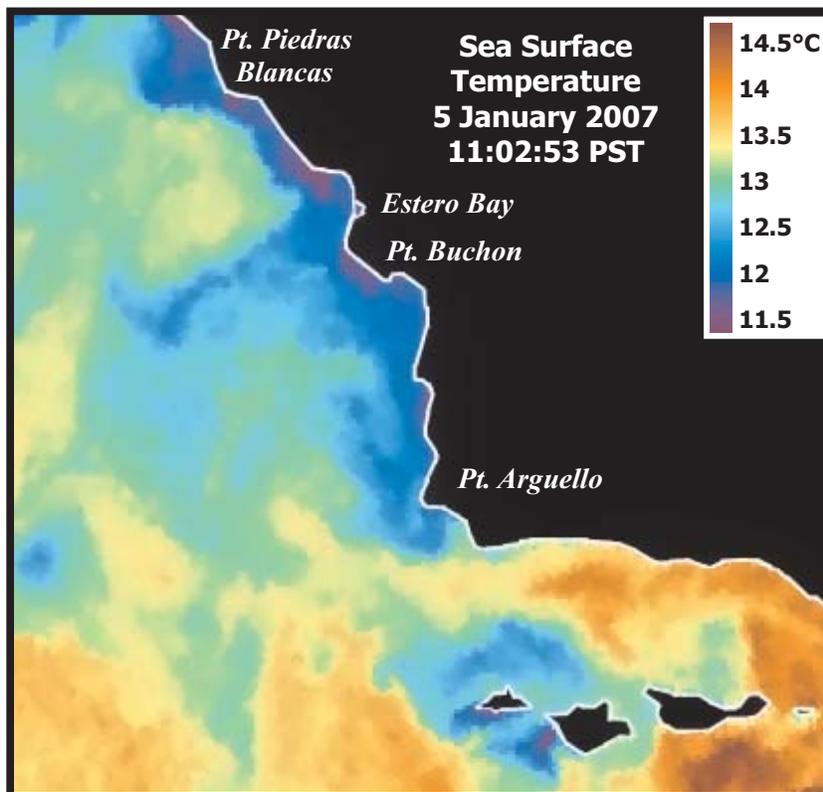


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING JANUARY 2007 SURVEY



Marine Research Specialists

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Ventura, California 93003

Report to

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

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Morro Bay, California 93442
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**OFFSHORE MONITORING
AND
REPORTING PROGRAM**

QUARTERLY REPORT

**WATER-COLUMN SAMPLING
JANUARY 2007**

Prepared by

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February 2007

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

27 February 2007

Reference: Quarterly Receiving-Water Report – January 2007

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on 3 January 2007. This first-quarter survey assessed the effectiveness of effluent dispersion during winter oceanographic conditions. Based on quantitative analyses of continuous instrumental measurements and qualitative visual observations, the wastewater discharge was found to be in compliance with the receiving-water limitations specified in the NPDES discharge permit, and with the objectives of the California Ocean Plan.

High-precision measurements clearly delineated discharge-related perturbations in five of the six seawater properties at two of the sixteen sampling stations. Both stations were located near the boundary of the zone of initial dilution. The anomalies in all of the seawater properties, except salinity and density, were generated by the upward displacement of ambient seawater entrained within the effluent plume. Dilution levels determined from the salinity anomalies within the discharge plume significantly exceeded those anticipated by modeling and outfall design criteria. Thus, all of the measurements were indicative of low organic loading within the discharged wastewater, and of an outfall operating as designed.

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

Sincerely,

Douglas A. Coats, Ph.D.
Program Manager

Enclosure (Five Report Copies)

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

Mr. Bruce Ambo
City of Morro Bay

Date _____

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INTRODUCTION

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. A National Pollutant Discharge Elimination System (NPDES) permit, modifying secondary treatment requirements, was originally issued to the MBCSD in March 1985. The permit was issued by Region IX of the U.S. Environmental Protection Agency (USEPA) and the Central Coast California Regional Water Quality Control Board (RWQCB). Following extensive evaluation processes, the permit has been re-issued twice, once in March of 1993 (RWQCB-USEPA 1993ab) and again in December 1998 (RWQCB-USEPA 1998ab).

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. The four quarterly surveys are 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 3 January 2007. Specifically, this first-quarter survey was conducted to capture ambient oceanographic conditions along the central California coast during the winter 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 January 2007 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 promulgated by the NPDES discharge permit.

The January 2007 field survey was the thirty-third 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 collection of discrete water samples at individual stations. These samples were collected using Niskin bottles, which was time consuming and interrupted the continuity of instrumental measurements collected by the CTD¹ instrument package. Continuous deployment of the CTD between stations now provides a more synoptic snapshot of the water properties immediately

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.

surrounding the diffuser structure. Consequently, the extent of the effluent plume and the amplitude of its associated water-property anomalies can be more precisely determined. The 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 a 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 33 of the subsequent water-quality surveys (MRS 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007), 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 (ZID) 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 January 2007 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 shoreline². 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 other six diffuser ports remain closed to improve dispersion by increasing the ejection velocity from the open ports. For a given flow rate, the diffuser ports were hydraulically designed to create an turbulent 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 in modeling studies is considered to be approximately 15 m from the centerline of the diffuser structure.

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

Beyond the ZID, the energetic waves, tides, and coastal currents within Estero Bay further disperse the discharge plume within the open-ocean receiving waters. Areas of special concern, such as sanctuaries and estuaries, are too distant to be affected by the effluent discharge. 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 2.8 km 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 helps to restrict 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 the 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 instances of elevated beach coliform levels that are occasionally observed have resulted from onshore non-point sources rather than the discharge of disinfected wastewater from the MBCSD outfall (MRS 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007).

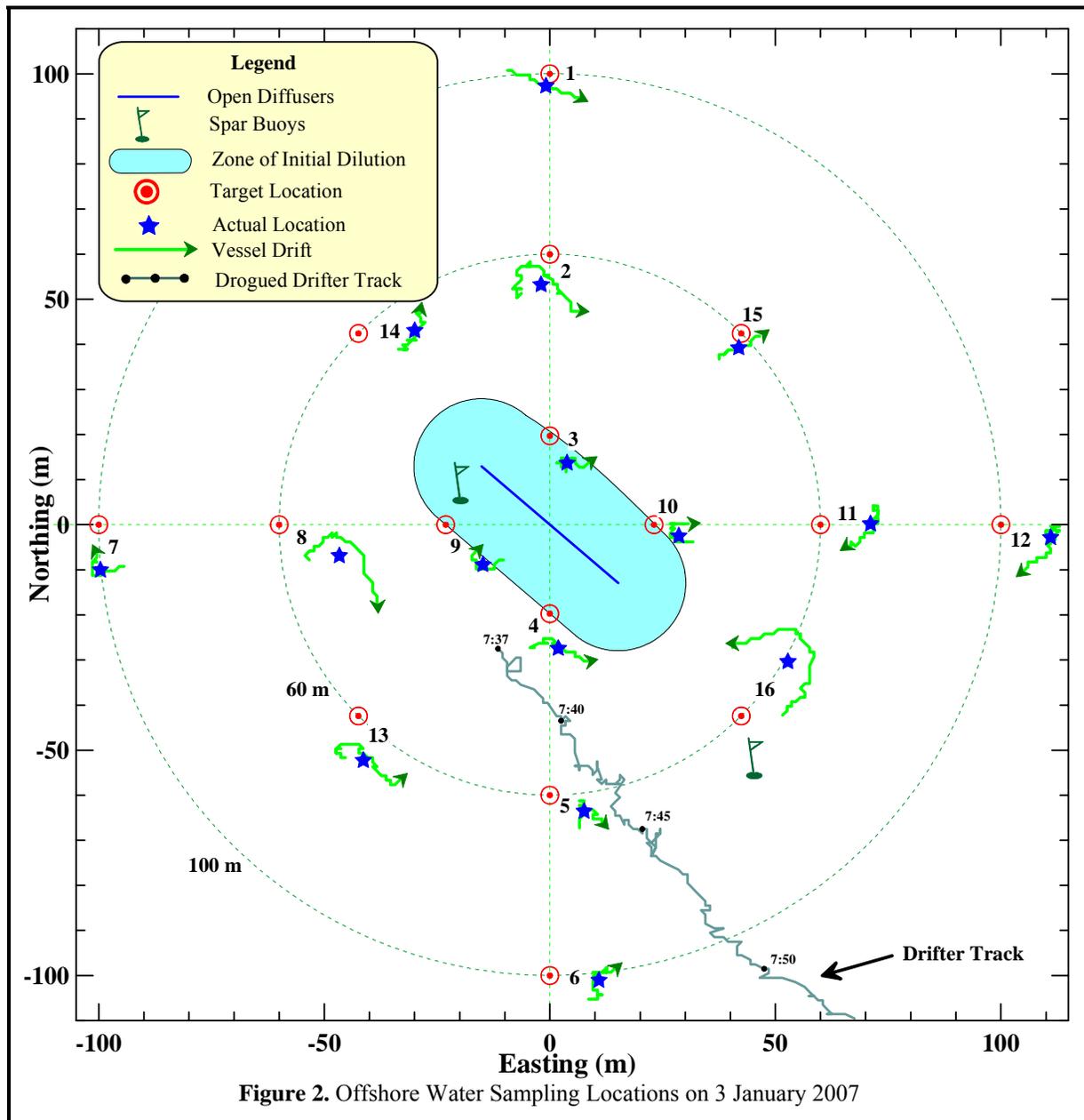
As shown in Figure 2, the water-sampling design consists of 16 fixed offshore stations located within 100 m of the outfall diffuser structure. The target locations of the 16 offshore sampling stations are indicated by the red ⊙ symbols in the Figure. The stations are situated at three distances relative to the center of the diffuser structure in order 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 center of the diffuser. 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 midfield 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 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

¹Distance to the closest open diffuser port.

²Distance to the center of open diffuser section.



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

An important consideration in the assessment of wastewater dispersion close to the discharge is the finite size of the diffuser. 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. Because of this distributed 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 this distributed seafloor source, the ‘*closest approach*’ distance is considerably less than the centerline distance normally cited in modeling studies (Table 1).

Another important consideration for compliance evaluation is the ability to determine the actual location of the measurements. 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 that are now typically less than 10 m.

Even so, extreme atmospheric conditions and physiographic obstructions can still cause satellite 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 provides an extremely stable and accurate offshore navigation reading, 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. The survey vessel is now fitted with two independent DGPS receivers to allow access to two separate land-based beacons for navigational intercomparison, which ensures extremely accurate and uninterrupted navigational reports.

Frequent DGPS navigational reports allow precise determination of sampling locations during the vertical CTD profiling at individual water-quality stations. Knowledge of the precise location of the actual sampling measurements 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. Equally important are the offsets caused by the residual momentum of the survey vessel as it approaches the target locations. Using DGPS, these offsets can be resolved and the vessel location can be precisely tracked throughout 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 the horizontal drift that occurred at each of the stations during the January 2007 survey is apparent from the length of the green tracklines in Figure 2. These tracklines trace the horizontal location of the CTD instrument package as it was lowered to the seafloor. Their lengths reflect the station-keeping difficulty experienced during the January 2007 survey. The substantial drift of the CTD instrument package during the January 2007 survey was due to larger-than-normal wind- and current-induced vessel drift. The elevated prevailing metocean conditions are reflected by the higher-than-normal wind speeds and wave heights that are reported in Table B-9. Because of these conditions, the vessel had

to be dynamically positioned³ to acquire CTD readings near the target station. The resulting CTD trajectories reflect the complex interaction between vessel propulsion, wind drift, and current transport. During the time it took the CTD to traverse the water column to the seafloor, which averaged 1 m 10 s, the instrument package moved as much as 18.6 m laterally. Overall, however, drift averaged 10.5 m during the survey.

At stations close to the diffuser structure, this magnitude of drift 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 is complete. Specifically, during the January 2007 survey, the vertical profiles at Stations 3 and 9 traversed the boundary of the ZID (Figure 2). Thus, strictly speaking, only a portion of the data recorded during these casts was subject to the receiving-water limitations specified in the NPDES discharge permit.

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 the January 2007 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 might 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 10.5 m average drift experienced during sampling at individual stations in the January 2007 survey would not have been resolved with the navigation available prior to 1999. In fact, before 1999 sampling was presumed to occur at a single, imprecisely determined, horizontal location near each station. Federal and State reporting of monitoring data still depends on identification of a single position for all of the CTD data collected at a particular station. Thus, for regulatory and historical consistency with past surveys, a single reportable sampling location was also determined for each station during the January 2007 survey. These positions were based on the average locations shown for each station by the blue stars in Figure 2. The 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 16.2 m closest-approach distance specified for Stations 9 would suggest that all of the data at that station were collected outside of the ZID. In reality, as shown by the green tracklines in Figure 2, the near-surface and deep measurements at Station 9 were recorded well within the ZID, where water-quality limitations do not apply.

In addition to high winds and waves, strong current flow toward the southeast affect the vessel's station-keeping ability during the January 2007 survey. A satellite-tracked drifter documented the prevailing flow during the survey. As in past reports, its trajectory is shown by the grey line with black dots in Figure 2. This drifter is designed to track the subsurface current, with little influence from the wind. Each dot along the drifter trackline represents a time span of five minutes. The drogued drifter was deployed just southeast of the center of the diffuser structure at 07:37 PST. The drifter was recovered just over an hour later, at 08:49 PST. In contrast to most other surveys, the strong southeastward current rapidly carried the

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.

Table 2. Average Coordinates of Vertical Profiles during the January 2007 Survey

Station	Time (PST)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ¹ (m)	Bearing ² (°T)
1	8:22:11	8:23:04	35° 23.252' N	120° 52.505' W	85.8	10
2	8:25:14	8:26:42	35° 23.228' N	120° 52.505' W	42.6	18
3	8:28:56	8:29:53	35° 23.207' N	120° 52.501' W	13.0³	41
4	8:36:23	8:37:18	35° 23.184' N	120° 52.503' W	19.5	221
5	8:39:53	8:41:14	35° 23.165' N	120° 52.499' W	51.0	189
6	8:44:04	8:44:59	35° 23.144' N	120° 52.497' W	88.0	183
7	8:13:51	8:14:44	35° 23.194' N	120° 52.570' W	87.5	255
8	8:06:54	8:08:23	35° 23.195' N	120° 52.535' W	37.1	238
9	8:04:04	8:04:59	35° 23.194' N	120° 52.514' W	16.2³	221
10	7:59:11	8:00:16	35° 23.198' N	120° 52.485' W	17.2	52
11	7:55:40	7:57:21	35° 23.199' N	120° 52.457' W	57.5	77
12	7:51:36	7:52:57	35° 23.198' N	120° 52.431' W	96.4	84
13	9:13:30	9:14:59	35° 23.171' N	120° 52.531' W	66.5	221
14	9:17:08	9:18:04	35° 23.222' N	120° 52.524' W	33.7	334
15	9:23:41	9:24:36	35° 23.220' N	120° 52.476' W	57.2	41
16	9:27:56	9:29:22	35° 23.183' N	120° 52.469' W	41.4	115

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

drifter out of the survey area. Its subsequent movement is presented in Figure 3. The trajectory shows that the drifter movement was constant in both speed and direction throughout its deployment. During that time, it traveled 593 m toward the southeast (141°T) at an average speed of 13.8 cm/s or 0.27 knots.

