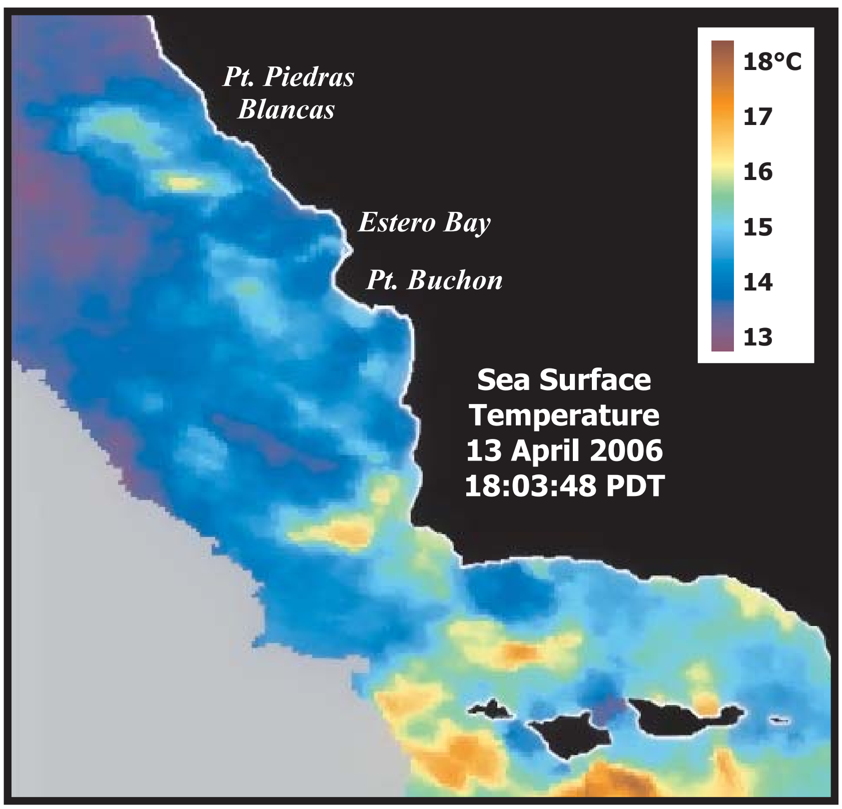
City of Morro Bay and
Cayucos Sanitary District

OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING APRIL 2006 SURVEY



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Report to

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QUARTERLY REPORT

WATER-COLUMN SAMPLING APRIL 2006

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May 2006

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

30 May 2006

Reference: Quarterly Receiving-Water Report – April 2006

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on 11 April 2006. This second-quarter survey assessed the effectiveness of effluent dispersion during spring 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.

High-precision measurements clearly delineated discharge-related perturbations in four seawater properties very close to a diffuser port. Small, highly localized anomalies in salinity, density, temperature, and turbidity documented rapid mixing within the turbulent jet shortly after discharge. A much more diffuse signature of the effluent plume was also detected at two other locations, one within and another beyond the zone of initial dilution. 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.
Program 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.

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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). This current 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 the current discharge permit (RWQCB 1998).

As part of the current 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 results of water-quality sampling conducted on 11 April 2006. Specifically, this second-quarter survey was conducted in April to capture ambient oceanographic conditions along the central California coast during the spring season.

The water-quality surveys also provide timely assessments 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 in the April 2006 field survey.

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 April 2006 field survey was the thirtieth 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 current sampling design also allowed surveying to be conducted more rapidly than previous surveys by eliminating the requirement for the time-consuming collection of discrete water samples using Niskin bottles. Continuous deployment of the CTD[1] instrument package between stations now provides a more synoptic snapshot of the water properties immediately surrounding the diffuser structure. Consequently,

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

the extent 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 current sampling design in 1999, the presence of well-mixed effluent near the diffuser structure was found in all 30 of the subsequent water-quality surveys (MRS 2000, 2001, 2002, 2003, 2004, 2005, 2006), 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. Additionally, the amplitudes of the effluent-related perturbations can be better determined by the denser sampling pattern. The amplitudes of discharge-related salinity anomalies reveal the details of dilution as the effluent plume disperses within receiving waters. Measured dilution factors lend insight into the current 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 April 2006 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 827 m from the shoreline[2]. 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 an 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 somewhat arbitrarily defined to be 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

[2] This distance was determined from a navigational survey conducted on 6 July 2005 to benchmark the locations of the current surfzone sampling stations along the shoreline adjacent to the diffuser structure. The beginning of the section of the diffuser structure containing open diffuser ports lies directly offshore surfzone Station C (Figure 1). This closest-approach shoreline position was determined at the water's edge when the tidal level was +2.7 ft, referenced to mean lower low water (MLLW).

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

and estuaries, are too distant to be affected by the effluent discharge. For example, the southern boundary of the Monterey Bay National Marine Sanctuary is located 38 km to the north, near Cambria Rock.

Similarly, 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.

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 827 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 occasional instances of elevated beach coliform levels result from onshore non-point sources rather than the discharge of disinfected wastewater from the MBCSD outfall (MRS 2000, 2001, 2002, 2003, 2004, 2005, 2006).

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 m 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	Shoreward ZID	35° 23.199' N	120° 52.489' W	15.0	23
11	Shoreward Nearfield	35° 23.199' N	120° 52.464' W	46.7	60
12	Shoreward 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

[1] Distance to the closest open diffuser port.
[2] Distance to the center of open diffuser section.

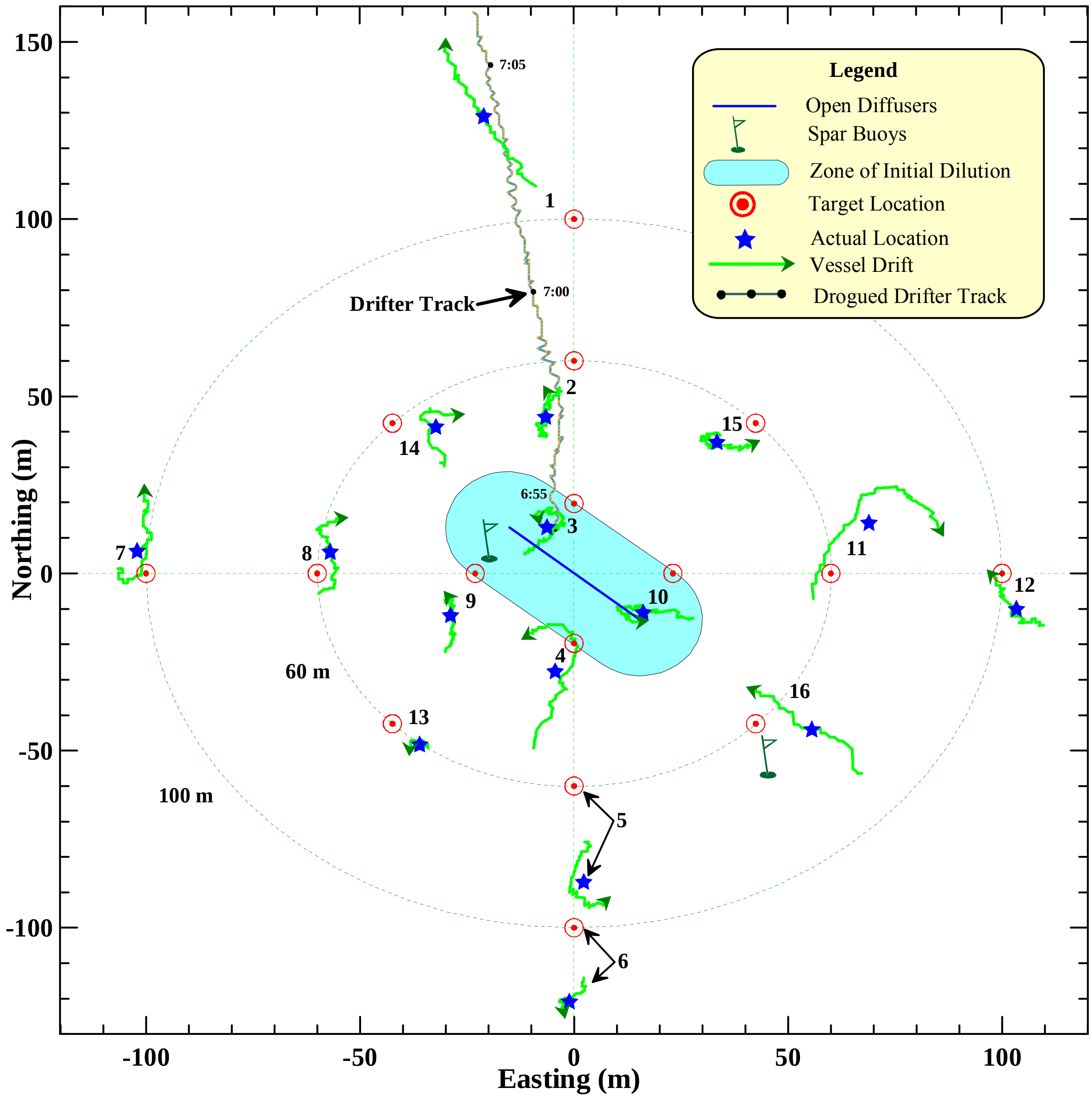

Figure 2. Offshore Water Sampling Locations on 11 April 2006

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 is an important consideration 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 normally cited in modeling studies (Table 1).

Station positioning within the compact sampling pattern specified in the current permit 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 equal to the total 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 m, although it altered most measurements by less than 30 m. 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 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 2 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.

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 during the April 2006 survey 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. Their length reflects the station-keeping difficulty experienced during the survey. The particularly severe drift of the CTD instrument package during the April-2006 survey was due to larger-than-normal wind- and current-induced vessel drift. For the second time since MRS began monitoring in July 1993, the vessel had to be dynamically positioned[3] to acquire CTD readings near the target station. The resulting CTD tracklines shown in Figure 2 reveal a complex pattern of lateral drift during the vertical casts conducted at most stations. During the time it took the CTD to traverse the water column to the seafloor, which averaged 1m 27s, the instrument package moved an average of 18 m laterally.

[3] Dynamic positioning or "*live boating*" is a method of maintaining a vessel in a fixed position by using her own propellers and thrusters. This allows operations at sea where mooring or anchoring is not feasible due to deep water, strong winds, or very short-term occupation of stations.

At stations close to the diffuser structure, this horizontal drift in the position of the CTD complicates the assessment of compliance with discharge limitations. Receiving-water limitations specified in the COP only apply to measurements recorded beyond the ZID boundary. Within the ZID, rapid turbulent mixing associated with the momentum of the effluent jet and the rise of the buoyant plume is expected, and the limitations apply to conditions after this initial mixing has occurred. Specifically, the vertical cast at Station 4 traversed the boundary of the ZID (Figure 2). Thus, strictly speaking, only a portion of the data recorded during that cast is subject to the receiving-water limitations specified in the NPDES discharge permit. Additionally, none of the measurements recorded at Stations 3 and 10 are subject to the limitations because the CTD was well within the ZID boundary throughout the entire vertical cast at those stations.

Compliance assessments notwithstanding, measurements recorded close to the diffuser structure within the ZID lend valuable insight into the outfall's effectiveness at dispersing wastewater during this particular survey. Damaged or broken diffuser ports would be reflected by low dilution rates and measurements of concentrated effluent throughout ZID. Without measurements recorded 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 now in use was instituted.

Surveys prior to 1999 also predated the advent of DGPS. Consequently, the 18 m average drift experienced during sampling at individual stations would not have been fully resolved with the navigation available at the time. In fact, before 1999 sampling was presumed to occur at a single, imprecisely determined, horizontal location near each station. For consistency with past surveys, a single reportable sampling location was also determined for each station during the April 2006 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 discharge permit. For example, the 24 m closest-approach distance specified for Station 4 would suggest that all of the data at that station was collected outside of the ZID. In reality, as shown by the green trackline in Figure 2, some of the deeper measurements at that station were recorded within the ZID, where water-quality limitations do not apply.

The vessel drift indicted by the green tracklines in Figure 2 was dictated by the complex interaction of winds, currents, and vessel maneuvering that was used to relocate the vessel near the station's target position. As summarized in Table B-8, strong winds out of the south prevailed throughout the survey. This along with a strong northward current made vessel positioning a constant struggle. The strong northward current velocity is apparent from the track of the drogued drifter that was deployed near the diffuser structure at 06:55 PST. The grey line with black dots shown in Figure 2 traces the path of the satellite-tracked drifter. The drifter is designed to track the subsurface current, with little influence from the wind. Each dot along the drifter trackline represents a five-minute interval. The drifter was recovered an 45 minutes later, at 07:40 PST. It had traveled 224 m toward the north-northwest (309°T) at an average speed of 8.1 cm/s or 0.16 knots.

The northward flow that was measured by the drogued drifter is consistent with the flood tide that prevailed during the survey (Figure 3). Normally a flood tide induces a weak northeastward flow in the survey region. However, tidal flow was augmented by a regional northward-directed flow that prevailed along this section of the central coast during the week of the survey. These wind-driven northward coastal flows are reflected in the satellite image shown on the cover of this report. The image was recorded two days after the survey when skies were clear enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA's polar orbiting satellites.

Table 2. Average Coordinates of Vertical Profiles during the April 2006 Survey

	Time (PST)				Closest Approach	
Station	Downcast	Upcast	Latitude	Longitude	Range[1](m)	Bearing[2](°T)
1	7:06:48	7:08:47	35° 23.269' N	120° 52.518' W	116.4	357
2	7:14:27	7:16:06	35° 23.223' N	120° 52.508' W	32.5	15
3	7:21:03	7:22:26	35° 23.206' N	120° 52.508' W	**5.9**[3]	41
4	7:25:54	7:27:36	35° 23.184' N	120° 52.507' W	**23.8**[4]	221
5	7:30:23	7:31:33	35° 23.152' N	120° 52.503' W	75.1	190
6	7:34:32	7:35:42	35° 23.134' N	120° 52.505' W	109.0	189
7	7:59:23	8:01:19	35° 23.203' N	120° 52.571' W	87.1	266
8	8:03:37	8:04:45	35° 23.202' N	120° 52.542' W	42.4	261
9	8:06:49	8:08:01	35° 23.193' N	120° 52.523' W	27.6	221
10	8:10:42	8:12:28	35° 23.193' N	120° 52.493' W	**2.2**[3]	221
11	8:14:20	8:15:44	35° 23.207' N	120° 52.459' W	60.3	63
12	8:18:23	8:19:38	35° 23.194' N	120° 52.436' W	88.3	88
13	8:26:28	8:27:40	35° 23.173' N	120° 52.528' W	60.0	221
14	8:30:00	8:31:20	35° 23.221' N	120° 52.525' W	33.4	329
15	8:35:09	8:36:43	35° 23.219' N	120° 52.482' W	50.0	41
16	8:22:44	8:24:12	35° 23.175' N	120° 52.467' W	50.9	127

[1] Distance from the closest open diffuser port. 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] All of the CTD cast was within the ZID boundary.
[4] Portions of the CTD (Conductivity-Temperature-Depth) cast were within the ZID boundary.

