Middle Santa Ana River Bacterial Indicator TMDL Data Analysis Report

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RISK SCIENCES

CDM

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

Agricultural Operators

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Section 1
Executive Summary

Several rivers and streams in San Bernardino and Riverside counties are on California's 303(d) list of impaired waterbodies, including: Reach 3 of the Santa Ana River, Reaches 1 and 2 of Chino Creek, Reach 1 of Mill Creek, Reach 1 of Cucamonga Creek, and the Prado Park Lakes. Recreational uses are adversely affected by excessive bacteria concentrations in these waterbodies.

In 2005, the Santa Ana Regional Water Quality Control Board (RWQCB) adopted a Total Maximum Daily Load (TMDL) for pathogen indicator bacteria and U.S. Environmental Protection Agency (EPA) approved the TMDL in 2007. The TMDL requires dischargers to establish a watershed-wide compliance monitoring program and to determine the sources of bacteria contributing to water quality standards violations. In the fall of 2007, the San Bernardino and Riverside County Flood Control Districts initiated the Urban Source Evaluation Study to comply with the new regulatory requirements. The State Water Resources Control Board (SWRCB) provided substantial grant funding to assist the Urban Source Evaluation Study and implement the TMDL.

Water quality samples were collected from 6 designated compliance monitoring locations and 13 source evaluation sites between July 2007 and June 2008. Samples were gathered during both warm and cool weather. Samples were also collected under dry weather and wet weather conditions. All samples were analyzed for both fecal coliform and *Escherichia coli (E. coli*). In addition, some samples were also analyzed using advanced microbial methods to determine whether there was specific bacterial contamination originating from human, dog, or cattle sources.

Results indicate that bacterial concentrations routinely exceed the applicable water quality objectives for fecal coliform and EPA's recommended water quality criteria for *E. coli* (see Section 5.3). Statistical analysis showed that significant differences in bacterial concentrations exist when the average for warm weather months was compared to the average for cool weather months. Bacterial counts increased as temperatures rose (see Section 5.5). Statistical analysis also showed that there were significant differences in bacterial concentrations when the average for dry weather conditions was compared to the average for wet weather conditions. *E. coli* and fecal coliform concentrations were lower during base flow conditions and higher when substantial stormwater runoff was flowing through the streams (see Section 5.7). In addition, the data indicate that coliform concentrations return to normal baseline levels approximately 48 to 72 hours after a storm event ends (see Section 5.8).

Further analysis revealed that statistically significant differences in bacterial concentrations occurred when results from the various sampling locations were compared with one another (see Section 5.4). Of particular interest is the fact that some locations (for example Carbon Canyon Creek) recorded unusually low *E. coli* counts. Understanding why this difference occurred may lead to more effective control strategies. Other locations (Mill Creek and Chino Creek) had significantly higher *E. coli* concentrations. And, finally, some locations on the 303(d) list (Prado Park Lakes) had much lower bacterial counts than expected. Additional investigation is merited for all of these areas.

Data analysis confirms that a strong positive correlation between fecal coliform concentrations and *E. coli* concentrations exists irrespective of location, season, or flow conditions (see Section 5.10). Additional analysis showed significant differences in the frequency with which molecular markers for humans, dogs, and cattle were detected at the various source evaluation sites (see Section 5.9). Preliminary review of land use data indicates that bacterial concentrations are positively correlated with degree of urban development and negatively correlated with the proportion of agricultural acreage and open space in the area (see Section 5.12).

A new tool for evaluating the relative risk associated with the frequency, magnitude, and type of bacterial contamination measured at each site was developed (see Section 5.11). Locations with the largest number of standards violations and highest concentration of bacteria and the most frequent indications of contamination by human sources were deemed to represent the greatest potential threat to recreational uses. This tool will be used to focus and prioritize available resources during the next phase of the investigation as part of a general adaptive management plan.

