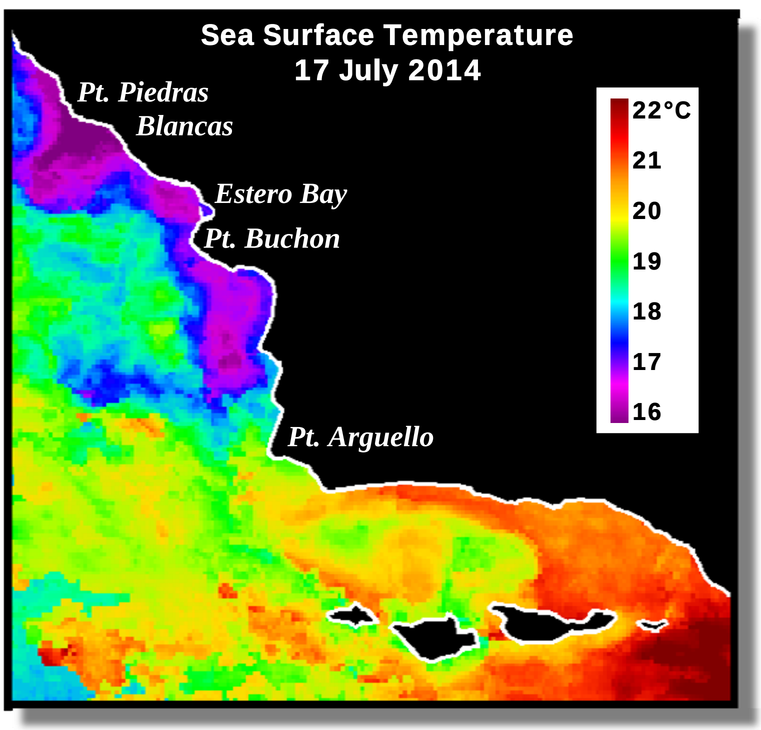
City of Morro Bay and
Cayucos Sanitary District

OFFSHORE MONITORING AND REPORTING PROGRAM

THIRD QUARTER RECEIVING–WATER SURVEY

JULY 2014



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Report to the

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THIRD QUARTER RECEIVING–WATER SURVEY

JULY 2014

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

15 October 2014

Reference: Third Quarter Receiving-Water Survey Report – July 2014

Dear Mr. Keogh:

The attached report presents results from a quarterly receiving-water survey conducted on Tuesday 15 July 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

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.

Bruce Keogh

Mr. Bruce Keogh
Wastewater Division Manager
City of Morro Bay

Date October 15, 2014

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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 July 2014 field survey described in this report was the twenty-second 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 15 July 2014. Specifically, this third-quarter survey captured ambient oceanographic conditions along the central California coast during the 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 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 CTD[1] 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.

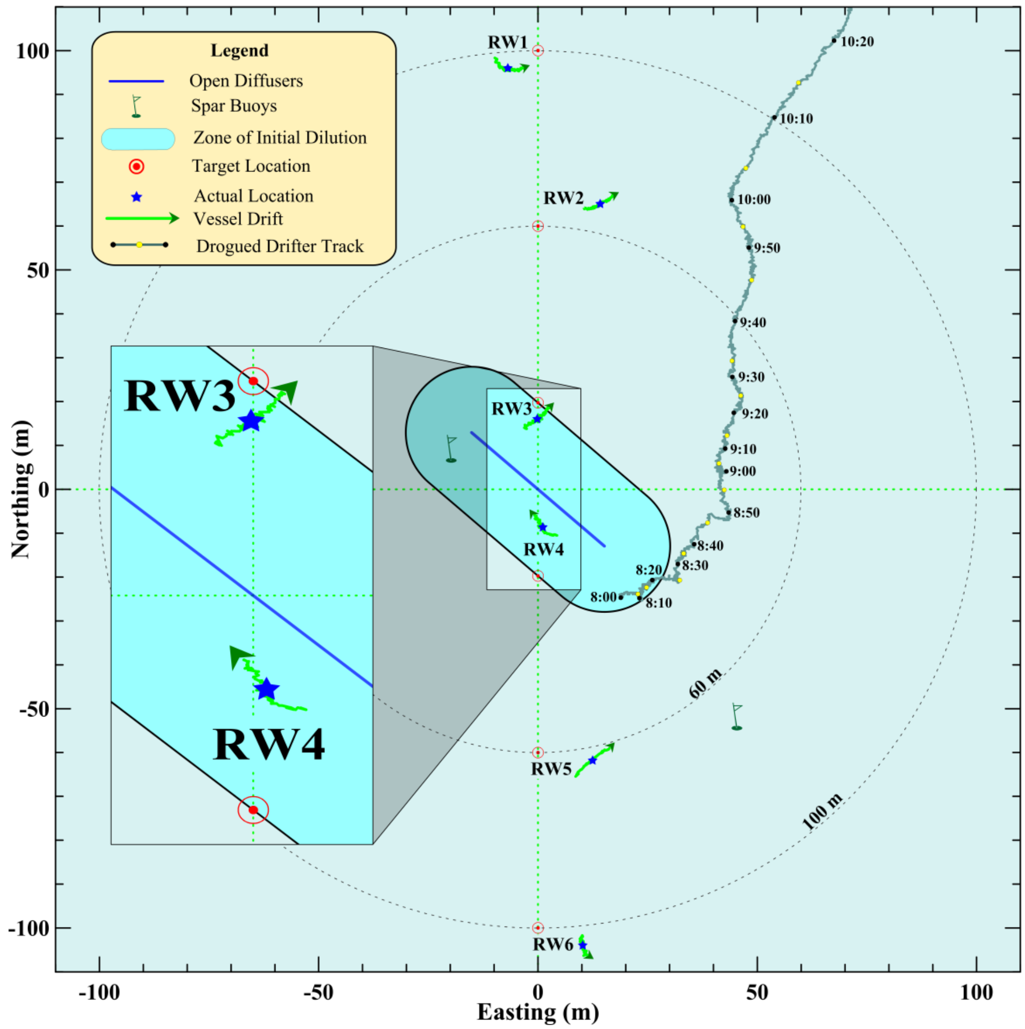

Figure 2. Station Locations

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 metocean[4] 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 July 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 July 2014 survey. During the time it took the CTD to traverse the water column to the seafloor, which averaged 1 min 26 s, the instrument package moved as much as 10.1 m laterally (Station 5). However, the average drift measured among all of the stations was 7 m, which is similar to that of prior surveys.

The downcasts during the July 2014 survey were conducted progressing from north to south, beginning with Station RW1. As seen in Figure 2, the CTD movement varied among the stations. The northeastward movement at Stations RW2, RW3, and RW5 was consistent with the northeastward transport of the drifter and the prevailing southwesterly winds.[5] In contrast, the CTD movement at the remaining stations was influenced by the vessel's residual momentum immediately prior to each downcast. For example, residual momentum temporarily counteracted the effects of the northeastward current and wind flow as the vessel approached Stations RW1 and RW6 from the northeast, resulting in a reduced amount of drift at these stations.

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 July 2014 survey, all of the CTD data at both RW3 and RW4 was collected within the ZID (see the inset in Figure 2), except for the data collected immediately above the seafloor at Station RW3. Therefore, nearly all of the measurements at these stations were excluded from the compliance evaluations.

