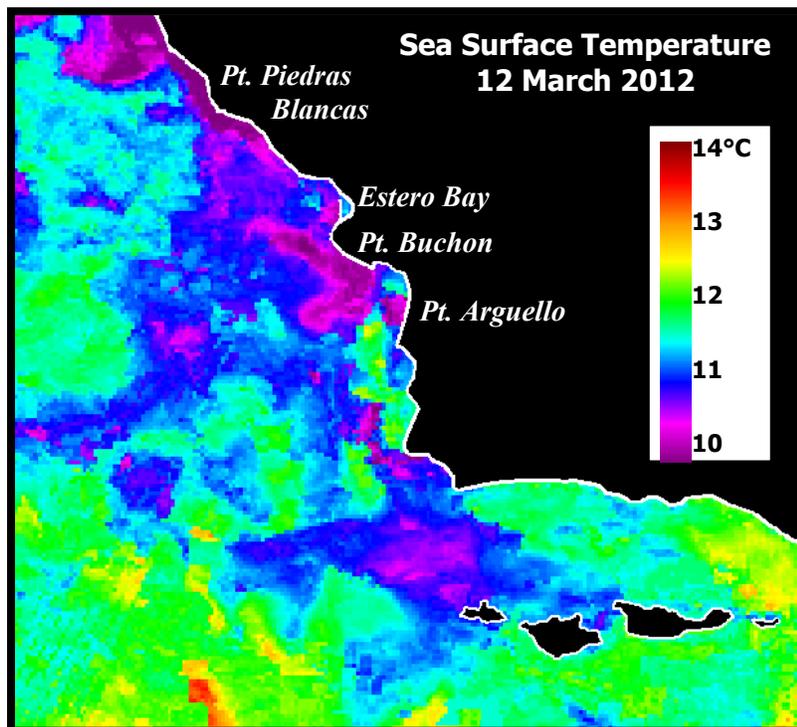


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

FIRST QUARTER RECEIVING-WATER SURVEY MARCH 2012



Marine Research Specialists

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

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

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

**FIRST QUARTER
RECEIVING-WATER SURVEY**

MARCH 2012

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April 2012

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

30 April 2012

Reference: First Quarter Receiving-Water Survey Report – March 2012

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Friday, 16 March 2012. 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. Quantitative analyses of continuous instrumental measurements and qualitative visual observations confirm that 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 a high level of performance. The measurements delineated a diffuse discharge plume containing low organic loads within a highly localized region surrounding 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 March 2012 field survey described in this report was the twelfth receiving-water survey conducted under the current permit.

The NPDES discharge permit requires seasonal monitoring of offshore receiving-water quality with quarterly surveys. This report summarizes the results of sampling conducted on 16 March 2012. Specifically, this first-quarter survey captured ambient oceanographic conditions along the central California coast during the winter 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 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 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 reach in modeling studies extends 15.2 m from the centerline of the diffuser structure. Beyond the ZID, energetic waves, tides, and coastal currents within Estero Bay further disperse the dilute effluent within the open-ocean receiving waters. Both vertical hydrocasts and horizontal tow surveys are conducted around 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 flow generally follows 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 may influence one or more of these stations. The up-current stations on the opposite side of the diffuser 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.

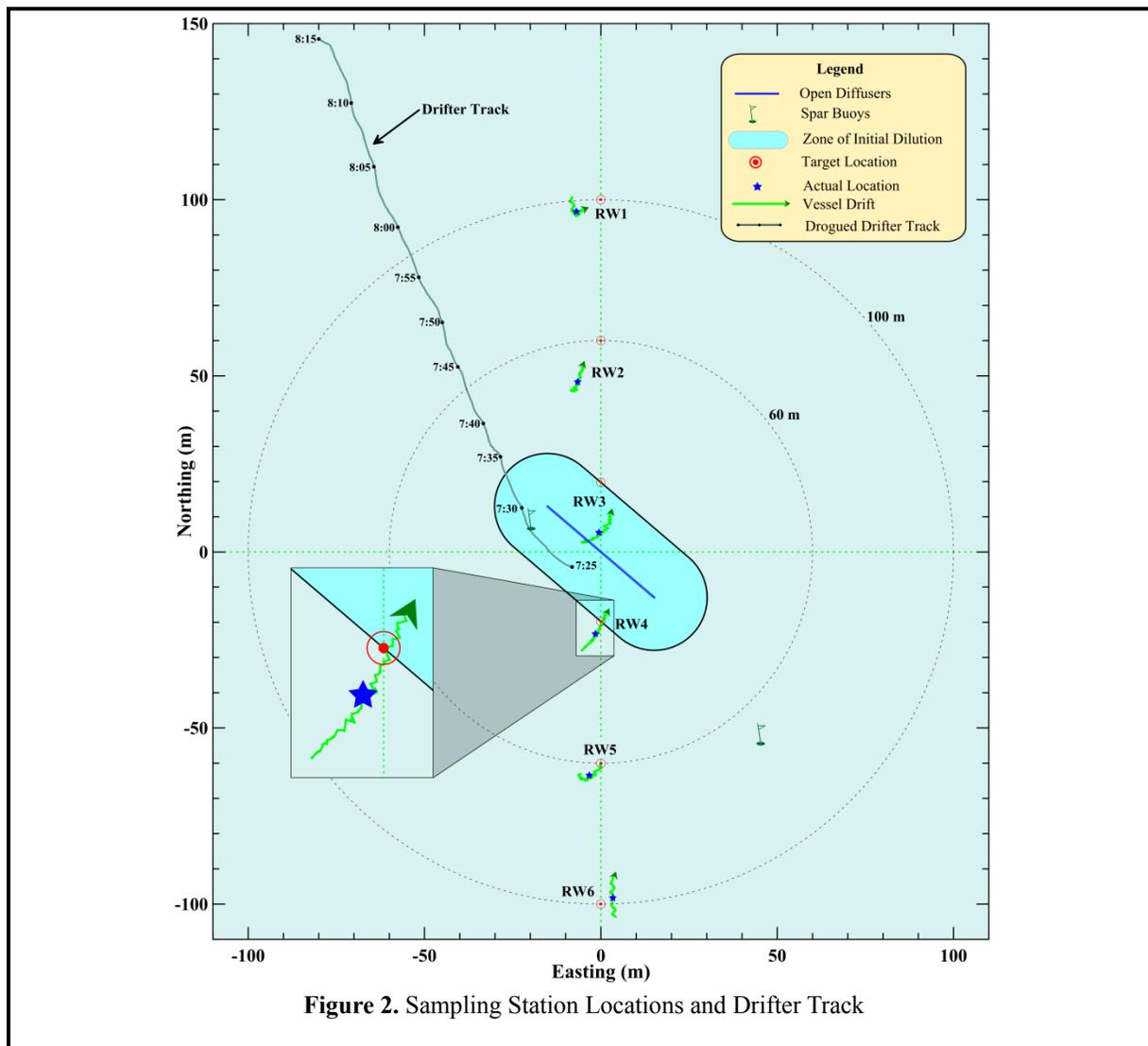


Table 1. Target Locations of the Receiving-Water Monitoring Stations

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

During a diver survey 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 determine 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 March 2012 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 lengths and offsets from the target locations reflect the overall station-keeping ability during the March 2012 survey. During the time it took the CTD to traverse the water column and reach the seafloor, which averaged 1 minute 27 seconds, the instrument package moved an average of 9.2 m. This amount of drift is comparable to that of most prior surveys conducted under similarly oceanographic conditions.

The CTD trajectories shown by the tracklines in Figure 2 reflect complex interactions between surface currents, wind forces, and any residual momentum of the survey vessel as it approached each station during the March 2012 survey. For example, all stations except RW1 had a northerly drift component, which was consistent with north-northwest transport by the subsurface current measured by the drogue drifter. The southward drift that occurred at RW1 resulted from the residual momentum of the vessel as it approached the station. Generally, winds affect the vessel's ability to maintain station to a greater degree than does current flow, however, this was not the case with the March 2012 survey because winds were negligible throughout the survey.

Compliance assessment can be complicated when the CTD drifts across the ZID boundary during vertical hydrocasts 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 March survey, none of the measurements acquired at RW3 were subject to receiving-water limitations because the CTD was within the ZID boundary throughout the hydrocast (Figure 2). Similarly, although the shallowest measurements at RW4 were subject to the compliance evaluation, as the CTD continued its descent to the seafloor it crossed the ZID boundary. Therefore, the deepest measurements at RW4 were not subject to the receiving-water limitations (inset in Figure 2).

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 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 State reporting of

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

monitoring data still mandates 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 March 2012 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 along with their distances from the diffuser structure.

Table 2. Average Position of Vertical Profiles during the March 2012 Survey

Station	Time (PDT)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ⁵ (m)	Bearing ⁶ (°T)
RW1	7:30:25	7:32:05	35° 23.251' N	120° 52.509' W	84.2	6
RW2	7:36:55	7:38:25	35° 23.225' N	120° 52.508' W	36.5	14
RW3	7:43:23	7:45:01	35° 23.202' N	120° 52.504' W	3.9 ⁷	41
RW4	7:49:29	7:50:50	35° 23.186' N	120° 52.505' W	18.6 ⁸	221
RW5	7:55:21	7:56:40	35° 23.165' N	120° 52.506' W	53.7	200
RW6	8:02:03	8:03:15	35° 23.146' N	120° 52.502' W	86.0	188

Compliance assessments notwithstanding, measurements acquired 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, demonstrates 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 steady north-northwestward flow throughout the March 2012 survey (Figure 2). Modeled after the curtain-shade design of Davis et al. (1982) and drogued at mid-depth (7 m), a drifter has typically been deployed during each of the quarterly water column surveys conducted over the past decade. In this configuration, the oceanic flow field rather than surface winds dictates the drifter’s trajectory, providing a good assessment of the plume’s movement after discharge.

