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Summary of Suspended-Sediment Concentration Data, San Francisco Bay, California, Water Year 2008

Data Series 634

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2011

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Conversion Factors, Datums, Abbreviation, and Acronyms

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per second (ft/s)	0.3048	meter per second (m/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, "North American Vertical Datum of 1988 (NAVD 88)."

Mean lower low water (MLLW): The average of the lower low water height above the bottom, in feet, of each tidal day observed during the National Tidal Datum Epoch. The National Tidal Datum Epoch is the specific 19-year period (1960–1978 for values given in this report) adopted by the National Ocean Service as the official time segment during which tide observations are taken and reduced to obtain mean values

Abbreviations and Acronyms

ADAPS automated data–processing system

DWR California Department of Water Resources

FNU formazin nephelometric unit

FTS Forest Technology Systems

mg/L milligram per liter

mV millivolt

nm nanometer

NTU nephelometric turbidity unit

OLS ordinary least squares (regression)

PI_{np} nonparametric prediction interval

PVC polyvinyl chloride

RMS root-mean-squared (error)

SSC suspended-sediment concentration

USCG U.S. Coast Guard

USGS U.S. Geological Survey

WY water year (October 1–September 30)

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By Paul A. Buchanan and Tara L. Morgan

Abstract

Suspended-sediment concentration data were collected by the U.S. Geological Survey in San Francisco Bay during water year 2008 (October 1, 2007–September 30, 2008). Optical sensors and water samples were used to monitor suspended-sediment concentration at two sites in Suisun Bay, two sites in Central San Francisco Bay, and one site in South San Francisco Bay. Sensors were positioned at two depths at most sites to help define the vertical variability of suspended sediments. Water samples were collected periodically and analyzed for concentrations of suspended sediment. The results of the analyses were used to calibrate the output of the optical sensors so that a record of suspended-sediment concentrations could be derived. This report presents the data-collection methods used and summarizes, in graphs, the suspended-sediment concentration data collected from October 2007 through September 2008. Calibration curves and plots of the processed data for each sensor also are presented.

Introduction

Sediments are an important component of the San Francisco Bay estuarine system. Bottom sediments provide habitat for benthic organisms and are a reservoir for nutrients that contribute to estuarine productivity (Hammond and others, 1985). Potentially toxic substances, such as metals and pesticides, can adsorb to sediment particles (Kuwabara and others, 1989; Domagalski and Kuivila, 1993; Flegal and others, 1996). Benthic organisms can then ingest these substances and introduce them into the food web (Luoma and others, 1985; Brown and Luoma, 1995; Luoma, 1996). The mobilization, resuspension, and deposition of suspended sediments are important factors in determining the transport and fate of sediment-associated contaminants. Large tidal-induced current velocities and wind waves in shallow water are capable of resuspending bottom sediments (Powell and others, 1989; Schoellhamer, 1996). Suspended sediments limit the penetration of light into San Francisco Bay and, thus, affect photosynthesis and primary phytosynthetic carbon production (Cloern, 1987, 1996; Cole and Cloern, 1987). Sediments also are deposited in ports and shipping channels, which then require dredging to remain navigable (U.S. Environmental Protection Agency, 1992).

In Suisun Bay, the maximum suspended-sediment concentration (SSC) typically marks the position of the turbidity maximum—a crucial ecological zone where suspended sediments, nutrients, phytoplankton, zooplankton, larvae, and juvenile fish accumulate (Peterson and others, 1975; Arthur and Ball, 1979; Kimmerer, 1992; Jassby and Powell, 1994; Schoellhamer and Burau, 1998; Schoellhamer, 2001). The U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers, is studying the factors that affect SSC in San Francisco Bay.

Purpose and Scope

This report summarizes suspended-sediment concentration (SSC) data collected by the USGS in San Francisco Bay during water year (WY) 2008 and is the latest in a series of reports that present the data collected beginning in WY 1992 (Buchanan and Schoellhamer, 1995, 1996, 1998, 1999; Buchanan and others, 1996; Buchanan and Ruhl, 2000, 2001; Buchanan and Ganju, 2002, 2003, 2004, 2005; Buchanan and Lionberger, 2006, 2007, 2009; and Buchanan and Morgan, 2010). Collection of SSC data in San Francisco Bay required development of monitoring methods and calibration techniques, which are presented in this report. SSC were monitored at two sites in Suisun Bay, two sites in Central San Francisco Bay, and one site in South San Francisco Bay. SSC data from WY 1992 through WY 2008 were used to help determine the factors that affect SSC in San Francisco Bay (U.S. Geological Survey, accessed March 30, 2010, at URL: http://ca.water.usgs.gov/user_projects/sfbay/publications_group.html). Numerical SSC data are available from the U.S. Geological Survey (accessed March 30, 2010, at URL: *http://sfbay.wr.usgs.gov/sediment/cont_monitoring/index.html*).

Study Area

San Francisco Bay (fig. 1) comprises several major subembayments: Suisun Bay, San Pablo Bay, Central San Francisco Bay (Central Bay), and South San Francisco Bay (South Bay). In San Francisco Bay, tides are semidiurnal (two high and two low tides per day) and have a range of about 5.5 feet (ft) in Suisun Bay, 6.5 ft at the Golden Gate and Central Bay, and about 10 ft in South Bay. The tides also follow a 14 and ¾-day spring-neap cycle. Typical tidal currents range from 0.6 foot per second (ft/s) in shallow water to more than 3 ft/s in deep channels (Cheng and Gartner, 1984; Smith, 1987). Typically, the strongest winds are sea breezes that blow onshore during summer afternoons. Most precipitation occurs from late autumn to early spring. Freshwater discharge into San Francisco Bay is greatest in the spring as a result of runoff from snowmelt flowing into the Sacramento-San Joaquin River Delta. About 90 percent of the discharge into the Bay is from the Sacramento-San Joaquin River Delta, which drains the Central Valley of California (Smith, 1987).

Typically, discharge from the Delta contains about 60 percent of the fluvial sediments that enter the Bay (McKee and others, 2006), though this percentage varies from year to year. During wet winters, turbid plumes of water from the Delta have extended into South Bay (Carlson and McCulloch, 1974). The bottom sediments in South Bay and in the shallow water areas (about 12 ft or less) of Central, San Pablo, and Suisun Bays are composed mostly of silts and clays. Silts and sands are present in the deeper parts of Central, San Pablo, and Suisun Bays and in Carquinez Strait (Conomos and Peterson, 1977).

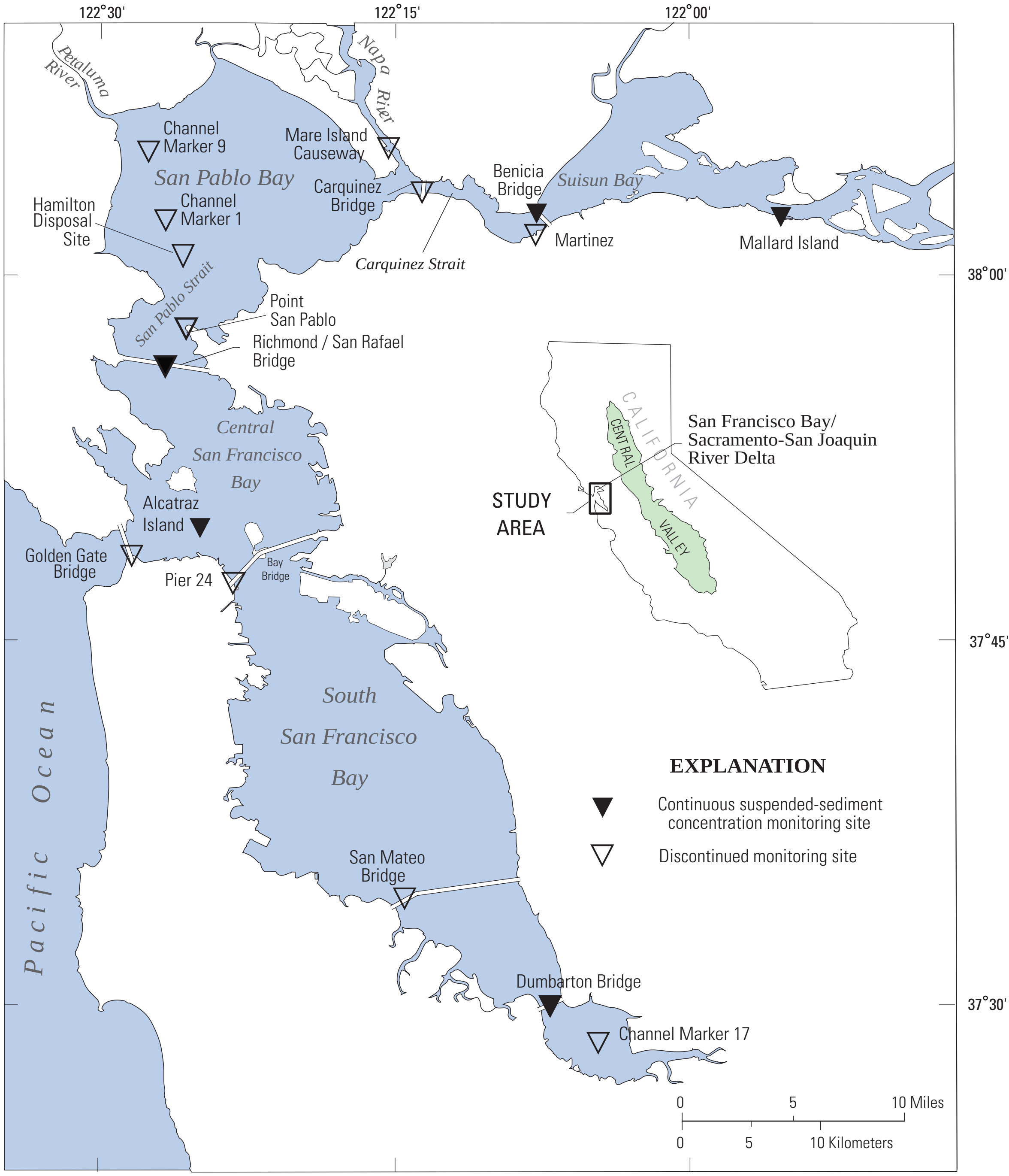

Figure 1. SanFrancisco Bay study area, California.

