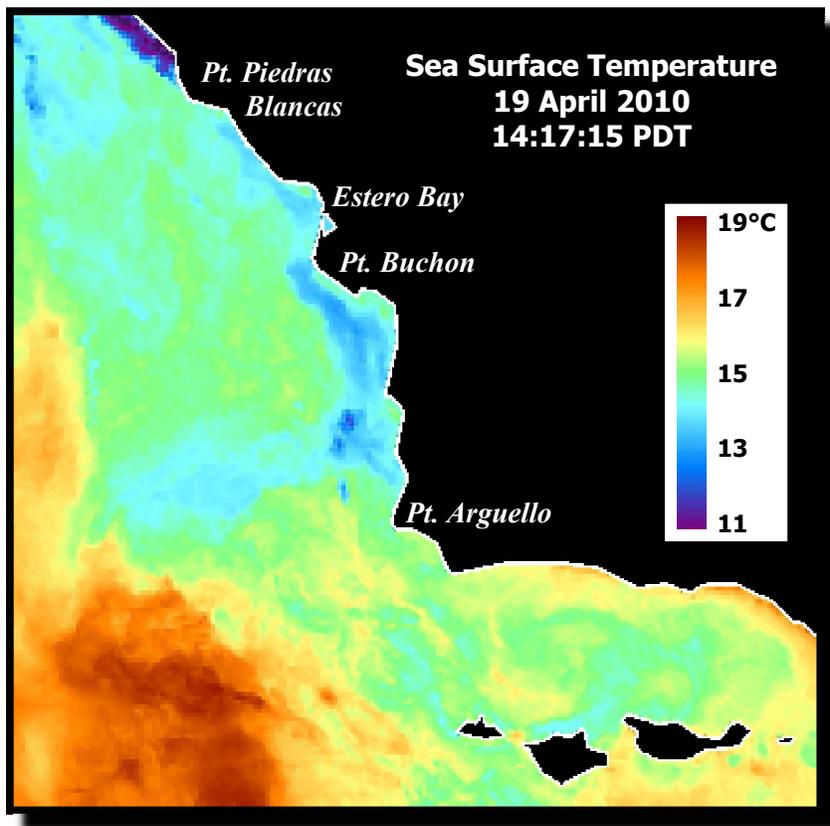


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

SECOND QUARTER RECEIVING-WATER SURVEY

APRIL 2010



Marine Research Specialists

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

**Report to the
City of Morro Bay and
Cayucos Sanitary District**

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

**OFFSHORE MONITORING
AND REPORTING PROGRAM**

**SECOND QUARTER
RECEIVING-WATER SURVEY**

APRIL 2010

Prepared by

**Bonnie Luke
Douglas A. Coats**

Marine Research Specialists

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

Telephone: (805) 644-1180

Telefax: (805) 289-3935

E-mail: Marine@Rain.org

July 2010

marine research specialists

3140 Telegraph Road, Suite A • Ventura, CA 93003 • (805) 644-1180

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

14 July 2010

Reference: Second Quarter Receiving-Water Survey Report – April 2010

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Monday, 19 April 2010. The survey was conducted in accordance with the requirements of the NPDES permit issued to the City and District for discharge of treated wastewater to Estero Bay. The report evaluated compliance with permit limitations and assessed the effectiveness of effluent dispersion during spring oceanographic conditions. Based on report's quantitative analyses of continuous instrumental measurements and qualitative visual observations, the wastewater discharge complied with the receiving-water limitations specified in the permit, and with the objectives of the California Ocean Plan.

The offshore measurements confirmed that the diffuser structure and treatment plant continued to operate at high performance levels. The measurements delineated a diffuse discharge plume containing low organic loads within a highly localized region immediately northeast of the discharge point. Dilution within the plume exceeded expectations based on modeling and outfall design criteria.

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

Sincerely,

Bonnie Luke
Program Manager

(Submitted Electronically)

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. Rob Livick
Director of Public Services
City of Morro Bay

Date _____

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INTRODUCTION

The City of Morro Bay and the Cayucos Sanitary District (MBCSD) jointly own the wastewater treatment plant operated by the City of Morro Bay. In March 1985, Region IX of the U.S. Environmental Protection Agency (USEPA) and the Central Coast California Regional Water Quality Control Board (RWQCB) issued the first National Pollutant Discharge Elimination System (NPDES) permit to the MBCSD. The permit incorporated partially modified secondary treatment requirements for the plant's ocean discharge. The permit has been re-issued three times, in March 1993 (RWQCB-USEPA 1993ab), December 1998 (RWQCB-USEPA 1998ab), and January 2009 (RWQCB-USEPA 2009). The April 2010 field survey described in this report was the fifth receiving-water survey conducted under the current permit.

Under the NPDES discharge permit, seasonal monitoring of offshore receiving-water quality is conducted on a quarterly basis. This report summarizes the results of sampling conducted on 19 April 2010. Specifically, this second-quarter survey captured ambient oceanographic conditions along the central California coast during the spring season. The survey's measurements were used to assess the discharge's compliance with the objectives of the California Ocean Plan (COP) and the central coast Basin Plan (RWQCB 1994) as promulgated by the receiving-water limitations specified in the NPDES discharge permit.

The monitoring objectives were achieved by evaluating empirical tabulations of instrumental measurements and standard field observations. In addition to the traditional, vertical water-column profiles, instrumental measurements were used to generate horizontal maps from high-resolution data gathered by towing a CTD¹ instrument package repeatedly over the diffuser structure. This allowed for a more precise determination of the plume's lateral extent.

SURVEY SETTING

The MBCSD treatment plant is located within the City of Morro Bay, which is situated along the central coast of California approximately halfway between Los Angeles and San Francisco. Effluent is carried from the onshore treatment plant through a 1,450-m long outfall pipe, which terminates at a diffuser structure on the seafloor approximately 827 m from the shoreline within Estero Bay (Figure 1). The diffuser structure extends an additional 52 m toward the northwest from the outfall terminus and consists of 34 ports that are hydraulically designed to create a turbulent ejection jet that rapidly mixes effluent with receiving seawater upon discharge. Currently, six of the diffuser ports are kept closed, thereby improving effluent dispersion by increasing the ejection velocity from the remaining 28 ports distributed along a 42-m section of the diffuser structure.

Following discharge from the diffuser ports, 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 extends approximately 15 m from the centerline of the diffuser structure. Beyond the ZID, energetic waves, tides, and coastal currents within Estero Bay further disperse the discharge plume within the open-ocean receiving waters. Both vertical hydrocasts and a horizontal tow survey are conducted in the vicinity of the diffuser structure to assess the efficacy of the diffuser, define the extent of the discharge plume, and evaluate compliance with the NPDES permit limitations.

¹ Conductivity, temperature, and depth (CTD)



Near the diffuser, prevailing currents generally follow bathymetric contours that 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, in the event of a failure in the treatment plant's disinfection system, collection and analysis of water samples at the surfzone sampling stations shown in Figure 1 would be conducted to monitor for potential shoreline impacts. These surfzone samples would be analyzed for total and fecal coliform, and enterococcus bacterial densities.

Areas of special concern, such as the Morro Bay National Estuary and the Monterey Bay National Marine Sanctuary, are not affected by the discharge because they are even more distant from the outfall location. For example, the southern boundary of the Monterey Bay National Marine Sanctuary is located 38 km to the north, while the entrance to the Morro Bay National Estuary lies 2.8 km south. The southerly orientation of the mouth of the Bay and the presence of Morro Rock 2 km to the south serve to further limit seawater exchange between the discharge point and the Bay (Figure 1).

SAMPLING LOCATIONS

As shown in Figure 2, the offshore sampling pattern consists of six fixed offshore stations located within 100 m of the outfall diffuser structure. The red ⊙ symbols in the Figure indicate the target locations of the sampling stations (Table 1). The stations are situated at three distances relative to the center of the diffuser structure and lie along a north-south axis at the same water depth (15.2 m) as the center of the diffuser. Depending on the direction of the local oceanic currents at the time of sampling, the discharge should conceivably influence one or more of these stations. The up-current stations on the opposite side of the diffuser can then act as reference stations. Comparisons of water properties at these antipodal stations quantify departures from ambient seawater properties that help determine compliance with the NPDES discharge permit.

The finite size of the diffuser is an important consideration in the assessment of wastewater dispersion close to the discharge. 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, and, ultimately, the amount of wastewater dispersion at a given point in the water column is dictated by its distance from the closest diffuser port, rather than its distance from the center of the diffuser structure. Therefore, the "closest approach" distance can be considerably less than the centerpoint distance normally cited in modeling studies.

Another important consideration for compliance evaluation is the ability to determine the actual location of the measurements. Discerning small spatial separations within the compact sampling pattern only became feasible after the advent of Differential Global Positioning Systems (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. DGPS incorporates a second signal from a fixed, land-based beacon that continuously transmits position errors in standard GPS readings to the DGPS receiver onboard the survey vessel. Real-time correction for these position errors provides an extremely stable and accurate offshore navigational reading with position errors of less than 2 m.

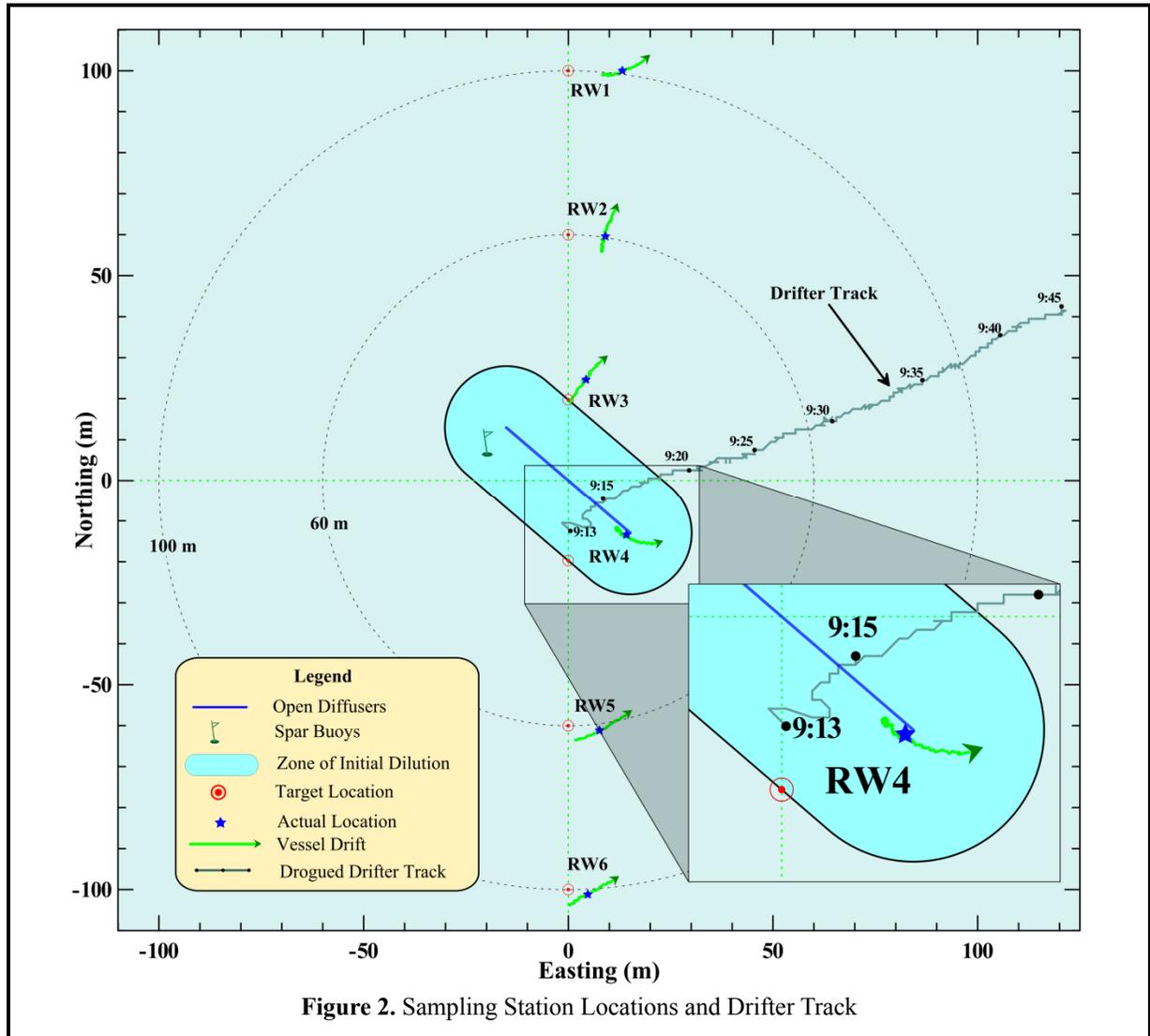


Figure 2. Sampling Station Locations and Drifter Track

Table 1. Target Locations of the Receiving-Water Monitoring Stations

| Station | Description | Latitude | Longitude | Center Distance ² (m) | Closest Approach Distance ³ (m) |
|---------|---------------------|---------------|----------------|-------------------------------------|-----------------------------------------------|
| RW1 | Upcoast Midfield | 35° 23.253' N | 120° 52.504' W | 100 | 88.4 |
| RW2 | Upcoast Nearfield | 35° 23.231' N | 120° 52.504' W | 60 | 49.4 |
| RW3 | Upcoast ZID | 35° 23.210' N | 120° 52.504' W | 20 | 15.0 |
| RW4 | Downcoast ZID | 35° 23.188' N | 120° 52.504' W | 20 | 15.0 |
| RW5 | Downcoast Nearfield | 35° 23.167' N | 120° 52.504' W | 60 | 49.4 |
| RW6 | Downcoast Midfield | 35° 23.145' N | 120° 52.504' W | 100 | 88.4 |

² Distance to the center of the open diffuser section

³ Distance to the closest open diffuser port

In July 1998, the survey vessel's DGPS navigation system, consisting of a Furuno™ GPS 30 and FBX2 differential beacon receiver, was used to precisely locate the position of the open section of the diffuser structure (MRS 1998) and establish the target locations for the receiving-water monitoring stations shown in Figure 2 and listed in Table 1. Currently, use of two independent DGPS receivers on the survey vessel allows access to two separate land-based beacons for navigational comparison, ensuring extremely accurate and uninterrupted navigational reports.

