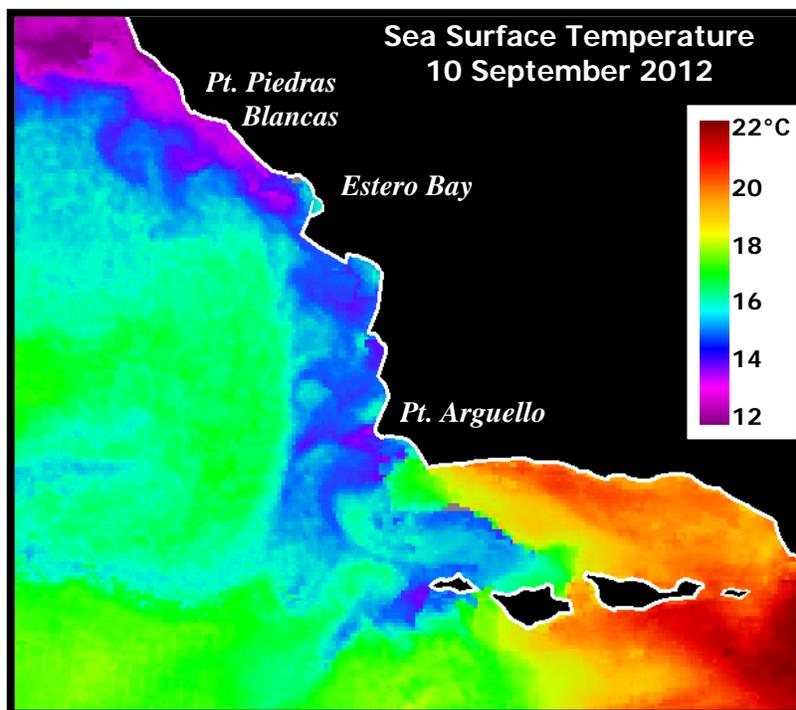


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

**THIRD QUARTER
RECEIVING-WATER SURVEY
SEPTEMBER 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**

**THIRD QUARTER
RECEIVING-WATER SURVEY
SEPTEMBER 2012**

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

26 October 2012

Reference: Third Quarter Receiving-Water Survey Report – September 2012

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Friday, 14 September 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.

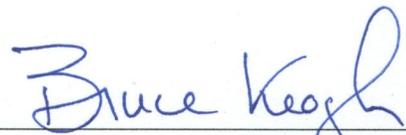
Please contact the undersigned if you have questions regarding the attached report.

Sincerely,



Bonnie Luke
Program Manager

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



Mr. Bruce Keogh
Wastewater Division Manager
City of Morro Bay

Date Oct 26, 2012

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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 September 2012 field survey described in this report was the fourteenth 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 14 September 2012. Specifically, this third-quarter survey captured ambient oceanographic conditions along the central California coast during the late summer 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)



Figure 1. Location of the Receiving-Water Survey Area

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. 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.

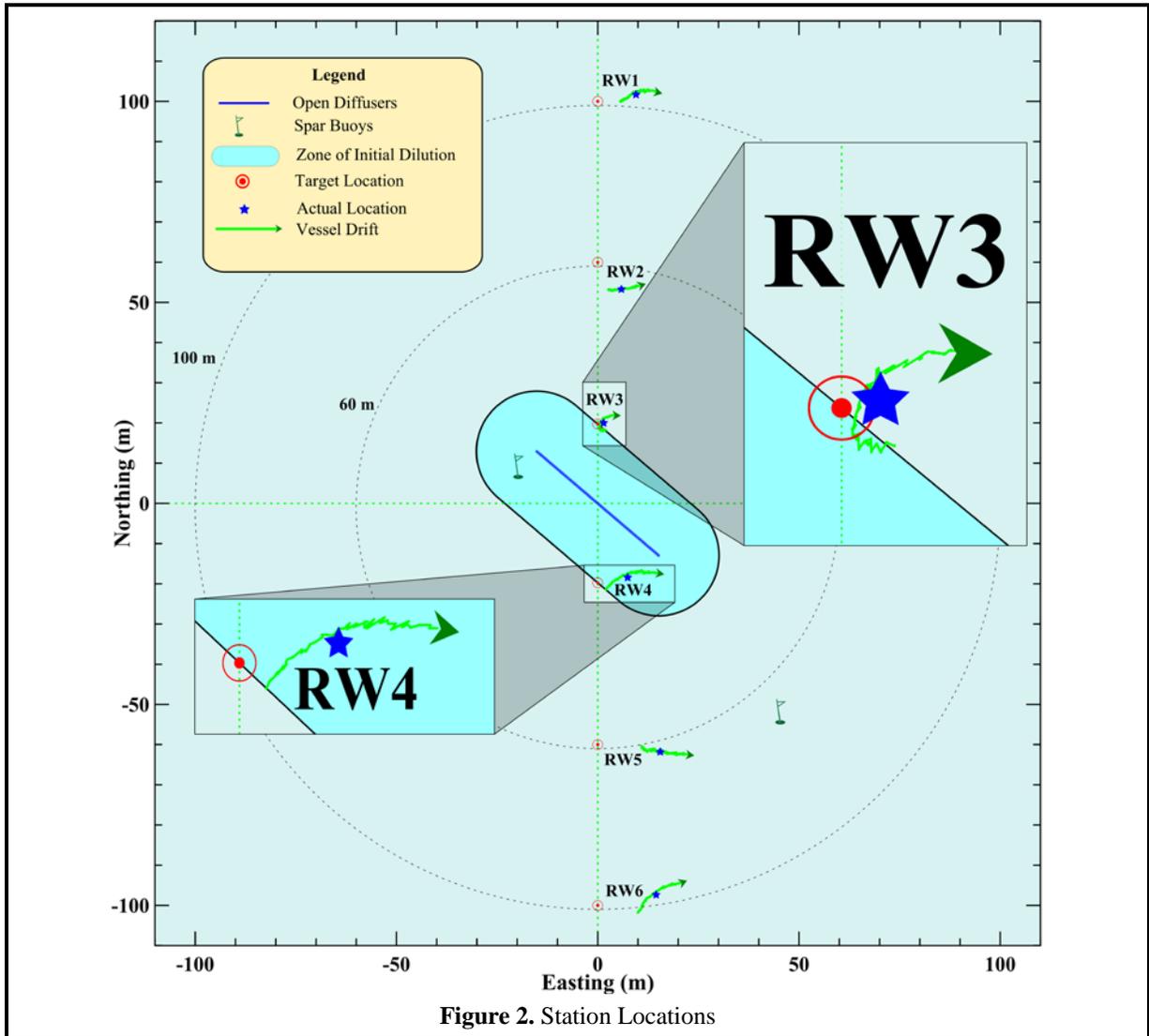


Figure 2. Station Locations

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.

