Annual Water Quality Report

Fiscal Year
2017

Report on data collected between July 1, 2016 and June 30, 2017, according to the FY 2017 Water Quality Research and Monitoring Plan.

City of Santa Barbara Creeks Division

Contents

Introduction

The following report describes sampling and results that were based on the Fiscal Year 2017 Research and Monitoring Plan (Research Plan; Appendix A). The Research Plan is organized around program elements and research questions that have been reviewed by the Creeks Advisory Committee (CAC). The Research and Monitoring Program is adaptive, and as questions are answered or modified, sampling strategies change as well. The program elements and research questions are provided below. Where possible, the report is organized around the research questions. ***The primary purpose of this report is to serve as an internal record of data collection and analysis. Please see the Creeks Division 2001-2006 report for a discussion of methods, information on water quality criteria, and a glossary of monitoring terms.***

Program Goals

The goals of the monitoring program are to:

1. Quantify the levels (concentration, flux, or load) of microbial contamination and chemical pollution in watersheds throughout the city.
2. Evaluate impacts of pollution on beneficial uses of creeks and beaches, including recreation and habitat for aquatic organisms.
3. Evaluate the effectiveness of the City's restoration and water quality treatment projects, which includes collecting baseline data for future projects.
4. Identify sources of contaminants and pollution in creeks and storm drains.
5. Evaluate long-term trends in water quality.
6. Meet monitoring requirements for grants.
7. Meet General Permit monitoring requirements.
8. Investigate 303(d)-listed waterbody impairments.

The underlying motivation behind the monitoring program is to obtain information that the City can use to:

1. Develop strategies for water quality improvement, including prioritization of capital projects and outreach/education programs.
2. Communicate effectively with the public about water quality.

FY 17 Research and Monitoring Plan

In support of the program goals, the Research Plan consists of six key elements and associated research questions:

1. Grant Project Requirements
2. General Permit Requirements
3. Watershed Assessment (including Creek Walks and Bioassessment)
4. Storm Monitoring
5. Restoration and Water Quality Project Assessment

6. Source Tracking

The Research Plan contains the program elements, associated research questions, and approach to obtaining answers. Many minor changes were made for FY 17:

1. Add neonicotinoid pesticide project to Grant Project Requirements due to confirmed project funding.
2. Add pollutant-load model selection and baseline modeling to General Permit element.
3. Remove Sycamore Creek sodium chloride investigation from Watershed Assessment due to completion of investigation.
4. Move Mission Creek toxicity question from Watershed Assessment to General Permit 303(d) monitoring.
5. Remove contaminated groundwater question from Watershed Assessment due to completion of sampling in FY16.
6. Add question about drought impacts and recovery to Watershed Assessment element.
7. Add Arroyo Burro Open Space and Trash Capture Devices to Project Assessment element, for purpose of baseline data collection.
8. Add question about low dissolved oxygen and low bioassessment scores to Watershed Assessment element.
9. Remove questions about Laguna Channel baseline bioassessment scores.
10. Add outfall monitoring and microbial source tracking follow up to Source Tracking element.

In FY 17, Creeks staff focused monitoring and research efforts primarily on the following seven projects, which are shaded in the attached Research Plan. Additional sample collection to address ongoing research questions is also noted in the Research Plan.

1. Neonicotinoid Pesticides

The "Impact of Neonicotinoid Pesticides on Estuaries and Coastal Streams Project" is a collaborative effort among the Creeks Division, the University of California, Santa Barbara (UCSB) and the United States Geological Survey (USGS). The project was designed to understand the potential ecological impacts of neonicotinoid pesticides (neonics) in local creeks and estuaries and is comprised of three integrated elements: 1) field testing to measure the concentrations of neonics in creeks and estuaries, 2) laboratory toxicity tests to understand the impact of neonics on aquatic insects, and 3) modeling to project the laboratory results to broader ecological impacts in creeks. The project is funded largely by a grant from the National Oceanic and Atmospheric Administration's California SeaGrant Grant Program to Principal Investigator Dr. Hunter Lenihan (UCSB), with additional Measure B funding for laboratory testing by USGS. Toxicity testing and mathematical modeling will be completed by UCSB. Field sampling will be conducted by the Creeks Division, with laboratory testing of field samples to be conducted by Dr. Michele Hladik (USGS Pesticide Fate and Transport Group) upon the award of a contract funded by the

Creeks Division. Dry-weather testing will begin in summer 2016 and storm monitoring will take place over multiple storm during the 2016-2017 wet season.

2. Pollutant Load Model Selection

The Phase II General Permit contains a requirement to quantify pollutant loads and pollutant load reductions achieved by the program as a whole. The Central Coast Regional Water Quality Control Board ("Regional Board") has stated in recent memos to Permittees that it expects catchment-scale spatial modeling and prioritization for BMP-associated improvements in the present permit cycle. The Creeks Division is a stakeholder in the development of a Regional Board-supported model (Total Estimation of Load Reduction, or TELR) produced by 2nd Nature Consultants. In addition, Geosyntec Consultants has produced the Pollutant Load Reduction Model. The Creeks Division will compare the costs, benefits, and scientific rigor of each model in order to select the best prioritization tool for the City's permit compliance efforts. Output from both models (ranking of catchment by pollutant load and loading rate) will be compared to a simple ranking by catchment imperviousness.

3. Low Dissolved Oxygen and Impact on Bioassessment Scores

Several creek sites in Santa Barbara have low bioassessment scores (Index of Biological Integrity, or IBI) due to development in the surrounding watersheds. Low dissolved oxygen is known to be one of many interacting variables related to watershed impairment, but it is not known as the main proximate driver of low bioassessment scores in Santa Barbara. The Creeks Division will work with Ecology Consultants and others in the coming year to examine if low dissolved oxygen is the mechanistic reason for the lack of "pollution-sensitive" insects recorded in low-scoring creek sites in Santa Barbara. Dissolved oxygen loggers will be purchased and installed for two weeks at a time at multiple locations, e.g. riffles and pools, within several creek sites where bioassessment has been conducted. Input will continue to be solicited from UCSB and the Department of Fish and Wildlife. This work addresses overall bioassessment scores in the City and the specific Clean Water Act listing for low dissolved oxygen impairment on Mission Creek.

4. Andreé Clark Bird Refuge Studies

The Creeks Division will continue to monitor the Bird Refuge weekly, collect storm monitoring data, and assess the scientific merit of treatment options at the Bird Refuge.

5. Microbial Source Tracking at Leadbetter and Sycamore Creek Watersheds

The Creeks Division will assist UCSB with sampling and serve as a stakeholder in the UCSB-led project.

6. Microbial Source Tracking for Identification and Elimination of New Leaks

In past research, microbial source tracking has identified sewage leaks that were quickly repaired by the City. Research has also ruled out numerous areas throughout the City where storm drains are not contaminated by sewage. Due to the aging nature of infrastructure, the Creeks Division plans to work with Dr. Holden at UCSB to develop a plan to monitor for potential future sewage leaks that may reach storm drains and/or creeks.

7. Outfall Monitoring and Source Tracking Follow Up

The Permit-required outfall monitoring and the Microbial Source Tracking at Leadbetter Beach and Sycamore Creek Project have generated a list of four storm drains that should be investigated for potential illicit discharge contamination. Each of the four locations will need to be investigated by closed circuit television in storm drains or other methods to determine sources of flow during dry weather.

8. Historical Fecal Indicator Bacteria Analysis

This project will be in partnership with Dr. Holden and include an update to previous statistical analysis conducted by the Creeks Division, and additional work in order to gain insight about results obtained thus far by UCSB in their current Microbial Source Tracking work (to be presented to the Committee as a separate agenda item).

9. Surfer Health Study

One of the underlying goals of the Creeks Water Quality Monitoring and Research Program is to communicate to the public about pollution issues. A specific research question in the Research and Monitoring Plan is: What is the risk to human health from recreation in creeks and beaches in Santa Barbara? The Creeks Division has reviewed recent epidemiology studies conducted in Southern California during dry and wet weather. Results show a similar illness rate in wet and dry weather of approximately 50% above background levels. Because background illness rates are low, this results in a small absolute risk of becoming ill after swimming or surfing (1% for no contact, and 1.5% after ocean contact during dry or wet weather). The illnesses are typical of those spread by fecal-oral transmission in schools, restaurants, and public restrooms. For someone who surfs twice per week over an entire year, regardless of weather, the averages translate to approximately one additional gastrointestinal illness, one additional bout of sinus pain or infection, and one additional earache or infection compared to not surfing at all over the year. While none of these studies were conducted in Santa Barbara, the results are likely applicable to Southern California beaches impacted by urban runoff.

Project Updates

Neonic Pesticides

The following text and figures are from a report to NOAA's SeaGrant. The material presented here includes data to support project objectives addressed by the City.

Objective 1: To determine the temporal (wet and dry season] patterns of imidacloprid and three related neonicotinoid insecticides as well as several major metabolites in stormwater feeding coastal streams and estuaries in agricultural and urban areas.

Objective 1 was completed. As detailed below, neonicotinoid pesticides and fipronil and its degradates were pervasive in Santa Barbara creeks and estuaries during dry and wet weather, In addition, imidacloprid and fipronil were found frequently above established chronic toxicity thresholds, raising concerns about ecological impacts of the widespread use of systemic pesticides.

Samples were collected during storm events, in order to determine peak concentrations, and following storm events, to assess how long aquatic organisms are exposed to lower concentrations of pesticides (Figure 1). As planned, samples were collected during a small, early storm, a medium, "design storm" (~1"/24 hrs), and a large storm (>2"/24 hrs).

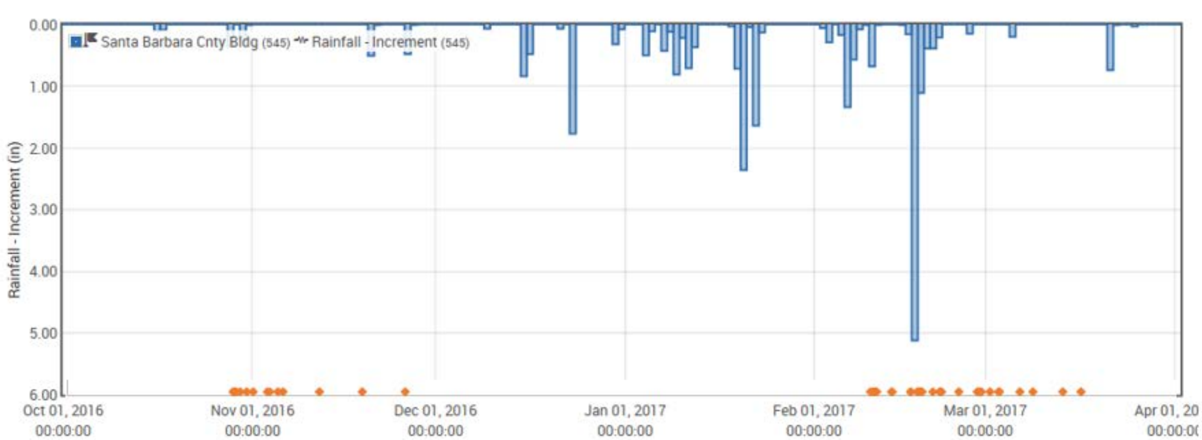


FIGURE 1. RAINFALL (BLUE BARS, INVERSE AXIS) AND SAMPLE POINTS (ORANGE SYMBOLS) DURING WINTER 2016-2017.

As expected, imidacloprid was detected in every wet weather sample collected (Figure 2). More surprising was that imidacloprid was also detected in every dry weather sample, i.e. the concentration never dropped below detection in samples collected in days to weeks after storm events. Previous sampling by the City found non-detectable levels of imidacloprid in creek samples collected in summer. Two neonicotinoid pesticides, clothianidin and thiacloprid, were not detected in any samples. Acetamiprid, which had not been tested previously by the City, was found in 50% of dry weather and 74% of wet weather samples. Two other neonicotinoid pesticides, dinotefuran and thiamethoxam, were found only in runoff from agricultural areas (see Obj. 2).

Fipronil and/or at least one of its degradates was found in 91% of samples overall (Figure 2). Fipronil was detected in 93% of wet weather and 80% of dry weather samples and fipronil sulfone was detected in 88% and 77% of wet and dry weather samples, respectively. Other degradates were detected less frequently.

Imidacloprid and fipronil were frequently above new US EPA Aquatic Life Benchmarks for chronic invertebrate toxicity in fresh water (Figure 2; US EPA 2017). Imidacloprid was found above the chronic benchmark in 90% of samples and fipronil exceeded the benchmark in 72 % of samples. All results were below acute benchmarks. Imidacloprid benchmarks were updated in 2017 and are now much lower than when this research began. Fipronil benchmarks were updated in 2016, but there is concern that chronic benchmarks are not sufficiently protective (US EPA 2017). All other pesticides were below chronic benchmarks at sites and time points, with the exception of thiamethoxam, for which no chronic benchmark exists.

During the post-storm sampling, no surface runoff was observed in the watersheds sampled, whereas flow continued to discharge from storm drain outlets. We suspect that imidacloprid-contaminated shallow groundwater (also called interflow) infiltrates into storm drains. The solubility of systemic pesticides leads longer discharges of contaminated water, compared to older pesticides with high adsorption coefficients.

Results generated under Obj. 1 will provide ample data for modelers to simulate winter exposure scenarios of imidacloprid and fipronil in coastal streams and estuaries. These results are among the first for surface waters following storm events and for California estuaries.

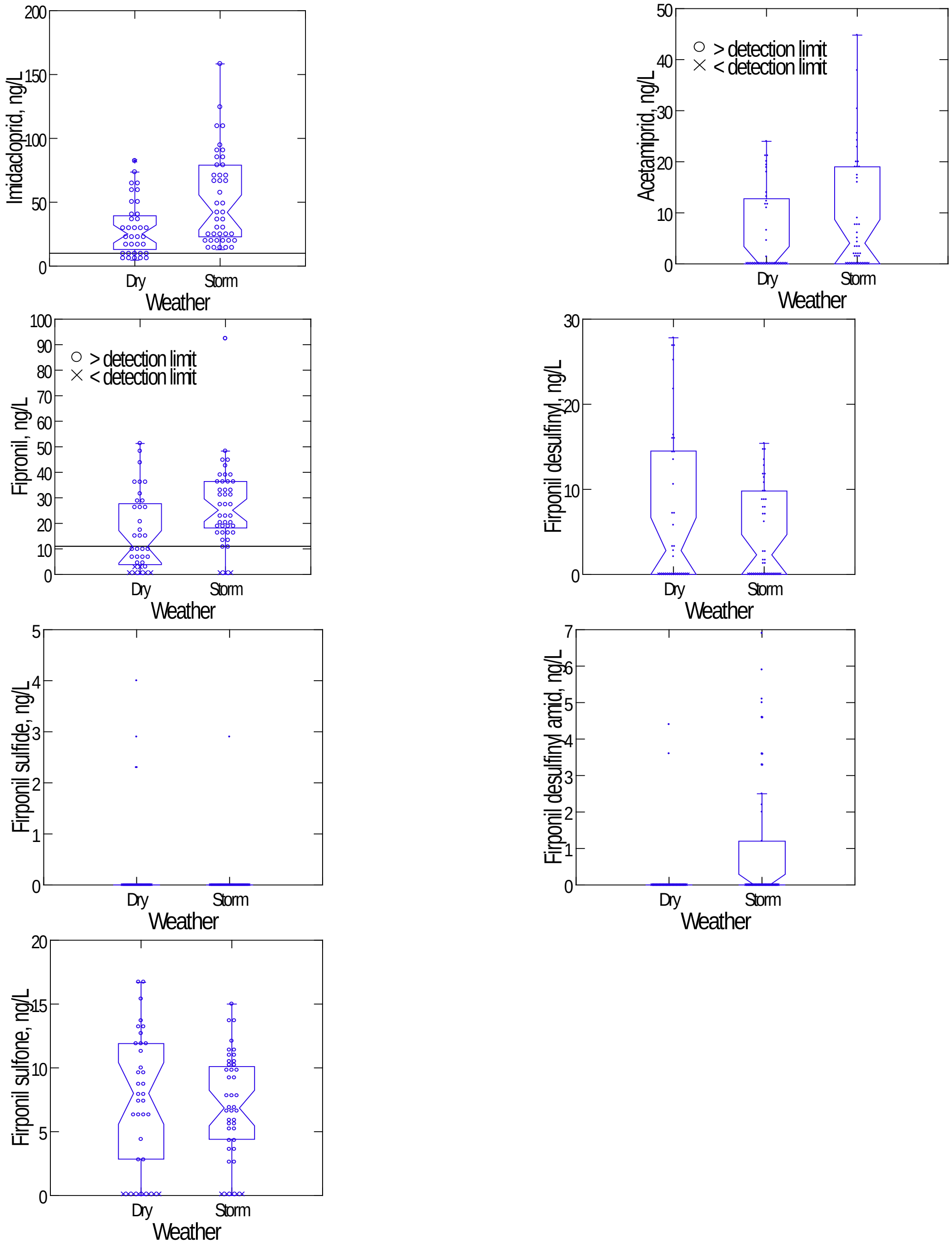


Figure 2. Concentrations of neonicotinoid pesticides, fipronil, and fipronil degradates during dry and wet weather. Samples below detections levels were plotted as zero for the purpose of ranking and nonparametric statistics. Boxes show the median (notch) and interquartile range. Extent of notches represent nonparametric confidence intervals (Systat 11). Dashed lines represent US EPA benchmarks for chronic toxicity to aquatic invertebrates (for panels with no dashed lines, results were all below available benchmarks.

Objective 2: To test the hypothesis that streams receiving runoff from urban land uses and agricultural (including nursery and greenhouses) land uses have different concentrations and/or loading rates of imidacloprid.

Objective 2 was completed. Imidacloprid was detected in both urban and agricultural runoff. During the storm event of 2/10/17, which was the fourth storm of the season, imidacloprid values were higher in agricultural runoff compared to urban runoff (Figure 3). During the weeks afterward, which was punctuated by a large storm event on 2/18/17, values remained higher in the Carpinteria Salt Marsh (Franklin Creek input, also receives urban runoff) compared to Laguna Channel Lagoon (receives only urban runoff). In the post-storm samples, values remained close to or above the US EPA chronic toxicity threshold.

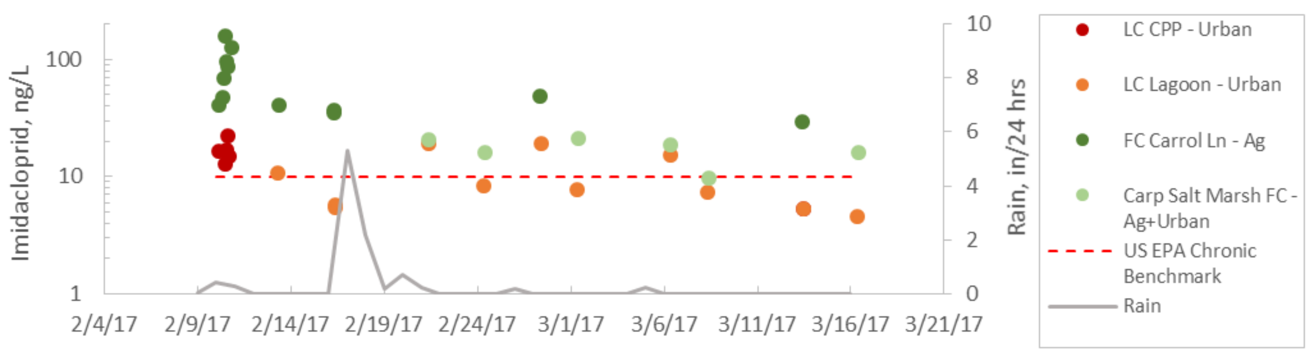


FIGURE 3. IMIDACLOPRID IN RUNOFF FROM URBAN (RED AND ORANGE SYMBOLS) AND AGRICULTURAL (GREEN SYMBOLS) DRAINAGES. DASHED LINE SHOWS US EPA BENCHMARK FOR CHRONIC TOXICITY OF AQUATIC INVERTEBRATES.

One reason that the agricultural area discharged higher concentrations may be more frequent applications of pesticides, compared to homeowners who may treat for ants and termites in summer months. In addition, the ratio of pesticide-treated area to total area may be higher in the agricultural drainage.

In addition to imidacloprid, two pesticides were detected in agricultural runoff that were not found in the urban area. Dinotefuran and thiamethoxam were detected frequently in storm runoff at FC Carroll Ln, but were not found in the urban sites of Santa Barbara.

Objective 3: To test the hypothesis that samples from creeks and estuaries in Santa Barbara will exhibit toxicity when neonicotinoid-sensitive test species and assays are used.

This objective has not yet been completed due to difficulty obtaining commercial laboratory services for toxicity tests using chironomids. The laboratory that the City contracts with was not able to complete the test successfully, due to cannabilism of the test organism, despite multiple attempts. The City is in discussion with alternative laboratories and will complete Objective 3 during winter 2018. Limited toxicity results, using ceriodaphia and hyalella 5-day tests in creek storm flow, showed in 95-100% survival, even when imidacloprid and fipronil were elevated. This result confirms the need for sensitive test species for neonicotinoid research.

Objective 4: To produce pilot-scale data on transport mechanisms of neonicotinoids to urban streams.

Objective 4 has been completed. Pilot scale testing was completed for neonicotinoids and fipronil in various environmental samples. None of the measured pesticides were detected in pure rainwater. Samples of tree pollen, mulch in a City park, and street sweeper material was used to leach pesticides prior to analysis. Of all of the pesticides tested, only imidacloprid was found, and only in the sample of street sweeper material (Table 1).

TABLE 1. PESTICIDES CONCENTRATIONS IN ENVIRONMENTAL SAMPLES THAT WERE LEACHED PRIOR TO ANALYSIS. "ND" SIGNIFIES RESULTS BELOW DETECTION LIMITS.

Site	Imidacloprid, ng/L	All other neonicotinoids, ng/L	Fipronil and degradates, ng/L	Hyalella Toxicity-96 hr, % survival	Ceriodaphnia Toxicity-96 hr, % survival
Rain	nd	nd	nd		
Rain	nd	nd	nd		
Stone Pine Polllen	nd	nd	nd	5	80
Mulch in City Park	nd	nd	nd	0	0
Street Sweeper Material	42.0	nd	nd	95	100
Field Blank	nd	nd	nd		

These results provide a mechanism for understanding previous results obtained in City testing, i.e. imidacloprid was found in runoff from a park that was not treated with pesticides. It is likely that dust, such as that found in street sweeping material, is wind-blown throughout the urban environment. In addition, this result suggests that a more detailed study would be required to develop a detailed model of fate and transport of imidacloprid.

Toxicity tests were also conducted on leached material, with very concerning results (Table 1). For the mulch leachate, 0% survival was found for both test species, and for the pollen, only 5% survival was found with hyalella. This is among the most problematic result obtained in years of testing by the City. The City will pursue additional studies of mulch, pollen, and street sweeper spoils in coming years.

Conclusions

These results, combined with recent US EPA updates to aquatic life benchmarks, present renewed urgency for understanding the ecological impacts of pervasive use of systemic pesticides in urban settings. Imidacloprid is found in hundreds of products sold in home and garden stores and is also used by professional applicators, whereas fipronil is used almost exclusively by professionals. As shown here these contaminants are reaching coastal streams and esturaries during storm events and persisting throughout the rainy season.

A recent study by Hallmann et al. (2017) showed a 76% decline in flying insects in German wildlife refuges; is such a reduction also occurring in urban settings in California? The larval stage of most flying insects occurs in surface waters. When these populations experience chronic toxicity month after month, what is the significance for food webs, including those involving restoration projects and estuary-dependent fisheries? The City and County of Santa Barbara have completed 18 years of bioassessment (aquatic macroinvertebrate community composition) monitoring in local creeks and estuaries. Results show dramatically lower “biological integrity” for urban sites compared to less developed areas, even when measures of habitat, traditional water quality, and traditional toxicity measurements rate high. Is chronic toxicity due to systemic pesticides a hidden stressor to coastal streams and estuaries?

Information for Resource Management

Outreach - The field concentration data, laboratory tests, and modelling results produced here will be used in outreach materials by the City of Santa Barbara. Outreach will include an update a City TV segment produced on neonicotinoid pesticides, printed material to be provided at outreach events, and information provided to landscaping and commercial pest control professionals during focus groups. The City will host an informational meeting specifically for structural pest control operators. In addition, the City is in discussion to renew a partnership with Our Water, Our World and other jurisdictions in Santa Barbara County, in order to update materials (these can be used throughout California) and train salespeople in home and garden stores to encourage sales of organic products. The three main messages to target are:

1) Use IPM/organic methods when practical.
2) Use poisons sparingly and to target known pest outbreaks, rather than using prophylactic products (for example, Bayer’s 12 Month Tree & Shrub Protect & Feed, with 1.1% imidacloprid).
3) Apply poisons in a way that decreases the likelihood for rain to transport the material off site (the solubility of imidacloprid and leaching through soil presents a challenge here).

The City will leverage results of the current research to promptly apply for a grant from the California Department of Pesticide Regulation to fund an outreach alliance for integrated pest management (IPM) outreach regarding systemic pesticides.

Additional Networking and Research – The results of the research thus far suggest the urgent need for a workshop to gather interdisciplinary researchers (academic, NGO, and citizen-science) to ascertain the ecological impacts of systemic pesticides in California, including coastal streams and estuaries. Now that concentration data are showing concerns, the first question to be addressed is whether aquatic and/or flying insect populations are decreasing. Pending a positive response, reasons for a decrease should be examined. In addition to systemic pesticides and habitat loss, there is also the possibility that aggressive mosquito abatement using Bti may impact nontarget insects at ecologically concerning levels.

Pesticide Assessment - Another serious question to address is whether it would be advantageous ecologically to recommend less soluble pesticides, such as pyrethroids, when poisons must be used. While pyrethroids have been implicated for causing stream toxicity in California, the replacement pesticides seem to be more frequently detected due to high solubility. Now that the US EPA has lowered the benchmarks for chronic toxicity, data collected previously should be reassessed in regard to ecological harm caused by various pesticides.

Citations:

Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, et al. (2017) More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE 12(10)

US EPA (2017). Aquatic Life Benchmarks and Ecological Risk Assessments for Registered Pesticides. Accessed 1/7/18 at www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-and-ecological-risk#benchmarks

Permit Requirements

Work conducted in support of the Phase II General Permit monitoring requirements included revising and approval of the 303(d) Monitoring Plan/QAPP, chemical testing of outfalls, and participation in a working group to develop modeling and monitoring for the Performance Evaluation Assessment & Improvement Plan.

Comments on Pollutant Load Modelling

City of Santa Barbara, June 29, 2017

Updated Proposed Modelling Approach July 21, 2017

Acronyms and Abbreviations

13267 Letter	Letter sent from the Regional Board on June 13, 2016 detailed requirements of the Phase II General Permit
2N	Second Nature, LLC
630	National Engineering Handbook Part 630 - Hydrology
City	City of Santa Barbara
CRC	Characteristic Runoff Concentration (multiplied by runoff volume to get total load of a pollutant). Can be used interchangeably with EMC.
EMC	Event Mean Concentration (multiplied by runoff volume to get total load of a pollutant). Can be used interchangeably with CRC.
HSG	Hydrologic Soil Group – A (sandy, high infiltration) to D (high clay, low infiltration and high runoff).
LTR, MTR, HTR	Low, medium and high traffic road. Land use categories used in TELR but no other models.
LU	Land use, e.g. Single Family Residential
LU-CRC	The CRC for a particular land use.
NSQD	National Stormwater Quality Database, a compilation of thousands of data points with pollutant concentrations from areas with different land uses.
PIA	Percent Impervious Area
TELR	Total Estimate of Load Reduction model produced by Second Nature
LU-PIA	The percent imperviousness of a given land use (within a catchment for TELR and City approach).

Summary

The City of Santa Barbara (City) has submitted the requirements under the Central Coast Regional Water Quality Control Board's (Regional Board) letter 13267 dated June 13, 2016 (13267 Letter) regarding pollutant modeling, specifically the runoff volume and pollutant load per catchment and the catchment rankings for both parameters. As proposed in the City's Program Effectiveness Assessment and Identification Program, the City used the Total Estimation of Load Reduction (TELR) model developed and administered by the private consulting firm Second Nature, LLC (2N) to obtain the submittal.

Moving forward, the City seeks approval, per the 13267 Letter, to use an alternative model developed and administered by the City. The reasons for the decision to request an alternative model are listed here. Each reason is discussed in detail below:

1. Access: TELR is unalterable by the City.
2. Reproducibility: TELR lacks reproducibility, particularly in catchment boundary mapping.
3. Accuracy: The accuracy of TELR cannot be ascertained. The model is extremely sensitive to parameters for which the state-of-the-science cannot provide accuracy, i.e., the event mean concentrations and soil impacts.
4. Precision: The precision of TELR is very low, including for parameters for which the model is extremely sensitive, i.e., soils and imperviousness.

The City recognizes the importance of assessing stormwater program impact over time; in fact, "Has water quality improved?" is by far the most common question posed to the City by the public.

Unfortunately, the drawbacks of moving forward with TELR outweigh the benefits. Most importantly, the potential for the model to provide an inaccurate understanding of hydrology in the City may lead water-quality improvement strategies awry. The City proposes to use a simpler model, the Simple Santa Barbara model, which is arguably as precise and accurate as TELR at the current time. The details of the proposed model are provided below. For the purpose of comparing approaches, the catchment boundaries were retained; however, after reviewing the results from the SSB model, it is suggested that catchment boundaries be modified in the coming year.

