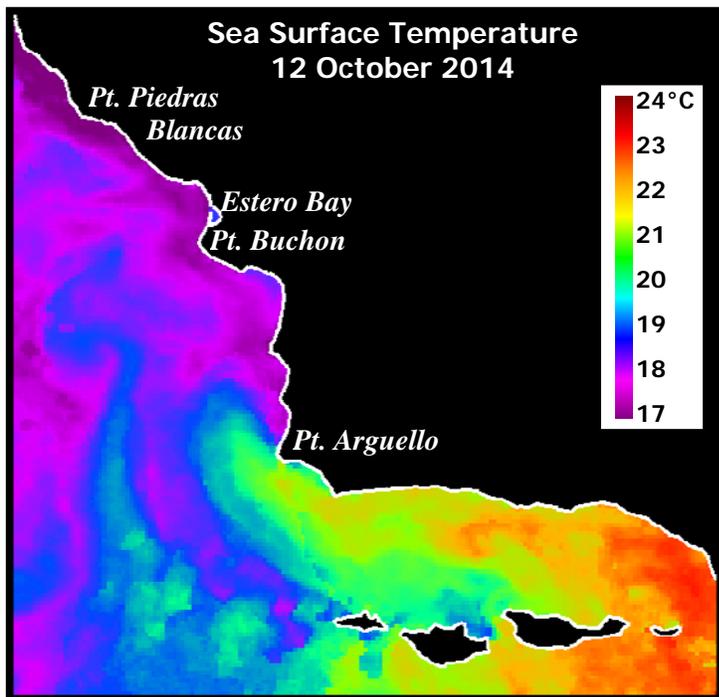


**City of Morro Bay and
Cayucos Sanitary District**

OFFSHORE MONITORING AND REPORTING PROGRAM

FOURTH QUARTER RECEIVING-WATER SURVEY OCTOBER 2014



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**

**FOURTH QUARTER
RECEIVING–WATER SURVEY**

OCTOBER 2014

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November 2014

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

7 November 2014

Reference: Fourth Quarter Receiving-Water Survey Report – October 2014

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Thursday, 9 October 2014. 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 November 7, 2014

TABLE OF CONTENTS

LIST OF FIGURES	i
LIST OF TABLES	ii
INTRODUCTION	1
SURVEY SETTING	1
SAMPLING LOCATIONS	3
OCEANOGRAPHIC PROCESSES	6
METHODS	9
<i>Auxiliary Measurements</i>	9
<i>Instrumental Measurements</i>	10
<i>Quality Control</i>	11
RESULTS	12
<i>Auxiliary Observations</i>	12
<i>Instrumental Observations</i>	13
<i>Outfall Performance</i>	21
COMPLIANCE	24
<i>Permit Provisions</i>	24
<i>Screening of Measurements</i>	25
<i>Other Lines of Evidence</i>	28
CONCLUSIONS	30
REFERENCES	31

LIST OF FIGURES

Figure 1. Location of the Receiving-Water Survey Area	2
Figure 2. Station Locations	4
Figure 3. Drogued Drifter Trajectory	7
Figure 4. Tidal Level during the October 2014 Survey	8
Figure 5. Five-Day Average Upwelling Index (m ³ /s/100 m of coastline)	8
Figure 6. CTD Tracklines during the October 2014 Tow Surveys	11
Figure 7. Vertical Profiles of Water-Quality Parameters	17
Figure 8. Horizontal Distribution of Mid-Depth Water-Quality Parameters 10.44 m below the Sea Surface	19
Figure 9. Horizontal Distribution of Shallow Water-Quality Parameters 2.75 m below the Sea Surface	20
Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b	23
Figure 11. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 9b	23

LIST OF TABLES

Table 1.	Target Locations of the Receiving-Water Monitoring Stations	4
Table 2.	Average Position of Vertical Profiles during the October 2014 Survey.....	6
Table 3.	CTD Specifications.....	10
Table 4.	Standard Meteorological and Oceanographic Observations.....	12
Table 5.	Vertical Profile Data Collected on 9 October 2014	14
Table 6.	Permit Provisions Addressed by the Offshore Receiving-Water Surveys.....	24
Table 7.	Receiving-Water Measurements Screened for Compliance Evaluation.....	25
Table 8.	Compliance Thresholds	27

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 October 2014 field survey described in this report was the twenty-third 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 9 October 2014. Specifically, this fourth-quarter survey captured ambient oceanographic conditions along the central California coast during the fall 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 empirically evaluating 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 delineation 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, to define the lateral extent of the discharge plume, and to 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 eight 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 between the water properties at these antipodal stations quantify departures from ambient seawater properties caused by the discharge and allow compliance with the NPDES discharge permit to be determined.

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. This "*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.

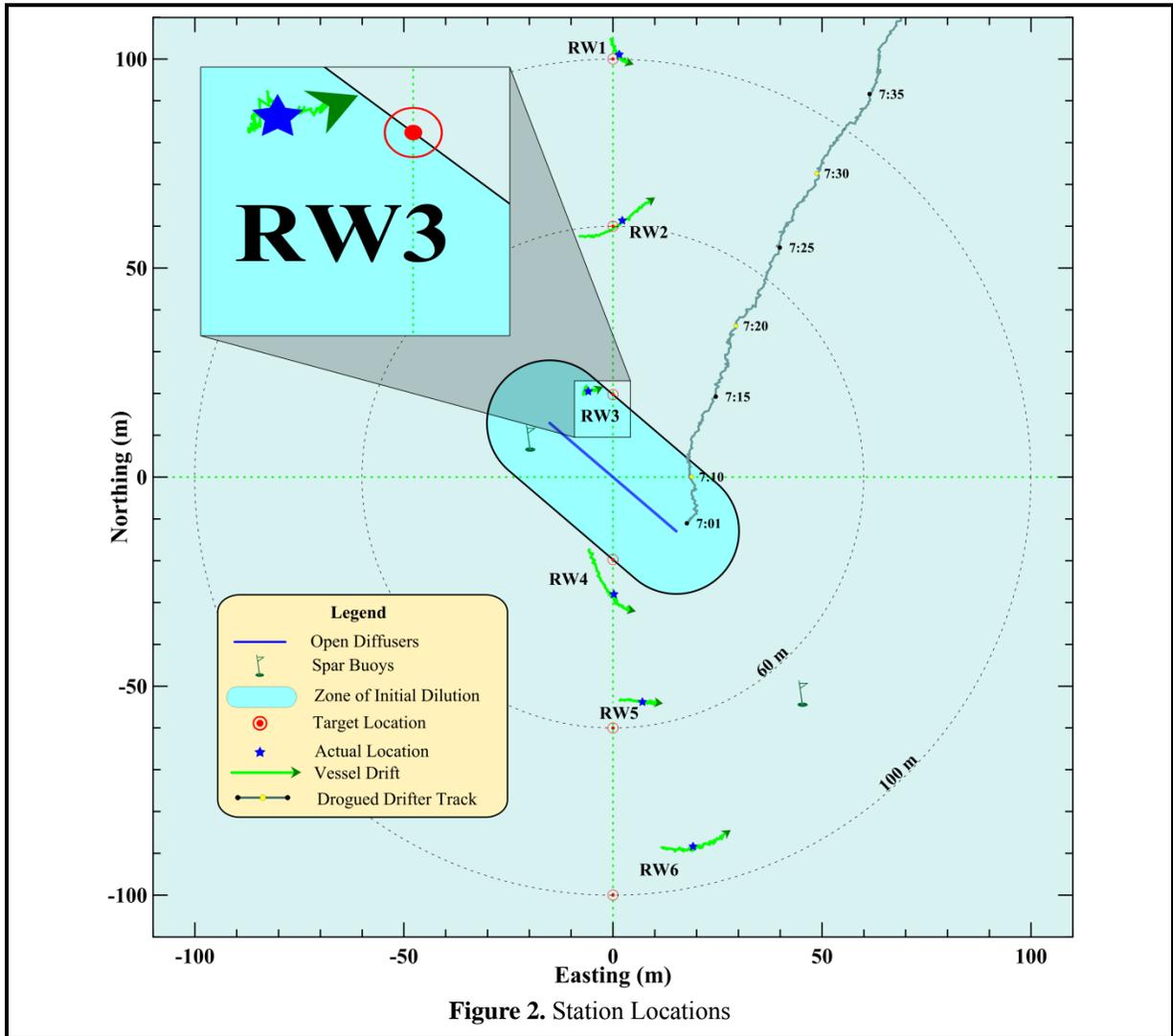


Figure 2. Station Locations

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. Presently, the use of two independent DGPS receivers onboard 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 downcasts during the October 2014 survey were conducted progressing from north to south, beginning with Station RW1. The magnitude of the drift at each of the six stations during the October 2014 survey is apparent from the length of the green tracklines in Figure 2. The tracklines trace the horizontal movement of the CTD as it was lowered to the seafloor at each station. Their lengths and offsets from the target locations reflect the overall station-keeping ability during the October 2014 survey.

Although the time it took the CTD to traverse the water column to the seafloor, which averaged 1 min 40 s, was consistent among stations, the lateral distance traversed by the instrument package varied considerably, from as little as 2.7 m at Station RW3, to 19.5 m at Station RW2. At 11.7 m, the average distance moved among all the stations was slightly greater than that of most prior surveys.