The strong southward flow that was measured by the drogued drifter was inconsistent with the incoming (flood) tide that prevailed during the survey (Figure 4). In the absence of external influences, a flood tide normally induces a weak northeastward flow in the survey region. However, the flow is more often influenced by external processes, such as wind-generated upwelling. Strong upwelling conditions prevailed shortly after the survey was completed, as seen in the satellite image 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.

The milder upwelling that occurred around the time of the January 2007 survey was largely responsible for the slight water-column stratification that is evident in the vertical profiles collected with the CTD (Figures A-1 through A-3 in Appendix A). Upwelling season normally begins sometime during late March and or early April when there is a "spring transition" to more persistent southward-directed winds along the Central California Coast. This transition is marked by the stabilization of a high atmospheric pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive the prevailing northwesterly winds along the Central Coast. These prevailing winds move surface waters southward and offshore. To replace these coastal surface waters, deep, cool, nutrient-rich waters upwell near the coast as delineated on the cover of this report.

Although the January survey was not conducted during what is normally thought of as upwelling season, strong southeastward winds were prevalent at the time of the survey. As a result of these upwelling winds, the satellite image on the cover shows cool (12°C) sea-surface temperatures were present within Estero

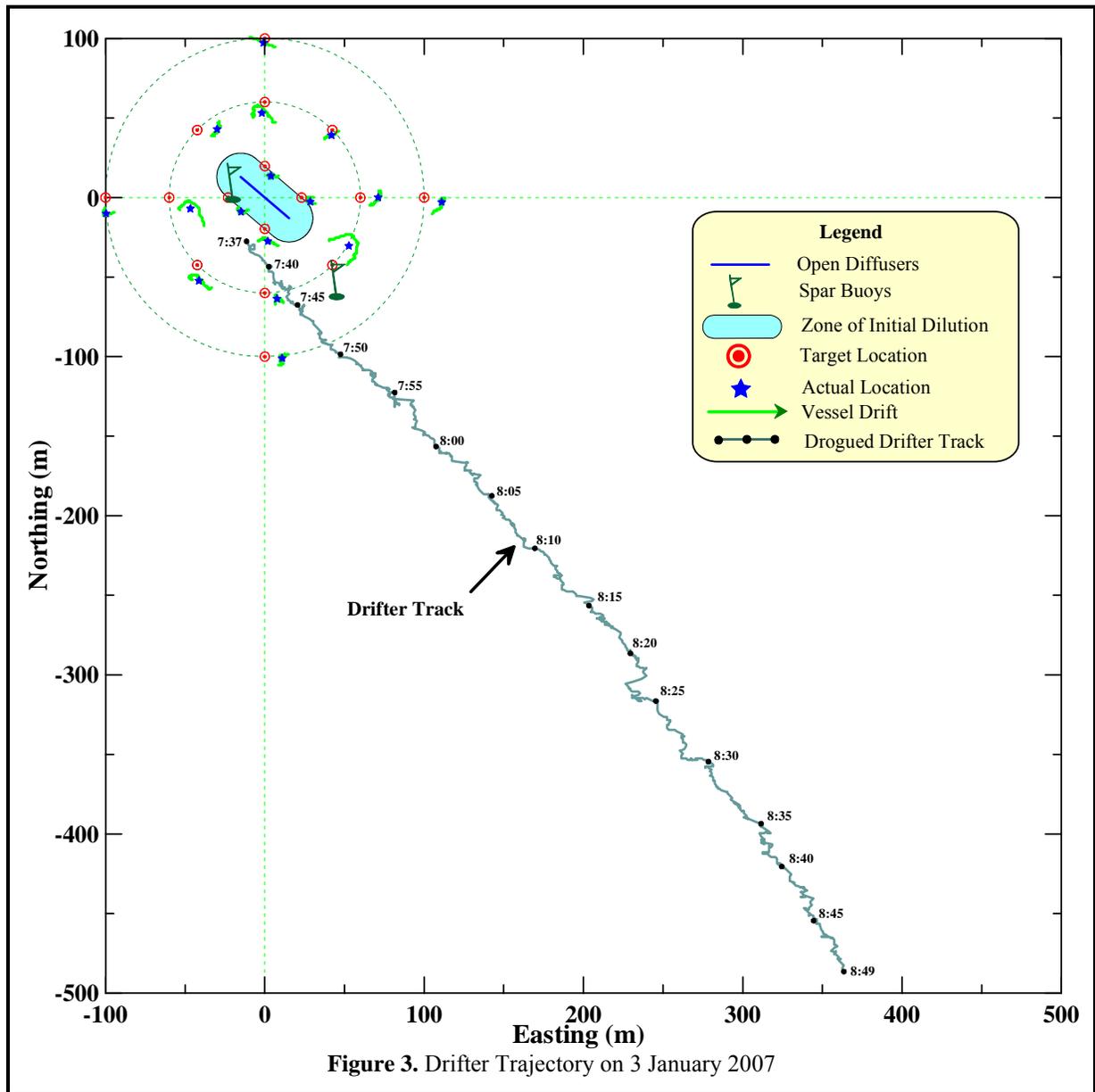


Figure 3. Drifter Trajectory on 3 January 2007

Bay, while temperatures farther offshore exceeded 13°C (yellow and orange) over much of the south-central coast. The lower Estero Bay temperatures represented in the satellite image were consistent with the near-surface temperatures measured by the CTD during the survey, which averaged 12.2°C (Table B-1 in Appendix B). The image also exhibits another upwelling characteristic, namely, a jet of cold coastal water (blue) extending offshore at Point Buchon. This jet reflects the offshore transport of upwelled water that occurs mostly at major promontories along the coast.

The nutrient-rich seawater that is brought to the sea surface near the coast 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 enhances vertical stratification of the water column. The presence of denser water at depth produces a shallow (<10 m) thermocline that is commonly maintained throughout summer and into the fall. In contrast, winter

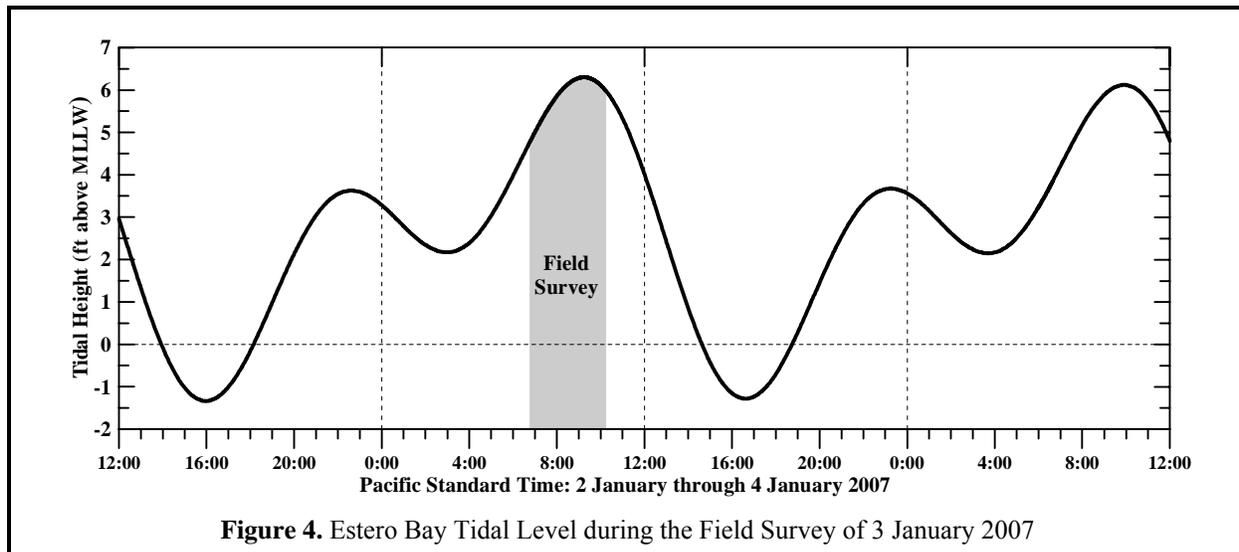


Figure 4. Estero Bay Tidal Level during the Field Survey of 3 January 2007

oceanographic conditions are normally characterized by vertically uniform conditions. Intense winds generated by passing local storm fronts, and large waves produced by distant Pacific storms, generally result in a well-mixed water column in winter. Although the vertical profiles show very well mixed conditions during the January survey, as expected in winter, they also exhibit a slight change in water properties near the seafloor. These different seawater properties were generated the intrusion of deep offshore waters.

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 3 January 2007. Dr. Douglas Coats and Ms. Bonnie Luke of Marine Research Specialists (MRS) provided scientific support. Captain Mark Tognazzini supervised vessel operations, while Mr. William 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 (Table B-9). 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-9). 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 up to 7 m were measured during the January 2007 survey, reflecting the presence of a comparatively deep euphotic zone, extending nearly to the seafloor. The presence of such a deep euphotic zone is fairly typical of mild upwelling conditions, but does not occur under stronger upwelling conditions. When strong upwelling conditions prevail, increased

primary production, namely, increased plankton density, markedly decreases light transmissivity within the upper water column. However, during the January 2007 survey, little reduction in light transmissivity in the upper water column was observed (light blue lines in Figures A-1 through A-3).

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 January 2007 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 times and precise positions of the drifter deployment and recovery were recorded to determine the overall strength and direction of plume transport during the January 2007 sampling effort. In addition, the January 2007 survey was the eighth MBCSD survey to 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.

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 and in June 2006 for testing and recalibration. Because of increasing temporal drift associated with the aging DO probe, it was replaced on both occasions with a new DO probe. As is the case before all surveys, the CTD system was recalibrated at the MRS laboratory prior to the January 2007 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.

Table 3. Instrumental Specifications for CTD Profiler

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

¹ Maximum depth limit in meters

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. Pressure housing 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 Table 3. 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 – stability) 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 initial intensity of a transmitted beam of light detected at the opposite end of a 0.25 m path. Increased transmittance indicates increased water clarity and decreased turbidity.

During the pre-cruise calibration, coefficients for the pH (alkalinity) sensor were determined from a linear regression of output voltage after immersion in three separate buffered solutions of known pH. Buffering solutions with a pH of 4±0.01, 7±0.01, and 10±0.02 were used to bracket the range of in situ measurements. The SeaTech transmissometer was air calibrated by fitting the voltages recorded with and without blocking of the light transmission path in air, as recommended by the manufacturer (SBE 1989). Revised calibration coefficients determined prior to the survey were used in the algorithms that converted 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, and the more recent June 2006 replacement and calibration of the DO probe, 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.

Before deployment at the initial station, the CTD was held below the sea surface for a six-minute equilibration period. Subsequently, the CTD was raised to within 1.0 m of the sea surface and profiling

commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at multiple stations were collected during two deployments of the CTD package by towing it below the water surface while transiting between adjacent stations. Upon retrieval of the CTD, the profile data were downloaded to a portable computer and examined for completeness and range acceptability.

Temporal Trends in the DO and pH Sensors

The DO and pH sensors exhibited temporal drifts during the January 2007 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. Previous attempts to further 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 January 2007 survey, a tube filled with seawater was placed around the pH sensor while in transit to the survey site to limit atmospheric exposure of the probe prior to deployment. This technique was successful at further ameliorating sensor drift.

However, these procedures did not entirely eliminate the temporal offsets, which were particularly evident against the background of nearly uniform ambient conditions. The required pH adjustments were small, and did not exceed 0.07 pH units, which is less than the accuracy of the probe (Table 3). Additionally, slight drift in the DO probe required a small (0.1 mg/L) adjustment to measured DO concentrations at four stations (13, 14, 15, and 16), which is, again, an adjustment that is less than the probe's reported accuracy (Table 3).

Removal of the artificial pH and DO trends was important because they were large compared to the overall range in measured values. As a result, they could potentially mask very slight discharge-related anomalies. Specifically, equilibration-related offsets created artificial differences in the DO concentrations reported at Stations 13, 14, and 16. These are apparent in the originally reported DO concentrations listed in Table B-8. The values listed in bold typeface and enclosed in boxes were statistically different from the DO concentrations measured at adjacent stations. In reality, the CTD measurements at Stations 13, 14, 15, and 16 were collected during a separate deployment. Table B-4 shows that these artifacts were removed after adjusting for the temporal offsets. As a counterpart to the DO adjusted data, Table B-6 provides temporally detrended pH data. However, in contrast to the DO measurements, the temporal drift in the original pH measurements, shown in Table B-7, was not large enough to be statistically significant.

RESULTS

The first-quarter water-quality survey began on Wednesday, 3 January 2007, at 07:37 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-9). Sunrise was at 07:12 PST and skies were clear throughout the survey, which ended at 10:00 PST when the vessel returned to port. Strong winds from the northwest prevailed throughout the survey. Average wind speeds, calculated over one-minute intervals, ranged from 1.8 kt to 9 kt, with peak speeds ranging from 4.3 kt to 11.4 kt. Additionally, a 4 to 5 ft swell moved through the survey area from the west. Atmospheric visibility was greater than 2 nM along the ocean surface owing to the absence of low-lying fog. As a result, Morro Rock and the shoreline remained visible throughout the survey. Air temperatures increased from 11.9°C to 13.3°C as the survey progressed. The surface seawater temperature (12.2°C) in the survey area was slightly lower than the

average air temperature, but was consistent with coastal sea-surface temperatures within Estero Bay as recorded by the satellite image shown on the cover of this report.

The discharge plume signature was visibly apparent below the sea surface to the south of the diffuser structure during the latter portions of the water-quality survey. However, the suspended particulates that were observed below the sea surface were of natural, rather than sewage, origin. As discussed below, they were part of a turbid benthic boundary layer that was entrained in the effluent plume as it rose through the water column. Moreover, the plume was only apparent because of the higher-than-normal ambient water clarity that was present in the upper water column at the time of the survey. Throughout the survey, there was also no visual evidence of floating particulates, oil and grease, or seawater discoloration at the sea surface that was associated with the discharge.

Beneficial Use

During the January-2007 survey, few beneficial uses were observed compared to previous surveys. This was predominately due to the unsettled weather present at the time of the January-2007 survey which included a substantial sea swell, and high winds. The survey took place between the passage of two strong storm fronts. Despite these adverse conditions, several seabirds were observed utilizing the receiving waters as marine habitat. Small numbers of western gulls (*Larus occidentalis*), Brandt's (*Phalacrocorax penicillatus*) and Pelagic cormorants (*Phalacrocorax pelagicus*) were all observed transiting the survey area. Additionally, two common murrelets (*Uria aalge*) were noted in the harbor.

Four otters were also observed while in transit to the survey area. The three adults and one pup were all seen within the shelter of the harbor mouth. Sea otters are a federally and state-protected species. Since the arrival of a raft of 30 to 40 sea otters just north of Port San Luis was observed in 1974 (Gotshall *et al.*, 1984), they have become increasingly prevalent in the vicinity of Estero Bay (Gotshall *et al.*, 1986). Sea otters feed almost entirely on macroinvertebrates (Ebert, 1968; Estes *et al.*, 1981; Riedman and Estes, 1990) and the southward expansion of the sea otter appears firmly correlated chronologically and geographically, to the demise of Pismo clams and the central coast abalone fishery (Morro Group, Inc., 2000; California Department of Fish and Game, 2001).