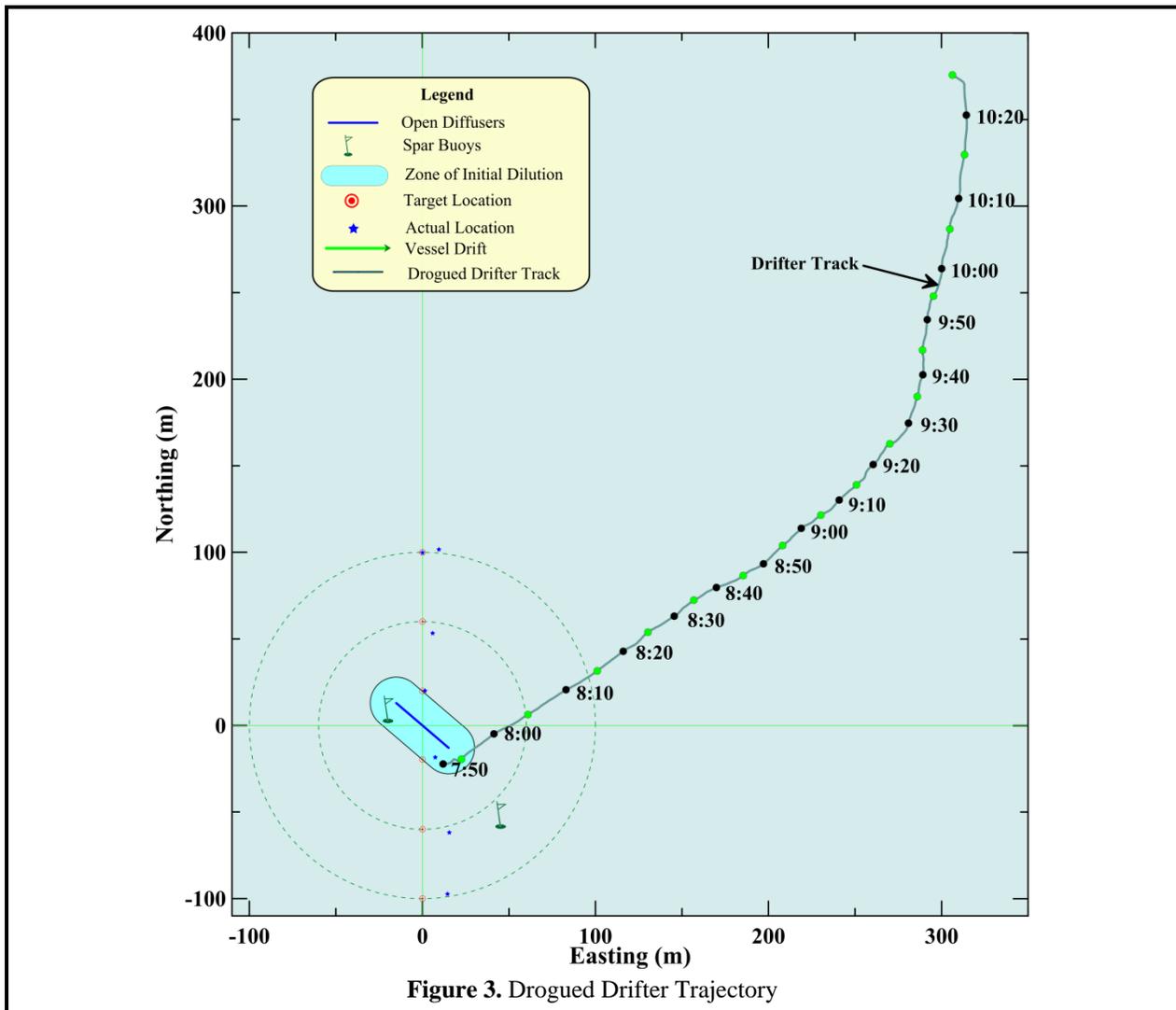
Recording of DGPS positions at one-second intervals allows precise determination of sampling locations throughout the vertical CTD profiling conducted at the six individual stations, as well as during the tow survey. Knowledge of the precise location of individual CTD measurements relative to the diffuser 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 September 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 September 2012 survey. During the time it took the CTD to traverse the water column and reach the seafloor, which averaged 1 minute 30 seconds, the instrument package moved an average of 9.9 m. This amount of drift is comparable to that of most prior surveys conducted under similar 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 September 2012 survey. Although winds generally affect the vessel's ability to maintain station to a greater degree than does current flow, this was not the case during the September 2012 survey as winds were light. Instead, the distinctive easterly drift component that was evident in the CTD trajectories at all six stations was consistent with northeastward transport of the drogued drifter by subsurface currents (Figure 3). The CTD's trajectory was also influenced by the residual momentum from the survey vessel's approach to each station. For example, in contrast to the other five stations, the survey vessel approached Station RW3 from the east (rightmost inset in Figure 3). The residual momentum of the vessel resulted in an initial westerly trajectory for the CTD that began outside the ZID at the sea surface, but moved into the ZID as the CTD began its descent through the water column. However, as the vessel's momentum dissipated, the influence of the flow-field became apparent, shifting the CTD's trajectory north and eastward. This reversal rapidly moved the CTD back outside the boundary of the ZID.

Not surprisingly, assessing compliance at Stations RW3 and RW4, which are closest to the diffuser structure, can be complicated by CTD drift during the downcasts, and by offsets from the target sampling locations, which are located on the ZID boundary. 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 complete. Consequently, during the September 2012 survey, none of the data collected at Station RW4 were subject to the limitations because the CTD was within the ZID boundary throughout the hydrocast, while only some of the measurements acquired in the upper portion of the water column at Station RW3 were subject to the limitations.

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



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 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 September 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 September 2012 Survey

Station	Time (PDT)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ⁵ (m)	Bearing ⁶ (°T)
RW1	8:31:15	8:32:49	35° 23.254' N	120° 52.498' W	92.2	16
RW2	8:25:14	8:26:38	35° 23.228' N	120° 52.500' W	45.5	27
RW3	8:19:22	8:20:53	35° 23.210' N	120° 52.503' W	16.3 ⁷	41
RW4	8:13:46	8:15:25	35° 23.189' N	120° 52.499' W	9.1 ⁸	221
RW5	8:06:49	8:08:18	35° 23.166' N	120° 52.494' W	48.8	180
RW6	8:00:10	8:01:36	35° 23.146' N	120° 52.494' W	84.3	180

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 the oceanic flow during the September survey (Figure 3). Modeled after the curtain-shade design of Davis et al. (1982) and drogued at mid-depth (7 m), a drifter has 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 7:50, and was recovered 2 hours 33 minutes later, at a location 495 m northeast of its initial location (Figure 3). The black dots in Figure 3 show the drifter's progress at ten-minute intervals, and their uniform spacing reflects the relatively constant speed of the drifter, which averaged 6 cm/s, or 0.12 knots. At this speed, the plume's residence time within the ZID was only four minutes.

The initial east-northeastward (onshore) flow direction was consistent with the flood tide that prevailed during the vertical-cast portion of the survey (Figure 4). However, with the onset of the slack tide that began at approximately 9:30, the drifter's direction shifted nearly 45 degrees, until it was traveling almost due north. This new flow regime persisted throughout the remainder of the survey, resulting in a northerly offset in the plume signature that was captured at mid-depth during the tow portion of the survey.⁹

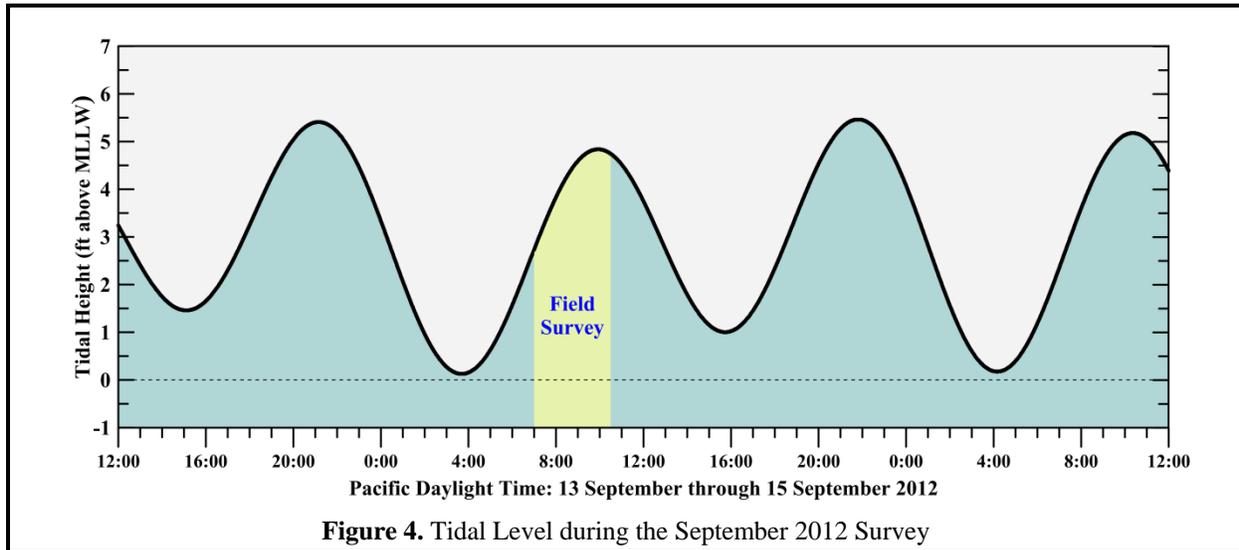
⁵ Distance from the closest open diffuser port to the average profile location.

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

⁷ Some of the shallow CTD measurements at Station RW3 were located within the ZID boundary (refer to the rightmost inset in Figure 2).

