Middle Santa Ana River Bacterial Indicator TMDL Implementation Final Report

June 2017

CDM Smith

ON BEHALF OF

Santa Ana Watershed Project Authority

San Bernardino County Stormwater Program

County of Riverside

Cities of Chino Hills, Upland, Montclair, Ontario, Rancho Cucamonga, Rialto, Chino, Fontana, Norco, Corona, Riverside, Pomona, and Claremont

Table of Contents

List of Figures

List of Tables

Appendices

Section 1

Introduction

This Triennial Report has been prepared to fulfill the Middle Santa Ana River (MSAR) Bacterial Indicator TMDL (TMDL) ("MSAR Bacterial Indicator TMDL") requirement to submit a Triennial Report to the Santa Ana Regional Water Quality Control Board (RWQCB) every three years. The purposed of this report is to provide an update regarding progress towards meeting wasteload allocations (WLA) and load allocations (LA) established by the TMDL. This section provides an overview regarding the regulatory background and purpose for this report. Subsequent report sections provide an update of knowledge gained over the past three years regarding sources of bacteria and progress towards meeting the dry and wet weather WLAs and LAs.

1.1 Regulatory Background and Purpose

Water quality data collected in 1994 and 1998 from waterbodies in the MSAR watershed showed exceedances of fecal coliform bacterial indicator water quality objectives. Based on these data and potential impacts to recreational uses, the RWQCB recommended that the following waterbodies be placed on the 303(d) list:

- Santa Ana River, Reach 3 – Prado Dam to Mission Boulevard (excludes Prado Basin Management Zone)
- Chino Creek, Reach 1 – Santa Ana River confluence to beginning of hard lined channel south of Los Serranos Road
- Chino Creek, Reach 2 – Beginning of hard lined channel south of Los Serranos Road to confluence with San Antonio Creek
- Mill Creek (Prado Area) – Natural stream from Cucamonga Creek Reach 1 to Prado Basin
- Cucamonga Creek, Reach 1 – Confluence with Mill Creek to 23rd Street in City of Upland
- Prado Park Lake

Waterbodies on the 303(d) list are subject to the development of a TMDL. Accordingly, on August 26, 2005 the RWQCB adopted Resolution No. R8-2005-0001, amending the Water Quality Control Plan for the Santa Ana Region (Basin Plan) to incorporate bacterial indicator TMDLs for the above-listed waterbodies in the watershed (e.g., MSAR Bacterial Indicator TMDL) (RWQCB 2005). The TMDLs adopted by the Board were subsequently approved by the State Water Resources Control Board (State Water Board) on May 15, 2006, by the Office of Administrative Law (OAL) on September 1, 2006, and by the Environmental Protection Agency (EPA) Region 9 on May 16, 2007. The EPA approval date is the TMDL effective date.

The MSAR Bacterial Indicator TMDL established WLAs for urban municipal separate storm sewer systems (MS4) and confined animal feeding operation (CAFO) discharges and LAs for agricultural and natural sources. When the TMDL was adopted, the WLAs and LAs were established for both fecal coliform and *E. coli*:

- Fecal coliform: 5-sample/30-day logarithmic mean (or geometric mean) less than 180 organisms/100 mL and not more than 10 percent of the samples exceed 360 organisms/100 mL for any 30-day period.

- *E. coli*: 5-sample/30-day logarithmic mean (or geometric mean) less than 113 organisms/100 mL and not more than 10 percent of the samples exceed 212 organisms/100 mL for any 30-day period.

The TMDL listed a number of required tasks for implementation by urban and agricultural dischargers in the MSAR portions of Riverside and San Bernardino Counties, including establishment of a watershed-wide compliance monitoring program and establishment of an urban and agricultural source evaluation programs. In addition, the TMDL required preparation of a Triennial Report every three years to assess the status of compliance with TMDL WLAs and LAs.[1]

1.2 Regulatory Actions

Subsequent to adoption of the TMDL, the following regulatory actions have occurred that are relevant to the implementation of the MSAR Bacterial Indicator TMDL:

- On January 29, 2010, the RWQCB adopted new MS4 permits for the Santa Ana Region of Riverside County (Order No. 2010-0033, NPDES No. CAS618033) and San Bernardino County (Order No. 2010-0036, NPDES No. CAS618036). These MS4 permits incorporated the TMDL requirements applicable to MS4 dischargers in the MSAR watershed. In addition, the MS4 Permit also required the development of a Comprehensive Bacteria Reduction Plan (CBRP) by each County. The CBRP is designed to provide a comprehensive plan for attaining the MS4 Permit's water quality based effluent limits for the MSAR Bacterial Indicator TMDL by integrating existing control programs and efforts with new permit mandates and other additional activities necessary to address controllable urban sources of bacterial indicators. Each County submitted final CBRPs to the RWQCB in June 2011. The RWQCB approved both CBRPs on February 10, 2012.[2]

- To fulfill Los Angeles County 2012 MS4 Permit requirements issued by the Los Angeles Water Quality Control Board, additional CBRPs were completed by the Cities of Pomona and Claremont for the portions of their cities that are within the MSAR watershed and subject to MSAR Bacteria TMDL requirements. These CBRPs were approved by the RWQCB on March 14, 2014.[3]

---

[1] Previous reports were prepared in 2010 and 2013

[2] RWQCB Resolutions: R8-2012-0015 (Riverside County MS4 Program); R8-2012-0016 (San Bernardino County MS4 Program)

[3] RWQCB Resolution: R8-2014-0030 (City of Claremont); R8-2014-0031 (City of Pomona)

- On June 15, 2012, the RWQCB adopted a Basin Plan amendment (BPA) to *Revise Recreation Standards for Inland Freshwaters in the Santa Ana Region*[4]. This BPA was developed in collaboration with the Stormwater Quality Standards Task Force, comprised of representatives from various stakeholder interests, including the Santa Ana Watershed Protection Authority (SAWPA); the counties of Orange, Riverside, and San Bernardino; Orange County Coastkeeper; Inland Empire Waterkeeper; and EPA Region 9. The BPA was approved by the State Water Board on January 21, 2014[5] and OAL on July 2, 2014[6]. The EPA issued its letter of approval/disapproval on April 8, 2015 and provided a letter of clarification on August 3, 2015.

  The approved BPA resulted in a number of key modifications to the Basin Plan for the Santa Ana region.[7] Of particular significance to the MSAR Bacterial Indicator TMDL was the removal of fecal coliform as a REC-1 water quality objective and identification of criteria for temporary suspension of recreation use designations and objectives (high flow suspension). While these changes to the Basin Plan became effective near the end of this Triennial Review period, the bacterial indicator analyses contained herein focus only on *E. coli* rather than fecal coliform. This approach was taken because with the approval of the BPA, the fecal coliform TMDLs, WLAs and LAs contained in MSAR Bacterial Indicator TMDL are no longer effective.[8]

1.3 Implementation Activities (2013-2015)

1.3.1 Urban Dischargers

During the 2012-2015 period leading up to this 2016 Triennial Review, the MS4 Permittees completed the CBRP requirements for implementation of an Inspection Program. The Inspection Program (CBRP Element 2) involved the development and implementation of bacteria source evaluations at outfalls from MS4s to receiving waters (Tier 1) and tracking and elimination of specific sources within MS4 drainage areas (Tier 2) to prioritized Tier 1 sites. Tier 1 source evaluations were conducted in the 2011 and 2012 dry seasons and were reported in the 2013 Triennial Review report. Tier 2 source evaluations have spanned 2013 through 2015 and are summarized in Section 3.1 of this report. More detailed data presentation and analysis from Tier 2 source evaluations can be found in the *Tier 2 Source Evaluation Report*, *Technical Memorandum on the results of the Residential Property Scale Bacteria Water Quality Study*, and *Draft Uncontrollable Bacteria Source Study Report*. These documents are included as Appendix A to this 2016 Triennial Review Report (see Appendix A).

---

[4] Santa Ana Water Board Resolution: R8-2012-0001, June 15, 2012

[5] State Water Board Resolution: 2014-0005, January 21, 2014

[6] Office of Administrative Law: #2014-0520 -02 S; July 2, 2014

[7] Page 2 of Attachment 2 to the Santa Ana Water Board Resolution: R8-2012-0001, as approved on June 15, 2012 and corrected on February 12, 2013 and November 15, 2013.

[8] Footnote "c" to Table 5-9x in the MSAR Bacterial Indicator TMDL Staff Report (Resolution R5-2005-0001) states that "The fecal coliform TMDLs, WLAs, and LAs become ineffective upon the replacement of the REC1 fecal coliform objectives in the Basin Plan by approved REC1 objectives based on *E. coli*." Table 4-pio (Pathogen Indicator Bacteria Objectives for Fresh Waters) in the BPA lists *E. coli* as the REC1 objectives (Page 39 of Attachment 2 to the Santa Ana Water Board Resolution R8-2012-0001, as corrected). These were approved by EPA on April 8, 2015.

The Tier 1 and 2 source evaluations were completed as required by the CBRP and were successful in characterizing all known sources of dry weather flow (DWF) to impaired waters and where controllable, mitigation actions should be considered. To our knowledge, there remain no MS4 drainages areas that have not been fully evaluated and as needed, incorporated into plans for bacteria source elimination or management with mitigation measures. Thus, MS4 Permittees do not plan to conduct any new large-scale synoptic source evaluations in the near term. Instead, source evaluations completed in subsequent years will be conducted on an as needed basis to supplement findings of the Inspection Program and assess effectiveness of new bacteria source elimination actions or other mitigation measures suspected to provide water quality improvement or reduction of DWF rates.

Other required elements of the CBRP include ordinances (Element 1), specific mitigation measures (Element 3), and structural controls (Element 4). Progress towards completing the recommended activities in the CBRP on these elements has been reported in annual Stormwater Program reports for the region and the Reports of Waste Discharge (ROWDs) submitted by the Riverside and San Bernardino County MS4 Programs to the RWQCB in 2014. Table 1-1 summarizes CBRP activities for each of MS4 program.

Table 1-1. Summary of CBRP implementation activities by MS4 Program (2013-2015)

MS4 Programs	Element 1 (Ordinances)	Element 2 (Inspection Program)	Element 3 (Mitigation Measures)	Element 4 (Structural Controls)
San Bernardino County Stormwater Program	All Permittees have reviewed and updated water conservation ordinances. Programs to enforce ordinances are complete and implementation is ongoing.	▪ Tier 1 and 2 source evaluations; ▪ Hydrologic connectivity studies updated in ROWD; ▪ Residential Property Scale Bacteria Study	▪ Outdoor water efficiency BMPs deployed and tracked through rebate program participation; ▪ More frequent MS4 training programs including CBRP in syllabus; ▪ Transient encampment management; ▪ IC/ID follow-up	▪ Mill Creek Wetlands; ▪ Chris Basin bottom reconfiguration; ▪ Collaboration with IEUA on extensive regional recharge
Riverside County Stormwater Program		▪ Tier 1 and 2 source evaluations Uncontrollable bacteria sources study; ▪ Flow contributions during dry weather evaluated in ROWD; ▪ Arlington Greenbelt Sampling	▪ Transient encampment management; ▪ IC/ID follow-up	▪ Diversion of Phoenix SD to Riverside WQCP; ▪ Monroe Basin Retrofit Phase 2; ▪ Lincoln/Cota Street Recharge Project; ▪ Eastvale MDP Line D and Line E Water Quality Enhancement Projects; ▪ Arlington groundwater extraction and treatment
Pomona and Claremont MS4s		▪ Tier 1 and 2 source evaluations		

1.3.2 Agricultural Dischargers

In December 2014, agricultural dischargers submitted a final Bacterial Indicator Agricultural Source Management Plan (BASMP) to the RWQCB for review and approval. Per the MSAR Bacterial Indicator TMDL, the BASMP includes plans and schedules for the following:

- Implementation of bacteria indicator controls, best management practices (BMPs) and reduction strategies designed to meet load allocations;
- Evaluation of effectiveness of BMPs; and
- Development and implementation of compliance monitoring program(s).

Pending RWQCB approval, the BASMP will replace the Agricultural Source Evaluation Plan, a 2008 TMDL deliverable that was previously approved by the RWQCB.[9]

[9] Santa Ana Water Board Resolution: R8-2008-0044, April 18, 2008

Section 2

Triennial Report

2.1 Introduction

The MSAR Bacterial Indicator TMDL requires implementation of a watershed-wide compliance monitoring program for bacterial indicators. This program, which was initiated in July 2007, has collected bacterial indicator data from five sites in the MSAR watershed during both the dry and wet seasons.[1] Specifically, dry weather samples have been collected weekly over 20 consecutive weeks generally from May to September in the summer and over 11 consecutive weeks generally from late December through early March in the winter. In addition, one wet weather event is sampled each year, typically during late fall or early winter.

Biannual data reports have been produced to provide the dry and wet season sample results (see SAWPA 2013a, 2013b, 2014a, 2014b, 2015a, and 2015b for reports prepared during the most recent triennial review period). These periodic monitoring reports are submitted to the RWQCB to comply with CBRP reporting requirements (see CBRP Table E-5). In addition to the biannual reporting requirement, the TMDL requires preparation of a water quality assessment every three years that summarizes the data collected for the preceding three-year period and evaluates progress towards achieving the WLAs and LAs. This requirement or Triennial Report is also included in the RWQCB-approved CBRPs for San Bernardino County and Riverside County (see CBRP Table E-5). Triennial Review Reports were completed in 2010 (SAWPA 2010) and 2013 (SAWPA, 2013c).

This section constitutes the third Triennial Report submitted for the MSAR Bacterial Indicator TMDL. It summarizes the results of dry and wet weather watershed-wide compliance monitoring conducted from the 2012-2013 wet season through the 2015 dry season. The findings are presented within the context of the WLAs and LAs applicable to the MSAR Bacterial Indicator TMDL.

2.2 Water Quality Program Summary (2012-2015)

The MSAR Bacterial Indicator TMDL required urban and agricultural dischargers to implement a watershed-wide bacterial indicator monitoring program by November 2007 (RWQCB 2005). The dischargers worked collaboratively through the MSAR Watershed TMDL Task Force[2] ("Task Force") to develop this program, and prepared a Monitoring Plan and Quality Assurance Project

[1] Prior to the 2009 dry season, Icehouse Canyon was included as watershed-wide compliance monitoring site. However, with RWQCB approval the Task Force removed this site from the sampling program prior to the start of the 2009 dry season monitoring program.

[2] This Task Force includes representation by key watershed stakeholders, including representatives of the MS4 programs for Riverside and San Bernardino Counties, the Cities of Claremont and Pomona, agricultural operators, RWQCB, and SAWPA.

Plan (QAPP) in 2007 that was subsequently approved by the RWQCB. These documents have been updated, as needed, to support MSAR Bacterial Indicator TMDL monitoring activities.[3]

The Task Force implemented the monitoring program in July 2007 following RWQCB approval of program documents; the program continues on a seasonal basis. This section focuses on the findings from the most recent three-year monitoring period.

2.2.1 Watershed-wide Compliance Monitoring Sites

The Task Force currently samples five watershed-wide compliance monitoring sites in the MSAR watershed.[4] Table 2-1 and Figure 2-1 identify these five locations. Attachment A of the Monitoring Plan (see footnote 2) provides additional information about each sample location.

Table 2-1 Watershed-Wide Compliance Monitoring Program Sample Sites

Waterbody	Sample Location	Site Code
Prado Park Lake	Prado Lake Outlet	WW-C3
Chino Creek	Central Avenue	WW-C7
Mill-Cucamonga Creek	Chino-Corona Road	WW-M5
Santa Ana River	MWD Crossing	WW-S1
Santa Ana River	Pedley Avenue	WW-S4

2.2.2 Water Quality Sampling Program

The RWQCB-approved Monitoring Plan and QAPP (SAWPA 2013d,e) provide detailed information regarding the collection and analysis of field data and water quality samples. The following sections provide a summary of these methods.

2.2.2.1 Water Quality Measurements

At each sample site water quality measurements include the collection of field parameter data and water samples for laboratory analysis:

- *Field Measurements*: Flow, temperature, conductivity, pH, dissolved oxygen, and turbidity.
- *Laboratory Analysis*: Fecal coliform, *E. coli*, and total suspended solids (TSS).

[3] The Middle Santa Ana River Monitoring Plan and Quality Assurance Project Plan are available at http://www.sawpa.org/collaboration/projects/middle-santa-ana-river-watershed-tmdl-taskforce/

[4] Prior to the 2009 dry season, Icehouse Canyon (WW-C1) was included as watershed-wide compliance monitoring site. However, with RWQCB approval the Task Force removed this site from the sampling program prior to the start of the 2009 dry season monitoring program.

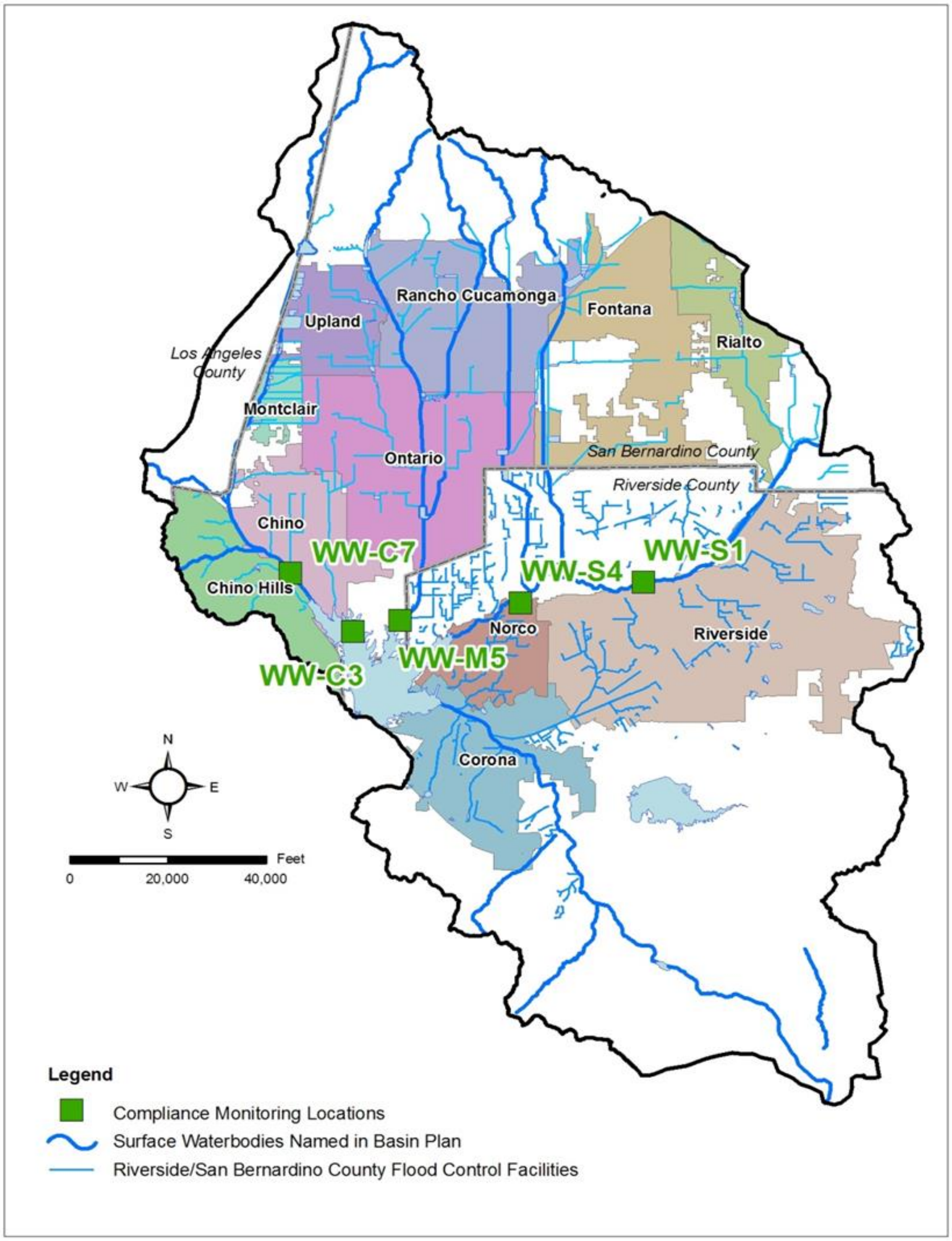


Figure 2-1 Location of Watershed-Wide Compliance Monitoring Program Sample Locations in the Middle Santa Ana River Watershed Sample Frequency

The Monitoring Plan established seasonal sample collection dates for each year of the monitoring program. No samples were missed during the period of record covered by this Triennial Report. Following is a summary of data collection efforts for the dry and wet seasons for the years 2013-2015.

Dry Season

- *2013* - Weekly samples were collected over a 20-week period from the week ending May 21, 2013, to the week ending October 1, 2013. Table 2-2 summarizes the sampling effort.

Table 2-2 Summary of water sample collection activity during 2013 dry season

Sample Month	Planned[1]	Collected	Samples Missed
May	10	10	0
June	20	20	0
July	25	25	0
August	20	20	0
September	20	20	0
October	5	5	0
Total	**100**	**100**	**0**

1 Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in August five sites were planned for sampling during each of the 4 sample weeks that occurred in August for a total of 20 samples.

- *2014* – Weekly samples were collected over a 20-week period from the week ending May 20, 2014, to the week ending September 30, 2014. Table 2-3 summarizes the sampling effort.

Table 2-3 Summary of water sample collection activity during 2014 dry season

Sample Month	Planned[1]	Collected	Samples Missed
May	10	10	0
June	20	20	0
July	25	25	0
August	20	20	0
September	25	25	0
Total	**100**	**100**	**0**

1 Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in August five sites were planned for sampling during each of the 4 sample weeks that occurred in August for a total of 20 samples.

- *2015* - Weekly samples were collected over a 20-week period from the week ending May 21, 2015, to the week ending September 30, 2015. Table 2-4 summarizes the sampling effort.

Table 2-4 Summary of water sample collection activity during 2015 dry season

Sample Month	Planned[1]	Collected	Samples Missed
May	10	10	0
June	20	20	0
July	25	25	0
August	20	20	0
September	25	25	0
Total	**100**	**100**	**0**

1 Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in August five sites were planned for sampling during each of the 4 sample weeks that occurred in August for a total of 20 samples.

Wet Season

- *2012-2013 Wet Season* - Weekly samples were collected over an 11-week period from the week ending December 13, 2012, to the week-ending March 19, 2013. In addition, one storm event was sampled. Storm event sampling includes: (1) collection of a sample on the day of the storm event; (2) collection of additional samples at 48, 72 and 96 hours after the onset of the storm event. During the 2009-2010 wet season a storm event was sampled on December 13, 2012. Additional samples were collected 48, 72 and 96 hours after the storm event on December 15th 16th and 17th, respectively. Table 2-5 summarizes the 2012-2013 wet season sampling effort.

Table 2-5 Summary of Water Sample Collection Activity during 2012-2013 Wet Season

Sample Month	Planned[1]	Collected	Samples Missed
Weekly Sampling			
January	20	20	0
February	20	20	0
March	15	15	0
Total	**55**	**55**	**0**
Storm Event Sampling			
December 13 - 17	20	20	0

1 Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in January five sites were planned for sampling during each of the 4 sample weeks that occurred in January for a total of 20 samples.

- *2013-2014 Wet Season* - Weekly samples were collected over an 11-week period from the week ending December 17, 2013, to the week ending March 4, 2014. During the 2013-2014 sampling period, a storm event was sampled on February 28, 2014. Additional samples were collected 48, 72 and 96 hours after the storm event on March 2nd, 3rd, and 4th, respectively. Table 2-6 summarizes the 2013-2014 wet season sampling effort.

Table 2-6 Summary of Water Sample Collection Activity during 2013-2014 Wet Season

Sample Month	Planned[1]	Collected	Samples Missed
Weekly Sampling			
December	10	10	0
January	25	25	0
February	20	20	0
Total	55	55	0
Storm Event Sampling			
February 28 - March 4	20	20	0

1 Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in January five sites were planned for sampling during each of the 4 sample weeks that occurred in January for a total of 20 samples.

- *2014-2015 Wet Season* – Weekly samples were collected over an 11-week period from the week ending December 2, 2014, to the week ending March 4, 2015. During the 2014-2015 wet season a storm event was sampled on December 2nd. Additional samples were collected 48, 72, and 96 hours after the storm event on December 4th, 5th, and 6th, respectively. Table 2-7 summarizes the 2014-2015 wet season sampling effort.

Table 2-7 Summary of Water Sample Collection Activity during 2014-2015 Wet Season

Sample Month	Planned[1]	Collected[2]	Samples Missed
Weekly Sampling			
December	15	10	5
January	20	20	0
February	20	20	0
March	0	5	0
Total	55	55	0
Storm Event Sampling			
December 2 - December 6	20	20	0

1 Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in January five sites were planned for sampling during each of the 4 sample weeks that occurred in January for a total of 20 samples.
2 No samples were originally planned to be collected during March, however due to laboratory constraints, the planned December 30, 2014 sample collection event was rescheduled to March 3, 2015 to complete the 11-week wet season monitoring. The Regional Board was notified of the change by electronic correspondence on December 29, 2014.

2.2.2.2 Sample Collection

San Bernardino County Flood Control District (SBCFCD) staff collected the field measurements and water quality samples. CDM Smith coordinated the activities of the sample team and the submittal of samples to the laboratory for analysis.

2.2.2.3 Sample Handling

Sample collection and laboratory delivery followed approved chain of custody procedures, holding time requirements, and required storage procedures for each water quality analysis. The Orange County Health Care Agency Water Quality Laboratory conducted all analyses for fecal coliform, *E. coli*, and TSS.

2.2.3 Data Management

The following sections describe data handling and analysis methods. Additional details are provided in the Monitoring Plan and QAPP (SAWPA 2013d,e).

2.2.3.1 Data Handling

CDM Smith and SAWPA maintain a file of all laboratory and field data records (e.g., data sheets, chain of custody forms) as required by the QAPP. CDM Smith enters all field measurements and laboratory analysis results into a project database that is compatible with guidelines and formats established by the California Surface Water Ambient Monitoring Program (SWAMP). CDM Smith periodically submits to SAWPA updates of compiled data for incorporation into the Santa Ana Watershed Data Management System (SAWDMS), which SAWPA manages. Prior to a data submittal to SAWPA, CDM Smith completes a quality assurance/quality control review of the data.

2.2.3.2 Data Analysis

Data analysis included the use of descriptive statistics and comparisons to water quality objectives or TMDL allocations. For any statistical analyses, the bacterial indicator data were assumed to be log-normally distributed as was observed in previous studies (SAWPA 2009). Accordingly, prior to conducting statistical analyses, the bacterial indicator data were log transformed.

Although only one storm event was targeted for sampling during each wet season, regular wet season sampling sometimes coincided with wet weather events. The following sources/criteria were evaluated to determine whether a wet season sample was influenced by wet weather conditions:

- Rainfall recorded at a nearby meteorological station;
- Daily flow record from several U.S. Geological Survey (USGS) or SBCFCD operated flow gauges in the watershed (as available); and
- Comparison of the flow measurement taken at the time of sample collection to the typical site baseflow observed during the sample period.
- The daily rainfall and flow data recorded during the 2012-2013, 2013-2014, and 2014-2015 wet season sampling events is provided in the corresponding wet season reports (SAWPA 2013a, 2014c, 2015a). Table 2-8 lists the wet season and dry season samples classified as influenced by wet weather. All other samples were classified as dry weather samples. Unless otherwise specified, wet weather samples were not included in analyses of wet season data.

Table 2-8 Summary of samples classified as wet weather samples during the 2012-2013, 2013-2014, 2014-2015 wet seasons and 2014 and 2015 dry seasons

Sampling Season	Sample Site	Sample Date	Preceding 3-Day Rainfall (inches)	Measured Flow (cfs)	Approximate Baseflow (cfs)
2012 -2013 Wet Season	Prado Park Lake Outflow	12/13/2012	0.58	15.3	4
		12/15/2012	0.77	6.5	4
	Chino Creek at Central Ave	12/13/2012	0.58	3.3	6.5
		12/15/2012	0.77	0.7	6.5
		12/16/2012	0.19	0.6	6.5
		12/17/2012	0.2	0.6	6.5
	Mill-Cucamonga Creek at Chino Corona Rd	12/13/2012	0.58	215	12.0
		12/15/2012	0.77	146	12.0
	Santa Ana River at MWD Crossing	12/13/2012	0.58	389	44.0
		12/15/2012	0.77	193	44.0
	Santa Ana River at Pedley Ave	12/13/2012	0.58	1,270	86.6
		12/15/2012	0.77	193	86.6
2013 -2014 Wet Season	Prado Park Lake Outflow	2/28/2014	0.84	1.55	4
		3/2/2014	2.35	0.85	4
		3/3/2014	1.72	0.57	4
		3/4/2014	0.26	0.75	4
	Chino Creek at Central Ave	2/28/2014	0.84	862	6.5
		3/2/2014	2.35	NA[1]	6.5
		3/3/2014	1.72	16.3	6.5
		3/4/2014	0.26	16.4	6.5
	Mill-Cucamonga Creek at Chino Corona Rd	2/28/2014	0.84	680	12.0
		3/2/2014	2.35	59	12.0
		3/3/2014	1.72	47	12.0
		3/4/2014	0.26	41	12.0
	Santa Ana River at MWD Crossing	2/28/2014	0.84	163	44.0
		3/2/2014	2.35	97.2	44.0
		3/3/2014	1.72	113	44.0
		3/4/2014	0.26	88.1	44.0
	Santa Ana River at Pedley Ave	2/28/2014	0.84	651	86.6
		3/2/2014	2.35	418	86.6
		3/3/2014	1.72	75.2	86.6
		3/4/2014	0.26	76.0	86.6
2014 Dry Season	Santa Ana River at MWD Crossing	8/5/2014	0.12	36.6	44.0
		9/9/2014	1.01	51.2	44.0
	Santa Ana River at Pedley Ave	8/5/2014	0.12	170	86.6
		9/9/2014	1.01	138	86.6

Sampling Season	Sample Site	Sample Date	Preceding 3-Day Rainfall (inches)	Measured Flow (cfs)	Approximate Baseflow (cfs)
2014-2015 Wet Season	Prado Park Lake Outflow	12/2/2014	0.01	NA[1]	4
		12/4/2014	1.89	NA[1]	4
		12/5/2014	2.38	NA[1]	4
		12/6/2014	2.37	NA[1]	4
	Chino Creek at Central Ave	12/2/2014	0.01	NA[1]	17.4
		12/4/2014	1.89	NA[1]	42.1
		12/5/2014	2.38	65.98	0.9
		12/6/2014	2.37	NA[1]	0.8
	Mill-Cucamonga Creek at Chino Corona Rd	12/2/2014	0.01	NA[1]	NA
		12/4/2014	1.89	NA[1]	43.4
		12/5/2014	2.38	NA[1]	58.1
		12/6/2014	2.37	NA[1]	59.7
	Santa Ana River at MWD Crossing	12/2/2014	0.01	NA[1]	33.9
		12/4/2014	1.89	NA[1]	112.7
		12/5/2014	2.38	NA[1]	70.5
		12/6/2014	2.37	9.93	28.3
	Santa Ana River at Pedley Ave	12/2/2014	0.01	NA[1]	NA
		12/4/2014	1.89	NA[1]	NA
		12/5/2014	2.38	NA[1]	NA
		12/6/2014	2.37	NA[1]	NA
2015 Dry Season	Prado Park Lake Outflow	7/22/2015	1.44	2.64	4
		9/17/2015	1.28	8.81	4
	Mill-Cucamonga Creek at Chino Corona Rd	9/17/2015	1.28	NA[3]	12.0
	Santa Ana River at MWD Crossing	7/22/2015	1.44	206	44.0
		9/17/2015	1.28	91.4	44.0
	Santa Ana River at Pedley Ave	7/22/2015	1.44	134	86.6
		9/17/2015	1.28	175	86.6

1) Water too high to sample
2) Flow too high to measure
3) Missing width measurement

2.3 Compliance with Wasteload Allocations

The watershed-wide compliance monitoring program samples five locations on a regular basis (see Table 2-1 and Figure 2-1). The data from these sites are used to evaluate compliance with WLAs. The MSAR Bacterial Indicator TMDL contains WLAs for urban discharges and CAFOs. The following sections summarize the bacterial indicator concentrations observed at the watershed-wide compliance sites during the last three years.

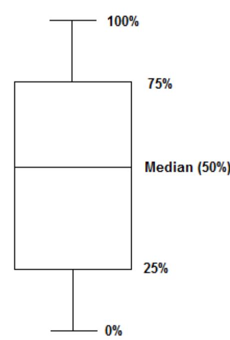
2.3.1 Bacterial Indicator Concentrations

The following tables summarize the observed *E. coli* and fecal coliform concentrations at each of the watershed-wide compliance sites during the dry and wet season sample periods covered by this report[5]:

- Table 2-9 summarizes observations during the wet season of 2012-2013.
- Table 2-10 summarizes the observations during the dry season of 2013.
- Table 2-11 summarizes the observations during the wet season of 2013-2014.
- Table 2-12 summarizes the observations during the dry season of 2014.
- Table 2-13 summarizes the observations during the wet season of 2014-2015.
- Table 2-14 summarizes the observations during the dry season of 2015.

Figures 2-2 and 2-3 illustrate the geometric mean of dry weather sample results for fecal coliform for the 2013 through 2015 dry seasons, and the 2012-2013 through 2014-2015 wet seasons for all sites, respectively. Figures 2-4 and 2-5 illustrate the same for *E. coli*. These charts show that bacteria concentrations are consistently highest for the Mill-Cucamonga TMDL compliance site. Bacteria concentrations for Prado Park Lake continue to be the lowest of the sites and may even suggest the waterbody is no longer impaired.

Figures 2-6 through 2-10 illustrate the trends in single sample and geometric mean results for fecal coliform for the 2007 through 2015 dry seasons for all sites. Figures 2-11 to 2-15 illustrate the same for *E. coli*. One key observation is the seasonal trend of increasing bacteria concentrations from the beginning to the end of the dry season for the two SAR sites.



Boxplot Distribution

Figure 2-16 provides box and whisker plots (boxplots) to illustrate the range of bacterial indicator concentrations observed during the 2012 – 2015 period for both dry (red) and wet (blue) seasons. The boxplots visually describe the distribution of a dataset, where the upper whisker depicts the maximum value, and the lower whisker depicts the minimum value. The box depicts the interquartile range (IQR), with the lower line corresponding to the 25th percentile, the middle line to the median, and the upper line to the 75th percentile. Superimposed on this figure are the individual wet weather event sample results (yellow dots), which typically fall above the median concentrations from dry weather

[5] The ">" qualifier does not indicate that additional dilutions are necessary. The qualifier is a methodology requirement and indicates the presence of background (atypical) bacteria growing on the same plate as the target (typical) bacteria (*E. coli* or fecal coliform in this case). When there are more than 200 colonies on the plate (atypical and typical), the qualifier is added to the results. However, the reported number is the concentration of typical colonies (*E. coli* or fecal coliform) and is less than 200 colonies on the plate. When there are more than 200 colonies of typical bacteria on the plate, additional dilutions are run until there are less than 200 colonies of typical bacteria. (Source: Email communication with Joe Guzman and Tania Chiem from OCPHL on August 4, 2016)

samples. Another apparent condition from this figure is the lower bacteria concentrations during dry weather in the wet season than in the dry season.

Table 2-9 Fecal coliform and *E. coli* (cfu/100 mL) concentrations observed at watershed-wide compliance sites during the 2012-2013 wet season

Bacterial Indicator	Fecal Coliform					*E. coli*				
Sample Week	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue
	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
Regular Sampling Events										
1/8/2013	120	490	580	60	140	50	430	370	60	80
1/17/2013	40	390	490	80	70	40	130	440	90	70
1/22/2013	40	340	3,400	140	60	20	200	3,600	100	50
1/29/2013	140	700	760	170	260	70	290	460	110	170
2/5/2013	110	560	1,470	200	200	120	370	1,260	130	140
2/12/2013	30	200	330	99	100	20	110	240	110	130
2/19/2013	110	370	370	210	240	60	140	180	140	170
2/26/2013	120	250	400	110	99	80	40	380	60	40
3/5/2013	99	410	470	270	140	170	200	560	240	190
3/12/2013	300	290	400	300	240	260	60	380	230	210
3/19/2013	120	200	510	140	180	70	130	470	140	270
Storm Event										
12/13/2012	>29,000	>12,900	>8,200	14,000	>8,900	20,000	>4,300	>6,300	>7,200	>8,300
12/15/2012	290	720	2,800	2,500	3,100	160	580	710	1,400	1,040
12/16/2012	170	260	260	260	250	130	160	180	140	210
12/17/2012	200	220	220	270	280	180	170	210	140	170

Table 2-10 Fecal coliform and *E. coli* concentrations (cfu/100 mL) observed at watershed-wide compliance sites during the 2013 dry season

Bacterial Indicator	Fecal Coliform					*E. coli*				
Sample Week	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue
	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
Regular Sampling Events										
5/21/2013	450	810	5,800	330	210	360	> 650	3,000	190	140
5/28/2013	490	> 260	> 4,200	240	120	310	> 140	> 1,060	150	40
6/4/2013	70	> 1,300	4,700	310	240	80	> 310	2,200	160	150
6/11/2013	> 9	> 360	19,000	180	40	> 9	> 140	7,600	120	99
6/18/2013	20	> 460	> 4,200	60	60	70	> 200	> 1,490	80	40
6/25/2013	> 1,600	> 280	> 2,800	180	230	> 1,100	140	2,200	180	130
7/2/2013	> 40	> 1,100	> 620	> 250	250	40	> 490	> 710	280	200
7/9/2013	30	> 260	> 430	220	200	30	> 140	> 620	270	210
7/16/2013	50	> 310	> 480	210	210	140	260	1,250	230	310
7/23/2013	40	> 240	> 360	> 250	> 340	> 50	> 300	> 440	> 260	> 360
7/30/2013	> 570	> 340	> 880	410	510	> 130	> 310	950	280	270
8/6/2013	> 600	> 380	> 3,700	300	230	> 600	> 410	> 4,600	400	230
8/13/2013	> 80	> 490	> 4,000	250	260	90	> 330	4,100	180	180
8/20/2013	40	> 650	> 740	110	180	50	320	2,300	250	150
8/27/2013	> 680	> 290	790,000	260	180	> 600	> 340	260,000	> 250	> 190
9/3/2013	> 330	> 430	2,600	> 370	1,200	630	610	> 1,160	> 610	> 580
9/10/2013	> 190	> 36,000	> 77,000	> 380	> 360	> 310	> 15,000	> 10,000	> 300	> 280
9/17/2013	40	160	140	130	180	20	910	460	160	230
9/24/2013	9	50	> 70	150	160	> 50	> 560	> 480	> 170	> 180
10/1/2013	40	> 140	> 460	> 100	> 250	70	> 290	> 570	180	> 250

Table 2-11 Fecal coliform and *E. coli* concentrations (cfu/100 mL) observed at watershed-wide compliance sites during the 2013-2014 wet season

Bacterial Indicator	Fecal Coliform					E. coli				
Sample Week	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue
	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
Regular Sampling Events										
12/17/2013	30	390	360	100	110	20	310	140	150	180
12/26/2013	50	100	420	70	150	80	99	360	110	30
1/2/2014	9	230	230	120	80	20	140	190	80	90
1/8/2014	40	99	800	40	60	90	110	950	60	40
1/14/2014	350	90	340	70	100	220	180	300	80	40
1/21/2014	30	210	>310	60	90	20	170	240	50	90
1/28/2014	20	370	>340	220	120	9	380	320	240	80
2/4/2014	9	120	130	150	130	9	110	60	40	70
2/11/2014	99	<9	270	130	60	200	9	390	80	110
2/18/2014	<9	30	>650	90	110	20	40	370	280	40
2/25/2014	30	70	210	200	70	20	9	220	170	60
Storm Event										
2/28/2014	40	32,000	31,000	11,200	7,600	40	19,000	12,800	9,400	7,600
3/2/2014	490	2,600	1,400	890	3,600	750	2,200	790	860	2,000
3/3/2014	150	180	99	560	560	80	160	90	530	420
3/4/2014	100	230	410	370	400	120	130	140	220	250

Table 2-12 Fecal coliform and *E. coli* concentrations (cfu/100 mL) observed at watershed-wide compliance sites during the 2014 dry season

Bacterial Indicator	Fecal Coliform					*E. coli*				
Sample Week	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue
	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
Regular Sampling Events										
5/20/2014	130	> 260	> 80	180	230	170	> 260	40	200	160
5/27/2014	130	> 490	> 550	450	200	80	120	530	290	220
6/3/2014	9	> 2,100	> 540	360	> 150	> 30	> 750	> 510	320	> 110
6/10/2014	> 380	> 560	> 370	470	70	> 300	> 300	420	430	110
6/17/2014	140	> 330	> 350	220	50	160	> 110	290	190	60
6/24/2014	> 230	910	> 260	> 360	> 230	200	> 480	160	350	90
7/1/2014	170	> 330	> 370	> 270	> 240	110	140	300	220	80
7/8/2014	> 700	> 4,500	> 930	> 370	> 270	> 280	> 3,900	> 450	> 270	140
7/15/2014	> 230	> 370	> 400	660	250	120	200	550	420	120
7/22/2014	> 120	> 2,000	> 270	> 330	160	80	920	240	160	30
7/29/2014	> 490	> 1,700	> 700	3,200	320	> 440	> 440	> 320	800	99
8/5/2014	> 460	> 4,000	> 4,300	> 28,000	> 35,000	> 370	> 2,400	> 2,000	> 3,600	> 7,700
8/12/2014	190	> 150	> 2,000	3,300	3,400	120	190	1,300	> 410	> 470
8/19/2014	110	> 370	> 2,000	> 490	780	> 80	220	> 700	> 290	210
8/26/2014	40	> 320	> 360	1,300	2,200	30	320	350	380	200
9/2/2014	70	> 190	> 680	470	470	60	150	540	170	210
9/9/2014	40	> 1400	2,300	37,000	23,000	40	410	930	7,000	5,300
9/16/2014	> 2,200	> 330	> 590	> 360	> 330	> 950	180	> 460	280	> 230
9/23/2014	> 440	> 270	> 2,800	> 270	> 340	> 450	> 120	> 2000	140	210
9/30/2014	20	> 230	> 430	> 340	310	30	> 60	> 320	170	130

Table 2-13 Fecal coliform and *E. coli* concentrations (cfu/100 mL) observed at watershed-wide compliance sites during the 2014 -2015 wet season

Bacterial Indicator	Fecal Coliform					*E. coli*				
Sample Week	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue
	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
Regular Sampling Events										
12/21/2014	510	450	270	390	360	350	40	80	150	150
12/28/2014	210	120	9	150	190	150	70	9	80	40
1/11/2015	480	250	1,800	130	80	230	60	99	70	9
1/18/2015	310	260	350	390	250	280	250	280	250	180
1/25/2015	170	210	350	120	100	160	150	210	80	40
2/1/2015	40	1,140	590	1,600	1,600	20	750	490	1,280	1,500
2/8/2015	50	340	1,850	180	140	20	150	1,490	140	40
2/15/2015	40	2,100	770	120	60	40	2,100	550	70	20
2/22/2015	300	90	580	100	240	210	100	520	70	140
3/1/2015	9	160	260	250	180	9	110	140	60	140
3/8/2015	40	210	230	270	99	20	110	110	60	70
Storm Event										
12/2/2014	14,000	22,000	9,500	1,000	300	20,000	22,000	8,200	670	160
12/4/2014	4,900	9,700	5,700	16,000	36,000	3,300	4,500	3,800	11,400	20,000
12/5/2014	2,800	2,600	540	5,100	3,900	1,460	1,110	310	3,200	4,200
12/6/2014	810	440	200	860	2,000	570	220	160	400	560

CDM Smith

Table 2-14 Fecal coliform and *E. coli* concentrations (cfu/100 mL) observed at watershed-wide compliance sites during the 2015 dry season

Bacterial Indicator	Fecal Coliform					*E. coli*				
Sample Week	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue	Prado Park Lake Outlet	Chino Creek @ Central Avenue	Mill-Cucamonga Creek @ Chino-Corona Rd	SAR @ MWD Crossing	SAR @ Pedley Avenue
	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
Regular Sampling Events										
5/24/2015	60	> 150	> 1000	150	60	40	80	1350	60	30
5/31/2015	170	560	2100	140	230	220	570	1490	140	130
6/7/2015	80	> 700	> 250	250	330	40	340	190	140	110
6/14/2015	20	140	> 420	200	260	20	170	410	210	240
6/21/2015	160	> 70	> 150	99	120	100	170	310	91	80
6/28/2015	30	> 110	> 40	200	210	9	200	40	130	120
7/5/2015	270	> 310	> 2100	90	95000	160	350	860	40	> 2000
7/12/2015	60	> 260	> 390	340	560	40	330	770	140	50
7/19/2015	9	> 20	> 220	290	500	30	330	470	210	200
7/26/2015	20	1000	700	> 2000	> 1700	40	> 320	> 530	> 860	> 940
8/2/2015	> 40	> 1200	> 3200	2000	1700	60	280	> 991	40	150
8/9/2015	> 170	> 160	> 200	> 450	> 540	150	280	440	200	230
8/16/2015	470	> 200	2400	> 430	320	220	130	2200	130	90
8/23/2015	290	> 170	> 1580	590	540	200	80	1000	140	220
8/30/2015	< 9	> 220	3500	360	390	< 9	190	2400	99	150
9/6/2015	50	220	> 270	400	350	20	230	220	120	40
9/13/2015	40	> 510	> 270	> 270	480	< 9	500	130	130	90
9/20/2015	> 130	900	500	> 2100	> 6000	150	320	390	> 1140	3900
9/27/2015	9	> 220	> 300	> 310	1300	9	180	290	80	140
10/4/2015	> 9	> 180	> 780	> 230	> 620	9	220	850	140	230

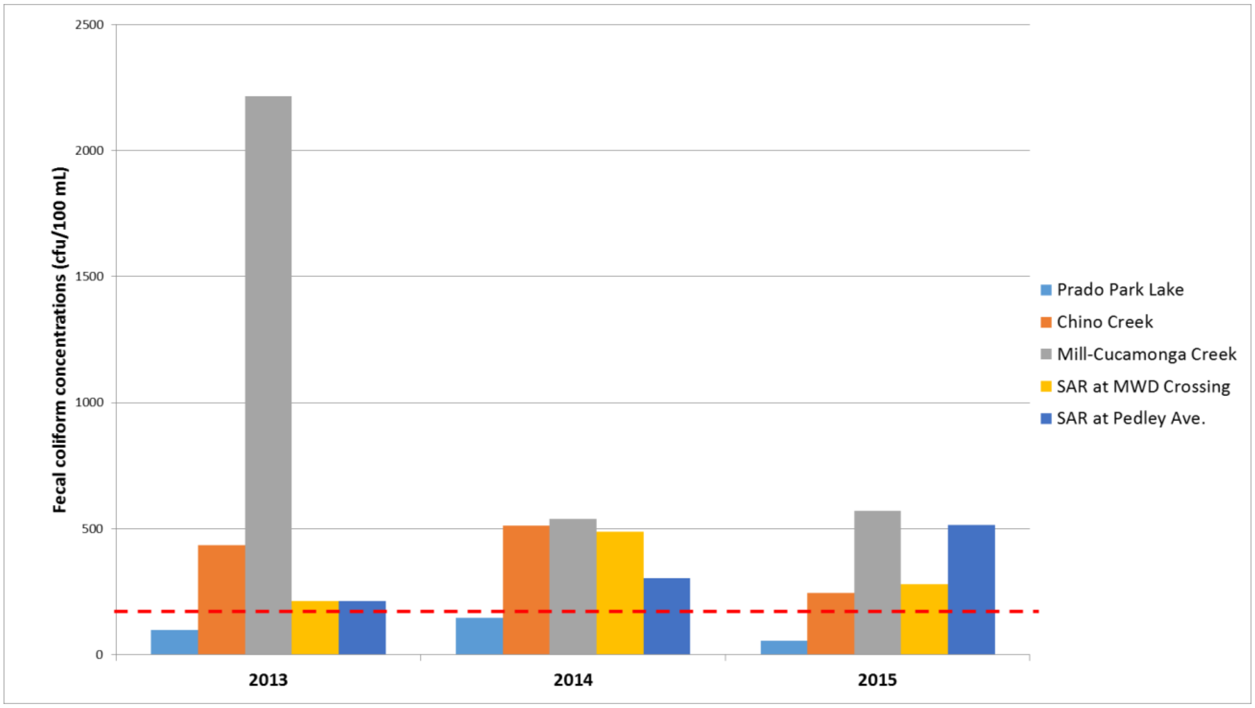


Figure 2-2 Fecal coliform geomean concentrations (cfu/100 mL) by sample location during the 2013, 2014 and 2015 dry seasons (dry weather only, excluding samples listed in Table 2-8) (red line indicates geomean WLA of 180 org/100 mL)

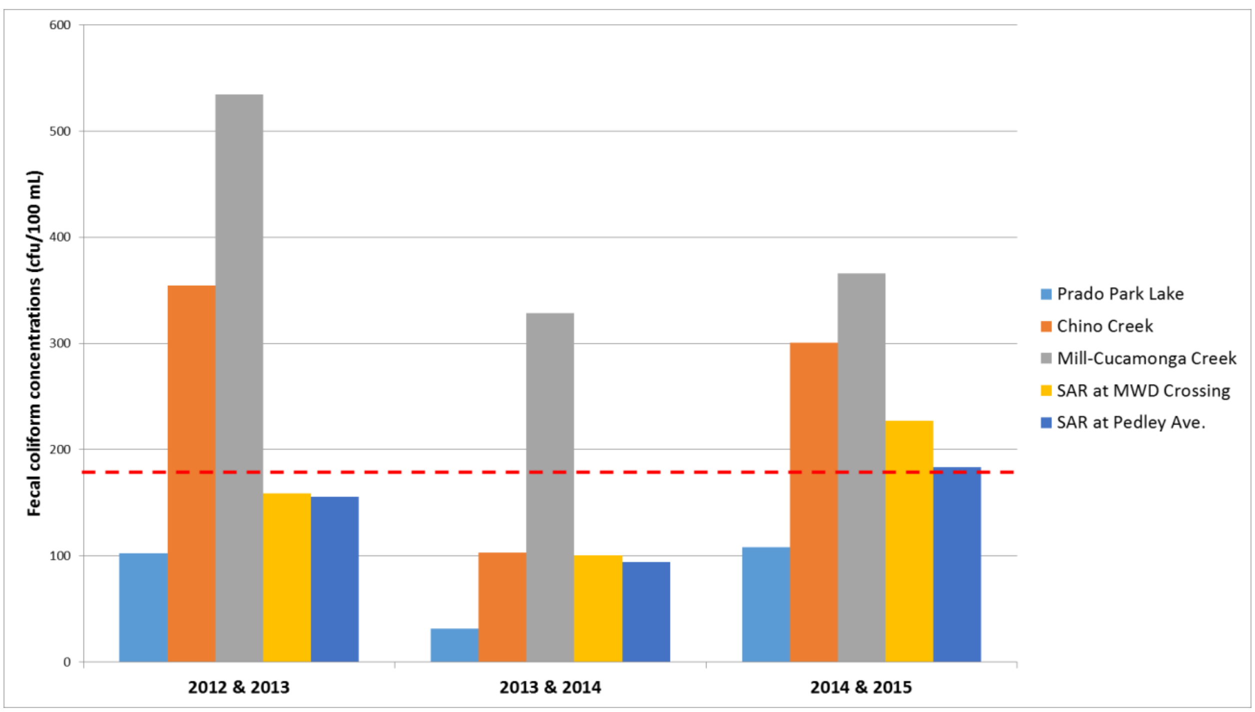


Figure 2-3 Fecal coliform geomean concentrations (cfu/100 mL) by sample location during the 2012-2013, 2013-2014, 2014-2015 wet seasons (dry weather only, excluding samples listed in Table 2-8) (red line indicates geomean WLA of 180 org/100 mL)

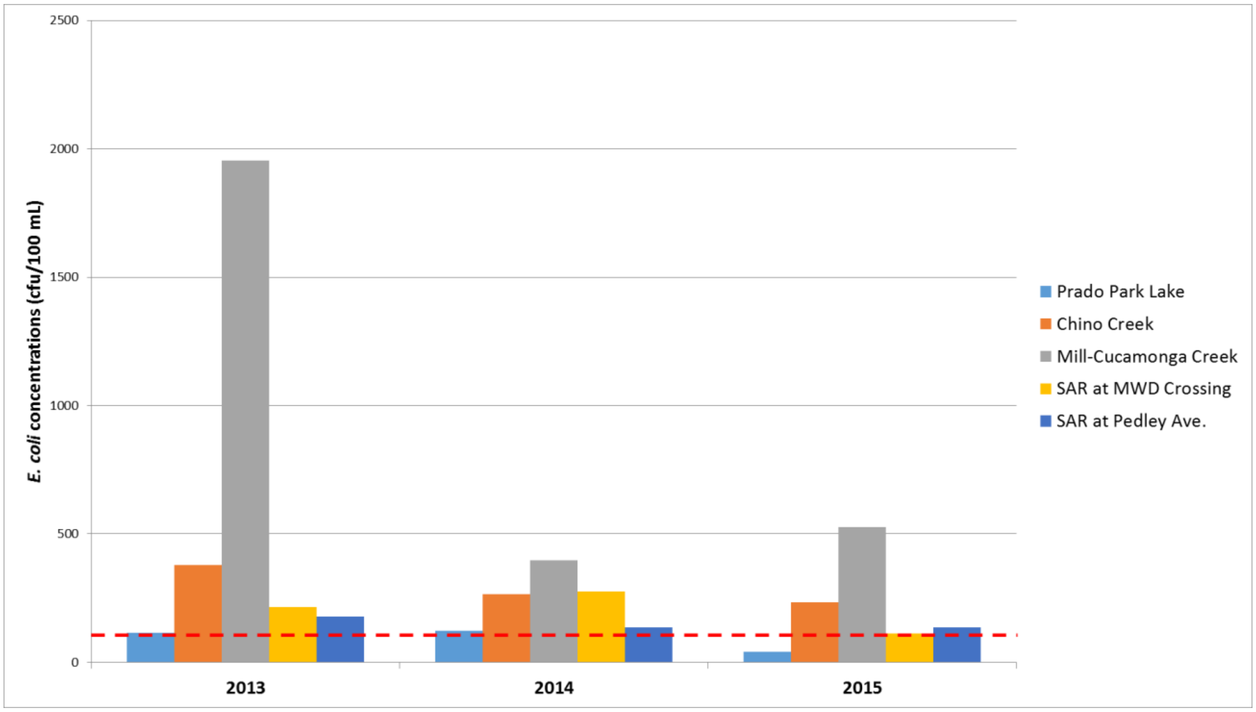


Figure 2-4 *E. coli* (cfu/100 mL) geomeans by sample location during the 2013, 2014 and 2015 dry seasons (dry weather only, excluding samples listed in Table 2-8) (red line indicates geomean WLA of 113 org/100 mL)

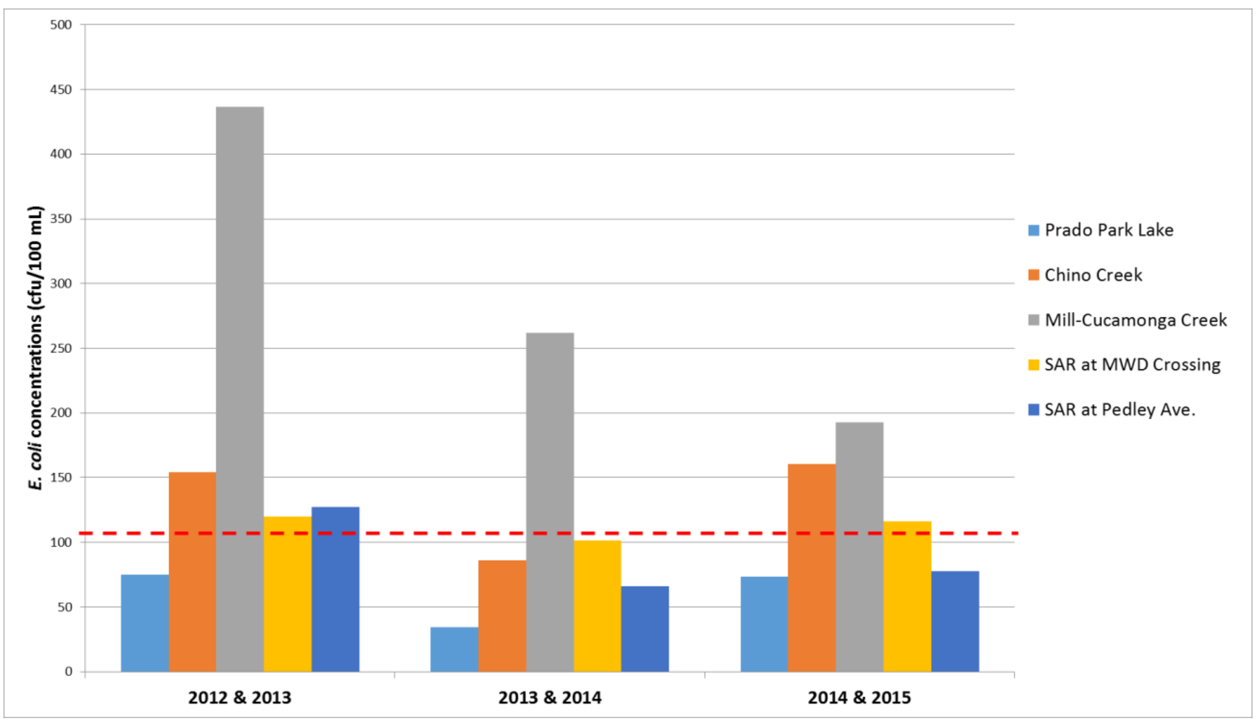


Figure 2-5 *E. coli* concentrations (cfu/100 mL) geomeans by sample location during the 2012-2013, 2013-2014, and 2014-2015 wet seasons (dry weather only, excluding samples listed in Table 2-8) (red line indicates geomean WLA of 113 org/100 mL)

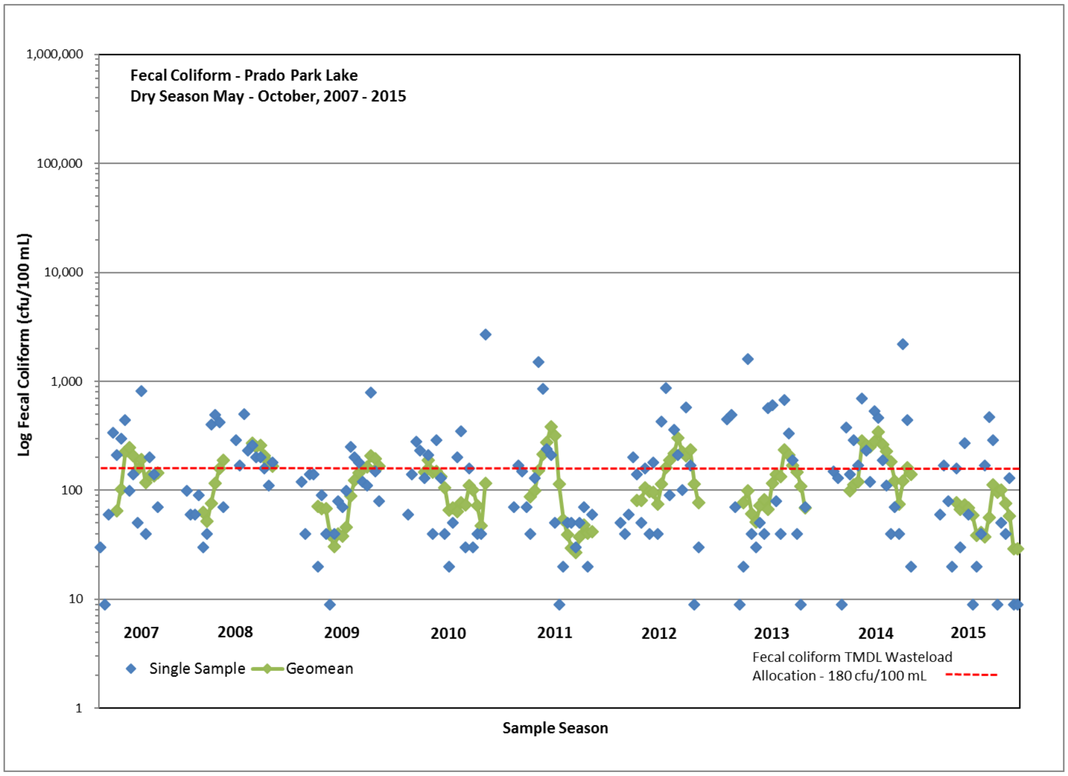


Figure 2-6 Time series plot of fecal coliform single sample results and geometric means for samples collected from Prado Park Lake, 2007 through 2015 dry seasons

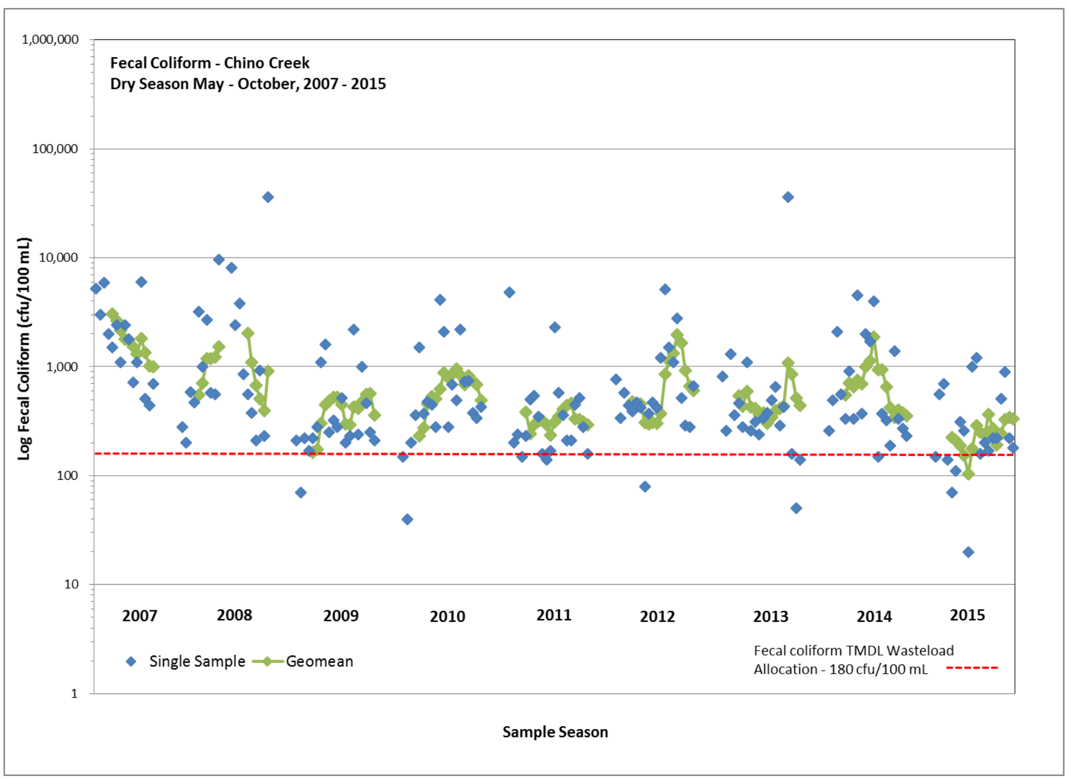


Figure 2-7 Time series plot of fecal coliform single sample results and geometric means for samples collected from Chino Creek, 2007 through 2015 dry seasons

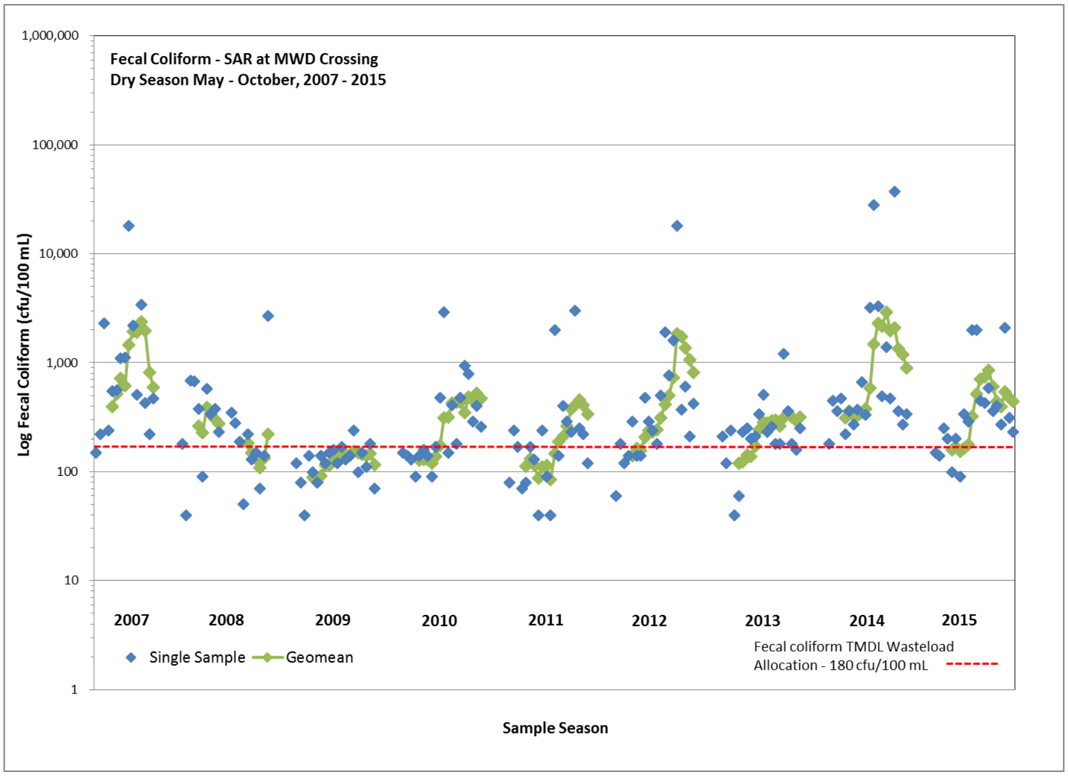


Figure 2-8 Time series plot of fecal coliform single sample results and geometric means for samples collected from Mill-Cucamonga Creek 2007 through 2015 dry seasons

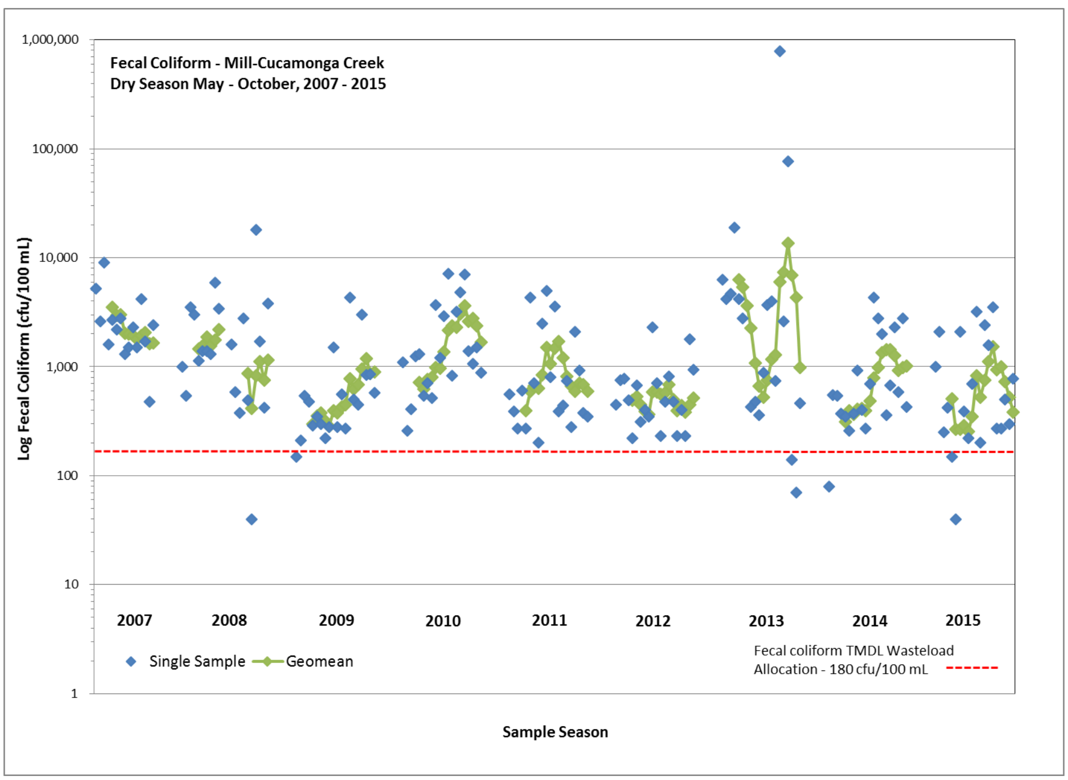


Figure 2-9 Time series plot of fecal coliform single sample results and geometric means for samples collected from Santa Ana River at MWD crossing, 2007 through 2015 dry seasons

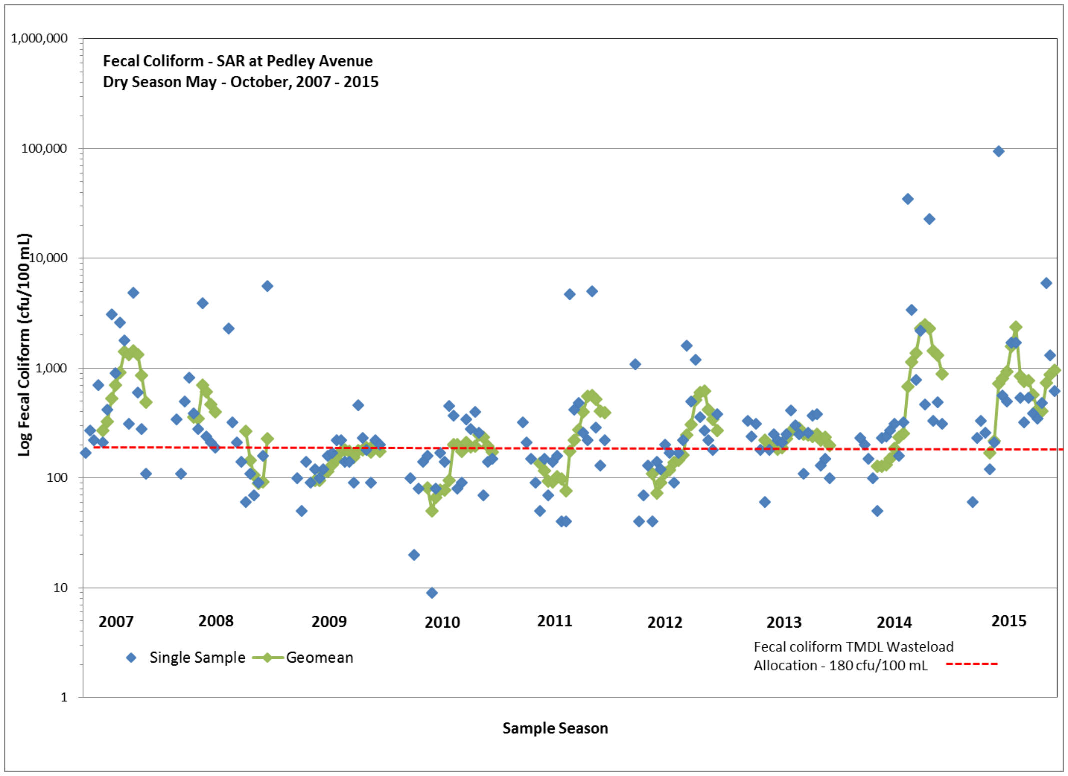


Figure 2-10 Time series plot of fecal coliform single sample results and geometric means for samples collected from Santa Ana River at Pedley Avenue, 2007 through 2015 dry seasons

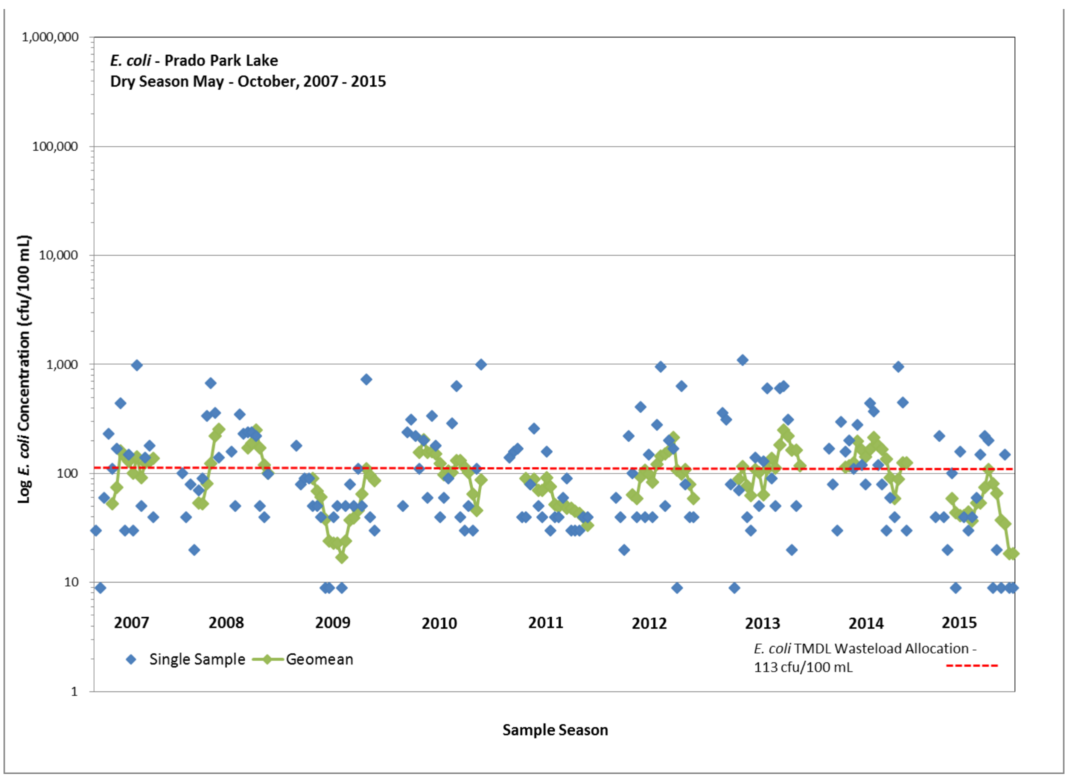


Figure 2-11 Time series plot of *E. coli* single sample results and geometric means for samples collected from Prado Park Lake, 2007 through 2015 dry seasons

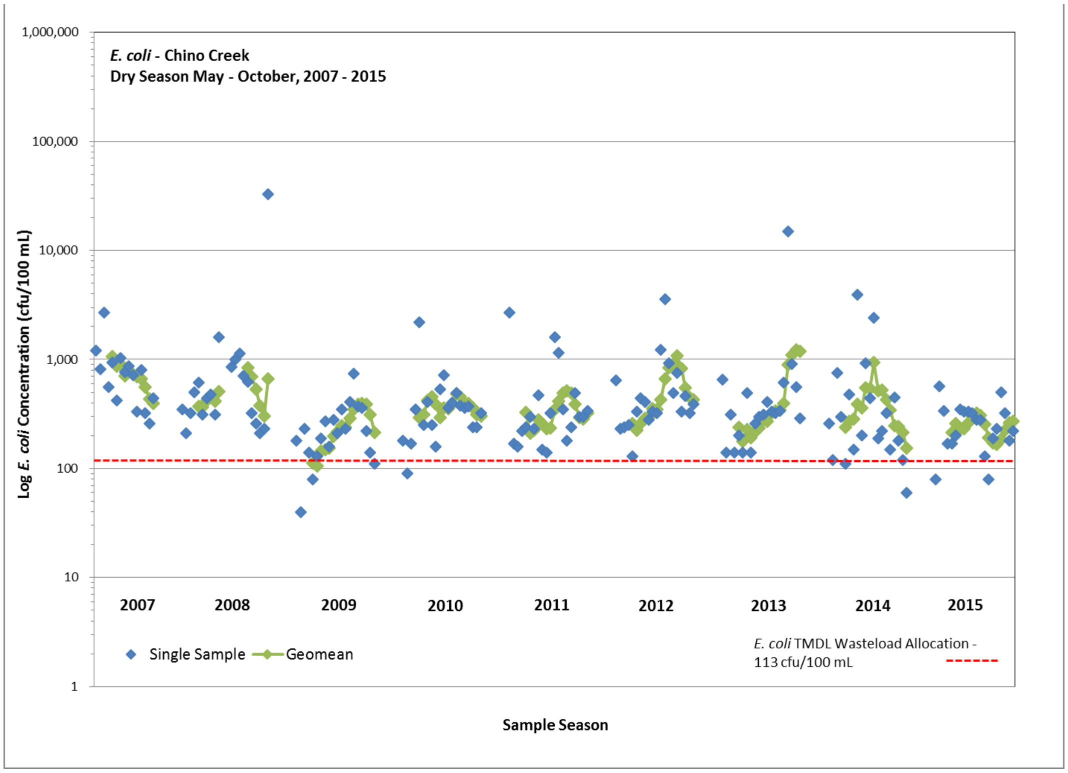


Figure 2-12 Time series plot of *E. coli* single sample results and geometric means for samples collected from Chino Creek, 2007 through 2015 dry seasons

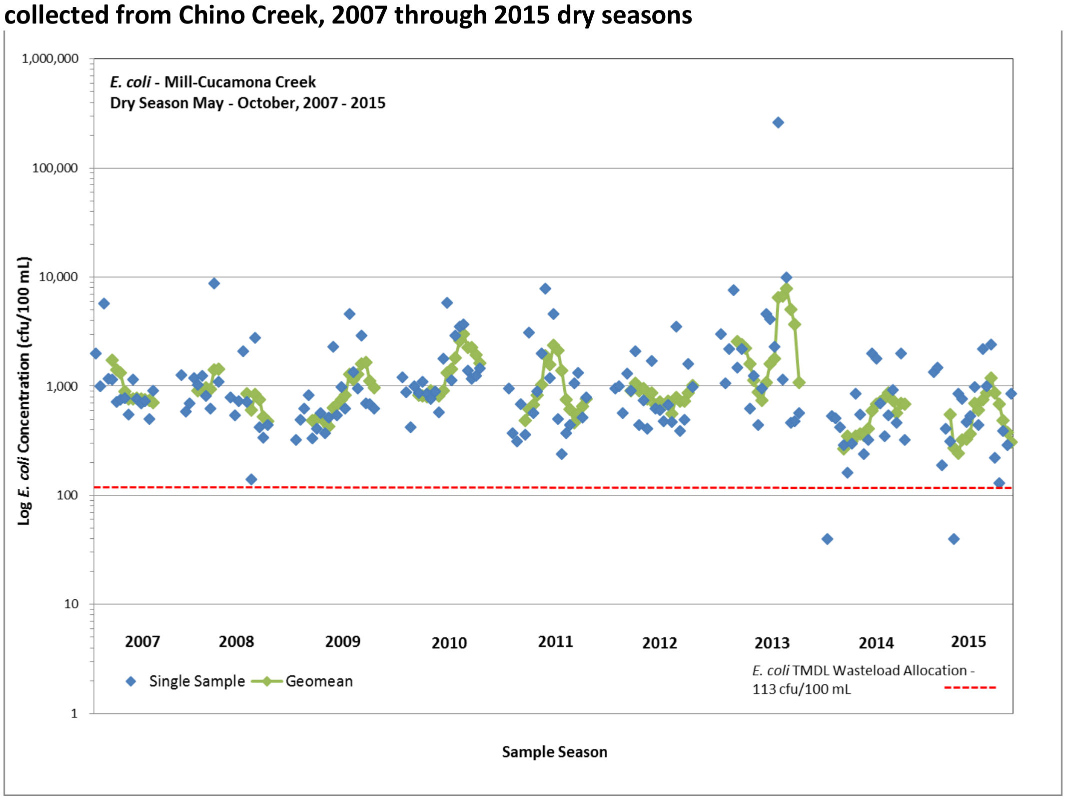


Figure 2-13 Time-series plot of *E. coli* single sample results and geometric means for samples collected from Mill-Cucamonga Creek, 2007 through 2015 dry seasons

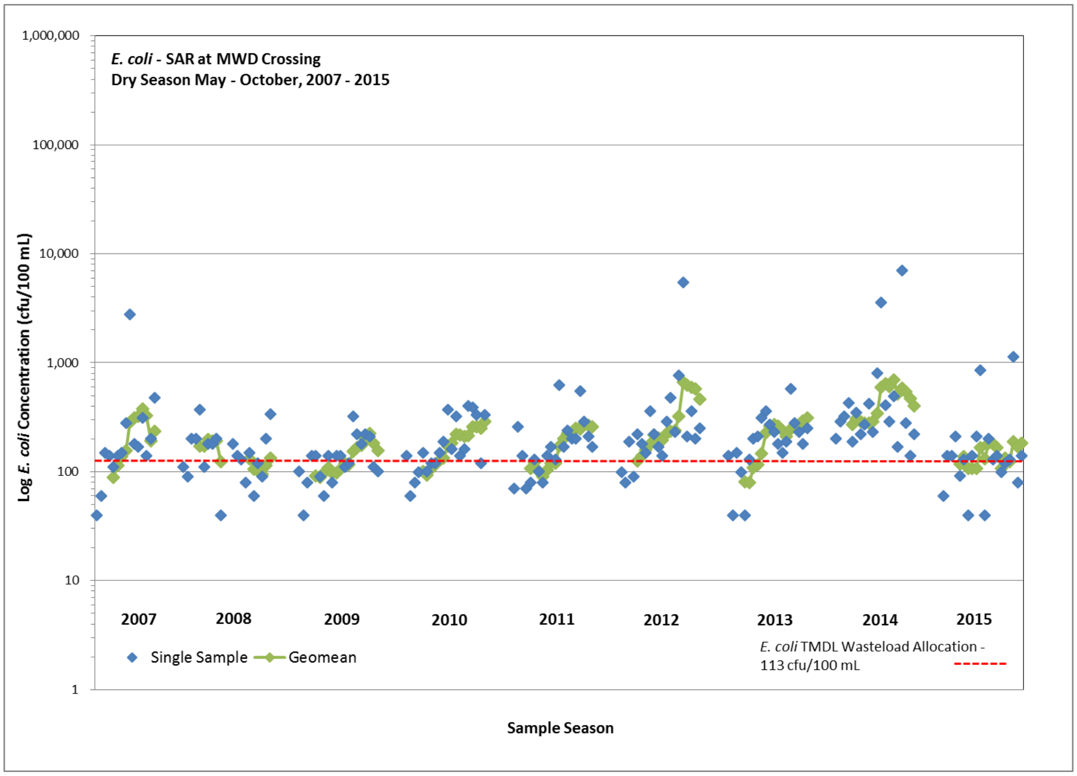


Figure 2-14 Time series plot of *E. coli* single sample results and geometric means for samples collected from Santa Ana River at MWD Crossing, 2007 through 2015 dry seasons

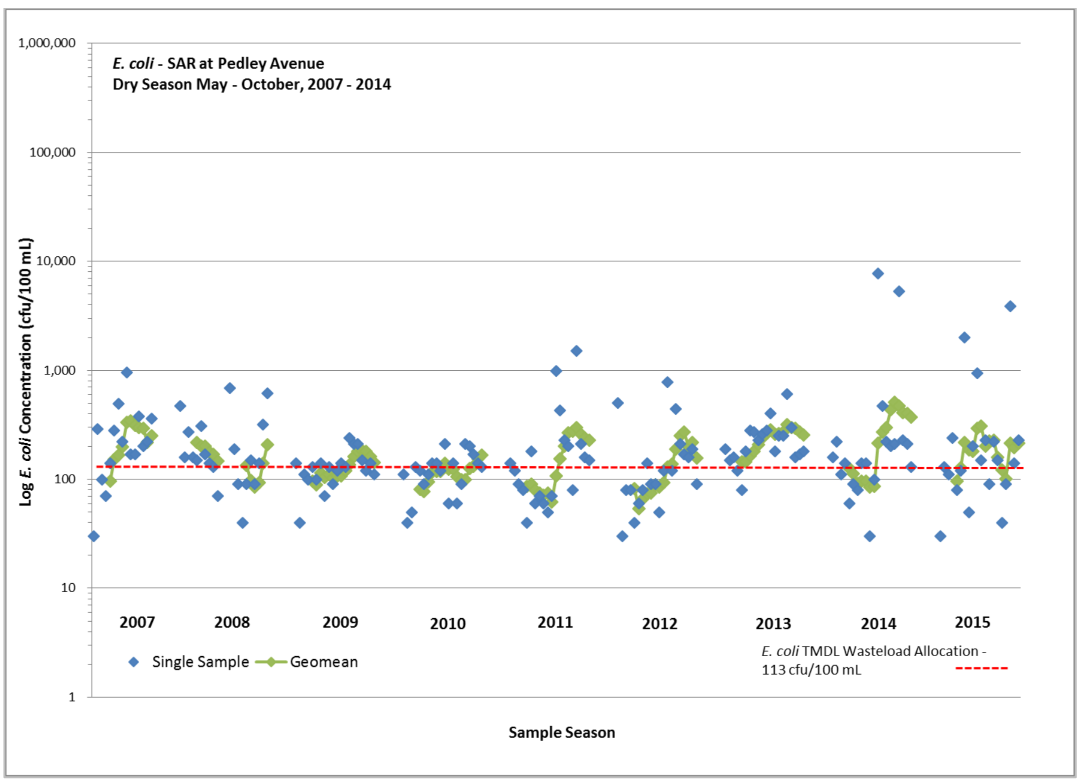


Figure 2-15 Time series plot of *E. coli* single sample results and geometric means for samples collected from Santa Ana River at Pedley Avenue, 2007 through 2015 dry seasons

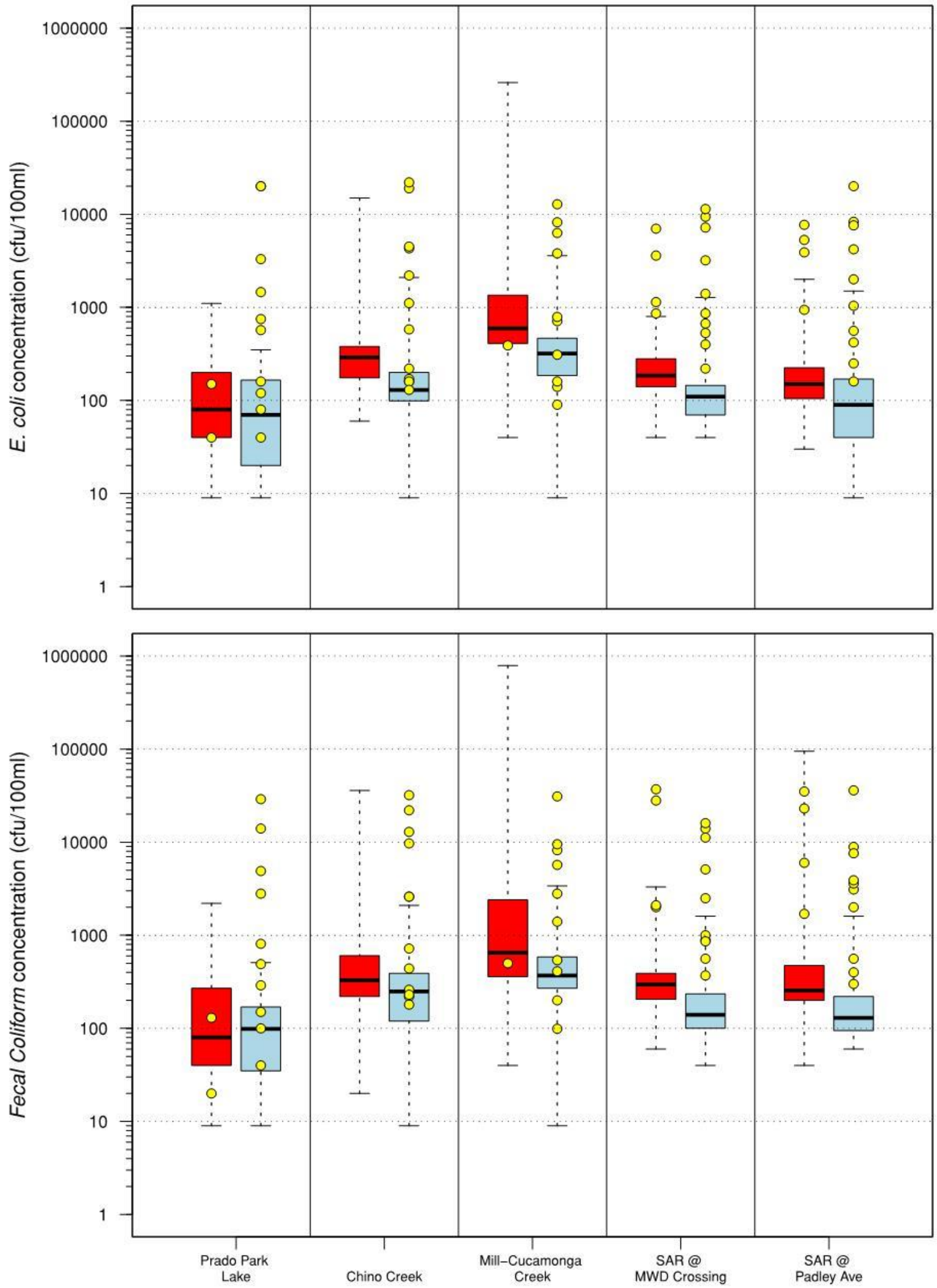


Figure 2-16 Box-whisker plots of bacteria indicator concentrations from 2012-2015 during dry weather in the dry season (red) and wet season (blue), and wet weather events (yellow points)

2.3.2 Compliance Frequency

Tables 2-15 and 2-16 summarize the frequency of compliance with geometric mean and single sample water quality objectives for *E. coli* (geometric mean maximum: 126 cfu/100 mL; single sample maximum: 235 cfu/100 mL) during the 2013, 2014, and 2015 dry seasons and 2012-2013, 2013-2014, and 2014-2015 wet seasons. Geomeans were calculated for dry and wet weather samples combined, when five or more samples were taken in a five-week period.