In addition to marine mammal and bird life, several large pieces of kelp (*Macrocystis*) holdfast were seen floating near the spar buoys. Towards the end of the survey, two private vessels were also seen to leave the harbor and transit northbound. No other evidence of beneficial use of receiving waters was noted during the survey

Ambient Seawater Properties

Data collected during the January 2007 survey reflected mildly stratified conditions that are indicative of upwelling conditions that were present at the time of the survey. Upwelling results in an influx of dense, cold, saline water at depth and normally leads to a sharp thermocline, halocline, and pycnocline where temperature, salinity, and density change rapidly over short vertical distances. Under heavily stratified conditions, isotherms crowd together to form a thermocline that restricts the vertical transport of the effluent plume and reduces its dispersion.

However, data from the January 2007 survey only exhibit weak, but perceptible, upwelling-induced vertical gradients near the seafloor. A thermocline, where temperature steadily decreases with increasing depth, is evident in most of the vertical profiles shown in Figures A-1 through A-3 (red lines). As described in the following sections, the presence of the effluent discharge plume altered the vertical

structure of the water column at Stations 4 and 9. However, at the other stations, most ambient seawater properties exhibited vertical stratification nearly identical to that of the thermal structure. For example, the shape of the temperature profile at any given station is closely reflected in the profiles of transmissivity (light-blue lines), dissolved oxygen (dark blue lines), and to a lesser extent, in the profiles of pH (olive-colored lines). Similarly, the steady decreases in temperature, transmissivity, DO, and pH with increasing depth just above the seafloor, are mirrored by a pycnocline where density (black lines) steadily increases with depth. Thus, at most stations, upwelling-induced stratification influenced the vertical structure of all ambient seawater properties except salinity (green lines).

The benthic boundary layer that is apparent in most of the vertical profiles was generated by upwelling-induced cross-shore transport. The layer is characterized by a comparatively high density, reduced temperature, DO, and pH, and at many stations, markedly reduced transmissivity. The upwelling process transported this cold, dense seawater onshore to replace nearshore surface waters that were driven offshore by prevailing winds. The undersaturated DO found at depth is a clear indicator of the deep offshore origin of this watermass. Deep offshore waters are undersaturated in oxygen because they have not had direct contact with the atmosphere for long periods of time, and biotic respiration and decomposition have slowly depleted the dissolved-oxygen levels. Respiration and decomposition within this deep watermass also increased dissolved CO₂ (carbonic acid), resulting in a concomitant decline in pH, reflecting the seawater's slightly more acidic nature. Finally, in contrast to the other water properties, transmissivity exhibited a sharp reduction immediately above the seafloor at some stations (light blue lines in Figure A-1 through A-3). This distinctive decrease in transmissivity within a thin layer immediately above the seafloor indicates the presence of a bottom nepheloid layer (BNL), which is a widespread phenomenon on continental shelves (Kuehl et al. 1996). The increased turbidity observed within the BNL during the January 2007 survey was caused by the presence of naturally occurring particulates formed from light-weight flocs of detritus. This detritus is easily suspended by oscillatory bottom currents generated by passing surface gravity waves. Its presence is not apparent at some of the stations largely because there are slight variations in the thickness of the BNL, and the deepest measurements of the CTD did not always penetrate this very thin layer just above the seafloor.

Lateral Variability

The influence of the effluent discharge can be best identified from localized anomalies in seawater properties, particularly salinity. In contrast to the vertical profiles, discharge-related anomalies become especially apparent in the cross-sections which highlight differences in seawater properties at adjacent stations. Accordingly, the salinity sections in the top frames of Figure A-4 and A-6 show the influence of the discharge at Stations 4 and 9. The density sections shown in the bottom frames exhibit nearly identical anomalies associated with the effluent plume. Vertical sections of most other seawater properties exhibit discharge-related anomalies at the same locations. However, in contrast to salinity and density anomalies, which are vertically isolated, the other seawater anomalies have the same characteristics as ambient seawater at depth. Thus, in contrast to the salinity and density anomalies, they were not generated by the presence of wastewater particulates. Instead, they were generated by the upward displacement of ambient seawater near the seafloor. As described above, ambient seawater properties near the seafloor differed sharply from the uniform water properties in the rest of the water column. The shallow, non-salinity anomalies were generated when this deep ambient seawater became entrained in the discharge plume and was displaced upward into the water column where the surrounding seawater characteristics differed. Both the entrainment-generated and the wastewater-induced anomalies become apparent when seawater properties measured at the same depth level are compared at adjacent stations. Because of this, the

analysis of lateral variability in seawater properties forms the basis for assessments of water-quality impacts in this report.

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. These different depth references are used 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-8. 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 then 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-8 by bolded values enclosed in boxes.

After correction for temporal trends in pH and DO, all six of the seawater properties exhibited statistically significant departures from mean conditions (Tables B-1 through B-6). However, most of the highlighted departures were not associated with the discharge. Except for the anomalies in the upper water column at Stations 4 and 9, the statistical significance of other random fluctuations was an artifact of the extraordinarily uniform conditions that were present during the January 2007 survey. Statistical significance is a function of the overall variability, and, during most other surveys, these small fluctuations would not be found to be statistically significant. These small fluctuations, however, were clearly not associated with the discharge because they were not spatially coincident with one another, and their locations were not consistent with the southeastward transport of the plume.

The presence of statistically significant fluctuations that are unrelated to the discharge is expected from the nature of statistical hypothesis testing itself. From the definition of a 95% confidence level, one ‘*significant*’ departure out of every 20 measurements should occur by chance alone. With 530 measurements examined for each of the six parameters, it would not be surprising if a few departed from the mean by an amount more than the 95% confidence interval. Moreover, when multiple hypotheses are being tested (*i.e.*, one for each observation), the error rate for each individual test should be adjusted to achieve the overall experimentwise error rate of 5% (95% confidence). By definition, this error rate is the probability that one or more of the hypothesis tests would incorrectly find a significant difference when none exists. Thus, without correcting for repeated hypothesis testing, the individual tests are conservative and “*significant*” departures will be found more often than if a single test were being performed at the 95% confidence level.

Discharge-Related Perturbations

During the January 2007 survey, three distinct perturbations in seawater properties were unequivocally related to the discharge (Perturbations P1 through P3 in Table 4). A discharge-related perturbation is a group of anomalies in one or more seawater properties that are spatially contiguous at a particular station. The vertical distribution of seawater properties within and below the perturbations lends insight into

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

Perturbation ^b	Station	Depth Range	Depth of		Property	Magnitude	Process
			Extremum				
P1 Dilution \geq 549:1	4	1.0 to 6.5 m	4.0 m		Salinity	-0.061 ‰	Effluent
		4.0 to 8.0 m	6.0 m		Temperature	-0.07 °C	Entrainment
		0.5 to 6.5 m	4.0 m		Density	-0.039 σ_t	Effluent
		4.5 to 7.5 m	6.5 m		Transmissivity	-10.3 %	Entrainment
		5.5 to 7.0 m	6.5 m		Dissolved Oxygen	-0.07 mg/L	Entrainment
P2 Dilution \geq 670:1	9	1.5 to 3.0 m	2.5 m		Salinity	-0.050 ‰	Effluent
		1.5 to 3.0 m	2.5 m		Density	-0.037 σ_t	Effluent
		1.0 to 3.0 m	2.5 m		Transmissivity	-4.1 %	Entrainment
P3 Dilution \geq 341:1	9	6.5 to 11.0 m	9.0 m		Salinity	-0.098 ‰	Effluent
		6.5 to 10.5 m	9.0 m		Density	-0.071 σ_t	Effluent
		8.5 to 16.0 m	11.5 m		Transmissivity	-10.1 %	Entrainment
		9.0 to 15.0 m	10.5 m		Dissolved Oxygen	-0.08 mg/L	Entrainment

^a Anomalies shown in bold type were statistically significant

^b Perturbations are composed of a group of spatially consistent anomalies in several different seawater properties

which of the two discharge processes were responsible for generating a particular anomaly. As indicated in Table 4, only the salinity and density anomalies reflected the presence of dilute wastewater, while the anomalies in other water properties were generated by entrainment of ambient seawater within the rising effluent plume. The mechanism that produces discharge-related anomalies is an important consideration when assessing the discharge's compliance with the receiving-water objectives of the COP, and the requirements of the NPDES permit.

The anomalies in salinity and density could not have been generated by the movement of ambient seawater alone. The top and bottom frames of Figure A-4 and A-6 show that the anomalously low salinity and density measurements observed in the upper water column at Stations 4 and 9 were vertically isolated, and far lower than the salinity and density of the ambient seawater located anywhere else, even within the BNL near the seafloor. In contrast, the corresponding temperature, transmissivity, and DO anomalies at Stations 4 and 9 were not vertically isolated. They contained temperatures and concentrations that were comparable to the range of properties within ambient seawater at depth. Furthermore, the character of some of these entrainment-generated anomalies was not consistent with changes that would be induced by the presence of dilute wastewater. In particular, the negative thermal anomaly within Perturbation P1 was 0.07°C lower than the surrounding seawater. Normally, dilute effluent would be expected to be warmer, not colder than the receiving seawater.

Initial Dilution Computations

The amplitude of negative salinity anomalies at Stations 4 and 9 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 would become 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, dilutions computed from salinity anomalies observed during the January 2007 survey demonstrated that the effluent plume actually achieved a far higher dilution (>341:1) at depths (9 m) well below the predicted trapping depth (6.4 m). 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 were thought to be necessary in order to meet Ocean-Plan standards.

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

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

where: C_e = the concentration of a constituent in the effluent,
 C_o = the concentration of the constituent in the ocean after dilution by D (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:

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

where: D = the dilution ratio of the volume of seawater mixed with effluent,
 C_o = the salinity of the effluent-seawater mixture after dilution by D ,
 C_s = the background seawater salinity (approximately 32.9‰), and
 $A = C_o - C_s$ = the salinity anomaly.

The salinity anomalies listed in Table 4 were used in Equation 2 to compute the dilution levels listed in the first column of the table. The dilutions using the January 2007 data demonstrate that the modeled dilution factors were significantly more conservative than those actually achieved by the discharge. Specifically, the minimum dilution computed from the largest salinity anomaly exceeded 341:1. The largest discharge-induced salinity anomaly (-0.098‰) was recorded 9 m below the sea surface at Station 9 (Perturbation P3). Based on Equation 2, this translates to a dilution that was 2.5 times higher than the dilution predicted by modeling. Moreover, the anomaly was measured at a depth that was 2.6 m deeper than the trapping depth predicted by modeling. Theoretically, the dilution should be lower than the model predictions at this depth because the effluent plume had not experienced as much buoyancy induced dispersion as predicted by modeling.

Moreover, this discharge-related salinity anomaly was associated with a large negative density anomaly, as shown in the bottom frame of Figure A-6. The unstable density inversion apparent within Perturbation P3, where a buoyant mixture of dilute wastewater is surrounded by denser ambient seawater, almost never occurs under natural conditions in the ocean. Seawater overturn takes place rapidly and the associated turbulent mixing produces a stable water column with steadily increasing density with increasing depth. Perturbation P3's instability indicates that the dilute, buoyant effluent plume was continuing to mix and rise in the water column. Consequently, initial dilution was not complete within Perturbation P3, even though the measurements were collected at the boundary of the zone of initial dilution. This is a case where the strong southeastward current carried the plume beyond the ZID before it had a chance to achieve full dilution. In fact, depth of Perturbations P1 and P2 demonstrate that during the January 2007 survey, the buoyant effluent plume rose all the way to the sea surface, whereupon it had been diluted more than 500-fold. This is five-times the dilution level predicted by the modeling. These dilution computations demonstrate that, during the January 2007 survey, the outfall was performing better than designed, and was rapidly diluting effluent more than 500-fold beyond the boundary of 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 January 2007 survey indicated that the wastewater discharge was in compliance with the receiving-water limitations specified in the NPDES permit, and with the water-quality objectives of the COP (SWRCB 1997) and the Central Coast Basin Plan (RWQCB 1994). Specifically, there were no particulates of sewage origin seen floating on the ocean surface at any of the stations sampled during the January 2007 water-quality survey, and the discharge complied with all quantitative limits on seawater properties.

Although discharge-related changes in five of the six water properties were observed during the January 2007 survey, the changes were either not statistically significant, were measured near the boundary of the ZID before initial dilution was complete, or resulted from the displacement of ambient seawater rather than the presence of effluent constituents. Receiving-water limitations only apply to statistically significant changes caused by the presence of effluent constituents after initial dilution has been completed beyond the ZID boundary. The limitations do not apply to measurements within the ZID because the discharged wastewater is still undergoing rapid initial mixing with the surrounding seawater. This was the case for the mid-depth anomalies associated with Perturbation P3. Those measurements were collected at Station 9 along the boundary of ZID as the CTD drifted in and out of the ZID (Figure 2). The buoyant instability associated with Perturbation P3 demonstrated that it was continuing to undergo initial mixing.

Other than salinity and density, the transmissivity anomalies within Perturbations P1 and P3 at Stations 4 and 9 were the only discharge-related changes in seawater properties that were found to be statistically significant. However, these localized reductions in transmissivity were generated by the upward displacement of ambient seawater rather than the presence of wastewater particulates. The cross-sections in the middle frames of Figures A-5 and A-7 show that the transmissivity anomalies were generated when the discharge entrained naturally turbid seawater that was present within the BNL. . The dilute effluent plume carried this turbid water upward where the contrast with the extremely high clarity of the surrounding seawater became readily apparent. These transmissivity anomalies would not have been present without this naturally occurring vertical contrast in turbidity. Under conditions of uniformly low ambient seawater turbidity, and a dilution of at least 341-fold, average wastewater particulate

concentrations of 20.5 mg/L would be reduced to 0.06 mg/L within the effluent plume. Based on transmissometer calibrations, this would induce a change in transmissivity of only about 0.4%, which is close to the 0.1% limit on the accuracy of the instrument (Table 3), and an order of magnitude lower than the amplitude of the anomalies reported in the perturbations.

Outfall Performance

Small anomalies in salinity indicated the presence of dilute wastewater at Stations 4 and 9. 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 both within and beyond the ZID. A dilution of 341:1 was determined from the salinity anomaly located at mid-depth at Station 9. This is well above the minimum critical dilution of 133:1 specified in the NPDES permit. The statistically significant salinity anomalies at the other stations were even smaller in amplitude. They indicate that wastewater had been diluted more than 500-fold, which is four times higher than the 133:1 dilution used in the NPDES permit to establish end-of-pipe concentration limits on effluent constituents. Thus, with the higher dilution ratio that was determined from actual measurements during the January 2007 survey, contaminant concentrations within the wastewater could have been more than four times the limits specified in the NPDES discharge permit, and the receiving-water objectives of the California Ocean Plan (COP) would still have been achieved.

NPDES Permit Limits

The seawater properties measured during the January 2007 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 occurrence of the following conditions.

