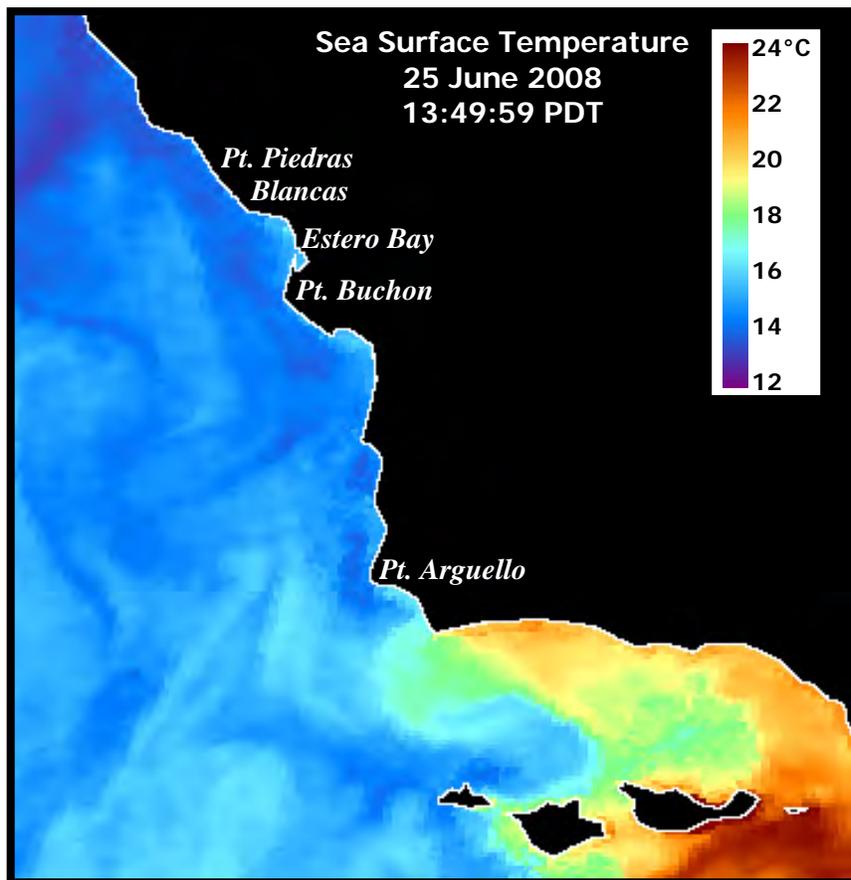**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING
AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING
JULY 2008 SURVEY

Sea Surface Temperature
25 June 2008
13:49:59 PDT

Pt. Piedras Blancas

Estero Bay

Pt. Buchon

Pt. Arguello

24°C
22
20
18
16
14
12

Marine Research Specialists

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

Report to

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

**955 Shasta Avenue
Morro Bay, California 93442
(805) 772-6272**

OFFSHORE MONITORING
AND REPORTING PROGRAM

QUARTERLY REPORT

WATER-COLUMN SAMPLING
July 2008 SURVEY

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August 2008

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Mr. Bruce Keogh   19 August 2008
Wastewater Division Manager
City of Morro Bay
955 Shasta Avenue
Morro Bay, CA 93442

Reference: Quarterly Receiving-Water Report – July 2008

Dear Mr. Keogh:

Enclosed is the Quarterly Report for the Water-Quality Survey conducted on Monday, 21 July 2008. This third-quarter survey assessed the effectiveness of effluent dispersion during summer 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 all six seawater properties at five of the sixteen sampling stations. Most of these stations were located southeast of the diffuser structure in a direction consistent with plume transport by prevailing currents. The anomalies in five of the six seawater properties were generated by the upward displacement of ambient seawater entrained within the rising effluent plume. Although variations in salinity captured the presence of wastewater constituents, dilutions appreciably exceeded those anticipated by modeling and outfall design criteria. All of the measurements were indicative of low organic loading within the discharged wastewater, and of an outfall operating as designed to achieve acceptable effluent dilution levels.

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 _____

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 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 21 July 2008. Specifically, this third-quarter survey captures ambient oceanographic conditions along the central California coast during the summer.

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 July 2008 field survey.

Both monitoring objectives were achieved through an evaluation of the water-column profiles and cross 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 July 2008 field survey was the thirty-ninth water-quality 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 recorded by the CTD[1] instrument package. Continuous deployment of the CTD between stations provides a more synoptic snapshot of the water properties immediately 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 onboard the

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[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.

CTD instrument package are capable of detecting minute changes in water properties. These sensors are described in the Methods Section below.

Surveys conducted prior to 1999 rarely detected the effluent plume because sampling stations were too widely separated to resolve the dilute wastewater signature that is highly localized around the outfall diffuser. With the implementation of the current sampling design in 1999, the presence of well-mixed effluent near the diffuser structure was found in all of the subsequent water-quality surveys (MRS 2000–2008), including the one described in this report. Moreover, improved navigation, in concert with the denser sampling pattern, more precisely delineated the lateral extent of the discharge-related perturbations in seawater properties.

Precision navigation is important for assessing compliance because most receiving-water limitations apply only beyond the narrow zone of initial dilution that surrounds the outfall. Additionally, the amplitudes of the discharge-related perturbations can be better determined by the denser sampling pattern. The amplitudes of discharge-related salinity anomalies reflect dilution levels as the effluent plume disperses within receiving waters. These 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 south of the diffuser structure, which was continuing to undergo turbulent mixing within the strongly stratified water column, was delineated by the data collected during the July 2008 survey.

STATION LOCATIONS

The water-sampling stations surround the area where effluent is discharged within Estero Bay (Figure 1). The 1,450 m long outfall pipe, which carries the effluent from the onshore treatment plant, terminates at the diffuser structure, which lies on the seafloor approximately 827 m from the shoreline.[2] The diffuser structure itself extends an additional 52 m toward the northwest from the outfall terminus.

Twenty-eight of the 34 available ports discharge effluent along a 42 m section of the diffuser structure. The 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 a 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.

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, the entrance to the Morro Bay National Estuary lies 2.8 km south of the discharge and 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

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[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 Water-Quality Sampling Stations within Estero Bay

feature of the adjacent coastline and extends into Estero Bay approximately 2 km south of the point of discharge (Figure 1). Its presence further restricts the direct exchange of seawater between the discharge point and 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 the annual reports. The instances of elevated beach coliform levels that are occasionally observed have all resulted from onshore non-point sources rather than the discharge of disinfected wastewater from the MBCSD outfall (MRS 2000–2008).

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 seawater 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.

Six other stations (7 through 12) are 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*" for modeling and regulatory purposes, 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

Table 1. Target Locations of the Offshore Water-Quality Monitoring Stations

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

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

Figure 2. Offshore Water Sampling Locations on 21 July 2008
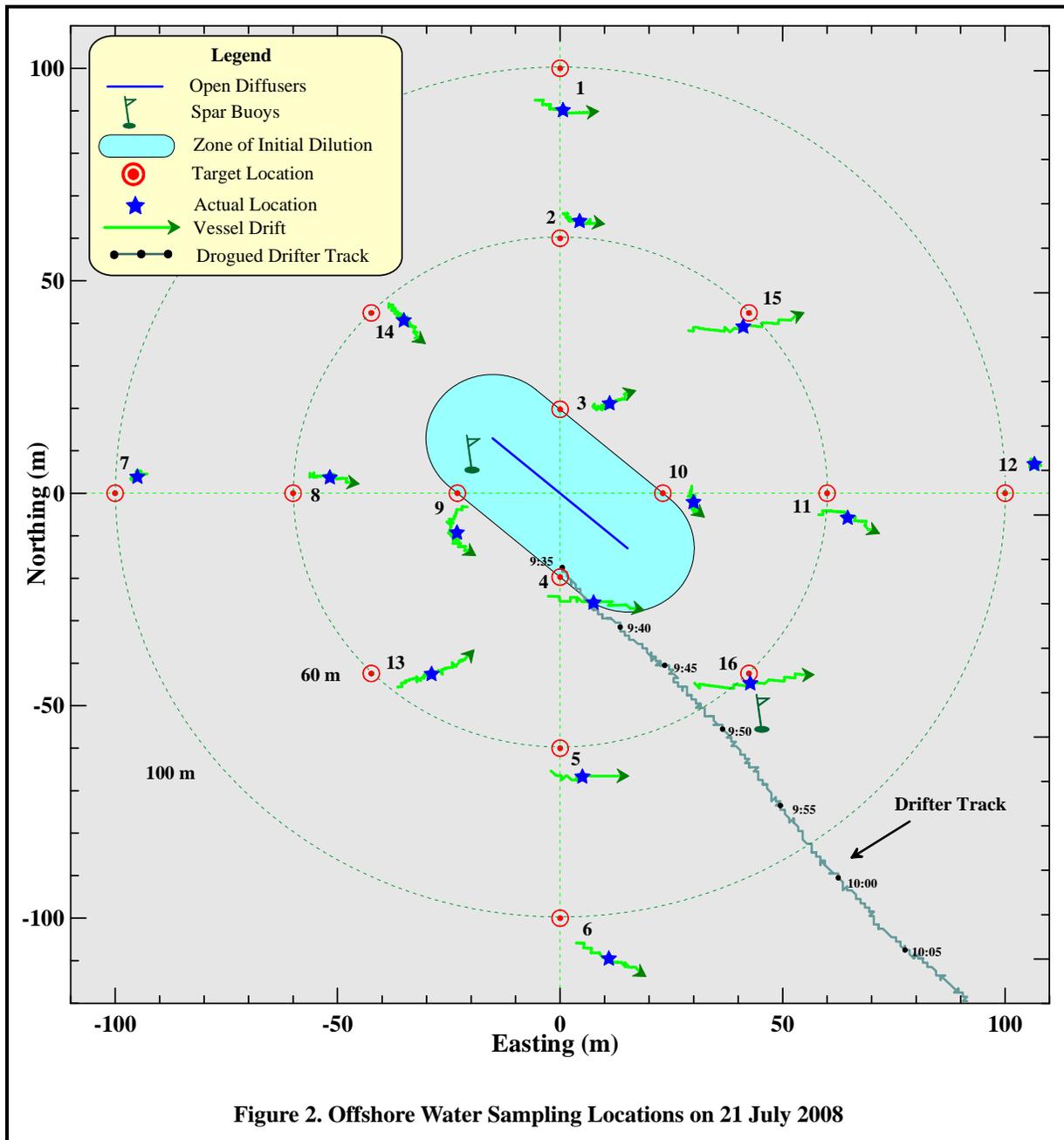
distance to the center of the diffuser structure. The "*closest approach*" distance can be considerably less than the centerpoint distance normally cited in modeling studies (Table 1).

Another important consideration for compliance evaluation is the ability to determine the actual location of the measurements. The ability to discern small spatial separations among stations within the compact sampling pattern became feasible only after the advent of DGPS. The accuracy of traditional navigation systems such as LORAN or standard GPS is typically ±15 m, a span equal to half 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 to enhance offshore navigation. 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 extremely stable and accurate offshore navigational readings, 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 recording of DGPS readings allows precise determination of sampling locations throughout the vertical CTD profiling at individual stations. Knowledge of the precise location of individual CTD measurements relative to the diffuser position is crucial for accurate interpretation of the water-property fields. During any given survey, the actual sampling locations rarely 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 upon its approach to 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 a key consideration for compliance evaluations 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 July 2008 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 is lowered to the seafloor. Their lengths reflect the station-keeping capability during the July 2008 survey. During the time it took the CTD to traverse the water column to the seafloor, which averaged 1 min 11 s, the instrument package moved as much as 25.1 m laterally (Station 16). Overall, however, the drift was only 12.4 m when averaged over all the stations. This amount of drift is fairly typical of most surveys.

The CTD trajectories reflect the complex interaction between surface currents, wind forces, and residual momentum as the vessel approached each station. Generally, winds can move the vessel to a greater degree than current flow. However, as summarized in Table B–8, moderately fresh winds were directed toward the southeast, in a direction aligned with the prevailing waves and currents. As a result, the relative influence of these individual processes on vessel drift cannot be determined for the July 2008 survey. Regardless of which was the dominant process, however, vessel drift at most stations was toward the east, as shown by the green tracklines in Figure 2. The minimal vessel drift observed at Stations 7 and 12 was due to residual momentum as the vessel approached these stations from the east. This momentum counteracted the influence of the prevailing surface flow field. The influence of vessel momentum was evaluated at each station by examining the vessel's track immediately prior to the downcast.

Although small and comparable to the survey vessel's 12-m length, drift in the CTD location during the downcasts complicates the assessment of compliance with discharge limitations at stations close to the

diffuser structure. 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 July 2008 survey, the vertical profile at Station 4 traversed the boundary of the ZID (Figure 2). Thus, strictly speaking, only a portion of the data recorded during the cast 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 July 2008 survey. Damaged or broken diffuser ports would be reflected by low dilution rates and measurements of concentrated effluent throughout the 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 that is now in use was instituted.

Surveys prior to 1999 also predated the advent of DGPS. Consequently, the 12.4-m average drift experienced during sampling at individual stations in the July 2008 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 reporting, and for historical consistency with past surveys, a single sampling location was also reported for each station during the July 2008 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, when CTD casts traverse the ZID boundary, such as at Station 4, an average reported station position that happens to lie within the ZID does not imply that all of the measurements collected at that particular station are exempt from the receiving-water objectives in the discharge permit.

Table 2. Average Coordinates of Vertical Profiles during the July 2008 Survey

	Time (PDT)				Closest Approach	
Station	**Downcast**	**Upcast**	**Latitude**	**Longitude**	**Range[1](m)**	**Bearing[2](ºT)**
1	10:15:05	10:16:26	35° 23.248' N	120° 52.504' W	79.0	12
2	10:19:55	10:21:02	35° 23.234' N	120° 52.501' W	54.9	21
3	10:23:51	10:24:58	35° 23.211' N	120° 52.497' W	23.4	41
4	10:28:46	10:30:00	35° 23.185' N	120° 52.499' W	**14.8[3]**	211
5	10:35:36	10:36:44	35° 23.163' N	120° 52.501' W	54.6	191
6	10:42:26	10:43:30	35° 23.140' N	120° 52.497' W	96.5	182
7	10:07:03	10:08:18	35° 23.201' N	120° 52.567' W	80.3	264
8	10:03:13	10:04:25	35° 23.201' N	120° 52.538' W	37.7	256
9	9:58:21	9:59:39	35° 23.194' N	120° 52.519' W	22.0	221
10	9:53:19	9:54:30	35° 23.198' N	120° 52.484' W	18.5	53
11	9:49:34	9:50:42	35° 23.196' N	120° 52.461' W	50.0	82
12	9:43:27	9:44:46	35° 23.203' N	120° 52.434' W	93.6	78
13	10:46:22	10:47:26	35° 23.176' N	120° 52.523' W	51.0	221
14	10:11:11	10:12:25	35° 23.221' N	120° 52.527' W	34.3	324
15	10:53:59	10:55:06	35° 23.220' N	120° 52.477' W	56.7	41
16	10:49:34	10:50:36	35° 23.175' N	120° 52.476' W	42.0	139

[1] Distance from the closest open diffuser port to the average station position. Stations with some or all observations collected within the ZID are shown in bold.

[2] Direction measured clockwise in degrees from true north from the closest diffuser port to the average sampling location.

[3] Portions of the CTD cast were within the ZID boundary.

FLOW FIELD

A satellite-tracked drifter documented the prevailing southeastward flow during the July 2008 survey. The drifter is designed to track the subsurface current, with little influence from the wind. As in past reports, its trajectory is shown by the grey line with black dots in Figure 3. Each dot along the drifter track represents a time span of five minutes. The drogued drifter was deployed near Station 4 at 9:35 PDT and was recovered an hour and twenty-four minutes later, at 10:59 PDT. Throughout the survey, a moderate current carried the drifter steadily southeast, and out of the survey area. During its deployment, the drifter traversed a total of 369 m toward the southeast (134°T) at an average speed of 7.34 cm/s or 0.143 knots.