Methods

Instrument Description and Operation

Two types of optical sensors were used to monitor SSC during WY 2008. The first type of sensor, a digital turbidity sensor, the DTS–12, manufactured by Forest Technology Systems (FTS), is self-cleaning and measures the intensity of light scattered at 90 degrees between a laser diode (780 nm wavelength) and a high-sensitivity silicon photodiode detector. The output, in formazin nephelometric units (FNU), is converted to millivolts (mV) when recorded on a separate data logger. The second type of sensor, model 6136 manufactured by Yellow Springs Instruments (YSI), Inc., also measures the intensity of light scattered at 90 degrees between a light-emitting diode (860 +/– 30 nm wavelength) and a high-sensitivity photodiode detector, and the output (FNU) is processed by internal software. In previous reports, the output of the DTS–12 and the YSI, Inc., sensors was reported as nephelometric turbidity units (NTU). The USGS has created new reporting units for turbidity that are based on the instrument design (Office of Water Quality, 2004). The design of both the DTS–12 and the YSI, Inc., instruments specify the use of FNU as the reporting unit. The YSI, Inc. instruments (sondes) are self-contained and include a power source (AA-sized batteries), data logger, and the capability of supporting additional sensors. The YSI, Inc., and FTS data loggers collect instantaneous values every 15 minutes. Power to the data logger used with the FTS sensor was supplied by 12-volt batteries.

Optical sensors were positioned in the water column by using polyvinyl chloride (PVC) pipe carriages coated with an antifoulant paint to impede biological growth. Carriages were designed to align with the direction of flow and to ride along a stainless steel suspension line attached to an anchor weight, which allowed sensors to be easily raised and lowered for servicing (fig. 2). The plane of the optical window maintained a position parallel to the direction of flow as the carriage aligned itself with the changing direction of flow. Optical sensor depths in the water column are listed in table 1.

Biological growth (fouling) interferes with the collection of accurate optical-sensor data. Self-cleaning optical sensors were used at all sites. Fouling generally was greatest on the sensor closest to the water surface. Fouling of the cleaning mechanism or the sensor body could begin to obscure the sensor optics and affect sensor output from 5 days to several weeks after servicing a monitoring station, depending on the level of biological activity in the bay. Because of the difficulty in servicing some of the monitoring stations, sensors were cleaned manually every 3–5 (usually 3) weeks. Generally, fouling was greatest during spring and summer.

On-site checks of sensor accuracy were performed using turbidity solutions prepared from a 4,000-NTU formazin standard. Formazin is an aqueous suspension of an insoluble polymer and is the primary turbidity standard (Greenberg and others, 1992). The turbidity solutions were prepared by diluting a 4,000-NTU stock standard with de-ionized water in a clean, sealable container. Prepared solutions ranged from 0 to 200 NTU, which defined the expected range of turbidity values in WY 2008. Prepared solutions were checked with a Hach Drel 2000 Spectrophotometer for accuracy (5 percent of measured value as specified by Wagner and others, 2006). At the field site, the cleaned sensors were immersed in the solution and the output was recorded on the station log. Monitoring a period of sensor performance in a known standard helps to identify output drift or sensor malfunction.

Monitoring Sites

Suisun Bay Installations

SSC data were collected in Suisun Bay at Mallard Island and at Benicia Bridge (fig. 1, table 1). Optical sensors were installed at the DWR Mallard Island Compliance Monitoring Station on February 8, 1994. Optical sensors were positioned to coincide with DWR near-surface and near-bottom electrical conductance and temperature sensors. DWR replaced the near-bottom sensors, near-surface pump intake, and associated flow-through water-quality monitor with YSI, Inc., monitors on April 16, 2008. The DWR near-surface YSI, Inc., monitor is attached to a float which positions the monitor about 3 ft below the surface. The near-surface optical sensor is attached to a separate float and positioned at the same depth as the DWR near-surface monitor.

Optical sensors were installed at Pier 7 on the Benicia Bridge on March 15, 1996. The Benicia Bridge station was shut down August 7, 1998, for seismic retrofitting of the bridge and was reestablished May 1, 2001 using sondes equipped with optical, conductance, and temperature sensors. A monitoring station at the Martinez Marina fishing pier was discontinued in WY 1996 because data from the Benicia Bridge site were considered more representative of SSC in the Carquinez Strait area of Suisun Bay (Buchanan and Schoellhamer, 1998).

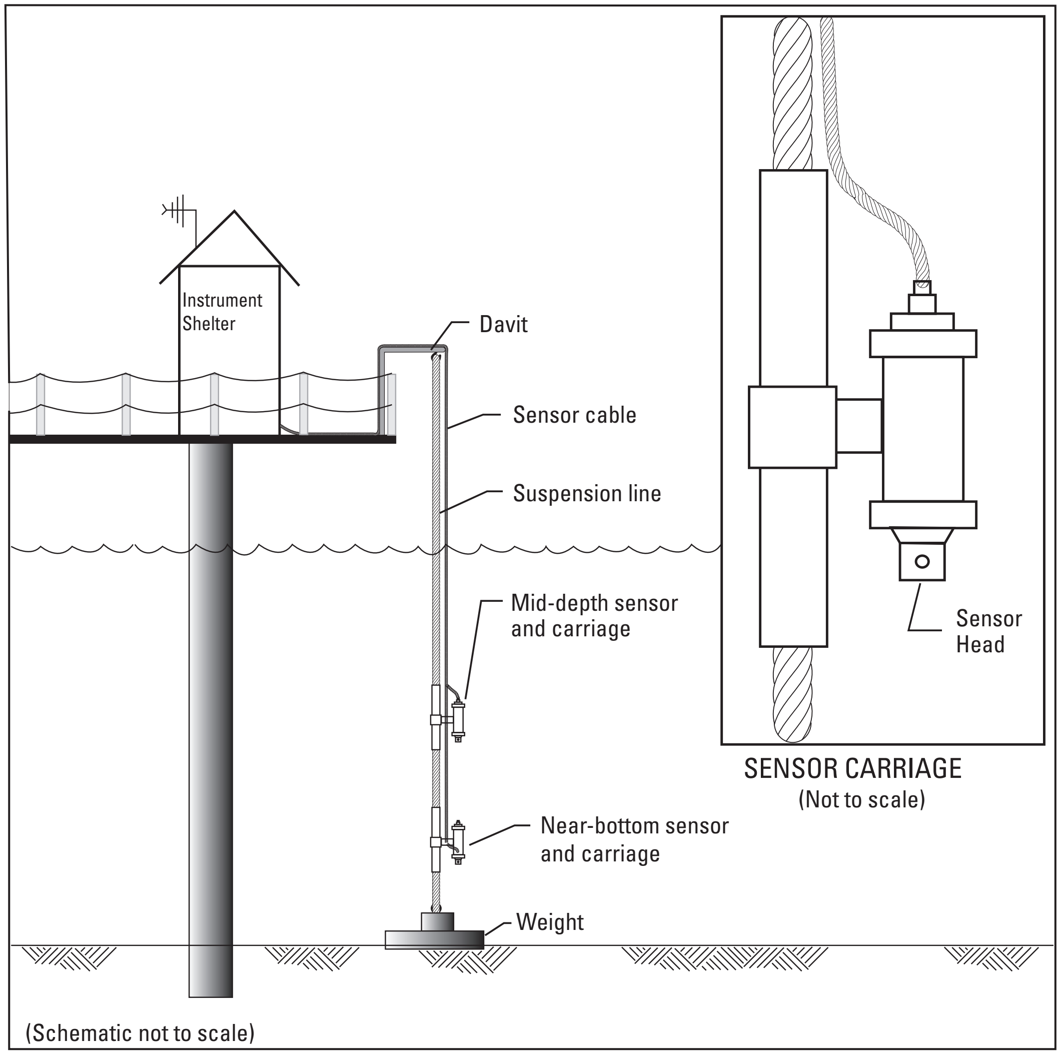

Figure 2. Typical monitoring installation, San Francisco Bay study.

Table 1. Optical sensor depths (in feet) below mean lower low water (MLLW), Suisun Bay, San Pablo Bay, and Central and South San Francisco Bays, California, water year 2008.

[For definition of MLLW, see Conversion Factors, Datum, Abbreviations and Acronyms entry at front of this report]

Site	Station number	Latitude	Longitude	Sensor depth	Depth below MLLW[1]	Water depth at MLLW
Mallard Island	11185185	38°02′34″	121°55′09″	Near-surface	3.3	25
				Near-bottom	20	
Benicia Bridge	11455780	38°02′42″	122°07′32″	Near-surface	9	80
				Near-bottom	61	
Richmond/San Rafael Bridge	375607122264701	37°56′07″	122°26′47″	Mid-depth	15	45
				Near-bottom	40	
Alcatraz Island	374938122251801	37°49′38″	122°25′18″	Mid-depth	6	16
Dumbarton Bridge	373015122071000	37°30′15″	122°07′10″	Mid-depth	20	45
				Near-bottom	41	

[1]Depth below water surface.

San Pablo Bay Installations

No SSC data were collected in San Pablo Bay in WY 2008 (fig. 1). A monitoring station at USCG Channel Marker 9 was discontinued October 7, 2003. A monitoring station at USCG Channel Marker 1 was discontinued September 28, 2005. A monitoring station at Napa River at Mare Island Causeway was discontinued October 11, 2005. SSC monitoring was discontinued at Carquinez Bridge October 19, 2005 (specific conductance and water temperature were monitored at this site in WY 2008). A monitoring station at Point San Pablo was discontinued on August 1, 2006. A monitoring station at the Hamilton Disposal Site was discontinued November 16, 2006. The Hamilton site was reestablished July 24, 2008, but no usable SSC data were collected in WY 2008.

Central San Francisco Bay Installations

SSC data were collected in Central San Francisco Bay at Alcatraz Island and at Richmond/San Rafael Bridge (fig. 1, table 1). A sonde with optical turbidity, conductance, and temperature sensors was installed on the northeast side of Alcatraz Island on November 6, 2003. Sondes with optical, conductance, and temperature sensors were installed on the Richmond/San Rafael Bridge pier west of the main channel on October 18, 2006. A monitoring station at the south tower of the Golden Gate Bridge was operational during WY1996 and WY1997. A monitoring station at San Francisco Bay at Pier 24 was discontinued on January 3, 2002.

South San Francisco Bay Installations

SSC data were collected in South San Francisco Bay at Dumbarton Bridge (fig. 1, table 1). Optical sensors were installed at Pier 23 on the Dumbarton Bridge on the west side of the ship channel on October 21, 1992. SSC monitoring was discontinued at San Mateo Bridge on October 19, 2005 (specific conductance and water temperature were monitored at this site in WY 2008). A monitoring station at USCG Channel Marker 17 was discontinued on October 26, 2005.

