FIELD OPERATIONS MANUAL FOR MARINE WATER-COLUMN, BENTHIC, AND TRAWL MONITORING IN SOUTHERN CALIFORNIA

by

Southern California Bight Pilot Project Field Coordination Team

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THE PHILOSOPHY OF REGIONAL OCEAN MONITORING IN SOUTHERN CALIFORNIA

The Southern California Bight Pilot Project is a collaborative effort among 12 local, state, and federal agencies to assess environmental conditions on the mainland shelf off Southern California. The Pilot Project demonstrated that the largest publicly owned treatment works can integrate their marine monitoring methods and coordinate their field sampling programs. The Pilot Project also demonstrated that the regulatory agencies are willing to make the necessary changes in the National Pollution Discharge Elimination System permits to facilitate regional monitoring and to allow permittees to participate in innovative monitoring approaches.

Five different agencies participated in the Pilot Project field survey using a standard set of protocols and sampling methods described in a field operations manual. As a result, the participating agencies produced comparable data that allowed bightwide comparisons of environmental conditions. Following the survey, the Pilot Project modified the field manual to provide guidelines for field operations used in compliance, as well as regional, monitoring programs of the four largest publicly owned treatment works. The Pilot Project developed this manual to insure that comparable data will be produced by the ocean monitoring programs in the future. The focus of the manual is on the best way to conduct ocean monitoring based on the extensive experience of all the involved agencies.

The Steering Committee of the Southern California Bight Pilot Project recognized that monitoring methods will change over time and that a mechanism was needed to evaluate new methods and recommend changes to old methods. The Steering Committee proposed the formation of a Marine Monitoring Methods Committee (MMMC) composed of technical representatives of the participating agencies. The MMMC would do the following:

- · review the field manual on a regular basis and revise it as new technology or methods are developed;
- · standardize the methods used in ocean monitoring programs that are not covered in this manual; and
- · encourage the use of these standard methods in ocean monitoring programs by agencies that were not participants in the Pilot Project, which may require adding representatives of these entities to the Marine Monitoring Methods Committee.

The Steering Committee of the Southern California Bight Pilot Project recommends that the regulatory agencies use the field manual as a guideline for the ocean monitoring programs conducted by the discharge agencies. This manual should be referred to in its entirety with allowance for revisions as described above.

Steering Committee
Southern California Bight Pilot Project
August 8, 1995

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ABSTRACT

Local, state, and federal agencies monitor the status and trends of environmental quality and natural resources of the mainland shelf of the Southern California Bight, often in accordance with National Pollutant Discharge Elimination System (NPDES) permits which require dischargers to comply with the California Ocean Plan and Federal Clean Water Act. Although these compliance monitoring programs provide useful information, they address local questions and not questions of regional interest. Many of these programs are designed to answer similar questions and hence use similar but not identical methods. While interagency differences in sampling procedures may not be important to the individual local monitoring programs, they do affect any regional use of the data. Interagency differences in sampling methodology can reduce

the intercomparability of data among the programs and hence necessitate specific regional studies to assess conditions of the Southern California Bight as a whole.

The need for and interest in developing regional monitoring in Southern California has been expressed by both environmental managers and dischargers. This resulted in the formation of the Southern California Bight Pilot Project (SCBPP) in summer 1993. The SCBPP is a collaborative effort among twelve federal, state, regional, and municipal agencies. In summer of 1994, the SCBPP conducted a survey of the mainland shelf of the of the Southern California Bight to assess regional environmental conditions. Although five different agencies conducted the field study, they used a standard set of protocols and sampling methods that were described in a field operations manual. Based on the success of this survey and the need to standardize methods used in routine monitoring programs of the major dischargers, the SCBPP Steering Committee requested that the manual be modified to produce a new manual that would provide protocols and methods for routine as well as regional monitoring programs.

The SCBPP Field Coordination Team (consisting of representatives of the major monitoring programs) revised the SCBPP field operations manual to produce a field operations manual that could be used for major monitoring programs of the four largest publicly owned treatment works (POTW) in Southern California. This manual focuses on the three major receiving-water monitoring programs (water-column, benthos/sediments, and trawl) of the POTWs. The manual describes standard protocol and methods for these programs as well as for navigation. It also describes the protocol by which changes to the manual can be made so that the document can be updated as better methods become available.

SECTION 1

INTRODUCTION

The mainland shelf of the Southern California Bight (SCB) (defined here as extending from Point Conception, California, to the United States - Mexico border) is an important ecological and economic area to the nearly 15 million people that live in Southern California. It is the home or is part of the migratory route of many species of marine organisms and is used extensively for recreational and commercial activities, including the discharge of waste from municipal wastewater treatment plants, power generating stations, industrial plants, and storm drains.

Many local, state, and federal agencies monitor the status and trends of environmental quality and natural resources of the mainland shelf of the SCB, often in accordance with National Pollutant Discharge Elimination System (NPDES) permits which require dischargers to comply with the California Ocean Plan and Federal Clean Water Act. Although these compliance monitoring programs provide useful information, they address local questions and not questions of a regional interest. Many of these programs are designed to answer similar questions and hence use similar but not identical methods. While interagency differences in sampling procedures may not be important to the individual local monitoring programs, they do affect any regional use of the data. Interagency differences in sampling methodology can reduce the intercomparability of data among the programs and hence necessitate specific regional studies to assess conditions of the SCB as a whole.

The need for and interest in developing regional monitoring in Southern California has been expressed by both environmental managers and dischargers. This resulted in 1993 in a cooperation between regulatory agencies and dischargers of Southern California with the United States Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP), which had developed an approach to assessing environmental conditions over large areas. This resulted in the formation of the Southern California Bight Pilot Project (SCBPP).

The SCBPP is a collaborative effort between the EPA (EMAP and EPA Region IX); California State Water Resources Control Board (CSWRCB); California Regional Water Quality Control Board, Los Angeles Region (CRWQCBLAR); California Regional Water Quality Control Board, Santa Ana Region (CRWQCBSAR); California Regional Water Quality Control Board, San Diego Region (CRWQCBSDR); the City of Los Angeles, Environmental Monitoring Division (CLAEMD); County Sanitation Districts of Los Angeles County (CSDLAC); County Sanitation Districts of Orange County (CSDOC); City of San Diego, Metropolitan Wastewater Department (CSDMWWD); Southern California Coastal Water Research Project (SCCWRP); and Santa Monica Bay Restoration Project (SMBRP) (EPA National Estuary Program). Its primary purpose was to plan and conduct a survey to assess conditions on the mainland shelf of the SCB. The study assessed conditions in the water column (temperature, salinity, transmissivity, dissolved oxygen), benthos (infauna; sediment characteristics, chemistry, and toxicity), and demersal fish and invertebrate fauna (assemblages, tissue contamination).

The SCBPP Steering Committee (consisting of representatives of all of the above agencies) planned and conducted the study. The Steering Committee identified a Project Manager, Quality Assurance and Information Management Officers, and Field, Laboratory, and Report Coordinators. The Field Coordinator established a Field Coordination Team consisting of representatives of each of the agencies participating in the field survey. The purpose of this group was to produce a field operations manual that would specify standard field methods and protocol to be used by all five agencies during the SCBPP survey. The resulting manual (SCBPP,FCT 1994) was used by all five agencies (CLAEMD, CSDLAC, CSDOC, CSDMWWD, and SCCWRP) and their contractors during the SCBPP survey of July-August 1994.

The SCBPP survey showed that the five agencies could conduct a survey using a set of methods that was acceptable to all participants. These methods represented the minimum that was acceptable to all agencies. Some agencies met these minimum standards while others went beyond. Thus the SCBPP Steering Committee requested that the SCBPP field operations manual be revised to produce a field operations manual that could be used in the monitoring programs of the four largest publicly owned treatment works (POTWs) in Southern California (e.g., Hyperion Treatment Plant of CLAEMD; CSDLAC; CSDOC; and Point Loma Wastewater Treatment Plant of CSDMWWD). The SCBPP Field Coordination Team met in January 1995 to make these modifications. This manual is a result of discussions conducted in those meetings.

The purpose of this document is to provide a manual of minimum standard field operations methods and protocol that can be applied to the major marine monitoring programs of the four largest POTWs of Southern California. Thus it addresses water-column, benthos/sediment, and trawl monitoring programs, as well as navigation. It also proposes the formation of a standing Marine Monitoring Methods Committee to address method issues and describes protocol by which changes to the manual can be made so that the document can be updated as better methods become available. It does not address all program elements of each particular POTW (e.g., rig fishing, discrete water quality sampling) but focuses on and refines what was done during the SCBPP survey.

SECTION 2 GENERAL CONSIDERATIONS

SAFETY

Collection of samples in field surveys is inherently hazardous and this danger is greatly compounded in bad weather. Thus, the safety of the crews and equipment is of paramount importance. Each person working on board a vessel should take personal responsibility for his or her own safety. Since a large portion of each sampling crew's time is spent on a research vessel, all field personnel must be able to swim. Many accidents at sea are preventable. "Safety awareness" by the captain and all crew members is the greatest single factor that will reduce accidents at sea. Each survey crew should follow established rules and provisions within their respective agency's safety program. Field personnel should be aware of Material Safety Data Sheets for any hazardous materials that they are likely to encounter.

Sampling should be canceled or postponed during hazardous weather conditions. The final decision is made by the vessel captain, who is responsible for the safety of everyone on board. As with any field program, the first priority is the safety of the people on board, followed by the safety of the equipment, and the recovery of the data.

IMPORTANT TELEPHONE NUMBERS

The names and phone numbers of emergency services, California Department of Fish and Game wardens, monitoring vessels, and appropriate agency personnel are listed in Appendices 1 and 2.

NAVIGATION

Accurate location of sampling sites is important to the success of all monitoring surveys. For standard operations, differential global positioning system (DGPS) is required. Standard GPS or a Long-range Aid to Navigation (LORAN-C) are acceptable back-ups in the event that the differential GPS is down. Radar and fathometer can be used as a backup for differential GPS where LORAN-C is inaccurate (as may be the case near the coast).

Each agency is responsible for maintaining a log of station locations during the cruise. Coordinates of each station must be based on North American Datum 1983 (NAD 83) and should be expressed in degrees, minutes, and thousandths of a minute. Coordinates and fathometer readings should be recorded electronically, if possible. Each vessel must also have a fathometer. Depth should be recorded for each station in meters and included with the navigation data. Direction should be reported as degrees from magnetic north.

