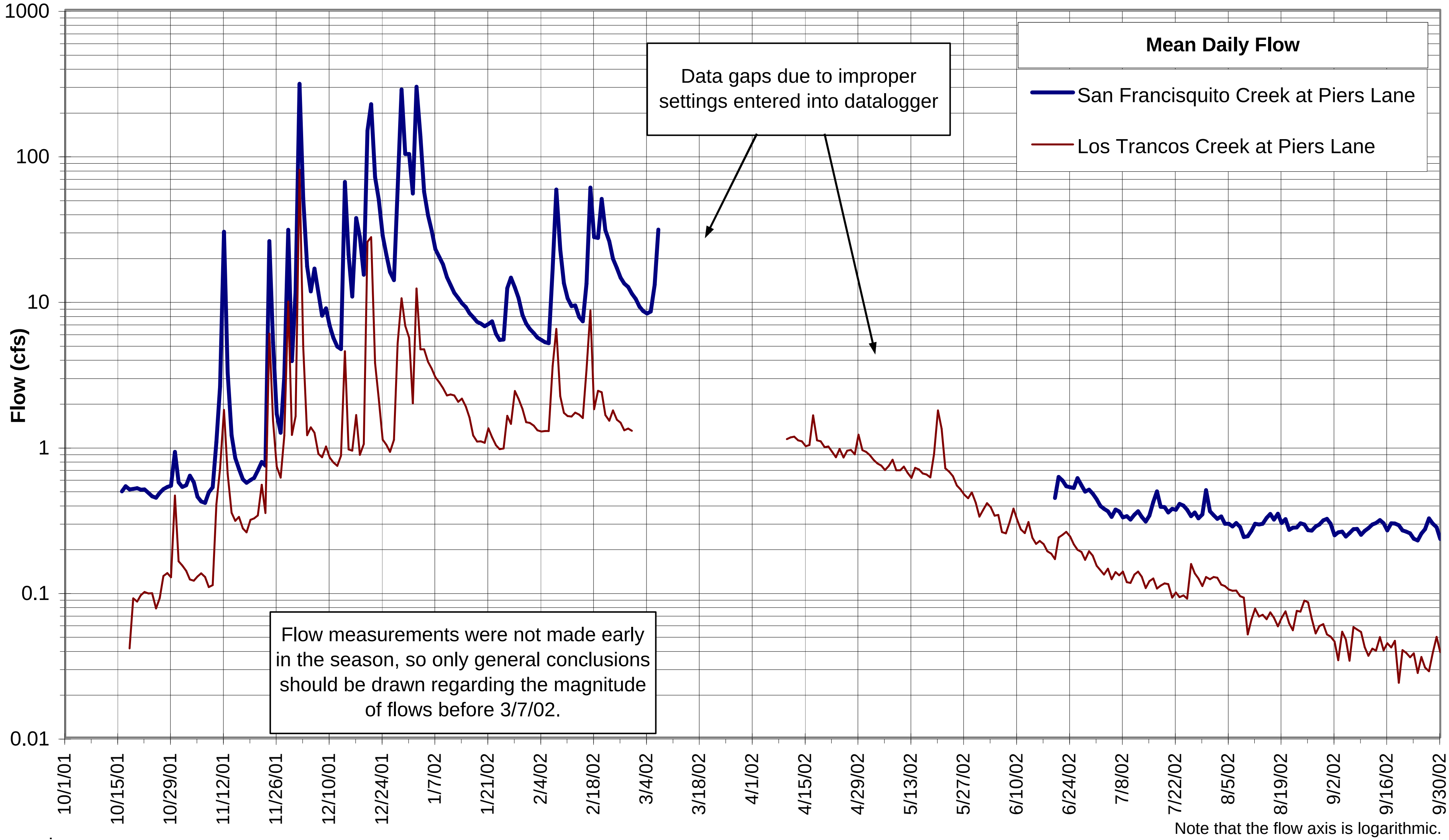
Figure 1. Site location and watershed map.

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



Balance Hydrologics, Inc.

Figure 2. Daily flow hydrographs for San Francisquito and Los Trancos Creeks at Piers Lane, water year 2002. Flow in San Francisquito Creek is greater than flow in Los Trancos Creek, as one would expect by its larger drainage area. Daily peak flows are not shown here, but are higher than the mean daily flows (Figures 4 and 5).

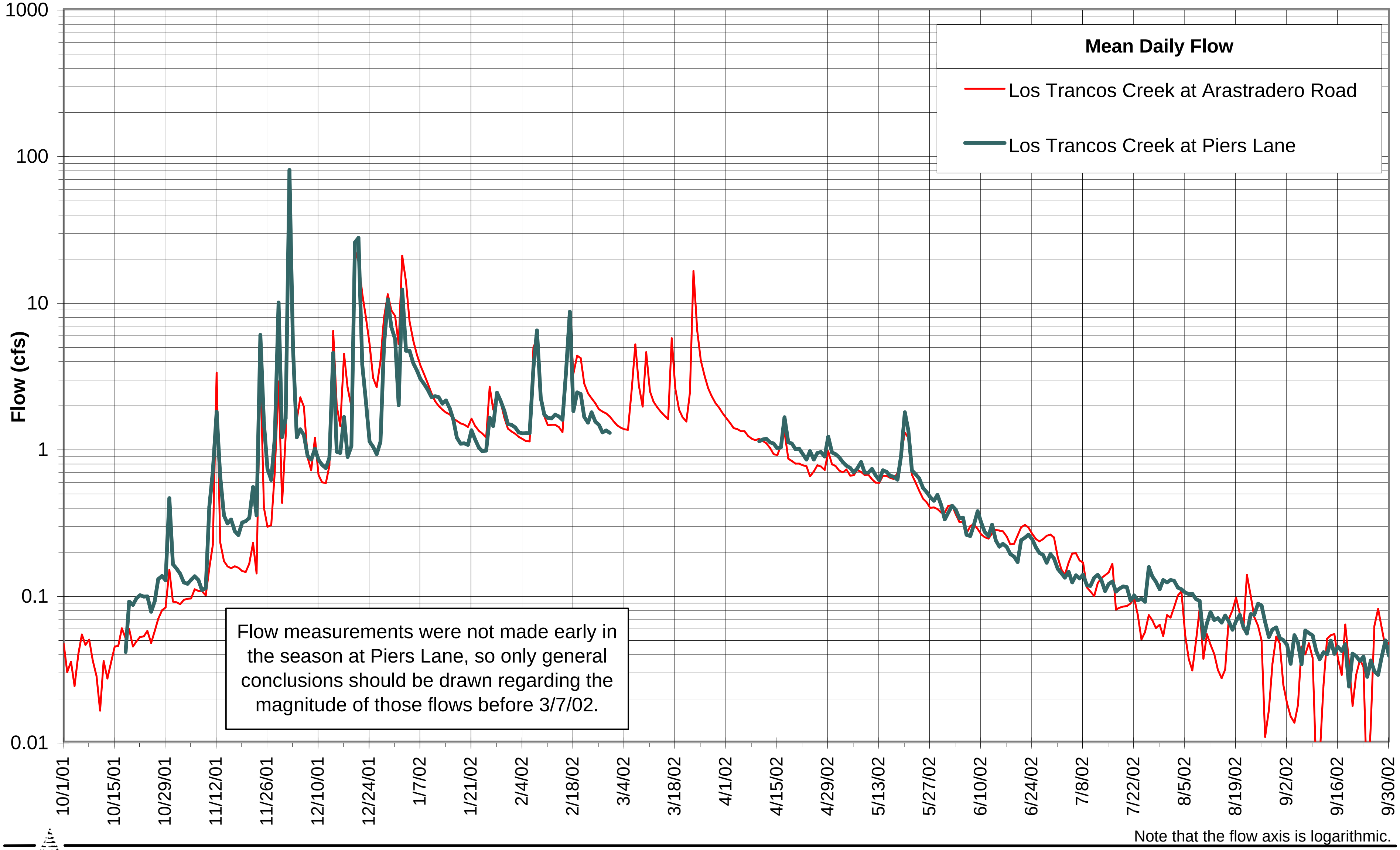


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Figure 3. Daily flow hydrographs for Los Trancos Creek, at both Piers Lane and Arastradero Road, water year 2002. This plot is intended as a general check of the data; based on this graph the Piers Lane record seems valid. The Arastradero Road site is about 1.5 miles upstream from Piers Lane.