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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 within 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 July 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 July 2014 Survey

	Time (PDT)				Closest Approach	
Station	**Downcast**	**Upcast**	**Latitude**	**Longitude**	**Range[6](m)**	**Bearing[7](ºT)**
RW1	8:06:11	8:07:35	35° 23.251' N	120° 52.509' W	83.6	6
RW2	8:13:35	8:15:01	35° 23.234' N	120° 52.495' W	59.9	29
RW3	8:21:45	8:23:24	35° 23.208' N	120° 52.504' W	**12.2**[8]	41
RW4	8:29:45	8:31:13	35° 23.194' N	120° 52.503' W	**5.8**[9]	221
RW5	8:40:01	8:41:19	35° 23.166' N	120° 52.496' W	48.9	183
RW6	8:46:57	8:48:15	35° 23.143' N	120° 52.497' W	91.0	183

OCEANOGRAPHIC PROCESSES

The trajectory of a satellite-tracked drogued drifter measured oceanic flow throughout the July 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 Except for a few of the deepest measurements, CTD measurements at Station RW3 were located within the ZID boundary (refer to the inset in Figure 2)
9 All of the CTD measurements collected at Station RW4 were located within the ZID boundary (refer to the inset in Figure 2).

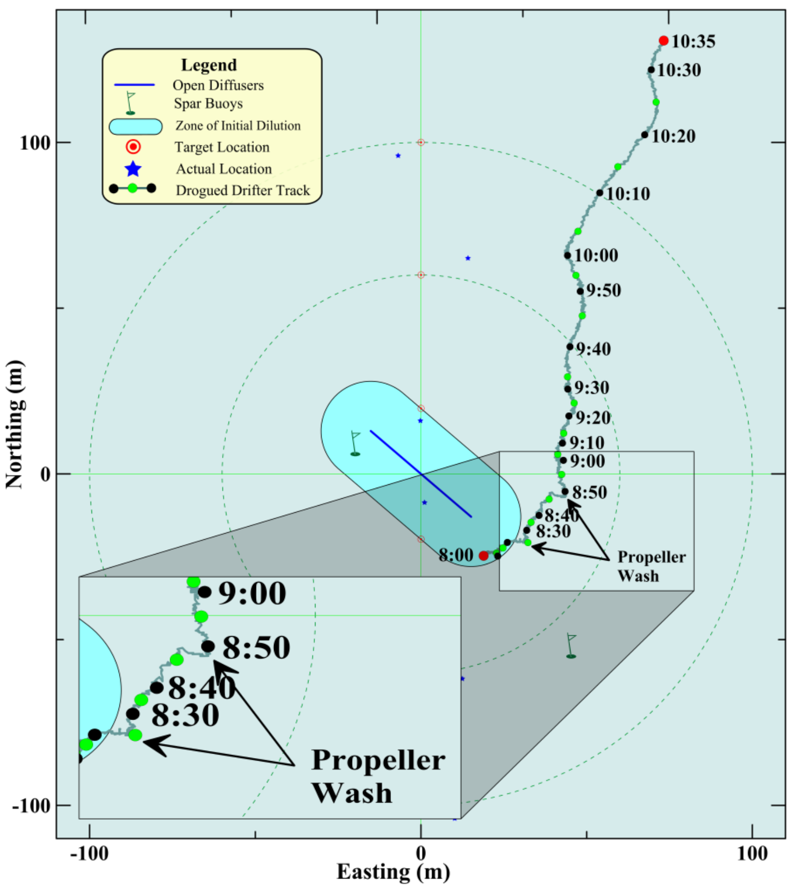

Figure 3. Drogued Drifter Trajectory

During the July 2014 survey, the drifter was deployed near the diffuser structure at 8:00 AM, and was recovered at 10:35 AM at a location 165 m to the north-northeast (19ºT[10]) of its original release point (red dots in Figure 3). However, the drifter's movement was not uniform. For the first two hours after its deployment, it traveled for 105 m along a slightly curved path at a speed of 1.5 m/s[11], ending up 94 m from its release point. During the last 35 minutes of the survey, however, when the mid-depth tow was being conducted, current speeds more than doubled to 3.4 cm/s[12] and the 24ºT flow direction was comparatively constant. The increased flow speed is reflected by the increased distance between the green and black dots in Figure 3. The dots show the drifter's progress at five- and ten-minute intervals. At this increased transport rate, the effluent would have experienced a brief, seven-minute residence time within the ZID, as compared to the 17-minute residence time that applied during most of the rest of the survey.

[10] Direction measured clockwise relative to true (rather than magnetic) north
[11] 0.0283 kt
[12] 0.0664 kt

On two occasions shortly after its deployment, the drifter trajectory exhibited brief departures from its general path (see the inset in Figure 3). These two 4-m offsets do not reflect actual variations in current velocity. Instead, they were caused when propeller-wash from the survey vessel temporarily affected drifter's surface buoy, pushing it away from its position directly above the subsurface drogue. As noted in the survey log, wash from the propeller was visually observed impinging on the surface buoy at 8:25, as the survey vessel was being positioned for the vertical cast at Station RW4. Comparison of the vessel and drifter navigation data confirmed that the vessel also passed close to the drifter at around 8:45, after the Secchi depth was measured at Station RW5.

The overall flow direction and speed increases measured by the drifter were consistent with the flood tide that increased in strength during the July 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 induce a northeastward flow at depth as offshore waters move shoreward and upwell to replace near-surface waters driven offshore by the winds.

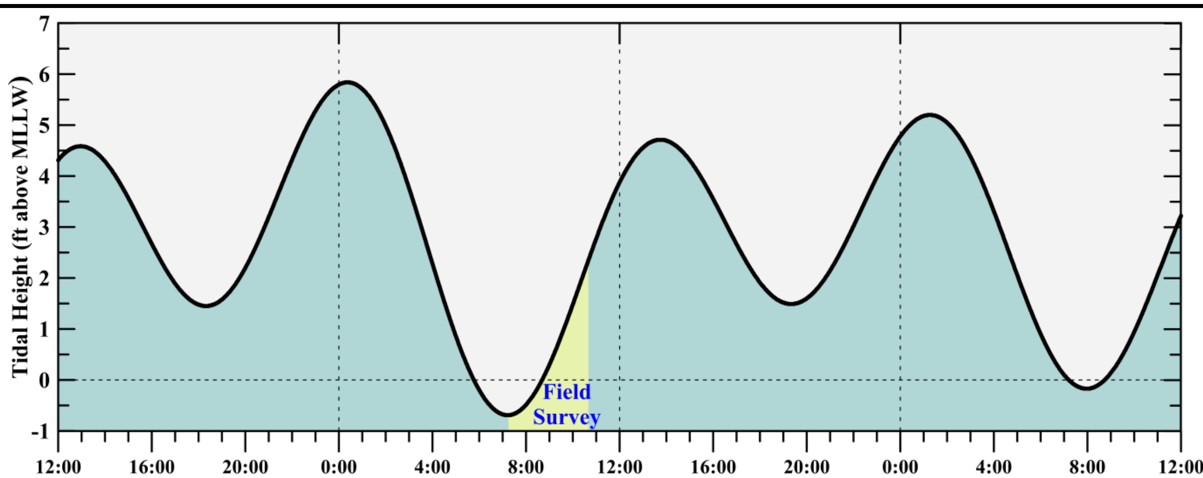

Figure 4. Tidal Level during the July 2014 Survey

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.