As seen in Figure 2, the direction of the CTD movement varied among the stations. The northeastward movement at Station RW2, and to a lesser extent RW6, was consistent with the northeastward transport of the drifter. In contrast, the southeastward CTD movement at Stations RW1 and RW4 was consistent with vessel movement by winds out of the northwest.⁵ In reality, the CTD movement at any given station was determined by the complex interplay between these external influences and the vessel's residual momentum immediately prior to each downcast. For example, residual momentum balanced the effects of the northeastward current as the vessel approached Station RW3 from the northeast, resulting in minimal perceptible drift during the downcast at that station.

Detailed knowledge of the CTD's location during downcasts is important for the interpretation of the water-quality measurements. Because the target locations for Stations RW3 and RW4 lie along the ZID boundary (red ⊙ symbols in Figure 2), knowledge of the CTD's location during the downcasts at those stations is especially important in the compliance evaluation. This is because the receiving-water limitations specified in the COP only apply to measurements recorded along or beyond the ZID boundary, where initial mixing is assumed complete. During the October 2014 survey, all of the CTD data at Station RW3 was collected within the ZID (see the inset in Figure 2). Therefore, all of the measurements at this station were excluded from the compliance evaluations. In contrast, all of the measurements collected at Station RW4 were collected beyond the ZID boundary, and were subject to the compliance analysis.

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

⁵ Refer to the meteorological and oceanographic observations listed in Table 4 later in this report.

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 and a half 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 vessel drift, the extremely dilute discharge plume might remain undetected within all the vertical profiles collected during a given survey.

It has not always been possible to determine which measurements were subject to permit limits among hydrocasts near the ZID boundary, however. For example, prior to 1999 and before the advent of DGPS, CTD locations could not be determined with sufficient accuracy to establish whether the average station position 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 October 2014 survey also identifies a single sampling location for each station. These average station positions are identified by the 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 October 2014 Survey

Station	Time (PDT)		Latitude	Longitude	Closest Approach	
	Downcast	Upcast			Range ⁶ (m)	Bearing ⁷ (°T)
RW1	7:12:31	7:14:02	35° 23.254' N	120° 52.503' W	89.8	11
RW2	7:17:03	7:18:37	35° 23.232' N	120° 52.503' W	51.6	20
RW3	7:26:22	7:27:55	35° 23.210' N	120° 52.508' W	11.8⁸	41
RW4	7:30:25	7:32:11	35° 23.184' N	120° 52.504' W	21.1	221
RW5	7:34:13	7:36:10	35° 23.170' N	120° 52.499' W	41.5	191
RW6	7:38:41	7:40:19	35° 23.151' N	120° 52.491' W	75.4	177

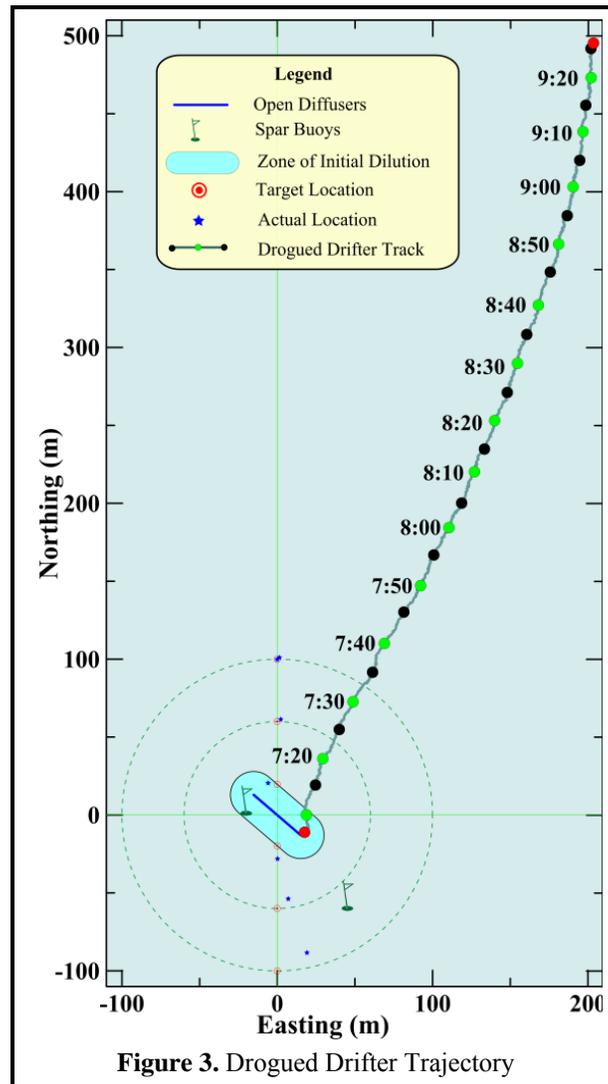
OCEANOGRAPHIC PROCESSES

The trajectory of a satellite-tracked drogued drifter measured oceanic flow throughout the October 2014 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 two decades. In this configuration, the oceanic flow field rather than surface wind dictates the drifter’s trajectory, providing a good assessment of the plume’s movement after discharge.

⁶ Distance from the closest open diffuser port to the average profile location

⁷ Angle measured clockwise relative to true north from the closest diffuser port to the average profile location

⁸ All of the CTD measurements collected at Station RW3 were located within the ZID boundary (refer to the inset in Figure 2).



During the October 2014 survey, the drifter was deployed near the diffuser structure at 7:01 AM, and was recovered at 9:26 AM at a location 539 m to the north-northeast ($20^{\circ}T^9$) of its original release point (red dots in Figure 3). In contrast to the last two surveys, the direction and speed of the drifter was relatively uniform throughout its deployment. The steady flow speed is reflected by the uniform spacing of the green and black dots in Figure 3, which show the drifter’s progress at five- and ten-minute intervals. Additionally, the drifter’s average speed of 6.5 m/s^{10} was nearly double the maximum speeds measured during the prior two surveys. At the rapid transport rate, effluent would have experienced only a brief, four-minute residence time within the ZID.

⁹ Direction measured clockwise relative to true (rather than magnetic) north

¹⁰ 0.1257 kt

The overall flow direction measured by the drifter was consistent with the flood tide that prevailed during the October 2014 survey (Figure 4). Flood tides normally induce a weak northeastward (onshore) flow in the survey region. However, flow within the survey area is often also affected by other processes, such as upwelling. Upwelling winds can also induce a northeastward flow at depth as offshore waters move shoreward and upwell to replace near-surface waters driven offshore by the winds.

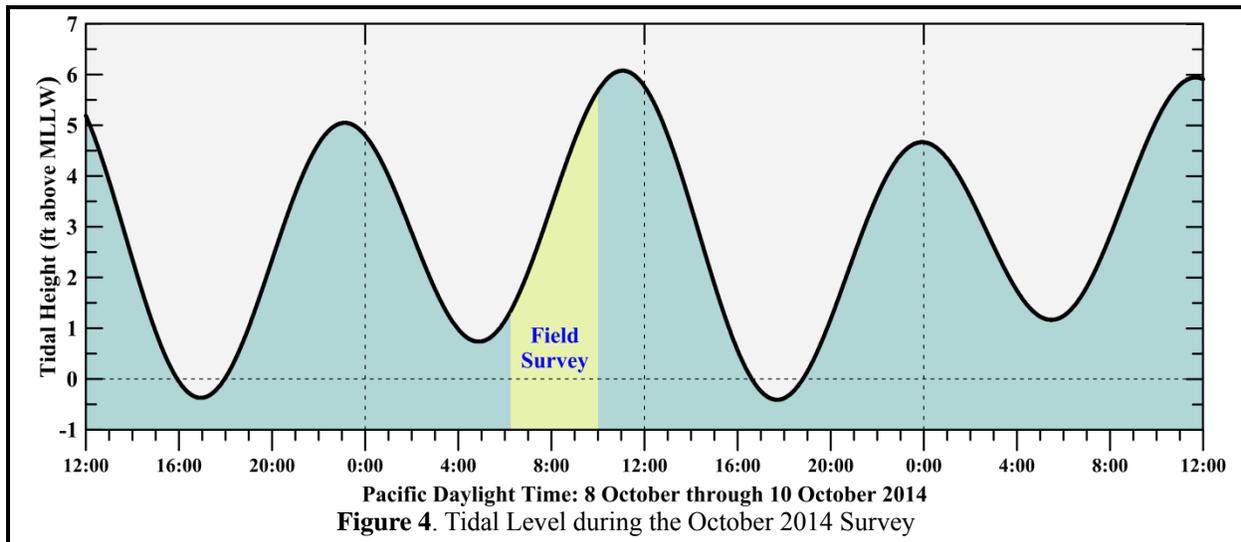


Figure 4. Tidal Level during the October 2014 Survey

The onset of upwelling-dominated processes begins with a rapid intensification of southeastward-directed winds along the central coast during late March and or early April as shown by the positive (blue) upwelling indices in Figure 5. This transition to more persistent southeastward winds is initiated by the stabilization of a high-pressure field over the northeastern Pacific Ocean. Clockwise winds around this pressure field drive prevailing northwesterly winds along the central California coast. These winds move warmer surface waters southwestward and offshore, allowing deep, cool, nutrient-rich waters to move shoreward and upwell near the coast.