The southeastward flow component that was measured by the drogued drifter was only partially consistent with the incoming flood tide that prevailed during the July 2008 survey (Figure 4). In the absence of other external influences, a flood tide normally induces a weak north northeastward flow in the
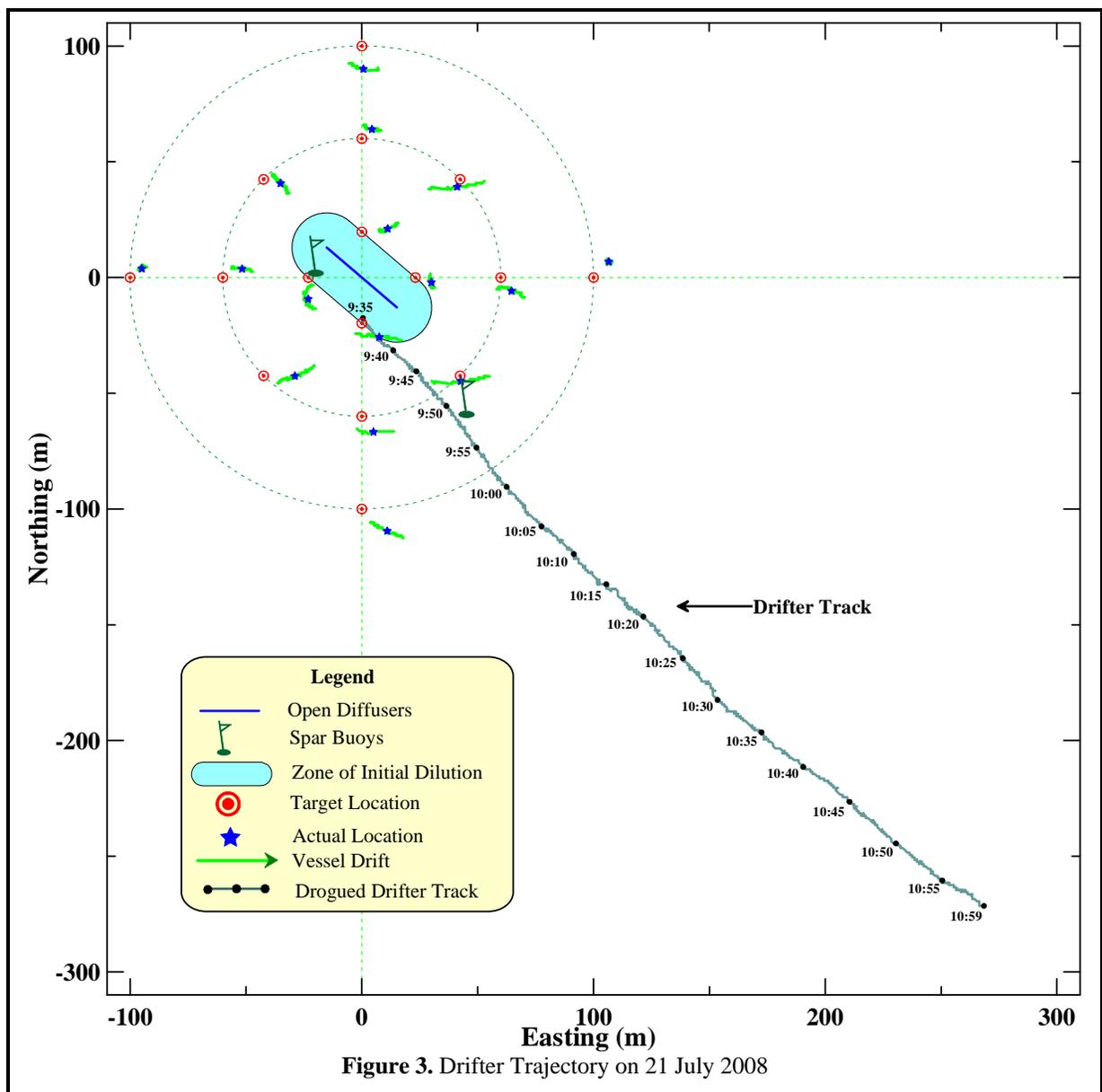
Figure 3. Drifter Trajectory on 21 July 2008

Figure 4. Estero Bay Tidal Level during the Field Survey of July 2008
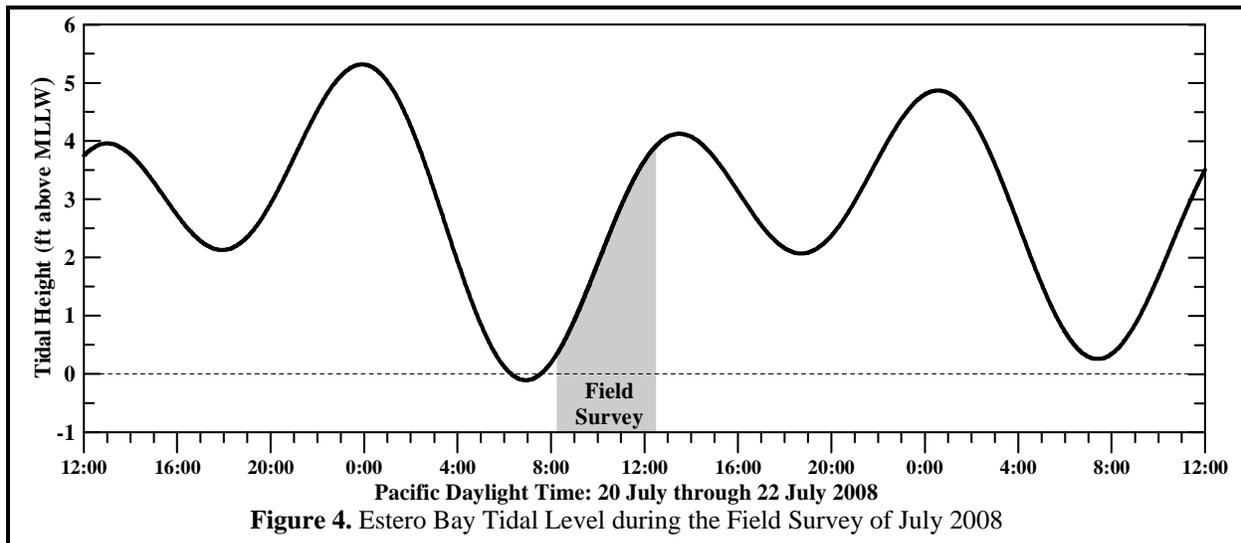
survey region. However, flow is more often influenced by external processes, such as wind-generated upwelling or by passing offshore eddies. During the July 2008 survey, the steady southeastward flow measured by the drogue drifter was indicative of the strong upwelling conditions that prevailed during July 2008 (Figure 5).

Cross-shore counter-currents are generated during upwelling conditions when warmer surface waters are driven offshore by the prevailing winds and are replaced by shoreward transport of cooler waters at depth. During the July 2008 survey; however, these warmer surface waters were restricted to an unusually thin 4-m layer. This thin surface mixed layer was contained within the sharp thermocline that is apparent at most stations in the vertical temperature profiles (red lines in Figures A–1 through A–3). As described below, the drifter was drogued at 7 m, and thus reflected the shoreward transport occurring within the deeper uniform layer below the thermocline.

Figure 5. 30-Day Running Mean Upwelling Index (m^3/s/100m of coastline) Offshore Estero Bay with the Dates of the Quarterly Water-Quality Surveys Indicated
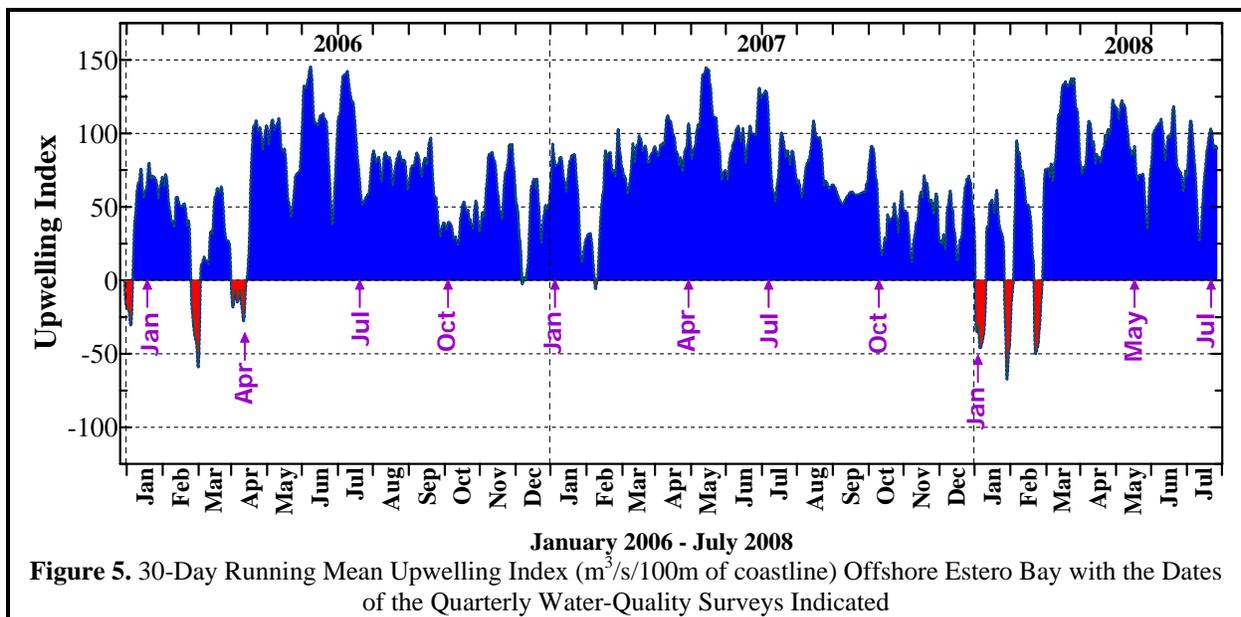
Upwelling season normally begins sometime during late March and or early April when there is a "spring transition" to more persistent southward-directed winds along the central California coast. This transition is initiated by the stabilization of a high atmospheric pressure field over the northeastern 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. The spring upwelling conditions in 2008 began in early March, and were particularly sustained and intense. As a result, monthly average seawater temperature measured near the upwelling center at Pt. Buchon for the month of April was 9.7°C, which was the coldest for any month since 1976, when the Diablo Canyon Ocean Lab began regular measurements.

Southeastward winds continued to prevail along the central California coast into July 2008, and resulted in cooler sea-surface temperatures close to the coastline around the time of the survey. The satellite image on the cover of this report depicts this cooler water, with temperatures at or below 14°C, in dark blue. Farther offshore, surface water temperatures were as much as three degrees warmer, as delineated by the areas with light blue shading. The image was recorded four 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. Changes in upwelling intensity over this time interval may account for the slightly cooler near-surface temperatures that were measured within Estero Bay by the CTD during the survey, which averaged 12.7°C (Table B–1 in Appendix B).

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on 21 July 2008. Dr. Douglas Coats of Marine Research Specialists (MRS) was the Chief Scientist while Captain Mark Tognazzini supervised vessel operations and Mr. William Skok acted as marine technician. Ms. Bonnie Luke provided general scientific support and collected auxiliary measurements of meteorological and oceanographic conditions throughout the survey. These included Secchi depth measurements and standard observations for weather, sea conditions, and water clarity/coloration as recorded in Table B–8. Wind speeds and air temperatures were measured with a Kestrel® 2000 Thermo-Anemometer. These auxiliary observations were collected contemporaneously with the rapid water-column profiling that was conducted at each station using a CTD instrument package. Mr. Tyler Eck, also of MRS, conducted navigational logging and other computer support during the endeavor.

Auxiliary Measurements

At all stations, a Secchi disk was lowered through the water column to determine its depth of disappearance (Table B–8). Secchi depths provide a visual measure of near-surface turbidity or water clarity. The depth of disappearance is inversely proportional to the average amount of organic and inorganic suspended material along a line of sight in the upper water column. As such, the Secchi depth measures natural light penetration, which can be limited by increased suspended particulate loads from plankton blooms, onshore runoff, seafloor resuspension, and wastewater discharge. It is also of biological significance because the depth of the euphotic zone, where most oceanic photosynthesis occurs, extends to approximately twice the Secchi depth. Secchi depths averaged 5.2 m at the eleven stations unaffected by the discharge during the July 2008 survey. This reflects the presence of a moderately deep, 10.4-m euphotic zone that spanned most, but not the entire water column. A limited euphotic zone is typical of upwelling conditions when increased primary production, namely, increased plankton density, decreases the transmission of ambient light though the near-surface mixed layer.

Although the distribution of Secchi depths measured at the 16 stations lends some insight into spatial variability in ambient light penetration, these measurements are less precise than measurements recorded by the transmissometer mounted on the CTD instrument package. They can also be biased. 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. The amount of ambient light penetrating the sea surface increased over the course of the survey, both because the solar incidence angle increased as the sun rose farther in the sky, and because cloud cover decreased from 80% to 35% (Table B–8). The Secchi depth reading can also artificially change by as much as 0.5 m depending on whether the sample is taken on the sunny or shady side of the survey vessel. During the July survey, Secchi depth measurements were collected in a consistent manner to minimize the effects of varying lighting conditions. Secchi depths also incorporate turbidity levels within a meter of the sea surface where, because of the physical size of the CTD package, the transmissometer cannot reach.

Despite these confounding influences, the Secchi depth measurements collected during the July 2008 survey accurately reflected general turbidity levels within the upper portion of the water column. Specifically, average Secchi depths among the five stations (3, 4, 5, 9, and 16) where the diffuse effluent plume approached the sea surface, were 1.5 m deeper than the average at the remaining stations. This difference was highly significant, as confirmed by a statistical hypothesis test for a difference between the mean depths.[3] Increased shallow-water clarity at the stations influenced by the discharge resulted from entrainment of low-turbidity seawater at depth, which was carried upward to the sea surface by the buoyant effluent plume where it displaced the naturally turbid seawater within the shallow surface layer.

During the July 2008 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 July 2008 sampling effort. In addition, the July 2008 survey was the fourteenth MBCSD survey to record the drifter position continuously throughout its deployment, rather than merely calculating the average flow velocity solely from the vessel position at the time of the drifter's deployment and recovery. Knowledge of the drifter trajectory throughout its deployment is of interest because it can reveal vagaries in the drifter's trajectory and speed that would otherwise go unnoticed.

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.

The CTD instrumentation receives regular maintenance and calibration. After the January 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 January 2001 survey indicated that the sensitivity of these probes had degraded because of an accumulation of marine growth. During the factory repair, both the pH probe and the electrolyte in the oxygen sensor were replaced. The entire CTD system was then calibrated at the factory. Upon return of the instrument, the transmissivity, dissolved oxygen, and pH sensors were

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[3] The probability (*p*) that this large of a difference in averages could be ascribed to chance was exceedingly small (*p*<0.0000376).

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 calibration. 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 July 2008 survey. Calibration at upper-bound DO concentrations was established by immersing the CTD is an aerated, temperature controlled calibration tank. In addition to oxygen readings at full saturation, a zero-oxygen calibration point was determined by filling the oxygen-sensor plenum with an 8% solution of sodium sulfite (Na_2SO_3). Oxygen calibration coefficients were determined by regression analysis of sensor-membrane current and temperature, as recommended by the manufacturer (SBE 1993). As with prior factory calibrations, pre-cruise calibration coefficients determined by MRS closely corresponded to those determined by the factory.

The six seawater properties used to assess receiving-water quality in this report 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).

Table 3. Instrumental Specifications for CTD Instrumentation Package

Component	Depth[1]	Units	Range	Accuracy	Resolution
Housing	600	—	—	—	—
Pump	3400	—	—	—	—
Pressure	680	Psia	0 to 1000	± 5.0	± 0.5
Depth	—	Meters	0 to 690	± 3.0	± 0.3
Conductivity	600	Siemens/m	0 to 6.5	± 0.001	± 0.0001
Salinity	600	‰	0 to 38	± 0.006	± 0.0006
Temperature	600	°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

All three of the physical parameters (salinity, temperature, and density) were used to determine the lateral extent of the effluent plume. Additionally, they quantified the layering, or vertical stratification and stability of the water column, 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 characterized 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 five separate buffered solutions of known pH. Buffering solutions with a pH of 4 ± 0.01, 6 ± 0.01, 7 ± 0.01, 9 ± 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 after 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 four 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 all the stations were collected during single deployment 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

In comparison to past surveys, the July 2008 survey was unique in that the pH sensor readings exhibited no evidence of temporal drift while drift was identified in the DO sensor. Perceptible drift in pH measurements has been consistently observed in prior water-quality surveys as the result of ongoing sensor equilibration during profiling. For the pH sensor, prolonged exposure to the atmosphere between surveys has resulted in the largest offsets and also affected the dynamic range of the measurements. During past surveys, equilibration offsets were also observed when the CTD was redeployed after being brought onboard to download data during the middle of the survey. Use of a single deployment during the July 2008 survey, however, obviated the need for mid-survey adjustments for pH drift.