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. 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

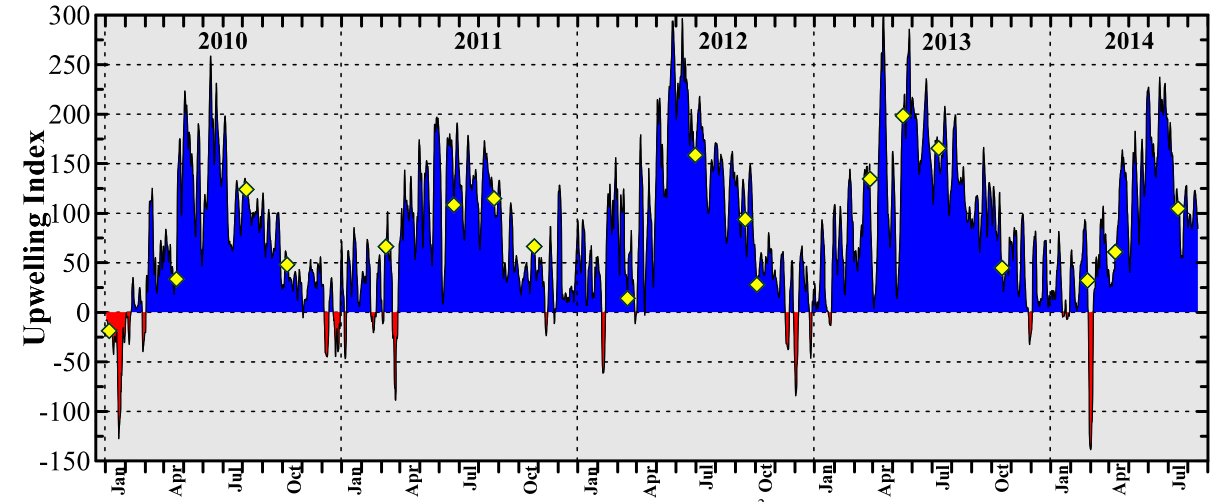

Figure 5. Five-Day Average Upwelling Index ($m^3/s/100$ m of coastline)

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.

Upwelling winds were relatively strong prior to the July 2014 survey (last yellow diamond in Figure 5). The sustained afternoon upwelling winds around the time of the survey 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 close to the south-central coastline (purple shading), and the 4°C contrast between nearshore and offshore sea-surface temperatures is typical of strong 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 well stratified at the time of the July 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 Tuesday, 15 July 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. 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 July2014 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	ºC	–5 to 35	± 0.005	± 0.0001
Transmissivity (WETLabs C-Star)[13]	%	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%.

[13] 25-cm path length of red (660 nm) light

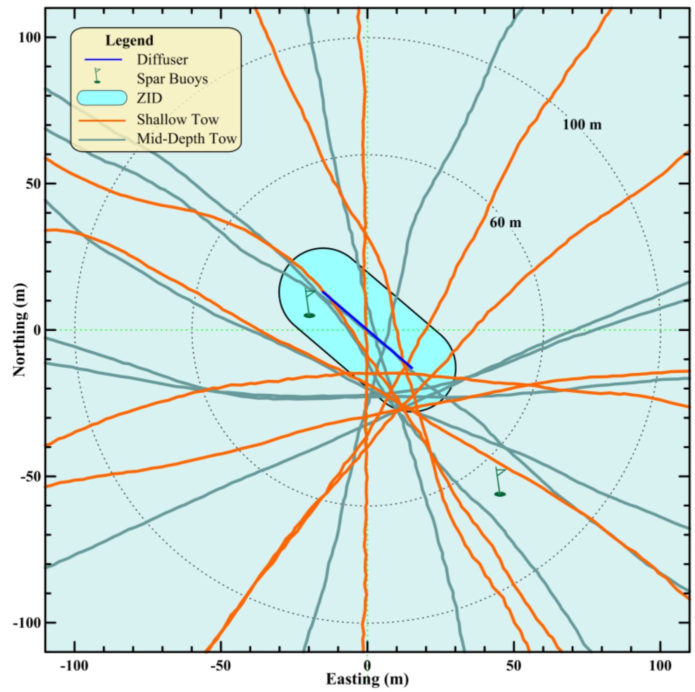

Figure 6. CTD Tracklines during the July 2014 Tow Surveys

Before the first vertical hydrocast at Station RW1, 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 8:49 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 below the thermocline, in accordance with the monitoring requirements of the NPDES discharge permit (Figure 6).

Initially, the reconfigured CTD package was towed for 38 minutes at an average depth of 5.14 m, and an average speed of 1.70 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 8.04 m. During this 37-minute mid-depth tow, vessel speed averaged 1.73 m/s. At the observed towing speeds and the 4 Hz sampling rate, at least 2.3 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.[14]

Quality Control

During the vertical-profiling and horizontal-towing phases of the survey, real-time data were monitored for completeness and range acceptability. The monitoring indicated the recorded properties were complete and within acceptable coastal seawater ranges.[15]

[14] Figures 8 and 9 later in this report

[15] 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.

RESULTS

The third-quarter receiving-water survey was conducted on the morning of Tuesday, 15 July 2014. The receiving-water survey commenced at 7:57 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 10:35 AM with the retrieval of the drogued drifter. Collection of required visual observations of the sea surface was unencumbered throughout the survey.

Auxiliary Observations

On the morning of 15 July 2014, skies were overcast, with light southwesterly winds. Average wind speeds, calculated over one-minute intervals, ranged from 0.0 kt to 1.9 kt (Table 4). Similarly, peak wind speeds ranged from 0.0 kt to 3.0 kt. The swell was out of the northwest with a significant wave height of three feet. Air temperatures remained fairly constant throughout the survey, averaging 17.7°C.

Table 4. Standard Meteorological and Oceanographic Observations

Station	Location[16] Latitude	Longitude	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)
RW1	35° 23.258' N	120° 52.503' W	97.4	8:09:16	18.3.	100	0.0	0.0	SW	2-3 NW	8.0
RW2	35° 23.237' N	120° 52.490' W	67.8	8:16:43	17.6	100	1.0	1.7	SW	2-3 NW	8.0
RW3	35° 23.214' N	120° 52.500' W	25.0	8:24:36	18.2	100	0.6	1.1	SW	2-3 NW	5.0
RW4	35° 23.193' N	120° 52.504' W	7.2	8:32:14	17.4	100	1.4	1.8	SW	2-3 NW	7.5
RW5	35° 23.169' N	120° 52.492' W	42.2	8:42:49	17.4	100	1.1	1.8	SW	2-3 NW	8.0
RW6	35° 23.143' N	120° 52.498' W	91.2	8:49:33	17.4	100	1.9	3.0	SW	2-3 NW	8.0

The 8.0 m Secchi depths recorded during the July 2014 survey reflected the presence of a 16-m euphotic zone that extended throughout the water column (Table 4). The lowest ambient water clarity during the survey was located at the sea surface and seafloor, with high transmissivities exceeding 90% throughout the rest of the water column. 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 zooplanktonic predators, these elevated plankton densities reduced the transmittance of ambient light in the upper water column during the July 2014 survey. However, even within the surface mixed layer, water clarity was high, exceeding 81% 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 1.006 million gallons of effluent discharged on 15 July had a temperature of 23°C, a suspended-solids concentration of 16.2 mg/L, and a pH of 7.6. The biochemical oxygen demand (BOD) of the effluent was measured one day later, on 16 July, at 42 mg/L.

During the July 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*

[16] 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.

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 and fog persisted throughout most of the survey, however pedestrians and surfers were visible along Atascadero State beach towards the end of the survey. Numerous small recreational fishing vessels were observed throughout 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 July 2014 survey reflect the presence of a strongly 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 watermasses is reduced, and stratification appears as a more gradual vertical change in seawater properties below the surface mixed layer. Both types of upwelling signatures are apparent in the July 2014 vertical profiles (Figure 7). A sharply defined interface with large changes in seawater properties over limited vertical extent is apparent between 2 m and 4 m, immediately beneath a relatively uniform surface mixed layer. In the rest of the water column below this shallow thermocline, seawater properties steadily change in a more gradual manner with increasing depth at all the stations unaffected by the discharge (Stations RW1, RW5, and RW6 in Figure 7aef).

In particular, all seawater properties exhibit steadily increasing or decreasing values below the sharply defined shallow thermocline. This transition zone separates the surface mixed layer from a deeper seawater mass situated immediately above the sea floor. 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 within the transition zone. These gradual vertical changes reflect the presence of a colder, saltier, nutrient-rich but oxygen-poor watermass that migrated shoreward along the seafloor as part of the upwelling process.