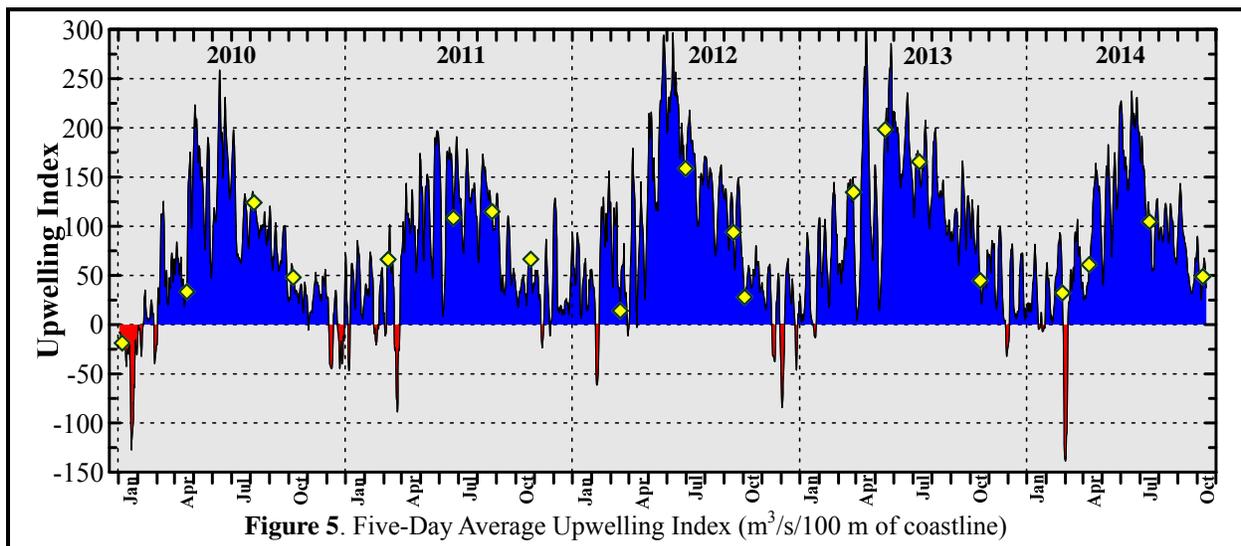


Figure 5. Five-Day Average Upwelling Index ($m^3/s/100$ m of coastline)

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 influx of denser water at depth produces a shallow thermocline (<10 m) that is commonly maintained throughout summer and into fall. As a result, some degree of upwelling is almost always present during offshore surveys (yellow diamonds in Figure 5). During winter, upwelling is typically weak, and occasionally downwelling events, indicated by the negative (red shaded) indices in Figure 5, occur 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.

Sustained afternoon winds around the time of the October 2014 survey (last yellow diamond in Figure 5) produced a pattern of sea surface temperatures indicative of upwelling processes within the region. This pattern was captured by the satellite image shown on the cover of this report. The image was recorded by infrared sensors on one of NOAA's polar orbiting satellites during a period of relatively cloudless skies two days after the survey. The presence of a pool of cooler, upwelled water is visually apparent along the south-central coastline (purple shading), and the 3°C contrast between these sea-surface temperatures and temperatures southwest of Pt. Arguello (light blue) is typical of moderate-strength upwelling events. Cross-shore counter-flows at the sea surface and seafloor were also generated by this upwelling event, and as a result, the water column was moderately stratified at the time of the October 2014 survey.

METHODS

The 38 ft F/V *Bonnie Marietta*, owned and operated by Captain Mark Tognazzini of Morro Bay, served as the survey vessel on Thursday, 9 October 2014. Bonnie Luke of Marine Research Specialists (MRS) supervised deck operations as Chief Scientist, and collected auxiliary measurements of biological, meteorological, and oceanographic conditions. Dr. Douglas Coats, provided data-acquisition and navigational support during the survey. Dean Dusette, also of MRS, assisted with the deployment and recovery of the CTD and drifter under the direction of crewmember William Skok.

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 October 2014 survey. The six seawater properties used to assess receiving-water quality in this report 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, so the maximum theoretical transmission in (pure) water is expected to be 91.3%.

Before the first vertical hydrocast at Station RW1, the CTD was held below the sea surface for two 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 7:41 AM, following completion of 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 the reconfigured 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

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

within the thermocline, in accordance with the monitoring requirements of the NPDES discharge permit (Figure 6).

Initially, the reconfigured CTD package was towed for 45 minutes at an average depth of 10.4 m, and an average speed of 1.54 m/s, passing over or near the diffuser structure ten times. Subsequently, eight additional passes were made with the CTD at an average depth of 2.7 m. During this 36-minute mid-depth tow, vessel speed averaged 1.63 m/s. At the observed towing speeds and the 4 Hz sampling rate, at least 2.4 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

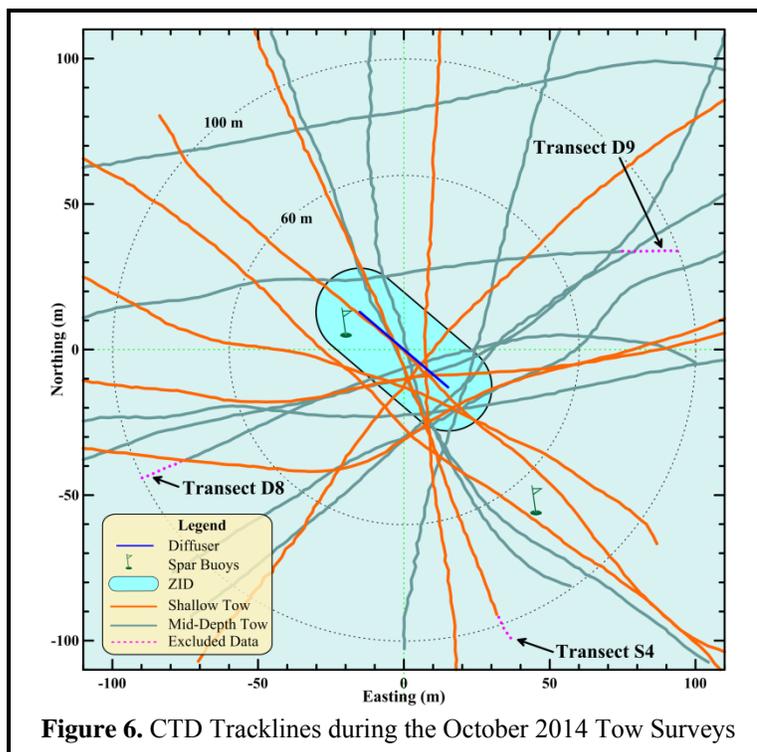


Figure 6. CTD Tracklines during the October 2014 Tow Surveys

Quality Control

During the vertical-profiling and horizontal-towing phases of the survey, real-time data were monitored 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 initiating 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 final portions of the mid-depth tows along Transects D8 and D9, and the shallow tow along Transect S4 (purple dotted lines in Figure 6).

Depth offsets are typically induced by changes in vessel speed that are 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 cannot always 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 in the horizontal

¹² Figures 8 and 9 later in this report

¹³ Field sampling protocols employed during the survey generally followed the field operations manual for the Southern California Bight Study (SCBFMC 2002), which includes CTD cast-acceptability ranges listed in Table 2 of the manual.

maps. This is true whenever the water column is stratified, as was the case during the October 2014 survey.

The exclusion of the small portions of Transects D8, D9, and S4 did not, however, adversely affect the compliance analysis because the remaining data adequately covered the 100-m survey area surrounding the diffuser structure. Specifically, the remaining data, shown by the solid orange and blue-green lines in Figure 6, met the permit monitoring requirement of at least five passes near the diffuser structure at each tow depth.

RESULTS

The fourth-quarter receiving-water survey was conducted on the morning of Thursday, 9 October 2014. The receiving-water survey commenced at 7:01 AM with the deployment of the drogued drifter. Over the following 2.5 hours, offshore observations and measurements were collected as required by the NPDES monitoring program. The survey ended at 9:26 AM with the retrieval of the drogued drifter. Collection of required visual observations of the sea surface was generally unencumbered throughout the survey, although the reduced Secchi depth at Station RW2 may have been due to lower ambient light that prevailed at the time of the measurement (Table 4). Note that the auxiliary observations at Station RW2 were collected prior to those at Station RW1, although the vertical CTD profiles were in sequence.

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location ¹⁴		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° 23.264' N	120° 52.500' W	108.4	7:23:33	14.2	100	1.4	2.7	NW	2-3 NW	9.0
RW2	35° 23.233' N	120° 52.497' W	55.5	7:17:56	14.5	100	0.9	1.7	NW	2-3 NW	8.0
RW3	35° 23.210' N	120° 52.512' W	8.6	7:27:15	14.2	100	1.7	2.5	NW	2-3 NW	9.0
RW4	35° 23.179' N	120° 52.504' W	27.6	7:31:25	14.3	100	3.1	4.0	NW	2-3 NW	9.0
RW5	35° 23.167' N	120° 52.501' W	47.2	7:35:05	14.0	100	2.4	3.5	NW	2-3 NW	9.0
RW6	35° 23.148' N	120° 52.496' W	80.5	7:39:23	14.0	100	2.4	4.1	NW	2-3 NW	9.0

Auxiliary Observations

On the morning of 9 October 2014, skies were overcast, with light northwesterly winds. Average wind speeds, calculated over one-minute intervals, ranged from 0.9 kt to 3.1 kt (Table 4). Similarly, peak wind speeds ranged from 1.7 kt to 4.1 kt. The swell was out of the northwest with a significant wave height of two feet. Air temperatures remained fairly constant throughout the survey, averaging 14.2°C.