Table 2-15 Frequency of exceedance of geometric mean water quality objectives for *E. coli* during the 2013, 2014, and 2015 dry seasons (dry weather only)

Site	Geometric Mean Criterion Exceedance Frequency (%)			Single Sample Value Exceedance Frequency (%)		
	2013	2014	2015	2013	2014	2015
Prado Park Lake	31%	30%	0%	35%	30%	0%
Chino Creek	88%	100%	88%	75%	50%	50%
Mill-Cucamonga Creek	88%	100%	93%	100%	90%	79%
SAR @ MWD Crossing	87%	100%	14%	45%	61%	0%
SAR @ Pedley Ave.	63%	43%	57%	30%	6%	11%

Table 2-16 Frequency of exceedance of geometric mean water quality objectives for *E. coli* during the 2012-2013, 2013-2014, and 2014-2015 wet seasons

Site	Geometric Mean Criterion Exceedance Frequency (%)			Single Sample Value Exceedance Frequency (%)		
	2012-2013	2013-2014	2014-2015	2012-2013	2013-2014	2014-2015
Prado Park Lake	0%	0%	14%	8%	0%	18%
Chino Creek	71%	57%	86%	27%	18%	27%
Mill-Cucamonga Creek	100%	100%	71%	77%	64%	46%
SAR @ MWD Crossing	29%	14%	71%	8%	18%	18%
SAR @ Pedley Ave.	29%	0%	0%	8%	0%	9%

2.3.3 Historical Data Analysis

2.3.3.1 Monotonic Trend Analysis

Figures 2-17 and 2-18 display annual geometric means of fecal coliform and *E. coli* samples, respectively, collected during the dry season from 2007 to 2015. The first three years of the watershed-wide monitoring were characterized by a steady annual decline in the geometric means of dry season fecal coliform and *E. coli* concentrations. Subsequent years were more variable, with some stations seeing an increase or decrease in bacteria concentrations from one year to the next. Figures 2-19 and 2-20 illustrate annual geometric means of fecal coliform and *E. coli* samples, respectively, collected during dry weather in the wet season from the 2007-2008 wet season through the 2014-2015 wet season.

E. coli data from 2007 through 2015 for dry and wet seasons (dry weather events) were analyzed at each site with a Mann-Kendall test to determine the presence of a monotonic trend over time. Table 2-17 presents the results of the Mann-Kendall analysis. The test results suggest that there was statistical evidence to reject the null hypotheses of "no trend" in the geomeans at the 0.05 confidence level for Chino Creek and Prado Park Lake in the wet season. In other words, a statistically significant downward trend was detected at these sites, indicating an improvement of bacteria water quality over time. All other sites and conditions had no statistically significant trend.

Table 2-17 Mann-Kendall test results for *E. coli* during the 2007-2015 dry seasons

Season	Parameter	Chino Creek	Mill-Cucamonga Creek	Prado Park Lake	SAR @ MWD Crossing	SAR @ Pedley Ave
Dry Season	Kendall's Tau	-0.33	-0.28	-0.06	0.22	0.11
	p-value	0.25	0.35	0.92	0.47	0.75
Wet Season	Kendall's Tau	-0.56	0.06	-0.72	-0.11	-0.22
	p-value	0.05	0.92	0.01	0.75	0.47

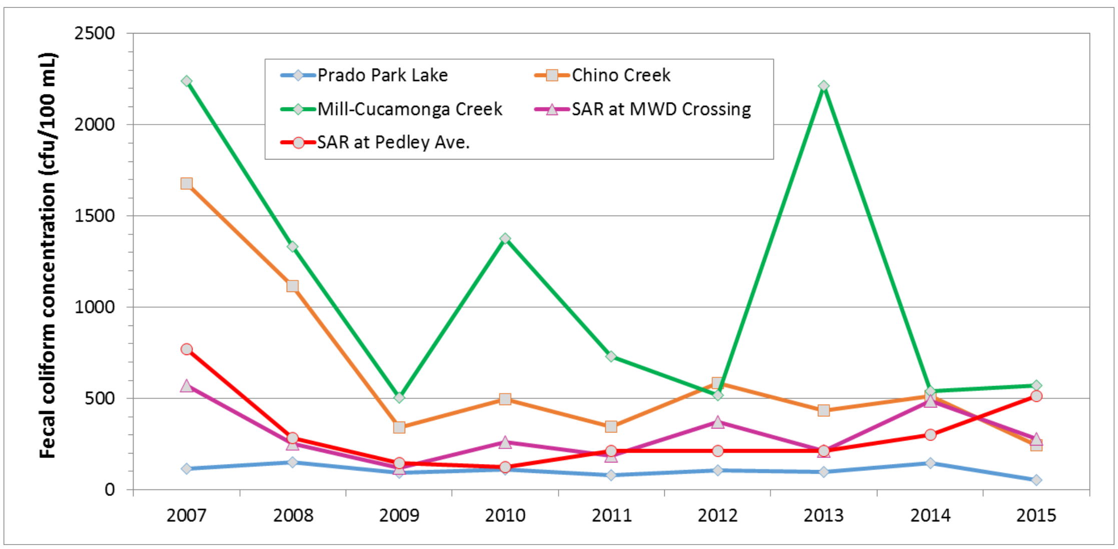


Figure 2-17 Fecal coliform dry season geometric means for 2007-2015

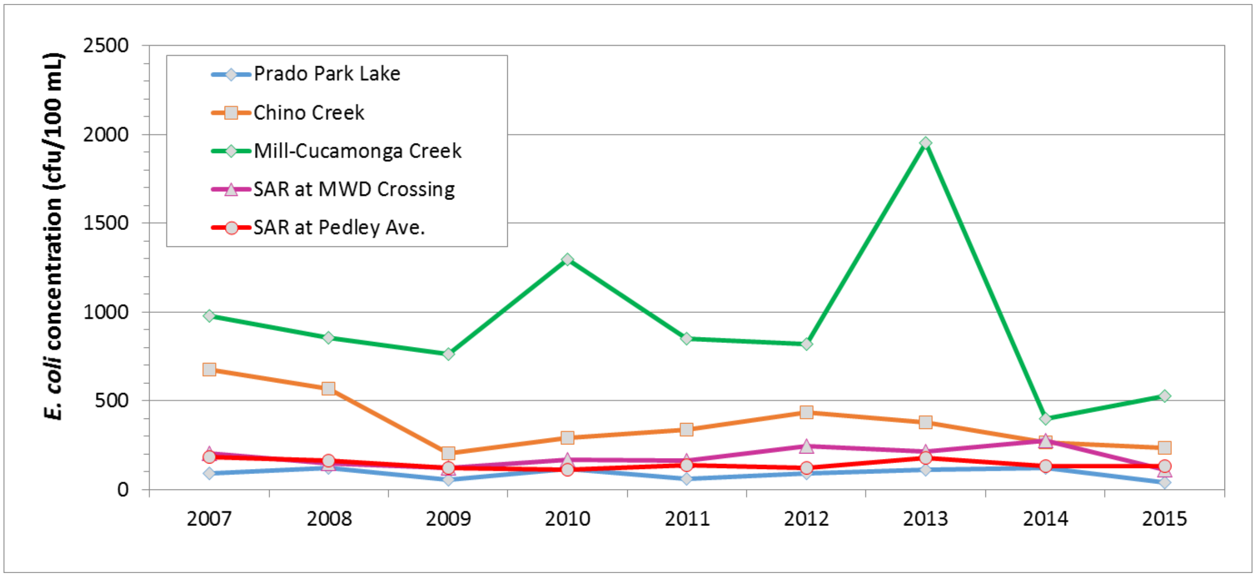


Figure 2-18 *E. coli* dry season geometric means for 2007-2015

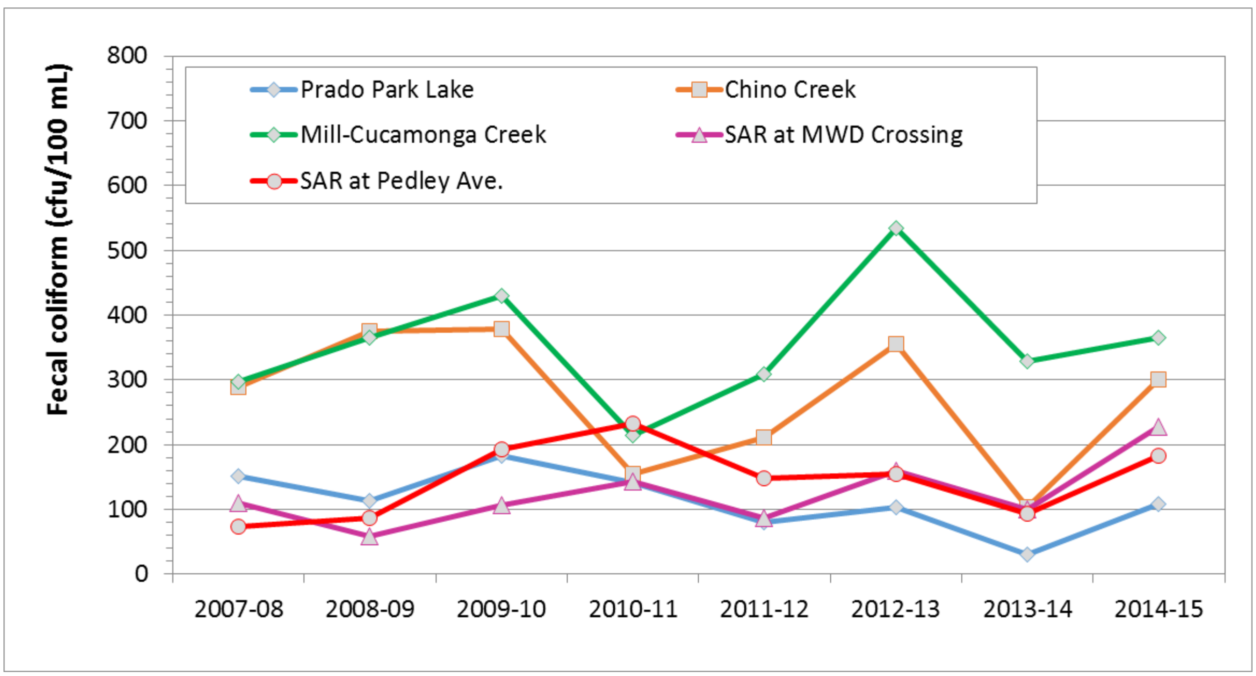


Figure 2-19 Fecal coliform wet season dry weather geometric means for 2007-2015

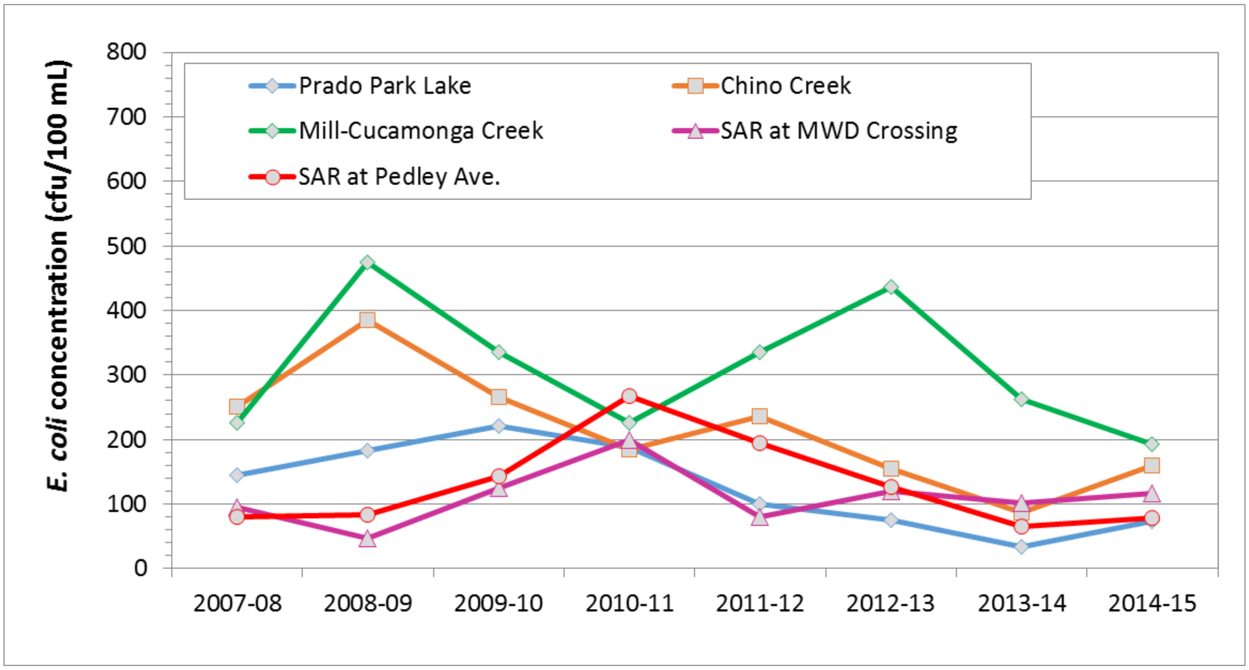


Figure 2-20 *E. coli* wet season dry weather geometric means for 2007-2015

2.4 Compliance with Load Allocations

The MSAR Bacterial Indicator TMDL contains LAs for agricultural runoff discharges and natural sources. These LAs are the same as the WLAs that have been established for urban dischargers and CAFOs. Section 2.3 summarizes these allocations. The following sections summarize the TMDL-related implementation activities associated with the LAs linked to agricultural runoff and natural sources.

As noted previously, the watershed-wide compliance monitoring program samples five locations on a regular basis, which includes natural sources during dry and wet weather and agricultural discharges during runoff events. Monitoring specific to agriculture discharges has also occurred during wet weather. Monitoring that targets natural sources has not occurred during the past three years. The following sections provide information about an inventory of bacteria monitoring to address agricultural or natural sources for the Triennial Review period.

2.4.1 Agricultural Sources

Agricultural dischargers implemented a source evaluation program in 2008. This program included wet weather sampling at select sites in the MSAR watershed where agricultural activity occurs. Sampling occurred during two separate storm events at four sites in 2008. The findings from this sampling effort are reported in the 2010 Triennial Report (SAWPA 2010). No additional wet weather sampling has occurred in relation to sources to agricultural discharger runoff since the 2008 sampling event.

In the 2013 Triennial Review report, it was noted that agricultural dischargers worked collaboratively with the RWQCB to finalize the mapping of agricultural lands in the MSAR watershed. Based on work completed by Aerial Information Systems, agricultural lands represent approximately 7 percent of the watershed. This work was completed in October 2012.[6]

In December 2014, agricultural dischargers submitted a final BASMP to the RWQCB for review and approval. Per the MSAR Bacterial Indicator TMDL, the BASMP should include, plans and schedules for the following:

- Implementation of bacteria indicator controls, best management practices (BMPs) and reduction strategies designed to meet load allocations;
- Evaluation of effectiveness of BMPs; and
- Development and implementation of compliance monitoring program(s).

When approved, the BASMP will replace the Agricultural Source Evaluation Plan, a 2008 TMDL deliverable that was previously approved by the RWQCB.[7]

During the 2015 dry season, the City of Riverside and RCFC&WCD collected samples for bacteriological analysis at two locations along Victoria Avenue in the City of Riverside. These sites were selected because they capture irrigation excess runoff from the Arlington Greenbelt Area. This agricultural region is comprised primarily of citrus groves. About half of the Arlington Greenbelt Area is within the Anza Drain subwatershed to the MSAR. Results of this monitoring are presented in Section 3.2.4 of this 2016 Triennial Review Report.

2.4.2 Natural Sources

The MSAR Bacterial Indicator TMDL establishes a LA for natural sources of bacterial indicators. The allocation for this source is the same as that established for other LA and WLA sources. Source contribution analysis has identified the degree of contribution of bacterial indicators from unaccountable sources. These findings were first reported in Section 3 of each County's CBRP[8], then in the 2013 Triennial Review Report and lastly in Section 3 of this 2016 Triennial Review report.

To characterize natural and uncontrollable bacteria sources, RCFC&WCD conducted an Uncontrollable Bacteria Sources Study to better understand and quantify the influence of uncontrollable sources on bacterial indicator concentrations in waterbodies in the MSAR watershed. Six site-specific technical pilot studies were conducted as part of the Uncontrollable Sources Study for the MSAR watershed to evaluate to the extent possible, what portion of bacterial indicators can be attributed to uncontrollable sources. Uncontrollable sources under consideration are defined in the Recreational Use Standards BPA and include the following:

- Wildlife activity and waste;

---

[6] http://www.sawpa.org/wp-content/uploads/2013/01/MSAR_final_10-24-112.pdf

[7] Santa Ana Water Board Resolution: R8-2008-0044, April 18, 2008

[8] Riverside County Stormwater Program, 2011 and SBCFCD, 2011

- Bacterial regrowth within sediment or biofilm;
- Resuspension from disturbed sediment;
- Concentration (flocks) of semi-wild waterfowl; and
- Shedding during swimming.

Section 3.2.3 of this report provides additional information regarding the Uncontrollable Bacteria Sources Study.

This page intentionally left blank.

Section 3

Analysis of Bacteria Sources

MS4 Permittees in the MSAR watershed have implemented tailored bacteria source tracking studies to identify and eliminate specific sources of fecal bacteria from prioritized drainage areas and to investigate the potential role of non-urban sources of bacteria that may meet the definition of uncontrollable set forth in the 2012 BPA. The following sections synthesize the methods and key outcomes from these activities over the 2013-2015 period. Generally, four types of source evaluations were undertaken:

- Tier 2 source evaluations – For prioritized MS4 drainage areas, a systematic approach was implemented to identify and eliminate potential fecal bacteria sources at Tier 2 sites, which are within MS4 systems and upstream of a Tier 1 outfall to a downstream impaired waterbody. In 2013, MS4 Permittees completed Tier 2 source evaluations throughout MS4 drainage areas to all prioritized Tier 1 sites. Supplemental Tier 2 source evaluations were conducted by some MS4 Permittees in 2014 and 2015. A summary of the Tier 2 source evaluations is provided in Section 3.1.

- Residential property scale bacteria water quality study – Tier 2 source evaluation results for MS4 drainage areas in the Cities of Chino and Chino Hills showed extreme spatial and temporal variability within small upstream subareas with no apparent explanatory factors. The one common finding for these and all other Tier 2 activities was that the predominant source of DWF in MS4s was from excess irrigation runoff from residential properties. Thus, a randomized study was designed and implemented in 2014 to characterize *E. coli* concentrations in DWF resulting from irrigation of individual residential properties in the Cities of Chino and Chino Hills. A summary of the study is provided in Section 3.2.

- Uncontrollable Bacteria Sources Study – Previous source contribution analyses have shown a significant portion of fecal bacteria measured at the watershed-wide TMDL compliance monitoring sites may not be attributed to known inputs of DWF from MS4s and publicly owned treatment works (POTW) effluent. RCFC&WCD conducted a series of pilot studies to investigate other uncontrollable sources of bacteria, including: riparian area wildlife, birds nesting under bridges, releases from sediments under normal DWF and during scouring flows from *de minimus* discharges, and release from swimming and equestrian use. A summary of the study is provided in Section 3.3.

- Arlington Greenbelt Sampling – Furrow irrigation for citrus groves in the Arlington greenbelt area creates DWF that is conveyed into the City of Riverside MS4 system upstream of Anza Drain outfall to the Santa Ana River. The City of Riverside and RCFC&WCD collected samples from this source of DWF during the 2015 dry season. Results are summarized in Section 3.4.

3.1 Tier 2 Source Evaluations

3.1.1 Introduction

Tier 1 source evaluation activities completed in the 2011 and 2012 dry seasons provided the basis for prioritizing MS4 drainage areas within the MSAR watershed for subsequent, upstream Tier 2 source evaluations. The drainage areas to each of the prioritized Tier 1 sites, shown in Figure 3-1, are spread across multiple cities in each of Riverside, San Bernardino, and Los Angeles Counties. Table 3-1 shows that the drainage areas range in size from 334 acres to 7,313 acres and also shows the frequency of human *Bacteroides* detection from the 2012 dry season.

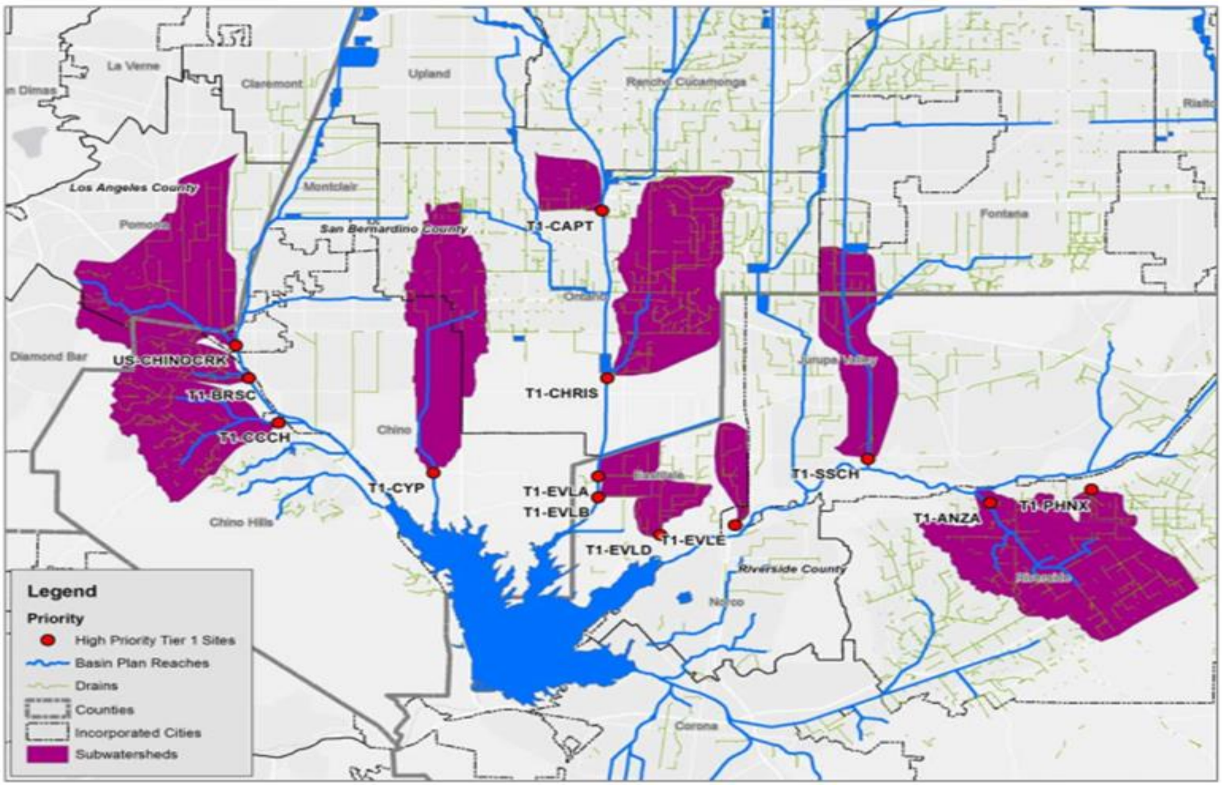


Figure 3-1
Map of Prioritized Tier 1 MS4 Drainage Areas for Tier 2 Source Evaluation

3.1.2 Methods

Dry weather flow samples were taken from a variety of outlets, including channels, manholes, storm drains, and culverts, within the drainage areas. In total, 114 sites were monitored covering 7 cities in 3 counties. MS4 Permittee staff collected field measurements and water quality samples from all Tier 2 sites during the 2013 dry season, and from a subset of sites in subsequent years, 2014 and 2015, in accordance with the QAPP[1].

[1] Middle Santa Ana River Quality Assurance Project Plan, July 2013, Version 4 (http://www.sawpa.org/wp-content/uploads/2013/01/MSAR-QAPP-July-2013.pdf)

3.1.3 Results and Discussion

Exceedance of WLAs for *E. coli* occurred in most samples collected from Tier 2 sites (Figure 3-2). In some Tier 1 MS4 drainage areas, the distribution of results from multiple upstream Tier 2 sites was significantly different from samples collected in other prioritized Tier 1 drainage areas. Thus, it may be concluded that certain MS4 areas, as a whole, are more important sources of fecal bacteria. Management actions would provide the greatest potential benefits to downstream water quality when focused in these areas.

Table 3-1 Prioritized Tier 1 Drainage Areas for Tier 2 Source Evaluation Activities

Site ID	Jurisdictions	Drainage Acres	Human Presence	MS4 Drainage Features
T1-EVLD	Eastvale	852	30%	Storm drains
T1-EVLE	Eastvale	798	100%	Storm drains
T1-CYP	Chino, Ontario	4,952	20%	Open channel with storm drain outfalls
T1-EVLB	Eastvale	334	80%	Storm drains
T1-ANZA	Riverside	7,313	20%	Open channel with storm drain outfalls
T1-CAPT	Ontario	1,050	40%	Storm drains
T1-CHRIS	Ontario	5,774	30%	Open channel with storm drain outfalls, culverts
T1-SSCH	Jurupa Valley, Fontana	3,337	40%	Open channel with storm drain outfalls
T1-EVLA	Eastvale	498	10%	Storm drains
CHINOCRK	Pomona, Claremont	6,032	30%	Storm drains
T1-PHNX	Riverside	503	10%	Storm drains
T1-CCCH	Chino Hills	3,934	0%	Open channel with storm drain outfalls
T1-BRSCH	Chino Hills	1,160	10%	Open channel with storm drain outfalls

A significant reduction of bacterial indicator concentrations was observed in subwatersheds where there is a segment of open channel prior to reaching the downstream Tier 1 site. Figure 3-2 illustrates this water quality improvement with the red diamonds showing the *E. coli* concentration at the Tier 1 site and the boxplot characterizing the range of *E. coli* concentrations for upstream Tier 2 sites. The box and whisker plots on the left side of the chart are for subwatersheds with an open channel segment. The reduction of *E. coli* was observed in Carbon Canyon Creek Channel (CCCH), Cypress Channel (CYP), Anza Drain, and Eastvale Line E (EVLE) subwatersheds. Conversely, for MS4s that are entirely underground (on right side of the chart in Figure 3-2), the Tier 1 site concentration generally falls within the range of upstream Tier 2 concentrations. In some subwatersheds, a higher concentration at the Tier 1 site relative to the range of upstream Tier 2 concentrations may point to an additional source of bacteria from within the MS4 facilities, such as wildlife, transient camps, or regrowth in biofilms where environmental conditions may create a habitat for bacteria.

Microbial source tracking methods were employed by nine MS4 Permittees, listed in Table 3-1, as part of the Tier 2 source evaluations. The human *Bacteroides* marker was evaluated in one-third of Tier 2 DWF samples (124 out of 376 collected samples). Only one Tier 2 site had more than one detection of human *Bacteroides*, T2-GARY in the City of Pomona. Other sites had one detection, including the Peyton drain in the BRSC subwatershed, the Tier 1 site EVLB, and Tier 2 sites within the drainage areas to Eastvale Lines D and E. Overall, the frequency of *Bacteroides* presence has decreased from the initial USEP studies conducted in 2007-2008 and the Tier 1 source evaluation. This line of evidence suggests that mitigation activities conducted in 2013-14 have been successful at reducing the frequency of human contribution from controllable sources of bacterial indicators in some subareas (Figure 3-3).

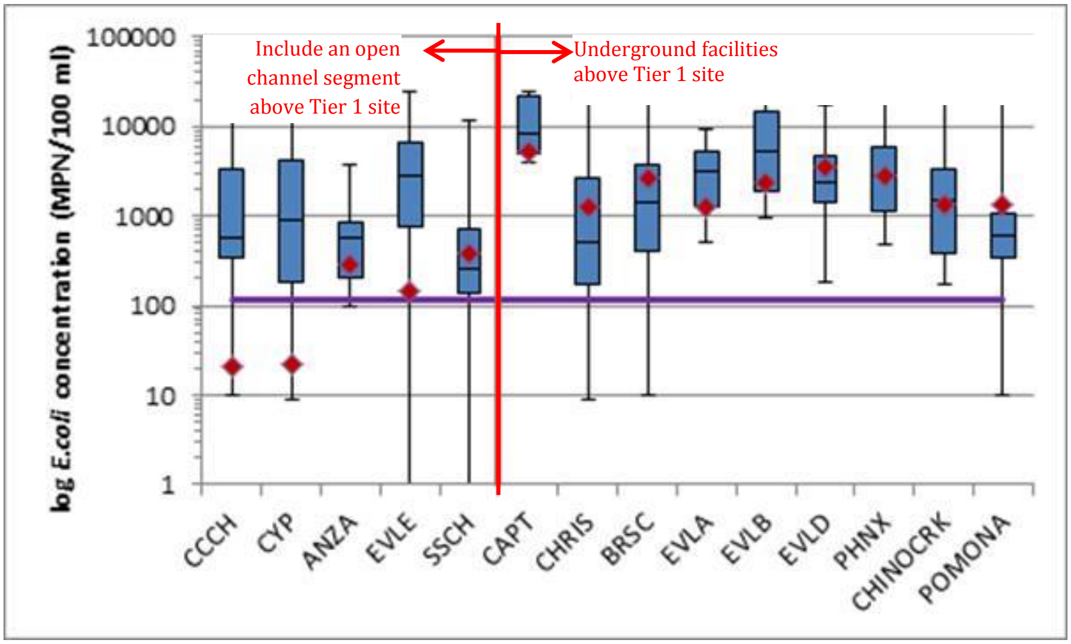


Figure 3-2
Box-Whisker Plot of *E. coli* Concentrations at Tier 2 Source Evaluation Monitoring Sites that Drain to a Downstream Tier 1 Site (Red Diamond Shows *E. coli* Concentration at Downstream Tier 1 Site).

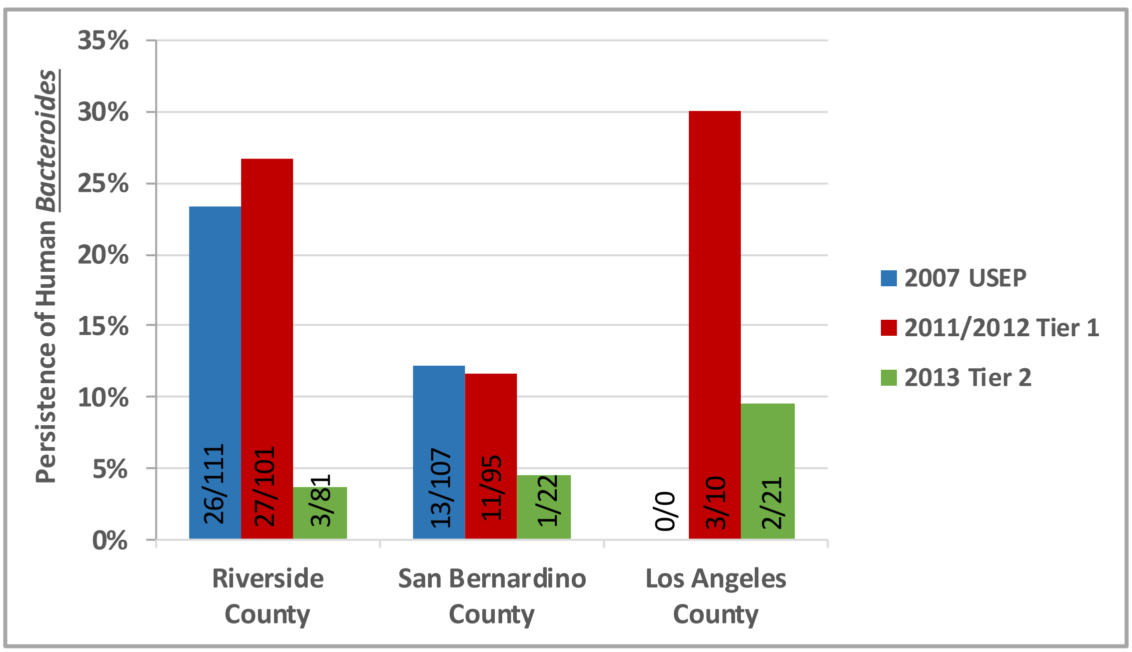


Figure 3-3
Change in Persistence of Human *Bacteroides* by County from 2007 to 2013 (Note that there are no data for Los Angeles County in 2007; not an absence of *Bacteroides.* Ratios indicate the number of samples with *Bacteroides* detected/the number of samples analyzed for *Bacteroides*)

Detailed results and interpretations from Tier 2 source evaluations in the 2013 dry season for individual MS4 Permittees are provided in the Tier 2 Source Evaluation Report[2] (SAWPA, 2013c). For many MS4 Permittees, the Tier 2 source evaluations were able to identify a specific source of fecal bacteria from drainage areas for mitigation. Below are several examples of Tier 2 Source evaluation findings, including sources that were eliminated or have planned control measures as a result of Tier 2 source evaluations:

- Eastvale Line E - The City of Eastvale worked with RCFC&WCD staff to conduct thorough field reconnaissance in the watershed land areas tributary to T1-ELVE, where there was a persistent detection of human *Bacteroides* over a ten-week period in the 2012 dry season. These investigations identified a potential source of human fecal bacteria in the MS4 system where migrant day laborers were congregating near a drop inlet tributary to the system. Eastvale Code Enforcement focused their efforts in this area to eliminate this potential source of human fecal bacteria. Water quality has since improved, as evidenced by a substantial reduction in the frequency of human *Bacteroides* detection between the 2012 and 2013 dry seasons.

- Anza Storm Drain - RCFC&WCD and Western Municipal Water District (WMWD) are working collaboratively to facilitate the construction of three stormwater recharge facilities in the Arlington area and expansion of the Arlington Desalter Project. Two of the stormwater recharge facilities will be integrated into Southwest Riverside MDP Line G. The third facility will be adjacent to Arlington Channel near Van Buren and Indiana Avenue. The project is estimated to develop 1,848 acre-feet per year of new water supply. A portion of the DWF at the Anza Drain outfall to the MSAR is from groundwater. This project is expected to shift the slope of the groundwater table away from the river and reduce DWF rates and associated bacterial indicator loads.

- Phoenix Storm Drain - Bacterial indicator concentrations in the Phoenix Storm Drain area are persistently high, but the rate of DWF is low (<0.1 cfs on average). The District is working with the City of Riverside to evaluate the feasibility of diverting this small volume of urban DWF from the MS4 to its own Riverside Water Quality Control Plant located about one-half mile west of the outfall. This would effectively eliminate all DWFs from this outfall and increase the volume of disinfected effluent in the river.

- Boys Republic South Channel - The City of Chino Hills has conducted rigorous sampling and field reconnaissance throughout the Boys Republic South Channel subwatershed since 2012. In the 2013 dry season, the City identified several specific sources of fecal bacteria and mitigation actions were taken. One involved the use of the BRSC culvert as a nesting site for cliff swallows. Netting was installed to inhibit these birds from nesting within this MS4 facility in upcoming years. The second involved a mobile fish market business that was washing off its equipment into the MS4. Despite these actions, high concentrations of bacterial indicators continued to occur and the Cities of Chino and Chino Hills developed

[2] http://www.sawpa.org/wp-content/uploads/2013/01/MSAR-Bacterial-TMDL-2013-Dry-Season-Tier-2_Final-2-Nov-2014.pdf

and implemented a residential property scale bacteria water quality study described in Section 3.2.3.

- Carbon Canyon Creek Channel – In the Carbon Canyon Creek Channel subwatershed, samples were collected from multiple Tier 2 sites in the underground portion of the Chino Hills MS4 upstream of the open channel segment. Data were also collected at the downstream Tier 1 site. These samples corroborated data interpretations from previous years, which suggested that natural decay, treatment, and/or channel bottom recharge processes in this stretch of open channel provide significant bacteria removal. A unique feature of this channel is the presence of rock check dams that impound flow in shallow pools.

- Cypress Channel – The improvement of bacterial water quality in Cypress Channel may be the result of stormwater program implementation and IC/ID activities. Natural decay by ultraviolet light exposure or channel bottom recharge in the unlined segment may be the primary mechanisms for providing significant bacteria reductions.

- Lower Deer Creek - The Lower Deer Creek subwatershed is one of the largest of the prioritized drainage areas in the MSAR. Results from the Tier 2 source evaluation as well as field observations indicated that a potentially significant issue is debris accumulation within MS4 facilities. Chris Basin receives runoff from Lower Deer Creek prior to the outfall to Cucamonga Creek. SBCFCD is planning a project to restructure the basin bottom following the 2015-2016 wet season to incorporate small levees of native soils to force low flows to meander from the inputs to the basin outflow throughout the dry season. This would facilitate longer residence time in the basin and more contact with soils, which have been shown to promote bacteria reduction (Kadlec and Wallace, 2009[3]).

- Cucamonga Creek - The Mill Creek wetland BMP was recently constructed at the downstream end of Cucamonga Creek. A portion of DWF is diverted from Cucamonga Creek to the wetland for treatment and is then discharged back to Mill-Cucamonga Creek at Chino Corona Road. The effectiveness of this BMP has not yet been evaluated.

- San Sevaine Channel – Longitudinal sampling along San Sevaine Channel within Riverside County suggests the presence of another source of bacteria between Jurupa Valley's most downstream MS4 outfall at Bellegrave Avenue and the Tier 1 site at the Santa Ana River.

- Declez Channel – DWF at the Declez Channel outfall to San Sevaine Channel had consistently high bacteria concentrations, which suggests there may be a persistent source in the subarea to this site. The drainage area within the City of Jurupa Valley to Declez Channel, downstream of the Declez Basin, is relatively small and made up of 3 residential neighborhoods. The City of Jurupa Valley in partnership with the RCFC&WCD developed a plan to conduct supplemental Tier 2 source evaluation in this area and are evaluating the

---

[3] Kadlec, Robert H. and Scott Wallace. *Treatment Wetlands; 2nd Edition*, CRC Press, 2009.

possibility of repurposing an abandoned basin downstream of this area for the purposes of infiltrating dry weather flows.

3.2 Residential Property Scale Bacteria Water Quality Study

3.2.1 Introduction

The primary objective of the residential property scale bacteria water quality study was to characterize *E. coli* concentrations in DWF resulting from irrigation of residential properties in the Cities of Chino and Chino Hills in San Bernardino County, California. Through field reconnaissance, it has been observed that the predominant source of DWF at MS4 outfalls throughout the MSAR watershed is irrigation excess runoff from residential properties, as is shown in Figure 3-4 below (personal communications with Ruben Valdez, City of Chino Environmental Coordinator; Robert Vasquez, RCFC&WCD Associate Civil Engineer; Tad Garrety, City of Chino Hills Environmental Program Coordinator, March 18, 2015).

Figure 3-4
Typical Irrigation Excess Runoff from Front Yards (left) and Back Yards via an Underdrain (right)
Photo Credit: Ruben Valdez

A common finding of most water quality monitoring programs investigating FIB in urbanized watersheds is that results show extreme variation with samples ranging from non-detect to exceeding the range of measurement even after multiple dilutions, typically >24,000 MPN/100 mL (Urban Water Resources Research Council, 2014[4]). This was also a general finding throughout the MSAR watershed for samples collected from MS4 outfalls and within networks in the 2012 and 2013 dry seasons. In fact, it was noted that such variability was discovered even when evaluating weekly samples collected during dry weather conditions from the same site and at similar times of day.

[4] http://www.asce-pgh.org/Resources/EWRI/Pathogens%20Paper%20August%202014.pdf

One hypothesis that may explain the apparent extreme variability in downstream results is that bacteria washoff is linked to the quantity and quality of irrigation excess runoff from individual properties. Unlike rainfall driven runoff, where rain is spread across the entire watershed, the primary source of DWF in an urban catchment at any given point in time is outdoor water use by a single or small group of properties. The typical duration of an irrigation station is less than 15 minutes, thus FIB from a given property can only generate irrigation excess during a brief period of a day, excepting any substantial malfunction or misuse. Accordingly, a sample taken at any given time downstream of a residential neighborhood is likely only representative of the properties that were actively generating irrigation excess runoff immediately prior to the sample collection. In other words, consecutive (with more than 15-minute separation) samples within MS4s or at outfalls taken from the same site may be representative of completely different contributing subareas.

Two key questions posed by stormwater managers were addressed in the study: 1) what is the proportion of properties with elevated DWF and/or FIB concentrations that may be contributing to downstream impairments and 2) are any unique characteristics of properties with elevated concentrations of FIB?

3.2.2 Methods

Together the Cities of Chino and Chino Hills visited over 300 randomly selected residential properties in the Cypress Channel (CYP) and Boys Republic South Channel (BRSC) drainage areas to observe DWF conditions and where possible, collect water quality samples for bacteriological analysis. The field crews targeted early morning hours (between 4:00 AM and 8:00 AM) to perform site visits in order to increase the likelihood of encountering DWF when residents are more likely to have scheduled irrigation timers per landscaping recommendations and local water conservation ordinances.

The study design recognized the challenge of collecting water samples from a randomly selected address, given the expected short duration of irrigation excess runoff from a randomly selected property (<30 minutes), and therefore involved an unbiased protocol to locate nearby DWF for collection of field observations and water samples (Figure 3-5). The protocol involved tracking any DWF in the street gutter adjacent to the randomly selected address to its most upstream source. Field observations and water samples were then collected at the address of the residential property that was the most upstream source of DWF.

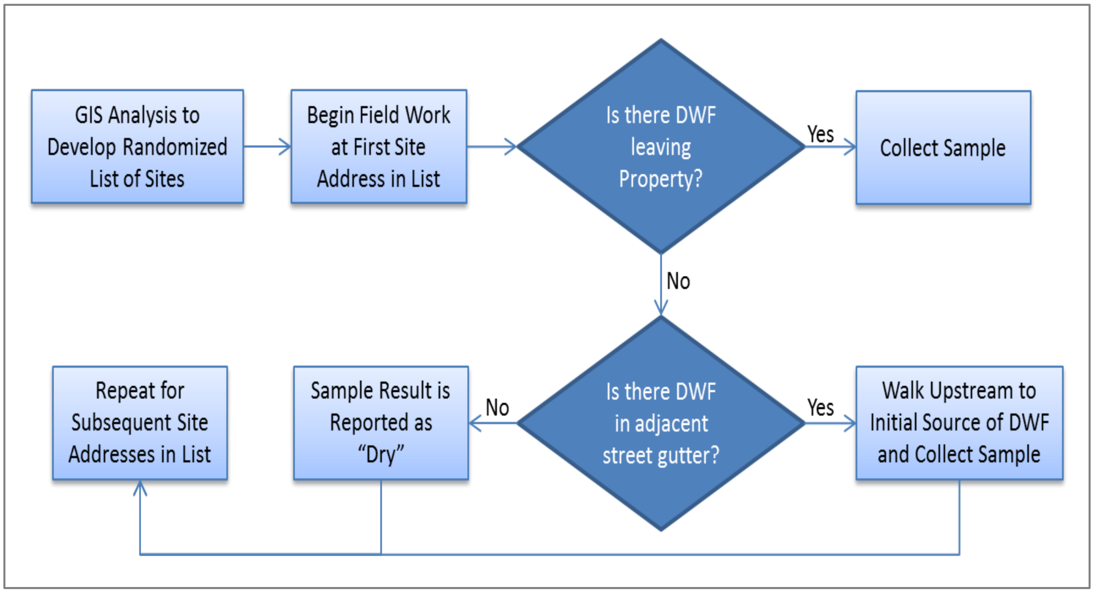


Figure 3-5
Protocol to Select Sites for DWF Sample Collection

3.2.3 Results and Discussion

Summary statistics for each of the subwatersheds are presented in Table 3-6. Geometric means of *E. coli* from properties in the BRSC and CYP drainage areas were 101 and 233 MPN/100 mL, respectively. When pooling the data from both drainages, the geomean of all 80 properties was 127 MPN/100 mL. The data show wide variability with many samples at the limits of detection (typically 10 MPN/100 mL) or upper range of countable measurement (typically 24,000 MPN/100 mL). A single-component lognormal model provided the best fit to the distribution of data from the pooled dataset. Given the lognormal distribution, the arithmetic mean is much greater than the geomean or median, as shown in Table 3-2.

Table 3-2 Summary statistics for *E. coli* concentration

Statistic	*E. coli* concentration (MPN/100 mL)		
	Boys Republic South Channel (n = 58)	Cypress Channel (n = 22)	Pooled Study Data (n = 80)
Geomean	101	233	127
Coefficient of variation	0.56	0.34	0.50
Minimum	1	10	1
Median	84	205	119
Arithmetic Mean	1,548	1,056	1,413
Maximum	24,196	9,200	24,196

For the 2014 study data, a workbook application was developed that uses bootstrapping to estimate a population parameter representing the average percentage of the population above an *E. coli* value of 235 MPN/100 mL, the current single sample maximum (SSM) water quality objective, and 410 MPN/100 mL, a recently published statistical threshold value (STV) for freshwaters (EPA, 2012), along with the margin of error (or confidence interval) for the estimated parameter. Results indicate that at the 95 percent confidence level, 41.2 percent + 11.3 percent of the population of properties in the two drainages would be expected to exceed the SSM, and that 29.9 percent + 10.0 percent would be expected to exceed the STV.

The dataset also included field observations, which were used to separate *E. coli* data into different groups that could be compared to determine whether differences between the groups are statistically significant. None of the sampled properties appeared to have any obvious sources of fecal bacteria, except for a few where dogs were noted in the backyard. One significant explanatory variable identified in the study was the flowpath where samples were collected between the irrigation spray-head and MS4. Three distinct types of flowpaths for irrigation excess runoff sampled during the Study were identified:

- Many properties are developed with small diameter (<4 inches) perforated backyard drains designed to convey water from oversaturated soil to the MS4. Typically, such drains are within 1 foot of the ground and outflow to the street gutter through an opening in the curb (see Figure 3-4);
- The soils underlying typical front yards are highly compacted and often cannot percolate irrigation water at the rate it is applied. Consequently, a portion of the irrigation water moves laterally downgradient through the thatch and ultimately exits the lawn and becomes sheet flow over sidewalks and driveways; and
- Some samples were collected directly from street gutters immediately downstream of the randomly selected address and may include a blend of DWF from upstream properties.

E. coli concentrations from the three flowpath groups are shown as box-whisker plots in Figure 3-6. Multiple comparison (parametric t-tests and nonparametric Wilcoxon-Mann-Whitney) tests were conducted to identify which of the individual groups are statistically different. Results indicated that front yard versus gutter is statistically different (p-value = 0.005 for both tests).

The study results indicate that variability of bacteria water quality is related to differences in source areas at the property scale, and that it is likely that elevated bacteria levels measured at MS4 outfalls may be caused by a minority of proprieties that contain a source of FIB. The concentration of *E. coli* at an MS4 outfall would be approximated by computing a flow-weighted arithmetic mean of irrigation excess from all properties contributing DWF at the point of sampling. Assuming the rate of irrigation excess DWF is similar for many properties, the *E. coli* concentration at MS4 outfalls would be best represented by the arithmetic means shown in Table 3-2 above. Thus, a small fraction of properties may skew downstream *E. coli* concentrations in DWFs to the MS4.

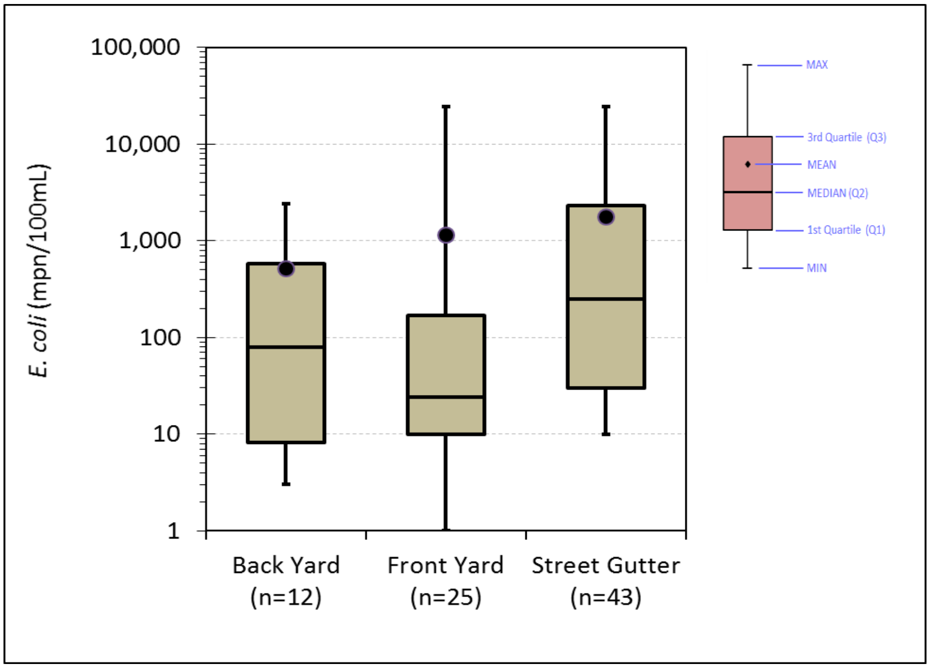


Figure 3-6
Box-Whisker Plots for *E. coli* Concentrations for Samples from Front Yard, Back Yard, and Street Gutter Flowpaths

3.3 Uncontrollable Bacteria Sources Study

3.3.1 Introduction

Bacteria source evaluation activities implemented through the CBRP have focused on identifying and mitigating controllable sources in the MS4 during the dry season. Source contribution analyses continue to suggest uncontrollable sources are likely a large component of FIB concentrations in receiving waters of the MSAR watershed. Thus, RCFC&WCD conducted an Uncontrollable Bacteria Sources Study to better understand and quantify the influence of uncontrollable sources on bacterial indicator concentrations in waterbodies in the MSAR watershed.

Six site-specific technical pilot studies were conducted as part of the Uncontrollable Sources Monitoring Program for the MSAR watershed to evaluate to the extent possible, what portion of bacterial indicators can be attributed to uncontrollable sources. Uncontrollable sources under consideration are defined in the BPA and include the following:

- Wildlife activity and waste;
- Bacterial regrowth within sediment or biofilm;
- Resuspension from disturbed sediment;
- Concentration (flocks) of semi-wild waterfowl; and
- Shedding during swimming.

While the study was not intended to be exhaustive in nature, each of the pilot studies was designed to provide information that increases understanding regarding the different types of potential uncontrollable sources of bacterial indicators in the MSAR watershed. These specialized studies were conducted to help understand the relative importance of various potential uncontrollable sources of bacterial indicators to exceedances of MSAR Bacterial Indicator TMDL targets in the MSAR watershed.

3.3.2 Methods

Dry weather water and sediment samples were collected from ten study locations along Reach 3 of the SAR and tributary open flood control channels for the six pilot studies (Table 3-3). RCFC&WCD staff collected field measurements and water quality samples during each sampling event during 2015. Water quality samples were analyzed for *E. coli* concentrations as well as presence of DNA markers representing various uncontrollable sources using molecular source tracking techniques.

Table 3-3 Uncontrollable Sources Monitoring Locations

Study	Study Location	Sample Frequency	Analysis
Natural	SAR downstream of RIX	Seasonal (3 times/year)	*E. coli*, human, dog, bird, rumen
Bird	Cucamonga Creek at Schleisman Avenue Bridge	Peak bird season (5 consecutive weeks)	*E. coli*, bird
Bird	SAR at Mission Boulevard Bridge	Peak bird season (5 consecutive weeks)	*E. coli*, bird
Sediment & Biofilm	Sunnyslope Channel	Seasonal (4 times/year)	*E. coli*, human, dog, bird, rumen
Sediment & Biofilm	Eastvale Line E	Seasonal (4 times/year)	*E. coli*, human, dog, bird, rumen
Sediment & Biofilm	John Bryant Park	Seasonal (4 times/year)	*E. coli*, human, dog, bird, rumen
Non-MS4	San Sevaine Creek	Summer (3 times/year)	*E. coli*
Non-MS4	Day Creek	Summer (3 times/year)	*E. coli*
Human (Swim)	SAR at Martha Mclean Anza Narrows Park	2 weekends	*E. coli*, human, dog
Horse	SAR at 66th Street & Etiwanda Avenue	2 weekends	*E. coli*, horse
Horse	SAR at Mary Tyo Equestrian Center	2 weekends	*E. coli*, horse
Horse	SAR at Downey Street & 64th Street	2 weekends	*E. coli*, horse

3.3.3 Results and Discussion

Four of the pilot studies were conducted to assess whether there is a specific source of fecal bacteria to the Santa Ana River and Cucamonga Creek that is uncontrollable by using multiple lines of evidence including FIB concentrations, biological surveys, flow monitoring, microbial source tracking, and isolation of a SAR segment with no urban inputs. Several key findings included:

- Microbial source tracking results included some detection of fecal bacteria associated with a specific host organism, including bird, dog, and human; however, these detections were not correlated with *E. coli* concentrations and did not consistently occur at sites downstream of suspected sources (e.g., swimming holes for human fecal bacteria and habitat areas for fecal bacteria from wildlife).

- In the bird study, birds were detected at both upstream and downstream sites and not consistently during high *E. coli* concentrations.

- In the swim study, *E. coli* concentrations were slightly elevated during the holiday weekend when presence of humans was observed to be high, however, humans were not detected during molecular analyses and the downstream site showed similar bacteria concentrations as the upstream site. Detection of dog in one of the samples correlated with one elevated *E. coli* sample, however dogs were not detected on other days when dogs were present.

- In studies involving sediment or biofilm samples, *E. coli* concentrations, reported as cfu/10 g, were substantially higher than *E. coli* concentrations in the overlying water, assuming a density of water of 1 g/mL. Typically, sediment *E. coli* is several orders of magnitude greater than the overlying water.

Fecal bacteria from a specific host released to the environment can settle to channel bottom and survive within sediments or biofilms for weeks or months over a wide range of temperature and moisture conditions. Growth of these initially deposited fecal bacteria within channel bottom sediments and biofilms results in colonies, where the majority of the population may be considered naturalized, reproducing outside of a specific organism. Once naturalized, it may be difficult to identify the ancestral bacterial hosts. At typical growth rates between 0.1 to 0.3 hr^{-1} (Jiang et al, 2007), the portion of the fecal bacteria population attributed to the initial host may be less than 5 percent within the first 12-24 hours of deposition (Figure 3-7).

The rate of growth or decay of naturalized colonies of *E. coli* in the bottom sediments and biofilms of the TMDL waterbodies during dry weather conditions has been shown to be less important to the concentration of bacteria in overlying water than the physical processes that cause releases of bacteria to the water column (Grant, 2011).

By process of elimination, it is possible that the majority of autochthonous *E. coli* is associated with releases from naturalized colonies in channel bottom sediment and biofilms. There are two possible transport process from naturalized colonies of *E. coli* in sediments and biofilms on channel bottoms to be released to the water column, including:

- Resuspension of sediment and attached *E. coli* by flows exceeding critical shear stress; and

- Advection of E. coli in porewater to overlying water column.

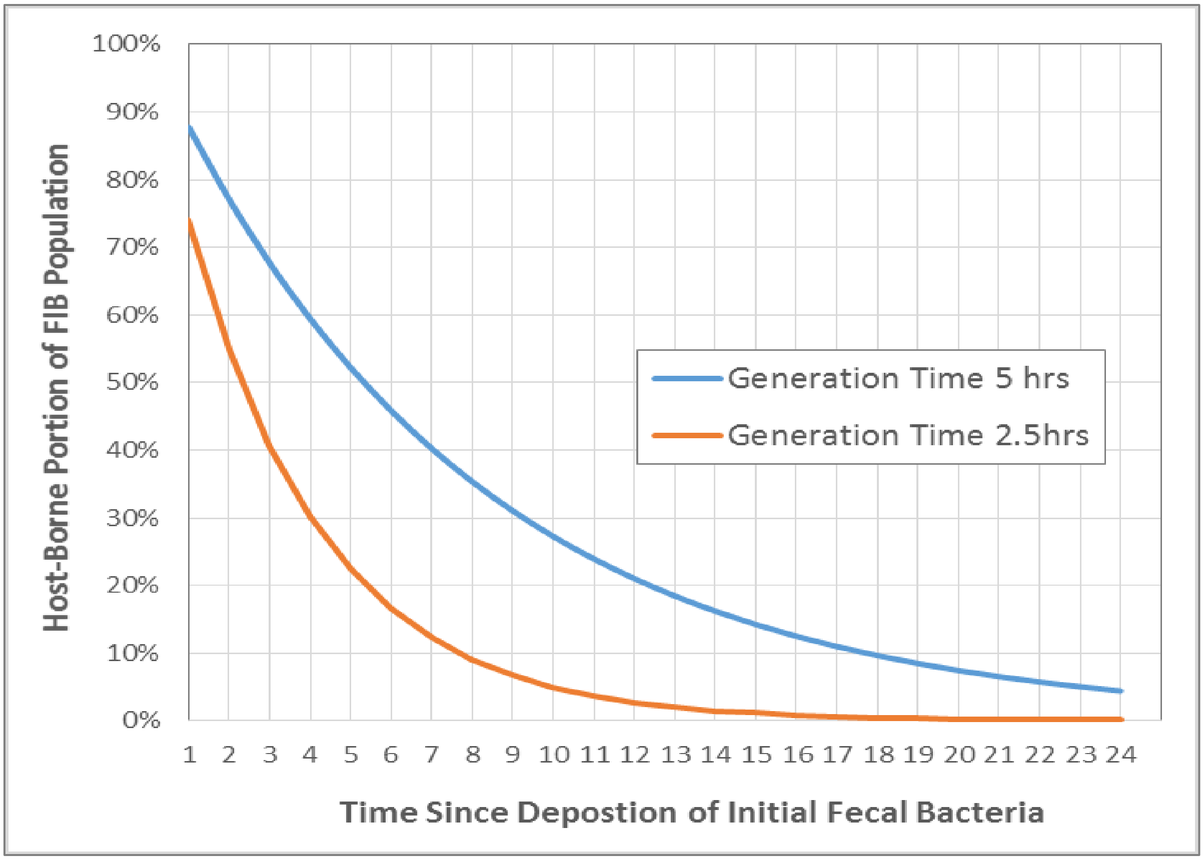


Figure 3-7
Ratio of host-borne to naturalized FIB with a range of exponential growth rate constants

Further study is necessary to identify the role of naturalized bacteria colonies on overlying water and would help to address which of these transport processes is most important. If the former, management plans could be developed to limit rates of DWF conveyed by flood control channels and impaired waters to avoid exceedances of critical shear stress thresholds, from sources including *de minimus* discharges, POTW effluent, and DWF from MS4s. Conversely, if the latter proves to control releases from sediments, then controlling rates of flow would not be an effective management approach. An alternative approach in this case would be to provide supplemental treatment to limit colonization in potential hot spots.

3.4 Arlington Greenbelt Irrigation Excess Sampling

3.4.1 Introduction

Tier 2 source evaluations by the City of Riverside and RCFC&WCD discovered a key source of DWF in the Anza Drain subwatershed was the Arlington Greenbelt Area. This area is situated upstream of the MS4 network from portions of the City of Riverside. This agricultural region is comprised primarily of citrus groves. Roughly half of the citrus groves employ furrow irrigation methods, which involve completely filling furrows between rows of citrus trees with water. In order to ensure that the downstream end of the furrows are completely filled, there is an unavoidable volume of excess irrigation water that becomes DWF. Irrigation excess is then discharged to street gutters or roadside ditches (Figure 3-8). Approximately half of the Arlington

Greenbelt Area is within the Anza Drain subwatershed to the MSAR. Specifically, DWF from this portion of the Arlington Greenbelt Area is all routed to Don Derr Park or the Jefferson Street storm drain, both of which outfall to Monroe Channel.

Figure 3-8
Photo of DWF from use of Furrow Irrigation in the City of Riverside Arlington Greenbelt Area

3.4.2 Methods

RCFC&WCD monitored two stations in the Anza MS4 drainage areas in the City of Riverside during the 2015 dry season, approximately May through October. MonroeAg01 is located at the southwest corner of Monroe Street and Victoria Avenue, while MonroeAg02 is located approximately 600 feet north of the intersection of Gratton Street and Victoria Avenue. (Figure 3-9).

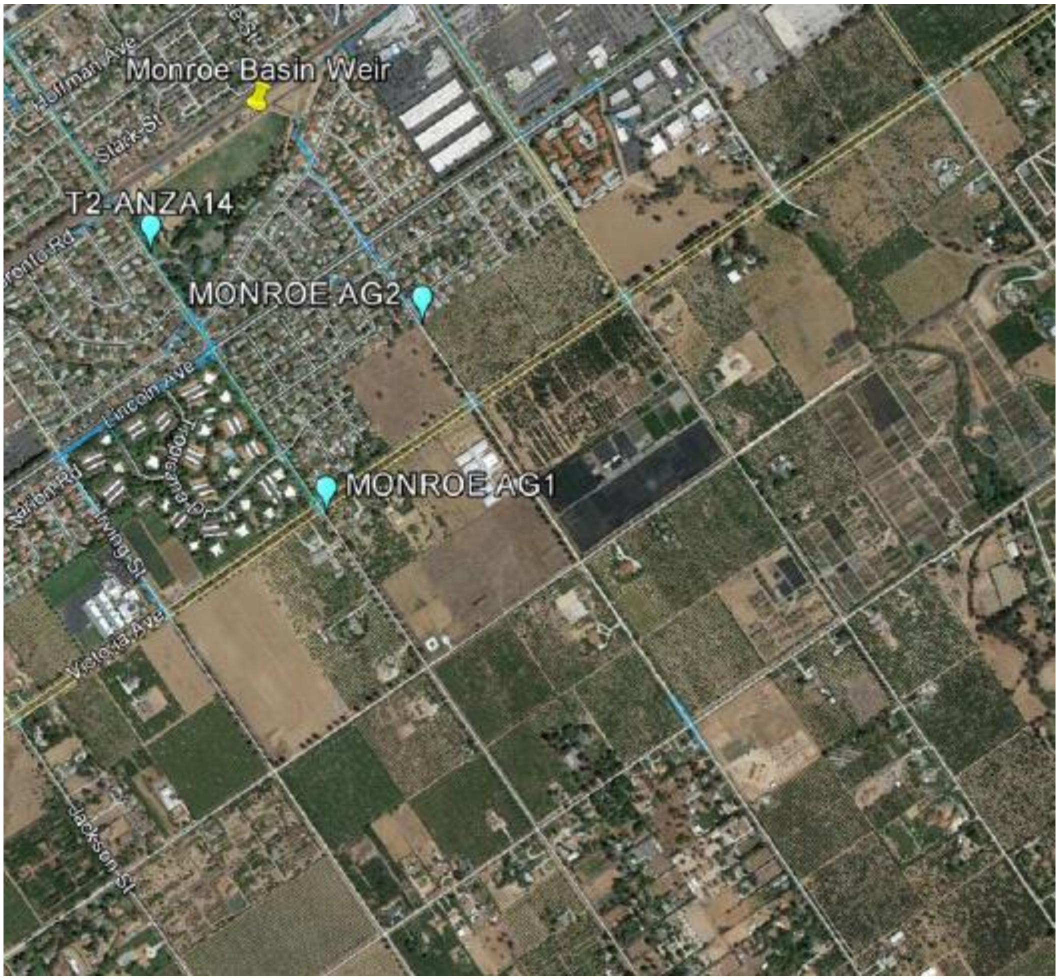


Figure 3-9
Sample Station Location Map

MonroeAg01 is upstream of the Don Derr Park which is a MS4 Tier 2 source evaluation site. Don Derr Park is a dual use basin: (i) during storm events, it is used as a flood control basin to capture large volumes of stormwater, which is subsequently released slowly; and (ii) during periods of dry weather, the basin bottom is used as a sports field.[5] While T2-ANZA 14 may have some contributions from urban land uses along Monroe Street, MonroeAg01 would be primarily composed of Arlington Greenbelt runoff. Likewise, MonroeAg02 isolates the Arlington Greenbelt runoff from urban contributions downstream along Gratton Street.

RCFC&WCD staff collected water quality samples and recorded field measurements from the Monroe sites. Water samples were collected before conducting any field measurements, including flow, to ensure measurements were representative of water chemistry and quality from time of collection. Site water quality measurements included the collection of field parameter data

[5] The City of Riverside, working together with the District, has begun preliminary designs to infiltrate the dry-weather flows from the upstream citrus groves as they enter Don Derr Park.

(where feasible) and water samples for laboratory analysis. Water samples were collected from the upstream side, preserved, stored, and transported as specified by protocol and chain-of-custody requirements.

Where field measurements were feasible, they included flow, temperature, electrical conductivity, pH, dissolved oxygen, and turbidity. These constituents were measured on site at the time of sampling using YSI or equivalent multi-parameter meters. Additionally, notes were compiled concerning site conditions (precipitation, odor, floatables, settleables, color, clarity, trash) and other observations. Estimates of flow were provided through a calculation using visual measurements – depth, width and velocity.

Water samples were collected for submittal to Babcock Laboratories, Inc. for *E. coli* analysis using method SM 9223B. Babcock is located in Riverside, CA.

3.4.3 Results and Discussion

Table 3-4 summarizes the samples collected as part of this study and Table 3-5 provides the field measurements.

MonroeAg01 was visited six times between May and August, 2015 and four samples were collected (there was no flow on June 16th and June 23rd). MonroeAg02 was visited five times between May and August, 2015 and five samples were collected. Figure 3-10 provides photos that show DWF at MonroeAg02 (left) and MonroeAg01 (right).

Table 3-4 Samples Collected During Dry Weather 2015

Sampling Agency	Station Name	Sample Date	Sample Time	Flow (cfs)	Notes
District	MonroeAg01	5/27/2015	11:55 AM	0.03	▪ Bubbles forming at surface
District	MonroeAg01	6/2/2015	7:20 AM	0.025	▪ Excessive leaf litter upstream of sampling location
District	MonroeAg01	6/8/2015	7:25 AM	0.043	▪ Excessive leaf litter upstream of sampling location
District	MonroeAg01	6/16/2015	9:00 AM	0	▪ No flowing water from any direction, all inlets were dry
District	MonroeAg01	6/23/2015	8:40 AM	0	▪ All inlets are dry flow of water (south to north) along Monroe that stops about 70' from SE corner of Monroe and Victoria
District	MonroeAg01	8/17/2015	8:38 AM	0.00456	
District	MonroeAg02	6/2/2015	7:45 AM	0.05	▪ Sampled water on eastern side of Gratton St.
District	MonroeAg02	6/8/2015	7:55 AM	0.028	▪ Sampled water on western side of Gratton St. ▪ Water flows past sampling location into catch basin at corner of (SW) Gratton St. and Lincoln Ave.
District	MonroeAg02	6/16/2015	9:20 AM	0.07	▪ Sampled water on eastern side of Gratton St.
District	MonroeAg02	6/23/2015	8:15 AM	0.10	▪ sampled water on western side of Gratton St ▪ Water flows past sampling location into catch basin at corner of (SW) Gratton St. and Lincoln Ave.
District	MonroeAg02	8/17/2015	9:03 AM	0.04	▪ Sampled water on eastern side of Gratton St. ▪ Water flows past sampling location into catch basin at corner of (SW) Gratton St. and Lincoln Ave.

Table 3-5 Field Measurements Recorded During Dry Weather 2015

Sampling Agency	WRMS Station Name	Sample Date	Sample Time	Water Temperature (°C)	pH	EC (µS/cm)	Turbidity (NTU)	DO (mg/L)
District	MonroeAg01	5/27/2015	11:55 AM	30.24	9.4	0.717	21.7	11.71
District	MonroeAg01	6/2/2015	7:20 AM	16.17	8	0.919	2.9	7.82
District	MonroeAg01	6/8/2015	7:25 AM	18.25	7.8	0.801	2.1	7.67
District	MonroeAg01	6/16/2015	9:00 AM					
District	MonroeAg01	6/23/2015	8:40 AM					
District	MonroeAg01	8/17/2015	8:38 AM	24.24	7.5		0.778	4.54
District	MonroeAg02	6/2/2015	7:45 AM	16.9	8.2	0.9	6.1	9.02
District	MonroeAg02	6/8/2015	7:55 AM	22.6	7.9	0.794	6.8	4.89
District	MonroeAg02	6/16/2015	9:20 AM	24.06	8.8	0.825	3.9	6.93
District	MonroeAg02	6/23/2015	8:15 AM	22.92	7	0.929	3.4	5.67
District	MonroeAg02	8/17/2015	9:03 AM	23.91	8.5	0.808		6.23

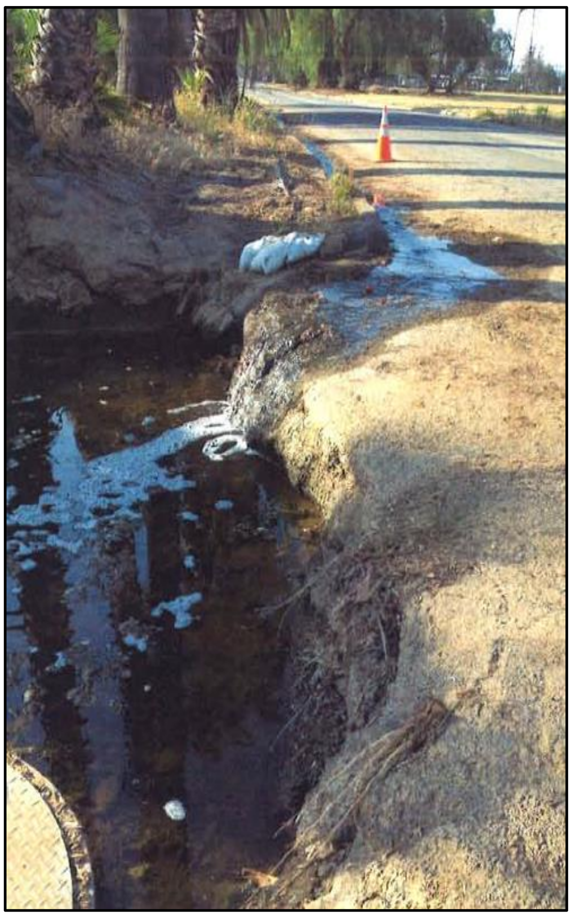


Figure 3-10
Photo of DWF at MonroeAg02 (left) and MonroeAg01 (right)

Sample results for *E. coli* are shown in Table 3-6. *E. coli* is typically high at both stations; exceeding 1,000 MPN/100 mL in four of the six DWF samples. A box and whisker plot is shown in Figure 3-11. Data are plotted for the two Monroe Stations and T2-ANZA14 at Don Derr Park.[6] The first and third quartile values are shown as the bounds of the open bars associated with each station. The median value (second quartile) is shown as the line splitting the open bars. Minimum and maximum values are shown as the whiskers above and below each bar. MonroeAg02 shows more variability in *E. coli* data, with a higher maximum and median values than MonroeAg01 or T2-ANZA14.

Table 3-6 Grab Sample Results for the Monroe Stations in the 2015 Dry Season

Station Name	Sample Date	Sample Time	*E. coli* (MPN/100 mL)	Method
MonroeAg01	5/27/2015	11:55	1600	SM9223B
MonroeAg01	6/2/2015	7:20	310	SM9223B
MonroeAg01	6/8/2015	7:25	600	SM9223B
MonroeAg01	8/17/2015	8:38	700	SM9223B
MonroeAg02	5/27/2015	12:20	2300	SM9223B
MonroeAg02	6/2/2015	7:45	410	SM9223B
MonroeAg02	6/8/2015	7:55	5600	SM9223B
MonroeAg02	6/16/2015	9:20	4100	SM9223B
MonroeAg02	6/23/2015	8:15	5500	SM9223B
MonroeAg02	8/17/2015	9:03	500	SM9223B

[6] These data are from dry weather samples collected in 2013.

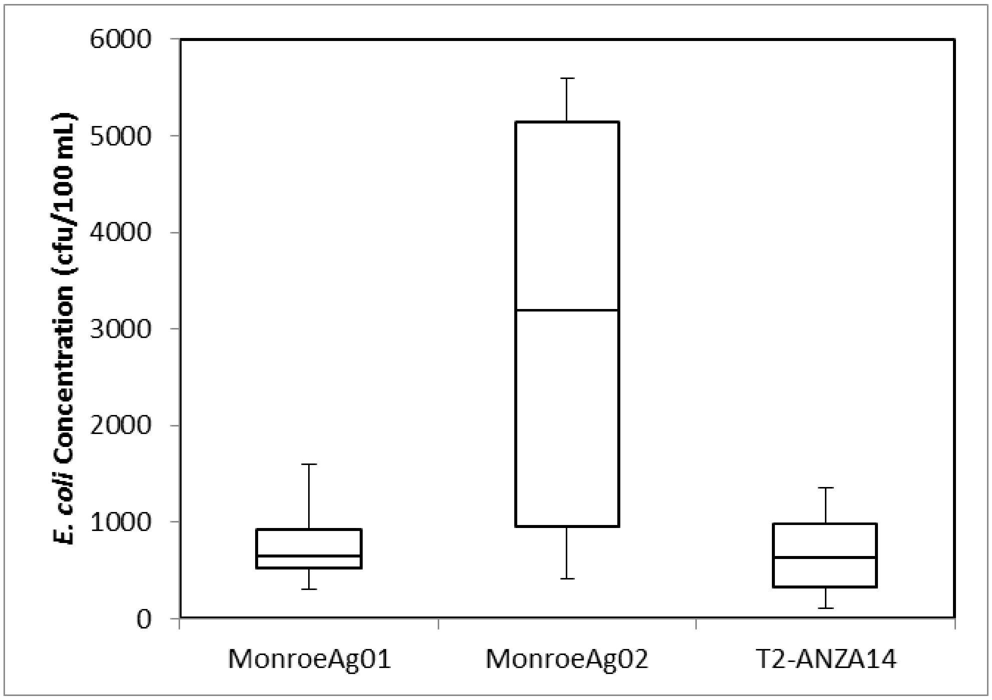


Figure 3-11
Box and Whisker Plot of *E. coli* at the Monroe Stations

This page intentionally left blank.

Section 4

Analysis of Bacteria Sources

4.1 Source Contribution Analysis Update

The predominant sources of DWF include POTW effluent and outflow from MS4 drainage systems. For each of the impaired waterbodies, Santa Ana River Reach 3, Mill-Cucamonga Creek, and Chino Creek, POTW effluent comprises the majority of DWF in the dry season. POTW effluent provides a source of tertiary treated (essentially free of any fecal bacteria) water to dilute inputs from MS4 outfalls. Despite this condition, compliance monitoring data show water quality objectives continue to be exceeded.

4.1.1 Background

Compliance analyses completed in 2010 as part of the development of the CBRP and in 2013 as part of the TMDL's Triennial Review both included a source contribution analysis to estimate flow-weighted average concentrations for segments of the impaired waters upstream of the compliance monitoring sites. These analyses employed newly obtained data on DWF rates and FIB concentrations from most MS4 outfalls to the TMDL waters, and are summarized below:

- For the CBRP compliance analysis, supporting data was collected from most tributaries to the impaired waters in the Urban Source Evaluation Program in 2007 and 2008. A total of 20 site visits were made to each of 13 sites. Flow measurements and water quality samples (for fecal indicators and microbial source tracking) were collected when DWF was present. The results were used to approximate the amount of DWF reduction from urban runoff sources that may be needed to result in compliance with the TMDL.

- For the 2013 analysis, monitoring implemented per the CBRP Tier 1 source evaluation program involved dry weather flow measurement and water quality sample collection from 34 MS4 outfalls to the impaired waterbodies over ten consecutive weeks. Tier 1 source evaluations were conducted between May 7 through July 9, 2012, for San Bernardino and Riverside County sites and from April 19 through June 24, 2011, for one site downstream of Los Angeles County MS4 drainage areas. A larger number of sites were visited and represent essentially all MS4 drainages to the downstream impaired waterbodies during dry weather. The results updated prior understanding of expected downstream concentrations after mixing with POTW effluent with new, more comprehensive data. Also, the Tier 1 monitoring program developed data needed to prioritize drainage areas for intensive source evaluation within MS4 networks, referred to as Tier 2 in the CBRP.

- For this 2016 Triennial Review, the source contribution analysis is updated to account for additional DWF and fecal bacteria data collected in the 2013-2015 dry seasons. New data were collected through implementation of Tier 2 source evaluations within upstream parts of prioritized drainage areas. The Tier 2 source evaluations were implemented by individual MS4 Permittees. Collection of data at the downstream Tier 1 site was included in many of the Permittees programs, but was not done synoptically for the watershed. The

2016 Triennial Review reviews changes to dry weather hydrology in the MSAR watershed that provides insight into our understanding of historical patterns in downstream fecal bacteria concentrations.

4.1.2 Source Contribution Analysis Methodology

Bacterial indicator concentrations in the flow-weighted blend of MS4 inputs and clean POTW effluent ($C_{blended}$) is compared with downstream bacterial indicator concentrations (C_{obs}) to assess the potential role of other non-MS4 sources to an impaired waterbody. The blended concentration is a function of MS4 inputs of flow (Q_{inflow}) and bacterial indicator concentrations (C_{inflow}) and POTW effluent flow ($Q_{effluent}$), as follows:

$$C_{blended} = \frac{[\sum_i^j (Q_{inflow} * C_{inflow})]}{(Q_{inflow} + Q_{effluent})}$$

$$C_{obs} = C_{blended} + e$$

This type of analysis characterizes the relative role of different flow sources in the watershed on downstream bacterial indicator concentrations. An important outcome of this analysis is the identification of the level of bacterial indicators (e) at the compliance sites that cannot be explained by MS4 inflows (referred to as "unaccounted-for sources"). The presence of an unbalanced set of inputs and outputs in relation to downstream bacterial indicator levels is not surprising, given the potential for increases in bacteria indicator levels from illegal and illicit discharges, direct input from wildlife, air deposition, transient encampments, environmental growth, or resuspension from sediments or biofilms, or decreases in bacterial indicator levels due to environmental decay or settling.

4.1.3 New Data to Support 2016 Source Contribution Analysis

4.1.3.1 Bacteria at MS4 Outfalls

In the 2013 and 2014 dry seasons, individual MS4 Permittees implemented Tier 2 source evaluations within the drainage areas upstream of prioritized Tier 1 outfalls (see Section 3.2.1). In some drainage areas, Tier 2 source evaluations included collection of a bacteria sample at the downstream Tier 1 site. In total, 46 samples from a subset of Tier 1 sites were collected in the 2013 dry season. Results for Tier 2 *E. coli* concentration corresponding to Tier 1 sites were appended to the 2012 Tier 1 results to update the geomean calculations (Table 4-1). The values in the far right of this table are used to update *E. coli* concentrations for specific MS4 outfalls in the source contribution analysis. For Tier 1 sites that were not sampled during 2013-14 Tier 2 source evaluations, geomeans of *E. coli* concentrations were not updated from previously reported geomeans in Section 3.2 of the 2013 Triennial Report.[1]

[1] See Figures 3-6, 3-9, 3-11, 3-13, 3-17, 3-19, 3-21, and 3-23

Table 4-1 Geometric Mean of *E. coli* Concentration in Samples from Tier 1 Sites

Watershed	Site ID	Description [1]	Geometric Mean of *E. coli* concentration (cfu/100 mL)		
			2012 (Tier 1)	2013/14 (Tier 2)	Pooled (2012-2014)
Chino Creek	T1-BRSC	Boys Republic South Channel	551	2,713	796
	T1-CCCH	Carbon Canyon Creek Channel	70	21	53
Mill-Cucamonga Creek	T1-CAPT	Airport Storm Drain	5,230	24,001	6,007
	T1-CHRIS	Lower Deer Creek	2,801	1,297	2,464
	T1-EVLA	Eastvale Line A	3,679	1,241	2,697
	T1-EVLB	Eastvale Line B	6,220	2,416	4,650
Santa Ana River	T1-PHNX	Phoenix Storm Drain	597	2,876	1,466
	T1-ANZA	Anza Storm Drain	287	280	285
	T1-SSCH	San Sevaine Channel	1,701	382	1,110
Downstream of compliance site	T1-EVLD	Eastvale Line D	3,844	3,577	3,766
	T1-EVLE	Eastvale Line E	1,516	142	771
	T1-CYP	Cypress Channel	1,124	18	143

1) Map showing these Tier 1 sites and MS4 drainage areas is provided in Figure 4-2
2) All sites in this table are hydrologically connected

Many samples collected in 2013 and 2014 had *E. coli* concentrations outside of the 25-75th percentile of 2012 sample results (Figure 4-1). For sites with significant reductions in *E. coli*, such as Cypress Channel, Eastvale Lines A, B, and E, and San Sevaine Channel, this may indicate that CBRP implementation activities have been effective. In fact, since the CBRP was approved, *E. coli* geomean concentrations from Cypress Channel (T1-CYP) and Carbon Canyon Creek Channel (T1-CCCH) are below the WLA and could be considered for removal from the list of prioritized outfalls. Conversely, all *E. coli* concentrations in 2013-14 samples from Boys Republic South Channel (n=3) and Phoenix Storm Drain (n=4) exceeded the 75th percentile of 2012 results. These MS4 drainage areas have been a primary focus in 2013-14 Tier 2 source evaluations as discussed in Section 3.2.

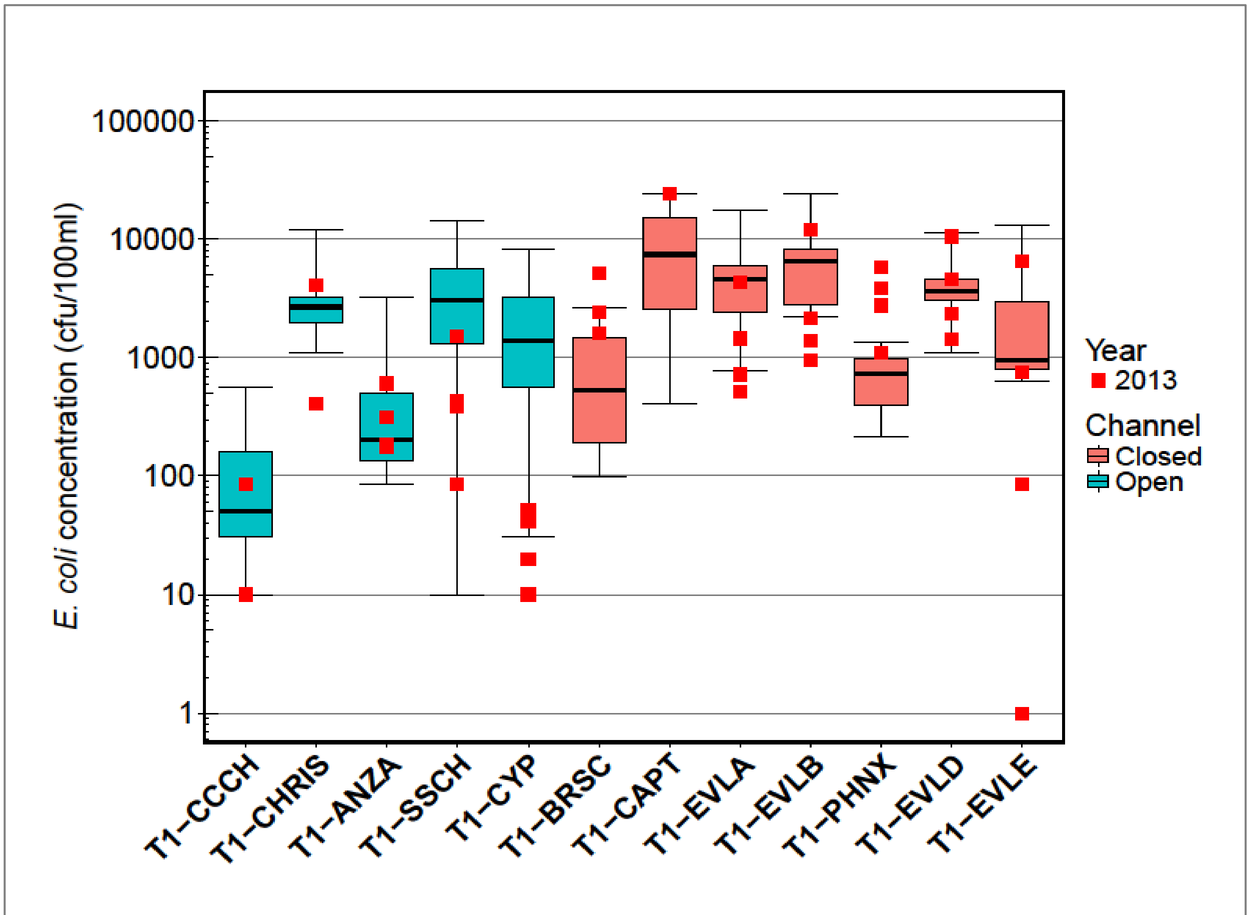


Figure 4-1
Box-Whisker of *E. coli* Concentrations from 2012 Tier 1 Source Evaluations and *E. coli* Concentrations from Samples Collected in 2013-2015 Shown as Red Squares

4.1.3.2 Dry Weather Flow Rates

Hydrologic Connectivity

Within the MSAR watershed, there are many MS4 drainage areas that do not typically cause or contribute any DWF to an impaired waterbody segment. DWF from these MS4 outfalls is hydrologically disconnected from the downstream receiving waterbodies, by either purposefully recharging groundwater in constructed regional retention facilities or through losses in earthen channel bottoms, where the recharge capacity of underlying soils exceeds dry weather runoff generated in upstream drainage areas (see hashed areas in Figure 4-2).

To verify that the DWF from MS4s that are shown to be hydrologically disconnected in Figure 4-2, MS4 Permittees have actively conducted field observations at key control points, collecting over 5,000 photos, as part of the Tier 2 source evaluation program. Results from these activities showed consistent hydrologic disconnectivity during dry weather as reported by each Permittee in their Annual Stormwater Program summaries (Table 4-2). Field observations support the assumption that MS4 drainage areas upstream of these locations meet the dry weather WLA by preventing runoff from reaching downstream impaired waters during dry weather.