CRUISE AND SITE DATA

A specific set of cruise and site data should be recorded for every CTD, benthic, and trawl survey. The following data should be recorded for each cruise:

1) date;
2) vessel;
3) crew and scientific party;
4) navigation check, consisting of three fields:
a) name of check site (e.g., LA Light, San Diego Berth 18; etc.);
b) the nominal or chart position of that site (e.g., from a list of light locations); and
c) the position of the site as determined by the on-board navigation system.

The following data should be recorded at each sampling site for each monitoring program (CTD, benthic, and trawl):
1) date;
2) coordinates (latitude and longitude in degrees, minutes, and thousandths of a minute) of sampling site;
3) time
4) depth (in meters) for each sampling position;
5) weather observations (sky, wind speed, and wind direction in degrees from magnetic north); <
6) sea conditions (swell height and direction, period, tide height, and time of low and high tides bracketing sampling event).

Additional specific data to be collected are discussed under water-column, benthic, and trawl sampling sections (Sections 3, 4, and 5).

CHAIN OF CUSTODY FORMS
Chain of custody forms are to be filled out at the end of each sampling day for transfer of samples from the vessel sampling crew to the laboratory or to delivery personnel. A form is to be filled out for each set of samples that will be transferred to a specific location. Sample identification numbers (or station and date) and sample and container types are to be included on the form to identify the samples being transferred. This form is to be signed by the chief scientist transferring the samples and the laboratory staff member receiving them. A copy of the form is to be kept and the original form with signatures will accompany the samples.

SECTION 3 WATER-COLUMN PROFILING

PURPOSE
Water-column profiles are collected at discrete sampling sites to characterize depth-related gradients in temperature, salinity, hydrogen ion content (pH), transmissivity, and dissolved oxygen (DO). For example, water-column profiles can describe whether stratification (layering) is present and, if so, the depth of the thermocline or pycnocline. Variation in these parameters at the same depth among stations may indicate anthropogenic or natural perturbations of the environment. For instance, low salinity values at some stations may indicate the presence of an effluent plume whereas high pH and dissolved oxygen, and low transmissivity may indicate a phytoplankton bloom.

EQUIPMENT
A conductivity-temperature-depth profiler (CTD) with additional sensors will be used to provide a continuous water-column profile of temperature, salinity, DO, pH, and transmissivity with depth (Figure 1). This instrument must meet the program performance specifications for temperature, salinity, DO, pH, transmissivity, and pressure (Table 1). (Protocols specific to CTDs currently used in marine monitoring surveys of the four largest POTWs in Southern California are described in Appendix 3).

TRAINING
Any individual who will be maintaining, calibrating, or operating the CTD should be trained in each of these operations. Prior to performing these operations unsupervised, an individual should demonstrate proficiency in that operation to a senior, CTD experienced staff member. Proficiency should be evaluated on the basis of successfully completing the operation following written procedures and demonstrating an understanding of the equipment. Additionally, the individual should be evaluated on his/her ability to troubleshoot common problems. All training and demonstration of proficiency should be documented. An agency using and deploying a CTD should be an active participant in the Southern California CTD Users Group.

Figure 1. Example of conductivity-temperature-depth profiler (CTD) used in marine receiving-water monitoring programs in Southern California (modified from unpublished figure, Sea-Bird Electronics, Inc.).

Table 1. Required instrument program specifications* for conductivity-temperature-depth profilers (CTD) to be used in receiving-water monitoring programs of the major publicly owned treatment works of Southern California.

Parameter	Acceptable Deviation
Dissolved Oxygen (DO)	± 0.30 mg/L
Salinity	± 0.009 ppt
Transmissivity	± 0.50 %
Temperature	± 0.03 °C
Hydrogen Ion Content (pH)	± 0.1 pH units
Pressure	± 1.3 decibars

* Program specifications are 95% confidence intervals derived from Southern California Bight Pilot Project intercomparison results of June 9, 1994.

CTD INTERCOMPARISON EXERCISE
A CTD intercomparison exercise will be conducted at least annually to evaluate the precision, accuracy, and comparability of the CTDs used by each agency. All of the CTDs will be placed in a common sea-water tank. The water temperature will be controlled with a chiller to a few degrees centigrade below ambient temperature and will be aerated to achieve oxygen saturation. DO values measured by the CTDs will be compared against expected saturation table values and winkler titrations. Salinity values will be compared to Association Internationale d’

Oceanographie Physique (IAPSO) salinity standards; temperature values will be compared to measurements made with a National Institute of Standards and Testing (NIST) certified thermometer; and pH values will be 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.

CTD PRECRUISE CHECKOUT AND CALIBRATION

Precruise Equipment Checkout

A precruise equipment checkout will be will be conducted prior to calibration and less than or equal to 24 hr prior to starting the cruise. This inspection should 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 and waterproof and lubricated with silicone;
- 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) cleansing 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 will be conducted less than or equal to 24 hr prior to starting the cruise for pH, DO, transmissivity, and pressure. There is no lab calibration for conductivity and temperature. Verification that the proper sensor coefficients are in the configuration file should be made before proceeding. A CTD calibration data sheet will be 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 ($> \pm 1°C$) thermal change during calibration.

Hydrogen Ion Content (pH)

. The pH sensor may 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 should 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 manufacturer's software and checked against three buffers, 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 should be rerun and the procedure repeated. Corrected values should be added to the CTD's software. When complete, the pH electrode should be 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 should be between 15 and 40 ml/sec. The DO sensor will be calibrated according to manufacturer procedures. 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 should match to within 0.1 ml/L (0.143 mg/L). Sensor performance is monitored and the membrane or sensor module should be replaced if results are unreliable or approach manufacturer's performance guidelines (see Appendix 3).

Transmissometer.

This calibration is performed in air. The transmissometer should be calibrated according to manufacturer procedures. The CTD software should be modified to reflect any changes that are made during the calibrations

Pressure Offset

This determination should 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 0.00 and -0.60 db. If out of this range, adjustments should be made if possible and the manufacturer software should be rerun to achieve a value between 0.00 and -0.60 db. If this does not correct the displayed pressure value, the unit should be serviced. The pressure output and any changes made 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.

Factory Calibration and Maintenance

Maintenance and calibration of the CTD and/or specific sensors should be documented, including dates of most recent servicing. Preventative maintenance should be conducted on the CTD unit periodically but not to exceed manufacturer's recommendations. Upon return from the factory, enter any new factory calibration coefficients and input where appropriate.

The temperature and conductivity sensor calibration should be conducted by the National Oceanic and Atmospheric Administration/National Regional Calibration Center (NOAA/NRCC) lab and certified and inspected by the manufacturer. Certification should be provided when the sensor is returned.

Postcruise Calibration

The Chief Scientist is responsible for deciding whether postcruise calibrations are within acceptable limits. The time between last cast and the completion of the postcalibration should be not more than 24 hr.

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. The water temperature should be recorded, as well as the pH and voltage output for each buffer. Agreement should occur between each sensor value and the known buffer value, and should be within 0.15 pH units. If agreement is out of this range, the unit should be recalibrated and the stations resampled if feasible.

Dissolved Oxygen (DO).
Postcalibration of the DO sensor should follow the same procedures as those for precalibration. However, the DO concentration should be evaluated 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 should be reviewed for consistency. If these data are deemed unreliable, the survey should be done again as soon as possible (if feasible). If stations cannot be resampled, data should be flagged or qualified in the data base. Following calibration, the oxygen sensor should be cleaned and stored following manufacturer procedures.

Transmissivity 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 on the calibration sheet.

CTD DEPLOYMENT

The CTD should be deployed with a means of data collection, such as a deck or RAM (random access memory -- an internal recording instrument) unit. The instrument should have a scan rate of no fewer than 8 scans/sec. All data will be averaged to no more than 1 scan/sec; however, if there is a risk of obtaining less than 1 datum/m, this average and/or the deployment descent rate should be decreased.

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 should be monitored with a meter wheel and timer. Descent rates should always be slower than 1 m/sec to minimize spiking of sensor output.

The objective of water-column profiling is to collect water-column data for every meter. Therefore, to avoid omissions in data from a given meter of depth, it is recommended that the scan rate should not be less than 1 scan/sec and a descent rate less than 1 m/sec be used. Optimal scan value and descent rate are dependent upon sea surface conditions during deployment and should be evaluated and adjusted accordingly. Additionally, during data processing, a cast whose average descent rate is found to exceed 1 m/sec should be considered for omission.

Use of an onboard water bath is recommended to prevent excessive heating of the sensors while on the ship's deck. If an onboard water bath is not used, a wet towel should 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.

Before beginning a cast, the CTD sensors are brought to thermal equilibration with the ambient sea-water. If applicable, the pump should be activated and bubbles should be purged from any tubing. This is best accomplished by lowering the CTD a few meters and (if capable) monitoring salinity and DO values to ensure their stabilization. In either case, a 3-min equilibration upon initial power-up at the first station and 90 sec at each station thereafter is the minimum soak time for thermal equilibration and sensor stabilization. After sensor stabilization and at least the 3 min or 90 sec, the CTD is raised so the top of the unit is at the water surface and profiling is begun.

CTD CAST ACCEPTABILITY

The goal of monitoring surveys is to collect water-column profiles at all stations. During field sampling, cast acceptability should be 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 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).

Casts should also be evaluated by comparison of values obtained at previous or nearby stations.

Table 2. Reasonable ranges of measurements from waters of the mainland shelf of Southern California.

Parameter	Typical Range
Dissolved Oxygen (DO)	3 - 12 mg/L
Salinity	32 - 34 ppt
Transmissivity	20 - 90 %
Temperature	8 - 24 °C
Hydrogen Ion Content (pH)	7.5 - 8.5 pH units

If anomalous values are present, the cause should be investigated and remedied before proceeding. If damage to the CTD (due to striking the bottom or some other event) is suspected, review that cast 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 should 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 should 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.) should be noted in the field logbook. If feasible, a station should be resurveyed when an unacceptable profile is obtained.

CTD QUALITY ASSURANCE/QUALITY CONTROL

No field quality control (QC) of any of the parameters is required beyond the cast acceptability check described above or the range checks (Table 1). Dissolved oxygen, pH, pressure offset, and transmissivity performance are carefully monitored and calibrated prior to and immediately following a survey. This evaluation is deemed sufficient to assure the quality of the performance. Conductivity and temperature are evaluated and calibrated on a strict factory maintenance schedule and traceable to NOAA/NRCC standards. Their performance and integrity from calibration to calibration are reliable to such a level that field QC is deemed unnecessary. The typical ranges (Table 2) are guidelines only and any value outside of them should be evaluated relative to the entire cast and the entire day's survey; legitimate values may exist outside of these ranges but the vast majority of values will fall within these ranges.

