Newport Bay Fecal Coliform TMDL 2018 Summary of Management Activities

County of Orange

OC Environmental Resources

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October 16, 2018
(update of May 18, 2016 report)

County of Orange
OC Environmental Resources
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List of Abbreviations & Acronyms

BMP	Best Management Practice
DWM	Dry Weather Monitoring
EC	*Escherichia coli*
ENT	*Enterococcus*
FC	Fecal Coliform
FIB	Fecal Indicator Bacteria
IRWD	Irvine Ranch Water District
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NTS	Natural Treatment System
OCFCD	Orange County Flood Control District
SCCWRP	Southern California Coastal Water Research Project
SDC	San Diego Creek
SJM	San Joaquin Marsh
TMDL	Total Maximum Daily Load
WQMP	Water Quality Management Plan
WQO	Water Quality Objective

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Executive Summary

In recognition of fecal indicator bacterial (FIB) data indicating that Newport Bay (Bay) was impaired for water contact recreation uses (REC-1), the Santa Ana Regional Water Quality Control Board (Regional Board) adopted the Newport Bay Fecal Coliform Total Maximum Daily Load (TMDL) on April 9, 1999.

The TMDL established numeric targets based on the water quality objective (WQO) and required a series of actions, including source identification studies and implementation of water treatment and source control best management practices (BMPs) designed to restore the REC-1 use in the Bay by decreasing FIB concentrations until they complied with the TMDL targets. A routine monitoring program was also required to measure progress in achieving these targets.

While these measures have been separately documented elsewhere, this report is the first update of a comprehensive effort to document the totality of measures that have been taken by Newport Bay watershed (watershed) stakeholders that have reduced FIB concentrations to current levels. The BMP data reported in 2016 were updated and, in some places, reclassified in the 2018 Report; therefore, some summary tables differ in approach from the previous report and such instances are identified. Since TMDL adoption, FIB concentrations have decreased substantially in nearly all parts of the Bay. More BMPs will be planned and implemented in the watershed and this report will be updated periodically to incorporate the new information.

A vast amount of effort has been expended to improve bacterial water quality in the Bay. In routine monitoring alone, about 1,500 FIB water quality samples are collected annually, with the total number of samples collected exceeding 27,000 since 2001.

There have also been numerous scientific studies of bacteria conducted in the Bay, the majority of which evaluated sources of FIB. Most of these studies concluded that San Diego Creek was the largest source, since it is also the largest source of freshwater flow in the Bay, that most FIB were not of human origin, and that most exceedances of bacterial water quality objectives were due to loading during wet weather and were therefore effectively uncontrollable by municipalities.

While few BMPs have been implemented that specifically target bacteria, a vast number of BMPs have been implemented throughout the watershed that accrue multiple water quality benefits, including decreased FIB. These BMPs can be grouped into three broad categories. Source control BMPs are typically programmatic and promote practices that reduce the initial introduction of bacterial sources into the environment. Water treatment BMPs are physical structures with some feature that removes FIB or removes trash or other factors that promote FIB growth. It is more efficient and more effective to control pollutant sources rather than treat water for pollutant removal after pollutants have already been introduced. Volume reduction BMPs reduce runoff volume, usually by infiltration.

Source control BMPs in the watershed include public education, water conservation measures, watershed cleanup activities, and water quality ordinances controlling litter and pet waste. Public education seeks to reinforce behaviors that promote water quality improvement and stewardship. Municipal stakeholders implement a multifaceted, countywide public education campaign that focuses on community-based social marketing, but includes traditional print and on-air advertising, water pollution brochures, and public outreach.

Watershed agencies partner with groups such as OC Coastkeeper to provide education on environmental science and stewardship to local schools, and to sponsor watershed cleanup activities. The County also continues to promote the Adopt A Channel program that allows companies and other interested groups to "adopt" portions of channels that they agree to help keep clean.

Trash and other debris may promote FIB growth by either serving directly as a growth medium for bacteria or by attracting animals that in turn may become sources of bacteria. Watershed municipalities sweep 150,000 street miles and inspect 10,000 catch basins annually, removing about 20,000 tons of debris from the watershed in the 2016-17 reporting year (County of Orange 2017).

Structural water treatment BMPs in the watershed include detention basins and other structures designed to impede flowing water, biological treatment BMPs, sanitary sewer diversions, media filters, and trash-related BMPs. Biological treatment BMPs use the natural abilities of plants and associated ecosystems to treat runoff. There are over 390 biological treatment BMPs in the watershed, including constructed wetlands and vegetated swales.

Detention basins and functionally similar structures impede the flow of water to create conditions that are more favorable for bacteria removal. These include basins in the Irvine Ranch Water District Natural Treatment System (NTS), sediment basins, and a number of other structures. There are about 53 such basins throughout the watershed. The San Joaquin Marsh currently treats all of the dry weather flow of San Diego Creek, which represents 70-85% of the dry weather freshwater flow into Upper Newport Bay (Upper Bay).

Sanitary sewer diversions divert surface runoff into sanitary sewers for treatment. Three diversions are in place, with three more planned for the near future, including Santa Ana-Delhi Channel, which is the second largest source of freshwater flow into the Upper Bay. Together, these diversions have potential to remove 25% or more of the dry weather flow of the entire watershed and its associated FIB load. Combined with the treatment of San Diego Creek through San Joaquin Marsh, the vast majority of the freshwater flow into the Bay is already being treated.

Diversions and detention basins, including the NTS, are the primary types of regional treatment BMPs in use in the watershed. Combined, their treatment area coverage includes nearly the entire Newport Bay watershed.

Trash and debris-related physical BMPs are numerous and in widespread use in the watershed. These include trash and debris booms, trash skimmers, and hydrodynamic separators. The most widespread BMP in use are trash and debris screens. At least 3,000 such devices are deployed throughout the watershed, including catch basin screens, inserts, and connector pipe screens. Notably, the Santa Ana-Delhi Channel diversion project removes 100% trash during dry weather and portion of wet weather. Another regional trash removal project is being planned in the San Diego Creek.

In addition to the three main categories of BMPs, low impact development (LID) and Water Quality Management Plans (WQMPs) now figure prominently in the development process. WQMPs are required of significant development projects to mitigate water quality issues on a site by site basis throughout the watershed as development and redevelopment occurs. LID seeks to restore or maintain the original hydrologic functions of the landscape to preserve ecosystem services, and is critical to water quality management planning.

Finally, watershed stakeholders maintain active programs to directly mitigate bacterial pollution. Agencies that own or operate sewer systems have programs in place for regular maintenance and leak detection. For example, the Irvine Ranch Water District (IRWD) cleans every pipe segment in their collection system at least once every two years (IRWD 2013). IRWD also employs two full-time technicians to conduct daily inspections of pipe segments for repair, rehabilitation, or replacement. Another program, Dry Weather Monitoring has been active for over 10 years monitoring storm drains for illegal discharges and illicit connections. For public reporting of incidents, a Water Pollution Hotline and an online reporting system allows concerned citizens to report active water pollution issues. Agencies also participate in the County Area Spill Containment Program, which, if activated, involves participation of municipal staff trained in responding to chemical and sewage spills, and usually requires owners of faulty sewage facilities to correct identified problems, including removal of spilled sewage.

Figure ES1 shows the treatment areas of regional BMPs, including sanitary sewer diversions and treatment basins, as a heat map. Parcels covered by WQMPs are also included. However, not all jurisdictional WQMP data is represented. This map will be updated as new data become available. BMPs whose treatment areas cannot be determined, including many of the trash related BMPs, catch basins, and programmatic BMPs, are not included, but their impact would likely be watershed-wide. More darkly shaded areas correspond to treatment by more than one regional BMP. The area delineated by the orange border is treated through the San Joaquin Marsh (SJM). Smaller areas within the SJM treatment area are also treated through either NTS basins or the Peters Canyon pipeline diversion, and are therefore darker in color. The area delineated in purple is the Big Canyon Wash watershed, which is being treated by multiple BMPs throughout the watershed.

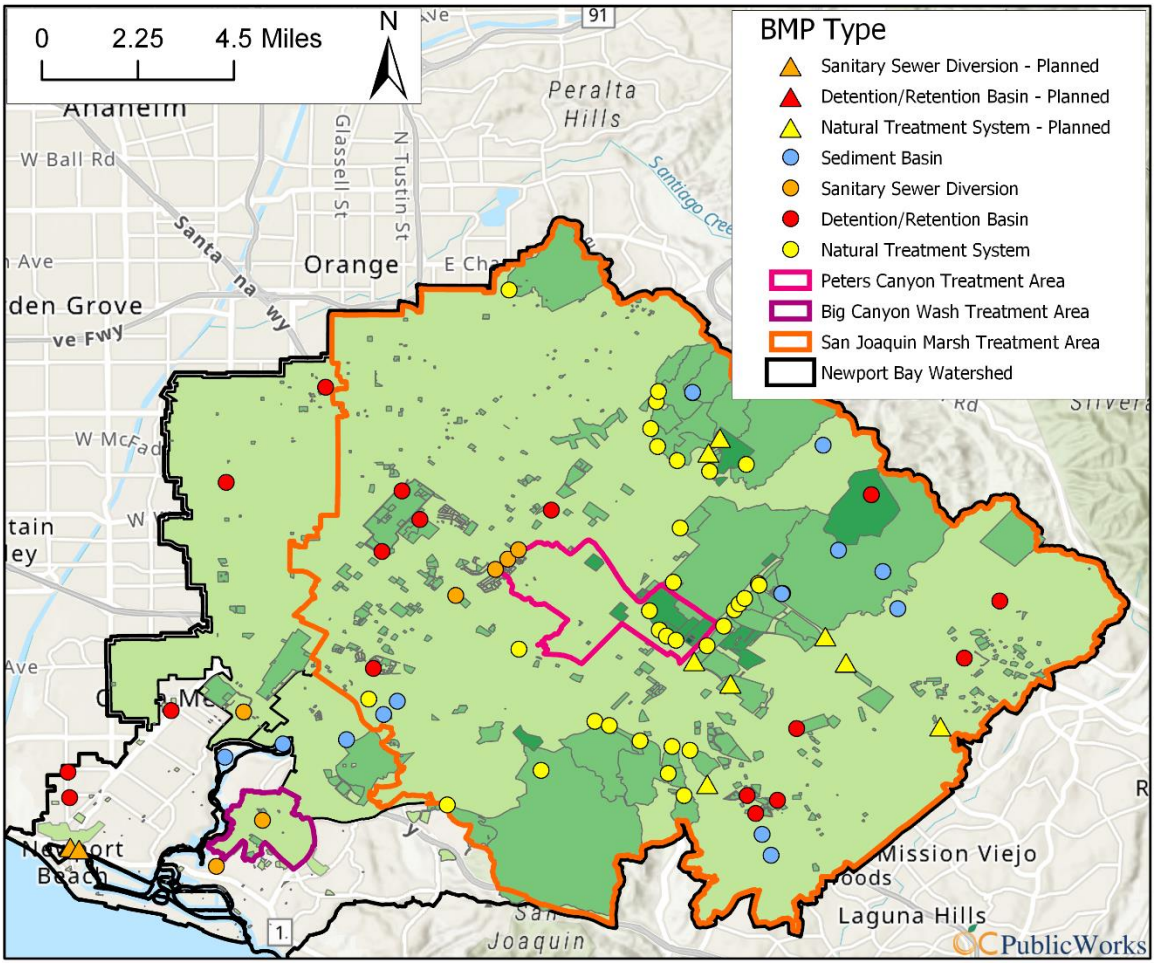

Figure ES1: Heat map of regional water quality treatment activities in the Newport Bay watershed as of July 2018. More darkly shaded areas correspond to greater numbers of treatment activities. [Trash and debris related BMPs were not included due to the difficulty in determining their treatment areas, but such BMPs are in place throughout the watershed. Additionally, the NTS in-development do not have coordinates and are not represented on this map.]