CDM Smith

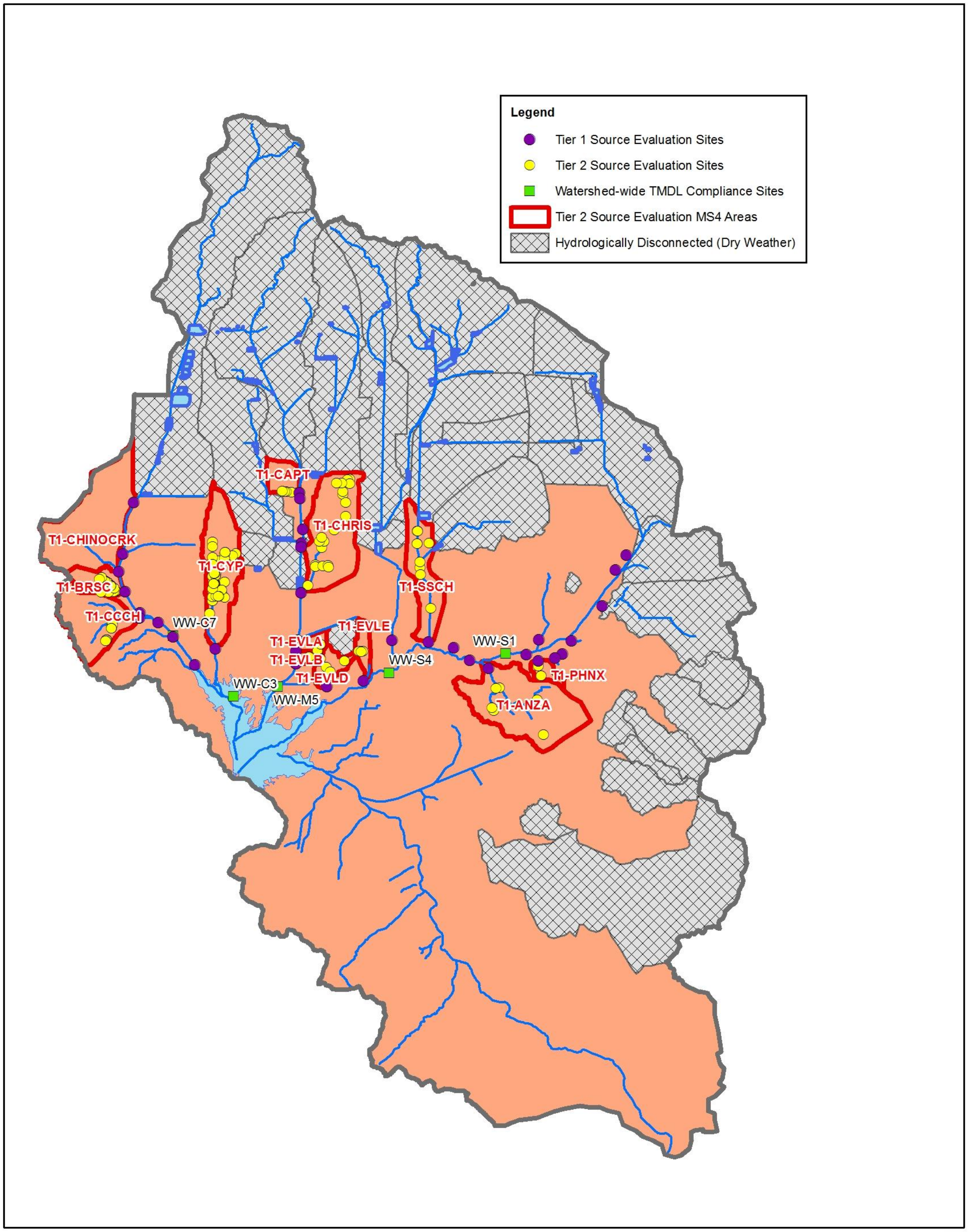


Figure 4-2
Map of MS4 Drainage Areas that have been determined to be Hydrologically Disconnected during Dry Weather

RCFC&WCD has found that MS4 drainage areas that have not been hydrologically disconnected are generating less DWF in recent years, and in some cases are completely dry during routine site visits, as evidenced by an analysis of the frequency with which dry weather water quality samples could be collected when a site was visited over the period of record (1990 – 2013). The results of this analysis show an increased frequency of finding insufficient flow available at the outfall to collect a sample (recorded as "visited not sampled" or VNS) (Figure 4-3).

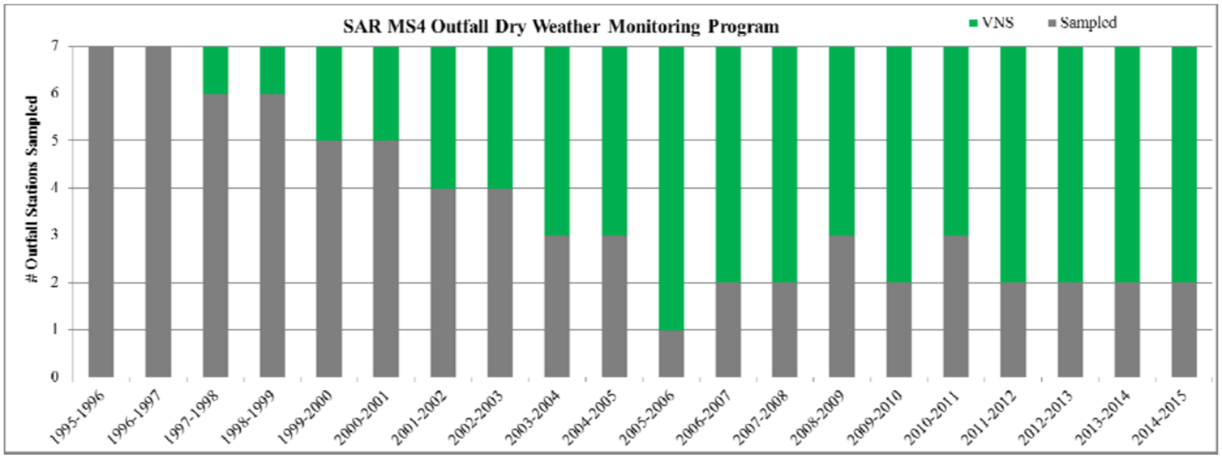


Figure 4-3
Changes in the Ratio of Outfalls "visited not sampled" (VNS) and Outfalls "sampled during a visit" (Sampled) over the history of the MS4 Outfall Dry Weather Sampling Monitoring Program (copied from Riverside County Stormwater Program Report of Waste Discharge (http://rcflood.org/downloads/NPDES/Documents/SA_Annual/2014-2015%20SAR%20Monitoring.pdf)

Table 4-2 Documentation of Hydrologic Disconnectivity during Dry Weather Conditions by MS4 Permittees

MS4 Permittee	Drainage Area (Basin)	Hydrologically Disconnected Acres	Surveillance Activities[2]	Period
City of Rancho Cucamonga	Cucamonga Creek (Turner)	31,893	Site visits, photos and videos at diversion points	Weekly: June – October 2012
City of Montclair	San Antonio Channel (Montclair, Brooks)	27,668	Site visits, photos at diversion points	Daily: April – August 2012
City of Rialto	Rialto Channel, Cactus Channel	15,435	Site visits, photos	Daily: March 2015 – January 2016
SBCFCD	Declez Channel (Declez)	8,405	Site visits, photos at diversion points	Daily: April 2014 - January 2016
	Day and Etiwanda Creeks (Wineville, Riverside)	20,570		
	San Sevaine Channel (Banana, Jurupa)	10,971		
	Santa Ana River Reach 4, Lytle Creek (channel bottom)	472,320		
RCFC&WCD	Highgrove Channel, University Wash	4,590	Site visits, photos	Snapshot: June 2015

Although recent data suggest that these drainage areas are hydrologically disconnected, periodic documentation (e.g., surveillance) is recommended to verify that the areas remain disconnected.

Flow Measurement at MS4 Outfalls

Measurement of DWF rates at MS4 outfalls was done during the 2011 and 2012 Tier 1 source evaluation studies. These measurements taken over ten consecutive weeks served as the basis for estimating downstream flow-weighted average bacteria concentrations for the impaired waterbodies, reported in the 2013 Triennial Report. Since 2012, limited hydrologic data has been collected at Tier 1 sites in the MSAR watershed.

RCFC&WCD installed water level meters within the bottom of 15 flood control channels representing the key tributaries from MS4s to Cucamonga Creek and the Santa Ana River. The objective of installing these meters was to assess relative changes in water level and DWF that may be attributed to factors such as diurnal water demand patterns or sporadic *de minimus* discharges. The data show a clear diurnal pattern whereby the depth of DWF in flood control channels is greatest in the morning when irrigation is typically scheduled. Incidentally, the time of greatest DWF at MS4 outfalls coincides with the time of day samples are typically collected. An example of water level readings for a representative week in the 2014 dry season is provided for San Sevaine Channel in Figure 4-4. Appendix B provides a one-week snippet of the total recorded period of record of water level data from each of the sites. These data were not able to be

[2] Photos for available in San Bernardino County 2014-2015 Annual Report Appendix F, Permittees' MSAR TMDL Compliance Reports, and webgis.cityofmontclair.org/DWF (Montclair)

developed into accurate estimates of flowrate, and therefore did not provide a quantitative update to the source contribution analysis.

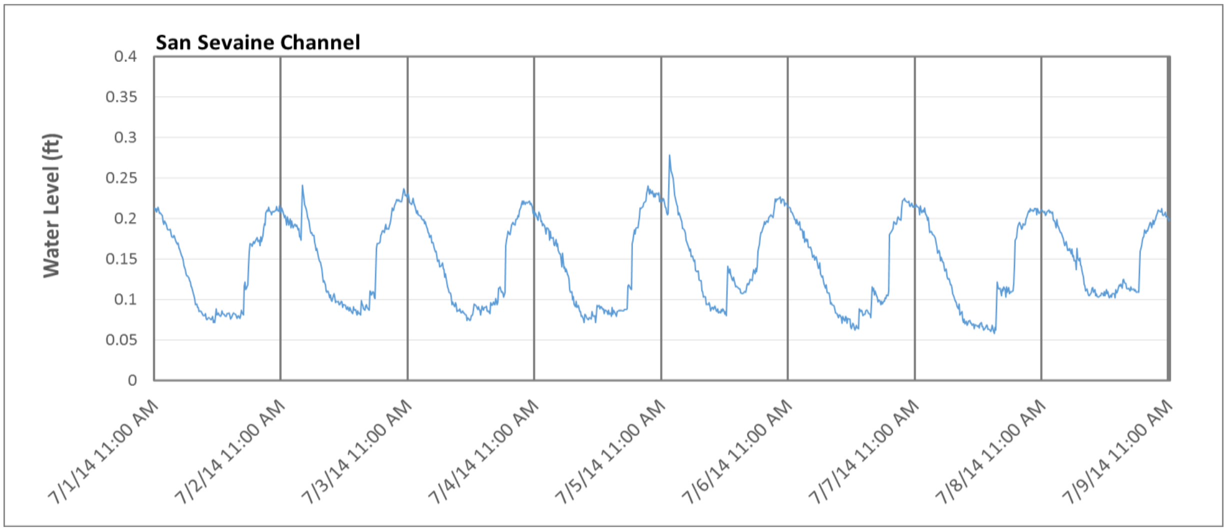


Figure 4-4
Snippet of Water Level Records collected by RCFC&WCD from San Sevaine Channel (see Appendix A for one week snippets from each of the meters deployed in the MSAR watershed)

Flow Gauge Trends for Chino Creek

Two USGS gauges in the MSAR watershed are located upstream of any POTW effluent and thus could be used to approximately quantify MS4 inputs of DWF from a portion of the Chino Creek drainage area. Other sources of runoff during dry weather to these gauges is negligible. USGS gauge data provides continuous and more accurate estimates of flow than Tier 1 source evaluations, which used simple velocity-area methods to obtain planning level flowrates for purposes of prioritization.

The USGS gauges on Chino Creek at Schaeffer Ave (Station 11073360) and San Antonio Channel at Riverside Drive (Station 11073300) are shown in Figure 4-5. Continuous flow records from these gauges may be used to approximate hydrologic inputs to Chino Creek from MS4 sources (several important outfalls from the Cities of Chino and Chino Hills are downstream of the USGS gauge). The increase in daily flow downstream of San Antonio Channel and upstream of the Chino Creek gauge is mostly caused by an ungauged tributary that conveys runoff from the City of Pomona eastward to Chino Creek. Figure 4-6 shows a significant decline in the annual median of dry season flow rate for both gauges since 1999. Several factors may explain this trend including:

- Drought conditions that may reduce natural canyon flows in the Phillips Ranch area. These canyon flows are conveyed through the City of Pomona's MS4 to Chino Creek.
- Economic recession of 2008 and associated reduction in water use due to foreclosure and hardship.
- Improved outdoor water use efficiency through implementation of water conservation BMPs.

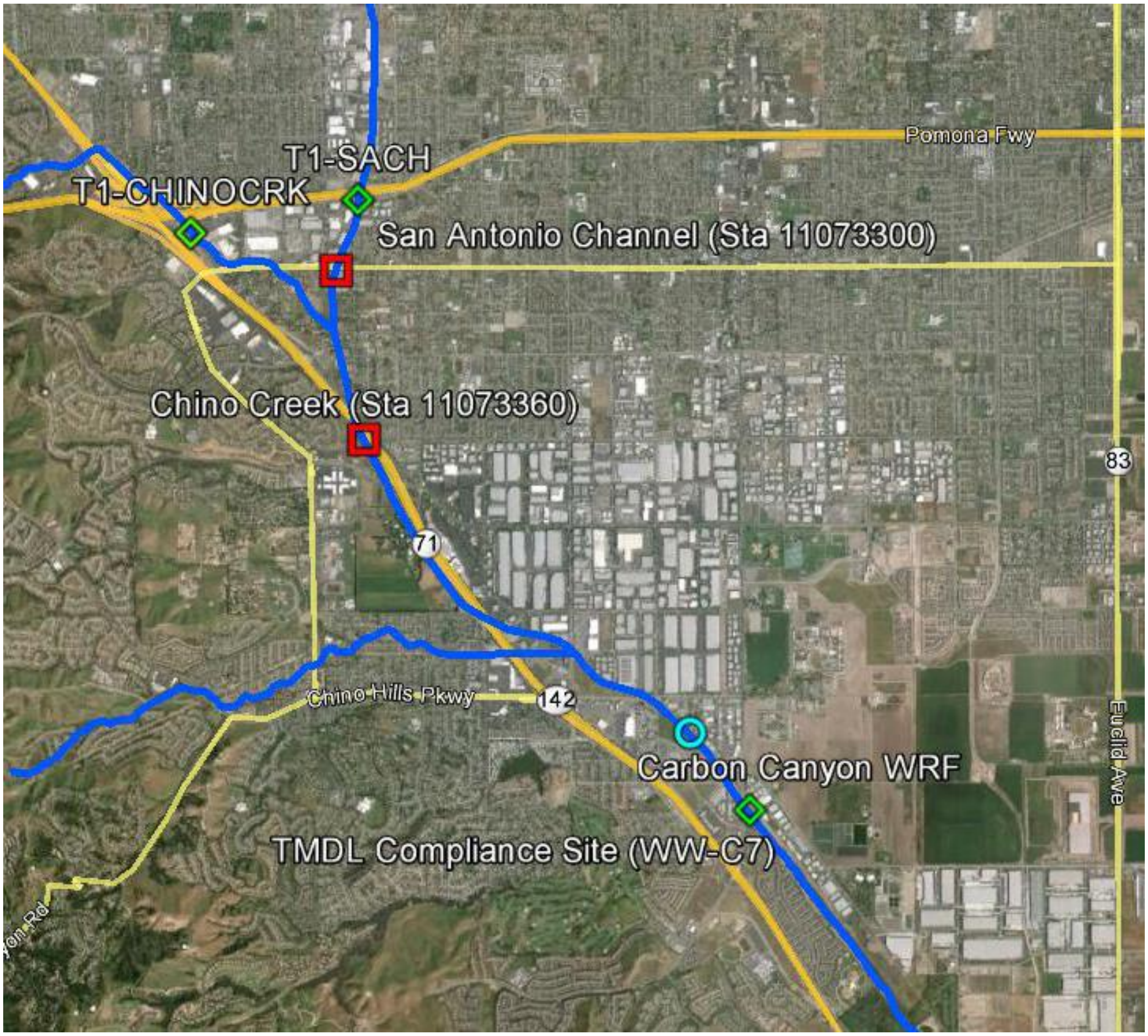


Figure 4-5
Location of USG Gauges in Chino Creek Watershed Upstream of the Carbon Canyon WRP

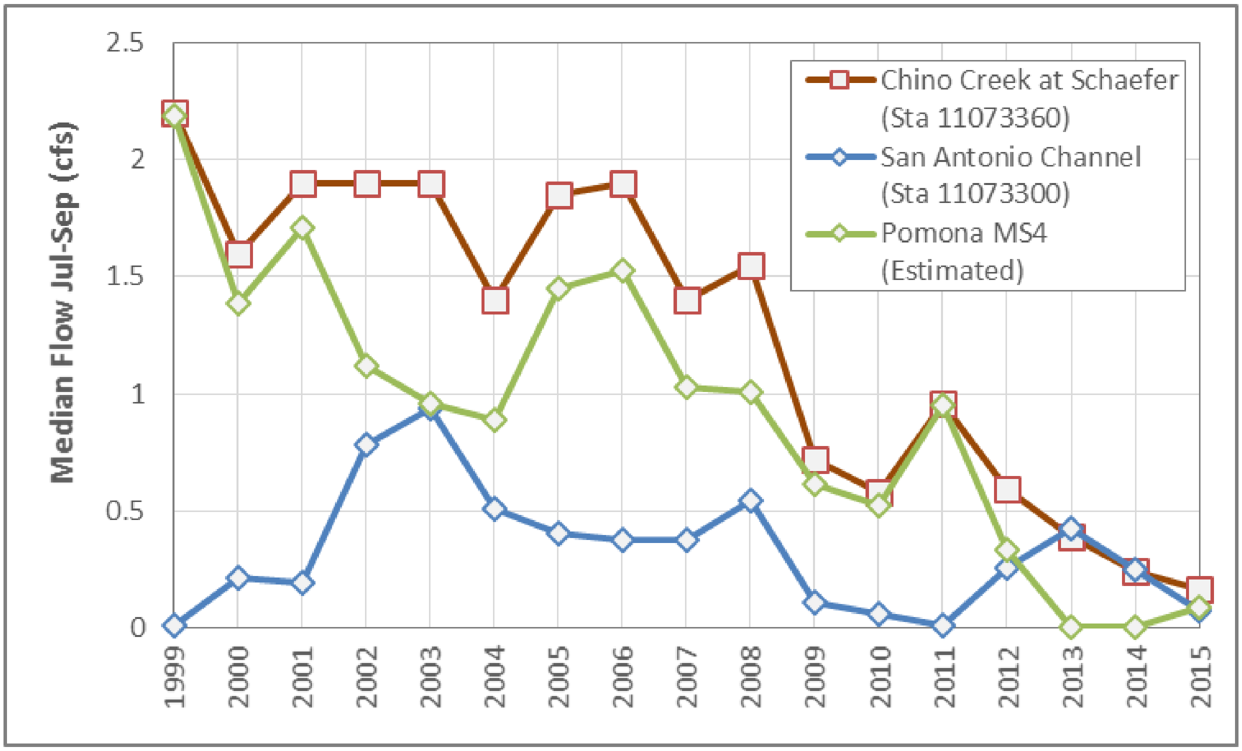


Figure 4-6
Annual Median Dry Season Flow Rates from 1999 through 2015 recorded by USGS Gauges in the Chino Creek Watershed located Upstream of any POTW Effluent

Data from these USGS gauges was used to update the source contribution analysis inputs for DWF rates for T1-CHINOCRK and T1-SACH outfalls (see Figure 4-5). The median flow during the dry seasons of 2012-2015 recorded at the USGS gauge on San Antonio Channel was determined and assumed for DWF inputs from T1-SACH. The same median was computed for the downstream Chino Creek gauge. The difference in these medians was assumed to be equal to DWF rates from the T1-CHINOCRK site. These USGS gauged based values replaced previously used field measurements collected during Tier 1 source evaluation for input parameters in the source contribution analysis (Table 4-3).

Table 4-3 Updated DWF Rate Estimates for MS4 inputs to Chino Creek

Tier 1 Outfall	Estimated DWF (cfs)	
	2013 Triennial Review [1]	2016 Triennial Review [2]
San Antonio Channel (T1-SACH)	0.01	0.31
Chino Creek (T1-CHINOCRK)	1.7	0.35

1) Average of ten consecutive weekly field estimates of flow rate in May-July 2012
2) Median dry season flowrate from daily USGS gauge records for 2012-2015. For T1-CINOCRK site, the difference between USGS gauges 11073300 and 11073360 was used to approximate flow

4.1.3.3 POTW Effluent

In the Santa Ana basin and worldwide, treated effluent from POTWs is regarded as a key water resource as opposed to a waste for disposal. Reuse of POTW effluent serves to reduce production from groundwater basins and limit demands for imported water sources that are typically more energy intensive and less reliable than local supplies. Figure 4-7 shows that all of the POTWs in the MSAR watershed have reduced discharges to the impaired waterbodies over the past 12 years as a result of increasing reuse.

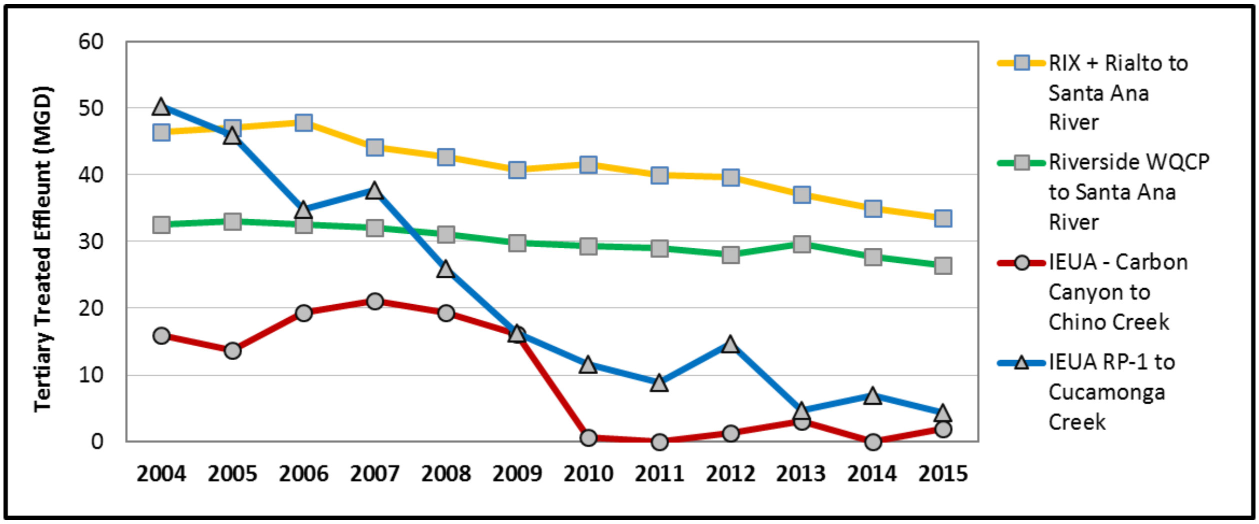


Figure 4-7
Average Daily POTW Effluent in August/September to Impaired Waters from 2004-15 (data provided by POTWs to support the Basin Monitoring Task Force, http://www.sawpa.org/wp-content/uploads/2012/05/20150615-Reach-3-TDS-Investigation-II-final.pdf)

One outcome of increased reuse of POTW effluent is a reduction in the discharge of bacteria free water to downstream impaired waterbodies in the MSAR watershed. As a result, there is less dilution of DWF inputs from MS4 outfalls, thus increasing the estimated blend of POTWs and MS4 inputs. Furthermore, IEUA and the City of Rialto plan to increase recycled water use in the future, thus average annual discharges to the impaired waters may continue to decline. The analysis in the following section shows how by themselves, reduced POTW effluent discharges to each of the impaired waterbodies, would result in an increase in the estimated flow-weighted average concentration that may be expected at the downstream compliance monitoring site.

In addition to long-term trends that show a gradual decline in discharge of tertiary treated effluent to impaired waters, reviews of discharge records show a persistent condition of very large daily fluctuations in effluent discharge rates. Appendix B shows a daily time series of effluent to the impaired receiving waters from 2012-2015. From these charts, it is apparent that frequent day-to-day fluctuations of greater than 90 percent in effluent from IEUA plants to Mill-Cucamonga and Chino Creeks exceed temporal variability that might be expected from patterns of indoor water use. These day-to-day fluctuations are the result of varying deliveries to the extensive reuse system in this part of the MSAR Watershed (Figure 4-8). During periods with higher demand or as storage reservoirs are drawn down and need to be refilled, effluent is sent to the reuse system and not discharged to the creeks (personal communication with Andy Campbell, IEUA Deputy Manager of Planning and Environmental Resources, December 30, 2015).

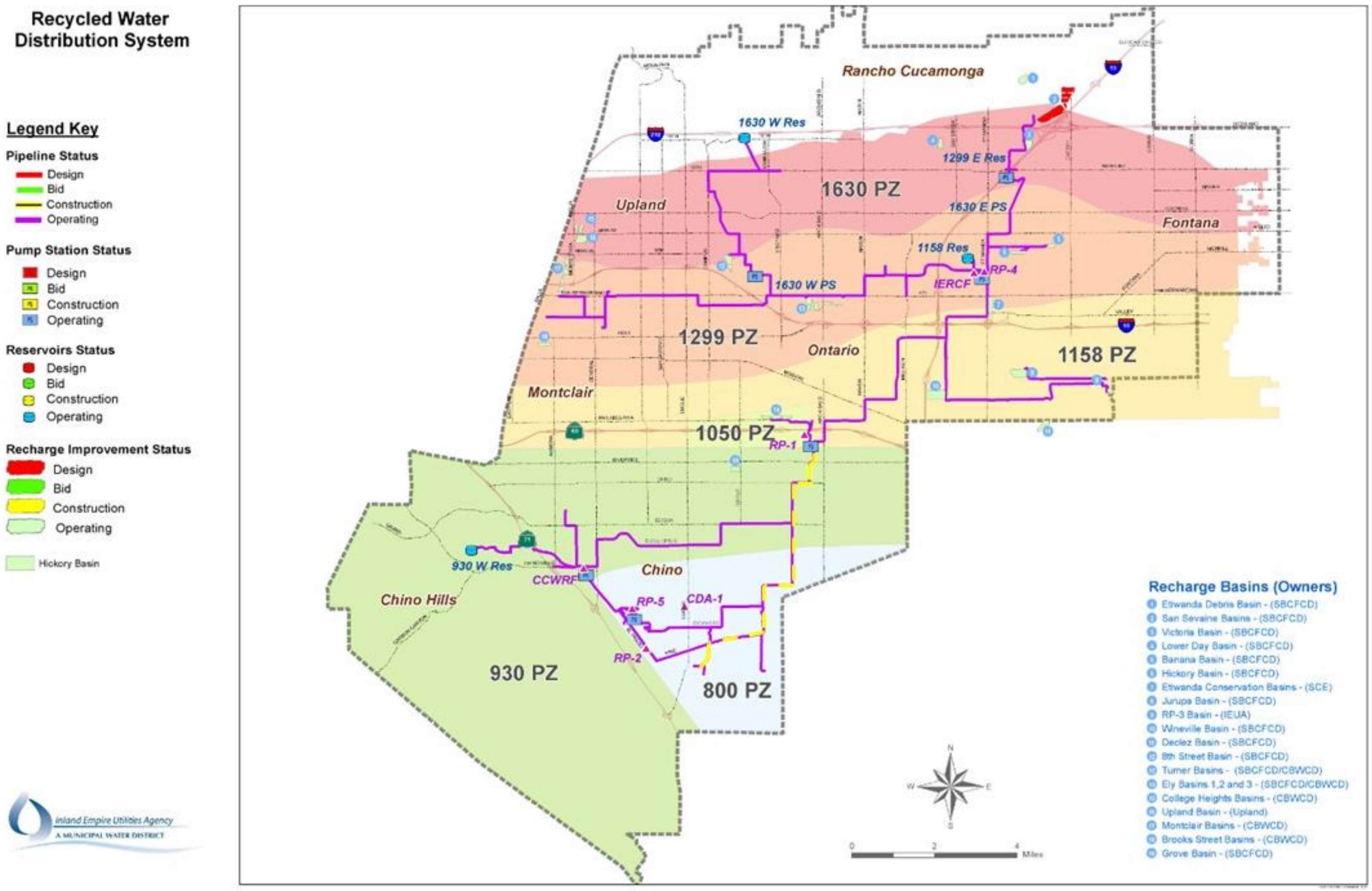


Figure 4-8
Facilities Map of IEUA's Recycled Water System (Reproduced with permission from IEUA)

Lastly, the means by which effluent is delivered to Prado Park Lake was changed in 2015. Historically, Prado Park Lake received a portion of the effluent from IEUA's Regional Plant 1 (RP1) via outfall #001 to Prado Park Lake (outfall #002 goes to Cucamonga Creek). The effluent was delivered by gravity via an underground pipeline. As of 2015, outfall #001 is no longer used to deliver effluent to Prado Park Lake. Instead, Prado Park Lake is provided water through IEUA's recycled water distribution system. Dry season *E. coli* concentrations have declined from typical levels of approximately 100 cfu/100 mL to 40 cfu/100 mL in the 2015 dry season, which may be the result of the change in the delivery mechanism for discharges to Prado Park Lake. Additional data will continue to assess this potential positive finding.

4.1.4 Source Contribution Update

4.1.4.1 Current condition results

New information obtained since the preparation of the 2013 Triennial Report was used to update the source contribution analysis for current conditions in each impaired waterbody. Sources of bacteria during dry weather conditions include MS4 discharges as well as non-MS4 sources such as wildlife and in-stream growth. This source evaluation estimates the relative role of MS4 sources in downstream receiving waterbody bacterial indicator concentrations. The bacterial indicator concentrations in the blend of MS4 inputs and clean POTW effluent ($C_{blended}$) was compared with downstream bacterial indicator concentrations (C_{comp}) to assess the potential role of other non-MS4 sources to an impaired waterbody. The blended concentration is a function of MS4 inputs of flow (Q_{inflow}) and bacterial indicator concentrations (C_{inflow}) and POTW effluent flow ($Q_{effluent}$) as follows (also described in Section 4.1.2):

$$C_{blended} = \frac{\left[\sum_{l}^{j}(Q_{inflow} \times C_{inflow})\right]}{Q_{inflow} + Q_{effluent}}$$

$$C_{comp} = C_{blended} + e$$

This type of analysis characterizes the relative role of different flow sources in the watershed on downstream bacterial indicator concentrations. An important outcome of this analysis is the identification of the level of bacterial indicators (e) at the compliance sites that cannot be explained by MS4 inflows (referred to as "unaccounted-for sources"). The presence of an unbalanced set of inputs and outputs in relation to downstream bacterial indicator levels is not surprising, given the potential for increases in bacteria indicator levels from illegal and illicit discharges, direct input from wildlife, air deposition, transient encampments, environmental growth, or resuspension, or decreases in bacterial indicator levels due to environmental decay or settling.

Schematic diagrams were used to portray flow and bacteria inputs from specific sources including POTW effluent and MS4 discharges in the February 2013 MSAR Bacterial Indicator TMDL Implementation Report which included the 2013 Triennial Report and Tier 1 Source Evaluation Program findings (see Figures 3-10, 3-13, and 3-16 in SAWPA 2013c). The source contribution analysis for this 2016 review is presented in the form of updates to these previously developed schematics, which contain all input values as well as the resulting flow-weighted *E. coli* concentrations for a blend MS4 and POTW sources (Figures 4-9 through 4-11).[3] However, MS4 flows are only updated where more recent data was available.

[3] POTW effluent flow data was provided by POTWs to support the Basin Monitoring Task Force (SAWPA 2015c). MS4 and bacteria data were supplied by the monitoring program.

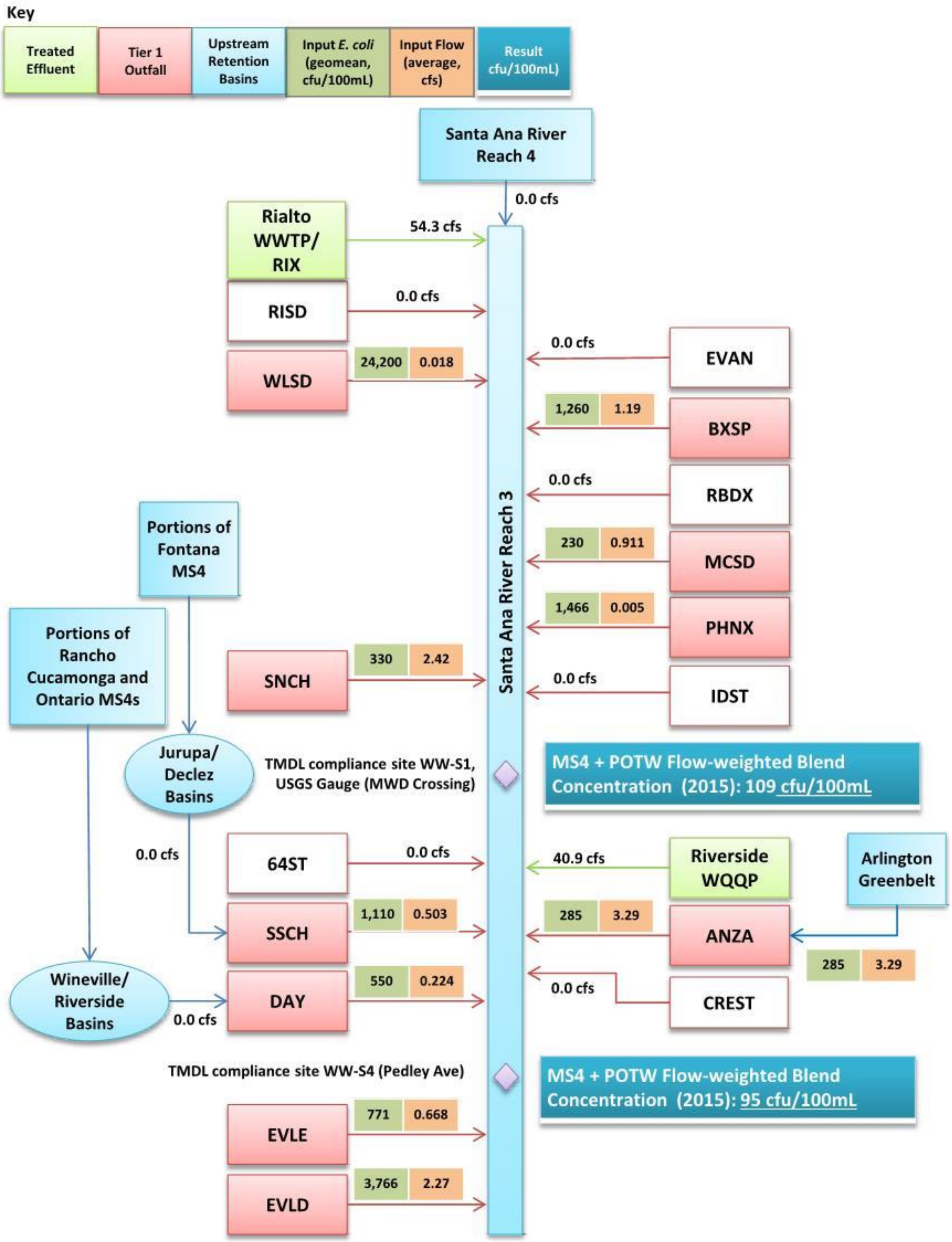


Figure 4-9
Schematic showing bacteria and DWF inflows to Santa Ana River in relation to downstream compliance monitoring site.

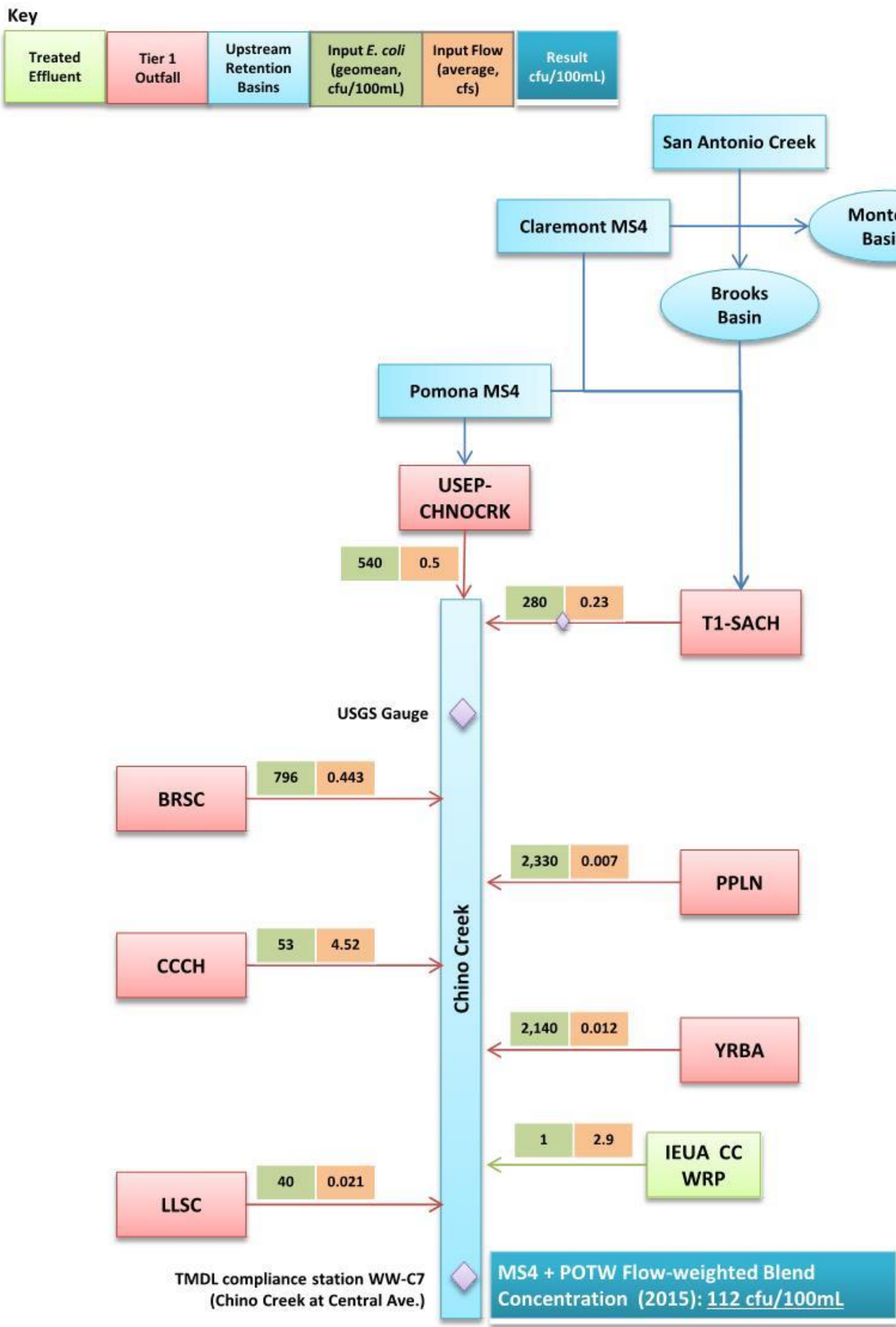


Figure 4-10
Schematic showing bacteria and DWF inflows to Chino Creek in relation to downstream compliance monitoring site.

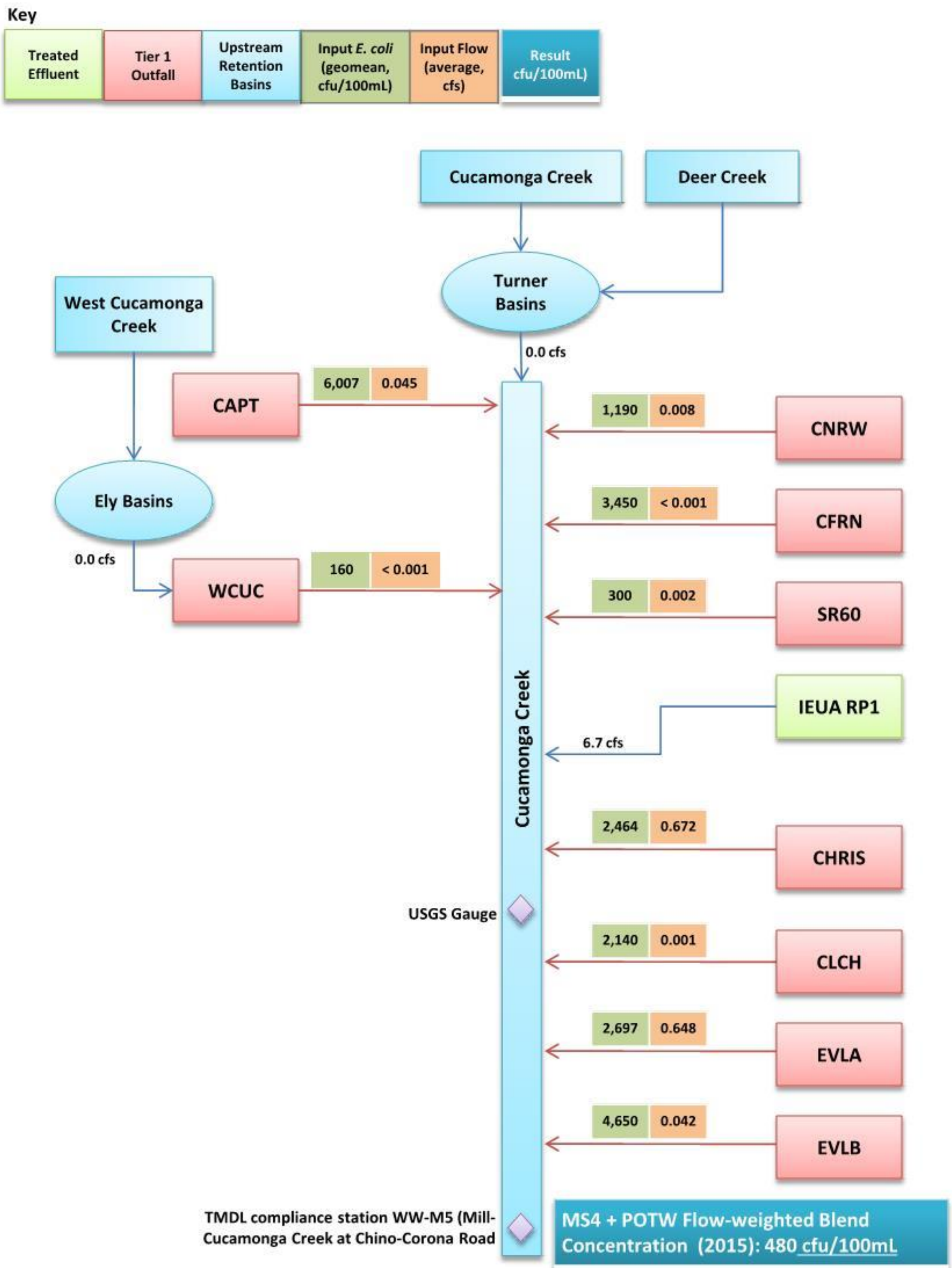


Figure 4-11
Schematic showing bacteria and DWF inflows to Cucamonga Creek in relation to downstream compliance monitoring site.

The relative source contribution from individual MS4 drainage areas was presented as a series of pie charts in the 2013 Triennial Report (see Figures 3-12, 3-15, and 3-19 in SAWPA 2013c). These pie charts are updated in Figure 4-12 below. The results show that the same MS4 drainage areas, as identified in previous analyses, continue to influence downstream fecal bacteria concentrations. The MS4 drainage areas of greatest concern to each TMDL compliance monitoring site, and current and planned mitigation actions, are discussed below:

- Santa Ana River at MWD Crossing – The greatest source of *E. coli* to the Santa Ana River at MWD crossing TMDL compliance site is from Box Springs Channel. This channel drains a large (~20,000 acre) residential neighborhood in the City of Riverside. Human sources were detected in the 2007 dry season and subsequently found to be caused by a restroom cross connection. Following elimination of the human source, the drainage area remains a key source of general fecal bacteria, however, MS4 inputs in total are not expected to cause non-compliance in the SAR at MWD crossing.

- Santa Ana River at Pedley Avenue – The greatest source of *E. coli* to the Santa Ana River at Pedley Avenue TMDL compliance monitoring site, aside from the combined contribution from all MS4s the upstream SAR, is from the Anza storm drain subwatershed (~13,000 acres). This MS4 input to the SAR drains a large part of the City of Riverside, including the Arlington Greenbelt area, however, MS4 and agricultural return flows are not expected to cause non-compliance in the SAR at Pedley Avenue.

- Chino Creek at Central Avenue – Three MS4 drainage areas are responsible for most *E. coli* that may reach the TMDL compliance site, including most of Pomona MS4 to the SAR (T1-CHINOCRK: ~6,000 acres) and Boys Republic South Channel (T1-BRSC: ~1,200 acres) and Carbon Canyon Creek Channel (T1-CCCH: ~3,900 acres) in the City of Chino Hills. These MS4s capture a combination of urban runoff and upstream natural canyon flows. Despite the finding that MS4 inputs in total are not expected to cause non-compliance in Chino Creek at Central Avenue when blended with effluent, these cities are working to reduce the urban runoff portion of MS4 discharges through deployment of outdoor water use efficiency BMPs.

- Mill-Cucamonga Creek at Chino-Corona Road – The source contribution analysis presented in this section shows that estimated flow-weighted average E. coli concentration for Mill-Cucamonga Creek may cause non-compliance with the TMDL. Through rigorous DWF diversion and source evaluation, the MS4 Permittees have reduced the prioritized MS4 sources to two MS4 drainage areas: Lower Deer Creek to Chris Basin (T1-CHRIS) in the City of Ontario (~5,800 acres) and a smaller (~500 acre) drainage area in the City of Eastvale (T1-EVLA). The City of Ontario and SBCFCD are developing a plan to reconfigure the bottom of Chris Basin at the beginning of the dry season to increase residence time and contact with soils and vegetation, and expect to achieve a reduction of fecal bacteria in outflows to Cucamonga Creek. For the Eastvale Line A MS4 outfall, the rates of DWF measured during the 2012 Tier 1 source evaluations are atypical from other sites with similar size drainage subwatersheds. Therefore, RCFC&WCD is working with the City of Eastvale to collect updated flow measurements at this outfall to assess whether there exists an excessive discharge or to update the source contribution analysis in the next Triennial Review.

In addition to these highlights, the MS4 Permittee completed a variety of Tier 2 source evaluations within these drainage areas during 2013-2015, which were effective in identifying and eliminating specific human sources of fecal bacteria. Section 3.2.1 summarizes the key findings from these source evaluations.

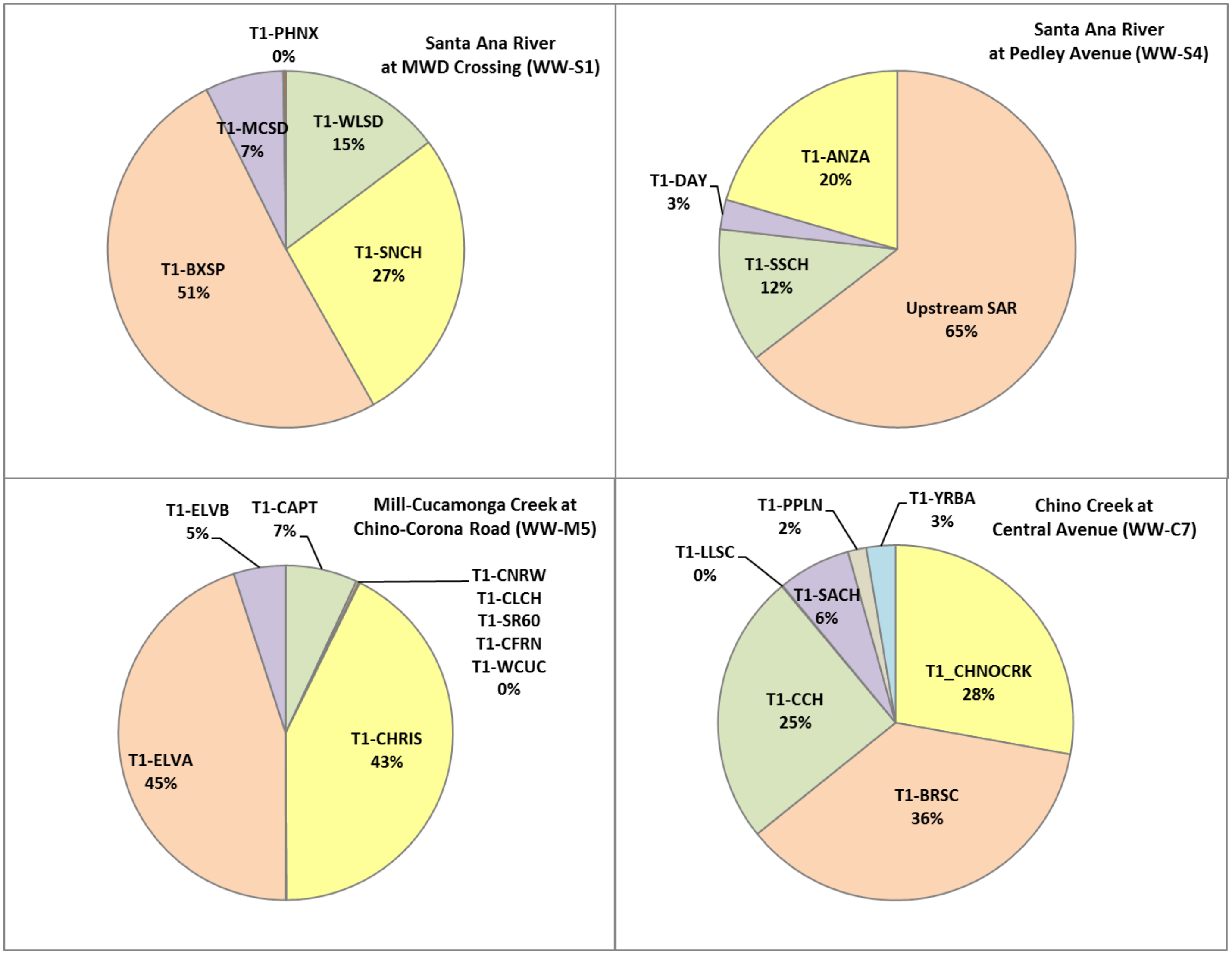


Figure 4-12
Relative *E. coli* Source Contribution for Individual MS4 Drainage Areas Upstream of the Watershed-Wide TMDL Compliance Monitoring Sites

4.1.4.2 Analysis of Historical POTW Effluent Rates

Another analysis was undertaken to assess the dynamics of declining dry season POTW effluent rates in recent years. This differs from the evaluation in the compliance analysis for the CBRP and in the 2013 Triennial Review report (Section 3 of the 2013 Triennial Report), which employed static effluent rates from POTWs intended to be representative of average conditions in 2008 for the CBRP and 2012 for the 2013 Triennial Review. The same calculation methods are applied to estimate expected bacteria concentrations in 2015, but an additional method was developed involving a dynamic estimation of potential downstream water quality to evaluate the importance of declining dry season POTW effluent rates over a 12-year historical period (2004-2015).

Figure 4-13 shows the results for the blended concentrations given current MS4 inputs and historical POTW effluent discharges for the Santa Ana River at MWD Crossing, Santa Ana River at Pedley Avenue, Mill-Cucamonga Creek at Chino-Corona Road, and Chino Creek at Central Avenue watershed-wide TMDL compliance monitoring sites. The plots also include the dry season geometric mean of *E. coli* concentration from each of these sites to assess the potential importance of other in stream fecal bacteria sources or transport processes.

The source contribution analysis shows an increasing flow-weighted average concentration that would be expected at downstream compliance monitoring sites, which may be largely driven by declining dilution flows from POTW effluent in the MSAR watershed. For example, a sharp reduction in effluent from the Carbon Canyon WRF to Chino Creek in 2010 (see Figure 4-6) was responsible for the increase in the flow-weighted average of MS4 and POTW sources between 2009 and 2010, apparent in the red line in Figure 4-13 for Chino Creek.

The blue lines in Figure 4-13 show actual dry season geometric means at the compliance monitoring sites. Two key findings common to each of the impaired waters are described below:

- Measurements of *E. coli* at the TMDL compliance sites have not increased despite the apparent reduction of dilution flows and increase in expected flow-weighted blend concentrations. For example, the expected blended *E. coli* concentration increases by an order of magnitude in Mill-Cucamonga Creek from approximately 50 cfu/100 mL in 2004 to approximately 500 cfu/100 mL in 2015. Actual concentrations of *E. coli* in Mill-Cucamonga Creek do not follow a trend and omitting 2013 (when DWF diversions were temporarily offline), there may even be evidence of a downward trend over the last five years. This may indicate effective implementation of the CBRPs for Riverside, San Bernardino, and Los Angeles counties to reduce urban DWF and eliminate identified fecal bacteria sources in upstream drainage areas.

- Another common finding for all of the impaired waters is the presence of greater downstream *E. coli* concentrations (blue lines in Figure 4-13) than was estimated based on a flow-weighted blend of MS4 and POTW inputs (red lines in Figure 4-13). This is consistent with result of the source contribution analysis for the original CBRP compliance analysis and 2013 Triennial Report findings. This means that additional sources of *E. coli* bacteria may be important to downstream concentrations at the TMDL compliance monitoring sites. Several possible sources of fecal bacteria were hypothesized to explain the net increase of bacteria within the impaired waters, including birds and other riparian wildlife, swimming, equestrian use, and resuspension from naturalized colonies that may thrive in sediment or biofilm. These sources were the subject of six special studies conducted by RCFC&WCD in 2015. Results and key findings from these studies (Section 3.3) suggest that host-specific bacteria sources (e.g., humans and dogs) are not the predominant source of FIB at study locations in MSAR waterbodies. However, humans and wildlife may indirectly influence FIB levels in the environment by depositing fecal bacteria that becomes naturalized within sediments and/or biofilms, where regrowth may occur. Bacteria from sediment and biofilm may subsequently be released into the water column through resuspension and shearing effects from increases in flow rate or disturbances in the waterbodies (e.g., human and wildlife presence). Additionally, conditions that promote growth or decay, including phosphorus and organic carbon levels, may be important factors affecting bacteria levels in the watershed and could result in bacterial "hotspots" and spatially variability.

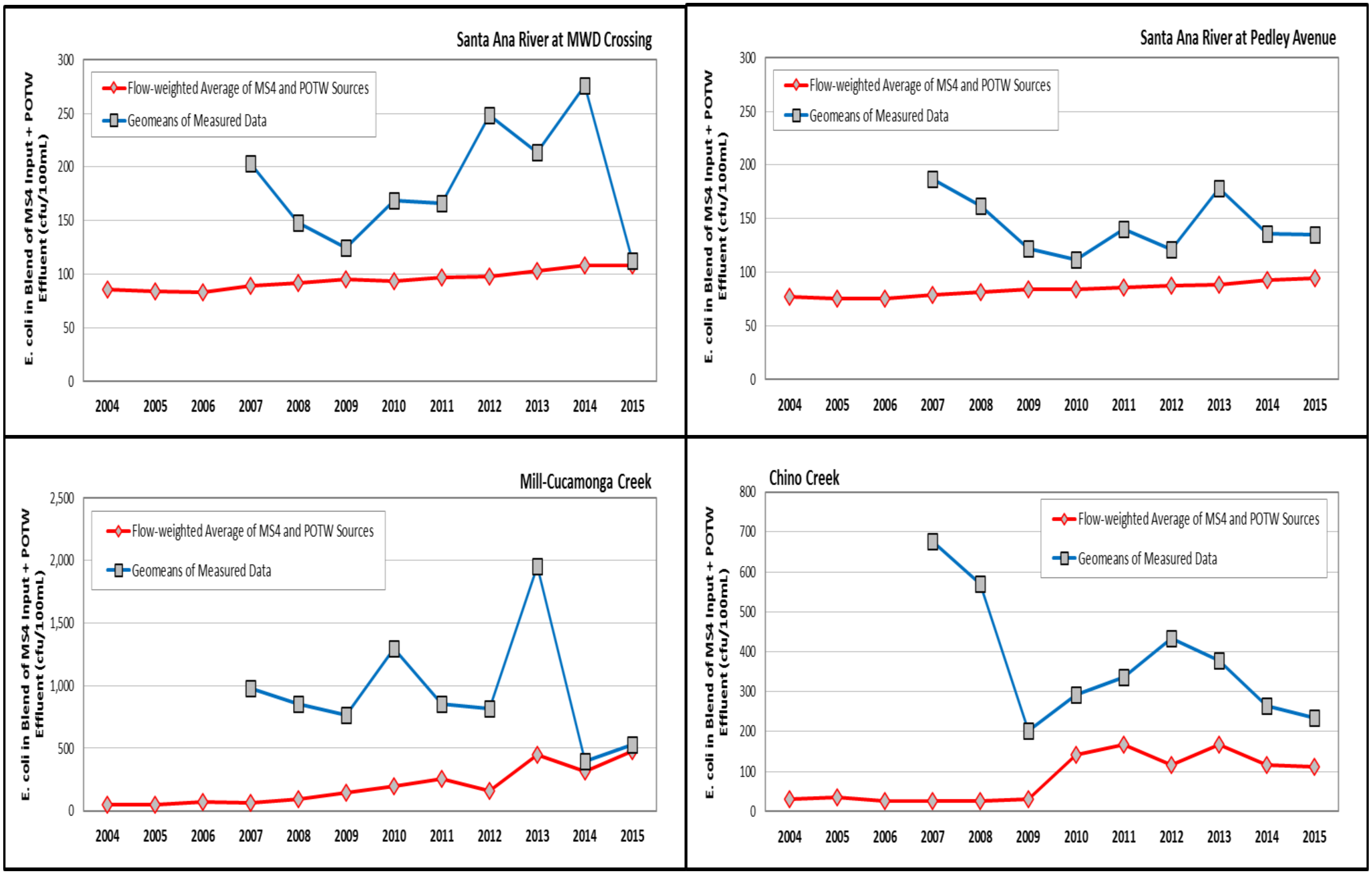


Figure 4-13
Flow-Weighted Average *E. coli* Concentrations for MS4 and POTW Sources and Geomeans of Measured Data during the Dry Season for each TMDL Compliance Monitoring Site

4.1.5 Compliance Assessment

4.1.5.1 CBRP Compliance Analysis

The CBRP compliance analysis allowed for demonstration of compliance with the TMDL through assessments of progress toward the needed DWF reductions within the drainage area to each watershed-wide compliance monitoring site. The same methods employed in the CBRP compliance analysis were reproduced in the 2016 Triennial Review, and are expressed in the following equations:

$$q_{red} = \frac{Q_{WW}(C_{obs} - C_{WLA})LF_{MS4}}{C_{MS4}}$$

$$LF_{MS4} = \frac{C_{blended}}{C_{obs}}$$

These equations use results of the source contribution analysis ($C_{blended}$) to approximate the reduction of dry weather flow from MS4s (q_{red}) that would reduce current concentrations at each TMDL compliance monitoring site (C_{obs}) to levels that would provide an equitable assimilative capacity for MS4 and uncontrollable sources to meet the WLA concentration (C_{WLA}), set to 113 cfu/100 mL for *E. coli*. Accordingly, a loading factor (LF_{MS4}) is applied so that MS4 Permittees are only required to achieve the portion of the needed reduction that could be attributed to MS4 sources. The loading factor is equivalent to the ratio of the red and blue lines in Figure 3-13. The flowrate at each compliance monitoring site (Q_{WW}) was computed as medians of USGS gauge data for the 2013-2015 dry seasons, adding in other measured flows between gauges and sites. Consistent with the CBRP, an *E. coli* concentration of 1260 cfu/100 mL was assumed for managed DWF from MS4 areas (C_{MS4}).

Table 4-4 Estimate of DWF Reductions from MS4 Source to Achieve Compliance with the Bacteria TMDL WLAs

TMDL Compliance Site	Average Dry Weather Flow (cfs)	Measured Geomean, 2013-2015 (cfu/100 mL)	Flow-weighted Average of MS4 and POTW Sources (cfu/100 mL)	DWF Reduction Target (cfs)
Santa Ana River at MWD	44	201	109	1.7
Santa Ana River at Pedley	87	150	95	1.6
Chino Creek at Central	6	293	112	0.4
Mill-Cucamonga Creek	12	960	480	4.0

Assumed *E. coli* in eliminated DWF (cfu/100 mL) of 1260

Results of the compliance analysis for the 2016 Triennial Review are presented in Table 4-4. The DWF reduction targets in this table may be used to achieve compliance with WLAs in the TMDL by demonstrating sufficient reduction of DWF rates from MS4 sources upstream of the impaired waters. It is important to note that even if these DWF reduction targets are achieved, exceedance of WQOs may still occur as a result of uncontrollable sources.

4.1.5.2 Outdoor Water Use Efficiency BMP Deployments

The CBRP compliance analysis relates the targeted DWF reductions to associated levels of implementation of outdoor water use efficiency BMPs (Table 4-5). The basis used to quantify DWF generation and potential runoff reduction effectiveness of water conservation BMPs is from a recent study conducted by Metropolitan Water District of Orange County and Irvine Ranch Water District. The study evaluated the effectiveness of Weather-based Irrigation Controllers (WBICs) and landscape irrigation system audits for residential runoff reduction during dry weather (Jakubowski, 2008). Several key findings of this study provide estimates of DWF reduction that were used to quantify benefits of increased use of water conservation BMPs in the MSAR watershed, including:

- DWF measurements downstream of a residential neighborhood showed approximately 500 gal/irrigated acre/day. This rate is used to approximate the runoff reduction benefit of replacing grass lawns with turf or xeriscape (i.e. no expected runoff implementation).
- Education and outreach reduced DWF by roughly 190 gal/irrigated acre/day. This rate is used to approximate the runoff reduction from education and outreach BMPs, including an on-site irrigation audit, and water waste enforcements.
- Installation of a weather based irrigation controller on a large portion of the urban landscape provided DWF reduction of 170 gal/irrigated acre/day.

For example, it is estimated that 1.7 cfs reduction of DWF from MS4 sources must be reduced to meet the WLA at the Santa Ana River at MWD Crossing. This reduction could be achieved by implementing a combination of outdoor water use efficiency BMPs that treat between 2100 – 6300 acres of irrigated lands. These DWF reduction targets require assumptions about DWF reductions that may be achieved with BMPs and the bacteria in typical irrigation excess runoff, two parameters that are known to be highly variable. Therefore, results should be used as planning level targets for the MS4 Permittees.

Table 4-5 Estimated DWF Reduction and Level of BMP Implementation Needed to Achieve Compliance with TMDL during Dry Weather (modified from CBRPs)

Compliance metric	Santa Ana River at MWD	Santa Ana River at Pedley	Mill-Cucamonga Creek	Chino Creek	Total
Estimated DWF reduction from MS4 source needed for TMDL compliance (cfs)[1]	1.7	1.6	4.0	0.4	7.7
Potential Irrigated acres to be managed with mix of outdoor water conservation BMPs (acres) [2]	2100 – 6300	2100 – 6100	5200 – 15300	500 – 1300	5500 – 15500

1) Assumes *E. coli* concentration in reduced or eliminated DWF of 1,260 cfu/100 mL (10 times the geometric mean WQO for *E. coli*)

2) Potential DWF reduction from outdoor water use efficiency BMPs of 170 – 500 gallons per irrigated acre per day

The MS4 drainage areas that contribute DWF to impaired waterbodies are spread over several different water purveyor service areas. BMP implementation by each purveyor at specific addresses that exist within hydrologically connected MS4 drainage areas has not been parsed from available data. However, Inland Empire Utilities Agency (IEUA) completed a service area wide summary of water conservation BMP implementation. This summary was synthesized to estimate the extent of irrigated acres in the region that have been treated with an outdoor water use efficiency BMP and would be expected to generate less DWF to MS4s (Table 4-6). For example, as many as 676 acres of irrigated area have been treated with outdoor water use efficiency BMPs in the City of Chino Hills. A portions of these treated areas are within the prioritized MS4 drainages areas and would therefore reduce DWF inputs to Chino Creek from MS4 sources.

In general, the IEUA service area wide deployment levels demonstrate that recent conservation BMP measures implemented in the region are of a sufficient magnitude to make significant progress toward meeting the DWF reductions needed to comply with MSAR Bacterial Indicator TMDL WLAs. Thus, continued deployment of such BMPs, if coordinated with CBRP activities, may eventually reach target levels for the effective DWF areas.

Table 4-6 Implementation of Outdoor Water Use Efficiency BMPs in IEUA's Service Area in 2012 - 2015

Member Agency	Irrigation Audits		WBICs, Efficient Nozzles		Drought Tolerant Landscape		Total Irrigated Acres
	Count	Irrigated Acres	Count	Irrigated Acres	Count	Irrigated Acres	
Chino	94	122.8	11,985	158	57	3.5	284
Chino Hills	98	104.2	16,523	558	107	13.7	676
CVWD	174	147.7	143,067	2,204	284	13.2	2,365
FWC	31	9.3	7,243	113	48	1.1	123
IEUA Facilities	28	50.7	277,038	2,951	775	47.7	3,049
MVWD	162	85.8	13,092	202	63	1.9	290
Ontario	122	136.3	27,464	695	100	8.2	840
SAWC	22	7.5	67	30	15	0.3	38
Upland	95	66.5	31,507	693	110	5.3	765
Total	826	731	527,986	7,60	1,559	95	8,430

The State of California has passed several important legislative actions to require water agencies to reduce per capita water use. In 2009, the Water Conservation Bill was passed and required a 20 percent reduction of per capita water use prior to 2020. Agencies have enhanced their programs of water conservation BMP implementation toward achieving the targets. More recently, Governor Brown has issued a series of executive orders to accelerate conservation as a result of the extended drought conditions, including a requirement for all water agencies to reduce water usage by 25%, with specific reduction goals for each water agency that are based on 2013 monthly water productions. The executive order also evoked water shortage contingency plans that call for mandatory cutbacks on outdoor water use. This, along with more rigorous deployment of outdoor water conservation BMPs is expected to continue as agencies strive to achieve reductions and avoid incurring fines, and thereby reduce the rate of DWF from MS4 drainage areas in the MSAR watershed.

Section 5

Summary Findings

This 2016 Triennial Review Report contains much information to report on current conditions and long term water quality trends in the impaired waters (Section 2), description of supplemental bacteria source studies that have been completed by Permittees (Section 3), and progress made through implementation of the CBRP toward compliance with the TMDL (Section 4). The following are several key findings that will be important to consider in preparation for a potential TMDL revision:

- The Permittees have fulfilled the requirements set forth in four base elements of the CBRP through: 1) revision and enforcement of city water conservation and stormwater ordinances, 2) deployment of a range of water quality BMPs to reduce DWF or control sources of fecal bacteria within the MSAR watershed, 3) implementation of an unparalleled source evaluation program and set of supplementary studies, and 4) completion of regional BMPs to provide additional treatment of DWFs.

- Prado Park Lake has bacteria concentrations that are consistently close to WQOs. In the 2015 dry season a significant reduction was discovered (geometric mean of *E. coli* of 40 cfu/100 mL), which may be attributable to a revision in the way IEUA delivers effluent to the lake. Thus, there is reason to believe lower bacteria levels may continue in the future, which would give cause for delisting this waterbody and removing it from the TMDL in the future.

- Updates to the source contribution analysis for MS4 and POTW inputs to each of the TMDL waters show that the expected bacteria concentration at 4 of 5 of the watershed-wide compliance monitoring sites is below water quality objectives (only Mill-Cucamonga had estimated MS4+POTW blend concentrations over the WQO). However, monitoring data has shown that exceedances of the WQOs continue to occur at varying frequencies at all of the sites.

- Since the TMDL was adopted, there has been a continuous decline in POTW effluent discharges to each of the impaired waterbodies caused by indoor water conservation measures and increasing reuse of wastewater, such as in the IEUA service area. Per the source contribution analysis, this would naturally result in an increase in the estimated flow-weighted average concentration that may be expected at the downstream compliance monitoring sites. No such rise in fecal bacteria has been observed at any of the watershed-wide compliance monitoring sites.

- By process of elimination, the Uncontrollable Bacteria Sources Study suggested that the majority of *E. coli* in the impaired waters may be from releases from naturalized colonies in channel bottom sediment and biofilms. Fecal bacteria from a specific host released to the environment can settle to channel bottom and survive within sediments or biofilms for weeks or months over a wide range of temperature and moisture conditions. Growth of these initially deposited fecal bacteria within channel bottom sediments and biofilms results in colonies, where the majority of the population may be considered naturalized, reproducing outside of a specific organism. The BPA determined that bacteria regrowth within sediment and biofilm is an uncontrollable source of fecal bacteria. As noted in Section 3.3, additional study would be necessary to better understand the potential for naturalized bacteria colonies to contribute to bacteria concentrations in overlying waters and the transport process by which bacteria is released.

- The Residential Property Scale Bacteria Water Quality Study proved the hypothesis that extreme variability in concentrations at MS4 outfalls is linked to the quantity and quality of irrigation excess runoff from individual properties. Unlike rainfall driven runoff, where rain is spread across the entire watershed, the primary source of DWF in an urban catchment at any given point in time is outdoor water use by a single or small group of properties. The statistically randomized study found that irrigation excess from a majority of properties (*n=80*) would be expected to meet WLAs in the TMDL. The reason for very high concentrations at some sites may be partially due to the sampling method, whereby samples collected from a wetted street gutter had significantly greater bacteria concentrations than those collected directly from the thatch.

Section 6

References

American Public Health Assocation. 1999. Standard Methods for the Examination of Water and Wastewater, 20th Edition.

Chino Basin Watermaster and Agricultural Pool. 2014. *Bacterial Indicator Agricultural Source Management Plan (BASMP)*. December.

Grant, S.B., Litton-Mueller, R.M., and Ahn, J.H. 2011. Measuring and modeling the flux of fecal bacteria across sediment-water interface in a turbulent stream. Water Resources Research. 47(5).

Jakubowski, S.D. 2008. Effectiveness of Runoff-Reducing Weather-Based Irrigation Controllers (SMARTIMERS). October.

Jiang, S.C., W. Chu, B. H. Olson, J.-W. He, S. Choi, J. Zhang, J. Y. Le, and P. B. Gedalanga. 2007. Microbial source tracking in a small southern California urban watershed indicates wild animals and growth as the source of fecal bacteria. Applied Microbiology and Biotechnology. 76(4):927-34.

Kadlec, R.H. and Wallace, S. 2009. *Treatment Wetlands; 2nd Edition*, CRC Press.

Riverside County Stormwater Program. 2011. *Comprehensive Bacteria Reduction Plan*. June.

RCFC&WCD. 2015. Santa Ana Region Monitoring Annual Report Monitoring Year 2014-2015. November.

RCFC&WCD. 2016. Middle Santa Ana River Watershed Uncontrollable Bacterial Sources Study. Prepared by CDM Smith on behalf of RCFC&WCD. June.

RWQCB. 2005. Resolution Amending the Water Quality Control Plan for the Santa Ana River Basin to Incorporate Bacterial Indicator Total Maximum Daily Loads (TMDLs) for Middle Santa Ana River Watershed Waterbodies. Regional Board Resolution R8-2005-0001.

SAWPA. 2009. *Middle Santa Ana River Bacterial Indicator TMDL Data Analysis Report*. Prepared by CDM Smith (formerly CDM) on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. March.

SAWPA. 2010. *Middle Santa Ana River Bacterial Indicator TMDL: Triennial Report*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. February.

SAWPA. 2013a. *Middle Santa Ana River Bacterial Indicator TMDL 2012-13 Wet Season Report*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. May.

SAWPA. 2013b. *Middle Santa Ana River Bacterial Indicator TMDL 2013 Dry Season Report*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. December.

SAWPA. 2013c. *Middle Santa Ana River Bacterial Indicator TMDL Implementation Report*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. February.

SAWPA. 2013d. *Middle Santa Ana River Water Quality Monitoring Plan, Version 4.0*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. July.

SAWPA. 2013e. *Middle Santa Ana River Quality Assurance Project Plan, Version 4.0*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. July.

SAWPA. 2013f. *Middle Santa Ana River Water Quality Monitoring Plan: Tier 2 Source Evaluation Addendum*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. July.

SAWPA. 2014a. *Middle Santa Ana River Bacteria Indicator TMDL 2013-2014 Wet Season Report*. Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. May.

SAWPA. 2014b. *Middle Santa Ana River Bacterial Indicator TMDL 2014 Dry Season Report.* Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. December.

SAWPA. 2015a. *Middle Santa Ana River Bacteria Indicator TMDL 2014-2015 Wet Season Report.* Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. May.

SAWPA. 2015b. *Middle Santa Ana River Bacterial Indicator TMDL 2015 Dry Season Report.* Prepared by CDM Smith on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. December.

SAWPA. 2015c. *Volume-Weighted TDS Concentration of POTW Discharge above Prado Dam during August-September Technical Memorandum.* Prepared by Wildermuth Environmental, Inc. (WEI) on behalf of SAWPA and the Middle Santa Ana River Watershed TMDL Task Force. June.

SBCFCD. 2011. Comprehensive Bacteria Reduction Plan. June.

Urban Water Resources Research Council. 2014. *Pathogens in Urban Stormwater Systems*. August.

Wolosoff, S., Chappell, R., Garrety, T., Valdez, R., and Rodabaugh, M. 2015. *Bacteria in Residential Subwatersheds is not Widespread – Results from a Residential Property-Scale Water Quality Study*.

Appendix A

Additional Studies

Middle Santa Ana River Bacterial TMDL 2013 Dry Season Tier 2 Source Assessment Final Report

November 2014

CDM Smith

ON BEHALF OF

Santa Ana Watershed Project Authority
San Bernardino County Stormwater Program
County of Riverside
Cities of Chino Hills, Upland, Montclair, Ontario, Rancho Cucamonga, Rialto, Chino, Fontana, Norco, Corona, Riverside, Eastvale, Jurupa Valley, Pomona, and Claremont

Table of Contents

List of Tables

List of Figures

Acronyms

BASMP	bacteria source management plan
BRSC	Boys Republic South Channel
CCCH	Carbon Canyon Creek Channel
CBRP	Comprehensive Bacteria Reduction Plan
CYP	Cypress Channel
District	Riverside County Flood Control & Water Conservation District
DWF	Dry Weather Flow
EVLD	Eastvale Line D
EVLE	Eastvale Line E
IRWD	Irvine Ranch Water District
mL	milliliter
MP	Monitoring Plan
MPN	most probable number
MS4	Municipal Separate Storm Sewer System
MSAR	Middle Santa Ana River
MWDOC	Metropolitan Water District of Orange County
OCWD	Orange County Water District
RWQCB	Riverside Water Quality Control Board
SBCFCD	San Bernardino County Flood District
TMDL	Total Maximum Daily Load
TSS	total suspend solids
USEP	Urban Source Evaluation Program
WRCAC	Western Riverside County Agricultural Coalition

Section 1
Introduction

The Santa Ana Regional Water Quality Control Board (Regional Board) adopted Resolution No. R8 2005-0001, amending the Basin Plan to incorporate Bacterial Indicator TMDLs for the Reach 3 of the Santa Ana River, Reaches 1 and 2 of Chino Creek, Mill-Cucamonga Creek, and Prado Park Lake (Regional Board, 2005[1]). The Total Maximum Daily Loads (TMDLs) adopted by the Regional Board were subsequently approved by the State Board on May 15, 2006, by the California Office of Administrative Law on September 1, 2006, and by EPA Region 9 on May 16, 2007. The EPA approval date became the TMDL effective date.

The most recent Municipal Separate Storm Sewer System (MS4) permit updates for Riverside, San Bernardino, and Los Angeles Counties within the Santa Ana River watershed required the development of Comprehensive Bacteria Reduction Plans (CBRP) by responsible parties within each County. The CBRP is a long term plan designed to achieve compliance with dry weather condition (April 1 – October 31) wasteload allocations for bacterial indicators established by the Middle Santa Ana River (MSAR) Bacterial Indicator TMDL ("MSAR Bacteria TMDL").

1.1 Comprehensive Bacteria Reduction Plan

The CBRP is designed to provide a comprehensive plan for attaining MSAR Bacterial Indicator TMDL WLAs applicable to urban runoff by integrating existing control programs and efforts with new permit mandates and other additional activities necessary to address controllable urban sources of bacterial indicators. Riverside and San Bernardino Counties submitted final CBRPs to the Regional Board in June 2011. The Regional Board approved both CBRPs on February 10, 2012 (Riverside County: Order No. R8-2012-0015; San Bernardino County: Order No. R8-2012-0016). CBRPs for the Cities of Pomona and Claremont in Los Angeles County were submitted to the Regional Board in January 2014. The Regional Board approved both CBRPs on March 14, 2014 (City of Claremont: Order No. R8-2014-0030; City of Pomona: Order No. R8 2014 0031). Each of these CBRPs contains the same basic elements with regard to source evaluation activities.

CBRP implementation includes inspection activities to (a) identify controllable MS4 Dry Weather Flow (DWF) sources and their contribution to elevated bacterial indicator concentrations; (b) prioritize controllable DWF sources for follow-up mitigation activity; and (c) identify alternatives to mitigate prioritized controllable urban sources. This effort was initiated in 2012, and will continue over an extended period so that MS4 outfalls to reach 3 of the Santa Ana River can be properly prioritized, investigated and evaluated for mitigation.

---

[1] http://www.swrcb.ca.gov/rwqcb8/water_issues/programs/tmdl/msar_tmdl.shtml

To date, two years of dry season bacteria source evaluation from MS4 systems in the MSAR watershed have been completed. Data from the first year, 2012, was analyzed and reported in Section 3 of the MSAR Bacteria TMDL Implementation Report (CDM Smith, 2013[2]). In 2012, source evaluations involved monitoring at all major MS4 outfalls to receiving waterbodies, referred to as Tier 1 sites. In total, 34 Tier 1 sites were monitored covering multiple jurisdictions (Figure 1-1). Some of the Tier 1 monitoring sites were also sampled in 2007-2008 as part of implementation of the Urban Source Evaluation Program (USEP)[3].

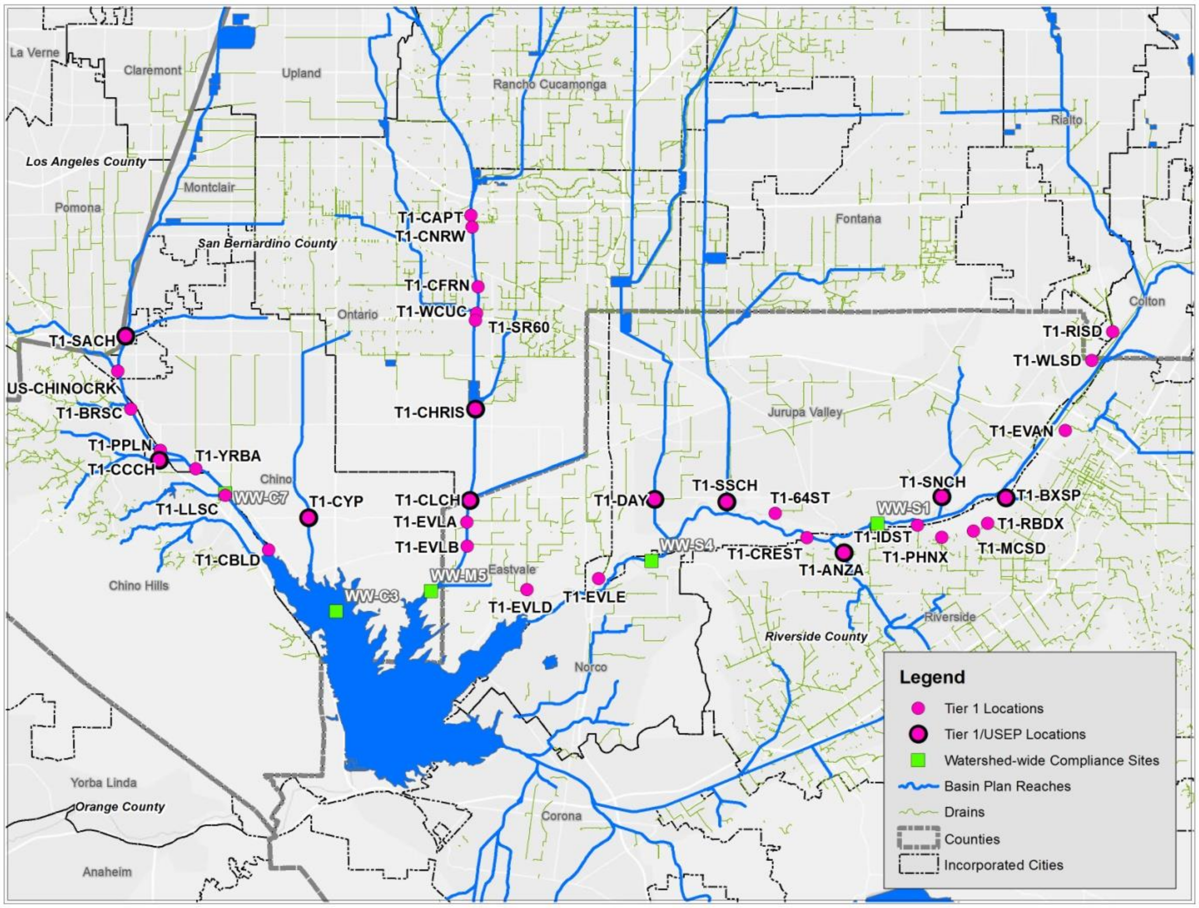


Figure 1-1
CBRP Tier 1 source evaluation monitoring sites

Tier 1 source evaluation activities were designed to gather sufficient DWF and bacterial indicator data to provide the basis for prioritizing MS4 drainage areas within the MSAR watershed for subsequent source assessments and, where necessary, development of alternatives to mitigate controllable urban sources of bacterial indicators.

---

[2] http://www.sawpa.org/collaboration/projects/tmdl-taskforce/

[3] The MSAR Bacterial Indicator TMDL required permitted MS4 discharges to develop the USEP within six months after TMDL adoption or by November 30, 2007. Per Section 4.1 of the TMDL, the purpose of the USEP was to identify specific activities, operations, and processes in urban areas that contribute bacterial indicators to MSAR waterbodies. The Regional Board approved the USEP developed by the MS4 permittees April 18, 2008 (RWQCB Resolution R8-2008-0044). The inspection activities identified in the CBRP (adopted February 15, 2012) replaced the requirements of this 2008-adopted USEP.

On February 11, 2013 MS4 Permittees within the MSAR watershed (Permittees) submitted a CBRP Tier 1 Source Evaluation Report to the Regional Board. The report contained the results of analysis of the monitoring data collected for 10 consecutive weeks in the 2012 dry season at Tier 1 outfalls to the TMDL waterbodies; Chino Creek, Mill-Cucamonga Creek, and the Santa Ana River. The report contained a prioritization of MS4 drainage areas upstream of Tier 1 outfalls (Figure 1-2).

The drainage areas to each of the prioritized Tier 1 sites are spread across multiple cities in each of Riverside, San Bernardino, and Los Angeles Counties and range in size from 334 acres to 7,313, acres (Table 1-1). Table 1-1 also shows the frequency of human *Bacteroides* detections from the 2012 dry season.

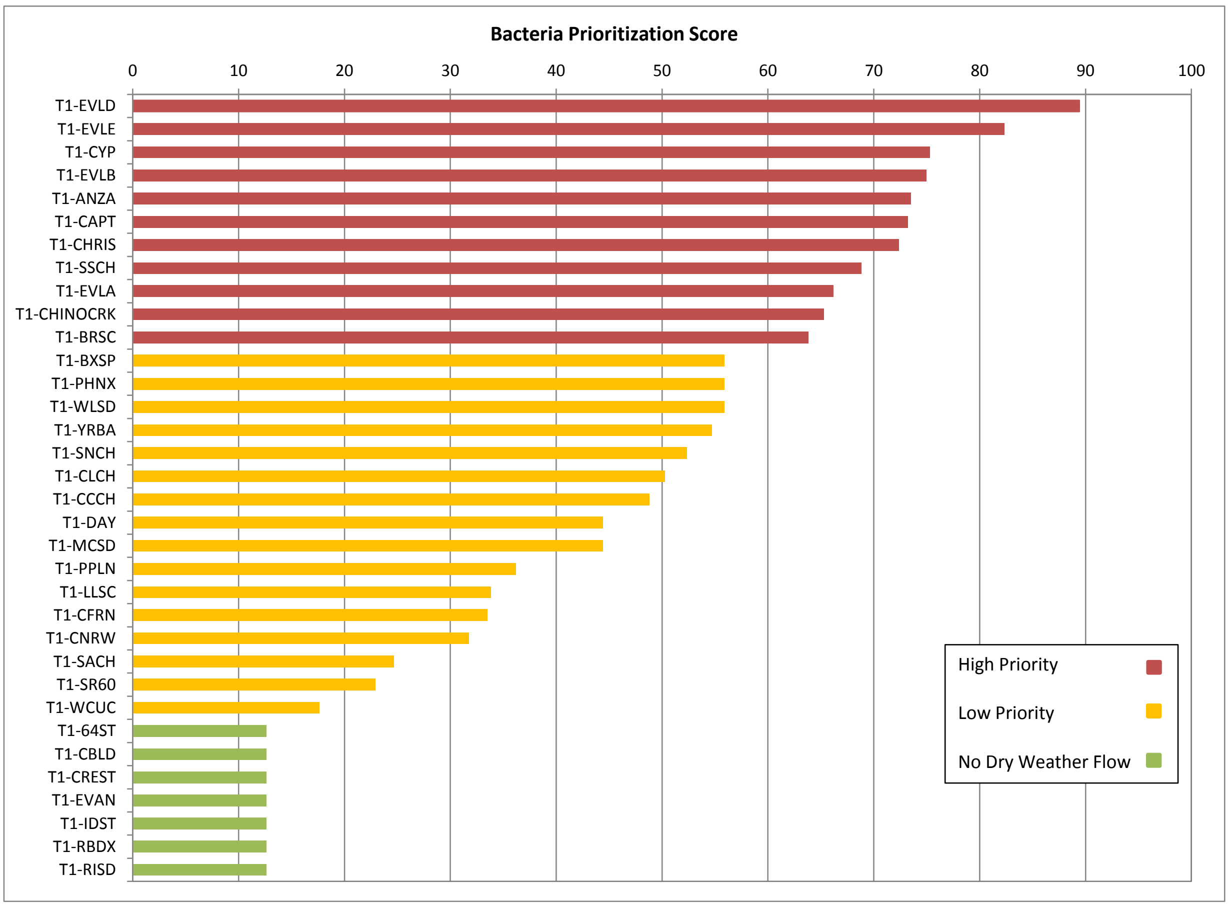


Figure 1-2
Bacteria Prioritization Score used to Prioritize Tier 1 sites for Tier 2 Source Evaluation

Table 1-1 Prioritized Tier 1 Drainage Areas for Tier 2 Source Evaluation Activities

Site ID	Jurisdictions	Drainage Acres	Human Presence	MS4 Drainage Features
T1-EVLD	Eastvale	852	30%	Storm drains
T1-EVLE	Eastvale	798	100%	Storm drains
T1-CYP	Chino, Ontario	4,952	20%	Open channel with storm drain outfalls
T1-EVLB	Eastvale	334	80%	Storm drains
T1-ANZA	Riverside	7,313	20%	Open channel with storm drain outfalls
T1-CAPT	Ontario	1,050	40%	Storm drains
T1-CHRIS	Ontario	5,774	30%	Open channel with storm drain outfalls, culverts
T1-SSCH	Jurupa Valley, Fontana	3,337	40%	Open channel with storm drain outfalls
T1-EVLA	Eastvale	498	10%	Storm drains
CHINOCRK	Pomona, Claremont	6,032	30%	Storm drains
T1-PHNX	Riverside	503	10%	Storm drains
T1-CCCH	Chino Hills	3,934	0%	Open channel with storm drain outfalls
T1-BRSCH	Chino Hills	1,160	10%	Open channel with storm drain outfalls

1.2 Tier 2 Source Evaluation Objectives

Tier 2 source evaluations were conducted within the drainage areas of high priority Tier 1 sites (see Figure 1-2). Tier 2 source evaluations focused on the stormwater networks of individual MS4 Permittees, each with unique drainage areas, DWF sources, and management challenges. Despite these differences, there were several objectives common to all MS4 Permittees, including:

- Identification of specific sources of human fecal bacteria within MS4 drainage areas that could be eliminated. In 2012, there were several Tier 1 sites with persistent detection of human *Bacteroides*. Rigorous field surveillance upstream of these sites was conducted by all Permittees and several potential sources of human bacteria were identified and mitigated.

- Segregation of smaller subareas; neighborhoods, street blocks, or in one case, individual properties, where DWF rates and bacteria is a greater concern.

- Development of supplemental source evaluation activities to reduce or eliminate controllable sources of bacteria within the MS4s.

- Characterization of urban dry weather hydrology to facilitate understanding of the potential to implement DWF controls at the subwatershed scale.

Section 2

Source Evaluation Methods in 2013 Dry Season

2.1 Monitoring Summary

2.1.1 Monitoring Locations

Tier 2 source evaluation activities took place in the drainage areas upstream of prioritized Tier1 sites (Figure 2-1). Dry weather flow samples were taken from a variety of outlets, including channels, manholes, storm drains, and culverts, within the drainage areas (Table 2-2). In total, 114 sites were monitored covering 7 cities in 3 counties. Some of the Tier 2 monitoring sites were also previously designated as Tier 1 monitoring sites; this allowed an evaluation of changes in DWF and bacterial indicators over time.

Prior to conducting Tier 2 source evaluation monitoring in 2013, MS4 Permittee staff visited the proposed sites to confirm the locations and assess the feasibility for collecting samples. In some cases, site locations were adjusted based on field reconnaissance.