Access

The City participated as a stakeholder in the development of the TELR model because the City does support the development of a model that is applicable across the region. The City joined the technical advisory committee with the understanding the model would be free and open source, using an academic or government-agency approach to development, refinement, and implementation. Late in TELR's development it became clear that the model would be closed-source and inaccessible. At the time, the City expressed concerns that the City would not be able to make changes to the model, e.g. characteristic runoff concentrations (CRC) as more data becomes available (Figure 1).

Comment	Team Response to Comment
Add bioretention BMP	*Bioretention is being added as part of Phase 2*
Per above, I feel this should be an open source project. I don't think the model should be maintained on a private website after it is complete. Perhaps it could be maintained on the RB website, under contract with 2N. Things happen - e.g. we never know which private company may buy another private company and stop supporting tools, etc., etc. I also would like the ability to modify the model if that's what we think is rational and most important for demonstrating water quality improvements in our area. Tax payer money should fund open source software, IMHO. As far as I can recall from my brief review, most stormwater models are downloadable.	*The technical document will describe all algorithms, defaults, and assumptions in the TELR tool. User will have access to all TELR outs (priorities for TELR outputs were previously requested to determine which outputs will be displayed graphically through the online tool). Continuous funds for the tools are required in order to maintain online software, manage software and security updates.*

Figure 4.Comment from City to 2N (third row).

In fact, the lack of ability to alter CRCs has been a significantly negative experience for the City. The City has concerns about the accuracy of the CRCs used in TELR (see below), and politely requested to pay for 2N to run the model with alternative CRCs for comparison purposes, only to be used by the City for stormwater management decisions. Unfortunately, 2N declined this request so there is no way for the City to make a definite comparison among suites of CRCs (more discussion below).

In addition, the City would prefer to use percent impervious area (PIA) values that are measured for the land uses within each catchment. Presently, TELR uses a regression equation to assign PIA to each land use based on the catchment PIA (see below). This potentially important adjustment is not possible for the City to undertake with the closed-source TELR model.

Upon paying for access to TELR through June 30, 2017, the City provided model inputs to 2N and received access to the website to obtain model results (see maps at end of this document). The City finds the user interface attractive and easy to use. However, the inputs to the model cannot be modified without sending updates to 2N. Recently, the City had questions about the soils map used for the model input. While 2N was very responsive and ran the model with new soil values, it was a cumbersome process compared to updating values of our own model. Furthermore, the City expects to update the soil values again when certain “null” values have been rectified; this can only be done in TELR by paying an annual fee to 2N.

Reproducibility

The City hired two part-time employees (one with a Master’s degree in GIS and the other a PhD candidate in GIS) to conduct catchment mapping for input to TELR. Based on experience of both employees and the City’s review of the frequently updated mapping guidance, the City is confident that no two people would create the same catchment map of the City of Santa Barbara MS4 Area. It is expected this would be true of any urban area transected by surface waters. In addition, some of the catchment attributes are subjective, such as how to handle null values in the soils data and the degree of connectivity.

Accuracy

The model is required by the 13267 Letter to be “technically defensible and sufficiently accurate to provide a credible relative ranking to inform program priorities and decisions.” The City finds TELR technically defensible in many aspects and minimally so in others. Of utmost importance, the City does not trust the accuracy of the relative rankings.

Model Inputs

The two main drivers of the modelled runoff volume are percent impervious area (PIA) and hydrologic soil group (HSG), as shown in Figure 1a. Once runoff is obtained for each land use (LU) within a catchment, then the LU-specific characteristic runoff concentrations (LU-CRCs), often called event mean concentrations (EMCs) in other models, drive the pollutant loads. In particular, road surface CRCs are important, i.e., those assigned to low traffic (LTR), medium traffic (MTR), and high traffic (HTR), as shown in Figure 1b. Therefore, the accuracy of these inputs is likely to be critical to model outputs.

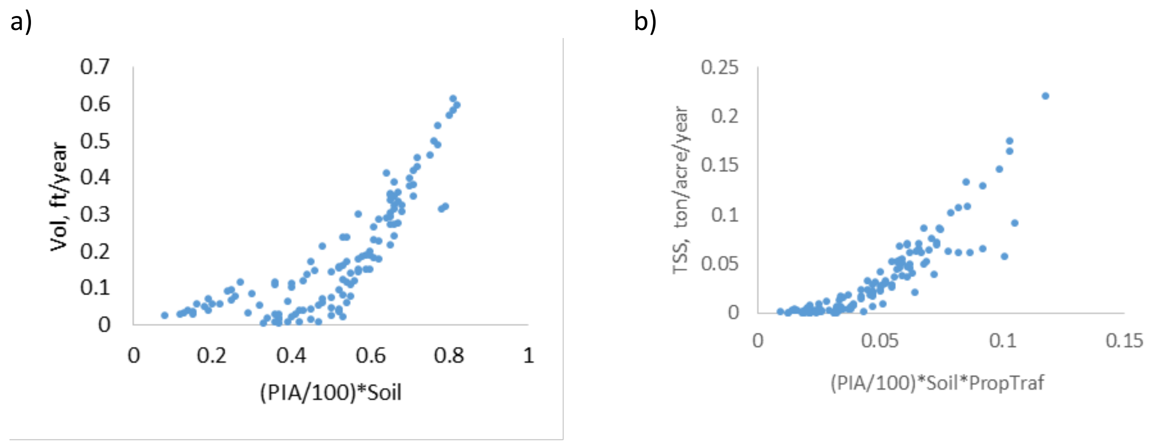


*Figure 5. TELR results for City catchments showing importance of PIA, Soil, and Road Surfaces in a) runoff volume for each catchment and b) pollutant loading rate for each catchment. In a), a simple model of Vol = (PIA/100)*Soil is plotted against the TELR Volume output. In b), a simple model of Loading = (PIA/100)*Soil*PropTraf is plotted against TELR results. Soil groups are assigned a value 1-4 for HSGs of A-D and PropTraf is the combined HTR, MTR, and LTR acres divided by the total acres of each catchment.*

PIA. The TELR model does not strive to provide accurate PIAs for each LU (LU-PIA) within a single catchment, as LU-PIA for each catchment is obtained from a regression equation based on catchments in unidentified California municipalities and "best professional judgement." In fact, for most LUs, the assigned PIA is nearly equal to the catchment PIA (TELR Technical Document March 2017). For example, if a catchment with an overall PIA of 70% is half commercial at 90% PIA and half single family residential at 50% PIA, then both land uses are assigned a PIA of ~70%. For the road LUs, the PIA may be assigned based on the overall MS4 PIA (there is a discrepancy in explanations from August 2016 to March 2017 for road PIA, but the graphs appear identical). For example, if an MS4 has some catchments with very little pervious area in the public right away, and some with wide parkways and narrow roads, both roads will be assigned a PIA based on the value for the entire City. To the best of the City's recollection, this simplification was not discussed with the technical advisory committee. In a quick-and-dirty check using aerial photos and GIS, City staff estimated LTR PIAs of <60% in a single-family residential area of Santa Barbara and >90% in a commercial area. It is likely that this approach is taken by 2N due to the choice to assign separate land uses to low and medium traffic roads (LTR and MTR); the resulting road polygons are narrower than the PIA pixels in most cases, biasing the LTR and MTR PIAs towards lower PIA due the PIA pixels overlapping with yards, etc.

HSG (Soil). After reviewing the model results and sample calculations, it is clear that HSG drives runoff volume nearly as much as PIA for moderately developed areas (PIA from 50-75%). As shown in Figure 3, the runoff calculated, using TELR's formula, from 1" of rainfall can vary 30% across HSGs for a given PIA.

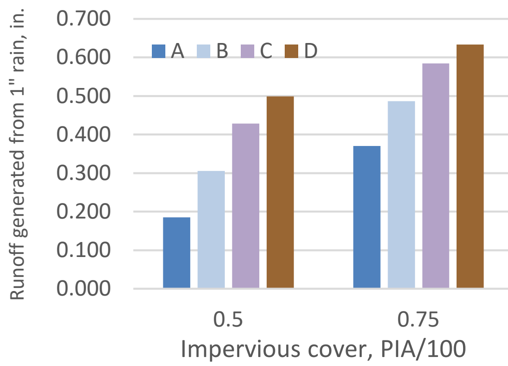


Figure 6. HSG (by color in legend) and PIA impact on calculated runoff from 1" of rain.

Indeed, several catchments in the City's TELR results stand out for their relatively low volume and pollutant load rankings compared to similarly developed catchments. Closer inspection shows this is due to the HSG of A assigned to these catchments, e.g. San 3 (Figure 4). The HSG is obtained from the United States Department of Agriculture (USDA), and is a reflection of soil qualities, not measured infiltration rates. The TELR model assigns a curve number for each soil type, assuming "open space" in "poor condition," according to the National Engineering Handbook 630 (630). The 630 reports many different curve numbers for each HSG in an urban area. For residential areas, the 630 assumes open space is in "good condition," rather than "poor condition." The 630 also provides a strong caveat about using listed HSGs in areas that have been developed (Figure 5).

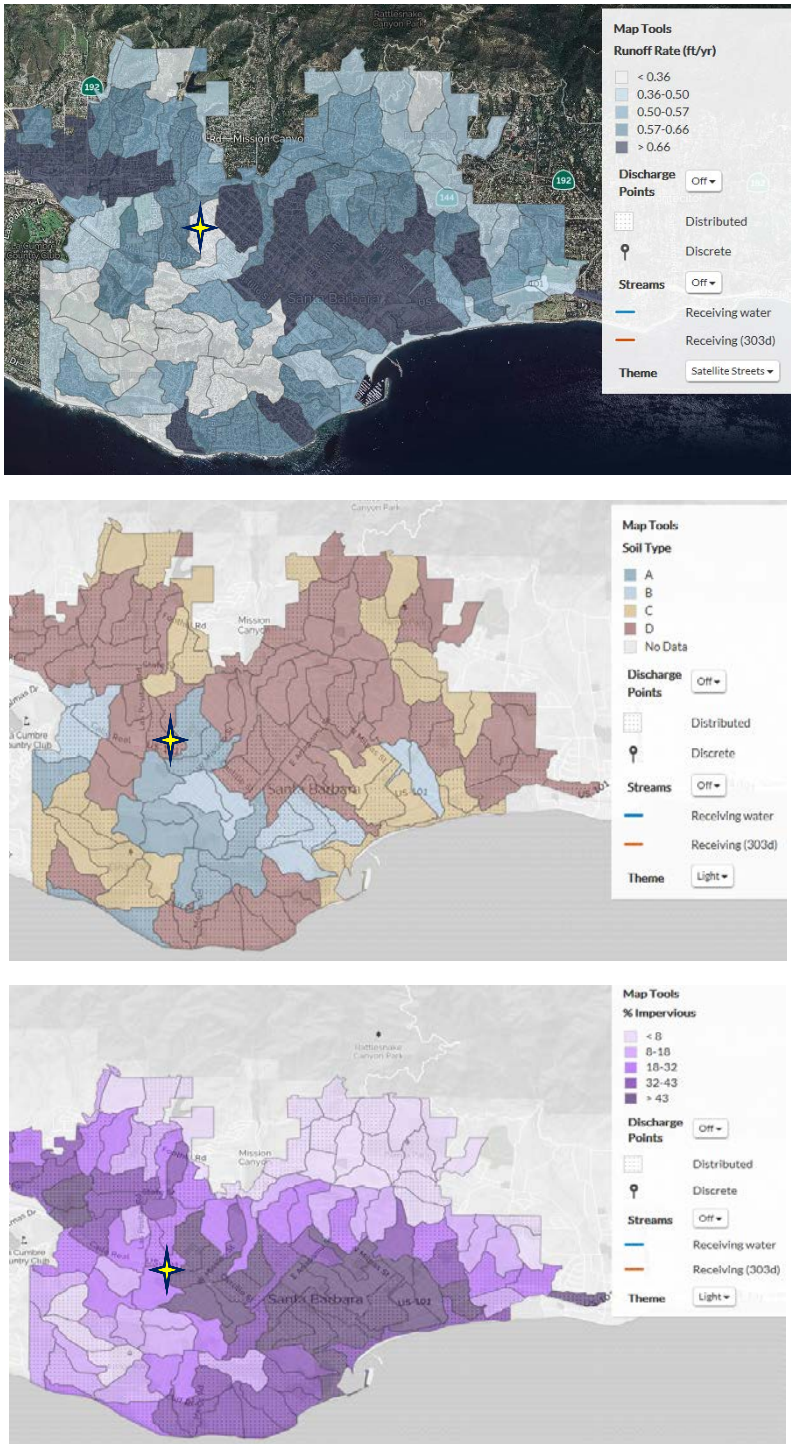


Figure 7. TELR Model Maps. Top: runoff volume. Middle: Soil type. Bottom: PIA. San 3 is identified by the yellow cross.

630.0702 Disturbed soils

As a result of construction and other disturbances, the soil profile can be altered from its natural state and the listed group assignments generally no longer apply, nor can any supposition based on the natural soil be made that will accurately describe the hydrologic properties of the disturbed soil. In these circumstances, an onsite investigation should be made to determine the hydrologic soil group. A general set of guidelines for estimating saturated hydraulic conductivity from field observable characteristics is presented in the Soil Survey Manual (Soil Survey Staff 1993).

Figure 8. Caveat about HSGs in developed urban areas from the 630.

The City's experience reflects the caveat in Figure 5. The Creeks Division has overseen the installation of permeable paver projects at nine different sites between 2011 and 2016. Before construction at each site, soil investigations were conducted to evaluate the feasibility of installing permeable pavers. This included review of soil maps, onsite soil testing, and infiltration testing. The City found that soil maps did not accurately reflect what was found during onsite soil evaluations. Mapped HSGs also do not correlate with measured infiltration rates (Table 1). As a result, the Creeks Division relies more heavily on field testing results than findings from soil maps.

CRCs The City's greatest concern about accuracy regards the CRCs used by TELR. The suite of CRCs was generated in a highly contrived manner, as detailed at the end of this commentary. The 2N choice of CRCs inflates the differences among LUs, in particular for road surfaces. While this may be justified for snowy areas such as Lake Tahoe, where sand is applied regularly to road surfaces, it does not appear true for Mediterranean-climate, urban areas. Figure 6 shows that the differences in TSS concentrations for a given LU vary substantially across three different CRC suites. In addition to the TELR suite, the City examined data used by Geosyntec in the SBPAT model and data from the National Stormwater Quality Database (NSQD). In addition to the absolute differences, the relative ranks are different among models (Figure 6). Of particular concern is that accurate CRC values will be nearly impossible to obtain for the TELR model. This is because TELR has a unique feature compared to all other models the City has scoped, which is that it treats non-freeway road surfaces as a separate land uses (low traffic and medium traffic, or LTR and MTR). Other models and datasets incorporate roads in residential, commercial, and industrial areas into the land use itself. It is difficult to conceive how runoff from purely residential and/or commercial land uses could be sampled without incorporating road runoff as well. This challenge makes testing the accuracy of TELR CRCs very difficult. One solution proposed by 2N is to use their artificial rainmaker to test runoff concentration on various impervious surfaces; this might be possible for roads but there are so many different types of residential surfaces, e.g. roofs and patios, that monitoring would likely be impossible.

Table 2. City of Santa Barbara Infiltration Testing Results

Site	HSG From USDA Soil Map	Boring #	Infiltration Rate (in/hr)	Average for Site, in/hr
Stevens Park	Not rated	1	0.74	0.50
		2	0.255	
Westside Neighborhood Center	D	1	0.815	0.46
		2	0.095	
Oak Park Tennis	A	1	0.05	0.05
Oak Park Main Lot	A	1	0.05	0.05
		2	n/a	
Oak Park Main Picnic	A	1	1.205	0.69
		2	0.165	
MacKenzie Park	C	1	0.24	3.40
		2	1.215	
		3	0.21	
		4	4.8	
		5	0	
		6	2.28	
		7	0	
		8	0.36	
		9	0.6	
		10	4.56	
		11	23.92	
		12	1.75	
		13	4.24	
Plaza De Vera Cruz	B	1	0.525	0.32
		2	0.12	
Alice Keck Park E. Arrellaga Sidewalk	D	1	1.9	1.9
Alice Keck Park Garden St. Sidewalk	D	1	0.135	0.35
Quarantina St.	D	1	0.075	0.54
		2	0.6	
		3	1.35	
		4	0.13	

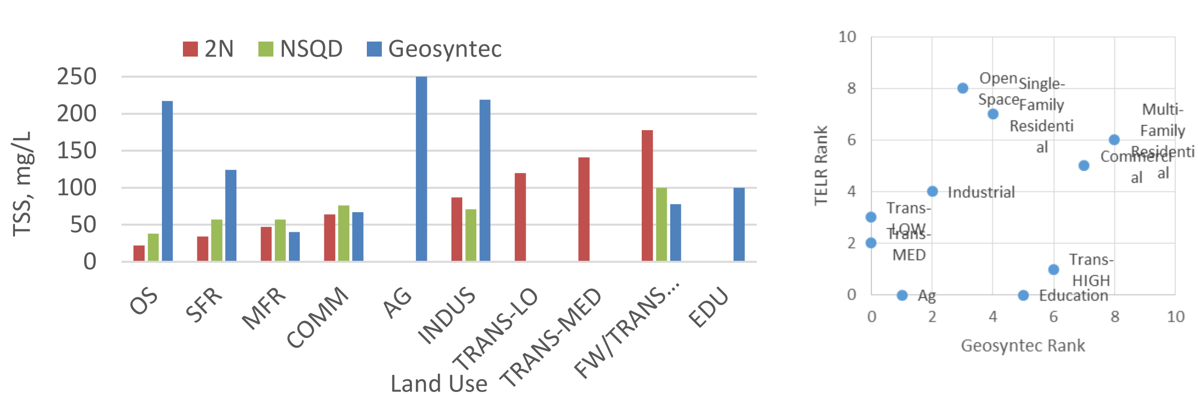


Figure 9. Comparison among TSS CRCs from Geosyntec's Southern California monitoring data, the National Stormwater Quality database (NSGD), and TELR's CRCs by land use. Left panel shows absolute values, right panel shows rankings for Geosyntec and TELR CRCs. Note: Ag value is 999 mg/L.

The City posits that the state-of-the-science shows there is little difference in TSS and other pollutant concentrations among LUs, as shown by the NSQD data (see CRC section at the end of this document) and summarized in the comment provided to 2N in Figure 7. While Geosyntec's data shows strong differences in medians among LU-EMCs, the results are not generally significant (based on t-tests applied to available statistical information; data not shown). On the other hand, NSQD differences among LUs are significant, but not substantial. It appears, based on the NSQD data and the City's own storm monitoring, that differences during and among storms (noise) dwarf the differences among land uses (signal). Wind-blown dust and pollutants, especially in arid southern California, could be one reason for a "smearing" of land use signals. The importance of wind-blown dust can be seen easily by how quickly outdoor furniture becomes dirty. While the makeup of the dust has not been studied, it likely contains sediment from a mix of sources.

Description Comment	Resources I would like the team to consider during development	Team Response to Comment
An extensive data review from 2014 shows limited impact of land use and %impervious on TSS runoff concentrations. It does show differences in loading rates, but the sample numbers are limited. In the summary see p. 18 and Figure 5 "There does not appear to be any major correlation between different types of urban land use and nutrient and sediment concentrations, loads or yields, with the possible exception of higher amounts of TN and TP (total nitrogen and phosphorus, respectively) in the runoff from residential lawns compared to other urban land uses. Two extensive analyses of stormwater outfall monitoring data clearly indicate there is little or no statistical difference in the event mean concentration of TN, TP, and TSS between "generic "impervious cover and its commercial, residential, institutional, and industrial components. " And in the detailed report, see Fig. 3 (among many others). This report is geared for the Eastern seaboard, but data were utilized from all over the country. This is a bit concerning, given the direction of the model.	Summary here: http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2015/03/Final-STAC-Peculiarities-of-Pervious-Cover-Report-3.26.15.pdf and details here: http://www.chesapeakebay.net/channel_files/21151/attachment_f--tetra_tech_urban_loads_literature_review_memo_20140331.pdf	We will review these references and consider as the algorithms for pollutant generation and BMP removal effectiveness are defined. We have references, data and issues with some of the conclusions from monitoring studies we can all debate in more detail in Phase 2. TELR v0.1 Phase 1 will allow the TAC to change land use algorithms easily and they will not be finalized until Phase 2.

Figure 10. Comment from City to 2N about LU CRCs.

Precision

Model Inputs

In addition to questions about TELR's accuracy, the precision of the inputs is a concern. In other words, even if the PIA, HSG, and CRC inputs were accurate, the averaging over entire catchments leads to alterations in catchment rankings.

Soil

Although HSG is a primary driver of catchment volume rankings, only a single "dominant" value is used for each entire catchment. The City reviewed the distribution of HSGs and found that of 127 catchments, 47 have a soil group that comprises >80% of the catchment, whereas 80 catchments are more mixed. Many catchments have a nearly equal distribution of 2 or 3 soil types. For the catchment noted above, San 3, the low runoff volume was caused by HSG A; however, A made up only 40% of the catchment area (data not shown). Furthermore, soil infiltration testing conducted by the City for permeable paving projects has shown enormous variation even within a project site (Table 1).

PIA

As discussed above, average catchment PIA is used throughout each entire catchment to assign PIA values. This lack of precision may change the rankings depending on the LU distribution.

Outputs

Concerned about the averaging, the City repeated TELR's approach but used measured PIA and HSG for each LU within a catchment, resulting in ~3000 sub-catchments. The City calculated runoff with the equation on p. 18 of the Mach 2017 Technical Document, applied to the entire average yearly rainfall in Santa Barbara (18.52"), rather than individual storm events. First, the runoff calculation used by the City was tested against the TELR output. The catchment-wide PIA and HSG were used in the calculation. Even ignoring the higher PIA values for road surfaces used by TELR and the more detailed rainfall event concentrations, the correlation was strong for absolute runoff values and rankings, explaining 94% and 92% of the variance, respectively (Figure 8).

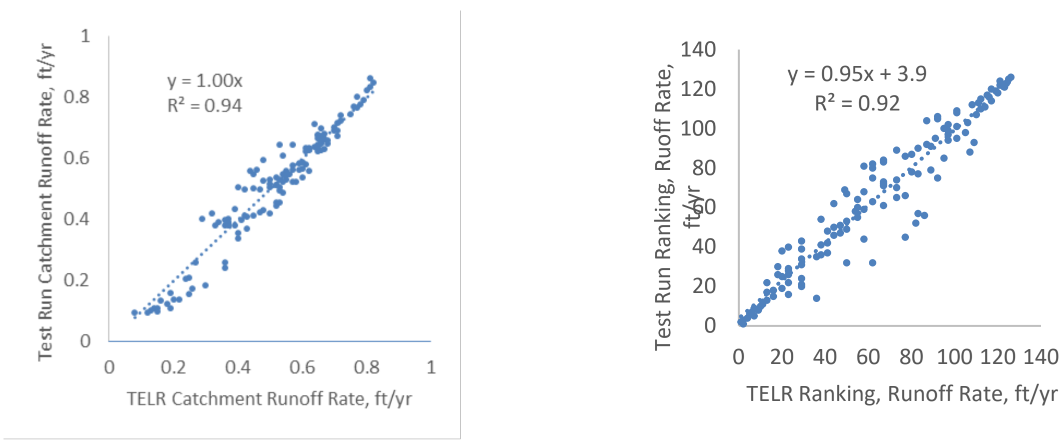
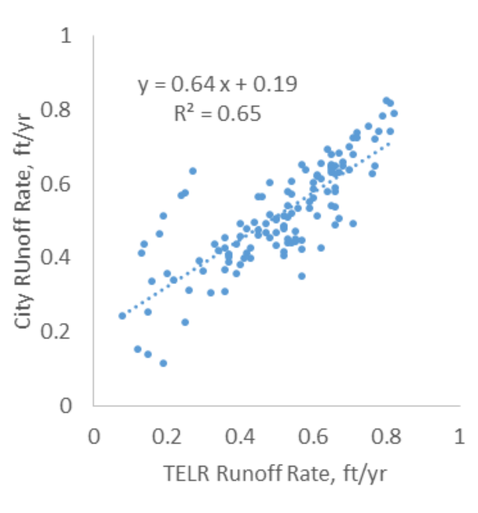


Figure 11. Comparison of City catchment-wide calculations of runoff volume compared to the TELR output. Left panel compares absolute values and right side compares relative rankings.

Next, the same equation was used to calculate runoff in each sub-catchment (divided by LU and HSG), and the sub-catchments were then summed for each catchment. The correlation against TELR results became less robust, explaining only 65% and 62% of the variance, suggesting that catchment wide averaging can have a substantial impact on model output (Figure 9).



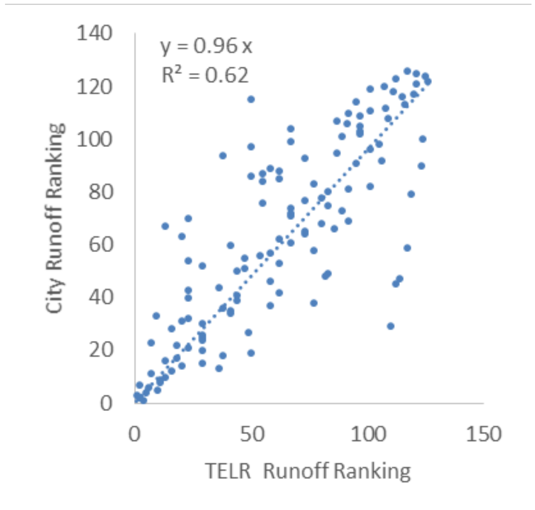


Figure 12. Comparison of City summed sub-catchment (see text) calculations of runoff volume compared to the TELR output.

Proposed Model

Because of the lack of accuracy in TELR model inputs for which the model is very sensitive, the City does not trust the absolute output or the relative rankings of the catchments and will not use them in stormwater management prioritization. The City seeks a model that is spatially explicit, reproducible, and objective, in order that it be capable of being used for many years to come in order to meet the requirements of the 13627 Letter, as detailed in Attachment 1 of the Letter. The following proposed model, the Simple Santa Barbara model, is described according to the outline in Attachment 1.

1. The Spatial Framework

a. Catchment Boundaries

A grid system using the City's existing Storm Drain and Sewer Atlas scheme will be used in place of hydrologically determined catchments. Each "catchment," or page in the atlas, is ~127 acres. Using this approach, it is easier to identify relevant infrastructure, such as storm drains and wastewater pipes, within each catchment because the naming scheme of the City's infrastructure includes the grid number. For example, Outfall N-G10-10 is a node in grid G10 of the City's Storm Drain Atlas. The City's Storm Drain atlas provides a wealth of information for stormwater work, e.g. it contains flow lines for each gutter. Subcatchments will be determined for each land use within each catchment, e.g. H08-COM, H08-SFR, etc. An additional GIS layer will divide the City, and via intersection, each catchment into associated receiving waters, e.g. H08-Laguna, HO8-Milpas Drain, etc. In the same vein, a GIS layer of drainage area to each major outfall can be intersected with the grid system. In other words, the City will have GIS tools to determine, for every location in the City, where runoff enters receiving waters and how it gets there. The benefit of the grid system is that “pages” can be printed that align with the existing storm drain and wastewater infrastructure documents.

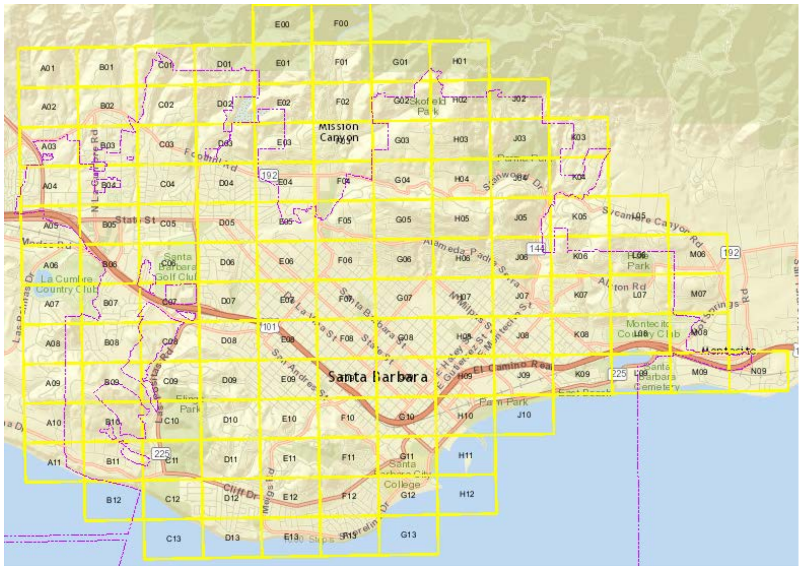


Figure 13. Proposed boundaries for the City’s spatially explicit model.

b. Catchment outfalls and receiving water.