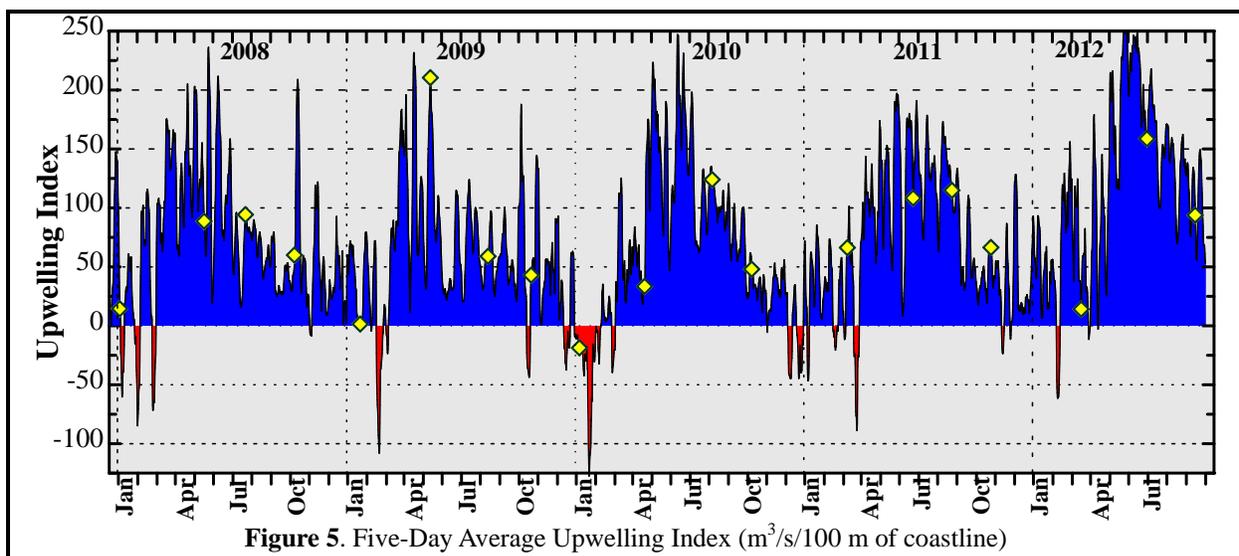
⁸ All of CTD measurements at Station RW4 were located within the ZID boundary (refer to the other inset in Figure 2).

⁹ See the horizontal distribution of seawater properties recorded during the mid-depth tow that is shown in Figure 8.



Despite the co-occurrence between tidal changes and flow-direction during the September 2012 survey, 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 example, can induce a southerly (offshore) flow in the upper water column, and a northerly (onshore) flow at depth. Moderate upwelling conditions prevailed around the time of the September 2012 survey (Figure 5).

Upwelling season normally begins sometime during late March and or early April as shown by the positive (blue) upwelling indices in Figure 5. 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 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 5, 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.

The satellite image on the cover of this report documents the influence of upwelling on sea-surface temperatures around the time of the September 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 (<16.0°C) within Estero Bay were comparable to the near-surface temperatures measured by the CTD during the September 2012 survey.¹⁰

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, 14 September 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.

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.

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 September 2012 survey. The six seawater properties used to assess receiving-water quality in this report

¹⁰ Refer to Table 5 and Figure 7 for receiving-water properties recorded during the vertical hydrocasts.

were derived from the continuously recorded output from the CTD's probes and sensors. Although pressure-housing limitations confine the CTD to depths less than 680 m (Table 3), this 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) ¹¹	%	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 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).

Assessments of 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. 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 the first vertical hydrocast at Station RW6, the CTD was held below the sea surface for six minutes. 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 8:33, following the last vertical profile at RW1, 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 the CTD was deployed, it was towed around and across the ZID at two separate depths, one within the surface mixed layer and one at mid-depth below the thermocline, in accordance with the monitoring requirements of the NPDES discharge permit (Figure 6).

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

Initially, the reconfigured CTD package was towed for 40 minutes at an average depth of 7.86 m, and an average speed of 1.76 m/s, passing over, or near the diffuser structure eight times. Subsequently, eight additional passes were made with the CTD at an average depth of 10.13 m. During this 41-minute mid-depth-tow, vessel speed averaged 1.79 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.¹²

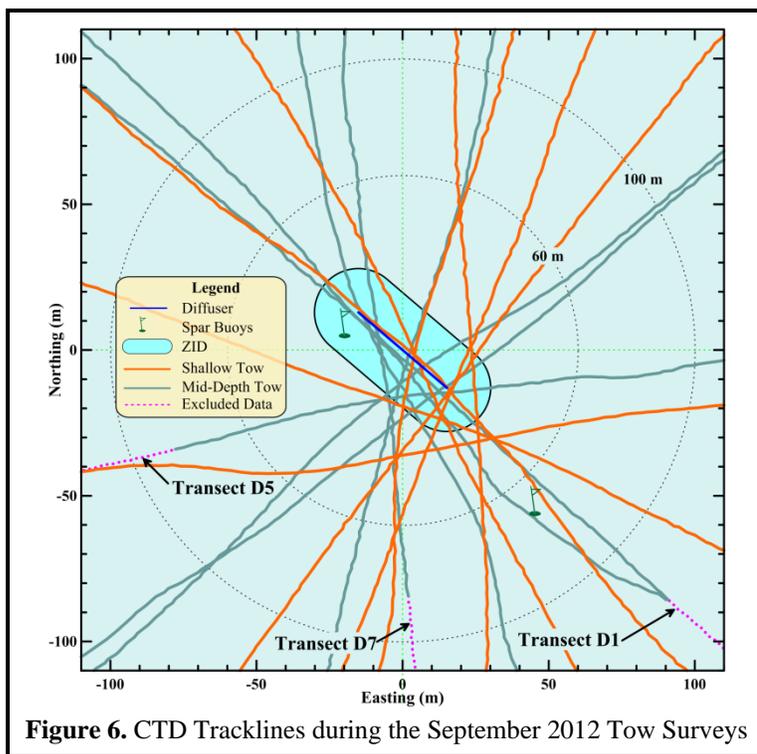


Figure 6. CTD Tracklines during the September 2012 Tow Surveys

Quality Control

Upon retrieval of the CTD following the tow survey, water-quality data were examined for completeness and range acceptability. Although real-time monitoring indicated the recorded properties were complete and within acceptable coastal seawater ranges,¹³ subsequent post-processing 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 (>1 m offset) during the latter portions of the mid-depth tows along Transects D1, D5, and D7 (purple dotted lines in Figure 6).

These depth fluctuations were induced by changes in vessel speed that were instituted to prevent the CTD from colliding with the seafloor during the execution of the turns used to align the vessel between each transect. Because of the complex interaction between turn radius, vessel speed, and CTD depth, the CTD's target depth could not be precisely maintained at these times.

Because the discharge-related anomalies used in the compliance analysis 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 depth levels are combined. This is particularly true when the water column is stratified, as was the case during the September 2012 survey.

The exclusion of small portions of Transects D1, D5, and D7 did not, however, adversely affect the compliance analysis because the remaining transects adequately covered the survey region. Specifically,

¹² Figures 8 and 9 later in this report

¹³ Field sampling protocols employed during the September 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.

the remaining data, shown by the solid orange and blue lines in Figure 6, met the permit monitoring requirement of at least five passes near the diffuser structure at each tow depth.

Quality-control screening of the vertical profile data was also 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 physical dimensions, 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. These height fluctuations are caused by wave and tidal-induced oscillations during its deployment at each station. For example, during the September 2012 survey, data on average seawater properties could not be reported within the deepest depth bin (17 m) except at Station RW4.¹⁴ Because this isolated observation within the deepest depth bin cannot quantify a horizontal trend, it was excluded from the subsequent compliance evaluation.

RESULTS

The third-quarter receiving-water survey was conducted on the morning of Friday, 14 September 2012. The receiving-water survey commenced at 7:50 with the deployment of the drogued drifter. Over the following three hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended at 10:24 with the retrieval of the drogued drifter. The collection of required visual observations of the sea surface was unencumbered throughout the survey, although, as during the March and June 2012 surveys, fog obscured views of both the shoreline and Morro Rock during the survey, generally restricting observations of beneficial uses to within a quarter mile of the survey vessel.

Auxiliary Observations

On the morning of 14 September 2012, skies were overcast, with only light and variable northwesterly winds. Average wind speeds, calculated over one-minute intervals, ranged from 0.8 kt to 3.9 kt (Table 4). Similarly, peak wind speeds ranged from 1.9 kt to 6.2 kt. The swell was out of the northwest with a significant wave height of 3 feet. A southerly swell with a significant wave height of 1 to 2 feet was also present. Air temperatures remained fairly constant throughout the survey, averaging approximately 13.2°C.

The 4 m Secchi depths recorded during the September 2012 survey reflected the presence of a shallow 8 m euphotic zone that spanned less than half of the 16.5-m water column (Table 4). The limited water clarity in the upper water column was associated with upwelling, which carries nutrients upward into the

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location ¹⁵		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° 52.485' W	103.1	8:34:47	13.1	100	2.0	2.5	NW	3 NW	4.0
RW2	35° 23.245' N	120° 52.488' W	82.0	8:28:25	13.6	100	0.8	1.9	NW	3 NW	4.0
RW3	35° 23.215' N	120° 52.493' W	33.6	8:22:15	12.7	100	3.2	4.3	NW	3 NW	4.0
RW4	35° 23.192' N	120° 52.487' W	11.6	8:16:56	13.2	100	2.4	3.9	NW	3 NW	4.0
RW5	35° 23.163' N	120° 52.494' W	52.9	8:10:57	13.1	100	3.9	6.2	NW	3 NW	4.0
RW6	35° 23.153' N	120° 52.483' W	74.7	8:03:06	13.5	100	2.2	3.0	NW	3 NW	4.0

¹⁴ Refer to Table 5 later in this report.