Previous additional attempts to mitigate sensor drift have included prolonging the soak time of the CTD prior to profiling. Soaking the sensor in ambient seawater was found to reduce, but not entirely eliminate sensor drift. During the July 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 immediately prior to deployment. This technique was successful at further ameliorating perceptible sensor drift.

Despite the absence of perceptible drift in the pH sensor, the artificial DO trend (>0.348 mg/L) was large compared to reported accuracy (±0.14 mg/L) and precision (±0.014 mg/L) reported by the probe manufacturer (Table 3). As a result, the trend could potentially mask very slight discharge-related anomalies. This was not the case for the July 2008 survey because offsets were apparent only at the first two stations (11 and 12) occupied during the survey. Before correction, equilibration-related offsets at these stations affected the amplitude of discharge-related anomalies observed at the other stations, and could have confounded the statistical tests for significance. In spite of this, the actual amplitudes of the discharge-related DO anomalies (>1.5 mg/L) were large compared to the corrections at Station 11 (–0.348 mg/L) and Station 12 (–0.544 mg/L), and thus did not affect the identification of the 15 anomalous measurements. This is apparent from a comparison of the boxed bold entries in the original, raw data (Table B–7) and the detrended data (Table B–5).

RESULTS

The third-quarter water-quality survey began on Monday, 21 July 2008, at 9:35 PDT with the deployment of the drogued drifter. Subsequently, all water-column measurements were collected as required by the NPDES monitoring program (Tables 2 and B–8). Sunrise was at 6:04 PDT; however, due to the presence of a substantial marine layer, skies remained partially overcast throughout the survey, which ended at 11:00 PDT with the retrieval of the drogued drifter and confirmation of downloaded CTD data. Atmospheric visibility was not limited along the ocean surface owing to the absence of low-lying clouds. Morro Rock and the shoreline remained visible throughout the survey.

Average wind speeds, calculated over one-minute intervals, ranged from 4.6 kt to 7.2 kt (Table B–8). Corresponding peak-wind speeds ranged from 6.0 kt to 8.7 kt. Seas were fairly calm with a significant swell height of two to four feet, mostly due to a swell out of the northwest (at 300 degrees). Air temperature observations varied between 13°C to 14.5°C throughout the survey, which was comparable to, or slightly higher than the sea-surface temperatures observed with the CTD (Table B–1).

Because the discharge plume had much lower turbidity than ambient seawater near the sea surface, a visual signature of the discharge was apparent near the sea surface southeast of the ZID. In addition to the increased water clarity in the upper water column, the surfacing plume was apparent as a slightly smoother sea surface because very small capillary waves were suppressed. Throughout the survey, there was no visual evidence of floating particulates, oil and grease, or seawater discoloration associated with the discharge. However, a few small strips of biofilm, which grow on the interior of the outfall, were evident within the water column southeast of the ZID.

Beneficial Use

During the July 2008 survey, observations of beneficial use demonstrated that the coastal waters within Estero Bay continued to be utilized by wildlife and for recreation. California brown pelicans (*Pelecanus occidentalis californicus)*, Heermann's gulls (*Larus heermanni*), and western gulls (*Larus occidentalis*) were observed during transit to and from the survey area, and during the course of the survey. Pelagic and Brandt's cormorants (*Phalacrocorax*), which nest on Morro Rock, were also observed passing through the survey area and foraging for bait fish. In addition to avian fauna, southern sea otters (*Enhydra lutris*) were observed rafted within the confines of the harbor channel, while a small pod of harbor porpoises (*Phocoena phocoena*) were observed transiting to the south just outside the harbor entrance. Two juvenile sea lions (*Zalophus californianus*) were observed just inside the harbor entrance, hauled out on one of the buoys that mark the navigational channel. A third juvenile sea lion was seen while in transit to the survey site. From the survey site, approximately 30 pedestrians were observed utilizing the beach and nearshore waters north of Morro Rock.

Ambient Seawater Properties

Data collected during the July 2008 survey documented a well stratified water column that was produced by the upwelling conditions present at the time of the survey. Upwelling results in an influx of dense, cold, saline water at depth that 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.

Strong upwelling-induced gradients are plainly evident between depths of 1.5 m and 6 m in the vertical profiles at twelve of the sixteen stations (Figures A–1 through A–3). Shallow vertical gradients at the remaining four stations (4, 5, 9, and 16) were eliminated by the buoyant effluent plume when it carried deep water properties to the sea surface and created a more uniform water column. The effluent plume

was also present at Station 3, where it did not reach the sea surface but compressed the thermocline and created an especially sharp vertical interface between 1 m and 2 m (center left frame in Figure A–2).

At the remaining eleven stations that were not influenced by the discharge, the contrast between the uniform conditions within the deep watermass and the ambient seawater properties within the shallow mixed layer accounted for a substantial portion of the overall range in all of the seawater properties. For example, the 1.8ºC average temperature decrease across the thermocline (red lines) spanned more than 90% of the overall temperature range, as did the $0.42\sigma_t$ density increase (black lines) relative to the overall density variation. Similarly, the 0.88 pH, 3.2 mg/L, and 23% vertical changes in pH (gold lines), DO (blue lines), and transmissivity (light blue lines) spanned more than 87% of their respective overall ranges. In contrast, the halocline was only weakly defined and was confounded by salinity spiking, as described below. Nevertheless, at most stations unaffected by the discharge, vertically averaged salinities tended to be lower in the surface mixed layer.

The large vertical contrast in ambient seawater properties observed during the July 2008 survey resulted from the juxtaposition of two very different watermasses. The surface water mass within and above the thermocline was subjected to wind- and wave-induced stirring which mixed the surface seawater downward, insolation which warmed the seawater, rapid oxygen equilibration with the overlying atmosphere which saturated the seawater with DO, and from primary production (photosynthesis) by phytoplankton that thrive on the nutrients that were brought close to the surface by upwelling, also increasing turbidity and pH. In contrast, the characteristics of the watermass below the thermocline reflect its deeper offshore origins. Upwelling moved this cold, dense, watermass shoreward from great depths to replace the nearshore surface waters that were driven offshore by southeastward directed winds. Within this deep watermass, DO concentrations were comparatively low because photosynthesis was limited to the 12-m euphotic zone, and because biotic respiration and decomposition had slowly depleted oxygen levels in the watermass during the period since its contact with the atmosphere. Biotic respiration and decomposition also produced dissolved CO_2 (carbonic acid), which resulted in measurably lower pH (more acidic) levels within the watermass.

The slightly higher salinity associated with the deep watermass arises from its origins in the Southern California Bight. These saline waters are carried northward below the sea surface by the Davidson Undercurrent. In contrast, surface salinity within Estero Bay is largely influenced by the diffuse southward-flowing California Current, which represents the eastern limb of the clockwise-flowing gyre that covers much of the North Pacific Ocean. Before turning south to form the California Current, sub arctic water is carried along at high latitudes where it is exposed to high precipitation and low evaporation. As a result, the surface waters of the California Current are characterized by a seasonably stable low salinity (32‰ to 34‰). The deep portions of the cross-shore vertical sections depict the intrusion process associated with upwelling (Figure A–6 and A–7). They delineate a cold, saline tongue of less-turbid seawater extending along the seafloor from Station 7 to Station 12.

The shape of the vertical profiles of salinity (green lines in Figures A–1 through A–3) departed from that of the other ambient seawater properties. In many cases, the weak salinity contrast between the two watermasses was overwhelmed by highly localized extrema that coincided with sharp changes in temperature. As is usually the case in stratified conditions, large-amplitude salinity spikes are instrumental artifacts that arise from the inherent mismatch between conductivity and temperature measurements due to the differing locations of the sensors on the CTD instrument. The spikes are evident as erroneous zigzag patterns or localized salinity decreases that appear in conjunction with the sharp changes in temperature. Some of the larger erroneous salinity spikes also manifest themselves in the vertical density profiles (black lines). Unless properly identified, salinity spikes can be misinterpreted as the signature of the low-salinity effluent plume.

The large spike at 1.5 m at Station 1 is particularly apparent in the salinity profile shown by the green line in the upper left frame of Figure A–1. Its amplitude was large enough to also influence the corresponding density measurement, shown by the black line. The spiking resulted in a reported salinity measurement that was significantly lower than the average ambient salinity at that depth (bold number surrounded by a thick box in Table B–2). An even larger spike was generated by the rising effluent plume at Station 3, where it compressed the near-surface thermocline. A series of large spikes in both density and salinity (black and green lines in the middle left frame of Figure A–1) occurred as a result of the especially sharp vertical temperature gradient between 1 m and 2 m. The negative salinity anomalies generated between 1 m and 1.5 m were statistically significant (Table B–2) as was the positive density anomaly at 2 m (Table B–3). The large, spike-induced modification of the reported salinity measurements at that location overwhelmed any small salinity reductions that may have been associated with the presence of dilute wastewater.

Spiking can also create artificially high salinity readings in addition to the negative salinity anomalies described above. This was the case at 1 m at Station 10 (green line in the middle right frame of Figure A–2). As a result of spiking, the reported positive salinity anomaly was determined to be a statistically significant departure from ambient conditions (italicized number within a thin-lined box in Table B–2).

Lateral Variability

The influence of the effluent discharge can be best identified from localized anomalies in seawater properties, particularly salinity. In contrast to the isolated vertical profiles, discharge-related anomalies become especially apparent in vertical cross-sections, which highlight differences in seawater properties at adjacent stations. Accordingly, all of the cross-sections reflect the influence of the discharge in the upper water column at Stations 3, 4, and 5 (Figures A–4 and A–5) and at Station 9 (Figure A–6 and A–7). The anomalies in all of the seawater properties, except salinity, are apparent as an upward excursion of deep seawater characteristics into the surface mixed layer. Station 16 also reflected a discharge-related modification of surface seawater properties but, because it was not located along a transect, it is not shown in the cross-sections. The cross-sections also demonstrate that the effluent plume had reached the sea surface at all of these stations except for Station 3. Although the deep seawater properties at Station 3 did not extend all the way to the sea surface, the influence of the buoyant effluent plume is still apparent as a localized uplift in isopleths between 1.5 m and 4.5 m.

The vertical cross-sections also lend insight into the mechanism that caused the discharge-related anomalies in each seawater property, namely, whether the anomaly was induced by the presence of dilute effluent or whether it was generated by the upward displacement of ambient seawater entrained in the rising wastewater plume. Specifically, the vertically isolated character of the shallow discharge-related salinity anomalies differs markedly from the vertically continuous character seen in other seawater properties at the same locations.

The cross-sections show that under the stratified conditions that were present during the July 2008 survey, both entrainment-generated and wastewater-induced anomalies became apparent when seawater properties measured at the same depth level were 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. For example, 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–7. First, anomalies from mean conditions were computed by subtracting a particular measurement from the average of all other measurements at the same depth level, whether measured relative to the sea surface or the seafloor. Natural variability was 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, which is determined from the standard deviation and number of observations used to compute the average. Statistically significant departures from ambient conditions are highlighted in Tables B–1 through B–7 by bold typeface enclosed in boxes.

Based on those statistical hypothesis tests, significant departures from mean conditions were found to occur in all six seawater properties measured in the July 2008. Out of the 479 salinity observations, ten represented statistically significant departures from ambient conditions (Table B–2). Of the ten statistically significant salinity anomalies, only the anomalies at Stations 4 and 16 (Perturbations P2 and P5 in Table 4) were actually caused by the presence of the dilute effluent. The remaining statistically significant anomalies were artifacts of salinity spiking. Salinity spiking is a common occurrence in CTD measurements collected within the upper-ocean thermocline, and is routinely observed in MBCSD surveys conducted when the water column is well stratified (MRS 2001–2008). Salinity spikes are artificially introduced when the CTD instrument package crosses a sharp thermal interface. Salinity is computed from conductivity and temperature readings from probes that do not measure the same water parcel because the sensors are physically separated on the CTD instrument package. In addition, the sensors do not have the same response times. Consequently, when passing though regions of sharp temperature gradients, the mismatch between the recorded conductivity and temperature measurements results in erroneous spikes in computed salinity. The sharper the thermal gradient, the larger the salinity spike. Although the spikes usually manifest as negative (low) salinity anomalies, positive anomalies can also occur, as documented by the statistically significant positive anomalies highlighted in Table B–2 at Stations 10 and 12. Salinity measurements that are significantly higher than surrounding readings are distinguished by italicized entries surrounded by thin-lined boxes. Because wastewater is far lower in salinity that seawater, these positive salinity anomalies could not have been induced by presence of dilute effluent.

As described above, these and other erroneous salinity spikes are apparent as zigzag patterns in the vertical profiles (green lines in Figures A–1 through A–3). However, these profiles reflect smoothed versions of the actual individual CTD measurements; and the spikes were actually larger and more localized than depicted in the figures. The figures and tables presented in this report were based on CTD measurements averaged over 0.5-m depth intervals. Although not shown here, high-resolution vertical profiles of raw temperature and salinity data were reviewed for evidence of salinity spiking. Spikes in the high-resolution profiles were apparent as highly localized outliers in salinity that only occurred within limited regions of the thermocline where the temperature changed abruptly. However, because they were generally less than 0.5 m thick, they appear as weaker, vertically distributed features in the lower-resolution salinity profiles included in this report.

Even without salinity spiking, the presence of statistically significant fluctuations 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 479 measurements examined for each of the parameters, it would not be surprising if a random 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 experiment-wise 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 experiment-wise 95% confidence level.

Discharge-Related Perturbations

In spite of the confounding influence of salinity spiking during the July 2008 survey, five distinct perturbations in seawater properties were unequivocally related to the discharge (Perturbations P1 through P5 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. In addition, as discussed above, the vertical distribution of seawater properties within and below the perturbation lends insight into which of two

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

Perturbation[b]	Station	Depth Range	Depth of Extremum	Property	Magnitude	Mechanism
P1 Dilution ≥ 462:1	3	2.5 to 7.0 m	5.5 m	Salinity	–0.073 ‰	Effluent
		1.5 to 4.5 m	**2.0 m**	**Temperature**	**–1.07 ºC**	Entrainment
		1.5 to 4.5 m	**2.0 m**	**Density**	**+0.232 σ_t**	Entrainment
		1.5 to 4.5 m	**1.5 m**	**Transmissivity**	**+14.5 %**	Entrainment
		1.5 to 4.5 m	2.0 m	DO	–1.53 mg/L	Entrainment
P2 Dilution ≥ 341:1	4	1.0 to 3.0 m	**1.0 m**	**Salinity**	**–0.099 ‰**	Effluent
		1.0 to 3.5 m	**1.0 m**	**Temperature**	**–1.48 ºC**	Entrainment
		1.0 to 4.0 m	**1.5 m**	**Density**	**+0.216 σ_t**	Entrainment
		1.0 to 4.5 m	**1.0 m**	**Transmissivity**	**+16.8 %**	Entrainment
		1.0 to 4.5 m	**1.5 m**	**DO**	**–2.74 mg/L**	Entrainment
		1.0 to 5.0 m	**2.0 m**	**pH**	**–0.205**	Entrainment
P3 Dilution Indeterminate [c]	5	1.0 to 3.5 m	**1.0 m**	**Temperature**	**–1.36 ºC**	Entrainment
		1.0 to 3.5 m	**1.5 m**	**Density**	**+0.237 σ_t**	Entrainment
		1.0 to 4.0 m	**1.0 m**	**Transmissivity**	**+16.3 %**	Entrainment
		1.0 to 4.0 m	**1.5 m**	**DO**	**–2.49 mg/L**	Entrainment
		1.0 to 4.5 m	**1.5 m**	**pH**	**–0.184**	Entrainment
P4 Dilution ≥ 614:1	9	1.0 to 4.0 m	4.0 m	Salinity	–0.055 ‰	Effluent
		1.0 to 3.5 m	**1.0 m**	**Temperature**	**–1.33 ºC**	Entrainment
		1.0 to 3.5 m	**1.5 m**	**Density**	**+0.237 σ_t**	Entrainment
		1.0 to 3.5 m	**1.0 m**	**Transmissivity**	**+15.7 %**	Entrainment
		1.0 to 3.5 m	**1.5 m**	**DO**	**–2.43 mg/L**	Entrainment
		1.0 to 4.5 m	**2.0 m**	**pH**	**–0.194**	Entrainment
P5 Dilution ≥ 407:1	16	5.5 to 9.5 m	**6.5 m**	**Salinity**	**–0.083 ‰**	Effluent
		1.0 to 3.5 m	**1.0 m**	**Temperature**	**–1.29 ºC**	Entrainment
		1.0 to 3.5 m	**1.5 m**	**Density**	**+0.243 σ_t**	Entrainment
		1.0 to 3.5 m	**1.0 m**	**Transmissivity**	**+15.9 %**	Entrainment
		1.0 to 3.5 m	**1.0 m**	**DO**	**–2.30 mg/L**	Entrainment
		1.0 to 4.5 m	**1.5 m**	**pH**	**–0.181**	Entrainment

[a] Anomalies shown in bold were statistically significant.