A similar decrease in transmissivity is also apparent within 2 m of the seafloor at most stations (light blue lines in Figure 7). 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.

Table 5. Vertical Profile Data Collected on 15 July 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	15.321	15.209	15.419	14.858	14.686	15.273	33.495	33.536	33.562	33.500	33.533	33.541
1.5	15.096	14.981	14.675	14.855	14.602	15.147	33.538	33.528	33.502	33.500	33.518	33.537
2.0	14.779	14.781	14.311	14.685	14.642	15.183	33.523	33.521	33.465	33.481	33.531	33.540
2.5	14.568	14.684	14.004	14.399	14.562	14.896	33.519	33.524	33.435	33.457	33.527	33.521
3.0	14.393	14.311	13.881	13.803	14.284	14.471	33.512	33.489	33.425	33.415	33.494	33.510
3.5	14.200	13.944	13.840	13.535	13.957	14.267	33.501	33.454	33.419	33.402	33.462	33.512
4.0	14.051	13.742	13.844	13.530	13.891	14.023	33.509	33.436	33.420	33.409	33.484	33.498
4.5	14.011	13.820	13.819	13.505	13.895	13.993	33.516	33.471	33.422	33.415	33.493	33.506
5.0	13.963	13.912	13.702	13.502	13.904	14.002	33.517	33.509	33.405	33.415	33.499	33.517
5.5	13.909	13.943	13.515	13.583	13.915	13.941	33.518	33.518	33.384	33.462	33.506	33.518
6.0	13.861	13.894	13.509	13.517	13.907	13.841	33.520	33.520	33.388	33.436	33.519	33.518
6.5	13.790	13.863	13.484	13.446	13.867	13.783	33.519	33.522	33.393	33.426	33.522	33.518
7.0	13.775	13.847	13.496	13.467	13.841	13.726	33.522	33.522	33.415	33.439	33.524	33.519
7.5	13.753	13.817	13.524	13.641	13.794	13.669	33.522	33.523	33.438	33.487	33.523	33.518
8.0	13.744	13.787	13.533	13.661	13.745	13.646	33.524	33.523	33.447	33.506	33.523	33.520
8.5	13.726	13.786	13.528	13.601	13.694	13.580	33.525	33.524	33.456	33.484	33.521	33.518
9.0	13.717	13.760	13.527	13.545	13.669	13.522	33.525	33.524	33.463	33.451	33.521	33.517
9.5	13.698	13.653	13.536	13.471	13.654	13.500	33.525	33.521	33.469	33.392	33.522	33.520
10.0	13.605	13.621	13.539	13.443	13.637	13.449	33.519	33.524	33.471	33.420	33.522	33.518
10.5	13.567	13.487	13.502	13.417	13.592	13.403	33.520	33.518	33.481	33.410	33.522	33.518
11.0	13.562	13.469	13.497	13.417	13.524	13.368	33.522	33.522	33.491	33.424	33.518	33.519
11.5	13.494	13.455	13.485	13.421	13.486	13.370	33.518	33.522	33.515	33.491	33.520	33.520
12.0	13.484	13.431	13.410	13.420	13.437	13.358	33.521	33.523	33.519	33.520	33.521	33.521
12.5	13.434	13.396	13.402	13.421	13.415	13.359	33.520	33.522	33.517	33.522	33.523	33.522
13.0	13.371	13.386	13.414	13.396	13.414	13.359	33.518	33.523	33.517	33.524	33.524	33.523
13.5	13.340	13.361	13.401	13.390	13.413	13.354	33.519	33.521	33.517	33.524	33.524	33.523
14.0	13.316	13.350	13.346	13.397	13.413	13.347	33.518	33.519	33.517	33.449	33.525	33.524
14.5	13.300	13.300	13.314	13.405	13.379	13.336	33.518	33.520	33.519	33.332	33.526	33.525
15.0	13.178	13.207	13.224	13.361	13.268	13.245	33.520	33.522	33.517	33.230	33.522	33.521
15.5			13.165	13.221	13.203	13.217			33.518	33.438	33.523	33.525

Table 5. Vertical Profile Data Collected on 15 July 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	24.742	24.798	24.772	24.846	24.909	24.788	8.053	8.056	8.042	8.028	8.040	8.055
1.5	24.824	24.841	24.887	24.847	24.915	24.812	8.055	8.055	8.046	8.034	8.044	8.061
2.0	24.881	24.879	24.936	24.869	24.916	24.806	8.054	8.052	8.033	8.035	8.043	8.060
2.5	24.923	24.902	24.977	24.911	24.931	24.855	8.049	8.050	8.022	8.031	8.045	8.061
3.0	24.955	24.955	24.995	25.003	24.964	24.937	8.046	8.045	8.018	8.022	8.045	8.060
3.5	24.987	25.004	24.999	25.048	25.007	24.981	8.039	8.035	8.011	8.009	8.042	8.056
4.0	25.025	25.032	24.998	25.054	25.039	25.022	8.037	8.026	8.005	7.996	8.034	8.055
4.5	25.038	25.043	25.005	25.064	25.044	25.034	8.035	8.016	8.001	7.987	8.031	8.050
5.0	25.049	25.053	25.016	25.065	25.047	25.041	8.033	8.016	7.997	7.985	8.030	8.047
5.5	25.061	25.054	25.038	25.084	25.050	25.054	8.032	8.023	7.993	7.985	8.029	8.044
6.0	25.072	25.066	25.042	25.078	25.062	25.075	8.031	8.026	7.985	7.984	8.029	8.041
6.5	25.086	25.073	25.051	25.085	25.072	25.087	8.028	8.026	7.980	7.982	8.028	8.036
7.0	25.091	25.077	25.066	25.090	25.079	25.099	8.024	8.026	7.977	7.979	8.025	8.031
7.5	25.096	25.084	25.078	25.092	25.089	25.110	8.021	8.025	7.977	7.982	8.022	8.028
8.0	25.100	25.090	25.083	25.103	25.099	25.117	8.018	8.021	7.979	7.989	8.019	8.026
8.5	25.104	25.091	25.091	25.098	25.107	25.129	8.012	8.018	7.980	7.996	8.018	8.025
9.0	25.106	25.096	25.096	25.084	25.113	25.139	8.009	8.015	7.983	7.996	8.019	8.023
9.5	25.110	25.116	25.099	25.053	25.117	25.146	8.006	8.013	7.984	7.989	8.018	8.020
10.0	25.124	25.125	25.100	25.081	25.120	25.155	8.007	8.008	7.986	7.985	8.018	8.020
10.5	25.133	25.147	25.116	25.078	25.129	25.164	8.005	8.003	7.987	7.981	8.019	8.019
11.0	25.135	25.154	25.124	25.089	25.140	25.172	8.005	7.995	7.988	7.977	8.018	8.017
11.5	25.146	25.157	25.145	25.140	25.149	25.173	8.004	7.991	7.990	7.981	8.017	8.015
12.0	25.151	25.163	25.163	25.162	25.159	25.176	8.004	7.988	7.994	7.986	8.016	8.013
12.5	25.160	25.169	25.163	25.164	25.165	25.176	8.004	7.985	7.992	7.988	8.012	8.011
13.0	25.171	25.172	25.161	25.170	25.166	25.177	8.001	7.983	7.987	7.988	8.005	8.008
13.5	25.178	25.175	25.164	25.172	25.167	25.178	7.999	7.982	7.987	7.986	8.000	8.005
14.0	25.182	25.176	25.175	25.112	25.168	25.181	7.996	7.981	7.984	7.986	7.994	8.002
14.5	25.185	25.186	25.183	25.020	25.175	25.183	7.990	7.977	7.981	7.977	7.990	7.998
15.0	25.211	25.206	25.200	24.950	25.195	25.199	7.980	7.972	7.975	7.962	7.986	7.993
15.5			25.212	25.139	25.209	25.207			7.969	7.947	7.978	7.982