This Data Analysis Report includes the results of an Urban Source Evaluation Study. The primary goal of this study was "to develop an investigative strategy at the highest priority sites, including site-specific or subwatershed-specific activities." The study results clearly identify the highest priority sites. Based solely on the frequency and magnitude of bacterial exceedances, Chino Creek and Mill Creek are the two highest ranking stream segments and Prado Park Lake and the Santa Ana River are the two lowest ranking waterbodies (see Table 5-27).

When data from specialized source studies are added to the risk analysis, Chris Basin and Cypress Channel are two of the highest ranking subwatersheds due to strong indications of bacterial contamination from human sources. Therefore, the next phase of the investigation should focus on these two subwatersheds. In addition, it would be useful to scrutinize the lowest ranking subwatersheds more closely. Doing so may help us better understand how to reduce bacterial loads elsewhere. The lowest ranking sites include Carbon Canyon Creek, Sunnyslope Channel, and Temescal Creek.

Follow-on investigations may be divided into two classes: 1) activities dedicated to further source evaluation; and 2) activities dedicated to bacterial load reductions. Source evaluation efforts should continue to move upstream, through the tributary system, collecting samples to identify the largest load contributors. Such sampling should focus on warm weather months when the bacterial concentrations are highest (Table 1-1).

Table 1-1. Relationship Between Air Temperature, Precipitation, and Relative Pathogen Indicator Concentrations

Precipitation	Air Temperature	
	Warm Months	Cool Months
Wet Weather	Highest	Mid-Range
Dry Weather	Mid Range	Lowest

Although bacterial concentrations are usually highest when it is raining, the actual risk of illness is nearly non-existent because there are virtually no people recreating under such conditions. In addition, wet weather days are relatively rare in southern California and the higher bacterial concentrations associated with urban runoff return to background levels very rapidly (<48 hours). So, the actual number of recreational days lost during storm events is comparatively small. Therefore, the greatest risk reduction can be achieved by focusing primarily on those conditions where the largest numbers of people are exposed to the highest pollutant concentrations from suspected human sources.

Apart from identifying sources, other significant load reduction activities should include using the tributary map to identify potential locations to establish regional Best Management Practices (BMPs). For example, Chris Basin has been identified as a site with unusually high bacterial counts. However, since most of the storm channels leading into and out of this area are likely to be reclassified as REC2 or REC-X (per the recommendation of the Stormwater Quality Standards Task Force)[1], it may be more appropriate to explore how the basin could be redesigned to serve as a BMP to protect actual recreation occurring further downstream. By focusing on warm, dry weather conditions, it is likely that cost-effective engineering solutions can be devised for the relatively low flows that occur during these conditions. Moreover, the TMDL requires compliance with dry weather targets in 2015; wet weather compliance is not required until 2025.

One location, Box Springs Channel, was identified very early in the study as having elevated *E. coli* concentrations and strong indications of possible contamination from human sources. Additional investigations revealed that a small restroom in a school park was cross-connected to a storm drain rather than the sewer line. Repairs were made and further investigation determined that general bacterial indicator concentrations were reduced significantly. Specialized molecular methods also showed that there were no longer detectable levels of bacteria originating from human sources after the cross-connection was repaired. Additional sampling may be warranted in the future to verify that the observed water quality improvement in Box Springs Channel is maintained.

[1] For more information, visit the Stormwater Quality Standards Task Force website at www.sawpa.org/projects/planning.htm

The stormwater management plans for San Bernardino and Riverside counties should be revised, as part of the pending permit renewal process to encourage the use of risk-based procedures for bacterial source identification and mitigation. Such a strategy is expected to provide the greatest potential improvement in human health protection in the shortest amount of time by concentrating on the most severe problem areas first. As each problem area is corrected, available resources will be retargeted toward new locations in order of their risk priority.

Section 2
Introduction

Various waterbodies in the Middle Santa Ana River watershed are listed on the state 303(d) list of impaired waters due to high levels of fecal coliform bacterial indicators. The Middle Santa Ana River (MSAR) Bacterial Indicator TMDL was adopted by the Santa Ana RWQCB and approved by the SWRCB to address these fecal coliform indicator impairments (RWQCB 2005). EPA Region 9 approved the TMDL on May 16, 2007 making the TMDL effective.