Piers Lane_2002_DAY_SUM.xls, Flow (LT,LT), 4/25/2003

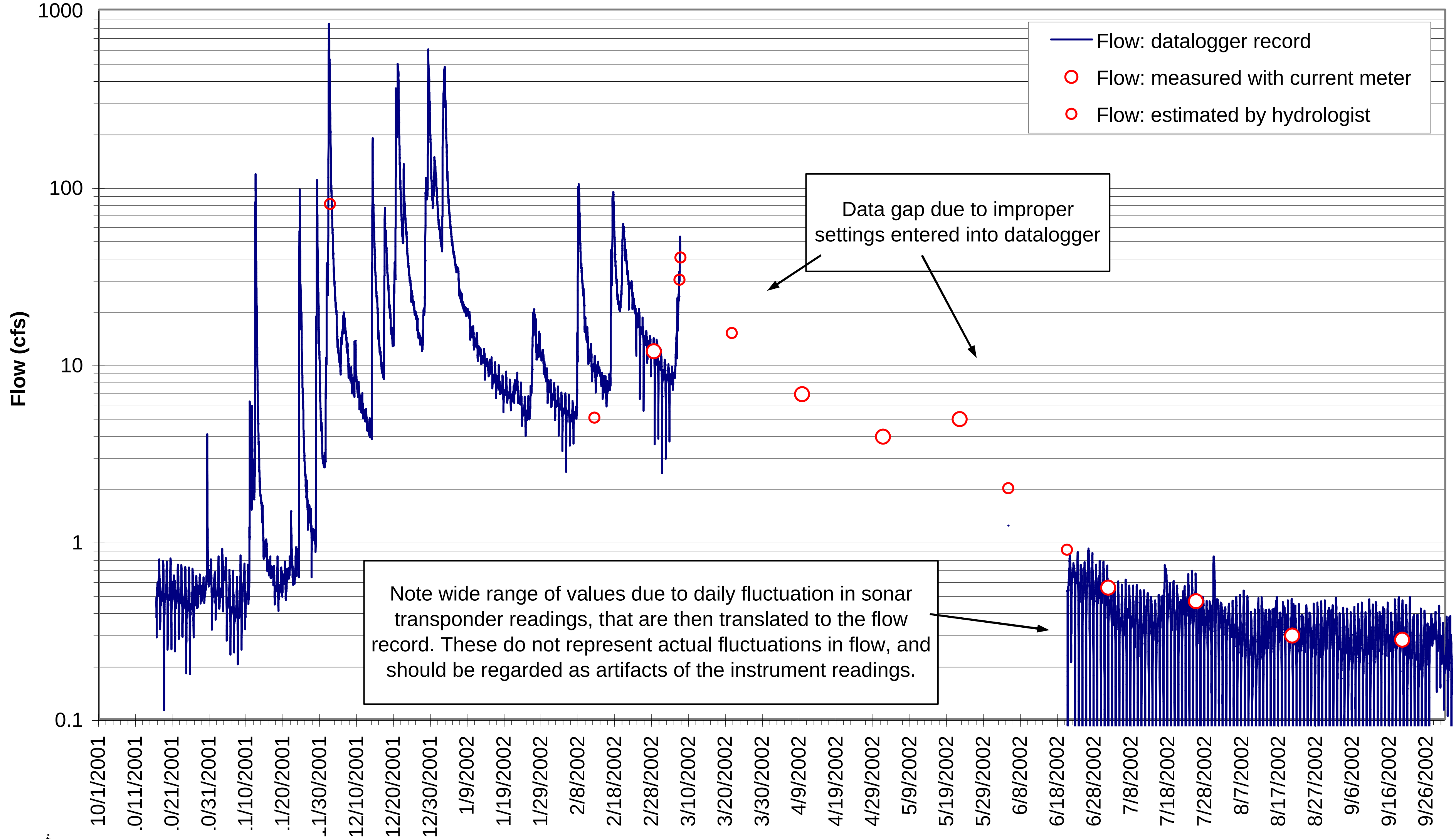

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Figure 4. Flow hydrograph (15-minute intervals): San Francisquito Creek at Piers Lane.
The peak flow occurred December 2, 2001, with a calculated peak of about 830 cfs.

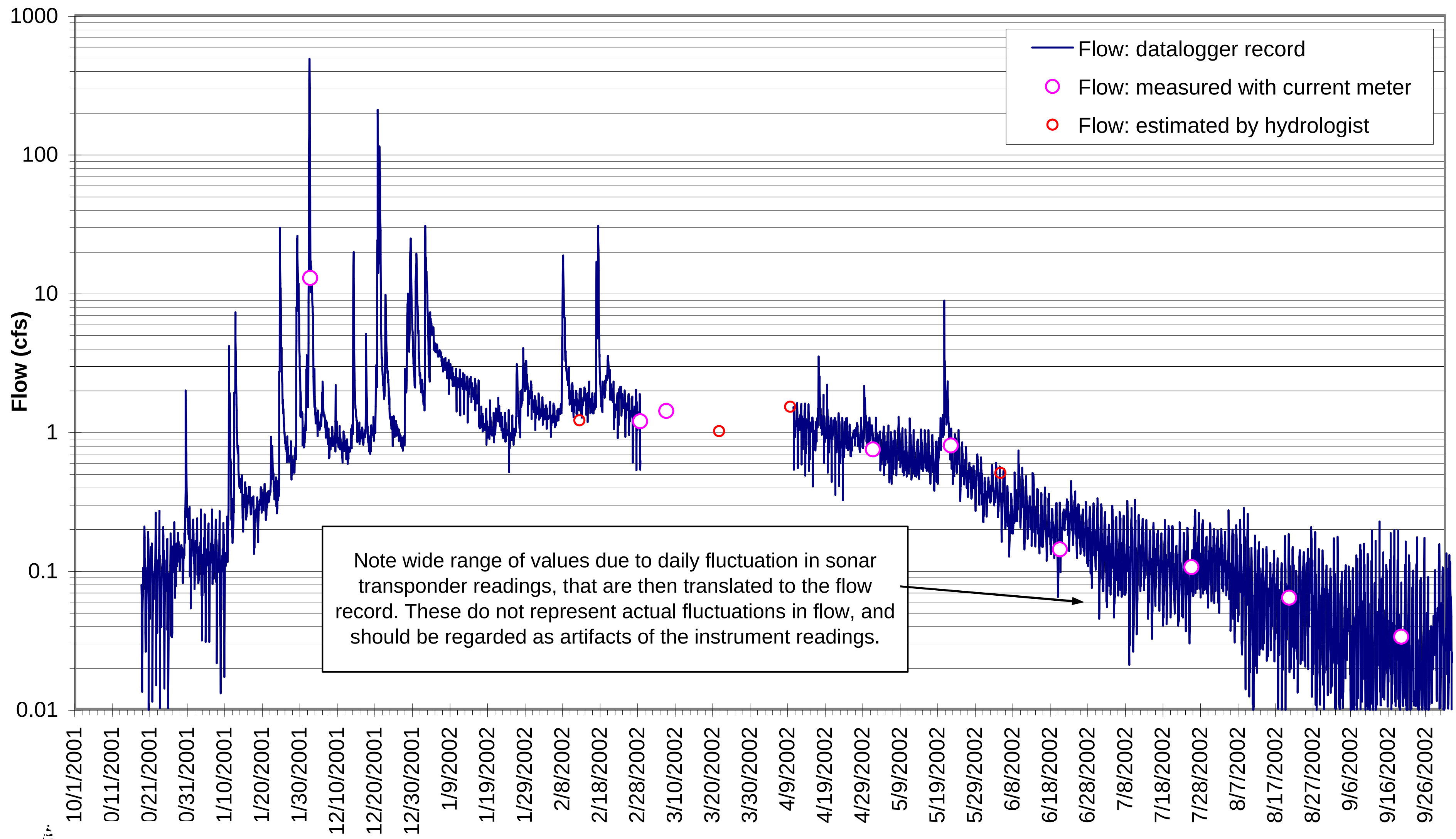

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Figure 5. Hourly flow record: Los Trancos Creek at Piers Lane. The peak flow occurred December 2, 2001, with a calculated peak of about 480 cfs.