I. Introduction

In 1986, the Santa Ana Regional Water Quality Control Board (Regional Board) added Upper and Lower Newport Bay to the Clean Water Act Section 303(d) list of impaired water bodies due to frequent high concentrations of FIB and the presence of swimming and other water contact recreational activities in the Bay. The listing initiated the first studies on FIB in the Bay, which continued for the next two decades.

Because high FIB concentrations persisted through this period, the Regional Board adopted the Newport Bay Fecal Coliform TMDL in April 1999. The TMDL set numeric targets for water contact recreation (REC-1) and shellfish harvesting (SHEL) for the Bay, with the shellfish targets the more stringent of the two. Recognizing the complexity of the FIB water quality problem, the paucity of relevant data on FIB sources, and the expected difficulties in implementing appropriate control measures, the TMDL included a prioritized, phased approach to achieving these targets. This phased TMDL approach called for a number of studies to help fill data gaps and iterative implementation actions designed to help meet these targets. The compliance date for the REC-1 targets was December 30, 2014. The compliance date for the SHEL target is December 30, 2019 (currently being extended to 2022).

Among the early implementation actions were the establishment of a routine monitoring program and studies to help identify FIB sources in the Bay and to assess the level of REC-1 and SHEL uses. The routine monitoring program was established in 2000 and is ongoing. Studies were initiated in 2000 and continued in the following years.

As FIB sources and pathways were identified, management activities to mitigate FIB concentrations began and are ongoing. Since TMDL adoption, water pollution mitigation activities have multiplied in the watershed. Most of these activities accrue multiple water quality improvement benefits including FIB reduction, resulting in a steady and substantial decline in Bay-wide FIB concentrations.

Following data requests issued to watershed stakeholders in 2015 and 2016 the initial Summary of Management Activities was completed (May 2016). The report catalogs many of the FIB BMPs undertaken by watershed stakeholders over the last several decades. A data request on management activities was issued to watershed stakeholders in February 2016, and again in 2018 to obtain current data. While a substantial amount of data was submitted, there were a number of issues with the data used in the report:

- While agencies covering most of the watershed did submit data, not all did. Therefore, some implementation activities are not included in the report, and the numbers reported were likely conservative.

- Different agencies submitted different kinds of data. For example, different agencies identified the same BMPs by different names or trade names, or were nonspecific about numbers of individual BMPs, or were nonspecific about BMP locations. An attempt was made to resolve as many of these issues as possible, but some discrepancies could not be resolved. BMPs that could not be identified by

type or specific location were omitted, which again suggests the numbers reported were conservative.

- Programmatic BMP implementation was reported by agencies on a jurisdictional basis, not by watershed. For example, cities reported the number of street miles swept or number of catch basins inspected and cleaned by jurisdiction, but for most cities, only a portion of their jurisdictional areas lie within the Newport Bay watershed. For these types of BMPs, the BMP effort expended in the Newport watershed was estimated by apportioning the effort according to the percentage of jurisdictional area lying within the watershed. For example, if 1,000 catch basins were inspected within a city, but only 25% of the area of the city lies within the watershed, an estimated 250 catch basins in the watershed were assumed to be inspected.

This update of the 2016 report uses more comprehensive data than was previously available and therefore provides a better characterization of BMPs in the watershed.

II. Newport Bay Watershed Bacterial Water Quality Improvement Activities

A. Monitoring Activities

There are currently four active County monitoring programs collecting bacteria samples in the watershed. Collectively, about 1,500 bacteria samples are collected per year in the watershed, totaling over 27,000 samples since 2001.[1]

By far the largest monitoring program is the cooperative Newport Bay Fecal Coliform TMDL/Orange County Health Care Agency AB411 monitoring program, which collects about 1,700 samples annually. A total of 35 sites are monitored weekly, although two of these sites encounter ongoing accessibility issues. Through this focused monitoring effort, a significant and sustained decline in fecal coliform concentrations has been documented throughout Newport Bay since adoption of the TMDL. Bay bacterial water quality is discussed in greater detail in Section III.

The Mass Emissions Program monitors discharges from major creeks and the Estuary and Wetlands Program monitors water quality in receiving waters, both as requirements of the County municipal storm sewer system (MS4) Permit. The Mass Emissions Program collects at least 120 samples annually from freshwater tributaries to the Bay. The Estuary and Wetlands Program collects at least 78 bacteria samples annually in the Bay. Neither of these totals includes storm samples, which vary considerably from year to year.

The Dry Weather Monitoring Program is intended to detect illicit connections and illicit discharges during the summer months (dry weather) using a combination of random and targeted sampling. The Dry Weather Program collects about 100 samples annually from watershed storm drains. The number of sites in the watershed varies somewhat, but it is typically about 25 drains per dry weather season throughout the various jurisdictions of the watershed.

[1] Changed from the 2016 BMP Report to reflect an annual sample baseline and a more specific timeframe.

Figure 1: County staff collecting a water sample from a storm drain in Lane Channel in Irvine as part of the Dry Weather Monitoring program.

B. Scientific Research and Investigation Activities

A vast amount of investigation has been conducted in the Bay, particularly as part of the TMDL implementation. Studies conducted by the County, watershed cities, University of California, Irvine, UC Cooperative Extension, Orange County Coastkeeper, Regional Board, and others have significantly improved our understanding of the dynamics of FIB in the watershed.

A public health risk assessment was performed by Soller *et al*. (2001) and concluded that the risk to public health from bathing in the Bay was below the US Environmental Protection Agency's acceptable level of risk.

One of the earliest efforts was the investigation of FIB sources in the Bay, a process that continues to this day. Jiang *et al*. (2002a) determined that storm-associated high bacteria loads were unlikely to be of human origin. They also found no correlation between FIB and human-associated viruses, indicating that FIB likely did not originate from human sewage. Pednekar *et al*. (2005) and Pednekar *et al*. (2007) found that the largest loading of bacteria to the Bay was from storms, and also concluded the high loading rate could not reasonably be attributed to human sewage. They reasoned that since high bacteria loads

were associated with storms, wet weather water quality was "dominated by factors outside of local management control." Finally, they concluded FIB concentrations decreased along an inland to ocean gradient, indicating San Diego Creek was a primary source.

More recent source identification efforts have focused on major facilities draining into Upper Newport Bay: San Diego Creek, Santa Ana-Delhi Channel, Costa Mesa Channel, and Santa Isabel Channel owned by the Orange County Flood Control District and Big Canyon Wash and the Arches Drain owned by the City of Newport Beach. Most of these are already treated by a host of BMPs throughout the watershed (all of the flow in San Diego Creek is treated through San Joaquin Marsh) or planned for diversion to the sanitary sewer (Santa Ana-Delhi Channel and the Arches Drain). Surveillance is underway at the other channels to assess their potential FIB contributions, but since flows at these channels are small, they are not likely to be significant sources of FIB.

Jiang *et al*. (2002b) were unable to distinguish a relationship between FIB concentrations and the number of recreational bathers in the Newport Dunes area. Similarly, Grant *et al*. (2004) found marinas were not a significant source of FIB to the Bay relative to watershed inputs.

Despite potentially large inputs of FIB from the watershed, a significant portion of the load may come from natural sources, including vegetation and birds. Kabashima & Haver (2003) found agricultural runoff contained high concentrations of FIB despite the absence of sources of fecal contamination from animals and birds. Indeed, they suggested that many naturally occurring bacteria on the surfaces of vegetation may be detected as fecal coliforms.

A large, comprehensive Newport Bay FIB source identification effort was conducted by Grant *et al*. (2009) and resulted in several significant conclusions. FIB concentrations declined along an inland to ocean gradient, which supported a previous study that concluded watershed inputs, and particularly San Diego Creek, were a main source of FIB in the Bay. Though they found that most Bay FIB appeared to be free-living, they also found that dry weather *Escherichia coli* (EC) tended to be particle-associated in the Upper Bay, suggesting perhaps that treatments to remove sediment could help decrease EC loads from the watershed.

An important element of the work by Grant *et al*. (2009) used microbial source tracking (MST) methods to identify sources of *Enterococcus* (ENT) and EC. For ENT, they found at least half of ENT concentrations were from non-fecal sources, including decaying plant material, and that regrowth may contribute to ENT concentrations. For EC, they found that wet weather EC was not particle-associated as it was in dry weather, suggesting that there may be two different primary sources of EC in dry and wet weather.

Grant *et al*. (2009) also conducted microcosm studies in which they showed bird feces harbored high concentrations of FIB and required several days to achieve 90% attenuation even in the presence of sunlight. Thus, bird populations contribute to sustained elevated concentrations of FIB in the Bay. They also suggested sediments may promote FIB

concentrations by providing shade from sunlight and nutrients, which again suggested sediment control could help reduce FIB concentrations. Finally, they found FIB from runoff did not rapidly die off in the saline water of the Bay.

Skinner *et al*. (2010) examined street gutter biofilms in Newport Beach and concluded that FIB multiplied in street gutter biofilms, consistent with results from unpublished work performed in 2006 by Donna Ferguson and others at the Orange County Health Care Agency Public Health Laboratory (Ferguson *et al*. 2006). FIB in street gutters apparently survived periods of desiccation as well. These results suggested that controlling FIB concentrations in storms would be nearly impossible, since storm runoff would re-suspend FIB in high numbers from street gutter biofilms.

The County participated in a special study of the Bight 13 Regional Monitoring Program to study bacterial indicators in southern California coastal creeks in dry and wet weather conditions. In addition to bacteria, the Bight 13 Micro Study also sought to determine the distribution of HF183 in coastal drainages. HF183 is a DNA marker found in a species of the bacterium *Bacteroides* that is thought to be specific to the human gut and therefore indicative of sewage, although work by Whitman et al. (2014) has shown *Bacteroides* can replicate in the environment under the right conditions. In the Newport Bay watershed, Costa Mesa Channel and Santa Ana-Delhi Channel were part of the study. Nearly 400 bacteria and DNA marker samples were collected from these two channels. The study was completed in 2017 and found that the HF183 human fecal marker was ubiquitous across the region; it was present at all but two sites in dry weather and at all sites during wet weather. There was considerable difference in the extent of human fecal contamination among sites. While site rankings remained consistent regardless of whether the ranking was based on frequency of HF183 detection or on average concentration of HF183, site ranking differed greatly between dry and wet weather. Site ranking also differed greatly depending if it were based on HF183 or on enterococci, which, unlike HF183, does not distinguish between human and non-human fecal contamination. Additional work as part of Bight 18 will look at the relevance and reliability of using coliphage viruses to track microbial water quality at Southern California beaches, and how coliphage compares to Enterooccocus as an indicator of microbial contamination.

The County and City of San Diego funded the Southern California Coastal Water Research Project (SCCWRP) to conduct a Surfer Health Study to answer four basic questions: Is surfing associated with an increased rate of illness? Are illness rates higher when surfing following wet weather compared to dry weather? What is the association between water quality and illness following wet weather events? What level of water quality corresponds to the same risk of illness as current water quality objectives? The participants, though focused in San Diego, included surfers from Orange County. The key findings were that surfers are likely to have an increased rate of gastrointestinal illness, the rate increases following wet weather and there was a relationship between surfer health and water quality measurements, but that relationship predicted less risk than current USEPA guidelines (Arnold *et al.*, 2016).

C. Watershed Implementation Activities

The County, watershed cities, IRWD, and the development community in the watershed have collectively implemented numerous BMPs throughout the watershed in the last several decades. These can be broadly categorized into three types (Goong 2009). Water treatment BMPs are usually a physical structure with some feature that removes FIB or removes trash or sediment or other factors that may promote FIB growth. Volume reduction BMPs primarily reduce the volume of runoff, thereby reducing FIB loads. Source control BMPs are typically programmatic in nature, encouraging practices that reduce initial introduction of bacterial sources into the environment. In addition, significant development and redevelopment projects require WQMPs that show how BMPs will be implemented to mitigate water quality impacts from the project. Thus, over time, development and redevelopment in the watershed will result in an increasing number of small urban runoff treatment facilities distributed throughout the watershed to help reduce FIB in receiving waters.

