

**Southern California Bight
1998 Regional Marine Monitoring Survey
(Bight'98)**

Water Quality Workplan

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I. INTRODUCTION

The Southern California Bight (SCB; Figure I-1), an open embayment in the coast between Point Conception and Cabo Colnett (south of Ensenada), Baja California, is an important and unique recreational resource. World renowned for its recreational waters, more than 100 million people visit Southern California beaches and coastal areas annually to sunbathe, surf, swim, skin- and SCUBA-dive. The average number of visitors to Santa Monica Bay beaches on a summer weekend alone is more than 600,000 (Economic Resources Data, 1993).

Southern California is also one of the most densely populated coastal regions in the country, which creates stress upon these recreational resources. Nearly 20 million people inhabit coastal Southern California, a number that is expected to increase another 20% by 2010 (NRC 1990). Population growth generally results in conversion of open land into non-permeable surfaces. This “hardening of the coast” increases the rate of runoff and can impact water quality through addition of sediment, toxic chemicals, microbial pathogens and nutrients to the ocean. Besides the impacts of land conversion, the SCB is home to fifteen municipal wastewater treatment facilities, eight power generating stations, 10 industrial treatment facilities, and 18 oil platforms that discharge to the open coast.

Assessing the effects of freshwater inputs from land based sources on the ocean environment requires an understanding of plume dynamics. In most years, sewage treatment plants are the largest of these freshwater sources and they discharge several kilometers offshore in relatively deep water. The size and direction of treated wastewater plumes are well described (e.g. Jones et al., 1990, 1991; Washburn et al., 1992; Wu et al., 1994; Petrenko et al, 1998a and b); most of the larger sewage treatment plants in southern California have conducted plume monitoring programs on a monthly basis for more than ten years. What these programs have shown is that since most sewage treatment plants have deep offshore diffusers, their plumes enter the ocean below the pycnocline, remain subsurface due to the density barrier, and rarely come into contact with the public.

In wet years, stormwater runoff can far exceed the freshwater input from sewage treatment plants. In southern California, most stormwater runoff is channeled into diversion systems that flow to the ocean through point source-like outfalls that occur almost exclusively at the shoreline. Stormwater plumes remain largely near the surface and tend to flow along the shoreline with the longshore currents, putting them in prime locations for human contact. However, stormwater plumes have been studied for only a few systems and for only a few storms (Bay et al., 1997; Jones et al., 1997). They are also less predictable than treated wastewater outfall plumes. Whereas treated wastewater plumes are relatively steady in size, stormwater plumes can vary several orders of magnitude in size. Moreover, the meteorological factors that cause stormwater plume volume to vary also alter predominant water movement patterns in the receiving waters through wind and wave forcing.

The ways in which stormwater and treated wastewater plumes interact is also not well understood. At a theoretical level, the subsurface offshore plumes from sewage treatment plants should rarely interact with the nearshore surface plumes from stormwater. However, most treated wastewater plume monitoring has occurred under quiescent oceanographic conditions that may differ from storm impacted conditions. Most of the larger sewage treatment plants in southern California are located immediately offshore of some of the largest stormwater outfalls (e.g. Orange County and Santa Ana River; Los Angeles City and Ballona Creek; Los Angeles County and Los Angeles River/

LA Harbor). Existing monitoring focuses on examining these sources individually, rather than simultaneously, making examination of their relative effects or interaction difficult.

Recognizing the need to look beyond the influence of an individual plume to cumulative effects and plume interactions, twenty-one organizations that conduct oceanographic studies in southern California have agreed to pool their effort during the fall/winter of 1998-99 to address the following regional-scale questions:

1. What are the contributions and spatial distribution of inputs from bays, harbors, rivers, and large storm water sources to the Southern California Bight relative to POTW (publicly owned treatment works) inputs?
2. How do these inputs vary during wet and dry seasons for near coastal areas and enclosed bays and harbors?

The study will be coordinated by the Southern California Coastal Water Research Project (SCCWRP) as one component of the Southern California Bight 1998 Regional Monitoring Program (Bight'98), in which 55 organizations (Table I-1) have agreed to cooperate in assessing the overall condition of the SCB ecosystem. Bight'98 builds upon the success of a similar SCCWRP-coordinated regional monitoring effort conducted in 1994 to assess the condition of offshore ecological habitats (SCBPP 1998). It also extends the efforts of the three largest sewage treatment plant operators in the Los Angeles/Orange County region to coordinate and spatially extend their sampling in ways that will provide more holistic information about local conditions.

This document presents the work plan for the water quality component of Bight'98. Similar work plans are available for coastal ecology and microbiological components of Bight'98.

II. STUDY DESIGN

The Water Quality component of Bight'98 will include four objectives to address the two questions presented in the introduction:

1. Determine the spatial extent and distribution of surface runoff from shoreline sources in the coastal ocean,
2. Evaluate the contribution of surface runoff to the physical, chemical and biological characteristics of the coastal ecosystem,
3. Evaluate and compare the contributions of surface runoff and POTW inputs into the coastal ocean, and
4. Develop tools for integrated assessment of water quality using *in situ* and remotely sensed data sets.

The first objective will be addressed by measurements of the cross-shelf and along-shelf extent of surface runoff plumes from known sources of freshwater along the Southern California coast. Low salinity and high turbidity, particularly during winter storm events generally characterize surface runoff. Both of these characteristics are easily measured and will be used to estimate the spatial extents and distributions of both dissolved and suspended particulate components of runoff, respectively. These spatial characteristics will also be compared with the volume flow associated with the respective freshwater sources, where flow gauges are available, and with coastal advection driven by a combination of tidal, wind, and remote forcing where current measurements are available. In addition, remotely sensed observations of surface plumes will be used to determine plume size at larger spatial scales than can be resolved by ship-based sampling and at time scales beyond which boat sampling is available.

The second objective will be addressed using *in situ* collections and laboratory analyses of water samples to examine the contribution of surface runoff samples to temperature, salinity, dissolved oxygen, pH, suspended particulate matter load (SPM, also referred to as total suspended solids, or TSS) which causes the turbidity, nutrient concentrations, and chlorophyll concentrations. Comparison with ambient water beyond the influence of the plume, and with water quality measurements during the dry weather study will provide a mechanism for evaluating the relative contributions of runoff to the coastal ocean. These measurements also provide possible ground-truthing for remotely sensed observations from ocean color and synthetic aperture radar (SAR) satellites.

The third objective will be addressed by combining data from the current study with that from historical water quality surveys conducted as part of POTW discharge monitoring to assess the relative spatial distributions and effects of surface runoff and POTW discharges on coastal water quality. A large body of monitoring observations spanning several decades exists for the larger POTWs. We will use that information to determine the historical spatial influence of POTW outfalls and compare that with the influence of stormwater outfalls. In addition, we will use data from the present study, which improves the linkage between POTW and stormwater sources to help identify potential stormwater intrusions into areas of typical POTW influence during historical studies conducted under storm conditions.

The fourth objective represents an evolutionary step in the approach taken by municipal agencies in monitoring and understanding the impact of natural and anthropogenic inputs into the coastal ocean. The technology of satellite sensors, telemetered mooring observations and sophisticated software tools provide a potential for understanding, predicting and managing the coastal ocean at a level not previously possible. This new technology will ultimately provide cheaper, more spatially and temporally comprehensive system-integrated information than ever before possible. However, this technology has not yet been fully tested or integrated with conventional coastal monitoring and management practices. The mutual involvement of most local municipal monitoring agencies with state/national regulatory, scientific and technical agencies in Bight'98 provides an excellent opportunity to develop integrated approaches for understanding and interpreting the contributions of coastal sources to the coastal ocean.

A. Sampling Design

The field sampling program that will contribute to achieving these objectives contains four elements, each of which is described below:

1. CTD surveys
2. Batch water sampling
3. Surface mapping surveys
4. Remote sensing observations

1. CTD Surveys

Three CTD (conductivity, temperature, depth) surveys, including one dry weather survey prior to the onset of the winter rainy season and two wet weather surveys during the winter, will be conducted as part of Bight'98. Each survey will consist of CTD profiles at 446 sites between Point Conception and the Mexican Border. Appendix A provides maps of the sample sites and appendix B provides site coordinates.

At each site, vertical profiles will measure the vertical distribution of temperature, salinity, dissolved oxygen, turbidity and chlorophyll fluorometry. Profiles will extend from the surface to within 2-3 meters of the bottom, except in water depths greater than 100 meters, where only the upper 100 meters of the water column will be profiled. At selected sites, CTD profiles will be supported by surface batch measurements of total suspended solids (TSS) and chlorophyll concentration to calibrate the transmissometer and fluorometer, respectively.

Site selection

Sampling sites for the CTD surveys were allocated to a series of transects perpendicular to shore. Nominal distance between transects will be 4-6 km, except in areas near POTW and stormwater runoff, where they will be closer. Near river mouths, transects will be located at the mouth and then at 1 km and 2 km in either direction. Beyond 2 km alongshore, additional transects will be placed at 4-6 km intervals. Near major POTW diffusers (>100 mgd), transects will be placed over the diffuser and at 2 km intervals for the first 4 km. Near smaller POTW diffusers, transects will

be placed over the diffuser and at 0.5 km intervals within the zone of initial dilution for the facility. These distances were selected to capture the areas of maximum response gradient based on historical data records.

Each transect will be sampled cross-shelf initially at 1 km intervals beginning at the 10 m isobath out to ~2 km, then at 2-3 km intervals out to 10 km offshore. Shorter transects will be placed at the sites lateral to small river mouths and a longer transects will be placed near the Santa Clara River where previous data suggests an offshore influence as far as the Channel Islands. A summary of these criteria is provided in Table II-1.

An effort has also made to incorporate existing survey sites if they occurred close (e.g. <0.5 km) to the desired transect locations and may result in some small modifications from Table II-1. This slight modification of the design to incorporate existing sites has two benefits. First, it will ease accomplishment of the third objective, which requires integration of present and historical survey data. Second, it increases the resources for the present survey by allowing us to incorporate effort that otherwise might have had to be expended independent of Bight'98 to maintain routine sites and provide a continuing historical record for POTW discharges.

Temporal Selection

Three field sampling events are planned for the fall winter of 1998-99. The first will be a dry weather sampling event, tentatively scheduled for October 13-15. The dry weather study will occur during a period when surface runoff is low, uncoupled from specific meteorological events. By sampling close to the onset of the winter rainy season we hope to characterize the water quality characteristics of the coastal ocean into which the early storm runoff would discharge. Should a significant rain event occur prior to October 13, dry weather sampling would be deferred until later in the spring, well after the end of winter rains, or until the following summer or early fall.

Two wet weather storm events will be sampled during the period of November-February, one during the early part of the season in November-December, and the other in January-February. If two wet weather samplings have not been obtained by the end of February, the period will be extended into March, but by the end of March the probability of having a major rain event will diminish considerably.

Storm event sampling will focus on a three-day period following the rain event, sea state permitting. A maximum of three days was selected because, depending on the size of the storm and coastal advection, freshwater plumes can dissipate rapidly, and beyond three days there is little certainty of being able to adequately observe the immediate contribution of stormwater input to the coastal ocean. This is not necessarily because the effects of the input will be gone, but because initial inputs will be diluted and may even change form beyond this period. Although a low salinity anomaly may still be present in the water column after several days, it is conceivable that the particulate load may have sunk from the water column, and perhaps even replaced by a phytoplankton bloom yielding biogenic rather than terrigenous particles. Because suspended particulates may be responsible for the transport of contaminants into the coastal ocean, measuring the initial load of suspended particulate matter in the water column is important.

While the project goal is to sample all of the SCB simultaneously, the water quality component of Bight'98 has been logistically defined into three zones that may be sampled independently

depending on rainfall conditions. Rainfall decreases from north to south within the Southern California Bight from an annual average of 16.1 inches in Santa Barbara to 9.5 inches in San Diego. It is unlikely that the entire SCB will receive adequate rainfall within a single event to provide significant surface runoff simultaneously throughout the entire region. Our objective will be to coordinate sampling within zones and to coordinate sampling across zones to the maximum extent possible. The three zones are:

- **Northern SCB** - Point Conception to Point Dume
- **Central SCB** - Point Dume to San Mateo Point
- **Southern SCB** - Oceanside to the Mexican Border

The size of rain event that triggers sampling will differ among regions. The northern region has the largest rainfall requirement, both because it receives more rain on average and because the Santa Clara River, which is the major surface runoff source for the region, requires a sizable rain event before significant flow from the river is realized. The minimum rainfall required to trigger sampling for each region is listed below:

Northern SCB: 2 inches
Central SCB: 1 inch
Southern SCB: 0.5 inch (after the first event meeting this criteria)

The level of 0.5 inches for the southern region is driven by the concern of catching any event. Because average annual rainfall for the San Diego area is only 9.5 inches, the sampling opportunities must be taken when available.

2. Batch Water Sampling

In the transect nearest each major freshwater runoff site, surface water samples will be taken from at least three CTD profile sites for the measurement of inorganic plant nutrients, total suspended solid (TSS) concentration, and extracted particulate chlorophyll concentration. These samples will allow us to assess the effects of water quality parameters not directly measured with CTD profiling and to provide field calibration samples for the fluorometer and TSS:

- **Total suspended solids** are a direct measure of the suspended particulate material remaining in the water column, and within stormwater plumes the bulk of the TSS is from stormwater. Where the particle field is relatively homogenous in composition, beam attenuation, a parameter calculated from transmissometry, will vary linearly with TSS, and therefore the TSS/beam attenuation relationship can be used to map the distribution of TSS from the continuously profiled beam attenuation.
- **Nutrient measurements** will be used to understand the additional contribution of the runoff to the dynamics of the coastal ecosystem. Previous work has shown that there is a significant nutrient load associated with surface runoff and that the concentrations and proportions of nutrients varies between different sources. These nutrients contribute to phytoplankton blooms, especially with the stratification that results from the buoyancy added by the freshwater.

- **Extracted particulate chlorophyll a** measurements provide an indication of the phytoplankton plant biomass in the water column. Some of the particulate chlorophyll in stormwater may be derived from terrigenous plant material that has been washed into the ocean by the runoff. These measurements will be used to convert the chlorophyll fluorescence measurements obtained with the CTD profiling in to actual chlorophyll concentrations. Although factory calibrations are provided with the fluorometers, in practice the fluorescence yield of phytoplankton varies as a function of phytoplankton taxonomy and physiological state. Direct chlorophyll measurements from the study system are important for obtaining meaningful calibration for the fluorescence sensor. The TSS and chlorophyll observations are also important for interpreting remote sensing color imagery, such as the ocean color data obtained by the SeaWiFs ocean color sensor.

Batch surface samples will be obtained at 10% or more of the CTD sites for each zone at sites indicated on the tables in Appendix B. These sites were selected to represent major gradients within a plume, but the cross-shelf extent of a plume will vary on a storm-specific basis and field crews will be given flexibility to adjust the sites accordingly to capture the gradient.

3. Surface Mapping Surveys

The CTD survey will yield a three dimensional description of spatial patterns by sampling the vertical component continuously and interpolating the values between CTD casts to describe horizontal components in the coastal ocean. An additional, complementary approach is to use a towed array which describes horizontal patterns on a continuous basis within the harbors. Since stormwater plumes generally remain near the surface, lateral gradients can provide greater description of plume dynamics than depth-related gradients. To capture these gradients, a towed array system will be used in two harbor areas, Los Angeles/Long Beach (LA/LB) Harbor and San Diego Bay, where these gradients are likely to be largest.

The US Navy's Marine Environmental Survey Capability (MESC) will be used as the towed array in these two harbors. The MESC is a real-time data acquisition system designed to provide integrated, rapid, continuous measurement and mapping physical, chemical, and biological characteristics (Table II-2) from a moving vessel utilizing state-of-the-art sensors, computer systems, and navigation equipment. This approach allows for direct *in situ* measurements that avoid extrapolation, and provides simultaneous measurements at a frequency commensurate with scales of natural and anthropogenic variability. The MESC provides the near-synoptic real-time data collection necessary to effectively map the highly dynamic nature of the coastal environment.

A single MESC survey will be conducted in each harbor during the October dry weather sampling, and during one of the winter storm sampling events. Data will be collected primarily while towing near the surface (1-2 m depth) though occasional vertical profiles will be performed to determine vertical structure. The planned track lines for San Diego Bay and LA/LB Harbor are shown in Figures II-1 and II-2, respectively. The track line planned for San Diego Bay follows one used on many previous MESC surveys. MESC has not previously been used in LA/LB Harbor.

Discrete seawater samples will be collected at specific locations for the purposes of calibrating MESC sensors, as well as to obtain nutrient samples not otherwise measured by MESC. The

exact sites for data collection will be determined in real-time to accommodate the widest range in parameter levels as possible. However, sites previously sampled in San Diego Bay (Figure II-1), have been found to provide a sufficient data range and will be used for some of the sites on the upcoming surveys. The total number of discrete samples planned for each survey are: 12 TSS, 12 Chl-a, 12 Nutrients, 24 Cu, and 15 PAH.

4. Remote Sensing Observations

Remote sensing measurements provide a third complementary mechanism for mapping large scale spatial and temporal extents of runoff plumes resulting from storm events. Sea surface temperature, ocean color and pigment concentration, and sea surface roughness can all be mapped with satellite remote sensing at temporal and spatial scales are relevant to storm-driven freshwater runoff events. While limited to near surface layers, remote sensing observations are synoptic, providing an instantaneous snapshot of ocean conditions free from blurring or distortion by changes in the system during the time of sampling. In contrast, ship-based mapping provides greater depth resolution and more accurate parameter measurement, but takes multiple days to complete during which advection, mixing, and tides may distort the spatial resolution.

Attempts will be made to quantify runoff plumes using three satellite sensors during this study (table II-3) and evaluate their usefulness for detection of these plumes. AVHRR (Advanced Very High Resolution Radiometer), which measures sea surface temperature, provides important descriptions of upper ocean physical processes, but may be of limited use for describing surface runoff plumes. First, AVHRR functions by detecting thermal radiation from the sea surface, which could be masked by clouds. Secondly, whether it can resolve coastal surface runoff depends on the temperature difference between the ambient ocean and the surface runoff water. If the temperature difference is less than 0.5°C, it may not differentiate ambient and runoff water. A third factor is the pixel size of the sensor. Because runoff plumes may have a fairly limited cross-shelf extent at times, it may be difficult to resolve the plume with a sensor having a 1 kilometer pixel size. An advantage of AVHRR is that there are several sensors flying making it currently possible to obtain up to four AVHRR images per day. Provided that the atmosphere is clear, one can potentially construct movie loops which show the time evolution of the SST field.

SeaWiFS (Sea-viewing Wide Field-of-view Sensor) measures ocean color and has already proven to be useful for examining the presence and spatial extent of surface runoff plumes along the southern California coastline. The satellite provides measurements of ocean color by detecting upwelling radiance from the sea surface at 9 wavelengths of visible and near-infrared light. SeaWiFS has similar limitations to AVHRR in that it will be limited by cloud cover, and also it has a similar pixel size to AVHRR. Because SeaWiFS is a visible light detector, it requires sun light to provide sufficient illumination of the ocean to provide a measurable upwelling radiance signal. Therefore, only one SeaWiFS image per day is possible.

Synthetic Aperture Radar (SAR) provides the greatest advantage for detection of surface runoff plumes because it has the ability to penetrate clouds, and has a very small pixel size (~20 m) which provides very high spatial resolution that is appropriate for the plumes that we expect to see from various runoff sources. However, the sensor is only in a position to obtain a useful image about once every 3 days. Its overflight, therefore, may not overlap with our selected storm events.

Finally, aerial photography will be employed for at least one of the storm events in the Los Angeles region. The resolution of the photographs will be much higher than the 1 km pixel size of the satellite sensors, but the spatial area will be much more limited.

B. Field and Laboratory Methods

1. CTD Profiles

All surveys will be conducted using SeaBird CTDs equipped with auxiliary sensors to measure dissolved oxygen, pH, beam transmission (turbidity), and chlorophyll fluorescence. Each of these sensors will be precalibrated prior to the field sampling. Once the CTD is deployed, it will be lowered to 5 to 10 meters where a three minute equilibration period will be used at the first station and 90 seconds at subsequent stations. After equilibration, the CTD will be brought back to the surface, then lowered to obtain the profile for the station. The CTDs will be lowered to within 2 meters of the bottom or to 100 meters, whichever is less. The CTD data will be logged at 8 scans per second, with a profiling rate of approximately 0.3-0.5 meters/second, yielding a vertical resolution of about 6 cm. Further details concerning profiling, intercalibrations, and precalibrations, are provided in the QA/QC section of this document and in Appendix C.

2. Batch Water Samples

Batch water samples will be obtained to assess the contributions of surface runoff to water quality parameters not directly measured with the CTD. These measurements include total suspended solids, inorganic nutrient (nitrate, nitrite, phosphate, and silicate) concentrations, and extracted particulate chlorophyll measurements.

All of the measurements will be made on a surface sample obtained with a bucket or other type of non-toxic, non-contaminating water sampling device. The sample will be obtained near the surface at the CTD site, while the CTD is in the water. This sample will preferably be taken at the beginning of the downcast of the CTD. The sample will be processed as soon as possible after being taken.