Subcatchments will also be delineated by watershed and receiving water. All outfalls will be noted. See section a, above.

c. Hydrologic connectivity

Connectivity will be assumed to be 100% for all catchments, unless detailed study suggests otherwise. The City is thoroughly storm drained, and open channels are generally short and steep, providing 100% conveyance of all but the smallest storms.

d. Land Use Designations

Land use designations will be:

- Single family residential
- Multi-family residential
- Industrial
- Commercial
- Cultivated
- Freeway/High Traffic
- Other (Open Space)

Low and medium traffic surfaces will be incorporated into the LU of the area, as in most other models. This will make the application of CRC/EMC suites and potential future monitoring data more feasible. This approach will also allow curve numbers to be used that have been developed for land uses that integrate low and medium traffic roads. Incorporation of roads into the land use will also make it easier to use measured PIA, rather than modeled PIA, because the PIA pixels will be much smaller than the land use polygons.

2. Runoff Characteristics

a. Precipitation

The average annual precipitation for Santa Barbara will be used (18.52”/yr). This will be used for comparison purposes even if average annual rainfall changes over time, e.g. due to climate change.

b. Imperviousness and soil permeability

PIA will be determined for each LU-based subcatchment. PIA will be taken from the National Land Cover Database; however, some adjustment for tree canopy may be made in the future. Santa Barbara has many areas in which tree cover inflates the PIA from land cover due to the high tree density. Soil mapping will be excluded from the model; HSG mapping has proven to not correlate with infiltration test results in the City.

c. Pollutant types for evaluation

As in TELR, TSS will be the modeled pollutant of concern. Additional pollutants, such as pesticides and nutrients, may be modeled in the future if valid concentration data becomes available.

d. Urban runoff pollutant data

The City will use a uniform pollutant concentration (th average of City TSS measurements from creek samples during storm events) until a valid data set demonstrating land use differences becomes available. The City will also test the use of the NSQD dataset described below. The catchment rankings will likely be similar.

e. Pollutant reduction estimates resulting from stormwater program actions.

This section will be expanded in future reports. In brief:

i. Street sweeping data will be used to estimate the reduction in TSS loads based on locations and frequency of sweeping activities.

ii. Parcels that been developed or redeveloped under Tier 3 will be assumed to have a 50% reduction in runoff volume and 50% reduction in TSS concentration in the remaining runoff. The acreage of each parcel will be included in the pollutant reduction model.

iii. Centralized BMPs will have areas of run-on incorporated. The volume reduction and treatment will be estimated for each project using monitoring and/or observations.

3. Computational Requirements

a. Annual stormwater volume and pollutant loads delivered from each catchment.

The volume and pollutant load estimates will be reliable, repeatable, and comparable among catchments. The Simple Method (Schueler) will be used to calculate annual stormwater volume and pollutant load for each land-use based subcatchment. The land use subcatchments will be summed to determine the runoff volume and pollutant load per catchment.

b. BMP incorporation

BMPs will be incorporated as described above. A database of each parcel, its PIA (derived from the LU-PIA, not measured by parcel), and the parcel acreage will be maintained. It will also include a field to note whether the parcel has undergone re/development under Tier 3.

c. Spatial and temporal comparisons.

The City will maintain a GIS "project" for mapping the spatial data. The data will be available in charts for temporal comparison.

d. Reporting formats

The City will provide data in desired reporting formats.

4. Standardized Protocols

a. Consistency

A consistent methodology will be applied within and across each catchment to estimate annual volume and pollutant load reductions. For example, even if average annual rainfall changes over time due to climate change, the City will continue to use the same annual rainfall value for the model.

b. Normalization.

Stormwater volume and pollutant load will be converted to rates per unit area for purpose of comparison among catchments. Catchment rankings will be based on normalized rates so that the catchments with the greatest risk to receiving waters can be identified.

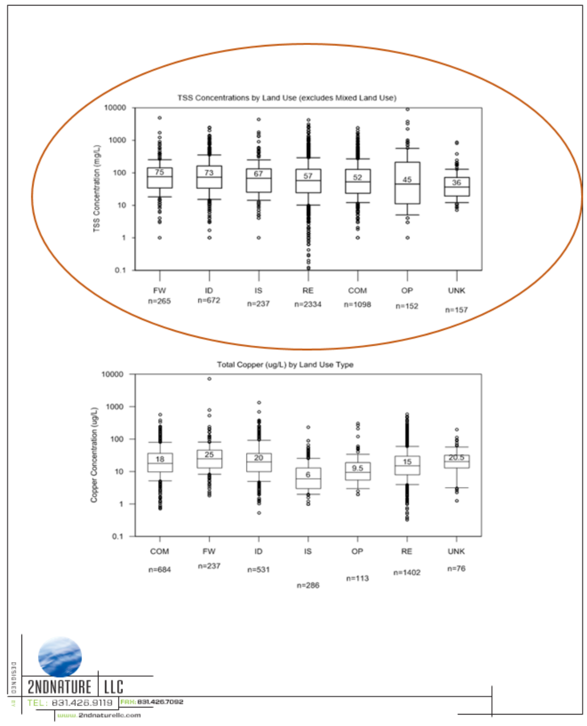
Additional Information - Characteristic Runoff Concentrations

In reviewing the TELR model, the City sought to understand the 2N CRCs used in the model. The City noticed that the values showed strong differences among LUs. The description in the TELR Technical Document provides a verbal explanation for the process to obtain CRCs, but a visual exploration is easier for the City to understand.

Approximate Process Used by 2N to Generate CRCs for TELR

Step 1 – Download data from NSQD and box plot by principal land use (LU). Rank LU by median TSS value.

FW = Freeway
IN = Industrial
IS = Institutional
RE = Residential
COM = Commercial
OP = Open Space
UNK = Unknown



Step 2. Review some literature based EMCs based on LU. Adjust LU classifications to match TELR LUs.

Table 12. *Literature review derived average annual TSS values. Mean values are presented unless otherwise specified.*

Land Use	TSS (mg/L)									
	NSQD 2015	*Li, et al. 2015*	*Gobell et al., 2007*	*Kayhanian et al., 2007*	*Smullen and Cave, 1998 (median)*	*US EPA, 1983 (median)*	*Whalen and Cullum, 1988*	*Gibb et al., 1998*	*Schueler, 1987*	*Claytor and Schueler, 1996*
Roads										
HTR	75		163	159						142
MTR			153	76	55			220		
LTR				70						
UPR										
Parcels										
CUL										
IND	73	298			55		108			124
COM	52	367				69	168			
MFR	57		43		55	101	228	150	100	
SFR	57		43		55	101	228	150	100	
OTH			12							

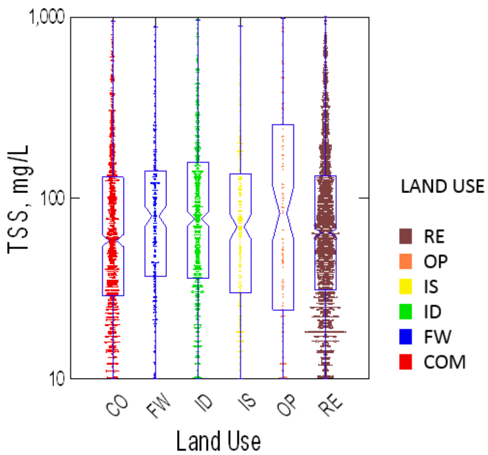
Step 3. Use best professional judgment to rank LUs.

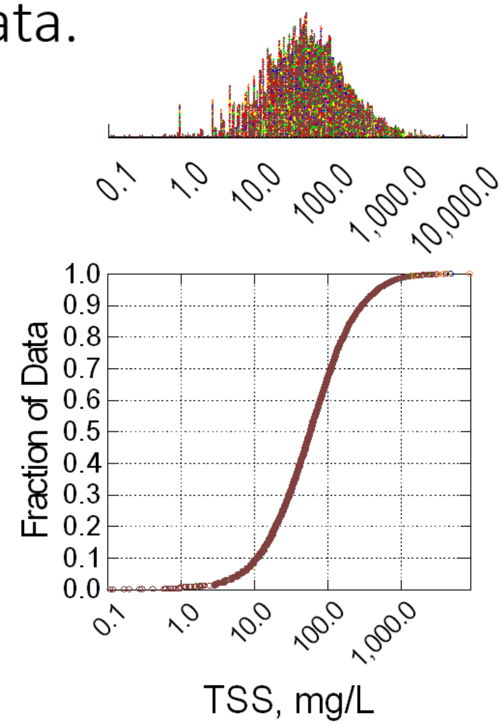
Table 13. *The unmitigated pollutant generation potenti*
selection of the TSS values using over 7,5

Relative pollutant generation ranking	Land Use Type
1	**HTR**
2	**MTR**
3	**LTR**
4	**IND**
5	**COM**
6	**MFR**
7	**SFR**
8	**OTH**
-	**UPR**
-	**CUL**

Rank RE (SFR and MFR) < COM despite multiple data sets showing the opposite.

Step 4. Combine all NSQD data.





Note - NSQD Data Set by Land Use (LU); here only data points with a single LU were included (~4700 data points), as opposed to 2N's analysis, which included 7,000 data points, including those with more than one land use. EMCs are medians. Note statistical differences between some LUs (notches are 95% confidence internval; calculated in Systat 2013).

Step 5. Assign percentiles to each LU, for the purpose of drawing from combined data.

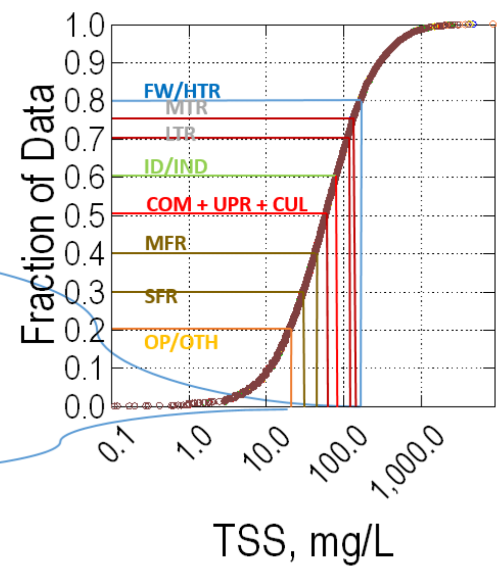
Table 13. *The unmitigated pollutant generation potential ranking by land use*
selection of the TSS values using over 7,500 data points from tl

Relative pollutant generation ranking	Land Use Type	Unmitiga NSQD percentile
1	HTR	80
2	MTR	75
3	LTR	70
4	IND	60
5	COM	50
6	MFR	40
7	SFR	30
8	OTH	20
-	UPR	50
-	CUL	50

Step 6. Obtain CRC from percentiles of combined data, by LU.

. The unmitigated pollutant generation potential ranking by land use type was used to inform the selection of the TSS values using over 7,500 data points from the NSQD 2015.

Relative pollutant generation ranking	Land Use Type	Unmitigated NSQD percentile	Unmitigated $[CRC_{lu,um}]$ (mg/L)
1	HTR	80	178
2	MTR	75	141
3	LTR	70	120
4	IND	60	87
5	COM	50	64
6	MFR	40	47
7	SFR	30	34
8	OTH	20	22
-	UPR	50	64
-	CUL	50	64



Note log scale in TSS – large differences among groups.

Concerns about 2N Process:

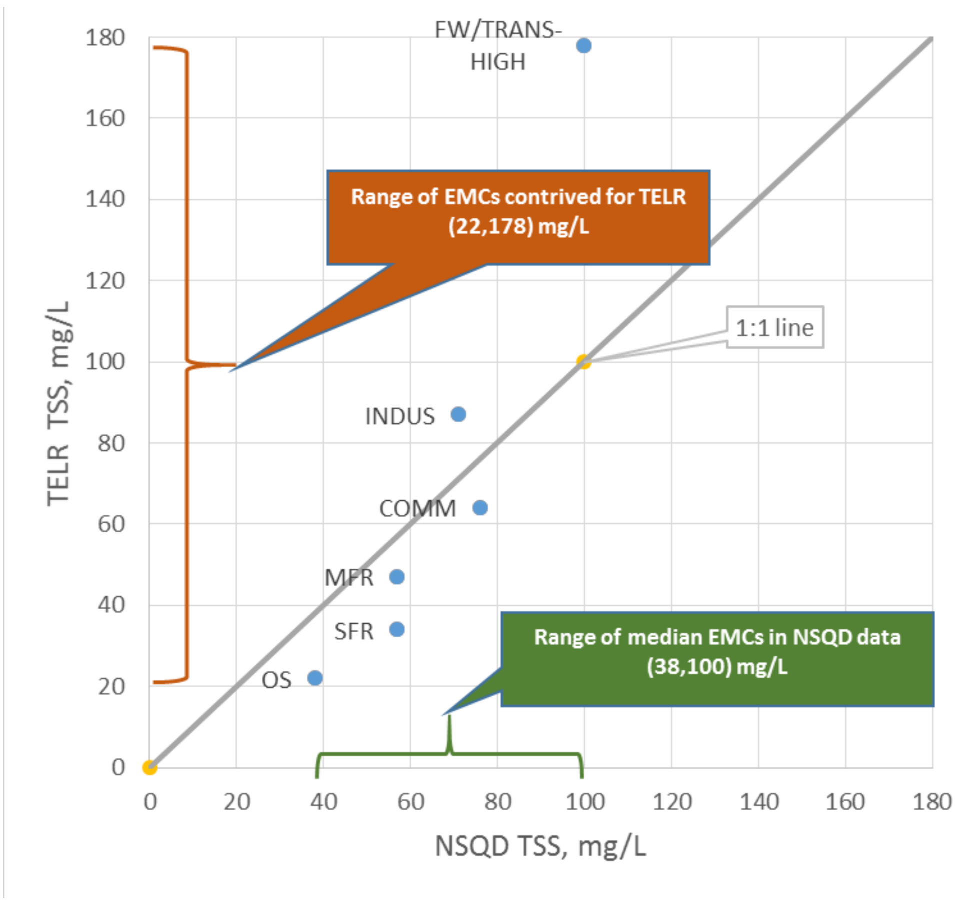
1. Process is contrived (at least the City has never seen anything like it).
2. The Technical Document states that because larger sample sizes show a greater range in concentrations that somehow the results are less valid. In any normally distributed sample (or

log normal), larger sample sizes are expected to have larger ranges compared to smaller sample sizes from the same population.

3. In reality, runoff concentrations at even a single sampling location are wildly variable based on time of year, rainfall intensity, and position on the hydrograph, etc. The variability should not be assumed to be errors in land uses classification, etc.

4. The NSQD data show very clearly that the effect size of land use is small compared to the variance within each LU. Although there are significant differences among LUs (see notches in box plots above), the difference among medians is small, i.e. the significance is high, the effect size of is small.

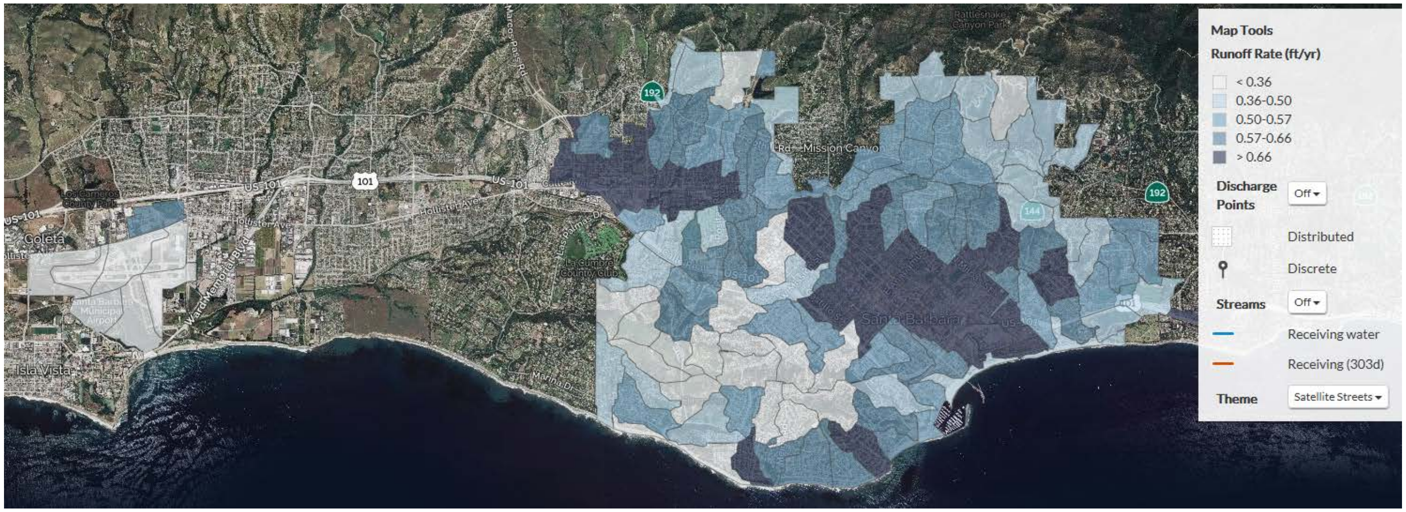
5. The net effect is an exaggeration of LU differences from the same dataset using 2N's approach:

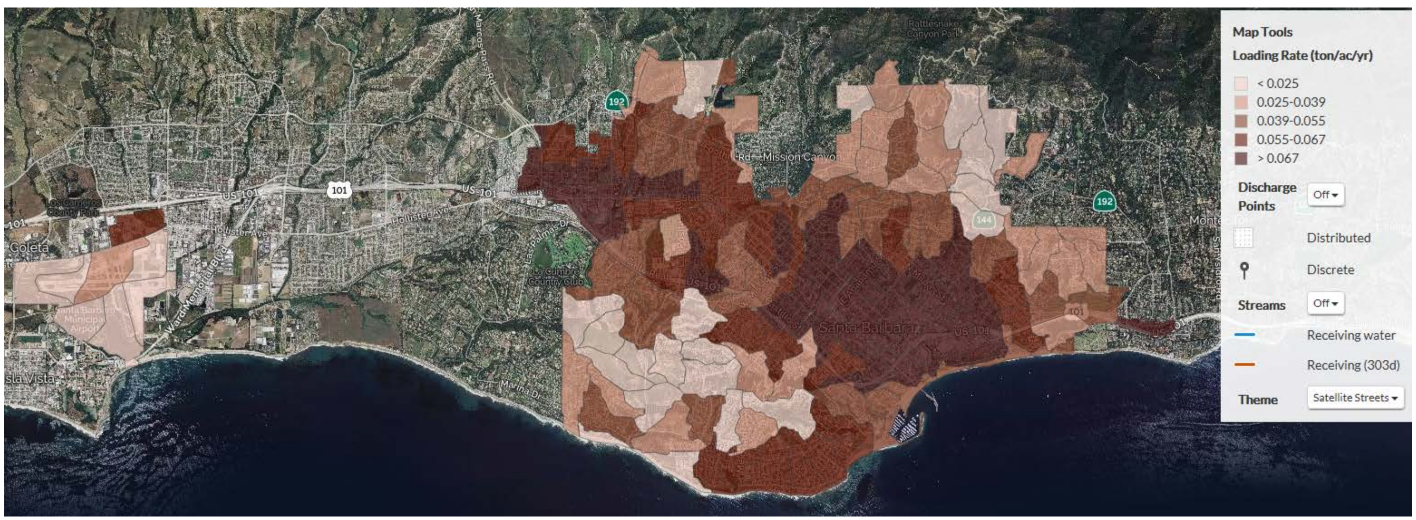


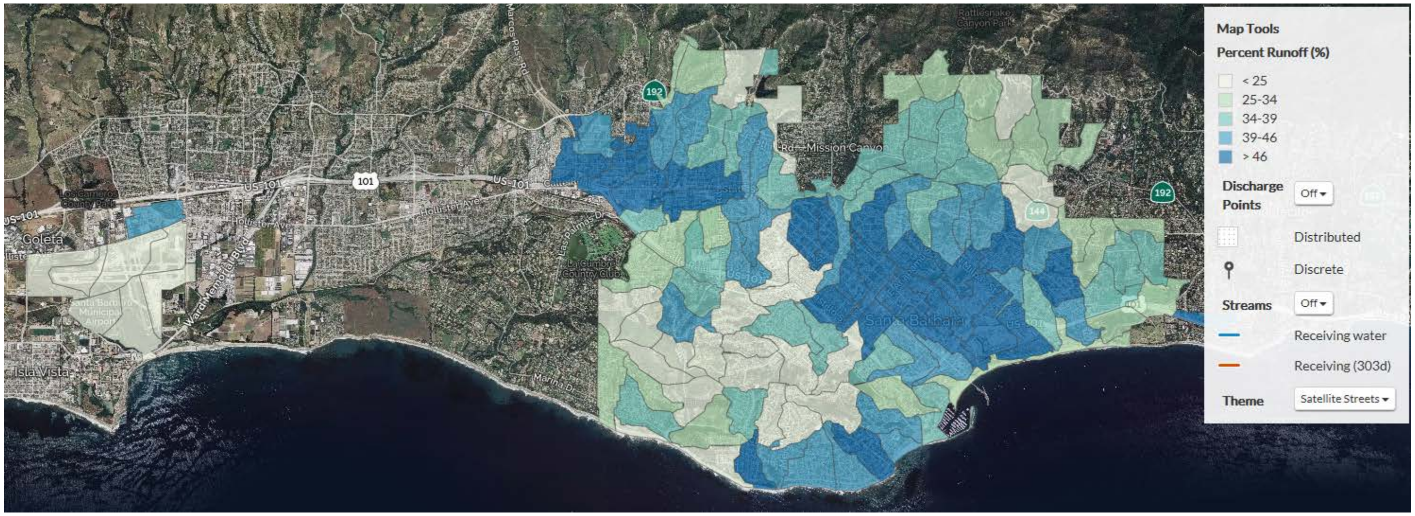
Comparison of the range of TELR CRCs) to the range of NSQD EMCs: the range is 2.5 x's greater for TELR than for NSQD. The ratio of HTR to OS is 8.1 for 2N and 2.6 for NSQD. This results in the inflation of the 2N model sensitivity to LU and to the rankings of LU CRCs compared to the NSQD dataset.

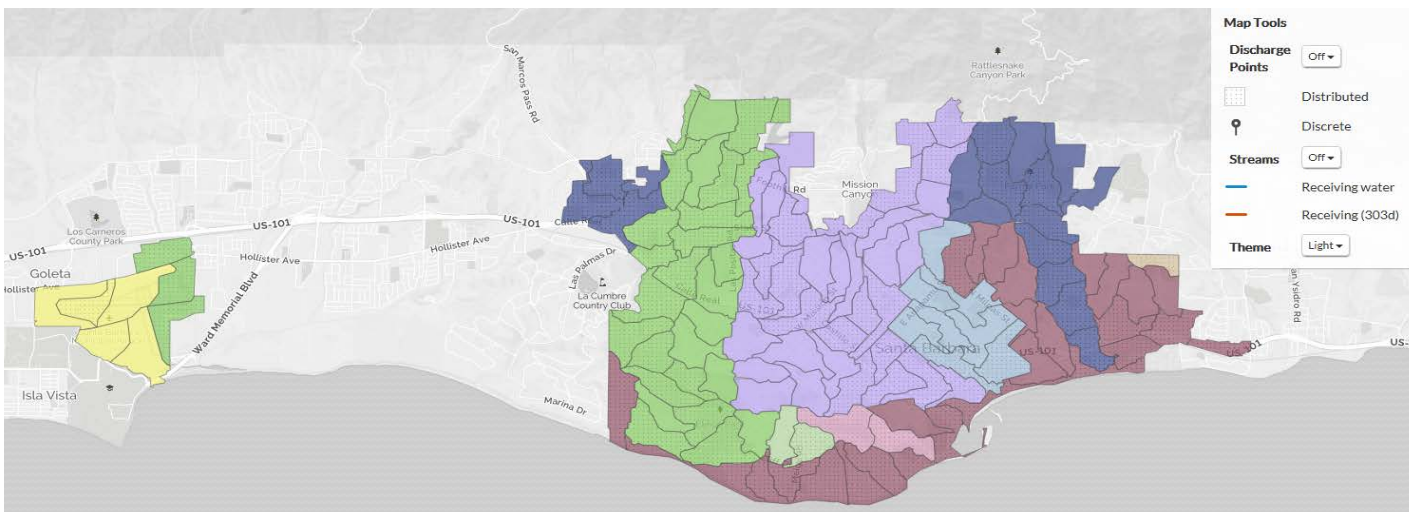
TELR Input and Output Maps

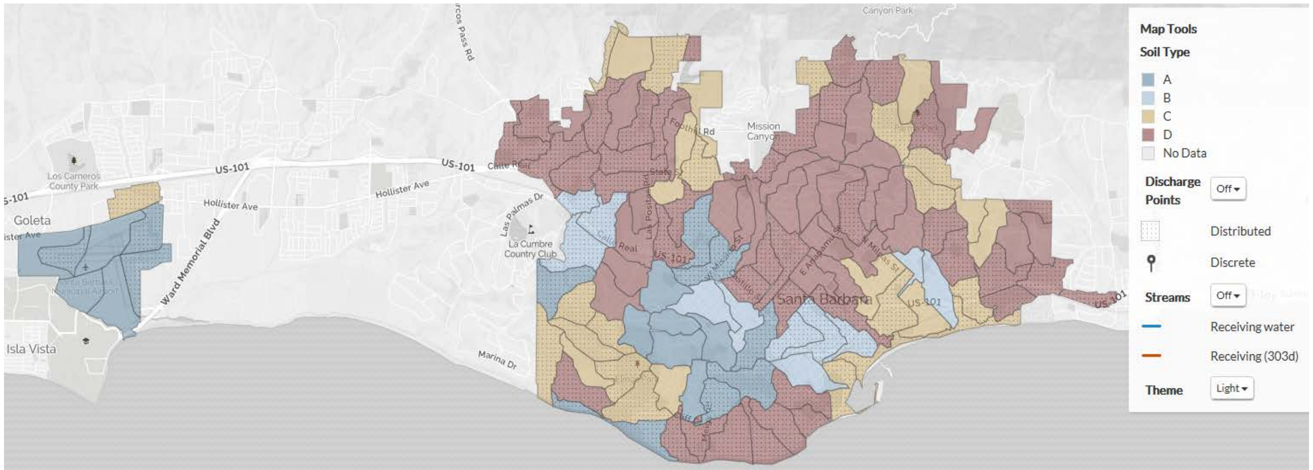
The following pages show the TELR Input and Output maps generated on June 22, 2017. A complete display of land use was not available.