[b] Perturbations are composed of a group of spatially coincident anomalies in several different seawater properties.

[c] Wastewater within this perturbation was too dilute to exhibit a discernable salinity anomaly from which dilution could be computed.

possible discharge processes was responsible for generating a particular anomaly. Those anomalies listed with an "Effluent" mechanism in the table were induced by the presence of dilute wastewater constituents, while the "Entrainment" mechanism indicates that the anomalies were largely generated by the upward displacement of ambient seawater that was entrained within the rising effluent plume.

In contrast to the entrainment-generated anomalies in the other seawater properties, the localized reductions in salinity shown in Table 4 could only have been induced by the presence of dilute wastewater constituents. They could not have been generated by the displacement of ambient seawater because the measured values were far lower than any of the other salinity observations, especially those recorded at depth. The absence of a discharge-related salinity anomaly at depth indicates that the plume was close to the surface at all of the stations where discharge-related perturbations were observed. Wastewater-induced anomalies only occur when the contrast between the properties of wastewater and seawater are large enough to remain apparent after rapid initial dilution. Because of the large difference in salinity between wastewater and seawater, wastewater-induced anomalies are usually only apparent in the salinity field, although they also occasionally appear in density as well.

In contrast to the vertically isolated character of the salinity anomalies, the corresponding discharge-related anomalies in all the other seawater properties arose from the upward displacement of ambient seawater. This is apparent not only because they are continuously connected to deep ambient characteristics, but also because the direction of the anomalous offsets in temperature and transmissivity is opposite of that induced by the presence of dilute wastewater constituents. Effluent is warmer than the receiving waters and its presence alone would result in a positive (warmer) anomaly, not the negative (cold) anomalies seen at Stations 3, 4, 5, 9 and 16. Similarly, wastewater particulates within the discharge plume would be expected to increase turbidity. Instead, markedly higher transmissivity within the perturbations demonstrate that they had noticeably lower turbidity, in fact, turbidity levels identical to those of ambient seawater at depth.

Entrainment-generated anomalies only arise when the water column is stratified, resulting in ambient seawater properties near the seafloor that differ significantly from properties in the upper water column. Such was the case during the July 2008 survey when the presence of strong, shallow stratification generated large contrasts between ambient seawater entrained within the rising plume as it became juxtaposed with shallow seawater properties. Entrainment and subsequent upward movement all the way to the sea surface resulted in vertical profiles at Stations 4, 5, 9, and 16 that were strikingly uniform compared to those of the other Stations (Figures A–1 through A–3). Without stratification, none of these anomalies would have been apparent.

Also, in contrast to wastewater-induced anomalies, which dissipate as the effluent becomes increasingly more dilute as the plume disperses with distance from the discharge point; once an entrainment anomaly is established, its amplitude is relatively unaffected by further dispersion of the plume within receiving waters. As a result, the amplitudes of the entrainment-generated anomalies were of similar magnitude at all five stations despite the fact that the stations were located at different distances from the discharge, and would have experienced different levels of dilution (Table 4). This is because the relatively constant magnitudes of the anomalies (transmissivity$\approx$–15%, density$\approx$0.2σ_t, temperature$\approx$–1.3ºC, DO$\approx$–2.45 mg/L, and pH$\approx$–0.19) were dictated by the difference between deep and shallow ambient conditions, rather than the disposition of the effluent constituents within the discharge plume.

The mechanism that produced a discharge-related anomaly 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. As indicated in Table 4, only the two statistically significant salinity anomalies associated with Perturbations P2 and P5 unequivocally captured the presence of dilute wastewater. As described previously, a few of the other 79 statistically significant anomalies highlighted in Tables B–1 through B–6

were artificially introduced by spiking. The vast majority of remaining significant anomalies were generated by entrainment of ambient seawater within the rising effluent plume, and as such, are not subject to water-quality restrictions that were developed to limit impacts from the presence of wastewater contaminants.

Initial Dilution Computations

The amplitude of the discharge-related negative salinity anomalies lends insight into the 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 under highly stratified conditions where trapping of the plume below the thermocline limited the mixing achieved during the buoyant plume's 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 beneath a thermocline and spread laterally with no further substantive dilution. A 9-m rise translates into a trapping depth that is 6.4 m below the sea surface.

However, as described below, computations of dilution based on salinity anomalies measured within the perturbations demonstrates that the effluent plume actually achieved far higher dilutions ($\geq$341:1) than that predicted by conservative modeling (133:1). Thus, the rapid mixing associated with the momentum of the discharge jet and the buoyant plume's subsequent rise through the water column was capable of achieving substantially higher dilutions than that predicted by discharge modeling. This demonstrates that, during the July 2008 survey, the diffuser structure was operating more efficiently than predicted.

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 objectives.

End-of-pipe limitations on contaminant concentrations within discharged wastewater were based on the definition of dilution (Fischer et al. 1979). From the mass-balance of a conservative tracer, the concentration of a particular contaminant within effluent before discharge (C_e) can be determined from Equation 1.

$$C_e \equiv C_o + D\left(C_o - C_s\right) \qquad \textbf{Equation 1}$$

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.

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

$$D = \frac{-C_o}{\left(C_o - C_s\right)} \equiv \frac{-C_o}{A} \qquad \textbf{Equation 2}$$

where: D = the dilution ratio of the volume of seawater mixed with effluent,
C_o = the salinity of the effluent-seawater mixture after dilution by D,
C_s = the background seawater salinity (approximately 33‰), and
$A = C_o - C_s$ = the salinity anomaly.

The magnitudes of the observed salinity anomalies within the perturbations were used in Equation 2 to compute the actual dilution levels associated with the perturbations (left column of Table 4). No dilution level was computed for Perturbation P3 at Station 5 because no perceptible discharge-related salinity anomaly was associated with this perturbation. Perturbation P2 (Station 4) was located approximately 15 m from the diffuser structure along the southeastward path of the discharge plume (Figure 2, Table 2). Accordingly, it had the largest-amplitude salinity anomaly (–0.099‰), and lowest measured dilution (341:1). At 42 m along the plume trajectory, Perturbation P4 (Station 16) had the next largest-amplitude salinity anomaly (–0.083‰) that reflected a slightly higher dilution (407:1), probably owing to the additional distance the plume had traveled at that point.

Stations 3 and 9 (Perturbations P1 and P4), despite being located closer to the ZID than Station 16, were not located directly in the path of the expected plume trajectory and thus captured lower effluent concentrations that occur near the margins of the effluent plume. Accordingly, smaller-amplitude salinity anomalies with even higher dilutions (>462:1) were recorded at each of these stations. By the time the plume reached Station 5 (Perturbation P3) at 55 m from the discharge, the salinity signature associated with dilute wastewater constituents had dissipated beyond recognition. However, anomalies in other seawater properties were still readily apparent at that location because they were generated by physical entrainment processes unrelated to mixing associated with the discharge jet and its buoyant rise through the water column.

The dilution computations demonstrate that, during the July 2008 survey, the outfall was performing far better than designed, and was rapidly diluting effluent more than 341-fold by the time the plume reached the sea surface. This is two-and-a-half times more dilution than the 133:1 critical dilution used to establish end-of-pipe permit limitations on contaminant concentrations within wastewater discharged from the MBCSD treatment plant. Consequently, during the July 2008 survey, COP receiving-water objectives were being easily met by the chemical concentration limits promulgated by the NPDES discharge permit issued to the MBCSD.

DISCUSSION

Sampling during the July 2008 survey demonstrated 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 July 2008 water-quality survey, and the discharge complied with all quantitative limits on seawater properties.

Although discharge-related changes in all six water properties were observed during the July 2008 survey, most 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 beyond the ZID boundary. The measurements collected during the July 2008 survey demonstrated that the receiving-water limitations were being met at the sea surface just beyond the boundary of the ZID (Perturbation P4). Moreover, the discharge-related anomalies in temperature,

density, transmissivity, DO, and pH recorded during the survey were all generated by the upward displacement of ambient seawater, rather than the presence of dilute effluent. This is an important consideration because seawater limitations promulgated in the COP restrict attention to changes caused by the presence of waste materials, not the movement of ambient seawater.

NPDES Permit Limits

The seawater properties measured during the July 2008 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–7, the statistical significance of departures from mean conditions at a given depth level were determined with an analysis of variance that compared 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 changes in instrumentally recorded light transmittance at five of the sixteen monitoring stations during the July 2008 survey (highlighted in boxes in Table B–6). Average Secchi depths at these five stations were significantly deeper than at the other stations. All five of these anomalies were positive anomalies, generated by the upward displacement of less-turbid ambient seawater at depth, rather than by the presence of wastewater. Thus, the observed increases in transmissivity were not generated "*…as the result of the discharge of waste*" (SWRCB 1997). Moreover, because these transmissivity anomalies were positive, they did not reflect a significant "*…reduction in the transmittance of natural light…*"

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*." However, effluent samples routinely collected prior to discharge demonstrate that the treatment process is highly effective at removing oxygen demanding material from the wastestream. As a result, reductions in DO caused by the presence of wastewater constituents have never been observed

within the receiving waters as part of this monitoring program. Additionally, the DO limitation does not apply to reductions in DO caused by the movement of ambient waters, regardless of whether they were induced by the physics of the discharge. As described previously, the discharge-related DO reductions were all generated by the entrainment and upward displacement of ambient seawater that was naturally depleted in oxygen. Although, the observed DO anomalies would not be subject to COP limitations for that reason alone, all of the DO measurements collected during the July 2008 survey also complied with the numerical limits on DO concentrations. Specifically, none of the DO concentrations measured during the July 2008 survey fell below the 5-mg/L minimum specified in the Basin Plan and the NPDES discharge permit. In fact, none of the 479 measurements collected fell below 5.37 mg/L. Similarly, none of the DO measurements can be considered "…*to be depressed more than 10 percent from that which occurs naturally*" because DO concentrations in ambient seawater at depth was at, or below, the concentrations observed in the discharge-related perturbations.

pH

As with the other water properties, all of the pH anomalies were generated by the upward displacement of ambient bottom water, which is naturally low in pH, rather than the presence of wastewater constituents. As such, the numerical limits do not apply to the anomalous pH measurements. However, regardless of origin, the pH data still complied with the numerical limits specified in the discharge permit. Specifically, the pH ranged between 7.89 and 8.14 and thus did not exceeded the lower (7.0 pH) and upper (8.3 pH) bounds on discharge-induced pH changes. Also, because natural oceanic processes were responsible for the large vertical variations in pH measurements, none of the measurements would be considered changed by "…*more than 0.2 pH units from that which occurs naturally*."

Temperature and Salinity

The total range in temperature of 2.0ºC across all observations was entirely due to naturally occurring vertical stratification. Even if changes this large were generated by the discharge, they would be considered too small '…*to adversely affect beneficial uses*….' The observed temperature range was much less than the large-scale spatial variability in sea-surface temperature shown in the satellite image on the cover of this report. The statistically significant discharge-induced decreases in temperature clearly resulted from the upward displacement of naturally occurring, cooler bottom water rather than as a result of the presence of warmer wastewater constituents. In any regard, the slightly depressed near-surface temperature anomalies were comparable to average temperatures measured near the seafloor throughout the July 2008 survey. Additionally, although salinity anomalies provide the best tracers of discharged effluent, the actual maximum amplitude (≈0.1‰) of the largest salinity anomaly observed during the July 2008 survey was small compared to the seasonal and spatial differences in salinity that occur along the south-central California coast. For example, seasonal differences in average salinity at this location are seven times higher (0.64‰) than the salinity anomaly recorded at Station 4 during the July 2008 survey. In any regard, the observed ranges in both the reported temperature (2.0ºC) and salinity (0.31‰) across all data collected during the July 2008 survey were too small to be considered harmful to marine biota or deleterious to beneficial uses.

Conclusions

All of the measurements recorded during the July 2008 survey complied with the receiving-water limitations specified in the NPDES discharge permit. The discharge-related anomalies that were found near the sea surface at Stations 3, 4, 5, 9, and 16 were caused by the upward displacement of ambient seawater. Furthermore, all of the anomalies met the numerical limits specified in the discharge permit. The salinity anomalies were caused by the presence of dilute effluent in the process of undergoing rapid

dilution. Measurements within the effluent plume recorded near the sea surface beyond the ZID demonstrated a dilution of more than 341-fold had been achieved. These measurements confirmed that the diffuser structure and the outfall were operating better than would be expected from the modeling.