Recording of DGPS positions at one-second intervals allows precise determination of sampling locations throughout the vertical CTD profiling conducted at the six individual stations, as well as during the tow survey. Knowledge of the precise location of individual CTD measurements relative to the diffuser is critical for accurate interpretation of the water-property fields. During vertical-profile sampling, the actual measurement locations rarely coincide with the target coordinates listed in Table 1 because winds, waves, and currents induce unavoidable horizontal offsets (drift). Even during quiescent metocean⁴ conditions, the residual momentum of the survey vessel as it approaches the target locations can create perceptible offsets. Using DGPS however, these offsets can be quantified, and the vessel location can be precisely tracked throughout sampling at each station.

The magnitude of the drift at each of the six stations during the April 2010 survey is apparent from the length of the green tracklines in Figure 2. These tracklines trace the horizontal movement of the CTD as it was lowered to the seafloor. Their length and offset from the target locations reflect the overall station-keeping ability during the April 2010 survey. During the time it took the CTD to traverse the water column and reach the seafloor, which averaged 1 min 17 s, the instrument package moved an average of 11.7 m, which was comparable to most prior surveys.

The CTD trajectories shown by the tracklines in Figure 2 often reflect complex interactions between surface currents and wind forces that act on the survey vessel during sampling. Due to the calm sea conditions at the time of the April 2010 survey; however, the tracklines in the Figure primarily reflect the residual momentum of the survey vessel as it approached each target location. As seen in Figure 2, the vessel approached most stations from the southwest. Although brief thrust reversals were successful at eliminating the majority of residual vessel momentum prior to initiation of the downcast, a limited northeastward drift is apparent at most stations.

Although relatively small, and comparable to the survey vessel's 12-m length, lateral drift of the CTD during the vertical hydrocasts can complicate the assessment of compliance with discharge limitations at stations close to the diffuser structure. This is because the receiving-water limitations specified in the COP only apply to measurements recorded beyond the ZID boundary, where initial mixing is assumed to be complete. For example, during the April 2010 survey, none of the measurements recorded at Station RW4 were subject to the limitations because the CTD was within the ZID boundary throughout the entire vertical cast at that station (see Figure 2 inset).

Determining which measurements are subject to permit limits within hydrocasts near the ZID boundary only became possible after the advent of DGPS. Prior to 1999, CTD locations could not be determined with sufficient accuracy or precision to establish whether a station was located within the ZID, much less how the CTD was moving laterally during the hydrocast. Because of these navigational limitations, sampling was presumed to occur at a single, imprecisely determined, horizontal location. Federal and

⁴ Meteorological and oceanographic conditions include winds, waves, tides, and currents.

State reporting of monitoring data still requires identification of a single position for all of the CTD data collected at a particular station. Thus, for regulatory reporting, and for consistency with past surveys, the April 2010 survey also identifies a single sampling location for each station. These average station positions are shown by blue stars in Figure 2, and are listed in Table 2 with their distances from the diffuser structure.

Table 2. Average Position of Vertical Profiles during the April 2010 Survey

| Station | Time (PDT) | | Latitude | Longitude | Closest Approach | |
|---------|------------|---------|---------------|----------------|-------------------------|---------------------------|
| | Downcast | Upcast | | | Range ⁵ (m) | Bearing ⁶ (°T) |
| RW1 | 9:22:27 | 9:23:55 | 35° 23.253' N | 120° 52.495' W | 91.7 | 18 |
| RW2 | 9:26:38 | 9:27:58 | 35° 23.231' N | 120° 52.498' W | 52.7 | 27 |
| RW3 | 9:30:33 | 9:31:39 | 35° 23.212' N | 120° 52.501' W | 21.6 | 41 |
| RW4 | 9:34:39 | 9:35:46 | 35° 23.192' N | 120° 52.495' W | 0.9 ⁷ | 221 |
| RW5 | 9:38:18 | 9:39:36 | 35° 23.166' N | 120° 52.499' W | 48.7 | 189 |
| RW6 | 9:41:40 | 9:43:02 | 35° 23.144' N | 120° 52.501' W | 88.7 | 187 |

Compliance assessments notwithstanding, measurements acquired from within the ZID lend valuable insight into the outfall’s effectiveness at dispersing wastewater. For example, low dilution rates and concentrated effluent throughout the ZID would indicate potentially damaged or broken diffuser ports. Analysis of the outfall’s operation over the past two decades, however, suggests that it has maintained a high level of effectiveness in effluent dispersal. In fact, without the occasional measurements recorded within the ZID due to CTD drift, the extremely dilute discharge plume might remain undetected within all vertical profiles collected during a given survey.

OCEANOGRAPHIC PROCESSES

The trajectory of a satellite-tracked drogued drifter documented a prevailing northeastward flow during the April 2010 survey (Figure 2). The drifter was drogued at mid-depth (7 m) using the curtain-shade design of Davis et al. (1982). In this configuration, the oceanic flow field rather than surface winds dictates the drifter’s trajectory. As such, the drifter track provides a good indication of the plume’s movement following discharge.

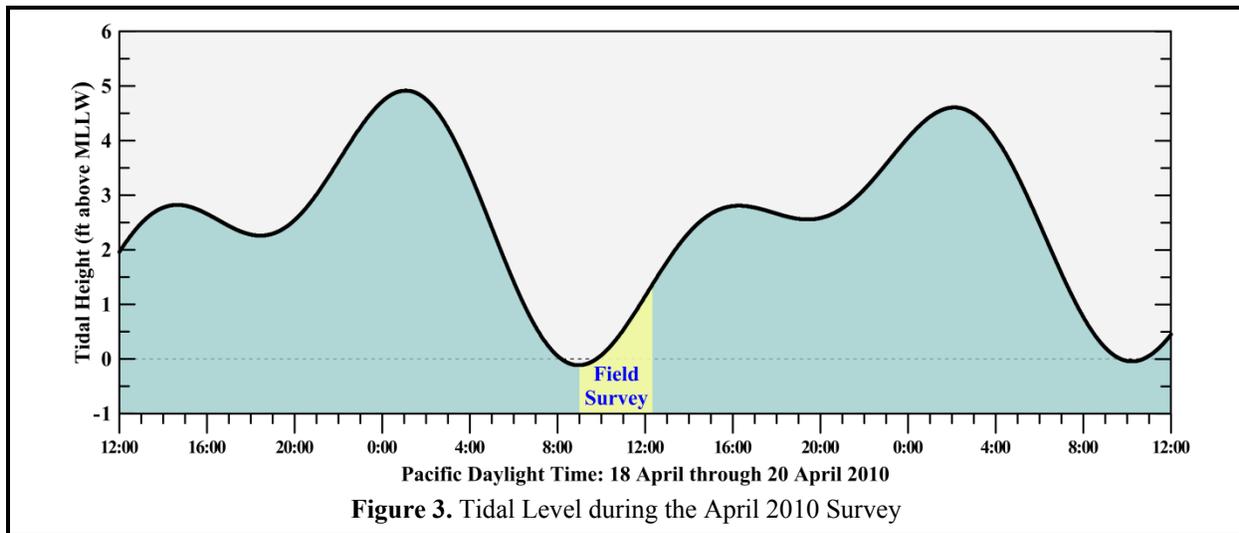
The drogued drifter was deployed just south of the diffuser structure near Station RW4 at 9:13 PDT, and was recovered one half-hour later, at a location 132 m northeast of its deployment location. The black dots in Figure 2 show the drifter’s progress at five-minute intervals. The uniform spacing between the time stamps reflects the relatively constant speed of the drifter throughout the survey, which averaged 7 cm/s, or 0.14 knots.

The moderate northeastward flow measured by the drifter was consistent with the incoming (flood) tidal phase that prevailed throughout the survey (Figure 3). In the absence of other influences, a flood tide normally induces a weak northeastward (onshore) flow in the survey region. However, flow is often also influenced by external processes, such as wind-generated upwelling or passing offshore eddies. The satellite image on the cover of this report documents the moderate upwelling conditions that prevailed during the April 2010 survey. The cover image was recorded in the afternoon on the day of the survey,

⁵ Distance from the closest open diffuser port to the average profile location.

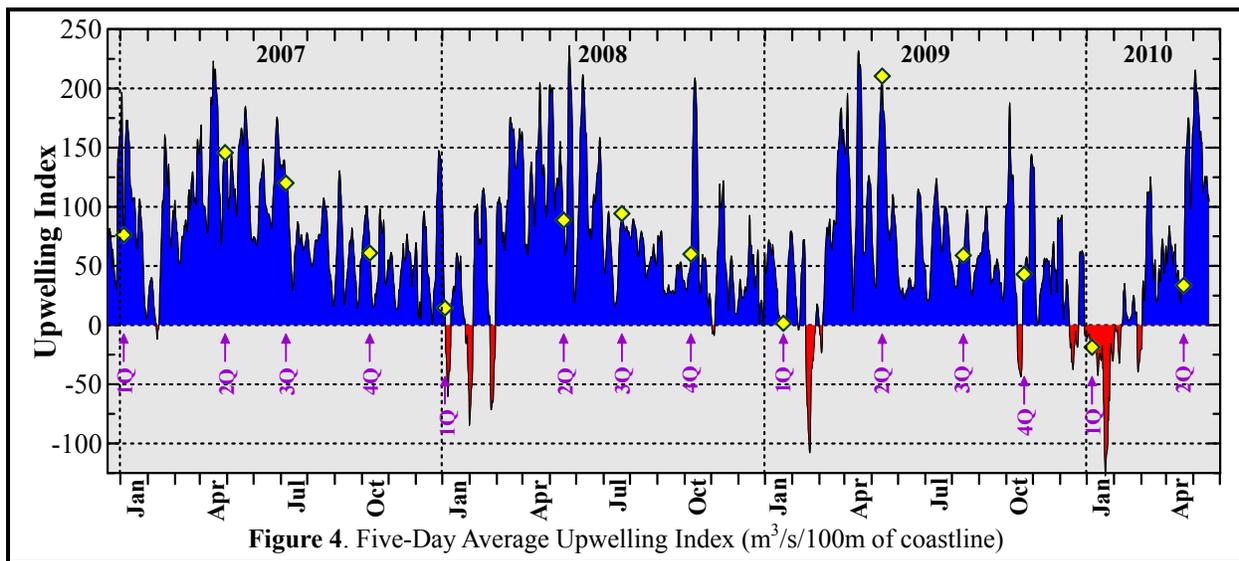
⁶ Angle measured clockwise relative to true north from the closest diffuser port to the average profile location.

⁷ All of the CTD cast at this station was located within the ZID boundary.



when skies had cleared enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA’s polar orbiting satellites.

Upwelling season normally begins sometime during late March and or early April as shown by the positive (blue) upwelling indices in Figure 4. At this time, there is a ‘spring’ transition to more persistent southeastward-directed winds along the central California coast. This transition is initiated by the stabilization of a high-pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive the prevailing northwesterly winds along the central California coast. These prevailing winds move warmer surface waters southward and offshore, allowing deep, cool, nutrient-rich waters to move shoreward and upwell near the coast, as seen in the image on the cover of this report. At the time of the survey, the satellite image shows cool (13°C) sea-surface temperatures were present within Estero Bay, while temperatures farther offshore exceeded 17°C (orange and red areas) over much of the



south-central coast. The lower Estero Bay sea surface temperatures depicted in the satellite image were consistent with the near-surface temperatures measured by the CTD during the April 2010 survey.⁸

The nutrient-rich seawater that is brought to the sea surface near the coast by upwelling enables phytoplanktonic blooms that are the foundation of the productive marine fishery found along the central California coast. The cross-shore flow associated with persistent upwelling conditions also enhances vertical stratification of the water column. The presence of denser water at depth produces a shallow thermocline (<10 m) that is commonly maintained throughout summer and into fall.