Map Tools
Runoff Rate (ft/yr)
< 0.36
0.36-0.50
0.50-0.57
0.57-0.66
> 0.66
Discharge Points
Off
Distributed
Discrete
Streams
Off
Receiving water
Receiving (303d)
Theme
Satellite Streets
101
192
144
Goleta
Isla Vista
Santa Barbara


Map Tools
Loading Rate (ton/ac/yr)
< 0.025
0.025-0.039
0.039-0.055
0.055-0.067
> 0.067
Discharge Points
Off
Distributed
Discrete
Streams
Off
Receiving water
Receiving (303d)
Theme
Satellite Streets
101
192
144
Goleta
Santa Barbara


Map Tools
Percent Runoff (%)
< 25
25-34
34-39
39-46
> 46
Discharge Points
Off
Distributed
Discrete
Streams
Off
Receiving water
Receiving (303d)
Theme
Satellite Streets
Goleta
Isla Vista
US-101
101
192
144


Map Tools
Discharge Points
Off
Distributed
Discrete
Streams
Off
Receiving water
Receiving (303d)
Theme
Light
Goleta
Isla Vista
US-101
Hollister Ave
Ward Memorial Blvd
Los Carneros County Park
San Marcos Pass Rd
Las Palmas Dr
La Cumbre Country Club
Marina Dr
Mission Canyon
Rattlesnake Canyon Park
Santa Barbara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B
C
D
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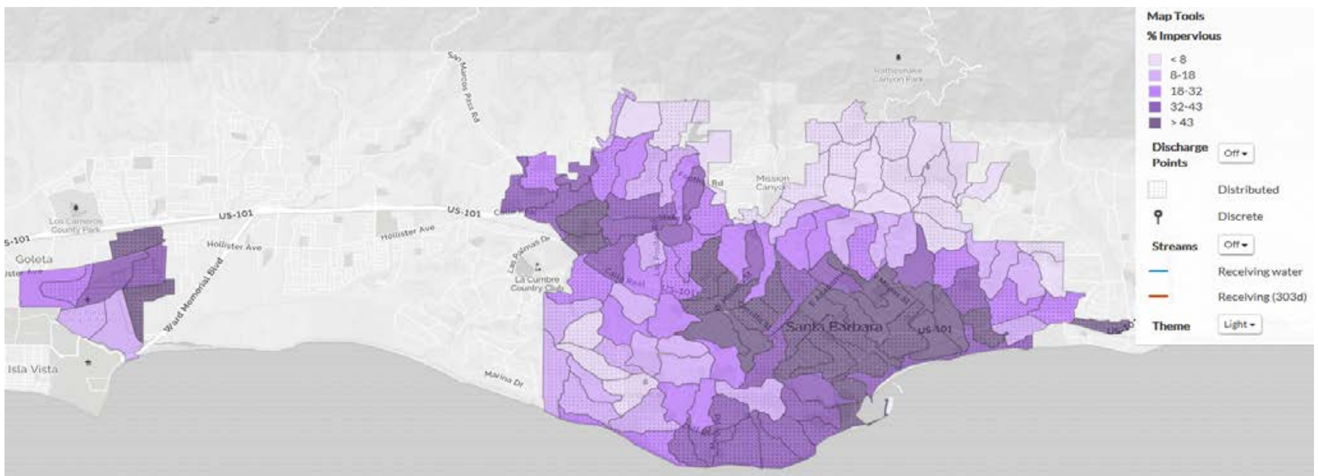
Off
Distributed
Discrete
Streams
Off
Receiving water
Receiving (303d)
Theme
Light
Goleta
Isla Vista
US-101
Hollister Ave
Ward Memorial Blvd
Los Cameros County Park
La Cumbre Country Club
Marina Dr
Mission Canyon
Santa Barbara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< 8
8-18
18-32
32-43
> 43
Discharge Points
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Distributed
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Streams
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Receiving water
Receiving (303d)
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Light
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US-101
Hollister Ave
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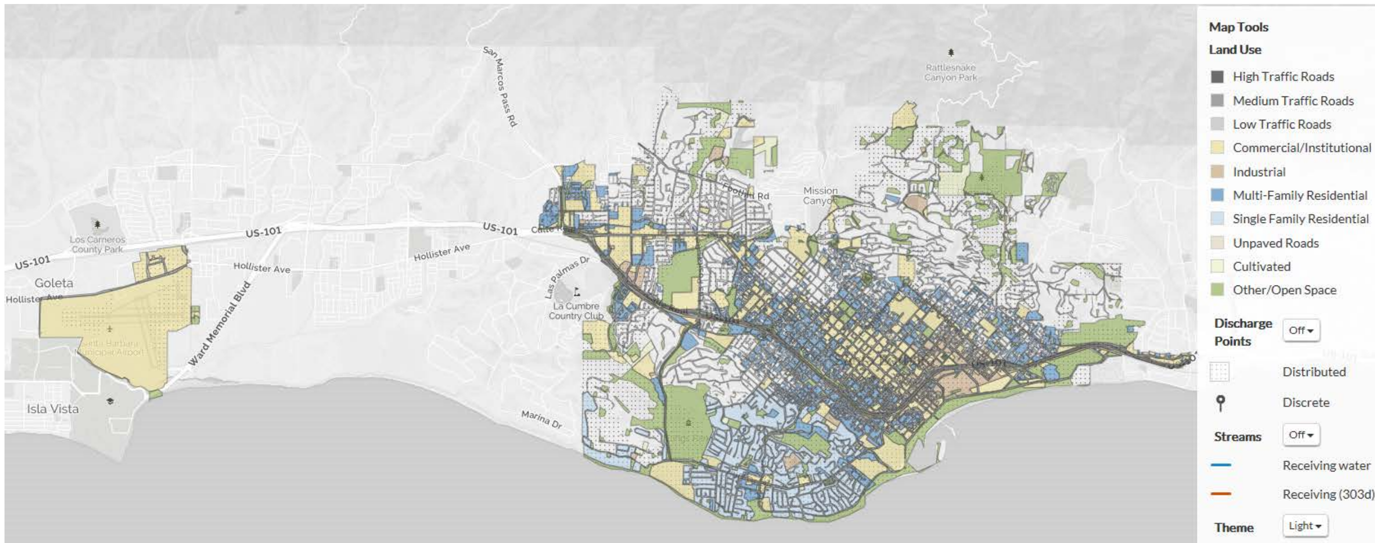
La Cumbre Country Club
Marina Dr
Santa Barbara


Map Tools
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High Traffic Roads
Medium Traffic Roads
Low Traffic Roads
Commercial/Institutional
Industrial
Multi-Family Residential
Single Family Residential
Unpaved Roads
Cultivated
Other/Open Space
Discharge Points
Off
Distributed
Discrete
Streams
Off
Receiving water
Receiving (303d)
Theme
Light
US-101
Goleta
Hollister Ave
Isla Vista
Ward Memorial Blvd
San Marcos Pass Rd
Las Palmas Dr
La Cumbre Country Club
Marina Dr
Mission Canyon
Rattlesnake Canyon Park
Los Carneros County Park

Grant Requirements

Load reduction calculations and analysis were completed for the LID Parking Lots Project. Sampling was completed for the LID Streets, Sidewalks, and Alleys Project.

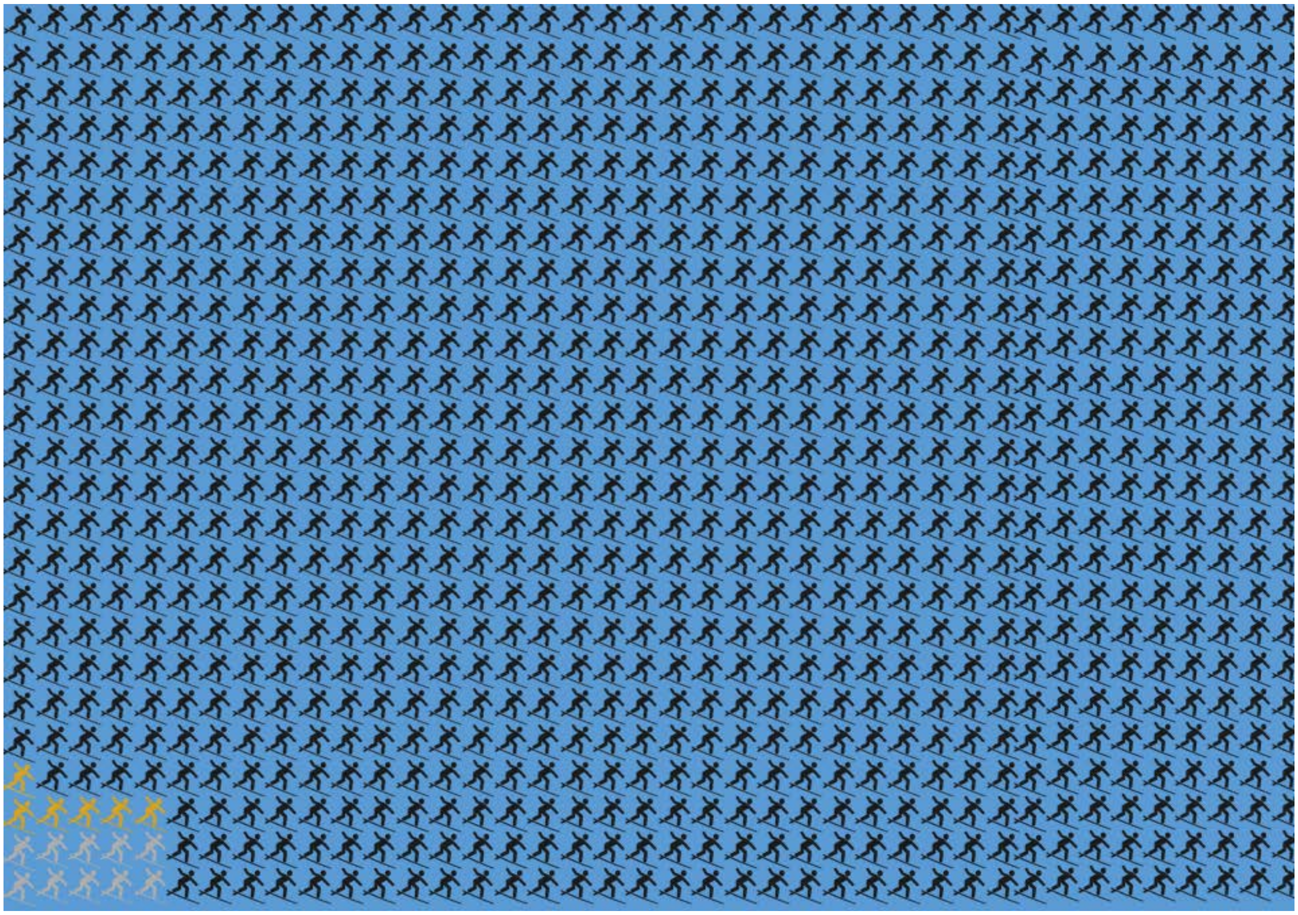
Risks to human health from winter recreation

One of the underlying goals of the Creeks Water Quality Monitoring and Research Program is to communicate to the public about pollution issues. A specific research question in the past several Research and Monitoring Plans, which are approved by the Creeks Advisory Committee, has been: *What is the risk to human health from recreation in creeks and beaches in Santa Barbara*? This chapter of the Water Quality Report will use the result of San Diego's Surfer Health Study to help address this question.

In an effort to understand the risks of recreation near urban creek outlets and stormdrain outfalls, several epidemiology ('epi') studies have recently been conducted at Southern California beaches. The results of these summer-focused studies in Southern California have shown that typical summer swimming in the ocean may lead to infrequent stomach bugs and skin rashes. These studies have provided useful information for beach managers, but for Santa Barbara surfers who seek to enjoy the ocean during rainy winter months, the results have not been applicable. Given the County-wide blanket beach warnings during rain events and anecdotes, many surfers have some to think that illness rates are much higher for winter surfers than summer swimmers. Several surfers have stated they would expect to get sick almost every time they go in the ocean after a rain. Furthermore, all of the summer epi studies focused on gastrointestinal illness, but surfers are often concerned about sinus and ear infections. Until now, there has been scant data to test these concerns.

The recently released San Diego Surfer Health Study is the first of its kind to rigorously address the risk of the surfing in winter, including during wet weather, at California beaches near sources of urban runoff. The project, funded by the City and County of San Diego and carried out by a partnership among scientists and the Surfrider Foundation, was well-designed and statistically conclusive despite several challenges with using surfers as research subjects: surfers do not always go the same surf spots, they surf sporadically (depending on the quality of waves), and they may or may not surf during rain events, depending on attitudes about water quality. The study design addressed these difficulties using reliable statistical methods. Over two winters, 654 surfers were focused and consistent enough in their reporting to allow researchers to track illness rates after 10,081 surf sessions (13% in wet weather, 87% in dry weather) spread over 33,000 surfer days. While the study targeted two main beaches in San Diego, both impacted by urban runoff, surfers were not excluded from the study if they also surfed at other beaches. The full study is found here: www.sccwrp.org/shs/

From an individual health perspective, the results of the Surfer Health Study are quite encouraging for California surfers. In summary (details provided below), a surfer entering the water twice per week for an entire year, regardless of weather, will, if they are of average health and if they surf at spots similar to the San Diego beaches in the study, likely suffer one half of an extra gastrointestinal illness, one extra bout of sinus pain or infection, and one extra earache or infection compared to not surfing at all over the year. The infectious illnesses are the same germs that can be picked up in places such as schools, restaurants and public bathrooms where fecal-oral transmission occurs, usually due to poor hand washing (except for colds and influenza – these germs are not typically spread via human waste and/or swimming).



Wet weather illness rates from the Surfer Health Study. Graphical representation of the rate of "any infectious illness" (gastrointestinal illness, diarrhea, vomiting, fever, eye infection, or open wound infection). The study found that for every 1,000 surf sessions during wet weather, on average 984 surfers remained symptom free ( ), 10 surfers would have become ill even if they didn't surf - this is the 'background' illness rate ( ), and 6 surfers ( ) had an infectious illness related to surfing. Rates for earache/infection and sinus pain/infection are presented below.

Results from the Surfer Health Study show that on any given day during the study period, the average likelihood of staying healthy was very high for surfers who paddled out (98.5%) and those who didn't surf (99%), as depicted in the graphic above. As discussed below, the increase in illness rates (yellow symbols in graphic) is a concern to public health managers, and blanket warnings are released by California counties about surfing in wet weather. The release of the Surfer Health Study generated several news articles with titles such as "This Study Proved that Surfing Makes You Sick More Often" (theintertia.com), and text such as this from Grind TV:

> Rain causes runoff into the ocean, and when surfers are exposed to the bacteria in that runoff it can cause illness. Other illness types that are greatly increased with wet weather are diarrhea,

sinus infections, skin rashes, fevers and much more. **Just more evidence to not go surfing after rain in San Diego, or any urban areas.**

Several mainstream articles included numbers and graphics, but did not include sufficient explanation to ascertain the meaning for an individual surfer.

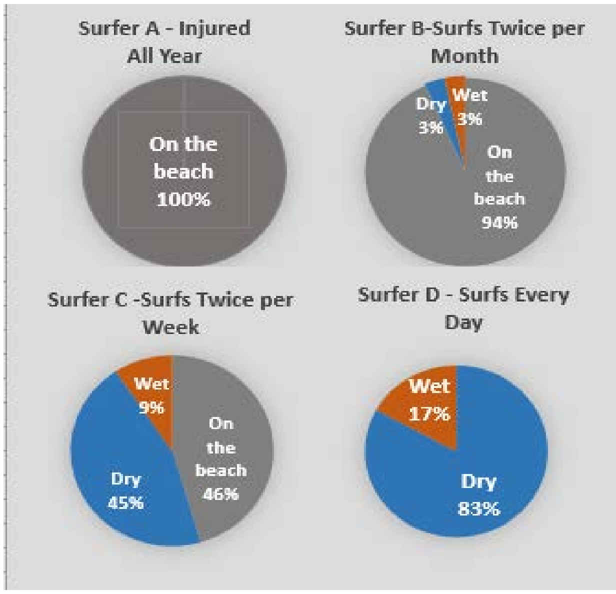
When reviewing an epidemiological study, it is important to separate public health questions from personal health questions. Public health questions, such as those posed by the Surfer Health Study, are aimed at the population level:

- *Is surfing associated with an increased rate of illness? How many surfers might get sick over an entire year? What is the health and economic impact?*
- *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?*

The answers allow coastal managers to make relevant policy decisions and infrastructure improvements needed to reduce public health risk.

On the other hand, each individual makes decisions based on their own perceptions of risk. Personal questions, such as these, can aid these decisions:

- *How bad is the bad outcome – illness, injury, or death?*
- *What is giving up by forgoing the risky activity (surfing in wet weather)?*
- *What would happen if the individual didn't surf – would they still get sick?*
- *How does the surfer's risk of illness increase from surfing?*
- *Regardless of the increase in risk due to surfing, is it common or rare to get sick?*
- *Is the surfer average, or do they have a condition that may increase their risk?*
- *Can they live with the risk in order to enjoy the benefits?*



After years of anecdotal evidence and partially relevant research, surfers are now fortunate to have a solid study to address these personal questions. Epidemiologists will use the results to inform coastal managers about policy decisions, but they do not typically communicate the results to individuals. By accepting that this is a single study producing results in the form of average risk, an approximate risk to an average individual facing conditions similar to that of the study can be calculated.

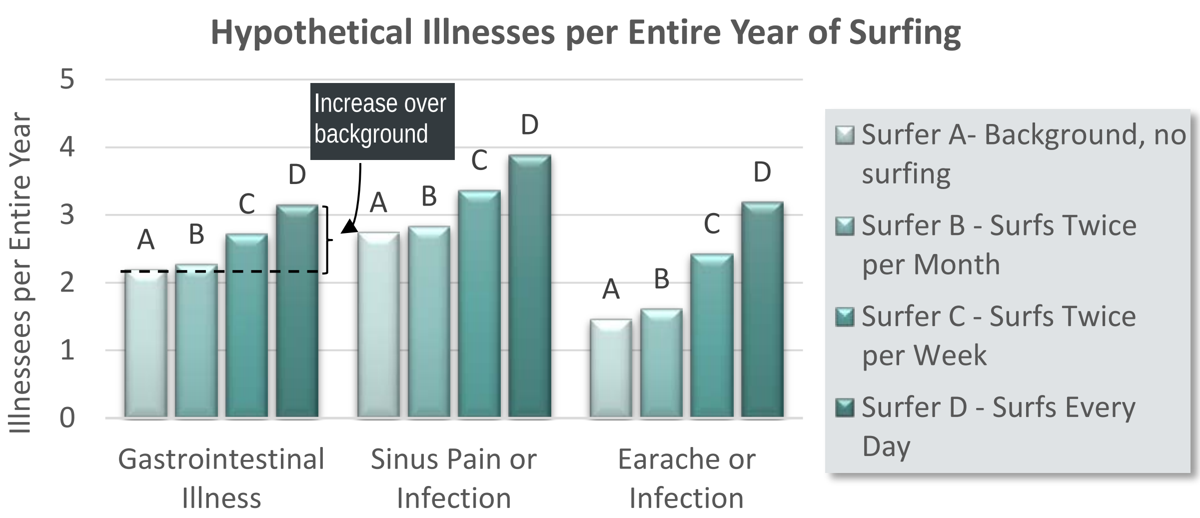
As a tool to assist in data interpretation, annual illness rates for four hypothetical surfers were calculated, based on the averages obtained by the Surfer Health Study:

- Surfer A does not surf all year.
- Surfer B surfs on average twice per month, more during the winter (50% of surf days within 3 days of >0.1" rain).
- Surfer C surfs twice per week, regardless of weather.
- Surfer D surfs every day, regardless of weather.

Based on Santa Barbara rain records, Surfers C and D surf 17% of the time during or after rain (within 72 hours of 0.1" rain or more). This is close to the 13% of surf sessions occurring in wet weather observed during the Surfer Health Study, which was probably low due to being during drought. Using these scenarios and data from study, which separates unexposed (non-surfing, or background), dry weather, and wet weather illness rates, the number of illnesses per year, on average, each hypothetical surfer would incur, for GI bugs, ear aches/infections, and sinus pain/infection, was calculated.

Percent of days spent not surfing, surfing during dry weather, and surfing during wet weather used in calculating annual illness rates.

As seen in the graph below, for the hypothetical average surfer based on the results of the Surfer Health Study, the illness rates for the twice-monthly surfer (Surfer B) are nearly indistinguishable from the injured surfer who never goes out (Surfer A - background). The twice-weekly surfer (Surfer C) picks up approximately one half of an extra GI bug and one each of earache/ear infection and sinus pain/sinus infection per year. The die-hard, rain-or-shine daily surfer suffers one extra GI bug, and 1.5 extra incidents of earache/infection and sinus pain/infection over the background level.



Yearly illness rates for four hypothetical surfers, based on results from the Surfer Health Study. Surfer A represents the background rate, and increases above Surfer A can be attributed to surfing in this calculation.

These numbers can aid in answering the individual health questions posed above.

1) *How bad is the bad outcome – illness, injury, or death?* The bad outcomes are gastrointestinal symptoms, skin rashes, infected open wounds, earache or infection, and sinus pain or infection.
2) *What is given up by forgoing the risky activity (surfing in wet weather)?* Surfers will forego recreational opportunities.
3) *What would happen if the individual didn't surf – would they still get sick?* According to the Surfer Health Study, the background (nonsurfing) rate of getting the illnesses discussed here is about 1% at any given time, or a handful of illnesses over the course of a year. This number is in line with other studies.
4) *How does the surfer's risk of illness increase from surfing?* On average, based on the Surfer Health Study, the risk will increase by 50% due to surfing in dry weather and 60% in wet weather, compared to not surfing.
5) *Regardless of the increase in risk due to surfing, is it common or rare to get sick?* Based on the study, the rate of illness after surfing is, on average, 1.5%, and 1% for not surfing.
6) *Is the surfer average, or do they have a condition that may increase their risk?* Surfers with weakened immune systems should not rely on "average" results for information. This study would not be applicable.
7) *Can they live with the risk in order to enjoy the benefits?* This is a personal question, to be answered by each individual (or lparent/guardian).

There are a few qualifiers and caveats to consider. On the conservative side, it is true that there are staph bacteria, including antibiotic resistant staph ('MRSA', pronounced mur-suh), everywhere these days. There are other naturally occurring bacteria, such as *Vibrio,* that have caused infections in San Diego, CA. Open wounds, especially deep wounds, should be kept out of the water (and other densely used places such as gyms, locker rooms, and dormitories) or cleaned thoroughly after surfing. Ears, eyes, and sinuses can be cleaned also – care should be taken because people have died from amoebic brain infection after using a neti pot filled with tap water.

Surfing in areas with raw sewage discharge, e.g. after a sewage spill (sanitary sewer overflow, or 'SSO') and in developing countries and areas of the United States with combined sewer overflows (CSOs) could be much riskier than the conditions found in the Surfer Health Study. Immunocompromised individuals and children might be more sensitive than the populations studied as well. Finally, the Surfer Health Study is only the first study to capture illness rates among surfers in wet weather, and the error bars on the risk estimates are quite large (because only 13% of the surf sessions were during wet weather). Additional studies should be funded, planned, and carried out, in a variety of regions.

Despite these caveats, thirty years of data collection ('surveillance') by the Centers for Disease Control has identified only a single disease outbreak in the marine environment in the United States (though many have occurred in swimming pools, fountains, to a lesser extent, lakes and reservoirs). In Santa Barbara County, most Hepatitis A comes from people visiting other countries, and the only swimming-related gastrointestinal illness outbreak was at the Santa Ynez River.

On the less conservative side, this study does not consider the benefits, public and personal, to an active surfer lifestyle. In this day of obesity and diabetes, safe physical activity should be promoted. Nor does the study address the benefits of harboring less anxiety regarding a favorite hobby. In addition, the study showed that surfing actually decreased the chances, by 50%, of having a fever when surfing during wet weather. This could be because surfers were not spending time in closed office buildings during their surf sessions, or perhaps their immunity to fever is improved due to a healthy lifestyle. The Surfer Health Study is not able to provide an explanation. Last, activities other than surfing can prove riskier. For example, studies show that visits to a pediatric office, a dirty public restroom, or a preschool can increase illness rates more than surfing in wet weather. Furthermore, if surfing prevents people from partaking in unhealthy habits such as smoking cigarettes, by all means their overall illness rate is lower and the illnesses less severe, even if they surf frequently in wet weather.

Population level impacts.

Despite reassuring results for individual illness rates, work should continue due to impacts on a population level. The study showed that surfers were 50% more likely to get sick if they surfed during dry weather (from 1% to 1.5%) and 60% more likely during wet weather (from 1% to 1.6%), compared to not surfing. Multiplied by the millions of surf sessions throughout California annually, this may represent substantial lost productivity and increased health care costs. The study also showed that DNA markers for human waste and pathogenic viruses (mostly norovirus) were found in nearly 100% of the 44 wet-weather samples that were collected from the discharge points at the two San Diego beaches. Forensic methods were used to identify likely locations of human waste inputs to the waterways and hopefully this quest will not stop until all hot spots are identified and rectified. Researchers will continue to work on measurement and tracking tools in order to improve local agencies' abilities to detect and fix compromised infrastructure and societal behaviors that lead to human fecal contamination of our waterways

SIDE BARS

What about Santa Barbara? The Surfer Health Study was carried out at two beaches in San Diego, CA. How do the results relate to surfing around Santa Barbara? While an exact comparison is impossible, there is some information available. Extensive water testing and research has been conducted locally in a partnership among the City of Santa Barbara's Creeks Division, the University of California, Santa Barbara, and Geosyntec Consultants, with primary funding from Measure B and the State of California's Clean Beaches Initiative Grant Program. Previous work in Arroyo Burro, Mission Creek, and Laguna Channel watersheds found several sources of human waste that were detectable at very low levels in creeks during dry weather. The sources of these signals were identified and fixed. Limited sampling in wet weather found no detections of human markers. More recently, as part of a current UCSB and Geosyntec research project on Leadbetter Beach (Honda Creek) and East Beach at Sycamore Creek, preliminary wet weather samples in creeks did contain markers for human waste; the difference may be improved testing methods and/or sampling during smaller storms and closer to sources of fecal input, which may lead to less dilution. No human waste markers were detected in the surf zone during wet weather. The square mileage of land generating urban runoff in South Coast watersheds (hundreds to thousands of acres) is within the range of the two watersheds in the Surfer Health Study (963 acres and 256,000 acres). In addition, the urban acreage is similar among the watersheds. Urban infrastructure is of similar age, and transient populations are found both here and in San Diego. Therefore, there is no reason expect that the results of San Diego's Surfer Health Study would be grossly different than a study carried out in Santa Barbara.

What about other pollutants? Extensive creek water testing by the City of Santa Barbara in dry weather has shown very few detections of chemical pollutants such as pesticides and hydrocarbons. During wet weather, runoff does pick up pollution as it runs across urban surfaces and reaches creeks. Very few detections of pesticides* and hydrocarbons have been found at creek outflows to the ocean, but metals are found in dry and wet weather. Creek outflow concentrations of metals exceed drinking water standards and goals, which are extremely precautionary when applied to recreational exposure, in approximately 10% of the samples. Given the dilution that occurs in the surf zone, occasional sips during surfing probably pose an insignificant risk. The risk of exposure to metals via dermal (skin) uptake during recreation has not been widely studied, but the City's results for creek outfall testing do not raise alarm bells. Newly considered pollutants, such as personal care products and endocrine disruptors ('contaminants of emerging concern'), are likely more harmful to aquatic life than to humans, at least in the context of swimming and surfing. In fact, all of the chemical pollutants described here can be harmful to creek life because concentrations can be higher near storm drain outfalls to creeks and the chemicals accumulate in sediments, where organisms are exposed for long periods of time. Chemicals can also bioaccumulate up the food chain, leading to problems with consumption of seafood. Reducing pollution in urban runoff is vital to ecological and human health, even if surfing concerns are not substantial.

*The exception is the neonicotinoid pesticide imidacloprid, which is not a concern for human health, but is the topic of extensive research by City of Santa Barbara and researchers at UCSB (see http://tinyurl.com/imida).

LID Streets, Sidewalks, and Alleys

Status: Some parts of the report were completed early and included in the FY16 WQ Report. Tim Burgess monitors the HOBO depth loggers and analyzes the data. The following includes plots of logger data during during a storm in January 2017, when the Quarantina St project was investigated. Toxicity was also tested.

Overview

The City measured the Project's benefits by monitoring the storm water runoff for pollutants and toxicity at each site before construction in order to calculate the pollutant loads associated with each site and establish a baseline condition. Monitoring was completed according to the approved LID Streets, Sidewalks and Alleys Project Monitoring Plan/QAPP. A sampling location was identified for each site where storm water runoff could be collected. Sampling took place at each of the four sites during three different storms. Composite samples were collected when possible (two of three storms). Samples were tested for fecal indicator bacteria, metals, pesticides, nutrients, hydrocarbons, surfactants, total suspended sediment, and toxicity (Table 1) and results were compared to Basin Plan water quality objectives where possible. All sample results were averaged to obtain event mean concentrations (EMC). The EMCs were compared among sites, and there were no significant differences among sites. Therefore, a project-wide EMC for each pollutant was used in calculating load reduction. Load reductions were calculated per inch of rainfall and for the time period between project completion and January 25, 2017.

Table 3. Constituents included in load reduction monitoring.

Parameter Group	Highest Reporting Limit	Central Coast Water Board Basin Plan Objective
Fecal Indicator Bacteria	100 MPN/100 ml	From AB 411, rather than Basin Plan: Total Coliform: 1000 MPN/100 ml E. coli: 400 MPN/100 ml Enterococcus: 104 MPN/100 ml
Organic Carbon (Dissolved)	0.5 mg/L	
Nutrients **Nitrate (as N)** **TKN** **Total Nitrogen** **Total Phosphorus**	 0.11 mg/L 0.5 mg/L 0.05 mg/L 0.05 mg/L	 Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Total Petroleum Hydrocarbons - Diesel	0.5 mg/L	Waters shall not contain oils, greases, waxes, or other similar materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses
Total Suspended solids	20 mg/L	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Total Metals 1 **Arsenic** **Cadmium** **Calcium** **Chromium** **Copper** **Iron** **Lead** **Magnesium** **Manganese** **Mercury** **Nickel** **Potassium** **Silver** **Sodium** **Zinc**	 0.01 m g/L 0.005 mg/L 0.1 mg/L 0.005 mg/L 0.01 mg/L 0.04 mg/L 0.005 mg/L 0.02 mg/L 0.02 mg/L 0.0008 mg/L 0.01 mg/L 0.5 mg/L 0.01 mg/L	 0.03 mg/L 0.05 mg/L 0.03 mg/L 0.03 mg/L 0.0002 mg/L 0.4 mg/L 0.2 mg/L

	0.5 mg/L 0.02 mg/L	
Surfactants	0.1 mg/L	0.2 mg/L
Pesticides		
Neonicotinoids	5-10 ng/L	None in Basin Plan.
Pyrethroids	2-100 ng/L	None in Basin Plan
Toxicity		All waters shall be maintained free of toxic substances in concentrations which are toxic to, or which produce detrimental physiological responses in, human, plant, animal, or aquatic life. Current 303(d) evaluations use the criteria of test results being significantly different than the control.

[1] Reporting limits in some samples were high due to dilutions performed for sample analysis.

Monitoring Locations

The following figures show the sampling location at each project site. One to four sampling sites were selected at each location in the Project area. Each site(s), shown by the red stars below, was selected to provide runoff that is inclusive of or representative of runoff from the project before construction, while excluding runoff that will not be infiltrated by the Project. Sampling sites were observed during dry weather, and in some cases prepared for sampling by digging out areas to place sample vessels for runoff collection. In some cases, alternative locations were identified during storm sampling events.