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APPENDIX A

Water Quality Profiles and Cross Sections
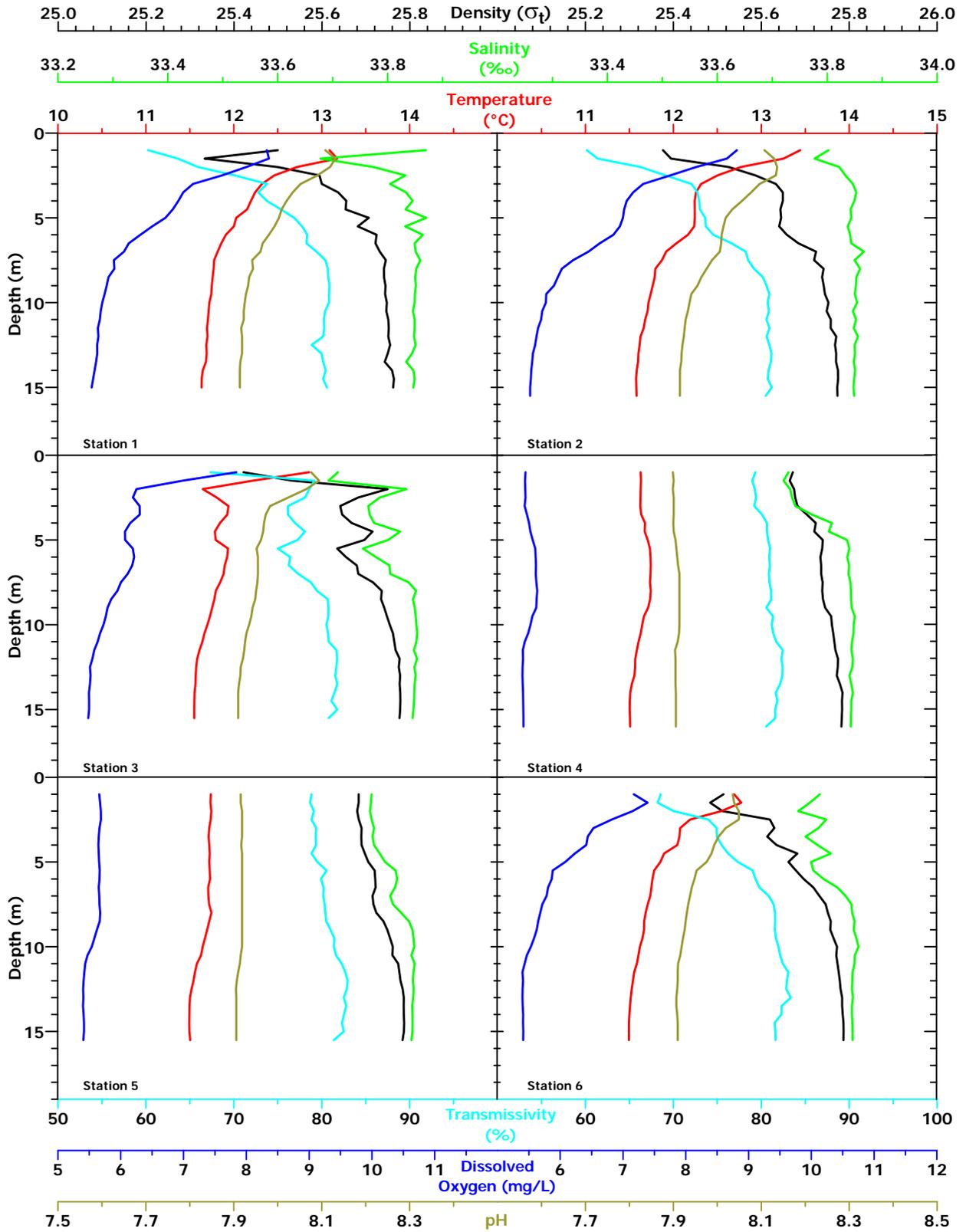
Figure A-1. Vertical Profiles of Water-Quality Parameters for Stations 1 through 6 measured on 21 July 2008
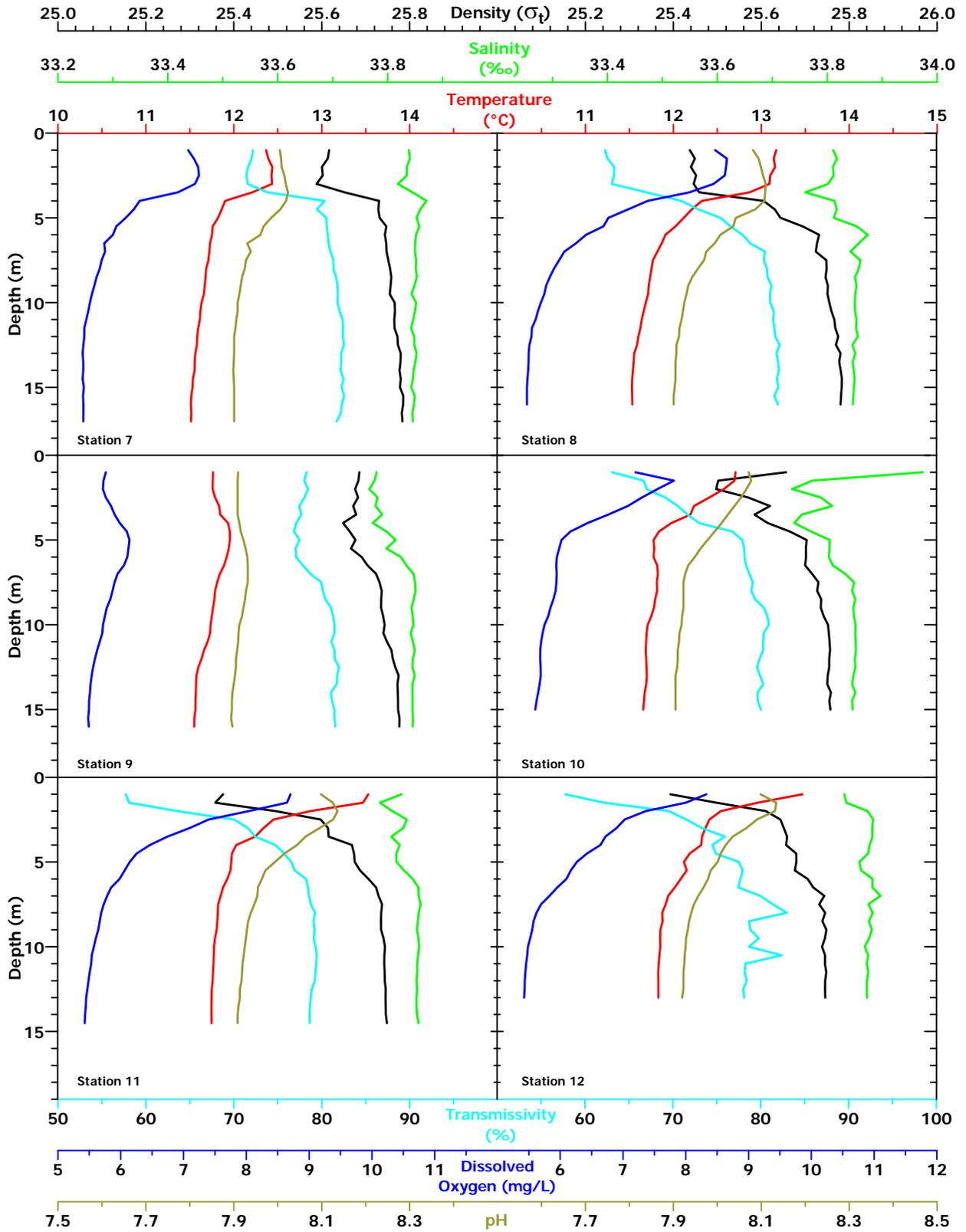
Figure A-2. Vertical Profiles of Water-Quality Parameters for Stations 7 through 12 measured on 21 July 2008
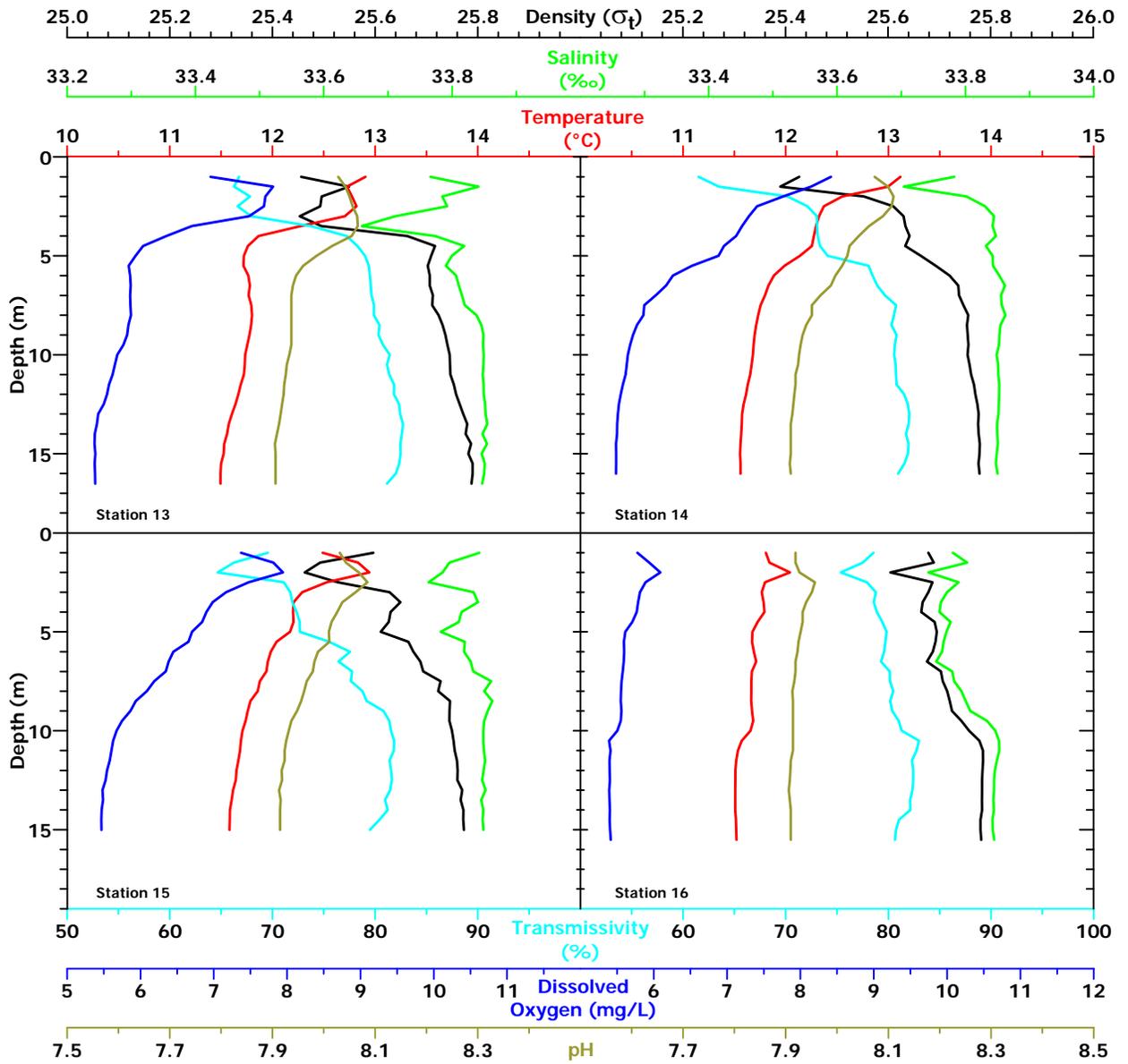
Figure A-3. Vertical Profiles of Water-Quality Parameters for Stations 13 through 16 measured on 21 July 2008
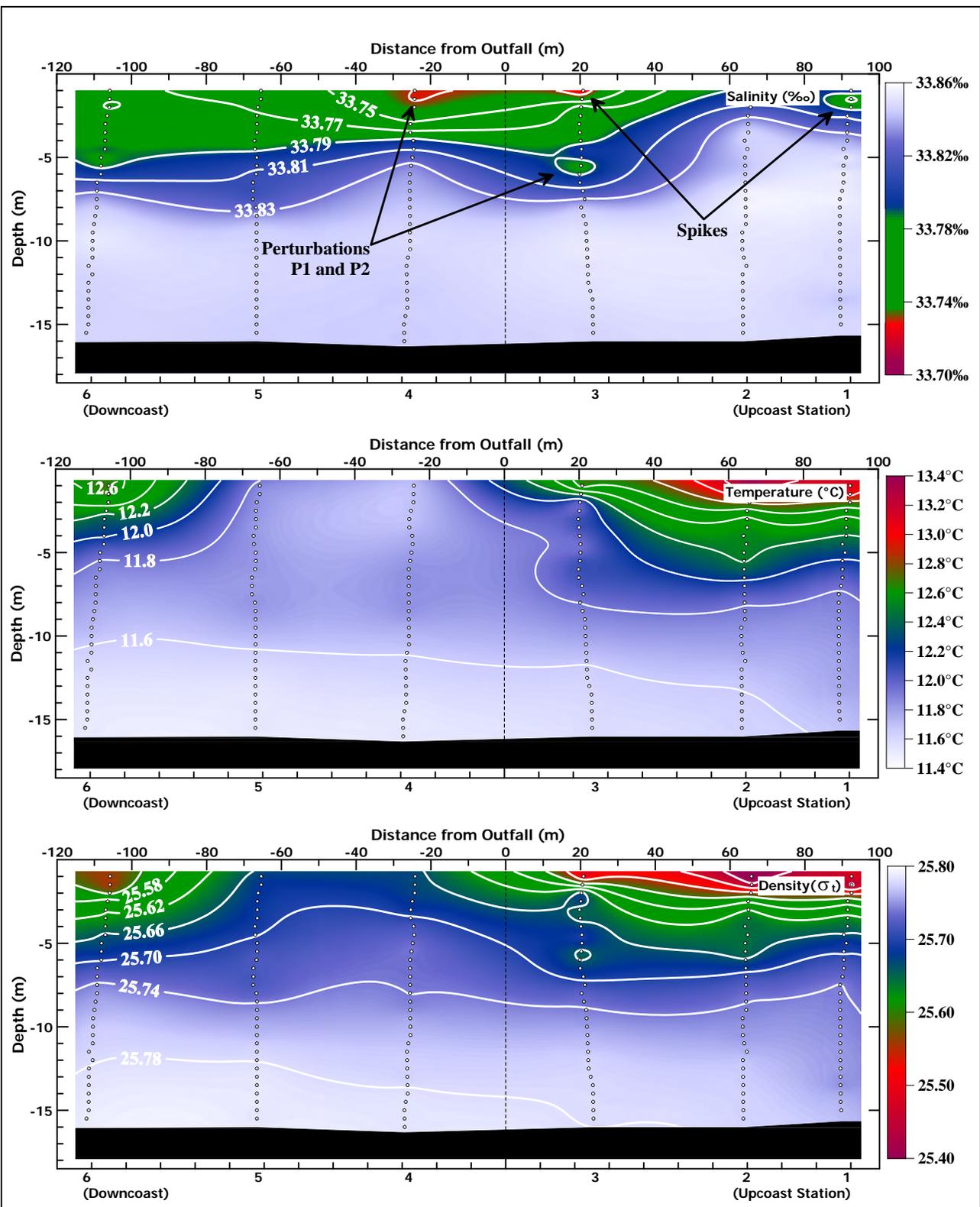
Figure A-4. Along-Shore Transects of Salinity, Temperature, and Density on 21 July 2008
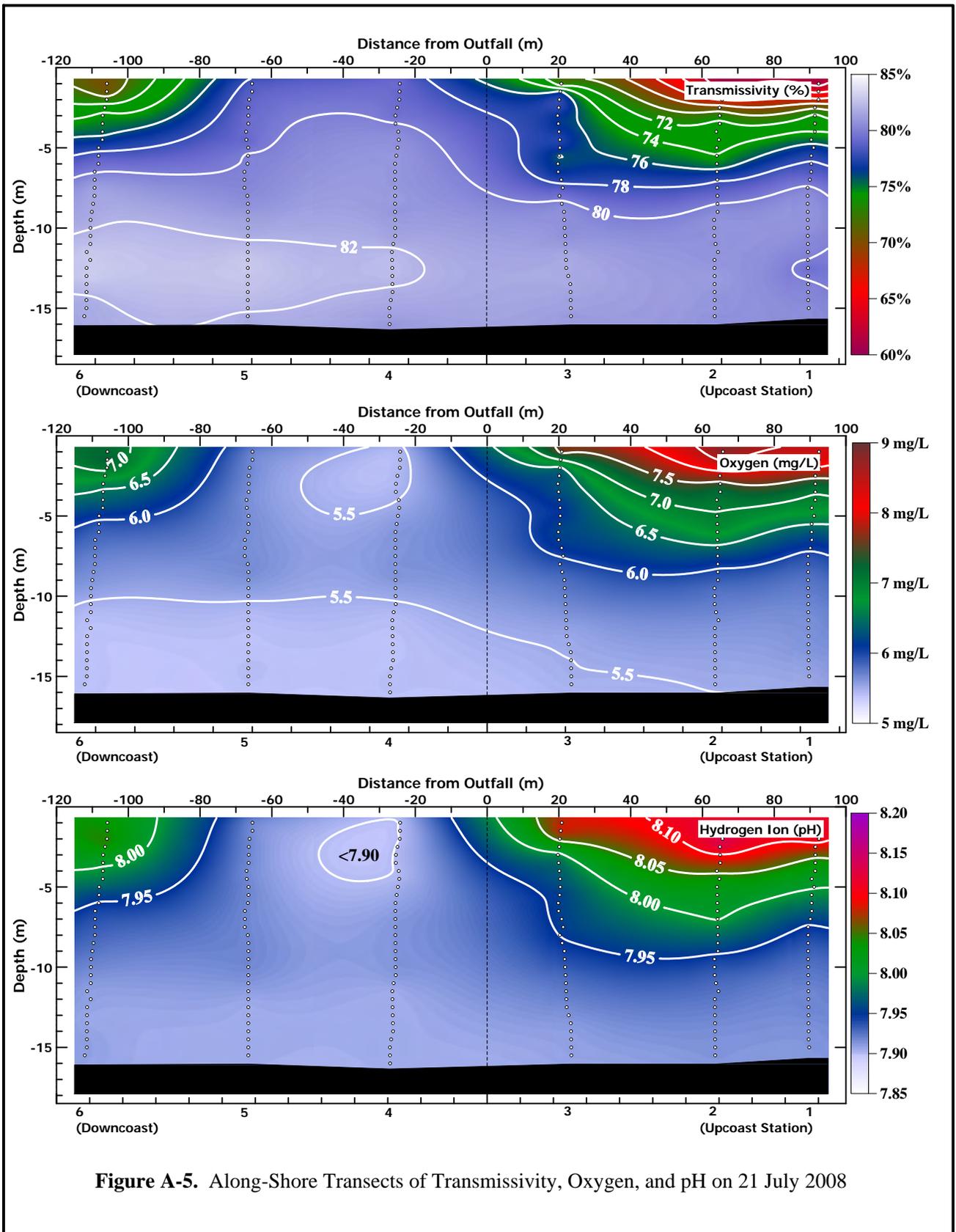
Figure A-5. Along-Shore Transects of Transmissivity, Oxygen, and pH on 21 July 2008
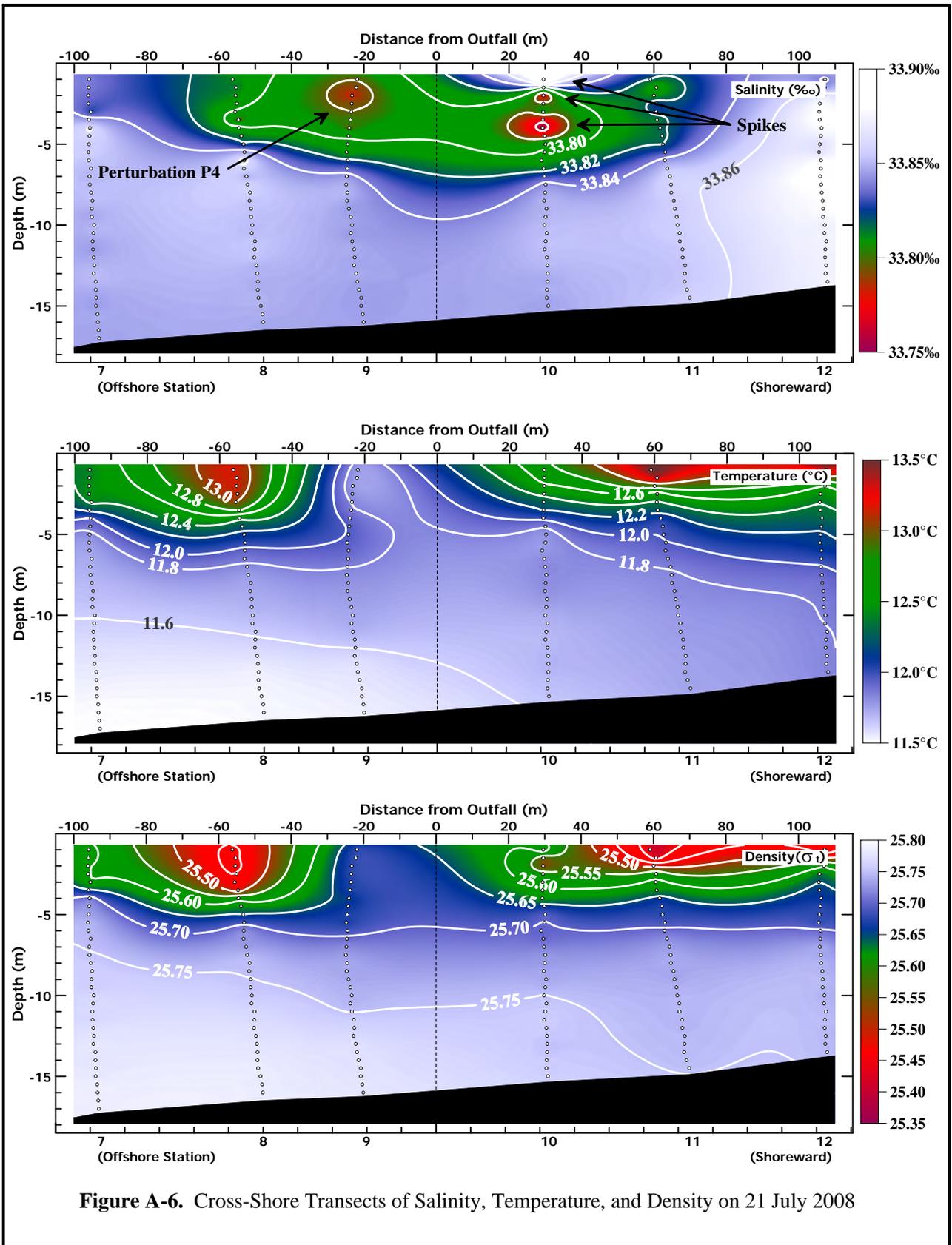
Figure A-6. Cross-Shore Transects of Salinity, Temperature, and Density on 21 July 2008
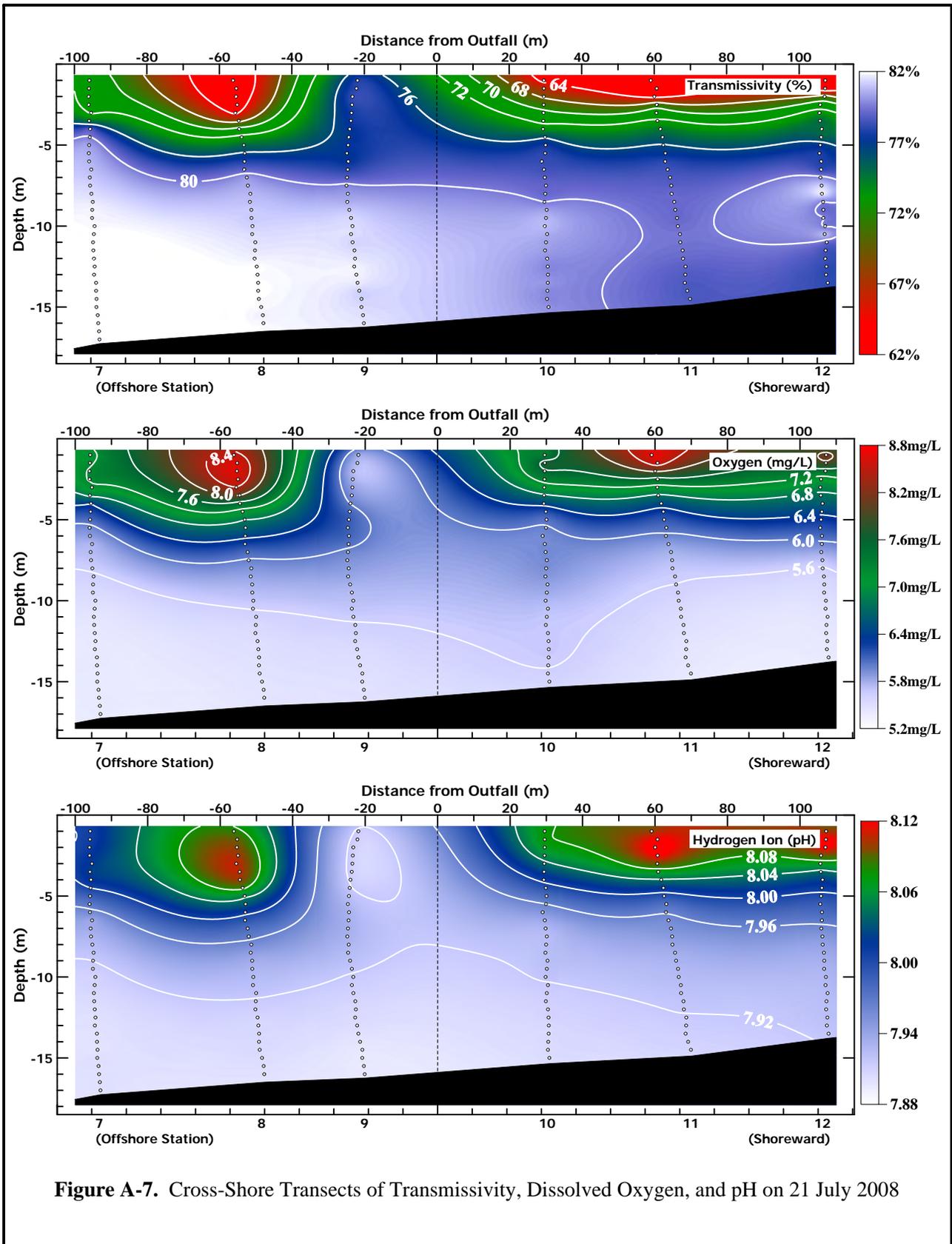
Figure A-7. Cross-Shore Transects of Transmissivity, Dissolved Oxygen, and pH on 21 July 2008

