Final Report

Coastal Observations and Monitoring in South Bay San Diego
IBWC / Surfrider Consent Decree

Prepared For

International Boundary and Water Commission
United States Section
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Contract: IBM04D0005
Task Order: IBM06T0026

Prepared By

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February 25, 2009

Supplemental Monitoring Program for the South Bay Ocean Outfall

Executive Summary

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<u>Period of Performance</u>

Contract Start:	December 30, 2006
Sampling Start:	July 2007
Sampling End:	October 2008
Contract End:	February 15, 2009

Pursuant to the Consent Decree entered in *The Surfrider Foundation v. Marin*, Case No 99-CV-2411-BTM (JFS), the International Boundary Water Commission (IBWC) implemented a supplemental monitoring program with the following goals:

- Identify and track plumes from the South Bay Ocean Outfall (SBOO)
- Characterize land-based sources, with a focus on the Tijuana River
- Identify the regional oceanographic conditions that lead to high concentrations of fecal indicator bacteria (FIB) on the South Bay beaches.

The resulting activities chosen and approved to achieve these goals fall into three general categories: (1) coastal ocean monitoring, with a more regional perspective; (2) plume monitoring at the SBOO; and (3) beach and kelp monitoring, including monitoring of land-based plumes. Possible sources of bacterial contamination responsible for beach closures in this region include the South Bay International Water Treatment Plant (SBIWTP) outfall, the Tijuana River outflow, northward flow of discharges from south of the International Border, and local runoff from Imperial Beach. As a result of a comprehensive supplemental monitoring program to investigate the potential sources of beach closures in the region, a number of findings were made and are summarized below.

1. Measurements of ocean stratification at the SBOO and subsequent modeling of the behavior of the buoyant plume rise height, estimates that the discharge plume surfaced a total of 1,889 hours (16 percent total time) during the 16-month supplemental monitoring program. These surfacing events occurred over 98 discrete days, representing 26 percent of the days over a calendar year. Similar analysis of data for the previous 3 years estimates SBOO plume surfacing to take place on average 27 percent of the time over the calendar year.

2. The surfacing of the plume is seasonal. When partitioned by dry season (April through September) and wet season (October through March), the plume surfacing was found to take place 100 percent of the time in the wet season. When the ocean is stratified, the typical cap depth of the plume is 8 meters.
3. Surface current maps measured by high-frequency (HF) radar coupled with temperature stratification measurements for plume rise height potential can be used to estimate the surface plume transport and derive probability maps of plume exposure. The surface plume can be tracked using maps of the surface currents from the HF radar, while the orientation of the plume at depth is estimated using measurements of subsurface currents obtained with an ocean buoy at the outfall. The statistical orientation of the SBOO plume is found to be in the north-to-south direction. This orientation can vary significantly for individual events.
4. When the SBOO plume surfaces, there is a probability of exposure of the shoreline to plume water. This probability is estimated to be approximately 10 to 25 percent during the plume surfacing events (98 days total over the 16-month period of the supplemental monitoring program). No shoreline FIB exceedances in samples from the San Diego Department of Environmental Health or from the Regional Water Quality Monitoring Plan (RWQMP) were found to correlate with these time periods.
5. Subsurface currents measured by the oceanographic mooring at the SBOO outfall can be used to estimate the transport and orientation of the SBOO subsurface plume. The statistics of the plume location over the supplemental monitoring period suggest that the plume is oriented in the northwest-to-southeast direction.
6. The Tijuana River is an intermittent source of high FIBs during rain events. The Tijuana River can disperse a coastal trapped plume several miles north and south of the river entrance during heavy rainfalls.
7. Shoreline FIB exceedances in the South Bay San Diego region are predominately a result of exposure of the shoreline to Tijuana River plume water. Tijuana River plume water was found to account for 94 percent of exceedances (a total of 81). Five additional exceedances occurred as single-station anomalies not associated with a rain or river flow event.
8. The discharge plume from the San Antonio de los Buenos treatment plant at Punta Bandera is typically oriented to the south. However, the plume is estimated to track north across the border 12 percent of the time (15 discrete events for a total of 60 days out of 490 days). In a historical 4-year analysis of data, the transport up the coast is estimated to occur 56 times for a total of 234 out of 1,461 days (approximately 16 percent of the time) over which the analysis occurred.
9. Nine suspected sewage contamination events were reported in the City of Imperial Beach region during dry weather (no recent rainfall). Subsequent processing of FIB samples by the Department of Environmental Health reported background levels. Ongoing analysis of the oceanographic conditions during these events remains inconclusive, with viable hypotheses suggesting the events are one of the following.
   - A result of subsurface transport of SBOO plume water

- From renegade flows into the Tijuana River estuary, which then are tidally pumped into the ocean

- Northward transport from Punta Bandera

10. One hypothesis explaining dry weather events is that the SBOO plume ”sweeps” along the coast during the transition from a weakly stratified southeast flow to a northerly flow. The weakly stratified southeast flow allows the plume to surface. Then, as the flow condition changes to the north, the surfaced plume sweeps shoreward resulting in temporary exposure to the outfall plume. Eight of the nine reported dry weather events meet criteria supporting this hypothesis. These events include:

    - Transition from southerly to northerly flow
    - Weak stratification during southerly flow
    - Shoreward flow during the transition from southerly to northerly flow

    This hypothesis requires quantitative analysis and supporting special studies.

11. Analysis of the conductivity/temperature/depth (CTD) cast data obtained as part of the RWQMP pursuant to the National Pollutant Discharge Elimination System (NPDES) permit for discharge through the SBOO detected the plume in both its surfaced and subsurface state. Of the 16 monthly surveys available, the SBOO discharge plume was detectable two times.

12. The autonomous underwater vehicle (AUV) using a conductivity, temperature, and depth probe, along with sensors for measuring changes in the ocean’s optical properties, was able to effectively map out the location of the subsurface plume. With proper vehicle configuration and mission programming, the vehicle was able to detect the plume 100 percent of the time. The mean dilution ratio of SBOO wastewater to seawater determined from AUV salinity measurements is 1:302. The ability of the vehicle to sense the subsurface plume was enabled using proper mission planning of the vehicle track and consideration of plume transport estimates using SBOO mooring data in near-real time. The plume orientation measured by the AUV matched estimated trajectories and rise heights from the ocean mooring velocity profile and stratification measurements for all missions. Over the period of the supplemental monitoring program, the plume was found to orient itself both to the south, northeast, and north. The plume was determined to have surfaced during four missions based on AUV measurements. A total of 18 sampling missions were conducted.

13. The SBOO plume, due to its small size (nominal 25 million gallons per day [mgd]) would be elusive to find in typical boat-based sampling. Use of the regional observational network that included the HF radar and ocean mooring enabled AUV sampling to take place at the right time and place to capture the plume.

14. Land-based sampling of the Tijuana River, for the purposes of quantifying FIB loads to the South Bay, shows high levels of indicator bacteria throughout the estuary. In general, samples taken at Hollister Road (Station 3) and in the main river channel (Station 3) have FIB concentrations considerably higher than those taken at the river mouth (Station 1) or at the background location (Station 2, Seacoast Drive). Peak concentrations at Hollister

Road exceeded 1.6 million most probable number (MPN)/100 milliliters (ml) for both total and fecal coliform (January 8, 2008).

15. Boat-based samples of land-based plumes indicate that FIB concentrations in the Tijuana River plume can exceed those in the SBOO plume by an order of magnitude or more. Samples taken in the river plume, 1 mile north of the river mouth, show total coliform concentrations of 90,000 MPN/100 ml. Peak total coliform concentrations measured in the SBOO plume samples were 3,000 MPN/100 ml.

16. Dry weather offshore sampling provides no indication that the SBOO plume is causing elevated FIB concentrations along the shoreline north of the Tijuana River mouth. All dry weather surface water samples at near-shore stations (Stations 4 through 11) yielded FIB concentrations below the detection limit of 20 MPN/100 ml.

17. There are two primary sources of contamination in the immediate region—the Tijuana River discharge and the SBOO discharge. Detectable levels of *Bacteroides* were observed for both sources. Whether these levels of *Bacteroides* concentrations pose a health risk is not known. To date, epidemiological studies that employ these human microbial tracers have not been performed; thus, a public health risk cannot be evaluated based on these observations.

18. Both of these sources create discharge plumes that have water quality characteristics that can be readily detected using standard physical and optical water quality instrumentation. Both plumes are characterized by decreased salinity, increased concentrations of colored dissolved organic matter, and generally increased suspended particulate concentration.

19. Although the two discharge plumes can be readily detected and are expected to have high levels of microbial contamination, there are observations from each survey that show measurable surface concentrations of *Bacteroides* indicating some level, albeit low, of widespread human contamination throughout the South Bay. These measurements are not necessarily associated with a water quality signature that is obviously traceable to either of the two sources.

20. If water quality variables indicate the presence of a plume from either of the two immediate sources, it is likely that *Bacteroides* will be detected, which is indicative of human fecal contamination. However, elevated *Bacteroides* concentrations that were detected in the absence of plume-indicating water quality did not indicate the presence of effluent. This may have been because the effluent was sufficiently diluted, such that, although the water quality variables were not distinct from background, there was sufficient *Bacteroides* genetic material to be detectable through the amplification methods that were used. This does not necessarily indicate a health risk, but it does indicate a presence at least at very low levels.

21. The "smelly water" sample that was analyzed was found to contain the highest concentration of *Bacteroides* that was measured. No water quality measurements were made on that water, so no correlation with water quality variables can be made.

I. Contents

Appendixes

Tables

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A. Acronyms

≤	less than or equal to
≥	greater than or equal to
°C	degrees Celsius
µg/L	micrograms per liter
µl	microliter
µm	micrometer
AB	Assembly Bill
ADCP	Acoustic Doppler Current Profiler
AUV	autonomous underwater vehicle
AWAC	Acoustic Wave and Current
c^3/s	cubic meters per second
CDIP	Coastal Data Information Program
CDOM	colored dissolved organic matter
CEM	Coastal Exposure Map
CFU	colony forming units
CICESE	Centro de Investigación Científica y de Educación Superior de Ensenada
cm/s	centimeters per second
CODAR	Coastal Ocean Dynamics Applications Radar
CORDC	Coastal Observing Research and Development Center
cpd	cycles per day
CTD	conductivity, temperature and depth
DEH	Department of Environmental Health
ENT	enterococcus
EPA	Environmental Protection Agency
FC	fecal coliform
FIB	fecal indicator bacteria
ft^3/s	cubic feet per second
GPS	Global Positioning System
HF	high-frequency

HPWREN	High-Performance Wireless Research and Education Network
IB	Imperial Beach
IBWC	International Boundary Water Commission
kHz	kilohertz
km	kilometers
km^2	square kilometers
LBL	Long BaseLine
m	meters
mgd	million gallons per day
ml	milliliters
mm	millimeters
MODIS	Moderate Resolution Imaging Spectroradiometer
MPN	most probable number
MUSIC	multiple signal classification
MWWD	Metropolitan Wastewater Department
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NERR	Natural Estuarine Research Reserve
ng	nanogram
nm	nanometers
NPDES	National Pollutant Discharge Elimination System
OCM	Ocean Color Monitor
PBD	Punta Bandera discharge
PCCS	Power Communication and Conversion System
PCR	polymerase chain reaction
PDF	probability distribution function
PEMEX	Petroleos Mexicanos
PLOO	Point Loma Ocean Outfall
ppb	parts per billion
ppt	parts per thousand
psu	practical salinity unit
QAPP	Quality Assurance Project Plan

REMUS	Remote Environmental Measuring UnitS
RFP	Request for Proposals
RSB	Roberts-Snyder-Baumgartner
RWM	Random Walk Model
RWQMP	Receiving Water Quality Monitoring Program
SBIWTP	South Bay International Wastewater Treatment Plant
SBOO	South Bay Ocean Outfall
SEAWIFS	Sea-viewing Wide Field-of-view Sensor
SEM	Shoreline Exposure Map
SIO	Scripps Institution of Oceanography
SST	sea surface temperature
TJR	Tijuana River
TS	Temperature-Salinity
TSM	total suspended matter
USBL	Ultra-Short BaseLine
USC	University of Southern California
USIBWC	United States Section, International Boundary Water Commission
WAP	WETLabs Archive Processing
WY	water year (starts on October 1 and ends on September 30)

II. Introduction

A. Background

This document serves as the final report to the United States Section, International Boundary Water Commission (USIBWC) to communicate in detail the components, findings, results, and recommendations from a supplemental monitoring program of the South Bay International Wastewater Treatment Plant (SBIWTP) discharge plume and surrounding environs conducted between the dates of July 2007 and October 2008. Impaired coastal water quality from point source discharges is a well-known concern for human health, detriment to marine ecosystems, and has negative impacts on coastal economies when beach closures result. At Imperial Beach located in southern San Diego County, a significant number of beach closures by the San Diego Department of Environmental Health result from the presence of high concentrations of fecal indicator bacteria (FIB) exceeding California health standards. Similarly, high FIB levels are periodically reported on the Tijuana shoreline in the sparse sampling that takes place south of the border. Not only is the incidence of bacterial contamination and associated beach closures a problem, but time lags between sampling of the coastal water and completion of the analysis likely result in situations when beach waters might be clean when posted, and not clean when not posted. The closure of a beach has similar economic consequences, regardless of the FIB levels, when the beach is posted.

Possible sources of bacterial contamination responsible for beach closures in this region include the SBIWTP outfall, the Tijuana River outflow, northward flow of discharges, and local runoff from Imperial Beach. The Tijuana River outflows just north of the border and drains precipitation from a watershed of 4,480 square kilometers (km^2), two-thirds of which is in Mexico. The City of Tijuana discharges pretreated waters directly onto the beach at Punta Los Buenos (6 miles south of the border) from the San Antonio de los Buenos treatment plant. Furthermore, the tourist corridor between Tijuana and Rosarito has increased its population fivefold leading to the potential of uncontrolled residential and commercial discharge points. The multiplicity of possible sources close to the beaches requires that the water quality of the area be examined using a framework of regional scales. Assessing the impact of these potential sources is the primary goal of this supplemental monitoring program.

B. History of Consent Decree and Timeline of Phases

The origin of this supplemental monitoring program arises from a series of earlier studies conducted pursuant to the Consent Decree entered in *The Surfrider Foundation v. Marin*, Case No 99-CV-2411-BTM (JFS).

In August 2004, the USIBWC completed a Phase I Study entitled "Evaluation of the South Bay International Wastewater Treatment Plant Receiving Water Quality Monitoring Program to Determine Its Ability to Identify Source(s) of Recorded Bacterial Exceedances." The purpose of the study was to determine whether the SBIWTP Receiving Water Quality Monitoring Program (RWQMP) produced sufficient data to determine the following.

- Whether the treatment plant effluent was a source of FIB exceedances at the San Diego Monitoring Stations, and if so the frequency and location of the exceedances caused by those discharges

- Whether discharges from sources are causing FIB exceedances, and if so the frequency and location of exceedances caused by those discharges

- Whether oceanographic conditions and weather events cause onshore transport of the SBIWTP effluent, and if so, to what extent

The report concluded that the RWQMP did not provide sufficient data to determine these issues, and made a general list of recommendations for different monitoring activities to supplement the RWQMP. The Study also indicated that likely observations of beach exceedances were from land-based sources, and recommended that a supplemental program take a balanced approach in assessing the SBIWTP discharge plume at the South Bay Ocean Outfall (SBOO), and nearby land-based sources.

In October 2005, the USIBWC completed a Phase II study, again pursuant to the Consent Decree entitled "Recommendations for Supplemental Monitoring" in addition to estimates for costs and schedule for recommended activities. The objective of the Phase II study was to design a specific recommended monitoring program that would provide data to determine the answers to the three questions raised in the Phase I study. The Phase II study provided specific supplemental monitoring activities that would complement the RWQMP currently conducted pursuant to the SBIWTP's National Pollutant Discharge Elimination System (NPDES) permit for discharge through the SBOO.

C. Goals and Activities within the Supplemental Monitoring Program

In July of 2006, the USIBWC issued a Request for Proposals (RFP) for a project to design and carry out a supplemental monitoring program that implements to the extent practical the recommendations of the Phase II study. The goals of the program requested by the International Boundary Water Commission (IBWC) are:

- Identify and track plumes from the SBOO

- Characterize land based sources with focus on the Tijuana River
- Identify the regional oceanographic conditions that lead to high FIB on the South Bay beaches

The recommended monitoring activities from the Phase I Study fall into three general categories:

- Coastal Ocean Monitoring, with a more regional perspective
- Plume Monitoring at the SBOO
- Beach and Kelp Monitoring, including monitoring of land based plumes

The classes of monitoring activities for which the IBWC had requested proposals due August 31, 2006, are the following:

SS1) SBOO plume mapping

SS2) Tijuana River plume mapping

SS3) Boat survey-mapping of land-based plumes

SS4) Continuous flow rate and loading of the Tijuana River

SS5) Ocean moorings at key areas

SS6) Mapping of ocean currents using Coastal Ocean Dynamics Applications Radar (CODAR) and improved data handling

SS7) Development of indicator studies to support source identification

SS8) Identification of spatial patterns

A joint proposal developed by the Scripps Institution of Oceanography (SIO), University of Southern California (USC), and CH2M HILL was successfully prepared and submitted. The following is a list by task of the activities proposed by SIO:

Task A: Monitoring Plan Development, Reporting, Operational Management and Supervision of Field Activities, Meetings

Task B: All SS 5—Oceanographic Moorings

Task C: All SS 1—SBOO Plume Mapping. All SS2—Tijuana River Plume Mapping and Mapping of Land-Based Sources. Portion of SS3—CTD operation from vessel conducting plume mapping operations

Task D: Portion of SS4—Gathering of Tijuana River flow rate data. SS6—Surface Current Mapping (CODAR) and related data handling improvements and upgrades. SS8—Spatial Pattern analysis

CH2M HILL was the prime contractor and provided overall management for the project. Staff at CH2M HILL were also responsible for SS4 (FIB loading of the Tijuana River).

Staff at USC were responsible for portions of SS3 (boat survey mapping of plumes) and SS7 (indicator studies to support source identification).

The tasks identified above, and described in detail in the Monitoring Plan (Appendix A), project onto the following three general areas of interest:

- Identify and track plumes from the SBOO
  - SS1, SS5, SS6, SS7, SS8
- Characterize land-based sources with focus on the Tijuana River (TJR)
  - SS2, SS3, SS4, SS5, SS6, SS7, SS8
- Identify the regional oceanographic conditions that lead to high FIB on the South Bay beaches
  - SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8

This suite of interrelated monitoring activities (SS1 through SS8) was enhanced through integration of data from other related regional monitoring programs. These programs are identified below.

- FIB indicator data obtained by shoreline monitoring programs conducted by the San Diego County Department of Environmental Health (DEH) supported through Assembly Bill (AB) 411 and the Environmental Protection Agency (EPA) BEACHES program.
- Ocean data generated by the City of San Diego for the Point Loma Outfall as part of its NPDES permit
- Ocean data generated by the City of San Diego for the IBWC SBOO as part of its NPDES permit
- TJR flow data from a gauge operated by IBWC
- TJR National Estuarine Research Reserve
- Data from the regional ocean observing systems—San Diego Coastal Ocean Observing System (www.sdcoos.org) and Southern California Coastal Ocean Observing System (www.sccoos.org)

A description of the work carried out for the three identified task areas, as well as our findings and results are presented in subsequent sections of this document.

D. *Dates of the Program*

August 2004	Completion of Phase I Study
October 2005	Completion of Phase II Study
July 2006	Issuance of RFP for Supplemental Monitoring (this project)
August 2006	Deadline for Proposal Submission
December 2006	IBWC makes award to CH2M HILL
February 2007	Subcontract to SIO completed
March 2007	Draft Monitoring Plan and Quality Assurance Project Plan (QAPP) submitted
July 2007	Received conditional approval from EPA and IBWC to begin sampling
October 2008	Sampling completed
January 2009	Draft report due to IBWC

E. *Description of Study Area*

The region of interest for the supplemental monitoring program is loosely defined to extend from Point Loma south to the United States border, and offshore to a distance of approximately 30 kilometers (km). Characterized by an area of complex topography resulting from the Point Loma headland and curving coastline; a shallow delta from the geology of sediment deposition from the Tijuana River and San Diego Bay; and variable forcing from winds, tides, and remote storms; the coastal waters of South Bay San Diego are oceanographically complex. The region of study is shown in Figure E.1.

As previously mentioned, the United States-Mexico border region has a confluence of several potential discharges that could lead to FIB exceedances on the coastline. These are the Tijuana River, the South Bay Ocean Outfall, and the Punta Bandera discharge at San Antonio de los Buenos shoreline. The locations of these discharges are shown in Figure E.2.

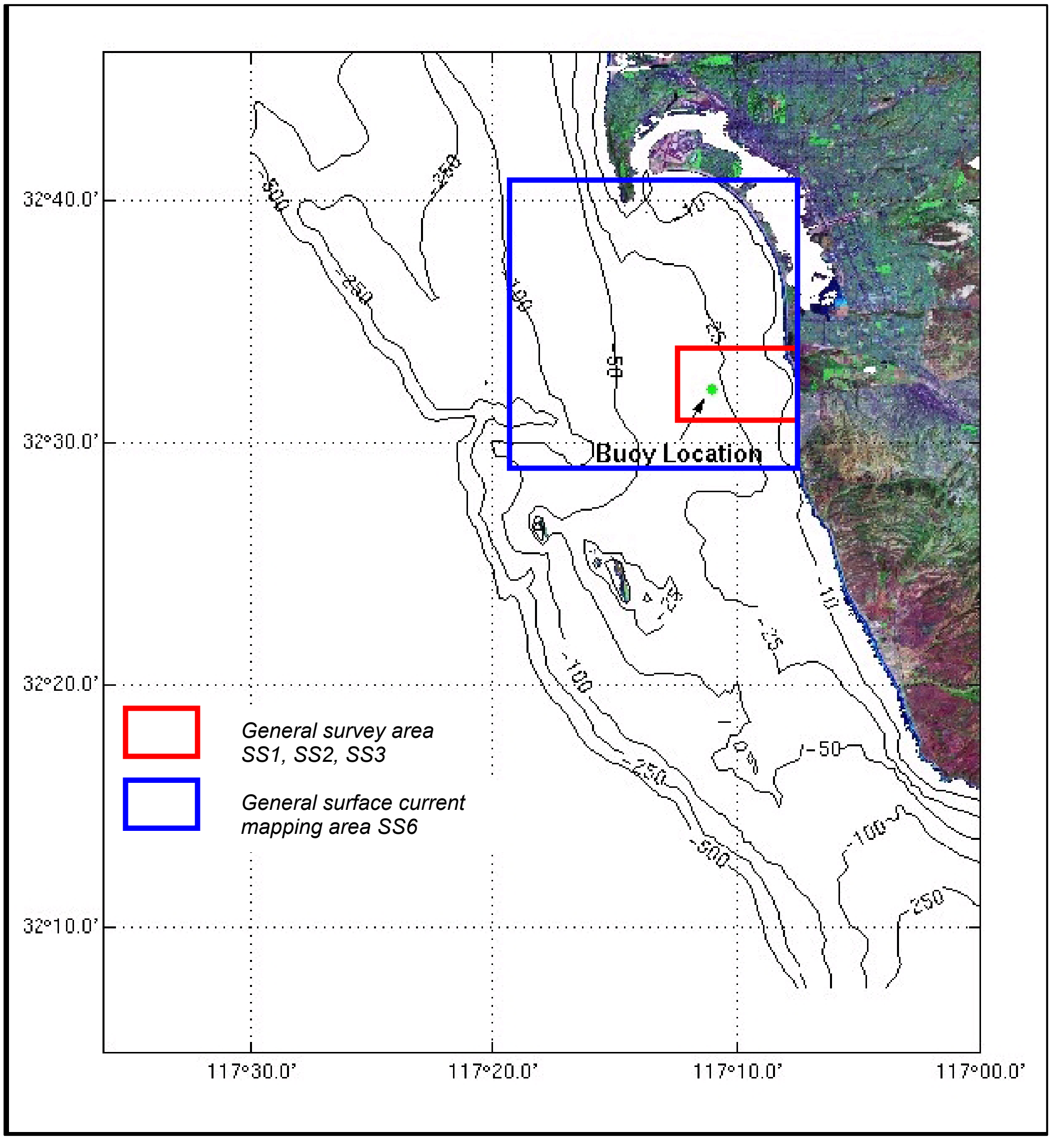


Figure E.1 Monitoring Vicinity Map
A map indicating the general areas in which the supplemental monitoring activities took place. Bathymetry lines (meters) are also provided. The buoy location (green dot) is near the wye of the South Bay Ocean Outfall diffusers.

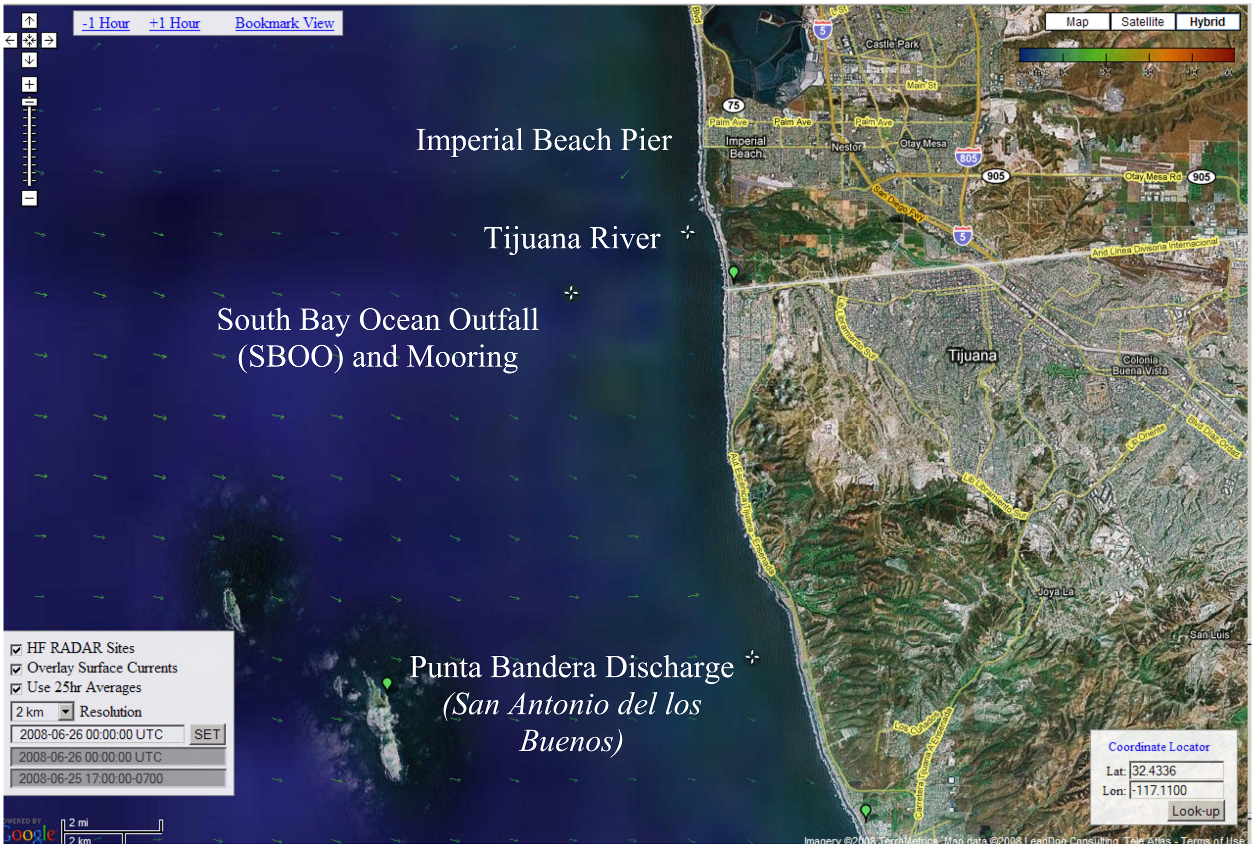


Figure E.2 Satellite Image of Coastal Discharges

A satellite image of the U.S. – Mexico border region illustrating the proximity of the three major coastal discharges in the region. Both Punta Bandera and the TJR discharge at the shoreline, while the SBOO discharges from a depth of approximately 28 meters and is located approximately 3.5 miles offshore.

Coastal circulation in San Diego waters result from a combination of local wind forcing, tides, and ocean response to remote forcing. As a result of the relatively weak atmospheric wind forcing of our coastal waters, these forcing terms are each responsible for approximately a third of the total forcing that drives the circulation. A generalized description of the currents in San Diego is represented in Figure E.4. The description is based upon a multi-year analysis of surface currents measured by high-frequency (HF) radar (Figure E.3) and a decomposition of the currents by their forcing terms (Kim, Cornuelle, Terrill 2008).

HF radar systems measure reflecting radio waves off the surface of the ocean. Each HF radar land-based installation is sited near the coastline and includes two antennas. The first antenna transmits a radio signal across the ocean's surface, and the second antenna listens for the reflected radio signal that is scattered from the ocean's surface. By measuring and processing the change in frequency of the radio signal that returns, known as the Doppler shift, the system determines how fast the water is moving toward or away from the antenna. Data from neighboring antennas are processed and displayed to the user as hourly surface currents are mapped in near real-time.

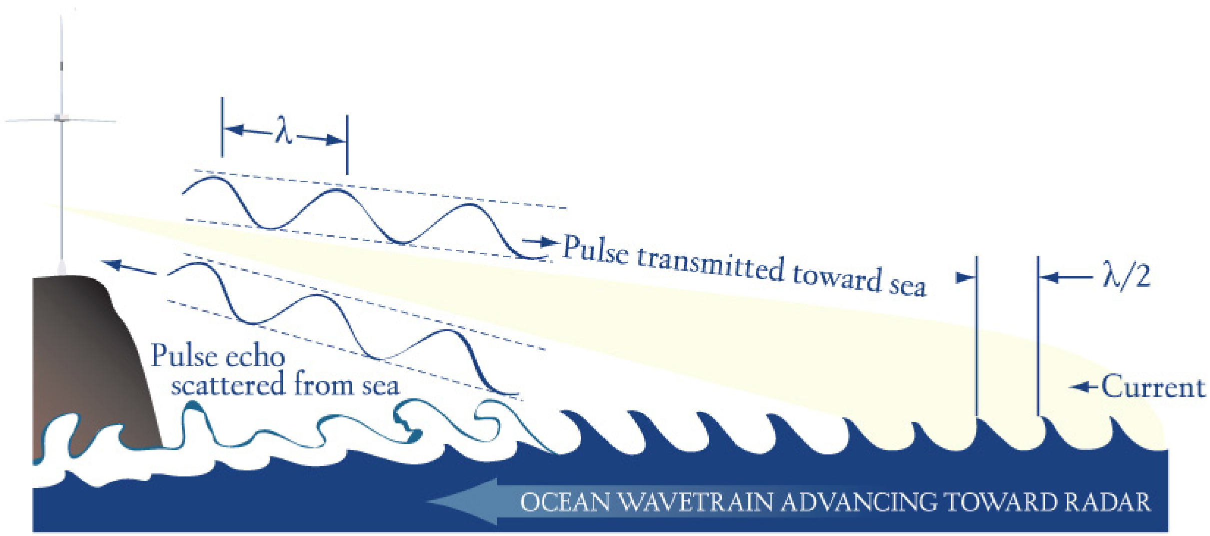


Figure E.3 Representation of HF Radar Technology

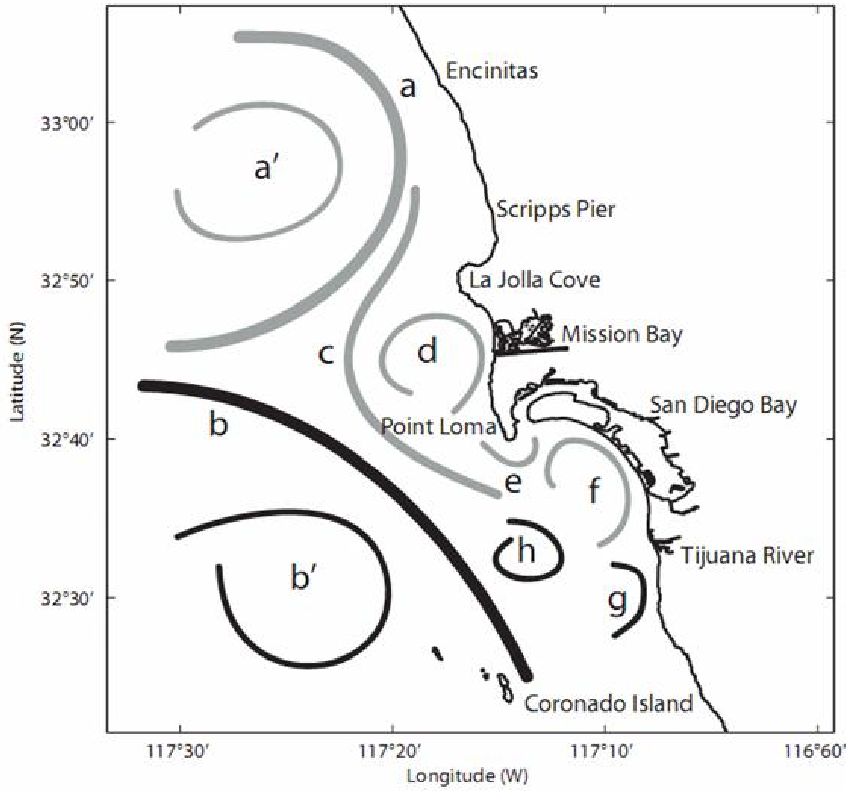


Figure E.4 Coastal Circulation Schematic
A generalized schematic of the dynamic features that influence coastal circulation in San Diego. The description is based upon the mapping of ocean surface currents using HF radar and statistically analyzing the data for the presence of eddies. In the schematic, flow strength is represented by thickness. Some flows have consistent direction (black) while the gray colors represent features that have been observed to have flow reversals. In the figure, b is southeastward flow, b', g, and h are clockwise flows, and f is counterclockwise.

A general description of the time scales of variability of the ocean currents in San Diego is estimated using a power spectrum of the currents, the domain over which the supplemental monitoring program took place. The spectrum shown in Figure E.5 represents a spatial average across the domain, and graphically illustrates the time scales of variability. These include semi-diurnal components of the tide (two cycles per day), diurnal components of the winds and tide (one cycle per day), and low-frequency motions that appear to occur with periods of 3 to 5 days. (Kim, Cornuelle, Terrill 2008). The time scales most relevant to pollutant transport, and the scales at which patterns in coastal circulation vary, are subtidal (greater than 24-hour periods).

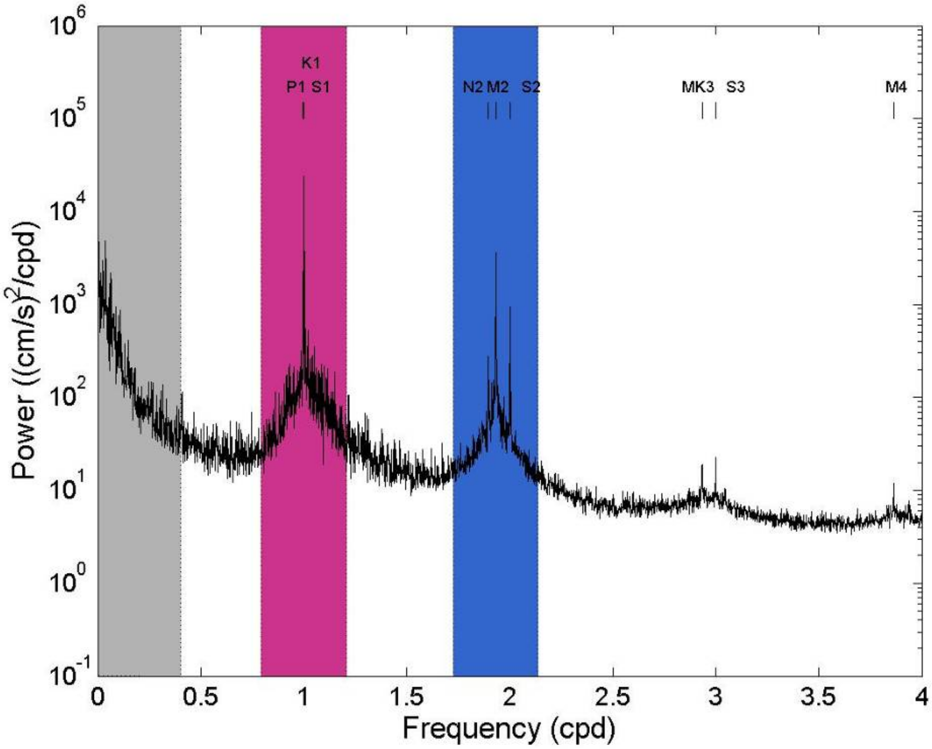


Figure E.5 Ocean Surface Current Power Spectrum

The ocean surface current power spectrum in the domain of the supplemental monitoring program. Circulation in San Diego is found to have energy in the semidiurnal band (blue band), diurnal band (purple band), and at lower frequency (gray band). These bands of energy are consistent with the forcing of the circulation by tides, winds, and larger-scale remote forcing.

cpd ***cycles per day***
cm/s ***centimeters per second***

III. Work Completed

Below is a scheduled list of activities during project implementation.

2007	
January	Initiated efforts for purchase order of the Remote Environmental Monitoring Unit System (REMUS) autonomous underwater vehicle (AUV)
February	Finalized contract with CH2M HILL Finalized purchase of AUV, equipment for SBOO and IB Pier moorings; 2: Conducted site and communication assessments at SBOO and Imperial Beach (IB) Pier
March	1: Submitted SIO Draft Monitoring and QAPP Finalized "Tideland Use and Occupancy Permit" with San Diego Unified Port District for access to IB Pier (May 15, 2007) (5 years)) 19-23: SIO staff attended HYDROID AUV training
April	20: Conducted test REMUS mission Submitted Schedule Update 1 Responded to IBWC comments from April 17
May	Finalized SBOO mooring fabrication and submitted location/description to United States Coast Guard (USCG) 10: CH2M HILL, USC, SIO conference call Responded to IBWC comments from May 4
June	4-5: IB Pier piling cleaning, and preparation 19: Deployed SBOO Mooring 19: Hosted IBWC, Gilbert Anaya and CH2M HILL, Richard Pyle lab tour and technology overview 28: Deployed IB Pier mooring and seafloor cable infrastructure
July	10: Conducted test SBOO REMUS survey to aid in determining vehicle mission planning 13: EPA, IBWC, CH2M HILL, USC, and SIO conference call to discuss EPA QAPP comments from July 3 23: Received conditional approval from EPA and IBWC to start monitoring Initiated programming for SBOO Mooring online display Conducted HF radar beam pattern calibrations at Point Loma and Border Field State Park
August	8, 22, 30: Conducted SBOO REMUS survey 14: Conducted SBOO sidescan survey of outfall pipe 30: IBWC public meeting held at IB Lifeguard Safety Center Initiated real-time data flow from IB mooring
September	4: Conducted SBOO REMUS survey 12: Conducted IB Pier mooring instrument assessment dive 24: Conducted Tijuana River REMUS survey (following rain event)
October	29: Conducted SBOO REMUS survey

2007	
November	2: SBOO maintenance trip 20: Replace data acquisition system at Imperial Beach facility Preparations for SBOO buoy turnaround and battery replacement 29: Conducted SBOO REMUS survey
December	9: Conducted Tijuana River REMUS survey (following rain event) 13: Conducted SBOO REMUS survey

2008	
January	7: Conducted a shoreline conductivity, temperature, and depth (CTD) survey (following rain event) 15: SBOO Buoy refurbishment (battery replacement and sensor maintenance) 22: SBOO Buoy inspection dive 24: Conducted Tijuana River REMUS survey (following rain event) in coordination with USC and CH2M HILL 28, 29, 30: Conducted shoreline CTD survey (following rain event)
February	4: Conducted shoreline CTD survey (following rain event) 5: Conducted Tijuana River REMUS survey (following rain event) 15: Conducted SBOO REMUS survey 21: SIO hosted IBWC informational community meeting 25 – 26: Conducted shoreline CTD survey (following rain event 2/24)
March	6: Conducted SBOO REMUS survey 17: Conducted Tijuana River REMUS mission following rain event (3/16) 21: IB mooring maintenance dive 26: Border 2012 Tijuana Watershed Task Force quarterly meeting
April	3: Conducted shoreline CTD survey and Tijuana River REMUS survey coordinated field efforts with USC/CH2M HILL (following rain event) 17: Conducted SBOO REMUS survey (vehicle in kelp)
May	6: HF Radar calibration and maintenance trip 11–16: IB Pier emergency maintenance following sewage spill at pier
June	5: Conducted SBOO REMUS survey 17: Conducted SBOO REMUS survey prior to “smelly event” 24: Conducted SBOO REMUS survey in response to lifeguard noted “smelly event” (June 18-20) 26: SIO attended IBWC public meeting providing project updates
July	1: Conducted SBOO REMUS survey coordinated field efforts with USC/CH2M HILL 1: Conducted SBOO REMUS survey coordinated field efforts with USC/CH2M HILL 30: Conducted SBOO REMUS survey

2008	
August	Extended contract to February 15, 2009 13: Meeting with IB lifeguards to discuss sampling smelly events 18: Pre-cruise SBOO buoy evaluation 21: SBOO Buoy turnaround cruise 22: Conducted SBOO REMUS survey responding to smelly event 26: Border 2012 Tijuana Watershed Task Force meeting
September	No smelly events reported
October	No smelly events reported
November	3: IBWC operational site visit to SBOO and review report outline 15: SBOO buoy offline
December	Analysis and data integration

2009	
January	16: Submitted Draft Final Report 25: Submitted Final Report

A. SBOO and Tijuana River Plume Mapping (SS1 and SS2)

1. REMUS Vehicle Description

The proposed technical approach for mapping the SBOO and TJR plumes included the use of an Autonomous Underwater Vehicle (AUV) designed for coastal monitoring. The Remote Environmental Measuring UnitS (REMUS) manufactured by Hydroid LLC (Figure A.1) utilizes onboard navigation for vehicle control and can be preprogrammed to map user-driven scenarios based on areas of interest. The vehicle is typically launched by two persons from the boat at a location nearest to the start position and receives a start command from an underwater acoustic control unit called a Ranger. At initial deployment, the vehicle always takes a Global Positioning System (GPS) fix and zeros the pressure sensor to initialize its horizontal and vertical navigation algorithms. After these fixes, the vehicle navigates using underwater transponders with fixed/known locations or by re-acquiring GPS throughout the deployment. Depth is monitored by a pressure sensor and altitude and speed of the vehicle over the seafloor is obtained with an Acoustic Doppler Current Profiler (ADCP) bottom ping. The Ranger continually queries the vehicle throughout the deployment to gain system status. The vehicle has a 100-meter maximum operating depth and 22-hour battery capacity for surveying at an optimum speed of 3 knots. This range decreases with increasing speed to 8 hours of surveying at 5 knots. Upon completion of the mission, the vehicle is again recovered by two personnel.

The vehicle includes an array of instrumentation for environmental monitoring. The combination of the CTD and optical sensors (the standard workhorse tools used by boat-based NPDES monitoring programs) placed onto a flexible platform such as REMUS, lends itself well to the problem of plume mapping through surveying changes in ocean properties. The REMUS has four main sections—a nose section, an RD Instruments 1200-kilohertz (kHz) ADCP, a mid-body, and tail section. The nose section includes both the Ultra-Short BaseLine (USBL) and Long BaseLine (LBL) acoustic navigation transducers. Initial instrumentation included the following sensors: YSI CTD, WETLabs BB2F (optical backscatter and chlorophyll-a). During the sampling period, scientists altered the instrumentation payload to further optimize plume tracking. Scientists added a higher resolution CTD sensor and replaced the WETLabs BB2F with a WETLabs ECO triplet (optical backscatter and CDOM) because the plume has a more specific CDOM signature. There are, however, other sources of CDOM present in the ocean, and having the CDOM measurement coupled with chlorophyll-a is a future recommendation for integration on the REMUS. Table A.1 describes the parameters measured onboard the REMUS vehicle and their usage for discharge plume detection.

Figure A.1 REMUS Vehicle
REMUS vehicle on boat prior to mission deployment (GPS, sidescan sonar, ADCP, CTD, backscatter, colored dissolved organic matter [CDOM])

Parameter	Ambient Values	Measured Plume Values	Measurement Value
Velocity	N/A	N/A	Subsurface velocity measurements can be used to calculate currents for comparison with fixed mooring assets and to assess changes in currents within the sampling region.
Chlorophyll-a	0.5 - > 10.0 µg/L	SBOO ≤0.7 micrograms per liter (µg/L)	Chlorophyll Fluorescence serves as a proxy for biological productivity in the water column simulated by both natural and anthropogenic influences. This measurement varies in both ambient seawater and plume water and did not serve as an independent plume detection variable, but was found useful in multi-variable identification of plume water.
Conductivity (Salinity)	33.7 - 34.2 practical salinity units (psu)	SBOO ≤ .07 - 0.2 psu below ambient Tijuana River < ambient	Conductivity measurements are used to calculate salinity values and can measure the freshwater signal of plume water compared to background ocean levels.
Temperature	N/A	N/A	Water temperature measurements are used to estimate ocean stratification, which controls the rise height of a buoyant discharge plume.
Optical backscatter	bb(650) <0.003 bb(880) <0.005	SBOO bb(650) <0.004 bb(880) <0.01 TJR bb(650) <0.03 bb(880) <0.03	Optical backscatter measured at two wavelengths (650 and 880 nanometers [nm]) is used as an indication of turbidity. The signal measured by this meter is directly correlated to particle concentrations. Higher turbidity measurements are indicative of plume water. The TJR plume is always clear in backscatter due to strong signal, but kelp can easily mask SBOO plume signature in the far field. Kelp forest has values bb(650) <0.01 and bb(880) <0.01. Ratios of the optical backscatter can serve as a proxy for the size distribution of ocean particles.
CDOM (Colored Dissolved Organic Matter)	≤ 4.8 parts per billion (ppb)	≥ 6 ppb	CDOM measurements serve as a clear indicator of plume water having values more elevated than ambient seawater. CDOM levels directly within kelp forests can also have elevated CDOM (5.5 to 7 ppb)

Table A.1 REMUS Sensing Capabilities
Onboard sensing capabilities of the REMUS vehicle and application to plume water detection

2. Mission Planning and Operational Adaptive Sampling

The essence of tasks SS1 and SS2 was to characterize the outfall and Tijuana River plume to determine their extents. Scientists utilized synthesized data sets to accurately program the REMUS to capture plume signature. In the case of the South Bay Ocean Outfall, near real-time HF-radar-derived surface currents, wave information from the Coastal Data Information Program (CDIP) buoy and velocity and temperature profiles from the SBOO mooring were reviewed daily to determine whether conditions indicated either northward advection of the plume and/or weakened stratification resulting in plume surfacing (see Figure A.2). There were 17 SBOO REMUS missions conducted throughout the sampling period from July 2007 through October 2008.

In mapping the Tijuana River, several other factors were taken into account including rain forecasts, near real-time data collected by the weather station located on the IB Pier, the IB Pier mooring, the IBWC flow gauge, and the real-time Tijuana River plume tracking model based on HF-radar-measured surface currents. Flow loading of the Tijuana River was monitored using the existing gauge operated by the IBWC. Although this gauge was not an optimal descriptor of flow rate into the ocean because its monitoring location is east of many of the gulches that drain into TJR (such as Smugglers Gulch, Goat Canyon, and Yoghurt Canyon), data from the gauge served as a proxy for total flow from the Tijuana River watershed into the ocean. A Tijuana River sampling event was performed following any rain event, as long as open water conditions permitted safe operation of a small boat. In the event of a small craft advisory, personnel conducted a shoreline survey, sampling the surfzone with a self-contained CTD instrument (Figure A.3). Low salinity measurements within the shoreline correlated with the freshwater plume providing indications of the northward extent of the Tijuana River plume. Staff monitored the SBOO mooring, looking for indications of northward or eastward currents, reduced or increased temperature stratification, and conditions specified in the monitoring plan. If conditions had not changed and more than 25 days had passed since sampling, a SBOO REMUS mission was conducted.

While the Tijuana River is a known source of contamination during rain events, the extent and persistence of the plume was relatively unknown prior to this study. Throughout the sampling period, five Tijuana River REMUS missions and eight shoreline surveys were conducted. These sampling efforts focused on plume measurements following rain events. Field engineers took shoreline measurements with a self-contained CTD when weather conditions restricted the use of a small boat following announcement of a small craft advisory. The shoreline CTD surveys appear to have mapped the Tijuana River plume as far north as the Hotel Del Coronado during the largest rainstorm.

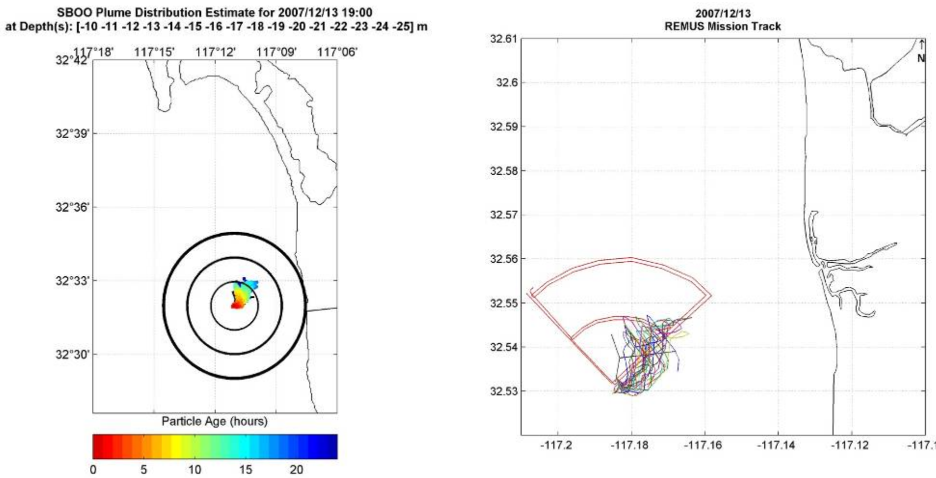


Figure A.2 SBOO Plume Trajectory
(left) Near real-time SBOO plume trajectory estimate overall depths from the SBOO mooring indicating northerly flow. (right) SBOO REMUS mission programmed to capture plume signature.

Figure A.3 Tijuana River Sampling
Field engineer sampling Tijuana River plume with self-contained CTD during rain event.

3. REMUS Survey Summary

Between July 2007 and October 2008, a total of 18 SBOO plume sampling missions were conducted using the REMUS and boat-based CTDs. The Tijuana River plume was sampled 15 times over the same period. Plume sampling is summarized in Table A.2 along with conditions during sampling. Tables A.3 and A.4 present similar information but focus specifically on sampling conditions outlined under activities SS1 and SS2. Summary plots for REMUS surveys are provided in Appendix 3.3.

a) SBOO Plume Surveys

The SBOO plume was sampled during dry weather when both high and low stratification conditions were present, as well as when the plume was being advected to the north and to the south (Table A.2). Wet weather sampling was primarily restricted to low levels of stratification; however, both northward and southward flow conditions were captured.

During earlier missions (prior to February 15, 2008) the plume was consistently detected by an elevated optical backscatter signal and low salinity in the near-field (within 1 km) while the low salinity signature often persisted in the far-field (up to 3.7 km). Seawater salinity in the vicinity of the outfall ranges from 33.7 psu in winter months to 34.2 psu during summer and the outfall plume has a signature of 0.07 to 0.2 psu below ambient seawater. However, these signatures were often obscured by other sources of variability. Large variations in the vertical salinity profile relative to the plume signature can obscure plume detection while other sources of suspended particles, such as the bottom nepheloid layer (a layer of sediment suspended near the seafloor by current scouring) and kelp beds, obscure the optical backscatter signature. Despite these limitations, the plume was consistently identified in all but one mission (September 4, 2007) by distinguishing the plume signature and confirming its spatial distribution using estimated distributions derived from the vertical velocity profile obtained from the SBOO buoy.

Group	Date	Location	Max Plume Range † (km)	Stratification			Dominant Along-shore Current	Dominant Cross-shore Current	Sea State			Last Rain Event (Start Date)	Last Rainfall Event Total to Date (mm)	No. of CTD Casts
				Subjective	ΔT (°C)	mld (m)			Sig. Wave Height (m)	Peak Period (s)	Peak Direction (deg.)			
SIO	**2007/07/10**	South Bay Ocean Outfall	3.7	Strong	8	7.5	North	On-shore	0.6	13	235	N/A	0.0	2
SIO	**2007/08/08**	South Bay Ocean Outfall	1.1	Strong	9	7.5	South	On-shore	0.8	7	290	N/A	0.0	7
SIO	**2007/08/22**	South Bay Ocean Outfall	0.1	Strong	8	11	South	On-shore	0.8	10	250	N/A	0.0	8
SIO	**2007/08/30**	South Bay Ocean Outfall	3.3[Δ]	Strong	5	5	North	Off-shore	0.7	18	240	N/A	0.0	4
SIO	**2007/09/04**	South Bay Ocean Outfall	N/A	Strong	7	12	North	Off-shore	1.2	8	260	N/A	0.0	9
SIO	**2007/10/29**	South Bay Ocean Outfall	1.3[Δ]	Weak	3	10	North	Off-shore	0.6	14	235	2007/10/17	1.0	17
SIO	**2007/11/29**	South Bay Ocean Outfall	1.0	Weak	4	20	South	On-shore	0.8	13	265	2007/11/12	2.6	0
SIO	**2007/12/13**	South Bay Ocean Outfall	3.1[Δ]	Weak	0.1	N/A	South	On-shore	0.6	15	250	2007/12/07	9.2	11
SIO	**2008/02/15**	South Bay Ocean Outfall	3.0[Δ]	Weak	0.3	20	North	Off-shore	1.3	15	270	2008/02/14	11.5	7
SIO	**2008/03/06**	South Bay Ocean Outfall	0.6	Weak	2.5	14	South	On-shore	0.8	15	235	N/A	0	9
SIO	**2008/04/17**	South Bay Ocean Outfall	1.7	Strong	5	11	South	On-shore	1.2	12	270	N/A	0	3
SIO	**2008/06/05**	South Bay Ocean Outfall	2.4	Strong	5	12	North	Off-shore	1.4	8.5	280	N/A	0	3
SIO	**2008/06/17**	South Bay Ocean Outfall	1.4	Strong	6	5	North	None	0.9	16.5	240	N/A	0	9
SIO	**2008/06/24**	South Bay Ocean Outfall	1.0	Strong	8	12	North	Off-shore	1.2	7	280	N/A	0	9
SIO	**2008/07/01**	South Bay Ocean Outfall	2.2	Strong	5	6	South	On-shore	1.1	7	285	N/A	0	9
SIO	**2008/07/30**	South Bay Ocean Outfall	0.5	Strong	8	10	South	On-shore	0.6	15	230	N/A	0	9
SIO	**2008/08/21**	South Bay Ocean Outfall	0.5	Strong	7	8	North	Off-shore	0.8	15	240	N/A	0	0

Group	Date	Location	Max Plume Range † (km)	Stratification			Dominant Along-shore Current	Dominant Cross-shore Current	Sea State			Last Rain Event (Start Date)	Last Rainfall Event Total to Date (mm)	No. of CTD Casts
				Subjective	ΔT (°C)	mld (m)			Sig. Wave Height (m)	Peak Period(s)	Peak Direction (deg.)			
SIO	**2007/09/24**	Tijuana River	0.8*	Strong	6	12	South	N/A	0.8	17	235	2007/09/22	2.2	6
SIO	**2007/12/09**	Tijuana River	3.6	Weak	0.5	23	North	N/A	1	13	270	2007/12/07	9.2	43
SIO	**2008/01/07**	Shoreline	3.0	Weak	0.1	N/A	South	N/A	1.8	12	260	2008/01/05	32.2	18
SIO	**2008/01/24**	Tijuana River	5.8*	Weak	0.2	N/A	North	N/A	1	15	270	2008/01/22	9.2	10
SIO	**2008/01/28**	Shoreline	17.0	Weak	0.1	N/A	South	N/A	1.8	10	250	2008/01/27	15.2	31
SIO	**2008/01/29**	Shoreline	17.0	Weak	0.2	N/A	South	N/A	1.5	7	260	2008/01/27	20.2	28
SIO	**2008/01/30**	Shoreline	17.0	Weak	0.1	N/A	South	N/A	1	12	245	2008/01/27	20.2	29
SIO	**2008/02/04**	Shoreline	17.0	Weak	1	21	South	N/A	2.3	10	280	2008/02/03	7.4	20
SIO	**2008/02/05**	Tijuana River	3.6*	Weak	1.8	15	South	N/A	1.8	13	275	2008/02/03	7.4	11
SIO	**2008/02/25**	Shoreline	2.5*	Weak	0.7	22	South	N/A	2.8	17	270	2008/02/22	2	29
SIO	**2008/02/26**	Shoreline	2.5*	Weak	2	18	South	N/A	1.5	8	270	2008/02/22	2	29
SIO	**2008/03/17**	Shoreline	2.5*	Weak	3	8	South	N/A	2.5	12	275	2008/03/16	6.6	24
SIO	**2008/04/03**	Tijuana River	2.0*	Weak	4.5	5	South	N/A	0.6	17	245	2008/04/03	0.2	8
SIO	**2008/07/28**	Tijuana River/ Shoreline	1.0	Strong	8	10	South	N/A	0.6	15	235	N/A	0	5

Group	Date	Location	Maximum Plume Range† (km)	Stratification			Dominant Along-shore Current	Dominant Cross-shore Current	Sea State			Last Rain Event (Start Date)	Last Rainfall Event Total to Date (mm)	No. of CTD Casts
				Subjective	ΔT (°C)	mld (m)			Sig. Wave Height (m)	Peak Period(s)	Peak Direction (deg.)			
SIO	**2008/08/22**	Source ID	N/A	Strong	8	10	North	Off-shore	0.7	14	230	N/A	0	5
SIO	**2008/10/21**	Source ID	TJR - 0.8 SBOO - 0.4	Weak	2	12	TJR - North SBOO - South	TJR - N/A SBOO - On-shore	1	17	240	N/A	0	8

Table A.2 REMUS Survey Summary
REMUS survey summary including date, location, oceanographic conditions, last rain event, and supplementary profiler casts.

† All SBOO plume maximum ranges are limited by sampling limitations, either by kelp to the north or the border to the south
** TJR plume detection limited by sampling*
△ SBOO plume observed to surface

Dry Weather Sampling Dates and Conditions							
		Stratification		Along-shore Flow		Cross-shore Flow	
Sampling Date	Location	Low	High	Northward	Southward	On-shore	Offshore
2007/07/10	SBOO		x	x		x	
2007/08/08	SBOO		x		x	x	
2007/08/22	SBOO		x		x	x	
2007/08/30	SBOO		x	x			x
2007/09/04	SBOO		x	x			x
2007/10/29	SBOO	x		x			x
2007/11/29	SBOO	x			x	x	
2008/03/06	SBOO	x			x	x	
2008/04/17	SBOO	x			x	x	
2008/06/05	SBOO		x	x			x
2008/06/17	SBOO		x	x			
2008/06/24	SBOO		x	x			x
2008/07/01	SBOO		x		x	x	
2008/07/28	TJR/Shoreline		x		x	N/A	N/A
2008/07/30	SBOO		x		x	x	
2008/08/21	SBOO		x	x			x
2008/08/22	TJR/SBOO		x	x			x
2008/10/21	TJR/SBOO	x		TJR	SBOO	SBOO	

Table A.3 REMUS Dry Weather Sampling
REMUS dry weather sampling oceanographic conditions summary

Wet Weather Sampling Dates and Conditions							
		Stratification		Along-shore Flow		Cross-shore Flow	
Sampling Date	Location	Low	High	Northward	Southward	On-shore	Offshore
2007/09/24	TJR		x		x	N/A	N/A
2007/12/09	TJR	x		x		N/A	N/A
2007/12/13	SBOO	x			x	x	
2008/01/07	Shoreline	x			x	N/A	N/A
2008/01/24	TJR	x		x		N/A	N/A
2008/01/28	Shoreline	x			x	N/A	N/A
2008/01/29	Shoreline	x			x	N/A	N/A
2008/01/30	Shoreline	x			x	N/A	N/A
2008/02/04	Shoreline	x			x	N/A	N/A
2008/02/05	TJR	x			x	N/A	N/A
2008/02/15	SBOO	x		x			x
2008/02/25	Shoreline	x			x	N/A	N/A
2008/02/26	Shoreline	x			x	N/A	N/A
2008/03/17	Shoreline	x			x	N/A	N/A
2008/04/03	TJR	x			x	N/A	N/A

Table A.4 REMUS Wet Weather Sampling
REMUS wet weather sampling oceanographic conditions summary

As SBOO sampling evolved, it was determined that the plume had an elevated CDOM signature based on results from boat-based CTD casts. CDOM exists naturally in seawater and freshwater environments and generally consists of decaying organic matter from living organisms. Near-shore CDOM has both marine and terrestrial sources due to riverine input. CDOM concentrations near shore may be further elevated by human activities such as logging, agriculture, and wastewater discharge. Starting with the mission conducted on February 15, 2008, the REMUS was outfitted with a new optical sensor capable of measuring CDOM in place of chlorophyll. Subsequent missions showed that ambient seawater concentrations of CDOM are below 4.8 ppb while the outfall and river plumes exceed 6 ppb. The kelp forest also has elevated CDOM concentrations (5.5 to 7 ppb) relative to ambient seawater but is assumed to be naturally occurring due to elevated biological activity. The elevated levels within the kelp were found to be local phenomena and were constrained to the footprint of the areas of dense kelp.

At the same time that the AUV was outfitted with the CDOM sensor, an additional CTD capable of faster and more accurate salinity and temperature measurements was installed. The combination of an improved salinity sensor and the ability to measure CDOM resulted in clear plume detection in every subsequent mission.

SBOO plume sampling was spatially restricted to the south by the International Border and to the north by the presence of kelp patches that would trap the REMUS. As a result, the maximum extent of the plume distribution was limited to the sampling domain that extended up to 3.7 km to the north of the outfall and 200 m to the south.

Typical visualizations of the SBOO plume provide some examples of plume detection, surfacing and spatial distribution described above. The mission conducted on March 6, 2008 (Figure A.4), was designed to focus on resolving the near-field of the outfall plume. Velocity measurements from the SBOO buoy show that flow is toward the south-southeast, and temperature measurements show that stratification is relatively weak with a 3 degrees Celsius (°C) temperature difference between bottom and surface waters. However, due to the limited range of the mission, the plume is not observed to surface.

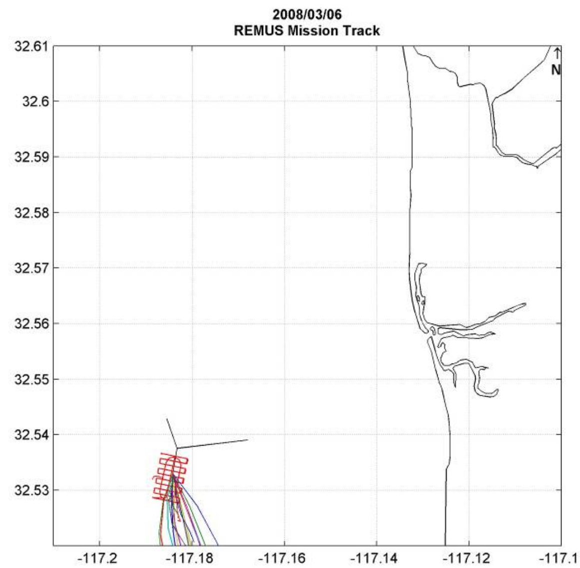


Figure A.4 REMUS Mission Tracks Southern Wye SBOO
REMUS vehicle mission track (red) centered over the lower third of the southern wye of the SBOO (shown in black) for sampling conducted on March 6, 2008. Colored lines indicate the estimated plume trajectory based on SBOO buoy velocity profiles.

Plume signatures of elevated optical backscatter and CDOM in the south-southeast are consistent with the estimated plume distribution based on SBOO buoy velocity measurements because the core of the plume is aligned with the estimated distribution (Figures A.5 and A.6).

The core of the plume has CDOM values as high as 10 ppb while optical backscatter at 650 nm exceeds 5 x 10^{-3} m^{-1}. Observations presented as a function of salinity, temperature, and CDOM show that the SBOO plume has a distinct water mass with a relatively fresh signature (approximately -0.7 parts per thousand [ppt] lower than ambient waters) and elevated CDOM values (Figure A.7).

The TS diagram can be used to derive a dilution ratio for the observed SBOO plume based on salinity measurements. The observed plume water mass has a value of 33.4 ppt, while ambient seawater with the same density has a value of 33.57 ppt. Assuming that SBOO wastewater is fresh, the dilution ratio of wastewater to seawater is 1:196. Once the plume characteristics have been identified in CDOM and salinity, samples falling within given thresholds identifying the water mass can be plotted to show the spatial distribution of the plume (Figure A.8). The horizontal spatial distribution shows the plume advecting toward the south as far as sampling was conducted (0.5 km), while the vertical distribution shows the core of the plume between 15 and 16 meters (m). Given the relatively weak stratification, it is likely that the plume rose to shallower depths farther south.

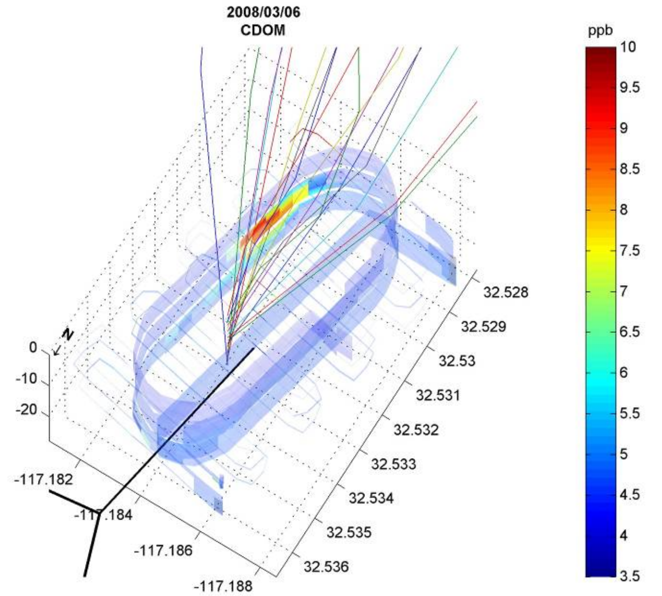


Figure A.5 SBOO Plume Organic Matter Concentrations
Elevated values of CDOM (>7 ppb) indicate high concentrations of organic matter in the SBOO plume. The SBOO is shown in black with the observed plume toward the south-southeast. The observed plume is coincident with the plume trajectory (colored lines) estimated from the SBOO buoy velocity profiles.

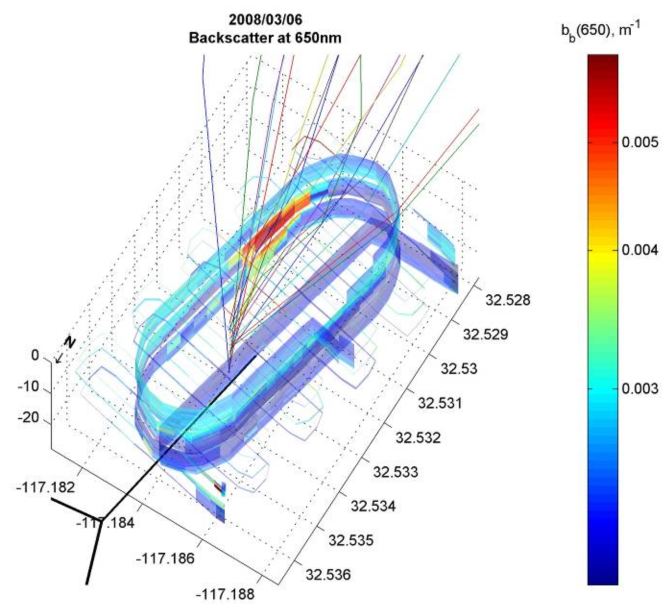


Figure A.6 SBOO Plume Turbidity
Elevated values (>0.004 m^{-1}) of optical backscatter at 650 nm indicate elevated turbidity in the SBOO plume. The SBOO is shown in black with the observed plume toward the south-southeast. The observed plume is coincident with the plume trajectory (colored lines) estimated from the SBOO buoy velocity profiles.

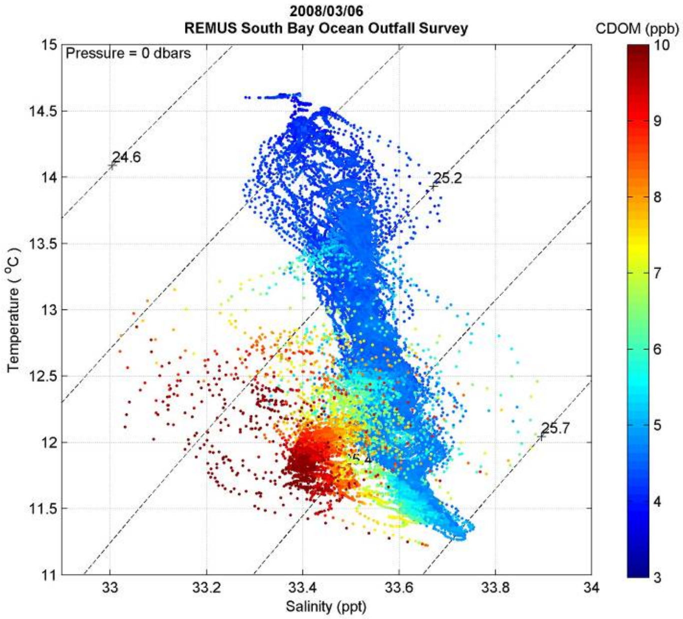


Figure A.7 Temperature Salinity Diagram – March 6, 2008
A Temperature-Salinity (TS) Diagram colored by CDOM concentrations for sampling conducted on March 6, 2008, shows the plume as a distinct water mass with a low salinity (approximately 33.4 ppt), high CDOM (>6 ppb) signature. Lines of constant density are shown with dashed lines.

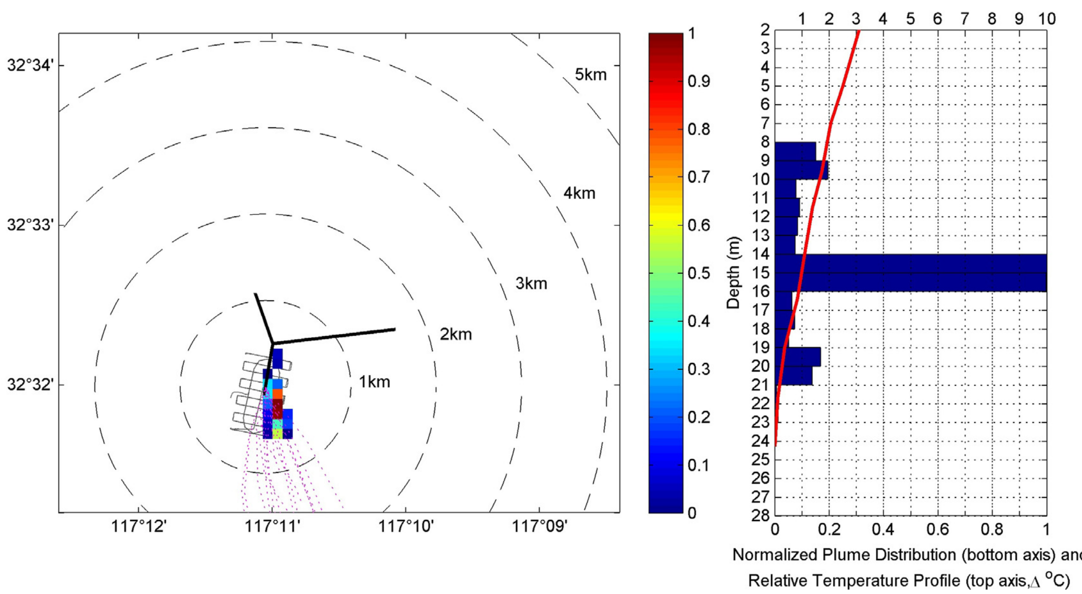


Figure A.8 Horizontal and Vertical SBOO Plume Distributions – March 6, 2008
Horizontal (left) and vertical (right) distributions of the SBOO plume measured on March 6, 2008. Plume distributions are based on the number of samples with CDOM > 6 ppb and salinity < 33.57 ppt falling within each spatial bin (50 x 50 m horizontally and 1 m vertically) then normalized by the maximum number of samples observed in a single bin. On the horizontal distribution plot, the REMUS mission path is shown in grey, the estimated plume trajectory based on buoy velocity measurements are shown in pink dashed lines and the SBOO outfall wye is shown in black. On the vertical distribution plot, the relative temperature profile (temperature profile relative to bottom water temperature) is plotted in red.

Another mission conducted on February 15, 2008, shows flow to the north based on the SBOO buoy velocity profile (Figure A.9). Stratification over the outfall was weak during this mission with only a 0.3°C temperature difference between bottom and surface waters. This allowed the plume to rise quickly and travel along the surface as observed in CDOM and salinity distributions (Figures A.10 and A.11). CDOM values in the core of the plume exceed 6 ppb, while salinity is depressed by approximately 0.1 psu relative to surrounding waters, giving a wastewater dilution ratio of 1:335. The core of the plume is observed just east of the estimated distribution, based on the velocity profile. The discrepancy between the estimated trajectory and the observed plume path is likely due to differences between measured velocities at 5 m and velocities in surface waters (above 5 m) where the plume was concentrated. The spatial distribution of the SBOO plume is determined by selecting samples specific to the SBOO plume, in this case CDOM values greater than or equal to (≥) 5.4 ppb and salinity values less than or equal to (≤) 33.5 ppt (Figure A.12). The plume was observed at the surface out to the edge of our sampling domain, 3 km to the north-northeast.

SBOO plume distributions based on water-mass characteristics in salinity and CDOM (when available) are presented in Figures A.13 and A.14. In all cases, there is good agreement between the estimated plume trajectory based on velocities measured by the buoy and the observed plume distribution. Similarly, there is good correspondence between the observed plume depth and the stratification strength measured by the buoy.

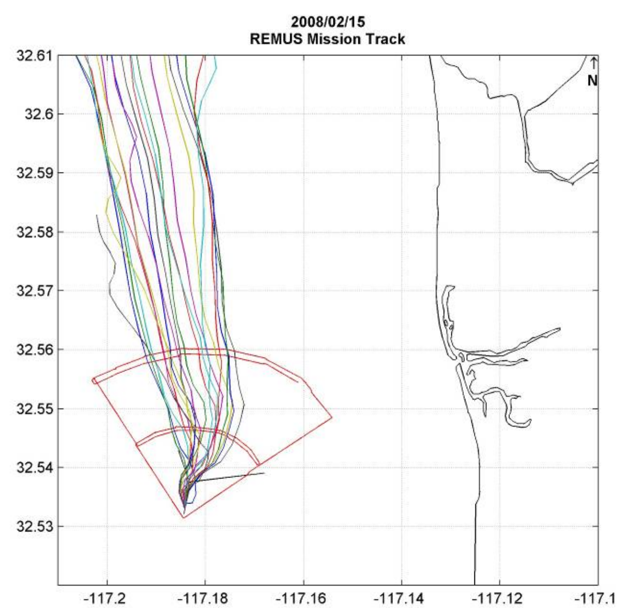


Figure A.9 REMUS Mission Track – February 15, 2008
REMUS vehicle mission track (red) spanning the estimated plume trajectory (colored lines) from the SBOO (black) for sampling on February 15, 2008.

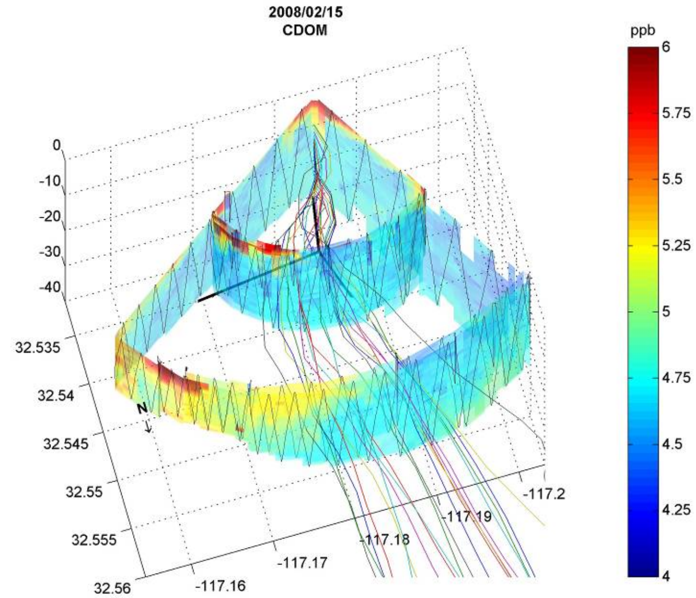


Figure A.10 SBOO Plume CDOM – February 15, 2008
The SBOO plume, as identified by elevated CDOM concentrations of up to 6 ppb, is shown to rise rapidly from the outfall (black) and advect northward. The observed plume trajectory is just east of the trajectory estimated from the SBOO buoy velocity profiles (colored lines).

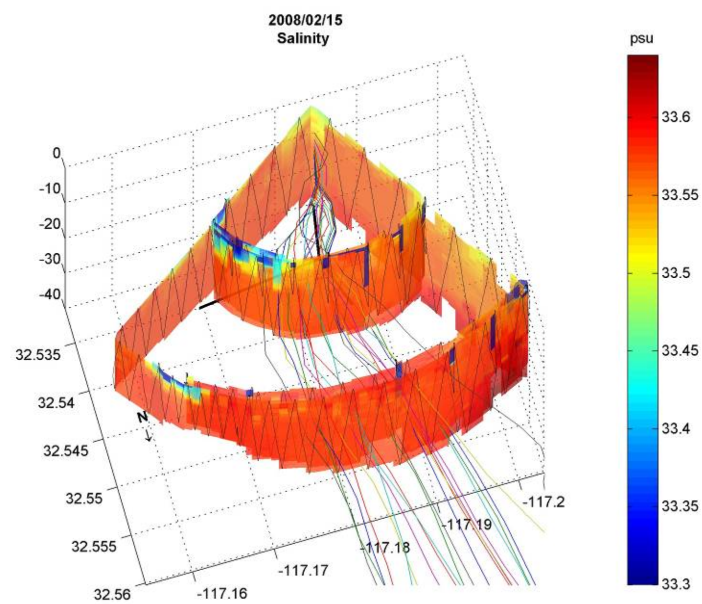


Figure A.11 SBOO Plume Fresh Water – February 15, 2008
The SBOO plume, as identified by relatively fresh water, is shown to rise rapidly from the outfall (black) and advect northward. The observed plume trajectory is just east of the trajectory estimated from the SBOO buoy velocity profiles (colored lines).

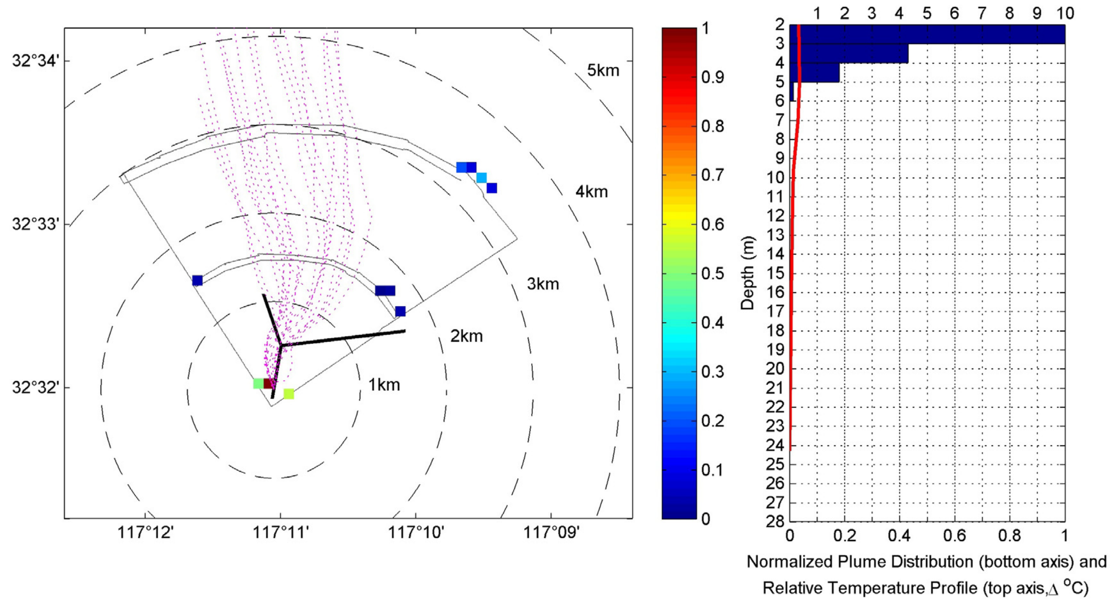


Figure A.12 Horizontal and Vertical SBOO Plume Trajectory – February 15, 2008
Horizontal (left) and vertical (right) distributions of the SBOO plume measured on February 15, 2008. Plume distributions are based on the number of samples with CDOM > 5.4 ppb and salinity < 33.5 ppt falling within each spatial bin (50 x 50 m horizontally and 1 m vertically) then normalized by the maximum number of samples observed in a single bin. On the horizontal distribution plot, the REMUS mission path is shown in grey, the estimated plume trajectory based on buoy velocity measurements are shown in pink dashed lines and the SBOO outfall wye is shown in black. On the vertical distribution plot, the relative temperature profile (temperature profile relative to bottom water temperature) is plotted in red.

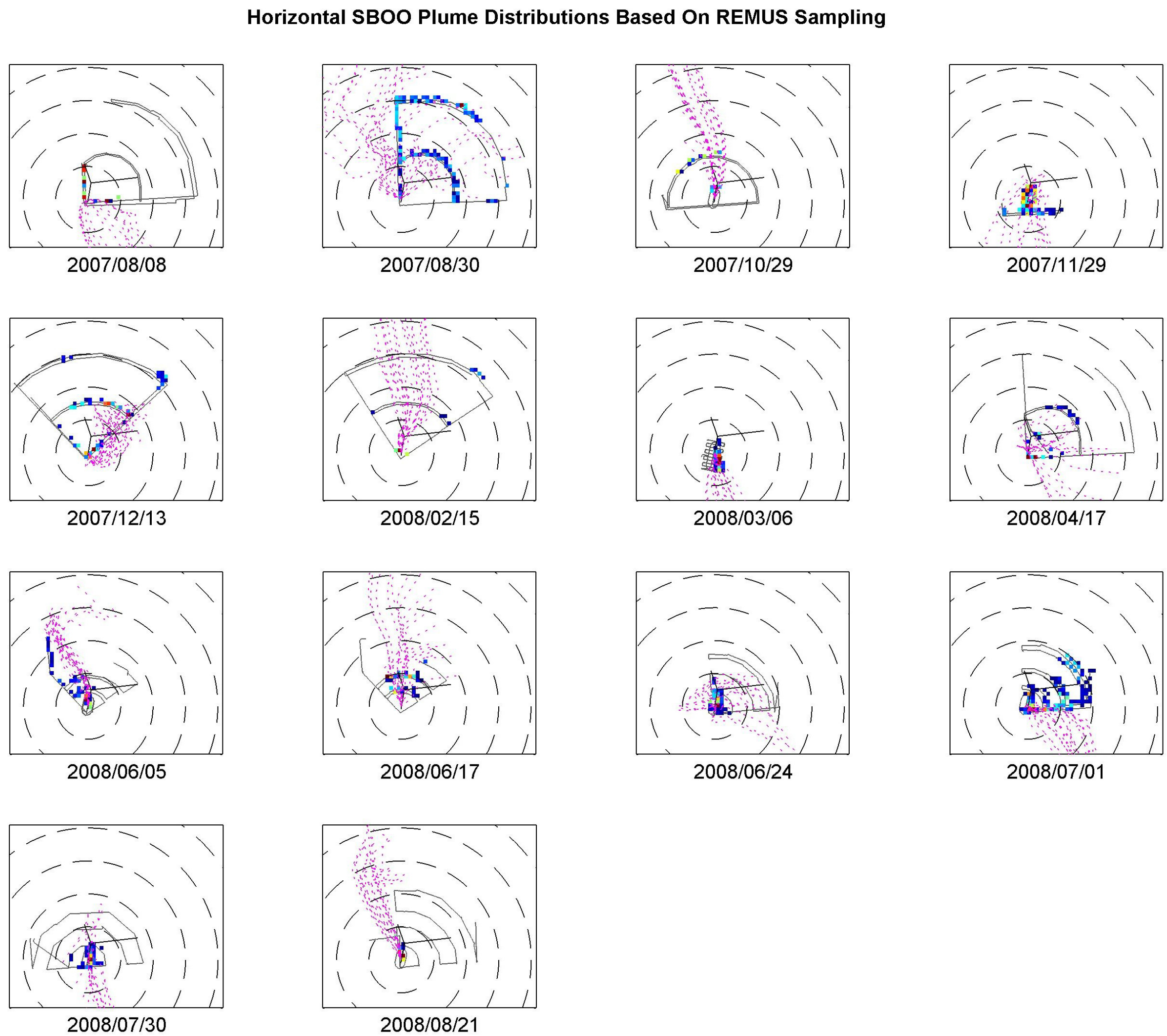


Figure A.13 Horizontal SBOO Plume Distributions
Plume distributions are based on the number of samples with characteristic CDOM and salinity values within spatial bins of 50 x 50 meters. The number of samples is then normalized by the maximum number of samples observed in a single bin for each mission. The REMUS mission path is shown in grey, the estimated plume trajectory based on buoy velocity measurements is shown in pink dashed lines and the SBOO outfall wye is shown in black.

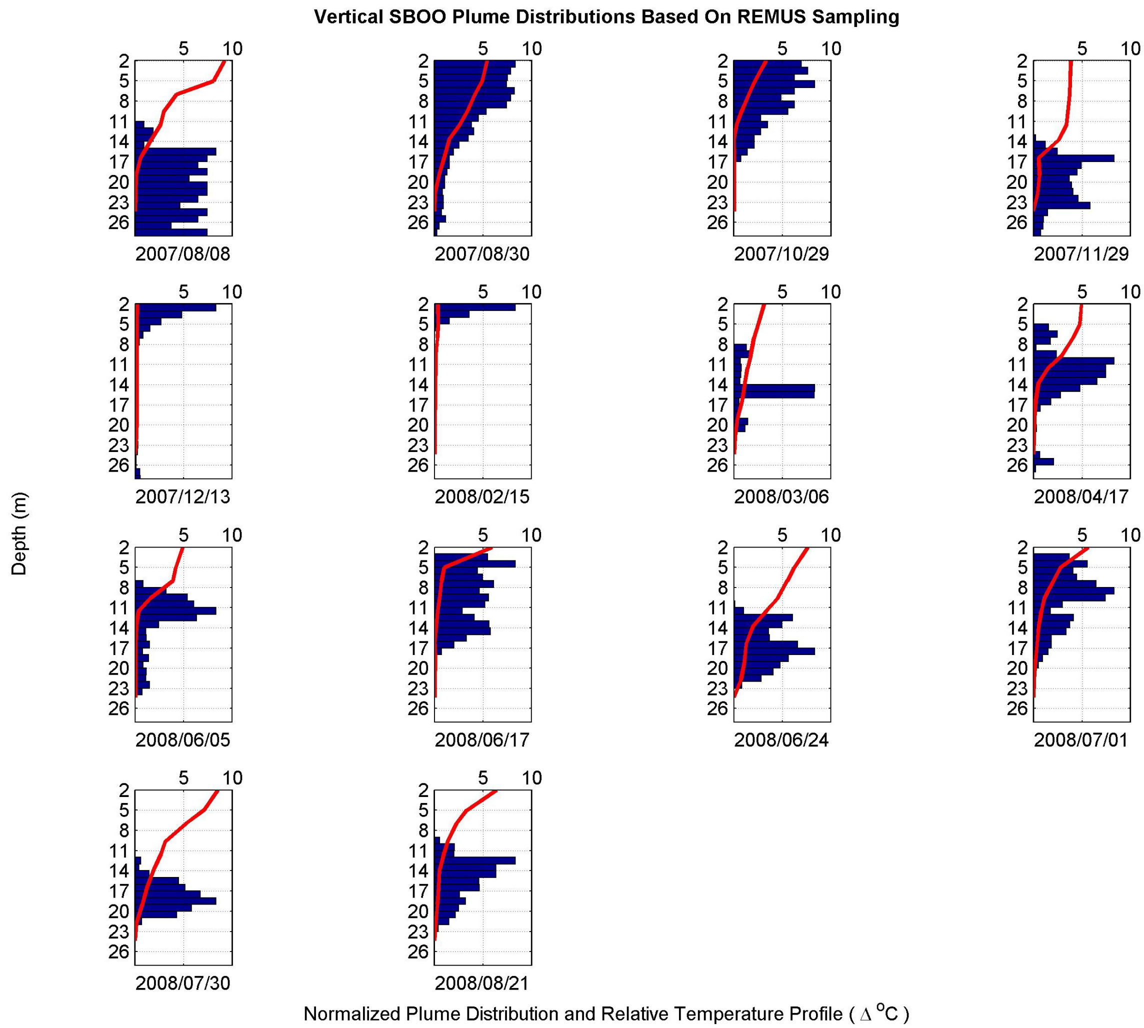


Figure A.14 Vertical SBOO Plume Distributions

Plume distributions are based on the number of samples with characteristic CDOM and salinity values within 1 meter vertical bins. The number of samples is then normalized by the maximum number of samples observed in a single bin for each mission. The relative temperature profile (temperature profile relative to bottom water temperature) is plotted in red.

Surfacing of the SBOO plume was detected during four sampling dates—August 30, 2007; October 29, 2007; December 13, 2007; and February 15, 2008. Weak stratification was observed for each of these dates with the exception of August 30. Although the temperature difference was 5^{o}C between the bottom and the top of the water column on August 30, the mixed layer was relatively shallow, which allowed the plume to obtain enough momentum to break through to the surface. Similar conditions with shallow mixed layers existed on June 17 and July 1 of 2008, and CDOM data suggest that it is possible that the plume surfaced while the core of the plume remained just below the surface. The plume was not observed to surface when the temperature difference between bottom water and surface waters was greater than 5^{o}C.

Missions starting from February 15, 2008, onward were conducted using a higher resolution CTD and CDOM sensor, which allowed for more precise determination of SBOO plume water-mass characteristics. Using the salinity characteristics of SBOO plume water and ambient seawater (with the same density), dilution ratios of wastewater to seawater were calculated (Table A.5). The range of dilution ratios is from 1:170 observed on July 30, 2008, to 1:487 observed on April 17, 2008, with a mean dilution ratio of 1:302 for all missions from February 15, 2008, onward.

Mission Date	Dilution Ratio (1:N)
2008/02/15	335
2008/03/06	196
2008/04/17	487
2008/06/05	244
2008/06/17	340
2008/06/24	189
2008/07/01	379
2008/07/30	170
2008/08/21	377

Table A.5 SBOO Plume Dilution Ratios
SBOO plume wastewater to seawater dilution ratios computed from AUV-based salinity measurements.

b) Tijuana River Plume Surveys

The Tijuana River plume was sampled primarily during wet weather when the river was flowing. Southward flow was observed at the river mouth during 11 of the wet weather sampling events, while northward flow was observed during 2 of them. The Tijuana River plume was sampled twice during dry weather to determine if there any exchange occurred between the ocean and estuary when no flow recorded at the

IBWC gauge and, if so, to determine the extent of the river plume. Both northward and southward flow conditions were observed during dry weather sampling.

Similar to the SBOO plume, the Tijuana River plume has a signature characterized by low salinity and high CDOM. However, the Tijuana River plume also has a much higher optical backscatter signature relative to the SBOO plume due to high concentrations of suspended sediment. Also, because the river flows onto the surface of the ocean and is relatively buoyant, it remains concentrated near the surface and is not forced to mix with surrounding waters. This helps to preserve its salinity signature relative to the SBOO plume.

The southern edge of the Tijuana River plume sampling domain was spatially restricted by the International Border, approximately 3.6 km away. During wet weather sampling, the plume was observed to extend as far as 3.6 km to the south on December 9, 2007, and appeared to extend northward to the City of Coronado (17 km) following one of the larger events starting on January 27, 2008 (Table A.2). A diffuse plume was also observed to extend approximately 1 km to either side of the river mouth during dry weather on July 28, 2008, and October 21, 2008, when the IBWC gauge reported no flow.

Visualizations of typical Tijuana River plume observations provide some examples of the spatial coverage of the plume and its signature contrast to receiving waters. On December 9, 2007, 43 boat-based CTD casts were taken along the coast from the International Border north to Coronado. Northward flow of 5 cm/s was observed for surface waters near the river mouth while the river was discharging at a rate of 48 mgd (Figure A.15).

The plume was observed up to 3.6 km northward in nearly all parameters sampled including CDOM, salinity, temperature and light attenuation (Figures A.16 through A.19). Salinity values of 32.5 psu were observed in the plume, approximately 0.7 to 1.0 psu below surrounding waters. indicating a dilution ratio of roughly 1:40 (riverwater:seawater). A temperature signature of 14.7^{o}C (which is 0.4 ^{o}C below the ambient surface ocean temperature) was observed. CDOM within the plume reached 8 ppb (similar to SBOO plume values), while the beam attenuation coefficient at 660 nm (a measure of light attenuation, in this case due to suspended sediment) reached 10 m^{-1} indicating the presence of highly turbid water.

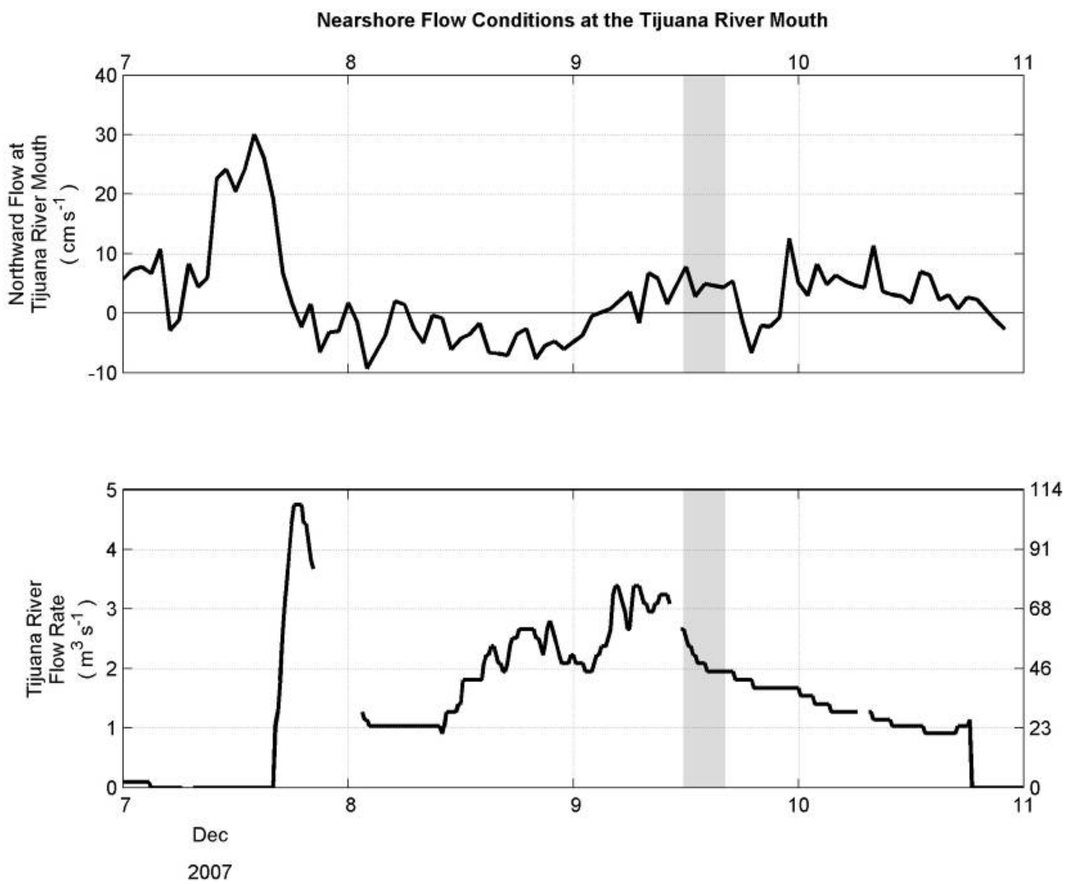


Figure A.15 Tijuana River Mouth Near-shore Flow Conditions – December 9, 2007
Along-shore flow (positive values are northward, negative values are southward) at the Tijuana River mouth and the river flow rate are shown surrounding sampling conducted on December 9, 2007. Sampling (grey window) was conducted during northward flow at 5 cm/s when discharge from the river was approximately 50 mgd.

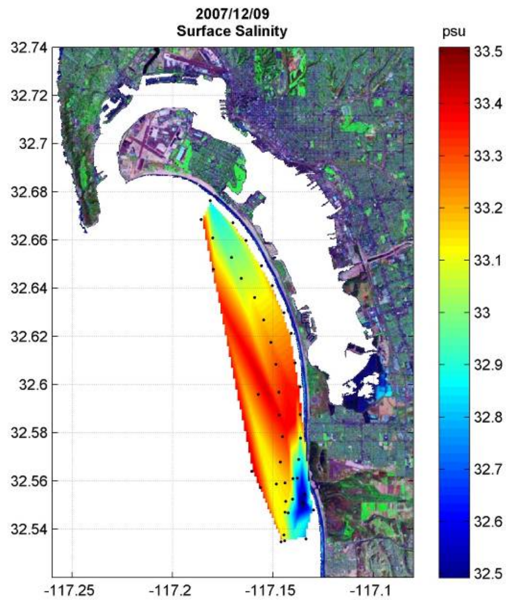


Figure A.16 Surface Salinity – December 9, 2007
Surface salinity mapped from 43 casts conducted on December 9, 2007. Depressed salinity values of 32.5 psu were observed in the core of the plume, approximately 0.7 – 1.0 psu below surrounding waters, indicating a dilution ratio of roughly 1:40 (riverwater : seawater) within 1 km of the river mouth.

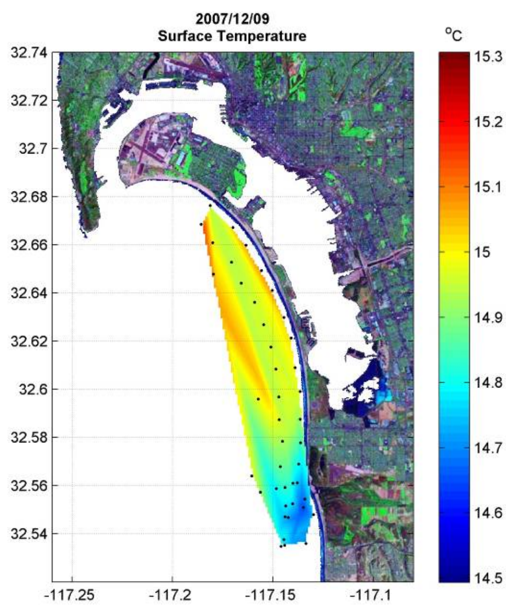


Figure A.17 Surface Temperature– December 9, 2007
Surface temperature mapped from 43 casts conducted on December 9, 2007. A temperature signature of 14.7^{o}C, 0.4^{o}C below the ambient surface ocean temperature is observed at the Tijuana River mouth. For this survey, the plume water was cooler than the background ocean.

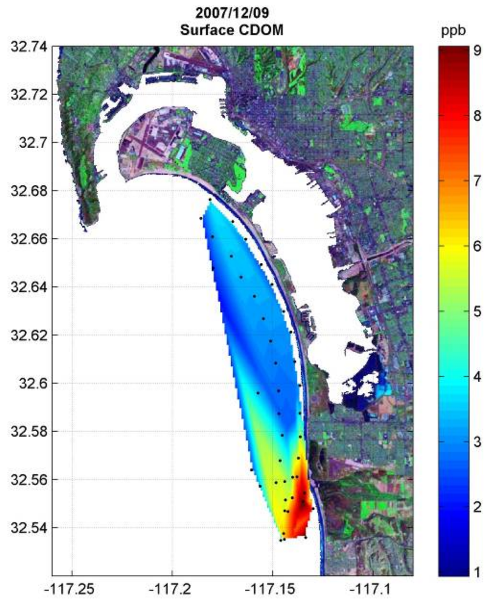


Figure A.18 Surface CDOM – December 9, 2007
Surface CDOM mapped from 43 casts conducted on December 9, 2007. CDOM within the core of the plume exceeds 6 ppb. Typical ocean levels of CDOM are 1 ppb or less.

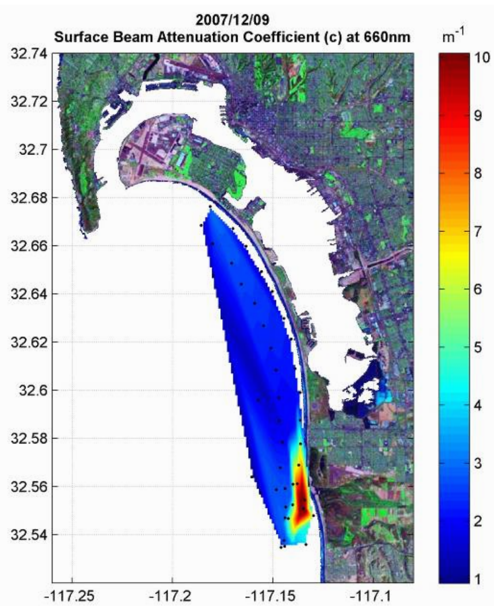


Figure A.19 Surface Beam Attenuation Coefficient – December 9, 2007
Surface light attenuation mapped from 43 casts conducted on December 9, 2007. The beam attenuation coefficient at 660 nm (a measure of light attenuation, in this case due to suspended sediment) reached 10 m^{-1} within the river plume indicating the presence of highly turbid water.

On January 24, 2008, surface waters near the Tijuana River mouth were flowing northward following rainfall from the same day. While a salinity signature is observed in the river plume, tracking the river plume by depressed salinity alone becomes increasingly difficult as the plume mixes and the discharge dilutes with seawater. The optical scatter, representative of the turbidity, is found to extend much farther north and allows tracking of the plume at higher levels of dilution (Figures A.20 and A.21). Based on the optical backscatter signature, the plume extends as far north as was sampled, 5.8 km.

The patchy nature of the river plume revealed by optical backscatter is also observed in salinity measurements on February 5, 2008 (Figure A.23). The river was discharging at a rate of 65 mgd, and surface waters were flowing southward in the vicinity of the river mouth during the majority of sampling (Figure A.22), which is consistent with the observed plume distribution. However, as was observed on January 24, the optical backscatter signature is retained for higher levels of dilution and reveals the plume water to be transported north of the estuary as well (Figure A.24). Although along-shore velocities were southward on February 4, both northward and southward along-shore velocities were observed throughout February 5, which would explain the presence of plume water to the north.

When conditions did not allow boat-based surveys or REMUS missions, shore-based CTD sampling in the surfzone was conducted to measure the along-shore extent of the Tijuana River plume. On January 27, 2008, flow from the TJR peaked from the rainstorm at 250 mgd, which coincided with strong (44 cm/s) northward flow resulting in plume waters reaching as far north as Coronado Island (Figure A.25). A minimum salinity of 8 psu was measured at the river mouth with a strong salinity front to the south and increasingly diluted plume water to the north in the direction of advection. FIB samples were collected and analyzed by the San Diego County Department of Environmental Health, mirroring the spatial distribution of the plume's salinity signature (Figure A.26). Fecal coliforms below 10 colony forming units (CFU) per 100 ml are observed to the south of the estuary with a sharp increase to over 10,000 CFU/100 ml at the river mouth. North of the river mouth fecal coliform concentrations decrease due to dilution of the plume but never reach below 100 CFU/100ml. Total suspended sediment concentrations measured by satellite remote sensing show the extent of the Tijuana River plume during sampling (Figure A.27). The distribution of the plume along the coast northward to Coronado then offshore indicates that the plume may recirculate inshore of Point Loma.

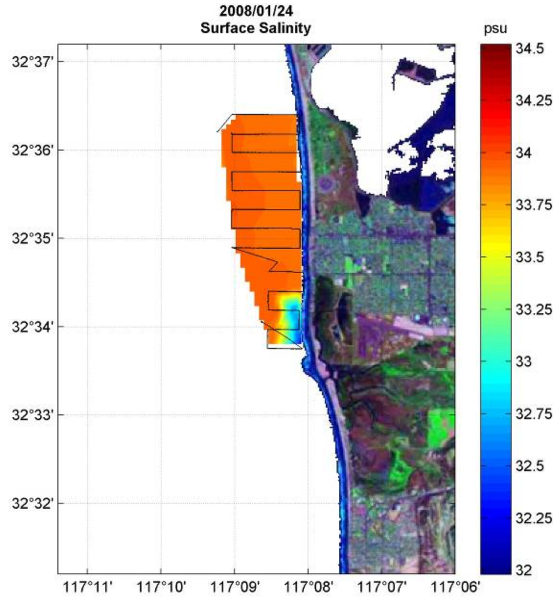


Figure A.20 Surface Salinity – January 24, 2008
Surface salinity mapped from a REMUS mission (black line) conducted on January 24, 2008.

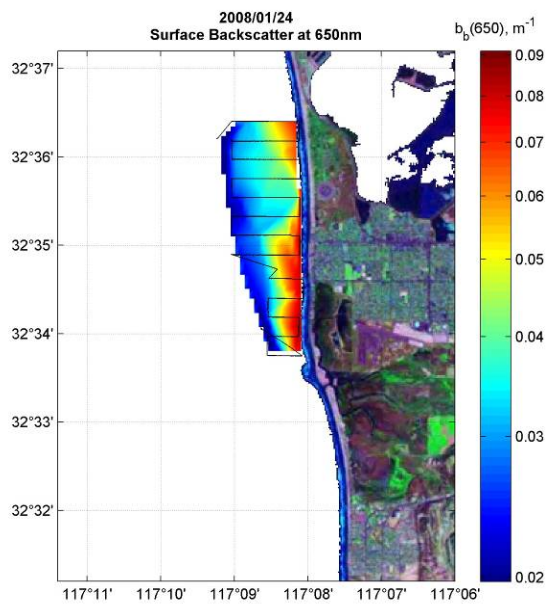


Figure A.21 Surface Backscatter – January 24, 2008
Surface optical backscatter mapped from a REMUS mission (black line) conducted on January 24, 2008.

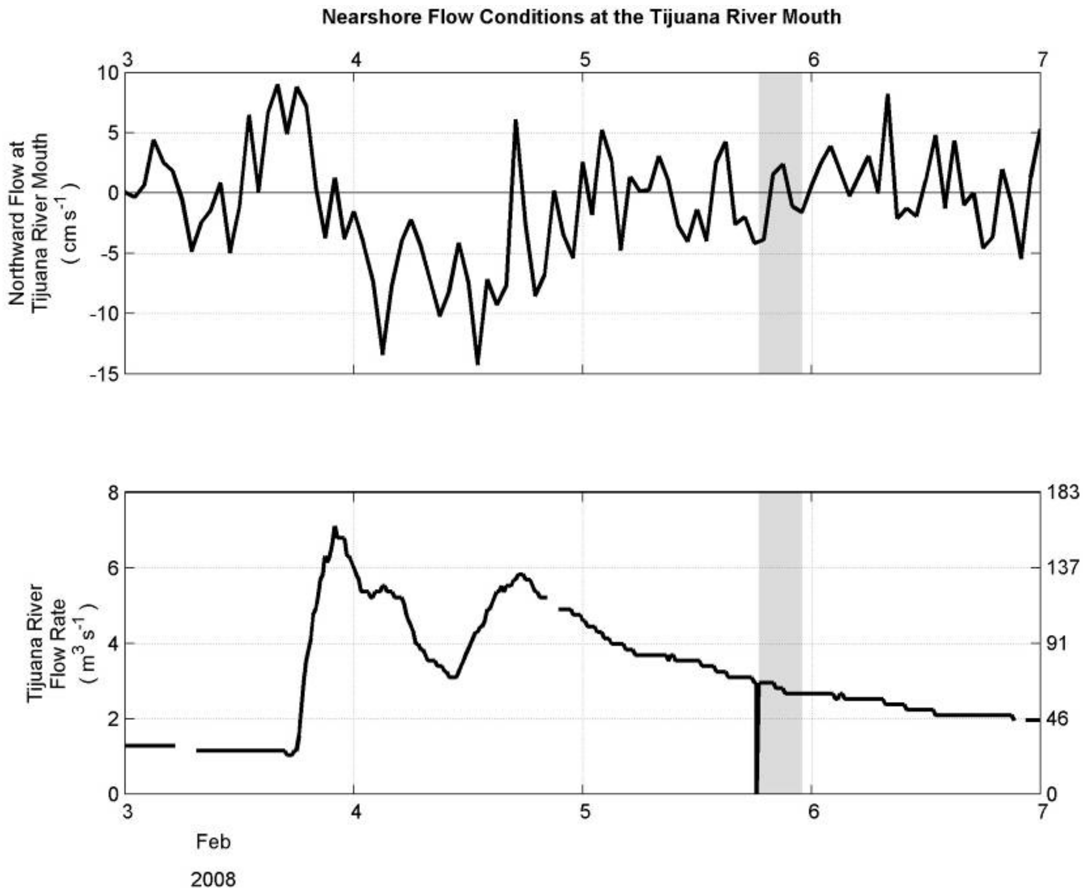


Figure A.22 Tijuana River Mouth Near-shore Flow Conditions – February 5, 2008
Along-shore flow (positive values are northward, negative values are southward) at the Tijuana River mouth and the river flow rate are shown surrounding sampling conducted on February 5, 2008. Sampling (grey window) was conducted during weak (< 5 cm/s) flow to the north and south when discharge from the river was 65 mgd. Flow was predominantly southward during peak levels of discharge from rainfall on February 4.

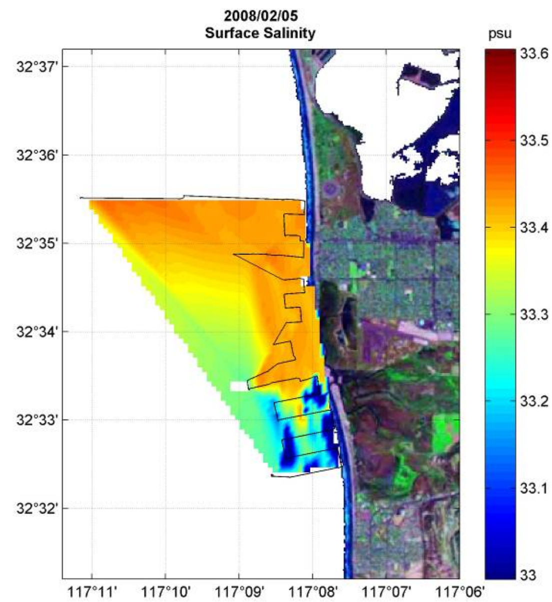


Figure A.23 Surface Salinity – February 5, 2008
Surface salinity mapped from a REMUS mission (black line) conducted on February 5, 2008. Salinity values below 33 psu are observed south of the river mouth (in the direction of mean along-shore currents during sampling) while salinity values to the north reflect ambient seawater values.

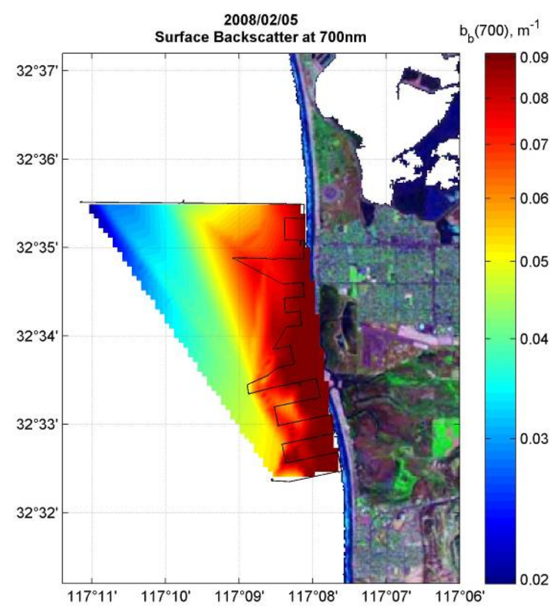


Figure A.24 Surface Backscatter – February 5, 2008
Surface optical backscatter mapped from a REMUS mission (black line) conducted on February 5, 2008. Backscatter at 700 nm is elevated along shore(> 0.5 m^{-1}) due to the presence of highly turbid Tijuana River plume water. The plume is found to be present both north and south of the discharge resulting from the variable currents in the area.

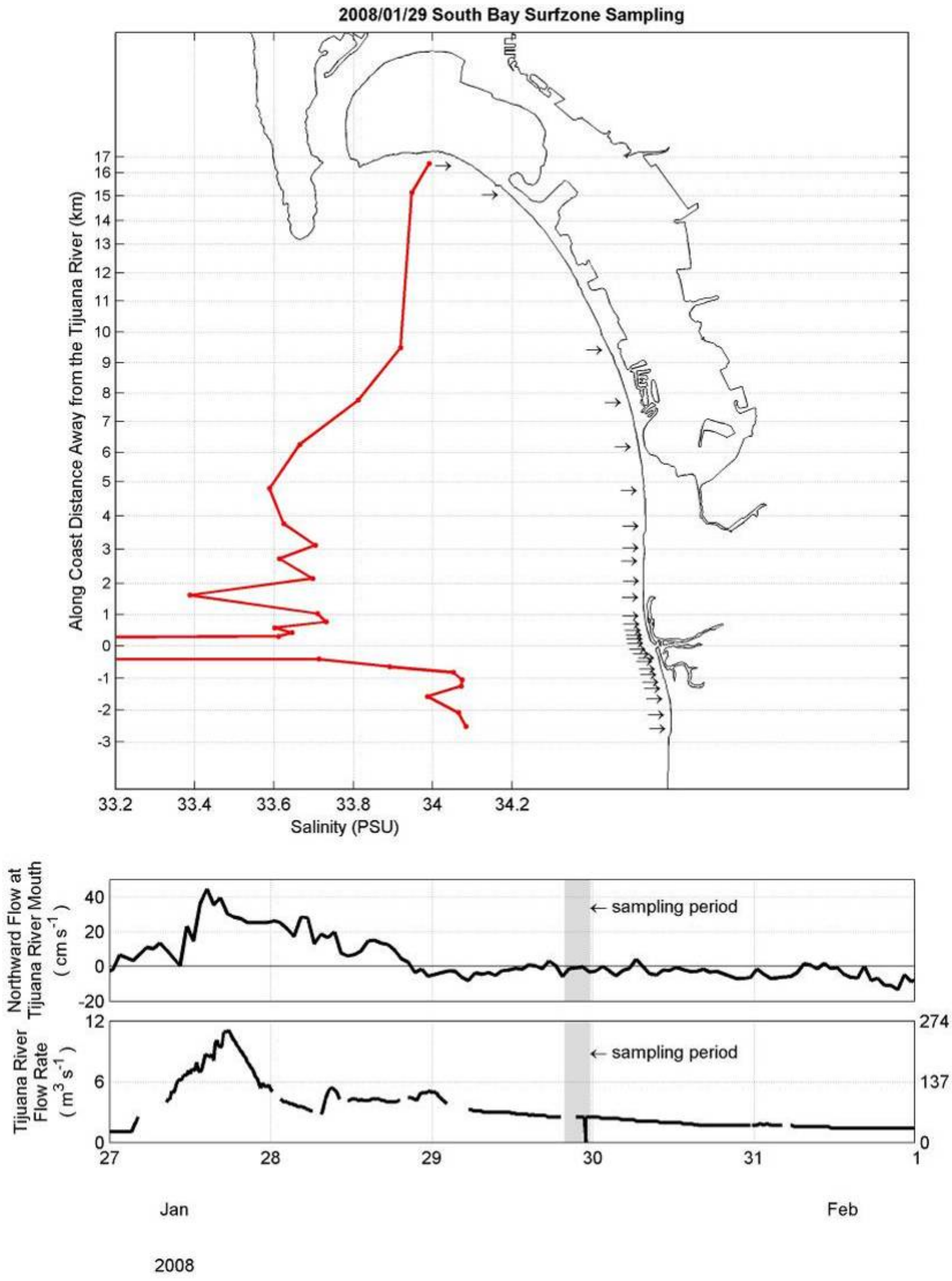


Figure A.25 South Bay Surfzone Sampling – January 29, 2008

Top panel - Twenty-eight salinity measurements were conducted in the surfzone from the International Border to Coronado and used to map the freshwater signal of the Tijuana River plume distributed along the coast. The salinity values are superimposed on a map of the area, with the along-coast values spatially plotted. Along-shore flow (positive values are northward, negative values are southward) at the Tijuana River mouth. Bottom panel - River flow rate sampled. The day of sampling, January 29, 2008, is indicated by the grey region.

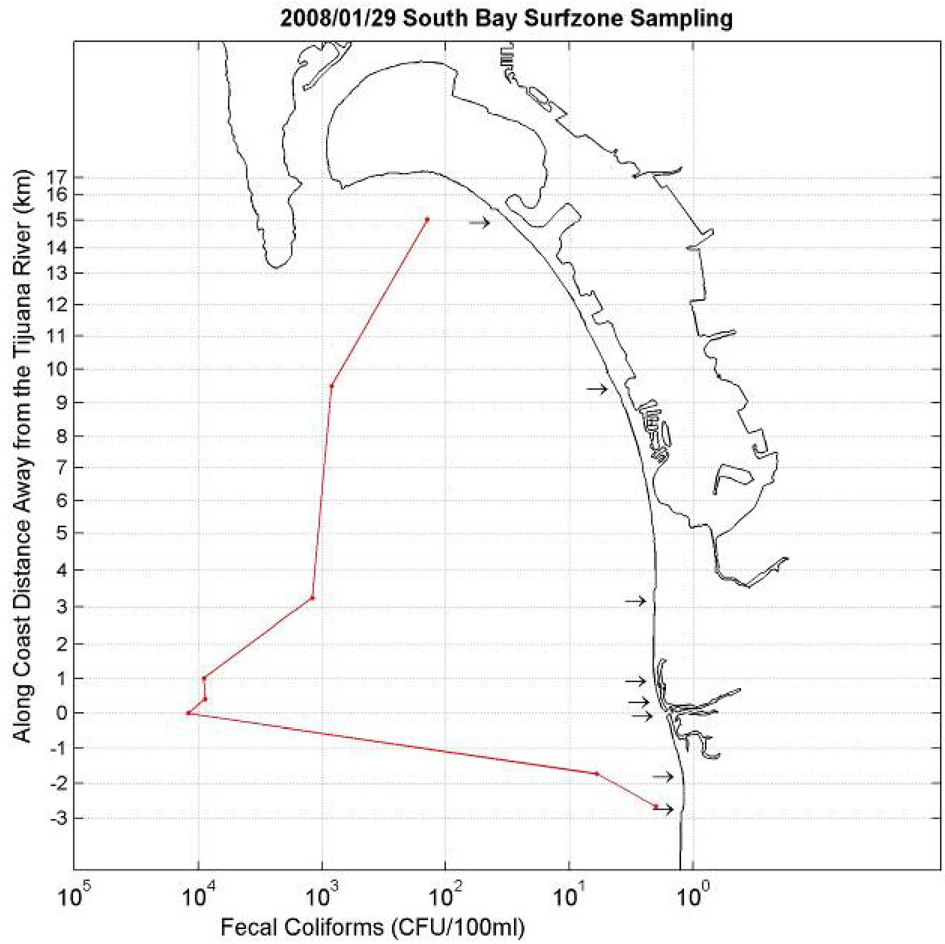


Figure A.26 South Bay Surfzone Sampling – January 29, 2008
Along-coast distribution of fecal coliform concentrations measured by the San Diego County Department of Environmental Health on January 29, 2008. The values are superimposed on a map of the South Bay San Diego region. Fecal coliforms below 10 CFU per 100 ml are observed to the south of the estuary with a sharp increase to over 10,000 CFU/100ml at the river mouth. North of the river mouth fecal coliform concentrations decrease due to dilution of the plume but never reach below 100 CFU/100ml. The pattern in FIB concentrations is consistent with the trends in along-coast salinity that result from the Tijuana River discharge.

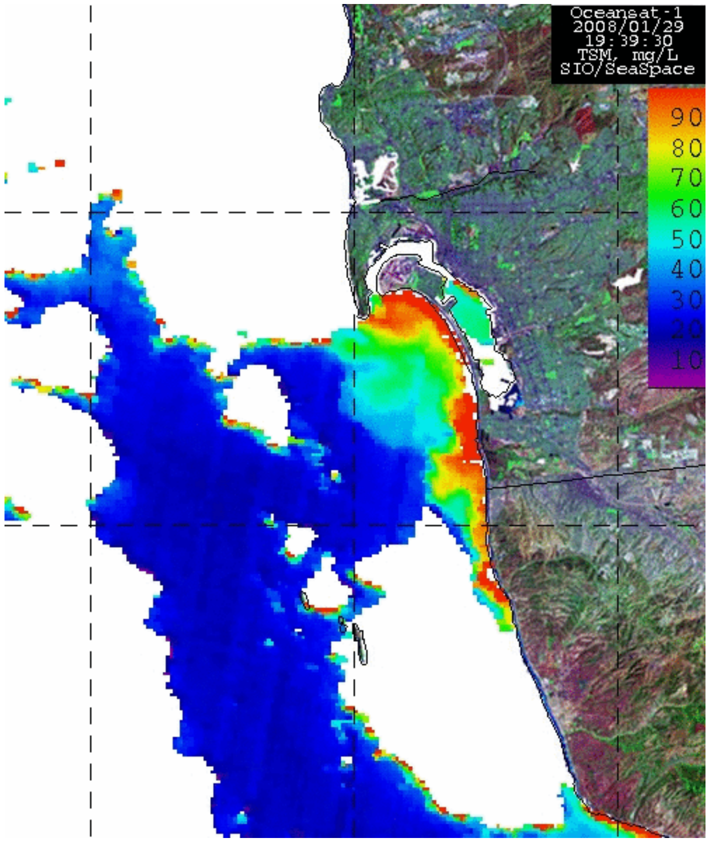


Figure A.27 Total Suspended Sediment – January 29, 2008
Total suspended sediment from river plumes following rainfall as measured by satellite remote sensing on January 29, 2008.

c) SBOO and Tijuana River Hybrid Survey

A hybrid SBOO and Tijuana River sampling mission was designed and performed to help determine the source of contamination affecting South Bay beaches. The mission utilizes key features from both the SBOO and Tijuana River plume sampling missions and provides a synoptic picture of both plumes. The mission was run on October 21, 2008, and clearly resolves both plume signatures in CDOM and salinity (Figures A.28 and A.29). One important observation was the presence of the Tijuana River plume approximately 0.8 km to the north during dry weather (no flow reported at the IBWC flow gauge). Northward advection of the Tijuana River plume is consistent with northward along-shore flow observed in surface currents at the river mouth. The SBOO plume is observed toward the south and east, which is consistent with the trajectory estimated from the SBOO buoy velocity profile.

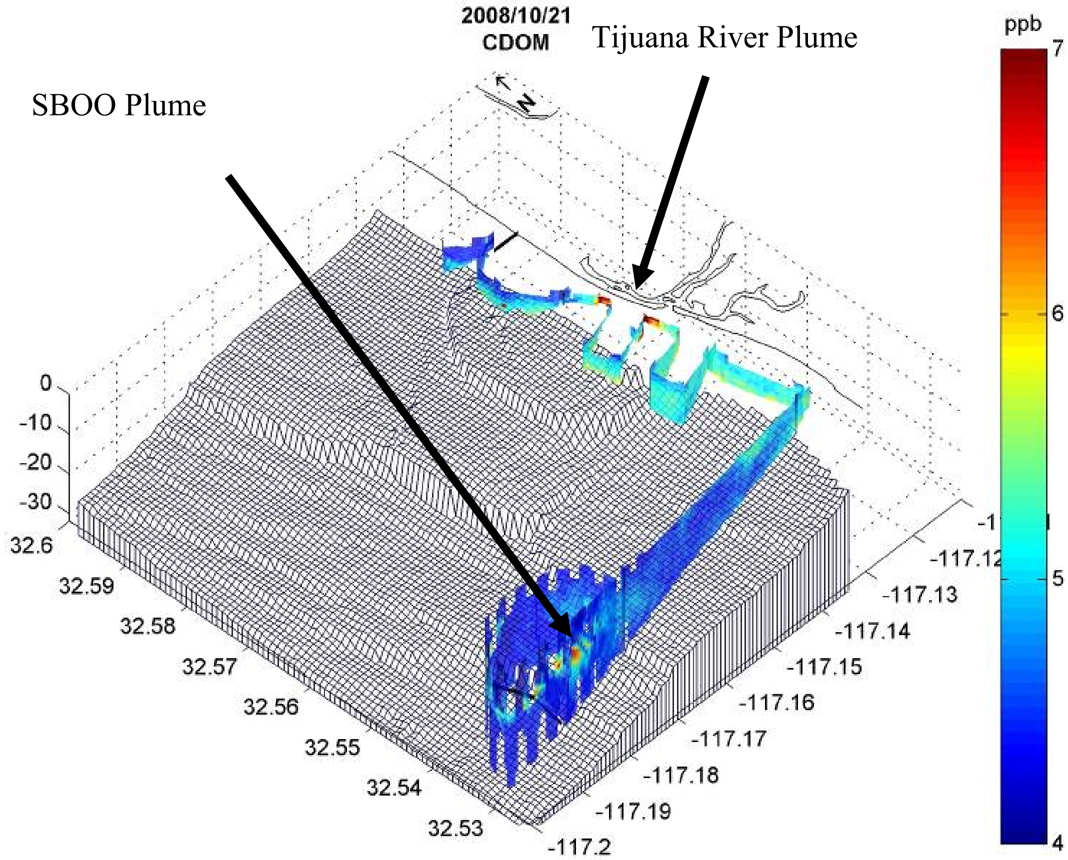


Figure A.28 SBOO and Tijuana River Plumes – October 21, 2008
The SBOO and Tijuana River plumes, as identified by elevated CDOM concentrations of up to 7 ppb, are shown in a single synoptic mission run on October 21, 2008.

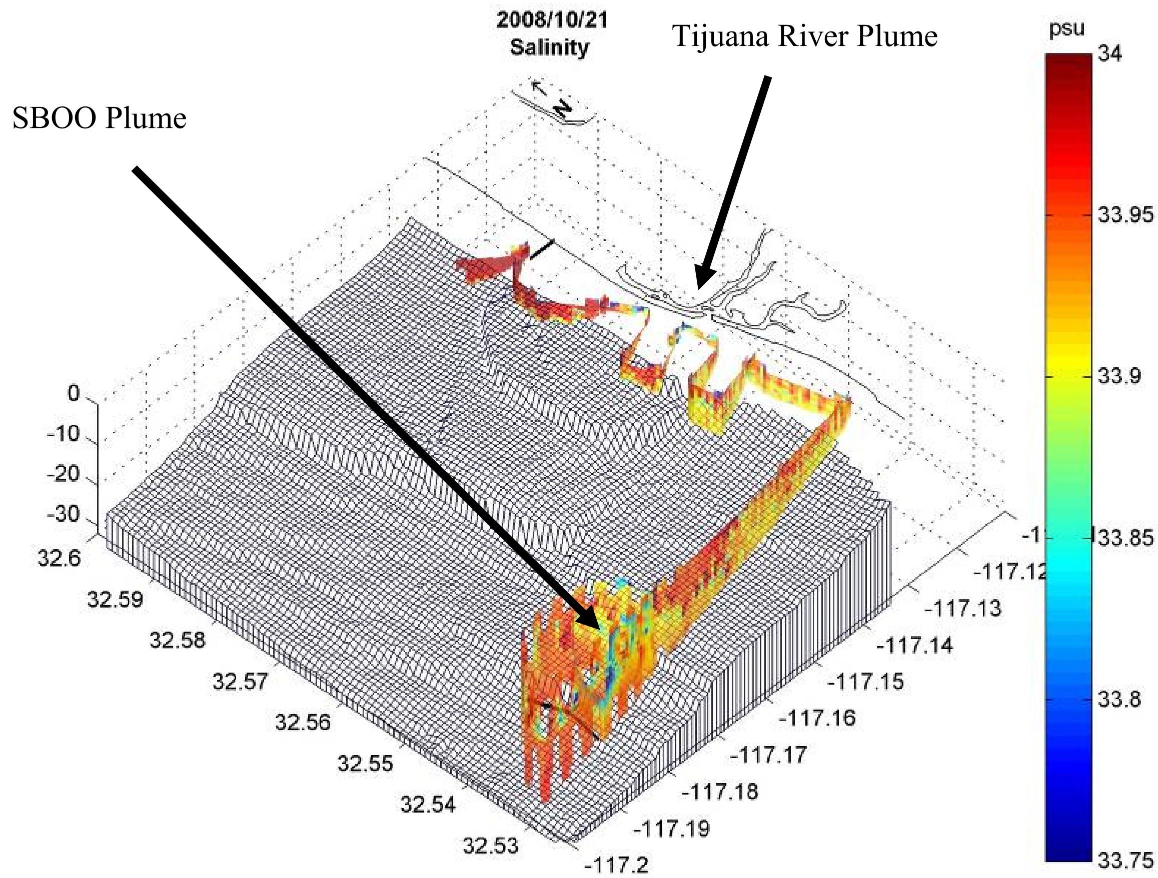


Figure A.29 SBOO and Tijuana River Plumes – Fresh Water – October 21, 2008
The SBOO and Tijuana River plumes, as identified by relatively fresh signatures, are shown in a single synoptic mission run on October 21, 2008.