4/25/2003, WY02_LTPL_15min.xls, hour flow

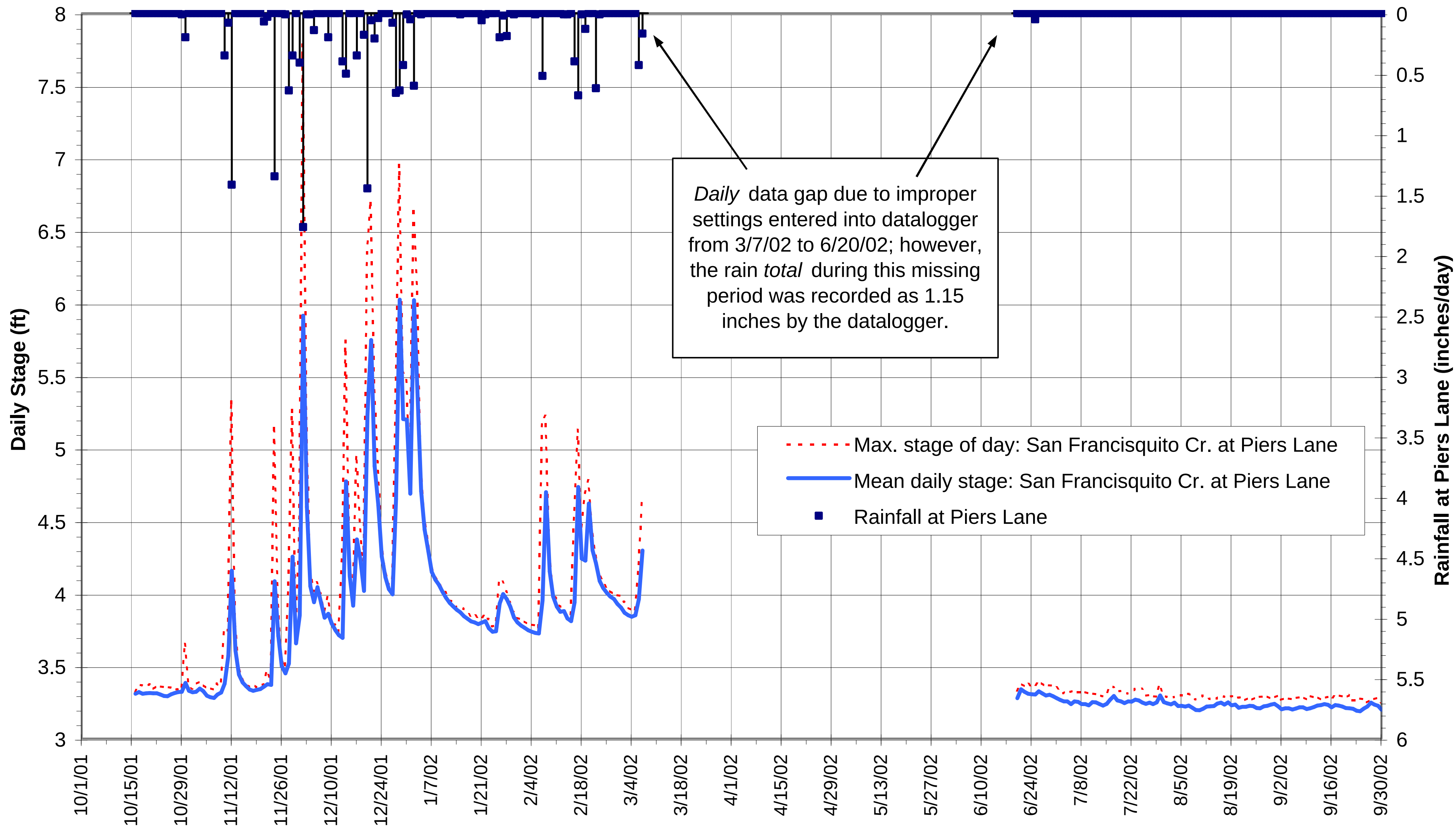

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Figure 6. Daily stage hydrograph and rainfall record for San Francisquito Creek at Piers Lane, water year 2002. Total rainfall for the year was 17.42 inches (this includes the period of missing daily data for which the instruments recorded only an accumulated total. Rainfall at Piers Lane is expected to be much lower than in the headwaters of the watershed.

Piers Lane_2002_DAY_SUM.xls, Stage SF, 4/25/2003

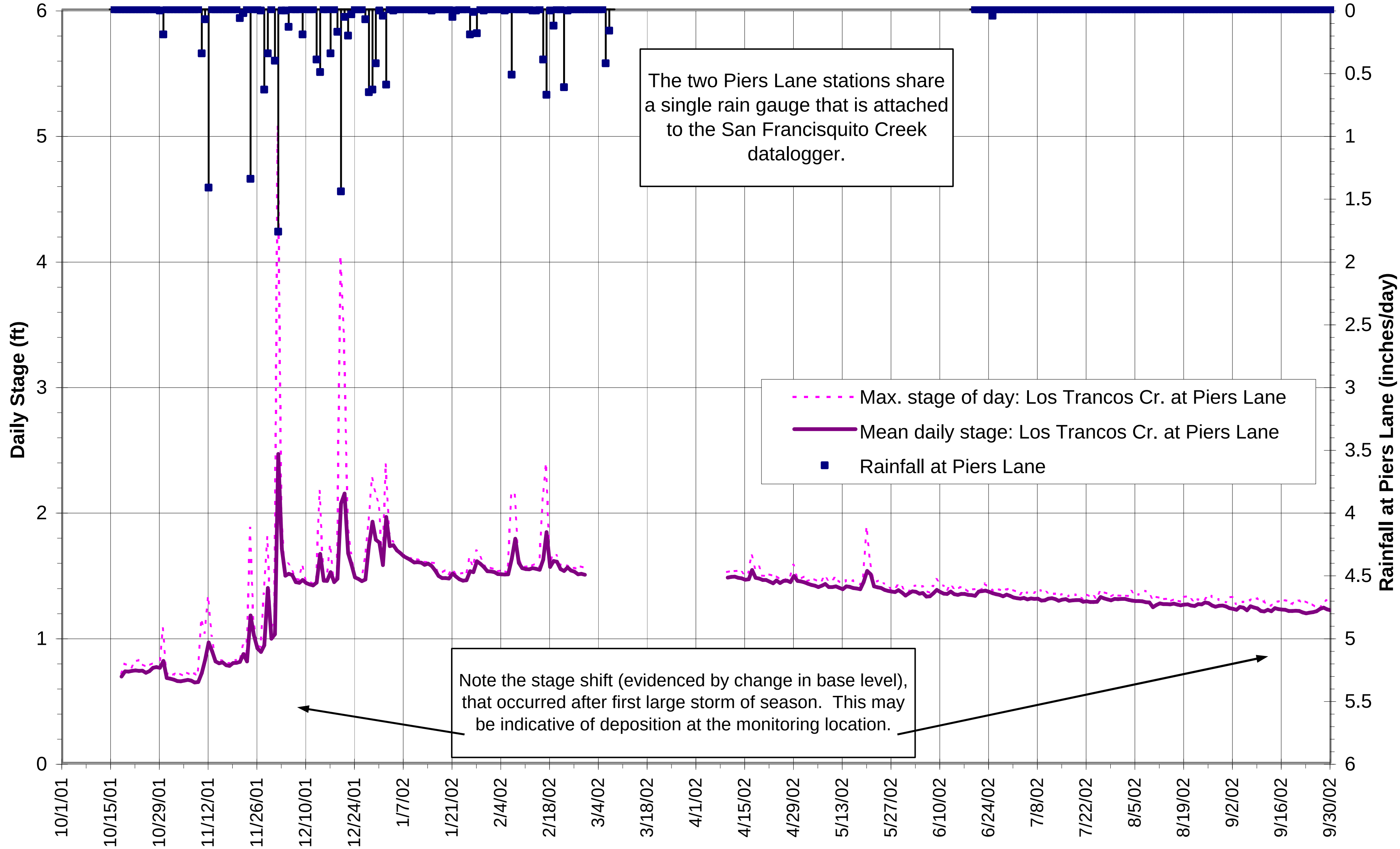

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Figure 7. Daily stage hydrograph and rainfall record for Los Trancos Creek at Piers Lane, water year 2002. Rainfall totals and intensities, at Piers Lane, are expected to be lower and lighter than in the headwaters of the watershed.