APPENDIX B

Tables of Profile Data and Standard Observations

Table B-1. Seawater Temperature[1] on 21 July 2008

| Depth (m) | Temperature (°C) | | | | | | | | | | | | | | |
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	13.09	13.44	12.86	**11.63**	**11.74**	12.69	12.37	13.17	**11.76**	12.71	13.53	13.47	12.91	13.12	12.49	**11.81**
1.5	13.18	13.25	12.22	**11.63**	**11.73**	12.77	12.39	13.14	**11.76**	12.70	13.47	12.96	12.73	13.00	12.83	**11.84**
2.0	12.72	12.77	**11.65**	**11.63**	**11.74**	12.55	12.44	13.16	**11.76**	12.57	12.87	12.54	12.77	12.55	12.94	12.04
2.5	12.46	12.50	11.81	**11.63**	11.74	12.19	12.43	13.10	11.79	12.41	12.45	12.41	12.82	12.37	12.53	11.80
3.0	12.32	12.32	11.94	11.62	11.72	12.08	12.44	13.09	11.83	12.23	12.34	12.36	12.70	12.32	12.29	11.77
3.5	12.24	12.26	11.93	11.64	11.71	12.07	12.21	12.87	11.85	12.19	12.25	12.33	12.28	12.29	12.21	11.78
4.0	12.20	12.24	11.84	11.68	11.72	12.05	11.90	12.32	11.93	11.98	12.03	12.32	11.86	12.27	12.20	11.79
4.5	12.15	12.24	11.78	11.67	11.73	11.89	11.86	12.21	11.96	11.84	11.98	12.19	11.76	12.25	12.20	11.73
5.0	12.03	12.24	11.79	11.71	11.72	11.85	11.82	12.12	11.96	11.77	11.97	12.12	11.72	12.14	12.17	11.68
5.5	12.00	12.24	11.93	11.73	11.73	11.78	11.76	12.02	11.94	11.78	11.96	12.15	11.72	11.99	12.04	11.67
6.0	11.91	12.17	11.93	11.74	11.73	11.76	11.75	11.91	11.92	11.77	11.93	12.08	11.76	11.88	11.98	11.69
6.5	11.86	12.03	11.90	11.74	11.71	11.75	11.73	11.87	11.89	11.82	11.88	12.02	11.78	11.83	11.95	11.71
7.0	11.82	11.92	11.88	11.74	11.71	11.74	11.72	11.82	11.84	11.82	11.85	11.94	11.77	11.80	11.94	11.67
7.5	11.78	11.87	11.85	11.74	11.72	11.71	11.71	11.77	11.81	11.81	11.82	11.91	11.80	11.75	11.88	11.66
8.0	11.77	11.80	11.80	11.74	11.75	11.69	11.69	11.75	11.79	11.82	11.82	11.87	11.80	11.73	11.86	11.66
8.5	11.76	11.79	11.78	11.74	11.72	11.67	11.68	11.74	11.78	11.79	11.81	11.88	11.79	11.71	11.79	11.66
9.0	11.75	11.76	11.75	11.71	11.70	11.67	11.67	11.72	11.77	11.78	11.81	11.85	11.78	11.70	11.76	11.67
9.5	11.74	11.74	11.73	11.66	11.67	11.65	11.66	11.71	11.75	11.75	11.79	11.85	11.76	11.69	11.74	11.68
10.0	11.72	11.72	11.70	11.65	11.65	11.62	11.63	11.69	11.74	11.71	11.77	11.85	11.73	11.68	11.71	11.66
10.5	11.72	11.71	11.67	11.63	11.63	11.60	11.62	11.66	11.73	11.70	11.77	11.84	11.73	11.67	11.69	11.57
11.0	11.71	11.68	11.64	11.60	11.58	11.58	11.62	11.64	11.70	11.69	11.77	11.83	11.72	11.65	11.68	11.54
11.5	11.70	11.66	11.61	11.59	11.56	11.55	11.60	11.62	11.66	11.69	11.76	11.83	11.69	11.63	11.67	11.52
12.0	11.70	11.63	11.58	11.57	11.54	11.54	11.58	11.60	11.63	11.69	11.76	11.83	11.67	11.61	11.65	11.51
12.5	11.69	11.62	11.57	11.56	11.52	11.53	11.58	11.59	11.60	11.69	11.75	11.83	11.64	11.59	11.64	11.51
13.0	11.69	11.60	11.57	11.56	11.50	11.51	11.56	11.55	11.57	11.70	11.75	11.83	11.60	11.57	11.62	11.51
13.5	11.68	11.60	11.56	11.53	11.50	11.51	11.56	11.55	11.57	11.69	11.75		11.57	11.57	11.60	11.51
14.0	11.65	11.58	11.55	11.51	11.50	11.50	11.55	11.54	11.57	11.67	11.75		11.56	11.57	11.59	11.51
14.5	11.63	11.58	11.55	11.50	11.49	11.49	11.53	11.53	11.56	11.67	11.75		11.53	11.56	11.58	11.52
15.0	11.63	11.58	11.55	11.50	11.49	11.49	11.53	11.53	11.56	11.66			11.52	11.55	11.58	11.52
15.5		11.58	11.55	11.51	11.50	11.50	11.52	11.53	11.55				11.50	11.56		11.52
16.0				11.51			11.51	11.53	11.55				11.49	11.56		
16.5							11.52						11.49			
17.0							11.51									

[1] Values enclosed in boxes were significantly lower than the mean ambient temperature measured at the same depth.