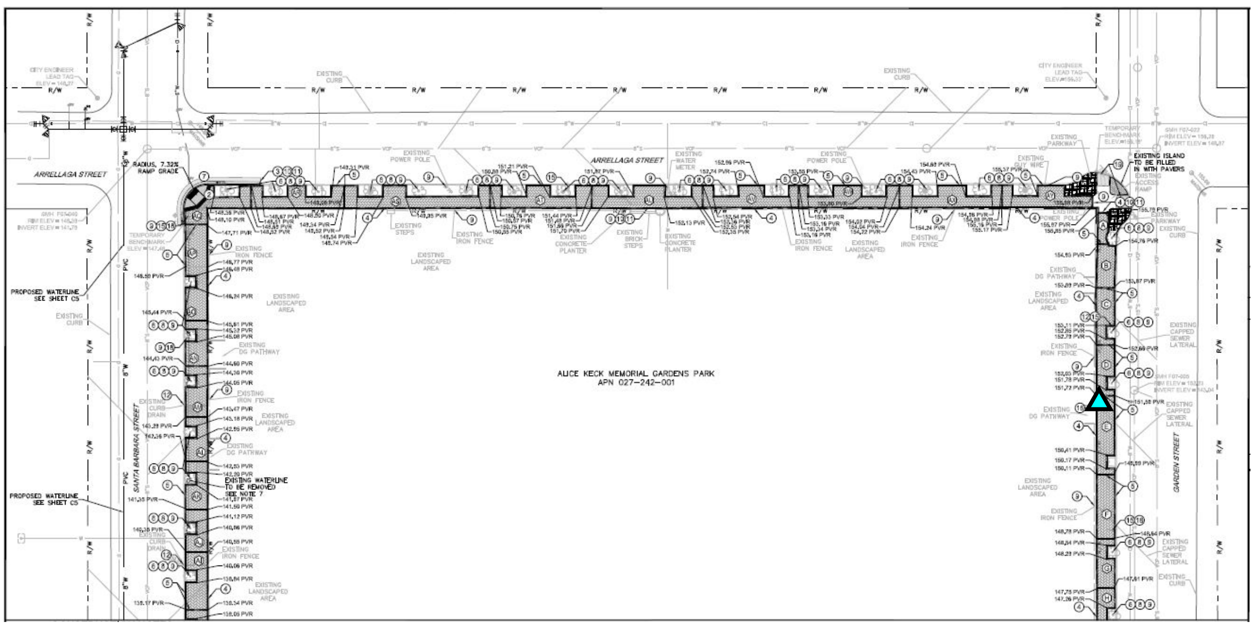
To confirm the amount of rainfall infiltrated by the project, monitoring ports were installed below the permeable pavers. These ports allow access from the surface of the pavers to the sub-grade soil, so the depth of water stored beneath the pavers in the sub-grade can be measured. Measurements are made using water level loggers that record water depth every five minutes. Data from these loggers reveal the changing depth of the stored water during a rainstorm as it fills and infiltrates into the ground below. Locations of these monitoring ports are shown as yellow triangles in the maps below. Coordinates are provided in Table 2.

Table 4. Sampling Locations. NAD 83 datum used for GPS coordinates

Site Name	Sample Site Code	Sample Site Specific Location	Comments	Latitude	Longitude
Plaza de Vera Cruz Alley Project Site			GPS Location of each end of project site	34.4193 34.4185	-119.6950 -119.6938

Plaza de Vera Cruz Alley Monitoring Port				34.4187	-119.6941
Plaza de Vera Cruz Alley Runoff Sample Site	LIDVeraCru	Where runoff flows off of alley.		34.4186	-119.6940
Alice Keck Park Memorial Gardens Sidewalk Project Site			GPS Location of each corner of project site	34.4302 34.4293 34.4284 34.4292	-119.7062 -119.7050 -119.7060 -119.7072
Alice Keck Park Memorial Gardens Sidewalk Monitoring Ports				34.4297 34.4287	-119.7055 -119.7057
Alice Keck Park Memorial Gardens Sidewalk Sample Sites	LIDAliceKe	Where runoff discharges off of sidewalk into gutter, and where runoff discharges off of a concrete sidewalk in adjacent Alameda Park		34.4290 34.4275	-119.7054 -119.7047
700 block of N. Quarantina St. Project Site			GPS Location of each end of project site	34.4270 34.4259	-119.6913 -119.6898
700 block of N. Quarantina St. Monitoring Port				34.4265	-119.6907
700 block of N. Quarantina St. Runoff Sample Site	LIDQuarS	Runoff collected from sidewalk runoff and street runoff into gutter.		34.4264	-119.6904

800 block of N. Quarantina St. Project Site			GPS Location of each end of project site	34.4279 34.4270	-119.6926 -119.6915
800 block of N. Quarantina St. Monitoring Port				34.4273	-119.6919
800 block of N. Quarantina St. Runoff Sample Site	LIDQuarN	Runoff collected from sidewalk runoff and street runoff into gutter.		34.4263	-119.6904



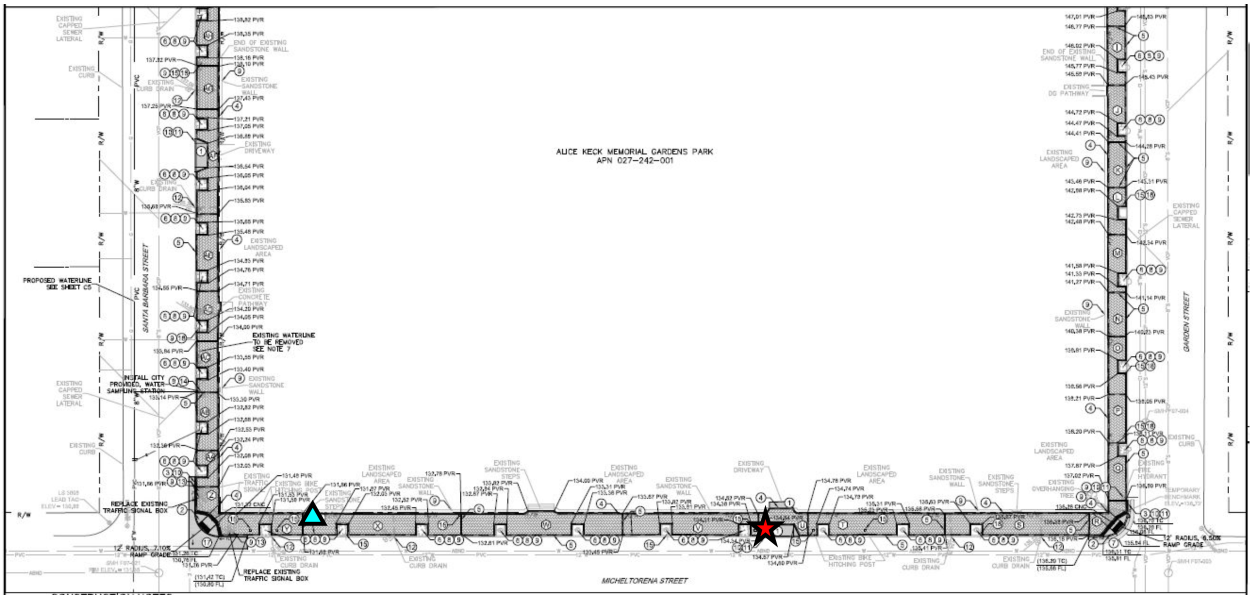


Figure 1. Alice Keck Park Memorial Gardens Sidewalks site with monitoring ports (blue triangles) and pre-project stormwater sampling locations (red star).

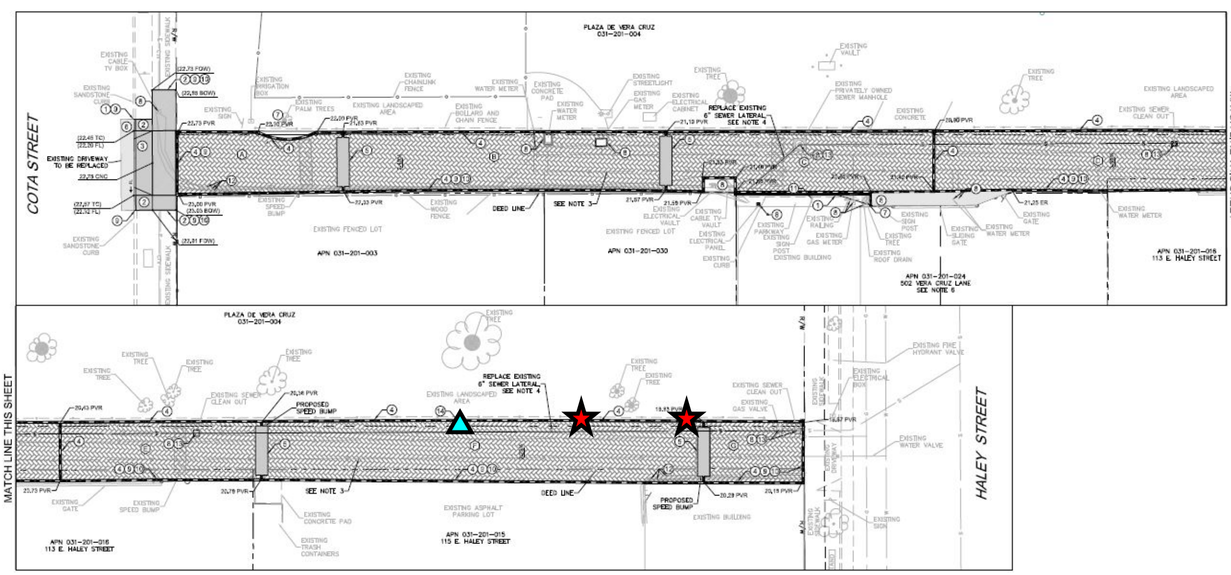


Figure 3. Vera Cruz with monitoring port (blue triangle) and pre-project stormwater sampling location (red stars).

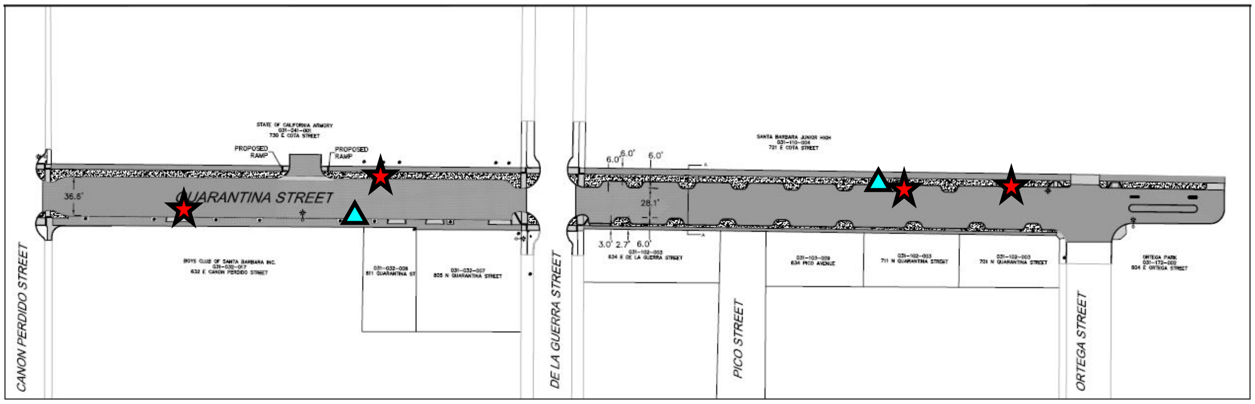


Figure 4. 800 and 700 blocks of N. Quarantina Street with sampling ports (blue triangles) and pre-project stormwater sampling locations (red stars).

Storm Sampling

Despite below-average rainfall, samples were collected and tested during three storms (Table 3). Rainfall patterns show that the storms were representative of rainfall throughout the year (Figure 1). Due to rapidly changing forecasts, staff limitations, and small storms during most of the year, the goal of composite samples covering three time points for each storm was not achieved. Two samples were composited with two time points per location, and the third storm was sampled as a grab sample (although multiple sampling sites were used, as mapped above, at most locations).

Table 5. Summary of Sampled Storms

Storm Number	Date	Time Period	Grab or Composite	Total Rainfall during storm
1	12/2/2014	7:20 am – 1:00 pm	Composite (2 time points)	2.1”
2	2/7/2015	12:00 pm – 2:00 pm	Composite (2 time points)	0.6”
3	4/7/2015	12:30-1:30 pm	Grab	0.28”

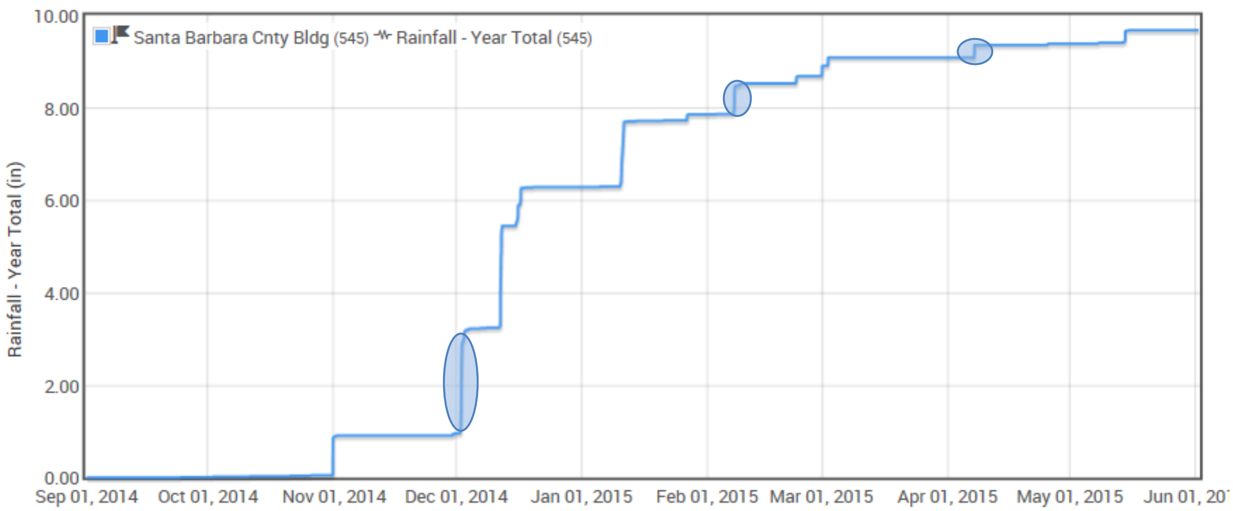


Figure 5. Total rain accumulation in Water Year 2014-2015. Blue ovals indicate sampled events.

The following figures show the precipitation patterns and sampling windows for each of the three storms.

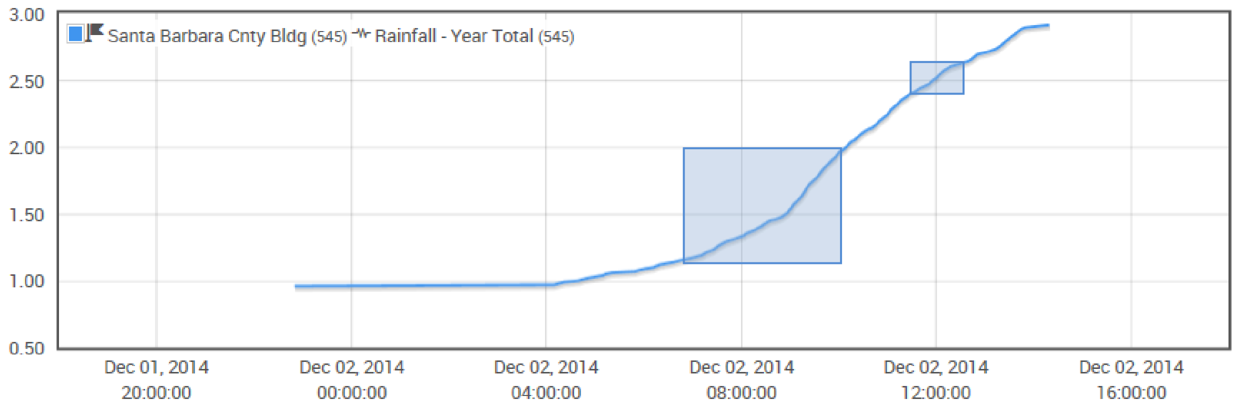


Figure 7. Total rainfall and sample collection times during Storm 1.

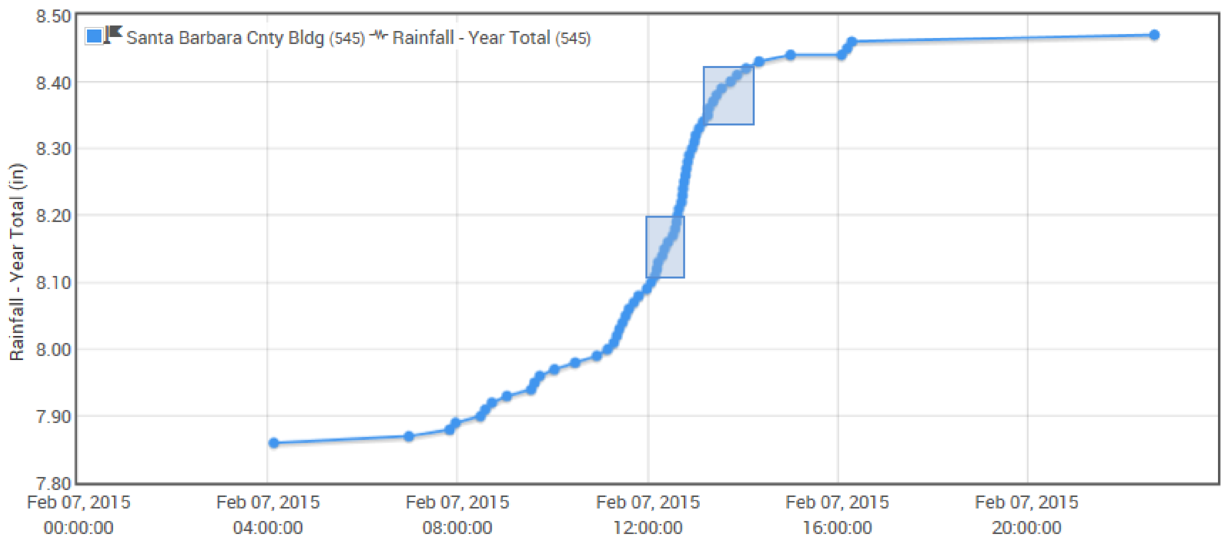


Figure 8. Total rainfall and sampling times during Storm 2.

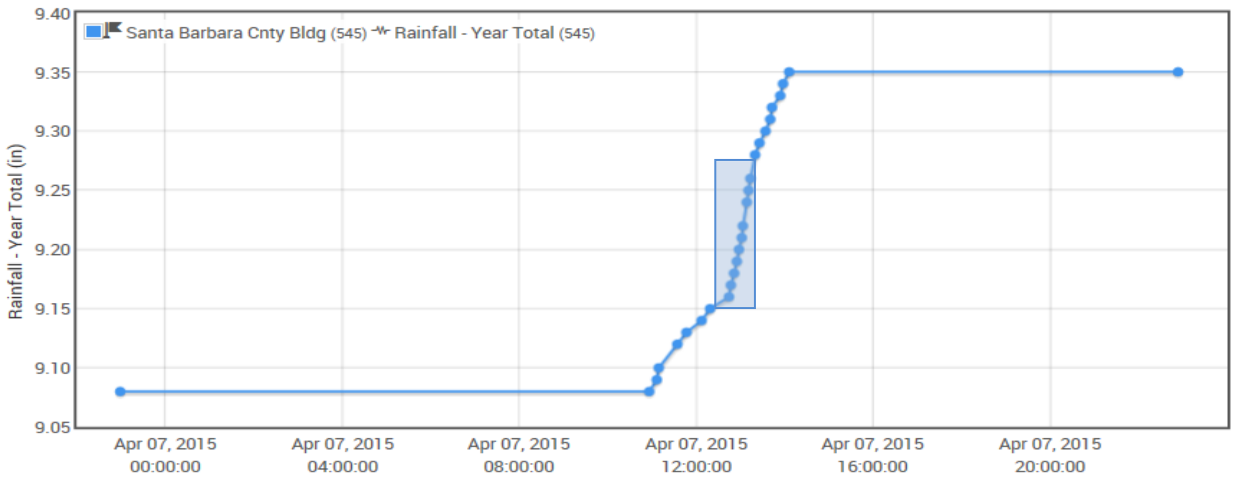


Figure 9. Total rainfall and sampling times during Storm 3.

Sample Results

In the following figures, all parameters are graphed by site (horizontal axis) and coded by storm (color). Box plots are not used due to limited sample sizes for each parameter/site combination (n=2-4). Censored data, e.g. results above or below method detection limits (DL), and/or data between the DL and reporting limit (RL) re marked using partially filled symbols (see legends). Non-detects (ND) are plotted at DL for the sample analysis; however the true value could lie anywhere between zero and the DL. The highest DL for each parameter is plotted as a dashed line. Data above method detection limits (only relevant for fecal indicator bacteria) are plotted at the upper detection limit; the true value could lie anywhere above the limit. Data between the DL and RL are plotted at the laboratory-provided result but are known to have less precision than data above the RL. Water quality objectives are shown by red dashed lines where available.

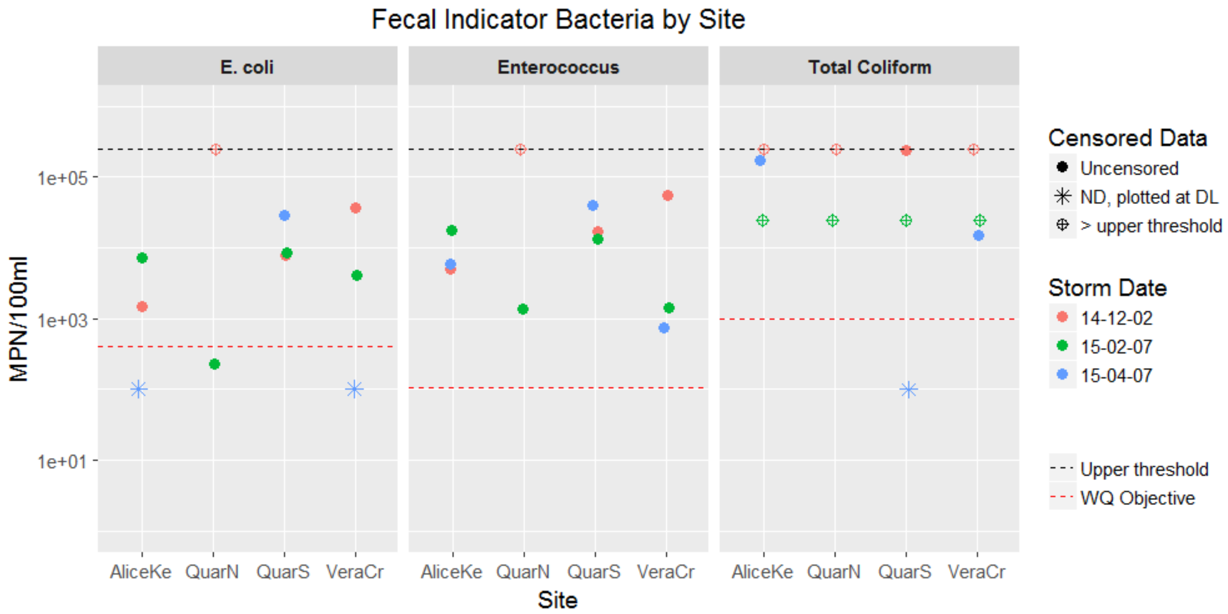


Figure 10. Fecal indicator bacteria results for storms 1-3. Black lines show upper method limit. Red lines show AB411 water quality objectives for each bacterial group.

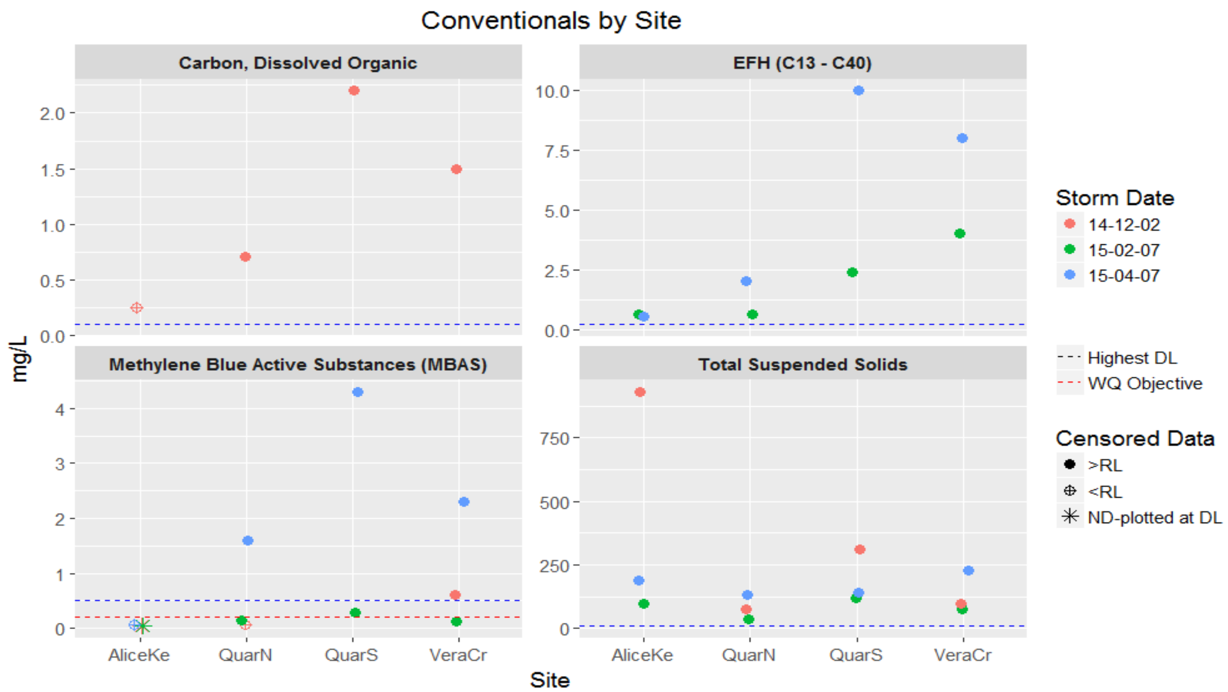


Figure 11. Conventional parameters, including Dissolved Organic Carbon, Hydrocarbons, Surfactants, and Sediment, for Storms 1-3.

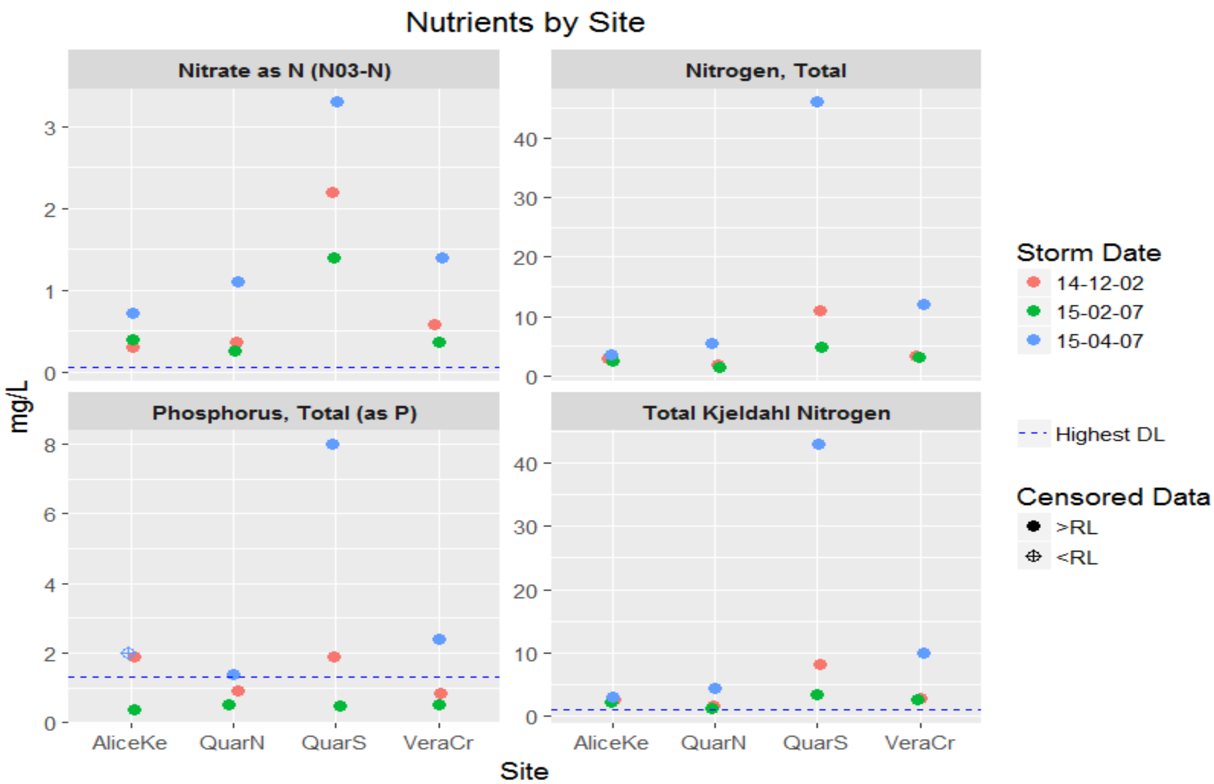


Figure 12. Nutrient results for Storms 1-3.