One liter of seawater will be filtered through a preweighed type GFF glass fiber filter for TSS. The sample will be drawn with a vacuum of no more than 0.5 atmospheres. If the entire portion of the 1 liter sample cannot be filtered through the filter because of clogging, which is likely to occur in stormwater samples, the volume that has filtered through the filter will be recorded along with the date, time, and location. The filter will then be placed into a petri dish and stored chilled until it can be transferred to the laboratory for processing. In the laboratory, the sample will be dried at 60°C for 24 hours and weighed on a precision balance.

Nutrients samples will be taken directly from the filtrate of the surface TSS sample. Prelabeled sample bottles (60 mL. capacity) will be rinsed twice with the filtrate and then filled to between half and two thirds full and stored frozen. In the laboratory, the samples will be analyzed for nitrate, nitrite, ortho-phosphate, and silicate. The general methods have been described in the WOCE and JGOFS methods manual (Gordon et al., 1993) but are briefly described here. Nitrate will be converted into nitrite with a cadmium reduction and then the nitrite will be diazotized using sulfanil-

amide and N-(1-naphthyl)-ethylenediamine to quantitatively form a red azo dye which will be measured with a colorimeter (Armstrong et al., 1967) Phosphate will be measured with a modification of the procedure of (Bernhardt and Wilhelms, 1967) in which molybdc acid combines with phosphate to form phosphomolybdc acid which is reduced to phosphomolybdous acid. Reactive silicate will also be measured with a molybdate complexation to form silicomolybdc acid which is reduced with stannous chloride to silicomolybdous acid (Armstrong et al., 1967). Operational standards for all of the nutrients will be made in the laboratory using the following reagents: Phosphate - KH_2PO_4 ; Silicate - Na_2SiF_6 ; Nitrate - KNO_3 ; Nitrite - NaNO_2 . The running standards will be compared with commercially available oceanographic standards obtained from a source yet to be determined.

For chlorophyll measurements, 100 mL of sample will be filtered through a 25 mm GFF type glass fiber filter with no more than 0.5 atmospheres of vacuum. When the filtration is complete, the filter will be placed into a glass scintillation vial containing 10 mL of 90% acetone/10% deionized water solution. This sample will be stored chilled for return to the laboratory, where it will be maintained at 4°C for 24 hours in the dark to allow for complete extraction. The sample will then be measured on a laboratory fluorometer that has been calibrated with 1 mg of chlorophyll *a* obtained from Sigma Scientific Corporation. The sample will be measured both before and after the addition of 5% HCl. From these readings and their ratio, both chlorophyll *a* and phaeopigment concentration will be calculated according to (Holm-Hansen et al., 1965). A complete description of pigment analyses is provided by (Jeffrey et al., 1997).

3. Surface Mapping Surveys

The MESC employs both a towed sensor package and an all-TEFLON sea water flow-through system that provides a continuous stream of near-surface sea water, nominally 1.5m deep, to a suite of on-board sensors. Sensors in the towed package consist of a conductivity, temperature, and depth (CTD) profiler, outfitted with pH and dissolved oxygen sensors, a 25-cm pathlength light transmissometer (660 nm), an oil (PAH) fluorometer using ultra-violet (UV) fluorescence, and a photosynthetically active radiation (PAR) sensor. On-board sensors include multiple fluorometers for oil and chlorophyll measurements, an automated Trace Metals Analyzer (TMA) for the analysis of copper, lead, and cadmium, a PAR irradiance sensor, an Acoustic Doppler Current Profiler (ADCP), a digital fathometer, and a Differential Global Positioning System (DGPS) navigation receiver. A V-Fin depressor is used to keep the instrument package stable and submerged to the appropriate depth, while a hydraulic winch is used to raise and lower the package to the desired water depth.

Data will be collated at a nominal 4-Hz sampling rate, pre-processed, displayed in real-time, and stored on magnetic media using IBM compatible personal computers and the acquisition/control hardware system. A software package designed specifically for this purpose will be used to perform these tasks. Data from the ADCP will be averaged over 10 seconds, while the TMA collects data at 6-minute intervals. Integration of the DGPS navigation system allows all data to be directly linked to a location in latitude and longitude coordinates.

Real-time sensor data will be intercalibrated with discrete sample measurement data to derive absolute calibration and/or to provide correlation data that can be used to enhance the spatial resolution of the more limited, more costly, and time consuming traditional analyses. In the case of Chl-*a*,

discrete samples analyzed with traditional laboratory methods described above provide an absolute calibration for the real-time flow-through fluorometers. Similarly, discrete analyses for dissolved Cu will provide an absolute calibration for the real-time TMA Cu data. Discrete samples analyzed for PAH data will be used to develop a regression equation with UV-fluorescence data, a relationship that previously was found to be well correlated with total PAH (Katz et al., 1991). Discrete samples analyzed for TSS data will be used to develop a regression equation between TSS and real-time light transmission data (Katz 1998).

The intercalibrations will be performed by comparing the average value of the real-time sensor data collected during each sampling interval with the discrete sample value. Hose lag will be taken into consideration when computing the average value. In the case of Cu, split samples taken during sampling and analyzed directly on the TMA in discrete mode will be compared to the analyses performed by the contract laboratory using EPA methods. The regression equations developed are then applied to the real-time data to derive TSS, chlorophyll a, Cu, and TPAH values for the entire data set.

The discrete water sample data for these calibration exercises will be collected and processed as follows:

- **TSS, Chl-a, Nutrients:** Twelve samples for TSS, Chl-a, and nutrients will be collected on each survey. TSS, and Chl-a samples will be filtered and processed as described above for batch water samples.
- **Polynuclear Aromatic Hydrocarbons:** Fifteen seawater samples will be collected on each survey for PAH and kept refrigerated until analysis. PAH samples will be analyzed using the National Oceanic and Atmospheric Administration's Status and Trends version of the EPA Method 8270M. Samples will be acidified to pH 2.0 with 6N HCl, spiked with PAH surrogates, then solvent extracted in dichloromethane using a method similar to EPA Method 3501B, Separatory Funnel Liquid-Liquid Extraction. The extracts will be dried using sodium sulfate and concentrated to approximately 1 mL using Kuderna-Danish concentrators followed by nitrogen evaporation. The concentrated samples will be analyzed by Gas-Chromatography-Mass-Spectrometry run in Single Ion Mode. Forty-one individual PAH analytes will be quantified at a detection limit of 5 ng/L.
- **Copper:** Twenty-four seawater samples will be collected on each survey for dissolved Cu and kept refrigerated until analysis. Dissolved Cu samples will be analyzed using EPA Method 1640. In the laboratory, samples will be filtered through a 0.45- μ m capsule filter and acidified with 10% HNO₃ to bring the sample to a pH <2. The filtered samples will then preconcentrated by tetrahydroborate reductive precipitation (Nakashima et al.,) and determined by Inductively Coupled Plasma-Mass Spectrometry. The method detection limit for these analyses will be 0.1 μ g/L. Discrete seawater samples will also be collected for analysis of Cu on the TMA in discrete mode. While the TMA collects data while underway about every 6 minutes, the discrete samples will allow direct comparison of the Cu data analyzed by EPA methods. In either continuous or discrete analysis modes, the TMA automatically analyzes the seawater for dissolved copper using a potentiometric stripping analysis method. A 3-mL aliquot of water is drawn into an electrochemical cell along with chemical reagents

to facilitate the analysis. A negative potential is applied to the solution using a mercury film electrode that binds the Cu in solution. The electrode potential is then reversed and the Cu is driven off at a characteristic voltage. The concentration of copper is then determined by the length of time it remains bound to the film at its characteristic stripping potential.

C. Coordinated Studies in Mexico

While the focus of Bight'98 is on the US side of the border, a comparable, coordinated study will be conducted in Mexican coastal shelf waters. The Mexican component will share the same objectives as the US study, and will assess the area between the Mexican border and Ensenada. The sample sites, shown in Appendix D, were selected using the same criteria as in the US portion of the study.

The Mexican component is presently limited to the CTD survey element, which may not include use of a fluorometry sensor, though additional funding is being sought to add the sensor, as well as other program elements. All sampling effort and laboratory analysis for Mexican sampling sites will be conducted by Mexican scientists, who have helped prepare, and will follow, the procedures outlined in Appendix C. Mexican scientists have also participated in all intercalibration exercises conducted by their US counterparts.

Coordinating these programs will allow the first comparison of relative condition of the coastal waters of the two countries. Joint participation in intercalibration exercises also provides an opportunity to establish comparability that can be utilized in cooperative programs that extend beyond the tenure of Bight'98.

III. INFORMATION MANAGEMENT

A. Overview of Approach

Information gathering in Bight'98 will be based on the principle of partnership; all participating organizations will have equal and complete access to the data collected during the project. Historically, data sharing between agencies performing monitoring programs has been impeded because each agency organized and managed its own data using its own information management system. Bight'98 will address this challenge by developing and implementing an integrated, uniform, and well-documented information management system (IMS).

The core of the IMS will be a set of standardized data transfer protocols (SDTP) for data submittal. These protocols will detail the information to be submitted for each sample. Data will be submitted in defined column comma-delimited ASCII format. Information will include collection or processing elements unique to that particular sample, the units of measure and allowable values for each parameter. Use of SDTP allows each participating organization to retain their existing data management system, yet output the data in a manner that allows merging the data into a single data base.

A second attribute of the IMS will be centralized data storage. The water quality component of Bight'98 includes almost twenty collaborating organizations responsible for sampling and/or analyses. Many of these groups have limited internet capacity, which precludes a distributed system. The centralized location will be at SCCWRP, where data will be stored on personal computers in Microsoft Access.

Standardized Data Transfer Protocols (SDTP)

Four types of data entry tables will be used for the water quality SDTP in Bight'98. The first is the station table (Appendix E) which will be entered once for each station that is sampled in the survey. The table includes station descriptors, such as location in latitude, longitude and landmarks that can be used to locate the site.

The second table is the station occupation table that will include one entry for every visit to the site. This table includes sampling date, time, and environment descriptors such as wave height and weather conditions that will provide information on the sample from that particular day. It also includes information associated with batch samples, such as the volume of water filtered to achieve a chlorophyll sample.

The third table is the CTD cast table which includes a single record for every depth sampled. Each record will contain measurements for each of the channels on the CTD (temperature, transmissometry, etc.) normalized to an 8 Hz scan rate (1 Hz = once per second). Records in the CTD cast table will be related to the station occupation table through the StationID and date parameter fields.

The fourth table is the discrete water sample table which will include results of the laboratory analyses for chlorophyll, nutrients etc. Each record will include the result for a single parameter. Records in this table will be related to the station occupation table through the StationID and date parameter fields.

The SDTP are based on a relational structure in which these four data tables containing different types of data are linked by one or more common fields. Use of four data tables allows temporally independent data (e.g., lab vs. field data) to be entered at the time of data production, minimizing the possibility of data loss. Linking tables that contain data recorded at different frequencies also minimizes redundant data entry.

Data Flow and Quality Assurance

Each laboratory/participant generating data will sample the water column at a rate of 8 Hz and subject it to quality assurance/quality control (QA/QC) procedures outlined in appendix C. After each sampling event, all data is submitted to SCCWRP in proper format (appendix E) for review from the program manager, or appointee, and the project Information Management Officer (IMO).

Upon receipt, the IMO will check the data for errors, such as inclusion of all required fields, range checks, and proper naming conventions for text fields. Most of the error checking will be automated, conducted by a computer program developed specifically for Bight'98. The program will identify potential errors in the data by comparing the submitted values to expected ranges and formats specified in the information management plan. Small errors will be corrected by the IMO and the submitting lab will be notified of the corrections; data sets with larger errors will be returned to the submitting lab for correction, along with a list of corrections that the organization needs to make.

Once the IMO has certified that the data is consistent with the SDTP requirements, the data will be sent to the Water Quality Committee Chair (B. Jones) for data review and processing. The committee chair, with assistance of the Water Quality Committee (WQC), will review the data with respect to scientific content. This review may involve plotting of data and examining interrelationships among individual parameter responses and will address more extensive data quality issues which cannot be accomplished by range checking alone. Technical issues or questions of scientific content will be resolved by the WQC.

All corrections to the data will be made by the IMO who alone will have authority to modify the database. All other users will only receive the data in read-only form. Prior to making any changes, the IMO will document the changes and receive (written or electronic) concurrence of the organization that generated the data. The IMO will only make changes in the centralized data base; originating organizations will be responsible for making corresponding changes in their own internal data storage systems. All changes to the data will be documented in a computerized file that is available to all data users.

Data Availability

All data from Bight'98 will be made publicly available, though the schedule of availability will vary by user class. The different schedules recognize the differing levels of quality assurance and data documentation that will have been completed at various stages in the project. Four classes of user have been identified:

- **Information Management Officer:** All organizations will submit data to the IMO within one month of completing their assigned sample collection/processing task.
- **Water Quality Committee Members:** The Water Quality Committee Chair (WQCC) will be provided data from all labs immediately following certification by the IMO that the data follows the SDTP formats. The WQCC will work with the WQC members to conduct scientific content review.
- **Steering Committee Members:** All project participants will have access to data once the WQCC has conducted initial scientific review for data quality. The WQCC will be asked to complete this review within three months.
- **General Public:** Data will be released to the general public once a draft report documenting the study has been prepared and presented orally to the Steering Committee. The WQCC will be asked to prepare the report and make the presentation within six months of releasing data to the Steering Committee.

Each release of data will include comprehensive documentation. This documentation will include a lookup table used to populate specific fields in specific tables, access control, and database table structures (including table relationships). It will also include quality assurance classifications of the data (flags, as appropriate) and documentation of the methodologies by which the data were collected (metadata).

IV. QUALITY ASSURANCE / QUALITY CONTROL

A quality assurance/quality control (QA/QC) program is an important part of any environmental monitoring project. A carefully planned QA/QC program ensures that the data collected are scientifically valid, comparable, and adequate to meet the goals of the study. QA/QC is particularly important for large monitoring projects like Bight'98 that involve many participants.

The QA/QC program for Bight'98 consists of two distinct but related activities: quality assurance and quality control. Quality assurance includes design, planning, and management activities conducted prior to the study to ensure that the appropriate kind, quantity and quality of data are collected. Quality control activities are implemented during the project to evaluate the effectiveness of the QA activities in controlling measurement bias and error. QA activities are emphasized in Bight'98 due to the distributed implementation of the project.

A. Quality Assurance Elements

Two types of QA activities will be conducted prior to the implementation of the program:

- 1) Standardizing methods for those activities that can be standardized given differences in the underlying measurement methods, and
- 2) Intercalibration exercises to assess and control the variability introduced by inclusion of multiple laboratories and measurement methods.

Methods standardization

Participants will ascribe to common guidelines regarding equipment and instrumentation, calibration, and data handling. Much of the standardized procedures for CTD measurements that will be followed during Bight'98 are given in Appendix C and follows from standardization of methods established during the 1994 SCBPP.

All participants will use a SeaBird CTD. The CTDs will carry probes for measuring pressure, temperature, conductivity, dissolved oxygen, pH, beam transmission (660 nm), and chlorophyll fluorescence. The CTDs will be capable of recording at rates of 8 Hz or faster. The temperature and conductivity sensors are to have a current factory calibration from SeaBird Electronics, Inc. that has been obtained within 6 months of the intercalibration date. The other sensors will be calibrated using appropriate standards and calibration methods as described in Appendix F.

Intercalibration exercises

Data comparability among laboratories will be assessed prior to the survey through an intercalibration exercise to be held at SCCWRP on September 29, 1998 (table IV-1). The intercalibration will consist of simultaneously immersing all project CTDs into in a single freshwater

tank at constant temperature and dissolved oxygen to assess variability among the instruments. All participating organizations will precalibrate their CTDs within 24 hours of the intercalibration exercise using the procedures to be used during the survey. The chlorophyll standard (coproporphyrin standard at 50 µg/l) will be prepared by a single laboratory and distributed to all participants during the exercise.

All participants probes will be required to meet the following performance criteria in the intercalibration exercise prior to participating in the survey: the equilibrium data for each probe (temperature, dissolved oxygen, salinity, beam transmission, and chlorophyll must be within the 95% confidence limits for the group mean. Participants failing to meet these acceptance criteria, will work with the QA Officer to troubleshoot the problem, and will be required to successfully perform an additional intercalibration test prior to participating in the project.

Laboratory nutrient analyses chemistry will be calibrated by using standards made with measured amounts of nutrient standards as listed in Table IV-2. These running standards will be made for each run from primary standard stocks and will be run prior to and after each set of samples. Extracted particulate chlorophyll measurements will be measured on a laboratory fluorometer which has been calibrated with pure chlorophyll a obtained from Sigma Scientific. The fluorometer will be calibrated at the before running the first set of dry weather samples, and after running the last set of wet weather samples.

B. Quality Control Elements

Quality control procedures will be implemented during the project to quantify whether the water quality measurements obtained during the project continue to meet the measurement criteria above.

Drift of the temperature and conductivity sensors will be assessed using a factory re-calibration by SeaBird Electronics. Drift should be minimal as these sensors are generally stable. The oxygen and pH sensors will be calibrated before and after each cruise with the procedures described in the CTD field manual (Appendix C). The transmissometer will be calibrated before and after each cruise by measuring the output voltage in air with cleaned windows, and the blocked path voltage as described in the manufacturers' instrument manuals. The fluorometers will be calibrated before and after cruises using coproporphyrin standard (50 µg/l check this) to check for instrument drift and degradation.

The nutrient analysis will be checked with nutrient standards obtained from a commercial vendor yet to be determined to provide an independent check on the nutrient calibrations performed in the laboratory. This comparison will be performed during the run prior to running the first set of samples from the dry weather field study. If more than one laboratory is involved in nutrient and chlorophyll measurements, two methods of intercalibration will be used. For nutrients, the two laboratories will interchange their routine nutrient standards and run them as samples on their respective machines. In addition, a small number of samples (5) will be split and sent to each laboratory for comparison of results. The difference between laboratories is to be less than 5% of the full measurement range for each analyte on their analysis systems.

Laboratory comparisons for chlorophyll analysis will consists of field samples which are split and submitted to all laboratories. Measurement differences between the laboratories should be less than or equal to 0.2 µg/l chlorophyll a.

V. PROJECT MANAGEMENT

A. Management Structure

Almost a thousand people from more than 40 organizations are involved in the planning and implementation of Bight'98. Success of the program depends largely on an effective management structure to communicate project objectives and coordinate the effort among participants to produce data that are reliable and comparable. This is being accomplished with a three-tier management structure; the three tiers have distinct roles and provide the opportunity for participation by different levels of personnel from within each participating organization.

At the center of the Bight'98 management structure is the Steering Committee, that is composed of scientifically trained, mid-level managers from each of the participating agencies (Table V-1). The Steering Committee is responsible for overall planning of the project, including establishing project objectives, developing the sampling design and selecting the indicators to be measured. Steering Committee members are responsible for defining the resources their organization bring to the project and for ensuring that the objectives set forth for the project are consistent with the cumulative set of resources available. The Steering Committee also serves as a point of technical review for all documents that are produced by the project. Participation on the Steering Committee ensures each participating organization the opportunity to direct the program through a consensus building process.

The Steering Committee is supported by eight technical subcommittees, which are responsible for recommending technical approaches to accomplish the objectives set forth by the Steering Committee. For the Water Quality Component of Bight'98, the Steering Committee is supported by the Water Quality Technical Committee (Table V-2). Members of this group typically manage, or are technical experts, for various water quality monitoring programs of receiving/recreational waters throughout the region. Many also are involved in the development of regulatory policy associated with the safety of swimmers and the quality of receiving /recreational waters.

The Water Quality Technical Committee is responsible for preparing methods and quality assurance procedures for the project, implementing the quality assurance procedures (e.g. intercalibration exercises) prior to the study and the quality control assessments during the study, and for preparing the reports that summarize the water quality data. The role of the Water Quality Committee differs from that of most other Technical Committees in that they have also been asked to develop a recommended sampling design for the water quality component; this work plan was produced primarily by the Water Quality Committee for Steering Committee review. The Water Quality Committee has a larger role because the questions and habitats to be sampled in the water quality component differ from those being addressed by most other technical committees.

audience for the products of this project. SCCWRP is a joint powers agency, that is coordinating Bight'98. The SCCWRP Commission is a nine-member board that is composed of the highest level of management from each of the largest municipal dischargers to Southern California Bight and from each of the agencies responsible for regulating discharge to the Bight. Reporting to the SCCWRP Commission, which meets on a quarterly basis, ensures that the questions addressed by Bight'98 remain relevant to current management issues. Reporting to the Commission also maximizes the

likelihood that the project results will be incorporated into the southern California environmental management decision-making arena.

Logistics

The large scale grid of stations which is based on the design criteria presented in section II (Appendices A and B), will be subdivided into three management zones (northern, central, and southern) rather than being executed as a single Bight-wide study as is being done for the other Bight'98 components. The Water Quality component is being approached in a zonal fashion because the most appropriate rainfall events to study may not occur simultaneously throughout the SCB. A zone structure provides greater flexibility to respond to the proper conditions, but also requires an additional layer of management and decision-making.