Southward-directed winds normally prevail throughout much of the year along the Central California Coast. Those winds drive surface waters southward and offshore. To replace coastal waters driven offshore by the winds; deep, cool, nutrient-rich waters are upwelled near the coast. This upwelling typically results in a highly stratified water column near the coast that persists throughout the spring and summer months. The nutrient-rich seawater that is brought to the sea surface by upwelling enables phytoplanktonic blooms that are the foundation of the productive marine fishery found along the central California coast. The cross-shore flow associated with persistent upwelling conditions also leads to

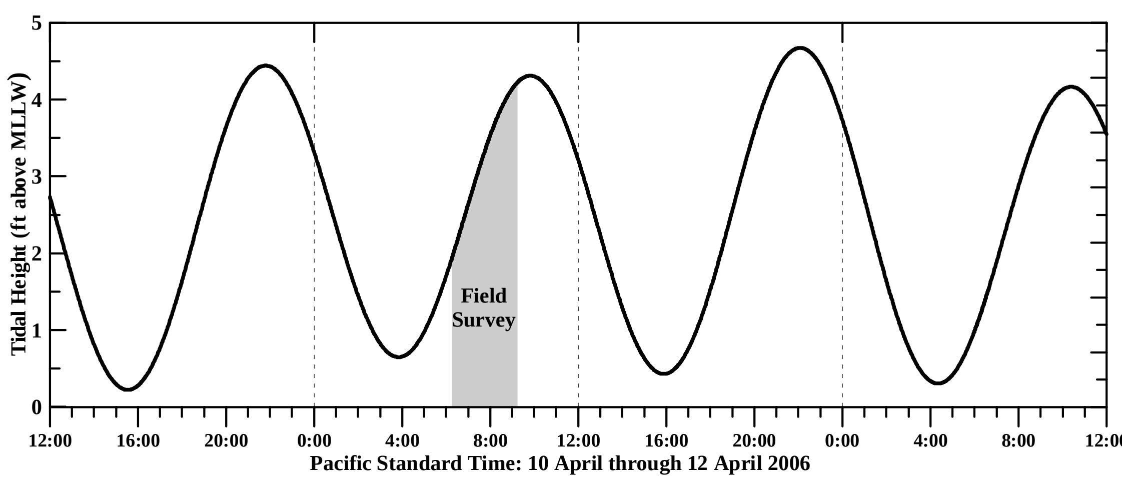

Figure 3. Estero Bay Tidal Level during the Field Survey of 11 April 2006

vertical stratification of the water column.

However, in April 2006, the winds were predominately northerly-directed, allowing northward-flowing currents to intensify near the coast, and resulting in a relatively unstratified water column more typically associated with winter oceanographic conditions. During winter, the water column is generally vertically uniform, having been well mixed by intense winds generated by passing local storm fronts and large waves produced in distant Pacific storms. This was also the case during the April 2006 survey, which occurred during a brief window between two late-season storms. The northerly coastal flow can be seen in the light tan features extending westward and then northward from the Santa Barbara Channel on the cover of this report. The satellite image also shows that because of the lack of coastal upwelling, sea-surface temperatures were higher than usual for this time of year, around 13°C within Estero Bay. This is consistent with the near-surface temperatures measured by the CTD during the survey, which were around 13.3°C as shown in Table B-1 in Appendix B.

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 11 April 2006. Dr. Douglas Coats and Ms. Bonnie Luke of Marine Research Specialists (MRS) provided scientific support. Captain Mark Tognazzini supervised vessel operations, while Mr. Bill Skok 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-8). 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 plankton blooms, 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. Secchi depths of between 6 m and 6.5 m that were observed during the April 2006 survey are typical of the unstratified conditions that prevailed during the survey.

Secchi depths are less precise than measurements recorded 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 general 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.

During the April 2006 survey, a satellite-tracked drifter was deployed near 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 April 2006 survey was the sixth 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 April 2006 survey, the added satellite-tracking capability of the drifter revealed some curvature in the path of the drifter and changes in its speed as shown in Figure 2. Drifter data collected in most prior surveys lacked information on this and other 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 April 2006 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.

Prolonged equilibration times 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 April 2006 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 markedly reduced their amplitude. The required pH adjustments were small, and did not exceed 0.079 pH units.

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, 8±0.01and 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 an 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.

Table 3. Instrumental Specifications for CTD Profiler

Component	Depth[1]	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	ºC	–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

Temporal Trends in the pH Sensor

The pH sensor exhibited a slight temporal drift during the April 2006 survey. Perceptible drift in pH measurements has been consistently observed in prior water-quality surveys as the 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 during the middle of the survey. 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 six minutes at the beginning of a survey were found to reduce but not entirely eliminate sensor drift. During the April 2006 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 beginning of the CTD deployment. The pH measurements at the first station (1) averaged 0.079 pH units lower than the measurements recorded later in the deployments. Comparison with Table 3 shows that this artificial reduction in measured pH is smaller than the instrumental accuracy (± 0.1 pH). However, it is larger than the instrumental resolution (±0.006 pH). As a result, slight artificial differences are embedded in the measurements reported at Stations 1, 14, and 15 in Table B-7. Statistically significant anomalies are indicated by values listed in bold typeface and enclosed in a box. Station 1 was the first station occupied during the survey, and Stations 14 and 15 were the last stations. These stations required the largest adjustments for sensor drift. Temporal detrending at these and other stations removed most of the instrumental anomalies, and the results are tabulated in Table B-6. The temporal correction did not eliminate the reduced dynamic range of the pH probe at the beginning of the survey. As a result, very slight (0.008 pH) but statistically significant departures from mean conditions were generated by the analysis near the seafloor at Stations 1 and 2 in Table B-6. This was largely because the overall range in pH was small during the April-2005 survey, causing even slight differences in the pH measurements to become relatively important.

RESULTS

The water-quality survey for the second quarter of 2006 began on Tuesday, 11 April 2006, at 06:55 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 06:36 PST; however, skies were overcast throughout the survey, which ended at 09:40 PST when the vessel arrived back at port. Light rain showers occurred during the latter portion of the survey. Average wind speeds, calculated over one-minute intervals, were moderate throughout the survey and ranged from approximately 1.0 kt to 6.6 kt, with peak speeds ranging from 5.0 kt to 10.5 kt. A 4 ft swell moved through the survey area from the southwest. Atmospheric visibility was greater than 2 nM along the ocean surface owing to the absence of low-lying fog. Morro Rock and the shoreline remained visible throughout the survey. Air temperatures remained stable at 13.0°C to 13.5°C during the course of the survey. The surface seawater temperature (13.3°C) in the survey area was comparable to 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 readily visible near the sea surface at any time during the survey. Throughout the survey, there was also no visual evidence of floating particulates, oil and grease, or seawater discoloration associated with the discharge.

Beneficial Use

During the April 2006 survey, observations of beneficial use demonstrated that the coastal waters in the outfall vicinity continued to be utilized by wildlife and for recreation. Surf scoters (*Melanitta perspicillata*), California brown pelicans (*Pelecanus occidentalis californicus),* and western gulls (*Larus occidentalis*) were all observed transiting through or resting near the survey area. Surf scoters are common along the Pacific coast in late winter and usually stay some distance from shore, feeding on shellfish. The males are distinguished by a bright red-orange pattern on their bill. In addition to bird life, a southern sea otter (*Enhydra lutris*) was observed on the sea surface 100 m northwest of the survey area. Owing to the inclement weather conditions, no other vessels were observed near the survey area during the course of the survey, nor were there pedestrians seen utilizing Atascadero Beach. No other evidence of beneficial use of receiving waters was noted during the survey.

Ambient Seawater Properties

Data collected during the April-2006 survey reflect the exceptionally uniform, unstratified conditions that are indicative of a well-mixed water column. The vertically uniform seawater properties were generated by convective cooling and mechanical stirring from winds and waves. Seawater temperatures averaged over the entire water column were higher than usual because of the absence of upwelling conditions. Spring oceanographic conditions normally consist of persistent and strong upwelling, which brings cool deep offshore waters toward the coast. The influx of cool seawater results in strong thermal stratification and cooler overall seawater temperatures near the coast. However, during the downwelling conditions that prevailed around the time of the April 2006 survey, receiving waters exhibit little vertical stratification. Under these unstratified conditions, there is little to inhibit the vertical exchange of nutrients and other water properties. Consequently, water parcels move easily through the water column and the associated mixing enhances the dilution of contaminants introduced by seafloor point sources such as an ocean outfall.

The unstratified conditions that were present during the 11-April survey are reflected in the vertical profiles shown in Figures A-1 through A-3 where all the seawater properties except transmissivity (light blue line in the middle of the profiles) are nearly constant with depth. Unstratified conditions are also evident in the vertical sections of Figures A-4 through A-7, where the range in measurements shown in the scales to the right of the sections is exceedingly small. The only exceptions are the scales for salinity and density in Figure A-6 because they encompass larger excursions within the effluent plume near the seafloor at Station 10. Near-surface salinity and density measurements were also slightly reduced at some stations due to the presence of pools of turbid freshwater (green and black lines on the right of the profiles in Figures A-1 through A-3). These pools were generated by coastal runoff from rainfall that occurred along the Central California Coast in the days prior to, and during the survey. The presence of these freshwater pools is reflected in the vertical profiles as a near-surface reduction in salinity, density, and transmissivity. Except for these slight reductions in near-surface transmissivity, salinity, and density, there was no evidence of horizontal layers that would be indicative of heavily stratified conditions. The uniformity of the thermal structure is particularly noteworthy and indicative of downwelling conditions.

In contrast to other seawater properties measured during the April 2006 survey, water clarity (transmissivity) also exhibited a distinctive reduction in transmissivity near the seafloor at all the stations (light blue line in Figures A-1 through A-3). In combination with the near-surface reduction in water clarity, the seafloor decline in transmissivity creates a mid-depth maximum in transmissivity. This mid-depth increase in water clarity can be seen as a bluish-white area in the vertical sections shown in the top frames of Figures A-5 and A-7. As with the near-surface reduction in transmissivity, the decline near the seafloor is a product of natural processes. The decreased water clarity near the seafloor results from resuspension of surficial sediments. Resuspension within a near-bottom boundary layer is driven by energetic benthic currents coupled with oscillatory motions generated by surface gravity waves. Wave climate is more intense during the stormy periods, and increased seafloor turbidity is its hallmark.

Lateral Variability

The influence of the effluent discharge can be best identified from localized anomalies in seawater properties, particularly salinity. These discharge-related anomalies are most evident at mid-depth at Stations 2 and 3 in the top and bottom frames of Figure A-4, and near the seafloor at Station 10 in Figure A-6. In contrast to the vertical profiles, discharge-related anomalies become especially apparent in the vertical sections when seawater properties from the same depth level are compared at adjacent stations. The top frame of Figure A-5 also shows that the mid-depth anomalies in transmissivity at Stations 2 and 3 have the same characteristics as ambient seawater at depth. The transmissivity anomalies are only apparent because deep naturally turbid seawater has been displaced upward into the water column where the surrounding seawater has higher clarity. Because these types of contrasts provide useful tracers of the effluent plume, 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 was statistically evaluated by comparing its amplitude to the natural background variability. Each observation at a particular station was compared with the observations from other stations at the same depth level. Measurements recorded 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 recorded 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, whether measured relative to the sea surface or the 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 April 2006 dataset, several DO observations were found to be statistically significant, but were unrelated to the effluent discharge. In particular, the four isolated anomalies in the upper water column at Stations 5, 7, 13, and 15 were artifacts of a slight instabilities in the oxygen sensor that became apparent only because of the relatively uniform field of ambient DO measurements (Table B-4). These DO anomalies were not spatially coincident with the three discharge-related perturbations discussed below. During most surveys, the vertical variation in DO is much more substantial and the slight DO anomalies would not have been found to be statistically significant.

Even without vertically uniform DO conditions, 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 more than 510 measurements examined for each of the six parameters, it is not surprising that 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 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 April 2006 survey, three perturbations in seawater properties were unequivocally related to the discharge (Perturbations P1, P2, and P3 in Table 4). A discharge-related perturbation is a group of anomalies in one or more seawater properties that are contiguous at a particular station. The vertical distribution of seawater properties within and below the perturbations lends insight into which of two discharge processes were responsible for generating a particular anomaly. As indicated in Table 4, the salinity, density, and thermal anomalies reflect the presence of dilute wastewater, while the transmissivity anomalies were generated by entrainment of naturally turbid seawater within the rising effluent plume.

The salinity and density anomalies associated with the perturbations could not have been generated by the movement of ambient seawater alone. For example, the top frame of Figure A-4 shows that the anomalously low salinity observed at mid-depth at Station 3 was far lower than the ambient seawater at depth. Furthermore, the bottom frame of Figure A-4 shows that the mid-depth reduction in density that coincides with the salinity anomaly was vertically isolated, indicating that the water-parcel with the anomalous properties was highly buoyant, and was in the process of rising through the water column. Similarly, the salinities of less than 32.7‰ that are associated with Perturbation P1 (delineated by green and red in the top frame of Figure A-6) were well below the lowest ambient salinity. The lowest ambient salinity (32.8‰) was measured near the sea surface within relatively freshwater pools of rainwater runoff. The naturally low salinity associated with this rainwater is apparent above 5 m in the top frame of Figure A-4. Note that the two cross-sections employ different salinity scales so the green and red areas in Figure A-4 delineated salinities between 32.8‰ and 32.9‰. These salinity comparisons show that the upward movement of deep ambient seawater cannot account for the observed salinity anomaly associated with Perturbation P2 at Station 3, and any movement, even downwelling could not have accounted for the very low salinity associated with Perturbation P1 near the seafloor at Station 10.

