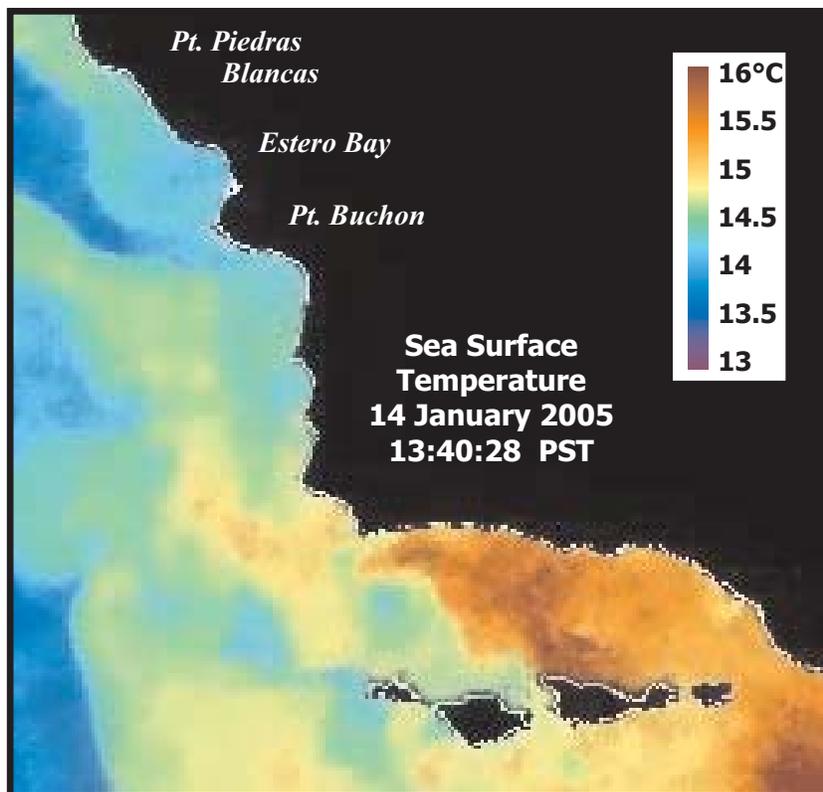


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING JANUARY 2005 SURVEY



Marine Research Specialists

**3140 Telegraph Rd., Suite A
Ventura, California 93003**

Report to

**City of Morro Bay and
Cayucos Sanitary District**

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**OFFSHORE MONITORING
AND
REPORTING PROGRAM**

QUARTERLY REPORT

**WATER-COLUMN SAMPLING
JANUARY 2005**

Prepared by

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February 2005

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Mr. Bruce Keogh
Wastewater Division Manager
City of Morro Bay
955 Shasta Avenue
Morro Bay, CA 93442

26 February 2005

Reference: Quarterly Receiving-Water Report – January 2005

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on 14 January 2005. This first-quarter survey assessed the effectiveness of effluent dispersion during winter oceanographic conditions. Based on quantitative analyses of continuous instrumental measurements and qualitative visual observations, the wastewater discharge was found to be in compliance with the receiving-water limitations specified in the NPDES discharge permit and with the objectives of the California Ocean Plan.

Lateral perturbations in all of the water-property fields clearly delineated the effluent signature near the boundary of the zone of initial dilution that surrounds the diffuser structure. Measured dilution levels within the plume exceeded those anticipated by modeling and outfall design criteria. Other lateral perturbations in water properties were also observed at near-surface locations outside of the zone of initial dilution. However, these perturbations were generated by naturally occurring pools of turbid rainwater, rather than the presence of wastewater constituents. All of the measurements were indicative of low contaminant concentrations within the discharged wastewater, and of an outfall operating as designed.

Please contact the undersigned if you have any questions regarding this report.

Sincerely,

Douglas A. Coats, Ph.D.
Project Manager

Enclosure (Seven Copies)

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Mr. Bruce Ambo
City of Morro Bay

Date _____

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INTRODUCTION

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. A National Pollutant Discharge Elimination System (NPDES) permit, modifying secondary treatment requirements, was issued to the City of Morro Bay and the Cayucos Sanitary District in December 1998 (Permit No. CA0047881). The permit was issued by Region 9 of the Environmental Protection Agency (EPA) and the Central-Coast California Regional Water Quality Control Board (RWQCB-EPA, 1998a). The previous permit expired in early 1998. An administrative extension was granted through 11 December 1998 to allow time for review and issuance of a new discharge permit (RWQCB, 1998).

As part of the new permit provisions, the previous monitoring program was modified to better evaluate short- and long-term effects of the discharge on receiving waters, benthic sediments, and infaunal communities (RWQCB-EPA, 1998b). The program continued to include a requirement for receiving-water-quality monitoring performed on a seasonal basis. Four quarterly surveys were intended to record ambient water properties that approximate winter, spring, summer, and fall conditions. In keeping with seasonal synopses, this quarterly report summarizes the methods and results of water-quality sampling conducted on 14 January 2005. This first-quarter survey was conducted in January to capture ambient oceanographic conditions along the central California coast during winter.

This water-quality survey also provides a timely assessment of the performance of the diffuser structure in dispersing wastewater within stratified receiving waters. Any significant, recent damage to the diffuser structure would be revealed by a decline in the level of wastewater dispersion measured in this survey compared to that of prior surveys, and compared to design specifications. As described in this report, no such decline was observed.

Both monitoring objectives were achieved through an evaluation of the water-column profiles and vertical sections of water-property distributions that are presented in Appendix A. Appendix B tabulates instrumental measurements and standard field observations. These data were used to assess compliance with the objectives of the California Ocean Plan (COP) as specified in the NPDES discharge permit.

The January-2005 field survey was the twenty-fifth receiving-water survey to be conducted under the monitoring provisions of the current permit. Compared to the previous permit, the number of stations increased from 11 to 16, and the stations were relocated closer (≤ 100 m) to the diffuser structure. Sampling at these more closely spaced stations could only be achieved because of the availability of increased navigational accuracy that resulted from implementation of the differential global positioning satellite (DGPS) system. This system was commissioned during the March 1998 survey (MRS, 1998a) and was subsequently employed in the precise determination of the open section of the diffuser structure during a diver survey on 29 September 1998 (MRS, 1998bc).

The new sampling design also allowed surveying to be conducted more rapidly than before by eliminating the requirement for the time-consuming collection of discrete water samples using Niskin bottles. Continuous deployment of the CTD¹ instrument package between stations now provides a more synoptic snapshot of the water properties immediately surrounding the diffuser structure. Consequently, the extent

¹ Conductivity, Temperature, and Depth (CTD) were the original measurements collected by this standard oceanographic instrument package but the moniker now connotes an electronic instrument package with a broad suite of probes and sensors capable of *in situ* measurement of dissolved oxygen, transmissivity, and pH.

of the effluent plume and the amplitude of its associated water-property anomalies can be more precisely determined. The highly sensitive sensors in the CTD instrument package are capable of detecting minute changes in water properties. These sensors are described in the Methods section below.

Surveys conducted prior to 1999 rarely detected the effluent plume because sampling stations were too widely separated to resolve the dilute wastewater signature that is highly localized around the outfall diffuser. With the implementation of the new sampling design in 1999, the presence of well-mixed effluent near the diffuser structure was found in all 25 of the subsequent water-quality surveys (MRS, 2000, 2001, 2002, 2003, 2004, 2005), including the one described in this report. Moreover, improved navigation in concert with the denser sampling pattern more precisely delineated the location of the discharge-related perturbations in seawater properties.

Precision navigation is important for assessing compliance because most receiving-water limitations apply only beyond the narrow zone of initial dilution that surrounds the outfall. Finally, the amplitudes of the effluent-related perturbations are better determined by the denser sampling pattern. The amplitude of the discharge-related salinity anomalies reveals the dilution experienced by the effluent plume. Dilution factors lend insight into the operational performance of the outfall and diffuser structure. As described in this report, the presence of dilute effluent undergoing turbulent mixing close to the diffuser structure was clearly delineated by the data collected during the January-2005 survey.

STATION LOCATIONS

The water-sampling stations surround the area where effluent is discharged within Estero Bay (Figure 1). The 1,450-m long outfall pipe, which carries the effluent from the onshore treatment plant, terminates at the diffuser structure, which lies on the seafloor approximately 880 m from the shoreline. The diffuser structure itself extends an additional 52 m toward the northwest from the outfall terminus.

Twenty-eight of the 34 available ports discharge effluent along a 42-m section of the diffuser structure. The remaining six diffuser ports remain closed to improve dispersion by increasing the ejection velocity from the remaining ports. For a given flow rate, the diffuser ports were hydraulically designed to create the ejection jet, which serves to rapidly mix effluent with receiving seawater immediately upon discharge. Additional turbulent mixing occurs as the buoyant plume of dilute effluent rises through the water column. Most of this buoyancy-induced mixing occurs within a zone of initial dilution (ZID), whose lateral extent is approximately 15 m from the centerline of the diffuser structure.

Beyond the ZID, the energetic waves, tides, and coastal currents within Estero Bay further disperse the discharge plume within the open-ocean receiving waters. Areas of special concern, such as sanctuaries and estuaries, are too distant to be affected by the effluent discharge. The southern boundary of the Monterey Bay National Marine Sanctuary is located 38 km to the north, near Cambria Rock. Although the entrance to the Morro Bay National Estuary lies only 2.8 km to the south of the discharge, direct seawater exchange between the discharge point and the Bay is restricted by the southerly orientation of the mouth of the Bay, and by the presence of Morro Rock. Morro Rock is the largest physiographic feature of the adjacent coastline and extends into Estero Bay approximately 2 km south of the point of discharge (Figure 1). Its presence blocks the direct incursion of unmixed wastewater into the Bay.



Figure 1. Regional Setting of Receiving-Water Sampling Stations within Estero Bay

Near the diffuser, prevailing currents generally follow bathymetric contours, which parallel the north-south trend of the adjacent coastline. Because of rapid initial mixing achieved within 15 m of the diffuser structure, impingement of unmixed effluent onto the adjacent coastline 880 m away is highly unlikely. Nevertheless, water samples are regularly collected along the shoreline at the surfzone sampling stations shown in Figure 1.

These surfzone samples are analyzed for total and fecal coliform levels. Results of these analyses are reported in monthly operational summaries and in annual reports. The isolated instances of elevated beach coliform levels that are occasionally observed result from onshore non-point sources rather than the discharge of disinfected wastewater from the MBCSD outfall (MRS, 2000, 2001, 2002, 2003, 2004, 2005).

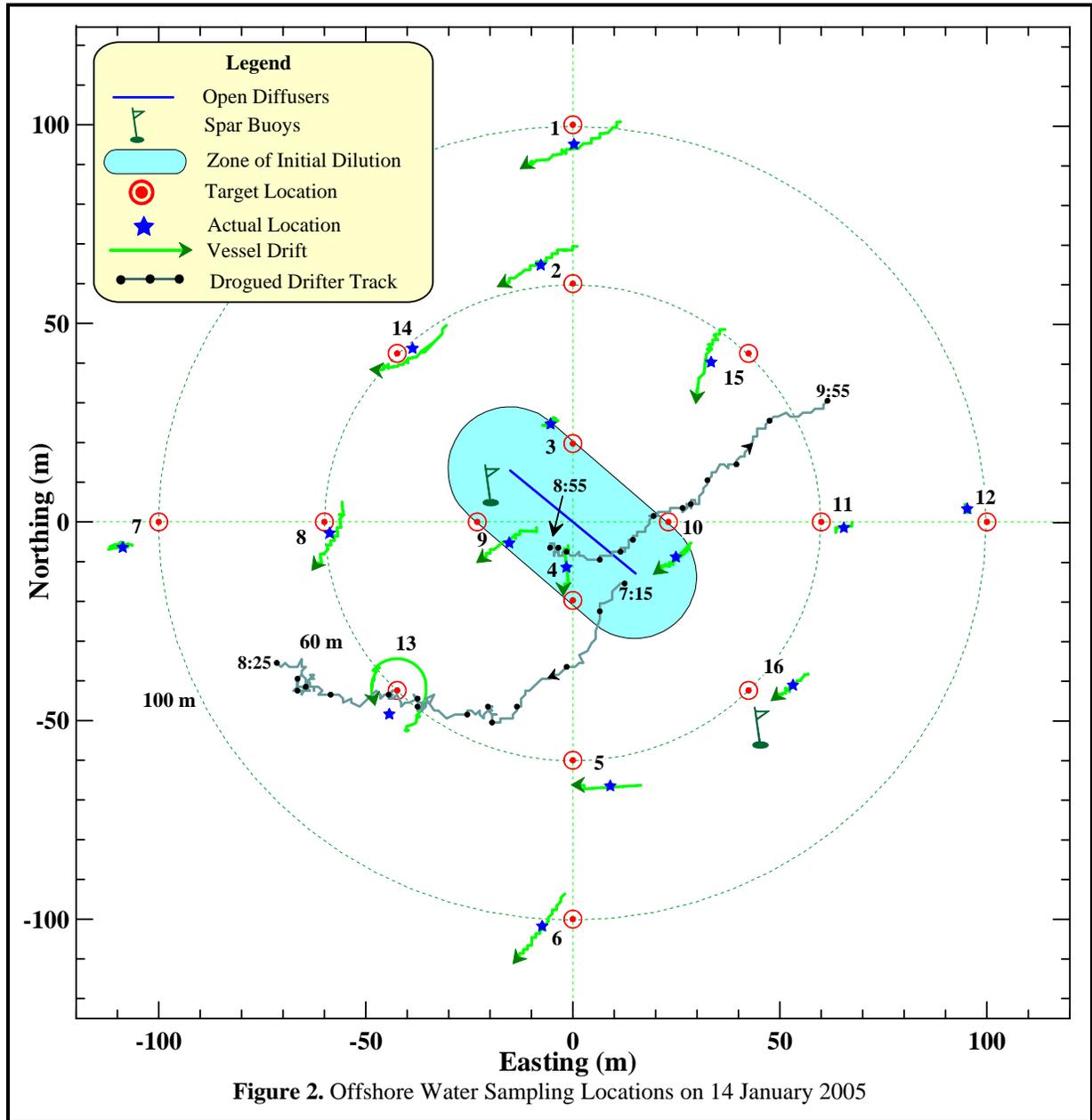
As shown in Figure 2, the water-sampling design consists of 16 fixed offshore stations located within 100 m of the outfall diffuser structure. The target locations of the 16 offshore sampling stations are indicated by the red ⊙ symbols in the Figure. Stations are situated at three distances relative to the center of the diffuser structure to capture any discharge-related trends in water properties. Six of the stations lie along a north-south axis at the same water depth (15.2 m) as the diffuser centroid. Stations 3 and 4 are positioned at the upcoast and downcoast boundaries of the ZID, at a distance of 15 m from the closest diffuser ports (Table 1). Stations 2 and 5 are located at nearfield distances (60 m) from the diffuser centroid. Stations 1 and 6 represent reference stations and are situated 100 meters upcoast and downcoast of the centroid. Depending on the direction of the local oceanic currents at the time of sampling, one or more of these near and midfield stations could conceivably be influenced by the discharge. Under those circumstances, the midfield station on the opposite side of the diffuser can act as a reference station. Comparisons of water properties at these antipodal stations quantify departures from ambient seawater properties so that compliance with the NPDES discharge permit can be evaluated.

