Tijuana River Bacterial Source Identification Study

Final Report

Prepared For:

City of Imperial Beach
Public Works Department
495 10th Street
Imperial Beach
CA 91932

August 2012

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AB411	Assembly Bill 411 – Title 17 of the California Code of Regulations, Section 7958
ADCP	Acoustic Doppler Current Profiler
ARA	antibiotic resistance analysis
ARM	Agricultural Runoff Model
BASINS	Better Assessment Science Integrating Point and Non-Point Sources
BMP	best management practice
BOD	biochemical oxygen demand
BPJ	Best Professional Judgment
BSI	bacterial source identification
BST	Bacterial Source Tracking
Cal-EPA	California Environmental Protection Agency
CBI	Clean Beach Initiative
CBOD	carbonaceous biochemical oxygen demand
CESPT	Comisión Estatal de Servicios Públicos de Tijuana
cfs	cubic feet per second
CILA	Comisión Internacional de Límites y Aguas
CODAR	Coastal Dynamics Application Radar
COLEF	El Colegio de la Frontera Norte
CONEPO	Consejo Estatal de Población
CTR	California Toxic Rule
CWA	Clean Water Act
DEH	County Of San Diego Department of Environmental Health
DEM	digital elevation model
DNA	deoxyribonucleic acid
DO	dissolved oxygen
EMC	event mean concentration
FIB	fecal indicator bacteria
GAO	Government Accountability Office
GIS	geographic information system
HAV	Hepatitis A virus
HSA	hydrological sub-area
HSPF	Hydrological Simulation Program – Fortran
IB	Imperial Beach
IDEXX	Trade name of a fecal indicator bacteria analytical technique developed by IDEXX Laboratories, Inc. (Environmental Protection Agency-approved testing method)
IMPlan	Instituto Municipal de Planeacion
HBSA	Human bifid sorbitol agar
JBIC	Japanese Bank for International Cooperation
LDM	library-dependent methods
LIM	library-independent methods
LLC	limited liability corporation
MBAS	methylene blue active substances
mgd	million gallons per day
MLS	mass loading station
MPN	most probable number
MS4	Municipal Separate Storm Sewer System
MST	microbial source tracking
NAS	Naval Air Station
NOEC	No observable effect concentration
NPDES	National Pollutant Discharge Elimination System
NPS	non-point source
OLF	Outlying Field
PFGE	pulsed-field gel electrophoresis
Q-PCR	Quantitative Polymerase Chain Reaction

qRT-PCR	Quantitative Reverse Transcription Polymerase Chain Reaction
REP-PCR	repetitive extragenic palindromic polymerase chain reaction
RT-PCR	Real-Time Polymerase Chain Reaction
RWQMP	Receiving Water Quality Monitoring Program
SANDAG	San Diego Association of Government
SANGIS	San Diego Geographic Information Systems
SBIWTP	South Bay International Wastewater Treatment Plant
SBOO	South Bay Ocean Outfall
SDCOOS	San Diego Coastal Ocean Observing System
SDRWQCB	San Diego Regional Water Quality Control Board
SDSU	San Diego State University
SIO	Scripps Institute of Oceanography
SWMM	Stormwater Management Model
SWRCB	State Water Resources Control Board
TR-20	Technical Release 20
T-RFLP	terminal restriction fragment length analysis
TRNERR	Tijuana River National Estuarine Research Reserve
TMDL	total maximum daily load
TRW	Tijuana River Watershed
UCSB	University of California, San Diego
USIBWC	United States Section of the International Boundary and Water Commission
U.S.	United States
USEPA	United States Environmental Protection Agency
WER	water effects ratio
Weston	Weston Solutions, Inc.
WMA	Watershed Management Area
WURMP	Watershed Urban Runoff Management Program
WQO	water quality objective

EXECUTIVE SUMMARY

In April 2008, the City of Imperial Beach (City) was awarded a Clean Beach Initiative (CBI) grant by the State Water Resources Control Board (SWRCB) (Grant Program Agreement No. 07-584-550-2) to assess the potential sources of indicator bacteria on the United States (U.S.) side of the Tijuana River Watershed that may be impacting the Tijuana River Estuary and adjacent beaches. The resultant project was named the *Tijuana River Bacterial Source Identification Study*. The contract timeline for the work identified for the study was as follows:

- The SWRCB Contract for the City of Imperial Beach was awarded in February 28, 2008.
- The Contract was closed by the SWRCB due to the State-wide funding crisis on December 17, 2008.
- The Project was reopened on May 6, 2010.
- The Project end date is October 1, 2012.

Study Objectives

The overall goal of the study was to identify sources of indicator bacteria in the Tijuana River Watershed within the U.S. side of the U.S./Mexico border that have the potential to impact the Tijuana River Estuary and adjacent beaches. Within this larger framework, the study had several specific objectives:

1. Identify anthropogenic sources of bacteria,
2. Identify non-anthropogenic sources of bacteria,
3. Assess annual bacteria loads into the Tijuana River,
4. Identify point and non-point sources (NPSs) of bacterial pollutants, and
5. Develop best management practices (BMPs) to reduce bacterial loads originating in from the U.S. side of the border.

To address these objectives, the project had several elements:

- Sanitary and Dry Weather Surveys,
- Wet Weather Assessments,
- A Series of Special Studies, and
- BMP Concept Designs and Prioritization.

Each of these elements is discussed below.

Sanitary and Dry Weather Surveys

The primary objectives of the sanitary surveys were to identify anthropogenic and non-anthropogenic sources of indicator bacteria that could impact receiving waters in the estuary. Three two-week sanitary surveys were conducted over the course of the study, targeting approximately 100 sampling locations per survey, covering the entire urbanized area on the western portion of the U.S. side of the Tijuana River Watershed. Follow-up dry weather surveys were conducted if high bacterial concentrations were found, if the sample tested positive for human-specific *Bacteroides* (a genetic marker that is specific to human fecal contamination), or if visual observations suggested follow up was necessary.

- The results of the first two sanitary surveys identified several sites where indicator bacterial concentrations were high or tested positive for human-specific *Bacteroides*. In all cases, follow up dry weather surveys indicated that water at the site was either ponded, had very low trickle flows, and/or the flow could not be traced upstream to any source.

- These results of these extensive surveys suggest that with few exceptions, elevated levels of indicator bacteria or the potential presence of human fecal contamination at numerous sites assessed in the watershed were ephemeral and did not represent a consistent source of bacteria to the estuary.

- Sanitary Survey 3 was a dry weather survey that focused primarily on sites within the estuary itself. Thorough visual observations on all sides of the watershed adjacent to the estuary revealed that with one exception there was no apparent hydrologic connection between surface waters in the watershed and those in the estuary. That is, during dry weather, the vast majority of the flows in the sub-drainages on the U.S. side of the border never reach the estuary.

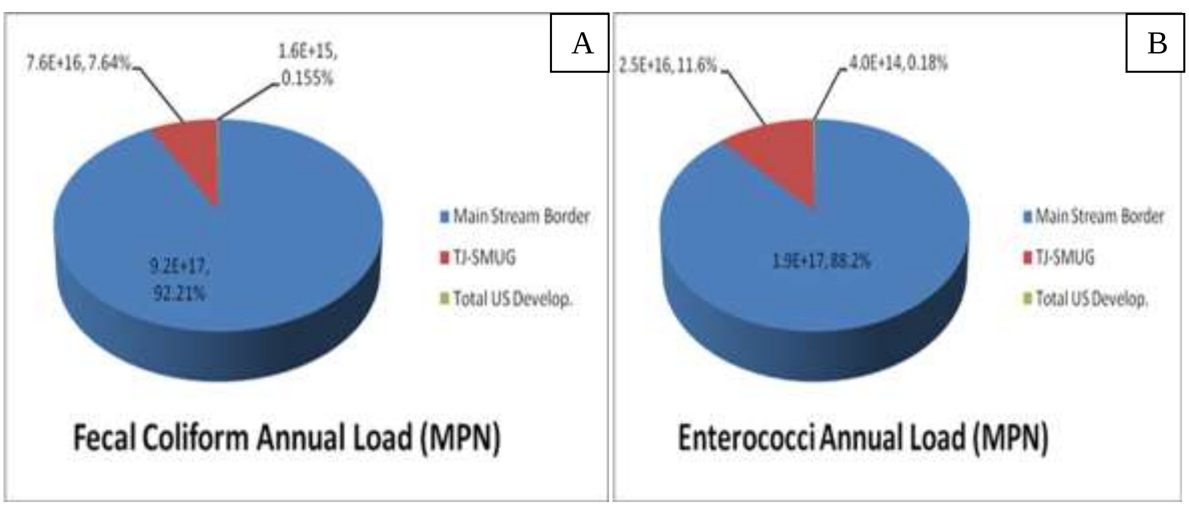
Further assessments conducted in January and February, 2012 confirmed that the substantial majority of dry weather from the U.S. side of the border never reaches the estuary because the majority of the sub-drainages discharge to a soft-bottom creek or other semi-natural feature (*e.g.,* ponds) where dry weather flows infiltrate rapidly. The one area of direct, but very small flow to the estuary was the outfalls of the E and F Lines in Imperial Beach that discharge directly to the estuary. Dry weather flows from these outfalls were very low. Thus, one of the major findings of this study was that potential impacts to the estuary from dry weather flows are limited to these small sub-drainages and episodic and infrequent rogue flows from the Mexico side of the border when the diversion structures are bypassed.

E-line storm drain outfalls showing minimal dry weather flow directly to the Tijuana River Estuary. The majority of dry weather flow from other sub-drainages on the U.S. side of the border never reaches the estuary.

Wet Weather Assessments

The objective of the wet weather monitoring was determine the concentrations and loads of indicator bacteria and other constituents that impact the estuary from the mainstem of the Tijuana River (Dairy Mart Bridge and Hollister Bridge), Smuggler's Gulch (a tributary to the mainstem originating in Mexico), and Veterans Park (a tributary to the estuary originating in the City of Imperial Beach).

- The results of the wet weather assessments were similar among the three storms monitored. Indicator bacteria concentrations were in the 1,000,000 to 10,000,000 MPN/100 mL range over the course of the storm from all three sites originating from Mexico. However, indicator bacteria concentrations from the Veterans Park site (which originates in the City of Imperial Beach) were one to two orders of magnitude lower than those from sites originating from Mexico.
- When these concentrations were combined with flow data collected during the storm events, it was determined that approximately 90% of the annual bacterial load that enters the Tijuana River Estuary (and has the potential to impact area beaches) originates from the Tijuana River mainstem.
- Smuggler's Gulch, which also originates in Mexico, accounts for approximately 11 and 8% of the *Enterococcus* and fecal coliform loads, respectively.
- The contribution from the entire U.S. urbanized portion of the watershed that flows directly to the estuary accounts for less than 1 % of the *Enterococcus* and fecal coliform loads entering the estuary.
- In addition, nearly all of the samples originating from Mexico were positive for the human-specific *Bacteroides* marker (indicating the presence of human fecal matter), while none of those from the U.S. drainage were positive for the marker.



Annual Loads of Fecal Coliforms (A) and Enterococci (B) showing that approximately 90% of the bacterial load that enters the Tijuana River Estuary originates from the Tijuana River mainstem (blue), approximately 10% originates from Smuggler's Gulch in Mexico (red), and less than 1% originates from the entire urbanized portion on the U.S. side of the border (green).

Seacoast Drive Special Study

During the first sanitary survey conducted in July, 2010, human-specific *Bacteroides* (indicator of the presence of human fecal contamination) and elevated bacterial levels were found in the northern arm of the Tijuana River Estuary adjacent to Seacoast Drive in Imperial Beach. As a result, the Seacoast Drive Special Study was initiated to identify the source or sources of bacteria and the potential for human sewage in this portion of the estuary. Prior to the initiation of the study, leaking sewer infrastructure had been identified by the City as a potential problem along Seacoast Drive in a length of sewer pipe approximately ½ mile long that ended in a pump station on the northern end of Seacoast Drive. As a result, the City took proactive steps and re-sealed the pump station to eliminate any potential leakage from the sewage infrastructure to the adjacent estuary.

The goal of the Seacoast Drive Special Study was to assess the effectiveness of sewage infrastructure repairs and to determine if there was evidence of human sewage impacting the estuary after the repairs had been made. In February, 2011 rhodamine dye was placed in the sewer pipe on the southern end of Seacoast Drive where it flowed north to the newly sealed pump station. Samples were collected from several sites in the northern arms of the estuary (adjacent to Seacoast Drive) and from the pump station. All samples were analyzed for indicator bacteria and human-specific *Bacteroides* on the day the dye was injected and for two subsequent days. In addition, filter packs containing absorbent media were anchored in the estuary for the same three day period, then analyzed for the presence of the rhodamine dye.

- The results of the study suggest that sealing the pump station had prevented any potential leakage of sewer water from the Seacoast Drive sewer line and pump station that may have been entering the estuary.
- Over the course of the three day sampling event, none of the more than 60 samples collected were positive for the human-specific *Bacteroides* marker.
- In addition, none of the absorbent media filter bags anchored in the estuary had even trace amounts of the rhodamine dye.

Seacoast Drive Special Study showing insertion of rhodamine dye and collection of dye and bacterial samples in the Tijuana River Estuary adjacent to Seacoast Drive. Evidence of bacteria from human origin was not observed in the estuary after the Seacoast Drive pump station was sealed by the City of Imperial Beach.

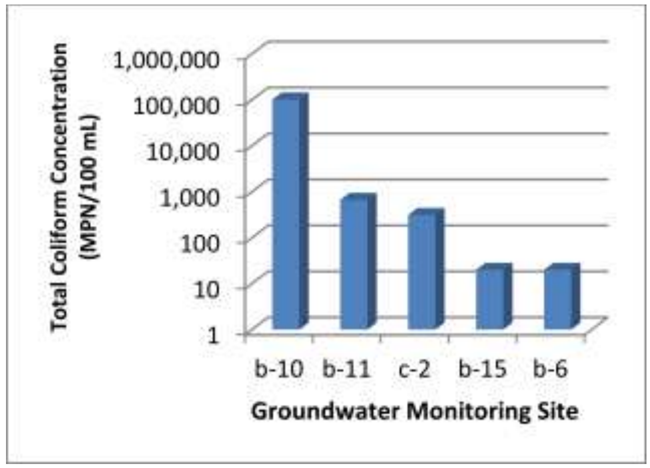
The results suggest that sealing the sewage infrastructure along Seacoast Drive was effective in preventing sewage from entering the Tijuana River Estuary. These results were confirmed in subsequent monitoring conducted in the estuary in the summer of 2011 as part of a dry weather survey. During this follow-up investigation, all samples collected from the estuary (including several sites in the estuary's northern arm adjacent to Seacoast Drive) were negative for the human-specific *Bacteroides* marker.

Groundwater Special Study

This project element was designed and implemented in order to assess the presence of indicator bacteria as well as human-specific *Bacteroides* and enterovirus (a marker of potential human pathogens) in groundwater within the western portion of the Tijuana River Watershed and to assess the extent to which groundwater may impact surface waters within the estuary. The objective was to determine if groundwater is a source of microbes to the estuary and to assess the spatial distribution of microbes in groundwater in the western portion of the watershed.

In order to address these objectives, five previously existing groundwater monitoring wells were sampled over a period of 16 months and analyzed for indicator bacteria, human-specific *Bacteroides*, enterovirus, and a suite of chemical constituents.

- In general, indicator bacteria concentrations were low in most groundwater samples and all samples were negative for the human-specific *Bacteroides* marker.
- There appeared to be a spatial gradient in bacterial and nutrient concentrations among the groundwater wells monitored, with relatively high concentrations in groundwater closest to the U.S. / Mexico Border and lower concentrations found in groundwater closest to the Tijuana River Estuary.
- The one exception to this pattern was that observed for enterovirus. Among the 35 samples collected over the course of the study, three were identified as positive for enterovirus, all of which were found at sites closest to the estuary (sites b-15 and b-6).



Mean total coliform concentrations in groundwater wells showing higher concentrations at sites closest to the U.S./Mexico Border (Sites b-10 and b-11) compared to sites closest to the Tijuana River Estuary (Sites b-15 and b-6).

The low concentrations of indicator bacteria and nutrients in groundwater closest to the estuary and the absence of human-specific *Bacteroides* throughout the study suggest that groundwater may not be a likely source of fecal contamination to the receiving waters of the estuary. However, positive results for the enterovirus assay at the two sites closest to the estuary indicate the potential for groundwater contamination and suggest that further investigations may be necessary to determine the potential impact to the estuary from groundwater sources.

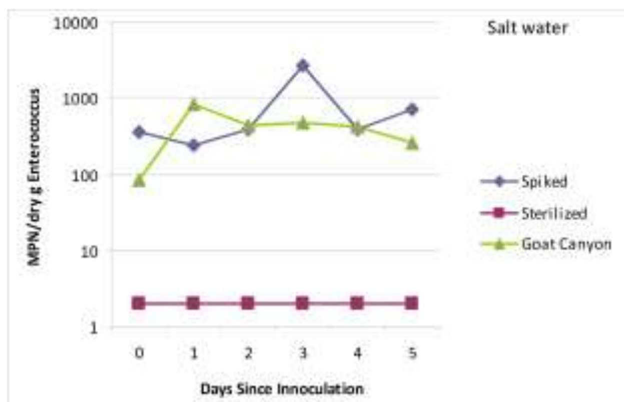
Goat Canyon Dredged Sediment Special Study

Goat Canyon is located at the southern end of the Tijuana River National Estuarine Research Reserve in the western portion of the Tijuana River Watershed and spans the U.S. / Mexico Border. Ninety percent of the Canyon's sub-watershed lies in Mexico. In recent decades, human-induced disturbance originating primarily upstream in Mexico has resulted in increased sedimentation in Goat Canyon, which increases sediment loads to the Tijuana River Estuary. Sediment basins have been installed on the U.S. side of the border to trap Goat Canyon sediment before reaching the estuary. The goal of the Goat Canyon Dredged Sediment Special Study was to determine if dredged material removed from the basins is a reservoir for indicator bacteria and to assess the potential for the dredged material to impact surface waters if the sediment were used for beach replenishment purposes.

To address these goals, sediment samples were collected in November, 2010 from sediment that had been dredged from the Goat Canyon sediment basins and stockpiled adjacent to the site. The sediment was suspended in sterile solutions of water of varying salinities (fresh, brackish, and marine). Sub-samples were then drawn from each of the solutions over a period of five days and quantified for indicator bacteria.

- The results indicated that the relatively fine-grained, high nutrient sediment in the Goat Canyon sediment basins do serve as a reservoir for both fecal coliforms and enterococci.

- The inoculation test results suggest that the Goat Canyon dredged sediments can contribute elevated bacterial concentrations to the water columns in fresh, brackish and marine systems, and that the indicator bacteria can survive in these solutions for at least several days.



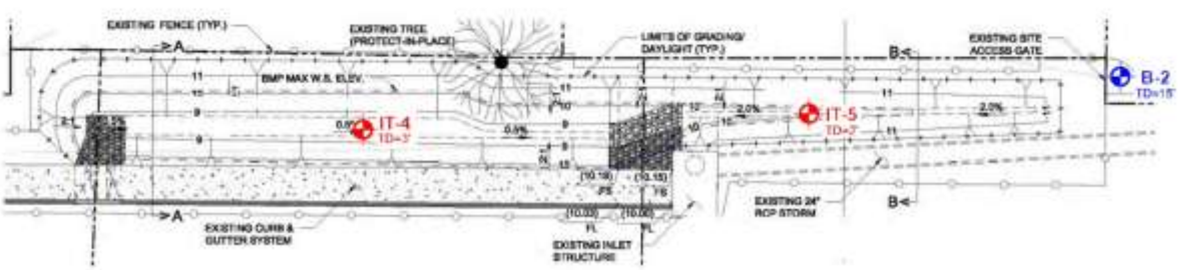
Results of Goat Canyon Sediment Study showing elevated enterococcus concentrations over time in salt water. The results suggest that bacteria (especially enterococci) in basin sediments may persist in seawater if sediments were used for beach replenishment.

The persistence of enterococci, compared to fecal coliforms, in each of the three water treatments is similar to results observed in other studies which have shown that enterococci tend to survive better in the environment than fecal coliforms. It also supports the findings of other studies that suggest that sediments play an important role in the survival of bacteria by providing a favorable, environment for microbes. When taking into account the complex environment of the Pacific Ocean, the results of this special study suggest that if Goat Canyon dredged material was used for beach replenishment, it could cause an initial increase in both enterococcus and fecal coliform concentrations in the receiving waters. However, that increase is most likely to be transitory in nature when sea temperatures, hydrologic flow patterns, and UV radiation are taken into account.

BMP Concept Designs and Prioritization

The purpose of this part of the study was to conduct a hydrologic and water quality analysis to assess and prioritize concept designs to reduce bacterial loads to the Tijuana River Estuary. The best BMPs proposed in the selected concept designs were based on low impact development (LID) features at selected sites with the Tijuana River Watershed. The study was performed to determine and document the water quality flows and volumes (storm water runoff) from the tributary area for each concept design site. The BMPs are proposed to provide water quality improvement of storm water runoff with some attenuation of peak flows, which in itself also provides water quality benefits (less downstream flow equates to less potential for downstream sediment transport). Locations for the BMPs were determined based on the findings of the wet and dry weather studies conducted as part of this project.

Based on the criteria listed above, six concept designs were produced as part of this study using established BMPs to reduce bacterial loading, such as bioretention basins at Imperial Beach Boulevard Parkway and Mar Vista Church, porous concrete on Thorn Street Cul de Sac and Donax Avenue, an eco bike lane and green street BMP on Imperial Beach Boulevard, and bioretention basins on East San Ysidro Boulevard. The tributary drainage areas for these BMPs ranged from 0.46 to 5.3 acres with estimated bacterial load reductions ranging from 62 to 100% removal. Estimated project capital costs to achieve these load reductions ranged from $50,250 to $1,110,750. Based on these costs and the estimated annual load removal, a priority ranking of the BMPs was conducted based on a cost / benefit analysis. Among the six projects for which concept designs were produced, the Donax Avenue project had the lowest cost per annual load removed and the Imperial Beach Boulevard Eco-Bike Lane had the highest cost per annual load removed. Watershed managers may use this cost / benefit analysis as one of many tools to facilitate decisions about future implementation of BMPs to reduce bacterial loading to the Tijuana River Estuary. Other factors should be taken into consideration, such as existing conditions, public perception, and multiple benefits provided by projects.



BMP Concept Designs were produced as part of the project to decrease bacterial loads to the Tijuana River Estuary

Summary of Major Findings

There were numerous findings from this multi-year, multi-faceted study. The major conclusions drawn from the results of the monitoring and special studies are summarized below.

- The pollution sources and their impact on the Tijuana River Estuary vary dramatically by season. During dry weather, the estuary is relatively un-impacted from the watershed, and the estuary is a healthy, vibrant and vital ecosystem. During storm events, flows from Mexico transform the estuary into a severely impacted, polluted and hazardous waterbody with extremely elevated bacterial concentrations and elevated potential health risk to the environment and the public.

- Extensive dry weather and sanitary surveys revealed several locations in the watershed where indicator bacterial concentrations were high, or there was evidence of human fecal contamination, but the contamination was determined to be ephemeral and not related to a consistent source (such as leaking infrastructure).

- Dry weather surveys also revealed that there is very little hydrologic connection between watershed surface waters and the estuary (with the exception of some small drainages).

- Semi-natural BMPs such as soft-bottom sediments and ponds at the base of the major sub-drainages prevent the large majority of dry weather flows from entering the estuary.

- During wet weather, approximately 99% of the indicator bacterial loads entering the Tijuana River Estuary and Pacific Ocean originate from un-diverted flows from the Tijuana River mainstem and tributary channels from Mexico.

- Proactive steps to reline the sewage system along Seacoast Drive by the City of Imperial Beach appear to have eliminated a suspected source of human fecal contamination from entering the northern arm of the estuary.

- Groundwater associated with the mainstem of the Tijuana River at the U.S. Mexico Border may have elevated bacterial and nutrient levels compared to relatively clean sites closest to the estuary, suggesting the groundwater may not be a likely source of bacterial contamination to the estuary. However, the presence of enterovirus at sites closest to the estuary suggest that further studies may be needed to better understand surface groundwater interactions and the potential risk to estuary surface waters from groundwater resources.

- Sediments within the Goat Canyon Sediment Basins appear to act as a reservoir for indicator bacteria that has the potential to impact receiving waters for several days if the sediment were used for beach replenishment. Further studies are needed to clarify potential impacts indicated by this initial, small-scale study.

- Based on the findings of these studies, BMPs were designed and prioritized on their ability to reduce bacterial loads and will serve as a tool for managers to reduce potential impacts to the Tijuana River Estuary.

Recommendations

Based on the major findings of the study, the following recommendations may be considered:

- One of the major goals of this study was to identify sources of indicator bacteria on the U.S. side of the border and produce designs for BMPs that can reduce those loads. The designs for low impact development BMPs produced as part of this study are focused on providing the most efficient and cost-effective means of reducing bacterial loads in areas that flow directly to the Tijuana River Estuary. They should be considered for implementation based on the prioritization assessment provided in the report and additional priorities and constraints of the City of Imperial Beach.

- During the sanitary and dry weather surveys, positive results for human-specific *Bacteroides* suggested the presence of human fecal matter at some sites. Although specific sources were never identified, the cities of Imperial Beach and San Diego may wish to consider prioritizing and implementing sewer system upgrades to minimize the potential for sewage in the sanitary sewer from contaminating the storm drain system and potentially impacting the estuary.

- The Goat Canyon Special Study demonstrated that elevated bacterial levels exist in sediment dredged from the basins. Understanding the role of beneficial reuse of the dredged sediment is a critical component of effective management of the basins. Further studies to understand the potential risk factors and fate and transport variables associated with the sediment under various management scenarios (*e.g.*, beach replenishment) should be considered to enhance potential management options.

- This study was focused on understanding the sources of indicator bacteria in the Tijuana River Watershed and the potential impacts it may have on the estuary. However, further study is needed to understand how bacteria (and potential pathogens) associated with the river and the estuary may affect water quality at adjacent beaches. Studies designed to use rapid indicators of fecal contamination combined with an understanding of environmental variables that affect beach water quality (*e.g.*, storm events or rogue flows from Mexico) could provide a more precise assessment of potential human health risks from the river and potentially reduce beach closures in the area.

- The Special Study on Groundwater suggested that groundwater quality at sites close to the U.S. / Mexico Border may be impacted by indicator bacteria, but sites closer to the estuary appeared to have better water quality. These results conflicted with the enterovirus results, which showed the presence of enterovirus at sites closest to the estuary. To better understand the fate and transport of bacterial and viral pathogens in groundwater and the potential risk associated with groundwater / surface water interactions, groundwater modeling may be considered to enhance the small scale study conducted as part of this project.

1.0 INTRODUCTION

In April 2008, the City of Imperial Beach (City) was awarded a Clean Beach Initiative (CBI) Grant to assess the potential sources of bacterial impacts on the United States (U.S.) side of the Tijuana River Watershed (TRW) under the Grant Program Agreement No. 07-584-550-2. The resultant study was named the *Tijuana River Bacterial Source Identification Study*. The contract timeline for the work was as follows:

- The State Water Resources Control Board (SWRCB) Contract for the City of Imperial Beach was awarded in February 28, 2008
- The Contract was closed by the SWRCB due to the State-wide funding crisis: December 17, 2008
- Project was reopened: May 6, 2010
- Project end date is: March 1, 2012

The aim of the project was to undertake a comprehensive assessment of the bacterial impacts with the US portion of the watershed. Through collaboration with the SWRCB, the Scientific Advisory Group and other interested stakeholders, a study design was developed which included the study components presented below.

The overall purpose of the study was to assess the sources and impacts of bacterial pollution in the Tijuana Watershed during both dry and wet weather. Review of historical data shows that the pollution sources and impact vary significantly between these two seasonal variables. In dry weather (regardless of whether it is winter or summer) the watershed is relatively un-impacted with little overland flow and little discharge into waterways. The estuary is a healthy, vibrant and vital ecosystem. However, during wet weather, the watershed transforms into a severely impacted, polluted and hazardous waterbody with bacterial concentrations so elevated it is often difficult to quantify effectively. In addition to fecal pollution, trash sediments, chemicals and metals are also extremely elevated. The impact on the surrounding ecosystem is severe with poor water quality for weeks after an event. The study was therefore designed to assess these two seasonal conditions as separately and clearly defined environmental conditions.

Funding for this project has been provided in full or in part through an agreement with the SWRCB. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names of commercial products constitute endorsement or recommendation for use (Governor Code Section 7550, 40 CFR 31.20).

For further information about the report, please use the following contact information:

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1.1 Study Objectives

The objectives of this study were to:

1. Identify anthropogenic sources of bacteria;
2. Identify non-anthropogenic sources of bacteria;
3. Assess annual bacteria loads into the Tijuana River;
4. Identify point and non-point sources (NPSs) of bacterial pollutants; and
5. Better understand mitigation strategies aimed at the reduction of bacteria loads.

The monitoring program was developed to address these objectives as well as the following questions (Table 1-1):

Table 1-1. Key Management Questions to be Answered by the Tijuana River Bacterial Source Identification Study

Type	Key Questions to Be Answered	Project Element(s) that Will Address these Questions	Project Outcomes
Questions that characterize the sources of bacterial contamination	• What are the non-anthropogenic sources of bacteria? • What are the anthropogenic sources of bacteria? • What are the point and non-point sources of bacterial pollutants?	• Analysis of *Bacteroides* as indicator of human fecal contamination • Sample collection during sanitary surveys • Targeting of key land use activities which might contribute to bacterial loads	• Data from the sanitary survey which accurately reflects the presence of point and non-point sources of contamination in the watershed
Questions that characterize the loads of bacterial contamination	• What are the annual indicator bacterial loads in the Tijuana River?	• Sample collection and flow monitoring during dry and wet weather	• Report data from watershed and tributaries which accurately reflect current bacterial loads, including analytical data, flows, and calculated loads
Questions that relate to the implementation of mitigation strategies	• What are possible mitigation strategies for reducing bacterial loads?	• Development of concept designs and recommended BMPs	• Acceptable BMPs for implementation in the TRW

1.2 Stakeholders and Advisory Groups

A vital component of the development of the project design was a facilitated workgroup which approved each study component. This group was the Scientific Advisory Group and comprised project managers from the State Water Quality Control Board, Mark Gold (Heal the Bay) and Dr. Alexandria Boehm (University of Stanford), together with staff from the City of Imperial Beach and Weston Solutions, Inc.

In addition, a larger community stakeholder group (Table 1-2) was consulted quarterly with updates on the program's progress and asked to contribute to study design. Engaging a diverse stakeholder group from the beginning of the study served as an important information gathering tool that provided insight on bacterial sources from local and historical perspectives. This information was invaluable in designing the special studies of the project, which revealed some of the major findings of the study.

Table 1-2. Summary of Stakeholder Organizations

Organization
City of Imperial Beach
City of San Diego
City of Coronado
County of San Diego
Department of Environmental Health, County of San Diego
Department of Public Works, County of San Diego
Environmental Protection Agency (EPA)
Fish and Wildlife Service
General Services, City of San Diego
Heal the Bay
International Boundary Water Commission (IBWC)
San Diego Regional Water Quality Control Board Region 9 (SDRWQCB)
State Water Resources Control Board (SWRCB)
San Diego State University (SDSU)
Scripps Institute of Oceanography (SIO)
Southern California Coastal Water Research Program (SCCWRP)
Stanford University
State Water Quality Control Board (SWQCB)
Tetra Tech
Tijuana River National Estuarine Research Reserve (TRNERR)
URS Corporation
United States Environmental Protection Agency (USEPA) Region 9
United States EPA (USEPA) Border Office
United States Section of the International Boundary and Water Commission (USIBWC)
Wild Coast

1.3 Study Components

The components of the study included:

- Task 1 – Project Management and Stakeholder Workgroup Development. Under this task quarterly stakeholder group meetings were held with attendance from key interested parties. A total of 10 stakeholder meetings were held. Minutes of meetings, presentations and attendance is presented in Appendix X.
- Task 2 – Data Review and Field Reconnaissance (Appendix B). Under this task a comprehensive summary of historical information regarding the Tijuana River Watershed was compiled and summarized. The summary acted as a data gap analysis in order to gain a better understanding of the current knowledge of the watershed, particularly as it pertained to US sources of fecal pollution.
- Task 3 – Develop Project Plans: Quality Assurance Project Plan (QAPP) and Monitoring Plan (MP) (Appendix C). The QAPP and MP were developed in draft prior to final approval by the SWRCB. All actions undertaken in this study were done in compliance with the methods and techniques laid out in the QAPP. Any deviations from the QAPP were authorized by the SWRCB prior to implementation.
- Task 4 – Bacterial Source Identification (BSI) Study Implementation; and
  - Subtask 4a – Sanitary Survey. A total of three comprehensive sanitary surveys were undertaken during this study. Specifics regarding this element of the work are presented in Section 4.
  - Subtask 4b – Flow Study. Comprehensive flow monitoring of key locations within the watershed was undertaken during the course of the study. Details of this work element are presented in Section 5.
  - Subtask 4c – Dry Weather Sampling. Dry weather monitoring in both summer dry and winter dry conditions was undertaken on four occasions. Details of the monitoring are presented in Section 4.
  - Subtask 4d – Wet Weather Sampling. Wet weather sampling during winter was undertaken on three occasions, with monitoring throughout the watershed to assess wet weather loads throughout the watershed. Details of this monitoring are presented in Section 5.
  - Subtask 4e – Special Studies. This task encompassed all targeted monitoring and special studies. A number of special studies were designed and implemented based on results of the sanitary survey. These are presented in Sections 6, 7, and 8.
  - Subtask 4f – Project Feasibility Analysis. Under this task specific concept designs were proposed and evaluated. The aim of this task was to prepare “shovel” ready projects for implementation in the watershed that could have a demonstrated impact on water quality improvements. This assessment and associated concept designs are presented in Section 9.
- Task 5 – Reporting. This report represents Task 5, providing a summary of those study components which were undertaken within Task 4.

Table 1-3 summarizes the work completed to date for the Project.

Table 1-3. Summary of Work Completed to Date

Work Item	Items for Review	Due Date	% Of Work Complete	Date Submitted
A. PLANS AND COMPLIANCE REQUIREMENTS				
1.0	GPS information for Project Site and Monitoring Locations	Day 90	100%	April 2008
2.0	Project Assessment Evaluation Plan (PAEP)	January 2008	100%	January 2008
3.0	Monitoring Plan (MP)	August 2008	100%	August 2008
4.0	Quality Assurance Project Plan (QAPP)	August 2008	100%	August 2008
5.0	Copy of final CEQA/NEPA Documentation	N/A	N/A	N/A
6.0	Applicable Permits	N/A	N/A	N/A
B. WORK TO BE PERFORMED BY GRANTEE				
1.1	Copy of Sub-consultant Agreement	April 2008	100%	March 2008
2.1	List of Members in Stakeholder Workgroup	June 2008	100%	July 2008
2.2	Agenda and minutes of stakeholder meetings	Quarterly	100%	Quarterly
3.2	Summary Report of Data Review	July 2008	100%	July 2008
3.3	Summary Report of Field Reconnaissance	May 2010	100%	June 2010
4.1	Sanitary Surveys		100%	
4.2	Flow Monitoring		100%	
4.3	Dry Weather Sampling		100%	
4.4	Wet Weather Sampling		100%	
4.5	Special Studies		100%	
5.1	Develop Water Quality Recommendations		100%	
5.2	BMP Concept Plan		100%	
A. INVOICING	August, 2012 Invoice	Monthly	100%	September 25, 2012
B. REPORTS				
1.0	Grant Summary Form	Day 90	100%	September 27, 2012
2.0	Progress Reports monthly	Monthly	100%	Monthly
2.1	August Progress Report	Sept.18, 2012	100%	Sept 27, 2012
3.0	Annual Progress Summary	September 30, 2010 and 2011	100%	Annually in September
4.0	Natural Resource Projects Inventory (NRPI) Project Survey Form	Before final invoice	100%	Sept. 26, 2012
5.0	Draft Project Report	June 1, 2012	100%	June 16, 2012
6.0	Final Project Report	Sept. 1, 2012	100%	Sept. 27, 2012

This project was funded through a grant from the Proposition 50 funds, administered by the SWRCB. A total of $1,324,784 was provided for the Project (solely from grant funds), nearly all of which was used to complete the study. Future projects based on the best management practices (BMP) concept designs (see Section 9.0) and recommendations from the study (see Section 10) will be used to obtain funding for BMP implementation and additional, follow-on studies.

2.0 STUDY AREA

This section describes the general characteristics of the U.S. portion of the TRW together with an overview of the water quality issues. Full details of historical data, watershed characteristics and other background information can be found in Appendix B: Tijuana River Watershed Bacterial Source Identification Study – Literature Review.

2.1 Watershed Characteristics

2.1.1 Watershed Hydrology

The TRW Management Area (HU 911.00) is the largest of the San Diego watersheds, covering over 1.1 million acres. The watershed is divided by the U.S.–Mexico border with approximately 27% lying within San Diego County. Hydrologic areas on the U.S. side of the border include Tijuana Valley, Potrero, Barrett Lake, Monument, Morena, Cottonwood, Cameron, and Campo. Major water bodies include the Tijuana River, Cottonwood Creek, and the Tijuana River Estuary. The Tijuana River is formed outside of the Mexican city of Tijuana by two major drainage networks. The river flows towards the U.S.–Mexico border through a concrete trapezoidal channel, enters the U.S. west of the San Ysidro border crossing, flows to the Tijuana River Estuary salt marsh, and discharges into the Pacific Ocean (SDSU, 2005). Annual precipitation varies from less than 10.5 inches along the coast to more than 22.5 inches in the inland areas. This rainfall occurs predominantly between the months of October and February with flows from the river system causing beach closures. During the dry months, beach closures are intermittent and often attributed to off shore wastewater discharge sources.

2.1.2 Population in the Tijuana River Watershed

There are 12 million people currently living along the U.S.–Mexico border, and residents of San Diego County and Tijuana account for approximately 40% of the population of the border region (Ganster et al., 2000). The population of the TRW is proportionately smaller with approximately 1.5 million residents, but urban growth on both sides of the border is expected to double the population by the year 2020 (Ganster et al., 2000). Population growth and urbanization will place additional stress on the TRW’s resources, especially in terms of water supply and sanitation.

Population distribution within the U.S. area of the watershed is sparse in most areas with the exception of the major population centers located at Campo, Imperial Beach and San Ysidro (Figure 2-1). The population in the U.S. portion of the watershed is estimated at 82,123 people, 176 persons per square mile. The population is projected to increase by 45% to reach over 118,838 people by the year 2020 (SANDAG, 2005).

The cities of Tijuana and Tecate are the major population centers on the Mexican side of the watershed. According to Juana María Nahoul Porras, a representative of Consejo Estatal de Población (CONEPO) (translated to State Population Council), the population in the City of Tijuana in 2000 was 1,125,200 and will grow to 1,491,300 in 2010 (Ganster, 2006). In 2005, the city of Tecate was estimated to have a population of 59,124 (INEGI, 2005).

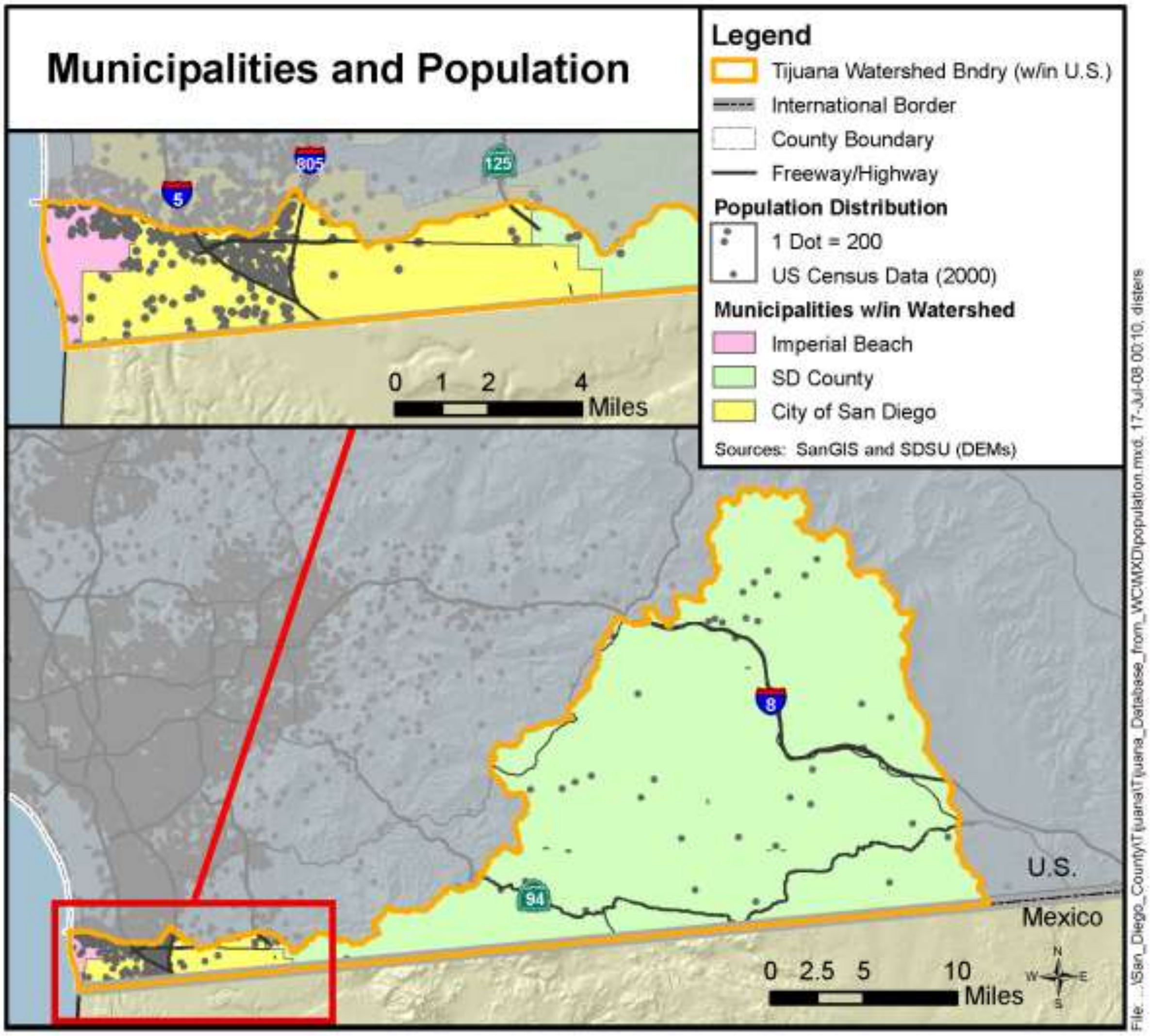


Figure 2-1. Tijuana River Watershed Population – U.S. Portion of Watershed

2.2 Beneficial Uses

The Tijuana River Watershed provides a variety of beneficial uses and sensitive habitats, including the Tijuana River Estuary, which is a National Estuarine Sanctuary. Beneficial uses are shown in Table 2-1. The major aquifer in the watershed is the Lower Tijuana River Valley Basin. The upper US portion of the watershed contains two reservoirs, including Lake Morena and Barrett Lake. The Mexican portion of the watershed contains the Rodriguez Reservoir and the El Carrizo Reservoir. Also of note is that the Dulzura Conduit conveys Barrett Lake discharge from the Tijuana River WMA to Otay Lakes in the San Diego Bay WMA.

Table 2-1. Beneficial Uses within the Tijuana Watershed

Beneficial Uses	Inland Surface Waters	Coastal Waters (excluding Pacific Ocean)[a]	Pacific Ocean	Reservoirs and Lakes	Ground-waters
Municipal and domestic supply	●			●	●
Agricultural supply	●			●	●
Industrial service supply	●		●	●	●
Industrial process supply	●			●	
Groundwater recharge					
Freshwater replenishment	●			●	
Hydropower generation					
Navigation			●		
Contact water recreation	●	●	●	●	
Non-contact water recreation	●	●	●	●	
Commercial and sport fishing		●	●		
Warm freshwater habitat	●			●	
Cold freshwater habitat	●			●	
Estuarine habitat		●	●		
Wildlife habitat	●	●		●	
Biological habitats of special significance	●	●	●		
Rare, threatened, or endangered species	●	●	●	●	
Marine habitat		●	●		
Migration of aquatic organisms		●	●		
Aquaculture			●		
Shellfish harvesting		●	●		
Spawning, reproduction, and/or early development	●	●	●		

(a) = Tijuana River Estuary
● = Existing
Note: Beneficial uses vary by HU basin number. Please refer to the Basin Plan for individual HUs.
Source: Basin Plan September 8, 1994 (tables 2-2, 2-3, 2-4, and 2-5), amendments adopted through February 8, 2006.

2.3 Soils, Vegetation and Hydrology

The soils in the Tijuana River Valley on the U.S. side of the border are characterized by varying graded fines (coarse sands with medium to low amounts of silts and clays) and rocky zones composed of gravels, cobbles, and localized boulders (Weston, 2007).

For the purposes of this report, soils were classified in terms of estimated runoff potential. Runoff potential has a significant impact on the transportation of microbes with potentially adverse public health risk. Soils were assigned to one of four groups according to the rate of water infiltration. The soils were assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

- **Group A –** Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

- **Group B –** Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- **Group C –** Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- **Group D –** Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

The soils in the western portion of the TRW are characterized by a high infiltration rate around the area of the river bed. This might allow the rapid transport of microbes through the subsurface and potential contamination of groundwater. This area of the sub-watershed is surrounded by soils with very slow infiltration rates suggesting that there is an increased risk of runoff from the overlying urbanized areas.

In terms of vegetation, two species of shrub lands cover approximately 74% of the entire TRW. Coastal sage scrub is the dominant fauna in the western (U.S.) portions of the watershed. It previously covered the land around the City of Tijuana, but urban development has replaced this vegetation. Chaparral is the dominant species in the eastern (Mexican) portions of the watershed (Conway et al., 2000).

The hydrology of the TRW, together with sub-hydrological areas and directional flows, is shown in Figure 2-3. It can be seen that, with the exception of the two western-most sub-drainages of the watershed, all tributaries travel south into Mexico to join the Tijuana River.

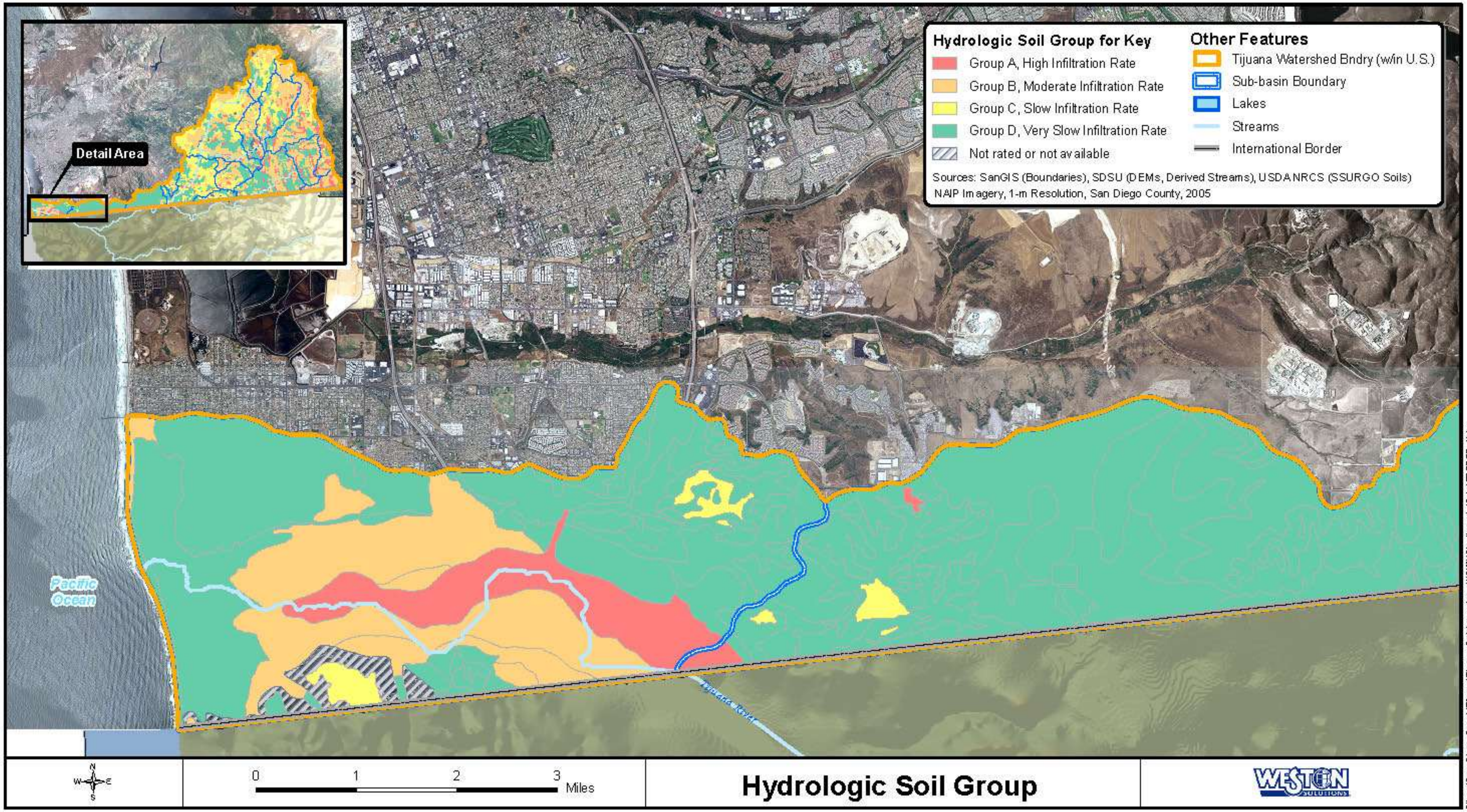


Figure 2-2. Tijuana River Watershed Soils – Western U.S. Portion of Watershed

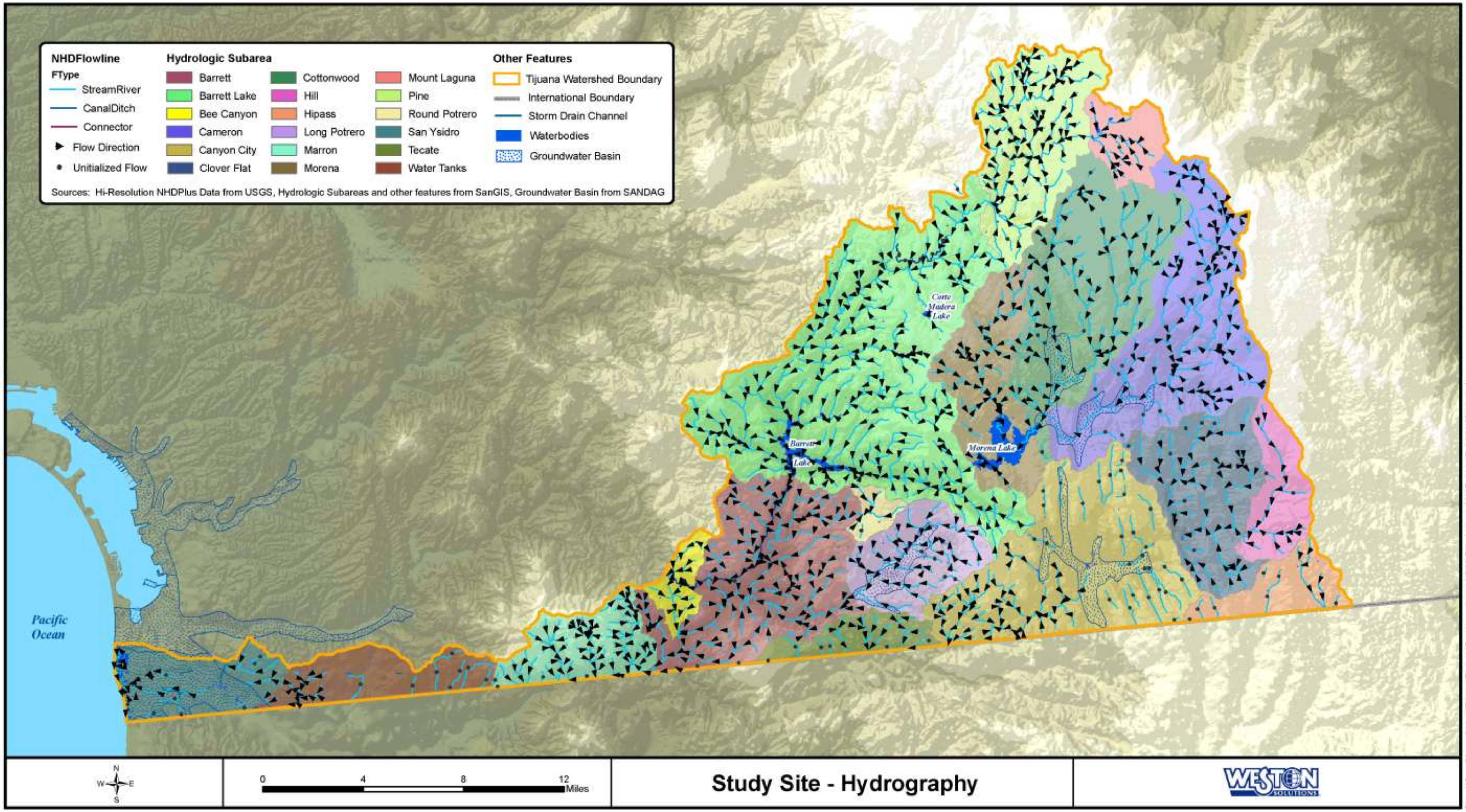


Figure 2-3. Tijuana River Watershed Hydrography – Western U.S. Portion of Watershed

2.4 Potential Land Use Activities and Sources

Mexico governs 73% of the TRW. The land is predominately undeveloped or vacant (81.8%), as much of this land is used for low-intensity cattle and goat grazing.

The remaining 27% of the TRW falls under the jurisdiction of the U.S. The land is predominately undeveloped/vacant areas (60.3%) or parks (25.3%). Other dominant land uses include residential (7.3%), agriculture (2.9%), and transportation (2.4%). Commercial, commercial recreation, industrial, military, public facility, construction, and water land uses constitute less than 2% of the land area in the U.S. portion of the watershed (Figure 2-4) (SANDAG, 2006).

The western U.S. portion of the TRW is comprised of differing land uses including military, reserve and commodity agricultural (Figure 2-5).

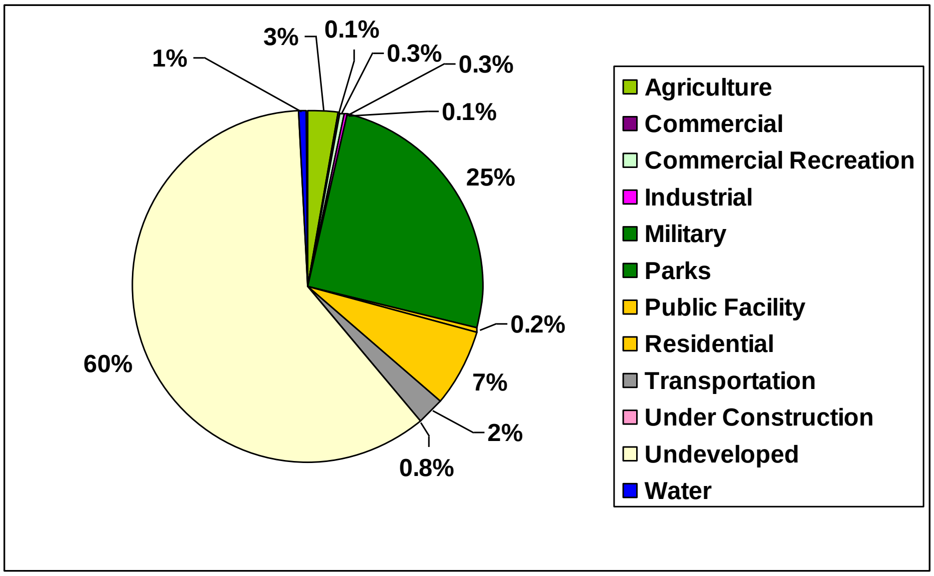


Figure 2-4. Percent Land Use for Tijuana River Watershed Management Area

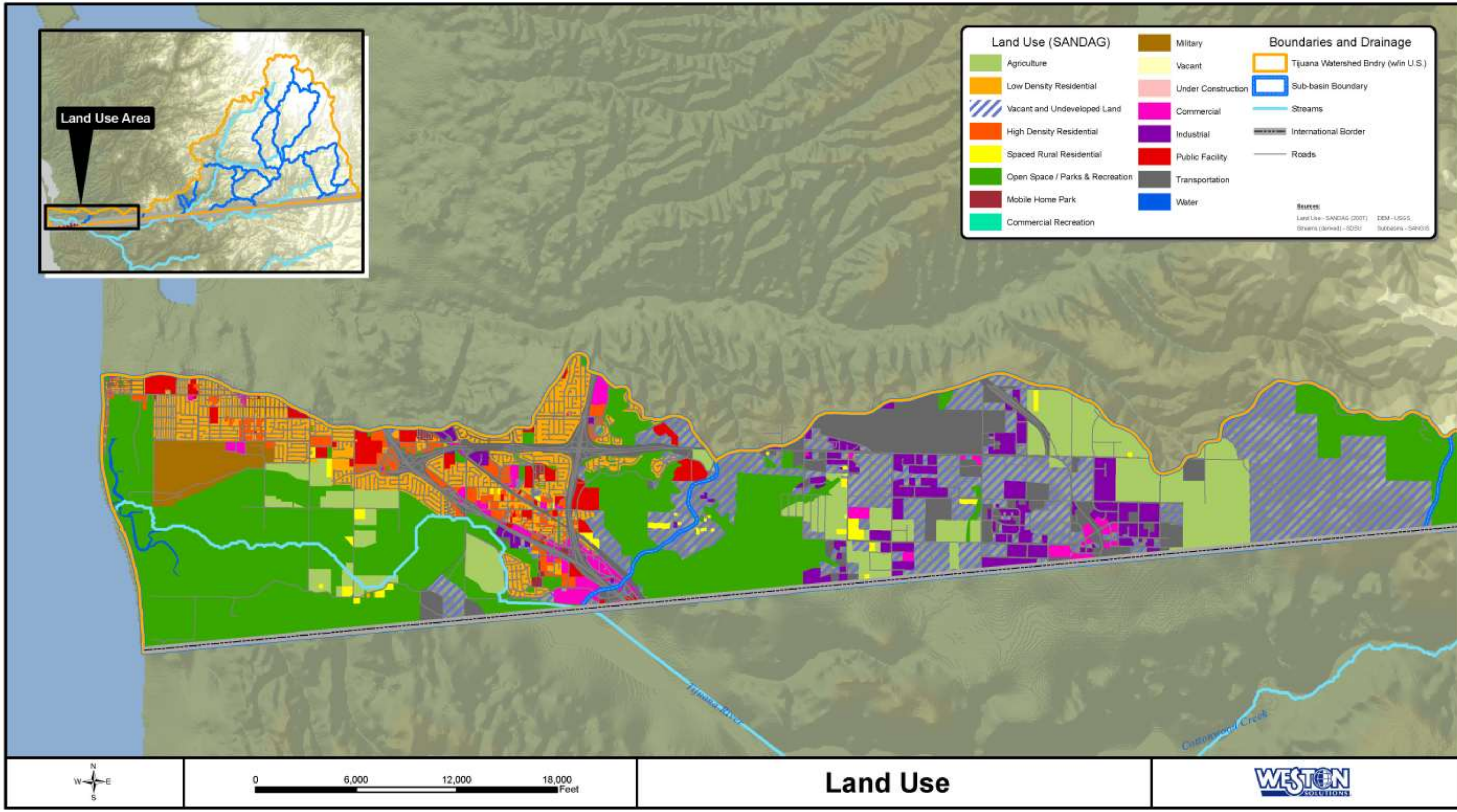


Figure 2-5. Tijuana River Watershed Land Use – Western U.S. Portion of Watershed

2.4.1 Septic Systems

In 1928, Tijuana installed a network of septic tanks, the city's first municipal wastewater collection system. This system was under-designed, and its capacity to serve 500 inhabitants was overloaded by 1933. Tijuana expanded the facilities to serve 5,000 inhabitants, but the system again became overloaded (Fischhendler, 2006). Since these early sanitation efforts, the number of septic tanks in Tijuana and Playas de Rosarito has steadily grown. The 2000 Instituto Nacional de Estadística Geografía e Informatíca (INEGI) census reported that 24,708 residences were connected to septic tanks (53% of the total connections in Playas de Rosarito and 8% of the total in Tijuana), and 46,557 residences had no sewage connection at all (CDM, 2003).

On the U.S. side of the watershed, septic tanks are still commonly used in many portions of the eastern watershed where sanitary sewerage systems are not available. There are also a number of suspected septic tank installations in the western portion of the watershed. The age and condition of these septic systems is unknown. Some regulatory monitoring of septic systems is undertaken by the DEH but comprehensive records of condition and age is not readily available (DEH pers. comm. 2008).

In addition to septic systems, there are a number of trailer park areas in the western portion of the watershed which are not connected to the sanitary sewer. Sanitary provisions to these areas are minimal and unregulated.

2.4.2 Ranches

Several ranches growing intensive row crops are located on the U.S. side of the border (Figure 2-6). Approximately 57 acres of crops are grown along the northern boundary of the Tijuana River Valley near Hollister Street Bridge at the base of Spooner's Mesa north of Monument Road and just south of the Tijuana River on the eastern side (Weston, 2007). In addition to these agricultural land uses, there are both private and commercial horse ranches which provide breeding and trail riding services to the region. Regulation and oversight of the discharges from these facilities is intermittent. There is anecdotal evidence of manure dumping in the Tijuana riverbed to the west of Saturn Blvd. This has been identified and brought to the attention of the SDRWQCB where investigations are ongoing (Keir–City of Imperial Beach pers. comm. 2008).

Manure Piles Found in Estuary

Figure 2-6. Example of Ranches in Tijuana River Valley[1]

2.4.3 Sod Farms

The USIBWC leases land to commercial groups adjacent to the Tijuana River. In order to retain the lease, only low-growing row crops, such as sod, lima beans, and strawberries, are farmed (Figure 2-7). Water is pumped from groundwater wells adjacent to the Tijuana River and used to irrigate the land. Any irrigation runoff flows back into the Tijuana River (Melvin–USIBWC pers. comm. 2008).

[1] Source: GoogleEarth
[2] Source: California State Parks. Accessed at: http://www.parks.ca.gov/.

Figure 2-7. Sod Farms Leased from IBWC1

2.4.4 Military

Naval Air Station (NAS) North Island operates the Outlying Field (OLF) Imperial Beach, located 10 miles south of the NAS base and within the city limits of Imperial Beach (Figure 2-8). OLF is part of Naval Base Coronado. The Operations Department manages 23,400 flights a month at OLF. The site consists of a small (5,000-foot) runway and five helicopter landing pads which hosts Navy Pacific Fleet helicopter training, especially traffic pattern training.

In 1941, the U.S. Navy leased 245 acres of land for gunnery training in Imperial Beach. The Border Field Auxiliary Landing Field property included 35 buildings, one barrack, a galley, and a machine gun range. The U.S. Navy also acquired Ream Field, located just north of the Tijuana River estuary. In 1955, Ream Field was used as the home base for the Pacific Fleet helicopters. By filling and diking significant stretches of salt marsh, these military activities increased sedimentation and degraded the watershed. In 1971, 372 acres of this former U.S. Navy property was developed into Border Field State Park (California Department of Parks and Recreation, 2000).

Presently, OLF encompasses 1,204 acres, 270 of which are leased out for agricultural purposes, and 284 acres are leased to the State of California for a wildlife refuge in the TRNERR at the southeast corner of the naval base.