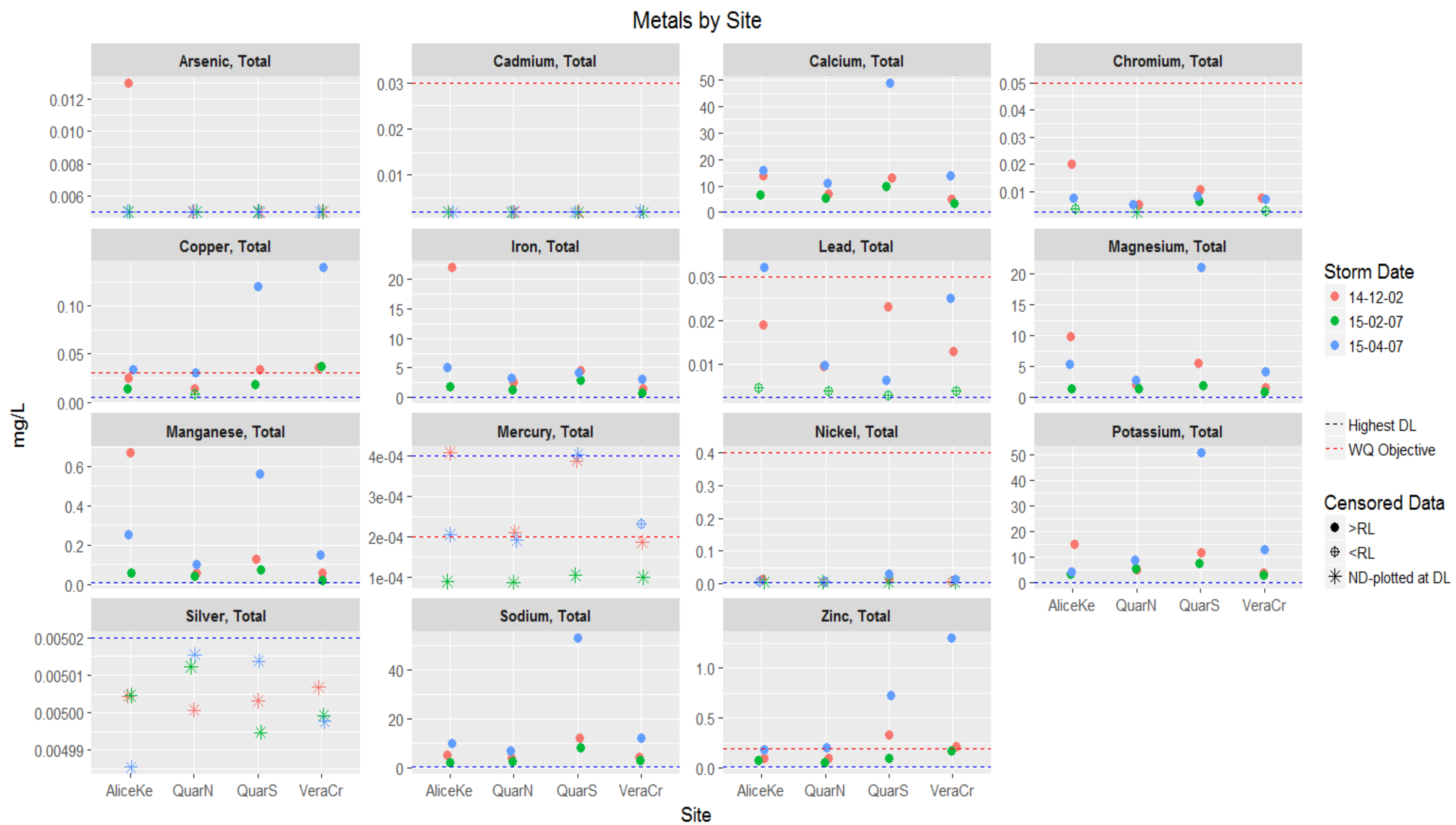

Metals by Site
Arsenic, Total
Cadmium, Total
Calcium, Total
Chromium, Total
Copper, Total
Iron, Total
Lead, Total
Magnesium, Total
Manganese, Total
Mercury, Total
Nickel, Total
Potassium, Total
Silver, Total
Sodium, Total
Zinc, Total
mg/L
Site
AliceKe
QuarN
QuarS
VeraCr
Storm Date
14-12-02
15-02-07
15-04-07
Highest DL
WQ Objective
Censored Data
>RL
<RL
ND-plotted at DL

Figure 13. Total metals results for Storms 1-3. Red lines show Basin Plan objectives where available. Mercury has a quality objectives below the highest detection limits (blue lines), so exeedances cannot be determined for all samples.

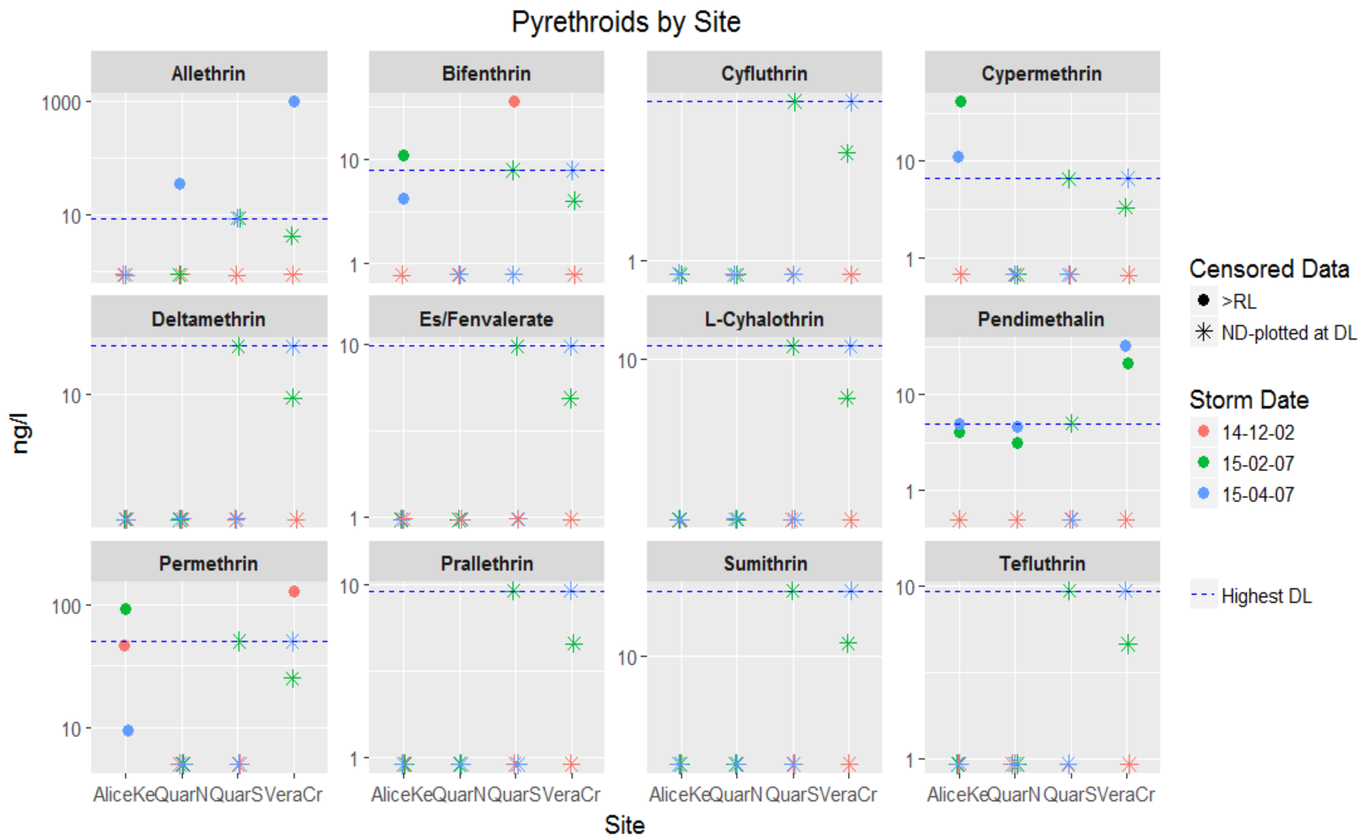


Figure 14. Pyrethroid pesticide results for storms 1-3.There are no water quality objectives available for comparison.

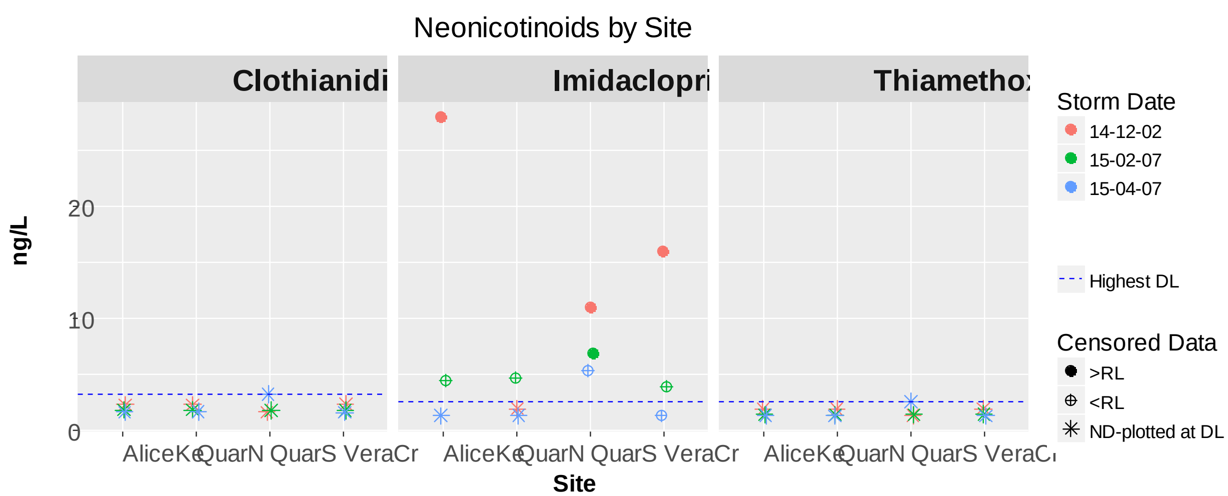


Figure 15. Neonicotinoid pesticide results for storms 1-3.There are no water quality objectives available for comparison.

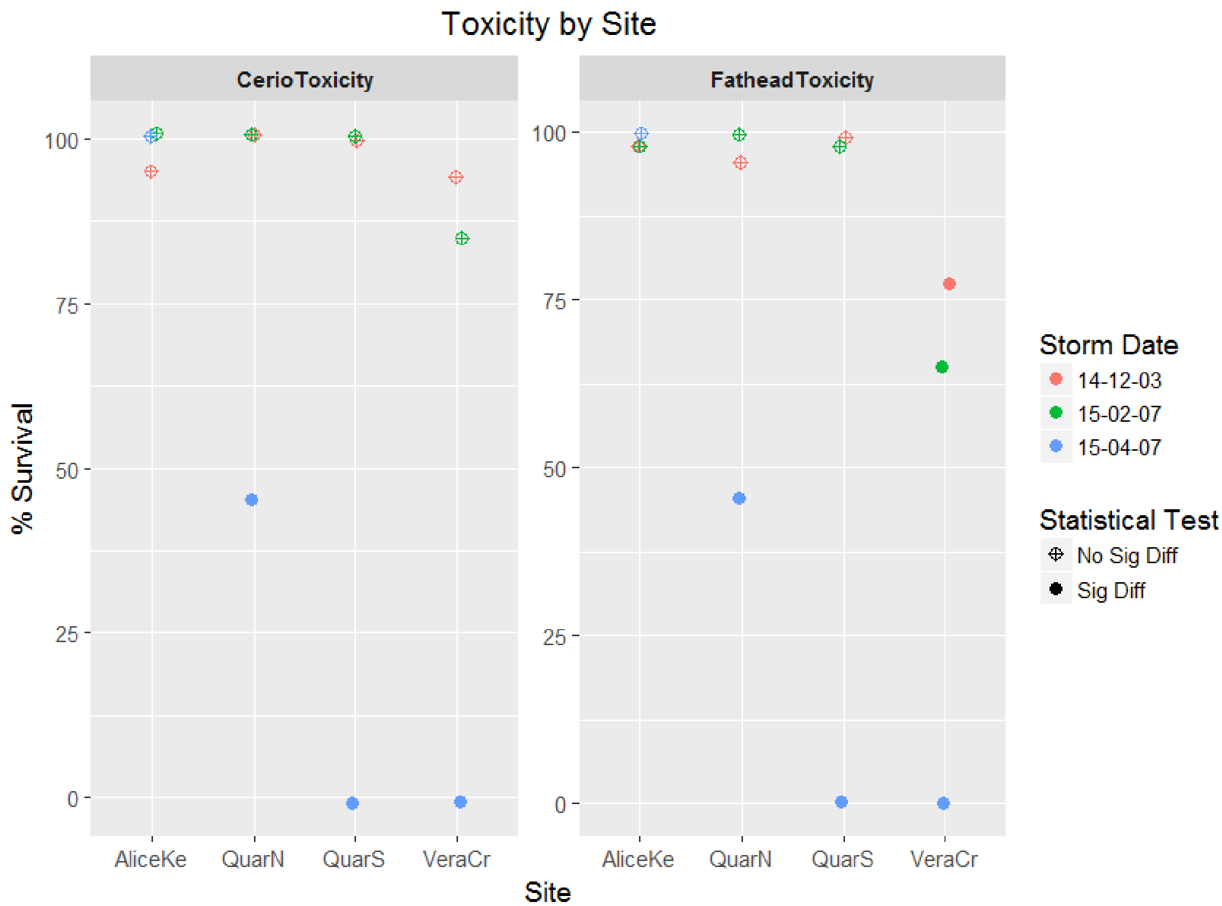


Figure 16. Toxicity results for storm 1-3. Left panel shows *Ceriodaphnia* 96-hr survival rates and right panel shows Fathead Minnow96-hr rates. All test results are scaled to the control. Filled symbols denote samples with a statistically significant difference from the control sample, as reported the out-sourced laboratory.

Post-Project Rainfall

Post project rainfall data are used in the interpretation of monitoring-well logger data and in load reduction calculations.

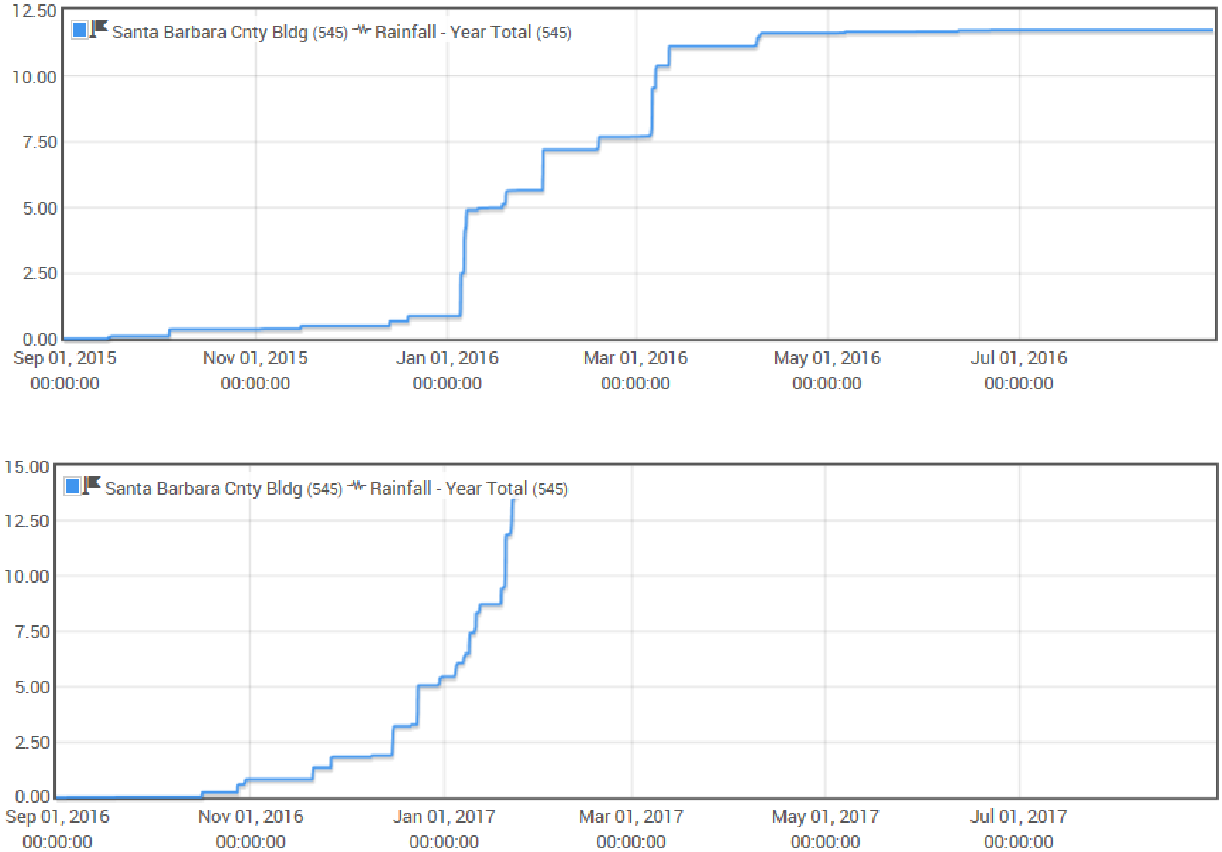


Figure 17. Rainfall during the 2015-2016 rain year (upper panel) and the 2016-2017 rain through January 25, 2017 (lower panel).

Data from Water Level Loggers

Water level loggers were placed in the monitoring ports during storm events in order to measure the depth of the water as it rose from heavy rainfall and fell from infiltration into the subgrade soil below. Water level logger data shows the rise and fall of water in the basins corresponding with precipitation from storms. The data shows water levels reaching the top depth of the basins during some recent periods of precipitation that exceeded one inch of rainfall. Field observations confirmed that during some of these recent large storms, the basins filled, and water flowed out of the lower end of the basins to the overflow storm drain system designed into the project. The City will continue to monitor stormwater levels at the project sites to gain a better understanding of project performance in storms. The rise and fall of the water is plotted against rainfall accumulation and shown in the graphs below. The depth of basins varies from six inches to almost 24 inches. (Figure 11, Figure 12, Figure 13, Figure 14, and Figure 15).

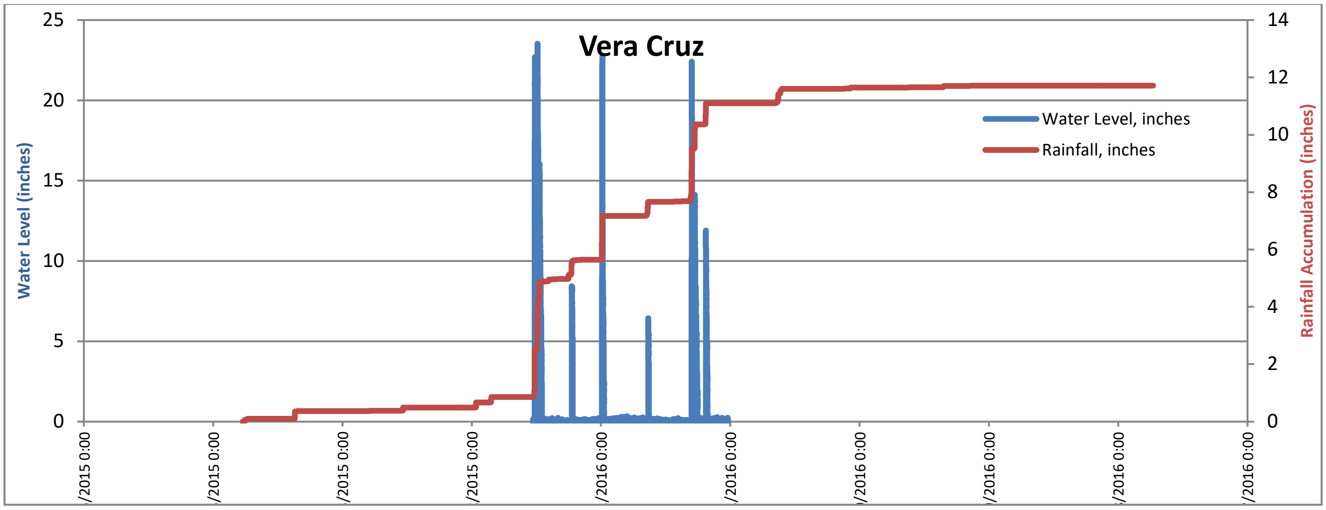


Figure 18. Graph showing water level in a Plaza de Vera Cruz basin during the 2015-2016 Water Year. The water level is shown in blue and rainfall accumulation is shown in red.

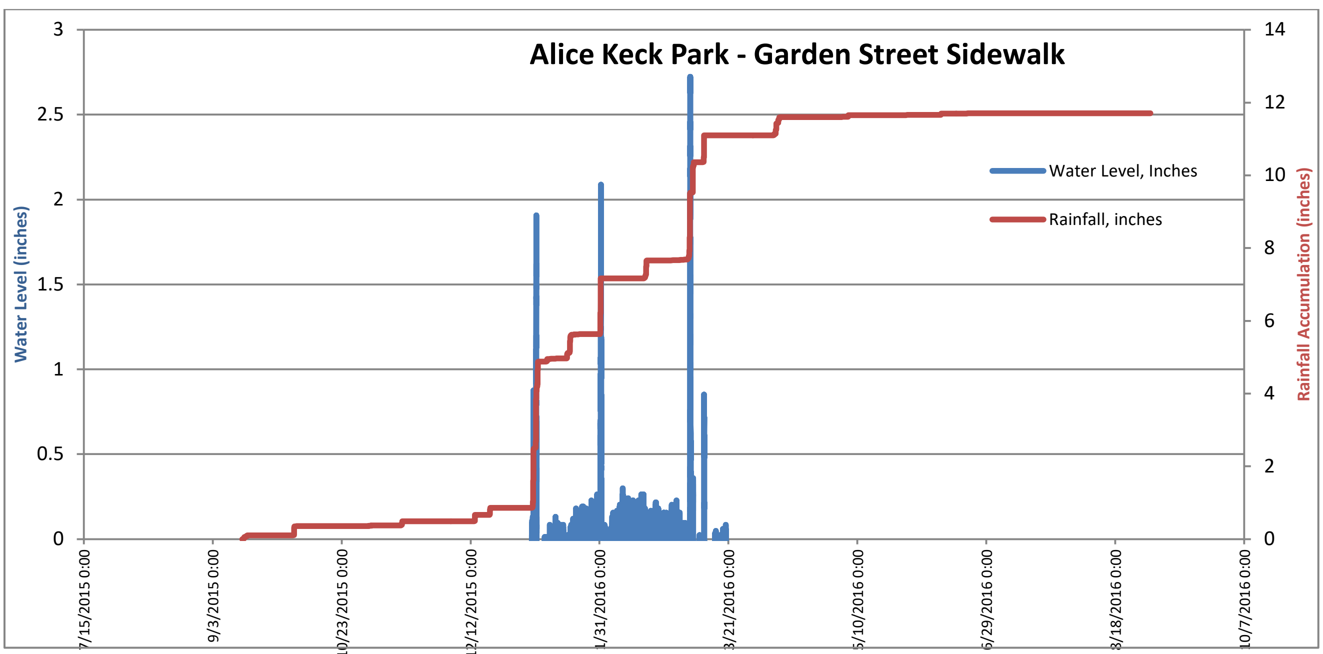


Figure 19. Graph showing water level in an Alice Keck Park Sidewalk basin during the 2015-2016 Water Year. The water level is shown in blue and rainfall accumulation is shown in red.

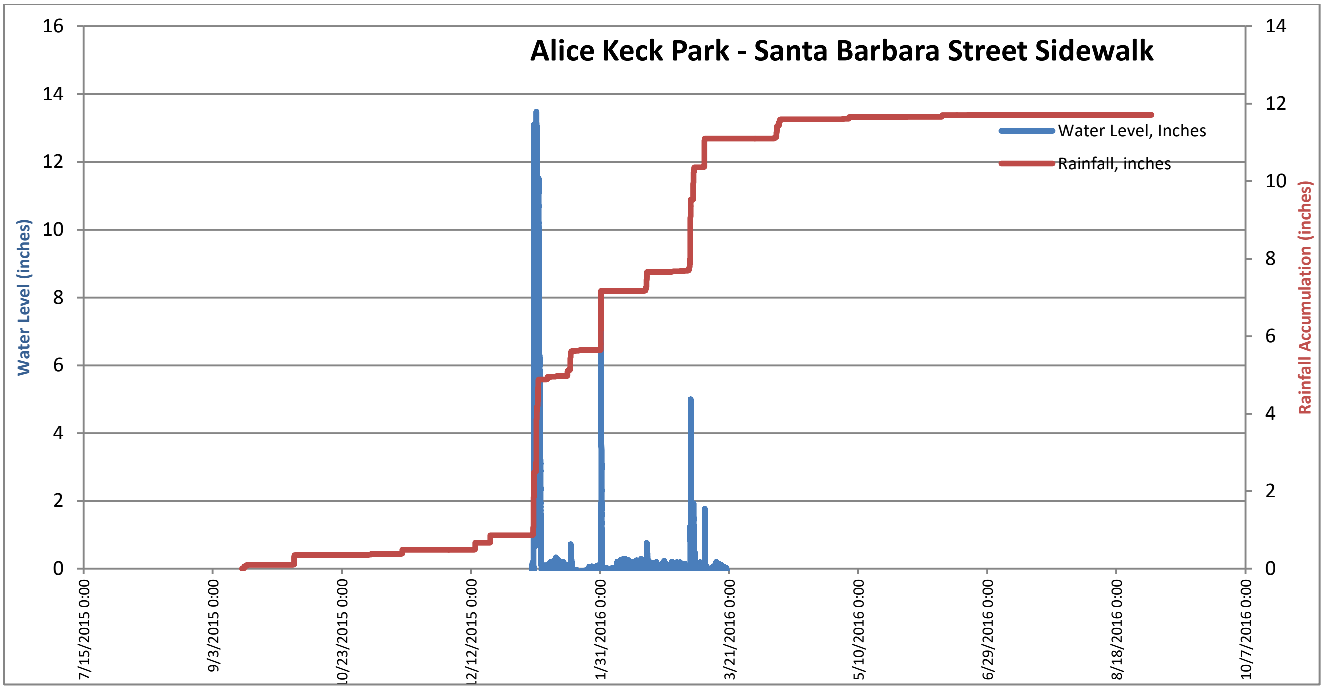


Figure 20. Graph showing water level in an Alice Keck Park sidewalk basin during the 2015-2016 Water Year. The water level is shown in blue and rainfall accumulation is shown in red.

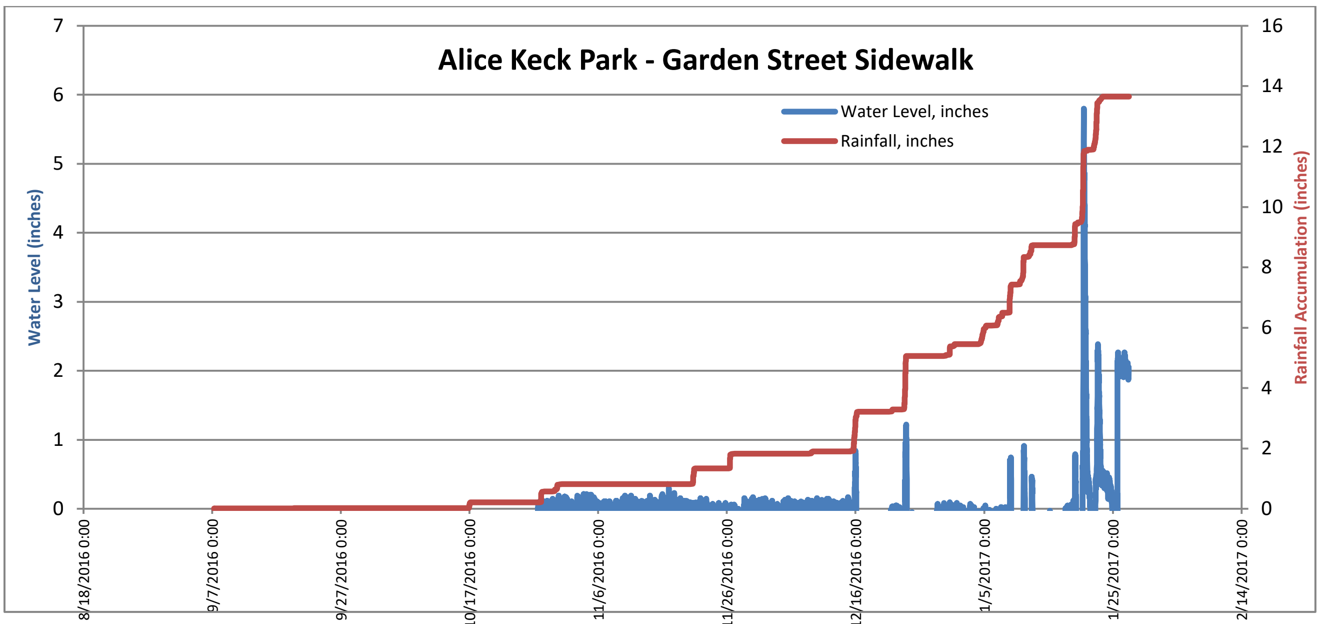


Figure 21. Graph showing water level in an Alice Keck Park sidewalk basin during the 2016-2017 Water Year up to January 27, 2017. The water level is shown in blue and rainfall accumulation is shown in red.