1. Water Treatment BMPs

Water treatment BMPs include wet or dry detention basins, constructed wetlands, media filters, diversions to sanitary sewers, vegetated swales, and disinfection. All of these BMPs except disinfection are operating in the Newport Bay watershed. The maps on the following pages show these BMPs located throughout the watershed. Table 1 shows the water treatment BMPs implemented or planned for implementation in the watershed.

Table 1: Water treatment BMP implementation in the Newport Bay watershed as of June 2018.[2]

BMP Type	Subtype	Implemented	Planned
Detention/retention basin	Natural Treatment System	35	21
	Other	18	
Trash and debris BMPs	Retractable screen	200	
	Connector pipe screen	1355	399
	Insert/filter	1754	2
	Hydrodynamic separator	54	
	Trash and debris boom	5	
	Trash skimmer	6	
Sanitary sewer diversions		3	3
Sediment/drop structure basins	Sediment basins	13	
	Drop structure basins	11	
Biotreatment BMPs	Constructed wetlands	273	11
	Vegetated swale/strip	123	
Media filters		33	

[2] Data from 2016 was reclassified; therefore, subtotals may differ from previous report. In addition, data was not received from every jurisdiction.

a. IRWD Natural Treatment System (NTS) and Detention Basins

The IRWD NTS is one of the major water treatment BMPs in the watershed. NTS consists of 35 constructed ponds and wetlands distributed throughout the watershed (Figure 2). The largest such component is the San Joaquin Marsh located adjacent to the IRWD Michelson Water Recycling Plant in Irvine. San Joaquin Marsh (Figure 3) is a series of five large treatment ponds that are primarily designed to promote nitrogen removal. Dry weather flow from San Diego Creek is pumped into the San Joaquin Marsh ponds upstream of a weir. After treatment in the ponds, water is discharged back into San Diego Creek downstream of the weir. The weir effectively separates untreated flows from treated flows, since there is no dry weather flow over the weir. All of the dry weather flow of the San Diego Creek watershed, which represents about 65% of the dry weather freshwater flow to Newport Bay, is treated through San Joaquin Marsh.

While much of the NTS was not designed specifically for bacteria treatment, most NTS sites have proven effective at decreasing FIB concentrations. Only 10 NTS sites have bacterial monitoring data. Two of these sites were not effective at removing EC, but the remaining sites remove an average of 85% of EC (unpublished data, IRWD). All sites appear to help remove ENT, with an average reduction of 78%. From 2008-2018, the San Joaquin Marsh has removed an average of 96% of EC and 56% of ENT.

Most NTS sites are detention or retention basins and are maintained by IRWD. These large basins impound dry or wet weather runoff to create lentic conditions. All of the NTS sites are essentially flow-through ponds and the water is returned to creeks after being detained in the pond for treatment. In some cases, the NTS will permanently impound water to allow infiltration or evaporation. Ponds that permanently impound runoff effectively prevent all pollutant loads from discharging to receiving waters.

Developers propose new NTS basins as a form of regional treatment and are approved by the Regional Board as part of a Consistency Determination prior to construction. After construction, the developer maintains the NTS for a year while IRWD monitors its functional and water quality performance. Once accepted by IRWD, the basin is then maintained by IRWD operations & maintenance. There are 21 such basins anticipated to be turned over to IRWD for O&M. Out of the 21 sites, six are in the 1-year performance period and 15 are in the development phase. Most of the planned sites that are in-development do not have coordinates and are not represented in either Figure 2 or Figure ES1.

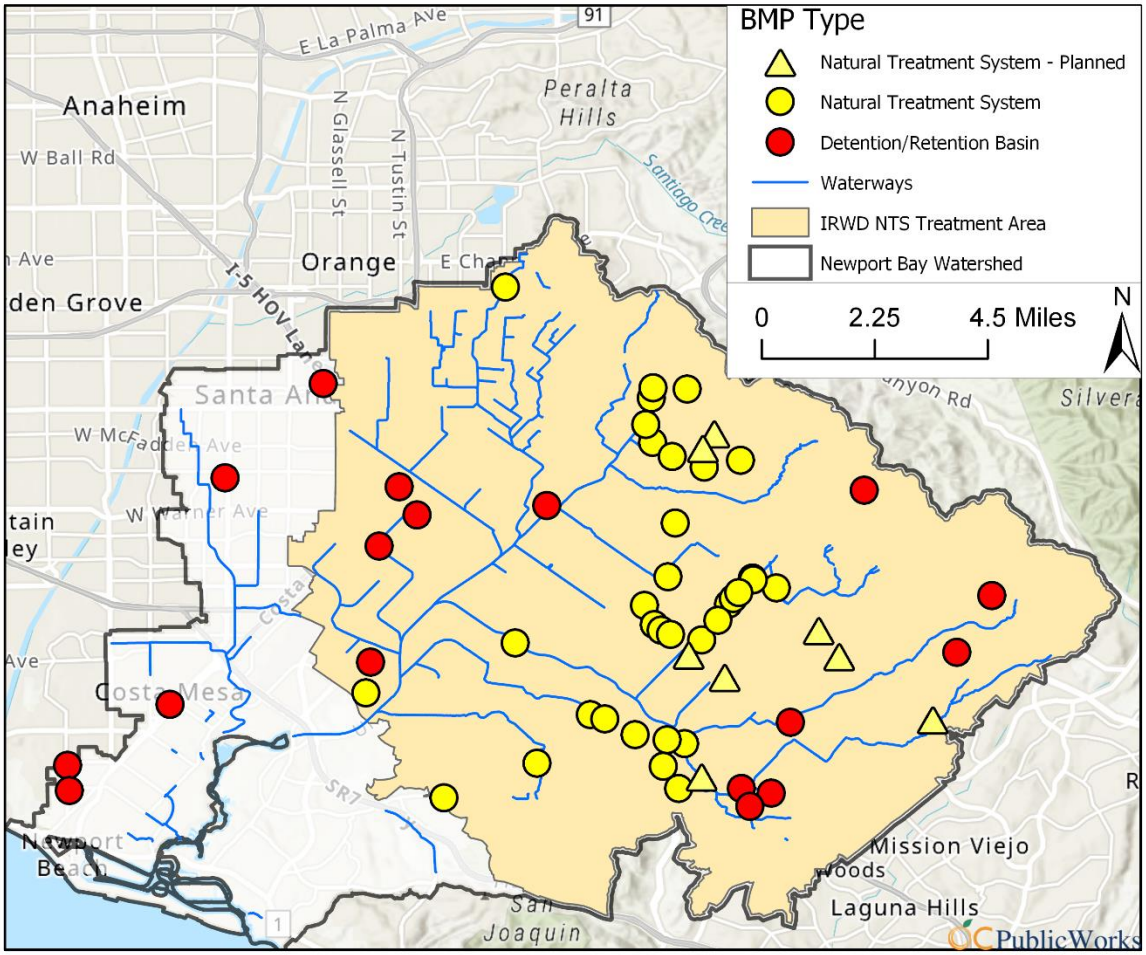

Figure 2: IRWD NTS sites and detention or retention basins in the Newport Bay watershed. The light brown shaded area is the portion of the watershed being treated through San Joaquin Marsh. [The majority of planned NTS do not have coordinates and are not represented on this map.]

Figure 3: County staff sampling from one of the ponds at San Joaquin Marsh.

Reduction in flow plays a substantial role in the FIB treatment capacity of these wetlands. Reduced flow through these systems helps settle particle-associated FIB, removing them from the water column. It also increases contact time with sunlight. Ultraviolet radiation from sunlight causes lethal DNA damage in FIB. Finally, lentic waters promote zooplanktonic communities, which increase predation pressure on FIB.

b. Constructed Wetlands and other Biological Treatment BMPs

Biotreatment is used in numerous smaller scale BMPs throughout the region (Figure 4). Constructed or modular wetlands (Figure 5), bioretention, and vegetated swales (Figure 6) or strips are especially in wide use. These BMPs often use the physical properties of vegetation to slow the flow of storm runoff, allow particulates to settle, help retain water, allow infiltration, and allow runoff to filter through soil or media.

The normal biological functions of vegetation also directly remove some runoff constituents through uptake, and help reduce flows by consumption of water to support plant growth and by evapotranspiration to support normal metabolic functions.

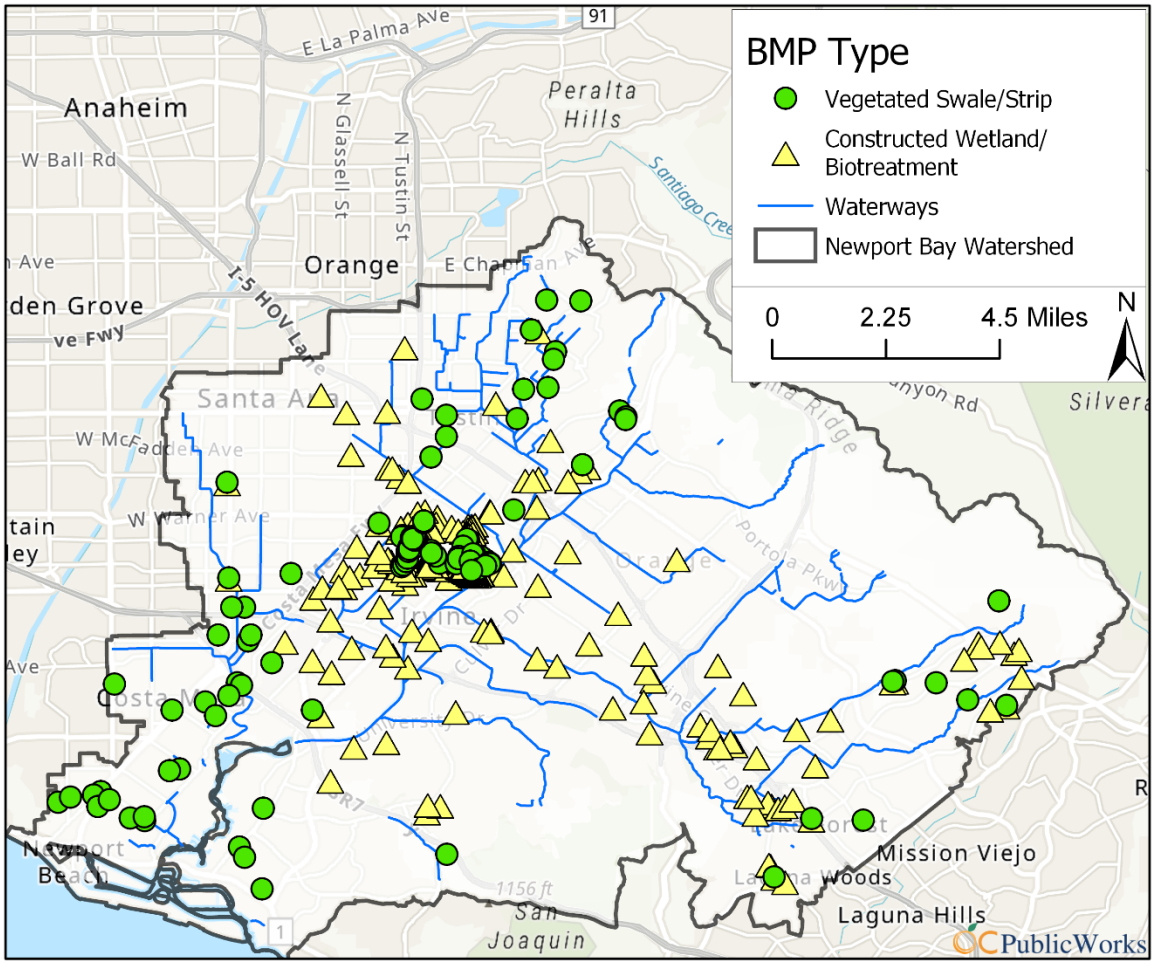

Figure 4: Map of constructed wetlands/biological treatment BMPs and vegetated swales and strips in use in the Newport Bay watershed.