Implementation of this TMDL includes requirements for the implementation of a watershed-wide compliance monitoring program and an evaluation of urban sources of bacterial indicators. This report summarizes the findings from the first year of activities associated with these TMDL requirements.

2.1 Regulatory Background

Table 3-1 of the Santa Ana Regional Water Quality Control Plan (Basin Plan) designates beneficial uses for surface waters in the Santa Ana River watershed (RWQCB 1995). The beneficial uses applicable to waterbodies in the MSAR watershed include Water Contact Recreation (REC-1), which is defined in the Basin Plan as follows:

> "waters are used for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses may include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, whitewater activities, fishing, and use of natural hot springs" (Basin Plan, page 3-2).

The Basin Plan (Chapter 4) specifies fecal coliform as a bacterial indicator for pathogens ("bacterial indicator"). Fecal coliform present at concentrations above certain thresholds are believed to be an indicator of the presence of fecal pollution and harmful pathogens, thus increasing the risk of gastroenteritis in bathers exposed to the elevated levels. The Basin Plan currently specifies the following water quality objectives for fecal coliform:

> ***REC-1*** *- Fecal coliform: log mean less than 200 organisms/100 mL based on five or more samples/30-day period, and not more than 10 percent of the samples exceed 400 organisms/ 100 mL for any 30-day period.*

EPA published new bacteria guidance in 1986 (EPA 1986). This guidance advised that for freshwaters *E. coli* is a better bacterial indicator than fecal coliform. Epidemiological studies found that the positive correlation between *E. coli* concentrations and the frequency of gastroenteritis was better than the correlation between fecal coliform concentrations and gastroenteritis.

The RWQCB is currently considering replacing the REC-1 bacteria water quality objectives for fecal coliform with *E. coli* objectives. This evaluation is occurring through the work of the Stormwater Quality Standards Task Force (SWQSTF). The SWQSTF is comprised of representatives from various stakeholder interests, including the Santa Ana Watershed Protection Authority; the counties and cities of Orange, Riverside, and San Bernardino; Orange County Coastkeeper; Inland Empire Waterkeeper; the RWQCB; and EPA Region 9.

In 1994 and 1998, because of exceedances of the fecal coliform objective established to protect the REC-1 use, the RWQCB added various waterbodies in the MSAR watershed to the state 303(d) list of impaired waters. The MSAR Watershed TMDL Task Force ("TMDL Task Force"), which includes representation by many key watershed stakeholders, was subsequently formed to address bacterial indicator impairments in the following waterbodies:

- Santa Ana River, Reach 3 – Prado Dam to Mission Boulevard
- 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

The TMDL for these waters established compliance targets for both fecal coliform and *E. coli*:

- 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.

2.2 TMDL Implementation Requirements

The MSAR Bacterial Indicator TMDL addresses bacterial indicator impairments by establishing requirements for urban and agricultural discharges (RWQCB 2005) (Figure 2-1):