Piers Lane_2002_DAY_SUM.xls, Stage LT, 4/25/2003

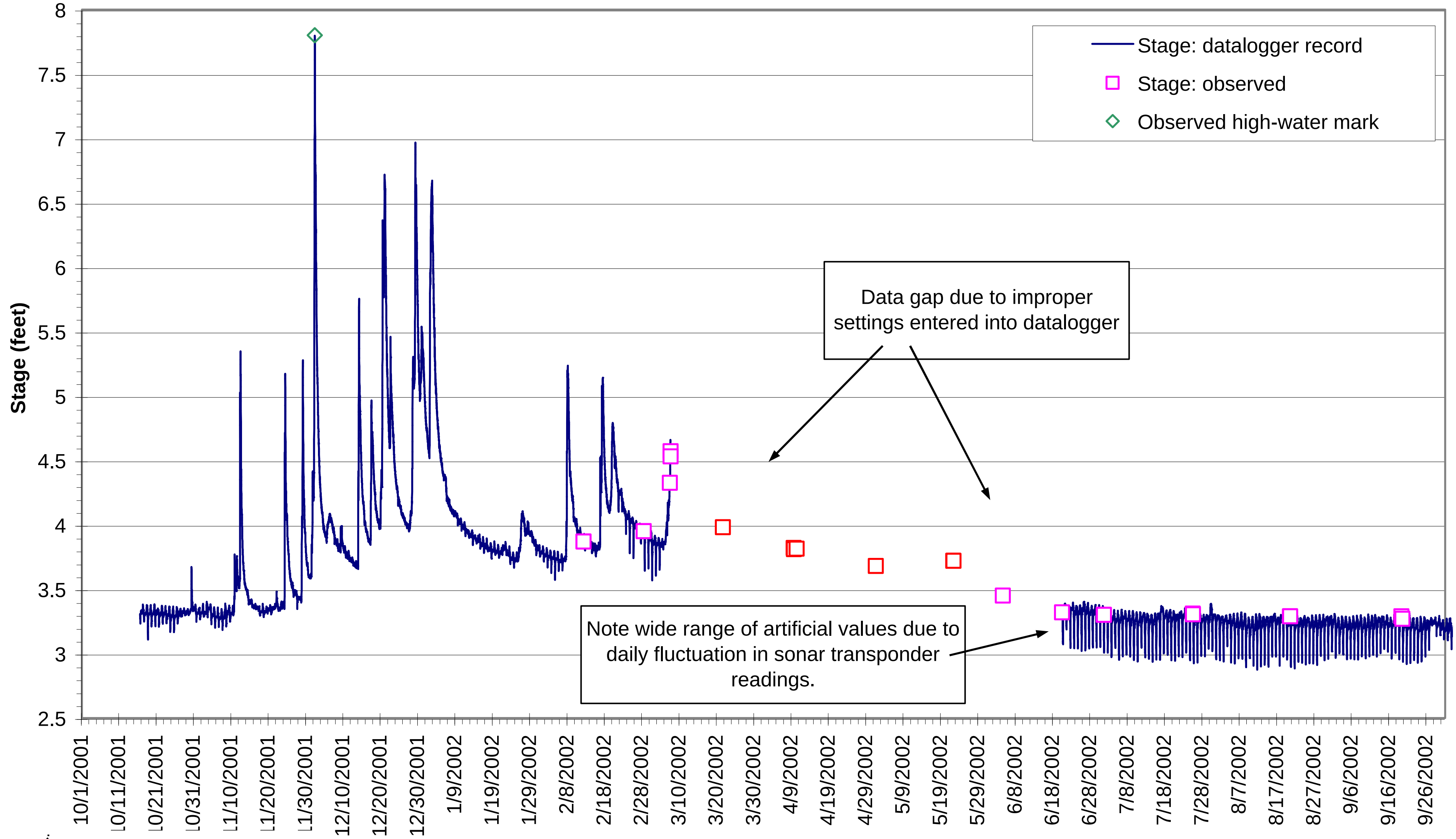

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Figure 8. Stage hydrograph (15-minute intervals): San Francisquito Creek at Piers Lane.
Stage refers to staff-plate readings and does not represent the absolute depth of water in the creek.

4/25/2003, WY02_SFPL_15min.xls, 15-stage

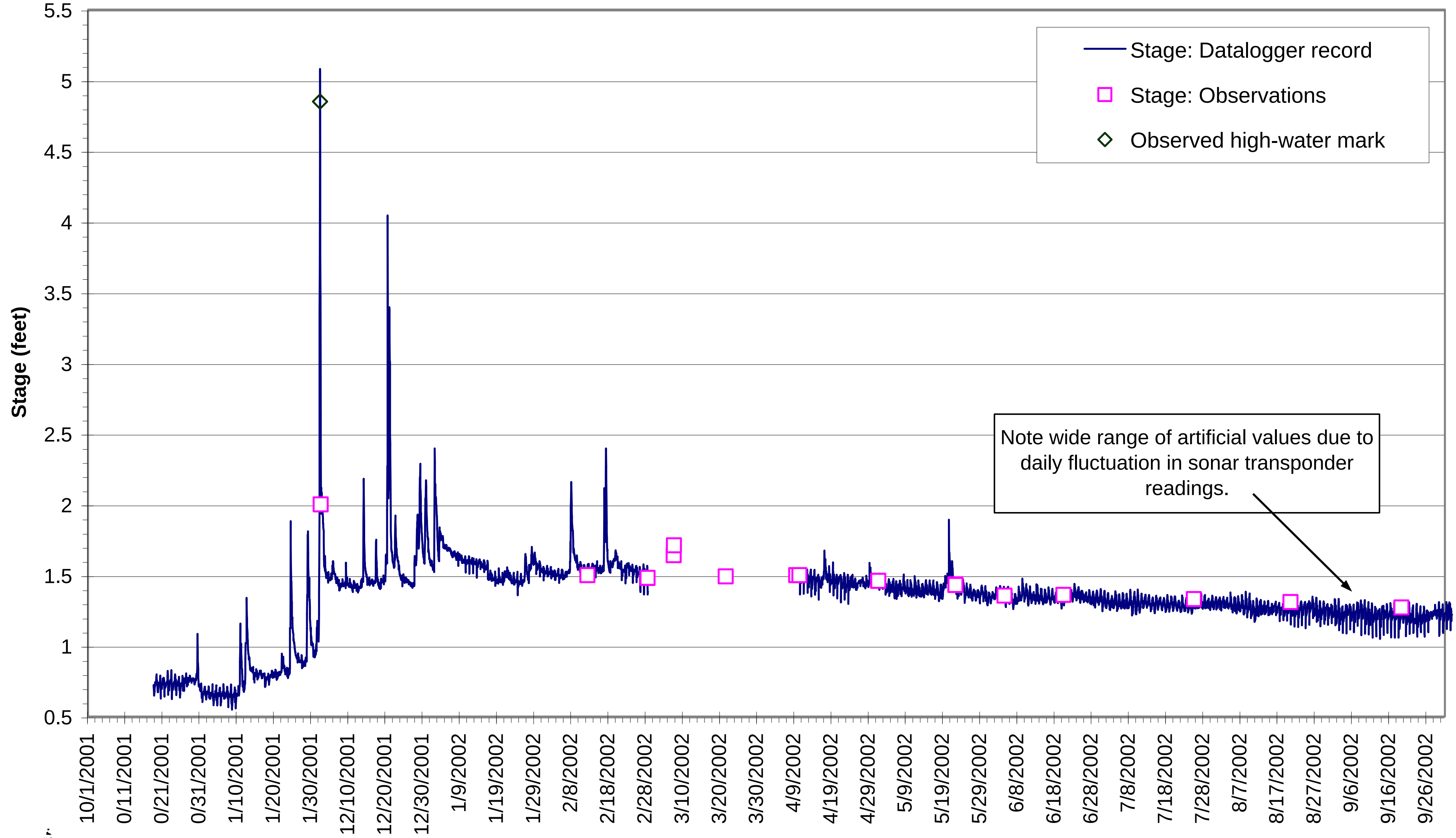

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Figure 9. Stage record (hourly): Los Trancos Creek at Piers Lane. Stage refers to staff-plate readings and does not represent the absolute depth of water in the creek.