B. Boat Survey Mapping of Land Based Plumes (SS3)

1. NPDES Permit Overview

The goal of Task SS3 targeted mapping land-based plumes through a collection of boat-based surveys. Scientists proposed analyzing data gathered by the SBIWTP Regional Water Quality Monitoring Plan and the Point Loma Ocean Outfall (PLOO) permit because these data have been collected for several years, and then supplementing the data with CTD/optical property casts and limited bottle collections. To meet the specifications of the SBOO NPDES discharge permit, the IBWC is required to conduct ocean sampling that monitors the receiving waters. These specifications that are designed to ensure compliance with water quality standards are detailed in NPDES Permit No. CA108928 and Cease and Desist Order No. 96-52. The City of San Diego, Ocean Monitoring Group, Metropolitan Wastewater Department (MWWD) is under contract by IBWC to perform all the regulatory-mandated ocean and shoreline monitoring associated with the NPDES permit. The frequency and type of monitoring conducted by the City of San Diego MWWD is detailed in Tables 2.3.2 and 2.3.2 of the Phase II Consent Decree report entitled "Evaluation of the South Bay International Wastewater Treatment Plant Receiving Water Quality Monitoring Program to Determine Its Ability to Identify Source(s) of Recorded Bacterial Exceedances."

The sampling effort conducted on behalf of the IBWC consists of five monitoring components: 1) water quality, 2) sediment characteristics, 3) benthic infauna, 4) demersal fishes and megabenthic invertebrates, and 5) bioaccumulation of contaminants in fish tissues. Different sampling frequencies are used depending on the component. The monitoring program can also be defined by three regions within the receiving waters (shoreline [beach], kelp [near shore], and offshore stations). While the shoreline sampling principally consists of sampling for FIBs, the kelp and offshore stations involve measurements of physical water properties such as temperature, salinity, and light transmittance as a function of depth at each of the stations in addition to microbial sampling for FIBs.

The offshore water quality stations, a component of the ocean monitoring program are a set of approximately 40 stations in a box-shaped area that is 24 km (15 mi) in the north-south direction and 14 km (9 miles) in the east-west direction. A map of the offshore sampling stations is shown in Figure B.1. The principal constituent of interest for this analysis is the output from the CTD sensor. Salinity and density are computed from output from this sensor, and reported at approximately 1-meter intervals. These data can be interpolated spatially to show an estimate of the extent of a freshwater plume.

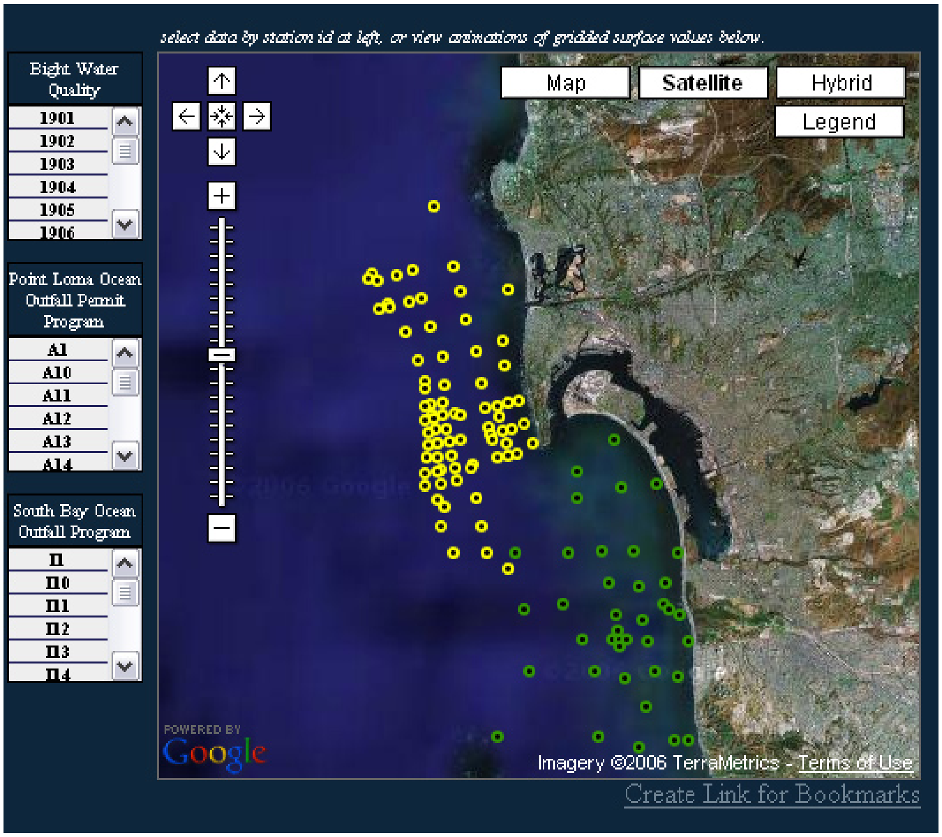


Figure B.1 Ocean Monitoring Stations
A map of the ocean monitoring stations for the SBOO (green). Also shown for reference are the stations for the City of San Diego PLOO. Only data from the SBOO are used for this analysis due to time discrepancies between sampling for the two receiving water programs.

2. WETLabs Profiler Description and Application

The CTD/optical property casts are taken at selected sites from the vessel supporting REMUS operations. At a minimum, two CTD casts were conducted with each survey, one ambient cast (outside the plume) and one close to the river mouth or at the wye of the ocean outfall. The instrument package was lowered over the side using a controlled winch from a shipboard davit shown in Figure B.2. The WETLabs profiler used for the CTD/optical property casts included a suite of high accuracy and stable instruments combined in one package/cage (CTD) with the following sensors: Seabird SBE37-SI (conductivity, temperature, pressure), WETLabs ECO-VSF (optical backscatter), WETLabs CST (light transmittance), WETLabs WS3S (chlorophyll-a fluorescence), and WETLabs ECO-FLCDRT (CDOM).

Figure B.2 Deploying Profiler
(left) SIO staff deploying profiler during REMUS mission. (right) Profiler is lowered with controlled winch to improve data quality.

These profiler casts were used in conjunction with the REMUS mission data to validate onboard measurements. Data were reviewed qualitatively to compare spatial patterns between datasets. While the profiler casts were helpful in validating the REMUS data, a full analysis and tracking of the plume could not have been accomplished with casts alone due to the small spatial scales that characterize the plume. The data density and continuous sampling of the ocean waters as the AUV transits through the sampling region are invaluable in detecting and mapping plumes. Casts alone would have severely under-sampled the area and may have missed the plume altogether. Undulating the vehicle throughout the water column while simultaneously tracking a preprogrammed path allowed the plume to be mapped both vertically and horizontally throughout the sampling domain.

Having supplementary profile casts enabled verification of REMUS patterns and guided near-field SBOO plume detection techniques. Initially, REMUS missions were programmed to survey a cone shape around the SBOO with the southern wye of the outfall located at the apex. The arc of the cone was doubled at approximately 1 km to a secondary arc at approximately 3 km. Throughout the sampling period, mission paths were altered based on post analysis and experience. As mentioned previously, the REMUS vehicle initially had the WETLabs BB2F sensor measuring optical backscatter and chlorophyll. By comparing results from the REMUS with the suite of instruments on the profiler, it became apparent the plume signature was most discernable in the CDOM signature. This prompted the purchase of a new ECO triplet for integration into the REMUS with measurements of backscatter and CDOM.

A high-resolution race track pattern in the near-field of the outfall discharge was conducted to allow accurate characterization of plume water. Data from the dense, high resolution provided information for characterizing plume water in the near-field, which was used for identifying far-field plume signatures. To further improve validation, approximately nine profiler casts were also taken at the discharge location or apex of the mission in a regular pattern, and these remained stationary throughout the sampling period. These provided a regular set of stations to be taken from the boat. Combination of data from the boat casts and the underwater vehicle improved identification of the source plume. Ship operators noted large kelp paddies approximately 3 km east of the outfall. These kelp paddies were highlighted in the data by a decrease in speed of the REMUS during the outer arc, and at one point the vehicle was lodged in the kelp requiring recovery. Future missions were altered to avoid these paddies by decreasing the distance of the outer arc. Due to these limitations, the full extent of the detectable limits of the SBOO to the north probably fell outside the region sampled. SIO staff were unable to operate the REMUS vehicle in Mexican waters and, therefore, were unable to map the plume south of the U.S. border. The southern extent of the outfall is mapped in later sections of the report using data from the ocean buoy and HF-radar-derived surface currents. All aspects of data collection are deemed critical in developing a complete picture of both the SBOO and Tijuana River plume.

3. Example Surveys and General Results

The SBOO and Tijuana River plumes were both consistently observed by their CDOM signature in the boat-based CTD/optics casts. Salinity and backscatter signatures were observed for the Tijuana River plume but were more difficult to discern, if at all, for the SBOO plume. This is in part due to the sampling design for CTD/optical casts, which was primarily for spot checking features observed with the REMUS. The spacing and density of the sampling stations were not designed for mapping the plume. However, two surveys were conducted that aimed at resolving the Tijuana and SBOO plumes by cast data alone as part of the projects overall sampling evolution. While the plumes were observed in both attempts, the resolution was much coarser than would otherwise be seen by REMUS sampling. The relatively low flow rates of the SBOO and its mixing in the water column were found to make tracking the SBOO plume elusive.

As mentioned previously, CTD/optics casts were primarily used for spot checking features observed with the REMUS. Tijuana River sampling conducted with the REMUS on February 5, 2008, showed the plume advecting to the south based on its salinity signature with some patchiness resulting from mixing with ambient seawater (Figure A.20). The patchiness was also observed, although at lower resolution and reduced range inshore, with boat-based CTD casts (Figure B.3). The plume was also observed by elevated CDOM concentrations indicating high concentrations of organic matter (Figure B.4).

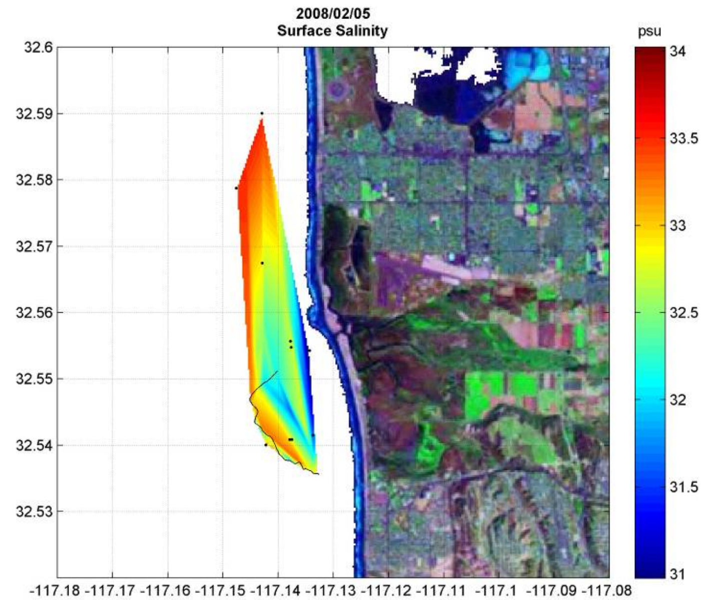


Figure B.3 Surface Salinity – February 5, 2008
Tijuana River plume surface salinity signature (≤ 32.5 psu) observed from boat-based CTD/optics casts (black dots). The CTD/optics package was also towed along the surface to increase spatial resolution from cast data (black line).

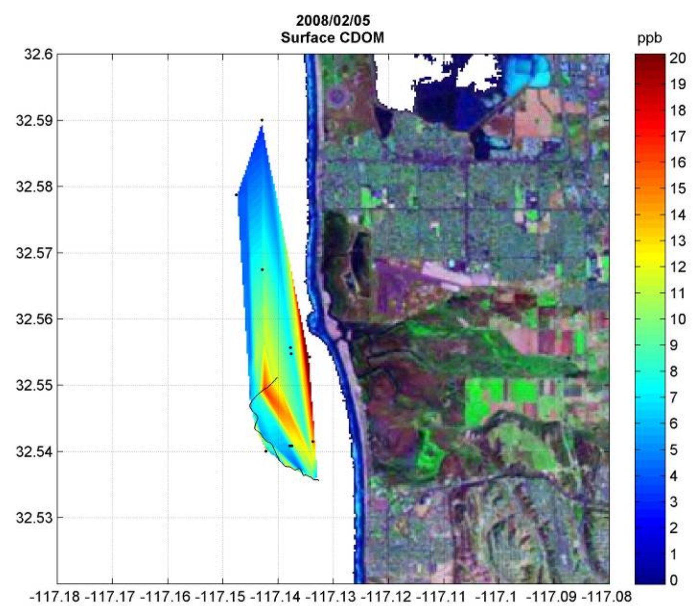


Figure B.4 Tijuana River Plume Surface CDOM – February 5, 2008
Tijuana River plume surface CDOM signature (> 6 ppb) observed from boat-based CTD/optics casts (black dots). The CTD/optics package was also towed along the surface to increase spatial resolution from cast data (black line).

The SBOO plume was most consistently and clearly resolved by its CDOM signature indicating high concentrations of organic matter (Figure B.5). Sampling on October 29, 2007, coincided with northward flow at the outfall, which is consistent with elevated CDOM concentrations (> 3.5 ppb) north of the outfall. This particular set of CTD/optics casts resulted in acquiring a CDOM sensor for the REMUS to improve SBOO plume detection.

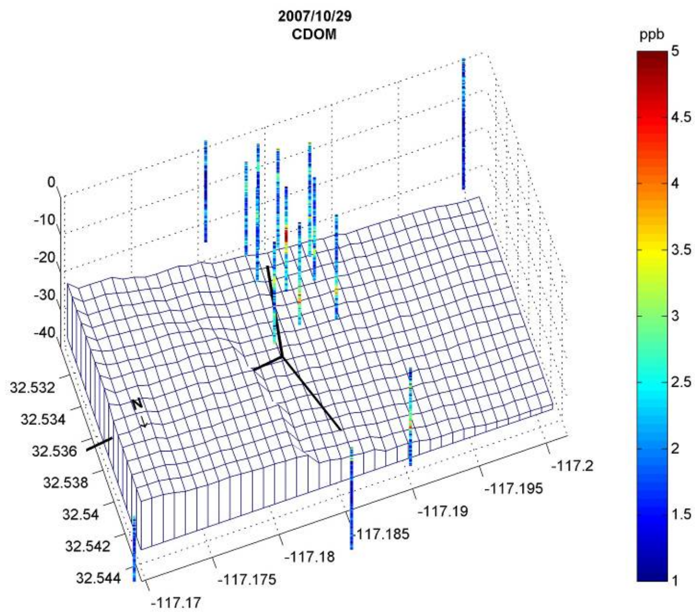


Figure B.5 CDOM – October 29, 2007
SBOO plume as observed by CDOM (> 3.5 ppb) sampled from boat-based CTD/optics casts. The SBOO wye is shown in black while the blue mesh represents bathymetry. Elevated levels of CDOM indicate patches of detectable SBOO plume water.

4. Long-Term Analysis

As described in the Consent Decree Phase II report, analysis of the data for mapping plume behavior can be difficult due to the 6-hour time interval requirement for conducting the sampling. This interval is driven by the FIB sampling, which requires timely processing of the samples. However, the interval often forces the 40 stations to be occupied over a period of multiple days, which introduces aliasing as a result of ocean dynamics changing the water-mass properties on a day-to-day basis. As a result, caution must be exercised when attempting to interpret spatial patterns from data that span multiple days.

The cast data from the program are analyzed for both SBOO and Tijuana River plume identification. This effort is motivated by the goals to examine the efficacy of the cast data for capturing the plumes and to provide insight on the spatial scales of the plumes to assist with sampling techniques used in the supplemental monitoring program. Only data from surveys that spanned a maximum of 2 consecutive days were used to minimize the previously mentioned aliasing. As a result, not all surveys were suitable for this analysis. Because the plumes are principally fresh water, mapped fields of salinity are used to identify the plumes. For the time span of the supplemental monitoring program, two sampling periods were identified in which the plumes were evident or detectable—December 10 to 11, 2007, and January 16 to 17, 2008.

During the December 10 to 11 sampling window, the ocean was stratified and the SBOO plume had a maximum rise height to a depth of approximately 12 meters. Figure B.6 presents a linearly interpolated map of the ocean salinity field (psu) at depths of 22 m, 20 m, 15 m, and 10 m. Station locations from which data were used for the analysis are shown as circles. In the maps (below), the SBOO plume is visible by the offshore region of depressed salinity to a depth of approximately 15 m, and appears at the deepest depths to be oriented to the north. At 10-m depth, depressed levels of salinity values are apparent in the area south of the Tijuana River mouth and north near Silverstrand. Due to the spatial scales of sampling, the Silverstrand region is a result of data from a single station, while the depressed levels of salinity south of the Tijuana River mouth are apparent in several of the stations. Of note also is that the range of salinity plotted extends from 33.36 to 33.5. The apparent dilution of the SBOO plume water visible in the maps ranges from approximately 250:1 (salinity of 33.36 or blue) to approximately 840:1 (salinity of 33.44 yellow-green) when compared against a background salinity level of 33.48. The vertical structure of the plume within the water column is examined by plotting an average cross-section of the ocean extending from the Tijuana River entrance offshore 12 km, encompassing the SBOO diffusers. This cross-section, shown in Figure B.7, illustrates the vertical extent of the plume located approximately 6 km offshore. Fine-scale structure within the figure is an interpolation artifact from the coarse spacing of the data.

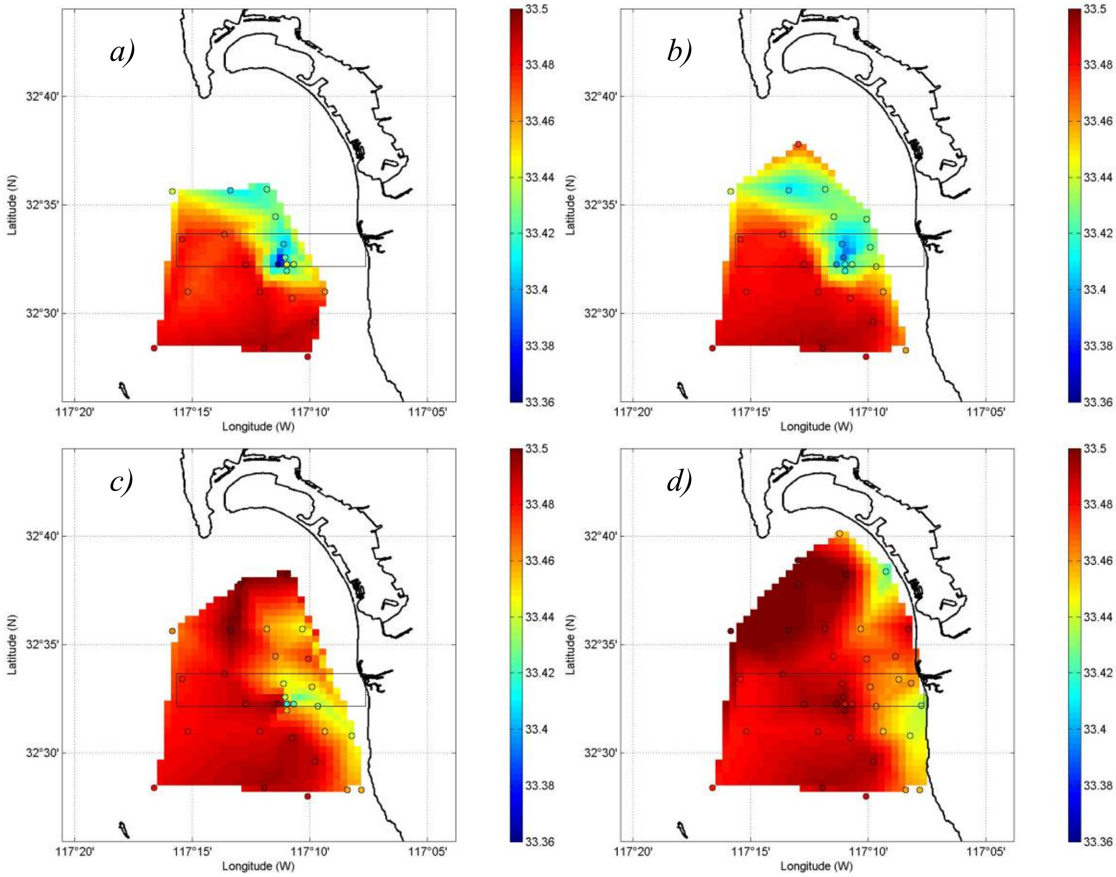


Figure B.6 Salinity Maps – December 10-11, 2007
Linearly interpolated salinity (psu) maps at depths (right to left, top and bottom) of a) 22 m, b) 20 m, c) 15 m d) 10 m. Data are from casts obtained December 10-11, 2007.

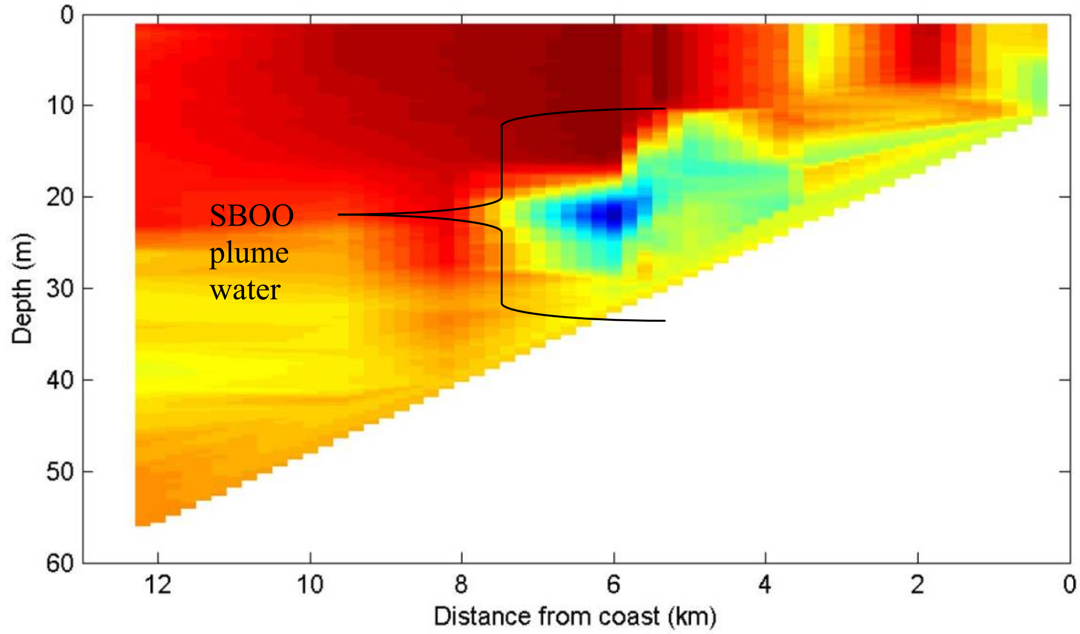


Figure B.7 Ocean Vertical Section – December 10-11, 2007
A linearly interpolated vertical section of the ocean in the cross-shore direction as defined by the black box in Figure B.6. Data are from the CTD casts obtained during the December 10 to 11, 2007, sampling days pursuant to the SBOO NPDES permit.

A similar analysis was conducted with the cast data obtained during the sampling conducted January 16 to 17, 2008. During this sampling period, stratification was weak, and the SBOO plume surfaced. In addition, the region had experienced rain approximately 1 week prior, and the Tijuana River had flow rates of approximately 25 mgd. As a result, both the SBOO and the Tijuana River plume are evident in the data. Figure B.8 (top) presents the surface values of salinity mapped over the region and (bottom) a vertical section of salinity. While the spacing of the CTD data is too coarse to comment if the two plumes are separate, the data suggest that plume behavior following rain events can lead to situations when the two plumes could commingle and mix.

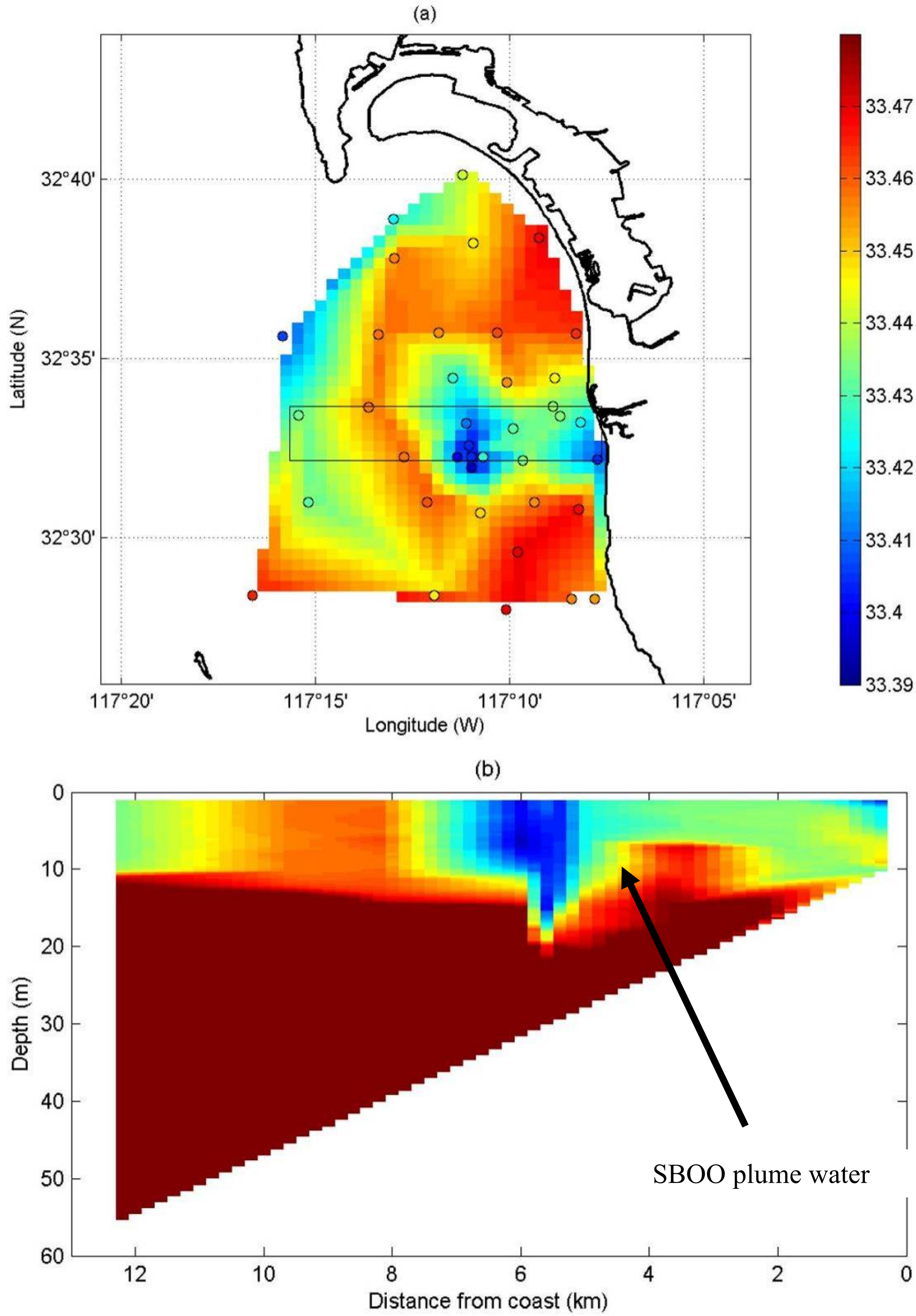


Figure B.8 Surface Salinity and Ocean Vertical Section – January 16-17, 2008
(top) Linearly interpolated representation of salinity at the surface. (bottom) A linearly interpolated vertical section of the ocean in the cross-shore direction as defined by the black box in Figure B.7. Data are from the CTD casts obtained during the January 16 to 17, 2008, sampling days pursuant to the SBOO NPDES permit.

C. Continuous Flow Rate and Loading of the Tijuana River (SS4)

1. IBWC Gauge Data Acquisition and Presentation

Flow-loading from the Tijuana River was monitored using the existing gauge operated by the IBWC, although this gauge was not optimal. The existing gauge is designed for measuring flood conditions and is not optimized for low flow rates. In addition, there are several canyons downstream of the gauge, which introduce ungauged flow into the estuary. Regardless of these potential deficiencies, Scripps monitored the output from this gauge, archived the data and displayed the results in near-real-time online to serve as an indicator of river flow events, as shown in Figure C.1. Time series data show when the instrumented tributary had flow. Data from the gauge were used to monitor flow conditions and trigger coastal sampling.

2. Land-Based Sampling of Tijuana River Estuary

Task SS4 includes a land-based sampling program of the Tijuana River Estuary to characterize the loading of indicator bacteria to the South Bay region. Water surface samples were collected over a period of 4 days from four locations in the Tijuana River Estuary. The water samples were analyzed by Enviromatrix Analytical, a state-certified analytical laboratory located in San Diego, for FIB including total coliform, fecal coliform, and enterococcus.

The proposed sampling plan assumed between 6 and 10 sampling events following rainfall events affecting the Tijuana River, and the collection of between four and six water surface samples during each event. Sampling was to be conducted on 2 consecutive days to ascertain the consistency of concentrations of FIB in the river. Rainfall events exceeding 0.5 inches of rain in a 24-hour period, as measured by the rain gauge, were to trigger sampling events.

Unfortunately, below average rainfall during the course of the study period limited the number of sampling events. Another issue was the occurrence of storm events on Friday, when the analytical lab would not be available for processing the water samples over the weekend. Finally, the tide conditions following one storm event (January 27, 2008) precluded surface water sampling because the tide was rising during the daylight hours. Sampling on ebb tide could not be conducted in time to deliver the samples to the laboratory during business hours.

Tijuana River Flow Rate

Latest Observations	24hr Maximum	24hr Minimum
26.02 MGD	44.51 MGD	20.77 MGD
1.14 cm/s	1.95 cm/s	0.91 cm/s
2009-01-15 12:15:00 UTC	2009-01-14 19:45:00 UTC	2009-01-15 08:15:00 UTC

MGD = Millions of gallons per day. cm/s = Cubic meters per second.
Values in red indicate the data is greater than 24 hours old. Otherwise values are displayed in black.

Tijuana River

IBWC Flow Gauge

UTC Time: 2009-01-15 21:33:28
Local Time: 2009-01-15 13:33:28

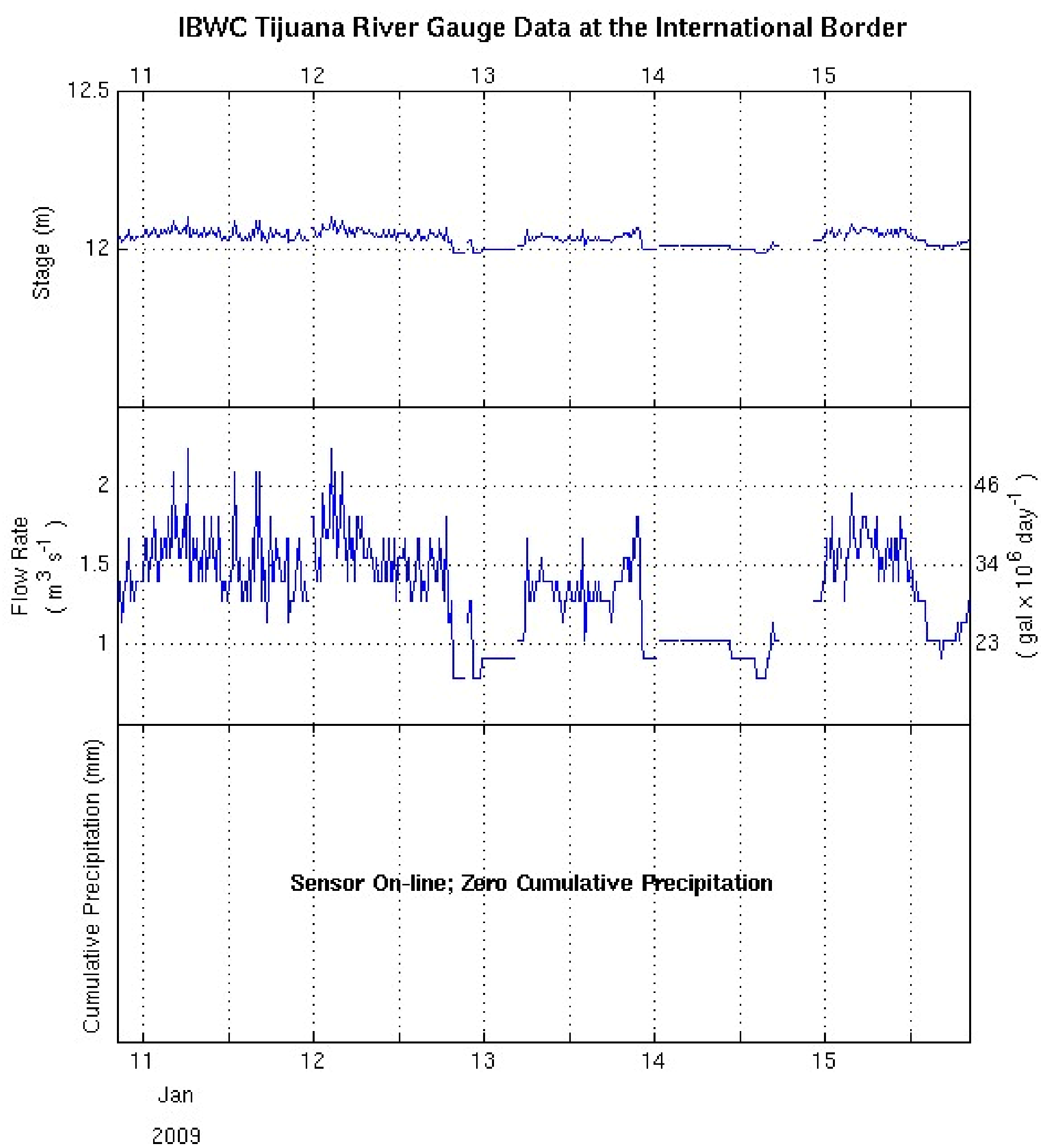


Figure C.1 Tijuana River Flow Gauge
Online near-real-time tabular and graphical display of the Tijuana River flow gauge

Figure C.2 presents a comparison of the annual rainfall totals at San Diego International Airport for a 21-year period from 1988 to 2008. Data are presented as water year (WY) totals, which start on October 1 (WY 1988 runs October 1, 1987, to September 30, 1988). The average annual rainfall over this period is 9.7 inches. Rainfall has been considerably below normal for the past 3 years, with water year totals of 5.4 inches in 2006, 3.9 inches in 2007, and 7.2 inches in 2008.

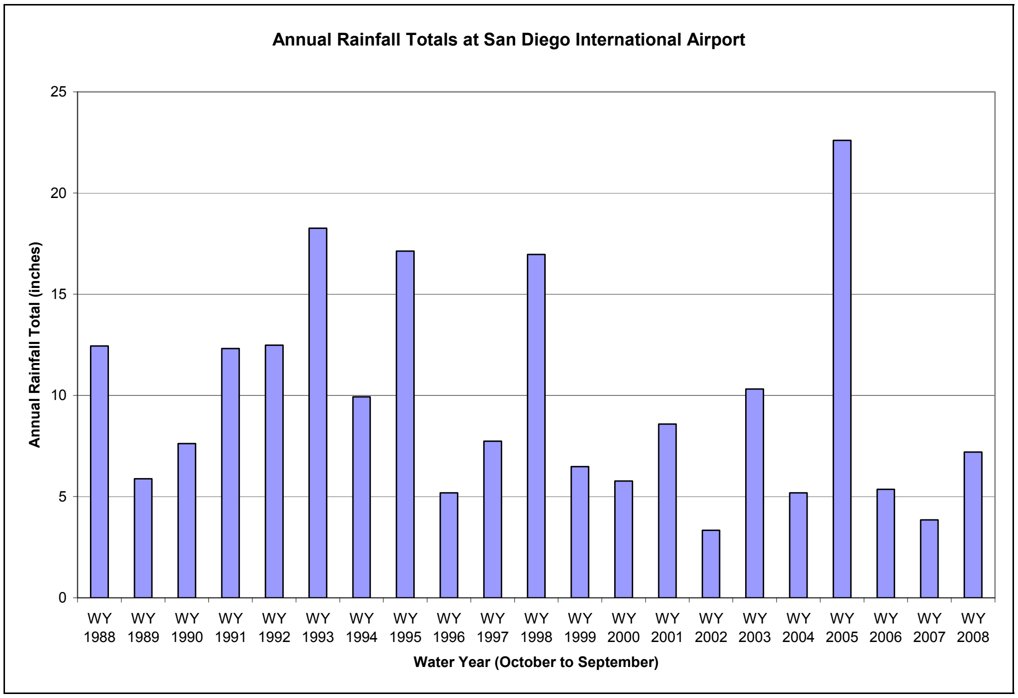


Figure C.2 San Diego Annual Rainfall Totals
Comparison of Annual Rainfall Totals in San Diego (WY 1988 to WY 2008)

Table C.1 presents a summary of the daily rainfall totals at Brown Field as downloaded from the National Climatic Data Center (NCDC) website. The data are arranged by weeks for the months of September 2007 through April 2008. There were three events between September 1, 2007, and April 30, 2008, that had a daily rainfall exceeding 0.5 inches. These events occurred on Friday, November 30, 2007; Monday, January 7, 2008; and Sunday, January 27, 2008.

Jan 2009 Brown Field Download Data from NCDC

Week of	Sun	Mon	Tue	Wed	Thu	Fri	Sat
9/2/2007	0	0	0	0	0	0	0
9/9/2007	0	0	0	0	0	0	0
9/16/2007	0	0	0	0	0	0	0.11
9/23/2007	0	0	0	0	0	0.03	0
9/30/2007	0	0	0	0	0	0	0
10/7/2007	0	0	0	0	0	0.01	0.04
10/14/2007	0	0	0	0.08	0	0	0
10/21/2007	0	0	0	0	0	0	0
10/28/2007	0	0	0	0	0	0	0
11/4/2007	0	0	0	0	0	0	0
11/11/2007	0.05	0	0	0	0	0	0
11/18/2007	0	0.01	0	0	0	0	0
11/25/2007	0	0	0	0	0	0.85	0.04
12/2/2007	0	0	0	0	0	0.18	0.2
12/9/2007	0	0	0	0	0	0	0
12/16/2007	0	0	0.04	0.05	0.04	0	0
12/23/2007	0	0	0	0	0	0	0.03
12/30/2007	0	0	0	0	0	0	0.44
1/6/2008	0.44	0.65	0	0	0	0	0
1/13/2008	0	0	0	0	0	0	0
1/20/2008	0	0.01	0.06	0.29	0	0	0.27
1/27/2008	0.55	0.09	0	0	0	0	0
2/3/2008	0.43	0.03	0	0	0	0	0
2/10/2008	0	0	0	0	0.36	0	0
2/17/2008	0	0	0	0.02	0	0.04	0.02
2/24/2008	0.14	0	0	0	0	0	0
3/2/2008	0	0	0	0	0	0	0
3/9/2008	0	0	0	0	0	0	0.01
3/16/2008	0.21	0	0	0	0	0	0
3/23/2008	0	0	0	0	0	0	0.13
3/30/2008	0.04	0	0	0	0	0	0
4/6/2008	0	0	0	0	0	0	0
4/13/2008	0	0	0	0	0	0	0
4/20/2008	0	0	0	0	0	0	0
4/27/2008	0	0	0	0	0	0	0

Table C.1 Daily Rainfall Totals
Daily Rainfall Totals at Brown Field, San Diego (9/1/2007 to 5/2/2008)

The November 30 event was the first large storm of the season. Peak rainfall was on Friday, and thus this event was not sampled because it was not possible to have the samples analyzed at the lab within the required time. Samples must be delivered to the lab within 4 to 6 hours of collection, and the lab keeps regular business hours. The January 7, 2008, rainfall event was sampled on January 8 and 9, 2008. Finally, the January 27 rainfall event was not sampled because of the tides, which need to be receding to sample the stations in the lower estuary and still be representative of riverine water. Tides on January 28, 2008, were rising from a low at 7:30 a.m. to a high at 12:42 a.m. as shown in Figure C.3 (generated by Nautical Software's "Tides and Currents" program). This did not allow sufficient time to sample the four stations during ebb tide conditions and deliver the samples to the laboratory before closing. In retrospect, a lower rainfall trigger would have resulted in more sampling events. Future rainfall-based sampling criteria should adopt a lower trigger value.

The sampling plan calls for the collection of surface water samples from four locations in the estuary spanning from Hollister Bridge (east) to the estuary inlet (west). Figure C.4 shows the four locations. Dr. Jeff Crooks at the Tijuana River National Estuarine Research Reserve assisted in siting the monitoring locations in the Tijuana Estuary.

Station 1 is located at the mouth of the Tijuana River. The station is approached by walking south approximately 0.8 miles from the southern end of Seacoast Drive in Imperial Beach to the river mouth. Samples were taken from the northern bank on the inland side of the inlet.

Station 2 is located in a north/south channel draining the portion of the estuary preserve north of the Tijuana River. This station is located at the southern end of Seacoast Drive in Imperial Beach. Sampling was conducted in the main channel, in line with a wooden overlook structure.

Station 3 is located on Hollister Road where it crosses the main stem of the Tijuana River. Sampling was conducted approximately 30 feet east of the bridge, at the northernmost river crossing. During sampling events in early 2008, the Tijuana River approached Hollister Road from the east, crossed under the bridge, turned north and back east to cross under the bridge a second time, and then turned north and west to cross Hollister Road a final time.

Station 4 is located in the main channel approximately 0.5 miles east of the inlet. This station was reached by parking at the corner of 5th Street and Iris Avenue in Imperial Beach, walking south along the western fenceline of the Imperial Beach Naval Air Station (Ream Field), turning east at the end of the fenceline, walking along the southern fenceline approximately 700 feet, and then turning south toward the main river channel. The sampling location was marked with a survey stake and flagged for easy visibility.

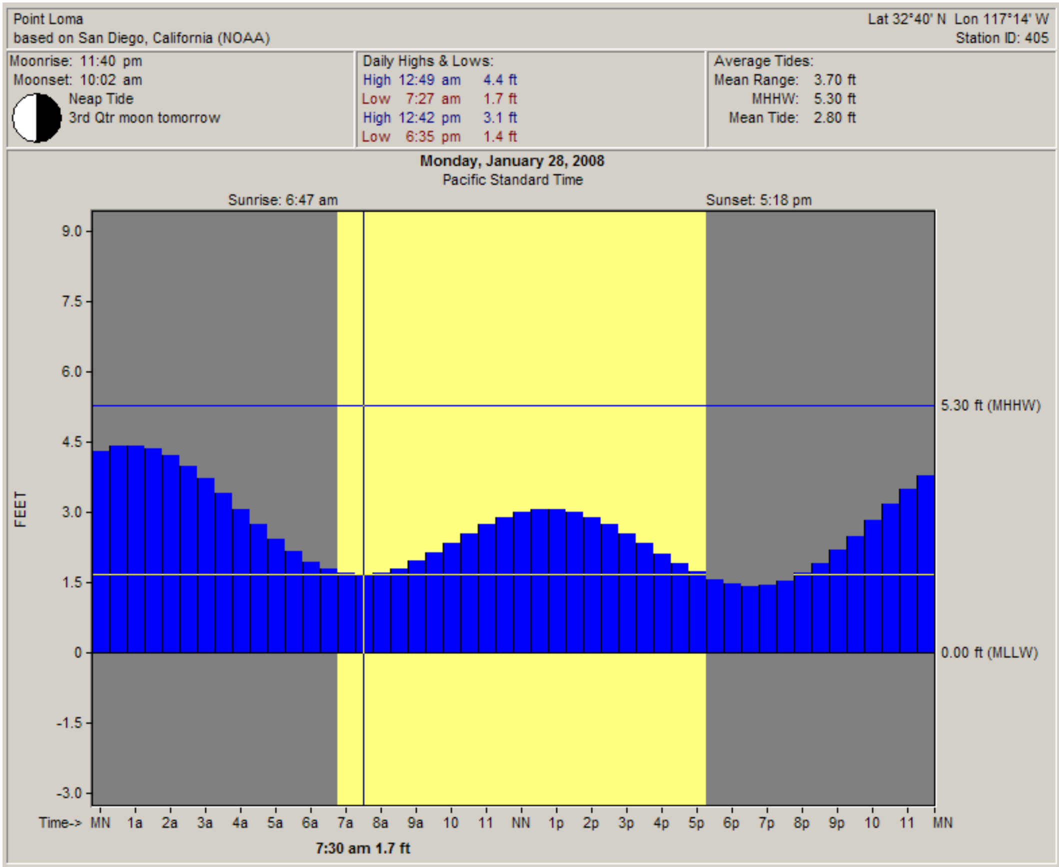


Figure C.3 Predicted Tides
Predicted tides on January 28, 2008, following storm event of January 27, 2008

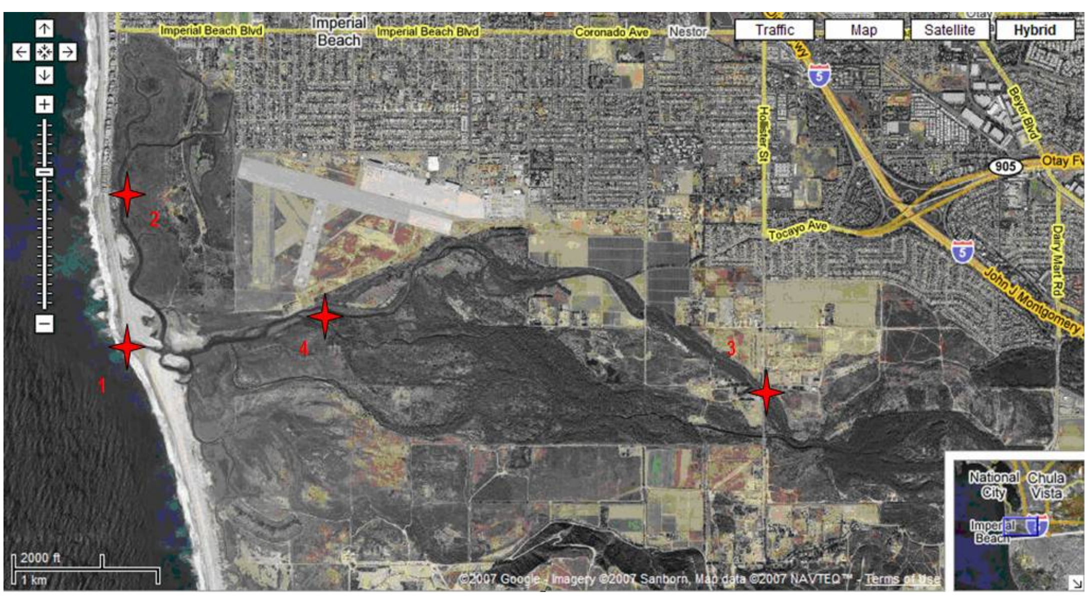


Figure C.4 Location of FIB Sampling Stations in Tijuana Estuary

Land-based surface water sampling for Task SS4 was conducted on December 10 to 11, 2007, and January 8 to 9, 2008 (yellow highlighted cells in Table C.1). Offshore FIB samples were collected on January 24, 2008, and April 3, 2008. These events are discussed further below under Task SS7.

The sampling event on December 10, 2007, followed 2 consecutive days of rain where the storm total approached 0.4 inches of rain. Samples were collected between 11:05 a.m. and 1:50 p.m., following a morning high tide at 8:35 a.m., allowing time for the entire estuary to start to drain. Figure C.5 presents the predicted tides near the mouth of the Tijuana River for December 10, 2007, as generated by Nautical Software "Tides and Currents" program (Nautical Software, 1996).

The sampling event on January 8, 2007, followed 3 consecutive days of rain where the storm total was 1.5 inches of rain. Samples were collected between 12:10 p.m. and 2:08 p.m., following a morning high tide at 8:27 a.m., allowing time for the entire estuary to start to drain. Figure C.6 presents the predicted tides near the mouth of the Tijuana River for January 8, 2008.

Figures C.7 and C.8 present records of the flow in the Tijuana River collected by the flow gauge every 15 minutes during the land-based sampling in the estuary in December 2007 and January 2008, respectively. The 2-day sampling events in December 2007 and January 2008 are marked on the figures. The rainfall event preceding the December 2007 sampling event was lower than the triggering event outlined in the plan of study. The decision was made by project staff to sample this event because of the scarcity of trigger events prior to December. River flows peaked at 4.75 cubic meters per second (m^3/s) (170 cubic feet per second [ft^3/s]) on Friday December 7, 2007, and receded to 1.1 m^3/s (40 ft^3/s) before sampling was initiated on Monday December 10, 2007.

The rainfall event that preceded sampling on January 8 and 9, 2008, was considerably larger than the event in December 2007 that preceded the first sampling effort. The 1.5 inches of rainfall between January 5 and 7, 2008, yielded a peak flow of 17 m^3/s (600 ft^3/s) on January 7, 2008. Sampling was initiated just after midday on January 8, 2007, while flows were still above 3 m^3/s (110 ft^3/s).

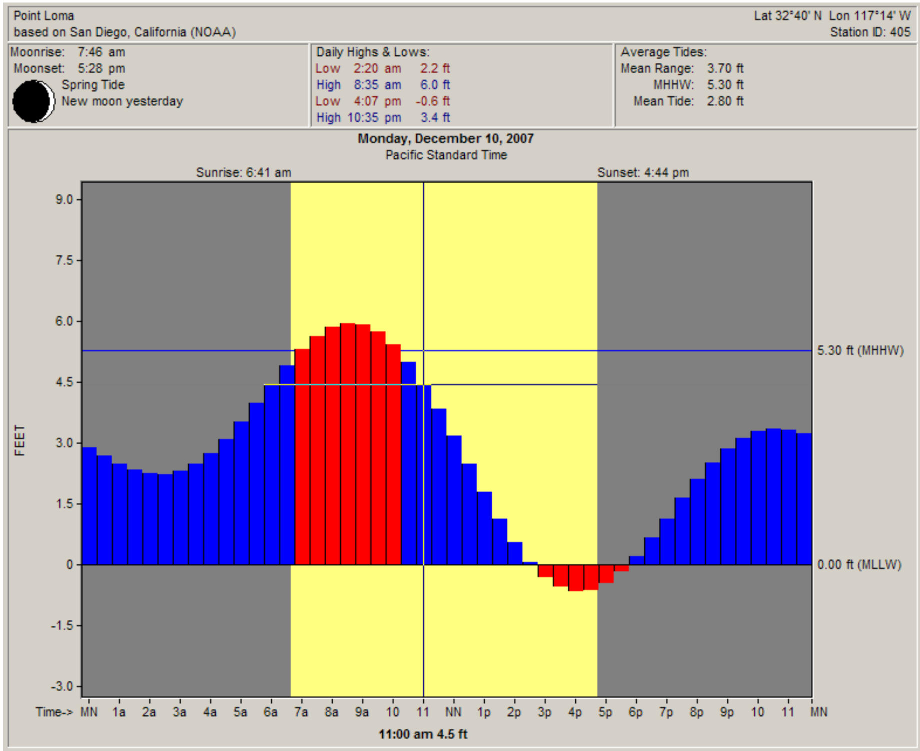


Figure C.5 Predicted Tides for December 10, 2007

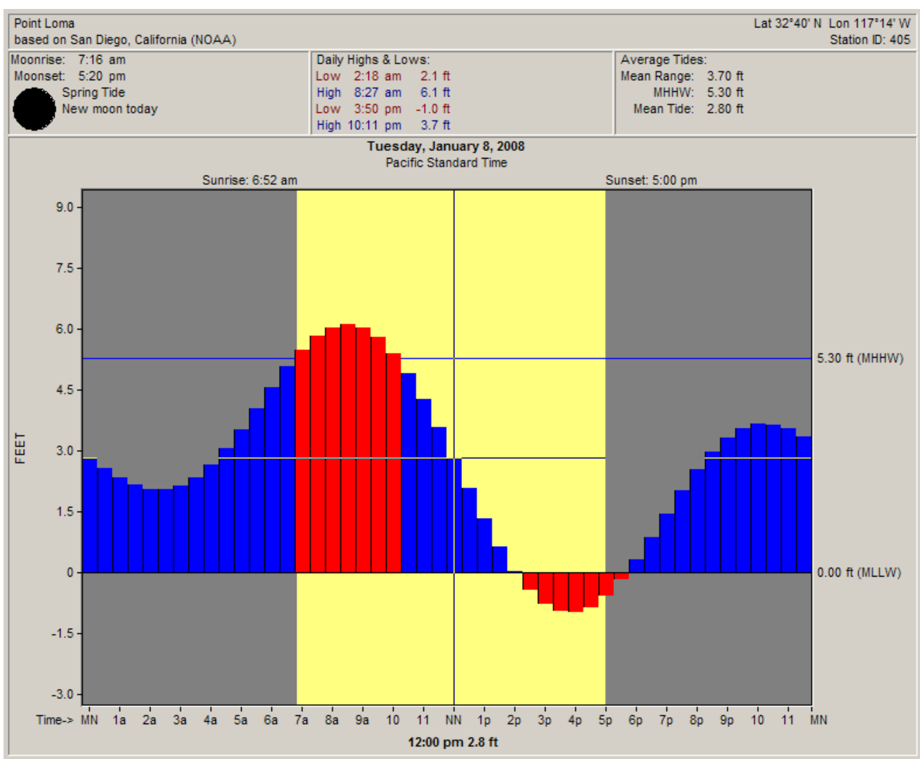


Figure C.6 Predicted Tides for January 8, 2008

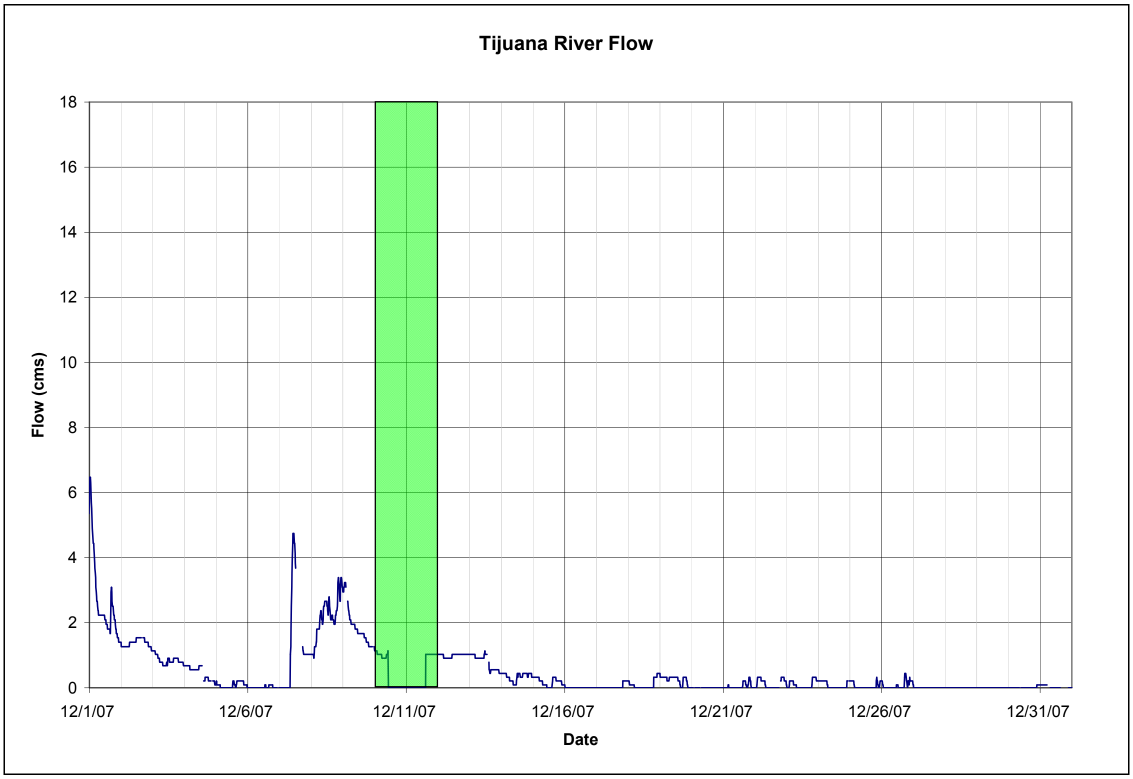


Figure C.7 Tijuana River Flow during December 2007 (sampling dates shaded)

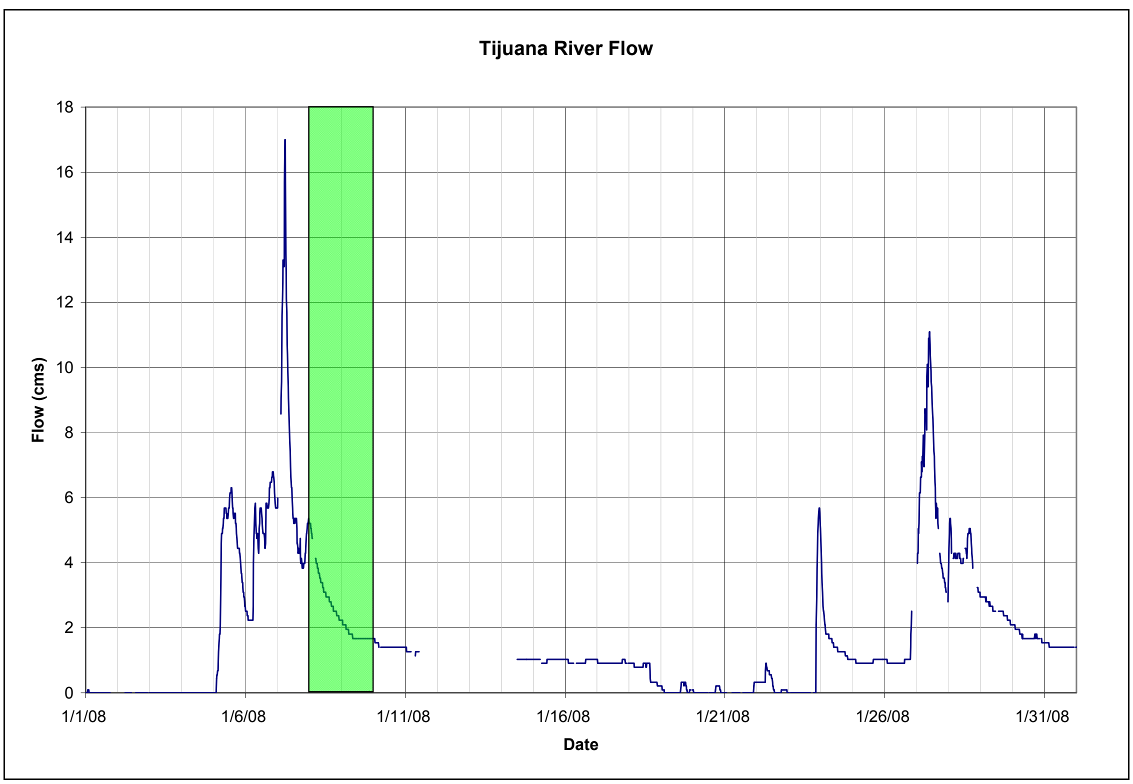


Figure C.8 Tijuana River Flow during January 2008 (sampling dates shaded)

3. Results of Microbial Analysis

Results of the microbial analysis of the land-based surface water samples collected for Task SS4 are summarized in Table C.2. The majority of laboratory results for the first two sampling events (December 10 and 11, 2007) indicate a value of >1,600 most probable number (MPN)/100 milliliters (ml). This result was based on an assumption of the maximum expected concentration in the surface water samples, because laboratory analyses are different for stormwater and wastewater. On subsequent sampling events, this issue was corrected, and the laboratory diluted the samples such that higher maximum concentrations could be measured.

Although the total coliform and fecal coliform values from the sampling events in December 2007 are of limited use, the enterococcus results from December 10 provide some information on the distribution of indicator bacteria throughout the Tijuana River estuary for a small rainfall event. The highest concentration of enterococcus was measured at the Hollister Bridge. Intuitively, this location would have little or no dilution from seawater and tidal flushing, and should have the highest concentrations. Interestingly, it is the only location that had a value less than 1,600 MPN/100 ml for fecal coliform. This result seemingly conflicts with the enterococcus results.

Date	Time	Station ID	Station	TC (MPN/100 ml)	FC (MPN/100 ml)	Enterococcus (MPN/100 ml)
12/10/2007	11:05	1	Inlet	>1600	>1600	90
12/10/2007	11:48	2	Seacoast Drive	>1600	>1600	30
12/10/2007	13:50	3	Hollister Bridge	>1600	900	900
12/10/2007	12:45	4	Main Branch	>1600	>1600	>1600
12/11/2007	13:32	1	Inlet	>1600	>1600	>1600
12/11/2007	13:08	2	Seacoast Drive	>1600	>1600	>1600
12/11/2007	11:55	3	Hollister Bridge	>1600	>1600	>1600
12/11/2007	12:35	4	Main Branch	>1600	>1600	>1600
1/8/2008	14:03	1	Inlet	900,000	140,000	22,000
1/8/2008	13:41	2	Seacoast	900,000	110,000	30,000
1/8/2008	12:10	3	Hollister Bridge	900,000	300,000	80,000
1/8/2008	12:51	4	Main Branch	900,000	500,000	110,000
1/8/2008	14:08	1	Inlet (2)	900,000	300,000	11,000
1/9/2008	14:00	1	Inlet	110,000	30,000	3,000
1/9/2008	13:39	2	Seacoast Drive	80,000	23,000	8,000
1/9/2008	12:31	3	Hollister Bridge	>1,600,000	>1,600,000	80,000
1/9/2008	13:12	4	Main Branch	1,600,000	300,000	23,000

Table C.2 FIB Results – December 2007 and January 2008
Summary of FIB Results for December 2007 and January 2008 sampling events

The lowest measured enterococcus concentration was at the Seacoast Drive Site (Station 2). This station was designed as a background station and should, in theory, contain cleaner water than that in the main channel, considering Station 2 is not on the main stem of the Tijuana River. Finally, the concentrations at the inlet were between those at the background station and those in the main stem of the Tijuana River (Stations 3 and 4). The results at the inlet are expected to be below those in TJR because of dilution with seawater through tidal action.

Laboratory results from the January 2008 sampling event provide more information than results for the December 2007 event because of the correction in the laboratory process, which allows for reporting of concentrations of up to 1.6 million per 100 ml. In general, the FIB concentrations were considerably higher in the samples collected on January 8, 2008, than those collected on January 9, 2008. This is likely related to the decrease in river flow from January 8 to January 9.

Concentrations of total coliform, fecal coliform, and enterococcus from samples collected on January 8, 2008, were generally two to three orders of magnitude above water quality criteria, as published by the San Diego County Department of Environmental Health. The single sample water quality standard for total coliform is 1,000 per 100 ml, while that for fecal coliform is 400 per 100 ml. The standard for enterococcus is 104 per 100 ml.

Total coliform bacteria were measured at 900,000 per 100 ml at each of the four sampling stations on January 8, 2009. Results indicate that concentrations increased on January 9, 2008, at the two upstream stations, with values at the Hollister Bridge exceeding 1.6 million per 100 ml. Results indicate that concentrations at the inlet (Station 1) and at Seacoast Drive (Station 2) were reduced by approximately one order of magnitude on January 9, 2008, compared to January 8, 2008.

Fecal coliform results ranged from 110,000 per 100 ml at Station 2 to 500,000 per 100 ml at Station 4 on January 8, 2008. As with the total coliform results, measured fecal coliform concentrations decreased at Stations 1 and 2 on January 9, 2009. Values fell by roughly 75 percent at the inlet and Seacoast Drive stations. Conversely, concentrations of fecal coliform increased considerably at Hollister Bridge (Station 4).

Enterococcus concentrations ranged from 11,000 per 100 ml at the inlet to 110,000 per 100 ml at Station 4 on January 8, 2008. Concentrations were elevated at Hollister Bridge (80,000 per 100 ml) and lower at the Seacoast Drive location (30,000 per 100 ml). Results show that concentrations in the two easternmost stations are approximately three to four times higher than those near the inlet and at Seacoast Drive. Samples taken on January 9, 2008, indicate a large reduction in enterococcus concentrations at the inlet (Station 1) and Seacoast Drive. Concentrations at Hollister Bridge were identical to those on January 8, 2008 (80,000 per 100 ml). Laboratory results indicate that the water quality in the western estuary (Stations 1 and 2) improved considerably from January 8, 2009, but still exceeded water quality criteria.

The combination of flow measurements and FIB concentrations allows for a rough calculation of the load of indicator bacteria to the South Bay for the two storm events sampled in December 2007 and January 2008. The average daily flow in the Tijuana River, as measured at the flow gauge, was multiplied by the coliform concentration measured at Hollister Road (Station 3) and converted to a daily load. Table C.3 summarizes these calculations. When lab results indicated a coliform concentration above a limit (in other words, > 1,600 MPN/100 ml), the calculations assumed the upper reporting limit as the measured concentration. This may significantly underestimate the loads in cases where coliform concentrations were reported in this manner. These calculations demonstrate the considerable load of FIB emanating from the Tijuana River watershed.

Estimate of Tijuana River Loading of Coliform to South Bay					
		Concentration at Station 3		Approximate River Load	
Date	Flow (cms)	Total Coliform	Fecal Coliform	Total Coliform	Fecal Coliform
	(cms)	(MPN/100ml)	(MPN/100ml)	(MPN/day)	(MPN/day)
12/10/2007	1.1	>1600	900	1.52E+14	8.55E+13
12/11/2007	1.1	>1600	>1600	1.52E+14	1.52E+14
1/8/2008	3.0	900,000	300,000	2.33E+17	7.78E+16
1/9/2008	1.7	>1,600,000	>1,600,000	2.35E+17	2.35E+17

Table C.3 Estimate of Tijuana River Loading of Coliform to South Bay

D. *Ocean Mooring at Key Areas (SS5)*

1. South Bay Ocean Outfall Mooring

An oceanographic buoy designed by Scripps for monitoring ocean conditions at the SBOO was fabricated and moored for the supplemental monitoring program. The mechanics of the SBOO mooring consists of a surface buoy that contained an ADCP manufactured by Teledyne RD Instruments (located in Poway, California), a temperature chain manufactured by Precision Measurement Engineering (located in Encinitas, California), a self-contained temperature and salinity sensor manufactured by Seabird Electronics (located in Seattle, Washington), and Scripps-built data logger, satellite telemetry unit, GPS receiver, and battery pack. All mechanical aspects of the buoy, mooring, and anchoring system were fabricated by Scripps (Figures D.1 and D.2).

The system was designed for a nominal 6-month servicing interval to replace sensor batteries and offload data from the internal memory recorders. Due to mechanical wear and fatigue on the mooring components, major components of the mooring (swivels, chain, and shackles) were also replaced at this time.

Ocean currents are measured using the ADCP. The ADCP operates by transmitting pulses of underwater sound through the water column and measuring the Doppler shift of the signal scattered from particles moving with the ocean currents. The unit was oriented to be downward looking from the surface buoy and provides a profile of ocean currents from 4.3 meters to the seafloor. The settings for the unit are given in Table D.1.

System Parameter	Setting
Acoustic frequency	600 kHz
Pings per ensemble	25
Ensemble interval	5 minutes
Range cell size	1 meter
Measurement standard deviation	1.4 cm/s
Number of depth cells	28

Table D.1 Acoustic Doppler Settings
Settings for the Acoustic Doppler Current Profiler used to monitor subsurface currents at the SBOO.

Measurements of water column stratification are made using temperature sensors located at different depths. For the SBOO buoy, a temperature chain was employed, which consisted of 10 nodes equally spaced across the water column, each measuring ocean temperature with accuracy of 0.01°C.

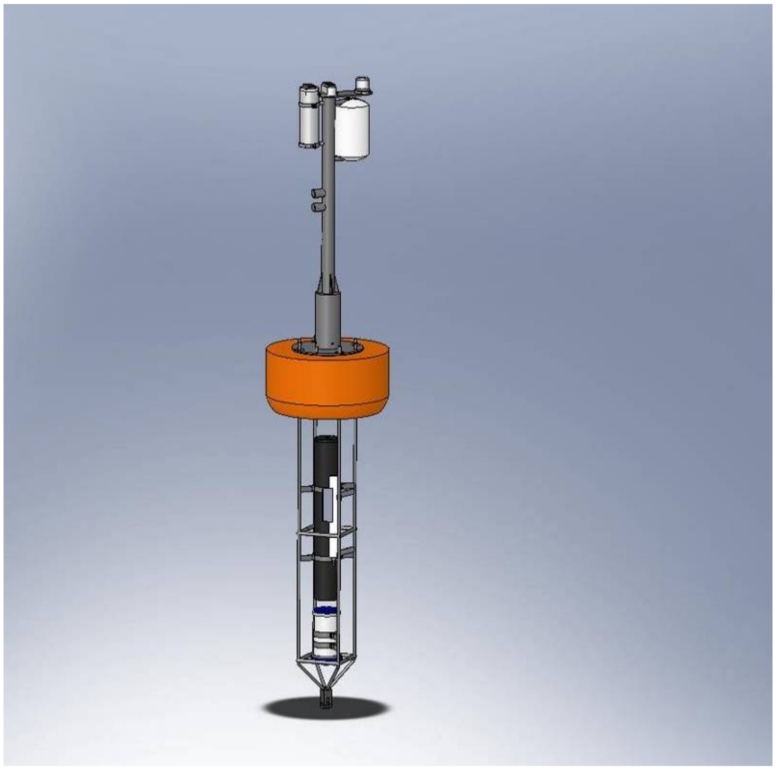


Figure D.1 Coastal Buoy Drawing and Photo
Drawing and a photograph of the Scripps-designed coastal buoy system for measuring stratification and currents at the South Bay Ocean Outfall.

Figure D.2 Ocean Deployed Buoy
Photograph of the deployed ocean buoy at the SBOO. The white cylinder on the right is a radar reflector and the cylinder on the left is a GPS tracking device.

Measurements at each depth were synchronized to provide a water column profile of stratification at 5-minute intervals. Use of the interconnected temperature measurements provided consistent timing across different water depths and eliminating clock drift problems that often occur when individual, self-recording temperature probes are used. The depths of measurement are 1.6 m, 5.0 m, 7.0 m, 9.6 m, 11.5 m, 13.7 m, 16.4 m, 19.0 m, 21.7 m, and 24.3 m.

Buoy position, currents, and ocean temperature data are transmitted to shore once each hour using an Iridium Satellite modem. Receiving the data in near-real-time allowed observation of present ocean conditions to estimate the plume rise height and the direction of the SBOO plume. The GPS-based buoy positions are reported hourly to allow monitoring of the buoy position relative to its original deployment location.

The mooring was deployed just west of the wye of the diffusers at 32.53325N, -117.18111W in 28 m of water. The all-chain mooring was secured with a 900-lb anchor (Figure D.3). The mooring was deployed on June 19, 2007, and subsequently serviced on January 15, 2007. Deployment and servicing were conducted using Scripps-owned research vessels.

2. Imperial Beach Pier Mooring

The Imperial Beach Pier mooring was located just offshore the pier in approximately 8 meters of water. While providing functionality similar to the SBOO mooring, the pier mooring included a bottom-mounted offshore current profiler with a power/data cable integrated into an existing data relay infrastructure located at the lifeguard tower. The mooring consists of an upward-looking acoustic Doppler current profiler to allow full water column profiling of the subsurface currents at the beach, which is the one most highly impacted by plume water from the Tijuana River. Placement of the velocity measurements at this location will provide a continuous record of the near-shore currents and complement the surface current maps generated by HF radar. A temperature chain was installed along an outer pier piling located at 1-meter intervals (Figure D.4). Both the velocity and temperature measurements were made several times an hour to resolve internal waves at the pier.

Conditions at the Imperial Beach pier were monitored over the sampling period and integrated into analysis efforts. The temperature chain provided a comparison for observations taken at the outfall, ensuring accuracy of measurements. Similarly, current profiles were compared to the SBOO mooring results and supplemented full water column data integration. The presence of an offshore CDIP buoy measuring waves allowed for wave confirmation from the AWAC. Measurements from the Imperial Beach pier were used as validation.

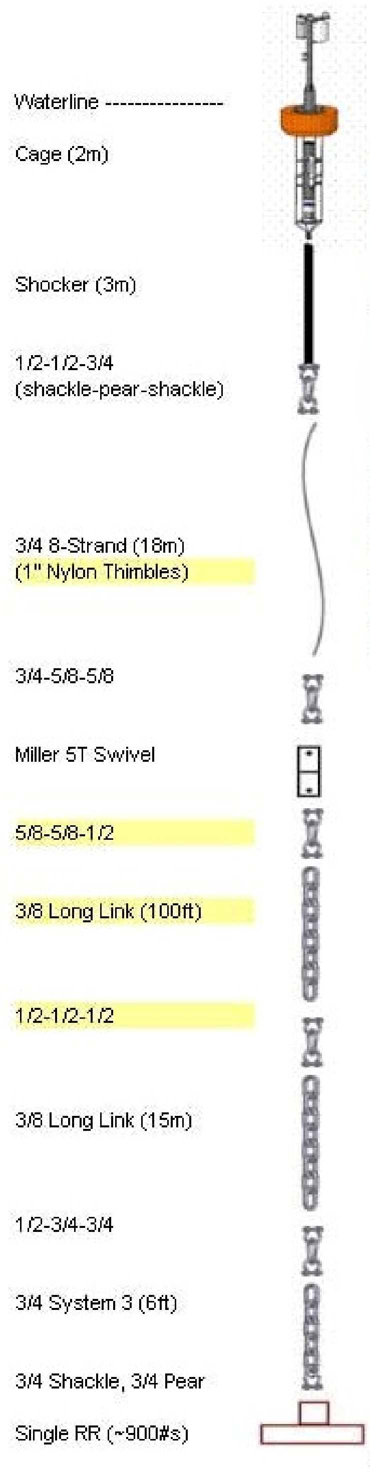


Figure D.3 SBOO Buoy Mooring Diagram
Mooring diagram for the SBOO buoy. The diagram outlines the major mechanical components of the mooring used to keep the buoy in place for the duration of the supplemental monitoring program.

Figure D.4 Acoustic Wave and Current Profiler
(left) Acoustic Wave and Current (AWAC) profiler installed offshore of the Imperial Beach Pier. (right) temperature chain deployed on a pier piling for ocean stratification measurements

3. Summary of Data

A summary of the vertical structure of ocean temperature and water velocity is provided in this section. Figure D.5 presents a color contour plot of time records of ocean temperature at the outfall site. The contour is based upon using the 10 temperature probes that span the water column. The time duration of the figure spans the entire 16-month period of the supplemental monitoring program. The seasonality of the ocean temperatures is clearly evident, with warmer waters and a stratified ocean present in the dry season (April through September), with the warmest temperatures occurring in August and September. Cooler waters and weak stratification characterize the ocean conditions during the wet season (October through March), with an almost complete breakdown in stratification between December through March.

Because the display of data (sampled at 5-minute intervals) over the 16-month period makes it difficult to appreciate the temporal variability in ocean temperatures at the site, a 7-day example time period is provided in Figure D.6. The 7-day period (February 14 to 21, 2008) graphically illustrates how the vertical structure of the ocean can vary day to day.

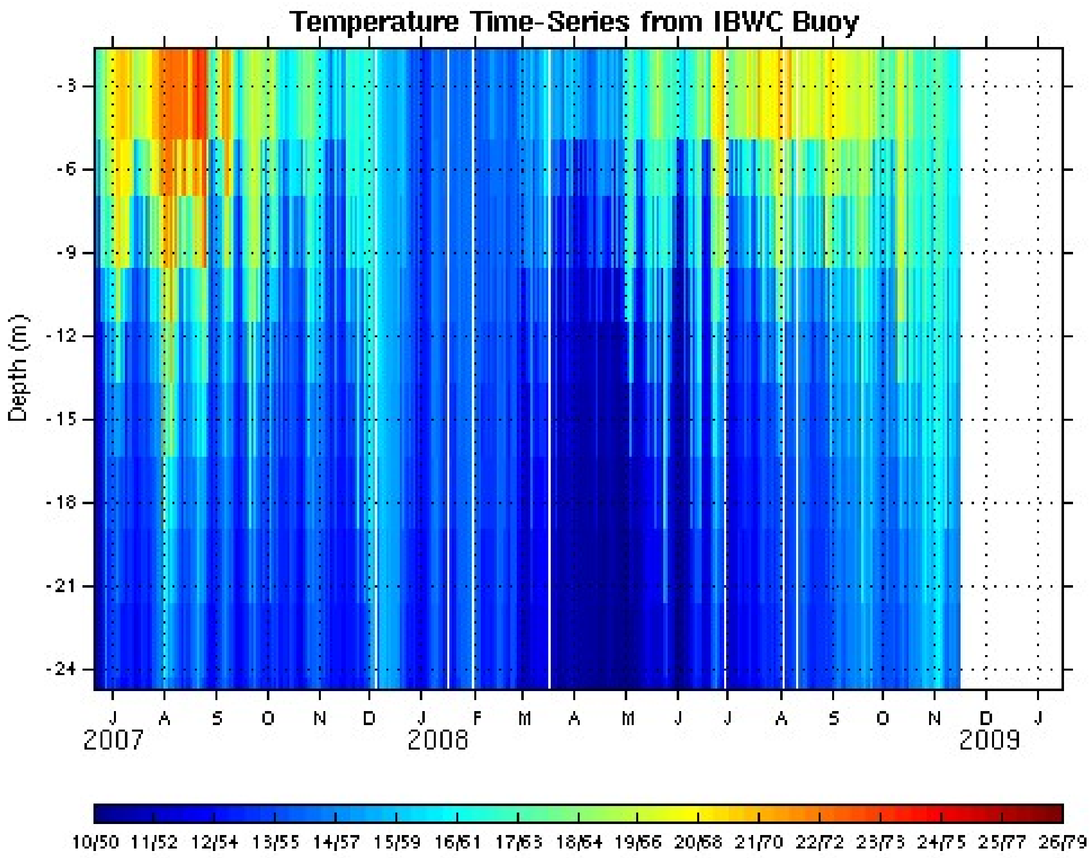
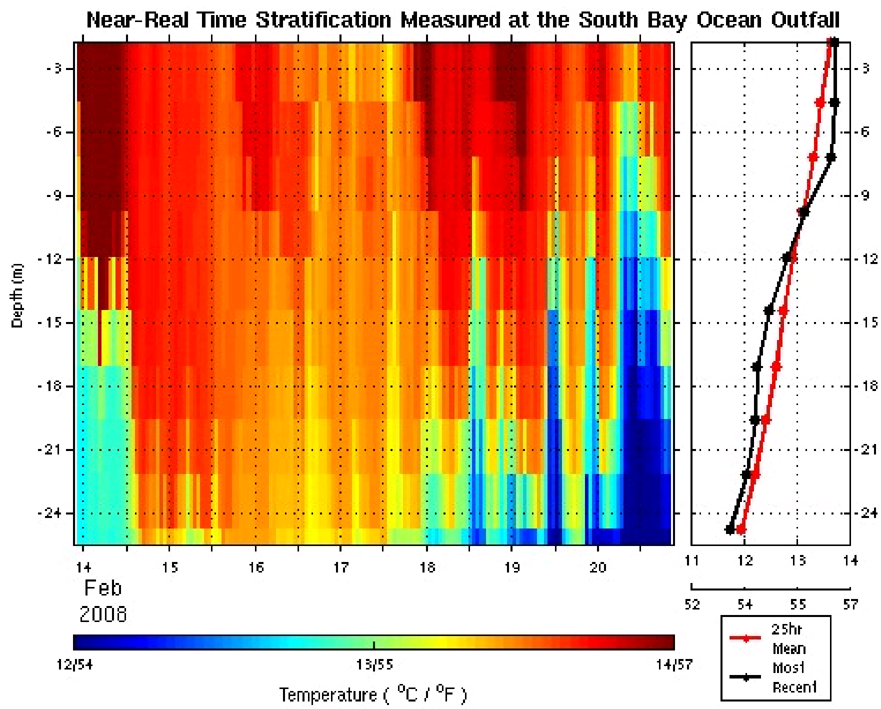


Figure D.5 Ocean Temperature Time Series
Time series of ocean temperature during the supplemental monitoring program. The color bar indicates the temperature in both Celsius and Fahrenheit.

South Bay Ocean Outfall
Ocean Stratification

UTC Time: 2008-02-20 21:36:11
Local Time: 2008-02-20 13:36:11



Last Sample Values

Depth	Temp. °C	Temp °F
1.7 m	13.73 °C	56.71 °F
4.6 m	13.72 °C	56.70 °F
7.2 m	13.66 °C	56.59 °F
9.8 m	13.16 °C	55.69 °F
11.9 m	12.83 °C	55.09 °F
14.4 m	12.49 °C	54.48 °F
17.1 m	12.26 °C	54.07 °F
19.6 m	12.22 °C	54.00 °F
22.2 m	12.05 °C	53.69 °F
24.8 m	11.74 °C	53.13 °F

2008-02-20 20:29:25 GMT

Figure D.6 South Bay Ocean Outfall Stratification

The north/south and east/west currents measured at the site are summarized in Figure D.7. While the data shown include higher frequency motions (tides), the figures give some insight into the vertical structure of the currents, with it being evident that shear is most prevalent during periods of strong stratification. In the winter months, shear is weak. While the currents are typically to the south, northward-flow events are common. Another way of assessing the general trends of the currents at the site is to examine the depth-averaged flow. For this analysis, the currents are vertically averaged and a 25-hour time averaging window is used to average out the tidal motion to make the subtidal motions more visible. The subtidal motions are most relevant for tracking plume behavior since tidal motions do not result in net transport. Figure D.8 presents the depth and tidally filtered velocity records for the site. The data illustrate the temporal variability present in the currents at the site.

Similar to the temperature records, graphically presenting dense data over a 16-month period makes it nearly impossible to appreciate the shorter time-scale fluctuations in the ocean currents. As an example of the currents in the region, a time series of the velocity at the site for the time period February 14 to 21, 2008, is provided in Figure D.9_. The figure illustrates the changes in the currents that can occur over a few days, with the flow dominant northward at the start of the record and changing to a southward flow in the period of 3 days. The probability distribution function of the north-south and east-west currents are computed for both the summer and winter months and shown in Figure D.10. For the summer months (Figure D.10 top), the Gaussian-like distributions are centered about zero, with a slight bias towards more flow to the south. This bias is more prevalent in the winter months (Figure D.10, bottom).

To illustrate the depth dependence of the currents, a principal component analysis was performed for each depth measured by the ADCP. This technique allows the determination of the major and minor axes of the variance of the current signal. The results of this analysis indicate that the major axis of the flow is aligned to the north-northwest for most of the water column, with a turning of the major axes with depth, resulting in the major axis of the flow to have a more east/west component (Figure D.11).

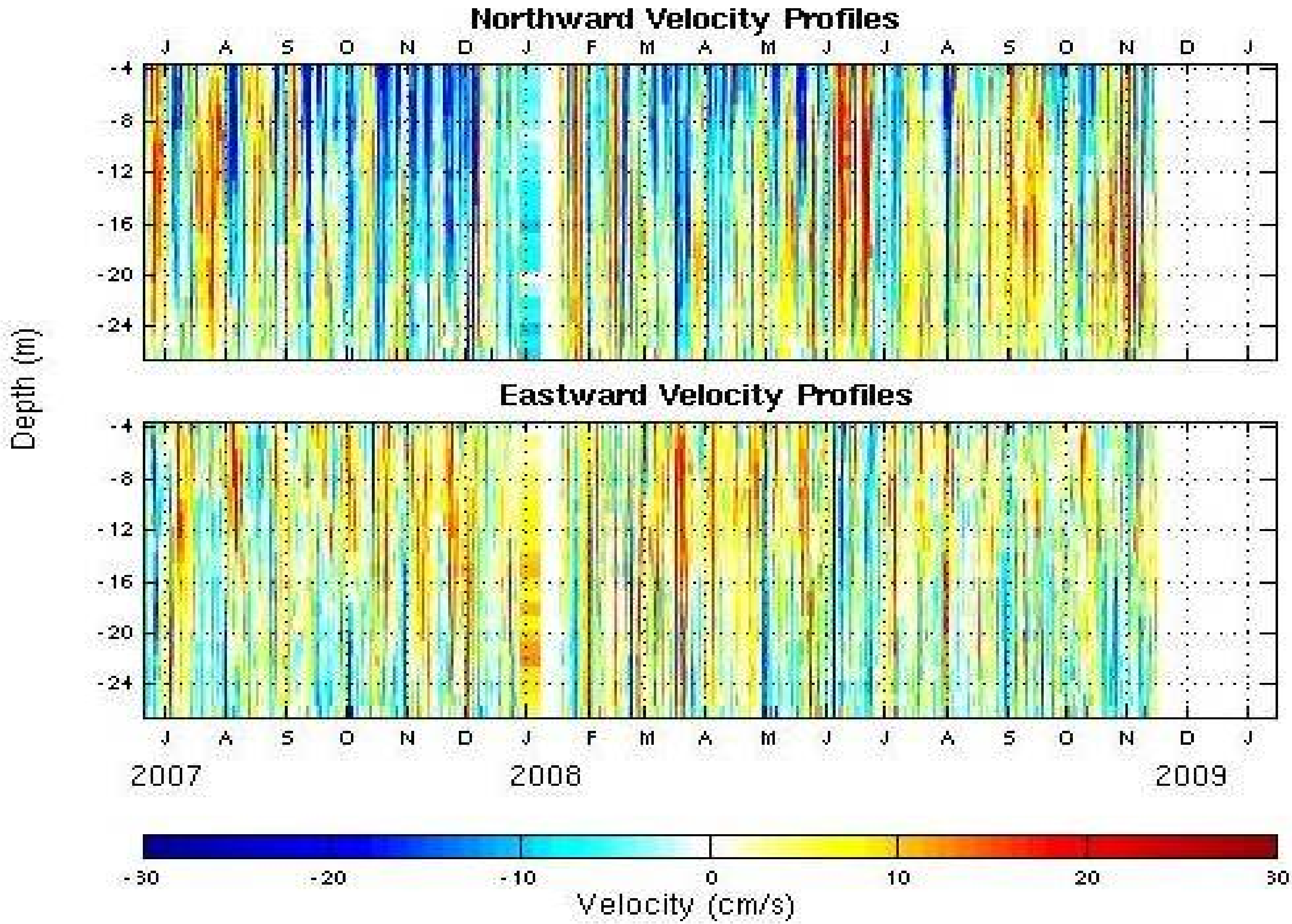


Figure D.7 Velocity Profiles
North/South (top) and East/West (bottom) current records measured by the ADCP on the SBOO buoy. Red is positive north/east.

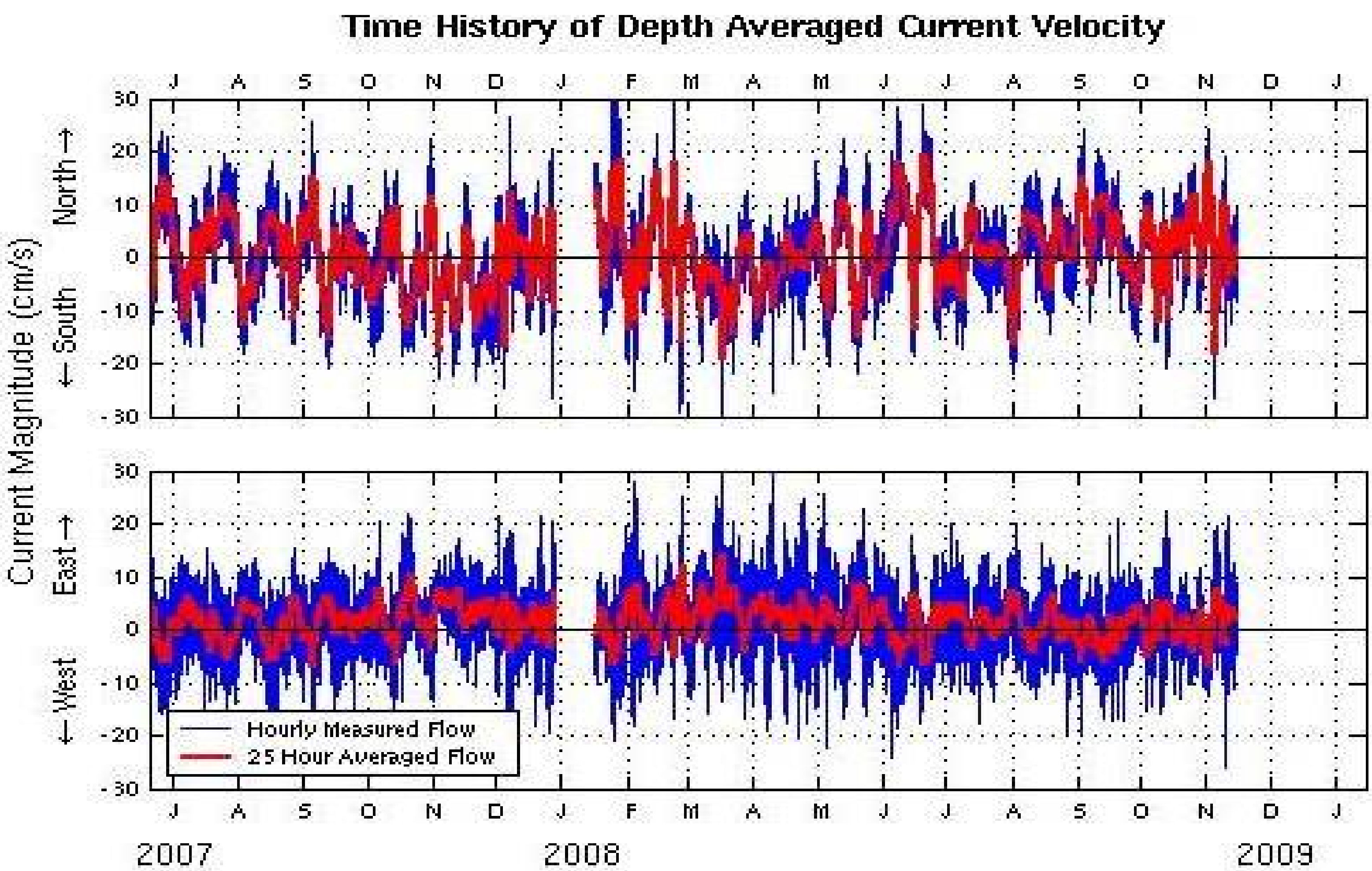


Figure D.8 Time History of Depth-Averaged Current
Depth averaged currents for the north/south and east/west components at the SBOO mooring site. The blue line is hourly data while the red line is a 25-hour running average to remove the tides.

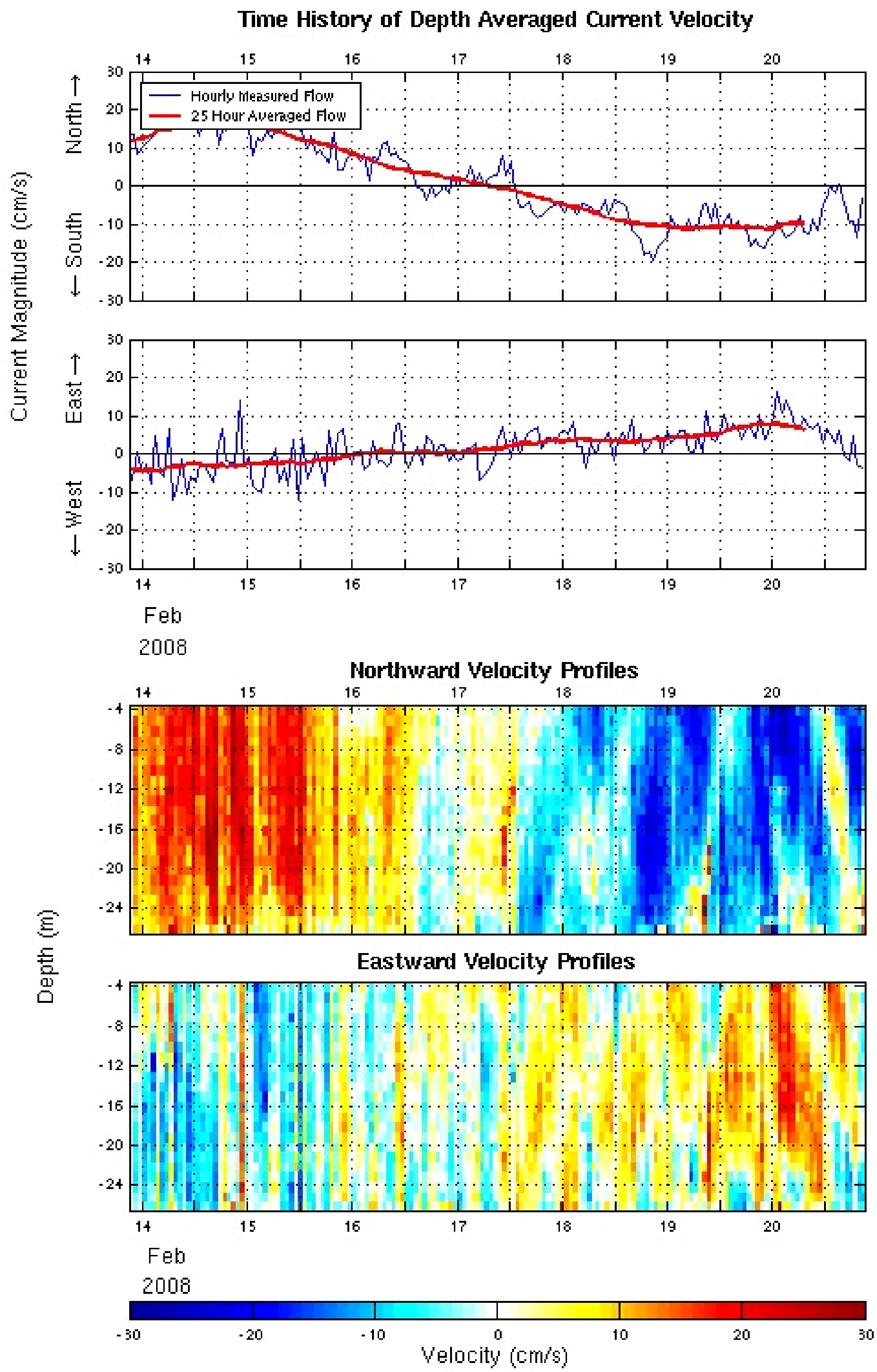


Figure D.9 Depth-Averaged Current February 14-21, 2008
The depth-averaged (top) and vertical structure (bottom) of the north/south and east/west current components at the SBOO mooring site from February 14-21, 2008. As a result of the weak stratification, very little shear is present in the water column.

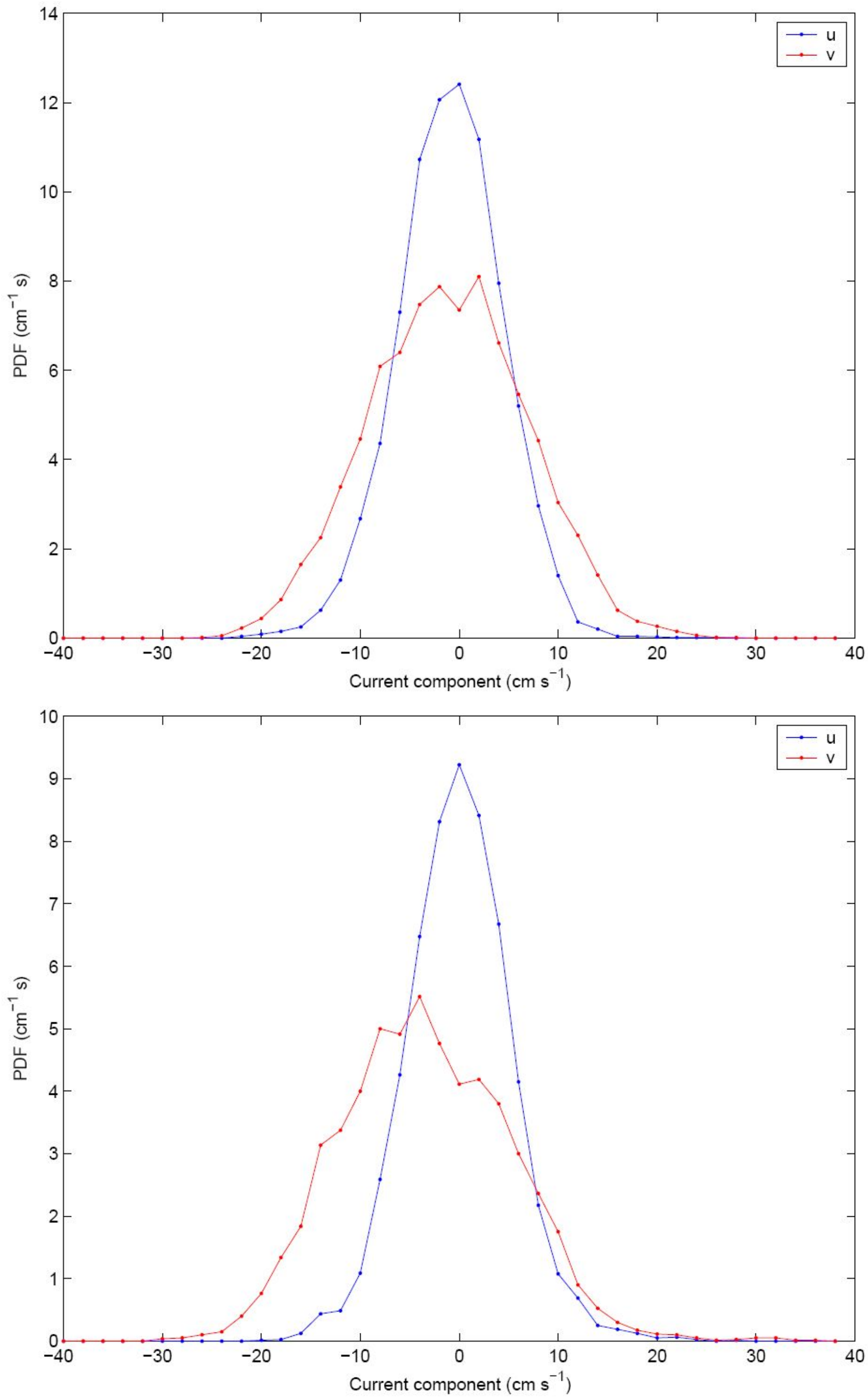


Figure D.10 Depth-Averaged Currents Probability Distribution
Probability distribution functions for the depth-averaged currents at the SBOO for summer (top) and winter months (bottom). The statistics of the east/west currents are represented by the blue line and the north/south statistics are represented by red.

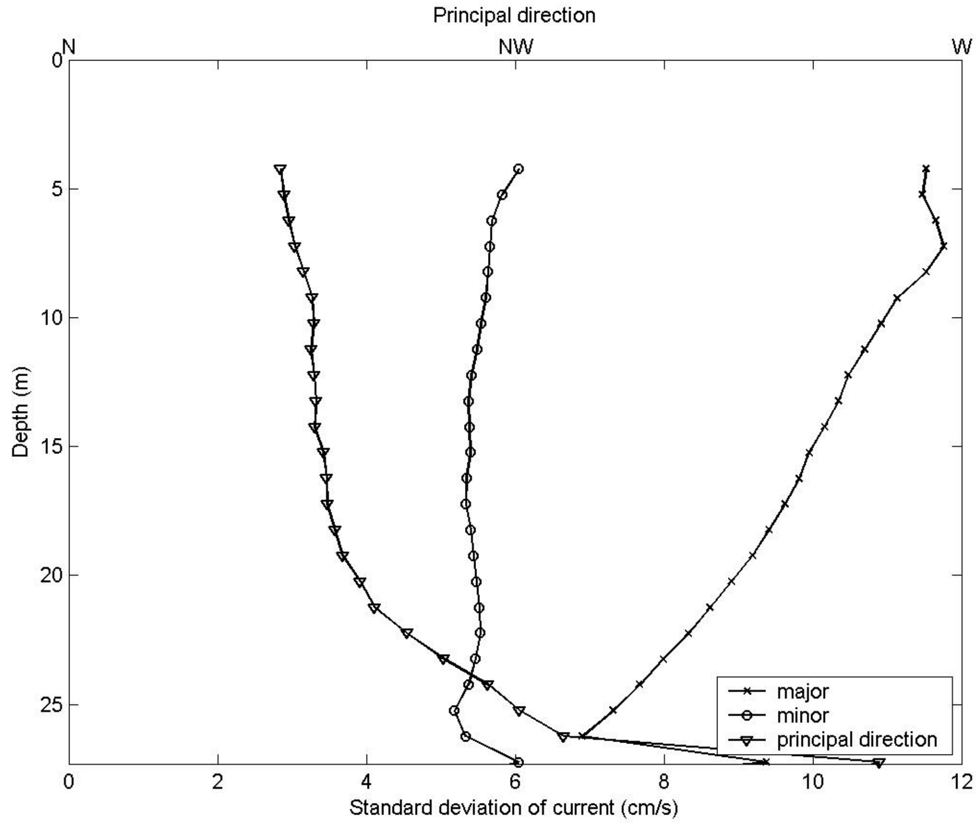


Figure D.11 Current Principal Direction

Results of a principal component analysis of the ADCP currents for all depths measured. The data indicate that the major axis of the flow is aligned to the north-north west, with some turning with depth resulting in the flow to have more of an onshore/offshore component. The minor axes does not vary much with depth (approximately 5.5 cm/s) while the major axis ranges from 12 cm/s.

4. Data Usage

The intended usages of the ocean mooring data are for the following purposes:

- To monitor ocean variables (ocean stratification, velocity) that serve as input to a discharge plume rise height model. Operation of the model on the continuous records will allow accurate determination of the plume surfacing statistics
- To estimate the orientation of the subsurface plume using trajectory algorithms applied to the ocean current information provided by the ADCP
- To provide near-real-time data to guide in-situ plume sampling efforts

5. Plume Rise Height

In this section a framework is presented for estimating the rise height of the SBOO plume using the ocean mooring data. The output of these time dependent computations will allow a statistical analysis of the potential for the plume to surface. A subsequent section will address the tracking the horizontal transport of the surfaced plume using Lagrangian trajectory analysis based upon the hourly surface current maps measured by the HF radar.

The dynamic of a buoyant discharge plume is controlled by the outfall design and density structure with depth in the near-field and ocean circulation in the far-field. The latter is controlled by winds, tides, along-shore pressure gradients, and internal waves. The U.S. EPA Roberts-Snyder-Baumgartner (RSB) plume model will be applied to the mooring data to predict the height of the plume and its potential to surface in the near-field (Roberts et al. 1989, Roberts 1999a, Roberts 1999b). The RSB model is based on piece-wise linear stratification assumptions between observations, uniform currents, straight diffusers, and Gaussian distribution of the concentration of waste field at the end of near-field (Roberts 1999a, Roberts 1999b, Frick et al. 2001). The plume height (h) is parameterized in the RSB model as:

$$h = h(\rho(z), \mathbf{u}(\mathbf{x}, z_0), q;\ n, D, \Delta d, z_0, \theta_0, \rho_q),$$

where $\rho(z)$, $u(x;\ z_0)$, and q denote the ambient density profile, the currents at the plume depth, and the amount of outfall flow (m^3/s). The SBOO engineering parameters and the RSB model output are described in Tables D.2a and D.2b.

(a)

Model inputs	Input data
Number of ports, n	60
Port diameter, D (m)	5
Port spacing, Δd (m)	3.66
Discharge depth, z_0 (m)	28
Diffuser orientation, θ_0 (degrees, clockwise @ N)	11.7
Effluent density, ρ_q (g cm^{-3})	0.997
Discharge amounts, q (MGD)	20
Number of points in density profile	13

(b)

Model outputs
Minimum dilution at the end of near-field, S_n
Rise height from the bottom, z_e (m)
Thickness of plume, h_e (m)
Height to level of near-field dilution, z_m (m)
Length of the near-field, x_n (m)

Table D.2 RSB Plume Model Parameters
A list of the parameters used in the Roberts-Snyder-Baumgartner (RSB) plume model. a) Outfall configuration parameters and b) Model outputs.

While ocean density is not directly measured by the buoy, the density stratification in Southern California has been found to be strongly dependent on temperature (Bratkovich 1985, Winant and Bratkovich 1981), allowing the density profile to be calculated from measured temperature profiles and climatological estimates of salinity (Millero and Poisson 1981, Fofonoff and Millard Jr. 1983).

The predicted ceiling depth (*ze*) and bottom depth (*z*) of the plume, computed hourly for the 16-month record, are shown superimposed with the ambient ocean density for the period of the program (Figure D.12). The plume height is highly dependent on the stratification. The strong stratification in summer forces the plume to stay in the middle of the water column, and the weak stratification in winter allows the buoyant plume to surface. While there are seasonal trends to the surfacing the plume, there are also intermittent time periods in which the stratification can break down for short periods of time, resulting in a surfaced plume that is transient in time. An example of a short-time scale surfacing event is shown in Figure D.13.

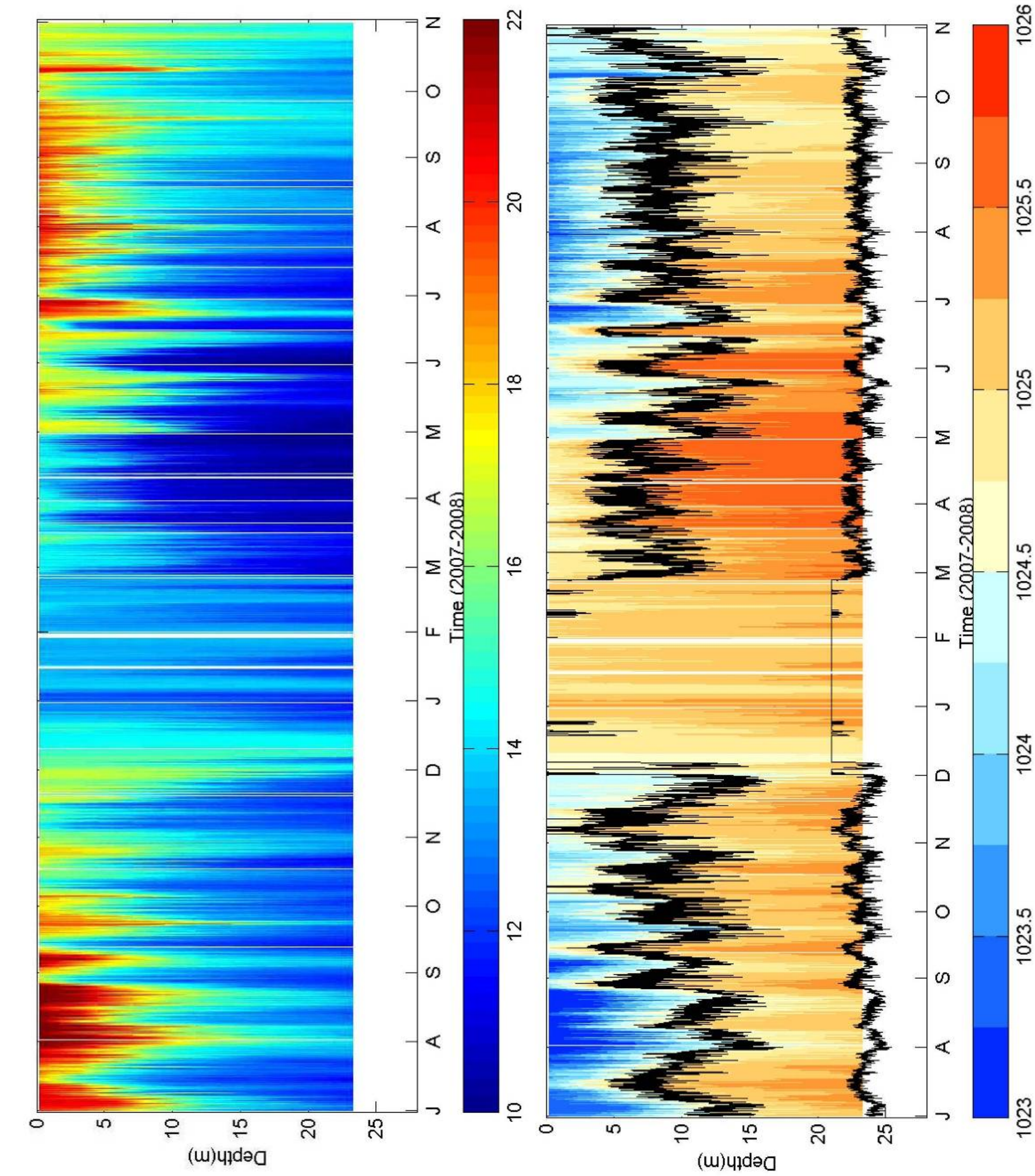


Figure D.12 SBOO Ocean Temperatures – December 2007-February 2008
Left - Ocean temperatures records at the SBOO during the supplemental monitoring program. Right - Density structure at the SBOO for the same period of time. Also shown are the rise height and plume base estimated using the RSB buoyant plume model. The estimated time-dependent depth extents of the plume are bound by these two black lines, surfacing events are clear in December – February.

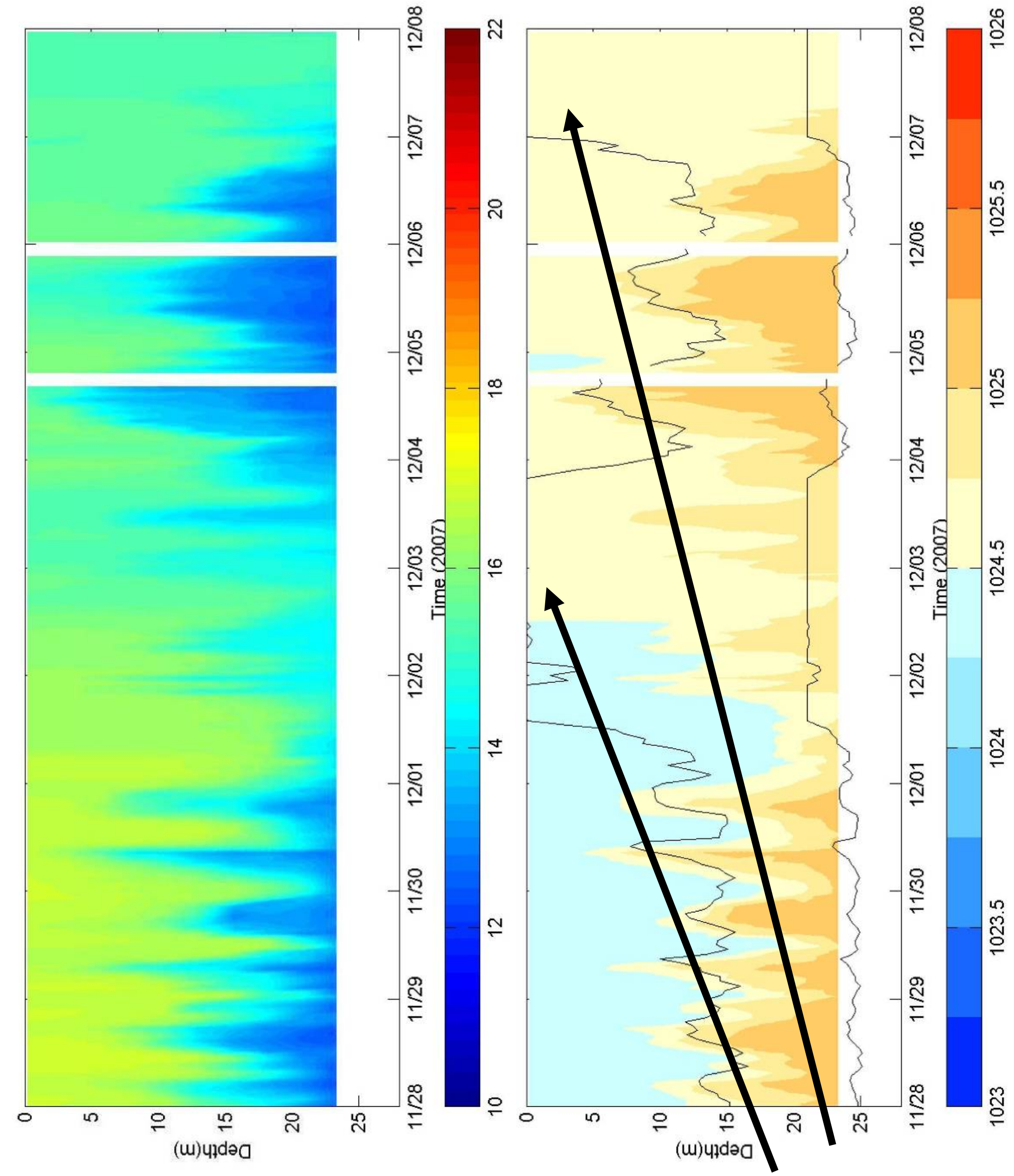


Figure D.13 SBOO Plume Ocean Temperatures – November 28-December 8, 2007
(Top) Ocean temperatures records and (Bottom) the density field and computed rise height for SBOO plume between 11/28/2007-12/8/07. As a result of the breakdown in stratification, the plume is estimated to surface between 12/2/07-12/4/07. The rise height and plume base elevation is estimated using the RSB buoyant plume model. The surface plume is shown by the arrows.

The statistics of the surfacing plume were computed for each month of the study and are shown in Table D.3.

	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O
hours	0	0	0	4	13	594	688	569	2	0	0	0	0	0	0	19
days	0	0	0	3	5	28	31	26	2	0	0	0	0	0	0	3

Table D.3 SBOO Outfall Plume Surfaces
The number of hours and discrete days per month that the SBOO outfall plume surfaces.

Based upon the Table D.3, the computations suggest that the discharge plume surfaced a total of 1,889 hours (16 percent total time) during the 16-month supplemental monitoring program. All surfacing events took place in the October through March timeframe. For a calendar year, the surfacing days represent approximately 26 percent of the calendar year. This statistic was compared against identical computations using an expanded (and historical) data set for the 3 years previous to this study. The results of those computations found that SBOO mooring site surfaces on average 27 percent of the time in any given calendar year.

A histogram of the plume rise height for the 16-month period of the program is shown in Figure D.14. The distribution is bimodal, with typical plume rise heights to a depth of 8 to 10 m, except when the stratification is weak.

To remove the bias in the statistics, a 12-month period spanning October 2007 through September 2008 is used, equally weighting the data in wet and dry weather months. The resulting probability distribution is shown in Figure D.15.

The same PDF computations, now based upon a 3-year window of data are shown in Figure D.16. The PDF is similar to the previous figure, except for the elevated statistics for a surfacing plume. This 27 percent surfacing statistic is consistent with the surfacing statistic estimated when the data from the study are transformed into a 12-month period balanced between wet and dry months.

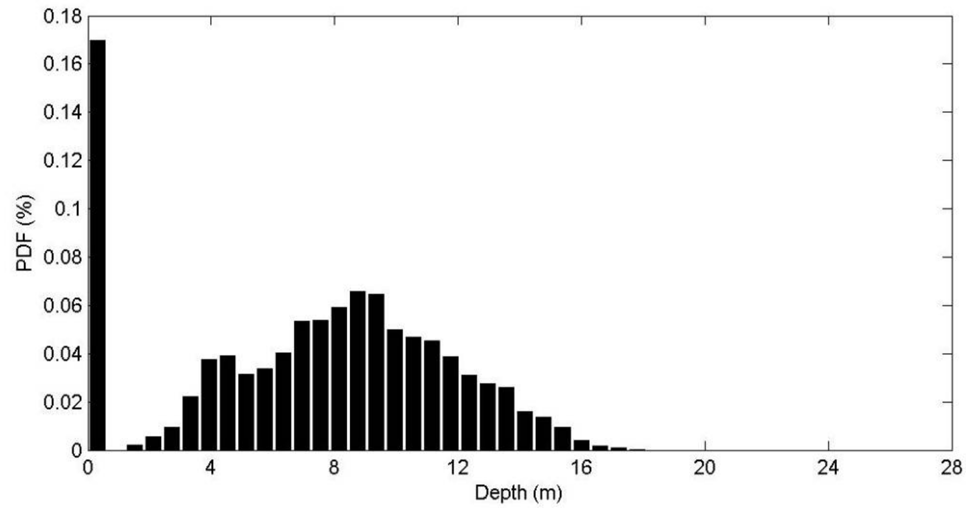


Figure D.14 SBOO Discharge Plume PDF
The probability distribution function (PDF) for the depth of the SBOO discharge plume for the 16-month supplemental monitoring program. Since the period of the program is not balanced in time between the dry and wet weather seasons, the surfacing statistics are biased low.

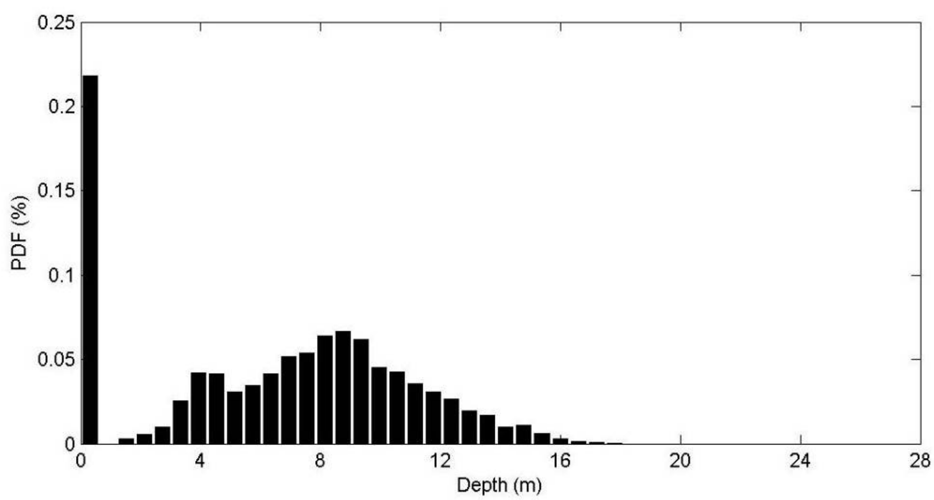


Figure D.15 SBOO Discharge Plume PDF
Similar to the previous probability distribution function, but the analysis is conducted over a 12-month window spanning October 2007 through September 2008.

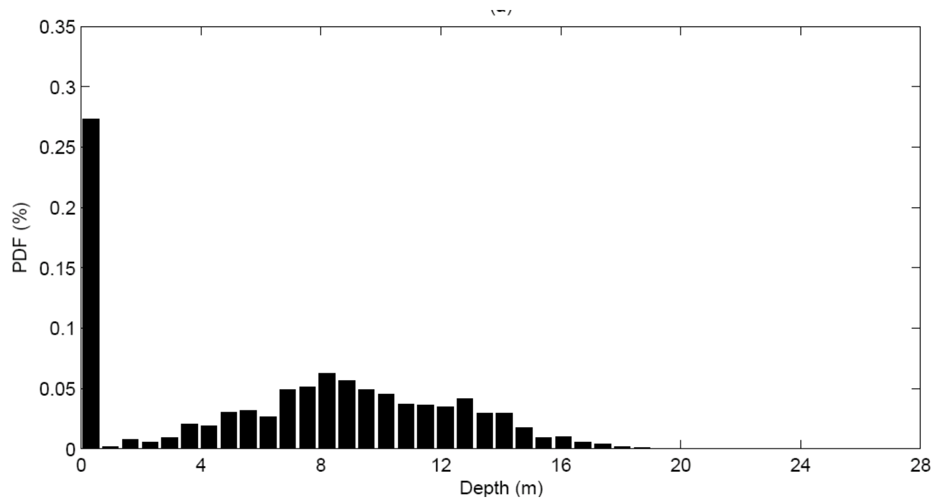


Figure D.16 SBOO Discharge Plume PDF
Similar to the previous figure, but this time the statistics are for the time period between 2003 and 2007. A balanced window of wet and dry seasons is used for computing the statistic, resulting in a higher probability of surfacing

6. Transport of Plume at Depth

The direction of the subsurface plume is estimated using a trajectory analysis based upon the time-dependent currents measured by the ADCP. Since the wastewater plume is distributed in depth, we estimate the transport of water from the SBOO site on a per-depth basis. Similar to using progressive vector diagrams, a time-integrated displacement for parcels of water at each depth within the plume is computed. In this analysis, the time-dependent rise height (computed hourly) are advected by the currents measured at that depth. A key component to this analysis technique is the assumption that the currents are the same wherever the parcel of water is displaced. Given the spatial variability seen in the surface current maps, this assumption is sure to be invalid at large distances from the single current measurement location used. Nevertheless, the approach provides insight into orientation and statistics of the subsurface plume location.

The trajectories are computed on an hourly basis, using hourly averages of the currents and plume rise height. To minimize errors in the assumption of a spatially uniform current, the trajectory is computed to 24 hours only. An example trajectory for all depths of the water column is shown in Figure D.17. The four panels illustrate the plume trajectory estimate at 1-meter intervals at depths between 5 to 25 meters. Each panel is a 5-meter increment.

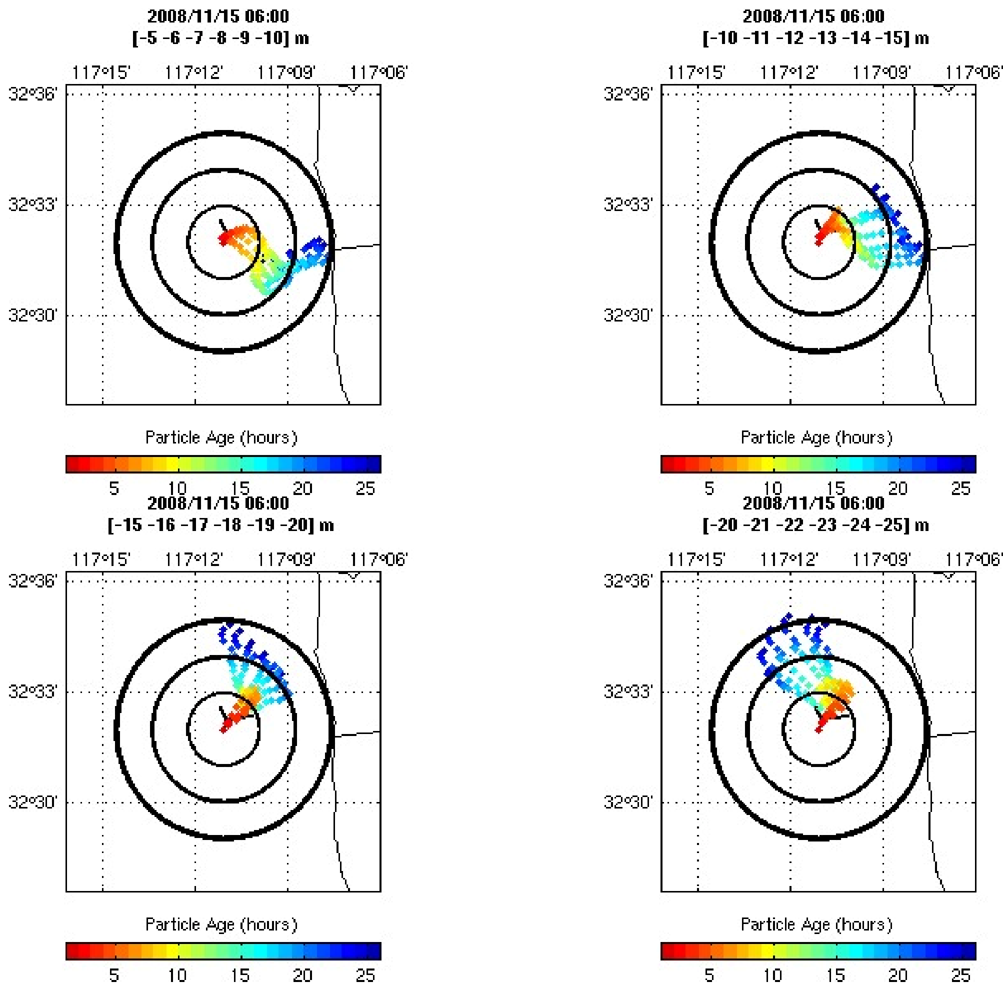


Figure D.17 Subsurface Plume Trajectory – November 15, 2008
Example trajectories of subsurface plume water at 1 meter depth intervals ranging from 5 meters to 25 meters. Each panel represents 5 meter increments. For this time period (11/15/2008), vertical shear is evident by the eastward transport at the shallower depths while the deeper depths are displaced to the northwest.

These displacement computations, conditioned by the plume rise height output, are conducted for the 16-month record at hourly intervals over the entire 16-month record, resulting in over 11,000 realizations. A two-dimensional probability map for the subsurface plume displacement, for a 24-hour window is then computed for each depth interval. These probability maps are shown in Figures D.18 through D.21. The maps show the probable subsurface location of the subsurface plume for plume water ranging in age from 0 to 24 hours. While FIBs are assumed to be viable in the seawater for up to 3 days, the plume was modeled to 24 hours because the measured currents were not assumed to be valid at distances far from the mooring. The maps show the statistical alignment of the plume to the northwest and to the southeast. The calculations suggest that the plume has a non-zero chance of being transported to the shoreline south of the Tijuana River at depths of 6 m or greater within a day.

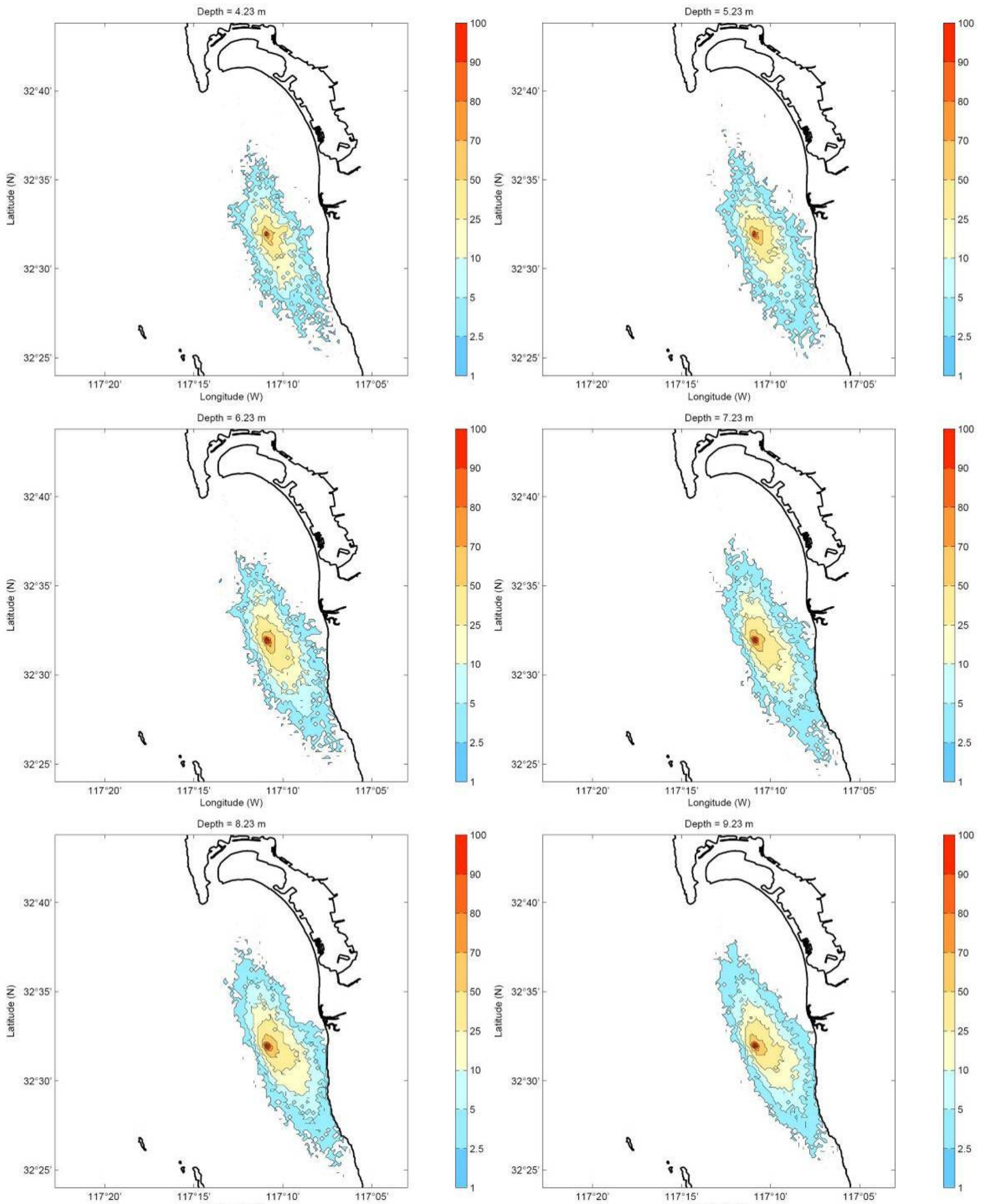


Figure D.18 Subsurface Transport Estimates – 4.23 m-9.23 m
Subsurface transport estimates over a 24-hour time period. Panels from left to right are for depths 4.23 m, 5.23 m, 6.23 m, 7.23 m, 8.23 m, and 9.23 m.