Table B-2. Salinity[1] on 21 July 2008

Depth (m)	Salinity (‰)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	33.87	33.80	**33.71**	**33.73**	33.77	33.79	33.84	33.81	33.78	*33.97*	33.83	33.83	33.77	33.78	33.84	33.78
1.5	**33.68**	33.78	**33.69**	33.72	33.77	33.77	33.84	33.82	33.78	33.77	33.79	33.83	33.84	33.70	33.80	33.80
2.0	33.77	33.82	33.83	33.73	33.77	33.75	33.84	33.81	33.77	33.74	33.81	33.87	33.78	33.80	33.79	33.74
2.5	33.83	33.83	33.79	**33.74**	33.77	33.80	33.84	33.81	33.78	33.79	33.84	33.88	33.79	33.83	33.76	33.79
3.0	33.80	33.85	33.77	33.74	33.78	33.78	33.82	33.80	33.78	33.81	33.83	33.88	**33.71**	33.84	33.83	33.77
3.5	33.83	33.85	33.77	33.77	33.77	33.76	33.85	33.76	33.79	33.75	33.81	*33.88*	**33.66**	33.84	33.84	33.76
4.0	33.85	33.85	33.78	33.81	33.78	33.78	33.87	33.81	33.77	33.80	33.82	33.88	33.77	33.85	33.81	33.76
4.5	33.83	33.84	33.82	33.80	33.79	33.81	33.86	33.82	33.80	33.77	33.82	33.87	33.82	33.83	33.81	33.78
5.0	33.87	33.84	33.80	33.84	33.80	33.77	33.85	33.81	33.81	33.80	33.82	33.86	33.80	33.84	33.78	33.77
5.5	33.83	33.84	33.76	33.84	33.81	33.77	33.86	33.85	33.80	33.80	33.83	33.86	33.79	33.84	33.82	33.77
6.0	33.86	33.84	33.78	33.84	33.82	33.79	33.85	33.87	33.82	33.80	33.85	33.88	33.81	33.85	33.82	33.76
6.5	33.85	33.84	33.80	33.84	33.81	33.82	33.85	33.86	33.83	33.81	33.86	33.88	33.81	33.86	33.83	**33.75**
7.0	33.85	33.87	33.80	33.84	33.81	33.83	33.85	33.84	33.85	33.83	33.86	33.90	33.82	33.86	33.83	33.78
7.5	33.86	33.85	33.84	33.84	33.81	33.84	33.85	33.86	33.85	33.85	33.86	33.87	33.82	33.86	33.86	33.78
8.0	33.85	33.86	33.85	33.84	33.82	33.85	33.85	33.86	33.85	33.85	33.86	33.88	33.84	33.86	33.85	33.79
8.5	33.85	33.85	33.85	33.84	33.84	33.85	33.85	33.85	33.85	33.85	33.86	33.88	33.85	33.85	33.86	33.80
9.0	33.85	33.85	33.85	33.84	33.85	33.85	33.85	33.85	33.84	33.85	33.85	33.88	33.85	33.85	33.86	33.81
9.5	33.85	33.85	33.85	33.85	33.85	33.85	33.84	33.85	33.85	33.85	33.86	33.88	33.85	33.85	33.85	33.83
10.0	33.85	33.85	33.85	33.85	33.85	33.86	33.85	33.85	33.85	33.85	33.86	33.87	33.85	33.85	33.85	33.85
10.5	33.85	33.85	33.85	33.85	33.84	33.85	33.85	33.85	33.84	33.85	33.86	33.87	33.85	33.85	33.85	33.85
11.0	33.85	33.85	33.85	33.85	33.85	33.85	33.85	33.85	33.85	33.85	33.85	33.87	33.85	33.85	33.85	33.85
11.5	33.85	33.85	33.85	33.84	33.85	33.85	33.84	33.85	33.85	33.85	33.85	33.87	33.85	33.85	33.85	33.85
12.0	33.85	33.86	33.85	33.85	33.85	33.85	33.85	33.86	33.85	33.85	33.85	33.87	33.85	33.85	33.85	33.85
12.5	33.85	33.85	33.85	33.85	33.85	33.84	33.85	33.85	33.85	33.85	33.85	33.87	33.85	33.85	33.85	33.84
13.0	33.84	33.85	33.85	33.84	33.85	33.85	33.85	33.85	33.85	33.85	33.85	33.87	33.85	33.85	33.85	33.84
13.5	33.83	33.85	33.85	33.84	33.84	33.84	33.85	33.85	33.85	33.85	33.85		33.86	33.85	33.85	33.84
14.0	33.85	33.85	33.85	33.85	33.85	33.84	33.85	33.85	33.85	33.85	33.85		33.85	33.85	33.85	33.84
14.5	33.85	33.85	33.85	33.84	33.85	33.85	33.85	33.85	33.85	33.85	33.86		33.85	33.85	33.85	33.84
15.0	33.85	33.85	33.85	33.84	33.85	33.85	33.84	33.85	33.85	33.85			33.85	33.85	33.85	33.84
15.5		33.85	33.85	33.84	33.84	33.85	33.85	33.85	33.85				33.85	33.85		33.84
16.0				33.84			33.85	33.85	33.85				33.85	33.85		
16.5							33.85						33.85			
17.0							33.85									

[1] Values enclosed in boxes differed significantly from the mean ambient salinity measured at the same depth.
  The thinner boxes encompass values that were significantly higher than the mean, while the values within thick boxes were lower than the mean.

Table B-3. Seawater Density¹ on 21 July 2008

Depth (m)	Density (sigma-t)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	25.50	25.38	25.42	**25.67**	**25.68**	25.51	25.62	25.44	**25.69**	**25.66**	25.38	25.39	25.46	25.43	25.60	**25.68**
1.5	25.33	25.39	25.53	**25.66**	**25.68**	25.48	25.61	25.45	**25.68**	25.50	25.36	25.50	25.55	25.39	25.49	**25.69**
2.0	25.50	25.53	**25.75**	25.67	25.68	25.51	25.60	25.44	25.68	25.50	25.50	25.61	25.50	25.55	25.46	25.60
2.5	25.59	25.59	25.68	25.68	25.68	25.62	25.60	25.45	25.68	25.57	25.60	25.64	25.49	25.61	25.53	25.69
3.0	25.60	25.63	25.64	25.68	25.69	25.63	25.59	25.45	25.67	25.62	25.61	25.65	25.45	25.63	25.63	25.68
3.5	25.64	25.65	25.65	25.70	25.69	25.61	25.65	25.46	25.68	25.58	25.62	25.66	25.50	25.63	25.65	25.67
4.0	25.66	25.65	25.67	25.72	25.69	25.63	25.73	25.61	25.65	25.61	25.67	25.66	25.66	25.64	25.63	25.66
4.5	25.65	25.64	25.72	25.72	25.70	25.68	25.73	25.63	25.66	25.67	25.67	25.68	25.72	25.63	25.63	25.69
5.0	25.71	25.65	25.70	25.74	25.71	25.66	25.73	25.64	25.68	25.70	25.68	25.68	25.71	25.66	25.61	25.69
5.5	25.68	25.64	25.63	25.74	25.72	25.68	25.75	25.69	25.67	25.70	25.69	25.68	25.70	25.69	25.66	25.69
6.0	25.72	25.66	25.65	25.73	25.72	25.70	25.74	25.73	25.69	25.70	25.71	25.71	25.71	25.72	25.67	25.69
6.5	25.72	25.68	25.68	25.74	25.72	25.72	25.75	25.73	25.70	25.70	25.72	25.72	25.71	25.74	25.69	25.68
7.0	25.73	25.72	25.68	25.74	25.72	25.73	25.75	25.72	25.72	25.72	25.72	25.73	25.74	25.71	25.74	25.69	25.70
7.5	25.75	25.72	25.72	25.74	25.72	25.75	25.75	25.75	25.73	25.73	25.74	25.73	25.71	25.75	25.73	25.71
8.0	25.74	25.74	25.74	25.74	25.72	25.75	25.76	25.75	25.74	25.73	25.74	25.75	25.72	25.76	25.72	25.72
8.5	25.74	25.74	25.73	25.74	25.74	25.76	25.76	25.75	25.74	25.74	25.73	25.74	25.73	25.75	25.75	25.72
9.0	25.74	25.74	25.74	25.75	25.75	25.76	25.76	25.75	25.74	25.74	25.74	25.75	25.74	25.76	25.75	25.72
9.5	25.74	25.74	25.75	25.76	25.76	25.76	25.75	25.75	25.74	25.74	25.74	25.74	25.74	25.76	25.74	25.74
10.0	25.75	25.75	25.75	25.76	25.76	25.77	25.77	25.75	25.74	25.75	25.74	25.74	25.75	25.75	25.75	25.76
10.5	25.75	25.75	25.76	25.76	25.76	25.77	25.77	25.76	25.74	25.75	25.74	25.75	25.75	25.76	25.75	25.78
11.0	25.75	25.76	25.76	25.77	25.77	25.77	25.77	25.77	25.75	25.76	25.74	25.74	25.75	25.76	25.76	25.79
11.5	25.75	25.76	25.77	25.77	25.78	25.78	25.77	25.77	25.76	25.76	25.74	25.75	25.75	25.77	25.76	25.79
12.0	25.75	25.77	25.78	25.77	25.78	25.78	25.77	25.78	25.76	25.75	25.74	25.75	25.76	25.77	25.76	25.78
12.5	25.76	25.77	25.77	25.77	25.78	25.78	25.77	25.77	25.77	25.75	25.75	25.75	25.76	25.77	25.76	25.78
13.0	25.75	25.77	25.78	25.77	25.79	25.78	25.78	25.78	25.78	25.75	25.75	25.75	25.77	25.78	25.77	25.78
13.5	25.74	25.77	25.78	25.78	25.79	25.78	25.78	25.78	25.77	25.75	25.75		25.78	25.78	25.77	25.78
14.0	25.76	25.77	25.78	25.78	25.79	25.79	25.78	25.78	25.77	25.76	25.75		25.78	25.78	25.77	25.78
14.5	25.76	25.77	25.78	25.78	25.79	25.79	25.78	25.78	25.77	25.75	25.75		25.79	25.78	25.77	25.78
15.0	25.76	25.77	25.78	25.78	25.79	25.79	25.78	25.78	25.77	25.76			25.78	25.78	25.77	25.78
15.5		25.77	25.78	25.78	25.78	25.79	25.79	25.78	25.78				25.79	25.78		25.78
16.0				25.78				25.79	25.78	25.78			25.79	25.78		
16.5								25.78					25.79			
17.0								25.78								

¹ Values enclosed in boxes were significantly higher than the mean ambient density measured at the same depth.

Table B-4. pH[1] on 21 July 2008

Depth (m)	Hydrogen Ion Concentration (pH)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	8.108	8.107	8.076	**7.899**	**7.916**	8.035	8.005	8.081	**7.910**	8.071	8.098	8.098	8.028	8.073	8.031	**7.919**
1.5	8.131	8.129	8.094	**7.901**	**7.916**	8.038	8.008	8.094	**7.909**	8.077	8.125	8.134	8.042	8.099	8.043	**7.919**
2.0	8.119	8.136	8.065	**7.899**	**7.919**	8.049	8.009	8.099	**7.909**	8.066	8.136	8.131	8.050	8.110	8.068	**7.927**
2.5	8.090	8.133	8.024	**7.901**	**7.919**	8.049	8.015	8.104	**7.909**	8.054	8.126	8.090	8.056	8.106	8.085	7.957
3.0	8.052	8.096	7.983	**7.901**	**7.919**	8.019	8.018	8.110	**7.909**	8.039	8.095	8.066	8.065	8.089	8.062	7.951
3.5	8.034	8.077	7.973	**7.901**	7.919	8.003	8.023	8.109	**7.909**	8.024	8.063	8.035	8.066	8.062	8.036	7.940
4.0	8.020	8.056	7.969	**7.900**	7.917	7.993	8.019	8.107	7.913	8.010	8.044	8.019	8.054	8.042	8.026	7.933
4.5	8.009	8.034	7.967	7.901	7.919	7.987	8.006	8.086	7.916	7.994	8.015	8.008	8.016	8.024	8.015	7.933
5.0	8.003	8.019	7.962	7.905	7.919	7.976	7.985	8.042	7.922	7.978	7.994	8.001	7.986	8.020	8.010	7.929
5.5	7.993	8.014	7.952	7.907	7.919	7.953	7.968	8.036	7.927	7.962	7.972	7.985	7.960	8.010	8.011	7.925
6.0	7.980	8.010	7.955	7.909	7.919	7.948	7.961	8.007	7.931	7.949	7.964	7.979	7.946	7.997	7.989	7.923
6.5	7.966	8.009	7.955	7.911	7.919	7.942	7.931	7.994	7.932	7.934	7.955	7.969	7.940	7.988	7.982	7.919
7.0	7.961	8.006	7.955	7.914	7.919	7.938	7.939	7.975	7.932	7.927	7.954	7.957	7.937	7.968	7.979	7.919
7.5	7.942	7.988	7.954	7.914	7.919	7.934	7.928	7.970	7.932	7.923	7.947	7.947	7.937	7.951	7.967	7.917
8.0	7.944	7.976	7.951	7.914	7.919	7.931	7.925	7.956	7.928	7.923	7.939	7.941	7.937	7.951	7.962	7.913
8.5	7.935	7.964	7.949	7.914	7.919	7.928	7.919	7.943	7.926	7.923	7.933	7.936	7.937	7.940	7.956	7.914
9.0	7.933	7.955	7.943	7.914	7.919	7.926	7.916	7.934	7.922	7.923	7.930	7.933	7.937	7.933	7.948	7.914
9.5	7.928	7.941	7.940	7.914	7.919	7.922	7.913	7.930	7.919	7.920	7.928	7.929	7.937	7.929	7.937	7.914
10.0	7.925	7.937	7.935	7.914	7.919	7.919	7.909	7.925	7.913	7.919	7.925	7.928	7.933	7.926	7.932	7.914
10.5	7.923	7.933	7.929	7.913	7.916	7.916	7.909	7.922	7.911	7.914	7.923	7.926	7.928	7.924	7.927	7.914
11.0	7.923	7.928	7.926	7.910	7.914	7.911	7.906	7.919	7.910	7.913	7.920	7.925	7.926	7.919	7.924	7.914
11.5	7.917	7.926	7.924	7.904	7.910	7.910	7.904	7.914	7.908	7.910	7.919	7.923	7.923	7.919	7.924	7.910
12.0	7.919	7.924	7.921	7.905	7.907	7.910	7.901	7.913	7.905	7.910	7.918	7.923	7.922	7.917	7.918	7.909
12.5	7.919	7.921	7.916	7.905	7.905	7.909	7.901	7.907	7.905	7.909	7.914	7.923	7.919	7.915	7.919	7.908
13.0	7.919	7.919	7.915	7.905	7.906	7.907	7.901	7.907	7.903	7.905	7.914	7.920	7.916	7.913	7.913	7.906
13.5	7.915	7.918	7.912	7.905	7.906	7.907	7.900	7.905	7.900	7.905	7.911		7.913	7.910	7.916	7.908
14.0	7.914	7.915	7.910	7.906	7.906	7.909	7.899	7.905	7.897	7.905	7.909		7.909	7.910	7.915	7.910
14.5	7.914	7.915	7.910	7.906	7.906	7.910	7.900	7.905	7.896	7.905	7.909		7.905	7.910	7.915	7.910
15.0	7.914	7.915	7.910	7.906	7.906	7.910	7.901	7.903	7.896	7.905			7.906	7.910	7.915	7.910
15.5		7.915	7.910	7.906	7.906	7.910	7.901	7.901	7.894				7.906	7.908		7.910
16.0				7.906			7.901	7.901	7.897				7.906	7.910		
16.5							7.901						7.906			
17.0							7.901									

[1] Values enclosed in boxes were significantly lower than the mean ambient pH measured at the same depth.

Table B-5. Detrended[1] Dissolved Oxygen[2] on 21 July 2008

Depth (m)								Dissolved Oxygen (mg/L)								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	8.33	8.81	7.84	**5.45**	**5.66**	7.17	7.07	8.47	**5.76**	7.20	8.70	8.33	6.96	8.42	7.37	**5.78**
1.5	8.36	8.66	6.99	**5.44**	**5.67**	7.39	7.16	8.65	**5.72**	7.81	8.65	8.00	7.81	8.14	7.81	**5.94**
2.0	8.00	8.17	6.25	**5.44**	**5.68**	7.15	7.23	8.64	**5.72**	7.55	8.04	7.36	7.70	7.76	7.94	6.09
2.5	7.61	7.75	6.20	**5.45**	**5.69**	6.82	7.25	8.62	**5.76**	7.30	7.40	7.03	7.68	7.41	7.48	5.89
3.0	7.15	7.32	6.30	**5.43**	5.66	6.53	7.18	8.44	5.85	7.08	7.10	6.90	7.48	7.30	7.17	5.81
3.5	6.99	7.16	6.30	5.47	5.65	6.44	6.91	8.06	5.90	6.76	6.75	6.72	6.70	7.20	6.98	5.79
4.0	6.92	7.06	6.15	5.50	5.64	6.42	6.30	7.39	5.99	6.44	6.47	6.64	6.35	7.12	6.90	5.77
4.5	6.83	7.02	6.07	5.52	5.65	6.23	6.21	7.08	6.10	6.16	6.25	6.42	6.04	6.96	6.84	5.71
5.0	6.71	7.00	6.07	5.56	5.66	6.08	6.08	6.77	6.14	6.02	6.14	6.27	5.93	6.88	6.70	5.61
5.5	6.50	6.95	6.19	5.60	5.66	5.88	5.93	6.69	6.12	5.98	6.06	6.17	5.84	6.52	6.65	5.59
6.0	6.31	6.85	6.21	5.61	5.66	5.86	5.87	6.41	6.11	5.94	5.98	6.10	5.86	6.26	6.45	5.60
6.5	6.13	6.63	6.18	5.61	5.65	5.81	5.74	6.25	6.05	5.94	5.85	5.95	5.87	6.17	6.38	5.59
7.0	6.05	6.45	6.11	5.61	5.66	5.78	5.75	6.06	5.95	5.94	5.78	5.83	5.86	6.03	6.35	5.58
7.5	5.89	6.21	6.00	5.62	5.66	5.72	5.70	5.98	5.90	5.94	5.73	5.70	5.86	5.87	6.19	5.56
8.0	5.90	6.02	5.95	5.63	5.67	5.68	5.66	5.90	5.87	5.93	5.69	5.62	5.87	5.86	6.09	5.55
8.5	5.80	5.96	5.85	5.62	5.67	5.65	5.62	5.83	5.83	5.89	5.67	5.57	5.84	5.77	5.94	5.55
9.0	5.78	5.90	5.79	5.62	5.62	5.63	5.58	5.78	5.78	5.84	5.64	5.55	5.82	5.72	5.86	5.56
9.5	5.74	5.78	5.76	5.56	5.58	5.58	5.54	5.74	5.75	5.81	5.61	5.52	5.77	5.68	5.75	5.55
10.0	5.71	5.77	5.73	5.52	5.54	5.53	5.51	5.69	5.72	5.75	5.57	5.49	5.68	5.65	5.67	5.50
10.5	5.68	5.71	5.67	5.49	5.47	5.47	5.48	5.64	5.71	5.72	5.54	5.47	5.65	5.63	5.63	5.39
11.0	5.67	5.70	5.63	5.43	5.43	5.43	5.45	5.61	5.67	5.70	5.53	5.45	5.62	5.61	5.60	5.41
11.5	5.64	5.65	5.58	5.40	5.42	5.40	5.42	5.55	5.62	5.68	5.51	5.44	5.57	5.58	5.58	5.40
12.0	5.64	5.62	5.55	5.41	5.41	5.41	5.42	5.54	5.59	5.68	5.49	5.43	5.54	5.55	5.54	5.40
12.5	5.63	5.60	5.51	5.40	5.40	5.40	5.40	5.51	5.56	5.69	5.47	5.43	5.50	5.53	5.52	5.40
13.0	5.63	5.57	5.52	5.40	5.41	5.40	5.39	5.50	5.54	5.69	5.45	5.42	5.42	5.51	5.48	5.39
13.5	5.61	5.55	5.51	5.40	5.40	5.40	5.40	5.49	5.52	5.67	5.44		5.41	5.50	5.49	5.40
14.0	5.58	5.54	5.50	5.40	5.41	5.41	5.40	5.49	5.51	5.65	5.43		5.38	5.50	5.47	5.40
14.5	5.56	5.53	5.50	5.41	5.42	5.41	5.40	5.48	5.50	5.62	5.43		5.37	5.49	5.47	5.40
15.0	5.54	5.52	5.50	5.41	5.41	5.41	5.41	5.47	5.50	5.60			5.39	5.49	5.47	5.40
15.5		5.52	5.48	5.41	5.41	5.41	5.40	5.47	5.48				5.38	5.49		5.41
16.0				5.41			5.41	5.47	5.49				5.38	5.48		
16.5							5.41						5.38			
17.0							5.40									