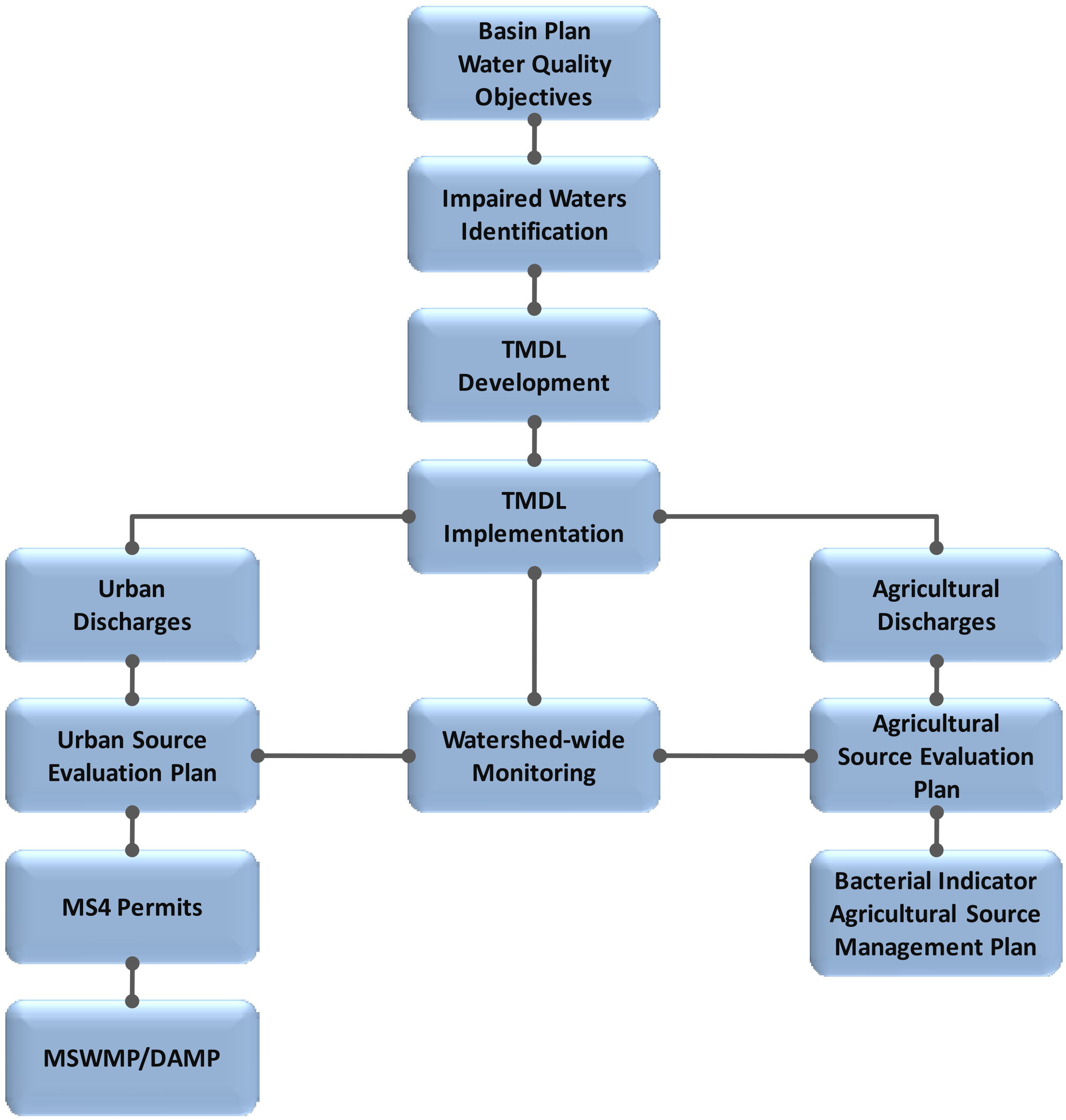

Figure 2-1. Outline of the TMDL development process for the MSAR Bacterial Indicator TMDL and TMDL implementation requirements applicable to urban and agricultural dischargers. This Data Analysis Report supports implementation of the "Watershed-wide Monitoring" and "Urban Source Evaluation Plan" elements.

- Urban and agricultural dischargers shall develop a Watershed-wide Bacterial Indicator Monitoring Program by November 30, 2007. This program is to be implemented following RWQCB approval. The dischargers developed the monitoring program by June 2007, and following RWQCB approval the monitoring program was implemented. This report provides the findings from the first year of implementation of this monitoring program.

- Permitted Municipal Separate Storm Sewer System (MS4) dischargers shall develop an Urban Source Evaluation Plan (USEP) by November 30, 2007 and implement it following RWQCB approval.