Table 1. Description of Receiving-Water Monitoring Stations

Station	Description	Latitude	Longitude	Closest Approach Distance ¹ (m)	Center Distance ² (m)
1	Upcoast Midfield	35° 23.253' N	120° 52.504' W	88.4	100
2	Upcoast Nearfield	35° 23.231' N	120° 52.504' W	49.4	60
3	Upcoast ZID	35° 23.210' N	120° 52.504' W	15.0	20
4	Downcoast ZID	35° 23.188' N	120° 52.504' W	15.0	20
5	Downcoast Nearfield	35° 23.167' N	120° 52.504' W	49.4	60
6	Downcoast Midfield	35° 23.145' N	120° 52.504' W	88.4	100
7	Offshore Midfield	35° 23.199' N	120° 52.570' W	85.8	100
8	Offshore Nearfield	35° 23.199' N	120° 52.544' W	46.7	60
9	Offshore ZID	35° 23.199' N	120° 52.519' W	15.0	23
10	Onshore ZID	35° 23.199' N	120° 52.489' W	15.0	23
11	Onshore Nearfield	35° 23.199' N	120° 52.464' W	46.7	60
12	Onshore Midfield	35° 23.199' N	120° 52.438' W	85.8	100
13	Southwest Nearfield	35° 23.176' N	120° 52.532' W	59.8	60
14	Northwest Nearfield	35° 23.222' N	120° 52.532' W	40.2	60
15	Northeast Nearfield	35° 23.222' N	120° 52.476' W	59.8	60
16	Southeast Nearfield	35° 23.176' N	120° 52.476' W	40.2	60

¹Distance to the closest open diffuser port.

²Distance to the center of open diffuser section.



Six other stations (7 through 12) were aligned along a cross-shore transect in a pattern matching that of the along-shore transect. The four additional nearfield stations (13 through 16) measure the nearfield influence of effluent transported by ocean currents flowing at oblique angles to the bathymetry.

Although the discharge is considered a ‘point source,’ it does not occur at a point of infinitesimal size. Instead, the discharge is distributed along a 42-m section of the seafloor. This finite size must be considered when assessing wastewater dispersion close to the discharge. Because of the finite length of the discharge, the amount of wastewater dispersion at a given point in the water column is dictated by its distance to the closest diffuser port, rather than its distance to the center of the diffuser structure. Because

of the finite size of the source, this ‘*closest approach*’ distance is considerably less than the centerline distance (Table 1).

Station positioning within the compact sampling pattern became feasible only after the advent of DGPS. The accuracy of traditional navigation systems such as LORAN or standard GPS is typically ± 15 m, a span approaching the width of the ZID itself. Prior to 2 May 2000, standard commercial GPS receivers were not allowed to be perfectly accurate by law; and a built-in-error system called Selective Availability (SA) was encoded into GPS transmissions. SA could introduce a misreading of up to 100 meters, although it altered most measurements by less than 30 meters. After May 2000, SA was turned off and the accuracy of standard GPS receivers improved substantially, with horizontal position errors of typically less than 10 m.

Nevertheless, extreme atmospheric conditions and physiographic obstructions can cause signals to bounce around, leading to errors in position beyond those that were previously introduced by SA. These other errors are greatly reduced with the Differential GPS (DGPS) system that was first implemented by the U.S. Coast Guard. DGPS incorporates a second signal from a nearby land-based beacon. Because the beacon is fixed at a known location, the position error in the reading from the GPS satellites can be precisely calculated at any given time. This correction is continuously transmitted to the DGPS receiver onboard the survey vessel and results in extremely stable and accurate offshore navigation, typically with position errors of less than 4 m.

At the beginning of 1998, the survey vessel F/V *Bonnie Marietta* was fitted with a Furuno™ GPS 30 and FBX2 differential beacon receiver. This navigational system was used on 29 July 1998 to precisely locate the position of the open section of the diffuser structure (MRS, 1998b) and establish the new target locations for the receiving-water monitoring stations shown in Figure 2 and listed in Table 1.

In addition, DGPS allows precise determination of sampling locations during individual water-quality surveys. Knowledge of the precise location of the actual sampling sites relative to the diffuser position is crucial for accurate interpretation of the water-property fields. During any given survey, the actual sampling locations do not coincide with the exact target coordinates listed in Table 1. Winds, waves, and currents induce offsets during sampling. Using DGPS, these offsets can be resolved and the vessel location can be precisely tracked during sampling at each station. This is an important consideration because vertical profiling conducted at an individual station can cover a large horizontal distance relative to the ZID. The magnitude of this horizontal drift is apparent in Figure 2 from the length of the green tracklines. These tracklines trace the horizontal location of the CTD instrument package as it was lowered to the seafloor at each station.

These tracklines show that the assessment of compliance with discharge limitations is particularly complex at Stations 3, 9 and 10. Station 10’s green trackline in Figure 2 shows that the CTD instrument package was initially outside of the ZID boundary when it was first deployed at the sea surface. Receiving-water limitations specified in the COP apply to measurements collected at this location because the rapid initial turbulent mixing associated with the effluent discharge is expected to be complete beyond the boundary of the ZID. However, as the CTD package was lowered, the southward drift carried it into the ZID, where it reached the seafloor close to the diffuser structure. At this location, measurements reflect conditions immediately after discharge, where turbulent mixing has just begun and where receiving water limitations do not apply. The hydrocasts at Stations 3 and 9 began within the ZID boundary, and the CTD package drifted into the region where receiving-water limitations apply as it approached the seafloor. All of the hydrocast at Station 4 was within the ZID boundary.

Notwithstanding their inapplicability for compliance assessments, measurements collected close to the diffuser structure within the ZID lend valuable insight into the outfall's effectiveness at dispersing wastewater at the time of this particular survey. Damaged or broken diffuser ports would be reflected by low dilution rates and measurements of concentrated effluent throughout ZID. Without measurements collected within the ZID, the discharge plume would probably go undetected. This was the case in nearly every water-quality survey conducted prior to 1999, before the denser sampling pattern was instituted by the monitoring program specified in the current NPDES discharge permit.

Surveys prior to 1999 also predated the advent of DGPS, and the 13-m average drift experienced during sampling at each station would not have been resolved with the navigation available at the time. In fact, before 1999, sampling was presumed to occur at a single, imprecisely determined, horizontal location at each station. For consistency, a single reportable sampling location was also determined for each station during the January-2005 survey. These were based on the average location as shown by the blue stars in Figure 2. Average positions are also listed in Table 2, along with their distance from the diffuser structure. However, based on the foregoing discussion, the distance between the average station position and the ZID does not determine whether all the measurements at that station are subject to the receiving-water objectives in the COP. For example, 15.4-m closest-approach distance specified for Station 3 would suggest that all of the data was collected outside the ZID. In reality, as shown by the green tracklines in Figure 2, the near-surface measurements were collected well within the ZID where water-quality limitations do not apply. Conversely, the 13.9-m distance reported for Station 9, does not accurately reflect the fact that sampling traversed nearly half of the ZID and terminated at the seafloor well beyond the boundary of the ZID.

Table 2. Average Coordinates of Vertical Profiles in January 2005

Station	Time (PST)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ¹ (m)	Bearing ² (°T)
1	8:04:31	8:05:57	35° 23.251' N	120° 52.504' W	83.7	11
2	7:59:58	8:01:25	35° 23.234' N	120° 52.509' W	52.4	8
3	7:54:31	7:55:37	35° 23.212' N	120° 52.508' W	15.4 ³	39
4	7:48:12	7:49:18	35° 23.193' N	120° 52.505' W	9.6 ⁴	221
5	7:42:13	7:43:17	35° 23.163' N	120° 52.498' W	53.7	187
6	7:36:16	7:37:43	35° 23.144' N	120° 52.509' W	91.5	194
7	9:15:21	9:16:38	35° 23.196' N	120° 52.576' W	95.5	258
8	9:20:43	9:21:54	35° 23.198' N	120° 52.543' W	46.3	250
9	9:26:31	9:28:04	35° 23.196' N	120° 52.514' W	13.9 ³	221
10	9:32:54	9:34:16	35° 23.194' N	120° 52.488' W	10.6 ³	66
11	9:38:29	9:39:36	35° 23.198' N	120° 52.461' W	51.6	77
12	9:42:22	9:43:38	35° 23.201' N	120° 52.441' W	81.8	78
13	9:51:06	9:52:38	35° 23.173' N	120° 52.533' W	65.5	221
14	8:19:03	8:20:28	35° 23.223' N	120° 52.530' W	38.9	323
15	8:13:06	8:14:24	35° 23.221' N	120° 52.482' W	52.4	41
16	9:46:56	9:48:02	35° 23.177' N	120° 52.469' W	47.2	126

¹ Distance from the closest open diffuser port with observations collected within the ZID shown in bold

² Direction measured clockwise in degrees from true north from the closest diffuser port to the actual sampling location

³ Portions of the CTD (Conductivity-Temperature-Depth) cast were within the ZID boundary

⁴ All of the CTD cast was within the ZID boundary

The vessel drift indicated by the green tracklines in Figure 2 was largely dictated by the winds and to a lesser extent, currents, at the time of sampling. As summarized in Table B-7, the prevailing wind was from the northeast during the survey. This largely accounts for the southwestward drift shown by the green tracklines for most stations in Figure 2.

Current flow reversed direction during the January-2005 survey. This is apparent from the tracks of the drogued drifter that was deployed on two separate occasions during the survey. The dark lines with black dots shown in Figure 2 trace the paths of the drifter that was released near the diffuser structure at 07:15 PST and 8:55 PST. The satellite-tracked drifter is designed to drift with the current, with little influence from the wind. Each dot along the drifter trackline represents a time span of five minutes. During the first deployment, the drifter was recovered at 08:25 PST at a location 86 m west-southwest of the diffuser. During the second deployment, just a half-hour after recovery from the first deployment, the drifter traveled in the opposite direction, toward the east-northeast, and was recovered at 09:56 PST, 76 m from its drop-off location. During each deployment, the drifter traveled at a speed of 2.1 cm/s, or 0.4 kt, but in opposite directions. As shown in Table B-7, there was no obvious change in the wind direction that coincided with the reversal in flow.

Astronomical tides were also not responsible for the current reversals. Figure 3 shows that during the period of current reversal, there was no tidal reversal. Instead, an incoming tide prevailed throughout the survey. Normally, a flood tide induces a weak northeastward flow in the survey region.

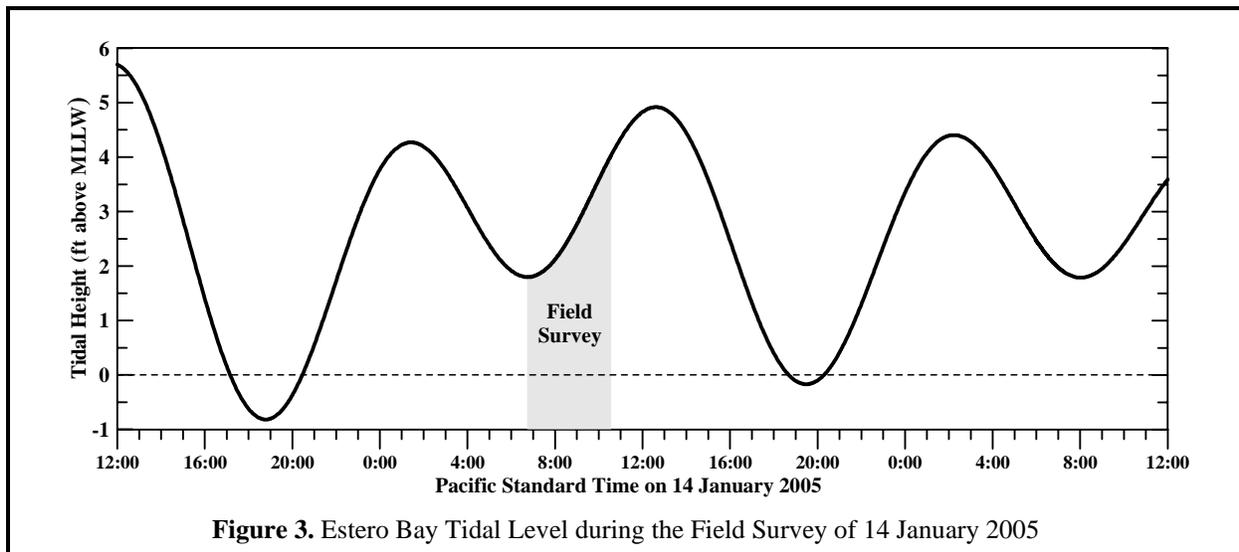


Figure 3. Estero Bay Tidal Level during the Field Survey of 14 January 2005

The low wind speed that was experienced during the January-2005 survey reflects a quiescent period between a series of strong winter storms that prevailed along the coast before and after the survey. The survey was delayed because of high waves that were generated during the first half of January by the southward shift in the winter storm track. Record rainfalls led to significant runoff of turbid freshwater into coastal waters. Pools of freshwater floating on the sea surface led to the patchy character of sea-surface temperature along the Central California Coast that is shown in the satellite image on the cover of this report. The image was collected on the day of the survey and was measured by infrared sensors on NOAA's polar orbiting satellite. During surveys conducted in other seasons, surface temperatures near the

coastline are much lower than offshore temperatures because of upwelling. Upwelling was not a dominant physical process during the January-2005 survey. Instead, winter oceanographic conditions are generally characterized by a vertically uniform water column that has been well mixed by intense winds generated by passing local storm fronts and by large waves produced in distant Pacific storms.

METHODS

The 38-ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 14 January 2005. Dr. Douglas Coats and Mr. Carlos Penalzoa of Marine Research Specialists (MRS) provided scientific support. Captain Mark Tognazzini supervised vessel operations, while Mr. Marc Tognazzini acted as marine technician. Secchi depth measurements and standard observations for weather, seas, water clarity/coloration, and the presence of any odors, floating debris, and oil and grease were recorded during the survey. Wind speeds and air temperatures were measured with a Kestrel[®] 2000 Thermo-Anemometer. These ancillary observations were collected during the rapid water-column profiling that was conducted at each station using a CTD instrument package.

Ancillary Measurements

At all stations, a Secchi disk was lowered through the water column to determine its depth of disappearance (Table B-7). Secchi depths provide a visual measure of near-surface turbidity or water clarity. The depth of disappearance is inversely proportional to the average amount of organic and inorganic suspended material along a line of sight in the upper water column. As such, the Secchi depth measures natural light penetration, which can be limited by increased suspended particulate loads from onshore runoff, seafloor resuspension, and wastewater discharge. It is also of biological significance because the depth of the euphotic zone, where most oceanic photosynthesis occurs, extends to approximately twice the Secchi depth. The comparatively deep euphotic zone observed during the January-2005 survey, which reached to a depth of approximately 10 m, is fairly typical of mild upwelling conditions, in which moderate levels of primary productivity decrease light transmissivity within the upper water column.

Secchi depths are less precise than measurements collected by the transmissometer mounted on the CTD instrument package. For example, the visibility of the disk, and hence its depth of disappearance, depends on the amount of natural light available at the time of the measurement. Thus, the Secchi depth reading can artificially change by as much as 0.5 m depending on whether the sample is taken on the sunny or shady side of the boat. Moreover, a temporal drift in the measurements can be introduced as the sun rises in the sky while the survey progresses. Nevertheless, Secchi depth measurements reflect turbidity levels within the upper portion of the water column, including waters within a meter of the sea surface where, because of the physical size of the CTD package, the transmissometer cannot record turbidity.