Water-Sample Collection

Water samples used to calibrate the output of the optical sensors to SSC were collected by using a horizontally positioned Van Dorn-style sampler, usually after the sensors were cleaned. In previous water years, samples were collected before the sensors were cleaned; however, the time-series data collected before cleaning was often unusable as a result of fouling, and the calibration points from the water samples were discarded. The Van Dorn-style sampler is a plastic tube with rubber stoppers at each end that snap shut when triggered by a small weight dropped down a suspension cable. The Van Dorn-style sampler was lowered to the depth of the sensor by a reel and crane assembly, and then triggered while the sensor was collecting data. After collection, the water sample was marked for identification and placed in a clean, 1-liter plastic bottle for transport. The SSC of water samples collected with a Van Dorn-style sampler and a P–72 point sampler, used until WY 1994, were virtually identical (Buchanan and others, 1996).

SSC samples were analyzed at the USGS Sediment Laboratory in Marina, California. Suspended sediment includes all particles in the sample that do not pass through a 0.45-micrometer membrane filter. The analytical method used to quantify concentrations of suspended solid-phase material was consistent from 1992 through the present study; however, the nomenclature used to describe sediment data was changed. Suspended-sediment concentrations were referred to as suspended-solids concentrations in previous reports (Buchanan and Schoellhamer, 1995, 1996, 1998, 1999; Buchanan and others, 1996; Buchanan and Ruhl, 2000, 2001), but, because the total water-sediment mass and all sediment were measured in the analysis, these data are more appropriately referred to as SSC (Gray and others, 2000). Water samples collected for this study were analyzed for SSC, in milligrams per liter (mg/L), by filtering samples through a pre-weighed, tared, 0.45-micrometer membrane filter. The filtrate was rinsed with de-ionized water to remove salts, and the insoluble material and filter were dried at 103°C then weighed (Fishman and Friedman, 1989).

Data Processing

Data loggers recorded the optical-sensor output at 15-minute intervals (96 data points per day). Recorded data were downloaded from the data loggers onto either a storage module or laptop computer during site visits. Raw data from the storage modules or laptop computer were loaded into the USGS Automated Data–Processing System (ADAPS) and stored with appropriate data descriptors for electrical output and turbidity.

The time-series data were retrieved from ADAPS and processed to remove invalid data. Invalid data included rapidly increasing voltage outputs and unusually high voltage outputs of short duration. As biological growth accumulated on the optical sensors, the voltage output of the sensors increased. An example time-series of raw and processed optical sensor data is presented in figure 3. After sensors were cleaned, sensor output immediately decreased (fig. 3A: November 20; cleaning dates are represented by vertical dashed lines). Because the signal was highly variable, efforts to correct data for biofouling proved to be unsuccessful. Thus, data affected by biofouling often were unusable and were removed from the record (fig. 3B). Identifying the point at which fouling begins to affect optical sensor data is somewhat subjective. Indicators, such as an elevated baseline, increasingly variable signal, and comparisons with the other sensor at the site, are used to help define the point at which fouling begins to take place. Spikes in the data, which are anomalously high readings probably caused by debris temporarily wrapped around the sensor or by large marine organisms (fish, crabs) on or near the sensor, also were removed from the raw data record (fig. 3B). Sometimes, incomplete cleaning of a sensor would cause a small, constant shift in sensor output that could be corrected by using water-sample data that had been collected for calibration of the sensors.

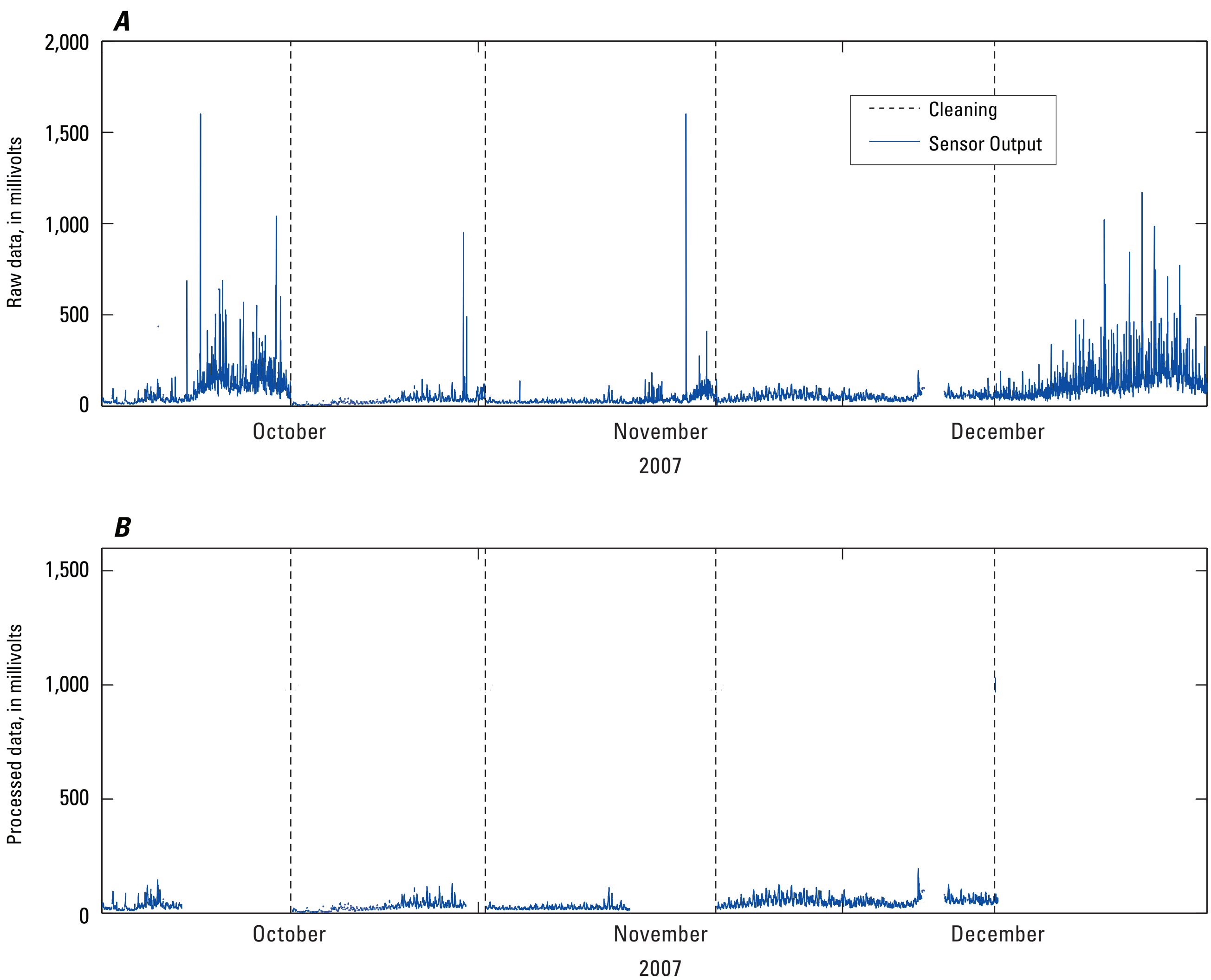

Figure 3. Example of (***A***) raw and (***B***) processed optical sensor data, near-bottom sensor, Dumbarton Bridge, South San Francisco Bay, California, water year 2008.

Sensor Calibration And Suspended-Sediment Concentration Data

The output from each of the two types of sensors used for this study is proportional to the SSC in the water column at the depth of the sensor. SSC calculated from the output of side-by-side sensors with different instrument designs were virtually identical (Buchanan and Schoellhamer, 1998). Calibration of the sensor output to SSC will vary according to the size and optical properties of the suspended sediment; therefore, the sensors must be calibrated by using suspended material from the field (Levesque and Schoellhamer, 1995).

The output from the optical sensors was used to calculate SSC by linear regression using the robust, nonparametric, repeated median method (Siegel, 1982) rather than ordinary least squares (OLS) regression. Constant variance of residuals is a necessary condition for use of OLS regression to obtain the best linear unbiased estimator of a variable (Helsel and Hirsch, 1992, p. 225). The variance of the residuals for some datasets in this study increased with voltage and was not constant; therefore, robust regression was considered to be more appropriate than OLS regression for the development of calibration curves in most cases.

The prediction interval and the 95-percent confidence interval were calculated and presented for each calibration equation. Whenever possible, water-sample data collected in previous water years were included in the calibrations to incorporate the largest range of observed concentrations. Previously collected water-sample data were discarded if the calibration of a sensor had drifted.

The repeated-median method calculates the calibration slope in a two-part process. First, for each point (X, Y) in a set of *n* data points, the median of all possible "point i" to "point j" slopes was calculated:

$$\beta_i = \text{median}\,\frac{(Y_j - Y_i)}{\left(X_i - X_i\right)} \text{ for } j = 1 \ldots n, j \neq i \tag{1}$$

The calibration slope was calculated as the median of b*i* :

$$\text{slope} = \hat{\beta}_1 = \text{median}\,(\beta_i) \quad \text{for } i = 1 \ldots n \tag{2}$$

Finally, the calibration intercept was calculated as the median of all possible intercepts by using the slope calculated above:

$$\text{intercept} = \ddot{\beta}_0 = \text{median}\,(Y_i - \ddot{\beta}_i X_i) \quad \text{for } i = 1 \ldots n \tag{3}$$

The final linear calibration equation is

$$Y = \hat{\beta}_1 X + \hat{\beta}_0 \tag{4}$$

The nonparametric prediction interval (PI_{np}; Helsel and Hirsch, 1992, p. 76 and 243) used for data in this study is a constant-width error band that contains about 68-percent, or one standard deviation, of the calibration data set. The 68-percent value was selected because it has essentially the same error prediction limits as the root-mean-squared (RMS) error of prediction that was used to describe the error associated with parametric OLS regression methods in previous data reports (Buchanan and Schoellhamer, 1995, 1996, 1998, 1999; Buchanan and others, 1996). The prediction interval describes the likelihood that a new observation comes from the same distribution as the previously collected data set.

The PI_{np}, unlike the RMS error of prediction, often is not symmetrical around the regression line. For example, the PI_{np} may be reported as +10 and −7 mg/L. This asymmetry about the regression line is a result of non-normal distribution of the data set. The PI_{np} is calculated by computing and sorting, from least to greatest, the residuals for each point. Then, based on the sorted list of residuals:

$$\hat{Y} + e(L), \hat{Y} + e(U) \quad (5)$$

where

$\hat{Y}$ is the value of the predicted observation,

e(L) and e(U) are the Lth and Uth ranked residuals

$L = (n+1) \bullet a / 2$ and $U = (n+1) \bullet (1 - \frac{a}{2})$

n is the number of data points, and

α is 0.32 for a 68 percent confidence

Previously written as:

$$\text{nonparametric prediction interval} = \mathrm{PI}_{\mathrm{np}} = \hat{Y}_{\left(\frac{\alpha}{2}\right)(n+1)} \text{ to } \hat{Y}_{\left(1-\frac{\alpha}{2}\right)(n+1)} \quad (6)$$

where

$\hat{Y}$ is the residual value,

n is the number of data points, and

α is the confidence level of 0.068.