4/25/2003, WY02_LTPL_15min.xls, hour stage

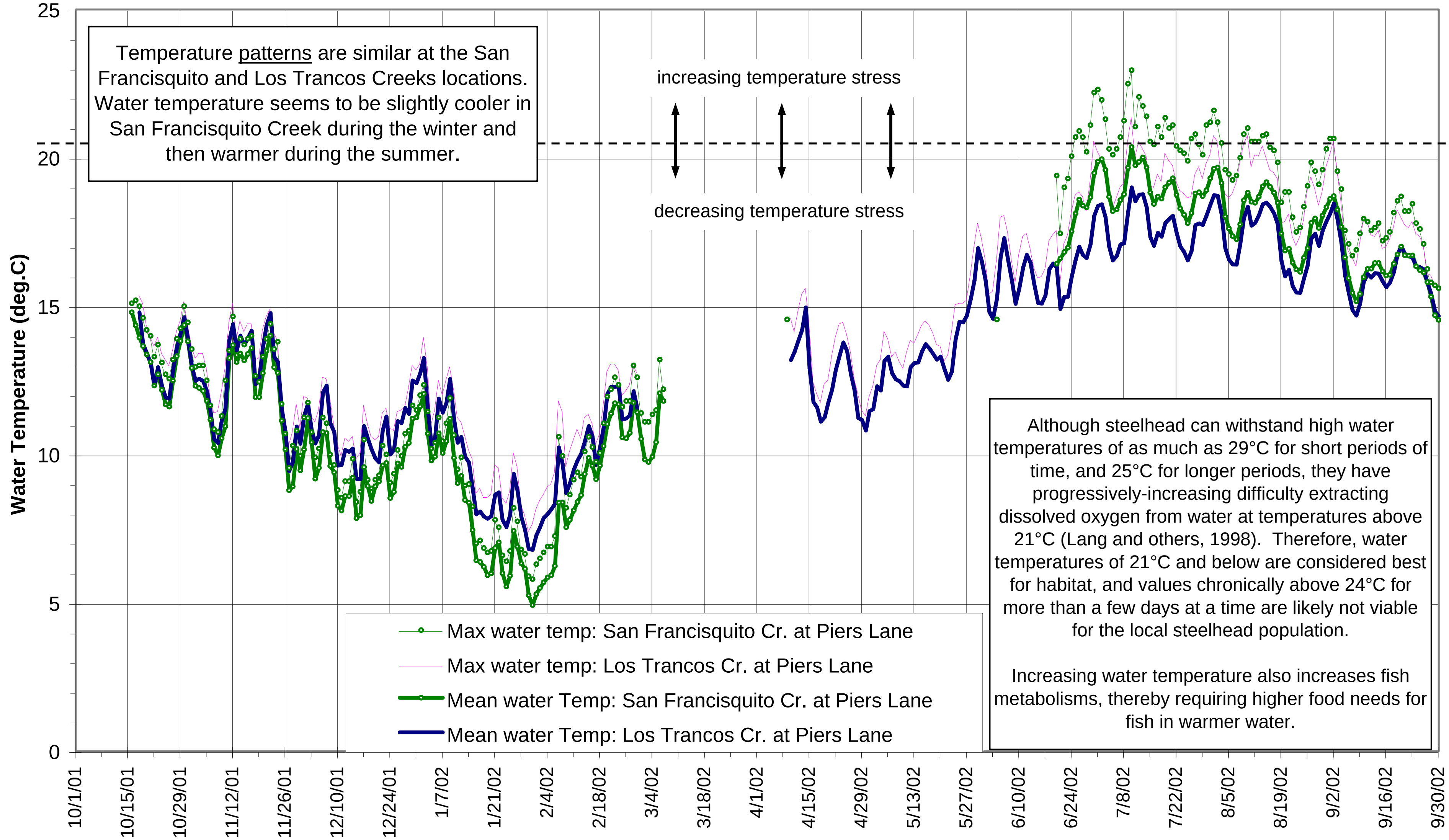

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Figure 10. Daily water temperature record at Piers Lane: San Francisquito and Los Trancos Creeks, water year 2002. Water temperatures are fairly high during short periods during the summer, particularly in San Francisquito Creek.

Piers Lane_2002_DAY_SUM.xls, Temp LTSF, 4/25/2003

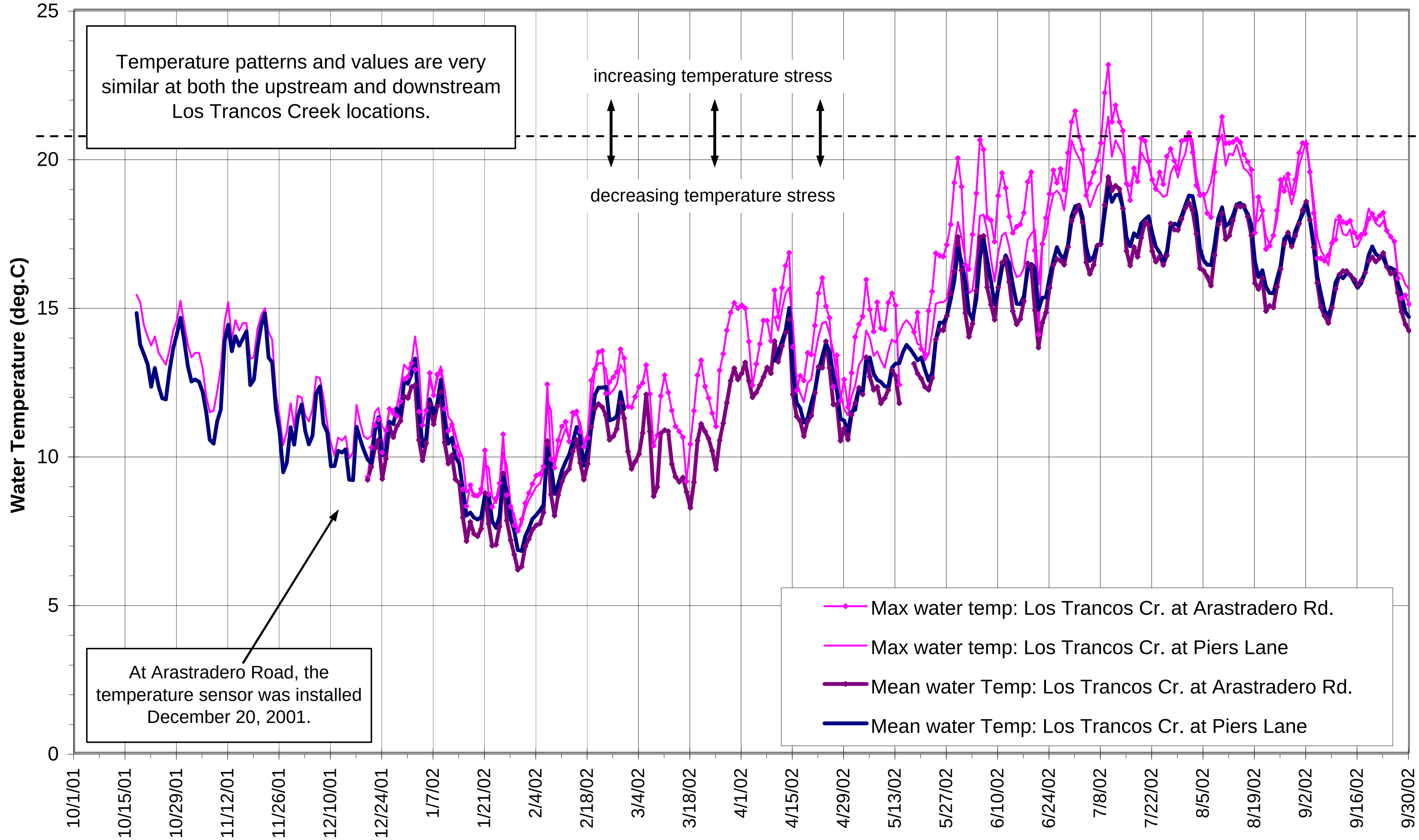

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Figure 11. Daily water temperature record: Los Trancos Creek at Piers Lane and Arastradero Road, water year 2002. Arastradero Road is about 1.5 miles upstream from Piers Lane.