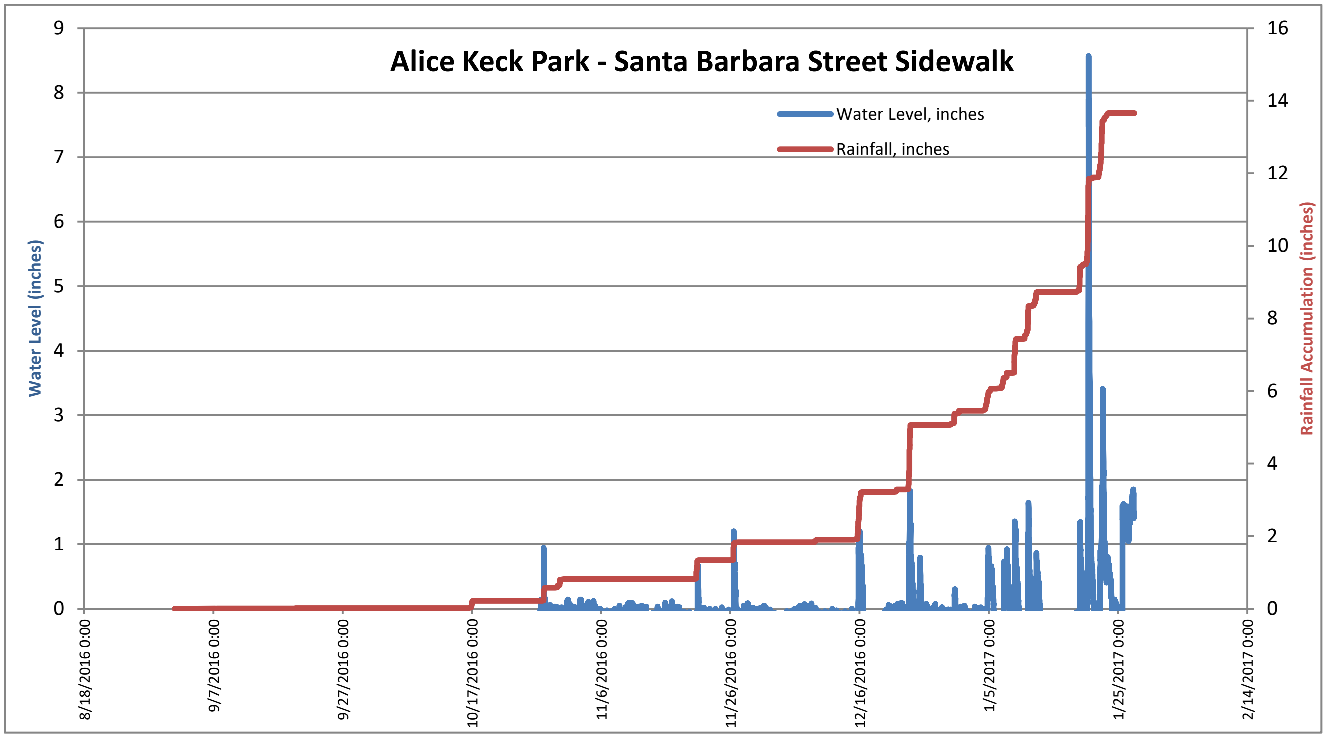


Figure 22. Graph showing water level in an Alice Keck Park sidewalk basin during the 2016-2017 Water Year up to January 27, 2017. The water level is shown in blue and rainfall accumulation is shown in red.

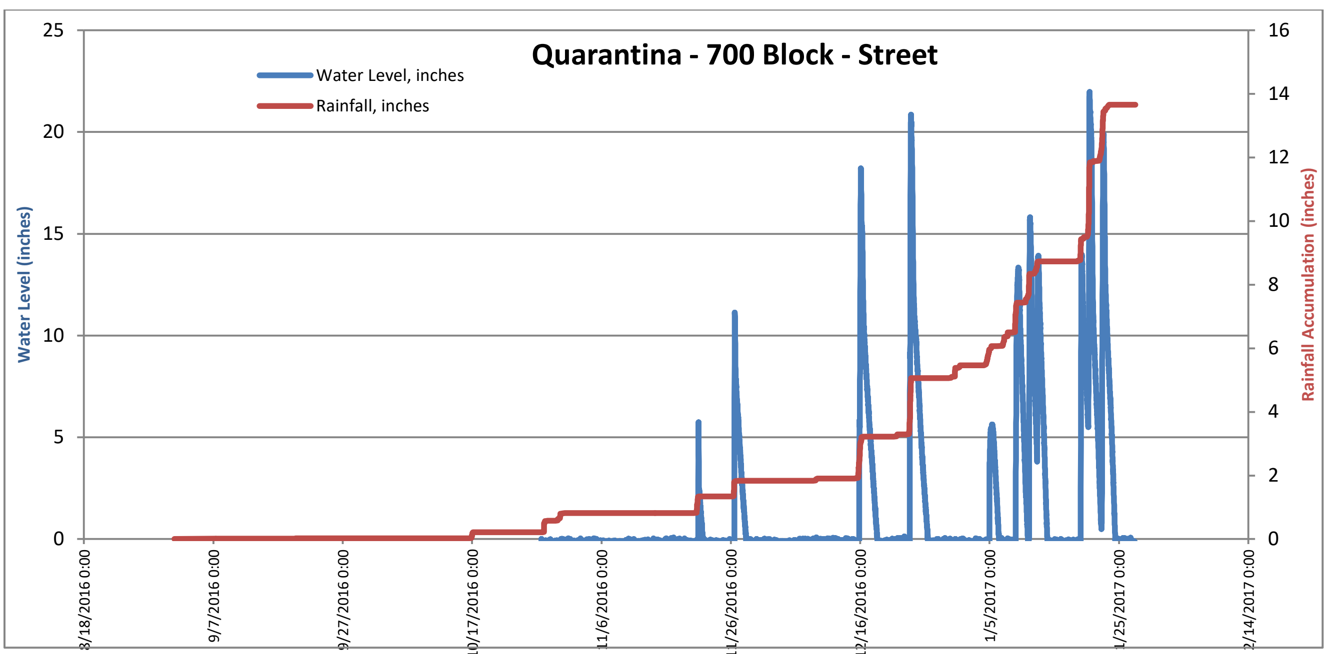


Figure 23. Graph showing water level in a Quarantina Street basin during the 2016-2017 Water Year up to January 27, 2017. The water level is shown in blue and rainfall accumulation is shown in red.

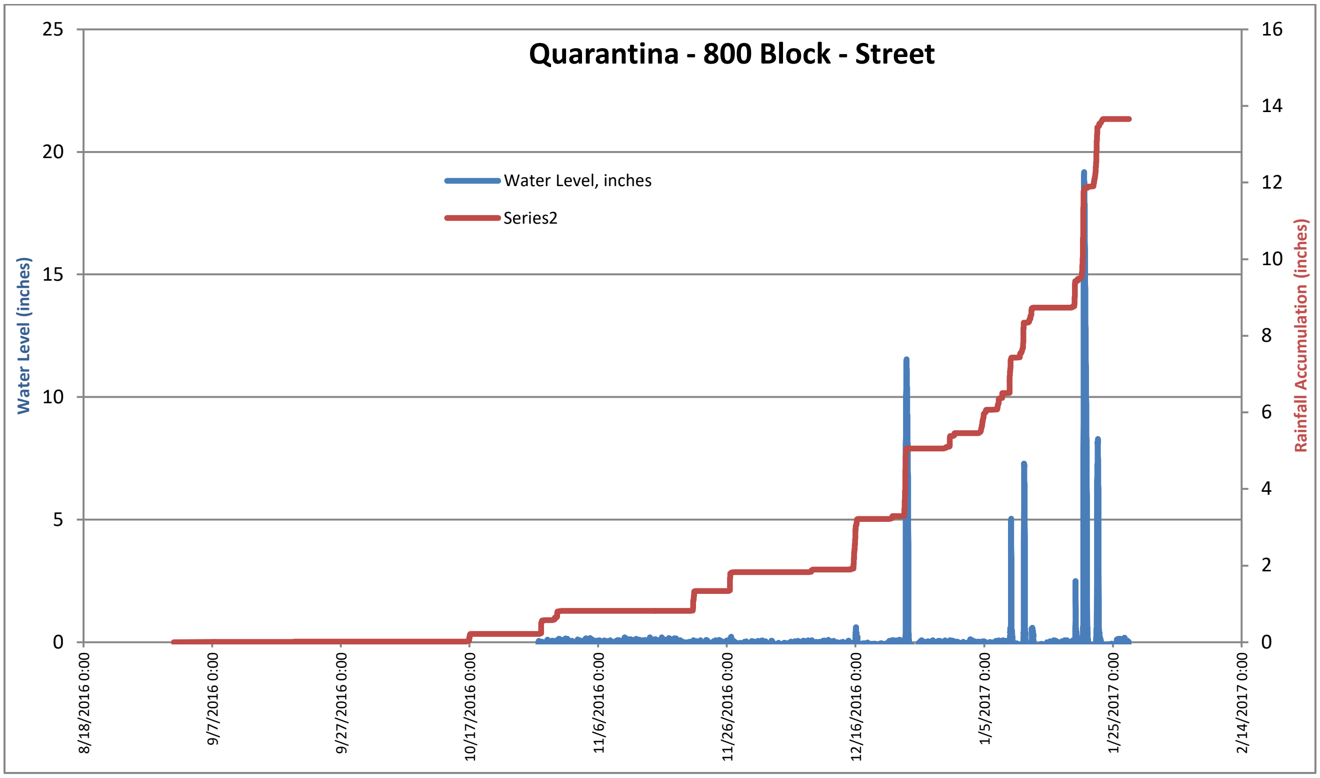


Figure 24. Graph showing water level in a Quarantina Street basin during the 2016-2017 Water Year up to January 27, 2017. The water level is shown in blue and rainfall accumulation is shown in red.

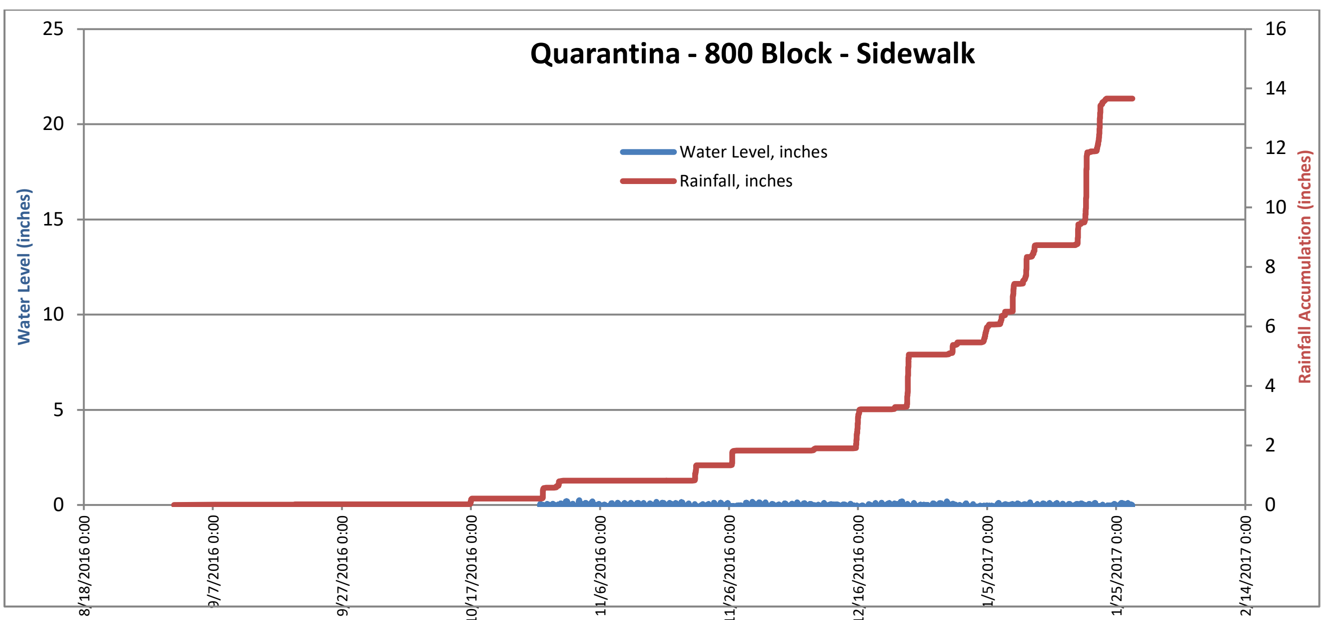


Figure 25. Graph showing water level in a Quarantina Sidewalk basin during the 2016-2017 Water Year up to January 27, 2017. The water level is shown in blue and rainfall accumulation is shown in red.

Data Evaluation/Pollutant Load Reduction

Data Evaluation

Runoff from the parking lots sites contained fecal indicator bacteria, dissolved organic carbon, nutrients, petroleum hydrocarbons, sediment, metals, surfactants, and pesticides. All but four of 34 fecal indicator bacteria samples were above the California Ocean Plan's AB411 fecal indicator bacteria criteria. Results showed that metals exceeded Basin Plan water quality in some cases for lead, copper, and zinc. For mercury, the highest detection limit was above the water quality objective for some samples, preventing the assessment of water quality impacts. One third of the samples exceeded the Basin Plan for surfactants (MBAS). Pesticide analysis showed detections of imidacloprid and several pyrethroids, especially in runoff from Alice Keck.

Toxicity was very high in several samples. There was 0% survival of both test species in two samples. Toxicity was significantly different from the control in 8 of 24 tests. Toxicity was highest in the samples from the third storm at Quar N, Quar S, and Vera Cruz, and this is likely due to the limited runoff and the need to sample from puddles in some cases, i.e. the sample was composed of "first flush" contaminants.

Pollutant Load Reduction

Using pollutant data collected before the project was built, and infiltration volumes calculated in the period after the project was built, load reductions were calculated for all parameters with detections (toxicity data is not included). Visual comparison showed no consistent difference among sites or storms; therefore, a City-wide, year-long event mean concentration (EMC) was calculated for each parameter (Table 4). A total area for all of the project sites was calculated (20,781 m^2).

Assuming complete infiltration, the load reduction is equal to the EMC multiplied times the volume of rainfall after the project. First, a load reduction per inch of rainfall was calculated:

Load Reduction (M/L) = EMC (M/L^3)*Area (L^2)

where M=Mass and L=Length

This is the equation used to calculate load in kg:

Load Reduction (kg/in)=EMC(g/m^3)*Total Area (m^2)*0.0254(m/in)

This value can be used in future estimates of load reduction. For the post-project period, the yearly rainfall of 9/1/15-9/1/16 plus 9/1/16-1/25/17 (25.34") was used for Alice Keck and Vera Cruz calculations. For Quarantina North and South, on the second year was used (13.64").

Total load reduction was calculated as the amount using EMC * Total Area * Rainfall Depth,

Total Load Reduction (M/T) = EMC (M/L^3)*Area (L^2)*Rainfall Depth/Year (L/T)

where M=Mass, L=Length and T=Time

This is the equation used to calculate the Post Project Load Reduction in kg:

Load Reduction (kg/yr)=EMC(g/m)^3*Total Area (m^2)*0.0254(m/in)*8.0 in/yr

Table 6. Load Reduction from Combined LID Parking Lot Sites.

Parameter	Event Mean Concentration, mg/L unless noted[1]	Load Reduction per Inch of Rain Infiltrated by Project, kg[2]	Total Load Reduction, By Project Through 1/25/2017, kg[3]
Fecal Indicator Bacteria			
E. coli	7300 MPN/100 ml	1.1×10^8 MPN	1.7×10^9 MPN
Enterococcus	1.3×10^4 MPN/100 ml	2.2×10^8 MPN	3.5×10^9 MPN
Total coliform	$>2.4 \times 10^4$ MPN/100 ml[4]	$>4.5 \times 10^9$ MPN	$>7.4 \times 10^{10}$ MPN
Organic Carbon (Dissolved)	1.1	0.58	9.5
Nutrients			
Nitrate (as N)	1.0	0.53	8.6
TKN	7.0	3.7	60
Total Nitrogen	8.2	4.3	71
Total Phosphorus	1.8	0.95	16
Hydrocarbons - EFH	3.5	1.8	30
Total Suspended solids	202	110	1700
Total Metals [1]			
Arsenic	<0.005[5]	<0.003	<0.04
Calcium	13	6.9	110
Chromium	0.0070	0.0037	0.060
Copper	0.043	0.023	0.37
Iron	4.4	2.3	38
Lead	0.013	0.0069	0.11

Magnesium	4.8	2.5	41
Manganese	1.8	0.95	16
Nickel	0.0079	0.0042	0.068
Potassium	6.5	3.4	56
Sodium	6.0	3.2	52
Zinc	0.18	0.095	1.6
Surfactants	0.22	0.12	1.9
Pesticides			
Neonicotioids			
Imidacloprid	4.6 ng/L	9.8×10^{-5}	0.0016
Pyrethroids			
Allethrin	<0.85 ng/L	$<3.6x10^{-5}$	$<5.8 x10^{-4}$
Bifenthrin	<2.4 ng/	$<1.5x10^{-4}$	<0.025
Cypermethrin	<0.66 ng/L	$1.2x10^{-4}$	$<9.0x10^{-4}$
Pendimethalin	3.6 ng/L	$8.3x10^{-4}$	0.0061
Permethrin	<17.1 ng/L	<0.0021	<0.037

[1] Medians were used for all fecal indicator bacteria and parameters that had any non-detect results.

[2] Uses total area of 20781.45 m^2.

[3] Uses total rainfall of 13.64 in. for Quarantina North and South, and 25.34 in. for Alice keck and Vera Cruz. Project areas for individual sites were used in calculations.

[4] For total coliform bacteria, the median was greater than the maximum quantification limit.

[5] For all parameters marked with <, the median was less than the highest detection limit, making it impossible to calculate an appropriate EMC. However, because there was at least one result with a detection, the EMCs and load reductions are somewhere between zero and the value listed. Parameters with all non-detect results were not included in the table.

TOXICITY FOLLOW UP

Neonicotinoid Pesticides in Santa Barbara

1. Conduct field work with assistance from UCSB. Field work was competed was is presented below.
2. Finalize contract with USGS to for laboratory analysis. *Contracting was completed.*
3. Meet monthly with UCSB (Lenihan, Means, Mueller). Monthly or more frequent meetings involved data analysis, discussion of laboratory methods, and literature review. An intern was hired to complete the laboratory work at UCSB.

The following is taken from grant reporting material provided to Lenihan for grant reporting (UCSB, Pi of grant project).

Objective 1. To determine the temporal (wet and dry season] patterns of imidacloprid and three related neonicotinoid insecticides as well as several major metabolites in stormwater feeding coastal streams and estuaries in agricultural and urban areas.

Objective 1 was completed. As detailed below, neonicotinoid pesticides and fipronil and its degradates were pervasive in Santa Barbara creeks and estuaries during dry and wet weather, In addition, imidacloprid and fipronil were found frequently above established chronic toxicity thresholds, raising concerns about ecological impacts of the widespread use of systemic pesticides.

Samples were collected during storm events, in order to determine peak concentrations, and following storm events, to assess how long aquatic organisms are exposed to lower concentrations of pesticides

As expected, imidacloprid was detected in every wet weather sample collected (Figure 2). More surprising was that imidacloprid was also detected in every dry weather sample, i.e. the concentration never dropped below detection in samples collected in days to weeks after storm events. Previous sampling by the City found non-detectable levels of imidacloprid in creek samples collected in summer. Two neonicotinoid pesticides, clothianidin and thiacloprid, were not detected in any samples. Acetamiprid, which had not been tested previously by the City, was found in 50% of dry weather and 74% of wet weather samples. Two other neonicotinoid pesticides, dinotefuran and thiamethoxam, were found only in runoff from agricultural areas (see Obj. 2).

Fipronil and/or at least one of its degradates was found in 91% of samples overall (Figure 2). Fipronil was detected in 93% of wet weather and 80% of dry weather samples and fipronil sulfone was detected in 88% and 77% of wet and dry weather samples, respectively. Other degradates were detected less frequently.

Imidacloprid and fipronil were frequently above new US EPA Aquatic Life Benchmarks for chronic invertebrate toxicity in fresh water (Figure 2; US EPA 2017). Imidacloprid was found above the chronic benchmark in 90% of samples and fipronil exceeded the benchmark in 72 % of samples. All results were below acute benchmarks. Imidacloprid benchmarks were updated in 2017 and are now much lower than when this research began. Fipronil benchmarks were updated in 2016, but there is concern that chronic benchmarks are not sufficiently protective (US EPA 2017). All other pesticides were below chronic benchmarks at sites and time points, with the exception of thiamethoxam, for which no chronic benchmark exists.

During the post-storm sampling, no surface runoff was observed in the watersheds sampled, whereas flow continued to discharge from storm drain outlets. We suspect that imidacloprid-contaminated shallow groundwater (also called interflow) infiltrates into storm drains. The solubility of systemic pesticides leads longer discharges of contaminated water, compared to older pesticides with high adsorption coefficients.

Results generated under Obj. 1 will provide ample data for modelers to simulate winter exposure scenarios of imidacloprid and fipronil in coastal streams and estuaries. These results are among the first for surface waters following storm events and for California estuaries.

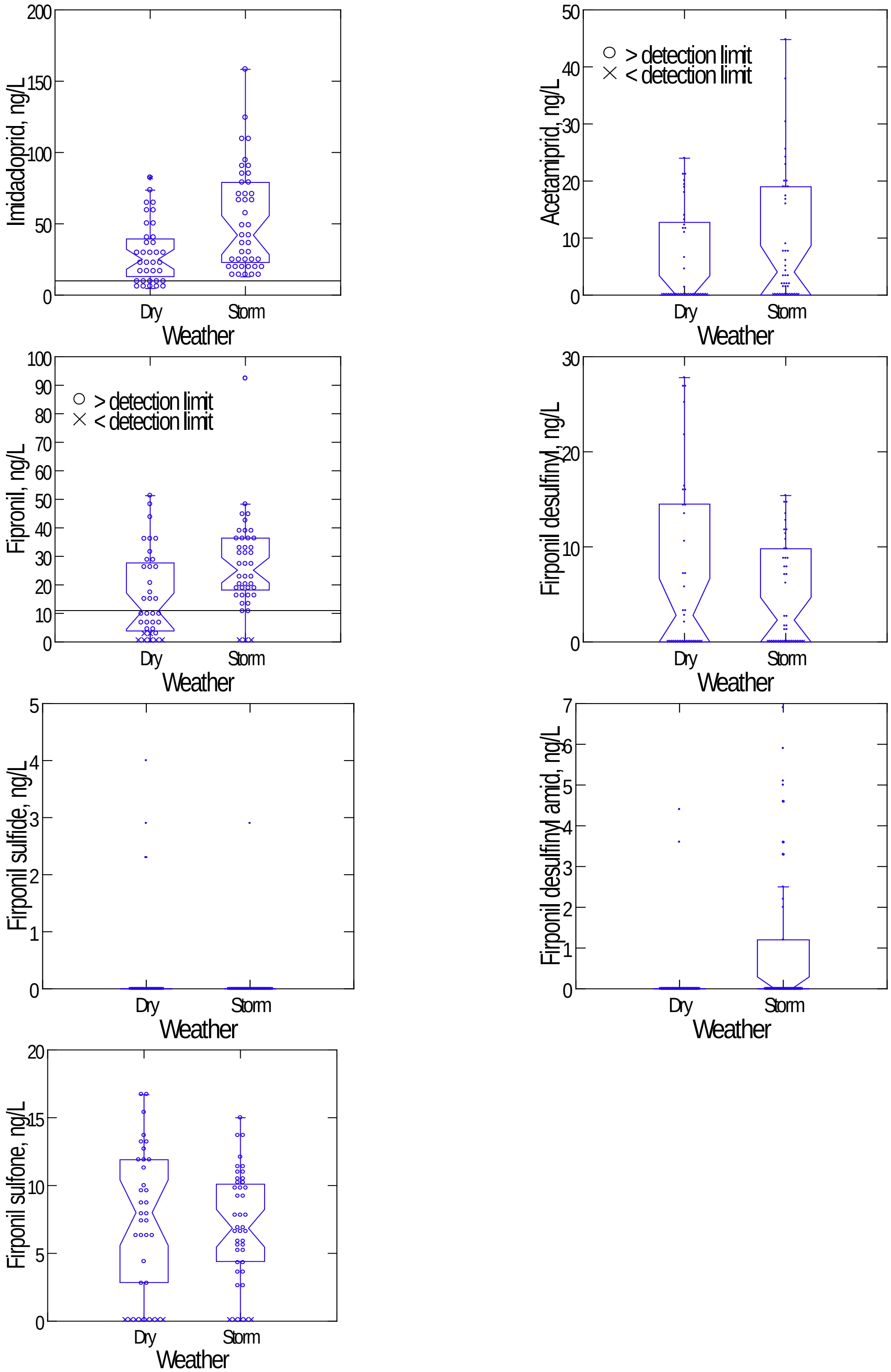

Imidacloprid, ng/L
Acetamiprid, ng/L
Fipronil, ng/L
Firponil desulfinyl, ng/L
Firponil sulfide, ng/L
Firponil desulfinyl amid, ng/L
Firponil sulfone, ng/L
○ > detection limit
× < detection limit
Dry
Storm
Weather

FIGURE 15. CONCENTRATIONS OF NEONICOTINOID PESTICIDES, FIPRONIL, AND FIPRONIL DEGRADATES DURING DRY AND WET WEATHER. SAMPLES BELOW DETECTIONS LEVELS WERE PLOTTED AS ZERO FOR THE PURPOSE OF RANKING AND NONPARAMETRIC STATISTICS. BOXES SHOW THE MEDIAN (NOTCH) AND INTERQUARTILE RANGE. EXTENT OF NOTCHES REPRESENT NONPARAMETRIC CONFIDENCE INTERVALS (SYSTAT 11). DASHED LINES REPRESENT US EPA BENCHMARKS FOR CHRONIC TOXICITY TO AQUATIC INVERTEBRATES (FOR PANELS WITH NO DASHED LINES, RESULTS WERE ALL BELOW AVAILABLE BENCHMARKS.

Objective 2: To test the hypothesis that streams receiving runoff from urban land uses and agricultural (including nursery and greenhouses) land uses have different concentrations and/or loading rates of imidacloprid.

Objective 2 was completed. Imidacloprid was detected in both urban and agricultural runoff. During the storm event of 2/10/17, which was the fourth storm of the season, imidacloprid values were higher in agricultural runoff compared to urban runoff (Figure 3). During the weeks afterward, which was punctuated by a large storm event on 2/18/17, values remained higher in the Carpinteria Salt Marsh (Franklin Creek input, also receives urban runoff) compared to Laguna Channel Lagoon (receives only urban runoff). In the post-storm samples, values remained close to or above the US EPA chronic toxicity threshold.

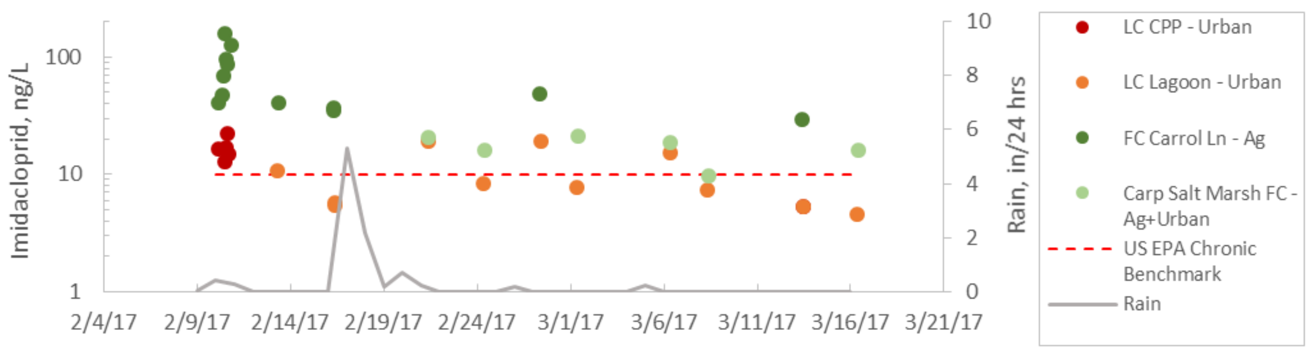


FIGURE 16. IMIDACLOPRID IN RUNOFF FROM URBAN (RED AND ORANGE SYMBOLS) AND AGRICULTURAL (GREEN SYMBOLS) DRAINAGES. DASHED LINE SHOWS US EPA BENCHMARK FOR CHRONIC TOXICITY OF AQUATIC INVERTEBRATES.

One reason that the agricultural area discharged higher concentrations may be more frequent applications of pesticides, compared to homeowners who may treat for ants and termites in summer months. In addition, the ratio of pesticide-treated area to total area may be higher in the agricultural drainage.

In addition to imidacloprid, two pesticides were detected in agricultural runoff that were not found in the urban area. Dinotefuran and thiamethoxam were detected frequently in storm runoff at FC Carroll Ln, but were not found in the urban sites of Santa Barbara.

Objective 3: To test the hypothesis that samples from creeks and estuaries in Santa Barbara will exhibit toxicity when neonicotinoid-sensitive test species and assays are used.