In contrast, downwelling events, indicated by the negative (red) indices in Figure 4, occur infrequently, and almost exclusively in winter, when passing storms temporarily reverse the normal wind pattern and drive surface waters shoreward. As the surface waters approach the coastline, they downwell, producing nearly uniform seawater properties throughout the water column.

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on Monday, 19 April 2010. Bonnie Luke of Marine Research Specialists (MRS) was the Chief Scientist and collected auxiliary measurements of biological, meteorological, and oceanographic conditions. Douglas Coats, also of MRS, provided navigational support during the survey. William Skok assisted with deployment and recovery of the CTD and drifter.

Auxiliary Measurements

Auxiliary measurements and observations were collected during the vertical water-column profiling conducted at each of the six stations. Standard observations of weather and sea conditions, and beneficial uses, were augmented by visual inspection of the sea surface for floating particulates, oil sheens, and discoloration potentially related to the effluent discharge. Other auxiliary measurements collected at each station included wind speeds and air temperatures measured with a handheld Kestrel[®] 2000 Thermo-Anemometer, and oceanic flow measurements made throughout the survey using a drogued drifter.

Additionally, at all six stations, a Secchi disk was lowered through the water column to determine its depth of disappearance. 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 sediment resuspension, and wastewater discharge. It is also biologically significant because the depth of the euphotic zone, where most oceanic photosynthesis occurs, extends to approximately twice the Secchi depth.

Instrumental Measurements

A Sea Bird Electronics SBE-19 Seacat CTD instrument package collected measurements of conductivity, temperature, light transmittance, dissolved oxygen (DO), pH, and pressure at a sampling rate of 2 Hz (0.5-s intervals) at each of the six vertical sampling stations, as well as during the towed survey. 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.

⁸ Refer to Table 5 and Figure 6 for receiving-water properties recorded during the vertical hydrocasts.

The CTD instrument package receives regular maintenance and calibration. After the January 2001 survey, the CTD was returned to the factory for comprehensive testing, repair, and calibration. The DO and pH sensors were returned to the factory in May 2003 and June 2006 for testing and calibration. Because of increasing temporal drift associated with aging DO probes, the DO probe was replaced on both occasions. As is the case before all surveys, the CTD system was calibrated at the MRS laboratory prior to the April 2010 survey. The upper-bound DO calibration point at full saturation was established by immersing the CTD in an aerated, temperature-controlled calibration tank. Similarly, a zero-oxygen calibration point was determined by filling the oxygen-sensor plenum with an 8% solution of sodium sulfite (Na₂SO₃). Oxygen calibration coefficients were established through regression analysis of sensor-membrane current and temperature, as recommended by the manufacturer (SBE 1993). As in previous surveys, the pre-cruise calibration coefficients determined by MRS closely corresponded with prior factory calibrations.

The six seawater properties used to assess receiving-water quality in this report were derived from the continuously recorded output of the CTD's probes and sensors. 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

Table 3. CTD Specifications

| Component | Depth⁹ | 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 |

in manufacturer's specifications, are also listed in the table. Salinity (‰) was calculated from conductivity measurements reported in units of Siemens/m. Density was derived from contemporaneous temperature (°C) and salinity data, and was expressed as 1000 times the specific gravity minus one, which is a unit of sigma-T (σ_t).

All three of the physical parameters (salinity, temperature, and density) helped determine the lateral extent of the effluent plume during the towing phase of the survey. Additionally, during the vertical-profiling phase, they quantified layering, or vertical stratification and stability of the water column, which determines the behavior and dynamics of the effluent as it mixes with seawater within the ZID. Data on the three remaining seawater properties, light transmittance (water clarity), hydrogen-ion concentration (acidity/alkalinity – pH), and dissolved oxygen (DO), further characterized the 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, 7±0.01, 8±0.01, and 9±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).

⁹ Maximum depth limit in meters

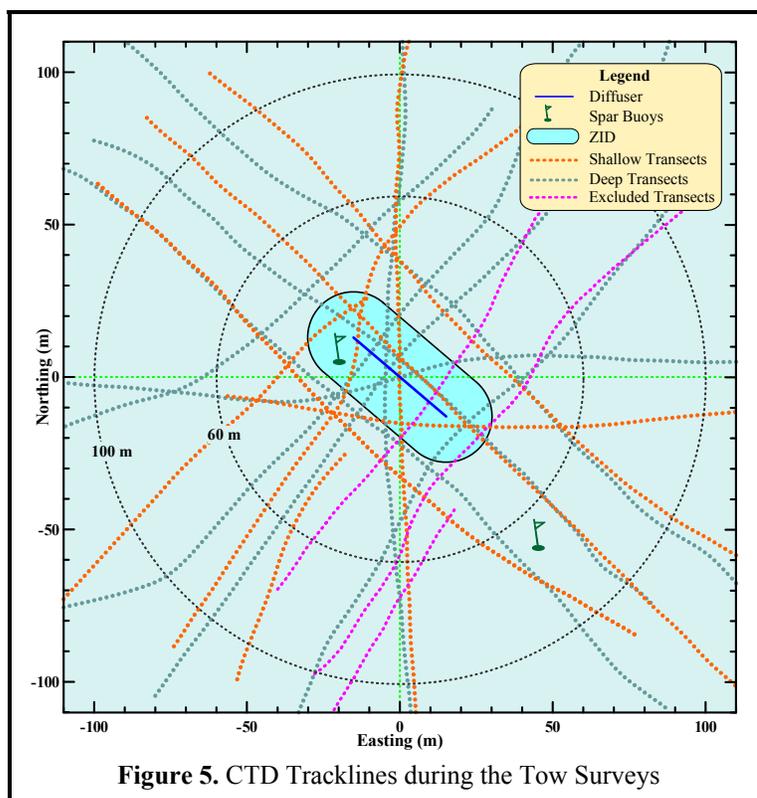
Algorithms that converted sensor voltage to engineering units during processing of the field data relied on calibration coefficients determined before the survey.

Comparison with the factory calibration of the entire CTD package 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. To correct for a slight drift in the pressure strain gauge since its calibration in 2001, a -0.25 Psia offset was incorporated in the conversion to depth measurements. In addition, a slight temporal trend in pH measurements arose from the sensor's ongoing equilibration during the survey. The trend was removed by fitting a seventh-degree orthogonal polynomial to the pH time series. The largest adjustment was 0.043 pH units.

Before initial deployment for the vertical hydrocasts, the CTD was held below the sea surface for a five-minute equilibration period. Subsequently, the CTD was raised to within 0.5 m of the sea surface and profiling commenced. The CTD was lowered at a continuous rate of speed to the seafloor. Measurements at all six stations were collected during a single deployment of the CTD package by towing it below the water surface while transiting between adjacent stations.

At 9:55 PDT, following the last vertical profile at RW6, the CTD instrument package was brought onboard the survey vessel and fitted with a depth-suppressor wing and horizontal stabilizer. This configuration allows the CTD to achieve constant-depth tows with forward-looking sensor probes. The CTD was then towed continuously around and across the ZID at two separate depths in accordance with the receiving-water monitoring requirements of the NPDES discharge permit (Figure 5).

First, the reconfigured CTD package was towed for 44 min at an average depth of 4.07 m,¹⁰ and an average speed of 1.79 m/s, passing near the diffuser structure eleven times. Subsequently, nine additional passes were made with the CTD at an average depth of 7.25 m. During this 32-minute mid-depth-tow, vessel speed averaged 1.72 m/s. At the observed towing speeds and 2 Hz sampling rate, 1.16 CTD measurements were collected for each meter traversed, which complies with the permit requirement for at least one sample per meter. Contemporaneous navigation fixes recorded onboard the survey vessel were adjusted



¹⁰ Average depth of the eight shallow tow transects evaluated in the compliance analysis. The three additional transects were removed from consideration due to a vertical offset in tow depth as described in the *Quality Control* section.

for CTD setback and aligned with time stamps on the internally recorded CTD data. The resulting data for the six seawater properties were processed to produce horizontal maps within the mid-depth and upper portions of the water column.¹¹

Quality Control

Upon retrieval of the CTD following both the vertical casts and the horizontal tows, the data were downloaded to a portable computer and examined for completeness and range acceptability. Preliminary review revealed several events that impacted portions of the data, resulting in the adjustment or exclusion of these data prior to initiation of the compliance analysis.

First, preliminary review determined that data recorded during the first three transects of the shallow tow survey were collected at a depth that was offset 2 m shallower from the remainder of the shallow tow transects, which averaged 4.07 m in depth. Because the water column was moderately stratified at the time of the April 2010 survey, however, this seemingly slight depth difference resulted in substantial differences in the measured water properties of the respective transects. Additionally, since the significance of potential discharge-related anomalies is evaluated by comparing the amplitudes of measurements acquired at the same depth level, the ability to resolve anomalies within the three very shallow transects with any statistical certainty was compromised. Therefore, data from the first three tow transects (shown by the purple lines in Figure 5) were excluded from the subsequent compliance analysis.

Similarly, because the overall length of the CTD is close to the 0.5-m standard depth bins used to report the vertical profile data, the ability to compute average values for seawater properties at locations very near the sea surface and seafloor varies, depending on how the CTD's depth is influenced by wave and tidal-induced oscillations during its deployment at each station. For example, during the April 2010 survey, data on average seawater properties were not recorded within the shallowest depth bin (0.5 m) at Stations RW1 and RW3 (see Table 5 on Page 14) or within the deepest depth bins (below 13.5 m) at Stations RW1, RW2, and RW3. Because, similar to the above tow survey data, the spatial coverage of the observations at the remaining stations was not sufficient to adequately quantify horizontal trends at these depth levels, these measurements were excluded from the subsequent compliance evaluation.

In addition to the spatial offsets described above, DO measurements collected throughout the April 2010 survey were found to be artificially depressed by approximately 4 mg/L due to a film of bacterial growth that had developed on a membrane within the DO sensor, following its pre-cruise calibration. However, post-processing of the DO data allowed for the successful correction of this offset, and compliance analysis was subsequently performed on the adjusted data. The fouled membrane was replaced in advance of the pre-cruise calibration effort for the 3rd quarter receiving-water survey.

Finally, DO data collected during portions of the tow survey were compromised by the entrapment of air bubbles within the ducting leading from the pump on the CTD to the DO plenum. This caused random, erroneous spiking within the dataset. As a result, 686 DO measurements collected within four of the eleven shallow tow transects, and one of the nine mid-depth tow transects were excluded from the subsequent compliance analysis. Additionally, the orientation of the ducting on the CTD will be reconfigured in future surveys to minimize the entrainment of air bubbles within the tubing during the tow survey.

¹¹ Figures 8 and 9 present the horizontal maps of seawater properties measured during the April 2010 survey.

Exclusion of the above data did not adversely affect the compliance analysis because the remaining transects adequately covered the survey regions (orange and blue dotted lines in Figure 5), as well as met the monitoring requirements in the permit, which require at least five passes near the diffuser structure at each tow depth.

RESULTS

The second-quarter receiving-water survey began approximately three hours after sunrise at 09:13 PDT on the morning of Monday, 19 April 2010, with the deployment of the drogued drifter. Over the following two hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended at 11:21 PDT with the recovery of the CTD from its mid-depth-tow configuration. Observations of beneficial use and the collection of required visual observations of the sea surface were unencumbered throughout the survey.

Auxiliary Observations

The day of the April 2010 survey represented the first substantial break between a succession of cold fronts that had brought high winds and heavy seas to the region since before the beginning of the month. The window for this 2nd quarter sampling was therefore limited, as yet another cold front was forecast to pass through the central coast the following day, followed by gale force (32-46 mph) northwesterly winds and another high northwesterly swell that would persist through the week's end.

Skies were overcast at the beginning of the survey, but cleared entirely by 10:30 PDT to end in sunny skies. Winds were mild throughout the survey, with average wind speeds, calculated over one-minute intervals, ranging from 1.8 to 3.6 kt, and peak wind speeds ranging from 2.7 to 4.3 kt (Table 4). The swell was out of the northwest with a significant wave height of 2 to 3 feet. Air temperatures were slightly warmer than average surface-water temperatures, varying from 13.4°C to 13.5°C.