Piers Lane_2002_DAY_SUM.xls, Temp LT, 4/25/2003

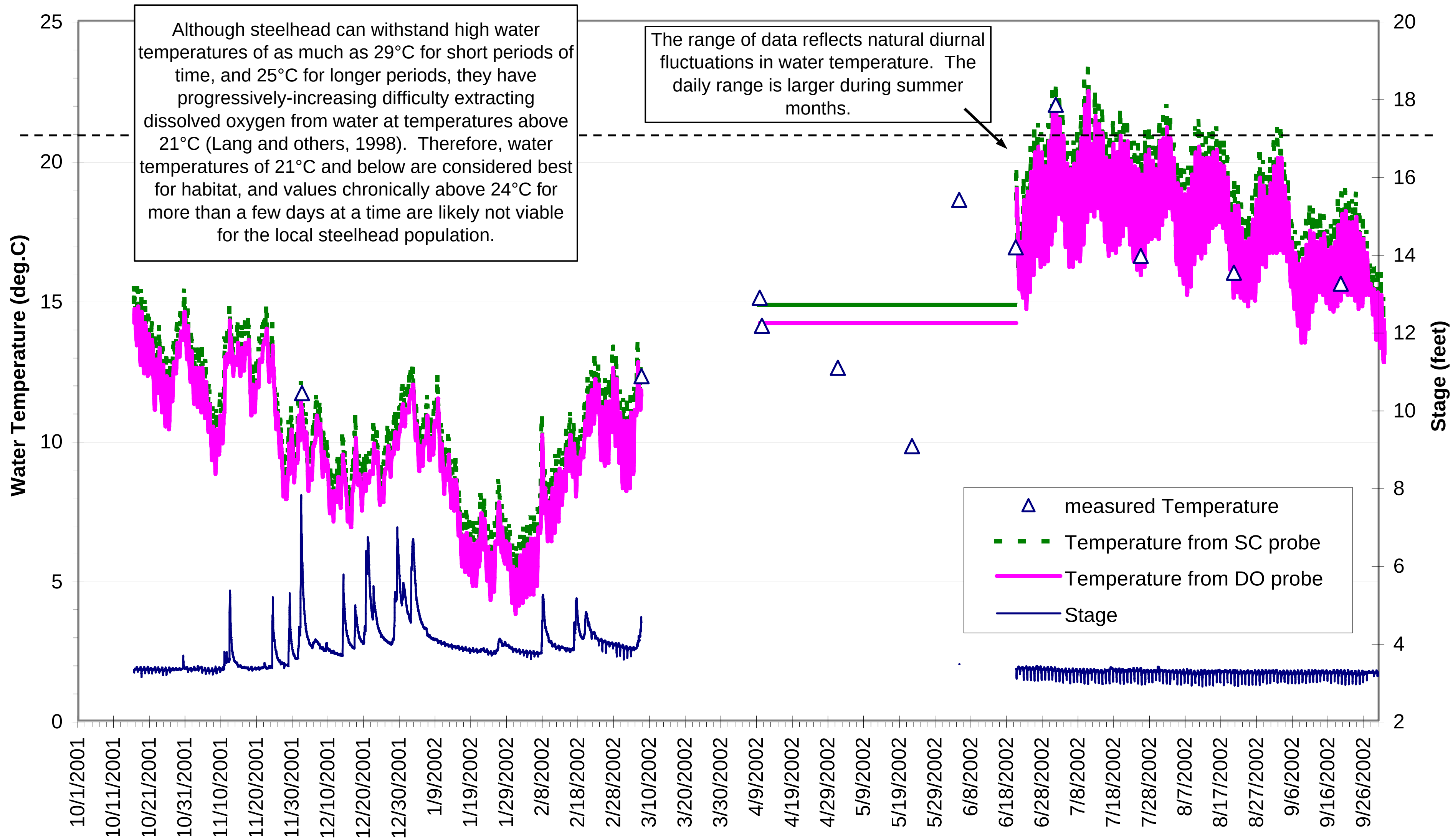

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Figure 12. Hourly water temperature record: San Francisquito Creek at Piers Lane. The temperature records generally agree with the manual measurements. The stage record is plotted for reference.

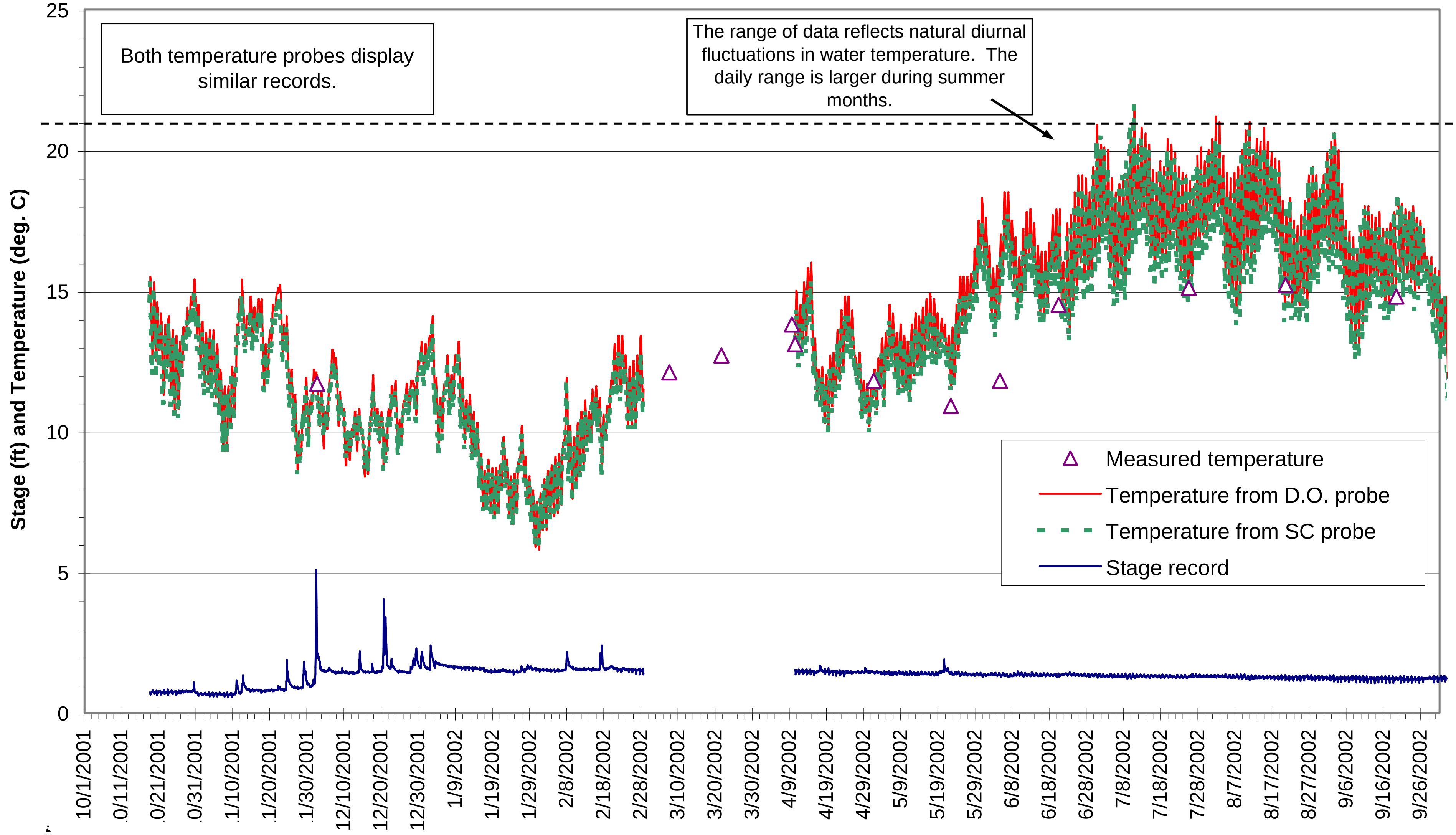

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Figure 13. Hourly water temperature record: Los Trancos Creek at Piers Lane. The temperature records generally agree with the manual measurements. The stage record is plotted for reference.