- 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-8, 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

Statistical analysis revealed significant reductions in instrumentally recorded light transmittance at a number of locations during in the January 2007 survey (highlighted by bold typeface in Table B-5). Although statistically significant, the deep transmissivity anomalies at Stations 8, 11, 13, and 15 were generated by natural fluctuations in the thickness of the turbid seafloor boundary layer that was present at all stations. Even if the seafloor transmissivity reductions were discharge-related, they would not represent a violation of the discharge permit. Because they were located on the seafloor, they could not have caused a “...reduction in the transmittance of natural light...” Based on the deepest measured Secchi depths of 7 m (Table B-9), the bottom of the euphotic zone was approximately 14 m, indicating that little natural light was reaching the seafloor where the statistically significant anomalies in transmissivity were observed.

Increased suspended material was visually evident within the water column south of the diffuser structure during part of the survey. This was confirmed by transmissivity measurements taken at Station 4 (top frame of Figure A-5) and Station 9 (top frame of Figure A-7). This decrease in transmissivity was also evident in the reduced Secchi Depth measurement of 4.5 m at Station 4 (Table B-8), and possibly Station 5. However, while this turbidity plume was undoubtedly related to the discharge, it was not caused by the presence of wastewater particulates. Instead, it was generated by the upward displacement of turbid bottom water entrained in the effluent as it was discharged near the seafloor. As such, any potential reduction in the transmission of natural light was not caused by the presence of ‘waste’ particulates within the discharged effluent as specified in the COP limitation.

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.” Clearly, then, the DO limitation does not apply to reductions in DO caused by the movement of ambient waters, regardless of whether or not they were induced by the physics of the discharge. Neither of the DO anomalies was significant, and both discharge-related DO reductions (Perturbation P1 at Station 4 and Perturbation P3 at Station 9) were generated by the entrainment of ambient seawater. Therefore, they were not subject to the limitations. Even so, the amplitudes of the DO anomalies were so small (-0.08 mg/L) that they did not constitute a statistically significant deviation from the norm, even though the ambient variation in the DO field was extraordinarily small at the time of the survey. This would have to be the case because the anomaly was created by the upward movement of ambient seawater that is naturally depleted in oxygen at depth, and therefore, was comparable to observed background concentrations. Regardless, all of the DO measurements complied with the numerical limits specified in the permit. Specifically, none of the DO concentrations measured during the January 2007 survey fell below the 5-mg/L minimum specified in the Basin Plan and the NPDES discharge permit. In fact, none of the 530 measurements collected during the January-2007 survey fell below 6.56 mg/L. As such, none of the DO measurements could be considered “...depressed more than 10 percent from that which occurs naturally,” given that the entire range in measurements constituted a variation of only 3.4%.

pH

After correcting for sensor drift, a number of pH measurements were found to depart from mean conditions by more than the 95% confidence interval (Table B-6). However, none of these anomalies coincided spatially with anomalies in other seawater properties, which would suggest that they were discharge related. Instead, as with the DO anomalies, the statistical significance of the pH anomalies arose

because of the extremely small range (0.065 pH units) among the 530 pH measurements collected during the January 2007 survey. This range is much smaller than the reported accuracy of the probe (± 0.1 pH units, Table 3), and far smaller than the limits specified in the discharge permit. Consequently, none of the measurements can be considered changed by ‘...more than 0.2 pH units from that which occurs naturally.’ In addition, measured pH remained between 8.004 and 8.069 in all 530 measurements. 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

At -0.07°C , the discharge-related thermal anomaly at Station 4 was far too small to adversely affect beneficial uses. Moreover, as shown in the middle frame of Figure A-4, it was generated by the upward displacement of ambient seawater. If it had, instead, been induced by the presence of dilute wastewater, it would have appeared as a positive (warmer) anomaly. In any regard, the slightly depressed temperature of 12.1°C was comparable to average temperatures measured within the BNL near the seafloor. In fact, as with the transmissivity anomalies, the statistically significant thermal anomalies that are highlighted near the seafloor in Table B-1 were caused by variations in the thickness of the cold, dense BNL. As with many other seawater properties, the statistical significance of the thermal anomalies noted during the January 2007 survey was largely due to the extraordinarily small range (0.181°C) in measured temperatures among all the measurements.

Additionally, although salinity anomalies provide the best tracer of discharged effluent, their actual amplitude ($<0.1\text{‰}$) 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 six times higher (0.64‰). In any regard, the observed ranges in both the measured temperature (0.181°C) and salinity (0.12‰) across all data collected during the January 2007 survey were too small to be considered harmful to marine biota or deleterious to beneficial uses.

Conclusions

All of the measurements recorded during the January 2007 survey complied with the receiving-water limitations specified in the NPDES discharge permit. Other than salinity and density, the discharge-related anomalies that were found near the ZID boundary southeast of the diffuser structure at Stations 4 and 9 were caused by upward displacement of ambient seawater rather than the presence of dilute effluent. At that point, effluent had been diluted at least 341-fold, and any perceptible trace of anomalous wastewater characteristics, other than low salinity, had long since disappeared. Farther up in the water column, dilution levels were more than four-times greater than those predicted by modeling. These measurements confirm that the diffuser structure and the outfall were operating better than expected from the modeling.