  Per Section 4.1 of the TMDL, the purpose of the USEP is to identify specific activities, operations, and processes in urban areas that contribute bacterial indicators to MSAR waterbodies (RWQCB 2005). The Plan should also include a proposed schedule for the activities identified and include contingency provisions as needed to reflect any uncertainty in the proposed activities or schedule.

  Per Sections 4.2, 4.3, 4.4, and 4.5 of the TMDL, the findings from the USEP activities will be used by the San Bernardino and Riverside County MS4 permit programs to mitigate urban sources of bacterial indicators to the extent practicable. The findings may also be used by the RWQCB to require revisions to the San Bernardino County Municipal Stormwater Management Program (MSWMP) and Riverside County Drainage Area Management Plan (DAMP). Wherever USEP activities identify bacterial indicator sources that are not covered by the San Bernardino and Riverside County MS4 permits, the RWQCB will be responsible for implementing follow-up actions.

  The USEP has been developed and approved by the RWQCB[2]. The monitoring program incorporated into the USEP was implemented during 2007-2008. This report provides the findings from the first year of USEP implementation.

- Agricultural dischargers shall develop an Agricultural Source Evaluation Plan (AgSEP) by November 30, 2007 and implement it with RWQCB approval. Agricultural dischargers are also required to develop a Bacterial Indicator Agricultural Source Management Plan (BASMP) at a later date.

  The purpose of the AgSEP is to identify specific activities, operations, and processes in agricultural areas that contribute bacterial indicators to MSAR watershed waterbodies (RWQCB 2005). The plan includes a proposed schedule for the steps identified and includes contingency provisions as needed to reflect any uncertainty in the proposed steps or schedule.

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[2] See http://www.waterboards.ca.gov/santaana/water_issues/programs/tmdl/msar_tmdl.shtml to review the RWQCB-approved USEP (SAWPA 2008c).

The AgSEP has been developed and approved by the RWQCB[3]. The monitoring program incorporated into the AgSEP will be implemented during 2008-2009. The findings from this effort will be reported in a future data analysis report.

2.3 Proposition 40 State Grant

In anticipation of EPA approval of the TMDL, the Santa Ana Watershed Project Authority (SAWPA), in cooperation with the San Bernardino County Flood Control District (SBCFCD), Riverside County Flood and Water Conservation District (RCFWCD), and Orange County Water District (OCWD) submitted a Proposition 40 grant proposal to the SWRCB to support the implementation of TMDL requirements. This grant proposal, Middle Santa Ana River Pathogen TMDL-BMP Implementation (Grant Project), was developed, in part, to initiate the watershed-wide compliance monitoring and characterize urban bacteria sources within the watershed. The state approved the grant proposal in fall 2006 and the Grant Project was initiated in early 2007.

2.4 Data Analysis Report: Purpose and Objectives

This Data Analysis Report provides the findings from the 2007-2008 water quality sampling conducted to support the watershed-wide compliance monitoring and urban source evaluation monitoring programs. Completion of this report fulfills the following objectives:

- *Grant Project Deliverable* – The 2007-2008 sampling was primarily funded by the Middle Santa Ana River Pathogen TMDL-BMP Implementation Grant Project. This report is a key deliverable for the Grant Project.

- *Watershed-wide Compliance Monitoring* - Provides the first annual report of monitoring results at watershed compliance monitoring sites.

- *USEP Deliverable* – The USEP requires the preparation of a report documenting the results of the first year of urban source monitoring. This report fulfills that requirement.

- *TMDL Implementation* - Provides recommendations for the next steps for TMDL implementation.

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[3] See http://www.waterboards.ca.gov/santaana/water_issues/programs/tmdl/msar_tmdl.shtml to review the RWQCB-approved AgSEP.

Section 3
Study Area

This section provides a description of the study area and the locations sampled during the sample period, July 9, 2007 through June 14, 2008.