4/25/2003, WY02_LTPL_15min.xls, hour temp

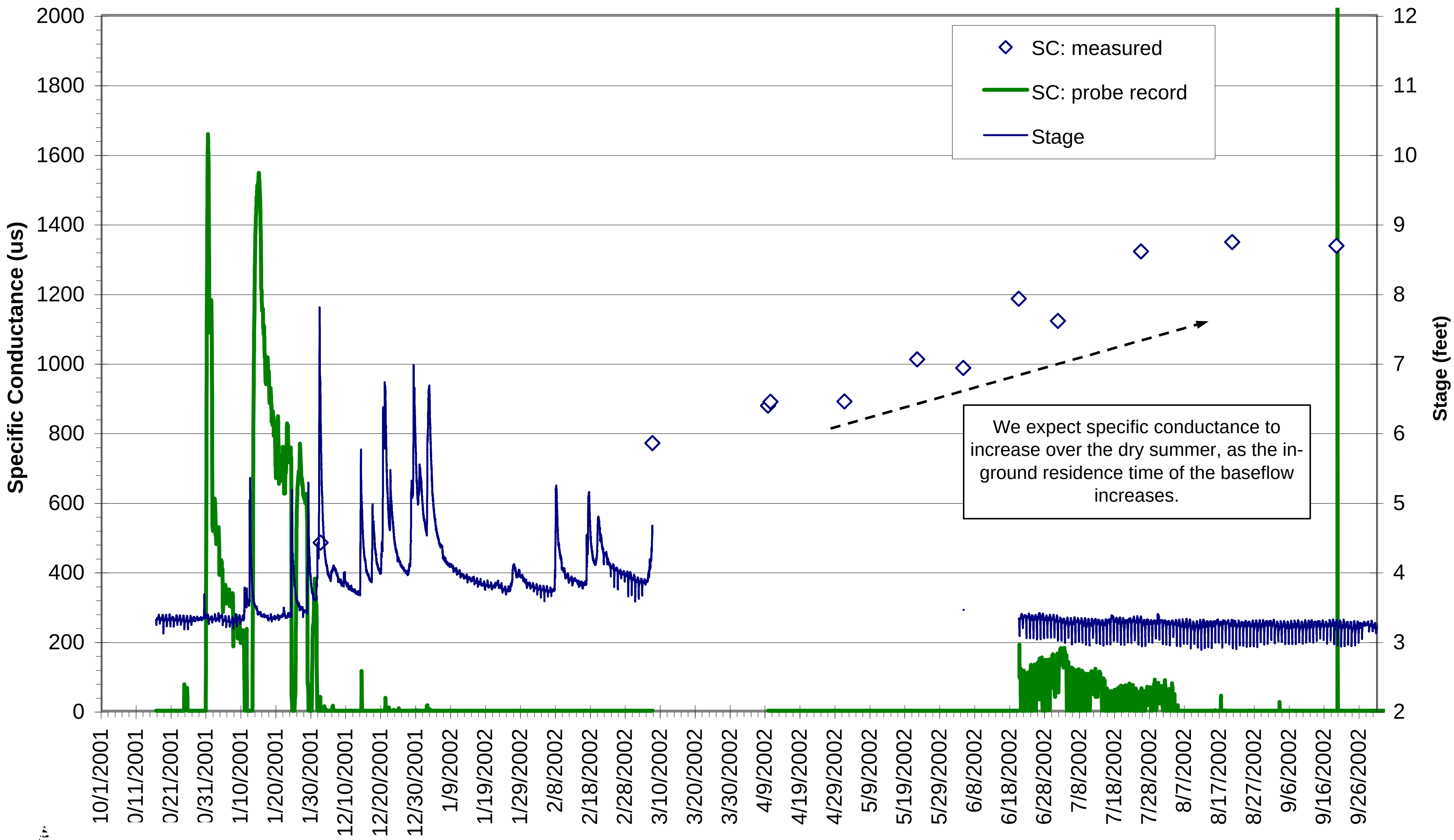
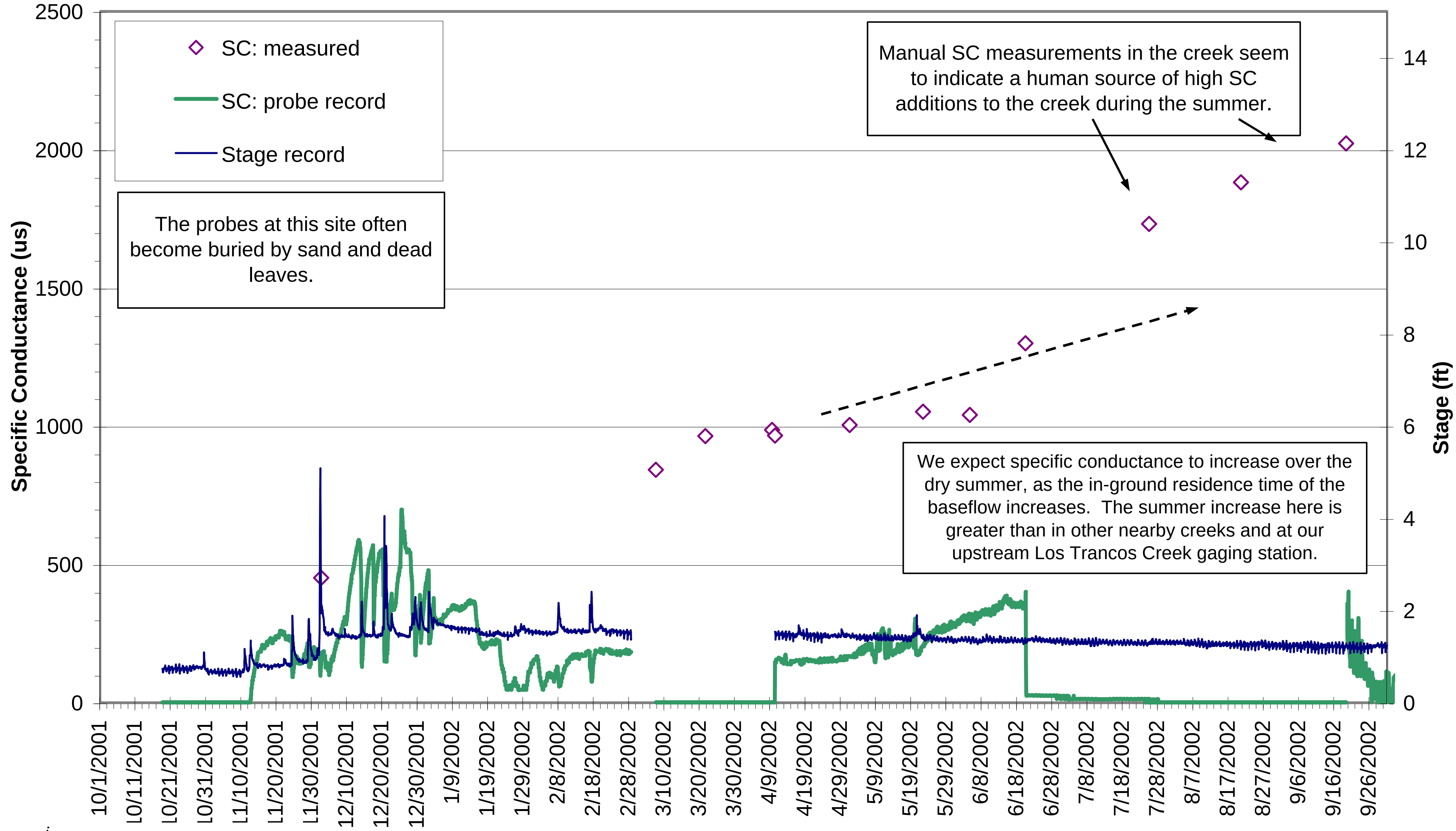


Figure 14. Hourly specific conductance record: San Francisquito Creek at Piers Lane. The specific conductance record does not agree with the manual measurements, indicating that the probe never worked properly. The stage record is plotted for reference.

Balance Hydrologics, Inc.



Balance Hydrologics, Inc.

Figure 15. Hourly specific conductance record: Los Trancos Creek at Piers Lane. The specific conductance record does not agree with the manual measurements, indicating that the probe never worked properly. The stage record is plotted for reference.