Table 4. Standard Meteorological and Oceanographic Observations

| Station | Location ¹² | | Diffuser Distance (m) | Time (PDT) | Air (°C) | Cloud Cover (%) | Wind Avg (kt) | Wind Max (kt) | Wind Dir (from) (°T) | Swell Ht/Dir (ft/°T) | Secchi Depth (m) |
|---------|------------------------|----------------|-----------------------------|---------------|-------------|-----------------------|---------------------|---------------------|----------------------------|----------------------------|------------------------|
| | Latitude | Longitude | | | | | | | | | |
| RW1 | 35° 23.257' N | 120° 52.493' W | 99.0 | 9:22:27 | 13.4 | 100 | 3.6 | 4.3 | NW | 2-3/NW | 8.0 |
| RW2 | 35° 23.235' N | 120° 52.498' W | 58.7 | 9:26:38 | 13.6 | 100 | 2.7 | 3.7 | NW | 2-3/NW | 7.5 |
| RW3 | 35° 23.215' N | 120° 52.500' W | 26.3 | 9:30:33 | 13.5 | 100 | 2.3 | 3.1 | NW | 2-3/NW | 8.0 |
| RW4 | 35° 23.191' N | 120° 52.492' W | 3.7 | 9:34:39 | 13.4 | 100 | 2.2 | 2.7 | NW | 2-3/NW | 8.0 |
| RW5 | 35° 23.168' N | 120° 52.500' W | 44.7 | 9:38:18 | 13.5 | 100 | 1.8 | 2.7 | NW | 2-3/NW | 8.0 |
| RW6 | 35° 23.148' N | 120° 52.499' W | 81.3 | 9:41:40 | 13.4 | 90 | 2.3 | 3.3 | NW | 2-3/NW | 8.0 |

The 8-m Secchi depths recorded at most stations during the April 2010 survey indicated a high level of ambient water clarity (Table 4). The Secchi depths reflected the presence of a 16-m euphotic zone that extended all the way to the sea floor. Additionally, there was no evidence of wastewater-related floating particulates, oil sheens, or discoloration of the sea surface observed at any of the stations during vertical profiling, or at any other time during the survey. Communication with plant personnel during the survey and subsequent review of effluent discharge properties on 19 April, indicate that the treatment process was performing nominally at the time of the survey.

¹² Locations are the vessel positions recorded at the time the Secchi depth was measured.

During the April 2010 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. Wildlife sightings during the survey were dominated by Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), western grebes (*Aechmophorus occidentalis*), and western gulls (*Larus occidentalis*). In addition, California brown pelicans (*Pelecanus occidentalis californicus*), a pigeon guillemot (*Cepphus columba*), and two pairs of elegant terns (*Sterna elegans*) were documented. Within the confines of the harbor mouth near Morro Rock, and en route to the survey site, a total of eight southern sea otters (*Enhydra lutris nereis*) were observed. Two otters were also sighted inshore of the survey site during the first half of the survey. Additional marine mammal observations included a harbor porpoise (*Phocoena phocoena*) that was observed transiting well offshore of the survey site near the beginning of the survey, and a California sea lion (*Zalophus californianus*) that was encountered while completing the mid-depth tow survey.

Beach usage by pedestrians, and nearshore water usage by surfers were evident during the April 2010 survey. In addition, a total of 12 fishing vessels and one kelp cutter were noted utilizing the waters offshore from the survey area. Although the recreational salmon fishing season had opened on 3 April 2010, rough sea conditions had prevented most boaters from venturing out earlier in the month. On the day of the survey, however, many recreational fishermen were seen taking advantage of the substantially calmer conditions afforded by the break in passing storm fronts. Another byproduct of the spring storms that bracketed the survey was an abundance of giant kelp (*Macrocystis pyrifera*) 'rafts' that were observed throughout the region during the course of the survey.

Instrumental Observations

Data collected during vertical profiling were processed in accordance with standard procedures (SCCWRP 2002), and are collated within 0.5-m depth intervals in Table 5. Data collected during the April 2010 survey reflect moderately stratified conditions indicative of upwelling conditions. Upwelling conditions prevail most of the year along the central California coast, generally beginning in March or April, and extending through the fall months. Upwelling results in an influx of dense, cold, saline water at depth and often leads to a sharp thermocline, halocline, and pycnocline where temperature, salinity, and density change rapidly over short vertical distances. Under highly stratified conditions, isotherms crowd together to form a density interface that restricts the vertical transport of the effluent plume, inhibiting the vertical exchange of nutrients and other water properties, and reducing dispersion.

Upwelling-induced gradients are evident as decreases in temperature (red lines), DO (dark blue lines), and pH (gold lines) with increasing depth in the vertical profiles of seawater properties shown in Figure 6. These decreases are mirrored by a pycnocline where density (black lines) steadily increases with depth. The profiles reflect the vertical juxtaposition of a near-surface mixed layer and a cold, nutrient-rich water mass at depth. Normally, upwelling induces a sharp interface between the two water masses, but high winds and heavy seas during the succession of cold fronts preceding the April 2010 survey eroded the interface and the vertical gradients extended throughout most of the water column.

Nevertheless, at the time of the April 2010 survey, the overall difference in seawater characteristics near the seafloor and sea surface was comparable to other upwelling periods. Near the seafloor, upwelling had transported cold, dense seawater (red and black lines in Figure 6) onshore to replace nearshore surface waters that were driven offshore by prevailing winds. These deep offshore waters had not been in recent direct contact with the atmosphere, and biotic respiration and decomposition had slowly depleted their DO levels (dark blue lines). Similarly, the slightly elevated salinity (green lines in Figure 6) within 5 m of the seafloor was indicative of waters that originated in the Southern California Bight and had been carried

Table 5. Vertical Profile Data Collected on 19 April 2010

| Depth (m) | Temperature (°C) | | | | | | Salinity (‰) | | | | | |
|-----------|------------------|--------|--------|--------|--------|--------|--------------|--------|--------|--------|--------|--------|
| | RW-1 | RW-2 | RW-3 | RW-4 | RW-5 | RW-6 | RW-1 | RW-2 | RW-3 | RW-4 | RW-5 | RW-6 |
| 0.5 | | 12.820 | | 12.667 | 12.679 | 12.852 | | 33.319 | | 33.156 | 33.322 | 33.297 |
| 1.0 | 12.656 | 12.830 | 12.772 | 12.444 | 12.708 | 12.873 | 33.327 | 33.323 | 33.314 | 33.329 | 33.322 | 33.323 |
| 1.5 | 12.580 | 12.852 | 12.763 | 12.362 | 12.659 | 12.830 | 33.332 | 33.332 | 33.312 | 33.250 | 33.315 | 33.303 |
| 2.0 | 12.538 | 12.795 | 12.728 | 12.256 | 12.632 | 12.701 | 33.334 | 33.317 | 33.314 | 33.274 | 33.319 | 33.295 |
| 2.5 | 12.506 | 12.711 | 12.690 | 12.156 | 12.588 | 12.603 | 33.329 | 33.312 | 33.314 | 33.226 | 33.318 | 33.303 |
| 3.0 | 12.481 | 12.645 | 12.637 | 12.100 | 12.563 | 12.541 | 33.332 | 33.309 | 33.316 | 33.241 | 33.315 | 33.309 |
| 3.5 | 12.465 | 12.595 | 12.625 | 12.068 | 12.546 | 12.497 | 33.330 | 33.315 | 33.318 | 33.253 | 33.309 | 33.318 |
| 4.0 | 12.444 | 12.543 | 12.603 | 12.028 | 12.510 | 12.486 | 33.337 | 33.326 | 33.320 | 33.259 | 33.311 | 33.319 |
| 4.5 | 12.439 | 12.490 | 12.537 | 12.014 | 12.474 | 12.473 | 33.337 | 33.326 | 33.323 | 33.260 | 33.318 | 33.321 |
| 5.0 | 12.403 | 12.454 | 12.503 | 12.108 | 12.447 | 12.459 | 33.328 | 33.331 | 33.323 | 33.284 | 33.320 | 33.321 |
| 5.5 | 12.272 | 12.428 | 12.479 | 12.125 | 12.400 | 12.447 | 33.330 | 33.331 | 33.321 | 33.282 | 33.315 | 33.315 |
| 6.0 | 12.211 | 12.317 | 12.450 | 12.062 | 12.343 | 12.411 | 33.361 | 33.329 | 33.320 | 33.280 | 33.313 | 33.318 |
| 6.5 | 12.213 | 12.252 | 12.427 | 12.035 | 12.301 | 12.394 | 33.358 | 33.333 | 33.326 | 33.288 | 33.311 | 33.323 |
| 7.0 | 12.161 | 12.235 | 12.398 | 12.042 | 12.256 | 12.378 | 33.361 | 33.329 | 33.327 | 33.297 | 33.307 | 33.324 |
| 7.5 | 12.210 | 12.236 | 12.305 | 12.041 | 12.151 | 12.324 | 33.342 | 33.330 | 33.338 | 33.298 | 33.293 | 33.320 |
| 8.0 | 12.257 | 12.179 | 12.208 | 12.043 | 12.126 | 12.251 | 33.348 | 33.334 | 33.334 | 33.296 | 33.294 | 33.283 |
| 8.5 | 12.274 | 12.131 | 12.128 | 12.060 | 12.103 | 12.181 | 33.350 | 33.337 | 33.334 | 33.284 | 33.285 | 33.297 |
| 9.0 | 12.233 | 11.999 | 12.065 | 12.074 | 12.005 | 12.145 | 33.349 | 33.362 | 33.341 | 33.280 | 33.293 | 33.301 |
| 9.5 | 12.154 | 11.880 | 12.002 | 12.043 | 11.942 | 12.041 | 33.341 | 33.385 | 33.358 | 33.272 | 33.300 | 33.299 |
| 10.0 | 11.988 | 11.765 | 11.867 | 12.030 | 11.935 | 11.981 | 33.377 | 33.390 | 33.372 | 33.289 | 33.321 | 33.304 |
| 10.5 | 11.887 | 11.711 | 11.759 | 11.925 | 11.939 | 11.897 | 33.388 | 33.403 | 33.388 | 33.328 | 33.344 | 33.342 |
| 11.0 | 11.756 | 11.645 | 11.711 | 11.871 | 11.869 | 11.819 | 33.400 | 33.406 | 33.395 | 33.361 | 33.350 | 33.357 |
| 11.5 | 11.675 | 11.542 | 11.607 | 11.847 | 11.697 | 11.726 | 33.408 | 33.416 | 33.407 | 33.368 | 33.377 | 33.385 |
| 12.0 | 11.642 | 11.512 | 11.533 | 11.650 | 11.615 | 11.669 | 33.410 | 33.422 | 33.421 | 33.379 | 33.380 | 33.373 |
| 12.5 | 11.560 | 11.504 | 11.523 | 11.555 | 11.548 | 11.588 | 33.418 | 33.421 | 33.418 | 33.399 | 33.404 | 33.391 |
| 13.0 | 11.516 | 11.503 | 11.527 | 11.522 | 11.522 | 11.517 | 33.424 | 33.419 | 33.414 | 33.412 | 33.417 | 33.405 |
| 13.5 | 11.514 | 11.494 | 11.507 | 11.517 | 11.512 | 11.502 | 33.421 | 33.420 | 33.417 | 33.410 | 33.412 | 33.412 |
| 14.0 | | | | 11.511 | 11.504 | 11.499 | | | | 33.413 | 33.414 | 33.410 |
| 14.5 | | | | | | 11.483 | | | | | | 33.412 |
| 15.0 | | | | | | | | | | | | |

Table 5. Vertical Profile Data Collected on 19 April 2010 (continued)