All data will be checked to be certain all data and configuration files are present and properly named. All data files should contain proper and complete header information. This check should be verified and documented by field personnel. All data will be reviewed graphically and statistically for single point outliers (spikes) as well as trends.

CTD DATA

If data are to be submitted to another agency, data will be output using a mutually agreed upon format. The following header information, parameters, units, and format is an example of output:

- 1) agency
- 2) station
- 3) date
- 4) depth (m)
- 5) temperature, IPTS-68 (o C)
- 6) conductivity (Siemens/m)
- 7) oxygen (mg/L)
- 8) light transmission (%)
- 9) salinity, PSS-78 (PSU)
- 10) pH
- 11) density (st), (kg/m3)

Hard copies of all sensor and equipment factory maintenance, pre- and postcruise calibration sheets, and CTD field data sheets should be maintained and made available upon request. Additionally, raw CTD files should be archived. These should include all data files, configuration files, header files, and any mark files created.

SECTION 4

BENTHIC SAMPLING

PURPOSE

The purpose of benthic sampling is to obtain a standard amount of sediment at a site to characterize the infauna and sediment type, contamination, and toxicity. This information is particularly useful in characterizing the extent and impact of the discharge from an outfall or other anthropogenic activities relative to natural conditions.

VAN VEEN GRAB

A 0.1 m2 modified Van Veen grab will be used to collect sediment samples for physical, chemical, and infaunal analysis (Figure 2) (Stubbs et al. 1987). (Currently these grabs are manufactured by Kahl Scientific Instrument Corporation, El Cajon, CA). The grab may be galvanized, stainless steel, or Teflon-coated. All surfaces of the grab must be clean and free of rust. Either single or tandem Van Veen grabs are acceptable.

Figure 2. Modified Van Veen grab sampler recommended for marine receiving-water monitoring programs in Southern California: a) cocked position; b) tripped position (modified from Stubbs et al. 1987).

GRAB SAMPLING PROCEDURES

Prior to deployment, the grab is cocked with the safety key in place. The grab is then hoisted over the side, the safety key is removed, and the grab is lowered at 2 m/sec until it is 5 m above the bottom. From this point, it is lowered at 1 m/sec to minimize the effects of bow wave disturbance. After bottom contact has been made (indicated by slack in the lowering wire), the tension on the wire is slowly increased, causing the lever arms to close the grab. Once the grab is back on board, the top doors are opened for inspection.

CRITERIA FOR ACCEPTABLE GRAB SAMPLES

Upon retrieval of the grab the acceptability of the sample must be determined. Acceptability is based upon two characteristics of the sample: sample condition and depth of penetration. Sample condition is judged using criteria for surface disturbance, leakage, canting, and washing (Figure 3). Acceptable sample condition is characterized by an even surface, with minimal surface disturbance, and little or no leakage of the overlying water. Heavily canted samples are unacceptable. Samples with a large amount of "humping" along the midline of the grab indicating washing of the sample during retrieval are also unacceptable. While some humping will be evident in samples from firm bottoms where penetration has been poor, this is due to the closing action of the grab and is not evidence of unacceptable washing.

Figure 3. Examples of acceptable and unacceptable grab sample condition (modified from Tetra Tech 1986).

If the sample condition is acceptable, the overlying water is drained off and the depth of penetration determined. The overlying water in grabs intended for infaunal samples may be drained but all drained water must be captured for screening with the sediments (see Sample Processing below). Extra caution should be taken to drain the overlying water from the grabs for chemistry and toxicity samples. It is recommended that siphoning or decanting be employed for these grabs to avoid disturbance and loss of the surface sediments.

It is important to get the best sample possible. For infaunal samples, sediment penetration depth must be at least 5 cm; however, penetration depths of 7-10 cm should be obtainable in silt (fine sand to clay). The depth of penetration is determined by insertion of a plastic ruler vertically along the grab midline and measurement of the depth of sediment to the nearest 0.5 cm.

SEDIMENT DESCRIPTION

The field description of sediments is required following measurement of penetration depth. At minimum the sediment should be characterized as being shell hash, gravel, sand, or mud (silt and/or clay). The presence of petroleum tar should also be recorded as well as any obvious odors, such as sulfide (the odor of H_2S or rotten eggs), oily (the odor of petroleum tar), or humic (a musty, organic odor). Typically, sediments will have no particular odor. General sediment colors (e.g., black, green, brown, red, yellow) should also be recorded.

SAMPLE PROCESSING

Benthic Infaunal Samples

After the sample description has been completed, the sediment sample intended for biological analysis is washed from the grab for screening. All wash waters used on the sample are to be filtered in some fashion to preclude the accidental introduction of surface-water organisms. Two methods that may be used are an in-line filter in the boat's sea-water pumping system, or the fitting of all wash hoses with fan nozzles having apertures <0.5 mm diameter. Either of these or other approaches that accomplish the same end may be employed. Thoroughly wash the sediment from the grab and transfer it to a sediment washing table for screening. A means of capturing all water drained from the grab, the grab sample, and the wash water must be used. The typical arrangement is a large-capacity tub (>70 L capacity) positioned under the grab.

A sediment washing table is recommended for benthic sample processing. The table provides a flat, smooth surface over which to spread and wash the sample. This provides a means of gently breaking up the sediment before it runs off the end of the table into the screen box. The screen box must be equipped with a stainless steel mesh with 1.0-mm openings. Wire diameter should be similar to that found in the U.S. Standard 1.00 mm Sieve (0.58 mm). The surface area of screen should be adequate to easily accept the sample without build up. Typical surface areas used in surveys in the Bight are 1500 to 2100 cm2. Water pressure should be controlled while washing the sample to avoid damaging the organisms. Minimize direct application of water from the hose to the material and organisms collecting on the screen.

Once the sample has been washed through the screen, transfer the material (debris, coarse sediment, and organisms) retained on the screen to a sample container. The sample container is to be labeled with a external adhesive label giving the station name, depth, date, and "split number" (i.e. 1 of 2, 2 of 2, etc.), if applicable. It is recommended that a label bearing the same information also be placed inside the infaunal samples. This label is written in pencil or indelible ink on a paper of a quality suitable for wet labels. The sample container must have an adequate closure and be sufficiently large to accommodate the sample material, fixative, and relaxant. If necessary, a sample may be split between two or more containers. However, each container must have appropriate labels (as described above) with the appropriate "split number" clearly marked. Splitting samples is to be avoided if possible. Field crews should have a broad range of sample container sizes available.

The material retained on the screen should be gently removed, taking care to avoid damaging the organisms. The sample container should be filled to approximately 40% of capacity with screened material. A container generally should never be filled with screen material above 50% of its capacity. After the bulk of material has been transferred to the container, the screen should be closely examined for any organisms caught in the mesh. Any organisms should be removed with forceps and added to the sample container. The screen box should be thoroughly washed and the mesh scrubbed with a stiff brush before the next sample is screened.

It is recommended that the infaunal sample be placed in a relaxant, such $MgSO_4$ (Epsom salts) or propylene phenoxytol, prior to fixation. If Epsom salts are used, 1 kg $MgSO_4$ per 20 L of seawater is added to the sample until the sample container is filled to 85 to 90% of its volume. The container is then closed and inverted several times to distribute the solution. The volume of relaxant used to fill the container should be noted as it will serve as diluent water for the fixative. The sample is then left in the relaxant for 30 min. After 30 min the container should be topped off with a quantity of sodium borate buffered formalin (which is 37% formaldehyde solution) solution adequate to achieve an approximately 10% formalin solution. Buffered formalin is made by mixing 50 g $Na_2B_4O_7$ (sodium borate) per liter of formalin. The container is then closed, inverted several times to assure mixing, and stored for return to the laboratory.

Propylene phenoxytol may be used as a relaxant in a solution of 30 ml to 20 L of seawater. The propylene phenoxytol solution can serve as diluent water for the fixative. In this case, after 30 min the container should be topped off with a quantity of sodium borate buffered formalin (which is 37% formaldehyde solution) solution adequate to achieve an approximately 10% formalin solution. Alternatively, after exposure of the sample material to the relaxant for 30 min, the solution may be decanted off the sample through a screen with a mesh size of 1.0 mm or less before adding fixative. Thus, 10% buffered formalin is added rather than undiluted formalin. Any organisms or debris captured on the screen during decanting must be returned to the sample.

Sediment Chemistry Samples
Sediment grain-size and chemistry (e.g., TOC, trace metals, trace organics) samples will be collected from the top 2 cm by randomly subsampling undisturbed surface material with a stainless steel, Teflon-coated, or plastic scoop. The scoop should be replaced if any signs of rust are visible. Sediment in contact with or within 1 cm of the metal sides of the grab should be avoided to reduce the chance of sample contamination. Care should be taken not to touch any surfaces of the Van Veen grab sampler with the scoop. At a minimum, the scoop will be washed with soap and water and rinsed with deionized (DI) water between stations. It may also be rinsed with methanol, followed by acetone, hexane, or methylene chloride between stations but these must be disposed of as Hazardous Materials. Use of a new scoop with each sample is also acceptable.

Samples should be placed in precleaned containers. Sediment grain-size and some sediment chemistry (e.g., TOC and trace metals) samples can be collected in glass or plastic containers but trace organics samples should be placed in glass containers. Sediment chemistry sample containers should have Teflon-lined lids (this is not a requirement for sediment grain-size samples). An air space should be left at the top of each sample. Sediment grain-size samples should not be frozen. They should be stored at approximately 4o C by placing them on wet ice or in a refrigerator until returned to the laboratory (within a week). Sediment chemistry samples may be stored at <4o C by placing them on wet ice or in a refrigerator but must be frozen at -20o C within 24 hr. If frozen, they should be returned to the laboratory within a week. If not frozen, they should be returned within 24 hr.

BENTHIC DATA
In addition to the general cruise and site information given in Section 2, information on penetration depth, characteristics of the sediment, and whether (and which) relaxant was used should be recorded for each sample.