Table 5. Vertical Profile Data Collected on 15 July 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	7.105	7.478	7.270	7.173	7.276	7.557	81.031	87.675	87.271	86.718	85.625	86.646
1.5	7.283	7.272	6.965	6.999	7.303	7.515	87.809	87.945	87.173	87.089	85.745	86.503
2.0	7.141	7.265	6.614	6.760	7.171	7.220	86.949	86.924	86.139	87.374	85.689	86.549
2.5	7.096	6.882	6.548	6.313	6.619	7.039	86.780	86.622	85.516	87.121	85.793	86.296
3.0	6.905	6.500	6.564	6.251	6.601	6.901	86.518	86.523	85.476	86.675	86.087	85.998
3.5	6.813	6.517	6.547	6.306	6.685	6.798	86.376	86.306	85.411	86.074	87.187	87.377
4.0	6.857	6.758	6.511	6.306	6.764	6.875	90.270	86.553	85.327	85.598	87.892	91.399
4.5	6.830	6.862	6.346	6.320	6.779	6.869	91.074	86.842	85.318	85.250	89.786	91.203
5.0	6.788	6.846	6.203	6.417	6.793	6.787	91.886	88.484	85.331	85.718	90.216	91.957
5.5	6.771	6.806	6.259	6.299	6.793	6.710	92.097	90.189	84.910	86.542	90.737	92.025
6.0	6.700	6.792	6.247	6.171	6.749	6.682	92.339	91.345	84.893	87.211	91.295	91.261
6.5	6.704	6.770	6.313	6.297	6.734	6.655	92.116	92.048	84.782	86.515	91.304	90.628
7.0	6.682	6.748	6.361	6.647	6.670	6.618	91.899	92.126	84.783	86.297	90.556	90.053
7.5	6.669	6.724	6.366	6.567	6.650	6.602	91.363	92.054	85.357	86.571	90.130	90.859
8.0	6.646	6.732	6.377	6.458	6.632	6.559	90.830	91.421	86.385	87.914	89.657	91.686
8.5	6.623	6.678	6.395	6.384	6.618	6.493	89.692	91.359	87.353	89.903	89.996	91.985
9.0	6.615	6.508	6.421	6.236	6.622	6.514	89.618	90.956	87.655	89.260	90.541	92.459
9.5	6.549	6.590	6.418	6.266	6.610	6.440	89.542	90.603	87.729	86.862	91.125	92.936
10.0	6.559	6.293	6.402	6.171	6.543	6.405	89.866	90.087	88.005	87.621	91.652	92.527
10.5	6.545	6.385	6.429	6.243	6.521	6.393	91.156	89.340	88.619	87.123	91.866	92.884
11.0	6.487	6.333	6.441	6.350	6.471	6.409	91.919	88.819	89.155	85.506	92.426	93.196
11.5	6.515	6.269	6.222	6.380	6.357	6.357	92.209	88.718	90.737	88.605	92.445	93.234
12.0	6.433	6.259	6.255	6.347	6.279	6.353	92.204	88.370	91.401	90.500	92.490	93.265
12.5	6.360	6.268	6.307	6.247	6.236	6.361	92.357	87.626	89.854	90.391	91.169	92.653
13.0	6.279	6.232	6.251	6.248	6.221	6.270	92.297	87.890	88.836	90.274	90.008	92.005
13.5	6.164	6.174	6.052	6.180	6.216	6.203	92.094	88.995	88.895	89.332	89.046	91.697
14.0	6.127	6.036	6.052	6.011	6.072	6.188	91.220	88.763	88.260	88.726	87.506	90.520
14.5	5.875	5.890	5.876	5.846	5.834	5.788	88.837	88.039	87.746	77.294	86.967	89.830
15.0	5.884	5.831	5.798	5.858	5.874	5.817	87.475	86.567	86.157	77.976	85.759	87.813
15.5			5.831	5.959	6.192	5.946			84.283	71.683	83.301	87.472

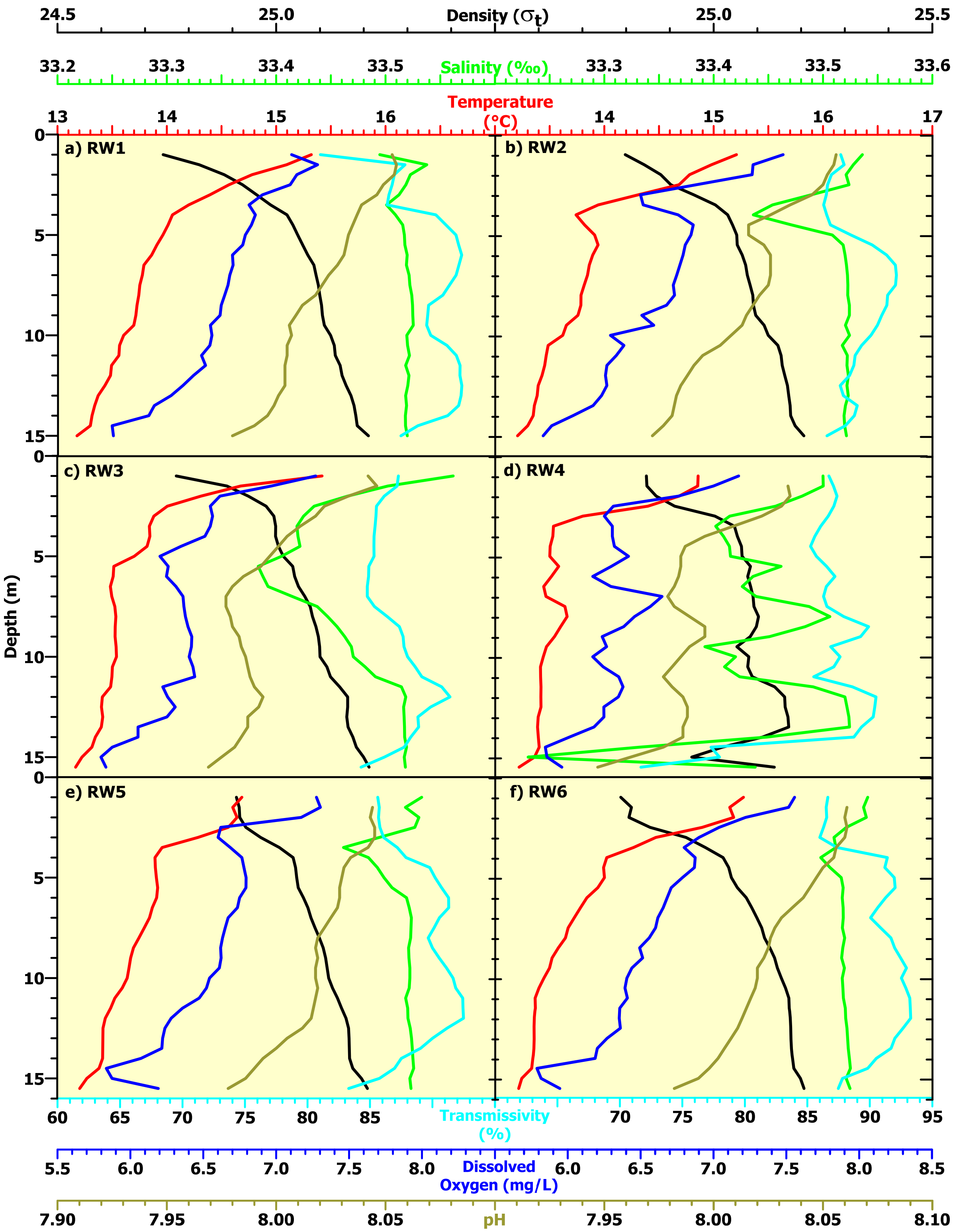

Figure 7. Vertical Profiles of Water-Quality Parameters

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 the case during the July 2014 survey, when the discharge plume spread horizontally beneath the surface mixed layer and did not appear to reach the sea surface. The increased presence of dilute effluent constituents trapped below the mixed layer is apparent in sharp reductions in salinity near 4 m at Stations RW2, RW3, RW4, and to a lesser extent RW5 (green lines in Figure 7bcde). These salinity reductions do not extend through the mixed layer to the sea surface however, indicating that the plume was trapped within the sharp thermocline immediately below 2 m, at these four stations.