Each of the three zones has been assigned a zone coordinator who has the responsibility of determining when sampling should begin (Table V-3). The zone coordinator will constantly check long-range forecasts and be required to notify sampling organizations within their zone about the possibility of a sampling event, and ask about availability of their vessels and crew, at least 72 hours prior to the potential event. The event criteria for deciding whether or not to sample a given storm in each zone are discussed in Section II.A.1.b. Zone coordinators are required to make a decision about whether to sample at least 24 hours prior to sampling. The zone coordinators, the organizations they coordinate, and the station commitments of each organization are listed in Table V-3. Our Mexican colleagues will collaborate with the southern zone in coordinating their field efforts.

Two black-out periods have been identified in an attempt to prevent inconveniencing field crews during the holiday season. No sampling will occur during the periods of:

Thanksgiving	November 25-29, 1999
Christmas and New Years	December 23, 1998 – January 3, 1999

While each of the zone coordinators are permitted to make independent decisions based on the anticipated weather conditions and the timing of personnel/equipment availability within their zone, they are encouraged to keep in close contact with other zone coordinators. Sampling of the Bight as an entirety is the preferable option. Zone coordinators are encouraged to coordinate their efforts, particularly if conditions are marginal in a particular zone.

The individual field studies will be considered a success if the participating organizations are able to occupy 75% or more of the stations that they have responsibility for sampling. If fewer than 75% of the stations are not able to be occupied for a given event, the sampling will be considered incomplete and require the sampling of another wet weather event within the designated time windows, if possible.

B. Project Reporting

The Bight'98 Water Quality component will produce a technical report that includes the following three elements: 1) a comparison of extent of influence of freshwater runoff from streams, bays, and harbors with those of POTW discharges during both wet and dry conditions (to include 3D

graphics for each parameter), 2) a summary of tools developed for the integrated assessment from in situ and remotely sensed data, and 3) a QA assessment of results from the intercalibration exercises.

VI. LITERATURE CITED

- Armstrong, F.A.J., C.R. Stearns, and D.H. Strickland, The measurement of upwelling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment., *Deep-Sea Research*, 14 (3), 381-389, 1967.
- Bernhardt, H., and A. Wilhelms, The continuous determination of low level iron, soluble phosphate, and total phosphate with the AutoAnalyzer., in *Technicon Symposium*, pp. 386, Technicon, 1967.
- Bay, S., K. Schiff, D. Greenstein, and L. Tiefenthaler. 1997. Stormwater runoff effects on Santa Monica Bay, toxicity, sediment quality, and benthic community impacts. In: O.T. Magoon, H. Converse, B. Baird, and M. Miller-Henson, eds., *California and the World Ocean '97*, Vol. 2, pp. 900-921. American Society of Civil Engineers, Reston, Virginia.
- Economic Resources Data, 1993
- Gordon, L.I., J.C. Jennings, A.A. Ross, and J.M. Krest, A Suggested Protocol for Continuous Automated Analysis of Seawater Nutrients (Phosphate, Nitrate, Nitrite and Silicic Acids) in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study, Oregon State University, Corvallis, OR, 1993.
- Holm-Hansen, O., C.J. Lorenzen, R.W. Holmes, and J.D.H. Strickland, Fluorometric determination of chlorophyll, *Journal du Conseil*, 30, 3-15, 1965.
- Jeffrey, S.W., R.F.C. Mantoura, and S.W. Wright, Phytoplankton Pigments in Oceanography, in *Monographs in Oceanographic Methodology*, pp. 661, UNESCO, Paris, 1997.
- Jones, B.H., A. Bratkovich, T. Dickey, G. Kleppel, A. Steele, R. Iturriaga, and I. Haydock, Variability of physical, chemical and biological parameters in the vicinity of an ocean outfall plume, in *Stratified Flows*, edited by E.J. List, and G.H. Jirka, pp. 877-890, ASCE, New York, 1990.
- Jones, B.H., L. Washburn, and Y. Wu, The dispersion of ocean outfall plumes: Physical and biological dynamics, in *Coastal Zone 91*, pp. 74-85, ASCE, Long Beach, CA, 1991.
- Jones, B.H., and L. Washburn, Storm water runoff into Santa Monica Bay: Identification, impact and dispersion, in *California and the World Oceans Conference 97*, ASCE, San Diego, CA, 1997.
- Katz, C.N., Seawater Polynuclear Aromatic Hydrocarbons and Copper in San Diego Bay, Space and Naval Warfare Systems Center, San Diego, CA, 1998.
- Katz, C.N., D.B. Chadwick, and G.S. Douglas, Real-time fluorescence measurements intercalibrated with GC-MS, in *Oceans 91*, pp. 351-358, IEEE, 1991.

- Nakashima, S., R.E. Sturgeon, S.N. Willie, and S.S. Berman, Determination of Trace Elements in Sea Water by Graphite-Furnace Atomic Absorption Spectrometry After Preconcentration by Tetrahydroborate Reductive Precipitation, *Analytical Chimica Acta*, 207, 291-299, 1988.
- National Research Council (NRC) 1990. Monitoring Southern California's coastal waters. National Academy Press, Washington, DC. 154 p.
- Petrenko, A., B.H. Jones, T.D. Dickey, and P.J.W. Roberts, Comparison of near-field dilutions from in situ measurements and simulated dilutions at the Sand Island sewage outfall plume, Hawaii, *Journal of Hydraulic Engineering*, In press, 1998a.
- Petrenko, A.A., B.H. Jones, T.D. Dickey, M. LeHaitre, and C. Moore, Characterization of particle fields in Mamala Bay, HI with special emphasis on the Sand Island sewage plume, *Journal of Geophysical Research*, 102 (C11), 25061-25071, 1998b.
- SCBPP Steering Committee. 1998. Southern California Bight 1994 Pilot Project: I. Executive summary. Southern California Coastal Water Research Project, Westminster, CA.
- Washburn, L., B.H. Jones, A. Bratkovich, T.D. Dickey, and M. Chen, Mixing, dispersion, and resuspension in the vicinity of an ocean outfall wastewater plume, *Journal of Hydraulic Engineering*, 118, 38-58, 1992.
- Wu, Y., L. Washburn, and B.H. Jones, Buoyant plume dispersion in a coastal environment: Observations of plume structure and dynamics, *Continental Shelf Research*, 14, 1001-1023, 1994.

Figure I-1. Map of the Southern California Bight.

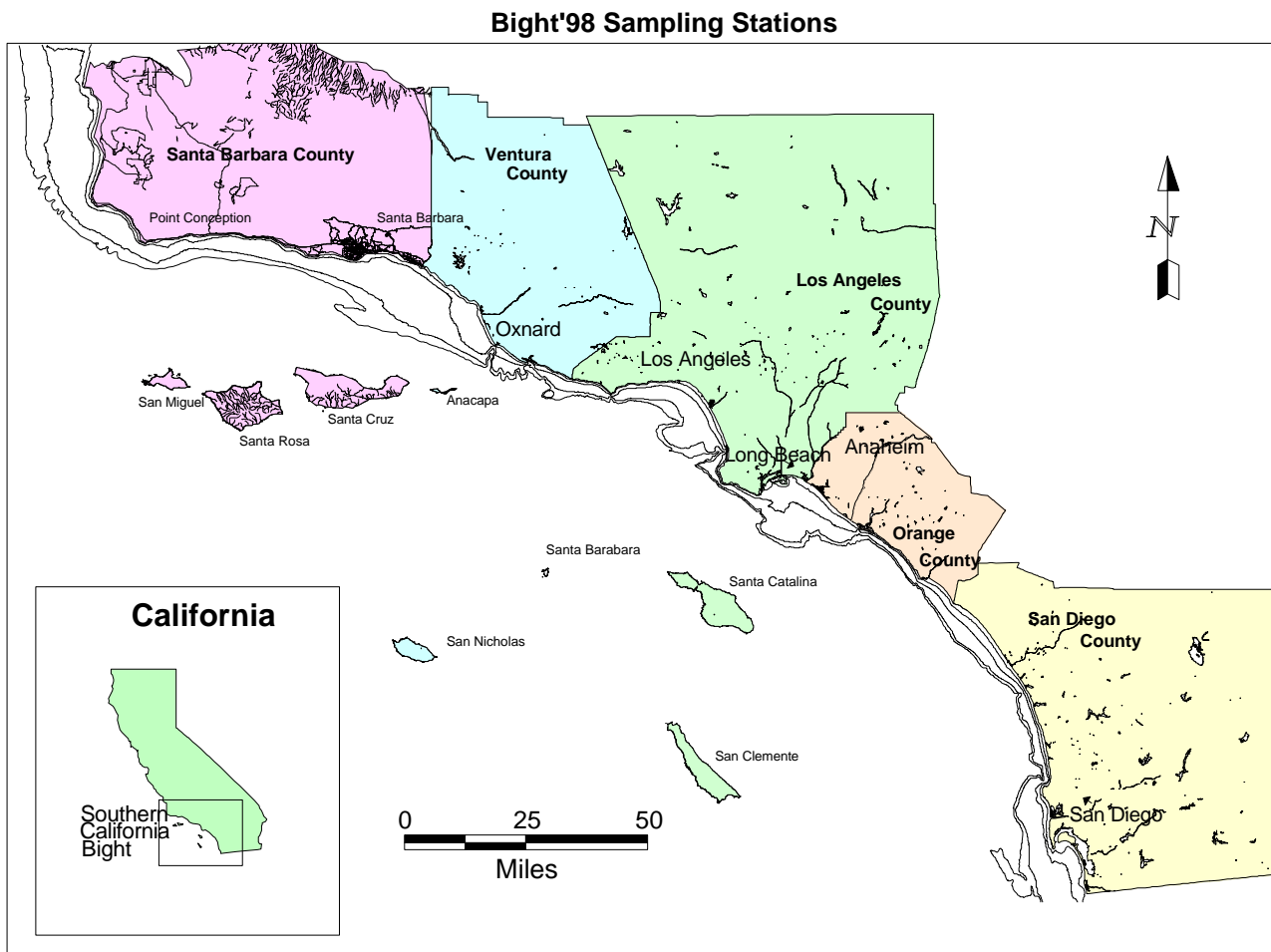


Figure II-1. Map of proposed San Diego Bay sampling track.

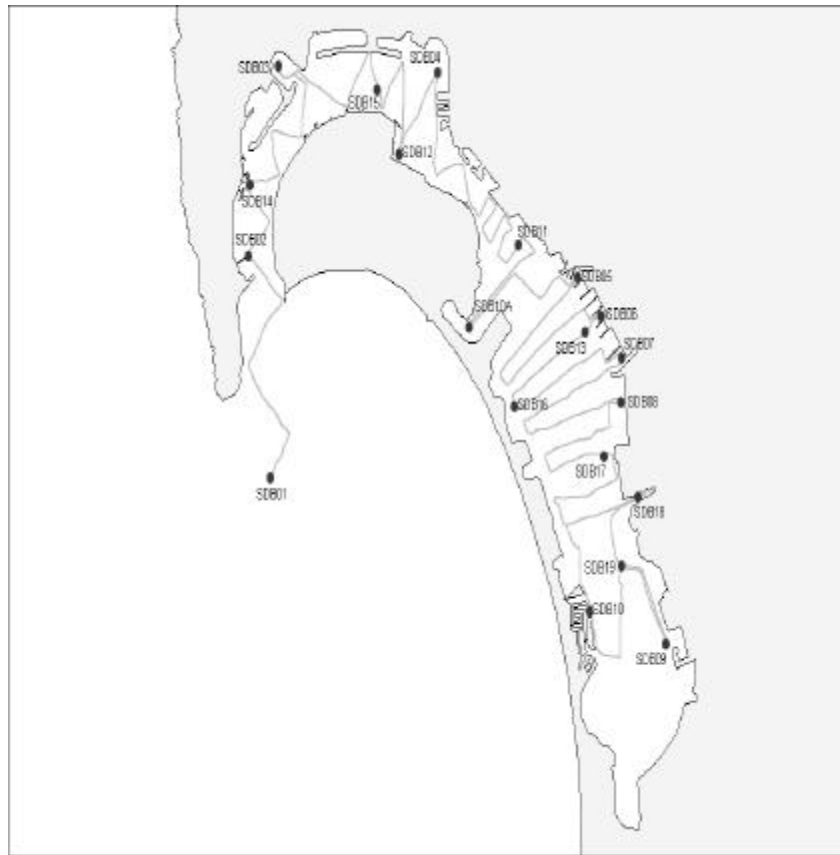


Figure II-2. Map of proposed Los Angeles/Long Beach Harbors sampling track.



TABLE I-1. Participants in the Southern California Bight 1998 Regional Monitoring Program (Bight'98). * Denotes participants in the water quality component.

AES Corporation
 Algalita Marine Research Foundation
 Aliso Water Management Authority (AWMA)*
 Aquatic Bioassay and Consulting (ABCL)*
 Center for Environmental Cooperation
 Central Coast Regional Water Quality Control Board
 Channel Islands National Marine Sanctuary (CINMS)*
 Chevron USA Products Company
 City of Long Beach
 City of Los Angeles Environmental Monitoring Division (CLAEMD)*
 City of Los Angeles Stormwater Management Division
 City of Oceanside*
 City of Oxnard*
 City of San Diego*
 City of Santa Barbara
 City of Ventura*
 Columbia Analytical Services
 Divers Involved Voluntarily in Environmental Rehabilitation & Safety (DIVERS)
 Encina Wastewater Authority*
 Goleta Sanitation District
 Granite Canyon Marine Pollution Studies Lab
 Houston Industries, Inc.
 Instituto de Investigacione, Oceanologicas University Autonomous de Baja California (UABC)*
 Los Angeles Department of Water and Power*
 Los Angeles County Dept. of Beaches & Harbors
 Los Angeles County Dept. of Health Services
 Los Angeles Regional Water Quality Control Board*
 Los Angeles County Sanitation Districts (LACSD)*
 Marine Corps Base - Camp Pendleton
 National Fisheries Institute of Mexico (SEMARNAP)
 NOAA International Programs Office
 NRG Energy, Inc.
 Orange County Environmental Health Division
 Orange County Public Facilities and Resources (OCPFRD)
 Orange County Sanitation District (OCSA)*
 San Diego County Dept. of Environmental Health
 San Diego Interagency Water Quality Panel (Bay Panel)
 San Diego Regional Water Quality Control Board (SDRWQCB)*
 San Elijo Joint Powers Authority*
 Santa Ana Regional Water Quality Control Board*
 Santa Barbara Health Care Services
 Santa Monica Bay Restoration Project
 Secretaria de Marina (Mexican Navy)*
 Southeast Regional Reclamation Authority (SERRA)*

TABLE I-1. (continued) Participants in the Southern California Bight 1998 Regional Monitoring Program (Bight'98). * Denotes participants in the water quality component.

Southern California Coastal Water Research Project (SCCWRP)*
Southern California Edison (SCE)
Southern California Marine Institute (SCMI)
State Water Resources Control Board (SWRCB)
Surfrider Foundation
USC Wrigley Institute for Environmental Studies (WIES)*
University of California, Santa Barbara*
US EPA Region IX
US EPA Office of Research and Development
US Geological Survey
US Navy, Space & Naval Warfare Systems Center, San Diego (USN)*

Table II-1. Site selection criteria for the CTD survey

Vertical	Bottom depth \leq 100m: Surface to near bottom (2m) Bottom depth >100m: Surface to 100m
Cross-shelf	
Transect Orientation:	Cross-shelf
Between station spacing:	First 2 km - 1km (i.e. 0, 1, 2 km) Beyond 2 km - 2-3 km
Maximum offshore distance:	10 km
Relative to POTWs:	One station on each transect will be on 60m isobath
Along-shelf	
Near POTW(Over ZID):	
Large discharge (>100mgd):	2 km
Small discharge (<50mgd):	0.5 km
Near river sources:	1 km for first 2 km
Away from river source:	4-6 km for distances >2km from source
Open Areas:	4-6 km

Table II-2. Chemical, physical, and biological parameters, and the frequency of their measurement made with the MESC.

Parameter	Measured	Derived	Frequency (s ⁻¹)
Local Time	x		4
Latitude	x		2
Longitude	x		2
Ship Velocity	x		2
Relative Wind Velocity	x		1
True Wind Velocity		x	1
Current Velocity (over full vertical range)	x		0.2
Sample Pressure	x		4
Sample Depth		x	4
Conductivity	x		4
Temperature	x		4
Salinity		x	4
Density		x	4
Bottom Depth	x		1
Light Transmission (turbidity)	x		4
Total suspended solids (TSS)		x	4
pH	x		4
Dissolved Oxygen	x		4
Oxygen Saturation		x	4
Oil fluorescence	x		4
Oil (DFME)		x	4
TPAH (polyaromatic hydrocarbons)		x	4
Chlorophyll fluorescence	x		4
Chlorophyll- <i>a</i> (Chl- <i>a</i>)		x	4
Nutrients	x		Various*
Metals Cu, Pb, Cd	x		Various*

Table II-3. Candidate Satellite Sensors and their characteristics

Sensor	Measurement(s)	Approx. Pixel Size
Advanced Very High Resolution Radiometer (AVHRR)	Sea surface temperature (SST)	1 km
Sea-viewing Wide Field-of-view Sensor (SeaWiFs)	Ocean color and pigment concentration	1 km
Synthetic Aperture Radar (SAR)	Ocean roughness	20 m

Table IV-1. Requirements for intercalibration exercise.

Parameter	Units	Acceptable Range
Temperature	°C	+/- 0.03 °C
Salinity	Practical salinity scale (pss)	+/- 0.01 pss
Dissolved Oxygen	mg/l	+/- 0.15 mg/l
pH		+/- 0.1
Beam transmission (660 nm)	% for 25 cm pathlength	+/- 0.5 %
Chlorophyll fluorescence	µg/l	+/- 0.1µg/l
Pressure	decibars (dbar)	+/- 0.5 dbar

Table IV-2. Standards used for nutrient analysis runs

Nutrient	Standard Compound	Standard Concentrations
Nitrate (NO ₃)	NaNO ₃	0, 10, 20 and 40
Nitrite (NO ₂)	NaNO ₂	0, 1, 2, and 4 µM
Phosphate (PO ₄)	KH ₂ PO ₄	0, 1, 2, and 4 µM
Silicate (SiO ₄)	Na ₂ SiF ₆	0, 20, 40, and 80 µM

TABLE V-1. 1998 Regional Monitoring Steering Committee Members.