Most of these BMPs are smaller in scale and designed to treat runoff from a single property or development project. The distribution of BMPs throughout the watershed (Figure 4) collectively retain runoff, and associated pollutants on-site, thereby reducing or preventing their discharge into waterways. Since not all agencies provided data for this report, there are likely many more such BMPs that are not represented. Further, as LID practices become increasingly incorporated into the watershed development process, such BMPs will increase in number over time

Figure 5: Modular wetlands in a parking lot in Tustin.

Figure 6: Vegetated swale along Newport Boulevard in Newport Beach.

c. Sanitary Sewer Diversions

Sanitary sewer diversion projects divert dry weather flows into the sanitary sewer for treatment. These are generally designed only for dry weather runoff, since storm flows are prohibited by the sanitation agencies and would overwhelm wastewater treatment plants. These are also generally reserved for areas with chronic, intractable water quality problems because construction and operation and maintenance costs may be high and because diversion of surface flows reduces or eliminates water for the support of downstream aquatic habitat.

Diversions are currently in operation at Newport Dunes and Big Canyon Golf Course in Newport Beach, and lower Peters Canyon Wash. Additional diversions in Newport Beach are planned for Hoag Hospital, Arches Drain, and Santa Ana Delhi. The Santa Ana-Delhi diversion is a cooperative project among the County, Orange County Flood Control District (OCFCD), Orange County Water District, IRWD, and the cities of Santa Ana, Costa Mesa, and Newport Beach. The Peters Canyon Wash diversion is a cooperative project being funded by the County, OCFCD, IRWD, CalTrans, and the cities of Irvine and Tustin, mainly intended to treat excess selenium loads (from groundwater exfiltration) in the region. However, it will also reduce loads of other dissolved contaminants and FIB loads by reducing flow and removing nutrients for bacterial growth.

In recent years, the Santa Ana-Delhi Channel supplied about 15% of the total freshwater flow into Upper Newport Bay, and an average of about 25% of dry weather flows. Since about 65% of the freshwater flow into Upper Newport Bay is supplied by San Diego Creek, most of which in turn is treated by passage through San Joaquin Marsh, the addition of the Santa Ana-Delhi diversion will result in nearly 90% of the freshwater flow into Upper Newport Bay being treated for bacteria.

In addition to the diversion at Newport Dunes, drain plugs are used in dry weather at targeted drains on the parcel. These plugs prevent drainage from these areas, instead allowing the typically small amount of dry weather runoff to evaporate. The plugs are removed during storms to prevent flooding.

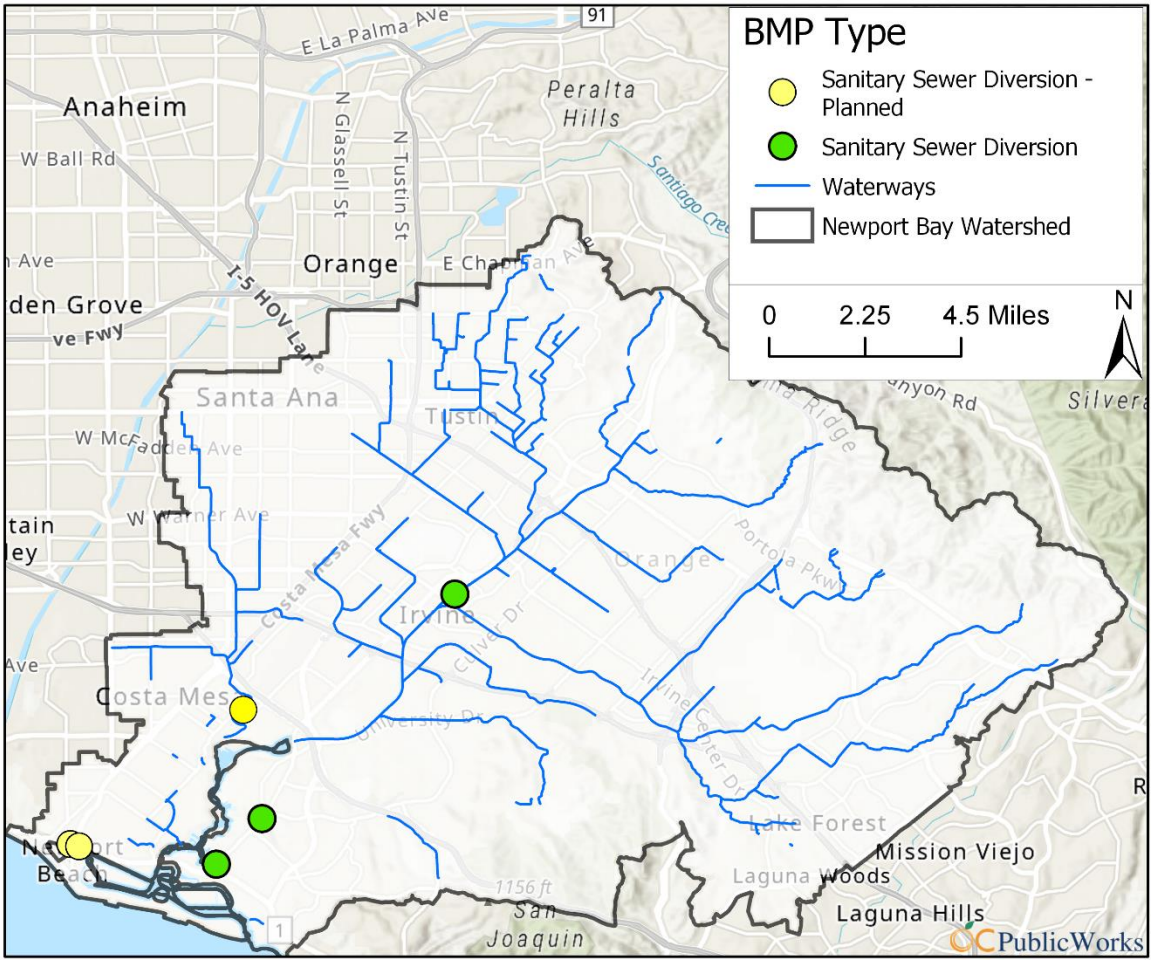

Figure 7: Sanitary sewer diversions in place or planned for implementation in the Newport Bay watershed.

d. Sediment Basins and Drop Structures

The primary function of sediment basins and drop structures is to retard flow. Sediment basins reduce flow and increase residence time, promoting settling of sediment and other particulates. Drop structures primarily function to reduce flow to restrain the destructive power of storm flows. However, since they reduce flow rates in storms, and their impact basins often function like detention basins in dry weather, they too will likely reduce FIB, especially particulate-associated FIB (Figure 8).

There are thirteen sediment basins in the Newport Bay watershed. These increase residence time and settling, increase exposure to sunlight, and increases predation pressure on FIB by promoting growth of zooplanktonic communities in basins with permanent pools. Eight of these are retarding basins in the foothills of the upper watershed. Three in-channel basins are in lower San Diego Creek, formed by a series of weirs to create lentic conditions in the lower Creek. Most of the finer suspended particulates are captured by sediment basins in Upper Newport Bay (see Figure 9). Fine particulates often stay suspended because their surface charges tend to repel other

particulates. The marine waters of upper Bay help neutralize these charges, allowing fine particulates to flocculate and settle.

Because the primary function of flood control channels is to move stormwater rapidly out to the ocean, drop structures are necessary to help restrain stream currents and reduce their destructive potential. But in dry weather flows, permanent ponds often form in their impact basins, allowing them to support some water quality improvement functions (Figure 10). Some of these ponds in the watershed support whole ecosystems, serving as refugia for fish and invertebrates during storms and in low flow conditions (Figure 8).

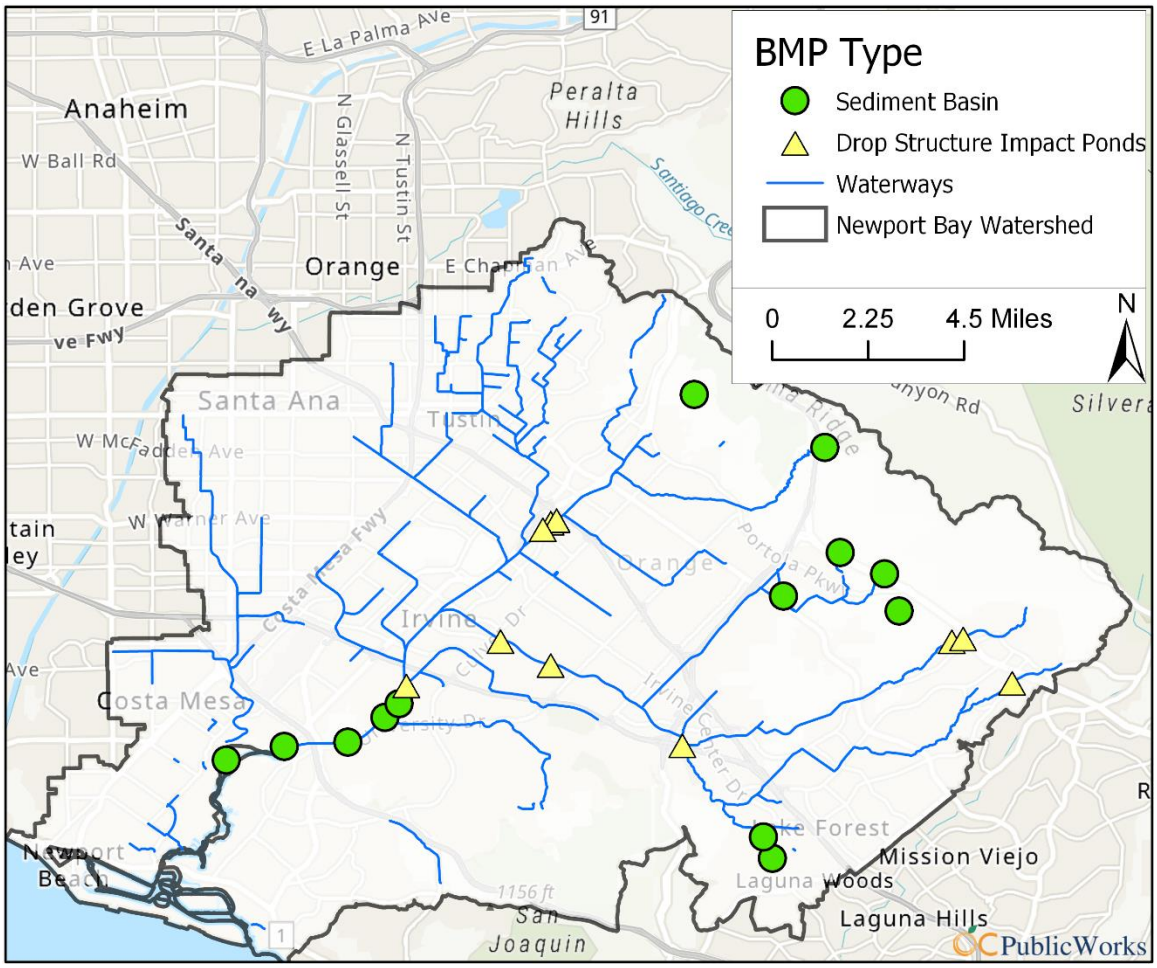

Figure 8: Sediment basins and drop structure impact ponds in Newport Bay watershed.

Figure 9: Unit I-III sediment basin in Upper Newport Bay.

Figure 10: Drop structure impact basin at the end of San Joaquin Channel, just before entering lower San Diego Creek.

e. Media Filters

Media filters utilize different kinds of media, which may include sand, charcoal, or gravel, to filter out pollutants. These can be effective at FIB removal if they are appropriately designed and maintained. Media filters can range in size from small, multi-chambered units designed as catch basin retrofits to large sand filters designed as regional treatment facilities. Most of the media filters in the Newport Bay watershed are designed for use in catch basins, often using deflectors to collect large debris, a baffle chamber to retard flow, and the media filter itself (Figure 11).