QUALITY ASSURANCE
The quality of benthic sediment samples is dependent on following the field procedures described in this manual with special attention to the following:

- 1) Prior to each deployment the interior of the grab must be thoroughly washed to remove any sediment from the previous sample.
- 2) During retrieval, the grab should be recovered as quickly as is safely possible when it nears the surface. A grab suspended just below the surface is subject to washing as the boat rolls in the sea.
- 3) When washing and screening infaunal samples, gentle water pressure should be employed to avoid damaging the organisms.
- 4) The screen must be thoroughly washed and scrubbed between samples.
- 5) A relaxant is recommended for use on all infaunal samples to minimize fragmentation during fixation.
- 6) The infaunal sample container should be filled no more than 50% full of screening material. After adding relaxant and fixative solutions, the container is to be inverted several times to assure thorough mixing and exposure to relaxant and fixative.
- 7) The handling of infaunal samples on deck should be coordinated so as to ensure that fixative is added at the appropriate time interval (e.g., 30 min) to all samples after exposure to relaxant solution. A distinctive sticker may be affixed to the lid of the sample container to visually distinguish the sample as having had fixative added.
- 8) Take extra care in draining the overlying water from grabs intended for chemistry samples. This minimizes disturbance and loss of surficial sediments. Use of a siphon is highly recommended.
- 9) Field personnel must be thoroughly trained to recognize and avoid potential sources of contamination of chemistry samples (e.g. engine exhaust, winch wires, deck surfaces, ice used for cooling).
- 10) Grabs for sediment chemistry samples must be of similar sediment type and have similar penetration as the grab used for the infaunal sample. This is to ensure an adequate volume of surface sediments for subsampling, and that the chemistry samples come from sediments of similar character as the infaunal sample. Optionally, double Van Veen grabs can be used to simultaneously collect sediment samples from the same site for chemistry and benthic analyses.
- 11) Samplers and utensils that come in direct contact with the chemistry samples should be made of noncontaminating materials (e.g. plastic, glass, high quality stainless steel, and/or Teflon) and should be thoroughly cleaned between sampling stations.

- 12) Chemistry sample containers must be of the recommended type and must be free of contaminants (i.e. carefully precleaned)
- 13) Sample holding conditions and holding times specified for chemistry samples must be followed.

SECTION 5
TRAWL SAMPLING
PURPOSE

The purpose of trawl sampling is to obtain data on the abundance, biomass, diversity, and disease prevalence of demersal fish and invertebrate assemblages. It is also used to collect fish and invertebrates for tissue contaminant analysis. This information is useful in characterizing the extent and impact of the discharge from an outfall or other anthropogenic activity on demersal fish and invertebrate populations relative to natural conditions. Mearns and Allen (1978) provides a comprehensive description of how small otter trawls should be designed and used for conducting biological surveys in coastal waters.

COLLECTION PERMITS

The local office of the California Department of Fish and Game (CDFG) (San Diego, 619/237-7311; Los Angeles/Orange County area, 310/590-5132) must be contacted prior to collecting fish and invertebrates. The caller will be asked for his or her name; scientific collector's permit number; date, time, and area of sampling; type of gear to be used; vessel size, color, and CF number or documentation; number of persons in party; and what organisms will be collected. The permit must be on-board during sampling and must be presented to any CDFG warden or personnel who request to see it.

OTTER-TRAWL SPECIFICATIONS

A semiballoon otter trawl will be used to collect epibenthic invertebrates and demersal fish (Figure 4). Net dimensions are the following: 7.6-m head rope (25 ft); 8.8-m foot rope (29 ft); 3.8-cm (1.5 in) body mesh; and a 1.3-cm cod-end mesh (0.5 in). This net will have 22.9-m (75 ft.) long bridles made of 1.0-1.6 cm (3/8 to 5/8 in.) diameter rope (e.g., Samson braid). The otter boards (doors) will have a width of 76.2 cm (30 in.), height of 50.8 cm (20 in.), and a suggested weight of 15.9 kg (35 lb) (Figure 5). Slight deviations (< 10%) from these dimensions are acceptable. The door chains should be 5-mm (3/16 in.) in diameter and should have the following numbers of links: front top -- 12; front bottom -- 11; back top -- 17; back bottom -- 16 (Figure 5).

PRETRAWL SURVEY

Trawl gear is likely to be lost if the trawl is hung up on bottom obstructions and replacement of nets can be costly. The bottom along a trawl course at a previously unsampled station should be examined by fathometer. A pretrawl survey can enable the navigator to avoid uncharted reefs and other obstacles that may cause damage to trawl gear. This survey should always be done when on location at a new sampling site to determine if the station can be sampled. The fathometer survey should follow the expected trawl path and the fathometer reading will be examined for rocks and other obstacles.

Figure 4. Semiballoon otter trawl recommended for marine receiving-water monitoring programs in Southern California (modified from Mearns and Allen 1978).

Figure 5. View of an otter board of a semiballoon water trawl with recommended numbers of chain (5-mm or 3/16 in. diameter) links (modified from Mearns and Allen 1978).

TRAWL DATA LOG

The chief scientist is responsible for keeping a trawl data log. The information recorded in the log includes water depth, length of tow wire used, times and coordinates (latitude and longitude) for net on the bottom and end of trawl (beginning of trawl retrieval); coordinates for net over and net on deck may also be recorded. Any anomalous conditions such as rocky bottom, rocks in the catch, and torn net are also recorded in the log.

NET PREPARATION

The trawl should be prepared prior to trawling so that the net can be deployed in an orderly and safe manner upon arrival at a desired station. The net is laid out and stacked on the stern of the vessel in the same configuration that it will fish, with the cod-end to the stern, floats up, and foot rope on bottom. The trawl should be checked to make sure that the cod-end is tied, that the doors are connected properly to the leg lines, and that the bridles are connected to the doors and tow wire.

TRAWLING

Trawls will be towed along, rather than across, isobaths. While the vessel is underway, the captain will order that the net and doors be placed in the water. It is important that the floats skim the surface and that the net is not entangled (i.e., crossed leg lines, bunched or hooked portions of the net) prior to letting out (deploying) the bridles. This small step could mean the difference between a successful or unsuccessful trawl. The bridles should be paid out by a person(s) on each side of the net, being careful to stand on the outside of the bridle lines and avoiding entanglement in the rigging during deployment.

Use of the proper scope (i.e., length of wire deployed out versus the water depth) is very important for successful catches. After the net touches the bottom, a sufficient length of hydrowire (towing wire) should be deployed to ensure that the net is pulled from a horizontal rather than a vertical position. If the scope is insufficient, the net will tend to leave the bottom and inadequately sample fishes residing at the sediment-water interface. In general, the required scope declines with increasing depth because the additional weight of the hydrowire enhances the horizontal component of the towing forces. Although a general rule of thumb is a 4 to 1 ratio of wire length to water depth, the appropriate scope is a function of water depth and hydrowire size (Table 3). These scopes are for 0.6 cm (0.25 in), 0.8 cm (0.31 in), and 1.0 cm (0.38 in) hydrowire. Larger diameter wire and greater depths require less scope.

Once on the bottom, the net is towed for 10 min at a speed of 1.0 m/sec (3.3 ft/sec or 2.0 kn), a distance of about 600 m. Trawl speed and distance can be determined by differential GPS. As an alternative, trawl speed can be determined by dropping a chip into the water at the bow and determining the time that it takes to reach the stern. The length of the vessel divided by the time taken for the chip to traverse the length of the vessel is the speed.

Table 3. Recommended scope and length of wire for trawling at different depths on the mainland shelf of Southern California.

Water Depth (m)	Tow Wire Out(m)	Scope Ratio (Tow Wire:Depth)
30	180	6.0:1
60	300	5.0:1
100	400	4.0:1
150	550	3.6:1
175	625	3.5:1
200	700	3.5:1

At the end of 10 min, the net is retrieved and brought on board the vessel. The cod-end is opened and the catch is dumped into a tub or holding tank. The catch is subsequently released to the scientific crew for work-up.

CRITERIA FOR ACCEPTING A TRAWL

If the bottom appears trawlable, the net will be deployed. If the trawl is retrieved with little or no catch, its acceptability will be evaluated according to whether the trawl was conducted properly. A trawl is conducted properly if the proper depth, scope, speed, and distance or duration is maintained, if it is not fouled (net tangled), and if there is some evidence (e.g., rocks, benthic invertebrates, benthic fish) that the net was on the bottom. If any of the trawl procedures were not followed, if the net was fouled or torn (the tear must be sufficient to allow escapement), or if there was no evidence of contact with the bottom, the trawl will be considered unacceptable. If so, then another trawl will be conducted at that site, if feasible.

SAMPLE PROCESSING

Sorting

The trawl catch should be sorted on deck into containers. Initially the catch should be rough sorted into major categories (e.g., urchins, shrimp, other invertebrates, flatfish, rockfishes, other fishes). The categories used are not important but it is more efficient to sort into rough categories before identifying to species. Debris should also be noted.

Identification

All fish and most invertebrates will be identified to species, using taxonomic keys and field guides as needed. Species of fish and invertebrates that cannot be identified to species in the field will be returned to the laboratory for further identification. When these have been identified in the laboratory, the correct identity of the species will be recorded on the original data sheet. If the laboratory identity differs from that recorded in the field, the original name should be crossed out with a line. Do not erase the original name.

If unresolveable conflicts arise in the field over the identification of an organism, the organism will be returned to the laboratory for identification. Under no circumstances should an organism be discarded if the identity is questioned. Each organization must know its own limitations in identifying organisms.

Although an identification will be made on all fish (either in the field or in the laboratory), only invertebrates meeting specific criteria will be identified. There are likely to be many small infaunal and pelagic species that are incidental to the trawl catch. These will not be processed. Only organisms that are greater than 1 cm in any dimension will be identified. Colonial and pelagic organisms will be noted but not enumerated. Infaunal organisms will not be documented. The presence of obvious free-occurring fish parasites, such as leeches or cymothoid isopods, will be noted.

Pertinent field guides and taxonomic aids should be used for identifying fish and invertebrates. The most basic and comprehensive guides for fish are Miller and Lea (1972) and Eschmeyer et al. (1983). Allen (1977) provides information for identifying juvenile rockfishes (Sebastes spp.) There are no comprehensive guides to the invertebrates.

Either common or scientific names of fish may be used in the field. Only standard common and scientific names of fishes given in Robins et al. (1991) or a list of California fishes (Allen, in prep.) will be acceptable. Scientific names of invertebrates will be used in the field (SCAMIT 1994).

Each organization should have a kit containing a variety of tools which will aid in field identification. This kit should include forceps (small with sharp points and large with blunt points); a hand lens; dividers or calipers; dissecting needles; scalpel with scalpel blades; probe; and plastic ruler in millimeters.

Length Measurement

Fish length data provide information on recruitment, age, maturity, feeding guilds, and disease. All fish species will be measured on measuring boards or, for very large specimens, by a meter stick or tape measure. A measuring board typically consists of either a flat or trough shaped board with a part of a meter stick running down the middle. A smaller board is attached across the zero-end of the meter stick. Trough-shaped boards facilitate keeping groups of fish on the board during measurement. Centimeter size-classes are marked along the side of the measuring board with the number of the size class marked next to the appropriate centimeter.