At two times during the survey, a satellite-tracked drifter was deployed near the center of the open section of the diffuser structure. The drifter was drogued at mid-depth (7 m) using the curtain-shade design of Davis *et al* (1982). In this configuration, the drifter's trajectory was largely dictated by the oceanic flow field rather than by surface winds. The time and precise position of the drifter deployment and recovery were recorded. The January-2005 survey was the second MBCSD survey to continuously record the drifter position throughout its deployment. In the past, the average ambient flow velocity during each survey was estimated solely from the deployment and recovery positions. However, during the January-2005 survey, the added satellite-tracking capability of the drifter revealed complex current reversals that

are apparent in the drifter trajectories shown in Figure 2. Drifter data collected in prior surveys lack information on short-term flow fluctuations that can occur within the duration of a survey.

Instrumental Measurements

Vertical water-column profiling was conducted using an electronic instrument package equipped with a number of probes and sensors. A Sea Bird Electronics SBE-19 Seacat CTD package was used to collect profiles of conductivity, salinity, temperature, light transmittance, dissolved oxygen (DO), pH, density, and pressure at each station. A submersible pump on the CTD continuously flushed water through the conductivity cell and oxygen plenum at a constant rate, independent of the CTD's motion through the water column. After the October-2001 survey, the CTD was returned to the factory for full testing, repair, and calibration. Temporal drifts in the oxygen and alkalinity readings during the October-2001 survey indicated that the sensitivity of these probes had degraded because of an accumulation of marine growth. During the factory repair, the pH probe was replaced and the electrolyte in the oxygen sensor was refurbished. The entire CTD system was then recalibrated at the factory. Upon return of the instrument, the transmissivity, dissolved oxygen, and pH sensors were recalibrated at the MRS laboratory. Calibration coefficients determined at the factory and by MRS were nearly identical, and confirmed the accuracy and stability of the refurbished sensors.

The DO and pH sensors were again returned to the factory in May 2003 for testing and recalibration. Because of increasing temporal drift associated with the aging DO probe, it was replaced with a new DO probe. As is the case before all surveys, the CTD system was recalibrated at the MRS laboratory prior to the January-2005 survey. Calibration at upper-bound DO concentrations was established by immersing the CTD in an aerated, temperature-controlled calibration tank. In addition to oxygen readings at full saturation, a zero-oxygen calibration point was determined by filling the oxygen-sensor plenum with an 8% solution of sodium sulfite (Na_2SO_3). Oxygen calibration coefficients were determined by regression analysis of sensor-membrane current and temperature, as recommended by the manufacturer (SBE, 1993). As with prior factory calibrations, pre-cruise calibration coefficients determined by MRS closely corresponded to those determined by the factory.

The prolonged equilibration time of the pH sensor has been an ongoing challenge that has required removal of temporal trends in the pH data collected in most surveys, even those following the pH-sensor replacement. Laboratory tests conducted in conjunction with pre-cruise calibrations have demonstrated that the equilibration time is reduced if the sensor is immersed in water prior to deployment. This was accomplished during the January-2005 survey by attaching a water-filled hose to the sensor during transit to the survey area. Immediately prior to deployment, the hose was removed. Although this procedure did not entirely eliminate the temporal offsets, it reduced their amplitude enough so that the required pH adjustments were small.

During the pre-cruise calibration, coefficients for the pH (alkalinity) sensor were determined from a linear regression of output voltage after immersion in three separate buffered solutions of known pH. Buffering solutions with a pH of 4 ± 0.01 , 7 ± 0.01 , and 10 ± 0.02 were used to bracket the range of *in situ* measurements. The SeaTech transmissometer was air calibrated by fitting the voltages recorded with and without blocking of the light transmission path in air, as recommended by the manufacturer (SBE, 1989). Revised calibration coefficients determined prior to the survey were used in the algorithms that convert sensor voltage to engineering units when the field data were processed. Comparison with the factory calibration of the entire CTD package that was conducted in December 2001 confirmed the continued accuracy and stability of the temperature, pressure, and conductivity sensors, as well as the operational integrity of the oxygen and pH probes.

Six seawater properties were used to assess receiving-water quality in this report. They were derived from the continuously recorded output from the probes and sensors on the CTD. Depth limitations on the combination oxygen/pH sensor confine the CTD to depths less than 200 m (Table 3), which is well beyond the maximum depth of the deepest station in the outfall survey. The precision and accuracy of the various probes, as reported in manufacturer's specifications, are also listed in the Table. Salinity (‰) was calculated from conductivity (Siemens/m) measurements. Density was derived from contemporaneous temperature (°C) and salinity data. It was expressed as 1000 times the specific gravity minus one, which is a unit of sigma-T (σ_t).

All three of these physical parameters (salinity, temperature, and density) were used to determine the lateral extent of the effluent plume. Additionally, they define the layering (vertical stratification) of the receiving waters, which determines the behavior and dynamics of the wastewater as it mixes with seawater within the ZID. Data on three remaining seawater properties, consisting of light transmittance (water clarity), hydrogen-ion concentration (acidity/alkalinity – pH), and dissolved oxygen (DO), further characterize receiving waters, and were used to assess compliance with water-quality criteria. Light transmittance was measured as a percentage of the transmitted beam of light detected at the opposite end of a 0.25-m path. Increased transmittance indicates increased water clarity and decreased turbidity.

Before deployment at the initial station, the CTD was held below the sea surface for a six-minute equilibration period. Subsequently, the CTD was raised to within 1.0 m of the sea surface and profiling commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at multiple stations were collected during each deployment by towing the CTD package below the water surface while transiting between adjacent stations. Upon retrieval of the CTD, the profile data were downloaded to a portable computer.

Temporal Trends in the pH Sensor

The pH sensor exhibited a slight temporal drift during the January-2005 survey. Perceptible drift in pH measurements has been consistently observed in prior water-quality surveys as a result of ongoing sensor equilibration during profiling. Prolonged exposure to the atmosphere between surveys results in the largest offsets and can also affect the dynamic range of the measurements. Smaller equilibration offsets have been observed when the CTD is redeployed after being brought onboard to download data. Previous attempts to mitigate sensor drift have included prolonging the soak time of the CTD after deployment below the sea surface prior to profiling. Soak times in excess of 6 minutes at the beginning of a survey

Table 3. Instrumental Specifications for CTD Profiler

Component	Depth¹	Units	Range	Accuracy	Resolution
Housing	600	—	—	—	—
Pump	3400	—	—	—	—
Pressure	680	Psia	0 to 1000	± 5.0	± 0.5
Depth	—	Meters	0 to 690	± 3.0	± 0.3
Conductivity	600	Siemens/m	0 to 6.5	± 0.001	± 0.0001
Salinity	600	‰	0 to 38	± 0.006	± 0.0006
Temperature	600	°C	-5 to 35	± 0.01	± 0.001
Transmissivity	2000	%	0 to 100	± 0.1	± 0.025
Dissolved Oxygen	200	mg/L	0 to 21.5	± 0.14	± 0.014
Acidity/Alkalinity	200	pH	0 to 14	± 0.1	± 0.006

¹ Maximum depth limit in meters

were found to reduce but not entirely eliminate sensor drift. During the January-2005 survey, a tube filled with seawater was placed around the pH sensor to limit atmospheric exposure before the CTD was first deployed. This technique was successful at further ameliorating sensor drift.

Temporal drift in the pH sensor was responsible for slight, but perceptibly lower pH measurements at those stations occupied during the first CTD deployment. The pH measurements at these stations were approximately 0.02 pH units lower than the measurements collected during the second deployment. Table 3 shows that this artificial reduction in measured pH is lower than the instrumental accuracy (± 0.1 pH). However, it is higher than the instrumental resolution (± 0.006 pH). As a result, slight but statistically significant, artificial differences are apparent in the measurements reported at Station 6 in Table B-7. Temporal detrending of the temporal drift removed these instrumental anomalies, as shown in Table B-6. The overall range in pH was small during the January-2005 survey, and this made the slight temporal drift in the pH sensor more apparent.

RESULTS

The water-quality survey for the first quarter of 2005 began on Wednesday, 14 January 2005, at 07:15 PST with the deployment of the drogued drifter. Subsequently, all water-column measurements were collected as required by the NPDES monitoring program (Table 2 and B-8). Sunrise was at 07:12 PST and skies were clear throughout the survey which ended at 10:35 PST. Although wind direction was relatively consistent throughout the survey, speeds were variable and ranged between 1.1 kt and 9.7 kt on average. Winds were directed offshore and, as a result, the accompanying waves were small, and less than 1 ft out of the west-northwest. Atmospheric visibility was greater than 2 nM along the ocean surface owing to the absence of fog and haze at that time. As such, Morro Rock and the shoreline remained visible throughout the survey. Air temperature was cooler ($<10^{\circ}\text{C}$) at the beginning of the survey and increased to more than 12°C as the day wore on. Surface seawater temperature (13°C) in the survey area was higher than the average air temperature, and was consistent with coastal sea-surface temperatures within Estero Bay recorded by the satellite image shown on the cover of this report.

The discharge plume was not visibly apparent at the sea surface at any time during the survey. Throughout the survey, there was no visual evidence of floating particulates, oil and grease, or seawater discoloration associated with the discharge. However, near-surface temperature, salinity, and turbidity were highly variable during the survey. The variability arose from pools of cold turbid freshwater that were generated by coastal runoff after heavy rains were experienced along the Central California Coast over a period of several weeks prior to the survey. The increased surface turbidity associated with these pools was visible during the second half of the survey. It was also reflected in the sharply reduced Secchi depths that were recorded after 09:00 PST in Table B-8. These turbid pools of surface runoff were not caused by effluent discharge because they were widely distributed throughout Estero Bay, and were observed at great distances from the ZID during the return to port.

Beneficial Use

During the January-2005 survey, observations of beneficial use demonstrated that the coastal waters in the outfall vicinity continued to be utilized by wildlife and for recreation. A number of unidentified seabirds were observed flying through the survey area. A western gull (*Larus occidentalis*) rested on top of the western spar buoy throughout most of the survey. In one curious event, a black rockfish (*Sebastes melanops*, Figure 4) was observed swimming slowly by the stern of the survey vessel during retrieval of the CTD at Station 2. These rockfish typically inhabit midwater and pelagic areas over high-relief rocky

reefs and are frequently found in and around kelp beds, boulder fields, and artificial reefs (CDFG, 2000). In the absence of naturally occurring hard substrate near the survey area, it is likely that the diffuser structure acts as an artificial reef for this species. In northern California, black rockfish are a major component of the recreational catch, but are uncommon south of Santa Cruz.



Figure 4. Photograph of a Black Rockfish (*Sebastes melanops*)

During the January-2005 survey, several vessels were observed near the survey area. A California Department of Fish and Game (CDFG) patrol boat passed close to the survey area but no contact was made. Sometime later, a small Boston Whaler fishing boat transited the survey area on its way north. No other evidence of beneficial use of receiving waters was noted during the survey.

Ambient Seawater Properties

Data collected during the January-2005 survey reflected the influence of freshwater runoff from a series of powerful winter storms that impacted the Central California Coastline in the days and weeks prior to the survey. Significant runoff carries a high load of terrigenous particulates, and, as a result, the sea surface near the coast typically takes on a tannish-brown hue for several days after the rainfall. During the January-2005 survey, patches of this turbid, relatively fresh water were observed both visually and instrumentally near the sea surface after 09:00 PST. Prior to that time, the sea surface was uniformly blue with high visibility. The patches of surface freshwater were probably transported into the survey area by a reversal in flow that occurred around 09:00 PST. As described previously, this current reversal was captured by the second deployment of the drogued drifter, which was released around 08:55 PST (Figure 2).

This abrupt change in surface seawater conditions was reflected in a distinct difference between measurements collected during the first and last halves of the survey. Table B-8 shows that the along-shore transect (Stations 1 through 6) and Stations 14 and 15, were occupied before 09:00, when surface turbidity was uniformly low. Accordingly, average Secchi depths were 6.9 m, and the euphotic zone reached to a depth of 13.8 m, which covers nearly the entire water column. After turbid water moved into the survey area, and the cross-shore stations (7 through 12) were occupied, average Secchi depths dropped to 5 m.

These temporal differences are also reflected in the vertical profiles of seawater properties shown in Figures A-1 through A-3. Specifically, all of the profiles shown in Figure A-1 were collected before the surface intrusion of turbid freshwater. Consequently, there is little vertical variation in properties between the sea surface and a depth of approximately 10 m. In contrast, most of the profiles shown in Figure A-2 exhibit sharp declines in temperature (red lines), salinity (green lines), density (black lines), and transmissivity (light blue lines) between the sea surface and approximately 3 m. However, two of the stations along this cross-shore transect, specifically Stations 8 and 11, did not exhibit a strong influence from the freshwater pools. This reflects the patchy distribution of the pools that was observed visually during the survey.

The configuration of the turbid freshwater pool that was captured in the cross-shore transect is apparent in the vertical sections shown in Figures A-6 and A-7. The center frame in Figure A-6 shows that the cold

temperature of this freshwater pool created a temperature inversion where warmer water was found below the pool. Temperature inversions are relatively unusual in the ocean because the density structure usually tracks the temperature structure, and a temperature inversion would normally imply a density inversion. Buoyancy processes quickly eliminate any density inversions in the ocean and leave the water column stable. Observation of a naturally occurring vertical instability would be highly unusual. However, in this case, the salinity in the surface pool was so low that it controlled the determination of density in the equation of state. As a result of the phenomenally low salinity, the density of the pool was also comparatively low, and there was no instability in the water column despite the presence of a temperature inversion.

Figure A-7 shows that transmissivity (top frame) was the only other seawater property that strongly reflected the presence of the near-surface pool. The high suspended particulate load within the pool was captured by the distinctly lower transmissivity measurements. The lowest transmissivity measured prior to 09:00 was 75.9%. However, in the turbid freshwater pool, transmissivity dropped to 58.9%. As shown by the bolded values enclosed by boxes in Table B-5, the reduced transmissivity found near the sea surface at Stations 9 and 10 represented a statistically significant departure from mean conditions. Note that the table shows that significantly reduced transmissivity was also observed near the sea surface at Station 13. This is one of the oblique stations, which are not located along a transect. Data at this station was collected at 09:51 and clearly also captured the presence of a turbid freshwater pool.

In addition to the presence of near-surface pools of freshwater runoff, ambient seawater properties also exhibited a distinct vertical structure at depth. Figures A-1 through A-3 show that vertical profiles at all of the stations exhibit a marked change below 10 m. This deep watermass is also apparent above the seafloor in the vertical sections shown in Figures A-4 through A-7. It represents the onshore migration of subsurface watermass that originates at depth well offshore. The origin of the watermass can be discerned from its seawater properties, namely, high salinity, density, and transmissivity, coupled with low temperature, dissolved oxygen (DO), and pH. Its relatively high salinity arises from the saline water that is carried northward by the Davidson Undercurrent from the Southern California Bight. It originates from offshore locations well below the sea surface. This is apparent from the low DO and pH concentrations. Deep offshore waters are undersaturated in oxygen because they have not equilibrated with the atmosphere for long periods of time, and biotic respiration and decomposition have slowly depleted dissolved-oxygen levels. Similarly, as the ratio of respiration to photosynthesis increases with depth, there is an increase in dissolved CO₂ (carbonic acid) and a concomitant decline in pH (more acidic).