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APPENDIX A

Water Quality Profiles and Vertical Sections

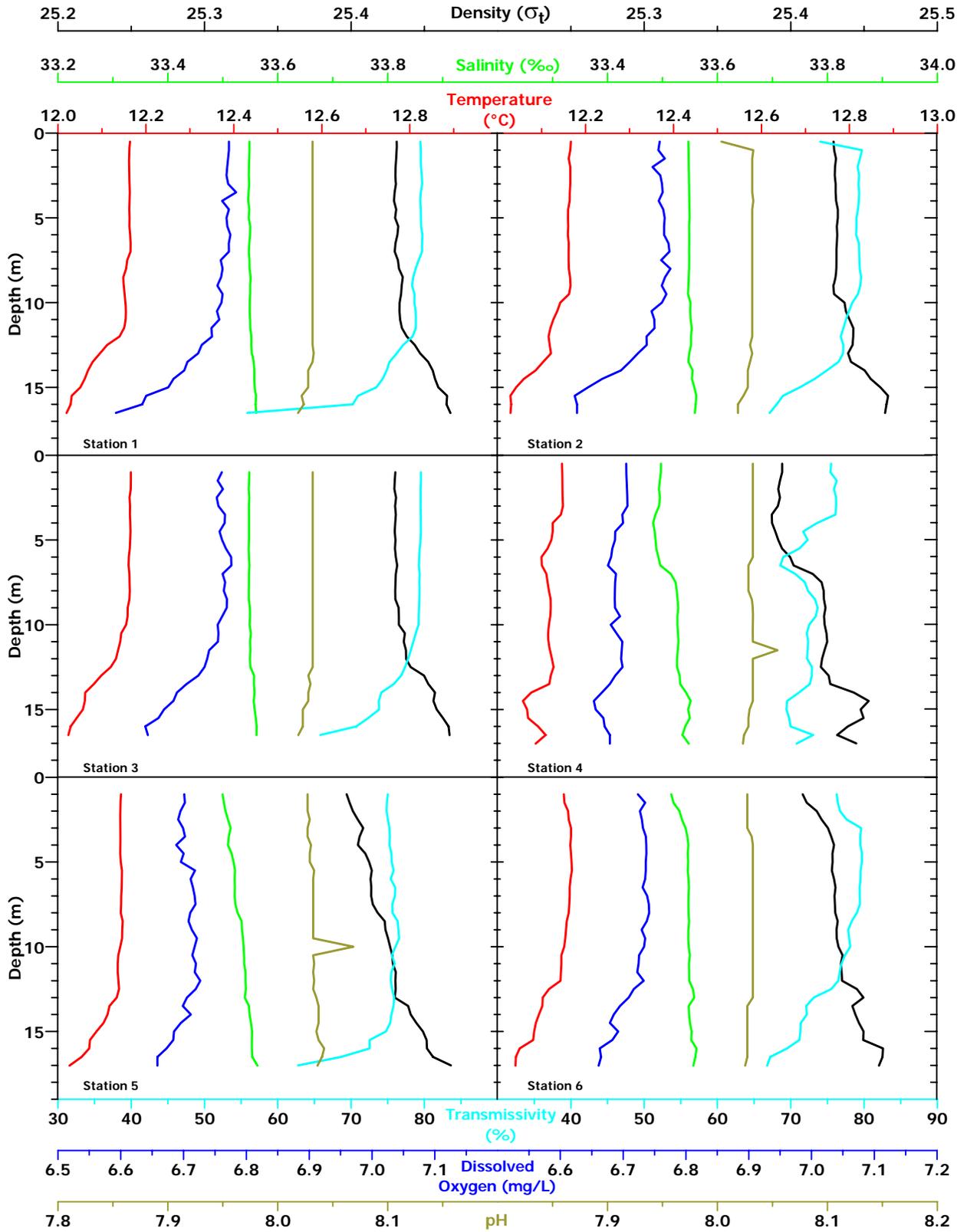


Figure A-1. Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 3 January 2007

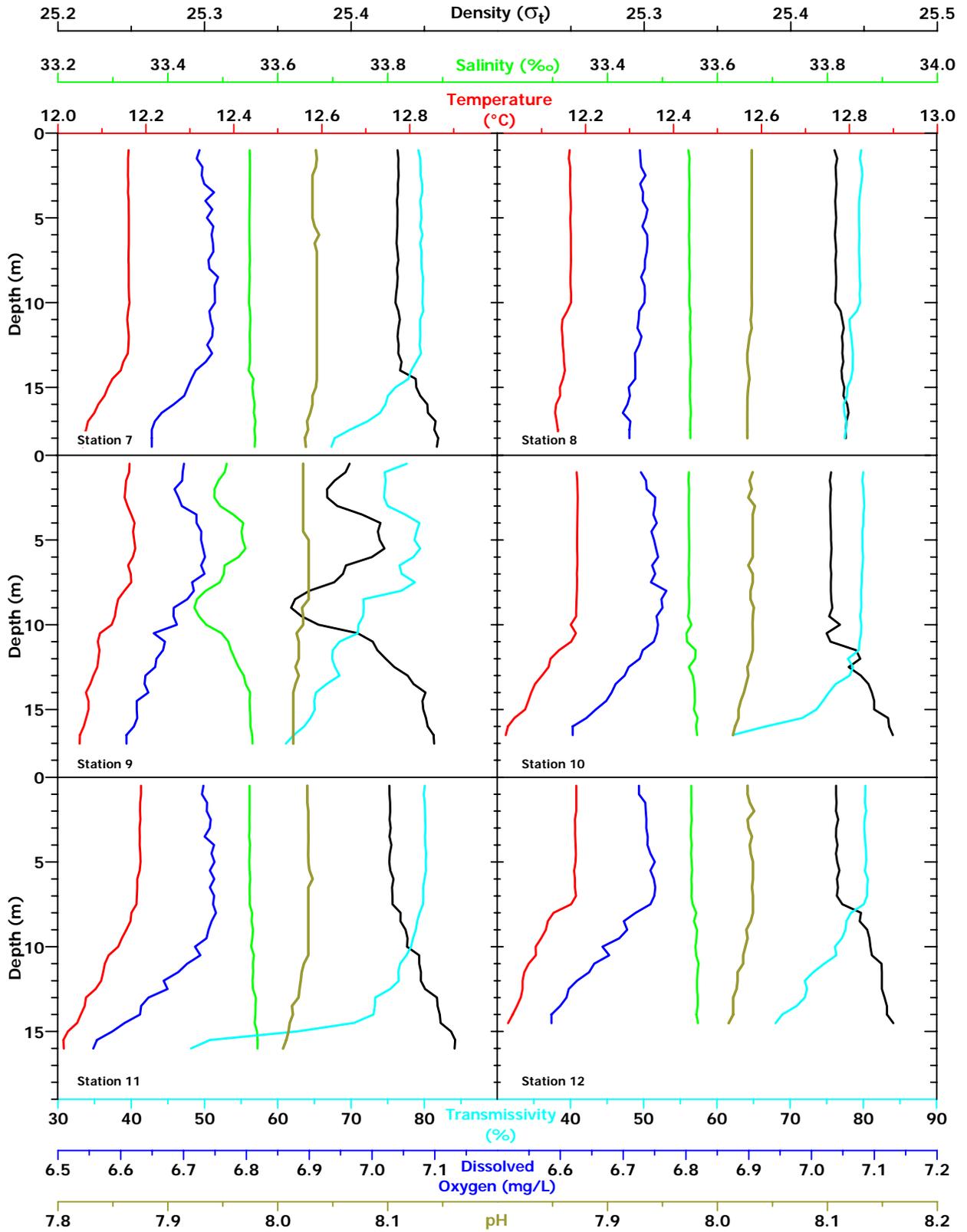


Figure A-2. Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 3 January 2007

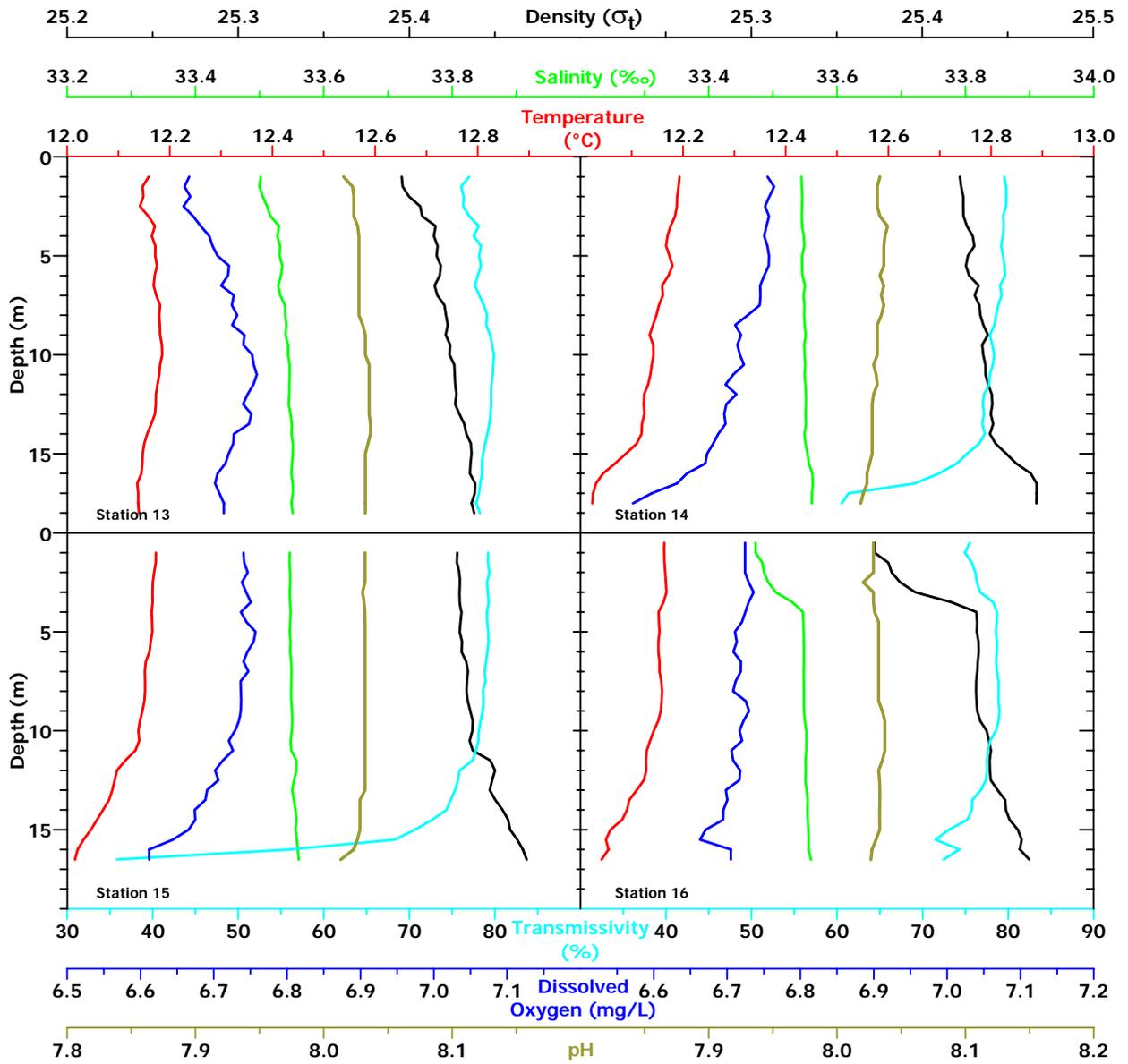


Figure A-3. Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 3 January 2007

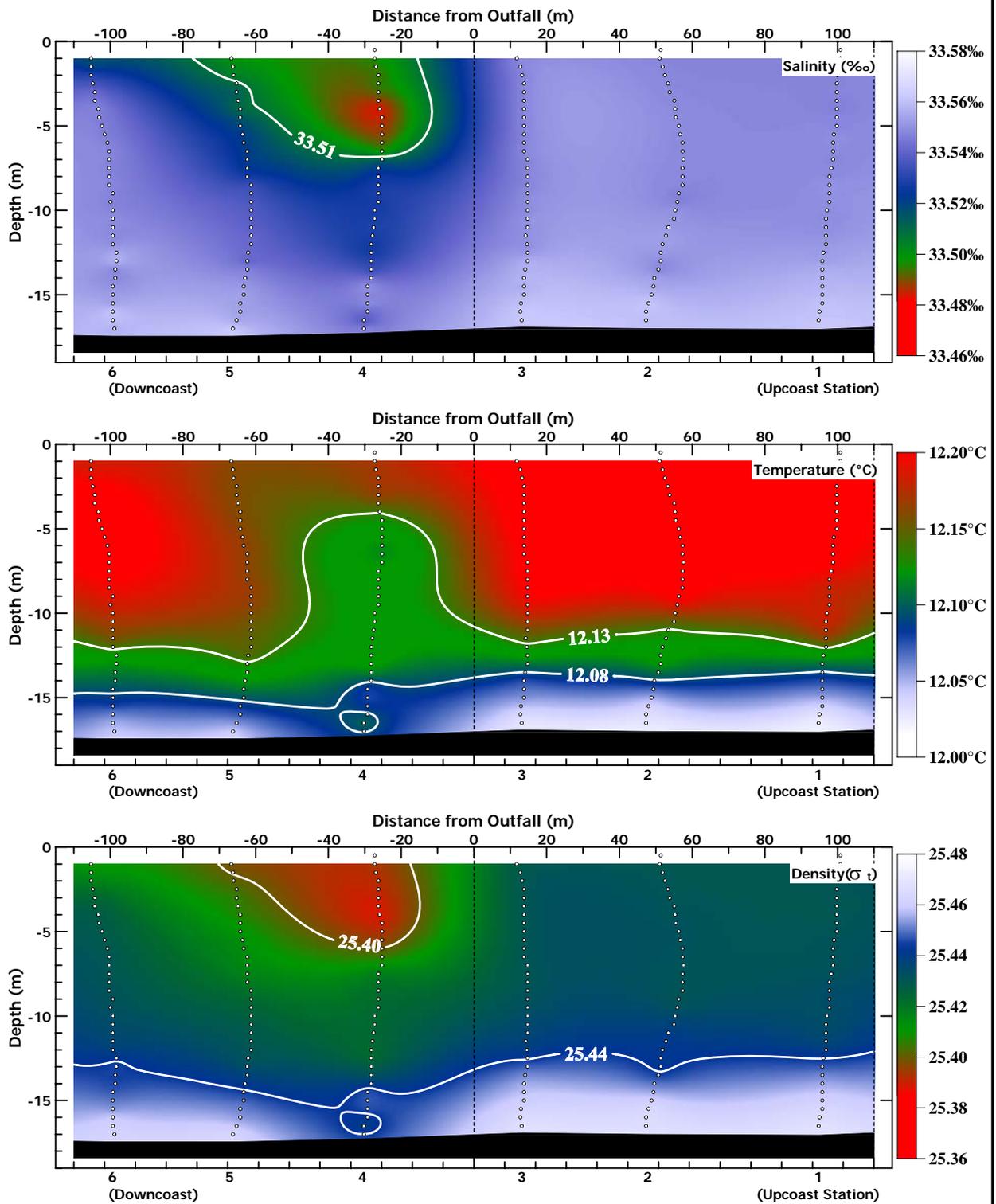


Figure A-4. Along-Shore Transects of Salinity, Temperature, and Density on 3 January 2007

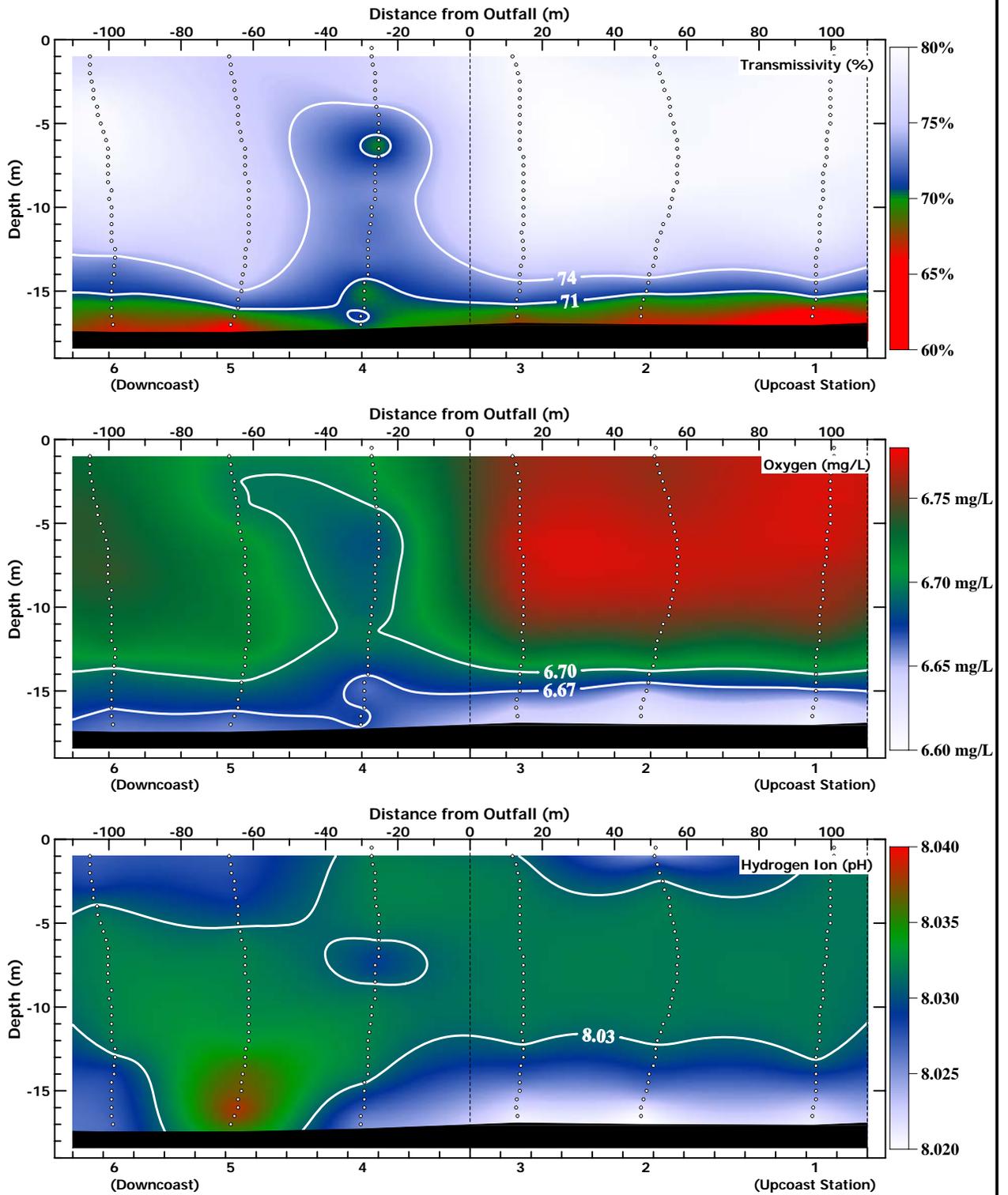


Figure A-5. Along-Shore Transects of Transmissivity, Oxygen, and pH on 3 January 2007

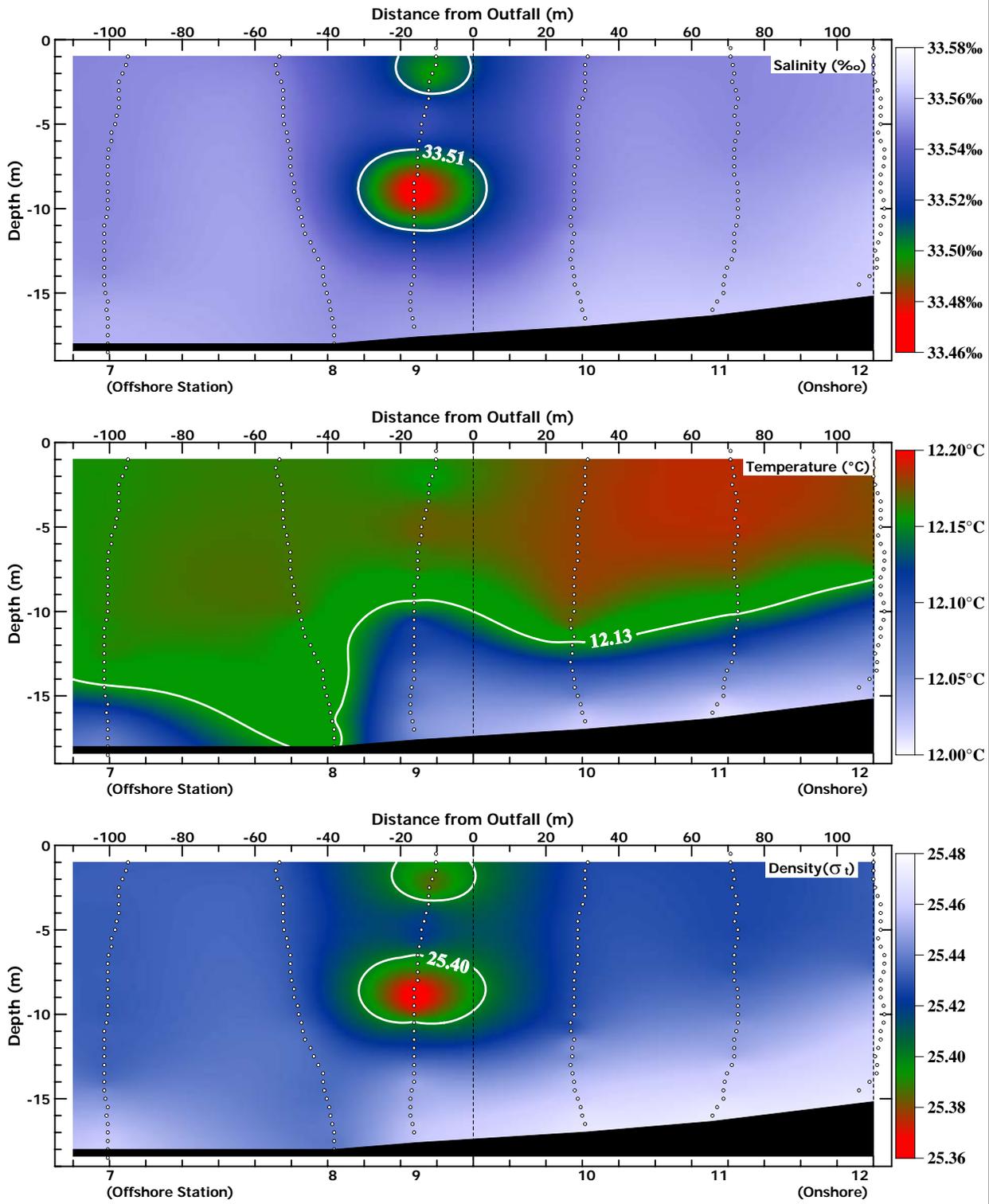


Figure A-6. Cross-Shore Transects of Salinity, Temperature, and Density on 3 January 2007

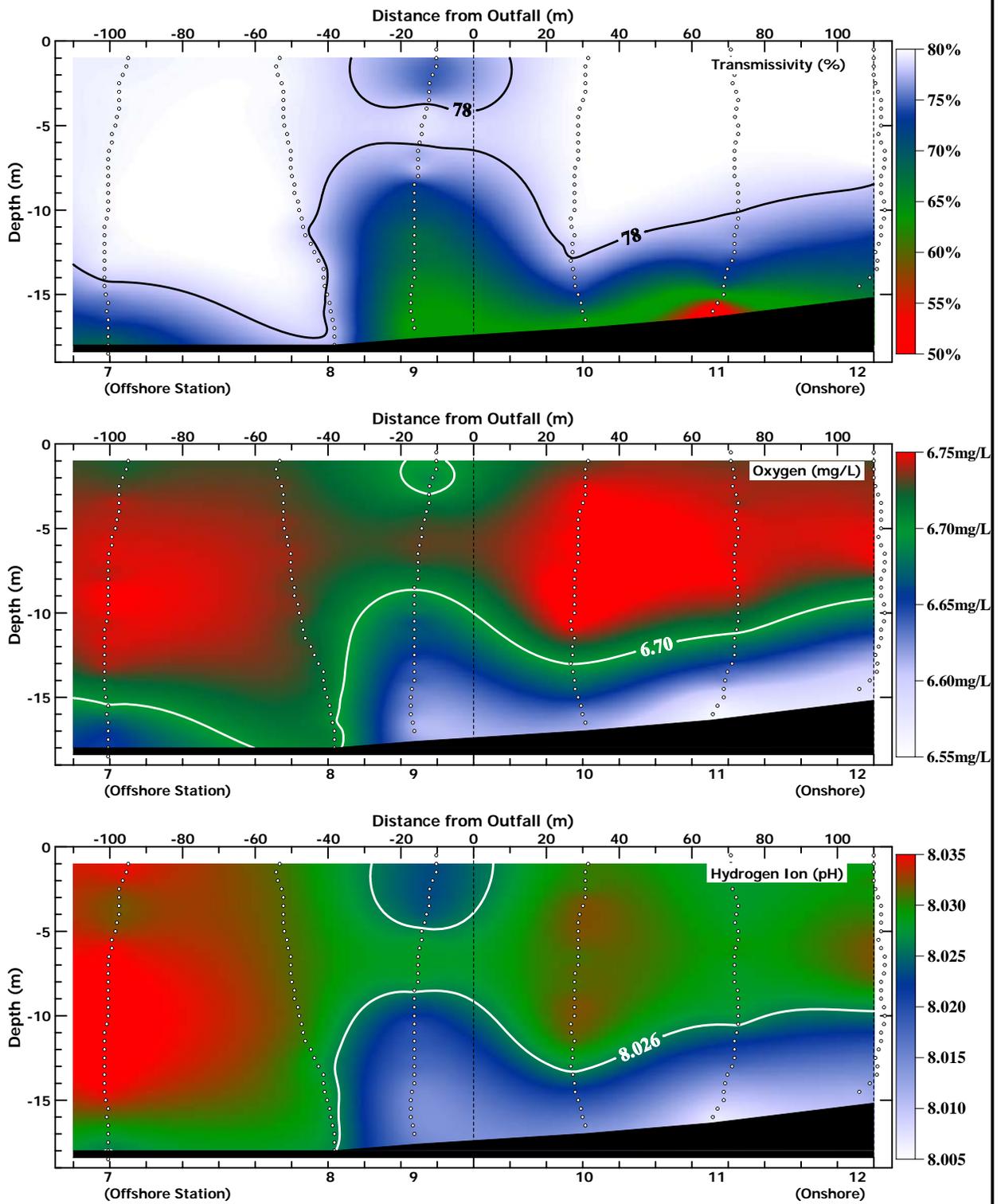


Figure A-7. Cross-Shore Transects of Transmissivity, Oxygen, and pH on 3 January 2007