During measurement, the anterior portion of the fish is pushed up against the crossboard at the zero-end of the measuring board. Maximum (board) standard length (i.e., anterior tip of head to base of caudal fin) will be measured on bony fishes and total length will be measured on cartilaginous fishes; wingspan will also be measured for stingrays because the tips of their tails are frequently broken off. Fish should be measured at a minimum to the nearest centimeter size class; however, measurements to the nearest millimeter are acceptable. It is recommended that the length of all fish specimens be reported in size classes of 1 cm intervals (Mearns and Allen 1978). The first centimeter size class (size class number 1) would extend from 0.1 to 1.0 cm, size class 2 would extend from 1.1 to 2.0 cm, and so forth.

All species will be listed on trawl fish and invertebrate species data sheets. For fish species with 10 or fewer individuals, each size measurement (e.g., size-class 8) will be recorded on the trawl fish species data sheet. The size-class number for each fish will be recorded in a line, separated by commas. For species with more than 10 individuals, the species is listed on the trawl fish species data sheet but the sizes are tallied on the size-class sheet.

An attempt should be made to size-class all fish. For the rare occasions when size classing is not possible (e.g., a huge catch of a single species), a subsample of several hundred fish should be measured and the reason for deviating from prescribed procedures should be documented. (Note: Catches of greater than 2,300 individuals of a single species have been measured in past surveys).

Lengths of invertebrate species will not be measured.

Weighing

Biomass data collected from fish and invertebrate species will be used to estimate total biomass of the catch and of each species. At a minimum each agency should have a range of spring scales that are capable of weighing to the nearest 0.1 kg o, and a tare bucket with holes through the bottom or another suitable container (e.g., net bag) on board. Spring scales should be calibrated on a daily basis using a standard set of at least three weights. Tare buckets should be washed periodically to remove slime.

Biomass of each species will be measured to the nearest 0.1 kg with a spring scale. The tare container will be weighed while empty and this weight will be subtracted from the weight of the gross weight (species plus tare container) to give the weight of the species (net weight). Tare and gross weight can be recorded on the data sheet but are not required. Small species weighing less than 0.1 kg will be set aside and weighed together to provide a composite weight. There will be one composite weight for fish and a separate composite weight for invertebrates. These weights are used in calculating the total biomass of the catch.

Large organisms may be weighed individually. Individual weights of smaller specimens may be collected optionally, using a range of scales capable of weighing to the nearest 0.1 g.

Enumeration

Fish are enumerated indirectly during the measurement of lengths. The total number of each species (including those size-classed) should be recorded on the fish species and size-class data sheets. Although the numbers of individuals will generally be determined by computer from length measurements, individuals are not measured occasionally; these should also contribute to the count. In addition, if a size-class sheet is lost, the numerical information may not be lost since the number of individuals was recorded on the species data sheet.

Most invertebrates will be enumerated following identification. However, the number of individuals in particularly abundant species may be estimated from the biomass of the species. First, the number of individuals that comprise a minimal weight (e.g., 1 kg or more) can be determined to provide a “number of individuals per kilogram” coefficient. Then the remaining individuals collectively will be weighed and the number of individuals will be determined by dividing the total biomass by the number of individuals per kilogram. This procedure will prevent the inherent inaccuracy of the spring scale at the low end from being multiplied throughout the entire biomass calculation.

Examination for Gross Pathology

During the identification and measurement procedures, fish and invertebrates will be examined for gross pathology. This entails a scan of the individual organism for anomalies and noting the type of pathology (by abbreviation) next to the length of the organisms during measurement (for fish). The following anomalies will be noted for fish:

- 1) fin (and tail) erosion;
- 2) tumors;
- 3) external parasites (e.g., copepods, isopods, leeches);
- 4) color anomalies (ambicoloration, albinism) (Mearns and Haaker 1973);
- 5) skeletal anomalies (Valentine 1975);
- 6) lesions; and
- 7) other anomalies.

Burnspots and other anomalies will be noted for invertebrates.

Fin erosion can be found on the dorsal, anal, and caudal fins of flatfishes, and on the lower caudal fin and pelvic fins of bilaterally symmetrical fishes. Tail erosion occurs on the top and bottom of the caudal fins of bilaterally symmetrical fishes. Tumors can be smooth and rounded (angioepithelial nodules) or furrowed (epidermal papillomas). Externally obvious copepod parasites occur on the eye, fins, or body of fish. Cymothoid isopods occur in the gill cavities of fish or on the body; they often fall off. Leeches occur on the body of some flatfishes. Skeletal deformities include crooked backs, snub noses, or bent fin rays. Lesions include sores that do not appear to be due to net damage. Burnspot disease is found on crabs and some shrimps; its lesions resemble cigarette burns. Fish and invertebrates with new diseases should be vouchered.

Processing Stage Monitoring

During the processing of a trawl catch, there are often several persons involved in different stages of processing. When this occurs, mistakes are sometimes made and species are sometimes not measured or weighed. This can be avoided by attaching a colored rubber tag (made of a square with a slit in one side) to the handle of each bucket to indicate the stage of processing. For instance, different tags can indicate that the contents of the bucket are ready for identification, measurement, weighing, preservation, or discarding. As the bucket progresses to the next stage, the current tag can be pulled off and a new tag can be added. This procedure is not necessary for small catches but is recommended when catches are large. Tags with commonly caught species names can also be temporarily attached to buckets to facilitate sorting and processing.

Safe Handling of Organisms

Field personnel can be harmed by several trawl-caught organisms if these organisms are not carefully. California scorpionfish (*Scorpaena guttata*) has venomous fin spines which can cause a very severe pain affecting much of the body. This species should be handled with leather gloves or pliers. Hot water, meat tenderizer, or ammonia should be applied to any puncture wound resulting from a spine; heat helps to break down the protein in the venom. Several other species of rockfishes and the spotted ratfish (*Hydrolagus colliei*) also have mildly venomous spines which can cause a burning sensation. Round sting ray (*Urolophus halleri*), California butterfly ray (*Gymnura marmorata*), and bat ray (*Myliobatis californica*) have a venomous stinger on the tail.

Pacific electric ray (*Torpedo californica*) can emit a strong electric shock. When handling this species, hold it by the tail. Do not grasp the disk with both hands!
Pacific angel shark (*Squatina californica*), spiny dogfish (*Squalus acanthias*), spotted ratfish, Pacific electric ray, and California halibut (*Paralichthys californicus*) can give painful bites.
Care must also be taken in handling blueleg mantis shrimp (*Hemisquilla ensigera californiensis*). This species can give a severe cut with its raptorial appendages. Care should also be taken in handling crabs.

Preservation of Samples
Incompletely identified fish and invertebrate specimens and those with diseases that require further examination should be returned to the laboratory. Fish and invertebrate specimens may be preserved or documented for QC or identification purposes in one of three ways:

- 1) fixing in buffered formalin-seawater;
- 2) freezing; or
- 3) photographing.

The preferred method for most smaller specimens is fixing in 10% buffered formalin-seawater. Buffered formalin is made by mixing 50 g $Na_2B_4O_7$ (sodium borate) per liter of formalin or 5 g per liter of 10% formalin. All specimens with tumors, fin erosions, or lesions should be fixed in this manner. Before fixing, the body cavity of fish (greater than 60 mm) should be slit with a scalpel on the right (for most bilaterally symmetrical fish), blind (for flatfish), or ventral (for dorsoventrally flattened fish, such as rays) side. Note that by convention, bilaterally symmetrical fish are photographed or drawn with their heads facing left and, hence, dissections are conducted only on the right side of the fish. The slit allows preservative to enter the body cavity and preserve the internal organs. Fish and invertebrates can be placed in either plastic bags or plastic jars and fixed in 10% buffered formalin-seawater. Fish should be inserted tail-first into jars so that they can be removed easily without destroying the fin rays or spines.

Fish should remain in the formalin solution for up to a week before being rinsed in freshwater. It is recommended that fish specimens be placed in fresh water for at least two days, changing the water at least once during that period. After rinsing in water, the fish should be transferred to 50% isopropanol (isopropyl alcohol) or 70% ethanol for preservation. Trawl-caught invertebrates will also be fixed in 10% buffered formalin-seawater and preserved in 70% ethanol.

Larger specimens can be placed in plastic bags and frozen on dry ice or placed in a freezer if sufficiently large containers are not available or if large quantities of fixative are required. These can then be thawed and fixed in the laboratory with 10% buffered-formalin solution. However, large specimens with tumors, fin erosion, or lesions should be fixed in the field with formalin rather than frozen.

Small invertebrates (e.g., nudibranchs) may be kept cold in seawater and returned alive to the lab for identification.
Large specimens (and colorful species) of fish and invertebrates can be photographed with color film in the field. For larger specimens, the photographs will document the species of organism. Photographs of unidentified rockfishes should be taken in the field as their color (which is an

important taxonomic character) fades during preservation. When photographing fish, bilaterally symmetrical species should be photographed facing left (unless an anomaly occurs on the right side). Flatfishes should be photographed on the eyed side, facing left (for left-eyed species) and right (for right-eyed species). The gill cover should cut the lower profile of the body. The blind side can also be photographed if important characteristics or anomalies occur there. Dorsoventrally flattened fishes, such as skates and rays, should be photographed from the top, with the fish facing left. The ventral side should also be photographed if important. All specimens should be photographed on a light background with a meter stick along side and a label giving date, station number, and species in large bold letters. Photographs should show the overall appearance of the specimen, plus important identifying features if possible. Note should be made of character states that are crucial for identification purposes (e.g., counts of fin rays, gill rakers, and scales).

Specimens preserved for further identification should be noted on the field data sheet. A note should be made whether the organism is fixed, frozen, or photographed. A log of all organisms photographed should be kept during the survey, recording the frame number, date, location, station, and subject of each photograph.

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Trawling Procedures

Demersal fish and invertebrate assemblage data (species identification, enumeration, biomass, and length) are significantly influenced by the collection methods. Therefore strict adherence to prescribed sampling protocols is critical. Fish catches are influenced by gear type and deployment, tow duration, and towing speed. All organizations collecting samples in the field must use standard nets and follow standard trawling procedures to ensure that comparable samples are collected. A combination of towing speed and duration along with an estimate of the width of the net mouth during the tow is the only way to estimate the area of bottom sampled. A record of the towing speed and duration must be kept.