¹⁵ 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.

euphotic zone where phytoplankton populations can assimilate them. The resulting increase in phytoplankton densities, along with their associated zooplanktonic predators, reduce the transmittance of ambient light during upwelling events.

Despite the limited visibility within the upper water column, there was no evidence of floating particulates, oil sheens, or any discoloration of the sea surface associated with wastewater-related constituents during the survey.

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 0.911 million gallons of effluent discharged on the day of the survey had a temperature of 22°C, a suspended-solids concentration of 23 mg/L, and a pH of 7.6. Biochemical oxygen demand (BOD) measured in an effluent sample collected two days before the survey was 40 mg/L.

During the September 2012 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. Observations of the adjacent beach and Morro Rock were restricted during the majority of the September 2012 survey due to fog; however, small numbers of Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), western gulls (*Larus occidentalis*), and California brown pelicans (*Pelecanus occidentalis californicus*) were noted transiting the survey area. Several pairs of Elegant terns (*Thalasseus elegans*) and a pair of red-necked phalaropes (*Phalaropus lobatus*) were observed foraging in the survey area, while numerous sea lions (*Zalophus californianus*), and southern sea otters (*Enhydra lutris nereis*) were observed within and just outside of the mouth of the harbor. During the towed portion of the survey, a large number (>100) of sooty shearwaters (*Puffinus griseus*) were observed to aggregate in the waters inshore of the survey area.

During the tow portion of the survey, a small recreational fishing boat and a kelp cutter were also observed offshore of the survey area, while pedestrians were visible along Atascadero State beach.

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 September 2012 survey reflect the presence of a strongly stratified water column indicative of upwelling conditions that had prevailed within Estero Bay throughout much of the spring and summer (Figure 5).

Upwelling of varying intensity occurs most of the year along the central California coast, with the strongest upwelling 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 a small vertical distance. 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 the initial dilution of the effluent plume.

Although winds were mild on the morning of the September 2012 survey, the upwelling signature of the strong, sustained winds that had been present in the days prior to the survey (Figure 5) was still readily apparent in the vertical structure of the Estero Bay seawater characteristics (Figure 7). Specifically, the strong water-column stratification was comparable to that found at the onset of intense upwelling, when a sharply defined thermocline forms within the upper 15-m of the water column throughout the survey area.

Table 5. Vertical Profile Data Collected on 14 September 2012

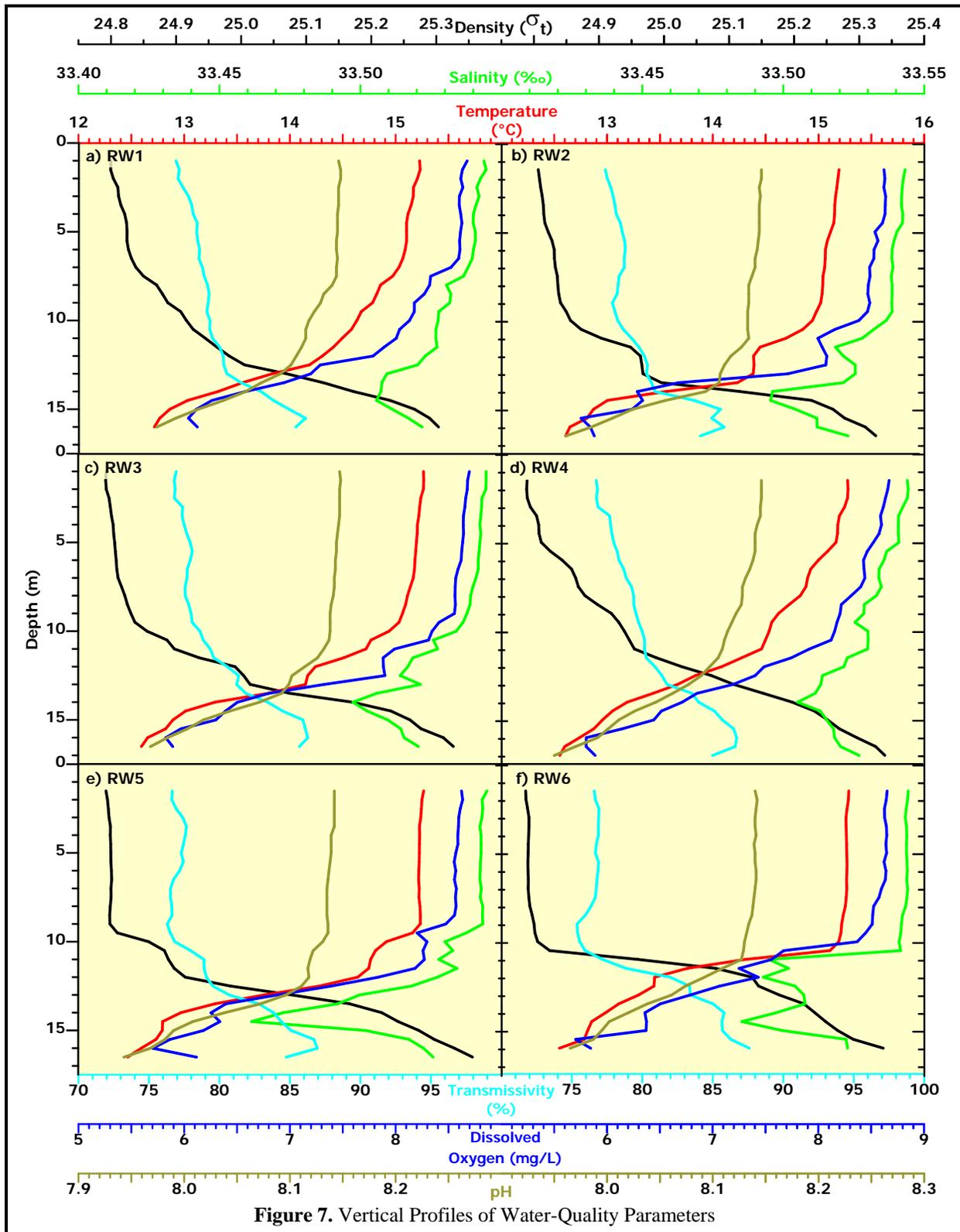
Depth (m)	Temperature (°C)						Salinity (‰)					
	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6	RW-1	RW-2	RW-3	RW-4	RW-5	RW-6
1.0	15.227	15.203	15.263				33.544	33.544	33.545			
1.5	15.232	15.194	15.266	15.275	15.265	15.286	33.545	33.543	33.545	33.544	33.545	33.544
2.0	15.206	15.184	15.262	15.279	15.249	15.283	33.543	33.543	33.545	33.544	33.543	33.544
2.5	15.169	15.173	15.238	15.274	15.244	15.270	33.541	33.542	33.543	33.544	33.543	33.544
2.0	15.167	15.161	15.228	15.247	15.238	15.260	33.542	33.542	33.543	33.542	33.543	33.543
2.5	15.147	15.154	15.219	15.198	15.226	15.261	33.541	33.542	33.543	33.541	33.542	33.544
4.0	15.117	15.152	15.206	15.182	15.228	15.264	33.540	33.542	33.542	33.541	33.543	33.544
4.5	15.103	15.145	15.204	15.180	15.225	15.265	33.540	33.542	33.543	33.541	33.543	33.544
5.0	15.103	15.114	15.196	15.165	15.224	15.267	33.541	33.540	33.542	33.541	33.543	33.544
5.5	15.104	15.084	15.190	15.085	15.223	15.270	33.541	33.539	33.542	33.537	33.543	33.544
6.0	15.091	15.066	15.183	14.998	15.219	15.269	33.540	33.539	33.542	33.536	33.543	33.544
6.5	15.068	15.063	15.179	14.926	15.217	15.265	33.540	33.539	33.542	33.534	33.542	33.544
7.0	15.032	15.058	15.167	14.897	15.223	15.268	33.538	33.539	33.541	33.534	33.543	33.544
7.5	14.972	15.042	15.139	14.880	15.221	15.262	33.537	33.538	33.540	33.535	33.543	33.544
8.0	14.857	15.040	15.112	14.827	15.230	15.254	33.531	33.539	33.539	33.533	33.543	33.543
8.5	14.822	15.034	15.094	14.722	15.234	15.234	33.532	33.539	33.539	33.529	33.543	33.542
9.0	14.782	15.020	15.065	14.622	15.233	15.219	33.532	33.539	33.538	33.529	33.543	33.542
9.5	14.675	14.980	15.032	14.557	15.161	15.212	33.528	33.539	33.536	33.525	33.538	33.542
10.0	14.633	14.942	14.938	14.533	14.912	15.191	33.528	33.537	33.534	33.530	33.530	33.541
10.5	14.582	14.852	14.766	14.498	14.809	15.108	33.527	33.532	33.526	33.530	33.533	33.542
11.0	14.494	14.692	14.720	14.461	14.763	14.305	33.527	33.528	33.527	33.530	33.528	33.495
11.5	14.411	14.448	14.508	14.273	14.745	13.760	33.527	33.519	33.519	33.523	33.534	33.502
12.0	14.307	14.386	14.241	14.084	14.641	13.450	33.523	33.521	33.517	33.522	33.527	33.493
12.5	14.185	14.390	14.169	13.837	14.280	13.444	33.520	33.526	33.514	33.514	33.518	33.504
12.0	13.833	14.382	14.148	13.667	13.759	13.299	33.509	33.526	33.521	33.513	33.500	33.507
12.5	13.552	14.234	13.798	13.436	13.291	13.111	33.508	33.521	33.506	33.511	33.492	33.508
14.0	13.321	13.556	13.292	13.190	12.968	12.986	33.507	33.496	33.497	33.505	33.473	33.498
14.5	13.034	13.004	13.014	13.051	12.796	12.855	33.506	33.496	33.502	33.513	33.461	33.485
15.0	12.864	12.872	12.894	12.957	12.793	12.817	33.511	33.504	33.510	33.515	33.502	33.500
15.5	12.770	12.811	12.825	12.875	12.735	12.784	33.517	33.512	33.514	33.518	33.517	33.522
16.0	12.718	12.649	12.655	12.740	12.595	12.549	33.522	33.512	33.516	33.518	33.522	33.523
16.5		12.608	12.595	12.600	12.465			33.523	33.521	33.520	33.526	
17.0				12.552					33.527			