Although the presence of dilute effluent within the upper water column was delineated by a sharp reduction in salinity at these four stations, changes observed in other water properties were not caused by the presence of wastewater constituents. 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 shallow and deep ambient seawater properties.

During the July 2014 survey, deep seawater properties were carried into the upper water column by the rising plume, creating a mid-depth water column with a vertical distribution of seawater properties that was more uniform compared to the vertical gradients seen at the other stations (*cf*. the dark blue, red, and olive lines between 3 and 14 m in Figure 7bcde as compared to Figure 7af). With the exception of salinity, the mid-depth water properties within the plume at Stations RW2, RW3, RW4, and RW5 were similar to the seawater properties found near the seafloor at all stations.

It also clear that the anomalies in seawater properties within the upper water column at these four stations were caused by entrainment rather than wastewater loading because for some properties, the offsets were opposite of the changes that would be expected if 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 (<13.5°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 (*cf*. the red lines at 4 m in Figure 7d and 7f).

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.

These post-initial-dilution signatures of the effluent plume as it spread well beyond the ZID are particularly apparent in maps created from the horizontal tow data during the shallow survey (Figure 9). During the mid-depth tow survey, however, the lateral extent of the plume was limited, and the presence of wastewater constituents, as indicated by slightly reduced salinity, was largely confined to a small area immediately northeast of the diffuser structure (green, and red shading in Figure 8b). This lateral offset is consistent with the direction of current flow as measured by the drogued drifter. Highly localized entrainment anomalies in transmissivity and pH (Figures 8df) coincided with the mid-depth salinity signature of the rising plume. However, plume-related anomalies in other seawater properties were more difficult to discern against the backdrop of natural variability in seawater properties (Figure 8ace). Specifically, reduced temperature, density, and DO measurements that would otherwise be indicative of entrainment anomalies near the diffuser structure were comparable to random fluctuations in areas where plume transport by ambient currents would not be expected.

In contrast, the distributions of near-surface seawater properties were more diagnostic of the location and extent of the discharge plume as it spread toward the northeast beneath the shallow thermocline (Figure 9). Because of the presence of strong vertical gradients immediately below the sea surface, ambient seawater properties near the 5-m tow depth differed substantially from those of the rest of the water column, and thus provided a greater contrast with the near-bottom seawater properties that were entrained in the rising effluent plume. As a result, the disposition of the effluent plume could be more easily traced using the entrainment anomalies.

While the largest anomalies in all the seawater properties generally coincided with the salinity anomaly near the ZID (Figure 9b), they also traced the plume as it spread to the northeast, well outside of the ZID. For example, the cooler 13.3°C temperature of the bottom seawater entrained within the rising effluent plume exhibited a well-defined thermal anomaly (Figure 9a) against the backdrop of the warmer, ambient shallow seawater temperatures. The cooler ambient seawater at mid-depth, however, the did not provide a sharp thermal contrast (Figure 8a). Similar entrainment-generated anomalies in DO and pH delineated the spread of the plume beneath the shallow thermocline (Figure 9ef), but at mid-depth, where DO and pH are naturally lower, the plume signature was substantially weaker and largely restricted to the ZID (Figure 8ef).

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 transmissivity largely eliminated the contrast in plume transmissivity (Figure 9d).

The general absence of a plume-related density anomaly at the shallow tow depth level (Figure 9c) indicates that the plume was neutrally buoyant and would not be expected to continue to rise within the water column. This suggests that the plume had become trapped at a depth near 5 m.

Outfall Performance

The efficacy of the outfall can be evaluated through a comparison of dilution levels measured at the time of the July 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

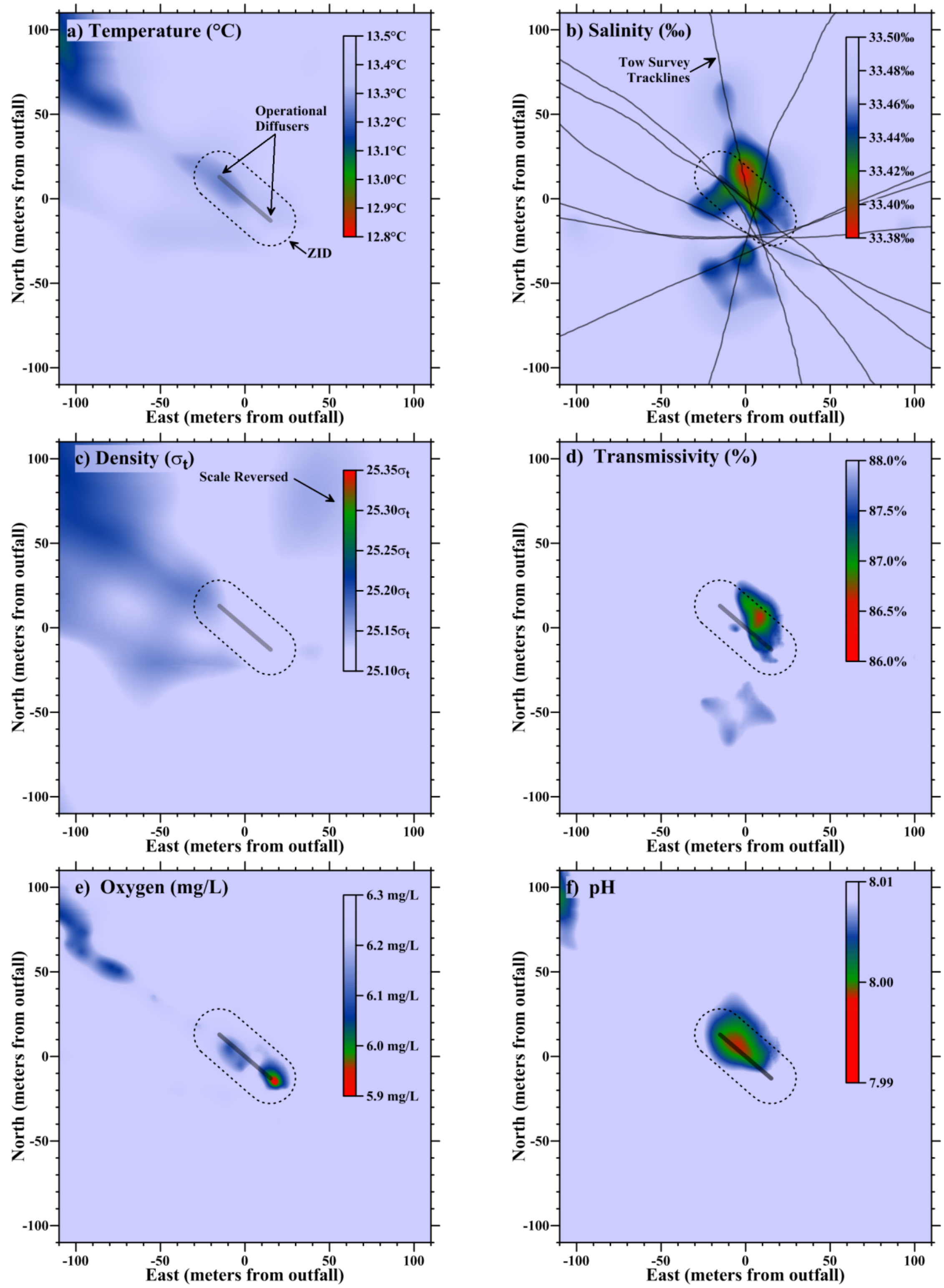

Figure 8. Horizontal Distribution of Mid-Depth Water-Quality Parameters 8.04 m below the Sea Surface