The drifter was deployed near the diffuser structure at 7:25 PDT, and was recovered 50 minutes later, at a location 166 m north-northwest of its initial location (Figure 2). The black dots in Figure 2 show the drifter’s progress at five-minute intervals, and their uniform spacing reflects the relatively constant speed of the drifter, which averaged 5.4 cm/s, or 0.11 knots. At this speed, the plume would have traversed the ZID in just over four-and-a-half minutes.

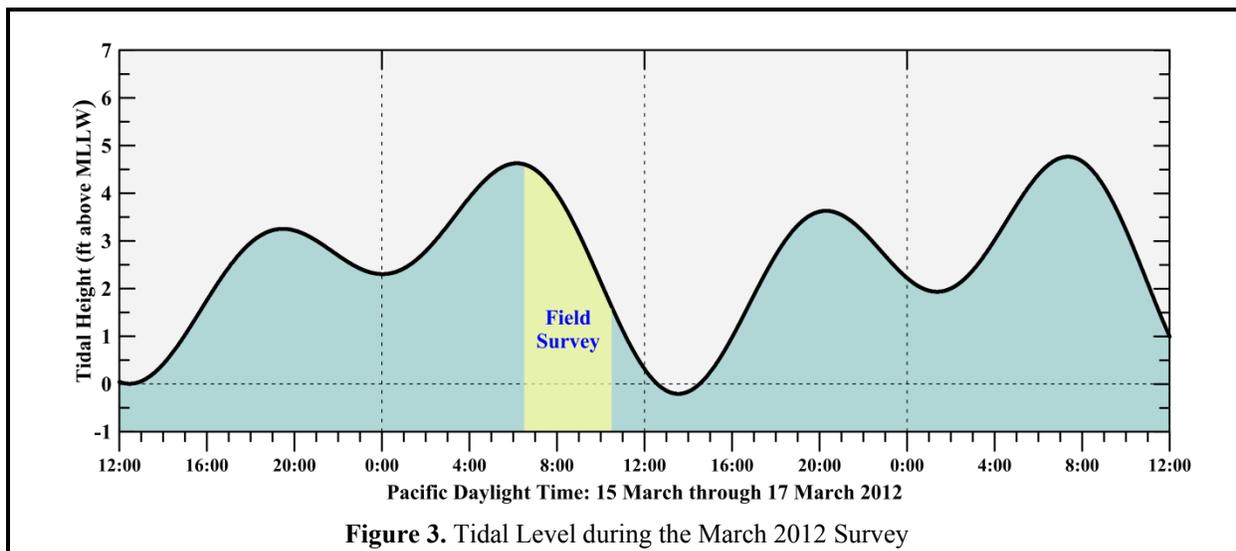
The moderate northward oceanic flow measured by the drifter was inconsistent with the ebb tide that prevailed during the survey (Figure 3), which normally results in a slight southward flow. However, flow within Estero Bay is also often strongly influenced by external processes, such as wind-generated upwelling, downwelling, or the passing of offshore eddies propagating along the coastline. Upwelling, for

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 measurements at Station RW3 were located within the ZID boundary.

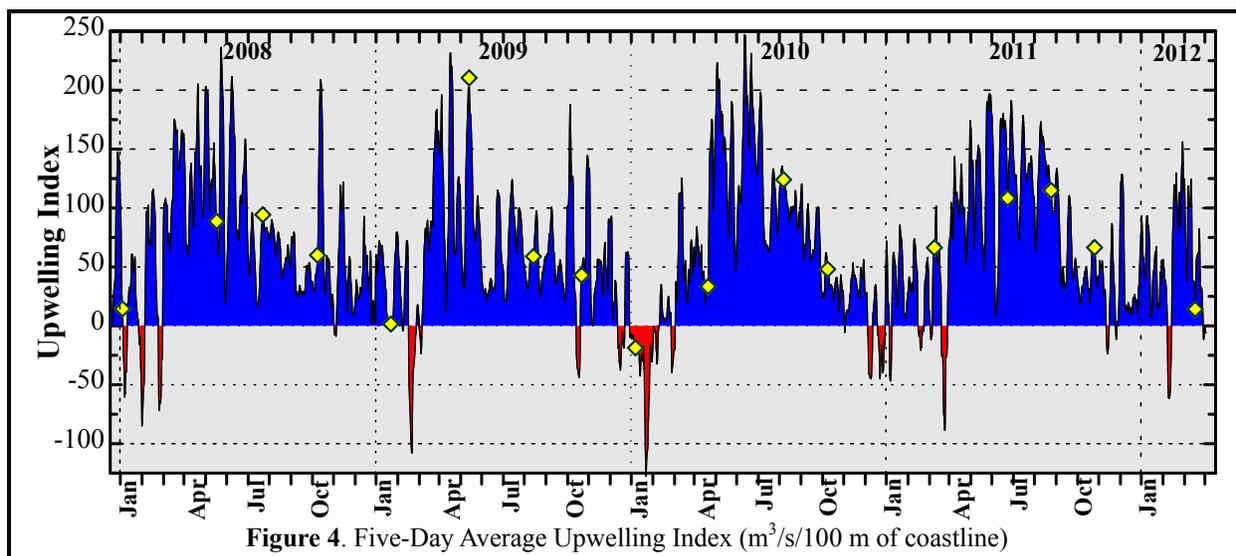
⁸ The deepest CTD measurements at Station RW4 were located within the ZID boundary.



example, can induce a southerly (offshore) flow in the upper water column, and a northerly (onshore) flow at depth.

Upwelling was occurring around the time of the March 2012 survey. Upwelling season normally begins sometime during late March and or early April as shown by the positive (blue) upwelling indices in Figure 4. At the onset of upwelling season, there is a spring transition to more persistent southeastward 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.

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.

Winds were mild during the March 2012 survey, as reflected by the associated upwelling index (rightmost yellow diamond in Figure 4). However, strong northwesterly winds prevailed along the central California coast from the latter half of February until just prior to the March survey.

The satellite image on the cover of this report documents the upwelling that was present immediately prior to the March 2012 survey. The image was recorded four days before the survey, when skies were clear enough for sea-surface temperatures to be measured by infrared sensors on one of NOAA's polar orbiting satellites. As is apparent in the cover image, the cool, nearshore sea-surface temperatures (<11.0°C) within Estero Bay were slightly cooler than the 11.5°C near-surface temperatures measured by the CTD during the March 2012 survey.⁹

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on Friday, 16 March 2012. Bonnie Luke of Marine Research Specialists (MRS) was Chief Scientist and collected auxiliary measurements of biological, meteorological, and oceanographic conditions. Dr. Douglas Coats, also of MRS, provided navigational support during the survey. William Skok assisted with deployment and recovery of the CTD and drifter. Bruce Keogh, the MBCSD wastewater division manager, was present on board as an observer.

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, Secchi depths measure natural light penetration, which can be limited by increased suspended particulate loads from plankton blooms, onshore runoff, seafloor sediment resuspension, and wastewater discharge. They are also biologically meaningful because the depth of the euphotic zone, where most oceanic photosynthesis occurs, extends to approximately twice the Secchi depth.

⁹ Refer to Table 5 and Figure 6 for receiving-water properties recorded during the vertical hydrocasts.

Instrumental Measurements

A Sea Bird Electronics SBE-19plusV2 Seacat CTD instrument package collected measurements of conductivity, temperature, light transmittance, dissolved oxygen (DO), pH, and pressure during the March 2012 survey. This new CTD instrument package was commissioned in May 2011 to replace an older model SBE-19 profiler that was retired from regular use following the June 2011 survey.

The new CTD system offers many advantages over the older unit, which was in service for nearly two decades. The 4 Hz sampling rate¹¹ on the new instrument collects data at twice the rate of the older unit, allowing much higher spatial resolution for a given tow, or descent rate. In addition, the probes and sensors have a much faster response time, further enhancing the spatial resolution of seawater properties. Lastly, the probes and sensors on the new CTD are more stable and exhibit negligible long-term drift. As a result, and in accordance with the manufacturer's recommendations, the new CTD package does not require calibration of the sensors prior to each field survey.

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 confine the CTD to depths less than 680 m (Table 3), which is well beyond the maximum depth of the deepest station in the outfall survey.

Table 3. CTD Specifications

Component	Units	Range	Accuracy	Resolution
Housing (19p-1a; Acetron Plastic)	m	0 to 680	—	—
Pump (SBE 5P)	—	—	—	—
Pressure (19p-2h; Strain-Gauge)	dBar	0 to 680	±1.7	± 0.10
Conductivity	Siemens/m	0 to 9	± 0.0005	± 0.00005
Salinity	‰	0 to 58	± 0.004	± 0.0004
Temperature	°C	-5 to 35	± 0.005	± 0.0001
Transmissivity (WETLabs C-Star) ¹⁰	%	0 to 100	± 0.3	± 0.03
Oxygen (SBE 43)	% Saturation	0 to 120	± 2	—
pH (SBE 18)	pH	0 to 14	± 0.1	—

The precision and accuracy of the various probes, as reported in manufacturer's specifications, are also listed in Table 3. Salinity (‰) was calculated from conductivity 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 tow 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.

¹⁰ 25-cm path length of red (660 nm) light

¹¹ 0.25-s sampling interval

Transmissivity readings are reported relative to 100% transmission in air. Therefore, transmission in pure water is expected to be 91.3% of the reported values for this transmissometer.