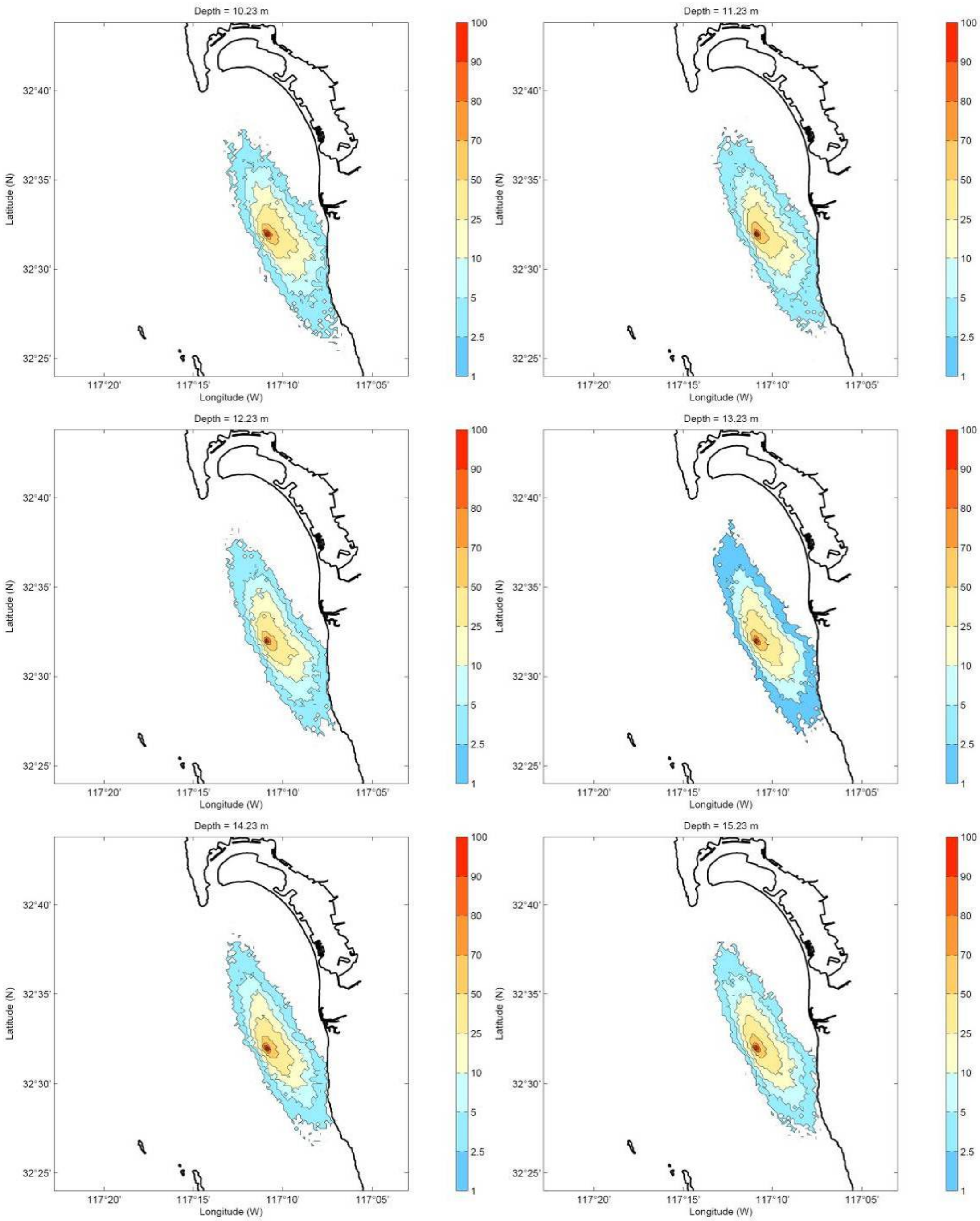


Figure D.19 Subsurface Transport Estimates – 10.23 m-15.23 m
Subsurface transport estimates over a 24-hour time period. Panels from left to right are for depths 10.23 m, 11.23 m, 12.23 m, 13.23 m, 14.2 3m, and 15.23 m.

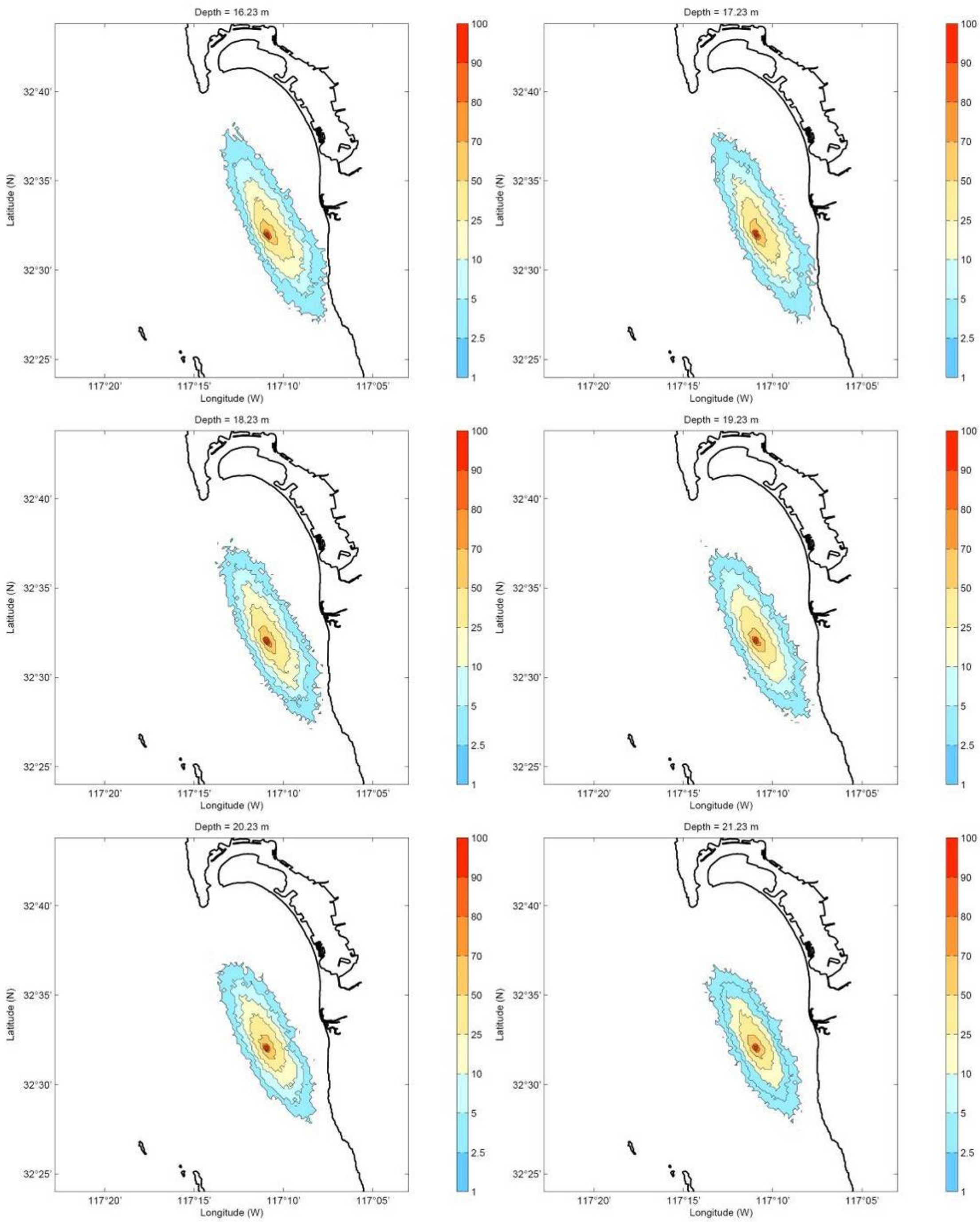


Figure D.20 Subsurface Transport Estimates – 16.23 m-21.23 m
Subsurface transport estimates over a 24-hour time period. Panels from left to right are for depths 16.23 m, 17.23 m, 18.23 m, 19.23 m, 20.23 m, and 21.23 m.

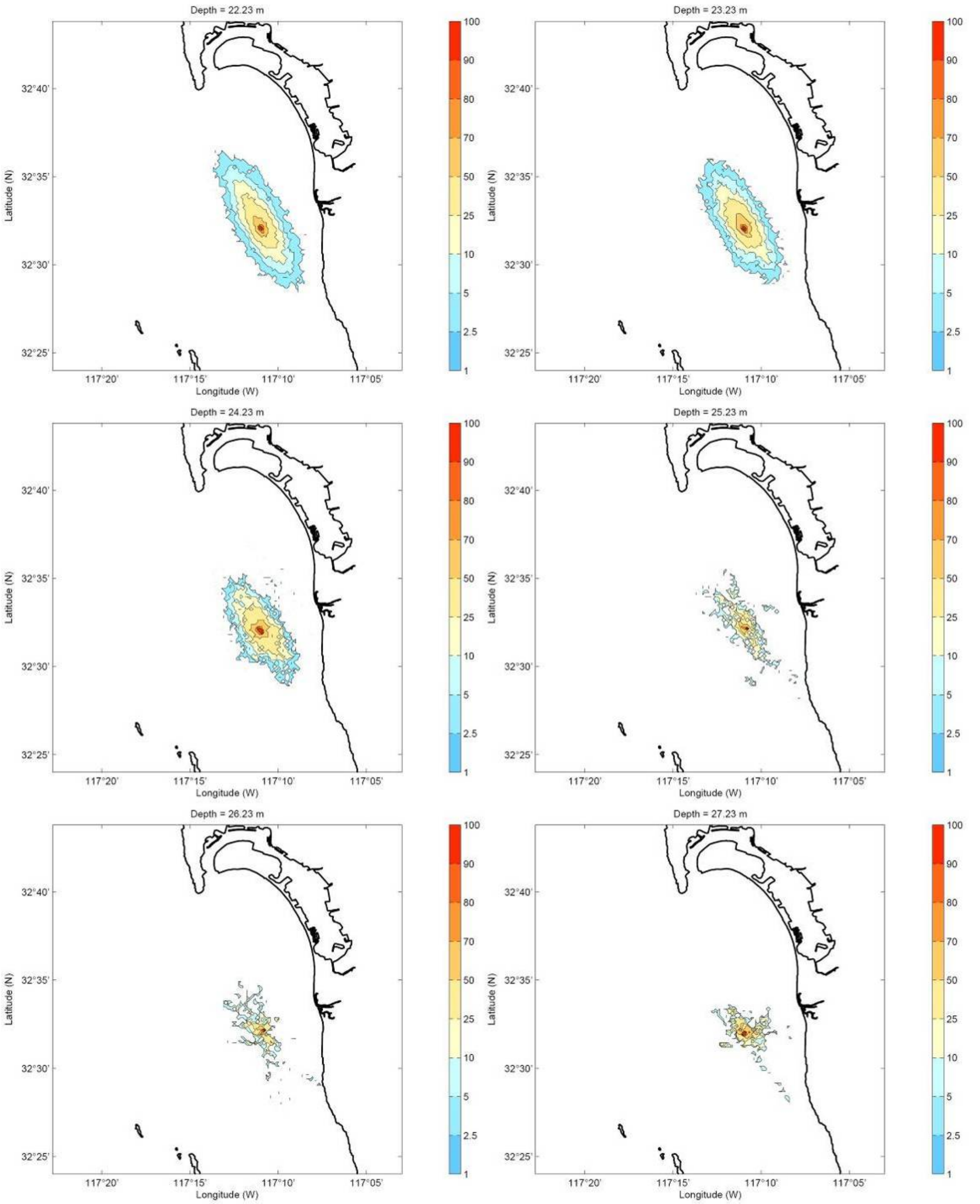


Figure D.21 Subsurface Transport Estimates – 22.23 m-27.23 m
Subsurface transport estimates over a 24-hour time period. Panels from left to right are for depths 22.23 m, 23.2 3m, 24.23 m, 25.2 3m, 26.23 m, and 27.23 m.

E. Mapping of Ocean Currents Using CODAR and Improved Data Handling (SS6)

1. High-Frequency (HF) Radar Overview

The backbone of the coastal monitoring system is an array of high-resolution radars designed to provide a spatial map of the local ocean surface currents on a real-time basis. The basis for the system is the scattering of radio waves from ocean surface waves over known regions of the ocean. Through appropriate signal processing of the radio waves scattered back to the radar, currents can be determined at a large number of discrete locations, referred to as range cells (Figure E.1). Typical range resolution is 1 km. The regional coverage provided by the current array and the direct measurement of the ocean's surface currents allows the tracking of transport routes from various potential pollution sites and has provided a framework for interpreting results from the collective datasets throughout this program.

HF radar sites in the South Bay region have been operating since 2001. The infrastructure was installed as part of a “Clean Beaches Initiative Program” funded by the City of Imperial Beach launching the scientific analysis of circulation patterns in the area. Systems have remained operational with limited down-time for maintenance. As with any hardware, the HF radars require system maintenance and upgrades to remain functional throughout the sampling period. Field analysts upgraded the communications system from offshore Coronado Islands to Point Loma networked into the High-Performance Wireless Research and Education Network (HPWREN) backbone providing reliable and secure data transmission. Sites required supporting hardware, such as new universal power supplies to prevent equipment damage due to power spiking and brownouts as experienced at Border Field, external hard drives for raw data collection, and replacement antenna whips because radials damaged over time introduce noise into the system. Surface currents are derived based on direction finding algorithm using the multiple signal classification (MUSIC) method developed for HF radar.

The radar system requires a calibration antenna pattern for proper data processing and vector calculations. The antenna pattern and antenna response may be altered if the surrounding environment changes. For example, installation of a chain-link fence or new lightpost could distort the antenna response, causing improper algorithm calculations. Periodic site visits to observe environmental modifications and semi-annual calibrations are highly recommend to maintain proper HF radar operation. The Coastal Observing Research and Development Center (CORDC) staff has developed an online diagnostic utility to aid in system maintenance and troubleshooting (Figure E.2). These pages are monitored for changes in system operation.

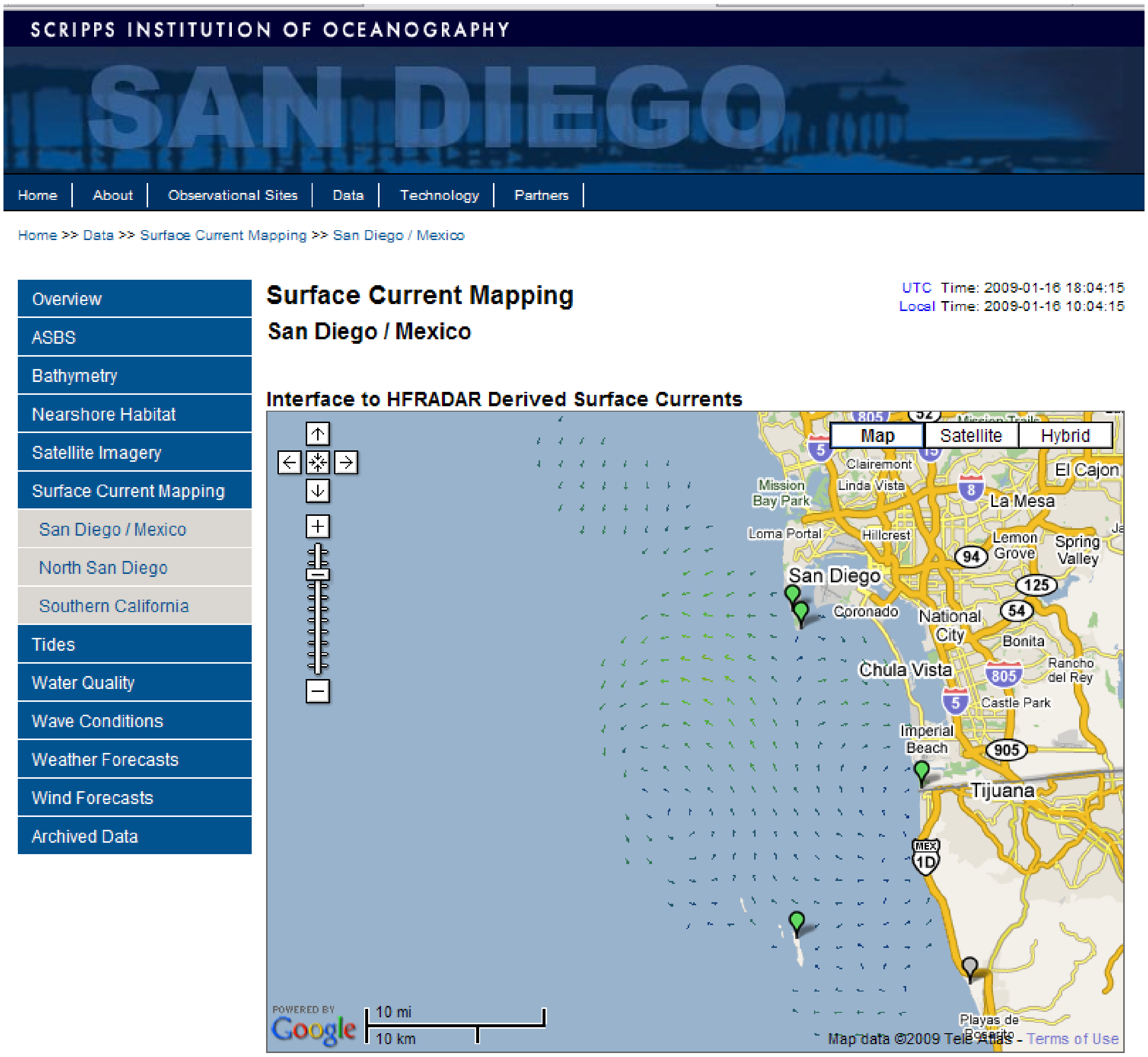


Figure E.1 HF Radar Display

Online display of HF Radar derived surface currents in the South Bay. Sites maintained through this effort include Point Loma, Border Field State Park, and Coronado Islands.

SIO field analysts interfaced with Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) to re-establish the HF radar site located at the Petroleos Mexicanos (PEMEX) plant in Rosarito, Mexico. The site became operational in December 2007 following a long lead time for equipment delivery through Mexico. The site remained operational for several months but, unfortunately, has undergone another set of hardware failures and is currently offline. SIO staff remain available for coordination and guidance and are hopeful for a full system recovery and integration into the HF radar network.

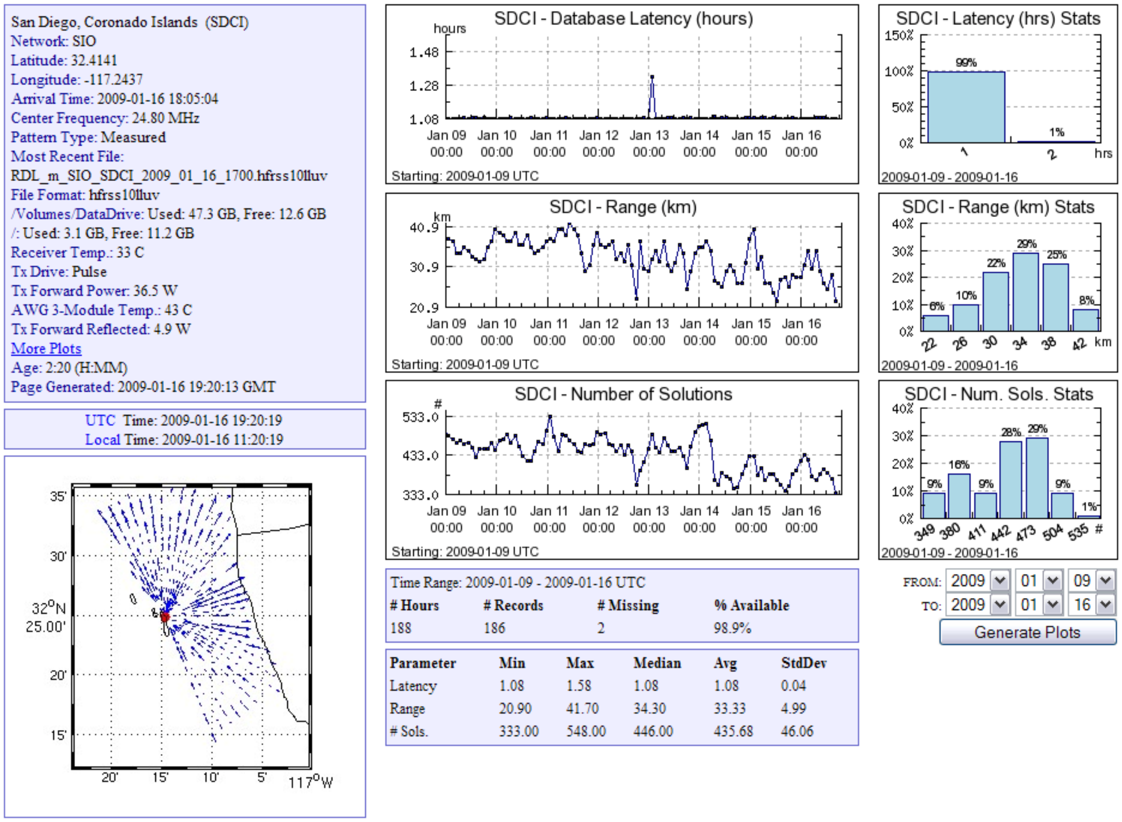


Figure E.2 HF Radar Diagnostic Utility
Online individual HF radar site diagnostic utility for observation of system health and site statistics.

2. Online Data Delivery

Data collected from this program have been integrated with supporting measurements and are made publicly available online. Significant efforts were dedicated to overhauling the backend infrastructure of this site. When the site was first constructed all programming was written in ColdFusion, an application server and software language developed primarily for dynamic websites. This service, however, became increasingly difficult to maintain as new routines were developed, and code versions became unsupported. Throughout this program, the online delivery system was entirely rewritten into an updated and currently supported suite of programming modules (Figure E.3). This has stabilized the web data delivery. Correspondingly, the menus and web layout were redesigned with direct input from users such as DEH health officers, Imperial Beach lifeguards, and city managers. The new layout offers greater ease and usability of information.

Figure E.3 San Diego Coastal Observations Website
Revised San Diego coastal observations website with quick access to South Bay water quality and La Jolla focus areas.

Online data access includes the following:

- Observational Sites
  - Coronado Islands
    - Meteorological Station
    - HF Radar Site
  - Imperial Beach Pier
    - Meteorological Station
    - Water Temperature Profile
    - Web Camera

- Scripps Pier
  - Water Temperature Profile
  - Wave Data
  - Web Camera
- South Bay Ocean Outfall
  - Current Profile
  - Water Temperature Profile
  - Buoy Location
  - Historical Buoy Data
- Tijuana River
  - Near-shore Currents
  - IBWC Flow Gauge
  - Plume Tracking

- Regional Data
  - Area of Biological Significance
  - Bathymetry
  - Satellite Imagery
    - Ocean Colour Monitor
    - Moderate Resolution Imaging Spectroradiometer
    - Geostationary Operational Environmental Satellite
  - Surface Current Mapping
  - Tides
  - Water Quality
  - Wave Conditions
  - Weather Forecasts
  - Wind Forecasts

3. Surface Current Data Used for Particle Trajectories and Integration with Data

CORDC at SIO maintains an experimental near-real-time Tijuana River plume tracking model that is publicly available online. This model utilizes HF-radar-derived surface currents to advect simulated particles from the mouth of the Tijuana River to regions along the coast. The DEH uses this information to assist in its beach closure and advisory efforts. Following a rain event, health officers are better able to adaptively sample and guide recommendations for closures based on where the model shows plume impact. CORDC staff has integrated DEH repetitive sampling locations into the display as shown in Figure E.4.

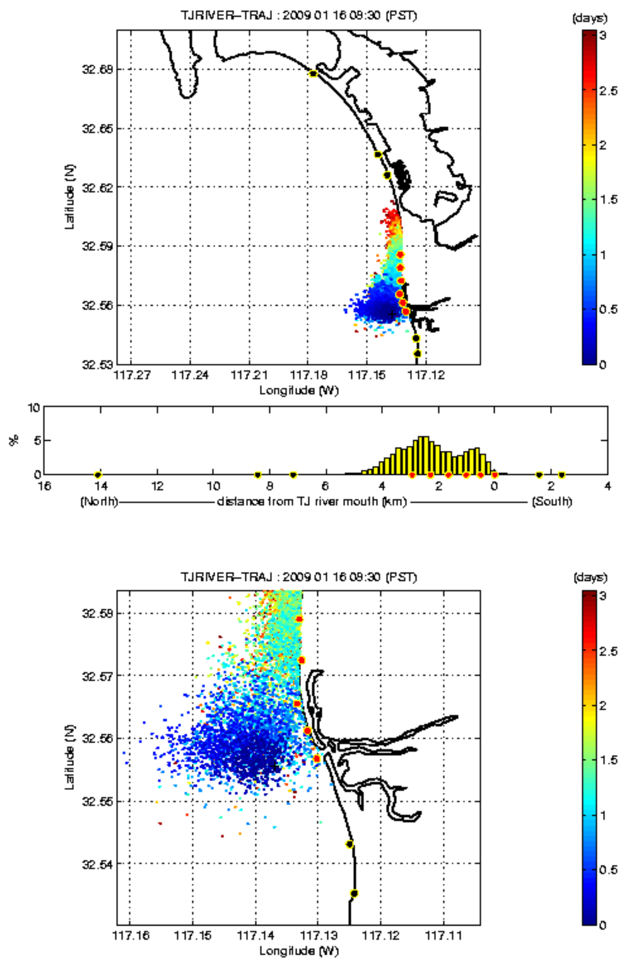


Figure E.4 Tijuana River Plume Tracking Model
(top) Tijuana River plume tracking model showing highlighted DEH stations with plume potential impact. Particles are color coded based on age (0-3 days). (bottom) Tijuana River estuary zoomed region.

Maps of ocean surface currents measured by the HF radar array are used to compute trajectories from the point discharges in the study region to assess the potential exposure of plume water to different locations within the receiving waters. A data-driven model of the transport of shoreline and offshore discharges was developed and operated in a hindcast mode using data collected over the time period of the supplemental monitoring program. A statistical analysis of the time-dependent trajectories from the regional discharges was conducted. Because not all of the regional discharges are continuous, only times of surface water discharge are used for this analysis.

a) Description of the Discharges

The three regional discharges that were considered for this study are listed in Table E.1.

Sources	Location		Discharge type	Flow rate ($m^3\ s^{-1}$ (MGD))
	Longitude (W)	Latitude (N)		
TJR	32.5556	117.1369	Wet season	$\sim$ 2.9 (66)
SBO	32.5373	117.1835	Plume surfacing	$\sim$ 0.9 (20)
PBD	32.4336	117.1100	Continuous	1–1.5 (22-35)

Table E.1 Potential FIB Sources
The potential sources of FIB in southern San Diego are summarized with location, discharge type, and flow rate (in mgd): Tijuana River (TJR), South Bay Ocean Outfall (SBOO), and Punta Bandera discharge (PBD). The wet season indicates the time period from November to March.

For the plume connectivity estimates, only time periods of when the discharge source was active were considered. As such, the environmental conditions that trigger a discharge were considered.

(1) Submerged Discharge: South Bay Ocean Outfall

The dynamics of the plume are controlled by the outfall design and density structure with depth in the near-field and with the ocean variability in the far-field (for example, winds, tides, along-shore pressure gradients, and internal waves). The EPA RSB plume model was used to predict the height of the plume and the potentials for active surfacing within near-field (Roberts et al. 1989, Roberts 1999a, Roberts 1999b). For tracking the fate of the surfaced plume, only time periods of active surfacing, previously identified in Section D.5, were used.

(2) Coastline Discharge: Punta Bandera

The Los Buenos Creek continuously discharges 0.97–1.46 m^3/s of minimally treated sewage effluent from the San Antonio de Los Buenos Sewage Treatment Facility near Tijuana (Svejkovsky and Jones 2001, Orozco-Borbon et al. 2006). The latter reference reports that the higher bacteria concentration near the PBD is due to the treatment facility, and also mentions that the impaired water quality at the U.S.–Mexico border dominantly resulted from the TJR not the PBD. Since Punta Bandera is a continuous discharge, no time-dependent, conditional trigger for the source is necessary for the plume exposure analysis.

(3) Coastline Discharge: Tijuana River

The Tijuana River drains precipitation from a binational watershed approximately 4,440 km^2 in size. The climate is Mediterranean, with average precipitation levels of 150 millimeters per year (mm/year), but ranging from 150 to 650 mm (levels quoted by EPA: http://epa.gov/region09/water/watershed/tijuana.html). Due to the intermittency of rainfall, and otherwise dry and semi-arid climate, the river is nominally dry, interspersed with flood events driven by local rainfall.

A multi-year analysis of the daily flow rate of the Tijuana River, as measured by the IBWC gauge at Dairy Mart Road, and daily rainfall measured on the U.S. side of the border at San Diego Lindbergh Field is shown in Figure E.5. Analysis was conducted using rainfall data from the Tijuana River Natural Estuarine Research Reserve (NERR) and a rain gauge at the end of the Imperial Beach Pier with similar results (not shown). The scatter in the figure is attributable to several factors. First, the IBWC gauge was designed and intended to be accurate for large flow or flood events. Secondly, the Tijuana River flow is variable in its response to precipitation, and finally a single rain gauge on the U.S. side of the border is not an accurate proxy for total precipitation loading the watershed. Despite the scatter (most dominant at the low rain/flow events), there is a clear trend between amount of rain and flow levels out of the Tijuana River. The watershed and estuary is assumed to take 7 days to drain rainwater that may have high FIB.

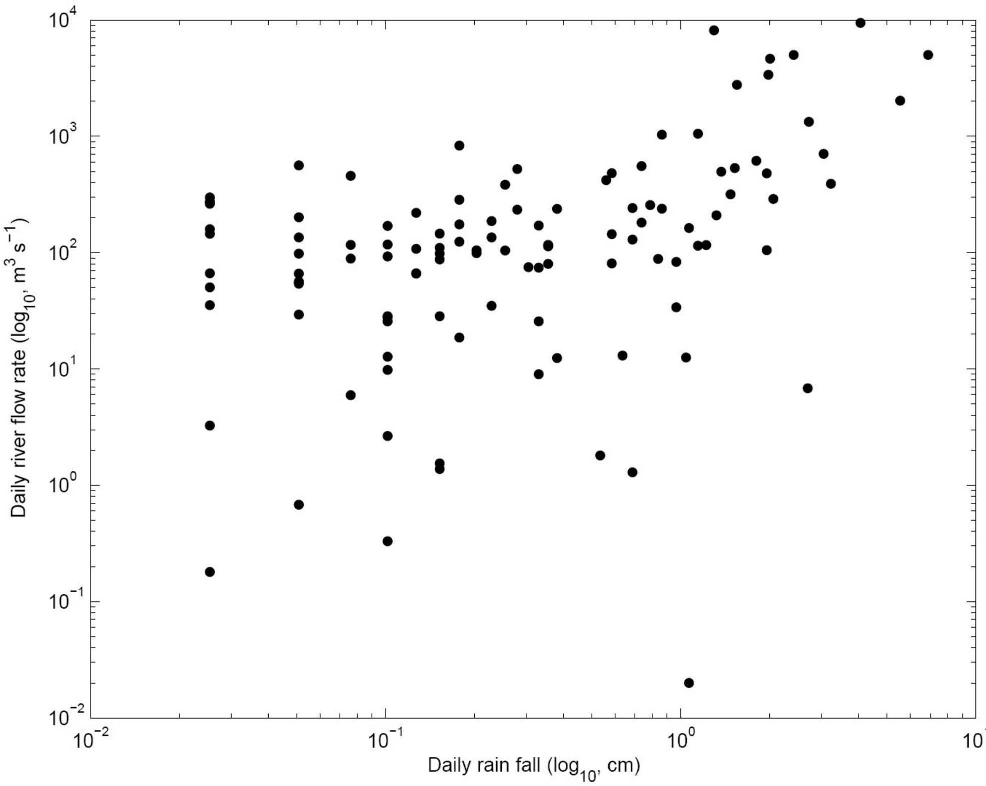


Figure E.5 Tijuana River Gauge Flow Rate
Flow rate measured at the IBWC Tijuana River gauge versus daily rainfall measured at San Diego Lindbergh field. The graph illustrates the response of the watershed to precipitation. The scatter within the data is attributed to the river gauge poor low-flow response and poor representation of the total precipitation loading the watershed by a single rain gauge on the U.S. side of the border while two-thirds of the watershed is in Mexico.

b) Shoreline FIB Sampling

The FIB sampling locations in the cross-border region are summarized in Table E.2. Their locations are shown, ordered by a unique shore station identification designation, shown in Figure E.6. These data are provided by San Diego County DEH as part of its AB 411 (Statutes of 1997, Chapter 765) ocean sampling program, as well as the City of San Diego Wastewater District, which monitors the SBOO for the NPDES permit both under contract to the IBWC and for the City's co-located water reclamation plant. Although the water quality data at C1 and C14 stations are identified, those data are not included in this analysis because the stations were sparsely sampled compared to the other stations. The FIB sampling and processing were conducted using accepted standards and protocols on a scheduled basis, except for targeted shoreline samples by the DEH during suspected contamination events such as the dry weather events (see Section IV).

Water quality standards in the State of California Health and Safety Code (AB 411) establish a set of criteria for identifying a human health risk. These criteria are based on a single sample result for Total Coliform (TC, c1), Fecal Coliform (FC, c2), and Enterococcus (ENT, c3), as well as on the ratio of FC to TC. The exceedance relations are posed as a water quality indicator (g) with a binary state – clean (C) or contaminated (D):

$$g = \{g|c_1 > 10000, c_2 > 400, c_3 > 104, \left(\frac{c_2}{c_1} > 0.1\right) \cap (c_1 > 1000)\},$$

where c1, c2, and c3 indicate the amount in 100 ml, measured in CFU for TC and FC and in MPN for ENT.

ID	City ID	County ID	Station name
C0	S0	BC-010	Playa Blanca
C2	S2	BC-020	El Vigia
C3	S3	BC-030	Playas de Tijuana
C4	S4	IB-010	Border Fence
C5	S10	IB-020	Monument Road
C6	S5	IB-030	Tijuana River Mouth
C7	S11	IB-040	3/4 miles North of Tijuana River
C8	S6	IB-050	End of Seacoast Drive
C9		EH-010	Cortez Avenue
C10		EH-020	Imperial Beach Boulevard
C11		EH-030	Imperial Beach Pier
C12	S12	IB-060	Carnation Avenue
C13		EH-041	Camp Surf Jetty
C15	S8/D2	IB-070	Silver Strand Beach
C16	S9/D3	IB-080	Avenida del Sol
C17		EH-050	Loma Avenue
C18		EH-060	Navy Fence

Table E.2 Shoreline Sampling Stations
Shoreline Sampling stations (City and County ID codes) and their station names for the U.S.-Mexico border region. Locations are shown in Figure E.6.

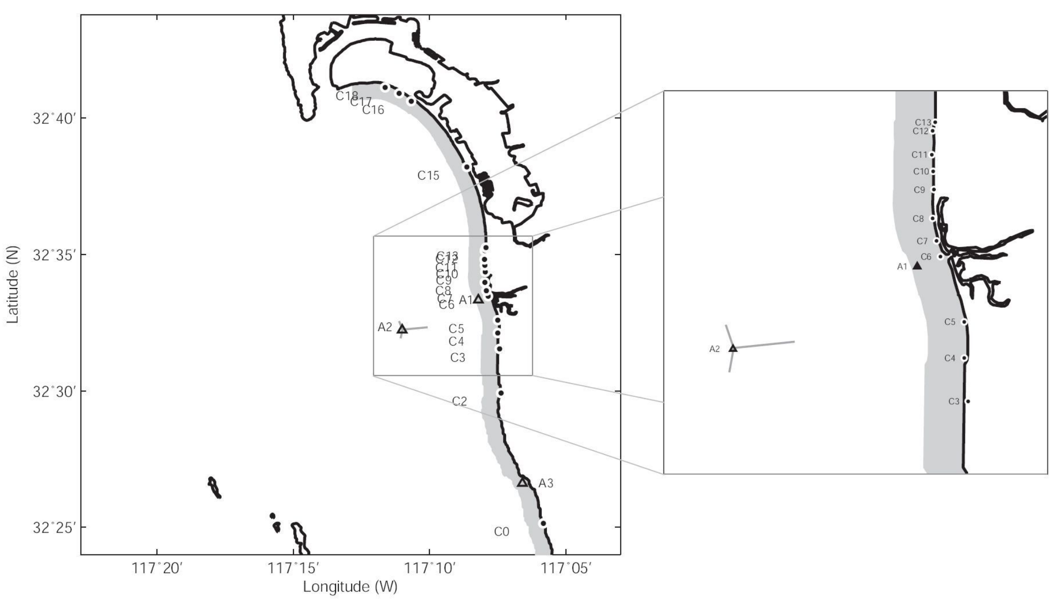


Figure E.6 Shoreline Sampling Locations
Shoreline sampling locations for FIBs in the west coast U.S. – Mexico border region.

c) Summary of FIB Exceedances, Rainfall, and River Flow

A summary of FIB exceedances for each sampling station, rainfall, and river flow is provided in Figure E.7 for the duration of the supplemental monitoring program. The top panel of the graph presents exceedance data for 2007 and 2008 as a function of each station. The dots represent that a sample was taken with no FIB exceedances. The red triangles indicate that exceedances occurred. The middle panel presents hourly rainfall, and the lower panel is the flow rate. The figure illustrates the high correspondence of wide area FIB exceedances associated with rainfall and TJR flow events during the November through March wet season. Ninety-four percent of the exceedances (a total of 81) are found to occur when there is measurable flow from the TJR. Five additional exceedances occurred at single stations (neighboring stations were not in exceedance) during periods not associated with rain or river flows.

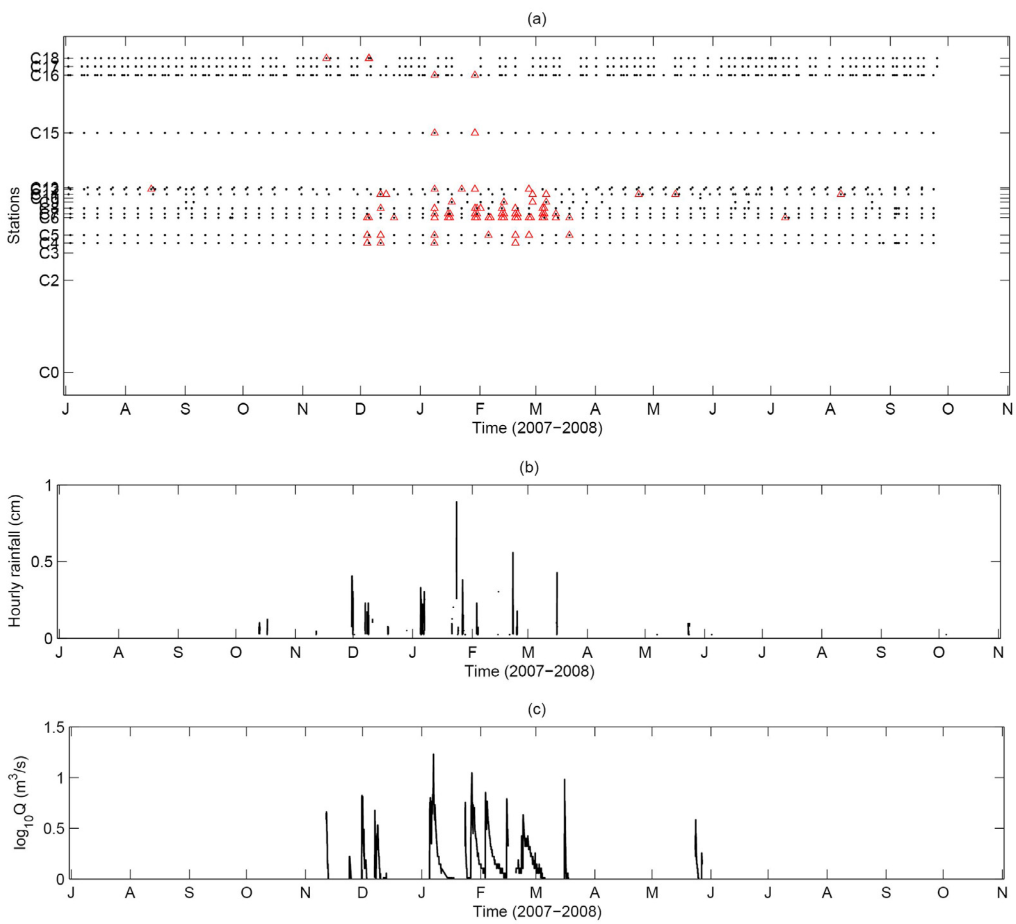


Figure E.7 Water Quality Data – July 2007-November 2008
(top panel) Water quality sampling data along the U.S. – Mexico border for the time period of the supplemental monitoring program (July 2007 through November 2008). The triangles and dots indicate FIB exceedances and clean conditions based upon the FIB criteria respectively. (middle panel) Hourly cumulative rainfall (cm) measured at San Diego Lindbergh Field. (bottom panel) Daily Tijuana River flow (m^3/s) presented on a logarithmic scale.

d) Trajectory Analysis Using Random Walk Model (RWM) - Background

The framework of this analysis is based upon the application of a time-domain integration of velocity data to track where parcels of water move within the changing circulation patterns in the U.S.-Mexico border region. A random-walk approach is used to account for small-scale velocities not resolved by the surface current mapping radar systems and the velocity uncertainty associated with those measurements. In numerical hydrodynamic models, the former is often referred to as sub-grid scale motions (such as those fine-scale motions whose physics are not resolved). Assumptions of Gaussian spreading of a tracer (in air or water) are an example of using a simplified model to approximate sub-grid turbulent motions.

For the hindcast model used in this analysis, the forward particle trajectory in the finite time domain is calculated as:

$$\mathbf{x}(t) = \int_{t_0}^{t} \left(\mathbf{u}(t') + \varepsilon e^{i\theta}\right) \mathrm{d}t' + \mathbf{x}(t_0)$$
$$\approx \sum_{k} \left(\mathbf{u}(t_k) + \varepsilon e^{i\theta}\right) \Delta t_k + \mathbf{x}(t_0),$$

where x(t) = $x(t) + iy(t)$ and u(t) = $u(t) + iv(t)$ denote the location of the particle and the surface currents at the particle location at a given time (t), respectively. θ is a uniformly distributed random variable ($0 \leq \theta \leq 2\pi$).

Expression of the RWM in this way preserves the shape of the power spectrum of the original current field. The diffusion parameter (ε) in the above equation represents the uncertainty in the HF radar measurements and is chosen based upon previous studies examining differences between radar-derived velocities, drifters, and point measuring current meters. These reports suggest that $\varepsilon = 5\ m^3/s$ is a reasonable value. The procedure used to statistically assess where plume water is transported was to release a large number of numerical tracers (particles) and track their positions with each hourly time step. The hourly time step was chosen to coincide with the hourly maps of new surface current information resolved by the radar systems over the time period of this supplemental study. Statistics of the distribution of these numerical tracers were then computed to infer a probability of exposure for a given discharge based upon where those tracers were transported during the study.

The RWM was applied to investigate the statistics of the particle transport for the three regional discharges. For this study, all discharges are assumed to be passive with no dynamical impact to the flow, allowing the mapped surface currents to be the initial current field into which the discharge occurs. Fifty particles were released hourly at each source location for 2 years of data. In the case that the particle crossed over the coastline boundary in a given current field, the trajectory was recalculated by applying the along-shore currents to constrain the particle to follow the coastline. Particles are tracked for 3 days, which is consistent with the estimated lifetime of FIB (Griffa et al. 1995, Griffa 1996, Siegel et al. 2003). No time-dependent decay of FIB was used for the analysis because the goal was to examine the plume water exposure probability as opposed to predicting FIB concentrations. To estimate FIB concentrations, their initial concentrations within the discharge would be required, which was deemed too uncertain to attempt their usage.

Two snapshots of output from the trajectory model applied to the Tijuana River discharge are shown in Figures E.8 and E.9. A histogram of the particle concentration within the near-coast cell – an along-shore band extending 1 km from the coast (shaded area in Figure E.8) – is also shown. Because the Tijuana River was found to be a leading contributor to FIB exceedances in the Imperial Beach region, the trajectory model was implemented in a near-real-time basis for use by the County DEH. The weblink to the near-real-time TJR plume tracker is http://sdcoos.ucsd.edu/data/particles/IB/. The DEH uses this information to assist in its beach closure and advisory efforts. Following a rain event, health officers are better able to adaptively sample and guide recommendations for closures based on where the model shows plume impact. CORDC staff has integrated DEH sampling locations into the display, and those locations are highlighted if there is a non-zero probability estimate for the presence of plume water.

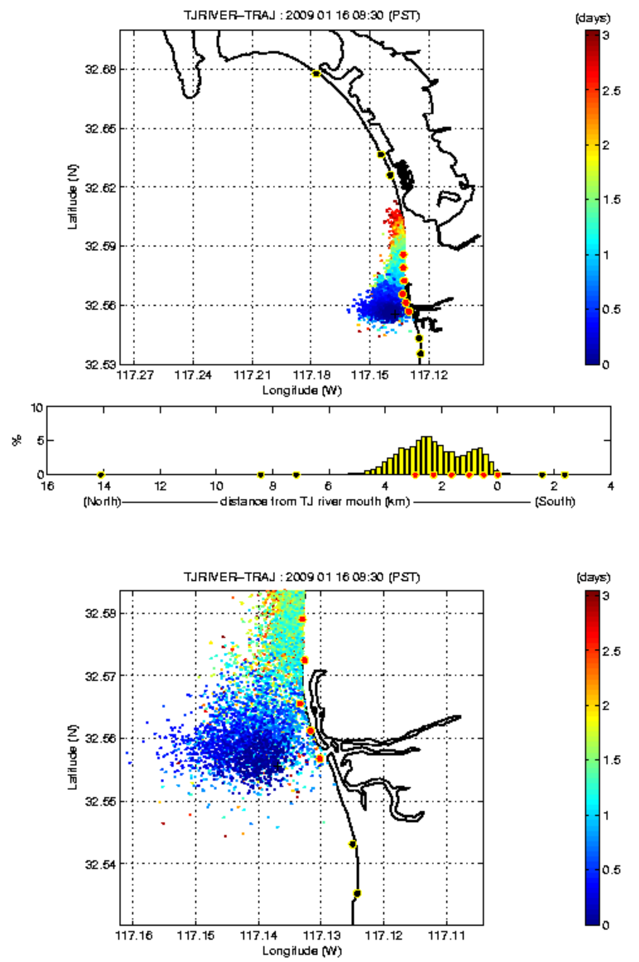


Figure E.8 Tijuana River Plume Tracking with DEH Stations
(top) Tijuana River plume tracking model showing highlighted DEH stations with plume potential impact. Particles are color coded based on age (0-3 days). (bottom) Tijuana River estuary zoomed region.

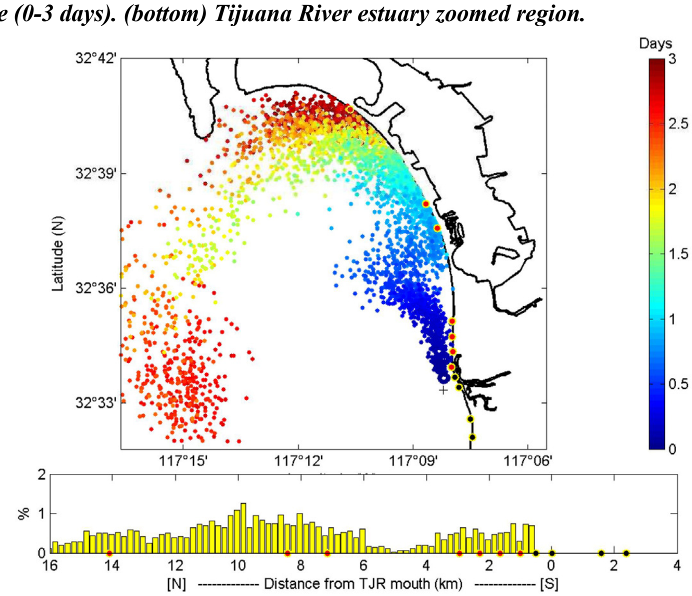


Figure E.9 Trajectory Model Output
Another example of the trajectory model applied to the Tijuana River during a rain event. In this example, the plume is found to extend north toward Point Loma.

e) Verification of the Trajectories

The viability of using the RWM for tracking parcels of water has been tested in other contexts, including the comparison against drifters and dye for oil spills and water quality studies (Ohlmann et al. 2007, Clifton et al. 2007, Payne et al. 2007). An example of the performance of the model to place Tijuana River plume water coincident with time periods of FIB exceedances is shown in Figure E.10. The data are for a time period between April 17 to 29, 2004. The top panel presents the shoreline station data as either exceedances (red triangle) or no exceedances (blue). The y-axis is an along-coast distance, with S4 representing the City sampled station at the border fence, with numerically increasing stations representing sites north, and lower-numbered stations south of the border. The black/grey areas of the figure represent a probability of water parcels (random walk particles) that originate at the Tijuana River to any point along the coast. The lower panels present rainfall and flow rate data. This 12-day example illustrates how a hindcast analysis of the discharge could be used to assess along-coast plume exposure.

f) Synthesis of the Model Output

A time-averaged synthesis of the particle trajectories are used to construct two statistically-derived products to describe the potential for surface transport of the regional discharges to reach neighboring regions. These two probabilities are referred to as a Coastal Exposure Map (CEM) and Shoreline Exposure Map (SEM) and are described in the following sections:

g) Coastal Exposure Map

The coastal exposure map (p, CEM) of each source is the *spatial* PDF of the plume within the receiving waters, and is calculated as

$$p_k(x,y) = \frac{q_k(x,y)}{\max(q_k(x,y))} \times 100,$$

where

$$q_k(x,y) = \frac{N_k(x,y)}{\sum_{\forall x} \sum_{\forall y} N_k(x,y)}$$

and $N_k(x;y)$ denotes the number of particles in space (x;y) for the k-th source. The numerical bookkeeping for this computation is conducted for all release periods from a source for the time period of the study.

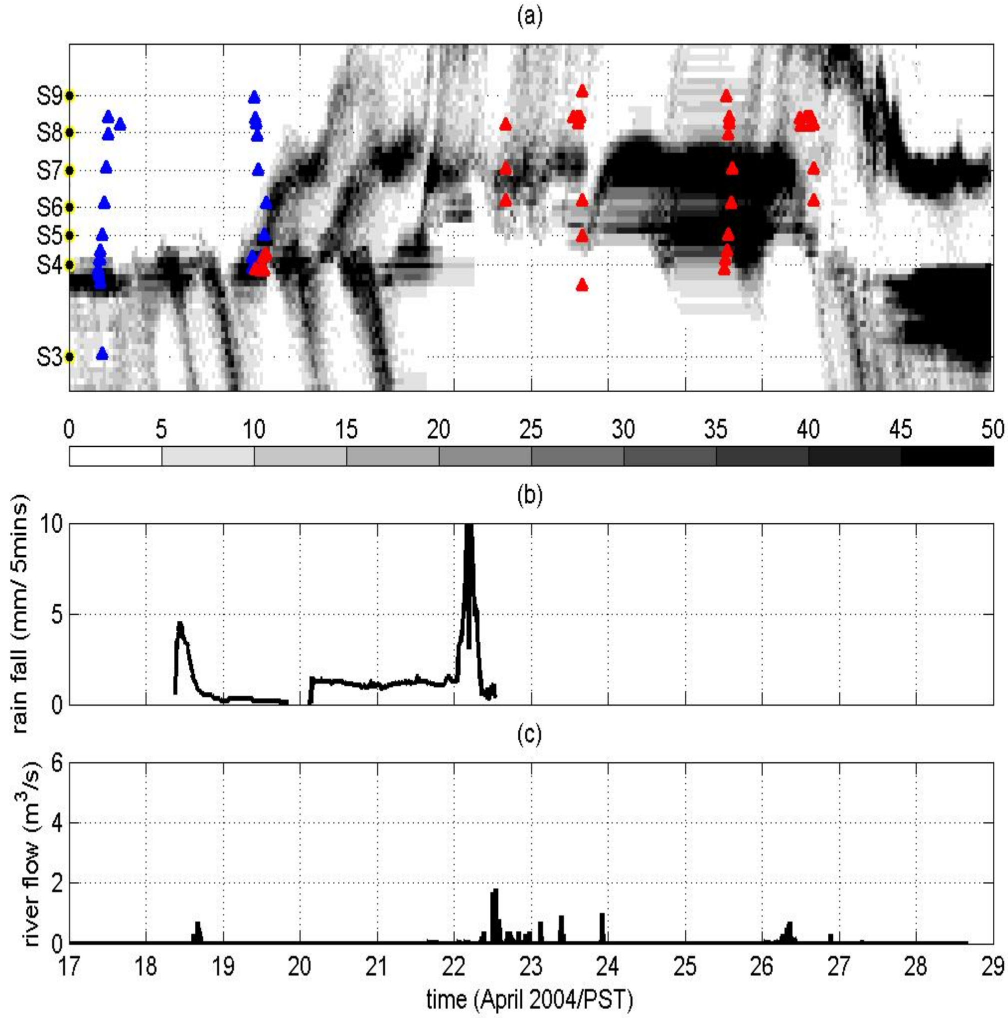


Figure E.10 Random Walk Plume Trajectory – April 17 and 29, 2004
An example output of the random walk plume trajectory model for the Tijuana River between April 17 and 29, 2004. (a) Station FIB exceedances data from County and City shoreline monitoring program (red triangle – exceedances, blue triangle – clean). Also superimposed on the graph are the number of plume water 'particles' that were tracked using a random walk model. Fifty particles/hour are discharged from the Tijuana River and advected using circulation maps generated by the HF radar systems. (b) Rainfall rate in mm/5-minute increments and (c) River flow in m^3/s.

h) Shoreline Exposure Map

In a similar way, the shoreline exposure map (p^*, SEM) is the probability of plume water from a particular discharge present in a strip of water *along* the coast and is given as

$$p_k^*(l) = \frac{q_k^*(l)}{\max\left(q_k^*(l)\right)} \times 100,$$

where

$$q_k^* = \frac{f_k(l)}{\sum_{\forall l} f_k(l)}.$$

and $f_k(l)$ denotes the number of particles at the location l within the near-coast cell for the k-th source.

The particles, counted to derive plume probability statistics within the near-coast cell, are counted using the projection to a piece-wise linear approximation of the coastline boundary. The along-shore width (w) of the near-coast cell is set to 200 m to collect particle statistics of the probability of the discharge and to understand upcoast/downcoast transports in time. The bins of the CEM and SEM are a square box of $0.2 \times 0.2\ km^2$ and a rectangular box of $0.2 \times 1\ km^2$, respectively. The CEM is normalized by the number of particles at the source location or maximum, and is contoured at 100, 90, 80, 70, 50, 25, 10, 5, 2.5, 1 percent, and fractional percentages.

The SEM is made for the count of particles in the near-coast cell – the sum of the hourly/instantaneous histograms (shown in example plume trajectories), and is normalized to a maximum of 1. This procedure is intended to allow rapid examination of how a discharge may expose itself along-coast, but should be used with caution if relative impacts of different sources are desired since the volume of the discharge and concentrations of contaminants within the discharge can vary. The statistics of particles within the near-coast cell are computed using a piece-wise linear method that considers the curvature of the coastline. In summary, the CEM is the probability of exposure within the receiving waters, and the SEM is the relative probability of exposure along a linear stretch of coastline. Both probability maps are for when the sources are active (in other words, how the plume might expose itself when the discharge is active).

i) Results

South Bay Ocean Outfall

The Coastal and Shoreline Exposure Maps describing the statistics of surfaced SBOO plume water are presented in Figure E.11. As summarized in Section D.5, the discharge plume was estimated to surface 98 discrete days representing 26 percent of the days in a calendar year. The CEM (left panel) illustrates how the general orientation of the plume is biased south as a result of mean flow conditions in the area. Elevated percentages at the coastline are a result of increased residence time of the tracers of water when they flow to the coast. These coastline levels have probabilities of approximately 10 to 15 percent. No FIB exceedances were found to correspond with these events. The Shoreline Exposure Map (right panel), presents the relative along-coast probability of the plume water on the y-axis as a function of along-coast distance. The values are scaled to 100 percent so that along-coast variations are visible. The station codes represent where shoreline FIB data are collected (see Table E.2 and Figure E.6). The three vertical lines on the graph indicate the along-coast location that Punta Bandera, SBOO, and TJR discharge respectively.

Punta Bandera

The exposure maps for Punta Bandera are presented in Figure E.12. Both maps illustrate how the dominant southward flow along the coast dominates the statistical distribution of the plume. The offshore transport is a result of eddies that can move the plume water offshore. Statistically, these are not common events. The SEM shows a peak at the discharge location (blue vertical line), with the dominant exposure to the south. The exposure to the north results in the plume to track north of the border approximately 12 percent of the time.

A time series of the along-coast plume water statistics is presented in Figure E.13 to illustrate the intermittency of the northward plume transport events. The time series presents the relative particle statistics output from the RWM as a function of latitude. Reference lines for the discharge source (red) and the U.S.-Mexico border (blue) are shown. Analysis of the statistics indicate that plume water had the potential to move north across the border 15 discrete times for a total of 60 days out of the 490 days of the supplemental monitoring program. The northward flow events do not appear seasonal, since eight events (total of 24 days) occurred in summer and seven events (total of 36 days) occurred in winter.

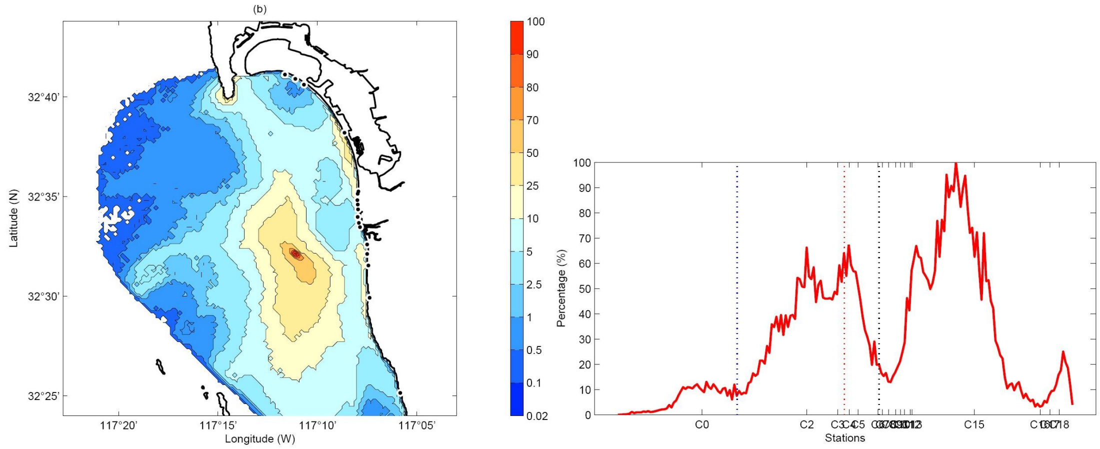


Figure E.11 SBOO CEM

(left). The Coastline Exposure Map (CEM) for the SBOO. The figure presents probability estimates of the existence of plume water when the discharge surfaces. The computation is only done for those days that the plume surfaces (see section D5. (right). Regions of elevated statistics on the shoreline are a result of high residence time regions and are more clearly identified in the Shoreline Exposure Map (SEM). The SEM, normalized to 100%, shows the relative along-coast statistics. The horizontal axis is distance along coast, with station C0 representing Playa Blanca to the South and C18 the Navy Fence station to the north.

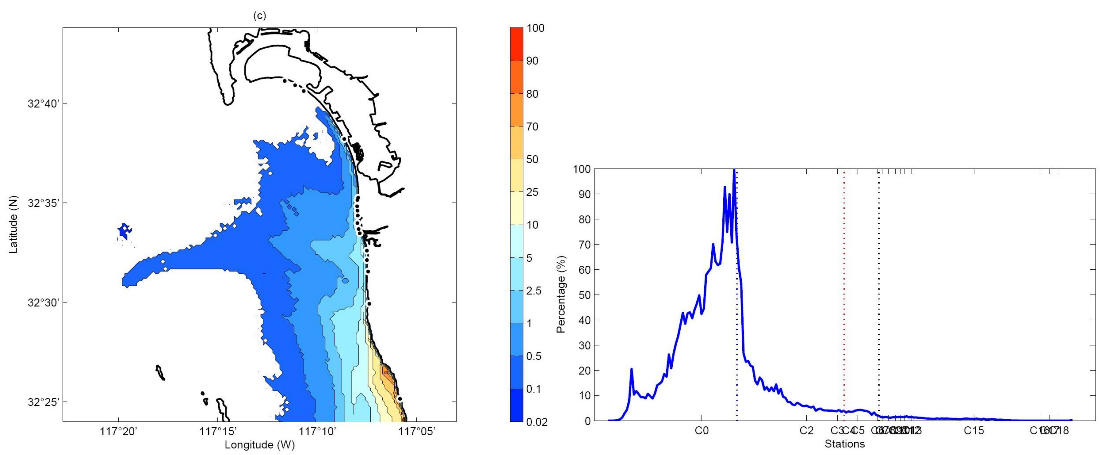


Figure E.12 Punta Bandera CEM

(left). The Coastline Exposure Map (CEM) for the Punta Bandera discharge. Punta Bandera is a continuous discharge. The flow is dominant south, with northward plume exposure to the coastline north of the U.S.-Mexico border occurring approximately 12% of the time during the study period.

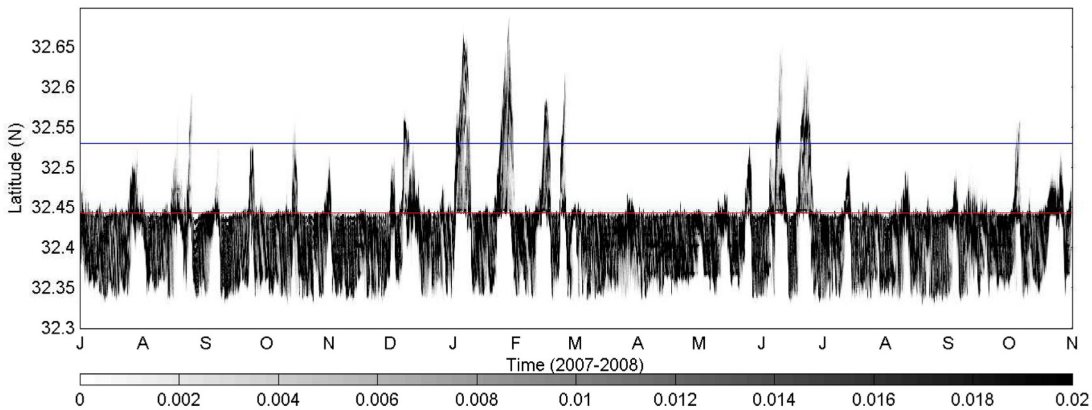


Figure E.13 Punta Bandera Plume Water Statistics
Along-coast plume water statistics for the Punta Bandera discharge as a function of latitude during the July 2007 through November 2008 period of the supplemental monitoring program. Plume water from the coastline discharge was found to move northwards

Tijuana River

The exposure maps for the Tijuana River are presented in Figure E.14 and represent time periods when flow was present (Figure E.7). The discharge is noticeably different from the Punta Bandera discharge in that its offshore extent is greater and its along-coast exposure is significantly more balanced to both the north and south. These features are attributed to intermittent offshore eddies (see Introduction and Figure E.4), which are efficient at transporting material. The northward exposure of the plume, estimated by the RWM, is consistent with FIB exceedances occurring at the northern shoreline water quality stations (Figures E.7 through E.10).

The offshore and along-coast exposure of the Tijuana River plume water is supported through the examination of ocean color satellite remote sensing imagery. CORDC has access to high resolution (250 m) ocean color data from the Ocean Color Monitor (OCM) sensor onboard the Oceansat-1 satellite operated by the Indian Space Agency. The ocean color channels are similar to that available from the National Aeronautics and Space Administration (NASA) SEAWIFS and MODIS satellites, but with higher resolution than the -km data provided by those instruments.

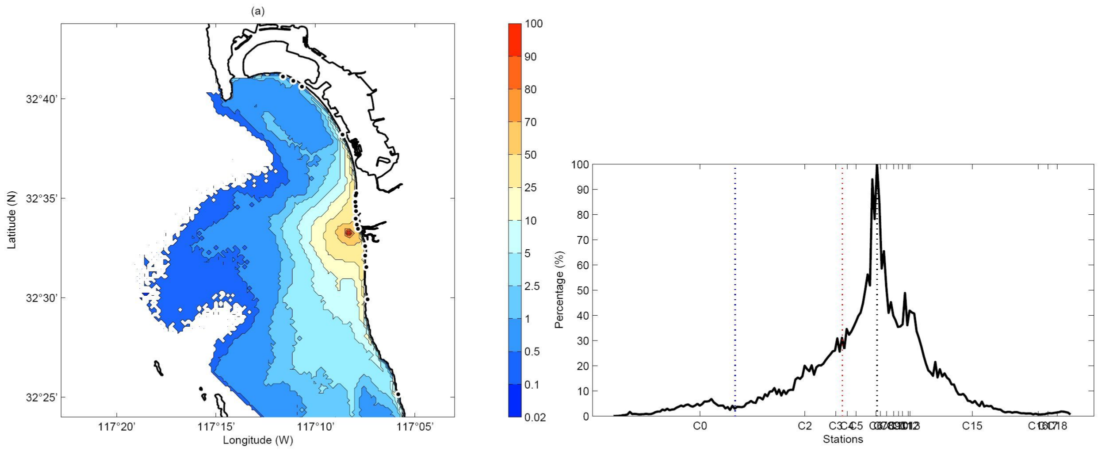


Figure E.14 Coastal and Shoreline Exposure Maps
The Coastal Exposure (left) and Shoreline Exposure (right) Maps for the Tijuana River discharge. In contrast to the Punta Bandera discharge, the Tijuana River exhibits a broader exposure of its plume both offshore and north of the river mouth.

Satellite remote sensing of ocean color by OCM provides valuable information on the spatial extent of the Tijuana River plume following rainstorms. Clear imagery is available for several Tijuana River sampling dates while, in other cases, imagery is available a day or two prior and/or after sampling. Remote sensing imagery provides large-scale context for spatial patterns observed from sampling in situ. It also offers insight into flow dynamics based on features present. For example, imagery was available on January 29, 2008, when shoreline salinity and FIB sampling were conducted (see Sections A.22 through A.24). The in-situ sampling suggests that the river plume advected northward to Coronado. Satellite remote sensing estimates of total suspended sediment concentration supports the observations in situ while suggesting that the plume might be recirculating inshore of Point Loma.

MODIS imagery was found to be too coarse in resolution for detecting the Tijuana River plume. However, sea surface temperature (SST) imagery from MODIS has proven useful when integrated with the SBOO buoy and IB pier temperature profiles for determining regional conditions associated with upwelling. Examples of this integration are given in Section IV.7.

Maps of total suspended matter (TSM) and chlorophyll-A during a storm event on January 26, 2005, are shown in Figure E.15, which qualitatively illustrates how the TJR plume can extend far offshore, consistent with the exposure map analysis.

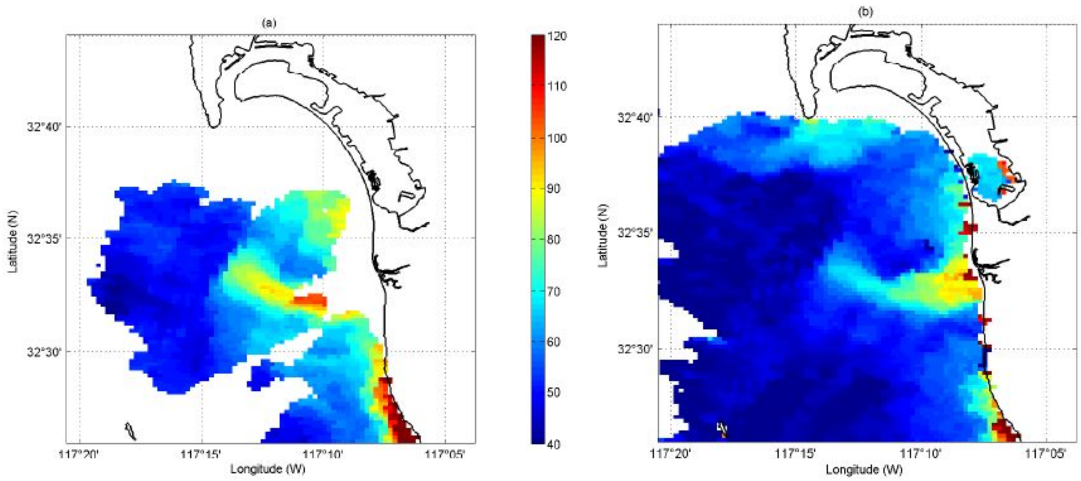


Figure E.15 Tijuana River Offshore Transport
An example of the offshore transport of TJR plume water as observed by satellite ocean color products. (a) Total suspended matter (mgL^{-1}) and (b) Chlorophyll-a (mg/m^{3}) during a heavy rain event on January 6, 2005. The white gaps shown on the left panel are a result of the TSM algorithm (a proxy for turbidity), not able to work in the dense plume water near the coast. While inaccuracies probably exist in the interpretation of satellite-derived Chlorophyll levels, the map illustrates the offshore extent of a plume whose origin is in the TJR.

j) Summary

Presented is an analysis to generate a statistical description of the surfaced SBOO plume, the Tijuana River plume, and the Punta Bandera plume. The description provides a framework for assessing the surface waters and shoreline that may be exposed by the individual discharges. Each statistical description is normalized based upon the time that the individual discharge was active using supporting environmental data gathered as part of the supplemental monitoring program. The hindcast analysis on which the descriptions are based use the surface current mapping radar data, which was found to provide skill in predicting coastal FIB exceedances for plume water exiting the Tijuana River. The present framework excludes any mechanism for transport within the surfzone, which would provide additional fidelity in tracking plume water bounded by the coast.

To assess the annual probabilities of the discharge plume exposure to points on the coast, the Coastal Exposure Maps (Figures E.11, E.12, and E.14) are normalized by the number of days the source is active for an annual wet/dry season cycle and presented in Figure E.16. While the Punta Bandera discharge is assumed to be continuous, the Tijuana River and surfacing of the SBOO are seasonal and intermittent. For the supplemental monitoring program, this figure is made for the period between October 2007 and September 2008. These scaled shoreline exposure maps, with units of % exposure per time, provide some insight into the relative probabilities that plume water may present itself to a particular region of the coastline. Similar to the previous exposure maps presented in this section, their interpretation must be used with caution because the maps do not reflect dilution that may occur within the plume and do not represent the spatial extent of the detectable limits of the plume. The maps are presented for the total annual cycle, and for the summer and winter months. The figures suggest the following:

- The continuously discharging Punta Bandera plume has annual and seasonal statistics indicating that it can reach north of the U.S.-Mexico border with annual statistics similar to Tijuana River and SBOO.
- The probability of the Tijuana River plume is larger than the SBOO for the majority of the coastline.
- The probability of the SBOO during summer months is typically less than 0.1 percent, while in winter it could be 2 to 6 percent. An elevated probability of SBOO plume water exists near Station C15 (Silverstrand), potentially as a result of persistent eddies in the area.

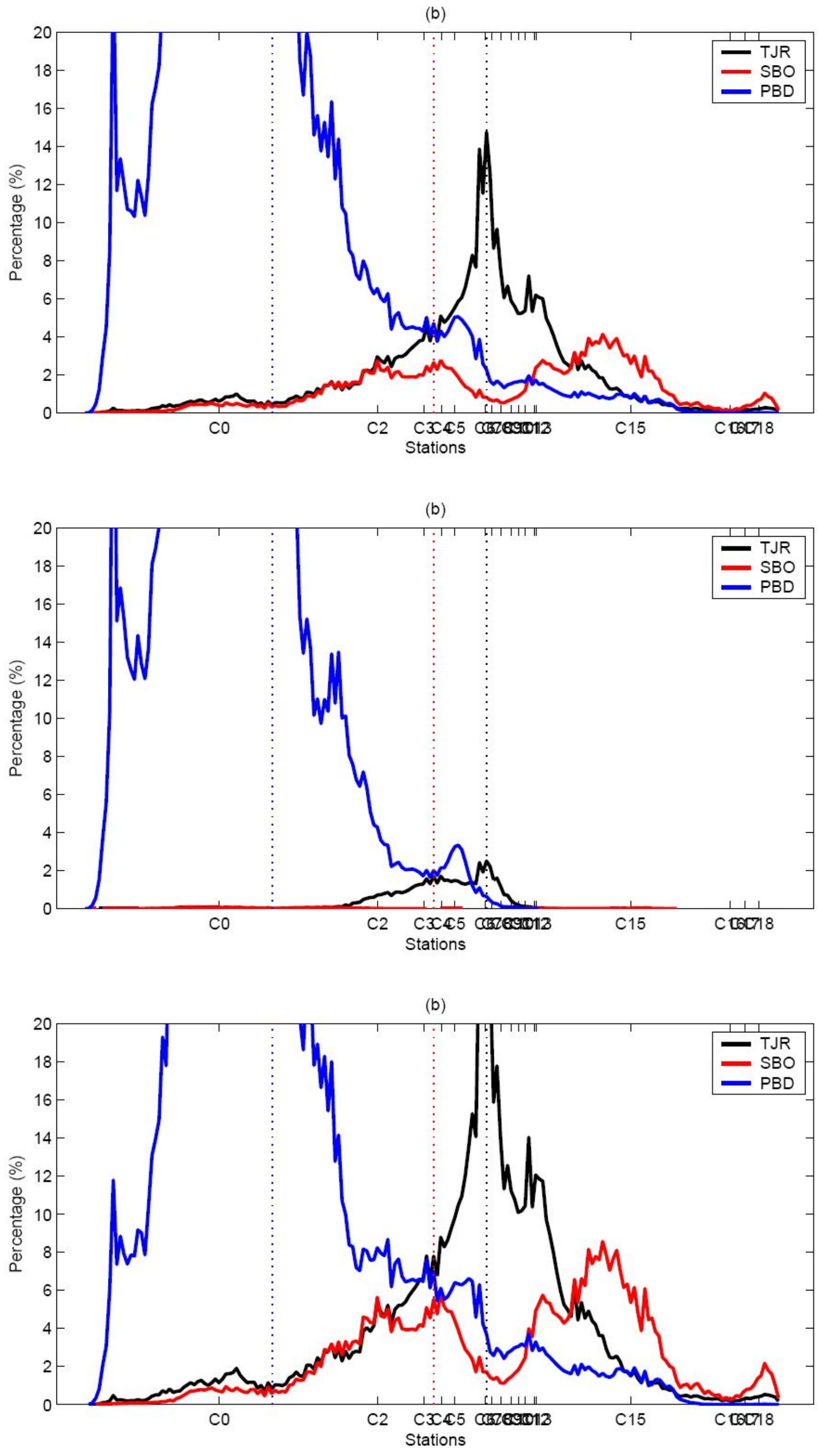


Figure E.16 Shoreline Exposure Maps

Shoreline Exposure Maps scaled by the number of days the particular discharge is active (TJR, SBOO, and PBD). a)The annual exposure. b) The scaled exposure maps for summer. c) The scaled exposure maps for winter. Note that the y-axes in the figures are 0 to 20% to emphasize the relative differences between the discharges. For reference, the U.S.–Mexico border is between Stations C4 and C5.

F. Development of Indicator Studies to support Source Identification and Discriminate Plume Water (SS7)

1. Overview

The *primary* goals of this effort were to perform source tracking of the bacteria and water masses by evaluating the most likely sources of contamination on Imperial Beach and by providing tools that will provide rapid evaluation of possible contamination without having to wait for the results from microbial analyses.

The approaches used in this effort to evaluate source water are based on previous work by our group that focused on evaluating sewage plumes (Petrenko et al. 1997, Jones et al. 2002) and stormwater plumes (Washburn et al. 2003, Reifel et al. 2008).

Using physical, optical, and microbial measurements, we characterized the water-mass variability and the possible human sources of microbial contamination in the South Bay during four different surveys that included a winter runoff event.

2. Methods

a) Water Column Characterization

Water-mass variability was characterized with a Sea-Bird 49 CTD measuring conductivity, temperature and depth. In addition to the physical variables, optical variables were obtained to provide additional information about the environment that could help to resolve water mass sources in the local region. The optical sensors included a WETLabs ECO FL3 (three-channel fluorometer) and a WETLabs ECO BB3 (three-channel optical backscatter). The calibrations were based on factory sensor calibrations (CTD from Seabird Electronics, and the FL3 and BB3 sensors by WETLabs).

The data were telemetered via a WETLabs DH-4 data handler. Power was provided to the profiler using a WETLabs Power Communication and Conversion System (PCCS). Data from the various sensors was acquired and merged using the WETLabs Archive Processing (WAP) program.

Optical backscattering was obtained at three wavelengths (532 nm, 660 nm, and 800 nm). The goal of using these three wavelengths was to minimize the effects of optical absorption by water and its constituents. The ratio of optical backscatter at 532 nm to optical backscatter at 880 nm is used as an index of the particle size distribution. Typically, optical backscatter spectrum decreases approximately exponentially with increasing wavelength. The shape of this spectrum is a function of the particle size distribution (Twardowski et al. 2001). The greater relative abundance of smaller particles increases the scattering at shorter wavelengths. Thus, a higher ratio of bbp532/bbp880 indicates relative increase of smaller particles, while a lower value of the ratio indicates a shift toward larger particles.

b) Microbial Detection and Identification

Bacteroides

Samples Preparation

All samples were filtered onto 47-mm 0.2-micrometer (µm) pore size Durapore filters on the day collected, and the filters were subsequently frozen. The volume filtered was dependent on the amount of suspended sediments in the sample (to avoid clogging). DNA was extracted for all samples using the MoBio Ultraclean Fecal DNA kit and eluted in 50-microliter (µl) volumes. The resulting DNA was quantified using Molecular Probes dsDNA Quantitation kit.

c) Quantitative PCR for Human Bacteroides

Bacteroides levels were determined by SYBR Green-based quantitative PCR, as described in "Detection and Quantification of the Human-Specific HF183 Bacteroides 16S rRNA Genetic Marker with Real-Time PCR for Assessment of Human Faecal Pollution in Fresh Water" (Seurinck et al. 2005). Our only significant modification was the use of the Bio-Rad iQ SYBR Green supermix, which is the functional equivalent of the Eurogentec kit that is not readily available in the U.S. For samples with quantifiable DNA levels >0.2 ng/µl, 2 nanograms (ng) of DNA were used for the quantitative polymerase chain reaction (PCR). All samples were run in duplicate reactions simultaneously with a standard curve (range 10^0 to 10^7 copies from a plasmid containing the target gene fragment).

Enterovirus

Samples Preparation

All samples were filtered onto 47-mm GF/F filters on the day collected and then frozen. RNA was extracted using the Qiagen RNeasy Mini Kit (tissue protocol) with the QIAvac Manifold.

d) Reverse-Transcription and Quantitative PCR

Reverse transcription and the quantitative PCR were performed in a single reaction (Fuhrman et al. 2005). All samples were run in duplicate with additional duplicate samples spiked with vaccine-type poliovirus to test for inhibition. Samples were diluted until inhibition was removed. A standard curve was run simultaneously with a range 3.3×10^{0} to 3.3×10^{4} poliovirus particles per assay.

3. Survey Layout

The survey was intended to take samples across the shelf and near the coast in the area from the U.S.-Mexico border northward past Imperial Beach (Figure F.1). The stations were set up to be approximately 1.5 km apart. An additional station inshore from the main along-shore line was placed north of the Tijuana River mouth because a plume was observed inshore of the main sampling line on January 24. These stations were repeated for each survey.

Likely sources of microbial contamination include the Tijuana River and the SBOO, which are circled in yellow in Figure F.1. It is also expected that contaminated water could be transported along-shore from the south; thus, the inshore station of the cross-shelf line (Station 4) could be considered a site for detecting source water.

4. Overview of the Observational Events / Periods

The goal of sampling for the winter season of 2007-2008 was to capture the ocean conditions with respect to water quality characteristics and microbial contamination after two winter rain events. After the rainy season, the goal was to capture two events when microbial contamination was being observed along Imperial Beach.

The rainfall record for 2007-2008 at the Imperial Beach Pier is shown in Figure F.2. While the events are portrayed in this figure, the amounts are underreported. For example, during the rain event of January 5 through 7, 3.8 cm of rain (1.49 inches) were reported at Lindbergh Field, while only a total 1.5 cm (0.6 inch) was reported for the Imperial Beach Pier. During the winter (wet) season, the overall rainfall in San Diego at Lindbergh Field was approximately 18.3 cm (7.2 inches), which was about 67 percent of the average annual rainfall.

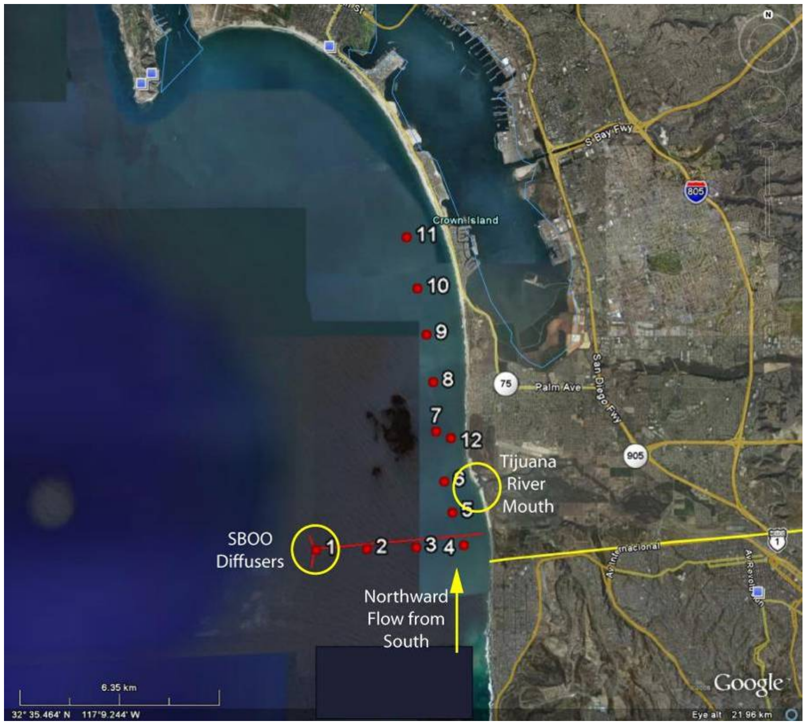


Figure F.1 Source Tracking Study Stations
Map of station locations for source tracking study. Station 1 is over the South Bay Ocean Outfall and is positioned to detect active outfall plume. Station 4 is situated at the U.S.-Mexico border to detect any source water that might be transported northward from south of the border. Station 6 is positioned directly offshore from the Tijuana River for detection of river source water, and Station 12 was added because the plume often moves northward closer to shore.

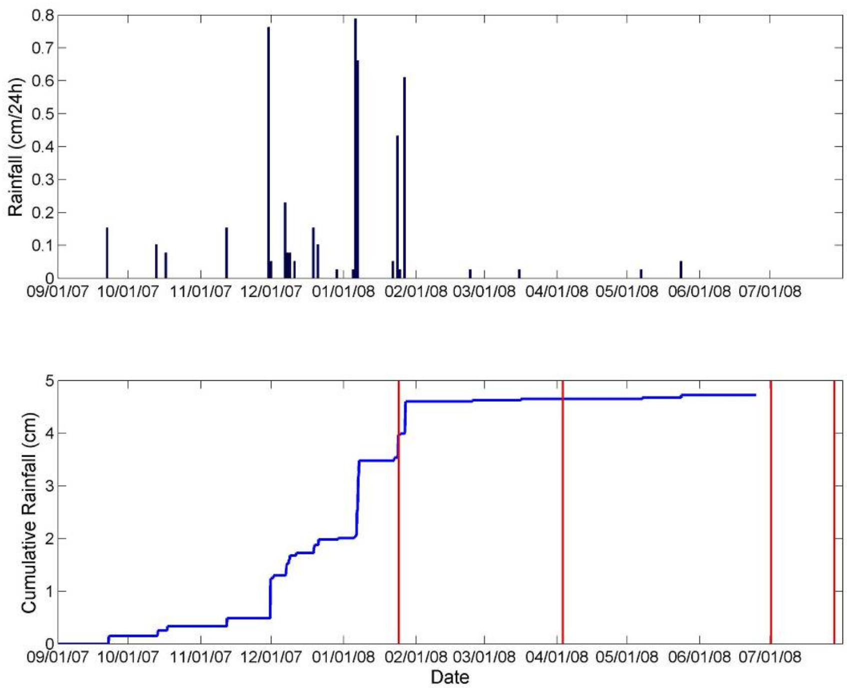


Figure F.2 Imperial Beach Pier Rainfall
The time series of rainfall at the Imperial Beach Pier for the period of September 1, 2007, through July 31, 2008. The top panel shows the 24-hour rainfall for individual days. The bottom panel shows the cumulative rainfall through the season. The red lines indicate the time of field sampling cruises.

5. Individual Cruise Results

January 24, 2008

The first field survey took place on January 24, 2008. This sampling event occurred immediately after a small rain event. The rainfall at the Imperial Beach Pier for the 24 hours preceding the sampling was about 0.9 cm (approximately 0.37 inches). During the same period the rainfall at Lindbergh Field was about 3.8 cm (1.5 inches). Therefore, the goal of this survey was to capture a runoff event when significant flow from the Tijuana River was expected.

The cross-shelf transect that extends from the outfall toward the coast shows a weakly stratified water column, illustrated by a minimal density gradient between the surface and subsurface region (Figure F.3). This is evident in the temperature, salinity, CDOM, and particle concentration (indicated by $b_{bp}532$) data.

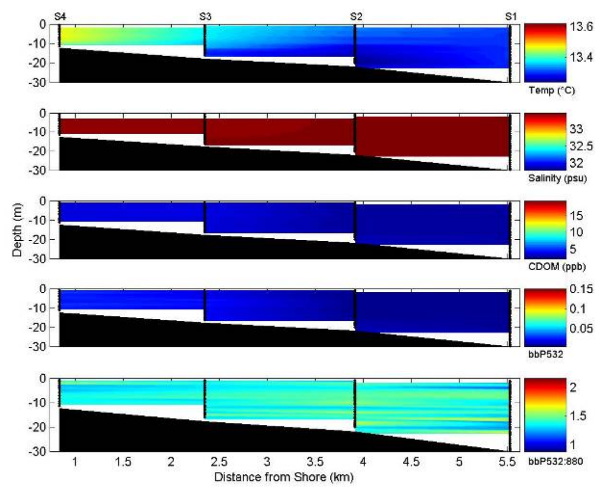


Figure F.3 Cross-Shelf Section – January 24, 2008
Cross-shelf section on January 24, 2008. The coast is on the left and distances are based on the point of intersection of the cross-shelf transect with the coastline. The panels from top to bottom are: temperature, salinity, CDOM, optical backscatter at 532 nm (bbp532), and the optical backscatter ratio of $b_{bp}532/b_{bp}880$.

The along-shore transect, Stations S4 to S9 (Figure F.4A), is also relatively homogeneous but with temperatures that are slightly warmer than offshore, salinities that are slightly fresher, and optical backscatter that is slightly higher than that in the cross-shelf transect. Sampling at Station 12, which is slightly inshore of the main line (Figure F.4B), indicates that there is a distinct signal from the Tijuana River that shows up as slightly warmer than the ambient water, significantly saltier, and higher in CDOM and suspended particles. It is clear from this data set that the discharge from the Tijuana River remained close to shore and advected northward along the coast. (See Appendix 3.8 for supporting AUV and environmental data). Somewhat surprising is that the particle-size distribution of the Tijuana River plume did not seem to be distinct from the other coastal water (Figure F.4B, bottom panel). The particle size distribution would be reflected in smaller particles if bbp532/bbp880 were larger, or larger particles if bbp532/bbp880 were smaller.

The relationship between salinity, temperature, and CDOM is shown in Figure F.5. The red-circled area indicates the area of river plume found in the near-surface region at Station 12, slightly upcoast from the Tijuana River mouth, which is consistent with AUV maps of the plume.

The distribution and magnitude of *Bacteroides* concentration are shown in Figure F.6. Samples were taken at five sites during this survey. The sample at the offshore station was taken at 26 meters, while all other samples were taken at the surface. *Bacteroides* was detected at all of the sites sampled, but human enteroviruses were not detected at any of the five sites. The four sites along the two main sampling transects had relatively low *Bacteroides* concentrations, but the Tijuana River plume at Station 12 showed, by far, the largest concentration, correlating with the low salinity, high CDOM, and high particulate concentration associated with this site.

The lack of detectable human enteroviruses does not negate the detected human *Bacteroides*. Tracer concentrations are known to diverge in the environment (Griffin et al. 2003). Enteroviruses are not shed by all people all the time; however, *Bacteriodes/Prevotella* is always found in the human population. The fact that *Bacteroides* was detected in all five samples suggests that there is some level of human fecal contamination throughout the area. Whether it is at a level that is infectious cannot be stated from these results because the epidemiological comparison has not been performed.

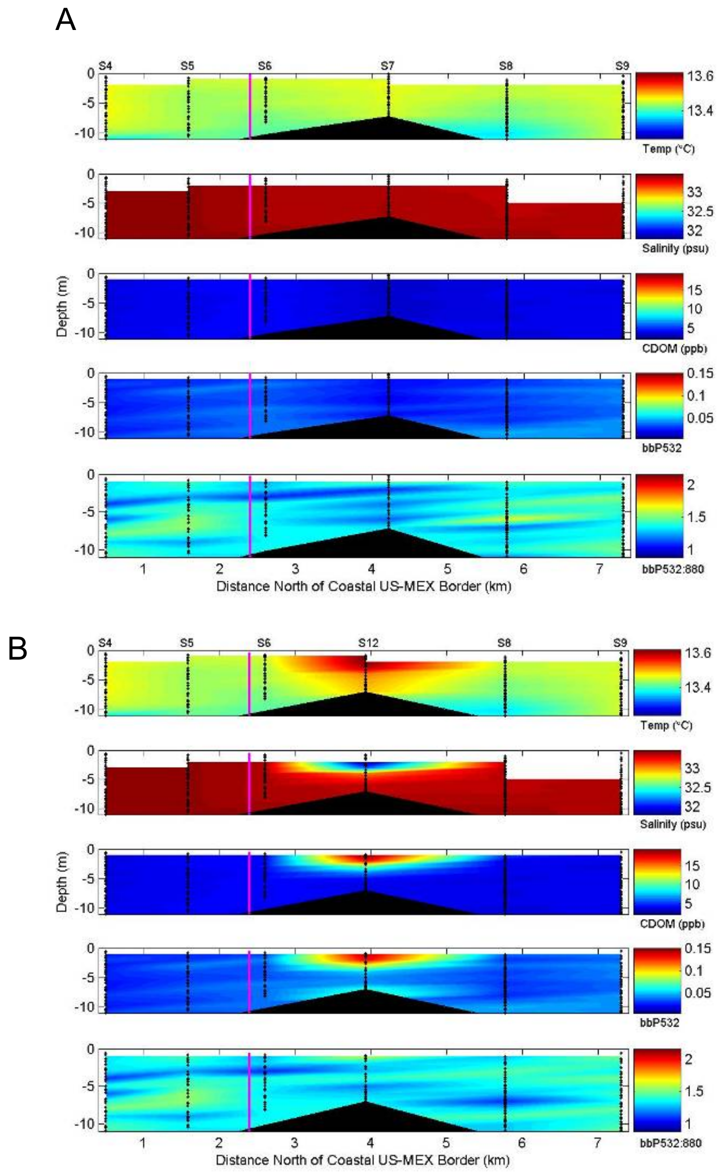


Figure F.4 Along-Shelf Transect – January 24, 2008
Along-shelf transect of stations from south (left) to north (right). Distance is measured as distance north of the U.S.-Mexico border. The panels are the same as in Figure F.3. The magenta line indicates the along-shore location where the Tijuana River intersects the coast. The left-hand set of panels (A) represents Stations 4 to 11 from south to north. The right-hand set of panels represents the same set of stations with station 12, closer to shore, substituted for station 7.

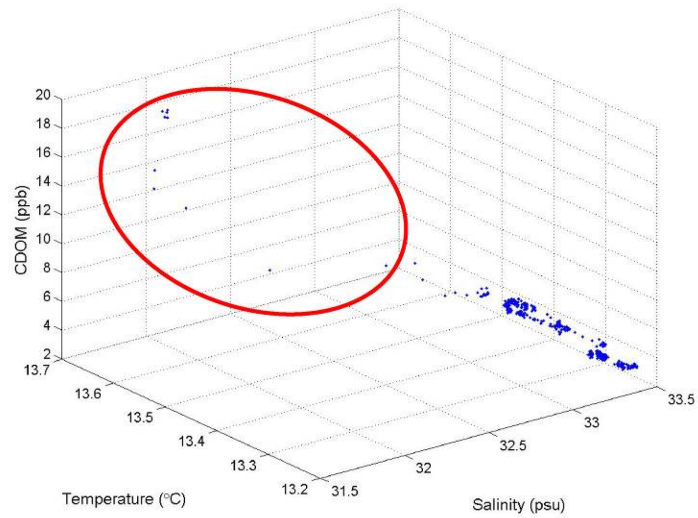


Figure F.5 Three-Dimensional Data Set – January 24, 2008
This is the three-dimensional representation of the entire data set for temperature, salinity, and CDOM. The Tijuana River plume portion of the data is circled in red. In addition to the low salinity and high CDOM, this water was also characterized by a high concentration of suspended particulate.

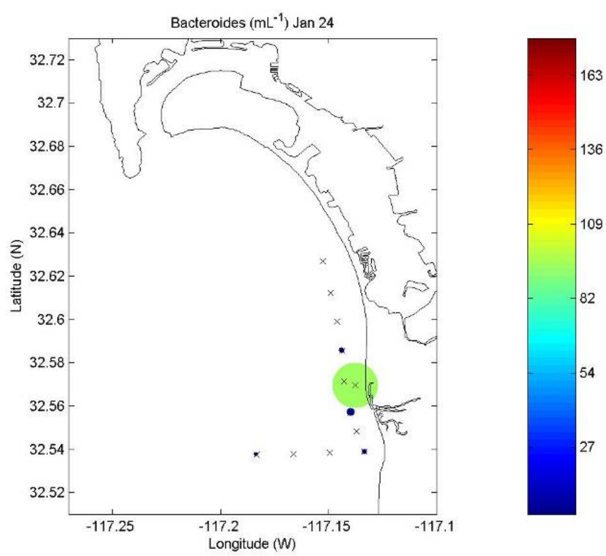


Figure F.6 Bacteroides Surface Distribution – January 24, 2008
Surface distribution of Bacteroides on January 24, 2008. The x symbols indicate the location of the routine sampling sites. The colored circles indicate where samples were taken on this cruise. The color and size of the circle represents the actual and relative concentrations of Bacteroides. The color bar on the right indicates the color scaling for concentration in number of copies per ml. No human enteroviruses were detected for this survey.

April 3, 2008

The second hydrographic/microbiological survey was performed on April 3, 2008. There was a forecast of possible rain; however, none materialized for this sampling event, and there was no significant precipitation preceding this sampling event. The same set of stations that were occupied on January 24 were occupied for this survey (see Figure F.1).

The most obvious difference between this survey event and the January 24 survey is more stratification indicated in the temperature and salinity data. The stratification is demonstrated by a vertical temperature gradient of about 5°C and a salinity decrease from nearly 33.9 at depth to less than 33.8 near-surface (Figures F.7 and F.8). The discharge from the South Bay Ocean Outfall (SBOO) was more distinct in the profile from near the outfall than in the previous survey (Figure F.9). The vertical profiles of all the stations are shown in Figure F.9, with Station 1 (green profile line) showing a clear signature of the effluent plume below 20 meters. The plume was low in salinity and conversely high in CDOM and suspended particles (b_{bp}532). The density of the plume (sigma- θ) for the plume is lower than the density of the water column above it, indicating instability in this part of the water column. Based on this, it appears that this profile sampled the turbulent, actively mixing portion of the plume that had not yet reached density equilibrium and the turbulence has not yet collapsed (Roberts, et al., 1989; Roberts et al., 1999). No indication of effluent plume was detected at any of the other sampling stations. The data suggests that the cast station was positioned to be in the developing nearfield of the discharge. Consistent with previous findings of the other boat-based sampling tasks, the small scales of the SBOO plume make it elusive to map using the coarse spatial coverage provide by boat-based sampling.

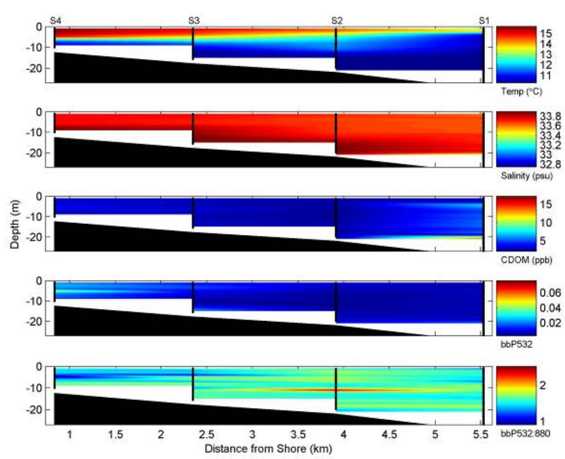
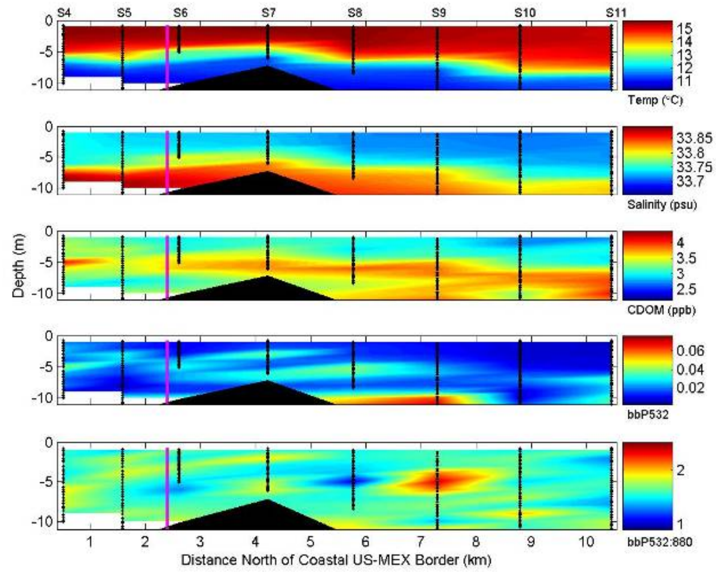


Figure F.7 Cross-Shelf Section – April 3, 2008

Cross-shelf section on April 3, 2008. The coast is on the left and distances are based on the point of intersection of the cross-shelf station line with the coastline. The panels are (from top to bottom) temperature, salinity, CDOM, optical backscatter at 532 nm (bbp532), and the optical backscatter ratio of b_{bp}532/b_{bp}880.

A



B

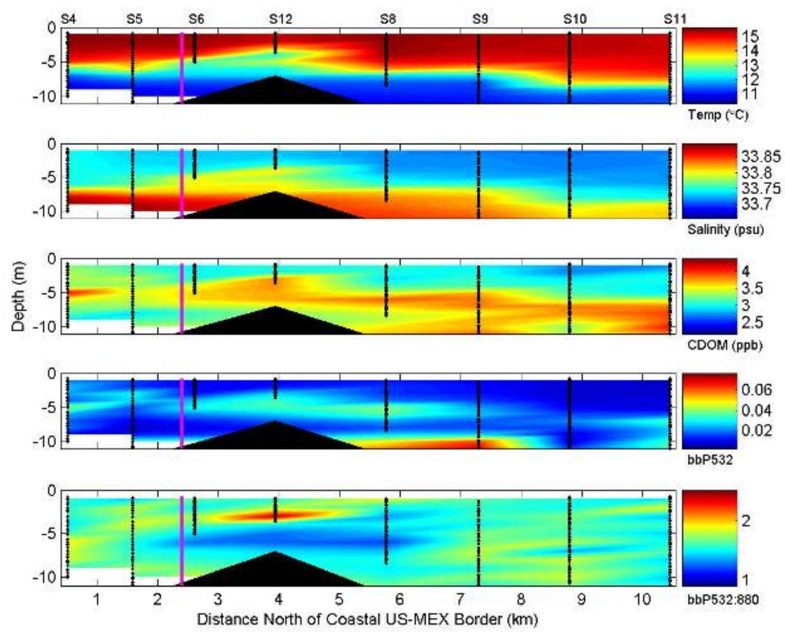


Figure F.8 Along-Shelf Transect – April 3, 2008

Along-shelf transect of stations from south (left) to north (right). Distance is measured as distance north of the U.S.-Mexico border. The panels are the same as in Figure 4. The magenta line indicates the along-shore location where the Tijuana River intersects the coast. The left-hand set of panels (A) represents Stations 4 to 11 from south to north. The right-hand set of panels represents the same set of stations, but Station 12, closer to shore, replaces Station 7.

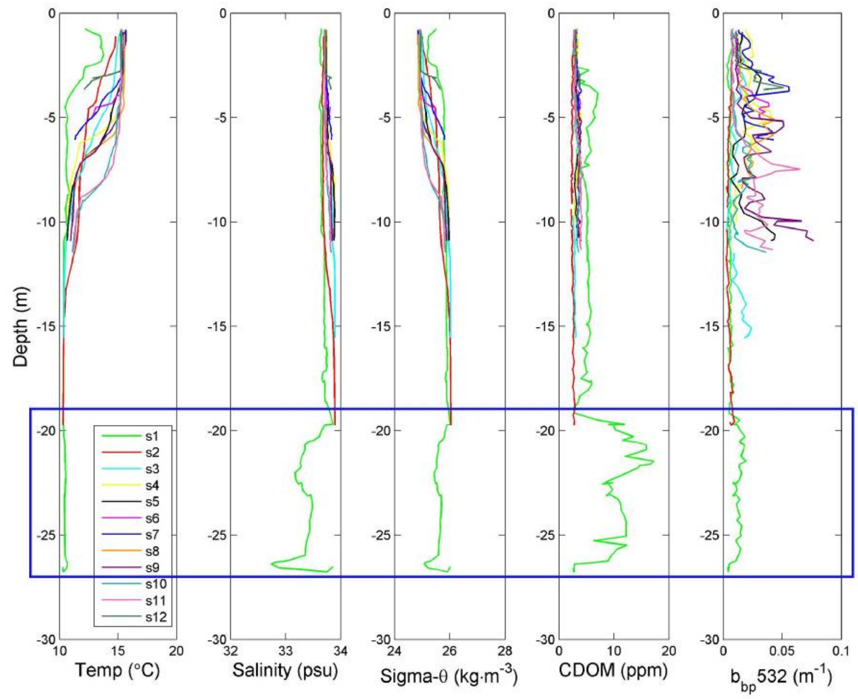


Figure F.9 Vertical Profiles – April 3, 2008
Vertical profiles from all of the stations sampled during the April 3, 2008, survey. This figure demonstrates the presence of the effluent plume from the SBOO detected at Station 1 as identified by the blue box.

Evaluation of the salinity-temperature-CDOM distribution shows clear evidence of the SBOO effluent plume where CDOM increases approximately linearly with decreasing salinity (Figure F.10, blue-circled data). Salinity in the surface layer (red-circled data) was slightly less than the salinity of the water immediately beneath. The low CDOM concentration in the surface layer suggests that this layer is not the result of significant, recent land-based input (red-circled data points).

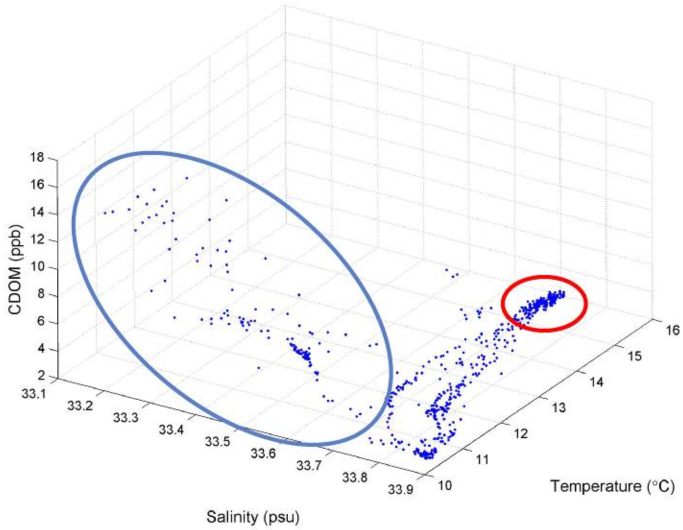


Figure F.10 Three-Dimensional Data Set – April 3, 2008
The three-dimensional representation of the entire data set for temperature, salinity, and CDOM. The data from the surface layer are circled in red, and the observations from the SBOO effluent plume are circled in blue.

Bacteroides concentrations were highest over the SBOO outfall (Figure F.11). The *Bacteroides* concentration in the effluent plume at 22.5 meters deep was 174 per ml. *Bacteroides* was also detected in the surface sample from the outfall station. The surface concentration of *Bacteroides* was 50 per ml. At all other surface sites where *Bacteroides* was sampled, its presence was indicated, but the concentrations were very low (<1 per ml). Enteroviruses were not detected in the sample from 22.5 meters. Despite the stratification, there may have been some effluent present throughout the water column, as evidenced by slightly elevated CDOM concentrations above 19 meters (Figure F.9). The surface presence could have been due to at least two factors. 1) Despite the mildly stratified water column, the buoyancy of the plume may have transported some of the plume water to the surface. 2) Plume water might be transported through oil and grease in the effluent, which might rise to the surface and carry with it attached bacteria and viruses from the effluent (Schulz et al. 1994).

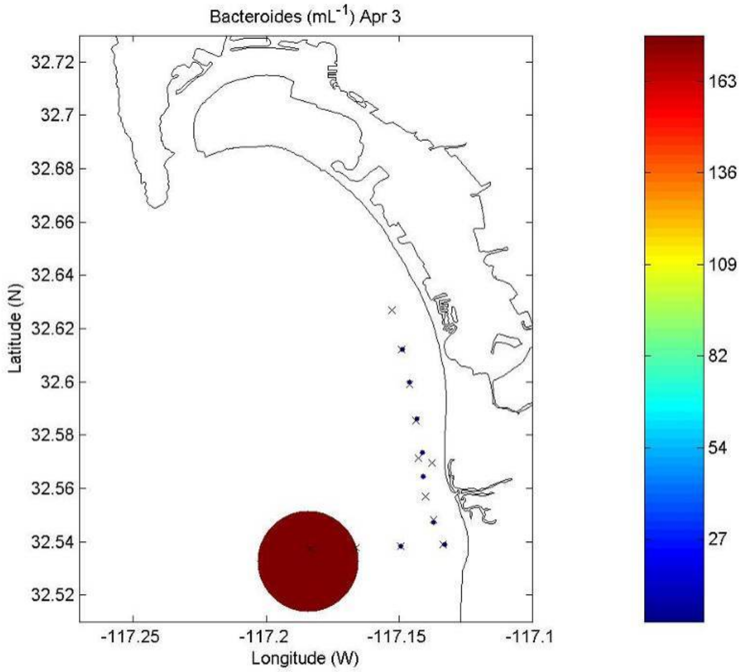


Figure F.11 Bacteroides Surface Distribution – April 3, 2008
Surface distribution of Bacteroides on April 3, 2008. The "x" symbols indicate the locations of the routine sampling sites. The colored circles indicate where Bacteroides samples were taken on this cruise. The color and size of the circle represents both the actual and relative concentration of Bacteroides. No human enteroviruses were detected for these samples.

July 1, 2008

The survey on July 1, 2008, occurred when conditions were relatively quiescent. Near the outfall, the water column was not strongly stratified except in the upper 5 to 7 meters (Figures F.12 and F.13). The strongest indication of a possible contaminant input was from the SBOO effluent plume on Station 1 positioned over the outfall (Figure F.12). A low-salinity, high-CDOM, elevated-particulate concentration feature was observed between 10 and 15 meters deep. This feature was embedded in a generally lower salinity feature that extended from about 6 meters depth to 25 meters at this station, and had continuity with a low-salinity feature observed at Stations S2 and S3 nearer to shore. At these two stations, the low salinity appeared to be as shallow as 5 meters. However, CDOM levels were at background levels at the depths of the lower salinity feature in Stations 2 and 3, suggesting that this low-salinity feature is not connected with the effluent plume. It is more likely that this is low-salinity California Current water that typically exists subsurface in coastal waters during summer.

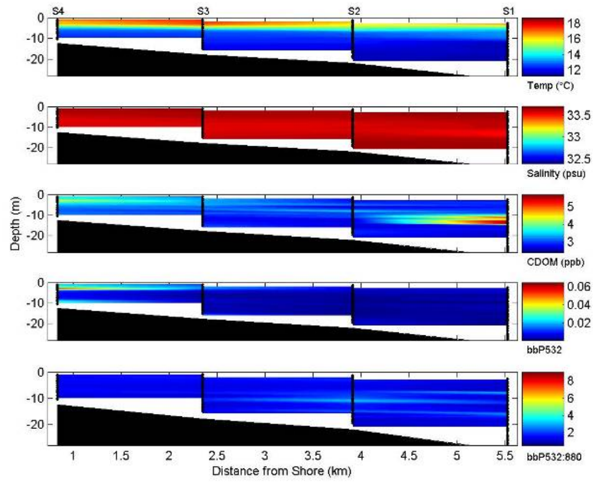


Figure F.12 Cross-Shelf Section – July 1, 2008
Cross-shelf section on July 1, 2008. The coast is on the left and distances are based on the point of intersection of the cross-shelf station line with the coastline. The panels are (from top to bottom) temperature, salinity, CDOM, optical backscatter at 532 nm (bbp532), and the optical backscatter ratio of b_{bp}532/b_{bp}880. The effluent plume is indicated by the lower salinity and higher CDOM at 10 to 15 meters on the right-hand side of the figure panels.

Although the suspended particulate concentration (represented by optical backscatter) was elevated relative to concentrations from below the plume at Station 1, it was low compared to the levels observed closer to shore (Figures F.12 and F.13). However, if one looks at the individual profile, the increase in optical backscatter coincident with the low-salinity, high-CDOM feature indicates that suspended particulate matter increases within the SBOO effluent plume, although it is not a large increase compared with the near-shore increases in suspended particulate matter.

A significant near-shore low-salinity feature was not observed during this survey (Figure F.13). Resuspended sediments were evident in the near-shore transect, particularly in the shallowest stations (Stations 6, 7 and 12).

The signature of the effluent plume can be seen in the Temperature-Salinity-CDOM plot (Figure F.14). The points where temperature is less than 13°C, salinity is <33.55, and CDOM is >4 µg/l, in particular clearly denote the plume.

Significant concentrations of *Bacteroides* were observed at several sites (Figure F.15). Two samples were taken at Station 1 near the tip of the southern diffuser, one from 25 meters deep and the other from the surface. The highest concentration of *Bacteroides*, 124 per ml, occurred at the surface, compared with a value of 73.5 per ml at a depth of 25 m. The surface values do not show a direct correlation with salinity or CDOM because salinity was higher and CDOM was relatively low compared with the core of the plume at 10 to 15 meters (Figures F.12 and F.13). As in previous cruises, enteroviruses were not detected, even directly over the outfall.

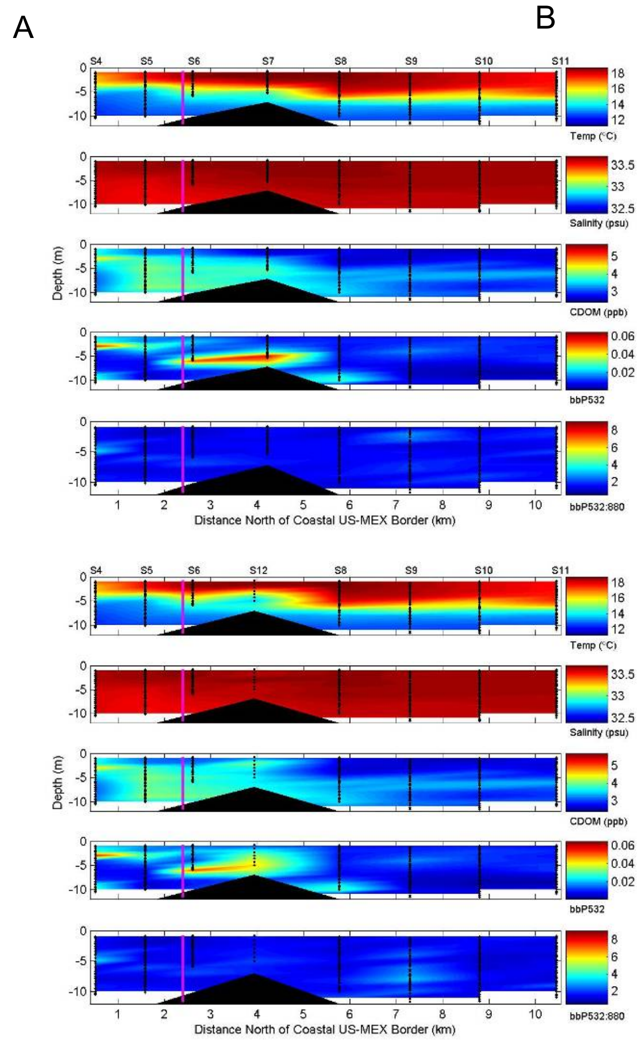


Figure F.13 Along-Shelf Transect – July 1, 2008

Along-shelf transect of stations from south to north. Distance is measured as distance north of the U.S.-Mexico border. The panel order is the same as in Figure F.12. The magenta line indicates the along-shore location where the Tijuana River intersects the coast. The left-hand set of panels (A) represents Stations 4 to 11 from south to north. The right-hand set of panels represents the same set of stations, but the more shoreward Station 12 is substituted for Station 7.

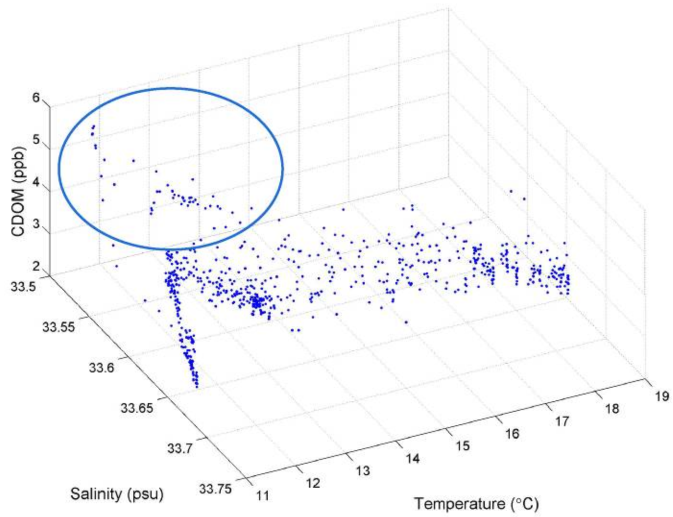


Figure F.14 Three-Dimensional Data Set – July 1, 2008
The three-dimensional representation of the entire data set for temperature, salinity, and CDOM. The observations from the SBOO effluent plume are circled in blue.

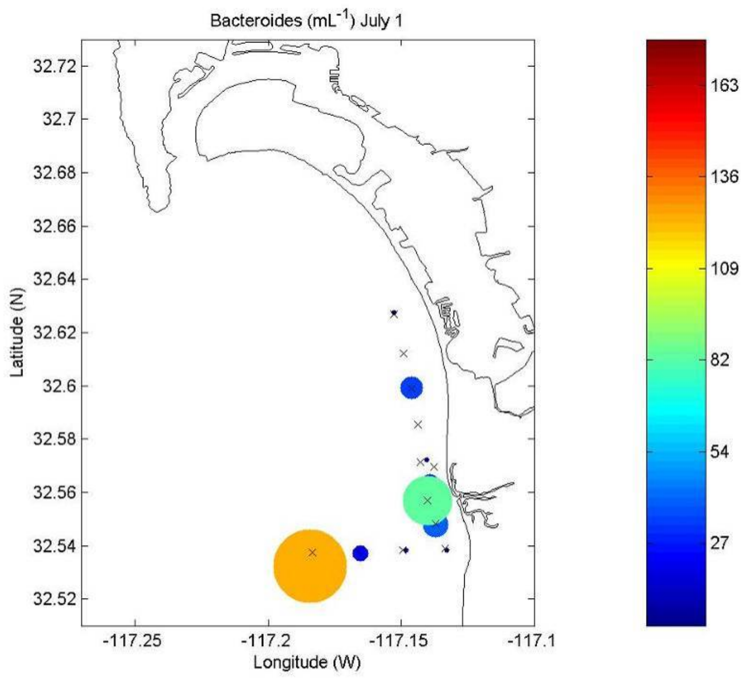


Figure F.15 Bacteroides Surface Distribution – July 1, 2008
Surface distribution of Bacteroides on July 1, 2008. The x symbols indicate the locations of the routine sampling sites. The colored circles indicate where samples were taken on this cruise. The color and size of the circle represent the actual and relative concentration of Bacteroides. No human enteroviruses were detected for these samples.

July 28, 2008

The second summer cruise occurred on July 28, 2008. It was a period of light oceanographic forcing with clear sky and calm sea conditions. The standard cross-shelf and along-shelf stations were sampled on this cruise except for Station 12, the inshore station just north of the Tijuana River mouth.

The upper 10 meters were well stratified near the coast (Figure F.16). The thickness of this stratified layer decreased offshore. There were no near-surface, low-salinity features that could indicate the presence of terrigenous runoff or a surfacing effluent plume. CDOM generally increased with depth, and optical backscatter (b_{bp}532) was high at several near-shore stations. The clearest indication of the SBOO effluent plume was the concentration of CDOM in the offshore station over the outfall (S1 in Figure F.16). However, particle concentrations were not significantly higher within the plume, and there was an offset between the low-salinity feature and the CDOM signature of the plume (Figures F.16 and F.17).

It did not appear that the effluent plume was rising higher within the water column, at least in the immediate vicinity of the SBOO diffuser.

As in previous surveys, detectable *Bacteroides* concentrations were found at several stations. On this occasion detectable enteroviruses was observed at depth in the effluent plume (Figure F.18, right panel). Bacteroides was found in surface samples away from the outfall and the river mouth. The two highest concentrations were found at Station 3 in the cross-shelf transect and at Station 11 in the along-shore transect.

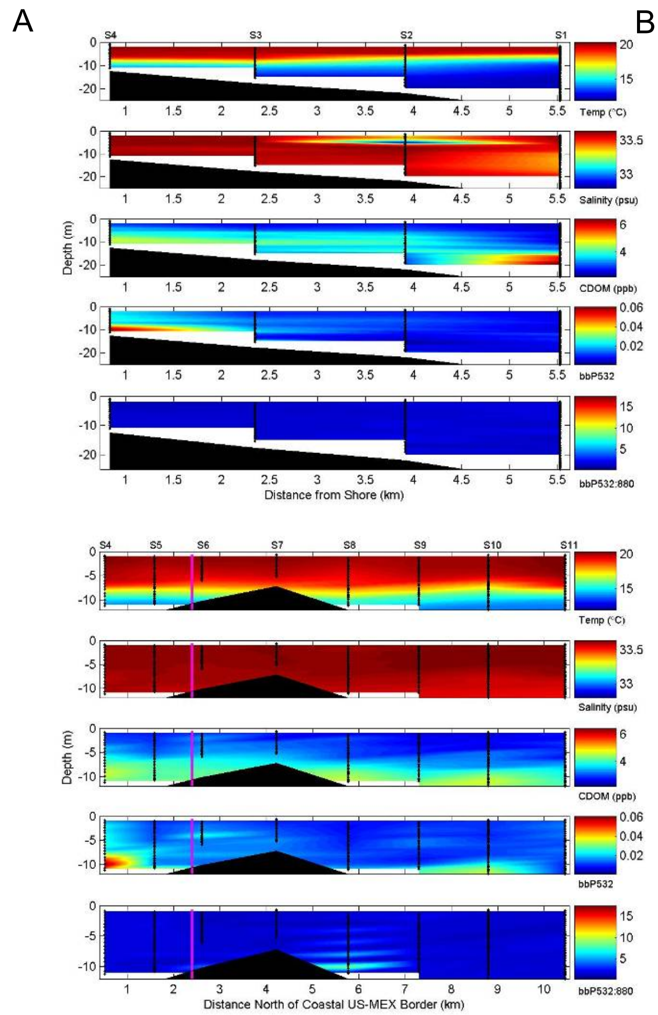


Figure F.16 Cross-Shelf and Along-Shelf Sections – July 28, 2008

Cross-shelf (A) and along-shelf (B) sections on July 28, 2008. The distances are referenced as in the previous section plots. The panels are (from top to bottom) temperature, salinity, CDOM, optical backscatter at 532 nm (bbp532), and the optical backscatter ratio of $b_{bp}532/b_{bp}880$. The effluent plume is indicated by the low-salinity and high-CDOM feature near the bottom of the offshore station in panel A.

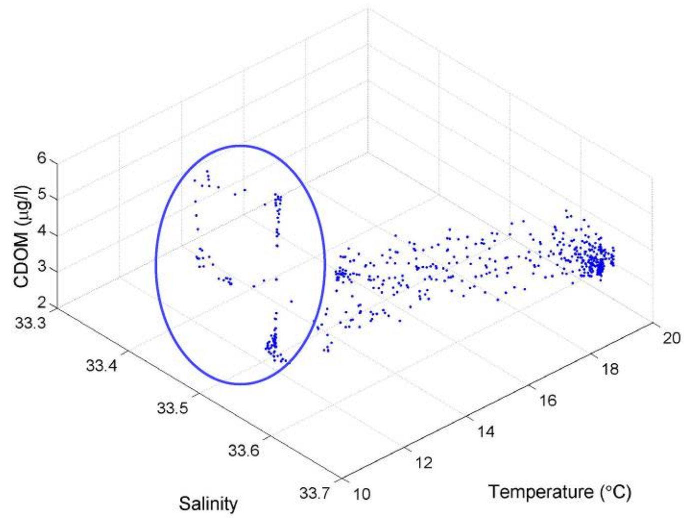


Figure F.17 Three-Dimensional Data Set – July 28, 2008
The three-dimensional representation of the entire data set for temperature, salinity, and CDOM for July 28, 2008. The observations from the SBOO effluent plume are circled in blue.

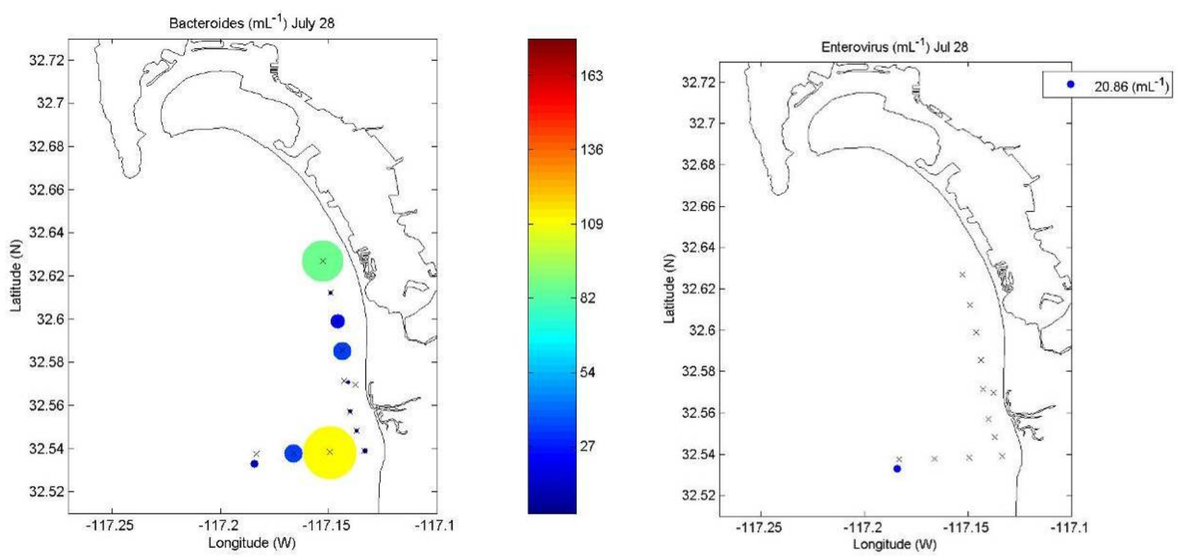


Figure F.18 Bacteroides Surface Distribution – July 28, 2008
Surface distribution of Bacteroides (left panel) and enteroviruses (right panel) on July 28, 2008. The "x" symbols indicate the locations of the routine sampling sites. The colored circles indicate where Bacteroides samples were taken on this cruise. The color and size of the circle represent the actual and relative concentrations of Bacteroides or enteroviruses detected.

6. "Smelly Water" Sample

In addition to the water quality surveys described above, a sample from a "smelly water" event was evaluated to determine if it contained human-associated bacteria and viruses. Smelly water is sometimes apparent to beachgoers because of its odor and, often, the color associated with it. Three samples were obtained from Imperial Beach on August 22, 2008, and were analyzed for *Bacteroides* and enteroviruses. Results are summarized in Table F.1. No enteroviruses were detected, but the highest *Bacteroides* concentration that we encountered was measured in one of the samples.

No water quality measurements were taken on these samples.

Sampling Date	Filter	Filter Time	Description	Bacteroides per ml±SEM*	Enterovirus per ml±SEM*
8/22/08	1	13:57	1B-050	44.8 ± 19.8	0.0±0.0
8/22/08	2	14:15	EH-010	1226.5 ± 155.5	0.0±0.0
8/22/08	3	14:42	EH-030	150.2 ± 72.3	0.0±0.0

Table F.1 Bacteroides and Enterovirus Results for Smelly Water Samples

*Values are mean number of gene copies or enteroviruses ± standard error of the mean, per ml of sample water

7. Discussion

The four surveys spanned seasonal and event (rain/dry) periods. It is clear from the four surveys that runoff plumes and effluent plumes can be readily differentiated using the water quality variables that we utilized. These plumes are, in general, characterized by lower salinity, elevated CDOM concentrations, and higher suspended particulate concentrations.

Relationships among measured variables were evaluated to determine if water quality variables could be used to identify likely contamination with human bacteria and virus indicators, and to assess to what extent different microbial sources could be differentiated on the basis of the water quality measurements. The relationship between water quality variables and *Bacteroides* is shown in Figure F.19. The clearest relationship comes from the sampling on January 24, 2008, when there was a small discharge from the Tijuana River. For this event there is a clear relationship between salinity, CDOM, and particle concentration with the abundance of *Bacteroides*. This is consistent with the results that have been observed throughout the Southern California Bight in the relationship between water quality variables and indicator bacteria (Reifel et al. 2008).