| Depth (m) | Density (σ_t) | | | | | | pH | | | | | |
|--------------|------------------------|--------|--------|--------|--------|--------|-------|-------|-------|-------|-------|-------|
| | RW-1 | RW-2 | RW-3 | RW-4 | RW-5 | RW-6 | RW-1 | RW-2 | RW-3 | RW-4 | RW-5 | RW-6 |
| 0.5 | | 25.127 | | 25.030 | 25.156 | 25.103 | | 8.740 | | 8.701 | 8.723 | 8.720 |
| 1.0 | 25.164 | 25.128 | 25.132 | 25.207 | 25.150 | 25.119 | 8.731 | 8.740 | 8.731 | 8.712 | 8.720 | 8.720 |
| 1.5 | 25.183 | 25.130 | 25.132 | 25.162 | 25.155 | 25.112 | 8.732 | 8.739 | 8.731 | 8.711 | 8.720 | 8.719 |
| 2.0 | 25.193 | 25.130 | 25.140 | 25.201 | 25.163 | 25.131 | 8.732 | 8.740 | 8.731 | 8.715 | 8.722 | 8.721 |
| 2.5 | 25.195 | 25.142 | 25.148 | 25.182 | 25.171 | 25.156 | 8.731 | 8.740 | 8.731 | 8.711 | 8.720 | 8.722 |
| 3.0 | 25.202 | 25.152 | 25.160 | 25.204 | 25.173 | 25.173 | 8.731 | 8.741 | 8.731 | 8.702 | 8.721 | 8.718 |
| 3.5 | 25.204 | 25.167 | 25.164 | 25.219 | 25.172 | 25.189 | 8.728 | 8.739 | 8.730 | 8.697 | 8.718 | 8.719 |
| 4.0 | 25.213 | 25.186 | 25.169 | 25.232 | 25.181 | 25.191 | 8.728 | 8.737 | 8.728 | 8.693 | 8.718 | 8.718 |
| 4.5 | 25.214 | 25.196 | 25.184 | 25.236 | 25.192 | 25.195 | 8.728 | 8.737 | 8.727 | 8.693 | 8.718 | 8.718 |
| 5.0 | 25.214 | 25.207 | 25.191 | 25.236 | 25.200 | 25.198 | 8.728 | 8.736 | 8.727 | 8.691 | 8.718 | 8.718 |
| 5.5 | 25.241 | 25.211 | 25.194 | 25.232 | 25.205 | 25.196 | 8.728 | 8.733 | 8.727 | 8.694 | 8.715 | 8.717 |
| 6.0 | 25.276 | 25.231 | 25.199 | 25.242 | 25.214 | 25.205 | 8.725 | 8.733 | 8.726 | 8.697 | 8.712 | 8.715 |
| 6.5 | 25.274 | 25.247 | 25.208 | 25.253 | 25.221 | 25.212 | 8.720 | 8.734 | 8.723 | 8.694 | 8.706 | 8.714 |
| 7.0 | 25.286 | 25.247 | 25.214 | 25.259 | 25.226 | 25.216 | 8.719 | 8.731 | 8.723 | 8.692 | 8.705 | 8.714 |
| 7.5 | 25.261 | 25.248 | 25.240 | 25.260 | 25.235 | 25.223 | 8.717 | 8.729 | 8.724 | 8.692 | 8.700 | 8.713 |
| 8.0 | 25.257 | 25.262 | 25.256 | 25.258 | 25.241 | 25.208 | 8.715 | 8.729 | 8.721 | 8.695 | 8.697 | 8.708 |
| 8.5 | 25.255 | 25.273 | 25.271 | 25.245 | 25.238 | 25.232 | 8.715 | 8.726 | 8.719 | 8.694 | 8.692 | 8.703 |
| 9.0 | 25.263 | 25.317 | 25.288 | 25.240 | 25.263 | 25.243 | 8.719 | 8.723 | 8.715 | 8.692 | 8.691 | 8.699 |
| 9.5 | 25.271 | 25.357 | 25.314 | 25.239 | 25.280 | 25.261 | 8.720 | 8.720 | 8.712 | 8.692 | 8.684 | 8.695 |
| 10.0 | 25.331 | 25.383 | 25.350 | 25.255 | 25.297 | 25.276 | 8.717 | 8.714 | 8.710 | 8.690 | 8.679 | 8.690 |
| 10.5 | 25.359 | 25.403 | 25.382 | 25.305 | 25.314 | 25.321 | 8.711 | 8.705 | 8.703 | 8.693 | 8.679 | 8.684 |
| 11.0 | 25.392 | 25.418 | 25.397 | 25.340 | 25.332 | 25.347 | 8.706 | 8.702 | 8.697 | 8.693 | 8.679 | 8.683 |
| 11.5 | 25.414 | 25.444 | 25.425 | 25.350 | 25.385 | 25.386 | 8.702 | 8.697 | 8.694 | 8.693 | 8.680 | 8.680 |
| 12.0 | 25.421 | 25.454 | 25.450 | 25.395 | 25.403 | 25.388 | 8.697 | 8.689 | 8.688 | 8.691 | 8.674 | 8.677 |
| 12.5 | 25.442 | 25.455 | 25.449 | 25.428 | 25.434 | 25.416 | 8.693 | 8.682 | 8.685 | 8.681 | 8.665 | 8.670 |
| 13.0 | 25.455 | 25.454 | 25.446 | 25.444 | 25.448 | 25.440 | 8.684 | 8.676 | 8.678 | 8.675 | 8.661 | 8.664 |
| 13.5 | 25.453 | 25.456 | 25.451 | 25.444 | 25.446 | 25.448 | 8.668 | 8.677 | 8.672 | 8.670 | 8.657 | 8.661 |
| 14.0 | | | | 25.447 | 25.449 | 25.448 | | | | 8.664 | 8.657 | 8.658 |
| 14.5 | | | | | | 25.452 | | | | | | 8.658 |
| 15.0 | | | | | | | | | | | | |

Table 5. Vertical Profile Data Collected on 19 April 2010 (continued)

| Depth (m) | Dissolved Oxygen (mg/L) | | | | | | Transmissivity (%) | | | | | |
|-----------|-------------------------|-------|-------|-------|-------|-------|--------------------|--------|--------|--------|--------|--------|
| | RW-1 | RW-2 | RW-3 | RW-4 | RW-5 | RW-6 | RW-1 | RW-2 | RW-3 | RW-4 | RW-5 | RW-6 |
| 0.5 | | 8.184 | | 7.688 | 8.031 | 8.102 | | 75.711 | | 77.603 | 77.376 | 75.488 |
| 1.0 | 8.187 | 8.221 | 8.161 | 7.787 | 8.031 | 8.100 | 77.846 | 75.930 | 77.297 | 78.915 | 77.547 | 75.288 |
| 1.5 | 8.177 | 8.219 | 8.162 | 7.737 | 8.033 | 8.080 | 79.142 | 75.724 | 77.458 | 79.036 | 78.092 | 76.020 |
| 2.0 | 8.169 | 8.200 | 8.155 | 7.704 | 8.027 | 8.070 | 79.600 | 76.421 | 77.615 | 79.091 | 78.721 | 78.655 |
| 2.5 | 8.165 | 8.188 | 8.139 | 7.679 | 8.024 | 8.060 | 79.812 | 77.796 | 77.836 | 79.391 | 79.140 | 80.417 |
| 3.0 | 8.157 | 8.187 | 8.141 | 7.674 | 8.023 | 8.055 | 80.075 | 78.625 | 78.429 | 79.433 | 79.584 | 80.590 |
| 3.5 | 8.157 | 8.177 | 8.141 | 7.670 | 8.026 | 8.057 | 80.229 | 79.083 | 78.955 | 79.548 | 80.153 | 80.910 |
| 4.0 | 8.150 | 8.171 | 8.132 | 7.666 | 8.019 | 8.061 | 80.386 | 79.542 | 78.994 | 79.382 | 80.528 | 80.962 |
| 4.5 | 8.150 | 8.160 | 8.125 | 7.679 | 8.015 | 8.058 | 80.471 | 79.755 | 79.913 | 79.427 | 80.788 | 80.998 |
| 5.0 | 8.120 | 8.156 | 8.122 | 7.700 | 8.012 | 8.057 | 80.442 | 80.136 | 80.306 | 79.479 | 81.012 | 81.166 |
| 5.5 | 8.081 | 8.143 | 8.115 | 7.696 | 7.991 | 8.048 | 80.969 | 80.247 | 80.375 | 79.679 | 80.908 | 81.265 |
| 6.0 | 8.068 | 8.110 | 8.105 | 7.681 | 7.972 | 8.038 | 81.160 | 81.050 | 80.398 | 80.051 | 80.657 | 81.271 |
| 6.5 | 8.054 | 8.090 | 8.096 | 7.677 | 7.958 | 8.035 | 81.194 | 81.746 | 80.358 | 80.015 | 80.567 | 81.280 |
| 7.0 | 8.028 | 8.083 | 8.087 | 7.681 | 7.927 | 8.029 | 81.110 | 81.906 | 80.523 | 80.335 | 80.493 | 81.242 |
| 7.5 | 8.041 | 8.071 | 8.050 | 7.688 | 7.899 | 7.989 | 80.988 | 81.937 | 80.791 | 80.508 | 80.149 | 81.149 |
| 8.0 | 8.052 | 8.048 | 8.025 | 7.692 | 7.878 | 7.962 | 80.664 | 82.161 | 81.448 | 80.345 | 80.157 | 80.606 |
| 8.5 | 8.041 | 8.015 | 7.991 | 7.689 | 7.869 | 7.947 | 80.853 | 81.866 | 81.778 | 79.575 | 80.098 | 80.398 |
| 9.0 | 8.021 | 7.967 | 7.961 | 7.681 | 7.823 | 7.913 | 80.768 | 81.128 | 81.691 | 79.494 | 80.219 | 80.495 |
| 9.5 | 7.977 | 7.901 | 7.924 | 7.680 | 7.804 | 7.878 | 80.734 | 81.554 | 81.104 | 79.565 | 80.455 | 80.427 |
| 10.0 | 7.929 | 7.859 | 7.873 | 7.655 | 7.805 | 7.856 | 80.522 | 82.992 | 81.692 | 79.995 | 80.688 | 80.947 |
| 10.5 | 7.878 | 7.820 | 7.842 | 7.645 | 7.796 | 7.814 | 81.438 | 82.636 | 82.830 | 81.424 | 81.262 | 81.433 |
| 11.0 | 7.822 | 7.761 | 7.792 | 7.642 | 7.739 | 7.778 | 82.989 | 82.595 | 82.670 | 81.859 | 81.345 | 82.109 |
| 11.5 | 7.772 | 7.700 | 7.739 | 7.602 | 7.678 | 7.737 | 82.666 | 81.760 | 82.283 | 81.907 | 81.968 | 81.496 |
| 12.0 | 7.734 | 7.659 | 7.696 | 7.541 | 7.644 | 7.702 | 82.759 | 81.191 | 81.702 | 81.824 | 81.654 | 81.737 |
| 12.5 | 7.674 | 7.632 | 7.668 | 7.508 | 7.610 | 7.649 | 82.196 | 80.916 | 81.611 | 81.394 | 81.649 | 81.922 |
| 13.0 | 7.624 | 7.606 | 7.638 | 7.491 | 7.585 | 7.619 | 81.379 | 80.803 | 81.371 | 81.136 | 81.623 | 81.850 |
| 13.5 | 7.621 | 7.577 | 7.600 | 7.468 | 7.564 | 7.598 | 80.589 | 80.590 | 80.999 | 80.773 | 81.522 | 81.715 |
| 14.0 | | | | 7.486 | 7.538 | 7.565 | | | | 80.340 | 80.483 | 81.750 |
| 14.5 | | | | | | 7.545 | | | | | | 81.512 |
| 15.0 | | | | | | | | | | | | |

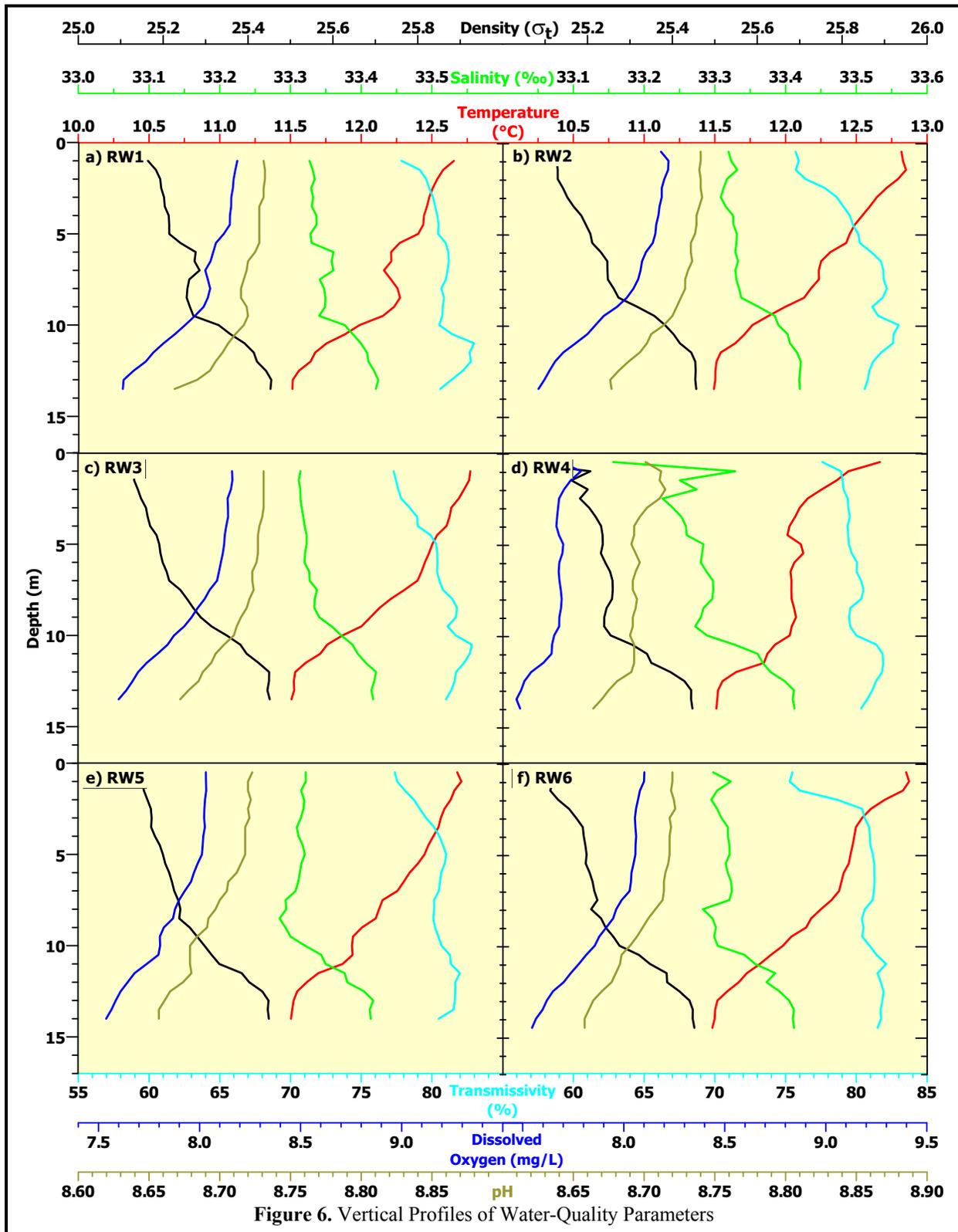


Figure 6. Vertical Profiles of Water-Quality Parameters

northward by the Davidson undercurrent. These waters differ from the relatively fresh surface waters associated with the southward-flowing California Current.