The thermal anomaly associated with Perturbation P1 is particularly diagnostic of the presence of dilute wastewater. The positive thermal anomaly was observed less than 2 m from a discharge port and reflects a 0.13ºC higher temperature than the surrounding seawater near the seafloor. This increase in temperature is opposite of discharge-related thermal anomalies observed in other surveys. Most discharge-related thermal anomalies exhibit lower temperatures than the surrounding seawater. They arise during stratified conditions when cooler ambient seawater at depth is entrained in the rising effluent plume. After being displaced upward, the cooler bottom water is juxtaposed with warmer shallow-water properties, and the contrast becomes apparent as an anomaly. However, entrainment-generated anomalies are dependent on strong vertical gradients in ambient seawater properties. Otherwise, there is no marked difference between the upwardly displaced bottom seawater and shallow seawater. Most surveys exhibit a number of entrainment-generated anomalies in different seawater properties because the surveys are conducted when

Table 4. Discharge-Related Water-Property Anomalies[a]

Perturbation[b]	Station	Depth Range	Depth of Extremum	Property	Magnitude	Process
P1 Dilution≥56:1	10	13.0 to 15.5 m	**15.5 m**	**Salinity**	**–0.581 ‰**	Effluent
		13.0 to 15.5 m	**15.5 m**	**Density**	**–0.476 σ_t**	Effluent
		15.5 m	**15.5 m**	**Temperature**	**+0.13 ºC**	Effluent
		13.0 to 15.5 m	**13.5 m**	**Transmissivity**	**–5.9 %**	Effluent/ Entrainment
P2 Dilution≥245:1	3	9.5 to 12.5 m	**12.0 m**	**Salinity**	**–0.134 ‰**	Effluent
		9.5 to 12.5 m	**12.0 m**	**Density**	**–0.106 σ_t**	Effluent
		9.5 to 12.5 m	9.5 m	Transmissivity	–2.0 %	Entrainment
P3 Dilution≥427:1	2	7.0 to 9.0 m	8.5 m	Salinity	–0.077 ‰	Effluent
		7.0 to 9.0 m	8.5 m	Density	–0.051 σ_t	Effluent
		7.0 to 9.0 m	7.5 m	Transmissivity	–3.9 %	Entrainment

[a] Anomalies shown in bold type were statistically significant
[b] Perturbations consist of a group of spatially consistent anomalies in different seawater properties

the water column is stratified. However, except for transmissivity, entrainment-generated anomalies were notably absent during the April 2006 survey because of the vertical uniformity of most other seawater properties.

During the April 2006 survey, transmissivity was the one seawater property that had different ambient conditions near the seafloor. Because of the comparatively low transmissivity within ambient seawater near the seafloor, mid-depth entrainment-generated anomalies are apparent Stations 2 and 3 (Perturbations P2 and P3 in Table 4 and the top frame of Figure A-5). It is also likely that the transmissivity anomaly within Perturbation P1 at Station 10 was partially generated by entrainment of turbid bottom water (top frame of Figure A-7), particularly since it was located 2 m above the seafloor at a depth that did not coincide with the largest salinity and density anomalies (Table 4). As with the other transmissivity anomalies, it was generated, at least in part, by the upward displacement of naturally turbid bottom water. However, in this case, it is not clear how much of the increased turbidity was induced by the presence of wastewater particulates, and how much was generated by the entrainment of naturally turbid water near the seafloor. In any regard, this transmissivity anomaly was relatively small in amplitude, considering the close proximity of the measurement to the point of discharge. Even though it was statistically significant, it is apparent from the red delineations in the top frame of Figure A-7 that the magnitude was comparable to ambient seawater near the seafloor at Stations 7 and 8.

It is noteworthy that there were no anomalies in DO and pH associated with the high-amplitude effluent-induced Perturbation P1. This supports the hypothesis that the properties of discharged wastewater contribute little to anomalies in DO and pH, and that anomalies in those properties that have been observed in past surveys were generated instead by the upward displacement of ambient waters. In the absence of strong vertical differences in DO and pH during the April 2006 survey, entrainment-generated anomalies were not apparent in those water properties.

Perturbation P1 was measured very close to the discharge and reflects effluent that was continuing to undergo rapid dilution (Station 10 in Figure 2). The large negative density anomaly associated with this perturbation (Table 4) clearly demonstrates that it was highly buoyant and would continue to rise through the water column. This is also apparent in the vertical density section shown in the bottom frame of Figure A-6. The very low-density anomaly near 11 m (delineated in red) is situated just below a water parcel of more dense seawater (shown in blue). This kind of density inversion reflects a strong buoyancy instability that is never seen under natural conditions in the ocean because it would be rapidly dissipated during turbulent overturn. Rapid turbulent overturn is expected to occur with the discharge-induced perturbation, resulting in substantial additional dilution. Thus, Perturbation P1 captured conditions within the turbulent jet immediately after discharge and measures the early stages of the dilution process before buoyancy induced mixing has played a significant role in dilution.

In contrast, the other two perturbations (P2 and P3) reflect conditions after the plume has risen through the water column and accordingly, the salinity anomalies are far smaller, as are the associated negative density anomalies. Nevertheless, the negative density anomalies associated with Perturbations P2 and P3 are indicative of a plume that has yet to reach buoyant equilibrium. This is particularly noteworthy because Perturbation P3 at Station 2 lies well outside of the ZID (Figure 2), where buoyancy induced dilution is normally thought to be complete. However, the location of the perturbation is consistent with transport by the strong northward current that prevailed during the survey. This current carried the plume at least 35 m beyond the ZID, where it still had not achieved buoyant equilibrium. However, at this point, the plume was too dilute to generated statistically significant departures from mean condition for any of the seawater properties (none of the entries for Perturbation P3 are shown in bold in Table 4).

Initial Dilution Computations

The amplitude of negative salinity anomalies at Stations 2, 3, and 10 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 using highly stratified conditions where the trapping of the plume below the thermocline limited the mixing achieved during the plume's buoyant rise through the water column. The dispersion modeling determined that, after initial mixing was complete, 133 parts of ambient water would have mixed with each part of wastewater. The modeling predicted that this dilution would be achieved after the plume rose only 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.

However, as described below, computations of dilution based on the salinity anomaly within the mid-depth perturbations at Stations 2 and 3 demonstrate that the effluent plume actually achieved a far higher dilution below the predicted trapping depth. More importantly, the deep measurements at Station 10 demonstrate that mixing within the turbulent discharge jet very close to a diffuser port achieved a dilution (56:1) nearly half of the total dilution (133:1) predicted by conservative modeling. Thus, rapid mixing associated with the momentum of the discharge jet alone is capable of achieving much of the dilution predicted by modeling, without even considering the additional dilution that is provided by the buoyant rise of the plume. All of 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 the modeling. Use of a higher critical dilution ratio would relax the stringent end-of-pipe effluent limitations that are 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:

$$C_e \equiv C_o + D\left(C_o - C_s\right)$$ **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 (*i.e.,* the COP objective),
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:

$$D = \frac{-C_o}{\left(C_o - C_s\right)} \equiv \frac{-C_o}{A}$$ **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 32.9‰), and
$A = C_o - C_s$ = the salinity anomaly.

Computed dilutions during the unstratified conditions of the April 2006 survey demonstrate that the modeled dilution factors are more conservative than those actually achieved by the discharge. Specifically, dilutions exceeding 245-fold were measured within the upper water column at Station 3 at a depth nearly twice the 6.4 m trapping depth predicted by modeling. This high measured dilution was computed from Equation 2 using the salinity anomaly (–0.134‰) that was observed at Station 3 within Perturbation P2 (Table 4). The smaller-amplitude salinity anomaly (–0.077‰) observed at the shallower Perturbation P3, yields a higher dilution of over 400-fold. The negative density anomaly that is also associated with this perturbation indicates that buoyancy equilibrium had yet to be reached, and that additional dilution would be expected to occur before equilibrium is reached.

Conversely, the much larger-amplitude salinity anomalies associated with Perturbation P1 at Station 10 only span a short 2.5-m distance above the seafloor. This perturbation was highly localized around the discharge point and yielded dilution ratios in excess of 56:1 (Table 4). This dilution was nearly half of the final dilution (133:1) predicted by modeling after a 9 m rise of the plume through the water column. It demonstrates that the momentum of the discharge jet alone is capable of achieving dilution levels close to the permit-specified dilution ratio, without even considering the additional dilution achieved when the plume reaches equilibrium within the water column. This also explains why the discharge consistently meets receiving water limitations, and why the presence of dilute wastewater particulates is rarely detected in the upper water column, beyond the ZID.

Accordingly, during the April 2006 survey, the next-smallest dilution (245:1) was measured at mid-depths and was nearly twice the 133:1 critical dilution used to establish permitted limitations on contaminant concentrations within wastewater discharged from the MBCSD treatment plant. As the plume rose farther in the water column and approached the trapping depth, the measured dilution was over three-times the dilution predicted by modeling. These dilution computations demonstrate that, during the April 2006 survey, the outfall was performing better than designed, and was rapidly diluting effluent more than 245-

fold within the ZID, and more than 425-fold beyond the ZID. 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 April 2006 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 April 2006 water-quality survey, and the discharge complied with all other numeric limits on seawater properties.

Although statistically significant discharge-related changes in four of the six water properties were observed during the April 2006 survey, the changes were measured very close to a diffuser port, and well within the boundary of the ZID at Stations 3 and 10 (Figure 2). Receiving-water limitations do not apply to measurements within the ZID because the discharged wastewater is thought to be undergoing rapid initial mixing with the surrounding seawater. This was certainly the case for the large anomalies in salinity and density that were associated with Perturbation P1, which was located just above the seafloor, within 2 m of a diffuser port. The very low density associated with this perturbation was indicative of a highly buoyant plume that would undergo significant additional mixing as it rose through the water column.

Accordingly, the amplitude of the shallower salinity anomaly at Station 2 (Perturbation P3) was much smaller than those associated with the Perturbations P1 and P2, which were located within the ZID. This small-amplitude salinity anomaly indicates that buoyancy-induced mixing had increased dilution by more than seven-fold relative to the dilution measured within the turbulent jet. Accordingly, none of the anomalies in salinity, density, and transmissivity were found to be statistically significant beyond the ZID at Station 2. Furthermore, the shallow anomaly in transmissivity was generated by the upward displacement of turbid deep ambient seawater that was entrained by the rising effluent plume. This is an important consideration because seawater limitations promulgated in the COP restrict attention to changes caused by the presence of waste materials, not the movement of ambient seawater.

Outfall Performance

The large salinity anomaly measured in the turbulent ejection jet close to a diffuser port demonstrated that the receiving-water objectives of the COP were being met at depth, well within the ZID. These high-precision observations demonstrated that the turbulent jet was achieving dilutions approaching the minimum critical dilution of 133:1 within a few meters of the discharge. Thus, the dilution objective was nearly achieved without consideration of the substantial additional dilution provided by the buoyant plume's subsequent rise through the water column. With the added buoyancy-induced mixing, measured dilutions increased seven fold, to at least 427:1. All of these high-precision observations demonstrated that the diffuser structure was operating better than predicted by modeling, and that the discharged wastewater experienced high levels of dilution well within the ZID. With the higher dilution ratio (427:1) that was determined from actual measurements during the April 2006 survey, contaminant concentrations within the wastewater could have been more than triple 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 April 2006 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 the following events to occur.

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-7, 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 (Sokal and Rohlf 1997, p228; 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

Based on the statistical analysis, there was only one station where significant reductions in instrumentally recorded light transmittance were found. Table B-5 shows two significant transmissivity decreases near the seafloor at Station 10. However, Station 10 lies within the ZID where the COP limitation does not apply. Furthermore, the transmissivity anomaly was observed at depth where little natural light penetrates. The shallowest transmissivity anomaly was located at 13.5 m, which is below the 13-m euphotic zone (twice the maximum Secchi depth of 6.5 m listed in Table B-8). Thus, the presence of this "*significant*" transmissivity anomaly could not have caused a significant "*…reduction in the transmittance of natural light….*" The other two discharge-related transmissivity anomalies were not statistically significant and were not generated "*…as the result of the discharge of waste*" (SWRCB 1997). Instead, the turbidity anomalies in the mid-water column associated with Perturbations P2 and P3 were generated by the upward movement of ambient seawater, not the presence of wastewater particulates.

Dissolved Oxygen

Although it is not explicitly 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*." None of the four significant DO reductions identified at Stations 5, 7, 13, and 15 (Table B-4) by the statistical analysis spatially coincides with the three discharge-induced perturbations at Stations 2, 3, and 10. Instead, the random reductions in DO caused by the instability in the sensor that only became apparent because DO was comparatively uniform during the April-2006 survey. Thus, the slightly reduced DO concentrations observed in the upper water column were not the result of the discharge of oxygen-demanding material, and would not be subject to the COP limitations for that reason alone. Even so, all of the apparently significant DO anomalies complied with the numerical limits specified in the permit. Specifically, none of the DO concentrations measured during the survey fell below the 5 mg/L minimum specified in the Basin Plan and the NPDES discharge permit (Table B-4). Similarly, the DO concentrations measured within the anomalies, which were depressed by less than 0.2 mg/L compared to the average 8.25 mg/L, were too small"*…to be depressed more than 10 percent from that which occurs naturally*."

pH

As with the DO anomalies, none of the statistically significant pH anomalies found in the April 2006 survey coincided with discharge-related perturbations. Instead, because of the uniform pH field, the slight anomalies in pH that were found near the seafloor at Stations 1 and 2 were due to the incomplete equilibration of the pH sensor. Regardless of their source, all of the pH anomalies complied with the numerical limits specified in the permit. Namely, the range in pH among all of the measurements was only 0.02 pH units, 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 8.161 and 8.182, 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 0.22ºC across all observations was very small compared to the normal range in temperature that normally occurs because of 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….*' For example, the observed 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. The small, highly localized, discharge-induced increase in temperature (0.13ºC), which is visually apparent near the seafloor at Station 10 in the cross-shore vertical section, resulted from the presence of warm dilute wastewater. Nevertheless, the temperature of 13.34ºC measured within the anomaly was lower than the maximum temperature of 13.40ºC that was measured in ambient seawater 5 m below the sea surface at Station 4 (Table B-1).