Table 5. Vertical Profile Data Collected on 14 September 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	24.800	24.805	24.793				8.146	8.146	8.147			
1.5	24.799	24.807	24.792	24.790	24.792	24.787	8.148	8.146	8.148	8.146	8.142	8.140
2.0	24.804	24.809	24.793	24.789	24.795	24.788	8.148	8.146	8.147	8.146	8.142	8.142
2.5	24.811	24.810	24.797	24.790	24.796	24.790	8.146	8.144	8.147	8.146	8.142	8.141
2.0	24.812	24.813	24.799	24.795	24.797	24.792	8.146	8.145	8.147	8.145	8.142	8.140
2.5	24.815	24.815	24.801	24.804	24.799	24.792	8.146	8.144	8.147	8.145	8.142	8.140
4.0	24.821	24.815	24.803	24.807	24.799	24.792	8.145	8.144	8.146	8.142	8.139	8.141
4.5	24.824	24.817	24.804	24.808	24.800	24.791	8.145	8.144	8.145	8.140	8.139	8.139
5.0	24.825	24.822	24.806	24.811	24.800	24.791	8.145	8.144	8.144	8.140	8.139	8.140
5.5	24.825	24.828	24.807	24.825	24.800	24.791	8.144	8.143	8.144	8.140	8.138	8.140
6.0	24.827	24.831	24.808	24.844	24.801	24.791	8.144	8.142	8.143	8.138	8.137	8.141
6.5	24.831	24.832	24.809	24.858	24.801	24.792	8.145	8.140	8.143	8.135	8.136	8.141
7.0	24.838	24.833	24.811	24.864	24.800	24.791	8.144	8.140	8.142	8.131	8.135	8.140
7.5	24.850	24.836	24.816	24.868	24.800	24.792	8.144	8.137	8.142	8.128	8.135	8.139
8.0	24.870	24.837	24.821	24.879	24.799	24.794	8.140	8.134	8.141	8.128	8.135	8.138
8.5	24.879	24.838	24.825	24.898	24.798	24.797	8.132	8.134	8.139	8.127	8.135	8.137
9.0	24.887	24.841	24.831	24.919	24.798	24.800	8.129	8.134	8.138	8.122	8.136	8.134
9.5	24.907	24.850	24.837	24.931	24.810	24.802	8.123	8.133	8.138	8.118	8.136	8.132
10.0	24.916	24.856	24.855	24.939	24.858	24.806	8.118	8.133	8.138	8.114	8.131	8.130
10.5	24.926	24.873	24.886	24.947	24.882	24.824	8.115	8.133	8.137	8.111	8.122	8.129
11.0	24.945	24.904	24.897	24.954	24.888	24.960	8.115	8.134	8.132	8.109	8.119	8.127
11.5	24.963	24.948	24.936	24.988	24.897	25.079	8.111	8.127	8.126	8.105	8.117	8.109
12.0	24.982	24.964	24.991	25.027	24.914	25.135	8.106	8.117	8.114	8.097	8.118	8.092
12.5	25.005	24.966	25.004	25.073	24.984	25.145	8.101	8.111	8.102	8.089	8.111	8.074
12.0	25.070	24.968	25.014	25.107	25.078	25.177	8.091	8.107	8.099	8.077	8.096	8.061
12.5	25.126	24.996	25.074	25.152	25.167	25.215	8.073	8.106	8.092	8.062	8.072	8.038
14.0	25.173	25.116	25.171	25.197	25.216	25.232	8.058	8.093	8.071	8.046	8.038	8.020
14.5	25.229	25.227	25.230	25.231	25.241	25.248	8.037	8.055	8.043	8.026	8.008	8.002
15.0	25.267	25.260	25.260	25.251	25.273	25.267	8.013	8.024	8.018	8.011	7.990	7.995
15.5	25.290	25.278	25.277	25.269	25.297	25.291	7.992	8.005	8.003	8.001	7.982	7.987
16.0	25.304	25.309	25.311	25.296	25.328	25.337	7.974	7.985	7.984	7.991	7.968	7.965
16.5		25.326	25.326	25.325	25.356			7.961	7.968	7.970	7.943	
17.0				25.340						7.950		

Table 5. Vertical Profile Data Collected on 14 September 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	8.677	8.649	8.698				76.915	77.166	76.937			
1.5	8.632	8.622	8.681	8.670	8.623	8.651	77.152	77.377	76.794	76.729	76.660	76.592
2.0	8.616	8.630	8.678	8.658	8.634	8.643	77.065	77.518	76.859	76.826	76.627	76.674
2.5	8.636	8.621	8.663	8.636	8.611	8.626	77.417	77.768	76.801	76.743	76.924	76.923
2.0	8.603	8.638	8.655	8.616	8.597	8.628	77.806	77.932	77.388	76.867	77.396	76.900
2.5	8.602	8.633	8.642	8.588	8.595	8.645	78.037	78.058	77.353	77.686	77.661	76.883
4.0	8.616	8.631	8.640	8.598	8.588	8.648	78.138	78.153	77.497	77.754	77.581	76.883
4.5	8.627	8.607	8.643	8.575	8.589	8.640	78.434	78.447	77.680	77.840	77.446	76.745
5.0	8.614	8.536	8.634	8.521	8.570	8.646	78.385	78.576	77.923	77.978	77.292	76.676
5.5	8.605	8.565	8.625	8.463	8.554	8.622	78.456	78.748	78.077	78.212	77.438	76.890
6.0	8.609	8.527	8.620	8.427	8.569	8.640	78.597	78.795	77.931	78.352	77.173	76.862
6.5	8.596	8.526	8.591	8.433	8.556	8.635	78.546	78.714	77.718	78.687	76.739	76.783
7.0	8.524	8.485	8.569	8.441	8.574	8.598	78.791	78.729	77.697	78.860	76.531	76.739
7.5	8.332	8.489	8.564	8.401	8.566	8.574	78.920	78.355	77.566	79.242	76.532	76.670
8.0	8.322	8.473	8.562	8.311	8.572	8.524	79.156	78.282	77.571	79.389	76.618	76.358
8.5	8.272	8.469	8.565	8.217	8.558	8.514	79.268	78.216	77.823	79.396	76.644	75.964
9.0	8.178	8.487	8.557	8.206	8.475	8.511	79.203	77.879	77.987	79.552	76.307	75.370
9.5	8.177	8.465	8.411	8.177	8.203	8.448	79.108	78.059	78.071	79.736	76.511	75.411
10.0	8.131	8.383	8.345	8.154	8.297	8.367	79.329	78.262	78.620	79.988	76.836	75.567
10.5	8.037	8.156	8.311	8.120	8.259	7.672	79.311	78.650	78.855	80.163	77.960	75.939
11.0	8.005	7.996	7.989	7.915	8.272	7.556	79.508	79.246	79.346	80.145	78.900	77.188
11.5	7.890	8.036	7.881	7.743	8.184	7.250	80.023	79.767	79.599	80.280	78.915	78.854
12.0	7.785	8.080	7.884	7.487	7.833	7.432	80.273	80.148	80.565	80.900	79.076	81.979
12.5	7.287	8.071	7.898	7.402	7.388	7.065	80.306	80.366	81.368	81.394	79.536	83.351
12.0	7.197	7.710	7.321	7.191	6.878	6.787	80.536	80.299	81.222	81.753	80.699	83.398
12.5	6.943	6.676	6.800	6.851	6.393	6.504	81.543	80.654	81.871	83.521	82.797	85.020
14.0	6.577	6.287	6.503	6.710	6.254	6.359	82.957	80.894	83.426	83.996	83.847	85.806
14.5	6.262	6.337	6.391	6.514	6.337	6.374	83.833	83.688	84.485	85.120	84.393	85.641
15.0	6.116	6.238	6.299	6.443	6.182	6.370	84.942	85.546	85.928	85.681	85.083	85.685
15.5	6.040	5.754	5.968	6.143	5.867	5.703	86.109	84.923	86.092	86.479	86.698	86.278
16.0	6.125	5.842	5.826	5.803	5.703	5.846	85.421	85.809	86.267	86.690	86.947	87.602
16.5		5.880	5.892	5.803	6.117			84.123	85.676	86.591	84.741	
17.0				5.888						84.987		