Anson, Nancy	Encina Wastewater Authority
Branch, Nicki	San Elijo Joint Powers Authority
Dojiri, Mas	City of Los Angeles Environmental Monitoring Division (CLAEMD)
Fangman, Sarah	Channel Islands National Marine Sanctuary (CINMS)
Fleming, Terry	US EPA, Region IX
Grovhoug, Jeff	US Navy, Space & Naval Warfare Systems Center, San Diego
Harley, Ann	Aliso Water Management Authority (AWMA) Southeast Regional Reclamation Authority (SERRA)
Herbinson, Kevin	Southern California Edison (SCE)
Ito, Neil	Chevron USA Products Company
Jones, Darcy	San Diego Regional Water Quality Control Board (SDRWQCB)
Lyons, Michael	Los Angeles Regional Water Quality Control Board (LARWQCB)
Mayville, Steve	Santa Ana Regional Water Quality Control Board.
Michael, Pete	San Diego Regional Water Quality Control Board (SDRWQCB)
Mikel, Tim	Aquatic Bioassay & Consulting Laboratories (ABCL)
Mofidi, Fazi	Los Angeles Department of Water and Power (LADWP)
Moore, Bruce (OCPFRD)	Orange County Public Facilities and Resources Department
Noble, Rachel	USC Wrigley Institute for Environmental Studies (WIES)
Pennell, Gus	City of Oceanside
Rao, Linda	State Water Resources Control Board (SWRCB)
Robertson, George (Co-chair)	Orange County Sanitation District (OCSD)
Stull, Jan	Los Angeles County Sanitation Districts (LACSD)
Vereker, Lori	City of San Diego
Weisberg, Steve (Chair)	Southern California Coastal Water Research Project (SCCWRP)

Table V-2. Water Quality Committee Members

Canino, Raul	Facultad de Ciencias Marinas (UABC)
Diehl, Dario	Southern California Coastal Water Research Project
Duggan, Ross	City of San Diego
Fangman, Sarah	Channel Islands Marine Sanctuary
Helyer, Karen	MEC Analytical
Jones, Burt (Chair)	University of Southern California
Katz, Chuck	US Navy, Space & Naval Warfare Systems, Center, San Diego
Lyons, Michael	Los Angeles Regional Water Quality Control Board
Meyer, Marty	Aquatic Bioassay and Consulting Laboratories
Mengel, Mike	Orange County Sanitation District
O'Brien, Fred	Orange County Sanitation District
O'Donohue, Diane	City of San Diego
Shisko, John	City of Los Angeles Environmental Monitoring Division
Steele, Alex (Co-Chair)	Los Angeles County Sanitation Districts
Stern, Fred	Los Angeles County Sanitation Districts
Weisberg, Steve	Southern California Coastal Water Research Project
White, Brian	City of Los Angeles Department of Water and Power

Table V-3. Summary of Coordination Zones, Participating Agencies, and Agency Commitment

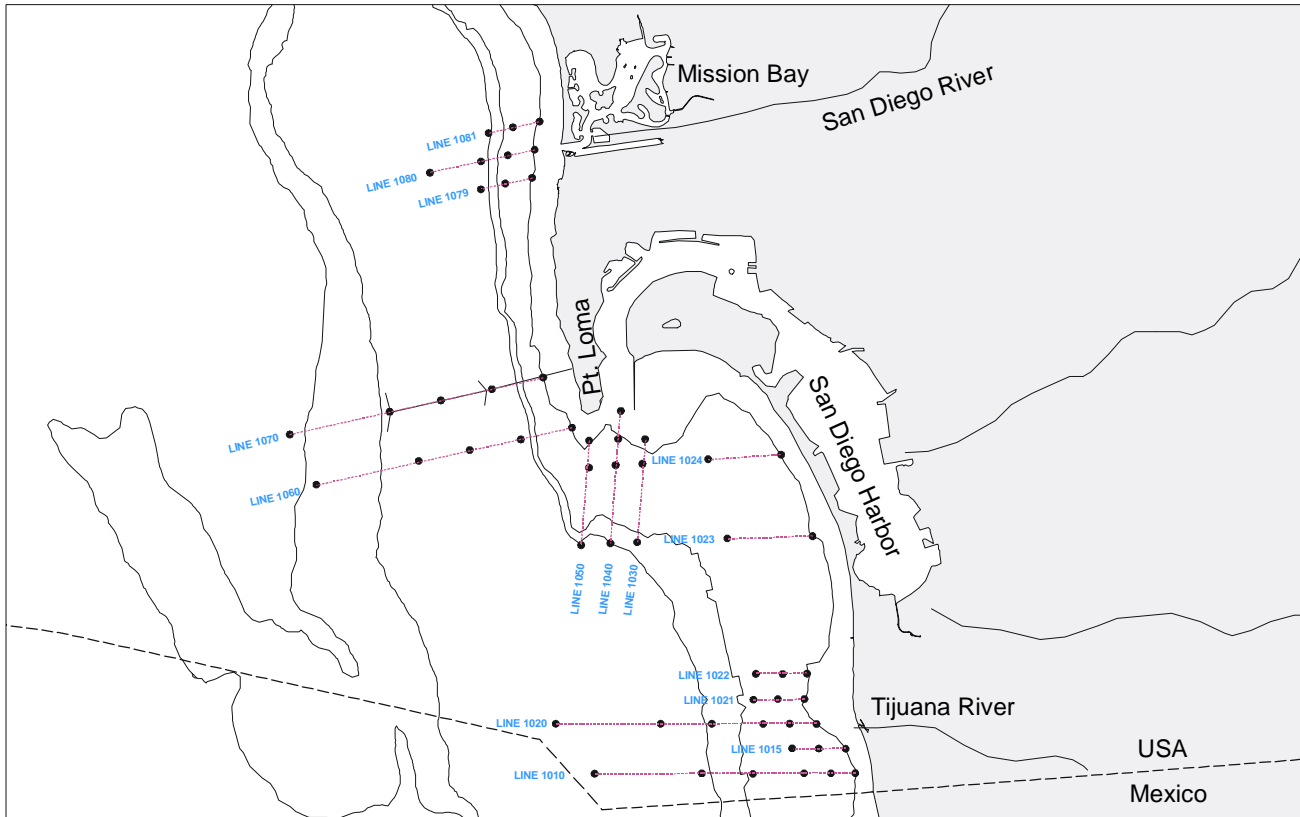
Zone	Coordinator, Agency	Agencies in Zone	No. Stations per event	No. Events	Total Commitment
Northern Zone	Sarah Fangman, (CINMS)	CINMS/ UCSB	28	3	84
		Oxnard (ABC)	36	3	108
Central Zone	Alex Steele (LACSD)	County of LA (LACSD)	86	3	258
		City of LA (EMD)	84	3	252
		Orange County (OCSD)	66	3	198
		SPAWAR	Map LA/LB Harbor	2	
		SCCWRP	43	3	129
Southern Zone	Ross Duggan (SDSD)	Encina (MEC)	20	3	60
		San Elijo (MEC)	28	3	84
		San Diego Mexico (UABC)	55	3	165
		SPAWAR	Map SD Harbor	2	
Total Station Commitment:			446	3	1338

APPENDIX A.

Maps of Sampling Sites

Sampling Agency:

City of San Diego



Map by Dario Diehl

MEC Analytical

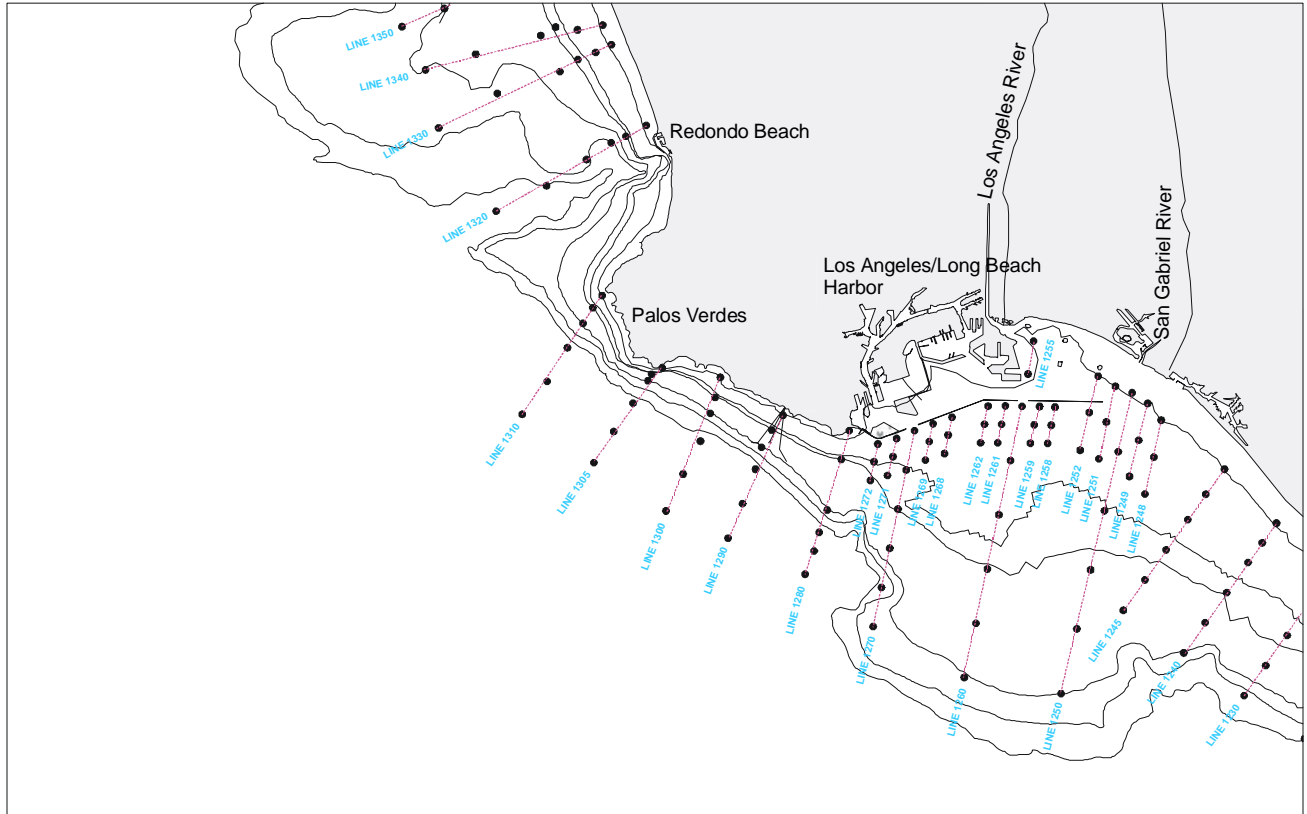


Los Angeles County Sanitation Districts
Orange County Sanitation District
MEC Analytical



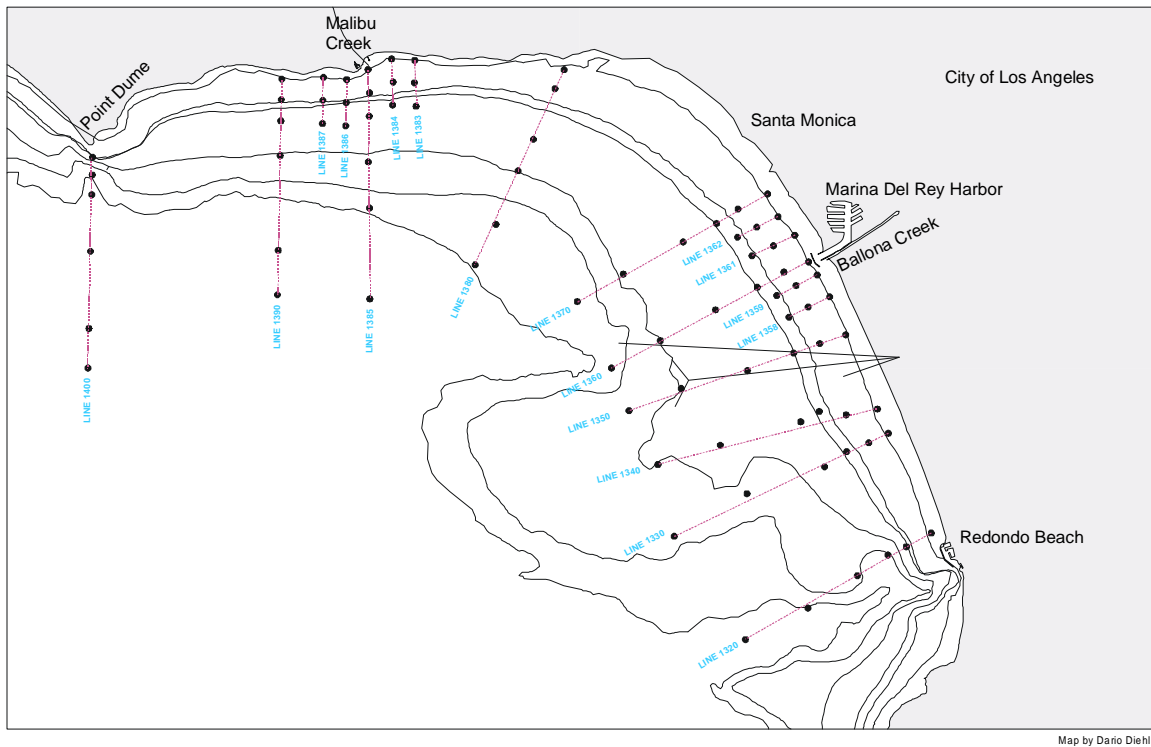
Sampling Agencies:

City of Los Angeles
Los Angeles County Sanitation Districts
Orange County Sanitation District

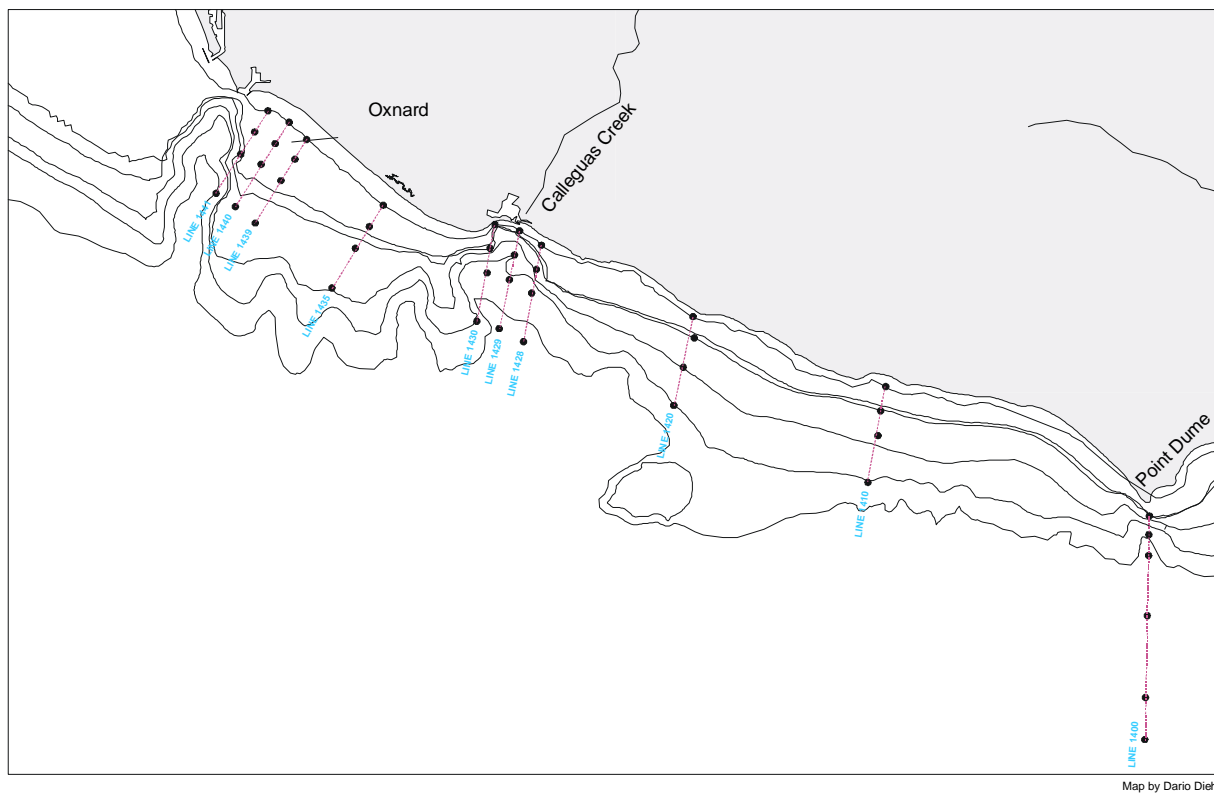


Map by Dario Diehl

Sampling Agency:
City of Los Angeles

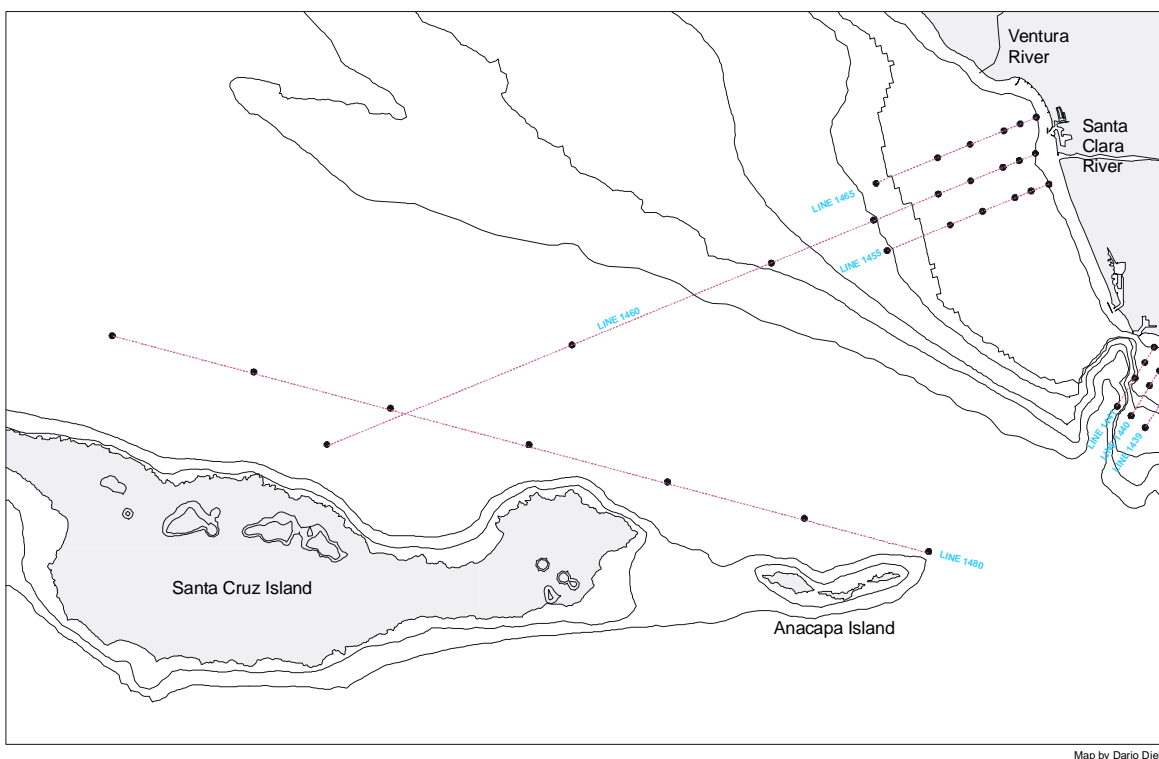


City of Los Angeles
ABC (Aquatic Bioassay and Consulting)



Sampling Agencies:

ABC (Aquatic Bioassay and Consulting)
Channel Islands National Marine Sanctuary
University of California, Santa Barbara



Map by Dario Diehl

APPENDIX B.

Sampling site coordinates

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
101001	32°	32.436	117°	7.920	No	SD	South
101002	32°	32.430	117°	8.520	No	SD	South
101003	32°	32.430	117°	9.180	No	SD	South
101004	32°	32.412	117°	10.440	No	SD	South
101005	32°	32.418	117°	11.700	No	SD	South
101006	32°	32.400	117°	14.340	No	SD	South
101501	32°	32.946	117°	8.160	No	SD	South
101502	32°	32.946	117°	8.820	No	SD	South
101503	32°	32.946	117°	9.480	No	SD	South
102001	32°	33.462	117°	8.880	Yes	SD	South
102002	32°	33.462	117°	9.540	Yes	SD	South
102003	32°	33.456	117°	10.200	No	SD	South
102004	32°	33.456	117°	11.460	Yes	SD	South
102005	32°	33.450	117°	12.720	No	SD	South
102006	32°	33.438	117°	15.300	No	SD	South
102101	32°	33.978	117°	9.180	No	SD	South
102102	32°	33.978	117°	9.840	No	SD	South
102103	32°	33.960	117°	10.440	No	SD	South
102201	32°	34.506	117°	9.120	No	SD	South
102202	32°	34.500	117°	9.720	No	SD	South
102203	32°	34.500	117°	10.380	No	SD	South
102301	32°	37.380	117°	9.000	No	SD	South
102302	32°	37.326	117°	11.100	No	SD	South
102401	32°	39.078	117°	9.780	No	SD	South
102402	32°	38.976	117°	11.580	No	SD	South
103001	32°	39.390	117°	13.140	No	SD	South
103002	32°	38.874	117°	13.200	No	SD	South
103003	32°	37.236	117°	13.320	No	SD	South
104001	32°	39.978	117°	13.740	Yes	SD	South
104002	32°	39.390	117°	13.800	No	SD	South
104003	32°	38.844	117°	13.860	Yes	SD	South
104004	32°	37.212	117°	13.980	Yes	SD	South
105001	32°	39.354	117°	14.520	No	SD	South
105002	32°	38.790	117°	14.520	No	SD	South
105003	32°	37.170	117°	14.700	No	SD	South
106001	32°	39.624	117°	14.940	No	SD	South
106002	32°	39.372	117°	16.200	No	SD	South
106003	32°	39.144	117°	17.460	No	SD	South
106004	32°	38.910	117°	18.720	No	SD	South
106005	32°	38.400	117°	21.240	No	SD	South
107001	32°	40.668	117°	15.660	No	SD	South
107002	32°	40.416	117°	16.920	No	SD	South
107003	32°	40.176	117°	18.180	No	SD	South
107004	32°	39.930	117°	19.440	No	SD	South
107005	32°	39.444	117°	21.900	No	SD	South
107901	32°	44.832	117°	15.960	No	SD	South
107902	32°	44.712	117°	16.620	No	SD	South
107903	32°	44.586	117°	17.220	No	SD	South
108001	32°	45.420	117°	15.900	Yes	SD	South
108002	32°	45.300	117°	16.560	Yes	SD	South
108003	32°	45.168	117°	17.220	No	SD	South
108004	32°	44.928	117°	18.480	Yes	SD	South
108101	32°	46.008	117°	15.780	No	SD	South