Lateral Variability

The influence of the effluent discharge can be best identified from localized anomalies in seawater properties. Discharge-related anomalies are particularly apparent when seawater properties from the same depth level are compared at adjacent stations. This is evident from a comparison of the vertical sections shown Figures A-4 and A-5, which exhibit a discharge-related anomaly, with Figures A-6 and A-7, which do not. The discharge-related anomalies are not vertically isolated like salinity anomalies, or the anomalies associated with freshwater pools. Because of this characteristic, the analysis of lateral variability in seawater properties forms the basis for assessments of water-quality impacts.

In particular, the significance of each potential discharge-related anomaly can be evaluated statistically by comparing its amplitude to the natural background variability. To that end, each observation at a particular station was compared with the observations from other stations at the same depth level. Measurements collected within 10 m of the sea surface were compared with other measurements at the same depth level below the sea surface. However, deeper measurements were compared with other measurements collected

at the same height above the sloping seafloor. This is done because deep seawater properties tend to parallel the sloping seafloor rather than the horizontal sea surface.

The statistical significance of departures from ambient seawater properties was computed from the raw CTD data listed in Tables B-1 through B-7. First, anomalies from mean conditions were computed by subtracting a particular measurement from the average of all other measurements at the same depth level, be it measured relative to the sea surface or seafloor. Natural variability was estimated from the standard deviation of all measurements (excluding the one in question) for a given seawater parameter (*e.g.*, salinity). Statistically significant anomalies were those that departed from mean conditions by more than the 95% confidence interval determined from the standard deviation and number of observations used to compute the average. Statistically significant departures from ambient conditions are highlighted in Tables B-1 through B-7, with bolded values enclosed in boxes.

In the January-2005 dataset, a number of observations that were found to be statistically significant were unrelated to the effluent discharge. For example, the low salinity anomalies that are highlighted in Table B-2 near the sea surface at Stations 9 and 13 were the direct result of an encounter with a turbid freshwater pool that was generated by rainwater runoff. This was also the case for the corresponding significant reductions in density (Table B-3) and transmissivity (Table B-5).

In contrast, the statistically significant reduction in pH that is highlighted at Station 6 in Table B-7 was not related to a natural phenomenon, or to the discharge. Instead, it was an artifact of the temporal drift in the pH probe that was described in the section entitled *Temporal Trends in the pH Sensor*. Station 6 was the first station occupied in the January-2005 survey, and, as a result, the pH measurements required the greatest adjustment (0.037) to account for ongoing equilibration. The anomalous measurements at Station 6 (Table B-7) are eliminated (Table B-6) after removal of the slight temporal trend in pH.

Even without instrumental discrepancies, the presence of statistically significant anomalies that are unrelated to the discharge is expected. From the definition of a 95% confidence level, one ‘*significant*’ departure out of every 20 measurements should occur by chance alone. With nearly 500 measurements examined for each of the six parameters, it would not be surprising if a few departed from the mean by an amount more than the 95% confidence interval. Moreover, when multiple hypotheses are being tested (*i.e.*, one for each observation), the error rate for each individual test should be adjusted to achieve the overall experimentwise error rate of 5% (95% confidence). By definition, this error rate is the probability that one or more of the hypothesis tests would incorrectly find a significant difference when none exists. Thus, without correcting for repeated hypothesis testing, the individual tests are conservative and “significant” departures will be found more often than if a single test were being performed at the 95% confidence level.

Discharge-Related Perturbations

During the January-2005 survey, there was only one perturbation in seawater properties that was unequivocally related to the discharge (Perturbation P1 in Table 4). A discharge-related perturbation is a group of anomalies in one or more seawater properties that are contiguous in depth at a particular station. In addition to their spatial co-occurrence, the sign, or direction of the anomalies, lends insight into their origins. For example, the negative salinity anomaly at 11 m definitively indicates the presence of dilute wastewater constituents. This anomaly is delineated in red in the top frame of Figure A-4. Its vertical isolation is a signature unique to salinity anomalies.

In contrast, discharge-related anomalies in other water properties reflect ambient conditions near the seafloor. This indicates that these anomalies were generated by the upward displacement of ambient bottom water, rather than the presence of effluent constituents. These entrainment-generated anomalies are generated when ambient bottom water is entrained in the rising effluent plume. After being displaced upward, the differing bottom-water properties are juxtaposed with shallow-water properties and the contrast becomes apparent as an anomaly. During the January-2005 survey, the presence of a deep watermass caused seawater immediately above the seafloor to be naturally low in temperature, pH, and DO, and high in density and transmissivity. Figures A-4 and A-5 show that all of these unique seafloor

Table 4. Discharge-Related Water-Property Anomalies^a

Perturbation^b	Station	Depth	Property	Magnitude	Process
P1 Dilution=807:1	3	11 m	Salinity	-0.041 ‰	Effluent
		3 to 8 m	Temperature	-0.20 °C	Entrainment
		1 m	Density	+0.063 σ_t	Entrainment
		1 m	Transmissivity	+8.4 %	Entrainment
		3 m	Dissolved Oxygen	-0.41 mg/L	Entrainment
		1 to 12.5 m	pH	-0.037 pH	Entrainment

^a Anomalies shown in bold type were statistically significant

^b Perturbations consist of a group of spatially consistent anomalies in different seawater properties

properties can be traced to the anomalies observed in the upper water column at Station 3.

Entrainment-generated anomalies only become apparent when ambient seawater properties near the seafloor are distinctly different from those of the rest of the water column. Without distinctive properties at depth, entrainment of deep ambient seawater within the rising effluent plume would not produce obvious differences between the entrained water and shallow water properties. Thus, the entrained bottom seawater acts as a tracer of the effluent plume after discharge. These entrainment-generated anomalies could have been produced by the discharge of warm seawater, containing no suspended solids or other contaminants whatsoever.

Not only is the connection between the shallow entrainment-generated anomalies and the ambient seafloor properties clear from Figures A-4 and A-5, but the character of the anomalies demonstrates why they could not have been induced by the presence of wastewater constituents. Wastewater is less dense, warmer, and carries higher suspended particulate loads than receiving ocean waters. If wastewater properties were materially contributing, then positive thermal and negative transmissivity anomalies would result. Instead, the thermal anomaly was negative, indicating that the perturbation was cooler than surrounding waters, a phenomenon that could only be produced by the entrainment of cooler bottom water.

The positive transmissivity anomaly is even more diagnostic. The top frame of Figure A-5 shows that low-turbidity seawater above the seafloor, shown in blue, was moved upward into the water column by the buoyant effluent plume. As a result of this low-turbidity seawater near the sea surface, the transmission of natural light is increased. This is opposite of the negative impact on ambient light transmission that is normally thought to be produced by discharge of wastewater particulates. It emphasizes why many of the receiving-water limitations specified in the COP explicitly state that limitations only apply to impacts caused by the presence of wastewater constituents, and, by implication, not to changes generated by the entrainment of ambient seawater. This is also implied by the 95%

significance tests, which restrict attention to discharge-induced changes beyond the range in ambient seawater properties. Otherwise, credit would have to be given for the beneficial impact of the discharge whenever the buoyant plume happens to mix with less-turbid bottom water, as in the case of the January-2005 survey. In any regard, entrainment-generated impacts, beneficial or otherwise, are largely dictated by the existing ambient seawater stratification rather than the quality of discharged wastewater. Naturally occurring vertical differences in seawater properties are eventually mixed throughout the water column by natural nearshore processes anyway; plume entrainment simply serves to accelerate this process over a localized area.

Initial Dilution Computations

The amplitude of negative salinity anomaly at Station 3 lends insight into effectiveness of the outfall at dispersing effluent and, ultimately, compliance with the receiving-water objectives of the COP and NPDES discharge permit. The critical initial dilution applicable to the MBCSD outfall was conservatively estimated to be 133:1 (Tetra Tech, 1992). This estimate was based on worst-case modeling results using highly stratified conditions. These dispersion models found that 133 parts of ambient water would have mixed with each part of wastewater after initial mixing was complete. This dilution ratio was predicted to occur after the plume rose 9 m from the seafloor, whereupon it became trapped below a thermocline and spread laterally with no further substantive dilution. A 9-m rise translates into a trapping depth 6.4 m below the sea surface. This trapping depth is much shallower than the depth (11 m) of the maximum salinity anomaly that was observed at Station 3 during the January-2005 survey (Table 4). Consequently, the amount of dilution found within the anomaly should be much less than that predicted by the initial dilution model. However, as described below, the dilution ratio of 807:1 that was computed from the salinity anomaly was far larger than the ratio predicted by modeling. This demonstrates that the diffuser structure was operating more efficiently than predicted by the modeling.

The conservative nature of the dilution ratio determined from modeling is an important consideration because it was used to specify permit limitations on chemical concentrations in wastewater discharged from the treatment plant. These end-of-pipe effluent limitations were back-calculated from the receiving-water objectives listed in the COP (SWRCB, 1997) using the 133:1 dilution ratio determined from modeling. Use of a higher critical dilution ratio would relax the stringent end-of-pipe effluent limitations that were thought to be necessary in order to meet Ocean-Plan standards.

End-of-pipe effluent limitations are based on the definition of dilution (Fischer *et al.*, 1979), where the concentration of a particular contaminant in effluent is given by:

$$C_e \equiv C_o + D (C_o - C_s) \quad \text{Equation 1}$$

where: C_e = the concentration of a constituent in the effluent,
 C_o = the concentration of the constituent in the ocean after dilution by D ,
 D = the dilution ratio of the volume of seawater mixed with effluent, and
 C_s = the background concentration of the constituent in ambient seawater.

The actual dilution achieved by the outfall can also be computed from Equation 1 using measured seawater anomalies. This measured dilution can then be compared with the critical dilution factor determined from modeling. Salinity is an especially useful tracer because it directly reflects the magnitude of ongoing dilution. Specifically, the salinity concentration in effluent is negligible so C_e is eliminated in Equation 1 and the dilution ratio (D) can be computed from the salinity anomaly ($A = C_o - C_s$) as:

$$D = \frac{-C_o}{(C_o - C_s)} \equiv \frac{-C_o}{A} \quad \text{Equation 2}$$

where: D = the dilution ratio of the volume of seawater mixed with effluent,
 C_o = the salinity of the effluent-seawater mixture after dilution by D ,
 C_s = the background seawater salinity (approximately 33.75‰), and
 $A = C_o - C_s$ = the salinity anomaly.

Computed dilutions during the moderately stratified conditions of the January-2005 survey demonstrate that the modeled dilution factors are more conservative than those actually achieved by the diffuser structure. Specifically, the largest salinity anomaly (-0.041‰) was observed well below the trapping depth identified in the model. This magnitude of salinity anomaly yields a dilution ratio of 807:1 in Equation 2. It indicates a dilution ratio that is six-times higher than the 133:1 critical dilution used to establish limitations on contaminant concentrations in wastewater. The dilution computation demonstrates that, during the January-2005 survey, the outfall was performing better than designed, and was rapidly diluting effluent more than 800-fold. Consequently, COP receiving-water objectives were easily met by the chemical concentration limits promulgated by the NPDES discharge permit issued to the MBCSD.

DISCUSSION

Sampling during the January-2005 survey indicated that the wastewater discharge was in compliance with the receiving-water limitations specified in the NPDES permit, and with the water-quality objectives of the COP (SWRCB, 1997) and the Central Coast Basin Plan (RWQCB, 1994). Specifically, there were no particulates of sewage origin seen floating on the ocean surface at any of the stations sampled during the January-2005 water-quality survey. Although statistically significant reductions in pH were generated by the discharge plume, they were small compared to the receiving-water limits specified in the NPDES discharge permit. Moreover, the anomalies found in the upper water column at Station 3 were generated by entrainment of deep ambient seawater and not by the presence of wastewater itself. The amplitude of the associated salinity anomaly demonstrated that wastewater constituents were too dilute to measurably contribute to anomalies observed in the other seawater properties.

Outfall Performance

A very slight salinity anomaly indicated the presence of dilute wastewater near the boundary of the ZID at Station 3. The precise instrumental observations of salinity demonstrated that the diffuser structure was operating better than predicted by modeling, and that the discharged wastewater experienced high levels of dilution close to the diffuser. A dilution of 807:1 was determined from the salinity anomaly located at Station 3, only 4 m above the seafloor. This is more than six times the minimum critical dilution of 133:1 specified in the NPDES permit. With the higher dilution ratio that was determined from actual measurements during the January-2005 survey, contaminant concentrations within the wastewater could have been more than six times higher than the limits specified in the NPDES discharge permit, and the receiving-water objectives of the California Ocean Plan (COP) would still have been achieved.

NPDES Permit Limits

The seawater properties measured during the January-2005 survey were statistically evaluated for compliance with the pertinent receiving-water limitations promulgated by the NPDES discharge permit and the COP. Specifically, the permit and COP state that the discharge shall not cause:

1. *Natural light to be significantly reduced at any point outside the initial dilution zone as the result of the discharge of waste.*
2. *The dissolved oxygen concentration outside the zone of initial dilution to fall below 5.0 mg/L or to be depressed more than 10 percent from that which occurs naturally.*
3. *The pH outside the zone of initial dilution to be depressed below 7.0, raised above 8.3, or changed more than 0.2 units from that which occurs naturally.*
4. *Temperature of the receiving water to adversely affect beneficial uses.*

The COP (SWRCB, 1997) further defines a ‘significant’ difference as ‘...a statistically significant difference in the means of two distributions of sampling results at the 95 percent confidence level.’ For each observation in Tables B-1 through B-6, the statistical significance of departures from mean conditions at a given depth level were determined with an analysis of variance that compares a single observation with the mean of a larger set of samples (see Page 228 in Sokal and Rohlf, 1997; Ury, 1976). Although 15 independent hypothesis tests were performed at each depth level, no Bonferroni adjustment to the error rate was included, so the tests are conservative. Specifically, Bonferroni adjustment indicates that the actual confidence level for the overall null hypothesis test for differences in properties is higher, around 99.7%, rather than the 95% level that applies to a single test. The standard deviation that was applied in the tests was determined from the entire data set to reflect the full range in ambient properties, including vertical variations.

Light Transmittance

Statistical analysis revealed significant reductions in instrumentally recorded light transmittance near the sea surface at Stations 9, 10, and 13 (Table B-5). Although statistically significant, the transmissivity reductions were unrelated to effluent discharge. Instead, they were generated by pools of turbid freshwater that originated from rainwater runoff during storms that occurred in the days prior to the survey. The only statistically significant transmissivity anomaly that was associated with the discharge was observed in the upper water column at Station 3. However, this anomaly was a positive anomaly, reflecting less turbid water. It was generated by the entrainment and upward displacement of ambient bottom water that was less turbid than near-surface water. Because the anomaly contained less turbid water, it could not have caused a “...reduction in the transmittance of natural light...”