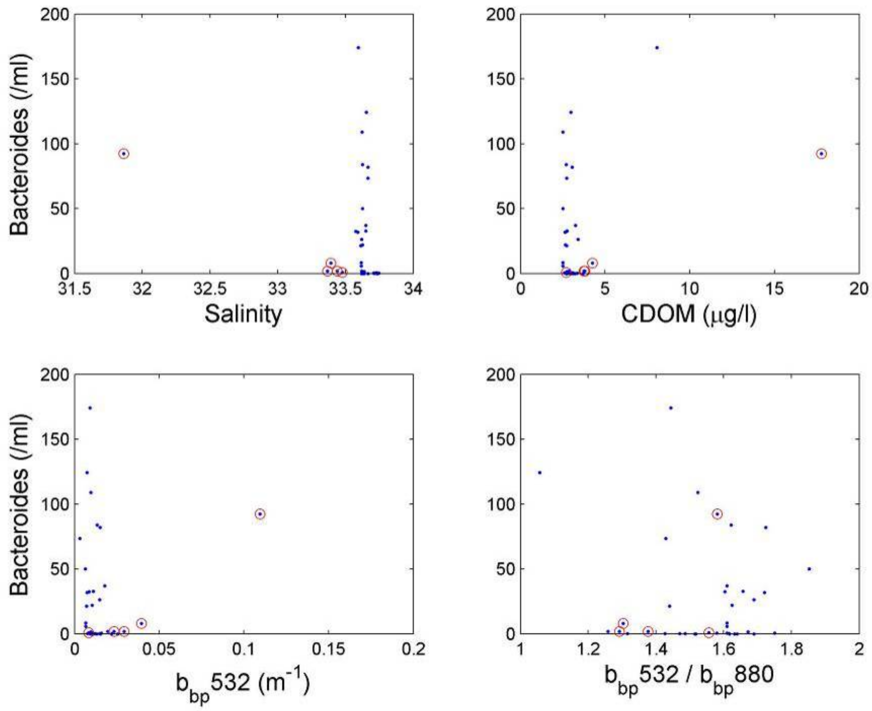


Figure F.19 Bacteroides and Water Quality – January 24, 2008
Relationship between Bacteroides and water quality variables. The data circled in red indicate the samples from January 24, 2008, which included measurable runoff from the Tijuana River.

The relationships between water quality variables were similar to our expectations. The magnitude of concentrations in the river runoff dominates the scale of these relationships (Figure F.20). However, without the river runoff, there is a positive relationship between suspended particulate material and CDOM concentration. The close relationship between the two variables could result from several factors:

- The sources of the particles are consistent with an effluent or river discharge that contains elevated concentrations of particles and CDOM.
- The particles contain a proportional amount of organic particles and/or flocs that fluoresce like CDOM does.
- The sensor may be sensitive to optical scattering that interferes with the CDOM measurement.

The first explanation is consistent with results from the Bight'03 project (Reifel et al. 2008). The second case has been observed large river plumes such as the Po River plume in the Adriatic Sea.

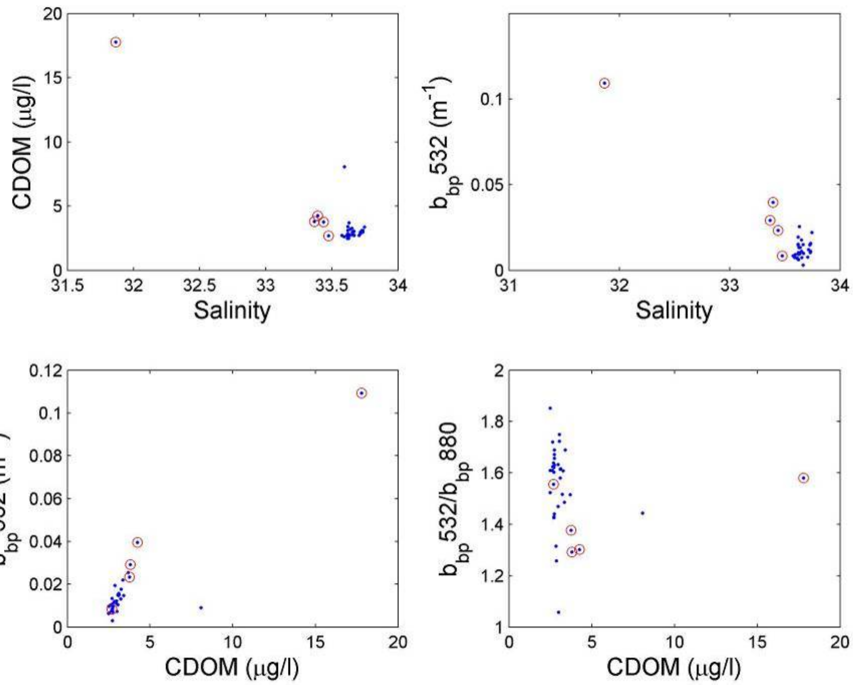


Figure F.20 Water Quality Variables

Relationships among water quality variables for the four SBOO surveys. The points circled in red are from the wet weather survey on January 24, 2008.

IV. Dry Weather Event Analysis – "Smelly Water"

Between March 2007 and September 2008, nine dry weather events were recorded by the San Diego County Department of Environmental Health. A dry weather event is defined as a period of suspected impaired water quality during a period when no rainfall has occurred and runoff is not the suspected cause. The dates of these events are:

June 12, 2007
June 24, 2007
July 17, 2007
September 1, 2007
September 4, 2007
January 4, 2008
June 12, 2008
June 19, 2008
August 22, 2008

The dry weather events that occurred are characterized by detergent-like odors at the beach (smelly water) during periods when the IBWC gauge reports no flow from the Tijuana River and there have been no recent rainfall events (Figures IV.1 and IV.2). Elevated counts of FIB have not been observed during these events (Figure IV.3). Data around these events were analyzed for common environmental conditions in an effort to determine forcing factors and potential sources.

Northward flow in the surface layer sampled by HF radar is observed on the day of each of these events in the South Bay, suggesting that the source may originate from the south (Figure IV.4). Sea state (swell height and direction) and tidal forcing do not appear to play a role in these events based on time-series analysis, and no apparent clear trend was common between events (for example, south swell did not always precede each event).

A combined assessment of surface currents, satellite imagery, SBOO stratification and velocity profiles, and IB Pier temperature was conducted for the events that occurred. The analysis suggests that it may be possible for beaches near the U.S.–Mexico border to be exposed to the SBOO plume during a transition from southward to northward flow under certain conditions.

Working hypotheses for the processes at play that lead to these conditions include:

- Ocean conditions consist of weakened ocean stratification that allows the plume to rise to shallow conditions during southward flow.
- Surface (and near-surface) currents "sweep" the plume shoreward during a transition from southward flow to northward flow, causing temporary coastline exposure to the outfall plume. Of the nine dry weather events analyzed, seven of them meet these criteria.

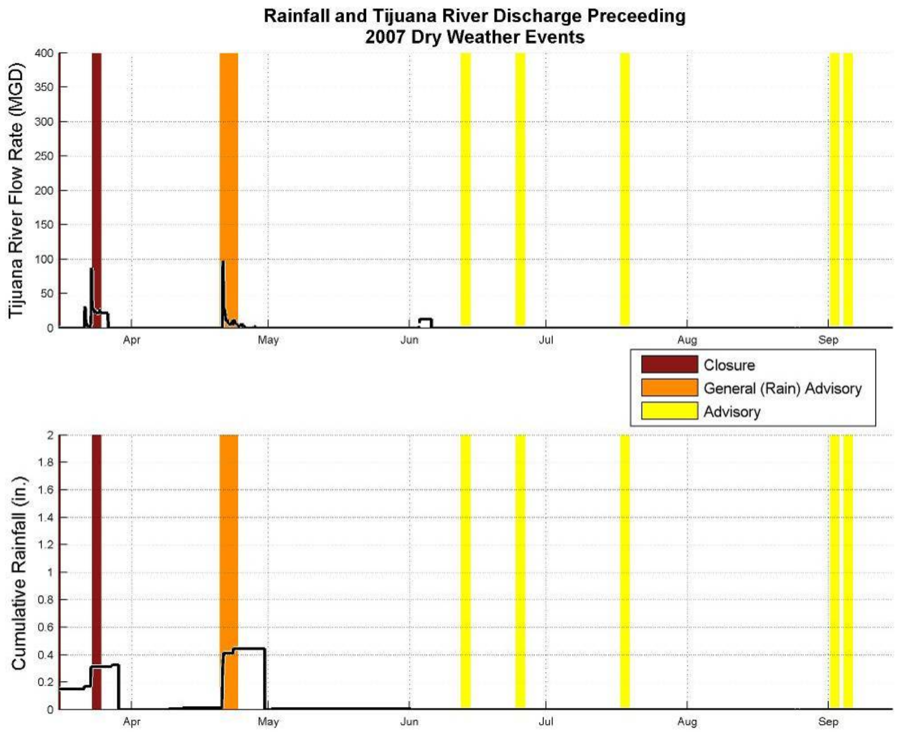


Figure IV.1 2007 Dry Weather Events
A lack of rainfall or flow from the Tijuana River (as recorded by the IBWC gauge) characterized dry weather events (categorized as advisories) during 2007.

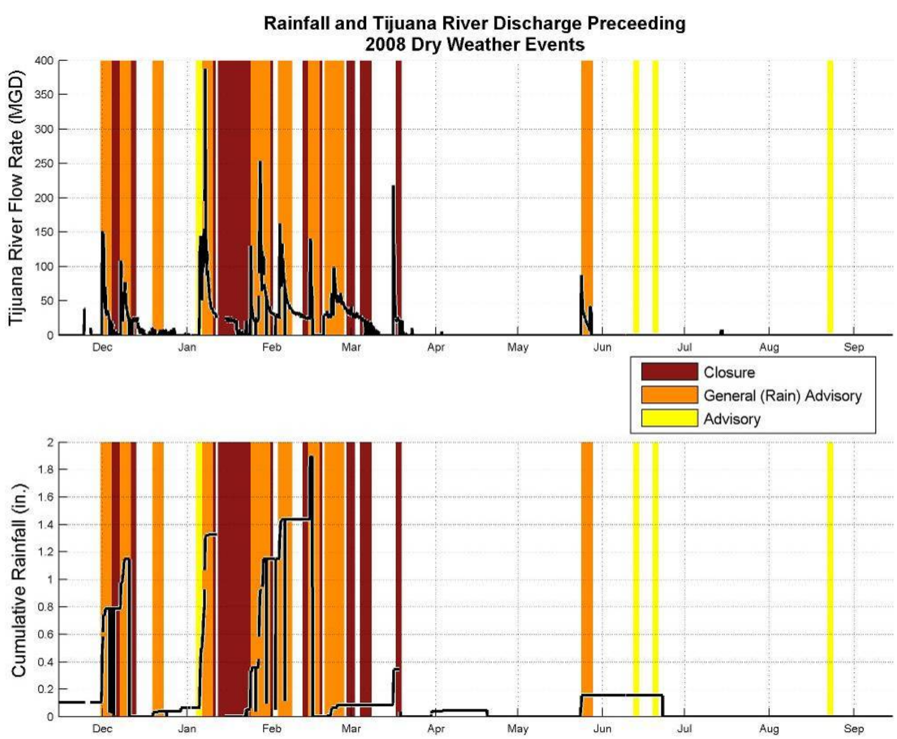


Figure IV.2 2008 Dry Weather Events
A lack of rainfall or flow from the Tijuana River (as recorded by the IBWC gauge) characterized dry weather events (categorized as advisories) during 2008.

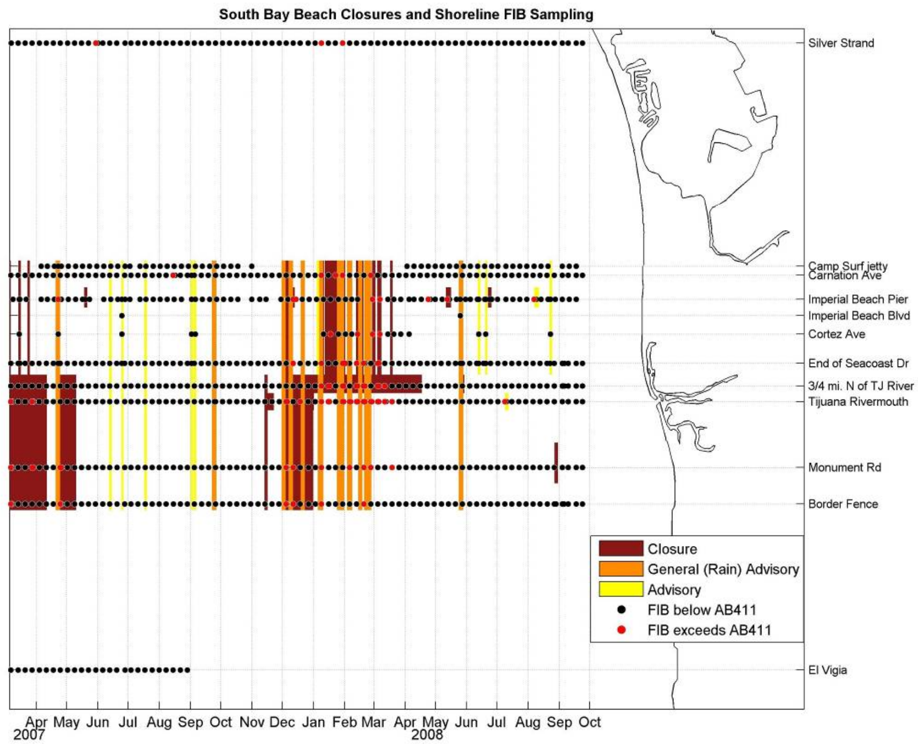


Figure IV.3 2008 Rainfall and Dry Weather Events
Dry weather events (categorized as advisories) are characterized by a lack of AB411 FIB exceedances. (Note that two advisories shown, July 11, 2008, and August 10, 2008, are not dry weather events.)

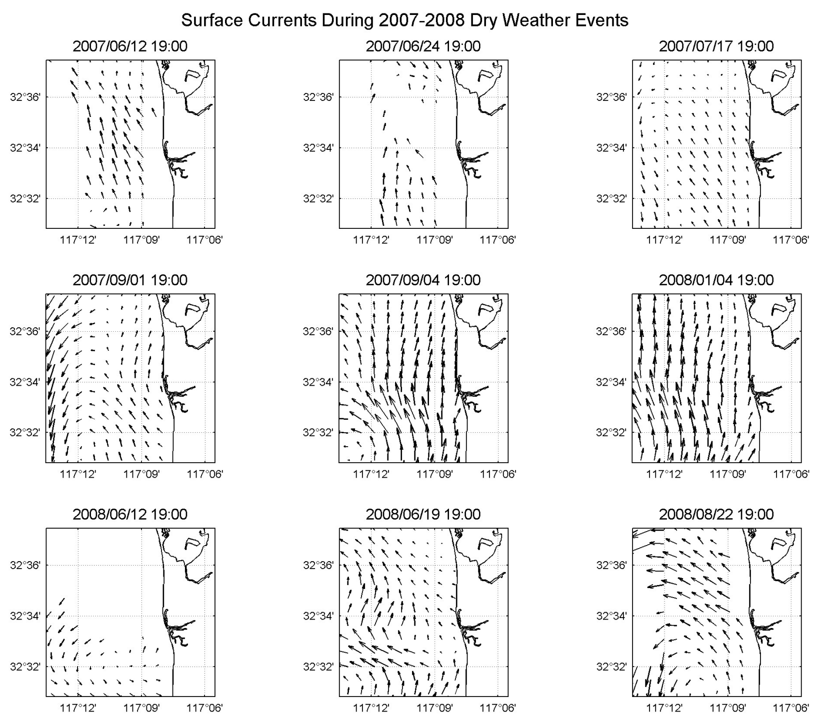


Figure IV.4 Surface Current Measurements
25-hour averaged surface currents measured by HF-radar show that northward flow in the South Bay region is a feature common (though not unique) to all dry weather events.

The September 1, 2007, dry weather event is presented to show how conditions might arise that expose South Bay beaches to the SBOO plume. All figures presented start 4 days prior to the date of the dry weather event to show how conditions evolve leading up to the event. Surface currents show regionwide southward flow from August 28 through August 29 (Figure IV.5). On August 30, flow becomes northward inshore of -117°12' East longitude and north of 32°30' North latitude and continues through September 2. Flow remains southward throughout the period west of -117°12' East longitude.

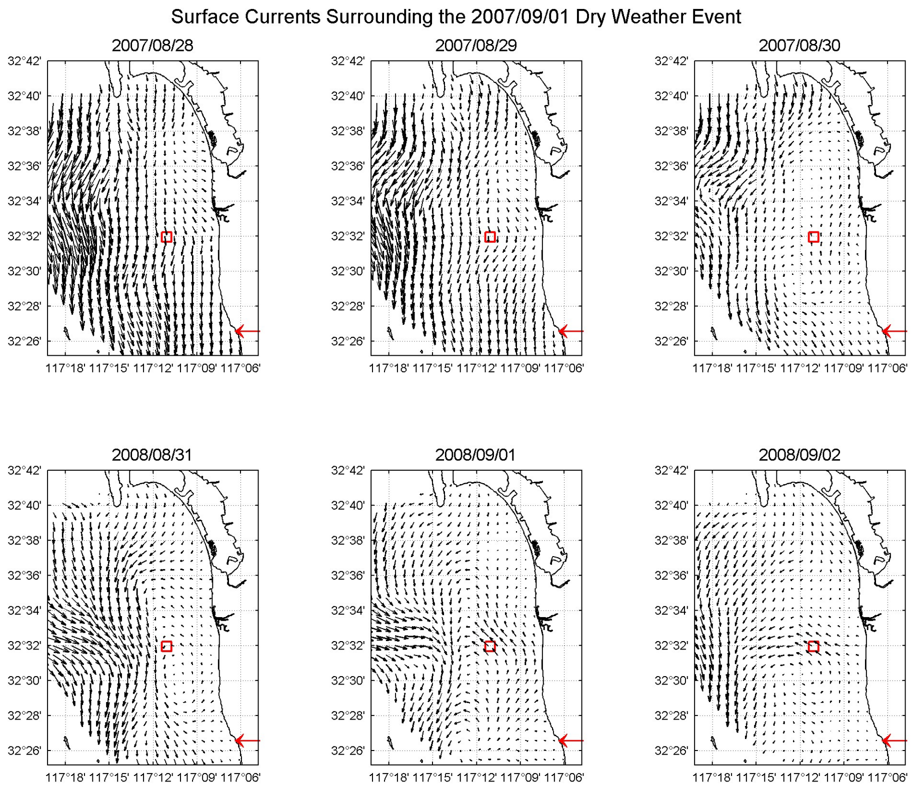


Figure IV.5 Surface Current Measurements – August 28-September 2, 2008
25-hour averaged surface currents leading up to a dry weather event on September 1, 2007. The location of the SBOO discharge is shown with a red box.

The 4 days prior to the dry weather event showed weakened stratification. Surface waters cooled from approximately 22 °C on August 26 down to 16°C on the August 28 at both IB Pier and the SBOO. SBOO temperature profiles show that the thermocline domed up from approximately 15 meters deep to 5 meters, while the IB Pier shows very weak stratification in the near-surface layer (0 to 6 m). These conditions allowed the SBOO plume to surface, as observed from sampling on August 30 (Table A.2). Satellite imagery of SSTs shows that cooling was a result of upwelling off Point Loma on August 28 and 29, followed by a relaxation and warming of surface waters (Figures IV.6 and IV.7).

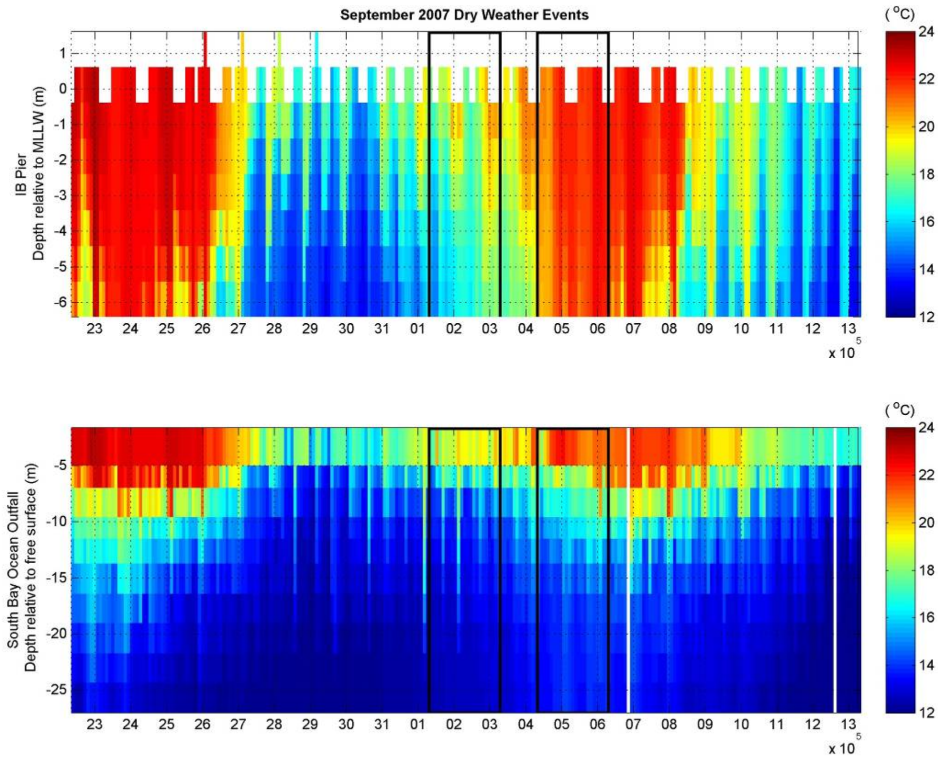


Figure IV.6 IB Pier and SBOO Buoy Temperature Profiles
Temperature profiles measured at IB Pier and the SBOO buoy surrounding the September 2007 dry weather events (black windows).

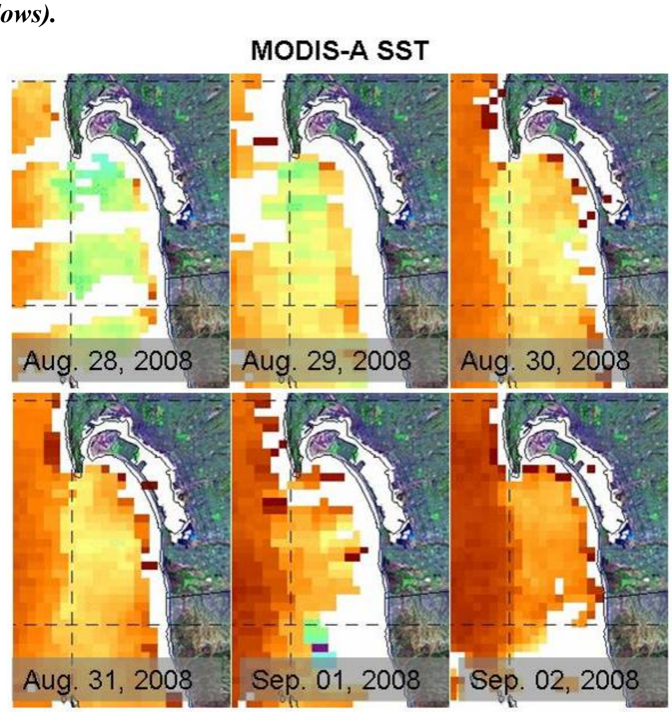


Figure IV.7 Sea Surface Temperature Images
MODIS-A Sea Surface Temperature images leading up to a dry weather event on September 1, 2007. All images are on the same color scale.

Vertical velocity profiles measured over the SBOO show that cross-shore flow was shoreward on August 28 and 29 during weakest stratification. By August 30, flow had reversed northward. However, it may be possible that the tail of the surfaced plume toward the south was advected northward on September 1 (Figure IV.8).

Statistical descriptions of the SBOO plume distribution based on periods when the plume is predicted to have surfaced and advection by surface currents suggest that South Bay beaches may be exposed to plume water from the outfall between 10 to 25 percent of the time that the outfall surfaces (Figure IV.9). This widespread exposure of plume water (potentially very dilute) is consistent with the *Bacteroides* sampled in the region. Animations of the simulations suggest that the pathway for particles arriving at South Bay beaches is consistent with in-situ observations presented above. Further work on this hypothesis will require detailed quantitative analysis of conditions surrounding individual dry weather events.

Two other potential sources causing dry weather events are the Tijuana River and the San Antonio de los Buenos discharge at Punta Bandera. Statistical distributions for each of the plumes show potential impact to South Bay beaches (Figure IV.9). However, as with the SBOO plume analysis, quantitative analysis for individual dry weather events must be performed to obtain more conclusive results. The Tijuana River distribution is based only on periods when flow is measured by the IBWC gauge, which essentially describes the distribution of the plume during wet weather events. However, because dry weather events occur during periods when no flow is reported for the river, re-analysis of the distribution is required. This is particularly relevant because exchange between the estuary and ocean has been observed during periods of no flow.

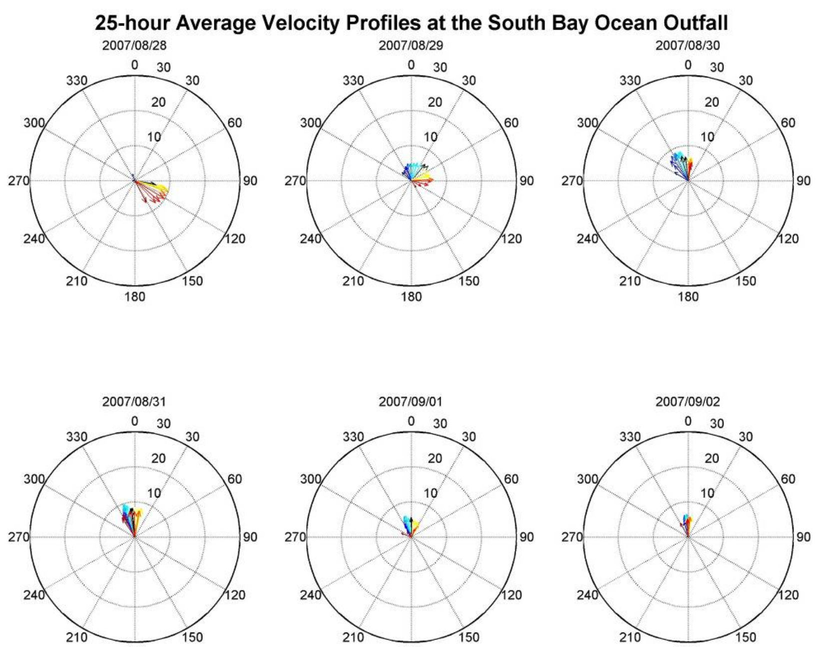


Figure IV.8 SBOO Average Velocity Profiles
Velocity profiles measured over the SBOO leading up to a dry weather event on September 1, 2007. Velocity vectors are colored by depth with warmer colors representing surface waters and cooler colors representing deeper waters.

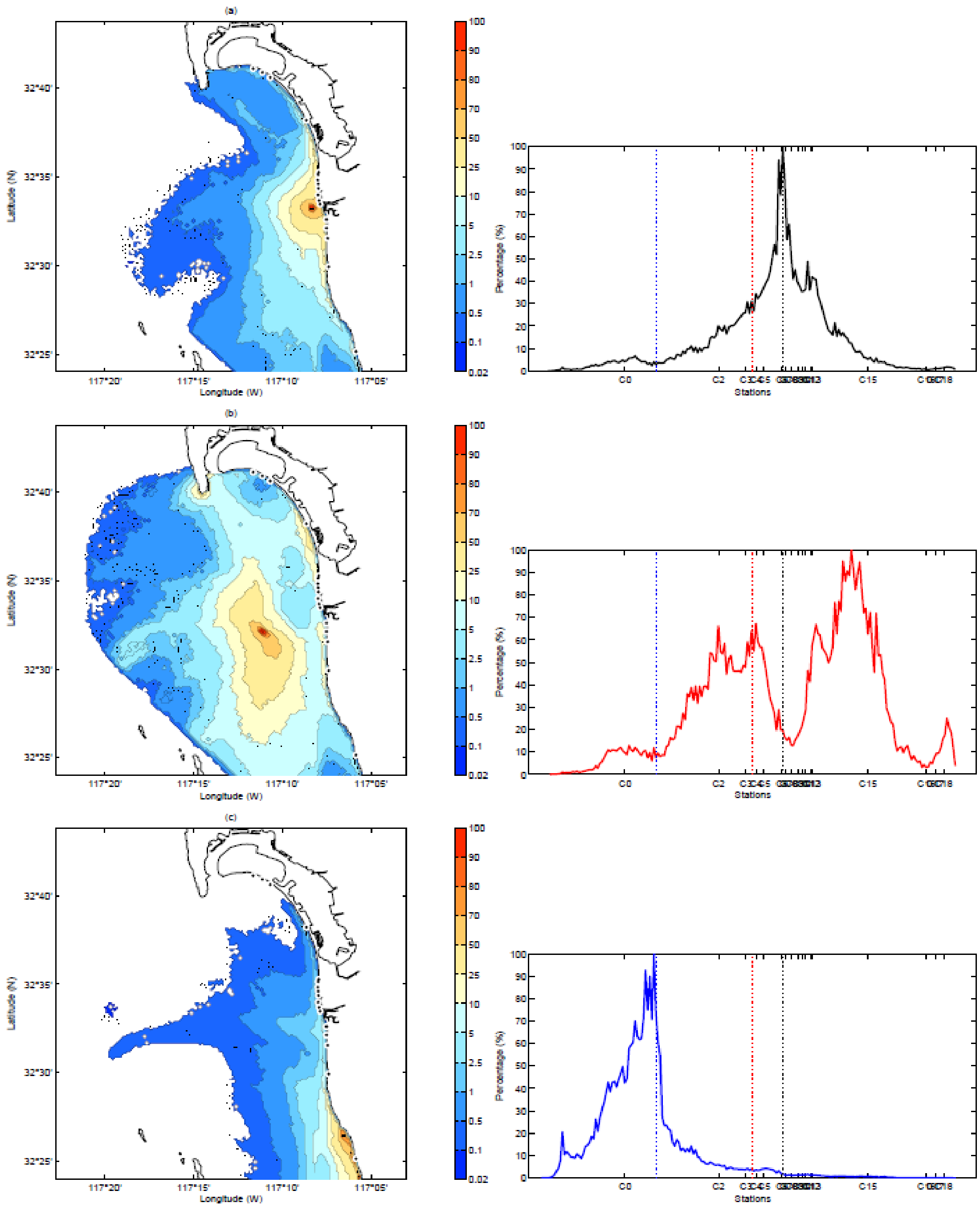


Figure IV.9 Tijuana River, SBOO, and Antonio de los Buenos Plumes
Probability distributions for the Tijuana River, SBOO, and Antonio de los Buenos plumes based on advection by surface currents measured by HF radar. Panels on the right present relative distributions of the respective plumes within 1 km of the coastline from the south (C0) toward the north (C18). The Tijuana plume distribution is based on periods when flow is observed. The SBOO plume distribution is based on periods when the plume rise height model predicts that the plume has surfaced. The San Antonio de los Buenos discharge is based on continuous release. A 3-day particle lifetime was used for all distributions.

V. Conclusions

A. Overview

Despite the political, ecosystem, and public health interests in coastal water quality, ocean monitoring of the physics responsible for the transport of a land-based or offshore wastewater discharge plume is difficult. Water quality sampling required of an NPDES permit holder in the receiving waters of their discharge typically is designed for assessing the quality of the water on a statistical basis, not for assessing the fate and transport of their discharge. The sampling required of an NPDES permit provides snapshots of ocean conditions, but under-samples the ocean in the time and space domains to estimate the position of the plume. In addition, the transport and orientation of discharge plumes are highly variable because of ocean dynamics and can be elusive to track using a fixed grid of boat-based sampling stations. As a result, assessment of station data is often inconclusive. One reason sampling protocols for monitoring receiving water have not evolved significantly over the years is the lack of available tools that can provide appropriate monitoring at the appropriate scales required to accurately estimate the fate and transport of the discharge plume. Methods using vessel-based sampling at fixed grid sampling stations in the receiving waters have not changed significantly in 30 years.

For the San Diego coastline in the U.S.-Mexico border region, possible sources of bacterial contamination responsible for beach closures in this region include the SSBIWTP outfall, the Tijuana River outflow, northward flow of discharges, and local runoff from Imperial Beach. The Tijuana river outflows just north of the border and drains precipitation from a watershed of 4,480 km^2, two-thirds of which is in Mexico. The City of Tijuana discharges pretreated waters directly onto the beach at Punta Los Buenos (6 miles south of the border) from the San Antonio de los Buenos treatment plant. Furthermore, the tourist corridor between Tijuana and Rosarito has increased its population fivefold, leading to the potential of uncontrolled residential and commercial discharge points. The multiplicity of possible sources close to the beaches has required that a regional approach be taken in monitoring the receiving waters of these many sources. A summary of the major discharges is provided in Table V.1.

Sources	Location		Discharge type	Flow rate ($m^3 s^{-1}$ (MGD))
	Longitude (W)	Latitude (N)		
TJR	32.5556	117.1369	Wet season	$\sim$ 2.9 (66)
SBO	32.5373	117.1835	Plume surfacing	$\sim$ 0.9 (20)
PBD	32.4336	117.1100	Continuous	1–1.5 (22-35)

Table V.1 U.S.-Mexico Border Major Dischargers
The major discharges in the U.S.-Mexico border region that may impact coastal water quality. The sources are summarized by location, discharge type, and flow rate: TJR, SBOO, and Punta Bandera. The wet season in the region is typically October through March.

Pursuant to the Consent Decree entered in *The Surfrider Foundation v. Marin*, Case No. 99-CV-2411-BTM (JFS), a comprehensive supplemental monitoring program was implemented in South Bay San Diego to assess the impact of these potential sources. The Consent Decree was carried out in two phases. The Phase I study was entitled "Evaluation of the South Bay International Wastewater Treatment Plant Receiving Water Quality Monitoring Program to Determine Its Ability to Identify Source(s) of Recorded Bacterial Exceedances."

The purpose of the study was to determine if the SBIWTP Receiving Water Quality Monitoring Program produced sufficient data to determine:

Is the treatment plant effluent a source of FIB exceedances at the San Diego monitoring stations, and if so, what are the frequency and locations of the exceedances caused by those discharges?

- Are the discharges from sources causing FIB exceedances, and if so, what are the frequency and location of exceedances caused by those discharges?
- Do oceanographic conditions and weather events cause onshore transport of the SBIWTP effluent, and if so, to what extent?

The report concluded that the RWQMP did not provide sufficient data to determine these issues, and made a general list of recommendations for different monitoring activities to supplement the RWQMP. The study also indicated that likely observations of beach exceedances were from land-based sources, and recommended that a supplemental program take a balanced approach in assessing the SBIWTP discharge plume at the SBOO and nearby land-based sources.

As a result of the report, and the subsequent Phase II study entitled "Recommendations for Supplemental Monitoring," a comprehensive supplemental monitoring program was developed and performed. The recommended activities were designed to complement the RWQMP currently conducted pursuant to the SBIWTP's NPDES permit for discharge through the SBOO, and had the goals of:

- Identify and track plumes from the SBOO
- Characterize land-based sources, with a focus on the Tijuana River
- Identify the regional oceanographic conditions that lead to high concentrations of FIB on the South Bay beaches

The recommended monitoring activities from the Phase I study fall into three general categories: (1) coastal ocean monitoring, with a more regional perspective; (2) plume monitoring at the SBOO; and (3) beach and kelp monitoring, including monitoring of land-based plumes.

The specific activities carried out in support of the supplemental monitoring program are the following:

SS1) SBOO plume mapping

SS2) Tijuana River plume mapping
SS3) Boat survey-mapping of land based plumes
SS4) Continuous flow rate and loading of the Tijuana River
SS5) Ocean moorings at key areas
SS6) Mapping of ocean currents using CODAR and improved data handling
SS7) The development of indicator studies to support source identification
SS8) Identification of spatial patterns

B. Findings

The sampling for the supplemental monitoring program was carried out between July 2007 and October 2008. As summarized in the Executive Summary, analysis of the data from the program has resulted in the following findings:

1. Measurements of ocean stratification at the SBOO and subsequent modeling of the behavior of the buoyant plume rise height, estimates that the discharge plume surfaced a total of 1,889 hours (16 percent total time) during the 16-month supplemental monitoring program. These surfacing events occurred over 98 discrete days, representing 26 percent of the days over a calendar year. Similar analysis of data for the previous 3 years estimates SBOO plume surfacing to take place on average 27 percent of the time over the calendar year.

2. The surfacing of the plume is seasonal. When partitioned by dry season (April through September) and wet season (October through March), the plume surfacing was found to take place 100 percent of the time in the wet season. When the ocean is stratified, the typical cap depth of the plume is 8 m.

3. Surface current maps measured by HF radar coupled with temperature stratification measurements for plume rise height potential can be used to estimate the surface plume transport and derive probability maps of plume exposure. The surface plume can be tracked using surface current maps from the HF radar, while the orientation of the plume at depth is estimated using subsurface current measurements obtained with an ocean buoy at the outfall. The statistical orientation of the SBOO plume is found to be oriented in the north-to-south direction. This orientation can vary significantly for individual events.

4. When the SBOO plume surfaces, there is a probability of exposure of the shoreline to plume water. This probability is estimated to be approximately 10 to 25 percent during the plume surfacing events (98 days total over the 16-month period of the supplemental monitoring program). No shoreline FIB exceedances in samples from the San Diego DEH or from the RWQMP were found to correlate with these periods.

5. Subsurface currents measured by the oceanographic mooring at the SBOO outfall can be used to estimate the transport and orientation of the SBOO subsurface plume. The statistics of the plume location over the supplemental monitoring period suggest it is oriented in the northwest-to-southeast direction.

6. The Tijuana River is an intermittent source of high FIBs during rain events. The Tijuana River can disperse a coastal trapped plume several miles north and south of the river entrance during heavy rainfalls.

7. Shoreline FIB exceedances in the South Bay San Diego region are predominately a result of exposure of the shoreline to Tijuana River plume water. Tijuana River plume water was found to account for 94 percent of exceedances (a total of 81). Five additional exceedances occurred as single-station anomalies not associated with a rain or river flow event.

8. The discharge plume from the San Antonio de los Buenos treatment plant at Punta Bandera is typically oriented to the south. However, the plume is estimated to track north across the border 12 percent of the time (15 discrete events for a total of 60 days out of 490 days). In a historical 4-year analysis of data, the upcoast transport is estimated to occur 56 times for a total of 234 out of 1,461 days (approximately 16 percent of the time) over which the analysis occurred.

9. Nine suspected sewage contamination events were reported in the City of Imperial Beach region during dry weather (no recent rainfall). Subsequent processing of FIB samples by the Department of Environmental Health reported background levels. Ongoing analysis of the oceanographic conditions during these events remains inconclusive, with viable hypotheses suggesting the events are:

    - A result of subsurface transport of SBOO plume water
    - From renegade flows into the Tijuana estuary, which then are tidally pumped into the ocean
    - Northward transport from Punta Bandera

10. One hypothesis explaining dry weather events is that the SBOO plume “sweeps” along the coast during the transition from a weakly stratified southeast flow to a northerly flow. The weakly stratified southeast flow allows the plume to surface. Then, as the flow condition changes to the north, the surfaced plume sweeps shoreward resulting in temporary exposure to the outfall plume. Eight of the nine reported dry weather events meet criteria supporting this hypothesis. These events include:

    - Transition from southerly to northerly flow
    - Weak stratification during southerly flow
    - Shoreward flow during the transition from southerly to northerly flow

This hypothesis requires quantitative analysis and supporting special studies.

11. Analysis of the CTD cast data obtained as part of the RWQMP pursuant to the NPDES permit for discharge through the SBOO detected the plume in both its surfaced and subsurface state. Of the 16 monthly surveys available, the SBOO discharge plume was detectable two times.

12. The AUV using a CTD probe, along with sensors for measuring changes in the ocean's optical properties, was able to effectively map out the location of the subsurface plume. With proper vehicle configuration and mission programming, the vehicle was able to detect the plume 100 percent of the time. The mean dilution ratio of SBOO wastewater to seawater determined from AUV salinity measurements is 1:302. The ability of the vehicle to sense the subsurface plume was enabled using proper mission planning of the vehicle track and consideration of plume transport estimates using SBOO mooring data in near-real time. The plume orientation measured by the AUV matched estimated trajectories and rise heights from the ocean mooring velocity profile and stratification measurements for all missions. Over the period of the supplemental monitoring program, the plume was found to orient itself both to the south, northeast, and north. The plume was determined to have surfaced during four missions based on AUV measurements. A total of 18 sampling missions were conducted.

13. The SBOO plume, due to its small size (nominal 25 mgd) would be elusive to find in typical boat-based sampling. Use of the regional observational network that included the HF radar and ocean mooring enabled AUV sampling to take place at the right time and place to capture the plume.

14. Land-based sampling of the Tijuana River, for the purposes of quantifying FIB loads to the South Bay, indicate high levels of indicator bacteria throughout the estuary. In general, samples taken at Hollister Road (Station 3) and in the main river channel (Station 3) have FIB concentrations considerably higher than those taken at the river mouth (Station 1) or at the background location (Station 2, Seacoast Drive). Peak concentrations at Hollister Road exceed 1.6 million MPN/100 ml for both total and fecal coliform (January 8, 2008).

15. Boat-based samples of land-based plumes indicate that FIB concentrations in the Tijuana River plume can exceed those in the SBOO plume by an order of magnitude or more. Samples taken in the river plume, 1 mile north of the river mouth, show total coliform concentrations of 90,000 MPN/100 ml. Peak total coliform concentrations measured in the SBOO plume samples were 3,000 MPN/100 ml.

16. Dry weather offshore sampling provides no indication that the SBOO plume is causing elevated FIB concentrations along the shoreline north of the Tijuana River mouth. All dry weather surface water samples at near-shore stations (Stations 4 through 11) yielded FIB concentrations below the detection limit of 20 MPN/100 ml.

17. There are two primary sources of contamination in the immediate region: the Tijuana River discharge and the SBOO discharge. Detectable levels of *Bacteroides* were observed for both sources. Whether these levels of *Bacteroides* concentrations pose a health risk is not known. To date, epidemiological studies that employ these human microbial tracers have not been performed; thus, a public health risk cannot be evaluated based on these observations.

18. Both of these sources create discharge plumes that have water quality characteristics that can be readily detected using standard physical and optical water quality instrumentation. Both plumes are characterized by decreased salinity, increased CDOM concentrations, and generally increased suspended particulate concentration.

19. Although the two discharge plumes can be readily detected and are expected to have high levels of microbial contamination, there are observations from each survey that show measurable surface concentrations of *Bacteroides* indicating some level, albeit low, of widespread human contamination throughout the South Bay. These measurements are not necessarily associated with a water quality signature that is obviously traceable to either of the two sources.

20. If water quality variables indicate the presence of a plume from either of the two immediate sources, it is likely that *Bacteroides* will be detected, which is indicative of human fecal contamination. However, elevated *Bacteroides* concentrations were detected in the absence of plume-indicating water quality did not indicate the presence of effluent. This may have been because the effluent was sufficiently diluted, such that, although the water quality variables were not distinct from background, there was sufficient *Bacteroides* genetic material to be detectable through the amplification methods that were used. This does not necessarily indicate a health risk, but it does indicate a presence at least at very low levels.

21. The “smelly water” sample that was analyzed was found to contain the highest concentration of *Bacteroides* that was measured. No water quality measurements were made on that water, so no correlation with water quality variables can be made.

VI. Monitoring Recommendations

As a result of the findings reported from the Supplemental Monitoring Program, a recommended set of activities is proposed to assist with future ocean monitoring activities in South Bay San Diego. Recommendations are organized by discharge.

South Bay Ocean Outfall

1. Continued operation of an oceanographic mooring designed to measure subsurface velocity and ocean stratification is recommended to document the state of the receiving waters into which the outfall discharges. Present sampling pursuant to the NPDES permit is too coarse in time for identifying periods when the outfall plume is surfacing. Likewise, the NPDES permit has no sampling requirements for knowing the ocean currents into which the discharge takes place. During this supplemental monitoring program, measurements showed the outfall plume surfaces for a significant fraction of the calendar year. When the plume was submerged, the subsurface velocity measurements proved invaluable for estimating the location of the plume so that it could be effectively sampled.
2. In light of the surfacing statistics of the discharge plume, it is recommended that surface current maps derived from HF radar, in conjunction with plume rise height estimates based upon the ocean mooring data, be used to estimate where the surfaced plume is located in the receiving waters.
3. Present sampling pursuant to the NPDES permit is too coarse in space to accurately identify where the submerged plume of the SBOO is located. If NPDES monitoring goals are to sample the receiving waters to measure plume location and dilution levels, it is recommended that continued usage of the mobile underwater vehicle be in place and its usage be integrated with near-real-time reports of stratification and subsurface velocity. The approach used for the supplemental monitoring program involved programming an AUV to sample the ocean in locations probable for the plume to be present. The mission programming was guided by hourly reports of stratification and subsurface velocity provided by an ocean buoy located at the wye of the outfall (see Recommendation 1). When the plume was detected, it was found to have an average dilution ratio of 1:300, even at distances several kilometers from the discharge.

Punta Bandera

4. Beyond the scope of those findings reported in this document, very little is known about the Punta Bandera discharge. It is recommended that a program involving in-situ sampling and tracking of the plume be developed to better understand where the plume is transported, dilution rates associated with the plume, and constituents within the plume. Because FIB are only one indicator of potential health risks associated with a discharge plume, it is recommended that the plume's constituents, as well as its fate and transport, be monitored. Since the results of the present study suggest that the plume is coastally trapped, human

health risks and ecosystem impacts to rocky-intertidal habitats might be elevated. The sampling program should involve approaches used in the present study with some expansion aimed at understanding the role of south swell in transporting waters within the surfzone northward.

Tijuana River

5. The results of the supplemental monitoring program suggest that some adaptive management of ocean waters with impaired water quality might be feasible for the shoreline of the U.S.–Mexico border. Tijuana River plume modeled trajectory results driven by near-real-time surface current maps are now used by the County of San Diego DEH and the marine safety office at the City of Imperial Beach. These now-cast river plume models should be continued on a proto-operational basis, and model results should be communicated to the water quality community in Mexico. Web-based products could be distributed in near-real-time on a bi-national basis.
6. In-situ measurements of environmental conditions at the Imperial Beach Pier should be continued because this represents “ground zero” conditions for plume water exposure should there be flow from the river during northward ocean currents. These in-situ measurements should be complemented by more comprehensive sampling of non-FIB constituents (bacteria, viruses, metals, and organics).
7. Better characterization of the Tijuana River during low-flow conditions is recommended. The present gauge is designed for flood events. Similarly, renegade flows from canyons draining into the estuary (west of the existing gauge) should be monitored. This would include Smuggler’s Gulch and Yogurt Canyon. At this time, very little is known about low flows into the estuary – flows which ultimately exit to the ocean. The river mouth should be sampled periodically at the end of an ebb tide for non-FIB constituents.
8. There exists no rain gauge network within the Tijuana River Watershed. A bi-national network of rain gauges within the watershed should be developed to provide accurate data for issuing flood warnings and initializing hydrologic models.

Dry Weather Events

9. Suspected sewage contamination events in the Imperial Region deserve additional attention. To date, sampling of the suspected contaminated water has resulted in low FIBs. However, elevated levels of *Bacteroides* were sampled during this study, suggesting the potential for the water to have human contamination. Potential hypotheses suggest that the events are a result of SBOO plume water transported at depth, Punta Bandera discharge water, low-flow Tijuana River water, or that the signs are actually a result of biological activity dependent (or independent) of the discharge plume water. It is recommended that a special study be conducted that may include the following:

a. A dense array of moored velocity, temperature, salinity, and optical sensors placed from the U.S.–Mexico border north to the Imperial Beach Pier, and offshore to the SBOO. The array would allow tracking of the subsurface flows and ocean conditions that lead to the reported events.

b. Underwater vehicle sampling surveys during the events.

c. Water sampling and processing for pathogens, bacteria, viruses, algal blooms, and nutrients. Since the events are short lived, preparations for sampling must be made before an event occurs.

VII. References

Ackerman, D., and S.B. Weisberg. 2003. "Relationship Between Rainfall and Beach Bacterial Concentrations on Santa Monica Bay Beaches." *Journal Water and Health.* Pp. 85–89.

Bratkovich, A. 1985. "Aspects of the Tidal Variability Observed on the Southern California Continental Shelf." Journal of Physical Oceanography. Volume 15. Pp. 225–239.

Clifton, C., S.Y. Kim, and E. Terrill. 2007. "Using Real Time Observing Data for Public Health Protection in Ocean Waters, Coastal Zone." Portland, Oregon. July 22 – 26.

Fofonoff, N.P. and R.C. Millard Jr. 1983. "Algorithms for Computation of Fundamental Properties of Seawater." *Unesco Technical Papers in Marine Science*. UNESCO, Place de Fontenoy, 75700, Paris, France.

Frick, W.E., P.J.W. Roberts, L.R. Davis, J. Keyes, D.J. Baumgartner, and K.P. George. 2001. *Dilution Models for Effluent Discharges (Visual Plumes).* 4th Edition; Standard and Applied Science Division Office of Science and Technology.

Fuhrman, J.A., X.L. Liang, and R.T. Noble. 2005. "Rapid Detection of Enteroviruses in Small Volumes of Natural Waters by Real-Time Quantitative Reverse Transcriptase PCR." *Applied and Environmental Microbiology*. Volume 71, Issue 8. Pp. 4523-4530.

Griffa, A. 1996. "Applications of Stochastic Particle Models to Oceanographic Problems." In *Stochastic Modeling in Physical Oceanography*. Editors: R.J. Adler, P. Müller, and B. Rozovskii. Progress in Probability: Birkhauser. Cambridge, MA. Pp. 114 – 140.

Griffa, A., K. Owens, L. Piterbarg, and B. Rozovskii. 1995. "Estimates of Turbulence Parameters from Lagrangian Data Using a Stochastic Particle Model." *Journal of Marine Research.* Volume 53. Pp. 371 – 401.

Griffin, Dale W., Kim A. Donaldson, John H. Paul, and Joan B. Rose. 2003. *Clinical Microbiology Reviews*. Volume 16, Issue 1. Pp. 129 – 143.

Jones, B.H., M.A. Noble, and T.D. Dickey. 2002. "Hydrographic and Particle Distributions over the Palos Verdes Continental Shelf: Spatial, Seasonal and Daily Variability." *Continental Shelf Research*. Volume *22* (6-7). Pp. 945-965.

Millero, F. J., and A. Poisson. 1981. "International One-Atmosphere Equation of State of Seawater." Deep Sea Resources, 28A. Pp. 625–629.

Noble, R.T.; I.M. Lee, and K.C. Schiff. 2004. “Inactivation of Indicator Micro-Organisms from Various Sources of Fecal Contamination in Sea Water and Fresh Water.” *Journal of Applied Microbiology.* Volume 96. Pp. 464–472.

Noble, R.T.; M.K. Leecaster, C.D. McGee, D.F. Moore, V. Orozco-Borbon, K. Schiff, P. Vainik, and S.B. Weisberg. 2000. “Southern California Bight 1998 Regional Monitoring Program Volume III: Storm Event Shoreline Microbiology.” Technical Report. p 65.

Ohlmann, C., P. White, L. Washburn, E. Terrill, B. Emergy, and M. Otero. 2007. “Interpretation of Coastal HF Radar Derived Surface Currents with High Resolution Drifter Data.” *Journal of Atmospheric and Oceanic Technology.* Volume 24, Issue 4. Pp. 666-680. April.

Orozco-Borbon, M.V.; R. Rico-Mora, S.B. Weisberg, R.T. Noble, J.H. Dorsey, M.K. Leecaster, and C.D. McGee. 2006. “Bacteriological Water Quality Along the Tijuana-Ensenada, Baja California, Mexico Shoreline.” *Marine Pollution Bulletin*. Volume 52. Pp. 1190–1196.

Payne, J., R. Terrill, E. Carter, M. Otero, M. Middleton, W. Chen, A. McCay, D.F. Müeller, C. Jayko, and K. Nordhausen. 2007. “Evaluation of Field-Collected Drifter and Subsurface Fluorescein Dye Concentration Data and Comparisons to High Frequency Radar Surface Current Mapping Data for Dispersed Oil Transport Modeling.” Presented at Arctic and Marine Oil Spill Program Technical Seminar. Conference 30. Volume 2. Pp. 681-712.

Petrenko, A.A., B.H. Jones, T.D. Dickey, M. LeHaitre, and C. Moore. 1997. “Effects of a Sewage Plume on the Biology, Optical Characteristics, and Particle Size Distributions of Coastal Waters.” *Journal of Geophysical Research-Oceans.* Volume 102, Issue C11. Pp. 25061-25071.

Reifel, K.M., S.C. Johnson, P.M. DiGiacomo, M.J. Mengel, N.P. Nezlin, J.A. Warrick, and B.H. Jones. 2008. “Impacts of Stormwater Runoff Contaminants in the Southern California Bight: Relationships among Plume Constituents.” *Continental Shelf Research*, *in Review*. 2008.

Roberts, P.J.W. 1999a. “Modeling Mamala Bay Outfall Plumes. I: Near Field.” *Journal of Hydraulic Engineering-ASCE*. Volume 125, Issue 6. Pp. 564-573.

Roberts, P.J.W. 1999b. “Modeling Mamala Bay Outfall Plumes. II: Far Field.” *Journal of Hydraulic Engineering-ASCE*. Volume 125, Issue 6. Pp. 574-583.

Roberts, P.J.W., W.H. Snyder, and D.J. Baumgartner. 1989. “Ocean Outfalls I: Submerged Wastefield Formation.” *Journal of Hydraulic Engineering-ASCE*. Volume 115, Issue 1. Pp. 1-25.

Schulz, T.J., P.J. Marczan, and A.G. Fane. 1994. “Behavior of Sewage Effluent Oil and Grease in the Ocean.” *Water Environment Research*. Volume 66, Issue 6. Pp. 800-804.

Seurinck, S., T. Defoirdt, W. Verstraete, and S.D. Siciliano. 2005. “Detection and Quantification of the Human-Specific HF183 Bacteroides 16S rRNA Genetic Marker with Real-Time PCR for Assessment of Human Faecal Pollution in Fresh Water.” *Environmental Microbiology.* Volume 7, Issue 2. Pp. 249-259.

Siegel, D.A., B.P. Kinlan, B. Gaylord, and S.D. Gaines. 2003. “Lagrangian Descriptions of Marine Larval Dispersion.” *Marine Ecology Progress Series.* Volume 260. Pp. 83 – 96.

Svejkovsky, J. and B. Jones. 2001. “Detection of Coastal Urban Stormwater and Sewage Runoff with Synthetic Aperture Radar Satellite Imagery.” EO8 2001, 82. Pp. 621, 624–625, and 630.

Twardowski, M.S., E. Boss, J.B. Macdonald, W.S. Pegau, A.H. Barnard, and J.R.V. Zaneveld. 2001. “A Model for Estimating Bulk Refractive Index from the Optical Backscattering Ratio and the Implications for Understanding Particle Composition in Case I and Case II Waters.” *Journal of Geophysical Research-Oceans.* Volume 106, Issue C7. Pp. 14129-14142.

Washburn, L., K.A. McClure, B.H. Jones, and S.M. Bay. 2003. “Spatial Scales and Evolution of Stormwater Plumes in Santa Monica Bay.” *Marine Environmental Research.* Volume 56, Issue 1-2. Pp. 103-125.

Winant, C. D., and A.W. Bratkovich. 1981. “Temperature and Currents on the Southern California Shelf: A Description of the Variability. Journal of Physical Oceanography. Volume 11. Pp. 71–86.

Appendix 1
Monitoring Plan

MONITORING PLAN
Coastal Observations and Monitoring in South Bay San Diego
IBWC / Surfrider Consent Decree

Prepared For

International Boundary and Water Commission
United States Section
4171 N. Mesa, C-100
El Paso, Texas 79902

Contract: IBM04D0005
Task Order: IBM06T0026

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July 20, 2007

Introduction

This monitoring plan describes a program to enhance regional oceanographic monitoring efforts in South Bay San Diego. Through a series of external reviews and assessments, a prioritized list of monitoring and data collection activities was identified that addressed the following goals:

a) Identify and track plumes from the South Bay Ocean Outfall (SBOO)
b) Characterize land based sources with focus on the Tijuana River
c) Identify the regional oceanographic conditions which lead to high fecal indicator bacteria (FIB) on the South Bay Beaches.

Approach

The classes of monitoring activities in which the IBWC has requested effort are the following:

SS1) SBOO plume mapping
SS2) Tijuana River plume mapping
SS3) Boat survey-mapping of land based plumes
SS4) Continuous flow rate and loading of the Tijuana River
SS5) Ocean moorings at key areas
SS6) Mapping of ocean currents using CODAR and improved data handling
SS7) The development of indicator studies to support source identification
SS8) Identification of spatial patterns

In order to meet these goals, technical approaches were successfully proposed to the IBWC and are described within this Monitoring Plan. The activities project onto the following three general areas of interest:

a) Identify and track plumes from the South Bay Ocean Outfall (SBOO)
SS1, SS5, SS6, SS7, SS8
b) Characterize land based sources with focus on the Tijuana River
SS2, SS3, SS4, SS5, SS6, SS7, SS8
c) Identify the regional oceanographic conditions which lead to high fecal indicator bacteria (FIB) on the South Bay Beaches.
SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8

This suite of inter-related monitoring activities (SS1-SS8) will be greatly enhanced through appropriate integration of data from other related regional monitoring programs. These programs are identified below:

- FIB indicator data obtained by shoreline monitoring programs conducted by the San Diego County Department of Environmental Health (DEH) supported through AB411 and the EPA BEACHES program.

- Ocean data generated by the City of San Diego for the Point Loma Outfall as part of their NPDES permit.
- Ocean data generated by the City of San Diego for the IBWC SBOO as part of their NPDES permit.
- Tijuana River flow data from a gauge operated by IBWC
- The Tijuana River National Estuarine Research Reserve
- San Diego Coastal Ocean Observing System (www.sdcoos.org)

Monitoring Activities SS1-SS8

In this section, a description of the monitoring components is presented. Detailed sampling protocols are provided separately in the QAPP. Table 1 (below) outlines the scope of technical components and their dependence on the requested monitoring activity and goals of the program.

Technical component	Monitoring Activity	Goals addressed
REMUS AUV Operations	SS1, SS2, SS7, SS8	all goals
Ocean Moorings	SS1-SS3, SS5, SS6	all goals
CODAR Operations	SS1 – SS8	all goals
Tijuana River Monitoring	SS2 – SS8	Tijuana River plume, FIB impacts
Boat Surveys	SS1-SS8	all
Special Plume Water Discriminator Study	SS7	SBOO and Tijuana River plume

The proposed monitoring activities are to take place in the South Bay San Diego region as shown in Figure 1. Potential sources of FIBs in the area include the Tijuana River plume, urban runoff, South Bay Ocean Outfall plume, San Antonio de los Buenos creek, and PLOO.

Figure 1. A map of the San Diego South Bay region showing bathymetry contours at 5m, 10m, 15m, 20m, and 25m. The SBOO is offshore the U.S. – Mexico border at approximately 27m water depth. Also shown are the relative locations of the Imperial Beach region (IB), the Tijuana River (TJR), San Antonio de Los Buenos (LBC) and the South Bay Ocean Outfall (SBOO).

SS1) SBOO plume mapping and SS2) Tijuana River plume mapping - Scripps

The technical approach to mapping the SBOO and Tijuana River plumes are to operate an autonomous underwater vehicle (AUV) designed for coastal monitoring. A REMUS (Remote Environmental Measuring UnitS) 100 will be acquired from Hydroid, Inc. and outfitted with the most up-to-date technology. The REMUS AUV is a 19 cm diameter, propeller-driven platform weighing 37 kg, making it hand deployable by two people from a small boat. Powered by four lithium-ion batteries, the vehicle is capable of a maximum mission distance of approximately 100 km at 3 kts. The REMUS has four main sections: a nose section, an RD Instruments 1200kHz Acoustic Doppler Current Profiler (ADCP), a mid-body, and tail section. The vehicle will be equipped with the following sensors:

Sensor	Purpose
Conductivity, Temperature, Depth	measurements of ocean temperatures, and salinities, ocean density and stratification
optical backscatter	turbidity
fluorometer	Chlorophyll fluorescence
1200 kHz ADCP	measurements of currents, bathymetry, and vehicle speed

Sensor	Purpose
SideScan Sonar	seafloor characterization
Global Positioning System (GPS)	Vehicle position while at the surface
Acoustic Transponder/Navigation System	Vehicle positioning while underwater
Iridium	satellite-based communication system

The combination of the CTD and optical sensors are similar to those used for boat-based NPDES monitoring programs.

Prior to deployment, a mission plan will be developed based upon our best understanding of the plume locations as determined by supporting environmental data from the San Diego Coastal Ocean Observing System. This mission plan will be developed the day prior, with options built in for adjusting tracks should the environment differ the following morning. On the day of deployment, transponders will be deployed to provide accurate vehicle positioning. The navigation of the vehicle is provided by the transponder network, coupled with the onboard positioning sensors which measure the velocity of the vehicle. The autonomy of the vehicle provides the added capability of surveying the very near surface of the ocean with minimal disturbance. This capability is critical when surveying buoyant freshwater plumes which may be present only as a thin layer at the surface. These thin layers (plumes can be 1m or less) can be disturbed when sampled by a vessel towing equipment, presenting difficulties in boat-based mapping efforts.

We plan to sample on a nominal 2 week cycle over the course of a year, no less than 24 surveys, to measure a broad range of conditions. The surveys are scheduled to begin July, 2007 and end June, 2008. The distribution of surveys will be comprised of at least 12 at the ocean outfall and 12 at the Tijuana River mouth. When necessary, attempts will be made to survey both regions on the same day, once during a dry weather event and once during a wet weather event. Mapping both regions in the same day reduces survey resolution at each location, and therefore will not be standard operating procedure. Initial mapping efforts will focus on individual plumes to identify how far they can be tracked from the source. The boundaries as displayed in Figure 3 will vary depending upon oceanographic conditions. At this point we do not know how much area the Tijuana River and South Bay Ocean Outfall plumes cover under “typical” San Diego environmental conditions (mild temperature (70^{o}F), moderate wind speeds (4m/s), NW swell). However, these conditions clearly fluctuate. The essence of task SS1 and SS2 is to characterize the outfall and Tijuana River plume to determine their extents. We will modify the survey areas throughout the field effort component of this proposal.
Example scenarios in which the plumes will be mapped include:

- High levels of stratification in both winter and summer conditions as indicated by the moorings
- Minimum (isothermal) stratification in both winter and summer conditions as indicated by the moorings
- On-shore flow conditions indicated by the surface current mapping array and trajectory models of flow from the SBOO

- Northward, southward, and offshore flow events from the Tijuana River during wet weather events as indicated by the river gauge and trajectory model outputs from the surface current mapping array
- Similar scenarios to above during reported dry weather flows
- Generalized upwelling and downwelling favorable conditions as suggested by regional wind models and buoy observations
- Anomalous plume events from the San Antonio de Los Buenos Creek observed by ocean color satellite imagery or visual reports

Go/No go survey decisions will be determined the night before a survey. We anticipate that a 1 day lead time for the survey work will be required. Data from the vehicle will be processed to generate maps of surveyed fields in between field sampling efforts.

For the SBOO plume, the plume will be tracked over a depth range which is expected to span the plume layer depth. This guidance will be provided through the real-time water column stratification measurements provided by the oceanographic mooring. Since little is known about the distance from diffusers over which the SBOO plume can be tracked, the sampling plan will evolve over the course of the program once the spatial scales of the plume are resolved to develop optimal methods of tracking the furthest extent of the plume.

A photograph of the REMUS autonomous underwater vehicle is shown in Figure 2.

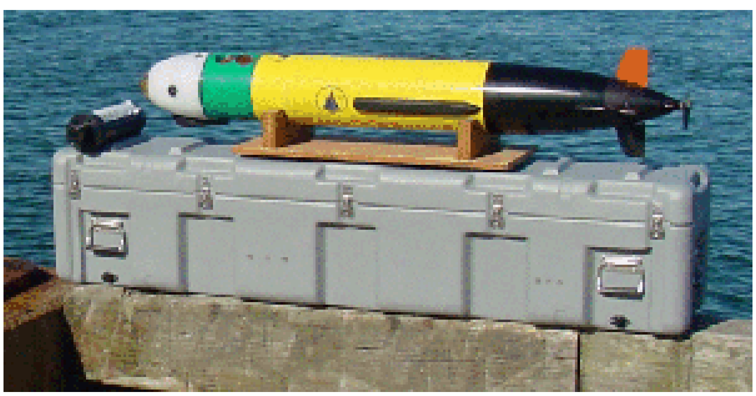


Figure 2. The REMUS autonomous underwater vehicle. A vehicle equipped with sensors specific for tracking the plumes of the Tijuana River and South Bay Ocean Outfall will be routinely deployed in support of this program.

The sampling tracks for the REMUS vehicle when mapping the Tijuana River plume will be to nominally operate the vehicle in an undulating fashion along the 5m, 10m, 15m, and 20m contours from the border northwards to the Imperial Beach pier. All four contours will be mapped during each survey. A general map of the region that will be surveyed for the Tijuana River and South Bay Ocean Outfall plume is bounded by the boxes shown in Figure 3. This same area will be sampled when plume water from San Antonio de Los Buenos is thought to be entering U.S. waters.

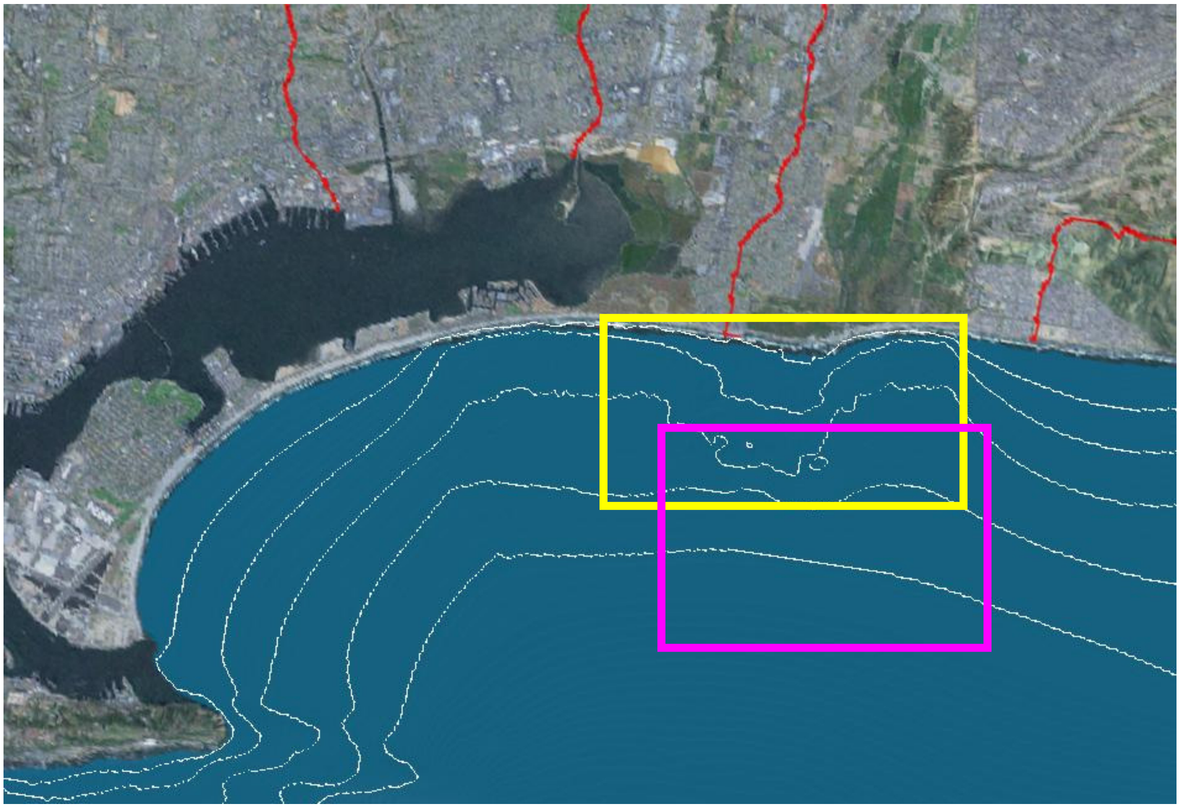


Figure 3. General region of survey interest for mapping the SBOO (purple) and Tijuana River plume (yellow). Depth contours shown at 5m, 10m, 15m, 20m, and 25m. Surveys for the Tijuana River plume will nominally extend from the 5m to 20m isobaths while the SBOO plume surveys will be focused in the region of the outfall. While not represented by the purple box, the program will support tracking to its furthest, detectable extent.

SS3) Boat survey-mapping of land based plumes, Scripps and CH2M HILL

This component involves:

- Performing CTD/optical property casts at selected sites from the vessel supporting the AUV operations. Two CTD casts will be taken with each survey, one ambient cast (outside of the plume) and one close to the river mouth or at the wye of the ocean outfall.
- Integrating the cast data from the existing monitoring of the South Bay International Wastewater Treatment Plant (SBIWTP) Regional Water Quality Monitoring Plan (RWQMP) and similar data gathered by the Point Loma Ocean Outfall (PLOO) permit.
- Support of the plume water discriminator study to be conducted for SS7. CTD + optical data would be obtained using casts as mentioned above, and limited bottles will be triggered for FIB measurements in regions of identified plume water. The FIB samples will be taken either on the vessel used for the REMUS surveys or on the City of San Diego vessel used for taking bacteria samples as part of the SBIWTP RWQMP. A minimum of two bottles representing two depths will be collected at each of two stations. A separate vessel for task SS7 is required to support the more rigorous boat based sampling effort.

To illustrate the density of sampling stations already maintained as part of the PLOO and SBOO NPDES monitoring, a map of their locations is provided in Figure 4.

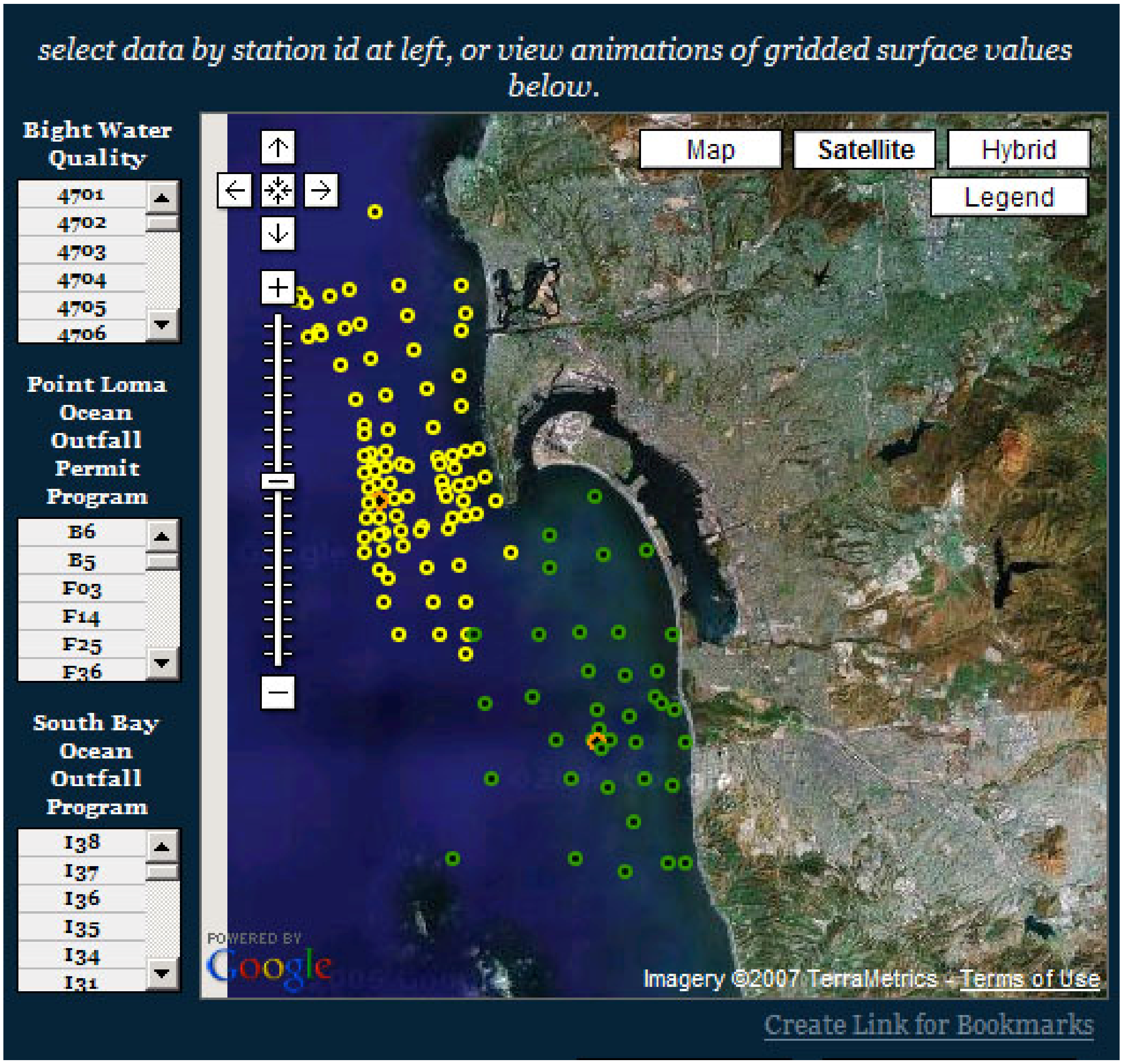
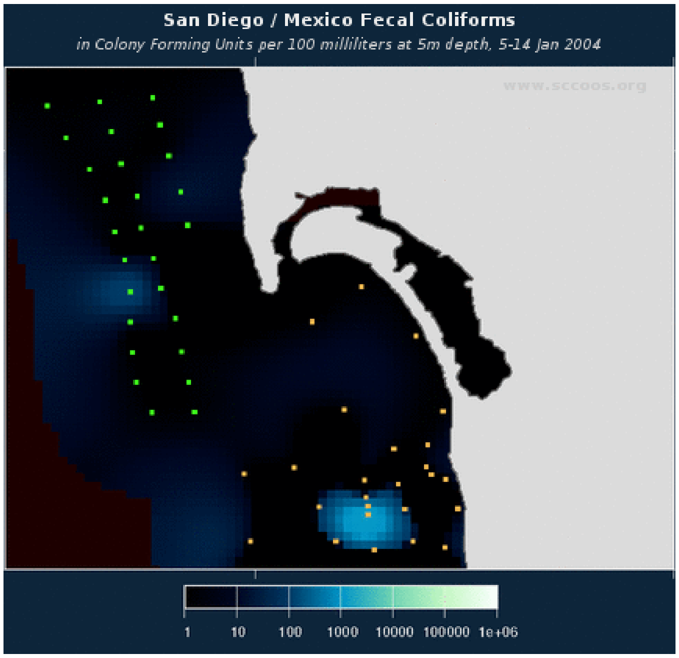


Figure 4. Map of sampling stations occupied by the NPDES permits of SBOO and PLOO. SBOO and PLOO are indicated by orange icons.

Conductivity, Temperature, and Depth profiles are obtained at the stations, along with FIB measurements of total and fecal coliform bacteria at various discrete depths. These data, when gridded during the monthly survey efforts, can provide individual snapshots of conditions and provide some insight of the space scales of the plumes. Examples are shown in the following figures of mapped values of 5m depth fecal coliform concentrations measured at the stations occupied during these sampling efforts. The examples in Figure 5 illustrate the presence of FIBs near both the SBOO and the Tijuana River. This analysis of the data would be conducted by Scripps.



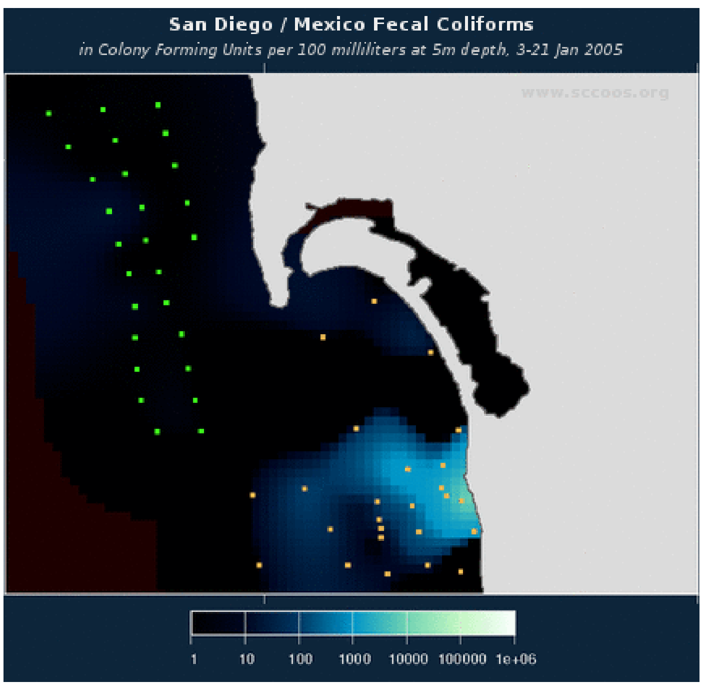
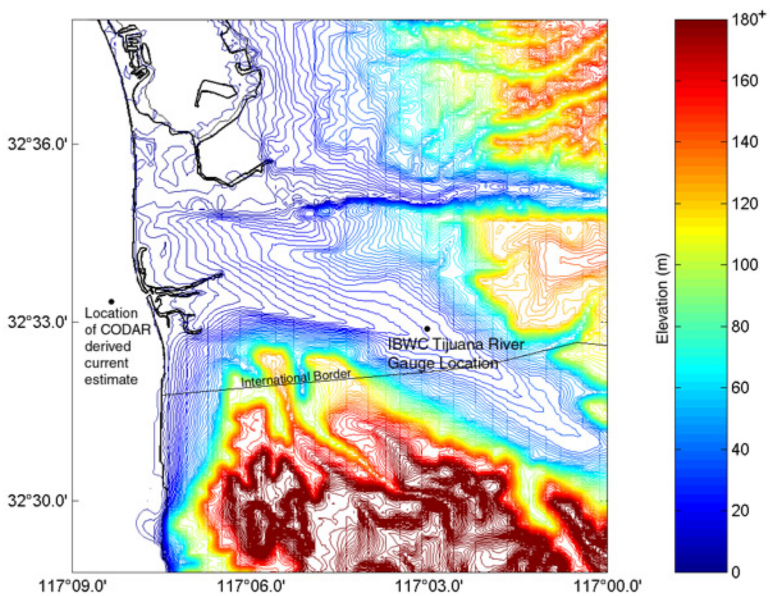


Figure 5. Spatial patterns of fecal coliform levels at 5m depth as measured by the existing SBOO permit activities. The data illustrates high levels of FIB near the SBOO outfall (top) and near the Tijuana River (bottom).

SS4) Continuous flow rate and loading of the Tijuana River – Scripps and CH2M HILL

Flow loading of the Tijuana River will be monitored using the existing gauge operated by the IBWC, despite this gauge not being an optimal descriptor of flow rate into the ocean since its monitoring location is east of many of the gulches which drain into the river (e.g. – Smugglers Gulch, Goat Canyon, and Yoghurt Canyon). Nevertheless, data from the gauge will serve as a proxy for total flow from the Tijuana River watershed into the ocean. Data from this gauge will be obtained directly from IBWC via online ASCII download, archived by Scripps, and provided to members of the team for review on an as-needed basis. Time series data will show when the instrumented tributary had flow. The location of this gauge, 32.542135,-117.050311, is shown in Figures 6 and 7.



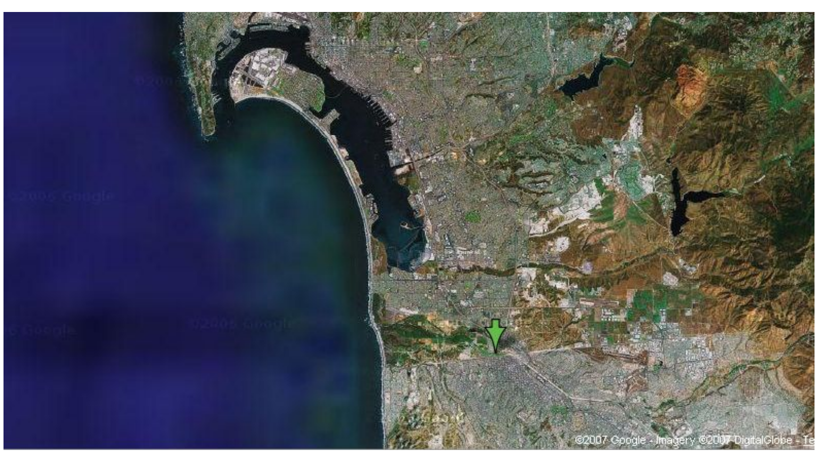


Figure 6. Topography and satellite image of the Tijuana River region near the ocean inlet and the approximate location of the existing IBWC river gauge.

Figure 7. Additional photographs showing the location of the IBWC gauge on the Tijuana River. Note, photograph above is of water behind the culvert which houses the pressure gauge. The vertical post is part of a manual staff, and is not the automatic gauge.

The mouth of the Tijuana River will be sampled during wet weather events to characterize the fecal loads entering the receiving waters. Parameters that will be sampled include: total coliform, fecal coliform, and enterococci. Microbial analysis will be conducted by Enviromatrix Analytical, a state-certified analytical laboratory located in San Diego.

The proposed sampling plan will include no fewer than 6 and no more than 10 individual wet weather events, with each event consisting of between 4 and 6 water quality samples taken in the vicinity of the mouth of the Tijuana River (Figure 8). Wet weather events will be defined as rainfall events exceeding 0.5 inches of rain in a 24 hour period. Samples will be collected at:

1. the mouth of the estuary,
2. in the north arm of the estuary adjacent to the end of Seacoast Drive,
3. in the main branch of the Tijuana River at Hollister Road, and
4. in the main branch approximately 0.5 miles east of the mouth of the estuary.

Samples will be taken at locations marked with either survey stakes or other means established at the onset of monitoring activities. Photographic documentation of each sampling event will be collected.

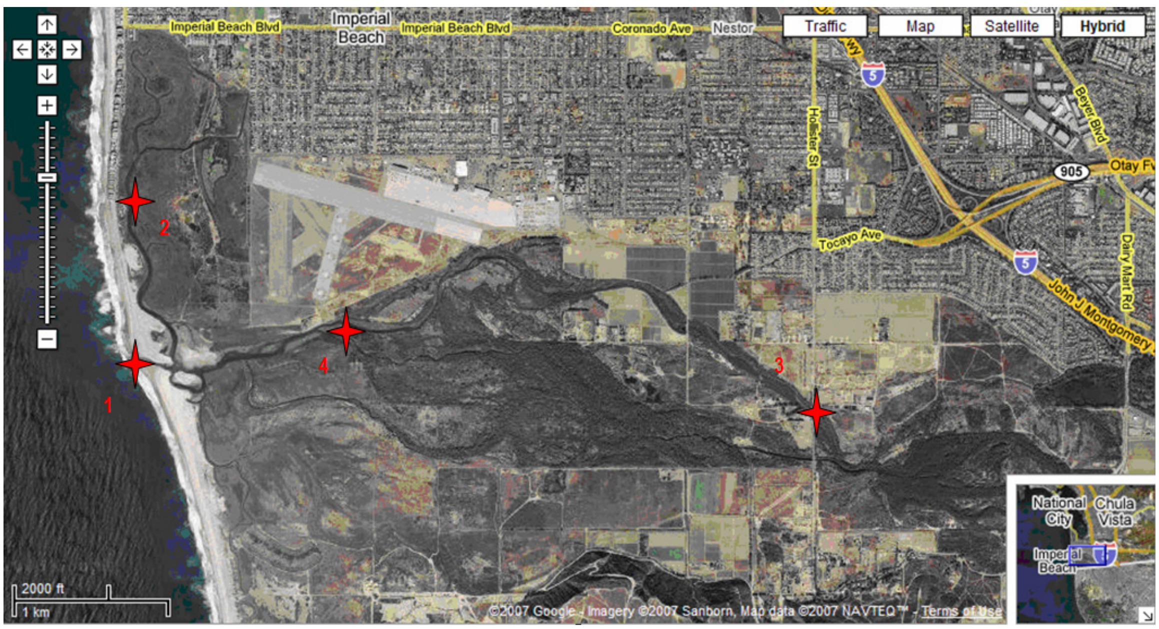


Figure 8. Location of FIB Sampling Stations in Tijuana Estuary

Each event will be comprised of sampling on two consecutive days, for a total of no more than 20 days of sampling. Water quality samples will adhere to standard sampling protocols. Sampling will be conducted during ebb tide as feasible. Where possible, sampling will be conducted concurrently with sampling performed by the City of San Diego (South Bay Ocean Outfall Monitoring Program) and the San Diego County Department of Environmental Health (Bay and Beach Water quality Monitoring Program), when occurring during storm events. Discussions with Dr. Jeff Crooks at the Tijuana River National Estuarine Research Reserve assisted in the location of monitoring locations in the Tijuana Estuary. Analysis of historic rainfall events affecting the Tijuana River watershed (Figure 9) indicates a limited number of rainfall induced runoff events.

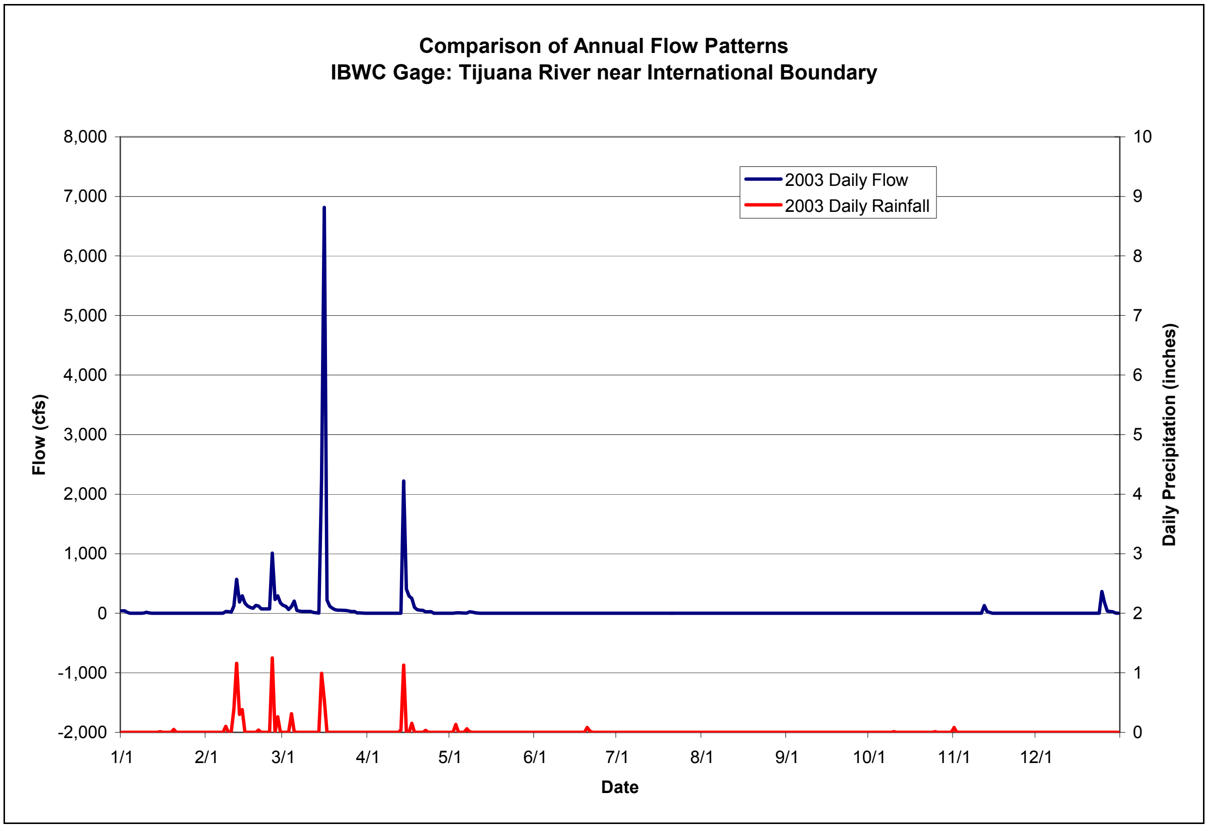


Figure 9. Correlation of rainfall and runoff in Tijuana River (2003)

<u>SS5) Ocean moorings at key areas - Scripps</u>

Two oceanographic moorings will be deployed:

1. A surface mooring (Figure 10) will be deployed near the wye of the diffuser at the SBOO in 28 m water depth re. MLLW. The mechanics of the SBOO mooring consists of a surface buoy, cable and chain, and an anchor. Temperature measurements will be made at 10 depths equally spaced from the surface to 26m. In addition, a Seabird Electronics (Seattle, WA) Seacat temperature/salinity recorder will be deployed near the surface at 1 meter depth. The measurements of temperature and salinity will be augmented by a downward looking, 600kHz Acoustic Doppler Current Profiler (San Diego, CA) to provide measurements of the subsurface currents from a nominal 4m water depth to the seafloor. Measurements will be made at 5 minute intervals at 1 meter range resolution. Temperature will be measured at similar time and space intervals. Data will be telemetered using IRIDIUM satellite communications once per hour to allow near real-time estimates of the water column stratification at the SBOO location. In addition, a separate GPS and IRIDIUM unit will be onboard to allow daily positions of the buoy to be obtained. This unit provides positioning information should the buoy break free of its mooring. A drawing of the surface buoy design is shown in Figure 11.

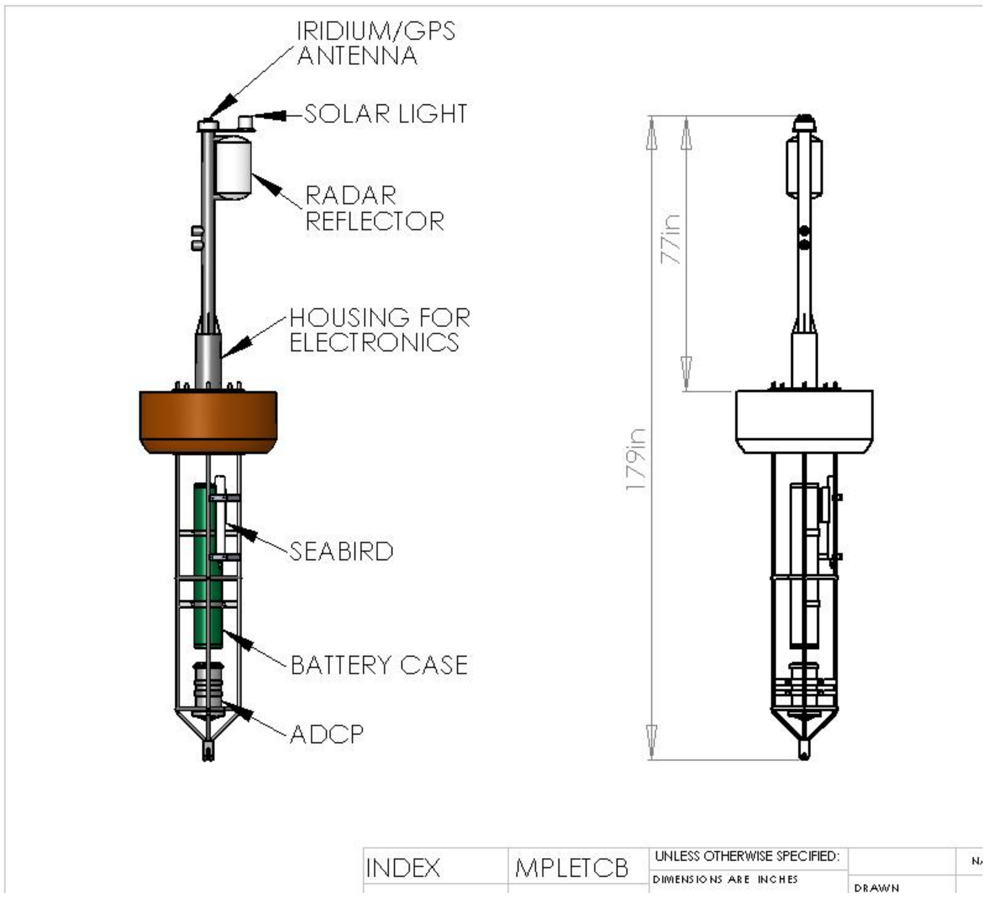


Figure 10. Mechanical drawing of the surface buoy to be deployed near the WYE of the SBOO. Not shown is the temperature chain which will measure ocean temperatures from 1m to the seafloor at approximately 3m spacing.

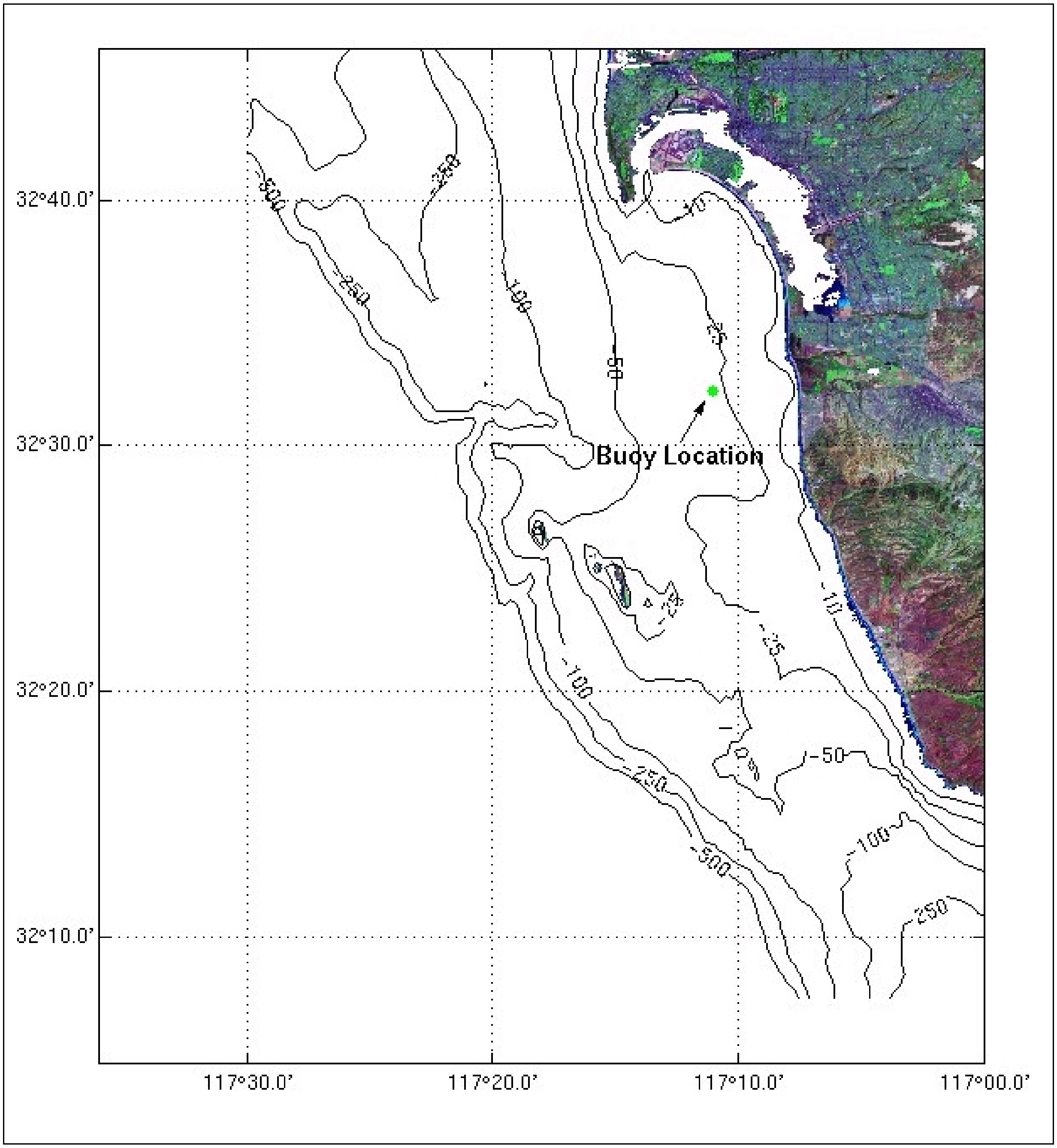


Figure 11. A map showing the location of the proposed SBOO buoy location. The second mooring will be located at the Imperial Beach pier approximately 3.5 miles in-shore of this location.

2. The second mooring will be located just offshore the Imperial Beach pier (Figure 12) in approximately 8m of water. While providing similar functionality as the SBOO mooring, the pier mooring will be bottom mounted offshore and a power/data cable run to the pier to existing data relay infrastructure located at the lifeguard tower (Figure 13). The mooring will consist of an upward looking Acoustic Wave and Current (AWAC) profiler (Nortek Corporation, USA) to allow full water column profiling of the subsurface currents at the beach most highly impacted by plume water from the Tijuana River. The system will also provide accurate directional wave measurements. Vertical temperature measurements at 1m intervals will also be installed and maintained during the course of the program. Placement of the velocity measurements at this location will provide a continuous record of the nearshore currents and complement the surface current maps generated by HF radar. Temperature will be sampled no less than every 5 minutes. Average currents will be provided three times per hour and wave measurements provided no less than once per hour. Wave direction is a useful parameter as it governs the direction of the longshore surf zone currents. Data from both moorings will be made available in near real time throughout the time period covered by this contract. Scripps Institution of Oceanography will obtain, as is standard practice, a 'Notice to Mariners' through the US Coast Guard for this location.

Logistics related to installing the cable used for this mooring: A similar cable has already been tested and had remained operational for more than two years before it was damaged and removed. A new cable will be deployed using existing agreements Scripps has with the City of Imperial Beach and the Port of San Diego. From previous work conducted at Imperial Beach Pier, Scripps Institution of Oceanography holds a Tideland Use and Occupancy Permit from the San Diego Unified Port District, which allows for installation and maintenance of scientific instruments on the Imperial Beach Pier. Scripps technical staff will work in conjunction with Imperial Beach Public Works Director, Hank Levien.

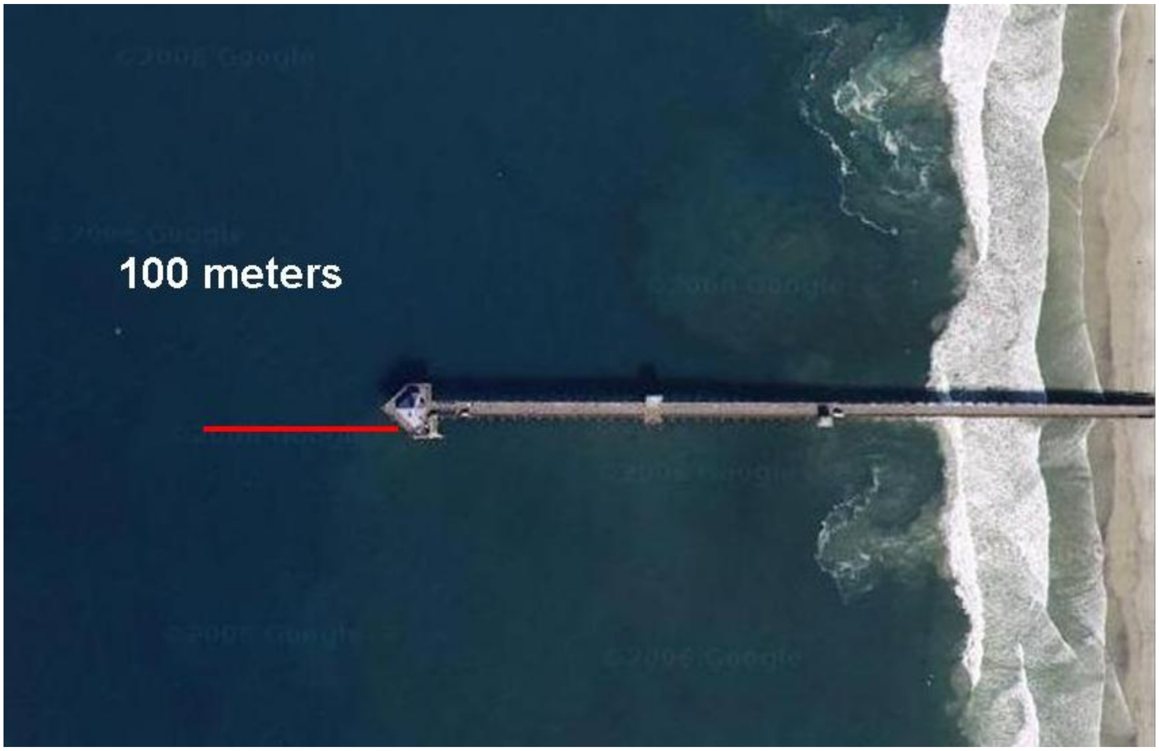


Figure 12. Aerial image of the Imperial Beach. The subsurface instrumentation will be located approximately 100m – 200m offshore the pier.

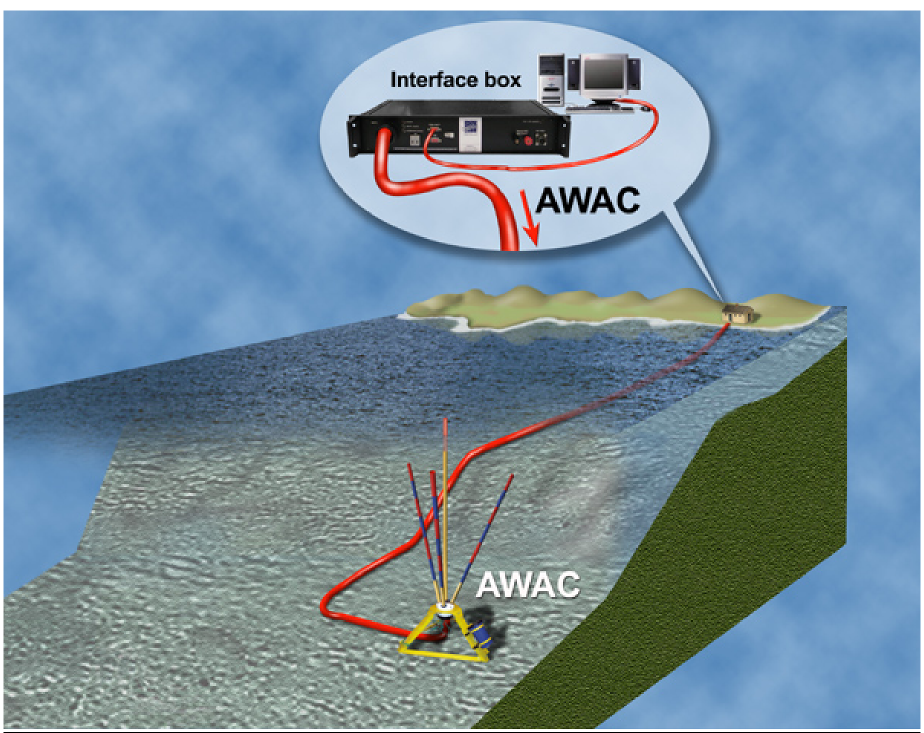


Figure 13. A concept drawing of the acoustic current meter / directional wave gauge that will be deployed from the Imperial Beach pier.

SS6) Mapping of ocean currents using CODAR and improved data handling - Scripps

Infrastructure part of the San Diego Coastal Ocean Observing System (SDCOOS www.sdcoos.org) will be operated, maintained, and enhanced during the period of performance defined for this program. Scripps Institution of Oceanography established the San Diego Coastal Ocean Observing System in 2001 under contract to the City of Imperial Beach through funding provided by the California Clean Beach Initiative. The area monitored encompasses a region spanning from Point Loma to the U.S. - Mexico Border and waters offshore to distances of approximately 16nm (30 km). The backbone of the coastal monitoring system is an array of high-resolution radars designed (Figure 14). to provide a spatial map of the local ocean surface currents on a real-time basis. The basis for the system is the scattering of radio waves from ocean surface waves over known regions of the ocean. Through appropriate signal processing of the radio waves scattered back to the radar, currents can be determined at a large number of discrete locations, referred to as range cells. Typical range resolution is 1km. The regional coverage provided by the current array and the direct measurement of the ocean's surface currents allows the tracking of transport routes from various potential pollution sites and will identify which regions of the coastline may be impacted by surface flow from offshore or non-local sites. The immediate application of the current maps (Figure 15) has been to provide a framework for interpreting results from water quality testing programs. Much has been learned from investigating time histories of the surface current fields in regions of contamination as time histories allow transport routes to be tracked backwards in time to determine the source origins.

Figure 14. A surface current mapping HF radar antenna (left) and the electronics enclosure which houses the equipment. The photographs are from the tip of Point Loma.

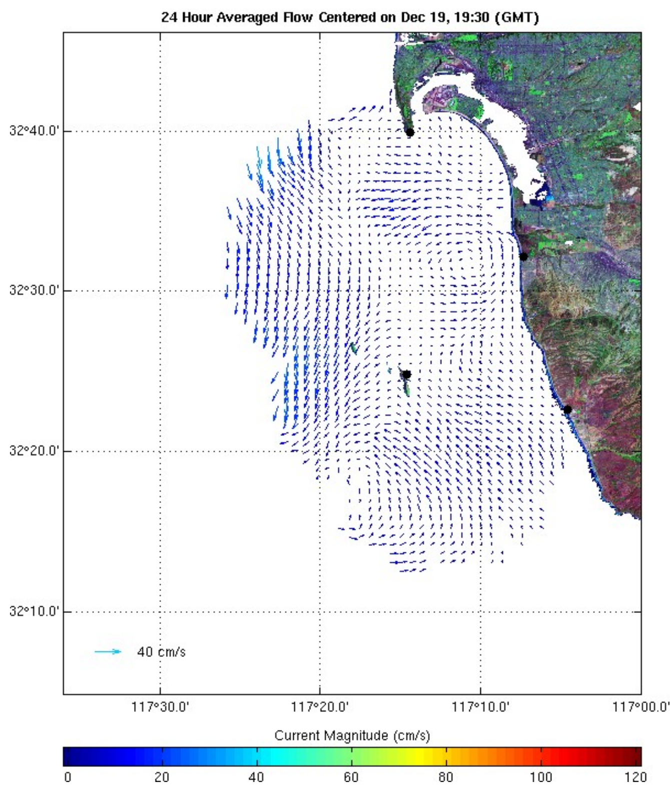


Figure 15. An example coverage map of observed surface currents. The radar locations are shown as black dots. This counter-clockwise eddy was observed on several occasions and can persist for anywhere between one and five days. One important feature of this eddy is the localized northward flow that brings water from the Tijuana Estuary to South Bay beaches. Ongoing studies will help determine the mechanisms that give rise to this eddy formation and provide a predictive capability to the region.

The radar array is composed of three installations located at the following sites: Border Field State Park, Point Loma, and a third site located on the Coronado Islands. The installation on the Coronado Islands was made possible through a collaborative arrangement with Mexican research scientists at Universidad Autonoma de Baja California (UABC) The Center for Scientific Investigation and Higher Education of Ensenada (CICESE), who operate a similar current mapping radar unit south of the border. The placement of the radar at an offshore site is highly favorable since it provides current mapping coverage very close to the shore (Figure 16). The real-time surface current maps generated by the radar array are complemented by satellite remote sensing.

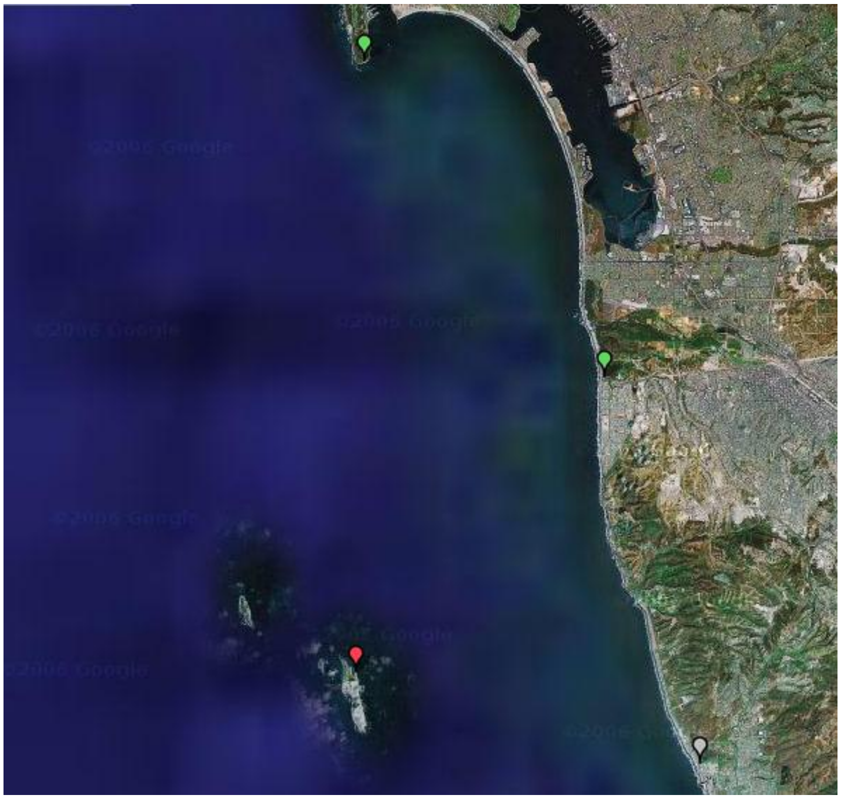


Figure 16. A map showing the locations of the surface current mapping HF radars hat will be used for this work. Systems are located at Point Loma (green), Border Field State Park (green), and the Coronado Islands (red). Data from a system located at Rosarito Beach, MX (gray) (owned by UABC/CICESE) will be integrated into the analysis where possible to enhance coverage to the south. Integrating this data will assist in tracking the flow from Punta Bandera.

The long-term benefits of the monitoring system result from two modes of use. In the first mode, direct operation of the system provides real-time information regarding the environment, providing an early warning of potential contamination due to onshore flow. First responders for water quality (Department of Environmental Health, Marine Safety Officers, City officials) are the primary users of this information. This real-time information can also be fed into near-real-time trajectory models of flow to visualize where plumes (Tijuana River, San Antonio de Los Buenos, SBOO surface plume) are transported. This data provides a backbone for guiding the intermittent sampling efforts and planning optimal locations for deployment of the REMUS AUV for detailed plume structure mapping.

The second mode of using the information is to generate a large data base describing how this coastal region responds to different environmental forcing such as tides, wind, different swell conditions, and heavy precipitation, and how these forcing events and the different flow configurations associated with them coincide with the occurrence of fecal contamination at the beaches. Through an understanding of the coastal response to these various forcing events, statistical predictors of beach closures can be developed. These predictors can be tested against the existing FIB sampling conducted by both the San Diego DEH and those data collected for the SBOO and PLOO NPDES permits.

This task will support the following activities:

- Telemetry and hardware upgrades to the three surface current mapping radars to include needed system air conditioning, new telemetry routers and antennas, calibration runs, external hard drive upgrades, software patches, enclosure maintenance (cleaning, painting, new locks, etc.), antenna tuner, and improved processor speeds.

- Interfacing with CICESE to guide the operation of, and obtain data from, a surface current mapping radar located at Rosarito Beach, MX. Integration of this data will provide better coverage to the San Antonio de Los Buenos plume.
- Operations and maintenance of the surface current mapping radars and supporting measurements (e.g. – meteorological sensors) during the duration of the program
- Implement improvements to the data handling of the surface current maps, including the implementation and support of near-real-time trajectory models that can be triggered by wet weather events and SBOO plume surfacing events
- Data handling efforts required for the REMUS AUV and mooring efforts.
- Integration of data with other available data sources from regional programs.
    - FIB indicator data obtained by shoreline monitoring programs conducted by the San Diego County Department of Environmental Health (DEH) supported through AB411 and the EPA BEACHES program
    - Ocean data generated by the City of San Diego for the Point Loma Outfall as part of their NPDES permit.
    - Ocean data generated by the City of San Diego for the IBWC SBOO as part of their NPDES permit.
    - The Tijuana River National Estuarine Research Reserve FIB indicator data
    - San Diego Coastal Ocean Observing System (www.sdcoos.org)
        - Moderate-resolution Imaging Spectroradiometer (MODIS)
        - Ocean Color Monitor (OCM)

An example of computing trajectories from the surface current maps is shown in Figure 17.

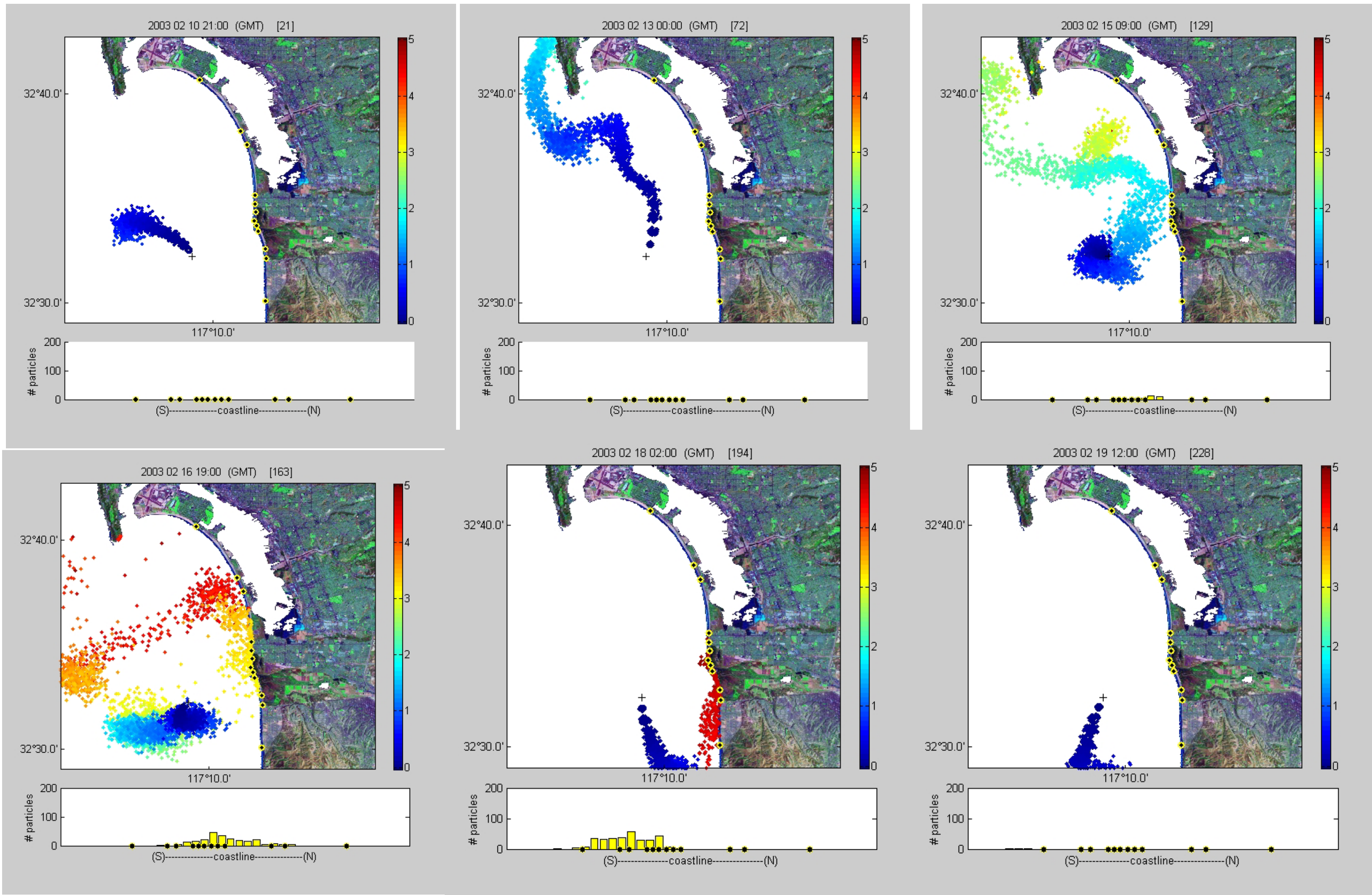


Figure 17. The 6 panels above are example output of trajectory modeling of surface flows near the South Bay Outfall for a time period in February, 2003. The trajectories are based upon surface current data measured by the SDCOOS system. The colors of the particles are referenced to the age of the particle from leaving the release point. Tasks proposed in SS6 will include the improvement and operation of these models with data integrated from both the mooring data to initialize a plumes model and with the surface currents measured by the HF radar.

Computation of surface current maps, and subsequent analysis to derive plume trajectories are useful for the interpretation of other data sources. One example are the shoreline water quality data collected by the San Diego County Department of Environmental Health (DEH). These data will be gathered by technical staff during the duration of this program and integrated with measurements conducted. Figure 18 illustrates the distribution of these shoreline stations occupied by DEH staff. The collection and analysis of this data will facilitate the assessment of when and why FIBs have impacted the coastline.

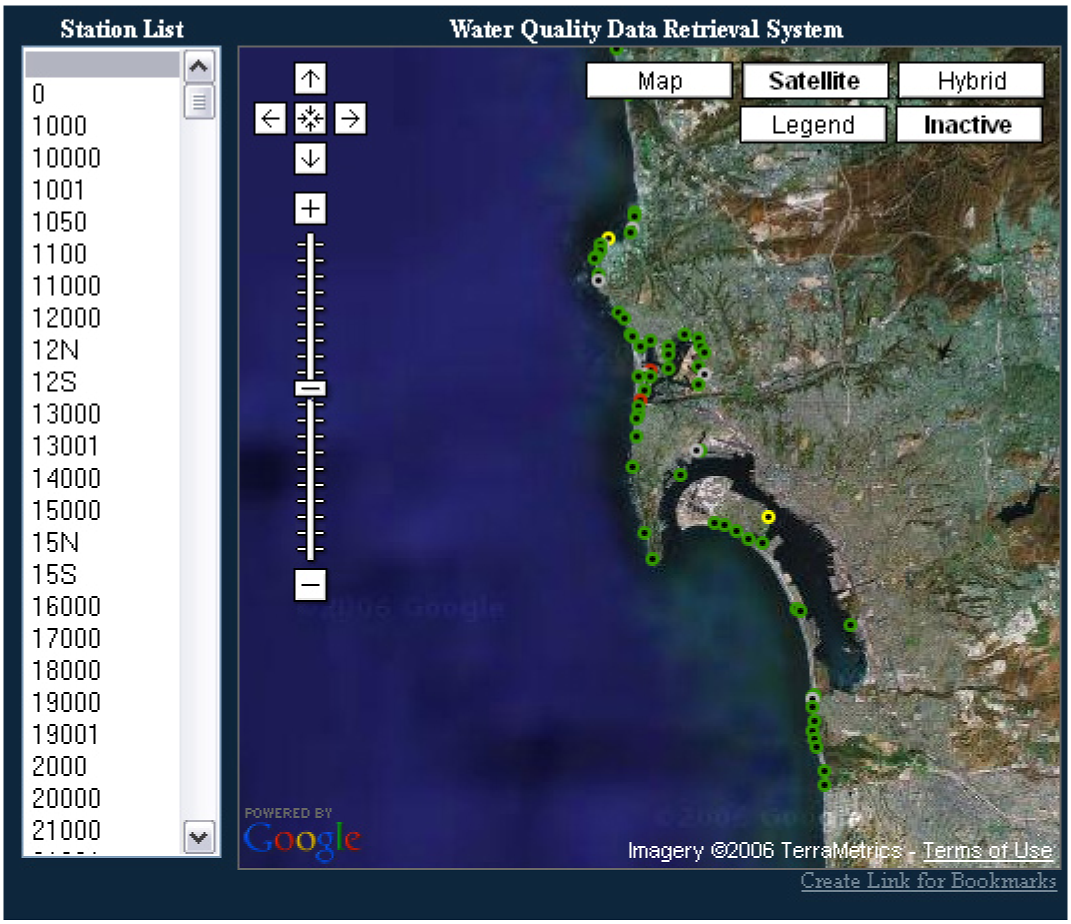


Figure 18. A map of DEH shoreline sampling stations. Data from these stations will be obtained and used in the ocean data interpretation.

SDCOOS also routinely collects satellite remote sensing data of ocean color. Collected at 1km and 300m resolution from both U.S. (MODIS) and international (OCM) satellites, ocean color data provides supporting information for defining the spatial extent of plumes when clear sky is available (Figure 19). These data will be collected and analyzed for plume signals during the project.

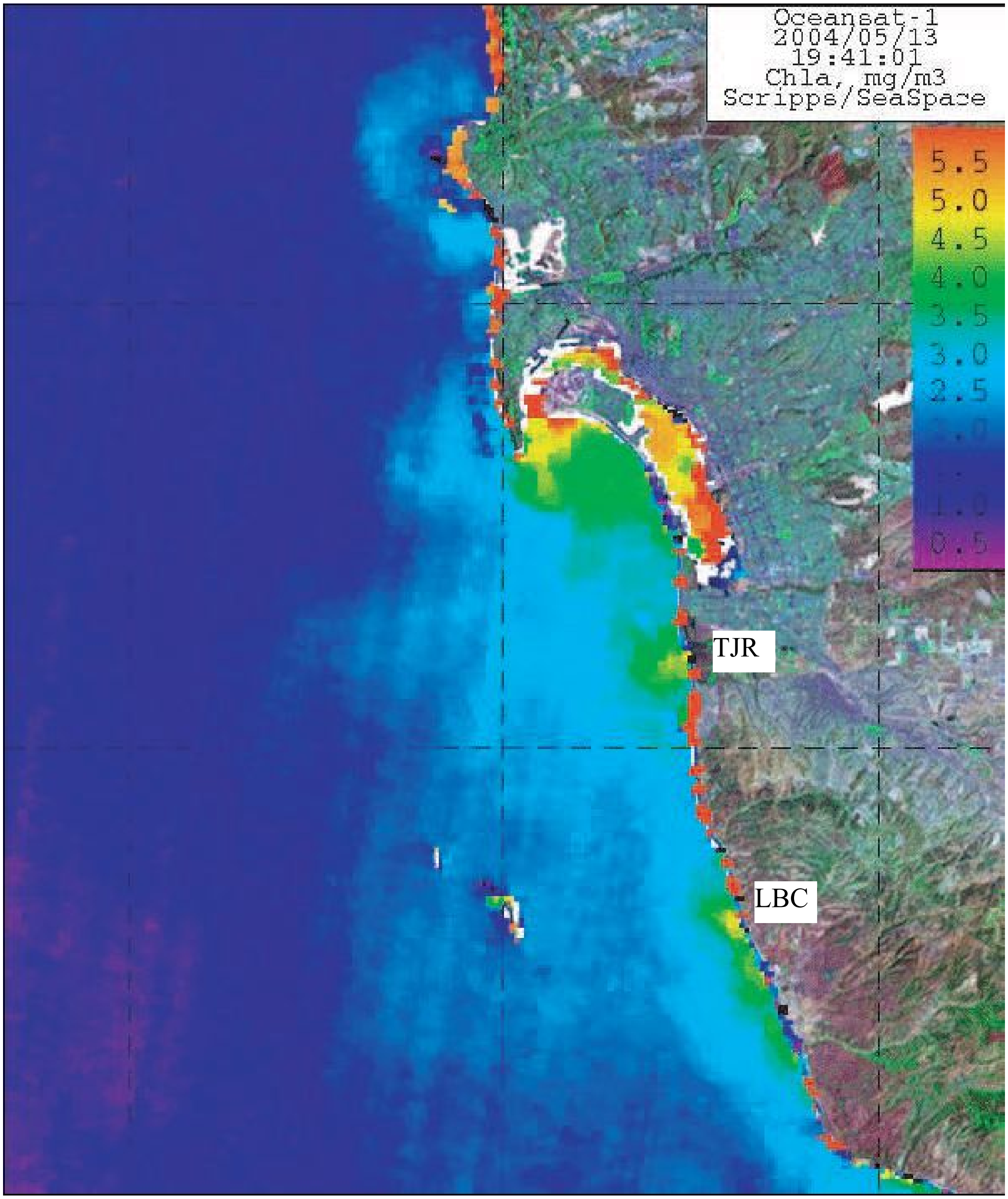


Figure 19. Ocean color image of chlorophyll-a with arrows indicating large scale sources of freshwater flux to the San Diego Region. TJR = Tijuana River, LBC = Los Buenos Creek. The South Bay Ocean Outfall is to south, ~3.5 miles offshore of the TJR. The data are obtained from the Ocean Color Monitor sensor onboard the OceanSat-1 satellite and processed by the San Diego Coastal Ocean Observing System (SDCOOS).

SS7) Development of indicator studies to support source identification and discriminate plume water – USC

The goals of this task are to evaluate the source identification and health risks associated with the inputs from the Tijuana River and from the South Bay Ocean Outfall. Both discharges can yield high concentrations of fecal indicator bacteria. But the associated health risk is dependent on whether or not there are human sources of bacteria and viruses in the discharges. Fecal indicator bacteria do not differentiate between human and other sources of bacterial contamination. In order to accomplish these goals, this task will sample in collaboration with SS3 (Boat-Survey Mapping, Figure 3).

As part of this study, two types of observations will be obtained:

1) The water column will be characterized by a CTD/bio-optical profiler that measures the following variables: temperature, salinity, pressure/depth, chlorophyll fluorescence, CDOM fluorescence, phycoerythrin/rhodamine WT fluorescence, and 3 wavelengths of optical backscatter (530, 660, and 880 nm). These variables have proven to be useful tracers for both treated sewage plumes and coastal runoff.
2) Water samples will be analyzed for bacterial and viral constituents that are known to come from human sources. The specific analyses include:
    a. Human-specific *Prevotella/Bacteroides*
    b. Human pathogenic viruses including:
        i. Enteroviruses
        ii. Norwalk-like viruses
        iii. Adenoviruses

We plan to sample four (4) opportunistic sampling events. The criteria for these events are as follows:

1) Wet weather storm events where the rainfall exceeds 0.5 inches of rain
2) Very weakly stratified conditions when a possible outfall plume surfacing could occur
3) Periods of beach exceedances which would most likely be associated either factors 1 or 2.

A minimum of four stations will be occupied during each of the four sampling events. Samples will be taken at one or two depths at each station, for a total of four to eight samples per sampling event. The goal is that the sampling would include at least two wet weather events. Periods of weak stratification when the SBOO plume might surface are not necessarily associated with wet weather events, and can occur even during summer periods. Decisions about these events will be made in collaboration with the Scripps Coastal Observing R&D Center and CH2M Hill.

The regions from both the Tijuana River plume and from the SBOO plume will be sampled during each of these events. Several stations will be taken within each of the plume areas to provide a representative characterization of the discharges from both plumes. As minimum, we would want to obtain two profiles each from the Tijuana River plume, the SBOO plume, and outside the area affected by either of these plumes (i.e., ambient water). Sampling will based on the real-time data sets that are being provided by other tasks within this project, and from the SCCOOS observations. Six to ten microbial samples would be taken on each of these cruises characterizing both surface and subsurface plumes.

The data sets from these observations will then be evaluated with the goal that a set of physical/bio-optical criteria can be developed that differentiate these plumes and the potential microbiological impacts from each of these plumes.

SS8) Identification of spatial patterns - Scripps

The identification of plume spatial patterns is an analysis effort, and not monitoring. Examples include those spatial patterns maps shown in figure 5 and 19. Goal of this effort will be to catalog the spatial patterns of plume water according to the environmental data which control their shape and distribution. Plumes will be characterized by the data collected by the program, and include

- Outside data sources (FIB, CTD)
- boat-based sampling
- autonomous under water vehicle data sets
- remote sensing ocean color imagery

Direct microbial measurements will be used in conjunction with other measurable properties of plume water (e.g. – temperature, salinity, and optical signatures) to develop proxies used for mapping the spatial extent of the plumes.

These data will also be used in conjunction with trajectory models of surface plume transport (figure 17) that use the HF radar surface current maps. Triggers for the trajectory models will be based upon rainfall (TJ River) and surfacing of the SBOO plume, as predicted by the EPA plumes model driven by the stratification and velocity data collected by the offshore mooring.