Nevertheless, at the time of the April 2010 survey, the overall difference in seawater characteristics near the seafloor and sea surface was comparable to other upwelling periods. Near the seafloor, upwelling had transported cold, dense seawater (red and black lines in Figure 6) onshore to replace nearshore surface waters that were driven offshore by prevailing winds. These deep offshore waters had not been in recent direct contact with the atmosphere, and biotic respiration and decomposition had slowly depleted their DO levels (dark blue lines). Similarly, the slightly elevated salinity (green lines in Figure 6) within 5 m of the seafloor was indicative of waters that originated in the Southern California Bight and had been carried northward by the Davidson undercurrent. These waters differ from the relatively fresh surface waters associated with the southward-flowing California Current.

Nutrient-rich seawater brought to the sea surface by upwelling facilitated phytoplankton blooms that produced oxygen and consumed carbon dioxide (CO₂). Direct, gaseous exchange with the overlying atmosphere, combined with this increased primary productivity, resulted in supersaturated DO concentrations near the sea surface. With depth, however, the rate of respiration to photosynthesis increased, resulting in a corresponding increase in dissolved CO₂ (carbonic acid) and a concomitant decline in pH. These processes account for the steady decline in pH (olive-colored lines) with increasing depth that is apparent in each of the vertical profiles.

As expected, the associated increases in primary productivity generated by upwelling also resulted in the slightly reduced water clarity (light-blue lines) near the sea surface compared to waters at depth. For example, although transmissivities exceeding 80% were observed at mid-depth at most stations, slight decreases in transmissivity are evident in the upper water column, particularly at Stations RW5 and RW6 (Figure 6ef), which were unaffected by the discharge.

The influence of the discharge plume can be seen in the vertical profiles at Station RW4 (Figure 6d), where entrainment of bottom waters by the rising effluent plume compressed the thermocline (red line) near the sea surface, resulting in artificial spikes in salinity (green lines) caused by the offset of the sampling probe locations on the CTD. Compared to other stations, DO, pH, and temperature at RW4 were slightly, but uniformly depressed throughout the upper half of the water column, reflecting entrainment of these cooler, saltier, more acidic waters in the rising effluent plume. Elevated salinities below 10 m at Stations RW1, RW2, and RW3 (Figure 6abc) also reflected the entrainment of ambient seawater at depth within the rising effluent plume as it moved northward with the prevailing current.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the April 2010 survey, and dilutions anticipated from modeling studies that were codified in the discharge permit through limits imposed on effluent constituents. Specifically, the critical initial dilution applicable to the MBCSD outfall was conservatively estimated to be 133:1 (Tetra Tech 1992). That is, dispersion modeling estimated that, at the conclusion of the minimum expected initial mixing, 133 parts of ambient seawater would have mixed with each part of wastewater.

The 133:1 dilution estimate was based on worst-case modeling under highly stratified conditions, where trapping of the plume below a strong thermocline would curtail the buoyant mixing normally associated with turbulence generated by the plume's rise through the water column. Additionally, the modeling

assumed quiescent oceanic flow conditions, thereby restricting initial mixing processes to the ZID. Under those conditions, the modeling predicted that a 133:1 dilution would be achieved after the plume rose only 9 m from the seafloor, whereupon it would become trapped. A 9-m rise at the MBCSD outfall translates into a trapping depth that is 6.4 m below the sea surface, just slightly above the depth of the mid-depth (7.3 m) tow survey and below the shallow (4.1 m) tow survey conducted on 19 April 2010.

The conservative nature of the critical initial dilution determined from the 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 in the COP (SWRCB 2005) using the projected 133-fold dilution determined from the modeling. Use of a higher critical dilution would relax the stringent end-of-pipe effluent limitations thought necessary to meet COP objectives after initial dilution is complete.

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 chemical constituent within effluent before discharge (C_e) can be determined from Equation 1.

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

where: C_e = the concentration of a constituent in the effluent,
 C_o = the concentration of the constituent in the ocean after dilution by D (*i.e.*, the COP receiving-water objective),
 D = the dilution expressed as the volumetric ratio 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 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. Wastewater-induced patches of low salinity are apparent near the ZID in the tow-survey maps (Figures 7b and 8b). These localized salinity anomalies reflect the presence of dilute wastewater within the effluent plume as it rose and spread within the water column.

Because the salinity concentration in effluent is negligible, C_e is eliminated in Equation 1 and the dilution ratio (D) can be computed from the salinity anomaly ($A = C_o - C_s$) as:

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

where: D = the dilution ratio of the volume of seawater mixed with effluent,
 C_o = the salinity of the effluent-seawater mixture after dilution by D ,
 C_s = the background seawater salinity (approximately 33.8‰), and
 $A = C_o - C_s$ = the salinity anomaly.

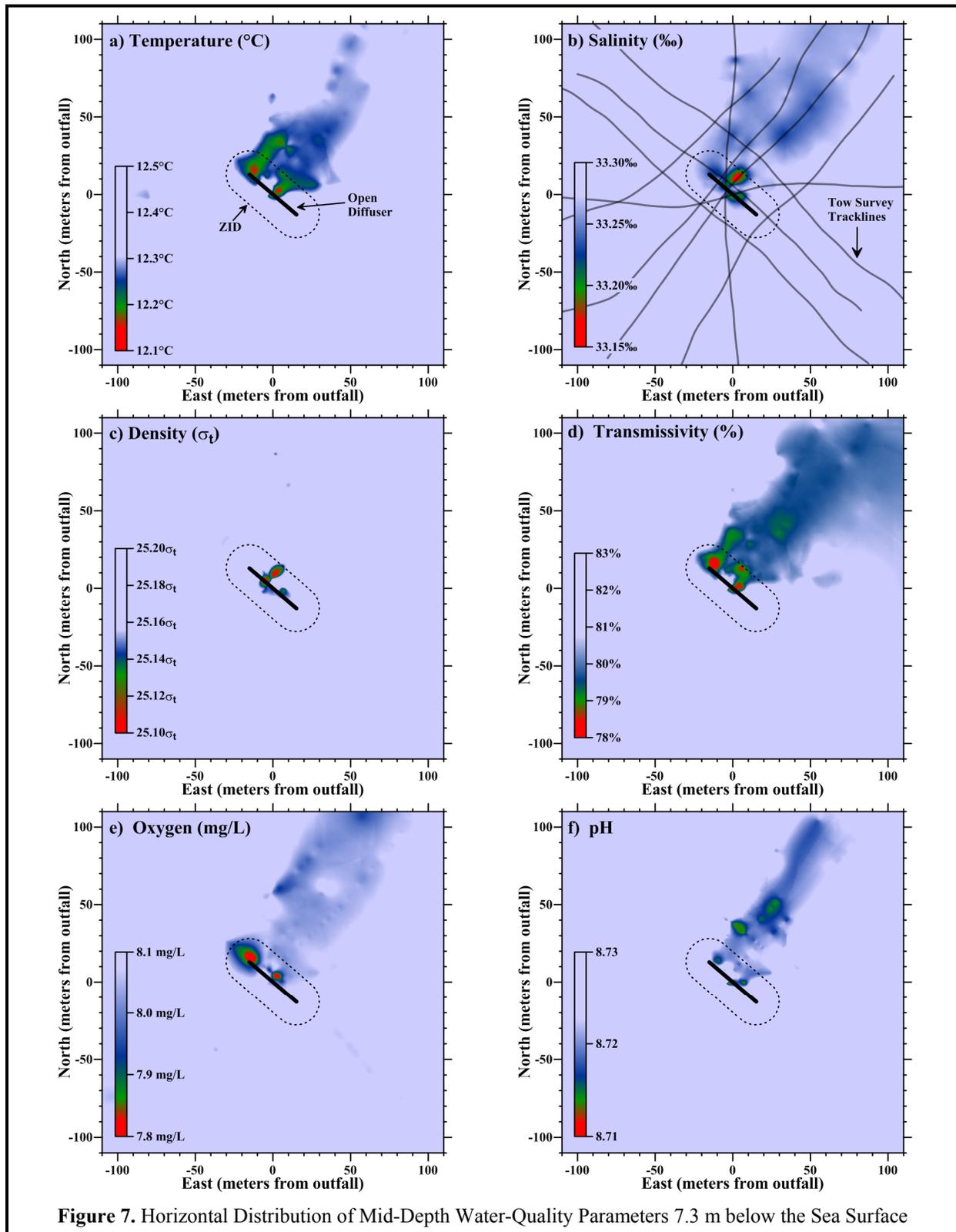


Figure 7. Horizontal Distribution of Mid-Depth Water-Quality Parameters 7.3 m below the Sea Surface

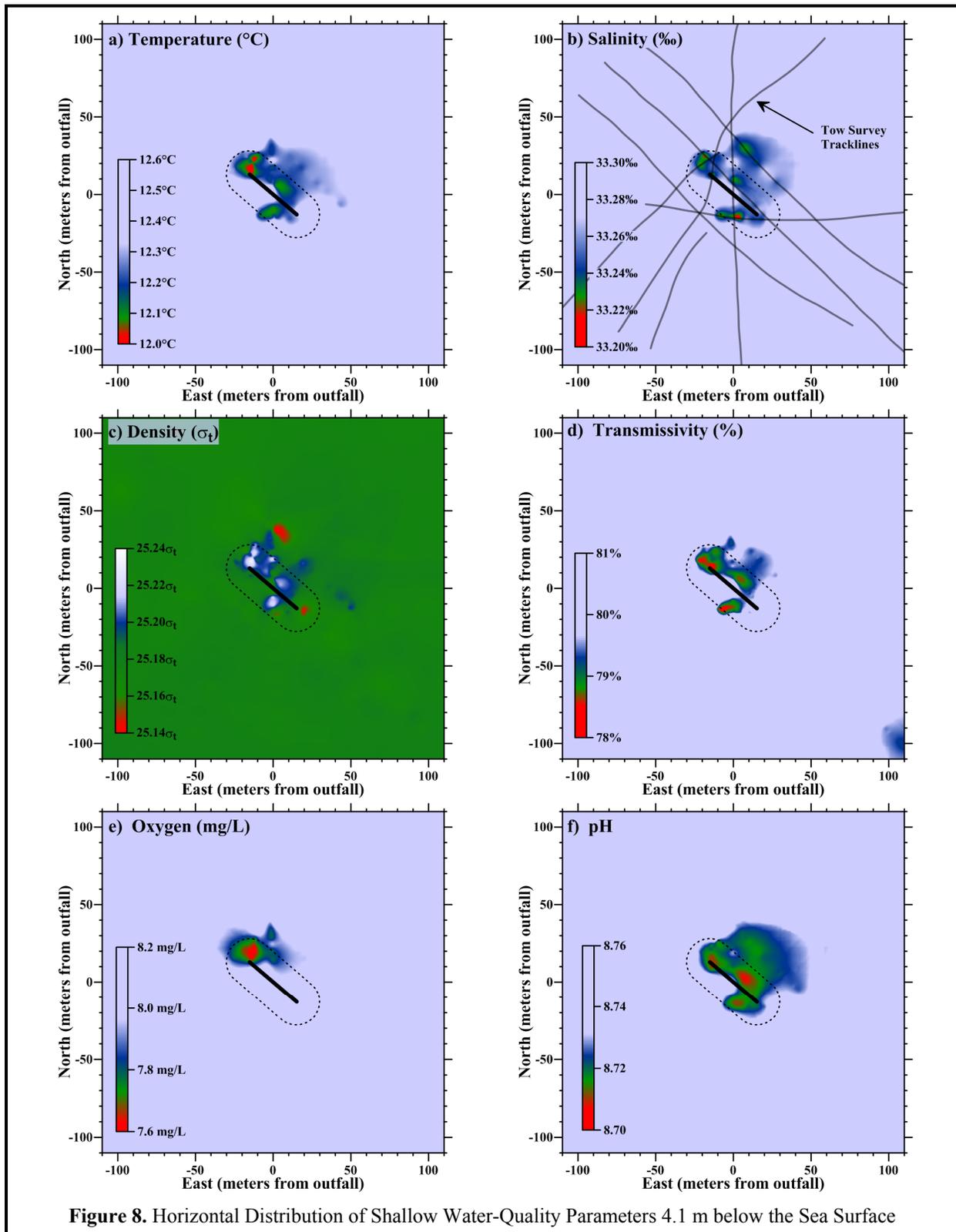


Figure 8. Horizontal Distribution of Shallow Water-Quality Parameters 4.1 m below the Sea Surface

The mid-depth tow shown in Figure 7 captured the plume signature while it was undergoing intense initial mixing during its rise through the water column. Using Equation 2 to recast the salinity distribution shown in Figure 7b, resulted in the delineation of a highly localized plume signature that was largely restricted to the ZID and covered a 131-m² area (Figure 9). During the mid-depth tow, the lowest salinity (33.141‰) was measured within the ZID, 8.8 m northeast of the nearest diffuser port. This salinity reduction corresponds to a wastewater-induced salinity anomaly of -0.149‰ below the mean ambient salinity of 33.290‰ that was measured at the same depth level well beyond the influence of the discharge, and corresponds to wastewater that has been diluted by more than 220-fold.