Station Name	Latitude (deg) (min)		Longitude (deg) (min)		Water Sample	Sampling Org.	Sample Area
108102	32°	45.888	117°	16.440	No	SD	South
108103	32°	45.762	117°	17.040	No	SD	South
108901	33°	0.174	117°	17.160	No	MEC	South
108902	33°	0.060	117°	17.820	No	MEC	South
108903	32°	59.940	117°	18.480	No	MEC	South
109001	33°	0.468	117°	17.220	Yes	MEC	South
109002	33°	0.354	117°	17.880	Yes	MEC	South
109003	33°	0.234	117°	18.540	No	MEC	South
109004	33°	0.006	117°	19.800	Yes	MEC	South
109101	33°	0.750	117°	17.280	No	MEC	South
109102	33°	0.636	117°	17.940	No	MEC	South
109103	33°	0.522	117°	18.600	No	MEC	South
109201	33°	2.934	117°	18.420	No	MEC	South
109202	33°	2.832	117°	19.020	No	MEC	South
109203	33°	2.724	117°	19.680	No	MEC	South
109301	33°	5.124	117°	19.260	Yes	MEC	South
109302	33°	5.034	117°	19.860	Yes	MEC	South
109303	33°	4.914	117°	20.520	Yes	MEC	South
109901	33°	6.582	117°	19.860	No	MEC	South
109902	33°	6.480	117°	20.520	No	MEC	South
109903	33°	6.372	117°	21.120	No	MEC	South
110001	33°	6.846	117°	19.980	No	MEC	South
110002	33°	6.738	117°	20.580	No	MEC	South
110003	33°	6.636	117°	21.240	No	MEC	South
110004	33°	6.414	117°	22.560	No	MEC	South
110101	33°	7.116	117°	20.100	No	MEC	South
110102	33°	7.014	117°	20.700	No	MEC	South
110103	33°	6.894	117°	21.360	No	MEC	South
110201	33°	8.550	117°	21.060	No	MEC	South
110202	33°	8.286	117°	21.600	No	MEC	South
110203	33°	8.016	117°	22.200	No	MEC	South
110901	33°	10.110	117°	22.380	No	SCCWRP	South
110902	33°	9.792	117°	22.860	No	SCCWRP	South
110903	33°	9.468	117°	23.400	No	SCCWRP	South
111001	33°	10.314	117°	22.620	No	SCCWRP	South
111002	33°	9.990	117°	23.100	No	SCCWRP	South
111003	33°	9.660	117°	23.640	No	SCCWRP	South
111004	33°	9.036	117°	24.660	No	SCCWRP	South
111101	33°	10.518	117°	22.800	No	SCCWRP	South
111102	33°	10.200	117°	23.340	No	SCCWRP	South
111103	33°	9.888	117°	23.880	No	SCCWRP	South
111901	33°	11.418	117°	23.580	No	MEC	South
111902	33°	11.106	117°	24.120	No	MEC	South
111903	33°	10.770	117°	24.660	No	MEC	South
112001	33°	11.772	117°	24.120	No	MEC	South
112002	33°	11.436	117°	24.660	No	MEC	South
112003	33°	11.112	117°	25.200	No	MEC	South
112004	33°	10.476	117°	26.220	No	MEC	South
112101	33°	12.222	117°	24.540	No	MEC	South
112102	33°	11.898	117°	25.080	No	MEC	South
112103	33°	11.562	117°	25.560	No	MEC	South

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
112901	33°	13.062	117°	25.140	No	MEC	South
112902	33°	12.744	117°	25.680	No	MEC	South
112903	33°	12.420	117°	26.220	No	MEC	South
113001	33°	13.518	117°	25.560	Yes	MEC	South
113002	33°	13.194	117°	26.100	Yes	MEC	South
113003	33°	12.870	117°	26.580	No	MEC	South
113004	33°	12.228	117°	27.660	Yes	MEC	South
113101	33°	13.968	117°	25.920	No	MEC	South
113102	33°	13.644	117°	26.460	No	MEC	South
113103	33°	13.314	117°	27.000	No	SCCWRP	South
113201	33°	14.436	117°	26.280	No	SCCWRP	South
113202	33°	14.118	117°	26.820	No	SCCWRP	South
113203	33°	13.782	117°	27.360	No	SCCWRP	South
115001	33°	25.302	117°	38.280	No	SCCWRP	Central
115002	33°	24.978	117°	38.820	No	SCCWRP	Central
115003	33°	24.636	117°	39.420	No	SCCWRP	Central
115901	33°	26.370	117°	39.900	No	SCCWRP	Central
115902	33°	26.058	117°	40.440	No	SCCWRP	Central
115903	33°	25.728	117°	40.980	No	SCCWRP	Central
116001	33°	26.652	117°	40.620	Yes	SCCWRP	Central
116002	33°	26.334	117°	41.100	Yes	SCCWRP	Central
116003	33°	26.058	117°	41.580	No	SCCWRP	Central
116004	33°	25.368	117°	42.660	Yes	SCCWRP	Central
116101	33°	26.904	117°	41.220	No	SCCWRP	Central
116102	33°	26.580	117°	41.760	No	SCCWRP	Central
116103	33°	26.256	117°	42.240	No	SCCWRP	Central
116201	33°	27.192	117°	41.820	No	SCCWRP	Central
116202	33°	26.862	117°	42.360	No	SCCWRP	Central
116203	33°	26.526	117°	42.900	No	SCCWRP	Central
117001	33°	28.812	117°	43.920	No	SCCWRP	Central
117002	33°	28.476	117°	44.460	No	SCCWRP	Central
117003	33°	28.134	117°	45.000	No	SCCWRP	Central
117901	33°	30.144	117°	45.000	No	SCCWRP	Central
117902	33°	29.808	117°	45.540	No	SCCWRP	Central
117903	33°	29.472	117°	46.140	No	SCCWRP	Central
118001	33°	30.552	117°	45.420	Yes	SCCWRP	Central
118002	33°	30.210	117°	45.960	Yes	SCCWRP	Central
118003	33°	29.874	117°	46.560	No	SCCWRP	Central
118004	33°	29.244	117°	47.580	Yes	SCCWRP	Central
118101	33°	30.972	117°	45.900	No	SCCWRP	Central
118102	33°	30.636	117°	46.440	No	SCCWRP	Central
118103	33°	30.300	117°	46.980	No	SCCWRP	Central
119001	33°	33.682	117°	49.654	No	OCSD	Central
119002	33°	33.165	117°	49.944	No	OCSD	Central
119003	33°	32.762	117°	50.182	No	OCSD	Central
119004	33°	31.787	117°	50.734	No	OCSD	Central
119005	33°	30.810	117°	51.285	No	OCSD	Central
119006	33°	29.829	117°	51.842	No	OCSD	Central
119801	33°	34.811	117°	51.564	No	OCSD	Central
119802	33°	34.323	117°	51.844	No	OCSD	Central
119803	33°	33.836	117°	52.123	No	OCSD	Central

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
119901	33°	35.131	117°	52.099	No	OCSD	Central
119902	33°	34.643	117°	52.379	No	OCSD	Central
119903	33°	34.156	117°	52.658	No	OCSD	Central
120001	33°	35.335	117°	52.692	No	OCSD	Central
120002	33°	34.755	117°	53.028	No	OCSD	Central
120003	33°	34.565	117°	53.144	No	OCSD	Central
120004	33°	33.589	117°	53.708	No	OCSD	Central
120005	33°	32.613	117°	54.263	No	OCSD	Central
120006	33°	31.647	117°	54.824	No	OCSD	Central
120101	33°	35.557	117°	53.288	No	OCSD	Central
120102	33°	35.077	117°	53.560	No	OCSD	Central
120103	33°	34.592	117°	53.843	No	OCSD	Central
120201	33°	35.771	117°	53.882	Yes	OCSD	Central
120202	33°	35.283	117°	54.162	No	OCSD	Central
120203	33°	34.796	117°	54.442	Yes	OCSD	Central
121001	33°	36.183	117°	55.749	No	OCSD	Central
121002	33°	35.631	117°	56.206	No	OCSD	Central
121003	33°	35.089	117°	56.678	No	OCSD	Central
121004	33°	34.199	117°	57.414	No	OCSD	Central
121005	33°	33.309	117°	58.150	No	OCSD	Central
121006	33°	32.420	117°	58.885	No	OCSD	Central
121801	33°	36.877	117°	56.752	No	OCSD	Central
121802	33°	36.272	117°	57.264	No	OCSD	Central
121803	33°	35.695	117°	57.744	No	OCSD	Central
121901	33°	37.185	117°	57.290	No	OCSD	Central
121902	33°	36.594	117°	57.778	No	OCSD	Central
121903	33°	36.003	117°	58.266	No	OCSD	Central
122001	33°	37.493	117°	57.831	Yes	OCSD	Central
122002	33°	36.901	117°	58.314	No	OCSD	Central
122003	33°	36.313	117°	58.810	No	OCSD	Central
122004	33°	35.423	117°	59.546	Yes	OCSD	Central
122005	33°	34.534	118°	0.282	No	OCSD	Central
122006	33°	33.644	118°	1.018	Yes	OCSD	Central
122101	33°	37.801	117°	58.368	No	OCSD	Central
122102	33°	37.210	117°	58.852	No	OCSD	Central
122103	33°	36.619	117°	59.343	No	OCSD	Central
122201	33°	38.099	117°	58.908	No	OCSD	Central
122202	33°	37.522	117°	59.374	No	OCSD	Central
122203	33°	36.924	117°	59.858	No	OCSD	Central
123001	33°	38.572	118°	0.064	Yes	OCSD	Central
123002	33°	38.053	118°	0.495	No	OCSD	Central
123003	33°	37.537	118°	0.936	No	OCSD	Central
123004	33°	36.649	118°	1.674	Yes	OCSD	Central
123005	33°	35.760	118°	2.412	No	OCSD	Central
123006	33°	34.871	118°	3.149	No	OCSD	Central
124001	33°	39.920	118°	2.103	No	OCSD	Central
124002	33°	39.342	118°	2.593	No	OCSD	Central
124003	33°	38.765	118°	3.072	No	OCSD	Central
124004	33°	37.875	118°	3.808	No	OCSD	Central
124005	33°	36.986	118°	4.544	No	OCSD	Central
124006	33°	36.096	118°	5.280	No	OCSD	Central
124501	33°	41.475	118°	3.944	No	OCSD	Central
124502	33°	40.739	118°	4.584	No	OCSD	Central

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
124503	33°	39.987	118°	5.204	No	OCSO	Central
124504	33°	39.098	118°	5.946	No	OCSO	Central
124505	33°	38.210	118°	6.675	No	OCSO	Central
124506	33°	37.318	118°	7.411	No	OCSO	Central
124801	33°	42.882	118°	6.180	No	LACSD	Central
124802	33°	41.802	118°	6.420	No	LACSD	Central
124803	33°	40.716	118°	6.720	No	LACSD	Central
124901	33°	43.362	118°	6.660	No	LACSD	Central
124902	33°	42.282	118°	6.960	No	LACSD	Central
124903	33°	41.226	118°	7.260	No	LACSD	Central
125001	33°	43.672	118°	7.215	Yes	LACSD	Central
125002	33°	41.942	118°	7.667	Yes	LACSD	Central
125003	33°	40.213	118°	8.120	Yes	LACSD	Central
125004	33°	38.483	118°	8.572	No	LACSD	Central
125005	33°	36.754	118°	9.025	No	LACSD	Central
125006	33°	34.861	118°	9.545	No	LACSD	Central
125101	33°	43.854	118°	7.800	No	LACSD	Central
125102	33°	42.804	118°	8.100	No	LACSD	Central
125103	33°	41.730	118°	8.340	No	LACSD	Central
125201	33°	44.142	118°	8.400	No	LACSD	Central
125202	33°	43.074	118°	8.700	No	LACSD	Central
125203	33°	41.970	118°	9.000	No	LACSD	Central
125501	33°	45.132	118°	10.680	Yes	LACSD	Central
125502	33°	44.172	118°	10.860	No	LACSD	Central
125801	33°	43.218	118°	9.900	No	LACSD	Central
125802	33°	42.690	118°	10.020	No	LACSD	Central
125803	33°	42.156	118°	10.140	No	LACSD	Central
125901	33°	43.230	118°	10.440	No	LACSD	Central
125902	33°	42.696	118°	10.620	No	LACSD	Central
125903	33°	42.156	118°	10.740	No	LACSD	Central
126001	33°	43.226	118°	11.056	No	LACSD	Central
126002	33°	41.639	118°	11.430	No	LACSD	Central
126003	33°	40.051	118°	11.804	No	LACSD	Central
126004	33°	38.464	118°	12.179	No	LACSD	Central
126005	33°	36.877	118°	12.554	No	LACSD	Central
126006	33°	35.290	118°	12.928	No	LACSD	Central
126101	33°	43.230	118°	11.640	No	LACSD	Central
126102	33°	42.696	118°	11.760	No	LACSD	Central
126103	33°	42.156	118°	11.880	No	LACSD	Central
126201	33°	43.218	118°	12.240	No	LACSD	Central
126202	33°	42.690	118°	12.360	No	LACSD	Central
126203	33°	42.144	118°	12.480	No	LACSD	Central
126801	33°	42.876	118°	13.500	No	LACSD	Central
126802	33°	42.354	118°	13.620	No	LACSD	Central
126803	33°	41.814	118°	13.740	No	LACSD	Central
126901	33°	42.678	118°	14.160	No	LACSD	Central
126902	33°	42.156	118°	14.280	No	LACSD	Central
126903	33°	41.610	118°	14.400	No	LACSD	Central
127001	33°	42.465	118°	14.800	Yes	LACSD	Central
127002	33°	41.318	118°	15.067	Yes	LACSD	Central
127003	33°	40.172	118°	15.335	No	LACSD	Central
127004	33°	39.025	118°	15.603	Yes	LACSD	Central
127005	33°	37.879	118°	15.871	No	LACSD	Central

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
127006	33°	36.732	118°	16.139	No	LACSD	Central
127101	33°	42.228	118°	15.420	No	LACSD	Central
127102	33°	41.700	118°	15.540	No	LACSD	Central
127103	33°	41.148	118°	15.720	No	LACSD	Central
127201	33°	42.066	118°	16.080	No	LACSD	Central
127202	33°	41.544	118°	16.200	No	LACSD	Central
127203	33°	40.998	118°	16.320	No	LACSD	Central
128001	33°	42.436	118°	17.084	No	LACSD	Central
128002	33°	41.596	118°	17.345	No	LACSD	Central
128003	33°	40.107	118°	17.808	No	LACSD	Central
128004	33°	39.460	118°	18.077	No	LACSD	Central
128005	33°	38.912	118°	18.242	No	LACSD	Central
128006	33°	38.225	118°	18.551	No	LACSD	Central
129001	33°	42.858	118°	19.407	Yes	LACSD	Central
129002	33°	42.416	118°	19.790	No	LACSD	Central
129003	33°	41.908	118°	20.141	Yes	LACSD	Central
129004	33°	41.270	118°	20.340	Yes	LACSD	Central
129005	33°	40.256	118°	20.771	No	LACSD	Central
129006	33°	39.245	118°	21.258	No	LACSD	Central
130001	33°	43.930	118°	21.618	No	LACSD	Central
130002	33°	43.343	118°	21.789	No	LACSD	Central
130003	33°	42.877	118°	21.955	No	LACSD	Central
130004	33°	42.059	118°	22.279	No	LACSD	Central
130005	33°	41.095	118°	22.864	No	LACSD	Central
130006	33°	40.007	118°	23.445	No	LACSD	Central
130501	33°	44.179	118°	23.658	No	LACSD	Central
130502	33°	43.989	118°	24.026	No	LACSD	Central
130503	33°	43.797	118°	24.148	No	LACSD	Central
130504	33°	43.136	118°	24.659	No	LACSD	Central
130505	33°	42.298	118°	25.319	No	LACSD	Central
130506	33°	41.380	118°	25.988	No	LACSD	Central
131001	33°	46.260	118°	25.810	No	LACSD	Central
131002	33°	45.899	118°	26.123	No	LACSD	Central
131003	33°	45.438	118°	26.463	No	LACSD	Central
131004	33°	44.716	118°	26.986	No	LACSD	Central
131005	33°	43.726	118°	27.674	No	LACSD	Central
131006	33°	42.752	118°	28.531	No	LACSD	Central
132001	33°	51.250	118°	24.367	No	HYP	Central
132002	33°	50.917	118°	25.067	Yes	HYP	Central
132003	33°	50.717	118°	25.583	Yes	HYP	Central
132004	33°	50.217	118°	26.433	No	HYP	Central
132005	33°	49.433	118°	27.817	No	HYP	Central
132006	33°	48.666	118°	29.567	No	HYP	Central
133001	33°	53.583	118°	25.633	No	HYP	Central
133002	33°	53.350	118°	26.183	No	HYP	Central
133003	33°	53.133	118°	26.800	No	HYP	Central
133004	33°	52.767	118°	27.417	No	HYP	Central
133005	33°	52.100	118°	29.600	No	HYP	Central
133006	33°	51.067	118°	31.633	No	HYP	Central
134001	33°	54.150	118°	25.950	No	HYP	Central
134002	33°	54.000	118°	26.833	No	HYP	Central
134003	33°	54.066	118°	27.600	No	HYP	Central
134004	33°	53.816	118°	28.116	No	HYP	Central

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
134005	33°	53.233	118°	30.383	No	HYP	Central
134006	33°	52.750	118°	32.133	No	HYP	Central
135001	33°	55.883	118°	26.883	No	HYP	Central
135002	33°	55.666	118°	27.616	Yes	HYP	Central
135003	33°	55.433	118°	28.350	No	HYP	Central
135004	33°	55.000	118°	29.650	No	HYP	Central
135005	33°	54.550	118°	31.516	Yes	HYP	Central
135006	33°	54.000	118°	32.983	No	HYP	Central
135801	33°	56.772	118°	27.360	No	HYP	Central
135802	33°	56.520	118°	27.960	No	HYP	Central
135803	33°	56.274	118°	28.500	No	HYP	Central
135901	33°	57.276	118°	27.720	No	HYP	Central
135902	33°	57.024	118°	28.320	No	HYP	Central
135903	33°	56.778	118°	28.860	No	HYP	Central
136001	33°	57.584	118°	27.975	Yes	HYP	Central
136002	33°	57.333	118°	28.666	Yes	HYP	Central
136003	33°	56.966	118°	29.416	No	HYP	Central
136004	33°	56.416	118°	30.586	Yes	HYP	Central
136005	33°	55.666	118°	32.133	No	HYP	Central
136006	33°	55.000	118°	33.500	No	HYP	Central
136101	33°	58.200	118°	28.380	No	HYP	Central
136102	33°	57.948	118°	28.980	No	HYP	Central
136103	33°	57.702	118°	29.580	No	HYP	Central
136201	33°	58.632	118°	28.860	No	HYP	Central
136202	33°	58.380	118°	29.460	No	HYP	Central
136203	33°	58.134	118°	30.000	No	HYP	Central
137001	33°	59.166	118°	29.166	No	HYP	Central
137002	33°	58.800	118°	30.000	No	HYP	Central
137003	33°	58.450	118°	30.600	No	HYP	Central
137004	33°	58.000	118°	31.533	No	HYP	Central
137005	33°	57.216	118°	33.216	No	HYP	Central
137006	33°	56.550	118°	34.500	No	HYP	Central
138001	34°	2.000	118°	35.000	No	HYP	Central
138002	34°	1.550	118°	35.250	No	HYP	Central
138003	34°	0.350	118°	35.833	No	HYP	Central
138004	33°	59.600	118°	36.250	No	HYP	Central
138005	33°	58.333	118°	36.850	No	HYP	Central
138006	33°	57.366	118°	37.416	No	HYP	Central
138301	34°	2.154	118°	39.240	No	HYP	Central
138302	34°	1.626	118°	39.240	No	HYP	Central
138303	34°	1.074	118°	39.180	No	HYP	Central
138401	34°	2.178	118°	39.900	No	HYP	Central
138402	34°	1.632	118°	39.840	No	HYP	Central
138403	34°	1.092	118°	39.840	No	HYP	Central
138501	34°	1.914	118°	40.560	Yes	HYP	Central
138502	34°	1.368	118°	40.500	Yes	HYP	Central
138503	34°	0.816	118°	40.500	No	HYP	Central
138504	33°	59.742	118°	40.500	Yes	HYP	Central
138505	33°	58.656	118°	40.440	No	HYP	Central
138506	33°	56.514	118°	40.380	No	HYP	Central
138601	34°	1.668	118°	41.160	No	HYP	Central
138602	34°	1.128	118°	41.160	No	HYP	Central
138603	34°	0.582	118°	41.160	No	HYP	Central

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
138701	34°	1.710	118°	41.820	No	HYP	Central
138702	34°	1.170	118°	41.820	No	HYP	Central
138703	34°	0.624	118°	41.820	No	HYP	Central
139001	34°	1.650	118°	43.000	No	HYP	Central
139002	34°	1.166	118°	43.000	No	HYP	Central
139003	34°	0.666	118°	43.000	No	HYP	Central
139004	33°	59.850	118°	43.000	No	HYP	Central
139005	33°	57.616	118°	43.000	No	HYP	Central
139006	33°	56.566	118°	43.000	No	HYP	Central
140001	33°	59.716	118°	48.316	No	HYP	Central
140002	33°	59.300	118°	48.316	No	HYP	Central
140003	33°	58.833	118°	48.316	No	HYP	Central
140004	33°	57.500	118°	48.316	No	HYP	Central
140005	33°	55.683	118°	48.316	No	HYP	Central
140006	33°	54.750	118°	48.316	No	HYP	Central
141001	34°	2.460	118°	55.440	No	ABC	North
141002	34°	1.920	118°	55.560	No	ABC	North
141003	34°	1.368	118°	55.620	No	ABC	North
141004	34°	0.324	118°	55.860	No	ABC	North
142001	34°	3.919	119°	0.643	No	ABC	North
142002	34°	3.444	119°	0.593	No	ABC	North
142003	34°	2.784	119°	0.874	No	ABC	North
142004	34°	1.933	119°	1.098	No	ABC	North
142801	34°	5.418	119°	4.740	No	ABC	North
142802	34°	4.878	119°	4.860	No	ABC	North
142803	34°	4.350	119°	4.980	No	ABC	North
142804	34°	3.270	119°	5.160	No	ABC	North
142901	34°	5.730	119°	5.340	Yes	ABC	North
142902	34°	5.190	119°	5.460	No	ABC	North
142903	34°	4.638	119°	5.580	Yes	ABC	North
142904	34°	3.546	119°	5.820	Yes	ABC	North
143001	34°	5.856	119°	6.000	No	ABC	North
143002	34°	5.322	119°	6.120	No	ABC	North
143003	34°	4.776	119°	6.180	No	ABC	North
143004	34°	3.696	119°	6.420	No	ABC	North
143501	34°	6.222	119°	9.000	No	ABC	North
143502	34°	5.736	119°	9.360	No	ABC	North
143503	34°	5.250	119°	9.720	No	ABC	North
143504	34°	4.356	119°	10.320	No	ABC	North
143901	34°	7.632	119°	11.100	Yes	ABC	North
143902	34°	7.194	119°	11.400	No	ABC	North
143903	34°	6.708	119°	11.760	Yes	ABC	North
143904	34°	5.754	119°	12.420	No	ABC	North
144001	34°	8.010	119°	11.580	No	ABC	North
144002	34°	7.530	119°	11.940	No	ABC	North
144003	34°	7.062	119°	12.300	No	ABC	North
144004	34°	6.108	119°	12.960	No	ABC	North
144101	34°	8.254	119°	12.155	No	ABC	North
144102	34°	7.775	119°	12.496	No	ABC	North
144103	34°	7.280	119°	12.850	No	ABC	North
144104	34°	6.392	119°	13.488	No	ABC	North
145501	34°	13.230	119°	16.260	No	UCSB	North
145502	34°	13.008	119°	16.920	No	UCSB	North