APPENDIX B

Tables of Profile Data and Standard Observations

Table B-1. Seawater Temperature¹ on 3 January 2007

Depth (m)	Temperature (°C)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	12.16	12.17		12.15					12.16		12.19	12.18				12.16
1.0	12.16	12.17	12.17	12.15	12.14	12.15	12.16	12.16	12.16	12.18	12.19	12.18	12.16	12.19	12.17	12.16
1.5	12.16	12.16	12.17	12.15	12.14	12.15	12.16	12.16	12.15	12.18	12.19	12.18	12.15	12.19	12.17	12.16
2.0	12.16	12.17	12.17	12.15	12.14	12.16	12.16	12.16	12.15	12.18	12.19	12.18	12.15	12.19	12.17	12.17
2.5	12.16	12.17	12.16	12.15	12.14	12.16	12.16	12.17	12.15	12.18	12.19	12.18	12.14	12.19	12.17	12.17
3.0	12.16	12.17	12.16	12.15	12.14	12.17	12.16	12.16	12.16	12.18	12.19	12.18	12.16	12.18	12.17	12.17
3.5	12.16	12.16	12.16	12.14	12.14	12.17	12.16	12.17	12.17	12.18	12.19	12.18	12.17	12.18	12.17	12.16
4.0	12.16	12.16	12.16	12.13	12.14	12.17	12.16	12.17	12.17	12.18	12.19	12.18	12.17	12.17	12.16	12.15
4.5	12.16	12.16	12.17	12.13	12.14	12.17	12.16	12.17	12.17	12.18	12.19	12.18	12.17	12.17	12.17	12.15
5.0	12.16	12.16	12.16	12.12	12.14	12.17	12.16	12.17	12.17	12.18	12.19	12.18	12.17	12.17	12.17	12.15
5.5	12.16	12.16	12.16	12.11	12.15	12.17	12.16	12.17	12.18	12.18	12.19	12.17	12.18	12.18	12.16	12.15
6.0	12.16	12.16	12.16	12.10	12.15	12.17	12.16	12.17	12.17	12.18	12.18	12.18	12.17	12.17	12.16	12.15
6.5	12.17	12.16	12.16	12.10	12.14	12.16	12.16	12.17	12.16	12.18	12.18	12.18	12.17	12.16	12.15	12.15
7.0	12.16	12.16	12.16	12.11	12.14	12.16	12.16	12.17	12.17	12.18	12.18	12.18	12.17	12.16	12.15	12.15
7.5	12.16	12.16	12.16	12.11	12.14	12.16	12.16	12.17	12.17	12.18	12.18	12.17	12.18	12.15	12.15	12.16
8.0	12.15	12.16	12.16	12.12	12.14	12.16	12.16	12.17	12.15	12.18	12.17	12.13	12.18	12.15	12.15	12.16
8.5	12.15	12.16	12.16	12.12	12.15	12.16	12.16	12.17	12.14	12.18	12.16	12.11	12.18	12.14	12.15	12.16
9.0	12.15	12.17	12.16	12.12	12.15	12.16	12.16	12.17	12.13	12.18	12.16	12.11	12.18	12.13	12.15	12.16
9.5	12.15	12.16	12.16	12.12	12.15	12.15	12.16	12.17	12.13	12.18	12.15	12.10	12.18	12.14	12.14	12.15
10.0	12.15	12.14	12.16	12.12	12.14	12.15	12.16	12.17	12.12	12.17	12.14	12.09	12.19	12.14	12.14	12.14
10.5	12.15	12.14	12.14	12.11	12.14	12.15	12.16	12.16	12.10	12.18	12.12	12.09	12.18	12.14	12.14	12.14
11.0	12.15	12.13	12.14	12.12	12.14	12.15	12.16	12.15	12.09	12.17	12.11	12.07	12.18	12.14	12.13	12.13
11.5	12.15	12.12	12.14	12.12	12.14	12.14	12.16	12.15	12.09	12.14	12.10	12.06	12.18	12.13	12.11	12.13
12.0	12.14	12.12	12.13	12.12	12.14	12.14	12.16	12.15	12.09	12.12	12.10	12.06	12.17	12.12	12.10	12.13
12.5	12.11	12.12	12.12	12.13	12.14	12.12	12.16	12.15	12.09	12.12	12.09	12.06	12.17	12.12	12.09	12.12
13.0	12.10	12.12	12.10	12.12	12.13	12.10	12.16	12.15	12.08	12.10	12.06	12.05	12.17	12.12	12.09	12.11
13.5	12.08	12.10	12.08	12.12	12.12	12.10	12.15	12.15	12.07	12.08	12.06	12.04	12.16	12.12	12.08	12.10
14.0	12.07	12.09	12.06	12.08	12.11	12.09	12.14	12.15	12.06	12.08	12.05	12.03	12.16	12.12	12.07	12.09
14.5	12.06	12.06	12.06	12.06	12.10	12.09	12.12	12.15	12.07	12.07	12.04	12.02	12.15	12.11	12.06	12.08
15.0	12.05	12.04	12.06	12.07	12.09	12.08	12.11	12.14	12.07	12.06	12.02		12.15	12.09	12.05	12.06
15.5	12.03	12.03	12.04	12.07	12.07	12.08	12.11	12.14	12.06	12.04	12.01		12.15	12.07	12.03	12.05
16.0	12.03	12.03	12.03	12.09	12.07	12.05	12.09	12.13	12.06	12.02	12.01		12.14	12.04	12.02	12.05
16.5	12.02	12.03	12.02	12.11	12.05	12.04	12.08	12.13	12.05	12.02			12.14	12.03	12.02	12.04
17.0				12.09	12.03	12.04	12.07	12.13	12.05				12.14	12.02		
17.5							12.06	12.14					12.14	12.02		
18.0								12.06	12.14				12.14			
18.5								12.06								

¹ Values enclosed in boxes were significantly higher than the mean of other temperature measurements at the same distance above the seafloor.

Table B-2. Salinity¹ on 3 January 2007

Depth (m)	Salinity (‰)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	33.548	33.547		33.497					33.507		33.549	33.552				33.473
1.0	33.548	33.547	33.548	33.497	33.500	33.516	33.549	33.547	33.503	33.548	33.549	33.552	33.502	33.544	33.547	33.473
1.5	33.548	33.548	33.548	33.495	33.502	33.520	33.549	33.549	33.492	33.547	33.549	33.553	33.500	33.545	33.547	33.483
2.0	33.548	33.548	33.547	33.494	33.505	33.531	33.549	33.548	33.485	33.548	33.549	33.552	33.505	33.546	33.548	33.486
2.5	33.547	33.548	33.548	33.495	33.509	33.535	33.549	33.549	33.485	33.548	33.549	33.553	33.512	33.546	33.548	33.493
3.0	33.548	33.549	33.548	33.494	33.514	33.542	33.549	33.549	33.495	33.548	33.549	33.552	33.517	33.545	33.547	33.504
3.5	33.547	33.548	33.548	33.487	33.511	33.545	33.549	33.549	33.519	33.548	33.548	33.552	33.530	33.545	33.547	33.530
4.0	33.546	33.549	33.548	33.483	33.509	33.547	33.549	33.548	33.537	33.548	33.550	33.553	33.528	33.548	33.548	33.547
4.5	33.548	33.549	33.548	33.486	33.516	33.546	33.549	33.549	33.534	33.548	33.549	33.552	33.532	33.549	33.548	33.548
5.0	33.547	33.549	33.548	33.488	33.520	33.547	33.549	33.549	33.536	33.548	33.548	33.553	33.531	33.546	33.547	33.548
5.5	33.550	33.549	33.547	33.489	33.522	33.546	33.549	33.549	33.541	33.549	33.549	33.554	33.535	33.546	33.548	33.548
6.0	33.550	33.549	33.548	33.493	33.521	33.547	33.548	33.548	33.529	33.548	33.550	33.552	33.533	33.546	33.547	33.549
6.5	33.548	33.549	33.548	33.496	33.522	33.548	33.548	33.549	33.503	33.548	33.549	33.553	33.529	33.550	33.549	33.548
7.0	33.547	33.548	33.548	33.515	33.522	33.547	33.549	33.549	33.502	33.548	33.549	33.553	33.532	33.548	33.550	33.548
7.5	33.548	33.548	33.548	33.524	33.523	33.547	33.550	33.549	33.495	33.548	33.549	33.555	33.539	33.549	33.549	33.548
8.0	33.549	33.548	33.547	33.526	33.527	33.547	33.549	33.549	33.469	33.548	33.553	33.562	33.540	33.549	33.549	33.548
8.5	33.551	33.548	33.547	33.527	33.534	33.548	33.549	33.549	33.453	33.548	33.552	33.557	33.542	33.549	33.549	33.548
9.0	33.550	33.547	33.549	33.529	33.535	33.547	33.548	33.549	33.448	33.549	33.555	33.563	33.540	33.551	33.551	33.549
9.5	33.550	33.546	33.549	33.527	33.537	33.547	33.548	33.549	33.457	33.546	33.554	33.562	33.544	33.549	33.551	33.550
10.0	33.549	33.551	33.549	33.527	33.538	33.548	33.548	33.549	33.470	33.553	33.552	33.560	33.544	33.550	33.550	33.552
10.5	33.549	33.550	33.551	33.528	33.539	33.550	33.549	33.551	33.498	33.544	33.557	33.561	33.547	33.550	33.549	33.552
11.0	33.549	33.551	33.550	33.529	33.539	33.548	33.550	33.550	33.510	33.545	33.555	33.566	33.547	33.550	33.549	33.552
11.5	33.550	33.553	33.550	33.528	33.541	33.549	33.549	33.551	33.515	33.560	33.555	33.564	33.546	33.551	33.557	33.551
12.0	33.552	33.552	33.549	33.526	33.541	33.549	33.549	33.550	33.522	33.559	33.554	33.563	33.546	33.551	33.557	33.551
12.5	33.552	33.552	33.550	33.526	33.542	33.555	33.550	33.551	33.529	33.548	33.555	33.563	33.545	33.552	33.554	33.551
13.0	33.553	33.549	33.557	33.531	33.540	33.558	33.549	33.551	33.538	33.555	33.560	33.564	33.548	33.551	33.551	33.552
13.5	33.556	33.547	33.557	33.532	33.548	33.548	33.549	33.552	33.542	33.558	33.560	33.564	33.550	33.552	33.553	33.554
14.0	33.557	33.555	33.558	33.543	33.549	33.549	33.547	33.551	33.550	33.559	33.559	33.562	33.550	33.549	33.556	33.554
14.5	33.557	33.554	33.556	33.551	33.551	33.550	33.556	33.550	33.549	33.559	33.558	33.565	33.552	33.551	33.557	33.554
15.0	33.558	33.558	33.558	33.547	33.553	33.553	33.554	33.550	33.549	33.557	33.562		33.552	33.554	33.556	33.555
15.5	33.561	33.561	33.560	33.550	33.553	33.552	33.555	33.550	33.550	33.564	33.563		33.551	33.556	33.558	33.556
16.0	33.560	33.560	33.562	33.541	33.553	33.562	33.558	33.551	33.550	33.561	33.563		33.550	33.561	33.559	33.556
16.5	33.561	33.559	33.561	33.536	33.554	33.560	33.557	33.552	33.554	33.563			33.552	33.562	33.561	33.559
17.0				33.547	33.563	33.556	33.560	33.551	33.554				33.552	33.561		
17.5							33.558	33.551					33.549	33.561		
18.0								33.559	33.551				33.552			
18.5								33.558								

¹ Values enclosed in boxes were significantly lower than the mean of other salinity measurements at the same distance below the sea surface.