Before initial deployment for the vertical hydrocasts, the CTD was held below the sea surface for a four-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 08:06 PDT, following the last vertical profile at RW6, the CTD instrument package was brought aboard the survey vessel and reconfigured for horizontal towing with forward-looking probes. The CTD was fitted with a horizontal stabilizer wing and a depth-suppression weight was added to the towline to achieve constant-depth tows. After retrieval of the drifter, the CTD was deployed and towed around and across the ZID at two separate depths, one within the surface mixed layer and one below the thermocline, in accordance with the monitoring requirements of the NPDES discharge permit (Figure 5).

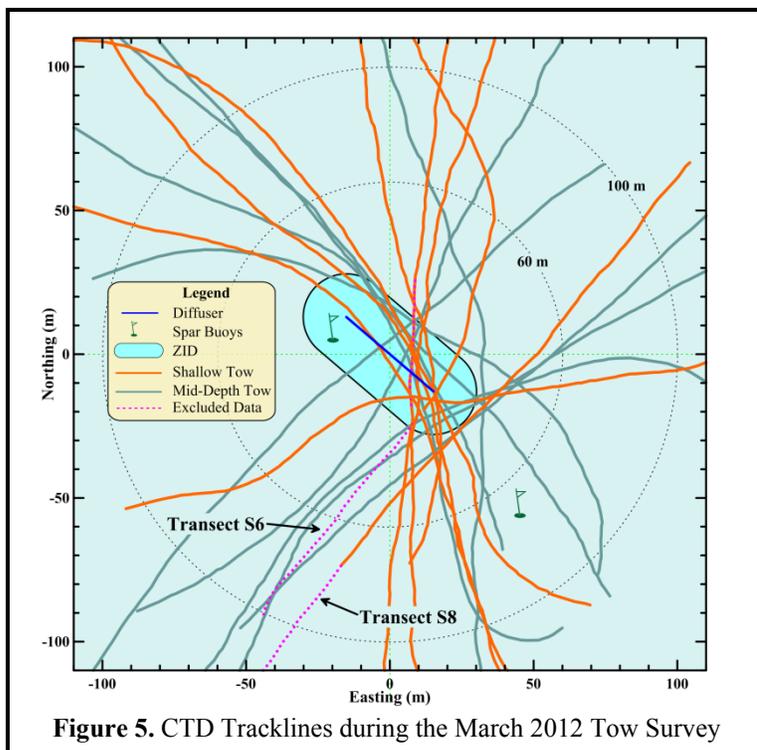


Figure 5. CTD Tracklines during the March 2012 Tow Survey

Initially, the reconfigured CTD package was towed for 34 minutes at an average depth of 3.75 m, and an average speed of 1.79 m/s, passing over, or near the diffuser structure nine times.¹² Subsequently, ten additional passes were made with the CTD at an average depth of 7.03 m. During this 43-minute mid-depth-tow, vessel speed averaged 1.87 m/s. At the observed towing speeds and a 4 Hz sampling rate, 2.2 CTD measurements were collected for each meter traversed. This complies with the permit requirement for minimum horizontal resolution of at least one sample per meter. Contemporaneous navigation fixes recorded onboard the survey vessel were adjusted for CTD setback and aligned with time stamps on the internally recorded CTD data. The resulting data for the six seawater properties were then processed to produce horizontal maps within the upper and sub-thermocline portions of the water column.¹³

¹² The tow depths during portions of shallow transects S6 and S8, as shown by the dashed lines in Figure 5, were removed from subsequent analysis due to their vertical offset as described in the *Quality Control* section.

¹³ Figures 7 and 8 present the horizontal maps of seawater properties measured during the tow-survey portion of the field survey.

Quality Control

Upon retrieval of the CTD following the tow survey, water-quality data were downloaded to a portable computer and examined for completeness and range acceptability. Real-time monitoring revealed that the recorded seawater properties were complete and within acceptable coastal seawater ranges.¹⁴

Subsequent post-processing of the data 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. For example, review of the tow data revealed that the CTD was tracking at a slightly different depth during portions of the shallow tow (dashed lines in Figure 5). Specifically, slight increases in vessel speed during the initial portions of Transects S6 and S8 resulted in tow depths that were more than 0.6 m shallower than average. While this depth offset appears small, it created artificial horizontal differences in the combined data set because of vertical gradients associated with the upwelling-induced stratification present in the water column at the time of the survey. Because discharge-related anomalies are identified by comparing the amplitudes of measurements acquired at the same depth level, the ability to resolve anomalies with statistical certainty is compromised when data from different levels are combined, particularly when the water column is moderately stratified, as was the case during the March 2012 survey.

Because of their depth offsets, data collected during these portions of the tow surveys were incompatible with the rest of the tow data, and were excluded from the subsequent analysis to avoid introducing erroneous lateral differences in the horizontal property maps.¹⁵ Exclusion of these transects, shown by the dotted purple lines in Figure 5, did not, however, adversely affect the compliance analysis because the remaining transects adequately covered the survey region. The remaining transects, shown by the solid orange and blue lines in Figure 5, also met the permit monitoring requirement of at least five passes near the diffuser structure at each tow depth.

Similarly, quality-control screening of the vertical profile data was required because the length of the CTD is close to the 0.5-m standard depth bins used to report the vertical profile data. Because of the CTD's size, 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 reported depth is influenced by temporal differences in sea-surface height caused by wave and tidal-induced oscillations during its deployment at each station. For example, during the March 2012 survey, data on average seawater properties was not reported within the deepest depth bin (17 m) at Stations RW2, RW3, RW4, and RW6.¹⁶ Because the limited spatial coverage of the observations within this deepest depth bin cannot adequately quantify horizontal trends, the remaining observations were excluded from the subsequent compliance evaluation.

RESULTS

The first-quarter receiving-water survey was conducted on the morning of Friday, 16 March 2012. The receiving-water survey commenced at 07:23 PDT with the deployment of the drogued drifter. Over the following two-and-a-half hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended at 09:48 PDT with the retrieval of the CTD from its mid-depth-tow configuration. The collection of required visual observations of the sea surface was unencumbered throughout the survey, although dense fog obscured views of both the shoreline and Morro Rock and restricted observations of beneficial uses to within a quarter mile of the survey vessel.

¹⁴ Field sampling protocols employed during the March 2012 survey generally followed the field operations manual for the Southern California Bight Study (SCBFMC 2002), which includes CTD cast-acceptability ranges in Table 2 of the manual.

¹⁵ Figures 7 and 8

¹⁶ Refer to Table 5

Auxiliary Observations

On the morning of 16 March 2012, skies were heavily overcast, with very light northwesterly winds. Average wind speeds, calculated over one-minute intervals, ranged from 0.8 kt to 2.3 kt (Table 4). Similarly, peak wind speeds ranged from 2.3 kt to 4.2 kt. The swell was out of the northwest with a significant wave height of three feet. Air temperatures, which varied from 13.0°C to 14.3°C, were several degrees warmer than the average sea-surface temperatures.

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location ¹⁷		Diffuser Distance (m)	Time (PDT)	Air Temp (°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° 23.261' N	120° 52.503' W	102.4	7:33:47	13.4	100	0.8	3.2	NW	3 NW	8.0
RW2	35° 23.237' N	120° 52.503' W	59.5	7:39:57	13.5	100	0.9	3.2	NW	3 NW	8.0
RW3	35° 23.219' N	120° 52.507' W	25.5	7:46:54	14.3	100	0.9	3.2	NW	3 NW	7.0
RW4	35° 23.202' N	120° 52.498' W	11.0	7:52:18	13.2	100	2.0	2.3	NW	3 NW	7.0
RW5	35° 23.180' N	120° 52.503' W	26.1	7:58:08	13.0	100	2.3	4.2	NW	3 NW	8.0
RW6	35° 23.167' N	120° 52.492' W	45.5	8:06:00	13.0	100	2.2	3.1	NW	3 NW	7.0

The 7-to-8 m Secchi depths recorded during the March 2012 survey indicated a high level of ambient water clarity (Table 4). The Secchi depths reflected the presence of a 14-to-16 m euphotic zone that spanned the full extent of the 15.5-m water column. There was no evidence during the survey of floating particulates, oil sheens, or any discoloration of the sea surface associated with wastewater-related constituents. Communication with plant personnel during the survey, and subsequent review of effluent discharge properties, confirm that the treatment process was performing nominally at the time of the survey. The 1.13 million gallons of effluent discharged on the day of the survey had a temperature of 17°C, a suspended-solids concentration of 21 mg/L, and a pH of 7.6. Biochemical oxygen demand (BOD) and oil-and-grease concentrations measured in an effluent sample collected four days after the survey were 44 mg/L and 3.2 mg/L, respectively.

During the March 2012 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. Small numbers of Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), western gulls (*Larus occidentalis*), and California brown pelicans (*Pelecanus occidentalis californicus*) were all noted transiting the survey area. Observations of the adjacent beach were restricted during the March 2012 survey due to fog.

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 March 2012 survey reflect the presence of a moderately stratified water column indicative of upwelling conditions that prevailed prior to the survey. Upwelling of varying intensity occurs most of the year along the central California coast, with the strongest winds beginning in March or April and extending through the summer. 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

¹⁷ Locations are the vessel positions at the time the Secchi depths were measured. They may depart from the CTD profile locations listed in Table 2.