To calculate the confidence interval for the regression line slope, all possible point-to-point slopes must be sorted in ascending order. On the basis of the confidence interval desired, 95-percent for the purposes of this report, the ranks of the upper and lower intervals are calculated as follows:

$$Ru = \frac{\frac{n(n-1)}{2} + 1.96\left(\sqrt{\frac{n(n-1)(2n+5)}{18}}\right)}{2} + 1, \quad (7)$$

$$R_l = \frac{\frac{n(n-1)}{2} - 1.96\left(\sqrt{\frac{n(n-1)(2n+5)}{18}}\right)}{2}, \quad (8)$$

where

Ru is the rank of the upper interval slope,

R_l is the rank of the lower interval slope,

n is the number of samples.

To establish the 95-percent confidence interval, the ranks calculated above are rounded to the nearest integer, and the slope associated with each rank in the sorted list is identified. Equations 6 and 7, which represent large-sample approximations for the ranks, were used for each of the confidence intervals presented in this report. However, for those sites that had 10 or fewer samples, an alternative and presumably slightly more accurate method, described by Helsel and Hirsch (1992, p. 273–274), was used to calculate upper and lower bound ranks.

A statistical summary of the SSC calculated from optical sensor data is presented in table 2. The usable percentage of a complete year of valid data (96 data points per day × 366 days) for each site also is presented in table 2.

This section of the report also includes figures showing graphical results of the regression analyses (calibration) relating SSC (in mg/L) to optical sensor output. The calibration figures (for example, fig. 4) include the number of water samples (points; all water samples used to develop calibration, including those from previous water years), the linear regression equation, the nonparametric prediction interval (shown on the calibration figures as a grey band), and the 95-percent confidence interval for the regression-line slope. In addition, the time-series plots of calculated SSC data are shown for each site.

Table 2. Statistical summary of calculated suspended-sediment concentration data and usable percentage of a complete year of valid data (96 data points per day x 365 days) collected using optical sensors, Suisun Bay, San Pablo Bay, and Central and South San Francisco Bays, California, water year 2008.

[All values are in milligrams per liter except percent valid data. Lower quartile is 25th percentile; upper quartile is 75th percentile]

Site	Depth	Mean	Median	Lower quartile	Upper quartile	Percent valid data
Mallard Island	Near-surface	30	25	19	37	96
	Near-bottom	33	28	21	40	99
Benicia Bridge	Near-surface	39	30	21	47	90
	Near-bottom	80	68	49	98	84
Richmond/San Rafael Bridge	Mid-depth	24	19	15	27	85
	Near-bottom	27	21	16	30	71
Alcatraz Island	Mid-depth	21	18	14	24	82
Dumbarton Bridge	Mid-depth	56	39	24	66	61
	Near-bottom	85	56	31	101	67

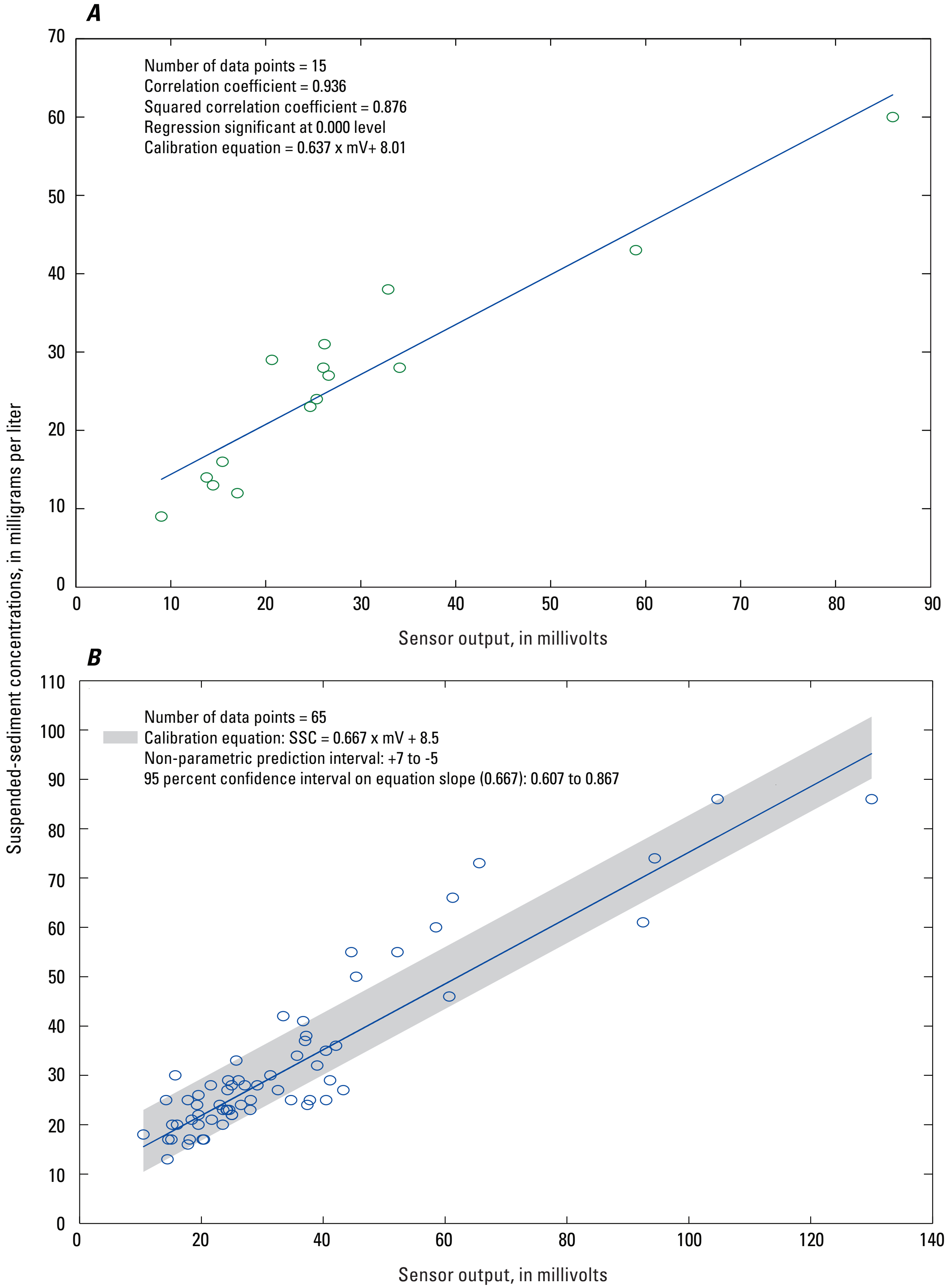

Figure 4. Calibration of near-surface and near-bottom optical sensors at Mallard Island, Suisun Bay, California, water year 2008.

Suisun Bay

Mallard Island

PERIOD OF CALIBRATION.—
NEAR-SURFACE SENSOR: WY 2008 (fig. 4A).
NEAR-BOTTOM SENSOR: WY 2008 (fig. 4B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
NEAR-SURFACE SENSOR: 15 (9 from WY 2008).
NEAR-BOTTOM SENSOR: 65 (9 from WY 2008).
LINEAR REGRESSION EQUATION.—
NEAR-SURFACE SENSOR: SSC = 0.637 × millivolt (mV) + 8.01.
NEAR-BOTTOM SENSOR: SSC = 0.667 × mV + 8.5.
PARAMETRIC PREDICTION INTERVAL.—
NEAR-SURFACE SENSOR: +8 to –1 mg/L.
NONPARAMETRIC PREDICTION INTERVAL.—
NEAR-BOTTOM SENSOR: +7 to –5 mg/L.
95-PERCENT CONFIDENCE INTERVAL ON SLOPE CALCULATION.—
NEAR-SURFACE SENSOR: 0.252 to 1.641.
NEAR-BOTTOM SENSOR: 0.607 to 0.867.

REMARKS—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. Sensors were positioned at near-surface (attached to float assembly) and near-bottom depths to coincide with DWR near-surface and near-bottom sensors. The near-surface sensor calibration was developed using OLS regression because of the poor distribution of data points (fig. 4A). The calculated SSC time-series data collected for WY 2008 are presented in figure 5.

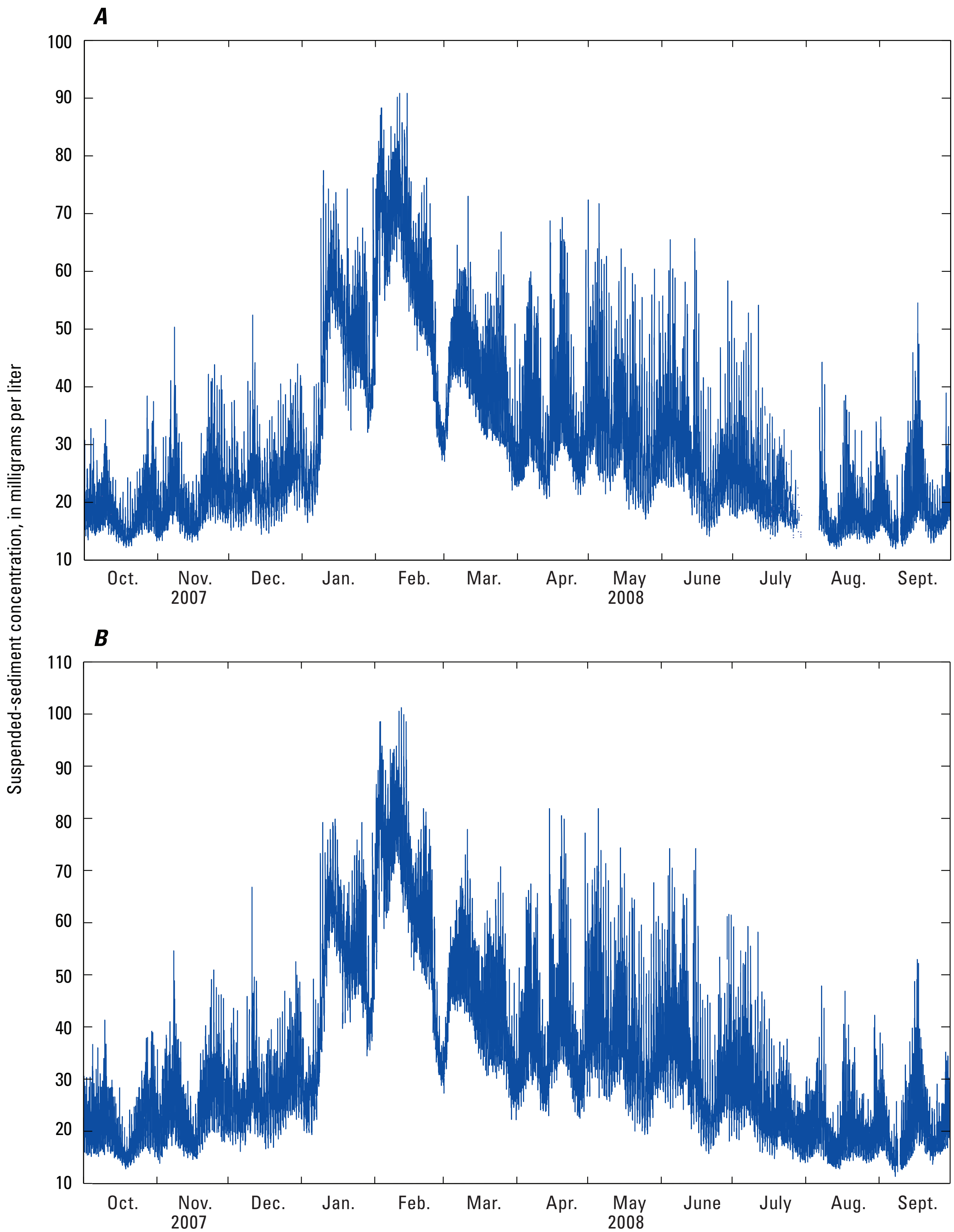

Figure 5. Time series of near-surface and near-bottom suspended-sediment concentrations calculated from sensor readings at Mallard Island, Suisun Bay, California, water year 2008.