Figure 2-8. NAS North Island OLF 1

2.4.5 Tijuana River National Estuarine Research Reserve

The TRNERR is located in the western-most portion of the TRW (Figure 2-9). The TRNERR is bordered by the Pacific Ocean to the west, the US–Mexico border to the south, Saturn Boulevard to the east, and the City of Imperial Beach to the north. Nearly one-quarter of the reserve is land leased from the OLF.

The TRNERR is primarily a shallow coastal plain habitat, though it is also defined an "intermittent estuary," as it is subjected to extreme changes in stream flow at different times of the year. Extended periods of drought leave parts of the estuary dry during some parts of the year, while flooding can also inundate the same areas during rain.

The TRNERR contains several different habitats[2], including:

- Sand dunes;
- Beaches;
- Open tidal channels;
- Mudflats;
- Low, middle, and high salt marshes;
- Fresh-brackish marshes dominated by bullrushes and cattails; and
- Upland and riparian habitats.

[2] Source: California State Parks. Accessed at: http://www.parks.ca.gov/.

The TRNERR has resident populations of eight threatened and endangered species. These include seven bird species:

- Light-footed clapper rail;
- California least tern;
- Least Bell's vireo;
- Snowy plover;
- Brown pelican;
- White pelican; and
- Peregrine falcon.

One listed plant species is known to occur in the TRNERR, the salt marsh bird's beak (*Cordylanthus maritimus* Nutt. ssp. *maritimus*)[3].

Figure 2-9. Tijuana River National Estuarine Research Reserve 1

One of the most significant land uses which impacts water quality is the bi-national wastewater treatment processes currently treating wastewater from Mexico.

2.5 Sewerage Infrastructure

This section presents an overview of the bi-national wastewater treatment processes—focusing predominantly on the SBIWTP—which serves both the City of Tijuana and the U.S.

[3] Source: Tijuana River National Estuarine Research Reserve website. Accessed at: http://trnerr.org

2.5.1 History of Infrastructure Development

The City of Tijuana, which has grown in population from 21,977 in 1940 to 1,490,111 in 2007, has experienced difficulty in constructing, operating, and maintaining a sewage collection system in pace with the rapidly growing city. The wastewater collection and treatment system intermittently fails. When these failures occur, sewage flows into TRW's natural drainage path into the Tijuana Estuary and ultimately onto the beaches near the San Diego–Tijuana border.

Tijuana River as it Enters the U.S.

From the 1930s through the 1960s, an international collector and septic tank system with a discharge pipe was installed in the TRW. In the 1960s, Mexico installed two pump stations and pumped untreated sewage 5.6 miles offshore. When this system broke down, Mexico would divert sewage from the main collector in the City of Tijuana through an emergency pipeline to a branch collector line of the San Diego Metropolitan Sewage System. This system was used extensively from 1966 to 1998 (Gersberg et al., 1994). Between 1985 and 1990, Mexico constructed a new sewage conveyance system and the San Antonio de los Buenos Wastewater Treatment Plant near Tijuana. The treatment plant treated 17 million gallons of Tijuana sewage per day and discharged the treated water to the Pacific Ocean (USIBWC, 2008).

In 1990, when Mexico was planning to construct the second module of the San Antonio de los Buenos Wastewater Treatment Plant along Rio El Alamar, the U.S. stepped forward with an alternative solution. The U.S. suggested that Mexico could help the U.S. build, operate, and maintain a bi-national facility on the U.S. side of the border. The project would have an equivalent cost, but the facility would comply with the more stringent water quality standards of the U.S.[4] Mexico agreed to the proposal, and the two countries moved forward under the framework of IBWC Minute 283, the *Conceptual Plan for the International Solution to the Border Sanitation Problem in San Diego, California/Tijuana, Baja California*, to construct and manage the SBIWTP.

The SBIWTP site was located on the U.S. side of the international border (32.544719 latitude, 117.071067 longitude) at a 75-acre site just west of San Ysidro near the intersection of Dairy Mart Road and Monument Road (USIBWC and USEPA, 1999).

The SBIWTP was subsequently constructed in phases in order to provide treatment as quickly as possible. The construction of the first phase, the advanced primary treatment plant, was completed in 1997. In 1997, the facility began providing advanced primary treatment, the first level of treatment, to 25 million gallons per day (mgd) of Mexican wastewater. In addition, in 1997, transboundary raw sewage from diversion and conveyance facilities in Smuggler's Gulch, Goat Canyon, Stewart's Canyon, Silva Drain, and Canyon Del Sol was diverted to the SBIWTP for treatment. Treated wastewater is discharged through the South Bay Ocean Outfall (SBOO) to

[4] Source: Bajagua LLC. Accessed at: http://www.bajagua.com/

the Pacific Ocean 3.5 miles from the coastline at a depth of 95 feet. Construction of this pipe began in late 1991 and was completed in June 1998 (USIBWC and USEPA, 1995).

Figure 2-10 illustrates the complex infrastructure of the Tijuana and U.S. sewerage system. Flows from the Tijuana Interceptor are gravity led to Pump Station 1 where flows bifurcate for treatment either at SBIWTP or the San Antonio de los Buenos Wastewater Treatment Plant. The SBIWTP treats a quantity of Tijuana sewage, not to exceed an average 25 mgd per month. Prior to the Pump Station 1 bifurcation, river flows from the Tijuana River are diverted at Pump Station Comisión Internacional de Límites y Aguas (CILA).

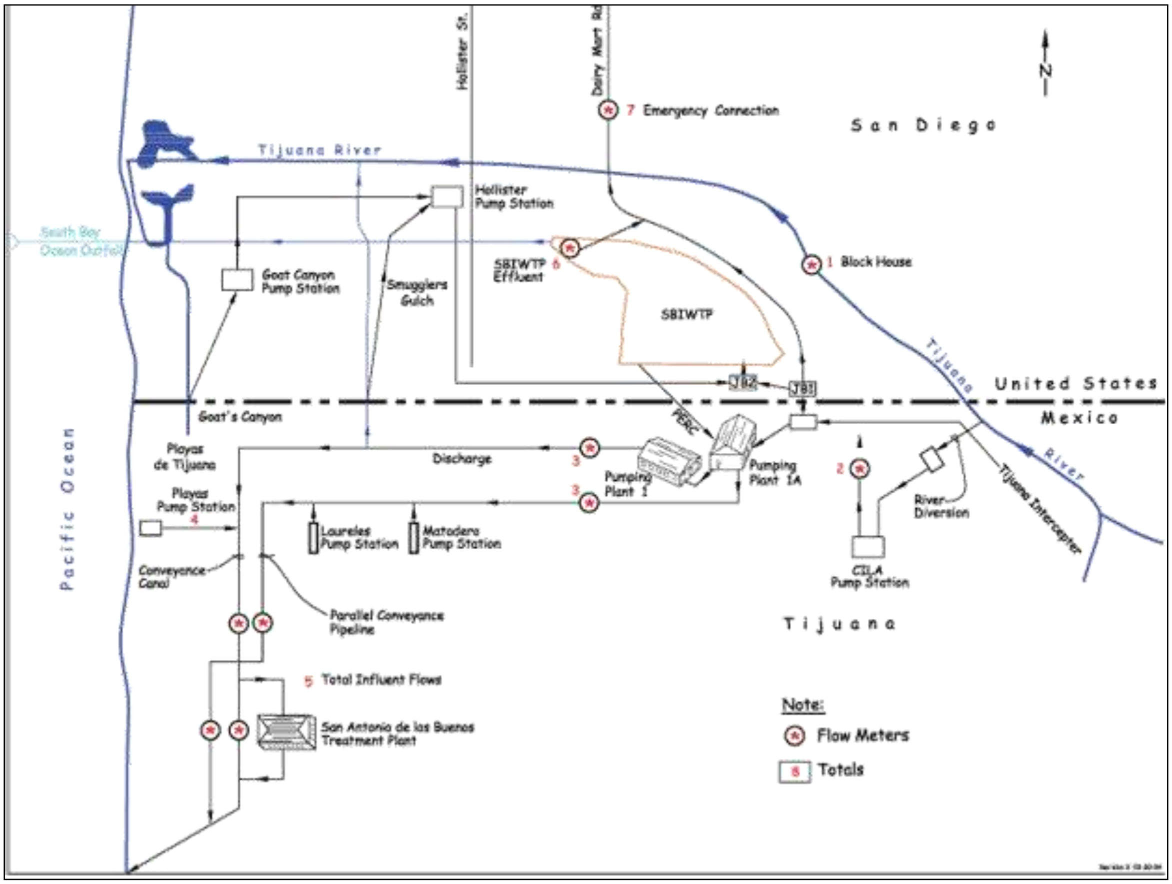


Figure 2-10. Schematic of the Transboundary Sewerage Conveyance System[5]

The network of sewerage lines within the U.S portion of the TRW, including the diversion piping from individual canyons and the SBOO pipeline, is shown in Figure 2-11.

[5] Source: IBWC website. Accessed at: http://www.ibwc.state.gov

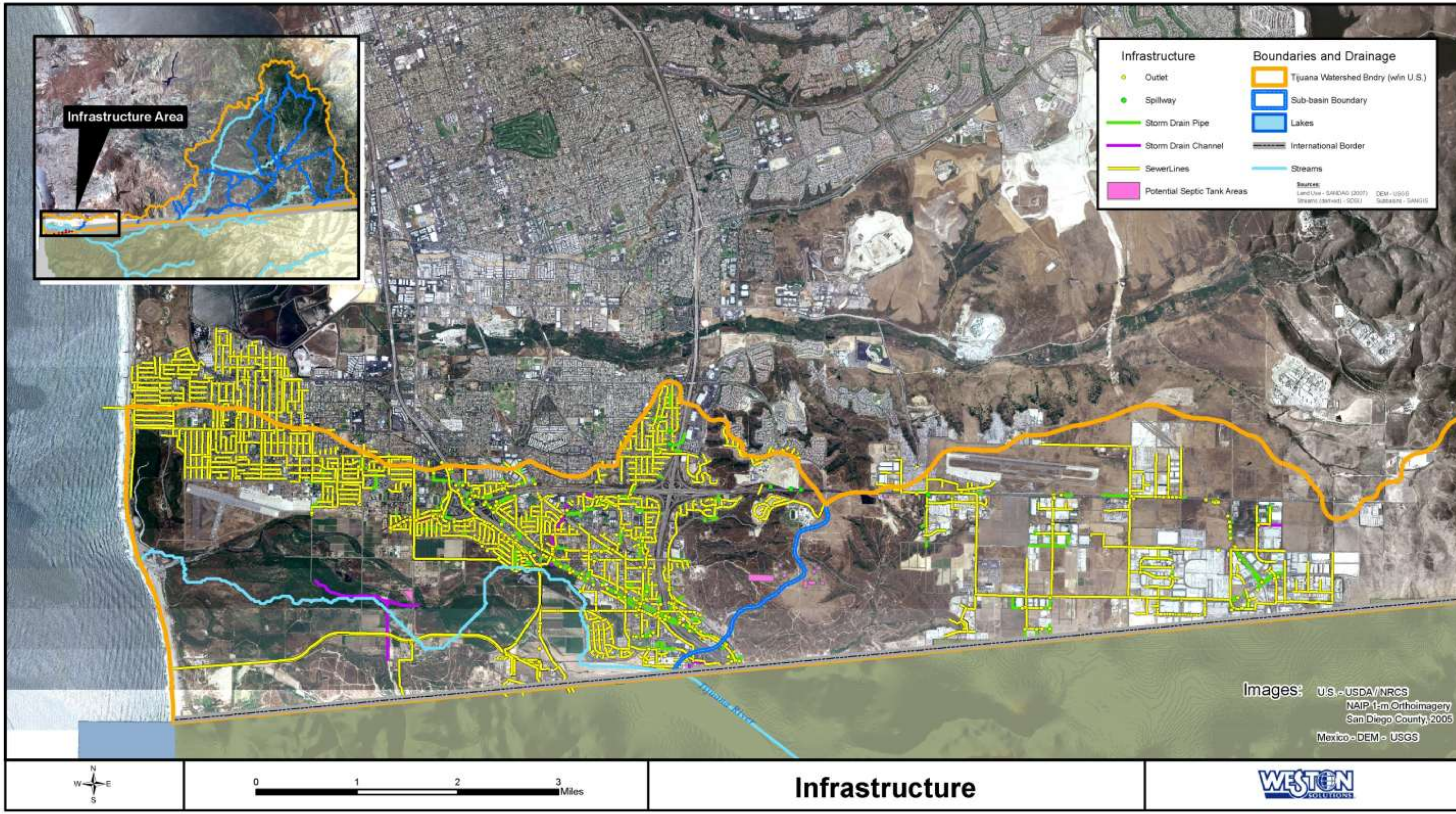


Figure 2-11. Infrastructure within the Western U.S Portion of the Tijuana River Watershed

Pump Station CILA

Raw sewage flows redirected from Pump Station 1 enter the SBIWTP through the Headworks Inlet Structure where metal screens mechanically trap all solids greater than 5/8 inches in diameter. All remaining liquids are mixed with coagulants and sent through primary sedimentation tanks where settling takes place.

The part of the facility that would have provided secondary treatment, allowing the wastewater to meet Clean Water Act (CWA) standards for discharge into the Pacific Ocean, was not constructed due to a lack of funding and legal challenges. As a result, water discharged from the SBIWTP is treated to advanced primary and currently does not comply with the requirements of the CWA. For more than a decade, the USIBWC has considered a variety of alternatives to bring the wastewater into CWA compliance and now faces a federal court order requiring it to achieve CWA compliance by September 30, 2008. The following section reviews that proposal evaluation and its results.

2.5.2 History of the Proposed Wastewater Treatment Solutions

In November 2001, President Clinton signed Public Law 106-457 after it was passed unanimously by the U.S. Congress. Title VIII of the law dealt with the Bajagua Project and requested that the relevant U.S. agencies negotiate with their Mexican counterparts to amend the governing Treaty Minute and complete the construction of the secondary sewage treatment component of the IWTP in Mexico. In 2003, Congress unanimously reauthorized the law which resulted in the signing of Minute 311 by USIBWC and their counterparts in Mexico, CILA.

Minute 311 is a sub-agreement to a treaty between the U.S. and Mexico that stipulates conceptual plans for developing solutions for wastewater collection, treatment, and disposal issues on the U.S.–Mexico border.

Minute 311 provides an update to Minute 283 which includes provisions for the construction and operation of a 25-mgd secondary wastewater treatment plant by the IBWC. This would complement the advanced primary treatment system already constructed at SBIWTP. Under Minute 283, Mexico has the responsibility to provide for pre-treatment, dispose of the sludge generated by the SBIWTP, and contribute to funding the project. Treaty Minute 311 also allowed for the construction of a private treatment plant in Tijuana with 59-mgd capacity.

In response to an explanatory statement of the House Appropriations Committee that accompanied the 2008 Consolidated Appropriations Act, the U.S. Government Accountability Office (GAO) provided a report that:

- Described the two proposed treatment alternatives;
- Described the estimated costs and timelines for each proposal; and
- Assessed the reliability of these estimates.

The explanatory statement directed the GAO to report to the House Appropriations Committees within 120 days of enactment of the law which occurred on December 26, 2007. On April 7, 2008, the GAO briefed members of Congressional staff on their findings.

Two proposals were considered to bring the discharge from SBIWTP into compliance with the CWA (Figure 2-12):

1. IBWC upgrade – Upgrade the SBIWTP to provide secondary treatment at the existing plant site.
2. Bajagua, LLC proposal – Build a new plant in Mexico where wastewater that has received primary treatment at the SBIWTP would be pumped for secondary treatment.

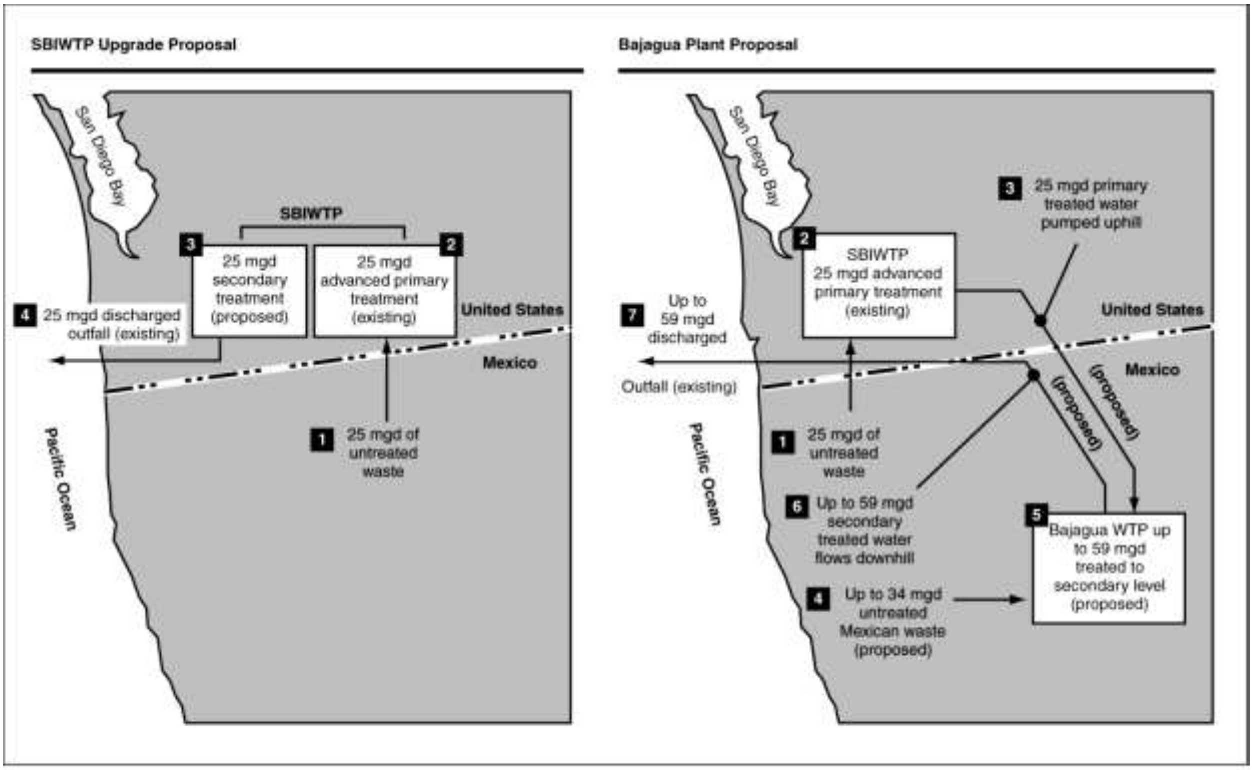
Under both proposals, the treated effluent would be discharged into U.S. waters of the Pacific Ocean through a pipeline known as the SBOO, a facility used by both the USIBWC and the City of San Diego.

Although both proposals were designed to enable the USIBWC to meet CWA requirements, the approaches were significantly different.

SBIWTP Upgrade – The USIBWC proposal would expand the SBIWTP in order to provide secondary treatment to the 25 mgd of wastewater already receiving primary treatment at the plant, bringing it to CWA standards. According to the USIBWC, construction would follow a final design provided in June 2008 by an engineering consulting firm based on its update of the original SBIWTP design. U.S. appropriations would pay for the expansion's construction and operations and maintenance (O&M) costs.

Bajagua LLC Proposal – Under the Bajagua, LLC proposal, Bajagua, LLC would contract with another company to design, build, and operate a new facility in Mexico that would provide secondary treatment to 25 mgd of wastewater. The Bajagua Plant would take effluent from the SBIWTP and provide additional treatment so the water could be resold to *maquiladoras*[6] and other users in Tijuana. The facility would have a treatment capacity of 59 mgd and would have to operational by September, 2008, in order to comply the Court ordered deadline (USEPA, Region 9 2003, Bajagua Project LLC, 2008) (Figure 2-12). The Bajagua Plant would also have the capacity to provide primary and secondary treatment for up to an additional 34 mgd of wastewater from Tijuana.

[6] A factory that imports materials and equipment on a duty-free and tariff-free basis for assembly or manufacturing and then re-exports the assembled product, usually back to the originating country



Source: GAO analysis of data provided by U.S. Section, IBWC, and Bajagua, LLC.

Figure 2-12. Illustration of the Two Proposed Alternatives – Bajagua and SBITP Upgrade[7]

The GAO report to Congress in April 2008 failed to provide a clear recommendation as to whether the plant would be a preferred solution when compared with a SBIWTP upgrade. The Bajagua option required approximately $539 million in funding and would be completed by 2010, while the SBIWTP upgrade option would be completed by 2011 and cost $331 million.

In May 2008, it was determined that the SBIWTP facility would be upgraded to treat wastewater from Mexico and that the Bajagua plant would not move forward. This decision was based on the following reasons:

- Funding had been appropriated to start construction;
- The upgrade cost was less than the option of constructing secondary facilities in Mexico;
- The upgrade had an earlier completion date (January 2011) than secondary facilities in Mexico;
- There was greater certainty in completing the upgrade within the estimated timeframe;
- The upgrade included fewer uncertainties than the option of constructing secondary facilities in Mexico;
- The upgrade allowed for potential expansion of up to 100mgd to meet long-term needs of the San Diego–Tijuana region;
- The upgrade was consistent with existing agreements with Mexico (Minute 283 and Minute 311); and
- There was no additional approval required from governmental entities in Mexico.

[7] Source: IBWC website. Accessed at: http://www.ibwc.state.gov

2.5.3 Canyon Conveyance System

In addition to sewered wastewater flows from Mexico, the SBIWTP treats diverted flows from a number of different canyons which drain from the Mexican side of the border (Figure 2-10). The diversion of these flows ensures that, under normal low-flow conditions, no untreated effluent enters the U.S. receiving waters.

The canyons with the low-flow diversions are:

- Smuggler's Gulch;
- Goat Canyon;
- Stewart's Drain;
- Silva Drain; and
- Canyon Del Sol.

Construction of Border Fence

The diversion system currently in place at Smuggler's Gulch and Goat Canyon is being completely restructured due to the construction of the extended border fence. The U.S. Customs and Border Protection agency is the responsible party for the construction efforts. The project will consist of constructing an earthen berm across Smuggler's Gulch canyon to support a 3.5-mile long, 15-foot secondary steel-mesh fence as well as all-weather patrol and access roads (Figure 2-13). Diversion structures at these sites have not yet been finalized, and therefore, the impact of changed flows from these sites is still not known. It is envisioned that the reconfigured diversions will be significantly more robust than those currently present at the sites (Smullen–USIBWC pers. comm. 2008).

Figure 2-13. Border Fence Construction[8]

[8] Source: Berestein, 2008

The USIBWC conveyance system for the five canyons and two pump stations are presented in Table 2-2 below.

Table 2-2. Canyon Collector Capacities and Pipeline Sizes

Diversion	Peak Capacity (mgd)	Pipeline Size
Smuggler's Gulch	14.0	30-inch gravity pipeline
Goat Canyon	7.0	24-inch gravity pipeline
Stewart's Drain	5.0	18-inch gravity pipeline
Canyon Del Sol	2.0	16-inch gravity pipeline
Silva's Drain	1.0	12-inch gravity pipeline
Goat Canyon Pump Station	7.0	12- and 16-inch force mains
Hollister Street Pump Station	21.0	16- and 30-inch force mains

2.5.3.1 Yogurt Canyon (Cañón de los Sauces)

The Yogurt Canyon Subwatershed is a largely north–south running drainage that crosses the border just east of the Tijuana Bullring. Runoff from intensive recent development in the Playas de Tijuana area drains into this canyon. At the point where Yogurt Canyon crosses the border, the border fence functionally represents the transition from a riparian habitat to that of a salt marsh habitat. Due to an extremely low gradient at the mouth of the canyon on the U.S. side of the border, water draining from the canyon forms a pond immediately north of the fence.

Yogurt Canyon

2.5.3.2 Goat Canyon (Cañón de los Laureles)

Goat Canyon is one of the larger sub-watersheds that drains off of the western portion of Tijuana directly into the south–north running canyon that enters the U.S. just west of Spooner's Mesa. Sediment loading, trash, and sewage-tainted effluent are of known concern in this canyon. An extensive sediment retention basin was installed just north of the border fence to help address water quality issues associated with this canyon. Upscale housing developments on the top of the mesa above Playas de Tijuana have been identified as a potential source, because development drains untreated wastewater into Goat Canyon just south of the international border fence.

Goat Canyon

By nature, storm flows in Goat Canyon are rapid and unpredictable. Large volumes of sediment, cobble, and trash will hamper acquisition of storm flow data. Dry weather flows in the canyon are periodic in nature. Residents of a seemingly permanent camp just south of the border fence have broken into a Mexican water line and use the domestic water for bathing and washing. Thus, what appears to be significant dry flow in the canyon is largely due to a vandalized water mainline just south of the fence.

2.5.3.3 Smuggler's Gulch (Cañón del Matadero)

Smuggler's Gulch is the largest of the south–north subwatersheds that drains much of western Tijuana directly into the U.S. terminal portion of the Tijuana River. This canyon is characterized by extremely steep canyon walls. Insufficient Mexican sewage infrastructure, as well as a non-permitted hillside residential development, has contributed to ongoing water quality impairment issues from Smuggler's Gulch. Sewage-tainted effluent, sediment, and trash are of known concern.

Smuggler's Gulch

By nature, storm flows in Smuggler's Gulch are also rapid and unpredictable. Large volumes of sediment, cobble, and trash will hamper acquisition of storm flow data. Dry weather flows in the canyon are periodic in nature.

2.5.3.4 Canyon Del Sol

The Canyon Del Sol drainage is relatively small compared to Goat Canyon and Smuggler's Gulch. However, it appears that flows from the drainage area in Mexico travel through a highly urbanized section of the City of Tijuana and transport associated runoff to the U.S. border.

2.5.3.5 Silva Drain

The Silva Drain is relatively small compared to Goat and Smuggler's Gulch but still can contribute significant runoff because of the highly urbanized land use in the Mexican drainage area. Periodic Tijuana sewer infrastructure failures allow raw sewage to flow through this drainage.

Silva Drain

2.5.3.6 Stewart Canyon

The Stewart Canyon drainage is also one of the smaller canyons crossing the border. The canyon drains land from a highly urbanized section of Tijuana which has been identified as having poor wastewater infrastructure. Periodic Tijuana sewer infrastructure failures allow raw sewage to flow through this drainage.

2.5.3.7 Summary of Canyon Flows

Stewart Canyon

This section summarizes the flows from each diverted canyon and provides insight into the frequency and duration of flows in the canyons. In order to assess the frequency and impact of these transboundary spills, flow data recorded by USIBWC at each of these canyon locations was analyzed. Compiled data from 2006 and 2007 are presented on Figure 2-14.

It can be seen from these figures that the majority of flows occur during rain events. Goat Canyon has the most frequent flows, occurring on almost a daily basis. The flows from this canyon are generally very low flows of between 0.01 and 0.5 cubic feet per second. Observational data from this canyon shows that the majority of these flows originate from tampering with a potable water line which runs adjacent to the border fence. At this location, transient populations use the water supply for washing and drinking. This creates a constant nuisance flow from the Goat Canyon location.

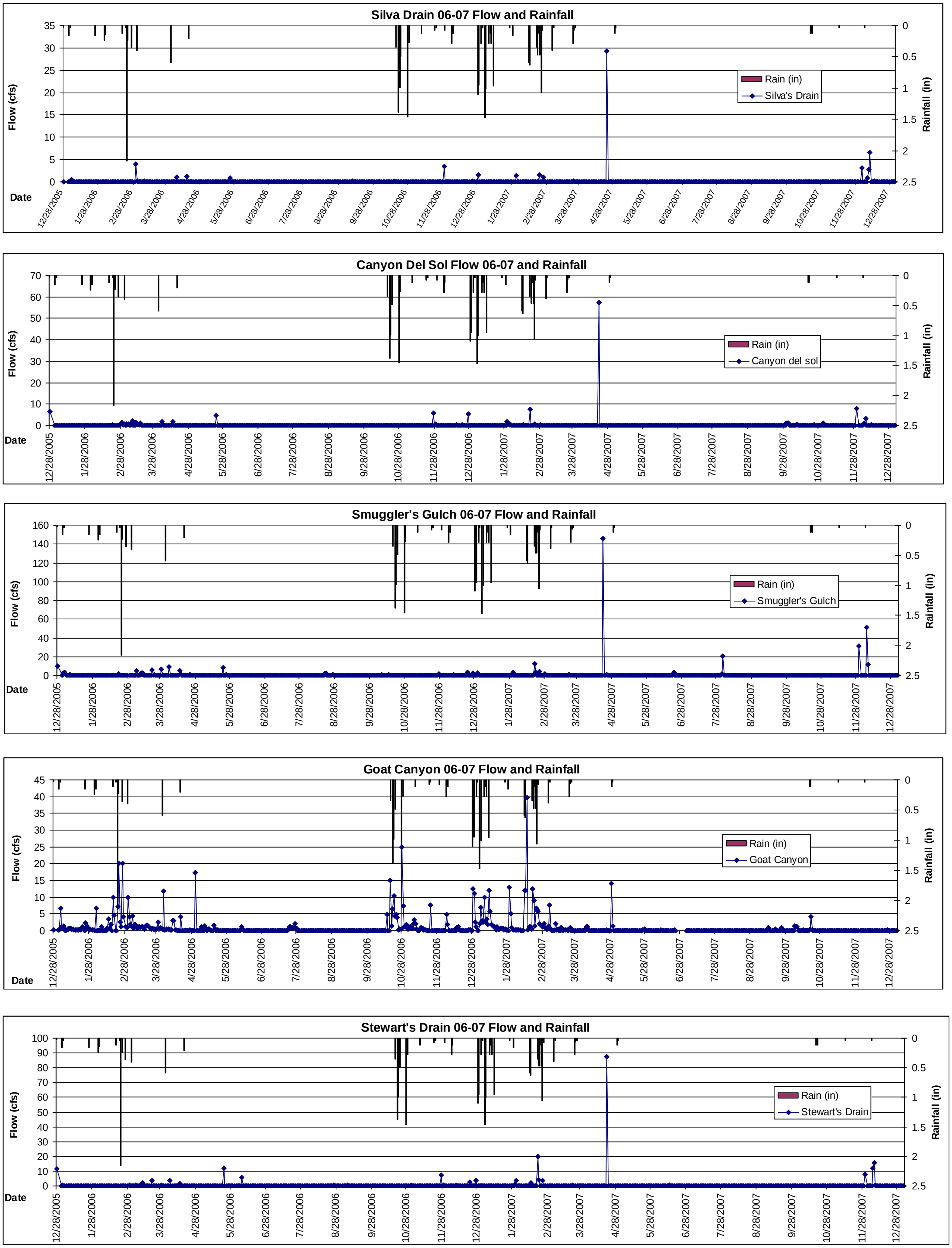


Figure 2-14. Flows and Rainfall from Diverted Canyons – 2006 and 2007

2.5.4 Recorded Spills

USIBWC provided historical wastewater spill reports from 2004 through 2007 for comparison against canyon flow data. The compilation of wastewater spill reports is presented in Table 2-3. Only one border canyon wastewater spill was recorded. This was due to a sewage spill at Smuggler's Gulch in April 2004. All other sewage spills occurred in the main trunk of the Tijuana River. It should be noted that these spills do not include occasions when the CILA pump station is overwhelmed, causing flows from the Tijuana River to enter the U.S.

Table 2-3. Recorded Spills from Canyons and the River – 2004–2008

Date	Location	Duration (hours)	Spill Volume (gallons)
04/30/2004	Smuggler's Gulch	6.5	750,000
02/03/2005	Hollister Street Pump Station	5.5	119,000
12/26/2005	Tijuana River at international boundary	3.25	646,693
0921/2005	Tijuana River at international boundary	2.25	830,000
10/28/2005	Tijuana River at international boundary	5.75	3,500,000
10/31/2005	Tijuana River at international boundary	1.75	95,000
12/03/2005	Tijuana River at international boundary	20	2,985,672

2.6 Loan-Funded Sewerage Infrastructure Projects

In March 2000, the Japanese Bank for International Cooperation (JBIC) signed a loan to fund the "Baja California Water Supply and Sanitation Project" in Mexico. One of the substantial projects funded under the loan is being coordinated by the State Public Services Commission of Tijuana (Comisión Estatal de Servicios Públicos de Tijuana {CESPT}). The project will involve installing and/or increasing the capacity of 1,219,528 meters (755 miles) of wastewater collection pipe, sewer laterals, collectors, sub-collectors, and pump stations as well as constructing four small, decentralized treatment/reclamation plants. The new treatment plants will have an estimated total capacity of approximately 15mgd (USEPA, 2003). In 2003, the cities of Tijuana and Rosarito used loan money to develop a water/wastewater master plan which analyzed requirements and future needs in five-year increments (USEPA, 2003).

These wastewater treatment plants will discharge treated water from the wastewater conveyance system back into the Tijuana River. Upgrades to the Pump Station CILA should ensure that this increased volume will be diverted for further treatment and will not lead to increased dry weather flows in the Tijuana River (Smullen–USIBWC pers. comm. 2008).

2.7 Summary of Issues

The TRW has a variety of water quality issues. Major impacts to the watershed include surface water quality degradation, trash, sedimentation, eutrophication, habitat degradation and loss, flooding, erosion, and invasive species. This section will summarize those issues.

Historically, river flows from the Tijuana River have been associated with poor water quality as well as extremely elevated concentrations of indicator bacteria, toxicity, nutrients, and suspended solids (Weston, 2007; Gersberg, 2004). Recent studies have also strongly linked elevated concentrations of indictor bacteria to the presence of viral pathogens, such as Hepatitis A and enterovirus, in wet weather flows at the mouth of the Tijuana River. During one study, three strains of poliovirus were detected, and human fecal bacterial densities (*Escherichia coli* and Enterococci) during wet weather exceeded California Water Quality Standards in 86% (12 of 14) of the samples (Gersberg et al., 2006).

Historical water quality data suggest that the majority of beach closures occur when the Tijuana River has overflowed the diversion system, thereby allowing bacteria-impacted water to enter the Pacific Ocean. Although the main source of the problem is located in Mexico, there is some evidence that there are sources within the U.S. which contribute to the bacterial loads. Identifying and managing these agricultural, industrial, commercial, residential, and natural sources of bacterial impact will help protect public health and reduce the number and duration of beach closures.

2.7.1 Impaired Water Bodies

Table 2-4 provides a summary of the impaired water bodies in the Tijuana River Watershed based on constituents that have been placed on the SWRCB 2006 303(d) list.

Table 2-4. Tijuana Watershed Management Area Waterbodies 2006 State Water Resources Control Board Section 303(d) List

Waterbody Name	HSA	HSA No.	Pollutant/Stressor
Tijuana River	San Ysidro	911.11	Indicator bacteria, eutrophic conditions, low dissolved oxygen (DO), pesticides, solids, synthetic organics, trace elements, and trash
Tijuana River Estuary	San Ysidro	911.11	Indicator bacteria, eutrophic conditions, lead, low DO, nickel, pesticides, thallium, trash, and turbidity
Pacific Ocean Shoreline, Tijuana HU	San Ysidro	911.11	Indicator bacteria
Barrett Lake	Barrett Lake	911.30	Color, manganese, and pH
Pine Valley Creek (upper)	Pine	911.41	Enterococci, phosphorus, and turbidity
Morena Reservoir	Morena	911.50	Color, manganese, and pH

Source: SWRCB, 2007.

One of the greatest challenges to addressing water quality in the TRW is the varied sources of pollutants including: urban runoff, sewage spills, industrial discharges, agricultural/orchards, livestock/domestic animals, natural sources, and septic systems (Gersberg, 2000; Weston, 2007).

The fertile soils and warm climate in the TRW encourage landowners to optimize agricultural land use by growing two different crops per year and planting intensive row crops (Weston, 2007). When compared to other crop classes, intensive row crops (predominately fruits and vegetables) allow the most erosion and produce the highest pollutant loadings (Finco et al., 1998). Although agricultural areas are generally classified as a NPS of pollution, some agricultural areas may produce higher pollutant loadings during certain growing seasons. Studies indicate elevated bacterial concentrations in the Tijuana River between the Dairy Mart Road and the Hollister Street Bridge, but further delineating the source within the 57 acres of agricultural land is a challenge. Source identification becomes even more challenging when there are two potential sources of pollution from the sod farms.

Studies have shown that trash is a contributing source of bacterial pollution. Source control is often promoted as the solution, with potential regulatory measures such as fees for excessive trash. The effectiveness of bacterial load reduction through trash source control depends on the type and effectiveness of educational programs and whether relevant education reaches target audiences. Depending on the original circumstances (baseline of trash as a source of bacteria), the load reduction through source control may or may not be cost effective (Center for Watershed Protection, 2000).

Using coastal lagoons and marshes to naturally filter and improve water quality has been a common best management practice (BMP) for treating urban runoff. During the summer dry season when inflow is low and predominately composed of urban runoff, lagoons can improve water quality. Reduced pollutant loadings are a result of low velocities and longer retention times which allow the fine-grained, pollutant-carrying particulates to settle out of the water. However, during winter months, increased velocities and flows during storms reduce retention time by orders of magnitude compared to summer conditions. Sediments do not settle out, and pollutants are carried into receiving waters together with re-suspended sediments from historical deposition (Street, 2003). Fecal coliform bacteria loads increase because winter conditions reduce bacteria die-off conditions by reducing solar irradiation, decreasing water temperature and increasing exposure to sunlight. A combination of these factors may raise the fecal coliform bacteria loading three to four orders of magnitude from summer dry periods to winter storms (Street, 2003).

Atmospheric deposition of oxides of nitrogen, volatile organic compounds, and metals to the TRW may also pose a significant source of air and water pollution (Ganster et al., 2000; Weston, 2007; Sabin et al., 2005). Commercial and non-commercial vehicular border crossings are a major source of ambient air pollution in the TRW. Some 50,000 passenger vehicles cross into San Diego each day from Tijuana, typically driving poorly maintained, older vehicles without air pollution control equipment (Ganster et al., 2000). Long lines of these vehicles, usually purchased in San Diego, idle at the border for 20 minutes or more and release ozone, copper from brake pads, and other pollutants. These pollutants are carried and deposited by the winds to other portions of the TRW which can subsequently cause water quality degradation.

2.7.2 Bacteria Sources

The primary source of impacted water quality has always been attributed to the rapid and disorganized development of poor infrastructure in the Mexican city of Tijuana. The hilly, impermeable topography of Tijuana and the unplanned squatter settlements on slopes produce significant erosion and flooding during the rainy season. The inadequacy or lack of municipal storm drain systems and, in many cases, sewerage conveyance systems leads to stormwater flows which contain significant concentrations of wastewater from both residential and industrial sources. In addition, the lack of vegetation on hillsides adds to rapid water flow, while trash and sediment clog stream channels.

During dry weather flows, there are additional “rogue” flows which are discharged from an increasing number of housing developments in Tijuana. Anecdotal evidence suggests that for many developers in Tijuana, it is cheaper to discharge sewage into canyon areas than to link those houses to municipal conveyance systems. As a result, flows of untreated raw sewage often find their way into canyons that ultimately lead to the Tijuana River Basin.

3.0 MATERIALS AND METHODS

This section presents all basic methodologies and materials used in the Tijuana River Bacterial Source Identification Project. Appendix B may also be used as a reference for all aspects of this work. In addition, individual studies and project elements contained in further sections of this report contain methodologies specific to those individual elements.

3.1 Overview of Study Components

The monitoring components of the study are encompassed under Task 4 (a – e) of the outline provided below. This section presents the materials and methods used for the completion of Task 4.

The tasks undertaken in the Tijuana River Source Identification Project under Task 4 are:

- Subtask 4a – Sanitary Survey.
- Subtask 4b – Flow Study.
- Subtask 4c – Dry Weather Sampling.
- Subtask 4d – Wet Weather Sampling.
- Subtask 4e – Special Studies.
- Subtask 4f – Project Feasibility Analysis.

The following sections describe the individual methodologies associated with each of the columns in Table 3-1.

Table 3-1. Summary of Study Components and Attributed Methods

	Continuous Water Quality Monitoring	Continuous Flow Monitoring	Field Observations	Instantaneous Flow Monitoring	Field Analytical Methods	Standard Microbiology for Fecal Indicator Bacteria	Molecular Microbiology for *Bacteroides* and Enterovirus	Chemistry Analysis - Field	Chemistry Analysis - Laboratory	Sample Handling + Chain of Custody
Sanitary Survey			•	•	•	•	•	•	•	•
Flow Study	•	•	•							
Dry Weather Sampling			•	•	•	•	•		•	•
Wet Weather Sampling	•	•	•		•	•	•		•	
Special Studies	•	•	•	•	•	•	•		•	•

3.2 Continuous Water Quality Monitoring

Monitoring of core chemical parameters was measured continuously via *in situ* probes (data sondes) in order to assess variations in water quality parameters (Table 3-2) in the Tijuana River during seasonal changes.

Continuous water quality monitoring was undertaken at a number of locations within the Tijuana River watershed during both the flow study and the wet weather monitoring. The continuous water quality monitoring locations are described in detail in the sections pertaining to those individual study components.

At each location Weston installed a YSI model 6920 V2 data sonde programmed to record data at 15-minute intervals. Data collection included those analytes presented in Table 3-2.

Table 3-2. Field Measurement List and Corresponding Surface Water Ambient Monitoring Program-Compliant Method Detection and Reporting Limits

Analyte	Method	Minimum Detection Limit	Reporting Limit	Units
Field Measurements				
Temperature	Data sonde	-5.0	0.1	°C
Conductivity	Data sonde	0	2.5	mS
Turbidity	Data sonde	0	0.5	NTU
pH	Data sonde	0.0	0.2	pH Unit
DO	Data sonde	0	1.0	mg/L

The equipment was deployed in a fabricated, protective, locking housing. Prior to deployment, the data sondes were calibrated following manufacturer recommendations. The data from this continuous monitoring was then used to assess seasonal and spatial water quality in the Tijuana River.

In addition, a rain gauge was deployed at the Hollister Bridge location.

3.3 Continuous Flow Monitoring

Continuous flow monitoring was undertaken at a number of locations within the watershed during wet weather monitoring and the dry weather monitoring, additional flow monitoring was undertaken during the special studies at select locations. The continuous flow monitoring locations are described in detail in the sections pertaining to those individual study components.

At each location Weston installed:

- American Sigma 950 (or 920) Area Velocity flowmeter and an area velocity pressure transducer programmed to log data every five minutes. Water levels were measured using data sondes described in Section 3.2.
- American Sigma SD900 auto sampler to provide automated sampling capabilities during dry and wet weather monitoring.

Stream rating measurements were collected at each of the individual the monitoring locations to ensure accurate flow measurements were recorded. The equipment was deployed in a fabricated, protective, locking housing. Prior to deployment, the flow meters were calibrated following manufacturer recommendations. The data from this continuous flow monitoring was then used to assess seasonal and spatial water quality in the Tijuana River.

3.4 Field Observations

During every field-related aspect of the project, personnel collected visual observation data including multiple photographic records of the sampling locations. Visual observations were collated using a standardized log entry. Field crews were equipped with cameras, GPS units, and field logbooks to document their observations. Field observations were completed on the designated field forms (Figure 3-1). Field crews also made additional observations of flowing or ponded water visible in storm drains and/or on surface areas. Examples of observations are described in Table 3-3.

Table 3-3. List of Required Field Observations for Documentation

Observation Category	Examples of Observations	
Site specific information	• Project name • Date • Project manager • Latitude and longitude • Station name	• Time started at site • Time finished at site • Sample collection time • Field team
Land use	• Residential • Commercial • Industrial	• Agricultural • Parks • Open
Conveyance type	• Manhole • Catchbasin	• Outlet • Open channel • Other – describe
Construction	• Concrete • Natural	• Steel • Plastic • Other – describe
Atmospheric conditions	• Wind direction • Last rainfall	• Rainfall amount • Cloud cover
Potential fecal source	• Wildlife • Pets • Birds	• Encampments • Bathers • Other – describe
Water quality appearance	• Odor • Color • Floating material • Biology	• Turbidity • Deposits • Vegetation • Comments
Trash	• Presence and description	
Photographic record	• Photo number	
Signatory authority	• Team leader sign-off	

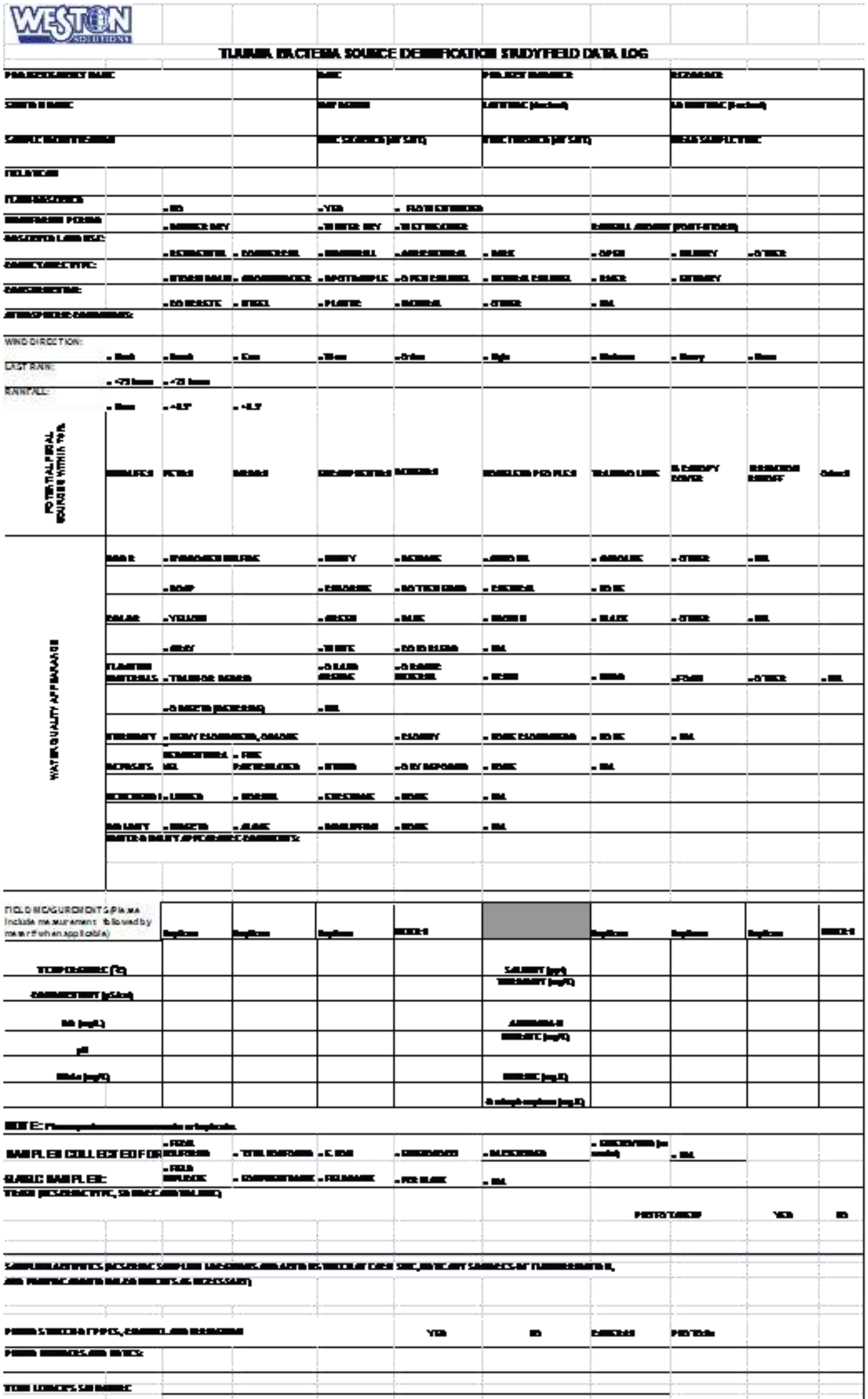


Figure 3-1. Field Observation Data Entry Sheet

3.5 Instantaneous Flow Monitoring

During sanitary surveys, dry weather sampling and special studies, instantaneous flow measurements were collected from all sites with flowing water. The following methodologies represent those used for instantaneous measurements in low flow conditions.

- **Hand-Held Meter**—A Marsh-McBirney Model 2000 Portable Flowmeter (Table 3-4) or a Son-Tec Flow Tracker (Table 3-5) was used where applicable. Appropriate hand-held flow monitoring equipment was determined by site conditions and flow characteristics.
- **Bottle Filling Method**—The bottle filling method requires a known volume of water be collected within a known period of time in order to estimate flow volumes. This test was performed in triplicate for accuracy.
- **Leaf Method**—The leaf method was used during the sanitary survey for sites with a water depth of less than 2 inches. An object of neutral buoyancy (e.g., an orange peel or leaf) was floated in the main channel of the observed flow, and its transport is timed over a specified distance. This technique was performed in triplicate to ensure precision.

Table 3-4. Marsh McBirney Analysis Parameters

Sensor	Zero Stability	Accuracy	Range
Open-channel velocity sensor	±0.05 ft/sec	±2% of reading + zero stability	-0.5 to +19.99 ft/sec -0.15 m/sec to +6 m/sec

Table 3-5. SonTek Analysis Parameters

Parameter	Value
SNR (signal to noise ratio)	Ideally > 10 dB Minimum ≥ 4 dB
σV (standard error of velocity)	< 0.01 m/s (0.03 ft/sec)
Spikes	< 5% of total samples – Should be < 10% of total samples
Angle	< 20°
%Q	Ideally < 5% Maximum < 10%

3.6 Instantaneous Water Quality Measurements

Instantaneous water quality parameters, such as dissolved oxygen, pH and temperature were collected during sanitary surveys, dry weather monitoring and special studies. A number of probes were used for collecting instantaneous field measurements:

- An Oakton probe (pH/CON 10 model) was used to measure pH, conductivity, and temperature.
- A Hach portable Turbidimeter model 2100P was used to measure turbidity.

- YSI 6-Series Multiparameter Water Quality Sonde (YSI) was used to measure pH, conductivity, temperature, turbidity, and DO.

Table 3-6, Table 3-7, Table 3-8, and Table 3-9 detail the analytical methods for analytes measured in the field.

Table 3-6. Field Analytical Methods

Analyte	Target Reporting Limits	Analytical Method	
		Analytical Method/SOP	Modified for Method (Yes/No)
Temperature	0.00 – 35.00°C	Calibrated and measured following manufacturer instructions	No
Conductivity	0.00 – 19.99 mS		No
Turbidity	0.00 – 1,000 NTU		No
pH	0.00 – 14.00		No
DO	0.00 – 12.00 mg/L		No

Table 3-7. Oakton Analysis Parameters

Mode	pH	Temperature	Conductivity
Range	0.00–14.00 pH	0.0–100.0°C	0–19.99 µS 0–199.9 µS 0–1999 µS 0–19.99 mS
Resolution	0.01 pH	0.1°C	0.01 µS 0.1 µS 1.0 µS 0.01 mS
Accuracy	± 0.01 pH	± 0.5°C	± 1% full scale or ± 1 digit

Table 3-8. YSI-6 Series Analysis Parameters

Mode	pH	Temperature	Conductivity	Turbidity	Dissolved Oxygen
Sensor type	Glass combination electrode	Thermistor	Four-electrode cell with autoranging	Optical, 90° scatter with mechanical cleaning	Optical luminescence lifetime
Range	0.00–14.00 pH	-5.0–50.0°C	0–100 mS/cm	0–1,000 NTU	0–50 mg/L
Resolution	0.01 pH	0.01°C	0.001–0.1 mS/cm (range dependent)	0.1 NTU	0.01 mg/L
Accuracy	± 0.2 pH	± 0.15°C	± 0.5% of reading + 0.001 mS/cm	± 2% of the reading or 0.3 NTU (whichever is greater)	0–20 mg/L, ±1% of the reading or 0.1 mg/L, whichever is greater; 20–50 mg/L, ±15% of the reading

Table 3-9. Hach Turbidity Analysis Parameters

Mode	NTU
Automatic range mode	0.00–1,000
Manual range mode	0.01–9.9, 10–99.9, 100–1,000 NTU
Resolution	± 2%
Accuracy	0.02 on lowest range

Operation of field equipment was conducted as per manufacturer instructions. Calibrations and replicates were performed and recorded to ensure accurate functionality of the probe. All analyses were performed in triplicate to insure accuracy.

3.7 Water Sample Collection

This section describes the water sample collection methodologies for chemistry, standard microbiology and molecular analysis. Water samples were collected in every program within this study. The following described the basic methods used for water sampling. Any deviations from these protocols are described in the individual project Sections.

3.7.1 Chemistry Analysis

Field scientists wearing clean, disposable gloves collected water grab samples in sterile, plastic containers. Chemistry water samples for analysis were collected from the horizontal and vertical center of the channel if possible. Conventional analytes were collected from beneath the water surface to a depth of 0.1 meter if possible because this near-surface water typically is representative of the water mass. Care was taken to avoid contaminating the sample with debris. Care was also taken to decontaminate the sampling device between stations or samples. Samples were stored on ice in a covered cooler in the field and during pick-up and delivery to the analytical laboratory. COC forms for samples were submitted to the laboratory. Sample volume, sample container, and preservation requirements for chemistry analyses are presented in Table 3-10.

Table 3-10. Chemistry Analytes with Sample Volume, Container Type, Holding Time, and Preservation Method

Analyte	Volume/Container	Holding Time	Preservation
Water			
TSS	1 L HDPE plastic	7 days	Cool to 4ºC
Ammonia-N	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2
Nitrate-N	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2
Nitrite-N	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2
Orthophosphate-P	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2

3.7.2 Standard Microbial Analysis for Indicator Bacteria

Field scientists wearing clean, disposable gloves collected bacterial grab samples in sterile, plastic containers. Sampling containers were kept in clear Ziploc™ bags until use. During sampling the bottle was removed from the bag, submerged open-end down approximately 6 inches below the water's surface and allowed to fill. As sampling containers contain trace amounts of sodium thiosulfate, individual bottles were filled only once and drained to the desired volume. The bottle was then be closed and placed back in the Ziploc™ bag, and the bag sealed. Samples were stored on ice in a covered cooler in the field and during pick-up and delivery to the laboratory. COC forms for samples were submitted to the laboratory. Laboratory analysis will begin as quickly as possible and always within the maximum holding time of six hours. Sample volume, sample container, and preservation requirements for indicator bacteria are presented in Table 3-11.

Table 3-11. Bacterial Analytes with Sample Volume, Container Type, Holding Time, and Preservation Method

Analyte	Volume/Container	Holding Time	Preservation
Total coliform	100 mL	6 hours	Sodium thiosulfate – cool to below 10°C (but above freezing)
Fecal coliform	100 mL	6 hours	Sodium thiosulfate – cool to below 10°C (but above freezing)
Enterococci	100 mL	6 hours	Sodium thiosulfate – cool to below 10°C (but above freezing)

3.7.3 Molecular Analysis for *Bacteroides* and Enterovirus

Polymerase Chain Reaction (PCR) analysis for *Bacteroides* and enterovirus yields presence or absence results. Therefore, the genetic material from one single cell could potentially cause a false positive result for human contamination. For this reason, only well-trained staff may sample for PCR analysis. Samples were collected with a strict "clean hands" aseptic technique, which is more precise than required by the SDRWQCB Surface Water Ambient Monitoring Program (SWAMP) protocols. Full details of this protocol are provided in the QAPP (Appendix C). Sample volume, sample container, and preservation requirements for indicator bacteria are presented in Table 3-12 and Table 3-13.

Table 3-12. Molecular Analytes with Sample Volume, Container Type, Holding Time, and Preservation Method

Analyte	Volume/Container	Holding Time	Preservation
Water			
Bacteroides presence/absence	100 mL/DNA free	24 hours	Cool to 4°C
PCR	100 mL/DNA free	24 hours	Cool to 4°C
Enterovirus presence/absence	100 mL/DNA free	24 hours	Cool to 4°C

3.8 Sample Handling

This section describes the sampling handling practices used in this study.

Analytical water quality and sediment samples were labeled with the project name, site location, date and time collected, analyses to be performed, and sample preservatives, if any. Samples were then stored and transported on ice, maintaining 4°C, until processed. Samples were delivered, under strict Chain of Custody procedures, as outlined in the QAPP (Appendix B) COC, to the appropriate laboratory, and analyses were initiated within specified holding times, as outlined in Table 3-13.

Water chemistry samples were couriered to CRG (2008) or EMA (2009-2011) by Weston or contract laboratory staff. Bacteria samples were delivered to the Weston Microbial Sciences Laboratory by Weston staff. Enterovirus samples were pre-processed by Weston's molecular laboratory staff and shipped on ice to Stanford University for enterovirus presence/absence analyses.

The samples were kept on ice from the time of sample collection until delivery to the Weston Microbial Sciences laboratory.

Each field sample was uniquely identified with a sample label written or printed in indelible ink. Sample containers are identified with the project title, appropriate identification number, the date and time of sample collection, and preservation method.

Table 3-13. Full List of Analytes with Sample Volume, Container Type, Holding Time, and Preservation Method

Analyte	Volume/Container	Holding Time	Preservation
Field Measurements			
Flow	*In situ*		
Temperature	*In situ*		
Conductivity	*In situ*		
Turbidity	*In situ*		
pH	*In situ*		
DO	*In situ*		
Water			
TSS	1 L HDPE plastic	7 days	Cool to 4ºC
Ammonia-N	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2
Nitrate-N	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2
Nitrite-N	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2
Orthophosphate-P	250 mL HDPE plastic	48 hours	Cool to 4ºC; $H2_SO_4$ to pH<2
Total coliform	100 mL	6 hours	Sodium thiosulfate – cool to below 10°C (but above freezing)
Fecal coliform	100 mL	6 hours	Sodium thiosulfate – cool to below 10°C (but above freezing)
Enterococci	100 mL	6 hours	Sodium thiosulfate – cool to below 10°C (but above freezing)
Bacteroides presence/absence	100 mL/DNA free	24 hours	Cool to 4°C
PCR	100 mL/DNA free	24 hours	Cool to 4°C
Enterovirus presence/absence	100 mL/DNA free	24 hours	Cool to 4°C

3.9 Analytical Methods

This section describes the analytical methods used by the individual laboratories to assess and quantify the presence targeted constituents of concern.

3.9.1 Indicator Bacteria Analysis

All standard microbiological analyses were performed by the Weston in-house microbiology laboratory. Standard microbiological analyses used in this study included both multiple tube fermentation (Method SM 9230B) and the "Enterolert" method. The microbiological analytical methods used for this project are listed in Table 3-14. The Enterolert method provides rapid results (within 24 hours) and was used primarily in the sanitary survey during initial site visits. All other sampling, including follow-up sampling at sanitary survey sites was performed using the multiple tube formation method, which, while taking longer, provides improved accuracy.

Table 3-14. Laboratory Analytical Methods for Standard Microbiology

Analyte	Analytical Method		Achievable Laboratory Limits
	Analytical Method/SOP	Modified for Method (Yes/No)	MDLs (1)
Total coliform	SM 9221B	No	2 MPN/100 mL
Fecal coliform	SM 9221 E	No	2 MPN/100 mL
Enterococci	SM 9230 B	No	2 MPN/100 mL
Enterococci	Enterolert	No	1 MPN/100 mL

3.9.2 Molecular Analysis of *Bacteroides* and Enterovirus

All molecular analyses were performed by Weston Solution's in-house microbiology laboratory or by Stanford University.

Three molecular markers were used in this study:

1. The human specific *Bacteroides* marker (HF183) which signals the presence of recent human fecal material
2. The general *Bacteroides* marker which signals the presence of recent mammalian fecal material.
3. The enterovirus marker, which signals the presence of enterovirus in a sample.

The molecular microbiological analytical methods used for this project are listed in Table 3-15.

Table 3-15. Molecular Laboratory Analytical Methods

Analyte	Analytical Method		Laboratory
	Analytical Method/SOP	Modified for Method (Yes/No)	
Bacteroides presence/absence	LAB068.00	–	Weston
Enterovirus presence/absence	Noble et al., 2006	–	Stanford University

3.9.3 Chemistry Analysis

During the first sanitary survey, commercial test kits for nutrients were used to provide an indication of water quality parameters. The analytical methods for this are presented in Table 3-16.

Table 3-16. Chemistry Field Kit Analytical Methods

Analyte	Analytical Method		Achievable Laboratory Limits
	Analytical Method/SOP	Modified for Method (Yes/No)	MDLs (1)
MBAS	CHEMetrics K-9400	No	0.5 mg/L
Ammonia-N	CHEMetrics K-1510	No	0.01 mg/L
Nitrite-N	CHEMetrics K-7004D	No	0.01 mg/L
Nitrate-N	CHEMetrics K-6902	No	0.01 mg/L
Orthophosphate-P	CHEMetrics K-8510	No	0.01 mg/L

However, during all subsequent sampling assessments chemistry analyses were performed by certified laboratories (CRG or EMA). The chemistry analytical methods used for this project are listed in Table 3-17.

Table 3-17. Chemistry Laboratory Analytical Methods

Analyte	Analytical Method		Achievable Laboratory Limits
	Analytical Method/SOP	Modified for Method (Yes/No)	MDLs (1)
TSS	SM 2540-D	No	0.5 mg/L
Ammonia-N	SM 4500-NH_3 B,C	No	0.01 mg/L
Nitrite-N	SM 4500 NO2 B	No	0.01 mg/L
Nitrate-N	SM 4500 NO3 E	No	0.01 mg/L
Orthophosphate-P	SM 4500 P E	No	0.01 mg/L

3.10 Water Quality Criteria

Applicable data were compared to the Water Quality Control Plan (RWQCB, 1994) for the San Diego Region, Title 40 of the Code of Federal Regulations (Part 131, Water Quality Standards) (USEPA, 2000a), and the National Pollutant Discharge Elimination System (NPDES) Stormwater Multi-Sector General Permit (USEPA, 2000b).

Table 3-18 presents the list of analytes that were monitored during this project and the applicable water quality objective (WQO).

Table 3-18. Analytes and Water Quality Objectives

Analyte	Objective	Source
Temperature	–	–
Conductivity	–	–
Turbidity	<20 NTU	Basin Plan (RWQCB, 1994)
pH	6.5–8.5 pH units	Basin Plan (RWQCB, 1994)
Total suspended solids (TSS)	<100 mg/L	Multi-Sector General Permit (USEPA, 2000b)
Dissolved oxygen (DO)	>5.0 mg/L	Basin Plan (RWQCB, 1994)
Ammonium-N	<25 µg/L (un-ionized ammonia as N)	Basin Plan (RWQCB, 1994)
Nitrate-N	<1mg/L	Basin Plan (RWQCB, 1994)
Nitrite-N	–	–
Orthophosphate-P	–	–
Total coliform	10,000 MPN/100mL	Basin Plan REC-1
Fecal coliform	400/4,000 MPN/100mL	Basin Plan REC-1/REC-2(b)
Enterococci	104 MPN/100mL	Basin Plan (RWQCB, 1994)
Bacteroides	–	–
Enterovirus	–	–

– = A WQO has not been developed.
MPN = most probable number

4.0 SANITARY AND DRY WEATHER SURVEYS

4.1 Background

A sanitary survey is most commonly used during assessments of drinking water supplies and is defined in 40 CFR 141.2 as "onsite review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water" (USEPA, 2010).

In the context of microbial source tracking, a sanitary survey forms the basis for effective evaluation and documentation of sources of contaminants that might adversely affect public health. In this component of a study, a comprehensive evaluation of every potential pollution source is evaluated on its threat to receiving waters and public health. The results of a sanitary survey can be used to provide information that helps in designing site-specific monitoring programs and selecting sampling locations. They can also be used to identify sources of pollution and to provide information on:

- source controls
- persistent problems
- magnitude of pollution from sources
- management actions

Specifics regarding the components and application of sanitary surveys can be found at the USEPA's *National Beach Guidance and Required Performance Criteria for Grants – June 2002.*

The main purpose of this portion of the study was to identify point and non-point sources of bacterial inputs throughout the U.S. portion of the Tijuana River Watershed (TRW) during dry weather. In order to accomplish this, three comprehensive sanitary surveys were performed in 2008, 2010, and 2011.