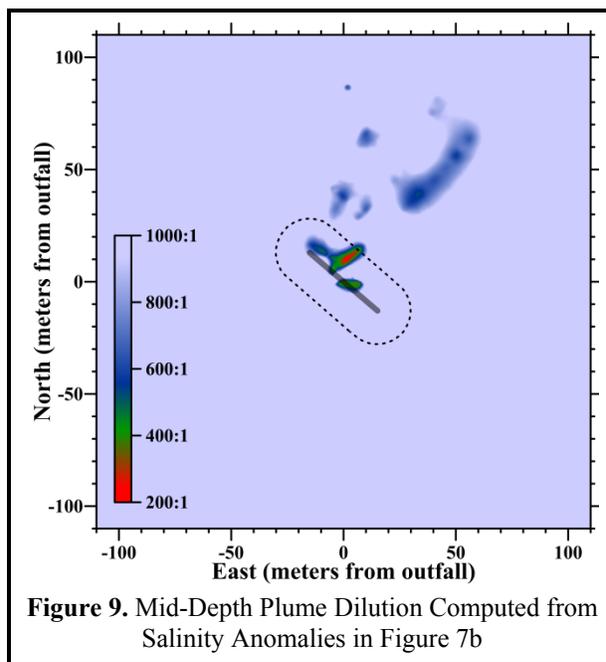


Figure 9. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 7b

A large negative density anomaly coincided with the plume's salinity signature (Figure 7c). Its presence demonstrates that the highly buoyant plume was continuing to undergo intense mixing at that location. Both of these mid-depth plume signatures were observed northeast of the diffuser structure, at locations consistent with the northeastward transport documented by the drogued drifter trajectory (Figure 2).

The high-resolution salinity measurements collected during the April 2010 mid-depth-tow demonstrate that the modeled dilution factor (133:1) was significantly more conservative than that actually achieved by the discharge (>220:1). Moreover, the plume was not trapped at the 6.4-m depth assumed in the conservative dilution model. Instead, the presence of the mid-depth negative density anomaly (Figure 7c) demonstrated that the plume was continuing to undergo intense buoyancy-induced mixing as it rose farther through the water column. This was confirmed during the shallow-tow survey, where dilutions exceeding 320-fold documented the plume's presence over a 460-m² area that extended slightly beyond the ZID toward the northeast (Figure 10).

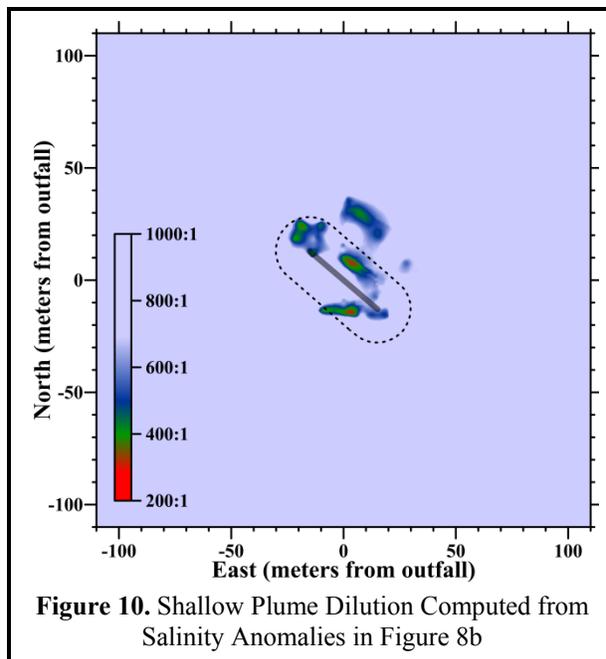


Figure 10. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 8b

In contrast to the mid-depth plume signature, the associated positive density anomaly (white areas within the ZID in Figure 8c) briefly captured the plume when it had overshoot its level of buoyant equilibrium, and was actually denser than the surrounding seawater at that depth. Shortly after, this 'heavy' plume would sink within the water column before overshooting the equilibrium level yet again, resulting in a vertical oscillatory motion that would continue to rapidly dilute the plume until frictional damping reduced its buoyancy to negligible levels. This slowly-damped vertical oscillatory motion is a

well-recognized phenomenon in atmospheric and oceanic dynamics when a parcel of water is vertically displaced within a statically stable environment, and demonstrates that the plume was still undergoing initial mixing 4.1 m below the sea surface.

These dilution computations demonstrate that, during the April 2010 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 220-fold well before completion of the initial-dilution process. This dilution level is more than one and a half times 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 April 2010 survey, the COP receiving-water objectives were being easily met by the limits on chemical concentrations within discharged wastewater that are promulgated by the NPDES discharge permit issued to the MBCSD.

COMPLIANCE

This section evaluates the compliance of the MBCSD discharge with the water-quality permit limits listed in the NPDES permit. The limitations themselves are based on criteria in the COP, the Central-Coast Basin Plan, and other state and federal policies that were designed to protect marine life and beneficial uses of ocean waters.

Because the limits only pertain to changes in water properties that are caused by the presence of wastewater constituents beyond the ZID, instrumental measurements undergo a series of screening procedures prior to numeric comparison with the permit thresholds. Specifically, the quantitative analyses described in this section focus on water-property excursions caused by the presence of wastewater constituents, their proximity to the ZID, and their amplitude compared to the natural variation in range found in ambient waters. A detailed understanding of ambient seawater properties, and their natural variability within the region surrounding the outfall, is therefore, an integral part of the compliance evaluation presented in this section.

The results of these analyses applied to the April 2010 data demonstrate that the MBCSD discharge fully complied with the NPDES discharge permit. Moreover, although observations within the ZID are not subject to compliance evaluations, they often still meet the permitted limits because dilution levels regularly exceed the conservative design specifications assumed in the discharge permit. The quantitative evaluation described in this section documents an outfall and treatment process that was exceeding design expectations during April 2010.

Permit Provisions

The offshore receiving-water surveys are designed to assess compliance with objectives dealing with undesirable alterations to six physical and chemical characteristics of seawater. Specifically, the permit states that wastewater constituents within the discharge shall not cause the limits listed in Table 6 to be exceeded.

The first two receiving-water limits, P1 and P2, rely on qualitative visual observations for compliance evaluation. As described previously, no floating wastewater materials, oil, grease, or discoloration of the sea surface were observed during the April 2010 survey.

Compliance with the remaining four receiving-water limitations is quantitatively evaluated through a comparison of instrumental measurements and the specific numerical limits listed in the NPDES permit. For example, the numeric limits P5 and P6 on absolute values of DO (>5 mg/L) and pH (7.0 to 8.3), which echo Basin Plan objectives, can be directly compared with field measurements within the dilute wastewater plume.

Table 6. Permit Provisions Addressed by the Offshore Receiving-Water Surveys

| Limit # | Limit |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| P1 | Floating particles or oil and grease to be visible on the ocean surface |
| P2 | Aesthetically undesirable discoloration of the ocean surface |
| P3 | Temperature of the receiving water to adversely affect beneficial uses |
| P4 | Significant reduction in the transmittance of natural light at any point outside the ZID |
| P5 | The DO 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 |
| P6 | 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 |

However, both P5 and P6 also contain narrative limits, which arise from the COP, and define unacceptable water-quality impacts in terms of “*significant*” excursions beyond that which occurs “*naturally*.” Quantitative evaluation of these limits requires a further comparison of field measurements with numerical thresholds that reflect the natural variation in transmissivity, DO, and pH within the receiving waters surrounding the outfall.

Natural variation in seawater properties is driven by the oceanographic processes described previously. Those processes determine the range in ambient seawater properties caused by natural spatial variation within the survey region at a given time (e.g., vertical stratification), and by temporal variations caused by seasonal and interannual influences (e.g. El Niño). Of particular interest are upwelling and downwelling processes that not only determine average properties at a given time, but also the degree of water-column stratification, or spatial variability, present during any given survey. An accurate characterization of stratification helps distinguish between discharge-related changes that arise from the presence of wastewater constituents, which are subject to a compliance evaluation, and changes that arise from the upward movement of ambient seawater, which are specifically excluded from the compliance evaluation.

Lines of Evidence

Evaluating whether any of the 4,828 CTD measurements collected during the April 2010 survey exceeded a permit limit is a complex process. For example, although apparently significant excursions in an individual seawater property may be related to the presence of wastewater constituents, they may also result from instrumental errors, natural processes, entrainment of ambient bottom waters in the rising effluent plume, statistical uncertainty, or other anthropogenic influences (e.g. dredging or oil spills).

Because of this complexity, both a tiered approach and abductive inference were applied to “*multiple-lines-of evidence*” (LOE) to evaluate compliance. Specifically, each receiving-water observation was screened for compliance by evaluating the measurement using the series of questions (lines of evidence) outlined in Table 7. Sequential (tiered) application of the initial four lines of evidence (final column in Table 7) served to both eliminate excursions unrelated to the discharge, and highlight potential non-compliance events.

The remaining measurements were then evaluated collectively (LOE#05 through LOE#07) to arrive at a “best explanation” using abductive inference (Suter 2007). This process, which has been used to implement sediment-quality guidelines for California estuaries (SWRCB 2009), emphasizes a pattern of reasoning which accounts for both the discrepancies among multiple lines of evidence as well as the concurrences. A best explanation approach serves to limit the uncertainty associated with each individual CTD measurement and provide a more robust compliance assessment. The detailed analysis described below demonstrates that all of the 4,828 CTD measurements collected during the April 2010 survey

Table 7. Receiving-Water Measurements screened for Permit Compliance based on Lines of Evidence

| LOE | Topic Addressed | Screening Questions | Answer | | Remaining Observations ¹³ |
|----------------------------------------------------|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------------------|--------------------------------------|
| | | | No ¹⁴ | Yes ¹⁵ | |
| <i>Tiered Evaluation</i> | | | | | |
| 01 | Anomaly Location | Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete? | 909 | 3,919 | 3,919 |
| 02 | Salinity Association | Did the measurement coincide with a quantifiable salinity anomaly ($\leq 550:1$ dilution level) indicating the presence of detectable wastewater constituents? | 3907 | 12 | 12 |
| 03 | Salinity Spiking | Was the salinity (dilution level) unaffected by salinity spiking? | 0 | 12 | 12 |
| 04 | Transport Direction | Was the measurement collected downstream of the prevailing flow path? ¹⁶ | 0 | 12 | 12 |
| <i>Abductive Inference Evaluation¹⁷</i> | | | | | <i>Parameter</i> |
| 05 | Outside Natural Range of Variation | Did the seawater properties associated with the measurement depart significantly from the natural range in ambient seawater variability present at the time of the survey? | 12 | 0 | all |
| 06 | Numerical Limits | Did the measurement's DO or pH exceed Basin-Plan numerical limits? | 12 | 0 | DO <5 mg/L |
| | | | 0 | 12 ¹⁸ | 7.0 > pH >8.3 |
| | | | 12 | 0 | pH |
| 07 | Directional Offset ¹⁹ | Was the observed offset in the seawater property consistent with the expected difference between wastewater and receiving-water properties? | 12 | 0 | Temperature |
| | | | 2 | 10 | Transmissivity |
| | | | 2 | 10 | DO |

¹³ Total number of CTD observations of potential compliance interest remaining after sequential application of the LOEs

¹⁴ Number of CTD observations eliminated by the specific LOE after application of the previous LOEs.

¹⁵ Number of CTD observations of potential compliance interest remaining after application of the specific LOE.

¹⁶ Semicircle ($\pm 90^\circ$ of plume-transport direction) relative to the upstream boundary of the ZID

¹⁷ Conducted on the remaining twelve observations that were of potential compliance interest

¹⁸ All of the pH observations collected during the April 2010 survey exceeded the Basin Plan numerical limit of 8.3; however, the presence of wastewater constituents could not have caused the exceedance because the pH of the wastewater (7.8) (MRS 2010) is substantially lower.

¹⁹ Salinity, pH, density, and transmissivity are generally lower in effluent than in Estero Bay receiving waters, while temperature is higher. The presence of oxygen-demanding materials within effluent depresses DO relative to receiving waters.

complied with receiving-water limitations, and that all documented excursions either occurred within the ZID where mixing was still ongoing, or were the result of natural processes unrelated to the discharge.

Anomaly Location

The COP states that compliance with its receiving-water objectives “*shall be determined from samples collected at stations representative of the area within the waste field where initial dilution is completed.*” Initial dilution includes the mixing that occurs from the turbulence associated with both the ejection jet, and the buoyant plume’s subsequent rise in the water column. The COP also states that dilution estimates shall be based on “*the assumption that no currents, of sufficient strength to influence the initial dilution process, flow across the discharge structure.*” Because of this, modeling used to establish the MBCSD critical initial dilution of 133:1 assumes completion of dilution within a standard regulatory mixing distance, which is equal to the 15.2-m water depth of the discharge. For the purposes of screening receiving-water data for compliance, this conservative 15.2-m ZID-distance threshold is used in LOE#01 to restrict attention to post-dilution observations. Application of LOE#01 to the original 4,828 receiving-water observations eliminated 909 receiving-water observations from further consideration because they were collected within the ZID (Table 7). This left 3,919 observations that were measured outside the ZID and were carried forward in the compliance analysis.