In particular, the vertical profiles reflect the presence of a relatively thick 10-m surface mixed layer containing relatively uniform seawater properties. However, the sharp vertical gradients that extend below this uniform mixed layer reflect the transition to a colder, clearer, saltier, nutrient-rich but oxygen-poor water mass that migrated shoreward along the seafloor in response to upwelling processes. Strong upwelling-induced gradients are readily apparent in Figure 7 as decreases in temperature (red lines), DO (dark blue lines), and pH (olive-colored lines) below 10 m. These decreases are mirrored by a pycnocline, where density (black lines) steadily increases with depth, as does transmissivity (light blue lines).

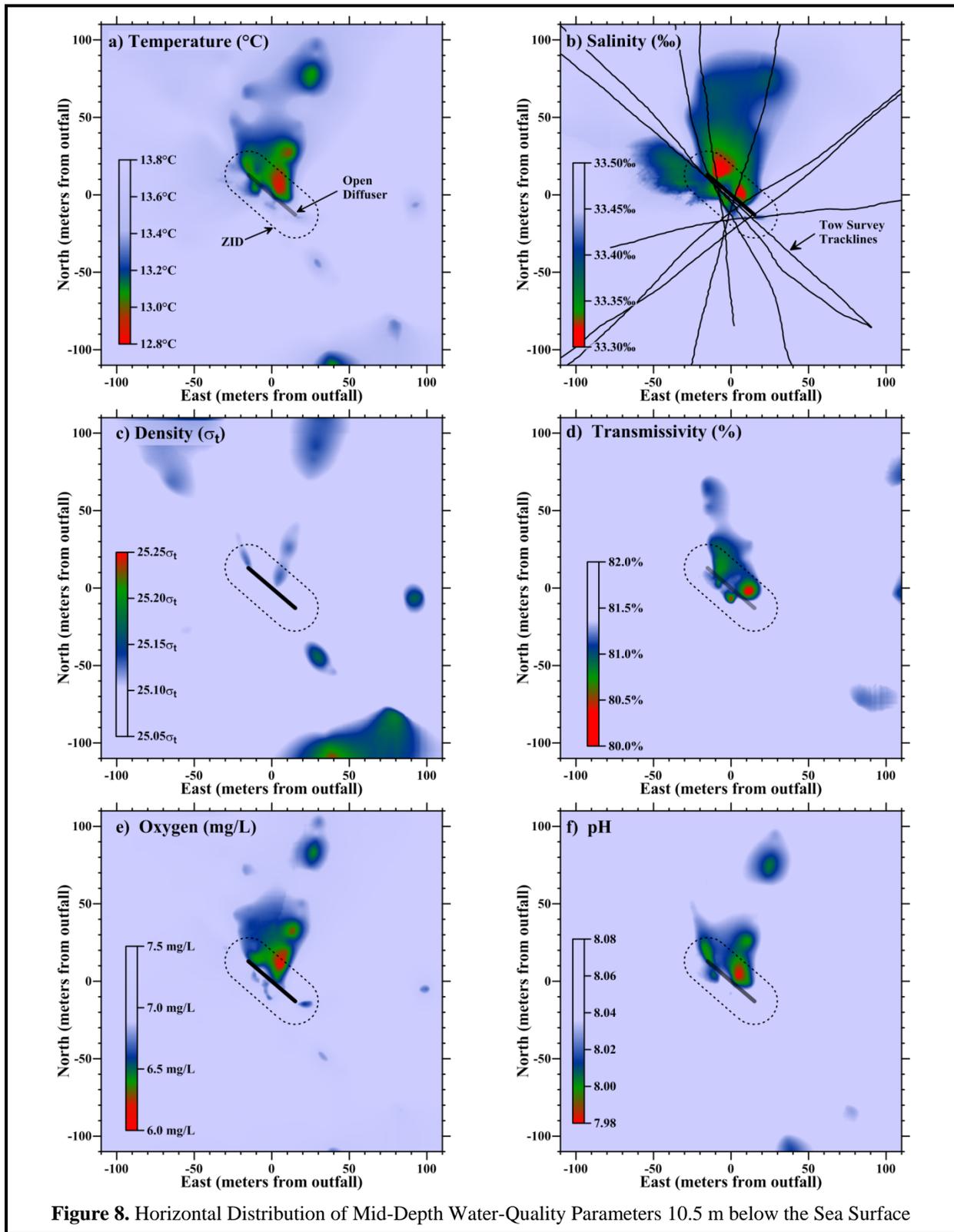
Along the seafloor, upwelling transported cold, dense seawater (red and black lines in Figure 7ab) onshore to replace nearshore surface waters that were driven offshore by prevailing winds. Because these deep offshore waters had not been in recent direct contact with the atmosphere, biotic respiration and decomposition had depleted their DO levels (dark blue lines). Meanwhile, nutrient-rich seawater brought to the sea surface by upwelling facilitated phytoplankton blooms that produced oxygen, consumed carbon dioxide (CO₂), and decreased water clarity (light blue lines). With increasing depth, however, respiration also increases relative to photosynthesis, and resulted 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.

The level of vertical stratification within the survey area is important for understanding the dynamics of the effluent plume dispersion at the time of the survey. For example, when the water column is strongly stratified, as was the case during the September 2012 survey, the rising plume becomes trapped at depth within the water column, thereby limiting its full capacity for dilution.

The influence of the effluent discharge can be seen clearly in the deepest portion of the vertical profiles of salinity recorded at Stations RW5 and RW6 (cf. green lines in Figure 7ef with 7abcd). Typically, and as was the case during the September 2012 survey, the presence of dilute wastewater appears as a reduction in salinity. The salinity anomalies at RW5 and RW6 are evident at depths below about 10.5 m. Discharge-related anomalies in seawater properties other than salinity are rare, and usually related to upward transport (entrainment) of deep ambient water that has mixed into the rising plume. For example, the profiles at RW5 and RW6 also reflect the influence of the rising effluent plume as it entrained deep seawater properties and moved them upward in the water column, resulting in a sharper, vertically compressed thermocline at these stations.

Salinity and temperature data collected during the subsequent mid-depth tow survey also delineated the discharge plume's signature. However, during this portion of the survey, the plume signature was predominately observed within the ZID and extending slightly northward from the diffuser structure (Figure 8ab), rather than to the south. The northerly offset in these plume anomalies was consistent with the northward flow component measured by the drifter trajectory at the time of the mid-depth tow (after 9:30 in Figure 3) suggesting that the pronounced water column stratification present during the September survey supported a sheared flow with a countercurrent below the sharp thermocline at 10 m. The drogue drifter, which was deployed at a depth of approximately 7 m, did not capture this separate, deeper countercurrent directed to the south toward Stations RW5 and RW6.

The absence of a perceptible density anomaly (Figure 8c) at the location of discharge-related anomalies in transmissivity, DO, and pH (Figure 8def) during the mid-depth tow demonstrates that the plume had already become neutrally buoyant at the 10.5 m depth. However, the presence of more localized discharge-related anomalies immediately north of the diffuser structure during the shallow tow survey (Figure 9abef) indicates that the upward momentum of the rising plume caused it to overshoot its buoyant equilibrium depth and reach to within 8 m of the sea surface.