Although salinity anomalies provide the best tracer of discharged effluent, their actual amplitude (0.581‰) was small compared to seasonal and spatial differences in salinity that occur along the south-central California coast. For example, in 2005, the difference in average salinity between the April and July survey was 0.64‰. In any regard, the observed range in both the measured temperature (0.22ºC) and salinity (0.59‰) across all data collected during the April 2006 survey was too small to be considered harmful to marine biota or deleterious to beneficial uses.

Conclusions

All of the measurements recorded during the April 2006 survey complied with the receiving-water limitations specified in the NPDES discharge permit. The discharge-related anomalies that were found just above the seafloor at Station 10 were caused by the presence of dilute effluent within 2 m of a discharge port. Salinity measurements demonstrated that discharged wastewater was undergoing rapid mixing of more than 50-fold within the turbulent discharge jet. The dilution levels achieved by the momentum of the jet alone immediately after discharge were nearly half of those predicted by modeling for the entire dilution process. Measurements within the effluent plume recorded at mid-depth beyond the ZID demonstrated a dilution of more than 400-fold. These measurements confirmed that the diffuser structure and the outfall were operating better than would be expected from the modeling.

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APPENDIX A

Water Quality Profiles and Vertical Sections

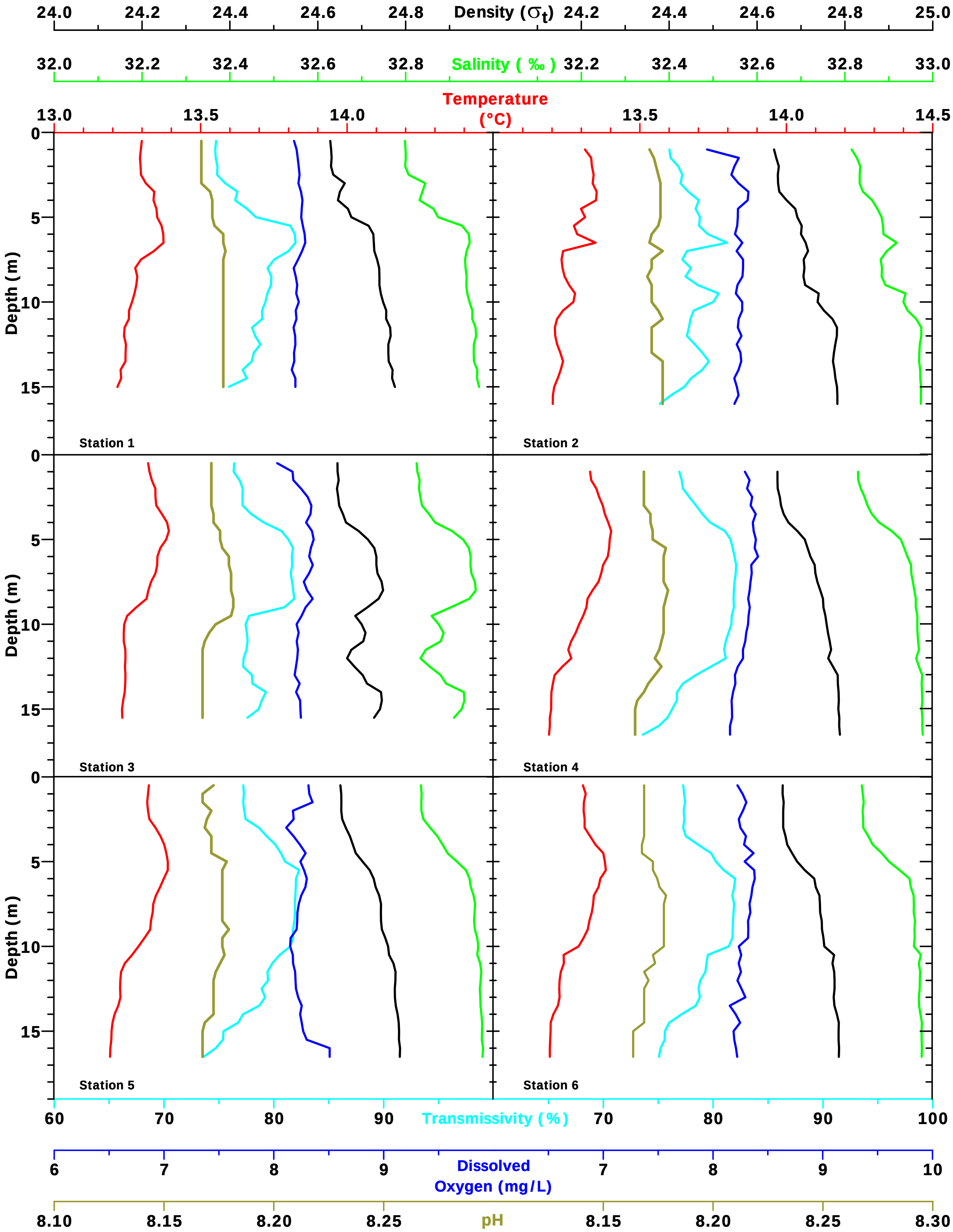

Figure A-1. Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 11 April 2006

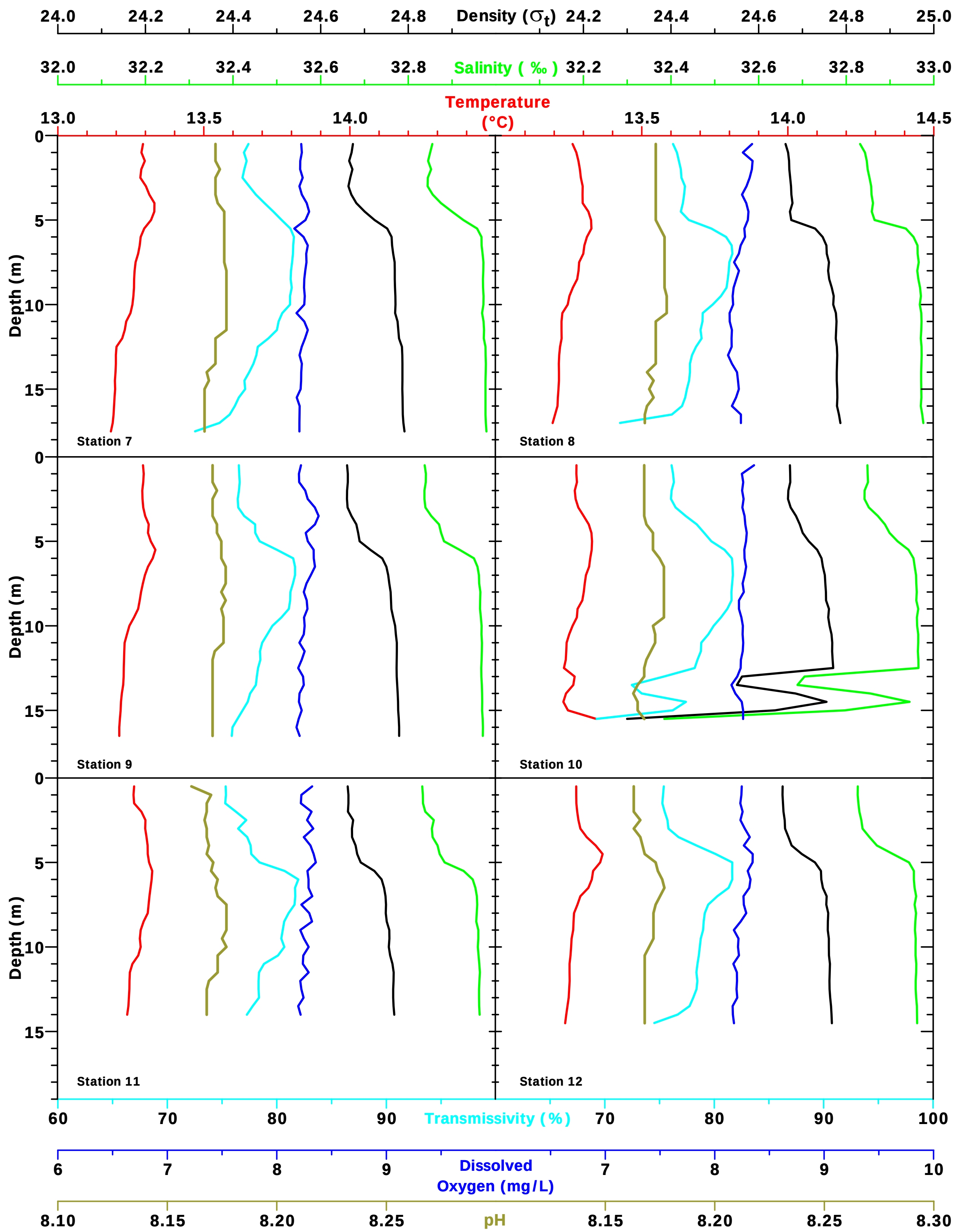

Figure A-2. Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 11 April 2006

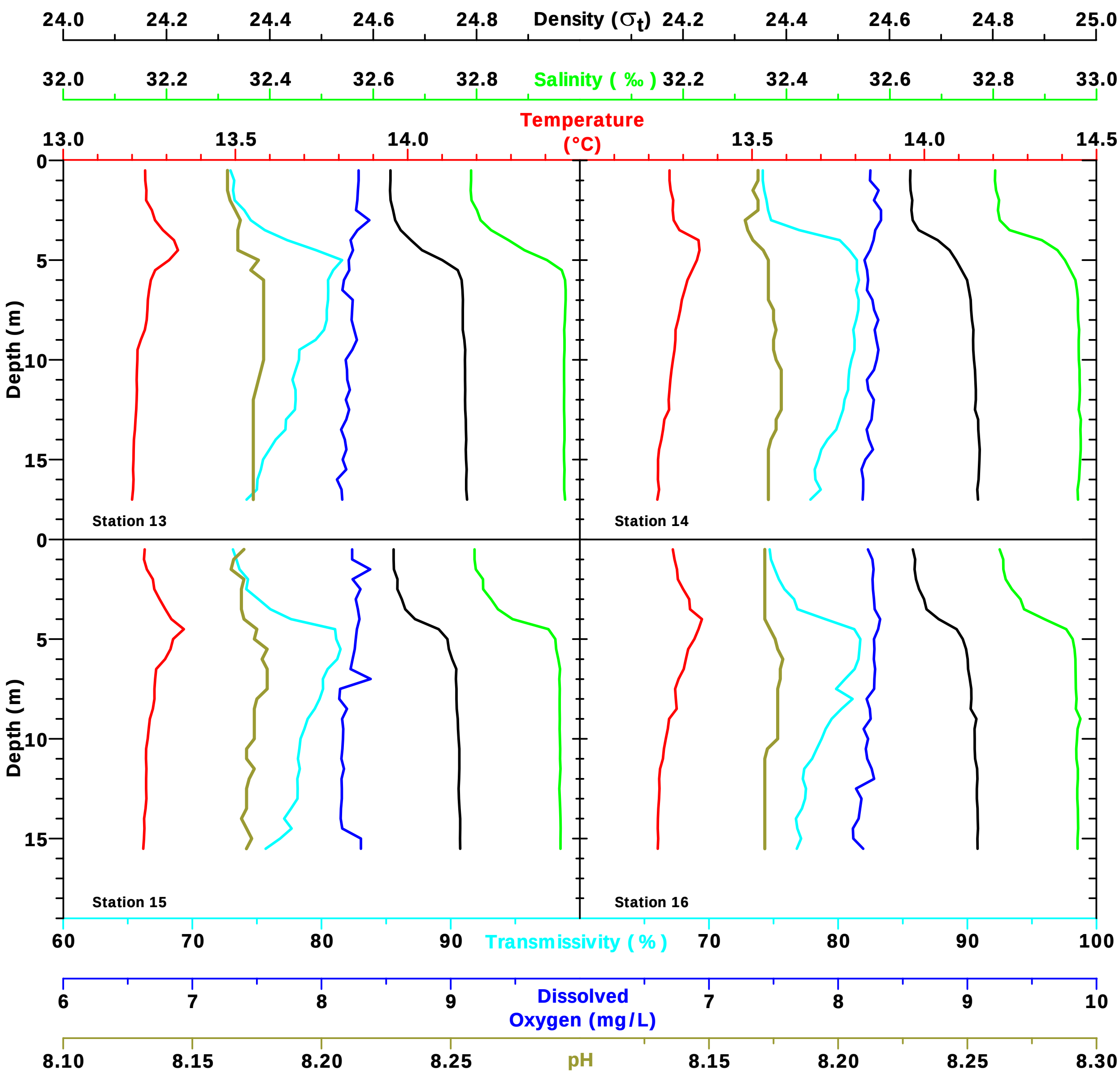

Figure A-3. Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 11 April 2006

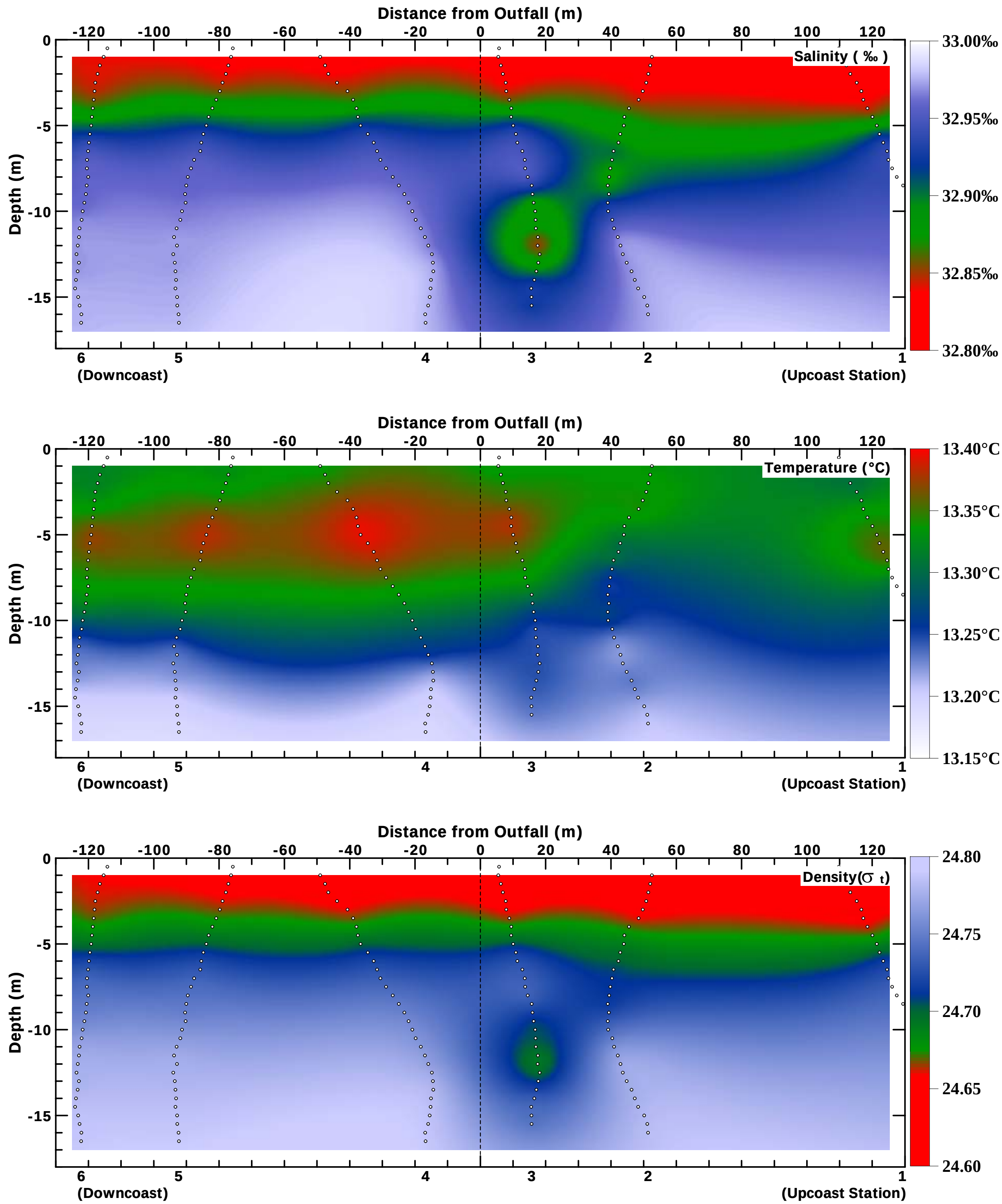

Figure A-4. Along-Shore Transects of Salinity, Temperature, and Density on 11 April 2006

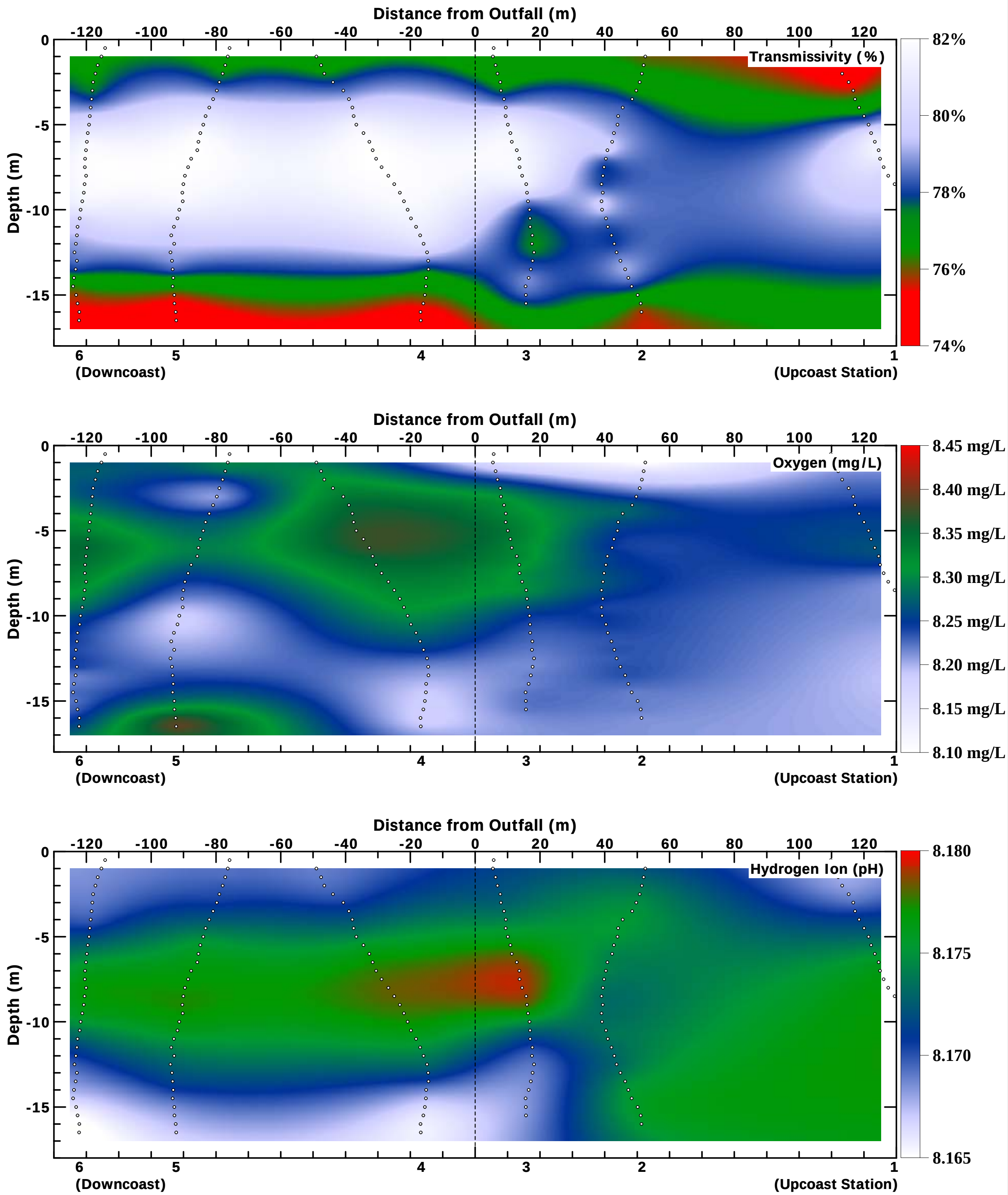

Figure A-5. Along-Shore Transects of Transmissivity, Oxygen, and pH on 11 April 2006

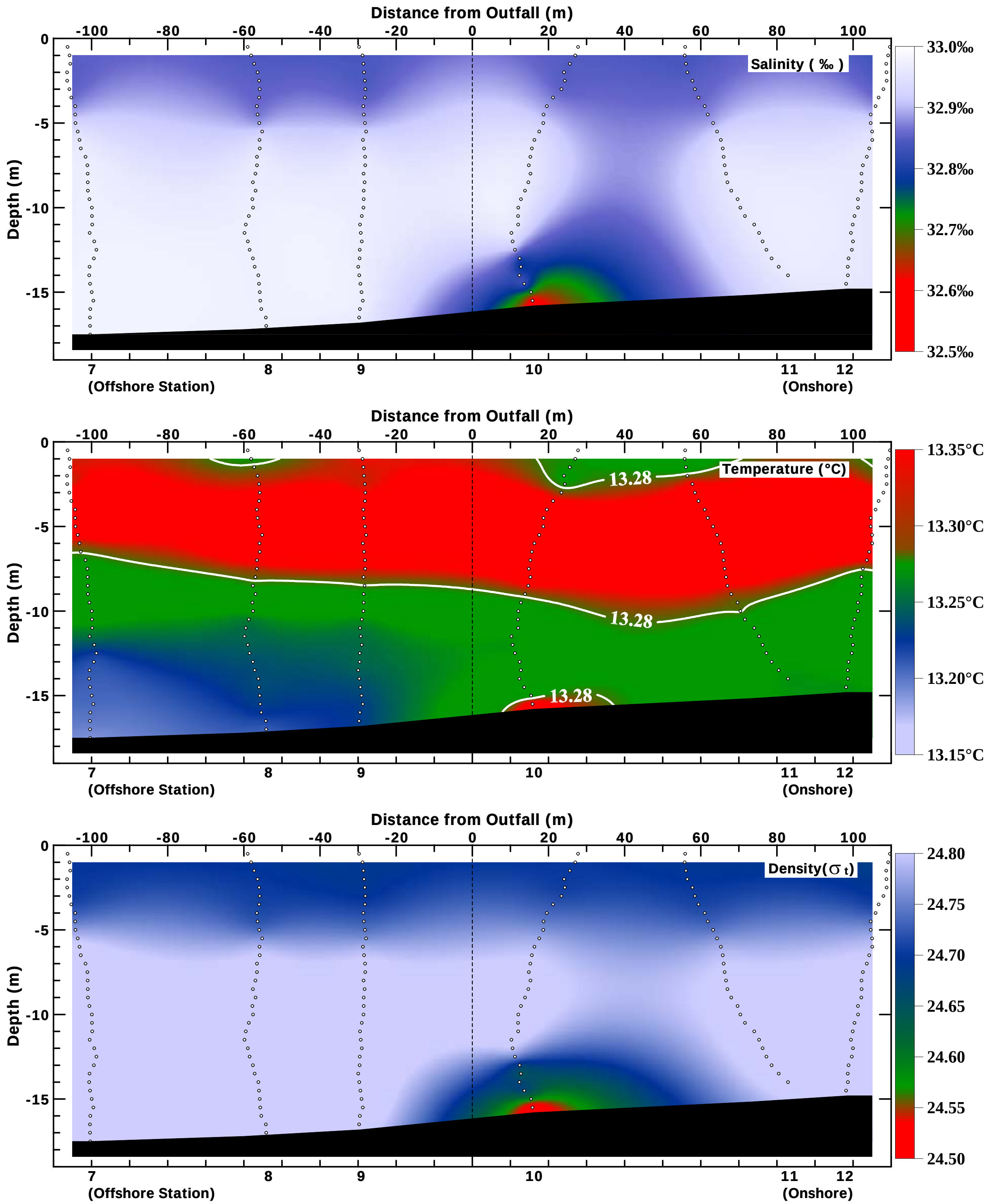

Figure A-6. Cross-Shore Transects of Salinity, Temperature, and Density on 11 April 2006

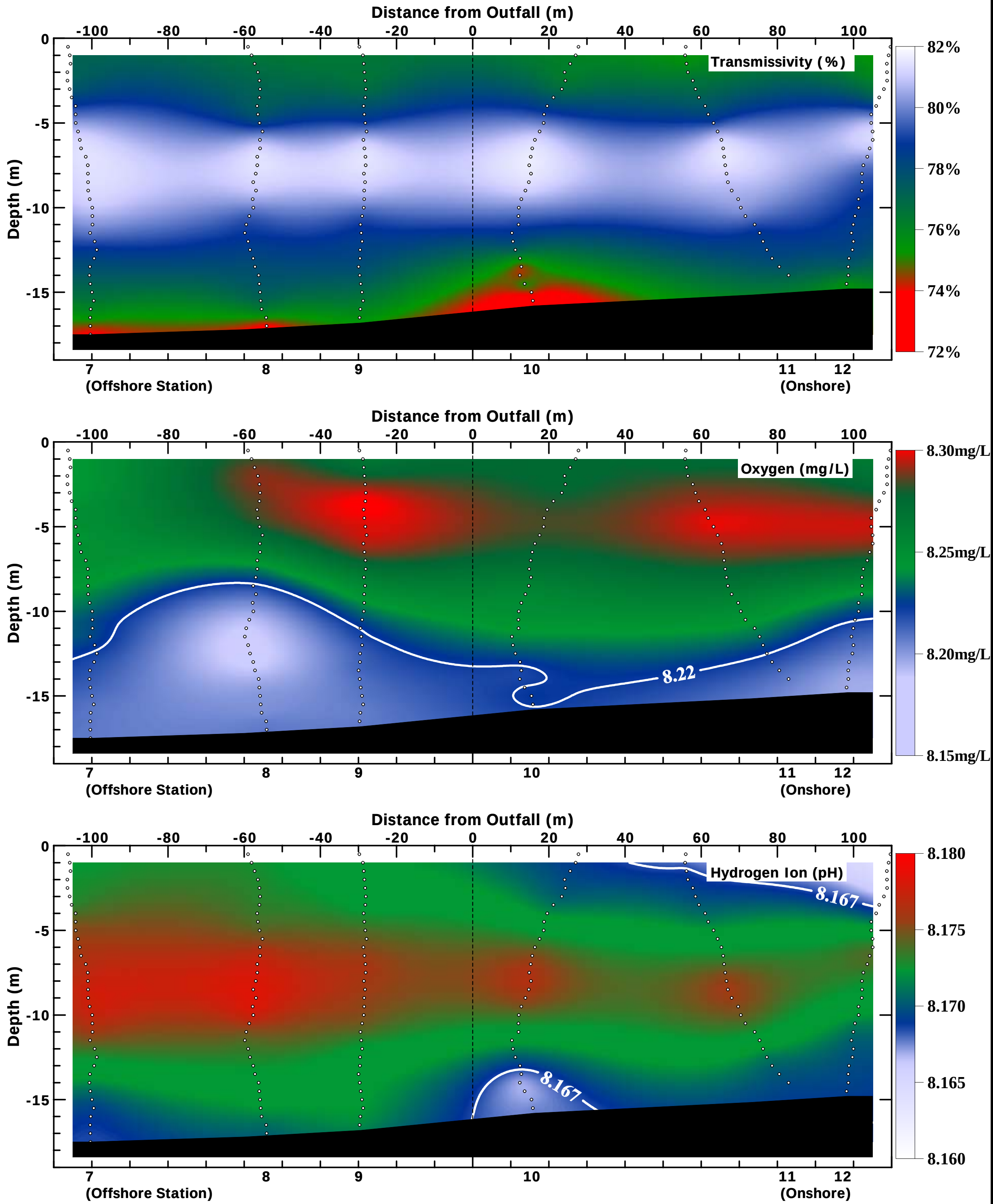

Figure A-7. Cross-Shore Transects of Transmissivity, Oxygen, and pH on 11 April 2006