Data Collection on Species

Fish species identification, enumeration, biomass, and individual lengths must be determined in the field following protocols presented in this manual. Field personnel will also be expected to have appropriate identification aids. All species that are difficult to identify in the field should be returned to the laboratory for identification. It is very important that the final identity of any specimens returned to the laboratory for identification be noted on the original data. Each agency will have access to each others voucher collection and to the SCCWRP voucher collection to aid in making and confirming species identifications.

During each survey day, two fish species with an abundance of at least 10 fish that have been size-classed will be recounted and reweighed. A record of the counts and weights of these quality control checks along with the original values will be maintained. If errors were made, the correct values will be reported in the data.

SECTION 6

PROTOCOL FOR MANUAL MODIFICATION

This manual describes current minimum standard protocols for CTD, grab, and trawl monitoring programs of the four major POTWs that discharge into the Southern California Bight. It is based on discussions and agreement by representatives of CLAEMD, CSDLAC, CSDOC, CSDMWWD, and SCCWRP on the SCBPP Field Coordination Team. While the Field Coordination Team felt that the protocol and methods described herein are the most acceptable to all groups at present (i.e., 1995), it recognized that better methods or improvements in protocol may be developed in the future. Hence, the Field Coordination Team proposed a means by which this manual could be reviewed and revised in the future to keep abreast of improved sampling methodologies.

The Field Coordination Team proposed that a Marine Monitoring Methods Committee (MMMC) be formed which would regularly review the manual and incorporate revisions as appropriate. This committee will consist initially of representatives of the five major agencies that participate in field monitoring (CLAEMD, CSDLAC, CSDOC, CSDMWWD, and SCCWRP) and representatives of the regulatory agencies (EPA, CSWRCB, CRWQCBLAR. CRWQCBSAR, CRWQCBSDR). Meetings of this committee will be open to all interested parties but only representatives of the five major agencies will have a vote. This will clarify the opinion of the agency representatives.

The MMMC will meet regularly twice a year. More frequent meetings will be arranged as issues before the committee demanded. Suggested modifications to the manual will be submitted to the committee chairman or introduced at an MMMC meeting. The ideas must be proposed in writing with appropriate support documentation, so that they can be distributed to all MMMC members. The proposal should address safety and fiscal concerns and how the proposed change would be more effective than the existing procedure. Each agency can then study or test the new procedure or method and then report on their conclusions to the MMMC. Alternatively, the MMMC may propose that a single study or test be conducted involving all or specific members. Any such studies should describe the value of the new method relative to the existing method and determine correction factors. This would make data collected with the new methods comparable to those collected by the old methods. The MMMC will not produce an updated manual more than once a year.

SECTION 7 LITERATURE CITED

Allen, M. J. 1977. Southern California trawl-caught juvenile rockfishes (Preliminary). S. Calif. Coastal Water Res. Proj., El Segundo, CA. Proc. Taxonomic Standardization Program 5 (4): 25-32.

Eschmeyer, W. N., E. S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast fishes of North America. Houghton Mifflin Co., Boston, MA. 336 p.

Mearns, A. J., and M. J. Allen. 1978. Use of small otter trawls in coastal biological surveys. U. S. Environ. Prot. Agcy., Environ. Res. Lab., Corvallis, OR. EPA-600/3-78-083. 33 p.

Mearns, A. J., and P. L. Haaker. 1973. Identifying and coding color anomalies in flatfishes. S. Calif. Coastal Water Res. Proj., El Segundo, CA. TM 200. 6 p.

Miller, D. J., and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dep. Fish Game, Fish. Bull. 157. 249 (addendum in 1976).

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. Common and scientific names of fishes from the United States and Canada. 5th edition. Am. Fish. Soc., Spec. Publ. 20. 183 p.

SCAMIT. See Southern California Association of Marine Invertebrate Taxonomists.

SCBPP,FCT. See Southern California Bight Pilot Project, Field Coordination Team.

Southern California Association of Marine Invertebrate Taxonomists. 1994. A taxonomic listing of soft bottom macroinvertebrates from infaunal monitoring programs in the Southern California Bight. S. Calif. Assoc. Mar. Invert. Tax., San Pedro, CA. 71 p.

Southern California Bight Pilot Project, Field Coordination Team. 1994. Southern California Bight Pilot Project field operations manual. So. Calif. Coastal Water Res. Proj., Westminster, CA. 183 p.

Stubbs, H. H., D. W. Diehl, and G. P. Hershelman. 1987. A Van Veen grab sampling method. S. Calif. Coastal Water Res. Proj., Long Beach, CA. Tech. Rep. 276. 4 p.

Tetra Tech. 1986. Quality Assurance and Quality Control for 301(h) Monitoring Programs: Guidance on field and laboratory methods. Final report prepared for U. S. Environ. Prot. Agency, MOD/OMEP. Contract No. 68-01-6938.

Valentine, D. W. 1975. Skeletal anomalies in marine teleosts. Pages 695-718 in W. E. Ribelin and G. Migaki (eds.), The pathology of fishes. Univ. Wis. Press, Madison, WI.

APPENDIX 1

Pertinent telephone and FAX numbers for major receiving-water monitoring programs of Southern California in 1995.

Agency Contacts	Agency	Phone Number	FAX
Allen, Jim, Dr.	**SCCWRP**	714/894-2222 x 220	714/894-9699
Cross, Jeff, Dr.	**SCCWRP**	714/894-2222 x 203	714/894-9699
Dalkey, Ann	**CLAEMD**	310/648-5611	310/648-5397
Fleming, Terry	**USEPA, Reg. IX**	415/744-1939	415/744-1078
Gossett, Rich	**CSDOC**	714/962-2411 x 3708	714/962-2591

Meistrell, Joe	**CSDLAC**	310/699-7411 x 2808	310/692-5103
Montagne, Dave	**CSDLAC**	310/830-2400 x 402	310/834-9013
Phillips, Tony	**CLAEMD**	310/648-5197	310/648-5397
Robertson, George	**CSDOC**	714/962-2411 x 3559	714/962-2591
Rothans, Tim	**CSDMWWD**	619/692-4914	619/692-4902
Santangelo, Richard	**CSDOC**	714/962-2411 x 3718	714/962-2591
Stubbs, Harold	**SCCWRP**	714/894-2222 x 212	714/894-9699
Velarde, Ron	**CSDMWWD**	619/692-4903	619/692-4902

Other Persons/Agencies	Phone Number
AT&T Marine Operator	1-800/SEA-CALL
Dana Point Marine Operator	714/675-0503
San Pedro Marine Operator	Local operator
Redondo Beach Marine Operator	310/325-1133
CDFG, Long Beach	310/590-5132
CDFG, San Diego	619/237-7311
Marine Weather	310/477-1463
Newport Weather	714/675-0503
U. S. Coast Guard, Long Beach	310/499-5555

CLAEMD = City of Los Angles, Environmental Monitoring Division; CSDLAC = County Sanitation Districts of Los Angeles County; CSDOC = County Sanitation Districts of Orange County; CSDMWWD = City of San Diego, Metropolitan Wastewater Department; SCCWRP = Southern California Coastal Water Research Project; USEPA = United States Environmental Protection Agency; Reg. = region; CDFG = California Department of Fish and Game.

APPENDIX 2.

Phone numbers, call signs, and identification numbers of marine research vessels used in receiving-water monitoring programs of Southern California in 1995.

Telephone Document Vessel Name Agency Type Number Call Sign or CF No. R/V La Mer CLAEMD Dock 310/823-4987 WAM 7628 956836 M/V Marine Surveyor CLAEMD Dock 310/823-4987 WO 5232 293521 R/V Ocean Sentinel CSDLAC Cell. 310/613-5434 WAA 9057 CF-2539-XC Dock 310/832-5623 R/V Phaon CSDLAC Dock 310/832-5623 WTA 5037 CF-2475-XC R/V Enchanter IV Enchanter, Inc. Cell. 714/299-0630 WTJ 9619 515881 R/V Crusader MEC Cell. 619/980-5318 WAR 4805 CF-298474 R/V Meter Maid MEC Cell. 619/994-0115 WUS 3434 CF-8361-KH R/V Monitor III CSDMWWD Cell. 619/988-8642 WUV

9304 CF-2220-XC R/V Metro CSDMWWD Cell. 619/855-9851 WUV 9304 CF-2129-XF R/V Westwind MBC Cell. 714/321-8204 WYZ 9810 517102

CLAEMD = City of Los Angles, Environmental Monitoring Division; CSDLAC = County Sanitation Districts of Los Angeles County; CSDOC = County Sanitation Districts of Orange County; CSDMWWD = City of San Diego, Metropolitan Wastewater Department; SCCWRP = Southern California Coastal Water Research Project; MEC = MEC Analytical Systems, Inc.; MBC = MBC Applied Environmental Sciences. Cell. = cellular

Figure 1. Example of conductivity-temperature-depth profiler (CTD) used in marine receiving-water monitoring programs in Southern California (modified from unpublished figure, Sea-Bird Electronics, Inc.).

Figure 2. Modified Van Veen grab sampler recommended for marine receiving-water monitoring programs in Southern California: a) cocked position; b) tripped position (modified from Stubbs et al. 1987).

Figure 3. Examples of acceptable and unacceptable grab sample condition (modified from Tetra Tech 1986).

Figure 4. Semiballoon otter trawl recommended for marine receiving-water monitoring programs in Southern California (modified from Mearns and Allen 1978).

Figure 5. View of an otter board of a semiballoon water trawl with recommended numbers of chain (5-mm or 3/16 in. diameter) links (modified from Mearns and Allen 1978).

(12 Links) (11 Links) (16 Links) (17 Links)

Draft Recommendation for Field Manual

The Field Coordination Team proposed that a Marine Monitoring Methods Committee (MMMC) be formed which would regularly **APPENDIX 3.**
PROTOCOL SPECIFIC TO SEA-BIRD CONDUCTIVITY-TEMPERATURE-DEPTH (CTD) PROFILERS

PURPOSE
Water-column profiles are collected at discrete sampling sites to characterize depth-related gradients in temperature, salinity, hydrogen ion content (pH), transmissivity, and dissolved oxygen (DO). For example, water-column profiles can describe whether stratification (layering) is present and, if so, the depth of the thermocline or pycnocline. Variation in these parameters at the same depth among stations may indicate anthropogenic or natural perturbations of the environment. For instance, low salinity values at some stations may indicate the presence of an effluent plume whereas high pH and dissolved oxygen, and low transmissivity may indicate a phytoplankton bloom.