Benicia Bridge

PERIOD OF CALIBRATION.—
NEAR-SURFACE SENSOR: WY 2008 (fig. 6A).
NEAR-BOTTOM SENSOR: WY 2008 (fig. 6B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
NEAR-SURFACE SENSOR: 35 (14 from WY 2008).
NEAR-BOTTOM SENSOR: 26 (13 from WY 2008).
LINEAR REGRESSION EQUATION.—
NEAR-SURFACE SENSOR: SSC = 1.278 × NTU + 4.0.
NEAR-BOTTOM SENSOR: SSC = 1.135 × NTU + 21.9.
NONPARAMETRIC PREDICTION INTERVAL.—
NEAR-SURFACE SENSOR: +9 to –12 mg/L.
NEAR-BOTTOM SENSOR: +12 to –26 mg/L.
95-PERCENT CONFIDENCE INTERVAL ON SLOPE CALCULATION.—
NEAR-SURFACE SENSOR: 0.927 to 1.346.
NEAR-BOTTOM SENSOR: 0.980 to 1.319.

REMARKS—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. MLLW was approximately 80 ft at the site but approximately 60 ft immediately adjacent. Therefore, the near-bottom sonde was set approximately 20 ft above the bottom so that the data are representative of the surrounding area. Water samples from WY 2009 were included in the near-surface sensor calibration to supplement the number of water samples collected in WY 2008. The near-surface sensor calibration was developed using OLS regression because of the poor distribution of data points (fig. 6A). The calculated SSC time-series data collected for WY 2008 are presented in figure 7.

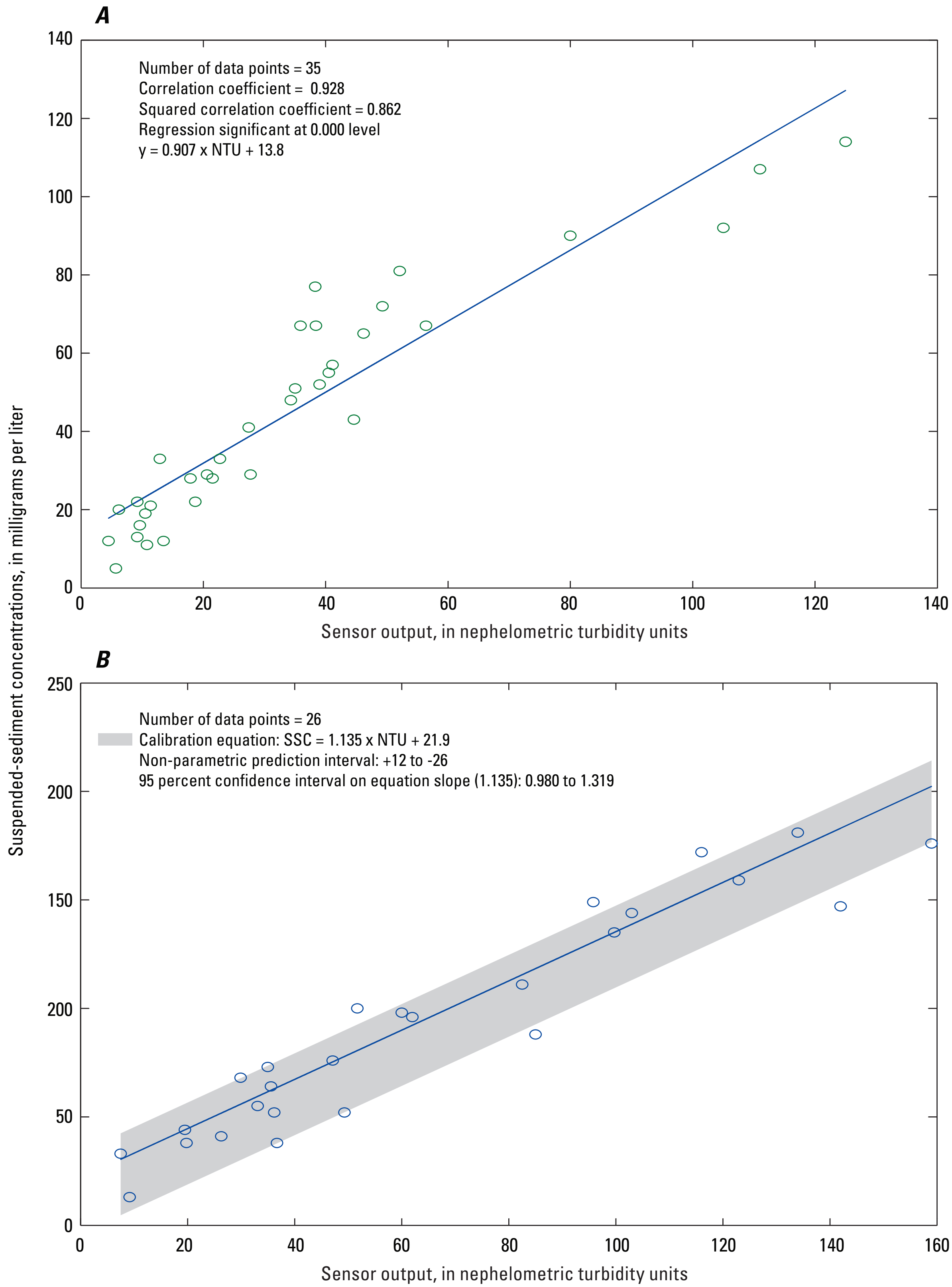

Figure 6. Calibration of near-surface and near-bottom optical sensors at Benicia Bridge, Suisun Bay, California, water year 2008.

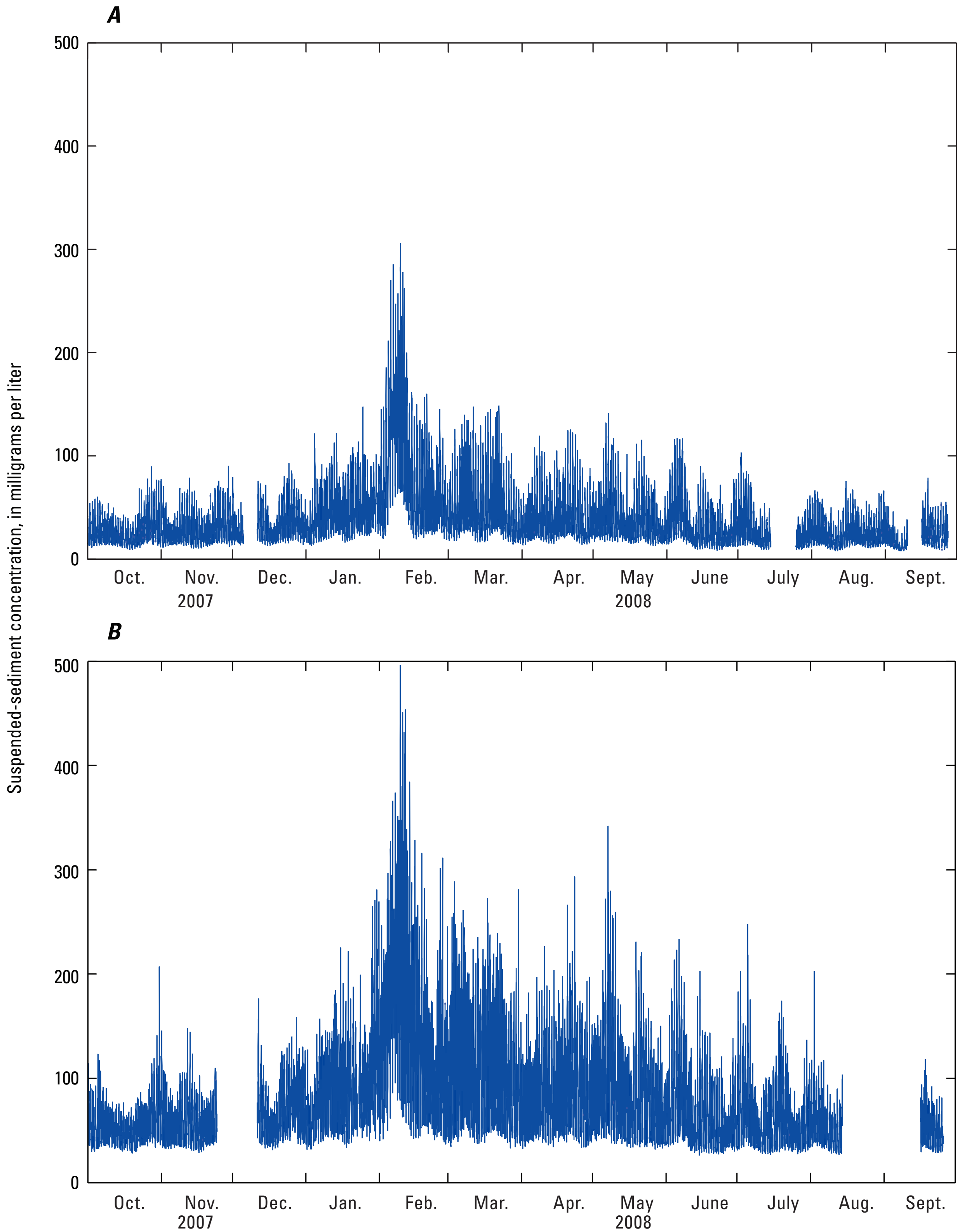

Figure 7. Time series of near-surface and near-bottom suspended-sediment concentrations calculated from sensor readings at Benicia Bridge, Suisun Bay, California, water year 2008.