The purpose of the surveys was to identify any flowing or ponded water within the watershed, sample and assess concentrations or presence of key indicator bacteria. By using a synoptic approach key bacteria "hotspots" were located. Synoptic sampling is the collection of samples from many locations during a short period of time, typically a day. This type of sampling will provide a "snapshot" of the watershed at a given point in time. These sanitary surveys were supported by an earlier literature review (Weston, 2008) and field reconnaissance efforts as part of the on-going Task 1 component projected for the study.

The sanitary surveys included the following elements:

- Flow estimation and location assessments via field survey by foot throughout the river and canyon areas including all border areas, canyons and associated gullies, trails, agricultural developments and equestrian areas on the U.S side of the border.

- Identification and inventory of all outfalls or drainage points into the canyons or the river including locating and quantifying dry weather flows and sites of significant contaminated flows via GPS.
- Characterization of the tributary areas to each outfall/drainage point.
- Sample collection and analysis for indicator bacteria using standard methods at selected sites to quantify the presence of indicator bacterial species and estimate loads based on flow data.
- Sample collection and quantification of human-specific *Bacteroides* species at selected sites to identify presence of anthropogenic bacterial pollution.
- Filtering and/or preservation of samples for future molecular analysis (as required).
- Visual observations and photo documentation of sites and conditions.
- Measurements of key water quality parameters such as pH, turbidity, and nutrients.

4.2 Study Questions

The following study questions formed the basis of this portion of the study:

- What are the anthropogenic sources of bacteria?
- What are the non-anthropogenic sources of bacteria?
- What are the point and non-point sources of bacterial pollutants?

4.3 Methods

Methodologies for microbial and chemical analyses, as well as continuous and instantaneous water quality monitoring, are presented in Section 3 – Materials and Methods. This section provides specific methodologies used in the sanitary survey portion of the study.

4.3.1 Survey Dates

Three sanitary surveys were conducted in the Tijuana River Watershed, targeting up to approximately 100 sampling locations during each survey. Each sanitary survey was conducted over a two-week period. As presented in Table 4-1, the first sanitary survey was conducted during dry weather in September and October 2008, prior to the rainy season. It was planned that the second survey would be conducted during April 2009 after the rainy season. However, due to the closure of the project during 2009, no sampling occurred. When the project contract was renewed, in 2010, the second sanitary survey was undertaken during July and August. The third survey was undertaken in August and September, 2011 and focused primarily on the key locations identified in Sanitary Surveys 1 and 2. In addition, a series of dry weather (set season) surveys were conducted in January and February, 2012. These surveys were designed to assess the potential for cross-contamination of the MS4 by the sanitary sewer within the major urbanized sub-drainages of the U.S. side of the watershed.

Table 4-1. Sanitary Survey Sampling Dates

	Sanitary Survey #1	Sanitary Survey #2	Sanitary Survey #3
Sampling Date	September-October 2008	July –August 2010	August-September 2011
Number of sites visited	127	98	84
Number of sites sampled	81	92	76

4.3.2 Survey Locations

The sanitary surveys included the following targeted areas of interest within the Tijuana river Watershed:

- **Tijuana River and Estuary**—monitoring of the Tijuana River and its tributaries provided important information regarding potential public health risk in the receiving waters.
- **Storm Drains**—A comprehensive inventory of outlets or drainage points into the canyons and the Tijuana River was used in the sanitary surveys to investigate potential transport of pollutants through the storm drain system and locate possible illegal connections or discharges.
- **Agricultural Land Use Assessment**—A number of private and commercial ranches are in operation in the TRW. Anecdotal evidence of horse manure stockpiles also led to concern that the ranches may be impacting water quality. In addition, a sod farm is in operation in the TRW and was investigated in the sanitary surveys.
- **Military Land Use Assessment**—Naval Air Station (NAS) North Island operates the Outlying Field (OLF) Imperial Beach, located 10 miles south of the base on the U.S.–Mexican border. As a distinct and unique land use, sanitary surveys were conducted around the air field to assess potential impact.
- **Canyons**—A number of canyons drain into the Tijuana River from the border with Mexico. These canyons have been documented to contain flows with high sewage content. The potential transport of these pollutants into receiving waters was an important aspect of the study.
- **Areas of Septic Tank Usage**—Areas of potential septic tank usage were identified and surveyed. Septic tank leachate fields may fail and be a source of fecal pollution.
- **Areas of Residential Land Use**—Areas of residential land use were surveyed, and samples of flowing water from storm drains, gutters, or overland flows were spot sampled.
- **Areas of Commercial Land Use—**Areas of commercial land use were surveyed, and samples of flowing water were spot sampled.
- **Spot Samples**—Spot samples were taken at any location which appeared to contribute flows or bacterial loads.

In order to effectively canvas the US portion of the TRW and target the identified land uses, the watershed was divided into eight distinct grids (Figure 4-1). Within each of those grids, specific land use types were identified (Table 4-2). These land uses, together with storm drain layers and sewer lines, provided the basis for the sanitary survey assessments.

Table 4-2. Targeted Areas of Interest and Associated Sub-drainage Area Tile

Tile Area of Tijuana River Watershed	Tijuana River and Estuary	Storm Drains	Agriculture	Military	Canyons	Groundwater	Septic Tanks	Residential	Commercial
Tile 1	●	●	●	●		●		●	●
Tile 2		●		●		●		●	●
Tile 3		●	●					●	●
Tile 4		●						●	●
Tile 5	●	●	●		●	●		●	
Tile 6		●	●		●	●		●	●
Tile 7		●	●		●			●	●
Tile 8		●			●			●	●

● = targeted activity or land use of interest

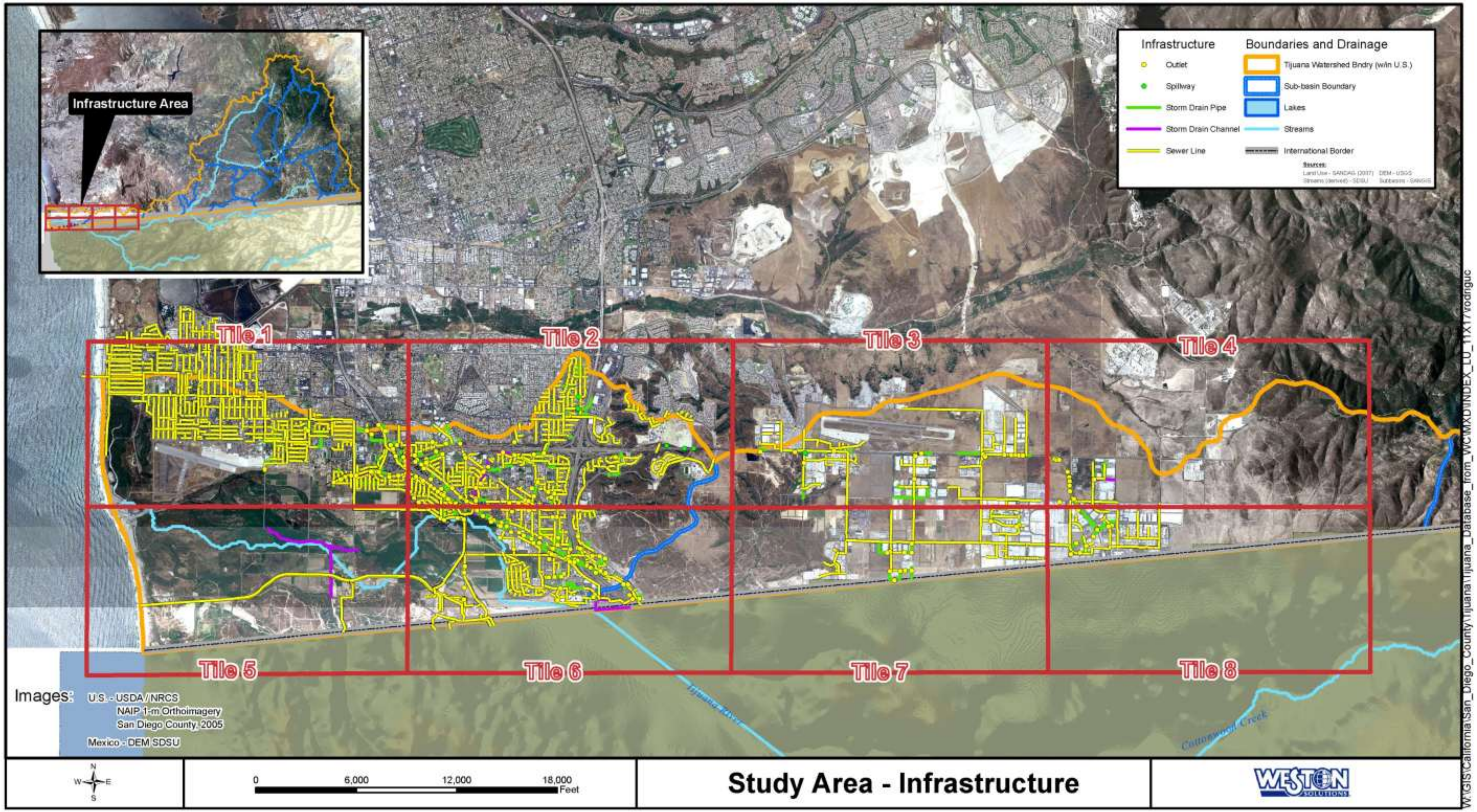


Figure 4-1. Grid System Used in Sanitary Surveys of the United States Portion of the Tijuana River Watershed

4.3.3 Initial Survey Inspections

A tiered approach was used for the sanitary surveys to identify potential areas of bacterial contamination. This tiered approach is illustrated on Figure 4-2. During each survey, two teams of two scientists were assigned four sampling grids each (Figure 4-1). Each team was provided with a unique set of sampling identification codes to be used in any areas where a site visit occurred. Surveys were conducted between 5:00 AM and 3:00 PM each day. The team then canvassed all portions of the grid, using topographical maps, survey maps, sewer and storm drain maps as well as local knowledge, best professional judgment and advice from local municipalities.

Each site visited was assigned a site-specific code, photographs were taken and field sheets were filled in. Once the sampling location had been identified, the presence of water determined whether or not a sample was collected. Water samples were collected for on-site chemistry analysis and for bacteriological analysis. During the first sanitary survey, on-site chemistry kits were used for nutrient analysis. During subsequent sanitary surveys, a certified laboratory was used for chemistry analysis. During all initial sanitary survey sampling, total, fecal and enterococci were enumerated using the rapid IDEXX method. This method provides results within 24 hours, allowing for rapid follow up. *Bacteroides* analyses were also performed with rapid turn-around (1-2 days) to ensure rapid follow-up.

4.3.4 Follow Up Sampling

The need for follow-up sampling was based on the results of observations, measurements, and analyses and using a weight of evidence approach. After initial site visits and bacteria analysis results had been completed, each site would be evaluated for the need for follow-up. Follow-up sampling was conducted in every instance:

- if high bacterial loads were found
    - Enterococci concentrations of over 15,000 MPN/100mL or
    - Fecal coliform concentrations of over 10,000MPN/100mL
- Or if human-specific *Bacteroides* analysis was positive at the site.
- Or if there were visual observations or other quantitative measurements suggested follow-up sampling was necessary.

Follow-up sampling occurred within three business days and included the same chemical and microbial analyses at the original site and surrounding, upstream locations. During each follow-up inspection, water samples were processed using the multiple tube fermentation technique. This method of analysis, while requiring a longer processing time, provides more accurate enumeration than the IDEXX method.

At any site where a source was determined to be present, further evaluation was made as to whether a special study or potential BMP could be undertaken.

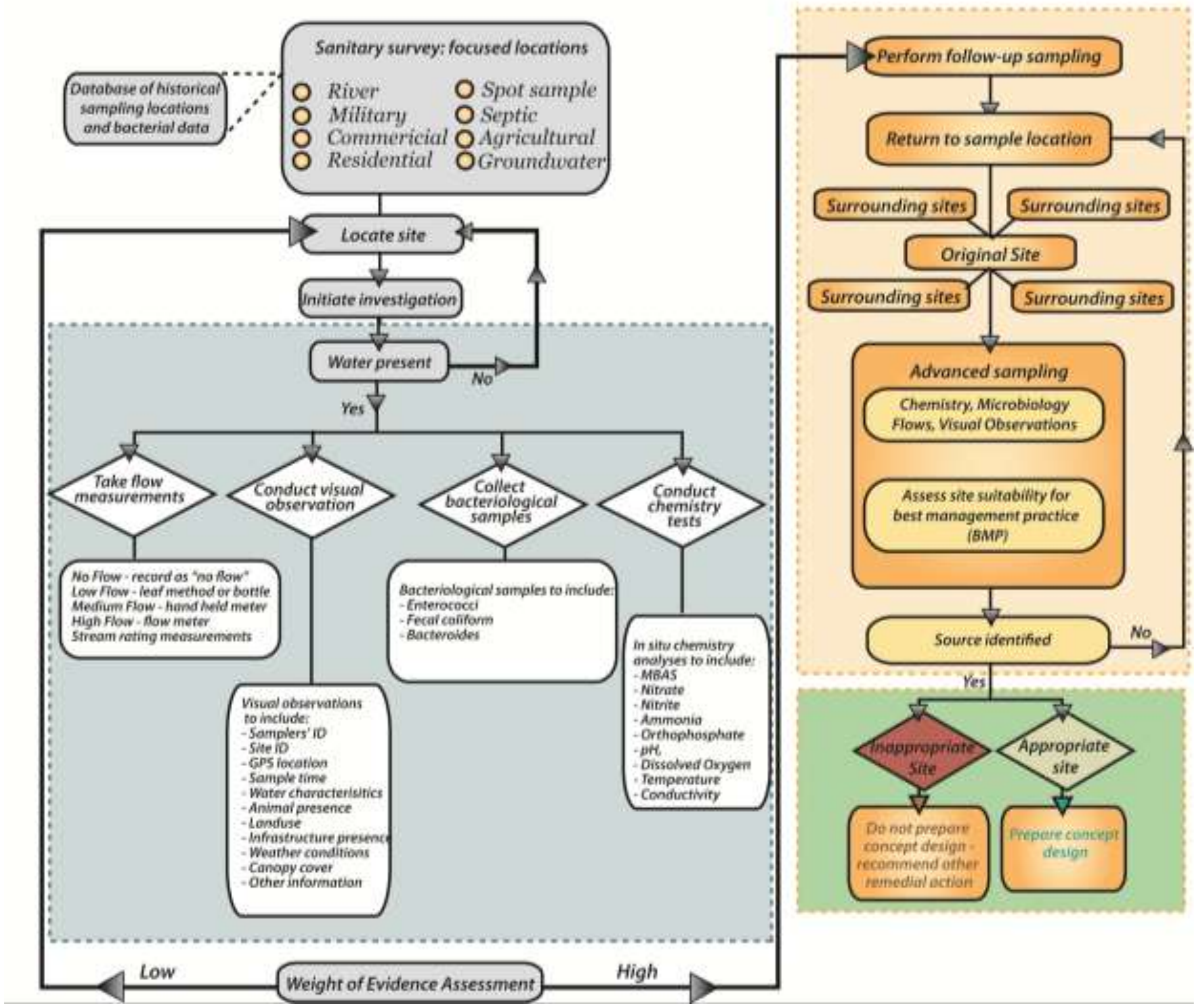


Figure 4-2. Illustration of Tiered Approach to Sanitary Survey Sampling and Development of Concept Designs

4.3.5 Sample Identification Codes

Unique sample identification codes were used in each of the sanitary surveys and follow-up investigations. The overall template for each sample identification code was:

Project Code – Study Component – Sample Number – Follow-up identifier. For example, a sample collected in the first sanitary survey in an initial investigation at Site 123 would have the following code: TJ-SS1-123. A follow up sample at the site would have the code TJ-SS1-123.1.

4.3.6 Sanitary Survey Field Analysis

Field analysis included comprehensive field observations and measurement of water quality parameters, including DO, pH, temperature, nitrate, nitrite, orthophosphate, and ammonia (Table 4-3). Flow measurements were made wherever sufficient flow was observed. Details are provided in Section 3 – Materials and Methods.

Table 4-3. Sanitary Survey Monitoring

Analyte	Initial Site Visit	Follow-Up
Flow	ɵ	ɵ
Temperature	ɵ	ɵ
Conductivity	ɵ	ɵ
Turbidity	ɵ	ɵ
pH	ɵ	ɵ
DO	ɵ	ɵ
Ammonia	●	●
Nitrate	●	●
Nitrite	●	●
Orthophosphate	●	●
Enterococci	●*	●
Total coliform	–	●
Fecal coliform	●*	●
Bacteroides	●	●
Enterovirus	–	○

ɵ: instantaneous measurement
○: analyte measured as needed
●: analyte measured
*: rapid method used
–: not measured

4.3.7 Field Observations

Field teams were equipped with cameras, GPS units, and field logbooks to document their observations. Field observations were completed on the designated field forms. Field crews made additional observations of flowing or ponded water visible in storm drains and/or on surface areas. Examples of field observations are described in Table 4-4 and are further detailed in Section 3 – Materials and Methods.

Table 4-4. Field Observations

Observation Category	Examples of Observations	
Site specific information	• Project name • Date • Project manager • Latitude and longitude • Station name	• Time started at site • Time finished at site • Sample collection time • Field team
Land use	• Residential • Commercial • Industrial	• Agricultural • Parks • Open
Conveyance type	• Manhole • Catch basin	• Outlet • Open channel • Other – describe
Construction	• Concrete • Natural	• Steel • Plastic • Other – describe
Atmospheric conditions	• Wind direction • Last rainfall	• Rainfall amount • Cloud cover
Potential fecal source	• Wildlife • Pets • Birds	• Encampments • Bathers • Other – describe
Water quality appearance	• Odor • Color • Floating material • Biology	• Turbidity • Deposits • Vegetation • Comments
Trash	• Presence and description	
Photographic record	• Photo number	
Signatory authority	• Team leader sign-off	

4.3.8 Field Measurements

Field crews collected the following instantaneous measurements of key water quality parameters at sites with flowing or ponded water:

- pH
- Temperature
- Conductivity
- Turbidity
- DO

All field measurements were made in triplicate as detailed in Section 3 – Materials and Methods.

4.4 Results

4.4.1 Overview of Sanitary Surveys 1 and 2

The results of the sanitary surveys are summarized in this Section. The complete results are detailed in Appendix D. In September and October 2008, field crews visited 127 sites during Sanitary Survey 1 (Table 4-5). Of those sites, 81 were sampled for bacteriological indicators, human-specific *Bacteroides*, ammonia, nutrients (*e.g.*, nitrate), and water quality parameters (*e.g.*, DO and turbidity). Nine of the samples exceeded the WQ benchmark for *Enterococcus* and 16 samples exceeded the benchmark for fecal coliforms. Four samples were positive for human-specific *Bacteroides*.

In July and August 2010, field crews visited 98 sites during Sanitary Survey 2. Of those sites, 92 were sampled for the same water quality parameters and analytes as those in Survey 1. Twenty-one of the samples exceeded the WQ benchmark for *Enterococcus* and 15 samples exceeded the benchmark for fecal coliform. Twelve samples were positive for the presence of human-specific *Bacteroides*.

Figure 4-3 and Figure 4-4 show all of the sites that were sampled during Sanitary Surveys 1 and 2, as well as which sites had exceedances for *Enterococcus* and fecal coliform.

Table 4-5. Summary of the Number of Samples that had Bacteriological and *Bacteroides* Exceedances for Sanitary Surveys 1 and 2

Summary	Sanitary Survey #1	Sanitary Survey #2
Number of sites visited	127	98
Number of sites sampled	81	92
Number of Human *Bacteroidales*	4	12
Number of Enterococcus samples > 10,000 MPN/00 mL	9	21
Number of fecal coliform samples > 10,000 MPN/00 mL	16	15

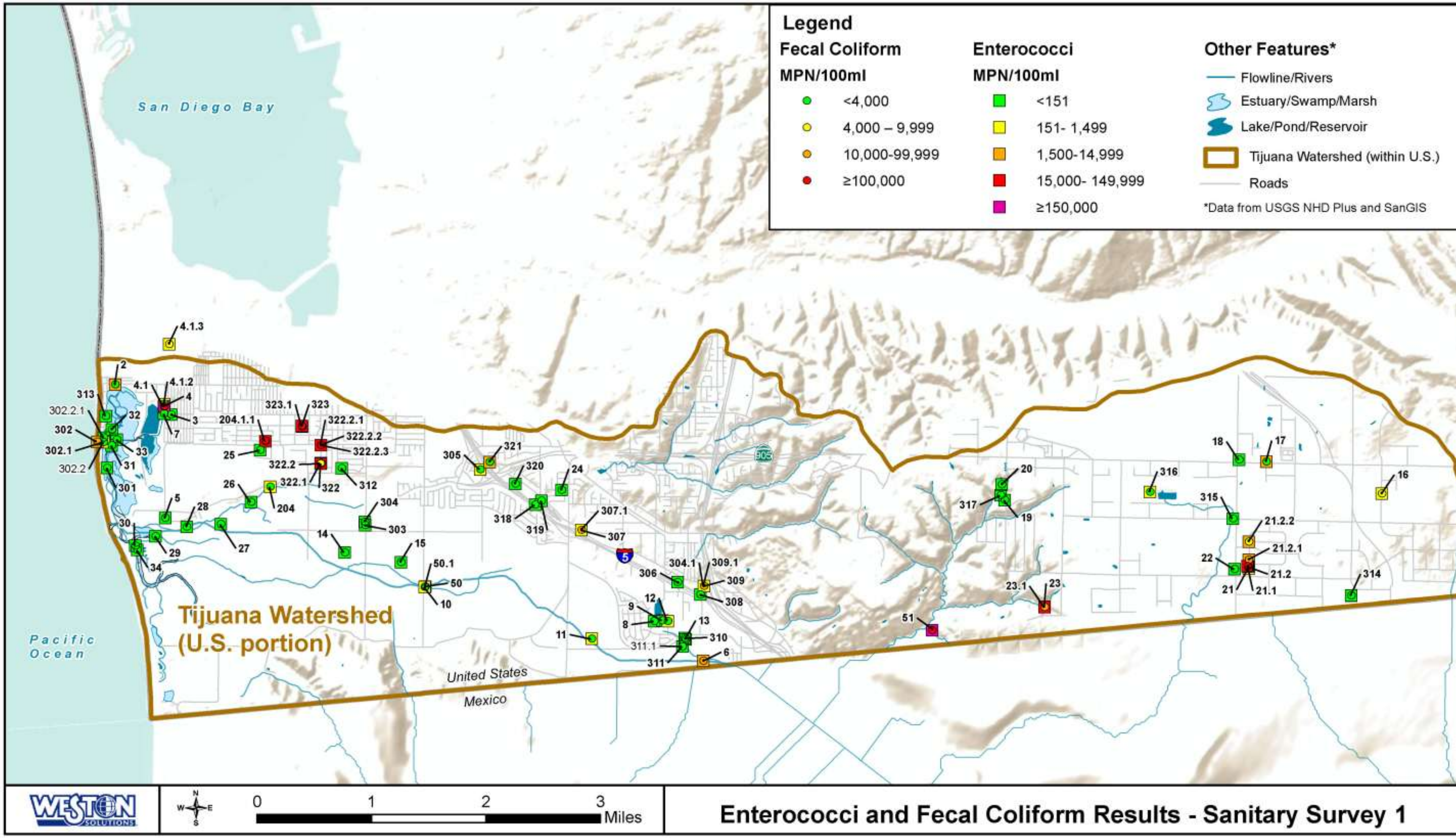


Figure 4-3. ***Enterococcus*** **and Fecal Coliform Results for Sanitary Survey 1**

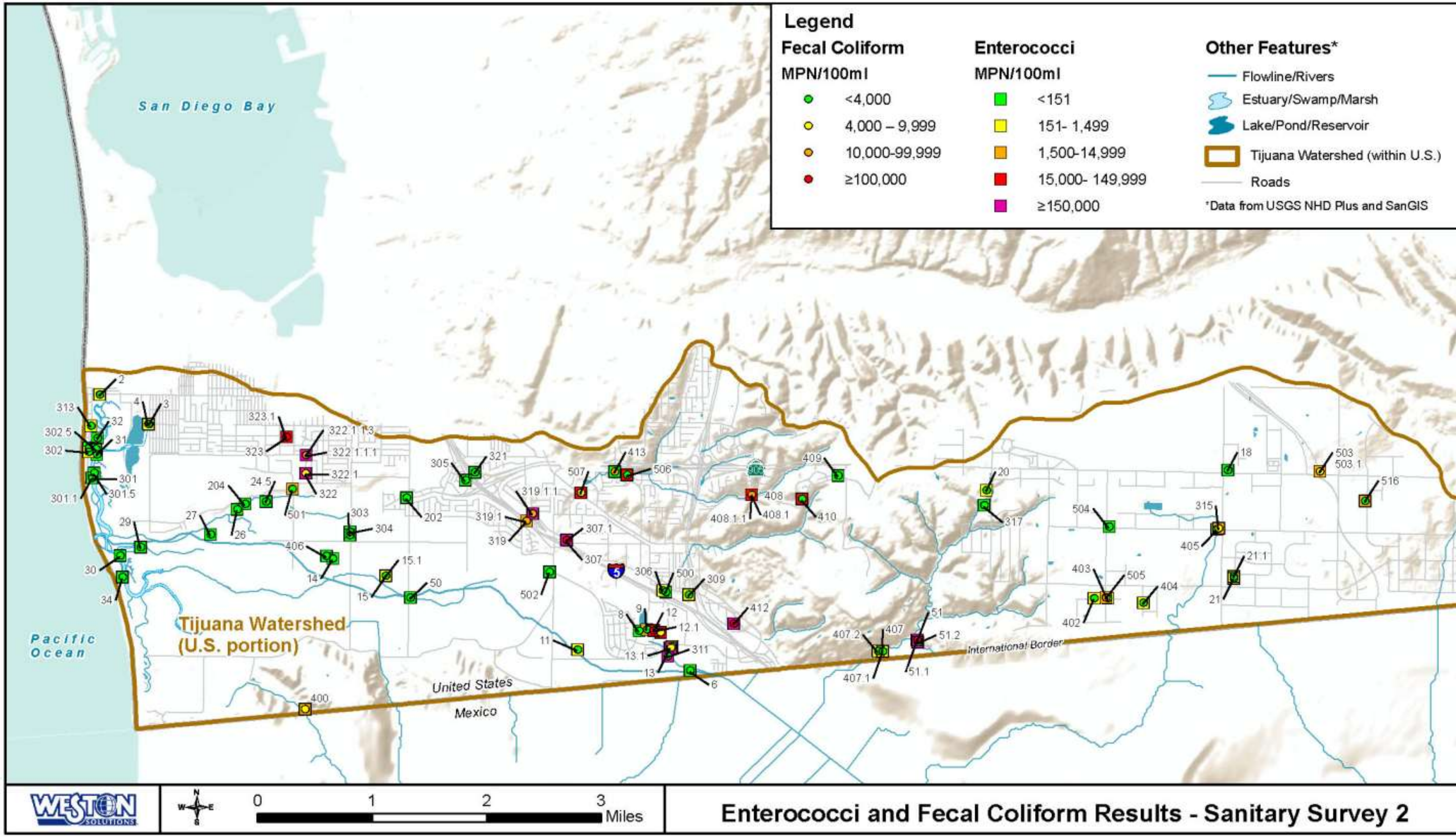


Figure 4-4. ***Enterococcus*** **and Fecal Coliform Results for Sanitary Survey 2**

4.4.2 Results for Sanitary Surveys 1 and 2

Several sites assessed in the first two sanitary surveys had bacterial concentrations greater than the established threshold concentrations. The results are summarized in Table 4-6 and presented in full in Appendix D. The results of the first two sanitary surveys identified several sites where indicator bacterial concentrations were high or tested positive for human-specific *Bacteroides*. In all cases, follow up dry weather surveys indicated that water at the site was either ponded, had very low trickle flows, and/or the flow could not be traced upstream to any source. In nearly all cases where a sample tested positive for human-specific *Bacteroides*, follow up surveys failed to re-produce a positive result. These results of these extensive surveys suggest that with few exceptions, elevated levels of indicator bacteria or the potential presence of human fecal contamination at numerous sites assessed in the watershed were ephemeral and did not represent a consistent source of bacteria to the estuary.

Table 4-6. Bacteriological Results of Sanitary Survey 1

Site	Date	Fecal Coliform (MPN/100 mL)	*Enterococcus* (MPN/100 mL)	Human-specific *Bacteroidales*
		Threshold		
		≥10,000	≥15,000	Presence/Absence
TJ-SS1-4	9/22/2008	**160,000**	**241,957**	NEG
TJ-SS1-6	9/22/2008	**13,000**	6,828	NEG
TJ-SS1-21	10/1/2008	**≥160,000**	698	NEG
TJ-SS1-21.1	10/3/2008	**90,000**	5,000	NEG
TJ-SS1-21.2	10/7/2008	**160,000**	**17,000**	NEG
TJ-SS1-21.2.1	10/7/2008	**30,000**	14,000	NEG
TJ-SS1-21.2.2	10/7/2008	7,000	3,000	**POS**
TJ-SS1-23	10/1/2008	**50,000**	75	NEG
TJ-SS1-23.1	10/3/2008	8,000	**17,000**	NEG
TJ-SS1-51	10/16/2008	**≥160,000**	**≥160,000**	**POS**
TJ-SS1-204.0	10/13/2008	300	1,300	**POS**
TJ-SS1-204.1	9/29/2008	**≥160,000**	**48,844**	NEG
TJ-SS1-204.1.1	10/1/2008	2,800	**24,000**	NEG
TJ-SS1-302	9/22/2008	**11,000**	2,098	**POS**
TJ-SS1-307	9/23/2008	**13,000**	743	NEG
TJ-SS1-309	9/24/2008	**17,000**	4,890	NEG
TJ-SS1-322.2	10/7/2008	5,000	**17,000**	NEG
TJ-SS1-322.2.1	10/7/2008	**160,000**	**50,000**	NEG
TJ-SS1-322.2.2	10/7/2008	**30,000**	5,000	NEG
TJ-SS1-323	10/1/2008	**50,000**	3,873	NEG
TJ-SS1-323.1	10/3/2008	**≥160,000**	**90,000**	NEG

Shaded text = exceeds threshold for follow-up monitoring
Pos = Positive
Neg = Negative

4.4.3 Overview of Sanitary Survey 3

On September 2, 2011 eight sites were sampled within the Tijuana River Estuary as part of Sanitary Survey 3 (Table 4-7, Figure 4-5). Samples were collected at each of the eight sites every two hours across the tidal cycle for a total of five to six samples per site. (Table 4-7, Figure 4-5). Two additional samples were collected at the mouth of the Tijuana River Estuary. The objective of this study was to determine if the estuary contained high concentrations of indictor bacteria and if those concentrations changed over the course of a tidal cycle. Additional samples were collected from several sites within the watershed, but no flow was observed at any of the sites visited. Ponded water was collected from those sites where it was present. The complete report for this assessment is provided in Appendix D.

Table 4-7. Site Identification Codes, Number of Samples, Sampling Dates, and Locations for the Tijuana River Estuary Sites

Sample ID	# of Samples	Sample Date	Latitude	Longitude
TJ-MOUTH (1305)	1	9/2/2011	32.55344	-117.12690
TJ-MOUTH (1455)	1	9/2/2011	32.55344	-117.12690
TJ-SS3-204	5	9/2/2011	32.56377	-117.10715
TJ-SS3-24.5	6	9/2/2011	32.56318	-117.10552
TJ-SS3-28	5	9/2/2011	32.55878	-117.11966
TJ-SS3-29	5	9/2/2011	32.55748	-117.12429
TJ-SS3-301	6	9/2/2011	32.56600	-117.13158
TJ-SS3-30	6	9/2/2011	32.55584	-117.12776
TJ-SS3-32	6	9/2/2011	32.57103	-117.13081
TJ-SS3-33	6	9/2/2011	32.56957	-117.13015

4.4.4 Results for Sanitary Survey 3

Analytical results for all of the estuary sites are presented in Appendix D and summarized here. Water quality parameters (*e.g.*, DO, turbidity), bacteriological indicators, and *Bacteroides* were collected at each of the sites; however, nutrients (*e.g.*, nitrate) and ammonia samples were only collected at four of the sites. All of the samples collected in the Tijuana River Estuary had water quality parameters, ammonia, and nutrient values below their respective WQ benchmarks. Results for both fecal coliform and *Enterococcus* in each of the samples were also below their respective WQ benchmarks. All of the samples indicated the presence of general *Bacteroides* except one sample collected at TJ-SS3-32 and one sample at TJ-SS3-301. None of the samples were positive for human-specific *Bacteroides*.

Figure 4-5. Sanitary Survey 3 Sample Locations in the Tijuana River Estuary

All of the sites were negative for human-specific *Bacteroides* during each sample round. Indicator bacteria concentrations were also below threshold concentrations at all sites during each sampling round. Most sites had indicator bacteria concentrations at or near the minimum detection limit throughout the tidal cycle.

This sampling event confirms results from the previous samples events in the estuary. Under typical dry weather conditions bacteria levels within the estuary are low. Rogue sewage spills originating in Mexico in the mainstem TJR and/or associated tributary canyons can lead to elevated indictor bacteria levels in the estuary if the IBWC low water diversion structures are over-burdened, but these conditions are not typical.

The north arm of the estuary was found to have a number of sites that tested positive for human-specific *Bacteroides* and had elevated bacterial concentrations during both Sanitary Survey 1 and Sanitary Survey 2. These results were attributed to leaking sewage system along Seacoast Drive in the City of Imperial Beach. The City of Imperial Beach relined the sewage system in question and the results from the Seacoast Drive Special Study (see Section 6.0) suggest that the improvements made to the sewage system solved the issue. These same sites were sampled during Sanitary Survey 3 and the results confirm the findings from the Seacoast Special Study, no elevated indicator bacteria concentrations nor the presence of human-specific B*acteroides* were encountered.

4.4.5 Overview of Cross-Contamination Dry Weather Surveys

In January and February 2012 a series of three final dry weather surveys were conducted for the Project. The Cross-contamination Dry Weather Surveys had three main objectives:

- Delineate the sub-drainages that discharge directly to the Tijuana River Estuary on the U.S. side of the U.S./Mexico Border.
- Assess the potential for dry weather flows to reach the estuary from each of the sub-drainages during dry weather, wet season conditions.
- Identify locations where there is the greatest potential for cross-contamination from the sewage system into the MS4.

To accomplish these goals, a GIS-based analysis was conducted to identify storm drain pipes that may be influenced by the sanitary sewer system in the Tijuana River Watershed. The analysis focused on the storm drain system within the U.S. portion of the Tijuana River Watershed, in which urban runoff flows directly to the Tijuana River Estuary (*i.e.,* does not flow into Mexico). This portion of the watershed was determined based on review of previously-defined sub-watershed boundaries, topography, storm drainage system, land use, and field reconnaissance.

Several criteria were used to identify potentially vulnerable storm drain pipes for additional investigation, including distance between storm drain and sanitary survey pipes, age and diameter of storm drain pipes (where these data were available), connectivity, and drainage area.

The original GIS data layers for the storm drain and sanitary sewer systems used in this analysis were obtained from the City of Imperial Beach and SanGIS (for the City of San Diego's systems).

The first step was to identify storm drain pipes within a 50-ft buffer of a sewer pipe in order to initially reduce the dataset for subsequent processing. Using this smaller dataset, the closest sewer pipe to each storm drain pipe was identified, and the horizontal proximity in feet, as well as the sewer pipe attributes, were linked to the storm drain data (note that because only the x and y locations were used in determining the distance, pipes that crossed below or above each other were assigned a distance of 0 feet, despite a separation in depth). Based on the proximity information, those storm drain pipes within 25-ft of a sewer line were selected for further analysis. In the next step, the diameter of the pipes (as provided in the GIS dataset) was used to select larger pipes based on a threshold of 24 inches. Supplemental information on approximate pipe age was provided by the City of San Diego for the pipes within their municipality. Therefore, within the City of San Diego portion of the watershed, pipe age was used to identify pipes installed prior to 1990 (greater than 20 years old).

The storm drain pipes identified in the stepwise filtering process and the monitoring locations for each of the three surveys are shown on Figure 4-6 within each of the U.S. sub-drainages that discharge to the Tijuana River Estuary. The point of discharge for each of the sub-drainages is shown with red dots on Figure 4-7.

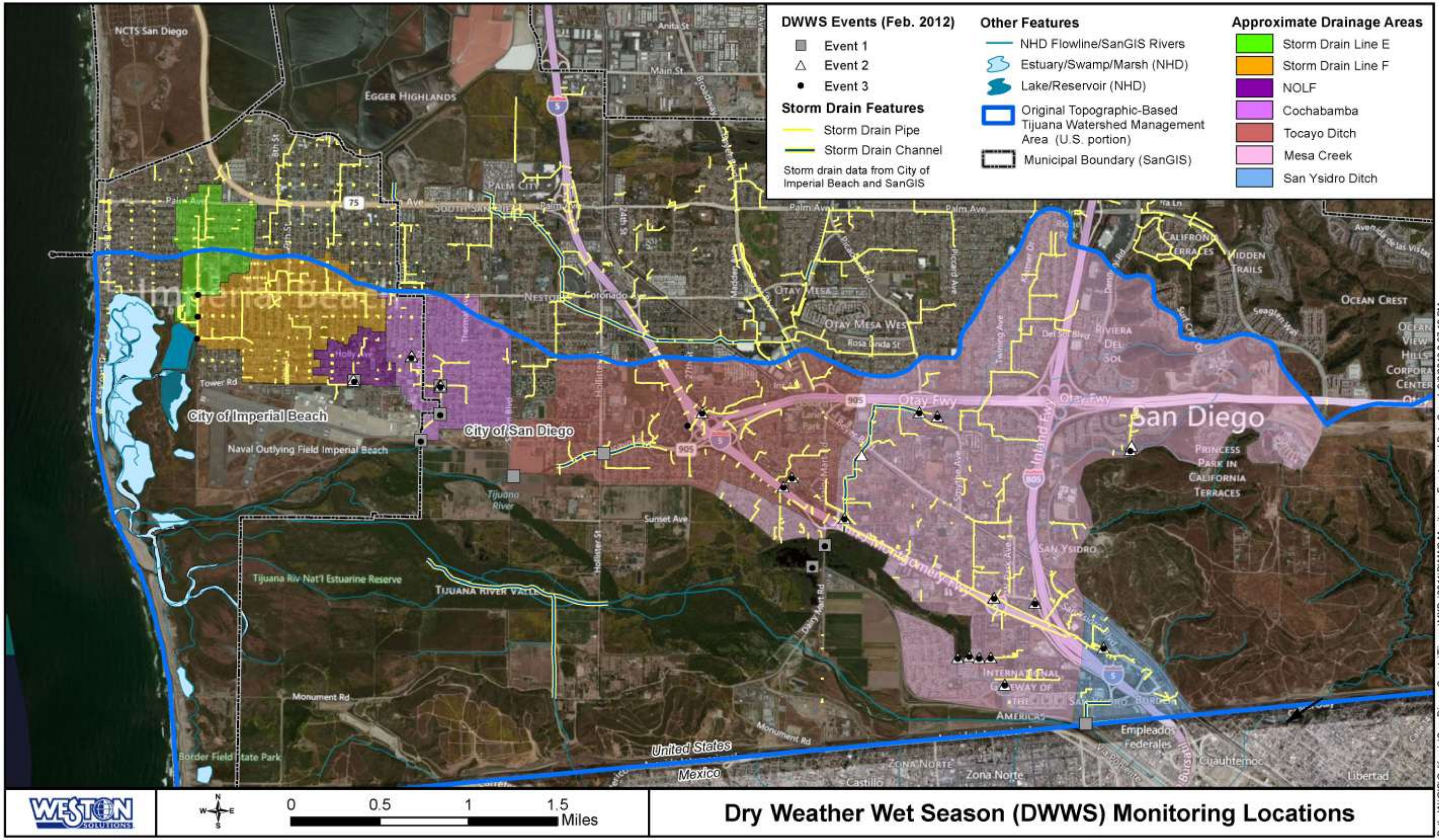


Figure 4-6. Cross Contamination Dry Weather Surveys Sample Locations Representing the Major Sub-drainages in the Tijuana River Watershed that Discharge Directly to the Tijuana River Estuary

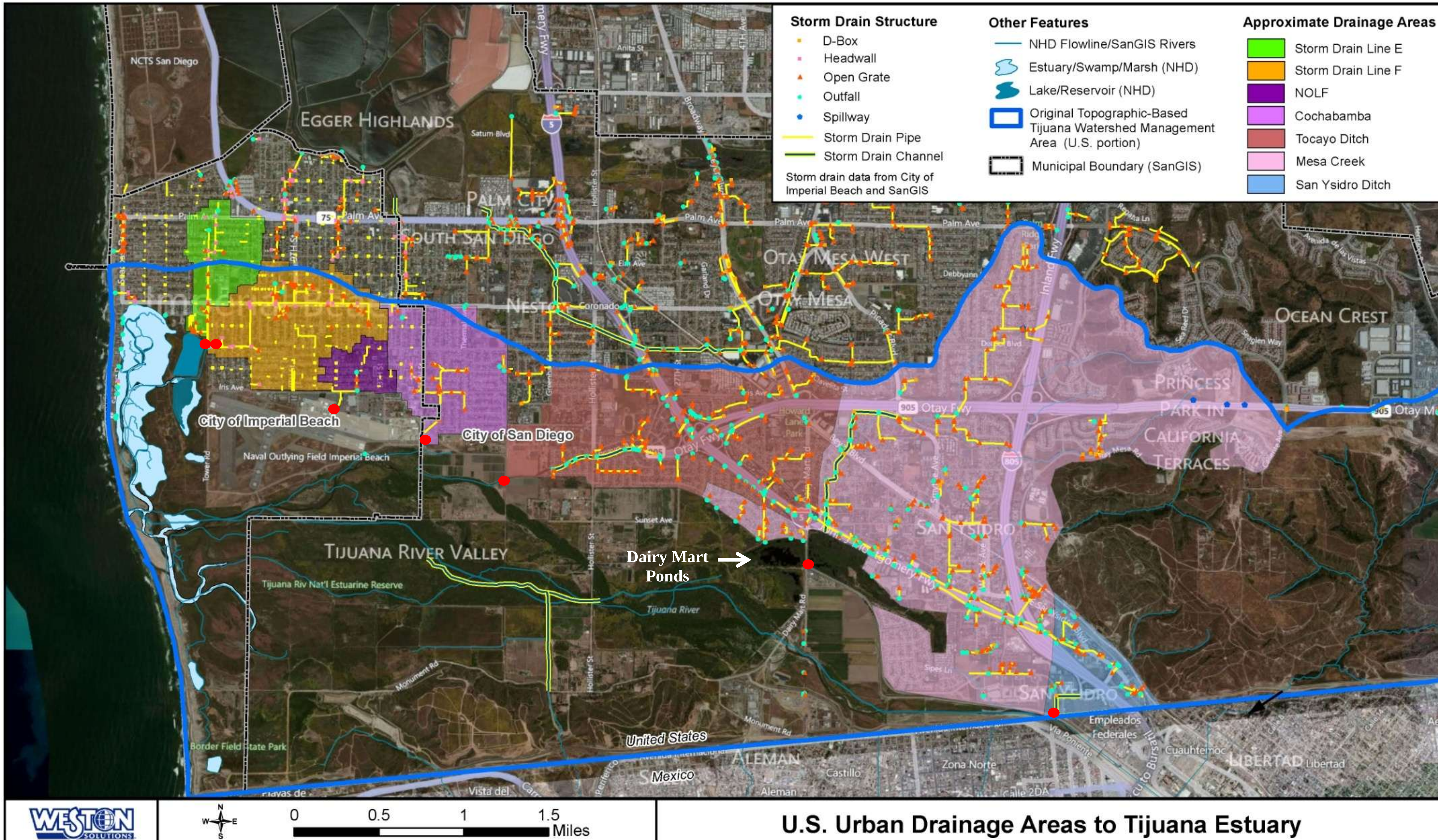


Figure 4-7. Cross Contamination Dry Weather Surveys Sample Locations Showing the Point of Discharge for each of the Major Sub-drainages in the Tijuana River Watershed that Discharge Directly to the Tijuana River Estuary

4.4.6 Results for Cross Contamination Dry Weather Survey

Extensive field investigations combined with GIS mapping techniques were used to identify the major sub-drainages on the U.S. side of the U.S. / Mexico Border that discharge directly to the Tijuana River Estuary. The assessment identified seven sub-drainages (sub-drainages were named based on City storm drain classification system, major street crossing, or creek name):

- E Line
- F Line
- National Outlying Field Imperial Beach (NOLF)
- Cochabamba
- Tocayo Ditch
- Mesa Creek
- San Ysidro Ditch

The results of the final cross contamination dry weather surveys are presented by Sub-basin below (no data are available for the F Line Sub-drainage because no sites were identified using the selection criteria discussed above). Results highlighted in red in the summary tables exceeded threshold concentrations defined in Section 4.4.1 for fecal coliform and *Enterococcus*.

4.4.6.1 E-Line Sub-drainage

The E Line Sub-drainage lies entirely within the City of Imperial Beach and is one of the smaller urban drainages in the watershed (Figure 4-6). Three sites were selected for monitoring based on potential for cross-contamination with the sewer system and the analytical results are shown in Table 4-8.

Figure 4-8. Terminus of E-Line Sub-drainage

- Ponded water was found at all three sites at the time of the survey.
- Bacterial concentrations did not exceed thresholds at any sites.
- Human-specific *Bacteroides* was not present at any site.
- Minimal flow was observed draining directly to the Tijuana River Estuary (Figure 4-8).

Table 4-8. Results of Cross Contamination Dry Weather Survey for Sites in the E-Line Sub-drainage (January and February, 2012)

Sample ID	Total Coliform	Fecal Coliform	Enterococcus	Human *Bacteroides*	Flow Type	Estimated Flow
TJ-DWWS-3-3	Dry-No Sample				Ponded	N/A
TJ-DWWS-3-3.2	5,000	20	41	Neg	Ponded	N/A
TJ-DWWS-3-3.3	28,000	80	292	Neg	Ponded	N/A

4.4.6.2 NOLF Sub-drainage

The NOLF Sub-drainage lies entirely within the City of Imperial Beach and is the smallest urban drainages in the watershed (Figure 4-6). Four sites were selected for monitoring based on potential for cross-contamination with the sewer system and the analytical results are shown in Table 4-9.

Figure 4-9. Terminus of NOLF Sub-drainage

- Ponded water was found at all four sites at the time of the surveys.
- Bacterial concentrations exceeded thresholds at two of the sampling periods.
- Human-specific *Bacteroides* was not present at any site.
- Minimal if any flow reaches the estuary during dry weather conditions from the NOLF Sub-drainage. The terminus for this site is accessible only from the estuary. Ponded water was observed at the time of the surveys at the vault upstream of the NOLF outfall and there was no evidence of flowing water at this location (Figure 4-9). It is assumed from these data and the results of the sanitary surveys that little if any runoff reaches the estuary from this sub-drainage during dry weather conditions.

Table 4-9. Results of Cross Contamination Dry Weather Survey for Sites in the NOLF Sub-drainage (January and February, 2012)

Sample ID	Total Coliform	Fecal Coliform	Enterococcus	Human *Bacteroides*	Flow Type	Estimated Flow
TJ-DWWS-1-204	30,000	800	**2,686**	Neg	Ponded	N/A
TJ-DWWS-2-204	500	20	51	Neg	Ponded	N/A
TJ-DWWS-3-204	300,000	2,200	**2,481**	Neg	Ponded	N/A
TJ-DWWS-2-204.1	600	<20	86	Neg	Ponded	N/A

4.4.6.3 Cochabamba Sub-drainage

The Cochabamba Sub-drainage lies partially within the City of Imperial Beach and partially within the City of San Diego (Figure 4-6). Twelve sites were selected for monitoring based on potential for cross-contamination with the sewer system and the analytical results are shown in Table 4-10.

Figure 4-10. Terminus of Cochabamba Sub-drainage

- Ponded or dry conditions were found at all sites at the time of the surveys, except one site where minimal flow was observed.
- Bacterial concentrations exceeded thresholds at three of the monitoring sites.
- Human-specific *Bacteroides* was not present at any site.
- The Cochabamba Sub-drainage discharges to a sandy, soft-bottom depression in the flood plain of the Tijuana River Estuary (Figure 4-10). Based on these dry weather investigations and numerous site visits it is apparent that runoff in the Cochabamba Sub-drainage does not reach the estuary during dry weather conditions.

Table 4-10. Results of Cross Contamination Dry Weather Survey for Sites in the Cochabamba Sub-drainage (January and February, 2012)

Sample ID	Total Coliform	Fecal Coliform	Enterococcus	Human *Bacteroides*	Flow Type	Estimated Flow
TJ-DWWS-3-501	600	20	10	Neg	Ponded	N/A
TJ-DWWS-3-501	2,200	70	<10	Neg	Ponded	N/A
TJ-DWWS-1-322	70,000	500	**1,565**	Neg	Ponded	N/A
TJ-DWWS-3-322	50,000	800	345	Neg	Ponded	N/A
TJ-DWWS-1-322.2	90,000	1,100	**2,395**	Neg	Ponded	N/A
TJ-DWWS-3-322.2	9,000	2,300	697	Neg	Ponded	N/A
TJ-DWWS-2-322.1.1.1	50,000	700	**3,873**	Neg	Trickle	N/A
TJ-DWWS-2-322.1.1.2	Insufficient volume to sample				Damp	N/A
TJ-DWWS-2-322.1.1.3	Insufficient volume to sample				Damp	N/A
TJ-DWWS-2-323	13,000	70	63	Neg	Ponded	N/A
TJ-DWWS-3-323	70,000	2,300	168	Neg	Ponded	N/A
TJ-DWWS-2-323.1	DRY – No sample				Dry	N/A

4.4.6.4 Tocayo Ditch Sub-drainage

The Tocayo Ditch Sub-drainage lies entirely within the City of San Diego and is the second largest Sub-drainage in the watershed (Figure 4-6). Nine sites were selected for monitoring based on potential for cross-contamination with the sewer system and the analytical results are shown in Table 4-11.

Figure 4-11. Terminus of Tocayo Ditch Sub-drainage

- Ponded or dry conditions were found at all sites at the time of the surveys.
- Bacterial concentrations exceeded thresholds at two of the monitoring sites.
- Human-specific *Bacteroides* was not present at any site.
- Tocayo Ditch is a concrete-lined canal in the upper part of the sub-drainage, however, the last half-mile is a soft-bottom swale (Figure 4-11). The swale was dry during the time of these surveys and in all previous dry weather monitoring events. Based on these results, it is apparent that runoff in the Tocayo Ditch Sub-drainage does not reach the estuary during dry weather conditions.

Table 4-11. Results of Cross Contamination Dry Weather Survey for Sites in the Tocayo Ditch Sub-drainage (January and February, 2012)

Sample ID	Total Coliform	Fecal Coliform	Enterococcus	Human *Bacteroides*	Flow Type	Estimated Flow
TJ-DWWS-1-202.0	DRY – no sample				Dry	N/A
TJ-DWWS-1-202.2	DRY – no sample				Dry	N/A
TJ-DWWS-3-305	280,000	5,000	350	Neg	Ponded	N/A
TJ-DWWS-2-319	300,000	130	683	Neg	Ponded	N/A
TJ-DWWS-3-319	23,000	20	41	Neg	Ponded	N/A
TJ-DWWS-2-319.1.1	900,000	300	1,246	Neg	Ponded	N/A
TJ-DWWS-3-319.1.1	500,000	500	**1,785**	Neg	Ponded	N/A
TJ-DWWS-2-321	170,000	500	1,314	Neg	Ponded	N/A
TJ-DWWS-3-321	300,000	**110,000**	**1,842**	Neg	Ponded	N/A

4.4.6.5 Mesa Creek Sub-drainage

The Mesa Creek Sub-drainage lies entirely within the City of San Diego and is the largest sub-drainage in the watershed (Figure 4-6). A total of 28 sites were selected for monitoring based on potential for cross-contamination with the sewer system. The analytical results from the surveys are shown in Table 4-12.

Figure 4-12. Terminus of Mesa Creek Sub-drainage

- Ponded or dry conditions were found at all sites except for two, where minimal flow was detected.
- Bacterial concentrations exceeded thresholds at seven of the monitoring sites.
- Human-specific *Bacteroides* was found at one of the monitoring sites (Site 408) during one of the surveys, however, subsequent samples collected at that site were negative for the human marker.
- The Mesa Creek Sub-drainage is over twice as large as any other sub-drainage in the watershed. The majority of the drainage lies on the eastside of Interstate 5, which crosses under the freeway and discharges to Mesa Creek. The sub-drainage west of Interstate 5 also discharges to Mesa Creek. Flows from the entire sub-drainage pass under Dairy Mart Road and discharge to a series of unlined ponds maintained by earthen berms (Dairy Mart Ponds) (Figure 4-12). Thorough field investigations were unable to reveal any surface water outlet from the ponds to the Tijuana River Estuary (although there is likely groundwater interaction). Based on these results, it is apparent that runoff from the Mesa Creek Sub-drainage does not reach the estuary during dry weather conditions.

Table 4-12. Results of Cross Contamination Dry Weather Survey for Sites in the Mesa Creek Sub-drainage (January and February, 2012)

Sample ID	Total Coliform	Fecal Coliform	Enterococcus	Human *Bacteroides*	Flow Type	Estimated Flow
TJ-DWWS-1-502	800	90	41	Neg	Ponded	N/A
TJ-DWWS-3-502	220	20	<10	Neg	Ponded	N/A
TJ-DWWS-1-502.1	170	<20	10	Neg	Flowing	Minimal
TJ-DWWS-3-502.1	230	<20	<10	Neg	Trickle	Minimal
TJ-DWWS-2-307	500,000	1,300	**4,352**	Neg	Ponded	N/A
TJ-DWWS-3-307	17,000	40	457	Neg	Ponded	N/A
TJ-DWWS-2-507.0	DRY – no sample			Neg	Ponded	
TJ-DWWS-2-413	1,400	20	73	Neg	Ponded	N/A
TJ-DWWS-3-413	17,000	<20	75	Neg	Ponded	N/A
TJ-DWWS-2-506	≥,1600,000	1,700	**12,591**	Neg	Ponded	N/A
TJ-DWWS-3-506	≥1,600,000	8,000	**77,010**	Neg	Ponded	N/A
TJ-DWWS-2-408	50,000	1,400	1,236	**Pos**	Ponded	N/A
TJ-DWWS-3-408	300,000	5,000	**1,607**	Neg	Ponded	N/A
TJ-DWWS-2-408.1	DRY – no sample				Dry	N/A
TJ-DWWS-2-8	2,300	<20	<10	Neg	Ponded	N/A
TJ-DWWS-3-8	600	20	20	Neg	Ponded	N/A
TJ-DWWS-2-9	500,000	300	189	Neg	Ponded	N/A
TJ-DWWS-3-9	80,000	300	**2,014**	Neg	Ponded	N/A
TJ-DWWS-2-12	11,000	1,100	110	Neg	Ponded	N/A
TJ-DWWS-3-12	13,000	1,300	571	Neg	Ponded	N/A
TJ-DWWS-2-12.1.1	1,100	<20	**1,576**	Neg	Ponded	N/A
TJ-DWWS-3-12.1.1	13,000	20	52	Neg	Ponded	N/A
TJ-DWWS-2-13	17,000	40	20	Neg	Ponded	N/A
TJ-DWWS-3-13	170,000	70	10	Neg	Ponded	N/A
TJ-DWWS-2-306	3,000	500	488	Neg	Ponded	N/A
TJ-DWWS-3-306	DRY – no sample				Dry	N/A
TJ-DWWS-2-309	80	<20	20	Neg	Ponded	N/A
TJ-DWWS-3-309	300,000	**300,000**	**>241,960**	Neg	Trickle	N/A

4.4.6.6 San Ysidro Ditch Sub-drainage

The San Ysidro Ditch Sub-drainage lies entirely within the City of San Diego and is one of the smaller sub-drainages in the watershed (Figure 4-6). Three sites were selected for monitoring based on potential for cross-contamination with the sewer system. The analytical results from the surveys are shown in Table 4-13.

Figure 4-13. Terminus of San Ysidro Sub-drainage

- Ponded or dry conditions were found at all sites monitored during the surveys.
- Bacterial concentrations exceeded thresholds at one of the monitoring sites.
- Human-specific *Bacteroides* was not found at any of the monitoring sites.
- The San Ysidro Ditch Sub-drainage is a small drainage that lies adjacent to the U.S./Mexico Border. The sub-drainage discharges to an earthen channel (Figure 4-13) where flow is directed under the International Border to the Tijuana River mainstem. The point of discharge is just downstream of the dry weather diversion structure and therefore dry flows have the potential of flowing into the Tijuana River Estuary. However, during the dry weather surveys and other dry weather monitoring events, no flows were observed in San Ysidro Ditch on either side of the border and it is unlikely that surface waters from the sub-drainage do not impact the receiving waters of the estuary.

Table 4-13. Results of Cross Contamination Dry Weather Survey for Sites in the San Ysidro Sub-drainage (January and February, 2012)

Sample ID	Total Coliform	Fecal Coliform	Enterococcus	Human *Bacteroides*	Flow Type	Estimated Flow
TJ-DWWS-1-600	700	40	<10	Neg	Ponded	N/A
TJ-DWWS-2-412	**280,000**	110	**1,722**	Neg	Ponded	N/A
TJ-DWWS-3-412	3,000	130	73	Neg	Ponded	N/A

4.5 Discussion

The main purpose of this portion of the study was to identify point and non-point sources of bacterial inputs throughout the U.S. portion of the Tijuana River Watershed during dry weather conditions that could potentially impact the Tijuana River Estuary. In order to accomplish this, three comprehensive sanitary surveys were performed in 2008, 2010, and 2011, with numerous follow-up dry weather surveys. The sanitary surveys incorporated numerous source tracking tools, including extensive field surveys and visual observations, flow estimation, outfall inventory, sample analysis for indicator bacteria and human-specific *Bacteroides*, and field and laboratory chemical analyses. The primary objectives of the sanitary surveys were to identify anthropogenic and non-anthropogenic sources of indicator bacteria that could impact receiving waters in the estuary. Three two-week sanitary surveys were conducted over the course of the study, targeting approximately 100 sampling locations per survey. Follow-up dry weather surveys were conducted if high bacterial concentrations were found, if the sample tested positive for human-specific *Bacteroides*, or if visual observations suggested follow up was necessary.

The results of the first two sanitary surveys identified several sites where indicator bacterial concentrations were high or tested positive for human-specific *Bacteroides*. In all cases, follow up dry weather surveys indicated that water at the site was either ponded, had very low trickle flows, and/or the flow could not be traced upstream to any source. In nearly all cases where a sample tested positive for human-specific *Bacteroides*, follow up surveys failed to re-produce a positive result. These results of these extensive surveys suggest that with few exceptions, elevated levels of indicator bacteria or the potential presence of human fecal contamination at numerous sites assessed in the watershed were ephemeral and did not represent a consistent source of bacteria to the estuary.

Sanitary Survey 3 was a dry weather survey that focused primarily on sites within the estuary itself and at sites that were identified as hot spots during the first two sanitary surveys. Thorough visual observations on all sides of the watershed adjacent to the estuary revealed that with one exception there was no apparent hydrologic connection between surface waters in the watershed and those in the estuary. The one area of direct, but very small flow to the estuary was the outfalls of the E and F Lines in Imperial Beach that discharge directly to the estuary. Flows from these drainages were low and generally contained low levels of indicator bacteria, but did flow directly to the northwestern portion of the estuary at the end of Grove Avenue in Imperial Beach.

Dry weather flows originating from Mexico were all diverted to the IBWC treatment facility during all dry weather investigations (although rogue flows from these have been documented). Drainages on the U.S. side of the border that drain directly to the estuary were dry (with the exception of the E and F lines) and there was no flow from these locations that reached the estuary that could be observed from the landward side. Further dry weather investigations were continued during Sanitary Survey 3 from samples taken in the estuary by boat. Samples collected at numerous locations in the estuary over several sampling periods covering a tidal cycle contained very low indicator bacterial concentrations and no evidence of human fecal contamination (human-specific *Bacteroides* assays were all negative). In addition, extensive visual observations by boat confirmed the lack of a hydrologic connection between the watershed and the estuary during summer dry weather conditions (with the exception of the E and F lines).

This lack of connection between the surface waters in the watershed and those of the estuary were further assessed in a series of surveys during winter dry weather conditions in January and February, 2012. The purpose of these final dry weather surveys was to identify the major sub-drainages within the western portion of the Tijuana River Watershed, identify the potential bacterial hot spots within those drainages that may be associated with sewage infrastructure, and determine the extent to which bacteria from those areas reaches the estuary. Visual observations and GIS mapping identified seven sub-drainages that discharge to the estuary on the U.S. side of the border, each of which terminate in a single outfall. Further assessments of these points of discharge revealed that the substantial majority of dry weather from the U.S. side of the border never reaches the estuary because the majority of the sub-drainages discharge to a soft-bottom creek or other natural feature (*e.g.,* ponds) where dry weather flows infiltrate rapidly. For instance, the Mesa Creek drainage is the largest sub-drainage on the U.S. side of the border, representing over 50% of the drainage area that could impact the estuary. Dry weather flows were documented in this primarily urban sub-drainage, but all flows are directed to a soft-bottom Creek that discharges to a series of retention ponds (Dairy Mart Ponds) just north of Dairy Mart Bridge. There are no surface flows leaving the ponds that connect to the estuary. Thus, Dairy Mart Ponds act as a semi-natural BMP that prevents dry weather flows from impacting the receiving waters of the Tijuana River Estuary. Similar, semi-natural BMPs were found at the base of the other sub-drainages, except the E and F Lines and a small sub-drainage (San Ysidro) where the Tijuana River crosses the U.S. / Mexico Border. Thus, one of the major findings of this study was that potential impacts to the estuary from dry weather flows are limited to these small sub-drainages and episodic and infrequent rogue flows from the Mexico side of the border when the diversion structures are bypassed.

5.0 WET WEATHER SURVEYS

5.1 Background

Historically, river flows from the Tijuana River have been associated with poor water quality as well as extremely elevated concentrations of fecal indicator bacteria, toxicity, nutrients, and suspended solids (Weston, 2007; Gersberg et al., 2004). Recent studies have also strongly linked elevated concentrations of indicator bacteria to the presence of viral pathogens, such as Hepatitis A and enterovirus, in wet weather flows at the mouth of the Tijuana River. During one study, three strains of poliovirus were detected, and human fecal bacterial densities (*E. coli*, *Escherichia coli* and Enterococci) during wet weather exceeded California Water Quality Standards in 86% (12 of 14) of the samples (Gersberg et al., 2006).

The primary source of this impacted water quality has always been attributed to the rapid and disorganized development of poor infrastructure in the Mexican city of Tijuana. The hilly, impermeable topography of Tijuana and the unplanned squatter settlements on slopes produce significant erosion and flooding during the rainy season. The inadequacy or lack of municipal storm drain systems and, in many cases, sewerage conveyance systems leads to storm water flows which contain significant concentrations of wastewater from both residential and industrial sources. In addition, the lack of vegetation on hillsides adds to rapid water flow, while trash and sediment clog stream channels.


New Housing Development in Tijuana

As part of the Regional San Diego County National Pollution Discharge Elimination System (NPDES) Permit, copermittees have been required to monitor water quality conditions in the Tijuana River during storm events on an annual basis. The primary site for this monitoring historically has been the Hollister Street Bridge. Water samples were collected at this site as a composite and event mean concentrations were determined for a suite of constituents (Weston, 2007).

The results of this monitoring has shown that the Tijuana River at Hollister Street Bridge consistently has the worst water quality during storm events of any site monitored in the region as part of the NPDES Permit (Weston, 2007). Enterococci concentrations were typically found to be greater than 600,000 MPN/100 mL on average indicating levels comparable to untreated wastewater. Similarly, fecal and total coliform concentrations were in the millions of MPN/100 mL. Other indicators of significant bacterial contamination that were found included extremely elevated concentrations of ammonia, total suspended solids, and turbidity. These analytes can be indicators of wastewater contamination.