EQUIPMENT
A conductivity-temperature-depth profiler (CTD) with additional sensors will be used to provide a continuous water-column profile of temperature, salinity, DO, pH, and transmissivity with depth (Figure 1). Currently (as of August 1995), Sea-Bird SBE 9 or SBE 25 units are used by the four major POTWs; units must meet the program performance specifications for temperature, salinity, DO, pH, transmissivity, and pressure (Table 1). If an SBE 9 unit is used, it should interface with either an SBE 17 RAM unit or an SBE 11 deck unit. The following sensors are currently being used: temperature, SBE 3; conductivity, SBE 4; pH, SBE 18; DO, SBE 13; transmissivity, Sea-Tech 25 cm path-length; and pressure (for depth), Sensor-Metrics strain-gauge interfacing pressure sensor or Paroscientific Digiquartz pressure sensor model #2300A-110. The interfacing software should be Seasoft version 3.5 D or greater. As of February, 1995, the current Seasoft version is 4.208.

TRAINING
Any individual who will be maintaining, calibrating, or operating the CTD should be trained in each of these operations. Prior to performing these operations unsupervised, an individual should demonstrate proficiency in that operation to a senior, CTD experienced staff member. Proficiency should be evaluated on the basis of successfully completing the operation following written procedures and demonstrating an understanding of the equipment. Additionally, the individual should be evaluated on his/her ability to troubleshoot common problems. All training and demonstration of proficiency should be documented. An agency using and deploying a CTD should be an active participant in the Southern California CTD Users Group.

Figure 1. Example of conductivity-temperature-depth profiler (CTD) used in marine receiving-water monitoring programs in Southern California (modified from unpublished figure, Sea-Bird Electronics, Inc.).

Table 1. Required instrument manufacturer and program specifications for conductivity-temperature-depth profilers (CTD) to be used in receiving-water monitoring programs of the major publicly owned treatment works of Southern California.

Parameter	Units Manufacturer*	Program* *	
Dissolved Oxygen (DO)	mg/L	± 0.14	± 0.30
Salinity	ppt	± 0.001	± 0.009
Transmissivity	%	± 0.50	± 0.50
Temperature	°C	± 0.01	± 0.03
Hydrogen Ion Content (pH)	pH units	± 0.1	± 0.1
Pressure	decibars	± 1.3	± 1.3

* Sea-Bird Electronics, Inc., SBE 9 CTD and sensors (temperature, SBE 3; hydrogen ion content (pH), SBE 18; dissolved oxygen (DO), SBE 13; conductivity (for salinity), SBE 4; and pressure (for depth), Sensor-Metrics strain-gauge interfacing pressure sensor or Paroscientific Digiquartz pressure sensor model #2300A-110.

** Program specifications are 95% confidence intervals derived from Southern California Bight Pilot Project intercomparison results of June 9, 1994.

CTD INTERCOMPARISON EXERCISE

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

CTD PRECRUISE CHECKOUT AND CALIBRATION

Precruise Equipment Checkout

A precruise equipment checkout will be conducted less than or equal to 24 hr prior to starting the cruise and prior to calibration. This inspection should 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 and waterproof and lubricated with silicone;
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) cleansing 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 will be conducted less than or equal to 24 hr prior to starting the cruise for pH, DO, transmissivity, and pressure. There is no lab calibration for conductivity and temperature. Verification that the proper sensor coefficients are in the configuration file should be made before proceeding. A CTD calibration data sheet will be 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 ($> \pm 1°C$) thermal change during calibration.

Hydrogen Ion Content (pH).

The pH sensor may 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 should 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 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 should 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 should be rerun and the procedure repeated. Corrected values should be added to the CTD's software. When complete, the pH electrode should be 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 should be between 15 and 40 ml/sec. The CTD will be calibrated according to Sea-Bird Application Note 13-1, Revision B (April 1993) (Appendix 4). 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 should match to within 0.1 ml/L (0.143 mg/L). Sensor performance is monitored and the membrane or sensor module should 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 should 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 should be modified to reflect any changes that are made during the calibrations The transmissometer should be calibrated according to procedures in the Sea Tech transmissometer manual and Sea-Bird Electronics Application Note No. 7 (Appendix 4). 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 should be sent in for servicing.

Pressure Offset. This determination should 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 should 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 should be changed until pressure is within range.

NOTE: If the offset value exceeds ±1.5, the sensor should 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.

Factory Calibration and Maintenance

Maintenance and calibration of the CTD should be documented, including dates of most recent servicing. Preventative maintenance should be conducted on the CTD unit periodically but not to exceed manufacturer's recommendations (i.e., 3 yr). All "O" rings, attached sensors, and seals should be checked at this time and the unit should be 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.

The temperature and conductivity sensor should be sent to the manufacturer, Sea-Bird Electronics, every 6-12 mo for calibration. Calibration should be conducted by the National Oceanic and Atmospheric Administration/National Regional Calibration Center (NOAA/NRCC) lab and certified and inspected by the manufacturer. Certification should be provided when the sensor is returned.

Postcruise Calibration

The Chief Scientist is responsible for deciding whether postcruise calibrations are within acceptable limits. The time between last cast and the completion of the postcalibration should be not more than 24 hr.

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. The water temperature should be recorded, as well as the pH and voltage output for each buffer. Agreement should occur between each sensor value and the known buffer value, and should be within 0.15 pH units. If agreement is out of this range, the unit should be recalibrated and the stations resampled if feasible.

Dissolved Oxygen (DO).

Postcalibration of the DO sensor should follow the same procedures as those for precalibration. However, the DO concentration should be evaluated 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 should be reviewed for consistency. If these data are deemed unreliable, the survey should be done again as soon as possible (if feasible). If stations cannot be resampled, data should be flagged or qualified in the data base. Following calibration, the oxygen sensor should be cleaned and stored following manufacturer procedures given in Sea-Bird Application Note 13-1, Revision B (April 1993) (Appendix 4).

Transmissivity 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.

CTD DEPLOYMENT
The CTD should 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. The SBE 9 and SBE 25 units measure data at 24 or 8 scans (data)/sec, respectively. The user should designate the average rate that the data should be recorded to memory or the computer. For example, SBE 9 set at 24 scans/sec and averaged at 24 scans/bin means one data line in memory per second. In the configuration file, the scan rate should be set at 24 scans/sec for SBE 9 or 8 scans/sec for SBE 25. If possible, all data will be averaged to no more than 24 scans/bin (i.e. number of scans to average per data line -- NAVG = 24 for SBE 9 and NAVG = 8 for SBE 25). However, if there is a risk of obtaining less than one datum per meter, this average and/or the deployment descent rate should be decreased.

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 should be monitored with a meter wheel and timer. Descent rates should always be slower than 1 m/sec to minimize spiking of sensor output.

The objective of water-column profiling is to collect water-column data for every meter. Therefore, to avoid omissions in data from a given meter of depth, it is recommended that an NAVG of less than 24 and a descent rate less than 1 m/sec be used. Optimal NAVG value and descent rate are dependent upon sea surface conditions during deployment and should be evaluated and adjusted accordingly. Additionally, during data processing, a cast whose average descent rate is found to exceed 1 m/sec should be considered for omission.

Use of an onboard water bath is recommended to prevent excessive heating of the sensors while on the ship's deck. If an onboard water bath is not used, a wet towel should 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.

Before beginning a cast, the CTD sensors are brought to thermal equilibration with the ambient sea-water. If applicable, the pump should be activated and bubbles should be purged from any tubing. This is best accomplished by lowering the CTD a few meters and (if capable) monitoring salinity and DO values to ensure their stabilization. (However, it should be noted that deployment with the SBE 17 RAM unit precludes monitoring salinity and DO values). In either case, a 3-min equilibration upon initial power-up at the first station and 90 sec at each station thereafter is the minimum soak time for thermal equilibration and sensor stabilization. After sensor stabilization and at least the 3 min or 90 sec, the CTD is raised so the top of the unit is at the water surface and profiling is begun.

CTD CAST ACCEPTABILITY

The goal of monitoring surveys is to collect water-column profiles at all stations. During field sampling, cast acceptability should be 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 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.

Table 2. Reasonable ranges of measurements from waters of the mainland shelf of Southern California.

Parameter	Typical Range
Dissolved Oxygen (DO)	3 - 12 mg/L
Salinity	32 - 34 ppt
Transmissivity	20 - 90 %
Temperature	8 - 24 °C
Hydrogen Ion Content (pH)	7.5 -8.3 pH units

If anomalous values are present, the cause should be investigated and remedied before proceeding. If damage to the CTD (due to striking the bottom or some other event) is suspected, review that cast 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 should 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 should 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.) should be noted in the field logbook. If feasible, a station should be resurveyed when an unacceptable profile is obtained.

CTD QUALITY ASSURANCE/QUALITY CONTROL

No field quality control (QC) of any of the parameters is required beyond the cast acceptability check described above or the range checks (Table 2). Dissolved oxygen, pH, pressure offset, and transmissivity performance are carefully monitored and calibrated prior to and immediately following a survey. This evaluation is deemed sufficient to assure the quality of the performance. Conductivity and temperature are evaluated and calibrated on a strict factory maintenance schedule and traceable to NOAA/NRC standards. Their performance and integrity from calibration to calibration are reliable to such a level that field QC is deemed unnecessary. The typical ranges (Table 2) are guidelines only and any value outside of them should be evaluated relative to the entire cast and the entire day's survey; legitimate values may exist outside of these ranges but the vast majority of values will fall within these ranges.

All data will be checked to be certain all data and configuration files are present and properly named. All data files should contain proper and complete header information. This check should be verified and documented by field personnel. All data will be reviewed graphically and statistically for single point outliers (spikes) as well as trends.

CTD DATA
If data are to be submitted to another agency, data will be output using a mutually agreed upon format. The following header information, parameters, units, and format is an example of output:

- 1) agency
- 2) station
- 3) date
- 4) depth (m)
- 5) temperature, IPTS-68 (o C)
- 6) conductivity (Siemens/m)
- 7) oxygen (mg/L)
- 8) light transmission (%)
- 9) salinity, PSS-78 (PSU)
- 10) pH
- 11) density (st), (kg/m3)

Hard copies of all sensor and equipment factory maintenance, pre- and postcruise calibration sheets, and CTD field data sheets should be maintained and made available upon request. Additionally, raw CTD files should be archived. These should include all data files, configuration files, header files, and any mark files created. review the manual and incorporate revisions as appropriate. This committee would consist initially of representatives of the five major agencies that participate in field monitoring (CLAEMD, CSDLAC, CSDOC, CSDMWWD, and SCCWRP) and representatives of the regulatory agencies (EPA, CSWRCB, CRWQCBLAR. CRWQCBSAR, CRWQCBSDR). Meetings of this committee would be open to all interested parties but only representatives of the five major agencies would have a vote. This was proposed so as to clarify the opinion of the agency representatives.