APPENDIX B

Tables of Profile Data and Standard Observations

Table B-1. Seawater Temperature[1] on 11 April 2006

Depth (m)	Temperature (°C)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	13.30		13.32		13.32	13.31	13.29	13.26	13.29	13.28	13.26	13.28	13.24	13.26	13.24	13.27
1.0	13.30	13.31	13.33	13.33	13.32	13.31	13.29	13.28	13.29	13.28	13.26	13.28	13.24	13.26	13.23	13.28
1.5	13.29	13.33	13.33	13.33	13.32	13.31	13.30	13.28	13.29	13.28	13.26	13.28	13.24	13.26	13.24	13.28
2.0	13.29	13.34	13.35	13.35	13.32	13.31	13.29	13.29	13.29	13.27	13.29	13.28	13.24	13.27	13.26	13.28
2.5	13.30	13.34	13.35	13.36	13.32	13.31	13.28	13.29	13.29	13.27	13.30	13.28	13.26	13.27	13.26	13.30
3.0	13.31	13.34	13.35	13.37	13.35	13.31	13.30	13.30	13.29	13.28	13.30	13.29	13.27	13.27	13.28	13.32
3.5	13.34	13.35	13.37	13.38	13.36	13.33	13.31	13.30	13.30	13.30	13.30	13.31	13.29	13.29	13.30	13.32
4.0	13.34	13.35	13.39	13.39	13.38	13.35	13.33	13.30	13.31	13.32	13.31	13.34	13.32	13.34	13.31	13.35
4.5	13.35	13.30	13.39	13.40	13.38	13.37	13.33	13.32	13.31	13.33	13.31	13.37	13.33	13.35	13.35	13.34
5.0	13.35	13.31	13.38	13.40	13.39	13.38	13.32	13.33	13.32	13.33	13.31	13.36	13.31	13.34	13.32	13.33
5.5	13.37	13.27	13.36	13.39	13.39	13.38	13.30	13.33	13.33	13.33	13.32	13.33	13.27	13.33	13.31	13.31
6.0	13.37	13.29	13.35	13.39	13.37	13.37	13.28	13.31	13.32	13.32	13.32	13.33	13.25	13.31	13.30	13.31
6.5	13.37	13.35	13.35	13.37	13.36	13.36	13.28	13.30	13.31	13.32	13.32	13.32	13.25	13.30	13.27	13.30
7.0	13.34	13.24	13.35	13.37	13.35	13.34	13.27	13.30	13.30	13.31	13.31	13.29	13.25	13.30	13.27	13.29
7.5	13.30	13.23	13.33	13.36	13.34	13.34	13.27	13.29	13.29	13.30	13.31	13.28	13.24	13.29	13.27	13.28
8.0	13.28	13.24	13.32	13.34	13.34	13.34	13.26	13.28	13.29	13.30	13.31	13.27	13.24	13.29	13.26	13.28
8.5	13.28	13.24	13.32	13.32	13.33	13.33	13.26	13.28	13.28	13.30	13.29	13.27	13.24	13.28	13.26	13.28
9.0	13.28	13.26	13.28	13.32	13.33	13.32	13.26	13.26	13.27	13.28	13.28	13.27	13.23	13.28	13.25	13.26
9.5	13.27	13.28	13.25	13.31	13.31	13.31	13.26	13.25	13.26	13.28	13.28	13.26	13.22	13.27	13.25	13.26
10.0	13.27	13.27	13.24	13.29	13.29	13.29	13.26	13.25	13.25	13.26	13.28	13.26	13.22	13.27	13.25	13.25
10.5	13.26	13.24	13.24	13.28	13.27	13.24	13.25	13.23	13.24	13.25	13.28	13.26	13.21	13.27	13.24	13.24
11.0	13.25	13.22	13.24	13.27	13.24	13.24	13.23	13.22	13.23	13.24	13.26	13.25	13.21	13.26	13.24	13.24
11.5	13.24	13.21	13.24	13.26	13.23	13.23	13.23	13.23	13.23	13.24	13.25	13.25	13.21	13.26	13.24	13.23
12.0	13.24	13.21	13.24	13.27	13.23	13.23	13.22	13.23	13.23	13.24	13.25	13.25	13.21	13.26	13.24	13.23
12.5	13.25	13.22	13.24	13.24	13.23	13.22	13.20	13.22	13.23	13.23	13.24	13.25	13.21	13.26	13.24	13.23
13.0	13.24	13.23	13.24	13.21	13.23	13.23	13.20	13.22	13.23	13.27	13.24	13.25	13.21	13.25	13.24	13.23
13.5	13.24	13.24	13.24	13.20	13.22	13.22	13.20	13.22	13.22	13.27	13.24	13.25	13.21	13.24	13.24	13.23
14.0	13.23	13.23	13.24	13.20	13.21	13.20	13.20	13.22	13.22	13.24	13.24	13.24	13.21	13.24	13.23	13.23
14.5	13.23	13.22	13.24	13.20	13.20	13.20	13.20	13.22	13.22	13.23		13.24	13.20	13.23	13.24	13.23
15.0	13.22	13.21	13.23	13.20	13.20	13.19	13.20	13.21	13.22	13.25			13.20	13.23	13.23	13.23
15.5		13.20	13.23	13.19	13.20	13.19	13.19	13.21	13.21	**13.34**			13.20	13.23	13.23	13.23
16.0		13.20		13.19	13.19	13.19	13.19	13.21	13.21				13.20	13.23		
16.5				13.19	13.19	13.19	13.19	13.20	13.21				13.20	13.23		
17.0							13.19	13.19					13.20	13.22		
17.5							13.18									

[1] Values enclosed in boxes were significantly higher than the mean of other temperature measurements at the same depth.

Table B-2. Salinity[1] on 11 April 2006

	Salinity (‰)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5	32.798		32.825		32.835	32.839	32.855	32.832	32.838	32.848	32.832	32.826	32.789	32.804	32.796	32.813
1.0	32.800	32.815	32.827	32.830	32.836	32.841	32.850	32.843	32.841	32.849	32.833	32.826	32.789	32.803	32.796	32.820
1.5	32.801	32.827	32.832	32.830	32.836	32.843	32.845	32.847	32.840	32.850	32.834	32.828	32.789	32.805	32.799	32.820
2.0	32.799	32.835	32.830	32.836	32.836	32.841	32.852	32.849	32.837	32.842	32.839	32.830	32.791	32.811	32.812	32.824
2.5	32.807	32.834	32.834	32.845	32.840	32.842	32.845	32.853	32.837	32.842	32.858	32.835	32.801	32.809	32.813	32.836
3.0	32.845	32.834	32.838	32.851	32.856	32.842	32.845	32.857	32.840	32.852	32.854	32.837	32.808	32.813	32.828	32.853
3.5	32.838	32.841	32.853	32.861	32.873	32.853	32.856	32.858	32.853	32.872	32.856	32.853	32.828	32.832	32.841	32.860
4.0	32.832	32.862	32.867	32.878	32.885	32.863	32.875	32.861	32.870	32.888	32.867	32.870	32.862	32.894	32.870	32.899
4.5	32.863	32.874	32.906	32.907	32.895	32.884	32.900	32.858	32.875	32.899	32.872	32.907	32.893	32.925	32.939	32.941
5.0	32.874	32.884	32.931	32.927	32.917	32.901	32.926	32.865	32.882	32.917	32.883	32.943	32.937	32.939	32.952	32.954
5.5	32.929	32.887	32.944	32.935	32.937	32.924	32.958	32.936	32.917	32.942	32.926	32.955	32.965	32.949	32.954	32.957
6.0	32.944	32.888	32.948	32.942	32.946	32.947	32.967	32.954	32.950	32.954	32.947	32.954	32.971	32.959	32.958	32.959
6.5	32.946	32.918	32.948	32.951	32.948	32.950	32.968	32.963	32.958	32.956	32.953	32.956	32.972	32.962	32.962	32.959
7.0	32.939	32.896	32.950	32.951	32.955	32.957	32.970	32.963	32.961	32.959	32.957	32.960	32.972	32.964	32.960	32.960
7.5	32.935	32.882	32.958	32.955	32.958	32.957	32.972	32.966	32.962	32.960	32.958	32.956	32.972	32.964	32.961	32.960
8.0	32.937	32.885	32.960	32.958	32.957	32.957	32.971	32.963	32.965	32.961	32.956	32.959	32.971	32.965	32.961	32.961
8.5	32.939	32.884	32.945	32.961	32.956	32.960	32.971	32.965	32.964	32.960	32.955	32.958	32.970	32.966	32.961	32.960
9.0	32.938	32.892	32.903	32.962	32.958	32.958	32.971	32.969	32.964	32.964	32.960	32.957	32.971	32.965	32.961	32.969
9.5	32.941	32.938	32.859	32.965	32.963	32.959	32.972	32.971	32.966	32.961	32.960	32.959	32.970	32.965	32.961	32.963
10.0	32.945	32.933	32.875	32.965	32.966	32.957	32.972	32.968	32.968	32.962	32.959	32.958	32.969	32.966	32.961	32.962
10.5	32.952	32.943	32.887	32.966	32.963	32.973	32.969	32.971	32.967	32.964	32.961	32.959	32.969	32.967	32.962	32.961
11.0	32.952	32.963	32.880	32.967	32.970	32.968	32.972	32.972	32.968	32.964	32.962	32.960	32.969	32.967	32.962	32.961
11.5	32.959	32.974	32.846	32.969	32.972	32.971	32.973	32.971	32.968	32.964	32.964	32.960	32.970	32.968	32.962	32.964
12.0	32.961	32.974	**32.834**	32.963	32.971	32.971	32.973	32.970	32.968	32.965	32.963	32.959	32.970	32.967	32.961	32.964
12.5	32.956	32.971	32.855	32.969	32.969	32.970	32.977	32.972	32.967	32.965	32.962	32.959	32.969	32.965	32.960	32.963
13.0	32.955	32.970	32.880	32.976	32.970	32.968	32.977	32.972	32.967	**32.705**	32.962	32.960	32.970	32.970	32.961	32.963
13.5	32.956	32.969	32.892	32.975	32.971	32.969	32.977	32.972	32.968	**32.689**	32.962	32.961	32.970	32.969	32.962	32.964
14.0	32.963	32.971	32.933	32.976	32.973	32.972	32.977	32.971	32.969	32.855	32.963	32.962	32.970	32.969	32.963	32.964
14.5	32.963	32.972	32.934	32.976	32.974	32.975	32.976	32.971	32.969	32.945		32.962	32.969	32.970	32.963	32.964
15.0	32.968	32.973	32.928	32.975	32.974	32.975	32.976	32.972	32.969	**32.797**			32.969	32.968	32.962	32.963
15.5		32.973	32.910	32.976	32.974	32.975	32.977	32.972	32.970	**32.385**			32.970	32.967	32.962	32.963
16.0		32.973		32.976	32.976	32.975	32.976	32.970	32.971				32.970	32.966		
16.5				32.978	32.975	32.975	32.976	32.974	32.971				32.970	32.964		
17.0							32.977	32.976					32.971	32.964		
17.5							32.979									

[1] Values enclosed in boxes were significantly lower than the mean of other salinity measurements at the same distance above the seafloor.