The 9.0 m Secchi depths recorded during the October 2014 survey reflected the presence of an 18-m euphotic zone that was projected to extend to the seafloor (Table 4). The unusually high seawater clarity that was present throughout most of the water column at the time of the survey was also reflected in the elevated transmissivities that were recorded throughout most of the water column. Most measurements exceeded 90.5% although there were slight reductions near the sea surface and seafloor. The slightly reduced clarity within the mixed layer near the sea surface (above 4 m) was caused by an increased planktonic density that resulted from upwelling. During upwelling, nutrients carried upward into the euphotic zone are assimilated by phytoplankton, whose populations increase. Along with their associated

¹⁴ Locations are the vessel positions at the time the Secchi depths were measured. These typically depart slightly from the CTD profile locations listed in Table 2.

zooplanktonic predators, these elevated plankton densities reduced the transmittance of ambient light in the upper water column during the October 2014 survey. However, even within the surface mixed layer, water clarity was high, exceeding 87% at all six stations. During the survey, no evidence of floating particulates, oil sheens, or any discoloration of the sea surface was visually observed that might be associated with wastewater constituents.

Communication with plant personnel and subsequent review of effluent discharge properties on the day of the survey, confirmed that the treatment process was performing nominally at time of the survey. The 0.794 million gallons of effluent discharged on 9 October had a temperature of 23°C, a suspended-solids concentration of 28.6 mg/L, and a pH of 7.6. The biochemical oxygen demand (BOD) of the effluent measured on the previous day, 8 October, was 38 mg/L.

During the October 2014 survey, visual observations demonstrated continued beneficial use of the coastal waters within Estero Bay by both wildlife and recreational users. California brown pelicans (*Pelecanus occidentalis*), Brandt's cormorants (*Phalacrocorax penicillatus*), pelagic cormorants (*Phalacrocorax pelagicus*), western grebes (*Aechmophorus occidentalis*), and western gulls (*Larus occidentalis*) were all observed transiting the survey area. Additionally, southern sea otters (*Enhydra lutris nereis*) were observed inside the mouth of Morro Bay during transit to the survey site. Restricted visibility from low clouds persisted throughout most of the survey, and only a few pedestrians were visible along Atascadero State beach towards the end of the survey.

Instrumental Observations

Data collected during vertical profiling were processed in accordance with standard procedures (SCCWRP 2002), and are collated within 0.5-m depth intervals in Table 5. Data collected during the October 2014 survey reflect the presence of a moderately stratified water column indicative of recent upwelling conditions within Estero Bay (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. The intensity of upwelling tends to decline into fall, although pulses of sustained northwesterly winds still occur. An intense upwelling event results in the rapid influx of dense, cold, saline water at depth and leads to a sharp thermocline, halocline, and pycnocline where temperature, salinity, and density change rapidly over a small vertical distance. Under these 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.

If the upwelling winds are weak, occur only briefly, or have not occurred recently; the contrast between the surface and deep water masses is reduced, and stratification appears as a more gradual vertical change in seawater properties below the surface mixed layer. This was the case during the October 2014 survey where the upwelling signatures in the vertical profiles appear as a steady change with depth (Figure 7). Absent are sharply defined interfaces where large changes in seawater properties occur over a limited vertical extent and are indicative of strong, recent upwelling conditions. In contrast, the thermocline that was present during the October 2014 survey extended through nearly the entire water column.

This transition zone separated the surface mixed layer (≤ 4 m) from a deeper seawater mass situated immediately above the sea floor. Within the wide-ranging thermocline, all seawater properties exhibited steadily increasing or decreasing values that were determined by well-defined oceanographic processes.

Table 5. Vertical Profile Data Collected on 9 October 2014

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	16.395	16.376	16.353	16.408	16.394	16.382	33.364	33.359	33.364	33.367	33.366	33.367
1.5	16.363	16.376	16.358	16.409	16.393	16.400	33.362	33.364	33.365	33.367	33.366	33.368
2.0	16.348	16.376	16.360	16.409	16.397	16.410	33.362	33.357	33.364	33.367	33.366	33.368
2.5	16.335	16.370	16.372	16.392	16.377	16.400	33.361	33.361	33.365	33.366	33.365	33.367
3.0	16.312	16.325	16.376	16.346	16.284	16.327	33.361	33.362	33.365	33.362	33.359	33.360
3.5	16.230	16.217	16.373	16.283	16.241	16.259	33.358	33.357	33.365	33.359	33.359	33.358
4.0	16.172	16.162	16.348	16.225	16.221	16.234	33.357	33.357	33.363	33.357	33.359	33.358
4.5	16.112	16.136	16.260	16.203	16.212	16.207	33.356	33.357	33.358	33.357	33.359	33.358
5.0	16.038	16.116	16.182	16.201	16.165	16.173	33.353	33.357	33.355	33.359	33.358	33.357
5.5	15.964	16.075	16.153	16.091	16.103	16.122	33.352	33.356	33.357	33.354	33.357	33.355
6.0	15.919	15.933	16.079	15.985	16.012	16.085	33.352	33.351	33.353	33.352	33.353	33.356
6.5	15.882	15.785	15.968	15.865	15.916	15.987	33.352	33.345	33.350	33.349	33.350	33.349
7.0	15.824	15.739	15.880	15.788	15.847	15.947	33.350	33.346	33.349	33.348	33.351	33.351
7.5	15.782	15.711	15.835	15.729	15.755	15.855	33.350	33.346	33.347	33.347	33.348	33.347
8.0	15.756	15.707	15.808	15.693	15.712	15.825	33.349	33.349	33.346	33.349	33.349	33.349
8.5	15.720	15.652	15.656	15.652	15.692	15.755	33.349	33.345	33.337	33.349	33.349	33.347
9.0	15.676	15.639	15.611	15.641	15.650	15.688	33.349	33.346	33.345	33.351	33.351	33.348
9.5	15.656	15.632	15.592	15.635	15.621	15.664	33.351	33.347	33.346	33.352	33.351	33.349
10.0	15.651	15.626	15.544	15.622	15.604	15.618	33.352	33.347	33.344	33.354	33.352	33.350
10.5	15.616	15.615	15.485	15.606	15.593	15.595	33.353	33.349	33.343	33.355	33.353	33.352
11.0	15.507	15.542	15.484	15.577	15.552	15.567	33.355	33.357	33.348	33.356	33.354	33.354
11.5	15.364	15.403	15.442	15.484	15.437	15.456	33.352	33.355	33.350	33.356	33.357	33.352
12.0	15.290	15.301	15.418	15.386	15.345	15.371	33.353	33.352	33.352	33.356	33.357	33.354
12.5	15.199	15.216	15.356	15.315	15.314	15.301	33.348	33.346	33.354	33.355	33.357	33.355
13.0	15.138	15.181	15.264	15.232	15.260	15.254	33.348	33.348	33.351	33.352	33.355	33.353
13.5	15.091	15.126	15.194	15.179	15.192	15.255	33.352	33.351	33.351	33.352	33.353	33.355
14.0	15.082	15.084	15.136	15.136	15.154	15.207	33.356	33.356	33.351	33.352	33.353	33.353
14.5	15.060	15.067	15.114	15.114	15.132	15.157	33.357	33.357	33.354	33.354	33.354	33.353
15.0	14.997	15.046	15.083	15.104	15.116	15.143	33.353	33.358	33.356	33.356	33.355	33.355
15.5	14.972	15.001	15.051	15.094	15.074	15.086	33.354	33.356	33.357	33.358	33.357	33.356
16.0	14.974	14.994	15.029	15.050	15.025	15.036	33.355	33.357	33.358	33.360	33.359	33.359
16.5			15.020	15.024		15.025			33.359	33.361		33.362