While the MMMC will focus initially on standardizing methods used in the major monitoring programs of the major POTWs, it may in the near future address standardization of methods of other receiving water monitoring programs of the major dischargers that are not covered in this manual (e.g., dive surveys, tissue sample collection, microbiology surveys, etc.). In addition, it may also address the standardization of monitoring programs used by the minor POTWs, power generating stations, and industrial dischargers. Outfalls of these dischargers generally occur in shallow water, which may necessitate modifying the manual to allow for a wider range of sampling conditions. Before addressing these monitoring programs, representatives of the agencies likely to be affected by the changes (particularly where the change in the program will increase costs) will be added to the MMMC as voting members.

APPENDIX 4.
SEA-BIRD CONDUCTIVITY-TEMPERATURE-DEPTH (CTD) PROFILER APPLICATION NOTES

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

GENERAL DESCRIPTION
Sea-Bird Electronics uses either a Beckman sensor element or a modified YSI 5739 oxygen proba 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, Soc, 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 a 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.

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]
doc/dt slope of oxygen current [microamps/sec]

Calibration Coefficients: 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)

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 should 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 should 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 should be applied to it. Before power is applied it should 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) should be recorded. To obtain oxygen readings that are within +/- 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.

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 Na2SO3 (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.

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 should be used for the calibration along with the plenum that was provided with the oxygen sensor. If another pump is used it should be a submersible type and configured to pump at a rate of 20 to 30 ml/s. In this case a plenum should 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 should 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 should 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 should 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.

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) sir 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 should be used for the calibration along with the plenum that was provided with the oxygen sensor. If another pump is used it should be a submersible type and configured to pump at a rate of 20 to 30 ml/s. In this case a plenum should 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.

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

OXFIT CALCULATION

OXFIT calculates Soc and Boc as follows:

Soc = nsa(T,bp)/[exp(tcor*)*(oc-zoc)]

Boc = -Soc*zoc.

oc = air saturated water current (microamps)

zoc = zero air water current (microamps)

See Appendix A for the definition of nsc(T,bp).

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[ml/l] =
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.
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 Appendix B 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.

VERIFICATION OF SOC AND BOC
OXFIT and OXFITW calculate and display the new Soc and Boc coefficients. These should 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 should 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 should 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 should 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 should 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.

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.

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 loose 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.

APPENDIX A CORRECTION FACTOR FOR NON-STANDARD ATMOSPHERE
nsa(T,bp) = (bp/pO) * (1 - pH2O/bp)) / (1 - pH2O/pO)

bp = barometric pressure in kilopascals
pO = 101.325 kilopascals
ph20 = water vapor pressure in kilopascals
T = water temperature in °C
pH20 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)] / nsa(T,bp)} * exp(tcor*T) = 1
Soc = nsa(T,bp) / [exp(tcor*T) * (oc-zoc)]
Boc = -Soc * zoc

APPENDIX B COMPUTATION OS OXSAT
OXSAT(T,s) = exp(A1 + A2*(100/T) + A3*In(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

APPENDIX C COMPILATION OF OXYGEN SATURATION VALUES
The following table contains oxygen saturation values at atmospheric pressure calculated using the OXSAT equation found in Appendix B. Units of oxygen are ml/l. To compute units of mg/l multiply the values in the table by 1.4276.

Salinity (PSU)
Temp °C 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 5376 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 5328 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

REFERENCES

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.

Gnaigner, E., and H. Forstner (eds.). 1983. Polarographic Oxygen Sensors: Aquatic and Physiological Applications. Springer-Veriag, 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 COEFFICIENTSFOR THE SEA-TECH TRANSMISSOMETER
SEA-BIRD ELECTRONICS, INC.
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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 transmissiometer 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 Y!

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.

FIGURES

Figure 1
Conductivity-temperature-depth profiler (CTD) recommended for marine recieving-water

monitoring programs in Southern California (modified from unpublished figure, Sea-Bird Electronics, Inc.)

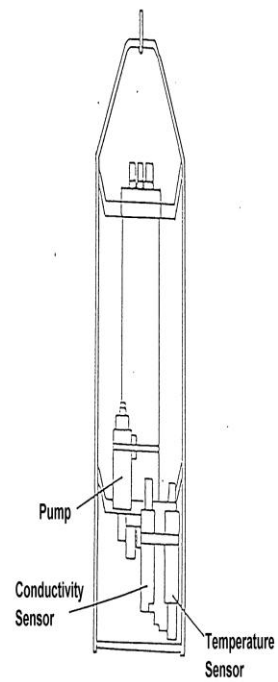


Figure 2
Modified Van Veen grab sampler recommended for marine recieiving-water monitoring programs in Southern California: a) cocked position; b) tripped position (modified from Stubbs et al. 1987)

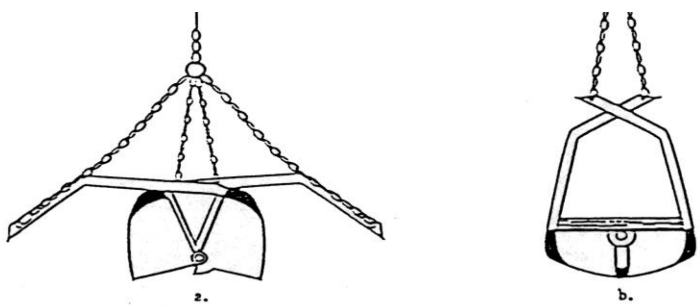


Figure 3
Examples of acceptable and unacceptable grab sample condition (modified from Tetra Tech 1986)

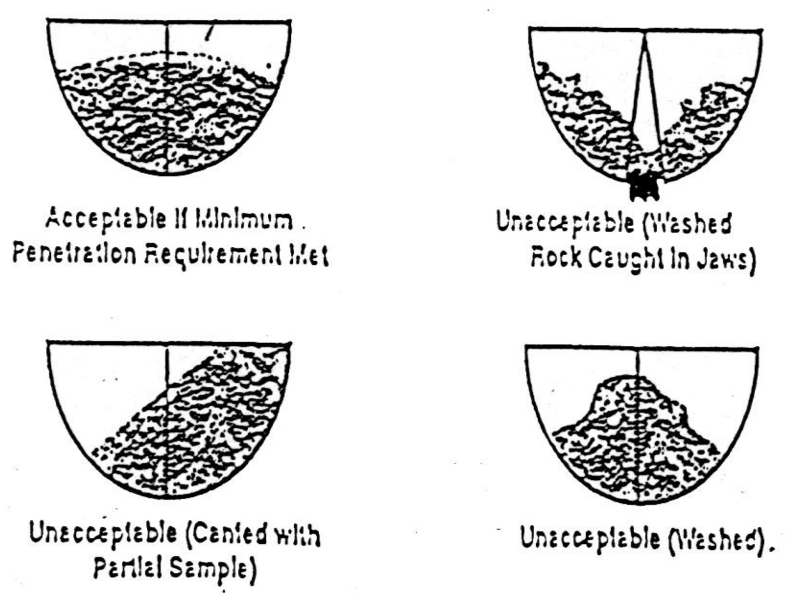


Figure 4
Semiballoon otter trawl recommended for marine recieiving-water monitoring programs in Southern California (modified from (Mearns and Allen 1978)

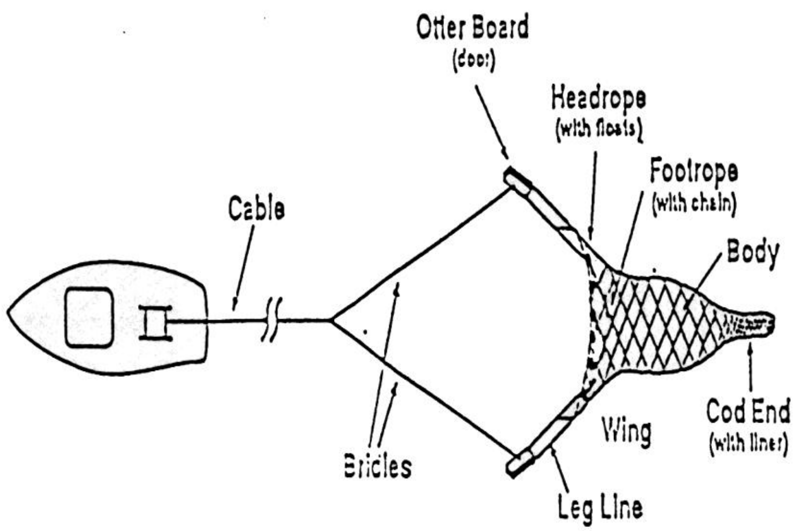
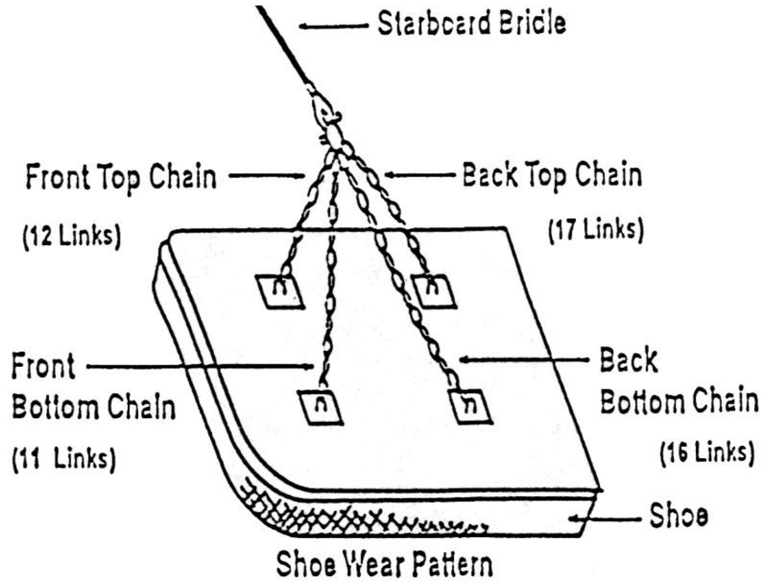


Figure 5
View of an otter board of a semiballoon otter trawl with recommeded numbers of chain (5-mm or 3/16 in. diameter) links (modified from Mearns and Allen 1978)


Starboard Bridle
Front Top Chain
(12 Links)
Back Top Chain
(17 Links)
Front
Bottom Chain
(11 Links)
Back
Bottom Chain
(16 Links)
Shoe
Shoe Wear Pattern