Presence of Wastewater Constituents

In recognition of the fact that anomalies can result from the upward movement of ambient seawater entrained within the buoyant effluent plume, the MBCSD discharge permit restricts application of the numerical receiving-water limits to excursions caused by the presence of wastewater constituents (LOE #02). As specified in the COP, this confines the compliance analysis to changes caused “*as the result of the discharge of waste.*”

Salinity provides a powerful tracer of dilute wastewater that is unrivaled by the other seawater properties. Wastewater’s lack of salinity allows the presence of effluent constituents to be identified within the receiving seawater even well beyond the 133-fold critical initial dilution assumed in the discharge permit. In fact, analyses conducted on quarterly receiving-water surveys over the last decade have demonstrated that negative salinity anomalies are the only consistent indicator of the presence of wastewater constituents within receiving waters; the presence of a distinct salinity minimum provides *de facto* evidence of the presence of wastewater constituents. In contrast, the direct influence of dilute wastewater is rarely observed in any other seawater property, except very close (<1 m) to a diffuser port and within its ejection jet.

As described previously, wastewater-induced reductions in salinity can be used to directly determine the amount of dilution achieved by initial mixing. Based on statistical analyses of the natural variability in salinity readings measured near the outfall over a five-year period between 2004 and 2008, the smallest reduction in salinity that can be reliably detected within receiving waters is 0.062‰. This represents a dilution level of at least 542-fold. Reductions that are smaller than 0.062‰, cannot be reliably discerned against the backdrop of natural variation and would not result in discernable changes in other seawater properties.

Application of LOE#02 restricts attention to excursions in temperature, light transmittance, DO, and pH that are related to the presence of wastewater constituents. Specifically, application of LOE#02 eliminates extremely small salinity reductions (<0.062‰) that would not result in discernable changes in other seawater properties. Of the 3,919 observations that were measured outside the ZID (LOE #01), application of LOE#02 effectively eliminated all but 12 of these measurements from further compliance interest (Table 7).

Salinity Spiking

In the presence of a sharp thermocline, a phenomenon known as ‘salinity spiking’ can occur due to the physical separation of the conductivity and temperature probes on the CTD package that are used to compute salinity. When the CTD crosses a sharp thermocline, the mismatch between the locations of the conductivity and the temperature probes results in the sensors sampling parcels of water with entirely different properties, thereby creating erroneous spikes in computed salinity. This is particularly common with data obtained at shallow depths, where entrainment of ambient waters by the rising effluent plume has ‘squeezed’ the thermocline, making it sharper.

The moderate vertical stratification present during the April 2010 survey was not strong enough to cause salinity spiking. However, the rising effluent plume at Station RW4 compressed the thermocline and produced a sharp vertical gradient in temperature within the upper 5 m (red line in Figure 6d). This strong, localized temperature change caused the CTD to record three salinity spikes within 3-m of the sea surface (green line). However, because all three measurements were recorded within the ZID, where initial mixing was still taking place, they were not subject to the receiving water limits of the permit (see LOE#01). Therefore, the application of LOE#03 did not eliminate any of the remaining 12 measurements from further compliance consideration.

Transport Direction

The plume signature is usually located downstream of the diffuser structure. Therefore, pursuant to LOE#04, excursions in receiving-water properties found in locations inconsistent with the path of plume transport are generally excluded from further evaluation. Specifically, LOE#04 excludes measurements that lie within a 180° arc centered at the western-most location along the ZID boundary, opposite (upstream) of the prevailing flow direction at the time of the April 2010 survey. Although exceptions to this LOE may occur when flow speeds are negligible (<1 cm/s) or when there is a complete reversal in flow during the survey, neither of these applied during the April 2010 survey.

Nevertheless, because all 12 of the remaining measurements of interest were located downstream of the path of plume transport, application of LOE#04 did not eliminate any of these measurements from further consideration.

Natural Variability

As stated previously, an integral part of the compliance analysis is determining whether a particular anomalous measurement resulted from the presence of wastewater constituents, or whether it simply became apparent because ambient seawater was relocated by the plume. If the measurement does not significantly depart from the natural range in ambient seawater properties at the time of the survey, then it is difficult to ascribe the departure to the discharge. Thus, quantifying the natural variability around the outfall is necessary for the compliance evaluation under LOE#05.

With that in mind, a statistical analysis of receiving-water data previously collected around the outfall was used to establish the range of variability in natural conditions surrounding the outfall (Table 8). These ranges in natural variability were used to identify significant departures from ambient conditions that could be indicative of adverse effects on water quality from the discharge. The same five-year database used to establish the natural within-survey salinity variation discussed previously was also used to establish one-sided 95% confidence bounds on transmissivity (-10.2%), temperature (+0.82°C), DO (-1.4 mg/L), and pH (± 0.094). These were combined with 95th percentiles determined from the April 2010 ambient seawater data, to establish natural-variability thresholds in a manner analogous to COP Appendix

Table 8. Thresholds of Natural Variation

| Water Quality Property | Basin Plan Limit ²⁰ | COP Allowance ²¹ | Natural Variability Threshold ²² | 95 th Percentile ^{23,24} | 95% Confidence Bound ²⁵ |
|------------------------|--------------------------------|-----------------------------|---------------------------------------------|----------------------------------------------|------------------------------------|
| Temperature (°C) | — | — | >13.68 | 12.86 | 0.82 |
| Transmissivity (%) | — | — | <67.1 | 77.3 | -10.2 |
| DO (mg/L) | <5.0 | -10% | <6.18 | 7.56 | -1.38 |
| pH (minimum) | <7.0 | -0.2 | <8.576 | 8.671 | -0.094 |
| pH (maximum) | >8.3 | 0.2 | >8.834 | 8.740 | 0.094 |

VI. The percentiles were determined from April 2010 vertical profile data, excluding measurements potentially affected by the discharge, specifically all of the measurements recorded within the ZID at Station RW4.

None of the remaining 12 CTD observations identified for further investigation during the tiered evaluation exceeded the thresholds of natural variability for temperature, DO, pH, or transmissivity established by LOE#05.

Exceedance of Numerical Limits

The NPDES permit specifies finite numerical limits for pH and DO measurements (P5 and P6 in Table 6) that are based on Basin Plan objectives for ocean waters. These numeric limits require that the discharge not cause DO measurements to be reduced below 5 mg/L, or cause pH measurements to be either below 7.0 units or above 8.3 units. Pursuant to LOE#06, all 12 of the measurements of interest remained well above the prescribed minimum DO threshold during the April 2010 survey. However, each of the 12 measurements exceeded the upper Basin-Plan limit for pH. These pH exceedances did not constitute a violation of the permit provision though, because, as outlined by the natural variability thresholds generated for LOE#05 (Table 8), the pH (~8.7) of ambient receiving waters in Estero Bay at the time of the survey exceeded the upper Basin-Plan limit (Tables 5 and 8). In fact, all 4,828 of the pH measurements collected during the April 2010 survey exceeded the Basin Plan’s pH objective. Therefore, these exceedances were clearly naturally occurring and not the result of the discharge.

²⁰ Permit limits P5 and P6 (Table 6) include specific numerical values promulgated in the RWQCB Basin Plan (1994) in addition to changes relative to natural conditions specified in the COP.

²¹ The discharge permit, in accordance with the COP, allows excursions in seawater properties that depart from natural conditions by specified amounts. DO cannot be “depressed more than 10% from that which occurs naturally,” and pH cannot be “changed more than 0.2 units from that which occurs naturally.”

²² Thresholds represent limits on wastewater-induced changes to receiving-water properties that significantly exceed natural conditions as specified in the discharge permit and COP. They are determined from the sum of columns to the right and are specific to the April 2010 survey. They do not include the COP allowances specified in the column to the left.

²³ The COP (Appendix I, Page 27, SWRCB 2005) defines a “significant” difference as “a statistically significant difference in the means of two distributions of sampling results at the 95 percent confidence level.” Accordingly, COP effluent analyses (Step 9 in Appendix VI, Page 42, Ibid.) are based “the one-sided, upper 95 percent confidence bound for the 95th percentile.”

²⁴ The 95th-percentile quantifies natural variability in seawater properties during the April 2010 survey, and was determined from vertical profiles excluding RW4 where there was possible influence by the discharge.

²⁵ The one-sided confidence bound is used to measure the ability to reliably estimate percentiles within surveys as a whole. They were determined from an analysis of the variability in ambient water-quality data collected during 20 quarterly surveys conducted between 2004 and 2008. Although water-quality observations potentially affected by the presence of wastewater constituents were excluded from the analysis, more than 9,200 observations for each of the six seawater properties accurately quantify the inherent uncertainty in defining the range in natural conditions.

Directional Offset

The final line of evidence used to assess compliance with the permit limits and objectives was an evaluation of the directional offset of the water properties of the 12 remaining CTD measurements. Wastewater and receiving-seawater properties vary from one another in several predictable ways. Upon discharge, wastewater is fresher, warmer, lighter, and more acidic than the ambient receiving waters of Estero Bay. Under most conditions, wastewater is also more turbid than the receiving waters. As such, salinity, pH, density, and transmissivity are generally lower in effluent (negatively offset) compared to receiving waters, while temperature is generally higher (positively offset). Similarly, the presence of oxygen-demanding materials in wastewater can result in a reduction in DO.

Application of LOE#07 to the twelve measurements identified water property offsets that were either inconsistent with known differences between receiving and wastewater properties, or inconsistent with an expectation of DO depletion. For example, all 12 measurements had pH levels that were much higher (~8.7) than the wastewater generated by the MBCSD plant, which has a pH of 7.8. The positive offset of the receiving-water pH was inconsistent with water-quality impacts induced by wastewater constituents. Similarly, the observed reduction in temperature in the 12 measurements could not have been caused by wastewater constituents, which were warmer than the ambient receiving waters. Instead, the lower temperatures associated with these measurements suggest that ambient seawater from near the seafloor was entrained within the rising effluent plume, resulting in the observed juxtaposition of properties.

Entrainment also presents the abductive “best explanation” for the observed transmissivity and DO reductions in the 12 observations, even though the directional offsets for these observations did not immediately discount the presence of wastewater constituents as a causative factor. For example, although ten of the 12 measurements exhibited DO concentrations were lower than the surrounding ambient seawater in the upper water column, their concentrations were substantially higher than the naturally depleted DO found in ambient seawater near the seafloor during the April 2010 survey. Consequently, the reduced DO within these observations was well within the natural DO variability observed at the time of the survey (LOE#05). Moreover, the 51-mg/L BOD measured in effluent three days prior to the survey (MBCSD 2010) would induce a DO depression of no more than 0.023 mg/L after dilution (MRS 2003). Thus, oxygen-demanding material within wastewater particulates was incapable of generating even the smallest-amplitude DO reduction (0.07 mg/L) observed within the ten measurements.

Similarly, although ten of the 12 measurements of interest exhibited slight transmissivity reductions in the upper water column, lower transmissivities were measured within ambient seawater elsewhere during the survey. Thus, the ten transmissivity reductions were within the range in natural variability (LOE#05) at the time of the survey. Additionally, after 220-fold dilution, the 27-mg/L TSS concentration measured in effluent on 19 April would have induced a reduction in transmissivity of no more than 0.86%, while the observed reductions exceeded 1.2% in nine of the ten observations with transmissivity reductions. The 0.04% transmissivity reduction associated with the remaining observation was far too small to cause a “significant reduction in the transmittance of natural light” (P4 in Table 6), regardless of its cause. Therefore, the 12 measurements were all in compliance with the permit limitations.

CONCLUSIONS

All measurements recorded during the April 2010 survey complied with the receiving-water limitations specified in the NPDES discharge permit, and were within natural variability that prevailed at the time of the survey. The presence of dilute wastewater constituents was delineated from salinity anomalies within a discharge plume that was localized near, and within the ZID. Observed excursions in other receiving-

water properties were associated with the entrainment and upward displacement of ambient seawater within the buoyant effluent plume, rather than the presence of wastewater constituents.

Within the upper water column, computed dilution levels of more than 220-fold were one and a half times the critical dilution levels predicted by design modeling. Additionally, all of the auxiliary observations collected during the April 2010 survey demonstrated that the discharge complied with the narrative receiving-water limits in the discharge permit and COP. All of these observations demonstrated that the treatment process, diffuser structure, and the outfall continue to perform at levels exceeding design expectations.

Although several discharge-related changes in seawater properties were observed during the April 2010 survey, the changes were either not of significant magnitude, were measured within the boundary of the ZID where mixing is still expected to take place, or were not directly caused by the presence of wastewater constituents within the water column. Beyond the ZID, the effluent was so dilute that only slight changes in seawater properties caused by the upward displacement of ambient seawater, rather than the presence of effluent itself, could be distinguished.

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