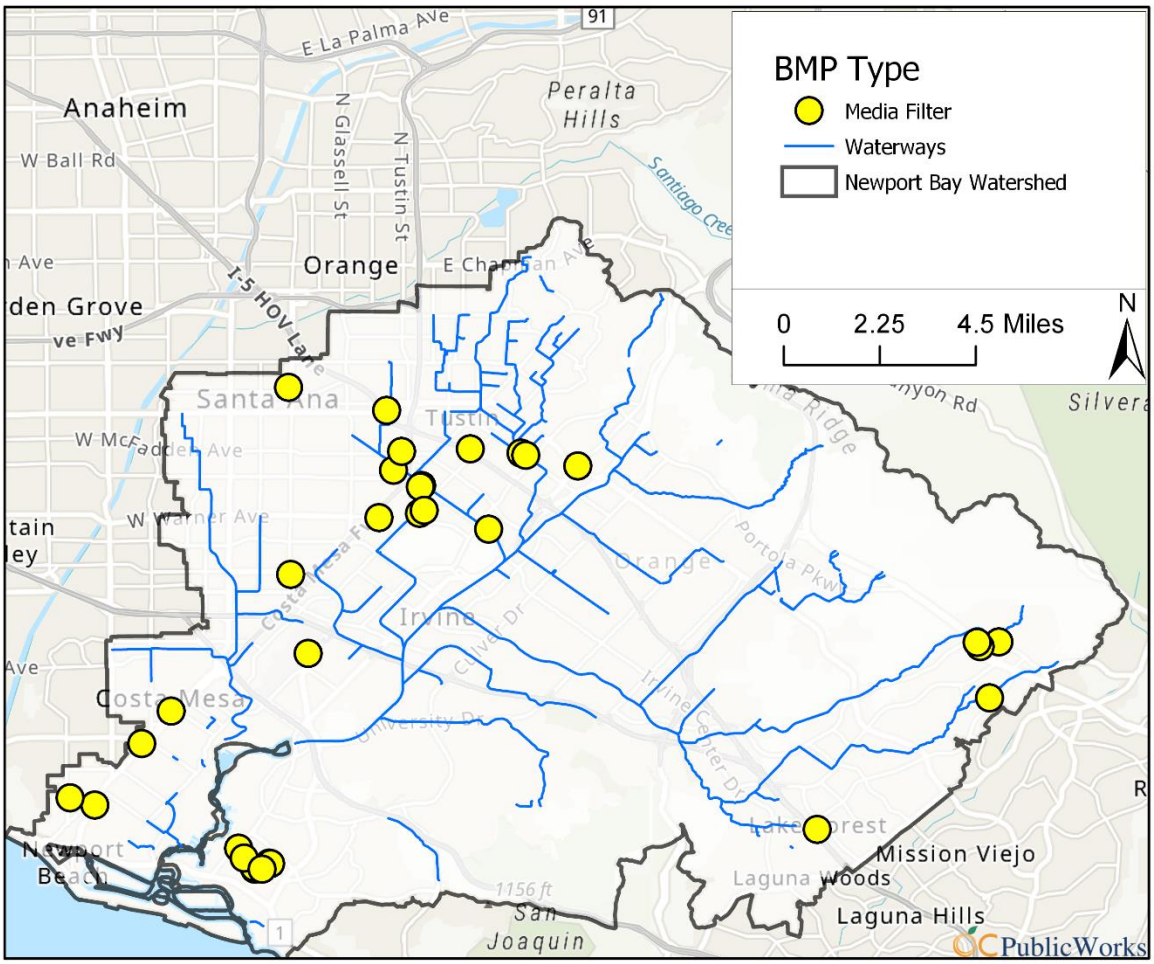

Figure 11: Locations of media filter BMPs in the Newport Bay watershed.

f. Trash and Debris-Related Physical BMPs

In recent years, increasing attention has been placed on trash in the watershed including the Trash Provisions approved by the State Water Resources Control Board. There are now numerous devices in use to keep trash out of receiving waters. While these BMPs do not directly treat FIB, food-related trash can itself be a source of FIB and act as an attractant for foraging animals and birds, which in turn can be additional sources of FIB. Therefore, BMPs which help remove trash from waterways or prevent trash from entering the storm drain system contribute to FIB load reduction.

There are currently five major types of trash and debris-related physical BMPs in use in the watershed. These include catch basin screens, catch basin filters and inserts, hydrodynamic separators, trash and debris booms, trash skimmers, and connector pipe screens. Trash and debris-related BMP location data were only available from the County, the cities of Tustin, Newport Beach, Irvine, and Santa Ana, and the Irvine Company. Therefore, the presence of these BMPs is highly underrepresented in the dataset (Figure 12).

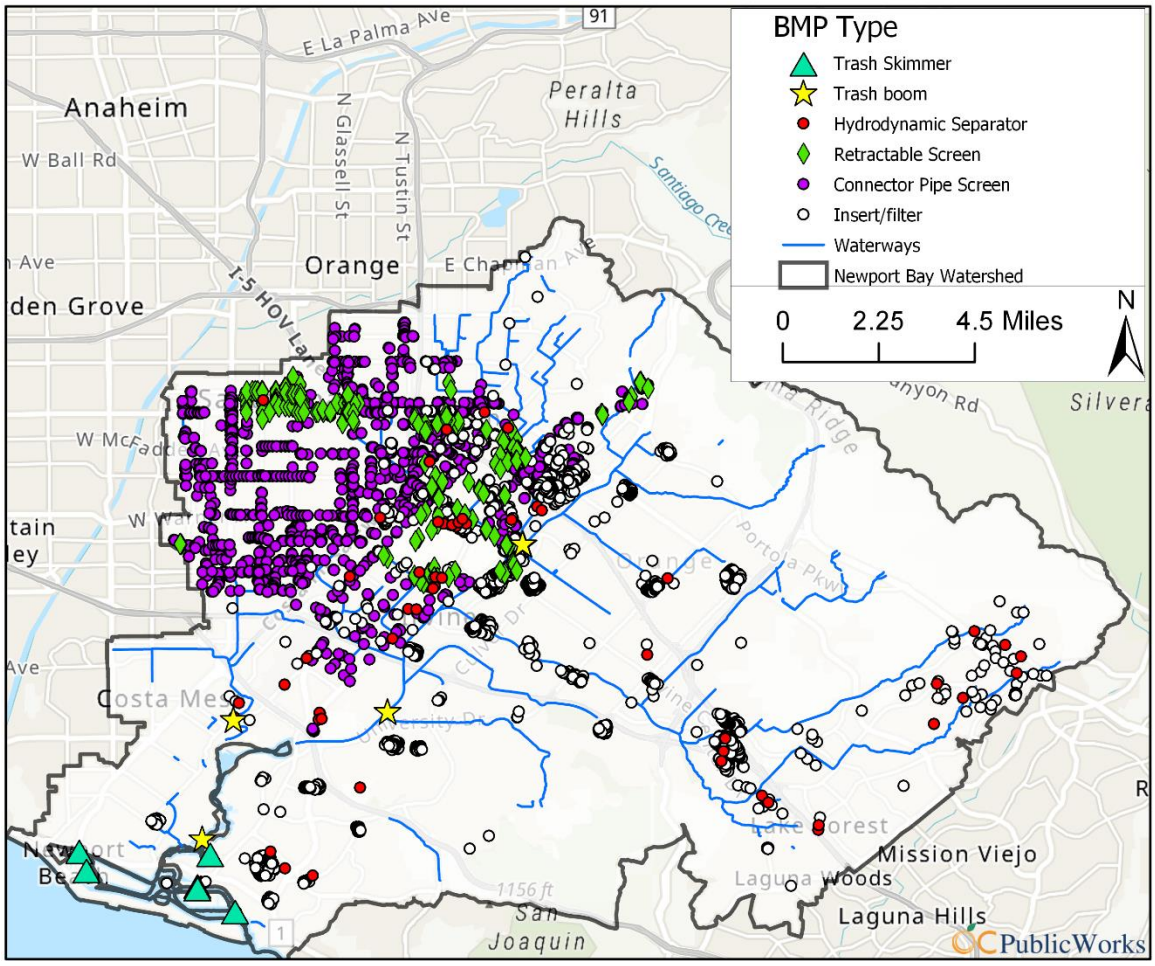

Figure 12: Locations of trash and debris-related BMPs in the Newport Bay watershed.

Catch basin screens are installed in catch basin openings (Figure 13). These range from pieces of rebar for screening out large debris to screens with openings of various sizes to filter out smaller pieces of debris. Catch basin filters or inserts (Figure 14) might be used in lieu of a screen or in addition to one, but they are typically placed in the catch basin itself. While exact numbers are not known, since municipalities do not inventory catch basins by watershed, there are probably over 10,000 catch basins in the Newport Bay watershed, thousands of which have screens or inserts.

Connector pipe screens are typically used inside a catch basin to screen out trash and debris before storm flows enter storm drain pipes. These are typically regarded as full

capture devices, which retains debris larger than 5 mm in size. These devices are used by several jurisdictions including Irvine, Santa Ana, Tustin, and unincorporated areas.

Hydrodynamic separators, or continuous deflective separators, are designed to perform three main purposes: sequester trash, remove hydrocarbons from runoff, and allow sediment to settle. The devices use gravity separation for heavier particulates to settle out of the water column while blocking the water surface to retain hydrocarbons and trash. There are at least 54 such devices currently used and maintained in the watershed.

Figure 13: Trash and debris screen in catch basin in Newport Beach.

Figure 14: Catch basin insert with filter and trash and debris grate in Tustin.

Figure 15: Trash and debris boom deployed across Santa Ana-Delhi Channel in Newport Beach, just before cleanout.

Trash and debris booms are typically used for floating debris, although some may have netting to trap underwater debris as well (Figure 15). These are deployed across lotic waters to catch debris coming from upstream and are usually cleaned out on a regular basis. There are currently five trash and debris booms in the Newport Bay watershed. One each is deployed in upper Peters Canyon Wash, El Modena-Irvine Channel, lower San Diego Creek, and Santa Ana-Delhi Channel. Another is deployed at North Star Beach in a swift current section of Newport Bay itself. A new trash and debris boom design is currently being deployed in the Santa Ana-Delhi Channel and will replace the existing boom at the end of 2018.

Trash skimmers create a current to allow floatables to flow into the device in locations where no appreciable current exists. There are currently six of these devices in use at various locations in lower Newport Bay.

Trash and debris-related BMPs that are more programmatic in nature will be discussed later in the source control section (Section II.C.3).

2. Volume Reduction BMPs

Physical volume reduction BMPs decrease the volume of flow and usually involve infiltration. Volume reduction is especially important for two reasons. FIB load is directly related to the volume of water, since load is calculated from volume and concentration. In addition, reduced volume means reduced urban runoff, which in turn reduces the amount of activated biofilm in street gutters and storm sewers. As Skinner *et al*. (2010) demonstrated, inert FIB, immobilized due to desiccation, can almost instantly become activated biofilm with the addition of water. The water then also serves as a transportation medium for FIB into storm drains and receiving waters.

Infiltration BMPs function primarily by allowing flow to infiltrate into the ground, thereby reducing or eliminating surface flows and associated pollutant loads. Infiltration BMPs may not be a good option in areas with shallow groundwater if pollution is a concern, or in areas with poor natural permeability. Some infiltration systems incorporate underdrains to ease flooding during high intensity rain events. Table 2 shows the numbers of volume reduction BMPs implemented in the Newport Bay watershed. Some of the different volume reduction BMPs in use in the watershed are also mapped in Figure 16.