In order to illustrate the magnitude of the water quality constituents with results above the benchmark water quality objective (WQO) for the County of San Diego Storm Water Monitoring Program, the ratio of water quality results to the benchmark WQOs were plotted for several of the most common constituents found in the Tijuana River. The average ratio of the water quality result to the benchmark WQOs was also determined for each constituent by calculating the ratio of mean water quality results to the benchmark WQOs for storm events monitored at Hollister Street Bridge from October, 2001 through April 2007. The results are shown on Figure 5-1.

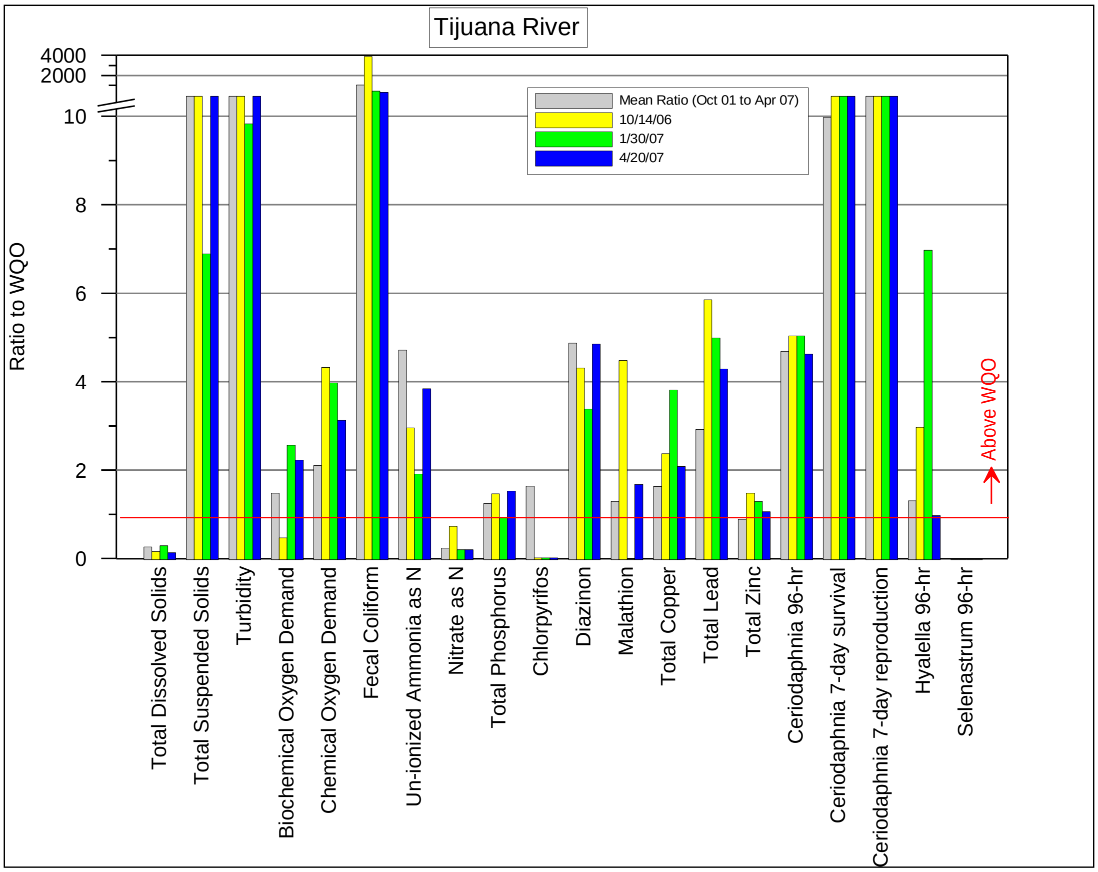


Figure 5-1. Tijuana River at Hollister Street Bridge Water Quality Exceedance Ratios (Ratio of Constituent Concentration to its Water Quality Objective) for data collected from October, 2001 through April, 2007

The largest single benchmark WQO ratio was for fecal coliform, which was approximately 4,000 times the benchmark WQO during the October 14, 2006 storm event and over 2,000 times the benchmark WQO during the January 30, 2007 event. These results reflect the discharges of raw wastewater during storm events and illustrate the significant impacts to water quality in the receiving waters of the Tijuana River. Other constituents with mean results above the benchmark WQO include total suspended solids, TSS, turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, total phosphorus, chlorpyrifos, diazinon, malathion, total copper, total lead, toxicity to the acute, chronic, and reproductive endpoints for *Ceriodaphnia dubia*.

5.2 Study Questions

In addition to the monitoring that has been conducted historically at the Hollister Street Bridge location, storm water monitoring has also been conducted at the bridge that crosses the Tijuana River mainstem at Dairy Mart Road. Located just over one mile upstream of Hollister Street, Dairy Mart Road has been monitored as part of the Regional NPDES Storm Water Permit as a Temporary Watershed Assessment Station (TWAS). Together, wet monitoring results from these two sites provides a good assessment of conditions on the mainstem during storm events, which eventually impact the downstream estuary and ocean receiving waters. In addition, to the mainstem sites, tributaries to the Tijuana River originating in Mexico also impact the river and downstream receiving waters. Smuggler's Gulch is the largest of three main tributary drainages from Mexico that discharge to the river (Goat Canyon and Yogurt Canyon are the other two tributaries). Thus, assessing the impacts from wet weather at three locations within the western portion of the Tijuana River provides a more finely tuned assessment of bacterial loads and associated chemical impacts in the Tijuana River.

Based on the sites discussed above the wet weather surveys were designed to answer the following study questions:

1. **How do concentrations of indicator bacteria vary over the course of a storm event in the main stem and tributary sites?**

2. **What are the bacterial loads entering the estuary during storm events?**

3. **How do wet weather bacterial loads originating from the U.S. side of the border compare to the loads originating from Mexico?**

In order to answer the first two study questions, storm water was monitored at several locations over the course of two storm events at sites where flows originated from Mexico (Hollister Street and Dairy Mart Road on the mainstem and Smuggler's Gulch, a tributary to the mainstem). The third question was addressed by monitoring an additional site in the City of Imperial Beach that drained a largely urban drainage originating in the United States. During each storm event, flow was monitored continuously and samples were collected over the course of the storm and analyzed individually for indicator bacteria and a suite of chemical constituents. The resulting pollutographs allow for a direct comparison between sites of the nature of the constituents over the course of the storm event. Pollutographs also allow for a more accurate assessment of loads than composite sampling because they capture the inherent variability of contaminant concentrations over the course of a storm event.

5.3 Methods

5.3.1 Wet Weather Events

Although the Quality Assurance Project Plan (QAPP) for this project required wet weather monitoring during two storm events, monitoring of three storm events was attempted on the dates outlined in Table 5-1. Monitoring for the first storm event was initiated at approximately noon on December 15 and was completed in the late afternoon of December 16. Although the monitoring was effective in capturing the storm, the State Water Resources Control Board (SWRCB) notified the project contractors On December 17, 2008 that funds for the project had been indefinitely frozen due to the state budget crisis. Because of the stop work order, sample analysis was immediately stopped and therefore only a partial data set exists for this storm.

Table 5-1. Storm Events Monitored during over the Course of the Project

Storm Event	Monitoring Dates	Outcome
Storm Event 1	December 15 – 16, 2008	Partial data set collected due to freezing of project
Storm Event 2	December 19 – 20, 2010	Full data set collected at four sites, but storm continued for several days beyond the initial sampling, making load calculations impractical
Storm Event 3	November 4, 2011	Full data set collected at four sites and entire storm captured.

The second storm event was conducted on December 19 and 20, 2010 after the state re-instated funding for the project. Monitoring for this storm was initiated at approximately midnight on December 19 and was completed approximately 20 hours later. Although the sampling for this storm event was also successful, the hydrograph (rise and fall of the river) did not come back to baseline levels for over a week, due to torrential rains that fell in the area for several days beyond the initial event. Pollutographs were successfully monitored and captured at all sites for this storm, but loads were not calculated because it took an extended amount of time for the river to return to base flows.

The third storm event was initiated at approximately noon on November 4, 2011 and was completed approximately 24 hours later on November 5. The monitoring was completed as the hydrograph returned to base flow (or just above it) at all sites. The pollutographs produced from the results cover the course of the storm and allow for good estimates of loads.

5.3.2 Monitoring Locations

As discussed above, four sites were monitored during storm events over the course of this study: Hollister Street and Dairy Mart Road on the Tijuana River mainstem, Smuggler's Gulch (a tributary to the mainstem originating from Mexico), and Veteran's Park (a tributary originating from the City of Imperial Beach in the United States. Coordinates for each site are given in Table 5-2 and they are mapped on Figure 5-2. A Description of each site is given below.

Table 5-2. Wet Weather Survey Monitoring Location Coordinates

Station	GPS Coordinates	
	Latitude	Longitude
Hollister Street	32.537732	-117.086284
Dairy Mart Road	32.551741	-117.084082
Smuggler's Gulch	32.548446	-117.064467
Veterans' Park	32.576578	-117.116177

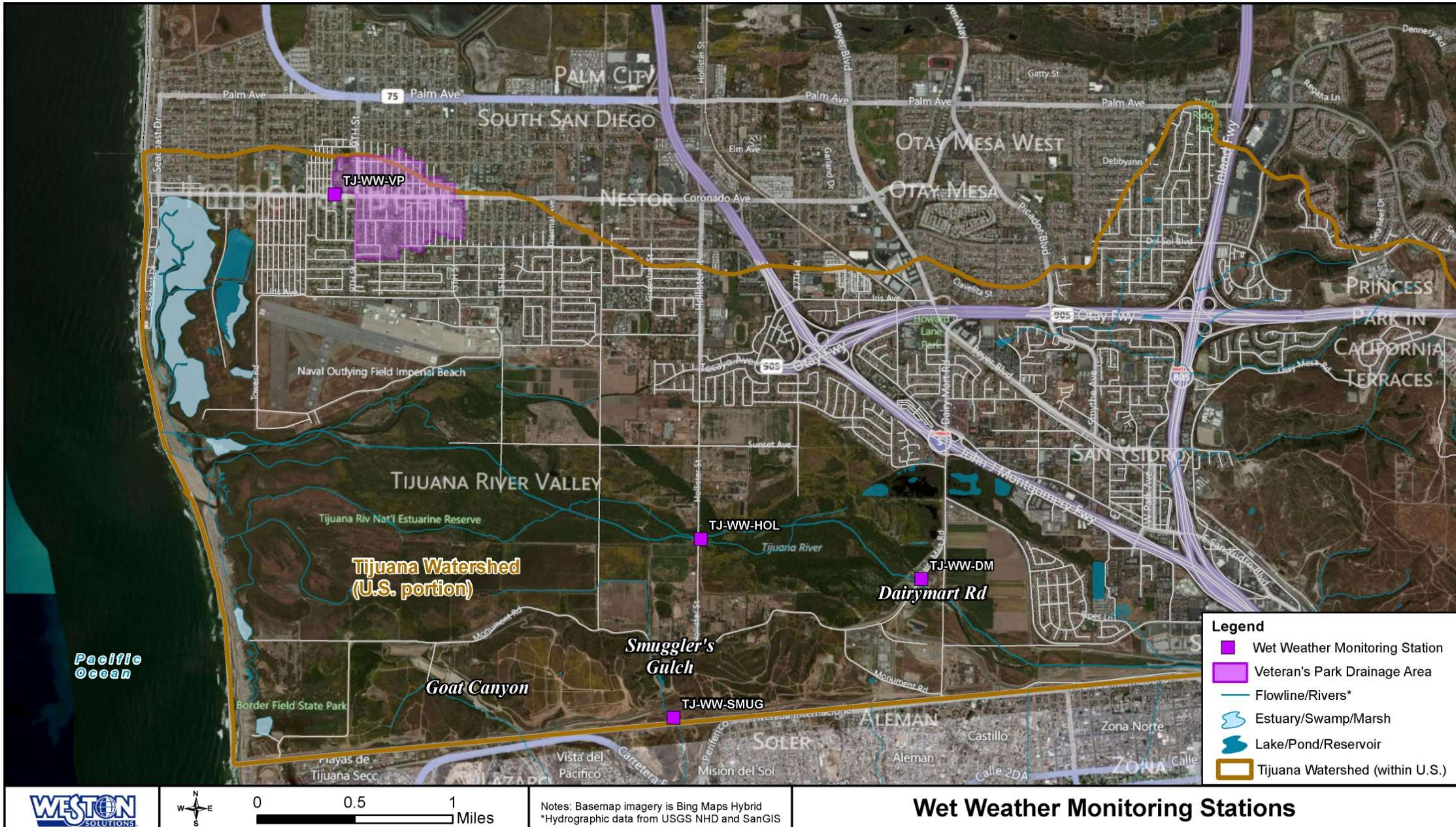


Figure 5-2. Wet Weather Monitoring Locations

5.3.2.1 Dairy Mart Road Bridge

The Dairy Mart Road sampling station is located under the Dairy Mart Road Bridge, approximately 1.1 miles upstream of the Hollister Street Bridge sampling site (Figure 5-2). Dairy Mart Road spans the mainstem of the Tijuana River directly downstream of the USIBWC diversion structure. During storm events, flows that pass under Dairy Mart Road Bridge in the Tijuana River, originates directly from Mexico. In addition to the monitoring conducted during this study, the Dairy Mart Road Bride sampling location has a Mass Loading Station (MLS) that is operated and maintained under the San Diego County Municipal Copermittee Monitoring Program as a temporary Watershed Assessment Site (TWAS) (Weston, 2007).

Dairy Mart Road Bridge

5.3.2.2 Hollister Street Bridge

The Hollister Street Bridge sampling site is located under the Hollister Street Bridge, downstream from the Dairy Mart Bridge and USIBWC's diversion structure and treatment plant (Figure 5-2). The mainstem of the Tijuana River at this site is an unimproved channel. The Hollister Street Bridge sampling location currently has a Mass Loading Station (MLS) operated and maintained under the San Diego County Municipal Copermittee Monitoring Program. This MLS monitors flow and water quality parameters during the wet season each year (Weston, 2007).

Hollister Street Bridge

5.3.2.3 Smuggler's Gulch (Cañón del Matadero)

Smuggler's Gulch is the largest of the south–north sub-watersheds that drains much of western Tijuana directly into the U.S. terminal portion of the Tijuana River (Figure 5-2). This canyon is characterized by extremely steep canyon walls. Insufficient Mexican sewage infrastructure, as well as a non-permitted hillside residential development, has contributed to ongoing water quality impairment issues from Smuggler's Gulch. Sewage-tainted effluent, sediment, and trash are of known concern. By nature, storm flows in Smuggler's Gulch are also rapid and unpredictable. Large volumes of sediment, cobble, and trash will hamper acquisition of storm flow data. Dry weather flows in the canyon are periodic in nature.

Smuggler's Gulch

5.3.2.4 Veterans' Park

Veterans' Park is located within the City of Imperial Beach near the corner of Imperial Beach Boulevard and 8th Street (Figure 5-2). Unlike the other sties monitored in the Wet Weather surveys, Veterans' Park drains a small urban drainage on the U.S. side of the border. Land use in this drainage is made up of low density housing with a small amount of public facility land use (see Section 2). The terminus of this U.S. sub-drainage flows directly to the northern arm of the Tijuana River Estuary via the F-Line outfall. Land use in this drainage is broadly similar to the land use found in the U.S. portion of the Tijuana River Watershed that drains directly to the Tijuana River of the Tijuana River Estuary.

Veterans' Park

5.3.3 Flow Monitoring

Continuous flow monitoring was conducted at all four sites during wet weather monitoring. At each location Weston installed the following
:

- American Sigma 950 (or 920) Area Velocity flowmeter and an area velocity pressure transducer programmed to log data every five minutes. Water levels were measured using data sondes described in Section 3.2.
- American Sigma SD900 auto sampler to provide automated sampling capabilities during dry and wet weather monitoring

Stream rating measurements were collected at each of the individual the monitoring locations to ensure accurate flow measurements were recorded. The equipment was deployed in a fabricated, protective, locking housing. Prior to deployment, the flow meters were calibrated following manufacturer recommendations. The data from this continuous flow monitoring was then used to assess seasonal and spatial water quality in the Tijuana River.

5.3.4 Pollutograph Sample Collection

Over the course of each storm event, grab samples were collected using methods described in Section 3.7.2. Sample frequency was determined in the field by the in situ flow monitoring equipment and anticipated changes in flow based on satellite imagery of the storm event conveyed to field staff via communication with a storm water coordinator in the office. A total of 7 to 11 samples were collected at each site, depending on the storm event.

5.3.5 Sample Analysis

5.3.5.1 Microbial Analysis

Samples for enumeration of fecal indicator bacteria (fecal coliforms and enterococci) were processed in accordance with the methods described in Section 3.7.1. The analytes measured and associated analytical methods are summarized below in Table 5-3.

Table 5-3. Analytical Methods for Standard Microbiology

Analyte	Analytical Method		Achievable Laboratory Limits
	Analytical Method/SOP	Modified for Method (Yes/No)	MDLs (1)
Fecal coliforms	SM 9221 E	No	2 MPN/100 mL
Enterococci	Enterolert	No	1 MPN/100 mL

In addition, the polymerase chain reaction technique (PCR) was used to assess presence/absence of general and human-specific *Bacteroides* in accordance with the methods described in Section 3.7.2. The analytes measured and associated analytical methods are summarized below in Table 5-4.

Table 5-4. Molecular Laboratory Analytical Methods

Analyte	Analytical Method		Laboratory
	Analytical Method/SOP	Modified for Method (Yes/No)	
Bacteroides presence/absence	LAB068.00	–	Weston

5.3.5.2 Chemical Analysis

Samples for chemical analysis were processed in accordance with the methods described in Section 3.7.3. The analytes measured and associated analytical methods are summarized below in Table 5-5.

Table 5-5. Chemistry Laboratory Analytical Methods

Analyte	Analytical Method		Achievable Laboratory Limits
	Analytical Method/SOP	Modified for Method (Yes/No)	MDLs (1)
TSS	SM 2540-D	No	0.5 mg/L
Ammonia-N	SM 4500-NH_3 B,C	No	0.01 mg/L
Nitrite-N	SM 4500 NO2 B	No	0.01 mg/L
Nitrate-N	SM 4500 NO3 E	No	0.01 mg/L
Orthophosphate-P	SM 4500 P E	No	0.01 mg/L

5.3.6 Quality Assurance/Quality Control Procedures

Quality assurance (QA) and quality control (QC) for sampling processes included proper collection of the samples to minimize the possibility of contamination. Sampling personnel wearing powder-free nitrile gloves collected all samples in laboratory-supplied, laboratory-certified, contaminant-free sample bottles. All sampling personnel were trained in accordance with the field sampling standard operating procedures (SOPs). Field personnel were informed of the significance of the project detection limits and the requirement to avoid contamination of samples at all times. A temperature blank was used to ensure sample holding temperatures were maintained from sample collection to laboratory delivery.

5.3.7 Chain-of-Custody Procedures

Chain-of-custody (COC) procedures were used for all samples throughout the collection, transport, and analytical process. Samples were considered to be in custody if they were (1) in the custodian's possession or view, (2) retained in a secured place (under lock) with restricted access, or (3) placed in a container and secured with an official seal such that the sample could not be accessed without breaking the seal. The principal documents used to identify samples and to document possession were COC records, field logbooks, and field tracking forms.

The COC procedures were initiated during sample collection. A COC record was provided with each sample or group of samples. Each person who had custody of the samples signed the form and ensured the samples were not left unattended unless properly secured. Documentation of sample handling and custody included the following:

- Sample identifier.
- Sample collection date and time.
- Any special notations on sample characteristics or analysis.
- Initials of the person collecting the sample.
- Date the sample was sent to the analytical laboratory.
- Shipping company and waybill information.

Completed COC forms were placed in a plastic envelope and kept inside the cooler with the samples. Once delivered to the analytical laboratory, the COC form was signed by the person receiving the samples. The condition of the samples (*i.e.*, confirming all samples were accounted for and properly labeled, the temperature of the samples, and integrity of the sample jars) was noted and recorded by the receiver. COC records were included in the final reports prepared by the analytical laboratories and are considered an integral part of the report.

5.4 Results

5.4.1 Storm Event 1

5.4.1.1 Indicator Bacteria

Monitoring for the first storm event was initiated at approximately noon on December 15 and was completed in the late afternoon of December 16. Although the monitoring was effective in capturing the storm, the State Water Resources Control Board (SWRCB) notified the project contractors On December 17, 2008 that funds for the project had been indefinitely frozen due to the state budget crisis. Because of the stop work order, sample analysis was immediately stopped and therefore only a partial data set exists for this storm.

Figure 5-3 depicts the pollutograph for Storm Event One at the Dairy Mart Bridge sampling location. The rain gauge at the site first recorded rainfall at approximately 9:00 a.m. on December 15 and it continued until just after 4 a.m. on December 16. The Tijuana River at this site responded at approximately 12 p.m. on December 15 and peaked sharply from baseline flow to approximately 1,000 cfs within six hours. Flow represented by the descending limb of the hydrograph fell slowly over the next 20 hours.

Eight samples were collected and analyzed over the course of the storm with good spatial coverage over the hydrograph, but only nine analyses were completed before the stop work order had been received (Figure 5-3). Fecal coliform concentrations were high throughout the storm, particularly at the beginning, where concentrations exceeded 10,000,000 MPN / 100 mL. By the end of the storm, fecal coliform concentrations had dropped several orders of magnitude to just over 100,000 MPN / 100 mL. The pattern observed for Enterococcus concentrations was similar to that seen for fecal coliform concentrations with very high initial concentrations that dropped towards the end of the storm.

Pollutograph monitoring at Hollister Street was completed for Storm Event 1, but bacteriological analyses were completed for only the first sample collected before the stop work order was received. Fecal coliform and enterococcus concentrations from this sample were of a similar magnitude to those measured at Dairy Mart Road (Figure 5-4). No other samples were analyzed for this storm.

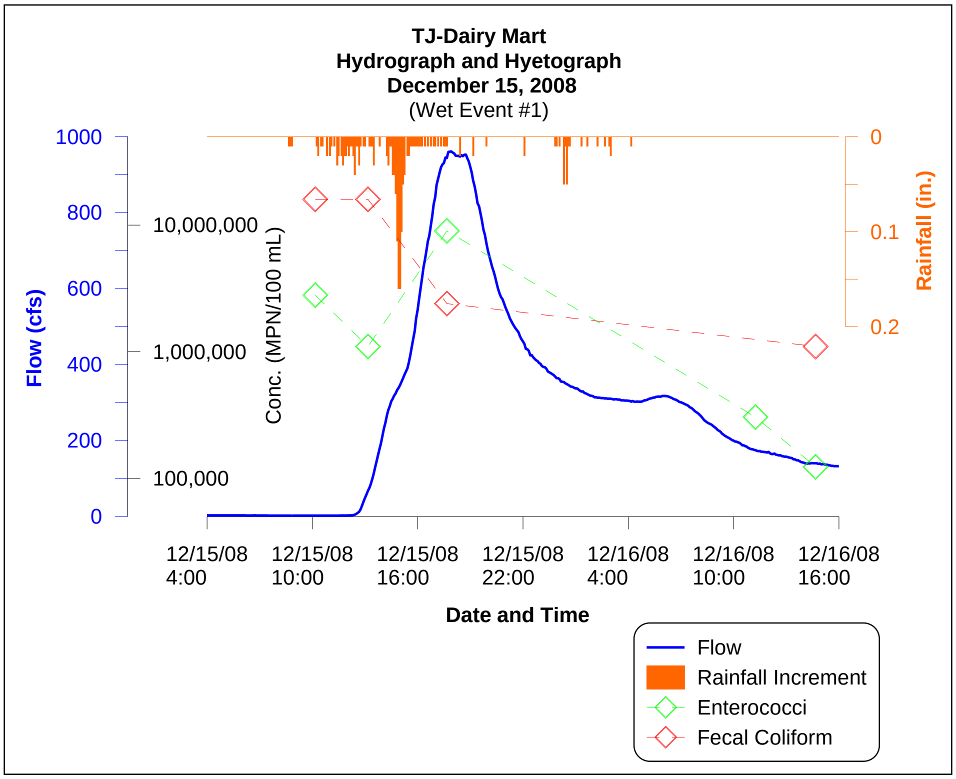


Figure 5-3. Pollutograph Results at Dairy Mart Road during Storm Event 1

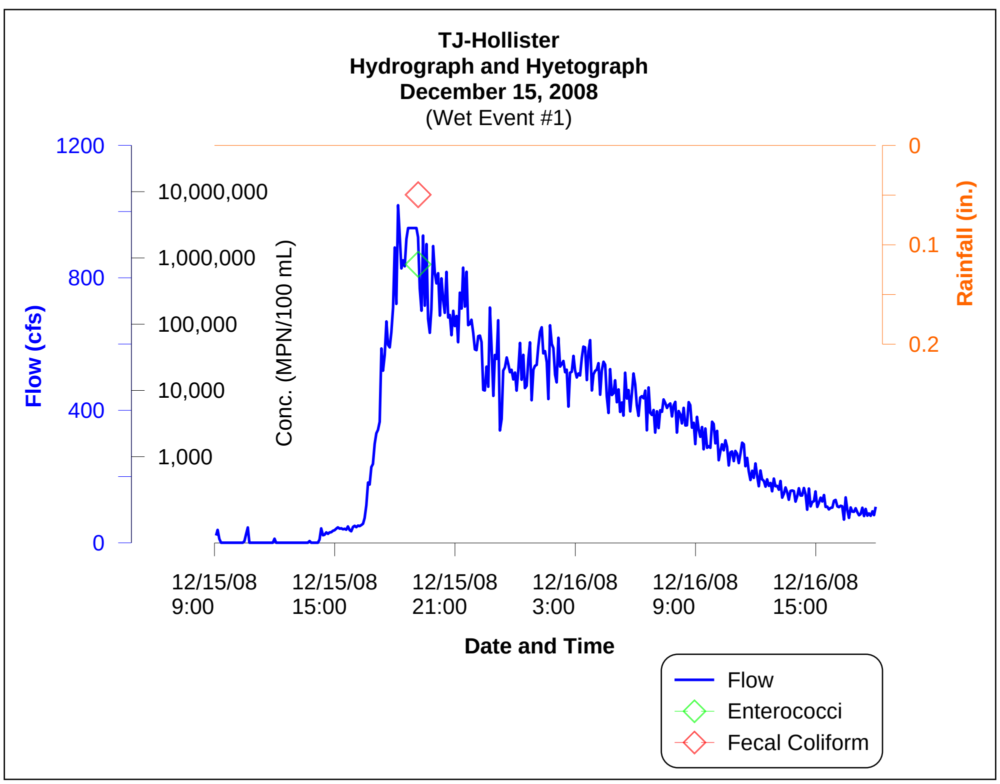


Figure 5-4. Pollutograph Results at Hollister Street during Storm Event 1

5.4.2 Storm Event 2

5.4.2.1 Indicator Bacteria

The second storm event was conducted on December 19 and 20, 2010. Monitoring for this storm was initiated at approximately midnight on December 19 and was completed approximately 20 hours later. Figure 5-5 depicts the pollutograph for Storm Event One at the Dairy Mart Bridge sampling location. The rain gauge at the Hollister Street Bridge site first recorded rainfall at approximately 10 p.m. on December 19 and it continued in three pulses for the subsequent 24 hours. The pulses of rain produced two distinct humps in the hydrograph at the Dairy Mart Road site centered at 7 a.m. and 3 p.m., with flow peaking at approximately 400 and 600 cfs, respectively. The third pulse of rain occurred at approximately 6 p.m. on December 20, which prevented the hydrograph from returning to base flow (the rise in flow can be seen at the end of the pollutograph in Figure 5-5). Heavy rains for the next several days at the end of 2010 dramatically increased flows in the river, which did not return to base flow for nearly a week.

Seven samples were collected and analyzed over the course of the storm depicted in Figure 5-5 with good spatial coverage over the hydrograph. Fecal coliform concentrations ranged between approximately 1,000,000 and 10,000,000 MPN / 100 mL and enterococcus concentrations ranged from 100,000 to just over 1,00,000 MPN / 100 mL. Concentrations remained high throughout the course of the storm. Concentrations measured in Storm Event 2 were similar to those observed in Storm Event 1, but there were no clear temporal patterns in the data for either indicator.

The pollutograph produced for Storm Event 2 at the Hollister Street Bridge site was similar to that observed at Dairy Mart Bridge with two distinct pulses in flow. The pulses at the Hollister Street Bridge site peaked at approximately 10 a.m. and 5 p.m., two to three hours later than those observed at Dairy Mart Bridge, reflecting the transit time of the flow between the two sites. Fecal coliform and enterococcus concentrations at Hollister Creek Bridge were similar to those measured at the Dairy Mart Bridge site with very high levels observed throughout the storm and no distinct temporal patterns. Concentrations were elevated at the onset of monitoring and remained high throughout the course of the storm.

The pollutograph produced for Storm Event 2 at the Smuggler's Gulch site was distinctly different from those observed at the mainstem Tijuana River sites, with a much more flashy pattern. The hydrograph increased sharply at approximately 2 a.m. to a flow rate of approximately 120 cfs, then fell back to an elevated flow of approximately 30 cfs where it remained for the course of the storm event. Although the flow pattern at Smuggler's Gulch was very different than those observed in the mainstem, bacterial concentrations were very similar to those observed at mainstem sites. Fecal coliform concentrations varied between 1,000,000 and 10,000,000 MPN / 100 mL and enterococcus concentrations were somewhat lower. Concentrations remained high throughout the course of the storm.

The pollutograph produced from data collected at Veteran's Park during Storm Event 2 is presented on Figure 5-8. The flow pattern showed several peaks with much lower flows (one to two orders of magnitude less) than those observed at the other monitoring sites (ranging between 1 and 3 cfs). Bacterial concentrations did not vary over the course of the storm, but were one to two orders of magnitude lower than those observed at all three sites originating from Mexico.

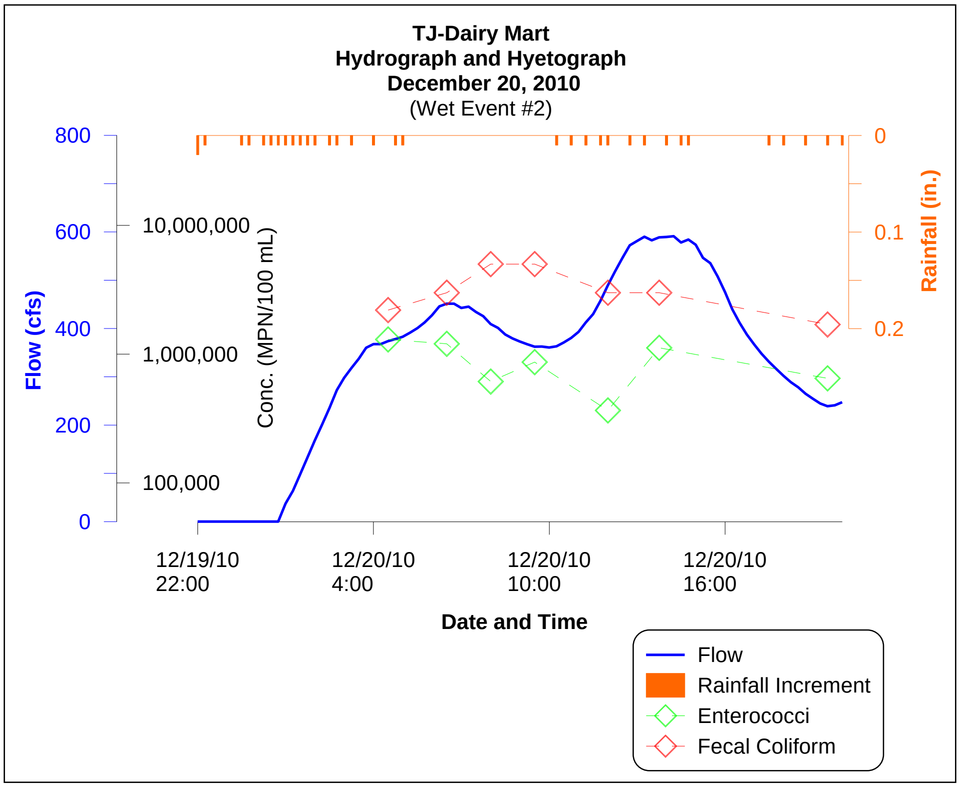


Figure 5-5. Pollutograph Results at Dairy Mart Road Bridge during Storm Event 2

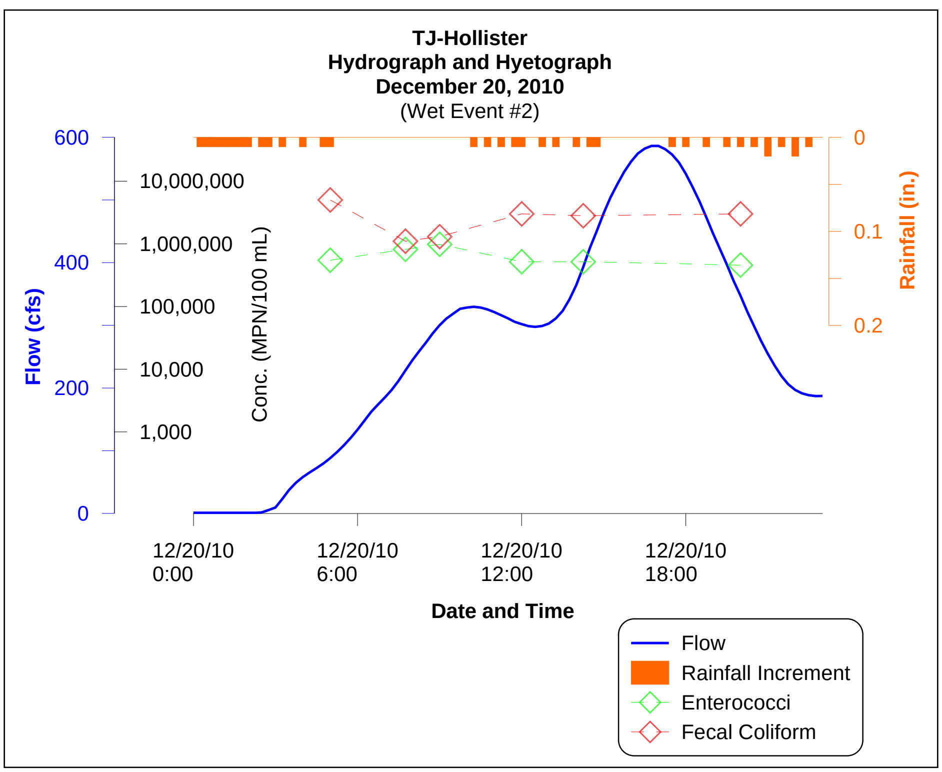


Figure 5-6. Pollutograph Results at Hollister Street Bridge during Storm Event 2

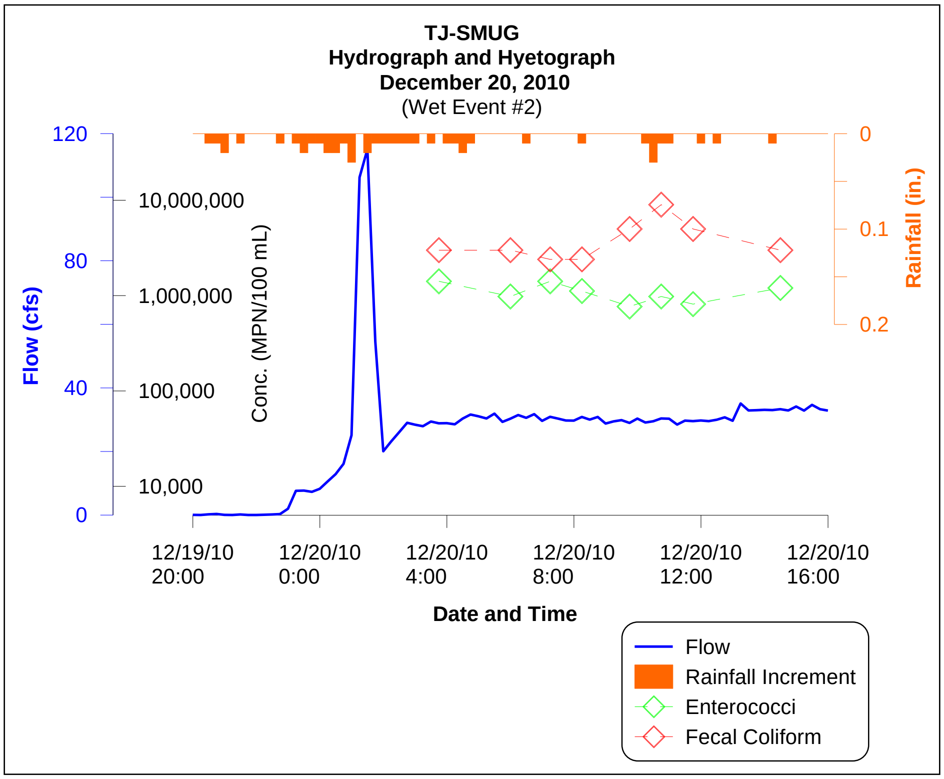


Figure 5-7. Pollutograph Results at Smuggler's Gulch during Storm Event 2

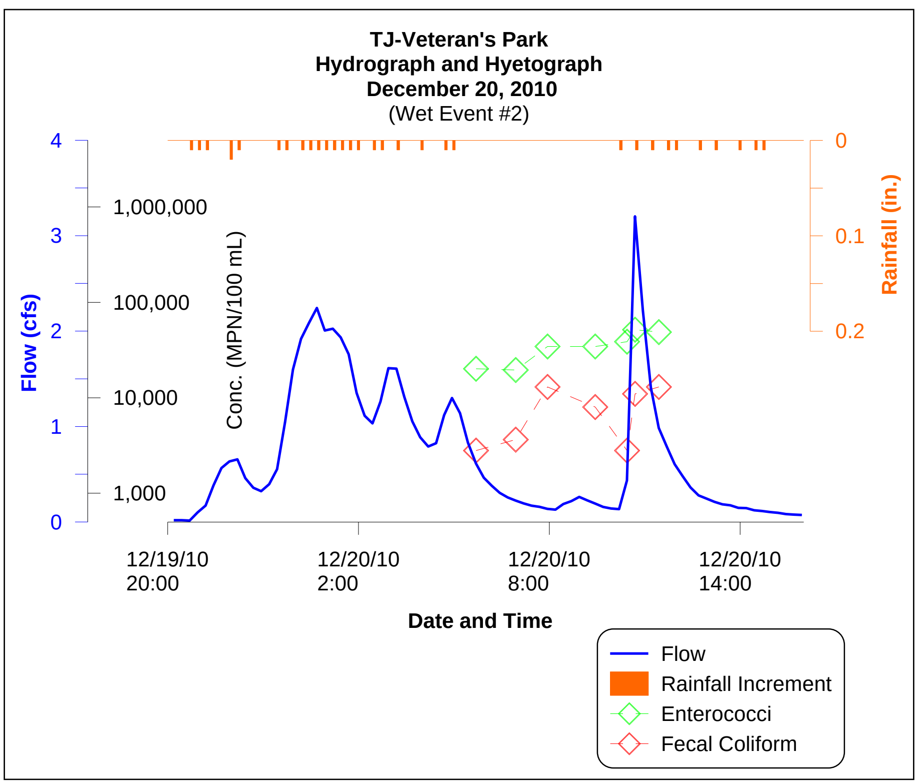


Figure 5-8. Pollutograph Results at Veterans' Park during Storm Event 2

5.4.3 Storm Event 3

5.4.3.1 Indicator Bacteria

The third storm event was conducted on November 4 and 5, 2011. Monitoring for this storm was initiated just after noon on November 4 and continued until approximately 6 p.m. on November 5. Figure 5-9 depicts the pollutograph for Storm Event Three at Dairy Mart Bridge. The hyetograph in Figure 5-9 shows that the rain started falling around 10 a.m. with a sharp rise in flow approximately two hours later. Flow peaked at approximately 7 p.m., followed by a second peak at approximately 5 a.m. the next day.

Nine samples were collected and analyzed over the course of the storm depicted in Figure 5-9, which bracketed the hydrograph well. Fecal coliform concentrations were somewhat more variable than those observed in the other storms, but concentrations were generally between 1,000,000 and 10,000,000 MPN / 100 mL. Enterococcus concentrations were between 100,000 and 1,000,000 MPN / 100 mL. These concentrations and temporal patterns were similar to those observed in Storm Events One and Two at Dairy Bridge Road Bridge.

The pollutograph produced for Storm Event 3 at the Hollister Street Bridge site was similar to that observed at Dairy Mart Bridge with two distinct pulses in flow, although there was a lag time of several hours between the sites (Figure 5-10). Aside from the first sample collected just prior to the rise in the hydrograph, fecal coliform and enterococcus concentrations at Hollister Creek Bridge were similar to those measured at the Dairy Mart Bridge site with very high levels observed throughout the storm and no distinct temporal patterns.

Consistent with Storm Event 2, the pollutograph for Storm Event 3 at Smuggler's Gulch was characteristic of a flashy watershed, with a sharp peak in flow at approximately 5 p.m. on November 4 (Figure 5-11). Flow peaked at approximately 250 cfs with a smaller, 50 cfs peak at approximately 2 p.m. Bacterial concentrations were similar to those measured in previous storms at sites originating from Mexico with fecal coliform concentrations ranging from 1,000,000 to 10,000,000 MPN / 100 mL and enterococcus concentrations ranging from 100,000 to 1,000,000 MPN / 100 mL (with the exception of the first sample for enterococcus, which was much lower).

The pollutograph produced from data collected at Veterans' Park during Storm Event 3 is presented on Figure 5-12. Similar to Storm Event 2 (Figure 5-8), the flow pattern at Veteran's Park during Storm Event 3 showed several peaks with much lower flows (one to two orders of magnitude less) than those observed at the other monitoring sites (ranging between 1 and 10 cfs). Bacterial concentrations did not show meaningful temporal trends over the course of the storm, but were one to two orders of magnitude lower than concentrations observed at all three sites originating from Mexico.

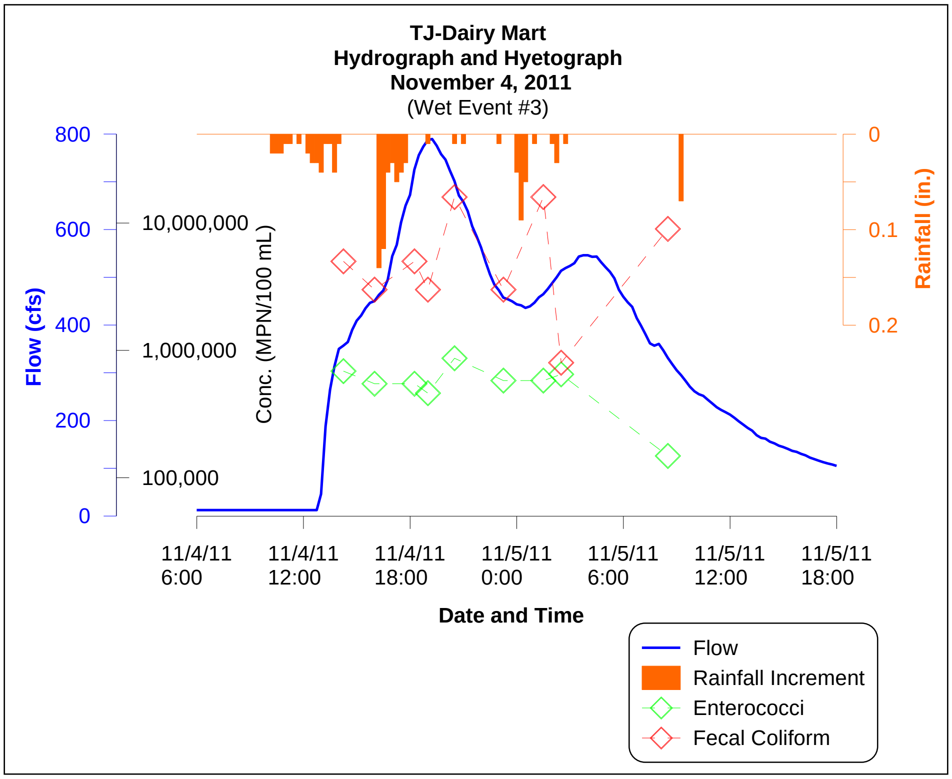


Figure 5-9. Pollutograph Results at Dairy Mart Road Bridge during Storm Event 3

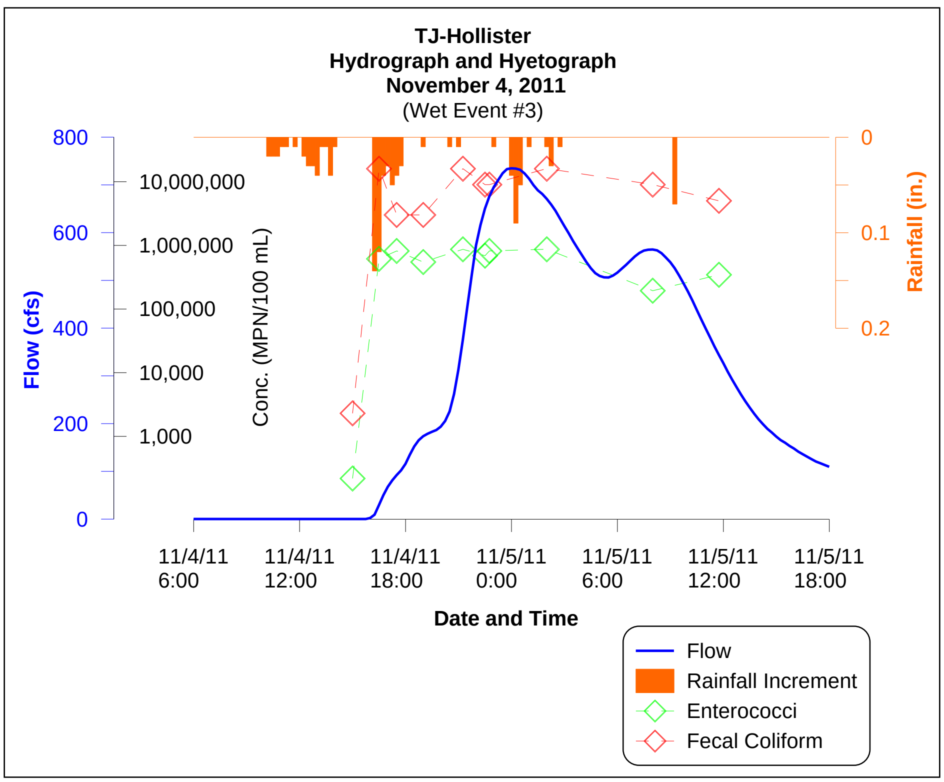


Figure 5-10. Pollutograph Results at Hollister Street Bridge during Storm Event 3

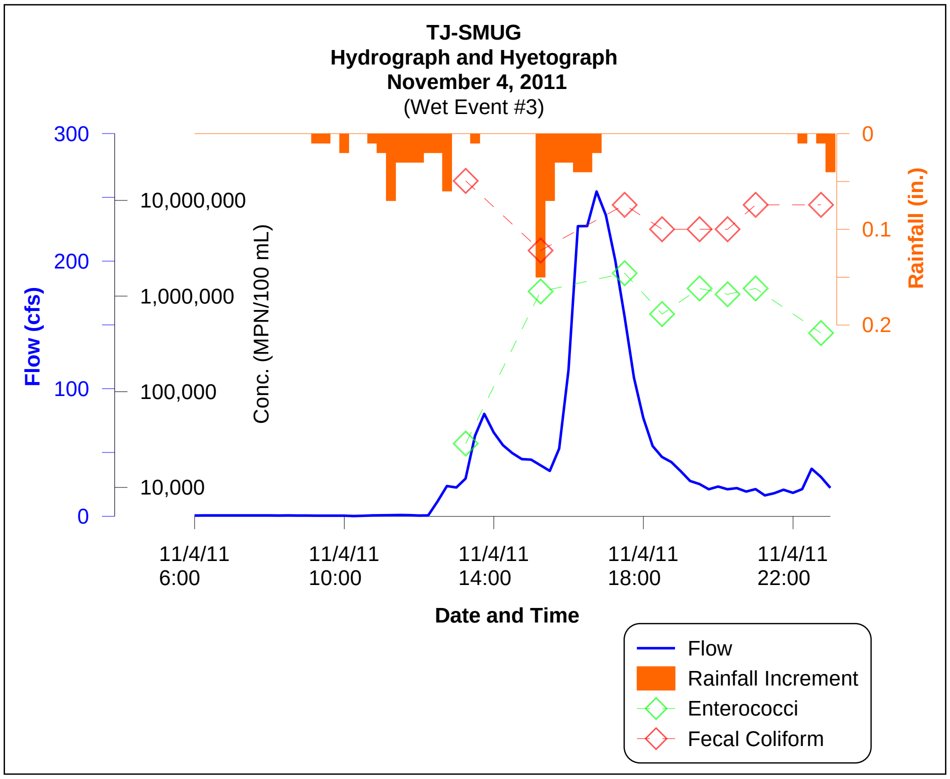


Figure 5-11. Pollutograph Results at Smuggler's Gulch during Storm Event 3

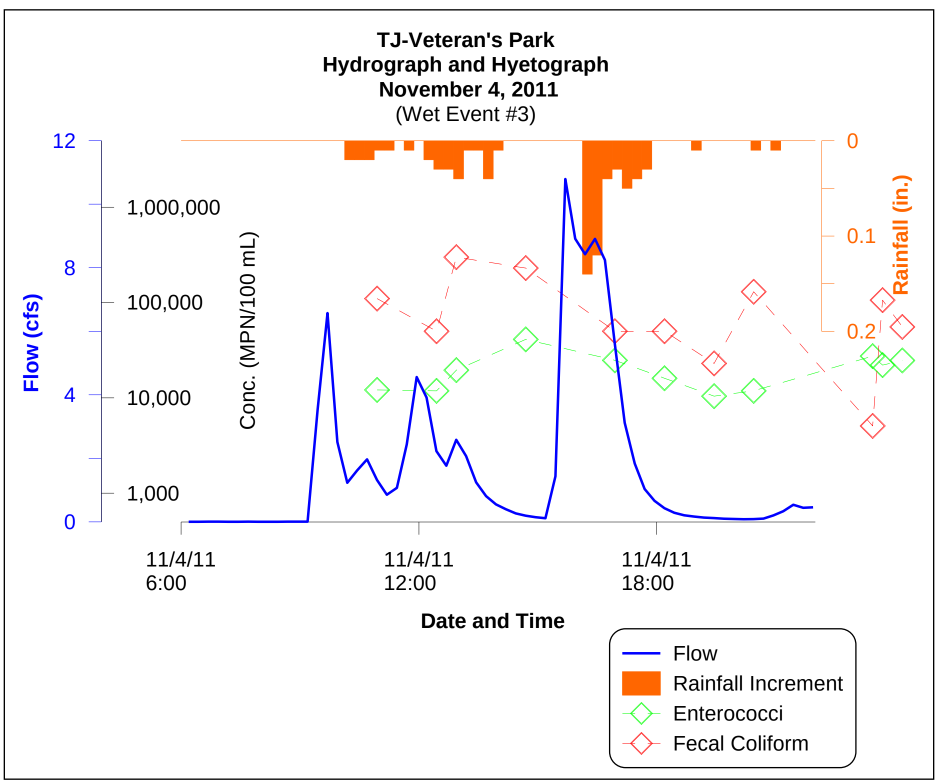


Figure 5-12. Pollutograph Results at Veterans' Park during Storm Event 3

In addition to the meaningful spatial representation provided by the individual samples collected in a pollutograph, this type of monitoring also allows for a comparison of the average concentrations and ranges of the data between sites. A comparison of the mean concentration and data distribution of fecal coliform and enterococcus concentrations obtained during Storm Event 3 is present in Figure 5-13A and Figure 5-13B, respectively. Fecal coliform concentrations are centered around the 10,000,000 MPN / 100 mL mark for all three monitoring sites originating from Mexico (Dairy Mart Road and Hollister Street on the Tijuana River mainstem and the tributary canyon of Smuggler's Gulch). In contrast, the mean fecal coliform concentration at the Veteran's Park site, a drainage that originates from the U.S. side of the border, was two orders of magnitude lower than those observed from the sites originating in Mexico. A similar pattern was observed for enterococcus concentrations. These results reflect the well-documented influx of raw sewage in the Tijuana River Watershed in Mexico.

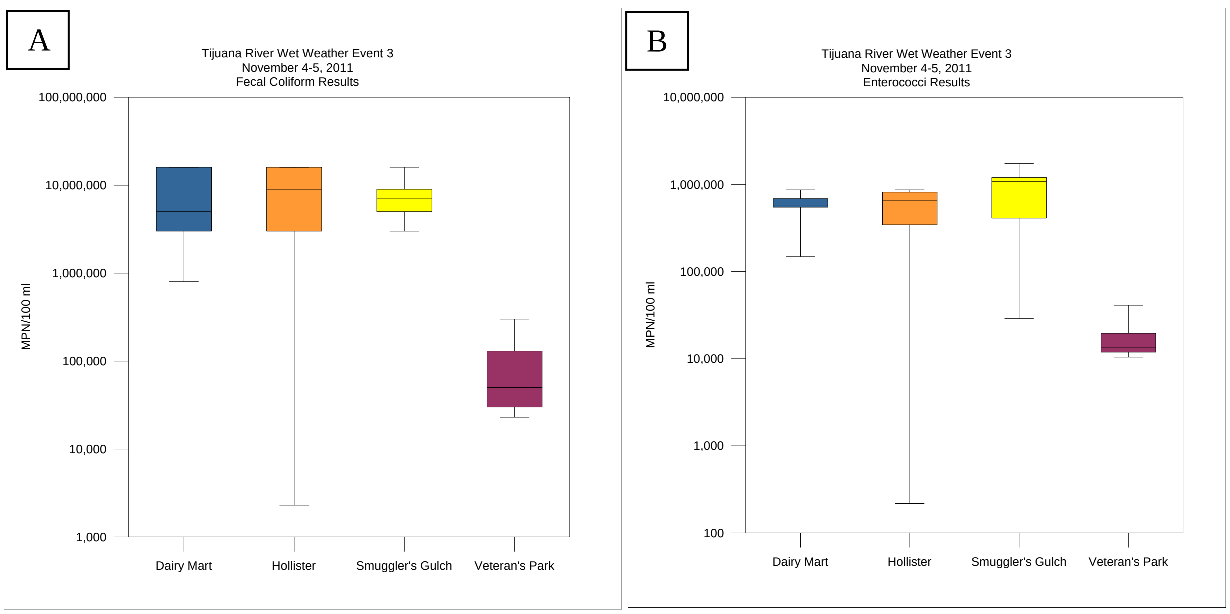


Figure 5-13. Comparison of Indicator Bacterial Concentrations from Four sties Monitored during Storm Event 3 for Fecal Coliforms (A) and Enterococci (B)

5.4.3.2 General and Human-specific Bacteroides

The influx of raw sewage from Mexico reflected in high concentrations of indicator bacteria at Dairy Mart Road, Hollister Street, and Smuggler's Gulch can also be seen in the presence of human-specific *Bacteroides*, which is a good indicator of human sewage. Samples were collected and analyzed for the presence of general and human-specific *Bacteroides* from all samples during Storm Event 3. The results are summarized in Table 5-6. All samples analyzed were positive for the General *Bacteroides* marker, indicating the presence of bacteria originating from warm-blooded animals. In addition, all samples but one collected from the three sites originating in Mexico (Dairy Mart Road Bridge, Hollister Bridge, and Smuggler's Gulch) were positive for the human-specific *Bacteroides* marker. These results suggest the consistent presence of human sewage in the Tijuana River mainstem and Smuggler's Gulch during the storm event. The one sample that was negative was the first sample collected at Hollister Street Bridge (TJ-WW3-

HOL-1). This sample was collected just before the river began to rise, suggesting that it may not have been influenced by sewage-tainted water from Mexico. In contrast to the sites originating in Mexico, the Veterans' Park site was negative for human-specific *Bacteroides*, which indicates the absence of human sewage at this location during Storm Event 3.

Table 5-6. General and Human-specific *Bacteroides* Results for Four Sites Monitored during Storm Event 3

Sample ID	Date Sampled	*Bacteroides*	
		General	Human
TJ-WW3-DM-1	11/4/11	POS	**POS**
TJ-WW3-DM-2	11/4/11	POS	**POS**
TJ-WW3-DM-3	11/4/11	POS	**POS**
TJ-WW3-DM-4	11/4/11	POS	**POS**
TJ-WW3-DM-5	11/4/11	POS	**POS**
TJ-WW3-DM-6	11/4/11	POS	**POS**
TJ-WW3-DM-7	11/511	POS	**POS**
TJ-WW3-DM-8	11/5/11	POS	**POS**
TJ-WW3-HOL-1	11/4/11	POS	NEG
TJ-WW3-HOL-2	11/4/11	POS	**POS**
TJ-WW3-HOL-3	11/4/11	POS	**POS**
TJ-WW3-HOL-4	11/4/11	POS	**POS**
TJ-WW3-HOL-5	11/4/11	POS	**POS**
TJ-WW3-HOL-6	11/4/11	POS	**POS**
TJ-WW3-HOL-7	11/5/11	POS	**POS**
TJ-WW3-HOL-8	11/5/11	POS	**POS**
TJ-WW3-SMUG-1	11/4/11	POS	**POS**
TJ-WW3-SMUG-2	11/4/11	POS	**POS**
TJ-WW3-SMUG-3	11/4/11	POS	**POS**
TJ-WW3-SMUG-4	11/4/11	POS	**POS**
TJ-WW3-SMUG-5	11/4/11	POS	**POS**
TJ-WW3-SMUG-6	11/4/11	POS	**POS**
TJ-WW3-SMUG-7	11/4/11	POS	**POS**
TJ-WW3-SMUG-8	11/4/11	POS	**POS**
TJ-WW3-VP-1	11/4/11	POS	NEG
TJ-WW3-VP-2	11/4/11	POS	NEG
TJ-WW3-VP-3	11/4/11	POS	NEG
TJ-WW3-VP-4	11/4/11	POS	NEG
TJ-WW3-VP-5	11/4/11	POS	NEG
TJ-WW3-VP-6	11/4/11	POS	NEG
TJ-WW3-VP-7	11/4/11	POS	NEG
TJ-WW3-VP-8	11/4/11	POS	NEG

5.4.4 Wet Weather Loads

5.4.4.1 Indicator Bacteria

Based on the flows and bacterial concentrations obtained during the wet weather surveys, loads of fecal coliforms and enterococci were calculated for the sites monitored. The load estimates in Figure 5-14 were calculated from the pollutographs for the Tijuana River mainstem at Dairy Mart Bridge, Smuggler's Gulch, and the total developed area on the U.S. side of the border that drains directly to the Tijuana River or the Tijuana River Estuary. This latter value was taken from the measured flows and loads at Veteran's Park and extrapolated to the total urbanized area on the U.S. side of the border as shown on Figure 5-15, which highlights the seven sub-drainages making up the U.S. contribution to wet weather flows. Based on the limited data set of the storms monitored in this study, an estimated 92.2% of the fecal coliform load entering the Tijuana River Estuary originates from the Tijuana River mainstem during storm events Figure 5-14A. An additional 7.6% enters the estuary from Smuggler's Gulch. Less than 1% of the overall fecal coliform load enters the estuary from the U.S. portion of the watershed shown in Figure 5-15. Similar results were estimated for enterococci, where an estimated 88.2% of the load enters the estuary from the Tijuana River mainstem, 11.6% from Smuggler's Gulch, and less than 1% from the U.S. side of the border Figure 5-14B.

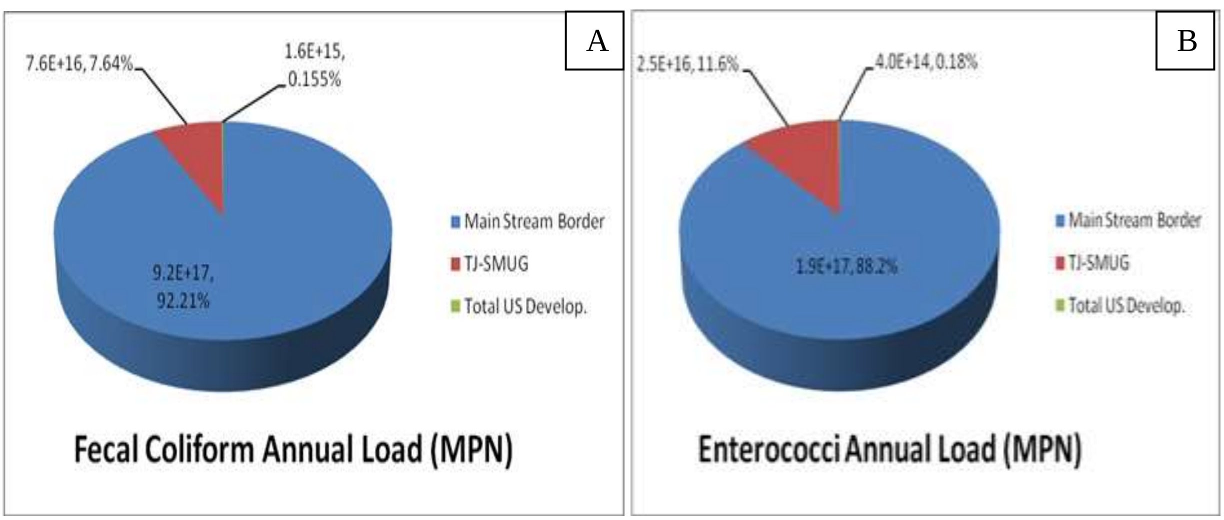


Figure 5-14. Annual Loads of Indicator Bacteria

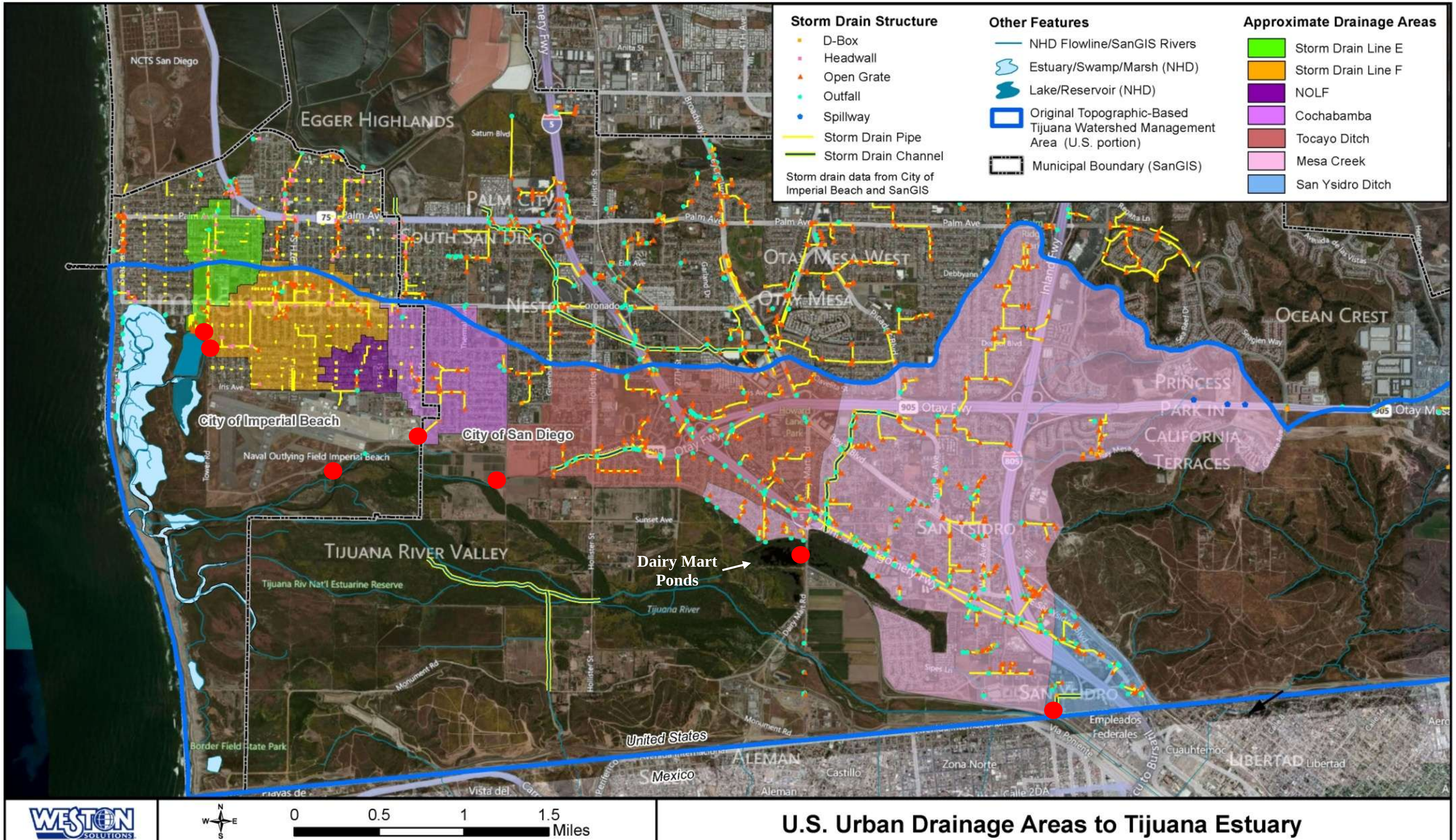


Figure 5-15. Sub-drainages in the United States that Discharge Directly to the Tijuana River or Tijuana River Estuary

5.5 Discussion

The wet weather surveys were designed to address three major study questions:

1. **How do concentrations of indicator bacteria vary over the course of a storm event in the main stem and tributary sites?**

2. **What are the bacterial loads entering the estuary during storm events?**

3. **How do wet weather bacterial loads originating from the U.S. side of the border compare to the loads originating from Mexico?**

The first question was addressed by conducting the pollutograph surveys. Storm events two and three clearly showed that indicator bacteria concentrations were very high throughout the storm events at the three sites originating from Mexico and showed no obvious trend over time (concentrations were elevated at the onset of the storm and stayed high throughout the storm event). Bacterial concentrations at these sites were approximately two orders of magnitude greater than those observed at the Veterans' Park site, which discharges flow originating from the U.S. Bacterial concentrations measured at Hollister Street Bridge and Dairy Mart Road are similar to those observed in other monitoring programs that monitor these sites and much higher than those measured during storm events at other sites throughout the region (Weston, 2007). The high bacteria levels reflect the documented presence of raw sewage in the Tijuana River originating from Mexico (Gersberg et al., 1994). The results of the human-specific *Bacteroides* assays suggests that raw sewage is likely entering the Tijuana River and estuary from the Tijuana River mainstem and tributary canyons (*e.g.*, Smuggler's Gulch). Bacterial concentrations at Veterans' Park were approximately two orders of magnitude lower than those collected at sites originating from Mexico and were similar to those observed in other urbanized areas in southern California (Weston, 2007). The lack of positive human-specific *Bacteroides* results in samples collected at Veterans' Park suggests that human sewage is an unlikely source of bacteria to the estuary from this drainage.