Dissolved Oxygen

Although it is not stated in the NPDES discharge permit, the COP specifies that the DO limitation only applies to reductions that occur “...as a result of the discharge of oxygen demanding waste materials.” Clearly, then, the DO limitation does not apply to reductions in DO caused by the movement of ambient waters, regardless of whether they were induced by the physics of the discharge or not. Thus, the slightly reduced DO concentrations observed in the upper water column at Station 3, which were generated by entrainment of ambient seawater, are not subject to the limitations. Even so, the amplitudes of the DO anomalies were so small (-0.41 mg/L) that they complied with the numerical limits specified in the permit. Specifically, none of the 495 DO concentrations measured during the January-2005 survey fell below the 5-mg/L minimum specified in the Basin Plan and the NPDES discharge permit. The lowest DO concentration of 6.88 mg/L was measured near the seafloor within a benthic water mass that was naturally depleted in oxygen due to its deep offshore origin. Therefore, the amplitude of the discharge-related DO measurements at Station 3 was too small to be considered “...to be depressed more than 10 percent from that which occurs naturally.”

pH

The only statistically significant lateral anomalies in pH (Table B-6) were measured at Station 3. As with the other water properties, these pH anomalies were generated by the upward displacement of ambient bottom water, which is naturally low in pH. Moreover, the maximum amplitude of the anomalies (-0.037) was so small that it easily complied with the numerical limit that restricts changes to less than 0.2 pH units. In fact, the range in pH among all of the measurements was only 0.045, so none of the measurements can be considered changed by ‘...more than 0.2 pH units from that which occurs naturally.’ The range across the entire pH field remained between 7.829 and 7.874, and thus, all of the measurements also complied with the lower (7.0 pH) and upper (8.3 pH) bounds on discharge-induced pH changes.

Temperature and Salinity

The total range in temperature of 0.42°C across all observations was largely due to naturally occurring vertical stratification. Even if changes this large were generated by the discharge, they would be considered too small ‘...to adversely affect beneficial uses...’ This is because the temperature range was much less than the large-scale spatial variability in sea-surface temperature shown in the satellite image on the cover of this report. Also, none of lateral differences in temperature observed during the January-2005 survey were statistically significant (Table B-1). The small, discharge-induced decreases in temperature (<0.2°C) that were visually apparent in the vertical section at Station 3 resulted from the upward displacement of naturally occurring, cooler bottom water. Therefore, the negative thermal anomalies could not have resulted from the presence of warmer wastewater constituents.

Although salinity anomalies provide the best tracer of discharged effluent, their actual amplitude (0.04‰) was small compared to ambient salinity variability observed during the January-2005 survey. The total range in measured salinities was 0.46‰. This salinity range is nearly twice the 0.25‰ average seasonal difference in mean surface salinity. The increased salinity variability observed during the January-2005 survey was caused by the presence of freshwater pools of rainwater runoff. In any regard, the observed range in measured temperature (0.42°C) and salinity (0.45‰) across all data collected during the January-2005 survey was too small to be considered harmful to marine biota or deleterious to beneficial uses.

Conclusions

The measurements collected at all stations during the January-2005 survey complied with receiving-water limitations specified in the NPDES discharge permit. The discharge-related anomalies found in the upper water column near the boundary of the ZID were caused by the upward displacement of ambient seawater, and not the presence of wastewater constituents. Observations of effluent mixing at depth demonstrated that discharged wastewater was undergoing rapid dilution close to the diffuser structure, and that the outfall was operating as designed.