Central San Francisco Bay

Richmond/San Rafael Bridge

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR: WY 2008 (fig. 8A).
NEAR-BOTTOM SENSOR: WY 2008 (fig. 8B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
MID-DEPTH SENSOR: 31 (17 from WY 2008).
NEAR-BOTTOM SENSOR: 31 (16 from WY 2008).
LINEAR REGRESSION EQUATION.—
MID-DEPTH SENSOR: SSC = 2.086 × NTU + 4.5.
NEAR-BOTTOM SENSOR: SSC = 1.362 × NTU + 6.2.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR: +9 to –9 mg/L.
NEAR-BOTTOM SENSOR: +15 to –5 mg/L.
95-PERCENT CONFIDENCE INTERVAL ON SLOPE CALCULATION.—
MID-DEPTH SENSOR: 1.254 to 2.471.
NEAR-BOTTOM SENSOR: 1.032 to 2.000.

REMARKS—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. The optical sensor wipers were ineffective during periods of heavy fouling because biological growth on the wiper obscured the optical ports. The mid-depth sonde malfunctioned and was replaced March 7, 2008. Because the two optical sensors (YSI, Inc.) deployed at the mid-depth position during WY 2008 responded similarly to the uniform sediment characteristics found in San Francisco Bay (Ganju and others, 2007), the calibration was developed by combining water samples collected during each sensor deployment. The mid-depth turbidity sensor, deployed from March 7, 2008, through the end of the water year, read low in zero turbidity standards, and a + 4.1 NTU correction was applied to the time-series record during this period. The near-bottom sonde malfunctioned and was replaced October 30, 2007. On March 7, 2008, the near-bottom sonde would not communicate during the site visit and was replaced. The sonde deployed at the near-bottom position from October 30, 2007, to March 7, 2008, read low in zero turbidity standards, and a +3.3 NTU correction was applied to the time-series during this period. The sonde deployed at the near-bottom position from March 7, 2008, through the end of the water year, read high in zero turbidity standards, and a –1.4 NTU correction was applied to the time-series during this period. The calculated SSC time-series data collected for WY 2008 are presented in figure 9.

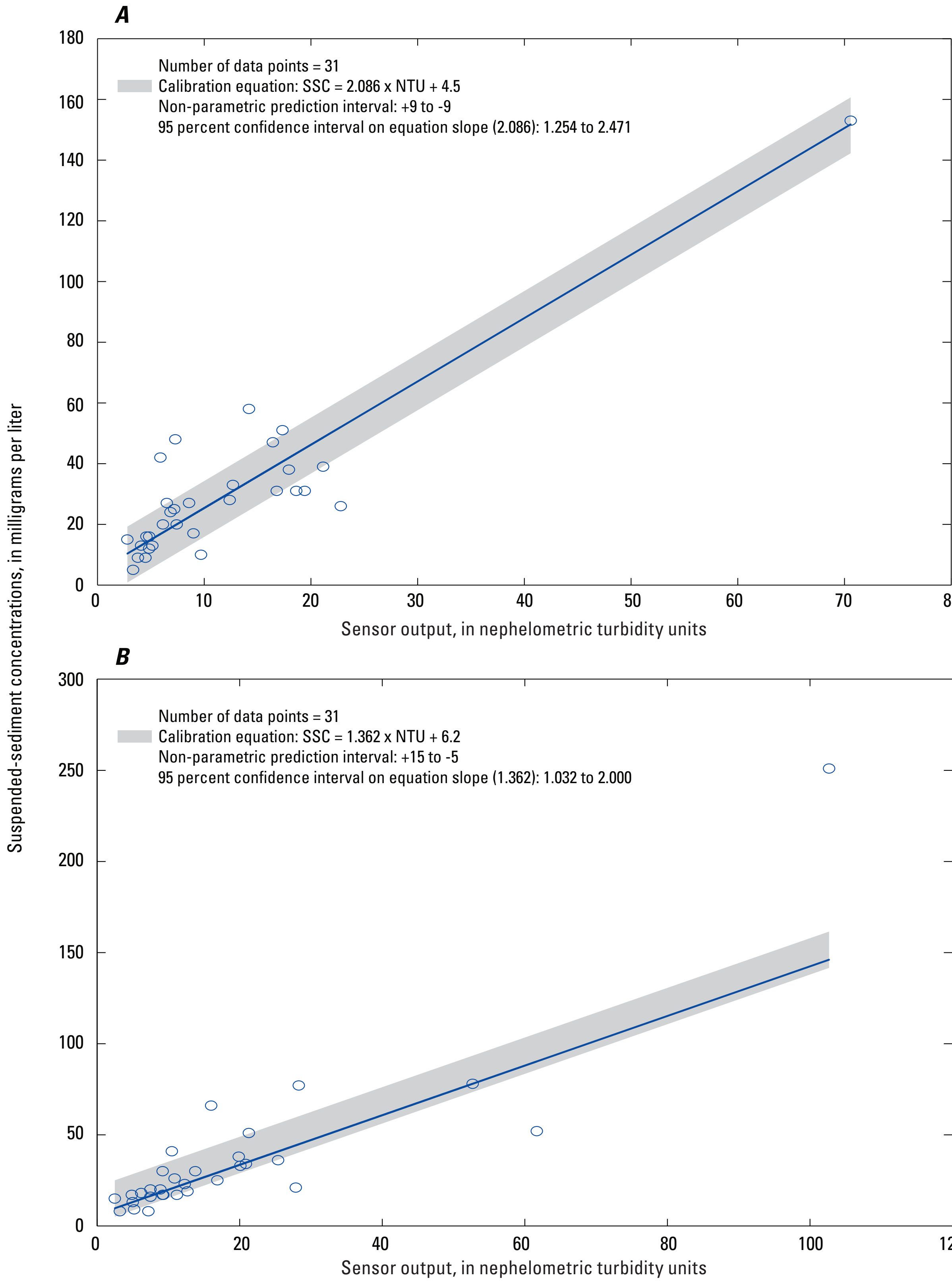

Figure 8. Calibration of mid-depth and near-bottom sensors at Richmond/San Rafael Bridge, Central San Francisco Bay, California, water year 2008.

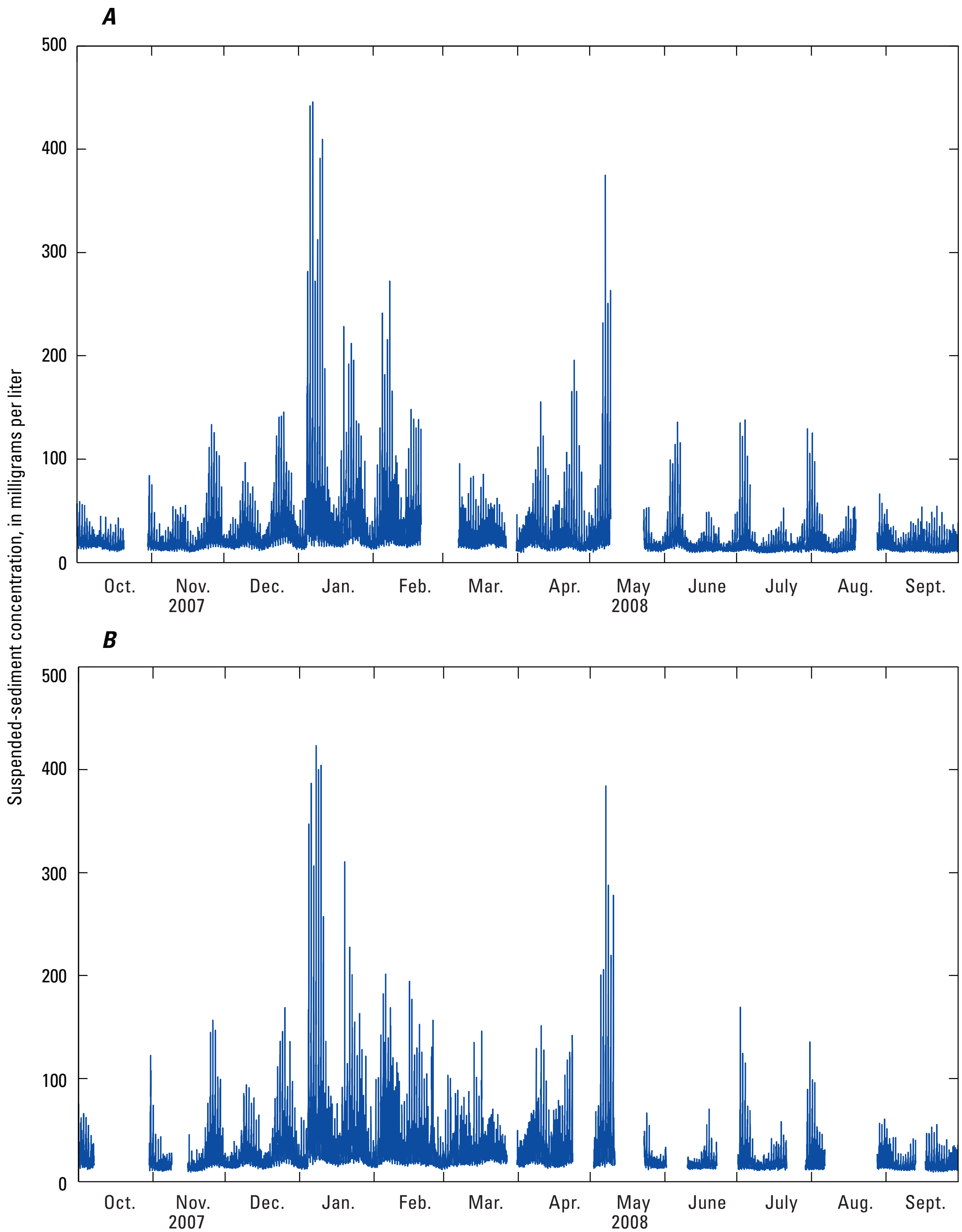

Figure 9. Time series of mid-depth and near-bottom suspended-sediment concentrations calculated from sensor readings at Richmond/San Rafael Bridge, Central San Francisco Bay, California, water year 2008.

Alcatraz Island

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR: WY 2008 (fig. 10).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
MID-DEPTH SENSOR: 17 (14 from WY 2008).
LINEAR REGRESSION EQUATION.—
MID-DEPTH SENSOR: SSC = 1.787 × NTU + 6.3.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR: +12 to –6 mg/L.
95-PERCENT CONFIDENCE INTERVAL ON SLOPE CALCULATION.—
MID-DEPTH SENSOR: 0.963 to 2.712.