Table 5. Vertical Profile Data Collected on 9 October 2014 (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	24.400	24.400	24.409	24.399	24.401	24.405	8.224	8.230	8.231	8.228	8.226	8.227
1.5	24.405	24.404	24.408	24.398	24.402	24.401	8.224	8.230	8.232	8.227	8.227	8.226
2.0	24.408	24.398	24.408	24.398	24.401	24.399	8.223	8.230	8.232	8.227	8.227	8.226
2.5	24.411	24.403	24.406	24.402	24.404	24.401	8.222	8.230	8.232	8.226	8.226	8.225
3.0	24.417	24.414	24.405	24.409	24.421	24.412	8.221	8.230	8.232	8.226	8.225	8.225
3.5	24.433	24.435	24.405	24.421	24.431	24.426	8.219	8.224	8.231	8.227	8.223	8.226
4.0	24.445	24.447	24.410	24.433	24.435	24.432	8.215	8.219	8.231	8.225	8.221	8.224
4.5	24.458	24.453	24.426	24.438	24.438	24.438	8.211	8.214	8.229	8.221	8.220	8.222
5.0	24.473	24.458	24.441	24.440	24.447	24.445	8.209	8.214	8.227	8.218	8.218	8.219
5.5	24.489	24.467	24.449	24.461	24.461	24.455	8.205	8.211	8.223	8.217	8.217	8.218
6.0	24.499	24.495	24.463	24.484	24.478	24.464	8.202	8.209	8.220	8.214	8.214	8.215
6.5	24.507	24.523	24.486	24.508	24.498	24.481	8.198	8.202	8.217	8.210	8.211	8.215
7.0	24.519	24.534	24.505	24.525	24.514	24.491	8.195	8.194	8.212	8.206	8.207	8.211
7.5	24.528	24.540	24.514	24.537	24.532	24.509	8.191	8.190	8.207	8.201	8.204	8.209
8.0	24.533	24.543	24.519	24.547	24.543	24.518	8.187	8.187	8.202	8.197	8.199	8.205
8.5	24.541	24.553	24.546	24.556	24.548	24.532	8.186	8.185	8.199	8.192	8.195	8.203
9.0	24.551	24.557	24.562	24.560	24.558	24.547	8.181	8.181	8.193	8.187	8.193	8.199
9.5	24.556	24.559	24.567	24.562	24.565	24.554	8.178	8.178	8.188	8.183	8.188	8.196
10.0	24.558	24.560	24.577	24.566	24.569	24.564	8.175	8.176	8.182	8.180	8.184	8.191
10.5	24.567	24.564	24.588	24.571	24.572	24.571	8.173	8.174	8.179	8.178	8.181	8.187
11.0	24.593	24.586	24.593	24.578	24.582	24.579	8.171	8.173	8.175	8.178	8.180	8.181
11.5	24.622	24.616	24.603	24.599	24.609	24.602	8.165	8.169	8.171	8.175	8.177	8.179
12.0	24.639	24.636	24.610	24.620	24.630	24.622	8.155	8.161	8.168	8.171	8.172	8.176
12.5	24.655	24.650	24.625	24.635	24.637	24.638	8.153	8.157	8.165	8.166	8.165	8.169
13.0	24.669	24.659	24.643	24.651	24.647	24.647	8.150	8.155	8.160	8.162	8.162	8.163
13.5	24.682	24.673	24.659	24.662	24.660	24.649	8.146	8.151	8.157	8.156	8.157	8.158
14.0	24.687	24.686	24.671	24.672	24.669	24.657	8.138	8.143	8.154	8.151	8.150	8.154
14.5	24.693	24.691	24.678	24.678	24.674	24.668	8.136	8.136	8.149	8.148	8.146	8.150
15.0	24.703	24.696	24.687	24.682	24.679	24.673	8.131	8.132	8.144	8.144	8.142	8.145
15.5	24.709	24.704	24.694	24.686	24.689	24.686	8.127	8.128	8.138	8.141	8.139	8.139
16.0	24.710	24.707	24.700	24.697	24.701	24.699	8.124	8.123	8.132	8.136	8.132	8.131
16.5			24.703	24.704		24.704			8.127	8.127		8.121

Table 5. Vertical Profile Data Collected on 9 October 2014 (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	9.052	9.083	9.068	8.959	8.960	8.911	91.736	87.199	92.509	91.156	91.117	91.501
1.5	9.044	9.087	9.052	8.918	8.956	8.889	90.173	90.686	92.490	91.003	91.154	91.560
2.0	9.037	9.073	9.038	8.963	8.975	8.916	88.475	91.535	92.451	90.973	90.221	90.948
2.5	8.995	9.052	9.034	9.028	8.977	9.019	88.594	89.970	92.180	90.442	89.008	90.494
3.0	8.948	8.934	9.038	8.978	8.988	8.992	88.224	91.346	92.002	88.292	87.921	89.353
3.5	8.904	8.917	9.008	8.951	8.979	8.971	88.246	88.969	91.615	88.283	89.164	88.343
4.0	8.873	8.913	8.962	8.959	8.963	8.951	88.458	89.110	91.053	88.843	89.932	89.618
4.5	8.825	8.903	8.895	8.941	8.924	8.911	88.863	89.792	89.177	89.761	90.037	89.605
5.0	8.809	8.866	8.874	8.860	8.872	8.892	89.505	89.697	89.777	89.782	90.217	90.293
5.5	8.793	8.678	8.820	8.809	8.859	8.881	89.408	90.022	90.136	91.076	90.937	90.697
6.0	8.751	8.612	8.770	8.754	8.802	8.830	90.104	89.979	90.761	91.192	91.141	91.029
6.5	8.665	8.620	8.734	8.716	8.796	8.825	90.243	90.265	91.388	91.757	91.628	91.123
7.0	8.619	8.595	8.706	8.681	8.705	8.765	90.544	90.532	91.125	91.592	91.644	91.332
7.5	8.597	8.591	8.643	8.615	8.689	8.796	90.527	90.432	91.120	91.389	91.511	91.479
8.0	8.537	8.448	8.354	8.506	8.678	8.692	90.244	90.447	91.079	91.239	91.414	91.567
8.5	8.465	8.498	8.433	8.510	8.533	8.608	89.739	90.402	90.893	91.003	91.202	91.517
9.0	8.449	8.459	8.395	8.482	8.482	8.603	89.906	90.244	90.519	90.921	91.288	91.399
9.5	8.452	8.454	8.346	8.466	8.454	8.456	89.709	90.051	90.223	90.622	91.084	91.213
10.0	8.401	8.418	8.277	8.426	8.424	8.440	89.643	89.831	90.347	90.391	90.779	91.302
10.5	8.249	8.282	8.282	8.388	8.357	8.394	89.652	89.964	90.344	91.005	90.448	90.842
11.0	8.078	8.175	8.251	8.255	8.190	8.204	89.948	90.253	90.465	90.566	90.652	91.023
11.5	8.151	8.170	8.228	8.161	8.132	8.149	90.419	90.312	90.456	90.806	91.196	91.387
12.0	8.171	8.185	8.170	8.118	8.140	8.128	90.497	90.682	90.340	91.027	91.076	91.150
12.5	8.156	8.217	8.127	8.068	8.107	8.092	90.638	90.827	90.369	91.146	91.143	91.390
13.0	7.922	8.071	8.097	8.063	8.011	8.114	91.006	91.119	90.728	91.197	91.013	91.070
13.5	7.930	7.814	8.044	8.043	7.977	7.953	91.334	91.226	90.966	91.177	91.039	91.175
14.0	7.865	7.844	7.973	7.966	7.981	7.867	90.745	90.813	91.228	91.014	90.960	91.392
14.5	7.829	7.861	7.788	7.905	7.937	7.889	90.219	89.763	91.290	91.075	90.751	90.343
15.0	7.845	7.740	7.763	7.856	7.736	7.589	90.108	89.417	90.992	90.388	90.588	90.174
15.5	7.831	7.738	7.709	7.688	7.699	7.517	89.781	89.042	89.612	89.657	89.857	89.532
16.0	7.847	7.769	7.666	7.649	7.656	7.560	89.473	88.795	88.614	88.788	87.811	87.663
16.5			7.671	7.717		7.804			87.917	87.187		87.562

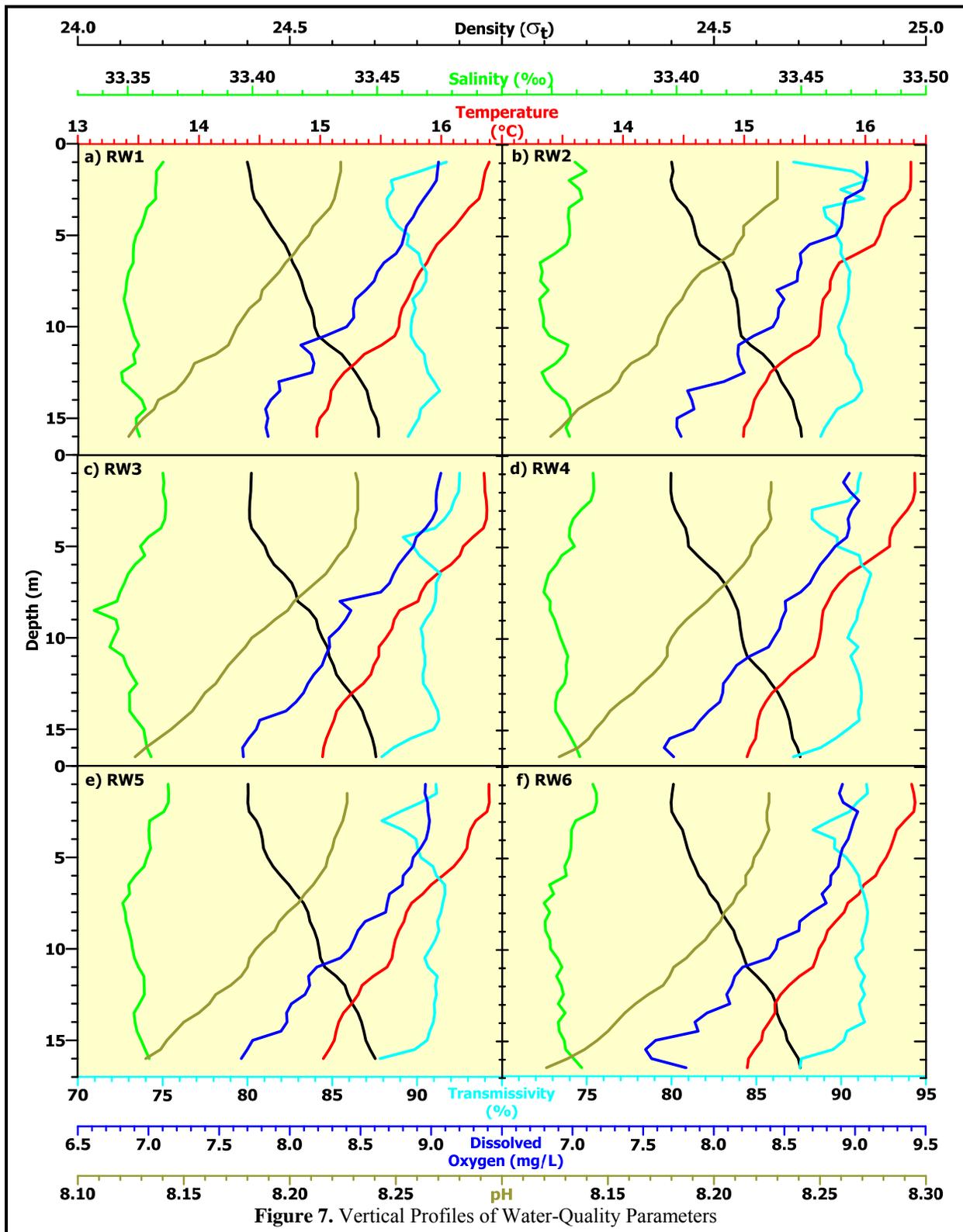


Figure 7. Vertical Profiles of Water-Quality Parameters

Steady decreases in temperature (red lines), DO (dark blue lines), and pH (olive-colored lines) with increasing depth reflect the lingering effects of upwelling in the days prior to the survey. These decreases are mirrored by a steady increase in density (black lines), with increasing depth beneath the mixed layer. These gradual vertical changes reflect the transition to a colder, saltier, nutrient-rich but oxygen-poor watermass that migrated shoreward along the seafloor as part of the upwelling process.