Station Name	Latitude		Longitude		Water Sample	Sampling Org.	Sample Area
	(deg)	(min)	(deg)	(min)			
145503	34°	12.786	119°	17.520	No	UCSB	North
145504	34°	12.336	119°	18.720	No	UCSB	North
145505	34°	11.886	119°	19.920	No	UCSB	North
145506	34°	11.034	119°	22.260	No	UCSB	North
146001	34°	14.178	119°	16.800	Yes	UCSB	North
146002	34°	13.938	119°	17.400	No	UCSB	North
146003	34°	13.716	119°	18.000	No	UCSB	North
146004	34°	13.272	119°	19.200	Yes	UCSB	North
146005	34°	12.834	119°	20.400	No	UCSB	North
146006	34°	11.970	119°	22.800	No	UCSB	North
146007	34°	10.548	119°	26.580	Yes	UCSB	North
146008	34°	7.830	119°	33.960	No	UCSB	North
146009	34°	4.506	119°	43.020	No	UCSB	North
146501	34°	15.300	119°	16.800	No	UCSB	North
146502	34°	15.078	119°	17.400	No	UCSB	North
146503	34°	14.850	119°	18.000	No	UCSB	North
146504	34°	14.406	119°	19.260	No	UCSB	North
146505	34°	13.956	119°	20.460	No	UCSB	North
146506	34°	13.116	119°	22.740	No	UCSB	North
148001	34°	1.728	119°	20.400	No	UCSB	North
148002	34°	2.652	119°	25.080	No	UCSB	North
148003	34°	3.660	119°	30.240	No	UCSB	North
148004	34°	4.692	119°	35.460	No	UCSB	North
148005	34°	5.694	119°	40.680	No	UCSB	North
148006	34°	6.690	119°	45.840	No	UCSB	North
148007	34°	7.674	119°	51.180	No	UCSB	North

APPENDIX C.

Procedures for Water-Column Profiling During
the Southern California Bight'98 Regional Survey

PROCEDURES FOR WATER-COLUMN PROFILING DURING THE SOUTHERN CALIFORNIA BIGHT'98 REGIONAL SURVEY

Nine different organizations are collecting data for the BIGHT'98 water quality survey using a standard set of protocols and sampling methods described in this Workplan and appendix. The Southern California Bight Pilot Project (SCBPP) Field Coordination Team and the CTD Users Group in Southern California initially developed the protocols for water column profiling during the 1994 regional survey (SCBPP 1994). The Marine Monitoring Methods Committee slightly modified these protocols in developing a field operations manual (SCBPP 1995) for ocean compliance monitoring programs of the four largest publicly owned treatment works (POTWs). The BIGHT'98 Water Quality Committee has modified these protocols for use in the 1998 regional study. This appendix describes those procedures, which were selected to ensure consistency in equipment operations and intercomparability of the acquired data sets.

A. Equipment

All participating organizations must sample using a conductivity-temperature-depth (CTD) profiler with additional sensors (Table C-1) to provide continuous water-column profiles of temperature, salinity, dissolved oxygen (DO), hydrogen ion content (pH), optical beam transmission at 660 nm, and chlorophyll fluorescence with depth. Sea-Bird SBE 9 or SBE 25 underwater CTD units are used by seven of the program participants; a SeaBird SeaCat (SBE 19) and an Idronaut CTD are used by two other participants. CTD units must meet the program performance specifications described earlier in this Workplan for temperature, salinity, DO, pH, beam transmission, and pressure before participating in the regional survey. The following sensors are currently being used with Sea Bird CTDs: temperature, SBE 3; conductivity, SBE 4; pH, SBE 18; DO, SBE 13; beam transmission, Sea-Tech or WETLabs 25 cm path-length; chlorophyll fluorescence, WETLabs Wet Star fluorometer or Chelsea Instruments fluorometer; and pressure (for depth), Sensor-Metrics strain-gauge interfacing pressure sensor or Paroscientific Digiquartz pressure sensor model #2300A-110. The data acquisition software for the Sea-Bird instruments will be Seasoft version 4.3 or higher.

Table C-1. Equipment used by participating agencies during the Bight'98 regional survey.

Agency	Unit(s)	Chlorophyll sensor	Transmis- someter	Dissolved Oxygen	pH	PAR	Real-time Display
CINMS (UCSB)	SBE9/11E	SeaTech	SeaTech	None	None	Biospherical	Yes
City of LA	SBE 9/11	WETLabs	SeaTech	Beckman	SBE	None	Yes
County of LA	SBE 9/11	WETLabs	SeaTech	Beckman	SBE	None	Yes
Oxnard (ABC)	SBE 19	WETLabs	Chelsea	YSI	SBE	None	Yes
MEC	SBE 25	WETLabs	SeaTech	Beckman	SBE	None	Yes
Navy	SBE 9/11	Turner	SeaTech	Beckman	SBE	Biospherical	Yes
OCSB	SBE 25	WETLabs	SeaTech	Beckman	SBE	None	Yes
	SBE 9/11	Chelsea	SeaTech	Beckman	SBE	None	Yes
City of San Diego	SBE 9/11	WETLabs	WETLabs	Beckman	SBE	None	Yes
Mexico (UABC)	Idronaut	WETLabs	None	Idronaut	Idronaut	None	Yes

B. CTD Deployment

The CTD must be deployed with a means of data collection, such as a SBE 11 deck unit, SBE 17 RAM (random access memory — an internal recording instrument) unit, or equivalent. The instrument should have a scan rate of no fewer than 8 scans/sec, except for the SBE19 and Idronaut. The SBE 9 and SBE 25 units measure data at 24 or 8 scans (data)/sec, respectively. The user must designate the average rate that the data will be recorded to memory or the computer. For example, SBE 9 set at 24 scans/sec and averaged at 3 scans/bin means 8 data lines in memory per second. In the configuration file, the scan rate is set at 24 scans/sec for SBE 9 or 8 scans/sec for SBE 25. To preserve as much data as possible we recommend that data be logged at 8 scans per second for both the SBE 9 and SBE 25 (set NAVG = 3 for SBE 9 and NAVG = 1 for SBE 25). If either the instrument is incapable of this data rate or the internal memory is not sufficient to log at this rate, data logging should be set at the highest rate possible.

The CTD descent rate must not exceed 1 m/sec (the recommended optimum speed is 0.25-0.50 m/sec). If deploying real-time, some manufacturer software allows this rate to be monitored by displaying and viewing the lowering rate variable. If RAM is used during deployment, the rate must be monitored with a meter wheel and timer. Descent rates must always be slower than 1 m/sec to minimize spiking of sensor output. Additionally, during data processing, a cast whose average descent rate is found to exceed 1 m/sec may be considered for omission. Before beginning any cast, position the vessel on station using DGPS. Record the required information for each station on CTD data sheets. Enter a new file name into the computer software on which the CTD data will be stored.

Begin a cast by initiating the instrument to start recording data. Lower the CTD to a depth of about 5 meters and, if possible, monitor salinity and DO values to ensure stable readings. (NOTE: deployment with the SBE 17 RAM unit precludes monitoring salinity and DO values). This step is important because CTD sensors will be brought to thermal equilibration with the ambient sea-water and the pump (if applicable) will be activated so bubbles are purged from any tubing. A three minute equilibration upon initial power-up at the first station of the day and 90 sec at each station thereafter is the minimum soak time for thermal equilibration and sensor stabilization. After sensor stabilization, the CTD should be raised slowly so that the sensors are near the water surface but not breaking the air-water interface (intrudes air bubbles to sensors). One goal of this survey is to resolve the nearsurface one-meter layer as well as possible. This is important because freshwater runoff plumes tend to float near the surface of the water and may be very thin. A line may be employed to raise the bottom of the instrument to a horizontal position or it may be useful to lift the package so that the top of the CTD is out of the water, but without raising the intake for the various sensors above the sea surface. Once the sensors have been brought near the surface the downward profile will begin. The CTD is lowered at the recommended descent rate to within 2-3 meters of the bottom or 100 meters, whichever comes first.

Use of an onboard water bath is recommended to prevent excessive heating of the sensors while the CTD is on the ship's deck. If an onboard water bath is not used, a wet towel will be wrapped around the instrument to prevent the sensors from heating excessively. If a water bath is not used, rinse the lenses of the transmissometer with deionized water to remove any crystallized salt prior to each cast.

C. Quality Assurance/Quality Control

Six types of quality assurance and quality control will be implemented to ensure the highest possible data quality during Bight'98:

- All participating organizations must have regular factory calibration and maintenance service on their instruments.
- All personnel participating in Bight'98 sampling will undergo training to ensure their familiarity with the instrumentation.
- Prior to the conduct of Bight'98, all sampling organizations will participate in an intercomparison exercise designed to assess instrument comparability.
- Each organization will complete a series of pre-cruise checks and calibrations prior to each sampling day
- The CTD data will be checked in the field prior to leaving each sampling station.
- Each organization will undergo a series of post-cruise checks at the end of each sampling day.

1. Factory Calibration and Maintenance

Maintenance and calibration of the CTD must be documented, including dates of most recent servicing. The temperature and conductivity sensor must be sent to the manufacturer every 6-12 months for calibration. Preventative maintenance must be conducted on the CTD unit periodically, according to manufacturer's recommendations (i.e., 3 yr.). All "O" rings, attached sensors, and seals are checked at this time and the unit is pressure tested. The pressure sensor is calibrated at this time. Upon return from the factory, enter any new factory calibration coefficients into the configuration file.

2. Training

Any individual who is maintaining, calibrating, or operating the CTD must be trained in each of these operations. Prior to performing these operations unsupervised, an individual must demonstrate proficiency in that operation to a senior, CTD experienced staff member. Proficiency is evaluated on the basis of successfully completing the operation following written procedures and demonstrating an understanding of the equipment. Additionally, the individual should demonstrate his/her ability to evaluate and troubleshoot common problems. All training and demonstration of proficiency must be documented.

3. CTD Intercomparison Exercise

A CTD intercomparison exercise will be conducted to evaluate the precision, accuracy, and comparability of the CTDs used by each participating organization. All of the CTDs are placed in a common sea-water tank. The water temperature is controlled with a chiller to a few degrees centigrade below ambient temperature and aerated to achieve oxygen saturation. DO values measured by the CTDs are compared against expected saturation table values and Winkler titrations. Salinity values are compared to Association Internationale d' Oceanographie Physique (IAPSO) salinity standards; temperature values are compared to measurements made with a National Institute of

Standards and Testing (NIST) certified thermometer; and pH values are compared to measurements made with NIST certified buffers. Prior to the exercise all CTDs must be within manufacturer calibration specifications and be calibrated as if user were preparing to deploy the instrument in a survey on the following day.

4. CTD Precruise Checkout and Calibration

Precruise Equipment Checkout

A precruise equipment checkout must be conducted within 24 hr prior to starting the cruise and prior to calibration. This inspection must include the following:

- 1) A visual inspection of the CTD for any obvious defects;
- 2) A check of all metal components for corrosion, cleaning or replacing as necessary;
- 3) An inspection and cleaning of all connections with contact cleaner, as necessary;
- 4) Verification that the plugs are secure, waterproof and lubricated with silicone grease;
- 5) An inspection of all cables for nicks, cuts, abrasions, or other signs of physical damage;
- 6) A test of the CTD to see if connections and software work properly;
- 7) Cleaning and/or replacement of all accessory tubing as necessary; and
- 8) Checking battery status for all units using RAM data storage.

Precruise Calibration

A precruise calibration must be conducted within 24 hr prior to starting the cruise for pH, DO, beam transmission, and pressure. There is no lab calibration for conductivity and temperature. Verification that the proper sensor coefficients are in the configuration file must be made before proceeding. A CTD calibration data sheet is prepared at that time, with all required information entered on that sheet.

Prior to the cruise, a calibration tank is filled with fresh tap water, which is aerated by placing an air-stone no more than 10 cm below the water surface and mixed with a pump. This aeration should last for 12 hr or sufficiently long to reach saturation. Moderate aeration should be maintained to avoid supersaturation. The water temperature is controlled with a chiller/heater or in a temperature controlled room, if possible. Water volume should be large enough to resist significant ($\pm 1^{\circ}\text{C}$) thermal change during calibration.

Hydrogen Ion Content (pH). The pH sensor should be calibrated by using commercially available buffer solutions. When sampling in the ocean, it is best to use three buffers of pH 7, 8, and

9. The manufacturer's specifications must always be followed during calibration of the probe. For example, when calibrating the sensor, it may be necessary to make an electrical connection between the body of the pH sensor module and the buffer solution. This connection may be made using any convenient piece of wire. One end of the wire is attached to one of the screws attaching the zinc anode. The other end of the wire is immersed in the solution. It is important that the buffer is thermally equilibrated with the water bath; this is best accomplished by keeping the CTD in the water bath and using a holding bracket for the cup of buffer. The water temperature, pH, and voltage output for each of the three buffers is then recorded. These values are entered into the Seasoft (SeaBird software) module PHFIT following the prompts. The residuals for each buffer, pH slope, and pH offset values are then recorded. The slope and offset values are entered into SEACON. SEASAVE will be reentered and checked against three buffers again, recording the pH values. Agreement between sensor output and known values should be within 0.1 pH unit. If agreement is outside this range, the buffers must be rerun and the procedure repeated. Corrected values are added to the CTD's software. When complete, the pH electrode is stored in pH buffer 4 saturated KCl solution.

Dissolved Oxygen (DO). With the power to the CTD off, the CTD is placed in the calibration tank. If a pump other than the CTD mounted pump is used, the flow rate over the sensor must be between 15 and 40 mL/sec. The CTD is calibrated according to Sea-Bird Application Note 13-1, Revision B (April 1993) (Appendix F). After new coefficients are calculated and entered into the configuration file, the DO sensor value is compared with saturation table values (Standard Methods, 18th., 1992, table 4500-O:1) and it must match to within 0.1 mL/L (0.143 mg/L). Sensor performance is monitored and the membrane or sensor module must be replaced if results are unreliable and if

- 1) the slope of oxygen current (SOC) 4.0;
- 2) SOC is less than 4.0 but increases by more than 0.3 between calibrations; or
- 3) response to anoxic conditions is slow (i.e., the sensor output will reach the asymptotic zero value within 2 min and remain relatively stable while fluctuating around a zero value). If this response is slower or a zero value cannot be reached, the membrane may be reaching the end of its life.

Transmissometer. This calibration is performed in air and the CTD software must be modified to reflect any changes that are made during the calibrations. The transmissometer is calibrated according to procedures in the Sea Tech transmissometer manual and Sea-Bird Electronics Application Note No. 7 (Appendix F). If the unblocked percent transmittance value is below 93.5%, the M and B coefficients are recalculated according to Sea-Bird Application Note No. 7, entered in SEACON, and reevaluated. If the value remains below 93.5%, the manufacturer should be consulted and the instrument must be sent in for servicing.

Pressure Offset. This determination must also be performed in air. The pressure sensor is checked before use, recording air sea-level values. The pressure reading in air at sea level should be a negative number between 0.0 and -0.60 db. If out of this range, adjustments must be made if possible and the manufacturer's software (i.e., SEACON) should be run to achieve a value between 0.0 and -0.60 db. The value 0.5 and the opposite sign of that shown on the SEASAVE display are

entered when prompted for “offset = ...new value = ...”. If this does not correct the displayed pressure value, the offset value must be changed until pressure is within range. **NOTE:** If the offset value exceeds ± 1.5 , the sensor must be serviced. The pressure output and any changes to the offset value are recorded on the calibration sheet.

Following calibration, the sensors and equipment should be disturbed as little as possible. The CTD should always be transported in its original shipping case or a comparably secure unit.

5. CTD Cast Acceptability

Cast acceptability is determined immediately following the first cast of the day (it is recommended that this be done following each cast for real time data) in one of two ways:

- 1) All parameters can be displayed graphically to determine if any grossly anomalous readings occurred. Graphs can be scaled to illustrate obviously anomalous values that lie outside the control limit range for each parameter (Table C-2); or
- 2) A range-checking computer program can be used to evaluate the presence of anomalous values on the basis of predetermined criteria (i.e. range acceptability checks).
- 3) Casts should also be evaluated by comparison of values obtained at previous or nearby stations.

If anomalous values are present, the cause must be investigated and remedied before proceeding. If damage to the CTD (due to striking the bottom or some other event) is suspected, that cast should be reviewed as described above to ensure acceptability. Further review of the subsequent cast in a like manner will ensure that all sensors are functioning properly. If a sensor is replaced during the day, a replicate cast must be made with the new sensor, at the last station at which the malfunctioning sensor was known to have been working properly. If a sensor is replaced, all coefficients for that sensor must be entered and saved in the configuration file. All activities relating to the occurrence of these types of events (e.g., repeated casts, damaged equipment and remedies, replaced sensors, etc.) are noted in the a field logbook. If feasible, a station should be resurveyed when an unacceptable profile is obtained.

Table C-2. Range of reasonable measurements from waters of the mainland shelf of Southern California.

Parameter	Typical Range
Dissolved Oxygen (DO)	3 - 12 mg/L
Salinity Near surface runoff source	32 - 34 psu <10 - 34
Beam transmission Near surface runoff source	20 - 90 % <5%
Temperature	8 - 24 °C
Hydrogen Ion Content (pH)	7.5 -8.3 pH units
Chlorophyll Fluorescence	0.1 to >20 µg/l

6. Postcruise Calibration

Postcalibration must be conducted within 24 hr of cruise completion. The Chief Scientist is responsible for deciding whether postcruise calibrations are within acceptable limits.

Hydrogen Ion Content (pH). The only similarity between the postcalibration and precruise calibration of the pH sensor is that the sensor is checked against the three buffers with no adjustments being made to the software. The water temperature is recorded, as well as the pH and voltage output for each buffer on data sheets. Agreement should occur between each sensor value and the known buffer value, and must be within 0.15 pH units. If agreement is out of this range, the unit is recalibrated and the stations resampled if feasible.

Dissolved Oxygen (DO). Postcalibration of the DO sensor must follow the same procedures as those for precalibration. However, the DO concentration must be evaluated and recorded on data sheets prior to adjusting the coefficients. If the preadjusted value is equal to or less than + 0.3 mg/L of the expected saturation table value, all DO data for the survey are tentatively acceptable until further review. If this preadjusted value is greater than ± 0.3 mg/L different than the saturation table value, all the DO data for the survey must be reviewed for consistency. If these data are deemed unreliable, the survey must be done again as soon as possible (if feasible). If stations cannot be resampled, data are flagged or qualified in the data base. Following postcalibration, the oxygen sensor is cleaned and stored following manufacturer procedures given in Sea-Bird Application Note 13-1, Revision B (April 1993) (Appendix F).

Beam transmission and Pressure. Postcalibration of the transmissometer and pressure sensors are the same as those performed in the precalibration. If the pressure reading in air at sea level is not a negative number between 0 and -0.60 db, record the pressure output and any changes to the offset value on the calibration sheet.