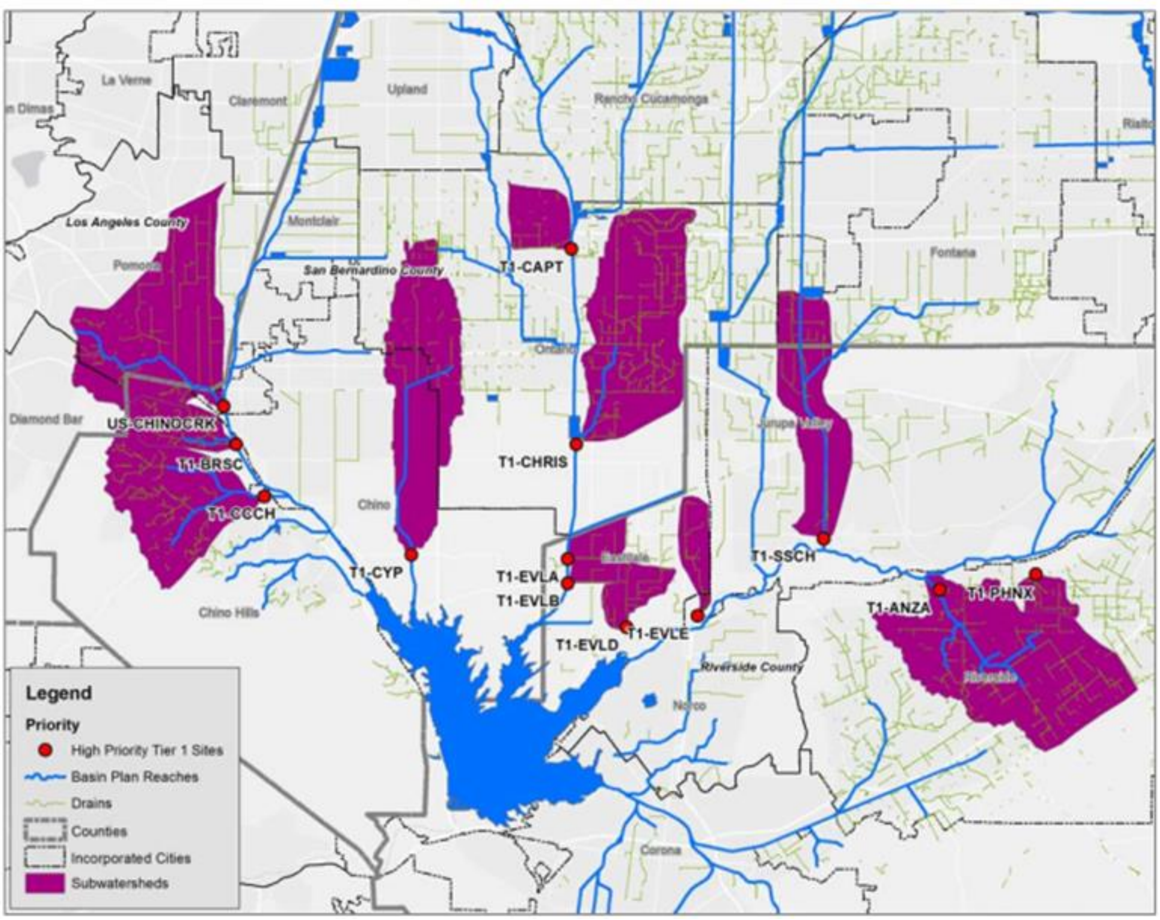


Figure 2-1
Map of Prioritized Tier 1 MS4 Drainage Areas

2.1.2 Data Collection

MS4 Permittee staff collected field measurements and water quality samples from Tier 2 sites during the 2013 dry season, approximately from May through October, in accordance with the QAPP[4]. Table 2-1 provides a summary of the number of samples collected by each jurisdiction in the 2011, 2012, and 2013 dry seasons. Generally, there were fewer Tier 1 sites when compared to Tier 2, however, during the Tier 1 effort samples collected weekly for ten consecutive weeks. In 2013, Tier 2 samples were taken from more sites; however, samples were taken less frequently, so that the total number of samples collected was not substantially different between the two efforts., Each Permittee developed a distinct approach to source evaluation in the 2013 dry season that best fit their needs. The Monitoring Plan[4] (MP) was designed be used like a toolbox from which permittees could customize their monitoring program to fill their needs., The monitoring plan enabled Permittees to implement an iterative program where they could adjust sites and sample analytes weekly, based on DWF observations and as bacterial indicator data was obtained.

Table 2-1 Tier 1 and Tier 2 Sampling Information

MSAR Bacteria TMDL Monitoring Type and Jurisdiction	Period of Record	Number of Sites	Number of Samples in Dry Season
Tier 1 Source Evaluation			
Riverside	May 2012 – July 2012	10	44
Jurupa valley	May 2012 – July 2012	3	18
Eastvale	May 2012 – July 2012	4	39
Ontario	May 2012 – July 2012	7	39
Chino	May 2012 – July 2012	4	31
Chino Hills	May 2012 – July 2012	4	25
Pomona	April 2011 – July 2011	1	10
Tier 2 Source Evaluation			
Riverside	Sept 2013 – Oct 2013	10	33
Jurupa Valley	Sept 2013 – Oct 2013	6	15
Eastvale	Sept 2013	14	42
Ontario	July 2013 – Nov 2013	32	60
Fontana	Aug 2013 – Oct 2013	4	36
Chino	Aug 2013 – Sept 2013	20	67
Chino Hills	Aug 2013 – Sept 2013	25	41
Pomona	Aug 2013 – Oct 2013	7	54

In-stream sampling consisted of grab samples collected approximately mid-stream and at the water surface where the stream appeared to be completely mixed and free from debris and algae. This condition was often difficult to achieve when sampling very low depth waters from MS4 facilities. Each Permittee developed a method to collect clean samples, ranging from the use of

[4] http://www.sawpa.org/collaboration/projects/tmdl-taskforce/

various scoop devices with sterile water sampling bags to having confined space certified staff climb down manholes to collect samples.

Water samples were collected first before conducting any field measurements, including flow, to ensure measurements were representative of water chemistry and quality from time of collection. Site water quality measurements included the collection of field parameter data (where feasible) and water samples for laboratory analysis. Water samples were collected from the upstream side, preserved, stored, and transported as specified by protocol and chain of custody requirements.

Where field measurements were feasible, they included flow, temperature, conductivity, pH, dissolved oxygen, and turbidity. These constituents were measured on site at the time of sampling using YSI or equivalent multi-parameter meters. Additionally, some Permittees chose to field measure ammonia, potassium chlorine, copper, and surfactant/detergent using Hach Company test strips or equivalent.

Water samples were collected for submittal to Orange County Public Health Laboratory for *E. coli* analysis. A subset of water samples was also analyzed by Orange County Water District (OCWD) for the presence/absence of the human *Bacteroides* marker. The Cities of Chino Hills, Chino, and Fontana also sent samples to Source Molecular in Florida for assessment of fecal sources.

Additional information regarding sample collection methods and requirements is available in the MP and the QAPP.

This page intentionally left blank

Section3

Summary of Results

3.1 Common Characteristics

Several findings were common for all of the drainage areas where Tier 2 source evaluations were conducted in the 2013 dry season, as described below. These findings are considered representative of urban subwatersheds in southern California. A finding common to all drainage areas evaluated was that irrigation excess runoff is the predominant source of DWF.

3.1.1 Exceedance of TMDL WLA

Analysis of average *E. coli* concentrations of all Tier 2 samples collected in each MS4 drainage area to prioritized Tier 1 sites showed bacteria levels exceeding WLA (Figures 3-1, 3-2). Some drainage areas had much greater average *E. coli* concentrations than others, such as shown for Tier 2 samples upstream of the T1-CAPT site. This information can be useful for Permittees when deciding where to allocate resources for locating controllable sources of bacterial indicators.

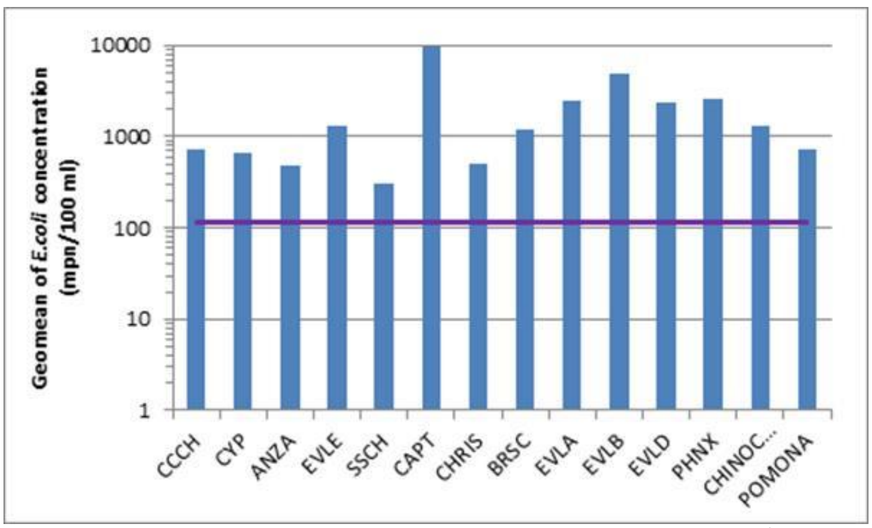


Figure 3-1

E. coli **Concentration in Tier 2 Source Evaluation Monitoring Sites**

3.1.2 Bacteria Growth/Decay in MS4 Systems

One very important finding for stormwater program managers was the change in bacterial indicator concentrations from the upstream Tier 2 sites to the associated downstream Tier 1 site. A significant reduction of bacterial indicator concentrations was observed in subwatersheds where there is a segment of open channel prior to reaching the downstream Tier 1 site. Figure 3-2 illustrates this water quality improvement with the red diamonds showing the *E. coli* concentration at the Tier 1 site and the box/whisker characterizing the range of *E. coli* concentrations for upstream Tier 2 sites. The box and whisker plots on the left side of the chart are for subwatersheds with an open channel segment. The reduction of *E. coli* was observed in Carbon Canyon Creek Channel (CCCH), Cypress Channel (CYP), Anza Drain, and Eastvale Line E (EVLE) subwatersheds. This information can be useful for Stormwater program managers, as it can present options for potential future BMP deployments where results from focused source evaluations do not locate a controllable source of impairment.

Conversely, for MS4s that are entirely underground (on right side of the chart in Figure 3-2), the Tier 1 site concentration generally falls within the range of upstream Tier 2 concentrations. In some subwatersheds, a higher concentration at the Tier 1 site relative to the range of upstream Tier 2 concentrations may point to an additional source of bacteria from within the MS4 facilities, such as wildlife, transient camps, or re-growth in biofilms where dark, warm, and damp conditions may create a habitat for bacteria. This could be the case in the MS4 networks upstream of the Boys Republic South Channel (BRSC), Lower Deer Creek (CHRIS), Eastvale Line D (EVLD), and Pomona Storm Drain Tier 1 sites.

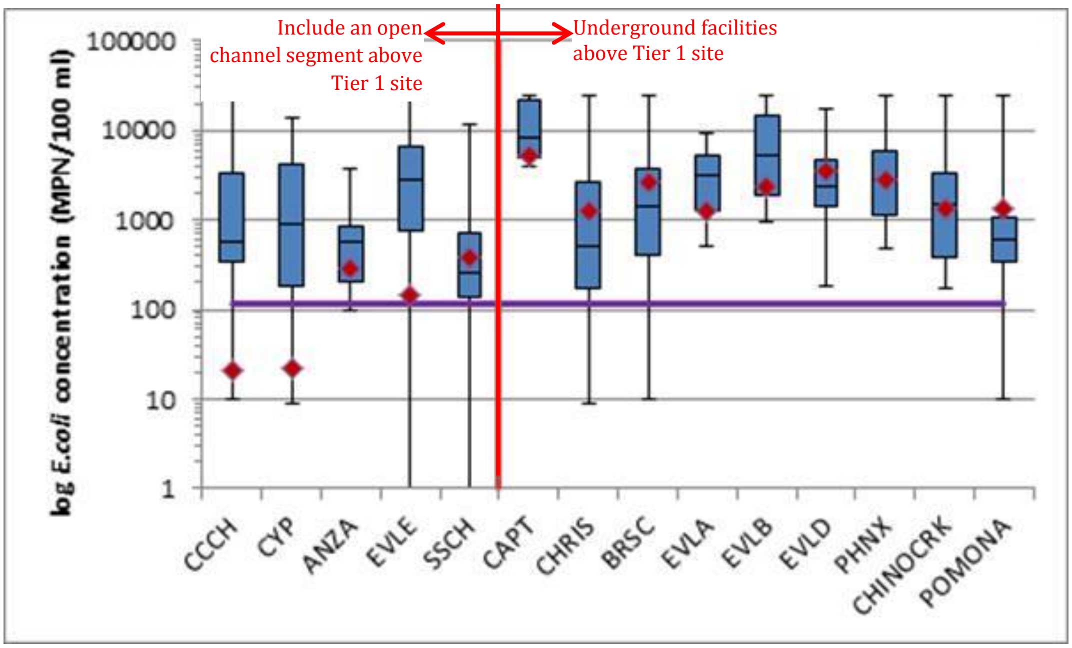


Figure 3-2
Box-Whisker Plot of *E. coli* Concentrations at Tier 2 Source Evaluation Monitoring Sites that Drain to a Downstream Tier 1 Site (Red Diamond Shows *E. coli* Concentration at Downstream Tier 1 Site)

3.1.3 Property Specific Influences

Bacterial indicator concentrations from the Tier 2 source evaluation sites were extremely variable with samples ranging from non-detect to greater than 24,000 MPN/100 mL *E. coli*. This finding was true, even when evaluating weekly samples collected from the same site and at similar times of day. One hypothesis that may explain this extreme variability in results is the differences among individual properties in the quantity and quality of irrigation excess runoff. Unlike rainfall driven runoff, where rain is spread across the entire watershed, the primary source of DWF in an urban catchment at any given point in time is outdoor water use by a subset of properties.

Numerous factors impact which property(ies) would be creating offsite runoff at the time a downstream sample is collected, including irrigation schedules, irrigation system efficiency, and timing of other outdoor water uses, which are a function of the day to day routine of each resident at each property. Data from the Residential Runoff Reduction (R3) Study by Irvine Ranch Water District (IRWD) and Metropolitan Water District of Orange County (MWDOC) shows that DWF from residential neighborhoods occurs at varying times of day, based on varying irrigation schedules of upstream properties (A & N Technical Services, 2006[5]).

The presence of DWF over extended period of time means that not all properties create irrigation excess runoff at the exact same time. Accordingly, a sample taken at any given time downstream of a residential neighborhood is likely only representative of the properties that were actively generating offsite runoff prior to the sample collection. Figure 3-3 shows an example of a field visit in the City of Chino, where DWF inputs to the MS4 is clearly generated from just one of three potential street gutters. In fact, it is likely that only a few properties caused the DWF shown in the photograph.

In routine site visits at a given street inlet, properties generating downstream DWF will likely be different, and the spatial variability of property specific bacteria water quality then translates into the extreme fluctuation in results between site visits. In other words, samples from the same site may be representative of completely different contributing subareas. The randomness in the timing of peak *E. coli* concentrations was particularly evident in data collected from City of Pomona Tier 2 monitoring sites, as described in Section 3.3.8 below.

Figure 3-3
Frequency of Detection of Human *Bacteroides* in Tier 2 Source Evaluation Monitoring Sites (photo taken by Ruben Valdez)

[5] A & N Technical Services, 2006. Commercial ET-Based Irrigation Controller Water Savings Study, prepared for Irvine Ranch Water District and US Bureau of Reclamation.

3.1.4 Reduction in Human Detections

The human *Bacteroides* marker was evaluated in a subset of Tier 2 DWF samples. Only one Tier 2 site had more than one detection of human *Bacteroides*; T2-GARY in the City of Pomona. Other sites had one-detection, including the Peyton drain in the BRSC subwatershed, the Tier 1 site EVLB and Tier 2 sites within the drainage areas to Eastvale Lines D and E. Results from analysis for human *Bacteroides* was not completed until the end of the 2013 dry season. The data regarding these instances was used to design focused source assessments to take place in 2014 dry season. Overall, the frequency of *Bacteroides* presence has decreased from the initial USEP studies conducted in 2007-2008 and the Tier 1 source evaluation. This line of evidence suggests that mitigation activities conducted in 2013-14 have been successful at eliminating controllable sources of Bacterial Indicators in some subareas (Figure 3-4).

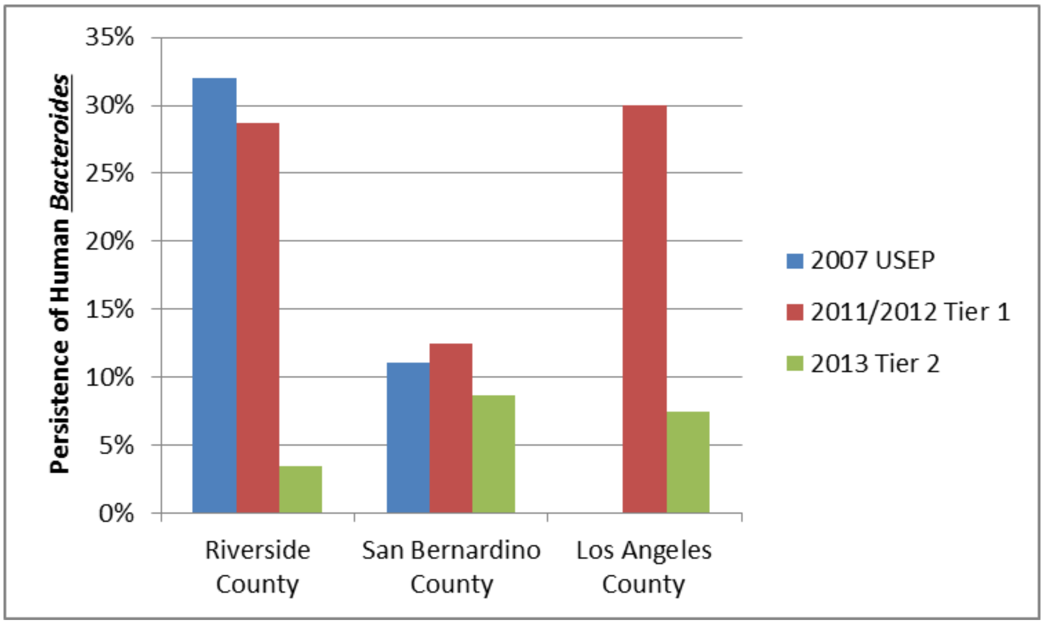


Figure 3-4
Change in Persistence of Human *Bacteroides* by County from 2007 to 2013 (Note that there are no data for Lo Angeles County In 2007; not an absence of *Bacteroides*)

3.2 MS4 Permittee Specific Analysis

The following sections briefly summarize MSAR Permittee-specific findings that were not necessarily common to the overall watershed. For each Permittee, sample sites are shown on a map overlying the MS4 network, field observations of DWF are described, monitoring results are summarized for *E. coli* and *Bacteroides*, and key findings are discussed.

3.2.1 Eastvale

All four Tier 1 MS4 drainage areas in the City of Eastvale were prioritized for Tier 2 source assessment based on the results of the 2012 Tier 1 source evaluation. The 2013 Tier 2 source evaluation sampling in the City of Eastvale was conducted over four events; on September 3rd, 19th, 23rd, and 30th. Prior to the sample collection events, a desktop survey was conducted to map out the layout of the MS4 system. The MS4 system layout was used to determine possible sampling locations within the drainage areas which would yield information to help the Permittees locate any potential controllable sources of Bacterial Indicators. Once sample locations were selected based on the desktop survey, field surveys were conducted to verify the accessibility of proposed sampling locations and to determine how far up the MS4 system dry weather flows occurred. This helped to eliminate some areas from further assessment. The criteria used to exclude areas for further assessment was that if the manhole downstream of a drainage area was observed to be dry after two visits, it was assumed to not require additional follow up. Furthermore, these field surveys helped to identify some potential sources of bacterial indicators. For example at the upper end of the Eastvale Line E drainage area there is an area where day laborers congregated near a Home Depot located at the corner of Hamner Avenue and Limonite Avenue in the City of Eastvale. This area drew attention because just upstream of this particular location there is a drop inlet which connects to Eastvale Line E. The drop inlet was constructed so that it was located approximately 3 feet below the surrounding surface. It was speculated that due to the lack of lavatory facilities nearby, this below grade drop inlet could potentially be used as a makeshift restroom facility. During Tier 1 source assessments, Eastvale Line E was a facility where the *Bacteroides* showed a human signal in every one of the ten samples analyzed. With this information, the City of Eastvale code enforcement efforts were directed at this area to enforce anti-loitering statues.

Sample sites included collection of bacterial water quality samples at the downstream Tier 1 sites as was conducted in the 2012 monitoring program; two within the Mill-Cucamonga Creek watershed (EVLA and EVLB) and two in the Santa Ana River watershed (EVLD and EVLE). Upstream of these Tier 1 sites, the City of Eastvale also collected DWF samples for bacterial water quality analysis at 10 Tier 2 sites, as shown in Figure 3-5 below. Tier 2 site names included reference to the downstream Tier 1 site (ex. Site T2-EVLB34 is within the T1-EVLB subwatershed), with two to three Tier 2 sites located within each of the Tier 1 subwatersheds. Samples were collected from entirely underground collection systems, except for the T1-EVLE site which is collected from within an open concrete lined channel.

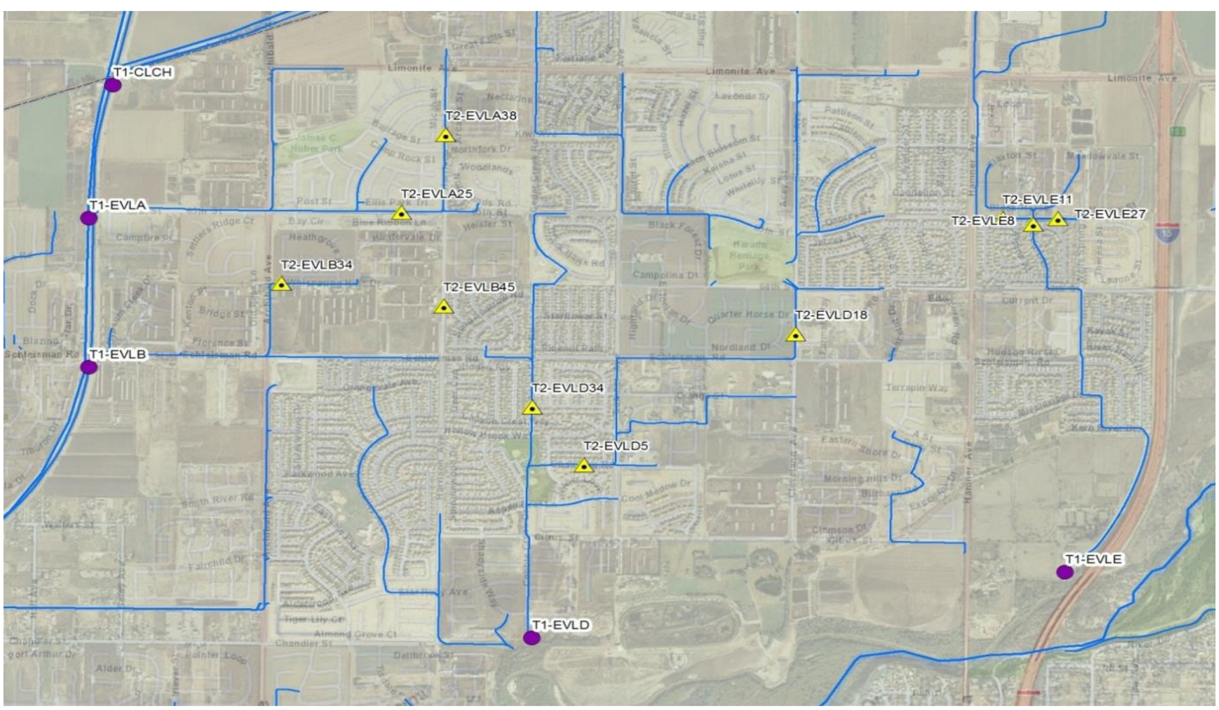


Figure 3-5
Map of Bacteria Source Evaluation Monitoring Sites in the City of Eastvale

Individual sample results for *E. coli* concentration are reported in Table 3-1 Three detections were found of the 35 samples analyzed for human *Bacteroides*, as noted in Table 3-1. The geometric mean of each site is shown in Figure 3-6, with the Tier 1 sites shown in green on the left side of the chart and the Tier 2 sites shown in blue on the right side of the chart.

Table 3-1 Grab Sample Results for City of Eastvale Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)			
	9/3/13	9/19/13	9/23/13	9/30/13
T1-EVLA	520	722	4,352	1,450
T2-EVLA25	CNS	CNS	7,701	9,208
T2-EVLA38	CNS	CNS	2,014	4,352
T1-EVLB	1,376 *	2,142	12,033	960
T2-EVLB34	CNS	24,196	2,098	8,664
T2-EVLB45	CNS	CNS	24,196	CNS
T1-EVLD	10,462	4,611	2,359	1,439
T2-EVLD18	2,187	4,106	CNS	CNS
T2-EVLD34	17,329 *	1,553	CNS	181
T2-EVLD5	4,884	2,909	959	650
T1-EVLE	6,488	754	84	1
T2-EVLE11	CNS	4,106	2,755	7,270
T2-EVLE27	CNS	4,884	650	CNS
T2-EVLE8	24,196 *	9,804	880	1,153

* Indicates samples that had a positive detection of human *Bacteroides*

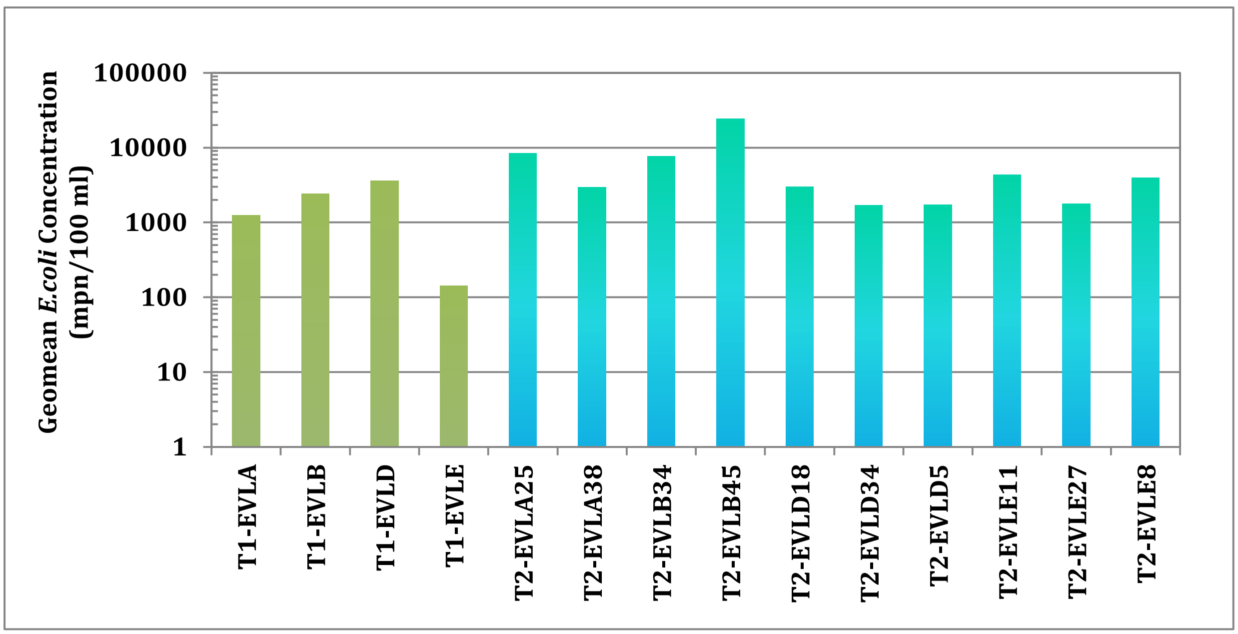


Figure 3-6
Geomean of *E. coli* Concentrations in City of Eastvale's Tier 2 Source Evaluations

Key findings from the City of Eastvale's Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- The most significant observation from the Tier 2 source evaluation in the City of Eastvale was the detection of human *Bacteroides* at three Tier 2 sites on September 3, 2013, each in a different MS4 drainage area (Eastvale Lines B, D, and E). None of the other 41 samples analyzed for *Bacteroides* in the City of Eastvale in 2013 had a human *Bacteroides* detection. This is a sharp

CDM Smith

decline from samples collected during the 2012 dry season, Tier 1 source assessments were positive detections were found in 10, 30, 80, and 100 percent of samples from site T1-EVLA, EVLD, EVLB, and EVLE, respectively. The detections that did occur were all along or just downstream of Schleismann Avenue (which transects the entire City), and all occurred on September 3, which was the Tuesday after Labor Day weekend. Thus, it is possible these detections are related, despite being in separate drainages, but no potential source has been identified. These results were not available prior to the conclusion of the 2013 dry season, therefore additional source assessments will take place in the 2014 dry season to locate and eliminate these potential controllable sources. Moreover, if the potential sources cannot be located, the Permittees are currently evaluating potential BMPs such as proprietary fiber rolls infused with a bacteria reducing agent and/or diversions to infiltration galleries.

- For T1-EVLE, samples taken during the same day at the downstream Tier 1 location had bacterial concentrations that were on average, three times lower than from the underground MS4 network. This finding suggests that bacteria decay from exposure to ultraviolet light in the daylighted open channel segment of Eastvale Line E, may play a significant role in bacteria concentrations. This revelation can potentially be used in the future as a possible solution to eliminate controllable sources of bacterial Indicators.

3.2.2 Riverside

Two MS4 drainage areas in the City of Riverside were prioritized based on the results of the 2012 Tier 1 source evaluation; Anza and Phoenix Drains. The 2013 Tier 2 source evaluation in the City of Riverside was conducted over four events; on September 5th, 10th, 24th, and October 1st. Prior to the sample collection events, a desktop survey was conducted to map out the layout of the MS4 system. The MS4 system layout was used to determine possible sampling locations within the drainage areas which would yield information to help the Permittees locate any potential controllable sources of Bacterial Indicators. Once sample locations were selected based on the desktop survey, field surveys were conducted to verify the accessibility of proposed sampling locations and to determine how far up the MS4 system dry weather flows occurred. This helped to eliminate some areas from further assessment. The criteria used to exclude areas for further assessment was that if the manhole downstream of a drainage area was observed to be dry after two visits, it was assumed to not require additional follow up.

Sample sites included collection of bacterial water quality samples at the same Tier 1 sites as was conducted in the 2012 monitoring program, T1-ANZA and T1-PHNX, both of which discharge DWF to the MSAR. Upstream of these Tier 1 sites, the City of Riverside also collected DWF samples for bacterial water quality analysis at 8 Tier 2 sites, as shown in Figure 3-7 below. Tier 2 site names included reference to the downstream Tier 1 site (ex. Site T2-ANZA 10 is within the T1-ANZA subwatershed). Six and two Tier 2 sites are located within the MS4 drainage areas to the T1-ANZA and T1-PHNX subwatersheds, respectively. Samples sites included a mix of underground collection systems (manholes) and open concrete lined channels.

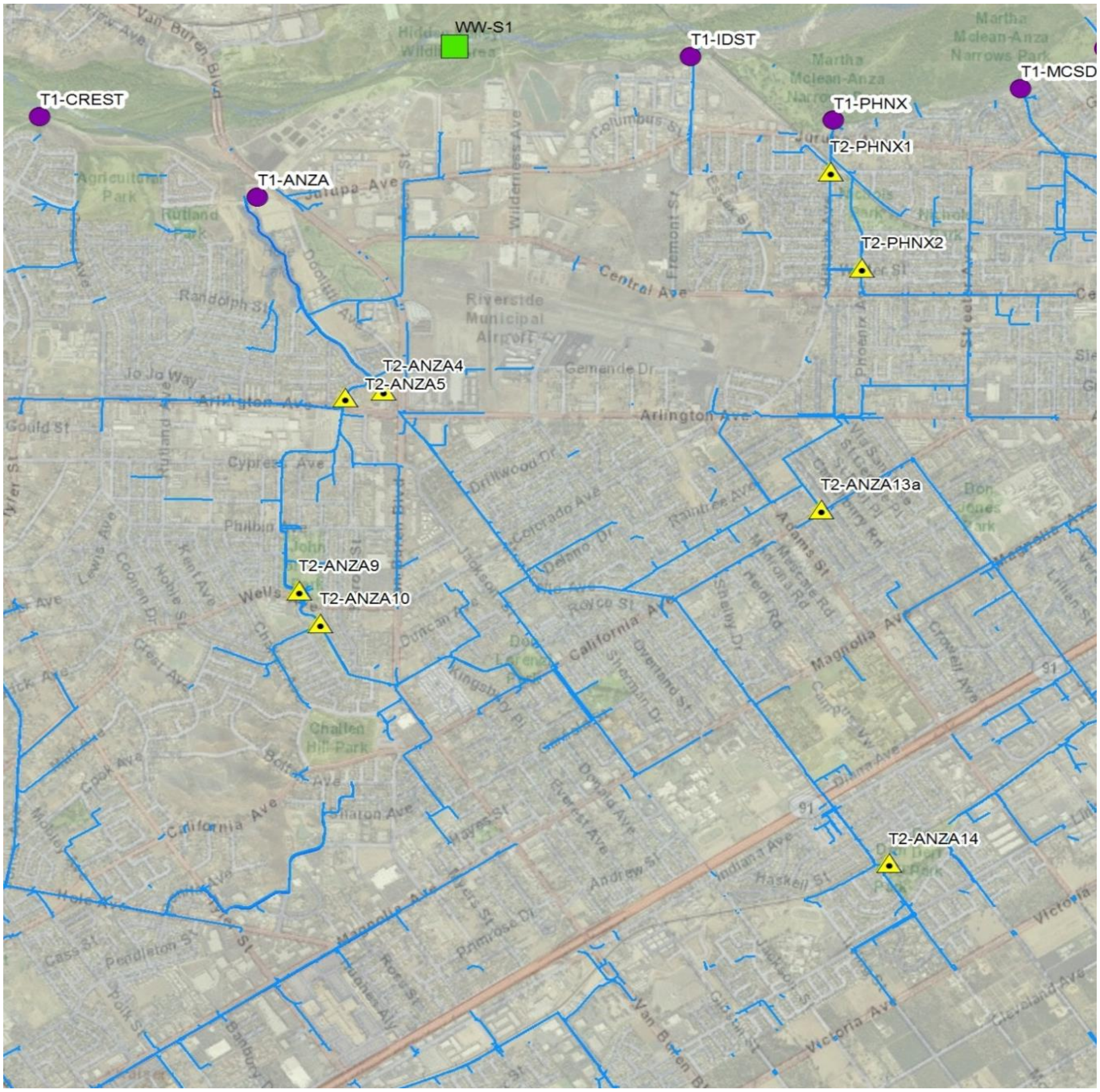


Figure 3-7
Map of Bacteria Source Evaluation Monitoring Sites in the City of Riverside

During the source assessment efforts in the drainage area to Anza channel, an area of interest as a source of dry weather flow was the Arlington Greenbelt Area which is situated upstream of the MS4 network from portions of the City of Riverside. This agricultural region is comprised primarily of citrus groves. Roughly half of the citrus groves employ furrow irrigation methods, which involve completely filling of furrows between rows of citrus trees with water. In order to ensure that downstream end of the furrows are completely filled, there is an unavoidable volume of excess irrigation water that becomes DWF. Irrigation excess is then discharged to street gutters or roadside ditches (Figures 3-7 and 3-8). About half of the Arlington Greenbelt Area is within the Anza Drain subwatershed to the MSAR. Specifically, DWF from this portion of the Arlington Greenbelt Area is all routed to Don Derr Park or the Jefferson Street storm drain, both of which outfall to Monroe Channel. The City of Riverside collected bacterial indicator samples at Don Derr Park at site

T2-ANZA 14 and Jefferson Street storm drain at T2-ANZA13a (Figure 3-7). Field observations noted a relatively high rate of DWF at these sites despite their position on the MS4 network. Don Derr Park is a dual use basin. during storm events it used as a flood control basin to capture large volumes of storm water and then slowly release storm water, during periods of dry weather the basin bottom is used as a sports field. The City of Riverside, working together with the Riverside County Flood Control & Water Conservation District (District), has begun preliminary designs to infiltrate the dry weather flows from the upstream citrus groves as they enter the park. The remaining portion of the Arlington Greenbelt Area drains westward to Arlington Channel and ultimately Temescal Wash (not currently on 303(d) list of impaired waters for bacterial indicators).

Figure 3-8
Photo of DWF from use of Furrow Irrigation in the City of Riverside Arlington Greenbelt Area

Individual sample results for *E. coli* concentration are reported in Table 3-2 There were no detections (n=32) of human *Bacteroides*. The geometric mean of each site is shown in Figure 3-9, with the Tier 1 sites shown in green on the left side of the chart and the Tier 2 sites shown in blue on the right side of the chart.

Table 3-2 Grab Sample Results for City of Riverside Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)			
	9/5/13	9/10/13	9/24/14	10/1/13
T1-ANZA	185	175	313	605
T2-ANZA4	288	602	3,654	1,336
T2-ANZA5	697	414	591	530
T2-ANZA9	1,354	670	907	213
T2-ANZA13a	121	97	135	
T2-ANZA14	860	399	1,354	98
T1-PHNX	5,794	3,873	1,106	2,755
T2-PHNX1	1,576	480		24,196
T2-PHNX2	7,270	480		

* No positive detection of human *Bacteroides* were found in Riverside's MS4

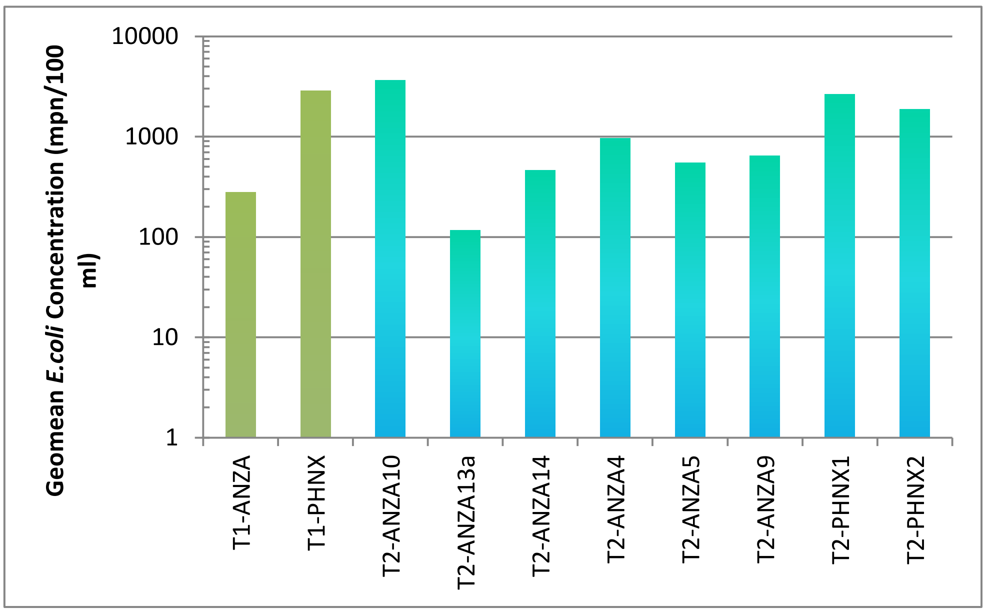


Figure 3-9
Geomean of *E. coli* Concentrations in Riverside's Tier 2 Source Evaluation

Key findings from the City of Riverside's Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- Each Tier 2 site had at least one sample with concentrations greater than 7,000 mpn/100ml; however, results were generally higher in the Phoenix Storm Drain subwatershed area than in the Anza Channel sub watershed. The amount of DWF observed at the outfall of Phoenix Storm Drain is small. As a result, In the 2014 dry season the City of Riverside and the District will work together to perform further source assessments to find and eliminate any potential controllable sources of Bacterial Indicators. Moreover, due to the small amount of flow present during dry weather the feasibility of a potential project to divert dry weather flows to the sanitary sewer is being evaluated.

- The Anza Drain subwatershed is one of the largest MS4s where source evaluation was performed in the 2013 dry season. This drainage area has two distinct subareas; upstream of the Tier 2 sites T2-ANZA4 (Monroe Channel) and T2-ANZA5 (Anza Drain past John Bryant Park). *E. coli* concentrations at T2-ANZA5 were fairly consistent, with a relatively narrow range of approximately 400-700 mpn/100ml. Conversely, *E. coli* in the Monroe Channel tributary was highly variable, ranging from approximately 300-3,700 mpn/100ml. Bacterial quality at the downstream Tier 1 site (T1-ANZA) was mostly influenced by changes in *E. coli* and flow in the Monroe Channel subarea. This finding makes sense since there are high volumes of DWF discharged into this portion of Riverside's MS4 from a combination of urban DWF, rising groundwater, and irrigation excess runoff from citrus groves in the Arlington Greenbelt Area. During the fourth and final sampling event on October 1, 2013, there was no DWF present at T2-ANZA13a. During this event, concentrations of *E. coli* at the Tier 1 site downstream doubled from approximately 300 mpn/100ml to 600 mpn/100ml, which could be caused by removing the dilution achieved during the first three events (*E. coli* concentration at T2 ANZA13a ranged from 97-135 mpn/100ml in first three events). As mentioned earlier at the other major drainage area to Monroe Channel (Monroe Basin/Don Derr park), preliminary design is underway to retrofit the basin to infiltrate dry weather flows.

3.2.3 Jurupa Valley

The entire San Sevaine subwatershed was prioritized based on the results of the 2012 Tier 1 source evaluation. This subwatershed includes jurisdictional areas in both the Cities of Jurupa Valley and Fontana. This section presents the findings from Tier 2 source evaluation conducted in the 2013 dry season by the City of Jurupa Valley and the District Staff (see Section 3.2.7 for the City of Fontana data summary and analysis). The 2013 Tier 2 source evaluation in the City of Jurupa Valley was conducted over four events; on September 5th, 10th, 24th, and October 1st. Preliminary work in the office and in the field was done to choose sample locations which would provide information to aid in locating and eliminating controllable sources of Bacterial Indicators (see description of desktop and field surveys in sections on Eastvale and Jurupa Valley above).

Sample sites included collection of bacterial water quality samples at the same Tier 1 site as was conducted in the 2012 monitoring program, T1-SSCH. Upstream of the Tier 1 site, the City of Jurupa Valley also collected DWF samples for bacterial water quality analysis at six Tier 2 sites, as shown in Figure 3-10 below. Tier 2 site names included reference to the downstream Tier 1 site (ex. Site T2-SSCH12 is within the T1-SSCH subwatershed). Samples sites included a mix of outfalls from underground collection systems (T2-SSCH10 and T2-SSCH12) and from within the open concrete lined segment of San Sevaine Channel at points upstream from the Tier 1 site (T2 SSCH1, T2-SSCH8a, T2-SSCH11). Tier 2 sites within the City of Fontana (T2-SSM-C, T2-SSM A, T2-PHSS, and T2-PHMB) are also shown in Figure 3-E and discussed in Section 3.2.7.

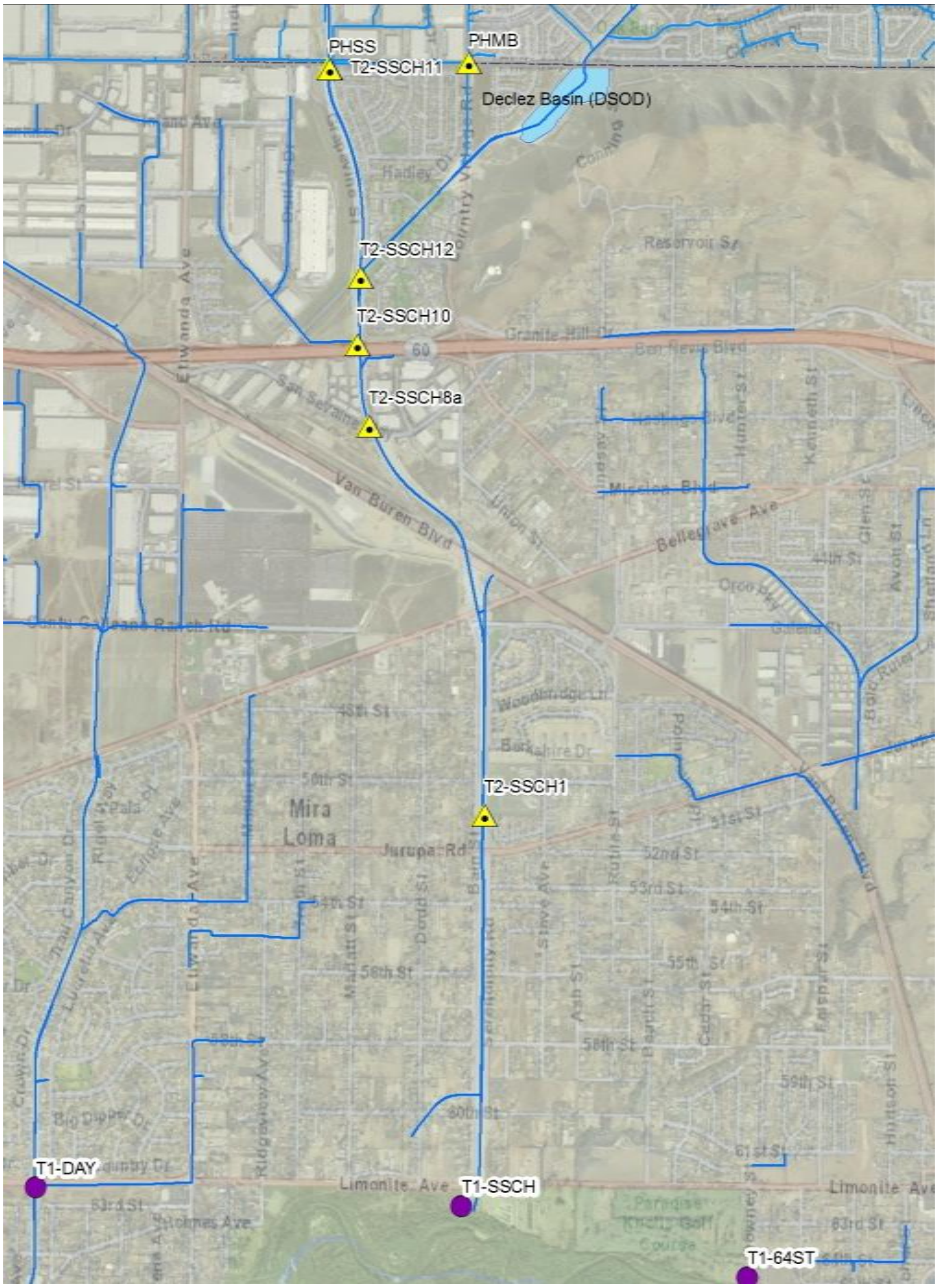


Figure 3-10
Map of Bacteria Source Evaluation Monitoring Sites in the City of Jurupa

Most of the DWF from the San Sevaine Channel subwatershed is captured and recharged in the Jurupa or Declez Basins in the southern part of the City of Fontana. The Jurupa Basin captures DWF from the upper mainstem of San Sevaine Channel, and Declez Basin captures DWF from Declez Channel. Declez Channel continues for one mile downstream of Declez Basin through the City of Jurupa Valley before the confluence with San Sevaine Channel. San Sevaine Channel then routes DWF in a large trapezoidal concrete lined channel for over three miles to the MSAR.

Individual sample results for *E. coli* concentration are reported in Table 3-3. There were no detections (n=14) of human *Bacteroides*. The geometric mean of each site is shown in Figure 3-11, with the Tier 1 site shown in green on the left side of the chart and the Tier 2 sites shown in blue on the right side of the chart.

Table 3-3 Grab Sample Results for City of Jurupa Valley Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)			
	9/5/13	9/10/13	9/24/14	10/1/13
T1-SSCH	1,515	84	384	437
T2-SSCH1	CNS	CNS	CNS	134
T2-SSCH8a	1	256	CNS	CNS
T2-SSCH10	CNS	CNS	CNS	CNS
T2-SSCH11	181	110	538	169
T2-SSCH12	3,441	10,462	2,510	1,723

* No positive detection of human *Bacteroides* were found in Jurupa Valley's MS4

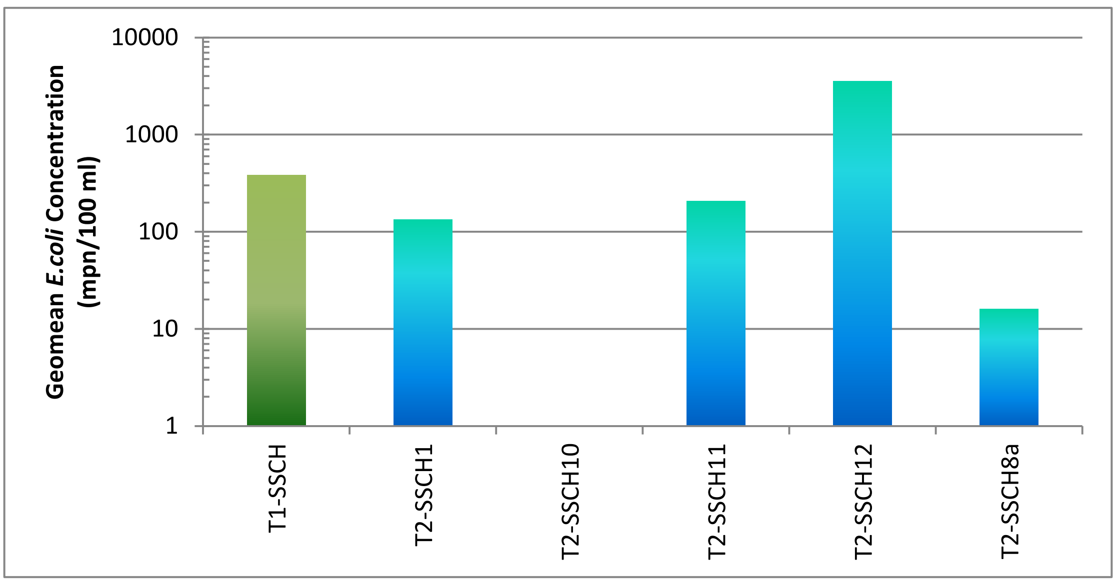


Figure 3-11
Geomean of *E. coli* Concentrations in Jurupa Valley's Tier 2 Source Evaluation

Key findings from the City of Jurupa Valley's Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- Both Fontana (T2-PHSS) and Jurupa Valley (T2-SSCH11) collected samples in San Sevaine Channel at the county boundary. Taken together the geomean of *E. coli* in San Sevaine Channel leaving San Bernardino County and entering Riverside County was 133 mpn/100ml, which is relatively close to the WLA.
- DWF at the Declez Channel outfall to San Sevaine Channel (T2-SSCH12) had consistently high bacteria concentrations over the four monitoring events, which suggests there may be a

persistent source in the subarea to this site. The drainage area within the City of Jurupa Valley to Declez Channel (site T2-SSCH12), downstream of the Declez Basin, is relatively small and is made up of 3 residential neighborhoods. The City of Jurupa Valley in partnership with the District is developing a plan to conduct supplemental Tier 2 source evaluation in this area during the 2014 dry season. Moreover the City of Jurupa Valley and the District are evaluating the possibility of repurposing an abandoned basin downstream of this area for the purposes of infiltrating dry weather flows.

3.2.4 Chino Hills

Two subwatersheds, Boys Republic South Channel (BRSC) and Carbon Canyon Creek Channel (CCCH), within the City of Chino Hills were identified as high priority for bacterial water quality and therefore the City conducted Tier 2 source evaluations in these drainage areas in the 2013 dry season. The 2013 Tier 2 source evaluation in the City of Chino Hills was conducted in ten weeks over a period of roughly three months beginning on August 2, 2013, and extending through October 25, 2013. Sample sites included collection of bacterial water quality samples at the same Tier 1 sites as was conducted in the 2012 monitoring program, T1-BRSC and T1-CCCH. Upstream of the Tier 1 site, the City of Chino Hills also collected DWF samples for bacterial water quality analysis at 14 Tier 2 sites in the BRSC subwatershed and nine Tier 2 sites in the CCCH subwatershed, as shown in Figure 3-12 below. Tier 2 site names are generally arranged alphabetically in order of downstream to upstream. (Sites T2-CH-B through T2-CH-M in the BRSC subwatershed; T2-CH-O through T2-CH-T in the CCCH subwatershed). Subscripts and superscripts to sites were employed to represent samples of DWF from different connections at the same manhole junction.

Most of the MS4 in the City of Chino Hills is underground, except for the downstream segment of CCCH. Both the CCCH and BRSC have open space areas upstream of the MS4 that are drained by natural channels. Additionally, both drainages receive some inputs from natural groundwater springs.

Individual sample results for *E. coli* concentration are reported in Table 3-4. The geometric mean of each site is shown in Figure 3-13, with the Tier 1 site shown in green on the left side of the chart and the Tier 2 sites shown in blue on the right side of the chart. Chino Hills also sent samples to OCWD (n=7) and Source Molecular Inc. (n=8) for molecular source tracking analysis. The samples sent for microbial source tracking represented distinct events, and did not allow for laboratory comparison. One of eight samples analyzed by Source Molecular detected human sourced fecal bacteria at the downstream end of the Peyton box culvert above the confluence with the Grand Avenue culvert on October 25, 2013. In addition, dogs were found to be persistent, detected in 7 of 8 samples analyzed by Source Molecular for dog markers. No human *Bacteroides* was detected in the samples analyzed by OCWD.

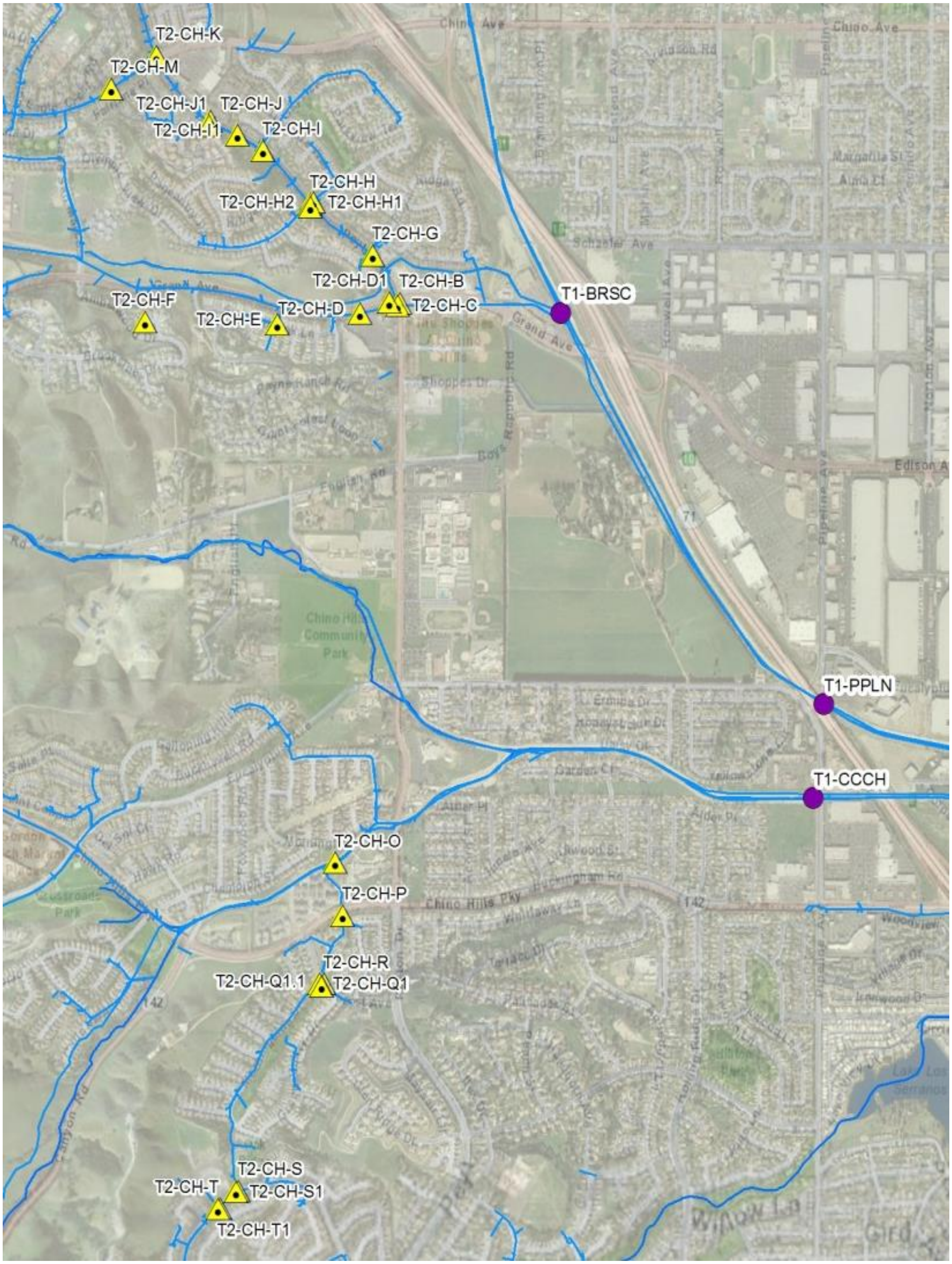


Figure 3-12
Map of Bacteria Source Evaluation Monitoring Sites in the City of Chino Hills

Table 3-4 Grab Sample Results for City of Chino Hills Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)						*Bacteroides* detections	
	8/1/13	8/8/13	8/15/13	8/22/13	9/5/13	9/26/13	10/4/13	10/25/13
T1-BRSC				1,600	5,200 [1]	2,400	Dog	
T2-CH-B	1,100	20,000	24,000					Human, Dog
T2-CH-C	270	450	6,100				Dog	Dog
T2-CH-D								
T2-CH-D1	460							
T2-CH-E				3,900				
T2-CH-F				2,300				
T2-CH-G				2,050				
T2-CH-H			7,500	300				
T2-CH-H1	160		1,200					
T2-CH-I				1,000				
T2-CH-I1			230					
T2-CH-J		10						
T2-CH-J1		380						
T2-CH-M			3,400					
T1-CCCH				10	10 [1]	86		Dog
T2-CH-O				3,100			Dog	Dog
T2-CH-P			8,200					
T2-CH-Q	500	320	16,000	1,500		2,600		
T2-CH-Q1	3,400							
T2-CH-Q1.1						41		
T2-CH-R		560	590	9,200				
T2-CH-S	500							
T2-CH-S1	24,000							

1) Ammonia detected in sample from T1-BRSC at 0.12 mg/L and at T1-CCCH at 0.86. All other samples were non-detect for ammonia

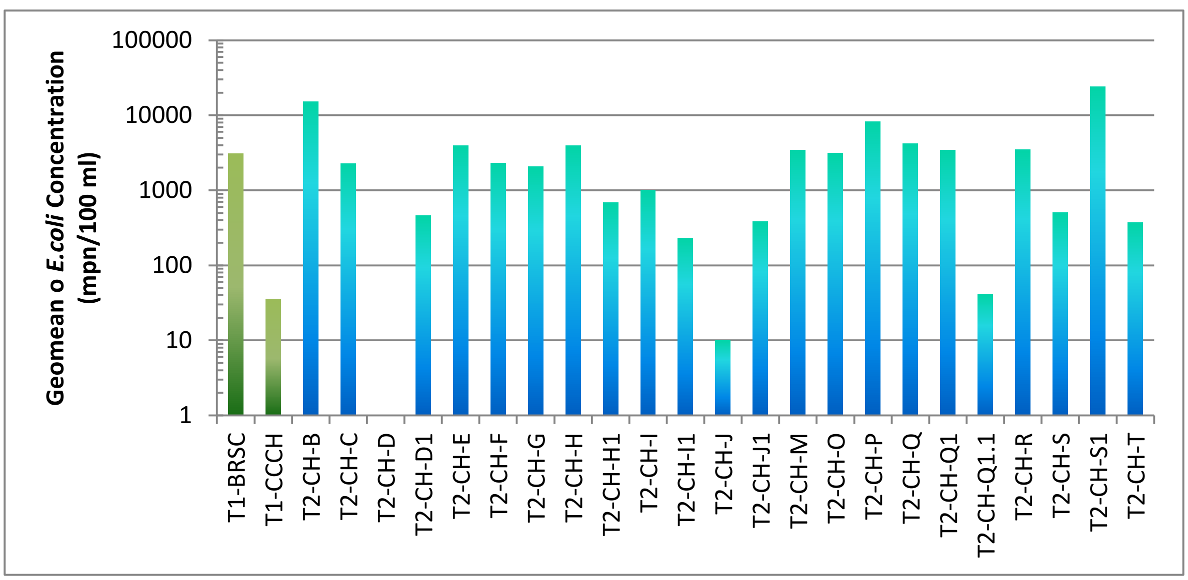


Figure 3-13
Geomean of *E. coli* Concentrations in Chino Hills

Key findings from the City of Chino Hills Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- Review of the bacterial indicator results did not suggest the presence of any single subareas that would be a greater concern to downstream bacterial 6water quality. Instead, Chino Hills identified a subwatershed-wide condition of high bacteria levels that vary significantly from week to week, which led to the interpretation discussed previously regarding property level influences in bacterial water quality of DWF in MS4s (see Section 3.1.3).

- In the Carbon Canyon Creek Channel subwatershed, samples were collected from multiple Tier 2 sites in the underground portion of the Chino Hills MS4 upstream of the open channel segment. Data was also collected at the downstream Tier 1 site. These samples corroborated data interpretations from previous years, which suggested that natural decay, treatment, and/or channel bottom recharge processes in this roughly one mile stretch of open channel provide significant bacteria removal. One unique feature of this channel is the presence of rock check dams that impound flow in shallow pools (Figure 3-14).

Figure 3-14
Photo of Unlined Segment of Carbon Canyon Creek Channel

3.2.5 Chino

The City of Chino conducted a rigorous source investigation in the Cypress Creek subwatershed in the 2013 dry season based on findings of elevated *E. coli* concentrations and multiple detections of human *Bacteroides* at the Tier 1 site in 2012. Sample sites included collection of bacterial water quality samples at the same Tier 1 site (T1-CYP) as was conducted in the 2012 monitoring program. Upstream of the Tier 1 site, the City of Chino collected samples from stations within the MS4 network, moving sites weekly to progressively track potential sources from the outfalls to laterals to street gutters and ultimately to individual property scale (Figure 3-14). Samples collected from street gutters are shown as orange triangles in Figure 3-15. Figure 3-16 shows how the types of facilities sampled changed weekly over ten consecutive weeks of the 2013 dry season.

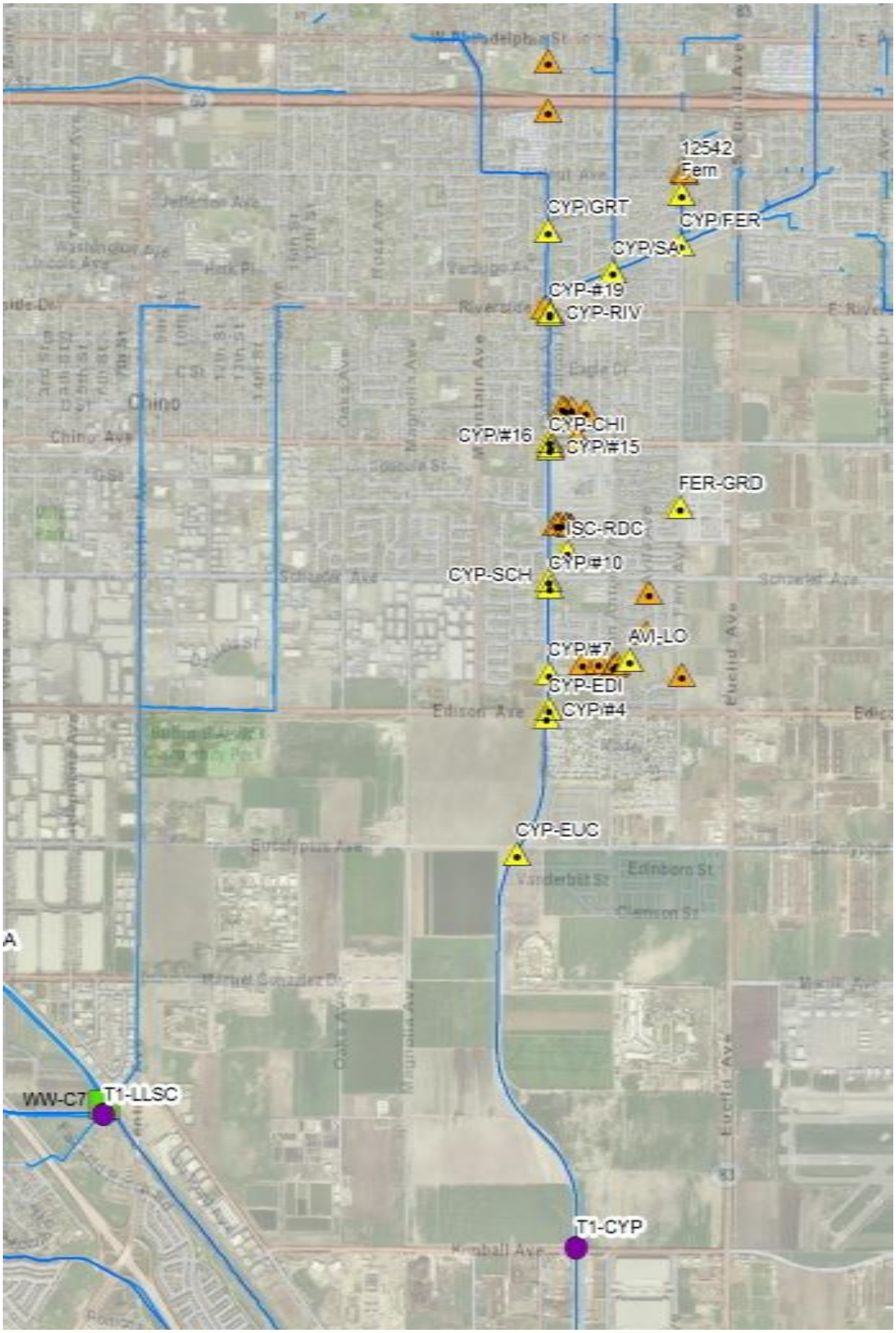


Figure 3-15
Map of Bacteria Source Evaluation Monitoring Sites in the City of Chino

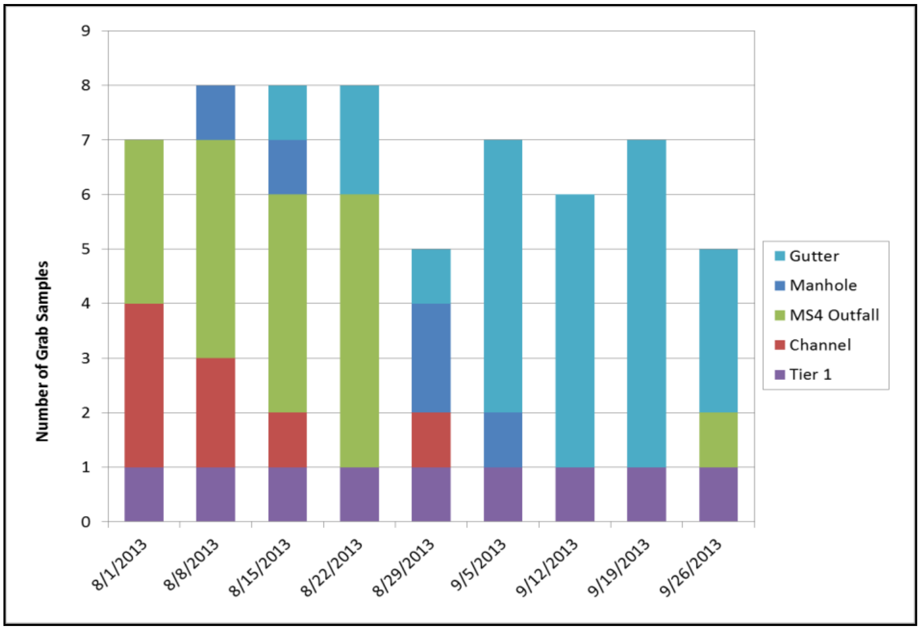


Figure 3-16
Weekly Distribution of Sampled Facility Types in the 2013 Dry Season

Individual sample results for *E. coli* concentration are reported in Table 3-5. The geometric mean of each site is shown in Figure 3-17, with the Tier 1 site shown in green on the left side of the chart and the Tier 2 sites shown in blue on the right side of the chart. Chino also sent three samples from street gutters (on Lunt Court, Potomac Drive, and Edam Street) collected on October 9, 2013 to Source Molecular Inc. for molecular source tracking analysis. There was no detection of human *Bacteroides* and one of the three samples was detected for the dog marker (Potomac Drive).

Key findings from the City of Chino Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- *E. coli* concentration at the downstream Tier 1 site met WQOs for all 10 weeks of the monitoring program in 2013, which is different from the significant exceedances observed in the 2012 dry season. Similarly, no human *Bacteroides* was detected in 2013, which is a significant water quality improvement from the 2012 dry season when 3 of 10 samples had a human *Bacteroides* detection. The improvement of bacterial water quality in Cypress Channel may be the result of stormwater program implementation and IC/ID activities. Another potential explanation of the bacterial water quality improvements is in-stream processes. As DWF passed through the open channel segment of Cypress Channel, between Eucalyptus Avenue and Kimball Avenue. Samples from Tier 2 sites, all upstream of Eucalyptus Avenue, had a geometric mean of 1500 mpn/100mL over the course of the dry season versus 18 mpn/100mL at downstream Tier 1 site. Natural decay by ultraviolet light exposure or channel bottom recharge in the unlined segment extending for ½ mile upstream from the Tier 1 site, may be the primary mechanisms providing for significant bacteria reductions. This same channel segment may not have provided the same removal effectiveness in 2012 because of maintenance activities that had removed most vegetation from Cypress Channel prior to the 2012 dry season. The channel bottom was completely re-vegetated prior to the 2013 dry season.

Table 3-5 Grab Sample Results for City of Chino Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)									
	8/1/13	8/8/13	8/15/13	8/22/13	8/29/13	9/5/13	9/12/13	9/19/13	9/26/13	10/3/13
T1-CYP	41	52	10	10	10	10	10	52	20	63
T2-AVI-LO						620				
T2-CHI	7,700									24,000
T2-CYP10			6,100	2,100						
T2-CYP15		4,100		4,400					11,000	
T2-CYP16			680							
T2-CYP19	600	880	220	20						990
T2-CYP4			2,100	3,900						
T2-CYP7				2,400						
T2-EDI	2,400									5,200
T2-EUC										6,500
T2-GIRD					1,200					
T2-ISC					5,800					
T2-RIV	2,600	203	270		1,200					150
T2-SA	620	390								
T2-SCH										6,100
T2-FERN	7,300	2,500								
T2-GRT		10								
T2-CURB Sites										
13223 ROBIN							4,900			
6513-LU									730	
6525-LU								24,000		
6531-PO									24,000	
6545-Poto										
6549-LU							24,000	24,000		
6609-PINON									540	
CHI-ROS		8,700		8,700				20,000		
Cyp-N60	120		120							
CYP-S60						350				
FER-CP						550				
FERN-CRK								230		
FER-WAL							1,300			
MAN/AVL					270					
NW-CYP/RIV		3,300		3,300						
OL-PI								4,100		
PA-AV							480			
RDC-L.E.						360				
RDC-L.W.						4,600				
RO-PO								24,000		
ROS-ORG						170				
SA-ED										
SA-ED.NE							2,800			
13223 ROBIN							4,900			
6513-LU									730	
6525-LU								24,000		
6531-PO									24,000	
6545-Poto										
6549-LU							24,000	24,000		

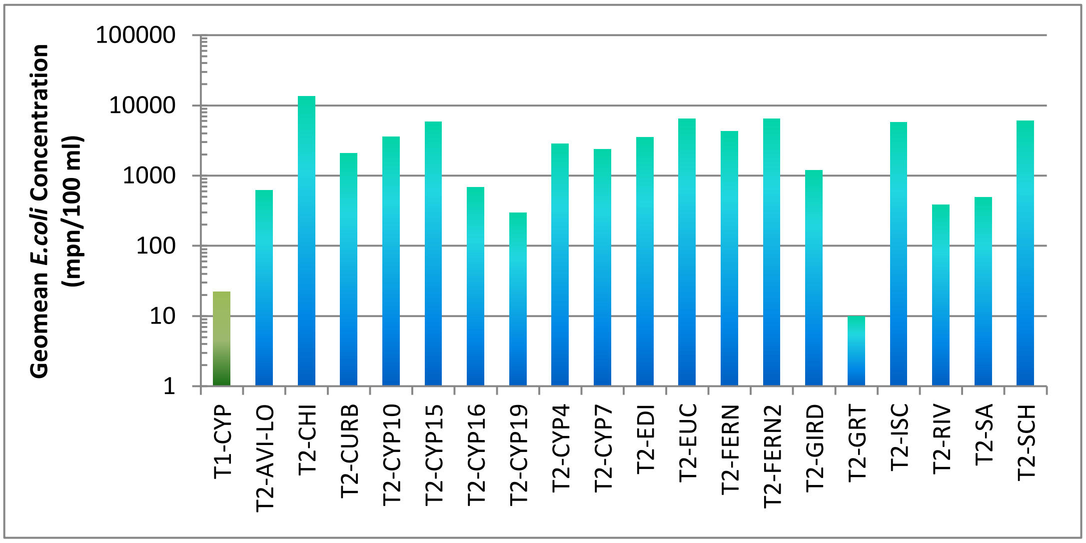


Figure 3-17
Geomean of *E. coli* Concentrations in Chino

- The approach taken by the City of Chino in the 2013 dry season, involving tracking bacteria from downstream to upstream by changing sites each week, effectively identified a specific property of concern on Lunt Court, where bacteria levels in street gutter samples showed a marked increase relative to samples from upstream. The effort expended to identify this property on Lunt Court would be difficult to implement for a larger watershed, especially if such properties are abundant. Instead, this finding has led the City of Chino, in conjunction with the City of Chino Hills, to embark upon a randomized bacterial water quality monitoring study of residential property scale irrigation excess DWFs. The objectives of the study are to determine the proportion of properties which generate high bacterial indicator concentrations, and to assess the unique features of such properties to guide watershed management approaches.

- During the 2013 dry season source evaluation in the Cypress Creek MS4 drainage area, the City also performed reconnaissance surveys of open channels within several neighborhoods, and identified multiple instances of illegal dumping that may have caused or contributed to high bacterial indicator concentrations in the MS4. The City performed outreach for each property where illegal dumping was identified and follow up surveillance has confirmed that the problems have been resolved

3.2.6 Ontario

The City of Ontario performed Tier 2 source evaluations in drainage areas upstream of three prioritized Tier 1 subwatersheds; T1-CAPT, T1-CYP, and T1-CHRIS. The City of Ontario collected 62 *E. coli* samples during the 2013 dry season from these drainage areas with 3, 6, and 30 sites within each subwatershed, in the order listed above (Figure 3-18). Sampling was also conducted at the same Tier 1 sites as was conducted in the 2012 monitoring program. Samples sites included a mix of underground collection systems (manholes) and open concrete lined channels. The 2013 Tier 2 source evaluation in the City of Ontario was conducted in 11 events over a 14 week period from July 30, 2013 to November 6, 2013.

The T1-CAPT subwatershed is a small MS4 system (less than 1,000 acre drainage area) west of Cucamonga Creek and just north of Ontario Airport. The MS4 is entirely underground in this area of the City of Ontario. The outfall to Cucamonga Creek is equipped with a large flap gate that is open enough to allow for a trickle of DWF to be discharged, but also creates a condition of trash accumulation within the pipe prior to the outfall. Tier 2 sites in the City of Ontario within the Cypress Creek subwatershed are from entirely underground MS4 systems that are conveyed into the City of Chino MS4. The Lower Deer Creek subwatershed (toT1-CHRIS) has the largest drainage area of all the prioritized Tier 1 sites in the MSAR watershed. The MS4 network in predominantly underground, except for the downstream segment of Lower Deer Creek from Hwy 60 to Chris Basin.

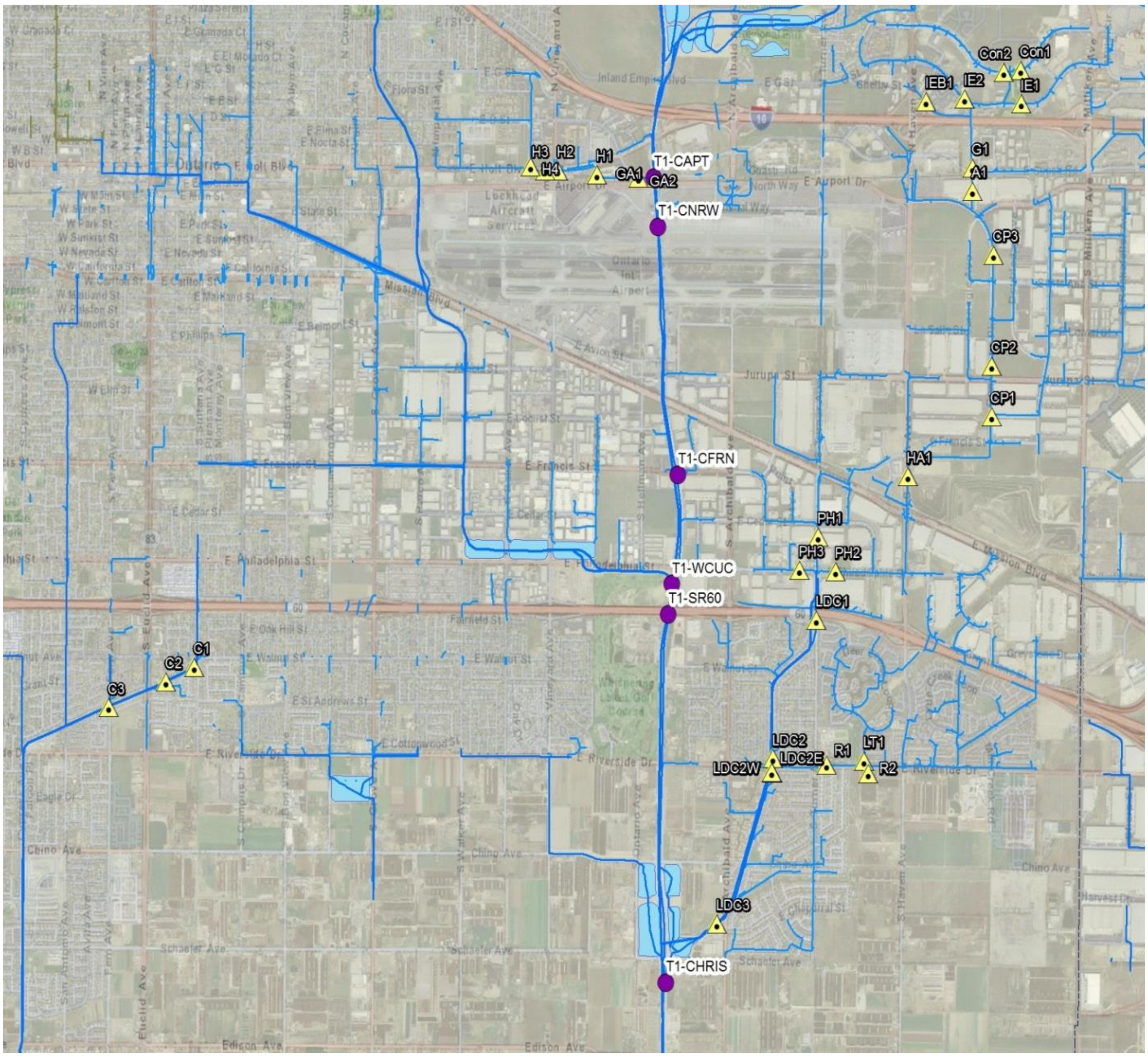


Figure 3-18
Map of Bacteria Source Evaluation Monitoring Sites in the City of Ontario

Individual sample results for *E. coli* concentration are reported in Table 3-6. The geometric mean of each site is shown in Figure 3-19, with the Tier 1 site shown in green on the left side of the chart and the Tier 2 sites shown in blue on the right side of the chart. Ontario did not collect samples for molecular source tracking analysis in the 2013 dry season.

Table 3-6 Grab Sample Results for City of Ontario Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)										
	7/30/2013	8/8/2013	8/15/2013	8/30/2013	9/12/2013	9/19/2013	9/24/2013	9/25/2013	10/9/2013	10/17/2013	11/6/2013
T1-CAPT	24,001										
T1-CHRIS		410		4,100							
T2-A1							510			24,001	
T2-C1	640		690	430	1,100						
T2-C2	160	360									
T2-C3			2,700	560	9						
T2-CP1						990		220			
T2-CP2								210			
T2-CP3								270	10,000		
T2-G1									16,000		41
T2-GA2		24,001	3,900								
T2-H1		4,400	4,100	9,200	6,500						
T2-H2					7,700						
T2-H3						17,000					
T2-H4						24,001					
T2-HA1						2,500					
T2-IE1									670		
T2-IEB1										24,001	9
T2-LDC1	340		240	1,300	580						
T2-LDC2	9	9	9	330							
T2-LDC2E					2,600			1,300	2,600		
T2-LDC2W					9			130			
T2-LDC3	31	130	9	24,001							
T2-LT1										24,001	
T2-PH1				370							
T2-PH2		170		920		2,600					
T2-PH3		8,700		220							
T2-R1									3,100		
T2-R2										680	

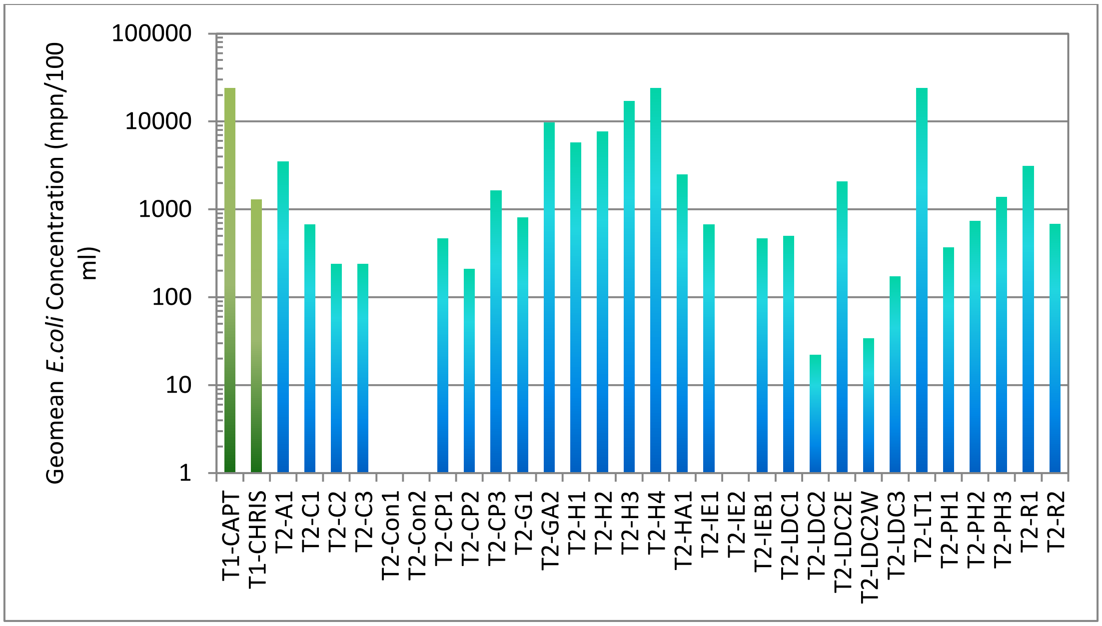


Figure 3-19
Geomean of *E. coli* Concentrations in Ontario

Key findings from the City of Ontario Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- The Lower Deer Creek subwatershed (to T1-CHRIS) has the largest drainage area of all the prioritized Tier 1 sites. Samples collected from this subwatershed were extremely variable. City staff observed very high DWF rates at T2-IEB1 that goes through the parking lot of the Ontario Airport Hotel. *E. coli* samples collected at this site as well as in other downstream Tier 2 sites exceeded 10,000 mpn/100ml in samples collected on October 9 and 17 of 2013; however, concentrations were less than 50 on this same portion of the MS4 on November 6, 2013. Human *Bacteroides* was not detected in three samples analyzed by OCWD from the Lower Deer Creek subwatershed on October 9, 2013.

- Another area of concern in the Lower Deer Creek subwatershed was just downstream of the Creekside neighborhood, where *E. coli* concentrations were consistently over 1,000 mpn/100ml. The City identified a MS4 facility in this area that has not been cleaned in many years and has accumulated a substantial amount of debris. The City is currently developing a plan to clean this potential source of bacteria from its MS4.

- The T1-CAPT MS4 drainage area in particular had the highest geomean of *E. coli* concentration of all drainage areas monitored in the 2013 dry season. All 10 samples from this drainage area, collected from six different sites over six weeks, exceeded 3900 mpn/100ml

3.2.7 Fontana

The City of Fontana performed Tier 2 source evaluations in a small portion of the southwest corner of its MS4 network that is not captured and recharged in either the Jurupa or Declez basins (approximate drainage area of 1,500 acres). This drainage area is entirely within the San Sevaine Channel subwatershed (Figure 3-20). Samples were collected at the Tier 1 sites by the City of Jurupa Valley (see Section 3.2.3). The 2013 Tier 2 source evaluation in the City of Fontana was conducted at four sites over nine weeks. Two of the sites were taken from outfalls on the west and east side of San Sevaine Channel from laterals on Marlay Avenue; T2-SSM-A and T2-SSM-C, respectively, one was taken from a manhole along Philadelphia Avenue on the east side of San Sevaine Channel; T2-PHMB, and one was taken from within San Sevaine Channel at the county boundary (T2-PHSS).

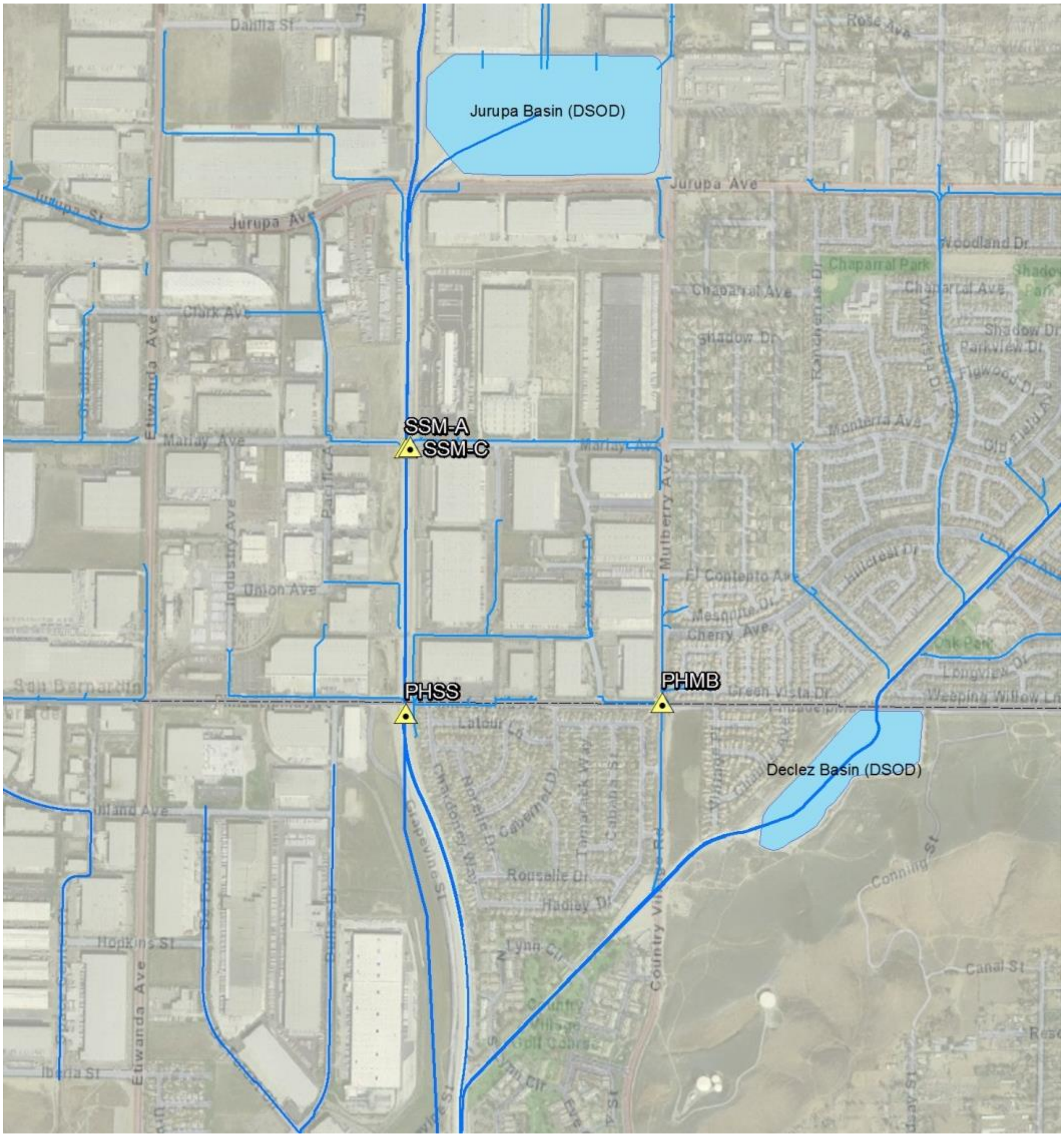


Figure 3-20
Map of Bacteria Source Evaluation Monitoring Sites in the City of Fontana

Individual sample results for *E. coli* concentration are reported in Table 3-7. The geometric mean of each site is shown in Figure 3-21, with the Tier 1 site shown in green on the left side of the chart (computed from data collected by the City of Jurupa Valley) and the Tier 2 sites shown in blue on the right side of the chart. Samples from the final sampling event on October 2, 2013 were sent to Source

Molecular for source tracking. No evidence of any cows, birds, dogs, horses, chickens, or other ruminant animals was found in the samples.