Table 5. Vertical Profile Data Collected on 16 March 2012

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
1.0	11.355		10.962	11.455	11.473	11.568	33.632		33.591	33.619	33.597	33.571
1.5	11.349	11.386	10.953	11.447	11.451	11.562	33.630	33.639	33.590	33.626	33.619	33.570
2.0	11.233	11.245	10.971	11.437	11.413	11.534	33.606	33.619	33.591	33.631	33.633	33.578
2.5	11.131	10.915	10.973	11.402	11.378	11.521	33.596	33.578	33.593	33.641	33.638	33.581
3.0	11.044	10.882	10.881	11.405	11.356	11.505	33.591	33.581	33.588	33.641	33.643	33.585
3.5	11.048	10.815	10.820	11.401	11.347	11.386	33.606	33.580	33.584	33.642	33.644	33.610
4.0	10.983	10.815	10.694	11.364	11.308	11.240	33.600	33.587	33.574	33.643	33.645	33.628
4.5	10.858	10.769	10.629	11.319	11.097	11.105	33.593	33.590	33.572	33.642	33.620	33.627
5.0	10.825	10.740	10.622	11.260	10.978	11.012	33.600	33.591	33.569	33.639	33.619	33.624
5.5	10.828	10.736	10.629	11.204	10.902	10.929	33.613	33.593	33.577	33.638	33.616	33.619
6.0	10.837	10.713	10.633	11.136	10.861	10.875	33.634	33.592	33.582	33.634	33.623	33.623
6.5	10.836	10.713	10.631	11.044	10.844	10.845	33.640	33.594	33.586	33.626	33.630	33.628
7.0	10.837	10.712	10.619	10.996	10.839	10.835	33.649	33.594	33.586	33.622	33.634	33.632
7.5	10.827	10.707	10.621	10.948	10.843	10.832	33.656	33.592	33.591	33.619	33.638	33.636
8.0	10.794	10.704	10.627	10.920	10.846	10.836	33.655	33.592	33.595	33.620	33.640	33.641
8.5	10.738	10.723	10.632	10.881	10.857	10.849	33.653	33.618	33.593	33.623	33.644	33.648
9.0	10.652	10.727	10.629	10.858	10.870	10.856	33.651	33.624	33.592	33.628	33.650	33.651
9.5	10.590	10.729	10.624	10.854	10.876	10.857	33.651	33.635	33.590	33.631	33.653	33.658
10.0	10.597	10.730	10.629	10.857	10.885	10.800	33.662	33.634	33.607	33.634	33.657	33.655
10.5	10.599	10.728	10.630	10.862	10.883	10.778	33.663	33.635	33.617	33.644	33.656	33.656
11.0	10.600	10.702	10.632	10.816	10.869	10.722	33.667	33.647	33.633	33.652	33.660	33.653
11.5	10.602	10.683	10.639	10.778	10.772	10.629	33.667	33.653	33.644	33.654	33.653	33.660
12.0	10.601	10.667	10.650	10.725	10.692	10.600	33.668	33.658	33.650	33.656	33.654	33.668
12.5	10.602	10.647	10.651	10.621	10.622	10.592	33.668	33.666	33.649	33.661	33.657	33.669
13.0	10.601	10.643	10.661	10.582	10.612	10.586	33.669	33.668	33.650	33.665	33.660	33.670
13.5	10.602	10.635	10.662	10.576	10.603	10.573	33.669	33.671	33.656	33.667	33.663	33.670
14.0	10.598	10.636	10.624	10.570	10.585	10.570	33.668	33.670	33.660	33.668	33.668	33.671
14.5	10.593	10.628	10.595	10.569	10.575	10.566	33.669	33.671	33.668	33.669	33.670	33.672
15.0	10.592	10.617	10.592	10.564	10.572	10.565	33.669	33.672	33.672	33.669	33.671	33.672
15.5	10.595	10.609	10.592	10.562	10.574	10.567	33.669	33.672	33.672	33.669	33.671	33.672
16.0	10.588	10.605	10.594	10.559	10.576	10.571	33.668	33.672	33.672	33.669	33.672	33.672
16.5		10.605	10.593	10.576	10.576	10.574		33.673	33.673	33.671	33.672	33.673
17.0			10.597		10.579				33.673		33.672	

Table 5. Vertical Profile Data Collected on 16 March 2012 (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
1.0	25.646		25.685	25.618	25.597	25.560	8.012		7.998	8.027	8.027	8.037
1.5	25.646	25.646	25.686	25.625	25.619	25.560	8.016	8.014	7.996	8.026	8.029	8.040
2.0	25.648	25.656	25.684	25.631	25.637	25.571	8.016	8.018	7.995	8.026	8.028	8.038
2.5	25.659	25.683	25.685	25.645	25.647	25.577	8.013	8.010	7.997	8.024	8.026	8.039
3.0	25.670	25.692	25.697	25.644	25.655	25.582	8.007	8.003	7.996	8.024	8.024	8.038
3.5	25.682	25.703	25.705	25.646	25.657	25.624	8.005	7.996	7.994	8.024	8.022	8.038
4.0	25.689	25.708	25.719	25.653	25.665	25.664	8.005	7.993	7.991	8.022	8.022	8.031
4.5	25.705	25.719	25.729	25.661	25.684	25.688	8.002	7.991	7.987	8.022	8.020	8.027
5.0	25.717	25.725	25.728	25.669	25.704	25.702	7.998	7.989	7.984	8.020	8.019	8.023
5.5	25.726	25.727	25.733	25.678	25.715	25.713	7.996	7.988	7.982	8.019	8.018	8.020
6.0	25.741	25.730	25.736	25.687	25.728	25.725	7.994	7.987	7.980	8.017	8.015	8.018
6.5	25.746	25.732	25.740	25.698	25.736	25.735	7.993	7.986	7.980	8.017	8.013	8.016
7.0	25.753	25.732	25.742	25.703	25.740	25.739	7.992	7.986	7.978	8.017	8.010	8.013
7.5	25.760	25.731	25.745	25.709	25.743	25.743	7.991	7.984	7.977	8.017	8.007	8.010
8.0	25.765	25.732	25.747	25.715	25.744	25.746	7.990	7.985	7.978	8.016	8.007	8.007
8.5	25.773	25.749	25.745	25.724	25.745	25.750	7.991	7.984	7.978	8.016	8.005	8.006
9.0	25.787	25.752	25.745	25.733	25.748	25.750	7.991	7.987	7.980	8.013	8.003	8.003
9.5	25.797	25.760	25.744	25.736	25.749	25.756	7.989	7.988	7.978	8.011	7.999	8.001
10.0	25.805	25.760	25.756	25.738	25.751	25.764	7.987	7.987	7.979	8.010	7.997	7.999
10.5	25.805	25.761	25.764	25.744	25.750	25.769	7.986	7.989	7.979	8.007	7.995	7.998
11.0	25.808	25.775	25.776	25.758	25.755	25.775	7.984	7.990	7.982	8.003	7.994	8.000
11.5	25.808	25.783	25.783	25.767	25.767	25.798	7.984	7.989	7.983	7.999	7.993	7.998
12.0	25.809	25.790	25.786	25.778	25.782	25.809	7.982	7.987	7.985	7.998	7.997	7.992
12.5	25.809	25.799	25.785	25.800	25.796	25.811	7.981	7.988	7.985	7.996	7.997	7.988
13.0	25.809	25.802	25.785	25.810	25.801	25.813	7.981	7.986	7.985	7.990	7.993	7.986
13.5	25.809	25.805	25.789	25.813	25.805	25.815	7.980	7.984	7.986	7.986	7.992	7.985
14.0	25.810	25.805	25.798	25.815	25.812	25.817	7.980	7.984	7.986	7.985	7.989	7.984
14.5	25.811	25.806	25.810	25.815	25.815	25.818	7.979	7.984	7.984	7.983	7.985	7.983
15.0	25.811	25.809	25.813	25.816	25.816	25.818	7.980	7.982	7.982	7.984	7.983	7.982
15.5	25.811	25.811	25.814	25.817	25.816	25.818	7.979	7.981	7.981	7.981	7.982	7.982
16.0	25.811	25.811	25.814	25.817	25.816	25.817	7.979	7.980	7.980	7.981	7.981	7.981
16.5		25.812	25.814	25.815	25.816	25.817		7.982	7.978	7.981	7.981	7.981
17.0			25.813		25.816				7.976		7.978	