Table B-3. Seawater Density¹ on 3 January 2007

Depth (m)	Density (sigma-t)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	25.431	25.429		25.394					25.399		25.426	25.431				25.372
1.0	25.431	25.430	25.430	25.394	25.397	25.408	25.432	25.430	25.396	25.428	25.426	25.431	25.396	25.422	25.428	25.372
1.5	25.431	25.431	25.430	25.393	25.399	25.411	25.432	25.432	25.389	25.427	25.427	25.431	25.396	25.423	25.428	25.380
2.0	25.430	25.430	25.430	25.391	25.401	25.418	25.432	25.431	25.384	25.427	25.427	25.431	25.400	25.424	25.429	25.382
2.5	25.430	25.430	25.431	25.393	25.405	25.421	25.432	25.431	25.384	25.427	25.426	25.432	25.406	25.424	25.430	25.387
3.0	25.431	25.431	25.430	25.391	25.408	25.425	25.432	25.431	25.391	25.427	25.427	25.431	25.408	25.424	25.429	25.396
3.5	25.430	25.431	25.431	25.387	25.406	25.428	25.432	25.431	25.408	25.427	25.426	25.431	25.415	25.426	25.429	25.417
4.0	25.429	25.431	25.430	25.387	25.405	25.430	25.431	25.430	25.420	25.427	25.428	25.432	25.414	25.430	25.431	25.432
4.5	25.431	25.432	25.430	25.389	25.410	25.428	25.432	25.431	25.418	25.427	25.426	25.431	25.417	25.431	25.430	25.432
5.0	25.430	25.432	25.430	25.391	25.412	25.429	25.432	25.431	25.420	25.427	25.426	25.432	25.416	25.427	25.429	25.432
5.5	25.432	25.431	25.430	25.394	25.414	25.428	25.432	25.431	25.423	25.428	25.427	25.433	25.418	25.426	25.431	25.433
6.0	25.432	25.432	25.431	25.400	25.413	25.430	25.431	25.430	25.414	25.427	25.429	25.432	25.418	25.427	25.431	25.433
6.5	25.430	25.431	25.431	25.402	25.414	25.431	25.431	25.431	25.396	25.427	25.428	25.432	25.415	25.433	25.433	25.433
7.0	25.430	25.431	25.431	25.415	25.414	25.430	25.432	25.431	25.394	25.428	25.428	25.431	25.416	25.431	25.434	25.432
7.5	25.432	25.431	25.430	25.421	25.415	25.430	25.432	25.430	25.388	25.427	25.428	25.435	25.421	25.433	25.434	25.432
8.0	25.433	25.431	25.430	25.422	25.418	25.430	25.431	25.431	25.371	25.427	25.434	25.448	25.421	25.434	25.433	25.432
8.5	25.435	25.431	25.430	25.423	25.423	25.432	25.432	25.431	25.362	25.428	25.434	25.447	25.422	25.436	25.434	25.432
9.0	25.435	25.429	25.432	25.424	25.423	25.431	25.431	25.431	25.359	25.428	25.437	25.452	25.421	25.438	25.436	25.432
9.5	25.434	25.430	25.433	25.423	25.425	25.431	25.431	25.430	25.366	25.426	25.439	25.454	25.424	25.435	25.437	25.434
10.0	25.433	25.437	25.433	25.423	25.427	25.433	25.430	25.430	25.378	25.434	25.438	25.454	25.424	25.436	25.437	25.438
10.5	25.433	25.438	25.437	25.424	25.428	25.435	25.432	25.434	25.405	25.424	25.446	25.455	25.426	25.437	25.435	25.439
11.0	25.433	25.440	25.436	25.425	25.429	25.434	25.433	25.435	25.415	25.427	25.447	25.462	25.427	25.437	25.437	25.440
11.5	25.435	25.443	25.437	25.423	25.431	25.435	25.432	25.436	25.418	25.445	25.45	25.462	25.427	25.439	25.447	25.439
12.0	25.438	25.443	25.438	25.421	25.430	25.435	25.432	25.435	25.424	25.447	25.448	25.462	25.428	25.441	25.450	25.440
12.5	25.443	25.442	25.441	25.421	25.430	25.445	25.432	25.435	25.430	25.440	25.451	25.462	25.427	25.441	25.448	25.440
13.0	25.447	25.439	25.450	25.426	25.430	25.450	25.432	25.435	25.439	25.448	25.459	25.464	25.429	25.440	25.447	25.444
13.5	25.453	25.441	25.453	25.427	25.439	25.442	25.434	25.436	25.443	25.453	25.459	25.466	25.432	25.442	25.450	25.449
14.0	25.456	25.450	25.457	25.443	25.441	25.444	25.433	25.435	25.451	25.455	25.461	25.466	25.433	25.440	25.455	25.449
14.5	25.457	25.455	25.456	25.453	25.445	25.447	25.444	25.435	25.449	25.457	25.461	25.470	25.436	25.443	25.458	25.451
15.0	25.460	25.461	25.458	25.448	25.449	25.450	25.445	25.437	25.449	25.457	25.468		25.436	25.449	25.459	25.456
15.5	25.466	25.466	25.463	25.450	25.452	25.449	25.447	25.436	25.451	25.466	25.471		25.436	25.455	25.463	25.458
16.0	25.465	25.465	25.467	25.439	25.452	25.463	25.452	25.439	25.452	25.467	25.471		25.435	25.464	25.466	25.457
16.5	25.468	25.464	25.467	25.432	25.456	25.463	25.452	25.439	25.456	25.470			25.439	25.467	25.469	25.463
17.0				25.445	25.468	25.460	25.458	25.438	25.457				25.438	25.467		
17.5							25.457	25.438					25.436	25.467		
18.0							25.459	25.438					25.438			
18.5							25.459									

¹ Values enclosed in boxes were significantly lower than the mean of other density measurements at the same distance below the sea surface.

Table B-4. Adjusted¹ Dissolved Oxygen² on 3 January 2007

Depth (m)	Dissolved Oxygen (mg/L)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	6.77	6.76		6.70					6.70		6.73	6.72				6.72
1.0	6.77	6.76	6.76	6.70	6.70	6.72	6.73	6.73	6.70	6.73	6.73	6.72	6.67	6.76	6.74	6.72
1.5	6.77	6.77	6.75	6.71	6.70	6.74	6.72	6.73	6.70	6.74	6.74	6.74	6.66	6.76	6.74	6.72
2.0	6.77	6.75	6.76	6.71	6.70	6.73	6.73	6.73	6.69	6.74	6.74	6.74	6.67	6.76	6.75	6.72
2.5	6.77	6.76	6.75	6.71	6.69	6.73	6.73	6.74	6.69	6.75	6.74	6.74	6.66	6.75	6.74	6.73
3.0	6.77	6.76	6.76	6.71	6.70	6.73	6.73	6.73	6.70	6.75	6.74	6.74	6.67	6.76	6.74	6.74
3.5	6.78	6.76	6.77	6.70	6.70	6.74	6.75	6.73	6.72	6.75	6.73	6.74	6.68	6.75	6.75	6.73
4.0	6.76	6.76	6.77	6.70	6.69	6.74	6.73	6.73	6.72	6.75	6.75	6.74	6.69	6.75	6.74	6.72
4.5	6.77	6.76	6.76	6.69	6.70	6.74	6.75	6.74	6.73	6.74	6.74	6.74	6.70	6.75	6.74	6.72
5.0	6.77	6.77	6.76	6.69	6.70	6.74	6.74	6.74	6.73	6.75	6.75	6.75	6.70	6.76	6.76	6.71
5.5	6.77	6.77	6.77	6.68	6.72	6.74	6.75	6.73	6.73	6.75	6.74	6.74	6.72	6.76	6.75	6.71
6.0	6.77	6.77	6.78	6.68	6.71	6.73	6.74	6.74	6.73	6.76	6.75	6.75	6.72	6.75	6.75	6.71
6.5	6.77	6.77	6.78	6.68	6.71	6.73	6.75	6.74	6.73	6.75	6.74	6.75	6.71	6.75	6.74	6.72
7.0	6.77	6.77	6.76	6.69	6.72	6.74	6.75	6.74	6.73	6.75	6.75	6.75	6.73	6.75	6.75	6.72
7.5	6.76	6.76	6.77	6.69	6.72	6.74	6.74	6.73	6.71	6.74	6.75	6.74	6.72	6.74	6.74	6.71
8.0	6.76	6.78	6.76	6.69	6.71	6.74	6.74	6.73	6.72	6.77	6.75	6.72	6.73	6.73	6.74	6.71
8.5	6.76	6.77	6.77	6.69	6.71	6.74	6.75	6.73	6.71	6.76	6.74	6.70	6.73	6.71	6.74	6.73
9.0	6.75	6.76	6.77	6.69	6.71	6.73	6.75	6.73	6.68	6.76	6.74	6.71	6.74	6.72	6.74	6.73
9.5	6.76	6.77	6.76	6.69	6.72	6.73	6.75	6.73	6.68	6.75	6.74	6.69	6.74	6.71	6.73	6.72
10.0	6.76	6.76	6.75	6.68	6.72	6.73	6.75	6.73	6.69	6.76	6.72	6.67	6.75	6.72	6.73	6.72
10.5	6.75	6.75	6.76	6.69	6.71	6.73	6.74	6.73	6.65	6.75	6.73	6.68	6.75	6.72	6.72	6.72
11.0	6.76	6.75	6.75	6.70	6.72	6.72	6.74	6.72	6.67	6.75	6.71	6.65	6.76	6.71	6.73	6.71
11.5	6.74	6.75	6.74	6.70	6.72	6.72	6.75	6.72	6.67	6.73	6.69	6.65	6.75	6.70	6.71	6.71
12.0	6.75	6.74	6.74	6.70	6.73	6.73	6.75	6.73	6.66	6.73	6.67	6.63	6.75	6.71	6.70	6.72
12.5	6.73	6.74	6.73	6.70	6.72	6.72	6.74	6.73	6.65	6.71	6.67	6.61	6.74	6.70	6.71	6.72
13.0	6.72	6.72	6.72	6.69	6.71	6.71	6.75	6.72	6.64	6.70	6.64	6.61	6.75	6.70	6.69	6.70
13.5	6.71	6.71	6.70	6.68	6.70	6.69	6.74	6.72	6.64	6.69	6.63	6.60	6.75	6.70	6.69	6.70
14.0	6.70	6.70	6.69	6.67	6.71	6.69	6.72	6.72	6.64	6.68	6.63	6.59	6.73	6.69	6.67	6.70
14.5	6.68	6.67	6.68	6.65	6.70	6.68	6.71	6.72	6.63	6.67	6.61	6.59	6.73	6.68	6.67	6.69
15.0	6.68	6.64	6.67	6.66	6.68	6.69	6.71	6.71	6.63	6.66	6.59		6.72	6.67	6.67	6.67
15.5	6.64	6.62	6.66	6.67	6.68	6.68	6.70	6.71	6.63	6.64	6.56		6.72	6.67	6.64	6.66
16.0	6.63	6.63	6.64	6.67	6.67	6.66	6.68	6.71	6.62	6.62	6.56		6.71	6.65	6.61	6.71
16.5	6.59	6.63	6.64	6.68	6.66	6.66	6.67	6.70	6.61	6.62			6.70	6.63	6.61	6.71
17.0				6.68	6.66	6.66	6.65	6.71	6.61				6.71	6.60		
17.5							6.65	6.71					6.71	6.57		
18.0							6.65	6.71					6.71			
18.5							6.65									

¹ Measured DO concentrations were corrected for temporal drift to account for ongoing equilibration of the sensor.

² The DO value enclosed in the box was significantly lower than the mean of other DO measurements at the same distance above the seafloor.

Table B-5. Light Transmittance¹ across a 0.25-m path on 3 January 2007

Depth (m)	Light Transmittance (%)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	79.47	74.03		75.50					77.60		80.07	80.28				75.51
1.0	79.53	79.72	79.54	75.43	75.00	76.26	79.19	79.72	74.58	79.99	79.93	80.25	76.98	79.55	79.20	74.95
1.5	79.53	79.44	79.54	76.27	74.88	76.42	79.45	79.54	74.72	79.86	80.07	80.21	76.05	79.75	79.19	75.75
2.0	79.54	79.12	79.48	75.88	74.84	76.72	79.49	79.76	74.58	80.03	80.09	80.40	76.37	79.80	79.37	76.16
2.5	79.67	79.33	79.51	76.19	75.02	77.62	79.49	79.85	74.51	80.05	80.13	80.17	76.28	79.72	79.09	76.33
3.0	79.70	79.24	79.47	76.18	75.25	79.61	79.71	79.71	75.00	80.13	80.17	80.13	77.01	79.41	79.16	76.73
3.5	79.52	79.34	79.52	76.10	75.29	79.49	79.72	79.55	77.38	80.01	80.08	80.23	78.12	79.50	79.29	78.25
4.0	79.45	79.29	79.53	73.59	75.24	79.50	79.44	79.43	79.35	80.01	80.15	80.27	77.52	79.38	79.07	78.69
4.5	79.53	79.17	79.52	71.68	75.50	79.73	79.56	79.41	78.94	79.85	80.24	80.38	78.39	79.18	79.11	78.69
5.0	79.54	78.97	79.48	72.30	75.54	79.70	79.59	79.42	78.66	79.88	80.18	80.40	78.14	79.41	79.23	78.55
5.5	79.56	78.97	79.37	71.16	75.80	79.54	79.45	79.44	79.45	79.87	80.22	80.19	78.38	79.56	79.24	78.70
6.0	79.75	78.93	79.30	68.97	75.40	79.53	79.77	79.45	78.51	79.96	80.03	80.61	78.00	79.64	79.12	78.67
6.5	79.68	79.30	79.27	68.57	76.02	79.41	79.45	79.43	76.61	79.89	79.84	80.53	77.66	79.04	78.97	78.61
7.0	79.69	79.35	79.37	70.60	75.99	79.43	79.61	79.42	76.90	79.80	79.86	80.53	78.19	79.22	78.79	78.69
7.5	79.23	79.36	79.32	71.92	75.63	79.44	79.59	79.47	78.73	79.79	79.83	80.05	78.71	78.83	78.93	78.88
8.0	78.81	79.42	79.35	72.36	75.67	79.03	79.65	79.51	76.84	79.70	79.37	78.31	79.10	78.57	78.58	78.89
8.5	78.49	79.61	79.33	73.31	76.36	78.33	79.82	79.50	71.68	79.71	79.03	77.67	78.99	78.40	78.66	78.86
9.0	78.32	79.49	79.25	73.67	76.46	77.85	79.79	79.57	71.76	79.73	78.85	77.56	79.43	77.87	78.58	79.01
9.5	78.66	79.16	79.26	73.40	76.57	77.97	79.77	79.50	71.62	79.56	78.46	77.05	79.68	78.15	78.32	78.87
10.0	78.64	78.40	79.21	72.52	76.06	78.13	79.74	79.56	71.00	79.73	78.18	76.12	79.88	78.37	78.14	78.56
10.5	78.81	77.94	78.85	72.19	75.56	77.39	79.86	79.12	70.91	79.70	77.57	76.32	79.82	78.21	78.09	77.89
11.0	78.85	77.54	78.48	72.37	75.96	76.92	79.41	78.11	68.43	79.48	76.69	74.66	79.75	77.84	77.78	77.62
11.5	78.85	77.19	78.14	72.29	75.49	76.66	79.43	78.17	67.48	79.40	76.44	73.15	79.60	77.79	77.38	77.50
12.0	78.38	76.82	77.80	72.22	75.42	76.49	79.46	78.35	67.40	77.89	76.52	71.99	79.55	77.16	75.89	77.54
12.5	77.10	77.17	77.37	72.88	75.58	75.52	79.37	78.45	67.81	78.60	75.34	72.32	79.58	77.03	75.69	77.39
13.0	76.25	77.14	76.83	72.87	75.88	73.15	79.55	78.57	68.42	78.14	73.29	71.99	79.48	77.19	75.35	76.80
13.5	75.25	76.52	75.85	72.62	75.78	72.11	78.88	78.55	66.67	76.24	73.24	70.89	79.34	76.96	74.82	75.81
14.0	74.87	74.92	74.12	71.12	75.50	72.20	78.22	78.54	65.21	75.28	73.06	68.92	79.13	77.26	74.35	75.74
14.5	74.31	73.27	73.79	69.50	75.35	71.37	77.84	78.31	64.96	74.47	70.40	68.04	78.88	76.61	72.67	75.23
15.0	73.44	71.23	73.82	69.40	74.77	71.30	76.06	77.83	65.07	73.60	62.62		78.60	75.20	70.65	73.07
15.5	70.95	68.95	72.34	69.77	72.55	71.16	75.02	77.76	64.47	71.65	50.75		78.52	73.99	68.29	71.51
16.0	70.22	68.07	70.70	69.97	72.53	69.48	74.69	77.33	63.59	66.67	48.20		78.53	71.90	56.04	74.30
16.5	55.88	67.14	65.83	73.05	68.60	67.19	73.97	77.39	62.19	62.18			78.28	69.08	35.85	72.44
17.0				70.80	62.78	66.78	72.26	77.67	61.11				78.14	61.35		
17.5							69.86	77.64					77.82	60.54		
18.0								67.78	77.45				78.24			
18.5								67.31								

¹ Values enclosed in boxes were significantly different than the mean of other transmissivity measurements at the same depth level. The thinner boxes encompass values that were significantly higher than the mean of other measurements at the same distance above the seafloor.