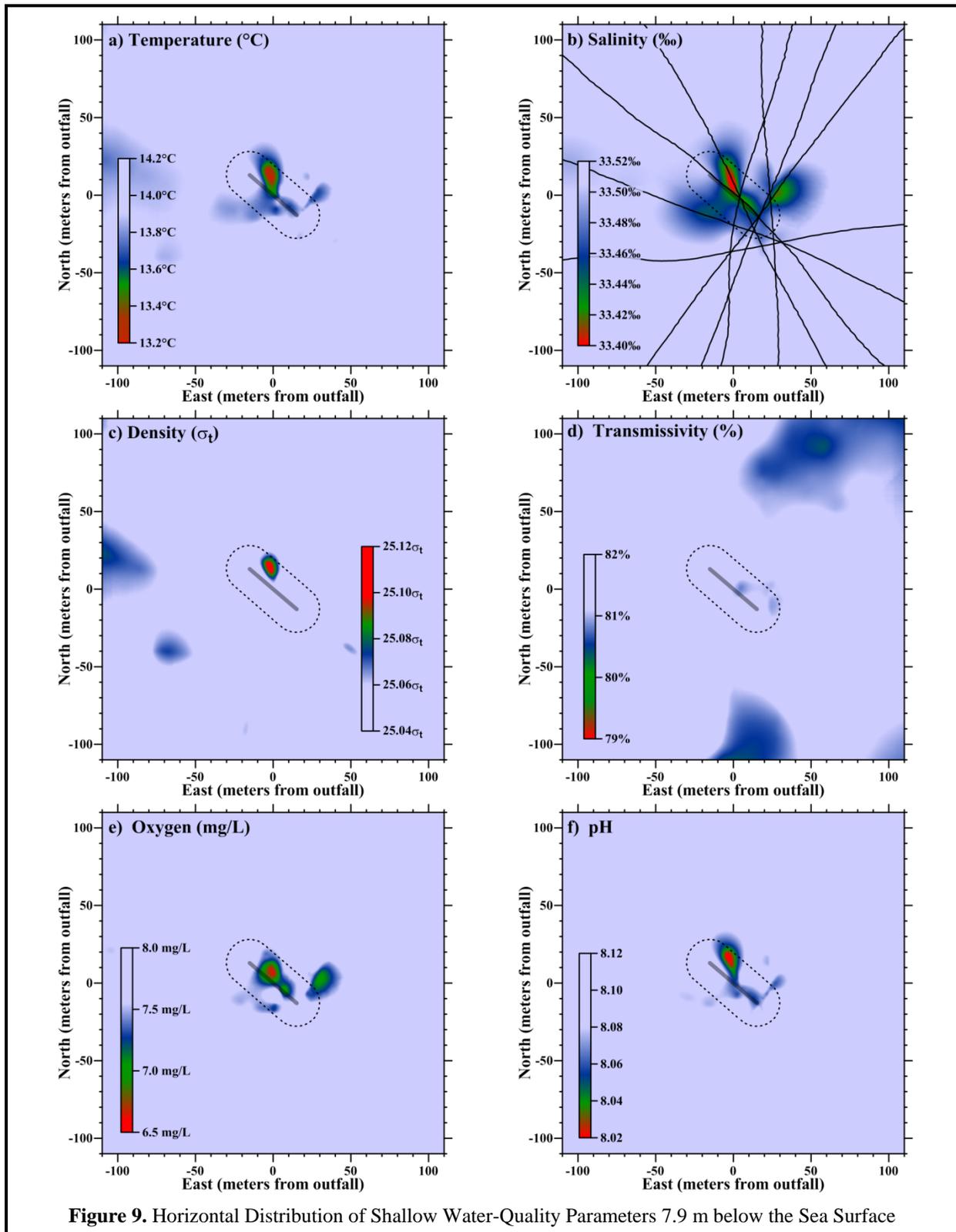


Figure 9. Horizontal Distribution of Shallow Water-Quality Parameters 7.9 m below the Sea Surface

At that point, however, the plume was negatively buoyant, as indicated by its increased density compared to surrounding ambient seawater (Figure 9c), and the plume began to rapidly sink, leaving only a highly localized signature within the ZID. Additionally, because the plume remained trapped near the thermocline, its increased water clarity (transmissivity signature) was not captured by the Secchi measurements, which only extended to 4 m at all stations (Table 4).

Although the observed temperature, transmissivity, DO, and pH anomalies identified in the towed surveys were clearly related to the plume mixing process, they were not associated with stressors caused by the presence of wastewater constituents. Instead, the lateral anomalies in these four seawater properties were created when near-bottom seawater was entrained within the rising effluent plume shortly after discharge. At that point, the diluted wastewater plume acquired the ambient seawater characteristics of the bottom seawater, namely, its low temperature, turbidity, DO, and pH. As these seawater properties were carried upward through the water column by the rising effluent plume, they became juxtaposed against the ambient seawater properties within the mixed layer above the thermocline.

It is clear that these entrainment anomalies were not caused by the presence of wastewater constituents because the offsets in their properties were consistent with the vertical differences in ambient seawater and, for some properties, the offsets were opposite of the changes that would be expected to be caused by wastewater. Specifically, the decreased transmissivity, temperature, DO, and pH measured within the entrainment anomalies in Figures 8adef fell within the range of ambient seawater properties found near the seafloor (Figure 7abcd). In contrast, wastewater discharged on the day of the survey was much warmer (22°C) than receiving seawater (<15.3°C), and thus the presence of warmer wastewater constituents could not have induced the negative thermal signature in which plume waters were cooler than the surrounding seawater.

The legacies of such entrainment anomalies can be particularly long-lived, remaining apparent within the water column well after completion of the initial dilution process when wastewater constituents have long since been dispersed beyond recognition. Regardless, such anomalies are irrelevant to the receiving-water compliance because the requirements restrict attention to changes caused solely by the presence of wastewater constituents.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the September 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 during 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, and 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 were apparent near the ZID boundary in the tow-survey maps (Figures 8b and 9b) and below 10 m in the vertical profiles measured at Stations RW5 and RW6 (green lines in Figure 7ef). These localized salinity anomalies reflect the presence of dilute wastewater within the effluent plume as it rose through the water column and became trapped near its buoyant equilibrium depth below 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)¹⁶ 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

¹⁶ Wastewater samples collected during March 2012 had an average salinity of 0.995‰.

proportional to the amplitude of the salinity anomaly. Thus, lower effluent dilution at a given location within receiving waters is directly reflected by a larger amplitude salinity reduction.

The lowest salinity (33.306‰) measured during the September 2012 survey was recorded only 3.3 m from the diffuser structure at a depth of 10.3 m during the seventh transect (D7) of the mid-depth tow survey (red shading near the northwest end of the diffuser structure in Figure 8b). This measured salinity corresponds to a 0.211‰ reduction below the mean ambient salinity of 33.516‰ that was measured at the same depth level, but well beyond the influence of the discharge. This salinity anomaly documented the presence of wastewater that had been diluted 153-fold (Figure 10). This measured dilution was much larger than the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater.

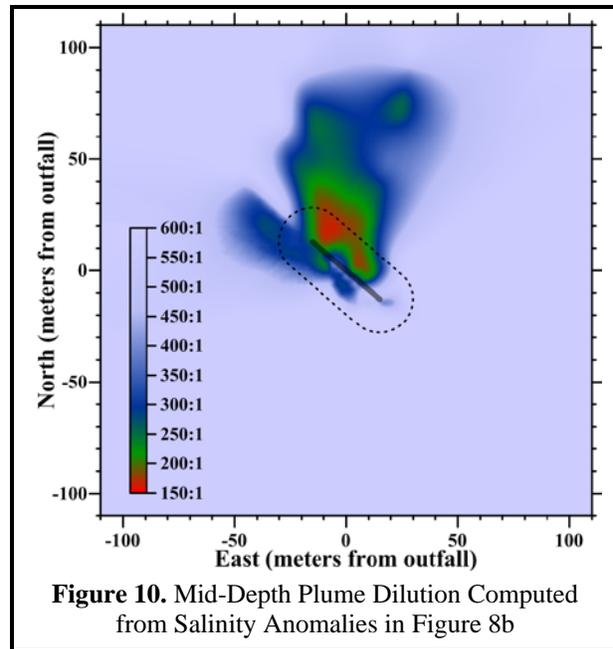


Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b

In addition, this lowest dilution was measured well within the ZID, near a diffuser port, and at a depth (10.3 m) well below the trapping depth (6.4 m) identified in the modeling that established the 133:1 minimum dilution ratio. Because of its location, the initial dilution process had yet to be completed, and dilution levels would be expected to be much less than 133:1. Instead, the dilutions measured during the mid-depth tow indicate that the diffuser structure was dispersing the effluent far more efficiently than predicted by the modeling.