Table B-3. Seawater Density[1] on 11 April 2006

Depth (m)	Density (sigma-t)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	24.628		24.645		24.652	24.658	24.674	24.662	24.660	24.672	24.662	24.655	24.634	24.640	24.640	24.645
1.0	24.630	24.639	24.645	24.647	24.654	24.658	24.671	24.667	24.662	24.672	24.663	24.655	24.634	24.640	24.640	24.650
1.5	24.631	24.644	24.648	24.646	24.654	24.661	24.665	24.669	24.662	24.672	24.663	24.656	24.633	24.641	24.640	24.648
2.0	24.630	24.650	24.644	24.647	24.653	24.659	24.673	24.670	24.660	24.668	24.662	24.657	24.634	24.644	24.647	24.651
2.5	24.636	24.647	24.646	24.652	24.656	24.659	24.668	24.672	24.660	24.667	24.675	24.660	24.639	24.643	24.647	24.657
3.0	24.662	24.648	24.649	24.655	24.664	24.660	24.664	24.674	24.662	24.673	24.671	24.661	24.642	24.645	24.655	24.667
3.5	24.651	24.651	24.657	24.661	24.673	24.665	24.670	24.675	24.671	24.685	24.672	24.668	24.653	24.656	24.662	24.672
4.0	24.646	24.667	24.664	24.671	24.680	24.669	24.681	24.677	24.682	24.694	24.680	24.676	24.673	24.693	24.681	24.695
4.5	24.669	24.687	24.693	24.692	24.687	24.680	24.701	24.671	24.686	24.701	24.684	24.699	24.695	24.716	24.727	24.730
5.0	24.677	24.692	24.714	24.709	24.702	24.691	24.723	24.674	24.689	24.714	24.691	24.729	24.734	24.729	24.744	24.742
5.5	24.716	24.702	24.729	24.715	24.718	24.709	24.752	24.729	24.714	24.734	24.723	24.742	24.764	24.740	24.746	24.748
6.0	24.727	24.700	24.734	24.722	24.727	24.730	24.762	24.746	24.741	24.744	24.739	24.743	24.771	24.750	24.753	24.751
6.5	24.728	24.711	24.734	24.731	24.732	24.734	24.763	24.755	24.750	24.747	24.745	24.747	24.773	24.754	24.761	24.752
7.0	24.729	24.716	24.736	24.733	24.740	24.742	24.766	24.756	24.755	24.751	24.748	24.755	24.774	24.757	24.760	24.756
7.5	24.735	24.706	24.745	24.737	24.744	24.743	24.769	24.761	24.757	24.753	24.749	24.754	24.774	24.758	24.761	24.758
8.0	24.740	24.708	24.749	24.744	24.744	24.744	24.770	24.759	24.760	24.754	24.749	24.759	24.773	24.760	24.761	24.759
8.5	24.740	24.706	24.739	24.750	24.744	24.748	24.769	24.761	24.761	24.754	24.751	24.758	24.773	24.763	24.762	24.757
9.0	24.740	24.709	24.713	24.751	24.746	24.748	24.770	24.767	24.762	24.761	24.757	24.758	24.776	24.762	24.764	24.768
9.5	24.743	24.741	24.686	24.756	24.754	24.751	24.771	24.771	24.766	24.759	24.757	24.761	24.778	24.762	24.764	24.765
10.0	24.749	24.738	24.700	24.759	24.760	24.753	24.771	24.770	24.770	24.762	24.756	24.760	24.777	24.764	24.765	24.765
10.5	24.756	24.752	24.709	24.761	24.763	24.775	24.770	24.776	24.772	24.766	24.759	24.761	24.778	24.766	24.767	24.765
11.0	24.756	24.772	24.704	24.765	24.772	24.772	24.776	24.778	24.774	24.768	24.764	24.763	24.778	24.766	24.767	24.766
11.5	24.765	24.782	24.677	24.769	24.777	24.776	24.777	24.777	24.774	24.768	24.77	24.763	24.778	24.767	24.767	24.770
12.0	24.766	24.782	**24.667**	24.762	24.777	24.776	24.779	24.776	24.774	24.769	24.766	24.762	24.778	24.767	24.766	24.770
12.5	24.761	24.778	24.683	24.773	24.775	24.776	24.786	24.779	24.773	24.770	24.766	24.762	24.778	24.766	24.765	24.769
13.0	24.761	24.775	24.703	24.784	24.776	24.775	24.786	24.780	24.774	**24.562**	24.766	24.763	24.779	24.772	24.766	24.769
13.5	24.761	24.773	24.712	24.784	24.778	24.776	24.787	24.779	24.775	**24.550**	24.766	24.765	24.779	24.772	24.767	24.771
14.0	24.770	24.776	24.744	24.786	24.782	24.782	24.787	24.778	24.776	24.684	24.768	24.766	24.780	24.773	24.768	24.771
14.5	24.770	24.778	24.746	24.786	24.784	24.786	24.787	24.779	24.777	24.755		24.767	24.779	24.775	24.768	24.771
15.0	24.776	24.782	24.742	24.785	24.785	24.786	24.787	24.779	24.777	**24.638**			24.780	24.774	24.768	24.770
15.5		24.783	24.728	24.787	24.785	24.786	24.787	24.780	24.778	**24.300**			24.781	24.773	24.769	24.771
16.0		24.783		24.787	24.788	24.787	24.787	24.779	24.779				24.780	24.773		
16.5				24.789	24.787	24.786	24.788	24.783	24.779				24.780	24.770		
17.0							24.789	24.787					24.782	24.771		
17.5							24.791									

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

Table B-4. Dissolved Oxygen[1] on 11 April 2006

Depth (m)	Dissolved Oxygen (mg/L)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	8.18		8.03		8.31	8.22	8.22	8.34	8.22	8.36	8.32	8.25	8.29	8.25	8.24	8.23
1.0	8.21	7.95	8.17	8.29	8.32	8.27	8.23	8.26	8.20	8.25	8.22	8.24	8.29	8.25	8.24	8.26
1.5	8.22	8.23	8.18	8.33	8.35	8.31	8.21	8.35	8.20	8.26	8.22	8.23	8.28	8.31	8.38	8.27
2.0	8.23	8.19	8.25	8.31	8.17	8.27	8.21	8.34	8.26	8.25	8.32	8.26	8.28	8.28	8.24	8.27
2.5	8.23	8.17	8.31	8.36	8.18	8.23	8.24	8.32	8.28	8.27	8.28	8.24	8.27	8.33	8.30	8.27
3.0	8.23	8.23	8.34	8.34	**8.11**	8.25	8.21	8.29	8.35	8.25	8.33	8.28	8.37	8.33	8.26	8.28
3.5	8.25	8.32	8.33	8.39	8.18	8.30	8.23	8.25	8.38	8.27	8.25	8.32	8.28	8.29	8.28	8.28
4.0	8.26	8.32	8.29	8.36	8.24	8.28	8.27	8.29	8.35	8.28	8.31	8.27	8.22	8.27	8.29	8.33
4.5	8.25	8.23	8.35	8.37	8.29	8.37	8.29	8.31	8.27	8.29	8.34	8.35	8.24	8.25	8.27	8.31
5.0	8.25	8.23	8.36	8.39	8.24	8.29	8.26	8.30	8.28	8.29	8.36	8.35	8.21	8.20	8.27	8.28
5.5	8.27	8.22	8.34	8.38	8.28	8.38	**8.16**	8.27	8.34	8.27	8.28	8.30	8.22	8.22	8.26	8.28
6.0	8.28	8.20	8.32	8.41	8.30	8.38	8.24	8.28	8.34	8.27	8.29	8.33	8.17	8.23	8.24	8.27
6.5	8.29	8.27	8.36	8.35	8.29	8.36	8.28	8.24	8.35	8.29	8.29	8.32	**8.16**	8.22	8.22	8.29
7.0	8.26	8.22	8.32	8.35	8.25	8.35	8.27	8.22	8.31	8.27	8.32	8.26	8.24	8.26	8.38	8.28
7.5	8.22	8.27	8.27	8.34	8.23	8.33	8.27	8.18	8.27	8.26	8.22	8.27	8.24	8.28	8.14	8.28
8.0	8.18	8.27	8.30	8.33	8.22	8.34	8.26	8.22	8.25	8.27	8.30	8.29	8.23	8.31	**8.14**	8.22
8.5	8.20	8.27	8.35	8.32	8.21	8.32	8.25	8.20	8.27	8.22	8.32	8.24	8.25	8.28	8.20	8.24
9.0	8.21	8.22	8.29	8.33	8.21	8.32	8.25	8.17	8.28	8.22	8.21	8.18	8.27	8.30	8.16	8.25
9.5	8.20	8.21	8.25	8.32	8.15	8.32	8.26	8.16	8.25	8.25	8.25	8.22	8.24	8.31	8.17	8.20
10.0	8.23	8.27	8.21	8.32	8.15	8.24	8.25	8.17	8.25	8.26	8.29	8.21	8.19	8.30	8.17	8.23
10.5	8.20	8.27	8.23	8.30	8.17	8.26	8.18	8.14	8.25	8.26	8.24	8.22	8.20	8.28	8.16	8.21
11.0	8.21	8.23	8.21	8.29	8.18	8.23	8.25	8.14	8.21	8.26	8.24	8.17	8.20	8.22	8.15	8.22
11.5	8.18	8.23	8.22	8.27	8.19	8.26	8.28	8.16	8.25	8.26	8.29	8.20	8.22	8.23	8.17	8.26
12.0	8.19	8.26	8.21	8.27	8.20	8.22	8.26	8.15	8.23	8.24	8.21	8.21	8.19	8.27	8.16	8.28
12.5	8.20	8.22	8.20	8.23	8.20	8.26	8.23	8.16	8.20	8.24	8.22	8.20	8.21	8.27	8.16	8.14
13.0	8.18	8.25	8.19	8.20	8.22	8.30	8.21	8.12	8.24	8.21	8.24	8.21	8.19	8.26	8.16	8.18
13.5	8.19	8.26	8.23	8.20	8.25	8.15	8.23	8.16	8.25	8.15	8.20	8.16	8.15	8.22	8.15	8.17
14.0	8.16	8.23	8.20	8.18	8.24	8.21	8.22	8.20	8.21	8.19	8.22	8.17	8.18	8.24	8.15	8.16
14.5	8.20	8.19	8.24	8.17	8.25	8.25	8.22	8.21	8.20	8.25		8.18	8.19	8.27	8.16	8.11
15.0	8.20	8.22	8.24	8.17	8.27	8.19	8.22	8.22	8.23	8.26			8.16	8.21	8.30	8.12
15.5		8.23	8.25	8.17	8.30	8.19	8.18	8.20	8.20	8.26			8.19	8.18	8.30	8.19
16.0		8.20		8.16	8.51	8.21	8.21	8.16	8.18				8.12	8.19		
16.5				8.16	8.51	8.22	8.21	8.24	8.21				8.16	8.19		
17.0							8.21	8.24					8.16	8.19		
17.5							8.21									

[1] Values enclosed in boxes were significantly lower than the mean of other dissolved oxygen measurements at the same depth.

Table B-5. Light Transmittance[1] across a 0.25-m path on 11 April 2006

	Light Transmittance (%)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5	74.74		76.40		77.22	77.27	77.41	76.24	76.52	76.09	75.33	75.39	72.96	74.15	73.15	74.69
1.0	74.66	76.02	76.34	76.91	77.27	77.37	77.00	76.59	76.57	76.23	75.36	75.33	73.24	74.16	73.41	74.80
1.5	74.72	76.13	76.89	77.14	77.21	77.45	77.24	76.77	76.60	76.32	75.29	75.25	73.16	74.28	73.65	75.08
2.0	74.87	76.83	77.16	77.24	77.31	77.32	77.04	76.96	76.54	76.10	76.26	75.47	73.27	74.45	74.30	75.41
2.5	74.84	77.20	77.14	77.83	77.44	77.38	76.86	77.00	76.43	76.05	77.21	75.72	74.02	74.57	74.17	75.83
3.0	75.58	77.04	77.17	78.45	78.63	77.27	77.47	77.32	76.47	76.47	76.47	75.81	74.51	74.81	75.12	76.58
3.5	76.68	77.74	77.94	79.04	79.35	77.52	78.09	77.24	77.03	77.39	77.31	76.74	75.60	76.99	76.03	76.85
4.0	76.48	78.70	79.09	79.73	80.14	78.63	78.87	77.13	78.02	78.41	77.61	78.38	77.34	80.12	77.63	79.00
4.5	77.55	78.40	80.70	81.07	80.65	79.83	79.69	76.95	78.04	79.08	77.67	80.12	79.59	80.87	81.05	81.25
5.0	78.38	78.81	81.32	81.59	81.03	80.25	80.44	77.69	78.43	79.74	78.42	81.65	81.60	81.44	81.14	81.71
5.5	81.51	78.72	81.74	81.78	82.31	80.97	81.25	79.75	80.00	80.94	80.71	81.64	80.90	81.45	81.48	81.64
6.0	81.91	79.51	81.65	81.95	82.02	82.01	81.57	81.09	81.50	81.62	81.96	81.65	80.50	81.61	81.21	81.57
6.5	81.98	81.27	81.67	82.09	82.00	81.91	81.50	81.60	81.65	81.69	81.67	81.31	80.51	81.38	80.47	81.27
7.0	81.36	77.63	81.53	82.06	81.97	81.75	81.47	81.66	81.67	81.70	81.68	80.29	80.49	81.58	80.10	80.53
7.5	80.03	77.20	81.66	81.95	81.91	81.92	81.39	81.39	81.48	81.64	81.62	79.45	80.41	81.55	80.11	79.83
8.0	79.44	77.99	81.77	81.90	81.92	81.86	81.29	81.32	81.24	81.57	81.07	79.14	80.40	81.39	79.84	81.12
8.5	79.79	77.49	81.86	81.86	81.88	81.80	81.26	81.23	81.22	81.58	80.67	79.04	80.19	81.16	79.47	80.25
9.0	79.74	78.59	80.97	81.90	81.76	81.78	81.37	81.13	81.10	81.20	80.54	78.98	79.54	81.27	78.92	79.48
9.5	79.41	80.50	77.75	81.70	81.75	81.76	81.20	80.62	80.43	80.62	80.41	78.76	78.29	81.26	78.68	79.02
10.0	79.23	80.02	77.43	81.66	81.50	81.43	81.20	79.86	79.59	79.95	80.69	78.68	78.24	81.02	78.36	78.72
10.5	78.92	78.24	77.54	81.41	80.53	79.52	80.50	78.95	79.13	79.45	80.11	78.60	78.00	80.86	78.29	78.34
11.0	78.94	77.95	77.60	81.15	79.86	79.40	80.17	78.93	78.66	78.82	78.84	78.47	77.76	80.80	78.17	77.99
11.5	78.02	77.79	77.51	81.00	79.42	79.31	80.01	78.76	78.46	78.78	78.38	78.37	77.99	80.77	78.31	77.37
12.0	78.30	77.61	77.25	81.15	79.48	78.83	79.24	78.84	78.50	78.48	78.33	78.45	77.99	80.49	78.13	77.27
12.5	78.78	78.34	77.21	79.81	78.89	78.68	78.27	78.34	78.28	78.22	78.32	78.38	77.94	80.38	78.16	77.50
13.0	78.19	79.01	78.01	78.43	79.20	78.79	78.12	77.96	78.18	75.41	78.38	78.09	77.25	80.11	78.14	77.43
13.5	77.99	79.63	78.05	77.25	78.67	78.42	77.86	77.78	78.09	**72.48**	77.79	77.75	77.21	79.84	77.63	77.20
14.0	77.16	79.00	79.28	76.71	77.19	77.14	77.48	77.78	77.57	73.37	77.28	76.66	76.45	79.16	77.09	76.73
14.5	77.55	78.00	78.90	76.70	76.76	76.01	77.05	77.69	77.33	77.42		74.53	75.97	78.69	77.68	76.83
15.0	75.91	77.38	78.63	76.28	75.42	75.61	77.12	77.50	76.88	76.21			75.48	78.48	76.80	77.12
15.5		76.17	77.61	75.84	75.37	75.58	76.53	77.35	76.41	**69.25**			75.30	78.18	75.69	76.80
16.0		75.15		75.04	74.71	75.22	76.17	77.05	75.95				75.04	78.23		
16.5				73.62	73.62	75.08	75.70	76.13	75.89				75.00	78.65		
17.0							74.77	71.40					74.21	77.86		
17.5							72.54									

[1] Values enclosed in boxes were significantly lower than the mean of other transmissivity measurements at the same distance above the seafloor.