3.1 Middle Santa Ana River Watershed

3.1.1 General Description

The Santa Ana River Watershed, located in southern California, is approximately 2,800 square miles in size. Surface water flows begin in the San Bernardino and San Gabriel Mountains and flow in a generally northwest to southwest direction to the Pacific Ocean. The MSAR Watershed is 488 square miles in size and located generally in the north central portion of the Santa Ana River Watershed. The watershed includes the southwestern part of San Bernardino County, the northwestern part of Riverside County, and a small portion of Los Angeles County (Figure 3-1).

Lying within an arid region, limited natural perennial surface water is present in the watershed. Flows derived from mountain areas (snowmelt or storm runoff) are mostly captured by dams or percolated in recharge basins. In the transition zone from mountains to lower lying valley areas, the source of surface water flows varies, e.g., dry weather urban runoff, such as occurs from irrigation, stormwater runoff during rain events, highly treated wastewater effluent, or rising groundwater.

The largest order waterbody in the MSAR Watershed is Reach 3 of the Santa Ana River, which flows from La Cadena to the Prado Basin, where Prado Dam controls flows from the middle to the lower part of the Santa Ana River Watershed. There are a number of major tributaries to the MSAR, many of which have been modified for flood control purposes.

Three major geographic areas comprise the MSAR watershed (RWQCB 2005) (Figure 3-2):

- Chino Basin (San Bernardino County, Los Angeles County, and Riverside Counties) – Surface drainage in this area, which is directed to Chino Creek and Mill-Cucamonga Creek, flows generally southward, from the San Gabriel Mountains toward the Santa Ana River and the Prado Flood Control Basin.

- Riverside Watershed (Riverside County) – Surface drainage in this area is generally northwestward or southwestward from the incorporated and unincorporated areas of Riverside County to Reach 3 of the Santa Ana River.

- Temescal Canyon Watershed (Riverside County) – Surface drainage in this area is generally northwest to Temescal Creek.