Table 2: Infiltration and volume reduction BMP implementation in the Newport Bay watershed as of June 2018. [3]

BMP Type	Subtype	Implemented	Planned
Volume reduction and infiltration BMP	Infiltration basin/trench	28	1
	Infiltration dry well	10	3
	Permeable concrete/asphalt	5	1
	Pervious pavers	7	1
	Rainwater harvest	5	
	Drain plugs	4	
	Porous landscape	5	
	Other	32	3

[3] Data from 2016 was reclassified; therefore, subtotals may differ from previous report. In addition, data was not received from every jurisdiction

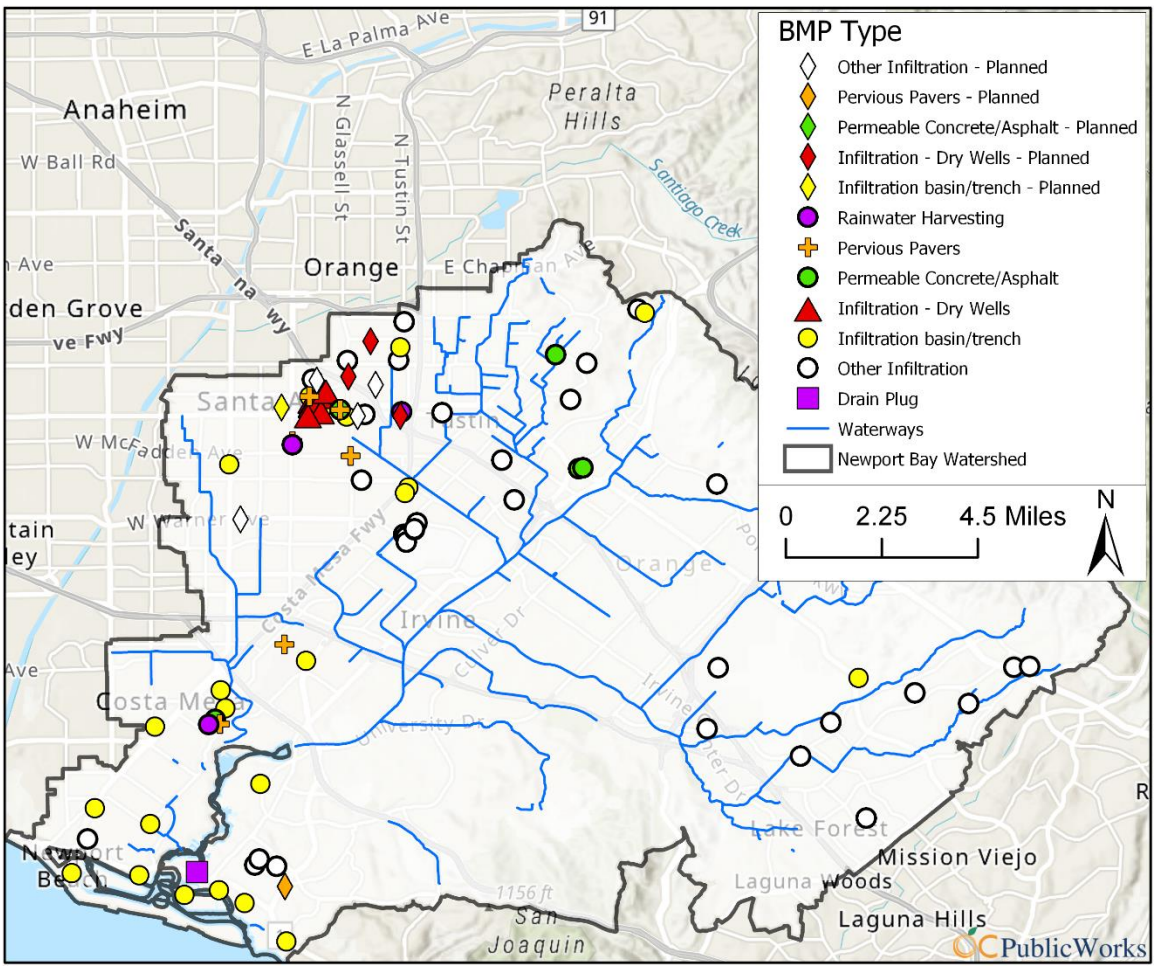

Figure 16: Infiltration and volume reduction BMPs in the Newport Bay watershed.

a. Infiltration Basins, Trenches, Galleries

These BMPs include infiltration basins, trenches, strips, or galleries. Some of these may be constructed to detain or retain flows and allow more time for infiltration, and may be constructed with more permeable soil types (Figure 17). While some of these BMPs may also have vegetation, their primary function is infiltration of water.

Figure 17: Example of an infiltration trench at the Katie Wheeler OC Public Library in Irvine, CA.

b. Permeable Landscape (Softscape)

Softscape elements, including vegetated strips and lawns, may also help with volume reduction, although infiltration effectiveness can vary depending on permeability of underlying soils. Many natural treatment BMPs, such as NTS sites, detention basins, or vegetated swales may also allow infiltration in addition to other treatment processes. Significant development and redevelopment projects now require incorporation of low impact development practices, which seek to recreate the pre-development hydrologic regime and restore associated ecosystem services. One such practice is to allow for infiltration of rainwater and retaining it on site. Therefore, as time passes, infiltration BMPs will be widely distributed through more of the watershed.

c. Permeable Landscape (Hardscape)

There has been an increase in the use of permeable landscaping materials, such as permeable concrete and asphalt and permeable pavers (Figures 18 & 19). These allow for a hardscape element when needed, but also allow water to permeate into the ground.

Figure 18: Permeable concrete in a parking lot in Orange.

Figure 19: Example of pervious pavers at OC Coastkeeper Garden in Orange.

Numerous developments in Orange County have included either infiltration or permeable hardscape BMP features for water quality purposes in their WQMPs in recent years. Although many of these are designed to infiltrate only runoff from one property or development project, like modular wetlands, these BMPs are widely distributed throughout the watershed and collectively help reduce the volume of flow and FIB discharging to the Bay.

d. Rainwater Harvesting

Rainwater harvesting systems capture rainwater for use in landscaping and sometimes other non-potable uses. Until the Rainwater Recapture Act of 2012, it was not technically legal to harvest rainwater in California, despite widespread promotion of rain barrels to help alleviate ongoing drought conditions. Today, rain barrels are in wide use in private residences. It is not possible to map rain barrels in the watershed, but three rainwater harvesting systems were reported on WQMPs and are shown in Figure 16.

3. Source Control BMPs

Source control BMPs are often programmatic in nature and seek to contain pollutants before they have an opportunity to enter waterways through implementation of various municipal activities, or to prevent pollutants from being deposited in the watershed by altering behavior.

a. Public Education

Public education and outreach is central to positively impacting public behavior. As principal NPDES permittee and on behalf of permittee cities, the County implements a multi-faceted public education program. The program includes television and print advertising, social media content, water pollution brochures, an informational website, and public outreach events, but is focused on community-based social marketing. One of the primary metrics used to assess effectiveness of the public education campaign is total "impressions," which are estimated exposures to the public education campaign message. In the 2016-17 reporting year, there were 87,010,037 overall impressions (County of Orange 2017).

The County's public education program focuses on water quality protection best practices through a broad level foundational campaign branded as H_2OC (County of Orange 2017). The County addresses specific behaviors with smaller, community-based level action campaigns, which includes the Overwatering is Out campaign. The Overwatering is Out campaign, to eliminate overwatering, began in the 2012-13 reporting period (year 1) and tracks actions on behalf of County residents exposed to the campaign message. The campaign recruits followers who voluntarily submit their e-mail addresses to obtain more information to practice an overwatering reduction BMP and will be expanded to contain additional, more general content. In 2016-17, the campaign recorded 3,978 e-mail opt-ins and 160 people who said they adopted a BMP. The action campaign will undergo an evaluation by the Permittees in 2017-18 (year 5) in an effort to keep the momentum going and the message relevant.

Water conservation measures in the watershed, Overwater is Out, and increased volume reduction BMPs, has helped to reduce summer dry weather flows in San Diego Creek (Figure 20). Average daily discharges during dry weather have been highly variable, particularly since there is so much groundwater exfiltration in the watershed. As a result, even though rainy days are excluded, years in which high rainfall was observed also resulted in higher base flows. However, a declining trend in dry weather flow is evident over the past 25 years. The geometric mean of average daily discharges between April to September was 17.33 cfs in 1992 and 5.10 cfs in 2017.

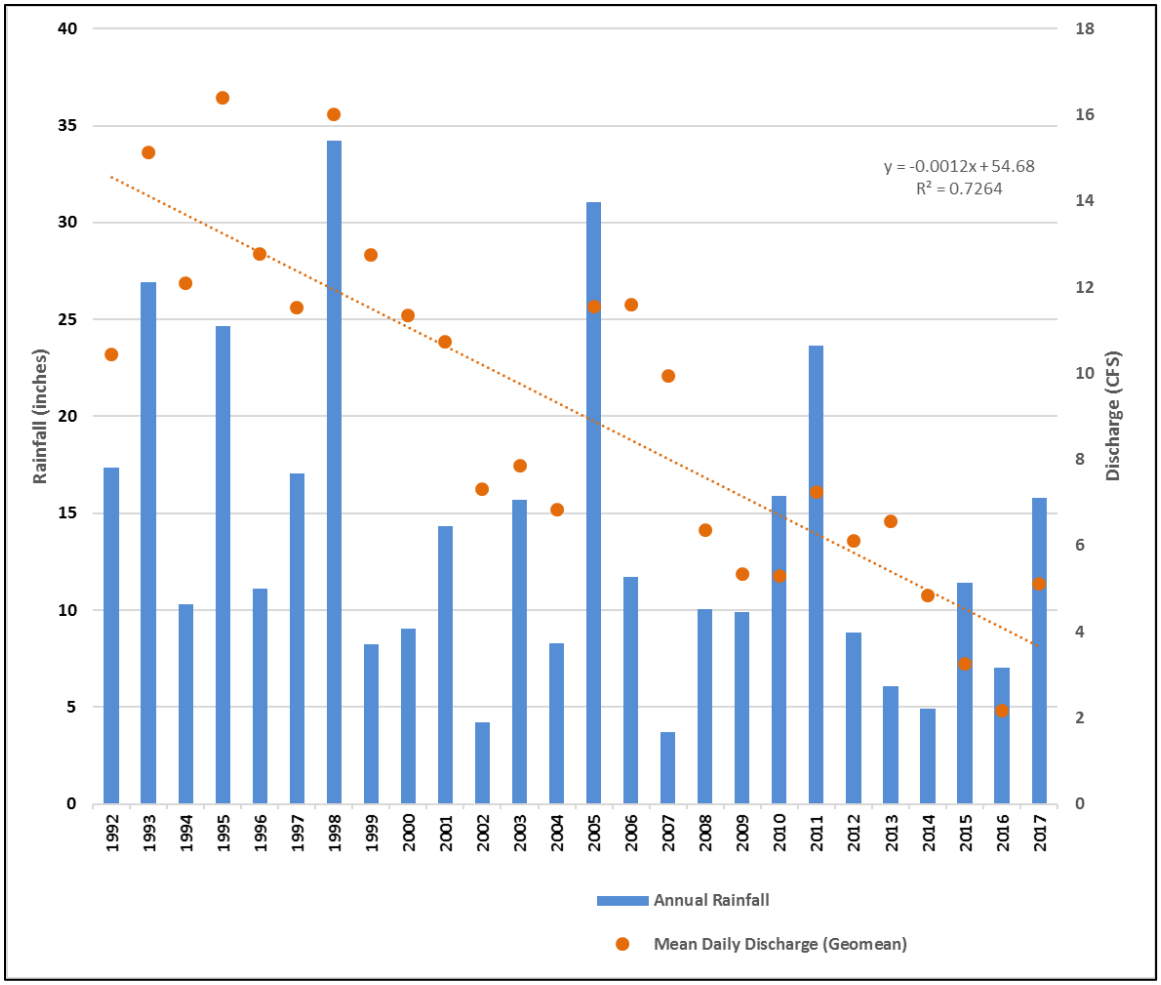

Figure 20: Geometric mean of average daily discharge between April-September in San Diego Creek (1992-2017).