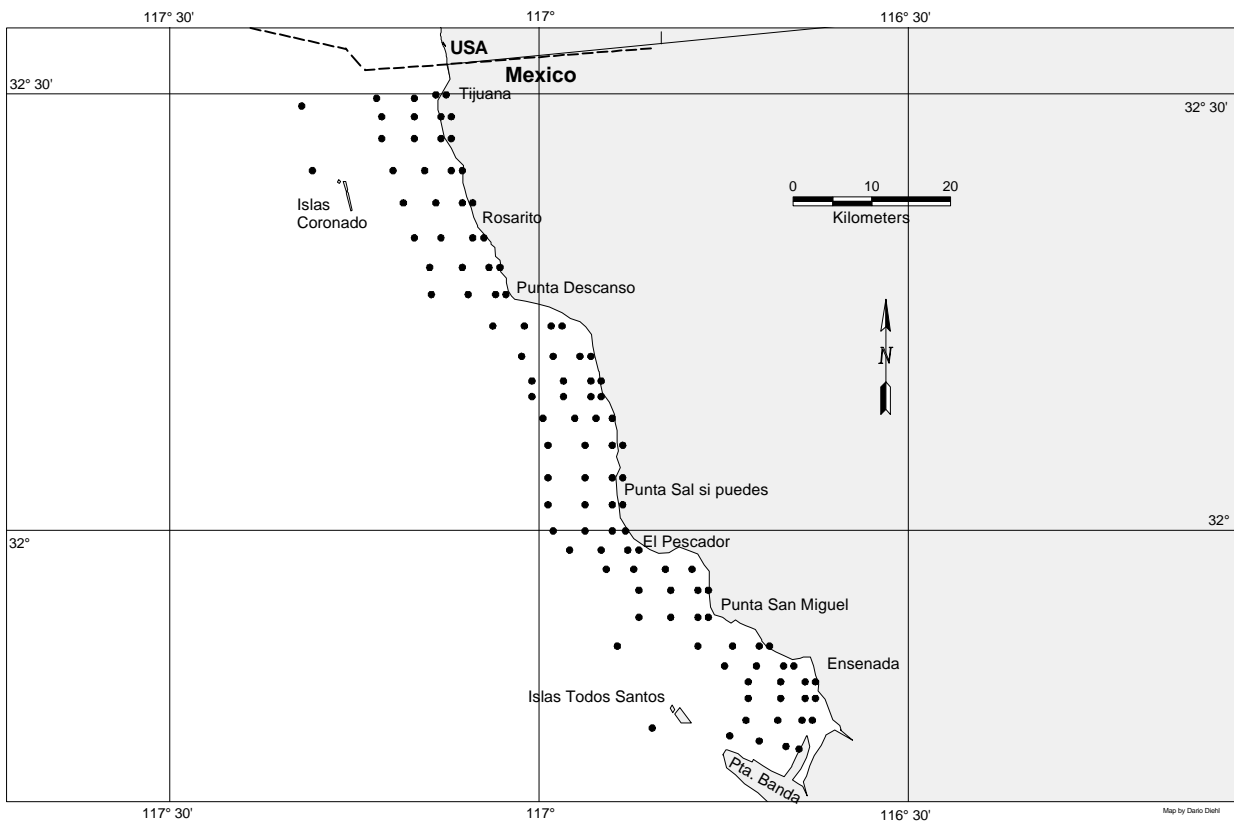
LITERATURE CITED

- Southern California Bight Pilot Project (SCBPP). 1994. Field operations manual for the Southern California Bight Pilot Project. Southern California Coastal Water Research Project. Westminster, CA.
- Southern California Bight Pilot Project. 1995. Field operations manual for marine water-column, benthic, and trawl monitoring in southern California. Southern California Coastal Water Research Project. Westminster, CA.

APPENDIX D.

Site Map and station coordinates
for Sampling Sites in Mexico

Mexico Sites



Mexico Station Name	Latitude (deg) (min)		Longitude (deg) (min)		Water Sample	Sampling Org.	Bight'98 Station Equivalence
1	32°	29.940	117°	7.500	Yes	UABC / Mex. Navy	99001
2	32°	29.940	117°	8.340	Yes	UABC / Mex. Navy	99002
3	32°	29.700	117°	10.080	Yes	UABC / Mex. Navy	99003
4	32°	29.700	117°	13.140	No	UABC / Mex. Navy	99004
5	32°	29.160	117°	19.230	Yes	UABC / Mex. Navy	99005
6	32°	28.440	117°	12.726	Yes	UABC / Mex. Navy	98004
7	32°	28.440	117°	10.080	No	UABC / Mex. Navy	98003
8	32°	28.440	117°	7.920	No	UABC / Mex. Navy	98002
9	32°	28.440	117°	7.080	Yes	UABC / Mex. Navy	98001
10	32°	26.940	117°	7.080	Yes	UABC / Mex. Navy	97001
11	32°	26.940	117°	7.920	Yes	UABC / Mex. Navy	97002
12	32°	26.940	117°	10.080	No	UABC / Mex. Navy	97003
13	32°	26.940	117°	12.720	No	UABC / Mex. Navy	97004
14	32°	24.720	117°	18.360	Yes	UABC / Mex. Navy	96005
15	32°	24.720	117°	11.820	No	UABC / Mex. Navy	96004
16	32°	24.720	117°	9.240	No	UABC / Mex. Navy	96003
17	32°	24.720	117°	7.080	No	UABC / Mex. Navy	96002
18	32°	24.720	117°	6.180	Yes	UABC / Mex. Navy	96001
19	32°	22.500	117°	5.340	Yes	UABC / Mex. Navy	95001
20	32°	22.500	117°	6.180	Yes	UABC / Mex. Navy	95002
21	32°	22.500	117°	8.340	No	UABC / Mex. Navy	95003
22	32°	22.500	117°	10.980	Yes	UABC / Mex. Navy	95004
23	32°	20.100	117°	10.080	No	UABC / Mex. Navy	94004
24	32°	20.100	117°	7.920	No	UABC / Mex. Navy	94003
25	32°	20.100	117°	5.340	Yes	UABC / Mex. Navy	94002
26	32°	20.100	117°	4.440	Yes	UABC / Mex. Navy	94001
27	32°	18.060	117°	3.120	Yes	UABC / Mex. Navy	93001
28	32°	18.060	117°	4.020	No	UABC / Mex. Navy	93002
29	32°	18.060	117°	6.180	No	UABC / Mex. Navy	93003
30	32°	18.060	117°	8.820	Yes	UABC / Mex. Navy	93004
31	32°	16.200	117°	8.700	Yes	UABC / Mex. Navy	92004
32	32°	16.200	117°	5.700	No	UABC / Mex. Navy	92003
33	32°	16.200	117°	3.480	No	UABC / Mex. Navy	92002
34	32°	16.200	117°	2.640	Yes	UABC / Mex. Navy	92001
35	32°	14.040	116°	58.080	Yes	UABC / Mex. Navy	91001
36	32°	14.040	116°	58.980	Yes	UABC / Mex. Navy	91002
37	32°	14.040	117°	1.140	No	UABC / Mex. Navy	91003
38	32°	14.040	117°	3.720	Yes	UABC / Mex. Navy	91004
39	32°	11.940	117°	1.380	Yes	UABC / Mex. Navy	90004
40	32°	11.940	116°	58.800	No	UABC / Mex. Navy	90003
41	32°	11.940	116°	56.640	No	UABC / Mex. Navy	90002
42	32°	11.940	116°	55.740	Yes	UABC / Mex. Navy	90001
43	32°	10.260	116°	54.900	Yes	UABC / Mex. Navy	89001
44	32°	10.260	116°	55.740	No	UABC / Mex. Navy	89002
45	32°	10.260	116°	57.960	No	UABC / Mex. Navy	89003
46	32°	10.260	117°	0.540	No	UABC / Mex. Navy	89004
47	32°	9.180	117°	0.540	Yes	UABC / Mex. Navy	88004
48	32°	9.180	116°	57.960	No	UABC / Mex. Navy	88003
49	32°	9.180	116°	55.740	No	UABC / Mex. Navy	88002
50	32°	9.180	116°	54.900	Yes	UABC / Mex. Navy	88001

Mexico Station Name	Latitude (deg) (min)		Longitude (deg) (min)		Water Sample	Sampling Org.	Bight'98 Station Equivalence
51	32°	7.680	116°	54.000	Yes	UABC / Mex. Navy	87001
52	32°	7.680	116°	55.320	Yes	UABC / Mex. Navy	87002
53	32°	7.680	116°	57.060	No	UABC / Mex. Navy	87003
54	32°	7.680	116°	59.640	Yes	UABC / Mex. Navy	87004
55	32°	5.820	116°	59.220	No	UABC / Mex. Navy	86004
56	32°	5.820	116°	56.220	No	UABC / Mex. Navy	86003
57	32°	5.820	116°	54.000	No	UABC / Mex. Navy	86002
58	32°	5.820	116°	53.160	Yes	UABC / Mex. Navy	86001
59	32°	3.600	116°	53.160	Yes	UABC / Mex. Navy	85001
60	32°	3.600	116°	54.000	No	UABC / Mex. Navy	85002
61	32°	3.600	116°	56.220	No	UABC / Mex. Navy	85003
62	32°	3.600	116°	59.220	Yes	UABC / Mex. Navy	85004
63	32°	1.740	116°	59.220	No	UABC / Mex. Navy	84004
64	32°	1.740	116°	56.220	No	UABC / Mex. Navy	84003
65	32°	1.740	116°	54.000	No	UABC / Mex. Navy	84002
66	32°	1.740	116°	53.160	Yes	UABC / Mex. Navy	84001
67	31°	59.940	116°	52.920	Yes	UABC / Mex. Navy	83001
68	31°	59.940	116°	54.000	No	UABC / Mex. Navy	83002
69	31°	59.940	116°	56.220	No	UABC / Mex. Navy	83003
70	31°	59.940	116°	58.800	Yes	UABC / Mex. Navy	83004
71	31°	58.620	116°	57.480	No	UABC / Mex. Navy	82004
72	31°	58.620	116°	54.900	No	UABC / Mex. Navy	82003
73	31°	58.620	116°	52.740	No	UABC / Mex. Navy	82002
74	31°	58.620	116°	51.840	Yes	UABC / Mex. Navy	82001
75	31°	57.300	116°	47.520	Yes	UABC / Mex. Navy	81001
76	31°	57.300	116°	49.680	Yes	UABC / Mex. Navy	81002
77	31°	57.300	116°	52.260	No	UABC / Mex. Navy	81003
78	31°	57.300	116°	54.480	Yes	UABC / Mex. Navy	81004
79	31°	55.860	116°	51.840	Yes	UABC / Mex. Navy	80004
80	31°	55.860	116°	49.260	No	UABC / Mex. Navy	80003
81	31°	55.860	116°	47.040	No	UABC / Mex. Navy	80002
82	31°	55.860	116°	46.200	Yes	UABC / Mex. Navy	80001
83	31°	54.000	116°	46.200	Yes	UABC / Mex. Navy	79001
84	31°	54.000	116°	47.040	No	UABC / Mex. Navy	79002
85	31°	54.000	116°	49.260	No	UABC / Mex. Navy	79003
86	31°	54.000	116°	51.840	No	UABC / Mex. Navy	79004
91	31°	52.020	116°	41.220	Yes	UABC / Mex. Navy	78001
90	31°	52.020	116°	42.060	No	UABC / Mex. Navy	78002
89	31°	52.020	116°	44.220	No	UABC / Mex. Navy	78003
88	31°	52.020	116°	47.040	No	UABC / Mex. Navy	78004
87	31°	52.020	116°	53.580	Yes	UABC / Mex. Navy	78005
95	31°	50.640	116°	44.880	Yes	UABC / Mex. Navy	77004
94	31°	50.640	116°	42.300	No	UABC / Mex. Navy	77003
93	31°	50.640	116°	40.080	Yes	UABC / Mex. Navy	77002
92	31°	50.640	116°	39.240	Yes	UABC / Mex. Navy	77001
99	31°	49.560	116°	37.500	Yes	UABC / Mex. Navy	76001
98	31°	49.560	116°	38.340	Yes	UABC / Mex. Navy	76002
97	31°	49.560	116°	40.320	No	UABC / Mex. Navy	76003
96	31°	49.560	116°	42.960	Yes	UABC / Mex. Navy	76004
103	31°	48.420	116°	42.960	No	UABC / Mex. Navy	75004

Mexico	Latitude		Longitude		Water Sample	Sampling	Bight'98
Station Name	(deg)	(min)	(deg)	(min)		Org.	Station
							Equivalence
102	31°	48.420	116°	40.320	No	UABC / Mex. Navy	75003
101	31°	48.420	116°	38.340	No	UABC / Mex. Navy	75002
100	31°	48.420	116°	37.500	Yes	UABC / Mex. Navy	75001
107	31°	46.920	116°	37.740	Yes	UABC / Mex. Navy	74001
106	31°	46.920	116°	38.580	No	UABC / Mex. Navy	74002
105	31°	46.920	116°	40.560	No	UABC / Mex. Navy	74003
104	31°	46.920	116°	43.140	Yes	UABC / Mex. Navy	74004
112	31°	46.380	116°	50.760	Yes	UABC / Mex. Navy	73005
111	31°	45.840	116°	44.460	No	UABC / Mex. Navy	73004
110	31°	45.480	116°	42.060	No	UABC / Mex. Navy	73003
109	31°	45.120	116°	39.900	Yes	UABC / Mex. Navy	73002
108	31°	44.940	116°	38.820	Yes	UABC / Mex. Navy	73001

APPENDIX E.

Information Management Tables

Nominal Stations

This table contains the nominal station location for the sampling stations in the Water Quality portion of the project. Each record represents the station position, the collecting agency, and expected depth of the station. The table will be submitted to the IMO in ASCII comma delimited format with the file name STATIONS.DAT.

Columns

Name	Type	Required	Description
StationID	Text	Y	A geographic location label
AgencyCode	Text	Y	Two digit code from list 1
LatDegrees	Number	Y	Two digit degree (NAD 83)
LatMin	Number	Y	Decimal minutes (NAD 83) three places
LonDegrees	Number	Y	Three digit degree (NAD 83)
LonMin	Number	Y	Decimal minutes (NAD 83) three places
ExpectedDepth	Number	Y	meters

Station Occupation

The master sample table holds data that is descriptive of station occupation during sampling events. Each record contains a characterization of the station at the time of sampling in terms of the weather, sea state, sample type, vessel name, agency, and quality of the GPS signal at the time of sampling. The NavType field allows the collecting agency to record the loss of the differential GPS signal. Additional comments may be included as well with up to 80 characters. This file will be provided to the IMO with the name STATION.MST by each agency.

Columns

Name	Type	Required	Description
StationID	Text	Y	A geographic location label from the station table
Date	Date	Y	dd/mm/yy
LatDegrees	Number	Y	Two digit degree (NAD 83)
LatMin	Text	Y	Decimal minutes (NAD 83) three places
LonDegrees	Text	Y	Three digit degree (NAD 83)
LonMin	Text	Y	Decimal minutes (NAD 83) three places
StartTime	Date/Time	Y	hh:mm
AgencyCode	Text	Y	Two digit code from list 1
Vessel	Text	Y	Name of the vessel
NavType	Text	Y	DGPS, GPS
WeatherCode	Text	Y	predetermined weather codes from list 8
WindSpeed	Number	Y	Meters/second
WindDirection	Text	Y	degrees
SeaSwellHeight	Number	Y	meters
SwellPeriod	Number	Y	seconds
SeaSwellDirection	Text	Y	degrees
SeaState	Text	Y	calm, rough, choppy
StationFailureCode	Text		From list 9
ChlorophyllVolume	Text		ml
Comments	Text		Additional comments

Cast Data

This table contains the raw qualified cast data as collected by an instrument. Each record represents a discrete set of measurements taken by the instrument during its descent throughout the water column. The “CastPortion” field flags the record as Equilibration, Downcast, or Upcast referring to its position in the cast. The “QAFlag” will be added by the Water Quality Technical Committee after a review of the data.

Columns

Name	Type	Required	Description
StationID	Text	Y	A geographic location label from the station table
Date	Date	Y	dd/mm/yy
Seconds	Number	Y	From the instrument
DescentRate	Number	Y	Meters per second
Depth	Number	Y	meters
Temperature	Number	Y	Degrees centigrade
Conductivity	Number	Y	Siemens/m
Salinity	Number	Y	PSS
OxygenMgL	Number	Y	Mg/L
Oxygen%saturation	Number	Y	%Saturation
Transmissivity	Number	Y	%light
pH	Number	Y	Hydrogen ion concentration
Density	Number	Y	Sigma-theta
Fluorescence	Number		From the instrument
CastPortion	Text	Y	E (equilibration) ,D (downcast) ,U (upcast)
QAFlag	Text	Y	000000000

Discrete Water Samples Table

This table contains chemical and particulate data collected at a subset of stations. Each record represents the result of an individual analysis for an individual parameter. This table will be submitted to the IMO in comma delimited ASCII format with the file name DISWTR.DAT.

Columns

Name	Type	Required	Description
StationID	Text	Y	A geographic location label from the station table
TestMaterial	Text	Y	Sediment/Tissue
ParameterCode	Text	Y	From list 18
QA Batch	Text	Y	batch number
QAType	Text	Y	From list 19
Lab Rep	Text	Y	count
Qualifier	Text	Y	From list 13
Result	Number	Y	(dry wt.)
Units	Text	Y	Units for result
True Value	Number		QA samples only
MDL	Number	Y	method detection limit
RL	Number	Y	reporting limit
Dilution	Number	Y	Dilution factor
PreparationCode	Text	Y	From list 34
PreparationDate	Date/Time	Y	dd/mm/yyyy
AnalysisMethod	Text	Y	From list 33
Analysis Date	Date/Time	Y	dd/mm/yyyy
QACode	Text	Y	From list 13
LabCode	Text	Y	From list 1
Comments	Text		Additional comments

APPENDIX F.

1. SEA-BIRD Conductivity-Temperature-Depth (CTD) profiler application notes.
 - A. Application Note No. 13-1, rev B - Revised April 1993
SBE 13/22/30 dissolved oxygen sensor calibration and deployment
 - B. Application Note No. 7 - Revised September 1989
Calculation of M and B coefficients for the SEA-TECH transmissometer

Application Note No. 13-1, rev B - Revised April 1993

SBE 13/22/30 DISSOLVED OXYGEN SENSOR CALIBRATION AND DEPLOYMENT

SEA-BIRD ELECTRONICS, INC.

1808 - 136th Place Northeast, Bellevue, Washington 98006

A. General Description

Sea-Bird Electronics uses either a Beckman sensor element or a modified YSI 5739 oxygen probe in its oxygen sensors. Present Sea-Bird oxygen sensors have two 0 to +5 volt outputs. One of these is proportional to the internal temperature of the sensor and the other is proportional to the oxygen current. SBE 13 sensors produced before February 1992 have a 0 to +5 volt output (oxygen current) and a -5 to +5 volt output (sensor temperature). CTD instruments made by Sea-Bird that are equipped with oxygen sensors record these voltages for later conversion to oxygen concentration using the algorithm by Owens and Millard (1985).

Oxygen sensors determine the dissolved oxygen concentration by 'counting' the number of oxygen molecules per second (flux) that diffuse through a membrane from the ocean environment to the working electrode. By knowing the flux of oxygen and the geometry of the diffusion path the concentration of oxygen in the environment can be computed. The permeability of the membrane to oxygen is a function of temperature and ambient pressure and this is taken into account in the calibration equation. The algorithm to compute oxygen concentration requires that the following measurements be made: water temperature, salinity, pressure, oxygen sensor current, and oxygen sensor temperature. When the oxygen sensor is attached to a Sea-Bird CTD all of these parameters are measured by the CTD.

At the working electrode (cathode) oxygen gas molecules are converted to hydroxyl ions (OH-) in a series of reaction steps where the electrode supplies four electrons per molecule to complete the reaction. The sensor counts oxygen molecules by measuring the electrons per second (amperes) delivered to the reaction. At the other electrode (anode) silver chloride is formed and silver ions (Ag+) are dissolved into solution. Consequently the chemistry of the sensor electrolyte changes continuously as oxygen is measured, and this produces a slow but continuous change of the sensor calibration with time (the slope coefficient, S_{oc} , changes by a factor of two after about 1000 hours of powered-up use in 'Beckman' sensors and after a few hundred hours in YSI sensors). Oxygen sensors have operating characteristics that require certain procedures be followed to insure that accurate and reliable measurements of oxygen concentration are obtained. These characteristics include:

1. When power is applied to the oxygen sensor it takes up to three minutes for the sensor to polarize and come to a stable reading. This implies that when a CTD is turned on it must be held at the surface for at least three minutes before a cast is started to insure accurate oxygen readings.
2. The oxygen sensor consumes the oxygen in the water near the sensor membrane. If there is not an adequate flow of new water past the membrane, the sensor will give a

reading which is lower than the true oxygen concentration. This requires that the sensor be moving through the water or that water be pumped past the sensor.

3. Temperature differences between the water and the oxygen sensor can lead to errors in the oxygen measurement. When profiling through areas of high temperature gradients this error can be substantial. Because of its different construction the Beckman sensor element is more susceptible to this error source than is the YSI sensor. Aligning the oxygen data in time with the ALIGNCTD program can minimize this problem and also correct for the water transit time in the plumbing on pumped systems and for the relatively slow response time of oxygen sensors in comparison to other CTD sensors.

B. Oxygen Algorithm

SEASOFT uses the algorithm by Owens and Millard (1985) to convert SBE 13/22/23/30 oxygen sensor data to oxygen concentration but treats the coefficients differently. Only Soc and Boc, the scale and offset coefficients, are allowed to be variable. The other four coefficients (tcor, pcor, tau and wt) are fixed at reasonable physical values. Sea-Bird provides two programs to compute the values for Soc, (sensitivity or scale) and Boc (offset). OXFIT uses the zero oxygen value and air saturated water readings. OXFITW uses the zero oxygen value and an oxygen value measured by Winkler or other methods.