Table 5. Vertical Profile Data Collected on 16 March 2012 (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
1.0	8.372		7.651	8.378	8.357	8.235	89.077		89.865	89.847	89.866	91.142
1.5	8.030	8.073	7.693	8.367	8.309	8.255	88.872	88.944	89.906	89.910	89.973	91.225
2.0	7.883	7.459	7.708	8.339	8.297	8.254	88.954	88.831	89.861	89.696	89.891	90.827
2.5	7.755	7.566	7.522	8.356	8.281	8.201	89.170	89.216	89.858	88.875	89.077	90.833
3.0	7.813	7.475	7.471	8.354	8.276	8.141	89.351	89.208	89.865	88.333	88.661	90.852
3.5	7.751	7.474	7.250	8.260	7.954	8.007	89.454	89.943	90.080	88.501	88.211	90.728
4.0	7.511	7.401	7.195	8.172	7.651	7.824	89.708	89.958	90.246	88.136	88.009	89.593
4.5	7.513	7.386	7.204	8.061	7.613	7.736	89.870	89.950	90.333	88.108	88.201	89.332
5.0	7.539	7.358	7.232	8.027	7.631	7.655	90.062	90.026	90.550	88.282	89.007	90.096
5.5	7.545	7.330	7.246	7.926	7.615	7.610	90.548	90.174	90.444	89.003	91.887	91.591
6.0	7.535	7.343	7.227	7.804	7.603	7.595	90.576	90.170	90.513	89.533	92.617	92.068
6.5	7.513	7.345	7.188	7.795	7.618	7.605	90.284	90.194	90.614	90.204	92.306	92.081
7.0	7.517	7.325	7.198	7.744	7.635	7.611	90.096	90.209	90.311	91.008	92.211	92.220
7.5	7.479	7.326	7.207	7.704	7.639	7.633	89.772	90.327	89.945	91.484	91.890	92.230
8.0	7.455	7.398	7.225	7.649	7.644	7.630	89.570	90.498	90.039	92.253	91.723	92.066
8.5	7.315	7.405	7.209	7.629	7.613	7.627	89.663	90.404	89.764	92.475	91.533	91.364
9.0	7.058	7.415	7.186	7.646	7.624	7.559	90.596	90.565	90.411	92.324	90.514	90.610
9.5	7.215	7.408	7.232	7.652	7.611	7.518	92.082	90.820	90.509	92.389	89.648	89.486
10.0	7.217	7.410	7.242	7.602	7.623	7.538	92.983	90.880	90.305	92.238	88.855	88.563
10.5	7.222	7.335	7.255	7.507	7.535	7.443	93.166	90.828	90.753	91.866	88.696	89.985
11.0	7.216	7.353	7.293	7.496	7.470	7.199	93.168	90.706	91.359	90.408	88.388	90.508
11.5	7.211	7.324	7.309	7.410	7.426	7.187	92.416	90.686	91.607	90.415	88.371	91.569
12.0	7.208	7.293	7.320	7.209	7.285	7.189	92.054	91.374	91.880	90.525	90.496	91.569
12.5	7.209	7.298	7.323	7.143	7.284	7.198	91.760	91.950	91.876	91.411	92.314	91.245
13.0	7.215	7.264	7.304	7.161	7.265	7.140	91.674	91.985	91.813	91.989	92.898	91.185
13.5	7.205	7.279	7.245	7.163	7.173	7.140	91.725	91.510	91.622	91.968	93.016	91.200
14.0	7.194	7.270	7.195	7.146	7.168	7.147	91.559	91.463	92.048	91.657	92.461	90.939
14.5	7.185	7.235	7.172	7.137	7.164	7.130	91.454	91.483	92.398	91.437	91.831	91.206
15.0	7.202	7.220	7.178	7.138	7.150	7.137	91.592	91.422	91.130	91.102	91.559	90.933
15.5	7.187	7.220	7.179	7.137	7.153	7.148	91.531	91.489	90.657	91.682	90.959	91.087
16.0	7.169	7.214	7.182	7.141	7.138	7.132	91.718	91.416	90.609	91.842	90.748	91.092
16.5		7.231	7.182	7.143	7.124	7.124		90.991	90.612	91.313	90.747	90.579
17.0			7.184		7.132				90.015		89.304	

that restricts the vertical transport of the effluent plume, inhibiting the vertical exchange of nutrients and other water properties, and reducing the initial dilution of the effluent plume.

Although winds were mild on the day of the March 2012 survey, the vertical structure of seawater characteristics was comparable to that of other upwelling periods due to the lingering effects of the sustained northwesterly winds that had prevailed for several weeks prior to the survey. The thermocline was no longer sharply defined; however, upwelling-induced gradients extending throughout the upper water column still remained, and are evident in the vertical profiles of the seawater properties shown in Figure 6. The upwelling-induced gradients appear as decreases in temperature (red lines), DO (dark blue lines), and pH (gold lines) with increasing depth down to 12 m. These decreases are mirrored by a pycnocline and halocline where density (black lines) and salinity (green line) steadily increase with depth. Specifically, the profiles exhibit a gradual vertical transition between a very thin, relatively uniform, near-surface mixed layer and a colder, saltier, nutrient-rich but oxygen-poor water mass immediately above the seafloor.

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 depleted their DO levels (dark blue lines). Additionally, in contrast to the relatively fresh surface waters associated with the southward-flowing California Current, the slightly elevated salinity at depth (green lines in Figure 6) was indicative of waters that originated in the Southern California Bight and had been carried northward by the Davidson Undercurrent.

Nutrient-rich seawater brought to the sea surface by upwelling facilitates phytoplankton blooms that produce oxygen, consume carbon dioxide (CO₂), and decrease water clarity. With increasing depth, respiration increases relative to photosynthesis, resulting in a corresponding increase in dissolved CO₂ (carbonic acid) and a concomitant decline in pH (olive-colored lines). Steadily increasing respiration with increasing depth also depleted DO concentrations near the seafloor relative to the sea surface (dark-blue lines). In contrast to the other seawater properties, water clarity (transmissivity) did not exhibit a consistent vertical structure (light-blue lines) during the March 2012 survey.

The influence of the effluent discharge can be seen in the vertical profiles of salinity recorded at Stations RW2 and RW3 (green lines in Figure 6bc). Typically, and as was the case during the March 2012 survey, the presence of dilute wastewater appears as a reduction in salinity. Discharge-related anomalies in seawater properties other than salinity are rare, and usually related to upward transport of deep ambient water that has mixed into the rising plume. For example, the profiles at RW2 and RW3 (Figure 6bc), and to a lesser extent at the more-distant Station RW1 (Figure 6a) reflect the influence of the rising effluent plume as it entrained the deeper water properties and moved them upward in the water column, resulting in a sharper, vertically compressed thermocline close to the sea surface. Because their locations were opposite the direction of plume transport, the three southerly receiving-water stations (RW4, RW5, and RW6 in Figure 6def) were not influenced by the effluent discharge. Therefore, their vertical profiles most accurately represent the ambient receiving water conditions at the time of the survey.

The presence of dilute effluent caused salinity to drop below 33.6‰ within the upper 9 m of the water column at RW2 and RW3. The plume dissipated further as it continued to rise through the water column and was carried northward by the prevailing flow, resulting in an even weaker and shallower salinity signature at RW1 (green line in Figure 6a). The vertical profiles indicate that the effluent plume did not

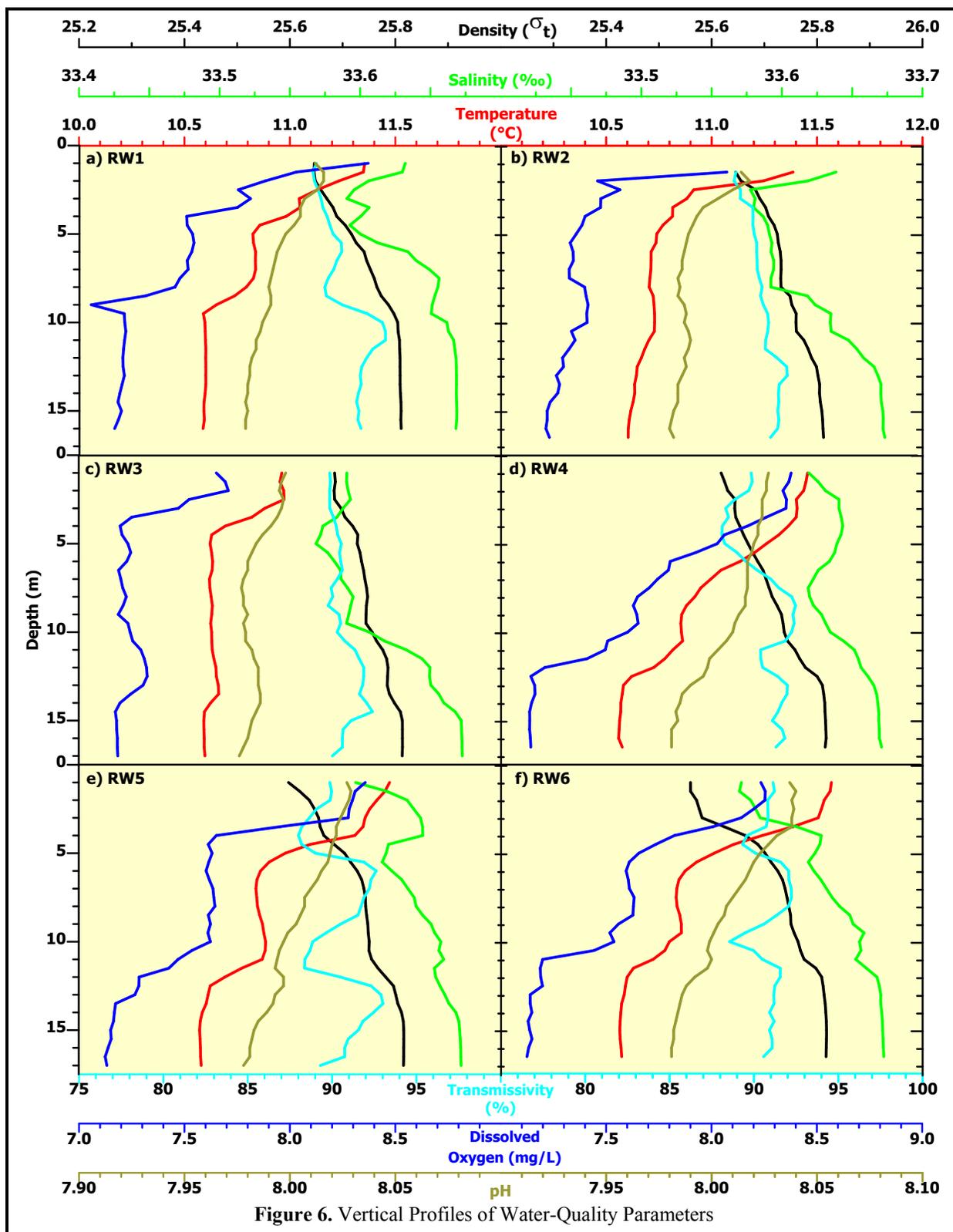


Figure 6. Vertical Profiles of Water-Quality Parameters

become trapped within the thermocline, but eventually reached the sea surface as it was transported slowly to the north.