Further dilution would be expected to result from the turbulence generated by the plume's subsequent rise through the water column. Accordingly, the lowest dilution of 200-fold recorded during the shallow-tow survey occurred only 5.7 m from the diffuser structure and was also located well within the ZID (Figure 11), at a depth of 8.4 m.

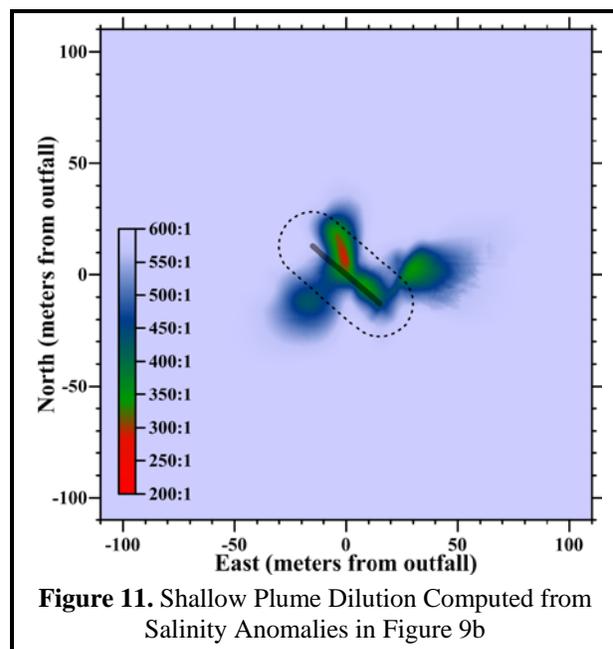


Figure 11. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 9b

At that location, the initial dilution process was still incomplete, because subsequent rapid mixing resulting from the plume's descent through the water column had yet to occur. As described previously, the plume's higher density (Figure 9c) indicated that it was negatively buoyant and was continuing the initial dilution process through the turbulence generated by the plume's vertical migration. At that time, the plume was also still below the 6.4-m trapping depth determined by modeling at the completion of the initial dilution process.

The dilution computations demonstrate that during the September 2012 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 153-fold immediately after discharge, and well before completion of the initial-dilution process. The measured dilution levels throughout the survey easily exceeded the 133:1 critical initial dilution used to establish end-of-pipe permit limitations on contaminant concentrations within wastewater discharged from the MBCSD treatment plant. Consequently, during the September 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.

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 September 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 actual dilution levels routinely exceed 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 September 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 September 2012 survey.

Compliance with the remaining four receiving-water limitations is quantitatively evaluated through a comparison between instrumental measurements and 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 13,795 CTD measurements collected during the September 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 discharges 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.

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.

Table 7. Receiving-Water Measurements Screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer		Parameter
		No	Yes ¹⁷	
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	1,667	12,128	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?	11,429	699	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?	699	0	Temperature
		699	0	Transmissivity
		699	0	DO
		699	0	pH

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 September 2012 dataset eliminated 1,667 of the original 13,795 receiving-water observations from further consideration because they were collected within the ZID (Table 7, Question 1). The remaining 12,128 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 waters. 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 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

¹⁷ Number of remaining CTD observations of potential compliance interest based on this screening question

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 542-fold. Reductions that are smaller than 0.062‰ cannot be reliably discerned against the backdrop of natural variation and would not result in discernible 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 8b and 9b, discharge-related salinity anomalies were largely restricted to the ZID, although a weak, low-salinity signature also extended beyond the ZID boundary to the north. Six-hundred-ninety-nine measurements had perceptible reductions in salinity that unequivocally identified the presence of dilute wastewater constituents beyond the ZID. The remaining 11,429 observations that were measured outside the ZID during the September 2012 survey did not have salinity reductions 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 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 (-1.38 mg/L), and pH (± 0.094). These were combined with 95th percentiles determined from the September 2012 ambient seawater data, to establish time-specific natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from September 2012 vertical profile data, excluding measurements potentially affected by the discharge.

Temperature, transmissivity, and DO concentrations associated with the 699 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 September 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 September 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 8 and 9 were consistent with the upward displacement of ambient bottom water rather than with the presence of the effluent plume. Additionally, even if the presence of wastewater particulates had contributed to the measured decreases in DO and pH, their influence would have been 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.

Table 8. Compliance Thresholds

Water Quality Property	95% Confidence Bound ¹⁸	95 th Percentile ^{19,20}	Natural Variability Threshold ²¹	COP Allowance ²²	Basin Plan Limit ²³	Extremum ²⁴
Temperature (°C)	0.82	15.27	>16.09	—	—	≤15.29
Transmissivity (%)	-10.2	76.6	<66.4	—	—	≥75.4
DO (mg/L)	-1.38	5.88	<4.50	<4.05	<5.00	≥5.70
pH (minimum)	-0.094	7.984	<7.890	<7.690	<7.000	≥7.943
pH (maximum)	0.094	8.146	>8.240	>8.440	>8.300	≤8.153

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 September 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 that accounts for both discrepancies and concurrences among multiple lines of evidence. 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 at the time of the September 2012 survey.

Natural Variability within the ZID: Although the permit limits only apply to changes in DO, pH, temperature, and transmissivity beyond the ZID, examination of measurements within the ZID frequently provides additional valuable insight into the potential for adverse effects on water quality beyond the ZID. During the September 2012 survey, salinity was the only seawater property that exhibited a perceptible difference from ambient conditions. Regardless of their association with the effluent salinity signature, none of the 13,795 temperature, DO, pH, or transmissivity observations exceeded the thresholds of natural variability specified in Table 8. This includes measurements collected within the ZID that were

¹⁸ 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 remaining observations for each of the six seawater properties accurately quantified the inherent uncertainty in defining the range in natural conditions.

¹⁹ 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.”

²⁰ The 95th-percentile quantifies natural variability in seawater properties during the September 2012 survey, and was determined from vertical-profiles data unaffected by the discharge.

²¹ 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 left and are specific to the September 2012 survey. They do not include the COP allowances specified in the column to the right.

²² 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.”

²³ 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. The Basin Plan upper-bound pH objective for ocean waters is 8.5, but the upper-bound objective 8.3, which applies to most beneficial uses was implemented in the MBCSD discharge permit.

²⁴ Maximum or minimum value measured during this survey

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 that is based on the requirement that they not adversely affect beneficial uses (P3 in Table 6). Increases in temperature caused by the discharge of warm wastewater constituents could be deemed to adversely affect beneficial uses if they exceeded the natural temperature range observed at the time of the survey (i.e. exceeded 16.09°C in Table 8). However, none of the 13,795 CTD measurements collected during the September 2012 survey exceeded 15.29°C (last column in Table 8). 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 8a and 9a).

Insignificant Wastewater Particulate Loads: The discharge of wastewater particulates on 14 September 2012 also did not contribute materially to turbidity within the dilute effluent plume. The suspended-solids concentration measured onshore within the effluent prior to discharge from the WWTP was 23 mg/L. After dilution by 153-fold, which was the lowest dilution measured during the survey, the effluent TSS concentration would have the reduced ambient transmissivity by only 1.1%.

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, 40-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 0.022 mg/L after dilution (MRS 2002). 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 subsection. 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 7.690 during the September 2012 survey (fourth column of Table 8). This value is well below the lowest pH measurement of 7.943 recorded during the September 2012 survey (last column of Table 8). Similarly, the lowest DO concentration measured during the survey (5.70 mg/L) was well above both the lower range in natural variation (4.50 mg/L) and the 10% compliance threshold promulgated by the COP (4.05 mg/L).

CONCLUSIONS

The quantitative screening analysis demonstrated that all measurements recorded during the September 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 the discharge plume, all the associated seawater properties were within the natural range of variability that prevailed at the time of the survey.

Shortly after discharge, the outfall was achieving dilution levels in excess of 153-fold, which exceeds the critical dilution levels predicted by design modeling. This lowest dilution level was observed within the discharge jet, at a location only 3.3 m from the diffuser structure, and well before the initial dilution process was complete. As the plume continued to rise through the water column, it was transported slowly

northward²⁵, quickly achieving dilution levels exceeding 200-fold and becoming ever more diffuse even though the strong stratification that was present in the water column trapped the plume at depth and inhibited its dilution. Lastly, all of the auxiliary observations collected during the September 2012 survey demonstrated that the discharge complied with the narrative receiving-water limits in the discharge permit and the COP. Together, 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 September 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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²⁵ Although the pronounced water column stratification present during the October survey was associated with vertically sheared flow, with a southerly countercurrent below the sharp thermocline at 10 m, the predominant flow direction throughout the majority of the water column was to the north.

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