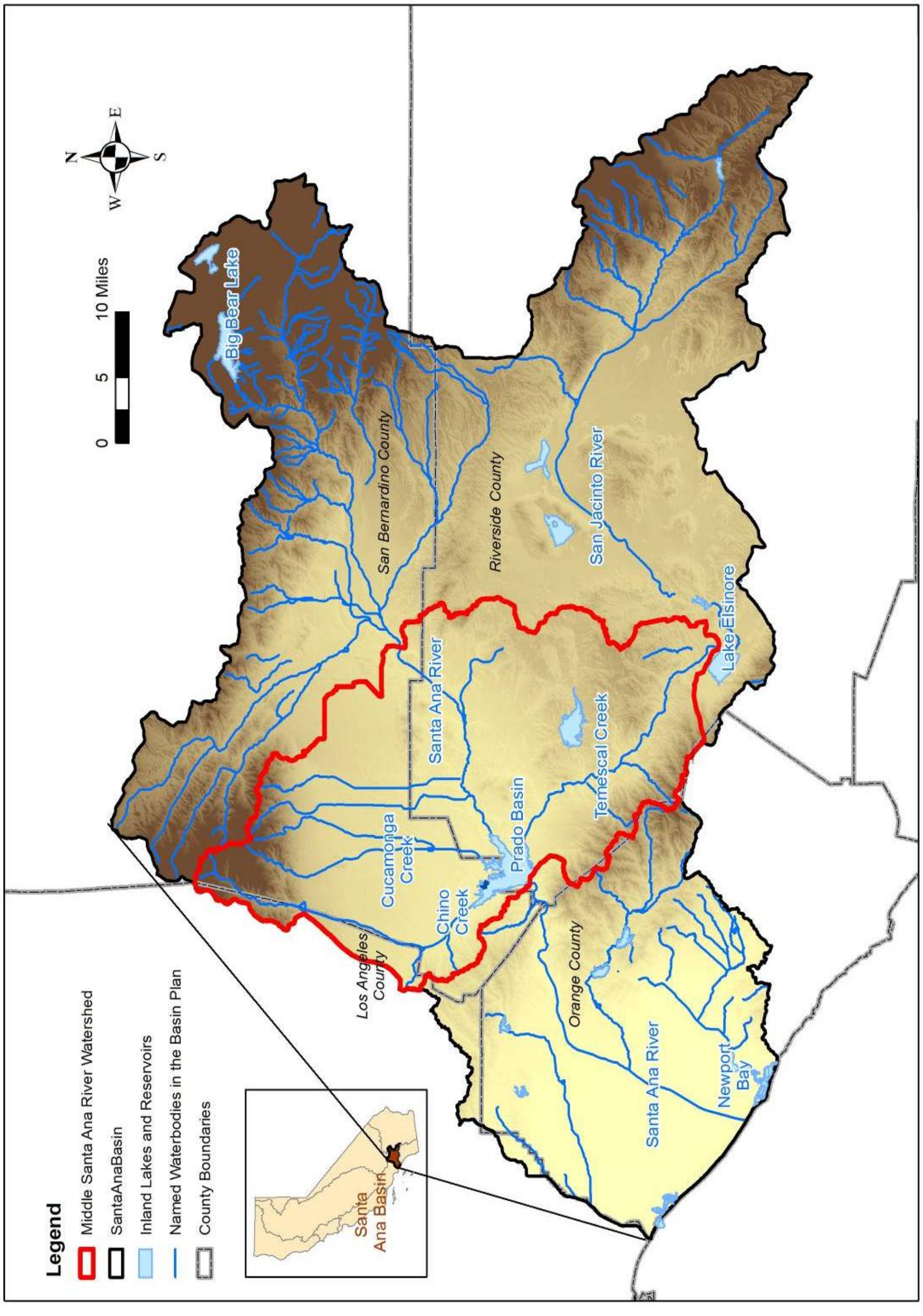


Figure 3-1. Location of the Middle Santa Ana River Watershed (red outline) within the Santa Ana River Watershed in southern California.