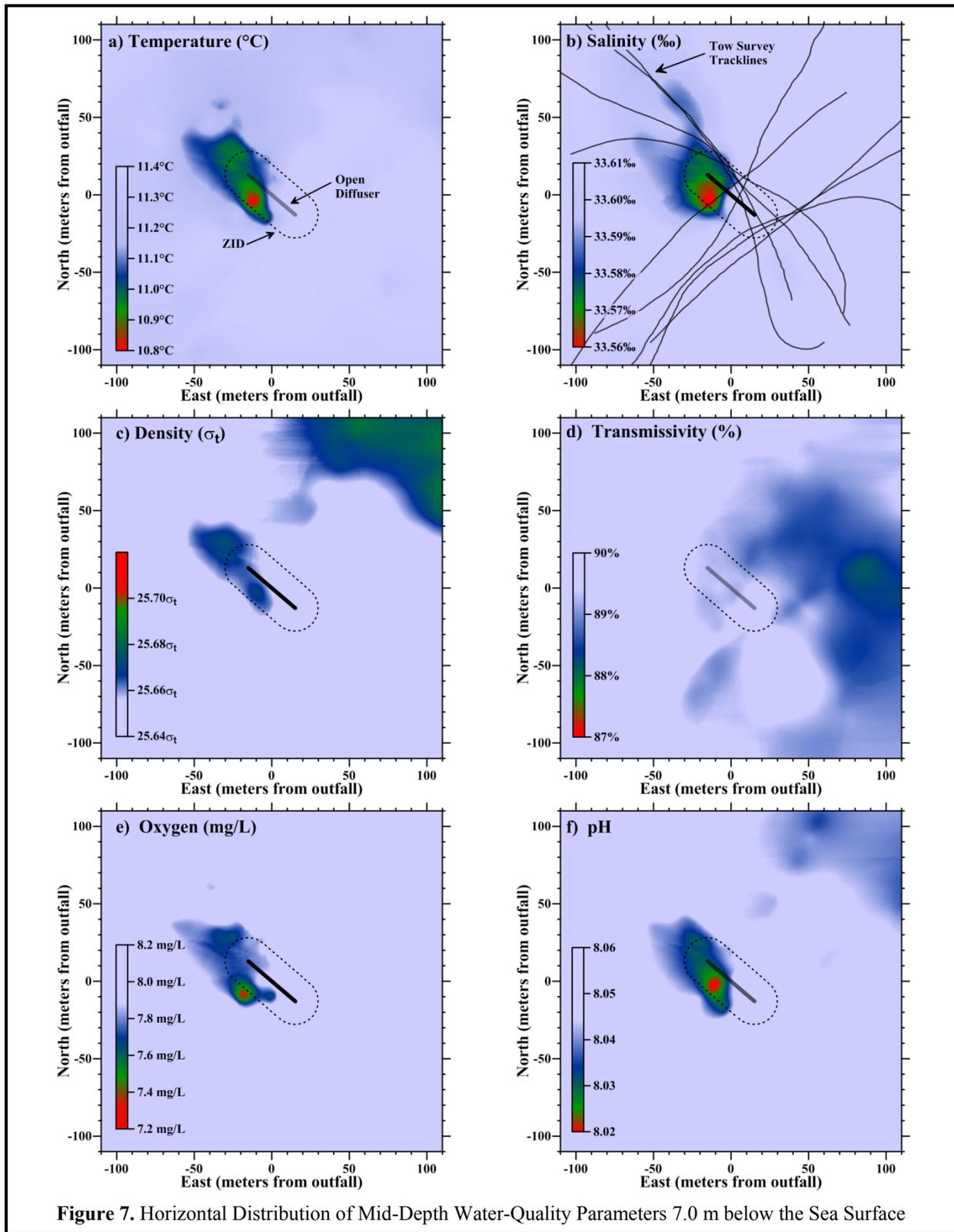
Although the plume reached the sea surface during the March 2012 survey, there was no visual evidence of its presence within the upper water column. This is because wastewater constituents had already become too dilute to reduce water clarity materially, and because the ambient transmissivity of seawater entrained within the plume near the seafloor was not tangibly different from that of the upper water column. Accordingly, the Secchi depths at Stations RW2 and RW3 did not differ significantly from stations (Table 4). Similarly, although all other water properties exhibited a clear plume signature near the diffuser structure in the horizontal maps generated by the tow survey (Figures 7abcef and 8abcef), there was no evidence of a corresponding transmissivity anomaly (Figures 7d and 8d). Instead, the slight variations in transmissivity apparent in the horizontal maps resulted entirely from the patchy distribution of ambient seawater properties at the time of the survey, and lacked any apparent relationship to outfall proximity.

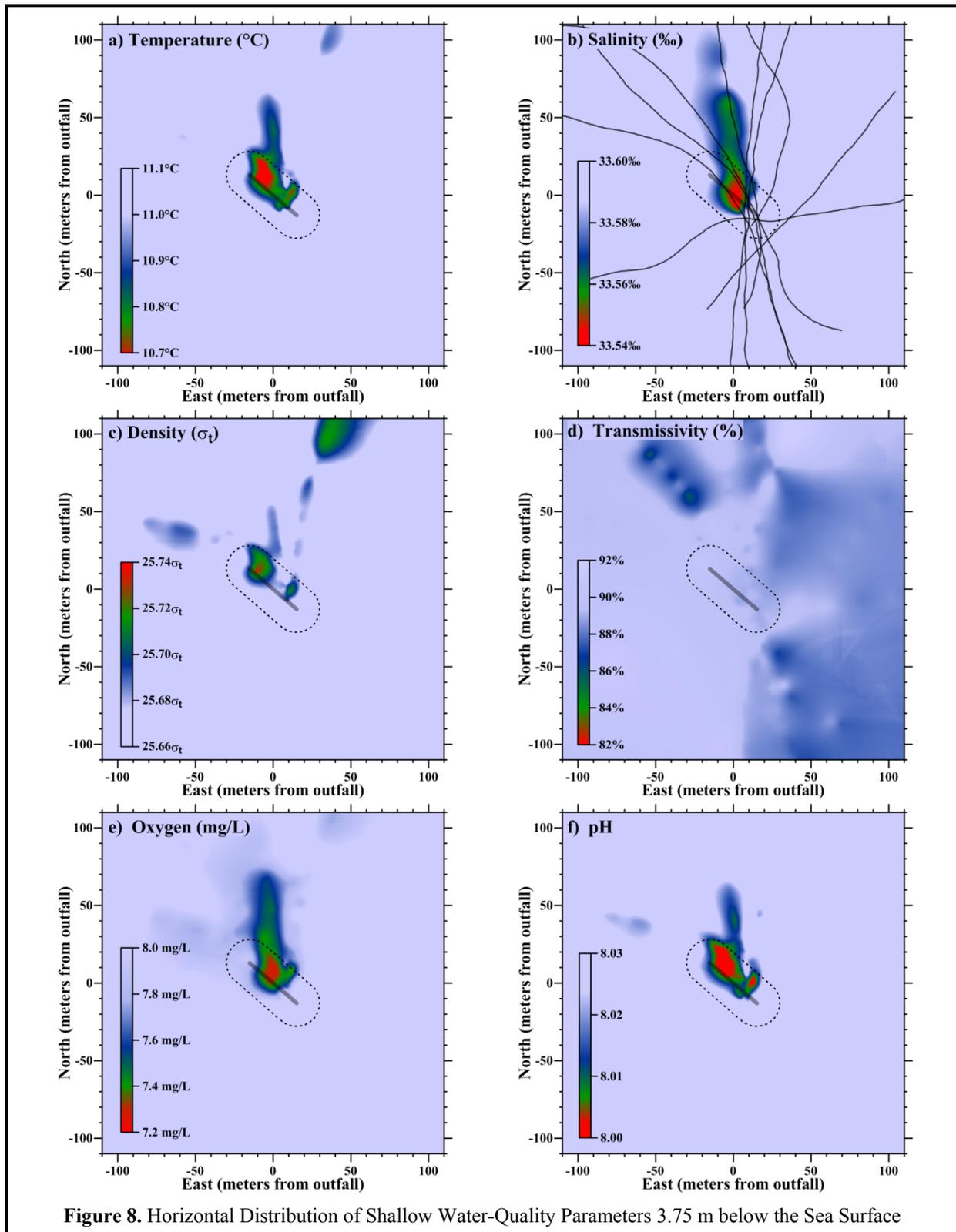
The plume signature in the horizontal tow data was located close to the diffuser structure and was largely restricted to the ZID. At mid-depth, where the drifter was drogued, diffuse portions of the plume signature extended toward the northwest (Figure 7) in a direction consistent with the current transport measured by the drifter. Near the sea surface, on the other hand, dilute portions of the plume tended to extend directly north (Figure 8), indicating the presence of vertical shear (baroclinicity) in the flow field that was unrelated to the Ekman spiral. In addition, the plume's sea-surface impingement resulted from the upward momentum of the rising plume rather than its buoyancy. The plume's buoyancy at mid-depth was nearly neutral, as is apparent from the horizontal density map (Figure 7c) where there was little contrast between the plume's density and that of the surrounding seawater ($\sim 0.02\sigma_t$). However, just below the sea surface (Figure 8c), the plume was clearly negatively buoyant ($\sim 0.06\sigma_t$) yet continued to rise to the sea surface. This reflects a common phenomenon when the water column is only moderately stratified; namely, the upward momentum of the rising effluent plume carries it past its neutral-equilibrium depth.