The algorithm has the following form:

$$OX = [Soc*(oc+tau*doc/dt)+Boc]*OXSAT(T,s) \\ *exp(tcor*[T+wt*(To-T)]+pcor*p)$$

where

Computed:	OX	dissolved oxygen concentration [mL/l]
Measured Parameters:	T	water temperature [°C]
	To	oxygen sensor internal temperature [°C].
	s	salinity [PSU]-[ppt]
	p	pressure [decibars]
	oc	oxygen current [microamps]
Calibration Coefficients:	doc/dt	slope of oxygen current [microamps/sec]
	Boc	oxygen current bias
	Soc	oxygen current slope
Constants:	wt	weighting fraction of oxygen sensor internal temperature
	tcor	temperature correction factor for membrane permeability
	pcor	pressure correction factor for membrane permeability
	tau	oxygen sensor response time

Calculated value: OXSAT(T,s) oxygen saturation value after Weiss (1970)

Values for tcor, tau and wt are taken from the Beckman polarographic oxygen sensor technical memorandum. The value for pcor recommended by Sea-Bird deviates from the Beckman memorandum and is based on more recent data analysis (see Application Note 13-3).

tcor	=	-0.033
pcor	=	1.50e-4
tau	=	2.0
wt	=	0.67 (Beckman type sensors)
wt	=	0.85 (YSI type sensors)

C. Oxygen sensor Calibration

The calibration method used by Sea-Bird is to measure the oxygen current output in a zero oxygen environment and the oxygen current and oxygen temperature outputs in either air-saturated water (OXFIT) or in water where the oxygen content is independently measured (OXFITW). The voltage outputs are converted to sensor temperature and oxygen current using the k and c coefficients for temperature and the m and b coefficients for current. The conversion coefficients are found on the original factory calibration sheet for the oxygen sensor. OXFIT and OXFITW calculate the coefficients Soc and Boc that are used in the oxygen algorithm. Use the SEASOFT module SEACON to enter the computed values for Soc and Boc.

The oxygen sensor can be calibrated by itself using a voltmeter to measure the sensor outputs and a power supply to provide power to the sensor. Alternatively the CTD system can be used to provide power to and acquire data from the oxygen sensor. In this methods the SEASOFT software can be used to display real time data from the instrument including oxygen concentration.

If the oxygen sensor is on a CTD system with a pump it is recommended that the entire CTD be submerged in the bath but not powered for at least one hour prior to the calibration. Supply power to the CTD, oxygen sensor, and pump for 15 minutes prior to the calibration. The oxygen sensor power must not be interrupted for 15 minutes prior to the calibration so that full polarization and equilibration can be established.

SBE 19 SeaCat Profilers with a pump and SBE 25 SEALOGGER CTDs have adjustable pump start frequencies which will be set to zero using the appropriate terminal program and the SP command for the SBE 19 and the CC command for the SBE 25. This will insure that the pump will start in fresh water. The SBE 9 CTD contains circuitry that turns the pump on when the conductivity sensor enters salt water. To insure that the pump will turn on in a fresh water bath, remove the end of the tygon tubing going between the conductivity cell and the oxygen sensor from the conductivity sensor and place a loop of tubing filled with salt water over both ends of the conductivity cell (or TC duct and conductivity cell). Please note that if salt water is in the conductivity cell and the oxygen sensor is in fresh water the CTD will compute salinity based on the water in the conductivity cell. In this case be sure to enter 0 for the salinity value in OXFIT or OXFITW and be aware that the values of OXSAT and Oxygen computed by the software will be incorrect because the wrong value of salinity will be used for the oxygen computation. Once the sensor has soaked for the required one

hour period, power will be applied to the sensor either by turning on the external power supply or the CTD. If a pump is being used that is not connected to the CTD, power will be applied to it. Before power is applied it will be verified that no air is trapped in the plumbing system. Trapped air will prevent the pump from establishing a good flow. Most oxygen sensors will come to within 1% of their asymptotic stable reading in five minutes after the application of power. This reading (either in units of current or voltage) will be recorded. To obtain oxygen readings that are within $\pm 1\%$ of the true reading the oxygen sensor temperature must be within 0.25°C of the bath water temperature as measured by the CTD or a thermometer.

1. Zero Oxygen Reading (OXFIT and OXFITW)

It is recommended that the zero oxygen point be taken first. This can be done by two different techniques; one can flush the sensor with a continuous stream of inert gas (e.g. Nitrogen or Argon), or place the sensor in a 5% - 10% by weight solution of Na_2SO_3 (sodium sulfite). Sea-Bird recommends the sodium sulfite methods. It is simpler and is not subject to errors that can occur when using an inert gas such as poor temperature control and incomplete displacement of oxygen gas diffusing out from inside the oxygen sensor. On Sea-Bird CTD systems that are equipped with a pump the oxygen sensor is provided with a plenum. This plenum can be filled with sodium sulfite solution and closed off with a piece of tubing (or alternatively inert gas can be flushed through the plenum). When using the sodium sulfite solution make sure that there are no air bubbles trapped on the oxygen sensor membrane. Insure that power has been applied to the sensor for several minutes before the inert gas or sodium sulfite solution is placed in the sensor. Watch the output of the sensor decrease rapidly towards zero volts. At some point the rapid change will stop, usually within one to two minutes. Record the output after three minutes seconds. This will be the zero value to use in the calibration. Often, depending on the individual sensor. the output will slowly drift towards zero volts. For the purposes of the calibration this slow drift is not considered. The original calibration sheet that accompanied the oxygen sensor will contain the zero oxygen current that was obtained during the factory calibration. If the sodium sulfite solution was used, rinse the oxygen sensor thoroughly several times to remove all traces of the solution and carefully clean your hands.

2. Air Saturated Reading (OXFIT)

The theory is to read the sensor's output in water which is exactly saturated with atmospheric gases. The saturated value of dissolved oxygen at atmospheric pressure and at a given temperature and salinity is computed with the program OXSAT. In practice this is accomplished by immersing the oxygen sensor in a volume of air saturated water and drawing water past the sensor with a small submersible pump. If the CTD system is equipped with a pump, this will be used for the calibration along with the plenum that was provided with the oxygen sensor. If another pump is used it will be a submersible type and configured to pump at a rate of 20 to 30 mL/s. In this case a plenum will be purchased from Sea-Bird to insure a reliable and repeatable flow of water past the membrane. The water is air saturated by aerating with an aquarium pump and air stone for 24 hours prior to the calibration. The air stone will be located within 10 cm of the surface. The air stone positioned at greater depths will tend to supersaturate the water because the air is injected at a pressure higher than atmospheric pressure. The water will be stirred during aeration and before measurements to insure that the whole volume contains saturated water. Stirring that is two vigorous can inject air bubbles deep into the bath supersaturating the bath water. For the highest accuracy work it is preferable that the temperature of the water used for the calibration be as close as possible to the temperature of the

water where the measurement will be taken. Care will be taken to minimize the ambient temperature changes that the container of water is subjected to. As water is heated its capacity to hold air is diminished and air will come out of saturation and form bubbles. These bubbles if present on the oxygen sensor membrane will interfere with the measurement. As the water heats it will also tend to supersaturate. If the container is cooled it will tend to drop below saturation. Since OXFIT assumes that the water is neither over or under saturated if the water temperature in the container changes faster than the oxygen can equilibrate the computed values of Soc and Boc will be incorrect. It may be necessary to wait more than fifteen minutes per liter of water in the container for every degree of temperature change.

3. Winkler Titration Value (OXFITW)

With this method the amount of dissolved oxygen in the water is independently measured so it is not necessary to aerate the water. For accurate results the oxygen concentration in the bath needs to be stable and constant over the period of the calibration. To insure this observe the following precautions: a) do not use freshly drawn water; it is typically supersaturated in gas and not equilibrated with the atmosphere, b) stir the bath vigorously (without mixing in air bubbles) to allow the water opportunity to come in contact with atmosphere and equilibrate to the atmospheric gas concentrations, and c) the bath temperature must remain stable to better than 0.1 deg C per hour prior to and during the calibration. If the CTD system is equipped with a pump, this will be used for the calibration along with the plenum that was provided with the oxygen sensor. If another pump is used it will be a submersible type and configured to pump at a rate of 20 to 30 mL/s. In this case a plenum will be purchased from Sea-Bird to insure a reliable and repeatable flow of water past the membrane. For the highest accuracy work it is preferable that the temperature of the water used for the calibration be as close as possible to the temperature of the water where the measurement will be taken. Allow enough time for the oxygen sensor to reach temperature equilibrium and then determine the amount of dissolved oxygen [mL/l] in the water using the Winkler or some other independent measurement method.

D. OXFIT Prompts

local barometric pressure (millibars)

- this is the pressure that would be read on a barometer (not corrected to sea level)

water temperature (°C)

water temperature read by the temperature sensor

oxygen current in air saturated water (microamps)

when displaying oxygen current with SEASAVE make sure the m and b coefficients from the dissolved oxygen sensor calibration sheet are entered using SEACON. If oxygen current voltage was recorded, use the m and b coefficients to convert the voltage to a current.

oxygen current in zero oxygen water (microamps)

enter the value determined when using the inert gas or the sodium sulfite solution

E. OXFIT Calculation

OXFIT calculates Soc and Boc as follows:

$$\begin{aligned}\text{Soc} &= \text{nsc}(\text{T}, \text{bp}) / [\exp(\text{tcor}^*) * (\text{oc} - \text{zoc})] \\ \text{Boc} &= -\text{Soc} * \text{zoc} \\ \text{oc} &= \text{air saturated water current (microamps)} \\ \text{zoc} &= \text{zero air water current (microamps)}\end{aligned}$$

See Table F-1 for the definition of $\text{nsc}(\text{T}, \text{bp})$.

F. OXFITW Prompts

oxygen serial number =

enter the serial number from the original calibration sheet

m = enter the value from the original calibration sheet

b = enter the value from the original calibration sheet

k = enter the value from the original calibration sheet

c = enter the value from the original calibration sheet

salinity [PSU] =

enter the salinity of the water in the container

water temperature [deg °C] =

enter the temperature of the water at the time of the measurement

Winkler value [mL/l] =

enter the measured amount of dissolved oxygen in milliliters per liter. The Winkler methods is described in Carritt, D.E. and J.H. Carpenter. 1966. Comparison and evaluation of currently employed modifications of the Winkler method for determining dissolved oxygen in seawater. J. Mar. Res. 24(3), 286-318, and Standard methods for the examination of water and wastewater, editors Clesceri et al.

oxygen current voltage for xx[mV] =

enter the voltage output by the oxygen current channel after the sensor has equilibrated in the water bath.

oxygen current voltage for air =

enter the voltage from the oxygen current channel when the sensor is in air. This value is for reference only and is not used to calculate the coefficients.

oxygen temperature voltage for xx [deg °C] =

enter the voltage output by the oxygen temperature channel after the sensor has equilibrated in the water bath.

oxygen current voltage for zero oxygen =

enter the voltage output by the oxygen current channel after the sensor has equilibrated to sodium sulfite or an inert gas.

G. OXFITW Calculation

Soc	=	measured oxygen / [oxsat(T, S)*exp(tcor*T)*(oc-zoc)]
Boc	=	-Soc*zoc
oc	=	air saturated water current (microamps)
zoc	=	zero air water current (microamps)

See Table F-2 for the definition of oxsat(T, S).

A file named SERIALNO. CAL will be written to the current directory containing a summary of the calibration data and computed coefficients.

H. Verification of SOC and BOC

OXFIT and OXFITW calculate and display the new Soc and Boc coefficients. These will be compared to the original factory calibration or the last calibration that was performed. Typically the Soc value will slowly increase with time as the sensor is used. The KCI electrolyte in the oxygen sensor is consumed as part of the reduction reaction. This loss of KCI decreases the sensitivity of the sensor which is reflected in the slowly increasing Soc value. Application note 13-4 will be consulted about the life expectancy of Beckman dissolved oxygen sensors. Application note 32 contains additional information about the YSI based oxygen sensors.

The new Soc and Boc values will be entered into the SEASOFT.CON file using the SEACON program. If the DERIVE program in SEASOFT Version 4 software is being used to calculate the oxygen concentration after the data has been aligned the Soc and Boc values will be entered into its configuration file. If the entire CTD was used in the oxygen calibration it can be run in real time mode to check the calibration results. Display parameters of oxygen concentration in mL/l, water temperature and salinity are necessary. The program OXSAT can be used to calculate the saturation value for the measured temperature and salinity and compared with the real time reading of oxygen concentration. Or if SEASOFT Version 4 is being used the saturated oxygen concentration can be displayed along with the oxygen sensor reading. If the oxygen sensor is healthy and the calibration was performed correctly, these values will agree to within 0.1 mL/l. For SBE 9s that must have salt water in the cell to turn the pump on, the real time oxygen readings will be in error because SEASAVE will assume that the water in the bath has the same salinity as the water in the tube.

I. Oxygen Sensor Cleaning and Storage

Care must be taken to avoid fouling the oxygen membrane with oil or grease, and it is recommended that the oxygen sensor be rinsed with a 1% water-solution of Triton X-100 and flushed with distilled water after each use. With pumped instruments having a clear plastic plenum, loop tubing from inlet to outlet and partly fill with distilled water between deployments (if there is freezing danger, shake all excess water out of the plenum). With unpumped instruments, put a few drops of water in the DO sensor's protective cap and fasten the cap securely. As an added benefit, the sensor will be kept free of airborne particulates that could otherwise coat the membrane and reduce the sensitivity.

For routine cleaning, soak the sensor in a 1% solution of Triton X-100 initially warmed to 50°C (122°F) for 30 minutes. After the soak, drain and flush with warm (not hot) fresh water for 1 minute.

J. Oxygen Sensor Deployment

Connect the pump tubing to the sensor plenum (pumped designs) or remove the protective cap (unpumped designs) before deployment. NOTE: Failure to remove the cap will result in the crushing of the cover at depth and will cause destruction of the oxygen sensor.

A large drop of Triton X-100 solution gently placed directly on the sensor membrane will protect the sensor from oil on the seawater surface. The Triton will quickly rinse away leaving behind a clean and fully functional sensor membrane.

To allow time for the oxygen sensor to polarize, the instrument to which it is connected must be powered for at least three minutes before beginning the water-column profile. Failure to wait will result in erroneously high oxygen readings. When taking water samples using a General Oceanics rosette and Sea-Bird 9/11 CTD which share a single conductor seacable, wait at least two minutes after the bottle has been tripped before resuming the CTD profile. Tripping the bottle momentarily interrupts power to the oxygen sensor which then must repolarize when power is reapplied. A SBE 911plus CTD which is being to control the rosette does not lose power when a bottle is tripped. When using an unpumped oxygen sensor, a water flow speed of at least 0.5 meter / second (horizontal motion, current, or vertical profiling rate) must be constantly maintained to avoid local oxygen depletion and erroneously low readings.

TABLE F-1: CORRECTION FACTOR FOR NON-STANDARD ATMOSPHERE

$$n_{sa}(T, bp) = (bp/pO) * (1 - p_{H_2O}/bp) / (1 - p_{H_2O}/pO)$$

bp = barometric pressure in kilopascals

pO = 101.325 kilopascals

p_{H₂O} = water vapor pressure in kilopascals

T = water temperature in °C

$$p_{H_2O} \exp[(-216961 * X - 3840.7) * X + 16.4754]$$

$$X = 1/(T+273.15)$$

For air saturated water at the surface:

oc = air saturated water current (microamps)

zoc = zero air water current (microamps)

$$\{[Soc * (oc - zoc)] / n_{sa}(T, bp)\} * \exp(t_{cor} * T) = 1$$

$$Soc = n_{sa}(T, bp) / [\exp(t_{cor} * T) * (oc - zoc)]$$

$$Boc = -Soc * zoc$$

TABLE F-2: COMPUTATION OF OXSAT

$$OXSAT(T, s) = \exp(A1 + A2 * (100/T) + A3 * \ln(T/100) + A4 * (T/100) + s * (B1 + B2(T/100) * (T/100)))$$

The units are mL/l, the oxygen saturation value is the volume of the gas (STP) absorbed from water saturated air at a total pressure of one atmosphere, per unit volume of the liquid at the temperature of measurement where:

s = salinity in parts per 1000

T = °C + 273.15 (absolute temperature)

A1 = -173.4292

A2 = 249.6339

A3 = 143.3438

A4 = -21.8492

B1 = -0.033096

B2 = 0.014259

B3 = -0.00170

TABLE F-3: COMPILATION OF OXYGEN SATURATION VALUES

The following table contains oxygen saturation values at atmospheric pressure calculated using the OXSAT equation found in Table F-2. Units of oxygen are mL/l. To compute units of mg/l multiply the values in the table by 1.4276.

Temp °C	Salinity (PSU)								
	0	5	10	15	20	25	30	32	35
-2	10.82	10.46	10.10	9.76	9.42	9.10	8.79	8.67	8.49
0	10.22	9.88	9.54	9.22	8.91	8.61	8.33	8.21	8.05
2	9.67	9.35	9.04	8.74	8.45	8.17	7.90	7.79	7.64
4	9.16	8.86	8.57	8.30	8.02	7.76	7.51	7.41	7.26
6	9.70	8.42	8.15	7.89	7.64	7.39	7.15	7.06	6.92
8	8.28	8.02	7.76	7.52	7.28	7.05	6.82	6.74	6.61
10	7.89	7.64	7.41	7.17	6.95	6.73	6.52	6.44	6.32
12	7.53	7.30	7.08	6.86	6.65	6.44	6.24	6.17	6.05
14	7.20	6.99	6.77	6.57	6.37	6.17	5.99	5.91	5.80
16	6.90	6.69	6.49	6.30	6.11	5.93	5.75	5.68	5.58
18	6.62	6.42	6.23	6.05	5.87	5.70	5.53	5.46	5.36
20	6.35	6.17	5.99	5.81	5.64	5.48	5.32	5.26	5.17
22	6.11	5.93	5.76	5.60	5.44	5.28	5.13	5.07	4.98
24	5.88	5.71	5.55	5.39	5.24	5.09	4.95	4.89	4.81
26	5.66	5.51	5.35	5.20	5.06	4.92	4.78	4.73	4.65
28	5.46	5.31	5.17	5.03	4.89	4.75	4.62	4.57	4.50
30	5.328	5.13	4.99	4.86	4.73	4.60	4.47	4.43	4.35
32	5.10	4.96	4.83	4.70	4.58	4.45	4.34	4.29	4.22

LITERATURE CITED

- Carritt, D.E., and J.H. Carpenter. 1966. Comparison and evaluation of currently employed modifications of the Winkler method for determining dissolved oxygen in seawater. *J. Mar. Res.* 24(3): 286-318.
- Clesceri, L. A., E. Greenberg, and R.R. Trussell (eds.). 1989. Standard methods for the examination of water and wastewater. 17th edition. Am. Public Health Assoc. Washington, DC. ISBN 0-87553-161-X.
- Gnainner, E., and H. Forstner (eds.). 1983. Polarographic Oxygen Sensors: Aquatic and Physiological Applications. Springer-Verlag, 370 p.
- Millard, R. C., Jr. 1982. CTD calibration and data processing techniques at WHOI using the 1978 practical salinity scale. Proc. Int. STD Conference and Workshop, La Jolla, Mar. Tech. Soc., 19 p.
- Owens, W.B., and R.C. Millard Jr. 1985. A new algorithm for CTD oxygen calibration. *J. Physical Oceanography* 15: 621-631.
- Weiss, R.F. 1970. The solubility of nitrogen, oxygen and argon in water and seawater. *Deep- Sea Res.* 17: 721-735.

APPLICATION NOTE NO. 7 - Revised September 1989

CALCULATION OF M AND B COEFFICIENTS FOR THE SEA-TECH TRANSMISSOMETER

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The data sheet supplied by SEA TECH indicates the air calibration voltage (approx. 4.7 volts) and the blocked path voltage (approx. 0.0 volts). These values along with the current air voltage and blocked path voltage are used to derive the M and B coefficients used in SEACON as follows: To calibrate the transmissometer with the Sea-Bird instrument to which it is interfaced, you must obtain readings with the light path in air (the lenses must be clean and dry for this to be meaningful) and then with the light path blocked. Run SEASAVE, answer 'y' to 'change data acquisition or display parameters (y/n)?'. Answer 'y' to the prompt 'change CRT parameters (y/n)?'. Select 'fixed display', and choose 'voltage' as the variable type. Enter the transmissometer's voltage number (see configuration page at beginning of manual); select real time data to get a display of the transmissometer output.

A0 is the AIR CALIBRATION voltage from the SEA TECH calibration sheet

Y0 is the blocked path voltage from the SEA TECH calibration sheet

A1 is the current air voltage

Y1 is the current blocked path voltage

then $M = 20(A0 - Y0)/(A1 - Y1)$

and $B = -M Y1$

For example:

If the SEA TECH calibration gave the following values:

A0 = 4.743 volts

Y0 = 0.002 volts

and the current calibration gave:

A1 = 4.719 volts

Y1 = 0.006 volts

then

$M = 20(4.743 - 0.002)/(4.719 - 0.006) = 20.119$

$B = -0.006 * 20.119 = -0.1207$

These are the M and B values that are to be entered into SEACON. If your instrument has AV = 2 inputs (used on some SBE 9 configurations) follow the same procedure. You will obtain A1 and Y1 values approximately twice as large as those in the example (9.348 volts and 0.012 volts respectively) leading to M = 10.0594 and B = 0.1207.