Statistical maps of spatial extent of the plumes will be generated on a time series basis and subsequently decomposed into the physical forcing mechanisms which control plume transport. These forcing processes include winds, tides, stratification differences, surface waves, and remote storm forcing. Since the chances of human health risk resulting from exposure to plume water is greatest at the coastline, a principal focus for the analysis will be to develop statistical indicators of where and when plume water from the two sources may be present near the shore. The domain for this analysis will extend from the U.S. border to Point Loma. Where possible, plume tracking models will be run in realtime to guide the boat-based sampling. A side benefit to operating the models in realtime are their usage by City and County staff in their AB411 shoreline and permit monitoring.

Schedule of Activities

A summary schedule of the proposed activities is presented below. We are anticipating a start date of January 1, 2007 for the project. The activities are classified as either intermittent (fixed interval sampling or environmentally triggered) or continuous. The mobilization time (MOB) reflects the time necessary to prepare for the sampling activities after acceptance of the Draft Monitoring Plan (Task 1).

Item	Description	intermittent/continuous	MOB time
SS1	SBOO plume mapping	intermittent	3 mos
SS2	Tijuana River plume mapping	intermittent	3 mos
SS3	Boat surveys	intermittent	3 mos
SS4	Tijuana River loading	continuous	immediate
SS5	Ocean moorings	continuous	3 mos
SS6	CODAR + data handling	continuous	immediate
SS7	Source discrimination study	intermittent	3 mos
SS8	Spatial patterns	intermittent	immediate

Agency	Task Name	Duration	Start	Finish
	IBWC	**502 days**	**Fri 9/29/06**	**Mon 9/1/08**
CH2MHILL	**TASK A - Project Management**	**502 days**	**Fri 9/29/06**	**Mon 9/1/08**
CH2MHILL	Contract Start Date	1 day	Fri 9/29/06	Fri 9/29/06
SIO	Quality Assurance Project Plan - SIO Draft	43 days	Mon 1/1/07	Wed 2/28/07
SIO	QAPP & Monitoring Plan - SIO Draft	43 days	Mon 1/1/07	Wed 2/28/07
CH2MHILL	QAPP & Monitoring Plan - CH2MHILL completion	8 days	Thu 3/1/07	Mon 3/12/07
IBWC	IBWC Plan Review	15 days	Wed 3/28/07	Tue 4/17/07
IBWC	QAPP and Monitoring Plan Acceptance	53 days	Wed 4/18/07	Fri 6/29/07
	Final Draft Summary Analysis	0 days	Mon 8/4/08	Mon 8/4/08
ALL	Final Report	0 days	Mon 9/1/08	Mon 9/1/08
SIO	**TASK B - Oceanographic Moorings (SS5)**	**391 days**	**Mon 1/1/07**	**Mon 6/30/08**
SIO	SBOO Buoy Mooring Fabrication	80 days	Mon 1/1/07	Fri 4/20/07
SIO	Notice to Mariners through USCG	0 days	Fri 4/20/07	Fri 4/20/07
SIO	IB Pier Mooring Fabrication	93 days	Mon 1/1/07	Wed 5/9/07
SIO	Mooring Deployment	37 days	Thu 5/10/07	Fri 6/29/07
SIO	Ocean Mooring at Key Areas	1 day	Mon 7/2/07	Mon 7/2/07
SIO	Real-time Data Collection and Display	260 days	Tue 7/3/07	Mon 6/30/08
ALL	**TASK C - Plume Mapping (SS1, SS2, SS3, SS7)**	**391 days**	**Mon 1/1/07**	**Mon 6/30/08**
SIO	REMUS Fabrication	75 days	Mon 1/1/07	Fri 4/13/07
SIO	Plume Mapping evaluation period	15 days	Tue 6/12/07	Mon 7/2/07
SIO	SS1 - SBOO Plume Mapping Efforts Begin	0 days	Mon 7/2/07	Mon 7/2/07
SIO	SS2 - Tijuana River Plume Mapping Efforts Begin	0 days	Mon 7/2/07	Mon 7/2/07
SIO	Optical backscatter plume mapping and data display	221 days	Mon 8/27/07	Mon 6/30/08
SIO	SS3 - CTD operation + Optical parameters	261 days	Mon 7/2/07	Mon 6/30/08
CH2MHILL	**SS3 - Boat Surveys**	**261 days**	**Mon 7/2/07**	**Mon 6/30/08**
CH2MHILL/SIO	**Summer/Dry Weather Monitoring '07**	**65 days**	**Mon 7/2/07**	**Fri 9/28/07**
CH2MHILL/SIO	High levels of Stratification	65 days	Mon 7/2/07	Fri 9/28/07
CH2MHILL/SIO	Minimal Stratification	65 days	Mon 7/2/07	Fri 9/28/07
CH2MHILL/SIO	Northward Flow	65 days	Mon 7/2/07	Fri 9/28/07
CH2MHILL/SIO	Southward Flow	65 days	Mon 7/2/07	Fri 9/28/07
CH2MHILL/SIO	Offshore Flow	65 days	Mon 7/2/07	Fri 9/28/07
CH2MHILL/SIO	**Winter/Wet Weather Monitoring '07-'08**	**131 days**	**Mon 10/1/07**	**Mon 3/31/08**
CH2MHILL/SIO	High levels of Stratification	131 days	Mon 10/1/07	Mon 3/31/08
CH2MHILL/SIO	Minimal Stratification	131 days	Mon 10/1/07	Mon 3/31/08
CH2MHILL/SIO	Northward Flow	131 days	Mon 10/1/07	Mon 3/31/08
CH2MHILL/SIO	Southward Flow	131 days	Mon 10/1/07	Mon 3/31/08
CH2MHILL/SIO	Offshore Flow	131 days	Mon 10/1/07	Mon 3/31/08
CH2MHILL/SIO	**Summer/Dry Weather Monitoring '08**	**65 days**	**Tue 4/1/08**	**Mon 6/30/08**
	Continue Summer monitoring	65 days	Tue 4/1/08	Mon 6/30/08
USC	SS7 - Indicator Studies	261 days	Mon 7/2/07	Mon 6/30/08
CH2MHILL/SIO	**TASK D - Surface Current Mapping Data Analysis (SS4, SS6, SS8)**	**326 days**	**Mon 1/1/07**	**Mon 3/31/08**
SIO	SS4 - Tijuana River Flow Rate Data	0 days	Mon 1/1/07	Mon 1/1/07
SIO	Online Real-time data display	301 days	Mon 2/5/07	Mon 3/31/08
SIO	SS6 - Surface Current Mapping and Instrument upgrades	326 days	Mon 1/1/07	Mon 3/31/08
CH2MHILL/SIO	SS8 - Spatial Pattern Analysis	261 days	Mon 4/2/07	Mon 3/31/08

Appendix 2
Quality Assurance Project Plan

QUALITY ASSURANCE PROJECT PLAN
Coastal Observations and Monitoring in South Bay San Diego
IBWC / Surfrider Consent Decree

Prepared For

International Boundary and Water Commission
United States Section
4171 N. Mesa, C-100
El Paso, Texas 79902

Contract: IBM04D0005
Task Order: IBM06T0026

Prepared By

Principal Contract: CH2M HILL
402 West Broadway, Suite 1450
San Diego, CA 92101

Additional Co-Investigators University of California Regents (UCSD) -
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University of Southern California
Marine Environmental Biology
3616 Trousdale Parkway
Los Angeles, CA 90089-0371

June 13, 2007

WATR 0594QV4

QAPP; Coastal Observations and Monitoring in South Bay San Diego IBWC/Surfrider Consent Decree

1. Title and Approval Sheets

APPROVAL SIGNATURES

PROJECT TEAM:

Title:	Name:	Signature:	Date*:
Project Manager (CH2M HILL)	Richard Pyle	[signature]	
Project Manager (SIO)	Eric Terrill	[signature]	
Project Manager (USC)	Burton Jones	Burton H. Jones	

IBWC:

Title:	Name:	Signature:	Date*:
Project Manager (IBWC)	Gilbert Anaya	Gilbert Anaya	
Project Officer (EPA)	Elizabeth Borowiec	Elizabeth Borowiec	10/23/07
QA Program Manager (EPA)	Eugenia McNaughton	Eugenia McNaughton	10/22/07

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Group B: Data Generation and Acquisition

Group C: Assessment And Oversight

Group D: Data Validation and Usability

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3. DISTRIBUTION LIST

Title:	Name (Affiliation):	Tel. No.:	QAPP No*:
Project Manager	Richard Pyle (CH2M HILL)	(619) 687-0120 x7236	
Project Manager	Eric Terrill (SIO)	(858) 822-23101	
Operations Manager	Lisa Hazard (SIO)	(858) 822-2873	
Project Manager	Burton Jones (USC)	(213) 740-5765	
Health and Safety Manager	Scott Dahle (CH2M HILL)	(435) 257-4960	
Designated Safety Coordinator and QA Officer	Kyle Winslow (CH2M HILL)	(619) 687-0120 x7222	
Environmental Compliance Coordinator	Pat Nelson (CH2M HILL)	(720) 286-5070	

4. PROJECT/TASK ORGANIZATION

4.1 Involved Parties and Roles

CH2M HILL
Richard Pyle is the Project Manager for the contract. He is responsible for project delivery and management.

Steve Costa is the Senior Consultant responsible for review of all project documents and reports, including the Monitoring Plan, Quality Assurance Project Plan, and the Draft and Final Reports.

Kyle Winslow is a senior project engineer at CH2M HILL. He is acting as the safety coordinator for the project and will oversee CH2M HILL's portion of Task SS4. He is also the designated QA officer for the project.

Scott Dahle, is the Director for Health and Safety at CH2M HILL. He is responsible for the development of the Project Health and Safety Plan.

Pat Nelson is the Environmental Compliance Coordinator for CH2M HILL

Scripps Institution of Oceanography (SIO), Coastal Observing Research and Development Center (CORDC)
Eric Terrill is the Director of the Coastal Observing Research and Development Center (CORDC). He is responsible for program management of the following tasks: SS1: SBOO Plume Mapping, SS2: TJ River Plume Mapping and Mapping of Land Based Sources, SS3 portion: CTD operation from vessel conducting plume mapping operations, SS4 portion: Acquisition of TJ River flow rate data, SS5: Oceanographic Moorings, SS6: Surface Current Mapping and related data handling improvements and upgrades, SS8: Spatial Pattern Analysis.

Lisa Hazard, Operations Manager, CORDC has responsibility for overseeing SIO field and data management activities, managing data handling improvements, and upgrades to existing HF radar systems, and providing input for reporting requirements. She is the designated QA officer for the tasks conducted by SIO staff.

Joel Hazard, Development Engineer, CORDC, will design and engineer moorings and instrument electronics for the South Bay Ocean Outfall and Imperial Beach Pier.

Mark Otero, Programmer/Analyst, CORDC, will analyze field data collected from REMUS, CTD, and HF radars.

Paul Reuter, Programmer/Analyst, CORDC, will manage TJ river flow rate data, develop data product visualizations, and administer data storage needs.

William Middleton, Development Engineer, CORDC, will conduct field operations of REMUS for plume, river, and land based sources, and CTD operations from vessel.

Shannon Scott, Development Engineer, CORDC, will conduct field operations of REMUS for plume, river, and land based sources, and CTD operations from vessel.

University of Southern California
Burton Jones is a Principal Investigator with the Marine Environmental Biology Division of the Biology Department at the University of Southern California. He is responsible for the program management of Task SS7, Fecal Indicator Bacteria Studies and Identification

Jed Fuhrman, Co-Principal Investigator and Professor in the Marine Environmental Biology Division of the Biology Department at the University of Southern California, is responsible for the microbiological component of the source tracking – Task SS7.

Matthew Ragan is the Operations Manager for the Coastal Observing Laboratory at the University of Southern California. He is responsible for overseeing USC field operations and data management.

Zhihong Zheng is the Laboratory Manager for the Coastal Observing Laboratory at the University of Southern California. He is responsible for equipment preparation, field sampling and data management and analysis.

4.2 Quality Assurance Officer Role
The QA Officers are responsible for guaranteeing the overall quality of the data produced and reported. Specific duties of the QA Officers include conducting audits of ongoing tests, data packages, and completed reports, , communicating potential quality control problems to the staff, and assuring that any problems are resolved. They are responsible for issuing Quality Assurance Reports to the project manager, and issuing the Quality Assurance Project Plan.

4.3 Persons Responsible for QAPP Update and Maintenance.
Changes and updates to this QAPP may be made after a review of the evidence for change by CH2M HILL's Quality Assurance Officer, Kyle Winslow, or by SIO Project Manager, Eric Terrill. Project Manager Richard Pyle will be responsible for making the changes, submitting drafts for review, preparing a final copy, and submitting the final for signature.

Table 1. Personnel Responsibilities

Name	Organizational Affiliation	Title	Contact Information (Telephone number, email address.)
Richard Pyle	CH2M HILL	Project Manager	(619) 687-0110 richard.pyle@ch2m.com
Kyle Winslow	CH2M HILL	Senior Engineer / QA Officer	(619) 687-0110 kyle.winslow@ch2m.com
Scott Dahle	CH2M HILL	Health and Safety Manager	(435) 257-4960 scott.dahle@ch2m.com
Pat Nelson	CH2M HILL	Environmental Compliance Coordinator	(720) 286-5070 pat.nelson@ch2m.com
Eric Terrill	SIO	Director, CORDC	(858) 822-3101 eterrill@ucsd.edu
Lisa Hazard	SIO	Operations Manager, CORDC	(858) 822-2871 lhazard@ucsd.edu
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Paul Reuter	SIO	Software Development Engineer, CORDC	(858) 822-2060 preuter@ucsd.edu
Joel Hazard	SIO	Development Engineer, CORDC	(858) 534-7482 jhazard@ucsd.edu
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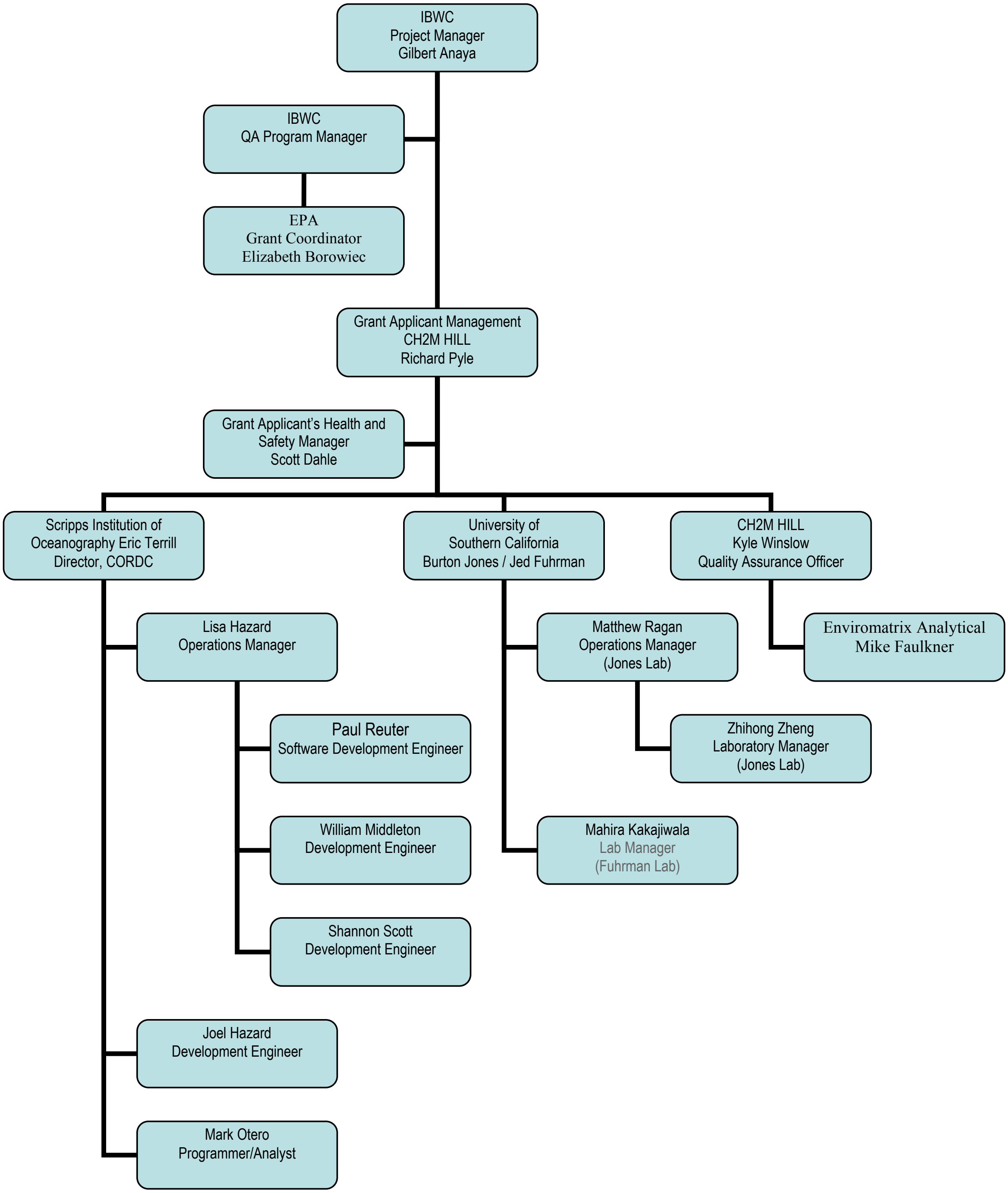
4.4 Organizational Chart and Responsibilities

Figure 1. Organizational chart.



5. PROBLEM DEFINITION/BACKGROUND

5.1 Problem Statement

The International Boundary Water Commission (IBWC) desires to enhance regional oceanographic monitoring efforts in South Bay San Diego. The region is loosely defined to extend from Point Loma south to the United States Border, and offshore to a distance of approximately 30 kilometers. Characterized by an area of complex topography resulting from the Point Loma headland and curving coastline; a shallow delta from the geology of sediment deposition from the Tijuana River and San Diego Bay; and variable forcing from winds, tides, and remote storms; the coastal waters of South Bay San Diego are oceanographically complex. As a result, difficulty has persisted in the ability of managers to identify the sources of high levels of fecal indicator bacteria that present themselves intermittently at various locations in the region. This difficulty has been compounded by the multiplicity of potential sources in the region, and little knowledge on the transport pathways of constituents from these sources. Through a series of external reviews and assessments, a prioritized list of monitoring and data collection activities was generated that addressed the following principle goals:

• Identify and track plumes from the South Bay Ocean Outfall (SBOO)
• Characterize land-based sources with focus on the Tijuana River
• Identify the regional oceanographic conditions that lead to high fecal indicator bacteria (FIB) on South Bay Beaches.

5.2 Decisions or Outcomes

IBWC has requested monitoring and analysis activities in the following classes:

SS1) SBOO plume mapping
SS2) Tijuana River plume mapping
SS3) Boat survey-mapping of land based plumes
SS4) Continuous flow rate and loading of the Tijuana River
SS5) Ocean moorings at key areas
SS6) Mapping of ocean currents using CODAR and improved data handling
SS7) The development of indicator studies to support source identification
SS8) Identification of spatial patterns

These activities were identified in previously work supported by IBWC (phase 1A, 1B, and costing studies). In order to meet the goals and budget of the program, technical approaches to these requested set of activities are being proposed. The activities were designed to project onto the goals of the project in the following manner:

a) Identify and track plumes from the South Bay Ocean Outfall (SBOO):
(SS1, SS5, SS6, SS7, SS8)
b) Characterize land based sources with focus on the Tijuana River:
(SS2, SS3, SS4, SS5, SS6, SS7, SS8)
c) Identify the regional oceanographic conditions which lead to high fecal indicator bacteria (FIB) on the South Bay Beaches: (SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8)

Monitoring Activities (SS1-SS7) are addressed in the QAPP while analysis activities (SS8) are addressed in the Monitoring Plan and proposal.

5.3 Water Quality or Regulatory Criteria

The sampling and testing that is to be performed for this project are not regulatory driven and are motivated to assess and characterize the South Bay region.

California beach bathing standards are 35 CFU/100ml seawater for Enterococcus, 200 CFU/100ml for Fecal Coliform, and 1,000 CFU/100 ml for total coliform. Exceedances of these values can lead to beach closures.

6. PROJECT/TASK DESCRIPTION

6.1 Work Statement and Produced Products.

The project monitoring activities include South Bay (SS1) and Tijuana River (SS2) Plume, Boat survey mapping of land based plumes (SS3), continuous flow rate and loading of Tijuana River (SS4), current and temperature measurements at ocean mooring locations near wye of South Bay Ocean Outfall (SBOO) and off Imperial Beach pier (SS5), and mapping of ocean surface currents (SS6).

(**SS1) SBOO Plume Mapping and (SS2) Tijuana River Plume Mapping**
SS1 and SS2 will utilize operation of a REMUS AUV from Hydroid, Inc. outfitted with the most up-to-date technology. The REMUS has four main sections: a nose section, an RD Instruments 1200 kilohertz (kHz) Acoustic Doppler Current Profiler (ADCP), a mid-body, and tail section. The nose section includes both the Ultra Short BaseLine (USBL) and Long BaseLine (LBL) acoustic navigation transducers. The vehicle will have GPS, IRIDIUM-based telemetry (necessary for near-border work), optical sensors for the measurement of light scattering and chlorophyll fluorescence, and an accurate CTD for ocean temperature/salinity/ density measurements. The combination of the CTD and optical sensors (the standard workhorse tools used by boat-based NPDES monitoring programs) placed onto a flexible platform such as REMUS, lends itself well to the problem of plume mapping through surveying changes in ocean properties.

(SS3) Boat Survey-Mapping of Land-based Plumes
SS3 will include a limited set of boat-based CTD + optical parameters (attenuation and backscatter) sampling efforts no fewer than two per survey (48), will be taken onboard the vessel operating the REMUS AUV during operations (Scripps), and will be complemented by the plume water discriminator study proposed for SS7 (to be conducted by USC). Of these two CTD casts, an ambient cast (outside of the plume) and one close to the river mouth or at the wye of the ocean outfall will be taken. Limited bottles (2 depths at each of two locations) will also be triggered for FIB measurements in regions of identified plume water. The FIB samples will be taken either on the vessel used for the REMUS surveys or on the City of San Diego vessel used for taking bacteria samples as part of the International Wastewater Treatment Plant (SBIWTP) Regional Water Quality Monitoring Plan (RWQMP). These two sampling efforts (CTD/optical casts and FIB collection) are complementary efforts to task SS7. A separate vessel utilized by USC for task SS7 is required to support the rigorous boat-based sampling effort.

(SS4) Continuous Flow Rate and Loading of the Tijuana River
Scripps will monitor flow loading of the Tijuana River using the existing gauge operated by the IBWC. While this gauge is not an optimal descriptor of flow rate into the ocean since it monitors only one of the many gullies which flow into the U.S., budgetary constraints prevent the establishment of a gauge at the river entrance. As such, this gauge data will serve as a proxy for total flow from the Tijuana River watershed. Data from this gauge will be obtained directly from IBWC via online ASCII download, archived by Scripps, and provided to members of the team for review as needed. Time series data will show when the instrumented tributary had flow.

CH2M HILL staff will collect grab samples for testing of fecal coliform, total coliform, and enterococcus. Grab samples will be conducted at four locations. Sampling will take place during six to ten wet weather events, and each event will include two days of sampling on the ebb tide. EPA suggested sampling protocols will be followed. Laboratory analysis will be conducted at Enviromatrix Analytical in San Diego, CA.

(SS5) Ocean Moorings at Key Areas

The two proposed sites are a mooring located at the wye of the diffusers at the SBOO, and a mooring located offshore Imperial Beach. The mechanics of the SBOO mooring consists of a surface buoy, cable and chain, and an anchor. Temperature measurements will be made at 10 depths equally spaced from the surface to 27 meters. In addition, a Seabird Seacat temperature/salinity recorder will be deployed near the surface. The measurements of temperature and salinity will be augmented by a downward looking acoustic Doppler current profiler to provide measurements of the subsurface currents from a nominal 4-meter water depth to the seafloor. Both the temperature and velocity measurements will be sampled at 5 minute intervals to allow fine scale changes in water column structure that results from internal waves. Data will be telemetered once per hour to allow near real-time estimates of the water column stratification at the SBOO location.

The second mooring will be located just offshore the Imperial Beach pier in 8 meters of water. While providing similar functionality as the SBOO mooring, the pier mooring will be bottom mounted offshore and a power/data cable run to the pier to existing data relay infrastructure located at the lifeguard tower. The mooring will consist of an upward looking acoustic Doppler current profiler to allow full water column profiling of the subsurface currents at the beach most highly impacted by plume water from the Tijuana River. Vertical temperature measurements at 1-meter intervals will also be installed and maintained during the course of the program. Placement of the velocity measurements at this location will provide a continuous record of the nearshore currents and complement the surface current maps generated by HF radar. Both the velocity and temperature measurements will be made several times an hour to resolve internal waves at the pier. Data from both moorings will be made available in near real time throughout the time period covered by this contract and will extend as long as can be maintained without exceeding budget costs. Scripps Institution of Oceanography will obtain, as is standard practice, a 'Notice to Mariners' through the United States Coast Guard for this location.

(SS6) Mapping of Ocean Surface Currents

The backbone of the coastal monitoring system is an array of high-resolution radars designed to provide a spatial map of the local ocean surface currents on a real-time basis. The basis for the system is the scattering of radio waves from ocean surface waves over known regions of the ocean. Through appropriate signal processing of the radio waves scattered back to the radar, currents can be determined at a large number of discrete locations, referred to as range cells. Typical range resolution is 1 kilometer. The regional coverage provided by the current array and the direct measurement of the ocean's surface currents allows the tracking of transport routes from various potential pollution sites and will identify which regions of the coastline may be impacted by surface flow from offshore or non-local sites. The immediate application of the current maps has been to provide a framework for interpreting results from water quality testing programs.

(SS7) Plume Source Tracking

Plume source tracking will be performed in conjunction with SS3 (Boat Survey Mapping of Land-Based Plumes). This task includes two components: 1) bio-optical characterization of the plumes to enable rapid differentiation of sources based on physical and bio-optical parameters; 2) Microbial characterization of the plumes for human pathogens. Multivariate physical/bio-optical observations can differentiate source waters from land runoff and ocean outfalls because the two sources have distinctly different optical characteristics, despite the fact that they are both freshwater discharges. The two sources differ optically in that surface runoff typically has higher particle concentrations (higher optical backscatter overall) and usually larger inorganic particles (different particle backscatter spectrum reflected in the 3-wavelength backscatter spectrum). Both surface runoff and outfall effluent contain CDOM, but the ratio of CDOM to backscatter is usually higher in ocean outfalls since much of the particulate material is organic flocculent that fluoresces similar to CDOM itself. The bio-optical measurements will enable the evaluation of whether remote sensing observations can be used to differentiate the sources of contamination and track them using satellite imagery.

Grab samples will be taken at no less than four locations on each of four sampling events. Water samples will be examined for the presence of human-specific bacteria and viruses. Although fecal indicator bacteria measurements are mandated by the California Ocean Plan for evaluation of human risks for water contact sports, these measurements provide no information about the source of the water, or certain identification of the presence of human pathogens. Therefore, human-specific bacteria and viruses will be measured including Prevotella/Bacteriodes, adenoviruses, enteroviruses, and Norwalk-like viruses. These measurements enable evaluation of direct human risks, and differentiate sources of human contamination from other sources.

6.2. Constituents to be Monitored and Measurement Techniques.

Table 2. Constituents to be Monitored

CONSTITUENT	MEASUREMENT	LOCATION	NOTES and Associated task number
Conductivity	Collected onboard REMUS CTD package	South Bay	SS1 & SS2 – 24 surveys over 1 year
Temperature	Collected onboard REMUS CTD package	South Bay	SS1 & SS2 – 24 surveys over 1 year
Depth	Collected onboard REMUS CTD package	South Bay	SS1 & SS2 – 24 surveys over 1 year
Chlorophyll Fluorescence	Collected onboard REMUS Wetlabs BB2F sensor	South Bay	SS1 & SS2 – 24 surveys over 1 year
Optical Backscatter	Collected onboard REMUS Wetlabs BB2F sensor	South Bay	SS1 & SS2 – 24 surveys over 1 year
Velocity (Currents)	Collected onboard REMUS 1200 kHz ADCP	South Bay	SS1 & SS2 – 24 surveys over 1 year
Conductivity	Collected with Seabird/Wetlabs Profiler CTD package	South Bay	SS3 – 24 surveys over 1 year SS7 – 4 surveys
Temperature	Collected with Seabird/Wetlabs Profiler CTD package	South Bay	SS3 – 24 surveys over 1 year SS7 – 4 surveys
Depth	Collected with Seabird/Wetlabs Profiler CTD package	South Bay	SS3 – 24 surveys over 1 year SS7 - 4 surveys
Chlorophyll Fluorescence	Collected with Seabird/Wetlabs Profiler CTD package	South Bay	SS3 – 24 surveys over 1 year SS7 – 4 surveys

CONSTITUENT	MEASUREMENT	LOCATION	NOTES and Associated task number
Optical Backscatter	Collected with Seabird/Wetlabs Profiler CTD package	South Bay	SS3 – 24 surveys over 1 year SS7 – 4 surveys
Light Transmittance	Collected with Seabird/Wetlabs Profiler CTD package	South Bay	SS3 – 24 surveys over 1 year SS7 – 4 surveys
Flow Rate	IBWC gauge	South Bay	SS4 – continuous over 1 year
Temperature	Collected with Temperature chain; ~3m interval to 28m depth	South Bay Ocean Outfall	SS5 – 5 minute interval continuous 1 year
Pressure	Collected with Temperature chain; ~28m depth	South Bay Ocean Outfall	SS5 – 1 minute interval continuous 1 year
Surface Temperature	Collected with Seabird Seacat	South Bay Ocean Outfall	SS5 – 5 minute interval continuous 1 year
Surface Conductivity	Collected with Seabird Seacat	South Bay Ocean Outfall	SS5 – 5 minute interval continuous 1 year
Velocity (Currents)	Collected with 600kHz downward looking ADCP ~1m interval to 28m depth	South Bay Ocean Outfall	SS5 – 3 minute interval continuous at 1 hour burst 1 year
Temperature	Collected with Temperature chain; ~1m interval to 8m depth	Imperial Beach	SS5 – 5 minute interval continuous 1 year
Pressure	Collected with Temperature chain; ~8m depth	Imperial Beach	SS5 – 1 minute interval continuous 1 year
Velocity (Currents)	Collected with 600kHz upward looking AWAC ~1m interval from 8m depth	Imperial Beach	SS5 – 5 minute interval continuous 1 year
Waves	Collected with 600kHz upward looking AWAC	Imperial Beach	SS5 – 1 hour interval continuous 1 year
Surface Currents	Collected with HF Radars located at Point Loma, Coronado Island (South Island), Border Field Sate Park	South Bay	SS6 – 1 hour interval continuous 1 year
Fecal Coliform	200ml grab samples	South Bay	SS3 - 24 sampling events (4 samples per event); SS4 – 6 to 10 2-day sampling events (4 to 6 samples per event); SS7 – 4 sampling events (4 to 6 samples per event)
Total Coliform	200ml grab samples	South Bay	SS3 - 24 sampling events (4 samples per event); SS4 – 6 to 10 2-day sampling events (4 to 6 samples per event); SS7 – 4 sampling events (4 to 6 samples per event)

CONSTITUENT	MEASUREMENT	LOCATION	NOTES and Associated task number
Enterococcus	200ml grab samples	South Bay	SS3 - 24 sampling events (4 samples per event); SS4 – 6 to 10 2-day sampling events (4 to 6 samples per event); SS7 – 4 sampling events (4 to 6 samples per event)
Human Specific *Prevotella/Bacteroides*	Real-time Quantitative Polymerase Chain Reaction (RT-QPCR)	South Bay	SS7 - 4 surveys
Human Specific enteroviruses	RT-QPCR	South Bay	SS7 - 4 surveys
Norwalk-like viruses	RT-QPCR	South Bay	SS7 - 4 surveys
Human Specific Adenoviruses	RT-QPCR	South Bay	SS7 - 4 surveys

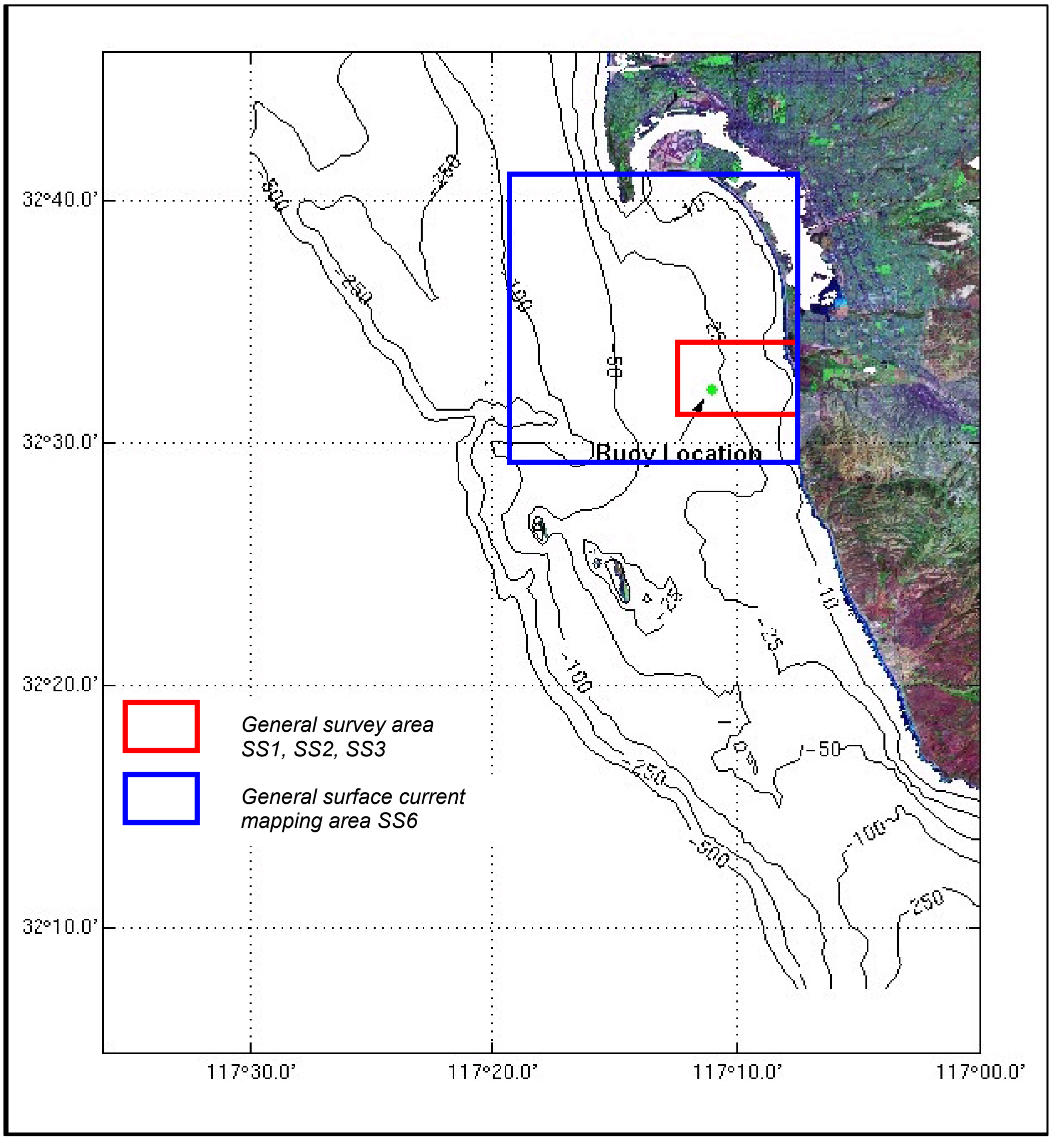
6.3 Project Schedule

Table 3. Project Schedule

Activity	Date (MM/DD/YY)		Deliverable	Deliverable Due Date
	Anticipated Date of Initiation	Anticipated Date of Completion		
Project Start	09/29/06	09/01/08	Report – Summary of Analysis	09/01/08
QAPP and Monitoring Plan	01/01/07	06/29/07	QAPP and Monitoring Plan	03/12/07
Surveys	07/02/07	06/30/08	None	N/A
Moorings at SBOO and IB Pier	01/01/07	06/29/07	Moorings Deployed	07/02/07
Monthly Progress Reports	01/01/07	06/30/08	Monthly Progress Report	1st Thursday of following month
Draft Project Report	06/30/08	08/04/08	Draft Project Report	08/04/08
Final Project Report	03/31/08	09/01/08	Final Report	09/01/08

6.4 Geographical Setting

The area monitored encompasses a region spanning from Point Loma to the U.S.-Mexico Border and waters offshore to distances of approximately 16nm (30 kilometers).



6.5 Constraints

There are several time constraints for this project. The study will involve collection of physical ocean observations and analyses during predetermined conditions in both wet and dry seasons. The wet weather study success is dependent on having enough rain events and oceanographic conditions as specified in the monitoring plan. The survey efforts are dependent upon delivery of the REMUS vehicle from Hydroid by March 30, 2007. The second constraint is the approval of the Monitoring Plan and QAPP by April 2, 2007.

7. QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

7.1 Data Quality Objectives for all field measurements and lab analyses

Data Quality Objectives (DQOs) for moored (fixed) and vessel-mounted current measurements are based on instrument manufacturer recommendations and considered appropriate for the goals of this program. They are consistent with standard approaches practiced by the oceanographic science community. Data Quality Objectives for field measurements are listed in Table 4; there are no lab analyses in the SIO task list for this project. Goals of the project: Identification and tracking plumes from the SBOO, Characterization of land based sources with focus on Tijuana River, Identification of the region oceanographic conditions, which lead to high fecal indicator bacteria (FIB) on the South Bay Beaches.

Data quality objectives for the microbiological analyses are based on best practices in the research community. There are currently no regulatory standard protocols for these measurements. The accuracy, precision, and recovery are based on work in our Laboratory (J. Fuhrman) at USC. Recovery is based on use of a known virus, such as the polio virus. Precision is based on prior experience with these techniques by ourselves and other microbial researchers.

Table 4. Data Quality Objectives for Field Measurements

Group	Parameter	Accuracy	Precision	Completeness
Wetlabs BB2F - Fluorometer	Chlorophyll Fluorescence	≥ .02 ug/l	.01 ug/l	No requirement; will use 90%.
Wetlabs WS3S - WETStar	Chlorophyll Fluorescence	≥ .03 ug/l	.01 ug/l	No requirement; will use 90%.
YSI CTD	Conductivity	± 5% of reading +.001 mS/cm	.001 - .1 mS/cm (range dependent)	No requirement; will use 90%.
SBE 37-SI	Conductivity	.003 mS/cm	.0001 mS/cm	No requirement; will use 90%.
SBE 37-SMP	Conductivity	.003 mS/cm	.0001 mS/cm	No requirement; will use 90%.
YSI CTD	Depth	± .12m	.001m	No requirement; will use 90%.
Wetlabs CST	Light Transmittance	± 10%	1%	No requirement; will use 90%.
Wetlabs BB2F	Optical Backscatter	(532nm – $7.7x10^{-6}$ m^{-1} sr^{-1}) (660nm – $3.32x10^{-6}m^{-1}$ sr^{-1})	.0024 m^{-1} .0024 m^{-1}	No requirement; will use 90%.
Wetlabs ECO-VSF	Optical Backscatter	~$1.24x10^{-5}$ m^{-1} sr^{-1}	.0012 m^{-1}	No requirement; will use 90%.
PME	Pressure	.5%	NA	No requirement; will use 90%.
YSI XL600	Temperature	± .15 °C	.01 °C	No requirement; will use 90%.
PME	Temperature	± .001 °C	.005 °C	No requirement; will use 90%.
SBE 37-SI	Temperature	.002 °C	005 °C	No requirement; will use 90%.
SBE 37-SMP	Temperature	.002 °C	.005 °C	No requirement; will use 90%.
ADCP	Current Velocity	± .3% of measured velocity ± 0.3 cm/s	.1cm/s	No requirement; will use 90%.
AWAC	Current Velocity	± 1% of measured velocity ± 0.5 cm/s	0.1 cm/s	No requirement; will use 90%.
AWAC	Wave Height	<1% of measured value	1 cm	No requirement; will use 90%.
AWAC	Wave Direction	2°	.1°	No requirement; will use 90%.
HF Radar (25MHz)	Surface Currents	~6 cm/s	.3cm/s	No requirement; will use 90%.
SBE 49	Temperature	0.002°C	.005 °C	No requirement; will use 90%.
SBE 49	Conductivity	0.0003 S/m	.001 S/m	No requirement; will use 90%.
SBE 49	Pressure	0.1 dbar	NA	No requirement; will use 90%.
Wetlabs Ecotriplet Fluorometer	Chlorophyll, CDOM, and cyanobacterial fluorescence (or rhodamine WT)	Chl. ≥ .02 µg/l CDOM ≥ . 0.2 ppb QS Phyoerythrin (Rhod. WT) . ≥ 0.14 ppb	Chl .01 µg/l CDOM 0.09 ppb QS Phyoerythrin (Rhod. WT) . ≥ 0.07 ppb	No requirement; will use 90%.

Group	Parameter	Accuracy	Precision	Completeness
Wetlabs Ecotriplet Backscatter	Optical Backscatter	(532nm – 7.7x10^{-5} m^{-1} sr^{-1}) (700nm – 3.35x10^{-5} m^{-1} sr^{-1})		No requirement; will use 90%.

Table 5. Data Quality Objectives for Laboratory Measurements

Group	Parameter	Accuracy	Precision	Completeness
FIB	Fecal Coliform	Laboratory positive and negative cultures – proper positive or negative response. Bacterial PT sample -–within the stated acceptance criteria.	R_{log} within 3.27*mean R_{log} (reference is section 9020B of 18th, 19th, or 20th editions of *Standard Methods*	No requirement; will use 90%.
FIB	Total Coliform	Laboratory positive and negative cultures – proper positive or negative response. Bacterial PT sample -–within the stated acceptance criteria.	R_{log} within 3.27*mean R_{log} (reference is section 9020B of 18th, 19th, or 20th editions of *Standard Methods*	No requirement; will use 90%.
FIB	Enterococcus	Laboratory positive and negative cultures – proper positive or negative response. Bacterial PT sample -–within the stated acceptance criteria.	R_{log} within 3.27*mean R_{log} (reference is section 9020B of 18th, 19th, or 20th editions of *Standard Methods*	No requirement; will use 90%.
Microbiology	Prevotella/ Bacteriodes	Expected within 25%[1]	**Typically ±25%**[1]	No requirement; will use 90%.
Microbiology	Enteroviruses	Expected within 25%[1]	**Typically ±25%**[1]	No requirement; will use 90%.
Microbiology	Norwalk-like viruses	Expected within 25%[1]	**Typically ±25%**[1]	No requirement; will use 90%.
Microbiology	Adenoviruses	Expected within 25%[1]	**Typically ±25%**[1]	No requirement; will use 90%.

[1]**Note these are estimates, as there are no established standards.**

7.2 Project action limits for all parameters of interest

As discussed in Section 10, field data collected for this program are intended for project goals and to supplement existing data that will be used eventually to characterize South Bay plumes and land based sources. These data are not intended for compliance assessments or regulatory actions.

7.3 Acceptance criteria for all previously collected information

Determinations of acceptance of previously collected information is not within the scope of this program.

7.4 Precision

Continuous measurements will be made using moored instruments that will be calibrated prior and post deployment. Use of duplicate instruments to assess precision is impractical. However, data collected by different instruments are expected to be comparable, within the range of expected spatial variability, and these comparisons can provide an indication of precision. Data will undergo standard QA/QC procedures to identify instrument drift and data outlier removal. QA procedures include factory calibration of all sensors prior to deployment for this project. QC procedures include valid range check based on instrument specification, outlier detection and removal of values outside of valid range. Any instrument reporting values that exceed range check or report repeated values over a period of 5 samples will be examined for instrument maintenance and functionality. If necessary, instrumentation will be sent in for calibration.

7.5 Bias

Potentials for bias in the measurements will be addressed by performing calibration procedures recommended by the instrument manufacturer.

7.6 Completeness

Completeness is the number of analyses generating useable data for each analysis divided by the number of samples collected for that analysis. The completeness objective for all data types is 90%. This would provide more than enough data to satisfy the objectives of this project.

8. SPECIAL TRAINING NEEDS/CERTIFICATIONS

8.1 Specialized Training or Certifications.

Field Sampling

No certification process exists for the class of observations that will be conducted as part of this study. However, all field personnel have been, or will be trained in proper field sampling and sample handling techniques prior to each data collection effort. These techniques will be reviewed prior to each sampling event. Field data collected for this program are intended for analysis of the South Bay oceanographic characteristics and to supplement existing data. These data are not intended for compliance assessments or regulatory actions.

8.2 Training and Certification Documentation

All personnel are responsible for complying with all quality assurance/quality control requirements that pertain to their organizational/technical function. Each technical staff member must have a combination of experience and education to adequately demonstrate a specific knowledge of their particular function and a general knowledge of laboratory operations, test methods, quality assurance/quality control procedures, and records management. Technical staff are required to read the instrument manuals and handle instrumentation according to operating instructions. All SIO staff members are required to take the Injury and Illness Prevention Program course. This course ensures staff are familiar University safety programs and will conclude with a certificate of completion.

8.3 Training Personnel

The Project Manager will provide training for field personnel in proper field sampling techniques prior to work initiation to ensure consistent and appropriate sampling, sampling handling/storage, and chain of custody procedures.

9. DOCUMENTS AND RECORDS

SIO will document and maintain copies of raw data files for the data generated under the following tasks:

(SS1) SBOO Plume Mapping and (SS2) Tijuana River Plume Mapping
Conductivity, Temperature, Depth, Chlorophyll Fluorescence, Optical backscatter, Velocity
(SS3) Boat Survey-Mapping of Land-based Plumes
Conductivity, Temperature, Chlorophyll Fluorescence, Optical backscatter, Light Transmittance
(SS4) Continuous Flow Rate and Loading of the Tijuana River
Flow Rate
(SS5) Ocean Moorings at South Bay Ocean Outfall and Imperial Beach Pier
SBOO – Surface Conductivity, Surface Temperature, Temperature (profile), Pressure, Velocity (profile)
IB Pier – Temperature (profile), Pressure, Wave Height, Wave Direction, Velocity (profile)
(SS6) Mapping of Ocean Surface Currents
Surface Currents

SIO will maintain a mirrored data set of oceanographic information collected in this project. Programmer /Analyst Mark Otero will maintain this data set. After verification and final data storage establishment, the raw data files and databases are copied to offsite to the San Diego Super Computer Center. All original data sheets, all statistical worksheets, and all reports produced are accumulated into project specific files that are maintained at SIO after the report has been submitted. Final report text and tables are also stored on a mirrored drive. Records will be maintained for at least five years.

Persons responsible for maintaining records for this project are as follows: Eric Terrill, Project Manager, will oversee the operations of the project and will arbitrate any issues relative to records retention and any decisions to discard records. Lisa Hazard, Operations Manager will oversee all field data transfer from instrument to computer storage. Development Engineers William Middleton and Shannon Scott will download data from REMUS and CTD packages upon completion of field measurements. Results of laboratory analyses for Tasks SS4 and SS7 will be compiled and archived by CH2M HILL.

Copies of this QAPP will be distributed to all parties involved with the project, CH2M HILL, SIO, and USC. Updates to this QAPP will be distributed in like manner, and all previous versions will be discarded from the project file.

Copies of the final report, including laboratory results and field records will be maintained for a minimum of 5 years after project completion.

GROUP B: DATA GENERATION AND ACQUISITION

10. SAMPLING PROCESS DESIGN

10.1 Sampling Design

Field sampling has four primary components: (1) periodic velocity current, CTD, optical backscatter, light transmittance, and chlorophyll measurements surveying SBOO, Tijuana River, and Land-based plumes at multiple locations (SS1, SS2, SS3); (2) Tijuana River flow rate continuous monitoring and FIB sampling (SS4); (3) continuous sampling of velocity currents (profile), temperature (profile) and pressure at two fixed locations mooring locations, as well as surface conductivity and temperature at SBOO; wave height and direction at Imperial Beach Pier (SS5); and continuous mapping of ocean surface currents (SS6). The field sampling program will span one year (approximately April 1, 2007, through March 31, 2008). The duration is constrained by the overall program schedule. Locations are within the region spanning from Point Loma to the U.S.-Mexico Border and waters offshore to distances of approximately 16nm (30 kilometers).

10.2 Design Strategy

The design strategy primarily reflects the need to characterize plumes from the SBOO, Tijuana River, and land-bases sources, as well as identify the regional oceanographic conditions which lead to high fecal indicator bacteria (FIB) on the South Bay Beaches. For this reason, the design emphasizes collection of survey measurements over varying oceanographic conditions complemented by continuous current data throughout the entire region. The time period for measurements (one year) is considered appropriate for capturing the important tidal, seasonal, and event-driven processes that are considered to be most important for analyzing circulation and water quality characteristics within the project area.

10.3 Types and number of samples

The types of samples/matrices and measurements that will be performed for this program are discussed in Section 6.2.

10.4 Sample Sites

Two oceanographic moorings with continuous current and temperature measurements will be deployed. The two sites are a) wye of the diffusers at the SBOO, and 2) offshore Imperial Beach. These sites were chosen as best locations to characterize Ocean Outfall and South Bay region. Logistical considerations, such as accessibility, vulnerability to vandalism, interferences with port operations, and potentials for commercial shipping traffic to interfere with data collection were also considered. The mouth of the Tijuana River will be sampled during wet weather events to characterize the bacterial loads entering the receiving waters. Samples will be collected at the mouth of the estuary, in the north arm of the estuary adjacent to the end of Seacoast Drive, in the main branch of the Tijuana River at Hollister Road, and in the main branch approximately 0.5 miles east of the mouth of the estuary.

11. SAMPLING METHODS

11.1 Sampling SOPs

Pathogen monitoring (Task SS4) will include sampling for pathogen indicator organisms (fecal and total coliform bacteria, and *Enterococcus* bacteria). Samplers will wear gloves when collecting any pathogen samples in order to prevent introduced bacterial contamination.

Samples analyzed for bacteria will be collected as near-surface grab samples. Sampling for bacteria will in most cases be performed according to the sampling procedures detailed for Standard Methods 9221B and 9221E (APHA et al. 1998). In brief, the sampling procedures are summarized as follows:

- Sample containers should be cleaned and sterilized using procedures described in Standard Methods 9030 and 9040 (APHA et al. 1998). In most cases, these containers are provided by the laboratories conducting the analyses. Alternatively, Whirl-pak bags may also be used, per protocol
- For waters suspected to contain a chlorine residual, sample bottles should contain a small amount of sodium thiosulfate sufficient to neutralize bactericidal activity. In most cases, bottles provided by contract laboratories already contain the sodium thiosulfate as a precautionary measure.
- Sample bottles may be glass or plastic with a capacity of at least 100 ml. After sterilization, sample bottles should be kept closed until they are to be filled.
- When removing caps from sample bottles, be careful to avoid contaminating inner surface of caps or bottles.
- Using aseptic techniques, fill sample bottles (or Whirl-pak bags), leaving sufficient air space to facilitate mixing by shaking. Do not rinse bottles.
- Recap bottles tightly.

If at any time the sampling crew suspects that the sample or sampling container has been contaminated, the sample should be re-collected into a new sample container.

Samples for fecal indicators (Task SS7 - Prevotella/Bacteroides, pathogenic viruses) are collected by CTD/Rosette (bottles closed at chosen depths, during the up-cast).

The 20th edition of Standard Methods (APHA et al. 1998) recommends analysis of samples as soon as possible, but specifies that non-drinking water samples analyzed for non-compliance purposes may be held for up to 24 hours (below 10˚C) until time of analysis. For this reason, data from these samples should not be used for assessment of regulatory compliance.

There are no SWAMP SOPs for the field measurements collected by SIO tasks.

11.2 Matrix and sample type collection

WETLABS DH4 CTD - A suite of high accuracy and stable instruments are combined in one package/cage (CTD) in order to vertically profile the water column, determine the mixed layer depth, and determine the general characteristics of the water sampled based on the following sensors: Seabird SBE37-SI (conductivity, temperature, pressure), Wetlabs ECO-VSF (Optical Backscatter), Wetlabs CST (light transmittance), and Wetlabs WS3S (Chlorophyll-a Fluorescence). Instruments will also undergo a battery and response check before each vertical

deployment in order to ensure data collection during profiles. Response checks will also be used for post-processing measurement validation. The instrument package will be lowered over the side using a controlled winch from a shipboard davit.
REMUS AUV – The REMUS Autonomous Underwater Vehicle includes array instrumentation for operation in coastal environments. Instrument suite includes the following sensors: YSI CTD (conductivity, temperature, and pressure), Wetlabs BB2F (optical backscatter and chlorophyll-a and 1200kHz ADCP (velocity). The REMUS is programmed using the Vehicle Interface Program (VIP) to map predetermined regions. The vehicle can be programmed to run packaged "mow the lawn" patterns and star search patterns or a user defined pattern. Upon initial deployment of the vehicle, the system always takes a GPS fix and zeros the pressure sensor ensuring accurate initial positioning and depth measurements. The vehicle can then navigate using underwater transponders with fixed/known locations or by re-acquiring GPS throughout the deployment. The system's depth is monitored by a pressure sensor and ADCP bottom ping. The vehicle is launched by two personnel from the boat at a nearest location to the start position and sent a start command from the ranger. The ranger continually queries the vehicle throughout the deployment to gain system status. Upon completion of the mission, the vehicle is again recovered by two personnel.

Chlorophyll Fluorescence as measured by the Wetlabs BB2F instrument "allows the user to monitor chlorophyll concentration by directly measuring the amount of chlorophyll-a fluorescence emission from a given sample volume of water. Chlorophyll, when excited by the presence of an external light source, absorbs light in certain regions of the visible spectrum and re-emits a small portion of this light as fluorescence at longer wavelengths. The ECO uses two bright blue LEDs (centered at 455 nm and modulated at 1 kHz) to provide the excitation source. A blue interference filter is used to reject the small amount of red light emitted by the LEDs. The blue light from the sources enters the water volume at an angle of approximately 55–60 degrees with respect to the end face of the unit. Fluoresced light is received by a detector positioned where the acceptance angle forms a 117-degree intersection with the source beam. A red interference filter is used to discriminate against the scattered blue excitation light. The red fluorescence emitted is synchronously detected by a silicon photodiode." (reference WETLabs BB2F manual pg. 7)

Chlorophyll Fluorescence as measured by the Wetlabs WS3S instrument "is primarily designed to measure the fluorescence of chlorophyll-containing phytoplankton, which absorb light of wavelengths between 400 and 520 nm and emit light between 670 and 730 nm. The chlorophyll WETStar uses two bright blue LEDs (centered at approximately 470 nm and modulated at 1 kHz) to provide the excitation. Blue interference filters are used to reject the small amount of red light emitted by the LEDs. A detector positioned at 90 degrees to the axis of the LED mounts measures the emitted light from the sample volume. The approximately 0.25 cm3 sample volume is defined by the intersection of the excitation light with the field of view of the detector, within the quartz flow tube. A red interference filter is used to discriminate against the scattered blue excitation light. The red fluorescence emitted at 90 degrees is synchronously detected at 1 kHz by a silicon photodiode. The amplified and demodulated voltage output of the photodiode is provided to the user for connection to a digital voltmeter, an A/D converter or RS232 input. The instrument contains two LEDs, doubling the excitation light, as well as mirrors and lenses to optimize the instrument's performance." (Reference WETLabs WETStar manual pg. 5)

Conductivity as measured by the YSI CTD "utilizes a cell with four pure nickel electrodes for the measurement of solution conductance. Two of the electrodes are current driven, and two are used to measure the voltage drop. The measured voltage drop is then converted into a conductance value in milli-Siemens (millimhos). To convert this value to a conductivity value in milli-Siemens per cm (mS/cm), the conductance is multiplied by the cell constant that has units of reciprocal cm (cm-1). The cell constant for the sonde conductivity cell is approximately 5.0/cm. For most applications, the cell constant is automatically determined (or confirmed) with each deployment of the system when the calibration procedure is followed. Solutions with conductivities of 1.00, 10.0, 50.0, and 100.0 mS/cm, which have been prepared in accordance with recommendation 56-1981 of the Organization International De Metrologie Legale (OIML), are available from YSI." (Reference YSI_600XL manual pg. 172)

Conductivity as measured by Seabird SBE 37-SI and SBE 37-SMP "is acquired using an ultra-precision Wien Bridge oscillator to generate a frequency output in response to changes in conductivity. A high-stability TCXO reference crystal with a drift rate of less than 2 ppm/year is used to count the frequency from the oscillator." (Reference 37SI_rs232 manual pg. 44; 37SMP_rs232 pg. 53)

Depth as measured by the YSI 600XL "measures the pressure of the water column plus the atmospheric pressure above the water. Depth must be calculated from the pressure exerted by the water column alone; therefore, when depth is calibrated in air, the software records the atmospheric pressure and subtracts it from all subsequent measurements. This method of compensating for atmospheric pressure introduces a small error. Because the software uses the atmospheric pressure at the time of calibration, changes in atmospheric pressure between calibrations appear as changes in depth. The error is equal to 0.045 feet for every 1mm Hg change in atmospheric pressure. In sampling applications, frequent calibrations eliminate the error. Considering typical changes in barometer during long term monitoring, errors of ± 0.6 feet (0.2m) would be common. In applications where this error is significant, we recommend using a level sensor in place of the depth sensor." (Reference YSI_600XL pg. 176) Long term monitoring is not applicable for this instrument as the pressure sensor will be zeroed at each REMUS AUV mission (less than one day each). Accuracy of +/- .12 therefore applies to instrument operation.

Light Transmittance as measured by the Wetlabs CST "measures light transmittance at a single wavelength over a known path. The instrument is configured at the time of purchase to have a path length of 10 cm and wavelength 660 nm. In general, losses of light propagating through water can be attributed to two primary causes: scattering and absorption. By projecting a collimated beam of light through the water and placing a focused receiver at a known distance away, one can quantify these losses. The ratio of light gathered by the receiver to the amount originating at the source is known as the beam transmittance (Tr)." (Reference Wetlabs C-Star manual pg. 1)

Optical Backscatter as measured by the Wetlabs BB2F "measures backscattering at two wavelengths (470 and 700 nm) at 117 degrees and chlorophyll fluorescence within the same volume. This angle was determined as a minimum convergence point for variations in the volume scattering function induced by suspended materials and water itself. Therefore, the signal measured by this meter is less determined by the type and size of materials in the water and more directly correlated to the concentration of the materials" (reference WETLabs BB2F manual pg. 7)

Optical Backscatter as measured by the Wetlabs ECO VSF "measures the optical scattering at 100, 125, and 150 degrees, thus providing the shape of the Volume Scattering Function (VSF) throughout its angular domain. Motivated by the need to better understand the relationship of water-leaving radiance with the backscattering into the same direction, the three-angle measurement allows determination of specific angles of backscattering through interpolation.

Conversely, it also can provide the total backscattering coefficient by integration and extrapolation from 90 to 180 degrees." (Reference Wetlabs ECO VSF manual pg. 7)

Pressure as measured by the PME Pressure transducer utilizes a "strain-gage transducer that converts pressure into a format that can be uploaded along the T-Chain. This Pressure transducer is only compatible with PME's T-Chain." (Reference PME TChain data sheet pg. 3)

Surface Currents as measured by the CODAR Ocean Sensors HF radar utilize "Radio waves are sent toward an object known as a "target." Reflections bounce back from the target. Reflections are analyzed to find the distance (called "range"), direction ("bearing") and speed of the target. Once again, radar measures the range, bearing, and speed of a target. American and British scientists invented Radar during World War II. The original targets were ships and airplanes. SeaSonde's "targets" are waves on the surface of the ocean. By measuring the speed of the ocean waves and the currents upon which they are propagating, the direction and speed of currents near the water's surface can be calculated, using proprietary software. Reference Codar Operating Theory pg. 3 (Codar Ocean Sensors, Palo Alto, CA).

Temperature as measured by the YSI 600XL "utilizes a thermistor of sintered metallic oxide that changes predictably in resistance with temperature variation. The algorithm for conversion of resistance to temperature is built into the sonde software, and accurate temperature readings in degrees Celsius, Kelvin, or Fahrenheit are provided automatically. No calibration or maintenance of the temperature sensor is required." (Reference YSI_600XL pg. 177)

Temperature as measured by the SBE 37-SI and SBE 37-SMP "is acquired by applying an AC excitation to a hermetically sealed VISHAY reference resistor and an ultra-stable aged thermistor with a drift rate of less than 0.002°C per year. A 24-bit A/D converter digitizes the outputs of the reference resistor and thermistor (and optional pressure sensor). AC excitation and ratiometric comparison using a common processing channel avoids errors caused by parasitic thermocouples, offset voltages, leakage currents, and reference errors." (Reference 37SI_rs232 manual pg. 44; 37SMP_rs232 pg. 53)

Current Velocity as measured by the ADCP utilizes the "Doppler effect by transmitting sound at a fixed frequency and listening to echoes returning from sound scatterers in the water. These sound scatterers are small particles or plankton that reflect the sound back to the ADCP. Scatterers are everywhere in the ocean. They float in the water and on average they move at the same horizontal velocity as the water." (Reference Broadband Primer pg. 6)

Current Velocity as measured by the AWAC "implements a narrowband auto-covariance method because it has been established as robust, reliable and accurate. Sound does not reflect from the water itself, but rather from particles suspended in the water. These particles are typically zooplankton, suspended sediment or small bubbles. Bubbles cause trouble at far lower acoustic frequencies, but they look like any other scatterer at the Aquadopp's frequency (2 MHz). Long experience with Doppler current sensors tells us that the small particles the Aquadopp sees move on average at the same speed as the water - the velocity it measures is the velocity of the water." (Reference Nortek Principals of Doppler http://www.nortekusa.com/principles/Doppler.html)

Wave Height as measured by the AWAC utilizes the decrease in velocity and pressure below the surface. "The rate of decrease is well understood and modeled by linear wave theory. This allows us to measure the pressure and the velocity near the bottom, and to rescale the measurements to obtain the wave elevation spectrum at the surface. And if you know the surface elevation spectrum, then you can compute the significant wave height as well. (Reference Nortek Wave Measurements pg. 2)

Wave Direction as measured by the AWAC "wave analysis compares pressure and velocity to determine the wave direction. However, instead of performing the analysis with the original time series as we have just done, it uses Fourier transforms to separate the signals into different frequency bands so that it can determine direction separately for each band. This means that if you have a long-period swell coming from one direction, and shorter wind waves coming from another, the direction of the two can be resolved. The PUV analysis makes one intrinsic assumption: Assumption Standard PUV wave analyses assume that waves at a given frequency come from one primary direction if waves with approximately equal size come from more than one direction, then the computed wave direction will be different from the direction of either wave set, likely somewhere in between." (Reference Nortek Wave Measurements pg. 2)

Varying instrument characteristics for measuring similar parameters will not be an issue during data analysis. Each instrument is calibrated for the parameter of measurement. Calibration techniques are specific to the instrument and ensure accurate measurements.

11.3 Sample handling

Samples for Task SS4 will be collected according to EPA recommendations on surface water sampling, according to the SOPs presented in Section 11.1 above. Samples will be transported from the field to the analytical laboratory by field personnel. Samples will not be shipped.

Fecal Indicator samples for Task SS7, including Prevotella/Bacteroides and human pathogenic viruses (enteroviruses, Norwalk-like viruses, adenoviruses) will be collected by CTD/rosette and placed in plastic bottles for later filtration. Gloves will be used to reduce contamination of samples.

A sample numbering scheme has been developed that allows each sample to be uniquely identified and provides a means of tracking the sample from collection though analysis. The numbering scheme indicates the location and sample type. The unique sample number will be entered in the field logbook, field tracking sheets, COC forms, and other records documenting sampling activities. The following field identification (ID) for sample numbering will have five components, a follows:

X Y Date Z

Where:

X = task and sampling location designations
SS3, SS4, or SS7, followed by two-digit Sampling Location Number. For field duplicates, a "1" will be added before the location number, resulting in a three digit number.
Y = unique ID for depth (a, b, or c)
Date = month, day, and year (mmddyy)
Z = other relevant information (as necessary):
MS = matrix spike
SD = matrix spike duplicate

11.4 Sample containers and sample volumes

Water quality samples collected for Task SS4 will utilize 250 ml plastic bottles provided by Enviromatrix Analytical. These bottles will contain sodium thiosulfate, and come pre-labeled with entries for the date of sample and the sample ID. Fecal indicator samples collected for Task SS7 will utilize 1 to 3 liter polyethylene bottles.

11.5 Sample preservation

After sample collection into a properly preserved container, samples for Tasks SS4 and SS7 will be placed in a cooler filled with ice for temporary storage prior to and during delivery to the analytical laboratory. The cooler will be sealed with packing tape and a custody seal will be properly placed across two sides of the cooler lid.

11.6 Sampling equipment decontaminated and sample disposal

All water quality samples remaining after successful completion of analyses will be disposed of properly. It is the responsibility of the personnel of each analytical laboratory to ensure that all applicable regulations are followed in the disposal of samples or related chemicals. Sample bottles for Task SS7 are rinsed in sample water and 5% HCl. Samples for Task SS7 are destroyed during extraction and analysis, so disposal is not necessary.

11.7 Equipment and support facilities

Field surveys likely will require use of a small boat for performing casts using a conductivity, temperature, and depth (CTD) system. Servicing of the current meters and CTD profiles may be accomplished for a wharf, bridge, or other facility if possible. Otherwise, these survey tasks will be accomplished from a small vessel. All survey operations also will require use of a portable navigation system.

No specialized equipment is required for the surface water quality samples conducted under Task SS4.

11.8 Problem recognition and corrective action

The SIO on-site Development Engineer will be responsible for all corrective actions related to field sampling operations. The field manager or operations manager will document the problem and corrective actions in a corrective action report that will be distributed to the program manager.

Table 6. Sampling Locations and Sampling Methods

Analytical Parameter	Sample Volume	Containers (#, size, type)	Preservation (chemical, temperature, light protected)
Water Samples			
Chlorophyll Fluorescence	N/A	Analyzed in Field	N/A
Conductivity	N/A	Analyzed in Field	N/A
Depth	N/A	Analyzed in Field	N/A
Flow Rate	N/A	Analyzed in Field	N/A
Light Transmittance	N/A	Analyzed in Field	N/A
Optical Backscatter	N/A	Analyzed in Field	N/A
Pressure	N/A	Analyzed in Field	N/A
Surface Currents	N/A	Analyzed in Field	N/A
Temperature	N/A	Analyzed in Field	N/A
Velocity Currents	N/A	Analyzed in Field	N/A
Wave Height	N/A	Analyzed in Field	N/A
Wave Direction	N/A	Analyzed in Field	N/A
FECAL COLIFORM	200 mL	250 mL Plastic Bottles	Sodium Thiosulfate
TOTAL COLIFORM	200 mL	250 mL Plastic Bottles	Sodium Thiosulfate
Enterococcus	200 mL	250 mL Plastic Bottles	Sodium Thiosulfate

12. SAMPLE HANDLING CUSTODY

12.1 Holding Times

There are no Sampling hold times for oceanographic field data collected as part of SIO's tasks within the project. Sample hold times for samples collected under Tasks SS4 and SS7 are summarized in Table 7.

Table 7. Sample Handling and Custody

Parameter	Container	Volume	Initial Preservation	Holding Time
Field measurements	Analyzed in Field	N/A	N/A	N/A
FECAL COLIFORM	Factory-sealed, pre-sterilized, disposable Whirl-pak® bags or 250 ml sterile plastic (high density polyethylene or polypropylene) container	200 ml volume sufficient for both fecal and total coliform analyses	Sodium thiosulfate is pre-added to the containers in the laboratory (chlorine elimination). Cool to 4°C; dark.	STAT: 6 hours at 4°C, dark if data for regulatory purposes; otherwise, 24 hrs at 4C, dark if non-regulatory purpose.
TOTAL COLIFORM	Factory-sealed, pre-sterilized, disposable Whirl-pak® bags or 250 ml sterile plastic (high density polyethylene or polypropylene) container	200 ml volume sufficient for both fecal and total coliform analyses	Sodium thiosulfate is pre-added to the containers in the laboratory (chlorine elimination). Cool to 4°C; dark.	STAT: 6 hours at 4°C, dark if data for regulatory purposes; otherwise, 24 hrs at 4C, dark if non-regulatory purpose.
Enterococcus	Factory-sealed, pre-sterilized, disposable Whirl-pak® bags or 250 ml sterile plastic (high density polyethylene or polypropylene) container	200 ml volume sufficient for both E. coli and Enterococcus analyses	Sodium thiosulfate is pre-added to the containers in the laboratory (chlorine elimination). Cool to 4°C; dark.	STAT: 6 hours at 4°C, dark if data for regulatory purposes; otherwise, 24 hrs at 4C, dark if non-regulatory purpose.
Fecal Indicators	Polyethylene bottles	1-3 liters	ice	12 hours

12.2 Chain of Custody Procedures

Chain-of-custody (COC) procedures require that possession of samples be traceable from the time the samples are collected until completion and submittal of analytical results. A complete chain-of-custody form is to accompany the transfer of samples to the analyzing laboratory. Appendix 5 contains an example of the COC form that will be used during the sampling events.

A COC records establishes the documentation necessary to trace sample possession from time of collections through sample analysis and disposition. A sample is in the custody of a person if any of the following criteria are met:

- The sample is in a person's physical possession.
- The sample is in a person's view after being in his or her physical possession.
- The sample was in a person's physical possession and was then locked up or sealed to prevent tampering.
- The sample is kept in a secured area.

For tasks SS4 and SS7, the sample collector will complete a COC form in the field while the samples are collected to accompany each sample delivery container (cooler) and will be responsible for delivering the samples to the local laboratory. The sample collector will provide the project number and the sample collector's signature as header information on the COC. Each COC will include the following elements:

- Project name
- Project number
- Project manager
- Name of laboratory
- COC identifier
- Site ID
- Station/location names
- Sample names
- Sampling dates
- Sampling times
- Sample matrices
- Total number of containers
- Container type
- Requested analytical methods
- Sampling team names
- Remarks
- Relinquished / received signatures with dates and times

There is no Chain of Custody Procedure for oceanographic field data samples collected by SIO. All activities will occur with the Coastal Observing R&D Center at Scripps Institution of Oceanography.

13. ANALYTICAL METHODS

Table 8. Field Analytical Methods

Analyte	Project Action Limit (units, wet or dry weight)	Analytical Method		Achievable Laboratory Limits	
		Analytical Method/ SOP	Modified for Method yes/no	MDLs (1)	Method (1)
Chlorophyll Fluorescence	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Conductivity	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Depth	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Flow Rate	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Light Transmittance	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Optical Backscatter	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Pressure	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Surface Currents	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Temperature	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Velocity Currents	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Wave Height	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*
Wave Direction	*None*	*Ref 11.2*	*No*	*N/A*	*N/A*

Table 9 lists the analytical methods for constituents analyzed in a laboratory.

Table 9. Laboratory Analytical Methods

Analyte	Project Action Limit (units, wet or dry weight)	Analytical Method		Achievable Laboratory Limits	
		Analytical Method/ SOP	Modified for Method yes/no	Method Detection Limit	Laboratory Reporting Limit
Fecal Coliform	MPN/100mL	SMEWW 9221E	No	2	2
Total Coliform	MPN/100mL	SM9221EWW A,B,C	No	2	2
Enterococcus	CFU/100mL	SMEWW 9230C	No	2	2
Virus RNA	Copies per Liter	Quantitative PCR		~1 viral copy	~1 viral copy
Bacteria DNA	Copies per Liter	Quantitative PCR		~1 bacterial copy	~ 1 bacterial copy

13.3 Field equipment operation

CTD measurements will be collected onboard the REMUS vehicle and the Seabird/Wetlabs CTD package during surveys. Measurements will be downloaded upon completion of field work. The REMUS vehicle will also measure depth, chlorophyll fluorescence, optical backscatter, and velocity currents. The Seabird/Wetlabs profiler CTD packages will measure depth, chlorophyll fluorescence, optical backscatter, and light transmittance.

13.4 Continuous monitoring instruments

The SBOO mooring will send continuous measurements of temperature (profile), pressure, velocity currents (profile) via iridium communications once per hour and internally store data in 5 minute intervals. The data subsequently are downloaded from the instruments upon recovery. The IB Pier mooring will send continuous measurements of temperature, pressure, velocity currents (profile), wave height, wave direction via TCP/IP through a cabled connection to an acquisition system at the IB Pier Lifeguard Tower. The South Bay surface currents are measured continuously (once per hour) and communicated via ssh from the acquisition computer to a central node at SIO. Continuous flow rate measurements will be collected from the IBWC flow gauge via TCP/IP protocol.

13.5 Laboratory SOPs

The FIB and human pathogen samples will be analyzed by Enviromatrix Analytical. FIB analysis SOPs for these methods follow Standard Methods for the examination of Water and Wastewater, as listed in Table 9. The QA Plan from Enviromatrix Analytical is included in Appendix 6.

PCR protocols are outlined in published papers, referenced in the QAPP. Electronic versions of these papers are attached in Appendix 6.

All water samples were be filtered upon collection and kept frozen at -80C until prepared for DNA or RNA extraction and PCR.

For all the PCR microbiology assays, both positive and negative controls will be tested for each PCR assay. All samples will be done in duplicate. The virus assays will also be analyzed with duplicate positive spikes to test for any PCR inhibition. If the positive controls fail to amplify or if the negative controls show positive amplification, those results will be discarded and the assay will be repeated. Additionally, the quantification of viral load is dependent upon an accurate standard curve. This standard curve will be done separately for each assay and only used with r>0.95. The curves have a high repeatability from PCR to PCR.

The processing of samples is best described in [*Fuhrman, et al.*, 2005].

The analytical methods for the different microbial groups are described in the following papers, which are included in Appendix 6:

Prevotella/Bacteriodes: Sampling is described in [*Noble, et al.*, 2006]
PCR assay is based on [*Seurinck, et al.*, 2005]

Norovirus: PCR assay is based on [*Katayama, et al.*, 2002]

Enterovirus: PCR assay is based on [*Fuhrman, et al.*, 2005]

Adenovirus: PCR assay is based on [*Heim, et al.*, 2003]

Fuhrman, J. A., et al. (2005), Rapid detection of enteroviruses in small volumes of natural waters by real-time quantitative reverse transcriptase PCR, *Applied and Environmental Microbiology*, *71*, 4523-4530.

Heim, A., et al. (2003), Rapid and quantitative detection of human adenovirus DNA by real-time PCR, *Journal of Medical Virology*, *70*, 228-239.

Katayama, H., et al. (2002), Development of a virus concentration method and its application to detection of enterovirus and Norwalk virus from coastal seawater, *Applied and Environmental Microbiology*, *68*, 1033-1039.

Noble, R. T., et al. (2006), Multitiered approach using quantitative PCR to track sources of fecal pollution affecting Santa Monica Bay, California, *Applied and Environmental Microbiology*, *72*, 1604-1612.

Seurinck, S., et al. (2005), Detection and quantification of the human-specific HF183 Bacteroides 16S rRNA genetic marker with real-time PCR for assessment of human fecal pollution in freshwater, *Environmental Microbiology*, *7*, 249-259.

13.6 Laboratory equipment or instrumentation

Electronic laboratory equipment usually has recommended maintenance prescribed by the manufacturer. These instructions will be followed as a minimum requirement. Due to the cost of some laboratory equipment, back up capability may not be possible. But all commonly replaced parts will have spares available for rapid maintenance of failed equipment. Such parts include but are not limited to: batteries; tubes; light bulbs; tubing of all kinds; replacement specific ion electrodes; electrical conduits; glassware; pumps; etc.

A separate log book will be maintained for each type of laboratory equipment. All preventive or corrective maintenance will be recorded. The total history of maintenance performed will be available for inspection during a systems audit.

Laboratory equipment required for the viral analysis includes a filtration manifold, vacuum pump, -80ºC freezer or dry ice, centrifuge, pipettors, and Stratagene MX3000P.
Disposable items include filters, sterile Whirlpaks, pipet tips, PCR plates, PCR reagents.

13.7 Method performance criteria

The efficiency of the QPCR used in the viral analysis will be assessed using a standard curve, generated from a plasmid with the desired gene. Negative and positive controls will be included with each PCR reaction. Negative controls consist of the addition of sterile water in lieu of DNA. Positive controls consist of a known quantity of poliovirus vaccine added to each sample to test for inhibition of the PCR reaction. Each sample will be tested in duplicate alongside duplicate positive controls.

13.8 Corrective action and documentation.

Failures in field and laboratory measurement systems involve, but are not limited to such things as, instrument malfunctions, failures in calibration, sample jar breakage, blank contamination, and quality control samples outside of the defined limits (Data Acceptability Criteria). In many cases, the field technician or lab analyst will be able to correct the problem. If the problem is resolvable by the field technician or lab analyst, then they will document the problem in their field notes or laboratory record and complete the analysis. If the problem is not resolvable, then it is conveyed to the respective supervisor, who will make the determination if the analytical system failure compromised the sample results and should not be reported. The nature and disposition of the problem is documented in the data report that is sent to the Project Manager.

The QPCR used in the viral analysis will be repeated if the negative control is positive OR if the positive controls are negative. If the positive controls are negative, the initial DNA sample will be diluted and reanalyzed.

13.9 Sample disposal procedures

All water quality samples remaining after successful completion of analyses will be disposed of properly. It is the responsibility of the personnel of each analytical laboratory to ensure that all applicable regulations are followed in the disposal of samples or related chemicals. Materials used in the viral analysis can be disposed of in the trash.

13.10 Laboratory turnaround times

The procedures used in the viral analysis can be performed from filtration through QPCR in less than one day (USC Marine Laboratory). Results of the bacterial sampling (Task SS4) will be provided within 4 days of the sample collection and delivery to Enviromatrix Analytical.

13.11 Method validation and information and SOPs for nonstandard methods and PBMS

The methods used in the viral analysis have been previously published by the USC Marine Laboratory and others. We continue to review new literature to improve our methods. If a new method were to show improved efficiency and accuracy, we would consider adapting our method.

14. QUALITY CONTROL

14.1 QC Requirements

There are no SWAMP QC requirements for field testing of temperature, conductivity, depth, transmissivity or chlorophyll. Routine maintenance and spot checks for proper operation of the CTD, following the manufacturer's recommendations, will be performed prior to each water quality survey. Similarly, there are no SWAMP QC requirements for current measurements using moored and vessel-mounted instruments. Maintenance and calibration of these instruments will be performed according to the manufacturer's specifications and recommended frequencies.

QC samples are collected in the field and used to evaluate the validity of the filed sampling effort. Field QC samples are collected for laboratory analysis when appropriate to check sampling and analytical precision and accuracy. A field duplicate is a sample collected at the same time and from the same source as the original sample, but submitted to the laboratory as a separate sample to assess the consistency of the overall sampling and analytical system. Field duplicates will be collected on a 10% basis for all analytical laboratory methods. Field duplicate samples will be collected, numbered, packaged, and sealed in the same manner as other samples, and submitted blind to the laboratory.

Laboratory QC checks are designed to determine the precision and accuracy of the analysis, to demonstrate the absence of interference and contamination from glassware and reagents, and to allow data comparability. Laboratory QC checks can consist of method blanks, matrix spikes, matrix duplicate samples, and internal standards. Laboratory matrix spikes will be sampled at a 10% frequency (1 per batch). The laboratory will also complete initial calibrations and continuing calibration checks according to specified analytical methods. These QC checks are consistent with EPA requirements.

For the fecal indicators (Bacteroides/pathogenic viruses), field blanks are not required (having been tested many times previously with no false positives). Laboratory blanks (DNA extracted from an unused filter, or distilled water) are run with each set of samples analyzed, and a full standard curve is included with each set as well.

14.2 Data quality indicators or applicable QC statistics for precision, bias, outliers, and missing data

Procedures for calculating precision, accuracy, and completeness are as follows:

Precision

Precision is usually expressed as Relative Percent Difference (RPD) based on duplicate analyses of a sample. The RPD is calculated as:

$$\text{RPD (\%)} = \frac{X_1 - X_2}{(X_1 + X_2)/2}$$

where X_1 and X_2 are, respectively, the first and second values obtained for the analysis. For some methods, a different procedure is specified wherein precision is evaluated via the use of

Matrix Spike (MS) and Matrix Spike Duplicate (MSD) samples. The difference or percent difference, as appropriate, will be compared against the Precision criteria established for field measurements in section 7.

<u>Accuracy</u>

Accuracy is usually expressed as percent recovery (% R) or agreement with a certified value for a standard reference material. The % R for spiked samples is calculated as:

$$\% R = \frac{X_s - X_u}{C_t} \times 100$$

where X_s is the measured concentration in the spiked sample, X_u is the measured concentration in the unspiked sample, and C_t is the true concentration of the spike. Standard Reference Materials available from NIST will also be used to assess accuracy. In this case, the relevant calculation is:

$$\% R = \frac{X_l}{C_t} \times 100$$

where X_l is the measured concentration in the SRM and C_t is the certified or "true" concentration.

<u>Completeness</u>

Completeness will be determined as the percentage of the sample data for which the associated QC data are found to be acceptable.

15. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

15.1 Maintenance of Field and Laboratory Equipment

Field Sampling

Field measurement equipment will be checked for operation in accordance with the manufacturer's specifications. This includes battery checks, routine replacement of membranes, and cleaning of conductivity electrodes. All equipment will be inspected when first handed out and when returned from use for damage. Prior to each potential storm event, field sampling equipment will be checked for proper operation. This check will include confirming proper communications between office computers and field samplers. Field crews will perform site visits to ensure the sampling equipment is in proper working order and batteries are fully charged. Field measurement equipment will be checked for operation in accordance with the manufacturer's specifications. Equipment will be inspected when first handed out and returned from use for damage. The Project Manager will be responsible for implementing the field maintenance program.

Table 10. Testing, inspection, maintenance of field sampling equipment

Equipment / Instrument	Maintenance Activity, Testing Activity or Inspection Activity	Responsible Person	Frequency	SOP Reference
REMUS AUV	Inspection, maintenance cleaning to prevent fouling, and data retrieval	Field Leader	Monthly or if QA/QC identifies a problem	Manufacturer's Manual
Seabird/ Wetlabs Profiler	Inspection and calibration	Field Leader	Monthly or if QA/QC identifies a problem	Manufacturer's Manual
SBOO MOORING	Inspection	Field Leader	Bi-annually or if QA/QC identifies a problem	Manufacturer's Manual
IB PIER MOORING	Inspection	Field Leader	Bi-annually or if QA/QC identifies a problem	Manufacturer's Manual
CODAR	Calibration	Field Leader	Bi-annually or if QA/QC identifies a problem	Manufacturer's Manual

15.2 Equipment test criteria

Instruments used in the field for in situ measurements will be maintained and inspected prior to use. The CTD will be inspected according to manufacturer's specification prior to each use (i.e., monthly).

Analytical instrumentation will be maintained, inspected, and calibrated using reference standards according to manufacturer's specification.

15.3 Availability and location of spare parts.

A source for critical spare parts for each instrument used for field measurements will be determined prior to the start of the field program.

Analytical chemistry laboratories are responsible for maintaining inventories of spare parts and/or service agreements with instrument manufacturer or responsible representative on all primary instrumentation.

15.4 Equipment inspection criteria

Inspection, maintenance, testing, and calibration procedures for field instrumentation are discussed in the manufacturer's manuals.

15.5 Personnel responsible for testing, inspection, and maintenance

The field leader is responsible for ensuring that all equipment used for field measurements is inspected and tested prior to deployment.

15.6 Deficiencies resolution, re-inspections, and effectiveness or corrective actions

Resolution of deficiencies or appropriate corrective actions associated with instrumentation used for field measurements will be determined by the Field Manager, who is experienced with the operation and maintenance of this equipment.

16. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

All equipment and instruments are operated and calibrated according to the manufacturer's recommendations as well as by criteria defined in individual SOPs. Operation and calibration are performed by personnel properly trained in these procedures. Documentation of all routine and special calibration information is recorded in appropriate log books and reference files. If a critical measurement is found to be out-of-compliance during analysis, the results of that analysis will not be reported, corrective action will be taken and documented, and the analysis will be repeated.

Table 11. Testing, inspection, maintenance of sampling equipment and analytical instruments

Equipment / Instrument	SOP reference	Calibration Description and Criteria	Frequency of Calibration	Responsible Person
REMUS AUV ADCP	Manufacturer's manual: TRDI_ADCP_CalibrationR1.pdf	Manufacturer's recommendations	Velocity - Upon Receipt of instrument (No SWAMP requirement)	Field leader or designee
REMUS AUV YSI CTD	Manufacturer's manual: YSI_CTD_600XL_Conductivity_Calibration.pdf	Manufacturer's recommendations	Conductivity- 1/yr (No SWAMP requirement) Temperature- N/A	Field leader or designee
REMUS AUV Wetlabs BB2F	Manufacturer's manual: WetLabs_bb2f_Calibration.pdf	Manufacturer's recommendations	Chlorophyll - 1/yr Optical Backscatter - 1/yr (No SWAMP requirement)	Field leader or designee
Wetlabs DH4	Manufacturer's manual: DH4_Seabird_ConTemp_Calibration.pdf DH4_Wetlabs_Optical_Calibration.pdf DH4_Wetlabs_LightTrans_Calibration.pdf DH4_Wetlabs_Chlorophyll_Calibration.pdf	Manufacturer's recommendations	Conductivity- 1/yr Temperature- N/A Optical Backscatter- 1/yr Light transmittance - 1/yr Chlorophyll fluorescence – 1/yr (No SWAMP requirement)	Field leader or designee

Equipment / Instrument	SOP reference	Calibration Description and Criteria	Frequency of Calibration	Responsible Person
IB PIER MOORING AWAC	Manufacturer's manual: N/A	Manufacturer's recommendations	Velocity, Waves - Upon Receipt of instrument (No SWAMP requirement)	Field leader or designee
IB PIER MOORING PME T-Chain	Manufacturer's manual: PME_TChain_Calibration.pdf	Manufacturer's recommendations	Temperature - 1/2yr Pressure - 1/2yr (No SWAMP requirement)	Field leader or designee
SBOO ADCP	Manufacturer's manual: TRDI_ADCP_CalibrationR1.pdf	Manufacturer's recommendations	Velocity - Upon Receipt of instrument (No SWAMP requirement)	Field leader or designee
SBOO PME T-Chain	Manufacturer's manual: PME_TChain_Calibration.pdf	Manufacturer's recommendations	Temperature - 1/2yr Pressure - 1/2yr (No SWAMP requirement)	Field leader or designee
SBOO SBE 37-SMP	Manufacturer's manual: Seabird_37SMP_Calibration.pdf	Manufacturer's recommendations	Conductivity- 1/yr (No SWAMP requirement) Temperature- N/A	Field leader or designee
SBE 49 (USC)	Manufacturer's manual: 49_011.pdf	Manufacturer's recommendations	Conductivity - 1/yr (No SWAMP requirement) Temperature - N/A	Field leader or designee
Wetlabs ECO Triplet Fluorometer	Manufacturer's manual:	Manufacturer's recommendations	Fluorescence – 1/yr	Field leader or designee
Wetlabs ECO Triplet Backscatter	Manufacturer's manual:	Manufacturer's recommendations	Backscatter – 1/yr	Field leader or designee

17. INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

17.1 Identifies critical supplies and consumables for field and laboratory, noting supply source, acceptance criteria, and procedures for tracking, storing, and retrieving these materials.

Instruments used to for in situ measurements/data collection do not rely on consumables that could affect data quality.

17.2 Identifies the individuals responsible for this.

The field leader/Development Engineer or his designee is responsible for inspecting supplies and consumables required for field operations.

18. NON-DIRECT MEASUREMENTS (EXISTING DATA)

18.1 Identify data sources, for example, computer databases or literature files, or models that should be accessed and used.

- FIB indicator data obtained by shoreline monitoring programs conducted by the San Diego County Department of Environmental Health (DEH) supported through AB411 and the EPA BEACHES program
- Ocean data generated by the City of San Diego for the Point Loma Outfall as part of their NPDES permit.
- Ocean data generated by the City of San Diego for the IBWC SBOO and Water Reclamation Plant as part of the NPDES permit.
- The Tijuana River National Estuarine Research Reserve FIB indicator data
- San Diego Coastal Ocean Observing System (*www.sdcoos.org*) ocean color satellite data from the following:
  - Moderate-resolution Imaging Spectroradiometer (MODIS) (1km resolution)
  - Ocean Color Monitor (OCM) (300m resolution)

18.2 Describe the intended use of this information and the rationale for their selection; i.e., their relevance to this project.

These data are routinely gathered in the region, and serve as a regional backdrop for the ocean state prior to intensive sampling. Due to budgetary constraints, Task SS3 was unable to be implemented in full detail. Scientists, therefore, will leverage data collection efforts with others ongoing in the South Bay area. Flow data collected from the IBWC gauge will serve as a proxy for high level flow into the Tijuana River. The gauge is located some distance upstream of the river mouth, and does not capture flows from Goat, Smuggler's, and Yoghurt Canyons which are west of the gauge. At present, this is the only flow measurement available and will serve as a proxy for indicating active discharge into the ocean.

18.3 Indicate the acceptance criteria for these data sources and/or models.

The identified data sources have existing QA/QC programs in place by the data provider. For example, data used from NPDES permit monitoring will have passed internal QA/QC and QAPP criteria as identified in their permits. All bacteria measurements undergo QC at the collection agency. OCM satellite products received from SeaSpace undergo re-navigation mapping at SIO in order to correct geographic offsets from the coastline and QC algorithms are in place to remove biases induced by clouds. Data will be used qualitatively for overview of ocean color patterns. MODIS satellite products undergo QC at NASA through the MODIS Characterization Support Team.

18.4 Identify key resources/support facilities needed.

Data will be transmitted to Scripps by the City of San Diego. No additional support facilities are needed for this program.

19. DATA MANAGEMENT

Data will be maintained as established in Element 9. All original data sheets, statistical worksheets and reports produced will be accumulated into project specific files that are maintained at SIO. Field Data sheets will be reviewed by project staff and checked by senior staff for completeness and accuracy prior to leaving the filed. A second review will be conducted by personnel other than those who entered the data to insure the accuracy of the entered data. Data files, databases, final report text and tables are copied onto diskette for storage onsite. Directories are archived on tape for storage offsite. Records will be maintained for a minimum of five years after project completion. Results will be transmitted to clients by telephone, facsimile or electronically.

A database system will be adopted for this task which will allow the storage of appropriate variables. The system will use structured query language (SQL) and base its schema using existing communication standards already used in the coastal observing community. Use of an SQL-based database and careful design will allow conversion of the data to a spatial database or geodatabase. The database schema is currently under development and is based on minimum FGDC standards. Current development includes cross reference and analysis of the North American Profile of ISO19115:2003 - Geographic information – Metadata standard (NAP – Metadata, version 1.0.1). This standard is still in draft format. The following schema is a close representation of the metadata required for each parameter. Each parameter will contain metadata information on the sensor it is measured from and if applicable the package it is integrated with.

```
Metadata
  Identification_Information
    Citation
      Citation_Information
        Originator
        Publication_Date
        Title
    Description
      Abstract
      Purpose
      Supplemental_Information
    Time_Period_of_Content
      Time_Period_Information
        Range_of_Dates/Times
          Beginning_Date
          Beginning_Time
      Currentness_Reference
    Status
      Progress

Maintenance_and_Update_Frequency
    Spatial_Domain
      Bounding_Coordinates
        West_Bounding_Coordinate
        East_Bounding_Coordinate
        North_Bounding_Coordinate
        South_Bounding_Coordinate
```

- Keywords
  - Theme
    - Theme_Keyword_Thesaurus
    - Theme_Keyword
- Access_Constraints
- Use_Constraints

Metadata_Reference_Information

- Metadata_Date
- Metadata_Review_Date
- Metadata_Future_Review_Date
- Metadata_Contact
  - Contact_Information
    - Contact_Person_Primary
      - Contact_Person
      - Contact_Organization
    - Contact_Position
    - Contact_Address
      - Address_Type
      - Address
      - City
      - State_or_Province
      - Postal_Code
    - Contact_Voice_Telephone
- Metadata_Standard_Name
- Metadata_Standard_Version

GROUP C: ASSESSMENT AND OVERSIGHT

20. ASSESSMENTS & RESPONSE ACTIONS

Corrective Action Plans
An out-of-control event is defined as any occurrence failing to meet pre-established criteria. A nonconformance is a deficiency in characteristic, documentation, or procedure sufficient to make the quality indeterminate or unacceptable. An out-of-control event is a subcategory of nonconformance.

When either situation is identified, it will be categorized as:

> **Deficiency:** Recognition of a specific requirement (e.g., program, process, or procedure) that has been violated.
>
> **Observation:** Recognition of an activity or action that might be improved but is not in violation of a specific requirement. Left alone, the activity or action may develop into a deficiency.

Criteria Used for Determination of an Out-of-Control Event
Factors that affect data quality (failure to meet calibration criteria, inadequate recordkeeping, improper storage, or preservation of samples) require investigation and corrective action.

When a nonconformance is recognized, each individual involved with the analysis in question has an interactive role and responsibility. These are as follows:

- **Technician:** He/She must be able to recognize non-conformances and immediately notify the Laboratory Manager and work with the Quality Assurance Officer to solve the problem. Each technician is responsible for documenting and correcting problems that might affect quality.

- **Laboratory Manager:** He/She must review all analytical and QC data for reasonableness, accuracy, and clerical errors. In an out-of-control event, the Laboratory Manager works with the analyst and Quality Assurance Officer to solve the problem and prevents the reporting of suspect data by stopping work on the analysis in question and insuring that all results that are suspect are repeated, if possible, after the source of the error is determined and remedied. Clients are notified in writing when their work is affected by an out-of-control event or results of an internal audit. In the event that a QC measure is out-of-control and the data are to be reported, qualifiers are reported together with sample results.

- **Quality Assurance Officer:** In the event that an out-of-control situation occurs that is unnoticed at the bench or supervisory level, the Quality Assurance Officer will notify the Laboratory Manager; help identify and solve the problem where applicable; ensure the work is stopped on the analysis; and verify that no suspect data are reported. The Quality Assurance Officer must review and approve all corrective action reports and submit them to the Laboratory Manager for review. The Quality Assurance Officer is responsible for reviewing nonconformance report forms, recommending or approving proposed corrective actions, maintaining an up-to-date nonconformance log, and verifying that corrective actions have been completed.

Procedures for Stopping Analysis

Whenever the analytical system is out-of-control, investigation and correction efforts are initiated by all concerned personnel as outlined in Table 14.

If the problem is instrumental or specific only to preparation of a sample batch, samples are reprocessed after the instrument is repaired and recalibrated.

Corrective Action

The need for corrective action comes from several sources: equipment malfunction; failure of internal QA/QC checks; failure of follow-up on performance or system audit findings; and noncompliance with QA requirements.

When measurement equipment or analytical methods fail QA/QC requirements, the problems will immediately be brought to the attention of the Laboratory Manager and Quality Assurance Officer. Corrective measures to be taken will depend entirely on the type of analysis, the extent of the error, and whether the error is determinant or not. The corrective action to be taken is determined by the Laboratory Manager, technicians, the Project Manager, and the Quality Assurance Officer or by all of them in conference, if necessary; but final approval is the responsibility of the Quality Assurance Officer and/or Project Manager.

If failure is due to equipment malfunction, the equipment will not be used until repaired; precision and accuracy will be reassessed, and the analysis will be rerun. All attempts will be made to reanalyze all affected parts of the analysis so that in the end, the product is not affected by failure of QC requirements.

Table 12. Laboratory Corrective Action Plan for Potential Analytical Problems

Problems in Lab Area		Actions to be Taken
A.	**Sample Receipt, Log-in, and Labeling**	
1.	Sample containers received broken	Notify Laboratory Manager
2.	Sample cannot be located	Notify Laboratory Manager
3.	Samples received without proper refrigeration of preservation	Notify Project Manager
4.	Illegible sample numbers or label missing from sample containers	Notify Project Manager
5.	No instructions received with samples	Notify Project Manager
6.	Shipment container received damaged upon arrival	Notify Laboratory Manager
7.	Chain-of-custody document does not match information indicated on sample label and containers received	Notify Laboratory and Project Managers
8.	Samples received past the holding time requirement	Notify Project Manager
B.	**Sample Refrigeration and Preservation**	
1.	No indication on the chain-of-custody or sample container that the sample was preserved	Notify Project Manager
2.	Discovery of sample storage (i.e., refrigeration) malfunction	Notify Laboratory and Project Managers
C.	**Analytical Method**	
1.	If at anytime you are not in agreement with the method to be used or some portion of the method	Notify Laboratory Manager
D.	**Sample Preparation**	
1.	Loss of sample	Notify Laboratory Manager
2.	Knowledge of making a mistake in analysis	Notify Laboratory Manager
3.	Calibration mistake	Notify Laboratory Manager
E.	**Storage**	
1.	Label or labels have come off of the storage container	Notify Laboratory Manager
F.	**Standard Preparation**	
1.	Doubt as to the purity of the standard material	Notify Laboratory Manager
2.	Question whether standard (stock or working) is "too old" (expired)	a. Check expiration of the standard if available; if not, check SOP on standard expiration. b. Notify Laboratory Manager
G.	**Instrument Analysis**	
1.	Blank or reference are out-of-compliance	a. Check instrument operating condition b. Do corrective maintenance c. Reanalyze affected samples as necessary
H.	**Data Review**	
1.	The recovery of material from spiked sample is not within the limits set prior to analysis (e.g., outside control chart limits)	a. Notify Laboratory Manager b. Check standard solutions c. Check instrument performance d. If no explanation, reprepare and reanalyze QC and affected samples
2.	The data are contrary to that expected (historical background does not agree)	Notify Laboratory and Project Manager

If an external audit (system or performance) report identifies deficiencies that require corrective action, the Quality Assurance Officer shall notify the responsible supervisor and log the pertinent information. The Quality Assurance Officer and the responsible supervisor shall assure that corrective action is taken. The Quality Assurance Officer shall verify that the problem has been corrected. The Laboratory Manager shall transmit the response to the external organization, with copies to the Quality Assurance file.

All incidents of QA failure and corrective action tasks will be documented and reports will be placed in the appropriate contract file. Also, corrective action will be taken promptly for deficiencies noted during the spot-check of raw data. When corrective actions are implemented, evidence of correction of deficiencies will be presented. Corrective action documentation will be forwarded to the Quality Assurance Officer and the Project Manager for evaluation and approval.

Documenting Corrective Action
If, at any time during analyses, a process is out-of-control, corrective action shall be taken, and documented, with regard to:

- What actions were taken to bring the process back into control
- What actions were taken to prevent recurrence of the out-of-control situation
- What was done with the data obtained while the process was out-of-control

This is accomplished by filling out a corrective actions form. This form is initiated either by the Laboratory Manager or the Quality Assurance Officer depending on where the problem is recognized. The report will include the following information:

- Nature of the problem
- Sample lot affected
- Corrective action measure(s) taken and final resolution of the problem
- Dates (date recognized, date occurred, date corrected)
- Signature of the Quality Assurance Officer, Project Manager, Reporter, and Laboratory Manager.

Field Corrective Action
The initial responsibility for monitoring the quality of field measurements lies with the field personnel. The Field Supervisor is responsible for verifying that all QC procedures are followed. This requires that the Field Supervisor assess the correctness of the field methods and the ability to meet QA objectives and make a value judgment regarding the impact a procedure has upon the field objectives and subsequent data quality. If a problem occurs that might jeopardize the integrity of the project, cause a QA objective not to be met, or impact data quality, the Field Supervisor will immediately notify the Project Manager. Corrective action measures are then decided upon and implemented. The Field Supervisor documents the situation, the field objective affected, the corrective action taken, and the results of that action. Copies of the documentation are provided to the Project Manager and the Quality Assurance Officer.

21. REPORTS TO MANAGEMENT

Table 13 outlines the schedule of reports due to the Principal Investigator and Grant Manager.

IBWC will include progress updates on the project in quarterly reports to EPA. These updates will be included in current quarterly reports providing progress updates on the entire work plan.

Final draft of project report will be provided to IBWC, who will provide draft report to EPA for comments. IBWC will relay comments back to project team for consideration in development of final report.

Table 13. Management Reports

Type of Report	Frequency (daily, weekly, monthly, quarterly, annually, etc.)	Projected Delivery Dates(s)	Person(s) Responsible for Report Preparation	Report Recipients
Progress Report	monthly-		Richard Pyle Eric Terrill Burton Jones	Gilbert Anaya, Project Manager, IBWC
Quality Assurance Project Plan	Once	3/12/07	Richard Pyle Eric Terrill Burton Jones	
Quality Assurance Project Plan	Once	3/12/07	Richard Pyle Eric Terrill Burton Jones	
Draft Project Report	-	05/19/08	Richard Pyle Eric Terrill Burton Jones	
Final Project Report	-	06/30/08	Richard Pyle Eric Terrill Burton Jones	

GROUP D: DATA VALIDATION AND USABILITY

22. DATA REVIEW, VERIFICATION, AND VALIDATION REQUIREMENTS

Data validation is the process whereby data are filtered and accepted or rejected, based on a set of criteria. It is a systematic procedure of reviewing a body of data against a set of criteria to provide assurance of its validity prior to its intended use. All data are checked for accuracy and completeness. The data validation process consists of data generation, reduction, and review (Element 23). Requirements of the NELAC Standards and Good Automated Laboratory Practices (EPA Document 2185, 1995) are followed for computer processing, manipulation, reporting, storage, and retrieval of data.

Data reduction, validation, and reporting are on-going processes which involve the technicians, Laboratory Managers, and QA personnel.

23. VERIFICATION AND VALIDATION METHODS

Database Generation

After each survey, the field data sheets are removed from the field log books and all sheets are checked for completeness and accuracy by the QA Officer or Project Manager. All appropriate field sheets must be present. If there are any questions, clarification from the Field Supervisor is obtained as soon as possible. Field data sheets and the field logbook are placed into folders by data type, labeled with the data type and survey number, and filed in the appropriate filing cabinet.

In the laboratory, technicians document sample preparation activities in bound laboratory notebooks or on benchsheets. Data validation includes dated and signed entries by technicians on the data sheets and logbooks used for all samples; the use of sample tracking and numbering systems to track the progress of samples through the laboratory; and the use of quality control criteria to reject or accept specific data.

The data for all laboratory analyses are entered directly onto data sheets. All data sheets should be filled-in in ink and signed by the technician, who is responsible for scanning the sheet to be sure it is complete and accurate.

The technician who generates the data has the prime responsibility for the accuracy and completeness of the data. Each technician reviews the data to ensure that:

- Sample description information is correct and complete
- Analysis information is correct and complete
- Results are correct and complete
- Documentation is complete

Error Checking and Verification

The QA Officer resolves and corrects on data sheets and in raw data file any errors reported in the files; the printout is notated with corrections, initialed and dated.

Data validation includes dated and signed entries by the technicians and Laboratory Manager on the benchsheets and notebooks used for all samples; the use of sample tracking and numbering systems to track the progress of samples through the laboratory; and the use of quality control criteria to reject or accept specific data.

The minimum requirements for each analytical run area:

- Matrix spike and duplicate analyses per concentration level and per matrix for every sample batch analyzed (where appropriate).

- Reference materials analyses are compared with "true" values and acceptable ranges. Values outside the acceptable ranges indicate that the sample values are invalid. Following correction of the problem, the reference material should be reanalyzed.

Data Reporting

Data tables are created and printed. Tables are reviewed for any errors or irregularities; if any are found it may be necessary to correct and reestablish the databases or the dictionaries. Tables are submitted to Project Manager for review. The tables and report are edited by at least two of the following three people; the QA Officer, the Project Manager, and the Laboratory Director. The report returns to the office staff for any corrections, and then the final draft is reviewed once again by the QA Officer. The Project Manager signs the letter of transmittal.

24. RECONCILIATION WITH USER REQUIREMENTS

The quality assurance personnel will review data after each survey to determine if data quality objectives (DQOs) have been met. If data do not meet the project's specifications, the quality assurance personnel will review the errors and determine if the problem is due to calibration/maintenance, sampling techniques, or other factors. They will suggest corrective action. It is expected that the problem would be able to be corrected by retraining, revision of techniques, or replacement of supplies/equipment. If not, then the DQOs will be reviewed for feasibility. If specific DQOs are not achievable, the quality assurance personnel will recommend appropriate modifications. Any revisions would need approval by the Principal Investigators.

Data will be reviewed internally on a routine basis within 30 days basis by project staff responsible for the collection and QA/QC of those data. Corrective action will be taken if necessary. Summary of data collection activities will be provided in monthly reports to IBWC as per the project scope.

APPENDIX 1. SWAMP Requirements and Recommendations --Information for Completing Element 7 (Quality Objectives and Criteria for Measurement Data)

Table 1-A Information for completing of Element 7 Data Quality Objectives

Group	Parameter	Element 7 Requirements			
		Accuracy	Precision	Recovery	Completeness
Field testing	Temperature	± 0.5 °C	No SWAMP requirement – suggest ± 0.5 or 5%	NA	No SWAMP requirement – suggest 90%
	Conductivity	± 5%	No SWAMP requirement – suggest ± 5%	NA	No SWAMP requirement – suggest 90%
	Depth	± 0.2 meters	No SWAMP requirement – not necessary	NA	No SWAMP requirement
Laboratory Analyses –	Conventional Constituents in Water See following table for more requirements	Standard Reference Materials (SRM, CRM, PT) within 95% CI stated by provider of material. If not available then with 80% to 120% of true value	Laboratory duplicate, Blind Field duplicate, or MS/MSD 25% RPD Laboratory duplicate minimum.	Matrix spike 80% - 120% or control limits at ± 3 standard deviations based on actual lab data.	No SWAMP requirement – suggest 90%
	Bacteria/ Pathogens	Laboratory positive and negative cultures – proper positive or negative response. Bacterial PT sample -–within the stated acceptance criteria.	R_{log} within 3.27*mean R_{log} (reference is section 9020B of 18th, 19th, or 20th editions of *Standard Methods*	NA	90%

APPENDIX 2. SWAMP Requirements and Recommendations --Information for Completing Element 12 (Sample Handling and Custody)

Table 2-A. Summary of Sample Container, Volume, Initial Preservation, and Holding Time Recommendations for Water Samples

Parameters for Analysis in WATER Samples	Recommended Containers (all containers pre-cleaned)	Typical Sample Volume (ml)	Initial Field Preservation	Maximum Holding Time (analysis must start by end of max)
Bacteria and Pathogens in Water Samples				
Enterococcus	Factory-sealed, pre-sterilized, disposable Whirl-pak® bags or 250 ml sterile plastic (high density polyethylene or polypropylene) container	200 ml volume sufficient for both E. coli and Enterococcus analyses	Sodium thiosulfate is pre-added to the containers in the laboratory (chlorine elimination). Cool to 4°C; dark.	STAT: 6 hours at 4°C, dark; lab must be notified well in advance
FECAL COLIFORM	Factory-sealed, pre-sterilized, disposable Whirl-pak® bags or 250 ml sterile plastic (high density polyethylene or polypropylene) container	200 ml volume sufficient for both fecal and total coliform analyses	Sodium thiosulfate is pre-added to the containers in the laboratory (chlorine elimination). Cool to 4°C; dark.	STAT: 6 hours at 4°C, dark; lab must be notified well in advance
TOTAL COLIFORM	Factory-sealed, pre-sterilized, disposable Whirl-pak® bags or 250 ml sterile plastic (high density polyethylene or polypropylene) container	200 ml volume sufficient for both fecal and total coliform analyses	Sodium thiosulfate is pre-added to the containers in the laboratory (chlorine elimination). Cool to 4°C; dark.	STAT: 6 hours at 4°C, dark; lab must be notified well in advance

In the field, all samples will be packed in wet ice or frozen ice packs during shipment, so that they will be kept at approximately 4˚C. Samples will be transported by field personnel to the laboratory in insulated containers. Ice will be double bagged. All caps and lids will be checked for tightness prior to transport.

All samples will be handled, prepared, transported and stored in a manner so as to minimize bulk loss, analyte loss, contamination or biological degradation. Sample containers will be clearly labeled with an indelible marker. Water samples will be kept in polyethylene bottles and kept cool at a temperature of 4˚C until analyzed. Maximum holding times for specific analyses are listed in Table 7.

Ice chests are sealed with tape before transport. Samples are placed in the ice chest with enough ice to completely fill the ice chest. COC forms are placed in an envelope and taped to the top of the ice chest or they may be placed in a plastic bag and taped to the inside of the ice chest lid. It is assumed that samples in tape-sealed ice chests are secure. The receiving laboratory has a sample custodian who examines the samples for correct documentation, proper preservation and holding times.

Contract laboratories will follow sample custody procedures outlined in their QA plans. Contract laboratory QA plans are on file with the respective laboratory.

All samples remaining after successful completion of analyses will be disposed of properly. It is the responsibility of the personnel of each analytical laboratory to ensure that all applicable regulations are followed in the disposal of samples or related chemicals. Chain-of-custody procedures require that possession of samples be traceable from the time the samples are collected until completion and submittal of analytical results. A complete chain-of-custody form is to accompany the transfer of samples to the analyzing laboratory. A sample is considered under custody if it is in actual possession, if it is in view after in physical possession, or if it is placed in a secure area (accessible by or under the scrutiny of authorized personnel only after in possession).

Field Log

Field crews shall be required to keep a field log for each sampling event. The following items should be recorded in the field log for each sampling event:

- time of sample collection;
- sample ID numbers, including etched bottle ID numbers for Teflon™ mercury sample containers and unique IDs for any replicate or blank samples;
- the results of any field measurements (temperature, D.O., pH, conductivity, turbidity) and the time that measurements were made;
- qualitative descriptions of relevant water conditions (e.g. color, flow level, clarity) or weather (e.g. wind, rain) at the time of sample collection;
- a description of any unusual occurrences associated with the sampling event, particularly those that may affect sample or data quality.

The field crews shall have custody of samples during field sampling. Chain of custody forms will accompany all samples during shipment to contract laboratories. All water quality samples will be transported to the analytical laboratory directly by the field crew or by overnight courier.

Laboratory Custody Log

Laboratories shall maintain custody logs sufficient to track each sample submitted and to analyze or preserve each sample within specified holding times.

APPENDIX 3. SWAMP Requirements and Recommendations --Information for Completing Element 13 (Analytical Methods)

Table 3-A. Target Reporting Limits for Conventional Water Quality Constituents

Analysis	Matrix	Reporting Units	Suggested Analytical Methods	Target Reporting Limit (TRL)
CONVENTIONAL CONSTITUENTS				
PATHOGENS				
E. Coli	water	MPN/100 ml	SM 9221B/E mod. MUG, SM 9223B	2
Enterococcus	water	colonies/100 ml	SM 9230C, ASTM D6503	1
Fecal Coliform	water	MPN/100 ml	SM 9221E, SM 9222C (25-tube dilution)	2
Total Coliform	water	MPN/100 ml	SM 9221B, SM 9222B (25-tube dilution)	2

All analytical methods listed above are suggested. Other methods may be employed, and modifications of standard methods are encouraged, as long as the methods used: 1) meet the sensitivity requirements of the TRL's, and 2) are contained in 40CFR36, the most current version of Standard Methods, or another reliable procedure as documented to produce results that are equal to or more stringent than the method being modified (modifications made according to CFR (Title 40, Part 136.4).

Any changes in procedures due to equipment changes or to improved precision and accuracy will be documented. Analyses and determinations must be performed by qualified personnel in conformance with the United States Environmental Protection Agency (EPA) or DHS approved test procedures described in the current Code of Federal Regulations (CFR) (Title 40, Part 136); "Test Methods for Evaluating Solid Waste," SW-846; or Title 22, CFR, Article 11, as appropriate. The test procedures may be modified subject to the application and approval of alternate test procedures under the CFR (Title 40, Part 136.4). The SWAMP Program strongly encourages the use of "performance-based methodology" (PBM) for conducting analytical procedures and therefore recognized the use of modified standard procedures, as appropriately documented following CFR 40, Part 136.4. The use of PBM allows for approved procedures to be modified according to these guidelines, which provide results that are equal to or better than (more stringent than) the standard protocol that was modified.

REFERENCES

American Public Health Association, et al. Standard Methods for the Examination of Water and Wastewater. 19th Edition, 1997.

APPENDIX 4. SWAMP Requirements and Recommendations --Information for Completing Element 14 (Quality Control) and Element 16 (Instrument Calibration and Frequency)

Table 4-A. Elements 14 – Quality Control, and 16 Instrument Calibration/Frequency

Group	Parameter	Element 14 Quality Control	Element 16 Instrument Calibration/Frequency
Field testing	Temperature	No SWAMP requirement – suggest replicate (3) measurements plus maintenance and calibration practices.	No SWAMP requirement – suggest calibration against NIST certified thermometer at least twice a year. Use correction factor table.
	Conductivity	No SWAMP requirement – suggest replicate (3) measurements plus maintenance and calibration practices	No SWAMP requirement – suggest calibration at start of sample run. Use calibration correction factor table for those devices not capable of being calibrated. *1
	Depth	No SWAMP requirement – suggest rely on maintenance and calibration practices	No SWAMP requirement – suggest quote manufacturer's calibration practices.
Laboratory analyses	Bacteria – pathogen indicators	Field and sterility checks (laboratory blanks) no detectable amounts or less than 1/5 of sample amounts for field blanks. Frequency – accuracy at 1 per culture medium or reagent lot. Precision at 1 in 10 (10%) with at least one per batch. All quality assurance and quality control procedures found in *Standard Methods* (20^{th} editions) section 9020 and in the selected analytical method including confirmation practices.	No SWAMP requirements. Suggest follow the requirements of *Standard Methods* (20^{th} edition) section 9020.

***1 – Start of sample run is anytime on the same day as sampling prior to the analysis of the first sample. Consider recalibrating during the sample run if the instrument is turned off.**

APPENDIX 5. Sample Chain of Custody Forms from Enviromatrix Analytical and Field Tracking Sheet

CHAIN-OF-CUSTODY RECORD

EnviroMatrix *Analytical, Inc.*

4340 Viewridge Ave., Ste. A - San Diego, CA 92123 - Phone (858) 560-7717 - Fax (858) 560-7763

EMA LOG #:

EMA DATE/TIME STAMP

Client:

Address:

Attn: Phone:

Sampled by: Fax:

Billing Address:

Project: PO #:

REQUESTED ANALYSIS

EMA ID #	Client Sample ID	Sample Date	Sample Time	Sample Matrix	Container(s) #	Type*	418.1 (TRPH)	Oil & Grease 413.1__ 413.2__ 1664__	TPH (8015B) Gas__ Diesel__	TPH-Extended 8015B __ ASTM D2887__	602 / 8021 B BTXE__ MTBE__	601 / 8021 B (Volatile Organics)	EPA 8021 B Aromatics__ Halogenated__	608 / 8081 (Pesticides)	608 / 8082 (PCB's)	624 / 8260 (Volatile Organics)	625 / 8270 (Semi Volatile Organics)	TTLC Metals (CAC Title 22)	STLC Metals (CAC Title 22)	TCLP (RCRA) Metals__ Organics__	Cd Cr Cu Pb Ni Ag Zn	pH EC TSS							
1																													
2																													
3																													
4																													
5																													
6																													
7																													
8																													
9																													
10																													

*Container Types: B=Brass Tube; V=VOA; G=Glass; P=Plastic; O=Other (list)		RELINQUISHED BY	DATE/TIME	RECEIVED BY
Tamper-Proof Seals Intact: Yes No N/A	Correct Containers: Yes No	Signature		Signature
Sample(s): Cold Ambient Warm	VOAs w/ZHS: Yes No N/A	Print		Print
All Samples Properly Preserved: Yes No N/A		Company:		Company:
Disposal: N/C (aqueous) *EMA (@$5.00/sample) Return Hold		Signature		Signature
Turnaround Time: 24 hr 48 hr 3 day 4 day 5 day Normal		Print		Print
Comments:		Company:		Company:
		Signature		Signature
		Print		Print
		Company:		Company:

* EMA reserves the right to return samples that do not match our waste profile. White - EMA Canary - Accounting Pink - Client (w/Report) Goldenrod - Client (Relinquish Samples

International Boundary and Water Commission, South Bay San Diego Monitoring
Field Tracking Sheet
Tasks SS4 and SS7

Date:	
Start Time:	
End Time:	

Staff	
1.	5.
2.	6.
3.	7.
4.	8.

Station ID	Station Name or Description	Sample ID	Time Sampled (HHMM)	Target Analysis	Sample Depth	Sample Volume	Comments

Weather Observations:	
Wind Speed	
Wind Direction	
Swell	
Tide	

APPENDIX 6. SOPs and QA Plans from Enviromatrix Analytical Laboratory and Fuhrman Lab at USC

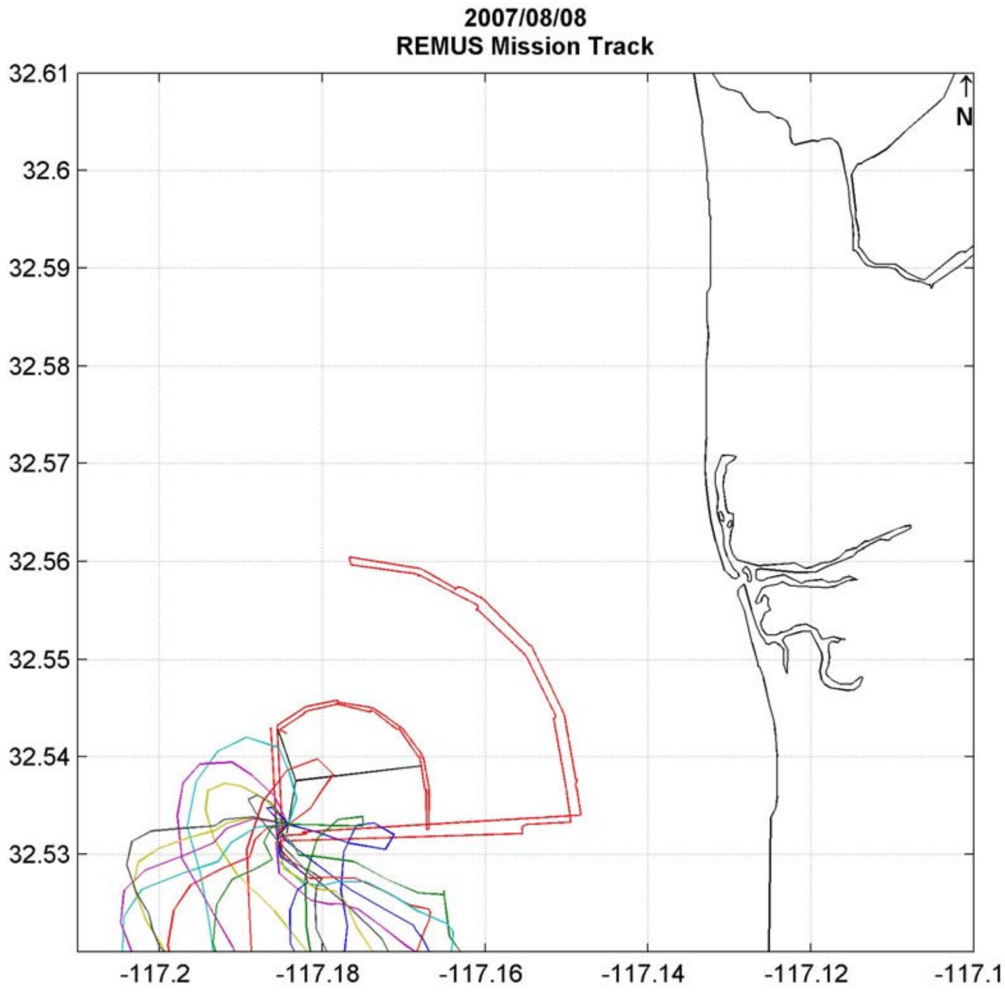
Enviromatrix Analytical Laboratory QA plan enclosed in file "QAPM2007.pdf"

Five journal articles describing SOPs for PCR analysis included as pdf files:

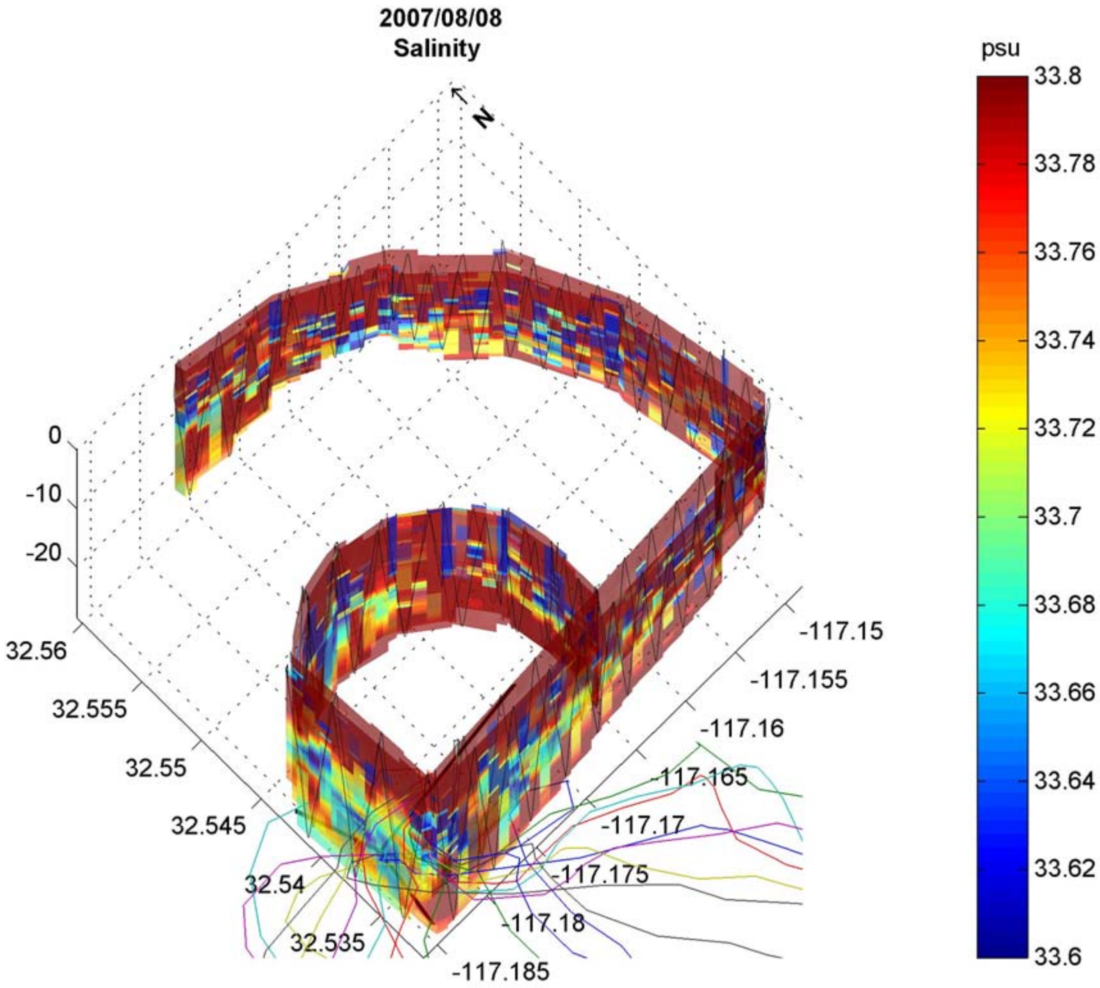
Fuhrman_et_al_AEM_2005.pdf
Heim_etal_jmv_2003.pdf
Katayama et al 2002 AEM RTPCR.pdf
Nobel et al AEM 06f.pdf
Seurinick_etal_EM_2005.pdf

Appendix 3
Mission Summary

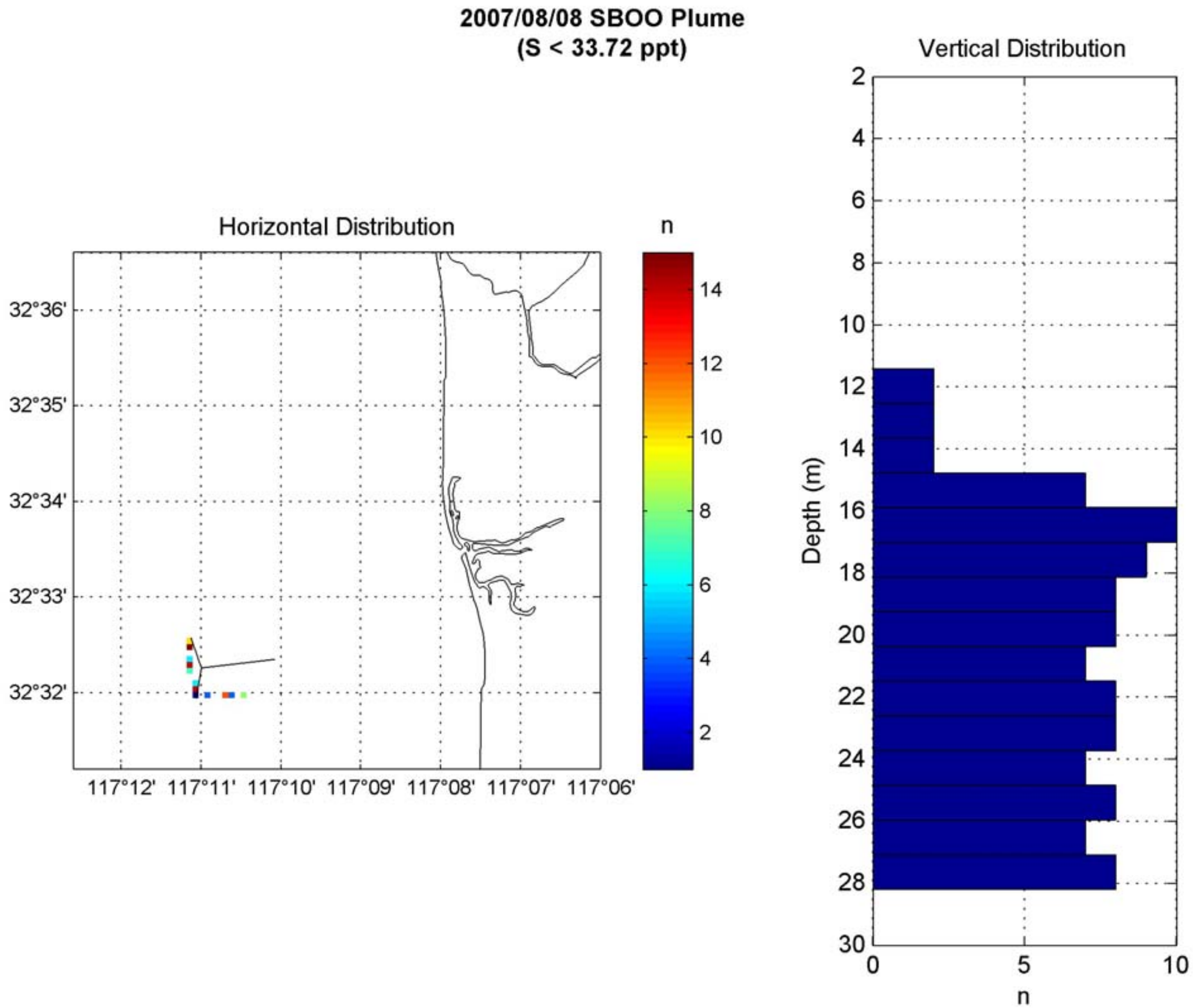
Appendix A.1 2007/08/08 Mission Summary



REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

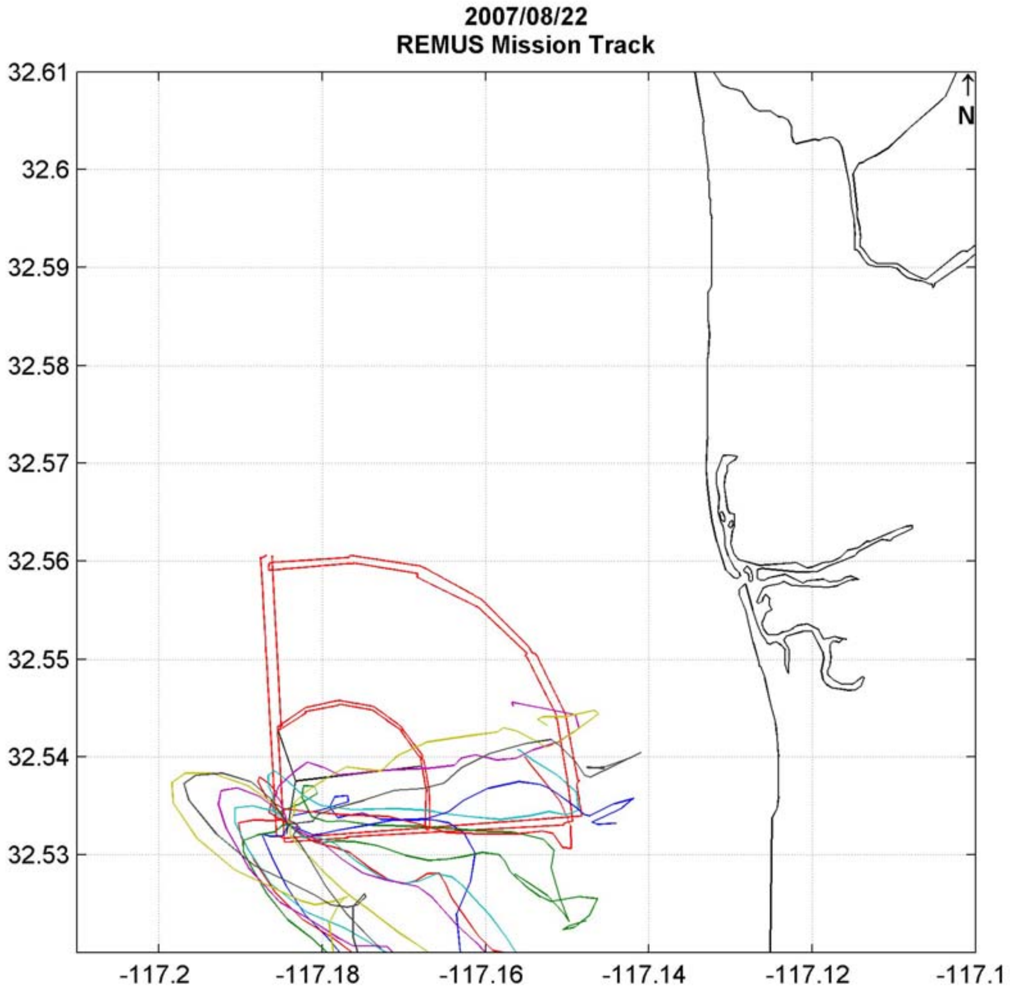


Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Noise at approximately 10m is due to transit across the thermocline. Low salinity (< 33.72 psu) near the outfall and around estimated trajectories indicate detection of the SBOO plume.