Table 3-7 Grab Sample Results for City of Fontana Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)								
	8/1/13	8/8/13	8/15/13	8/22/13	8/29/13	9/5/13	9/12/13	9/19/13	10/2/13
T2-PHMB	590	190	690	960	84	240	170	230	4,600
T2-PHSS	230	170	570	300	41	10	41	150	12,000
T2-SSM-A	CNS	CNS	CNS	3,300	720	63	110	120	CNS
T2-SSM-C	CNS	CNS	2,000	170	580	1,100	380	10	450

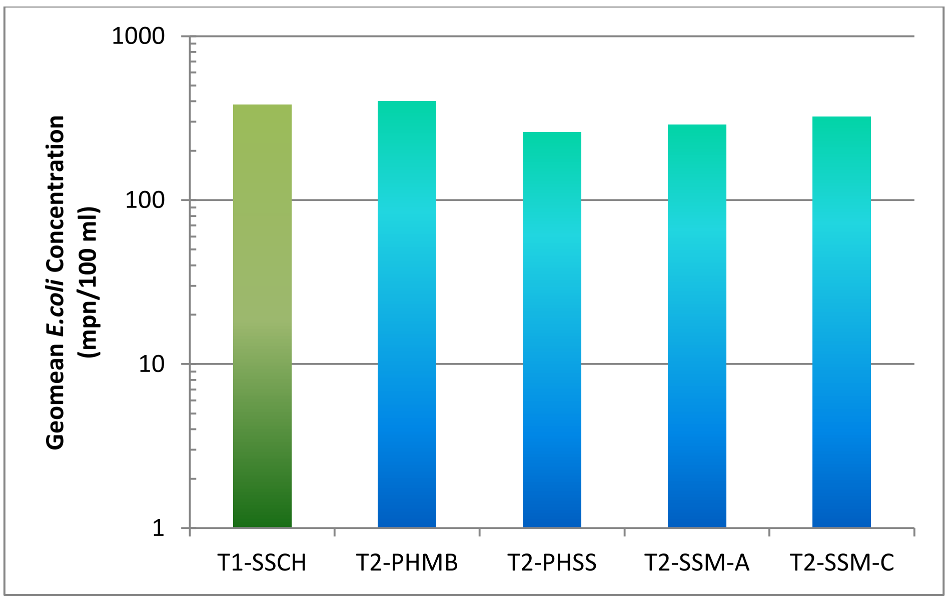


Figure 3-21
Geomean of *E. coli* Concentrations in Fontana

Key findings from the City of Fontana Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- Both Fontana (T2-PHSS) and Jurupa Valley (T2-SSCH11) collected samples in San Sevaine Channel at the county boundary. Taken together the geomean of *E. coli* in San Sevaine Channel leaving San Bernardino County and entering Riverside County was 133 mpn/100ml, which is very close to the WLA. Additionally, longitudinal sampling along San Sevaine Channel within Riverside County suggests the presence of another source of bacteria between Jurupa Valley's most downstream MS4 outfall at Bellegrave Ave and the Tier 1 site at the Santa Ana River (see Section 3.2.2 above).

3.3.8 Pomona & Claremont

The Cities of Pomona and Claremont represent the Los Angeles County jurisdictional areas within the MSAR watershed. Monitoring by these cities in 2011-2013 was conducted prior to the adoption of their respective CBRPs. The Cities implemented monitoring within Chino Creek just upstream of San Antonio Chanel (T1-CHINOCRK) in the 2011 dry season, which was categorized as a Tier 1 site in the CBRP implementation report (CDM Smith, 2013). This data was the basis for being included in the subset of prioritized MS4 drainage areas for Tier 2 source evaluation. During the 2012 dry season, Pomona continued to collect samples, but within San Antonio Channel downstream of Brooks Basin. In 2013, these cities joined forces with the rest of the Task Force to participate in a rigorous Tier 2 source evaluation.

For the City of Pomona, most of its MS4 network within the MSAR watershed fell into a high priority drainage area, which led to the strategic selection of Tier 2 sites at manholes where generally north-south stormdrains discharge into the underground box culvert segment of Chino Creek, which runs west to east and daylights just before reaching the Tier 1 site (Figure 3-22). Instead of increasing the number of sites to reduce upstream drainage areas for source evaluation, the cities opted to increase the frequency of monitoring, and collected weekly samples for eight consecutive weeks, to then prioritize subwatersheds for supplemental source evaluation. The City of Claremont is mostly tributary to San Antonio Channel upstream of diversions that capture 100 percent of DWF for groundwater recharge in the Montclair Basins or in Brooks Basin. A small portion of the City of Claremont flows into the City of Pomona's MS4 at Mountain Ave (T2-CLARM) and is then discharged to San Antonio Channel downstream of any DWF diversions at the T2-SIGNA, which was sampled in the Tier 2 source evaluation. The remaining five sites where Tier 2 samples were collected are all tributaries to T1-CHINOCRK.

Individual sample results for *E. coli* concentration are reported in Table 3-8. Figure 3-23 shows the eight week geometric mean from the seven Tier 2 sites sampled during the 2013 dry season. Samples were not collected from T1-CHINOCRK in the 2013 dry season to compare with the Tier 2 sample results. Two detections were found of the 21 samples analyzed for human *Bacteroides*, both from the T2-GARY site, as noted in Table 3-8.

Table 3-8 Grab Sample Results for City of Pomona and Claremont Tier 2 Source Evaluation in the 2013 Dry Season

Site	*E. coli* Concentration (MPN/100mL)							
	8/14/13	8/21/13	8/28/13	9/4/13	9/11/13	9/18/13	9/25/13	10/2/13
T2-CLARM		373	379	2,064	404	209	4,611	5,794
T2-SIGNA	1,333	1,989	405	7,270	24,196	1,723	1,467	175
T2-FICUS	327	529	382	857	573	609	4,352	780
T2-TOWN	146	10	52	605	842	216	41	52
T2-GARY	717 *	295	313	908	663	717		14,136 *
T2-RIOR	243	9,208	420	565	1,017	1,076	345	830
T2-OLDP	8,164	480	2,382	408	7,701	24,196	4,352	9,208

* Indicates samples that had a positive detection of human *Bacteroides*

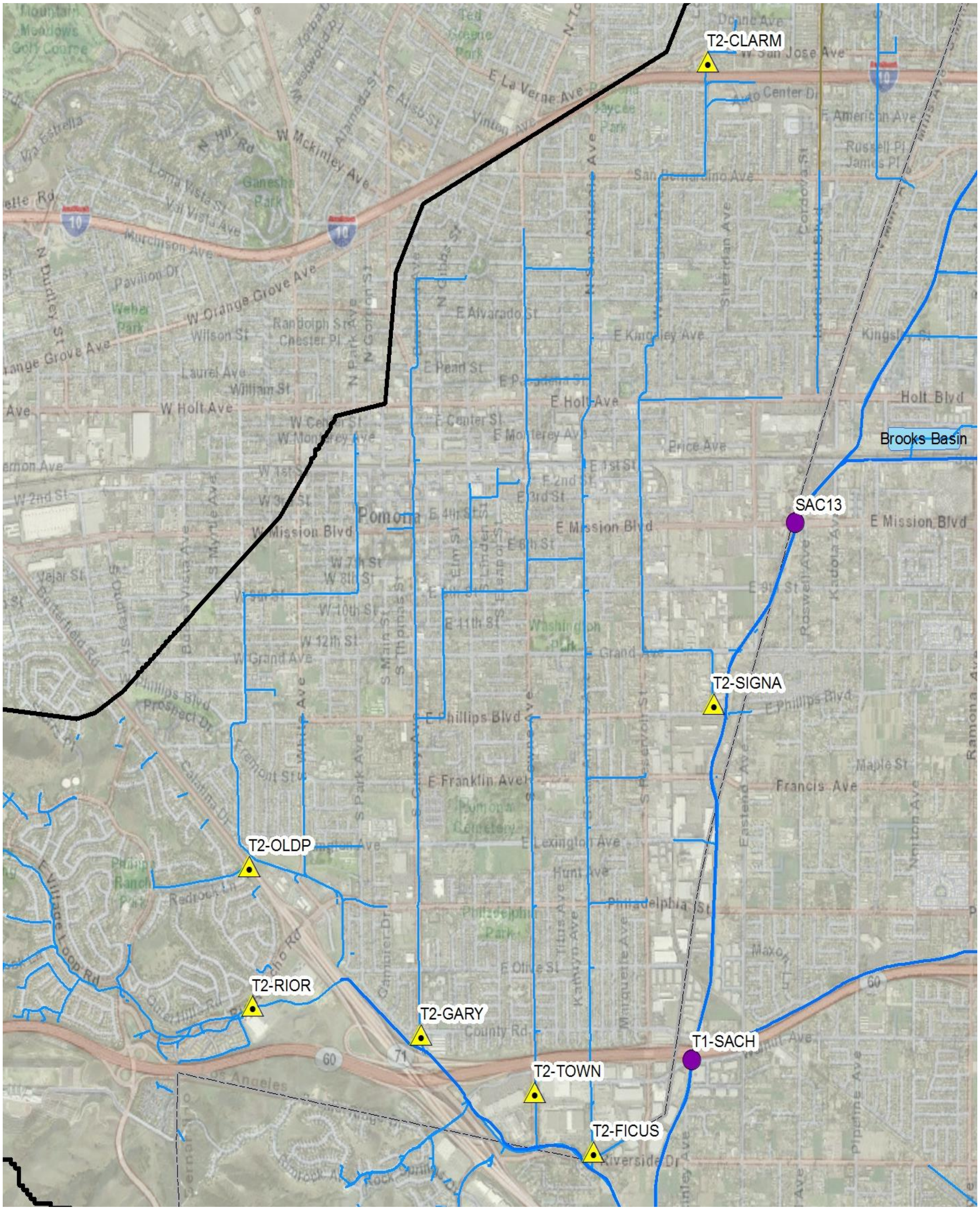


Figure 3-22
Map of Bacteria Source Evaluation Monitoring Sites in the Cities of Pomona and Claremont

Key findings from the City of Fontana Tier 2 bacteria source evaluation in the 2013 dry season are discussed below:

- The most significant finding for the City of Pomona was the detection of human *Bacteroides* in two of three samples analyzed from the T2-GARY site. The drainage area to this site is ~1,500 acres and includes the commercial center as well as City Hall. The City is in the process of developing an approach to track the specific source of human fecal bacteria in supplemental source evaluation activities.

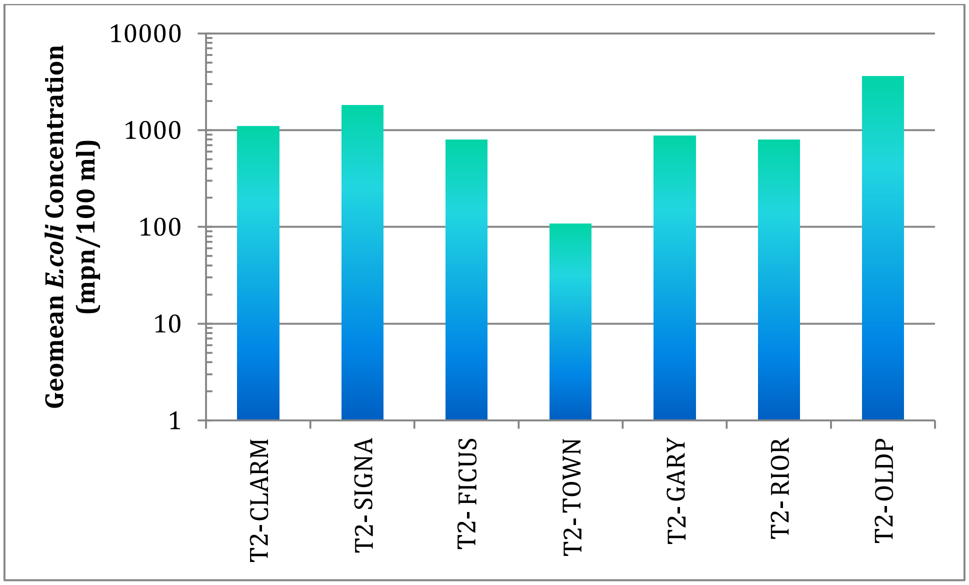


Figure 3-23
Geomean of *E. coli* Concentrations in Pomona and Claremont

- The highest DWF rates of all sites were consistently observed at the T2-RIOR site, which drains most of the Phillips Ranch development. The geometric mean of *E. coli* samples from this site was 800 mpn/100ml. The relatively higher volume of DWF and associated bacterial water quality carries a large weight in downstream *E. coli* concentrations which makes it a priority to reduce.

- While sometimes high in bacterial indicator concentration, the DWF from the City of Claremont is minimal and does not influence downstream concentrations. This observations is most apparent in asynchronous peaks of *E. coli* concentrations on September 11 (T2-SIGNA was over 24,000 mpn/100ml; T2-CLARM was 404 mpn/100ml), and conversely on December 11 (T2-CLARM was 5,794 mpn/100ml; T2-SIGNA was 175 mpn/100ml).

- The geometric mean of *E. coli* samples at the T2-TOWN site was below the wasteload allocation, therefore this drainage area is not a priority for supplemental source evaluation

This page intentionally left blank

Section 4

Management Actions

Concurrent with the Tier 1 and 2 source evaluations, the MSAR Permittees have also evaluated and in some cases implemented strategic bacteria source management options targeting DWF from the prioritized subwatersheds. Actions range from enforcement of City ordinances to construction of new structural BMPs. The following sections describe management actions taken within several of the high priority MS4 drainages by individual Permittees or multi-agency groups that may directly or indirectly improve bacterial water quality for the receiving waterbodies.

4.1 Eastvale Line E

The City of Eastvale Line E was prioritized for source evaluation as a result of high *E. coli* and human *Bacteroides* during Tier 1 source assessments. To locate the potential source the City of Eastvale worked with the District to undertake a rigorous field reconnaissance and drainage area monitoring program. These investigations identified a potential source of human fecal bacteria in the MS4 system. The evidence available suggested that migrant day laborers were congregating near a drop inlet tributary to the Eastvale line E. This drop inlet was located below grade and provided a semi private area which could have potentially been used as a makeshift restroom facility. Eastvale Code Enforcement focused their efforts in this area to eliminate this potential source of human fecal bacteria. Water quality has since improved, as evidenced by a substantial reduction in the frequency of human *Bacteroides* detection between the 2012 and 2013 dry seasons. The City is also planning to conduct additional source evaluation monitoring in the 2014 dry season at Tier 2 sites to track and take action to eliminate any remaining sources of human fecal bacteria. As mentioned earlier the District is working with the city to evaluate potential BMPs to deploy at this outfall if additional reduction is necessary. So far Fiber rolls infused with bacteria reducing agents have been deployed in the form of check dams. Monitoring upstream and downstream of these installations will be conducted to evaluate their effectiveness.

4.2 Anza Storm Drain

RCFC&WCD and WMWD are working collaboratively to facilitate the construction of three stormwater recharge facilities in the Arlington area and expansion of the Arlington Desalter Project. Two of the stormwater recharge facilities will be integrated into Southwest Riverside MDP Line G. The third facility will be adjacent to Arlington Channel near Van Buren and Indiana Avenue. The project is estimated to develop 1,848 acre-feet per year of new water supply. A portion of the DWF at the Anza Drain outfall to the MSAR is from groundwater. This project is expected to shift the slope of the groundwater table away from the river and reduce DWF rates and associated bacterial indicator loads.

Another key source of DWF in the Anza Drain watershed in irrigation runoff from the use of furrow irrigation in the citrus groves on the south side of the City of Riverside referred to as the Arlington Greenbelt Area. Western Riverside County Agricultural Coalition (WRCAC) is developing an agricultural bacteria source management plan (BASMP), which will address these flows. The MSAR MS4 Permittees will work with WRCAC to support projects that ultimately reduce the volume of DWF entering MS4 drains.

As mentioned earlier, the City of Riverside and the District are working together to evaluate preliminary designs to infiltrate the dry weather flows from the upstream citrus groves as they enter the Monroe basin (Don Derr park).

4.3 Phoenix Storm Drain

Bacterial indicator concentrations in the Phoenix Storm Drain area are persistently high, but the rate of DWF is low (<0.1 cfs on average). The District is working with the City of Riverside to evaluate the feasibility of diverting this small volume of urban DWF from the MS4 to its own Riverside Water Quality Control Plant located about one-half mile to the west of the outfall. This would effectively eliminate all DWFs from this outfall and increase the volume of disinfected effluent in the river.

4.4 San Sevaine Channel

San Sevaine Channel spans over 20 miles the mountains to the outfall to the SAR. During dry weather, most urban runoff is captured and retained upstream of Jurupa and Declez Basins. Tier 2 source evaluation monitoring by the City of Jurupa Valley and the District shows a very high concentration of bacterial indicators from the section of Declez Channel downstream of Declez basin. Urban DWF from this site is largely generated by three small Neighborhoods. The City of Jurupa Valley is working with the District to conduct detailed source assessments in this sub drainage area during the 2014 dry season. Moreover, the District and the City of Jurupa valley are evaluating the opportunity of repurposing an abandoned basin downstream of these neighborhoods to infiltrate these DWF and thus eliminate the potential to contribute controllable sources of Bacterial Indicators. .

4.5 Boys Republic South Channel

The City of Chino Hills has conducted rigorous sampling and field reconnaissance throughout the Boys Republic South Channel (BRSC) subwatershed since 2012. In the 2013 dry season, the City identified several specific sources of fecal bacteria were identified and mitigation actions were taken. One involved the use of the BRSC culvert as a nesting site for cliff swallows. Netting was installed to inhibit these birds from nesting within this MS4 facility in upcoming years. The second involved a mobile fish market business that was washing off its equipment into the MS4. The source was located by popping a series of manholes to track the source of DWF within the MS4 to its source.

In 2013, the City continued to find high concentrations of bacterial indicators, and identified a condition of extreme variability, with weekly samples ranging from non-detect to greater than 24,000 mpn/100ml. One hypothesis that may explain this extreme variability in results is that the variability is associated with differences among individual properties in the quantity and quality of irrigation excess runoff (see Section 3.1 for discussion on this concept). This hypothesis led the Cities of Chino and Chino Hills to identify two key scientific questions, which if better understood after investigation, could influence regional bacteria source management approaches, as follows:

- What is the proportion of problematic properties with elevated DWF and/or fecal bacteria concentrations that is likely contributing to downstream impairments?
- Are there any unique characteristics of problematic properties (focus group), including but not limited to the specific sources of fecal bacteria and reasons for excess water waste?

4.6 Cypress Channel

As discussed in earlier sections there was a substantial improvement to bacterial indicator water quality in Cypress Channel in the 2013 dry season, which was a result of in-stream processes in the open channel segment between Eucalyptus and Kimball Avenues. High levels in the upper part of the watershed led the City of Chino to partner with the City of Chino Hills in the development of the residential property scale bacteria water quality study.

4.7 Lower Deer Creek

The Lower Deer Creek subwatershed is one of the largest of the prioritized drainage areas in the MSAR. Results from the Tier 2 source evaluation as well as field observations indicated that a potentially significant issue is debris accumulation within MS4 facilities. The City of Ontario plans to conduct focused drain cleaning to remove accumulated debris in the 2014 dry season.

Chris Basin receives runoff from Lower Deer Creek prior to the outfall to Cucamonga Creek and could be modified to provide water quality treatment as well as flood protection. Soils in Chris Basin are not conducive to infiltration BMPs; therefore other types of treatment would be needed to reduce bacteria in outflow to Cucamonga Creek. The MSAR TMDL Task Force evaluated one alternative to retrofit the basin bottom to serve as a subsurface flow wetland. The City of Ontario and SBCFCD are collaborating on a revised basin bottom that would facilitate longer residence time in the basin and more contact with soils, which have been shown to promote bacteria reduction (Kadlec and Wallace, 2009[6]).

4.8 Cucamonga Creek

The Mill Creek wetland BMP was recently constructed at the downstream end of Cucamonga Creek. A portion of DWF is diverted from Cucamonga Creek to the wetland for treatment and is then discharged back to Mill-Cucamonga Creek at Chino Corona Road. The effectiveness of this BMP has not yet been evaluated.

[6] Kadlec, Robert H. and Scott Wallace. *Treatment Wetlands; 2nd Edition*, CRC Press, 2009.

This page intentionally left blank

Middle Santa Ana River Watershed Uncontrollable Bacterial Sources Study

Draft Report

Riverside County Flood Control

and Water Conservation District

1995 Market Street

Riverside, CA 92501

June 2016

CDM Smith

Table of Contents

List of Figures

List of Tables

Appendices

Acronyms

Basin Plan	Water Quality Control Plan for the Santa Ana River Basin
BMP	best management practice
BPA	Basin Plan Amendment
cfu	colony forming unit
DOC	dissolved organic carbon
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
FIB	fecal indicator bacteria
ft	feet
mL	milliliters
mg	milligrams
MOS	margin of safety
MPN	most probable number
MS4	Municipal Separate Storm Sewer System
MSAR	Middle Santa Ana River
MSAR Bacteria TMDL	MSAR Bacterial Indicator TMDL
MST	microbial source tracking
POTW	publicly-owned treatment works
qPCR	quantitative real-time polymerase chain reaction
RCFC&WCD	Riverside County Flood Control and Water Conservation District
REC1	water contact recreation
Regional Board	Santa Ana Regional Water Quality Control Board
RIX	Regional Tertiary Treatment Rapid Infiltration and Extraction Facility
SAR	Santa Ana River
Santa Ana Water Board	Santa Ana Regional Water Quality Control Board
SAWPA	Santa Ana Watershed Protection Authority
SSV	Single Sample Value
State Water Board	State Water Resources Control Board
SWQSTF	Stormwater Quality Standards Task Force
TMDL	Total Maximum Daily Load
TSS	total suspended solids
UBSS	Uncontrollable Bacterial Sources Study
VNS	Visited Not Sampled
WLA	wasteload allocation
WQO	water quality objective

This page intentionally left blank.

Section 1

Introduction

1.1 Background

Various waterbodies in the Middle Santa Ana River (MSAR) watershed are listed on the state 303(d) list of impaired waters due to high levels of fecal coliform bacterial indicators. Previous source evaluation efforts have focused on identifying and mitigating controllable sources in the MS4 during the dry season. These efforts suggest that uncontrollable sources are likely a large component of fecal bacteria indicator (FIB) concentrations in receiving waters of the MSAR watershed. The Recreational Use Standards Basin Plan Amendment (BPA), which has been adopted by the Santa Ana Regional Water Quality Control Board (Regional Board) and approved by the State Water Resources Control Board (State Water Board) and the Environmental Protection Agency (EPA), lists uncontrollable bacteria sources that may be present in the MSAR watershed as:

- Wildlife activity and waste
- Bacterial regrowth within sediment or biofilm
- Resuspension from disturbed sediment
- Concentration (flocks) of semi-wild waterfowl
- Shedding during swimming

To expand on source evaluation efforts to include uncontrollable sources, six site-specific technical pilot studies were conducted as part of the Uncontrollable Bacterial Sources Study (UBSS) for the MSAR watershed to evaluate to the extent possible what portion of bacterial indicators can be attributed to specific uncontrollable sources. While the UBSS was not intended to be exhaustive in nature, each of the pilot studies was designed to provide information that increases understanding regarding the different types of potential uncontrollable sources of bacterial indicators in the MSAR watershed. The uncontrollable sources studies in this UBSS target human, i.e. from swimming, and non-human sources, including wildlife and sediment and/or biofilm resuspension and regrowth. These specialized pilot studies were conducted to help understand the relative importance of various potential uncontrollable sources of bacterial indicators to exceedances of MSAR Bacterial Indicator TMDL targets in the MSAR watershed.

1.2 Regulatory Framework

Due to exceedances of the fecal coliform objective established to protect REC1 use, the Santa Ana Water Board added multiple waterbodies in the MSAR watershed to the state 303(d) List of impaired waters in 1994 and 1998. Subsequently, the Santa Ana Water Board adopted the MSAR Bacteria TMDL for freshwaters in the Santa Ana River Watershed in 2005[1], which was approved by the EPA on May

[1] Santa Ana Water Board Resolution: R8-2005-0001, August 26, 2005

16, 2007. The TMDL established compliance targets for both fecal coliform and *Escherichia coli* (*E. coli*) as follows:

- Fecal coliform: 5-sample/30-day logarithmic mean less than 180 organisms/100 mL and not more than 10 percent of the samples exceed 360 organisms/100 mL for any 30-day period.
- *E. coli*: 5-sample/30-day logarithmic mean less than 113 organisms/100 mL and not more than 10 percent of the samples exceed 212 organisms/100 mL for any 30-day period.

Per the TMDL, the above compliance targets for fecal coliform became ineffective upon EPA approval of the BPA[2]. The concentration based wasteload allocation (WLA) for MS4 Permittees for *E. coli* of 113 cfu/100mL is equal to the numeric water quality objective (WQO) (126 cfu/100mL), established for a geomean based on 5 samples within a 30-day period, minus a ten percent margin of safety (MOS). Although the 5-sample WQO is the preferred method for assessing compliance, the Basin Plan relies on the Single Sample Value (SSV) in cases where the criteria for using the 5-sample geomean target is not met.[3] The SSV of 235 MPN/100 ml, as defined in the Basin Plan, is used as a measure of water quality for the purposes of five of the six pilot studies because the frequency of sampling does not comply with the geomean criteria.

On June 15, 2012, the Regional Board adopted the BPA to Revise Recreation Standards for Inland Freshwaters in the Santa Ana Region[4]. The BPA also indicated that water quality objectives pertain to controllable sources that cause or contribute to impairment of beneficial uses. Uncontrollable sources are defined by the BPA as "contributions of bacteria within the watershed from nonpoint sources that are not readily managed through technological or natural mechanisms or through source control and that may result in exceedances of water quality objectives for indicator bacteria."[5]

Santa Ana Water Board staff developed this BPA in collaboration with the Stormwater Quality Standards Task Force (SWQSTF), comprised of representatives from various stakeholder interests, including the Santa Ana Watershed Protection Authority (SAWPA); the counties of Orange, Riverside, and San Bernardino; Orange County Coastkeeper; Inland Empire Waterkeeper; and the EPA Region 9. The BPA was approved by the State Water Board on January 21, 2014[6] and the California Office of Administrative Law on July 2, 2014.[7] The EPA issued its letter of approval/disapproval on April 8, 2015 and provided a letter of clarification on August 3, 2015.

As required by the TMDL, compliance monitoring is conducted within the receiving waterbody, where multiple sources of flow and bacteria may cause or contribute to any impairments. Several of these potential sources have been determined to be uncontrollable with the adoption of the BPA, as described above. Accordingly, where a source is identified as uncontrollable, it is not the responsibility of MS4 Permittees to reduce *E. coli* from such a source. This goal of this pilot study is to evaluate

---

[2] Attachment A to Santa Ana Water Board Resolution R8-2005-0001
[3] Santa Ana Region Basin Plan
[4] Santa Ana Water Board Resolution: R8-2012-0001
[5] Santa Ana Water Board Resolution: R8-2012-0001: Amendments to the Water Quality Control Plan for the Santa Ana River Basin, May 15, 2015
[6] State Water Board Resolution: 2014-0005, January 21, 2014
[7] Office of Administrative Law: #2014-0520 -02 S; July 2, 2014

whether uncontrollable sources of bacteria, as defined in the BPA, are significant contributors to downstream *E. coli* concentrations observed in the MSAR watershed.

1.3 Literature Review

To determine the current scientific understanding for each of the fecal bacteria sources under investigation in the pilot studies, a preliminary literature review was conducted on a selection of relevant studies. The literature review is categorized by the type of uncontrollable bacteria source as follows:

- Direct inputs from wildlife
- Resuspension from sediment and/or biofilm
- Shedding during swimming
- Equestrian recreational use

A technical memorandum was prepared in July, 2015 to summarize methods and pertinent findings in studies related to the uncontrollable sources being investigated by this Program (Appendix A). While this literature review is not meant to be comprehensive, it summarizes some conclusions observed by existing and past investigations. This section will review findings from the technical memorandum.

1.3.1 Direct inputs from wildlife

Six studies from 2004 through 2011 pertaining to the impacts of wildlife on bacterial water quality were reviewed. The study by Byappanahalli et al (2015) detected both gull markers and elevated FIB in water samples, they concluded that no relationship between the two could be established. Other studies (Edge et al, 2007; Jiang et al, 2007; Sejkora et al, 2011; Wither et al, 2005) suggest that bacteria levels are influenced by bird activity and other nonhuman sources including cows and rabbits. The study by Sejkora et al specifically compared *E. coli* concentrations upstream and downstream of a bridge where cliff swallows nest and inhabit. Their study showed a significant increase in bacteria levels at downstream sites in dry weather with greatest differences in upstream and downstream levels during the nesting period (approximately 45 days). Other factors considered to influence FIB concentrations in water samples were water temperature and shading (Tiefenthaler et al, 2008).

1.3.2 Resuspension from sediment and biofilm

Seven studies from 2000 through 2012 pertaining to FIB survival and growth in sediment, biofilms, and overlying water were reviewed. Results from all of the studies showed that FIB levels are much higher in sediment and biofilms than in overlaying water. In all water and biofilm samples in the study by Balzer et al (2007), differences in *E. coli* were at least one order of magnitude and the difference in geometric means was four orders of magnitude. Ksoll et al (2007) also showed that the predominant source of *E. coli* in periphyton samples from a shoreline was waterfowl and sources in the overlying water included waterfowl, naturalized colonies found in periphyton samples, and sewage. This result suggests that naturalized bacteria attached to periphyton communities may be released into overlying water. Studies also showed FIB levels were higher at sites downstream of bacteria-free discharges, such as publicly owned treatment works (POTW) effluent, (Skinner et al, 2010; Surbeck et al, 2010) and increased from potable to order of magnitude over recreational use WQOs as water moved downstream within street gutters (Skinner et al, 2010). Other factors considered to influence FIB concentrations in biofilm include dissolved organic carbon levels, shading, tides, drying and wetting periods, and seasons.

1.3.3 Shedding during swimming

Studies regarding bacteria contribution from shedding during swimming provide inconsistent results. While two of the five studies reviewed conclude that swimming and shedding is not a source of FIB in waterbodies (Jian et al, 2002; Zhu et al, 2011), other studies suggest that shedding during the first thirty minutes of water contact can account for over 16,000 viruses and 5.5 x 10^5 cfu/100 mL of *Enterococci* (Elmir et al, 2007; Gerba et al, 2000). Results from Elmir et al (2007) indicated that shedding continued to occur for multiple immersions by bathers and found that bacteria associated with sand contact was low relative to shedding from bathers. A literature review by Gerba et al (2000) also found that Rose et al (1991) reported bathwater from young children contained substantially higher fecal coliform concentrations compared to bathwater from adults (children: 10^5 MPN/100 ml; adults: 10^1 to 10^2 MPN/100 ml).

1.3.4 Equestrian recreational use

Similar to shedding studies, studies investigating the impact of horse recreation on water quality provide conflicting results. Tiefenthaler et al (2011) and Long et al (2004) both found highest FIB concentrations at or downstream of horse-related land use sites compare to other land uses (i.e. commercial, residential, industrial). At the horse farm site in the study by Long et al (2004), the fecal coliform concentration (1,200 cfu/100 ml) was more than five times the average fecal coliform concentration from other land uses (233 cfu/100 ml). Additionally, the microbial source tracking indicator for grazing animal manure was detected above the threshold only at the horse farm site, suggesting the source of bacteria at this site was from horse manure. However, Airaksinan et al (2007) found no difference in bacteria levels in cleaned and uncleaned horse paddocks with active horses in each paddock.

1.4 Study Framework

The purpose of the UBSS is to better understand and quantify the influence of uncontrollable sources on bacterial indicator concentrations in waterbodies in the MSAR watershed. Six specialized studies were developed to test the following hypotheses at a pilot study level:

- Natural sources study: This study evaluates the potential for natural (wildlife) sources of bacteria, including birds, rumen, and dogs, to contribute to *E. coli* concentrations in the MSAR watershed. In MSAR areas without MS4 discharges, elevated *E. coli* concentrations will be correlated to wildlife sources.
- Bird study: This study evaluates the impacts of bird nesting under bridges on FIB in the MSAR watershed. In MSAR areas with high levels of bird population and activity, *E. coli* concentrations will be higher downstream of the bird activity than upstream of bird activity.
- Stormwater channel study: Sediment and biofilm are reservoirs for bacterial indicators and watersheds with high biofilm growth and sediment presence will have higher levels of *E. coli* than overlying water.
- Non-MS4 flow study: Non-MS4 discharges can mobilize bacteria from sediments or biofilms in stormwater channels in the MSAR watershed. In waterbodies with sediment and biofilm

presence, *E. coli* loads will be higher downstream of non-MS4 discharges than upstream of discharges.

- Human recreation study: This study evaluates potential impact of human recreation on bacteria levels at a popular swimming hole in the SAR. In areas that are popular recreational sites, shedding from swimming in the waterbodies will elevate *E. coli* concentrations downstream of swimming recreation, particularly during a holiday weekend when potential for recreation will be higher.
- Horse recreation study: Equestrian uses exist within the SAR riparian area and may impact bacteria levels in SAR. This study evaluates whether feces from horses deposited along trails or directly into the river is a contributor to downstream FIB concentration. In MSAR areas that are near horse trails and equestrian activity, *E. coli* concentrations in waterbodies will be higher on a holiday weekend, when there will likely be more horse activity than a non-holiday weekend.

The remainder of this report includes the following sections:

- **Section 2 – Design of Pilot Studies** describes the sampling plan including goals, monitoring locations, sampling frequency, and laboratory analysis, for each study.
- **Section 3 – Results** presents the results for each pilot study.
- **Section 4 – Discussion and Conclusions** presents a discussion of the findings based on results from the pilot studies.
- **Section 5 – References** contains a list of references cited in the document.

This page intentionally left blank.

Section 2

Design of Pilot Studies

This section describes the sampling plan for each of the pilot studies. Monitoring activities were conducted only during dry weather conditions and included collection of water quality samples, water quality parameters measurements, and digital photographs during each sampling event. *E. coli* levels were quantified in water and sediment or biofilm samples while water quality parameters were measured using a multi-parameter water quality probe. Molecular analyses used for microbial source-tracking (MST) were utilized to identify uncontrollable source contributors to bacterial indicator levels in the watershed. MST analyses involved quantitative real-time polymerase chain reaction (qPCR) methods with genetic markers specific to different human and non-human sources. As each pilot study targets different uncontrollable sources, the bacterial hosts analyzed vary between each technical study (Table 2-1) and is further described below.

Table 2-1 Uncontrollable Sources Monitoring Locations

Study	Study Location	Sample Frequency	Analysis
Natural	SAR downstream of RIX	Seasonal (3 times/year)	*E. coli*, human, dog, bird, rumen
Bird	Cucamonga Creek at Schleisman Road Bridge	Peak bird season (5 consecutive weeks)	*E. coli*, bird
Bird	SAR at Mission Boulevard Bridge	Peak bird season (5 consecutive weeks)	*E. coli*, bird
Sediment & Biofilm	Sunnyslope Channel	Seasonal (4 times/year)	*E. coli*, human, dog, bird, rumen
Sediment & Biofilm	Eastvale Line E	Seasonal (4 times/year)	*E. coli*, human, dog, bird, rumen
Sediment & Biofilm	John Bryant Park	Seasonal (4 times/year)	*E. coli*, human, dog, bird, rumen
Non-MS4	San Sevaine Creek	Summer (3 times/year)	*E. coli*
Non-MS4	Day Creek	Summer (3 times/year)	*E. coli*
Human (Swim)	SAR at Martha Mclean Anza Narrows Park	2 weekends	*E. coli*, human, dog
Horse	SAR at 66th Street & Etiwanda Avenue	2 weekends	*E. coli*, horse
Horse	SAR at Mary Tyo Equestrian Center	2 weekends	*E. coli*, horse
Horse	SAR at Downey Street & 64th Street	2 weekends	*E. coli*, horse

Each of the specific studies is presented separately. None of the pilot studies is meant to be exhaustive; instead they are intended to identify and quantify the relative potential for a defined uncontrollable bacterial indicator source to cause an exceedance of water quality objectives in receiving waters. The following terminology is employed in this report:

- Study Location – A specific waterbody reach where the study is conducted.
- Monitoring Site – Specific location(s) within a Study Location where water and/or sediment samples are collected. Multiple monitoring sites were planned at some study locations to capture spatial variability in data results.

- Sample Event – Specific time period when a study is implemented at a Study Location. Multiple sample events were planned for each study to capture potential temporal variability in data results.

2.1 Natural Sources Study

The natural sources study investigated bacterial contributions from natural sources by measuring bacterial indicators in a natural channel where there are no MS4 discharges or other anthropogenic sources of bacteria.

2.1.1 Locations

The study location is the MSAR reach between the Regional Tertiary Treatment Rapid Infiltration and Extraction Facility (RIX) discharge location and Riverside Drive Bridge crossing (Figure 2-1). This reach of SAR is not under the influence of MS4 discharges and potential for wildlife activity is high due to the riparian habitat. Eight monitoring sites were selected across four transects within this study location as described in Table 2-2.

Figure 2-1 Natural Sources Study Location

Table 2-2 Monitoring Sites for the Natural Sources Study

Site	Description	Latitude	Longitude
Natural01A	Transition from concrete to natural channel on the east bank	34° 2'53.39"N	117°21'23.68"W
Natural01B	Transition from concrete to natural channel on the west bank	34° 2'53.33"N	117°21'23.80"W
Natural02A	500 ft downstream of RIX on the east bank	34° 2'23.70"N	117°21'16.98"W
Natural02B	500 ft downstream of RIX on the west bank	34° 2'23.81"N	117°21'17.40"W
Natural03A	4000 ft downstream of RIX on the east bank	34° 1'52.95"N	117°21'29.28"W
Natural03B	4000 ft downstream of RIX on the west bank	34° 1'52.98"N	117°21'29.46"W
Natural04A	6400 ft downstream of RIX on the east bank	34° 1'31.53"N	117°21'45.10"W
Natural04B	6400 ft downstream of RIX on the west bank	34° 1'31.60"N	117°21'45.31"W

2.1.2 Frequency and Schedule

To document seasonal variability of bacterial indicators, three sample events were conducted during different seasons throughout the year as follows:

- April 28, 2015
- June 11, 2015
- August 4, 2015

During each sample event, two water samples were collected along a transect at each monitoring site to allow characterization of sample variability (Table 2-3).

Table 2-3 Monitoring Plan for the Natural Sources Study

Number of Study Locations	1
Monitoring Sites per Location	8 (2 sites per transect)
Sample Events per Study	3
Water Samples per Monitoring Site	1
Sediment Samples per Monitoring Site	0
Sampling Period	seasonally year-round

2.1.3 Field and Laboratory Constituents

The following constituents were analyzed in water samples collected at each site on each sample date:

- Field Measurements – temperature, pH, turbidity, conductivity, dissolved oxygen
- Laboratory Water Quality Analysis – *E. coli*
- Laboratory Molecular Analysis – bacterial indicator sources (human, canine, bird, and rumen)

This list of constituents was developed to represent the key pollutants of concern relevant to identifying uncontrollable sources of bacteria.

2.2 Bird Study

As flocks of birds are present throughout MSAR waterbodies, it is important to determine the potential for birds to influence bacterial levels in the MSAR watershed. Birds are suggested to be contributors of bacterial indicators in other environments (Sejkora et al, 2011) and may also be a contributor in MSAR watershed waters at bridge structures used for nesting activity.

2.2.1 Locations

Study locations were selected based on evidence of notable bird nesting and presence so that the potential for bird impacts on water quality is high (Figure 2-2). The first study location is in Cucamonga Creek in Eastvale on Schleismann Road (Bird01), where more than forty swallow nests were observed underneath the Schleismann Road bridge crossing and multiple flocks of birds were observed along Cucamonga Creek in this area. Two monitoring sites were selected along a transect upstream and two monitoring sites were selected along a transect downstream of Schleismann Road bridge crossing to represent sites un-impacted and impacted by birds nesting under the bridge, respectively (Table 2-4).

The second location of the bird location is in the Santa Ana River (SAR) in Riverside on Mission Boulevard (Bird02). Several swallow nests were observed underneath the Mission Boulevard bridge crossing and multiple flocks of birds were observed along Santa Ana River in this area. Two monitoring sites were selected along a transect upstream and two monitoring sites were selected along a transect downstream of Mission Boulevard bridge crossing to represent sites un-impacted and impacted by birds nesting under the bridge, respectively (Table 2-4).

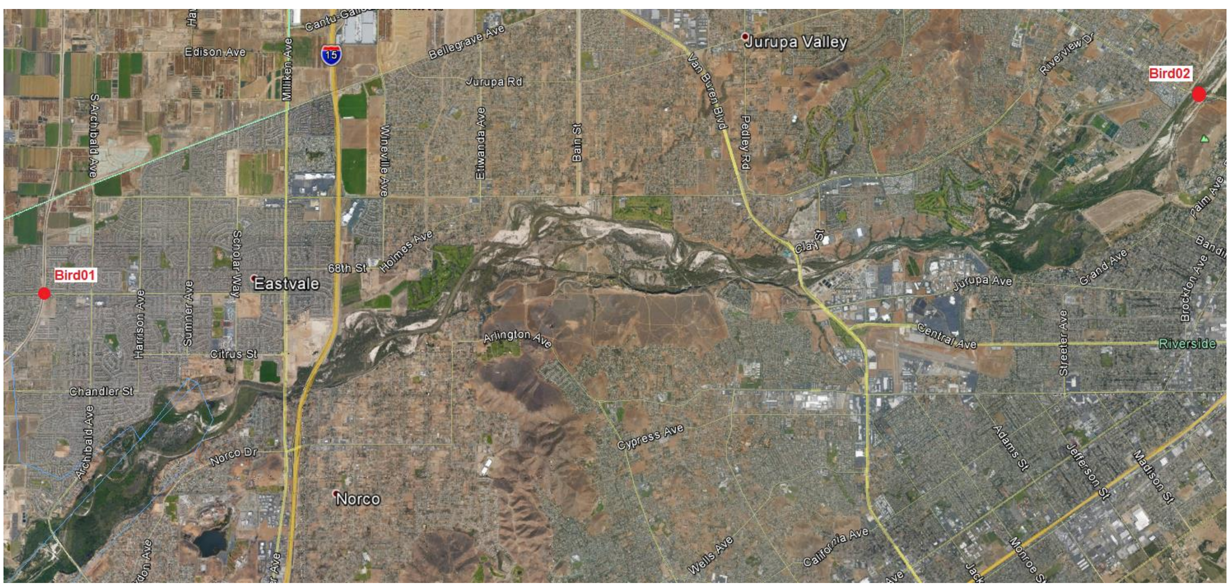


Figure 2-2 Bird Study Locations

CDM Smith

Table 2-4 Monitoring Sites for the Bird Study

Site	Description	Latitude	Longitude
Bird01A	Upstream of Schleismann Road bird activity on the east bank	33°57'41.61"N	117°36'06.47"W
Bird01B	Upstream of Schleismann Road bird activity on the west bank	33°57'41.61"N	117°36'06.62"W
Bird01C	Downstream of Schleismann Road bird activity on the east bank	33°57'37.56"N	117°36'06.78"W
Bird01D	Downstream of Schleismann Road bird activity on the west bank	33°57'37.56"N	117°36'07.88"W
Bird02A	Upstream of Mission Boulevard bird activity on the east bank	33°59'29.07"N	117°23'38.07"W
Bird02B	Upstream of Mission Boulevard bird activity on the west bank	33°59'29.08"N	117°23'38.12"W
Bird02C	Downstream of Mission Boulevard bird activity on the east bank	33°59'26.52"N	117°23'41.72"W
Bird02D	Downstream of Mission Boulevard bird activity on the west bank	33°59'26.57"N	117°23'41.83"W

2.2.2 Frequency and Schedule

Five sample events were conducted within a five week period targeting peak bird activity in late April through May. Two events occurred prior to peak activity, one event during, and two events after peak bird activity as follows:

- April 29, 2015 before peak activity
- May 7, 2015 before peak activity
- May 14, 2015 during peak activity
- May 21, 2015 after peak activity
- May 27, 2015 after peak activity

During each sample event, two water samples were collected along a transect at each monitoring site to allow characterization of sample variability (Table 2-5).

Table 2-5 Monitoring Plan for the Bird Study

Number of Sample Locations	2
Monitoring Sites per Location	4 (2 sites per transect)
Sample Events per Study	5
Water Samples per Monitoring Site	1
Sediment Samples per Monitoring Site	0
Sampling Period	Peak activity season

2.2.3 Field and Laboratory Constituents

The following constituents were analyzed in water samples collected at each site on each sample date:

- Field Measurements – temperature, pH, turbidity, conductivity, dissolved oxygen
- Laboratory Water Quality Analysis – *E. coli*
- Laboratory Molecular Analysis – bacterial indicator sources (bird)

This list of constituents was developed to represent the key pollutants of concern relevant to identifying uncontrollable sources of bacteria. In addition to water quality monitoring, biological evaluations of the study locations were conducted by a biologist to identify bird species commonly observed in the area and other relevant information. This includes nesting requirements, densities, feeding habits, life history attributes and potential habitats.

2.3 Stormwater Channel Study

The potential for sediment and biofilms to serve as a reservoir for bacterial indicators is high in any given waterbody. The goal of this study is to evaluate sediments and biofilms in selected stormwater channels to determine the extent to which bacterial indicators are associated with them in comparison to bacterial indicators found in the water column.

2.3.1 Locations

Three study locations with two monitoring sites each were planned, where two study locations are concrete-lined channels and the third is a natural-bottomed channels (Figure 2-3). Study locations are described as follows:

- John Bryant Park (Resuspension01) – Anza Drain along the west side of John Bryant Park in Riverside is a concrete-lined channel with sediment, biofilms, and vegetation mats. Low flow is regularly observed in this section of the channel.
- Eastvale Line E (Resuspension02) – Eastvale Line E is a concrete-lined channel that becomes a natural-bottom channel in the downstream section. Samples will be collected from the channel where it daylights, and will be comprised of mostly biofilm.
- Sunnyslope Channel (Resuspension03) – Sunnyslope Channel on the east side of the Louis Rubidoux Nature Center is a natural-bottom channel surrounded by vegetation. Samples will be collected in the natural section of the channel, and will be comprised mostly of sediment.

Figure 2-3 Stormwater Channel Study Locations

CDM Smith

At each study location, wet sediment deposits and/or biofilms are commonly present. Water and sediment/biofilm samples were collected at two monitoring sites along a transect at each study location (Table 2-6).

Table 2-6 Monitoring Sites for the Stormwater Channel Study

Site	Description	Latitude	Longitude
Resusp01A	John Bryant Park site on the north bank	33°56'07.19"N	117°27'36.95"W
Resusp01B	John Bryant Park site on the south bank	33°56'07.08"N	117°27'37.04"W
Resusp02A	Eastvale Line E site on the east bank	33°57'0.89"N	117°33'12.39"W
Resusp02B	Eastvale Line E site on the west bank	33°57'0.93"N	117°33'12.57"W
Resusp03A	Sunnyslope Channel site on east bank	33°58'31.26"N	117°25'34.68"W
Resusp03B	Sunnyslope Channel site on the west bank	33°58'31.34"N	117°25'34.92"W

2.3.2 Frequency and Schedule

Four sample events were conducted throughout the year to observe seasonal variability. The four events occurred as follows:

- May 13, 2015 before high summer temperatures occur
- July 9, 2015 during peak summer season
- October 13, 2015 under cooler conditions
- January 6, 2016 under winter dry conditions

During each sample event, sediment/biofilm samples were collected along a transect at each monitoring site to allow characterization of sample variability. If dry weather flow is present, water samples were collected from water overlying the sediment samples collected along the transect (Table 2-7).

Table 2-7 Monitoring Plan for the Stormwater Channel Study

Number of Study Locations	3
Monitoring Sites per Location	1
Sample Events per Study	4
Water Samples per Monitoring Site	2 (along transect)
Sediment Samples per Monitoring Site	2 (along transect)
Sampling Period	Dec/Jan, April/May, Jul/Aug, Oct/Nov

2.3.3 Field and Laboratory Constituents

The following constituents were analyzed in water samples collected at each site on each sample date:

- Field Measurements – temperature, pH, turbidity, conductivity, dissolved oxygen

- Laboratory Water Quality Analysis – *E. coli*
- Laboratory Molecular Analysis – bacterial indicator sources (human, canine, bird, rumen, and swine)
- Flow – the flow likely required to shear sediment or biofilm material and mobilize bacteria will be estimated based on channel characteristics. This will be compared with field measurements.

Sediment samples were analyzed for *E. coli* and bacterial indicator sources. This list of constituents was developed to represent the key pollutants of concern relevant to identifying uncontrollable sources of bacteria.

2.4 Non-MS4 Flow Study

To specifically address non-stormwater flows that could resuspend or shear bacteria present in sediment and biofilms, this study targeted stormwater channels that are often used to convey non-MS4 discharges.

2.4.1 Locations

Study locations were selected based on knowledge of when and what types of dry weather flows occur in the channels. These channels should primarily receive non-MS4 flows during summer months. Study locations are as follows (Figure 2-4):

- San Sevaine Channel (Scour01) – This is a concrete-lined channel bounded by the 60 freeway and Van Buren Boulevard and is located adjacent to a well blow-off facility. This treatment plant regularly releases well blow-off that results in small levels of flow in the channel.
- Day Creek (Scour02) – This is a concrete-lined channel bounded by Harrell Street and Riverside Drive. Sources of non-MS4 flows are predominantly publicly owned treatment works discharge.

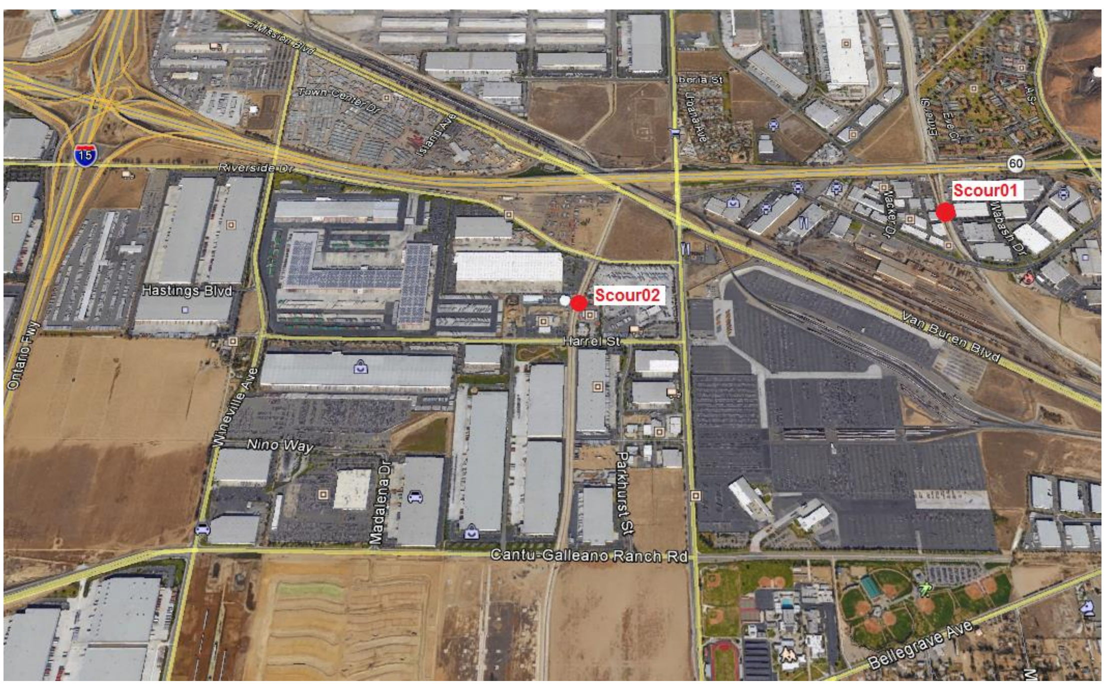


Figure 2-4 Non-MS4 Flow Study Locations

Sampling was planned at three monitoring sites located along different parts of the channel to reflect areas that are impacted by non-MS4 discharge to varying degrees (e.g., a site at or upstream of the point of non-MS4 discharge, a site immediately downstream of the non-MS4 discharge and another site further downstream of non-MS4 discharge) (Table 2-8). Only one of the planned study locations was intended to be sampled during each sample event, depending on which study location exhibited flow. Field staff performed reconnaissance at both study locations during each sample event but did not observe non-MS4 discharges at either location.

Table 2-8 Monitoring Sites for the Non-MS4 Flow Study

Site	Description	Latitude	Longitude
Scour01A	Site at point of non-MS4 discharge in San Sevaine Channel	34°01'07.95"N	117°30'49.00"W
Scour01B	300 feet downstream of non-MS4 in San Sevaine Channel	34°01'04.94"N	117°30'48.16"W
Scour01C	1900 feet downstream of non-MS4 in San Sevaine Channel	34°00'49.93"N	117°30'44.09"W
Scour02A	Site at point of non-MS4 discharge in Day Creek	34°00'47.30"N	117°31'42.83"W
Scour02B	240 feet downstream of non-MS4 discharge in Day Creek	34°00'45.01"N	117°31'43.49"W
Scour02C	575 feet downstream of non-MS4 discharge in Day Creek	34°00'41.62"N	117°31'43.80"W

2.4.2 Frequency and Schedule

Two sample events were conducted during following dry summer months:

- June 17, 2015
- July 9, 2015

Although one water sample was intended to be collected from each monitoring site at the flowing study location, none were collected during either sampling event as field staff did not observe flow. Additional coordination is ongoing with Jurupa Community Services District to collect samples during an upcoming scheduled discharge in April or May, 2016. Prior to the future sample event, field teams will be notified two days in advance of scheduled flow release times and be on site prior to anticipated non-MS4 discharge to collect one baseline water quality sample and estimate baseline flowrate at the point of discharge. After the discharge has begun, one water sample will be collected from each of the two sites downstream of the discharge to allow characterization of sample variability and discharge impacts (Table 2-9).

Table 2-9 Monitoring Plan for the Non-MS4 Flow Study

Number of Study Locations	1 (2 options provided)
Monitoring Sites per Location	3
Sample Events per Study	3
Water Samples per Monitoring Site	1
Sediment Samples per Monitoring Site	0
Sampling Period	Dry season

2.4.3 Field and Laboratory Constituents

The following constituents will be analyzed in water samples collected at each site on each sample date:

- Field Measurements – temperature, pH, turbidity, conductivity, dissolved oxygen
- Laboratory Water Quality Analysis – *E. coli*, total suspended solids (TSS)
- Flow – the flow likely required to shear sediment or biofilm material and mobilize bacteria will be estimated based on channel characteristics. This will be compared with field measurements.

This list of constituents was developed to represent the key pollutants of concern relevant to identifying uncontrollable sources of bacteria.

2.5 Human Recreation Study

Recreational activities in the Santa Ana River are a potential source of uncontrollable bacterial indicators especially in the summer months when people tend to vacation and recreate outdoors more frequently. While the TMDL is intended to protect swimmers from potentially harmful pathogens, it is possible that the act of swimming could release FIB to the receiving water. This study will evaluate humans as an uncontrollable source of bacterial indicators by comparing bacteria levels upstream and downstream of a popular swimming hole.

2.5.1 Locations

The human recreation (swim) study location is the Santa Ana River Reach 3 area adjacent to Martha Mclean-Anza Narrows Park (Figure 2-5). Its easy access and park area makes it a popular location for recreational activity. Water levels in this section are shallow, more suitable to wading and sitting in the water than swimming. However, the shallow water depth makes it a popular location for families that have younger children. It appeared to be popular for dog-walkers as both humans and canine have been observed to be wading in the river. Two monitoring sites, one upstream and one downstream of the recreational area, are selected to capture samples reflecting both un-impacted and impacted conditions, respectively (Table 2-10). Prior to collecting a sample, reconnaissance was conducted to verify that the study location adjacent to Martha Mclean-Anza Narrows Park is a popular recreational area, as expected.

Figure 2-5 Study Location for the Human Recreation Study (Martha Mclean – Anza Narrows Park)

Table 2-10 Monitoring Sites for the Human Recreation Flow Study

Site	Description	Latitude	Longitude
Swim01A	Site upstream of human recreation in SAR at Anza Narrows Park	33°58'07.14"N	117°25'57.15"W
Swim01B	Site downstream of human recreation in SAR at Anza Narrows Park	33°58'06.66"N	117°26'07.10"W

Note: These coordinates are approximate and monitoring sites at the study locations will be determined in the field to assess areas impacted and unimpacted by human recreation.

2.5.2 Frequency and Schedule

Two sample events were conducted on weekends during the summer recreational season when the amount of swimming and other recreational activities was high. One event occurred during a holiday weekend (e.g., Labor Day) where more people are likely to be contributing to bacteria levels and the second event occurred during a non-holiday weekend.

- Holiday event – July 2, 2015 through July 6, 2015
- Non-holiday event – August 13, 2015 through August 17, 2015

During both sample events, water samples were collected from each monitoring site daily from Thursday through Monday to capture sample variability and bracket peak times for recreational activity around the targeted weekend (Table 2-11).

Table 2-11 Monitoring Plan for the Human Recreation Study

Number of Study Locations	1
Monitoring Sites per Location	2
Sample Events per Study	2 (5 days per event)
Water Samples per Monitoring Site	1 (2 per day, 10 total over 5 days)
Sediment Samples per Monitoring Site	0
Sampling Period	Summer weekend (Thursday-Monday)

2.5.3 Field and Laboratory Constituents

The following constituents were analyzed in water samples collected at each site on each sample date:

- Field Measurements – temperature, pH, turbidity, conductivity, dissolved oxygen
- Laboratory Water Quality Analysis – *E. coli*
- Laboratory Molecular Analysis – bacterial indicator sources (human and dog)

This list of constituents was developed to represent the key pollutants of concern relevant to identifying uncontrollable sources of bacteria.

2.6 Horse Recreation Study

Horseback riding is a popular recreational activity in Riverside County, particularly during warmer summer months. It is possible that the presence of horses in and around the Santa Ana River can contribute bacteria to receiving waters. This study focuses on the potential for horses as a source of bacterial contamination in SAR Reach 3.

2.6.1 Locations

Three study locations with two monitoring sites along a transect at each location were selected for this study (Figure 2-6, Table 2-12). Due to the diffuse nature of horseback riding, additional field reconnaissance was necessary to determine areas in and around SAR Reach 3 that receive substantial horse activities. The study locations are as follows:

- Santa Ana River at 66th Street and Etiwanda Avenue (Horse01) – Equestrian activities occur regularly at a sandy area by SAR upstream of this site.
- Santa Ana River adjacent to Mary Tyo Trailhead Equestrian Staging Area (Horse02) – This location is adjacent to a parking lot area designed to load and unload horses for recreating along the Santa Ana River
- Santa Ana River southeast of Downey St. and 64th St. (Horse03) – Equestrian activities occur near this SAR site

Figure 2-6 Horse Recreation Study Locations

Table 2-12 Monitoring Sites for the Horse Recreation Flow Study

Site	Description	Latitude	Longitude
Horse01A	Site at the north bank of SAR at Etiwanda Avenue	33°58’02.57"N	117°31’19.78"W
Horse01B	Site at the south bank of SAR at Etiwanda Avenue	33°58’02.30"N	117°31’19.71"W
Horse02A	Site at the east bank of SAR at Mary Tyo Equestrian Area	33°58’13.22"N	117°30’51.51"W
Horse02B	Site at the west bank of SAR at Mary Tyo Equestrian Area	33°58’13.33"N	117°30’41.88"W
Horse03A	Site at the north bank of SAR at Downey St. and 64th St.	33°58'12.43"N	117°29'18.41"W
Horse03B	Site at the south bank of SAR at Downey St. and 64th St	33°58'12.00"N	117°29'18.43"W

2.6.2 Frequency and Schedule

Two sample events were conducted on Saturdays in the summer recreational season. One event was conducted during a holiday weekend, during which the potential for horse activities are greater, and the second event was conducted during a non-holiday weekend.

- Holiday event – July 4, 2015
- Non-holiday event – August 15, 2015

For each sample event, two water samples and two sediment samples were collected along a transect from each study location to develop an understanding of sample variability (Table 2-12).

Table 2-13 Monitoring Plan for the Horse Recreation Study

Number of Study Locations	3
Monitoring Sites per Location	2
Sample Events per Study	2
Water Samples per Monitoring Site	1
Sediment Samples per Monitoring Site	1
Sampling Period	Summer weekend days (Saturday)

2.6.3 Field and Laboratory Constituents

The following constituents were analyzed in water samples collected at each site on each sample date:

- Field Measurements – temperature, pH, turbidity, conductivity, dissolved oxygen
- Laboratory Water Quality Analysis – *E. coli*
- Laboratory Molecular Analysis – bacterial indicator sources (horse)

Sediment samples were analyzed for *E. coli* and bacterial indicator sources as listed above. This list of constituents was developed to represent the key pollutants of concern relevant to identifying uncontrollable sources of bacteria.

This page intentionally left blank.

Section 3

Results

This section presents summary results from biological and water quality monitoring for the six pilot studies. Water quality data, including *E. coli* concentrations, molecular analyses results, and water quality parameters in tabular form are included in Appendix C.

3.1 Natural Sources Study

In the natural sources studies, samples were collected from 4 sites not influenced by MS4 discharges to investigate the potential effects of natural sources on bacteria levels in SAR. Samples were collected three times during 2015 to observe possible seasonal effects.

3.1.1 Biological Assessment

A biological assessment was conducted on May 21, 2015 for the study reach, extending from RIX to the Riverside Avenue Bridge (Appendix B). The study reach consists of a wide sandy wash and well-vegetated riparian community. Prevalent horse tracks indicate that the reach is used for equestrian activities, which likely involves domestic dog as well. Other tracks indicated raccoon and rabbit presence and a feral dog and a number of bird species were observed. Vehicle tracks and evidence of homeless presence were also observed. This riparian and in-channel habitat likely supports reptiles, amphibians, possums, coyotes, and other small mammals.

3.1.2 Water Quality

In the natural sources study, *E. coli* concentrations were quantified in water samples collected along SAR seasonally in April, June, and August (Table 3-1, Figure 3-1). Although *E. coli* levels are relatively low overall (less than 100 MPN/100 ml in all samples), there is an increasing trend with distance from RIX in April and August samples as follows:

- Average *E. coli* concentrations in April 28th samples increase from 10 MPN/100 ml at the transition sites to 91 MPN/100 ml at the most downstream sites. *E. coli* concentrations from this sampling event may have been influenced by canyon flows from the April 26 rain event. Canyon flows from upstream mountains can lead to temporary environmental conditions (e.g., altered moisture or flow levels from typical dry weather conditions) that allows for prolonged bacteria survival or growth during dry weather.

- Average *E. coli* concentrations in August 4th west bank samples increase from 10 MPN/100 ml at the transition site to 52 MPN/100 ml at the most downstream site.

However, bacteria levels in other samples do not display the increasing trend:

- Average *E. coli* concentrations on June 11th remain less than 15 MPN/100 ml at all sites.

- August 4th east bank samples show a decrease in *E. coli* levels at the downstream sites.

The frequency of this study does not comply with the 30-day 5-sample geomean criteria. As a result, samples in this study are compared to the SSM of 235 MPN/100 ml and no sample in this section of the river exceeds the SSV in this study.

The increasing trend in *E. coli* concentrations with distance from RIX suggests there is the potential for bacteria levels to exceed WQO at further downstream locations. Using the April data as a basis, *E. coli* growth rate of approximately 13 MPN/100 ml for every 1000 feet was observed at this study location. If this growth rate were to continue for the entire 8 mile section, *E. coli* levels would be 535 MPN/100 ml at the end of the 8 miles, which exceeds the WQO for *E. coli* as well as typical ranges from downstream compliance monitoring sites. Applying a lower growth rate of 3 MPN/100 ml for every 1000 feet, as observed in the August data, the *E. coli* concentration would be 139 MPN/100 ml. This shows that natural sources may account for a majority of downstream bacteria.

Table 3-1 *E. coli* Concentrations Observed in the Natural Sources Study (MPN/100 ml)

Study Location	Monitoring Site	April 28	June 11	August 4	Frequency of Bird Detection[B]
Transition from Concrete Lined to Natural Bottom	East Bank	10	20 [A]	10 [A]	67%
	West Bank	10	10	10	0%
	Average	10	15	10	33%
500 ft Downstream of RIX	East Bank	31	10 [A]	41 [A]	67%
	West Bank	10	20	20	0%
	Average	20.5	15	30.5	33%
4000 ft Downstream of RIX	East Bank	74	10	20 [A]	33%
	West Bank	63 [A]	10 [A]	52 [A]	100%
	Average	68.5	10	36	67%
6400 ft Downstream of RIX	East Bank	96	20 [A]	10 [A]	67%
	West Bank	86	10 [A]	52 [A]	67%
	Average	91	15	31	67%

[A] DNA analysis showed presence of birds
[B] DNA analysis did not show presence of humans, canines, or rumen in any sample

Samples collected in this study were analyzed for human and wildlife (birds, canine, and rumen) as potential uncontrollable sources of bacteria. Bird DNA was detected by MST analyses in 50 percent of all samples collected in this study (Table 3-1). Results indicate that birds were detected more frequently during warmer months (June and August), as described below:

- Only one of the April 28th samples (13%) showed bird presence, at 4000 ft downstream of RIX.
- 63 percent of June 11th samples showed bird presence.
- 75 percent of August 4th samples showed bird presence.

Spatial trends indicate that bird DNA was detected more frequently from the two most downstream monitoring sites, where 67% of the samples that showed bird DNA were collected. The downstream sites are more riparian than the upstream sites where SAR transitions from a concrete-lined channel to a natural, soft-bottomed channel. Birds may prefer the more riparian habitat, particularly during

CDM Smith

warmer months with increased bird activity. However, samples in which birds were detected did not correspond to higher *E. coli* concentrations (8 out of the 12 samples with birds had bacteria concentrations of 20 MPN/100 ml or less). Humans, canines, and rumen were not detected at any site in this study, which may reflect limited activity by these potential hosts. Also, the absence of detection may reflect the challenge in capturing samples where specific hosts can be identified due to the limitations of MST methods.

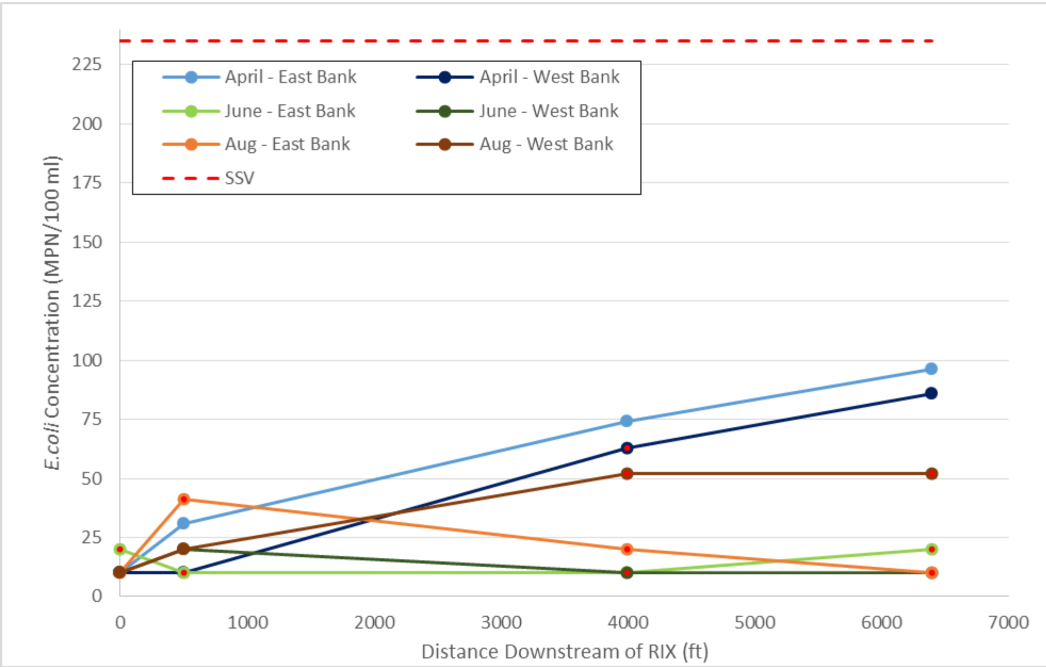


Figure 3-1 *E. coli* Concentrations Observed in the Natural Study
(Circles with red fill indicate bird detected by molecular analysis; The applicable SSV to evaluate the bacteria concentration is 235 MPN/ml. This is used where there is insufficient data to calculate a 30-day 5-sample geomean.)

Figure 3-2 Santa Ana River at transition site (Natural01)

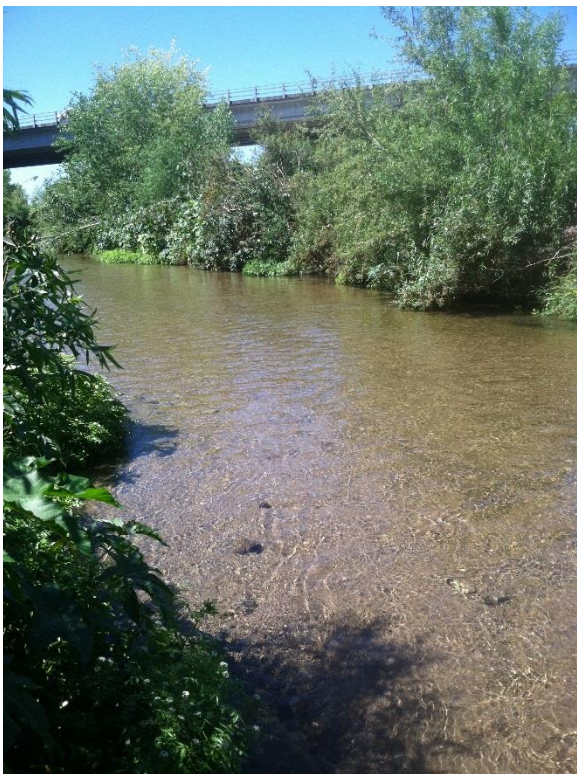


Figure 3-3 Santa Ana River 4000 ft downstream of RIX (Natural03)

Figure 3-4 Santa Ana River 6400 ft downstream of RIX (Natural04)

3.2 Bird Study

In the bird study, water quality samples were collected weekly for five weeks at two study locations where bird activity is prominent. The five weeks target periods of peak bird nesting and activity. Additionally, a biological survey was conducted on May 21, 2015 to assess bird nesting and wildlife habitat in conjunction with water quality monitoring at the Schleisman Road and Mission Boulevard Bridges. The assessment is included in its entirety in Appendix B.

3.2.1 Schleisman Road Bridge

3.2.1.1 Biological Assessment

At Schleisman Road Bridge over Cucamonga Creek, wire netting covered over half of the underside of the bridge, installed to deter bird nesting. Approximately 60 cliff swallows, 26 active nests, and a number of nestlings were observed at Schleisman Road Bridge. However, a total of 293 nests, including inactive nests, were observed. Two thirds of active nests were located over water and the remaining were located over dry parts of the channel. Adult birds visited the nests every few minutes and fecal waste was observed to be accumulating in the dry parts of the channel under the nests. Flow spanned 40 feet of the channel width. Other birds at the this study location included barn swallows, black phoebes, Brewer's blackbirds, American crows, turkey vultures, and merlins.

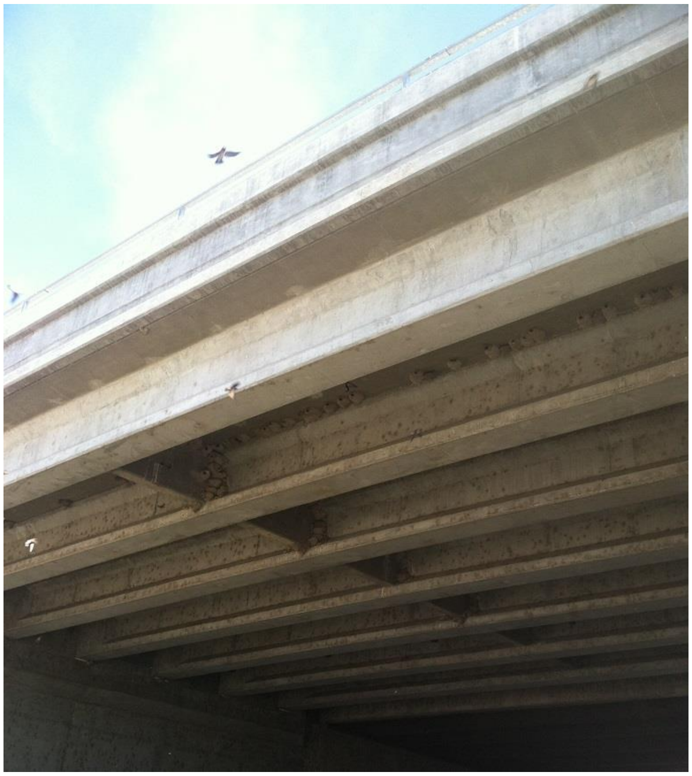


Figure 3-5 Swallow nests under Schleisman Road Bridge

3.2.1.2 Water Quality

All four monitoring sites have *E. coli* concentrations in similar ranges during each of the five weeks of monitoring (Table 3-2, Figure 3-6). However, the following observations regarding temporal and spatial variability were made based on results:

- *E. coli* levels are consistently highest on April 29 at all sites (average 3,923 MPN/100 ml) while bacteria levels during the following four weeks were substantially lower (average 758 MPN/100 ml). The elevated *E. coli* levels may have been influenced by the April 26 canyon flows, potentially resulting in more favorable environmental conditions for bacteria survival as previously described (see Section 3.1.2).

- The initial decrease (over 80%) in *E. coli* levels at all sites is followed by a generally increasing trend over the remaining four weeks. As mid-May was predicted to have peak activity during the bird season, the trend could reflect the increase in bird activity during later weeks.

- Average upstream and downstream *E. coli* levels showed differences on a weekly basis, with upstream concentrations greater than downstream concentrations two of the weeks sampled. This suggests that the upstream site may not be far enough upstream to reflect an un-impacted monitoring site and that bird activity near the bridge may extend farther upstream than anticipated.

- During the final week of monitoring, average levels at both upstream and downstream sites were similar (RPD less than 0.5 percent).

Molecular analyses detected the presence of birds in 70 percent of the samples collected. Similar to *E. coli* concentrations, detections varied temporally and spatially and are described as follows (Table 3-2):

- 9 out of 10 samples from upstream monitoring sites showed presence of bird DNA markers, which also suggests that the upstream site is not representative of un-impacted sites.
- 5 out of 10 samples from downstream monitoring sites showed presence of bird DNA markers.
- At both upstream and downstream sites, the third week of monitoring resulted in the lowest frequency (25%) of bird detection relative to other weeks.
- Although the first week of monitoring showed the highest *E. coli* concentrations, the second and fifth week had the highest frequency of bird detection (100% during both weeks).

In this study, elevated levels of *E. coli* were observed during the five week monitoring period. All twenty samples exceeded the Basin Plan single sample value of 235 MPN/100 ml (Figure 3-6). Elevated *E. coli* concentrations in conjunction with the high frequency of bird detection in the samples may reflect bird contributions to bacteria in areas where birds nest. Biofilms were also observed at this study location and could potentially increase bacteria levels in overlying water when disturbed.

Table 3-2 *E. coli* Concentrations Observed at Schleisman Avenue Bridge in the Bird Study (MPN/100 ml)

Date	Upstream Left Bank	Upstream Right Bank	Upstream Average	Downstream Left Bank	Downstream Right Bank	Downstream Average	Frequency of Bird Detection
04/29/15	4,884 [A]	4,106 [A]	4,495	3,255	3,448 [A]	3,352	75%
05/07/15	373 [A]	345 [A]	359	602 [A]	473 [A]	538	100%
05/14/15	471 [A]	836	654	464	545	505	25%
05/21/15	738 [A]	586 [A]	662	860	565	713	50%
05/27/15	1,722 [A]	906 [A]	1,314	1,624 [A]	1,017 [A]	1,321	100%
Geomean	**1,017**	**911**	**983**	**1,049**	**874**	**969**	--
Frequency of Bird Detection	**100%**	**80%**	**90%**	**40%**	**60%**	**50%**	--

[A] DNA analysis showed presence of birds

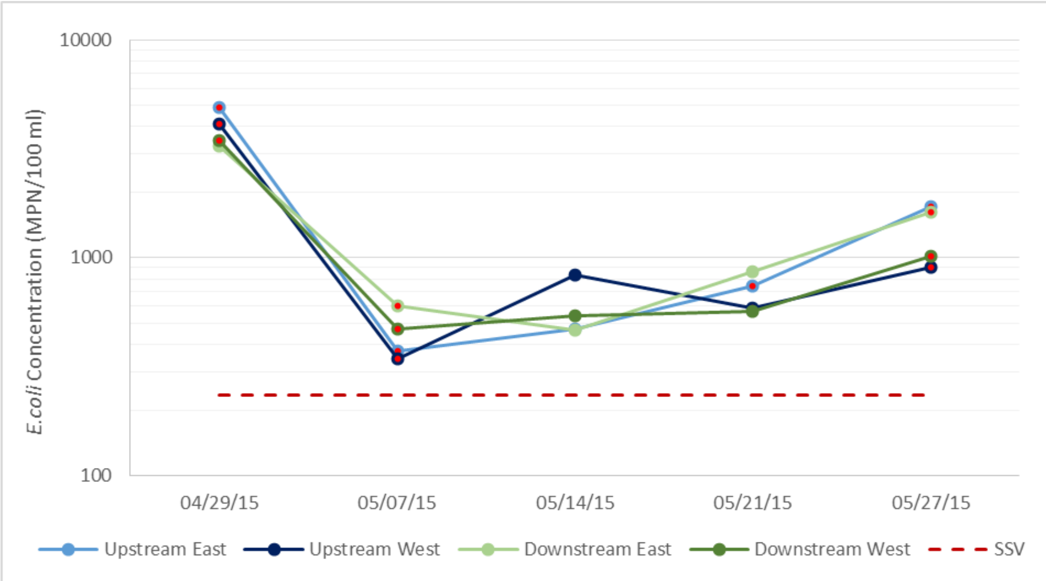


Figure 3-6 *E. coli* Concentrations Observed at Schleisman Avenue Bridge in the Bird Study
(Circles with red fill indicate bird detected by molecular analysis; The applicable SSV to evaluate the bacteria concentration is 235 MPN/ml. This is used where there is insufficient data to calculate a 30-day 5-sample geomean.)

Figure 3-7 Cucamonga Creek at Schleisman Road Bridge on April 29, 2015

3.2.2 Mission Boulevard Bridge

3.2.2.1 Biological Survey

At Mission Boulevard Bridge over Santa Ana River, water flowed approximately one foot deep across the western half of the river. Approximately 45 cliff swallows, 30 active nests, and nestlings were observed at this study location. However, a total of 128 active and inactive nests were observed under the western half of the bridge. Due to the depth of flow, the eastern half of the bridge was not surveyed due to safety concerns. Approximately two thirds of the active nests at this location were also located over the water. Rock doves (pigeons), who appeared to exhibit courtship and territorial behavior despite the lack of nests, were observed at the bridge also. Other wildlife include black phoebes, house wrens, yellow warblers, common yellowthroats, Wilson's warblers, bushtits, Anna's hummingbirds, house finches, and ground squirrels.

3.2.2.2 Water Quality

E. coli levels at Mission Boulevard Bridge are much lower than levels at Schleisman Road Bridge by more than an order of magnitude and showed no discernible temporal or spatial trends. All four monitoring sites have similar ranges of *E. coli* concentrations during the five weeks of monitoring, ranging from 20 to 130 MPN/100 ml (Table 3-3, Figure 3-8). The following observations regarding temporal and spatial variability were made based on results:

- *E. coli* concentrations varied temporally during the monitoring period with peak concentrations observed during different weeks for each monitoring site.
- Average upstream *E. coli* levels are higher than downstream levels during 4 out of 5 monitoring weeks, which may suggest that the upstream site does not represent an un-impacted site and/or that the presence of birds is ubiquitous in the area. Identifying a site without bird impacts in this region may not be possible. There may also be additional sources that contribute bacteria at these upstream sites, which could obscure impacts by birds.
- *E. coli* levels at both upstream and downstream west bank monitoring sites show an initial decrease followed by an increasing trend in later weeks. However, *E. coli* levels in east bank sites have no discernible trend. This suggests that bacteria levels vary spatially even across transects where monitoring sites are relatively close to one another.
    - The similarity in bacteria levels among the western monitoring sites may reflect the significant presence of birds (over 100 active and inactive nests) under the western half of Mission Boulevard Bridge observed by the biologist. The increasing trend in later weeks at these sites may be indicative of increased bird activity as peak bird season was estimated to occur around mid-May.

Molecular analyses detected the presence of birds in 50 percent of the samples collected. Similar to *E. coli* concentrations, molecular analyses resulted in temporal and spatial variations as follows:

- 7 out of 10 samples from upstream monitoring sites showed presence of bird DNA markers, which again suggests that the presence of birds is ubiquitous in this study location.
- 3 out of 10 samples from downstream monitoring sites showed presence of bird DNA markers.
- At both upstream and downstream sites, the fourth week of monitoring resulted in the lowest frequency (0 percent) of bird detection relative to other weeks.

Although active bird nests and birds were observed at Mission Boulevard Bridge, *E. coli* levels in all twenty samples did not exceed the Basin Plan SSV (Figure 3-8). It is unclear why bacteria levels at this study location are substantially lower than levels observed at the Schleisman Road Bridge study location, however, water is much deeper at these monitoring sites (1 foot minimum) than at Schleisman Road Bridge monitoring sites (6 inches) and the potential for spatial variability and dilution is increased. The biologist also observed that nests were more dispersed at Mission Boulevard

Bridge than at Schleisman Road Bridge, which may contribute to the lower frequency of bird detection at this study location as well as the potential for *E. coli* spatial variability.

Table 3-3 *E. coli* Concentrations Observed in the Bird Study at Mission Avenue Bridge (MPN/100 ml)

Date	Upstream Left Bank	Upstream Right Bank	Upstream Average	Downstream Left Bank	Downstream Right Bank	Downstream Average	Frequency of Brid Detection
04/29/15	97 [A]	132 [A]	115	98 [A]	85	92	75%
05/07/15	121 [A]	31 [A]	76	41	41 [A]	41	75%
05/14/15	20 [A]	109	65	122	52 [A]	87	50%
05/21/15	121	122	122	74	110	92	0%
05/27/15	85 [A]	121 [A]	103	52	98	75	50%
Geomean	**75**	**92**	**84**	**72**	**72**	**72**	--
Frequency of Bird Detection	**80%**	**60%**	**70%**	**20%**	**40%**	**30%**	--

[A] DNA analysis showed presence of birds

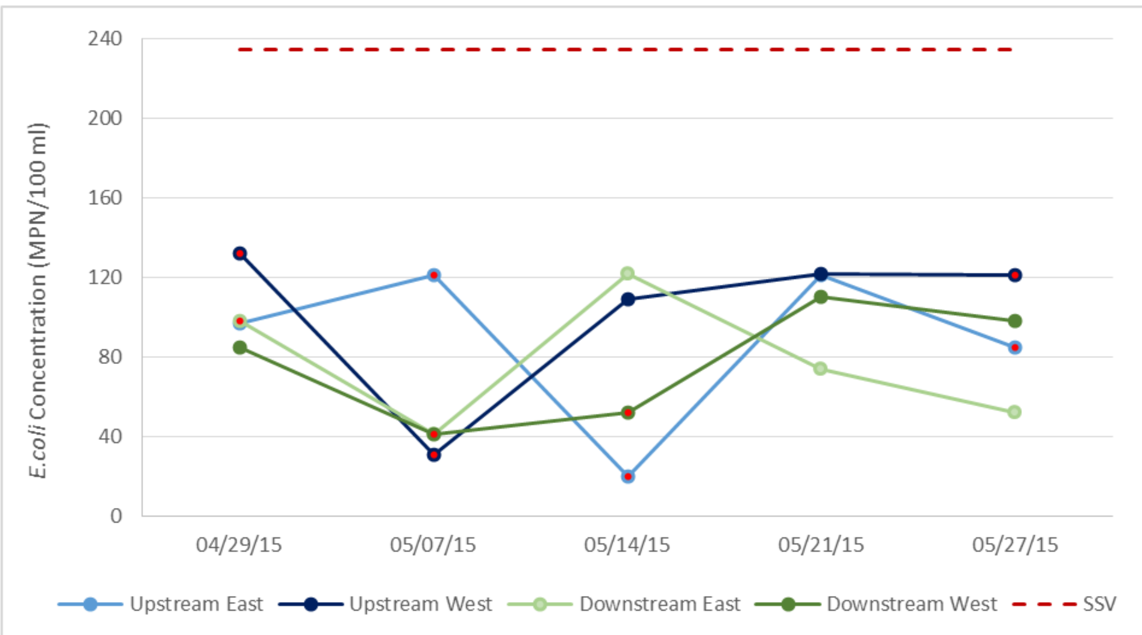


Figure 3-8 *E. coli* Concentrations Observed at Mission Avenue Bridge in the Bird Study
(Circles with red fill indicate bird detected by molecular analysis; The applicable SSV to evaluate the bacteria concentration is 235 MPN/ml. This is used where there is insufficient data to calculate a 30-day 5-sample geomean.)

Figure 3-9 Santa Ana River at Mission Boulevard Bridge on April 29, 2015

3.3 Stormwater Channel Study

In the stormwater channel study, water quality samples are collected seasonally from both the water column and sediment and biofilm to compare the extent to which *E. coli* is associated with water and sediment or periphyton. Wildlife has also been observed at both concrete-lined and soft-bottom channels and may be another potential uncontrollable sources of bacteria.

3.3.1 *E. coli* in Water Samples

E. coli concentrations in water samples (Table 3-4, Figure 3-10) have varying trends at each site:

- At John Bryant park, *E. coli* levels decreased after the first sampling event in May, where the average concentration across a transect was 370 MPN/100 ml to 9 MPN/100 ml in October. Bacteria levels increase in the final event in January with an average concentration across the transect of 260 MPN/100 ml.

- Average *E. coli* concentrations from a transect in Sunnyslope Channel are relatively stable throughout the four events with average concentrations ranging from 135 to 205 MPN/100 ml.

- At Eastvale Line E, average *E. coli* levels oscillate throughout the four events with average concentrations exceeding 2,000 MPN/100 ml during July 2015 and January, 2016, but are 240 MPN/100 ml during May and October, 2015. Concentrations were particularly high in October and January events.

3.3.2 *E. coli* in Sediment and Biofilm Samples

E. coli concentrations in sediment and biofilm samples (Table 3-4, Figure 3-11) have similar trends at John Bryant Park and Eastvale Line E, where concentrations are generally higher in the two latest events while concentrations observed at Sunnyslope Channel are higher only in October.