During the October 2014 survey, transmissivity did not exhibit a gradual vertical trend observed in the other seawater properties (light blue lines in Figure 7). Instead, reductions in water clarity occurred very near the sea surface and within 2 m of the sea floor. As described previously, the slight reduction in transmissivity that was apparent at the base of the surface mixed layer at most stations was caused by the increased presence of planktonic organisms due to upwelling. A sharper reduction in water clarity was apparent within 2 m of the seafloor at most stations. This decrease was due to the presence of a turbid benthic nepheloid layer (BNL) immediately above the seafloor. BNLs are caused by lightweight flocs of detritus that are resuspended by the turbulence generated by bottom currents. These particle-rich layers are a widespread phenomenon on continental shelves (Kuehl et al. 1996) and are frequently observed during the offshore surveys conducted within Estero Bay.

The degree of vertical stratification within the receiving seawater is important for understanding the dynamics of the effluent dispersion at the time of the survey. For example, when the water column is strongly stratified by upwelling, the rising plume can become trapped at depth within the water column, thereby limiting its full capacity for dilution. This was not the case during the October 2014 survey because the water column was only moderately stratified, and the signature of the discharge plume was measured close to the sea surface over a very limited spatial extent during the shallow tow survey. Thus, while the stratification was not strong enough to prevent a localized surface expression of the plume, it was strong enough to cause most of the plume to remain submerged. As a result, dilution levels were high, so there is little evidence of the plume in the vertical profiles except near 8.5 m at Station RW3 (green line in Figure 7c), where a slight reduction in salinity suggests the presence of dilute wastewater.

Although the presence of dilute effluent was not readily apparent in other water properties, they often exhibit excursions in conjunction with salinity anomalies when the water column is stratified. However, the excursions are not caused by the presence of wastewater constituents as in the case of salinity anomalies. Instead, they reflect the presence of ambient seawater that was entrained within the rising effluent plume shortly after its discharge near the seafloor.

Close to the seafloor, intense mixing is driven by the momentum of the effluent's ejection from the individual diffuser ports. Subsequent turbulent mixing caused by rise of the plume through the water column is less intense, and as a result, the dilute effluent plume tends to retain the ambient seawater properties it acquired at the seafloor. These deep seawater properties can become apparent as a signature of the buoyant effluent plume when they are juxtaposed against the ambient seawater characteristics in the mid and upper water column. These entrainment-generated anomalies are only apparent, however, when the water column is sufficiently stratified to cause a perceptible contrast between the shallow and deep ambient seawater properties.

Entrainment-generated anomalies are apparent in some of the horizontal maps produced by the tow surveys (Figures 8 and 9). For example, the slight 0.4°C reduction in temperature seen near the sea surface in Figure 9a is consistent with the upward movement of cooler 15.8°C seawater from near the seafloor. However, at depth (Figure 8a), no thermal signature associated with the plume can be readily discerned. It is clear that these types of localized anomalies in near-surface seawater properties were caused by entrainment rather than wastewater loading, because for some properties the offsets were

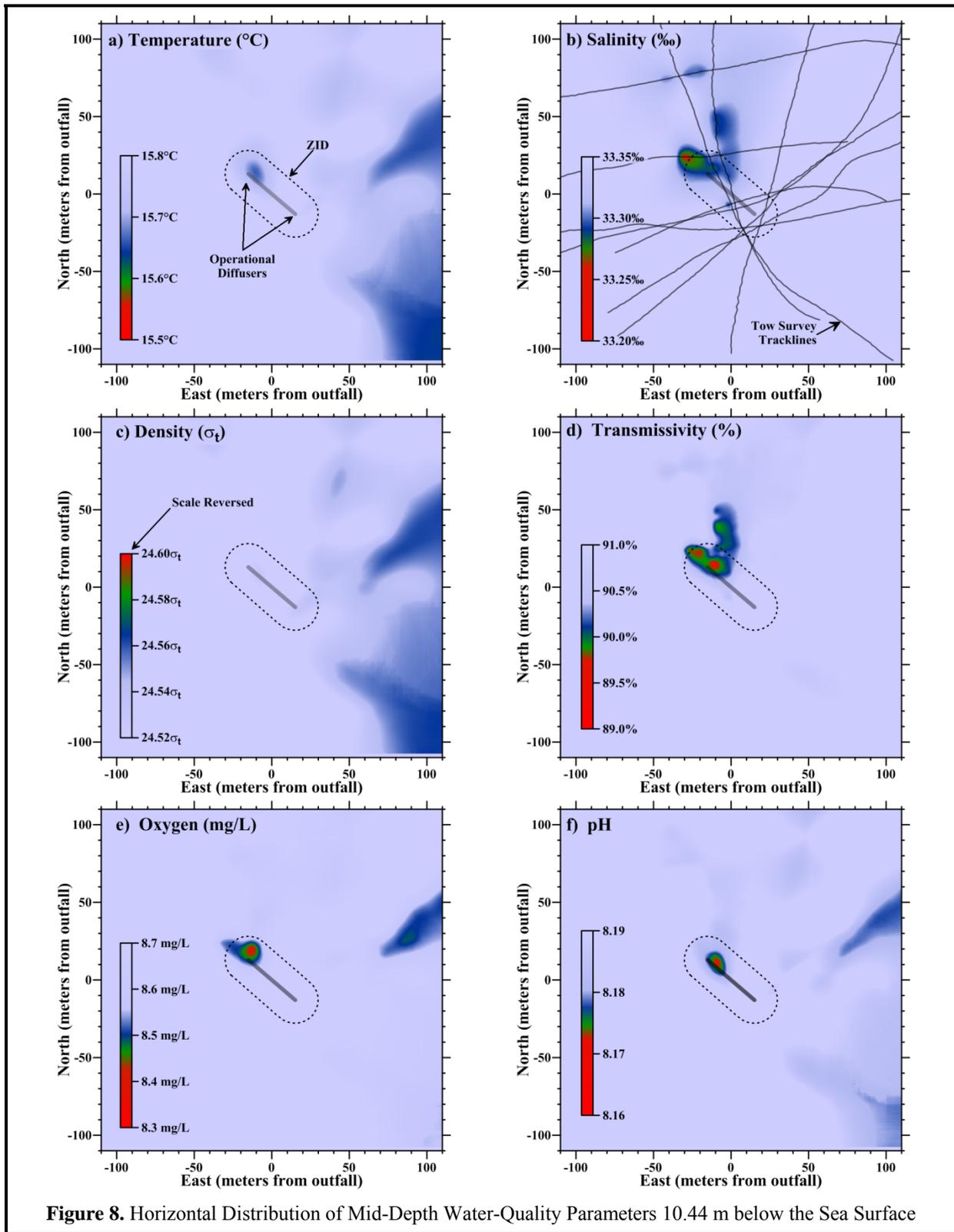


Figure 8. Horizontal Distribution of Mid-Depth Water-Quality Parameters 10.44 m below the Sea Surface