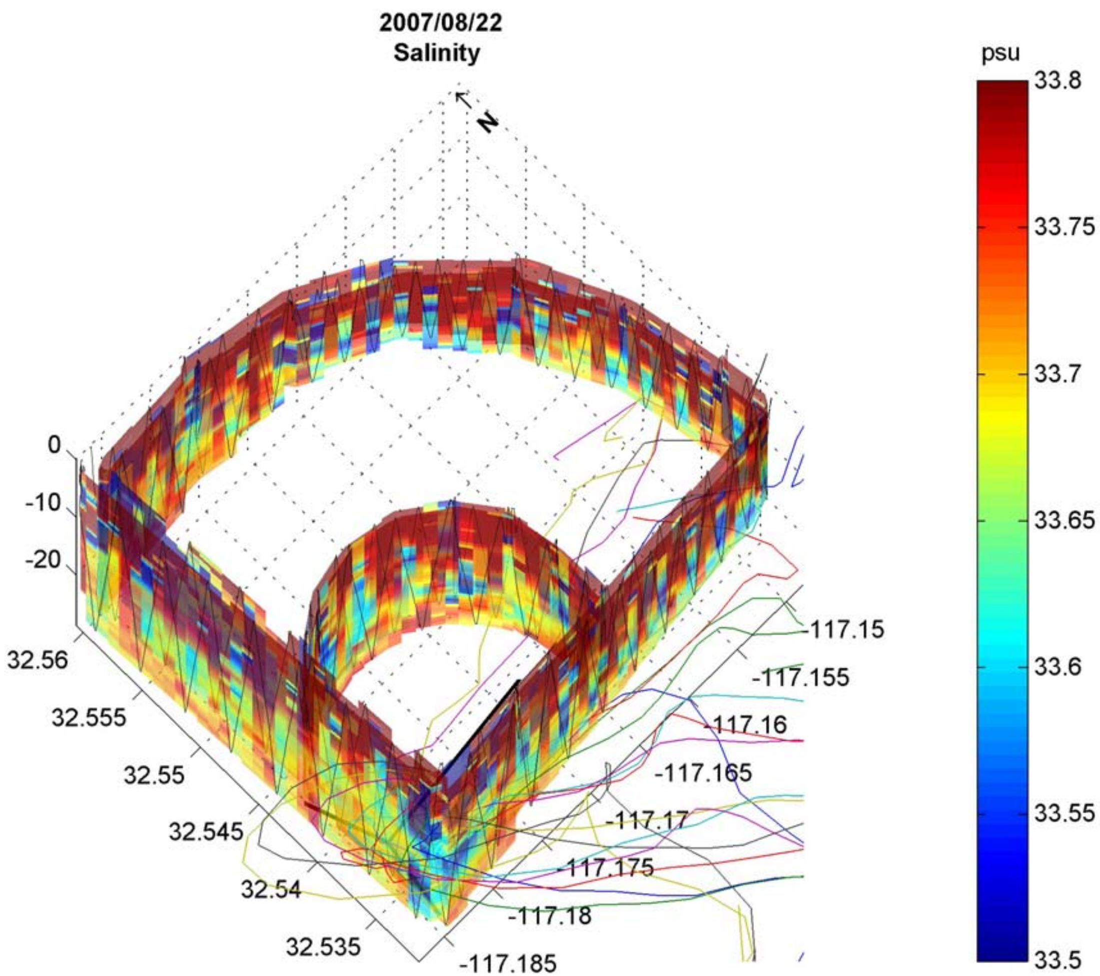


Horizontal and vertical plume distributions based on thresholding by the plumes' signature salinity value. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

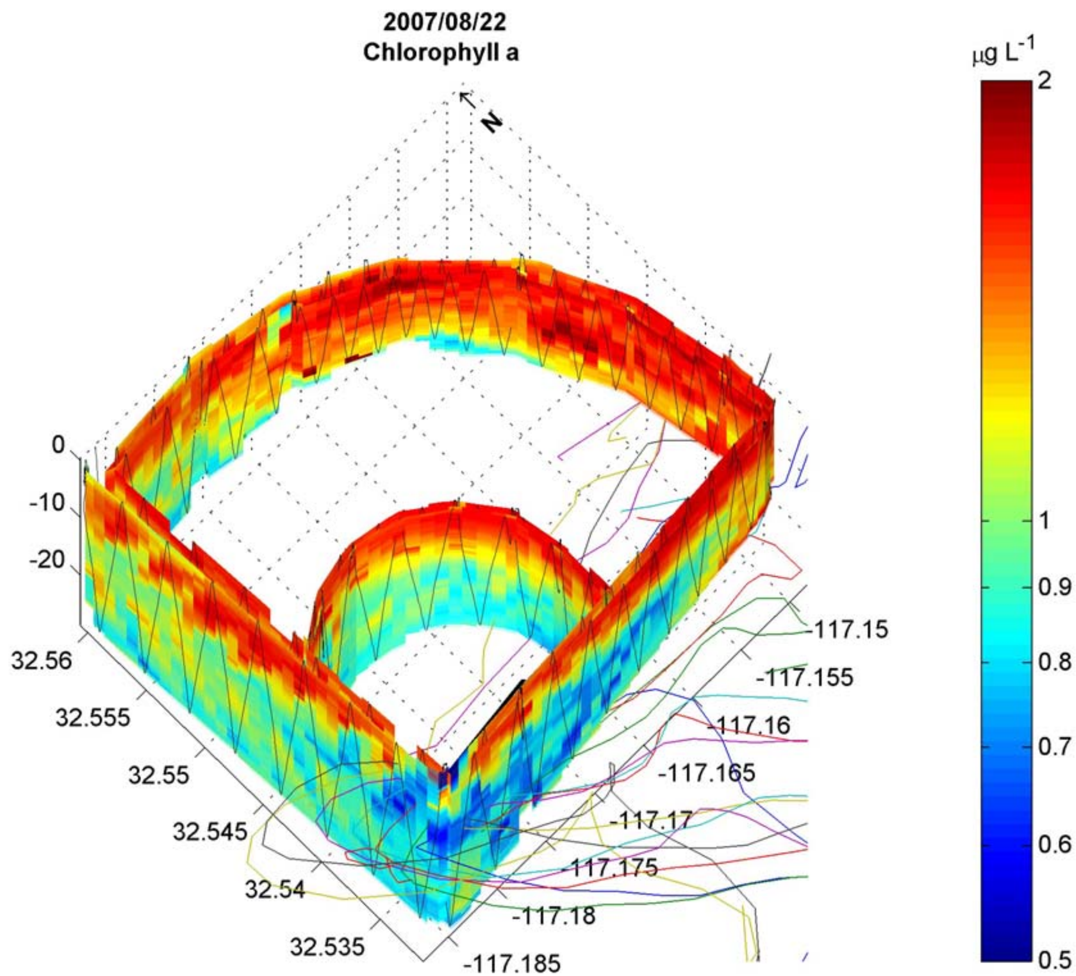
Appendix A.2 2007/08/22 Mission Summary



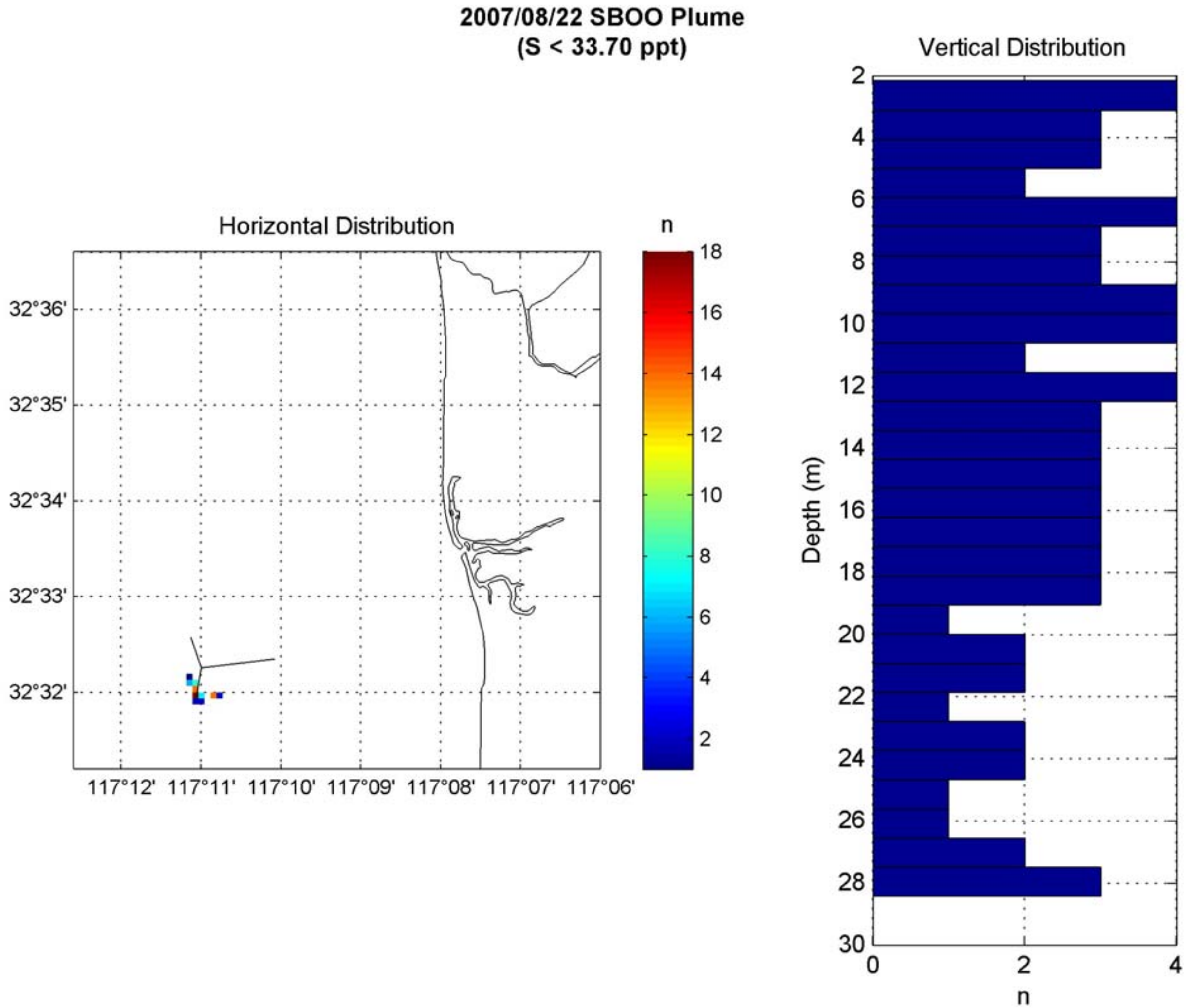
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Noise at approximately 10m is due to transit across the thermocline. Low salinity near the outfall shows the SBOO plume rose quickly and may have surfaced.

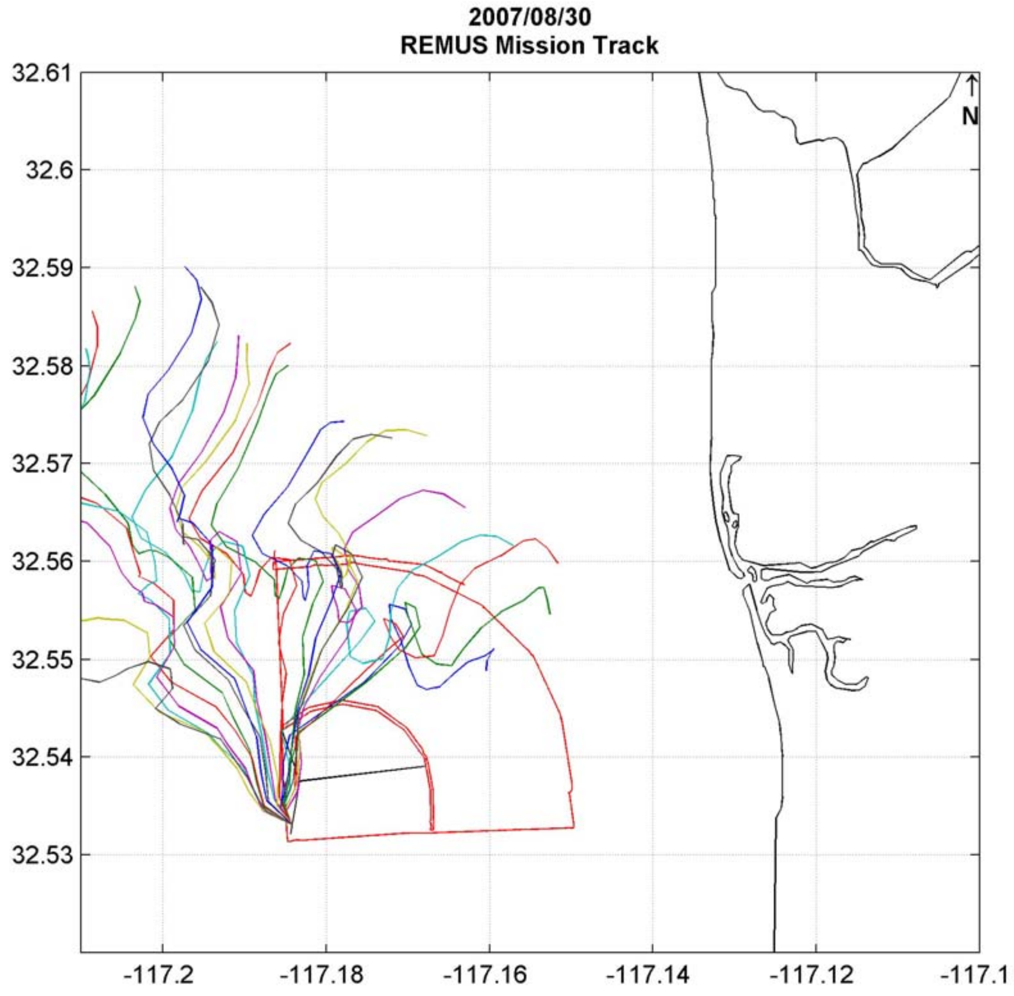


Chlorophyll a measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Correspondence between salinity and the estimated plume trajectory suggests that the SBOO plume is low in chlorophyll a (<0.7 μg L^{-1}).

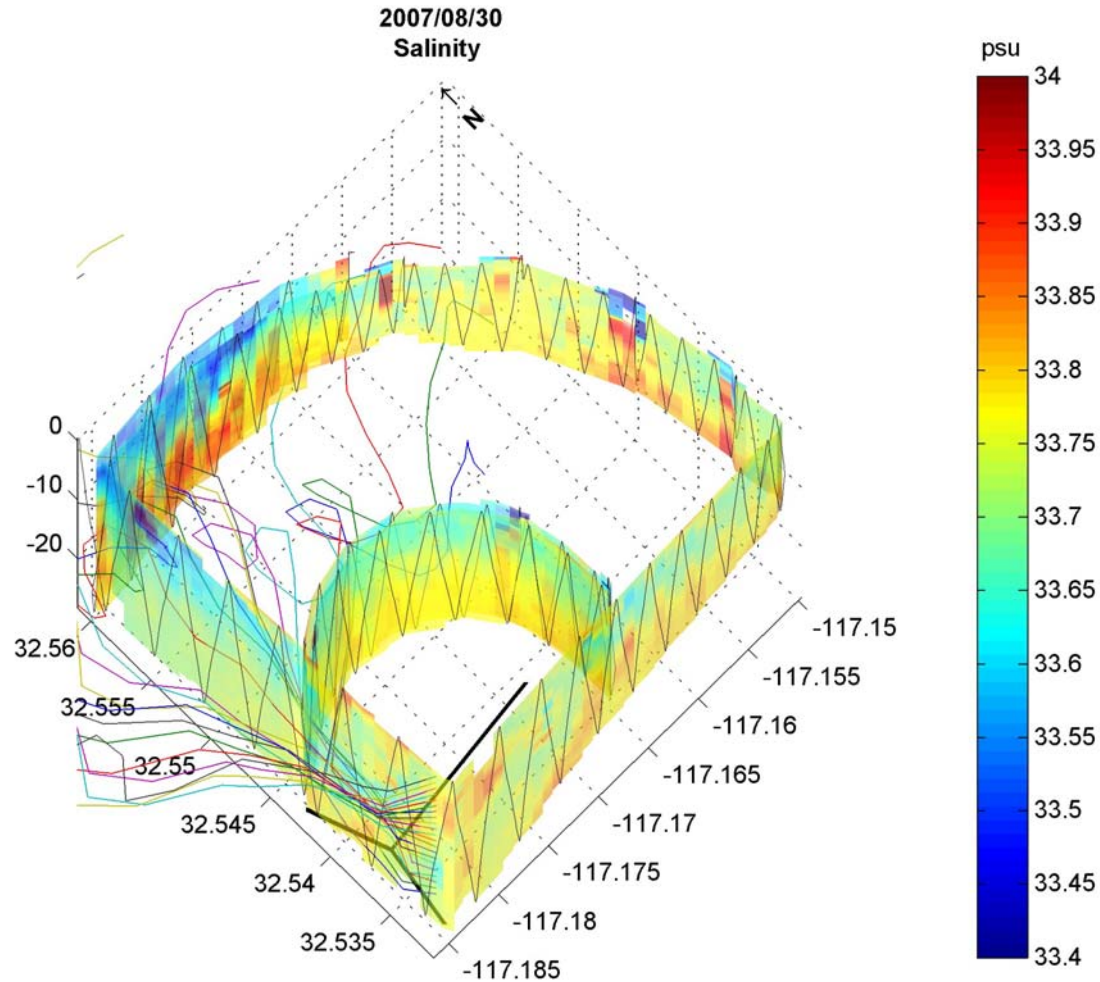


Horizontal and vertical plume distributions based on thresholding by the plumes' signature salinity value. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

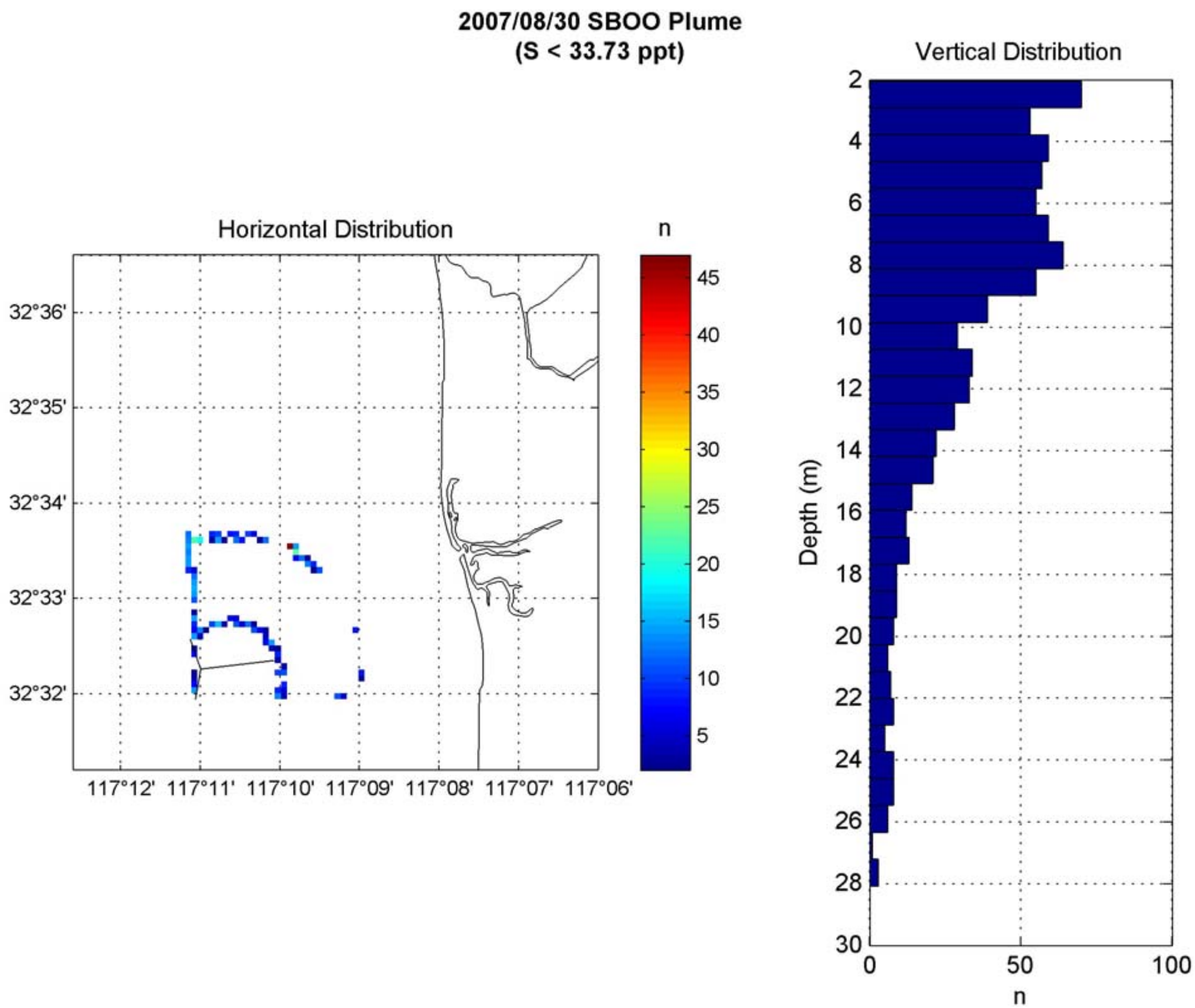
Appendix A.3 2007/08/30 Mission Summary



REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

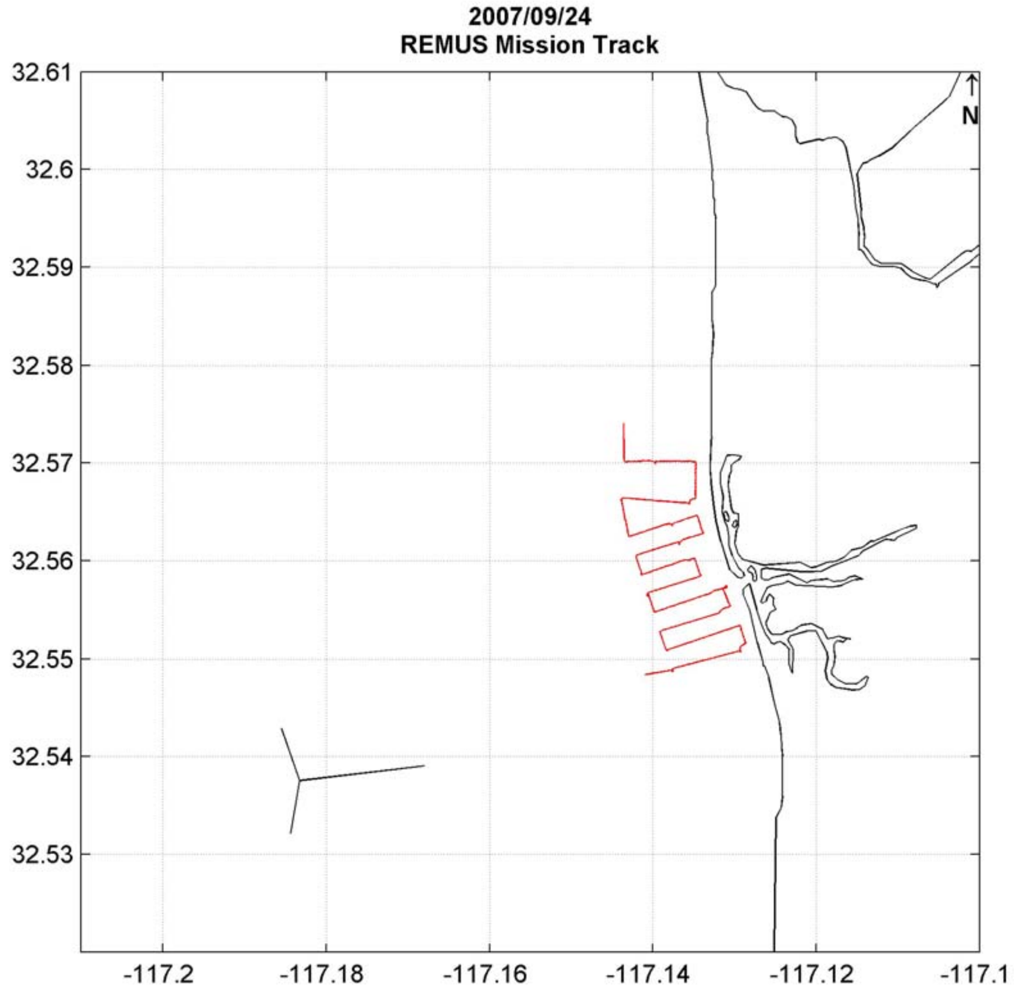


Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Low salinity near the outfall and northward shows the SBOO plume rising and surfacing.

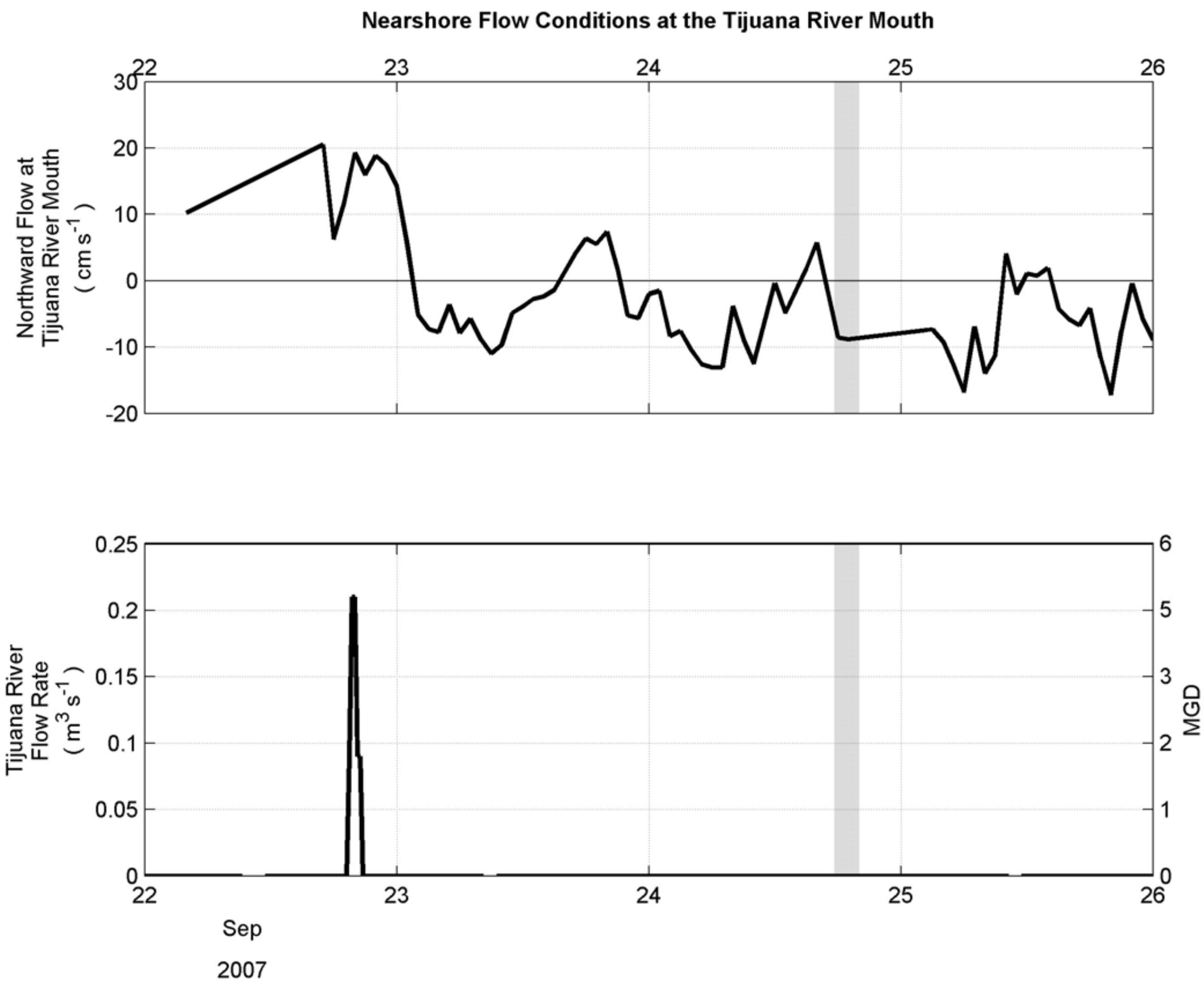


Horizontal and vertical plume distributions based on thresholding by the plumes' signature salinity value. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

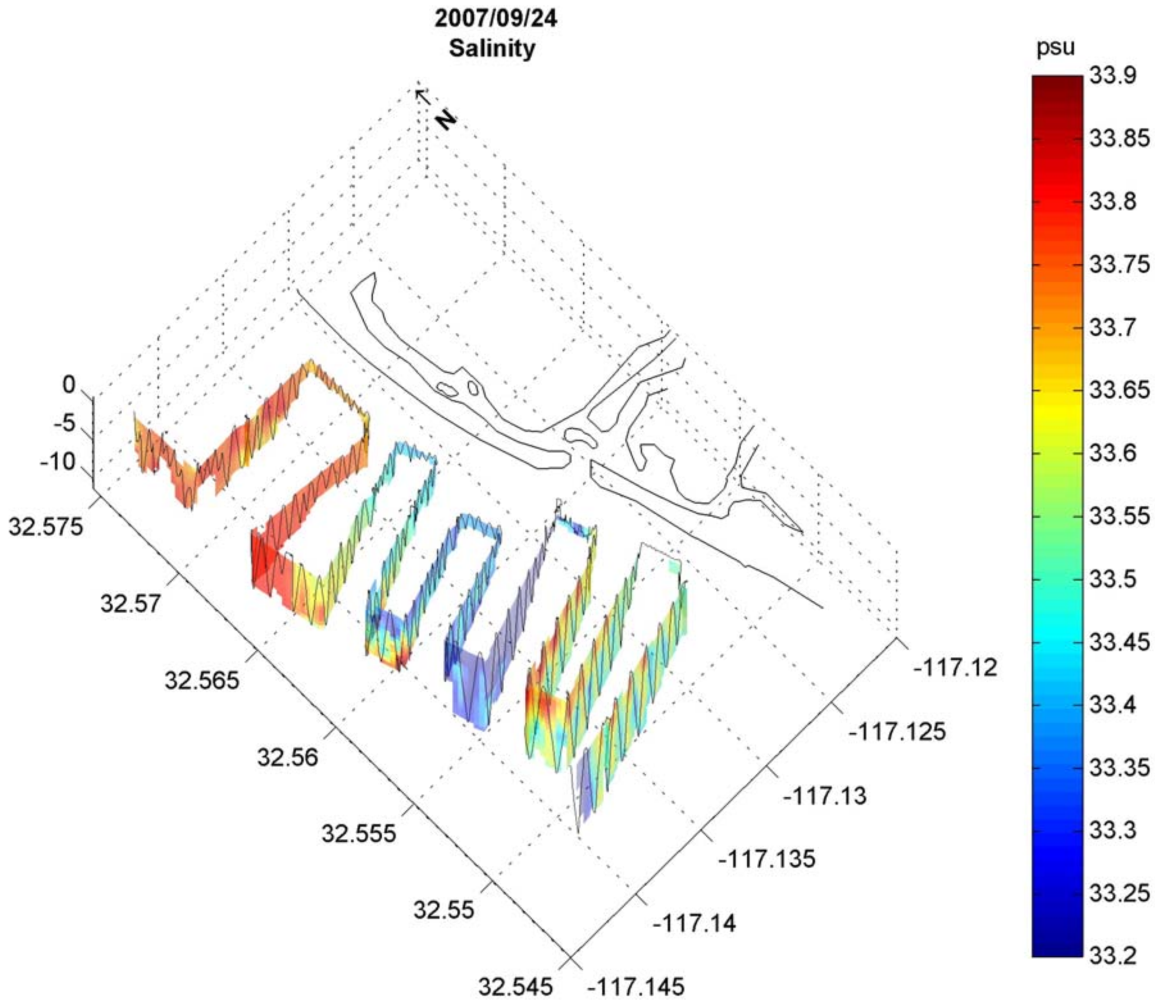
Appendix A.4 2007/09/24 Mission Summary



REMUS track (red) for a Tijuana River mission. The SBOO is shown in black offshore.

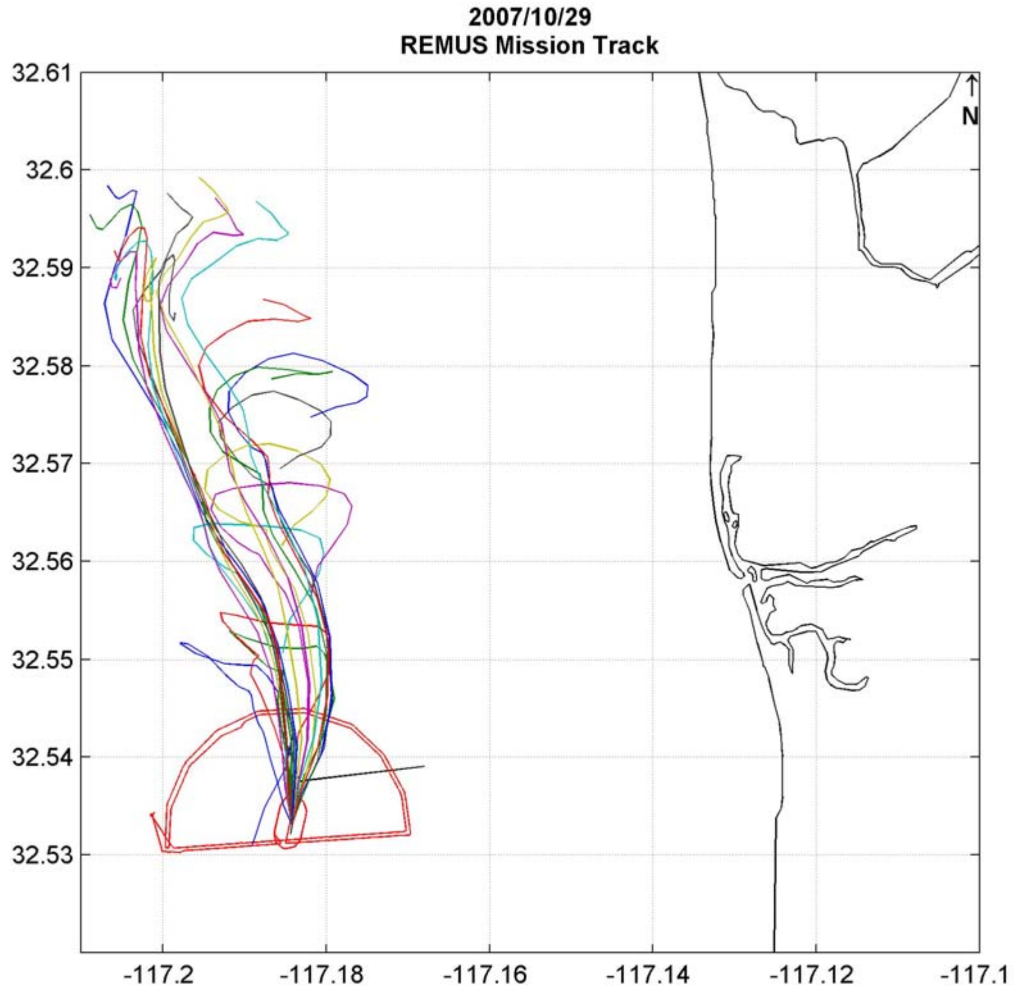


Alongshore surface current velocity measured by HF-Radar at the Tijuana River mouth (top) and flow rate from the Tijuana River as measured by the IBWC gauge (bottom). The grey panel indicates the sampling period.

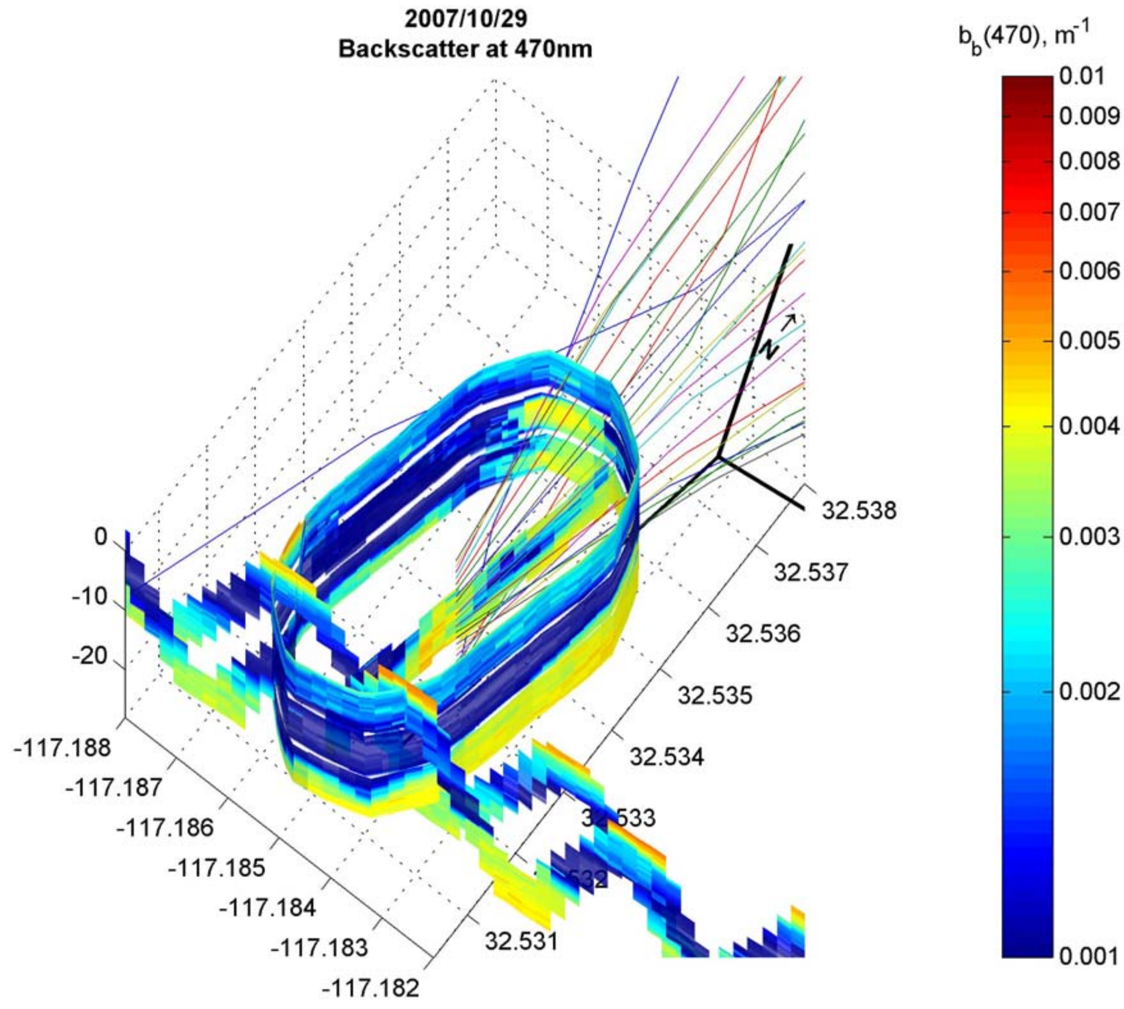


Low salinity values at the river mouth and to the south show the distribution of the Tijuana River plume.

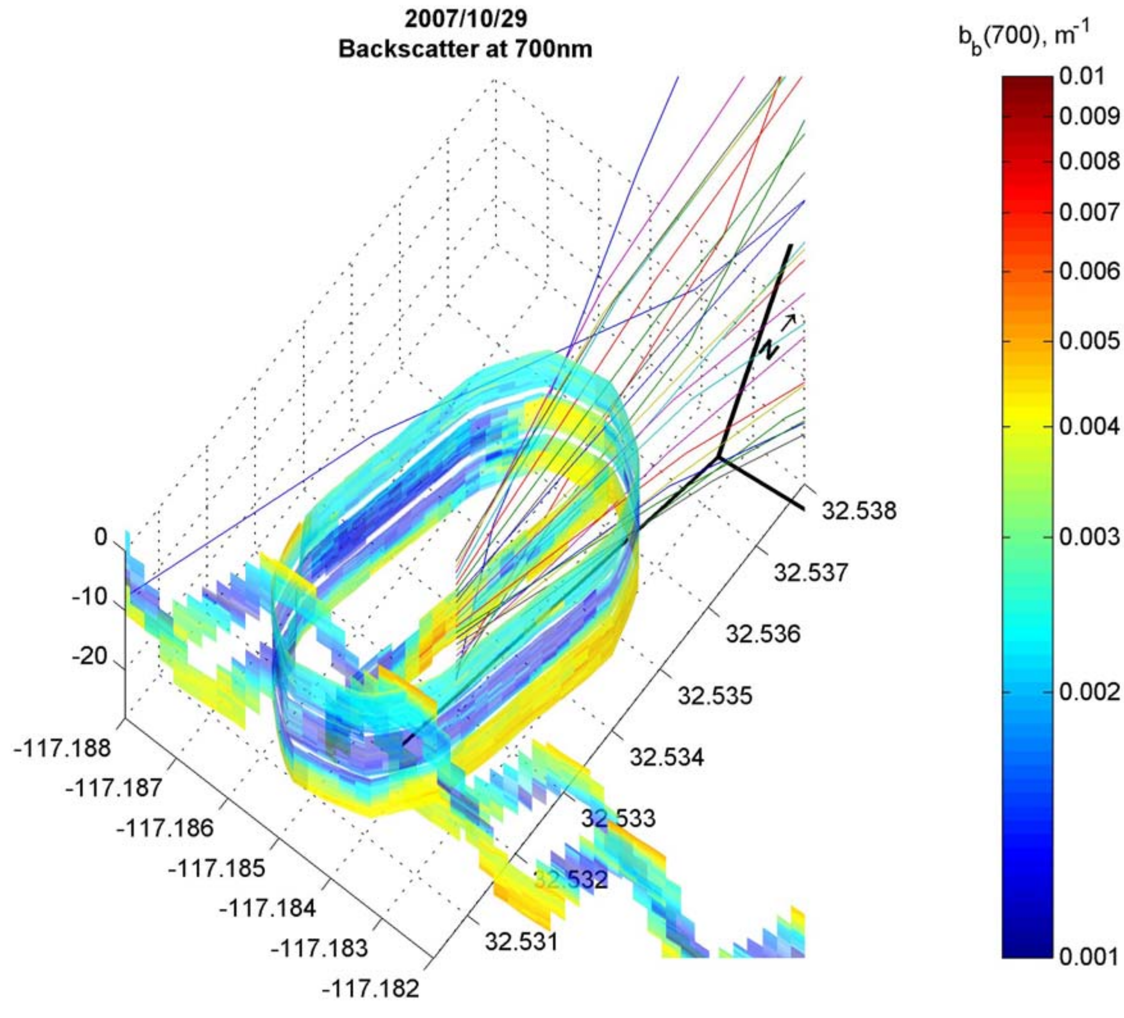
Appendix A.5 2007/10/29 Mission Summary



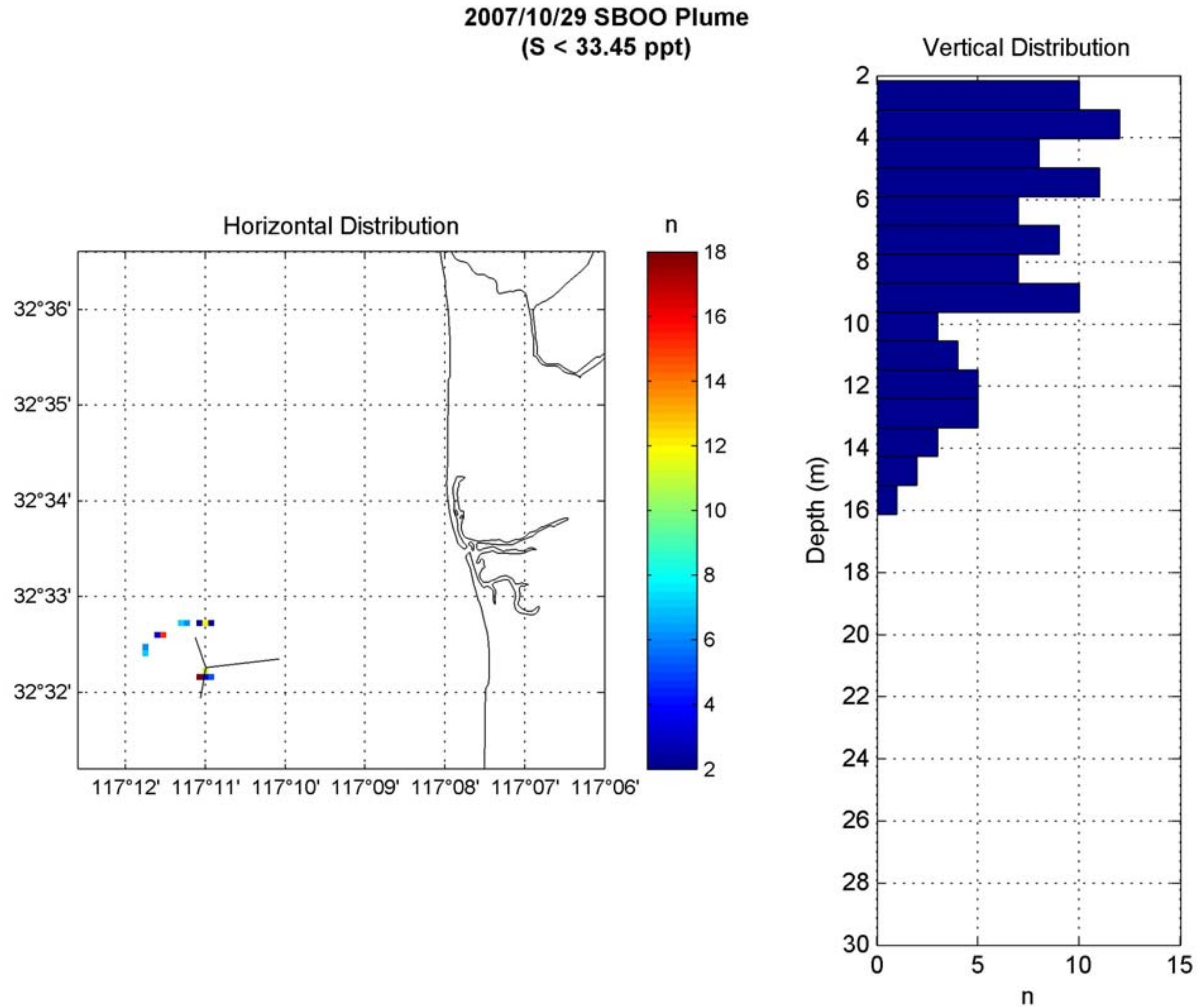
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Near-field backscatter measurements at 470nm show good correspondence between elevated values (>0.003 m^{-1}) and the estimated plume trajectory indicating elevated turbidity associated with the effluent.

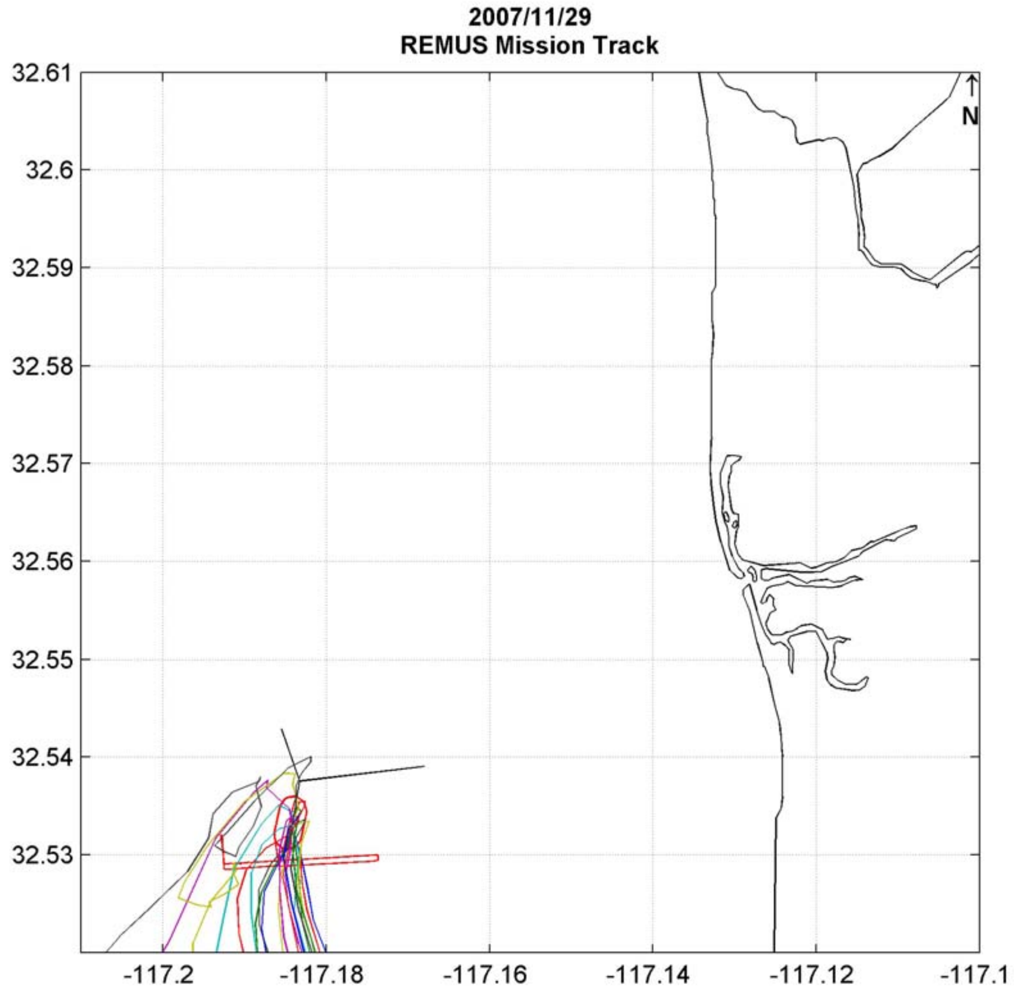


Near-field backscatter measurements at 700nm show good correspondence between elevated values (>0.004 m^{-1}) and the estimated plume trajectory indicating elevated turbidity associated with the effluent.

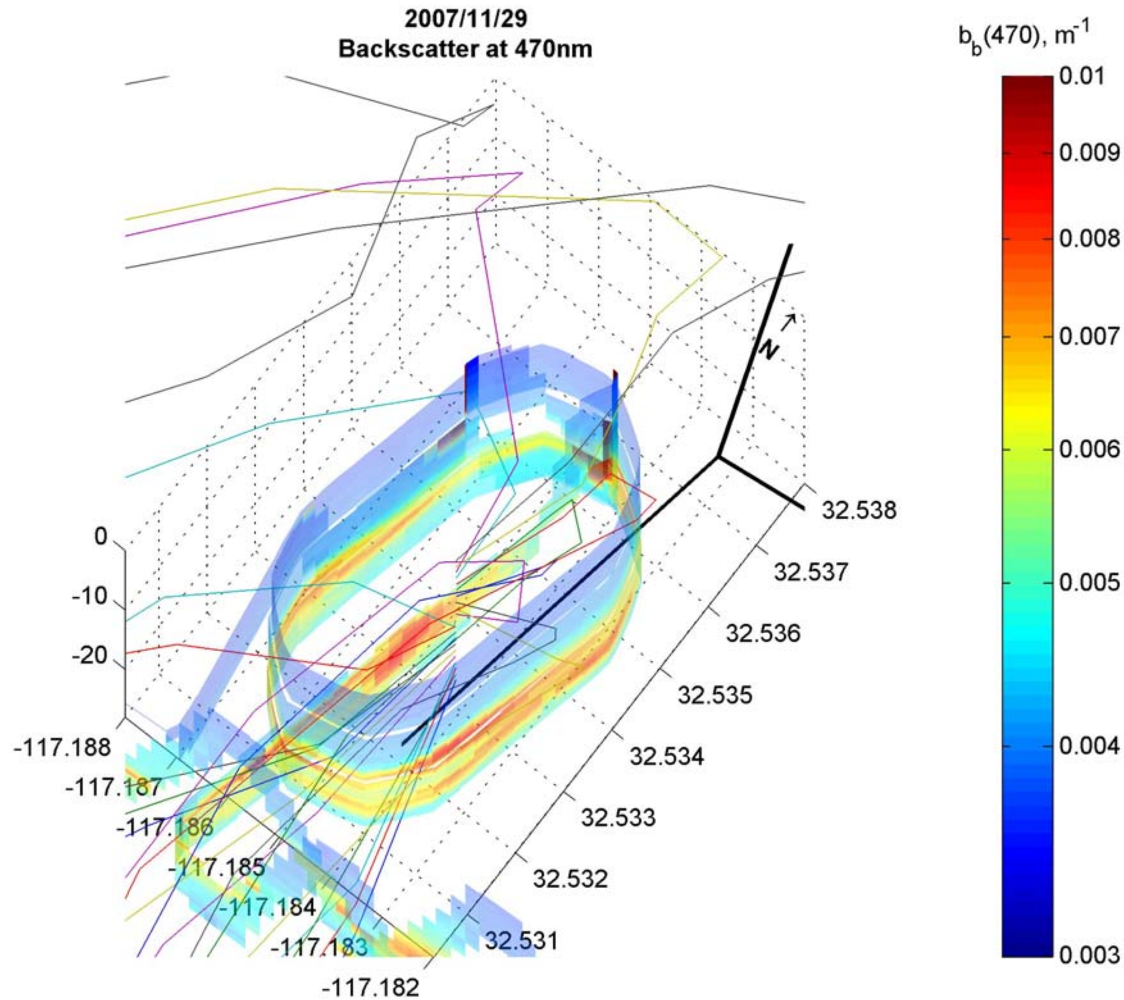


Horizontal and vertical plume distributions based on thresholding by the plumes' signature salinity value. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

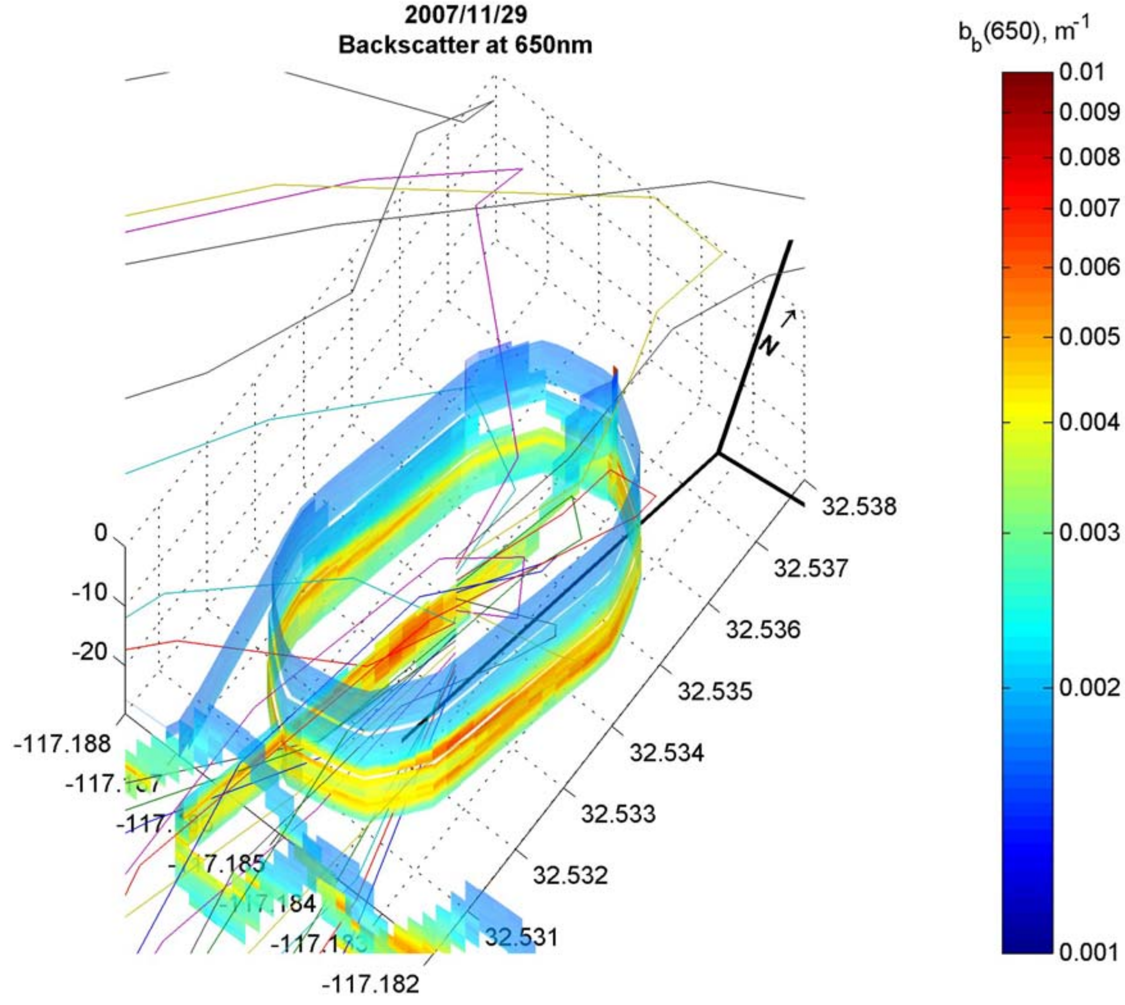
Appendix A.6 2007/11/29 Mission Summary



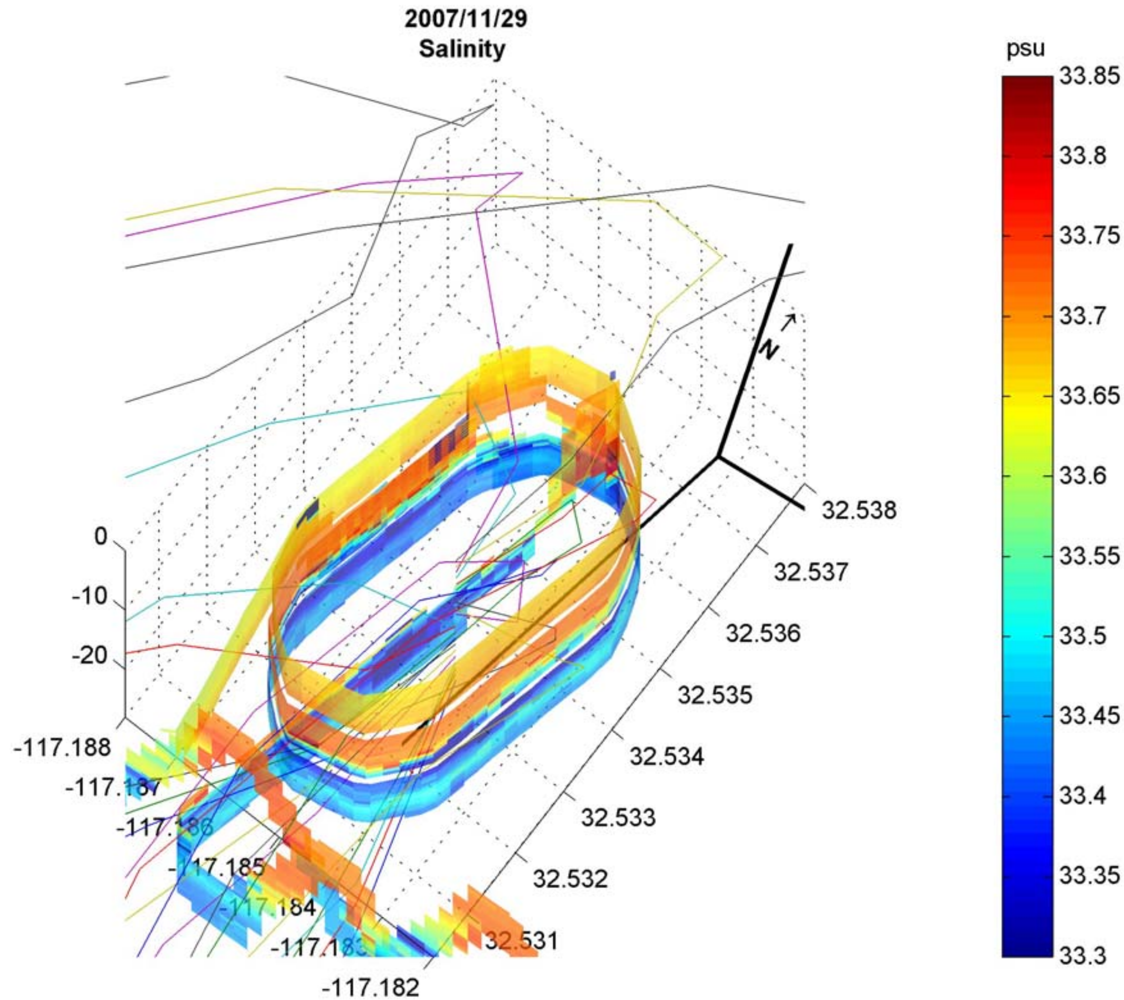
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



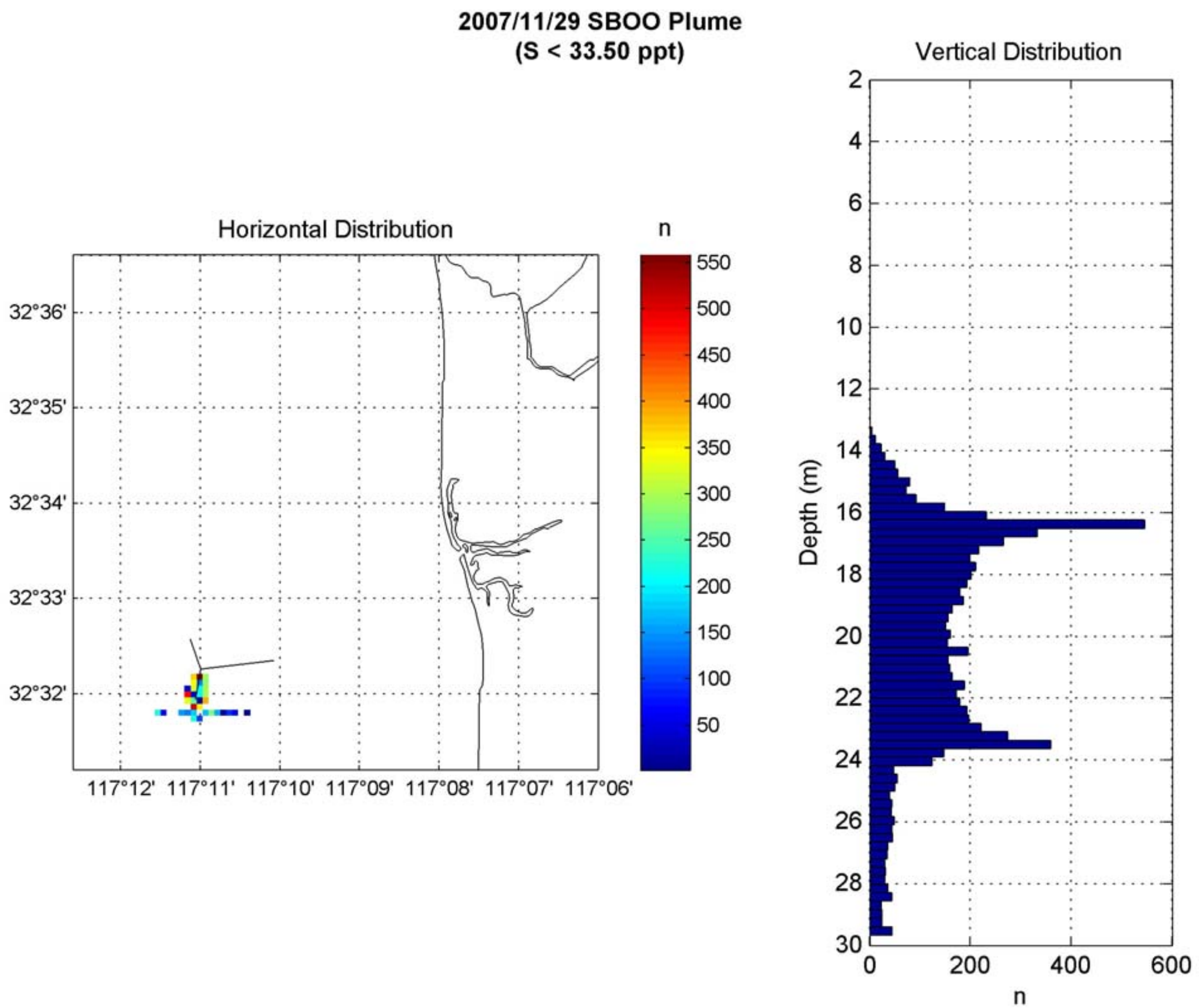
Near-field backscatter measurements at 470nm show good correspondence between elevated values (>0.006 m^{-1}) and the estimated plume trajectory indicating elevated turbidity associated with the effluent.



Near-field backscatter measurements at 650nm show good correspondence between elevated values (>0.004 m^{-1}) and the estimated plume trajectory indicating elevated turbidity associated with the effluent.

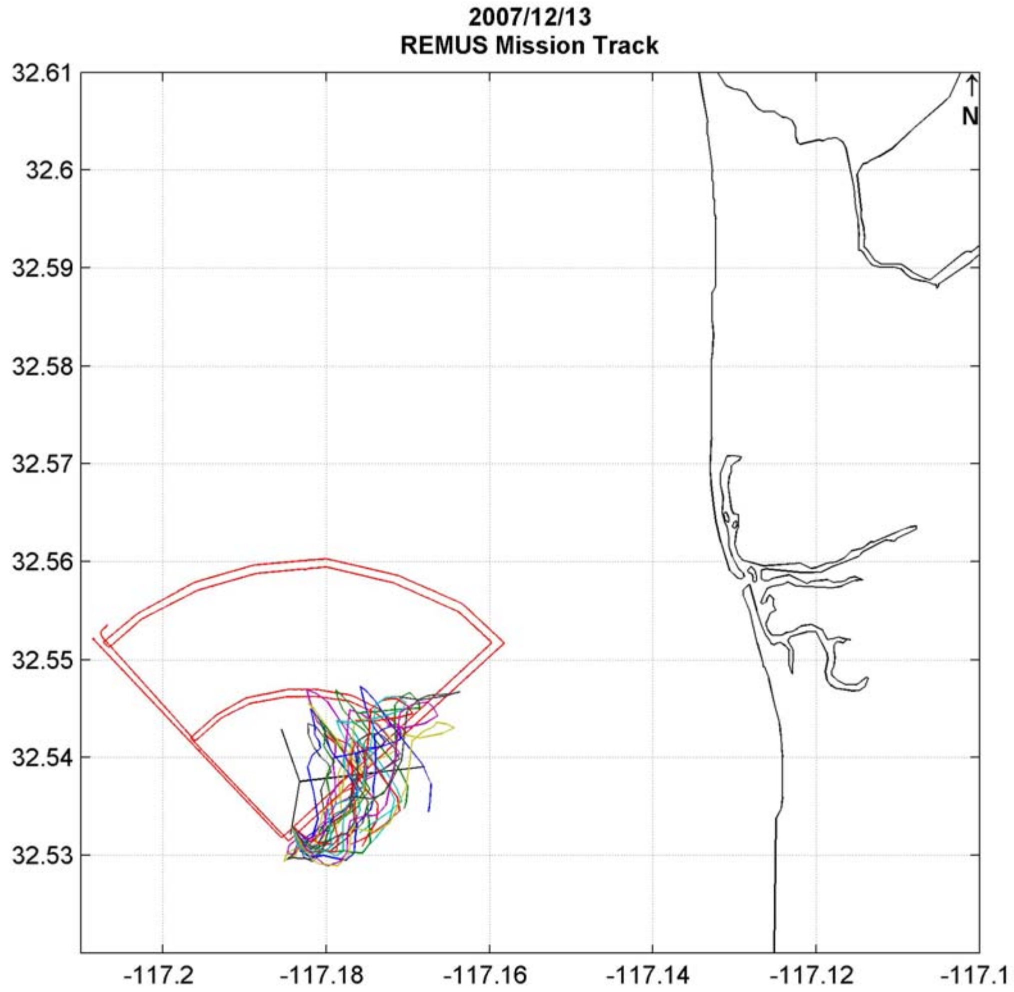


Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Low salinity at depth indicates the distribution of the SBOO plume.

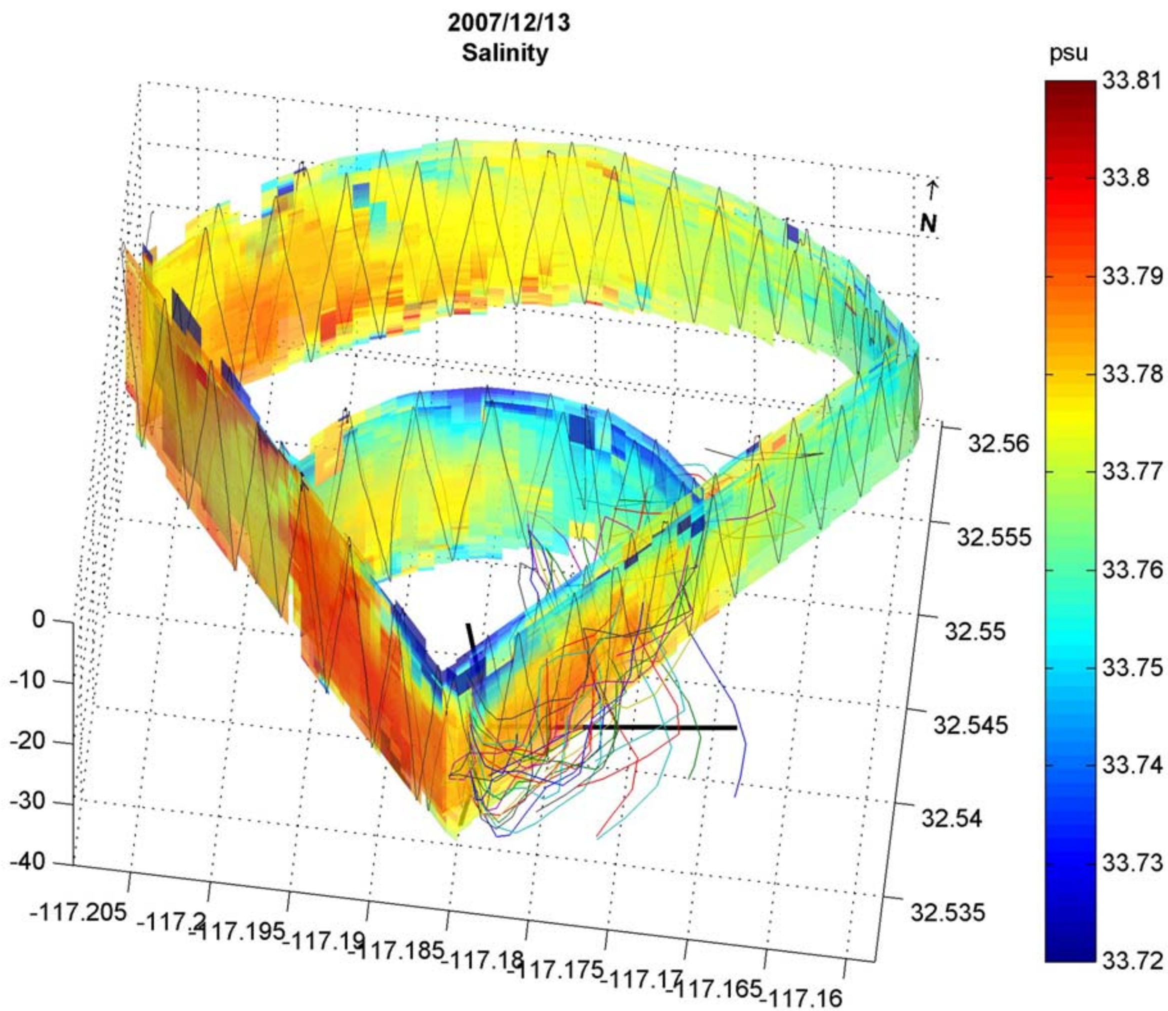


Horizontal and vertical plume distributions based on thresholding by the plumes' signature salinity value. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

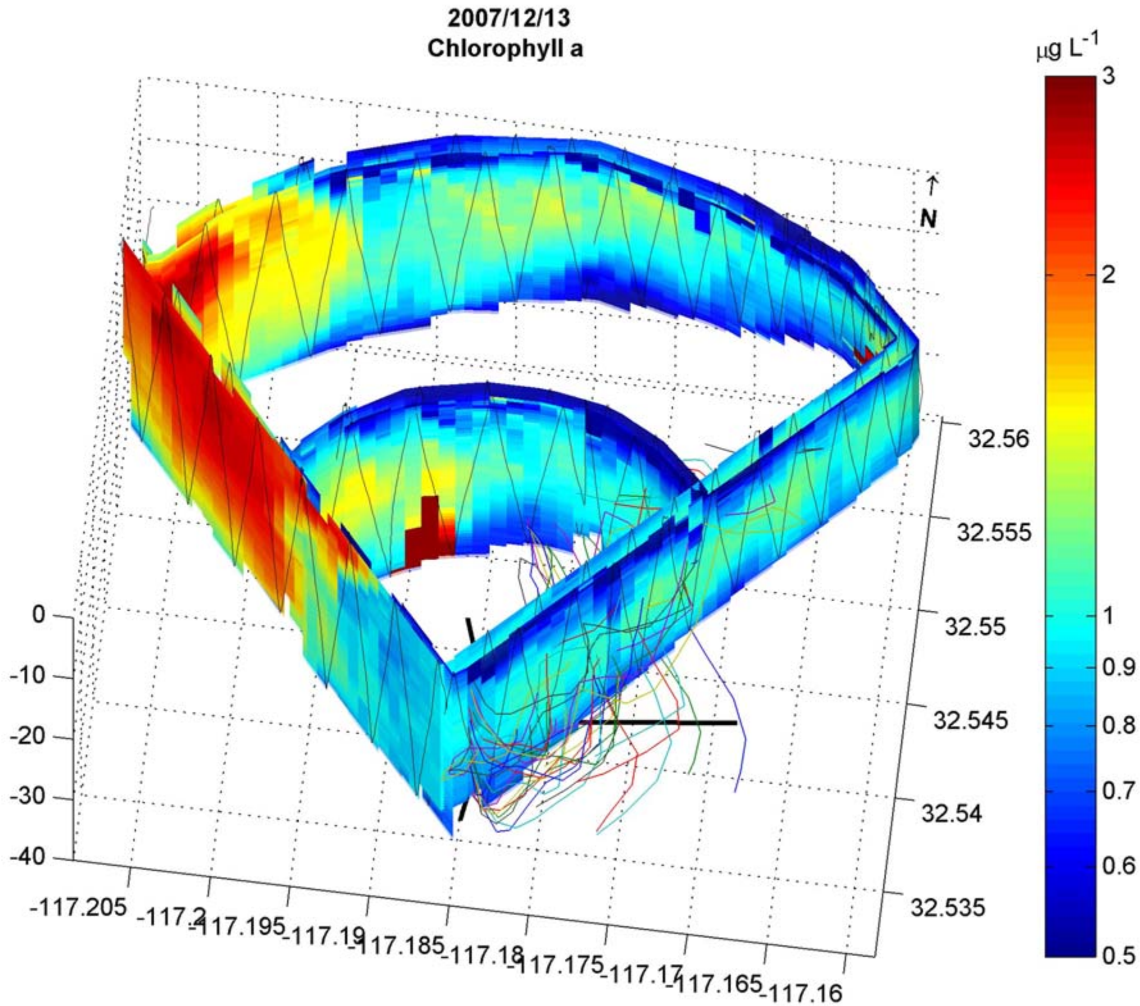
Appendix A.7 2007/12/13 Mission Summary



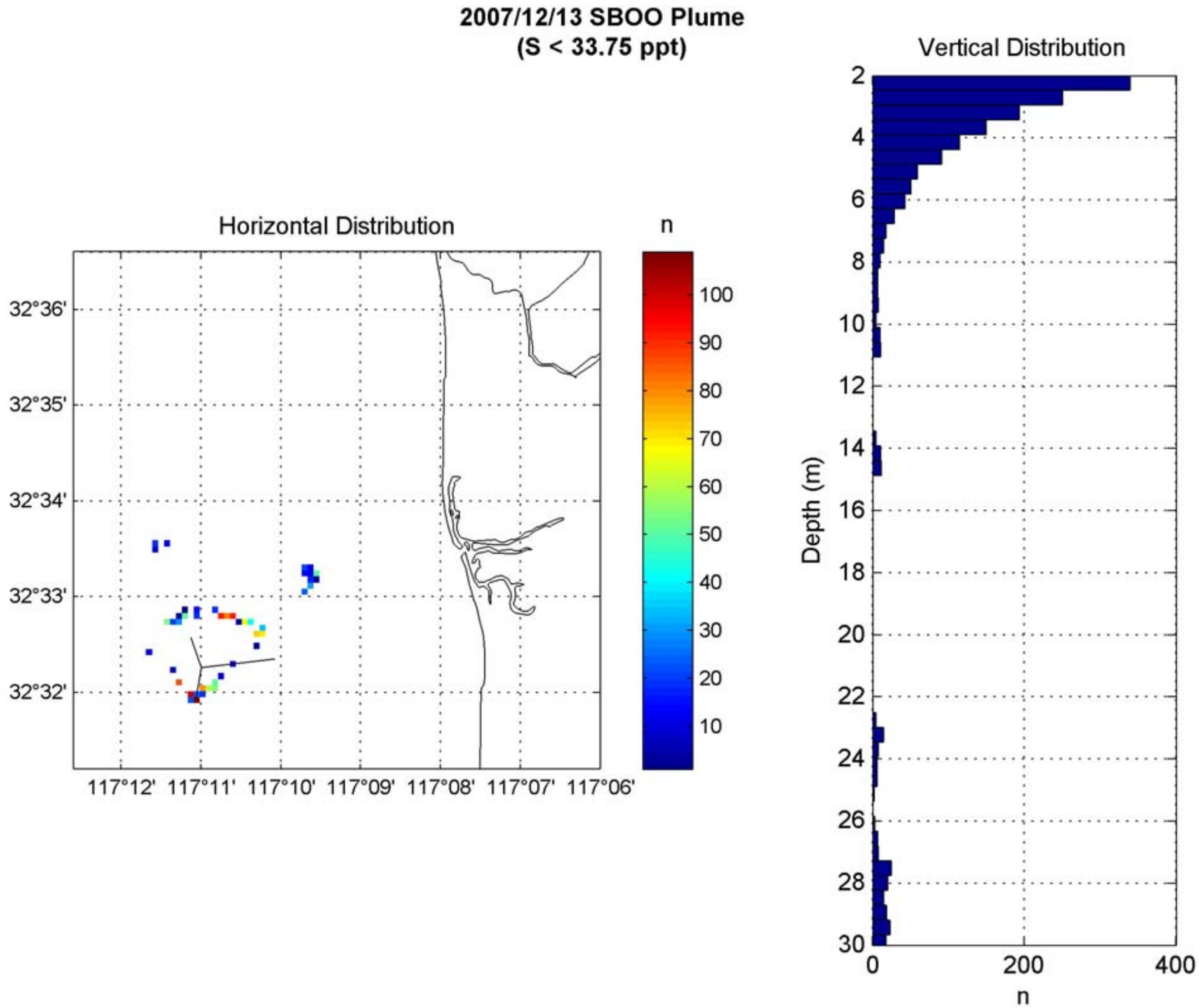
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Low salinity near the outfall and northward following the estimated trajectory shows the SBOO plume rises quickly and surfacing.

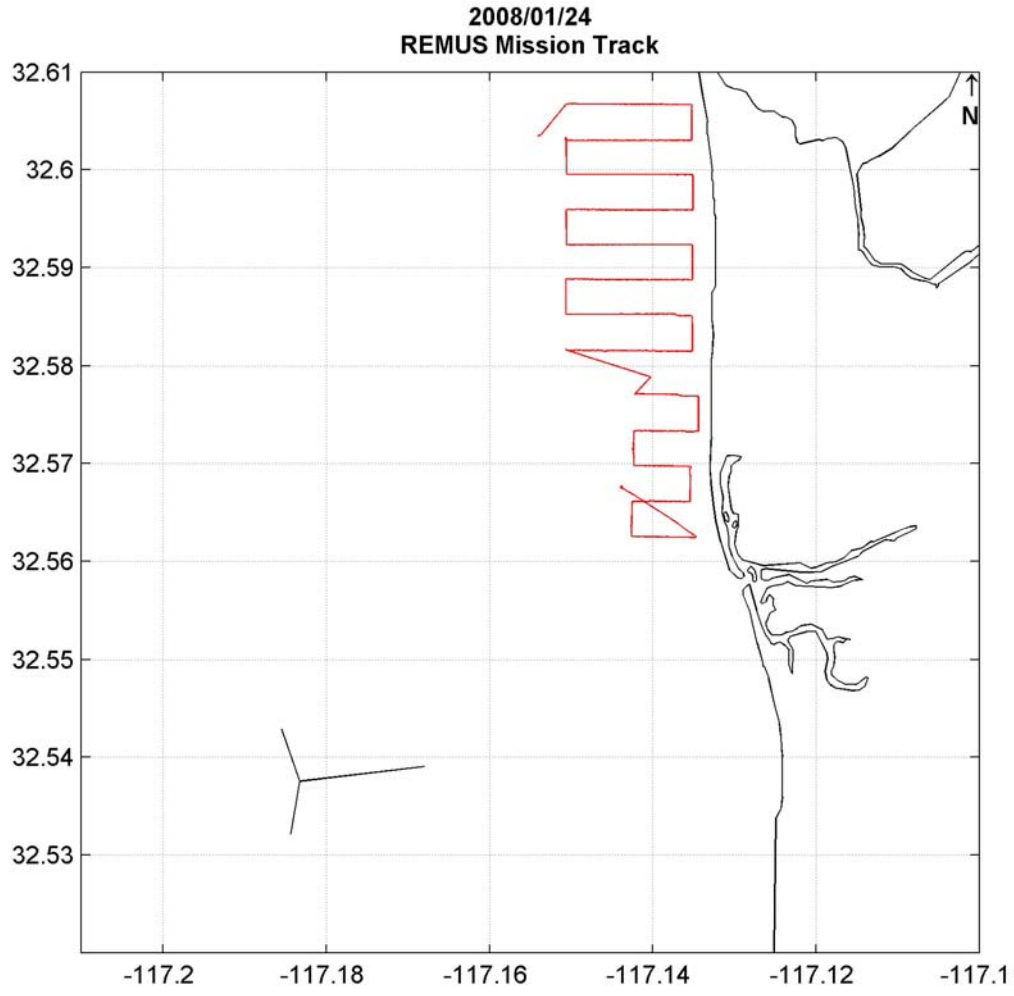


Chlorophyll a measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Correspondence between salinity and the estimated plume trajectory suggests that the SBOO plume is low in chlorophyll a (<0.7 μg L^{-1}).

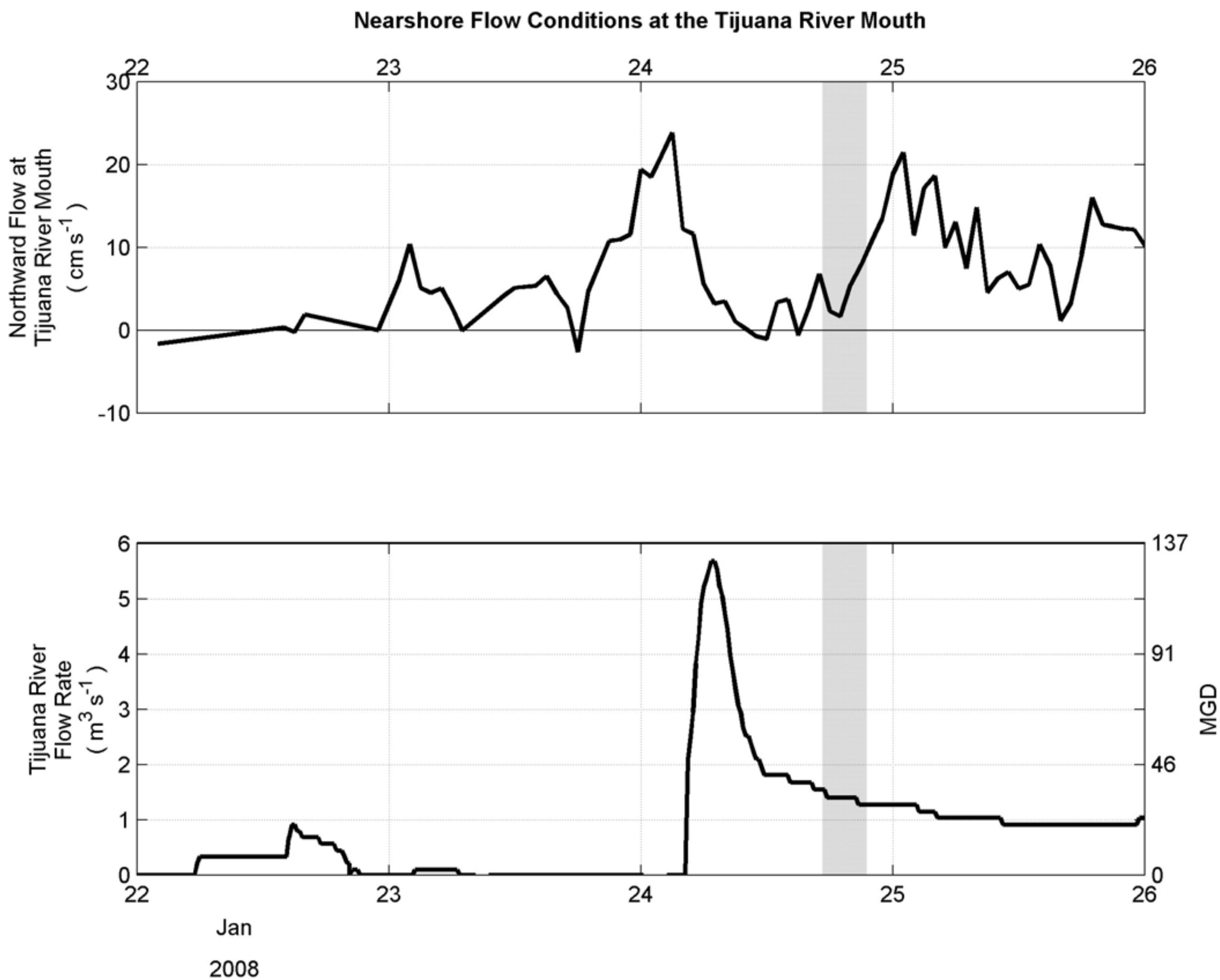


Horizontal and vertical plume distributions based on thresholding by the plumes' signature salinity value. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

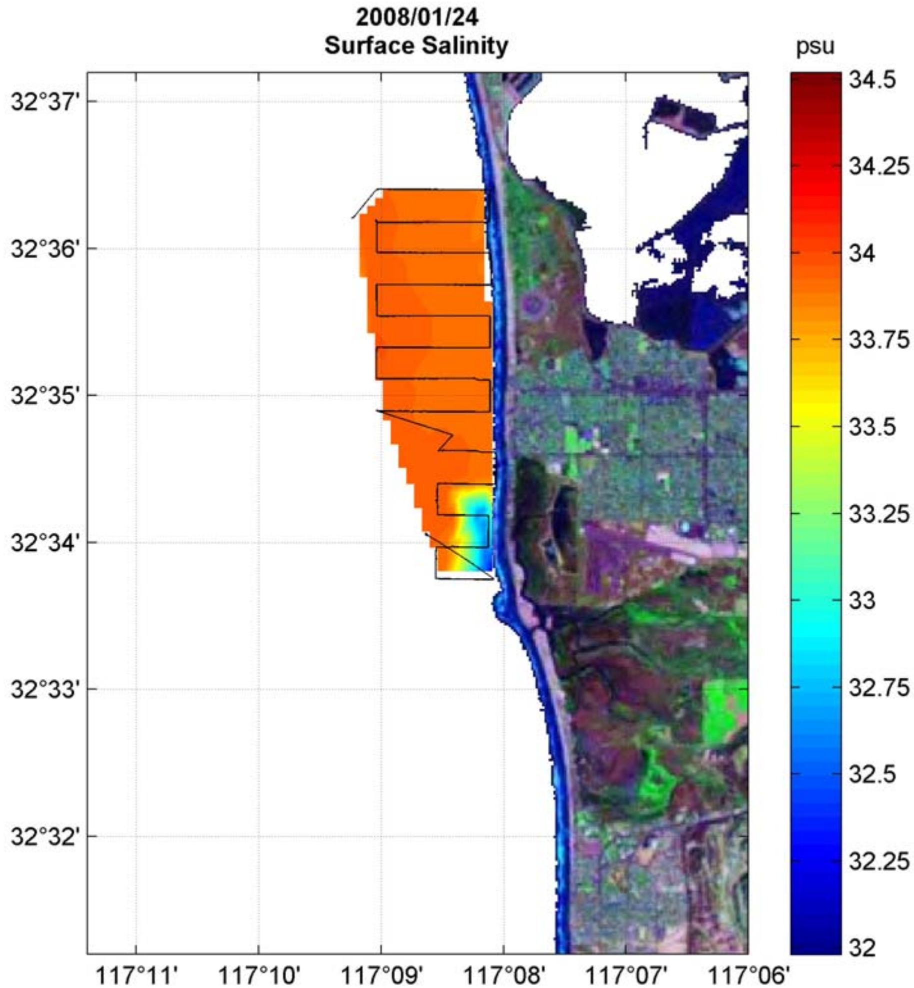
Appendix A.8 2008/01/24 Mission Summary



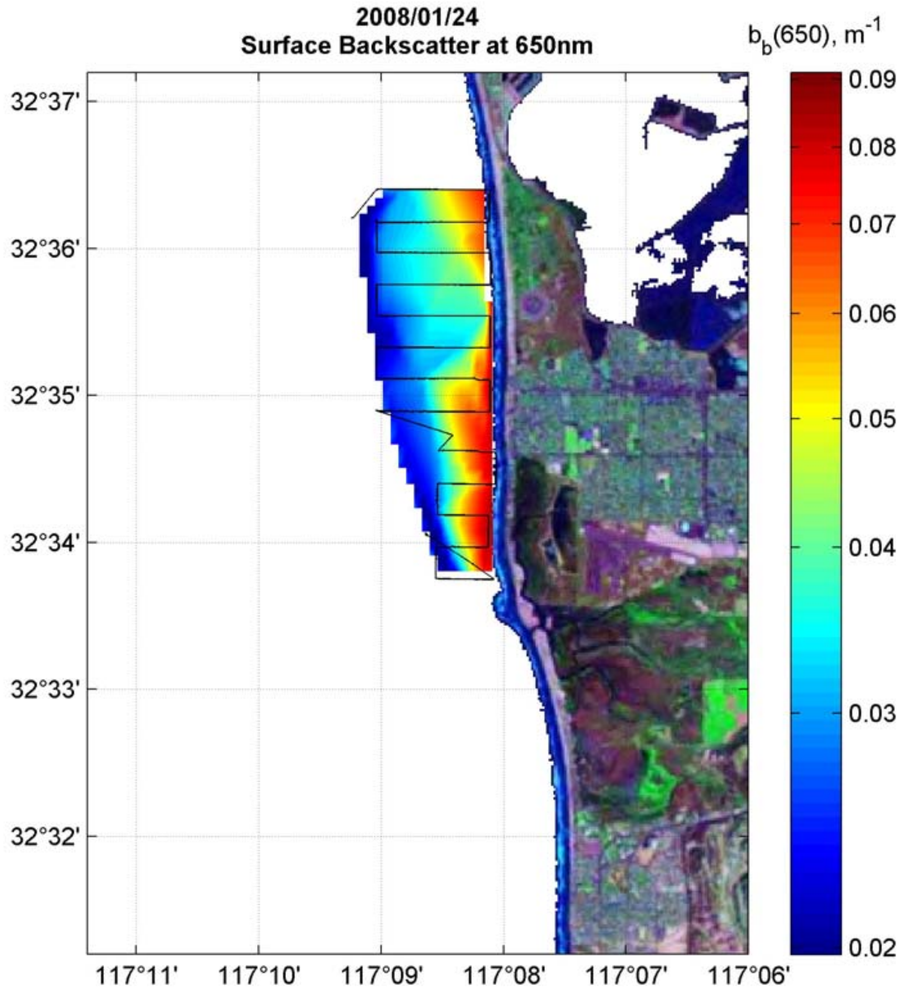
REMUS track (red) for a Tijuana River mission. The SBOO is shown in black offshore.



Alongshore surface current velocity measured by HF-Radar at the Tijuana River mouth (top) and flow rate from the Tijuana River as measured by the IBWC gauge (bottom). The grey panel indicates the sampling period.

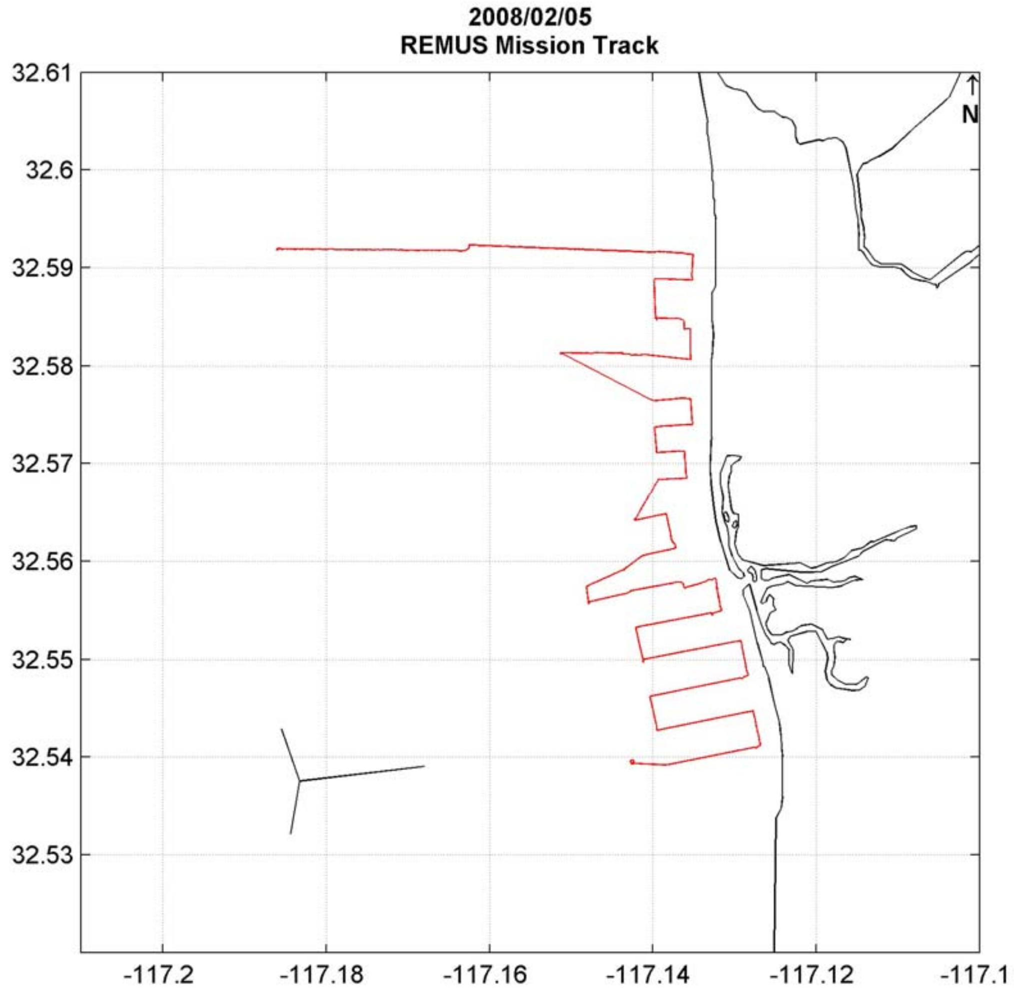


Low surface salinity values at the river mouth and to the north show the distribution of the Tijuana River plume.

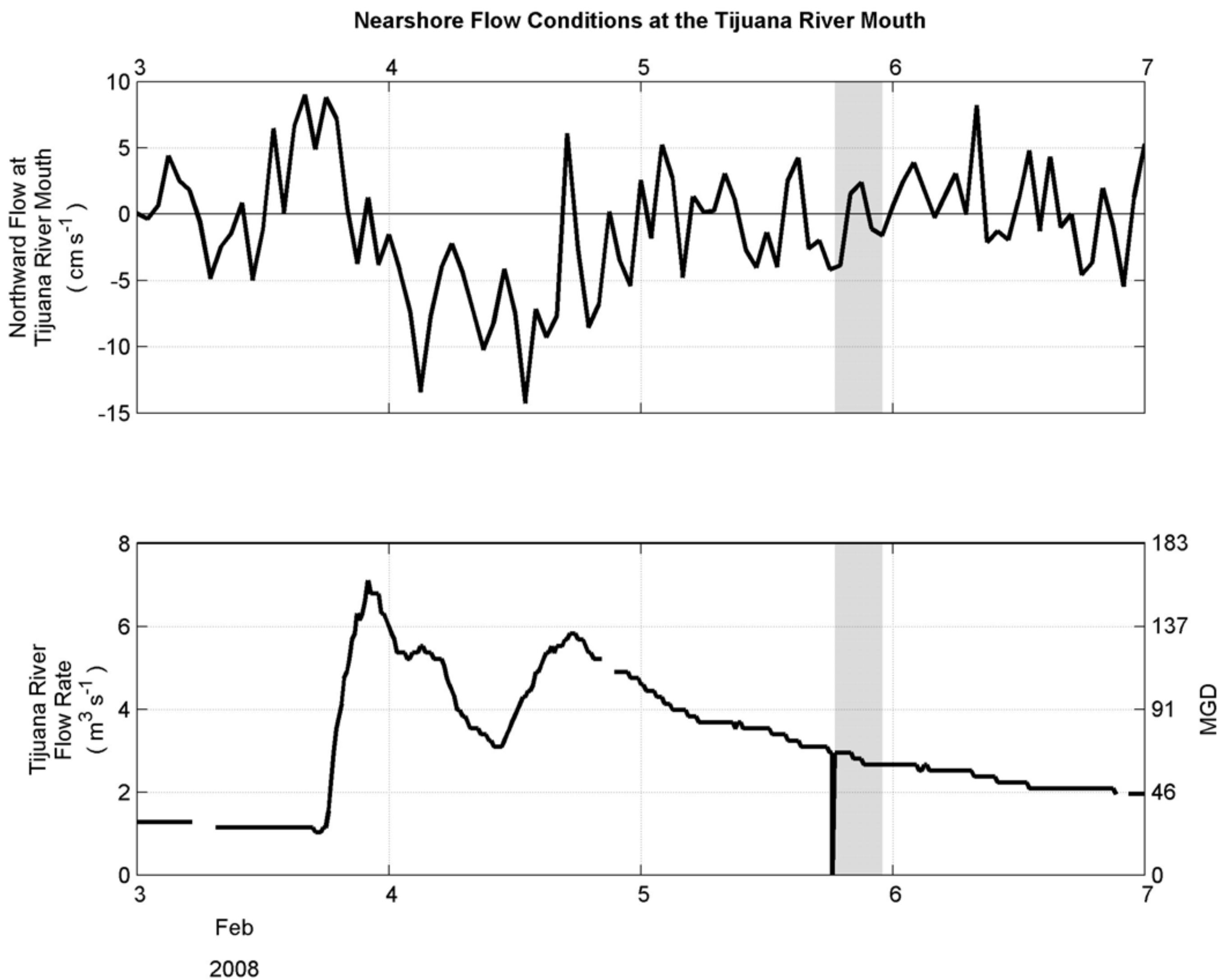


Elevated (>0.03 m^{-1}) nearshore surface backscatter measurements at 650nm indicate elevated turbidity associated the Tijuana River plume.

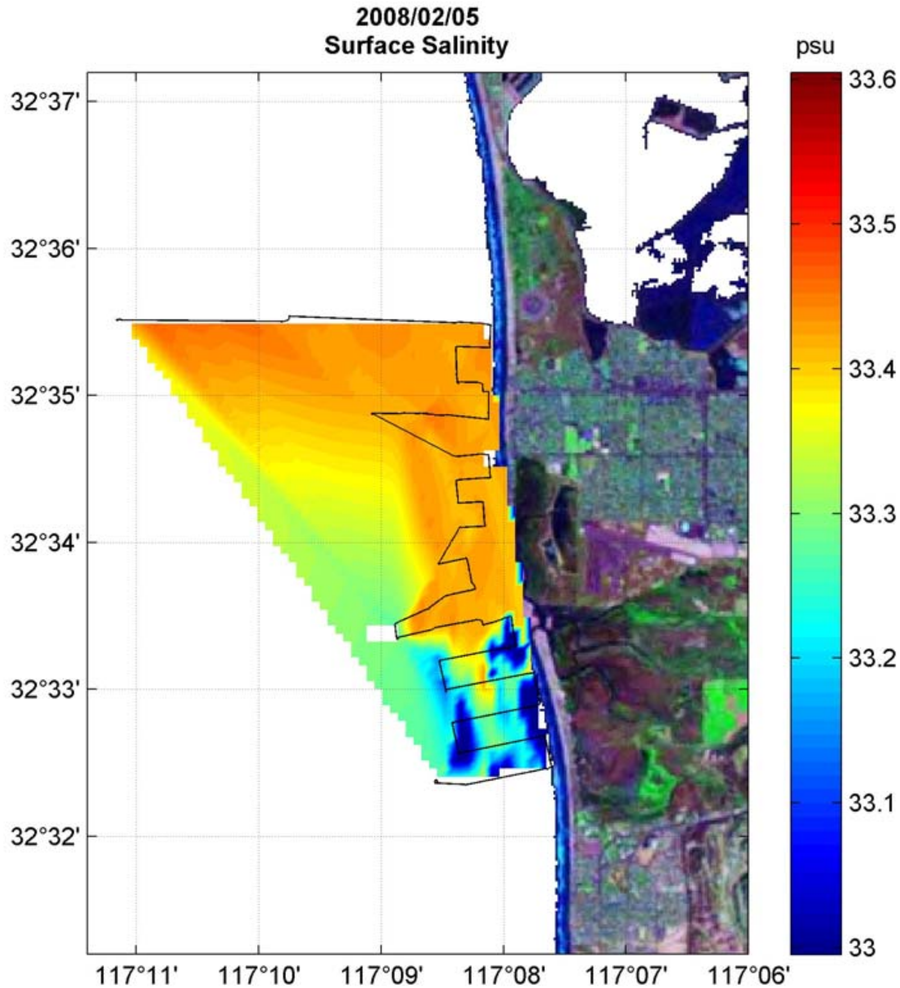
Appendix A.9 2008/02/05 Mission Summary



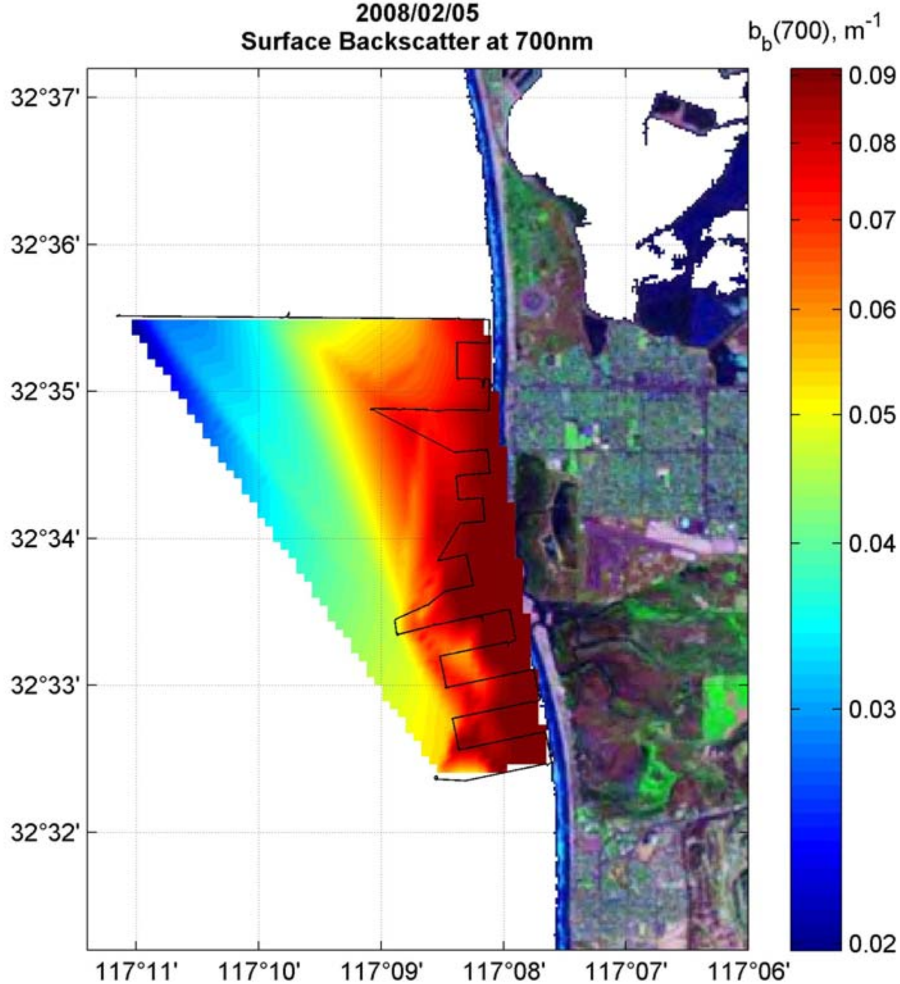
REMUS track (red) for a Tijuana River mission. The SBOO is shown in black offshore.



Alongshore surface current velocity measured by HF-Radar at the Tijuana River mouth (top) and flow rate from the Tijuana River as measured by the IBWC gauge (bottom). The grey panel indicates the sampling period.

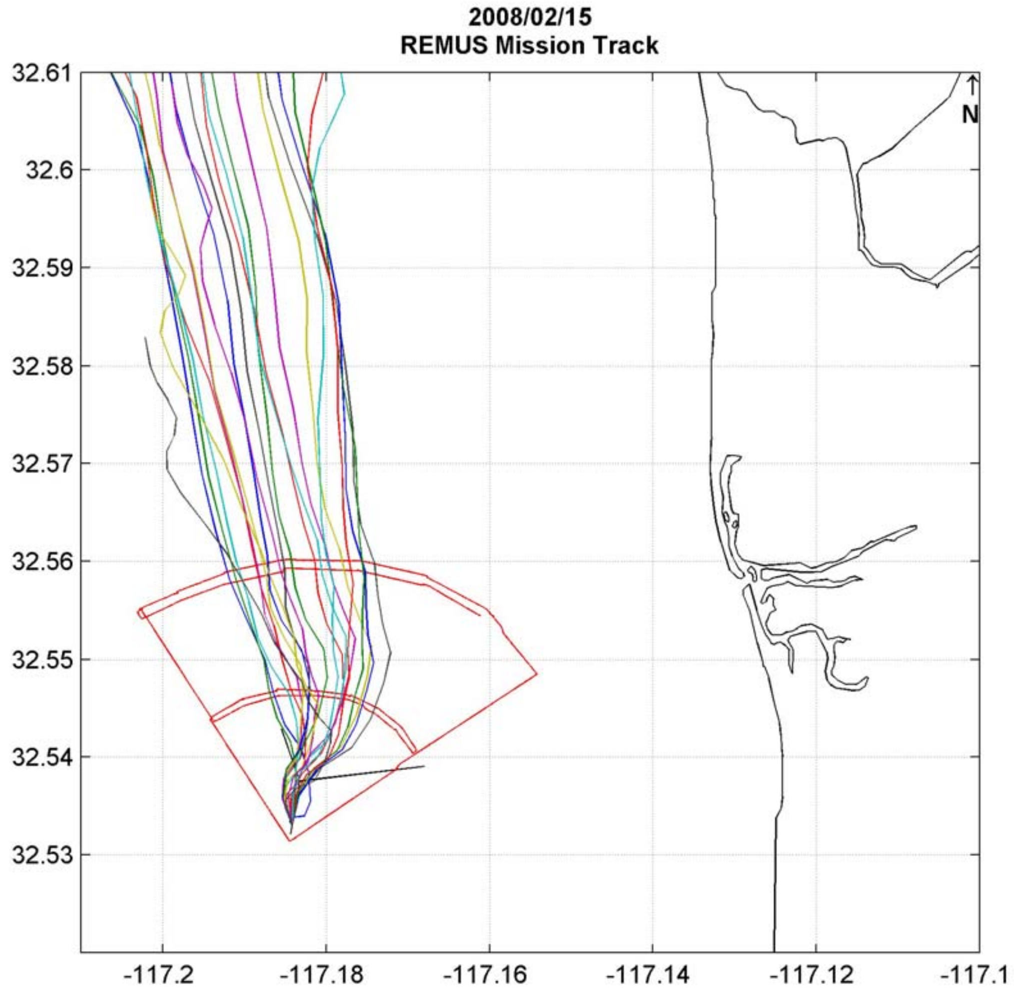


Low surface salinity values at the river mouth and to the south show the distribution of the Tijuana River plume.

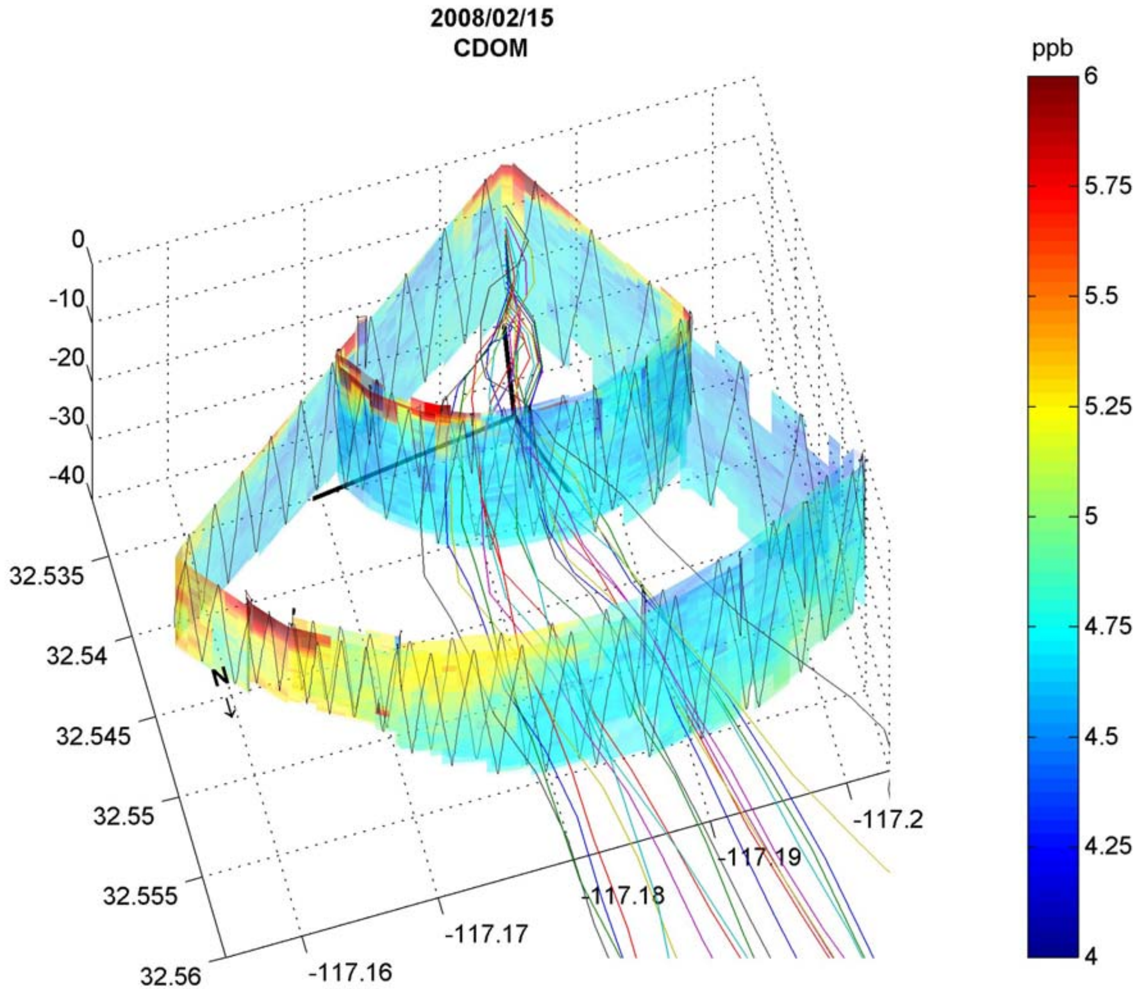


Elevated (>0.03 m^{-1}) nearshore surface backscatter measurements at 700 nm indicate elevated turbidity associated the Tijuana River plume.

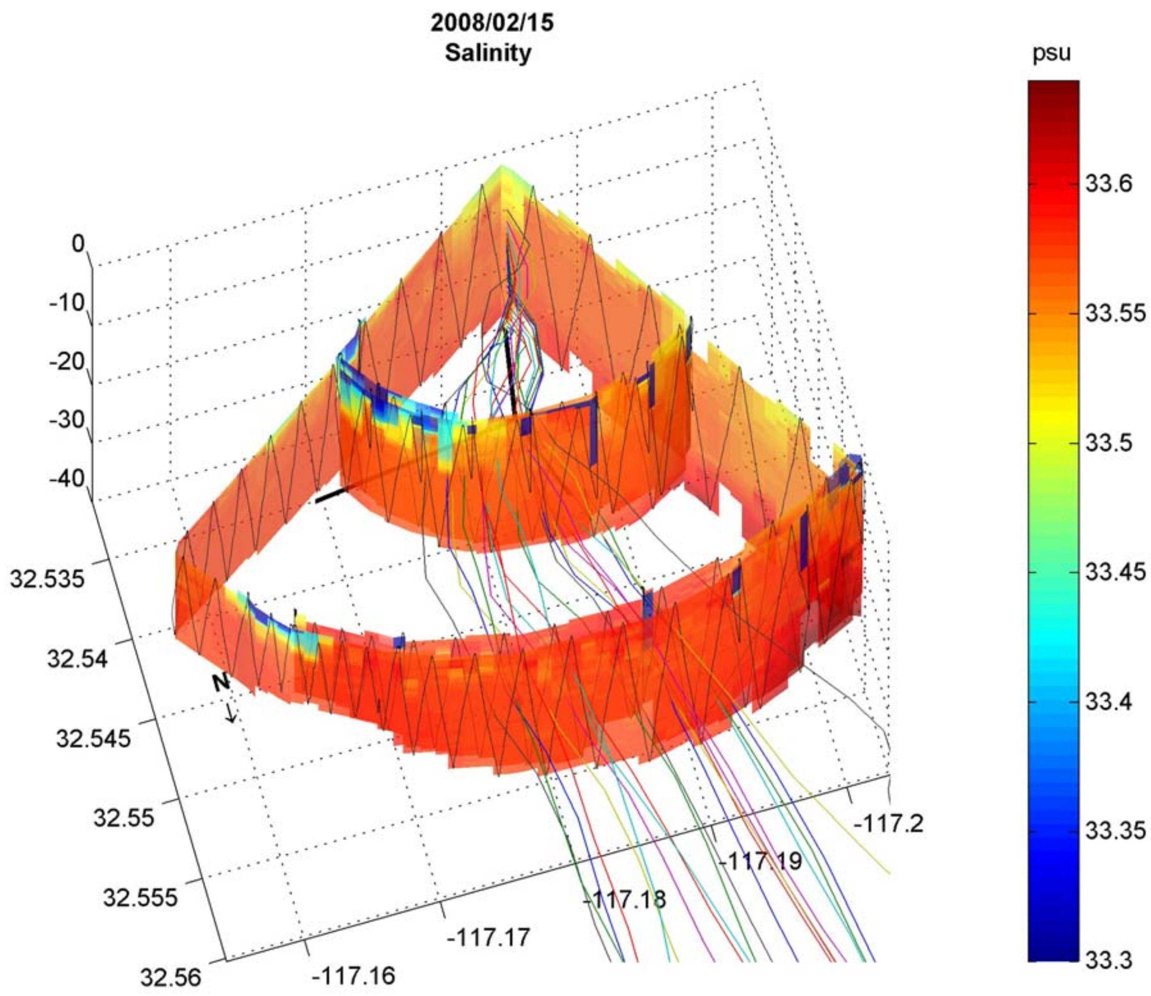
Appendix A.10 2008/02/15 Mission Summary



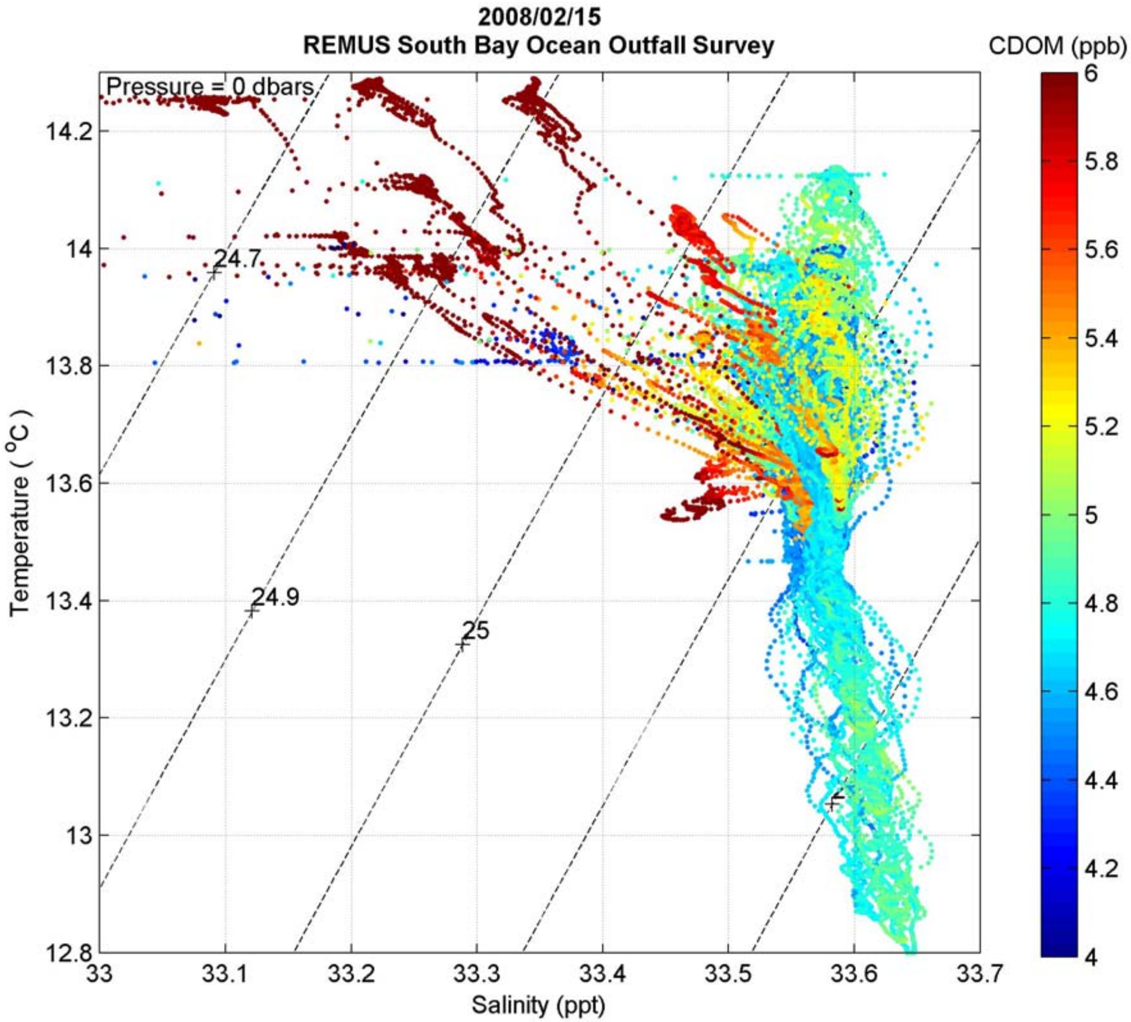
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



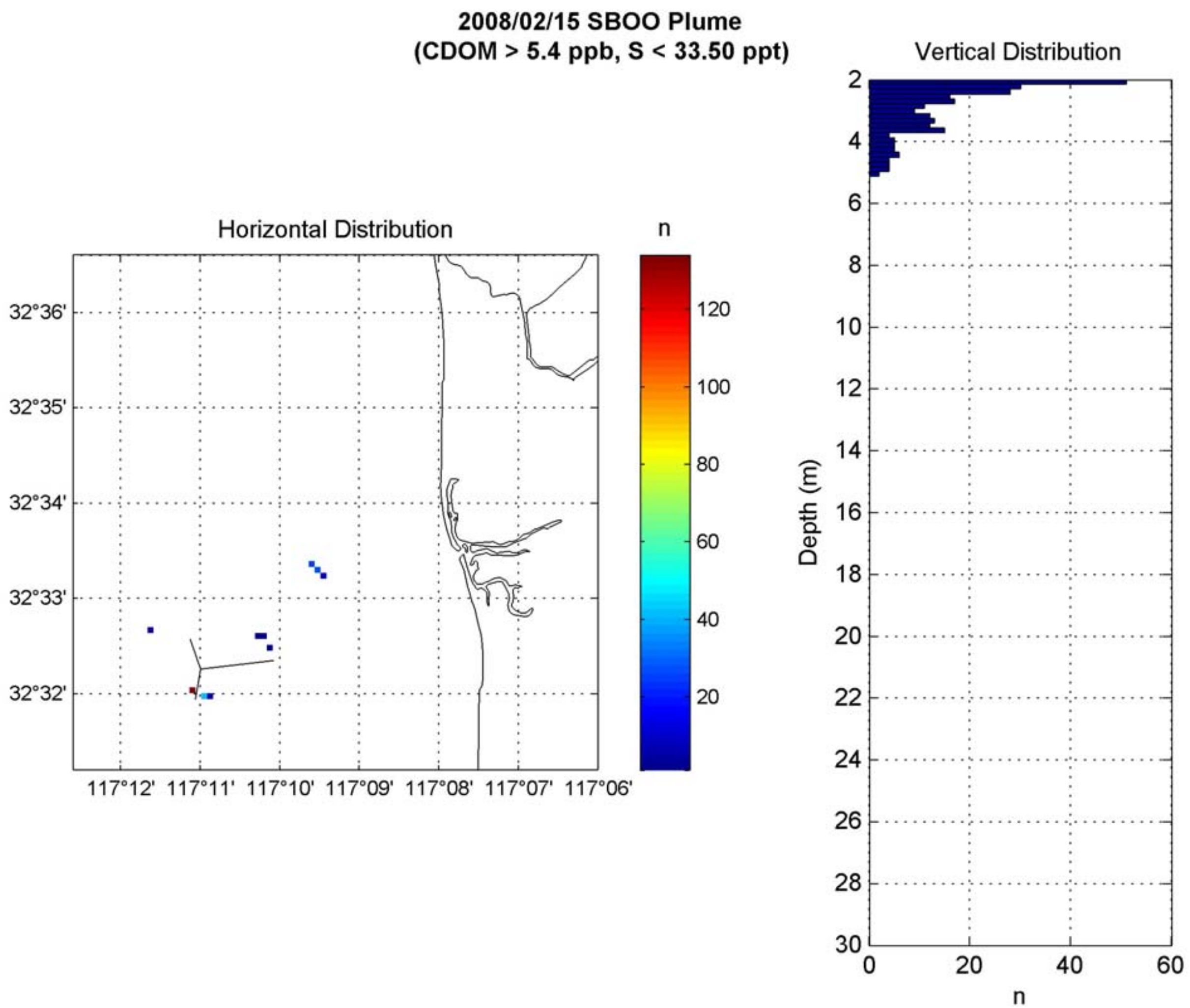
CDOM measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Elevated CDOM (> 5 ppb) near the outfall and northward following the estimated trajectory shows the SBOO plume rose quickly and surfaced.



Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Low salinity near the outfall and northward following the estimated trajectory shows the SBOO plume rose quickly and surfaced.