REMARKS—Interruptions in record caused by fouling or malfunction of the sensing and (or) recording instruments. The optical sensor wiper was ineffective during periods of heavy fouling because biological growth on the wiper obscured the optical ports. The communication port on the sonde flooded, and the unit was replaced on April 24, 2008. The conductivity/ temperature probe was found to have malfunctioned, and the sonde was replaced May 29, 2008. Because the optical sensors (YSI, Inc) deployed at the mid-depth position during WY 2008 responded similarly to the uniform sediment characteristics found in San Francisco Bay (Ganju and others, 2007), the calibration was developed by combining water samples collected during each sensor deployment. Water samples from WY 2009 were included in the calibration to supplement the number of water samples collected in WY 2008. The calculated SSC time-series data collected for WY 2008 are presented in figure 11.

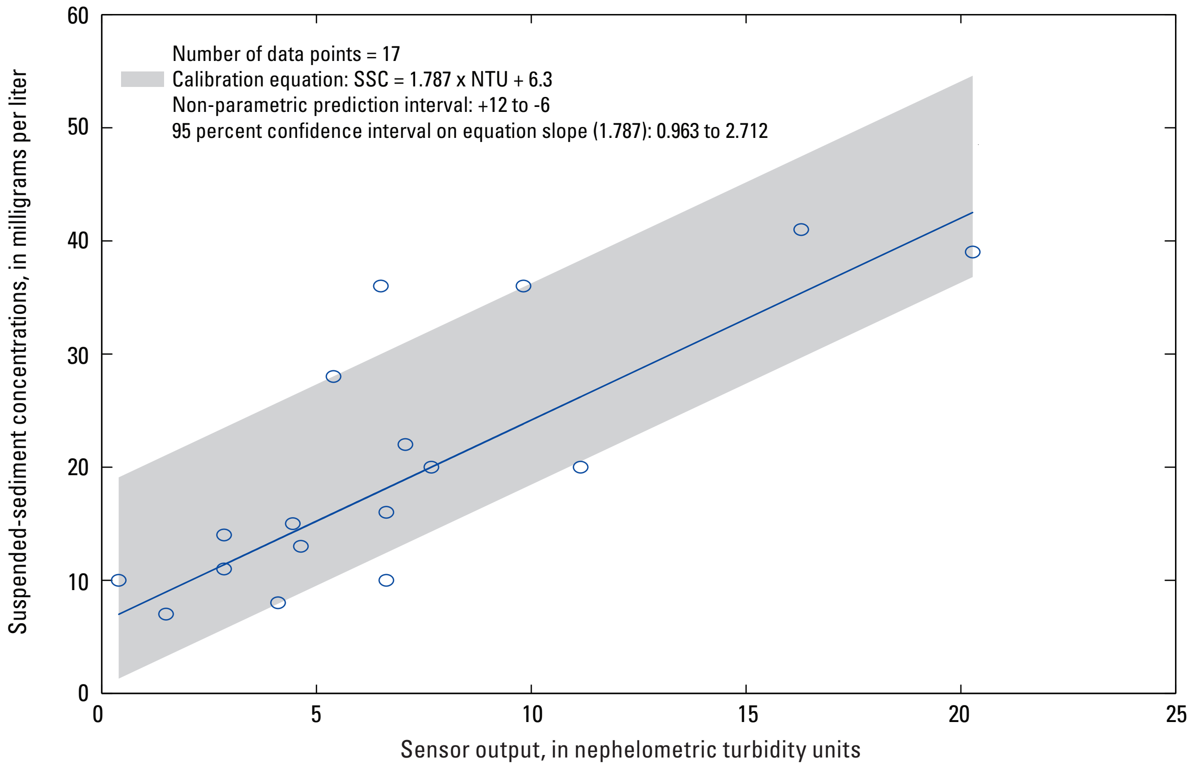

Figure 10. Calibration of mid-depth optical sensors at Alcatraz Island, Central San Francisco Bay, California, water year 2008.

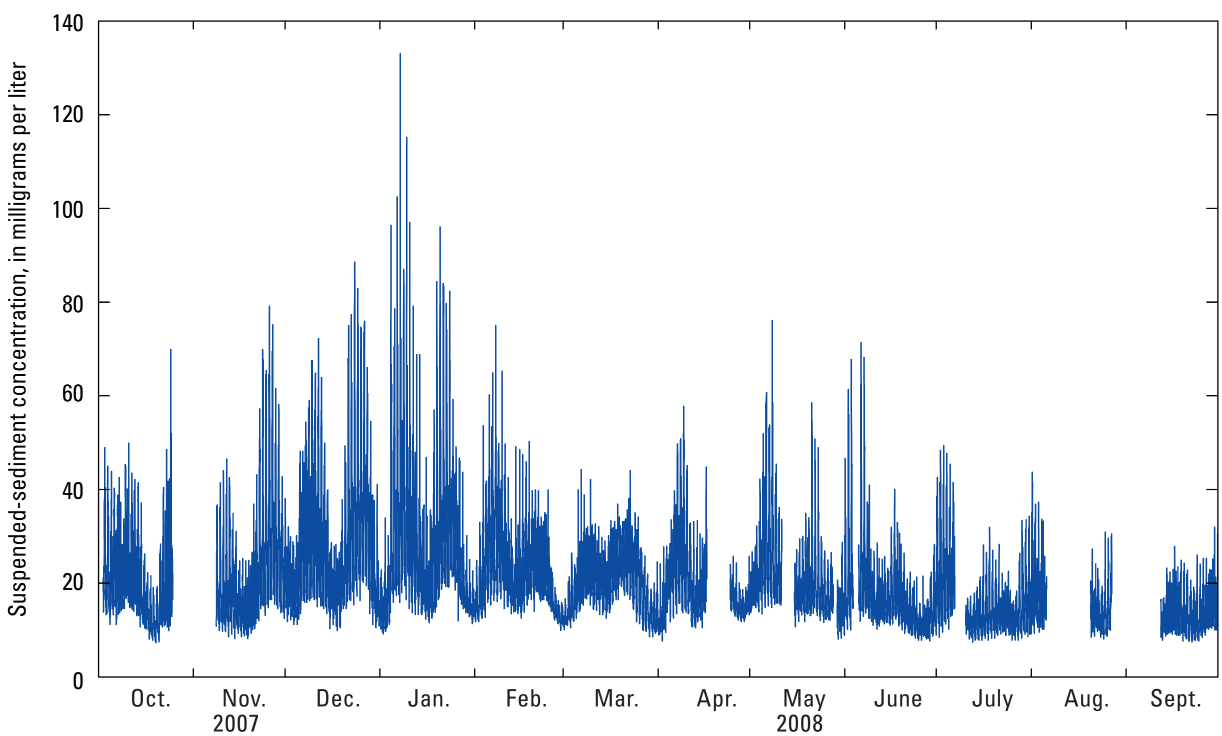

Figure 11. Time series of mid-depth suspended-sediment concentrations calculated from sensor readings at Alcatraz Island, Central San Francisco Bay, California, water year 2008.

South San Francisco Bay

Dumbarton Bridge

PERIOD OF CALIBRATION.—
MID-DEPTH SENSOR: WY 2008 (fig. 12).
NEAR-BOTTOM SENSOR (*A*): October 1–16, 2007 (fig. 13A).
NEAR-BOTTOM SENSOR (*B*): October 16, 2007, to September 30, 2008 (fig. 13B).
NUMBER OF DATA POINTS (WATER SAMPLES) USED FOR CALIBRATION.—
MID-DEPTH SENSOR: 13 (9 from WY 2008).
NEAR-BOTTOM SENSOR (*A*): 26 (0 from WY 2008).
NEAR-BOTTOM SENSOR (*B*): 11 (9 from WY 2008).
LINEAR REGRESSION EQUATION.—
MID-DEPTH SENSOR: SSC = 1.012 × mV +3.3.
NEAR-BOTTOM SENSOR (*A*): SSC = 1.335 × mV +3.9.
NEAR-BOTTOM SENSOR (*B*): SSC = 1.967 × mV –1.6.
NONPARAMETRIC PREDICTION INTERVAL.—
MID-DEPTH SENSOR: +9 to –2 mg/L.
NEAR-BOTTOM SENSOR (*A*): +23 to –13 mg/L.
NEAR-BOTTOM SENSOR (*B*): +9 to –17 mg/L.
95-PERCENT CONFIDENCE INTERVAL ON SLOPE CALCULATION.—
MID-DEPTH SENSOR: 0.864 to 1.120.
NEAR-BOTTOM SENSOR (*A*): 1.028 to 1.589.
NEAR-BOTTOM SENSOR (*B*): 1.622 to 2.329.

REMARKS—Interruptions in record were caused by fouling or malfunction of the sensing and (or) recording instruments. The mid-depth optical sensor malfunctioned, and the sensor was replaced on June 19, 2008. A water sample from WY 2009 was included in the mid-depth sensor calibration to supplement the small number of water samples collected in WY 2008. Because the optical sensors (FTS–12’s) deployed at the mid-depth position during WY 2008 responded similarly to the uniform sediment characteristics found in San Francisco Bay (Ganju and others, 2007), the calibration was developed by combining water samples collected during each sensor deployment. The near-bottom optical sensor malfunctioned, and the sensor was replaced on October 16, 2007. Because the optical sensors (FTS–12’s) deployed at the near-bottom position during WY 2008 did not respond similarly to the uniform sediment characteristic found in San Francisco Bay, a new calibration was developed. Water samples from WY 2009 were included in the mid-depth sensor calibration to supplement the small number of water samples collected in WY 2008. The calculated SSC time-series data collected for WY 2008 are presented in figure 14.