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APPENDIX A

Water Quality Profiles and Vertical Sections

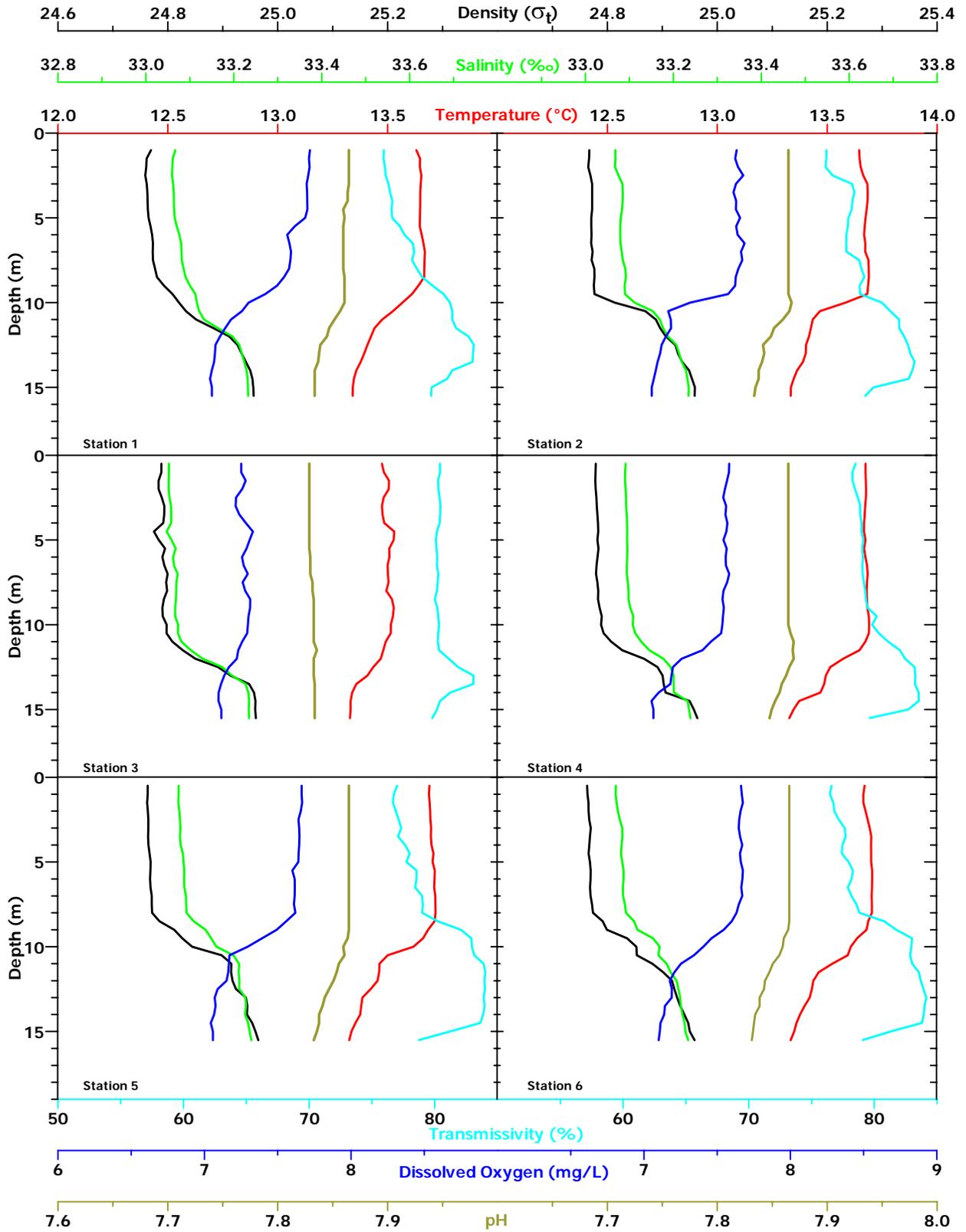


Figure A-1. Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 14 January 2005

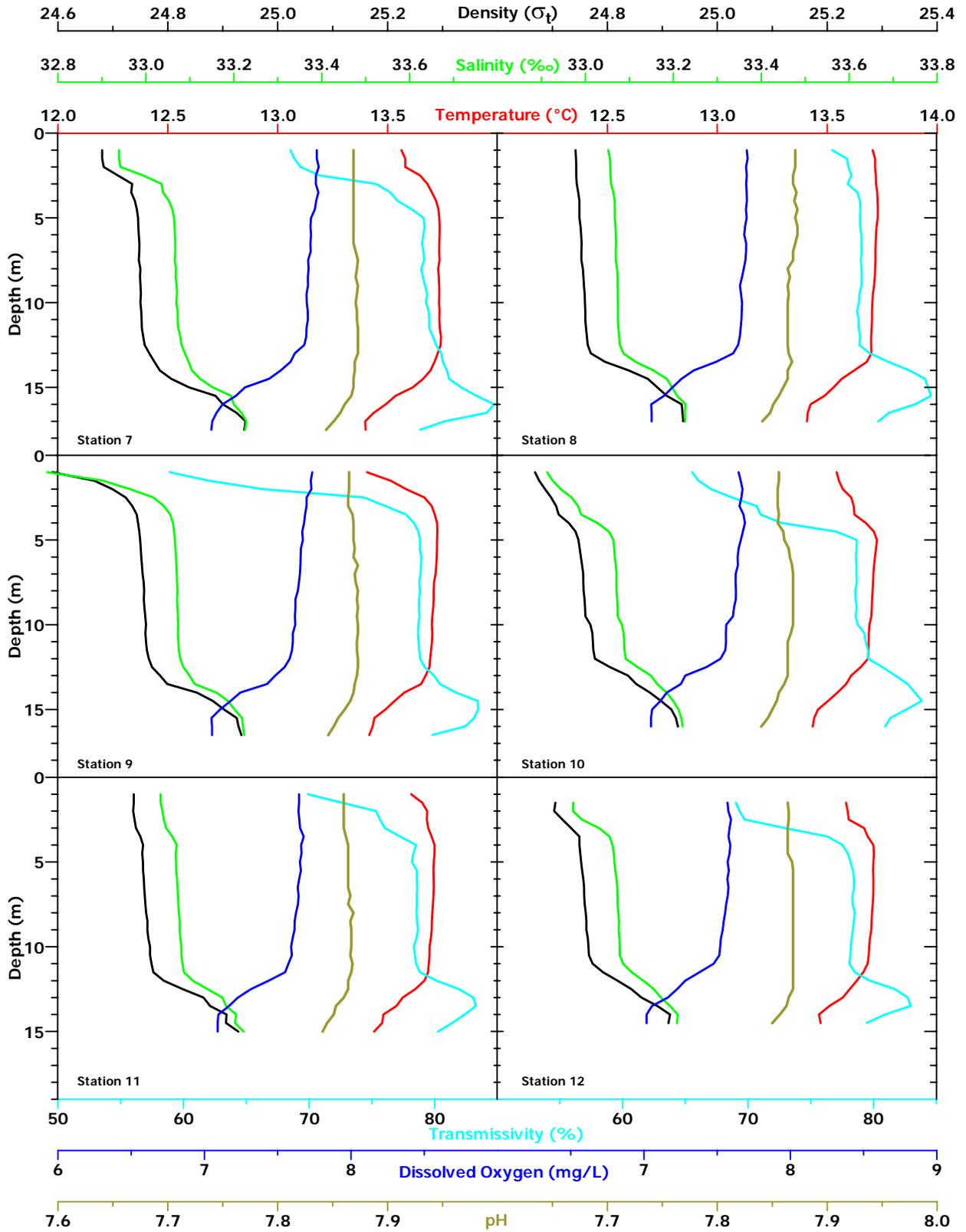


Figure A-2. Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 14 January 2005

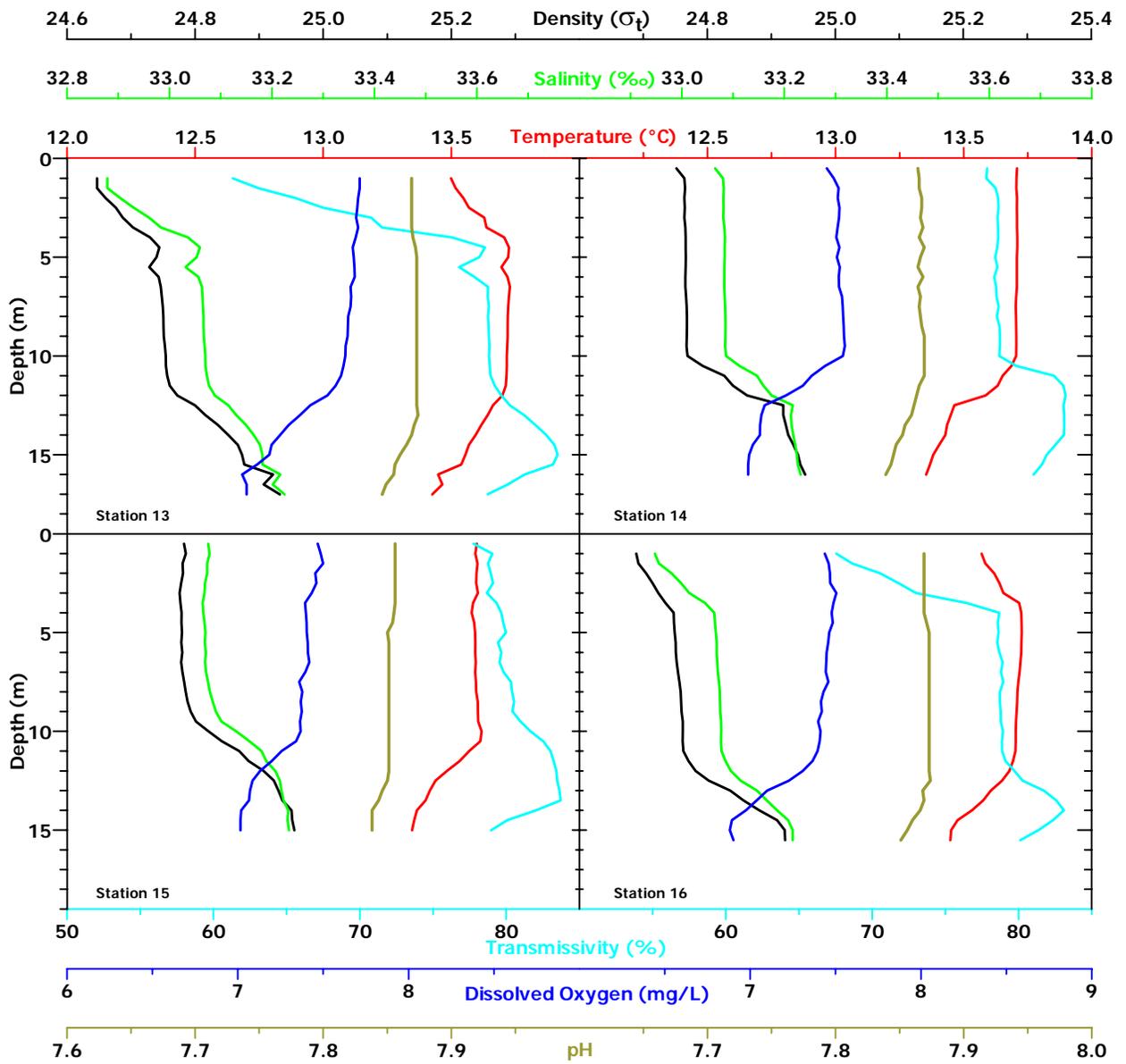


Figure A-3. Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 14 January 2005

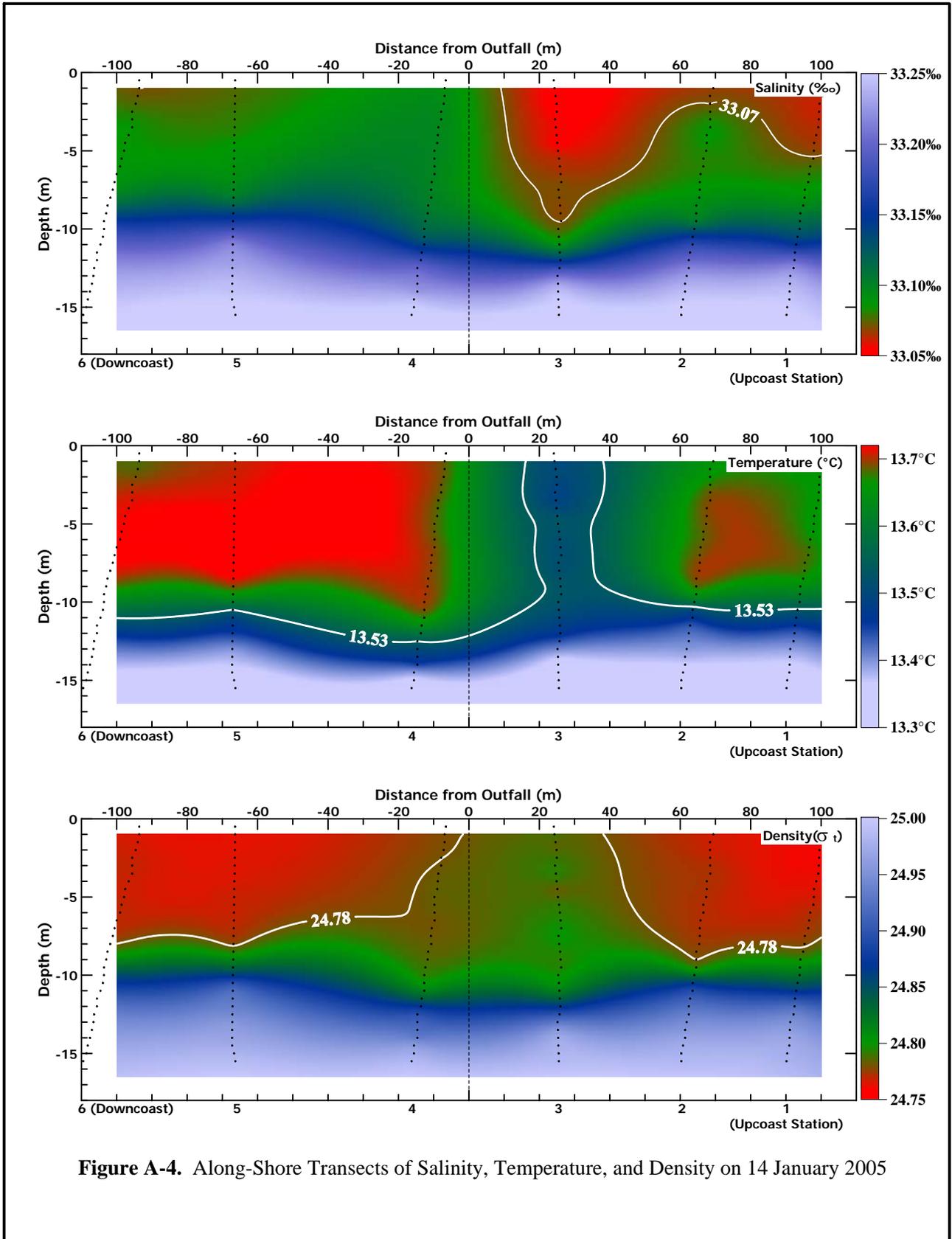


Figure A-4. Along-Shore Transects of Salinity, Temperature, and Density on 14 January 2005

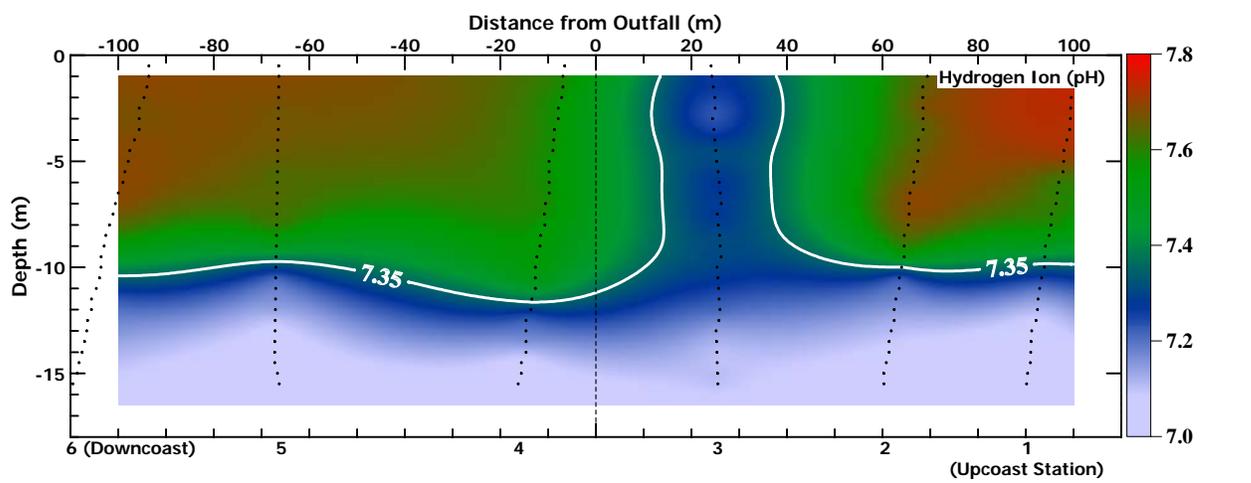
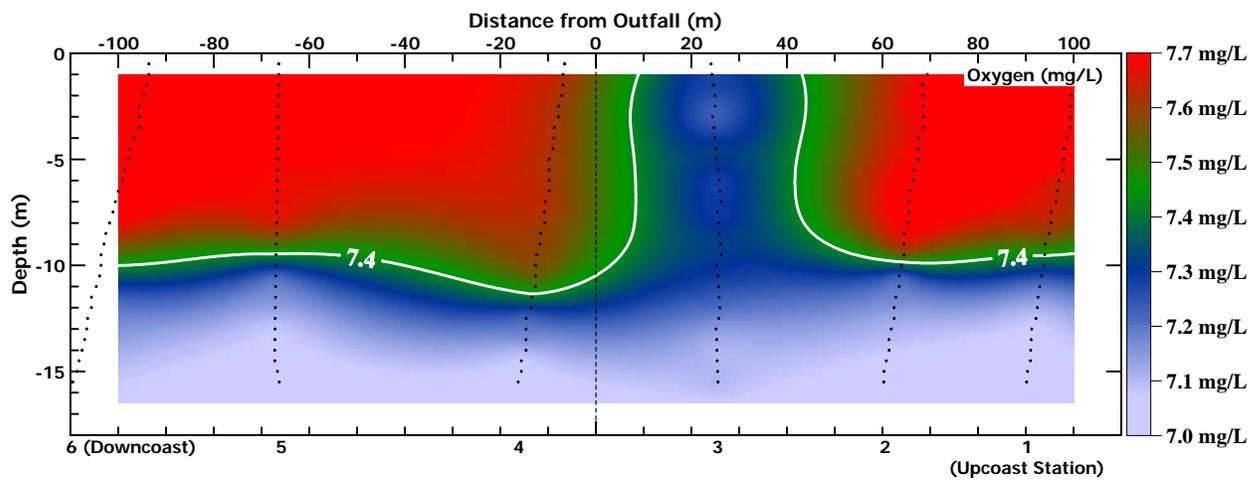
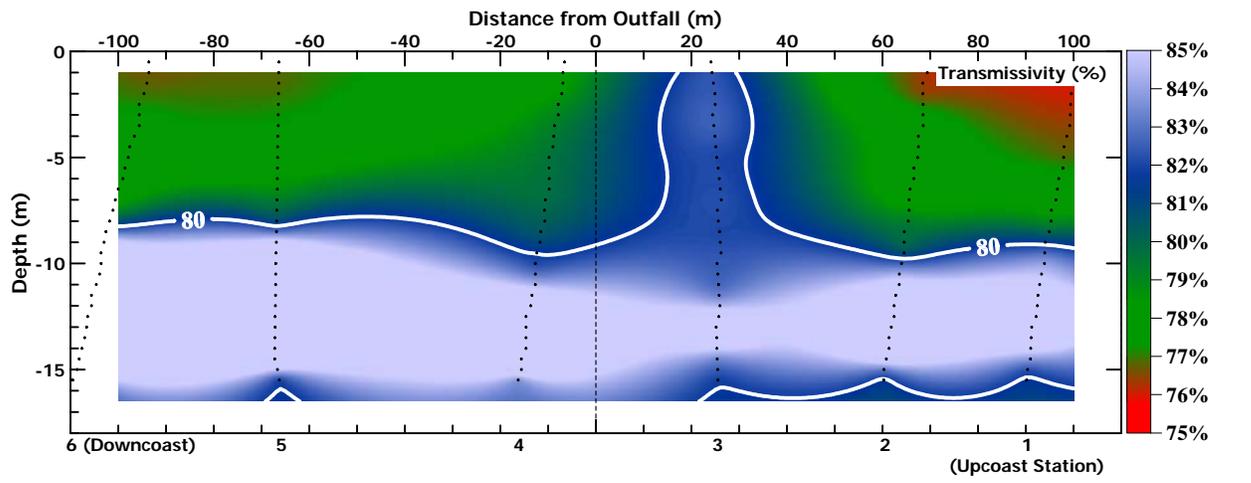


Figure A-5. Along-Shore Transects of Transmissivity, Oxygen, and pH on 14 January 2005

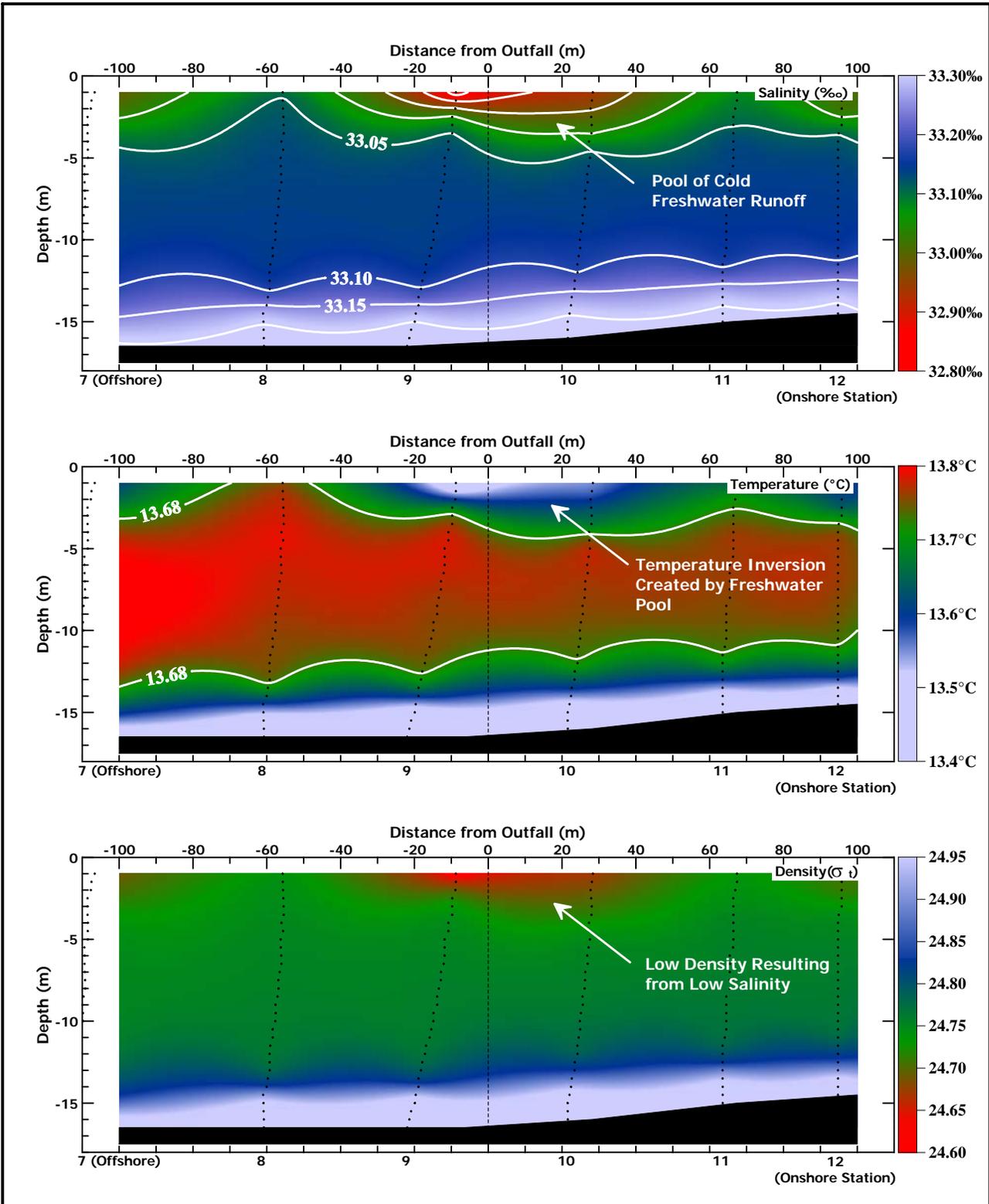


Figure A-6. Cross-Shore Transects of Salinity, Temperature, and Density on 14 January 2005

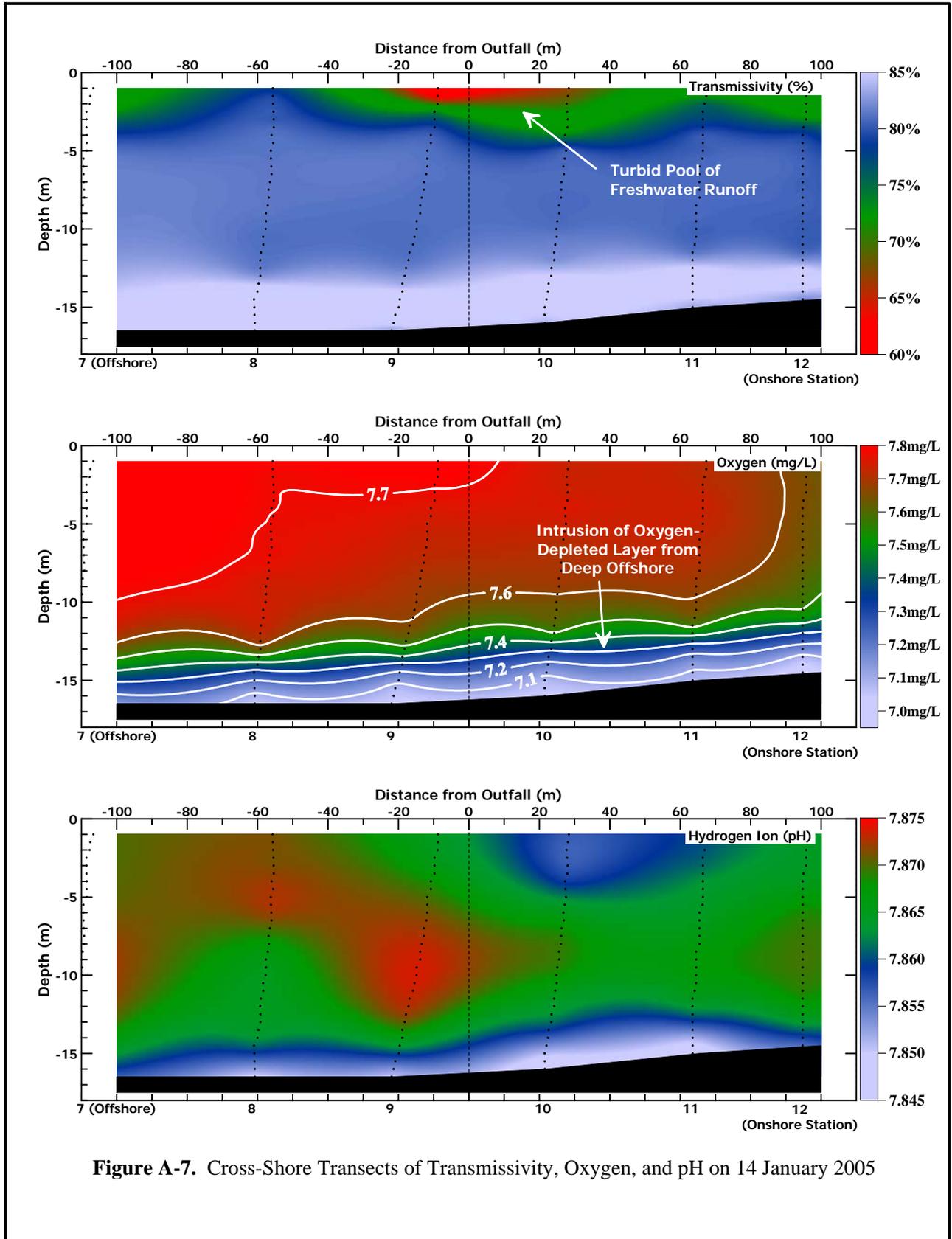


Figure A-7. Cross-Shore Transects of Transmissivity, Oxygen, and pH on 14 January 2005