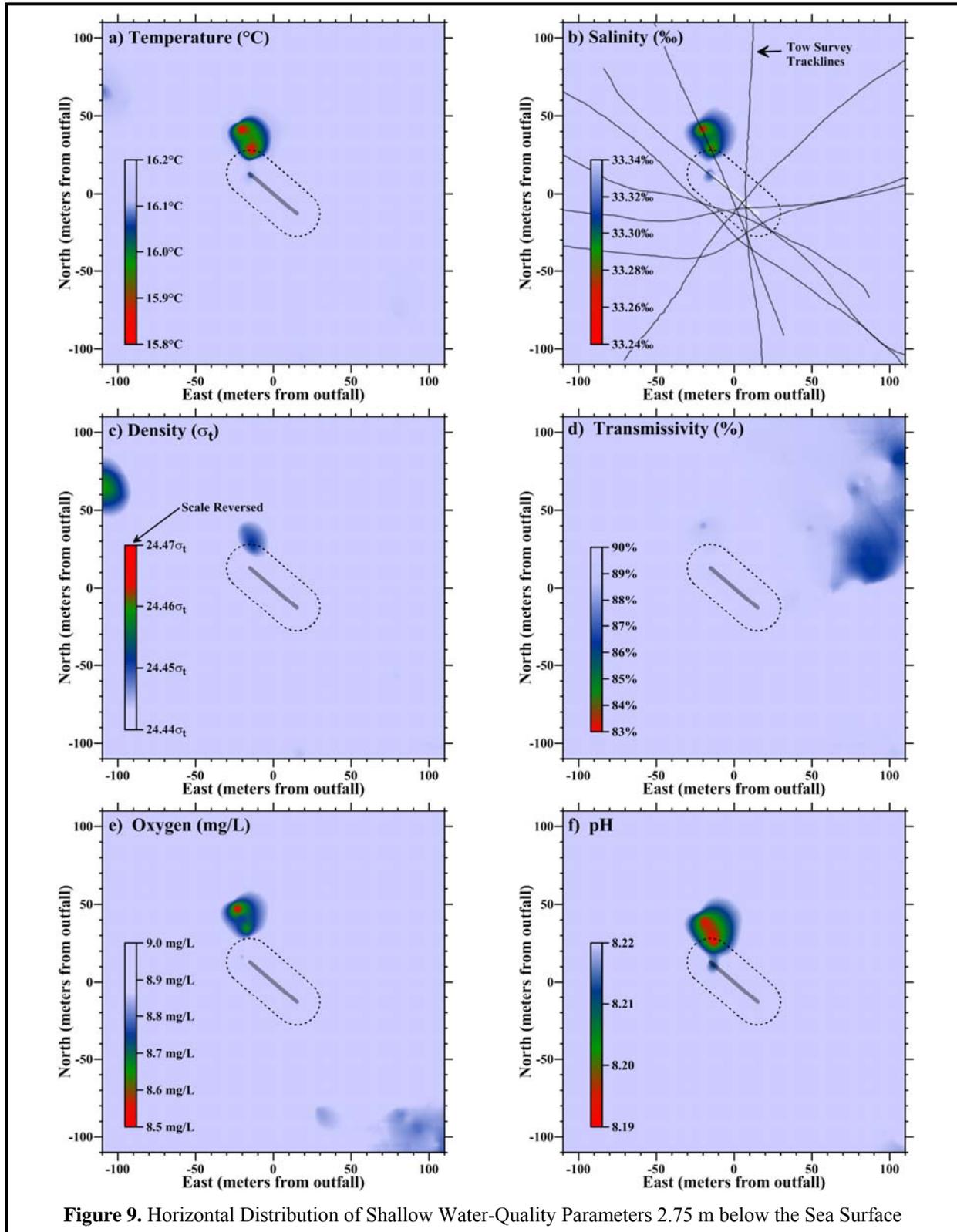


Figure 9. Horizontal Distribution of Shallow Water-Quality Parameters 2.75 m below the Sea Surface

opposite of the changes that would be caused by the presence of wastewater particulates. For example, wastewater discharged on the day of the survey was much warmer (23°C) than the receiving seawater at depth (15°C). Therefore, entrainment of bottom seawater is the only mechanism that could have created a plume that was cooler than the surrounding ambient seawater within the upper water column.

In contrast to the thermal anomalies, entrainment-generated reductions in DO and pH are apparent at depth (Figure 8ef) as well as near the sea surface (Figure 9ef). The locations and lateral extent of the DO and pH anomalies are consistent with the northward transport of the rising effluent plume. Specifically, the plume signatures near the sea surface (Figure 9ef) are offset to the north of the diffuser while the deeper DO and pH anomalies are centered close to the terminus of the diffuser structure (Figure 8ef). This offset was consistent with northward flow measured by the drogued drifter (Figure 3), particularly near the end of its deployment when the tow surveys were being conducted. Additionally, the lateral extent of the DO and pH anomalies at depth are perceptibly smaller than near the sea surface, where ongoing mixing had dispersed the plume and expanded its volume and lateral extent.

The opposite was the case for the entrainment-generated transmissivity anomaly (*cf.* Figures 8d and 9d). As described above, ambient seawater clarity was high throughout the water column except immediately above the seafloor and near the sea surface. As a result, turbid bottom water entrained within the rising plume was clearly evident at mid-depth against the backdrop of the naturally high transmissivity there (Figure 8d). However, as the mildly turbid water within the plume was carried farther upward and into the mixed layer, the increased presence of plankton and the concomitant reduction in ambient transmissivity largely eliminated the contrast (Figure 9d).

The legacies of entrainment anomalies can be particularly long-lived, remaining apparent within the water column well after completion of the initial dilution process. However, such anomalies are irrelevant to the receiving-water compliance assessment because the permit restricts attention to water-quality changes caused solely by the presence of wastewater constituents rather than a simple relocation of ambient seawater. Nevertheless, these anomalies provide useful tracers of the diffuse effluent plume after the completion of the initial dilution process.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the October 2014 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, ceasing to rise further in the water column, and spread laterally with no further dilution occurring. 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, however, the dilution levels

observed during the October 2014 survey were much higher than the 133:1 predicted by the modeling, and were measured at depths greater than the trapping depth predicted by 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. Application 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. The regions of slightly lower salinity apparent north of the diffuser structure in both of the tow-survey maps (Figures 8b and 9b) were induced by the presence of dilute wastewater. These salinity anomalies document mixing processes within the effluent plume shortly after discharge, and as it subsequently rose through the water column and approached the sea surface.

These salinity anomalies measure the magnitude of wastewater dilution at these various stages of the initial mixing process. 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)¹⁵ is generally small compared to that of the receiving seawater and, after dilution by more than 133-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, a lower effluent dilution at a given location within the receiving waters is directly mirrored by a larger salinity reduction.

¹⁵ Wastewater samples have an average salinity of 0.995‰.

The lowest salinities (<33.24‰) measured during the October 2014 survey were recorded near the terminus of the diffuser structure during the ninth transect of the mid-depth tow survey, and well north of the ZID boundary during the fourth transect of the shallow tow survey (red shading in Figures 8b and 9b). The lowest of these measured salinities corresponded to a reduction of 0.116‰ below the mean ambient salinity (33.352‰) measured at depth well beyond the influence of the discharge.

From Equation 2, that salinity anomaly corresponds to a dilution of 279-fold (Figure 10), which is double the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater. In addition, this dilution was measured at a depth of 9.4 m, which was 3 m deeper than the 6.4-m trapping depth identified in the modeling that established the 133:1 minimum dilution ratio. According to the conservative modeling results, dilution levels would be expected to be much less than 133:1 at that depth level. Instead, the much higher dilutions measured during the mid-depth tow indicate that the diffuser structure was dispersing the effluent far more efficiently than predicted by the modeling, even shortly after discharge and well before the completion of the initial dilution process.

As the buoyant plume rose within the water column and was carried northward by the prevailing current, turbulent mixing continued to dilute the wastewater. Accordingly, salinity data collected during the shallow tow demonstrated that the wastewater had been diluted by at least 284-fold by the time the dilute wastewater rose 6.7 m to a depth level of 2.7 m (Figure 11).

Overall, the dilution computations show that, during the October 2014 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 279-fold almost immediately after discharge, and well before completion of the initial-dilution process. After initial dilution was complete, effluent had been diluted at least 284-fold, easily exceeding 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. This demonstrates that, during the October 2014 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.

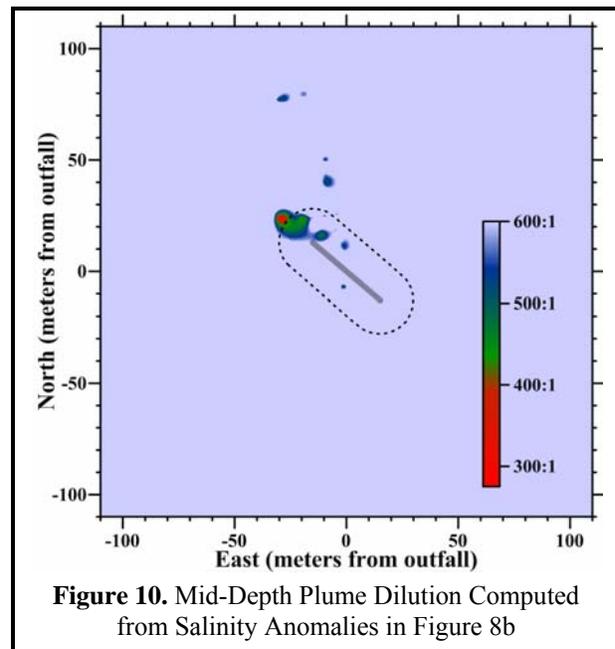


Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b

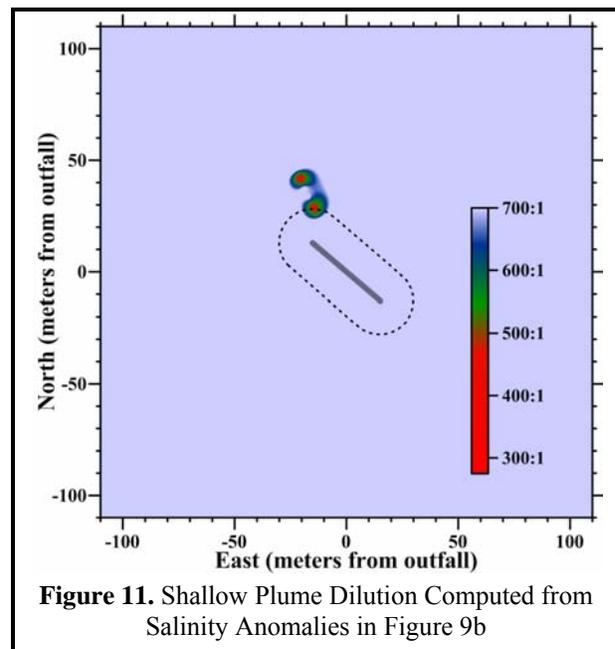


Figure 11. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 9b

COMPLIANCE

This section evaluates compliance with the water-quality limitations listed in the NPDES permit (Table 6). The limits 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 of the October 2014 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 met the prescribed limits because actual dilution levels routinely 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 October 2014 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. Compliance was demonstrated by the absence of floating wastewater materials, oil, grease, or discoloration of the sea surface during the October 2014 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.