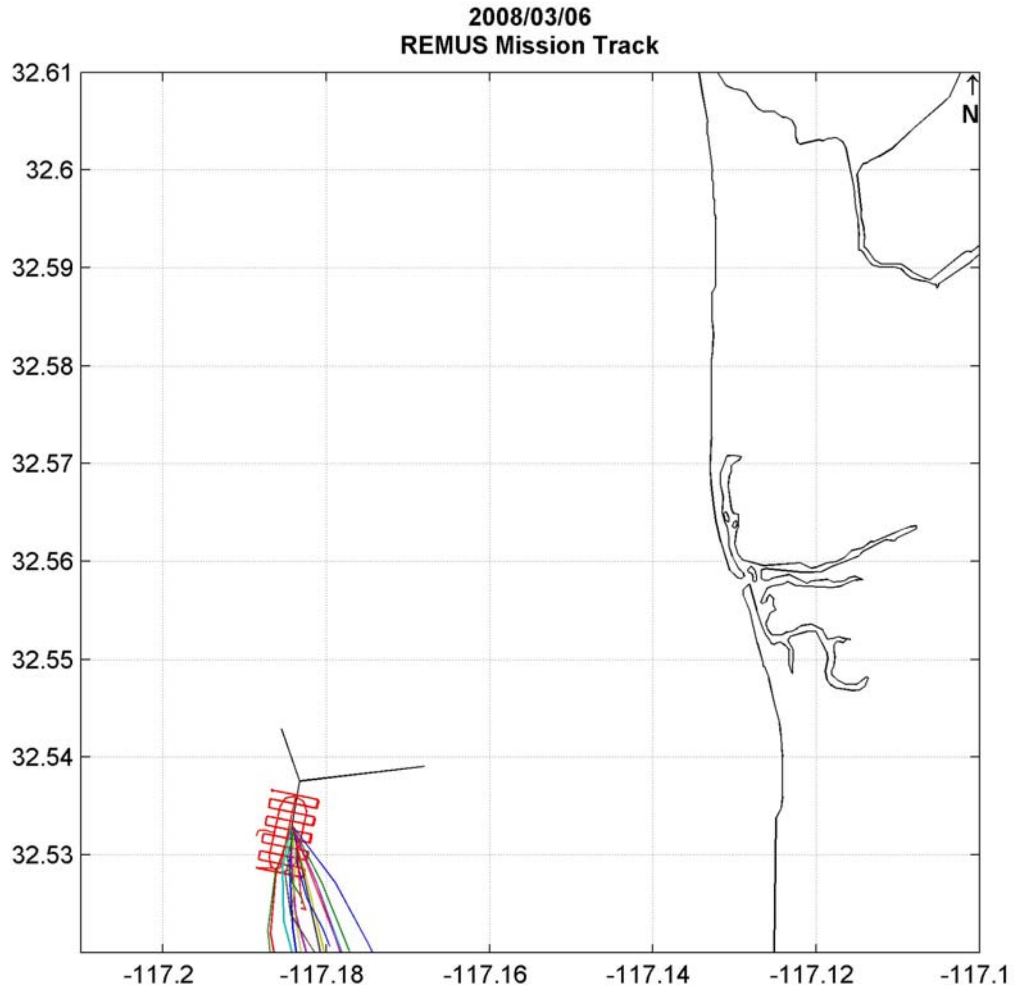


Temperature-Salinity (TS) diagram showing the distribution of watermasses by density (diagonal grid, units of kg/m^3 – 1000) and CDOM concentration. The outfall plume is distinguished as a fresher (lower salinity) watermass with high CDOM concentrations (> 5.4 ppb).

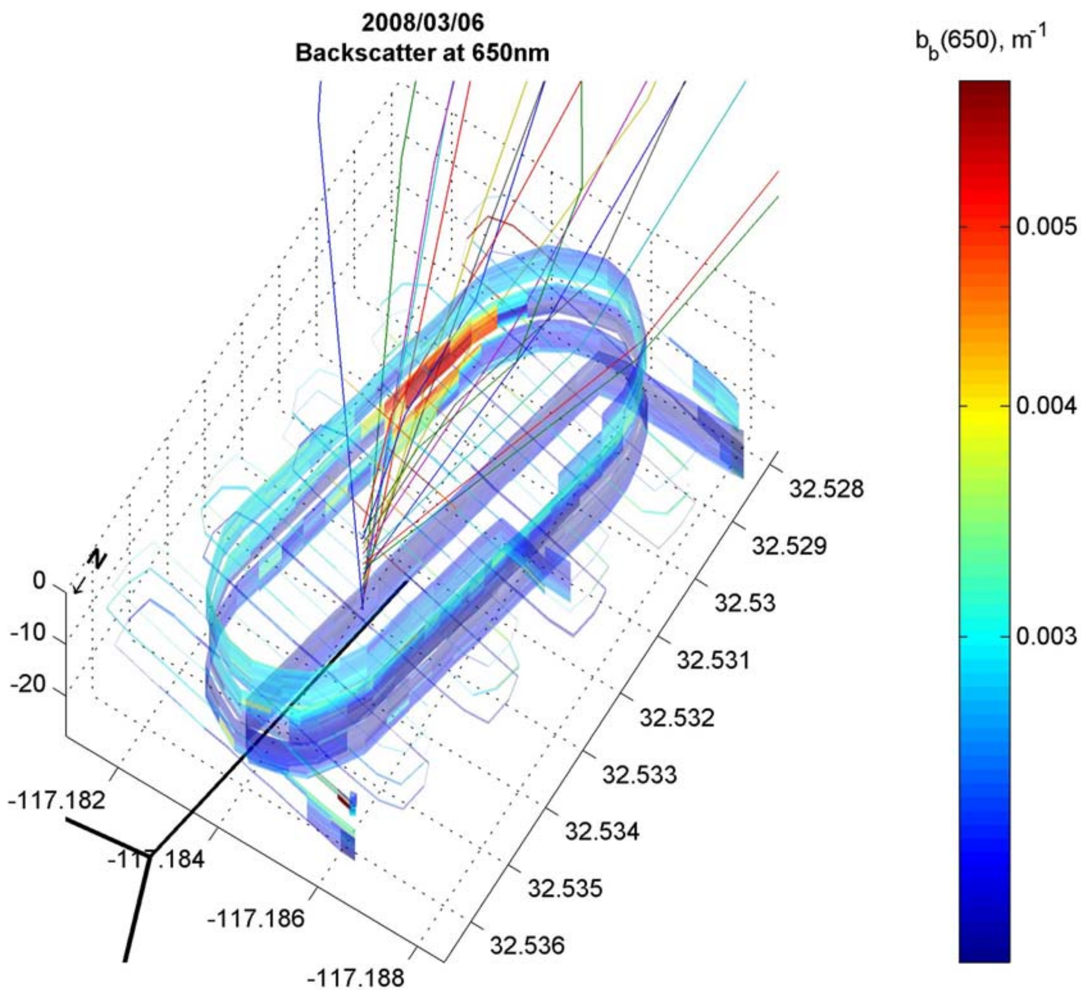


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

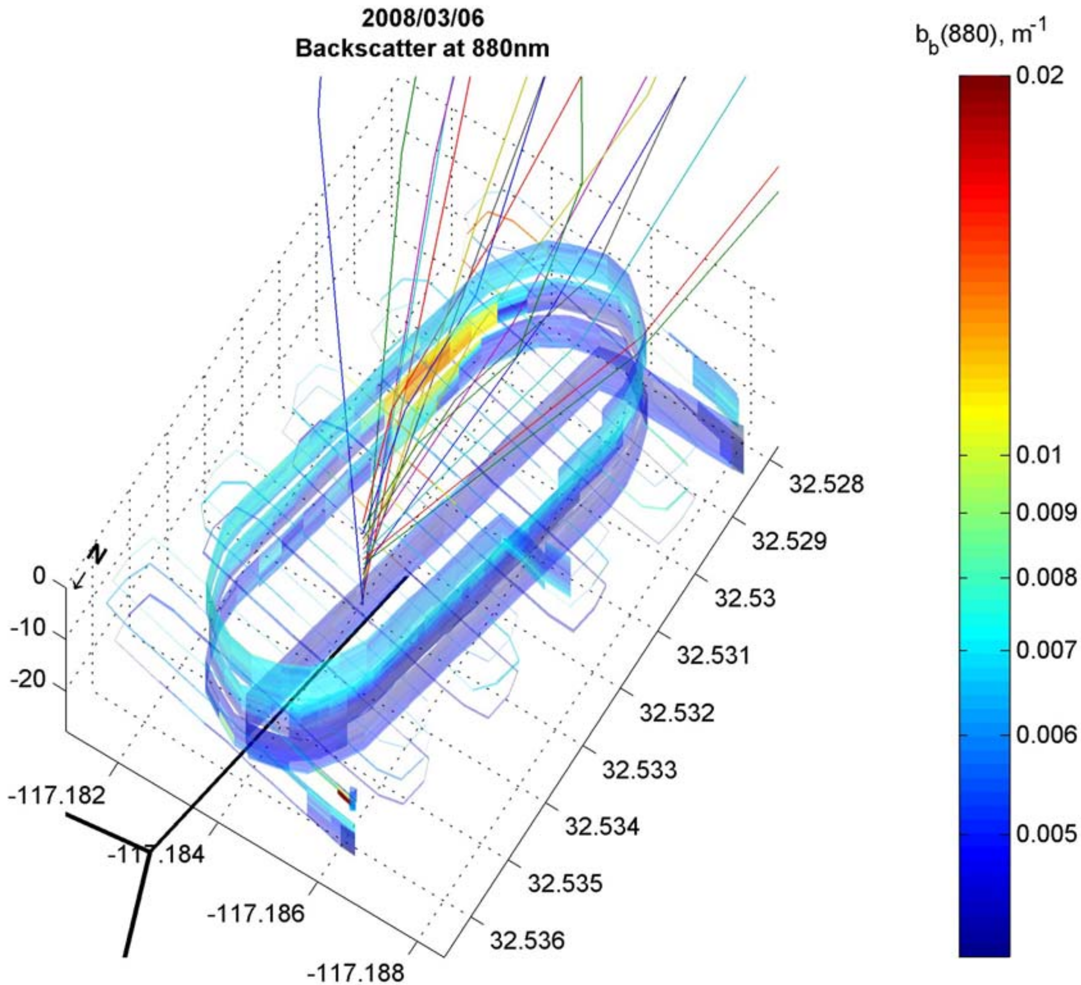
Appendix A.11 2008/03/06 Mission Summary



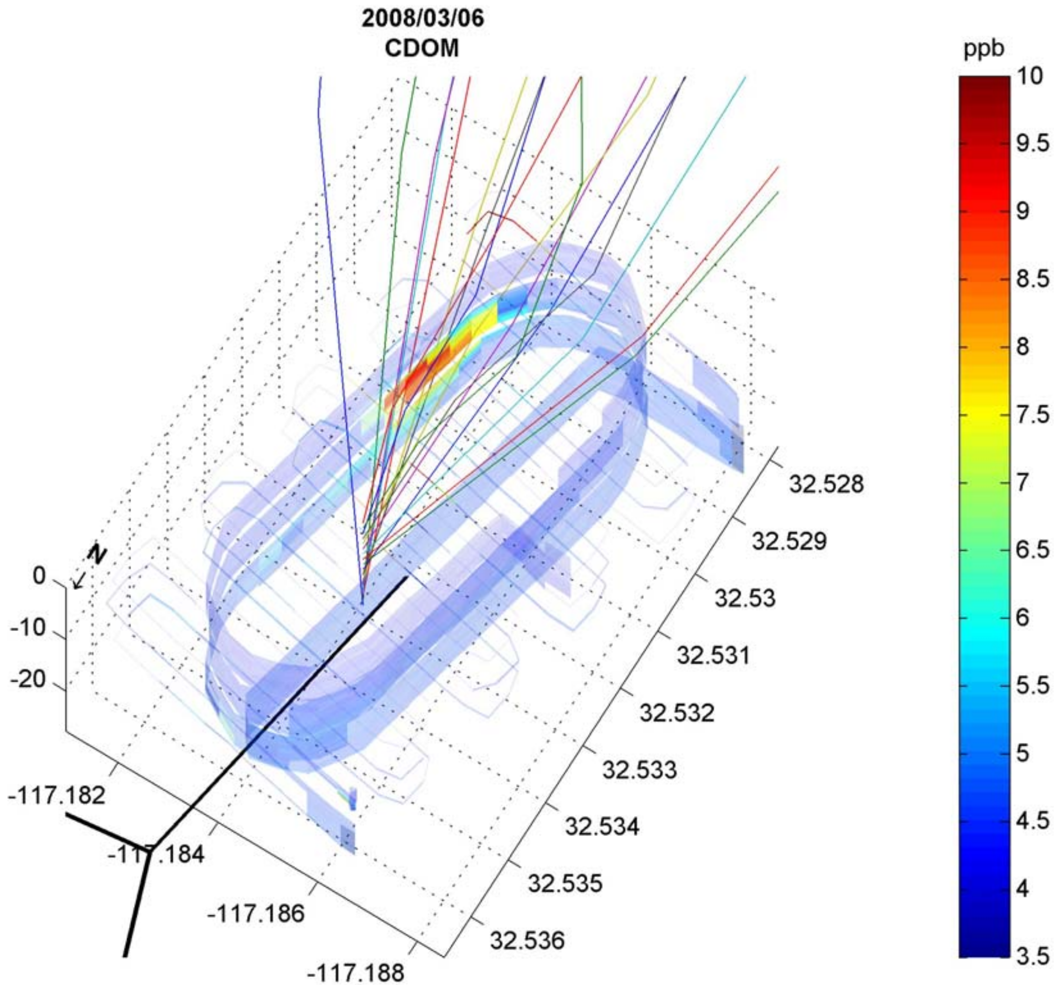
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



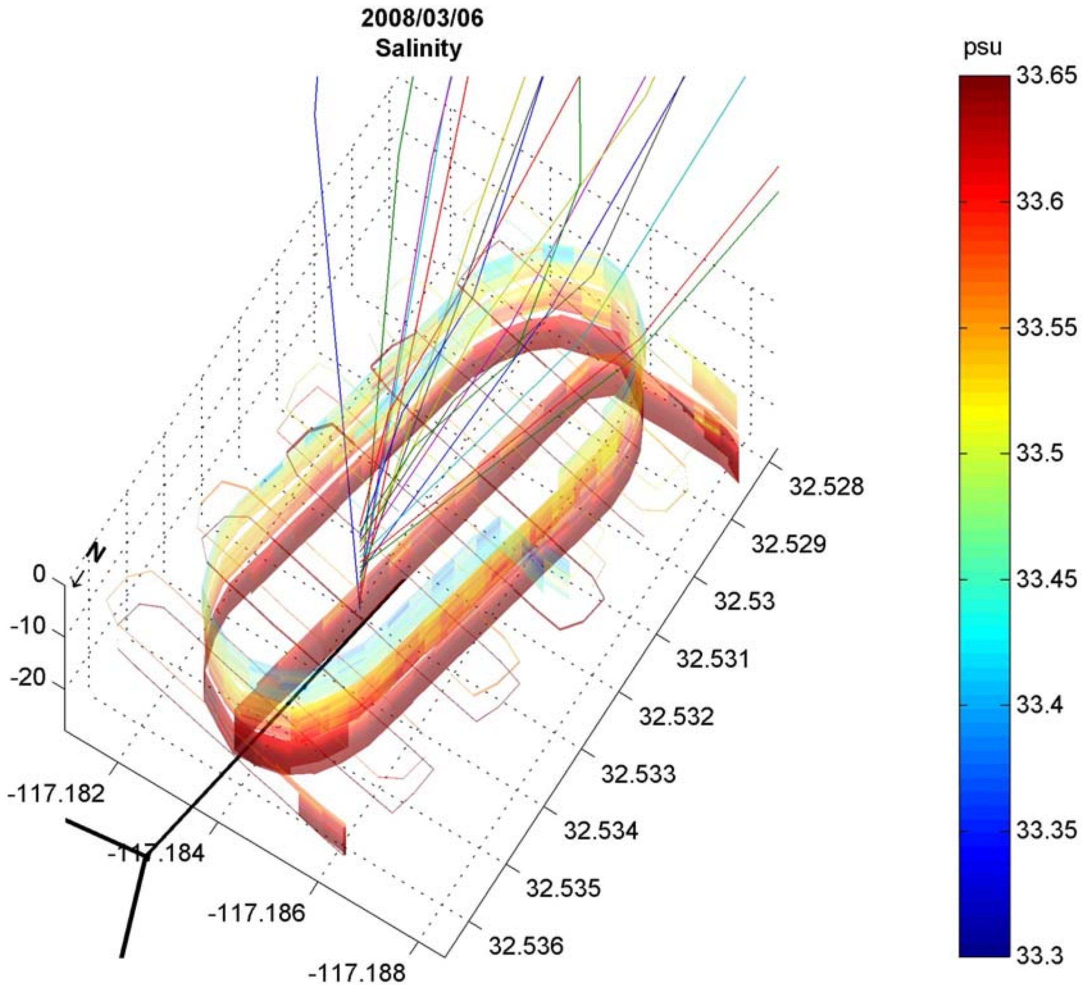
Near-field backscatter measurements at 650 nm shows good correspondence between elevated values (>0.004 m^{-1}) and the estimated plume trajectory indicating elevated turbidity associated with the effluent.



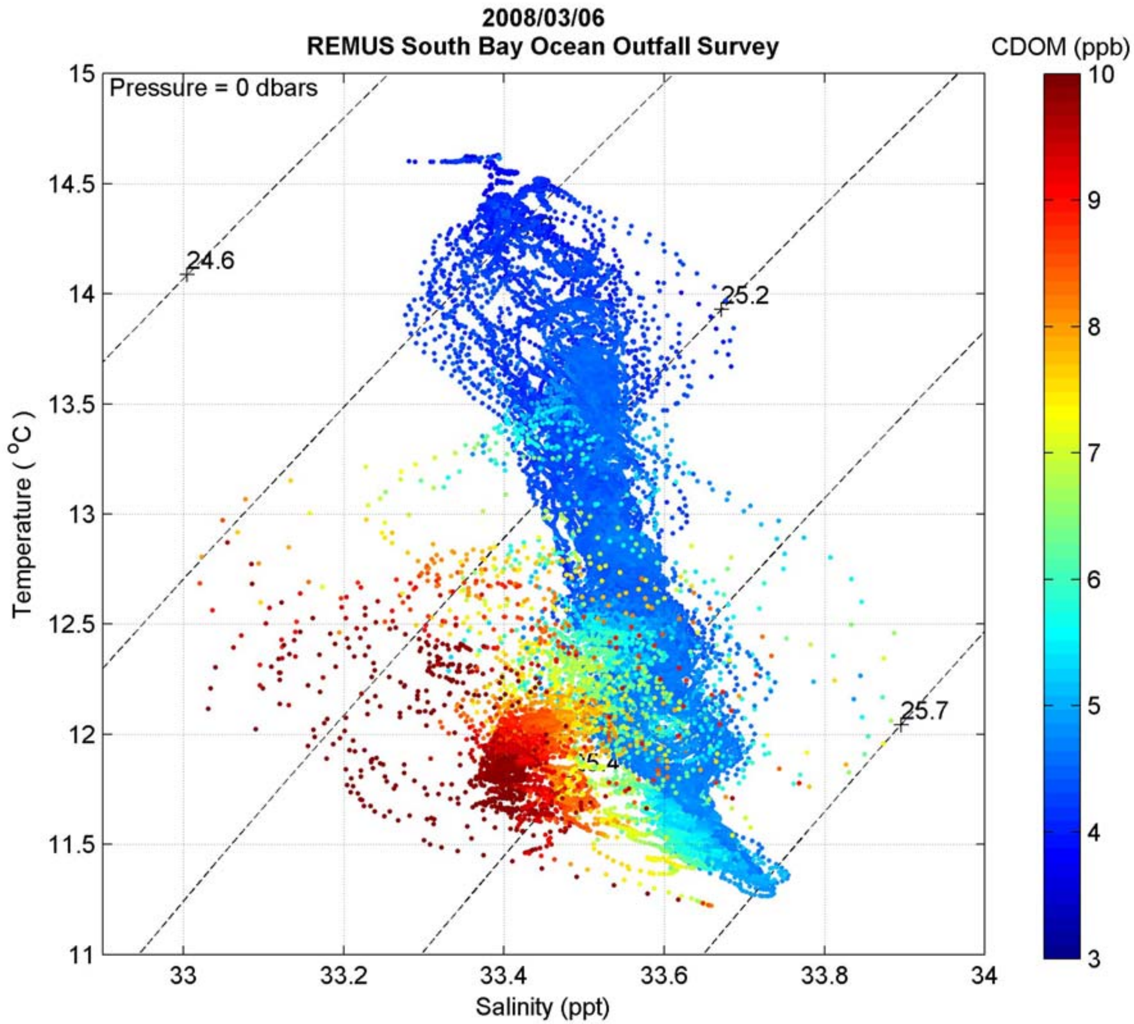
Near-field backscatter measurements at 880 nm shows good correspondence between elevated values (>0.01 m^{-1}) and the estimated plume trajectory indicating elevated turbidity associated with the effluent.



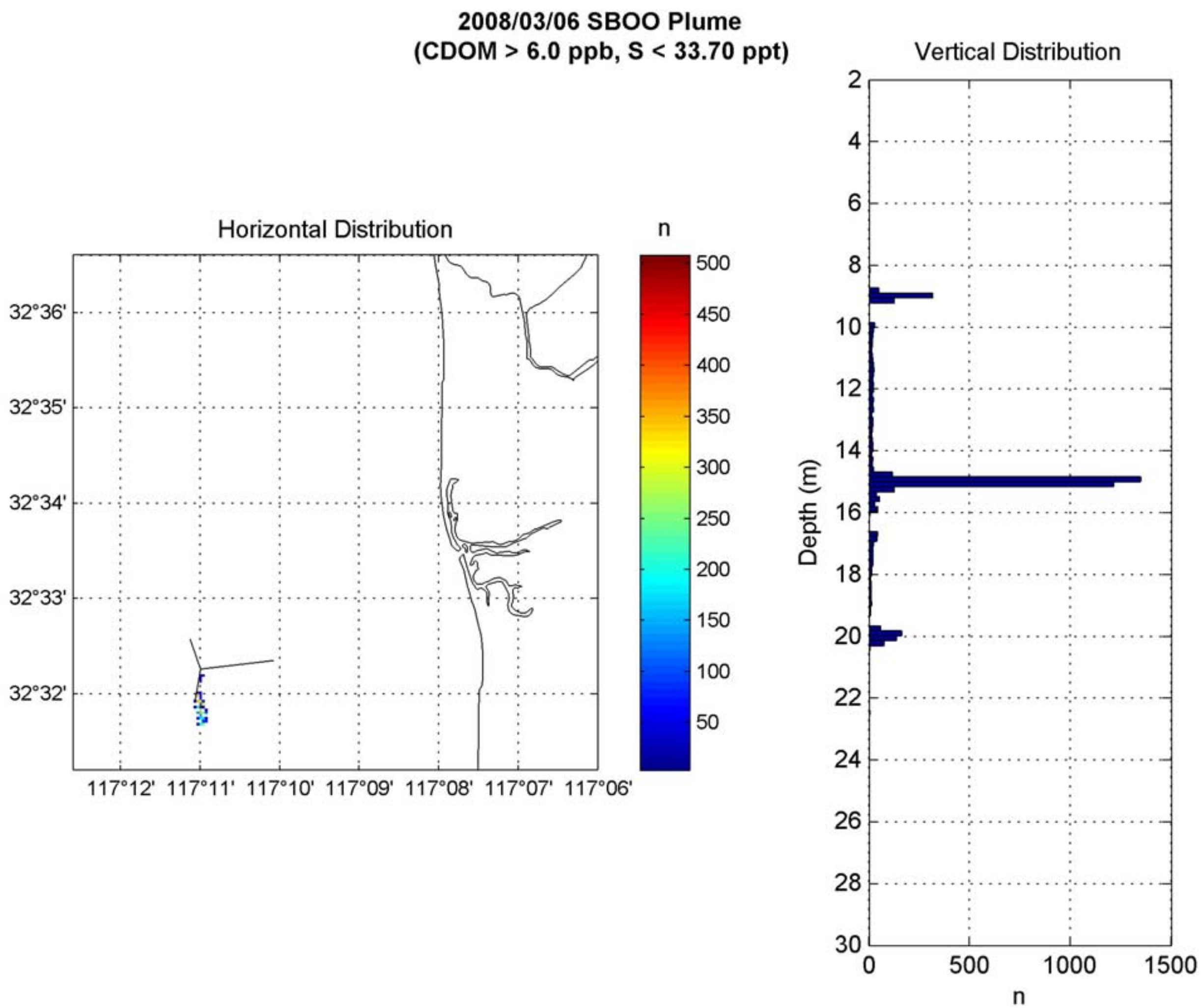
Near-field CDOM measurements shows good correspondence between elevated values (> 7 ppb) and the estimated plume trajectory.



Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Low salinity near the outfall and northward shows good agreement with the estimated trajectory.

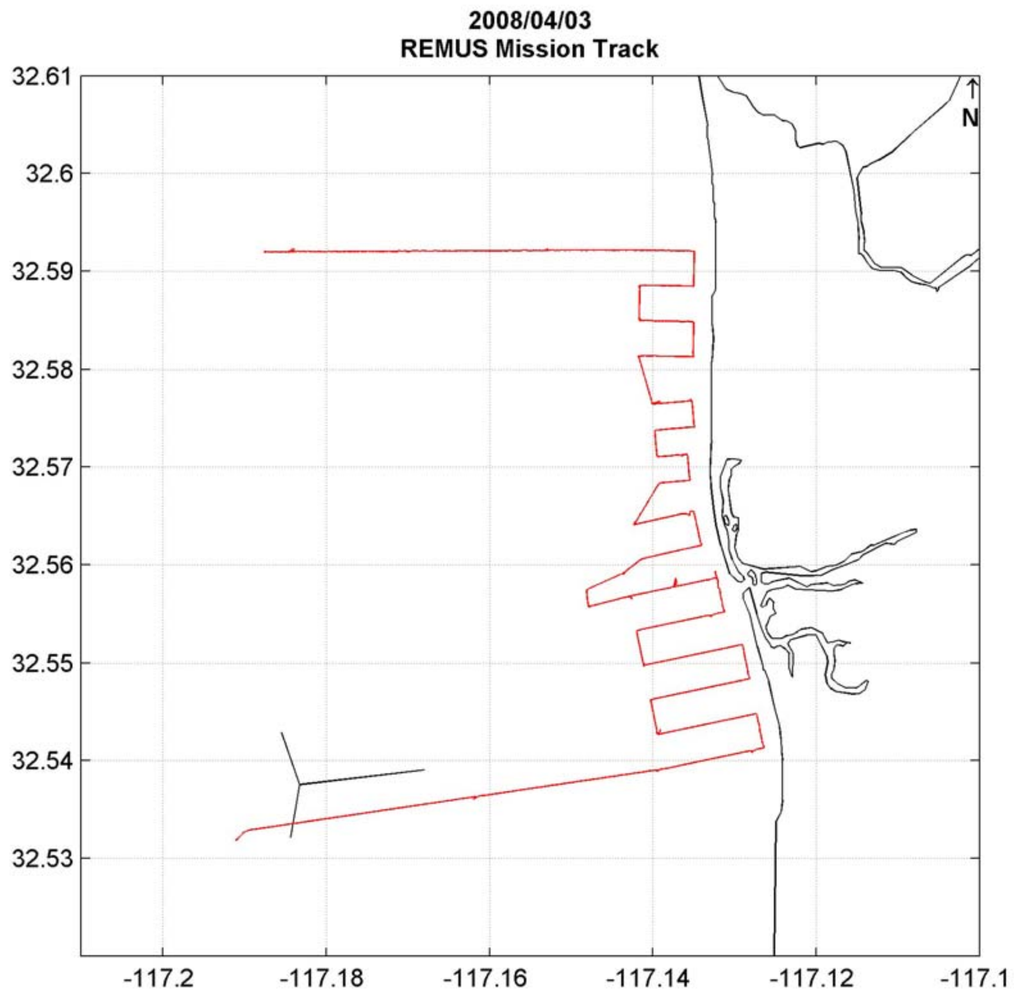


Temperature-Salinity (TS) diagram showing the distribution of watermasses by density (diagonal grid, units of kg/m^3 – 1000) and CDOM concentration. The outfall plume is distinguished as a fresher (lower salinity) watermass with high CDOM concentrations (> 6 ppb).

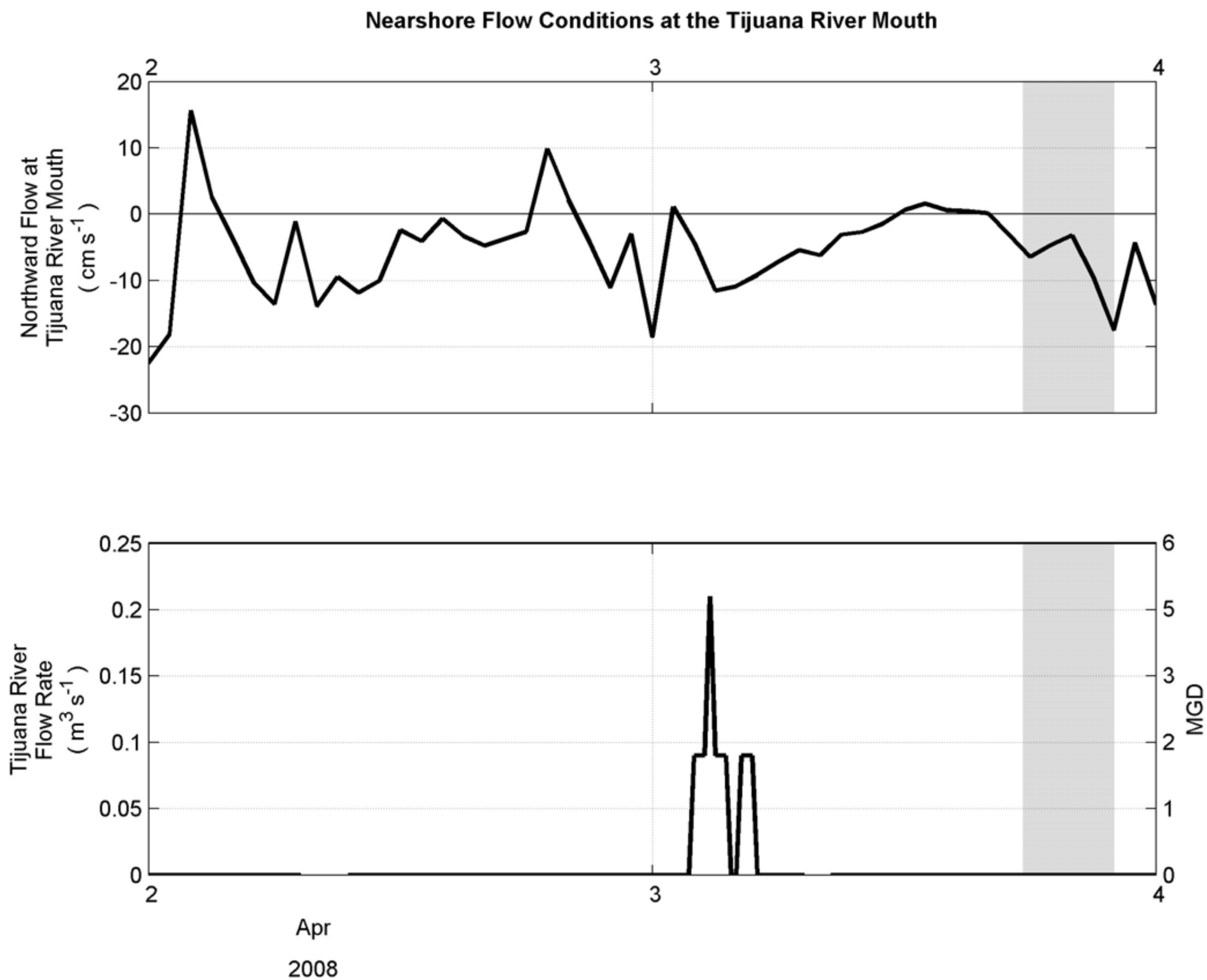


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

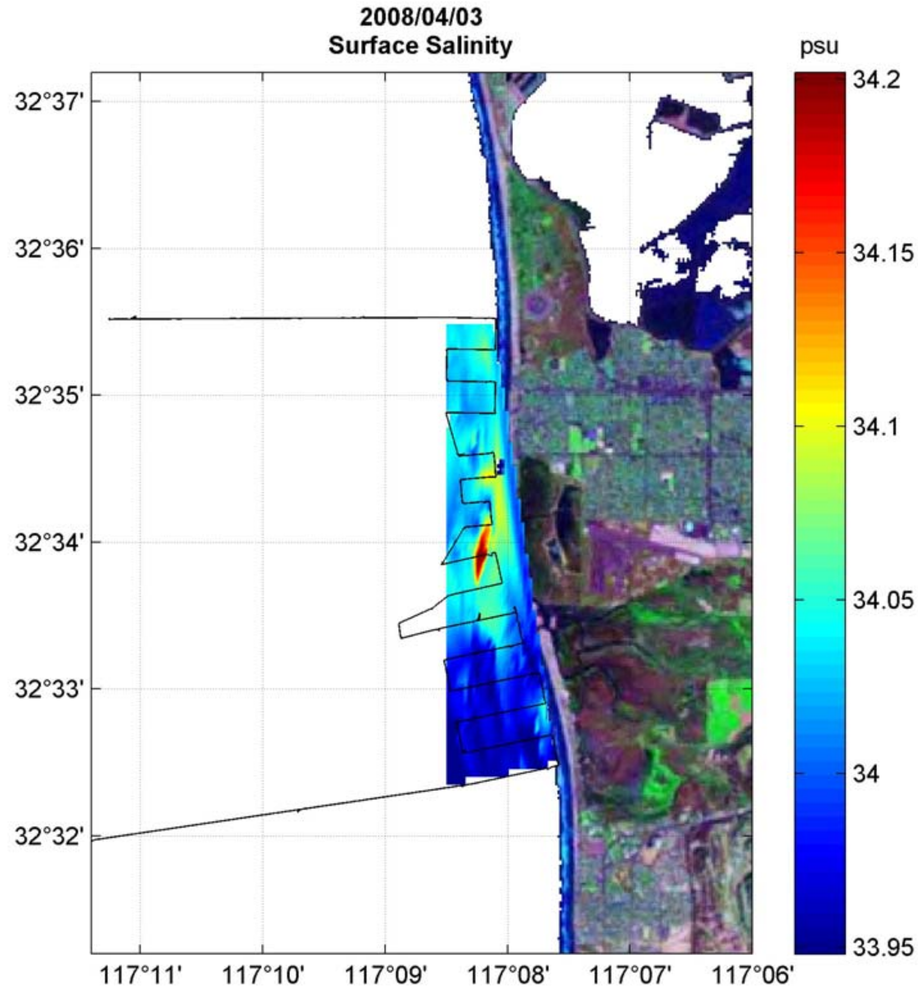
Appendix A.12 2008/04/03 Mission Summary



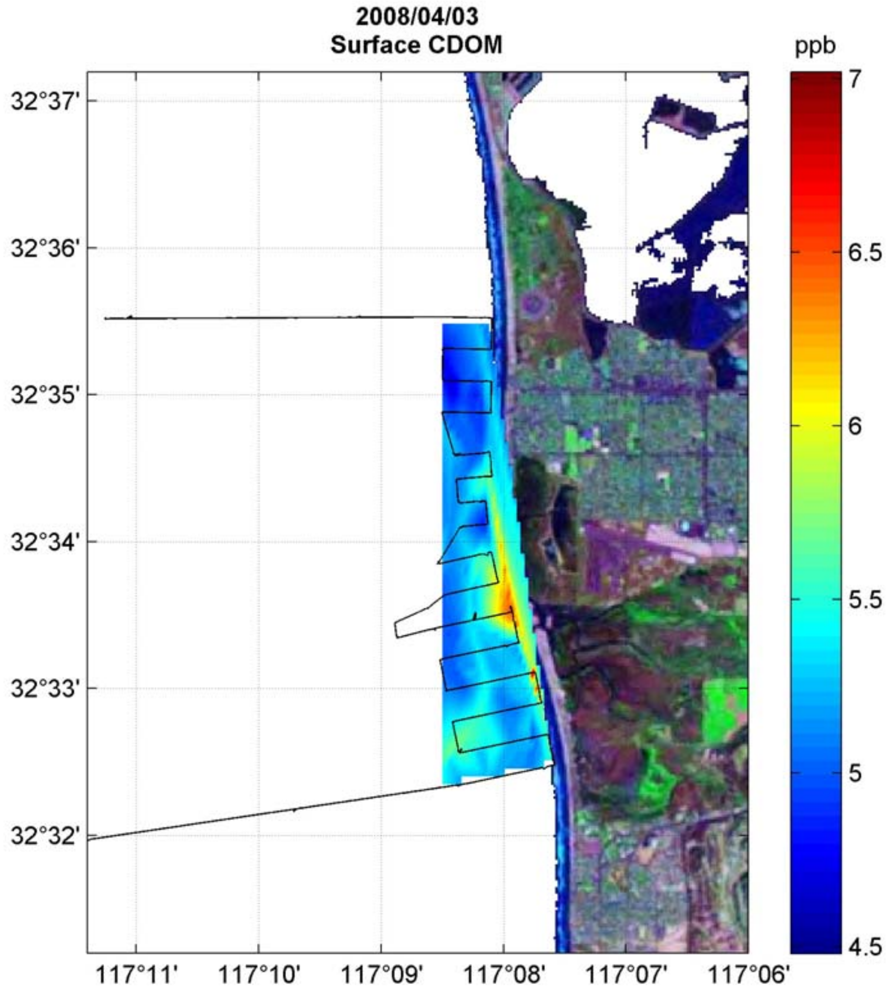
REMUS track (red) for a Tijuana River mission. The SBOO is shown in black offshore.



Alongshore surface current velocity measured by HF-Radar at the Tijuana River mouth (top) and flow rate from the Tijuana River as measured by the IBWC gauge (bottom). The grey panel indicates the sampling period.

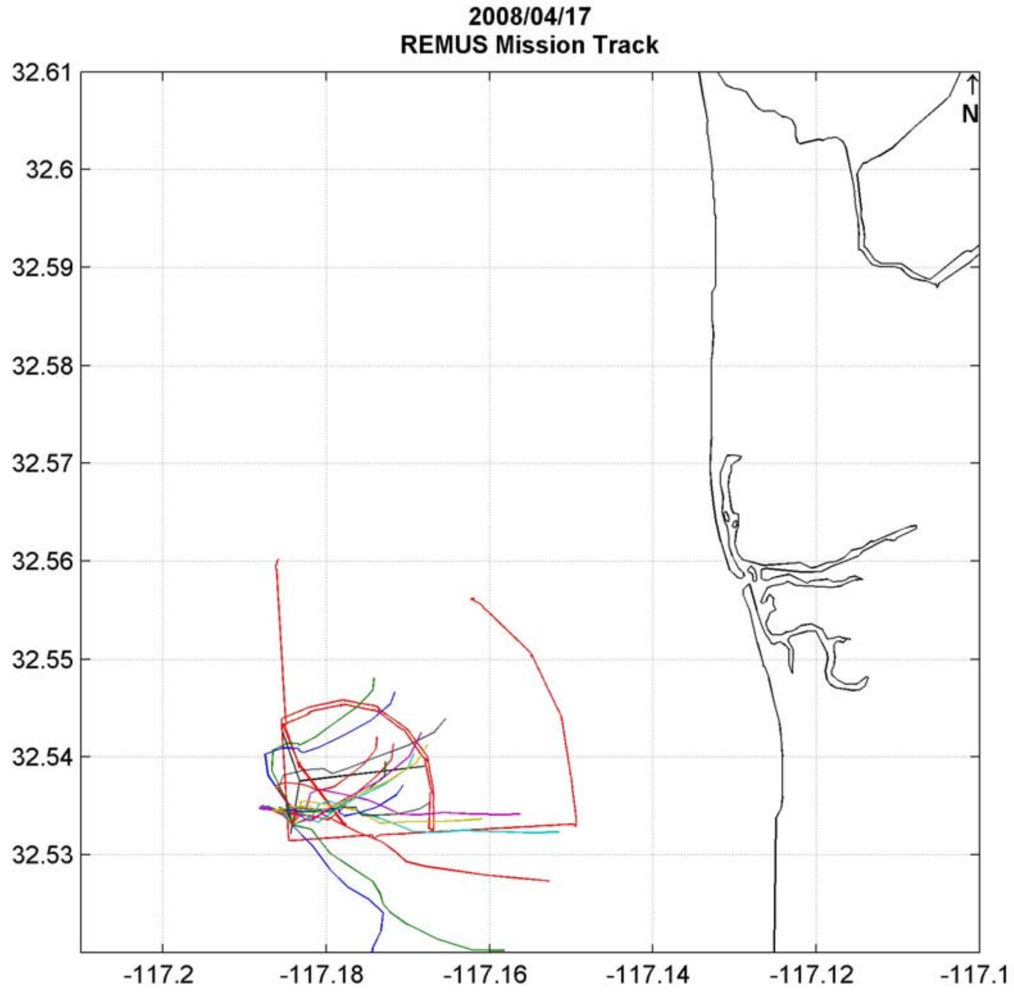


Low surface salinity values at the river mouth and to the south show the distribution of the Tijuana River plume.

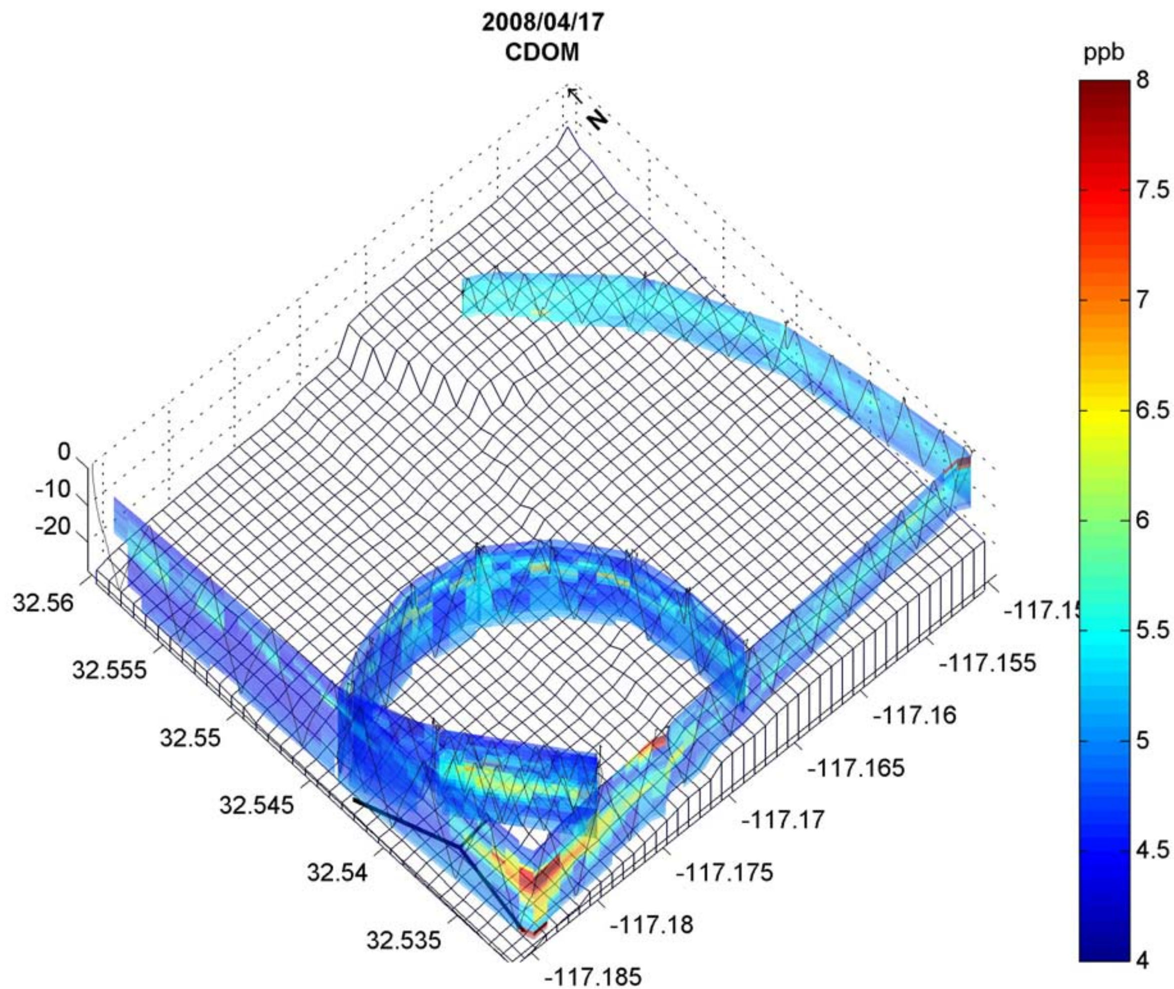


Elevated surface CDOM values (> 5 ppb) at the river mouth and to the south show the distribution of the Tijuana River plume.

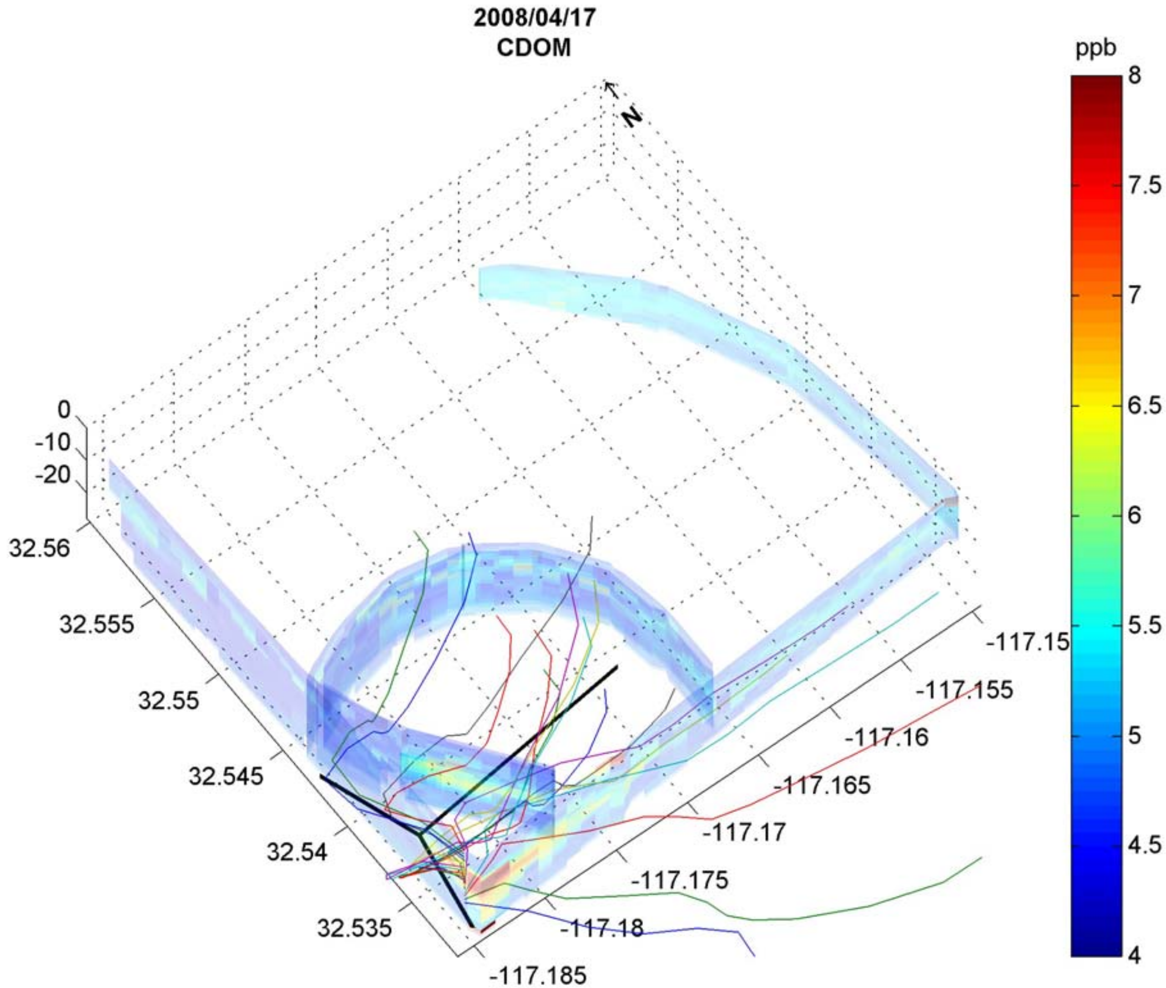
Appendix A.13 2008/04/17 Mission Summary



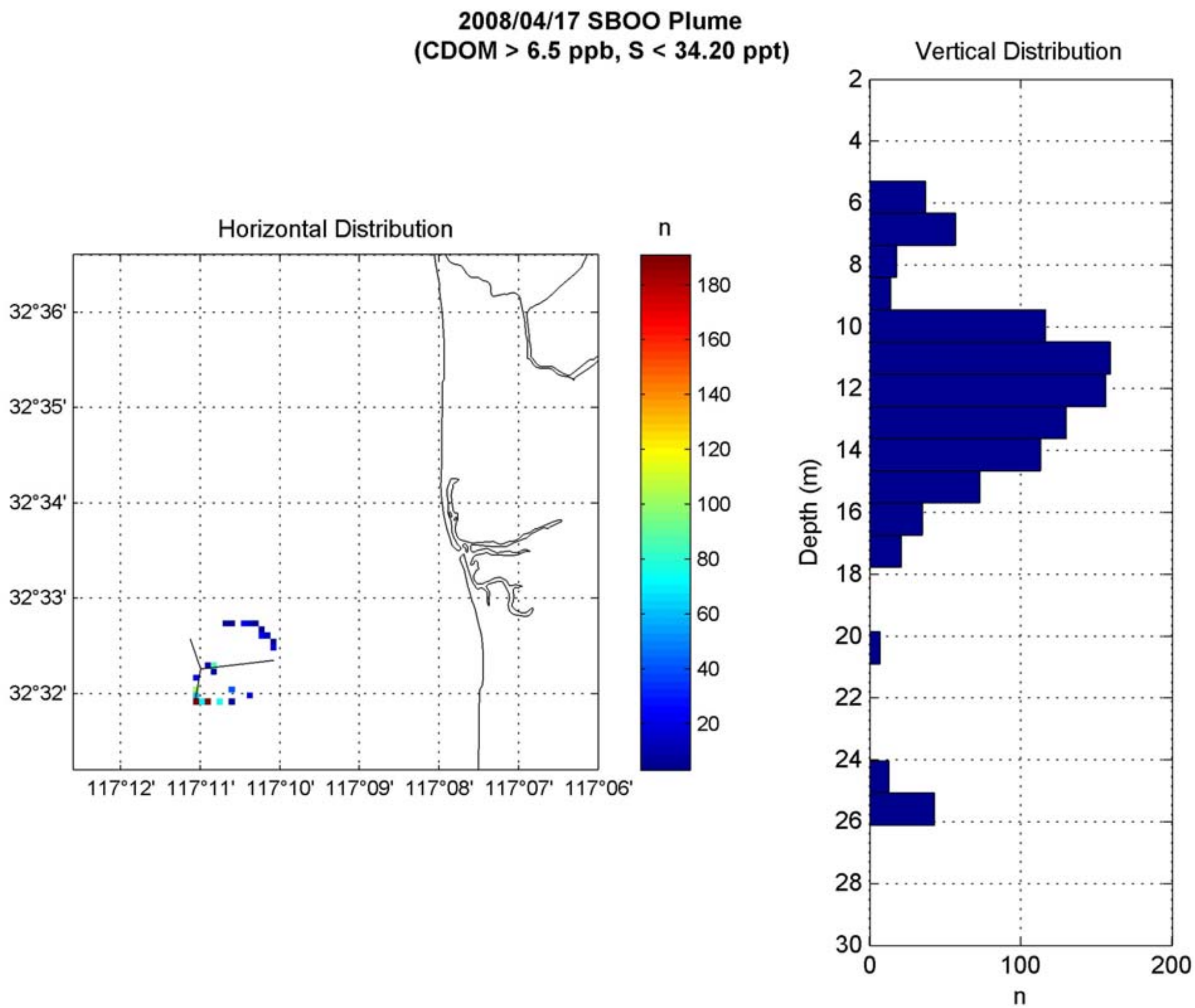
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Elevated CDOM values (> 5 ppb) near the outfall toward the south indicate detection of the outfall plume. CDOM values of approximately 5.5 ppb in the northeast are within the kelp forest and are presumably due to elevated biological activity.

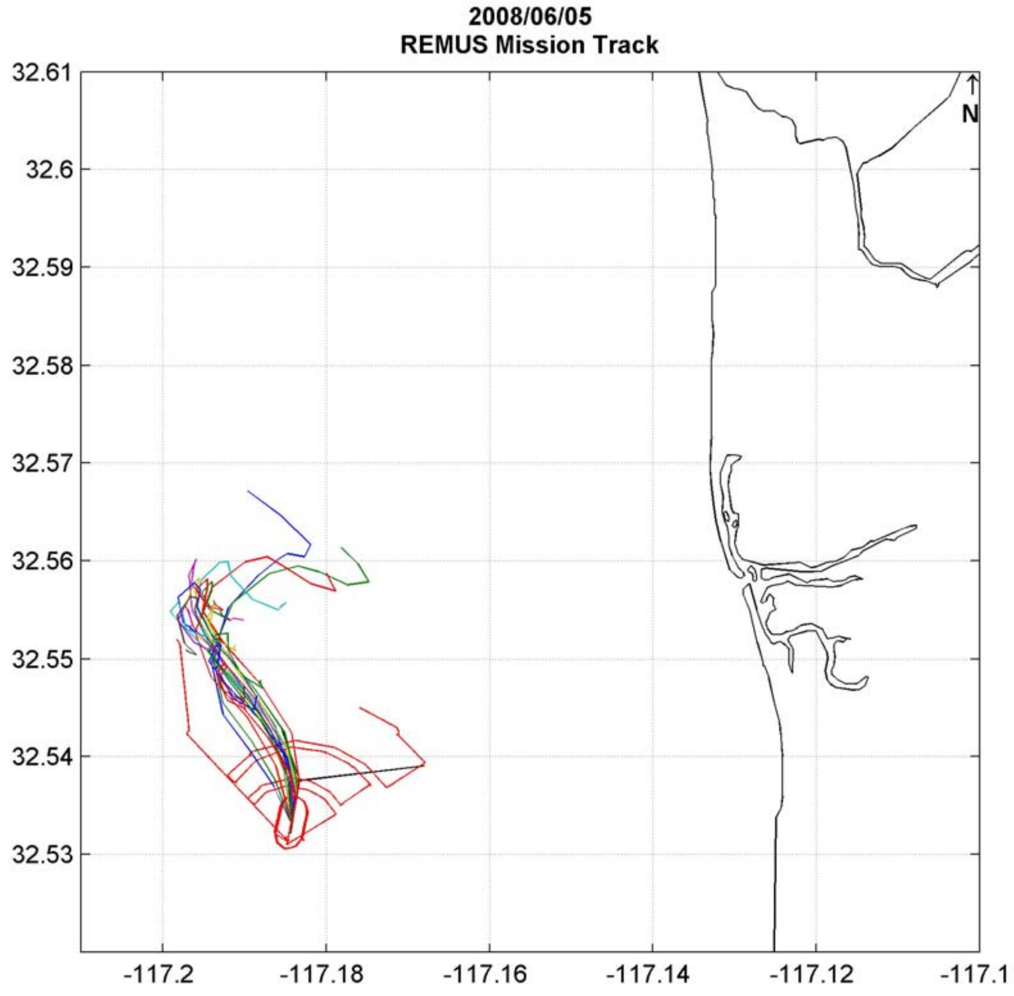


Correspondence between elevated CDOM measurements in the southwest over the outfall and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

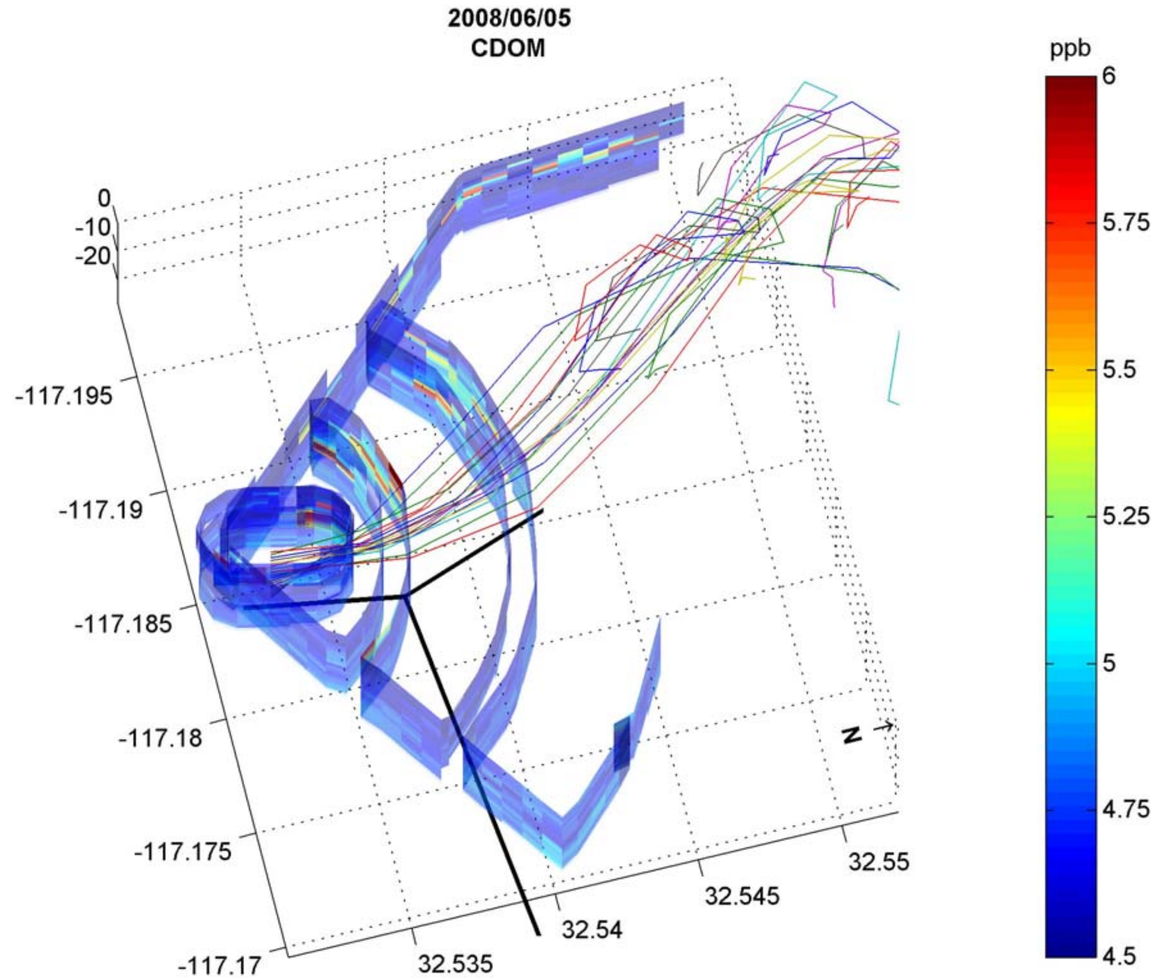


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

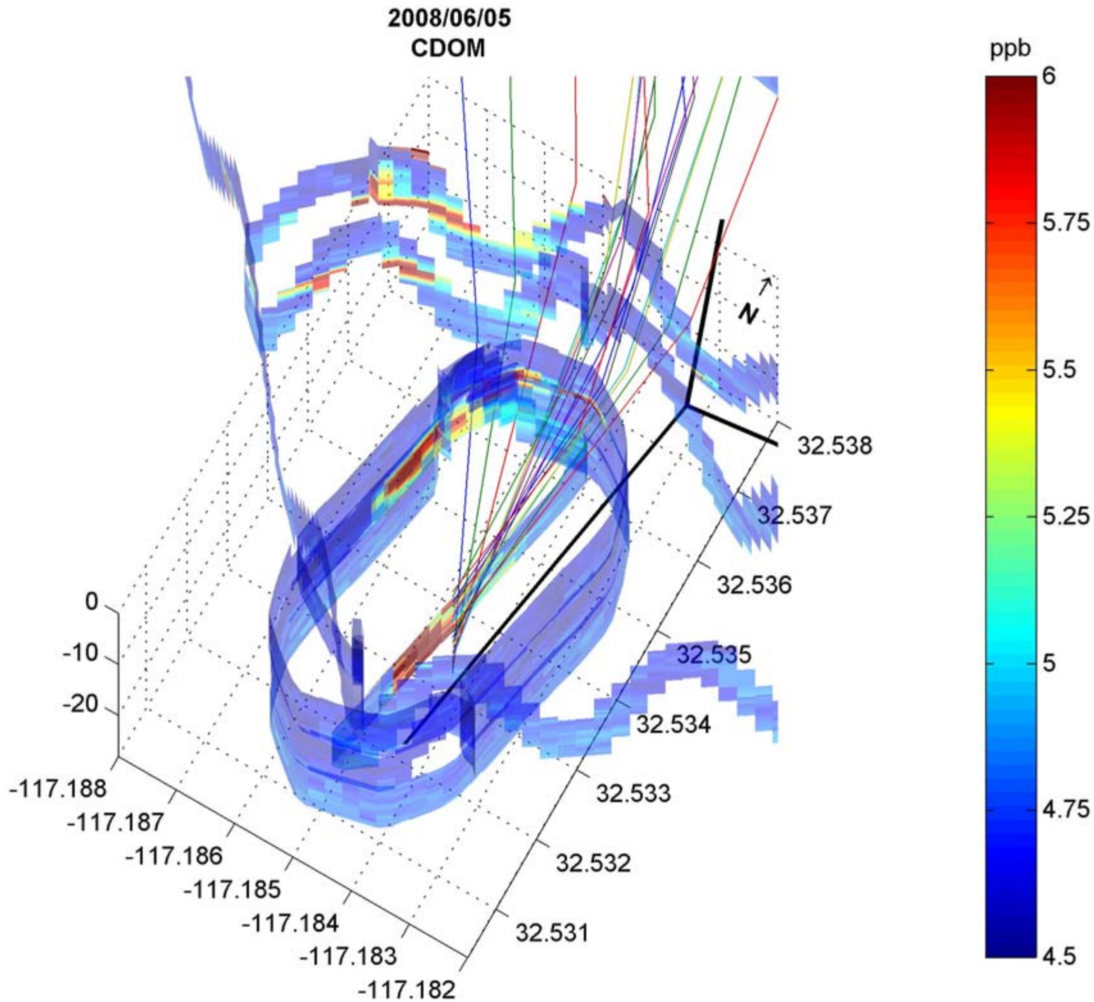
Appendix A.14 2008/06/05 Mission Summary



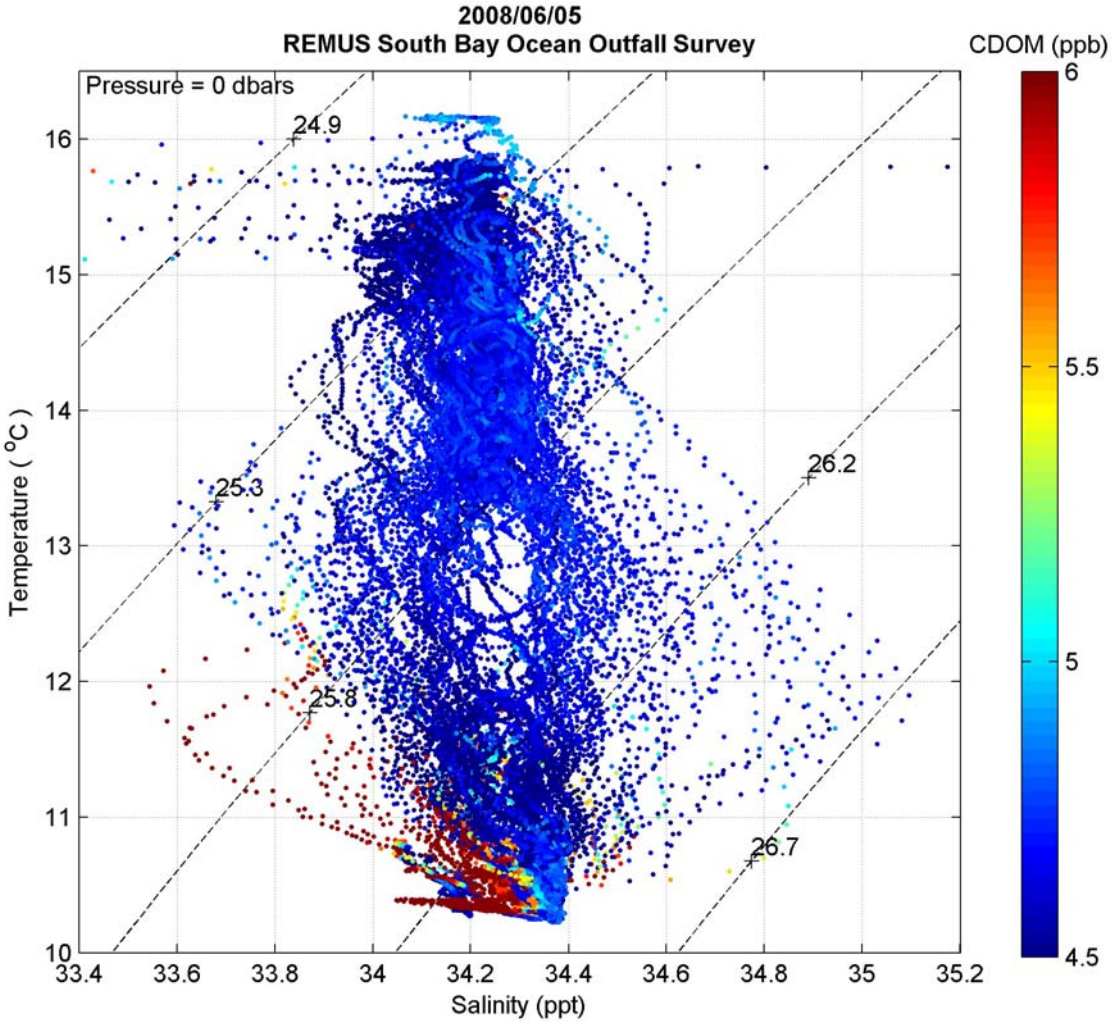
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



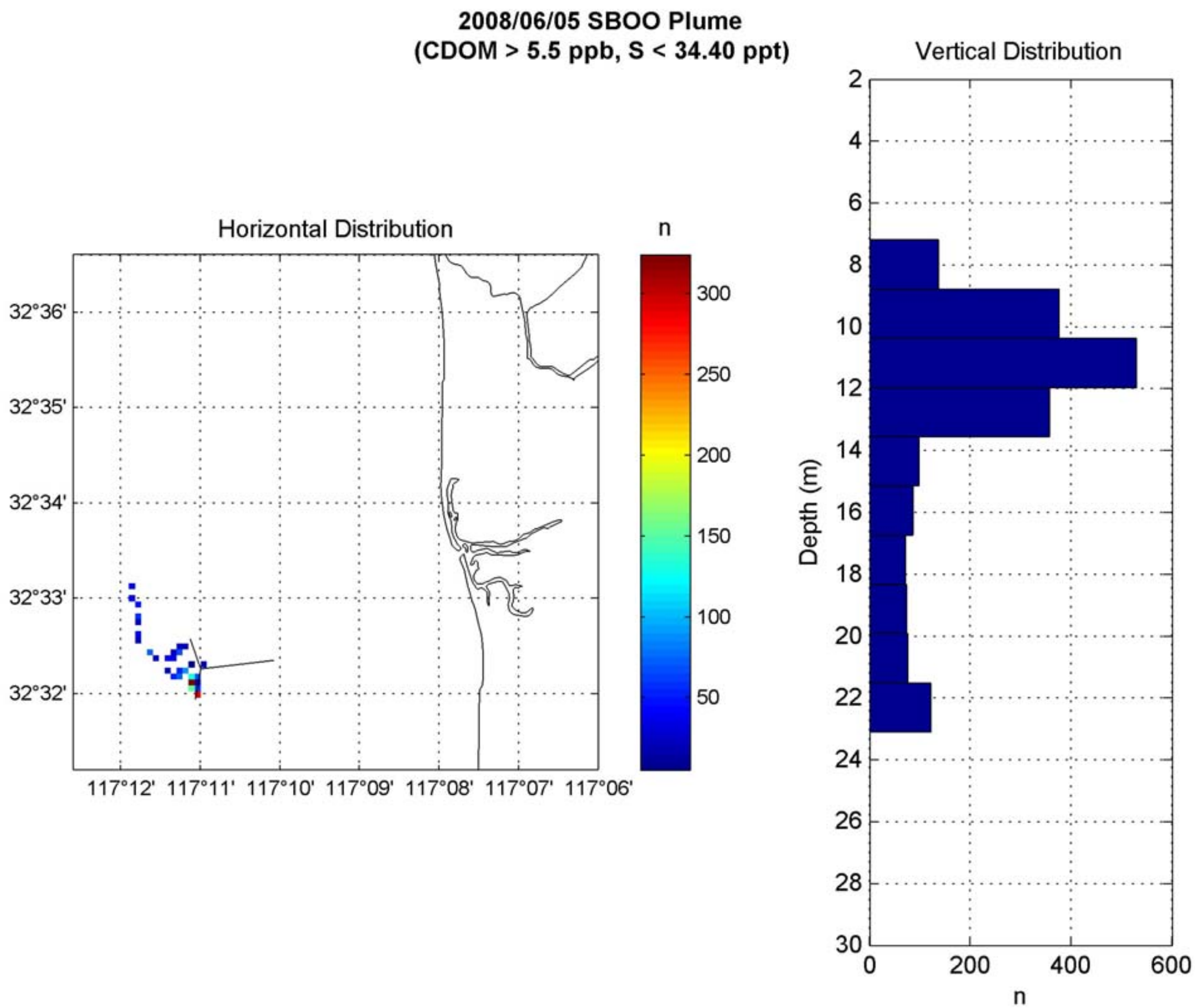
Elevated CDOM measurements (> 5 ppb) show good correspondence with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Near-field CDOM measurements greater than 5 ppb show good correspondence with the estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

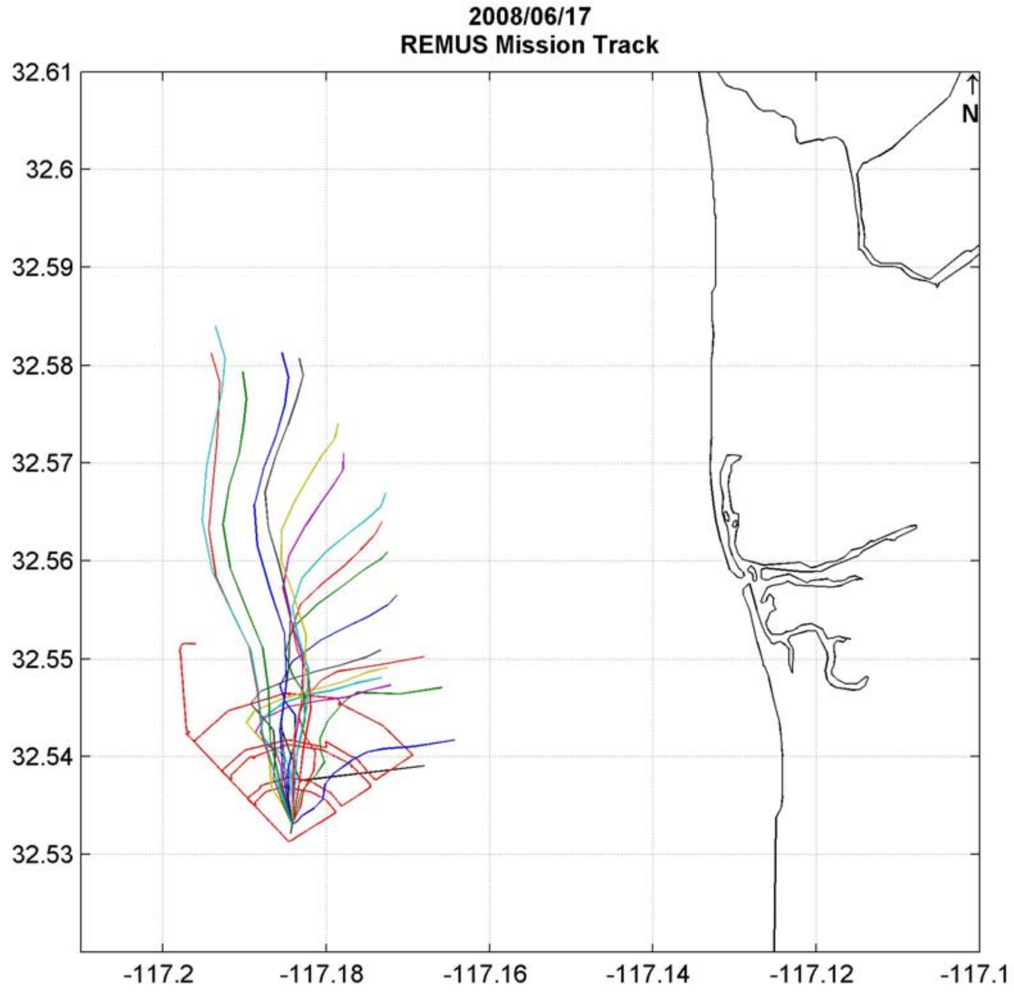


Temperature-Salinity (TS) diagram showing the distribution of watermasses by density (diagonal grid, units of kg/m^3 – 1000) and CDOM concentration. The outfall plume is distinguished as a fresher (lower salinity) watermass with high CDOM concentrations (> 5.5 ppb).

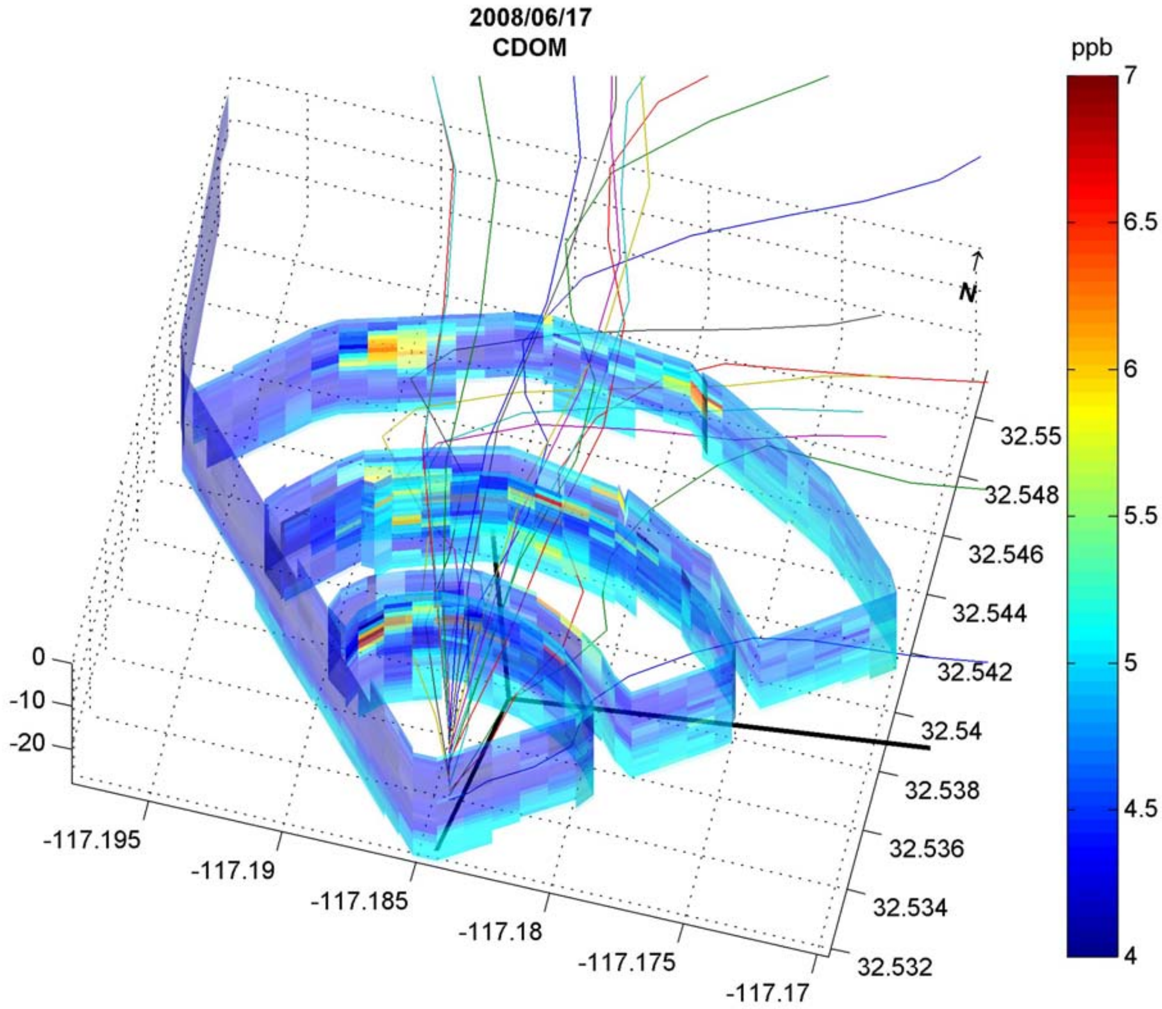


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

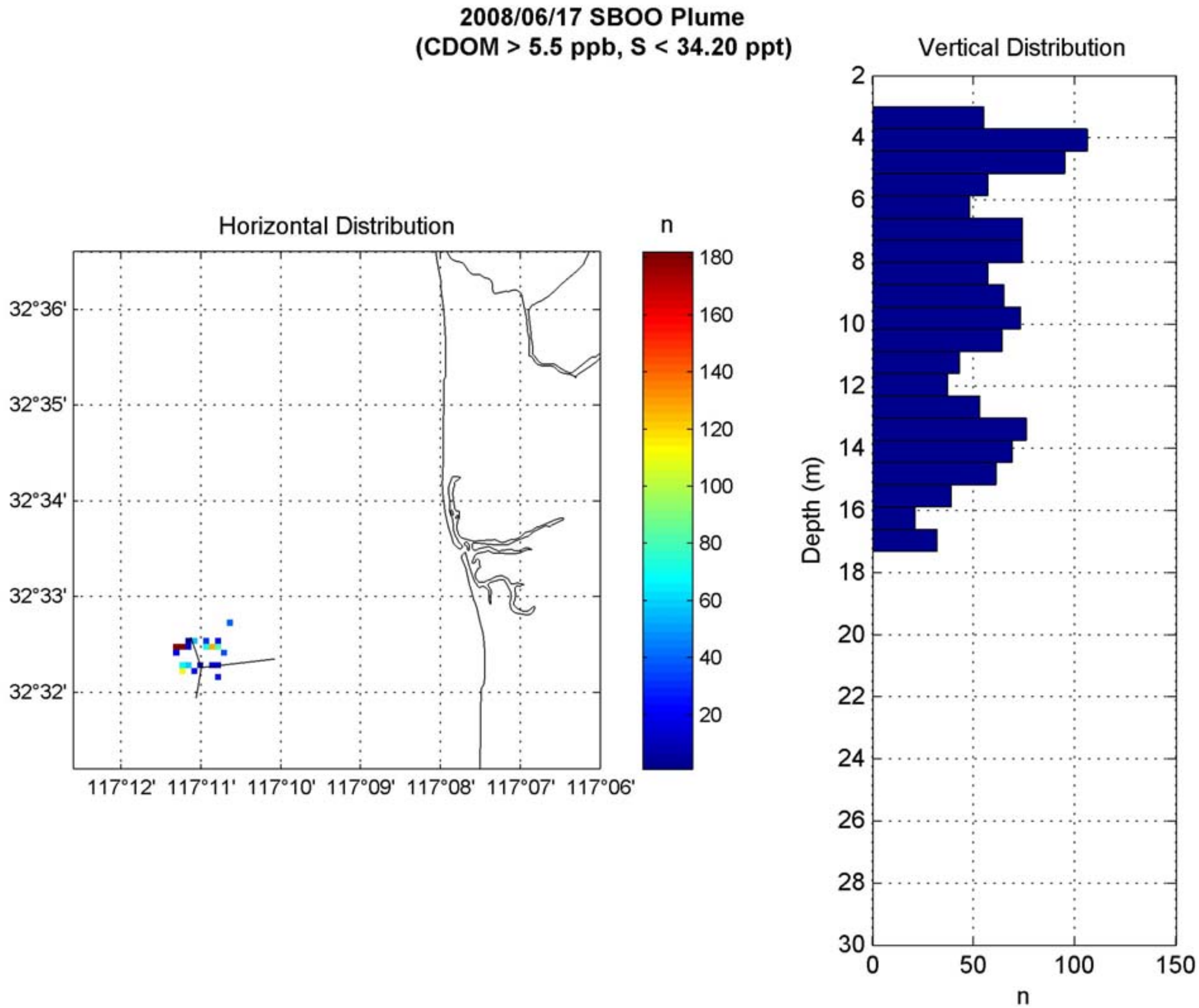
Appendix A.15 2008/06/17 Mission Summary



REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

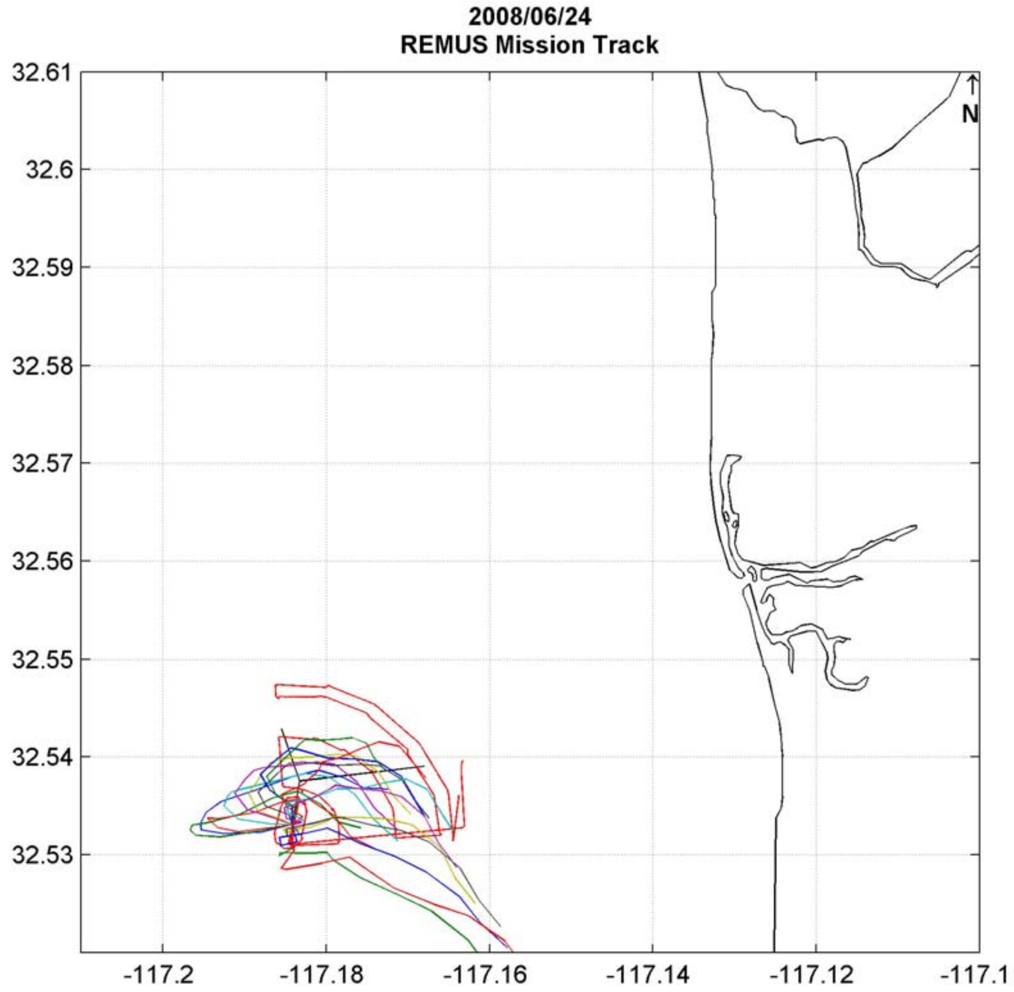


Elevated CDOM measurements (> 5 ppb) show good correspondence with the estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

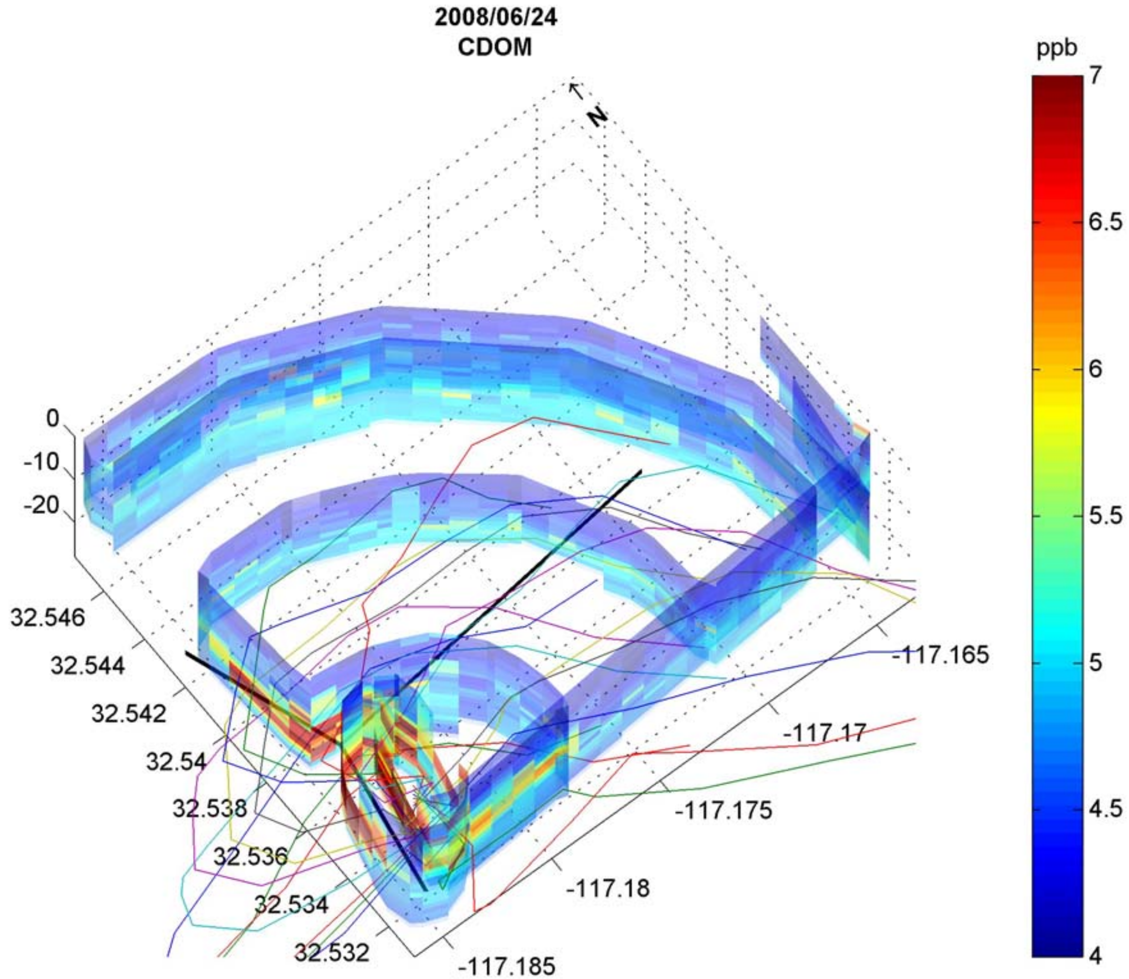


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

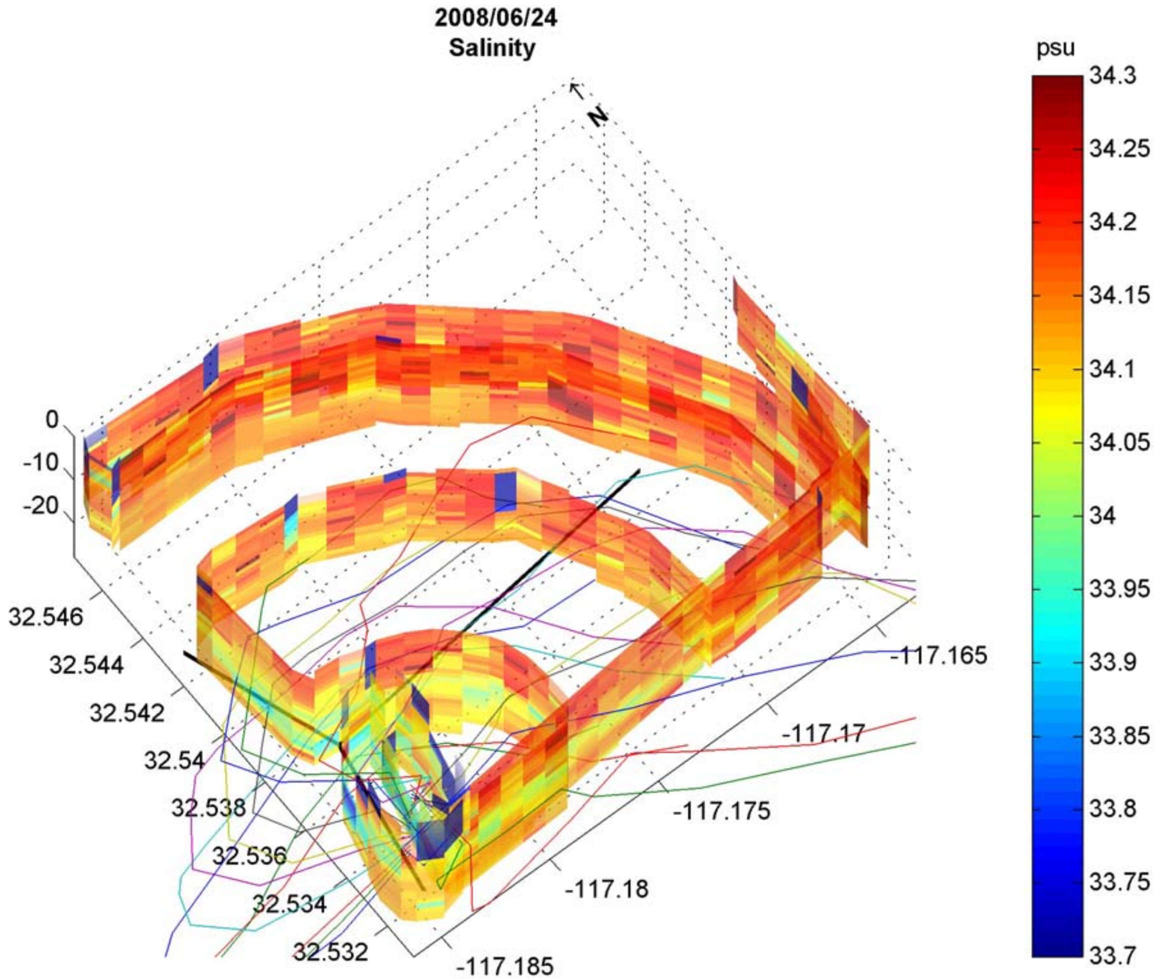
Appendix A.16 2008/06/24 Mission Summary



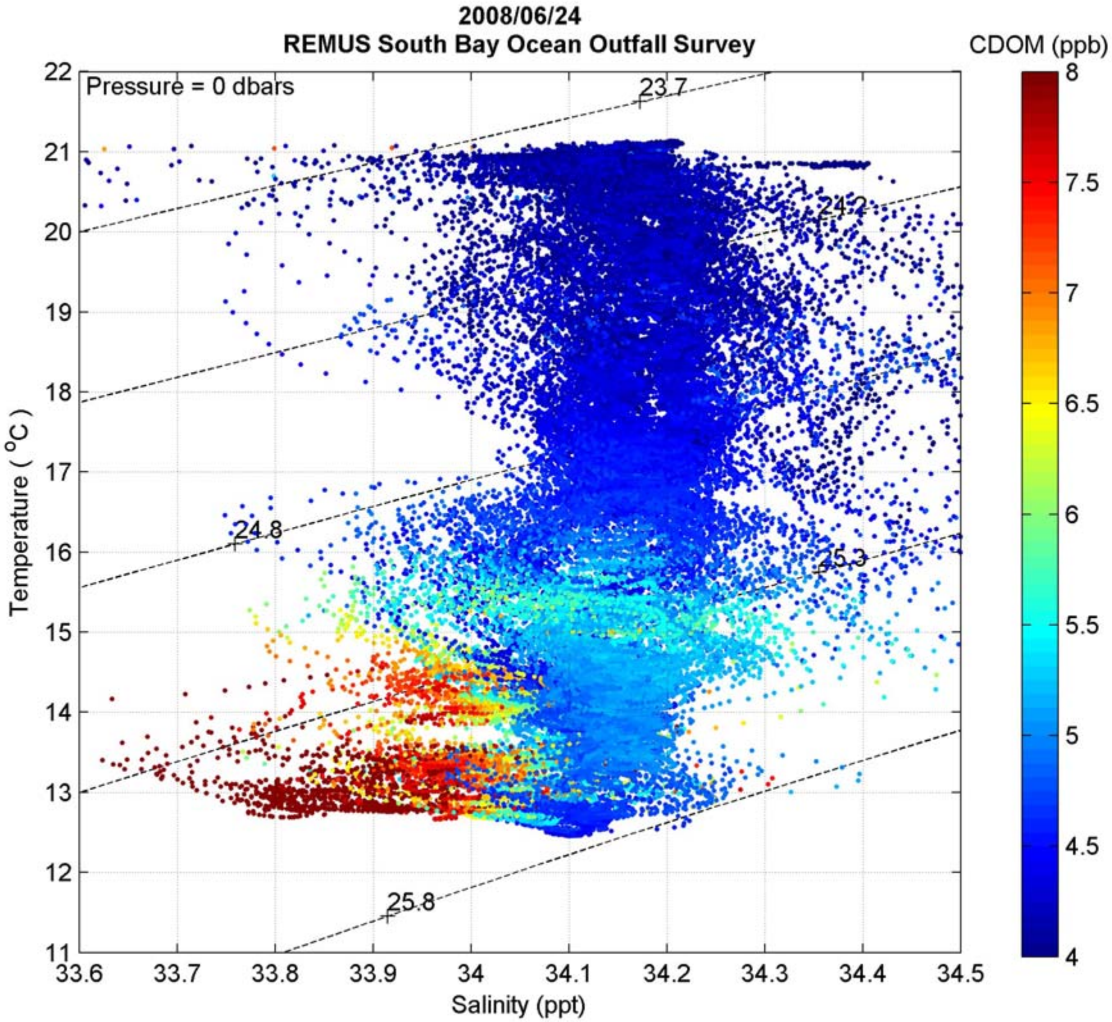
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



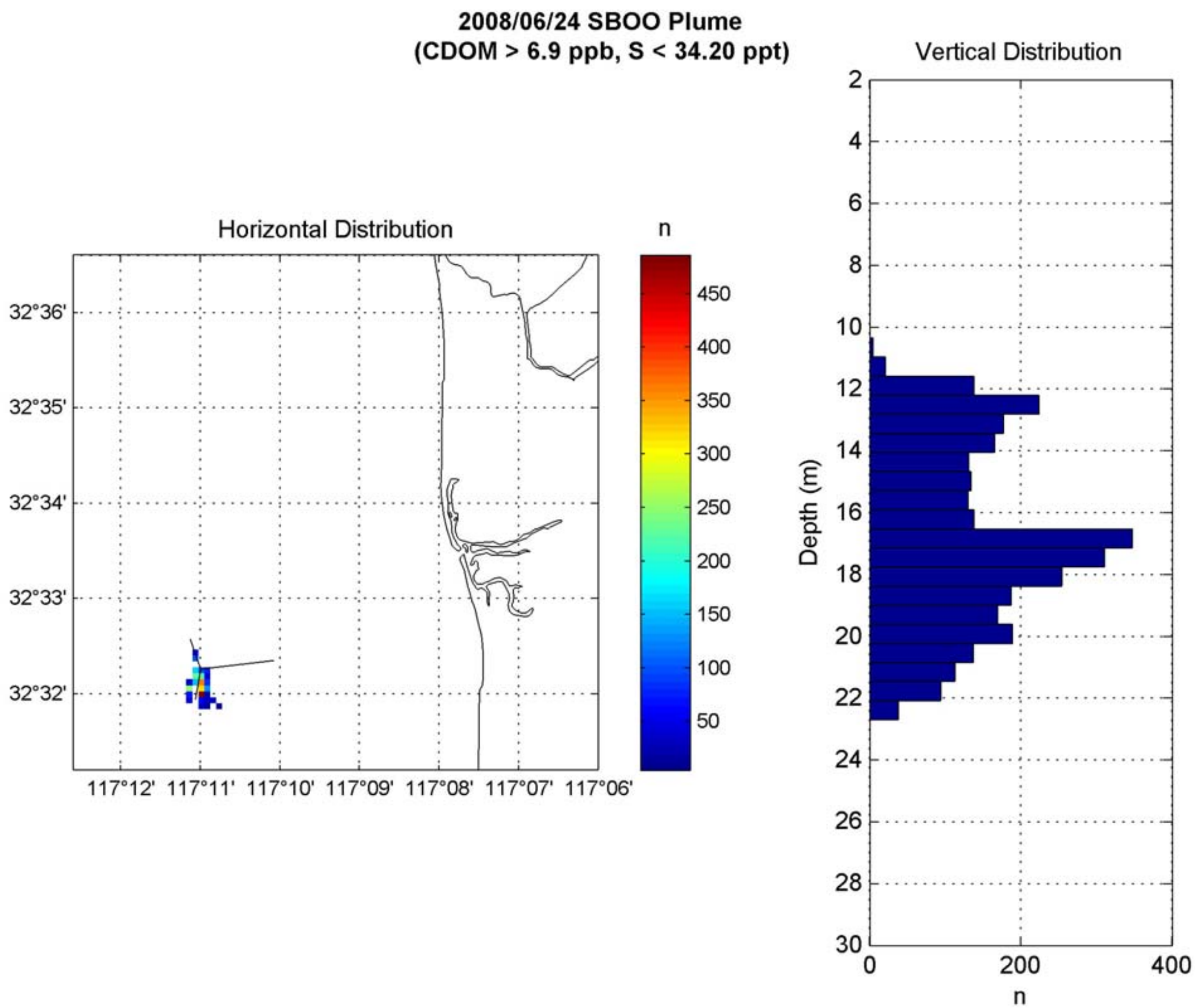
Elevated CDOM measurements (> 5.5 ppb) show good correspondence with the estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Salinity measurements shown with estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy. Low salinity near the outfall and eastward shows good agreement with the estimated trajectory.

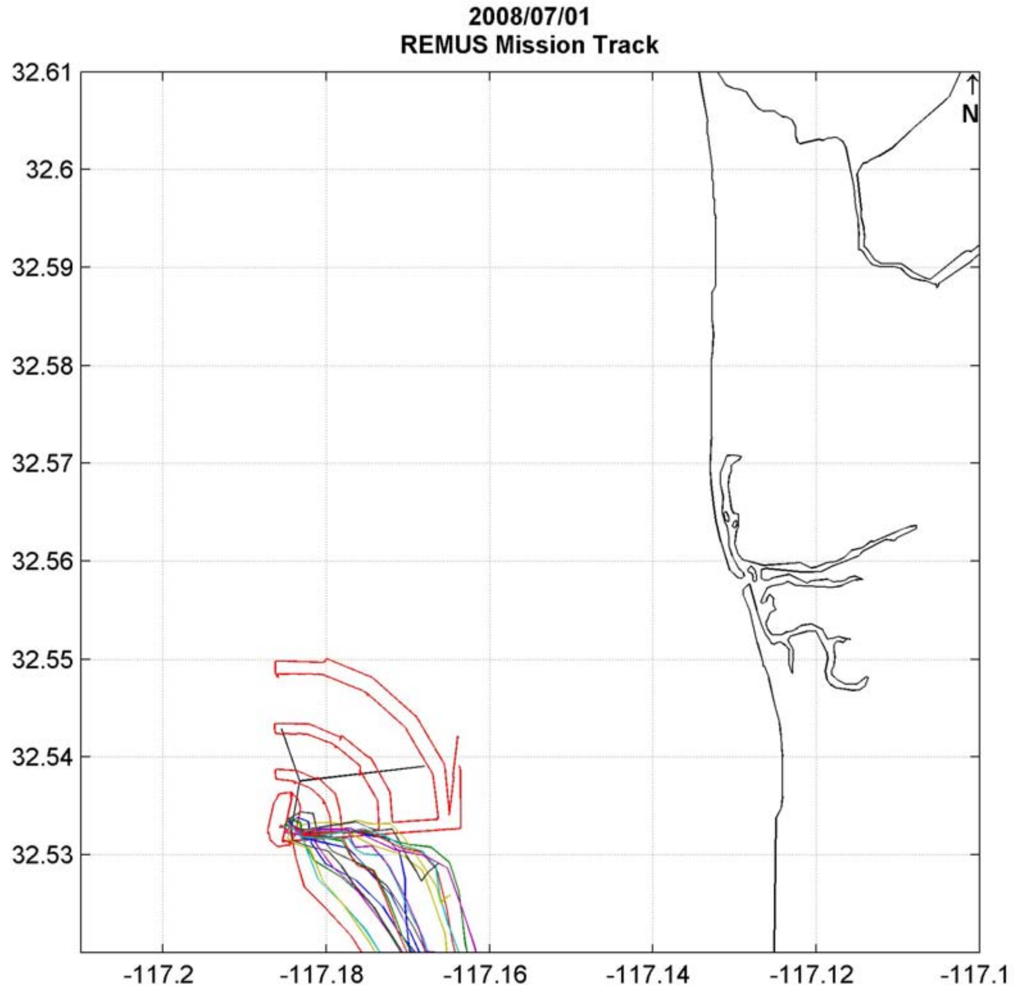


Temperature-Salinity (TS) diagram showing the distribution of watermasses by density (diagonal grid, units of kg/m^3 – 1000) and CDOM concentration. The outfall plume is distinguished as a fresher (lower salinity) watermass with high CDOM concentrations (> 7 ppb).

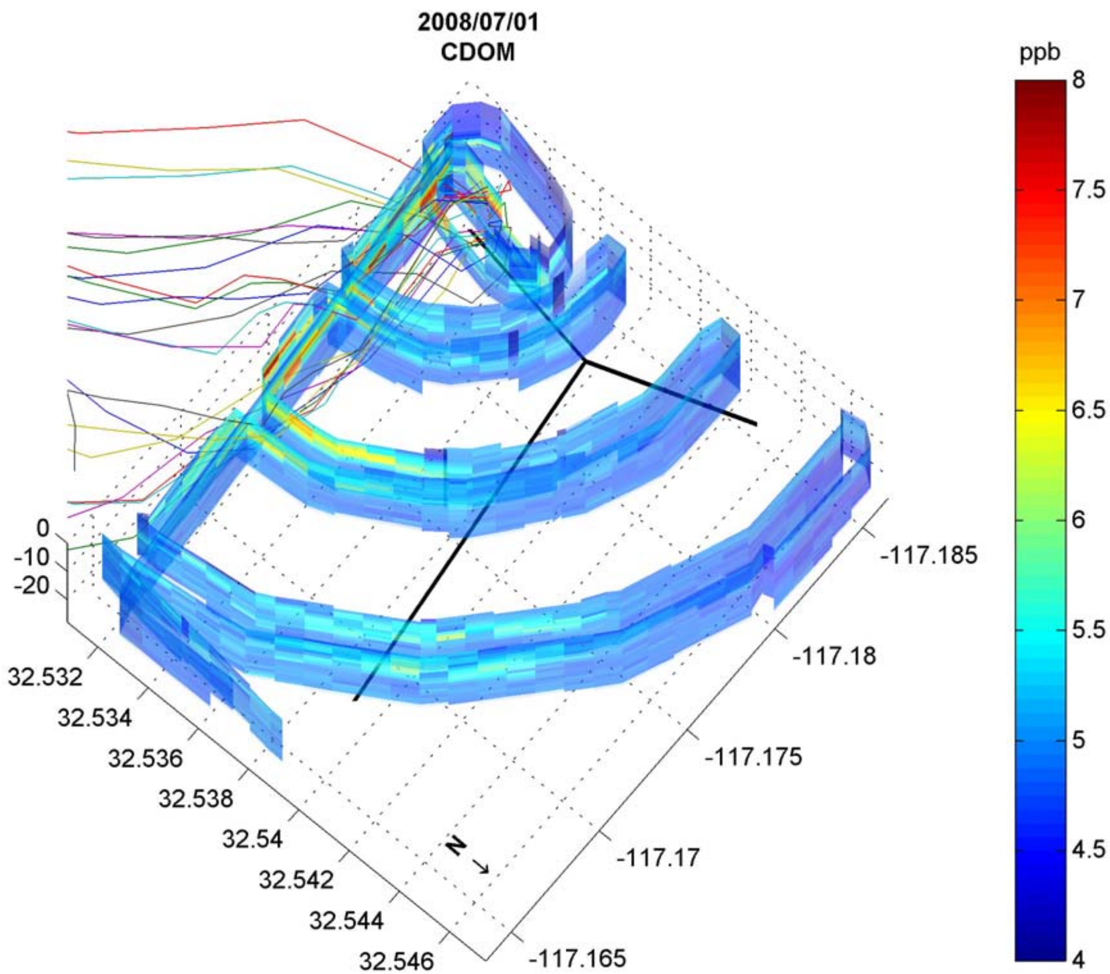


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

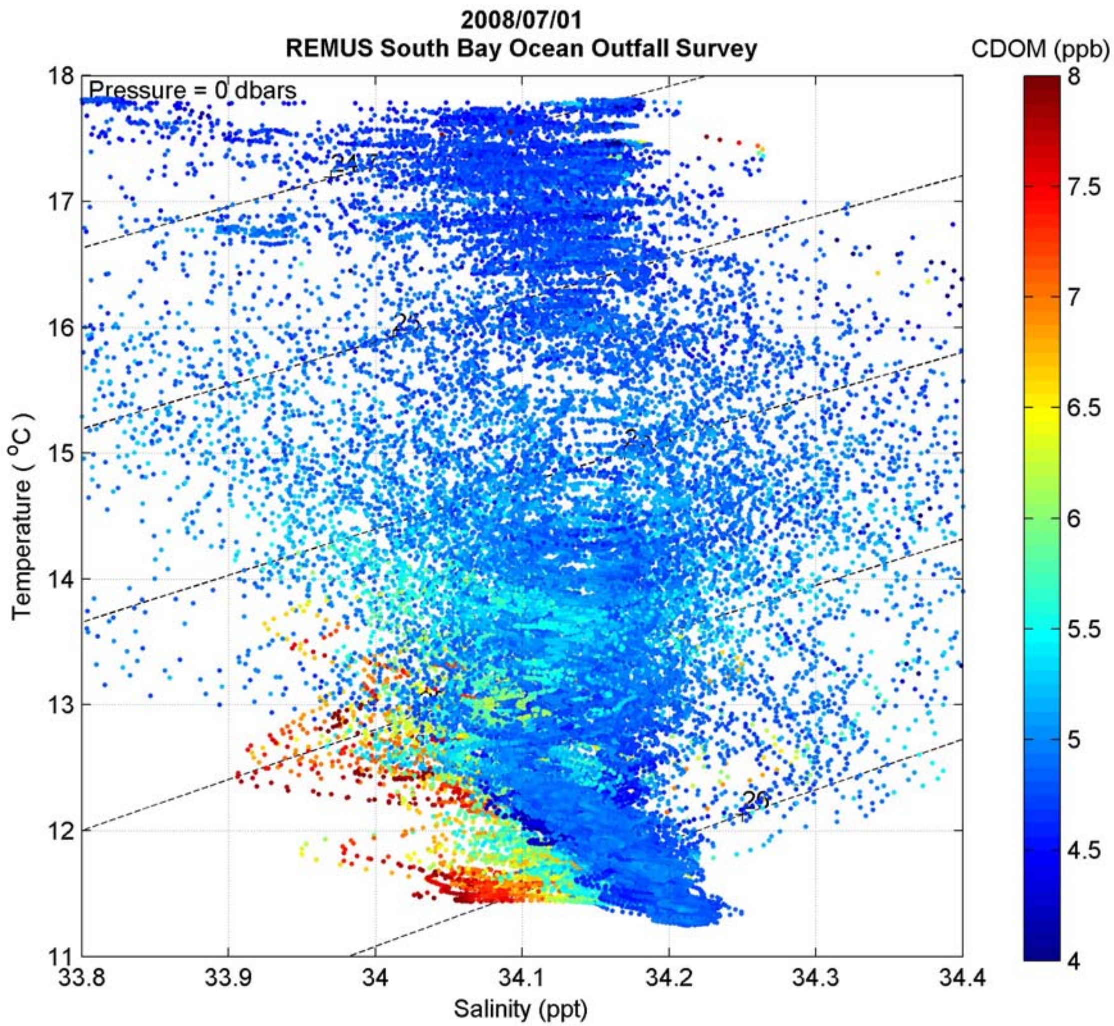
Appendix A.17 2008/07/01 Mission Summary



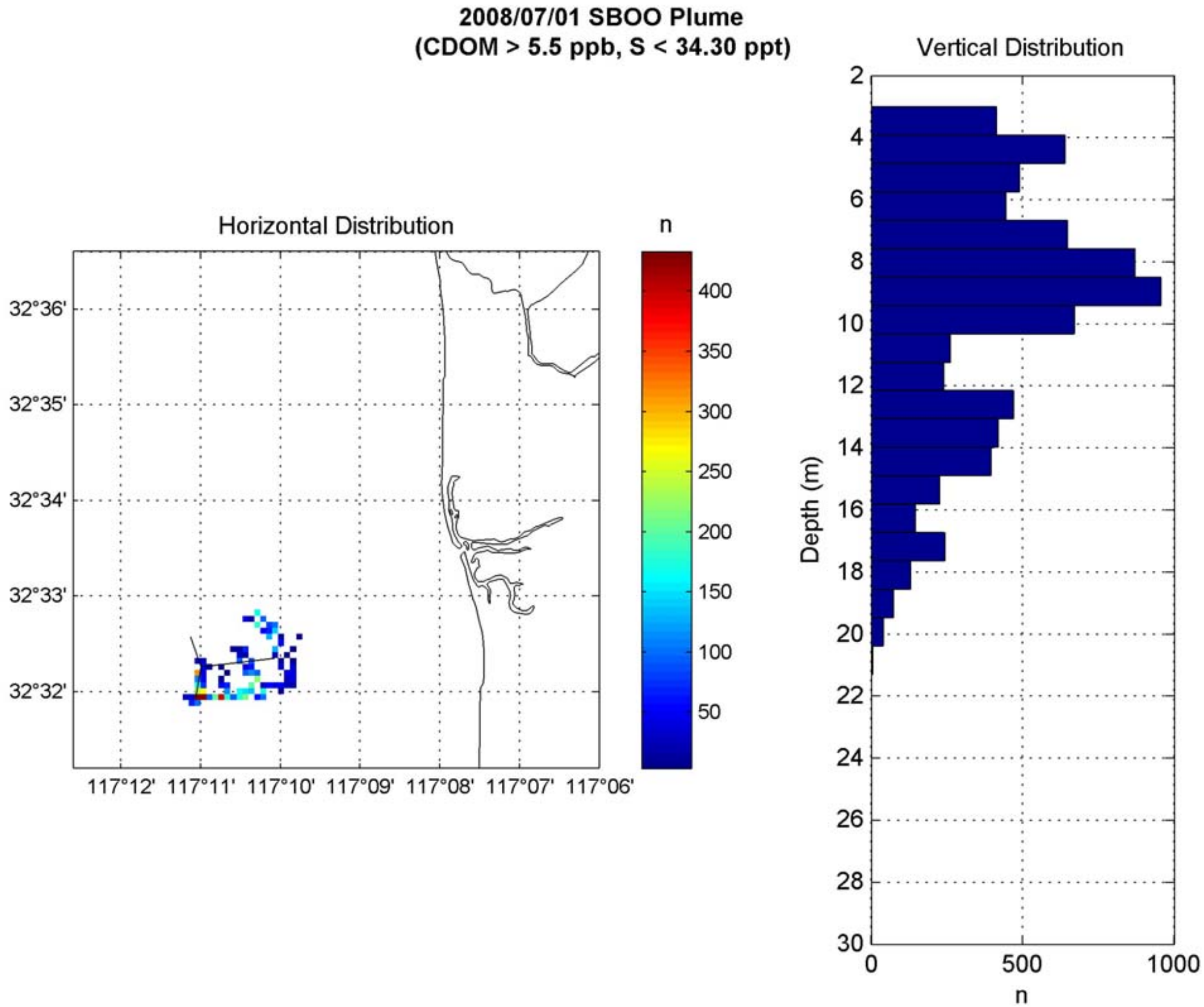
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Elevated CDOM measurements (> 5.5 ppb) show good correspondence with the estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

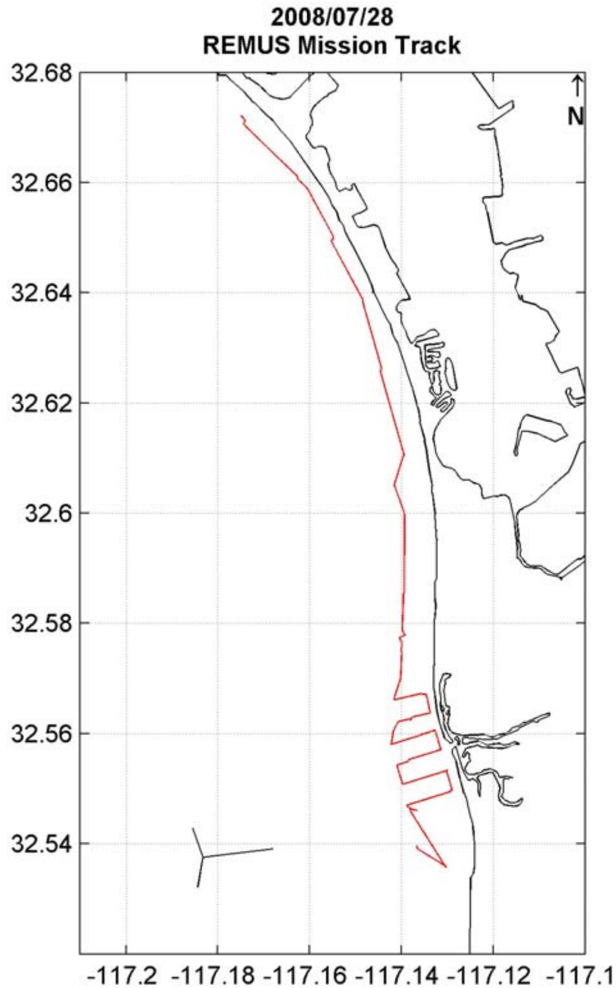


Temperature-Salinity (TS) diagram showing the distribution of watermasses by density (diagonal grid, units of kg/m^3 – 1000) and CDOM concentration. The outfall plume is distinguished as a fresher (lower salinity) watermass with high CDOM concentrations (> 5.5 ppb).

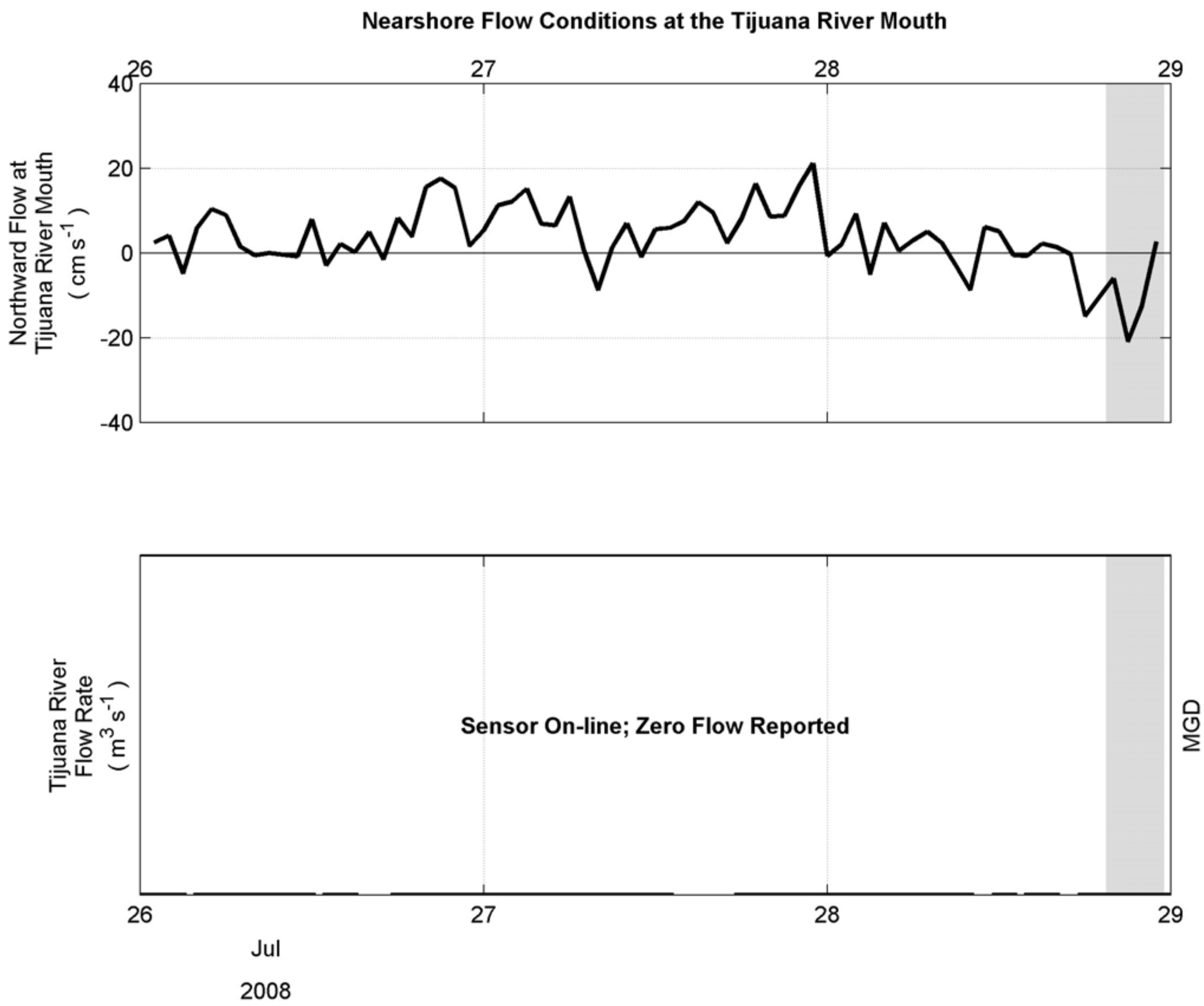


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

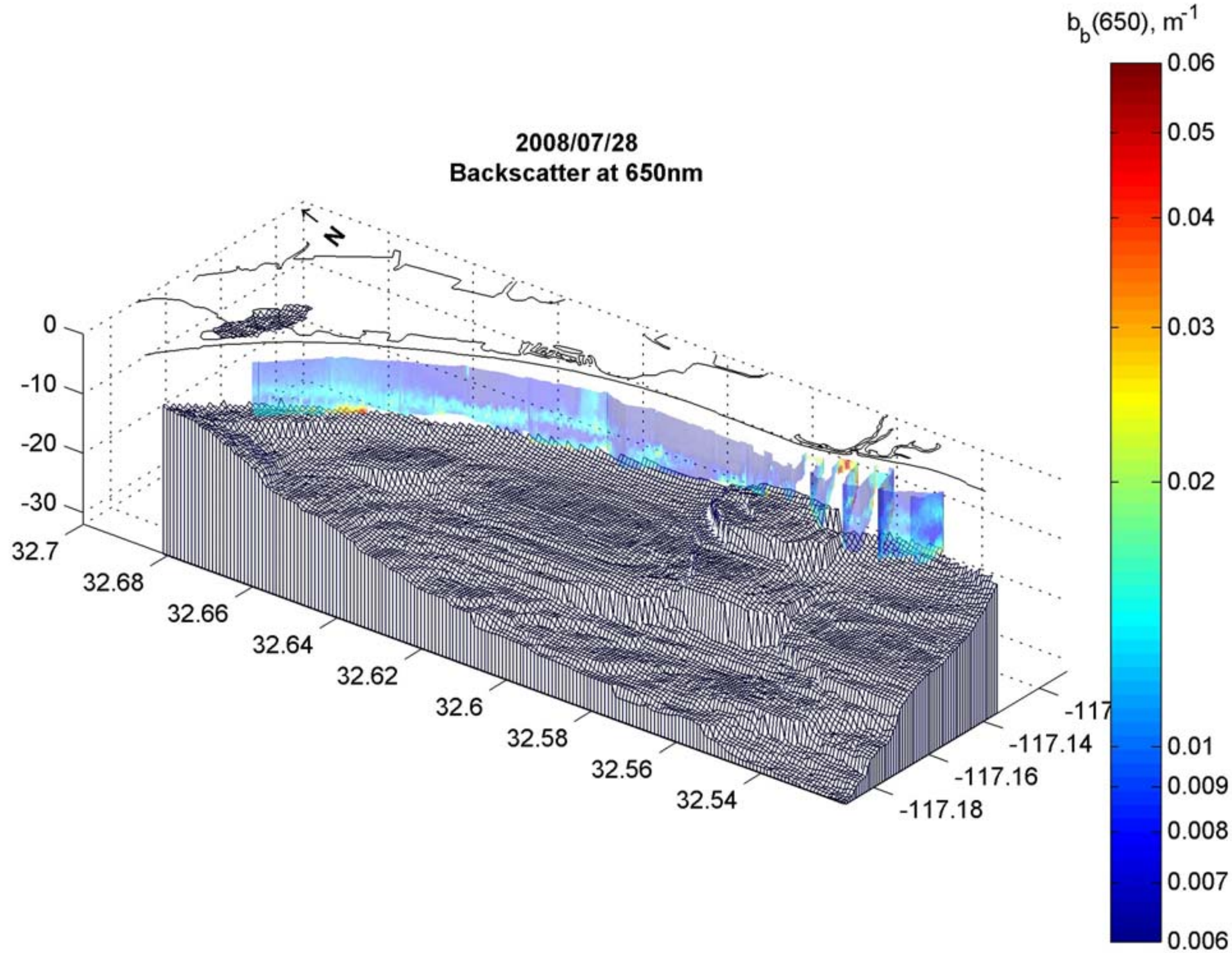
Appendix A.18 2008/07/28 Mission Summary



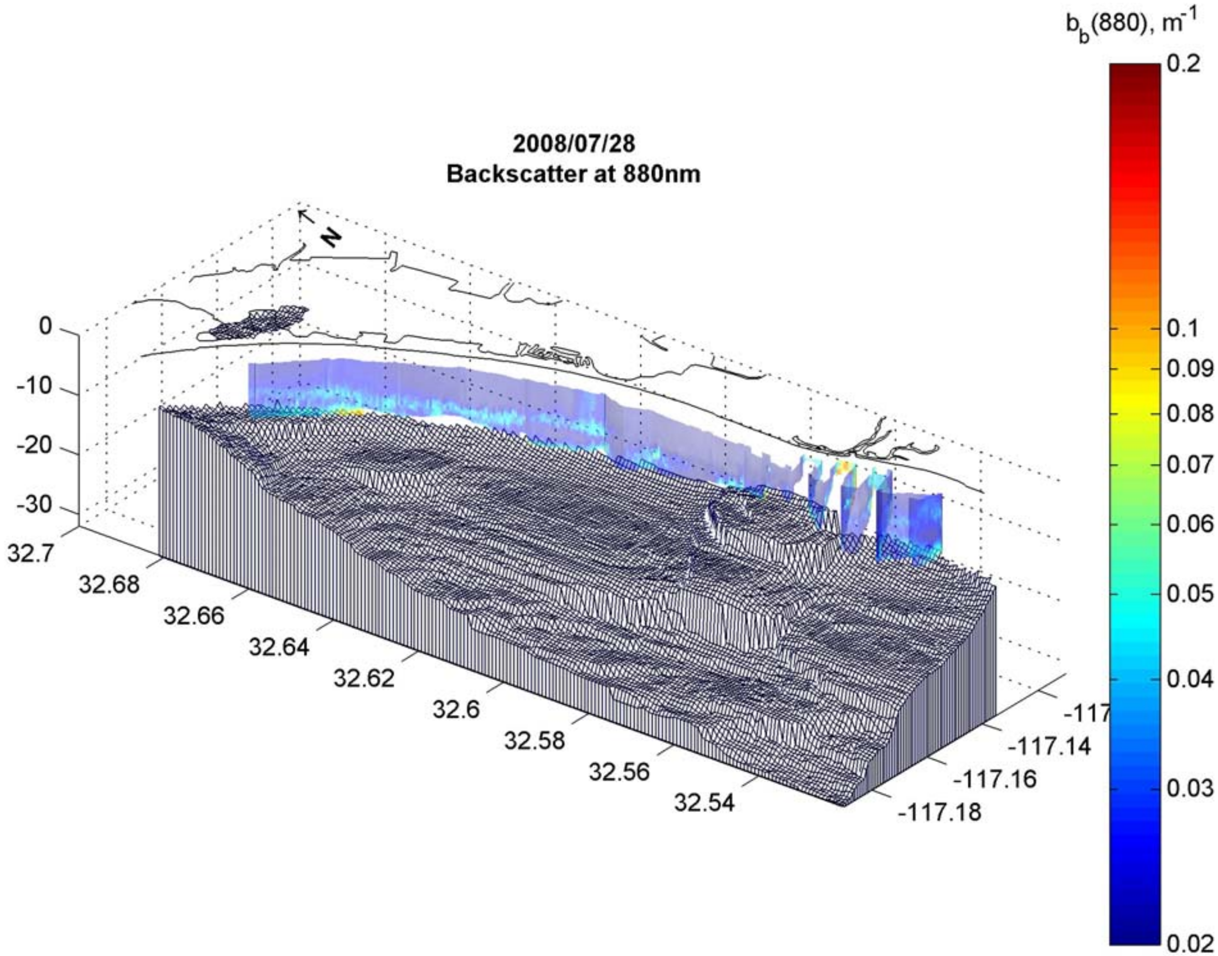
REMUS track (red) for a nearshore 'baseline' mission aimed at revealing background values for physical and optical parameters during dry weather and southward alongshore flow.



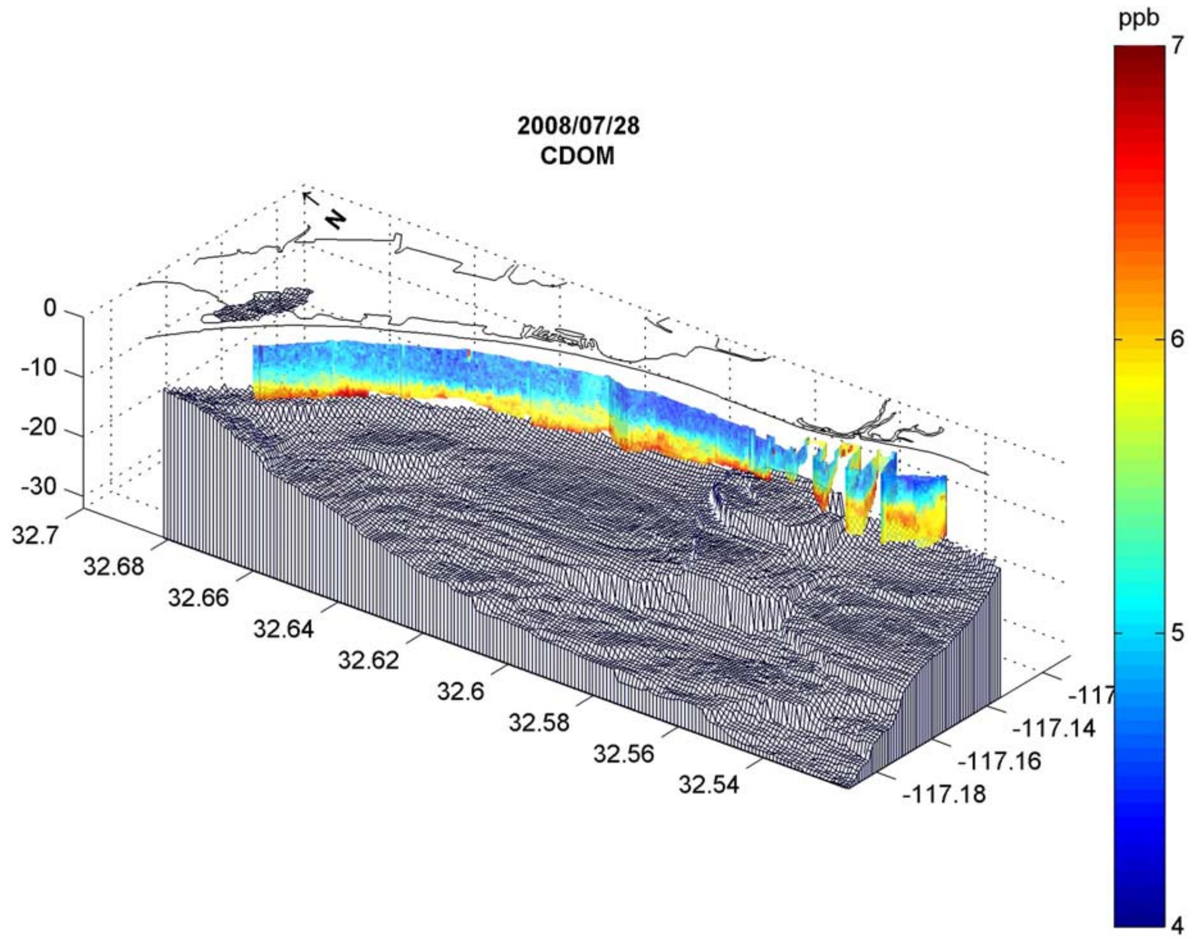
Alongshore surface current velocity measured by HF-Radar at the Tijuana River mouth (top) and flow rate from the Tijuana River as measured by the IBWC gauge (bottom). The grey panel indicates the sampling period.