This objective has not yet been completed due to difficulty obtaining commercial laboratory services for toxicity tests using chironomids. The laboratory that the City contracts with was not able to complete the test successfully, due to cannabilism of the test organism, despite multiple attempts. The City is in discussion with alternative laboratories and will complete Objective 3 during winter 2018. Limited toxicity results, using ceriodaphia and hyalella 5-day tests in creek storm flow, showed in 95-100% survival, even when imidacloprid and fipronil were elevated. This result confirms the need for sensitive test species for neonicotinoid research.

Objective 4: To produce pilot-scale data on transport mechanisms of neonicotinoids to urban streams.

Objective 4 has been completed. Pilot scale testing was completed for neonicotinoids and fipronil in various environmental samples. None of the measured pesticides were detected in pure rainwater. Samples of tree pollen, mulch in a City park, and street sweeper material was used to leach pesticides prior to analysis. Of all of the pesticides tested, only imidacloprid was found, and only in the sample of street sweeper material (Table 1).

TABLE 7. PESTICIDES CONCENTRATIONS IN ENVIRONMENTAL SAMPLES THAT WERE LEACHED PRIOR TO ANALYSIS. "ND" SIGNIFIES RESULTS BELOW DETECTION LIMITS.

Site	Imidacloprid, ng/L	All other neonicotinoids, ng/L	Fipronil and degradates, ng/L	Hyalella Toxicity-96 hr, % survival	Ceriodaphnia Toxicity-96 hr, % survival
Rain	nd	nd	nd		
Rain	nd	nd	nd		
Stone Pine Polllen	nd	nd	nd	5	80
Mulch in City Park	nd	nd	nd	0	0
Street Sweeper Material	42.0	nd	nd	95	100
Field Blank	nd	nd	nd		

These results provide a mechanism for understanding previous results obtained in City testing, i.e. imidacloprid was found in runoff from a park that was not treated with pesticides. It is likely that dust, such as that found in street sweeping material, is wind-blown throughout the urban environment. In addition, this result suggests that a more detailed study would be required to develop a detailed model of fate and transport of imidacloprid.

Toxicity tests were also conducted on leached material, with very concerning results (Table 1). For the mulch leachate, 0% survival was found for both test species, and for the pollen, only 5% survival was found with hyalella. This is among the most problematic result obtained in years of testing by the City. The City will pursue additional studies of mulch, pollen, and street sweeper spoils in coming years.

Conclusions

These results, combined with recent US EPA updates to aquatic life benchmarks, present renewed urgency for understanding the ecological impacts of pervasive use of systemic pesticides in urban settings. Imidacloprid is found in hundreds of products sold in home and garden stores and is also used by professional applicators, whereas fipronil is used almost exclusively by professionals. As shown here these contaminants are reaching coastal streams and esturaries during storm events and persisting throughout the rainy season.

A recent study by Hallmann et al. (2017) showed a 76% decline in flying insects in German wildlife refuges; is such a reduction also occurring in urban settings in California? The larval stage of most flying insects occurs in surface waters. When these populations experience chronic toxicity month after month, what is the significance for food webs, including those involving restoration projects and estuary-dependent fisheries? The City and County of Santa Barbara have completed 18 years of bioassessment (aquatic macroinvertebrate community composition) monitoring in local creeks and estuaries. Results show dramatically lower “biological integrity” for urban sites compared to less developed areas, even when measures of habitat, traditional water quality, and traditional toxicity measurements rate high. Is chronic toxicity due to systemic pesticides a hidden stressor to coastal streams and estuaries?

Information for Resource Management

Outreach - The field concentration data, laboratory tests, and modelling results produced here will be used in outreach materials by the City of Santa Barbara. Outreach will include an update a City TV segment produced on neonicotinoid pesticides, printed material to be provided at outreach events, and information provided to landscaping and commercial pest control professionals during focus groups. The City will host an informational meeting specifically for structural pest control operators. In addition, the City is in discussion to renew a partnership with Our Water, Our World and other jurisdictions in Santa Barbara County, in order to update materials (these can be used throughout California) and train salespeople in home and garden stores to encourage sales of organic products. The three main messages to target are:

4) Use IPM/organic methods when practical.
5) Use poisons sparingly and to target known pest outbreaks, rather than using prophylactic products (for example, Bayer’s 12 Month Tree & Shrub Protect & Feed, with 1.1% imidacloprid).
6) Apply poisons in a way that decreases the likelihood for rain to transport the material off site (the solubility of imidacloprid and leaching through soil presents a challenge here).

The City will leverage results of the current research to promptly apply for a grant from the California Department of Pesticide Regulation to fund an outreach alliance for integrated pest management (IPM) outreach regarding systemic pesticides.

Additional Networking and Research – The results of the research thus far suggest the urgent need for a workshop to gather interdisciplinary researchers (academic, NGO, and citizen-science) to ascertain the ecological impacts of systemic pesticides in California, including coastal streams and estuaries. Now that concentration data are showing concerns, the first question to be addressed is whether aquatic and/or flying insect populations are decreasing. Pending a positive response, reasons for a decrease should be examined. In addition to systemic pesticides and habitat loss, there is also the possibility that aggressive mosquito abatement using Bti may impact nontarget insects at ecologically concerning levels.

Pesticide Assessment - Another serious question to address is whether it would be advantageous ecologically to recommend less soluble pesticides, such as pyrethroids, when poisons must be used. While pyrethroids have been implicated for causing stream toxicity in California, the replacement pesticides seem to be more frequently detected due to high solubility. Now that the US EPA has lowered the benchmarks for chronic toxicity, data collected previously should be reassessed in regard to ecological harm caused by various pesticides.

Citations:

Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, et al. (2017) More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE 12(10)

US EPA (2017). Aquatic Life Benchmarks and Ecological Risk Assessments for Registered Pesticides. Accessed 1/7/18 at www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-and-ecological-risk#benchmarks

Bioassessment

The 2016 Southern Coastal Santa Barbara Streams and Estuaries Bioassessment Program Report (available at sbcreeks.com), produced by Ecology Consultants for the Creeks Division and Santa Barbara County Project Clean Water, documents the devastating impacts of the ongoing drought to stream health. The Program involves annual collection and analyses of benthic macroinvertebrate samples and other data at study streams and estuaries. The Index of Biological Integrity (IBI) is used to score the health of creek and estuary sites throughout the South Coast. In most years, reference sites (those considered to be nearly undisturbed by development) have much higher IBI scores than disturbed, urban stream sites. During this past year of drought, scores for reference sites were indistinguishable from disturbed sites due to low flows, separated pools, and very low dissolved oxygen. The bioassessment report contains additional details.

General Permit Requirements

IDDE

Conduct sampling for chemical indicators at any flowing drain in Priority Areas.

1. IDDE		**Sites**: All flowing outfalls in priority areas. **Parameters:** Ammonia, color, conductivity, surfactants, fluoride, hardness, pH, potassium, and turbidity. Add FIB. Frequency: Annually	4. Watershed Stewards to assist with sampling.
2. Monitoring-Special Studies	Conduct monitoring according to Special Studies Plan. Plan includes load reduction monitoring for FIB reduction projects, including: a. Hope Diviersion b. Haley Diversion c. SURF Project d. Parking Lot LID e. Streets, Alley, and Sidewalks LID	**Sites:** Hope Diversion, Haley Diversion, Westside Drain, OMC W. Anapamu. Parameters: FIB	5. Calculate load reductions for Year 3 Report (10/15/16).
3. Monitoring-303(d)	Biweekly FIB sampling as in C.1 and toxicity sampling as in C.8 and D.1.	Parameters: FIB	6. Submit data to CEDEN and

		Frequency: biweekly Parameter: toxicity Frequency:	report to SMARTS by 10/15/16.
4. Performance Evaluation, Assessment, and Identification Plan	General Permit requires quantification of pollutant load reduction by entire stormwater permit. Model choice has yet to be finalized. Creeks Division is on Technical Advisory Committee for Total Evaluation of Load Reduction model (TELR).	Creeks Division to choose between two pollutant models by testing performance, costs, and benefits of both. Model output (catchment ranking) will also be compared to simple ranking by % Impervious and Impervious Acres.	7. WQ Interns to conduct mapping and modeling under Creeks supervision.

Introduction

During Permit Year 4, the City carried out monitoring for Special Studies and 303(d) Monitoring under Regional-Board Approved Monitoring Plan/QAPPs. The City also carried out extensive monitoring and research under the Creeks Advisory Committee-approved Water Quality Research and Monitoring Plan (not included here).

Special Studies Monitoring

Special Studies Monitoring was carried out according to the approved Monitoring Plan/QAPP with the following exceptions: the Haley Drain was not sampled due to lack of flow during the drought. The Hope Drain and Westside Drain were not sampled due to lack of operation. As discussed in the Year 3 Monitoring Report, the City moved forward with a second LID project, the Streets, Sidewalks and Alleys Project.

The City will complete and have available a report (50 page maximum) that includes a comparison of data collection to baseline data, and discussion of monitoring program results, to be included with or attached to the fifth year Annual Report.

303(d) Monitoring

303(d) Monitoring was carried out according to the approved Monitoring Plan/QAPP with the following exceptions:

Sycamore Creek was not sampled on 17 sample dates due to non-existent flow in the creek. Mission Creek was not sampled on four samples dates, and Arroyo Burro was not sampled on seven sample dates due to holiday closures of City offices and staff illness. Fecal indicator bacteria results are shown in Figure 1. Project Action Limits are shown for visual comparison; however additional calculations are required to demonstrate exeedances. Table 1 shows the samples which exceed Project Action Limits; note, however, that the water quality objectives underlying the Project Action Limits were developed mostly for beach environments and are not typically applied to freshwater. For comparison purposes, beach water quality exceedances are summarized in Table 2 (these data were acquired from the County of Santa Barbara and were not sampled by the City).

Toxicity testing was partially completed during Permit Year 4 due to limited staff resources during particular storms, insufficient time between forecasted storm arrival and rain for the contract laboratory to prepare for samples, and the contract laboratory's inability to complete the *Chironomus* test successfully. City staff have communicated with Regional Board staff and will attempt to contract with an alternative laboratory during Permit Year 5.

There is no separate or specific report required by the Permit for this Project. Fecal indicator bacteria data generated under this project have been uploaded and checked by the Regional Data Center for upload to California Environmental Data Exchange Network (CEDEN). Toxicity data will be entered during Permit Year 5.

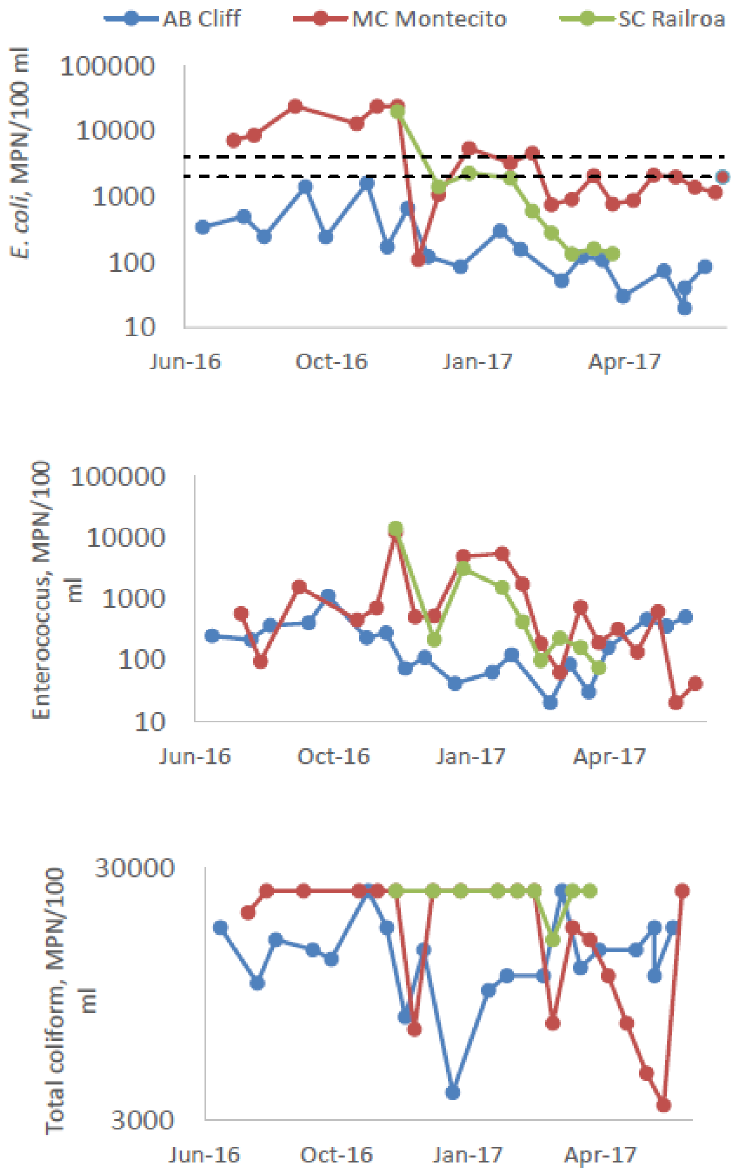


Figure 1. Fecal indicator bacteria results during Permit Year 4. Missing data points represent dates when creek was not flowing due to drought. Horizontal lines represent or partially represent Project Action Limits as follows: fecal coliform/E. coli, 10% of samples should not exceed 4,000 MPN/100 ml (upper line) during any 30 day period and 5-sample/30 day geomean should not exceed 2,000 MPN/100 ml (lower line); note that due to only two samples collected per 30-day period, the upper limit functions as a single sample maximum for these samples and note that geomeans were not calculated due to sampling frequency < 5 samples/30 days. Enterococcus: no Project Action Limit. Total coliform: Samples should not exceed 1,000 MPN/100 ml when the ratio of fecal coliform/total coliform>0.1.

Table 1. 303(d) Fecal Indicator Bacteria Monitoring Results, Permit Year 4. Shading represents exceedances. See Figure 1 heading for standards.

StationID	Date		E. coli		Enterooccus		Total Coliform	Ratio of Fecal:Total Coliform
AB Cliff	11/Jul/2016		345		246		17329	0.020
AB Cliff	08/Aug/2016		496		213		10462	0.047
AB Cliff	22/Aug/2016		246		369		15531	0.016
AB Cliff	19/Sep/2016		1430		404		14136	0.101
AB Cliff	03/Oct/2016		243		1112		12997	0.019
AB Cliff	31/Oct/2016		1607		231	>	24192	0.066
AB Cliff	14/Nov/2016		171		278		17329	0.010
AB Cliff	28/Nov/2016		663		73		7701	0.086
AB Cliff	12/Dec/2016		121		109		14136	0.086
AB Cliff	03/Jan/2017		86		41		3873	0.022
AB Cliff	30/Jan/2017		301		63		9804	0.031
AB Cliff	13/Feb/2017		156		121		11199	0.014
AB Cliff	13/Mar/2017		52		20		11199	0.005
AB Cliff	27/Mar/2017		121		85	>	24192	0.005
AB Cliff	10/Apr/2017		108		30		12033	0.009
AB Cliff	24/Apr/2017		30		161		14136	0.002
AB Cliff	22/May/2017		74		464		14136	0.005
AB Cliff	05/Jun/2017		20		359		17329	0.001
AB Cliff	19/Jun/2017		86		504		17329	0.005
MC Monteci	01/Aug/2016		7270		576		19863	0.366
MC Monteci	15/Aug/2016		8664		95	>	24192	
MC Monteci	12/Sep/2016	>	24192		1565	>	24192	
MC Monteci	24/Oct/2016		12997		450	>	24192	
MC Monteci	07/Nov/2016		24192		712	>	24192	
MC Monteci	21/Nov/2016	>	24192		12033	>	24192	
MC Monteci	05/Dec/2016		109		504		6867	0.016
MC Monteci	19/Dec/2016		1081		521	>	24192	0.045
MC Monteci	09/Jan/2017		5475		4884	>	24192	
MC Monteci	06/Feb/2017		3282		5475	>	24192	
MC Monteci	21/Feb/2017		4611		1726	>	24192	
MC Monteci	06/Mar/2017		754		185	>	24192	0.031
MC Monteci	20/Mar/2017		909		62		7270	0.125
MC Monteci	04/Apr/2017		2098		727		17329	0.121
MC Monteci	17/Apr/2017		771		189		15531	0.050
MC Monteci	01/May/2017		884		317		11199	0.079
MC Monteci	15/May/2017		2143		134		7270	0.295
MC Monteci	30/May/2017		1989		613		4611	0.431
MC Monteci	12/Jun/2017		1401		20		3448	0.406
MC Monteci	26/Jun/2017		1162		41		24192	0.048
SC Railroa	21/Nov/2016		19863		14136	>	24192	
SC Railroa	19/Dec/2016		1430		213	>	24192	0.059
SC Railroa	09/Jan/2017		2282		3130	>	24192	0.094
SC Railroa	06/Feb/2017		1935		1529	>	24192	0.080
SC Railroa	21/Feb/2017		605		426	>	24192	0.025
SC Railroa	06/Mar/2017		282		98		24192	0.012
SC Railroa	20/Mar/2017		134		228		15531	0.009
SC Railroa	04/Apr/2017		161		161	>	24192	0.007
SC Railroa	17/Apr/2017		135		74	>	24192	0.006

Exeedances			13				7	

Table 2. Santa Barbara County Beach Water Quality Results during Calendar Year 4 for Beaches Impacted by 303(d) impaired water sampled here. Warning means one or more of the AB 411 criteria were exceeded, and n.s. represents no sample was collected, typically on days where resamples were collected for some beaches but not others. Blank cells represents that the sample was collected and the results were within compliance with the standards.

Date	Arroyo Burro	Mission Creek at East Beach	Sycamore Creek at East Beach
7/5/2016	Warning		Warning
7/11/2016			
7/18/2016		Warning	
7/25/2016			
9/19/2016			
9/12/2016			
9/6/2016			
8/29/2016			
8/22/2016			
8/15/2016			
8/8/2016			
8/1/2016			
8/8/2016			
9/26/2016			
10/3/2016			
10/10/2016			
10/31/2016			
10/17/2016			
10/24/2016			
11/7/2016			
11/14/2016	Warning		
11/21/2016			
11/28/2016		Warning	
12/5/2016			
12/12/2016			
12/19/2016	Warning		
1/3/2017			
1/9/2017	Warning	Warning	Warning
1/17/2017			
1/23/2017	Warning	Warning	Warning
2/6/2017	Warning	Warning	Warning
2/13/2017			
2/13/2017			
2/21/2017	Warning	Warning	Warning
3/6/2017	Warning	Warning	
3/13/2017	Warning		
3/15/2017		n.s.	n.s.
3/20/2017	Warning		
3/27/2017			
4/11/2017			
4/17/2017			
5/1/2017			
5/8/2017		Warning	
5/10/2017	n.s.		n.s.

5/15/2017			
5/22/2017			
5/30/2017			
6/5/2017			
6/12/2017			
6/26/2017			

Sampling Table for FY 17 Research Plan.

Shaded rows mark areas of primary focus and staff time during FY 17, as described in the May 2016 Staff Report.

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
A. Grant Project Monitoring Requirements			
1	a. Calculate the load of pollutants infiltrated during 2014-15 rain events at 4 sites, based on Event Mean Concentration results from FY 2015 results. b. Maintain HOBO data loggers and graph results. c. Provide information for grant reporting. d. Report according to approved Monitoring Plan/Quality Assurance Project Plan.	No sampling required for FY 17, only data analysis and calculations.	8. Load calculations through October 2016. 9. Draft Final Report due January 2017

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
	a. Partnership with UCSB and USGS to study neonicotinoid pesticides in SB. b. Three components: a. Field work (City/USGS)	See storm monitoring below.	10. Conduct field work with assistance from UCSB. 11. Finalize contract with USGS to for laboratory analysis.

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
	b. Laboratory toxicology studies (UCSB) c. Modeling studies (UCSB)		12. Meet monthly with UCSB (Lenihan, Means, Mueller).

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
B. General Permit Requirements			
5. IDDE	Conduct sampling for chemical indicators at any flowing drain in Priority Areas.	**Sites**: All flowing outfalls in priority areas. **Parameters:** Ammonia, color, conductivity, surfactants, fluoride, hardness, pH, potassium, and turbidity. Add FIB. Frequency: Annually	13. Watershed Stewards to assist with sampling.
6. Monitoring-Special Studies	Conduct monitoring according to Special Studies Plan. Plan includes load reduction monitoring for FIB reduction projects, including: f. Hope Diviersion g. Haley Diversion h. SURF Project i. Parking Lot LID	**Sites:** Hope Diversion, Haley Diversion, Westside Drain, OMC W. Anapamu. Parameters: FIB	14. Calculate load reductions for Year 3 Report (10/15/16).

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
	j. Streets, Alley, and Sidewalks LID		
7. Monitoring-303(d)	Biweekly FIB sampling as in C.1 and toxicity sampling as in C.8 and D.1.	Parameters: FIB Frequency: biweekly Parameter: toxicity Frequency:	15. Submit data to CEDEN and report to SMARTS by 10/15/16.
8. Performance Evaluation, Assessment, and Identification Plan	General Permit requires quantification of pollutant load reduction by entire stormwater permit. Model choice has yet to be finalized. Creeks Division is on Technical Advisory Committee for Total Evaluation of Load Reduction model (TELR).	Creeks Division to choose between two pollutant models by testing performance, costs, and benefits of both. Model output (catchment ranking) will also be compared to simple ranking by % Impervious and Impervious Acres.	16. WQ Interns to conduct mapping and modeling under Creeks supervision.
C. Watershed Assessment			
1. Is overall water quality, in terms of indicator bacteria, field properties, and bioassessment getting better over time?	Long term sampling of integrator sites.	**Sites:** Integrator Sites (3), Honda and Lighthouse	17. Inform El Estero of sampling schedule for FY 17. 18. Review 2016 Bioassessment Report when available.

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
	Long term bioassessment at select sites.	**Parameters:** FIB, field parameters, flow. **Frequency:** Biweekly for integrators, quarterly for Honda and Lighthouse.	
2. Are pharmaceutical and personal care products (PPCPs) reaching creeks?	Sample discharge from recycled water spigots.	On hold. See SCCWRP list for parameters.	
3. What are the background daily cycles of water flow in Santa Barbara creeks? Is there a daily pumping in or removal of water from Arroyo Burro, including San Roque Creek	HOBO level loggers, creek walks, no sampling required.	None. San Roque Creek is dry now.	19. Internal deadline: Install level logger by 8/1/2016.
4. Are new and emerging contaminants detected in dry weather?	Integrator sites tested one time for pyrethroids and neonics, all ND. However, sumithrin and dichloran not included. Focus now on neonics in irrigation runoff.	**Sites:** Dry weather outfall sampling where we know irrigation runoff to occur (TBD). **Parameters:** Sumithrin, dichloran, neonics. **Frequency:** one time, dry weather.	20. Keep abreast of new pesticides, etc.
5. Are low dissolved oxygen concentrations responsible for some low bioassessment scores in	Use data loggers to record DO levels in pools and riffles.	**Sites:** Rattlesnake, Mission Canyon, Bioassessment Sites.	21. Formalize technical advisory input from UCSB.

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
Santa Barbara? What are nighttime DO concentrations throughout Mission Creek?		**Parameters:** DO, temperature, **Frequency:** Two week installations, log every 5 minutes.	
D. Storm Monitoring			
1. Is there toxicity in Mission Creek during storm events?	Two storms, per 303(d) Monitoring Plan to be approved by Regional Board.	**Sites:** Mission Creek at Montecito. **Parameters:** Selenastrum toxicity, other spp. **Frequency:** Two storms, may be first flush.	
2. New and Emerging Contaminants: Neonicotinoid Pesticides a. What is the spatial and temporal variability of neonics concentrations? b. What are the sources in the urban environment? **c.** What is the ecological impact of neonics at low concentrations?		**Sites:** Mission Creek at Cabrillo , Franklin Creek in Carpinteria, **Parameters:** Neonicotinoids, Fipronil **Frequency:** 3 storms, 12 time points per storm.	

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
1. Is runoff from coal tar sealed parking lots and slurry sealed roads more toxic than untreated surfaces?	On hold for FY 17.		Inquire with UCSB (Means) about partnership.
2. Upper Las Positas (Golf Course)	Measure infiltration rate of basins.	HOBO loggers installed in FY 16. Review data.	
3. MacKenzie LID	Maintain HOBO data loggers and graph results.	None.	
4. Parking Lot Storm Water Treatment Demonstration Project.	Maintain HOBO data loggers and graph results.	None.	
5. Streets, Sidewalks and Alleys LID	See A.2.		22. Tim Burgess
6. Fish Passage Projects	Flow measurements		23. George Johnson, Watershed Stewards
7. Permit PAEIP – Private BMPs	See B. 4	**Sites:** 5 private BMPs (TBD), upstream & downstream, 10 total.	24. Jim Rumbley to identify sites based on BMPS inspections.

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
		Parameters: Hydrocarbons, trash, nutrients, bacteria, TSS, pesticides, herbicides **Frequency:** 3 time points (same or different storms).	
8. Bird Refuge – What are source of nutrients in storm events?	On hold for FY 17.		25.
9. Are human waste markers present in creek flow during wet weather?	See Source Tracking below.	None.	
E. Restoration and Water Quality Project Assessment			
1. Westside SURF and Old Mission Creek Restoration (see annual report for details)		**Sites:** SURF up, SURF down, Westside Drain, OMC at W. Anapamu, **Parameters:** FIB, field. **Frequency:** Weekly for SURF operation, biweekly for downstream impacts when SURF in operation.	

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
2. Arroyo Burro Restoration.	Suspension of quarterly testing until results from biweekly testing warrant a change.	**Sites:** AB at Cliff, AB Estuary upper, AB Estuary Mouth **Parameters:** FIB, field. **Frequency:** biweekly.	Include results in FY16 WQ Report.
3. Hope and Haley Diversions	See B.2.	**Sites:** Hope Diversions, Haley Pump **Parameters:** FIB, field **Frequency:** Quarterly	
4. Upper Las Positas Restoration	See storm monitoring.		
5. MacKenzie Park Storm Water Treatment Retrofit	See storm monitoring.		
6. Storm Water Infiltration Demonstration Project (Parking Lot LID)	See storm monitoring		
7. Streets, Alleys, and Sidewalks LID	See Permit monitoring		
8. Debris Screens (Creek Walks)	Conduct thorough analysis of FIB data to test role of debris screens and leaf litter reduction.		

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
9. Mission Creek Fish Passage (Eutrophication/Dissolved Oxygen)	Dissolved Oxygen, pH, temperature, conductivity (nutrients as part of above study)	MC Lagoon, MC upper reaches	Analyze for summer months, collect data continuously.
10. Laguna Channel Disinfection	Include site in contract with UCSB.	Sample scavenger pump discharge for human waste markers.	
11. Bird Refuge	a. Continue monitoring aeration pilot project and annual cycles. b. Conduct sampling for potential project analysis as needed.	**Sites:** Aeration and open sites. Parameters: field Frequency: Weekly.	
12. Las Positas Creek Restoration Project. What are the flow patterns in dry weather?	Measure flow in channel and test for temperature increases along concrete channel.	**Sites:** Every 25' along concrete reach **Parameters:** Temperature **Frequency:** Quarterly	26. Manage HOBO logger in lower end of concrete reach
13. Upper Arroyo Burro Restoration (Barger) a. Is water being pumped from creek or adjacent groundwater? b. What is the historical water quality?	c.	**Sites:** Upper and lower end of project. **Parameter:** FIB, nutrients, field. **Frequency:** Quarterly	Purchase and install HOBO in lower end of concrete reach

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
c. Identify any data gaps. 10.			
14. Arroyo Burro Open Space	Conduct ongoing bioassessment for baseline measurements. WQ sampling to be determined.		
15. Trash Capture Devices	Develop monitoring plan to collect baseline data for trash capture.	No sampling in FY 17.	
F. Source Tracking			27.
1. Conduct IDDE investigation per General Permit (Section B).	See above.		28.
2. What are the causes of persistent beach warnings that occur?	Conduct additional surveillance and sampling (indicator bacteria and/or DNA techniques) up creek and within estuaries when persistent warnings occur.		As needed (none in FY 16)
3. Are there pathogens present in Santa Barbara creeks? Are SB beaches suitable for Quantitative	Hold for FY 17, except as included in UCSB MST project.		

PROGRAM ELEMENT and QUESTIONS	APPROACH/Methods	SAMPLING Sites, Parameters, FrEQUENCY	responsible Party IF NOT CREEKS/Deadlines
Microbial Risk Assessment (QMRA)?			
4. How do FIB, host-specific markers and pathogens decay in lagoons?			UCSB Project; results to be released soon.
5. Is RV dumping a problem in Santa Barbara?	Observation.	Situational.	
6. What is the risk to human health from recreation in creeks and beaches in Santa Barbara?	Use new epidemiology studies in Southern California to conduct simple model of illness rates at Santa Barbara beaches. No sampling required.		Include in FY 16 Annual Report.
7. Are human waste markers present and associated with beach warnings at Leadbetter Beach and E. Beach at Sycamore?	Clean Beaches Initiative Grant to fund microbial source tracking at Leadbetter and E. Beach at Sycamore.		UCSB and Geosyntec.
11. Are human waste markers present in creek flows during wet weather?	Grant in F.8 includes wet weather sampling.		UCSB sampling as part of MST project.
12. Historical FIB Data Analysis	Update previous historical analysis conducted in 2009 and submit to peer reviewed journal.		Partnership with UCSB.