Table B-6. Detrended¹ pH² on 3 January 2007

Depth (m)	Hydrogen Ion Concentration (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	8.032	8.004		8.032					8.023		8.027	8.027				8.028
1.0	8.032	8.033	8.032	8.032	8.027	8.027	8.035	8.031	8.023	8.032	8.027	8.027	8.015	8.033	8.032	8.028
1.5	8.032	8.032	8.032	8.032	8.027	8.027	8.036	8.031	8.023	8.029	8.027	8.029	8.022	8.031	8.032	8.028
2.0	8.032	8.032	8.032	8.032	8.027	8.027	8.035	8.031	8.023	8.031	8.028	8.033	8.023	8.031	8.032	8.028
2.5	8.032	8.032	8.032	8.032	8.029	8.027	8.032	8.031	8.023	8.028	8.028	8.027	8.023	8.031	8.032	8.020
3.0	8.032	8.032	8.032	8.032	8.027	8.027	8.032	8.031	8.023	8.034	8.028	8.028	8.023	8.033	8.030	8.028
3.5	8.032	8.032	8.032	8.032	8.027	8.031	8.032	8.031	8.023	8.032	8.028	8.031	8.026	8.039	8.031	8.028
4.0	8.032	8.033	8.032	8.032	8.030	8.032	8.032	8.031	8.023	8.032	8.028	8.029	8.027	8.037	8.032	8.029
4.5	8.032	8.032	8.032	8.032	8.029	8.032	8.032	8.031	8.023	8.032	8.028	8.030	8.027	8.036	8.032	8.032
5.0	8.032	8.032	8.032	8.032	8.029	8.032	8.032	8.031	8.028	8.032	8.028	8.032	8.027	8.036	8.032	8.032
5.5	8.032	8.032	8.032	8.032	8.033	8.032	8.034	8.031	8.028	8.032	8.029	8.032	8.027	8.036	8.032	8.032
6.0	8.032	8.032	8.032	8.032	8.032	8.032	8.038	8.031	8.028	8.032	8.032	8.032	8.027	8.033	8.032	8.032
6.5	8.032	8.032	8.032	8.028	8.032	8.032	8.034	8.031	8.028	8.028	8.028	8.031	8.027	8.036	8.032	8.032
7.0	8.032	8.032	8.032	8.028	8.032	8.032	8.036	8.031	8.028	8.032	8.028	8.032	8.027	8.034	8.032	8.032
7.5	8.032	8.032	8.032	8.028	8.032	8.032	8.036	8.031	8.028	8.032	8.028	8.032	8.027	8.036	8.032	8.032
8.0	8.032	8.032	8.032	8.028	8.032	8.032	8.036	8.031	8.028	8.030	8.028	8.032	8.027	8.034	8.032	8.032
8.5	8.032	8.032	8.032	8.031	8.032	8.032	8.036	8.031	8.028	8.030	8.028	8.030	8.030	8.031	8.032	8.032
9.0	8.032	8.032	8.032	8.032	8.032	8.032	8.036	8.031	8.022	8.033	8.028	8.026	8.032	8.031	8.032	8.035
9.5	8.032	8.032	8.032	8.032	8.032	8.032	8.036	8.031	8.023	8.032	8.028	8.027	8.032	8.031	8.032	8.037
10.0	8.032	8.032	8.032	8.032	8.069	8.032	8.036	8.031	8.023	8.032	8.028	8.025	8.032	8.031	8.032	8.037
10.5	8.032	8.032	8.032	8.032	8.032	8.032	8.036	8.031	8.017	8.032	8.028	8.023	8.035	8.028	8.032	8.037
11.0	8.032	8.032	8.032	8.032	8.033	8.032	8.036	8.030	8.019	8.032	8.024	8.023	8.035	8.030	8.032	8.037
11.5	8.032	8.032	8.032	8.055	8.032	8.032	8.036	8.031	8.019	8.032	8.022	8.018	8.035	8.031	8.032	8.035
12.0	8.032	8.032	8.032	8.032	8.033	8.032	8.036	8.029	8.019	8.030	8.021	8.018	8.035	8.028	8.032	8.032
12.5	8.032	8.030	8.032	8.032	8.032	8.032	8.036	8.028	8.016	8.027	8.020	8.017	8.035	8.027	8.032	8.033
13.0	8.033	8.032	8.028	8.032	8.035	8.032	8.036	8.027	8.019	8.028	8.019	8.014	8.035	8.027	8.032	8.033
13.5	8.032	8.030	8.030	8.032	8.037	8.027	8.036	8.027	8.016	8.026	8.013	8.014	8.036	8.027	8.028	8.033
14.0	8.028	8.028	8.028	8.032	8.037	8.027	8.036	8.028	8.014	8.024	8.014	8.014	8.036	8.027	8.028	8.033
14.5	8.028	8.028	8.028	8.032	8.037	8.027	8.036	8.029	8.014	8.021	8.011	8.010	8.034	8.027	8.028	8.033
15.0	8.028	8.028	8.023	8.029	8.035	8.027	8.035	8.028	8.014	8.019	8.010		8.032	8.027	8.028	8.033
15.5	8.022	8.024	8.023	8.028	8.037	8.027	8.032	8.027	8.014	8.019	8.008		8.032	8.025	8.026	8.030
16.0	8.024	8.019	8.023	8.028	8.042	8.027	8.032	8.027	8.014	8.016	8.005		8.032	8.023	8.023	8.027
16.5	8.019	8.019	8.019	8.024	8.040	8.027	8.030	8.027	8.014	8.014			8.032	8.023	8.013	8.026
17.0				8.023	8.036	8.025	8.027	8.027	8.014				8.032	8.020		
17.5							8.028	8.027					8.032	8.018		
18.0								8.025	8.027				8.032			
18.5								8.026								

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 level.

Table B-8. Unadjusted Dissolved Oxygen¹ on 3 January 2007

Depth (m)	Dissolved Oxygen (mg/L)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.5	6.77	6.76		6.70					6.70		6.73	6.72				6.82
1.0	6.77	6.76	6.76	6.70	6.70	6.72	6.73	6.73	6.70	6.73	6.73	6.72	6.77	6.86	6.84	6.82
1.5	6.77	6.77	6.75	6.71	6.70	6.74	6.72	6.73	6.70	6.74	6.74	6.74	6.76	6.86	6.84	6.82
2.0	6.77	6.75	6.76	6.71	6.70	6.73	6.73	6.73	6.69	6.74	6.74	6.74	6.77	6.86	6.85	6.82
2.5	6.77	6.76	6.75	6.71	6.69	6.73	6.73	6.74	6.69	6.75	6.74	6.74	6.76	6.85	6.84	6.83
3.0	6.77	6.76	6.76	6.71	6.70	6.73	6.73	6.73	6.70	6.75	6.74	6.74	6.77	6.86	6.84	6.84
3.5	6.78	6.76	6.77	6.70	6.70	6.74	6.75	6.73	6.72	6.75	6.73	6.74	6.78	6.85	6.85	6.83
4.0	6.76	6.76	6.77	6.70	6.69	6.74	6.73	6.73	6.72	6.75	6.75	6.74	6.79	6.85	6.84	6.82
4.5	6.77	6.76	6.76	6.69	6.70	6.74	6.75	6.74	6.73	6.74	6.74	6.74	6.80	6.85	6.84	6.82
5.0	6.77	6.77	6.76	6.69	6.70	6.74	6.74	6.74	6.73	6.75	6.75	6.75	6.80	6.86	6.86	6.81
5.5	6.77	6.77	6.77	6.68	6.72	6.74	6.75	6.73	6.73	6.75	6.74	6.74	6.82	6.86	6.85	6.81
6.0	6.77	6.77	6.78	6.68	6.71	6.73	6.74	6.74	6.73	6.76	6.75	6.75	6.82	6.85	6.85	6.81
6.5	6.77	6.77	6.78	6.68	6.71	6.73	6.75	6.74	6.73	6.75	6.74	6.75	6.81	6.85	6.84	6.82
7.0	6.77	6.77	6.76	6.69	6.72	6.74	6.75	6.74	6.73	6.75	6.75	6.75	6.83	6.85	6.85	6.82
7.5	6.76	6.76	6.77	6.69	6.72	6.74	6.74	6.73	6.71	6.74	6.75	6.74	6.82	6.84	6.84	6.81
8.0	6.76	6.78	6.76	6.69	6.71	6.74	6.74	6.73	6.72	6.77	6.75	6.72	6.83	6.83	6.84	6.81
8.5	6.76	6.77	6.77	6.69	6.71	6.74	6.75	6.73	6.71	6.76	6.74	6.70	6.83	6.81	6.84	6.83
9.0	6.75	6.76	6.77	6.69	6.71	6.73	6.75	6.73	6.68	6.76	6.74	6.71	6.84	6.82	6.84	6.83
9.5	6.76	6.77	6.76	6.69	6.72	6.73	6.75	6.73	6.68	6.75	6.74	6.69	6.84	6.81	6.83	6.82
10.0	6.76	6.76	6.75	6.68	6.72	6.73	6.75	6.73	6.69	6.76	6.72	6.67	6.85	6.82	6.83	6.82
10.5	6.75	6.75	6.76	6.69	6.71	6.73	6.74	6.73	6.65	6.75	6.73	6.68	6.85	6.82	6.82	6.82
11.0	6.76	6.75	6.75	6.70	6.72	6.72	6.74	6.72	6.67	6.75	6.71	6.65	6.86	6.81	6.83	6.81
11.5	6.74	6.75	6.74	6.70	6.72	6.72	6.75	6.72	6.67	6.73	6.69	6.65	6.85	6.80	6.81	6.81
12.0	6.75	6.74	6.74	6.70	6.73	6.73	6.75	6.73	6.66	6.73	6.67	6.63	6.85	6.81	6.80	6.82
12.5	6.73	6.74	6.73	6.70	6.72	6.72	6.74	6.73	6.65	6.71	6.67	6.61	6.84	6.80	6.81	6.82
13.0	6.72	6.72	6.72	6.69	6.71	6.71	6.75	6.72	6.64	6.70	6.64	6.61	6.85	6.80	6.79	6.80
13.5	6.71	6.71	6.70	6.68	6.70	6.69	6.74	6.72	6.64	6.69	6.63	6.60	6.85	6.80	6.79	6.80
14.0	6.70	6.70	6.69	6.67	6.71	6.69	6.72	6.72	6.64	6.68	6.63	6.59	6.83	6.79	6.77	6.80
14.5	6.68	6.67	6.68	6.65	6.70	6.68	6.71	6.72	6.63	6.67	6.61	6.59	6.83	6.78	6.77	6.79
15.0	6.68	6.64	6.67	6.66	6.68	6.69	6.71	6.71	6.63	6.66	6.59		6.82	6.77	6.77	6.77
15.5	6.64	6.62	6.66	6.67	6.68	6.68	6.70	6.71	6.63	6.64	6.56		6.82	6.77	6.74	6.76
16.0	6.63	6.63	6.64	6.67	6.67	6.66	6.68	6.71	6.62	6.62	6.56		6.81	6.75	6.71	6.81
16.5	6.59	6.63	6.64	6.68	6.66	6.66	6.67	6.70	6.61	6.62			6.80	6.73	6.71	6.81
17.0				6.68	6.66	6.66	6.65	6.71	6.61				6.81	6.70		
17.5							6.65	6.71					6.81	6.67		
18.0							6.65	6.71					6.81			
18.5							6.65									

¹ Values enclosed in boxes were significantly higher than the mean of other dissolved oxygen measurements at the same depth level.

Table B-9. Ancillary Observations on 3 January 2007 during the Receiving-Water Survey

Station	Location		Diffuser Distance (m)	Time (PST)	Air Temperature (°C)	Cloud Cover (%)	Wind Avg (kt)	Wind Max (kt)	Wind Dir (from) (°T)	Swell Ht/Dir (ft/°T)	Secchi Depth (m)
	Latitude	Longitude									
1	35° 23.254' N	120° 52.489' W	104.7	08:23:36	12.9	0	1.8	4.3	NW	4-5/W	7.0
2	35° 23.221' N	120° 52.481' W	53.2	08:27:23	11.9	0	4.4	8.4	NW	4-5/W	6.5
3	35° 23.201' N	120° 52.507' W	4.9	08:30:45	11.5	0	7.6	10.1	NW	4-5/W	7.0
4	35° 23.185' N	120° 52.483' W	42.1	08:37:58	12.9	0	6.9	8.7	NW	4-5/W	4.5
5	35° 23.164' N	120° 52.491' W	68.0	08:41:55	11.5	0	7.8	9.5	NW	4-5/W	5.0
6	35° 23.150' N	120° 52.500' W	90.9	08:45:38	11.9	0	8.3	10.2	NW	4-5/W	5.0
7	35° 23.207' N	120° 52.568' W	97.3	08:15:18	12.5	0	3.0	6.0	NW	4-5/W	7.0
8	35° 23.176' N	120° 52.521' W	49.9	08:09:11	11.7	0	6.5	10.8	NW	4-5/W	6.5
9	35° 23.196' N	120° 52.520' W	24.1	08:05:38	11.6	0	9.0	10.4	NW	4-5/W	6.5
10	35° 23.198' N	120° 52.476' W	43.5	08:00:54	12.1	0	5.4	9.5	NW	4-5/W	7.0
11	35° 23.200' N	120° 52.469' W	53.6	07:57:57	11.8	0	6.9	11.4	NW	4-5/W	7.0
12	35° 23.192' N	120° 52.444' W	92.1	07:53:33	11.9	0	7.4	9.8	NW	4-5/W	7.0
13	35° 23.183' N	120° 52.524' W	41.0	09:15:43	12.0	0	6.2	7.9	NW	4-5/W	7.0
14	35° 23.225' N	120° 52.522' W	54.5	09:18:39	12.4	0	7.8	9.7	NW	4-5/W	7.0
15	35° 23.221' N	120° 52.481' W	53.2	09:25:34	12.4	0	6.3	9.9	NW	4-5/W	6.5
16	35° 23.180' N	120° 52.488' W	42.9	09:30:06	13.3	0	6.8	8.8	NW	4-5/W	7.0

Due to the extraordinarily high seawater clarity at the time of the survey, the signature of the effluent plume, apparent as a slightly lighter color, was visible below the sea surface to the south of the diffuser structure. Neither odors nor debris of sewage origin were observed at any time during the survey.

Tidal Conditions (Pacific Standard Time)

Low Tide: 02:58 2.17 ft

High Tide: 09:14 6.30 ft

Low Tide: 16:37 -1.28 ft

High Tide: 23:15 3.68 ft