APPENDIX B

Tables of Profile Data and Standard Observations

Table B-2. Salinity¹ on 14 January 2005

Depth (m)	Salinity (‰)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5			33.053	33.091	33.075	33.069								33.065	33.076	
1.0	33.067	33.068	33.053	33.090	33.075	33.069	32.939	33.052	32.776	32.913	33.034		32.879	33.080	33.078	32.947
1.5	33.061	33.068	33.052	33.090	33.074	33.071	32.939	33.056	32.902	32.926	33.034	32.972	32.879	33.082	33.074	32.955
2.0	33.060	33.067	33.052	33.091	33.076	33.074	32.942	33.057	32.963	32.944	33.038	32.972	32.904	33.081	33.074	32.980
2.5	33.060	33.075	33.054	33.093	33.078	33.078	32.994	33.057	33.017	32.969	33.041	32.992	32.930	33.081	33.069	32.998
3.0	33.062	33.084	33.057	33.093	33.079	33.084	33.036	33.058	33.041	32.983	33.046	33.031	32.960	33.081	33.068	33.014
3.5	33.063	33.085	33.058	33.094	33.078	33.084	33.039	33.064	33.056	32.990	33.060	33.055	32.983	33.083	33.065	33.045
4.0	33.064	33.085	33.058	33.095	33.079	33.082	33.053	33.067	33.062	33.028	33.070	33.062	33.036	33.084	33.066	33.063
4.5	33.064	33.083	33.047	33.095	33.084	33.081	33.060	33.067	33.064	33.053	33.068	33.065	33.059	33.084	33.068	33.065
5.0	33.066	33.080	33.058	33.095	33.086	33.084	33.064	33.067	33.066	33.064	33.069	33.066	33.053	33.084	33.070	33.066
5.5	33.070	33.079	33.068	33.096	33.088	33.087	33.065	33.068	33.067	33.066	33.069	33.068	33.031	33.083	33.069	33.068
6.0	33.076	33.079	33.062	33.095	33.087	33.087	33.066	33.069	33.069	33.067	33.071	33.071	33.056	33.083	33.071	33.068
6.5	33.080	33.080	33.064	33.094	33.088	33.085	33.067	33.070	33.070	33.069	33.072	33.073	33.063	33.083	33.069	33.069
7.0	33.081	33.083	33.072	33.094	33.091	33.086	33.067	33.069	33.070	33.071	33.073	33.073	33.064	33.084	33.071	33.070
7.5	33.082	33.085	33.070	33.096	33.092	33.090	33.066	33.069	33.071	33.071	33.074	33.073	33.065	33.084	33.075	33.072
8.0	33.086	33.091	33.069	33.098	33.093	33.092	33.068	33.072	33.072	33.071	33.075	33.075	33.066	33.085	33.079	33.074
8.5	33.090	33.092	33.068	33.098	33.109	33.110	33.068	33.073	33.071	33.072	33.077	33.076	33.066	33.085	33.084	33.074
9.0	33.100	33.089	33.067	33.102	33.136	33.118	33.070	33.073	33.072	33.073	33.077	33.076	33.067	33.085	33.091	33.075
9.5	33.112	33.090	33.067	33.109	33.149	33.154	33.071	33.074	33.073	33.073	33.078	33.078	33.069	33.084	33.101	33.077
10.0	33.116	33.112	33.073	33.108	33.160	33.169	33.069	33.074	33.074	33.083	33.081	33.078	33.070	33.086	33.130	33.077
10.5	33.121	33.153	33.073	33.113	33.199	33.166	33.072	33.074	33.073	33.087	33.081	33.078	33.070	33.112	33.156	33.076
11.0	33.133	33.169	33.081	33.127	33.212	33.185	33.072	33.074	33.074	33.088	33.083	33.086	33.073	33.147	33.180	33.077
11.5	33.164	33.177	33.102	33.146	33.211	33.194	33.074	33.075	33.075	33.089	33.087	33.105	33.077	33.159	33.189	33.085
12.0	33.197	33.188	33.129	33.178	33.213	33.208	33.078	33.077	33.078	33.092	33.107	33.132	33.089	33.175	33.207	33.096
12.5	33.212	33.207	33.174	33.194	33.213	33.212	33.081	33.079	33.085	33.118	33.140	33.155	33.115	33.217	33.215	33.115
13.0	33.218	33.213	33.196	33.200	33.226	33.215	33.089	33.086	33.099	33.149	33.175	33.172	33.130	33.213	33.219	33.146
13.5	33.224	33.219	33.227	33.201	33.228	33.217	33.097	33.114	33.111	33.163	33.183	33.193	33.149	33.214	33.223	33.166
14.0	33.229	33.229	33.233	33.201	33.226	33.221	33.105	33.155	33.160	33.185	33.206	33.210	33.164	33.217	33.232	33.186
14.5	33.232	33.232	33.235	33.232	33.233	33.226	33.123	33.185	33.187	33.199	33.203	33.208	33.177	33.221	33.231	33.207
15.0	33.232	33.235	33.234	33.236	33.236	33.227	33.152	33.197	33.202	33.212	33.222		33.181	33.225	33.233	33.216
15.5	33.233	33.235	33.235	33.239	33.240	33.234	33.194	33.209	33.219	33.218			33.182	33.226		33.216
16.0								33.200	33.228	33.221	33.221		33.216	33.232		
16.5								33.218	33.226	33.224			33.202			
17.0								33.229	33.227				33.224			
17.5								33.226								

¹ Values enclosed in boxes were significantly lower than the mean of other salinity measurements at the same depth.

Table B-3. Seawater Density¹ on 14 January 2005

Depth (m)	Density (sigma-t)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5			24.788	24.779	24.763	24.763									24.752	24.783
1.0	24.769	24.767	24.788	24.778	24.763	24.764	24.681	24.742	24.590	24.668	24.738		24.647	24.764	24.786	24.689
1.5	24.761	24.767	24.783	24.778	24.762	24.766	24.681	24.743	24.666	24.676	24.738	24.705	24.647	24.766	24.780	24.693
2.0	24.761	24.765	24.783	24.779	24.764	24.766	24.683	24.743	24.699	24.686	24.737	24.703	24.660	24.764	24.781	24.705
2.5	24.759	24.769	24.789	24.780	24.765	24.767	24.709	24.743	24.723	24.698	24.740	24.718	24.676	24.765	24.778	24.714
3.0	24.762	24.772	24.794	24.781	24.765	24.770	24.735	24.744	24.735	24.707	24.742	24.734	24.687	24.764	24.776	24.724
3.5	24.763	24.772	24.793	24.782	24.764	24.768	24.733	24.747	24.743	24.711	24.750	24.749	24.703	24.766	24.777	24.735
4.0	24.763	24.772	24.792	24.783	24.765	24.767	24.740	24.749	24.746	24.730	24.755	24.749	24.730	24.766	24.779	24.747
4.5	24.764	24.772	24.775	24.784	24.767	24.766	24.744	24.749	24.748	24.742	24.753	24.751	24.744	24.766	24.779	24.748
5.0	24.765	24.771	24.784	24.782	24.769	24.768	24.746	24.749	24.750	24.748	24.755	24.752	24.740	24.766	24.780	24.749
5.5	24.769	24.771	24.795	24.784	24.768	24.770	24.746	24.751	24.751	24.750	24.755	24.754	24.728	24.766	24.778	24.751
6.0	24.772	24.771	24.790	24.782	24.768	24.769	24.747	24.752	24.752	24.752	24.756	24.756	24.743	24.766	24.780	24.751
6.5	24.773	24.770	24.794	24.780	24.769	24.769	24.748	24.753	24.753	24.754	24.757	24.758	24.746	24.766	24.778	24.752
7.0	24.773	24.773	24.800	24.780	24.771	24.769	24.748	24.753	24.754	24.756	24.758	24.758	24.748	24.767	24.780	24.754
7.5	24.773	24.771	24.797	24.782	24.771	24.772	24.747	24.753	24.756	24.756	24.759	24.759	24.750	24.768	24.783	24.757
8.0	24.777	24.776	24.799	24.783	24.771	24.774	24.750	24.755	24.757	24.757	24.761	24.761	24.750	24.768	24.785	24.758
8.5	24.780	24.777	24.793	24.783	24.785	24.791	24.749	24.757	24.756	24.758	24.763	24.762	24.751	24.768	24.788	24.759
9.0	24.793	24.775	24.790	24.786	24.812	24.799	24.750	24.757	24.757	24.759	24.763	24.762	24.751	24.768	24.793	24.760
9.5	24.808	24.777	24.791	24.790	24.826	24.836	24.751	24.759	24.759	24.760	24.765	24.765	24.753	24.768	24.801	24.762
10.0	24.820	24.813	24.798	24.788	24.844	24.853	24.750	24.759	24.760	24.769	24.768	24.766	24.754	24.769	24.821	24.762
10.5	24.833	24.869	24.798	24.793	24.898	24.853	24.752	24.760	24.759	24.773	24.768	24.766	24.754	24.793	24.842	24.762
11.0	24.852	24.888	24.808	24.807	24.916	24.882	24.752	24.760	24.760	24.774	24.770	24.773	24.757	24.827	24.869	24.763
11.5	24.883	24.896	24.827	24.827	24.915	24.901	24.753	24.761	24.762	24.774	24.77	24.792	24.761	24.840	24.883	24.771
12.0	24.912	24.906	24.850	24.867	24.918	24.917	24.755	24.763	24.765	24.777	24.793	24.819	24.772	24.862	24.907	24.782
12.5	24.927	24.924	24.892	24.891	24.924	24.922	24.758	24.764	24.771	24.805	24.827	24.843	24.800	24.919	24.923	24.802
13.0	24.934	24.929	24.914	24.900	24.942	24.927	24.766	24.770	24.786	24.837	24.865	24.862	24.816	24.919	24.930	24.836
13.5	24.942	24.936	24.948	24.902	24.945	24.933	24.776	24.796	24.799	24.853	24.877	24.891	24.836	24.923	24.936	24.857
14.0	24.950	24.949	24.957	24.906	24.944	24.940	24.785	24.839	24.853	24.877	24.907	24.914	24.852	24.926	24.951	24.881
14.5	24.954	24.954	24.960	24.950	24.954	24.947	24.806	24.874	24.882	24.897	24.906	24.911	24.867	24.934	24.952	24.909
15.0	24.956	24.959	24.959	24.957	24.960	24.950	24.839	24.891	24.902	24.916	24.928		24.873	24.942	24.955	24.921
15.5	24.956	24.959	24.960	24.964	24.965	24.958	24.887	24.908	24.926	24.925			24.877	24.945		24.922
16.0							24.900	24.935	24.929	24.928			24.922	24.953		
16.5							24.925	24.937	24.934				24.907			
17.0							24.942	24.938					24.933			
17.5							24.939									

¹ Values enclosed in boxes were significantly lower than the mean of other density measurements at the same depth.

Table B-5. Light Transmittance¹ across a 0.25-m path on 14 January 2005

Depth (m)	Light Transmittance (%)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5			80.41	78.52	76.99	76.59									77.85	77.77
1.0	75.94	76.18	80.43	78.26	76.75	76.46	68.52	76.69	58.90	65.55	69.89		61.32	77.80	79.06	67.55
1.5	75.93	76.17	80.27	78.28	76.68	76.74	68.82	77.87	62.00	66.06	72.60	69.03	63.06	78.43	78.76	68.62
2.0	76.04	76.11	80.30	78.46	76.91	76.82	69.31	78.00	66.28	67.04	75.34	69.33	65.58	78.59	78.95	70.54
2.5	76.08	76.67	80.38	78.69	77.13	77.16	70.81	78.23	74.37	68.72	75.64	69.72	67.49	78.63	79.10	71.79
3.0	76.32	78.23	80.46	78.88	77.34	77.64	75.32	77.93	76.06	70.68	76.03	72.92	70.79	78.56	78.68	72.98
3.5	76.44	78.42	80.43	78.88	77.09	77.72	76.46	78.72	77.72	70.99	77.25	76.34	71.51	78.60	79.35	76.44
4.0	76.63	78.26	80.40	78.99	77.64	77.45	77.04	78.92	78.35	72.69	78.51	77.52	76.30	78.61	79.66	78.68
4.5	76.57	78.20	80.18	78.98	78.01	77.42	78.18	78.96	78.70	77.01	78.30	77.95	78.55	78.54	79.80	78.59
5.0	76.62	77.93	80.09	79.14	77.74	77.96	79.11	78.90	78.84	78.67	78.19	78.17	78.16	78.40	79.98	78.64
5.5	77.23	77.89	80.13	79.03	78.56	78.30	79.20	78.93	78.82	78.65	78.58	78.36	76.79	78.56	79.44	78.54
6.0	77.60	77.78	80.20	79.10	78.55	78.20	79.10	79.03	78.94	78.60	78.57	78.44	77.82	78.34	79.67	78.69
6.5	78.26	77.76	80.17	79.05	78.45	77.88	79.00	79.02	78.92	78.64	78.62	78.44	78.76	78.47	79.55	78.91
7.0	78.36	77.78	80.29	79.07	78.98	78.18	79.10	79.05	78.88	78.63	78.57	78.33	78.74	78.50	79.82	78.80
7.5	78.20	78.80	80.24	79.17	79.05	78.57	79.17	78.99	78.78	78.66	78.58	78.32	78.82	78.65	80.32	78.94
8.0	78.58	78.97	80.18	79.29	79.01	78.80	78.93	79.04	78.83	78.54	78.55	78.50	78.76	78.52	80.40	78.73
8.5	79.01	79.20	80.01	79.33	80.24	80.78	79.07	79.07	78.76	78.57	78.60	78.43	78.79	78.70	80.54	78.72
9.0	79.83	78.83	80.21	79.46	82.08	81.74	79.23	79.03	78.75	78.66	78.68	78.36	78.82	78.73	80.43	78.77
9.5	80.71	78.88	80.27	80.20	82.92	83.00	79.40	78.88	78.80	78.57	78.53	78.25	78.86	78.72	80.97	78.78
10.0	81.21	80.60	80.35	79.84	82.95	82.94	79.31	78.84	78.70	78.73	78.34	78.19	78.83	78.68	81.65	78.94
10.5	81.40	81.28	80.28	80.36	83.16	82.85	79.52	78.68	78.66	79.27	78.43	78.15	78.88	79.85	82.53	78.87
11.0	81.40	81.98	80.25	81.10	83.88	83.02	79.58	78.82	78.73	79.36	78.52	78.08	78.93	82.41	83.02	78.88
11.5	81.70	82.00	80.34	82.04	84.03	83.54	79.56	78.81	78.77	79.57	78.83	78.50	79.21	83.06	83.24	79.11
12.0	82.69	82.38	81.12	82.46	83.95	83.69	79.86	78.94	78.85	79.56	80.14	79.71	79.67	83.21	83.43	79.71
12.5	83.11	82.69	81.85	83.21	84.00	83.92	80.10	78.86	79.19	80.69	81.91	81.68	80.24	83.07	83.49	80.28
13.0	83.05	82.87	83.09	83.26	83.90	84.14	80.53	79.70	79.95	81.74	83.06	82.72	81.22	83.11	83.64	81.72
13.5	83.00	83.22	83.07	83.24	83.98	84.00	80.65	81.19	80.41	82.72	83.28	82.96	81.99	83.12	83.72	82.57
14.0	81.40	83.03	81.24	83.53	83.86	83.93	80.96	82.85	81.69	83.28	82.38	80.94	82.73	83.08	82.03	83.09
14.5	80.98	82.73	80.43	83.54	83.63	83.80	81.13	84.09	83.42	83.84	81.40	79.45	83.29	82.52	80.06	82.35
15.0	79.76	79.94	80.19	82.70	81.22	81.31	82.13	84.34	83.46	82.61	80.28		83.51	81.93	78.99	81.36
15.5	79.72	79.30	79.81	79.65	78.76	79.10	83.33	84.57	83.13	81.34			83.20	81.59		80.11
16.0								84.75	83.30	82.42	80.94		81.25	81.04		
16.5								84.13	81.22	79.82			80.12			
17.0								80.81	80.37				78.75			
17.5								78.87								

¹ Values enclosed in boxes were significantly different from the mean of other transmissivity measurements at the same depth.