The load estimates also suggest that the U.S. portion of the watershed contributes a small amount of indicator bacteria to the Tijuana River Estuary compared to the large loads originating from the Tijuana River mainstem and Smuggler's Gulch. Load estimates, based on pollutograph monitoring, suggest that approximately 92% of the fecal coliform load and 88% of the enterococcus load entering the Tijuana River Estuary originates from the mainstem of the Tijuana River. An additional 8 and 12% of the fecal coliform and enterococcus loads respectively originated from Smuggler's Gulch. Less than 1% of the fecal coliform and enterococcus loads entering the estuary were calculated to have originated from the U.S. side of the border.

Estimates of bacterial load conducted in this study were based on a limited sample size of a single storm event (Storm Event 3) and a single sub-drainage to represent the U.S. contribution to the overall bacterial load. However, extensive visual observations during storm events suggests that other sub-drainages on the U.S. side of the border may have limited impact on the overall bacterial load relative to the very large loads originating in Mexico. Figure 5-15 shows the sub-drainages that flow directly to the Tijuana River and Tijuana River Estuary (areas to the east of these sub-drainages discharge to the Mexican side of the border where they co-mingle with flows originating in Mexico before entering the U.S. in the Tijuana River mainstem). The red circles in Figure 5-15 represent the point of discharge for each of the seven U.S. sub-drainages that discharge directly to the Tijuana River or the Tijuana River Estuary.

The largest of these is the Mesa Creek sub-drainage, which comprises approximately 50% of the total U.S. sub-drainage area (shown in pink in Figure 5-15). The Mesa Creek sub-drainage discharges to a series of ponds called Dairy Mart Ponds on the west side of Dairy Mart Road through a natural, soft-bottom channel called Mesa Creek. The ponds are formed by a series of man-made earthen levies, which trap upstream flows and limit their connection to the estuary. During several storm events in 2011 and 2012, Extensive visual observations were conducted around the ponds to determine the path of surface waters from the Mesa Creek sub-drainage to the estuary. Although flow was documented entering the ponds from Mesa Creek, there was no obvious hydrologic connection between the ponds and the Tijuana River or the estuary. Groundwater appeared to surface during storm events in several locations adjacent to the ponds, but no surface water connection was identified. These observations suggest that Dairy Mart Ponds act as a natural best management practice (BMP) for storm flows entering the ponds form the Mesa Creek sub-drainage. Since this sub-drainage represents approximately 50% of the developed area on the U.S. side of the border that could impact the estuary during storm events, Dairy Mart Ponds play a critical role in minimizing the potential impacts of storm water on the estuary from urbanized areas in the U.S.

In addition, two other sub-drainages on the U.S. side of the border (Tocayo Ditch and Chochabamba in Figure 5-15) also discharge to soft bottom channels before entering the estuary. Although flow has been documented in these channels during storm events, the soft bottom channels likely attenuate storm water flows from these drainages through natural infiltration. The remaining four sub-drainages discharge directly to the estuary (E Line, F Line and NOLF in Figure 5-15) or the river (San Ysidro). Because the sub-drainages that discharge directly to the estuary are most likely to impact estuary water quality during storm events, BMPs designed to reduce bacterial loads have been located in these sub-drainages (See Section 9).

6.0 SEACOAST DRIVE SPECIAL STUDY

6.1 Background

A major component of the Tijuana River Bacterial Source Identification Study was Sanitary Surveys, which were conducted to identify anthropogenic sources of elevated concentrations of indicator bacteria within the U.S. portion of the watershed from anthropogenic sources, such as municipal sewage infrastructure. Using a tiered weight-of-evidence approach, areas with the highest probability for bacteria loading were identified and monitored to assess their contribution to bacteria loading in the Tijuana River Watershed (TRW). Monitoring efforts included water samples collected for on-site chemistry analysis and for bacterial analysis, as well as visual observations and flow measurements. Based on the results of these investigations, follow up sampling occurred if:

- High bacterial loads were found, based on concentrations and flows.
- Human-specific *Bacteroides* were present at the site.
- Visual observations or other measurements that suggested follow-up sampling was warranted.

Sanitary survey investigations conducted by Weston in July, 2010 (Sanitary Survey 2, See Section 4) as part of the Study identified the presence of indicator bacteria at monitoring locations within the estuary along Seacoast Drive in Imperial Beach (Table 6-1 and Figure 6-1). Human-specific *Bacteroides* were detected, implying that human fecal material was being introduced into the estuary by an unknown source and transport mechanism (Table 6-2). Possible sources included land-based discharges into the MS4, sub-surface discharges from leaking sewer system infrastructure, or environmental introductions from another source within the estuary. In response to these preliminary findings, the City of Imperial Beach (City) performed inspections and repairs to its sewage infrastructure along Seacoast Drive in January, 2011, along with pressure washing the two storm drains in the vicinity of the sewer line that discharge into the estuary.

Table 6-1. Monitoring Station Locations within the Estuary - Sanitary Survey 2 (July 2010)

Station	GPS Coordinates	
	Latitude	Longitude
TJ-SS2-32	32.5710	-117.1308
TJ-SS2-34	32.5534	-117.1269
TJ-SS2-301	32.5660	-117.1315
TJ-SS2-301.1	32.5660	-117.1315
TJ-SS2-301.5	32.5666	-117.1312
TJ-SS2-302	32.5693	-117.1321
TJ-SS2-302.2	32.5693	-117.1321
TJ-SS2-302.2.1	32.5698	-117.1321
TJ-SS2-302.5	32.5696	-117.1310

Figure 6-1. Map of Monitoring Station Locations within the Tijuana River Estuary during Sanitary Survey 2 (July 2010)

Table 6-2. Sanitary Survey 2 Monitoring Results - Estuary Sites (July 2010)

Station	Sample Date	Total Coliform (MPN/100 mL)	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	*Bacteroides*	
		WQO=10,000	WQO = 400*	WQO = 500**	Human	General
TJ-SS2-32	8/4/10	NS	20	<10	NEG	**POS**
TJ-SS2-34	8/4/10	NS	<20	<10	**POS**	**POS**
TJ-SS2-301	7/19/10	NS	20	<10	**POS**	**POS**
TJ-SS2-301.1	7/21/10	40	20	90	**POS**	**POS**
TJ-SS2-301.5	8/4/10	NS	<20	<10	NEG	**POS**
TJ-SS2-302	7/19/10	NS	40	10	**POS**	**POS**
TJ-SS2-302.2	7/21/10	500	<20	220	**POS**	**POS**
TJ-SS2-302.2.1	7/21/10	8,000	230	130	NEG	**POS**
TJ-SS2-302.5	8/4/10	NS	<20	10	NEG	NEG

< = less than the reporting limit.
NS = Not Sampled NEG = Negative POS = Positive
*Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use.
** Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use and infrequent water contact.

6.2 Study Questions

Weston developed the Seacoast Drive Special Study on behalf of the City to evaluate the success of their repairs to the sewer line and pump station. The Special Study was designed to answer the following questions:

1. Are human-specific *Bacteroides* present during intensive monitoring over a three-day period adjacent to outfalls on Seacoast Drive?
2. If human-specific *Bacteroides* are detected during monitoring efforts conducted to answer Special Study Question #1, is failing sewage infrastructure along Seacoast Drive the source?

In order to answer these questions, an intensive and focused monitoring program was developed by Weston to evaluate:

- Presence and distribution of indicator bacteria and human-specific *Bacteroides* within the estuary along Seacoast Drive.
- Whether the City's sewage infrastructure was a contributing source of contamination.
- If the contamination was due to failures in the sewage infrastructure, what transport mechanisms are working within the estuary.

This report provides an assessment of the monitoring program and addresses the study questions of the Seacoast Drive Special Study.

6.3 Methods

6.3.1 Sample Collection

Located in the southern limits of the City of Imperial Beach, Seacoast Drive is bordered on the west by the Pacific Ocean and on the east the northern arm of the Tijuana River Estuary. Development along Seacoast drive consists of privately owned condominiums that connect to a municipal sewer line through a series of lateral pipes. The main line is connected to a nearby pump station that directs flows to the city's mainline sewer. In January, 2011 the City implemented corrective measures that included the relining of the pump station to eliminate potential leaks within the municipal sewage system along Seacoast Drive. Weston performed follow up dry weather investigations in February, 2011 and September, 2011 that indicated the City's sewage infrastructure located along Seacoast Drive was not leaking sewage contamination into the estuary.

Monitoring was conducted at stations located within the estuary and sewer line over a three-day period. Samples were taken throughout the day to capture the potential effects of tidal cycles on the presence/absence and concentrations of indicator organisms, as well as to help refine the possible source of transport. In addition a rhodamine study was conducted to detect possible leaks within sewage infrastructure and, if leaks were present, the transport of human-based contamination within the estuary and out to the Pacific Ocean.

Four monitoring locations were selected within the vicinity of Seacoast Drive (Table 6-3 and Figure 6-2). Stations TJ-SS-SD1 and TJ-SS-SD2 were located within the estuary near the two storm drains that discharge effluent into the estuary from Seacoast Drive. Data collected at these stations would be used to determine if sewage contamination was entering the estuary from these two storm drains. Station TJ-SS-E1 was located within a main channel of the estuary near Seacoast Drive. Data collected at this station could be compared to data collected at Stations TJ-SS-SD1 and TJ-SS-SD2 to help determine the potential contribution of the two storm drains with regard to bacterial contamination, as well as the extent and transport of contamination within the estuary. Station TJ-SS-PS2 was located within the sewage infrastructure at the pump station. Data collected at this station would be compared to data collected at the other three stations to help determine whether the sewer line was a contributing to bacterial contamination within the estuary.

Sampling was conducted at each monitoring location over a three-day period from February 8 – 10, 2011 during dry weather conditions. Grab samples were collected beginning at 4:00 am and continuing every 3 hours until 10:00 pm. Quality assurance and quality control (QA/QC) regarding proper sample collection and handling methods were followed to insure compliance with minimum acceptance criteria and allow for comparison with data collected before and after the sampling date. Samples were individually labeled with times and field observations recorded in field logbooks. Samples were then placed on ice within a cooler and transported to the lab for analysis within 6-hours of collection. Weston's Chain of Custody forms were used to document samples shipped to an outside lab.

Table 6-3. Seacoast Drive Special Study – Monitoring Station Locations (2011)

Station	GPS Coordinates	
	Latitude	Longitude
Estuary Sites		
TJ-SS-SD1	32.565913	-117.131543
TJ-SS-SD2	32.569010	-117.132046
TJ-SS-E1	32.565267	-117.131415
TJ-SS-E2	32.567467	-117.131732
TJ-SS-PS	32.570280	-117.132208

Figure 6-2. Seacoast Drive Special Study Monitoring Station Locations (February 2011)

6.3.2 Sample Analysis

6.3.2.1 Indicator Bacteria

Monitoring was performed within the main sewage line located along Seacoast Drive and within the adjacent estuarine channel to address Study Questions #1 and #2. Weston selected fecal coliforms and enterococci as indicator organisms, since both are used by regulatory agencies to determine water contamination and threats to public health. Additionally, Weston conducted polymerase chain reaction (PCR) analyses of Bacteroides (general and human-specific) as a more precise measure of fecal contamination from warm blooded animals (general) and human (human-specific) sources.

Fecal coliform is a bacteria associated with fecal matter and characterized by being facultatively-anaerobic organisms (*i.e.*, capable of cellular respiration in both oxygen-rich and oxygen poor environment). Monitoring for fecal coliform provides a quick, reliable and inexpensive indication of contamination by fecal matter. Generally, elevated levels of fecal coliforms within water bodies may indicate failure of sewage infrastructures and/or water treatment, as well as potential contamination with pathogens. However, elevated levels of fecal coliforms should not be used as a direct indicator of contamination by human fecal material, as it can be associated with animal feces, agricultural runoff or plant material. According to the San Diego Basin Plan (RWQCB, 2007), fecal coliform concentrations for REC-1 water use in estuaries and coastal lagoons is determined to be a public health risk when they exceed 400 Most Probable Number (MPN)/100 milliliters (mL) of solution within a single sample.

Enterococci is genus of bacteria associated with fecal matter and is characterized by being facultative anaerobic organisms and tolerant of a wide range of environmental conditions. Unlike fecal coliforms, enterococci are more closely associated with human fecal matter as two enterococci species (*E. faecalis* and *E. faecium*), which are common in the intestines of humans and may provide a higher correlation than fecal coliform with many of the human pathogens often present in municipal sewage. Acceptable levels of enterococci within water bodies are much lower than for fecal coliform. However, locating specific sources of enterococci contamination is often complicated by the ability of the bacteria to grow outside of its host origin. According to the San Diego Basin Plan (RWQCB, 2007), enterococci concentrations for REC-1 marine water use in estuaries and coastal lagoons are determined to be a public health risk when they exceed:

- 104 MPN/100 mL for beach areas.
- 276 MPN/100 mL for moderate to light use.
- 500 MPN/100 mL for infrequent use (SWRCB[1] 2007, SWRCB[2] 2007).

Bacteroides is a genus of bacillus bacteria that can be used as an alternative fecal indicator organism that serves to be more accurate than fecal coliform or enterococcus for identifying potential sources of sewage contamination. Since it makes up the most substantial portion of the mammalian gastrointestinal flora, monitoring *Bacteroides* better identifies the host species of fecal matter and provides a higher correlation than fecal coliform and enterococci to human pathogens found in municipal sewage. *Bacteroides* also have a small potential to grow within the environment, which can improve source identification efforts that can lead to management measures that eliminate these sources (*e.g,.* repairing leaks in sewage lines). *Bacteroides* can also be analyzed within the lab by quantifying the genetic markers that are specific to the host without culturing bacteria to help detect recent contamination. Currently, the Basin Plan does not have established limits for *Bacteroides* concentrations within water bodies to determine potential threats to public health. Weston analyzed both general and human-specific *Bacteroides* in the Special Study to improve detection of potential presence of sewage contamination within the estuary from leaks in the sewage infrastructure located along Seacoast Drive.

Once at the lab, QA/QC regarding sample preparation and analysis were followed, including the use of corresponding Surface Ambient Monitoring Program (SWAMP) Detection and Reporting Limits (Table 6-4). Fecal coliforms analysis was based on solutions providing results between 20-> 1,600,000 MPN/100 mL. Enterococci were analyzed using IDEXX Enterolert analysis based on dilutions providing results between 10 and 241,960 MPN/100mL. Specific details are discussed in Section 2 of this report.

Table 6-4. Analyte List and Corresponding Surface Water Ambient Monitoring Program-Compliant Method Detection and Reporting Limits

Analyte	Method	Minimum Detection Limit	Reporting Limit	Units
Total Coliforms	SM9221B	< 2	< 20	MPN / 100 mL
Fecal Coliforms	SM9221E	< 2	< 20	MPN / 100 mL
Enterococci	SM9230B or Enteroloert	< 2 or < 1	< 20 or < 10	MPN / 100 mL
Bacteroides Presence / Absence	SOPLAB068.00	–	–	Presence / Absence

6.3.2.2 Rhodamine Dye

In a response to Study Question #2, a rhodamine dye study was conducted as part of the Seacoast Drive Special Study in concert with the bacteriological assessment. Rhodamine is a chemical compound that can be used as a tracer dye within water to determine the rate and direction of flow and transport. For this study, rhodamine dye was placed directly in the sewer line on the southern end of Seacoast Drive (see Figure 6-2). Sewage from this end of the line runs north to a pump station (TJ-SS-PS in Figure 6-2) before it lifted to the main line. Monitoring of rhodamine concentrations was conducted within the pump station and at nearby locations within the estuary. The study was designed to:

- Detect leaks within the City's sewage infrastructure, located along Seacoast Drive, and input points in the estuary.
- Help to characterize the potential transport of sewage within the nearby estuarine channel from sewage leaks.
- Help to determine the contribution of failing sewage infrastructure along Seacoast Drive to contamination of the City's beach, located just north of the estuary's ocean inlet.

Prior to adding rhodamine dye to the sewer line, carbon filters were placed at four locations within the estuary to detect rhodamine presence. Two stations (TJ-SS-E1 and TJ-SS-E2) were located within the main channel near Seacoast Drive to assess presence and movement of rhodamine dye within the estuary and near the ocean inlet. Two stations (TJ-SS-SD1 and TJ-SS-SD2) were positioned below the two storm drains monitored for fecal indicator organisms to assess whether these outfalls were directing sewage leaks into the estuary. Rhodamine was also measured within the sewage line at the pump station to compare levels with those potentially detected in the estuary.

Once the carbon filters were in place, rhodamine dye was placed within the southern-most end of the main sewage line at Seacoast Drive. Carbon filters were replaced twice daily at each location over a three-day period. A single water sample for rhodamine was taken at TJ-SS-E1-BG and TJ-SS-SD1-BG. Rhodamine concentrations within the sewer system's pump station were also monitored twice daily, for the three-day monitoring period. Overall, 25 samples were taken and sent to the Ozark Underground Lab (OUL) for analysis.

In the lab, charcoal and water samples were analyzed for the presence of Rhodamine WT (RWT) dye. Peak wavelengths were reported in nanometers (nm) and dye concentrations were reported in parts per billion (ppb). Dye concentrations were based upon standards used at the OUL, with standard concentrations based upon the "as sold" weight of the dye that OUL uses.

6.3.3 Quality Assurance/Quality Control Procedures

Quality assurance (QA) and quality control (QC) for sampling processes included proper collection of the samples to minimize the possibility of contamination. Sampling personnel wearing powder-free nitrile gloves collected all samples in laboratory-supplied, laboratory-certified, contaminant-free sample bottles. All sampling personnel were trained in accordance with the field sampling standard operating procedures (SOPs). Field personnel were informed of the significance of the project detection limits and the requirement to avoid contamination of samples at all times. A temperature blank was used to ensure sample holding temperatures were maintained from sample collection to laboratory delivery.

6.3.4 Chain-of-Custody Procedures

Chain-of-custody (COC) procedures were used for all samples throughout the collection, transport, and analytical process. Samples were considered to be in custody if they were (1) in the custodian's possession or view, (2) retained in a secured place (under lock) with restricted access, or (3) placed in a container and secured with an official seal such that the sample could not be accessed without breaking the seal. The principal documents used to identify samples and to document possession were COC records, field logbooks, and field tracking forms.

The COC procedures were initiated during sample collection. A COC record was provided with each sample or group of samples. Each person who had custody of the samples signed the form and ensured the samples were not left unattended unless properly secured. Documentation of sample handling and custody included the following:

- Sample identifier.
- Sample collection date and time.

- Any special notations on sample characteristics or analysis.
- Initials of the person collecting the sample.
- Date the sample was sent to the analytical laboratory.
- Shipping company and waybill information.

Completed COC forms were placed in a plastic envelope and kept inside the cooler with the samples. Once delivered to the analytical laboratory, the COC form was signed by the person receiving the samples. The condition of the samples (*i.e.*, confirming all samples were accounted for and properly labeled, the temperature of the samples, and integrity of the sample jars) was noted and recorded by the receiver. COC records were included in the final reports prepared by the analytical laboratories and are considered an integral part of the report.

6.4 Results

6.4.1 Indicator Bacteria

Concentrations of indicator bacteria in samples collected during the Seacoast Drive Special Study on February 8, 9, and 10, 2011 are presented in Table 6-5, Table 6-6, and Table 6-7, respectively. Overall, concentrations of fecal coliform and enterococci frequently exceeded Basin Plan standards at all monitoring locations within the estuary during the three-day monitoring program. General *Bacteroides* were detected within the estuary, indicating that the bacteria may have originated from warm-blooded animals. However, human-specific *Bacteroides* were not detected in any sampled collected in the estuary or adjacent to the storm drain outlets. Tide was in the neap stage of the tidal cycle during the monitoring period with tidal height ranging from + 1.5 and + 4.7 feet Mean Lower Low Water (MLLW). It is not clear what role tidal stage tidal cycles played in concentrations or distribution of indicator bacteria within the estuary during dry weather conditions.

Concentrations of fecal coliforms and enterococci collected from the sewage pump station (TJ-SS-PS2) were, as expected, very high, at least three to four orders of magnitudes greater than levels detected at the monitoring stations within the estuary. Nearly all samples collected from the pump station were positive for both general and human-specific *Bacteroides*.

Table 6-5. Seacoast Drive Special Study - Indicator Bacteria and PCR (general and human-specific *Bacteroides*) Results – February 8, 2011

Station	Sample Date	Time Taken	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	*Bacteroides*		Tidal Flow, Range and Times
			WQO=400*	WQO=500**	General	Human	
TJ-SS-E1	2/8/11	0400	1,700	1,396	**POS**	NEG	Outgoing: -3' High: 4.6' at 1:03 am Low: 1.6' at 8:44 am
TJ-SS-SD1	2/8/11	0410	500	238	**POS**	NEG	
TJ-SS-SD2	2/8/11	0420	170	75	**POS**	NEG	
TJ-SS-PS2	2/8/11	0430	500,000	86,644	**POS**	**POS**	
TJ-SS-E1	2/8/11	0700	700	884	NEG	NEG	
TJ-SS-SD1	2/8/11	0710	170	201	**POS**	NEG	
TJ-SS-SD2	2/8/11	0720	70	41	NEG	NEG	
TJ-SS-PS2	2/8/11	0730	>1,600,000	>241,960	**POS**	**POS**	
TJ-SS-E1	2/8/11	1000	2,200	185	NEG	NEG	Incoming: +1.8' Low: 1.6' at 8:44 am High: 2.4' at 2:38 pm
TJ-SS-SD1	2/8/11	1010	1,700	148	NEG	NEG	
TJ-SS-SD2	2/8/11	1020	20	41	NEG	NEG	
TJ-SS-PS2	2/8/11	1030	>1,600,000	>241,960	**POS**	**POS**	
TJ-SS-E1	2/8/11	1300	700	233	NEG	NEG	
TJ-SS-SD1	2/8/11	1310	800	201	NEG	NEG	
TJ-SS-SD2	2/8/11	1320	< 20	294	NEG	NEG	
TJ-SS-PS2	2/8/11	1330	>1,600,000	>241,960	**POS**	**POS**	
TJ-SS-E1	2/8/11	1600	80	171	NEG	NEG	Outgoing: -0.2' High: 2.4' at 2:38 pm Low: 2.2' at 5:47 pm
TJ-SS-SD1	2/8/11	1610	170	359	**POS**	NEG	
TJ-SS-SD2	2/8/11	1620	< 20	216	**POS**	NEG	
TJ-SS-PS2	2/8/11	1630	>1,600,000	>241,960	**POS**	**POS**	
TJ-SS-E1	2/8/11	1900	230	259	NEG	NEG	Incoming: +2.4' Low: 2.2' at 5:47 pm High: 4.6' at 2:12 am
TJ-SS-SD1	2/8/11	1915	230	471	**POS**	NEG	
TJ-SS-SD2	2/8/11	1925	< 20	241	NEG	NEG	
TJ-SS-PS2	2/8/11	1935	>1,600,000	>241,960	**POS**	**POS**	
TJ-SS-E1	2/8/11	2200	5,000	341	NEG	NEG	
TJ-SS-SD1	2/8/11	2210	170	336	**POS**	NEG	
TJ-SS-SD2	2/8/11	2220	< 20	265	NEG	NEG	
TJ-SS-PS2	2/8/11	2230	500,000	>241,960	**POS**	NEG	

Red = Exceedance **POS** = Positive NEG = Negative
Pump Station site highlighted in blue
*Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use.
** Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use and infrequent water contact.

Table 6-6. Seacoast Drive Special Study - Indicator Bacteria and PCR (general and human-specific *Bacteroides*) Results – February 9, 2011

Station	Sample Date	Time Taken	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	*Bacteroides*		Tidal Flow, Range and Times
			WQO=400*	WQO=500**	General	Human	
TJ-SS-E1	2/9/11	0400	800	2,755	NEG	NEG	Outgoing – 3' High: 4.7' at 12:17 am Low: 1.7' at 7:07 am
TJ-SS-SD1	2/9/11	0415	230	216	**POS**	NEG	
TJ-SS-SD2	2/9/11	0425	110	107	NEG	NEG	
TJ-SS-PS2	2/9/11	0430	500,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/9/11	0700	2,300	1,935	**POS**	NEG	
TJ-SS-SD1	2/9/11	0710	1,100	119	**POS**	NEG	Incoming: +2.2' Low: 1.7' at 7:07 am High: 2.9' at 12:33 pm
TJ-SS-SD2	2/9/11	0720	230	259	NEG	NEG	
TJ-SS-PS2	2/9/11	0730	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/9/11	1000	3,000	62	**POS**	NEG	
TJ-SS-SD1	2/9/11	1010	700	275	**POS**	NEG	
TJ-SS-SD2	2/9/11	1020	1,700	173	NEG	NEG	
TJ-SS-PS2	2/9/11	1030	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/9/11	1300	170	74	**POS**	NEG	Outgoing: -1.1' High: 2.9' at 12:33 pm Low: 1.8' at 5:42 pm
TJ-SS-SD1	2/9/11	1310	300	213	**POS**	NEG	
TJ-SS-SD2	2/9/11	1320	130	134	NEG	NEG	
TJ-SS-PS2	2/9/11	1330	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/9/11	1600	80	246	**POS**	NEG	
TJ-SS-SD1	2/9/11	1610	800	173	NEG	NEG	
TJ-SS-SD2	2/9/11	1620	260	97	NEG	NEG	
TJ-SS-PS2	2/9/11	1630	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/9/11	1900	110	313	**POS**	NEG	Incoming: + 2.8' Low: 1.8' at 5:42 pm High: 4.6' at 1:03 am
TJ-SS-SD1	2/9/11	1920	700	546	**POS**	NEG	
TJ-SS-SD2	2/9/11	1930	300	173	**POS**	NEG	
TJ-SS-PS2	2/9/11	1940	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/9/11	2200	2,300	160	**POS**	NEG	
TJ-SS-SD1	2/9/11	2210	500	309	**POS**	NEG	
TJ-SS-SD2	2/9/11	2220	110	231	NEG	NEG	
TJ-SS-PS2	2/9/11	2230	1,600,000	241,960	**POS**	**POS**	

Red = Exceedance **POS** = Positive NEG = Negative
Pump Station site highlighted in blue
*Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use.
** Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use and infrequent water contact.

Table 6-7. Seacoast Drive Special Study - Indicator Bacteria and PCR (general and human-specific *Bacteroides*) Results – February 10, 2011

Station	Sample Date	Time Taken	Fecal Coliform (MPN/100 mL)	Enterococcus (MPN/100 mL)	*Bacteroides*		Tidal Flow, Range and Times
			WQO=400*	WQO=500**	General	Human	
TJ-SS-E1	2/10/11	0400	399	135	**POS**	NEG	Outgoing: -3' High: 4.6' at 1:03 am Low: 1.6' at 8:44 am
TJ-SS-SD1	2/10/11	0410	800	122	**POS**	NEG	
TJ-SS-SD2	2/10/11	0420	70	203	**POS**	NEG	
TJ-SS-PS2	2/10/11	0430	1,600,000	241,957	**POS**	**POS**	
TJ-SS-E1	2/10/11	0700	500	987	NEG	NEG	
TJ-SS-SD1	2/10/11	0710	500	218	**POS**	NEG	
TJ-SS-SD2	2/10/11	0720	130	187	NEG	NEG	
TJ-SS-PS2	2/10/11	0730	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/10/11	1000	40	512	NEG	NEG	Incoming: +1.8' Low: 1.6' at 8:44 am High: 2.4' at 2:38 pm
TJ-SS-SD1	2/10/11	1010	3,000	857	NEG	NEG	
TJ-SS-SD2	2/10/11	1020	130	620	NEG	NEG	
TJ-SS-PS2	2/10/11	1030	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/10/11	1300	80	249	NEG	NEG	
TJ-SS-SD1	2/10/11	1310	1,300	464	NEG	NEG	
TJ-SS-SD2	2/10/11	1320	40	880	NEG	NEG	
TJ-SS-PS2	2/10/11	1330	900,000	241,957	**POS**	**POS**	
TJ-SS-E1	2/10/11	1600	80	213	NEG	NEG	Outgoing: -0.2' High: 2.4' at 2:38 pm Low: 2.2' at 5:47 pm
TJ-SS-SD1	2/10/11	1610	1,700	529	**POS**	NEG	
TJ-SS-SD2	2/10/11	1620	20	990	**POS**	NEG	
TJ-SS-PS2	2/10/11	1630	1,600,000	241,960	**POS**	**POS**	
TJ-SS-E1	2/10/11	1900	90	565	NEG	NEG	Incoming: +2.4' Low: 2.2' at 5:47 pm High: 4.6' at 2:12 am
TJ-SS-SD1	2/10/11	1915	2,300	420	**POS**	NEG	
TJ-SS-SD2	2/10/11	1925	40	173	NEG	NEG	
TJ-SS-PS2	2/10/11	1935	1,600,000	241,960	**POS**	NEG	
TJ-SS-E1	2/10/11	2200	40	288	NEG	NEG	
TJ-SS-SD1	2/10/11	2210	1,300	663	**POS**	NEG	
TJ-SS-SD2	2/10/11	2220	20	644	NEG	NEG	
TJ-SS-PS2	2/10/11	2230	1,600,000	241,957	**POS**	**POS**	

Red = Exceedance **POS** = Positive NEG = Negative
Pump Station site highlighted in blue
*Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use.
** Water quality objective set by the San Diego Basin Plan for estuaries and coastal lagoons with REC-1 beneficial use and infrequent water contact.

6.4.2 Rhodamine Dye

Results from the Rhodamine Dye Study conducted between February 8 and 11, 2012 as part of the Special Study are provided in Table 6-8. Rhodamine dye was not detected at sampling stations located within the estuary during the three-day monitoring period, though its presence was detected in all samples taken from the pump station. Lack of rhodamine dye the estuary indicates that the City's sewage infrastructure along Seacoast Drive during the monitoring period was intact and not leaking into the estuary either through subsurface flows or from the two storm drain outfalls.

Table 6-8. Seacoast Drive Special Study - Rhodamine Dye Study Results

Station	Date & Time Placed	Date & Time Collected	RWT	
			Peak nm	Concentration (ppb)
TJ-SS-E1-BG	2/7/11 2355	2/8/11 0330	ND	ND
TJ-SS-E1-A	2/8/11 0330	2/8/11 1040	ND	ND
TJ-SS-E1-B	2/8/11 1040	2/9/11 1040	ND	ND
TJ-SS-E1-C	2/9/11 1040	2/10/11 1040	ND	ND
TJ-SS-E1-D	2/10/11 1040	2/11/11 1345	ND	ND
TJ-SS-E2-BG	2/7/11 1140	2/8/11 0345	ND	ND
TJ-SS-E2-A	2/8/11 0345	2/8/11 1055	ND	ND
TJ-SS-E2-B	2/8/11 1055	2/9/11 1055	ND	ND
TJ-SS-E2-C	2/9/11 1055	2/10/11 1430	ND	ND
TJ-SS-E2-D	2/10/11 1430	2/11/11 1255	ND	ND
TJ-SS-SD1-BG	2/7/11 1140	2/8/11 0345	ND	ND
TJ-SS-SD1-A	2/8/11 0345	2/8/11 1040	ND	ND
TJ-SS-SD1-B	2/8/11 1040	2/9/11 1040	ND	ND
TJ-SS-SD1-C	2/9/11 1040	2/10/11 1045	ND	ND
TJ-SS-SD1-D	2/10/11 1045	2/11/11 1345	ND	ND
TJ-SS-SD2-BG	2/7/11 1300	2/8/11 0350	ND	ND
TJ-SS-SD2-A	2/8/11 0350	2/8/11 1055	ND	ND
TJ-SS-SD2-B	2/8/11 1055	2/9/11 1055	ND	ND
TJ-SS-SD2-C	2/9/11 1055	2/10/11 1055	ND	ND
TJ-SS-SD2-D	2/10/11 1055	2/11/11 1355	ND	ND
TJ-SS-PS2-BG	2/7/11 1300	2/8/11 0340	ND	ND
TJ-SS-PS2-A	2/8/11 0340	2/8/11 1030	567.6	41,500
TJ-SS-PS2-B	2/8/11 1030	2/9/11 1030	568.2	9,650
TJ-SS-PS2-C	2/9/11 1030	2/10/11 1030	568.1	7,950
TJ-SS-PS2-D	2/10/11 1030	2/11/11 1420	568.7	8,760

Detection of rhodamine WT (RWT) dye highlighted in red. Only samples taken from the pump station (PS2) had detectable levels of rhodamine.
ND = Not Detected

6.5 Discussion

The results of the Seacoast Drive Special Study indicate that the potential presence of human fecal contamination indicated from positive human-specific *Bacteroides* results in the estuary along Seacoast Drive in July, 2010, was no longer present in the estuary after the City sealed the Seacoast Drive sewage infrastructure. This conclusion is based upon monitoring results conducted in February, 2011 as part of the Special Study, which failed to detect human-specific *Bacteroides* in any of the grab samples taken from the estuary and near storm drain outfalls. Follow up monitoring conducted within the estuary near Seacoast Drive by Weston in September, 2011 as part of the Sanitary Surveys supports this conclusion. Results from this monitoring effort show that concentrations of fecal coliforms and enterococci at estuary sites adjacent to Seacoast Drive (see Figure 6-1) were well below water quality objectives and in many cases below reporting limits (Table 6-9). In addition, none of the samples collected in the September, 2011 survey, after the sewage infrastructure had been re-lined, were positive for human-specific *Bacteroides*. This includes sites located adjacent to Seacoast Drive (summarized in Table 6-9) as well as numerous other sites throughout the estuary (See Section 4).

Table 6-9. Sanitary Survey 3 Results after Re-lining of Seacoast Drive Sewage Infrastructure - Estuary Sites Adjacent to Seacoast Drive (September 2011)

Station and Sample ID	Sample Date	Sample Time	Fecal Coliforms (MPN / 100 mL)	Enterococci (MPN / 100 mL)	*Bacteroides*	
			WQO = 400*	WQO = 500**	General	Human
Estuary Sites Adjacent to Seacoast Drive						
TJ-SS3-301-1	9/2/11	0730	< 20	20	POS	NEG
TJ-SS3-33-1	9/2/11	0755	20	< 10	POS	NEG
TJ-SS3-32-1	9/2/11	0815	< 20	31	NEG	NEG
TJ-SS3-301-2	9/2/11	0955	< 20	10	NEG	NEG
TJ-SS3-33-2	9/2/11	1010	20	10	POS	NEG
TJ-SS3-32-2	9/2/11	1025	< 20	20	POS	NEG
TJ-SS3-301-3	9/2/11	1130	< 20	< 10	POS	NEG
TJ-SS3-33-3	9/2/11	1145	< 20	< 10	POS	NEG
TJ-SS3-32-3	9/2/11	1200	< 20	< 10	POS	NEG
TJ-SS3-301-4	9/2/11	1415	70	10	POS	NEG
TJ-SS3-33-4	9/2/11	1425	< 20	< 10	POS	NEG
TJ-SS3-32-4	9/2/11	1435	20	< 10	POS	NEG
TJ-SS3-301-5	9/2/11	1640	< 20	10	POS	NEG
TJ-SS3-33-5	9/2/11	1650	< 20	< 10	POS	NEG
TJ-SS3-32-5	9/2/11	1655	20	< 10	POS	NEG
TJ-SS3-301-6	9/2/11	1855	< 20	52	POS	NEG
TJ-SS3-33-6	9/2/11	1840	40	10	POS	NEG
TJ-SS3-32-6	9/2/11	1830	20	20	POS	NEG

*Water quality objective set by the San Diego Basin Plan for estuaries & coastal lagoons with REC-1 beneficial use.
** Water quality objective set by the San Diego Basin Plan for estuaries & coastal lagoons with REC-1 beneficial use and infrequent water contact.

The Rhodamine Dye Study conducted within the City's sewer line and pump station as part of the Special Study indicates sewage from the municipal system along Seacoast Drive is not leaking into the estuary either through subsurface flows or from the two storm drain outfalls. Although rhodamine dye was measured within the sewer pump station, rhodamine dye was not detected at any of the estuary sites. These results also suggest that the sewage infrastructure along Seacoast Drive is not a source of fecal contamination to the estuary and that repairs performed by the City in January, 2011 were successful in eliminating any leaks that may have existed.

While *Bacteroides* from human sources were not detected within the estuary during dry weather monitoring conducted for the Special Study in February 2011, exceedances of water quality objectives for REC-1 (marine waters with limited contact) did occur for fecal coliform and enterococci. These findings indicate that there may be fecal contamination within the estuary near Seacoast Drive during winter dry weather conditions, though long-term data suggests that past contamination is probably episodic and/or seasonal. Since riverine input to the estuary during dry weather is minimal, additional source identification studies may be needed to locate potential point source and non-point sources located near or within the estuary near Seacoast Drive. Potential sources could include feral, domesticated and/or wild animals living near and within the estuary, as well as the relatively large bird population that includes both year round and seasonal populations. Serving as a critical stopover on the Pacific Flyway, the estuary receives an influx of migratory bird species during the winter months, which could account for the relatively high levels of fecal coliforms and enterococci detected during the monitoring efforts conducted in February, 2011. Bacterial re-growth could also be contributing to elevated levels of indicator bacteria. Fate and transport studies, during both dry and wet weather conditions, aimed at specific indicator bacterial organisms and bacterial "finger printing" may compliment source identification studies aimed at identifying contamination and determining subsequent risk to public health and avoiding beach closures based upon assumed risk.

Coastal processes within the border region may also contribute to bacterial contamination loading along Imperial Beach and within the estuary from both point and non-point sources located within the Pacific Ocean during both dry and wet weather conditions. Potential sources of fecal material within the Pacific Ocean include outfalls located offshore of San Diego and Tijuana, as well as contamination caused by direct discharges from sources located along the coast in Northern Baja California and transported north by ocean currents. Further studies may be needed to better quantify and qualify bacteria loading from these sources and their residency times within the estuary during both dry and wet weather conditions.

7.0 GROUNDWATER SPECIAL STUDY

7.1 Background

Transportation of microbes, particularly viruses, through groundwater has been well studied with results that suggest that groundwater may act as an effective mechanism for pathogen transport. This project element was designed and implemented in order to assess the presence of indicator bacteria as well as human-specific *Bacteroides* and enterovirus in groundwater within the western portion of the Tijuana River Watershed and to assess the extent to which groundwater may impact surface waters within the estuary.

7.1.1 Tijuana Soils

The soils in the Tijuana River Valley on the U.S. side of the border are characterized by varying graded fines (coarse sands with medium to low amounts of silts and clays) and rocky zones composed of gravels, cobbles, and localized boulders (Weston, 2007).

In this Section, soils in the western portion of the Tijuana River Watershed were classified in terms of estimated water infiltration because water infiltration has a significant impact on groundwater flow and the potential for transport of microorganisms (*e.g.*, bacteria and viruses). Soils were assigned to one of four groups according to the rate of water infiltration (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

- **Group A –** Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
- **Group B –** Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- **Group C –** Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- **Group D –** Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

In general, the soils in the western portion of the watershed (the area of interest in this study) are characterized by Group D soils with a very slow infiltration rate (denoted by blue color in Figure 7-1). However, the area associated with the riverbed of the mainstem Tijuana River are characterized by Group A and B type soils, which suggests high and moderate infiltration rates, respectively. Higher infiltration rates associated with the riverbed may allow for potential contamination of groundwater during storm events when human sewage has been documented in the mainstem of the river as it crosses the U.S./Mexico Border.

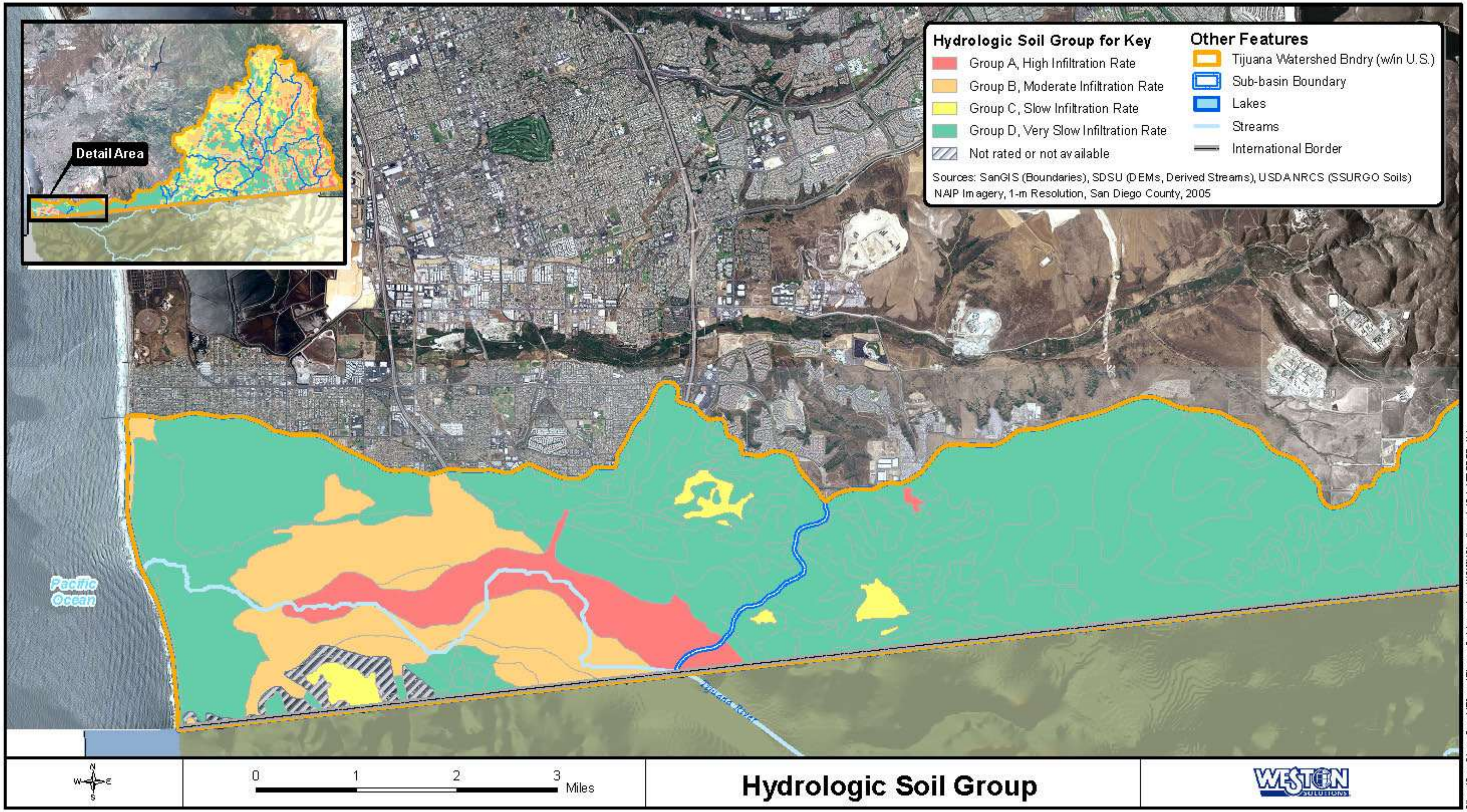


Figure 7-1. Tijuana River Watershed Soils – Western U.S. Portion of Watershed

7.1.2 Tijuana Groundwater Basin

The Tijuana Groundwater Basin lies below the portion of the Tijuana River Valley within the US portion of the watershed. The basin's southern boundary is the international border with Mexico. The eastern and northern boundaries are the contacts with semi-permeable Pleistocene and Pliocene marine deposits (Figure 7-1). The western boundary is the Pacific Ocean (California's Groundwater Bulletin 118).

Water levels have been shown to have declined in the alluvial aquifer during the 1950s through the early 1970s. This allowed seawater to enter the alluvial aquifer and move eastward, leading to a degradation of the groundwater quality and reducing the productivity of agriculture in the western part of the valley (Dudek, 1994). Changes in groundwater pumping in the 1970s allowed water levels to increase once more so that by the early 1990s, groundwater had resumed its westerly flow direction (Dudek, 1994).

Water quality of groundwater in the U.S portion of the Tijuana River Valley is characterized by high levels of dissolved solids and sodium chloride. The TDS content for this water typically ranges from 1,120 to 3,620 mg/L (Izbicki, 1985). Groundwater in the San Diego Formation has high sodium chloride content, and TDS content ranges from 380 to 2,360 mg/L (Izbicki, 1985). It is rated inferior for domestic drinking water due to high sulfate and fluoride concentrations (SDSU, 2005). This has been attributed to seawater intrusion, leakage from the San Diego formation, sewage from San Ysidro, and irrigation recharge. On the basis of this information it can be assumed that the groundwater flow, with no restrictions on recharge, or removal for agriculture, could allow for the transport of potential pollutants through the alluvial sediments from the east to the west and from there into the Pacific Ocean.

7.1.3 Groundwater Monitoring Wells within the Tijuana River Estuary

The U.S. Boundary Water Commission (USIBWC) has historically maintained 16 groundwater monitoring wells within the U.S portion of the TRW (Figure 7-2). These groundwater monitoring wells were originally constructed to assess water quality prior to and during the construction of the South Bay Ocean Outfall (SBOO) pipeline which was completed in 1998. The wells have historically been assessed for salinity, soil moisture (vadose wells), and elevation of the water table in feet above sea level (Table 7-1).

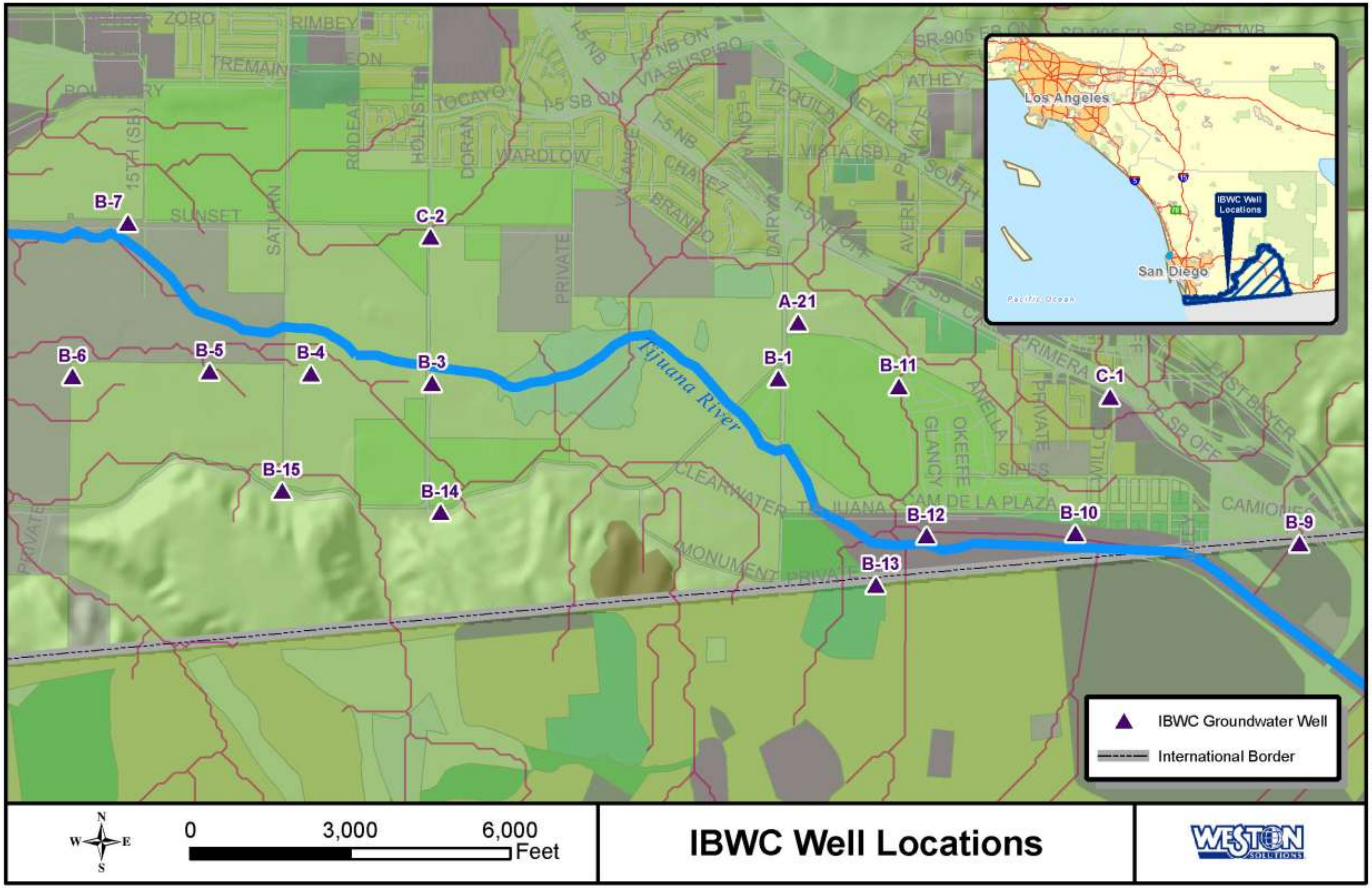


Figure 7-2. Location of USIBWC Groundwater Monitoring Sites

Groundwater elevation and salinity data from these wells are presented in Table 7-1 and indicate that groundwater wells closest to the Tijuana River and Pacific Ocean have the highest water elevation. Salinity does not appear to vary significantly between locations, suggesting that recharge from the Pacific Ocean is not significant.

Table 7-1. Groundwater Elevation and Salinity at USIBWC Monitoring Wells

Site ID	Average Elevation (feet above mean sea level)	Average Salinity (mmhos/cm)
B-1	24.57	–
B-3	14.05	2.91 and 3.03
B-4	11.09	–
B-5	9.10	2.76 and 3.07
B- 6	6.62	–
B-7	5.45	–
B-9	43.51	–
B-10	32.36	–
B-11	29.21	2.24 and 1.73
B-13	30.74	–
B-14	38.41	–
B-15	16.94	–
A-21	-	2.75

The moisture content assessment of the vadose zone around the USIBWC groundwater wells (Table 7-2) indicates that soil moisture increases toward the western portion of the estuary.

Table 7-2. Soil Moisture Content at USIBWC Groundwater Wells

Measurement Depth (feet)	Percentage Water by Volume					
	Well B-1	Well B-3	Well B-4	Well B-5	Well B-6	Well B-7
2	7.82	11.07	22.20	23.72	22.67	8.75
4	8.51	10.71	27.00	27.15	30.82	3.86
6	5.93	11.36	-	-	-	4.32
8	5.72	-	-	-	-	-
10	7.85	-	-	-	-	-

While there is evidence of pathogen presence in the surface waters of the Tijuana River Estuary (Gersberg and Brooks, 2006), no bacteriological data were available from groundwater wells. Based on this data gap, one important recommendation from the review of literature was to assess the impact of groundwater as a transport mechanism in the TRW. These data could then provide important information regarding the mechanism of bacterial and viral transport in the watershed.

With the presence of groundwater wells and records which established their suitability for monitoring, a study was proposed to use these as the sampling locations for regular water quality monitoring and sample collections. Of these 16 groundwater monitoring wells, five were selected for regular monitoring. The location and characteristics of the wells are presented in Section 7.3.

7.1.4 Groundwater Contamination as a Potential Public Health Risk

The following section presents an overview of the complex fate and transport of microbes in groundwater. The study design for the TRW groundwater involved assessment of both bacterial presence (indicator bacteria and human-specific *Bacteroides*) and virus presence (enterovirus). An understanding of the relevance of these microbes in groundwater assessment is important when reviewing the results of the study in terms of public health risk.

The fate and transport of microbes in groundwater are influenced by the physicochemical properties of the microbe and of the groundwater/aquifer media. In a review of the literature, Robertson and Edberg (1997) determined that the key properties of the groundwater system in determining fate and transport included flow velocity, aquifer grain (or pore) size, porosity, organic content, temperature, pH, and other chemical characteristics of water and mineral composition. The key characteristics of the microbe included size, inactivation (die-off) rate, and surface electrostatic properties, as well as individual characteristics based on species and age.

7.1.4.1 Properties of Groundwater Affecting Fate and Transport

Survival rate and transport of pathogens are the two key mechanisms that determine whether groundwater contamination by microbes occurs. The survival rate and transport of potential pathogens is influenced by a number of characteristics including:

- **Temperature**: Higher temperatures (above 20 degrees C) lead to increased bacterial and virus die-off (John and Rose, 2005)
- **Hydrology: t**he hydrology of the groundwater system including water input volumes and flow rates. Higher flow rates lead to faster and further migration of pollutants.
- **Grain properties**: the physical properties of soil in the system including hydrophobicity of the soil, grain or particle size impact microbe filtration. The more hydrophobic a soil, the more microbial adherence may occur, while smaller grain sizes in soil may cause decreases in transport distances.
- **Pore size:** the structure of the surrounding soils and their interactions with the water, including pore size, path length and friction impact microbial transport. Larger pore sizes, shorter path lengths and less friction all provide optimal transport through groundwater for microbes (Fallon and Perry, 1996).
- **Nutrient presence: C**hemical properties of water and soil in the system, including nutrient content can cause increases in biomass which in turn increase likely predation, and reduce transportation. Conversely, nutrients may allow for proliferation of indicator bacteria which may contribute to false positive public health assessments.
- **Filtration versus die-off:** Bacterial removal may be through either filtration or die-off in a groundwater system. Research suggests that, in general, viruses may be transported significantly further in groundwater systems than bacteria or protozoa, based on size and surface properties (Robertson and Edberg (1997). Research has suggested that bacteria are removed primarily through filtration (87-88%) and partially by die-off (12-13%). Conversely, virus removal occurs due to both die-off (45%) and filtration (55%) (Pang et al., 2004).

7.1.4.2 Microbe Presence in Groundwater and its Significance

The inactivation or die-off rate is usually the most important factor governing how far microbes can migrate in significant numbers in groundwater. Typical half-lives of microbes in groundwater range from a few hours to a few weeks (Robertson and Edberg (1997) but have been shown, under laboratory controlled conditions to be much longer (de Roda Husman et al., 2008).

Examples of maximum reported migration distances of microbes in groundwater include:

- bacteria, 600 m in a sandy aquifer:
- viruses, 1,000 to 1,600 m in channeled limestones and 250 to 408 m in glacial silt-sand aquifers;

Viruses present an especially important human health risk when associated with groundwater. Due to their smaller size, surface properties, longevity and resistance to inactivation (Hijnen et al., 2006), viruses can generally travel farther, for longer and cause infection in hosts with lower infective dose. In addition, viruses may cause waterborne diseases (such as meningitis and poliomyelitis) in a host that are more serious than common diseases caused by bacteria (such as gastroenteritis).

Virus Survival: A study of active and inactive enterovirus in artificial groundwater found survival of active virus for up to 150 days (at 22 degrees Celsius) or 400 days (at 4 degrees Celsius) while total virus concentrations (*i.e.*, active and inactive genome presence) remained constant (de Roda Husman et al., 2008). These results, while undertaken in a controlled, predator-free laboratory, demonstrate the longevity that viruses may present in groundwater systems. Other studies have also shown viruses have a temperature dependency, with greater inactivation at temperatures above 20 degrees Celsius (John and Rose, 2005) (Yates et al., 1985).

In a study undertaken in Newport Beach, California, seasonal differences were found in detection of viruses in marine receiving waters. Human adenoviruses and enteroviruses were detected by PCR in approximately 5% of samples collected in the summer (dry weather) but only once in wet weather (Jiang et al., 2007).

Conversely coliform bacteria die off in groundwater did not show the temperature dependency of viruses in a study by John and Rose (2005). They attributed this to a complex interplay of inactivation and reproduction subject to influences from native groundwater organisms, temperature, and water chemistry. The presence of native microorganisms was also found to negatively impact *E. coli* survival more so than viruses (John and Rose, 2005).

7.2 Study Questions

During the development of this special study, two study questions were proposed to assess the role of groundwater in the fate and transport of microbes in the TRW:

1. **Is groundwater a source of microbes to the estuary?**
2. **What is the distribution of bacteria concentrations in groundwater in the western portion of the watershed?**

In order to answer these questions, it was proposed that regular monitoring be undertaken at five of the 16 USIBWC groundwater wells, with sampling to include microbiological parameters as well as chemistry and physical water quality characteristics. An additional integral element of this study was the investigation into the possible presence of viruses in the groundwater. To this end, enterovirus was chosen as an indicator of viral pathogen presence and sampling was conducted accordingly.

7.3 Methods

7.3.1 Field Methods

Of the 16 USIBWC groundwater monitoring wells, five were chosen for monitoring in the Tijuana River Bacterial Source Identification Study (Figure 7-3).

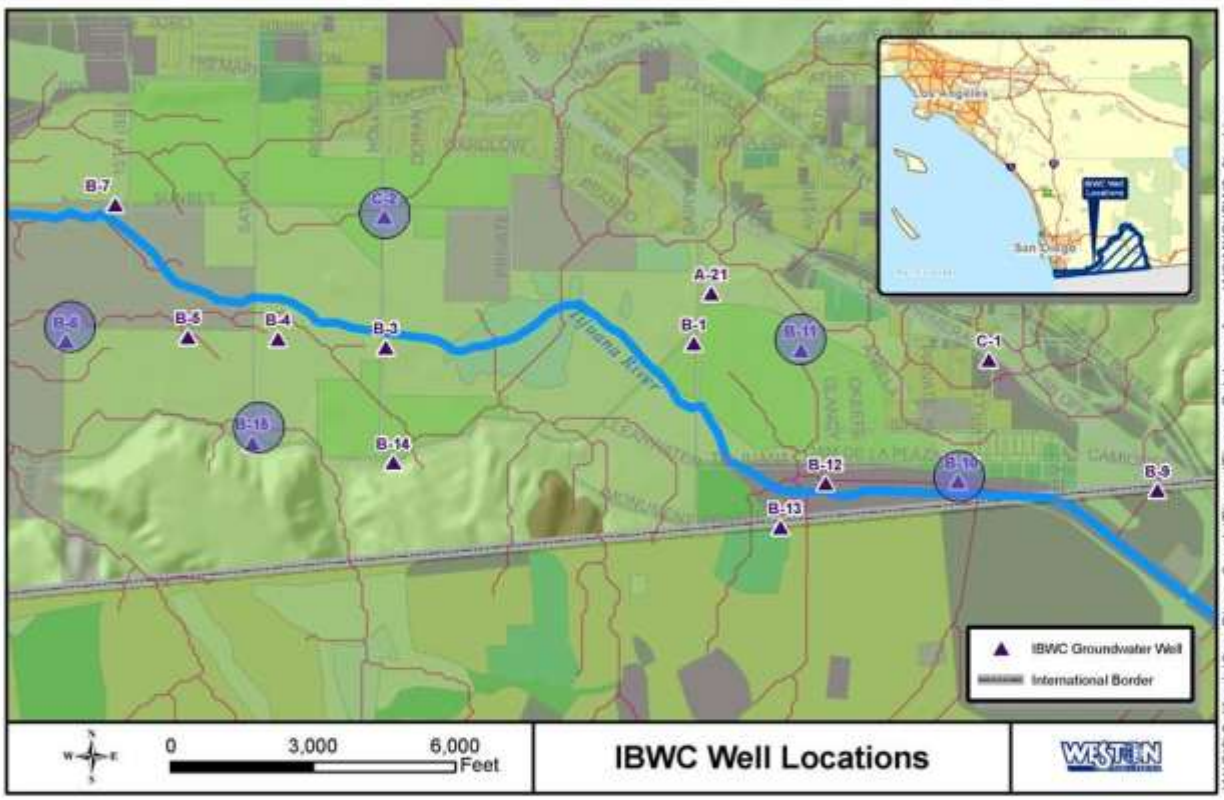


Figure 7-3. Groundwater Wells Monitored, 2010-2011 Study

These five wells were B-10, B-11, C-2, B-15, and B-6, listed in an east to west direction. The well closest to the Tijuana River and to the International Border was B-10. Well locations and characteristics are summarized in Table 7-3.

Table 7-3. Location of Groundwater Study Sites

Site	Latitude	Longitude	Well Type
B-10	32.542318	-117.043668	Single
B-11	32.551107	-117.055244	Cluster
C-2	32.558032	-117.084387	Single
B-15	32.544612	-117.092534	Single
B-6	32.557445	-117.108270	Cluster

7.3.1.1 Sample Collection

Samples were collected from each of the five groundwater monitoring wells during seven events. Samples were analyzed for nutrients, general chemistry, bacteria, presence/absence of *Bacteroides* (general and human) and viral presence/absence (enterovirus). Sampling occurred on August 31, October 14, and November 18, 2010 and on February 1, March 2, July 13, and December 14, 2011.

Each sample collection consisted of measurements of well depth to ground water, three-volume purges of the well with a submersible pump, and sample collection using a bailer. Purging was accomplished by using the pump to remove groundwater from the well at a low flow rate in order to minimize the impact of the purging process on groundwater chemistry. Initial depth data was used to verify that purging rates did not exceed the recharge capacity of the well. During purging, water quality parameters were measured to assess hydraulic effects of the purging. The submersible pump was decontaminated before each purge to prevent cross-contamination between wells. Purge volumes varied with seasonality but generally totaled 48 to 72 gallons per well during each event. The exception was well B-6, from which 16 to 17 gallons were purged during each event.