Table B-6. Detrended[1] pH[2] on 11 April 2006

Depth (m)	Hydrogen Ion Concentration (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	8.167		8.172		8.173	8.169	8.172	8.173	8.171	8.168	8.161	8.163	8.164	8.169	8.170	8.172
1.0	8.167	8.171	8.172	8.169	8.168	8.169	8.172	8.173	8.171	8.168	8.170	8.163	8.164	8.169	8.166	8.172
1.5	8.167	8.173	8.172	8.169	8.168	8.169	8.172	8.173	8.171	8.168	8.168	8.163	8.164	8.167	8.165	8.172
2.0	8.167	8.174	8.172	8.169	8.172	8.169	8.174	8.173	8.173	8.168	8.168	8.163	8.165	8.169	8.170	8.172
2.5	8.167	8.175	8.172	8.169	8.170	8.169	8.172	8.173	8.171	8.168	8.167	8.166	8.167	8.169	8.169	8.172
3.0	8.167	8.176	8.172	8.169	8.169	8.169	8.172	8.173	8.171	8.168	8.168	8.163	8.169	8.164	8.169	8.172
3.5	8.171	8.176	8.173	8.172	8.172	8.169	8.172	8.173	8.171	8.168	8.168	8.166	8.168	8.165	8.169	8.172
4.0	8.172	8.176	8.173	8.172	8.172	8.168	8.173	8.173	8.173	8.169	8.169	8.167	8.168	8.167	8.170	8.172
4.5	8.172	8.176	8.176	8.173	8.172	8.168	8.176	8.173	8.173	8.172	8.168	8.168	8.168	8.171	8.175	8.174
5.0	8.172	8.176	8.176	8.173	8.179	8.173	8.176	8.173	8.175	8.172	8.171	8.173	8.176	8.173	8.174	8.176
5.5	8.173	8.175	8.177	8.179	8.177	8.173	8.176	8.175	8.175	8.172	8.170	8.174	8.173	8.173	8.179	8.177
6.0	8.177	8.172	8.180	8.178	8.177	8.175	8.176	8.177	8.175	8.175	8.173	8.176	8.178	8.173	8.177	8.179
6.5	8.177	8.171	8.180	8.178	8.177	8.176	8.176	8.177	8.177	8.177	8.172	8.177	8.178	8.173	8.179	8.178
7.0	8.178	8.177	8.181	8.178	8.177	8.179	8.176	8.177	8.177	8.177	8.173	8.175	8.178	8.173	8.179	8.178
7.5	8.177	8.172	8.181	8.178	8.177	8.178	8.176	8.177	8.177	8.177	8.177	8.173	8.178	8.175	8.179	8.177
8.0	8.177	8.172	8.181	8.180	8.177	8.178	8.177	8.177	8.175	8.177	8.177	8.172	8.178	8.175	8.175	8.177
8.5	8.177	8.170	8.182	8.179	8.177	8.178	8.177	8.177	8.177	8.177	8.177	8.172	8.178	8.176	8.174	8.177
9.0	8.177	8.172	8.182	8.178	8.180	8.178	8.177	8.177	8.175	8.177	8.177	8.172	8.178	8.175	8.174	8.177
9.5	8.177	8.172	8.181	8.178	8.177	8.178	8.177	8.178	8.176	8.177	8.175	8.172	8.178	8.175	8.174	8.177
10.0	8.177	8.172	8.174	8.178	8.177	8.178	8.177	8.178	8.176	8.172	8.177	8.170	8.178	8.176	8.174	8.177
10.5	8.177	8.175	8.171	8.178	8.178	8.173	8.177	8.178	8.176	8.173	8.173	8.168	8.177	8.178	8.171	8.173
11.0	8.177	8.177	8.169	8.177	8.176	8.174	8.177	8.173	8.176	8.173	8.173	8.168	8.176	8.178	8.171	8.172
11.5	8.177	8.172	8.168	8.176	8.174	8.169	8.177	8.173	8.172	8.171	8.173	8.168	8.175	8.178	8.174	8.172
12.0	8.177	8.172	8.168	8.174	8.173	8.171	8.172	8.173	8.171	8.169	8.169	8.168	8.174	8.178	8.172	8.172
12.5	8.177	8.172	8.168	8.177	8.173	8.169	8.172	8.173	8.171	8.168	8.168	8.168	8.174	8.178	8.171	8.172
13.0	8.177	8.172	8.168	8.174	8.173	8.169	8.172	8.173	8.171	8.168	8.168	8.168	8.174	8.176	8.171	8.172
13.5	**8.177**	8.177	8.168	8.171	8.173	8.169	8.172	8.173	8.171	8.165	8.168	8.168	8.174	8.176	8.171	8.172
14.0	**8.177**	8.177	8.168	8.169	8.173	8.169	8.168	8.169	8.171	8.163	8.168	8.168	8.174	8.174	8.169	8.172
14.5	**8.177**	**8.177**	8.168	8.166	8.169	8.169	8.169	8.172	8.171	8.165		8.168	8.174	8.173	8.171	8.172
15.0	**8.177**	**8.177**	8.168	8.165	8.168	8.164	8.167	8.170	8.171	8.165			8.174	8.173	8.173	8.172
15.5		**8.177**	8.168	8.165	8.168	8.164	8.167	8.172	8.171	8.168			8.174	8.173	8.171	8.172
16.0		**8.177**		8.165	8.168	8.164	8.167	8.169	8.171				8.174	8.173		
16.5				8.165	8.168	8.164	8.167	8.168	8.171				8.174	8.173		
17.0							8.167	8.168					8.174	8.173		
17.5							8.167									

[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 different from the mean of other pH measurements at the same depth.

Table B-7. Uncorrected pH on 11 April 2006

	Alkalinity (pH)															
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
0.5	**8.167**		8.191		8.201	8.201	8.201	8.201	8.201	8.201	8.194	8.201	8.220	**8.244**	**8.249**	8.215
1.0	8.167	8.181	8.191	8.196	8.196	8.201	8.201	8.201	8.201	8.201	8.203	8.201	8.220	**8.244**	**8.245**	8.215
1.5	8.167	8.183	8.191	8.196	8.196	8.201	8.201	8.201	8.201	8.201	8.201	8.201	8.220	**8.242**	**8.244**	8.215
2.0	**8.167**	8.184	8.191	8.196	8.200	8.201	8.203	8.201	8.203	8.201	8.201	8.201	8.221	**8.244**	**8.249**	8.215
2.5	**8.167**	8.185	8.191	8.196	8.198	8.201	8.201	8.201	8.201	8.201	8.200	8.204	8.223	**8.244**	**8.248**	8.215
3.0	**8.167**	8.186	8.191	8.196	8.197	8.201	8.201	8.201	8.201	8.201	8.201	8.201	8.225	8.239	**8.248**	8.215
3.5	8.171	8.186	8.192	8.199	8.200	8.201	8.201	8.201	8.201	8.201	8.201	8.204	8.224	8.240	**8.248**	8.215
4.0	8.172	8.186	8.192	8.199	8.200	8.200	8.202	8.201	8.203	8.202	8.202	8.205	8.224	8.242	**8.249**	8.215
4.5	8.172	8.186	8.195	8.200	8.200	8.200	8.205	8.201	8.203	8.205	8.201	8.206	8.224	8.246	**8.254**	8.217
5.0	**8.172**	8.186	8.195	8.200	8.207	8.205	8.205	8.201	8.205	8.205	8.204	8.211	8.232	**8.248**	**8.253**	8.219
5.5	8.173	8.185	8.196	8.206	8.205	8.205	8.205	8.203	8.205	8.205	8.203	8.212	8.229	**8.248**	**8.258**	8.220
6.0	8.177	8.182	8.199	8.205	8.205	8.207	8.205	8.205	8.205	8.208	8.206	8.214	8.234	**8.248**	**8.256**	8.222
6.5	8.177	8.181	8.199	8.205	8.205	8.208	8.205	8.205	8.207	8.210	8.205	8.215	8.234	8.248	**8.258**	8.221
7.0	8.178	8.187	8.200	8.205	8.205	8.211	8.205	8.205	8.207	8.210	8.206	8.213	8.234	8.248	**8.258**	8.221
7.5	8.177	8.182	8.200	8.205	8.205	8.210	8.205	8.205	8.207	8.210	8.210	8.211	8.234	**8.250**	**8.258**	8.220
8.0	8.177	8.182	8.200	8.207	8.205	8.210	8.206	8.205	8.205	8.210	8.210	8.210	8.234	**8.250**	**8.254**	8.220
8.5	8.177	8.180	8.201	8.206	8.205	8.210	8.206	8.205	8.207	8.210	8.210	8.210	8.234	**8.251**	**8.253**	8.220
9.0	8.177	8.182	8.201	8.205	8.208	8.210	8.206	8.205	8.205	8.210	8.210	8.210	8.234	**8.250**	**8.253**	8.220
9.5	8.177	8.182	8.200	8.205	8.205	8.210	8.206	8.206	8.206	8.210	8.208	8.210	8.234	**8.250**	**8.253**	8.220
10.0	8.177	8.182	8.193	8.205	8.205	8.210	8.206	8.206	8.206	8.205	8.210	8.208	8.234	**8.251**	**8.253**	8.220
10.5	8.177	8.185	8.190	8.205	8.206	8.205	8.206	8.206	8.206	8.206	8.206	8.206	8.233	**8.253**	**8.250**	8.216
11.0	8.177	8.187	8.188	8.204	8.204	8.206	8.206	8.201	8.206	8.206	8.206	8.206	8.232	**8.253**	**8.250**	8.215
11.5	8.177	8.182	8.187	8.203	8.202	8.201	8.206	8.201	8.202	8.204	8.206	8.206	8.231	**8.253**	**8.253**	8.215
12.0	8.177	8.182	8.187	8.201	8.201	8.203	8.201	8.201	8.201	8.202	8.202	8.206	8.230	**8.253**	**8.251**	8.215
12.5	8.177	8.182	8.187	8.204	8.201	8.201	8.201	8.201	8.201	8.201	8.201	8.206	8.230	**8.253**	**8.250**	8.215
13.0	8.177	8.182	8.187	8.201	8.201	8.201	8.201	8.201	8.201	8.201	8.201	8.206	8.230	**8.251**	**8.250**	8.215
13.5	8.177	8.187	8.187	8.198	8.201	8.201	8.201	8.201	8.201	8.198	8.201	8.206	8.230	**8.251**	**8.250**	8.215
14.0	8.177	8.187	8.187	8.196	8.201	8.201	8.197	8.197	8.201	8.196	8.201	8.206	8.230	**8.249**	**8.248**	8.215
14.5	8.177	8.187	8.187	8.193	8.197	8.201	8.198	8.200	8.201	8.198		8.206	8.230	**8.248**	**8.250**	8.215
15.0	8.177	8.187	8.187	8.192	8.196	8.196	8.196	8.198	8.201	8.198			8.230	**8.248**	**8.252**	8.215
15.5		8.187	8.187	8.192	8.196	8.196	8.196	8.200	8.201	8.201			8.230	**8.248**	**8.250**	8.215
16.0		8.187		8.192	8.196	8.196	8.196	8.197	8.201				8.230	**8.248**		
16.5				8.192	8.196	8.196	8.196	8.196	8.201				8.230	**8.248**		
17.0							8.196	8.196					8.230	**8.248**		
17.5							8.196									

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

Table B-8. Ancillary Observations on 11 April 2006 during the Receiving-Water Survey

Station	Location Latitude	Location Longitude	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)
1	35° 23.269' N	120° 52.512' W	130.3	07:07:47	13.1	90	3.5	9.0	S	3-4 /SW	6.5
2	35° 23.235' N	120° 52.508' W	66.8	07:16:34	13.4	80	2.1	5.9	S	3-4 /SW	6.0
3	35° 23.212' N	120° 52.514' W	28.2	07:22:50	13.1	80	4.6	7.8	S	3-4 /SW	6.5
4	35° 23.192' N	120° 52.513' W	19.1	07:27:59	13.2	80	2.1	8.3	S	3-4 /SW	6.5
5	35° 23.158' N	120° 52.496' W	76.9	07:32:04	13.1	80	5.0	6.4	S	3-4 /SW	6.0
6	35° 23.144' N	120° 52.504' W	101.5	07:36:25	13.5	80	1.5	6.4	S	3-4 /SW	6.0
7	35° 23.211' N	120° 52.572' W	105.5	08:01:46	13.3	90	6.6	10.5	S	3-4 /SW	6.0
8	35° 23.203' N	120° 52.543' W	59.8	08:05:07	13.3	90	3.2	7.8	S	3-4 /SW	6.5
9	35° 23.211' N	120° 52.519' W	31.8	08:08:58	13.4	95 (Rain)	4.6	8.0	S	3-4 /SW	6.5
10	35° 23.198' N	120° 52.499' W	8.9	08:12:54	13.0	95 (Rain)	6.2	7.4	S	3-4 /SW	6.5
11	35° 23.194' N	120° 52.460' W	67.9	08:16:29	13.0	95 (Rain)	3.0	5.2	S	3-4 /SW	6.5
12	35° 23.206' N	120° 52.438' W	100.7	08:20:05	13.2	100 (Rain)	3.9	6.3	S	3-4 /SW	6.5
13	35° 23.177' N	120° 52.534' W	60.8	08:28:00	13.1	100	1.0	5.0	S	3-4 /SW	6.0
14	35° 23.227' N	120° 52.523' W	59.4	08:31:44	13.2	100	5.6	7.7	S	3-4 /SW	6.0
15	35° 23.222' N	120° 52.481' W	54.7	08:36:53	13.2	100	4.6	7.2	S	3-4 /SW	6.0
16	35° 23.183' N	120° 52.486' W	40.3	08:24:45	13.1	100	2.8	5.6	S	1-2 /W	6.0

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. Neither odors nor debris of sewage origin were observed at any time during the survey. Light precipitation occurred during sampling at stations 9, 10, 11, and 12.

Tidal Conditions (Pacific Standard Time)
Low Tide: 03:50 0.65 ft
High Tide: 09:49 4.31 ft
Low Tide: 15:53 0.43 ft
High Tide: 22:05 4.67 ft