[1] Measured dissolved oxygen levels were corrected for temporal drift to account for ongoing equilibration of the oxygen sensor.

[2] Values enclosed in boxes were significantly lower than the mean ambient dissolved oxygen measured at the same depth.

Table B-6. Light Transmittance[1] across a 0.25-m path on 21 July 2008

Depth (m)	Light Transmittance (%)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	60.27	60.15	67.36	*79.33*	*78.85*	68.56	72.19	62.30	*78.28*	63.09	57.71	57.76	66.75	61.52	69.54	*78.55*
1.5	63.64	61.40	*79.15*	*78.98*	*78.67*	68.21	72.01	62.56	*78.01*	66.70	58.07	62.16	66.26	63.49	66.25	*77.50*
2.0	65.93	66.24	*78.60*	*79.26*	*79.10*	70.02	71.62	63.32	78.44	67.03	63.58	69.53	67.81	70.18	64.66	75.37
2.5	70.14	69.11	78.11	79.41	78.83	73.97	71.44	63.31	78.05	69.14	70.03	71.54	66.62	72.10	71.10	77.91
3.0	73.80	72.06	76.16	79.21	79.36	74.92	71.58	63.04	77.45	70.56	71.61	73.30	67.95	73.03	71.74	78.77
3.5	72.77	72.72	76.17	80.09	79.33	74.96	73.83	67.00	77.67	71.68	72.43	75.90	73.73	73.04	71.95	78.57
4.0	73.76	72.95	76.97	80.64	79.36	75.49	80.33	70.96	77.12	72.99	74.73	74.51	77.22	73.11	72.36	78.88
4.5	75.36	73.02	78.08	80.64	78.84	76.23	79.48	72.92	76.84	76.78	75.72	74.89	78.28	73.35	72.66	79.41
5.0	76.88	73.63	77.26	80.77	79.49	77.33	80.53	75.42	77.48	77.90	76.53	77.51	79.03	74.10	72.67	79.82
5.5	77.78	73.70	75.01	81.01	80.55	79.02	80.57	76.56	77.03	78.13	76.92	77.95	79.38	78.08	75.53	79.70
6.0	78.35	74.54	76.41	80.88	79.91	79.34	80.69	77.95	77.08	78.16	78.23	77.69	79.50	78.45	77.54	79.60
6.5	78.26	76.62	76.26	80.97	80.23	79.79	80.80	78.79	77.85	78.34	78.42	77.44	79.57	78.92	76.44	79.27
7.0	79.40	78.23	77.32	80.87	80.17	80.84	80.99	80.47	78.72	78.71	78.56	79.95	79.64	79.65	77.75	80.12
7.5	80.41	78.50	78.76	80.92	80.33	81.40	81.32	80.36	79.94	79.11	78.76	81.38	79.90	80.75	77.65	80.15
8.0	80.69	79.17	79.47	81.13	80.40	81.55	81.32	80.71	80.13	78.92	79.24	82.96	79.87	80.54	78.77	80.47
8.5	80.74	80.17	80.69	81.13	80.51	81.58	81.62	80.77	80.41	79.36	79.05	78.67	80.42	80.30	79.18	80.18
9.0	80.89	80.59	80.77	80.57	80.99	81.53	81.81	81.23	81.06	80.36	79.20	78.82	80.33	80.80	80.81	80.37
9.5	80.82	80.91	80.73	81.33	81.43	81.67	81.83	81.04	81.31	80.76	79.07	79.79	80.77	80.63	81.37	81.00
10.0	80.82	80.72	80.53	81.18	81.39	81.96	81.80	81.09	81.45	80.93	79.31	78.67	81.42	80.56	81.54	81.30
10.5	80.39	80.87	80.72	81.35	81.62	82.15	82.04	81.50	81.46	80.35	79.43	82.37	81.16	80.70	81.86	82.97
11.0	80.25	80.59	80.81	81.70	82.28	82.44	82.37	81.43	81.09	80.27	79.40	78.25	81.38	80.74	81.82	82.73
11.5	80.29	80.94	81.68	82.46	82.68	83.07	82.43	81.56	81.45	80.27	79.28	78.18	81.84	80.80	81.40	82.29
12.0	80.16	80.61	81.76	82.29	82.96	82.91	82.40	81.64	81.47	79.88	79.23	78.43	81.85	81.52	81.55	82.42
12.5	78.85	80.91	81.66	82.43	82.86	82.85	82.53	82.16	81.95	79.58	78.87	78.01	82.34	81.90	81.62	82.42
13.0	79.97	81.16	81.53	82.39	82.51	83.35	82.20	81.79	81.75	79.93	78.75	78.12	82.44	82.03	81.45	82.35
13.5	80.16	81.08	81.78	82.15	82.78	82.30	82.22	81.97	81.71	80.29	78.66		82.71	81.98	80.95	82.11
14.0	80.46	80.82	81.46	81.64	82.54	82.29	82.14	82.06	81.04	79.64	78.61		82.61	81.71	81.23	82.14
14.5	80.15	80.74	81.09	81.82	82.30	81.51	82.48	81.85	81.18	79.68	78.64		82.46	81.96	80.43	81.02
15.0	80.59	81.20	81.78	81.57	82.51	81.61	82.26	82.01	81.44	80.03			82.47	81.90	79.51	80.74
15.5		80.52	80.81	81.58	81.40	81.62	82.55	81.54	81.44				82.35	81.55		80.63
16.0				80.57			82.29	81.96	81.56				82.03	80.96		
16.5							82.17						81.18			
17.0							81.70									

[1] Values enclosed in thin boxes were significantly higher than the mean ambient transmissivity measured at the same depth.

Table B-7. Uncorrected Dissolved Oxygen[1] on 21 July 2008

Depth (m)	Dissolved Oxygen (mg/L)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	8.33	8.81	7.84	5.45	5.66	7.17	7.07	8.47	5.76	7.20	9.05	8.87	6.96	8.42	7.37	5.78
1.5	8.36	8.66	6.99	5.44	5.67	7.39	7.16	8.65	5.72	7.81	9.00	8.54	7.81	8.14	7.81	5.94
2.0	8.00	8.17	6.25	5.44	5.68	7.15	7.23	8.64	5.72	7.55	8.38	7.91	7.70	7.76	7.94	6.09
2.5	7.61	7.75	6.20	5.45	5.69	6.82	7.25	8.62	5.76	7.30	7.75	7.57	7.68	7.41	7.48	5.89
3.0	7.15	7.32	6.30	5.43	5.66	6.53	7.18	8.44	5.85	7.08	7.45	7.44	7.48	7.30	7.17	5.81
3.5	6.99	7.16	6.30	5.47	5.65	6.44	6.91	8.06	5.90	6.76	7.09	7.26	6.70	7.20	6.98	5.79
4.0	6.92	7.06	6.15	5.50	5.64	6.42	6.30	7.39	5.99	6.44	6.81	7.19	6.35	7.12	6.90	5.77
4.5	6.83	7.02	6.07	5.52	5.65	6.23	6.21	7.08	6.10	6.16	6.60	6.97	6.04	6.96	6.84	5.71
5.0	6.71	7.00	6.07	5.56	5.66	6.08	6.08	6.77	6.14	6.02	6.49	6.81	5.93	6.88	6.70	5.61
5.5	6.50	6.95	6.19	5.60	5.66	5.88	5.93	6.69	6.12	5.98	6.41	6.71	5.84	6.52	6.65	5.59
6.0	6.31	6.85	6.21	5.61	5.66	5.86	5.87	6.41	6.11	5.94	6.33	6.64	5.86	6.26	6.45	5.60
6.5	6.13	6.63	6.18	5.61	5.65	5.81	5.74	6.25	6.05	5.94	6.20	6.50	5.87	6.17	6.38	5.59
7.0	6.05	6.45	6.11	5.61	5.66	5.78	5.75	6.06	5.95	5.94	6.13	6.37	5.86	6.03	6.35	5.58
7.5	5.89	6.21	6.00	5.62	5.66	5.72	5.70	5.98	5.90	5.94	6.08	6.24	5.86	5.87	6.19	5.56
8.0	5.90	6.02	5.95	5.63	5.67	5.68	5.66	5.90	5.87	5.93	6.04	6.16	5.87	5.86	6.09	5.55
8.5	5.80	5.96	5.85	5.62	5.67	5.65	5.62	5.83	5.83	5.89	6.01	6.12	5.84	5.77	5.94	5.55
9.0	5.78	5.90	5.79	5.62	5.62	5.63	5.58	5.78	5.78	5.84	5.99	6.10	5.82	5.72	5.86	5.56
9.5	5.74	5.78	5.76	5.56	5.58	5.58	5.54	5.74	5.75	5.81	5.95	6.07	5.77	5.68	5.75	5.55
10.0	5.71	5.77	5.73	5.52	5.54	5.53	5.51	5.69	5.72	5.75	5.92	6.03	5.68	5.65	5.67	5.50
10.5	5.68	5.71	5.67	5.49	5.47	5.47	5.48	5.64	5.71	5.72	5.89	6.02	5.65	5.63	5.63	5.39
11.0	5.67	5.70	5.63	5.43	5.43	5.43	5.45	5.61	5.67	5.70	5.88	6.00	5.62	5.61	5.60	5.41
11.5	5.64	5.65	5.58	5.40	5.42	5.40	5.42	5.55	5.62	5.68	5.86	5.99	5.57	5.58	5.58	5.40
12.0	5.64	5.62	5.55	5.41	5.41	5.41	5.42	5.54	5.59	5.68	5.84	5.98	5.54	5.55	5.54	5.40
12.5	5.63	5.60	5.51	5.40	5.40	5.40	5.40	5.51	5.56	5.69	5.82	5.98	5.50	5.53	5.52	5.40
13.0	5.63	5.57	5.52	5.40	5.41	5.40	5.39	5.50	5.54	5.69	5.80	5.97	5.42	5.51	5.48	5.39
13.5	5.61	5.55	5.51	5.40	5.40	5.40	5.40	5.49	5.52	5.67	5.79		5.41	5.50	5.49	5.40
14.0	5.58	5.54	5.50	5.40	5.41	5.41	5.40	5.49	5.51	5.65	5.78		5.38	5.50	5.47	5.40
14.5	5.56	5.53	5.50	5.41	5.42	5.41	5.40	5.48	5.50	5.62	5.78		5.37	5.49	5.47	5.40
15.0	5.54	5.52	5.50	5.41	5.41	5.41	5.41	5.47	5.50	5.60			5.39	5.49	5.47	5.40
15.5		5.52	5.48	5.41	5.41	5.41	5.40	5.47	5.48				5.38	5.49		5.41
16.0				5.41			5.41	5.47	5.49				5.38	5.48		
16.5							5.41						5.38			
17.0							5.40									

[1] Values enclosed in boxes were significantly lower than the mean ambient dissolved oxygen measured at the same depth.

Table B-8. Auxiliary Observations on 21 July 2008 during the Quarterly Water-Quality Survey

Station	Location Latitude	Location Longitude	Diffuser Distance (m)	Time (PDT)	Air Temperature (°C)	Cloud Cover (%)	Wind Avg (kt)	Wind Max (kt)	Wind Dir (from) (°T)	Swell Ht/Dir (ft/°T)	Secchi Depth (m)
1	35° 23.251' N	120° 52.502' W	96.5	10:15:51	13.3	50	6.2	7.5	NW	2-4 NW	5.0
2	35° 23.230' N	120° 52.500' W	57.8	10:20:44	14.1	40	6.1	7.2	NW	2-4 NW	5.0
3	35° 23.207' N	120° 52.498' W	18.2	10:24:35	14.4	40	5.8	7.1	NW	2-4 NW	6.5
4	35° 23.189' N	120° 52.499' W	20.4	10:29:29	13.5	40	7.2	8.5	NW	2-4 NW	7.0
5	35° 23.167' N	120° 52.502' W	59.7	10:36:08	13.4	40	6.0	8.5	NW	2-4 NW	7.0
6	35° 23.144' N	120° 52.499' W	102.9	10:42:58	14.2	40	5.1	6.0	NW	2-4 NW	5.5
7	35° 23.199' N	120° 52.568' W	97.5	10:07:54	13.4	50	6.4	7.4	NW	2-4 NW	6.5
8	35° 23.198' N	120° 52.540' W	53.6	10:03:46	13.5	60	6.5	7.9	NW	2-4 NW	5.0
9	35° 23.192' N	120° 52.523' W	31.5	09:58:51	13.2	70	5.9	7.8	NW	2-4 NW	6.0
10	35° 23.200' N	120° 52.485' W	29.6	09:54:23	14.4	80	5.0	8.7	NW	2-4 NW	5.0
11	35° 23.199' N	120° 52.463' W	62.5	09:50:04	14.5	80	4.6	7.6	NW	2-4 NW	5.0
12	35° 23.196' N	120° 52.432' W	109.5	09:45:03	14.0	85	5.1	6.1	NW	2-4 NW	5.5
13	35° 23.174' N	120° 52.529' W	59.9	10:46:49	13.6	35	6.4	8.2	NW	2-4 NW	5.0
14	35° 23.225' N	120° 52.531' W	62.3	10:11:42	13.5	50	6.6	8.3	NW	2-4 NW	5.0
15	35° 23.223' N	120° 52.472' W	66.5	10:54:43	13.6	35	5.2	6.2	NW	2-4 NW	5.0
16	35° 23.177' N	120° 52.473' W	62.4	10:50:04	13.0	35	6.3	8.1	NW	2-4 NW	7.0

Neither odors nor debris of sewage origin were observed at any time during the survey. Small strips of biofilm, which grow on the interior of the outfall pipe, were evident within the water column near the ZID.

Tidal Conditions (Pacific Daylight Time)
Low Tide: 06:55   -0.1 ft
High Tide: 13:29   4.1 ft
Low Tide: 18:42   2.1 ft