At each sampling station, field water quality measurements were also recorded using a YSI 6920 water quality data sonde. Field measurements included temperature, conductivity, dissolved oxygen, pH, turbidity, oxidation/reduction potential (ORP), and flow rate. In addition, the appearances of the purged and collected samples were described and static water levels and purge volumes were recorded. All data was recorded on a field data log.

7.3.1.2 Sample Handling

Samples for chemical and bacteriological analyses, *Bacteroides*, and enterovirus were collected, handled, and transported in accordance with the methods presented in Section 3.7. During each sampling event, a field duplicate sample and a field blank sample were also collected in order to ensure that no contamination originated from the collection, transport, storage, or processing of samples.

7.3.2 Analytical Methods

7.3.2.1 Microbial Analysis

Samples for enumeration of fecal indicator bacteria (total and fecal coliforms and enterococci) were processed in accordance with the methods described in Section 3.7.1. The analytes measured and associated analytical methods are summarized below in Table 7-4.

Table 7-4. Analytical Methods for Standard Microbiology

Analyte	Analytical Method		Achievable Laboratory Limits
	Analytical Method/SOP	Modified for Method (Yes/No)	MDLs (1)
Total coliforms	SM 9221B	No	2 MPN/100 mL
Fecal coliforms	SM 9221 E	No	2 MPN/100 mL
Enterococci	Enterolert	No	1 MPN/100 mL

In addition, the polymerase chain reaction technique (PCR) was used to assess presence/absence of general and human-specific *Bacteroides* and enterovirus in accordance with the methods described in Section 3.7.2. The analytes measured and associated analytical methods are summarized below in Table 7-5.

Table 7-5. Molecular Laboratory Analytical Methods

Analyte	Analytical Method		Laboratory
	Analytical Method/SOP	Modified for Method (Yes/No)	
Bacteroides presence/absence	LAB068.00	–	Weston
Enterovirus presence/absence	Noble et al. 2006	–	Stanford University

7.3.2.2 Chemical Analysis

Samples for chemical analysis were processed in accordance with the methods described in Section 3.7.3. The analytes measured and associated analytical methods are summarized below in Table 7-6.

Table 7-6. Chemistry Laboratory Analytical Methods

Analyte	Analytical Method		Achievable Laboratory Limits
	Analytical Method/SOP	Modified for Method (Yes/No)	MDLs (1)
TSS	SM 2540-D	No	0.5 mg/L
Ammonia-N	SM 4500-NH_3 B,C	No	0.01 mg/L
Nitrite-N	SM 4500 NO2 B	No	0.01 mg/L
Nitrate-N	SM 4500 NO3 E	No	0.01 mg/L
Orthophosphate-P	SM 4500 P E	No	0.01 mg/L

7.4 Results

7.4.1 Microbial Analysis

7.4.1.1 Total Coliforms

Total coliform concentrations measured in groundwater samples are presented in Table 7-7. The highest concentration observed during each of the seven sampling events was measured at Well B-10, the sampling location closest to both the Tijuana River and the International Border. Total coliform concentrations at the two westernmost sampling locations, wells B-15 and B-6, were at or below the laboratory reporting limit during all sampling events.

Table 7-7. Groundwater Study Total Coliform Concentrations (MPN/100 mL) with Comparisons to Benchmark

Sampling Event - Date	Well				
	B-10	B-11	C-2	B-15	B-6
1 – 08/31/10	**500,000**	2,200	110	<20	<20
2 – 10/14/10	170* (T)	40 (T)	<20 (T)	<20 (T)	<20
3 – 11/18/10	300	300	<20	20	<20
4 – 02/01/11	4,412"	500	300	<20	20
5 – 03/02/11	5,000	40	40	<20	<20
6 – 07/13/11	2,300	300	800	<20	<20
7 – 12/14/11	500	<20	<20	20	<20
Values in shaded cells were above the Basin Plan benchmark for surface waters of 10,000 MPN/100mL.					

There appeared to be a spatial gradient in bacterial and nutrient concentrations among the groundwater wells monitored, with relatively high concentrations in groundwater closest to the U.S. / Mexico Border (Site B-10) and lower concentrations found in groundwater closest to the Tijuana River Estuary (Site B-6) (Figure 7-4).

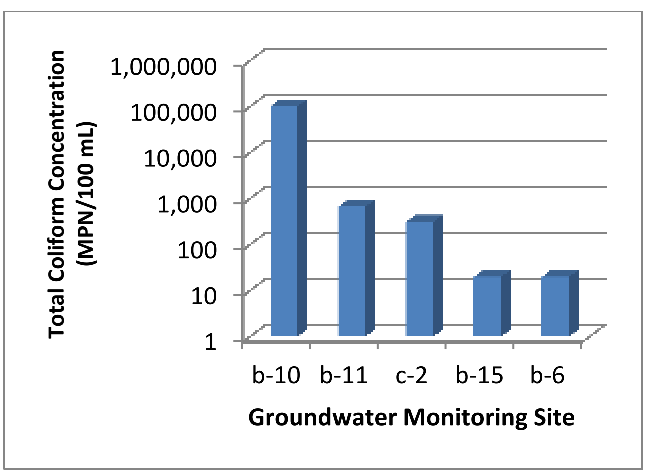


Figure 7-4. Mean Total Coliform Concentrations in Groundwater Wells

7.4.1.2 Fecal Coliforms

Fecal coliform concentrations measured in groundwater samples are presented in Table 7-8. Concentrations were at or below the reporting limit for every sample tested.

Table 7-8. Groundwater Study Fecal Coliform Concentrations (MPN/100 mL) with Comparisons to Benchmark

Sampling Event - Date	Well				
	B-10	B-11	C-2	B-15	B-6
1 – 08/31/10	<20	20	<20	<20	<20
2 – 10/14/10	<20 (T)	<20 (T)	<20 (T)	<20 (T)	<20
3 – 11/18/10	<20	<20	<20	<20	<20
4 – 02/01/11	<20	<20	20	<20	<20
5 – 03/02/11	<20	<20	<20	<20	<20
6 – 07/13/11	<20	<20	<20	<20	<20
7 – 12/14/11	<20	<20	<20	<20	<20

7.4.1.3 Enterococci

Enterococcus concentrations measured in groundwater samples are presented in Table 7-9. The highest concentrations observed were measured at wells B-10 and B-11. Enterococcus concentrations at the two westernmost sampling locations, wells B-15 and B-6, were generally at or below the laboratory reporting limit.

Table 7-9. Groundwater Study Enterococcus Concentrations (MPN/100 mL) with Comparisons to Benchmark

Sampling Event - Date	Well				
	B-10	B-11	C-2	B-15	B-6
1 – 08/31/10	20	**315**	120	<10	10
2 – 10/14/10	<10	<10	<10	<10	<10
3 – 11/18/10	<10	**173**	52	<10	41
4 – 02/01/11	<10	10	41	98	41
5 – 03/02/11	**712**	<10	120	<10	<10
6 – 07/13/11	**233**	**473**	146	<10	<10
7 – 12/14/11	10	31	<10	<10	<10
Values in shaded cells were above the Basin Plan benchmark for surface waters of 151 MPN/100mL.					

7.4.1.4 Bacteroides

The *Bacteroides* PCR assay provides a rapid way to determine the presence or absence of general or human fecal contamination in a particular water sample. In the *Bacteroides* PCR analysis, two specific molecular markers are used to characterize the bacterial DNA in a sample: a general marker, which indicates the presence of fecal bacteria from any warm blooded source, and a human marker, which indicates if the bacteria source is of human origin. Analysis of the groundwater study samples is provided below in Table 7-10. All samples collected from the groundwater monitoring wells were negative for the human-specific *Bacteroides* marker, which suggest, however, some samples were positive for the general *Bacteroides* marker. Wells B-10 and C-2 were positive for the general marker on August 31, 2010 and July 13, 2011. Well B-11 was positive for the general marker on October 14, 2010 Well B-15 was positive for the general marker on July 13, 2011. Well B-6, closest to the Pacific Ocean was negative for the general marker on all sampling events.

Table 7-10. Groundwater Study PCR Results (Presence/Absence)

Sampling Event / Date	Site									
	B-10		B-11		B-15		B-6		C-2	
	General	Human	General	Human	General	Human	General	Human	General	Human
1 – 08/31/10	**Pos**	Neg	Neg	Neg	Neg	Neg	Neg	Neg	**Pos**	Neg
2 – 10/14/10	Neg	Neg	**Pos**	Neg	Neg	Neg	Neg	Neg	Neg	Neg
3 – 11/18/10	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg
4 – 02/01/11	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg
5 – 03/02/11	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg
6 – 07/13/11	**Pos**	Neg	Neg	Neg	**Pos**	Neg	Neg	Neg	**Pos**	Neg
7 – 12/14/11	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg

Values shaded in purple indicate the presence of the general *Bacteroides* marker.
No samples were positive for the human-specific *Bacteroides* marker.

7.4.1.5 Enterovirus

Enterovirus was found in 3 out of the 35 ground water samples submitted to the Stanford laboratory over the course of the study: Well B-15 on October 14, 2010 and Well B-6 on August 31, 2010 and October 14, 2010. The number of enterovirus copies found in each sample was 0.117, 0.407, and 2.07 copies/ml filtered, respectively. All of the samples analyzed by the Stanford laboratory were run in triplicate and for the first two samples identified as positive above (Well B-15 on October 14, 2010 and Well B-6 on August 31, 2010), only one of the triplicate runs of each sample was positive for the enterovirus marker. This single Ct value was used to quantify the concentration in the sample. The third sample identified above (Well B-6 on October 14, 2010) was positive for the enterovirus marker in all three runs.

Table 7-11. Groundwater Study PCR Results (Presence/Absence)

Sampling Event / Date	Site				
	B-10	B-11	B-15	B-6	C-2
1 – 08/31/10	Neg	Neg	Neg	**Pos**	Neg
2 – 10/14/10	Neg	Neg	**Pos**	**Pos**	Neg
3 – 11/18/10	Neg	Neg	Neg	Neg	Neg
4 – 02/01/11	Neg	Neg	Neg	Neg	Neg
5 – 03/02/11	Neg	Neg	Neg	Neg	Neg
6 – 07/13/11	Neg	Neg	Neg	Neg	Neg
7 – 12/14/11	Neg	Neg	Neg	Neg	Neg

7.4.2 Chemical Analysis

Grab samples collected at each of the seven groundwater wells were analyzed for physical chemistry (parameters measured in the field) and general chemistry (parameters measured in the laboratory: ammonia, nutrients and total suspended solids (TSS)). Results of the chemical analyses are presented by sampling location in Table 7-12 to Table 7-14. Because the purpose of the chemistry analyses of well water samples was to help assess the groundwater / surface water interactions, groundwater constituent concentrations were compared to surface water quality benchmarks outlined in the Basin Plan for the Tijuana River. Values highlighted in green in the following tables were outside of the benchmark for a given constituent.

Among the physical chemistry parameters monitored in the groundwater special study, dissolved oxygen (DO) concentrations were below the water quality benchmark (> 5.0 mg/L) for all samples collected from all monitoring wells. This is not surprising, as groundwater DO concentrations are typically much lower than surface water concentrations due to the lack of photosynthesis and water to air interactions below the surface of the ground.

The hydrogen ion concentration (pH) of the groundwater samples were compared to the water quality objective for pH for inland surface waters, which has a designated range of 6.5 – 9.0. All samples collected from the monitoring wells were within this range except those collected from Well B-15 (Table 7-15), where pH during all sampling events was less than 6.5.

Salinity is a particularly important physical chemistry parameter when assessing potential groundwater / surface water interactions in an estuary because it provides a good indication of seawater intrusion on groundwater resources. Over the course of the groundwater special study, salinity ranged from 1.09 to 2.53 parts per thousand (ppt) (Table 7-12 through Table 7-15). This narrow range of salinities among sites and sampling events and relatively low values (salinity of seawater typically ranges from 32 to 34 ppt) suggests that there is little if any interaction between seawater in the ocean and groundwater at the sites monitored. Well B-6 is located approximately 1.3 miles from the mouth of the Tijuana River and is the closest monitoring well to the ocean of the five sites monitored. Although groundwater salinity at Well B-6 would be most expected to be influenced by seawater intrusion, salinity at this site ranged from 1.14 to 1.50 ppt (Table 7-16), which is much lower than what would be expected if there were significant groundwater / seawater interactions at this location in the estuary.

Concentrations of general chemistry parameters were all below water quality benchmarks for surface waters, except at Well B-11, where the TSS concentration was greater than the benchmark on February 1, 2011 and the Nitrate concentration was greater than the benchmark on December 14, 2011. These relatively low ammonia and nutrient concentrations suggests that surface water flows during storm events in the Tijuana River, which have been shown to contain elevated levels of ammonia and nutrients may not be impacting groundwater resources, based on the data from the sites monitored.

Table 7-12. Results of Chemical Analyses, Well B-10

Parameter	Units	Tijuana River Groundwater Well B-10						
		08/31/10	10/14/10	11/18/10	02/01/11	07/13/11	03/02/11	12/14/11
Physical Chemistry								
Conductivity	µS/cm	2,672	2,596	2,457	2,593	2,535	2,174	2,811
DO	mg/L	**1.9**	**2.11**	**1.79**	**1.62**	**2.76**	**1.51**	**1.55**
pH	pH units	6.61	6.98	6.98	7.04	6.94	6.88	6.9
Salinity	ppt	1.51	1.32	1.09	1.35	1.31	1.12	1.46
Temperature	Celsius	22.6	21.07	21.27	20.68	22.08	19.26	20.82
Turbidity	NTU	9.4	0	2	1.2	0.4	0.1	0.6
General Chemistry								
Ammonia-N	mg/L	0.14	0.15	0.21	0.12	0.18	0.13	0.31
Nitrate-N	mg/L	3.82	7.55	2.88	0.38	1.52	0.12	3.75
Nitrite-N	mg/L	<0.05	0.38	<0.05	<0.05	<0.05	<0.05	0.08
Total Orthophosphate	mg/L	0.58	0.32	0.56	0.29	0.65	0.29	0.47
TSS	mg/L	NS	NS	NS	<20	22	<20	47

NS - not sampled
Values in green are outside of Basin Plan water quality benchmarks for surface waters.

Table 7-13. Results of Chemical Analyses, Well B-11

Parameter	Units	Tijuana River Groundwater Well B-11						
		08/31/10	10/14/10	11/18/10	02/01/11	03/02/11	07/13/11	12/14/11
Physical Chemistry								
Conductivity	µS/cm	3,638	3,895	4,023	4,307	4,349	3,464	4,703
Dissolved Oxygen	mg/L	**1.61**	**2.3**	**2.05**	**1.81**	**2.47**	**2.29**	**2.42**
pH	pH units	6.62	6.71	7.29	7.1	7.14	7.05	7.23
Salinity	ppt	2.01	2.21	2.28	2.30	2.32	1.82	2.53
Temperature	Celsius	22.61	21.29	21.42	21.46	21	21.66	20.71
Turbidity	NTU	9.4	0.7	0	2.4	0.3	0.1	1.4
General Chemistry								
Ammonia-N	mg/L	0.15	0.21	0.16	0.66	0.13	0.15	<0.1
Nitrate-N	mg/L	6.24	6.3	7.4	7.99	8.22	<0.05	**11.1**
Nitrite-N	mg/L	0.21	0.19	0.15	0.15	0.18	<0.05	0.18
Total Orthophosphate	mg/L	0.32	0.26	0.26	0.11	0.39	0.3	0.1
TSS	mg/L	NS	NS	NS	**106**	62	56	31

NS not sampled
Values in green are outside of Basin Plan water quality benchmarks for surface waters.

Table 7-14. Results of Chemical Analyses, Well C-2

Parameter	Units	Tijuana River Groundwater Well C-2						
		08/31/10	10/14/10	11/18/10	02/01/11	03/02/11	07/13/11	-12/14/11
Physical Chemistry								
Conductivity	µS/cm	2,300	2,233	2,086	2,296	2,356	2,308	2,572
Dissolved Oxygen	mg/L	2.78	1.54	1.49	1.06	1.47	1.78	1.7
pH	pH units	7.15	7	7.05	7.07	7.05	7.28	7.27
Salinity	ppt	1.21	1.19	1.12	1.18	1.22	1.19	1.33
Temperature	Celsius	20.82	20.29	20.63	20.77	20.01	20.82	20.91
Turbidity	NTU	0.1	1.3	0	0	0.5	0.3	0
General Chemistry								
Ammonia-N	mg/L	0.12	0.2	0.12	<0.1	0.12	0.23	<0.1
Nitrate-N	mg/L	0.15	<0.05	0.28	0.36	0.39	<0.05	0.06
Nitrite-N	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Orthophosphate	mg/L	0.09	0.05	0.05	0.06	0.08	0.06	<0.05
TSS	mg/L	NS	NS	NS	<20	<20	<20	<20
NS - not sampled. Values in green are outside of Basin Plan water quality benchmarks for surface waters.								

Table 7-15. Results of Chemical Analyses, Well B-15

Parameter	Units	Tijuana River Groundwater Well B-15						
		08/31/10	10/14/10	11/18/10	02/01/11	03/02/11	07/13/11	12/14/11
Physical Chemistry								
Conductivity	µS/cm	2,451	2,407	2,285	2,488	2,519	2,537	2,950
Dissolved Oxygen	mg/L	1.22	2.44	1.82	2.01	1.04	1.16	2.84
pH	pH units	5.87	6.33	6.25	6.32	6.19	6.4	6.13
Salinity	ppt	1.39	1.24	1.12	1.28	1.30	1.31	1.54
Temperature	Celsius	22.15	21.05	20.69	21.03	20.97	23.6	20.97
Turbidity	NTU	1.4	0.8	0.8	1.5	1.3	0.1	0
General Chemistry								
Ammonia-N	mg/L	0.1	0.14	0.15	0.1	<0.1	0.21	<0.1
Nitrate-N	mg/L	0.41	0.16	0.58	0.37	0.28	<0.05	0.08
Nitrite-N	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Orthophosphate	mg/L	0.28	0.21	0.34	0.38	0.26	0.22	0.19
TSS	mg/L	NS	NS	NS	<20	<20	<20	<20
NS - not sampled. Values in green are outside of Basin Plan water quality benchmarks for surface waters.								

Table 7-16. Results of Chemical Analyses, Well B-6

Parameter	Units	Tijuana River Groundwater Well B-6						
		08/31/10	10/14/10	11/18/10	02/01/11	03/02/11	07/13/11	12/14/11
Physical Chemistry								
Conductivity	µS/cm	2,564	2,509	2,368	2,595	2,623	2,534	2,869
Dissolved Oxygen	mg/L	**2.00**	**2.38**	**1.78**	**1.67**	**1.89**	**2.56**	**1.98**
pH	pH units	6.84	7.51	7.41	7.31	7.47	7.37	7.09
Salinity	ppt	1.30	1.25	1.14	1.35	1.36	1.31	1.50
Temperature	Celsius	20.39	19.73	19.46	19.72	19.61	20.32	19.42
Turbidity	NTU	.	3.7	0.8	0.7	7.4	2.2	0
General Chemistry								
Ammonia-N	mg/L	<0.1	0.42	0.17	0.18	0.24	0.29	0.23
Nitrate-N	mg/L	0.36	<0.05	0.06	0.24	<0.05	<0.05	0.1
Nitrite-N	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Orthophosphate	mg/L	0.31	0.29	0.38	0.24	1.51	0.74	0.27
TSS	mg/L	NS	NS	NS	<20	29	26	<20

NS - not sampled.
Values in green are outside of Basin Plan water quality benchmarks for surface waters.

7.5 Discussion

The purpose of this special study on groundwater was to answer the following study questions

1. **Is groundwater a source of microbes to the estuary?**
2. **What is the distribution of bacteria concentrations in groundwater in the western portion of the watershed?**

To address these questions, a set of five pre-existing groundwater wells in the Tijuana River Estuary were monitored over the course of approximately 16 months for indicator bacteria, water chemistry constituents indicative of sewage input, and the presence of human-specific *Bacteroides* and enterovirus (as indicators of human sewage). The following characteristics of the watershed suggested that groundwater could act as a source of bacteria to the estuary:

- the nature of the Tijuana River Groundwater Basin, where soil structure and recharge characteristics suggest the potential for high infiltration and a westerly migration of flows towards the Tijuana River Estuary and the Pacific Ocean;
- a potentially nutrient-rich water flow, from sewage derived sources, could contribute to microbial survival and even proliferation in groundwater;
- the significant potential for pathogen presence from poor wastewater infrastructure in Mexico;
- the documented presence of viruses in the surface waters of the estuary (Gersberg and Brooks, 2006). While not specifically identifying groundwater as the transport

mechanism, it is possible that viruses could be transported through alluvial soils to the estuary and the Pacific Ocean.

The groundwater special study relied on three lines of evidence to determine if these characteristics create an atmosphere conducive to groundwater transport of bacteria to the estuary: 1. indicator bacteria, 2. water chemistry, and 3. human-specific *Bacteroides* and enterovirus monitoring. The results of the special study suggest that concentrations of indicator bacteria were relatively low in groundwater among the monitored wells. With the exception of one sample, total coliform concentrations were close to the detection limit and fecal coliform concentrations were at or below the detection limit in all samples collected. Enterococcus concentrations were elevated in some samples, particularly in those collected from wells B-10- and B-11, which are closest to the U.S. / Mexico Border, but in general were less than the Basin Plan objective for surface waters. Taken together, the relatively low concentrations of indicator bacteria from the monitoring wells suggests that groundwater is an unlikely source of these bacteria to the receiving waters.

The water chemistry results also suggest that groundwater associated with the wells monitored had relatively low to moderate concentrations and were not indicative of levels seen in groundwater that is influenced by sewage. In order to compare the results obtained in this study with groundwater conditions elsewhere in the region, we used a system developed by the U.S. Geological Survey and the State Water Resources Control Board (Wright and Belitz, 2011) in the California Groundwater Ambient Monitoring and Assessment (GAMA) Program. This large-scale, regional program assessed water chemistry from 58 groundwater monitoring wells throughout the San Diego Drainages Hydrogeologic Province, using the database provided by the California Department of Public Health (CDPH). In order to compare concentrations of constituents on a broad regional scale, the study used a relative concentration for a variety of constituents, which is the concentration of a constituent measured from a given site divided by that constituent's water quality benchmark. Although the GAMA Program did not assess wells within the western portion of the Tijuana River Valley, the GAMA Program results provide a useful comparison of the data collected in our study to those elsewhere in the region for two constituents: nitrate and nitrite (other constituents measured in our study were not assessed in the GAMA Program). The measured concentrations obtained in the groundwater special study are presented with the relative concentrations for nitrate (measured concentration divided by 10 mg/L) and nitrite (measured concentration divided by 1.0 mg/L) in Table 7-17.

Table 7-17. Comparison of Nitrate and Nitrite Concentrations in Groundwater Wells to Relative Concentration Based on Water Quality Benchmark

Sampling Event / Date	Nitrate (mg/L)	Relative Concentration[1]	Nitrite (mg/L)	Relative Concentration[1]
Well B-10				
1 – 08/31/10	3.82	0.382	<0.05	0
2 – 10/14/10	7.55	0.755	0.38	0.38
3 – 11/18/10	2.88	0.288	<0.05	0
4 – 02/01/11	0.38	0.038	<0.05	0
5 – 03/02/11	1.52	0.152	<0.05	0
6 – 07/13/11	0.12	0.012	<0.05	0
7 – 12/14/11	3.75	0.375	0.08	0.08
Well B-11				
1 – 08/31/10	6.24	0.624	0.21	0.21
2 – 10/14/10	6.3	0.63	0.19	0.19
3 – 11/18/10	7.4	0.74	0.15	0.15
4 – 02/01/11	7.99	0.799	0.15	0.15
5 – 03/02/11	8.22	0.822	0.18	0.18
6 – 07/13/11	<0.05	0	<0.05	0
7 – 12/14/11	11.1	1.11	0.18	0.18
Well C-2				
1 – 08/31/10	0.15	0.015	<0.05	0
2 – 10/14/10	<0.05	0	<0.05	0
3 – 11/18/10	0.28	0.028	<0.05	0
4 – 02/01/11	0.36	0.036	<0.05	0
5 – 03/02/11	0.39	0.039	<0.05	0
6 – 07/13/11	<0.05	0	<0.05	0
7 – 12/14/11	0.06	0.006	<0.05	0
Well B-15				
1 – 08/31/10	0.41	0.41	<0.05	0
2 – 10/14/10	0.16	0.16	<0.05	0
3 – 11/18/10	0.58	0.58	<0.05	0
4 – 02/01/11	0.37	0.37	<0.05	0
5 – 03/02/11	0.28	0.28	<0.05	0
6 – 07/13/11	<0.05	<0.05	<0.05	0
7 – 12/14/11	0.08	0.08	<0.05	0
Well B-6				
1 – 08/31/10	0.36	0.036	<0.05	0
2 – 10/14/10	<0.05	0	<0.05	0
3 – 11/18/10	0.06	0.006	<0.05	0
4 – 02/01/11	0.24	0.024	<0.05	0
5 – 03/02/11	<0.05	0	<0.05	0
6 – 07/13/11	<0.05	0	<0.05	0
7 – 12/14/11	0.1	0.01	<0.05	0

[1] Relative Concentration is the measured concentration of the sample divided by the water quality benchmark (10 mg/L for nitrate and 1.0 mg /L for nitrite), based on system used by Wright and Belitz, 2011.

Red Cells indicate a High Relative Concentration of > 1.0
Yellow Cells indicate Medium Relative Concentration of > 0.1
Green Cells indicate Low Relative Concentration of < 0.1

Wright and Belitz (2011) used the following ranking system for comparing relative concentrations among sites: High = > 1.0, Moderate = > 0.1, and Low = < 0.1. Table 7-17 presents the results of the data collected from our study using the same system, where high relative concentrations of nitrate and nitrite are highlighted in red, medium relative concentrations are highlighted in yellow, and low relative concentrations are highlighted in green. Among the 35 samples collected in the groundwater special study, only one (2.8%) had a high relative concentration (nitrate in Well B-11 on December 14, 2011). This frequency is very similar to that found throughout the region in the GAMA Program, where 3.4% of samples had high relative nitrate concentrations and 0% had high relative nitrite concentrations. A total of 11 samples from Tijuana River monitoring wells had moderate relative nitrate relative concentrations and seven had moderate nitrite relative concentrations. All of these samples were taken from wells B-10 and B-11 closest to the U.S. / Mexico Border. The percentage of moderate relative concentrations for nitrate (31%) and nitrite (20%) were substantially greater than those documented in the GAMA Program (6.8% and 0% for nitrate and nitrite, respectively), suggesting that groundwater nitrate and nitrite concentrations at these locations may be elevated compared to conditions found elsewhere in the region. However, the low relative concentrations of nitrate and nitrite measured at the other monitoring wells closer to the estuary (wells C-2, B-15, and B-6) suggest that any potential contamination of groundwater at sites close to the border is not observed at sites further down gradient. These results suggest that potentially contaminated groundwater is not a likely source of contamination to the estuary.

The low concentrations of indicator bacteria and nutrients in groundwater closest to the estuary and the absence of human-specific *Bacteroides* throughout the study suggest that groundwater may not be a likely source of fecal contamination to the receiving waters of the estuary. The spatial gradient of decreasing concentrations of bacteria and nutrients in groundwater closest to the estuary also suggests that there is no clear pathway for microbes from somewhat elevated levels near the U.S. / Mexico Border to the estuary receiving waters. However, positive results for the enterovirus assay at the two sites closest to the estuary indicate the presence of human fecal contamination in groundwater at these sites. Thus, the majority of the data from this study suggest that groundwater is an unlikely source of microbes to the estuary receiving waters, but the positive enterovirus results indicate the potential for groundwater contamination and suggest that further investigations may be necessary to determine the potential impact to the estuary from groundwater sources.

8.0 GOAT CANYON DREDGED MATERIAL SPECIAL STUDY

8.1 Background

Goat Canyon is located at the southern end of the Tijuana River National Estuarine Research Reserve (TRNERR) in the western portion of the Tijuana River Watershed and spans the U.S. / Mexico Border. Ninety percent of the Canyon's 4.6-square-mile sub-watershed lies in Mexico, where the canyon is known as Cañon de los Laureles (Coastal Conservancy 2002). Previously a gravel quarry, Goat Canyon was acquired by public agencies to become part of the TRNERR. In recent decades, human-induced disturbance originating primarily upstream in Mexico has resulted in increased sedimentation in Goat Canyon and the Tijuana River Estuary. High sediment loads from this increased urbanization are exacerbated by the steep erodible slopes and concrete-lined stream channels of the watershed and have severely degraded the downstream estuary. An estimated 30 acres of intertidal wetlands in the estuary were lost by the mid 1980s (National Oceanic and Atmospheric Administration (NOAA), 2001).

In 1997, the Coastal Conservancy, the Southwest Wetlands Interpretive Association (SWIA), and the California Department of Parks and Recreation (DPR) responded to the increased sedimentation and habitat loss issues by beginning the planning process for the Goat Canyon Enhancement Project. The Enhancement Plan was developed between 1998 and 2002 to protect the coastal wetland habitat of the Tijuana River Estuary from further degradation and included strategies to reduce sediment flows to the Estuary. Between 2003 and 2005, two sediment basins were constructed in series within the upper floodplain of Goat Canyon to annually retain over 40,000 cubic yards (y^3) of sediment. As a result, sedimentation to downstream marsh habitats has been reduced. However, due to the location of the basins downstream from the urbanized and degraded watershed in Mexico, regular sediment removal and maintenance is required. This was made especially evident in the winter of 2005 when a series of large storms loaded Goat Canyon with sediments, which overflowed the retention basins and resulted in the loss of 18 acres of wetland habitat. Upstream maintenance across the border in Cañon de los Laureles will also be necessary and will focus on stormwater management and slope instability issues (DPR, United States Fish and Wildlife Service (USFWS) and NOAA, 2010).

The DPR maintains the Goat Canyon sediment retention basins in order to prevent the Tijuana River Estuary from becoming buried in sediment. Annual costs for dredging and disposal to material stockpiles have ranged from $200,000 to $1.2 million (Coastal Conservatory, 2010). Due to the expense of removal and disposal, beneficial reuses may provide an economical alternative. One of the beneficial uses which has been considered is beach replenishment in Imperial Beach, in close proximity to the Goat Canyon retention basins. The beaches in Imperial Beach and the vicinity have been depleted by erosion and are in need of restoration and maintenance. However, several issues arise when considering the Goat Canyon sediments for use in beach replenishment projects. Specifically, sediments from Goat Canyon contain a higher percentage of fine-grained materials than what is considered suitable for beach nourishment. Goat Canyon sediments have been measured at approximately 40 percent fines and 60 percent sand, but regulatory agencies generally follow an 80/20 rule of thumb limiting the percentage of fines to 20 percent for beach nourishment. The reasoning behind the adoption of this rule of thumb is that pollutants may attach to fines in quantities sufficient to cause environmental issues. The 80/20 rule is also applied to sediments which are not suspected to contain pollutants due to concerns regarding turbidity and burial of area habitats (United States Geological Survey (USGS), 2008). In addition, small clay and silt particles also offer a preferred adsorption material for suspended bacteria with higher surface-to-volume ratios and higher hydrophobicity. Higher hydrophobicity encourages nutrient adsorption to surfaces which in turn promotes bacterial chemotactic responses to the surface (Costerton et al., 1987).

A sediment fate and transport study was performed by the California Coastal Conservancy and the TRNERR in 2009 to investigate the feasibility of using sediments from the Goat Canyon retention basins for beach replenishment despite the high percentage of fine-grained materials. Goat Canyon sediments were removed from the retention basins, screened to remove trash, staged on the upper beach, and bulldozed down to the lower beach when it was exposed during low tides. The effects of this replenishment on surfzone nutrient concentrations, phytoplankton abundances, and indicator bacteria loads were monitored by the Scripps Institution of Oceanography. Preliminary results indicated a correlation between sediment resuspension and enterococcus concentrations in the immediate vicinity of the replenishment (Rippy et al., 2010).

8.2 Study Questions

The goal of the Goat Canyon Dredged Material Study is to answer the following questions:

1. **Is dredged material a reservoir for indicator bacteria?**
2. **Does dredged material inoculate contact waters?**

To answer these questions, sediment samples from various depths within the stockpile dredged from the Goat Canyon sediment retention basins were collected and separated into segments by strata. Samples from each stratum were resuspended and enumerated over time for indicator bacteria. Question 1 will be answered by providing an assessment of the indicator bacteria content within the dredged material. Following this enumeration, a known measurement of the sediment with the highest indicator bacteria content was then used to inoculate waters of varying salinities, followed by bacterial enumeration over time in the resulting suspensions. Question 2 will be answered by providing an assessment of indicator bacteria concentrations in waters inoculated with the dredged material.

8.3 Methods

8.3.1 Sample Collection

Sampling was conducted by Weston Solutions Inc. (Weston) personnel on November 15, 2010. Samples were collected from Imperial Beach and from an Eastern location and a Western location within the stockpile dredged from the Goat Canyon sediment retention basins (Figure 8-1). At each location, samples were collected from the top layer and from depths of 12, 22, and 32 inches. Approximately 500 grams (g) of sediment were collected from each depth at each location with sterilized stainless steel shovels. Samples were placed in autoclaved sediment bags and transported in coolers on ice and in the dark to Weston's microbiology laboratory in Carlsbad, CA. Samples were processed within four hours of collection.

8.3.2 Sample Analysis

8.3.2.1 Baseline Testing

Sediment samples from each stratum of the Eastern and Western sampling locations and presumably clean Imperial Beach sand and samples of the fresh, brackish, and marine waters used in the study were enumerated for baseline indicator bacteria concentrations by Weston's microbiology laboratory on November 15, 2010. Testing was conducted in accordance with Standard Method (SM) 9221E and SM 9223B. Sediment suspensions for each sample were prepared by weighing between 9.5 and 10.5 g of each sample into a sterile 100 milliliter (mL) bottle. Actual weights were recorded, 100 mL of sterile phosphate buffered saline (PBS) was added to each sample, and bottles were agitated vigorously for approximately 30 seconds. Eluants were then decanted into a second sterile bottle, taking care not to transfer the sediment. Eluants were then considered ready for bacterial analysis.

Two types of traditional analyses were performed to quantify the number of indicator bacteria in the 100 mL sediment suspension samples. Fecal coliform concentrations were determined using the Multiple Tube Fermentation Direct Method, whereas enterococcus concentrations were determined using IDEXX Enterolert^{TM}. The IDEXX Enterolert^{TM} method uses a chromogenic substrate test to determine the concentration of enterococci, whereas the multiple tube fermentation technique uses multiple tubes in a dilution series to determine the approximate number of fecal coliforms. Results of each type of analysis are given as the most probable number (MPN) of organisms present. This number, based on the 19th Edition Standard Methods' probability formulas (1995), is an estimate of the mean density of coliforms per 100 mL of liquid sample. Coliform density provides the best assessment of water treatment effectiveness and the sanitary quality of untreated water.

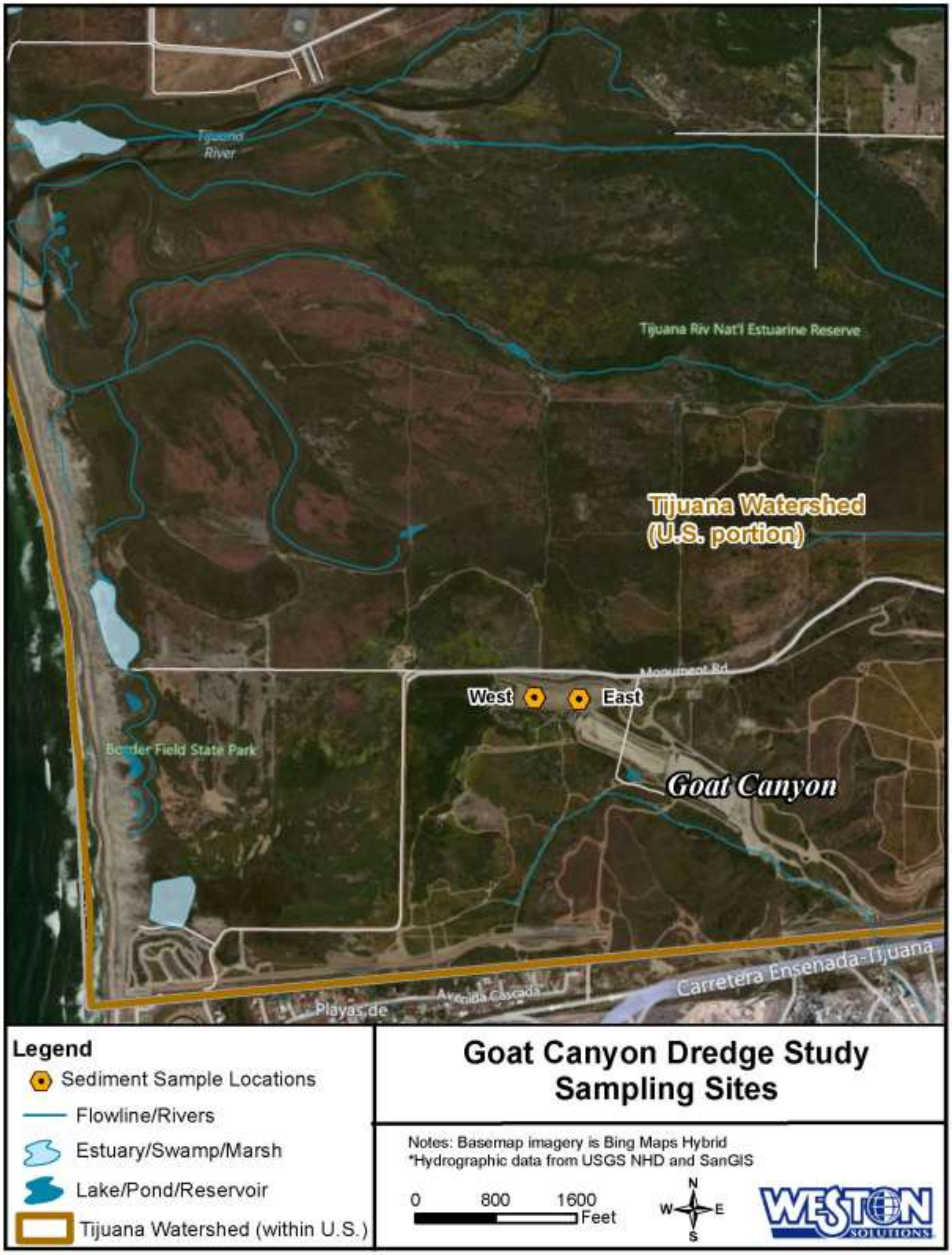


Figure 8-1.Goat Canyon Sampling Locations

8.3.2.2 Inoculation Potential Testing

Following the enumeration of indictor bacteria in each sample, the potential of sediment-associated bacteria to inoculate contact waters was assessed by combining the sediment with the highest levels of indicator bacteria (Table 8-1) with water of varying salinities. Western 22 inch sample sediment, hereafter referred to as Goat Canyon sediment, was combined with fresh water from Weston's bioassay laboratory, marine water from the ocean adjacent to Imperial Beach, and brackish water created by mixing equal parts of the fresh and marine waters. Each type of water was autoclaved for five minutes in order to achieve sterility and minimize loss of water-based nutrients. Native sediment was homogenized and a portion was wrapped in aluminum foil and autoclaved for five minutes to achieve sterility. Both non-sterile and sterile sediment were tested with each of the three types of water. 20 bottles of each sediment/water mixture were weighed out following the procedure described above but utilizing the sterilized fresh, brackish, and marine waters rather than sterile PBS. A set of bottles of sediment with each water type also received a spike of a known concentration of indicator bacteria. All of the sample bottles were wrapped in aluminum foil to prevent exposure to light and were placed into 18 degree Celsius (^{o}C) water baths. A batch of sample bottles was removed from the water bath each day for five days and analyzed for fecal coliforms and enterococci. Testing took place from November 15 to 22, 2010.

Following enumeration of indicator bacteria, the MPN per dry gram was calculated using the wet weights recorded when sediments were added to the 100 mL bottles. Dry weights were calculated by weighing out 10 to 15 g of wet sediment in a weighboat of known weight. The wet sediment was allowed to dry overnight at 103-105^{o}C and was then reweighed. From these weights, the weight of water evaporated from the sediment (and conversely the weight of the dry sediment) can be determined. This value is expressed as a percentage in terms of the amount of dry sediment, which is used to determine the dry weight of the initial 9.5 to 10.5 g of sediment. The MPN result from the indicator bacteria tests can then be divided by this dry weight to obtain the MPN per dry gram.

8.3.3 Quality Assurance/Quality Control Procedures

Quality assurance (QA) and quality control (QC) for sampling processes included proper collection of the samples to minimize the possibility of contamination. Sampling personnel wearing powder-free nitrile gloves collected all samples in laboratory-supplied, laboratory-certified, contaminant-free sample bottles. All sampling personnel were trained in accordance with the field sampling standard operating procedures (SOPs). Field personnel were informed of the significance of the project detection limits and the requirement to avoid contamination of samples at all times. A temperature blank was used to ensure sample holding temperatures were maintained from sample collection to laboratory delivery.

8.3.4 Chain-of-Custody Procedures

Chain-of-custody (COC) procedures were used for all samples throughout the collection, transport, and analytical process. Samples were considered to be in custody if they were (1) in the custodian's possession or view, (2) retained in a secured place (under lock) with restricted access, or (3) placed in a container and secured with an official seal such that the sample could not be accessed without breaking the seal. The principal documents used to identify samples and to document possession were COC records, field logbooks, and field tracking forms.

The COC procedures were initiated during sample collection. A COC record was provided with each sample or group of samples. Each person who had custody of the samples signed the form and ensured the samples were not left unattended unless properly secured. Documentation of sample handling and custody included the following:

- Sample identifier.
- Sample collection date and time.
- Any special notations on sample characteristics or analysis.
- Initials of the person collecting the sample.
- Date the sample was sent to the analytical laboratory.
- Shipping company and waybill information.

Completed COC forms were placed in a plastic envelope and kept inside the cooler with the samples. Once delivered to the analytical laboratory, the COC form was signed by the person receiving the samples. The condition of the samples (*i.e.*, confirming all samples were accounted for and properly labeled, the temperature of the samples, and integrity of the sample jars) was noted and recorded by the receiver. COC records were included in the final reports prepared by the analytical laboratories and are considered an integral part of the report.

8.4 Results

8.4.1 Baseline Results

Baseline indicator bacteria enumeration results for each of the three types of water, samples from each depth at the two sampling locations, and Imperial Beach sand are presented in Table 8-1.

Results indicated that the concentration of fecal coliform and enterococcus were less than 20 and less than 10, respectively, for all three types of water used in the study. Indicator bacteria values for sediment samples from the Eastern location ranged from less than 2 to 45 MPN/dry g for fecal coliform and from 16 to 193 MPN/dry g for enterococcus. Values for sediment from the Western location ranged from 2 to 534 MPN/dry g for fecal coliform and from 11 to 145 MPN/dry g for enterococcus.

The sample with the highest levels of indicator bacteria during baseline testing was the Western 22 inch sample, with a value of 534 MPN/dry g for fecal coliform and 145 MPN/dry g for enterococcus. To simulate a worst-case scenario the Western 22 inch sample, hereafter referred to as Goat Canyon sediment, was chosen to assess the potential of sediment-associated bacteria to inoculate contact waters. These results are presented in Section 8.4.2.

Table 8-1. Baseline Indicator Bacteria Results

Sample	Fecal Coliform (MPN/dry g)	Enterococcus (MPN/dry g)
FW-BL	<20*	<10*
BW-BL	<20*	<10*
SW-BL	<20*	<10*
Imperial Beach Top BL	ND	ND
Imperial Beach 12 inch	<2	<1
Imperial Beach 22 inch	ND	ND
Imperial Beach 32 inch	ND	ND
Eastern Top BL	2	16
Eastern 12 inch BL	45	193
Eastern 22 inch BL	<2	103
Eastern 32 inch BL	24	132
Western Top BL	2	11
Western 12 inch BL	54	86
Western 22 inch BL	534	145
Western 32 inch BL	4	72

FW – Fresh Water
BW – Brackish Water
SW – Marine Water
BL – Baseline
ND - Nondetect
*Reported in units of MPN/100 mL

8.4.2 Inoculation Potential Results

8.4.2.1 Fresh Water

Daily indicator bacteria concentrations for each of the sediments in fresh water are presented in Table 8-2. Daily means for fecal coliform and enterococcus are presented graphically on Figure 8-2 and Figure 8-3, respectively.

Table 8-2. Indicator Bacteria Results: Fresh Water + Sediments

Sample	Day of Study	Fecal Coliforms (MPN/dry g)			Enterococci (MPN/dry g)		
		Original	Duplicate	Triplicate	Original	Duplicate	Triplicate
FW + Sterilized Sediment	0	<4	NA	NA	<2	NA	NA
	1	<4	NA	NA	<21	NA	NA
	2	<4	NA	NA	<2	NA	NA
	3	<4	NA	NA	<2	NA	NA
	4	<4	NA	NA	<2	NA	NA
	5	<4	NA	NA	<2	NA	NA
FW + Goat Canyon Sediment	0	104	48	62	468	516	959
	1	106	233	106	771	666	1,234
	2	1,757	1,098	2,415	84	78	67
	3	51	66	38	92	145	138
	4	63	63	63	33	40	65
	5	4	15	4	180	201	242
FW + Spiked Sediment	0	172	365	236	591	831	934
	1	63	104	27	309	255	132
	2	110	66	66	367	455	286
	3	24	18	18	89	114	117
	4	171	171	107	240	211	161
	5	8	23	15	87	86	167

FW – Fresh Water
NA – Not Applicable

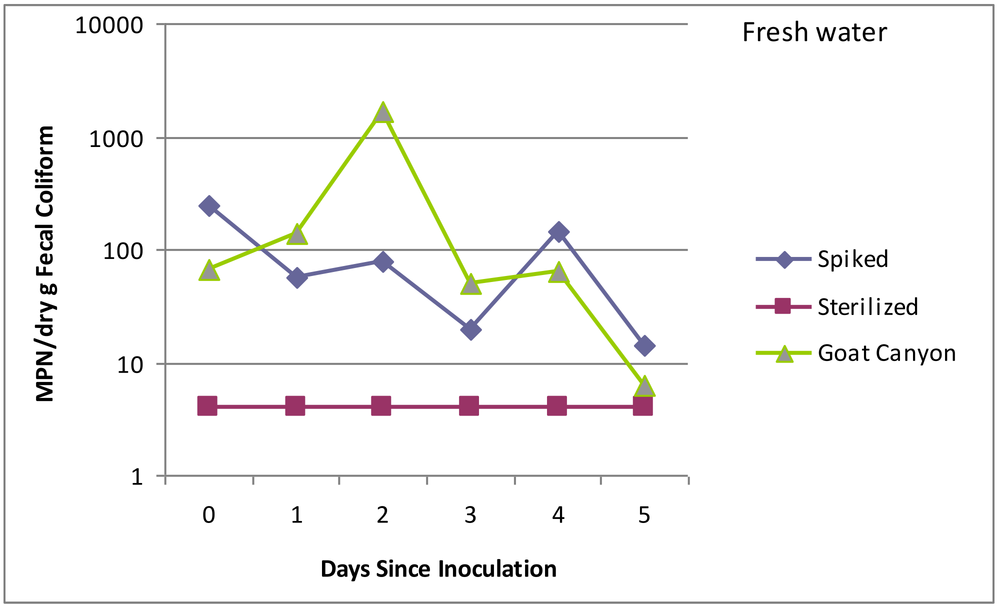


Figure 8-2. Fecal Coliform Concentrations Over Time in Fresh Water

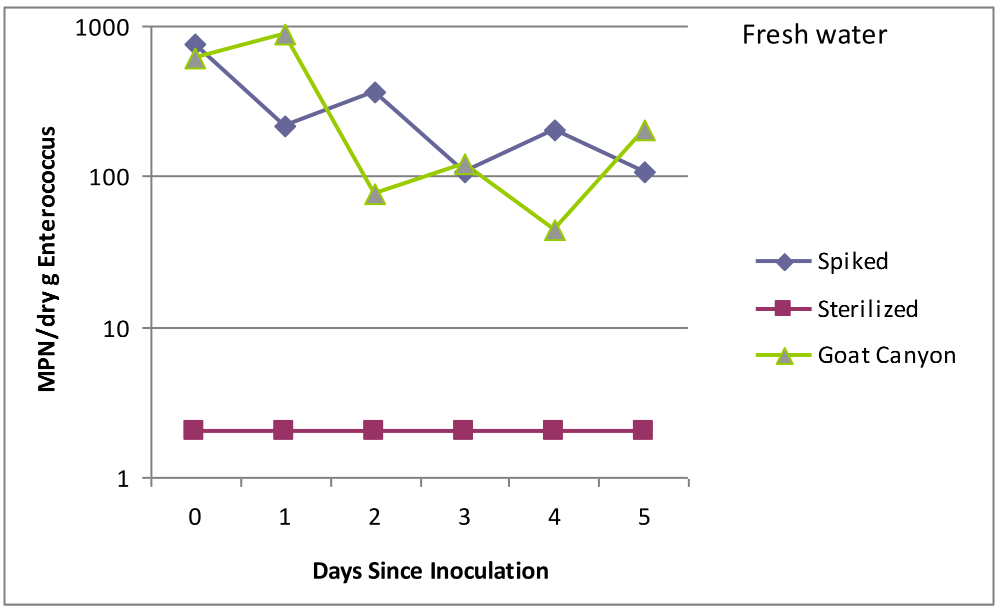


Figure 8-3. Enterococcus Concentrations Over Time in Fresh Water

8.4.2.2 Brackish Water

Daily indicator bacteria concentrations for each of the sediments in brackish water are presented in Table 8-3. Daily means for fecal coliform and enterococcus are presented graphically on Figure 8-4 and Figure 8-5, respectively.

Table 8-3. Indicator Bacteria Results: Brackish Water + Sediments

Sample	Day of Study	Fecal Coliforms (MPN/dry g)			Enterococci (MPN/dry g)		
		Original	Duplicate	Triplicate	Original	Duplicate	Triplicate
BW + Sterilized Sediment	0	<4	NA	NA	<2	NA	NA
	1	<4	NA	NA	<22	NA	NA
	2	<4	NA	NA	<2	NA	NA
	3	<4	NA	NA	<2	NA	NA
	4	<4	NA	NA	<2	NA	NA
	5	<4	NA	NA	<2	NA	NA
BW + Goat Canyon Sediment	0	288	177	155	344	256	274
	1	48	48	48	256	335	205
	2	109	65	109	569	634	514
	3	174	50	109	320	281	323
	4	23	15	36	5,073	5,073	5,073
	5	15	19	23	461	523	363
BW + Spiked Sediment	0	1,089	370	370	4,668	3,080	4,765
	1	6,373	10,622	6,373	537	557	458
	2	64	107	107	468	396	382
	3	65	284	65	566	594	671
	4	176	243	110	806	718	451
	5	630	1,260	630	646	472	450

BW – Brackish Water
NA – Not Applicable

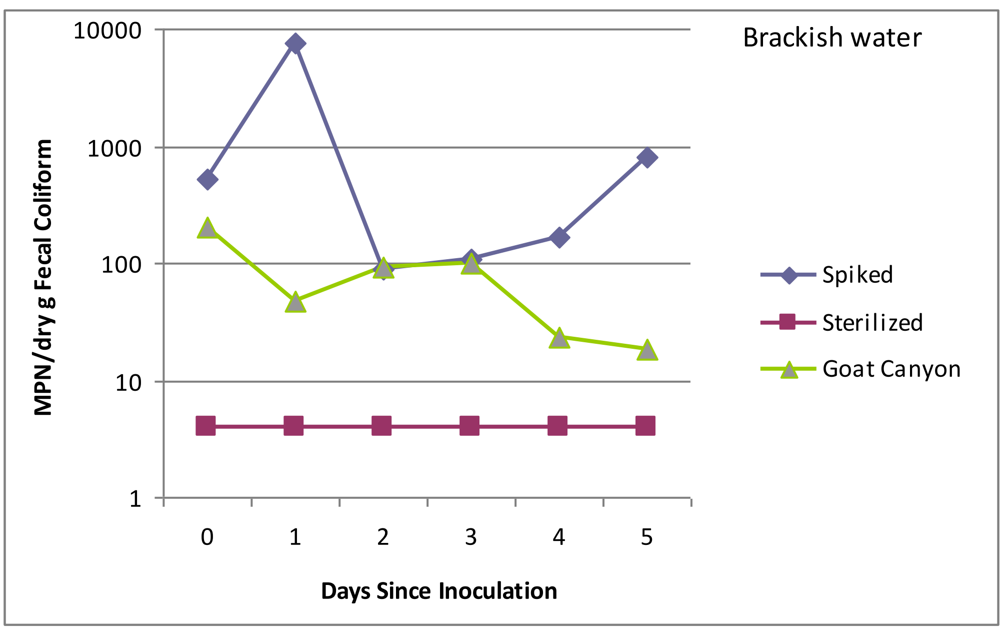


Figure 8-4. Fecal Coliform Concentrations Over Time in Brackish Water

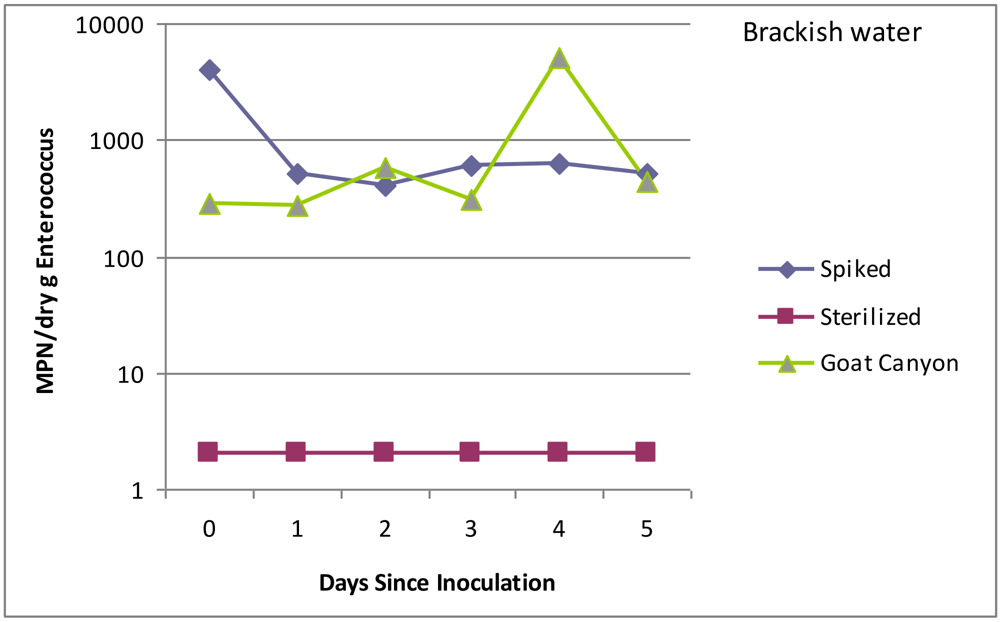


Figure 8-5. Enterococcus Concentrations Over Time in Brackish Water

8.4.2.3 Marine Water

Daily bacteria concentrations for each of the sediments in marine water are presented in Table 8-4. Daily means for fecal coliform and enterococcus are presented graphically on Figure 8-6 and Figure 8-7, respectively.

Table 8-4. Indicator Bacteria Results: Marine Water + Sediments

Sample	Day of Study	Fecal Coliforms (MPN/dry g)			Enterococci (MPN/dry g)		
		Original	Duplicate	Triplicate	Original	Duplicate	Triplicate
SW + Sterilized Sediment	0	174*	NA	NA	418*	NA	NA
	1	<4	NA	NA	<22	NA	NA
	2	<4	NA	NA	<2	NA	NA
	3	<4	NA	NA	<2	NA	NA
	4	<4	NA	NA	<2	NA	NA
	5	<4	NA	NA	<2	NA	NA
SW + Goat Canyon Sediment	0	18	51	38	88	87	74
	1	280	50	65	786	840	828
	2	29	63	104	437	468	397
	3	6,325	4,638	4,849	376	649	408
	4	1,753	1,534	657	570	352	377
	5	107	107	278	248	246	285
SW + Spiked Sediment	0	490	1,064	1,703	331	333	419
	1	505	659	285	187	215	350
	2	358	485	105	502	294	395
	3	51	67	38	2,325	2,888	2,674
	4	35	62	62	400	369	382
	5	107	278	107	877	696	558

SW – Marine Water
NA – Not Applicable
* Day 0 SW + Sterilized Sediment bottle may have been spiked w bacteria or sediment was not sterilized as required.

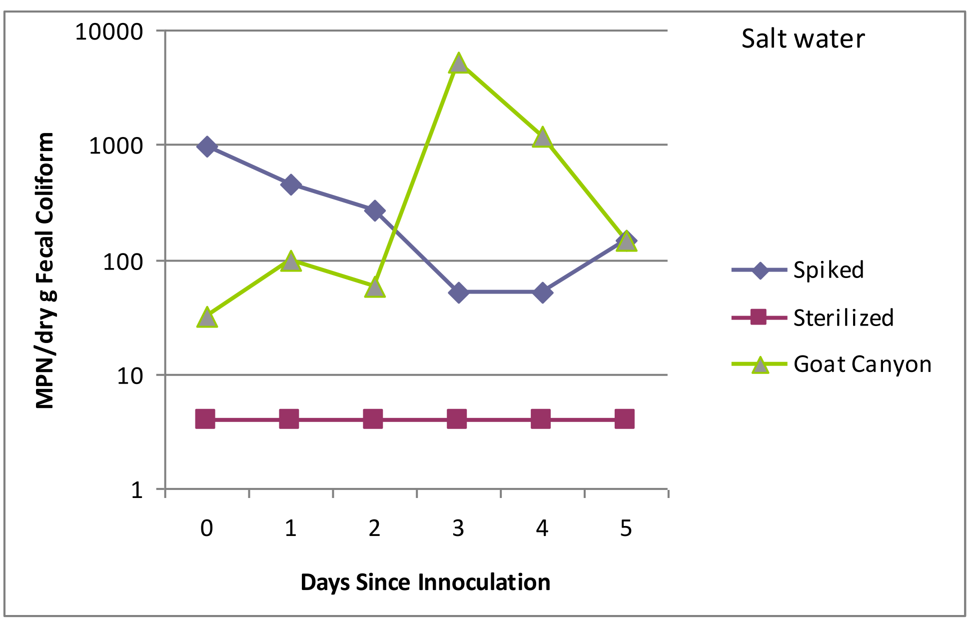


Figure 8-6. Fecal Coliform Concentrations Over Time in Marine Water

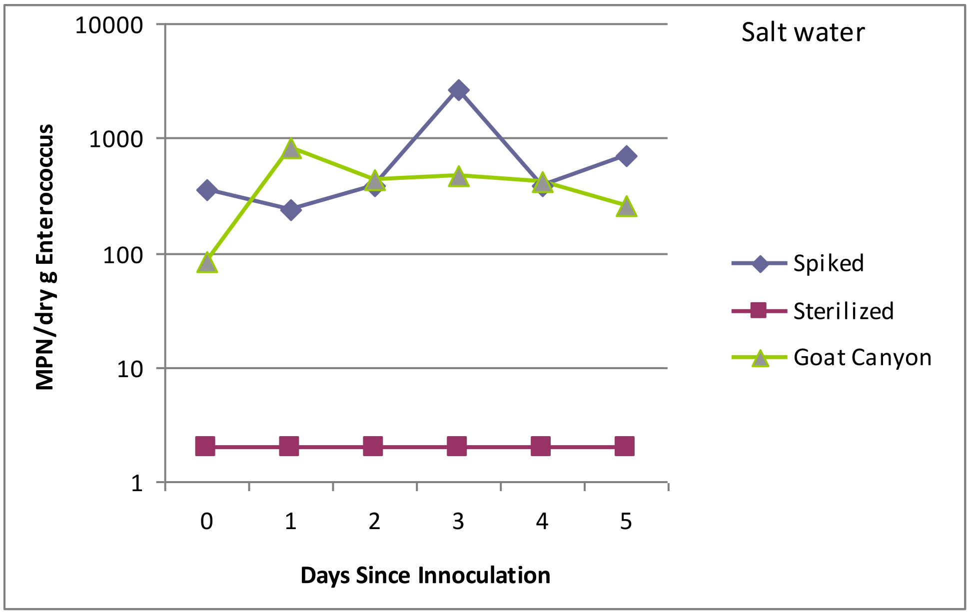


Figure 8-7. Enterococcus Concentrations Over Time in Marine Water

8.5 Discussion

Two main questions were posed in this study. These questions are addressed below.

1. **Is dredged material a reservoir for indicator bacteria?**

To answer this question, sediment samples from various depths within the stockpile dredged from the Goat Canyon sediment retention basins were collected and separated into segments by strata. Samples from each stratum were resuspended and enumerated over time for indicator bacteria. Presumably clean sand from Imperial Beach was also enumerated for indicator bacteria. Imperial Beach sand results ranged from non-detect to less than 2 MPN/dry g for fecal coliform and from non-detect to less than 1 MPN/dry g for enterococcus. Goat Canyon sediment bacterial concentrations ranged from less than 2 to 534 MPN/dry g for fecal coliform and from 11 to 193 MPN/dry g for enterococcus.

Goat Canyon sediments have been evaluated to contain approximately 40 percent fines. As previously discussed, the small grain size of these fine clay and silt particles offers a preferred adsorption material for suspended bacteria with higher surface-to-volume ratios and higher hydrophobicity, which in turn encourages nutrient adsorption to surfaces and promotes bacterial chemotactic responses. A recent study investigating the impact of grain size and other factors on indicator bacteria density in beach sands found that fine sands of uniform distributions contained the highest concentrations of indicator bacteria and that concentrations of bacteria in nearshore beach sands were significantly greater than those in submerged sands and sands farther from shore (Skalbeck et al., 2010).

The combination of indicator bacteria enumeration results and grain size data for Goat Canyon sediments indicate that these sediments act as a reservoir for indicator bacteria.

2. Does dredged material inoculate contact waters?

The potential of sediment-associated bacteria to inoculate contact waters was assessed by combining sterilized sediment, spiked sediment, and Goat Canyon sediment with waters of varying salinities. The persistence and differential survival of indicator bacteria in water and sediments has been found to be influenced by the presence of microbial predators (Davies et al., 1995), radiation (Sinton et al., 2002 and Fujioka et al., 1981), and temperature fluctuations (Noble et al., 2004) as well as the indicator organism species composition itself (Anderson et al., 2005). In order to assess the role of Goat Canyon dredged materials, experimental design focused on reducing the influence of these factors, thus allowing specific assessment of the role of the dredged sediment on fresh, brackish and marine waters.

In the freshwater system, fecal coliform concentrations decreased to negligible concentrations by day five. The decrease in fecal coliform concentrations in the Goat Canyon sediment sample suggests that it is the native populations of bacteria within the sediments which are contributing to the water quality impact. The spiked sediment, which was used to determine whether the presence of nutrients and habitat from the dredged materials might aid bacterial growth, also showed decreases during the same time frame. These results are contrary to some published literature which shows fecal coliform decay rates to be significantly lower than those of enterococcus in freshwater (Anderson et al., 2005). A similar but less pronounced decrease was observed in the enterococcus freshwater samples. Spiked and native enterococci showed the same pattern of decline but, while a one log decrease in concentrations was observed, the concentrations were still elevated. These results suggest that in freshwater systems, enterococci from the dredged material may cause initial spikes in water column concentrations, which may perpetuate for a number of days.

Previous research suggests that brackish water provides more optimal survival conditions than either fresh or marine waters for indicator bacteria (Anderson et al., 2005). In brackish waters in this study, fecal coliform concentrations varied over time with distinct differences observed in spiked versus native samples. In brackish water, spiked fecal coliform numbers increased between days 3 and 5. Native species of fecal coliforms in the Goat Canyon sediment however, showed a steady decline. These results may be interpreted as an indication of how complex microbial communities such as those found in native dredged sediments may act and interact, compared with cultured strains of fecal coliform. The decrease observed in the Goat Canyon samples may be attributed to the presence of predators such as viruses and protozoa which act to destabilize bacterial populations.