Backscatter measurements at 650 nm shows elevated values (>0.02 m^{-1}) near the surface at the Tijuana River mouth indicating exchange with the estuary during periods of no flow. Elevated values (>0.01 m^{-1}) near the seafloor may be due to sediment resuspension by currents scouring bottom sediment.

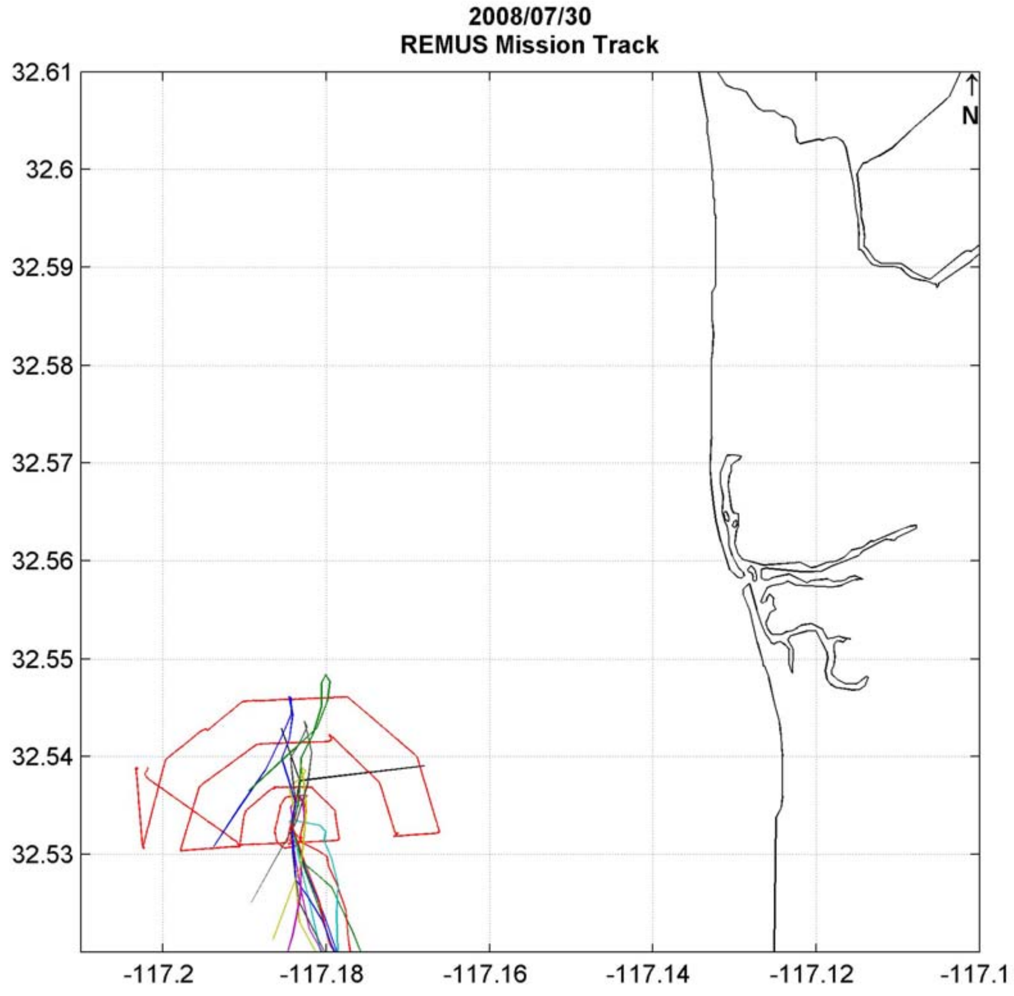


Backscatter measurements at 650 nm shows elevated values (>0.07 m^{-1}) near the surface at the Tijuana River mouth indicating exchange with the estuary during periods of no flow. Elevated values (>0.04 m^{-1}) near the seafloor may be due to sediment resuspension by currents scouring bottom sediment.

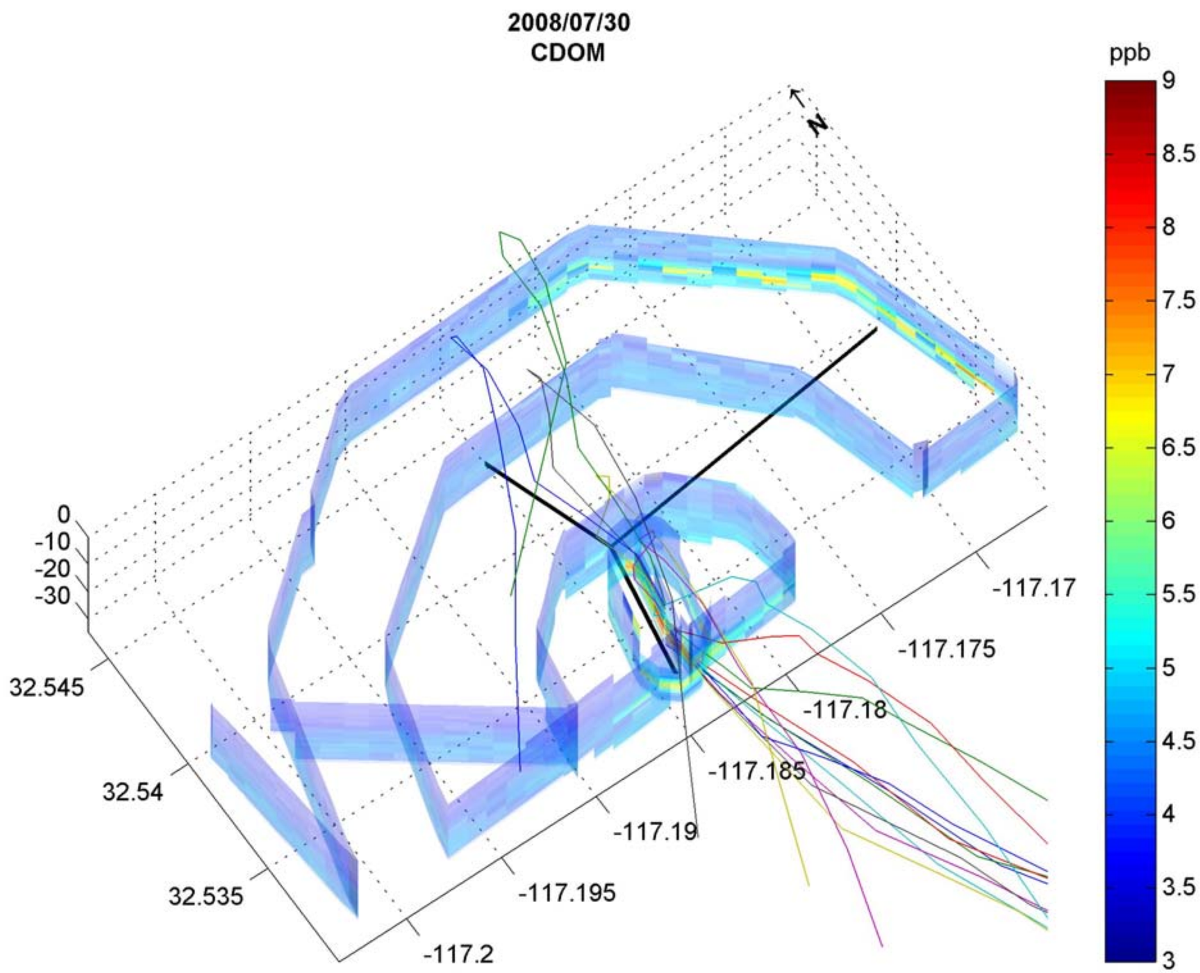


CDOM shows elevated values (>5 ppb) near the surface at the Tijuana River mouth indicating exchange with the estuary during periods of no flow. Elevated values (> 5.5 ppb) near the seafloor may be due to sediment resuspension by currents scouring bottom sediment.

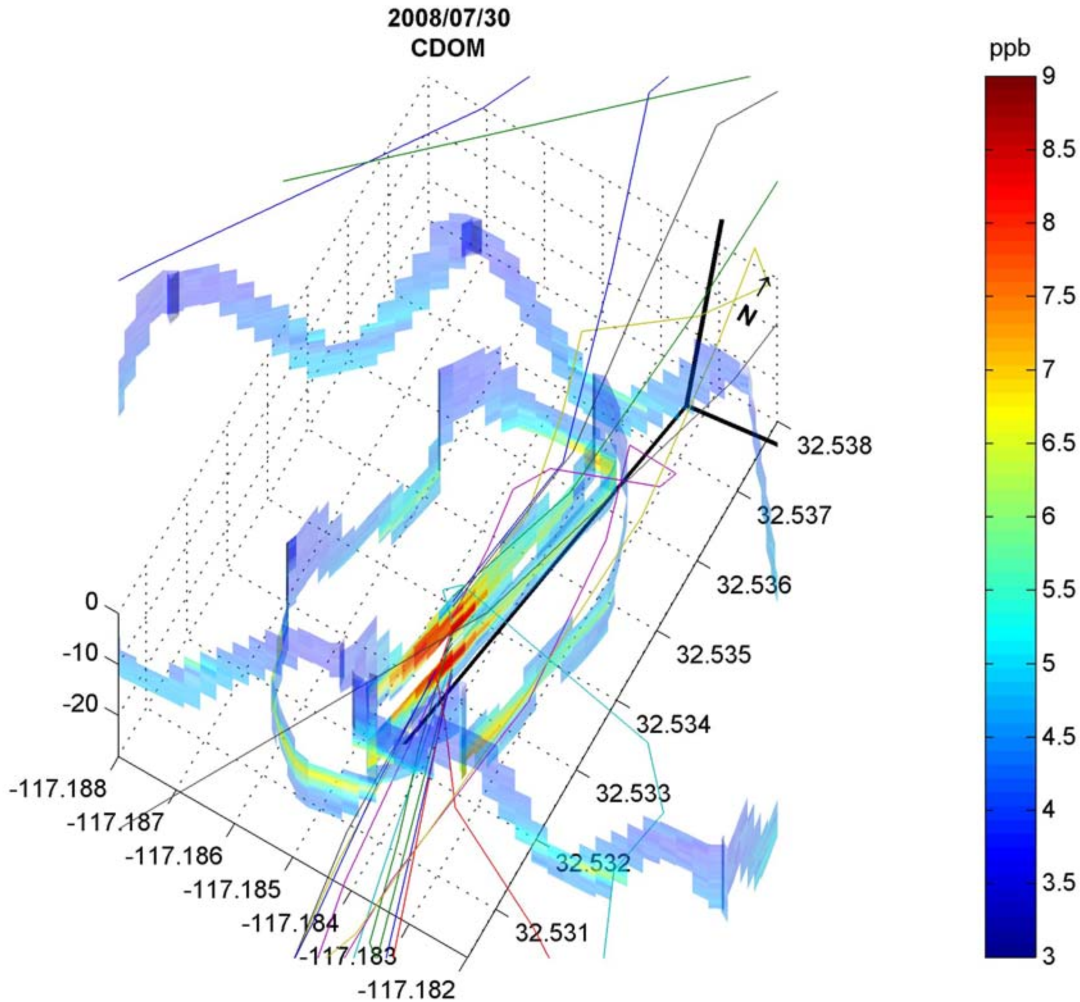
Appendix A.19 2008/07/30 Mission Summary



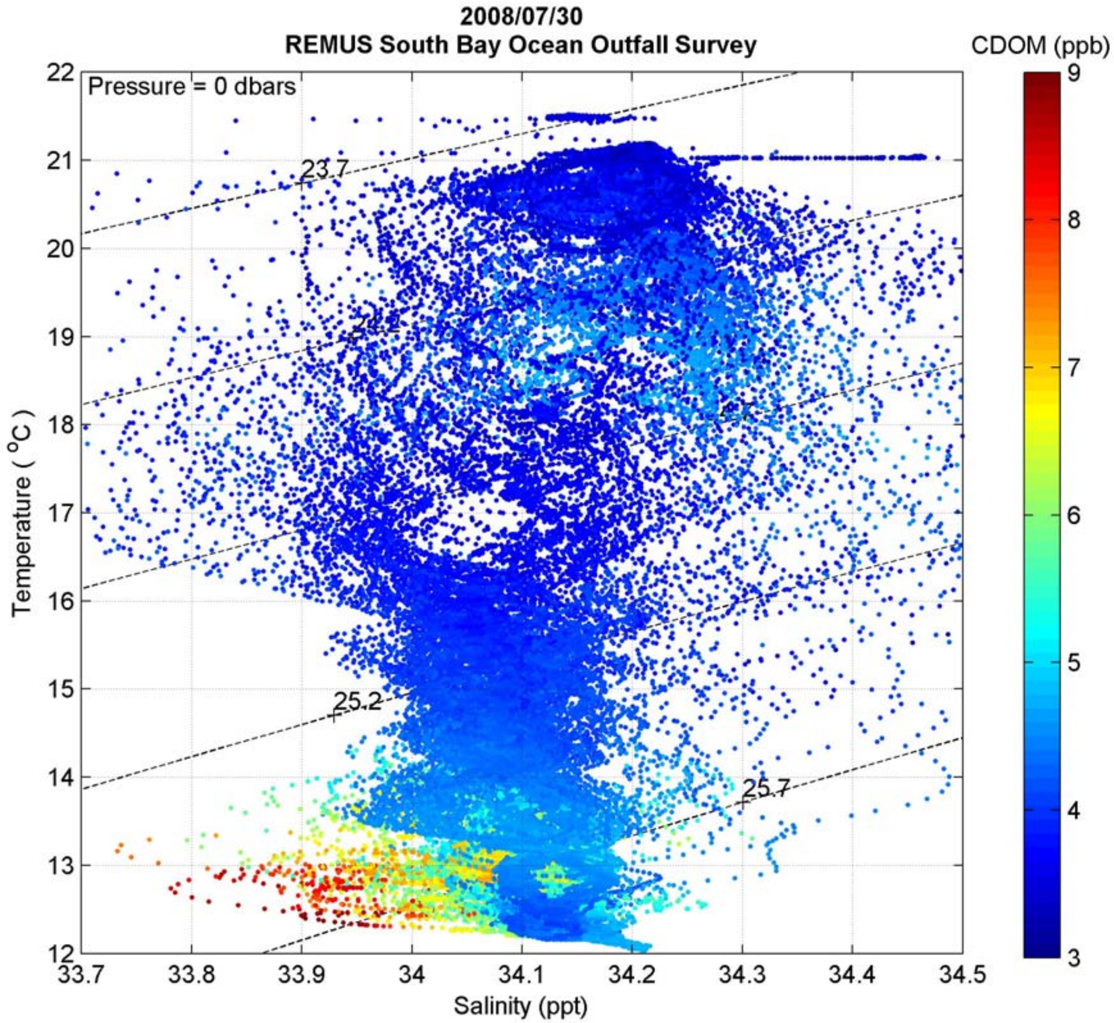
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



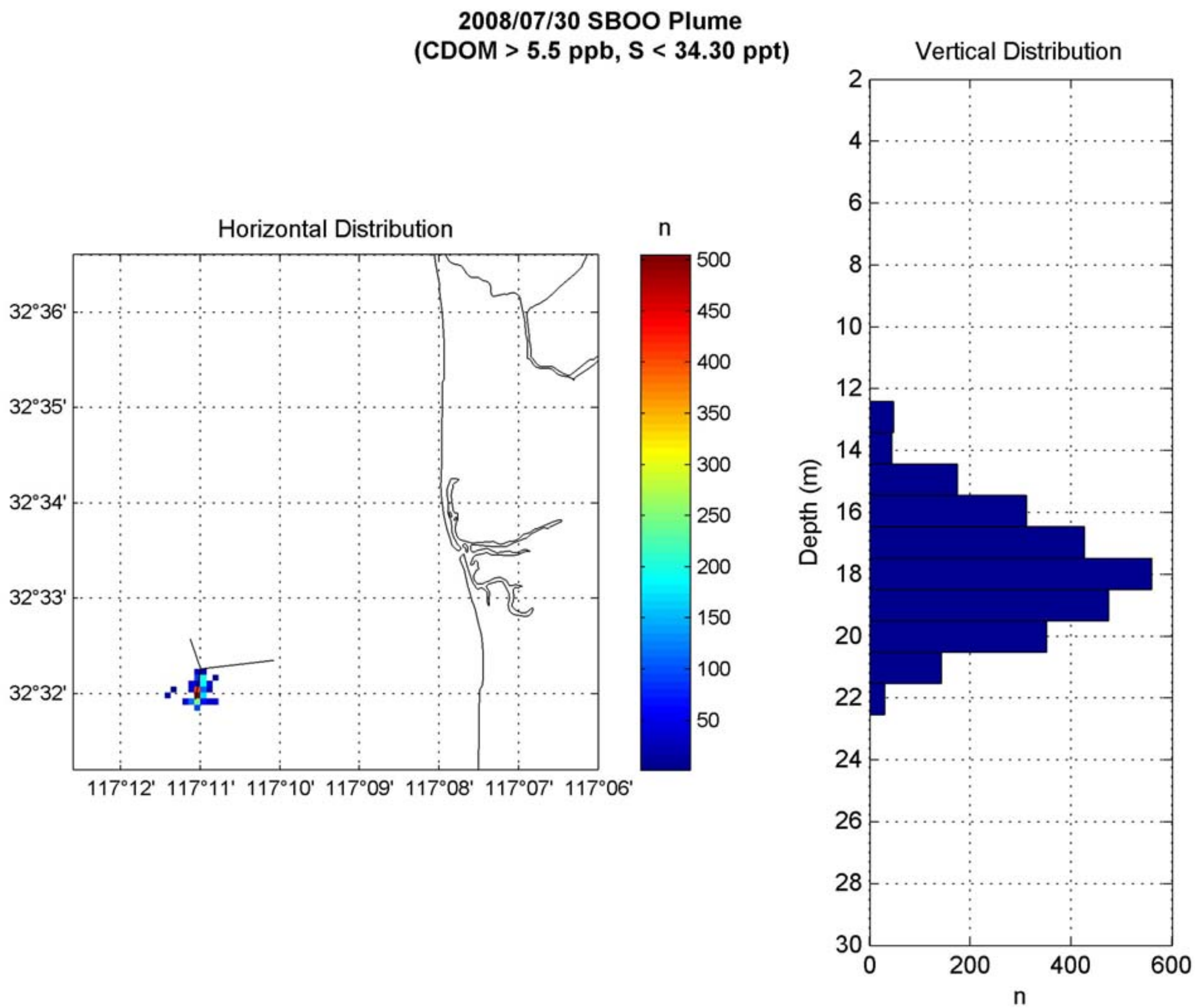
Elevated CDOM values (> 5.5 ppb) near the outfall shows the distribution of the outfall plume. CDOM values of approximately 5 – 7 ppb in the northeast are within the kelp forest and are presumably due to elevated biological activity.



Near-field CDOM measurements greater than 5.5 ppb show good correspondence with the estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

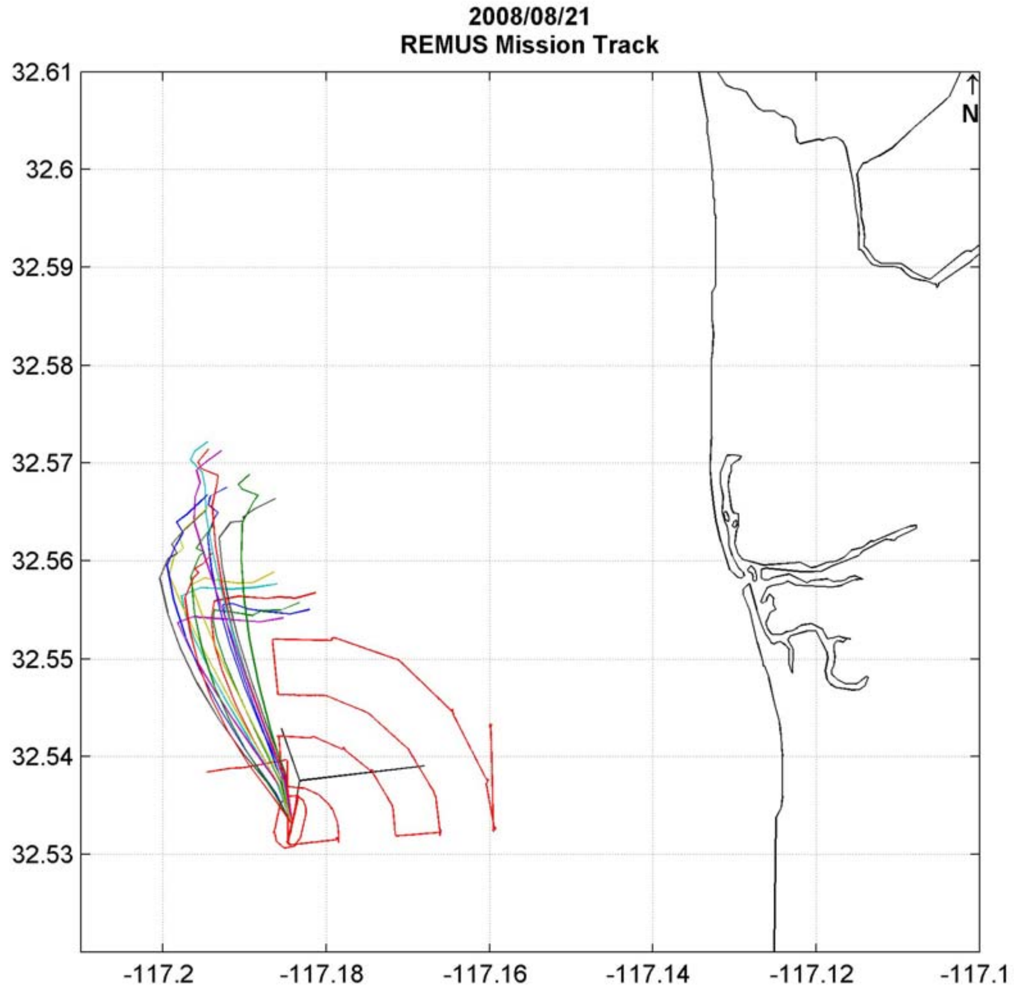


Temperature-Salinity (TS) diagram showing the distribution of watermasses by density (diagonal grid, units of kg/m^3 – 1000) and CDOM concentration. The outfall plume is distinguished as a fresher (lower salinity) watermass with high CDOM concentrations (> 5.5 ppb).

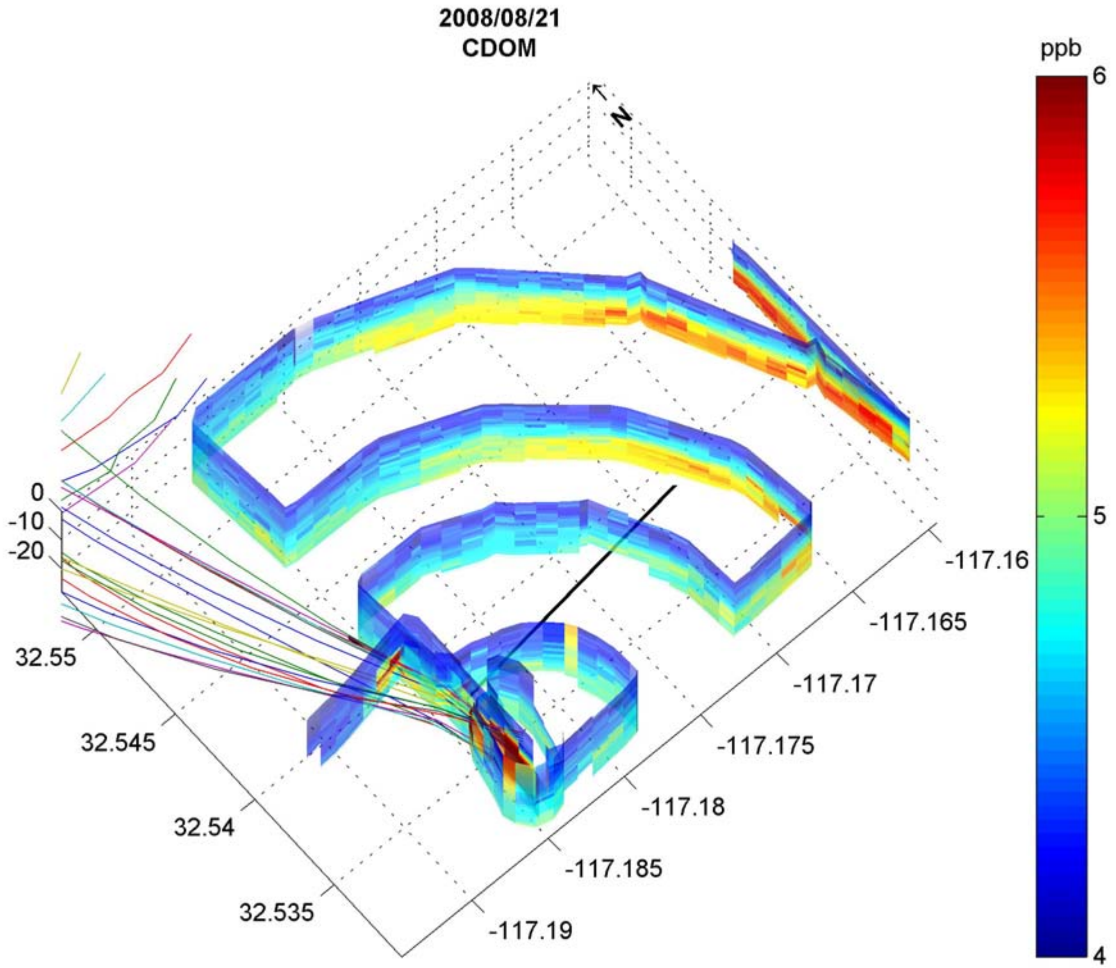


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

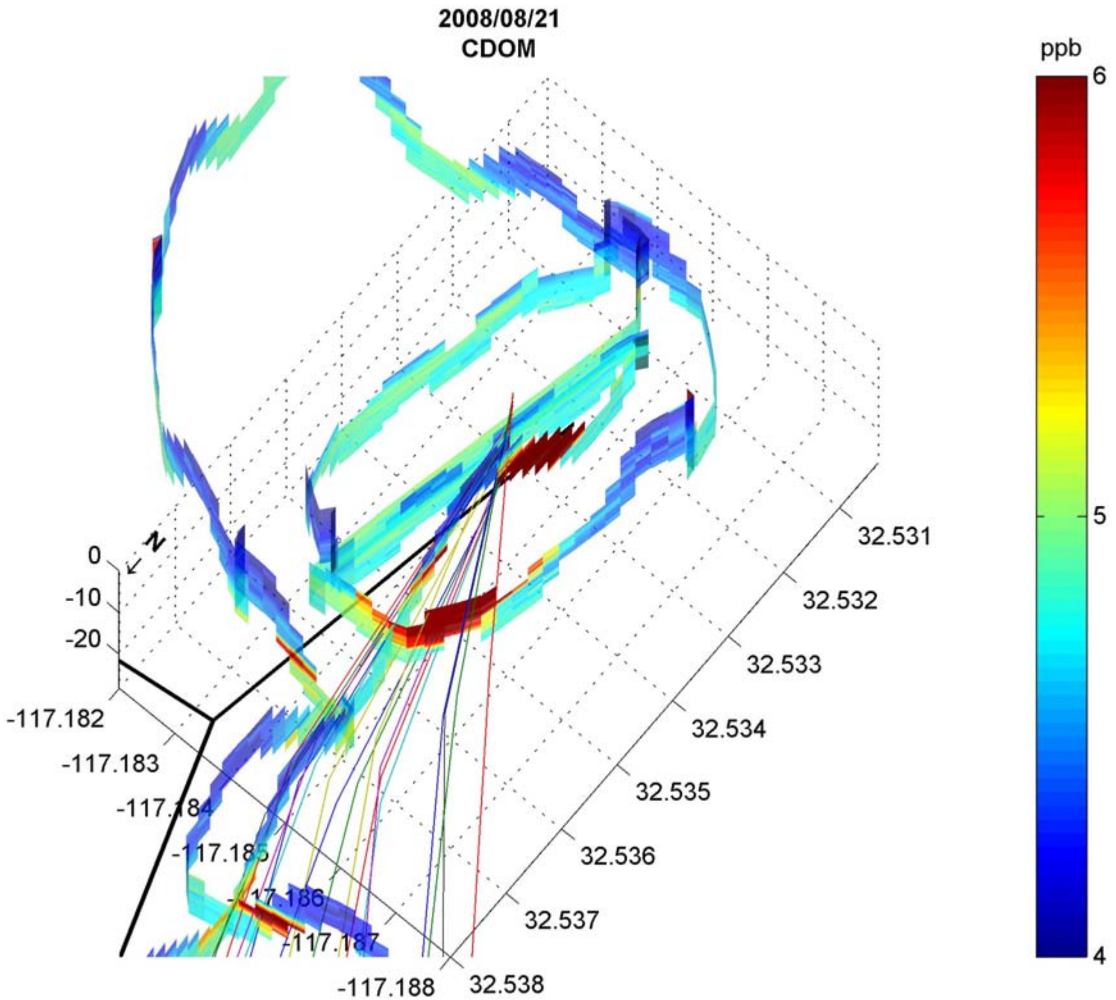
Appendix A.20 2008/08/21 Mission Summary



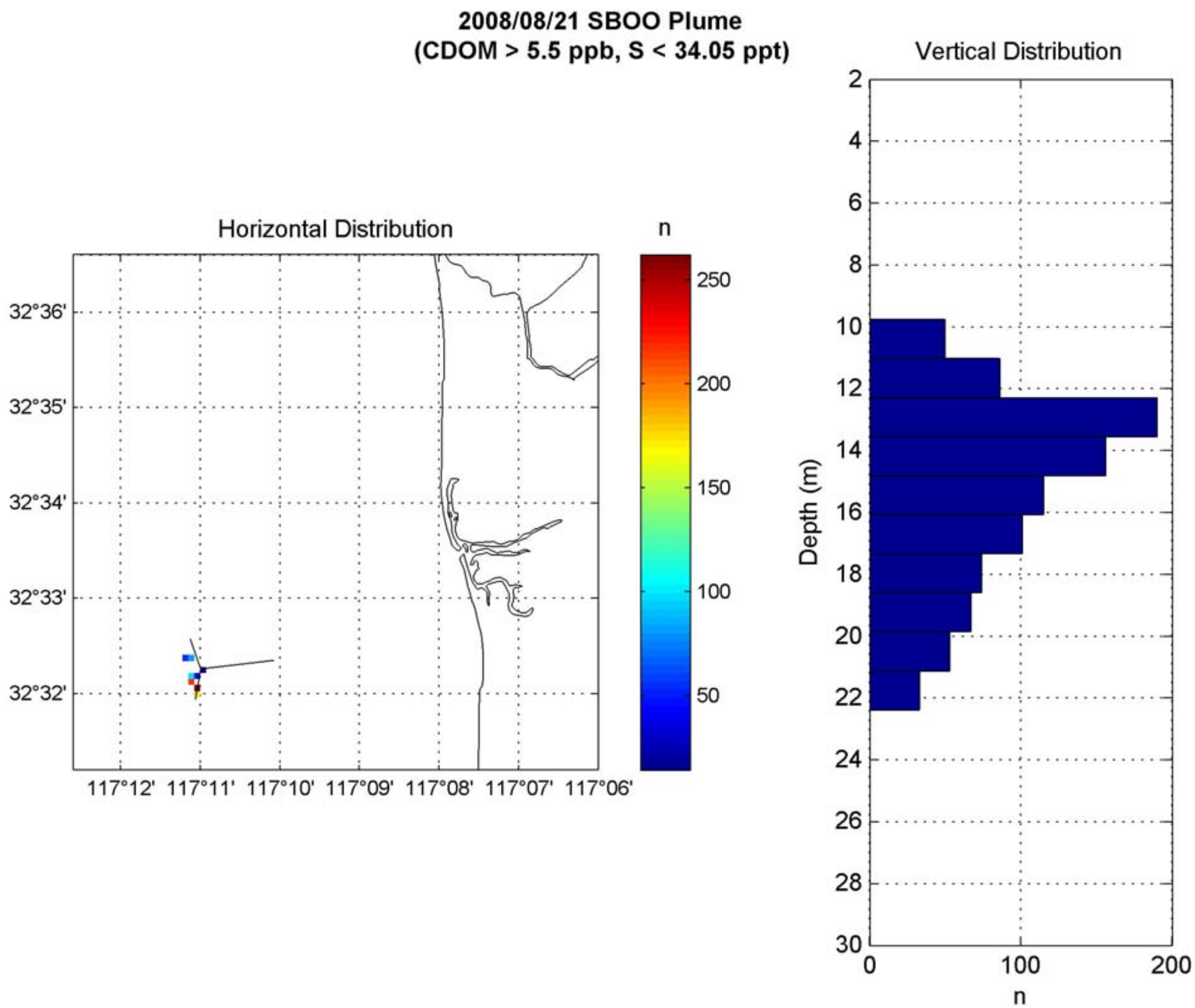
REMUS Mission track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.



Elevated CDOM values (> 5.5 ppb) near the outfall shows the distribution of the outfall plume. CDOM values of approximately 5 – 6 ppb in the northeast are within the kelp forest and are presumably due to elevated biological activity.

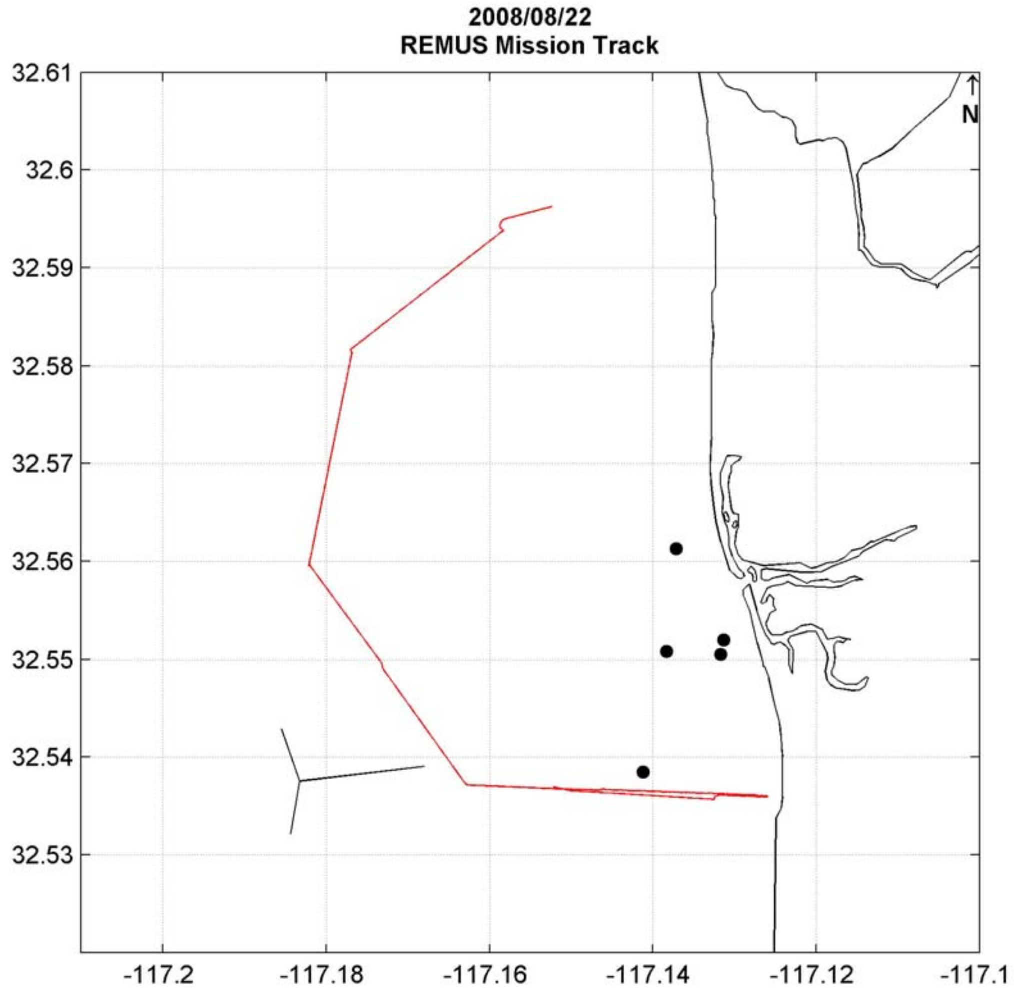


Near-field CDOM measurements greater than 5.5 ppb show good correspondence with the estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy.

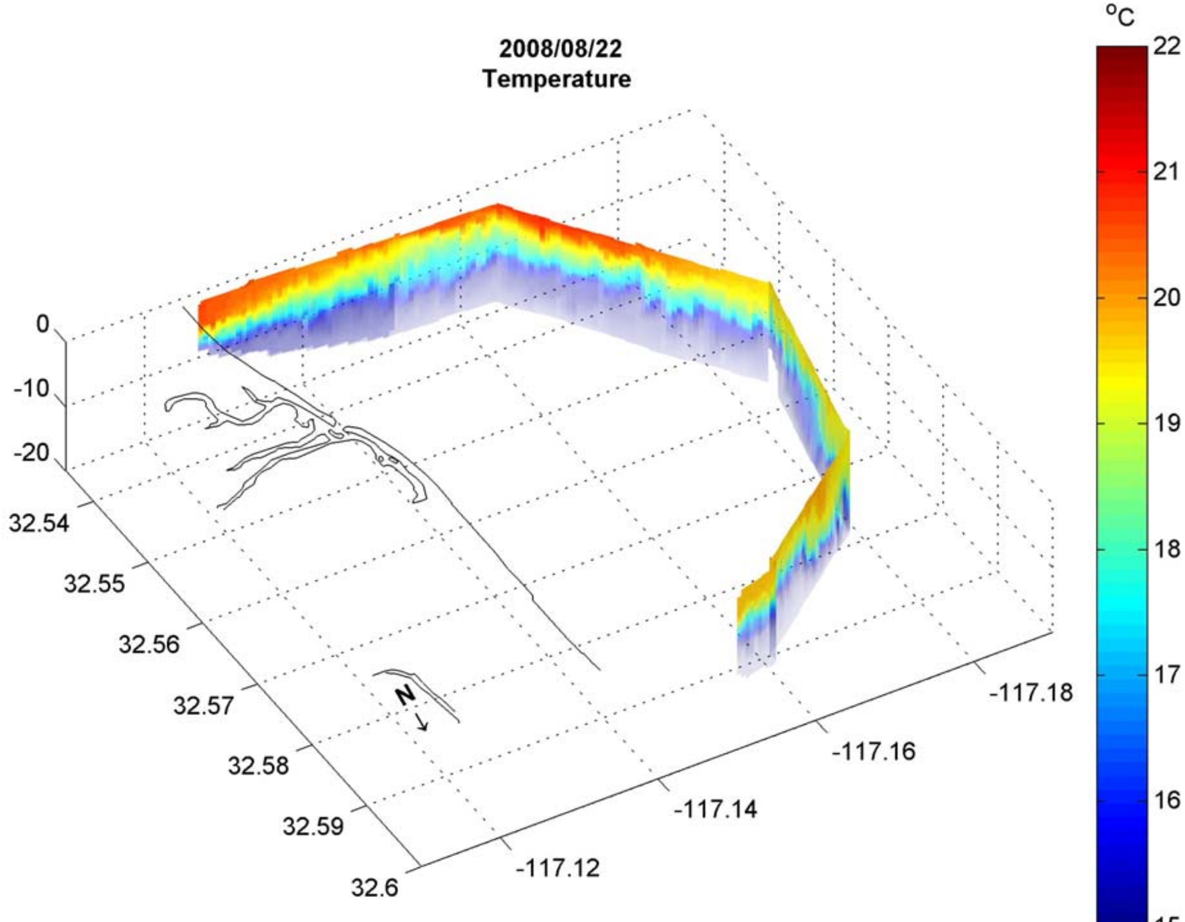


Horizontal and vertical plume distributions based on thresholding by the plumes' signature CDOM and salinity values. The number of samples satisfying the threshold criteria for a given horizontal or vertical bin is given by 'n'.

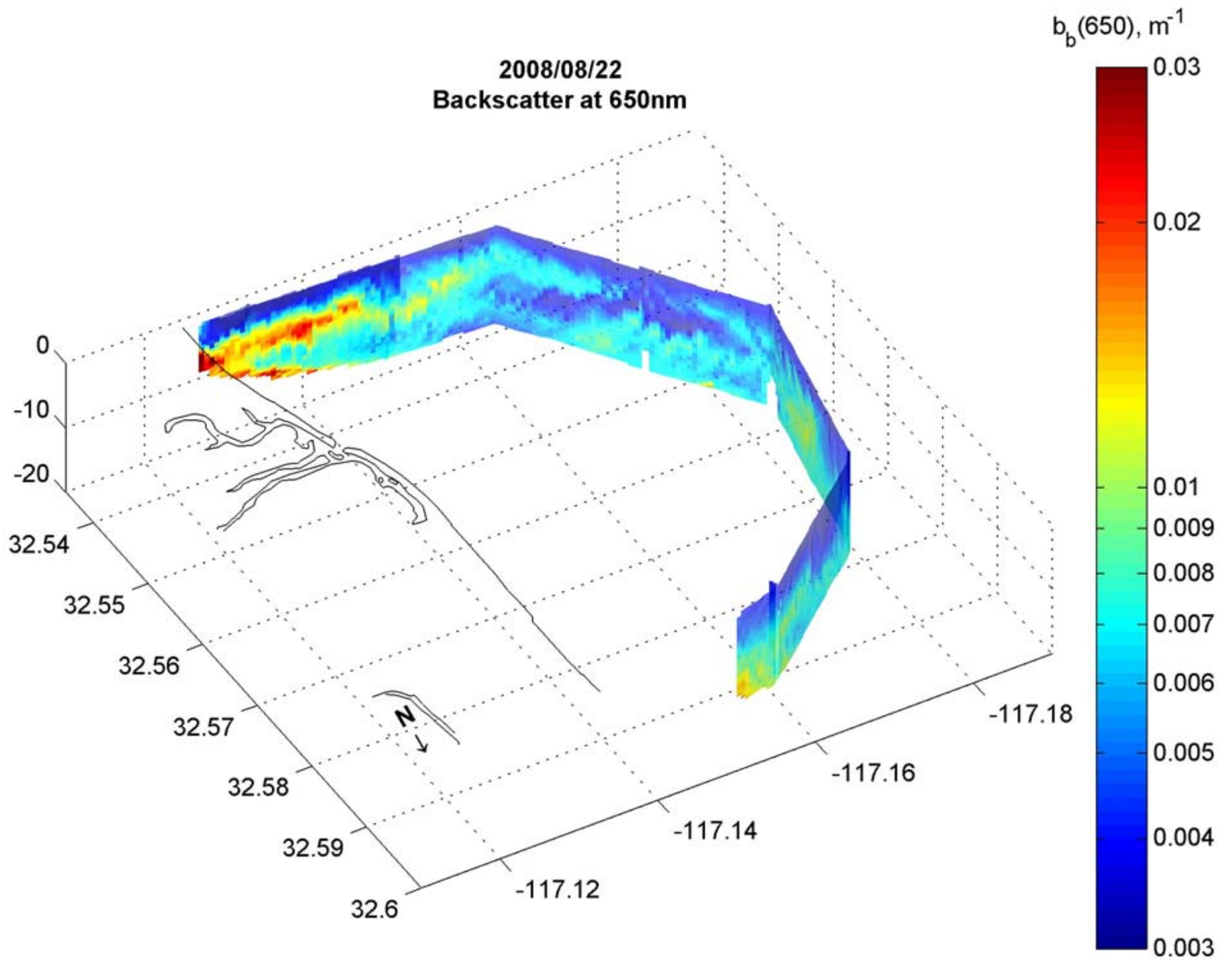
Appendix A.20 2008/08/22 Mission Summary



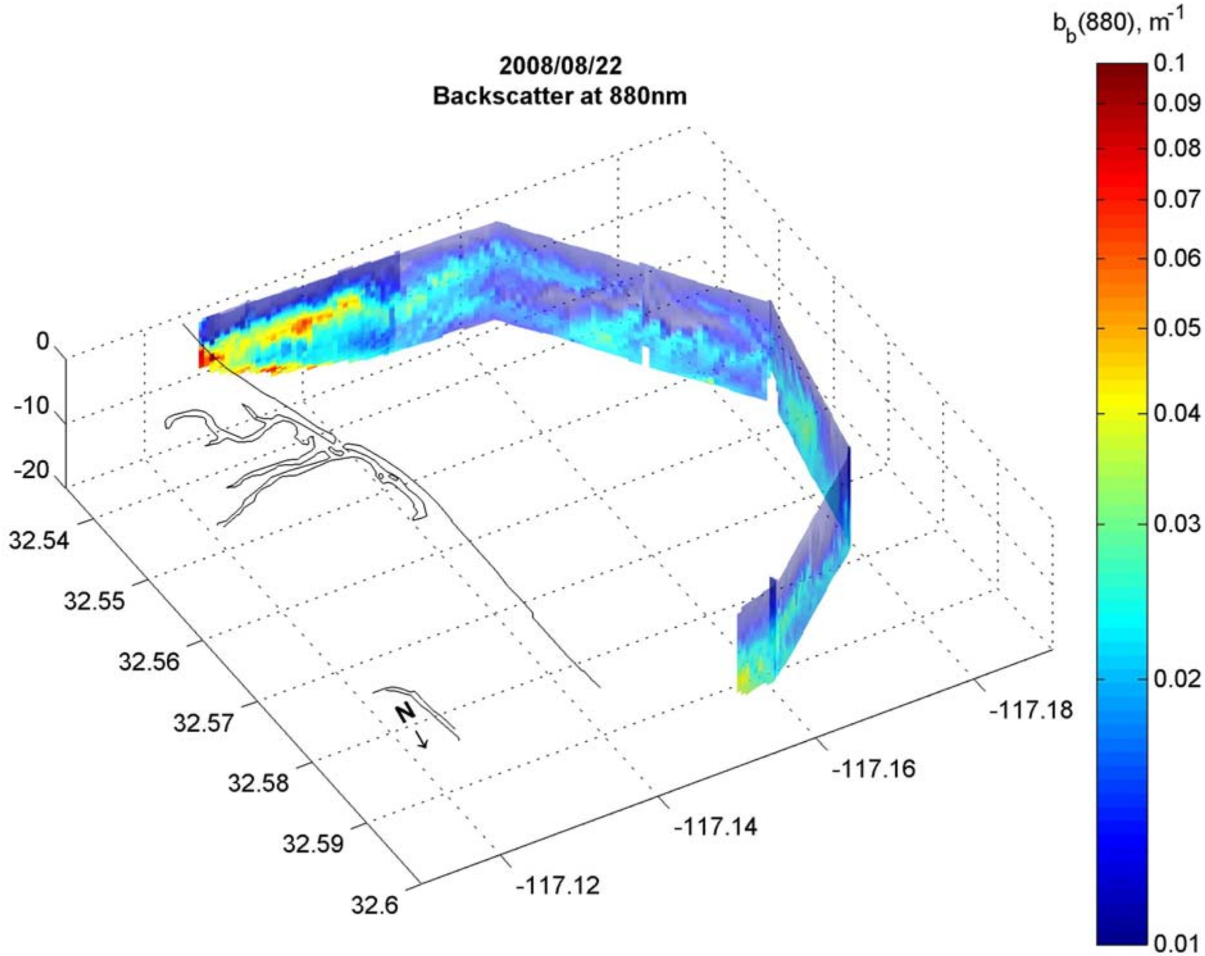
REMUS track (red) for an Imperial Beach source ID mission during a 'smelly event'. Black dots indicate CTD locations (data not shown).



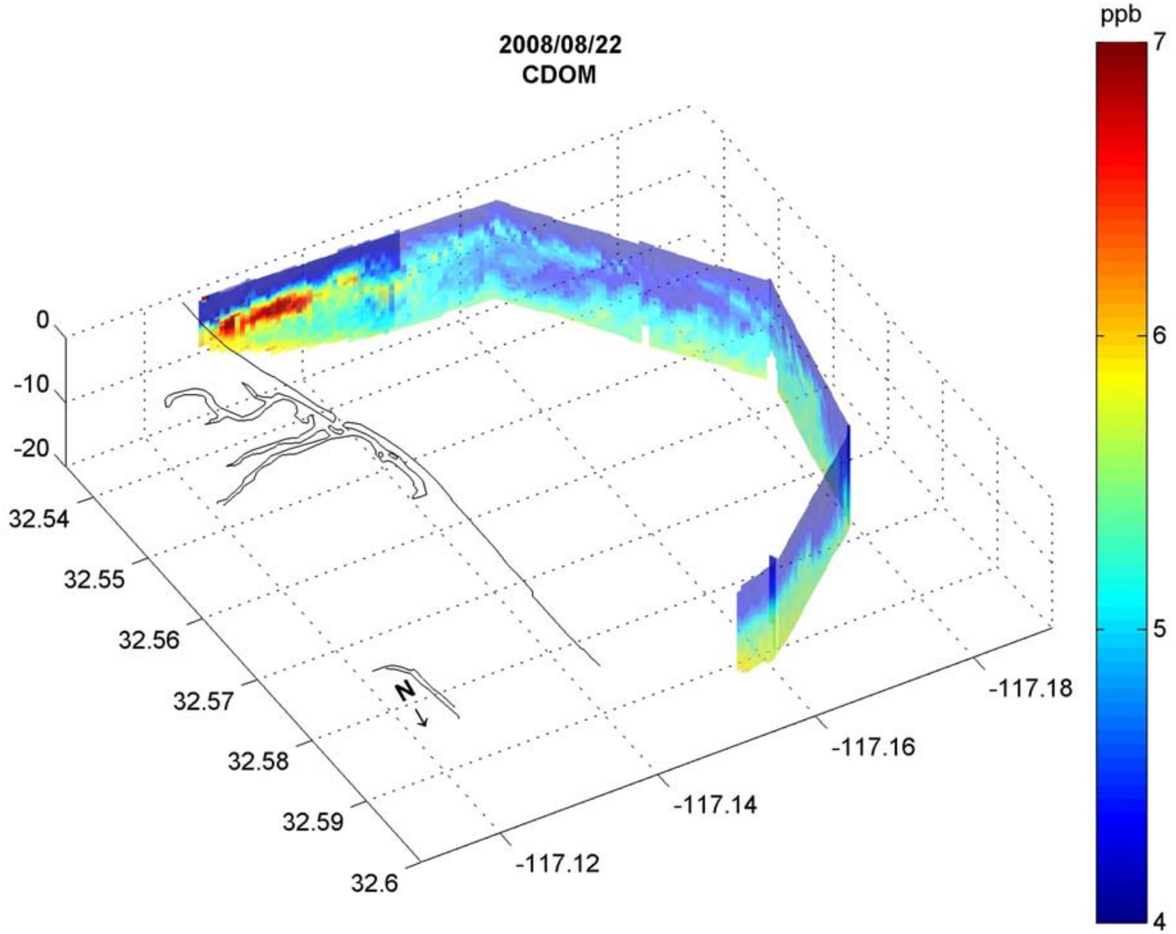
Temperature measurements show the water column is well stratified with surface values above 19 °C and deep water values of 15 °C.



Backscatter measurements at 650 nm shows elevated values (>0.006 m^{-1}) near the seafloor and just below the thermocline. Possible sources of elevated backscatter include sediment resuspension and phytoplankton.

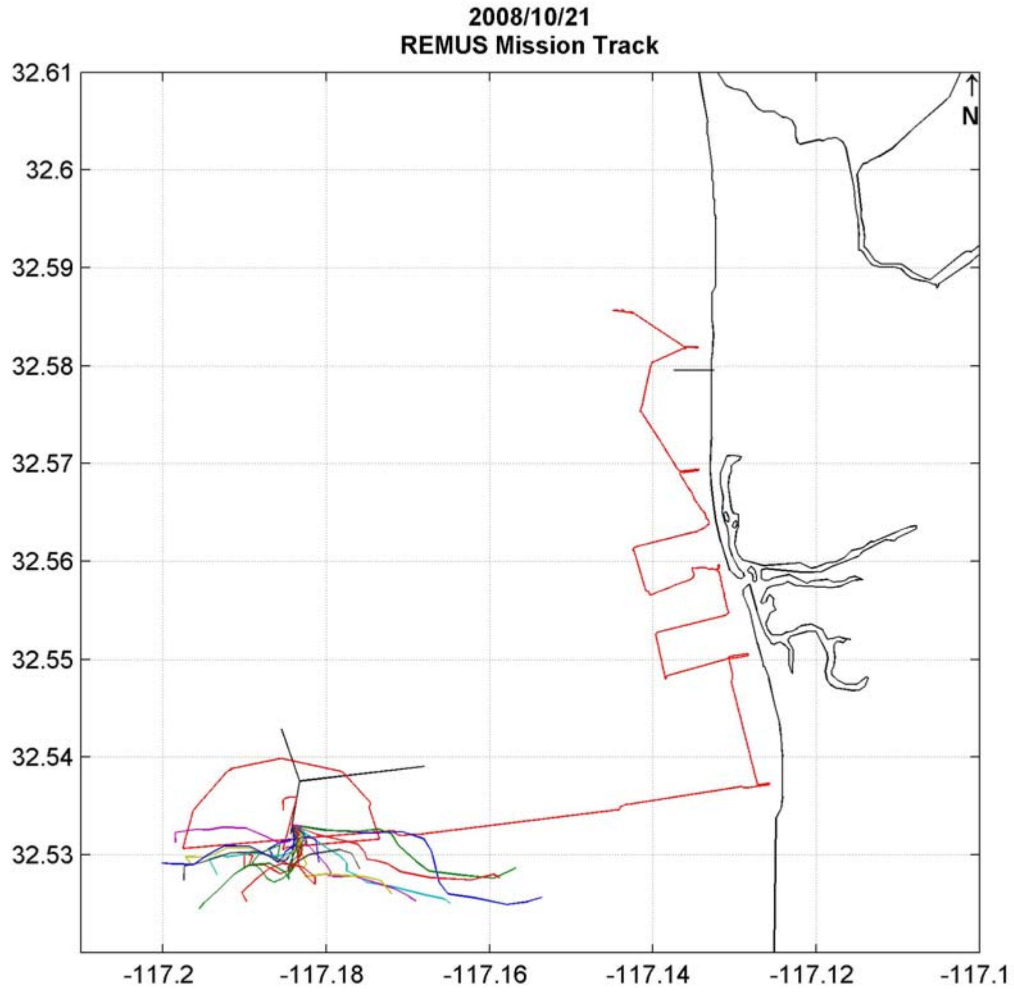


Backscatter measurements at 650 nm shows elevated values (>0.02 m^{-1}) near the seafloor and just below the thermocline. Possible sources of elevated backscatter include sediment resuspension and phytoplankton.

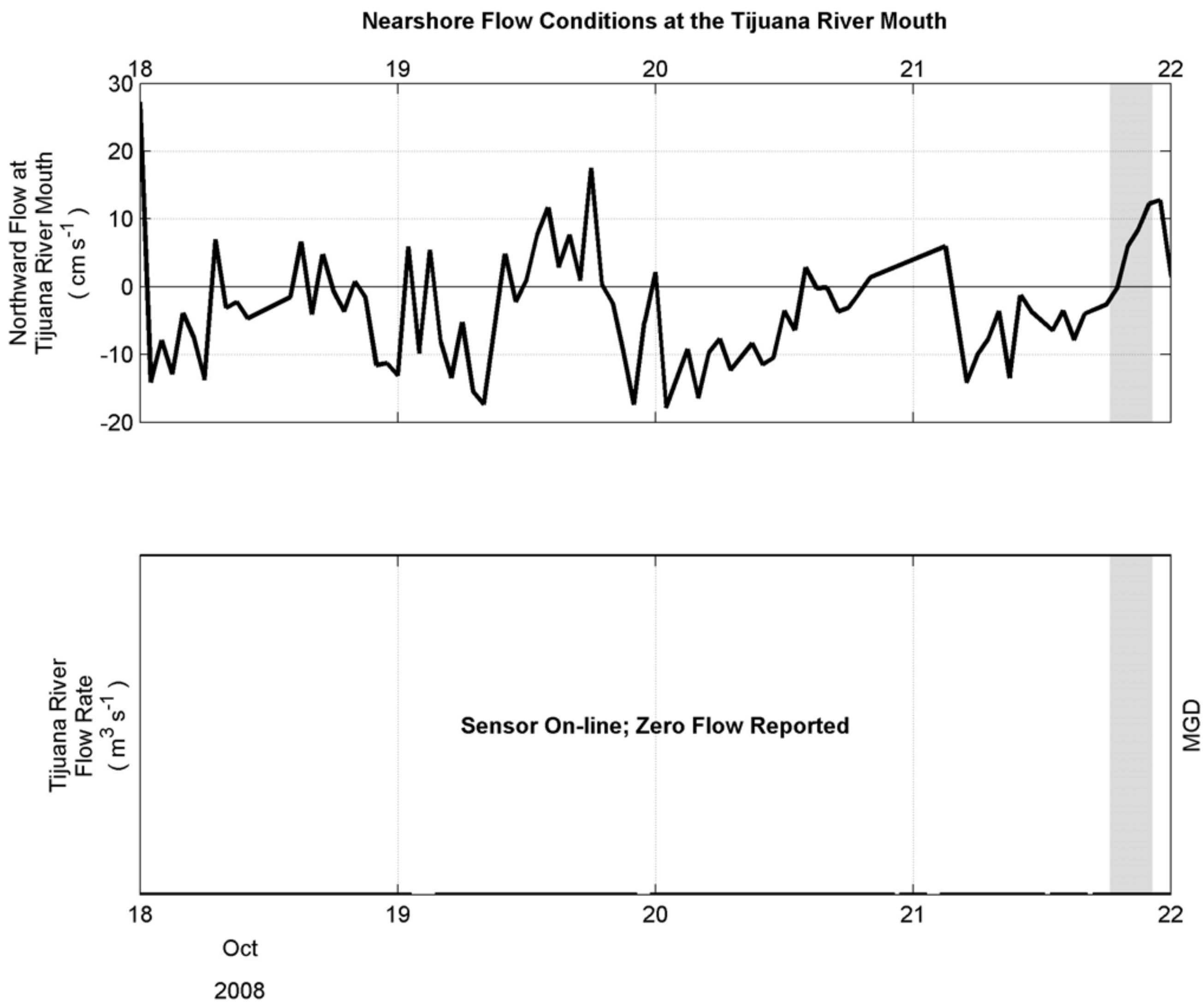


CDOM shows elevated values (> 5 ppb) near the seafloor and just below the thermocline. Possible sources of elevated CDOM include sediment resuspension and biological activity.

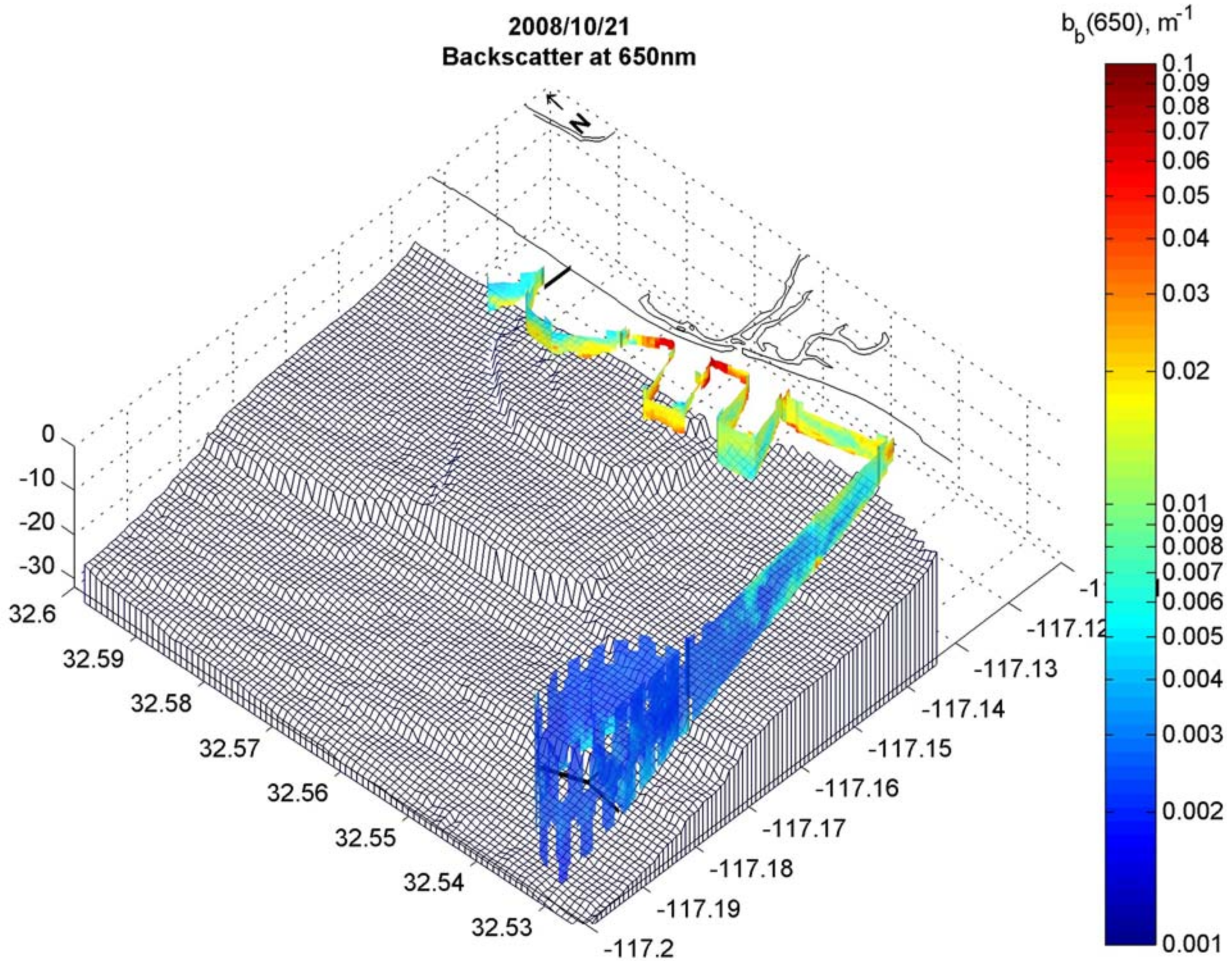
Appendix A.21 2008/10/21 Mission Summary



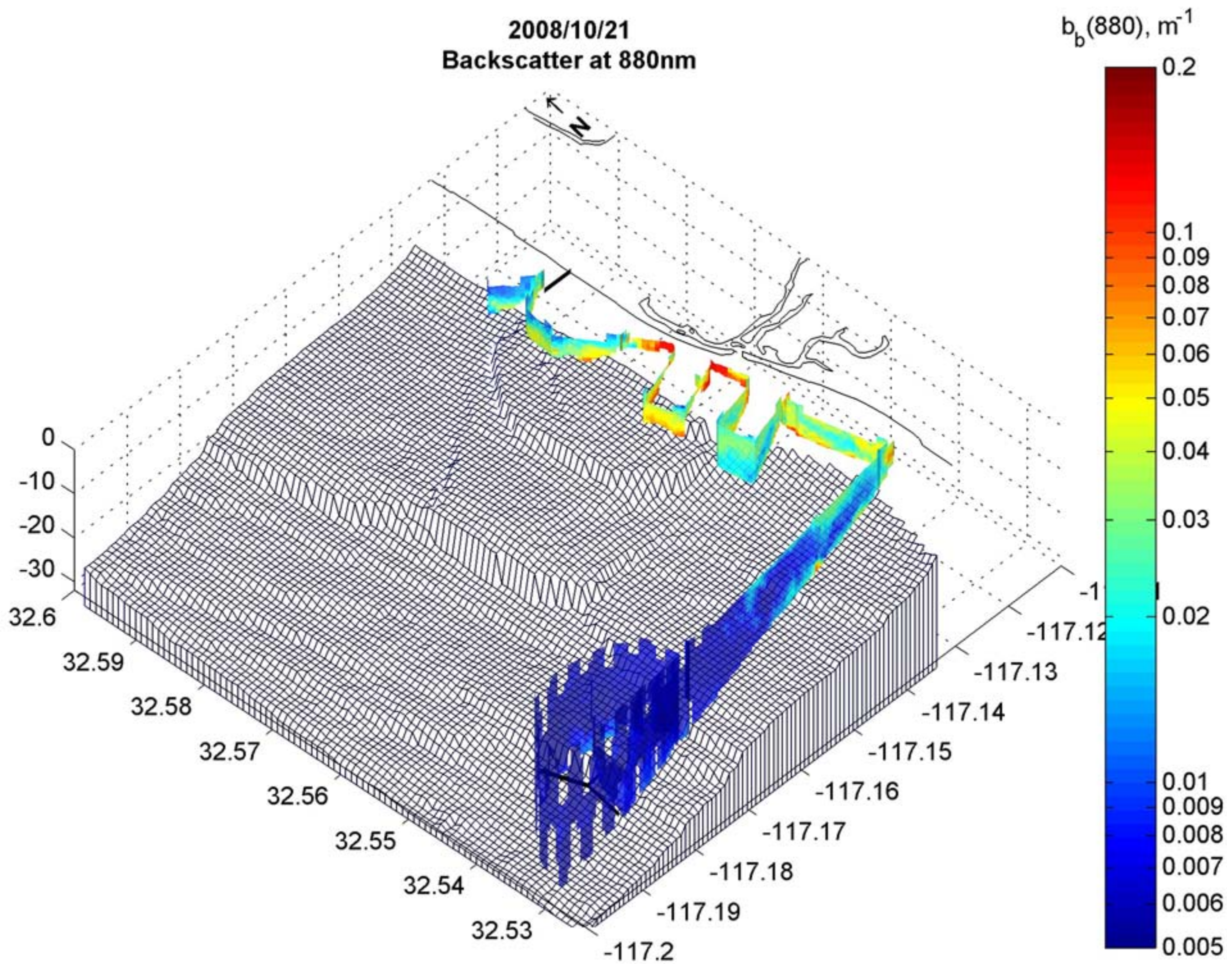
REMUS track (red) and estimated SBOO plume trajectory (colored lines) based on near-realtime velocity profiles measured by the SBOO buoy for a hybrid SBOO-Tijuana River mission.



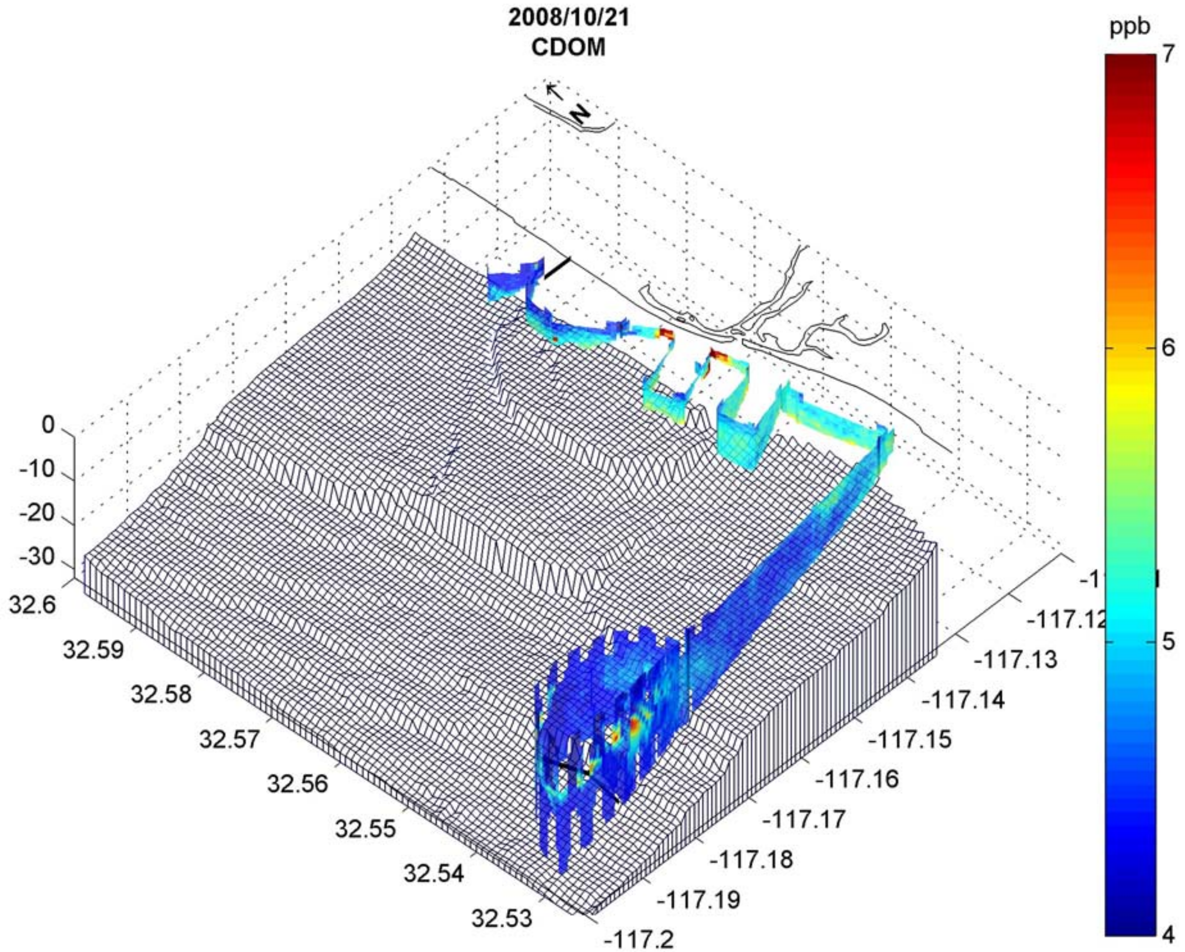
Alongshore surface current velocity measured by HF-Radar at the Tijuana River mouth (top) and flow rate from the Tijuana River as measured by the IBWC gauge (bottom). The grey panel indicates the sampling period.



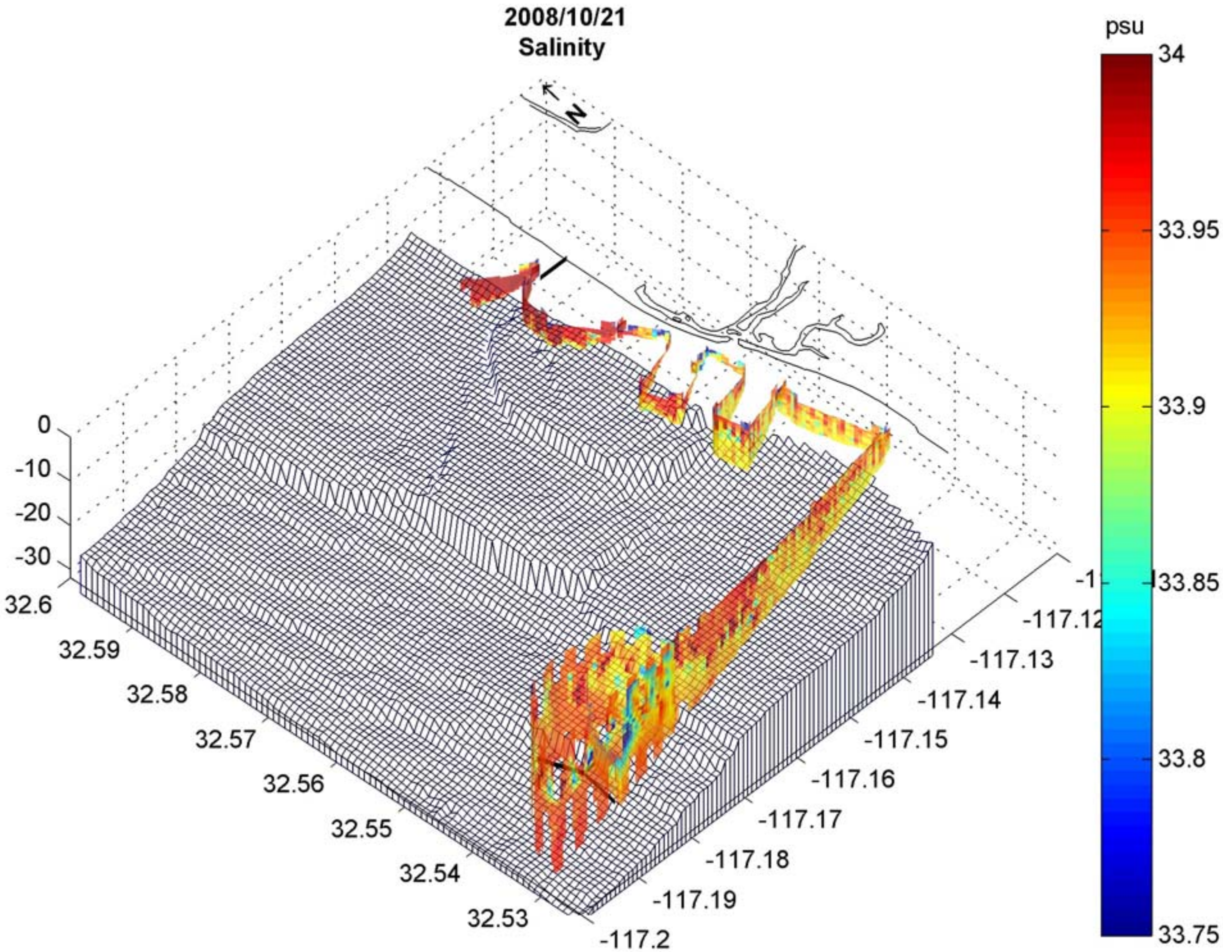
Backscatter measurements at 650 nm shows elevated values (>0.02 m^{-1}) near the Tijuana River mouth indicating exchange with the estuary during periods of no flow.



Backscatter measurements at 880 nm shows elevated values (>0.05 m^{-1}) near the Tijuana River mouth indicating exchange with the estuary during periods of no flow.

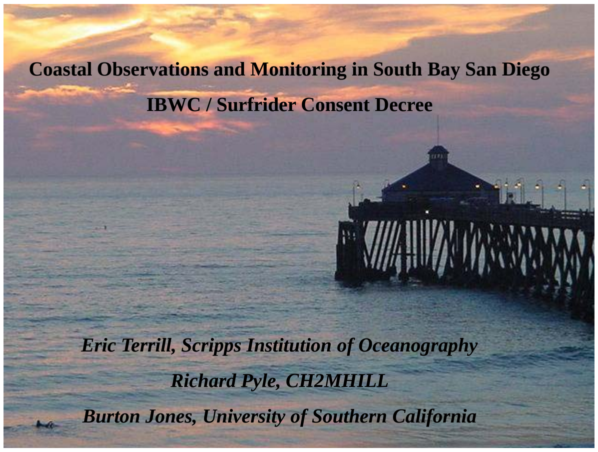


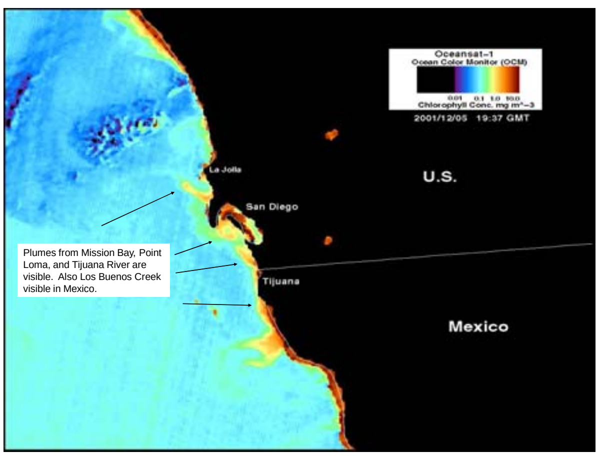
Elevated CDOM values (> 5 ppb) near the SBOO and Tijuana River mouth show the distribution of both plumes.

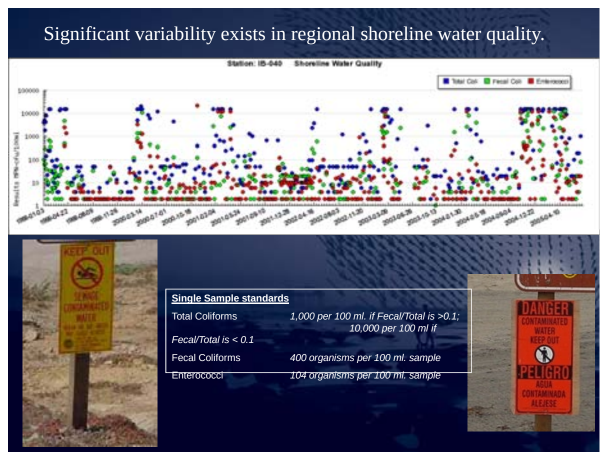


Low salinity values (< 33.9 psu) near the SBOO and Tijuana River mouth show the distribution of both plumes.

Appendix 4
Coastal Observations and Monitoring in South Bay San Diego – Public Meeting Presentations







Single Sample standards

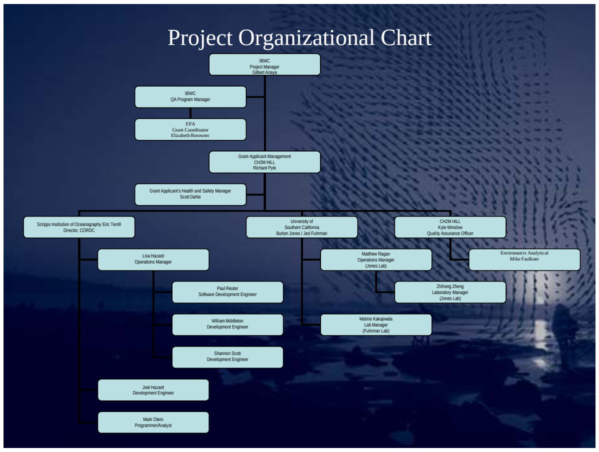
Total Coliforms	*1,000 per 100 ml. if Fecal/Total is >0.1; 10,000 per 100 ml if Fecal/Total is < 0.1*
Fecal Coliforms	*400 organisms per 100 ml. sample*
Enterococci	*104 organisms per 100 ml. sample*

IBWC Requested Monitoring Activities – Consent Decree

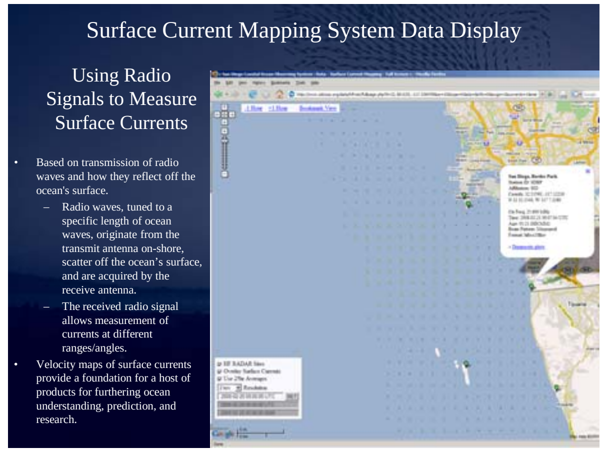
- SS1) SBOO plume mapping
- SS2) Tijuana River plume mapping
- SS3) Boat survey-mapping of land based plumes
- SS4) Continuous flow rate and loading of the Tijuana River
- SS5) Ocean moorings at key areas
- SS6) Mapping of ocean currents using HF radar and improved data handling
- SS7) The development of indicator studies to support source identification
- SS8) Identification of spatial patterns

Coastal Observations and Monitoring in South Bay San Diego GOALS

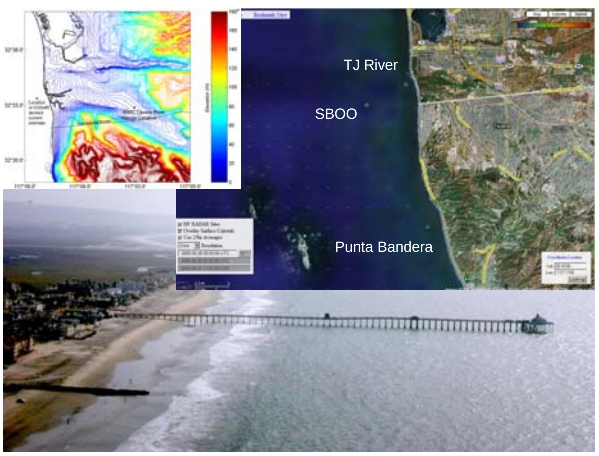
- A) Identify and track plumes from the South Bay Ocean Outfall (SBOO): (SS1, SS5, SS6, SS7, SS8)
- B) Characterize land based sources with focus on the Tijuana River: (SS2, SS3, SS4, SS5, SS6, SS7, SS8)
- C) Identify the regional oceanographic conditions which lead to high fecal indicator bacteria (FIB) on the South Bay Beaches: (SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8)



Project Organizational Chart
IBWC
Project Manager
Gilbert Anaya
IBWC
QA Program Manager
EPA
Grant Coordinator
Elizabeth Borowiec
Grant Applicant Management
CH2M HILL
Richard Pyle
Grant Applicant's Health and Safety Manager
Scott Dahle
Scripps Institution of Oceanography Eric Terrill
Director, CORDC
University of
Southern California
Burton Jones / Jed Fuhrman
CH2M HILL
Kyle Winslow
Quality Assurance Officer
Lisa Hazard
Operations Manager
Matthew Ragan
Operations Manager
(Jones Lab)
Enviromatrix Analytical
Mike Faulkner
Paul Reuter
Software Development Engineer
Zhihong Zheng
Laboratory Manager
(Jones Lab)
William Middleton
Development Engineer
Mahira Kakajiwala
Lab Manager
(Fuhrman Lab)
Shannon Scott
Development Engineer
Joel Hazard
Development Engineer
Mark Otero
Programmer/Analyst

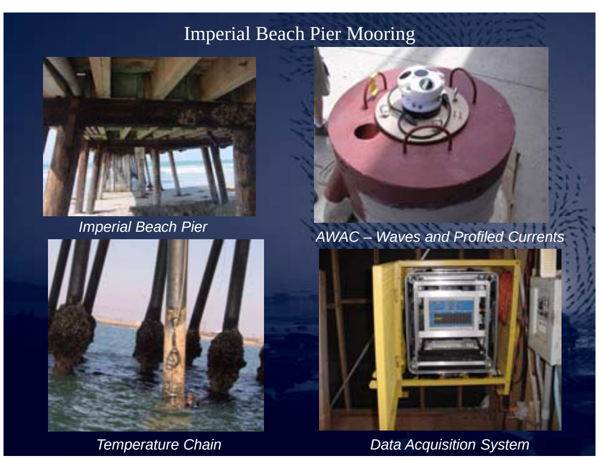


Surface Current Mapping System Data Display
Using Radio
Signals to Measure
Surface Currents
• Based on transmission of radio waves and how they reflect off the ocean's surface.
– Radio waves, tuned to a specific length of ocean waves, originate from the transmit antenna on-shore, scatter off the ocean's surface, and are acquired by the receive antenna.
– The received radio signal allows measurement of currents at different ranges/angles.
• Velocity maps of surface currents provide a foundation for a host of products for furthering ocean understanding, prediction, and research.



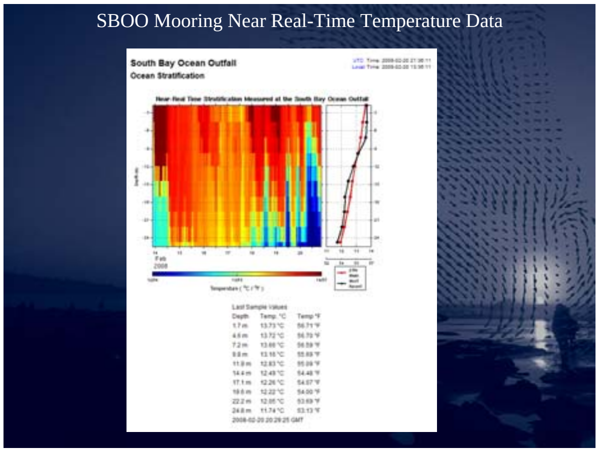
TJ River
SBOO
Punta Bandera

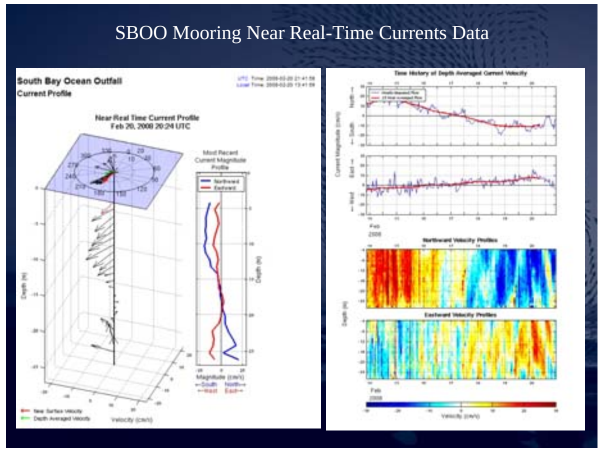
CORONADO ISLAND
Surface Current Mapping System
Solar and wind powered system
Meteorological Station
Wireless communications
Wind generator

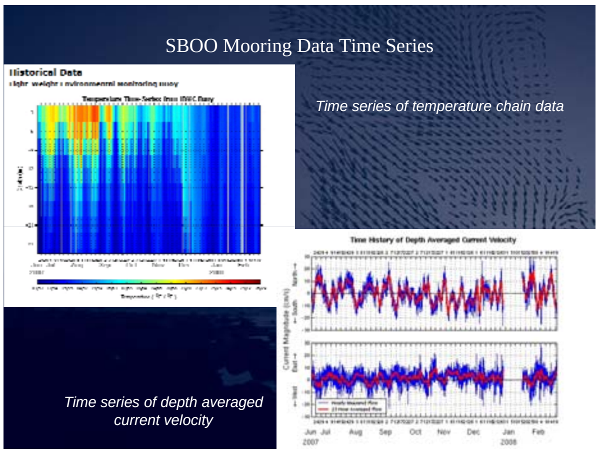


Imperial Beach Pier Mooring
Imperial Beach Pier
AWAC – Waves and Profiled Currents
Temperature Chain
Data Acquisition System

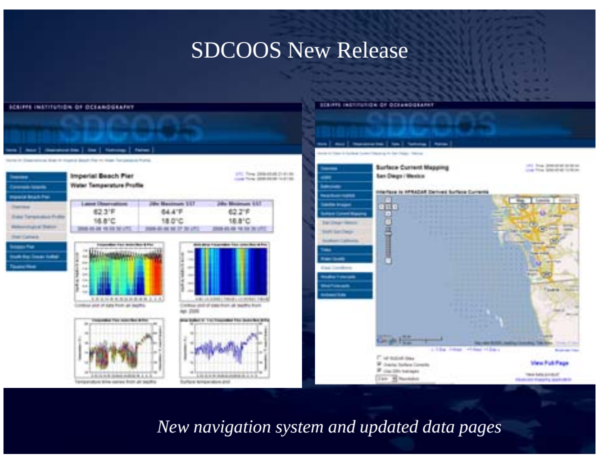
South Bay Ocean Outfall Mooring
• June 19, 2007 Mooring Deployment
• January 15, 2007 Mooring Refurbishment

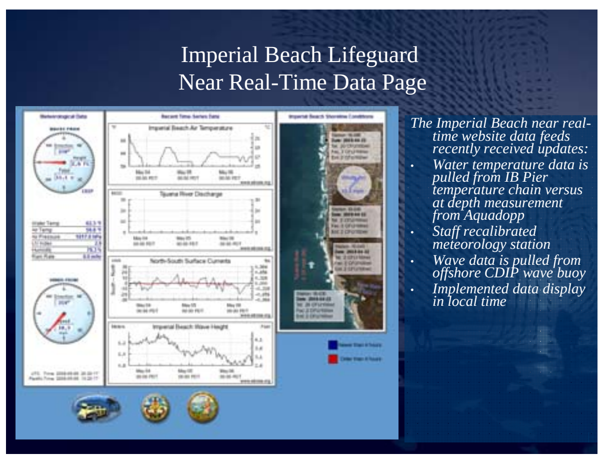

SBOO Mooring Near Real-Time Temperature Data
South Bay Ocean Outfall
Ocean Stratification


SBOO Mooring Near Real-Time Currents Data
South Bay Ocean Outfall
Current Profile

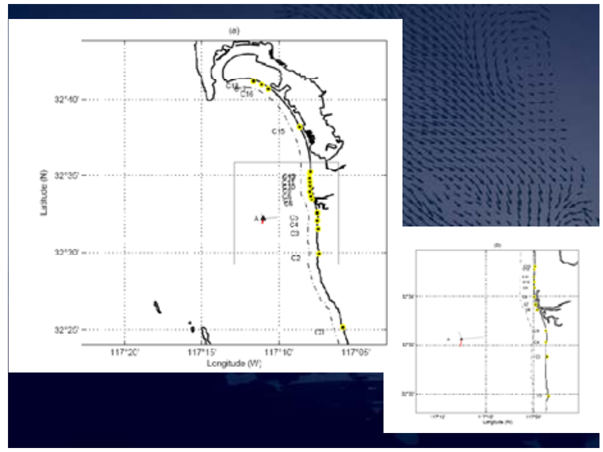

SBOO Mooring Data Time Series
Historical Data
Time series of temperature chain data
Time series of depth averaged current velocity
Time History of Depth Averaged Current Velocity

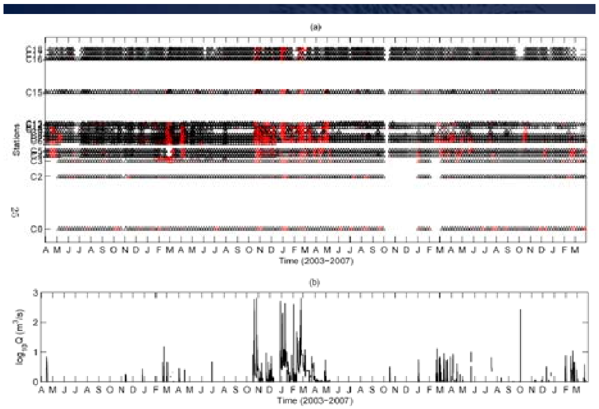

SDCOOS New Release
Updated website tools and navigation
Coordinated with local lifeguards for feedback on restructure
Updated data feeds with recalibrated sensors
Quick links highlighted on front page
South Bay
La Jolla
Reorganized data pages and updated data display
www.sdcoos.org


SDCOOS New Release
New navigation system and updated data pages


Imperial Beach Lifeguard
Near Real-Time Data Page
The Imperial Beach near real-time website data feeds recently received updates:
Water temperature data is pulled from IB Pier temperature chain versus at depth measurement from Aquadopp
Staff recalibrated meteorology station
Wave data is pulled from offshore CDIP wave buoy
Implemented data display in local time

South Bay Existing Water Quality Stations



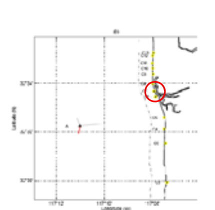


The WQ indicator (g) is a binary value for the contamination of the sampling area – $\mathcal{C}$ (clean) or $\mathcal{D}$ (contaminated), and is defined as based on the observations:

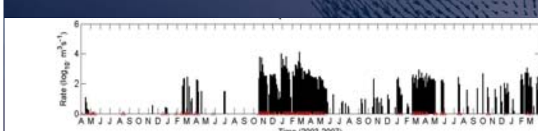
$$g = g(c_1, c_2, c_3, t_d)\,, \qquad (2.1)$$

where c_1, c_2, and c_3 are the amount in 100 ml called as the WQ criteria. c_1 is *Total Coliform* (CFU: Colony Forming Units), c_2 is *Fecal Coliform* (CFU), and c_3 is *Enterococcus* (MPN - Most Probable Number of colony forming units). t_d is the duration that the WQ sampling is valid. The criteria of $\mathcal{D}$ condition are

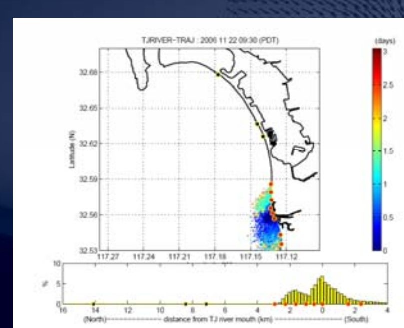
$$g = \{\, g \mid c_1 > 10000, c_2 > 400, c_3 > 104, \left(\frac{c_2}{c_1} > 0.1\right) \cap (c_1 > 1000)\}. \qquad (2.2)$$

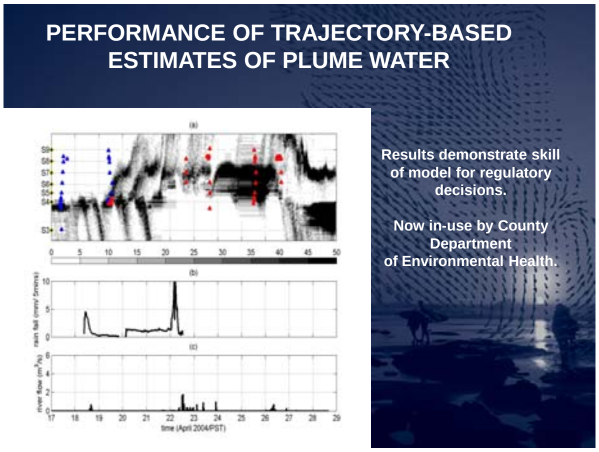


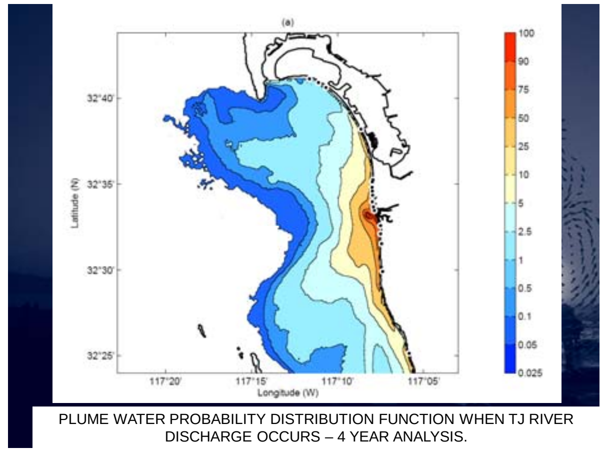
WATER QUALITY EXCEEDANCES AT MOUTH OF TJ RIVER: RAINFALL AND RIVER FLOW

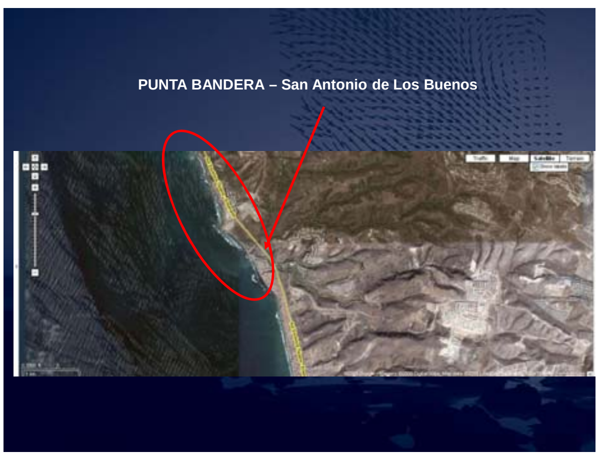


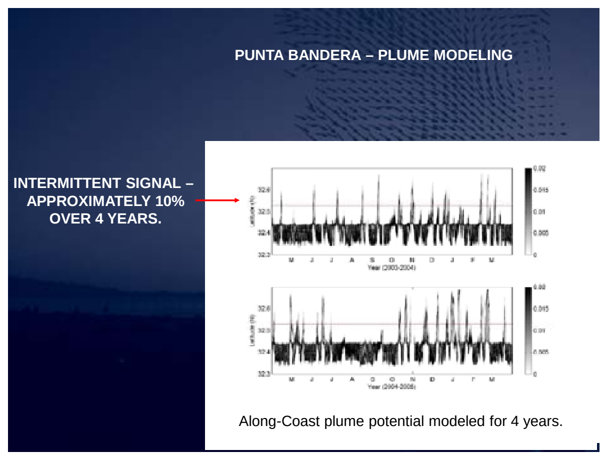
TRAJECTORY ANALYSES OF COASTAL DISCHARGE PLUMES

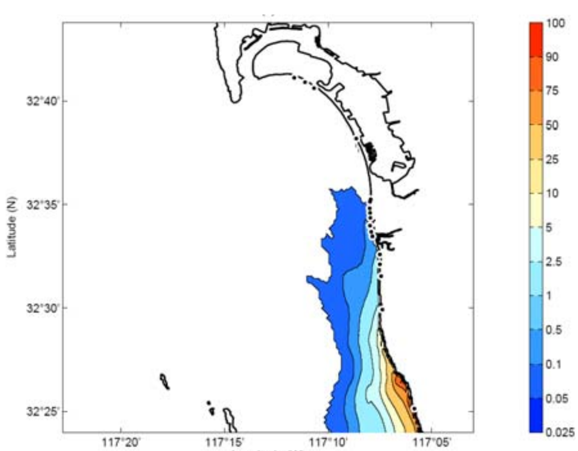



PERFORMANCE OF TRAJECTORY-BASED ESTIMATES OF PLUME WATER
Results demonstrate skill of model for regulatory decisions.
Now in-use by County Department of Environmental Health.
time (April 2004/PST)


Latitude (N)
Longitude (W)
PLUME WATER PROBABILITY DISTRIBUTION FUNCTION WHEN TJ RIVER DISCHARGE OCCURS – 4 YEAR ANALYSIS.


PUNTA BANDERA – San Antonio de Los Buenos


PUNTA BANDERA – PLUME MODELING
INTERMITTENT SIGNAL – APPROXIMATELY 10% OVER 4 YEARS.
Along-Coast plume potential modeled for 4 years.


Latitude (N)
Longitude (W)

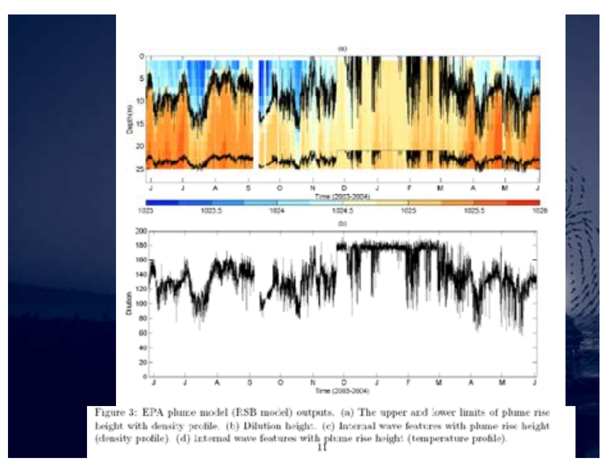
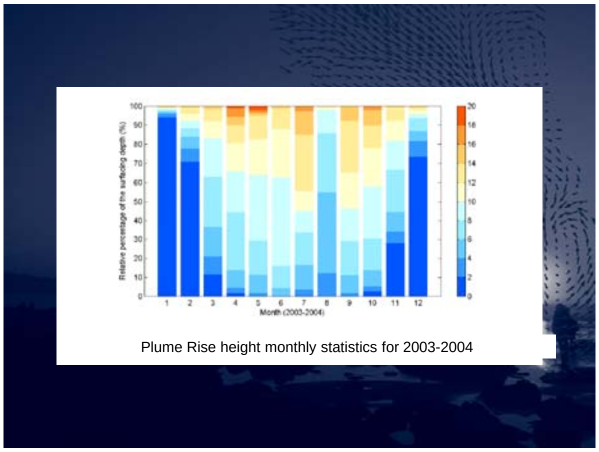
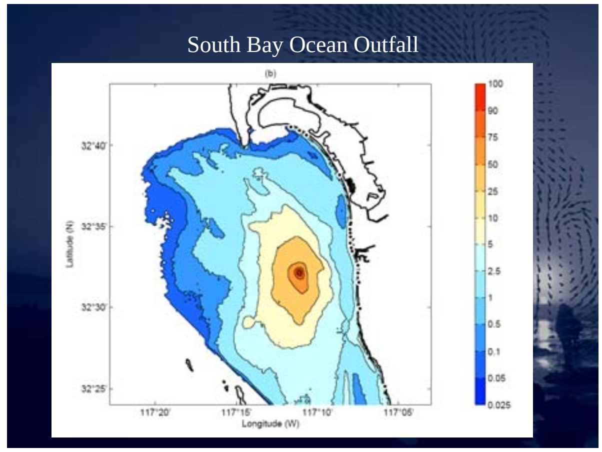
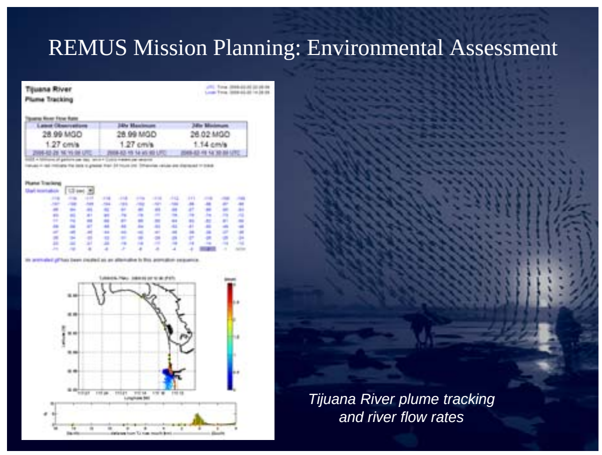


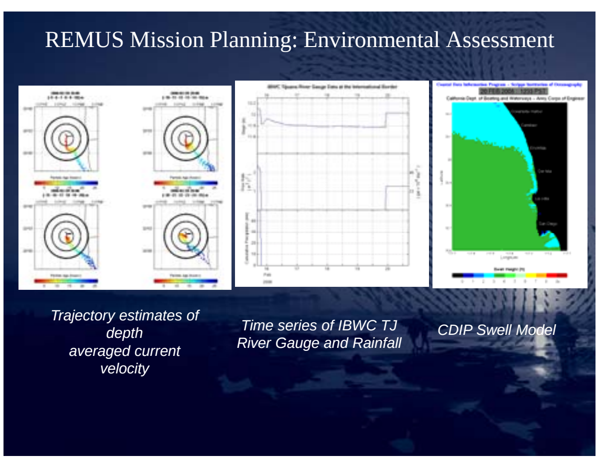
Figure 3: EPA plume model (RSB model) outputs. (a) The upper and lower limits of plume rise height with density profile. (b) Dilution height. (c) Internal wave features with plume rise height (density profile). (d) Internal wave features with plume rise height (temperature profile).

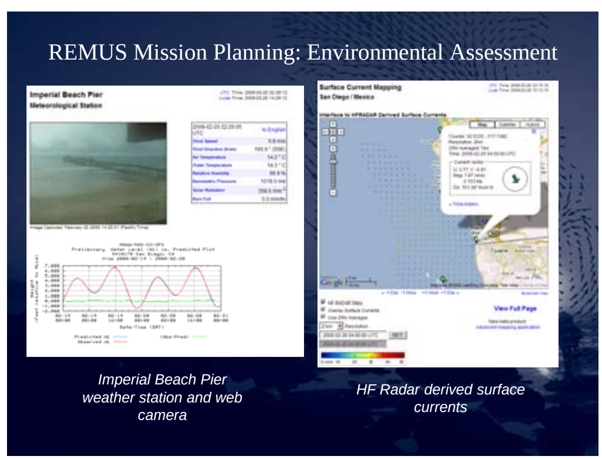

Plume Rise height monthly statistics for 2003-2004

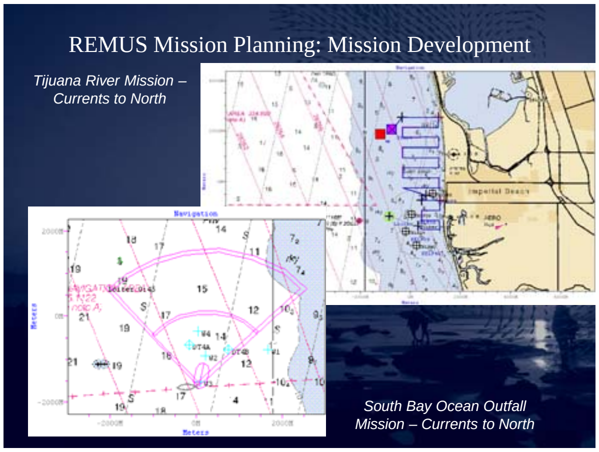

South Bay Ocean Outfall
(b)
Latitude (N)
Longitude (W)

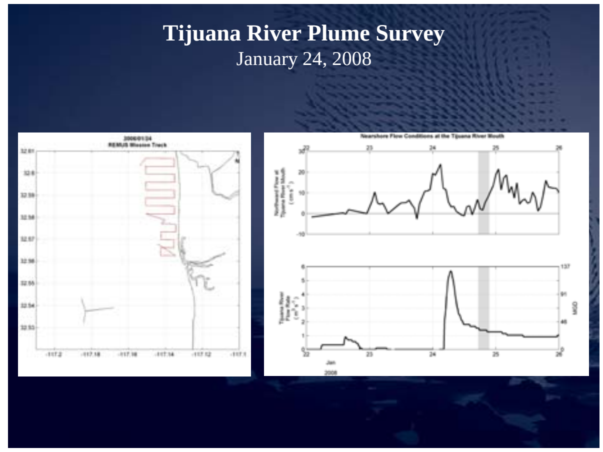

REMUS Mission Deployment
• REMUS Payload
– 900 kHz sidescan sonar
– 1200 kHz Acoustic Doppler Velocity Current Profiler (ADCP)
– Conductivity, Temperature, Depth (CTD)
– Optical Sensor
– Compass
– GPS
– Iridium communications
– Onboard navigation system
CTD and Optical Package

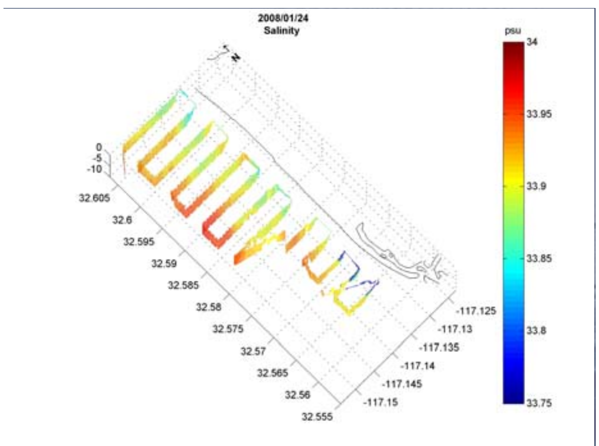

REMUS Mission Planning: Environmental Assessment
Tijuana River
Plume Tracking
Tijuana River plume tracking and river flow rates

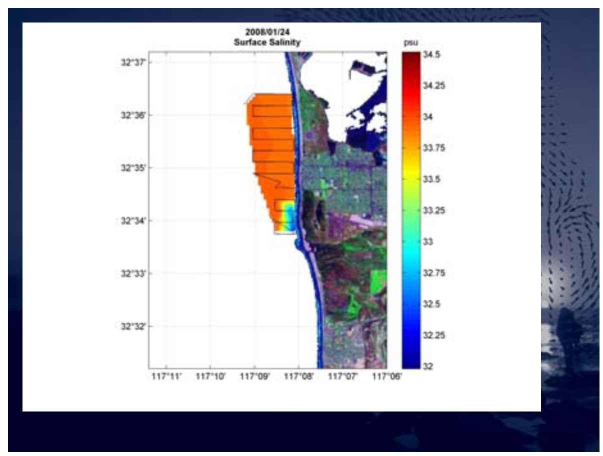

REMUS Mission Planning: Environmental Assessment
Trajectory estimates of depth averaged current velocity
Time series of IBWC TJ River Gauge and Rainfall
CDIP Swell Model

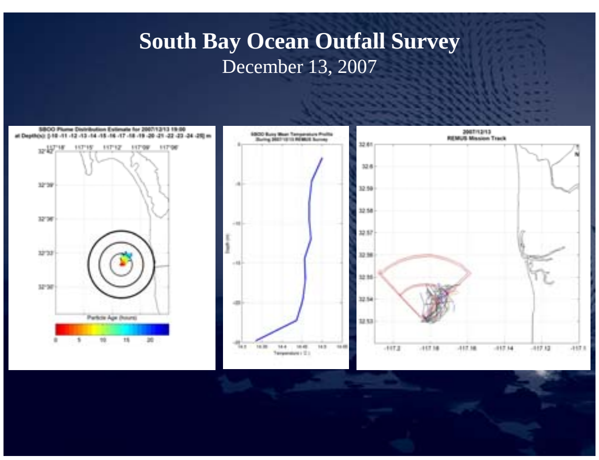

REMUS Mission Planning: Environmental Assessment
Imperial Beach Pier
Meteorological Station
Surface Current Mapping
San Diego / Mexico
Imperial Beach Pier weather station and web camera
HF Radar derived surface currents

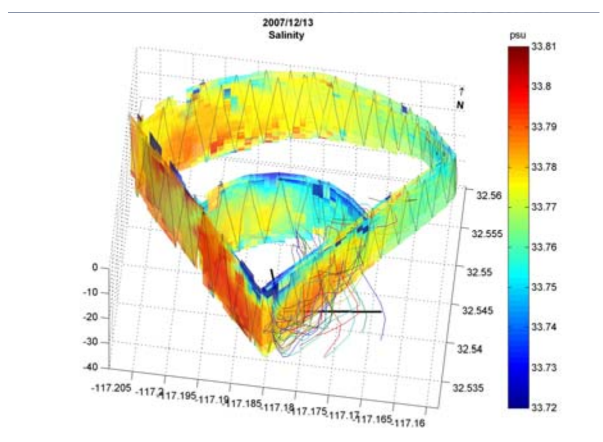

REMUS Mission Planning: Mission Development
Tijuana River Mission – Currents to North
South Bay Ocean Outfall Mission – Currents to North

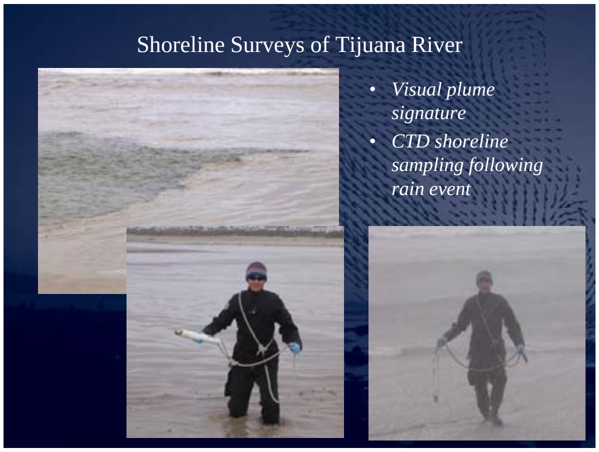

Tijuana River Plume Survey
January 24, 2008

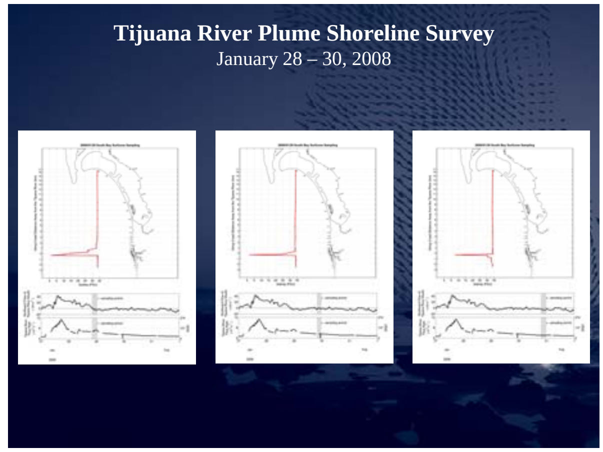

2008/01/24
Salinity
psu

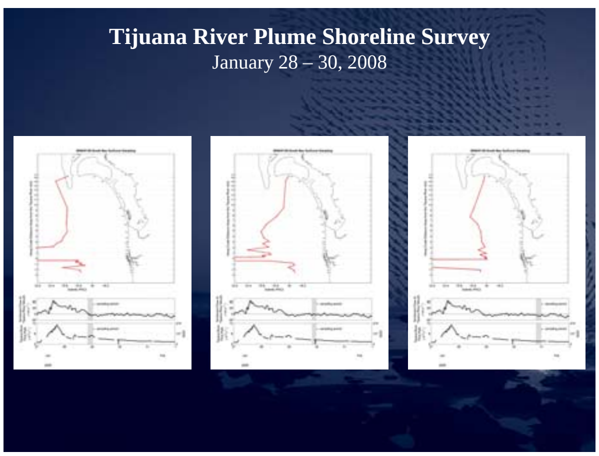

2008/01/24
Surface Salinity
psu

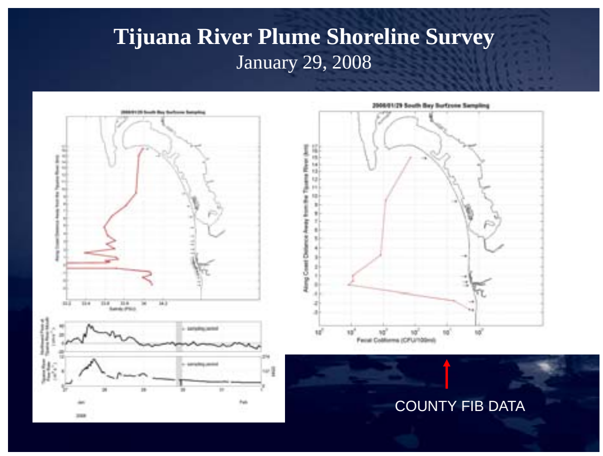

South Bay Ocean Outfall Survey
December 13, 2007

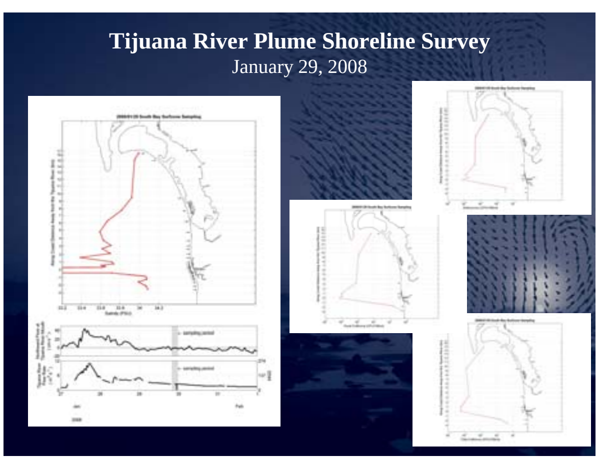

2007/12/13
Salinity
psu

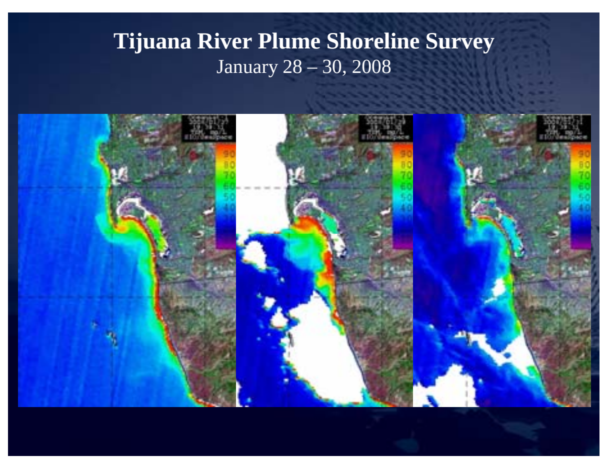

Shoreline Surveys of Tijuana River
• Visual plume signature
• CTD shoreline sampling following rain event


Tijuana River Plume Shoreline Survey
January 28 – 30, 2008


Tijuana River Plume Shoreline Survey
January 28 – 30, 2008


Tijuana River Plume Shoreline Survey
January 29, 2008
2008/01/29 South Bay Surfzone Sampling
COUNTY FIB DATA

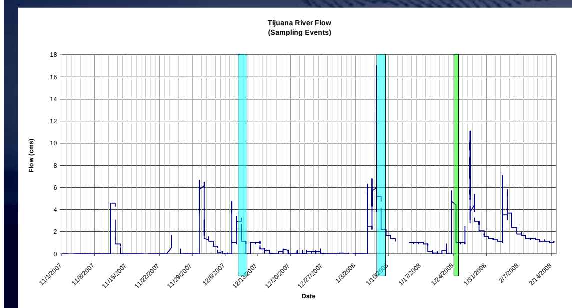

Tijuana River Plume Shoreline Survey
January 29, 2008


Tijuana River Plume Shoreline Survey
January 28 – 30, 2008

January 24, 2008 Plume Sampling (SS7)

Time	Station	Total Coliform	Fecal Coliform	Enterococcus
		(MPN/100 ml)	(MPN/100 ml)	(MPN/100 ml)
11:00	SS7-01 (Outfall)	260	20	ND
11:49	SS7-04	ND	ND	ND
12:20	SS7-06	300	80	40
12:52	SS7-A (River Plume)	90,000	8,000	5,000
13:08	SS7-08	300	ND	ND

CH2MHILL
Tijuana River Flow and Sampling Events



Task SS4 – Tijuana River Loading

FIB Results –Tijuana Estuary (SS4)

Date	Time	Station	Sample ID	TC	FC	Enterococcus
				(MPN/100 ml)	(MPN/100 ml)	(MPN/100 ml)
1/8/08	14:03	Inlet	SS4-01a-010808	900,000	140,000	22,000
1/8/08	13:41	Seacoast	SS4-02a-010808	900,000	110,000	30,000
1/8/08	12:10	Hollister Bridge	SS4-04a-010808	900,000	300,000	80,000
1/8/08	12:51	Main Branch	SS4-03a-010808	900,000	500,000	110,000
1/8/08	14:08	Inlet Dupe (turbid)	SS4-05a-010808	900,000	300,000	11,000
1/9/08	14:00	Inlet	SS4-01a-010908	110,000	30,000	3,000
1/9/08	13:39	Seacoast Drive	SS4-02a-010908	80,000	23,000	8,000
1/9/08	12:31	Hollister Bridge	SS4-03a-010908	>1,600,000	>1,600,000	80,000
1/9/08	13:12	Main Branch	SS4-04a-010908	1,600,000	300,000	23,000

Sampling Configuration

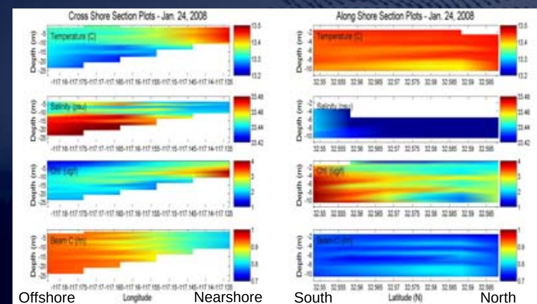
2 Wet Weather Sampling Events

- January 24, 2008
  - Measurable rain prior to sampling
- April 3, 2008
  - Rain inland, but trace near coast

Microbial Indicators – Human specific

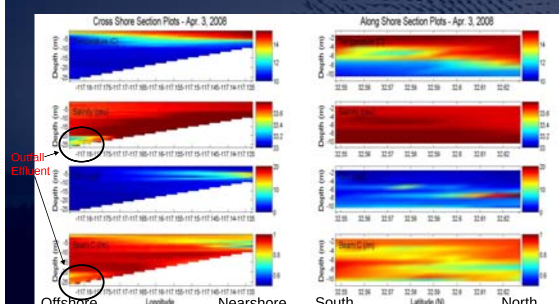
- Two indicators of human specific microbiological contamination were used.
  - **Bacteriodes/Prevotella** is a bacterium specific to the human digestive tract
  - **Enteroviruses** are human specific enteroviruses that can be shed from the digestive tract.

January 24 Physical/Optical Observations



Microbiological Observations – 1/24/08

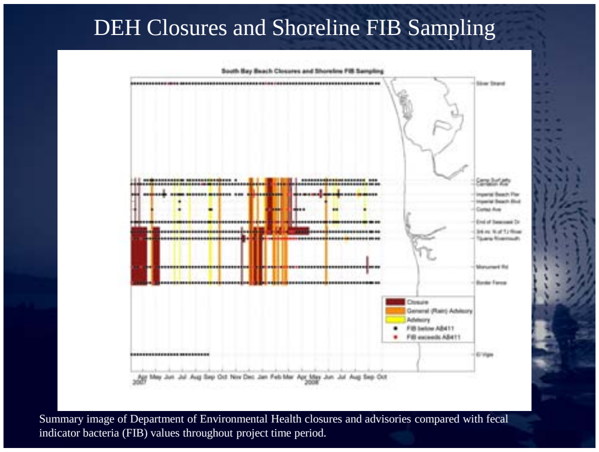
April 3 Physical/Optical Observations

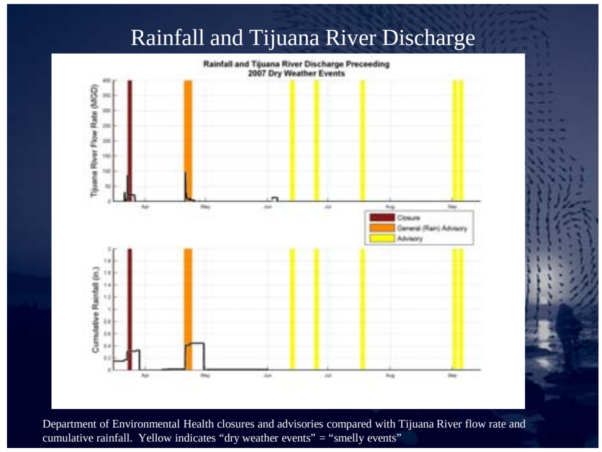


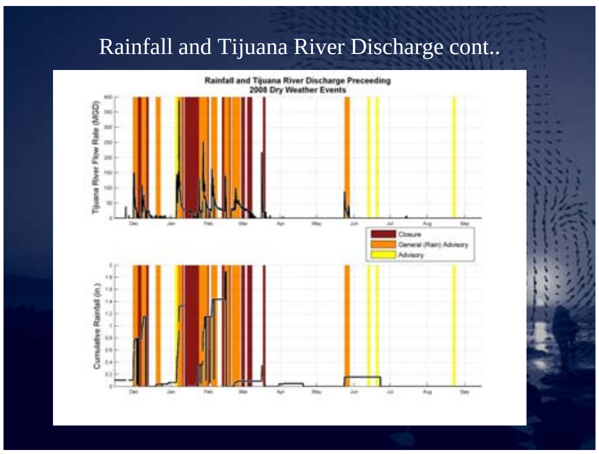
Microbiological Observations – 04/03/08

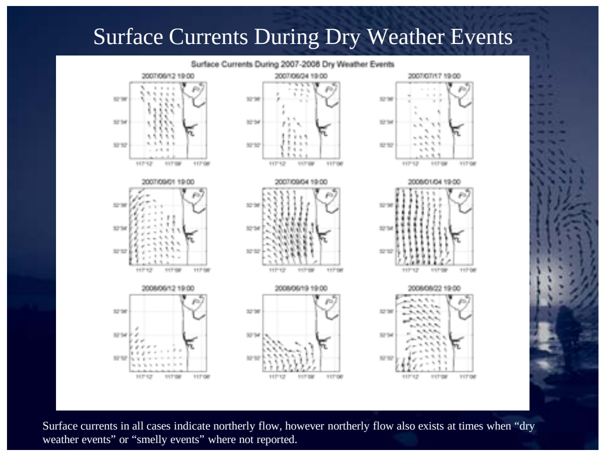
Conclusions

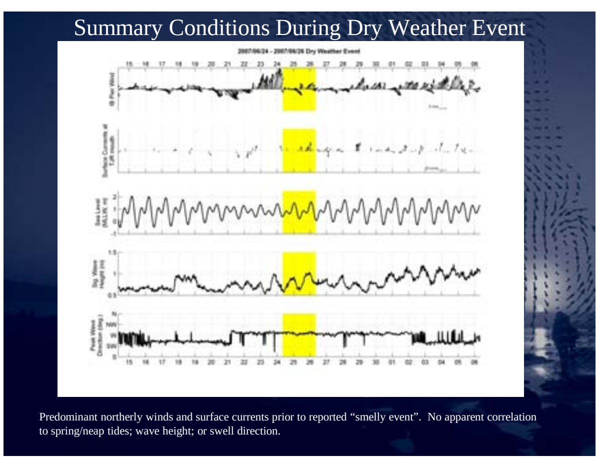
- Both sewage effluent plume and Tijuana River water have been detected
- The extent of both sources was spatially very limited during these 2 sampling events.
- Low levels of Bacteriodes, indicative of fecal material, were found in most of the surface waters during both sampling periods. Except for the outflow from the Tijuana River, these values were not high, but do indicate low-level presence of human fecal material in the surface waters.
- Enteroviruses were not detected. While their presence would be a confirmation of the Bacteriodes results, their absence does not negate the Bacteriodes observations.
- No evidence of increased concentrations of Bacteriodes from the south was detected in these sampling 2 events
- Two sets dry weather observations will be made in July 2008.

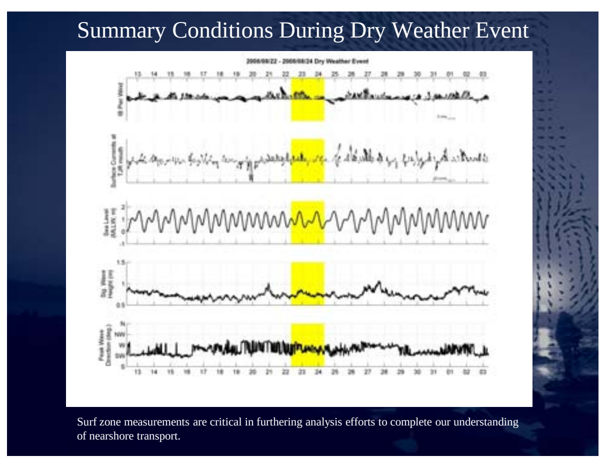

DEH Closures and Shoreline FIB Sampling
South Bay Beach Closures and Shoreline FIB Sampling
Summary image of Department of Environmental Health closures and advisories compared with fecal indicator bacteria (FIB) values throughout project time period.

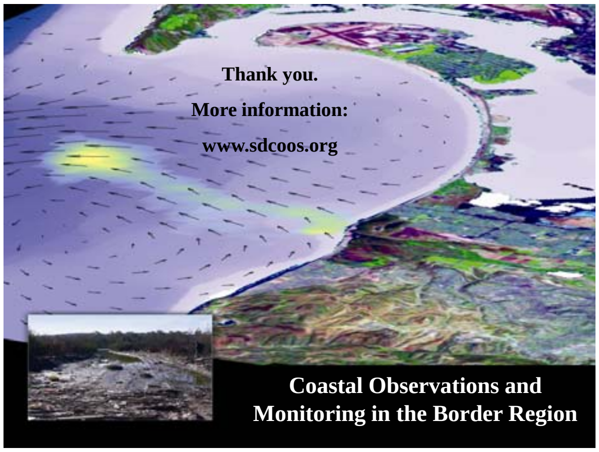

Rainfall and Tijuana River Discharge
Rainfall and Tijuana River Discharge Preceeding
2007 Dry Weather Events
Closure
General (Rain) Advisory
Advisory
Department of Environmental Health closures and advisories compared with Tijuana River flow rate and cumulative rainfall. Yellow indicates “dry weather events” = “smelly events”


Rainfall and Tijuana River Discharge cont..
Rainfall and Tijuana River Discharge Preceeding
2008 Dry Weather Events
Closure
General (Rain) Advisory
Advisory


Surface Currents During Dry Weather Events
Surface Currents During 2007-2008 Dry Weather Events
Surface currents in all cases indicate northerly flow, however northerly flow also exists at times when “dry weather events” or “smelly events” where not reported.


Summary Conditions During Dry Weather Event
Predominant northerly winds and surface currents prior to reported “smelly event”. No apparent correlation to spring/neap tides; wave height; or swell direction.


Summary Conditions During Dry Weather Event
Surf zone measurements are critical in furthering analysis efforts to complete our understanding of nearshore transport.


Thank you.
More information:
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Coastal Observations and
Monitoring in the Border Region