Water conservation and BMPs are as important as community engagement. County and city staff have partnered with other community organizations for a variety of public outreach and watershed cleanup events. For many years, the County has partnered in sponsoring the Children's Water Education Festival (Figures 22 & 23). This annual event allows third, fourth, and fifth grade students to learn about the difference between the sewer and storm drain systems, common pollutants in our neighborhoods, and ways to prevent pollution from reaching our waterways.

The County also utilizes existing partnerships to promote workshops and seminars on drought tolerant landscaping to help homeowners and landscapers conserve water. For example, the University of California-Cooperative Extension hosts the Annual Urban Landscape and Garden Education Expo for landscapers, residents, and Landscape Product Manufacturers. In 2016-17 reporting year a total of 290 attendees from sectors such as manufacturing and residential/commercial landscape attended the workshops (County of Orange 2017).

County and city staff continue to target the reduction of uncontrolled pet waste. Many permittees provide free pet waste bags in their municipal parks along with waste bins for ease of disposal to encourage proper practices along with educational and enforcement signage.

The County and watershed cities have also assisted OC Coastkeeper for many years in the Watershed Heroes - Actions Linking Education to Stewardship program, providing staff to help judge high school student presentations on environmental issues. In recent years, the County has partnered with OC Coastkeeper to bring hands-on water quality science-related activities to students at Troy High School (Figure 24). The success of this program may allow it to expand to other area high schools in coming years.

Figure 22: County staff demonstrating the problem solving game of Spillville where students play the part of source tracking investigators.

Figure 23: County staff teaching students about MS4 and water quality.

Figure 24: County staff teaching Troy High School students about water quality testing on a bridge over Fullerton Creek, in partnership with OC Coastkeeper.

b. Municipal Trash and Debris Management Measures

There are a number of programmatic implementation activities that, while not targeting FIB, would be expected to help reduce FIB in the watershed. These principally fall into two categories. The first are municipal activities designed to reduce or eliminate trash from entering storm drains, and the second are municipal activities that help reduce pollution in general, or "housekeeping" activities.

Trash and debris-related activities include street sweeping, inspection and cleaning of catch basins, use of trash containment devices such as catch basin inserts or screens, and cleaning of storm drains and channels. While most municipal debris is not trash, but rather vegetative debris, the trash component often contains food wastes that attract animals and birds and promote bacterial contamination, and also provide nutrients that fuel growth of FIB in biofilms. Municipalities typically collect data on these activities by their jurisdiction and not by watershed. Therefore, the following numbers reported in this section are based on data reported by each jurisdiction and prorated by its area in the watershed (Table 3).

Table 3: Source control BMP data from the Newport Bay watershed (2012-2017).

Source Control BMP	2012-13	2013-14	2014-15	2015-16	2016-17
Street Miles Swept	148,814	149,203	154,226	156,233	153,637
Debris Swept (tons)	11,045	13,249	14,387	21,778	26,242
Solid Waste Collected (tons)	581,949	704,935	700,365	611,651	800,264
Catch Basins Inspected	9,939	9,809	10,483	11,001	10,830
Catch Basins Cleaned	6,293	6,265	5,277	7,714	10,701
Channel/Pipe Miles Cleaned	22	26	43	23	75
Facility BMP Inspections	309	313	336	343	356
Public Notifications [4]	662	576	536	703	852

[4] 2016-17 reporting period corrected data

In the 2016-17 reporting period, over 150,000 street miles were swept in the Newport Bay watershed and 26,242 tons of debris collected as a result, which was the most debris swept in the last five years (County of Orange 2017). Over 86,000 tons of debris have been removed in the past five years by street sweeping.

Solid waste management is another important municipal housekeeping function that helps reduce FIB in the watershed. Solid waste is usually collected once per week, reducing its overall presence distribution in the watershed. Municipal solid waste programs collected over 800,000 tons in the watershed in 2016-17 (County of Orange 2017). In the last five years, they have collected over 3.3 million tons of solid waste.

Every jurisdiction also has a litter ordinance or a water quality ordinance with provisions to prevent littering in the public right of way. Similar to pet waste, littering can incur

administrative remedies or citations. Fines range up to $1,000 or more per occurrence, but usually require law enforcement personnel to observe the littering. To encourage compliance, waste disposal bins and educational signage can usually be found in public areas such as parks and bus stops, with regular trash management and maintenance.

Regular municipal maintenance activities typically include regular catch basin maintenance. The County and watershed cities inspect over 10,000 catch basins annually and clean all of those requiring cleaning, which usually amount to 50-60%. Thousands of trash and debris capture screens and catch basin inserts have been deployed in the watershed, with more deployed every year.

Maintenance activities of some jurisdictions include regular maintenance and cleaning of storm drains or channels, including drains identified as being high contributors of FIB to the Bay by source identification studies. In the 2016-17 reporting year, 75 miles of storm channels and pipes in the watershed were cleaned, which represents the greatest effort ever by far (County of Orange 2017). As part of this effort, the County initiated an Adopt A Channel program (Figure 24), whereby companies or civic groups can "adopt" portions of flood control channels and pledge to help keep them free of trash and graffiti. In the last year, County staff and interns identified six sites in the watershed as appropriate for adoption after evaluating them for presence of trash, safety, and accessibility. Portions of El Modena-Irvine Channel, Central Irvine Channel, and upper Peters Canyon Wash have already been adopted.

Figure 25: Logo of the OC Public Works Adopt A Channel Program.

c. Municipal "Housekeeping" Activities

"Housekeeping" activities include activities that promote overall pollution prevention or mitigate pollution problems if they occur. Watershed municipalities perform inspections of industrial, commercial, and food production facilities to ensure BMPs are appropriately implemented to prevent discharge of anything but rainwater into storm drains. Food

facilities may be especially problematic as sources of bacteria, but improper trash management at industrial or commercial facilities can also be problematic. Over 300 inspections of commercial and industrial facilities are conducted in the watershed annually (County of Orange 2017). There were over 2,300 food facility inspections in 2016-17.

In recognition of the fact that not every mile of storm channel can be monitored constantly, the County implements an illicit discharge/illicit connection surveillance program, called the Dry Weather Monitoring (DWM) Program, to help detect water pollution events and illegal connections to storm drains. The DWM Program tests about 20 sites per year in the watershed, performing a battery of tests per site, including collecting about 100 FIB samples per year from watershed storm drains. Any exceedances observed in the field by DWM staff are reported to the Cities for follow up investigation. For other instances of spills or public concern, the public is encouraged to contact the County online reporting system or the Water Pollution Hotline, which has resulted in approximately 500 reports in the watershed per year over the last few years (County of Orange 2017). The reporting systems not only help mitigate water pollution events, but also help in public outreach by giving the public a voice in keeping their waterways clean.

Some municipalities operate their own sanitary sewer system. These municipalities implement programs to clean and inspect sanitary sewer systems, which help reduce FIB contributions from broken sewer laterals or pump stations. As part of the County Area Spill Containment Program, these activities sometimes involve participation of County and city personnel trained in responding to hazardous material spills, and usually require owners of faulty facilities to correct identified problems. Detection and cleaning of sewage spills and detection of illicit connections to the storm drain system have helped to reduce the presence of FIB in the environment.

4. Low Impact Development Measures

Watershed municipalities have an active program to promote LID. Indeed, LID measures, including water pollution prevention measures, are required of significant development and redevelopment projects under the MS4 permit. They are required to be documented in WQMPs, which are followed by site inspections to ensure BMPs are implemented. Thus, these developments provide stormwater treatment at numerous properties throughout the watershed, which will increase as the development and redevelopment process continues.

Development projects with WQMPs on file with local agencies are shown in Figure 26. Often, WQMPs approved prior to the current (4th Term) MS4 permit were not digitized, which makes acquiring data from these WQMPs difficult. Therefore, some WQMPs may not be represented in this dataset. However, it is clear from the figure that WQMPs cover development projects throughout the watershed, and as the development and redevelopment process continues, such coverage will increase.

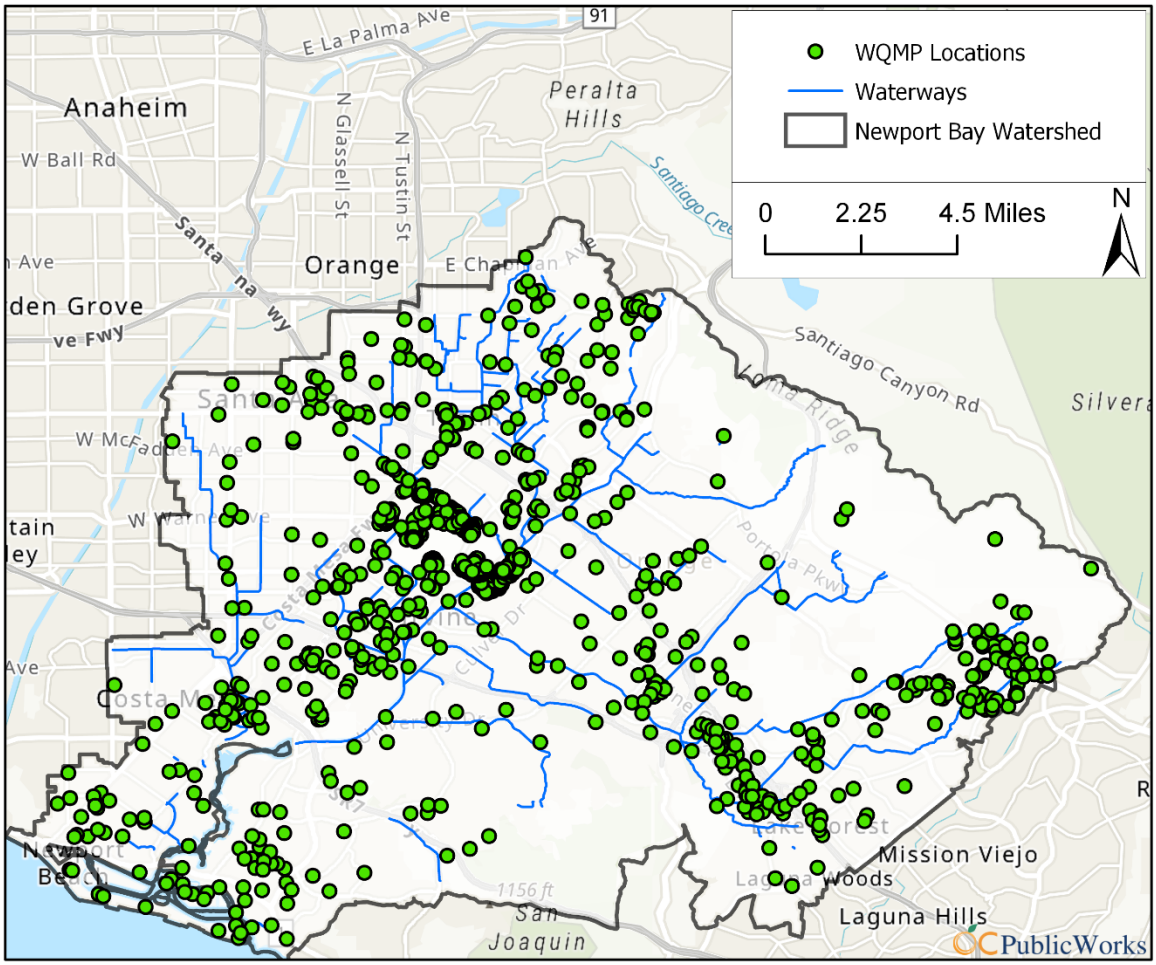

Figure 26: Locations of development projects covered by Water Quality Management Plans on file with watershed municipalities.