In the marine inoculation experiments, fecal coliform survival showed some decrease in spiked samples while in bacteria concentrations from native Goat Canyon samples rose sharply on day 3. Both native and spiked samples reached the same concentrations by day 5. Enterococcus concentrations in both spiked and native inoculation experiments showed similar trends with an observed increase in bacteria concentrations over time. These results are consistent with observed resilience in enterococcus, compared with fecal coliform, in higher saline environments (Bordalo et al., 2002).

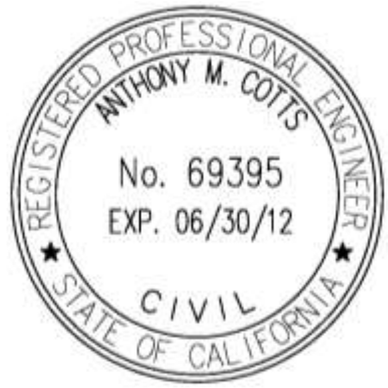
The inoculation test results suggest that the Goat Canyon dredged sediments can contribute fecal coliform and enterococcus concentrations to the water columns in fresh, brackish and marine systems. The persistence of enterococci, compared to fecal coliforms, in each water system is similar to results observed in other studies which show enterococci to have a higher resistance to environmental conditions compared with fecal coliforms (Bordalo et al., 2002). It also supports the findings of other studies which suggest that sediments play an important role in the survival of bacteria by providing a favorable, nonstarvation environment for the bacteria (Davies et al., 1995). When taking into account the complex environment of the Pacific Ocean directly adjacent to the proposed beach nourishment site, the results of this experimental design suggest that dredged materials could cause an initial increase in both enterococcus and fecal coliform concentrations. However, that increase is most likely to be transitory in nature when sea temperatures, hydrologic flow patterns and UV irradiation are taken into account. Beach mitigation measures such as mechanical grooming may also reduce bacteria densities by means of aeration, desiccation and UV penetration, along with reducing health risks posed directly by the sediment (Skalbeck et al., 2010).

By extrapolation of these indicator results together with the varied responses seen in the spiked inoculums, there is evidence that other microbes, including viruses and protozoa, may be embedded in the sediments, making their use in a sand replenishment strategy potentially impactful on public health.

9.0 CONCEPT DESIGNS AND PRIORITIZATION

DECLARATION OF RESPONSIBLE CHARGE

I hereby declare that I am the engineer of work for this project, that I have exercised responsible charge over the design of the project as defined in Section 6703 of the Business and Professional Code, and that the design is consistent with current standards.



ENGINEER OF WORK

Weston Solutions, Inc.
2433 Impala Drive
Carlsbad, California 92010
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5-1-2012

Anthony M. Cotts, R.C.E. 69395 — Date
Registration Expires June 30, 2012

9.1 Purpose and Scope

The purpose of this study was to conduct a hydrologic and water quality analysis to support the concept design and assessment of the proposed best management practices (BMPs), also referred to as low impact development (LID) features, at the selected sites within the Tijuana River Watershed. More specifically, this study has been performed to determine and document the water quality flows and volumes (storm water runoff) from the tributary area for each concept design site. The BMPs are proposed to provide water quality improvement of storm water runoff with some attenuation of peak flows, which in itself also provides water quality benefits (less downstream flow equates to less potential for downstream sediment transport). This document provides descriptions of the concept designs, methodology and results of hydrologic calculations, and methodology and results of quantification calculations.

The proposed project sites are not considered to be “new development” or “significant redevelopment” projects and therefore are not subject to requirements the current National Pollutant Discharge Elimination System (NPDES) permits currently held jointly by the Copermittees in the region. But rather, the overall focus of the concept design projects is to provide improved storm water quality by proactively implementing BMPs (instead of reacting to regulations). As such, the project does not require that a Water Quality Technical Report (WQTR) be prepared. However, the BMPs proposed were designed using the same references as those that would be used to design BMPs and prepare WQTR’s in the County of San Diego. In some cases (due to site constraints, soil conditions, etc.) the BMP designs may not capture the entire design storm event quantities that are specified in the *Standard Urban Stormwater Mitigation Plan* (SUSMP) (County of San Diego, 2011). In these cases, the BMPs have been designed to capture and treat storm water runoff to maximum extent possible and feasible given the site conditions, and these values are documented in this report.

The scope of the study included:

1. Determine the points of flow concentration and watershed boundary and sub-boundaries for the upstream drainage area for each concept design site.
2. Calculate the SUSMP design capture volume (DCV) or treatment flow rate for each concept design site in accordance with water quality and hydrology guidance documents for the County of San Diego.
3. Calculate the maximum peak flow or volume that each concept design project is designed to treat in accordance with water quality and hydrology guidance documents for the County of San Diego.
4. Quantify annual reductions in bacteria loading that may be achieved if proposed BMPs are implemented.
5. Preparation of report that consists of watershed description, methodology, results, and figures.

9.2 Imperial Beach Boulevard Parkway Bioretention Basins

9.2.1 Project Site

The Site is located along the north side of Imperial Beach Boulevard adjacent to the Mar Vista High School in the City of Imperial Beach. The parkway is approximately 7 feet wide and is currently non-landscaped. The site is shown in Figure 9-1. The proposed improvements are confined to the parkway area and small portions of the sidewalk and curb and gutter. The BMPs are proposed in parkway in areas where there are not existing improvements such as utility vaults, bus stop benches, etc. A vicinity map is provided in Figure 9-2.

Figure 9-1. Imperial Beach Blvd. Parkway BMPs Project Site

Figure 9-2. Vicinity Map

9.2.2 Project Soil Geology and Percolation Testing

A local geotechnical firm conducted a Limited Geotechnical and Infiltration Evaluation for the Site. Three percolation borings and one exploratory boring were excavated and evaluated in order to evaluate site geology and the infiltration characteristics of the near surface materials. The procedure used for conducting the percolation testing was in general accordance with the County of San Diego, Department of Environmental Health (DEH) guidelines (DEH, 2008).

The site is underlain by Soil Type D materials that include fill and old paralic deposits. Groundwater was not encountered at this site. Data were extracted from the evaluation report and presented below that includes Figure 9-3 showing the test boring locations and Table 9-1 showing the testing results. For more details on the field work methodology and results see the complete Limited Geotechnical and Infiltration Evaluation in Appendix E-1.

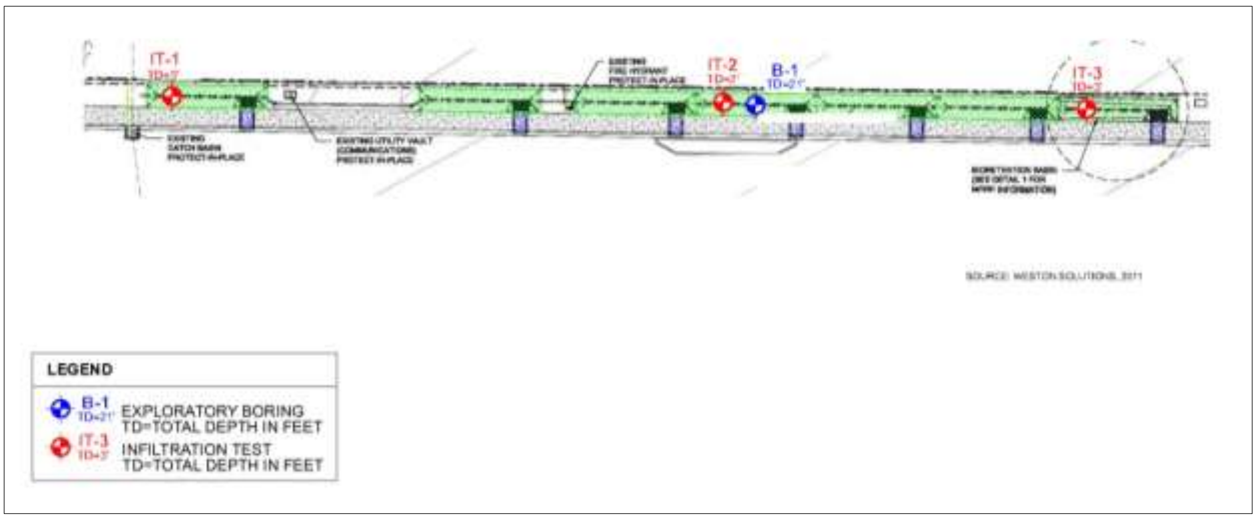

Figure 9-3. Test Boring Locations

Table 9-1. Infiltration Test Results Summary

Infiltration Test	Depth below ground surface (feet)	Designation	Adjusted Infiltration Rate (in/hr)
B-1	21	Silty Sand with clay and gravel (Fill over Old Paralic Deposits)	N/A
IT-1	3.0	Silty Sand (Fill over Old Paralic Deposits)	1.6
IT-2	2.0	Silty Sand (Fill over Old Paralic Deposits)	0.3
IT-3	3.0	Silty Sand and Sandy Clay (Fill over Old Paralic Deposits)	0.1

Based on the results of the soil evaluation, with the exception of the lower area (IT-1), the site soil conditions dictate that BMPs that rely primarily on infiltration as the treatment mechanism are not suitable for this location. Bioretention basins proposed for these areas of little ability to infiltrate should be designed with an underdrain system to convey treated water into the adjacent existing catch basin. The lower bioretention basin (in the area of IT-1) may be suitable for infiltration. However, due to the high seasonal variability that infiltration rates may have due to rainfall and the relatively small increase in cost to do so, it is recommended that even the lower bioretention basin be constructed with an underdrain system. A disconnect ball valve should be install in the underdrain system, and the normal position should be shut for this basin. This will promote infiltration of captured water in the lower basin while providing a means to drain the basin if runoff does not infiltration as the testing results indicate.

9.2.3 Project Description

The proposed project includes constructing four bioretention basin type BMPs to capture and treat storm water runoff from the adjacent portion of Imperial Beach Boulevard. For each basin a sidewalk underdrain will be constructed to convey runoff from the street curb and gutter into each basin. The sidewalk underdrain will be modified to so that invert slopes, at approximately 2 percent, towards the parkway and BMP. The bioretention basin will be construction by excavating a trench along the sidewalk that is 6 feet wide and approximately 2 feet deep. Along the center of the trench a second trench will be excavated with a width of 2 feet and an additional depth of 1 foot in order to house the underdrain (or subdrain) system. Permeable geotextile fabric will be placed on the bottom of the underdrain trench; the trench will be filled with gravel and a perforated smooth walled pipe. The underdrain pipe will be connected to non-perforated pipe and connected to the existing catch basin as shown on the plans. Above the smaller, subdrain trench additional geotextile fabric will be laid down and an amended soil mixture will be placed to fill the trench to match grades and elevations shown on the plans. The amended soils will consist of 65 percent sand and 35 percent compost (tolerance of plus or minus 5 percent). The sand and compost shall be well mixed prior to placement. Drought tolerant, low height, native vegetation shall be planted in the basin. Dependent on the final plant palate, in order to establish vegetation and provide water during extended dry periods, it may be necessary to extend the existing landscape irrigation system from the adjacent raised planter into the basins. For more information relating to the bioretention BMPs at this site see Figure 9-4 and Figure 9-5.

Storm water runoff from the area of Imperial Beach Boulevard that is adjacent to the Site will sheet flow into the existing curb and gutter along the north side of the street. Runoff will be conveyed from the curb and gutter into the proposed bioretention basins through the proposed sidewalk underdrains. The runoff will filter through the amended soils and into the subdrains of the BMPs. The process of filtering through the sand, compost, and vegetation roots will remove pollutants, including bacteria. The majority of treated runoff will flow into the subdrain pipe and be conveyed to the existing catch basin through a proposed penetration in the catch basin wall. A portion of the captured runoff will remain in the basin and either infiltrate into the soil substrata or evapotranspirate.

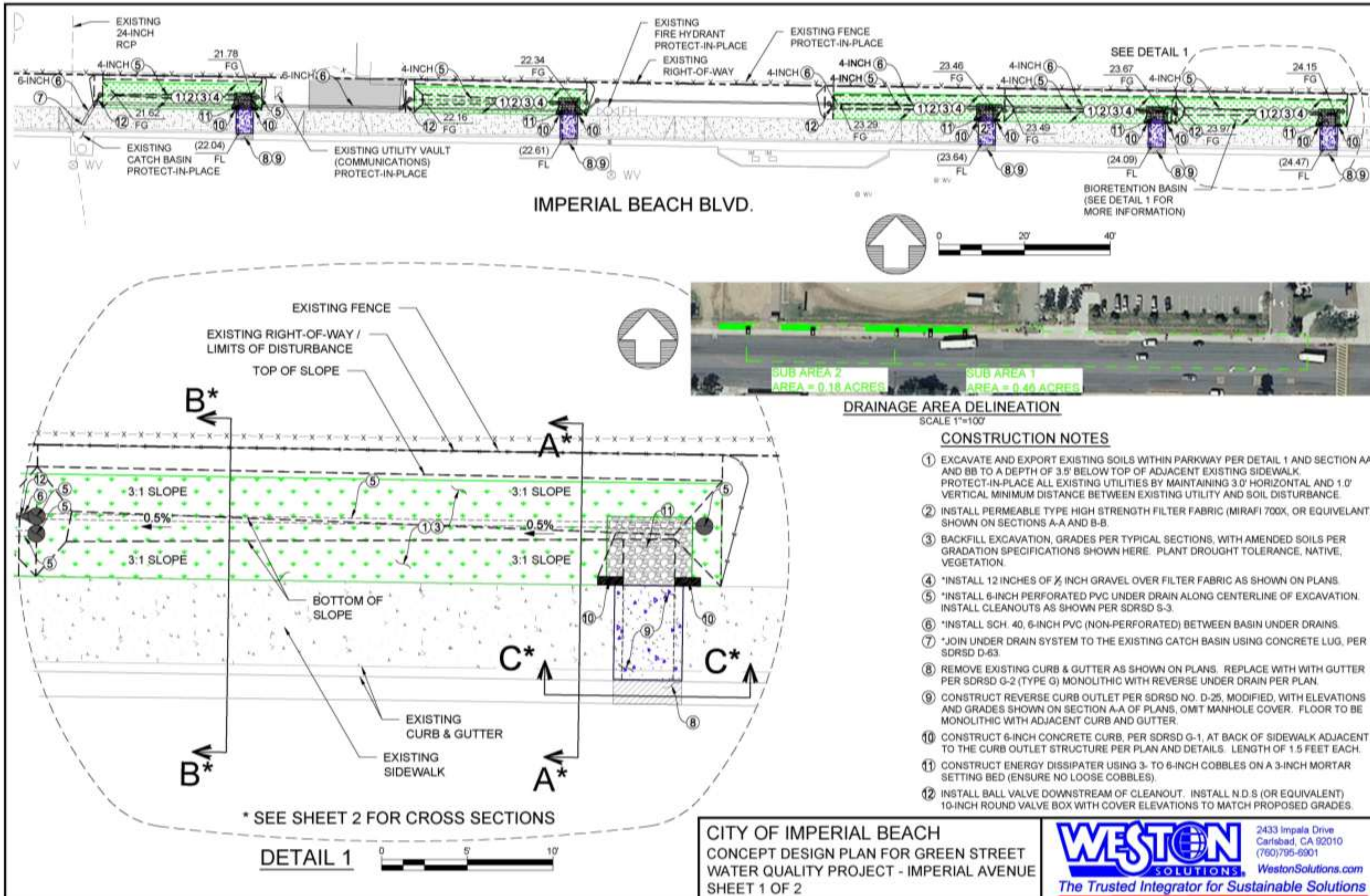

Figure 9-4. Imperial Beach Boulevard Parkway Bioretention Basins Concept Design Plan (1 of 2)

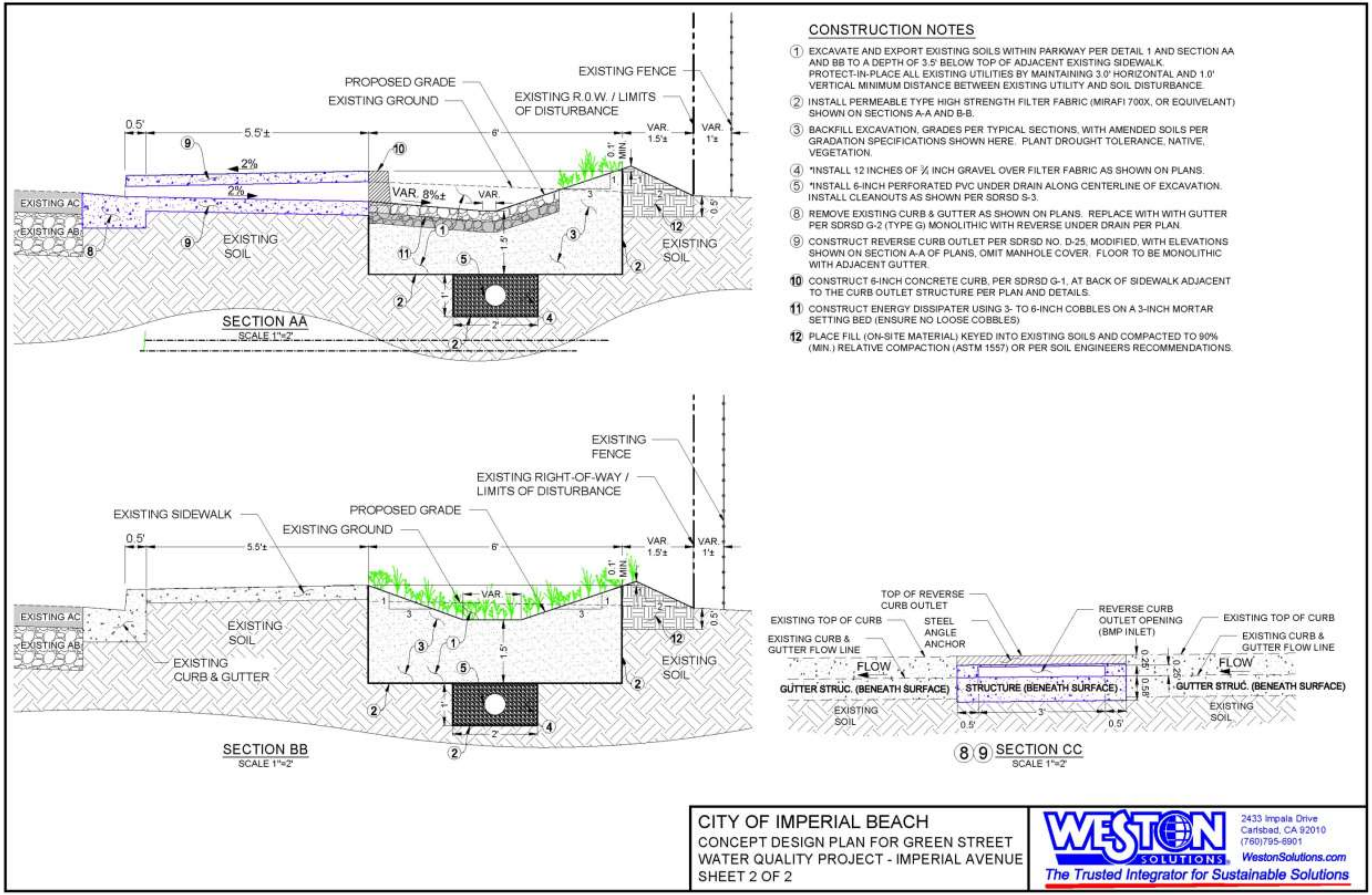

Figure 9-5. Imperial Beach Boulevard Parkway Bioretention Basins Concept Design Plan (2 of 2)

9.2.4 Water Quality Calculations

The tributary drainage area to the site has been depicted on sheet 1 of the conceptual design drawings (Figure 9-4). The drainage area consists of the adjacent portion of Imperial Beach Boulevard, to centerline crown, which measures an approximate area of 0.64 acres. For hydrologic calculations, the drainage area is considered to be 95% impervious. In accordance with guidance found in the SUSMP (CSD, 2011) and the County Hydrology Manual (CSD, 2003) water quality calculations were performed for the Site. Due to poor infiltration across the majority of the site, the selected BMPs consist of bioretention basins that primarily rely on filtration of captured storm water through bio-media (sand, compost, and vegetation roots) prior to discharge into the existing catch basin. The percolation results indicate that the west most bioretention basin may be able to function by infiltrating captured storm water. Therefore, both filtration and infiltration calculation have been prepared for the west most basin only. The water quality calculations and results are summarized in Table 9-2. Additional information relating to these calculations is provided in Appendix E-2.

Table 9-2. Calculation Summary (Filtration)

Water Quality Rain Intensity =	0.2	Inches per hour
Bioretention Basins (East 3 Basins)		
Tributary Drainage Area =	0.46	Acres
C =	0.87	
Q = CIA =	0.08	Cubic Feet Per Second
BMP Area =	720	Square Feet
Filtration Rate =	**4.82**	**Inches per hour**
Bioretention Basins (West 2 Basins)		
Tributary Drainage Area =	0.18	Acres
C =	0.87	
Q=CIA =	0.03	Cubic Feet Per Second
BMP Area =	480	Square Feet
Filtration Rate =	**2.83**	**Inches per hour**

Bioretention basins that rely on filtration are typically designed for a maximum of 5 inches per hour filtration rate (thumb rule flow rate value that provides pollutant removal developed in Contra Costa County, California based on BMP data). The calculations indicate that the design provides adequate BMP area to treat the design storm flow (*i.e.*, calculate filtration rates are less than 5 inches per hour). The 5 inches per hour maximum filtration rate is a rough estimate based on the ability of storm water runoff to pass through the voids of the amended soils while providing significant pollutant removal. Actual maximum flow through the BMPs is anticipated to be higher than this design value. In order to optimize the pollutant removal capability of the basins, the design of BMPs for this Site includes a valve located at the downstream end of each subdrain system that will allow for the calibration (restriction) of flow through the system to approximately 5 inches per hour or less.

Table 9-3. Calculation Summary (Infiltration)

Bioretention Basins 5 (West Basin) – Required Capture Storage	
85th Percentile Rainfall =	0.55 inches
Area =	0.09 Acres
C =	0.873
SUSMP Water Quality Capture Volume =	**157 Cubic Feet**
Bioretention Basins 5 (West Basin) – Capture Storage Provided	
Gravel Porosity (n) =	0.35
Gravel Storage (L*W*D*n) =	(40*2*1*0.35) = 28 Cubic Feet
Amended Soils Porosity (n) =	0.35
Amended Soils Storage (L*W*D*n) =	(40*6*1.5*0.35) = 126 Cubic Feet
Ponded Surface Storage =	23 Cubic Feet
Total Storage Provided (Summation) =	**177 Cubic Feet (Adequate Size)**
Bioretention Basins 5 (West Basin) – Draw Down Time	
Estimated Infiltration Rate =	1.6 Inches Per Hour
Basin Area =	240 Square Feet
Infiltration Flow Rate =	0.009 Cubic Feet Per Second
Draw Down Time (for 177 Cubic Feet) =	**5.5 Hours**

Calculations performed for the west most basin indicate that the BMP has adequate storage capacity (177 cubic) to capture the 0.55 inch (85^{th} percentile) design storm volume of 157 cubic feet. Once storm water is captured, the BMP has the ability to drawdown the stored runoff in approximately 5.5 hours. The westerly most basin, based on measured infiltration rate, has adequate area to function as an infiltration basin. During extremely wet years, the water table may raise and this basin may only function properly as a filtration type BMP. The basin has been design with a subdrain system and disconnect valve so that, depending on the position of the valve, the basin can function as either an infiltration (valve closed) or filtration (valve open) type BMP. The system shall be aligned for infiltration at the beginning of each wet season, and the site should be checked 24 to 48 hours after each rainfall event of greater than 0.5 inches of rainfall. The disconnect valve should be opened if persistent ponded water is observed in the bottom of the basin.

9.2.5 Load Quantification Analysis

The annual runoff in the drainage area was estimated for this site based on rainfall data obtained from the County of San Diego's Project Cleanwater website (CSD, 2012) and a simple method model calculation. The Project Cleanwater website contains approximately 50 years of precipitation data. The Lower Otay rain gauge station was select due to its proximity to the Site. The concentrations of constituents of concern (COC) were estimated based on the average of monitoring event values obtained in other tasks of this Clean Beaches Initiative (CBI) project. Pollutant removal efficiencies were estimated based on data published in the *International Stormwater Best Management Practices (BMP) Database* (WERF, 2011). The above-mention data were analyzed and a summary of the average annual pollutant removal is provided in Table 9-4.

Table 9-4. Annual Pollutant Load Removal

Average Annual Volume of Storm water Runoff Treated		
Average Rainfall =	10.4	
Capture Amount (<0.2 in/hr) =	9.6	
C =	0.873	
Area =	0.64	Acres
Rv (Coefficient to account for small rainfall amounts) =	0.9	
Annual Treatment Volume =	17,463	Cubic Feet
Average Annual Pollutant Load Removal		
Average Pollutant Load Reduction	62.6%	(WERF, 2011)
Average Enterococci EMC =	24,700	MPN/100 Milliliters
Average Fecal Coliforms EMC =	55,600	MPN/100 Milliliters
Enterococci Load Removal =	76,460	10^6 MPN
Fecal Coliforms Load Removal =	172,110	10^6 MPN

9.2.6 Performance Specifications

The goal of the Imperial Beach Boulevard Parkway Bioretention Basins for the Tijuana River Watershed Protection Project is to reduce the pollutant load entering Tijuana River National Estuary. This goal will be achieved by improving the existing dirt parkway with an amended soils and subdrain system to capture and treat storm water flows. In general, project treatment components shall be designed to remove pollutants (priority constituents of concern), including bacteria, heavy metals, and sediment. Every effort shall be made through the use of improved technologies and enhancing this concept design to further reduce pollutant loading entering the estuary. Refer to the project concept design plan for more details on the specification of project components.

9.2.7 Operations and Maintenance

It is anticipated that initial calibration of the system followed by semi-annual regular maintenance will be required to maintain the bioretention BMPs to optimal performance. The initial calibration of the BMP involves adjusting the underdrain disconnect valves to obtain an approximate 5-inch per hour flow rate through the basins. The basins have been designed to allow ponding of approximately 2 inches of captured water (*i.e.*, once soils become saturated, if flow rate into BMP exceeds discharge flow rate ponding will occur). Begin with the disconnect valve closed and allow for runoff to the fill the basins. With very little or no storm water runoff input into the basin, continuously measure depth and partially open disconnect valve to achieve an approximate flow rate of 12 minutes for 1 inch depth reduction (or 5 inches per hour). Since the basins have the same designed, the valve position for each basin should be about the same. The position of the valves should be logged and the field calibration sheet shall be provided to the City Watershed Manager. The flow rate should be verified by field observations and calculations during subsequent precipitation.

Semi-annual maintenance should be performed on the basin in September, prior to first wet weather, and towards the end of the wet season in April or May. This maintenance shall include visual observation of sidewalk underdrain checking for and removing debris such as trash and organic materials. Some soil is acceptable. It is not anticipated that the sidewalk underdrain will not have the potential to be clogged by sediment. This is based on no likely sources of heavily loaded total suspended soils currently identified in the drainage area. However, if clogging from soil is observed, maintenance crews shall remove soil if possible with shovel and broom. If necessary, a vacuum truck may be required to clear the sidewalk underdrain (although it is not anticipated). Trash and organic materials, if observed, shall be removed from the basin. The position of the disconnect valves shall be recorded during the semi-annual maintenance. If large rainfall events occur (greater than 2 inches) the above-mentioned regular maintenance shall be conducted.

9.2.8 Estimated Construction Cost

The estimated construction cost of implementing the Green Alley concept design is approximately $130,950. This includes labor and materials, engineering design, mobilization, traffic and erosion control, construction bond, miscellaneous landscaping, minor utility relocation, and a 10% contingency but excludes City staff costs associated with construction inspection and project management/review. Refer to Table 9-5 for more details on the cost estimate.

Table 9-5. Cost Estimate

Imperial Beach Boulevard Parkway Bioretention Basins Cost Estimate for Proposed Improvements Concept Design Level				
ITEM	**QUANTITY**	**UNIT**	**UNIT PRICE**	**COST**
Grading & Export	103	CY	$44.28	$4,561
Filter Fabric Permeable	4,000	SF	$2.60	$10,400
Amended Soils	88	CY	$150.00	$13,200
3/4" Gravel (under drain reservoir)	15	CY	$125.00	$1,875
4" PVC Perforated Subdrain	200	LF	$25.00	$5,000
4" Sch. 40 PVC Unperforated between drains	80	LF	$30.00	$2,400
6" Sch. 40 PVC Unperforated between drains	180	LF	$40.00	$7,200
Clean Out per SDRSD S-3 (Under Drain System)	16	EA	$450.00	$7,200
Connection to Existing Catch Basin	1	EA	$950.00	$950
Saw Cut Concrete Sidewalk	88	LF	$10.00	$880
Demo Existing Sidewalk to install curb outlet	175	SF	$5.50	$963
Demo Existing Curb & Gutter to install curb outlet	20	LF	$12.00	$240
Reverse Curb Outlet (SDRSD D-25, Modified)	5	EA	$2,500.00	$12,500
Curb per SDRSD G-1	15	LF	$22.00	$330
Energy Dissipater (3 to 6" rock set in mortar)	5	EA	$150.00	$750
Landscaping - Native Drought Tolerance	1,180	SF	$1.50	$1,770
Extend Existing Irrigation System into Bains	1	LS	$1,500.00	$1,500
Concrete Washout	1	EA	$825.00	$825
Construction Fence	350	LF	$4.00	$1,400
Gravel Bag	100	EA	$1.82	$182
Traffic Control	1	LS	$2,000.00	$2,000
Protect-in-place existing utilities	1	LS	$2,500.00	$2,500
			Construction Subtotal	**$78,625**
			WPCP	$8,000
			Field Orders	$5,000
			Engineering Design - 25% of construction subtotal	$19,656
			Mobilization - 10% of construction subtotal	$7,863
			Construction Bond - 5% of construction subtotal	$3,931
			Contingency - 10% of construction subtotal	$7,863
			Construction Total	**$130,950**

9.3 Mar Vista Church Drainage Easement Bioretention Basin

9.3.1 Project Site

The Site is located within a drainage easement that in is located north of the Mar Vista Church (888 5th Street, Imperial Beach) rear parking lot. The Site is accessible via the church parking lot access road and through a locked chain link fence gate. The Site is bound to the east and west by residences, and wooden fences border both the east and west side of the easement. A concrete curb and gutter system is located within the easement and serves as a conveyance for runoff with a slight gradient towards the south and into a raised inlet structure. The existing curb has a height of approximately 1 foot and gutter has a width of approximately 4 feet. In the area where the BMP is proposed the easement widens and varies in width between approximately 12 to 18 feet. The site is shown in Figure 9-6. The proposed improvements are confined the wide portion of the easement north of the chain link fenced and south of wooden fence that is located approximately 115 feet north of chain link fence. A vicinity map is provided in Figure 9-7.

Figure 9-6. Mar Vista Church Easement BMP Project Site

Figure 9-7. Vicinity Map

9.3.2 Project Soil Geology and Percolation Testing

A local geotechnical firm conducted a Limited Geotechnical and Infiltration Evaluation for the site. Two percolation borings one exploratory boring were excavated and evaluated in order to evaluate site geology and the infiltration characteristics of near surface materials. The procedure used for conducting the percolation testing was in general accordance with the County of San Diego, DEH guidelines (DEH, 2008).

The site is underlain by Soil Type D materials that include fill and old paralic deposits. Groundwater was encountered at this site at a depth of 9 feet below the surface. Data were extracted from the evaluation report and are presented below. These data includes Figure 9-8 showing the test boring locations and Table 9-6 showing the testing results. For more details on the field work and results see the complete Limited Geotechnical and Infiltration Evaluation in Appendix E-1.

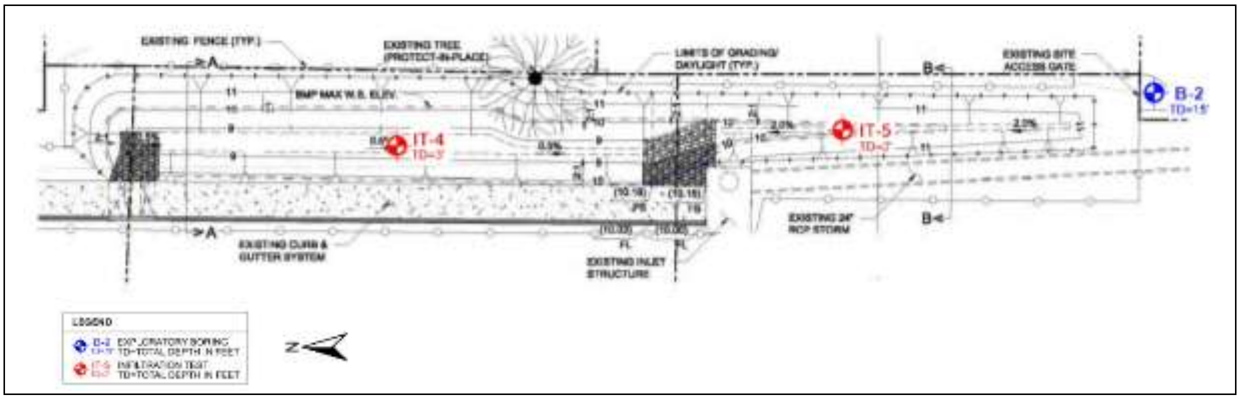

Figure 9-8. Test Boring Locations

Table 9-6. Infiltration Test Results Summary

Infiltration Test	Depth below ground surface (feet)	Designation	Adjusted Infiltration Rate (in/hr)
B-2	15	Clayey Sand / Sandy Clay (Fill over Old Paralic Deposits) Groundwater at 9 Feet	N/A
IT-4	3.0	Silty Sand / Sandy Clay (Fill over Old Paralic Deposits)	0.1
IT-5	2.0	Silty Sand / Sandy Clay (Fill over Old Paralic Deposits)	0.2

Based on the result of the testing, the Site soil conditions dictate that BMPs that rely primarily on infiltration as the treatment mechanism are not suitable for this location. Due to the shallow storm drain system, the proposed bioretention basin for this area cannot be designed with an subdrain system to convey treated water into the adjacent existing inlet or storm drain pipe. Therefore, the bioretention basin should be design to have minimal surface ponding and to utilize evapotranspiration and for treatment of captured storm water runoff. With type of design some of the captured water will infiltrate into the soil substrata.

9.3.3 Project Description

The proposed project includes minor grading to create a depressed basin adjacent to the existing concrete curb and gutter. Existing soils within this depressed area shall be removed, to an approximate depth of 2 feet below proposed elevations, and replaced with an amended soils mixture. Permeable geotextile shall be laid down beneath the amended soil mixture. The amended soils will consist of 65 percent sand and 35 percent compost (tolerance of plus or minus 5 percent). The sand and compost shall be well mixed prior to placement. A small portion of the curb and gutter system adjacent to the upstream and downstream of the BMP will be modified to divert low flows into, and out of, the BMP. The proposed landscaping in the basin may include drought tolerant, low height, native annual vegetation. Due to the location of the BMP, it may be better to leave the area un-landscape or landscaped with 3- to 6-inch diameter cobble. For more information relating to the bioretention BMP at this Site see Figure 9-9.

Storm water runoff from the tributary drainage area north of the BMP will flow into the existing curb and gutter system and flow towards the south and the proposed BMP. Adjacent to the BMP, modifications to the gutter will divert flows into the BMP. The runoff will be captured in the voids of the amended soils. Flows from the tributary drainage area south of the BMP, mainly the Mar Vista Church parking lot, will flow directly into the basin from an existing dirt swale. After the amended soils reach capacity (*i.e.*, void area are filled), runoff will flow through the BMP and through a small portion of modified gutter (modified to be a controlled re-entry point) and into the existing curb and gutter system. The captured runoff will filter through the amended soils and into the subsurface strata or evapotranspirate. Both of these processes will remove pollutants, including bacteria.

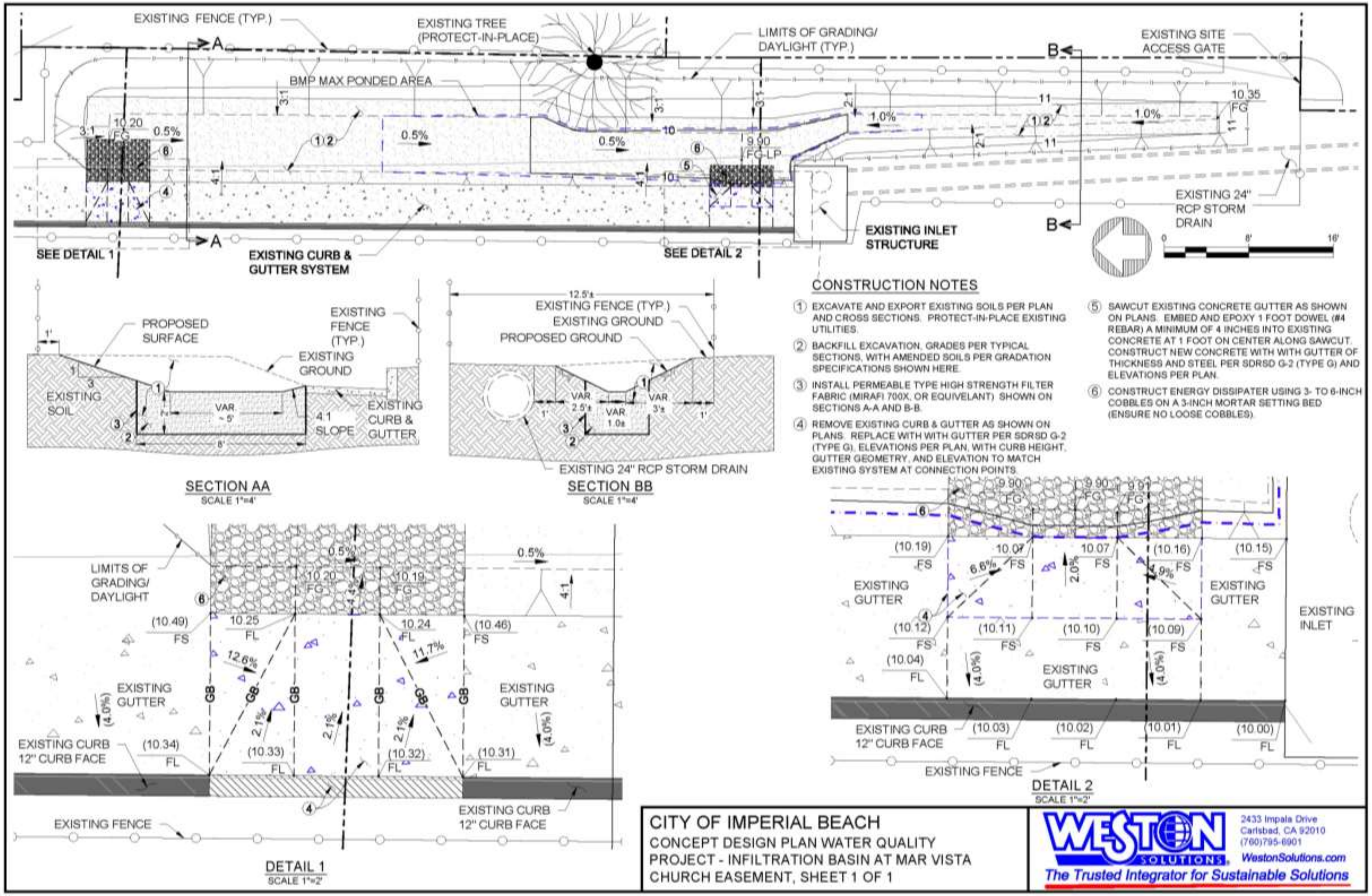

Figure 9-9. Mar Vista Church Drainage Easement Bioretention Basin Concept Design Plan

9.3.4 Water Quality Calculations

The tributary drainage area to the site is shown on Figure 9-10. The drainage area primarily consists of residential lots and a couple of churches (commercial lots). The overall drainage area measures an area of approximately 4.6 acres. The average, area weighted, impervious percentage used in calculations was 63%. In accordance with guidance found the SUSMP (CSD, 2011) and the County Hydrology Manual (CSD, 2003) water quality calculations were performed for the site. The water quality calculations and results are summarized in Table 9-7. Additional information relating to these calculations is provided in Appendix E-2.

Figure 9-10. Mar Vista Church Drainage Easement Drainage Area

Table 9-7. BMP Capacity Calculation Summary

85th Percentile Event =	0.55 Inches Per Hour
Bioretention Basin – Required Capture Storage	
Tributary Drainage Area =	4.2 Acres
C =	0.70
Q = CIA =	**5,856 Cubic Feet**
Bioretention Basin – Provided Capture Storage	
BMP Area =	628 Square Feet
Amended Soil Depth =	2.0 Feet
Soil Porosity	0.35
Amended Soils Storage (A*D*n) =	440 Cubic Feet
Ponded Surface Storage =	18 Cubic Feet
Total Storage Provided (Summation) =	**458 Cubic Feet**
Bioretention Basins 5 (West Basin) – Drawdown Time	
Estimated Infiltration Rate =	0.1 Inches Per Hour
Estimated Evapotranspiration Rate =	0.1 Inches Per Day
Basin Area =	628 Square Feet
Drawdown Flow Rate =	0.0011 Cubic Feet Per Second
Ponded Water Drawdown Time (18 Cubic Feet) =	4.5 Hours
BMP Recharge Time (to reach full capacity) =	114 Hours

The BMP proposed for the Mar Vista Church will not have adequate capacity to capture and treat the full 85^{th} percentile event, but rather capture a small portion of the runoff resulting from the 85^{th} percentile event. The BMP size is constrained to the relatively small area of the Site (drainage easement) in comparison to the size of the tributary drainage, which restricts the capacity of the proposed BMP. The BMP would provide complete capture of smaller rainfall events and would capture the initial runoff during larger storms, which may contain a large portion of the overall pollutants transported by storm water runoff during wet weather.

9.3.5 Load Quantification Analysis

The annual runoff in the drainage area was estimated for this Site based on rainfall data obtained from the County of San Diego's Project Cleanwater website (CSD, 2012). This website contains approximately 50 years of precipitation data. The Lower Otay rain gauge station was select due to its proximity to the site. The rainfall data was used to create a 21-year (1987-2007) continuous simulation model (CSM) that estimated runoff reaching the site and the portion of runoff that would be captured and treated by the proposed BMP on an hourly basis. The concentrations of COCs were estimated based on the average value of monitoring data obtained in other tasks of this Clean Beaches Initiative project. Pollutant removal efficiencies were estimated based on data published in the *International Stormwater BMP Database* (WERF, 2011). The above-mention data were analyzed and a summary of the average annual pollutant removal is provided in Table 9-8.

Table 9-8. Annual Pollutant Load Removal

Average Annual Volume of Storm water Runoff Treated		
Average Rainfall =	10.0	Inches Per Year
Capture Amount (Based on CSM) =	0.90	Inches Per Year
C =	0.70	
Area =	4.2	Acres
Rv (Coefficient to account for small rainfall amounts) =	0.9	
Annual Treatment Volume =	8,624	Cubic Feet
Average Annual Pollutant Load Removal		
Average Pollutant Load Reduction	100%	(Infiltration and Evapotranspiration)
Average Enterococci EMC =	24,700	MPN/100 Milliliters
Average Fecal Coliforms EMC =	55,600	MPN/100 Milliliters
Enterococci Load Removal =	60,300	10^6 MPN
Fecal Coliforms Load Removal =	135,800	10^6 MPN

9.3.6 Performance Specifications

The goal of the Mar Vista Church Drainage Easement Bioretention Basin for the Tijuana River Watershed Protection Project is to reduce the pollutant load entering Tijuana River National Estuary. This goal will be achieved by improving the existing drainage easement with amended soils and diverting flows from the adjacent curb and gutter into the amended soils for capture and treatment of storm flows. In general, project treatment components shall be designed to remove pollutants (priority constituents of concern), including bacteria, heavy metals, and sediment. Every effort shall be made through the use of improved technologies and enhancing this concept design to further reduce pollutant loading entering the estuary. Refer to the project concept design plan for more details on the specification of project components.

9.3.7 Operations and Maintenance

It is anticipated that semi-annual regular maintenance will be required to maintain the bioretention BMPs to optimal performance. Semi-annual maintenance should be performed on the basin in September, prior to first wet weather, and towards the end of the wet season in April or May. This maintenance shall include visual observation of the area checking for and removing debris such as trash and organic materials. If large rainfall events occur (greater than 2 inches) the above-mentioned regular maintenance shall be conducted.

9.3.8 Estimated Construction Cost

The estimated construction cost of implementing the Mar Vista Church Drainage Easement concept design is approximately $50,250. This includes labor and materials, engineering design, mobilization, traffic and erosion control, construction bond, miscellaneous landscaping, and a 10% contingency but excludes City staff costs associated with construction inspection and project management/review. Refer to Table 9-9 for more details on the cost estimate.

Table 9-9. Cost Estimate

Drainage Easement LID Feature Behind Mar Vista Church Cost Estimate for Proposed Improvements Concept Design Level				
ITEM	**QUANTITY**	**UNIT**	**UNIT PRICE**	**COST**
Grading & Export	90	CY	$44.28	$3,985
Amended Soils	53	CY	$150.00	$7,950
Saw Cut Concrete Gutter	18	LF	$10.00	$180
Demo Existing Curb & Gutter to Modify Flow Line	60	SF	$10.00	$600
Construct Curb & Gutter sloped towards BMP	60	SF	$30.00	$1,800
Remove Chain Link Fence (for site access)	15	LF	$15.00	$225
Re-install Chan Link Fence and Gate	15	LF	$30.00	$450
Energy Dissipater (3 to 6" rock set in mortar)	36	SF	$25.00	$900
Landscaping - Cobble and/or Native Vegetation	1,000	SF	$3.00	$3,000
Concrete Washout	1	EA	$825.00	$825
Construction Fence	250	LF	$4.00	$1,000
Gravel Bag	100	EA	$1.82	$182
Protect-in-place existing utilities / Tree	1	LS	$1,500.00	$1,500
	Construction Subtotal			**$22,597**
WPCP				$6,000
Field Orders				$5,000
Field Survey				$3,000
Engineering Design - 25% of construction subtotal ($8K Min.)				$8,000
Mobilization - 10% of construction subtotal				$2,260
Construction Bond - 5% of construction subtotal				$1,130
Contingency - 10% of construction subtotal				$2,260
Construction Total				**$50,250**

9.4 Thorn Street Cul-De-Sac Drainage Right-of-Way Porous Concrete

9.4.1 Project Site

The Site is within the City of Imperial Beach utility right-of-way that connects the west end of the Thorn Street cul-de-sac to Fifth Street. The Site is bound to the north and south by residences. The area is currently dirt and sparse vegetation with a swale located near the middle of the right-of-way to covey storm water runoff from Thorn Street to Fifth Street via a concrete sidewalk underdrain that is located adjacent to Fifth Street at the west boundary of the Site. The site is shown in Figure 9-11. The proposed improvements are confined to the area of the right-of-way, which is approximately 10 feet wide and 195 feet in length. A vicinity map is provided in Figure 9-12.

Figure 9-11. Thorn Street Cul-De-Sac Drainage Conveyance Site

Figure 9-12. Vicinity Map

9.4.2 Project Soil Geology and Percolation Testing

A local geotechnical firm conducted a Limited Geotechnical and Infiltration Evaluation for the site. Two percolation borings and one exploratory boring were excavated and evaluated in order to evaluate site geology and the infiltration characteristics of near surface materials. The procedure used for conducting the percolation testing was in general accordance with County of San Diego, DEH guidelines (DEH, 2008).

The site is underlain by Soil Type D materials including fill and old paralic deposits. Groundwater was encountered at this site at a depth of 10 feet below the surface. Data were extracted from the evaluation report and are presented below. These data includes Figure 9-13 showing the test boring locations and Table 9-10 showing the testing results. For more details on the field work and results see the complete Limited Geotechnical and Infiltration Evaluation in Appendix E-1.

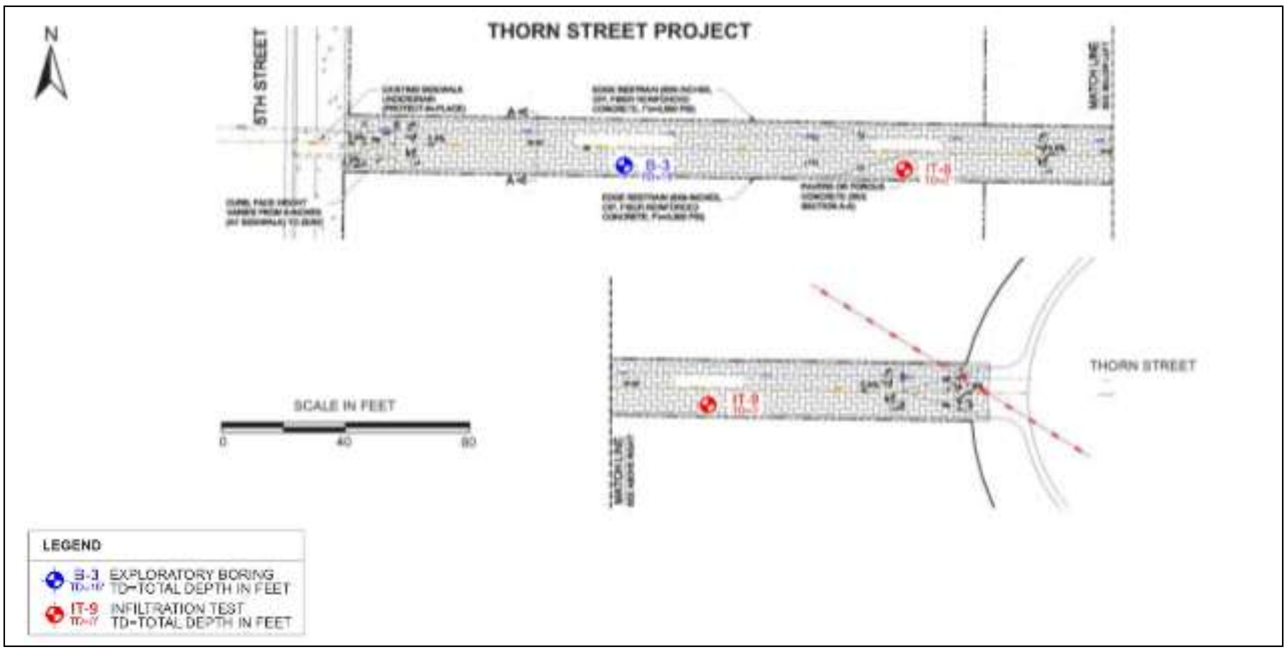

Figure 9-13. Test Boring Locations

Table 9-10. Infiltration Test Results Summary

Infiltration Test	Depth below ground surface (feet)	Designation	Adjusted Infiltration Rate (in/hr)
B-3	15	Clayey Sand / Sandy Clay (Fill over Old Paralic Deposits) Groundwater at 10 Feet	N/A
IT-8	2.0	Silty Sand / Sandy Clay (Fill over Old Paralic Deposits)	0.4
IT-9	3.0	Silty Sand / Sandy Clay (Fill)	0.1

Based on the results of the testing, the site soil conditions indicate that BMPs that store capture runoff in a ponded area and rely primarily on infiltration as the treatment mechanism are not suitable for this location. An underdrain system to convey treated water into the existing storm drain system does appear feasible due to the site not being adjacent to an existing inlet or storm drain pipe. Therefore, the BMP for this Site should be design to have minimal surface ponding and to utilize infiltration (0.1 inches per hour selected) for treatment of captured storm water runoff from a rock reservoir (such as porous concrete over a rock reservoir).

9.4.3 Project Description

The proposed project includes minor grading to create a swale having a uniform grade from the Thorn Street cul-de-sac to sidewalk underdrain located along Fifth Street. Existing soils within this Site shall be removed, to an approximate depth of 2.0 feet, and replaced with a rock reservoir including gravel and rocks layers and surface section that includes sand and a porous surface such as porous concrete. Permeable geotextile shall be laid down at the bottom of the excavation, and a second layer beneath the proposed sand layer. An edge restrain consisting of fiber reinforced concrete shall be constructed along both sides of the Site. For more information relating to the bioretention BMPs at this Site see Figure 9-14.

Storm water runoff from the tributary drainage area east of the Site will flow into the proposed porous surface and be captured and stored in the rock reservoir. After the system reaches capacity (*i.e.*, voids in the rock reservoir and porous concrete are filled to the maximum level), runoff will flow over the porous surface and through the Site like a normal concrete drainage conveyance. The runoff captured and stored in the rock reservoir will infiltrate into the subsurface strata, and this process will remove pollutants, including bacteria.

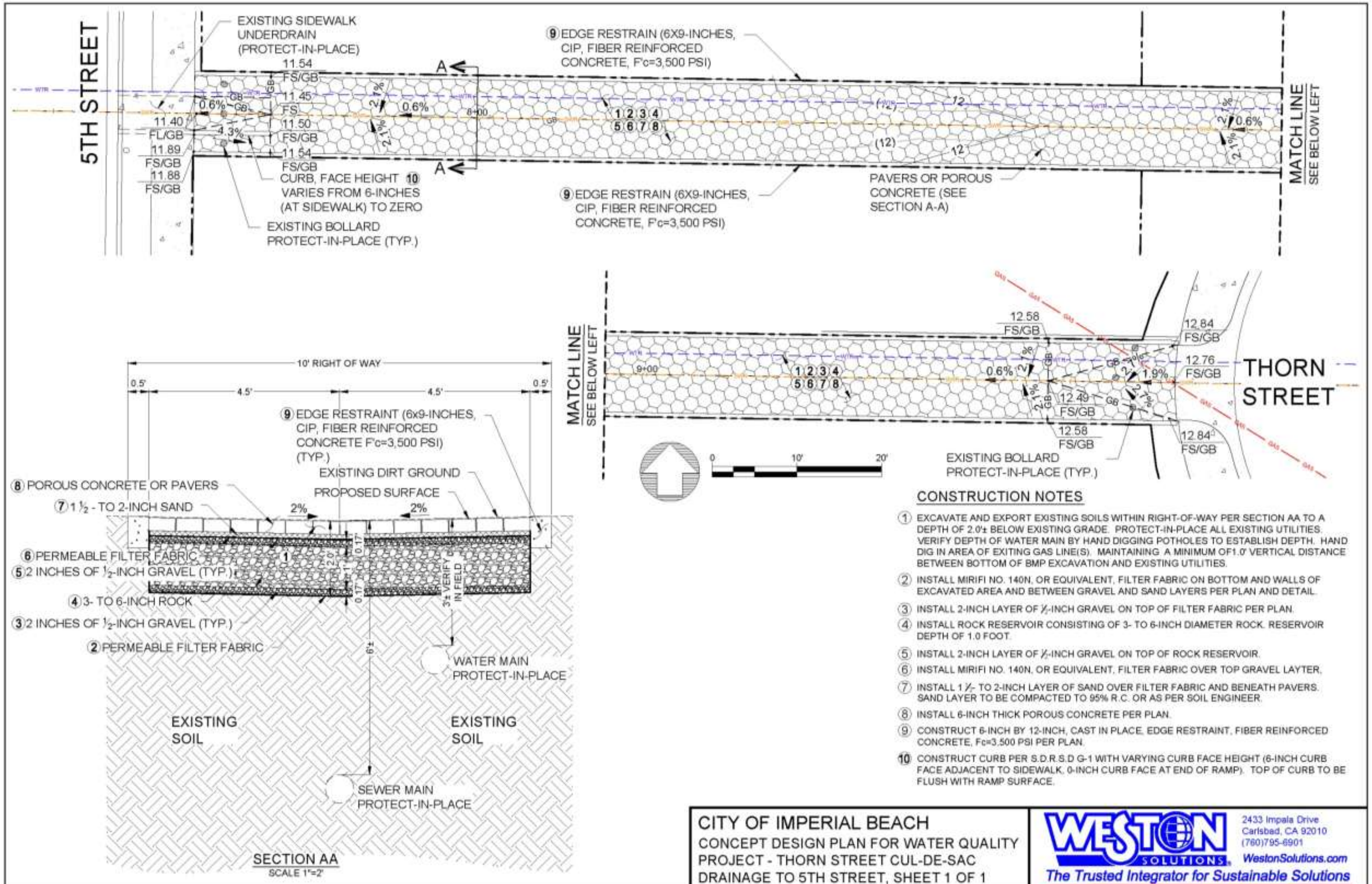

Figure 9-14. Thorn Street Cul-De-Sac Drainage Right-Of-Way Porous Concrete Concept Design Plan

9.4.4 Water Quality Calculations

Storm water runoff from Thorn Street collects in the curb and gutter system and travels west onto the Site. The drainage area consists of residential lots located along Thorn Street east of the Site and west of Carolina Street. The tributary drainage area to the site is shown on Figure 9-15. The overall drainage area measures an area of approximately 5.3 acres. The dwelling unity density is approximately 5.0 single-family dwelling per acre and the impervious percentage used in calculations was 40%. In accordance with guidance found the SUSMP (CSD, 2011) and the County Hydrology Manual (CSD, 2003) water quality calculations were performed for the site. The water quality calculations and results are summarized in Table 9-11. Additional information relating to these calculations is provided in Appendix E-2.

Figure 9-15. Thorn Street Cul-De-Sac Drainage Area

Table 9-11. BMP Capacity Calculation Summary

85th Percentile Event =	0.55 Inches Per Hour
Porous Concrete – Required Capture Storage	
Tributary Drainage Area =	5.3 Acres
C =	0.57
Q = CIA =	**6,031 Cubic Feet**
Porous Concrete – Provided Capture Storage	
BMP Area =	1,755 Square Feet
Average Water Depth in Rock Reservoir =	1.32 Feet
Rock Porosity	0.35
Rock Reservoir Storage (A*D*n) =	**811 Cubic Feet**
Bioretention Basins 5 (West Basin) – Drawdown / Recharge Time	
Estimated Infiltration Rate =	0.1 Inches Per Hour
BMP Area =	1,755 Square Feet
Drawdown Flow Rate =	0.0041 Cubic Feet Per Second
BMP Recharge Time (to reach full capacity) =	56 Hours

The BMP proposed for the Thorn Street cul-de-sac will not have adequate capacity to capture and treat the full 85th percentile event, but rather capture a small portion of the runoff resulting from the 85th percentile event. The BMP size is constrained by the relatively small area of the Site (drainage right-of-way) in comparison to the size of the tributary drainage, and this constraint restricts the capacity of the proposed BMP. The BMP would provide complete capture of smaller rainfall events and would capture the initial runoff during larger storms, which may contain a large portion of the overall pollutants transported by storm water runoff during wet weather.

9.4.5 Load Quantification Analysis

The annual runoff in the drainage area was estimated for this site based on rainfall data obtained from the County of San Diego's Project Cleanwater website (CSD, 2012). This website contains approximately 50 years of precipitation data. The Lower Otay rain gauge station was select due to its proximity to the site. The rainfall data was used to create a 21-year (1987-2007) CSM that estimated runoff reaching the site and the portion of runoff that would be captured and treated by the proposed BMP on an hourly basis. The concentrations of COCs were estimated based on the average of monitoring values obtained in other tasks of this Clean Beaches Initiative project. Pollutant removal efficiencies were estimated based on data published in the *International Stormwater BMP Database* (WERF, 2011). The above-mention data were analyzed and a summary of the average annual pollutant removal is provided in Table 9-12.

Table 9-12. Annual Pollutant Load Removal

Average Annual Volume of Storm water Runoff Treated		
Average Rainfall =	10.0	Inches Per Year
Capture Amount (Based on CSM) =	1.69	Inches Per Year
C =	0.57	
Area =	5.3	Acres
Rv (Coefficient to account for small rainfall amounts) =	0.9	
Annual Treatment Volume =	18,590	Cubic Feet
Average Annual Pollutant Load Removal		
Average Pollutant Load Reduction	100%	(Infiltration)
Average Enterococci EMC =	24,700	MPN/100 Milliliters
Average Fecal Coliforms EMC =	55,600	MPN/100 Milliliters
Enterococci Load Removal =	117,000	10^6 MPN
Fecal Coliforms Load Removal =	264,400	10^6 MPN

9.4.6 Performance Specifications

The goal of the Thorn Street Cul-De-Sac Drainage Right-of-Way Porous Concrete Project for the Tijuana River Watershed Protection Project is to reduce the pollutant load entering Tijuana River National Estuary. This goal will be achieved by improving the existing drainage with a hard surface comprised of porous concrete over a rock reservoir. In general, project treatment components shall be designed to remove pollutants (priority COCs), including bacteria, heavy metals, and sediment. Every effort shall be made through the use of improved technologies and enhancing this concept design to further reduce pollutant loading entering the estuary. Refer to the project concept design plan for more details on the specification of project components.

9.4.7 Operations and Maintenance

It is anticipated that semi-annual regular maintenance will be required to maintain the bioretention BMPs to optimal performance. Semi-annual maintenance should be performed on the BMP in September, prior to first wet weather, and towards the end of the wet season in April or May. This maintenance shall include visual observation of the area checking for and removing debris such as trash and organic materials. If large amounts of sediment are observed on the surface of the porous concrete, those sediments shall be removed by sweeping or with a vacuum truck. During maintenance a 5 gallon bucket of clean potable water shall be poured on the upstream, middle, and downstream locations of the porous surface to ensure that the water completely penetrates the surface with no runoff. If large rainfall events occur (greater than 2 inches) the above-mentioned regular maintenance shall be conducted. As needed, if clogging is observed, and every 10 years, at a minimum, the surface of the BMP shall be clean with a light weight vacuum truck.

9.4.8 Estimated Construction Cost

The estimated construction cost of implementing the Thorn Street Cul-De-Sac Drainage Right-of-Way Porous Concrete Project is approximately $107,700. This includes labor and materials, engineering design, mobilization, traffic and erosion control, construction bond, miscellaneous landscaping, and a 10% contingency but excludes City staff costs associated with construction inspection and project management/review. Refer to Table 9-13 for more details on the cost estimate.

Table 9-13. Cost Estimate

Utility Right-Of-Way LID Feature Between Thorn Street and 5th Street Cost Estimate for Proposed Improvements Concept Design Level				
ITEM	**QUANTITY**	**UNIT**	**UNIT PRICE**	**COST**
Grading & Export	140	CY	$44.28	$6,199
Filter Fabric Permeable	2,750	SF	$1.25	$3,438
1/2-inch Gravel - Bottom Course	12	CY	$125.00	$1,500
3- to 6-inch Rock Reservoir	70	CY	$125.00	$8,750
1/2-inch Gravel - Top Course	12	CY	$125.00	$1,500
Filter Fabric - Beneath Sand Course	2,000	SF	$1.25	$2,500
1 1/2- to 2-inch Sand Course	12	CY	$125.00	$1,500
Porous Concrete	1,800	SF	$15.50	$27,900
Concrete Edge Restrain	400	LF	$15.00	$6,000
Curb per G-1 (height varies 6" to 0" curb face)	9	LF	$22.00	$198
Concrete Washout	1	EA	$825.00	$825
Construction Fence	100	LF	$4.00	$400
Gravel Bag	100	EA	$1.82	$182
Traffic Control	1	LS	$2,000.00	$2,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
			Construction Subtotal	**$67,892**
			WPCP	$8,000
			Field Survey	$3,000
			Field Orders	$5,000
			Engineering Design - 15% of construction subtotal	$10,184
			Mobilization - 5% of construction subtotal	$3,395
			Construction Bond - 5% of construction subtotal	$3,395
			Contingency - 10% of construction subtotal	$6,789
			Construction Total	**$107,700**

9.5 Donax Avenue Cul-De-Sac Drainage Right-of-Way Porous Concrete

9.5.1 Project Site

The Site is within the City of Imperial Beach utility right-of-way that connects the west end of the Donax Avenue cul-de-sac to Fifth Street. The Site is bound to the north and south by residences. The area is currently occupied by a concrete drainage swale, with a width of 6 feet, and sparse grass vegetation on both sides of the swale. At the west boundary of the Site, the concrete swale conveys storm water runoff from the Site to Fifth Street via a steel plate cover sidewalk under located adjacent to Fifth Street. The site is shown in Figure 9-16. The proposed improvements are confined to the area of the right-of-way, which is approximately 10 feet wide and 192 feet in length. A vicinity map is provided in Figure 9-17.