- At John Bryant Park, average *E. coli* levels decreased in July by more than an order of magnitude (3,200 MPN/100 g) but increased significantly in following events by approximately two orders of magnitude (210,000 MPN/100 g)
- At Sunnyslope Channel, average bacteria levels increased in October by approximately two orders of magnitude (190,000 MPN/100 g) but decreased in January by three orders of magnitude (1,950 MPN/100 g).
- At Eastvale Line E, average *E. coli* concentrations oscillate throughout the four events similar to average concentrations observed in Eastvale Line E water samples. Average concentrations decrease or increase by more than an order of magnitude during each sampling event. However, events when average concentrations in water samples decrease, average concentrations in biofilm and sediment samples increase and vice versa. This may be due to bacteria settling into sediment, moving downstream, and attaching to particles for transport (Walters et al, 2014; Curtis and Trapp, 2014) and resuspension into the water column (Jamieson et al, 2005; McDaniel et al, 2013), although other factors and mechanisms are likely occurring as well.
    - Additionally, average *E. coli* concentrations at Eastvale Line E are also generally more than an order of magnitude or more greater than average concentrations observed at the other two study locations, with particularly high levels observed in October.

E. coli concentrations in biofilm samples (average: 202,000 MPN/100 g) showed no apparent trend of being greater or lesser than concentrations in sediment samples (220,000 MPN/100 g). Observations based on the type of sample (biofilm or sediment) are as follows:

- *E. coli* concentrations at John Bryant Park reflect biofilm samples in May and January events (range: 4,800 to 210,000 MPN/100 g, average: 85,000 MPN/100 g) and sediment samples in July and October events (range: 2,400 to 190,000 MPN/100 g, average: 54,000 MPN/100 g).
- *E. coli* concentrations at Eastvale Line E reflect biofilm samples only in the May east bank sample (670,000 MPN/100 g) and sediment samples in all other samples (range: 7,800 to 2,400,000 MPN/100 g, average: 505,000 MPN/100 g).
- *E. coli* concentrations at Sunnyslope Channel range from 90 to 270,000 MPN/100 g and are generally lower than concentrations observed at the other study locations.

The single sample SSV for water samples was exceeded most frequently at Eastvale Line E (100%) and less frequently at John Bryant Park (50%) and Sunnyslope Channel (13%). Bacteria concentrations in both water and sediment and biofilm samples from Eastvale Line E are higher than concentrations at other study locations. Although it is uncertain what is causing the high presence of *E. coli* at Eastvale Line E, these results are consistent with data from prior monitoring activities, including the Tier 2 Source Evaluation where Eastvale Line E was identified as a priority MS4 drainage area[8]. Sunnyslope Channel exhibited the lowest *E. coli* concentrations in both water and sediment samples. It is possible the canopy provided by surrounding trees reduces the ambient temperature in the study location and reduces bacterial growth rates as a result, however, it is likely a number of factors are influencing bacteria levels.

[8] Triennial Middle Santa Ana River Bacterial Indicator TMDL Implementation Final Report, February 2016

In this study, *E. coli* levels are higher in biofilm and sediment samples than levels in overlying water samples by as much as four orders of magnitude, indicating that biofilm and sediment are a reservoir for *E. coli.* At all study locations, biofilms and sediment also exhibit generally low *E. coli* concentrations in the July sampling event, during which higher temperatures and UV exposure may have impacted bacteria growth. The range of *E. coli* levels observed in biofilm and sediment also appear to be similar, implying that one site does not harbor *E. coli* more so than the other.

3.3.2 Source Tracking

Molecular analyses detected birds and canines in this study, however, humans and rumens were not detected in any sample. As these study locations are not popular areas for water recreation, it is not unexpected that humans were not detected. Rumens are also not likely to be present in the concrete-lined study location, which are located by housing communities. However, ruminant animals, specifically cattle, were observed at properties within 0.5 miles of the Sunnyslope Channel study location during initial site visits.

- At John Bryant Park, birds were detected in 38 percent of water samples and 13% of sediment and biofilm samples. Detection was observed only during the October and January events. Canine was also detected in one biofilm sample in January.

- At Sunnyslope Channel, birds were detected in 75 percent of the water samples and 25 percent of the sediment and biofilm samples. Spatially, bird DNA was observed more frequently at the west bank site than the east bank site. The higher frequency of bird detection at Sunnyslope Channel may be influenced by its location in the Louis Rubidoux Nature Center and the abundance of trees as potential bird habitats.

- At Eastvale Line E, birds were detected in 25 percent of the water samples but not in any sediment or biofilm samples. Detection was observed only during the October event. This study location is a concrete-lined channel adjacent to undeveloped land and housing communities and does not appear to be a good habitat for wildlife. The lack of source detection at Eastvale Line E, particularly in relation to the highest *E. coli* concentrations observed, may suggest that elevated bacteria levels are less influenced by direct wildlife inputs and more so by other sources.

Table 3-4 *E. coli* Concentrations Observed in the Stormwater Channel Study

Matrix	Date	John Bryant Park			Eastvale Line E			Sunnyslope Channel		
		North Bank	South Bank	Average	East Bank	West Bank	Average	East Bank	West Bank	Average
Water (CFU/100 ml)	May	360	380	**370**	580	240	**410**	120	150 [A]	**85**
	July	360	140	**250**	940	3,600	**2,270**	170	150 [A]	**160**
	Oct	9 [A]	9	**9**	830 [A]	240 [A]	**535**	290 [A]	120 [A]	**205**
	Jan	460 [A]	60 [A]	**260**	2,800	3,000	**2,900**	210 [A]	140 [A]	**175**
Sediment & Biofilm (CFU/100 g)	May	6.7E4	5.8E4	**6.3E4**	6.7E5	2.2E5	**4.5E5**	4.0E2	1.9E3 [A]	**1.2E3**
	July	2.4E3	3.2E3	**2.8E3**	7.8E3	7.8E3	**7.8E3**	9.2E3	4.0E2 [A]	**4.8E3**
	Oct	1.9E5	2.2E4	**1.1E5**	2.5E5	2.4E6	**1.33E6**	1.1E5	2.7E5	**1.9E5**
	Jan	4.8E3	2.1E5 [B]	**1.1E5**	3.8E5	2.7E5	**3.3E5**	3.0E2	9.0E1	**2.0E2**

[A] DNA analysis showed presence of birds
[B] DNA analysis showed presence of birds and canines

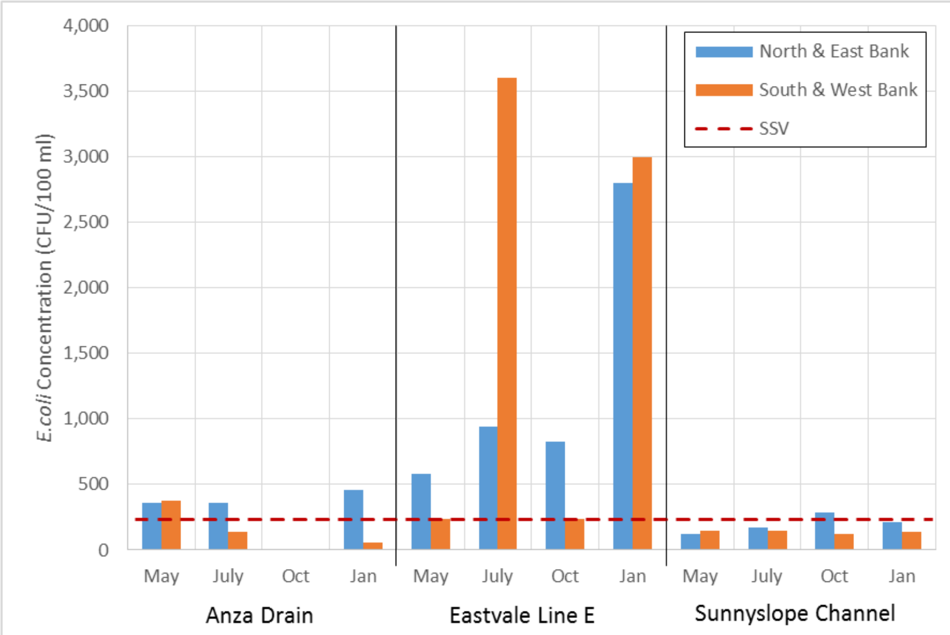


Figure 3-10 *E. coli* Concentrations Observed in Water Samples in the Stormwater Channel Study
(The applicable SSV to evaluate the bacteria concentration is 235 MPN/ml. This is used where there is insufficient data to calculate a 30-day 5-sample geomean.)

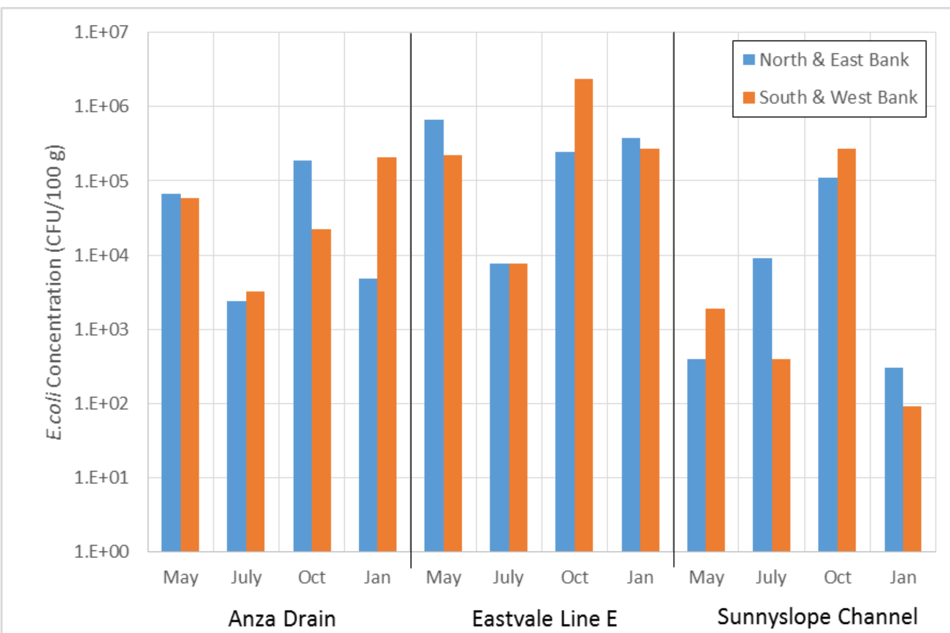


Figure 3-11 *E. coli* Concentrations Observed in Sediment and Biofilm Samples in the Stormwater Channel Study

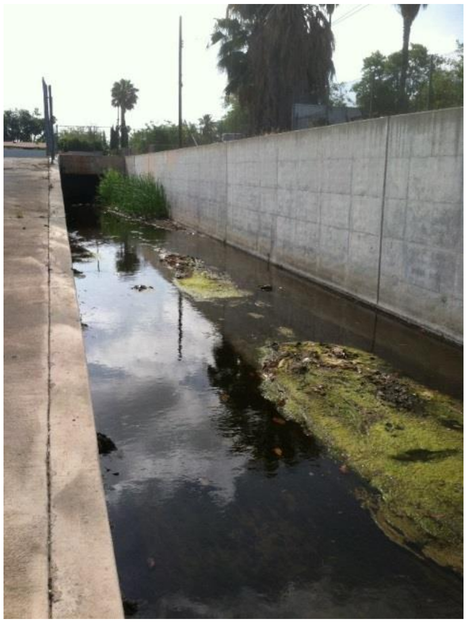


Figure 3-12 Anza Drain at John Bryant Park on May 13, 2015

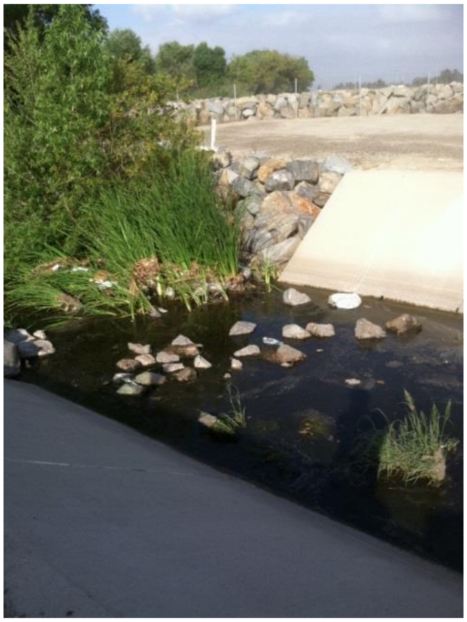


Figure 3-13 Eastvale Line E on May 13, 2015

Figure 3-14 Sunnyslope Channel on May 13, 2015

3.4 Non-MS4 Flow Study

The non-MS4 flow study intended to identify if non-stormwater flows could resuspend or shear bacteria present in sediment and biofilms by comparing *E. coli* levels in the water column and biofilm and sediment from sites upstream and downstream of non-MS4 flow discharge.

3.4.1 Monitoring Activities

Field staff were deployed on June 17 and July 22, 2015 to collect water quality samples as part of the non-MS4 flow study. Field staff were on site for an hour at each of the study locations during both sampling events. However, non-MS4 flow discharges at irregular times and field staff did not observe any flow from Jurupa Community Services District outfalls to either Day Creek (Figure 3-15) or San Sevaine Channel (Figure 3-16). As a result, no samples were collected for this study. Samples may be collected during upcoming, coordinated Jurupa Community Services District discharges in the summer of 2016.

While the study intended to test the hypothesis that non-MS4 discharges mobilize bacteria, samples were unable to be collected due to unpredictable discharge times. However, a review of water level data collected over a period of 2 months in 2014 from Day Creek and San Sevaine well blowoffs shows that water level varies up to 0.7 and 2.3 feet, respectively. This suggests that non-MS4 discharges result in highly variable flow in channels and has the potential to mobilize bacteria. As the supply for dry weather flow from tertiary effluent has decreased in recent years (Section 3.4.2), the role of non-MS4 discharges, such as *de minimus* discharges could potentially become more important.

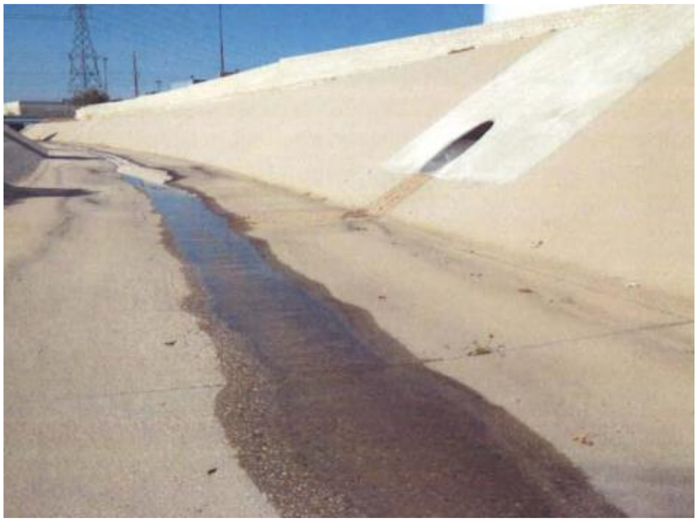


Figure 3-15 Day Creek on June 17, 2015

Figure 3-16 San Sevaine Channel on July 22, 2015

3.4.2 Historical Flow Record

Through the implementation of monitoring required to meet the Riverside County MS4 NPDES Permit for the Santa Ana River basin, RCFC&WCD and the co-permittees have assessed dry weather flow within MS4 facilities since 1990. As a result of drought conditions, economic concerns, and water conservation efforts, dry weather flow within MS4s have reduced during the last decade. Figure 3-17 shows that samples have become increasingly unable to be collected due to insufficient flow (noted as VNS in the figure) since 1996. To investigate the potential for dry weather flows to shear or resuspend bacteria from biofilms and sediment and how to address this mechanism as a source for bacteria, it is important to understand the sources and discharge rates of dry weather flow.

The predominant source of dry weather flow within the impaired waterbodies in from tertiary treated POTW effluent; however, rates have steadily declined since 2004 (Figure 3-18). This decline is largely due to implementation of projects to reuse wastewater and reduce demand on groundwater basins or imported water sources. Reduced flow rates and velocity would reduce shear stress on sediment and biofilm in the bottom of the impaired waters. On the other hand, the dilution of FIB in receiving waters provided by addition of tertiary treated effluent is diminishing (see Triennial Review Report for dynamic analysis of this condition).

Changes in water level and DWF may be attributed to factors such as diurnal water demand patterns or sporadic non-MS4 *de minimus* discharges. Water level records from San Sevaine Channel and Day Creek showed that *de minimus* discharges are highly sporadic and unpredictable (Figure 3-19), and can rapidly increase flow depths in channels. Perhaps most important to the potential for shearing and resuspension is a condition of extreme fluctuations in effluent discharge rates that is caused by operation of recycled water systems. The sharp increase or decrease in dry weather discharge to channels may facilitate deposition and scour processes that could allow for colonization and resuspension of FIB. This condition is most notable for Inland Empire Utility Agency RP1 discharge to Cucamonga Creek (Figure 3-20).

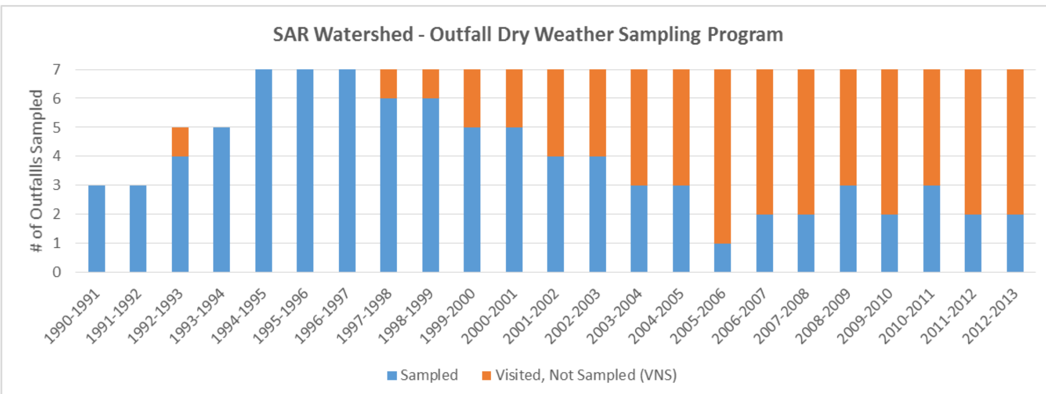


Figure 3-17 Changes in the Ratio of Outfalls "Visited Not Sampled" (VNS) and Outfalls Sampled During a Visit from 1990 through 2013[9]

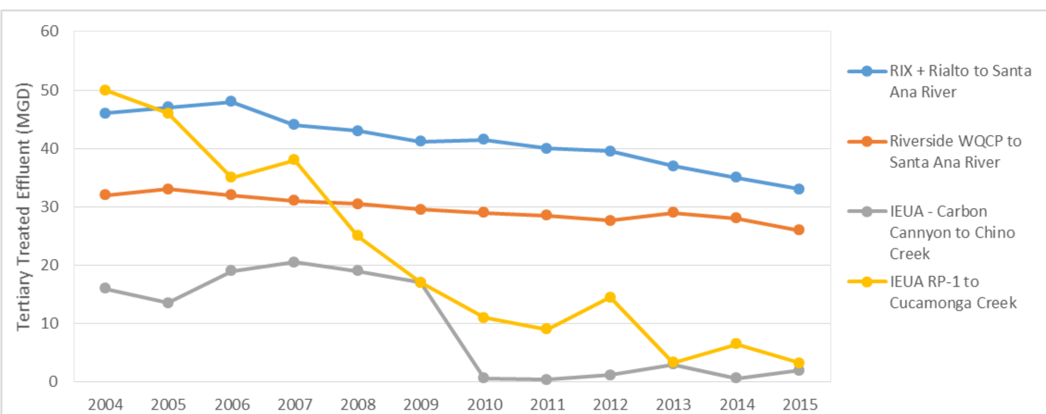


Figure 3-18 Average Daily POTW Effluent in August/September to be Impaired Waters in the MSAR Watershed from 2004 through 2005[10]

---

[9] Riverside County Stormwater Program Report of Waste Discharge
[10] http://www.sawpa.org/wp-content/uploads/2012/05/20150615-Reach-3-TDS-Investigation-II-final.pdf

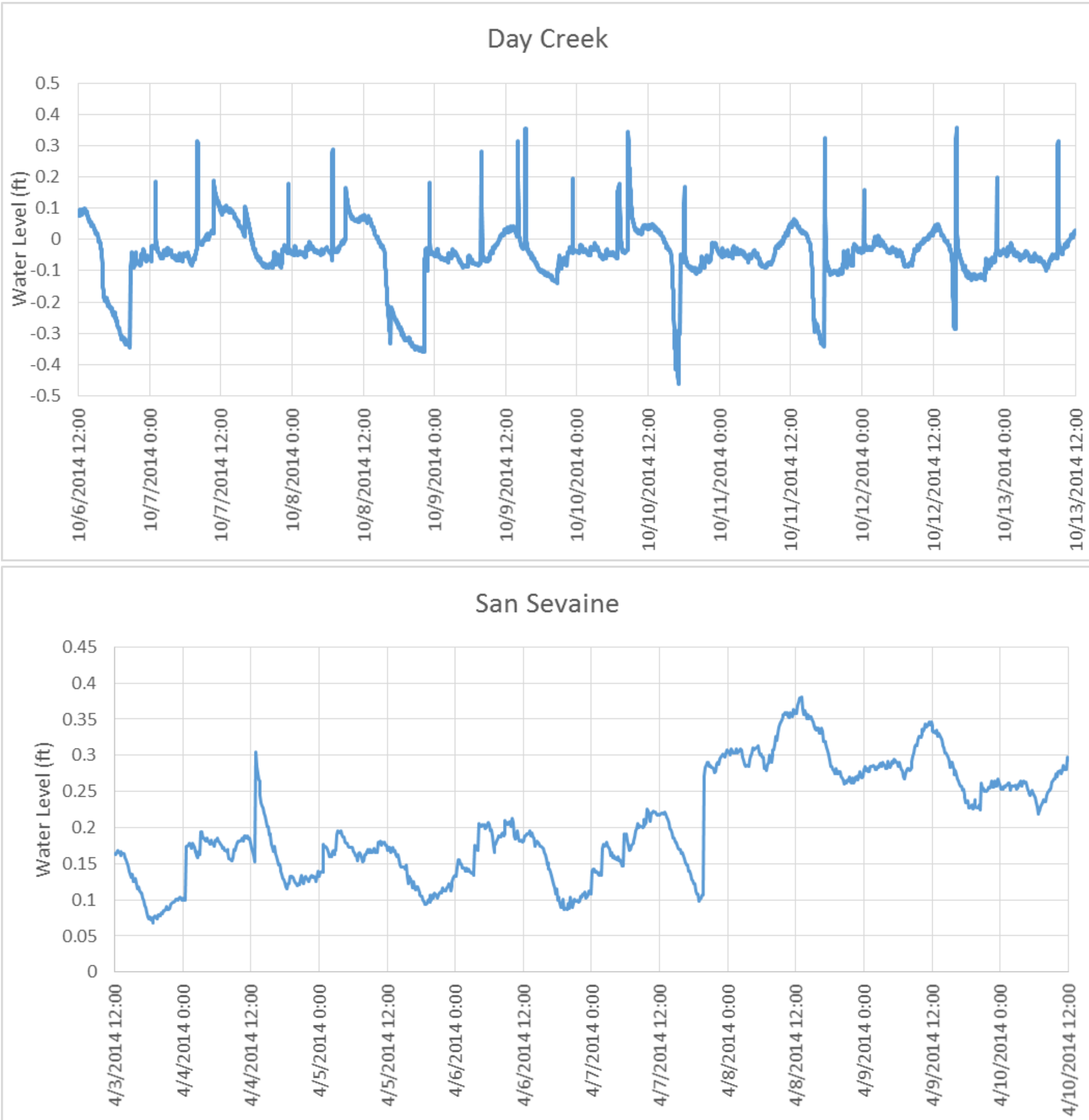


Figure 3-19 Water Level from *De Minimus* Discharges at (A) Day Creek and (B) San Sevaine Channel over a One Week Period

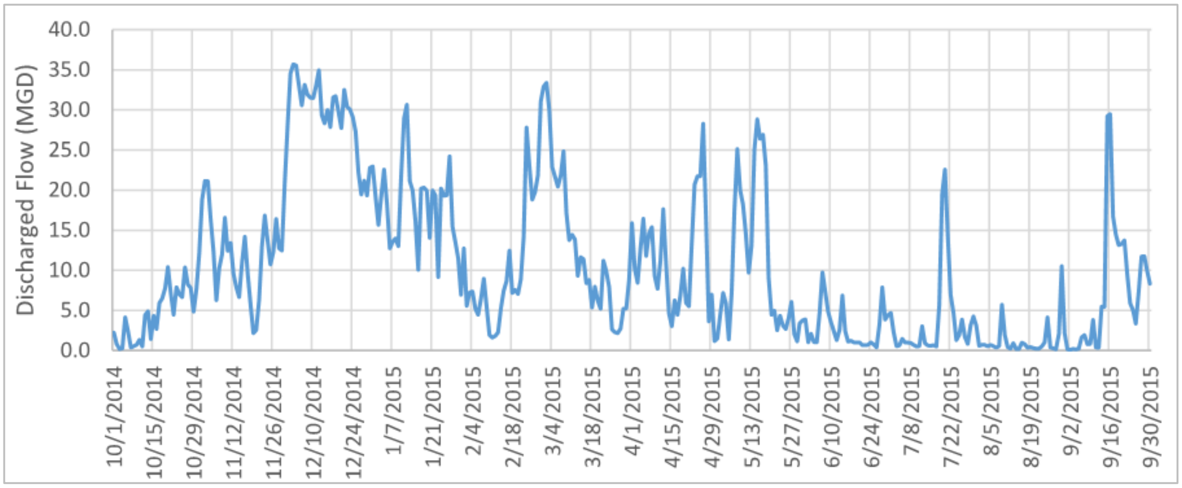


Figure 3-20 Daily Discharge of POTW Effluent to Cucamonga Creek over a One Year Period in 2014-2015

3.5 Human Recreation Study

In the human recreation study, water quality samples were collected daily for two five-day periods from the water column to observe effects of human recreation on bacteria levels. The two five-day periods target a holiday and a non-holiday weekend to compare effects of more human recreation during a holiday with that from less human recreation during a typical weekend.

3.5.1 Visual Observations

Based on visual observations (Figure 3-21 through 3-23), there were approximately a dozen or more people recreating in the river between the upstream and downstream sites on Thursday and Friday of the holiday weekend. On Saturday, July 4, more than a hundred people were in the river spanning the region upstream of the upstream site, between the two study sites, and downstream of the downstream site. On Sunday, only two people were observed in the river between the upstream and downstream sites and on Monday, nobody was in the river.

During the non-holiday weekend, three people were in the river between the two study sites on Thursday. One person was seen walking a dog in the river upstream of the upstream study site on Friday. Like the Saturday of the holiday weekend, people were observed in the river spanning the region upstream of the upstream site through downstream of the downstream site but in much fewer numbers (approximately a dozen people). People were also observed upstream of the upstream site on Saturday along with a person with a dog between the two study sites and dog feces on the sandbar in the river. Again, no person was observed in the river on Monday of the non-holiday weekend, however, a high volume of trash was present in the area.

Figure 3-21 SAR by Martha Mclean Anza Narrows Park on July 4, 2015

Figure 3-22 SAR by Martha Mclean Anza Narrows Park on July 4, 2015

Figure 3-23 SAR by Martha Mclean Anza Narrows Park on August, 2015

3.5.2 Water Quality

E. coli concentrations were analyzed in water samples collected daily over five day periods during two weekends during the summer of 2015 at Martha Mclean Anza Narrows Park (Table 3-5, Figure 3-24 and Figure 3-25). This included a holiday weekend, Independence Day, and a non-holiday weekend. During the holiday weekend, there is a generally increasing trend in *E. coli* concentrations through Sunday followed by a decrease on Monday, which is a similar trend to number of people recreating in the river throughout the weekend. This observation suggests that the presence of human recreation impacted bacteria levels in SAR at this study location. *E. coli* levels were higher at the downstream site than the upstream site on Thursday, Friday, and Monday by as much as 45%. However, *E. coli* levels were 36% and 22% higher at the upstream site on Saturday, July 4th, and Sunday, respectively. Elevated upstream *E. coli* concentrations on Saturday and Sunday may be influenced by the large number of people recreating on July 4th, extending farther upstream than the upstream monitoring site. The highest *E. coli* concentration over the holiday weekend was observed on Sunday at both upstream and downstream sites with 780 and 610 MPN/100 ml, respectively. These concentrations are much higher than typical ranges measured at the compliance monitoring sites.

Molecular analyses did not detect presence of humans or dogs on any day during the holiday weekend. Although MST analyses did not detect humans, *E. coli* concentrations may be impacted by the presence of humans. Human recreation in the river may lead to direct fecal deposition but even more so, it may result in sediment resuspension that leads to increased bacteria levels in the water column. As grab samples are not collected comprehensively in the study location, detecting sources of bacteria, which can be highly variable spatially, is challenging. Additionally, source-specific markers can degrade rapidly (within one day), making sources difficult to detect (Bae and Wuertz, 2015). Studies have suggested that detection of source-specific markers may be evidence of recent fecal deposition but associated bacteria contribution can persist longer (Balleste and Blanch, 2010).

E. coli levels at the upstream site during the non-holiday weekend remained relatively low from Thursday through Sunday (average: 288 MPN/100 ml) but increased significantly on Monday (1,200

MPN/100 ml), whereas levels at the downstream site during the non-holiday peaked on Saturday and remained relatively low otherwise. *E. coli* levels at the downstream site were higher than the upstream site on Thursday, Saturday, and Sunday by nearly as much as three-fold. These observations support a finding that bacteria levels are affected by human recreation and result in higher bacteria levels downstream of human recreation. Conversely, *E. coli* levels were higher at the upstream site on Friday and Monday by as much as 63%. Peak *E. coli* concentrations were observed on Monday at the upstream site and on Saturday at the downstream site, with 1,200 and 820 MPN/100 ml, respectively. This is more the three times and nearly twice the next highest *E. coli* levels observed at those sites.

During the non-holiday weekend, molecular analyses detected the presence of dog on Monday at the upstream site, which corresponds with elevated *E. coli* concentration. All other molecular analyses did not detect presence of humans or dogs otherwise. The lack of detection may reflect challenges described in the previous paragraph and does not necessarily eliminate humans as a source of bacteria. The presence of a few people may be enough to resuspend bacteria into the water column. The detection of dog in the sample with particularly high *E. coli* levels could reflect effects of direct deposition into the river or recent fecal deposition, as described by Balleste and Blanch (2010), given that dog feces were observed in the river.

The single sample SSV was exceeded by all but one samples and the 5-sample WQO was exceeded by geomeans calculated at each site (Figure 3-26).

Table 3-5 *E. coli* Concentrations Observed in the Swim Study (MPN/100 ml)

	Date		Swim01A (Upstream)	Swim01B (Downstream)	Average
Holiday Weekend	Thursday	7/2/2015	300	330	315
	Friday	7/3/2015	250	290	270
	Saturday	7/4/2015	440	280	360
	Sunday	7/5/2015	780	610	695
	Monday	7/6/2015	330	480	405
	Average		**420**	**398**	**409**
Non-Holiday Weekend	Thursday	8/13/2015	310	460	385
	Friday	8/14/2015	360	330	345
	Saturday	8/15/2015	220	820	520
	Sunday	8/16/2015	260	330	295
	Monday	8/17/2015	1,200 [A]	450	825
	Average		**470**	**478**	**474**

[A] Canine was detected

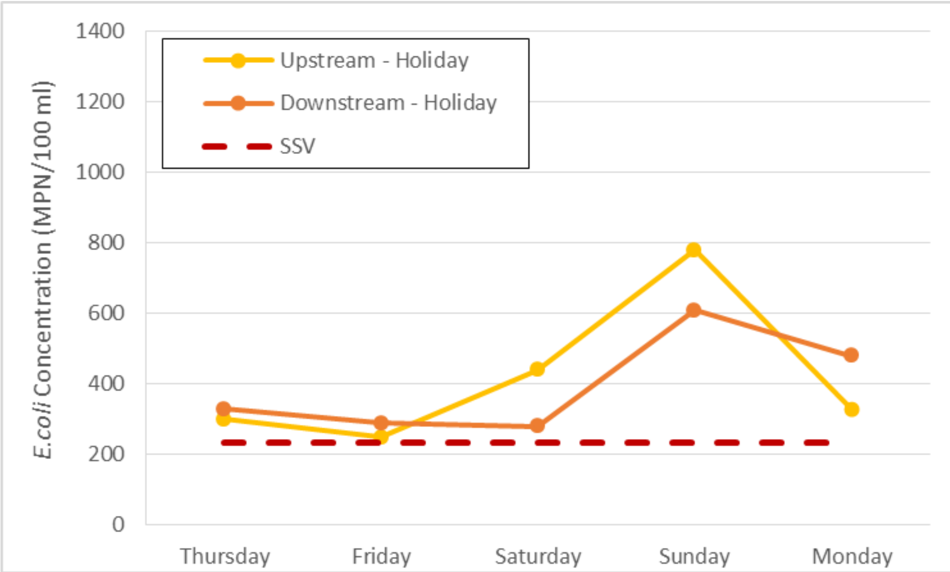


Figure 3-24 *E. coli* Concentrations Observed During a Holiday Weekend in the Swim Study
(Circles with red fill indicate birds detected in molecular analyses; The applicable SSV to evaluate the bacteria concentration is 235 MPN/ml. This is used where there is insufficient data to calculate a 30-day 5-sample geomean.)

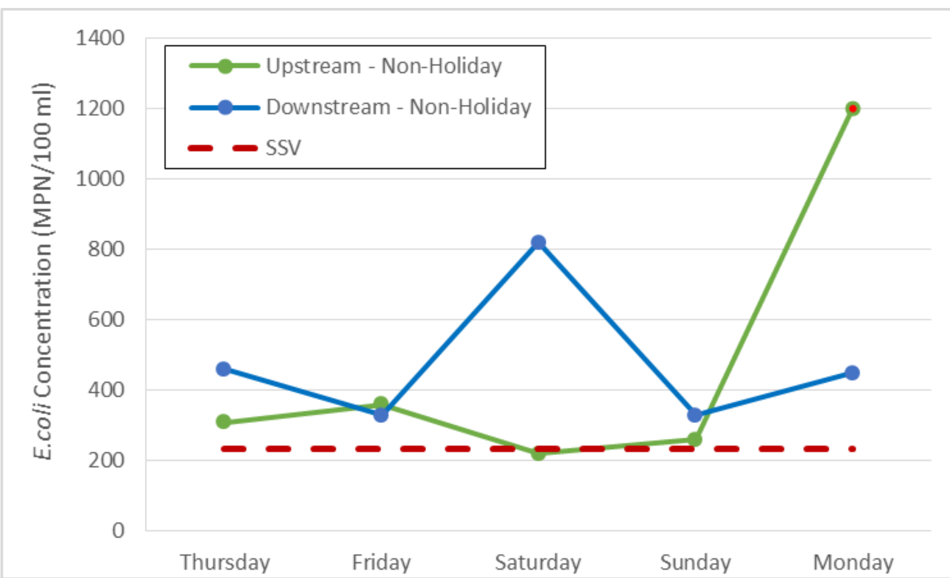


Figure 3-25 *E. coli* Concentrations Observed During a Non-Holiday Weekend in the Swim Study
(Circles with red fill indicate dogs detected in molecular analyses; The applicable SSV to evaluate the bacteria concentration is 235 MPN/ml. This is used where there is insufficient data to calculate a 30-day 5-sample geomean.)

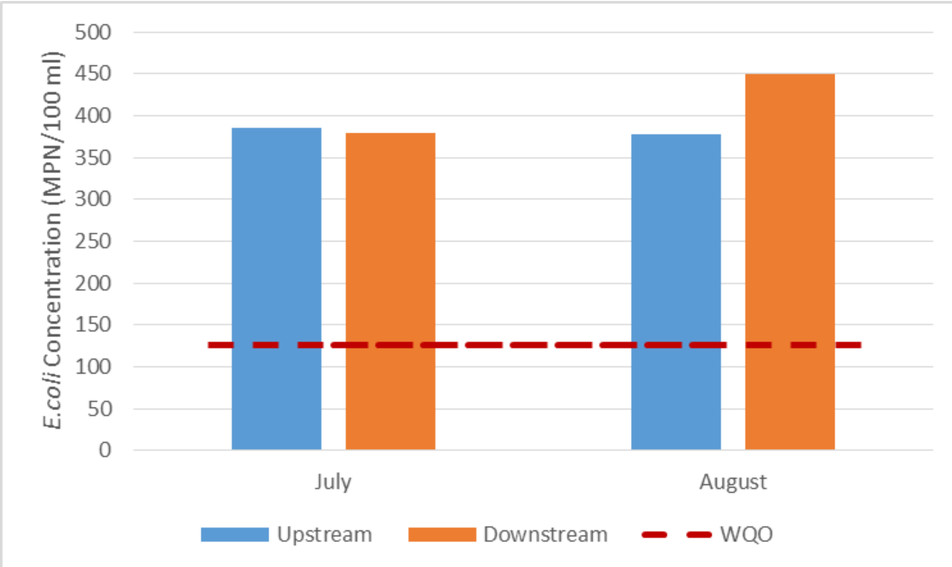


Figure 3-26 Geomean of *E. coli* Concentrations Observed During Holiday (July) and Non-Holiday (August) Weekends in the Swim Study

3.5.3 Transient Encampment Management

RCFC&WCD also conducted a transient encampment mitigation at (SAR at Market Street), where individuals have been observed using the SAR to bathe. RCFC&WCD analyzed bacteria concentrations in water samples collected prior to and after the cleanup (Table 3-6). While *E. coli* concentrations are generally low (less than 100 MPN/100 ml) at the site upstream of the homeless encampment, concentrations are higher downstream of the homeless encampment during two of the three sampling events. This finding suggests that the presence of the encampments cause an increase bacteria in concentrations in the SAR possibly due to bathing and other activities in the river. Average downstream bacteria levels were higher after the cleanup than before the cleanup (after: 900 MPN/100 ml, before: 254 MPN/100 ml). However, a detailed source investigation post cleanup was not conducted. Although humans were not detected in any sample collected, dogs were detected in both upstream and downstream samples from July 9, 2015.

Table 3-6 Data from Homeless Encampment Cleanup Conducted by RCFC&WCD

Analysis	Before Cleanup				After Cleanup	
	July 9, 2015		July 22, 2015		August 26, 2015	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
E. coli **(MPN/100 ml)**	8	7	80	500	80	900
Human	BDL	BDL	BDL	BDL	BDL	BDL
Canine	+	+	BDL	BDL	BDL	BDL

Note: BDL = Below detection limit; + = positive detection
Source: RCFC&WCD

3.6 Horse Recreation Study

In the horse recreation study, water quality samples were collected on a single day during two weekends from both the water column and sediment. The two Saturdays, during which samples were collected, target a holiday and a non-holiday weekend to compare effects of more recreation during a holiday with that from less recreation during a typical weekend.

3.6.1 Visual Observations

Visual observations during the holiday weekend showed recreational activity at SAR at Etiwanda Avenue and SAR at Downey Street only. At SAR at Etiwanda Avenue, approximately 5 people as well as a horse and rider were in the river downstream of the study location (Figure 3-27). Considerably more people (more than 300) were found to be recreating in the river around SAR at Downey Street (Figure 3-28), however, no horses were observed. Although recreation by humans or horses were not observed at SAR at Mary Tyo Equestrian Area at the time of sample collection, horses were seen approaching the river as the field staff was leaving this study location. During the non-holiday weekend, recreational activity was not observed at SAR at Etiwanda Avenue and SAR at Mary Tyo Equestrian Area. However, people (>10) were seen recreating both upstream and downstream of the SAR at Downey Street study location (Figure 3-29).

Figure 3-27 A rider and horse at SAR at Etiwanda Avenue & 66th Street on July 4, 2015

Figure 3-28 People recreating at SAR at Downey Street & 64th Street on July 4, 2015

Figure 3-29 People recreating at SAR at Downey Street & 64th Street on August 15, 2015

3.6.2 Water Quality

E. coli concentrations were analyzed in water samples collected from three study locations along SAR on a holiday Saturday, July 4, and a non-holiday Saturday, August 15 (Table 3-7, Figures 3-30 and 3-31). Although observed ranges of *E. coli* levels in water samples for this study were similar during holiday and non-holiday samples (150 to 350 MPN/100ml and 120 to 320 MPN/100 ml, respectively), *E. coli* levels in water samples from all but one site were higher during the holiday weekend than the non-holiday weekend by as much as two-fold. Average concentrations in water samples from SAR at Downey Street during both holiday and non-holiday weekends (195 and 120 MPN/100 ml, respectively) were slightly lower than average concentrations at the other two sites (SAR at Etiwanda Avenue: 325 and 165 MPN/100 ml; SAR at Mary Tyo: 300 and 250 MPN/100 ml). *E. coli* levels are similar across transects at all sites with the exception of the non-holiday sediment samples.

Molecular analyses did not detect the presence of horse in any water sample, despite 83 percent and 17 percent of July and August samples exceeding the single sample numerical target, respectively.

Although horses were not detected in this study, it is possible that horses are contributing to fecal contamination based on visual observations of horse presence in and around SAR but that horse DNA signals may be low at the time of sampling. Studies have shown a host-specific genetic markers decay rapidly (within one day) and that detections may reflect only very recent fecal deposition (Bae and Wuertz, 2015; Balleste and Blanch, 2010). These study locations are also inhabited by other wildlife as well as humans, however, these sources were not tested as part of this study. It is also possible that the bacteria concentrations are influenced by upstream activity, including human recreation observed at the time of sample collection. Human recreation at the study locations could lead to sediment resuspension that releases bacteria into the water column. Resuspended bacteria may be transported downstream over time as well, which could contribute to elevated levels at downstream study locations (Walters et al, 2014; Curtis and Trapp, 2014).

During the holiday weekend, *E. coli* concentrations in sediment were over three orders of magnitude higher than concentrations in corresponding water samples. Levels in sediment samples from the non-holiday weekend were generally one order of magnitude greater than corresponding water samples. Concentrations from the holiday weekend were also over three orders of magnitude higher than non-holiday concentrations (holiday: 8.5×10^5 to 1.9×10^6 MPN/100 g; non-holiday: non-detects to 3.1×10^3 MPN/100 g). *E. coli* concentrations in August sediment samples are generally lower than concentrations reported in other studies. Molecular analyses did not detect the presence of horse in any sediment sample, however the MST analyses for this study was limited to only horse. It is possible other uncontrollable sources that were not analyzed for may have contributed to bacteria levels at these study locations. It is interesting to note that sediment *E. coli* concentrations were approximately three orders of magnitude higher during the holiday weekend than the non-holiday weekend, although it is unclear what the source is.

Table 3-7 *E. coli* Concentrations Observed in the Horse Study (MPN/100 ml & MPN/100 g)

Study Location	Study Site	Water		Sediment	
		Holiday (July 4)	Non-Holiday (Aug 15)	Holiday (July 4)	Non-Holiday (Aug 15)
SAR @ Etiwanda Ave	North Bank	350	190	1,900,000	1000
	South Bank	300	140	1,500,000	ND
	Average	**325**	**165**	**1,700,000**	**n/a**
SAR @ Mary Tyo Equestrian Area	East Bank	320	180	1,500,000	1000
	West Bank	280	320	850,000	ND
	Average	**300**	**250**	**1,175,000**	**n/a**
SAR @ Downey Street & 64th Street	North Bank	150	120	n/a [A]	1000
	South Bank	240	120	n/a [A]	3100
	Average	**195**	**120**	**n/a**	**n/a**

[A] Sediment samples were not collected from this study location on July 4, 2015

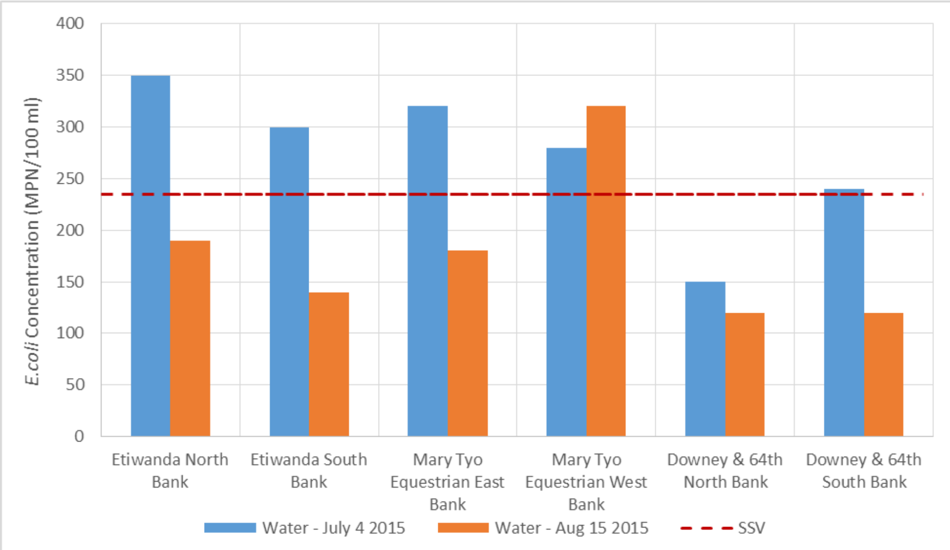


Figure 3-30 *E. coli* Concentrations Observed in the Horse Study Water Samples
(The applicable SSV to evaluate the bacteria concentration is 235 MPN/ml. This is used where there is insufficient data to calculate a 30-day 5-sample geomean.)

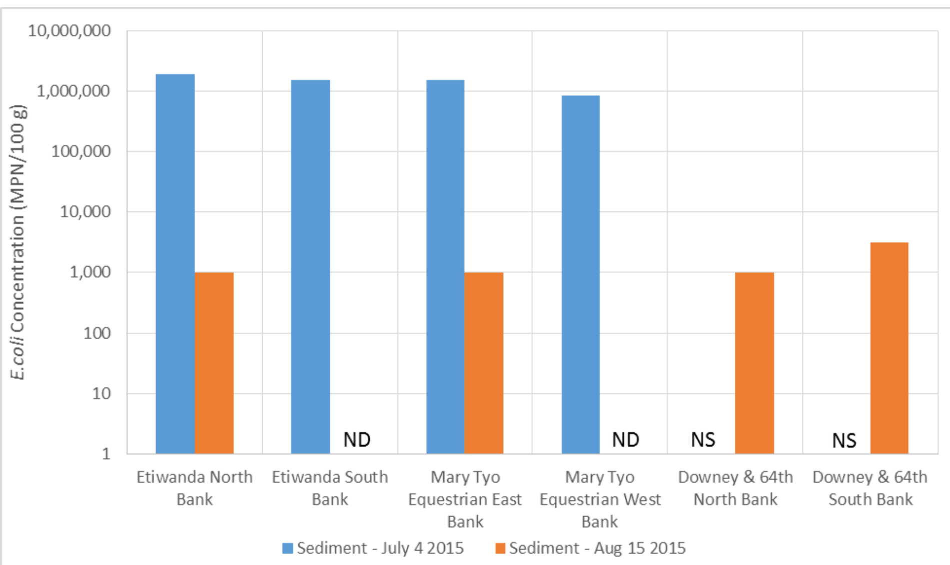


Figure 3-31 *E. coli* Concentrations Observed in the Horse Study Sediment Samples
(Note: July 4 sediment samples from SAR at Downey & 64th were not collected (NS – no sample). August 15 sediment samples were below detection limits (ND – non-detect).)

This page intentionally left blank.

Section 4

Discussion and Conclusion

Previous monitoring data has suggested that bacteria levels in the MSAR watershed cannot be explained solely by urban runoff. Bacteria concentrations within the SAR during the 2015 dry season showed significant fluctuation, with weekly samples varying by 1 to 2 orders of magnitude, despite the conditions of similar POTW effluent rates. The methods used to develop the source contribution analysis in the 2016 Triennial Review Report[11] were applied to weekly downstream concentrations during the 2015 dry season to determine the deviation from flow-weighted averages of *E. coli* in DWF from MS4s that would explain weekly variability measured downstream. This analysis found that deviations would be outside of the typical range for *E. coli* in DWF from all MS4s outfalls to the SAR. Most notable were two of the twenty weekly samples during 2015 dry season (July 5 and September 20). For example, the source contribution analysis for the 2016 Triennial Review estimated that downstream concentrations should be approximately 100 cfu/100 ml in the SAR at Pedley Avenue, based on historical MS4 outfall monitoring and 2015 POTW effluent rates. On July 5, 2015, the concentration of *E. coli* in the SAR at Pedley Avenue was approximately 2,200 cfu/100 ml. To be attributable to increased loads from MS4 discharges, *E. coli* in urban DWF would have to nearly simultaneously exceed 10,000 cfu/100mL for all eight major drainage areas with consistent DWF discharges to the SAR. Thus, it is completely plausible to consider that other uncontrollable sources of FIB are responsible for a significant fraction of downstream *E. coli*.

The UBSS was implemented to help identify to the extent possible whether specific uncontrollable sources of bacteria were contributing to the elevated levels observed in the watershed. Results for each of the six pilot studies are presented in Section 3 above. The UBSS investigated sources of fecal bacteria that can be categorized as host-specific (human, bird, dog, rumen, and horse) or naturalized (born in the environments such as in channel bottoms). The following sections synthesize the key findings from these two categories of fecal bacteria origin.

4.1 Host-Specific Bacteria Sources

Four of the pilot studies were conducted to assess whether there is a specific source (human, bird, dog, rumen, and horse) of fecal bacteria to the Santa Ana River and Cucamonga Creek. Multiple lines of evidence were developed to support the investigations, including FIB concentrations, biological surveys, microbial source tracking, and isolation of a Santa Ana River segment with no urban DWF discharges. Host specific sources were not consistently detected by MST analyses in samples that were hypothesized to be impacted, from sites downstream of 1) active riparian bird habitat areas, 2) bridges with nesting bird activity, 3) swimming recreation by humans and dogs, 4) equestrian use. Moreover, detections of a specific host were not well correlated with *E. coli* concentrations, suggesting that while these sources could contribute to elevated bacteria levels, they may not be the predominant source of fecal indicator bacteria at those monitoring sites. It is also possible that specific hosts were

[11] Middle Santa Ana River Bacterial Indicator TMDL Implementation Final Report; submitted to the Santa Ana Watershed Project Authority on behalf of the MSAR TMDL Task Force, February 2016

not detected by MST analyses due to low levels in the samples, rapid decay of markers, or detections reflecting recent fecal deposition (Bae and Wuertz, 2015; Ballaste and Blanch, 2010).

Separate from the UBSS, RCFC&WCD conducted a transient encampment water quality assessment during the summer of 2015. This assessment found that *E. coli* concentrations were substantially higher downstream of transient encampments but does not identify the encampments as the only contributor to high *E. coli* concentrations at that site. Further study of the impact of such encampments may provide additional insight to this potential source.

4.2 Naturalized Bacteria

Although fecal bacteria directly from human and wildlife sources were not well correlated with *E. coli* concentrations, these sources may indirectly influence fecal indicator bacteria levels in the environment. Fecal bacteria from a specific host released to the environment can settle to the channel bottom and survive within sediments or biofilms for weeks or months over a wide range of temperature and moisture conditions (Balzer et al, 2010). Growth of these initially deposited fecal bacteria within channel bottom sediments and biofilms results in colonies, where the majority of the population may be considered naturalized, reproducing outside of a specific organism (Ishii et al, 2007; Byappanahalli et al, 2012; Ran et al 2013). Regrowth in biofilms has been recognized as a process influencing in-stream dynamics of fecal indicator bacteria levels. Balzer et al (2010) conducted a study on biofilms in several German Rivers. They found that fecal indicator bacteria were two-orders of magnitude higher in biofilms than overlying water, demonstrating that they may be able to integrate into existing biofilms and multiply – and thus, be a reservoir for indicator bacteria in the environment.

Although growth varies based on a number of factors including environmental conditions, using typical growth rates between 0.1 to 0.3 hr^{-1} (Jiang et al, 2007), the portion of the fecal bacteria population attributed to the initial host may be less than 5 percent within the first 12-24 hours of deposition (Figure 4-1). Even higher exponential growth rates up to 2 hr^{-1} may be expected shortly after colonization when food is abundant (Chapra, 1997). Thus, bacteria source tracking methods used in this study and by others are often unable to determine the ancestral host organism(s) in samples comprised of mostly naturalized fecal bacteria as methods were developed and tested using more laboratory spikes of fecal sources or recent fecal deposition (personal communication with Menu Leddy, October 20, 2015; Bae and Wuertz, 2015).

The physical processes that releases bacteria from sediment and biofilms to the water column may be just as important as factors that control colonization and growth (Grant, 2011). Fecal bacteria are not like chemical pollutants that have interactions between solid and dissolved phases by adsorption and desorption. Instead, bacteria may shed from a colony with weakened attachment from aging and when exposed to increased shear stresses.

By process of elimination, the UBSS results suggest that host specific sources do not represent the majority of *E. coli* fecal indicator bacteria in downstream waters. Therefore, the processes of colonization within channel bottoms and subsequent resuspension may be the most important controls on the concentration of *E. coli* in surface water. Two potential transport mechanisms by which naturalized bacteria are shed from channel bottoms were described by Grant (2011), including:

- Resuspension of sediment and attached *E. coli*, where flows exceeding critical shear stress releases loosely attached *E. coli* into overlying water column.

- Advection of *E. coli* in porewater, where flow drives exchanges between the porewater of channel bottom sediments and biofilms and overlying water column.

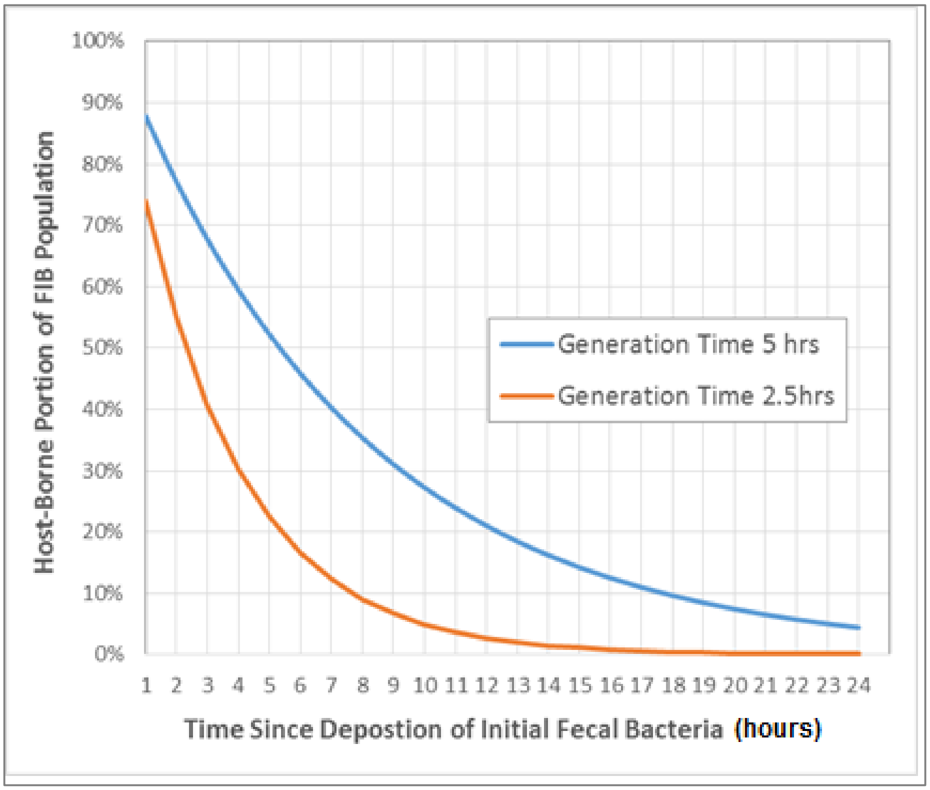


Figure 4-1 Ratio of Host-Borne to Naturalized FIB with a Range of Exponential Growth Rate Constants

Sediment is resuspended in streams when shear stress on the streambed exceeds the critical shear stress on the streambed. Resuspension of sediment depends on the type of sediment on the streambed and may be influenced by factors such as density, particle size, and the consolidation of the streambed. Resuspension of sediment particles has been identified to be a source of bacteria to overlying water, generally in wet weather conditions when high flows resuspend the sediment or in coastal areas where wave action can act to resuspend the sediment (Byappanahalli et al. 2003; Jamieson et al. 2005; Reeves et al. 2003; Solo-Gabriele and Perkins 1997; Whitman and Nevers 2003). In addition, work by Fries et al., 2006 and Fries et al, 2008 provided further evidence that resuspension of sediment can play an important role in the elevated concentrations of *E. coli* during and following rain events.

During dry weather conditions in the SAR and Cucamonga Creek, sharp increases in flow rate do occur in the form of increased POTW effluent, pulses of runoff from summer thunderstorms in far upstream mountains, and *de minimus* discharges. The final pilot study was intended to investigate whether flows that are not a source of bacteria could result in elevated downstream levels of *E. coli* through shearing effects. Given the unpredictability of these discharges, previous efforts were unable to provide new data, however, there is ongoing coordination occurring to utilize upcoming opportunities that will allow for further investigation.

4.3 Growth Factors for *E. coli*

Although the pilot studies did not investigate specifically what environmental factors may influence instream *E. coli* concentrations, it is important to consider other variables that may have impacted results observed in the six pilot studies. Resuspension may be an important mechanism for *E. coli* release into overlying water, however, variables influencing *E. coli* growth in the environment may be important as well. As bacterial growth, decay, and survival in environmental conditions may be related to a number of factors, it is likely that bacteria colonies persist and thrive in the environment under limited conditions. Not only could flow and resuspension result in dispersed colonies, areas or "hotspots" where conditions promote growth or decay may contribute to bacteria levels varying spatially. A study by Surbeck et al in 2010 suggested that nutrients, specifically dissolved organic carbon (DOC) and phosphorus, are correlated with *E. coli* growth trends observed in Cucamonga Creek. Microcosm experiments indicated that runoff is a significant source of bacteria, however, the experiments also suggested that nutrient levels may have a more important impact on how bacteria persists. *E. coli* growth was only observed when phosphorus and DOC were present at threshold levels and growth rates doubled with increasing DOC content. While Surbeck et al, 2010 suggested that treated wastewater effluent was not a source of bacteria, the study indicated that nutrient content (DOC, phosphorus, nitrate, and ammonium) in Cucamonga Creek is strongly correlated with the treated wastewater effluent.

4.4 Conclusion

Source contribution analysis conducted for the CBRP compliance analysis and in subsequent Triennial Reports have demonstrated that a significant portion of bacteria in the MSAR TMDL waterbodies during dry weather is not attributable to discharges from MS4s. The UBSS aimed to better understand and quantify the influence of other uncontrollable sources on bacterial indicator concentrations in these waterbodies. Findings from the six pilot studies include:

- Microbial source tracking analyses detected only birds and dog, mostly birds. However, these detections were not found consistently with higher *E. coli* concentrations in corresponding water and sediment or biofilm samples or consistently downstream of suspected sources.
- Extrapolation based on the gradual rise of *E. coli* concentrations observed in the natural sources study suggests there is the potential for bacteria levels to exceed WQO at further downstream locations and that natural sources may account for a majority of downstream bacteria.
- In the study targeting human recreation (swimming) as a source, *E. coli* concentrations were slightly elevated during the holiday weekend after presence of humans were observed to be high, however, humans were not detected in molecular analyses. Additionally, the highest *E. coli* concentration was observed when canine was also detected.
- Data collected by RCFC&WCD as part of a transient encampment water quality assessment showed higher *E. coli* levels downstream of the encampment before and after cleanup activities.
- In studies involving sediment or biofilm samples, *E. coli* concentrations were substantially higher in the sediment and biofilms than in the overlying water. However, sediment / biofilm concentrations were still lower than that observed in other studies.

Although the pilot studies did not suggest any human or wildlife source as a consistent significant contributor to elevated bacteria levels, the fact remains that unaccountable sources of *E. coli* are present. By process of elimination then, the UBSS results infer that the majority of uncontrollable *E. coli* in the impaired waters may be from releases from naturalized colonies in channel bottom sediment and biofilms. As noted above in Section 4.2, fecal bacteria from a specific host released to the environment can settle to channel bottom and survive within sediments or biofilms for weeks or months over a wide range of temperature and moisture conditions. Growth of these initially deposited fecal bacteria within channel bottom sediments and biofilms results in colonies, where the majority of the population may be considered naturalized, reproducing outside of a specific organism.

Resuspension of bacteria from channel bottoms may occur because of increased DWF (e.g., from *de minimus*, POTW effluent or dry weather MS4 discharges). As noted above, through the work of others, nutrients and DOC are examples of constituents that can influence bacteria growth rates in stream. If *in situ* growth is found to be a key source, then alternatives to reduce this growth could be evaluated. This evaluation could include additional studies to determine instream threshold levels for constituents that affect bacterial growth.

Finally, it is important to note that the UBSS represented pilot studies, which were developed and implemented as a preliminary effort to better understand uncontrollable sources of bacteria in the MSAR watershed to the extent possible. Though the study locations and monitoring sites did not identify specific uncontrollable sources as significant contributors of bacteria, it is important to note that it can be challenging to capture samples with detectable sources due to the high spatial variability of bacteria in the environment. Lack of detections may reflect absence of the source, however, it may also reflect a low, undetectable signal. While host-specific qPCR methods are often used in source tracking studies, it is also possible that alternative MST methods (e.g., library-dependent) could be more effective. It is likely that further investigation with additional and/or alternative study locations, MST methods, and additional analyses of uncontrollable sources would provide helpful and potentially more conclusive information to help better understand causes of elevated bacteria concentrations in the MSAR watershed.

This page intentionally left blank.

Section 5

References

Airaksinan, S., M.L. Heiskanen, and H. Heinonen-Tanski (2007) Contamination of surface runoff water and soil in two horse paddocks. *Bioresource Technology*. 98:1762-1766.

Bae, S., and S. Wuertz (2015) Decay of host-associated *Bacteroidales* cells and DNA in continuous-flow freshwater and seawater microcosms of identical experimental design and temperature as measured by PMA-qPCR and qPCR. *Water Research.* 70:205-213.

Balleste, E. and A.R. Blanch (2010) Persistence of *Bacteroides* species populations in a river as measured by molecular and culture techniques. *Applied and Environmental Microbiology*. 76(22):7608-7616.

Balzer, M., N. Witt, H.C. Fleming and J. Wingender (2010). Faecal indicator bacteria in river biofilms. *Water Science and Technology.* 61(5):1105-1111.

Byappanahalli, M., M. Fowler, D. Shively, and R. Whitman (2003) Ubiquity and persistence of Escherichia coli in a midwestern coastal stream. *Applied Environmental Microbiology*. 69(8):4549–4555.

Byappanahalli, M.N., T. Yan, M.J. Hamilton, S. Ishii, R.S. Fujioka, R.L. Whitman, and M.J. Sadowsky (2012) The population structure of Escherichia coli isolated from subtropical and temperate soils. *Science of the Total Environment*. 273–279.

Byappanahalli, M.N., M.B. Nevers, R.L. Whitman, Z. Ge, D. Shively, A. Spoljaric, K. Przybyla-Kelly (2015) Wildlife, urban inputs, and landscape configuration are responsible for degraded swimming water quality at an embayed beach. *Journal of Great Lakes Research*. v41:1456-163.

Chapra, S. (1997) *Surface Water Quality Modeling*. Waveland Press, Illinois.

City of Newport Beach and Santa Ana Regional Water Quality Control Board (2002). Swimmer Shedding Study in Newport Dunes, California. Report prepared by Sunny Jiang, Charlie McGee, Linda Candelaria, Garry Brown, and Dani Gold, http://www.waterboards.ca.gov/rwqcb8/water_issues/programs/tmdl/docs/swimmerreport.pdf

Curtis, T. and J.M. Trapp (2014) Evidence for the accumulation and steady-state persistence of *E. coli* in subtropical drainage basin sediments. *Water, Air, Soil, Pollution*. 225:2179

Edge, T.A. and S. Hill (2007) Multiple lines of evidence to identify the sources of fecal pollution at a freshwater beach in Hamilton Harbour, Lake Ontario. *Water Research.* v41: 3585-3594.

Elmir, S.M., M.E. Wright, A. Abdelzaher, H.M. Solo-Gabriele, L.E. Fleming, G. Miller, M. Rybolowik, M-T P. Shih, S.P. Pillai, J.A. Cooper, and E.A. Quaye (2007) Quantitative evaluation of bacteria released by bathers in a marine water. *Water Research*. v41:3-10.

Ferguson, D. (2006) Growth of *E. coli* and Enterococci in Strom Drain Biofilm, presentation at the National Beaches Conference, October 13, 2006, Niagara Falls, New York.

Fries, J. S., G.W. Characklis, and R.T. Noble (2006) Attachment of fecal indicator bacteria to particles in the Neuse River Estuary, N.C. *Journal of Environmental Engineering.* 132(10):1338–1345.

Fries, J.S., G.W. Characklis, and R.T. Noble (2008) Sediment–water exchange of Vibrio sp. and fecal indicator bacteria: Implications for persistence and transport in the Neuse River Estuary, North Carolina, USA. *Water Research*. 42(4-5):941-950.

Gerba, C.P. (2000) Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality. *Quantitative Microbiology.* v2:55-68.

Ishii S., D.L. Hansen, R.E. Hicks, M.J. Sadowsky (2007) Beach sand and sediments are temporal sinks and sources of Escherichia coli in Lake Superior. *Environmental Science and Technology.* 41(7):2203-2209.

Jamieson, R. C., D.M. Joy, H. Lee, R. Kostacschuk, and J.R. Gordon (2005) Resuspension of sediment-associated Escherichia coli in a natural stream. *Journal of Environmental Quality*. 34(2):581–859.

Jiang, S.C., W. Chu, B. H. Olson, J.-W. He, S. Choi, J. Zhang, J. Y. Le, and P. B. Gedalanga (2007) Microbial source tracking in a small southern California urban watershed indicates wild animals and growth as the source of fecal bacteria. *Applied Microbiology and Biotechnology.* 76(4):927-34.

Ksoll, W.B., S. Ishii, M.J. Sadowsky, and R.E. Hicks (2007) Presence and source of fecal coliform bacteria in epilithic periphyton communities of Lake Superior. *Applied and Environmental Microbiology.* v73(12):3771-3778.

Long, S.C. and J.D. Plummer (2004) Assessing land use impacts on water quality using microbial source tracking. *Journal of American Water Resources Association.* v40(6):1433-1448.

McDaniel, R.L., M.L. Soupir, R.B. Tuttle, and A.E. Cervantes (2013) Release, dispersion, and resuspension of *Escherichia coli* from direct fecal deposits under controlled flows. *Journal of the American Water Resources Association*. 49(2):319-327.

Moreira, S., A. Brown, R. Ha, K. Iserhoff, M. Yim, J. Yang, B. Liao, E. Pszczolko, W. Qin and K.T. Leung (2012) Persistence of Escherichia coli in freshwater periphyton: biofilm-forming capacity as a selective advantage. *Federation of European Microbiological Societies Microbiology Ecology.* v79:608-618.

Ran, Q., B.D. Badgley, N. Dillon, G.M. Dunny, and M.J. Sadowsky. (2013) Occurrence, Genetic Diversity, and Persistence of Enterococci in a Lake Superior Watershed. *Applied Environmental Microbiology.* 79(9):3067–3075.

Reeves, R.L., S.B. Grant, R.D. Morse, C.M.C. Oancea, B.F. Sanders, and A.B. Boehm (2003) Scaling and management of fecal indicator bacteria in runoff from a coastal urban watershed in southern California. *Environmental Science and Technology.* 38(9), 2637–2648.

Rose, J.B., G.S. Sun, C.P. Gerba, N.A. Sinclair (1991) Microbial quality and persistence of enteric pathogens in graywater from various household sources. *Water Research.* v25: 37-41.

Sanders, B.F., F. Arega, and M. Sutula (2005) Modeling the dry weather tidal cycling of fecal indicator bacteria in surface waters of an intertidal wetland. *Water Research*. 39(14):3394–3408.

Sejkora, P., M.J. Kirisits, and M. Barrett (2011) Colonies of cliff swallows oh highway bridges: a source of *Escherichia coli* in surface waters. *Journal of the American Water Resources Association.* v47(6):1275 – 1284.

Skinner, J.F., J. Kappeler, and J. Guzman. (2010) Regrowth of enterococci and coliform in biofilm. *Stormwater.* Santa Barbara, California.

Solo-Gabriel, H.M. (2000) Ecological control of fecal indicator bacteria in an urban stream. *Environmental Science and Technology*. v44(2):631-637.

Solo-Gabriele, H.M. and F.E. Perkins (1997) Streamflow and suspended sediment transport in an urban environment. *Journal of Hydraulic Engineering*. 123(9):807–811.

Surbeck, C. Q., S. C. Jiang, and S. B. Grant (2010) Ecological control of fecal indicator bacteria in an urban stream. *Environmental Science and Technology*. v44(2):631-637.

Tiefenthaler, L., E.D. Stein, and G.S. Lyon (2008) Fecal indicator bacteria levels during dry weather from southern California reference streams. Southern California Coastal Water Research Project Technical Report 542, January 2008.

Tiefenthaler, L., E. D. Stein and K. C. Schiff (2011) Levels and patterns of fecal indicator bacteria in stormwater runoff from homogenous land use sites and urban watersheds. *Journal of Water and Health*. v9(2):279-290.

Walters, E., K. Schwarzwalder, P. Rutschmann, E. Muller, and H. Horn (2014) Influence of resuspension on the fate of fecal indicator bacteria in large-scale flumes mimicking an oligotrophic river. *Water Research.* 48:466-477.

Whitman, R. L., and M.B. Nevers (2003) Foreshore sand as a source of Escherichia coli in nearshore water of a Lake Michigan beach. *Applied Environmental Microbiology.* 69(9):5555–5562.

Wither, A., M. Rehfisch, and G. Austin (2005) The impact of bird populations on the microbiological quality of bathing waters, *Water Science and Technology*. v 51(3-4):199-207.

Zhu, X., J.D. Wang, H.M. Solo-Gabriele, and L.E. Fleming (2011) A water quality modeling study of non-point sources at recreational marine beaches. *Water Research.* v45:2985-2995.

This page intentionally left blank.

Appendix A

Literature Review Technical Memorandum

Memorandum

To: *Riverside County Flood Control and Water Conservation District*

From: *CDM Smith*

Date: *July 31, 2015*

Subject: *Literature Review for Uncontrollable Bacteria Sources*

The MSAR Bacterial Indicator TMDL includes a concentration based wasteload allocations (WLA) for MS4 Permittees for *E. coli* of 113 cfu/100mL, which is equal to the numeric water quality objective (126 cfu/100mL) minus a ten percent margin of safety (MOS). There is no data currently available to assess the portion of fecal indicator bacteria (FIB) measured at the TMDL compliance sites that may be attributed to uncontrollable sources, as defined in the recently adopted Basin Plan Amendment (BPA). Consequently, six technical studies are underway and comprise the Uncontrollable Source Monitoring Program (Program) for the MSAR watershed. The purpose of the Program is to better understand and quantify the influence of uncontrollable sources of FIB in waterbodies in the MSAR watershed.

A key task for the six uncontrollable sources studies is to conduct a literature review to determine the current scientific understanding for each of the fecal bacteria sources under investigation. This technical memorandum provides the literature review in the format of an annotated bibliography. For each reference, a brief summary of the study methods and pertinent findings is provided. The reference material is organized into four sections that represent the six sources of fecal indicator bacteria (FIB) under investigation as follows;

- **Direct inputs from wildlife** – Two studies are underway to evaluate the importance of wildlife in the Santa Ana River (SAR) and Cucamonga Creek. First, is a 'Natural' source study that collects samples from a segment of the SAR that has zero inputs from MS4s during dry weather and second is a 'Bird' source study that evaluates FIB upstream and downstream of two bridges; Mission Avenue over the SAR and Schleismann Road over Cucamonga Creek.

- **Resuspension from sediment/biofilm** - Two studies are underway to evaluate the importance of resuspension of FIB from sediment and or biofilm within conveyance facilities. The first study is of 'Sediment/Biofilm', and involves sampling of channel bottom sediment and biofilm from four tributaries of the SAR to determine the magnitude of FIB available for resuspension. The second study is of the impact of 'Non-MS4 flows' that cause a flow condition that may cause resuspension of FIB from sediment and biofilm on channel bottoms, such as from well blow-offs.

- **Shedding during swimming** – While the TMDL is intended to protect swimmers from potentially harmful pathogens, it is possible that the act of swimming could release FIB to the receiving water. A study is underway to evaluate FIB upstream and downstream of one popular swimming holes in the SAR.

- **Equestrian recreational use** – Equestrian uses exist within the SAR riparian area. A study is underway to evaluate whether feces from horses deposited along trails or directly to the river is a key contributor to downstream FIB concentration.

Direct Inputs from Wildlife

Byappanahalli, Muruleedhara N., Meredith B. Nevers, Richard L. Whitman, Zhongfu Ge, Dawn Shively, Ashley Spoljaric, Katarzyna Przybyla-Kelly (2015). Wildlife, urban inputs, and landscape configuration are responsible for degraded swimming water quality at an embayed beach, *Journal of Great Lakes Research*, v41: 1456-163.

Water samples were collected weekly between June-August 2010 from three sites at knee depth from Jeorse Park Beach in southern Lake Michigan. A total of 54 water samples were analyzed using culture based methods, Colilert-18 for *E. coli* and membrane filtration for *Enterococci*, and molecular methods, quantitative polymerase chain reaction (qPCR) for *Enterococci*, *Bacteroides* marker (HF183) for human and *Catellicoccus* for gull. Genomic DNA extraction was performed for fecal samples collected from gull, goose, and cormorants. *Enterococci* concentrations measured using qPCR (CCE) were significantly higher than by culture based membrane filtration (CFU); however the resulted were positively correlated. Host-specific makers for human and gull were detected in 15 and 37 percent of the water samples respectively. No relationship was found between the detection of the gull marker and indicator bacteria concentration. Lastly, a hydrodynamic model showed that the sampled beach exists within an embayment that has highly stagnant water and a circulation patterns that tends to entrain up-current contamination sources. A wide range of potential control strategies are discussed as well as planned activities for Jeorse Park. The investigators point to a gap in current microbial source tracking approaches that does not allow for quantification of the relative contribution from host-specific sources to total FIB levels.

Edge, Thomas A. and Stephen Hill (2007). Multiple lines of evidence to identify the sources of fecal pollution at a freshwater beach in Hamilton Harbour, Lake Ontario, *Water Research*, v41: 3585-3594.

Weekly samples were collected during the 2004 bathing season from beach sand, water at ankle and knee depth and two offshore sites. Concentrations of *E. coli* measured by membrane filtration methods were similar to other studies for water (10^2 to 10^5 cfu/100mL) and sand (10^4 to 10^7 cfu/100g[12]). Two library dependent methods, antimicrobial resistance and Rep PCR DNA fingerprinting analyses, were used to develop a library from approximately 2,000 isolates collected from numerous fecal samples from gulls, geese, ducks, dogs, cats, WWTP effluent, CSOs, and beach sand. Several accuracy measures documented the level of correctness of the applied methods. These methods were used to enumerate the relative contribution to *E. coli* in a sample from specific

[12] Roughly, one milliliter of water weighs one gram, thus the concentrations in sediment and water are equivalent

sources. The investigators found that birds and beach sands were the prominent sources of *E. coli* in samples collected from near shore sites.

Jiang, Sunny C., W. Chu, B. H. Olson, J.-W. He, S. Choi, J. Zhang, J. Y. Le, and P. B. Gedalanga (2007), Microbial source tracking in a small southern California urban watershed indicates wild animals and growth as the source of fecal bacteria. *Applied Microbiology and Biotechnology,* 76(4):927-34.

This study involved collection of samples from a small Orange County subwatershed for microbial source tracking (MST) using three methods; antibody resistance analysis (ARA), polymerase chain reaction (PCR) for *E. coli* toxin genes, and PCR detection of human adenovirus and enterovirus. Agreement between the ARA and toxin gene biomarkers was achieved. There were no detection of human enterovirus or adenovirus. Results indicated that human sources were not a major contributor. The most significant sources included birds, cows, and rabbits (one sample). Investigators discussed the lack of any cows within this drainage area and suggest that persistent detection of cows may be from organic mulch used in local landscaping. The City of Laguna Niguel found high levels of fecal coliform in organic compost collected from the same neighborhood in an independent study. Lastly, samples of dry weather runoff from street gutters were collected and used in a laboratory microcosm assay to measure *E. coli* growth potential. Results showed an increase in *E. coli* of 4-5 logs within 6-7 days, and translate to an exponential rate constant of 5.4 hr^{-1}.

Sejkora, Patrick, Mary Jo Kirisits, and Michael Barrett (2011). Colonies of cliff swallows oh highway bridges: a source of *Escherichia coli* in surface waters, *Journal of the American Water Resources Association*, v47(6): 1275 – 1284.

A study was conducted in 2009-2010 to assess the impact on bacteriological water quality from nesting cliff swallows under a Bridge over Bull Creek in Austin, Texas. Approximately 100 nests were directly above Bull Creek and another 275 were over land in the vicinity of the bridge. Samples were collected upstream and downstream of the bridge when swallows were present during dry (n=23) and wet (n=4) weather conditions. Results for dry weather samples showed a statistically significant increase in *E. coli* geometric mean concentration as water passed under the bridge from the upstream site (43 MPN/100mL) to the downstream site (106 MPN/100mL). This difference was not significant when the data was constrained to samples collected only during foraging periods, before and after the ~45 day nesting period. The greatest differences occurred during the nesting period when birds were more likely to deposit feces directly into Bull Creek. For the small (not sufficient for statistical t-test) dataset of wet weather when swallows were present, downstream samples had a substantially higher geometric mean concentration of *E. coli* (688 MPN/100mL) than upstream (78 MPN/100mL), which was attributed to mobilization of feces from land in the vicinity of the bridge. A supplemental sampling for *E. coli* at six hour intervals over the course of a single day was conducted to assess temporal variability. Results showed a fairly similar concentration of *E. coli* over the course of a day in Bull Creek, and a persistent patterns of higher downstream concentrations. Lastly, a load analysis was developed and used to estimate the contribution of *E. coli* from a single over-water nest of $3.1E^8$ MPN/100mL.

Tiefenthaler, Liesl, Eric D. Stein, and Greg S. Lyon (2008). Fecal indicator bacteria levels during dry weather from southern California reference streams, Southern California Coastal Water Research Project Technical Report 542, January 2008.

Fecal indicator bacteria, *E. coli*, Enterococcus, and total coliforms, were measured weekly over the course of a year (2007-2008) from 15 unimpaired 'reference' streams in Southern California[13]. Reference streams have no upstream development. Median concentration from all samples at all sites was 10 MPN/100mL for *E. coli* and 20 MPN/100mL for enterococcus. FIB were significantly positively correlated with stream temperature and exceedences of water quality objectives for *E. coli* only occurred in the summer and from less shaded and lower elevation sites within Orange and San Diego Counties. Of all the samples, there was no detection of *B. thetaiotaomicron,* indicating FIB in reference streams were likely of nonhuman origin.

Wither, A., M. Rehfisch, and G. Austin (2005). The impact of bird populations on the microbiological quality of bathing waters, *Water Science and Technology*, v 51(3-4): 199-207.

A study was conducted to relate bird densities with FIB on the Flyde coast of northwest England. Bird surveys underneath several piers along this coast supported roosts of Starlings with population of over 30,000. Fecal matter deposited underneath the roosts was collected over a site and then extrapolated over the total area under the piers to estimate the total fecal load from birds of 210 kg/night. The geometric mean of *E. coli* concentration in sampled fecal matter of $4.6E^{9}$ cfu/100g (range of $6.0E^{8}$ – $2.4E^{11}$ cfu/100g), results in an estimated number of *E. coli* of $9.6E^{12}$ cfu/night.

Resuspension from Sediment/Biofilm

Balzer, M., N. Witt, H.-C. Fleming and J. Wingender (2010). Faecal indicator bacteria in river biofilms, *Water Science and Technology*, v61(5): 1105-1111.

Samples of water and biofilms were collected from three German streams for ten events in 2004-05 and analyzed for total coliform population and culturable *E. coli* and Enterococci. Biofilm samples were categorized as being sourced from epilithic biofilm or sediment. Results showed greater geometric means for *E. coli* concentration within biofilms (20,000 MPN/100g) than the overlying water (25 MPN/100mL), with at least one order of magnitude difference in all samples. The same pattern occurred in results for Enterococci. The study also showed a lower fraction of culturable to total coliform bacteria in biofilms than water, which is supported by other studies of autochthonous faecal bacteria (originating from growth within biofilm).

Ksoll, Winfried B., Satoshi Ishii, Michael J. Sadowsky, and Randall E. Hicks (2007). Presence and source of fecal coliform bacteria in epilithic periphyton communities of Lake Superior. *Applied and Environmental Microbiology*, v73(12): 3771-3778.

This study evaluated fecal coliform and *E. coli* in periphyton communities from three sites on the Minnesota shoreline of Lake Superior. The study found an increase of fecal bacteria in periphyton of

[13] No sites were selected within the Middle Santa Ana River watershed in Riverside County

four orders of magnitude in the spring. Library based DNA fingerprinting using horizontal, fluorophore-enhanced repetitive (HPERP) methods were used and compared with the Duluth source library (including HPERP fingerprint for *E. coli* strains from numerous isolates of deer, geese, gulls, terns, beavers, and sewage). Results indicate that waterfowl were the predominant source of *E. coli* within periphyton communities of the identifiable fraction, a minority of the total *E. coli* from the three sites (specifically 2, 23, and 44 percent). Unidentified periphyton strains were added to the source library as two groups, those that were discovered to be unique to periphyton and those that were non-unique. Subsequent HPERP analysis of samples of the overlying water (collected at the time of periphyton sampling) provided a relative contribution from different sources of *E. coli*, with the major sources including waterfowl, sewage, and periphyton. The study also involved a microcosm experiment which found 99 percent of *E. coli* cells remained on periphyton-covered rocks unless agitated.

Moreira, Stefan, A. Brown, R. Ha, K. Iserhoff, M. Yim, J. Yang, B. Liao, E. Pszczolko, W. Qin and K.T. Leung (2012). Persistence of Escherichia coli in freshwater periphyton: biofilm-forming capacity as a selective advantage. *Federation of European Microbiological Societies Microbiology Ecology*, v79: 608-618.

This study involved characterization of biofilm forming capacity of *E. coli* from various sources, including naturalized periphytic *E. coli* isolates, from three temperate freshwater lakes in Canada. The experiment employed a crystal violet assay to differentiate the growth of bacteria associated with biofilm as opposed to planktonic (floating) in a series of microsm assays. Results showed the periphytic *E. coli* were significantly more competent at forming biofilms than isolates from any other source grouping, which included bovine, human, and known Shiga-like toxin producing serotypes from a mix of human and bovine hosts. They study also employed an assay for the curli expression (a surface protein key to attachment stage of biofilm formation), which has been hypothesized to be primary controlling factor for environmental biofilm formation and subsequent colonization and persistence of periphytic *E. coli*. The study results showed little correlation and suggest that other factors are important for periphytic *E. coli* in biofilms.

Skinner, J.F., Kappeler, J., and Guzman, J. (2010). Regrowth of enterococci and coliform in biofilm. *Stormwater*, Santa Barbara, California.

In a Newport, CA residential neighborhood, a study was conducted to assess the potential release of FIB from biofilms in a street gutter. Bacteria free hose water was discharged to the street gutter and samples were collected at 10, 45, and 100 meters downstream prior to the flow entering a street inlet. Results showed an increasing fecal coliform concentration as the flow moved downstream reaching 14,000 cfu/100mL at 100 meters. A second test was performed following street sweeping and found fecal coliform at the same 100 meter downstream site at 870 cfu/100mL. Biofilm samples were also collected from the street gutter and showed very high concentrations of FIB; ranging from $4.1E^4$ to $9.0E^6$ *Enterococci*/100g and $1.0E^4$ to $6.0E^6$ fecal coliform/100g. The lowest concentrations of FIB in biofilm samples were in samples with the shortest duration since rain or manual scraping had removed biofilm from the gutter surface.

CDM Smith

Solo-Gabriel (2000). Ecological control of fecal indicator bacteria in an urban stream. *Environmental Science and Technology*, v44(2): 631-637.

Monitoring of the North Fork of the New River, a coastal river in an urbanized region of south Florida was conducted to assess sources of *E. coli* using a sampling design to characterize spatial and temporal variability of *E. coli*, including sampling of sediment. Samples collected from the river were greater than from storm sewers, and two hotspots were identified for more detailed investigation. To assess temporal variability, autosamplers were used to collect hourly samples for a one week period from the two sites. Results showed increasing *E. coli* during high tide. At the same sites, intensive grids (n=35 and n=21) were used to characterize the river segment. Results showed the greatest water column concentrations along the river banks. Sediment samples (n=40) were also collected from transects of five river bank segments, three of which were centered on the hotspots in the river. The highest concentrations in riverbank sediments occurred near the hotpsots in long, shallow, and shaded embankments. The study also included a laboratory experiment to determine if *E. coli* can grow in riverbank sediment samples under different conditions of wetting and drying representing the impact of tidal fluctuations. Results showed that the sediment that was allowed to dry for longer periods of time had higher *E. coli* concentrations than if kept wet throughout the experiment. *E. coli* are able to survive longer period of drying than predators, which could explain the greatest concentrations in sediment and water at the outer fringes of the river banks.

Surbeck, C. Q., S. C. Jiang, and S. B. Grant (2010). Ecological control of fecal indicator bacteria in an urban stream. *Environmental Science and Technology*, v44(2): 631-637.

This study attempted to characterize the changes in FIB, *E. coli* and Enterococcus, within Cucamonga Creek by collecting water samples upstream of the POTW effluent and at several sites downstream for seven events during 2005-06. In many instances downstream samples showed higher *E. coli* concentrations than would be expected with a loading analysis. Microcosm studies were conducted for sample water to assess the potential growth or decay of FIB in a controlled environment. Results showed that dissolved organic carbon (DOC) concentration is a controlling factor in FIB survival within Cucamonga Creek. A threshold of 7 mg/L DOC was identified as indicating increased potential for growth (>7 mg/L) or decay (<7 mg/L).

Ferguson, Donna (2006). Growth of *E. coli* and Enterococci in Strom Drain Biofilm, presentation at the National Beaches Conference, October 13, 2006, Niagara Falls, New York.

Biofilm and overlying water was sampled from Costa Mesa Channel and analyzed for FIB; *E. coli* and *Enterococci*. Results showed very high concentration of *E. coli* ($1.8E^6$ cfu/100g) and *Enterococci* ($4.6E^6$ cfu/100g) in biofilm. The slideshow also described a laboratory method to assess biofilm and bacteria growth on a glass slide by placing it into a stormwater sample and inoculating with *E. coli* and *Enterocci faecium*. Results are shown visually but no quantification is provided.

Shedding during Swimming

City of Newport Beach and Santa Ana Regional Water Quality Control Board (2002). Swimmer Shedding Study in Newport Dunes, California. Report prepared by Sunny Jiang, Charlie McGee, Linda Candelaria, Garry Brown, and Dani Gold, http://www.waterboards.ca.gov/rwqcb8/water_issues/programs/tmdl/docs/swimmerreport.pdf

A study was conducted by the City of Newport Beach to investigate whether swimming uses increases FIB in waters. The study site was the Newport Dunes Resort, one of southern California's most popular family vacation spots. Results showed that water quality objectives were met in most samples and did not indicate any difference in FIB concentration at sites or sampling times with more swimmers.

Elmir, Samir M., Mary E. Wright, Amir Abdelzaher, Helena M. Solo-Gabriele, Lora E. Fleming, Gary Miller, Michael Rybolowik, Meng-Ta Peter Shih, Segaran P. Pillai, Jennifer A. Cooper, and Elesi A. Quaye (2007). Quantitative evaluation of bacteria released by bathers in a marine water, Water Research, v41: 3-10.

This paper summarized findings from two experiments of fecal bacteria shedding from bathers; referred to as the 'large pool' and 'small pool' studies. The large pool study evaluated the shedding of fecal indicator bacteria (*Staphyloccocus aureus* and *Enterococci*) from 10 test subjects into a sterilized inflatable pool filled with off-shore water from a marine beach in Miami-Dade County, Florida. The greatest concentrations of fecal bacteria were recorded following the first of four immersions. Shedding from the first immersion amounted to $6.1E^{6}$ cfu/100mL of *S. aureus* and $5.5E^{5}$ cfu/100mL of *Enterococci*. These shedding rates are comparable to other studies of bather shedding that involved immersion in freshwater and in supplemental studies by the investigators in 2009[14]. The small pool study was designed to measure the amount of sand and associated fecal bacteria transported from single subjects after recreating on beach sand for 15-30 minutes. Results show that *Enterococci* from shedding of sand was small relative to the total shedding from bathers.