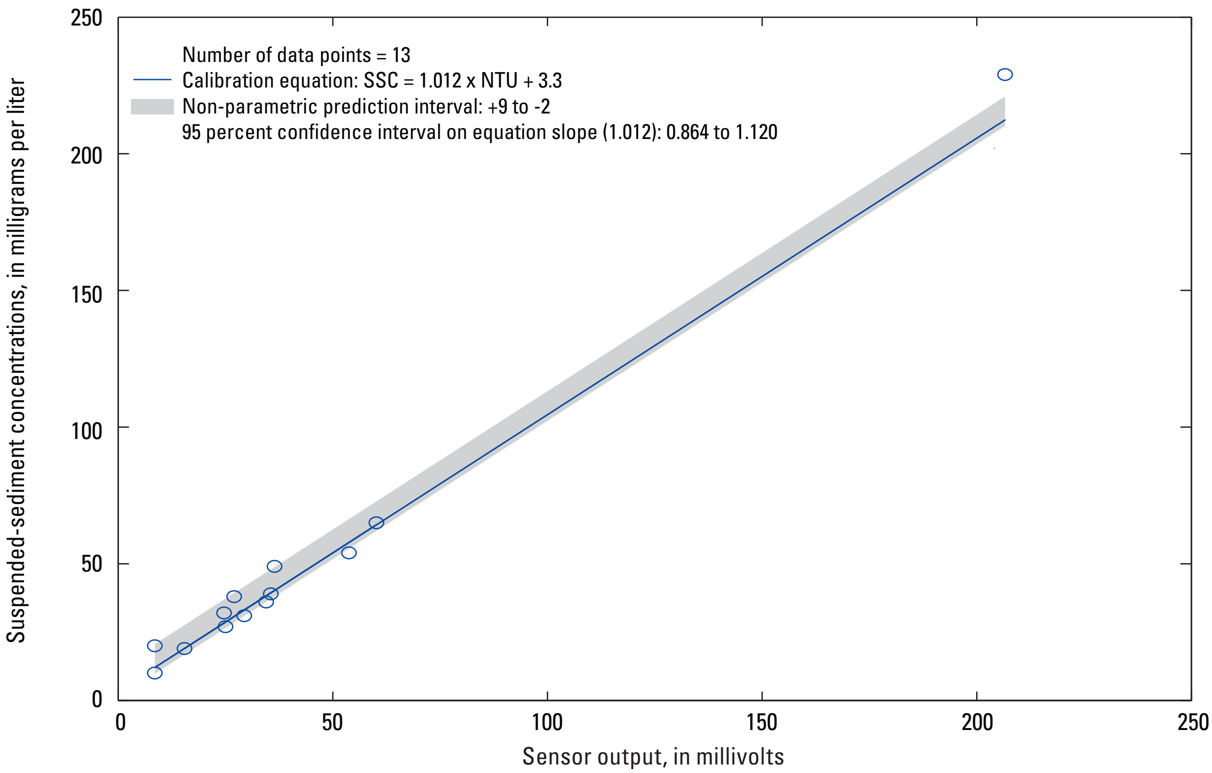

Figure 12. Calibration of the mid-depth optical sensor at Dumbarton Bridge, South San Francisco Bay, California, water year 2008.

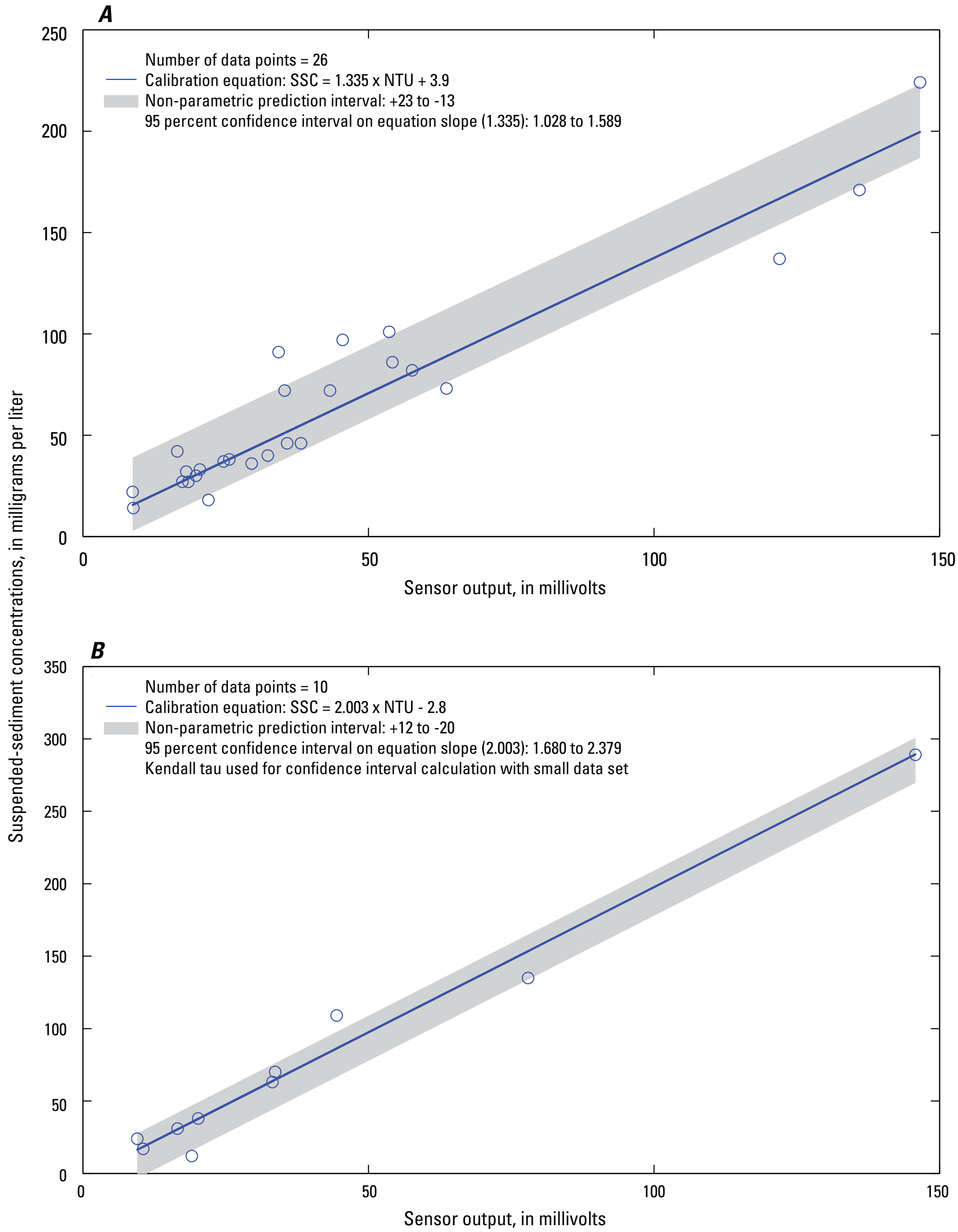

Figure 13. Calibration of the near bottom optical sensor for 2007, and the near-bottom optical sensor for 2008, at Dumbarton Bridge, South San Francisco Bay, California, water year 2008.

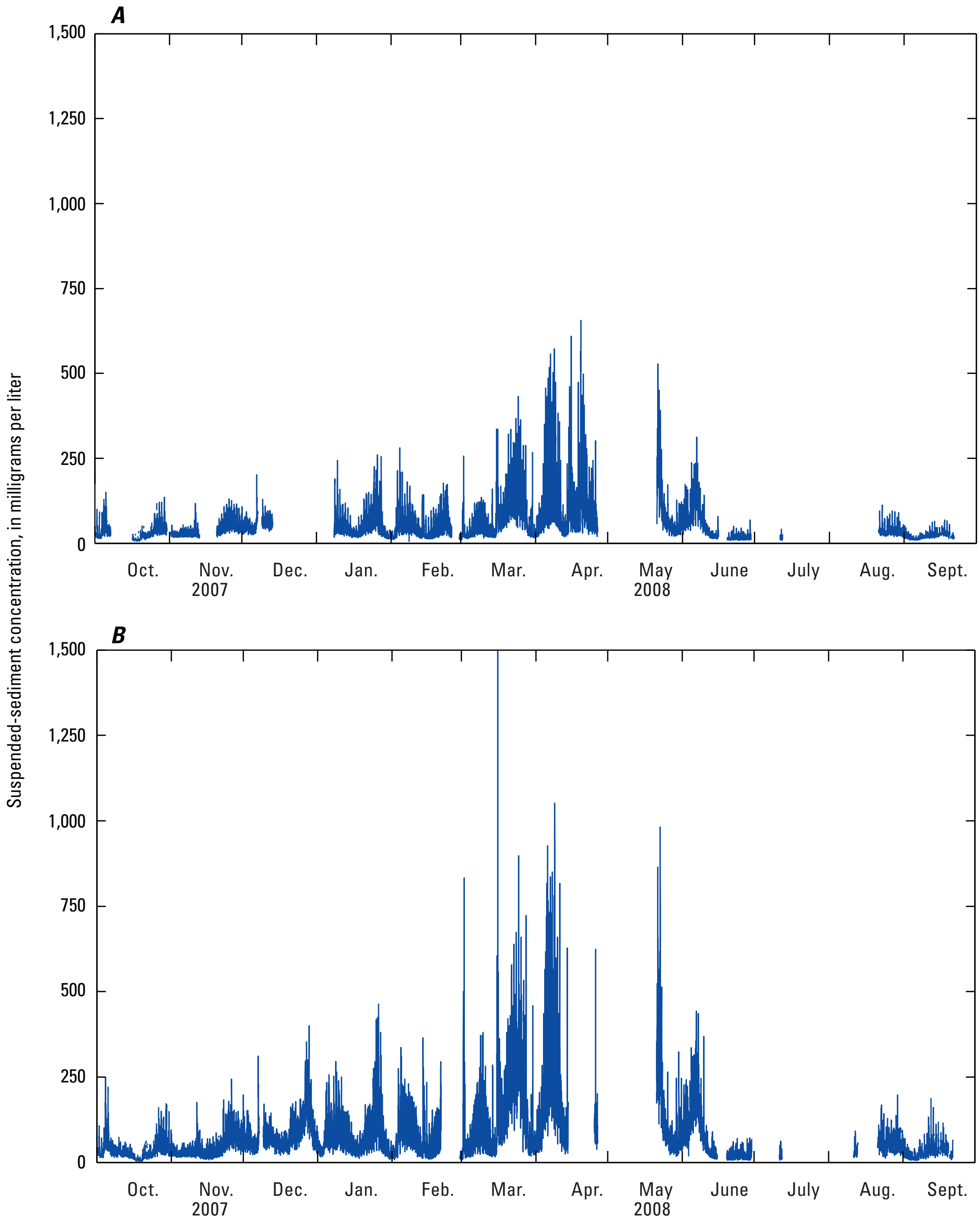

Figure 14. Time series of mid-depth and near-bottom suspended-sediment concentrations calculated from sensor readings at Dumbarton Bridge, South San Francisco Bay, California, water year 2008.

Summary

Suspended-sediment concentration (SSC) data were collected by the U.S. Geological Survey (USGS) at two sites in Suisun Bay, two sites in Central San Francisco Bay, and one site in South San Francisco Bay during water year 2008. Two types of optical sensors, each controlled by electronic data loggers, were used to monitor suspended sediment. Water samples were collected to calibrate the output of the optical sensors to SSC by using robust, nonparametric regression. Water-sample sediment-concentration data are available in the USGS Sediment Laboratory Environmental Database. Time-series data are available in the USGS sediment database and the USGS automated data-processing system database. The calculated SSC data are available from the USGS (accessed December 2, 2008).

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