Figure 9-16. Donax Avenue Cul-De-Sac Drainage Conveyance Site

Figure 9-17. Vicinity Map

9.5.2 Project Soil Geology and Percolation Testing

A local geotechnical firm conducted a Limited Geotechnical and Infiltration Evaluation for the site. Twp percolation borings and one exploratory boring (exploratory boring at Thorn Street Site used) were excavated and evaluated in order to evaluate site geology and the infiltration characteristics of near surface materials. The procedure used for conducting the percolation testing was in general accordance with County of San Diego, DEH guidelines (DEH, 2008).

The site is underlain by Soil Type D materials including fill and old paralic deposits. Groundwater was encountered at this site at a depth of 10 feet below the surface (see boring B-3 conducted for the Thorn Street Site. Data were extracted from the evaluation report and are presented below. These data includes Figure 9-18 showing the test boring locations and Table 9-14 showing the testing results. For more details on the field work and results see the complete Limited Geotechnical and Infiltration Evaluation in Appendix E-1.

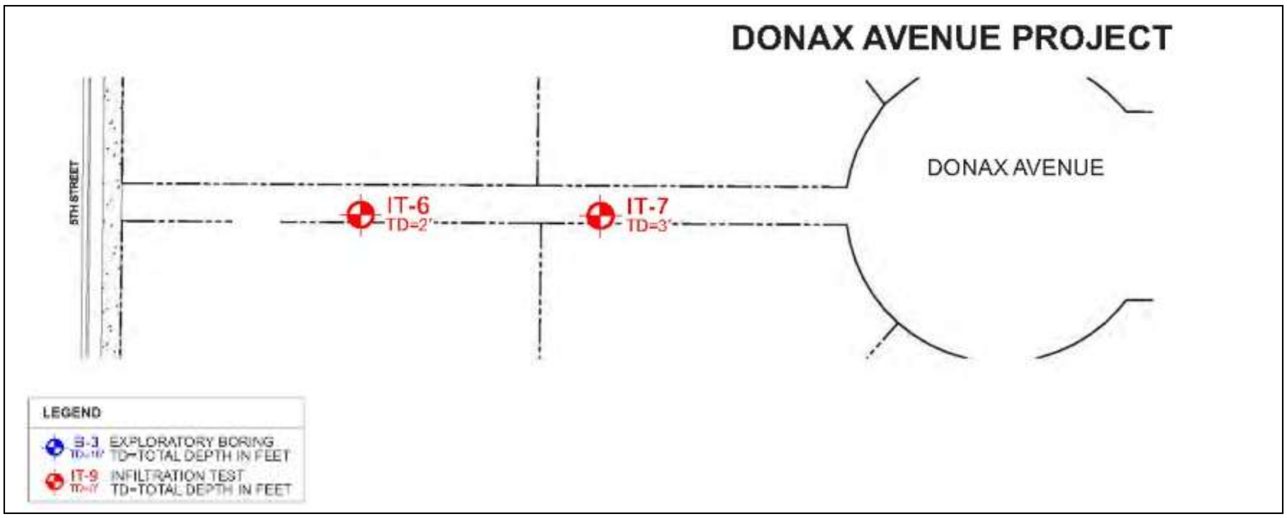

Figure 9-18. Test Boring Locations

Table 9-14. Infiltration Test Results Summary

Infiltration Test	Depth below ground surface (feet)	Designation	Adjusted Infiltration Rate (in/hr)
IT-6	2.0	Silty Sand (Fill over Old Paralic Deposits)	2.3
IT-7	3.0	Silty Sand (Fill over Old Paralic Deposits)	0.7

Based on the results of the testing, the Site soil conditions indicate that BMPs that utilize infiltration are suitable for this location. For calculations purposes, 0.7 inches per hour will be used.

9.5.3 Project Description

The proposed project includes minor grading to create a swale having a uniform grade from the Donax Avenue cul-de-sac to sidewalk underdrain located along Fifth Street. The existing concrete swale and soils within this Site shall be removed, to an approximate depth of 2.0 feet below existing surface elevations, and replaced with a rock reservoir including gravel and rock layers and surface section that includes sand and a porous surface such as porous concrete. Permeable geotextile shall be laid down at the bottom of the excavation and beneath the proposed sand layer. An edge restrain consisting of fiber reinforced concrete shall be constructed along both sides of the Site. For more information relating to the bioretention BMPs at this Site see Figure 9-19.

Storm water runoff from the tributary drainage area east of the Site will flow into the proposed porous surface and be captured and stored in the rock reservoir. After the system reaches capacity (*i.e.*, voids in the rock reservoir and porous concrete are filled to the maximum level), runoff will flow over the porous surface and through the Site like a normal concrete drainage conveyance. The runoff captured and stored in the rock reservoir will infiltrate into the subsurface strata, and this process will remove pollutants, including bacteria.

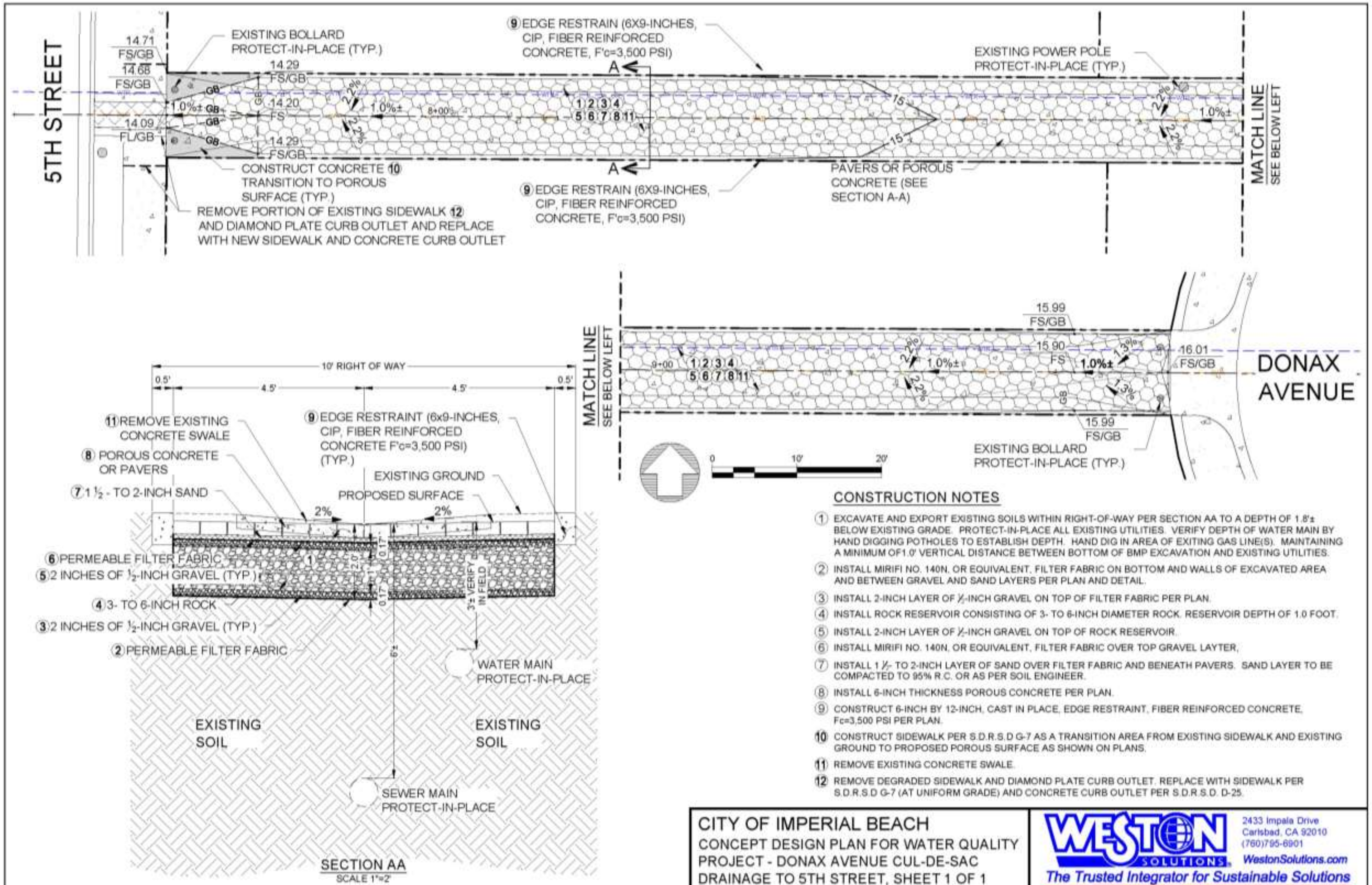

Figure 9-19. Donax Avenue Cul-De-Sac Drainage Right-of-Way Concept Design Plan

9.5.4 Water Quality Calculations

Storm water runoff from Donax Avenue collects in the curb and gutter system and travels west onto the Site. The drainage area consists of residential lots located along Donax Avenue east of the Site and west of Carolina Street. The tributary drainage area to the site is shown on Figure 9-20. The overall drainage area measures an area of approximately 5.3 acres. The dwelling unity density is approximately 5.0 single-family dwelling per acre, and the impervious percentage used in calculations was 40%. In accordance with guidance found the SUSMP (CSD, 2011) and the County Hydrology Manual (CSD, 2003) water quality calculations were performed for the site. The water quality calculations and results are summarized in Table 9-15. Additional information relating to these calculations is provided in Appendix E-2.

Figure 9-20. Donax Avenue Cul-De-Sac Drainage Area

Table 9-15. BMP Capacity Calculation Summary

85th Percentile Event =	0.55 Inches Per Hour
Porous Concrete – Required Capture Storage	
Tributary Drainage Area =	5.3 Acres
C =	0.57
Q = CIA =	**6,031 Cubic Feet**
Porous Concrete – Provided Capture Storage	
BMP Area =	1,690 Square Feet
Average Water Depth in Rock Reservoir =	0.95 Feet
Rock Porosity	0.35
Rock Reservoir Storage (A*D*n) =	**562 Cubic Feet**
Bioretention Basins 5 (West Basin) – Drawdown / Recharge Time	
Estimated Infiltration Rate =	0.7 Inches Per Hour
BMP Area =	1,690 Square Feet
Drawdown Flow Rate =	0.0274 Cubic Feet Per Second
BMP Recharge Time (to reach full capacity) =	5.7 Hours

The BMP proposed for the Thorn Street cul-de-sac will not have adequate capacity to capture and treat the full 85th percentile event, but rather capture a small portion of the runoff resulting from the 85th percentile event. The BMP size is constrained by the relatively small area of the Site (drainage right-of-way) in comparison to the size of the tributary drainage, and this constraint restricts the capacity of the proposed BMP. The BMP would provide complete capture of smaller rainfall events and would capture the initial runoff during larger storms, which may contain a large portion of the overall pollutants transported by storm water runoff during wet weather.

9.5.5 Load Quantification Analysis

The annual runoff in the drainage area was estimated for this site based on rainfall data obtained from the County of San Diego’s Project Cleanwater website (CSD, 2012). This website contains approximately 50 years of precipitation data. The Lower Otay rain gauge station was select due to its proximity to the site. The rainfall data was used to create a 21-year (1987-2007) CSM that estimated runoff reaching the site and the portion of runoff that would be captured and treated by the proposed BMP on an hourly basis. The concentrations of COCs were estimated based on the average value of monitoring data obtained in other tasks of this Clean Beaches Initiative project. Pollutant removal efficiencies were estimated based on data published in the *International Stormwater BMP Database* (WERF, 2011). The above-mention data were analyzed and a summary of the average annual pollutant removal is provided in Table 9-16.

Table 9-16. Annual Pollutant Load Removal

Average Annual Volume of Storm water Runoff Treated		
Average Rainfall =	10.0	Inches Per Year
Capture Amount (Based on CSM) =	3.13	Inches Per Year
C =	0.57	
Area =	5.3	Acres
Rv (Coefficient to account for small rainfall amounts) =	0.9	
Annual Treatment Volume =	30,900	Cubic Feet Per Year
Average Annual Pollutant Load Removal		
Average Pollutant Load Reduction	100%	(Infiltration)
Average Enterococci EMC =	24,700	MPN/100 Milliliters
Average Fecal Coliforms EMC =	55,600	MPN/100 Milliliters
Enterococci Load Removal =	216,000	10^6 MPN Per Year
Fecal Coliforms Load Removal =	486,500	10^6 MPN Per Year

9.5.6 Performance Specifications

The goal of the Donax Avenue Cul-De-Sac Drainage Right-of-Way Porous Concrete Project for the Tijuana River Watershed Protection Project is to reduce the pollutant load entering Tijuana River National Estuary. This goal will be achieved by improving the existing drainage with a hard surface comprised of porous concrete over a rock reservoir. In general, project treatment components shall be designed to remove pollutants (priority COCs), including bacteria, heavy metals, and sediment. Every effort shall be made through the use of improved technologies and enhancing this concept design to further reduce pollutant loading entering the estuary. Refer to the project concept design plan for more details on the specification of project components.

9.5.7 Operations and Maintenance

It is anticipated that semi-annual regular maintenance will be required to maintain the bioretention BMPs to optimal performance. Semi-annual maintenance should be performed on the BMP in September, prior to first wet weather, and towards the end of the wet season in April or May. This maintenance shall include visual observation of the area checking for and removing debris such as trash and organic materials. If large amounts of sediment are observed on the surface of the porous concrete, those sediments shall be removed by sweeping or with a vacuum truck. During maintenance a 5 gallon bucket of clean potable water shall be poured on the upstream, middle, and downstream locations of the porous surface to ensure to the water completely penetrates the surface with no runoff. If large rainfall events occur (greater than 2 inches) the above-mentioned regular maintenance shall be conducted. As needed, if clogging is observed, and every 10 years, at a minimum, the surface of the BMP shall be clean with a light weight vacuum truck.

9.5.8 Estimated Construction Cost

The estimated construction cost of implementing the Donax Avenue Cul-De-Sac Drainage Right-of-Way Porous Concrete Project is approximately $120,000. This includes labor and materials, engineering design, mobilization, traffic and erosion control, construction bond, miscellaneous landscaping, minor utility relocation, and a 10% contingency but excludes City staff costs associated with construction inspection and project management/review. Refer to Table 9-17 for more details on the cost estimate.

Table 9-17. Cost Estimate

Utility Right-of-Way LID Feature Between Donax Avenue and 5th Street Cost Estimate for Proposed Improvements Concept Design Level				
ITEM	**QUANTITY**	**UNIT**	**UNIT PRICE**	**COST**
Demo Existing Concrete Swale	1,200	SF	$4.00	$4,800
Grading & Export	125	CY	$44.28	$5,535
Filter Fabric Permeable	2,750	SF	$1.25	$3,438
1/2-inch Gravel - Bottom Course	13	CY	$125.00	$1,625
3- to 6-inch Rock Reservoir	73	CY	$125.00	$9,125
1/2-inch Gravel - Top Course	13	CY	$125.00	$1,625
Filter Fabric - Beneath Sand Course	1,960	SF	$1.25	$2,450
1 1/2- to 2-inch Sand Course	13	CY	$125.00	$1,625
Porous Concrete	1,700	SF	$15.50	$26,350
Concrete Edge Restrain	400	LF	$22.00	$8,800
Sidewalk (Transition to Porous Surface)	45	SF	$16.50	$743
Curb Outlet (SDRSD D-25)	1	EA	$2,500.00	$2,500
Concrete Washout	1	EA	$825.00	$825
Construction Fence	100	LF	$4.00	$400
Gravel Bag	100	EA	$1.82	$182
Traffic Control	1	LS	$2,000.00	$2,000
Protect-in-place existing utilities	1	LS	$5,000.00	$5,000
	Construction Subtotal			**$77,022**
WPCP				$8,000
Field Survey				$3,000
Field Orders				$5,000
Engineering Design - 15% of construction subtotal				$11,553
Mobilization - 5% of construction subtotal				$3,851
Construction Bond - 5% of construction subtotal				$3,851
Contingency - 10% of construction subtotal				$7,702
Construction Total				**$120,000**

9.6 Imperial Beach Boulevard Eco Bike Lane / Green Street

9.6.1 Project Site

The Site is located within the Imperial Beach Boulevard right-of-way between Seacoast Drive and Connecticut Street. The Site is bound to the north and south by residences, commercial properties, and Mar Vista High School. A portion of the site is shown in Figure 9-21. Note the traffic calming shown in the figure (conventionally landscaped planter), which are typical along the roadway near intersections. The proposed improvements are confined to the areas where existing traffic calming planters protrude out from the curb and gutter, mainly in the areas of intersections. A vicinity map is provided in Figure 9-22.

Figure 9-21. Imperial Beach Boulevard and Second Street Intersection

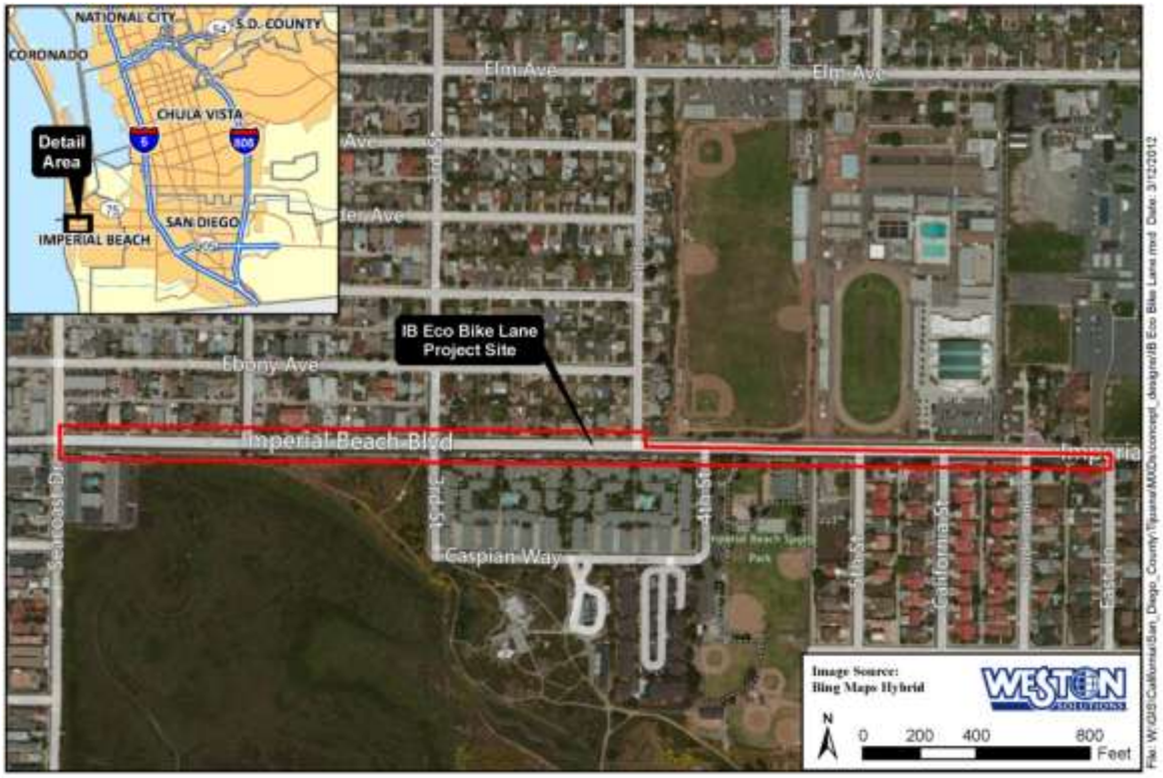

Figure 9-22. Vicinity Map

9.6.2 Project Soil Geology and Percolation Testing

A local geotechnical firm conducted a Limited Geotechnical and Infiltration Evaluation for the site. Six percolation borings, one exploratory boring, and two hand auger borings were excavated and evaluated in order to evaluate site geology and the infiltration characteristics of near surface materials. The procedure used for conducting the percolation testing was in general accordance with County of San Diego, DEH guidelines (DEH, 2008).

The site is underlain by Soil Type D materials including fill and old paralic deposits. Groundwater was encountered at this site at a depth of 8 feet below the surface. Data were extracted from the evaluation report and are presented below. These data includes Figure 9-23 showing the test boring locations and Table 9-18 showing the testing results. For more details on the field work and results see the complete Limited Geotechnical and Infiltration Evaluation in Appendix E-1.

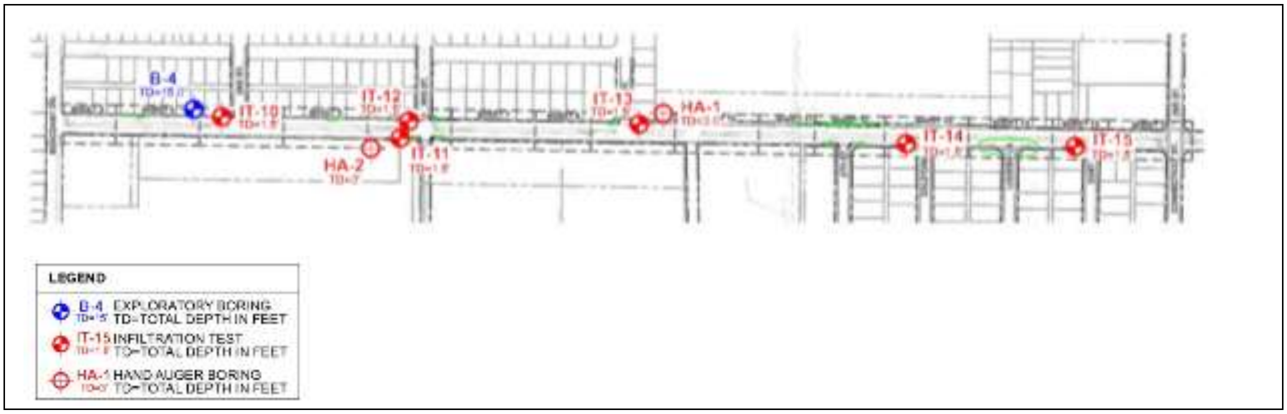

Figure 9-23. Test Boring Locations

Table 9-18. Infiltration Test Results Summary

Infiltration Test	Depth Below Ground Surface (feet)	Designation	Adjusted Infiltration Rate (in/hr)
B-4	12.0	Silty Sand (Fill over Old Paralic Deposits) Groundwater at 8 feet	N/A
HA-1	3.0	Silty Sand (Fill over Old Paralic Deposits)	N/A
HA-2	0.5	Silty Sand (Fill)	N/A
IT-10	1.5	Silty Sand (Fill over Old Paralic Deposits)	0.5
IT-11	1.5	Silty Sand (Fill over Old Paralic Deposits)	0.7
IT-12	1.5	Silty Sand and Clayey Sand (Fill over Old Paralic Deposits)	0.7
IT-13	1.5	Silty Sand (Fill over Old Paralic Deposits)	2.1
IT-14	1.5	Silty Sand (Fill over Old Paralic Deposits)	0.4
IT-15	1.5	Silty Sand (Fill)	0.4

Based on the results of the testing, the site soil conditions indicate that BMPs that utilize infiltration may be suitable for this Site. The Site conditions do appear favorable for the type of BMP that is proposed for this Site (bioretention basins with only shallow ponding of water that utilize both infiltration and evapotranspiration for treatment). For quantification calculations purposes, an infiltration rate of 0.5 inches per hour will be used.

9.6.3 Project Description

The proposed project includes modifying the existing curb and gutter configuration so that the curb and gutter will curve away (towards street centerline) from the current position and will provide room for a depressed planter (basin) that will vary in length and width, but typically will be about 40 feet in length and have a width of about 8 feet. Existing soils within the proposed basins will be excavated to a depth of 1.5 feet below proposed surface elevations and replaced with an amended soils mixture. Basins are proposed at the majority of the intersections in the general locations where conventional (raised) planters are currently located. The existing curb and gutter in the area of improvements will be removed. The sidewalk will remain unchanged. The proposed curb and gutter will have an opening so that runoff collected in the gutter can flow into the basin. At the downstream end of the basin, a second opening will allow water to flow out of the basin once capacity is reached. These modifications to the curb and gutter configuration at intermittent locations along Imperial Beach Boulevard will result the roadway cross slope (fall towards the curb and gutter) to vary slightly (become steeper) from the existing condition with maximum cross slopes of approximately 5 percent. In the areas of increased cross sloped, portions of the adjacent asphalt concrete will be cut and removed and replaced with asphalt concrete at varying cross slope to achieve smooth transitions from existing to proposed grades. The proposed modifications to the curb and gutter have been designed to allow for the ultimate roadway configuration, which includes parking, bike lane, vehicle lane, and median. For more information relating to the bioretention BMPs at this Site see Figure 9-24. The complete plan set for this project is provided in Appendix E-3.

Storm water runoff from the areas of Imperial Beach Boulevard that are adjacent to the proposed modifications will sheet flow into the existing curb and gutter and towards the proposed improvements. Runoff will be conveyed from the curb and gutter into the proposed bioretention basins through openings in the proposed curb and gutter. The runoff in the basins will fill the voids of the amended soils. Once soil voids are filled, minor ponding within the basin will occur until the water level in the basin reaches the outlet invert elevation (downstream curb opening) and flows out of the basin. The captured runoff will remain in the basin and either infiltrate into the soil substrata or evapotranspirate. Both processes will remove pollutants, including bacteria.

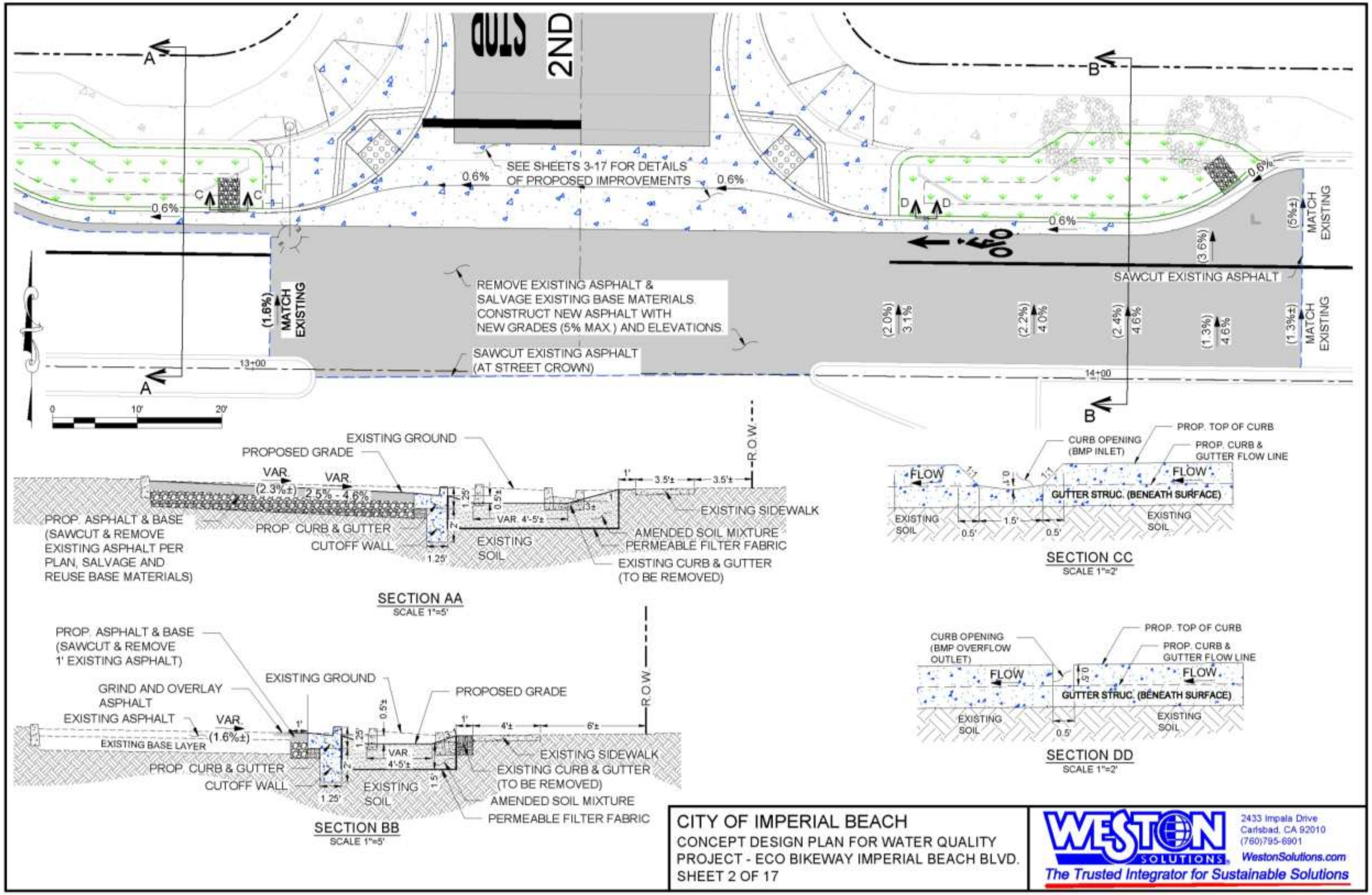

Figure 9-24. Imperial Beach Boulevard Eco Bike Lane / Green Street Concept Design Plan

9.6.4 Water Quality Calculations

The drainage area for each bioretention basin consists of the adjacent, upstream portion of Imperial Beach Boulevard, right-of-way to centerline crown. There are total of 15 bioretention basins proposed, and each basin has a slightly different drainage area and BMP area. In order to perform water quality calculations, the basins were grouped into four categories based on their relative drainage areas (very small, small, medium, and large drainage areas). For hydrologic calculations, the drainage is considered to be 95% impervious. In accordance with guidance found the SUSMP (CSD, 2011) and the County Hydrology Manual (CSD, 2003) water quality calculations were performed for the Site. The drainage area weighted, water quality calculations and results are summarized in Table 9-19. Additional information relating to these calculations is provided in Appendix E-1.

Table 9-19. Capacity of BMPs Calculation Summary

85^{th} Percentile Event =	0.55 Inches Per Hour
Bioretention Basins (15 Basins Total) – Required Capture Storage	
Total Tributary Drainage Area =	2.93 Acres
C =	0.87
Q = CIA =	**6,140 Cubic Feet**
Bioretention Basins (15 Basins Total) – Provided Capture Storage	
Total Area of BMPs =	4,533 Square Feet
Amended Soils Depth =	1.5 Feet
Rock Porosity	0.35
Amended Soils Storage (A*D*n) =	2,380 Cubic Feet
Total Volume of Ponded Water in BMPs =	432 Cubic Feet
Total Capture Storage Provided =	**2,812 Cubic Feet**
Single Basin (Drainage Area Weighted Average) – Drawdown / Recharge Time	
Estimated Infiltration Rate =	0.5 Inches Per Hour
Average BMP Area =	316 Square Feet
Drawdown Flow Rate =	0.0037 Cubic Feet Per Second
Ponded Water Drawdown Time =	**2.5 Hours**
BMP Recharge Time (to reach full capacity) =	**15.0 Hours**

Overall the BMPs proposed along Imperial Beach Boulevard in this project will not have adequate capacity to capture and treat the full 85^{th} percentile event, but rather capture a portion of the runoff resulting from the 85^{th} percentile event. The BMP being constrained to the relatively small area available to site BMPs (in general areas of existing planters) in comparison to the size of the tributary drainage restricts the capacity of the proposed BMP. The BMP would provide complete capture of smaller rainfall events and would capture the initial runoff during larger storms, which may contain a large portion of the overall pollutants transported by storm water runoff during wet weather.

9.6.5 Load Quantification Analysis

The annual runoff in the drainage area was estimated for this site based on rainfall data obtained from the County of San Diego's Project Cleanwater website (CSD, 2012). This website contains approximately 50 years of precipitation data. The Lower Otay rain gauge station was select due to its proximity to the site. The rainfall data was used to create a 21-year (1987-2007) CSM that estimated runoff reaching the site and the portion of runoff that would be captured and treated by the proposed BMP on an hourly basis. There are total of 15 bioretention basins proposed, and each basin has a slightly different drainage area and BMP area. In order to perform quantification analysis calculations, the basins were grouped into four categories based on their relative drainage areas (very small, small, medium, and large drainage areas). The concentrations of COCs were estimated based on the average value of monitoring data obtained in other tasks of this Clean Beaches Initiative project. Pollutant removal efficiencies were estimated based on data published in the *International Stormwater BMP Database* (WERF, 2011). The above-mention data were analyzed and a summary of the average annual pollutant removal is provided in Table 9-20.

Table 9-20.– Annual Pollutant Load Removal

Average Annual Volume of Storm water Runoff Treated		
Average Rainfall =	10.0	Inches Per Year
Capture Amount (Based on CSM) =	6.46	Inches Per Year
C =	0.87	
Area =	2.93	Acres
Rv (Coefficient to account for small rainfall amounts) =	0.9	
Annual Treatment Volume =	54,000	Cubic Feet Per Year
Average Annual Pollutant Load Removal		
Average Pollutant Load Reduction	100%	(Infiltration and Evapotranspiration)
Average Enterococci EMC =	24,700	MPN/100 Milliliters
Average Fecal Coliforms EMC =	55,600	MPN/100 Milliliters
Enterococci Load Removal =	377,700	10^6 MPN Per Year
Fecal Coliforms Load Removal =	850,200	10^6 MPN Per Year

9.6.6 Performance Specifications

The goal of the Imperial Beach Boulevard Bioretention Basins (Eco Bike Lane) for the Tijuana River Watershed Protection Project is to reduce the pollutant load entering Tijuana River National Estuary. This goal will be achieved by diverting flows from the curb and gutter into bioretention basins located along the roadway, which capture and treat runoff. In general, project treatment components shall be designed to remove pollutants (priority COCs), including bacteria, heavy metals, and sediment. Every effort shall be made through the use of improved technologies and enhancing this concept design to further reduce pollutant loading entering the estuary. Refer to the project concept design plan for more details on the specification of project components.

9.6.7 Operations and Maintenance

It is anticipated that semi-annual regular maintenance will be required to maintain the bioretention BMPs to optimal performance. Semi-annual maintenance should be performed on the BMP in September, prior to first wet weather, and towards the end of the wet season in April or May. This maintenance shall include visual observation of the area checking for and removing debris such as trash and organic materials. If large rainfall events occur (greater than 2 inches) the above-mentioned regular maintenance shall be conducted. Vegetation within the bioretention basins shall be maintained in conjunction with the maintenance activities that currently take place for the existing planters (*i.e.*, same attention given to existing planters should be given to the bioretention basins, which are the same approximate size and in the same general location as the existing raised planters).

9.6.8 Estimated Construction Cost

The estimated construction cost of implementing the Imperial Beach Boulevard Eco Bike Lane concept design is approximately $1,110,750. This includes labor and materials, engineering design, mobilization, traffic and erosion control, construction bond, miscellaneous landscaping, minor utility relocation, and a 10% contingency but excludes City staff costs associated with construction inspection and project management/review. Refer to Table 9-21 for more details on the cost estimate.

Table 9-21. Cost Estimate

Imperial Boulevard Eco Bike Lane / Green Street Cost Estimate for Proposed Improvements Concept Design Level				
ITEM	**QUANTITY**	**UNIT**	**UNIT PRICE**	**COST**
Demolition Items				
Protect-In-Place Existing Tree	14	EA	$250.00	$3,500
Protect-In-Place Existing Sign/Light	8	EA	$250.00	$2,000
Remove Existing Curb & Gutter	1,200	LF	$4.00	$4,800
Remove Existing Curb (planters)	1,275	LF	$3.75	$4,781
Remove Existing Curb (center median)	380	LF	$3.75	$1,425
Remove Existing Concrete (center median)	525	SF	$2.25	$1,181
Remove Existing Sidewalk and/or Ramp	14	EA	$500.00	$7,000
Relocate Sign	8	EA	$500.00	$4,000
Relocate Fire Hydrant	1	EA	$1,000.00	$1,000
Remove Existing Median Striping	800	LF	$0.50	$400
Saw Cut Asphalt Concrete	1,510	LF	$10.00	$15,100
Remove Asphalt Concrete & Base Materials	30,700	SF	$2.00	$61,400
Cold Plane Asphalt Surface (0.2 Min.)	3,020	SF	$1.00	$3,020
Salvage and reinstall Irrigation Sys. Components	16	EA	$1,200.00	$19,200
Subtotal				**$128,808**

Imperial Boulevard Eco Bike Lane / Green Street Cost Estimate for Proposed Improvements Concept Design Level				
ITEM	**ITEM**	**ITEM**	**ITEM**	**ITEM**
Construction Items				
Construct 6" Curb & Gutter per SDRSD G-2	1,815	LF	$22.00	$39,930
Construct Cutoff Wall Adjacent to Infilt. Basin	860	LF	$100.00	$86,000
Construct 4" PCC Sidewalk	3,551	SF	$8.00	$28,408
Construct Type "A" Curb Ramp Per SDRSD G-27	14	EA	$1,800.00	$25,200
Construct Truncated Domes per Caltrans A88A	14	EA	$200.00	$2,800
Construct PCC Cross Gutter per SDRSD G-12	3,233	SF	$13.20	$42,676
Construct 40'X10' Bus Pad	1,200	SF	$10.50	$12,600
Infiltration Basin - Grading and Export for	335	CY	$45.00	$15,075
Infiltration Basin - Amended Soils	252	CY	$150.00	$37,800
Infiltration Basin - Landscaping - Native	4,530	SF	$2.50	$11,325
Infiltration Basin - Energy Dissipator	15	EA	$150.00	$2,250
Asphalt Concrete (6" AC / 12" Base)	30,700	SF	$10.90	$334,630
Asphalt Concrete Overlay (0.2' Min., 0.3' Avg.)	3,020	SF	$4.00	$12,080
Construct Curb (center median)	380	LF	$12.00	$4,560
Construct Concrete (center median)	525	SF	$8.00	$4,200
Concrete Washout	6	EA	$825.00	$4,950
Construction Fence	2,000	LF	$4.00	$8,000
Gravel Bag	1,000	EA	$1.82	$1,820
Traffic Control	1	LS	$15,000.00	$15,000
Subtotal				**$689,304**
Signing & Striping Items				
Bike Lane Line (Std. A20D, Detail 39)	6,632	LF	$0.75	$4,974
Right Edge Line (Std A20B, Detail 27B)	4,156	LF	$0.75	$3,117
Bike Lane Symbol (Std. 24C)	32	EA	$400.00	$12,800
Bike Lane Arrow (Std. 24A)	32	EA	$350.00	$11,200
12" Crosswalk/Limit Line (Std. A24E)	950	LF	$2.50	$2,375
Stop (Std. 24D)	10	EA	$600.00	$6,000
Type IV Arrow (Std. 24A)	1	EA	$400.00	$400
Type VI Arrow (Std. 24A)	2	EA	$600.00	$1,200
Type VII (R) Arrow (Std. 24A)	2	EA	$600.00	$1,200
Channelized Line (Std. A20D, Detail 38A)	270	LF	$3.00	$810
Median Line Striping (Std. A20A, Detail 16)	800	LF	$3.00	$2,400
Subtotal				**$46,476**
	Construction Subtotal			**$864,587**
			WPCP	$12,000
			Field Survey	$8,000
			Field Orders	$10,000
			Engineering Design - 5% of construction subtotal	$43,229
			Mobilization - 5% of construction subtotal	$43,229
			Construction Bond - 5% of construction subtotal	$43,229
			Contingency - 10% of construction subtotal	$86,459
			Construction Total	**$1,110,750**

9.7 East San Ysidro Boulevard Bioretention Basins

9.7.1 Project Site

The Site is located within the City of San Diego right-of-way for East San Ysidro Boulevard. More specially, the Site is located within the parkway area along the north side of the roadway in front of the San Ysidro Community Center having the address 663 East San Ysidro Boulevard. The area is currently occupied by a conventional landscaping. The site is shown in Figure 9-25. The proposed improvements are confined to the area of the right-of-way, which is approximately 12 feet wide and 140 feet in length. A vicinity map is provided in Figure 9-26.

Figure 9-25. East San Ysidro Boulevard Site

Figure 9-26. Vicinity Map

9.7.2 Existing Soil Conditions

Percolation testing was not performed in conjunction with the preparation of the concept design for this Site. Based on the soil conditions in the area (*i.e.*, Soil Type D and comprised of dense, clayey materials), it is anticipated that the Site is not suited for infiltration type BMPs. The proposed BMPs have been designed with an underdrain system (subdrain) to be connected to the existing storm drain pipe in the roadway. During final engineering design, a Limited Geotechnical and Infiltration Evaluation for the site shall be conducted, and if the site exhibits good infiltration properties, the subdrain system may be omitted.

9.7.3 Project Description

The proposed project includes constructing 2 bioretention basins along East San Ysidro Boulevard. For each basin a sidewalk underdrain will be constructed to convey runoff from the street curb and gutter into basin. The sidewalk underdrain will be modified to so that invert slopes towards the parkway, and BMP, at approximately two percent. The bioretention basin will be construction by excavating a trench along the sidewalk that is approximately 12 feet wide and approximately 4.5 feet deep. Permeable geotextile fabric will be placed on the bottom of the trench. The bottom 1 foot of the trench will contain the subddrain system, which includes perforated smooth wall pipes and gravel. The underdrain pipes will be connected to non-perforated pipe and connected to existing storm drain pipe as shown on the plans. Above the gravel, additional geotextile fabric will be laid down and an amended soil mixture will be placed to fill the trench to match grades and elevations shown on the plans. The amended soils will consist of a 65 percent sand and 35 percent compost (tolerance of plus or minus 5 percent). The sand and compost shall be well mixed prior to placement. Drought tolerant, native vegetation shall be planted in the basin. In order to establish vegetation and provide water during extended dry periods, the existing landscape system for the site shall be salvaged and reinstalled to provide irrigation as needed to the BMP. For more information relating to the bioretention BMPs at this site see Figure 9-27.

Storm water runoff from the area of East San Ysidro Boulevard that is adjacent to the site will sheet flow into the existing curb and gutter along the north side of the street. Storm water runoff from the adjacent San Ysidro Community Center will discharge to the existing curb and gutter via a sidewalk underdrain. Runoff will be conveyed from the curb and gutter into the proposed bioretention basins through the proposed modified sidewalk underdrains. The runoff will filter through the amended soils and into the subdrain system. The process of filtering through the sand and vegetation roots will remove pollutants, including bacteria. The majority of treated runoff will flow into the subdrain pipe and be conveyed to the existing storm drain through a proposed manhole; however, a portion of the captured runoff will remain in the basin (in the soil voids) and either infiltrate into the soil substrata or evapotranspirate.

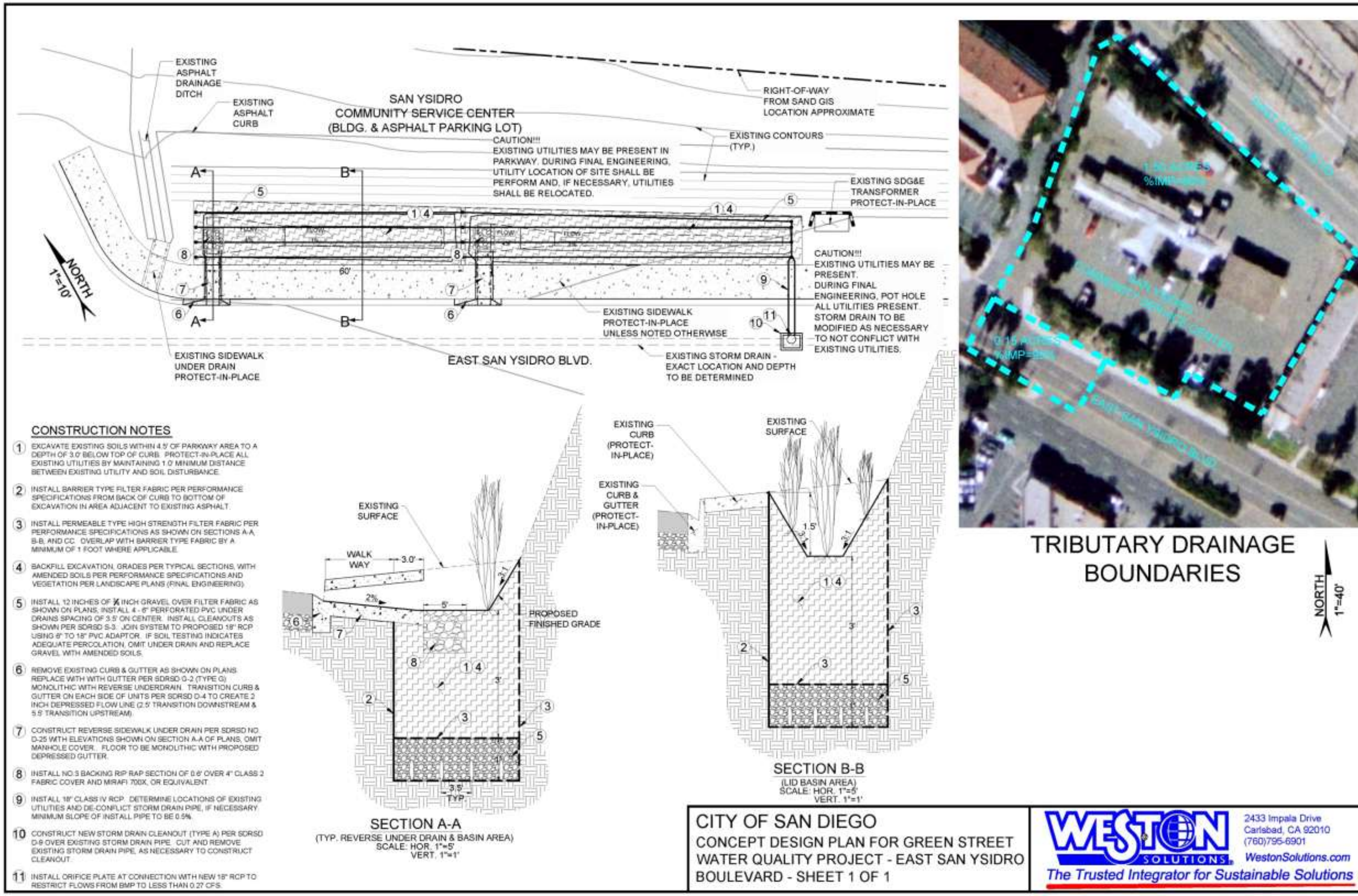

Figure 9-27. East San Ysidro Boulevard Bioretention Concept Design Plan

9.8 Water Quality Calculations

The tributary drainage area to the site has been depicted on the conceptual design drawing (Figure 9-27). The drainage area consists of the adjacent portion of San Ysidro Boulevard, to the centerline crown, and the area of the San Ysidro Community Center, which measures a total area approximately 1.65 acres. For hydrologic calculations, the overall drainage area is considered to be 87% impervious. In accordance with guidance found the SUSMP (CSD, 2011) and the County Hydrology Manual (CSD, 2003) water quality calculations were performed for the site. Due to anticipated poor infiltration across the Site, the selected BMPs consist of bioretention basins that primarily rely on filtration of captured storm water through the bio-media (sand, compost, and vegetation roots) prior to discharge into the existing catch basin. The water quality calculations and results are summarized in Table 9-22. Additional information relating to these calculations is provided in Appendix E-2.

Table 9-22. Capacity of BMPs Calculation Summary

85^{th} Percentile Event =	0.55 Inches Per Hour
Bioretention Basins – Required Capture Storage	
Tributary Drainage Area =	1.65 Acres
C =	0.83
Q = CIA =	**2,726 Cubic Feet**
Bioretention Basins – Provided Capture Storage	
Total Area of BMPs =	1,880 Square Feet
Material Porosity	0.35
Amended Soils Depth =	3.0 Feet
Amended Soils Storage (A*D*n) =	1,974 Cubic Feet
Rock Subdrain Depth =	1.0 Foot
Rock Storage (A*D*n) =	658 Cubic Feet
Total Volume of Ponded Water in BMPs =	250 Cubic Feet
Total Capture Storage Provided =	**2,882 Cubic Feet**
Bioretention Basins – Drawdown / Recharge Time	
Estimated Filtration Rate =	2.5 Inches Per Hour
BMP Area =	1,880 Square Feet
Drawdown Flow Rate =	0.105 Cubic Feet Per Second
Ponded Water Drawdown Time =	**0.7 Hours**
BMP Recharge Time (to reach full capacity) =	**8.0 Hours**

The proposed BMPs for this Site do have adequate capacity to capture the storm water runoff resulting from the 85^{th} percentile storm event. The bioretention basins are designed as filtration type BMPs that first capture storm water and then slowly discharge the treated runoff into the existing storm drain system. In order to restrict discharges from the BMPs to less than 5 inches per hours (thumb rule value developed in Contra Costa County, California based on BMP data), an orifice plate shall be installed at the connection with the proposed cleanout and storm drain system. The restriction of the discharge to less than 5 inches per hour allows for slower filtration and improved treatment of captured runoff. A filtration of value of 2.5 inches was assumed for water quality and quantification analysis calculations.

9.8.1 Load Quantification Analysis

The annual runoff in the drainage area was estimated for this site based on rainfall data obtained from the County of San Diego's Project Cleanwater website (CSD, 2012). This website contains approximately 50 years of precipitation data. The Lower Otay rain gauge station was select due to its proximity to the site. The rainfall data was used to create a 21-year (1987-2007) CSM that estimated runoff reaching the site and the portion of runoff that would be captured and treated by the proposed BMP on an hourly basis. The concentrations of COCs were estimated based on the average value of monitoring data obtained in other tasks of this Clean Beaches Initiative project. Pollutant removal efficiencies were estimated based on data published in the *International Stormwater BMP Database* (WERF, 2011). The above-mention data were analyzed and a summary of the average annual pollutant removal is provided in Table 9-23.

Table 9-23. Annual Pollutant Load Removal

Average Annual Volume of Storm water Runoff Treated		
Average Rainfall =	10.0	Inches Per Year
Capture Amount (Based on CSM) =	9.56	Inches Per Year
C =	0.83	
Area =	1.65	Acres
Rv (Coefficient to account for small rainfall amounts) =	0.9	
Annual Treatment Volume =	42,662	Cubic Feet Per Year
Average Annual Pollutant Load Removal		
Average Pollutant Load Reduction	62.6%	(WERF, 2011)
Average Enterococci EMC =	24,700	MPN/100 Milliliters
Average Fecal Coliforms EMC =	55,600	MPN/100 Milliliters
Enterococci Load Removal =	186,800	10^6 MPN Per Year
Fecal Coliforms Load Removal =	420,500	10^6 MPN Per Year

9.9 Performance Specifications

The goal of the East San Ysidro Boulevard Bioretention Basins Project for the Tijuana River Watershed Protection Project is to reduce the pollutant load entering Tijuana River. This goal will be achieved by improving the existing dirt and conventionally landscaped parkway with an amended soils and subdrain system that captures and treats storm flows. In general, project treatment components shall be designed to remove pollutants (priority COCs), including bacteria, heavy metals, and sediment. Every effort shall be made through the use of improved technologies and enhancing this concept design to further reduce pollutant loading entering the river. Refer to the project conceptual plan sheet for further information on component specifications.

9.9.1 Operations and Maintenance

It is anticipated that initial calibration/verification of the system followed by semi-annual regular maintenance will be required to maintain the bioretention BMPs to optimal performance. The initial calibration of the BMP involves verifying that the orifice plate restricts flow as designed (between 1- to 5-inches per hour or 0.04 to 0.21 cubic feet per second). The basins have been designed to have a ponding capacity of approximately 5 inches of captured water (*i.e.*, once soils become saturated, if the flow rate into BMP exceeds discharge flow rate ponding will occur. Begin the calibration process with the orifice plugged and allow runoff to the fill the basins. With very little or no storm water runoff input into the basin, unplug the orifice and continuously measure depth. Measure the flow through the basins (either at the cleanout or by rate of level decrease in the basins). If needed, make orifice hole larger or install plate with smaller orifice to achieve desired flow rate. The flow rate should be verified by field observations and calculations during subsequent precipitation. The calibration/verification conducted and size of orifice shall be logged and the field calibration sheet shall be provided to the City Watershed Manager.

Semi-annual maintenance should be performed on the basin in September, prior to first wet weather, and towards the end of the wet season in April or May. This maintenance shall include visual observation of sidewalk underdrain checking for and removing debris such as trash and organic materials. Some soil is acceptable. It is not anticipated that the proposed sidewalk underdrains will have the potential to become clogged by sediment. This is based on no likely sources of heavily loaded total suspended soils are currently identified in the drainage area. However, if clogging from soil is observed, maintenance crews shall remove soil if possible with shovel and broom. If necessary, a vacuum truck may be required to clear the sidewalk drain (although it is not anticipated). Trash and organic materials, if observed, shall be removed from the basin. If large rainfall events occur (greater than 2 inches) the above-mentioned regular maintenance shall be conducted.

9.9.2 Estimated Construction Cost

The estimated construction cost of implementing the East San Ysidro Boulevard concept design is approximately $199,900. This includes labor and materials, engineering design, mobilization, traffic and erosion control, construction bond, miscellaneous landscaping, minor (irrigation) utility relocation, and a 20% contingency but excludes City staff costs associated with construction inspection and project management/review. Refer to Table 9-24 for more details on the cost estimate.

Table 9-24. Cost Estimate

East San Ysidro Boulevard Bioretention Basins Cost Estimate for Proposed BMP FY2010 Concept Designs				
ITEM	**QUANTITY**	**UNIT**	**UNIT PRICE**	**COST**
Grading & Export	335	CY	$44.28	$14,834
Filter Fabric Barrier	850	SF	$3.25	$2,763
Filter Fabric Permeable	4,500	SF	$2.60	$11,700
Amended Soils	227	CY	$75.00	$17,025
3/4" Gravel (under drain reservoir)	70	CY	$85.00	$5,950
6" Sch. 40 PVC Perforated Under Drain	570	LF	$40.00	$22,800
Clean Out per SDRSD S-3 (Under Drain System)	8	EA	$633.00	$5,064
6" to 18" PVC Adaptor	1	EA	$450.00	$450
Remove Existing Curb & Gutter	22	LF	$15.00	$330
Construct Transition Curb & Gutter (Per G-2)	22	LF	$22.00	$484
Construct Reverse Curb Under Drain (Per D-25)	2	EA	$4,600.00	$9,200
No. 3 Backing Rip Rap	1.5	CY	$85.00	$128
Landscaping - Native Drought Tolerance	1,880	SF	$1.50	$2,820
Install 18" RCP	18	LF	$123.50	$2,223
Construct Type A Cleanout (Per D-9)	1	EA	$6,368.00	$6,368
Concrete Washout	1	EA	$825.00	$825
Construction Fence	200	LF	$4.00	$800
Gravel Bag	20	EA	$1.82	$36
Traffic Control	1	LS	$1,500.00	$1,500
Protect-in-place existing utilities	1	LS	$1,500.00	$1,500
			Construction Subtotal	**$106,799**
			WPCP	$8,000
			Field Orders	$5,000
			Engineering Design - 40% of construction subtotal	$42,720
			Mobilization - 10% of construction subtotal	$10,680
			Construction Bond - 5% of construction subtotal	$5,340
			Contingency - 20% of construction subtotal	$21,360
			Construction Total	**$199,900**

9.10 Cost Comparison and Prioritization

Utilizing data from the quantification analyzes and cost estimates prepared for each of the concept design plans, Table 9-25 provides of summary of total costs and costs per load removal.

Table 9-25. Cost to Benefit Comparison

Site	Project Capital Cost	Annual Load Removed (10^6 MPN Fecal Coliform)	Cost Per Annual Load Removed (\$ / 10^6 MPN Fecal Coliform)	Priority Ranking Based on Cost / Benefit
Imperial Beach Boulevard Parkway Bioretention Basins	$130,950	172,110	$0.76	5
Mar Vista Church Drainage Easement Bioretention Basin	$50,250	135,784	$0.37	2
Thorn Street Cul-De-Sac Right-of-Way Porous Concrete	$107,700	263,418	$0.41	3
Donax Avenue Cul-De-Sac Right-of-Way Porous Concrete	$120,000	486,580	$0.25	1
Imperial Beach Boulevard Eco Bike Lane / Green Street	$1,110,750	850,225	$1.31	6
East San Ysidro Boulevard Bioretention Basins	$199,900	420,471	$0.48	4
Total (Average)	$1,719,550	2,328,588	$0.59 (Average)	

Based on the cost per load removal the priority rankings are presented above. The lower capital cost projects have a higher ranking due to their relatively small cost combined with their capacity to remove a fairly high pollutant load. Watershed managers may use this table only as one, of many tools, to facilitate decisions about future implementation of BMPs. Other factors should be taken into consideration, such as existing conditions, public perception, and multiple benefits provided by projects. For example, the Thorn Street Project is shown with a lower ranking than the Donax Avenue Project. However, because the Donax Avenue Site is currently occupied by a concrete drainage swale while the Thorn Street Site consists of a dirt swale that becomes a very muddy area after rainfall (nuance to the public who use it as a walk and creates the potential for sediment transport into the waterway), the Thorn Street Project would most likely have a higher priority for the City.

The City plans to incorporate the BMP concept designs into future capital improvement projects or as funding becomes available. The City has already incorporated one of the BMP concept designs into a new proposed crosswalk along Imperial Beach Boulevard at the City’s Sports Park, which will be constructed later this year. The City also received a grant to implement similar storm water BMPs for a bikeway project along Palm Ave, which will start construction next year. The LID parkway BMPs proposed in this study are now an accepted concept design that are considered by the City’s traffic control engineer and incorporated into new street CIP projects when feasible.

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

There were numerous findings from this multi-year, multi-faceted study. The major conclusions drawn from the results of the monitoring and special studies are summarized below.

- The pollution sources and their impact on the Tijuana River Estuary vary dramatically by season. During dry weather, the estuary is relatively un-impacted from the watershed, and the estuary is a healthy, vibrant and vital ecosystem. During storm events, flows from Mexico transform the estuary into a severely impacted, polluted and hazardous waterbody with extremely elevated bacterial concentrations and elevated potential health risk to the environment and the public.
- Extensive dry weather and sanitary surveys revealed several locations in the watershed where indicator bacterial concentrations were high, or there was evidence of human fecal contamination, but the contamination was determined to be ephemeral and not related to a consistent source (such as leaking infrastructure).
- Dry weather surveys also revealed that there is very little hydrologic connection between watershed surface waters and the estuary (with the exception of some small drainages).
- Semi-natural BMPs such as soft-bottom sediments and ponds at the base of the major sub-drainages prevent the large majority of dry weather flows from entering the estuary.
- During wet weather, approximately 99% of the indicator bacterial loads entering the Tijuana River Estuary and Pacific Ocean originate from un-diverted flows from the Tijuana River mainstem and tributary channels from Mexico.
- Proactive steps to reline the sewage system along Seacoast Drive by the City of Imperial Beach appear to have eliminated a suspected source of human fecal contamination from entering the northern arm of the estuary.
- Groundwater associated with the mainstem of the Tijuana River at the U.S. Mexico Border may have elevated bacterial and nutrient levels compared to relatively clean sites closest to the estuary, suggesting the groundwater may not be a likely source of bacterial contamination to the estuary. However, the presence of enterovirus at sites closest to the estuary suggest that further studies may be needed to better understand surface groundwater interactions and the potential risk to estuary surface waters from groundwater resources.
- Sediments within the Goat Canyon sediment basins appear to act as a reservoir for indicator bacteria that has the potential to impact receiving waters for several days if the sediment were used for beach replenishment. Further studies are needed to clarify potential impacts indicated by this initial, small-scale study.
- Based on the findings of these studies, BMPs were designed and prioritized on their ability to reduce bacterial loads and will serve as a tool for managers to reduce potential impacts to the Tijuana river Estuary.

10.2 Recommendations

Based on the major findings of the study, the following recommendations may be considered:

- One of the major goals of this study was to identify sources of indicator bacteria on the U.S. side of the border and produce designs for BMPs that can reduce those loads. The designs for low impact development BMPs produced as part of this study are focused on providing the most efficient and cost-effective means of reducing bacterial loads in areas that flow directly to the Tijuana River Estuary. They should be considered for implementation based on the prioritization assessment provided in the report and additional priorities and constraints of the City of Imperial Beach.
- During the sanitary and dry weather surveys, positive results for human-specific *Bacteroides* suggested the presence of human fecal matter at some sites. Although specific sources were never identified, the cities of Imperial Beach and San Diego may wish to consider prioritizing and implement sewer system upgrades to minimize the potential for sewage in the sanitary sewer from contaminating the storm drain system and potentially impacting the estuary.
- The Goat Canyon Special Study demonstrated that elevated bacterial levels exist in sediment dredged from the basins. Understanding the role of beneficial reuse of the dredged sediment is a critical component of effective management of the basins. Further studies to understand the potential risk factors and fate and transport variables associated with the sediment under various management scenarios (*e.g.*, beach replenishment) should be considered to enhance potential management options.
- This study was focused on understanding the sources of indicator bacteria in the Tijuana River Watershed and the potential impacts it may have on the estuary. However, further study is needed to understand how bacteria (and potential pathogens) associated with the river and the estuary may affect water quality at adjacent beaches. Studies designed to use rapid indicators of fecal contamination combined with an understanding of environmental variables that affect beach water quality (*e.g.*, storm events or rogue flows from Mexico) could provide a more precise assessment of potential human health risks from the river and potentially reduce beach closures in the area.
- The Special Study on Groundwater suggested that groundwater quality at sites close to the U.S. / Mexico Border may be impacted by indicator bacteria, but sites closer to the estuary appeared to have better water quality. These results conflicted with the enterovirus results, which showed the presence of enterovirus at sites closest to the estuary. To better understand the fate and transport of bacterial and viral pathogens in groundwater and the potential risk associated with groundwater / surface water interactions, groundwater modeling may be considered to enhance the small scale study conducted as part of this project.

10.3 Lessons Learned

The Tijuana River Bacterial Source Identification Study spanned a period of over several years and revealed answers to numerous questions about the sources of indicator bacteria that influence the Tijuana River Estuary. Over this time period, several lessons were learned about what worked and didn't work in this study that may be useful for the design and implementation of future studies. These points are outlined below.

What Worked:

- A clear understanding of the objectives of the study and an understanding of area's history is crucial to a successful outcome. The Tijuana River Watershed is large with numerous land use characteristics that can complicate bacterial source tracking. By thoroughly reviewing the available data at the onset of the study (see literature review, Appendix B) and focusing on the objectives outlined in the QAPP (Appendix C), the study was able to identify the sources of bacteria originating from the U.S. side of the border and recommend BMPs to reduce their impact on the estuary.
- Engaging a diverse stakeholder group from the beginning of the study served as an important information gathering tool that provided insight on bacterial sources from local and historical perspectives. This information was invaluable in designing the special studies of the project, which revealed some of the major findings of the study.
- The study demonstrated that the most effective way of determining bacterial origin in source identification studies is through an adaptive approach, where the design is flexible enough to allow for investigations that are unique to the study area, rather than following a prescriptive, one size fits all approach.
- A combination of extensive observations combined with bacterial culture and molecular techniques has proven to be a powerful combination in source identification studies.
- Focusing from the onset of the project on BMPs that may eventually be used for reducing bacterial loads and concentrations proved to be important in designing the source identification elements of the study.

What Didn't Work:

- Delineating the sub-watershed that drain to the Tijuana River Estuary on the U.S. side of the border turned out to be a crucial step in understanding dry weather sources of bacteria and their potential impact on the estuary. The study may have been more effective and efficient if that delineation happened at the beginning of the investigation rather than near the end.
- Choosing the appropriate storms to monitor for this study turned out to be problematic in the wet weather element of this study. We wanted to select storms that were large enough to produce meaningful pollutographs, but not so large as to preclude effective monitoring. Storms 1 and 2 turned out to be much larger than anticipated and the resulting pollutographs were not as informative as they could have been for a smaller storm event.

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