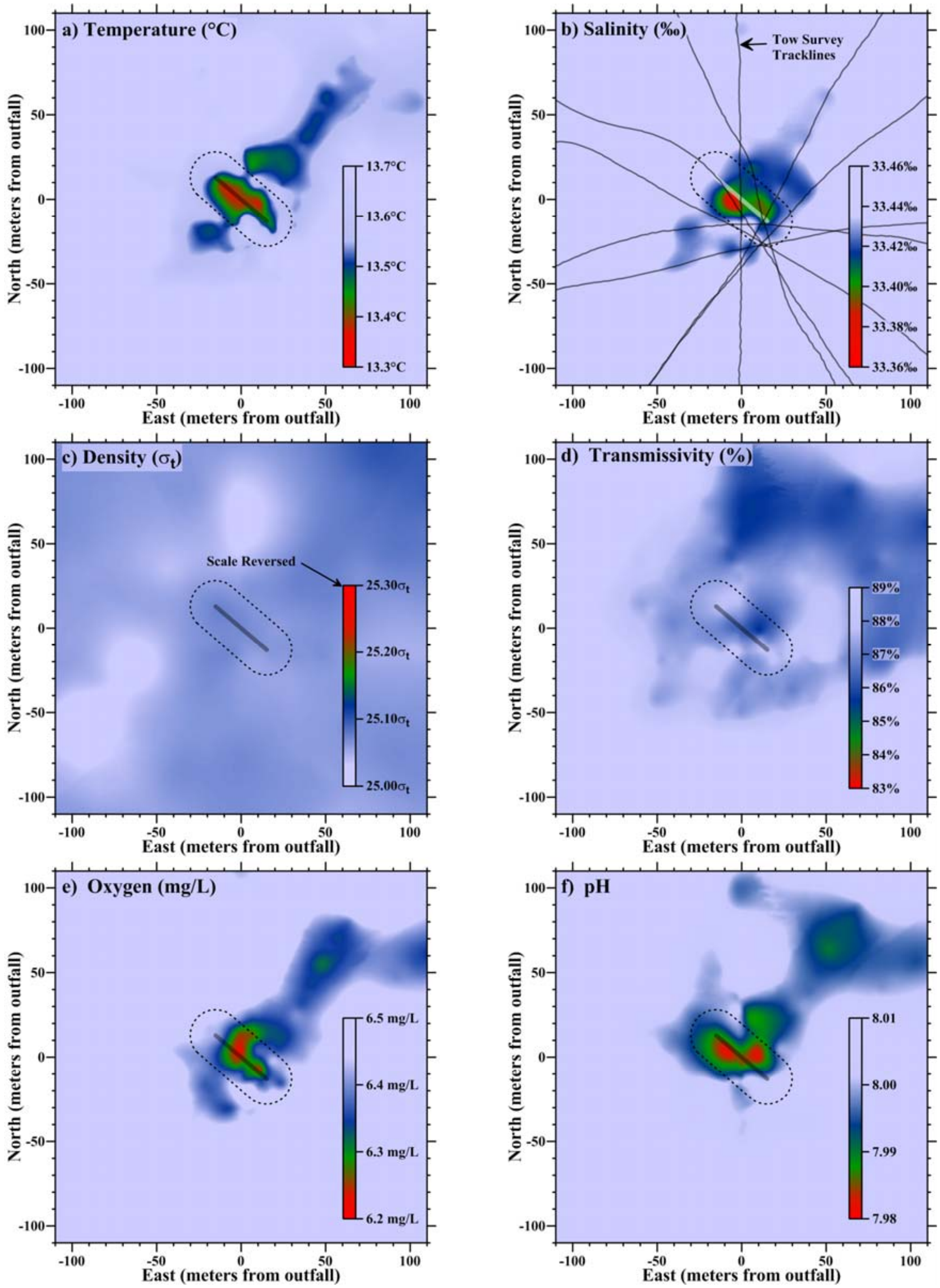

Figure 9. Horizontal Distribution of Shallow Water-Quality Parameters 5.14 m below the Sea Surface

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 observed dilution levels during the July 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.

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

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. As described above, wastewater-induced regions of slightly lower salinity were apparent in the upper water column in the vertical profiles measured at Stations RW2, RW3, and RW5 (green lines in Figure 7bce), and in localized patches of comparable salinity reductions near the diffuser structure in both of the tow-survey maps (Figures 8b and 9b). These salinity anomalies document mixing processes within the effluent plume as it rose through the water column and spread beneath the shallow thermocline.

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:

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

The salinity concentration within MBCSD effluent (C_e)[17] 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.

The vertical profile at Station RW4 provided a rare glimpse into effluent mixing dynamics immediately after discharge and within the turbulent ejection jet emanating from a single diffuser port. As shown in the inset of Figure 2, the CTD moved parallel to the diffuser structure as it was lowered to the seafloor well within the ZID. CTD data is not normally collected this close to the diffuser structure, and as a result of multiple encounters with the plume, the shapes of the vertical profiles measured during that hydrocast differ markedly from that of the other stations (Figure 7d). More importantly, as the CTD approached the seafloor near 15 m, it passed directly through an effluent ejection jet before reaching the seafloor at a depth of 15.5 m. The strongest effluent signature was located 0.5 m above the seafloor both because the buoyant jet rapidly carries the plume upward in the water column shortly after discharge, and because the diffuser ports themselves are slightly elevated above the seabed.

The measurements collected within the ejection jet lend valuable insight into dilution levels achieved shortly after discharge. The recorded 33.230‰ salinity was much lower than that of any other measurement collected during the July 2014 survey (green line in Figure 7d), and was 0.290‰ below the mean ambient salinity of 33.520‰ that was measured at the same depth level, but well beyond the influence of the discharge (Table 5). Based on Equation 2, this unusually close-in measurement indicated that wastewater had been diluted 111-fold shortly after discharge, and well before the initial-dilution process was complete. Nevertheless, the measured dilution at that point was already nearly as high as the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater after completion of the initial-dilution process.

As the momentum of the ejection jet dissipated and the buoyant plume rose within the water column, turbulent mixing continued to dilute the wastewater. Accordingly, salinity data collected during the mid-depth tow demonstrated that the wastewater had been diluted by at least 211-fold by the time the dilute wastewater rose 7.5 m to a depth level of 8 m (Figure 10). At that point, wastewater dilution was 50% higher than the 133:1 critical initial dilution used to establish limits on contaminant concentrations in wastewater.