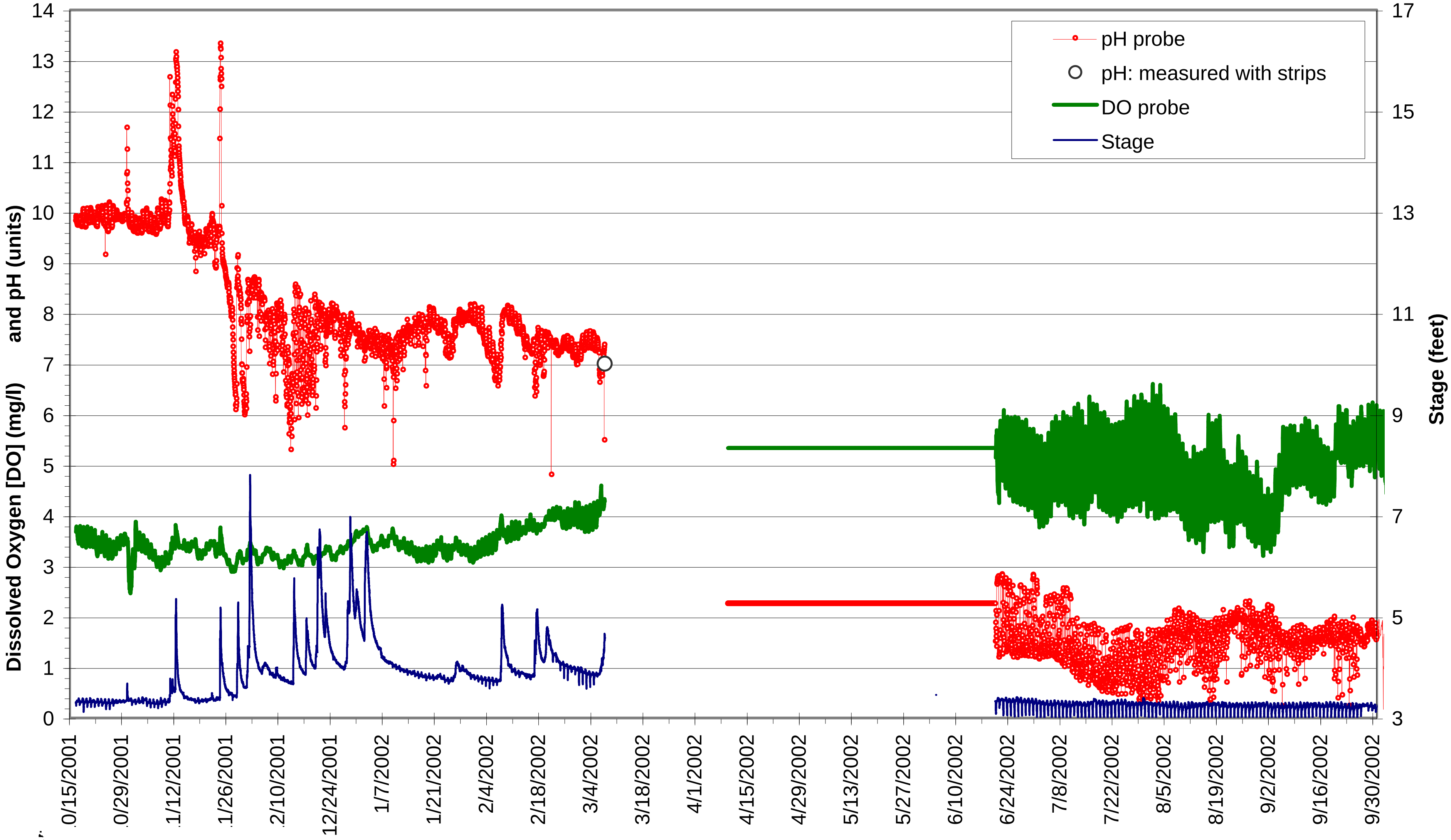


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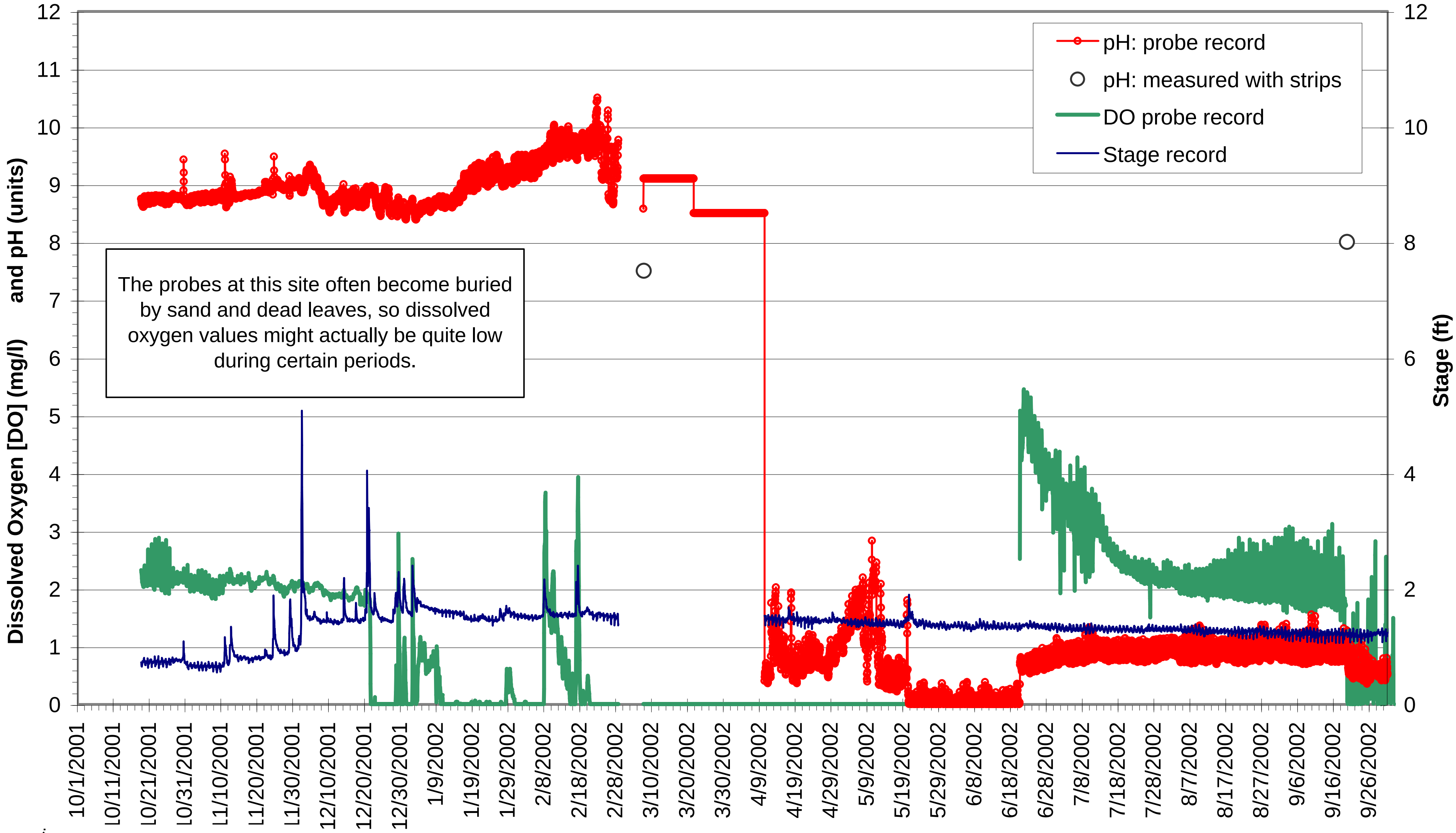
Figure 16. Hourly dissolved oxygen and pH records: San Francisquito Creek at Piers Lane. We made limited manual measurements for comparison, however the pH values seem realistic early in the season but not during the summer. In contrast, the dissolved oxygen values seem too low early in the year, but seem more realistic during the summer. The stage record is plotted for reference.



Balance Hydrologics, Inc.

Figure 17. Hourly dissolved oxygen and pH records: Los Trancos Creek at Piers Lane. We made limited manual measurements for comparison, however the pH values seem realistic early in the season, but unrealistic during the spring and summer. In contrast, the dissolved oxygen values seem too low early in the year, but seem more realistic during the summer. The stage record is plotted for reference.

APPENDICES

Appendix A

Not included in the electronic version of this report