Table B-6. Detrended¹ pH² on 14 January 2005

Depth (m)	Alkalinity (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5			7.829	7.865	7.865	7.865								7.864	7.856	
1.0	7.865	7.865	7.829	7.865	7.865	7.865	7.869	7.871	7.865	7.856	7.860		7.869	7.865	7.856	7.869
1.5	7.865	7.865	7.829	7.865	7.865	7.865	7.869	7.871	7.865	7.856	7.860	7.864	7.869	7.865	7.856	7.869
2.0	7.865	7.865	7.829	7.865	7.865	7.865	7.869	7.871	7.865	7.855	7.860	7.865	7.869	7.867	7.856	7.869
2.5	7.865	7.865	7.829	7.865	7.865	7.865	7.869	7.869	7.864	7.855	7.860	7.865	7.869	7.867	7.856	7.869
3.0	7.865	7.865	7.829	7.865	7.865	7.865	7.869	7.869	7.864	7.855	7.860	7.864	7.869	7.866	7.856	7.869
3.5	7.864	7.865	7.829	7.865	7.865	7.865	7.869	7.872	7.868	7.856	7.862	7.864	7.869	7.868	7.856	7.869
4.0	7.864	7.865	7.829	7.865	7.865	7.865	7.869	7.870	7.869	7.855	7.864	7.864	7.870	7.865	7.855	7.869
4.5	7.860	7.865	7.829	7.865	7.865	7.865	7.869	7.873	7.869	7.860	7.864	7.864	7.872	7.869	7.854	7.871
5.0	7.861	7.865	7.829	7.865	7.865	7.865	7.869	7.871	7.869	7.861	7.864	7.868	7.873	7.866	7.850	7.873
5.5	7.860	7.865	7.829	7.865	7.865	7.865	7.869	7.873	7.870	7.865	7.864	7.869	7.873	7.864	7.851	7.873
6.0	7.860	7.865	7.830	7.865	7.865	7.865	7.869	7.873	7.869	7.866	7.864	7.869	7.873	7.868	7.851	7.873
6.5	7.860	7.865	7.830	7.865	7.865	7.865	7.869	7.871	7.873	7.868	7.864	7.869	7.873	7.864	7.851	7.873
7.0	7.860	7.865	7.830	7.865	7.865	7.865	7.871	7.869	7.870	7.869	7.866	7.869	7.873	7.866	7.851	7.873
7.5	7.860	7.865	7.832	7.865	7.865	7.865	7.873	7.869	7.871	7.869	7.864	7.869	7.873	7.865	7.851	7.873
8.0	7.860	7.865	7.832	7.865	7.865	7.865	7.872	7.864	7.873	7.869	7.869	7.869	7.873	7.866	7.851	7.873
8.5	7.861	7.865	7.833	7.865	7.865	7.865	7.871	7.866	7.872	7.869	7.866	7.869	7.873	7.867	7.851	7.873
9.0	7.861	7.865	7.833	7.865	7.865	7.864	7.873	7.864	7.873	7.869	7.867	7.869	7.873	7.869	7.851	7.873
9.5	7.861	7.865	7.833	7.865	7.86	7.860	7.872	7.865	7.872	7.869	7.867	7.869	7.873	7.869	7.851	7.873
10.0	7.861	7.868	7.833	7.865	7.860	7.859	7.871	7.864	7.873	7.869	7.867	7.869	7.873	7.869	7.851	7.873
10.5	7.857	7.866	7.833	7.867	7.861	7.856	7.872	7.864	7.873	7.867	7.866	7.869	7.873	7.869	7.851	7.873
11.0	7.852	7.860	7.833	7.870	7.856	7.850	7.872	7.864	7.872	7.864	7.868	7.869	7.873	7.869	7.851	7.873
11.5	7.847	7.852	7.836	7.869	7.854	7.847	7.873	7.864	7.872	7.864	7.867	7.869	7.873	7.865	7.851	7.873
12.0	7.845	7.849	7.833	7.870	7.851	7.843	7.873	7.864	7.873	7.864	7.864	7.869	7.873	7.863	7.851	7.873
12.5	7.839	7.842	7.833	7.866	7.847	7.842	7.873	7.864	7.873	7.864	7.864	7.869	7.873	7.861	7.850	7.874
13.0	7.838	7.843	7.833	7.863	7.843	7.838	7.873	7.865	7.872	7.864	7.860	7.865	7.874	7.859	7.846	7.868
13.5	7.837	7.841	7.834	7.859	7.841	7.838	7.870	7.868	7.870	7.861	7.853	7.863	7.871	7.854	7.843	7.869
14.0	7.834	7.838	7.834	7.857	7.838	7.834	7.870	7.864	7.869	7.856	7.851	7.857	7.869	7.852	7.838	7.866
14.5	7.834	7.838	7.834	7.853	7.838	7.833	7.869	7.864	7.866	7.854	7.845	7.850	7.865	7.847	7.838	7.860
15.0	7.834	7.835	7.834	7.850	7.836	7.832	7.869	7.860	7.861	7.850	7.841		7.860	7.845	7.838	7.856
15.5	7.834	7.834	7.834	7.848	7.833	7.831	7.867	7.856	7.855	7.846			7.856	7.843		7.851
16.0							7.861	7.851	7.851	7.840			7.855	7.839		
16.5							7.857	7.848	7.846				7.849			
17.0							7.851	7.841					7.846			
17.5							7.844									

¹ Measured pH levels were corrected for temporal drift to account for ongoing equilibration of the pH sensor.

² Values enclosed in boxes were significantly lower than the mean of other pH measurements at the same depth.

Table B-7. Uncorrected pH¹ on 14 January 2005

Depth (m)	Alkalinity (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5			7.801	7.832	7.828	7.828								7.850	7.842	
1.0	7.846	7.846	7.801	7.832	7.828	7.828	7.869	7.871	7.865	7.856	7.860		7.869	7.851	7.842	7.869
1.5	7.846	7.846	7.801	7.832	7.828	7.828	7.869	7.871	7.865	7.856	7.860	7.864	7.869	7.851	7.842	7.869
2.0	7.846	7.846	7.801	7.832	7.828	7.828	7.869	7.871	7.865	7.855	7.860	7.865	7.869	7.853	7.842	7.869
2.5	7.846	7.846	7.801	7.832	7.828	7.828	7.869	7.869	7.864	7.855	7.860	7.865	7.869	7.853	7.842	7.869
3.0	7.846	7.846	7.801	7.832	7.828	7.828	7.869	7.869	7.864	7.855	7.860	7.864	7.869	7.852	7.842	7.869
3.5	7.845	7.846	7.801	7.832	7.828	7.828	7.869	7.872	7.868	7.856	7.862	7.864	7.869	7.854	7.842	7.869
4.0	7.845	7.846	7.801	7.832	7.828	7.828	7.869	7.870	7.869	7.855	7.864	7.864	7.870	7.851	7.841	7.869
4.5	7.841	7.846	7.801	7.832	7.828	7.828	7.869	7.873	7.869	7.860	7.864	7.864	7.872	7.855	7.840	7.871
5.0	7.842	7.846	7.801	7.832	7.828	7.828	7.869	7.871	7.869	7.861	7.864	7.868	7.873	7.852	7.836	7.873
5.5	7.841	7.846	7.801	7.832	7.828	7.828	7.869	7.873	7.870	7.865	7.864	7.869	7.873	7.850	7.837	7.873
6.0	7.841	7.846	7.802	7.832	7.828	7.828	7.869	7.873	7.869	7.866	7.864	7.869	7.873	7.854	7.837	7.873
6.5	7.841	7.846	7.802	7.832	7.828	7.828	7.869	7.871	7.873	7.868	7.864	7.869	7.873	7.850	7.837	7.873
7.0	7.841	7.846	7.802	7.832	7.828	7.828	7.871	7.869	7.870	7.869	7.866	7.869	7.873	7.852	7.837	7.873
7.5	7.841	7.846	7.804	7.832	7.828	7.828	7.873	7.869	7.871	7.869	7.864	7.869	7.873	7.851	7.837	7.873
8.0	7.841	7.846	7.804	7.832	7.828	7.828	7.872	7.864	7.873	7.869	7.869	7.869	7.873	7.852	7.837	7.873
8.5	7.842	7.846	7.805	7.832	7.828	7.828	7.871	7.866	7.872	7.869	7.866	7.869	7.873	7.853	7.837	7.873
9.0	7.842	7.846	7.805	7.832	7.828	7.827	7.873	7.864	7.873	7.869	7.867	7.869	7.873	7.855	7.837	7.873
9.5	7.842	7.846	7.805	7.832	7.83	7.823	7.872	7.865	7.872	7.869	7.867	7.869	7.873	7.855	7.837	7.873
10.0	7.842	7.849	7.805	7.832	7.823	7.822	7.871	7.864	7.873	7.869	7.867	7.869	7.873	7.855	7.837	7.873
10.5	7.838	7.847	7.805	7.834	7.824	7.819	7.872	7.864	7.873	7.867	7.866	7.869	7.873	7.855	7.837	7.873
11.0	7.833	7.841	7.805	7.837	7.819	7.813	7.872	7.864	7.872	7.864	7.868	7.869	7.873	7.855	7.837	7.873
11.5	7.828	7.833	7.808	7.836	7.817	7.810	7.873	7.864	7.872	7.864	7.867	7.869	7.873	7.851	7.837	7.873
12.0	7.826	7.830	7.805	7.837	7.814	7.806	7.873	7.864	7.873	7.864	7.864	7.869	7.873	7.849	7.837	7.873
12.5	7.820	7.823	7.805	7.833	7.810	7.805	7.873	7.864	7.873	7.864	7.864	7.869	7.873	7.847	7.836	7.874
13.0	7.819	7.824	7.805	7.830	7.806	7.801	7.873	7.865	7.872	7.864	7.860	7.865	7.874	7.845	7.832	7.868
13.5	7.818	7.822	7.806	7.826	7.804	7.801	7.870	7.868	7.870	7.861	7.853	7.863	7.871	7.840	7.829	7.869
14.0	7.815	7.819	7.806	7.824	7.801	7.797	7.870	7.864	7.869	7.856	7.851	7.857	7.869	7.838	7.824	7.866
14.5	7.815	7.819	7.806	7.820	7.801	7.796	7.869	7.864	7.866	7.854	7.845	7.850	7.865	7.833	7.824	7.860
15.0	7.815	7.816	7.806	7.817	7.799	7.795	7.869	7.860	7.861	7.850	7.841		7.860	7.831	7.824	7.856
15.5	7.815	7.815	7.806	7.815	7.796	7.794	7.867	7.856	7.855	7.846			7.856	7.829		7.851
16.0							7.861	7.851	7.851	7.840			7.855	7.825		
16.5							7.857	7.848	7.846				7.849			
17.0							7.851	7.841					7.846			
17.5							7.844									

¹ Values enclosed in boxes were significantly different than the mean of other measurements at the same depth.

Table B-8. Ancillary Observations on 14 January 2005 during the Receiving-Water Survey

Station	Location		Diffuser Distance (m)	Time (PST)	Air Temperature (°C)	Cloud Cover (%)	Wind Avg (kt)	Wind Max (kt)	Wind Dir (from) (°T)	Swell Ht/Dir (ft/°T)	Secchi Depth (m)
	Latitude	Longitude									
1	35°23.2487' N	120°52.5178' W	94.2	08:06:20	9.9	0	7.2	13.6	43	<1 WNW	6.0
2	35°23.2265' N	120°52.5157' W	53.8	08:01:46	10.0	0	8.0	11.4		<1 WNW	7.0
3	35°23.2106' N	120°52.5036' W	21.5	07:54:49	10.0	0	6.0	10.7	3	<1 WNW	8.0
4	35°23.1911' N	120°52.5041' W	14.5	07:48:26	10.0	0	6.3	7.5	13	<1 WNW	6.5
5	35°23.1651' N	120°52.5015' W	62.7	07:42:31	9.8	0	6.9	11.7	13	<1 WNW	6.5
6	35°23.1335' N	120°52.5175' W	122.8	07:38:05	9.6	0	7.4	12.6	13	<1 WNW	6.5
7	35°23.1919' N	120°52.5787' W	113.6	09:16:56	11.5	0	9.7	13.2	83	<1 WNW	5.0
8	35°23.1962' N	120°52.5436' W	59.9	09:21:05	12.3	0	4.8	11.0	53	<1 WNW	5.5
9	35°23.1962' N	120°52.5178' W	21.2	09:27:16	12.0	0	3.7	6.3	53	<1 WNW	5.0
10	35°23.1937' N	120°52.4941' W	18.2	09:34:01	12.3	0	4.9	5.7	53	<1 WNW	5.0
11	35°23.1970' N	120°52.4663' W	57.6	09:39:01	14.3	0	1.1	2.4	53	<1 WNW	5.5
12	35°23.2008' N	120°52.4371' W	101.6	09:42:44	14.7	0	1.9	4.0	283	<1 WNW	5.0
13	35°23.1770' N	120°52.5329' W	59.4	09:51:59							4.5
14	35°23.2230' N	120°52.5343' W	63.7	08:19:39	11.6	0	8.2	5.2	83	<1 WNW	7.3
15	35°23.2161' N	120°52.4797' W	48.9	08:14:07	10.1	0	6.1	12.0	73	<1 WNW	7.3
16	35°23.1739' N	120°52.4775' W	61.6	09:48:21	12.3	0	3.8	4.6	253	<1 WNW	4.5

There was no visual expression of the effluent plume at the sea surface. Neither odors nor debris of sewage origin were observed at any time during the survey.

Tidal Conditions (Pacific Standard Time)

High Tide: 01:25 4.27 ft
 Low Tide: 06:45 1.80 ft
 High Tide: 12:37 4.92 ft
 Low Tide: 19:29 -0.17 ft