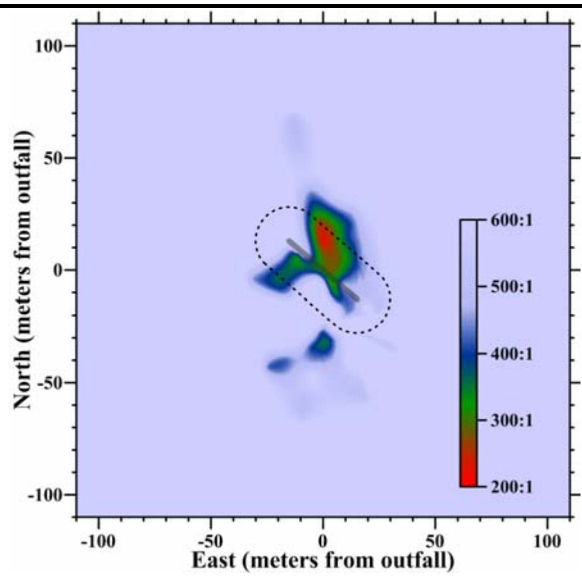

Figure 10. Mid-Depth Plume Dilution Computed from Salinity Anomalies in Figure 8b

[17] Wastewater samples have an average salinity of 0.995‰.

In addition, this dilution was measured 1.6 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 more efficiently than predicted by the modeling, well before the completion of the initial dilution process.

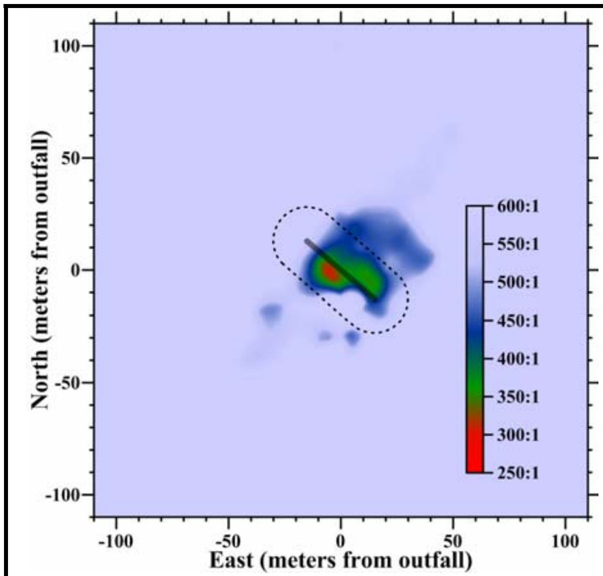

Figure 11. Shallow Plume Dilution Computed from Salinity Anomalies in Figure 9b

As the plume rose 3 m higher in the water column, to where the shallow tow was conducted, dilution levels exceeded 259-fold (Figure 11). Although the plume still remained largely within the ZID at that depth, the dilution process was nearly complete. Even though the plume was trapped below the sea surface, the shallow-tow data indicates that during the July 2014 survey, the outfall was achieving dilution levels more than double the dilution predicted by modeling after the completion of the initial dilution process.

Overall, the dilution computations show that, during the July 2014 survey, the outfall was performing better than designed and was rapidly diluting effluent more than 111-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 259-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 July 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.

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 July 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 July 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 July 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 15,078 CTD measurements collected during the July 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 the screening process has been concluded 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 No	Answer Yes[18]	*Parameter*
Location	1. Was the measurement collected beyond the 15.2-m ZID boundary where modeling assumes that initial dilution is complete?	*1,462*	*13,616*	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?	*12,700*	*916*	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?	*916*	*0*	Temperature
		916	*0*	Transmissivity
		916	*0*	DO
		916	*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 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.

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 July 2014 dataset eliminated 1,462 of the original 15,078 receiving-water observations from further consideration because they were collected within the

[18] Number of remaining CTD observations of potential compliance interest based on this screening question

ZID (Table 7, Question 1). The remaining 13,616 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 reliability 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 salinity was measured well within the ZID and near the seafloor at Station RW4 (green line in Figure 7d). Although other reductions in salinity caused by the presence of wastewater constituents were observed during the tow surveys, these were largely restricted to a localized area within the ZID boundary (Figures 8b, 9b, 10 and 11). Nevertheless, because the plume spread laterally within the upper water column below the thermocline, the presence of wastewater constituents were detected within 916 measurements collected beyond the ZID (Table 7). The remaining 12,700 observations that were measured outside the ZID during the July 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 natural-variability ranges 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 July 2014 ambient seawater data, to establish time-specific natural-variability thresholds in a manner analogous to COP Appendix VI. The percentiles were determined from July 2014 vertical profile data at Stations RW1, RW6, and deeper portions of RW5, thereby excluding measurements potentially affected by the discharge.

Table 8. Compliance Thresholds

Water Quality Property	95% Confidence Bound[19]	95th Percentile[20,21]	Natural Variability Threshold[22]	COP Allowance[23]	Basin Plan Limit[24]	Extremum[25]
Temperature (ºC)	0.82	14.96	>15.78	—	—	≤15.42
Transmissivity (%)	-10.2	85.9	<75.6	—	—	≥71.7
DO (mg/L)	-1.38	5.88	<4.50	<4.05	<5.00	≥5.75
pH (minimum)	-0.094	7.982	<7.888	<7.688	<7.000	≥7.947
pH (maximum)	0.094	8.056	>8.150	>8.350	>8.300	≤8.082

Temperature, transmissivity, pH, and DO concentrations associated with the 916 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 July 2014 survey from further consideration. In fact, all but one 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. The only exception was a drop in transmissivity measured within the discharge jet near the seafloor at Station RW4, which unequivocally revealed the presence of wastewater particulates. The 71.7% transmissivity measured at that location was below the 75.6% lower-bound transmissivity threshold indicative of natural variability during the July 2014 Survey (*cf.* the third and sixth data columns of Table 8).

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19 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.

20 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*."

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

22 Thresholds represent limits on wastewater-induced changes to receiving-water properties that significantly exceed natural conditions as specified in the discharge permit and COP. They are determined from the sum of columns to the left and are specific to the July 2014 survey. They do not include the COP allowances specified in the column to the right.

23 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.*"

24 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.

25 Maximum or minimum value measured during this survey

All the other measurements fell within the range of natural variability. In some cases, anomalies in seawater properties clearly delineated the plume, but those entrainment-generated excursions were not caused by the presence of wastewater constituents. As described previously, during periods when the water column is stratified, as it was during the July 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 July 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 July 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 15.78°C in Table 8). However, none of the 15,078 CTD measurements collected during the July 2014 survey exceeded 15.42°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, as described previously, only one of the transmissivity measurements collected during the July 2014 survey was below the 75.6% minimum compliance threshold. That measurement was located well within the ZID where the limit does not apply. Moreover, it was measured within the naturally turbid BNL near the seafloor, where little natural light is present.

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). As discussed previously, the reduced temperatures observed in conjunction with the effluent plume (Figure 9a) could not have been generated by the presence of the 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 15 July 2014 was 16.2 mg/L. After dilution by 259-fold, the effluent suspended-solids concentration would have the reduced ambient transmissivity by only 0.9% near the sea surface. This small potential decrease in transmissivity was insignificant compared to the naturally-occuring 6% 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, 42-mg/L BOD measured within the plant's effluent on the day following 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 7.688 during the July 2014 survey (fourth data column of Table 8). This value is well below the lowest pH measurement of 7.947 recorded during the July 2014 survey (last column of Table 8). Similarly, the lowest DO concentration measured during the survey (5.75 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).

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 DO.

CONCLUSIONS

The quantitative screening analysis demonstrated that all measurements recorded during the July 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 July 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.

Almost immediately after discharge, wastewater was diluted 111-fold within the turbulent jet emanating from a diffuser port. Shortly thereafter, and well before the initial dilution process was complete, the effluent was achieving dilution levels in excess of 211-fold, which substantially exceeds the critical dilution levels predicted by design modeling. As the initial dilution process was nearing completion, the submerged discharge plume achieved even higher dilution levels, exceeding 259-fold, as it continued to spread within the ZID. Beyond the ZID, and after initial mixing was complete, the wastewater had been diluted at least 303-fold. Therefore, during the July 2014 Survey, measured dilution levels far exceeded levels expected from 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 July 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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