Lateral anomalies in the other three seawater properties, temperature, DO, and pH, coincided with the plume's salinity anomaly (Figures 7aef and 8aef). However, in contrast to the salinity anomaly, they were all generated by entrainment and upward transport of ambient seawater from near the seafloor rather than the presence of dilute wastewater constituents. Specifically, the lower temperature, DO, and pH of near-bottom seawater created lateral anomalies when they were displaced upward, and became juxtaposed against the ambient seawater in the upper water column. For example, wastewater discharged during the survey was much warmer (17°C) than receiving seawater ($<11.6^\circ\text{C}$), yet the thermal signature of the plume (Figures 7a and 8a) was actually cooler than the surrounding seawater. Similarly, the observed thermal anomalies were also opposite of those that would have been generated by the presence of warm wastewater particulates. Finally, the lower DO (Figures 7e and 8e) and pH (Figures 7f and 8f) within the plume are consistent with the DO and pH found at depth. The entrainment and upward movement of deep seawater with low DO and pH is visually apparent from a comparison between the blue and gold lines in Figures 6abc and those of Figures 6def.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the March 2012 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 additional buoyant mixing normally experienced with 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, spread laterally, and cease to rise in the water column and dilute further. A 9-m rise at the MBCSD outfall translates into a trapping depth that is 6.4 m below the sea surface. As described below, observed dilution levels were higher than the conservative model prediction, at depths greater than the trapping depth predicted by modeling where measured initial dilution levels would be expected to be much lower than the 133:1 of the modeling.

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 lower salinity are apparent near the diffuser structure in the tow-survey maps (Figures 7b and 8b) and above 10 m in the vertical profiles measured at Stations RW2 and RW3 (green lines in Figure 6bc). These localized salinity anomalies reflect the presence of dilute wastewater within the effluent plume as it rose through the water column and reached the sea surface.

By rearranging Equation 1, the dilution ratio (D) can be computed from the salinity anomaly ($A = C_o - C_s$) as:

$$D \equiv \frac{(C_e - C_o)}{(C_o - C_s)} \propto A^{-1} \quad \text{Equation 2}$$

The salinity concentration within MBCSD effluent (C_e)¹⁸ is generally small compared to that of the receiving seawater and, after dilution by more than 100-fold, the salinity of the effluent-seawater mixture is close to ambient salinity. Consequently, to a close approximation, dilution levels are inversely proportional to the amplitude of the salinity anomaly. Thus, reduced effluent dilution at a given location within receiving waters is directly reflected by a larger amplitude salinity anomaly.

The lowest salinity (33.529‰) measured during the March 2012 survey was recorded 4.2 m from the diffuser structure at a depth of 3.55 m during the second transect of the shallow tow survey (red shading in Figure 8b). This measured salinity corresponds to a 0.085‰ reduction below the mean ambient salinity of 33.614‰ that was measured at the same depth level, but well beyond the influence of the discharge. The salinity anomaly documents the presence of wastewater that has been diluted 315-fold (Figure 9). This is more than double the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater.

In addition, the lowest dilution was measured well within the ZID, where receiving-water limitations do not apply. Although the plume's negative salinity anomaly extended well beyond the ZID, and was apparent as much as 70 m from the outfall (Figure 8b), its amplitude was exceedingly small. In fact, dilutions of less than 550-fold were only found within the ZID (Figure 9).

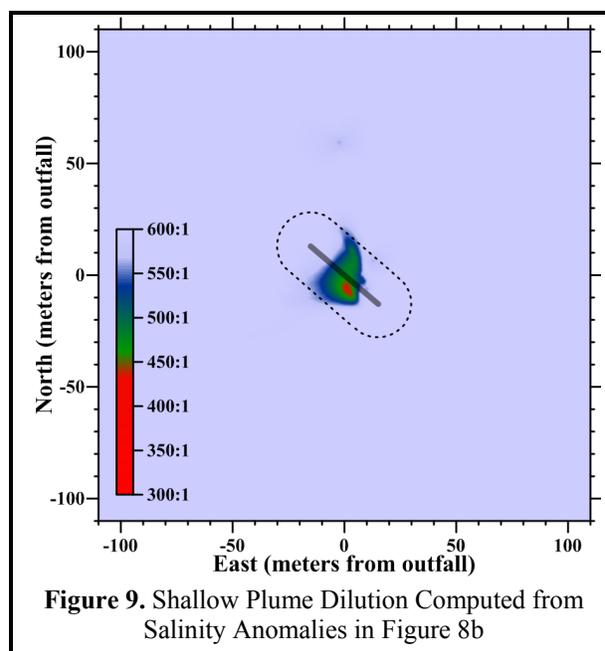


Figure 9. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 8b

Normally, the mid-depth survey would be expected to exhibit lower dilutions because full initial mixing had yet to be achieved. Additional dilution would result from the turbulence generated by the plume's subsequent rise through the rest of the water column. However, at mid-depth, the lateral extent of the plume was already so limited that it is likely that the tow tracklines missed the exact center of the plume. The spacing between the tracklines near the salinity anomaly at mid-depth (shown by dark lines in Figure 7b) was comparable to the localized lateral extent of the salinity anomaly. Consequently, the lowest measured salinity during the mid-depth tow corresponded to a dilution of 507-fold (Figure 10).

The dilution computations demonstrate that, during the March 2012 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 315-fold shortly after discharge, and

¹⁸ Wastewater samples collected during March 2012 had an average salinity of 0.995‰.

before completion of the initial-dilution process. This dilution level exceeds 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 March 2012 survey, the COP receiving-water objectives were being 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 compliance with the water-quality limits listed in the NPDES permit (Table 6). 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 beyond the ZID whose amplitudes can be reliably discerned against the backdrop of ambient fluctuations. 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.

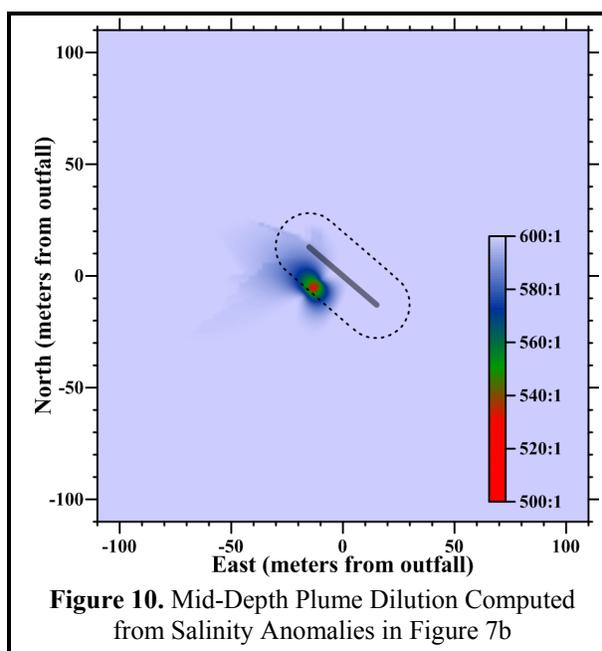


Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 7b

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% 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

The results of these analyses applied to the March 2012 data demonstrate that the MBCSD discharge complied with the NPDES discharge permit. Moreover, although observations within the ZID are not subject to compliance evaluations, they often meet the prescribed limits because dilution levels exceeded the conservative design specifications assumed in the discharge permit. Thus, the quantitative evaluation described in this section documents an outfall and treatment process that was performing at a high level during the March 2012 survey.

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 March 2012 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, in P5 and P6, the fixed numeric limits on absolute values of DO (>5 mg/L) and pH (7.0 to 8.3) can be directly compared with field measurements within the dilute wastewater plume beyond the ZID. However, both P5 and P6 also contain narrative limits, which originate in the COP, and define unacceptable water-quality impacts as “*significant*” excursions beyond those that occur “*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 a variety of oceanographic processes. These 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 and La Niña). 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 discharge-related changes that arise from the presence of wastewater constituents, which are subject to a compliance evaluation, from changes that arise because of the upward movement of ambient seawater, which are specifically excluded from the compliance evaluation.

Screening of Measurements

Evaluating whether any of the 13,615 CTD measurements collected during the March 2012 survey exceeded a permit limit can be 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, ongoing initial mixing within and beyond the ZID, or other anthropogenic influences (e.g. dredging or oil spills).

Because of this complexity, measurements were first screened to determine whether numerical limits on individual seawater properties apply (Table 7). The screening procedure sequentially applies three questions to restrict attention to: 1) the oceanic area where permit provisions apply; 2) changes due to the presence of wastewater particulates; and 3) changes large enough to be reliably detected against the backdrop of natural variation. The measurements that make it through the screening process, if any, can then be compared with Basin-Plan numerical limits and COP allowances. The following subsection provides additional lines-of-evidence that demonstrate compliance with numerical permit limits independent of the screening process. The rationale for evaluating observations for compliance analysis is provided in the following description of the three screening steps.

Table 7. Receiving-Water Measurements Screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer		Parameter
		No	Yes ¹⁹	
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	1,577	12,038	All
Wastewater Constituents	2. Did the beyond-ZID measurement coincide with a quantifiable salinity anomaly ($\leq 550:1$ dilution level) indicating the presence of detectable wastewater constituents?	12,032	6	All
Natural Variation	3. Did seawater properties associated with the wastewater measurements depart significantly from the expected range in ambient seawater properties at the time of the survey?	6	0	Temperature
		6	0	Transmissivity
		6	0	DO
		6	0	pH

1. Measurement 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 through the water column. Although currents often transport the plume beyond the ZID before the initial dilution process is complete, the COP 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, the regulatory mixing distance, which is equal to the 15.2-m water depth of the discharge, provides a conservative boundary to screen receiving-water data for subsequent compliance evaluation. Application of this initial screening question to the March 2012 dataset eliminated 1,577 of the original 13,615 receiving-water observations from further consideration because they were collected within the ZID (Table 7, Question 1). The remaining 12,038 observations were carried forward in the compliance analysis.