As described previously, natural variation in seawater properties can result from a variety of oceanographic processes. These processes establish 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.

Screening of Measurements

Evaluating whether any of the 14,786 CTD measurements collected during the October 2014 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 pertain; 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 remain after completing the screening process can then be compared with Basin-Plan numerical limits and COP allowances.

Table 7. Receiving-Water Measurements Screened for Compliance Evaluation

Topic Addressed	Screening Question	Answer		Parameter
		No	Yes ¹⁶	
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	1,642	13,162	All
Wastewater Constituents	2. Did the beyond-ZID measurement coincide with a quantifiable salinity anomaly (≤550:1 dilution level) indicating the presence of detectable wastewater constituents?	13,078	84	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?	84	0	Temperature
		84	0	Transmissivity
		84	0	DO
		84	0	pH

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 presented in the following description of the three screening steps.

¹⁶ Number of remaining CTD observations of potential compliance interest based on this screening question

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 well 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 October 2014 dataset eliminated 1,624 of the original 14,786 receiving-water observations from further consideration because they were collected within the ZID (Table 7, Question 1). The remaining 13,162 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 definitive 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 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. Salinity 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 discussed previously, the lowest salinities measured during the October survey were recorded north of the diffuser structure during the course of the tow surveys. Numerous other detectable reductions in salinity unequivocally identified the presence of dilute wastewater constituents in close spatial proximity to these minima. About half (84) of these measurements were located beyond the ZID boundary. The 84 salinity reductions measured beyond the ZID had dilutions less than 550:1 (Table 7). The remaining

13,078 observations that were measured outside the ZID during the October 2014 survey did not have salinity reductions that were greater than the 0.062‰ detection level.

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 the numeric permit limits.

A statistical analysis of receiving-water data previously collected around the outfall was used to establish the range in natural conditions surrounding the outfall (first three data columns of Table 8). These ambient-variability ranges were used to identify significant departures from natural 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 (\pm 0.094). These were combined with 95th percentiles determined from the October 2014 ambient seawater data, to establish time-specific natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from October 2014 vertical profile data collected at Stations RW4, RW5, and RW6, thereby excluding measurements potentially affected by the discharge.

Table 8. Compliance Thresholds

Water Quality Property	95% Confidence Bound ¹⁷	95 th Percentile ^{18,19}	Natural Variability Threshold ²⁰	COP Allowance ²¹	Basin Plan Limit ²²	Extremum ²³
Temperature (°C)	0.82	16.40	>17.22	—	—	≤16.41
Transmissivity (%)	-10.2	88.2	<78.0	—	—	≥83.8
DO (mg/L)	-1.38	7.68	<6.30	<5.67	<5.00	≥7.52
pH (minimum)	-0.094	8.138	<8.044	<7.844	<7.000	≥8.121
pH (maximum)	0.094	8.227	>8.321	>8.521	>8.300	≤8.235

¹⁷ 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.

¹⁸ 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.”

¹⁹ The 95th-percentile quantifies natural variability in seawater properties during the October 2014 survey, and was determined from vertical-profiles data unaffected by the discharge.

²⁰ 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 October 2014 survey. They do not include the COP allowances specified in the column to the right.

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

²² 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 a more-stringent upper-bound objective of 8.3, which applies to individual beneficial uses, was implemented in the MBCSD discharge permit.

²³ Maximum or minimum value measured during this survey

Temperature, transmissivity, pH, and DO concentrations associated with the 84 remaining measurements of potential compliance interest were all well within their respective ranges of natural variability (Table 7, Question 3). As such, the screening process unequivocally eliminated all of the remaining CTD measurements collected during the October 2014 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.

As described previously, anomalies in seawater properties clearly delineated the plume, but those entrainment-generated excursions were not caused by the presence of wastewater constituents. During periods when the water column is stratified, as it was during the October 2014 survey, ambient seawater properties near the seafloor differ from those within the rest of the water column, and their juxtaposition within the rising effluent plume appears as lateral anomalies within the upper water column. Regardless, if the presence of wastewater particulates had contributed to the measured decreases in DO and pH, their influence would still have been well within the natural range of the ambient seawater properties at the time of the survey. Consequently, their influence on water quality would not be considered environmentally significant.

Other Lines of Evidence

Several additional lines of evidence further support the conclusion that all the CTD measurements collected during the October 2014 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 October 2014 survey.

Insignificant Thermal Impact: Although there are no explicit numerical objectives for discharge-related increases 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 17.22°C in Table 8). However, none of the 14,786 CTD measurements collected during the October 2014 survey exceeded 16.41°C (last column in Table 8). Additionally, as mentioned previously, because the effluent entrained cooler bottom water shortly after discharge, the rising plume actually exhibited a lower temperature than most of the surrounding seawater (Figure 9a).

Limited Ambient Light Penetration: As with temperature, there are no explicit numerical objectives for discharge-related decreases in transmissivity. However, the COP narrative objective (P4) limiting significant reductions in the transmission of natural light can also be translated into a numerical objective. Specifically, because the COP does not specify an allowance beyond natural conditions, the same threshold on ambient transmissivity variations listed in Table 8 can be interpreted to constitute a numerical limit. However, none of the transmissivity measurements collected during the October 2014 survey fell below the 78% minimum compliance threshold. In fact, the lowest transmissivity measured during the survey was 83.8%. Accordingly, Secchi measurements were uniformly deep, and did not decrease with proximity to the diffuser structure or effluent plume (Table 4).

Directional Offset: Analysis of the directional offset of CTD measurements is useful because wastewater and receiving-seawater properties vary from one another in several predictable ways. For example, upon discharge, wastewater is fresher, warmer, and lighter than the ambient receiving waters of Estero Bay. Under most conditions, wastewater is also more turbid than the receiving waters. As such, the presence of wastewater constituents will reduce the salinity, density, and transmissivity of the receiving seawater (negative offset), while temperature will be increased (positive offset). Therefore, as discussed previously, the reduced temperatures observed in conjunction with the effluent plume (Figure 9a) could not have been generated by the presence of warmer wastewater constituents.

Insignificant Wastewater Particulate Loads: Another independent line of evidence demonstrates that the discharge of wastewater particulates could not have contributed materially to turbidity within the dilute effluent plume. The suspended-solids concentration measured onshore, within the effluent, prior to discharge from the WWTP on 9 October 2014 was 28.6 mg/L. After dilution by 279-fold, the effluent suspended-solids concentration would have the reduced ambient transmissivity by only 0.8% near the sea surface. This small potential decrease in transmissivity was insignificant compared to the naturally-occurring 3% decrease that was observed within the BNL near the seafloor.

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, 38-mg/L BOD measured within the plant's effluent on the day prior to 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 discharge 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 due to the lack of atmospheric equilibration.

COP Allowances: The COP does not explicitly require that wastewater-induced changes remain within the ranges in natural variation listed in the third data column of Table 8, even though these ranges were conservatively used in the data screening process described in the previous subsection. Consideration of these COP allowances in the receiving-water limits provides an additional level of confidence in the compliance evaluation.

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 7.844 during the October 2014 survey (fourth data column of Table 8). This limiting value is significantly less than the lowest pH measurement of 8.121 recorded during the October 2014 survey (last column of Table 8). Similarly, the lowest DO concentration measured during the survey (7.52 mg/L) was well above both the lower range in natural variation (6.3 mg/L) and the 10% compliance threshold promulgated by the COP (5.67 mg/L).

Excursions remained within the fixed Basin-Plan Limits: Permit provisions P5 and P6 (Table 6) combine receiving-water objectives from both the COP and the Basin Plan with regard to DO and pH limitations. As described previously, the COP requires that DO concentrations outside the ZID not be depressed more than 10% from that which occurs naturally, and restricts pH measurements to those within 0.2 units of that which occurs naturally. In contrast, the Basin-Plan's fixed numerical limits do not provide specific guidance as to how they might change in response to widespread changes in oceanographic conditions unrelated to the discharge. Specifically, the fixed numerical limits restrict DO concentrations outside the ZID to no less than 5 mg/L (P5 in Table 6), and pH levels to the 7.0-to-8.3 range (P6). All of the measurements complied with the Basin-Plan limits, including the more-restrictive limit on maximum pH.

CONCLUSIONS

The quantitative screening analysis demonstrated that all measurements recorded during the October 2014 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. Specifically, although discharge-related changes in seawater properties were observed during the October 2014 survey, the changes were either not of significant magnitude (i.e., they were within the natural range of variability that prevailed at the time of the survey), 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.

Shortly after discharge, and well before the initial dilution process was complete, the effluent was achieving dilution levels in excess of 279-fold, which is more than double the critical dilution levels predicted by design modeling. As the plume rose through the water column and approached the sea surface, near the completion of the initial mixing process, dilution levels exceeded 284-fold. All of the measured dilution levels far exceeded levels that were predicted by modeling and that were incorporated in the discharge permit as limits on contaminant concentrations within effluent prior to discharge. Lastly, all of the auxiliary observations collected during the October 2014 survey demonstrated that the discharge complied with the narrative receiving-water limits in the discharge permit and the COP. Together, these observations demonstrate that the treatment process, diffuser structure, and the outfall continue to surpass design expectations.

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