Gerba, Charles P. (2000). Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality, *Quantitative Microbiology*, v2:55-68.

A literature review of pathogen shedding by swimmers is presented in this paper. Only one study was found that has evaluated the release of enteric pathogens to recreational waters from swimming just downstream of a groundwater spring at the headwaters of Oak Creek, Arizona (Rose et al, 1987[15]).

---

[14] Elmir, Samir M., Tomoyuki Shibata, Helena M. Solo-Gabriele, Christopher D. Sinigalliano, Maribeth L. Gidley, Gary Miller, Lisa R.W. Plano, Jonathan Kish, Kelly Withum, and Lora E. Fleming (2009). Quantitative evaluation of *Enterococci* and *Bacteroides* released by adults and toddlers in marine water, *Water Research*, v43: 4610-4616.

[15] Rose, J.B., R.L. Mullinax, S.N. Singh, M.V. Yates, C.P. Gerba (1987). Occurrence of rotaviruses and enteroviruses in recreational waters of Oak Creek, Arizona, *Water Research*, v21: 1375-1381.

Based on the concentration and flow rate, it was estimated that bathers shed over 16,000 viruses during the 30 minute period of the monitoring. The paper uses this shedding rate to extrapolate the potential shedding into a southern California reservoir with frequent water contact recreational use. Other literature was presented that analyzed fecal indicator bacteria shed from swimmers or bathers, which showed a common finding of 10^5 to 10^6 fecal coliforms per bather are shed, mostly within the first 15 minutes of water contact. One study by Rose et al. (1991[16]) found substantially higher fecal coliform concentration in bathwater from young children (10^5 MPN/100mL) compared with adults (10^1 to 10^2 MPN/100mL).

Zhu, Xiaofang, John D. Wang, Helena M. Solo-Gabriele, and Lora E. Fleming (2011). A water quality modeling study of non-point sources at recreational marine beaches, *Water Research*, v45: 2985-2995.

This study involved the use of a hydrodynamic model of a coastal recreational marine beach in Biscayne Bay near Miami. Bacteria inputs from three non-point sources were simulated, including a single fecal event by a large dog, a holiday day of recreational swimming, and release from beach sand during high tide for one hour. Literature values were used for inputs of per bather shedding of FIB of ~10^6 cfu/event. These rates were then extrapolated to the number of swimmers observed in images collected by an on-site surveillance camera. When the load from bathers was added to the hydrodynamic model, increases in *Enterococci* concentration accounted for less than 1 cfu/100mL. Thus, for this receiving water, recreational swimming is most likely not a source of FIB contamination.

Equestrian Use

Airaksinan, S., M.-L. Heiskanen, and H. Heinonen-Tanski (2007). Contamination of surface runoff water and soil in two horse paddocks, *Bioresource Technology*, v98: 1762-1766.

Wet weather surface runoff samples were collected from three sites at two horse paddocks in Eastern Finland during three storm events in 2002. Analyses included nutrients as well as indicators of microbial water quality. Soil samples were also collected from the sites but only evaluated for nutrients. Three horses resided in each paddock over the course of the study. One of the paddocks was cleaned daily and the other was left uncleansed. The quantities and concentration in the cleaned and uncleansed paddocks were similar over the three sampling events.

Tiefenthaler, L., E. D. Stein and K. C. Schiff (2011). Levels and patterns of fecal indicator bacteria in stormwater runoff from homogenous land use sites and urban watersheds, *Journal of Water and Health*, v9(2): 279-290.

Regional monitoring was conducted to estimate land use based EMCs for southern California. Monitoring spanned over 13 storm events in 5 southern California watersheds during the 2000–2005 storm seasons, and the selected stations were representative of 8 different LU types. The highest mean FIB concentrations were measured at the station downstream of mostly recreational land use;

[16] Rose, J.B., G.-S. Sun, C.P. Gerba, N.A. Sinclair (1991). Microbial quality and persistence of enteric pathogens in graywater from various household sources, *Water Research*, v25: 37-42.

with a confidence interval for *E. coli* of 5.3 +/- 1.7E^{5} MPN/100mL and statistically significant difference relative to other land use types, including commercial, high density residential, industrial, and transportation. The investigators suggest that the high bacteria from recreational land use could be due to the site being an equestrian facility.

Long, Sharon C. and Jeanine D. Plummer (2004). Assessing land use impacts on water quality using microbial source tracking, *Journal of American Water Resources Association*, v40(6): 1433-1448.

Samples were collected from 13 sites within the watershed to the Wachusett Reservoir that were determined to have drainage areas characterized by a single predominant land use type. Land uses types characterized by the study included residential, horse and dairy (grazing animal) operations, and forested. One site was downstream of a large pasture land and horse farm with a resident population of 7-15 horses. Fecal coliform samples collected during summer dry weather conditions from this site were the highest (1,200 cfu/100mL) of the 13 sampled sites (average of 233 cfu/100mL). *R. coprophilus* is a microbial source tracking indicator that is found at high levels in manure of grazing animals (although it does not originate in the gastrointestinal tract of these animals). Only the horse farm site detected this indicator above a threshold that indicates the presence of manure from grazing animals. The investigators used this MST tool to suggest that the source of bacteria at this site was from horse manure. Samples were also collected from the 13 sites during wet weather and winter dry weather. Statistically significant differences for the pooled data were detected based on season and weather condition.

Appendix B

Biological Assessment Technical Memorandum

Memorandum

To: *Mr. Steven Wolosoff, CDM Smith*

From: *Jennifer Jones, CDM Smith*

Date: *May 28, 2015*

Subject: *Findings of the Biological Survey*

Introduction

This memorandum presents the findings of a biological survey conducted by Jennifer Jones, CDM Smith biologist, on May 21, 2015. A nesting bird survey was conducted at the Cucamonga Creek and Mission Boulevard bridge sites in conjunction with water quality monitoring performed by the Riverside County Flood Control and Water Conservation District. In addition, a wildlife habitat assessment was conducted along the "Natural Study" reach.

Cucamonga Creek- Schleisman Road Bridge Site

Cucamonga Creek at this location is a concrete-lined, trapezoidal box channel (Photo 1). Water was flowing over approximately 40 feet of the channel width, and was approximately six inches deep in the deepest spot in the center of the channel. Wire netting was observed to cover over half of the underside of the bridge, presumably to keep birds from nesting in that area. The downstream one third of the bridge underside was not covered in netting.

Cliff swallows were observed flying over the channel and under the bridge. Approximately 60 birds were observed flying over the channel and visiting nests. The swallows were visibly disturbed by the biologist's presence and would not approach the nests if the biologist was standing under the bridge.

Adult birds were observed sitting in nests; nestlings were also observed in some nests (Photo 2). Adults visited nests on average every 2-3 minutes. A nest was considered active if it was observed to have a bird in it (either adult or nestling), or an adult visited the nest (but no other bird could be seen in the nest). Twenty-six active nests were observed: 17 located over the water and nine located over the dry part of the channel. Fecal waste was observed to be accumulating in the dry parts of the channel under the nests. The total number of cliff swallow nests (active and inactive) was 293 nests. Of these, approximately 170 were not located over the water.

Other birds observed near the bridge included barn swallow (1 individual), black phoebe (2), Brewer's blackbird (12), American crow (2), turkey vulture (1), and merlin (1). One barn swallow was observed to be visiting a nest in a storm drain channel upstream of the bridge.

Photo 1. Cucamonga Creek at the Schleisman Road Bridge

Photo 2. Active cliff swallow nests at the Schleisman Road Bridge. Adult birds can be seen in the lower two nests.

Santa Ana River- Mission Boulevard Bridge Site

The Mission Boulevard Bridge is very wide (over 1,000 feet), with water flowing only along the far western end of the channel. The biologist observed one half (the western half) of the underside of the bridge. The water was approximately one foot deep in the deepest part of the channel under the bridge, which appeared to be a depositional area where sand accumulates (Photo 3). Upstream and downstream of the bridge, the water appeared to be deeper (Photo 4). Several tents, homeless/vagrant persons and trash (shopping carts, spray paint cans, etc.) were observed under the bridge.

Approximately 45 cliff swallows were observed flying over the channel and visiting nests. Adult birds and nestlings (Photo 5) were observed sitting in nests. A total of 30 active nests were identified. Of the active nests, 18 were located over the water. The total number of cliff swallow nests observed under the western half of the bridge was 128. Nests were more dispersed than at the Cucamonga Creek bridge site, and there were more old nests that had been used in previous years.

Approximately 15 rock doves (pigeons) were also present and appeared to be nesting and/or roosting under the bridge. Courtship and territorial behavior was observed among rock doves, although nests were not visible.

Photo 3. Water flow was confined to one section of the Mission Boulevard Bridge.

Other birds observed included black phoebe (2), house wren (2), yellow warbler (1), common yellowthroat (1), Wilson's warbler (1), bushtit (10), Anna's hummingbird (1), and house finch (2). Several ground squirrels were observed. Habitat within the Santa Ana River channel in this area likely supports many songbirds, waterbirds, reptiles and amphibians, and mammals such as raccoon, possum, and coyote.

Photo 4. The Santa Ana River upstream of the Mission Boulevard Bridge.

Photo 5. Cliff swallow nestings in a nest under the Mission Boulevard Bridge.

Natural Study Reach

The “Natural Study” reach of the Santa Ana River extends from the wastewater treatment plant downstream to the Riverside Avenue Bridge. The biologist performed a general reconnaissance of portions of this reach to assess habitat and the potential for wildlife use.

The Santa Ana River in this location consists of a wide sandy wash with a narrow but well-vegetated riparian community of cottonwoods and willows along the main channel (Photo 6). Dominant shrub species include mulefat and coyote bush. Invasive plant species are prevalent throughout the reach and include castor bean, fennel, and Arundo (giant reed). At the time of the site visit, water was flowing approximately 25 feet wide in the main channel which is located along the western bank portion of the reach. In some areas, the channel has split into two channels with a vegetated sand bar in the middle. Aerial photos (from Google Earth) indicate that the wetted channel moves to the eastern portion of the reach further downstream toward Riverside Avenue. This portion of the channel was not observed during the site visit.

The reach is used by horse riders, as evidenced by prevalent horse tracks. Domestic dogs are likely to use the reach in association with horse riders, and a feral dog was observed in the vicinity. Other tracks observed included raccoon and rabbit. In addition, off-road vehicle tracks were observed along with some evidence of use by homeless and/or vagrants.

Small numbers of several bird species were observed during the site visit, including mallard, common raven, bushtit mourning dove, olive-sided flycatcher, blue grosbeak, Wilson’s warbler, yellow warbler, common yellowthroat, song sparrow, house finch, and American goldfinch. Other animals observed included a group of several juvenile Western toads, and a side-blotched lizard.

Riparian and in-channel habitat within the Natural Study reach likely support many songbirds, waterbirds, reptiles and amphibians, and mammals such as raccoon, possum, and coyote. The adjacent La Loma Hills located to the east of the Santa Ana River in this area provide open space with sparse scrub vegetation. However, the general lack of cover provided by the scrub vegetation likely precludes use of the area by large mammals such as mule deer or mountain lion. The area is surrounded by freeways on the north, east, and south sides, with the Santa Ana River to the west.

Limitations

This memo provides information gathered during brief bridge nest surveys and site reconnaissance conducted on May 21, 2015. While this is an active time for migratory songbirds, including nesting cliff swallows, other wildlife may be more prevalent and active during other times of the year. For instance, gulls have been observed using the Santa Ana River in large numbers during the winter. Other potentially important sources of bacterial contamination in the River, such as number and extent of homeless encampments, were not assessed during the biological site visit.

Photo 6. Riparian vegetation along the Natural Study reach of the Santa Ana River.

This page intentionally left blank.

Bacteria in Residential Subwatersheds is not Widespread — Results from a Residential Property-Scale Water Quality Study

Steven Wolosoff[1*], Rick Chappell[2], Tad Garrety[3], Ruben Valdez[4], and Marc Rodabaugh[5]

[1]CDM Smith, Boston, Massachusetts
[2]Envrionmental Compliance Services, Denver, Colorado
[3]City of Chino Hills, California
[4]City of Chino, California
[5]San Bernardino County Flood Control District, San Bernardino, California
[*] Email:wolosoffse@cdmsmith.com

ABSTRACT

A fecal bacteria source evaluation study was implemented in two southern California communities to characterize bacteriological water quality in dry weather irrigation excess runoff from residential drainage areas. Unlike rainfall-driven runoff where rain is spread across a watershed, the primary source of dry weather flow in the studied urban catchments is outdoor water use by individual properties. Spatial variability in property-specific bacteria water quality yields may cause extreme fluctuation observed in downstream monitoring data. To test this hypothesis, the property-scale dry weather bacteria study sought to characterize *E. coli* concentrations in dry weather flow resulting from irrigation of residential properties in Chino and Chino Hills. Numerous factors affect which properties would create offsite runoff at the time a downstream sample is collected, including irrigation schedules, irrigation system efficiency and timing of other outdoor water uses, which are a function of the routine of each property's residents. To develop statistically significant results, sites for sample collection were randomly selected. Samples were collected downstream of 80 properties in the 2014 dry season. Results for *E.coli* concentration fit a lognormal distribution with a geometric mean close to the water quality objective (126 cfu/100mL). Local watershed managers recognize the potential benefit of identifying certain behaviors or the presence of certain hosts as more likely to produce elevated bacterial indicators in irrigation excess dry weather flow. It may then be effective to implement source control practices targeting such behaviors or hosts, and, if implemented across a watershed, could yield significant improvements to receiving water quality during dry weather conditions.

INTRODUCTION

Since adoption in 2012, the Permittee MS4 programs have been actively implementing the Comprehensive Bacteria Reduction Plan (CBRP). The CBRP is a long-term plan designed to achieve compliance with dry weather flow (DWF) wasteload allocations for bacterial indicators established by the Middle Santa Ana River (MSAR) bacterial indicator TMDL. The CBRP includes a schedule of activities, which in the 2012-2014 dry seasons required implementation of bacteria source evaluation activities. Source evaluations conducted in 2012 focused monitoring on all major MS4 outfalls to TMDL waters (n = 34) for purposes of prioritization of upstream source evaluation and mitigation within MS4 networks. In the 2013 dry season, source evaluations involved rigorous monitoring activities to track down specific sources of bacteria within prioritized MS4 networks, employing similar methods to the Center for Watershed Protection Illicit Discharge Detection and Elimination (IDDE) guidance (Center for Watershed Protection, 2004). These efforts were effective in tracking down a few specific sources of bacteria for mitigation action; however, it was determined that extrapolation of this technique over much larger tributary areas would be infeasible. Given this, and limited scientific understanding of specific sources of fecal indicator bacteria (FIB) in urban watersheds during dry weather, the Cities of Chino and Chino Hills developed the Residential Property Scale Bacteria Study ("Study" hereafter). The primary objective of the Study is to characterize *E. coli* concentrations in DWF resulting from irrigation of residential properties in the Cities of Chino and Chino Hills in San Bernardino County, California.

One common finding of most water quality monitoring programs investigating FIB in urbanized watersheds is that results show extreme variation with samples ranging from non-detect to exceeding the range of measurement even after multiple dilutions, typically >24,000 mpn/100 mL (Urban Water Resources Research Council, 2014). This was also a general finding throughout the MSAR watershed for samples collected from MS4 outfalls and within networks in the 2012 and 2013 dry seasons (SAWPA, 2013). In fact, it was noted that such variability was discovered even when evaluating weekly samples collected during dry weather conditions from the same site and at similar times of day. Such results have led many scientists to broadly characterize FIB in urban watersheds as 'ubiquitous' (UWRRC, 2014; Noble et al., 2006; CWP, 2000), because high counts seem to be widespread spatially and temporally. This Study investigates the corollary condition, whereby FIB sources come from drainage areas that are identifiable and distinct from uncontaminated areas.

One hypothesis that may explain the apparent extreme variability in results is that bacteria washoff is linked to the quantity and quality of irrigation excess runoff from individual properties. Unlike rainfall driven runoff, where rain is spread across the entire watershed, the primary source of DWF in an urban catchment at any given point in time is outdoor water use by a single or small group of properties. Data from the Residential Runoff Reduction (R3) Study by Irvine Ranch Water District (IRWD) and Metropolitan Water District of Orange County (MWDOC) validate this hypothesis (A & N Technical Services, 2006). The R3 study involved installation of flow gauges downstream of several residential neighborhoods in Orange County. These gauges measured DWF that extended throughout most of the day indicating that not all properties generate irrigation excess runoff at the exact same time of day. The typical duration of an irrigation station is less than 15 minutes, thus FIB from a given property can only generate irrigation excess during a brief period of a day, excepting any substantial malfunction or misuse. Accordingly, a sample taken at any given time downstream of a residential neighborhood is likely only representative of the properties that were actively generating irrigation excess runoff immediately prior to the sample collection. In other words, consecutive (with more than 15 minute separation) samples within MS4s or at outfalls taken from the same site may be representative of completely different contributing subareas.

Through field reconnaissance, it has been observed that the predominant source of DWF at MS4 outfalls throughout the MSAR watershed is irrigation excess runoff from residential properties (personal communication with Ruben Valdez and Robert Vasquez, March 18, 2015). Another study of dry weather bacterial water quality conducted in San Diego determined that 80 percent of DWF from residential MS4 outfalls is from irrigation excess runoff (Weston, 2009). Numerous factors impact which property(ies) would be creating irrigation excess runoff at the time a downstream sample is collected, including irrigation schedules, irrigation system efficiency, and timing of other outdoor water uses, which are a function of the day to day routine of each resident at each property. Most residential irrigation excess DWF is conveyed from an individual landscaped zone to the street gutter in one of two ways; either as sheet flow across the sidewalk and/or driveway (Figure 1a) or via a small underdrain that has an outfall in the curb and is typically used to collect excess runoff from a backyard (Figure 1b).

Figure 1

Typical irrigation excess runoff from front yards (a) and back yards via an underdrain (b) *Photo credit: Ruben Valdez*

The Study results address two key questions that will influence decisions by watershed managers charged with meeting the TMDL for bacteria in downstream waters; 1) what is the proportion of properties with elevated DWF and/or FIB concentrations that may be contributing to downstream impairments? And 2) whether there are any unique characteristics of properties with elevated concentrations of FIB?

METHODS

Together the Cities of Chino and Chino Hills visited over 300 randomly selected residential properties in the Cypress Chanel (CYP) and Boys Republic South Channel (BRSC) drainage areas to observe DWF conditions and where possible, collect water quality samples for bacteriological analysis. Table 1 provides an inventory of field visits and water quality sample collection over the course of the Study within the investigated MS4 drainage areas. The field crews targeted early morning hours (between 4:00am and 8:00am) to perform site visits in order to increase the likelihood of encountering DWF when residents are more likely to have scheduled irrigation timers per landscaping recommendations and local water conservation ordinances. The early morning sampling was also appropriate because travel times from an individual property to TMDL waterbody segment would lag the delivery of irrigation excess to receiving waters until mid-day when there is the greatest exposure potential from water contact recreational use.

Table 1. Dates and number of site visits and samples collected from each subwatershed during the Study

Sampled Week	BRSC		CYP		Total Sum of Visits	Total Sum of Samples
	Visits	Samples	Visits	Samples		
8/21/2014	21	8	10	0	31	8
8/28/2014	32	11	11	0	43	11
9/3/2014	47	9	12	3	59	12
9/11/2014	30	8	9	2	39	10
9/18/2014	20	8	10	4	30	12
9/25/2014	33	11	11	3	44	14
10/2/2014	12	3	12	4	24	7
10/9/2014			12	2	12	2
10/17/2014			9	4	9	4
Total (2014)	195	58	106	22	301	80

The Study design recognized the challenge of collecting water samples from a randomly selected address, given the expected short duration of irrigation excess runoff from a randomly selected property (<30 minutes), and therefore involved an unbiased protocol to locate nearby DWF for collection of field observations and water samples (Figure 2). The protocol involved tracking any DWF in the street gutter adjacent to the randomly selected address to its most upstream source. Field observation and water samples were then collected at the address of the residential property that was the most upstream source of DWF.

Care was taken to follow field sampling protocols detailed in a Regional Board approved QAPP for sample collection to avoid contamination by the sampler (http://www.sawpa.org/wp-content/uploads/2013/01/MSAR-QAPP-July-2013.pdf). Samples of DWF stored in iced coolers and chains of custody were delivered to Weck Labs in Industry, CA (weeks 1-3) and Clinical Labs in San Bernardino, CA (weeks 4-9) for analysis of *E. coli* concentration using the IDEXX Colilert method (SM 9223B). One QA/QC sample was collected at each field campaign including a replicate and equipment blank.

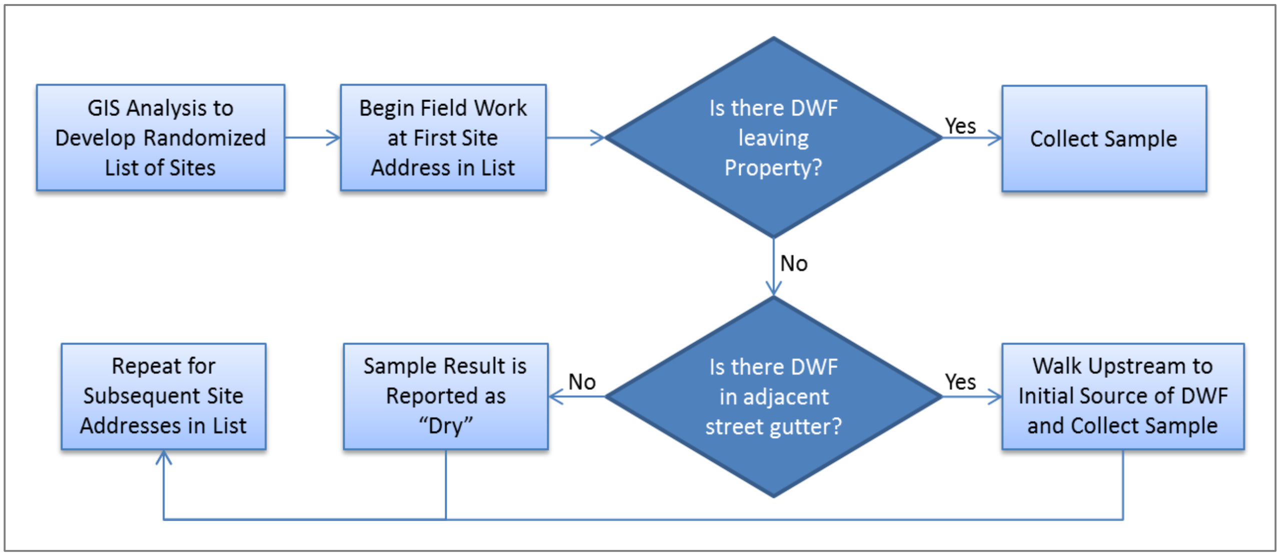


Figure 2
Protocol to select sites for DWF sample collection

Field observations included address of sampled property, description of the source of dry weather flow, if identifiable (e.g. front yard irrigation, backyard irrigation, car washing, etc.), qualitative descriptions of relevant water conditions (e.g., color, clarity, flow category, trash, odors, pets) and weather (e.g., wind, rain) at the time of sample collection.

RESULTS

Summary statistics for each of the subwatersheds are presented in Table 2. Geometric means of *E. coli* from properties in the BRSC and CYP drainage areas were 101 and 233, respectively. When pooling the data from both drainages, the geomean of all 80 properties was 127 mpn/100mL. The data show wide variability with many samples at the limits of detection (typically 10 mpn/100mL) or upper range of countable measurement (typically 24,000 mpn/100mL). A similar range of concentration was observed in a study of irrigation excess runoff *(n=23)* in Orange County, CA coastal drainages (Rippy et. al., 2014). As shown in Figure 4, a single-component lognormal model provided the best fit to the distribution of data from the pooled dataset. Given the lognormal distribution, the arithmetic mean is much greater than the geomean or median, as shown in Table 2.

For the 2014 Study data, a workbook application was developed that uses bootstrapping to estimate a population parameter representing the fraction (percentage) of the population above a certain *E. coli* concentration threshold, along with the margin of error (or confidence interval) for the estimated parameter. Bootstrapping involves resampling of the dataset with replacement, a nonparametric method of estimating a population parameter from a random sample. The workbook application generates bootstrap statistics for a selected threshold. The output of the bootstrapping is reported in Table 3 for the average percentage of the population above an *E. coli* value of 235 mpn/100 mL, the current single sample maximum (SSM) water quality objective, and 410 mpn/100mL, a recently published statistical threshold value (STV) for freshwaters (EPA, 2012). Results indicate that at the 95 percent confidence level, 41.2% ± 11.3% of the population of properties in the two drainages would be expected to exceed the SSM, and that

Table 2. Summary statistics for *E. coli* concentration

Statistic	*E. coli* concentration (mpn/100mL)		
	Boys Republic South Channel (n = 58)	Cypress Channel (n = 22)	Pooled Study Data (n=80)
Geomean	101	233	127
Coefficient of variation	0.56	0.34	0.50
Minimum	1	10	1
Median	84	205	119
Arithmetic Mean	1,548	1,056	1,413
Maximum	24,196	9,200	24,196

29.9% ± 10.0% would be expected to exceed the STV.

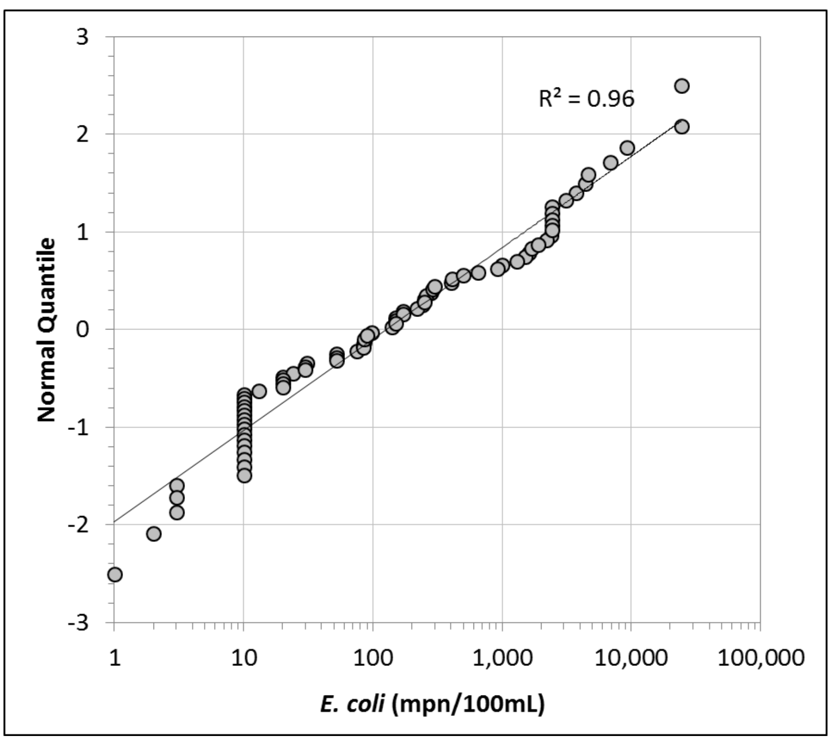


Table 3. Results of the Bootstrapping Analysis for Percent Exceedance Analysis		
Sample Size	80	80
Population Value	235	410 [1]
Confidence Level	95	95
Number of Resamples	10,000	10,000
Mean Fraction of Exceedances	41.2	29.9
Lower Confidence Limit	30.0	20.0
Upper Confidence Limit	52.5	40.0
Margin of Error	±11.3	±10.0

1) STV recommended in Recreation Water Quality Criteria (EPA, 2012). This STV is based on use of a different analytical method (EPA 1603) than was employed in this study; however, results have been shown to be comparable within +/- 15 percent (Buckalew et al., 2006)

The same bootstrapping method was applied to determine the uncertainties in the arithmetic and geometric mean *E. coli* concentrations, resulting in an estimated 95 percent confidence interval of 674 to 2384 mpn/100mL for the arithmetic mean and 68 to 200 mpn/100mL for the geometric mean (Table 4).

Table 4. Results of the Bootstrapping Analysis for Estimation of Population Central Tendency

Parameter	Mean	Geomean
Sample Size	80	80
Confidence Level	95	95
Number of Resamples	10,000	10,000
Confidence Level	95	95
Lower Confidence Limit	674	68
Upper Confidence Limit	2384	200
Margin of Error	-741 to +969	-53 to +80

Power analyses were also conducted to assess the dataset sizes needed to reduce the margin of errors or confidence intervals for planning of supplemental source evaluation studies. For the percent exceeding determination (Figure 5), results indicate that reducing the margin of error from about ±10 percent with the current data set of n=80 to about ±5% would require a sample size of over 300 samples, or an additional 220 samples. Correspondingly, such a sample size increase would decrease the 95% confidence interval around the mean from 674 - 2384 MPN/100mL (n=80) to 998 -1892 MPN/100mL (n=300), and would decrease the 95% confidence interval around the geomean from 68 – 200 MPN/100mL (n=80) to 87 – 153 MPN/100mL (n=300)

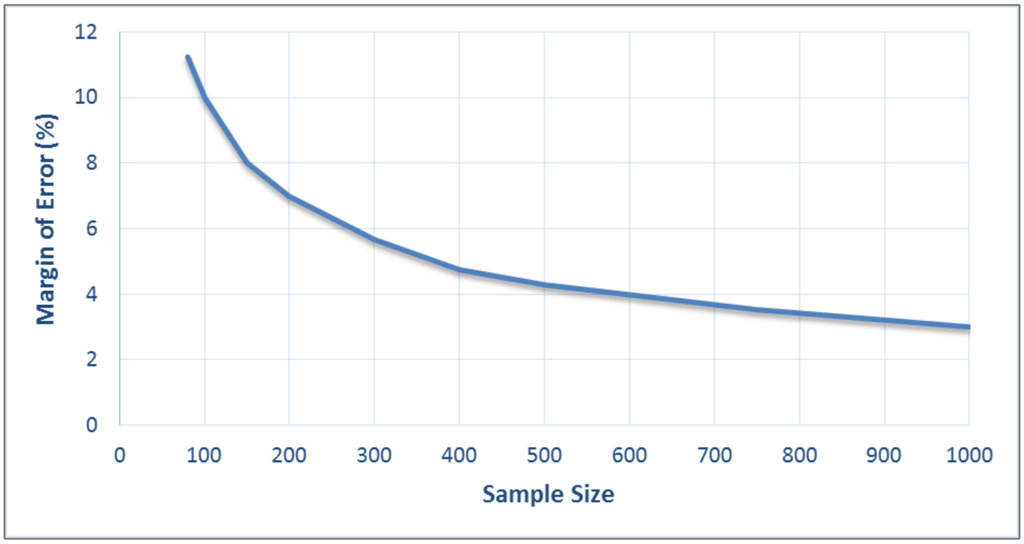


Figure 5
Power analysis for E. coli > 235 MPN/100mL for Margin of Error as a function of sample size

Potential Explanatory Variables

The dataset also included field observations, which were used to separate *E. coli* data into different groups that could be compared to determine whether differences between the groups are statistically significant. Field observations and desktop analysis of aerial imagery did not reveal any characteristics of residential properties to differentiate sampled properties. Attachment A contains field observations and photographs recorded by staff from the Cities of Chino and Chino Hills. None of the sampled properties appeared to have any obvious sources of fecal, except for a few where dogs were noted in the backyard.

One significant explanatory variable identified in the Study was the flowpath where samples were collected between the irrigation sprayhead and MS4. Three distinct types of flowpaths for irrigation excess runoff sampled during the Study were identified:

- Many properties are developed with small diameter (<4”) perforated backyard drains designed to convey water from oversaturated soil to the MS4. Typically, such drains are within 1 foot of the ground and outflow to the street gutter through an opening in the curb (see Figure 1b above);

- The soils underlying typical front yards are highly compacted and often cannot percolate irrigation water at the rate it is applied. Consequently, a portion of the irrigation water moves laterally downgradient through the thatch and ultimately exits the lawn and becomes sheet flow over sidewalks and driveways, and

- Some samples were collected directly from street gutters immediately downstream of the randomly selected address and may include a blend of DWF from upstream properties.

E.coli concentrations from the three flowpath groups are shown as box-whisker plots in Figure 6. Possible significant differences between the three sampled flowpaths were tested using the computer program ProUCL (USEPA, 2013). Both parametric on the log-transformed data and nonparametric tests on the ranked data were conducted. First, an analysis of variance (ANOVA) was conducted to determine whether there was a statistical difference among the three groups. The respective p-values were 0.0144 (parametric ANOVA) and 0.0125 (nonparametric ANOVA) which, since both p-values are below the critical alpha level of 0.05, indicate that indeed there is a statistically significant difference among the three groups. Next, multiple comparison tests were conducted to identify which of the individual groups are statistically different. The multiple comparison tests were parametric t-tests and nonparametric Wilcoxon-Mann-Whitney (WMW) tests. However, since the multiple comparisons involved multiple applications of the two tests, the critical alpha level was adjusted via the Bonferroni method by dividing the overall alpha by the number of groups (i.e., 0.05/3 = 0.017) to guard against inflation of the false positive error rate. The multiple comparison tests indicated that only front yard versus gutter is statistically different (p-value = 0.005 for both the parametric t-test and nonparametric WMW test); front yard versus back yard, and back yard versus gutter were not statistically different (p-value > 0.017).

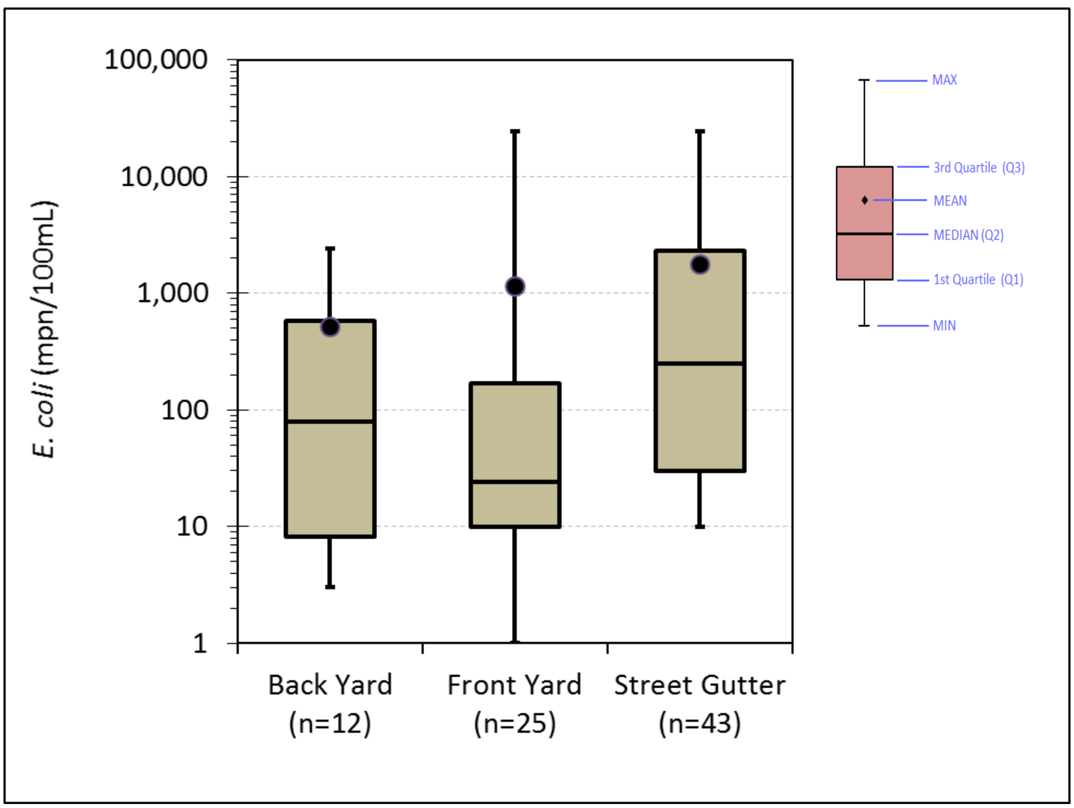


Figure 6

Box-Whisker Plots for *E. coli* Concentration for Samples from Front Yard, Back Yard, and Street Gutter Flowpaths

DISCUSSION

Irrigation water is potable when it is emitted from spray heads and has the potential to washoff FIB as it travels through lawns and other landscape areas to street gutters into MS4s and then to receiving waters. The Study collected samples from very small drainage areas, sometimes as small as the active irrigation zone at the time of sampling (~500 ft^2). A key question is whether such a small drainage area can significantly influence downstream water quality. In addressing questions related to water quality, it is first necessary to understand the hydrologic processes associated with downstream flow, in this case during the dry season. Data collected from MS4 outfalls to receiving waters in the Santa Ana River watershed conducted in 2011-2014 identified a persistent and not negligible rate of dry weather flow from urban drainage areas to tertiary treated effluent dominated receiving waters (SAWPA, 2013). Thus, bacteria contribution in irrigation excess runoff from residential properties, taken as a whole, are a key factor to complying with the TMDL requirements.

The lognormal distribution of *E.coli* concentration indicates that variability is related to differences in source areas at the property scale, and that it is likely that elevated bacteria levels measured at MS4 outfalls may be caused by a minority of proprieties that contain a source of FIB. The concentration of *E. coli* at an MS4 outfall would be approximated by computing a flow-weighted average of irrigation excess from all properties contributing DWF at the point of sampling. Assuming the rate of irrigation excess DWF is similar for many properties, then the *E. coli* concentration of inputs to the MS4 would be equal to the arithmetic mean shown in Table 2. Thus, a small fraction of properties may cause very high *E. coli* concentrations in DWFs to the MS4 compared with a typical (50^{th} percentile) property. In other words, a majority of properties may not cause or contribute to impairments of recreational use in downstream receiving waters. This finding serves to further reduce the area of concern for watershed managers within prioritized subwatersheds. Moreover, prioritization of watershed management actions at the subwatershed scale, as is commonly employed, may overallocate resources in some areas while neglecting to address sources in others. Given this conclusion, several scenarios should be considered by watershed managers charged with meeting WLAs in the MSAR bacteria TMDL, as follows:

- If the source of FIB is identifiable and determined to be controllable, then watershed managers will have the ability to conduct enhanced source control throughout their MS4 drainage areas, such as with a combination of targeted education and outreach and code enforcement. Effective control of select properties may be achieved by reducing irrigation excess runoff, as opposed to imposing restrictions involving other behaviors.

- If the source of FIB is identifiable and determined to be uncontrollable, watershed managers may demonstrate that human activities associated with the urban environment are not directly causing or contributing to downstream impairments of recreational use. Uncontrollable sources of bacteria in this watershed area have been defined in a recent Basin Plan Amendment (Santa Ana Regional Water Quality Control Board, 2014) and include several that may exist within residential neighborhoods, such as wildlife activity and waste, bacterial regrowth within sediment or biofilm, and resuspension from disturbed sediments.

- Lastly, if the source of FIB is not identifiable, then it may be the case that enhanced source control could be ineffective by not focusing on the key source, and instead watershed managers would be best served through further study (such as is proposed below) or implementation of downstream controls.

One significant explanatory variable was identified suggesting significantly higher *E. coli* concentrations in samples collected from street gutters, as opposed to from backyard drains or sheet flow from front yards. This finding suggests that the most important source of FIB from residential neighborhoods may be from street gutters and not residential lawns. A similar conclusion was drawn from a special study conducted by the City of Newport Beach. Potable hose water was discharged to four residential street gutters and samples collected from the same street gutter at a downstream site were found have been enriched with FIB to levels well above recreational use standards, ranging from 230-14,000 cfu/100mL (Skinner et al., 2009).

The presence of indicator bacteria in biofilms has been hypothesized to be the reason for their extended survival in sediments and their ability to act as a loading source to the overlying water (Ferguson, 2006; Sanders et al., 2005). Additionally, the presence of biofilm is believed to explain fecal indicator bacteria regrowth in storm drains. For example, in one study, concentrations increased three to four orders of magnitude over 48 hours (Martin and Gruber, 2005). Surbeck et. al. (2010) studied FIB survival and growth in Cucamonga Creek, a large open flood control channel, and concluded that FIB are not “static pollutants with land use based characteristics, but rather an ecological phenomenon, in which a dynamic balance between sources, nutrient availability, competition with other heterotrophic bacteria, and predator prevalence determines the magnitude and extent of FIB pollution and its human health implications.” Although not well studied to date, biofilms may also exist within segments of typical residential street gutters with favorable conditions. If so, it may be possible that irrigation excess runoff acts as an indirect source of FIB to street gutters, where survival and exponential growth is supported by a wetted habitat, prior to resuspension and transport to the MS4 network. Conversely, others have found that direct inputs of FIB to MS4s are a more important source than growth and resuspension from biofilms in urban subwatersheds, especially when human sewage sources are discovered (Ekklesia et. al., 2014; Sercu et al., 2009).

At this point in time, an obvious source of FIB was not determined from field observations and *E. coli* concentrations alone, although the importance of sediment and biofilm in street gutters as potential habitat provides a useful clue for developing supplemental monitoring and for focusing watershed management actions. There are many possible sources of FIB to street gutters and ultimately to MS4s and receiving waters during dry weather. This Study showed that one possible source could be associated with material mobilized from residential lawns with irrigation excess runoff. But what is the source of such material? Jiang et al (2007) identified a prevalence of *E. coli* markers specific to bovine sources in samples from an urban subwatershed in Orange County, CA that was attributed to the use of cow manure that is not completely inactivated in amended mulch. Many studies of FIB in urban DWF in southern California have identified wildlife as an important source (Mau and Stoeckel, 2012; Jiang et. al., 2007; Shergill and Pitt, 2004). Wildlife may be more attracted to street gutters than lawns because of the more persistent source of water for drinking or bathing. Another potential source of FIB to street gutter sediments is from vehicles' tires that had traveled to an area of greater potential bacteria contamination, such as a trash facility (Chambers et al., 2009).

A subset of samples collected in this Study have been preserved for future microbial source tracking (MST) analysis. Supplemental monitoring will involve testing of these samples as well as collection of additional samples for MST analysis. If the true source (i.e. host organism from where FIB originated) can be identified, it may provide the final clue needed to determine if a predominant source and pathway for FIB exits in the residential drainage areas within the Cities of Chino and Chino Hills as well as other suburban watersheds.

REFERENCES

A & N Technical Services, 2006. Commercial ET-Based Irrigation Controller Water Savings Study, prepared for Irvine Ranch Water District and US Bureau of Reclamation.

Buckalew, D. W., L. J. Hartman, G. A. Grimsley, A. E. Martin, and K. M. Register (2006). A long-term study comparing membrane filtration with Colilert ® defined substrates in detecting fecal coliforms and *Escherichia coli* in natural waters, *Journal of Environmental Management*, v80:191-197.

CDM Smith (2014). Residential Property Scale Bacteria Water Quality Study, Technical memorandum, August 7, 2014.

Center for Watershed Protection. 2004. Illicit Discharge Detection and Tracking Guide. Center for Watershed Protection, Ellicott City, MD.

Chambers, Molly K., Malcolm R. Ford, Daniel M. White, David L. Barnes, and Silke Schiewer (2009), Transport of fecal bacteria by boots and vehicle tires in a rural Alaskan community. *Journal of Environmental Management*, v90: 961-966.

Center for Watershed Protection and R. Pitt. (2004). Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments. Center for Watershed Protection, Ellicott City, MD, and University of Alabama, Tuscaloosa, AL. http://www.cwp.org/online-watershed-library/cat_view/64-manuals-and-plans/79-illicitdischarge-detection-and-elimination

Ekklesia, E., Shanahan P., Chua L. H., Eikaas H. S. (2015). Temporal variation of faecal indicator bacteria in tropical urban storm drains, *Water Research*, v68: 171-181.

Environmental and Water Resources Institute (2014). Pathogens in Urban Stormwater Systems. Report prepared by Urban Water Resources Research Council, Pathogens in Wet Weather Flows Technical Committee, EWRI American Society of Civil Engineers, with support from Urban Drainage and Flood Control District, Denver, CO and Urban Watersheds Research Institute, August 2014.

Ferguson, Donna (2006). Growth of E. coli and Enterococci in Strom Drain Biofilm, presentation at the National Beaches Conference, October 13, 2006, Niagara Falls, New York.

Jiang, Sunny C., W. Chu, B. H. Olson, J.-W. He, S. Choi, J. Zhang, J. Y. Le, and P. B. Gedalanga (2007), Microbial source tracking in a small southern California urban watershed indicates wild animals and growth as the source of fecal bacteria. *Appl Microbiol Biotechnology*, 76(4):927-34.

Martin, A., and Gruber, S. (2005). "Amplification of indicator bacteria in organic debris on Southern California beaches." StormCon Conference, July 18-21, 2005. Orlando, FL. Technical Report #0507 Weston Solutions.

Mau, David and Donald Stoeckel (2012). Evaluation of Fecal Contamination by Human and Ruminant Sources in Upper Fountain Creek, Colorado, 2007-08, by Using Multiple Lines of Evidence. US Geological Survey Fact Sheet 2011-3095.

Noble, R.T., Griffith, J.F., Blackwood, A.D., Fuhrman, J.A., Gregory, J.B., Hernandez, X., Liang, X., Bera, A.A., Schiff, K. (2006). "Multi-tiered approach using Quantitative Polymerase Chain Reaction for tracking sources of fecal pollution to Santa Monica Bay, CA." *Appl. Environ. Microbiol*. 72 (2): 1604-1612.

Rippy, Megan A., R Stein, BF Sanders, K Davis, K McLaughlin, JF Skinner. (2014). Small Drains, Big Problems: The Impact of Dry Weather Runoff on Shoreline Water Quality at Enclosed Beaches. *Environmental Science and Technology*, v48 (24): 14168-14177.

Sanders, B.F., Arega, F., and Sutula, M. (2005). Modeling the dry-weather tidal cycling of fecal indicator bacteria in surface waters of an intertidal wetland. *Water Research*. 39(14): 3394-3408.

Santa Ana Regional Water Quality Control Board (2014). Amendments to the Water Quality Control Plan for the Santa Ana River Basin, Resolution No. R8-2012-0001, www.swrcb.ca.gov/rwqcb8/water_issues/programs/basin_plan/recreational_standards.shtml.

SAWPA (2013). Comprehensive Bacteria Reduction Plan Implementation Report, prepared by CDM Smith, February 2013, http://www.sawpa.org/wp-content/uploads/2013/01/CBRP-TMDL-Implementation_Final.pdf

Sercu, B.S., Van De Werfhorst, L.C., Murray, J.L.S., and Holden P.S. (2009). Storm drains are sources of human fecal pollution during dry weather in three urban southern California watersheds. Environ. Sci. Technol. 43(2):293-8.

Shergill, S.S. and Pitt, R. (2004). "Quantification of Escherichia coli and enterococci levels in wet weather and dry weather flows." Presented at the *77th Annual Water Environment Federation Technical Exposition and Conference*. New Orleans, LA. Oct 4 – 7.

Skinner, J.F., Kappeler, J., and Guzman, J. (2010). Regrowth of enterococci and coliform in biofilm. *Stormwater*, Santa Barbara, California

Surbeck, C. Q., S. C. Jiang, and S. B. Grant (2010). Ecological control of fecal indicator bacteria in an urban stream. *Environmental Science and Technology*, v44 (2): 631-637.

USEPA (2013). ProUCL version 5.0.00. URL: http://www.epa.gov/osp/hstl/tsc/software.htm.

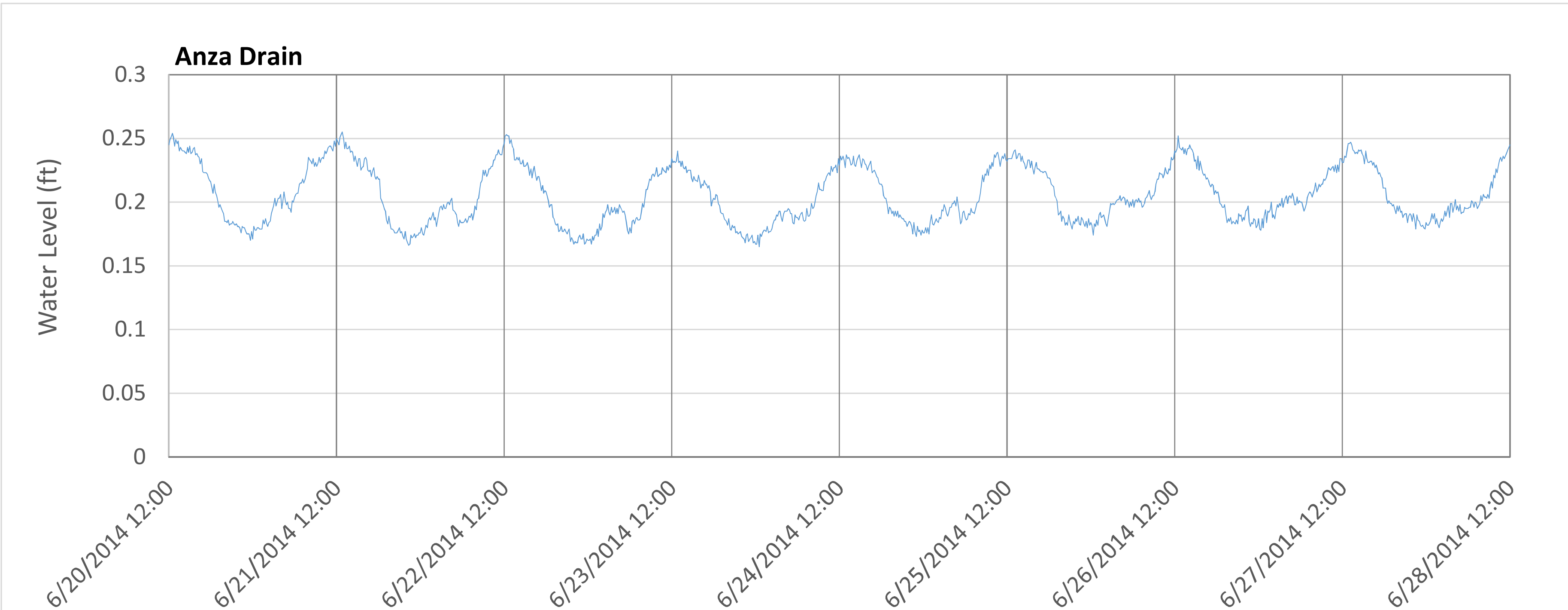
Appendix B

Hydrologic Data

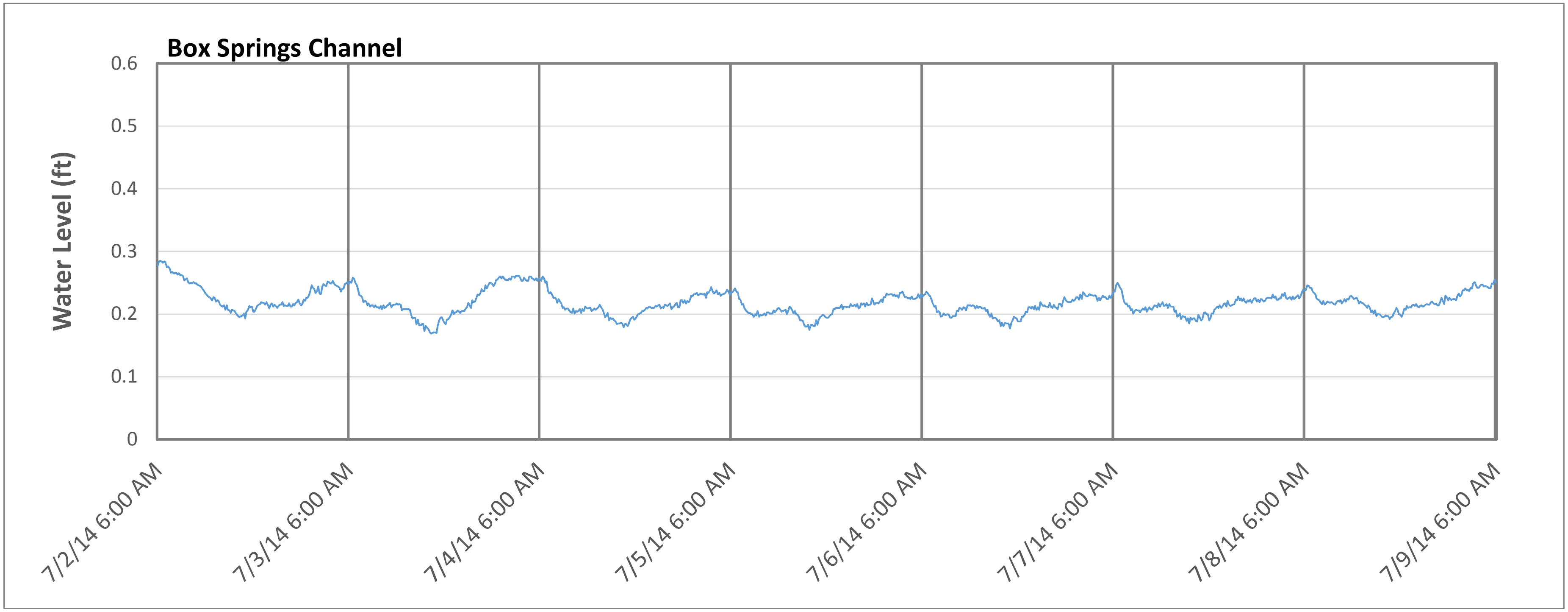
This appendix contains time series plots of continuous hydrologic data used to characterize discharges to the impaired waters, as follows:

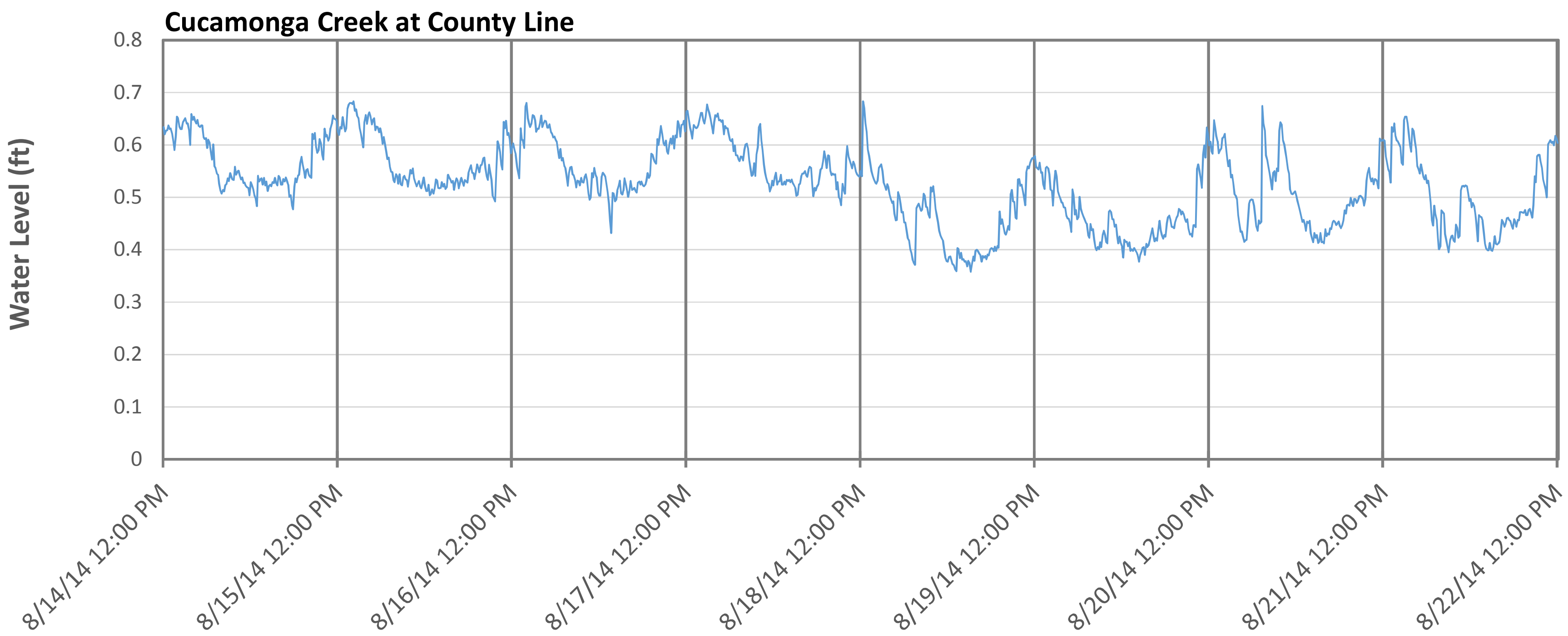
- Part 1 – Water level records from RCFC&WCD flood control channels in the MSAR watershed. One week snippets are provided herein; however the full period of record (up to 2 yrs) may be obtained as raw data from RCFC&WCD as needed. Pages A-2 through A-16

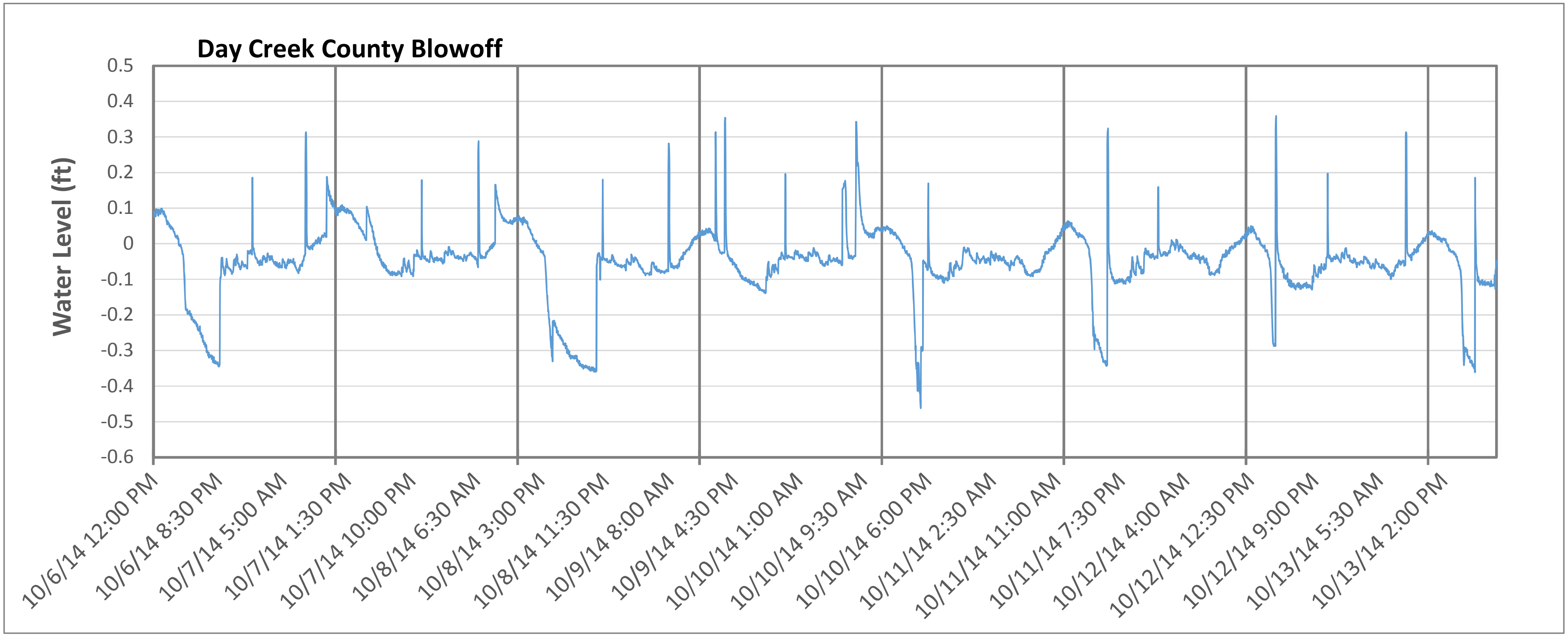
- Part 2 – Daily discharge from POTWs to the impaired waters in the MSAR watershed for water years 2012/13, 2013/14, and 2014/15. Pages A-17 through A-34

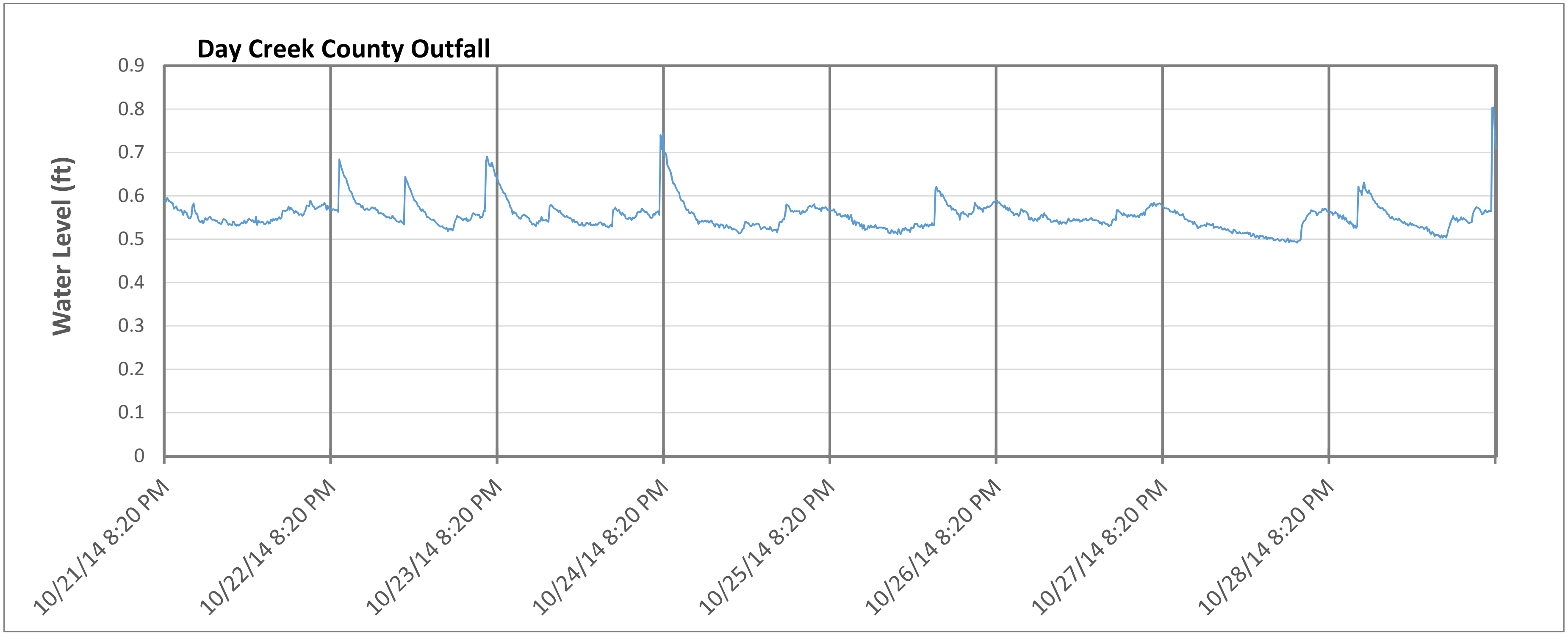


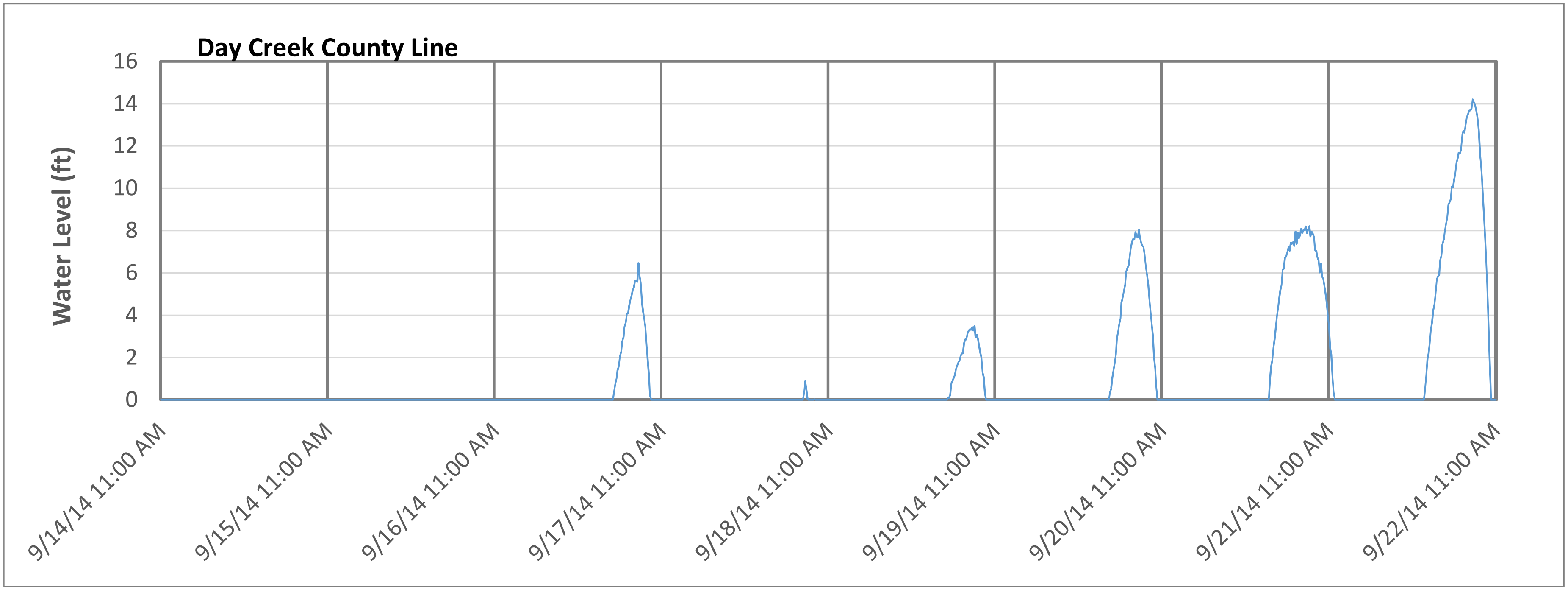
Anza Drain
Water Level (ft)
0.3
0.25
0.2
0.15
0.1
0.05
0
6/20/2014 12:00
6/21/2014 12:00
6/22/2014 12:00
6/23/2014 12:00
6/24/2014 12:00
6/25/2014 12:00
6/26/2014 12:00
6/27/2014 12:00
6/28/2014 12:00

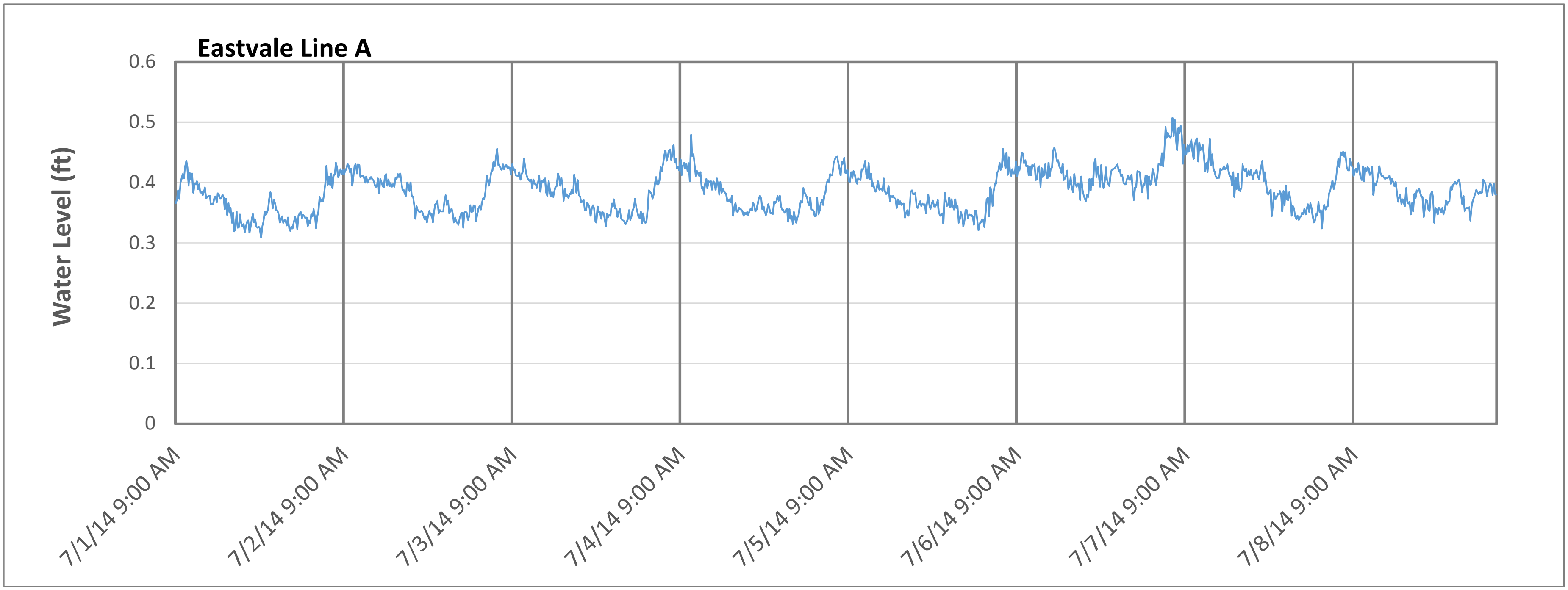

Box Springs Channel
Water Level (ft)
0.6
0.5
0.4
0.3
0.2
0.1
0
7/2/14 6:00 AM
7/3/14 6:00 AM
7/4/14 6:00 AM
7/5/14 6:00 AM
7/6/14 6:00 AM
7/7/14 6:00 AM
7/8/14 6:00 AM
7/9/14 6:00 AM

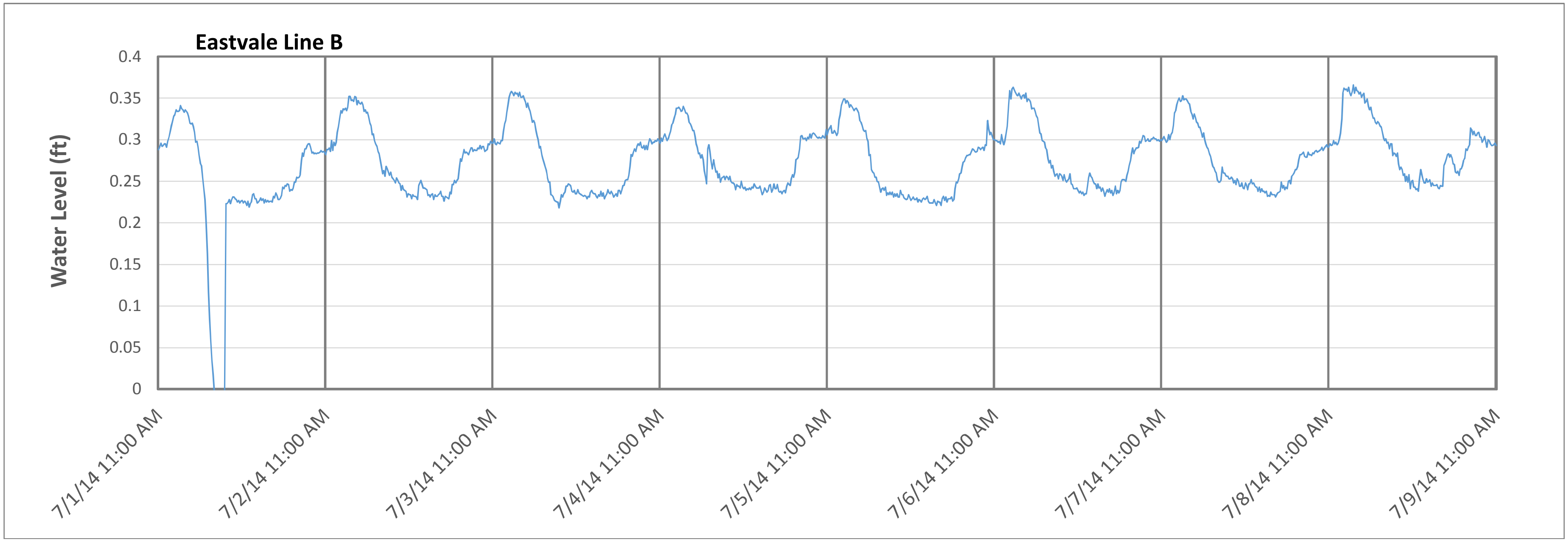

Cucamonga Creek at County Line
Water Level (ft)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
8/14/14 12:00 PM
8/15/14 12:00 PM
8/16/14 12:00 PM
8/17/14 12:00 PM
8/18/14 12:00 PM
8/19/14 12:00 PM
8/20/14 12:00 PM
8/21/14 12:00 PM
8/22/14 12:00 PM


Day Creek County Blowoff
Water Level (ft)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
10/6/14 12:00 PM
10/6/14 8:30 PM
10/7/14 5:00 AM
10/7/14 1:30 PM
10/7/14 10:00 PM
10/8/14 6:30 AM
10/8/14 3:00 PM
10/8/14 11:30 PM
10/9/14 8:00 AM
10/9/14 4:30 PM
10/10/14 1:00 AM
10/10/14 9:30 AM
10/10/14 6:00 PM
10/11/14 2:30 AM
10/11/14 11:00 AM
10/11/14 7:30 PM
10/12/14 4:00 AM
10/12/14 12:30 PM
10/12/14 9:00 PM
10/13/14 5:30 AM
10/13/14 2:00 PM

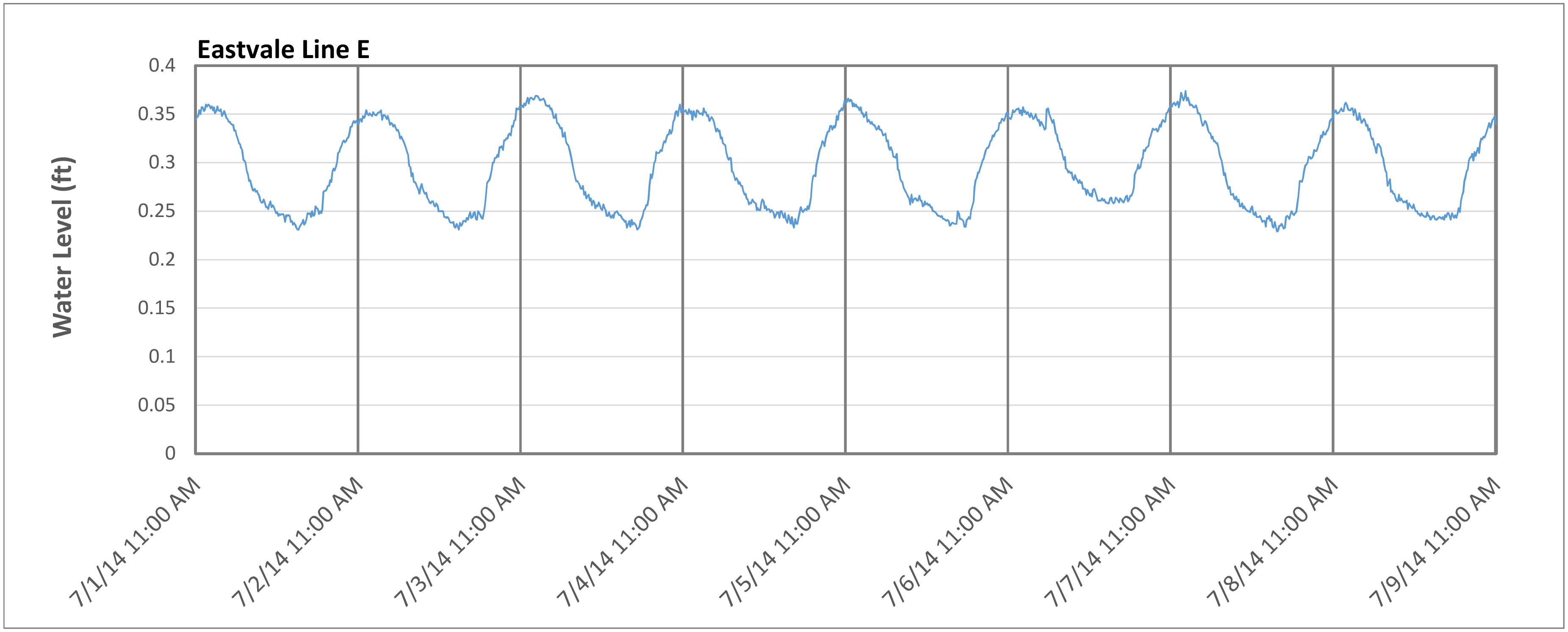

Day Creek County Outfall
Water Level (ft)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10/21/14 8:20 PM
10/22/14 8:20 PM
10/23/14 8:20 PM
10/24/14 8:20 PM
10/25/14 8:20 PM
10/26/14 8:20 PM
10/27/14 8:20 PM
10/28/14 8:20 PM


Day Creek County Line
Water Level (ft)
16
14
12
10
8
6
4
2
0
9/14/14 11:00 AM
9/15/14 11:00 AM
9/16/14 11:00 AM
9/17/14 11:00 AM
9/18/14 11:00 AM
9/19/14 11:00 AM
9/20/14 11:00 AM
9/21/14 11:00 AM
9/22/14 11:00 AM

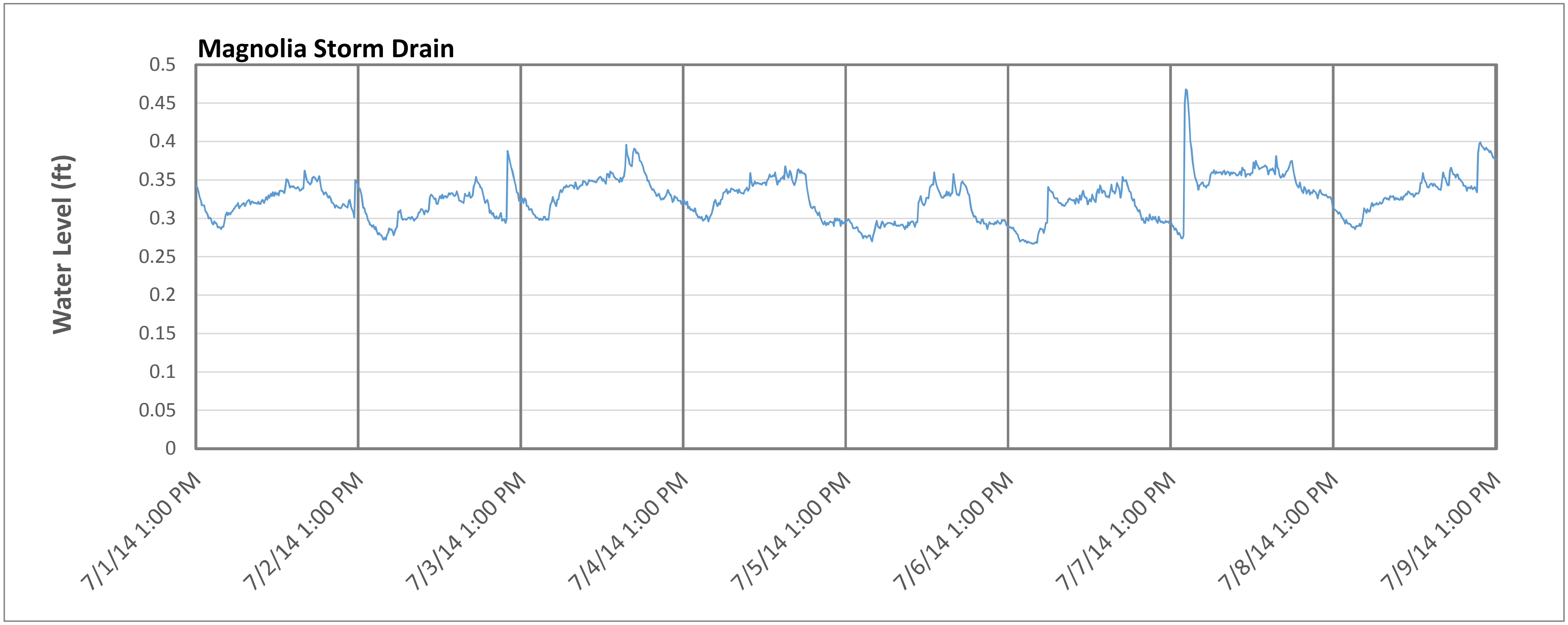

Eastvale Line A
Water Level (ft)
0.6
0.5
0.4
0.3
0.2
0.1
0
7/1/14 9:00 AM
7/2/14 9:00 AM
7/3/14 9:00 AM
7/4/14 9:00 AM
7/5/14 9:00 AM
7/6/14 9:00 AM
7/7/14 9:00 AM
7/8/14 9:00 AM

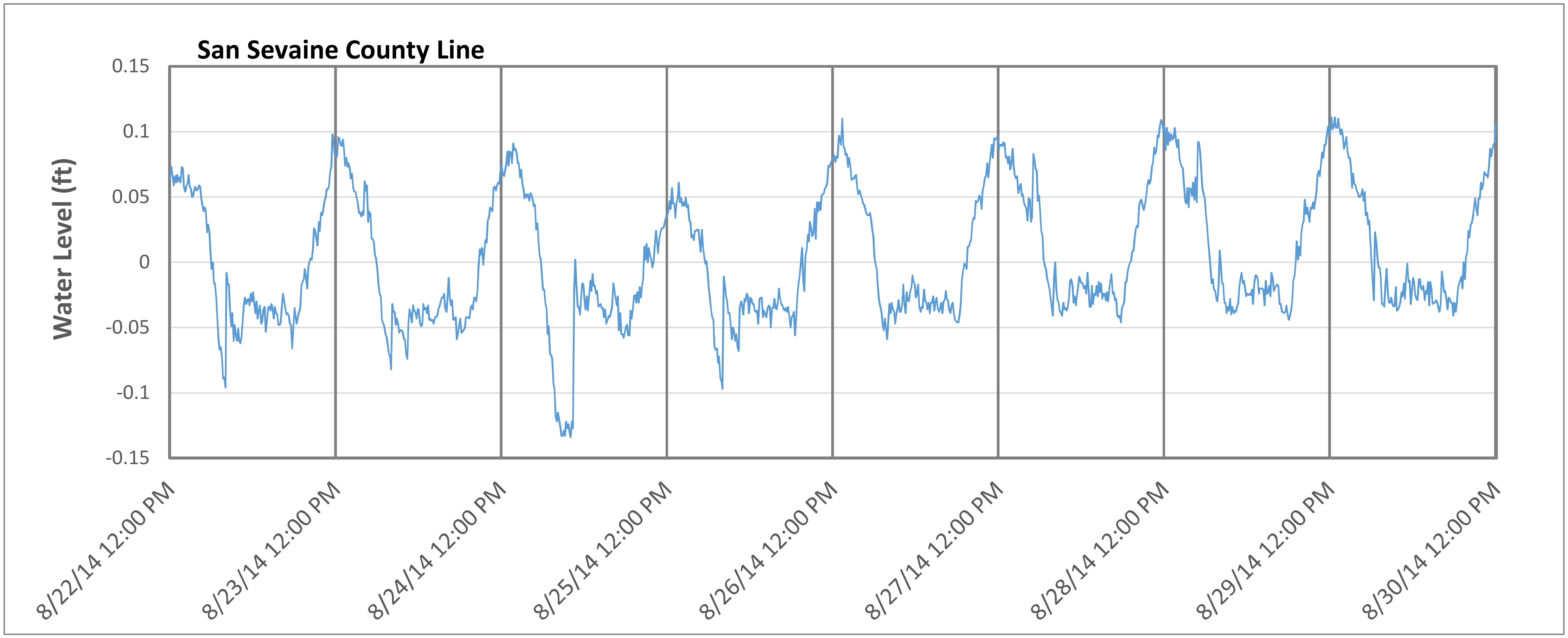


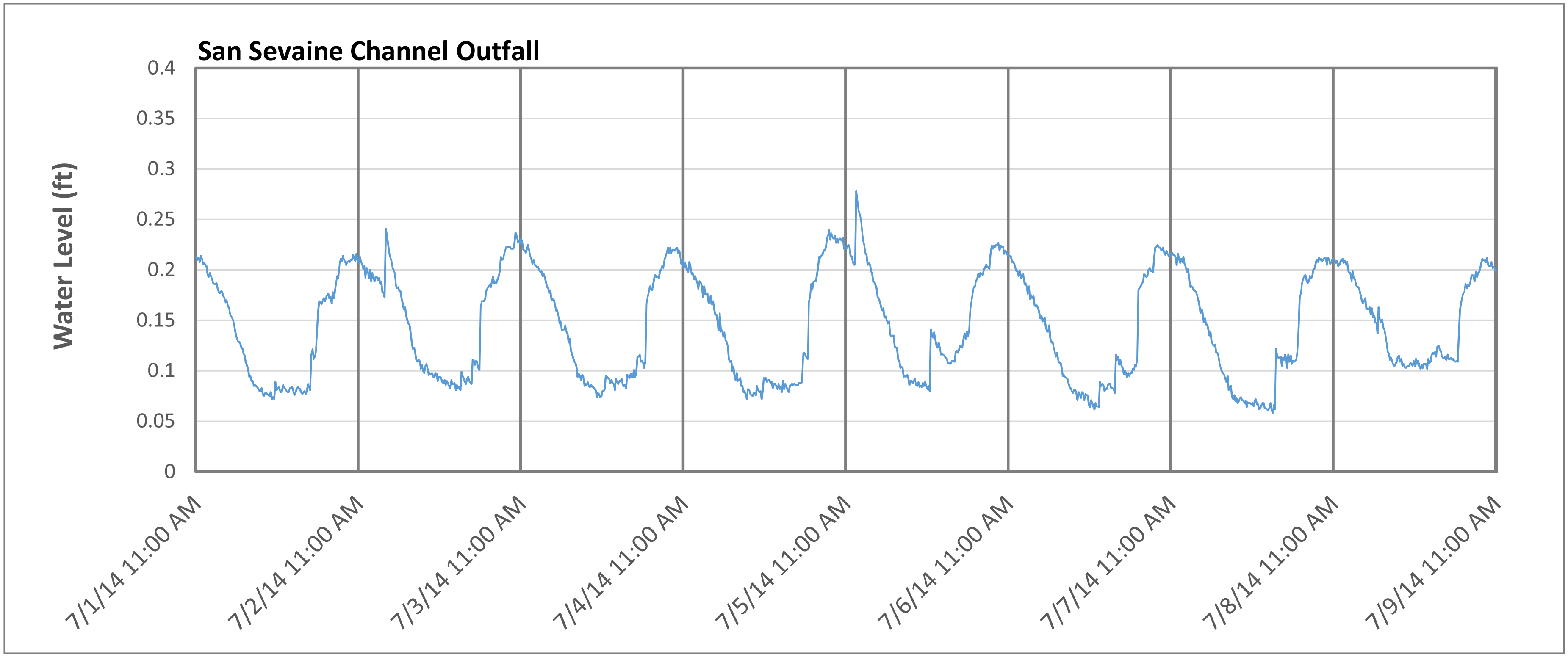
Eastvale Line B
Water Level (ft)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/1/14 11:00 AM
7/2/14 11:00 AM
7/3/14 11:00 AM
7/4/14 11:00 AM
7/5/14 11:00 AM
7/6/14 11:00 AM
7/7/14 11:00 AM
7/8/14 11:00 AM
7/9/14 11:00 AM