5. Upper Newport Bay Ecosystem Restoration/Dredging

Sediment basins in Upper Newport Bay require periodic dredging to restore sediment storage capacity. In 2006-2010, a $25 million ecosystem restoration project occurred in Upper Newport Bay to dredge the basins and major in-bay channels, as well as build up an island specifically for least tern nesting. These actions have helped restore ecosystem services in the Bay by improving circulation and flushing, which in turn has helped improve oxygenation and reduced nutrients that might fuel bacterial growth.

6. Channel Sediment Removal

Two projects are planned to remove sediment in separate reaches of San Diego Creek (SDC). The first project spans the length of SDC between both intersections of I-405 and is anticipated to begin soon. Over 6-8 months, the amount of sediment to be removed is estimated to be 170,000 cubic yards. A second project will be maintaining the in-channel sediment basins in lower SDC from Campus Dr. to I-405. The focus will be on removing sediment from the channel, and in-channel basins 2 and 3.

7. Channel Improvements

Several of the channels in the watershed have been or are planned to be improved either by means of widening to increase capacity or restored to original design specifications. For example, San Joaquin Channel recently underwent maintenance for stabilization and regrading, which will remove stagnant pools and improve flow. Other channels with projects similar to San Joaquin Channel include Lane Channel and Barranca Channel. In addition, the City of Tustin is currently working on the Peters Canyon Wash Widening Project to improve flow and increase the channel's flood control capacity.

III. Water Quality Data Summary

Through the management actions summarized in this report, Bay-wide fecal coliform concentrations have steadily and substantially declined. Statistical analysis suggests that water quality improved significantly subsequent to implementation of IRWD's Wetlands Treatment System (San Joaquin Marsh) in 2005 (Figure 27). The median bay-wide fecal coliform concentration from April 1,2005 to March 31, 2018 is significantly lower than that for April 1, 2001 to March 31, 2005 (Mann-Whitney Rank Sum; $p<0.001$)(County of Orange 2018).

In reporting year 2017-18, both Upper and Lower Newport Bay met the fecal coliform REC-1 numeric targets eleven and ten months, respectively, out of twelve months (County of Orange 2018). Both Lower and Upper Newport Bay met the *Enterococcus* REC-1 geomean target every month (Figure 28). Several individual stations with elevated bacteria levels corresponded to areas with planned future diversions of local storm drain inputs. However, wet weather influences on indicator concentrations continue to be the most prevalent issue.

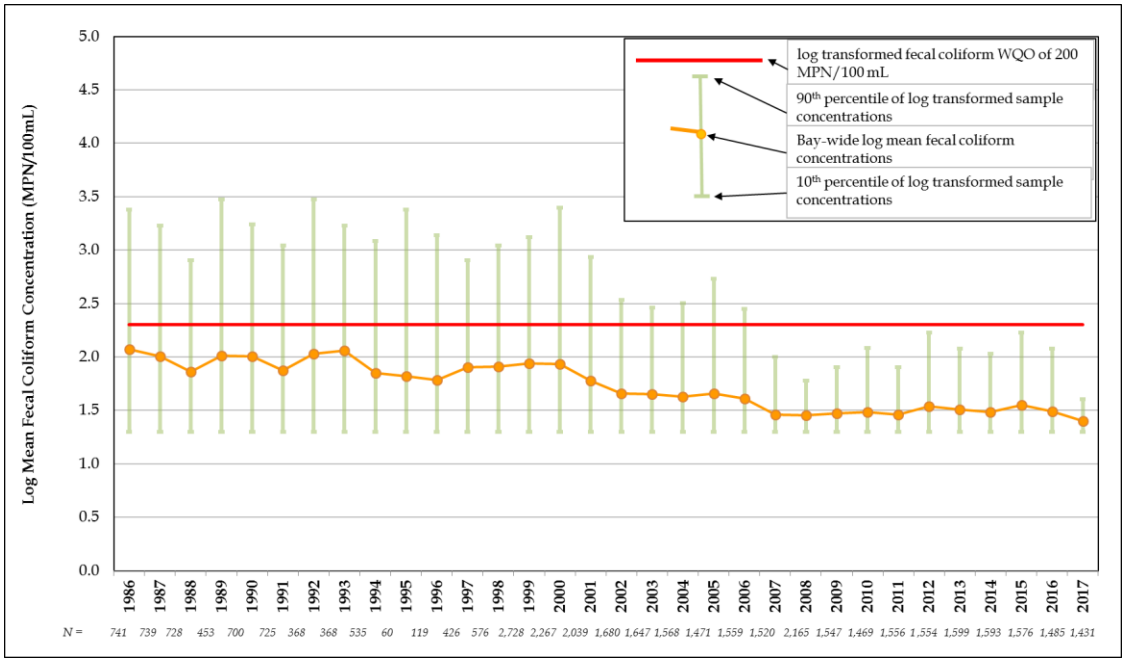

Figure 27: Bay-wide log mean fecal coliform concentrations in Newport Bay, 1986-2017.

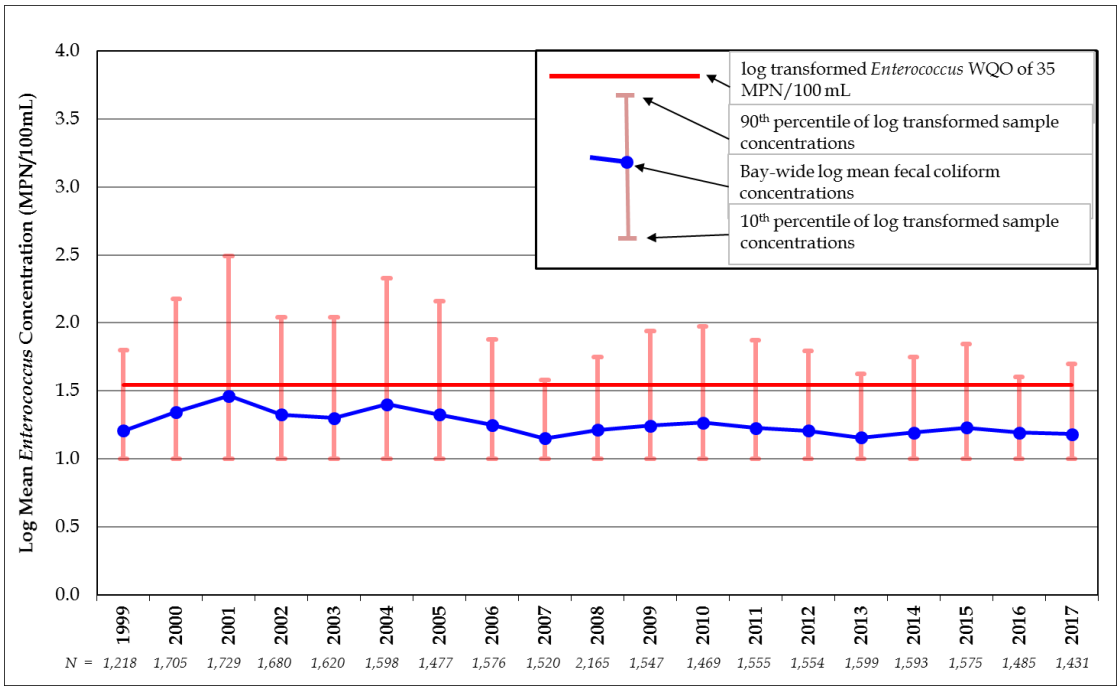

Figure 28: Bay-wide log mean *Enterococcus* concentrations in Newport Bay, 1999-2017.

References Cited

Arnold, B., K. Schiff, A. Ercumen, J. Benjamin-Chung, J. Steele, J. Griffith, S. Steinberg, P. Smith, C. McGee, R. Wilson, C. Nelson, S. Weisberg, J. Colford Jr. 2016. The Surfer Health Study: A Three-Year Study Examining Illness Rates Associated with Surfing During Wet Weather. Southern California Technical Report 943, Costa Mesa, CA. 117 pp.

County of Orange. 2016. Newport Bay Fecal Coliform TMDL 2016 Summary of Management Activities. OC Public Works, OC Environmental Resources. Orange, CA. 43 pp.

County of Orange. 2017. 2016-17 Santa Ana Region Unified Annual Progress Report Program Effectiveness Assessment. Technical report to Santa Ana Regional Water Quality Control Board, Orange, CA. 423 pp.

County of Orange. 2018. Newport Bay Fecal Coliform TMDL 2018 annual data report. OC Public Works, OC Environmental Resources. Orange, CA. 46 pp.

Ferguson, D., D. Moore, M. Getrich, R. Mahallati, M. Zhowandai, J. Wolfe, and P. Hannah. 2006. Growth of *E. coli* and enterococci in storm drain biofilm. County of Orange Health Care Agency Public Health Laboratory, Newport Beach, CA. Unpublished.

Goong, S.A. 2009. Stormwater bacteria BMPs. Fact sheet prepared for the Stormwater Quality Standards Task Force. County of Orange, OC Watersheds, Orange, CA.

Grant, S.B., Y. Jeong, S. Ritter, R. Reeves, A. Pednekar, H. Gates, J.H. Kim, N. Rekhi, B.F. Sanders, and L. Candelaria. 2004. The contribution of marinas to fecal indicator bacteria impairment in Lower Newport Bay, southern California. Technical report to City of Newport Beach and Santa Ana Regional Water Quality Control Board, Riverside, CA. 27 pp.

Grant, S.B., S.C. Jiang, B.F. Sanders, K. McLaughlin, J.H. Ahn, R. Litton, L. Ho, and D. Moore. 2009. Newport Bay fecal indicator bacteria source identification project. State Water Resources Control Board Agreement #04-198-558-2. Technical report to County of Orange and Santa Ana Regional Water Quality Control Board, Orange, CA. 333 pp.

Irvine Ranch Water District. 2013. Sewer System Management Plan. Irvine, CA. 86 pp.

Jiang, S., W. Chu, J. He, C. McGee, L. Candelaria, G. Brown, and D. Gold. 2002a. Fecal indicator bacteria and human viruses in Newport Bay, California. Technical report to City of Newport Beach and Santa Ana Regional Water Quality Control Board, Riverside, CA. 31 pp.

Jiang, S., C. McGee, L. Candelaria, G. Brown, and D. Gold. 2002b. Swimmer shedding study in Newport Dunes, California. Technical report to City of Newport Beach and Santa Ana Regional Water Quality Control Board, Riverside, CA. 13 pp.

Kabashima, J. and D. Haver. 2003. Monitoring of total and fecal coliform in surface runoff from agricultural operations in the Newport Bay/San Diego Creek watershed. State Water Resources Control Board Agreement #0-081-258-0. Technical report to Santa Ana Regional Water Quality Control Board, Riverside, CA. 5 pp.

Pednekar, A.M., S.B. Grant, Y. Jeong, Y. Poon, and C. Oancea. 2005. Influence of climate change, tidal mixing, and watershed urbanization on historical water quality in Newport Bay, a saltwater wetland and tidal emBayment in southern California. Environ. Sci. Technol. 39(23): 9071-9082.

Pednekar, A., S.B. Grant, and L. Candelaria. 2007. Assessing the seasonal impact of storm drains on water quality in western Newport Bay, southern California. Technical report to Santa Ana Regional Water Quality Control Board, Riverside, CA. 40 pp.

Skinner, J.F., J. Kappeler, and J. Guzman. 2010. Regrowth of enterococci and fecal coliform in biofilm. Stormwater Magazine, June 30, 2010.

Soller, J.A., S. Salvia, A.W. Olivieri, K. Kerr, R. Goebel, J.F. DeGeorge, S. Ginsberg, and J.N. Eisenberg. 2001. Public health risk assessment for the Newport Bay watershed: recreational contact and microbiological risk. Technical report to the Santa Ana Regional Water Quality Control Board, Riverside, CA. 158 pp.

Whitman, R.L., M.N. Byappanahalli, A.M. Spoljaric, K. Przybyla-Kelly, D.A. Shively, and M.B. Nevers. 2014. Evidence for free-living *Bacteroides* in *Cladophora* along the shores of the Great Lakes. Aquat. Microb. Ecol. 72: 117-126.