2. Presence of Wastewater Constituents: The MBCSD discharge permit restricts application of the numerical receiving-water limits to excursions caused by the presence of wastewater constituents. This confines the compliance analysis to changes caused “as the result of the discharge of waste,” as specified in the COP, rather than anomalies that arise from the movement of ambient seawater entrained in the effluent plume. Analyses conducted on quarterly receiving-water surveys over the last decade have demonstrated that the direct influence of dilute wastewater is almost never observed in any seawater property other than salinity, except very close (<1 m) to a diffuser port and within its ejection jet.

In fact, negative salinity anomalies are the only consistent indicator of the presence of wastewater constituents within receiving water. Wastewater salinity is negligible compared to that of the receiving seawater, so the presence of a distinct salinity minimum provides *de facto* evidence of the presence of wastewater constituents. Because of the large contrast between the nearly fresh wastewater and the salty receiving water, salinity provides a powerful tracer of dilute wastewater that is unrivaled by other seawater properties. Other properties do not exhibit such a large contrast and, as such, their wastewater signatures dissipate rapidly upon discharge with very little mixing. Wastewater’s lack of salinity, however, provides a powerful tracer that allows the presence of effluent constituents to be identified even

¹⁹ Number of remaining CTD observations of potential compliance interest based on this screening question

after dilution many times greater than the 133-fold critical initial dilution assumed in the discharge permit.

As described in the previous section, wastewater-induced reductions in salinity can be used to 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 reliability detected within receiving waters is 0.062‰. This represents a dilution level of 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. Eliminating those measurements from further evaluation restricts attention to excursions in temperature, light transmittance, DO, and pH that are potentially related to the presence of wastewater constituents. As shown in Figures 7b and 8b, the most significant salinity anomalies were largely restricted to the ZID, where 168 observations had significant reductions in salinity that unequivocally identified the presence of dilute wastewater constituents. In fact, of the 12,038 observations that were measured outside the ZID during the March 2012 survey, only 6 had reductions in salinity that were greater than 0.062‰ (Table 7).

3. Natural Variation: 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 (upward) 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 presence of wastewater constituents. Thus, quantifying the natural variability around the outfall is necessary for determining whether a particular observation warrants comparison with numeric permit limits.

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 (first three columns of Table 8). These ranges in natural variability were used to identify significant departures from ambient conditions that could be indicative of adverse discharge-related effects on water quality. 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 March 2012 ambient seawater data, to establish time-specific natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from March 2012 vertical profile data, excluding measurements potentially affected by the discharge.

Temperature, transmissivity, and DO concentrations associated with the six remaining measurements of potential compliance interest all remained within their respective ranges of natural variability (Table 7, Question 3). As such, the screening process unequivocally eliminated all of the CTD measurements collected during the March 2012 survey from further consideration. In fact, all of the documented excursions in these properties were the result of physical processes unrelated to the presence of wastewater constituents, namely, entrainment of near-bottom seawater within the rising effluent plume. During periods when the water column is stratified, such as during the March 2012 survey, ambient seawater properties near the seafloor differ from those within the rest of the water column, and their juxtaposition within the rising plume appears as lateral anomalies in the upper water column. As discussed previously, all of the anomalies in seawater properties that coincided with the salinity anomalies in Figures 7 and 8 were consistent with the upward displacement of ambient bottom water rather than with the presence of the effluent plume. Even if the presence of wastewater particulates had contributed to the measured decreases in DO and pH within the plume, their influence would have been

Table 8. Compliance Thresholds

Water Quality Property	95% Confidence Bound ²⁰	95 th Percentile ^{21,22}	Natural Variability Threshold ²³	COP Allowance ²⁴	Basin Plan Limit ²⁵	Extremum ²⁶
Temperature (°C)	0.82	11.43	>12.25	—	—	≤11.57
Transmissivity (%)	-10.2	88.5	<78.3	—	—	≥75.2
DO (mg/L)	-1.38	7.14	<5.76	<5.18	<5.00	≥6.99
pH (minimum)	-0.094	7.979	<7.885	<7.685	<7.000	≥7.976
pH (maximum)	0.094	8.027	>8.121	>8.321	>8.300	≤8.077

well within the natural range in ambient seawater properties at the time of the survey. Consequently, their influence on water quality cannot be considered environmentally significant.

Other Lines of Evidence

In addition to the analysis provided above, several additional lines of evidence support the conclusion that all the CTD measurements collected during the March 2012 survey complied with permit limits P3 through P6 in Table 6. In combination, these lines of evidence provide the “best explanation” of the origin and significance of individual measurements 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 concurrences. A best explanation approach serves to limit the uncertainty associated with each individual CTD measurement and provide a more robust compliance assessment. Together, these lines of evidence significantly strengthen the conclusion that the discharge fully complied with the permit during the March 2012 survey.

Natural Variability in other Seawater Properties: Although the permit limits only apply to changes in DO, pH, temperature and transmissivity, a comparative evaluation of changes in the remaining seawater properties (salinity and density) frequently provides additional valuable insight into the origins of any variations observed during a particular survey. For example, during the March 2012 survey, salinity was virtually the only seawater property that exhibited a perceptible difference from ambient conditions. Although three anomalously low transmissivity measurements were recorded, they were located 83 m north-northwest of the diffuser (refer to the isolated dark bluish-green dots in Figure 8d). These isolated

²⁰ 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.

²¹ 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% confidence level.” Accordingly, COP effluent analyses (Step 9 in Appendix VI, Page 42, Ibid.) are based “the one-sided, upper 95% confidence bound for the 95th percentile.”

²² The 95th-percentile quantifies natural variability in seawater properties during the October 2010 survey, and was determined from vertical profiles excluding RW3 and RW4 where there were possible influences from the discharge.

²³ 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 October 2010 survey. They do not include the COP allowances specified in the column to the left.

²⁴ 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.”

²⁵ 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.

²⁶ Maximum or minimum value measured during this survey

transmissivity reductions were not associated with the discharge because they did not coincide with anomalies in other water properties, including salinity, and because they were sharply defined rather than part of gradual trend indicative of a plume encounter. Instead, the anomalies were characteristic of random encounters with debris (including kelp or jellyfish) within the water column that briefly blocks the transmissometer's light path.

Regardless of their association with the effluent salinity signature, none of the 13,615 temperature, DO, pH, or 13,612 transmissivity observations exceeded the thresholds of natural variability specified in Table 8. This includes measurements collected within the ZID that were clearly associated with the presence of wastewater constituents, but were eliminated from further compliance consideration by the first screening question in Table 7.

Insignificant Thermal Impact: Although there are no explicit numerical objectives for discharge-related decreases in temperature, a numerical limit can be established for thermal excursions, which are not allowed to adversely affect beneficial uses (P3 in Table 6). Increases in temperature caused by the discharge of warm wastewater constituents would not be deemed to adversely affect beneficial uses if they remained within the natural temperature range at the time of the survey (less than 12.25°C in Table 8). Such was the case for all 13,615 CTD measurements collected during the March 2012 survey, none of the measured temperatures exceeded 11.6°C. In fact, as mentioned previously, because the effluent entrained cooler bottom water shortly after discharge, the rising plume actually had a lower temperature than the surrounding seawater (Figures 7a and 8a).

Insignificant Wastewater Particulate Loads: The discharge of wastewater particulates on 16 March 2012 did not contribute materially to turbidity within the dilute effluent plume. The suspended-solids concentration measured onshore within effluent prior to discharge was 21 mg/L. After dilution by 315-fold, which was the lowest dilution measured during the survey, the effluent TSS concentration would have the reduced ambient transmissivity by only 0.5%. Similarly, the MBCSD discharge could not have contributed materially to the observed DO fluctuations. The MBCSD treatment process routinely removes 80% or more of the organic material, as demonstrated by the low, 44-mg/L BOD measured within the plant's effluent around the time of the survey. That small amount of BOD would have induced a DO depression of no more than 0.023 mg/L after dilution (MRS 2003). In fact, in the absence of tangible BOD influence, wastewater constituents would actually be expected to increase DO within subsurface receiving waters, rather than decrease it. This is because effluent is oxygenated by recent contact with the atmosphere during the treatment process, whereas receiving waters at depth are typically depleted in DO.

COP Allowances: The COP does not explicitly require that wastewater-induced changes remain within the ranges in natural variation listed in the third column of Table 8, even though these ranges were conservatively used in the data screening process described in the previous subsections. For pH, the COP and the discharge permit allow changes up to 0.2 pH units from natural conditions, bringing the minimum allowed pH to 7.885 during the March 2012 survey. This value is well below the lowest pH measurement of 7.976 recorded during the March 2012 survey. Similarly, the lowest DO concentration measured during the survey (7.0 mg/L) was well above both the lower range in natural variation (5.76 mg/L) and the 10% compliance threshold promulgated by the COP (5.18 mg/L).

CONCLUSIONS

The statistical screening analysis quantitatively demonstrated that all measurements recorded during the March 2012 survey complied with the receiving-water limitations specified in the NPDES discharge permit. This conclusion was further strengthened by other lines of evidence supporting compliance with the discharge permit. Although the presence of dilute wastewater constituents was delineated from salinity

anomalies within a discharge plume, all the associated seawater properties were within the natural variability that prevailed at the time of the survey.

Immediately after discharge, the outfall was achieving dilution levels in excess of 315-fold, which substantially exceeded the critical dilution levels predicted by design modeling. As the plume rose through the water column it was transported slowly toward the north, becoming more and more diffuse, and achieving dilution levels exceeding 525-fold. Lastly, all of the auxiliary observations collected during the March 2012 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 discharge-related changes in seawater properties were observed during the March 2012 survey, the changes were either not of significant magnitude, were measured within the boundary of the ZID where initial mixing is still expected to occur, or were not directly caused by the presence of wastewater constituents within the water column.

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