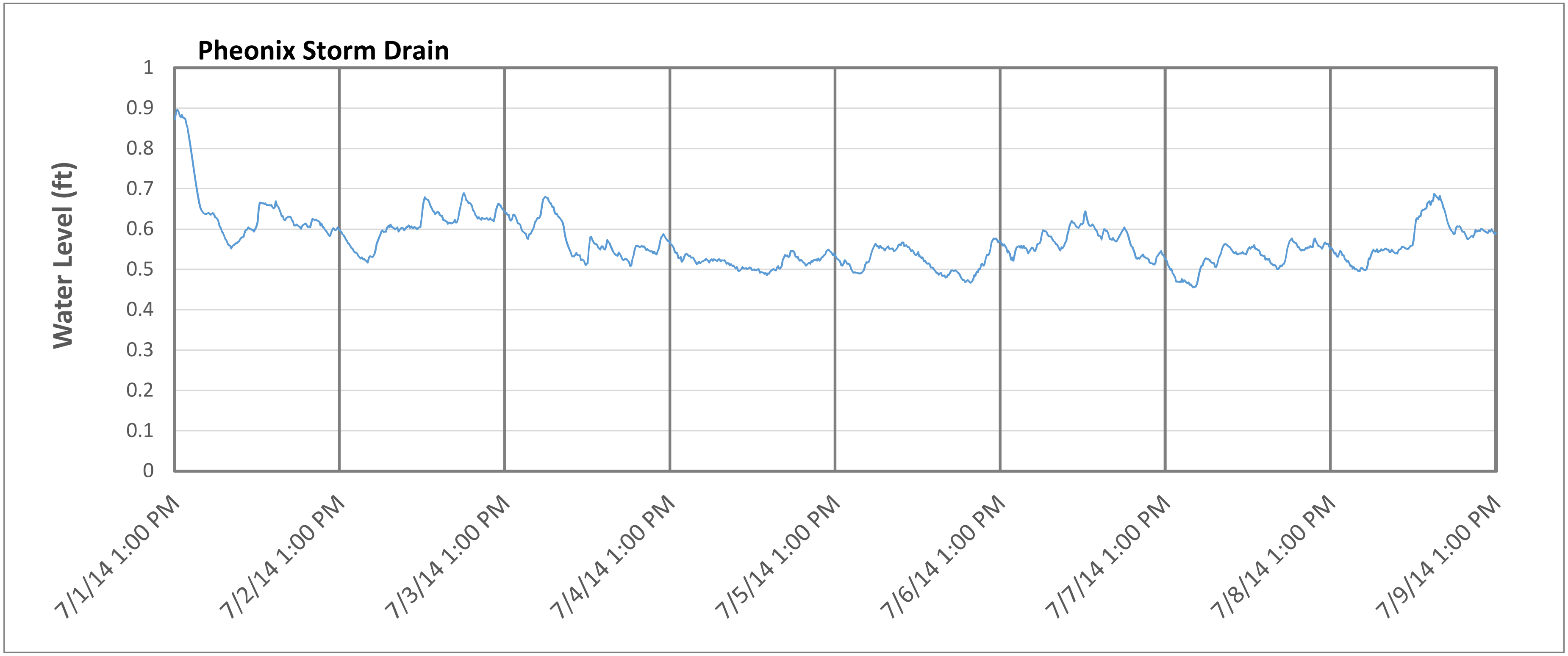


Eastvale Line E
Water Level (ft)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/1/14 11:00 AM
7/2/14 11:00 AM
7/3/14 11:00 AM
7/4/14 11:00 AM
7/5/14 11:00 AM
7/6/14 11:00 AM
7/7/14 11:00 AM
7/8/14 11:00 AM
7/9/14 11:00 AM

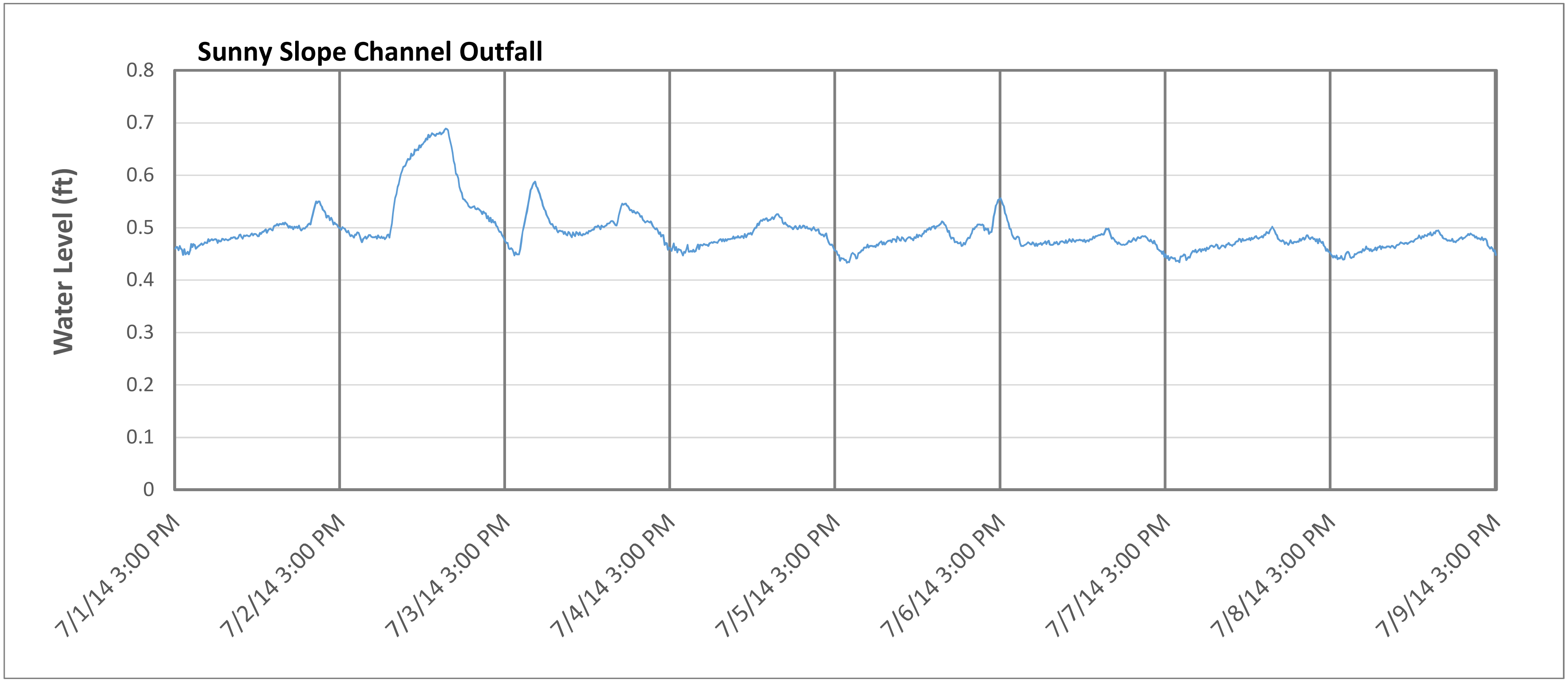

Magnolia Storm Drain
Water Level (ft)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/1/14 1:00 PM
7/2/14 1:00 PM
7/3/14 1:00 PM
7/4/14 1:00 PM
7/5/14 1:00 PM
7/6/14 1:00 PM
7/7/14 1:00 PM
7/8/14 1:00 PM
7/9/14 1:00 PM

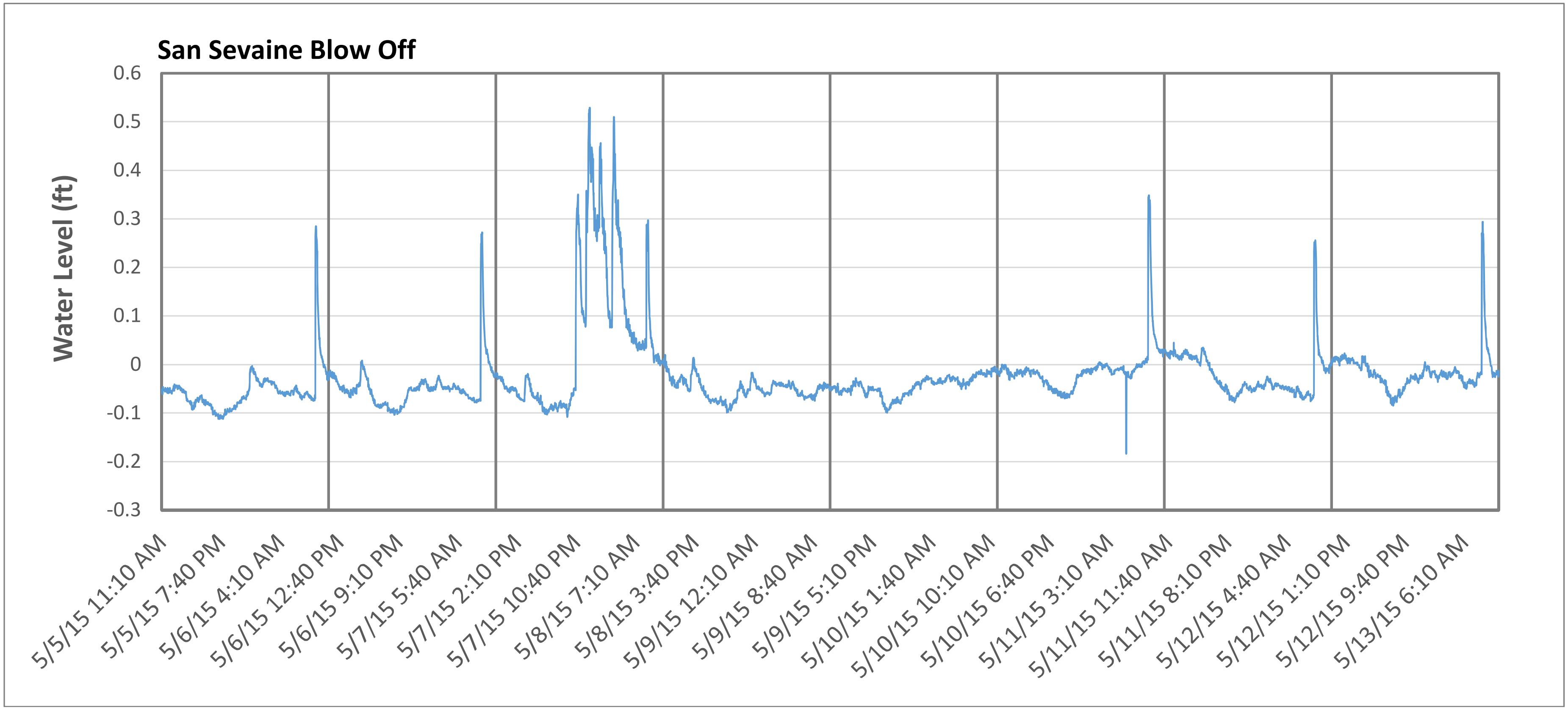

San Sevaine County Line
Water Level (ft)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
8/22/14 12:00 PM
8/23/14 12:00 PM
8/24/14 12:00 PM
8/25/14 12:00 PM
8/26/14 12:00 PM
8/27/14 12:00 PM
8/28/14 12:00 PM
8/29/14 12:00 PM
8/30/14 12:00 PM

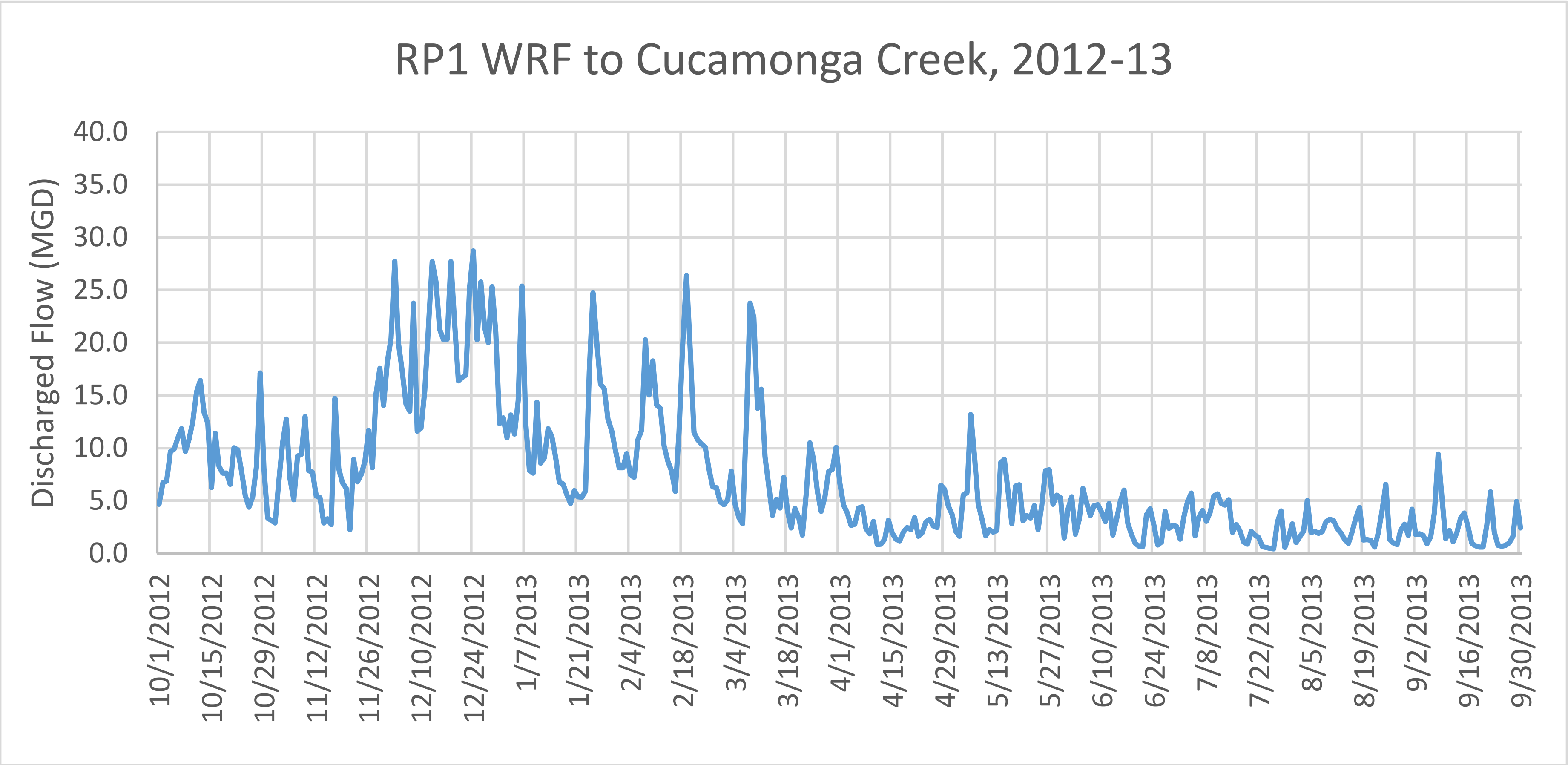

San Sevaine Channel Outfall
Water Level (ft)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7/1/14 11:00 AM
7/2/14 11:00 AM
7/3/14 11:00 AM
7/4/14 11:00 AM
7/5/14 11:00 AM
7/6/14 11:00 AM
7/7/14 11:00 AM
7/8/14 11:00 AM
7/9/14 11:00 AM

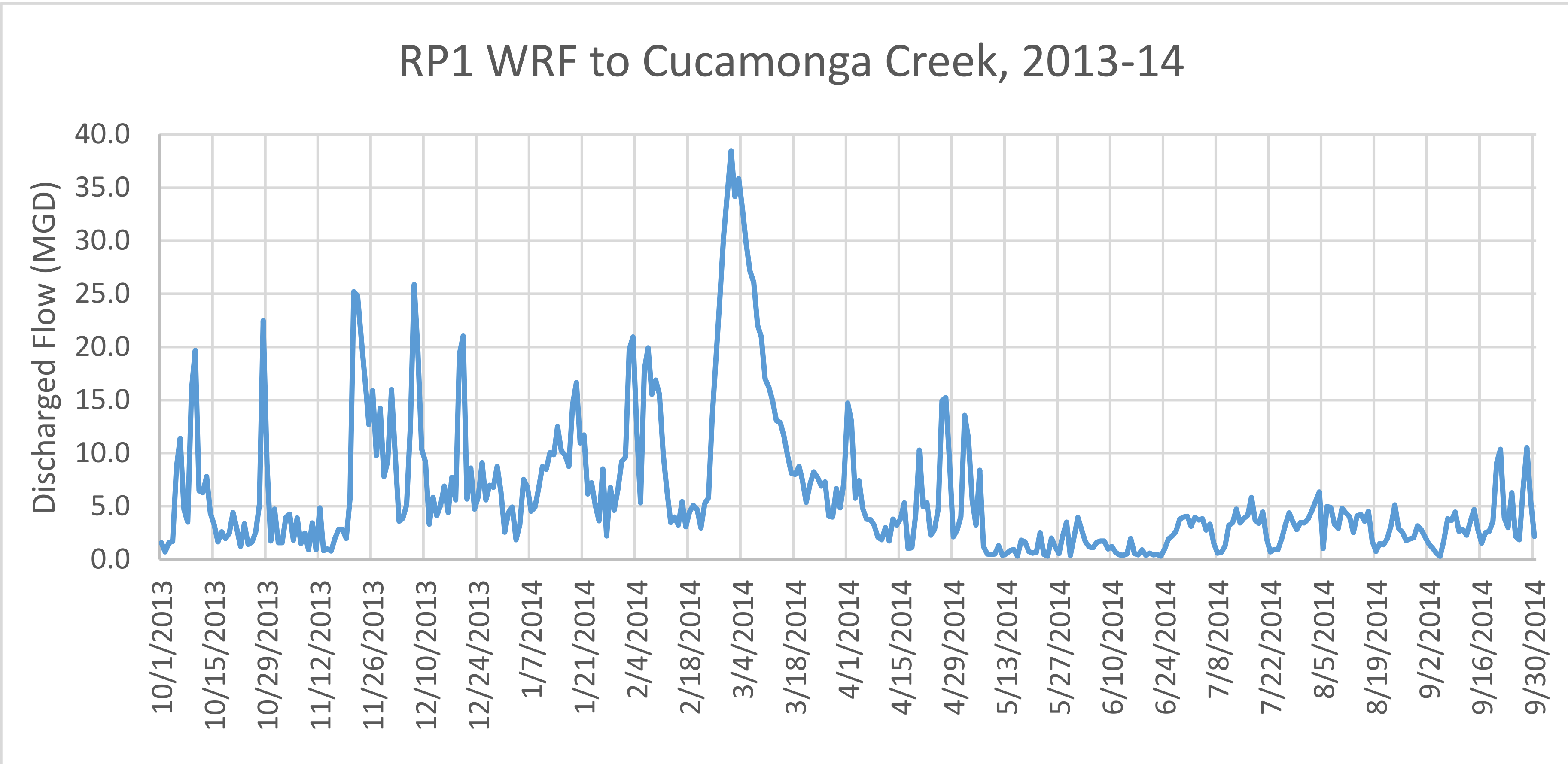


Pheonix Storm Drain
Water Level (ft)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7/1/14 1:00 PM
7/2/14 1:00 PM
7/3/14 1:00 PM
7/4/14 1:00 PM
7/5/14 1:00 PM
7/6/14 1:00 PM
7/7/14 1:00 PM
7/8/14 1:00 PM
7/9/14 1:00 PM

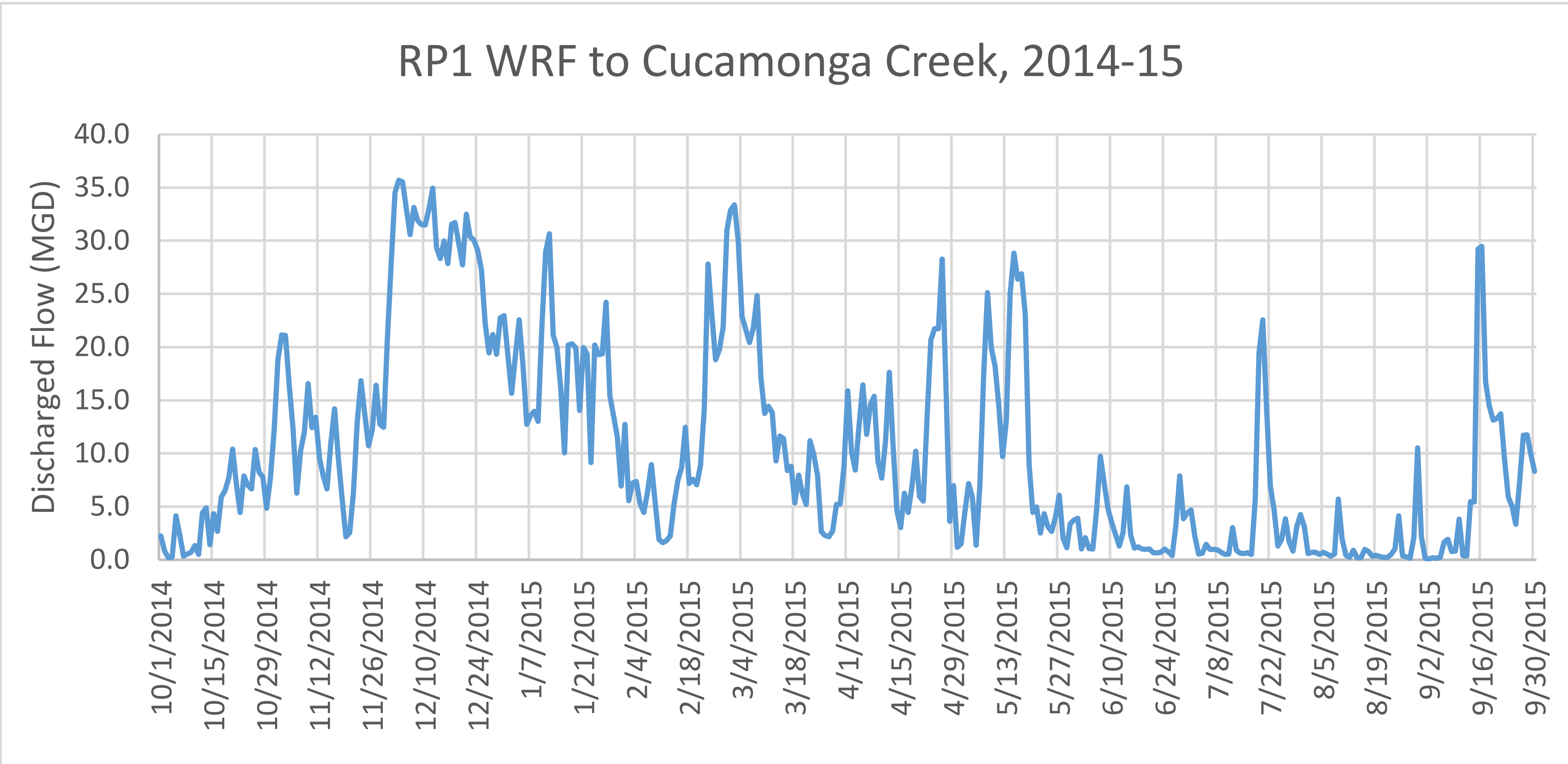

Sunny Slope Channel Outfall
Water Level (ft)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7/1/14 3:00 PM
7/2/14 3:00 PM
7/3/14 3:00 PM
7/4/14 3:00 PM
7/5/14 3:00 PM
7/6/14 3:00 PM
7/7/14 3:00 PM
7/8/14 3:00 PM
7/9/14 3:00 PM

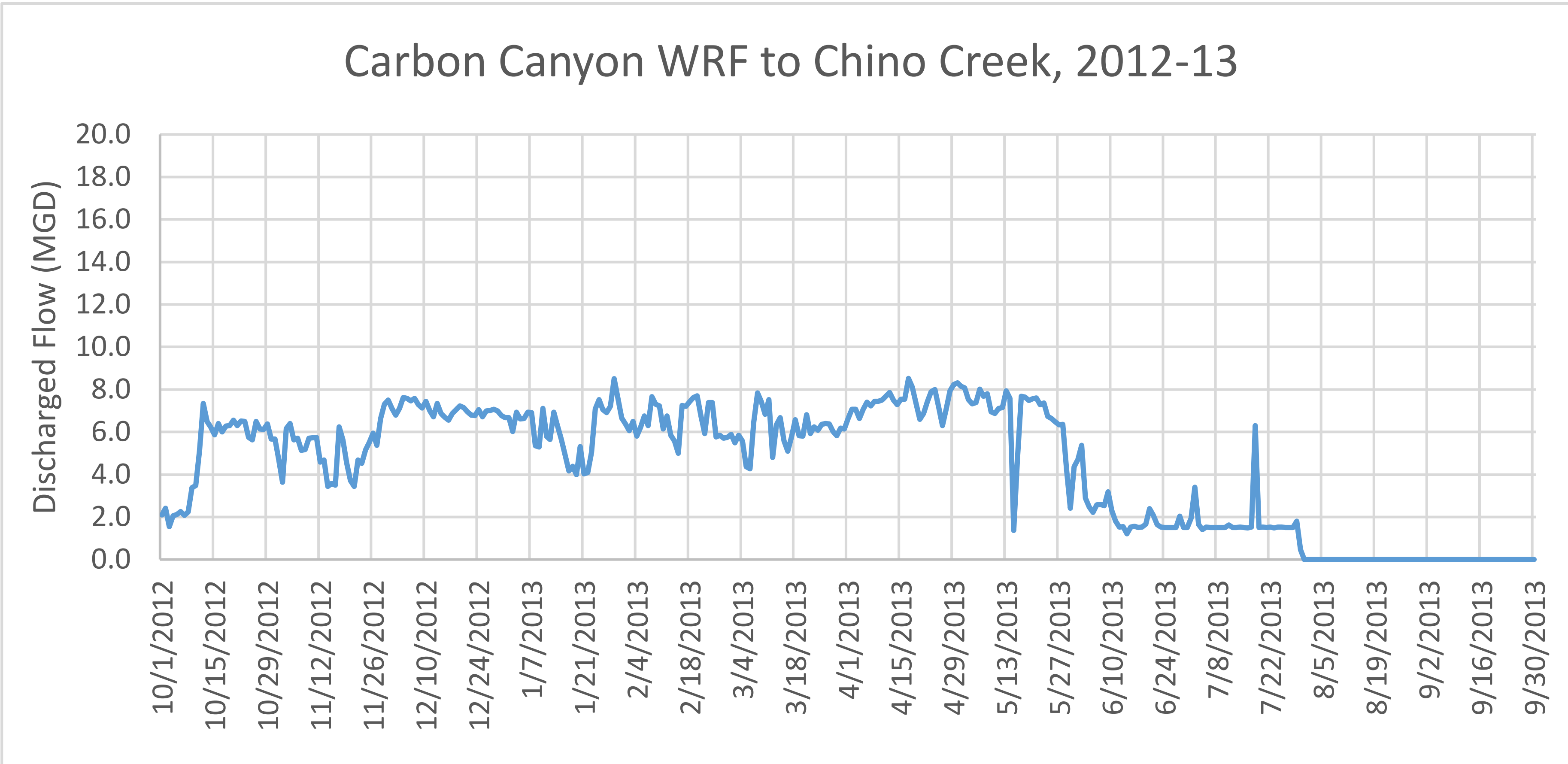

San Sevaine Blow Off
Water Level (ft)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
5/5/15 11:10 AM
5/5/15 7:40 PM
5/6/15 4:10 AM
5/6/15 12:40 PM
5/6/15 9:10 PM
5/7/15 5:40 AM
5/7/15 2:10 PM
5/7/15 10:40 PM
5/8/15 7:10 AM
5/8/15 3:40 PM
5/9/15 12:10 AM
5/9/15 8:40 AM
5/9/15 5:10 PM
5/10/15 1:40 AM
5/10/15 10:10 AM
5/10/15 6:40 PM
5/11/15 3:10 AM
5/11/15 11:40 AM
5/11/15 8:10 PM
5/12/15 4:40 AM
5/12/15 1:10 PM
5/12/15 9:40 PM
5/13/15 6:10 AM


RP1 WRF to Cucamonga Creek, 2012-13
Discharged Flow (MGD)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10/1/2012
10/15/2012
10/29/2012
11/12/2012
11/26/2012
12/10/2012
12/24/2012
1/7/2013
1/21/2013
2/4/2013
2/18/2013
3/4/2013
3/18/2013
4/1/2013
4/15/2013
4/29/2013
5/13/2013
5/27/2013
6/10/2013
6/24/2013
7/8/2013
7/22/2013
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013

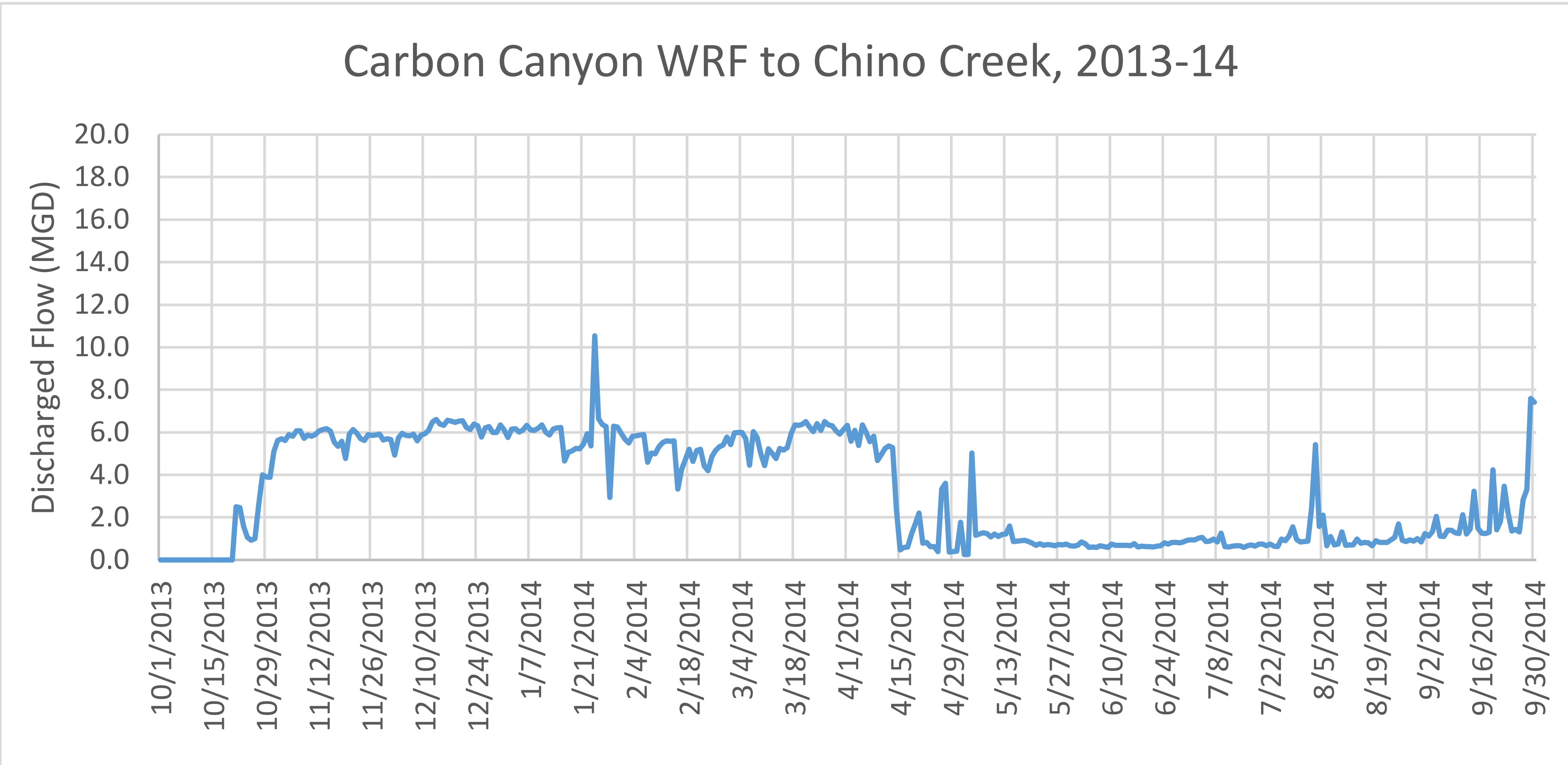


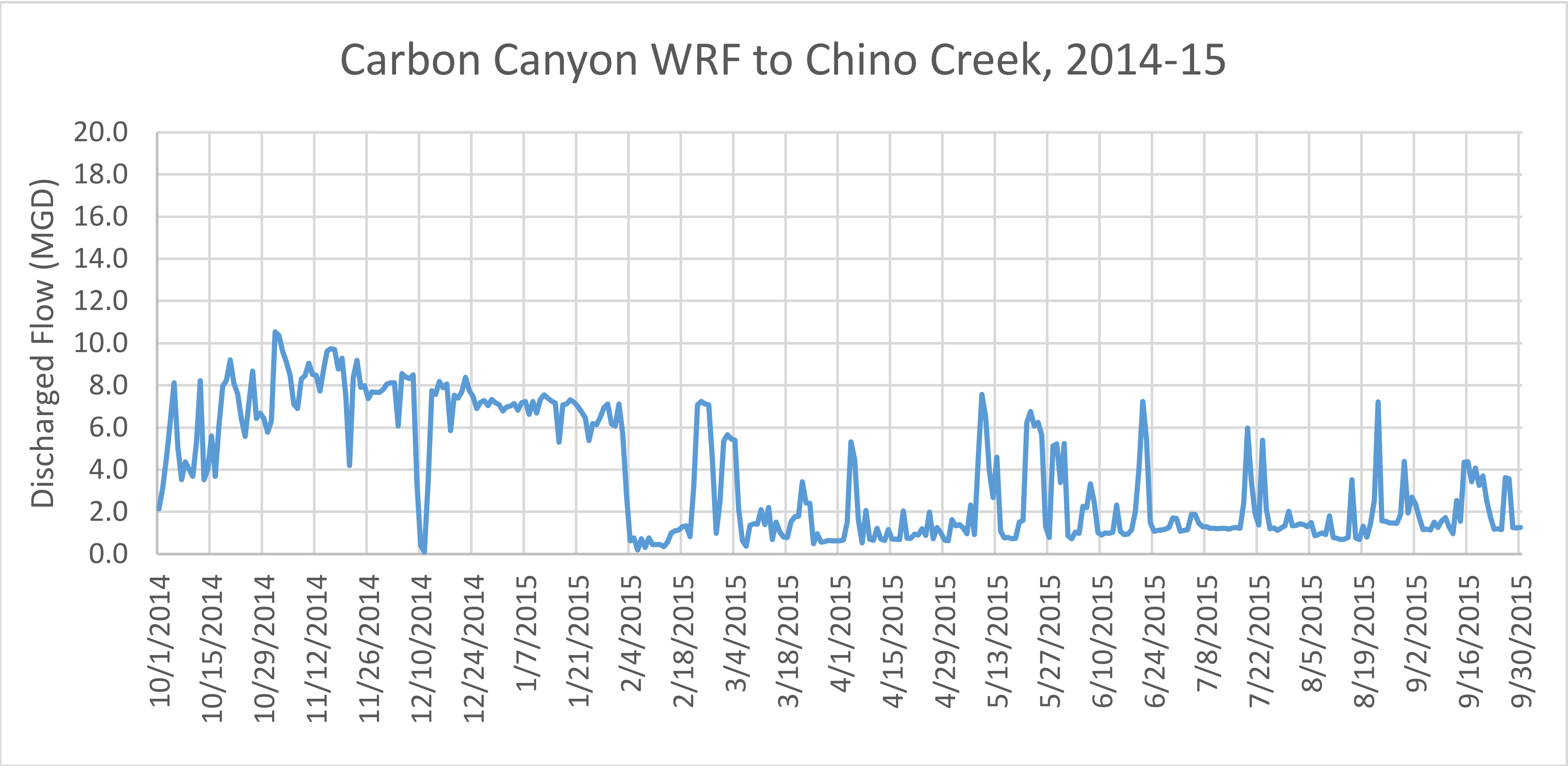
RP1 WRF to Cucamonga Creek, 2013-14
Discharged Flow (MGD)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10/1/2013
10/15/2013
10/29/2013
11/12/2013
11/26/2013
12/10/2013
12/24/2013
1/7/2014
1/21/2014
2/4/2014
2/18/2014
3/4/2014
3/18/2014
4/1/2014
4/15/2014
4/29/2014
5/13/2014
5/27/2014
6/10/2014
6/24/2014
7/8/2014
7/22/2014
8/5/2014
8/19/2014
9/2/2014
9/16/2014
9/30/2014

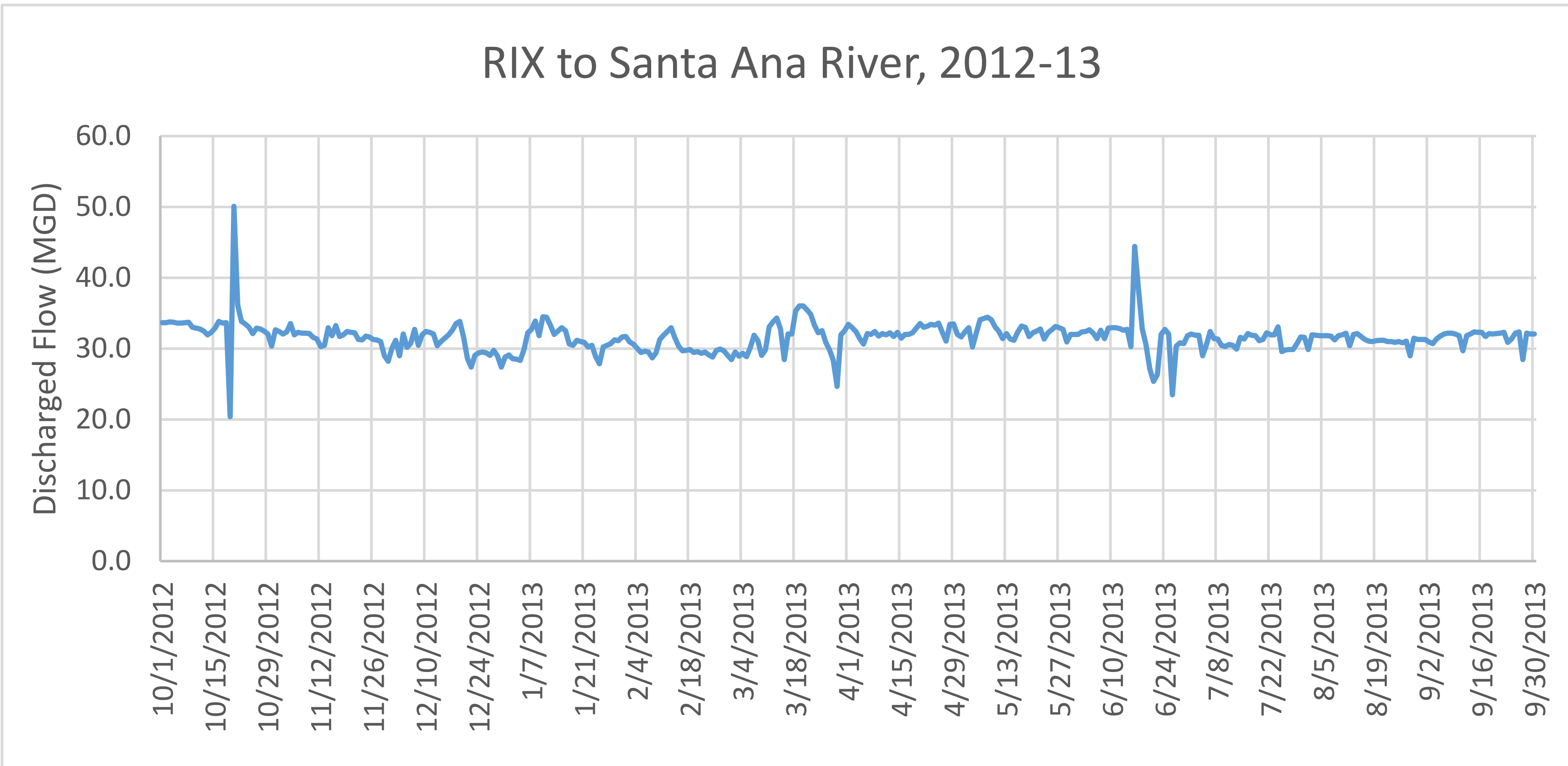

RP1 WRF to Cucamonga Creek, 2014-15
Discharged Flow (MGD)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10/1/2014
10/15/2014
10/29/2014
11/12/2014
11/26/2014
12/10/2014
12/24/2014
1/7/2015
1/21/2015
2/4/2015
2/18/2015
3/4/2015
3/18/2015
4/1/2015
4/15/2015
4/29/2015
5/13/2015
5/27/2015
6/10/2015
6/24/2015
7/8/2015
7/22/2015
8/5/2015
8/19/2015
9/2/2015
9/16/2015
9/30/2015

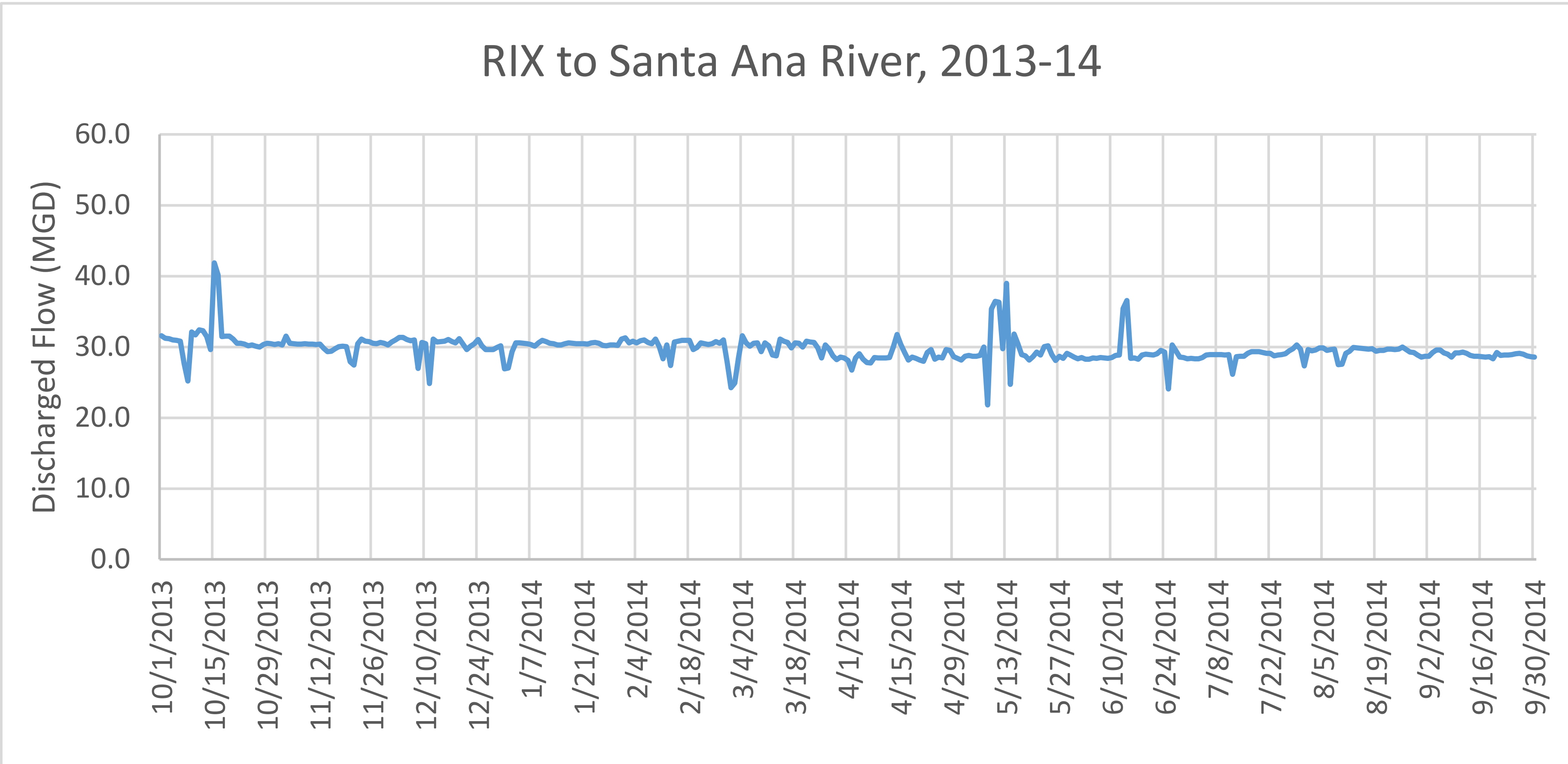


Carbon Canyon WRF to Chino Creek, 2012-13
Discharged Flow (MGD)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10/1/2012
10/15/2012
10/29/2012
11/12/2012
11/26/2012
12/10/2012
12/24/2012
1/7/2013
1/21/2013
2/4/2013
2/18/2013
3/4/2013
3/18/2013
4/1/2013
4/15/2013
4/29/2013
5/13/2013
5/27/2013
6/10/2013
6/24/2013
7/8/2013
7/22/2013
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013

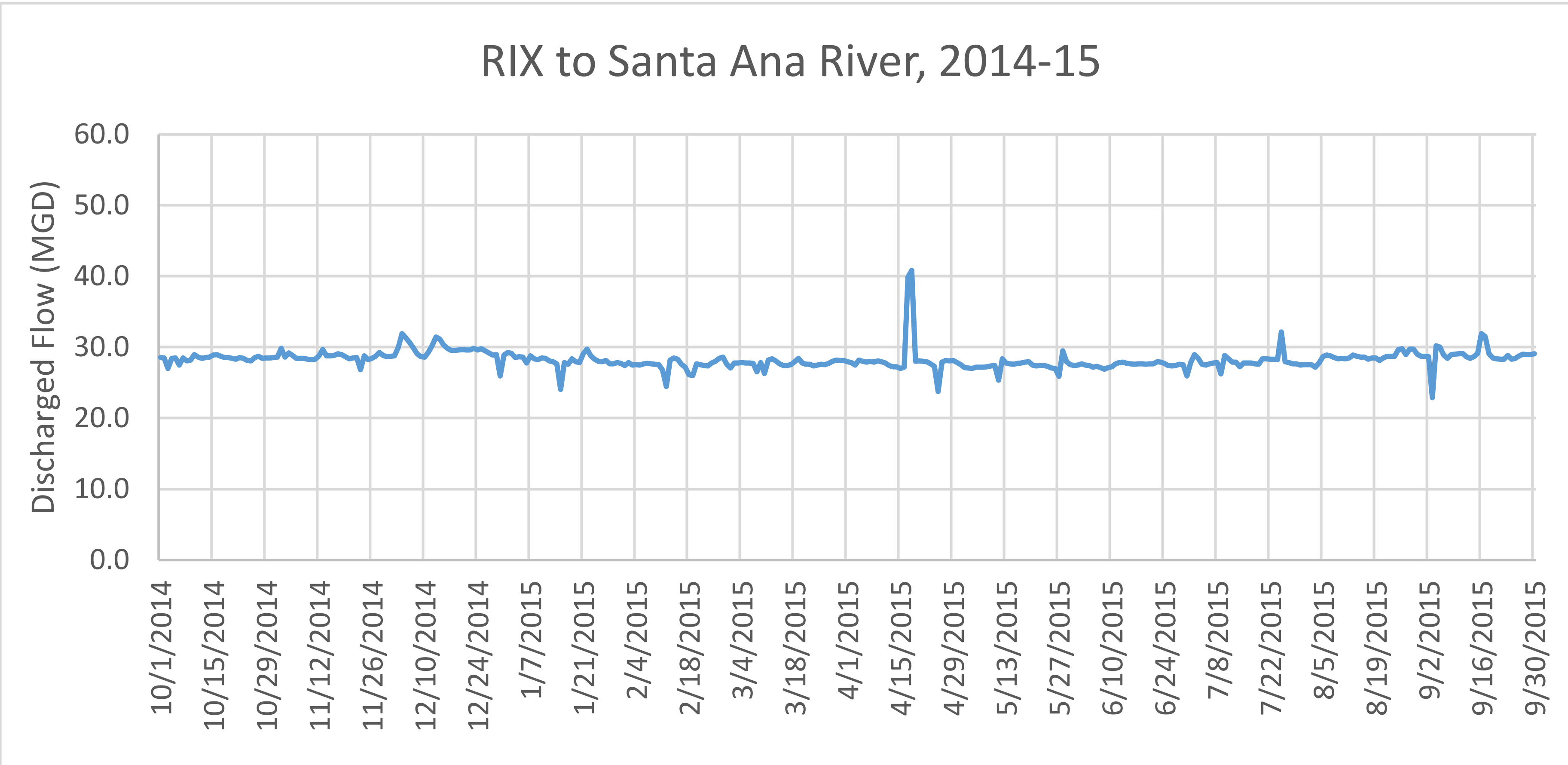

Carbon Canyon WRF to Chino Creek, 2013-14
Discharged Flow (MGD)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10/1/2013
10/15/2013
10/29/2013
11/12/2013
11/26/2013
12/10/2013
12/24/2013
1/7/2014
1/21/2014
2/4/2014
2/18/2014
3/4/2014
3/18/2014
4/1/2014
4/15/2014
4/29/2014
5/13/2014
5/27/2014
6/10/2014
6/24/2014
7/8/2014
7/22/2014
8/5/2014
8/19/2014
9/2/2014
9/16/2014
9/30/2014

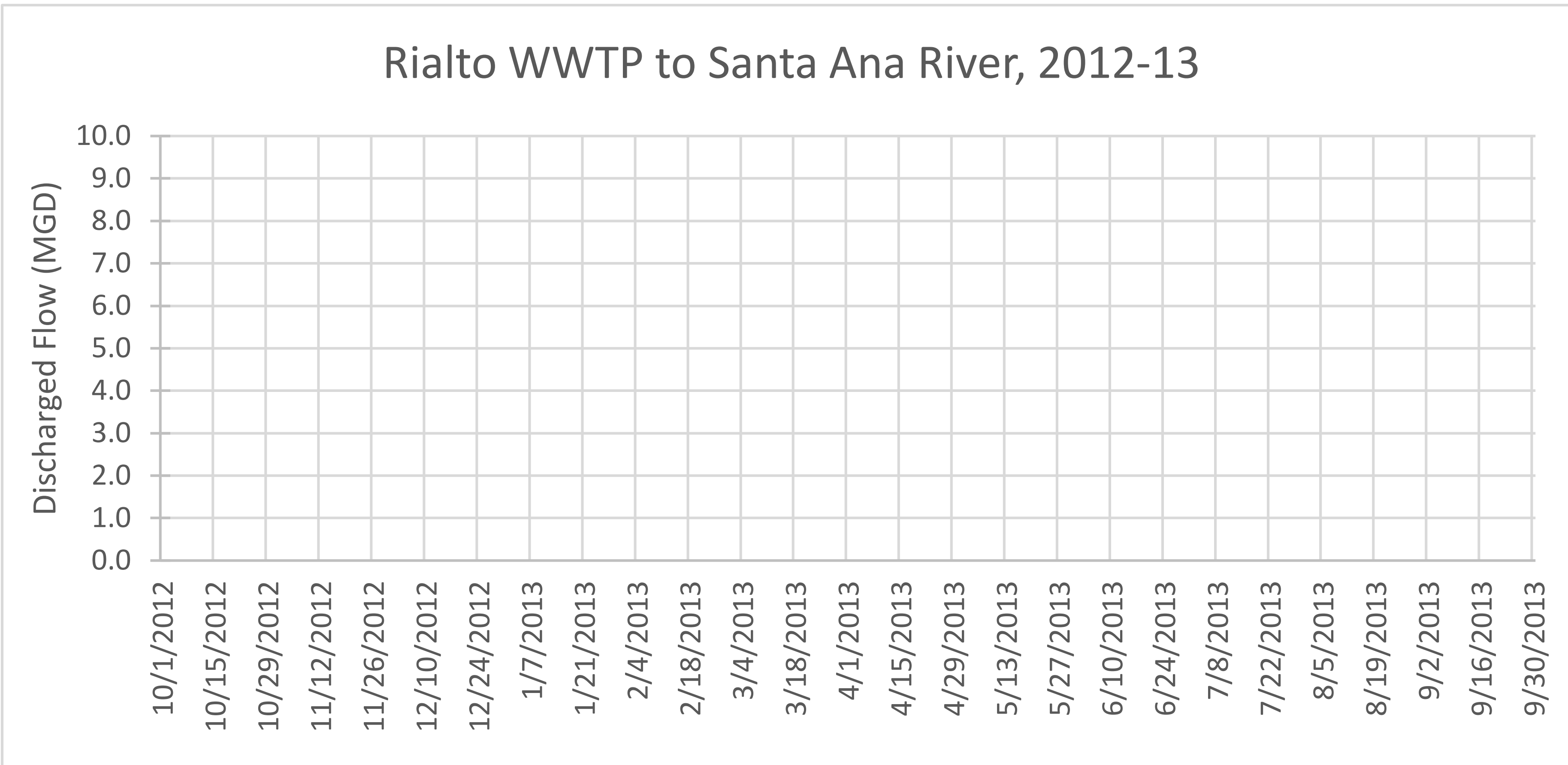

Carbon Canyon WRF to Chino Creek, 2014-15
Discharged Flow (MGD)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10/1/2014
10/15/2014
10/29/2014
11/12/2014
11/26/2014
12/10/2014
12/24/2014
1/7/2015
1/21/2015
2/4/2015
2/18/2015
3/4/2015
3/18/2015
4/1/2015
4/15/2015
4/29/2015
5/13/2015
5/27/2015
6/10/2015
6/24/2015
7/8/2015
7/22/2015
8/5/2015
8/19/2015
9/2/2015
9/16/2015
9/30/2015

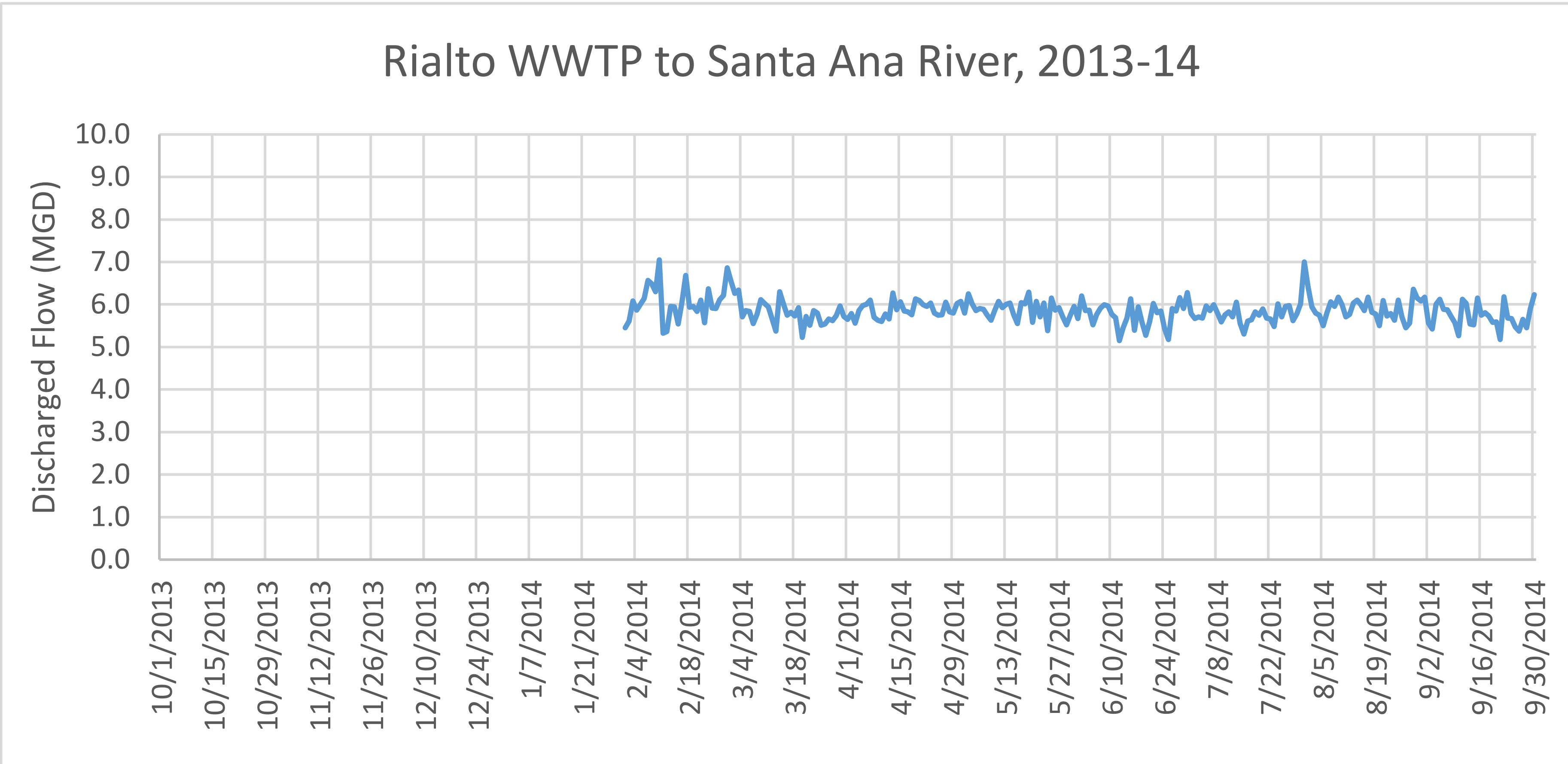

RIX to Santa Ana River, 2012-13
Discharged Flow (MGD)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
10/1/2012
10/15/2012
10/29/2012
11/12/2012
11/26/2012
12/10/2012
12/24/2012
1/7/2013
1/21/2013
2/4/2013
2/18/2013
3/4/2013
3/18/2013
4/1/2013
4/15/2013
4/29/2013
5/13/2013
5/27/2013
6/10/2013
6/24/2013
7/8/2013
7/22/2013
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013

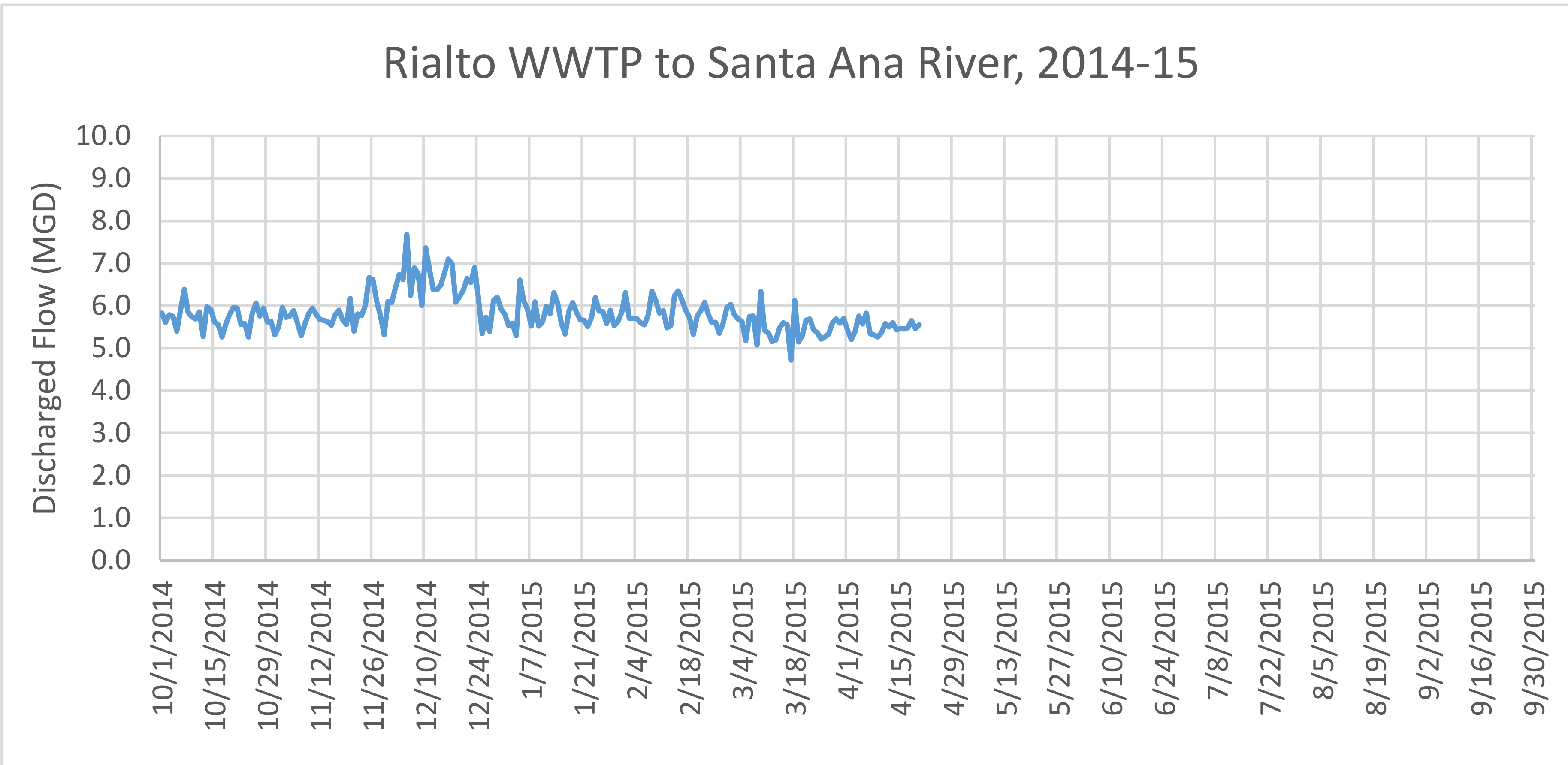


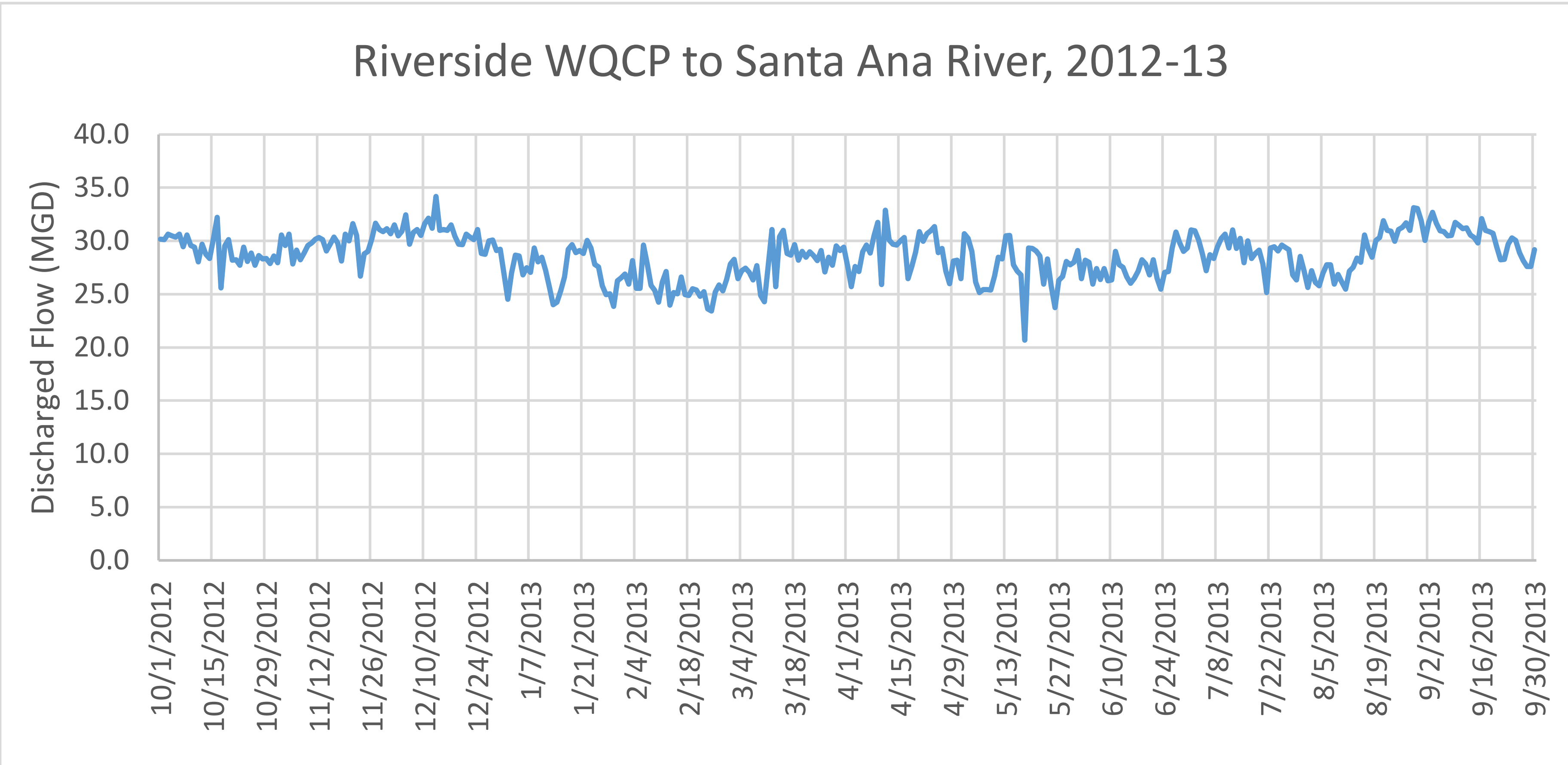
RIX to Santa Ana River, 2013-14
Discharged Flow (MGD)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
10/1/2013
10/15/2013
10/29/2013
11/12/2013
11/26/2013
12/10/2013
12/24/2013
1/7/2014
1/21/2014
2/4/2014
2/18/2014
3/4/2014
3/18/2014
4/1/2014
4/15/2014
4/29/2014
5/13/2014
5/27/2014
6/10/2014
6/24/2014
7/8/2014
7/22/2014
8/5/2014
8/19/2014
9/2/2014
9/16/2014
9/30/2014


RIX to Santa Ana River, 2014-15
Discharged Flow (MGD)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
10/1/2014
10/15/2014
10/29/2014
11/12/2014
11/26/2014
12/10/2014
12/24/2014
1/7/2015
1/21/2015
2/4/2015
2/18/2015
3/4/2015
3/18/2015
4/1/2015
4/15/2015
4/29/2015
5/13/2015
5/27/2015
6/10/2015
6/24/2015
7/8/2015
7/22/2015
8/5/2015
8/19/2015
9/2/2015
9/16/2015
9/30/2015

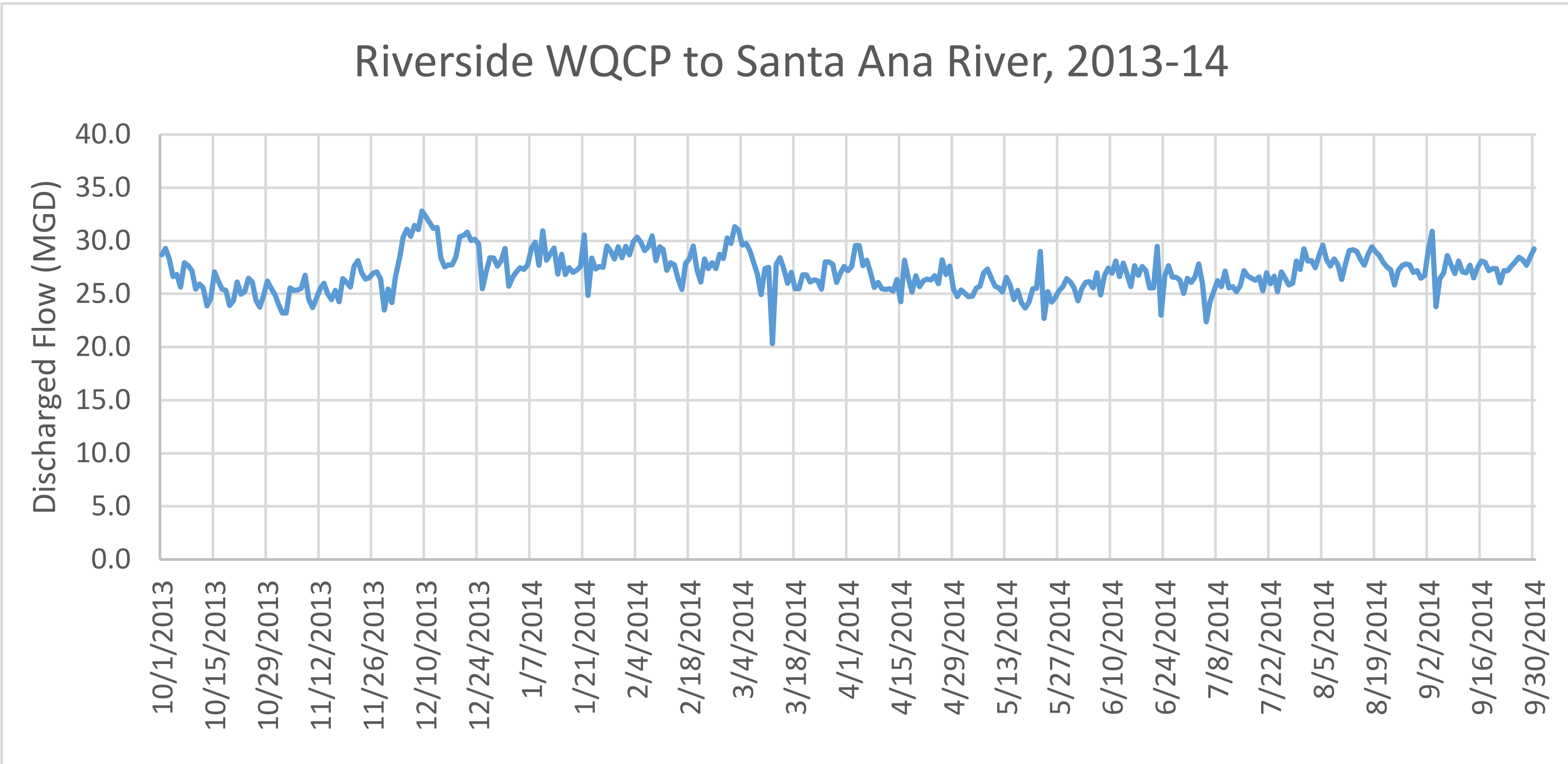

Rialto WWTP to Santa Ana River, 2012-13
Discharged Flow (MGD)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10/1/2012
10/15/2012
10/29/2012
11/12/2012
11/26/2012
12/10/2012
12/24/2012
1/7/2013
1/21/2013
2/4/2013
2/18/2013
3/4/2013
3/18/2013
4/1/2013
4/15/2013
4/29/2013
5/13/2013
5/27/2013
6/10/2013
6/24/2013
7/8/2013
7/22/2013
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013


Rialto WWTP to Santa Ana River, 2013-14
Discharged Flow (MGD)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10/1/2013
10/15/2013
10/29/2013
11/12/2013
11/26/2013
12/10/2013
12/24/2013
1/7/2014
1/21/2014
2/4/2014
2/18/2014
3/4/2014
3/18/2014
4/1/2014
4/15/2014
4/29/2014
5/13/2014
5/27/2014
6/10/2014
6/24/2014
7/8/2014
7/22/2014
8/5/2014
8/19/2014
9/2/2014
9/16/2014
9/30/2014

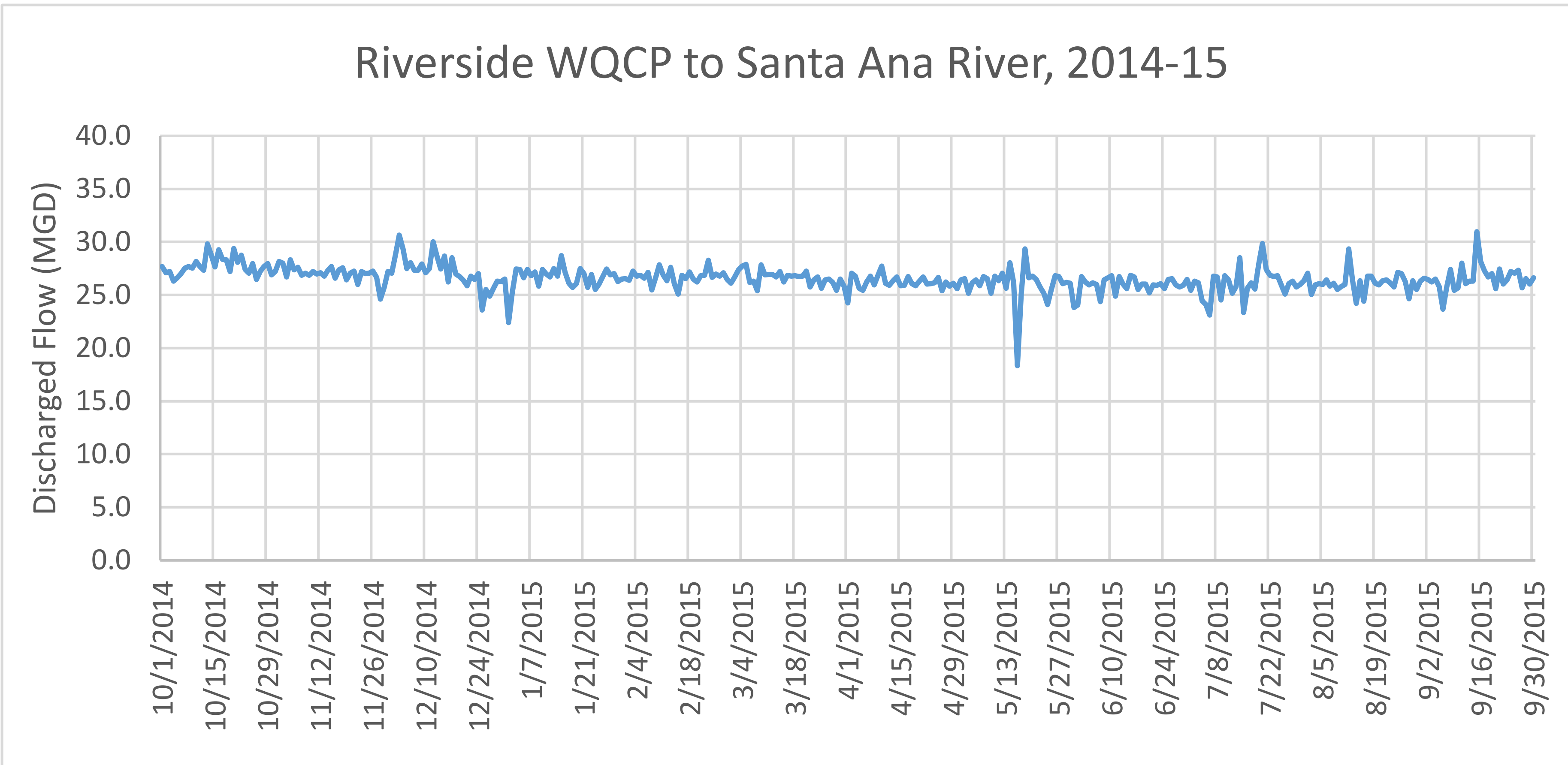

Rialto WWTP to Santa Ana River, 2014-15
Discharged Flow (MGD)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10/1/2014
10/15/2014
10/29/2014
11/12/2014
11/26/2014
12/10/2014
12/24/2014
1/7/2015
1/21/2015
2/4/2015
2/18/2015
3/4/2015
3/18/2015
4/1/2015
4/15/2015
4/29/2015
5/13/2015
5/27/2015
6/10/2015
6/24/2015
7/8/2015
7/22/2015
8/5/2015
8/19/2015
9/2/2015
9/16/2015
9/30/2015

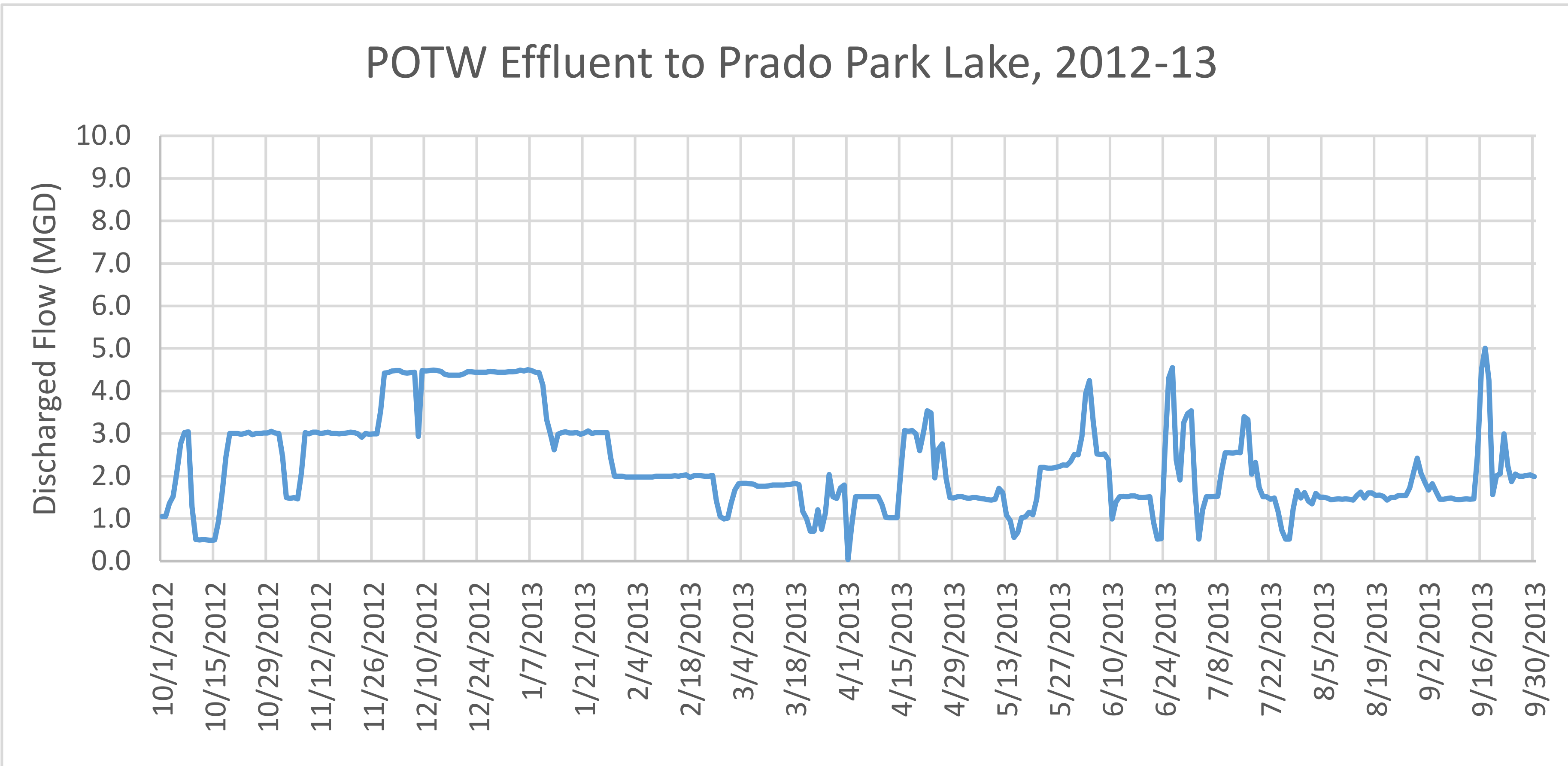


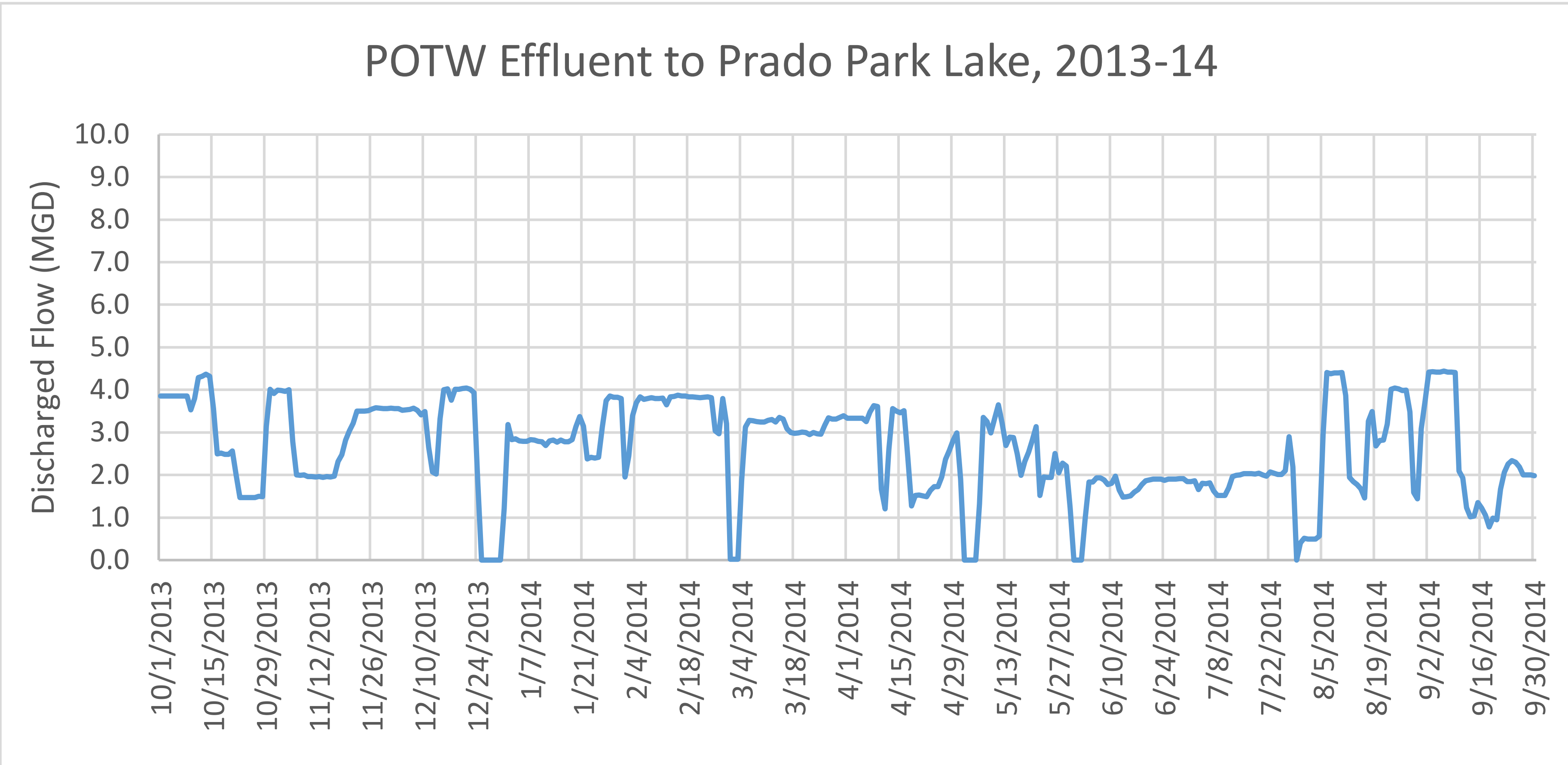
Riverside WQCP to Santa Ana River, 2012-13
Discharged Flow (MGD)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10/1/2012
10/15/2012
10/29/2012
11/12/2012
11/26/2012
12/10/2012
12/24/2012
1/7/2013
1/21/2013
2/4/2013
2/18/2013
3/4/2013
3/18/2013
4/1/2013
4/15/2013
4/29/2013
5/13/2013
5/27/2013
6/10/2013
6/24/2013
7/8/2013
7/22/2013
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013



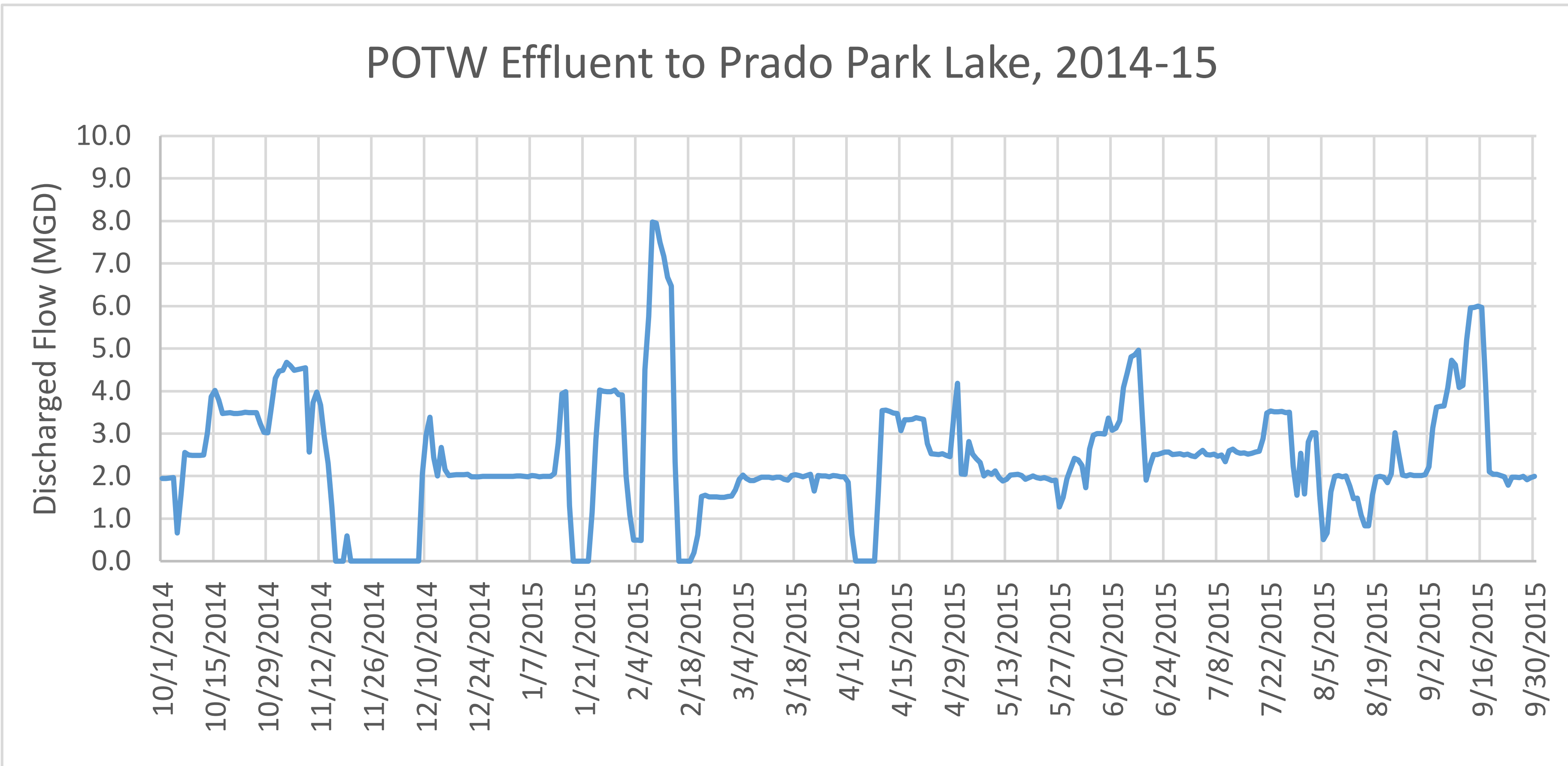
Riverside WQCP to Santa Ana River, 2013-14
Discharged Flow (MGD)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10/1/2013
10/15/2013
10/29/2013
11/12/2013
11/26/2013
12/10/2013
12/24/2013
1/7/2014
1/21/2014
2/4/2014
2/18/2014
3/4/2014
3/18/2014
4/1/2014
4/15/2014
4/29/2014
5/13/2014
5/27/2014
6/10/2014
6/24/2014
7/8/2014
7/22/2014
8/5/2014
8/19/2014
9/2/2014
9/16/2014
9/30/2014


Riverside WQCP to Santa Ana River, 2014-15
Discharged Flow (MGD)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10/1/2014
10/15/2014
10/29/2014
11/12/2014
11/26/2014
12/10/2014
12/24/2014
1/7/2015
1/21/2015
2/4/2015
2/18/2015
3/4/2015
3/18/2015
4/1/2015
4/15/2015
4/29/2015
5/13/2015
5/27/2015
6/10/2015
6/24/2015
7/8/2015
7/22/2015
8/5/2015
8/19/2015
9/2/2015
9/16/2015
9/30/2015


POTW Effluent to Prado Park Lake, 2012-13
Discharged Flow (MGD)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10/1/2012
10/15/2012
10/29/2012
11/12/2012
11/26/2012
12/10/2012
12/24/2012
1/7/2013
1/21/2013
2/4/2013
2/18/2013
3/4/2013
3/18/2013
4/1/2013
4/15/2013
4/29/2013
5/13/2013
5/27/2013
6/10/2013
6/24/2013
7/8/2013
7/22/2013
8/5/2013
8/19/2013
9/2/2013
9/16/2013
9/30/2013



POTW Effluent to Prado Park Lake, 2013-14
Discharged Flow (MGD)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10/1/2013
10/15/2013
10/29/2013
11/12/2013
11/26/2013
12/10/2013
12/24/2013
1/7/2014
1/21/2014
2/4/2014
2/18/2014
3/4/2014
3/18/2014
4/1/2014
4/15/2014
4/29/2014
5/13/2014
5/27/2014
6/10/2014
6/24/2014
7/8/2014
7/22/2014
8/5/2014
8/19/2014
9/2/2014
9/16/2014
9/30/2014


POTW Effluent to Prado Park Lake, 2014-15
Discharged Flow (MGD)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10/1/2014
10/15/2014
10/29/2014
11/12/2014
11/26/2014
12/10/2014
12/24/2014
1/7/2015
1/21/2015
2/4/2015
2/18/2015
3/4/2015
3/18/2015
4/1/2015
4/15/2015
4/29/2015
5/13/2015
5/27/2015
6/10/2015
6/24/2015
7/8/2015
7/22/2015
8/5/2015
8/19/2015
9/2/2015
9/16/2015
9/30/2015