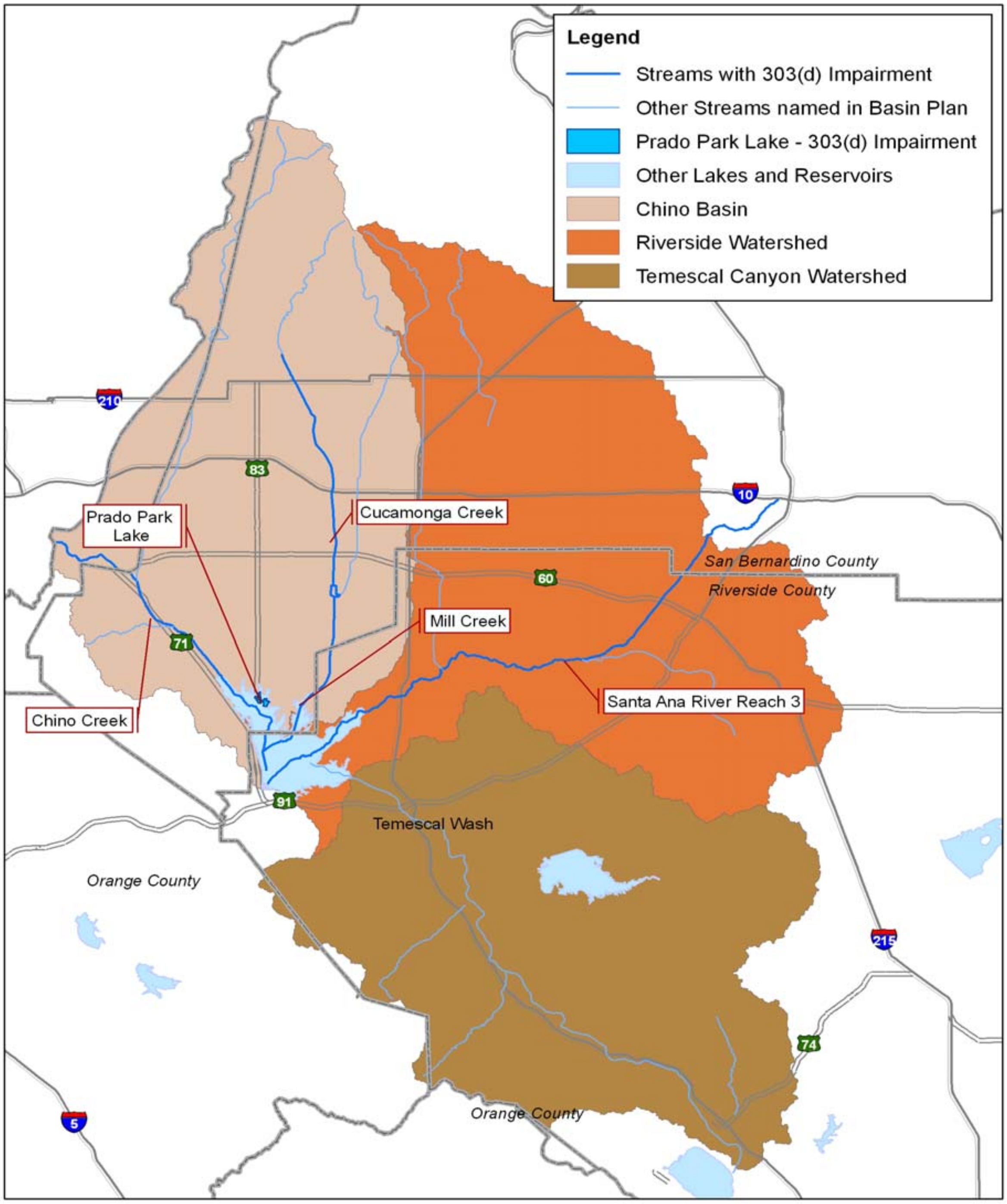


Figure 3-2. Major geographic areas of the Middle Santa Ana River Watershed

Based on 2000 census data, the population of the watershed is approximately 1.4 million people. Much of the lowland areas are highly developed; however, a portion of the watershed remains largely agricultural - the area formerly known as the Chino Dairy Preserve (see Figure 3-9). This area is located in the south central part of the Chino Basin subwatershed and contains approximately 300,000 cows (although this number is quickly declining as the rate of development increases) (RWQCB 2005). Recently, the cities of Ontario, Chino, and Chino Hills annexed the San Bernardino County portions of this area. The remaining portion of the former preserve, which is in Riverside County, remains unincorporated (RWQCB 2005).

3.1.2 Physical Description

The following sections summarize the regional hydrology, annual precipitation and temperature, and sources of information for previously reported bacterial indicator concentrations.

Regional Hydrology

The Santa Ana River Watershed experiences a Mediterranean type climate with hot, dry summers, and cooler, wetter winters. Average annual precipitation varies and ranges from 12 inches per year in the lower watershed along the Pacific coast to 18 inches per year in the inland valleys. In the mountains of the northern and eastern parts of the watershed annual precipitation may reach 40 inches per year. Most precipitation falls between November and March and may include variable amounts of snow in the higher mountains (SAWPA 2005).

On average, instream flows are typically low; however, periods of significant precipitation or localized intense rain events can result in rapid increases in surface flows by 1 to 2 orders of magnitude. Following such an event, streams tend to return to baseflow conditions quickly (SAWPA 2005). Instream flows in the watershed are influenced by the following (Figure 3-3):

- Dams capture wet weather flows in some subwatersheds resulting in attenuated flows in downstream waters. For example, the Chino Creek subwatershed receives releases from San Antonio Dam via its San Antonio Channel tributary.

- The effort to recharge groundwater by facilitating infiltration of surface water runoff reduces runoff in receiving waters by diversion and spreading of runoff in basins with high infiltration capacity.

- The importation of water to the watershed increases surface flows in certain areas, e.g., importation of water to Chino Creek.

- A number of publicly owned treatment works (POTW) discharge highly treated effluent to MSAR waterbodies, e.g., a significant portion of the flow along segments of Reach 3 of the Santa Ana River is comprised mostly of treated effluent.

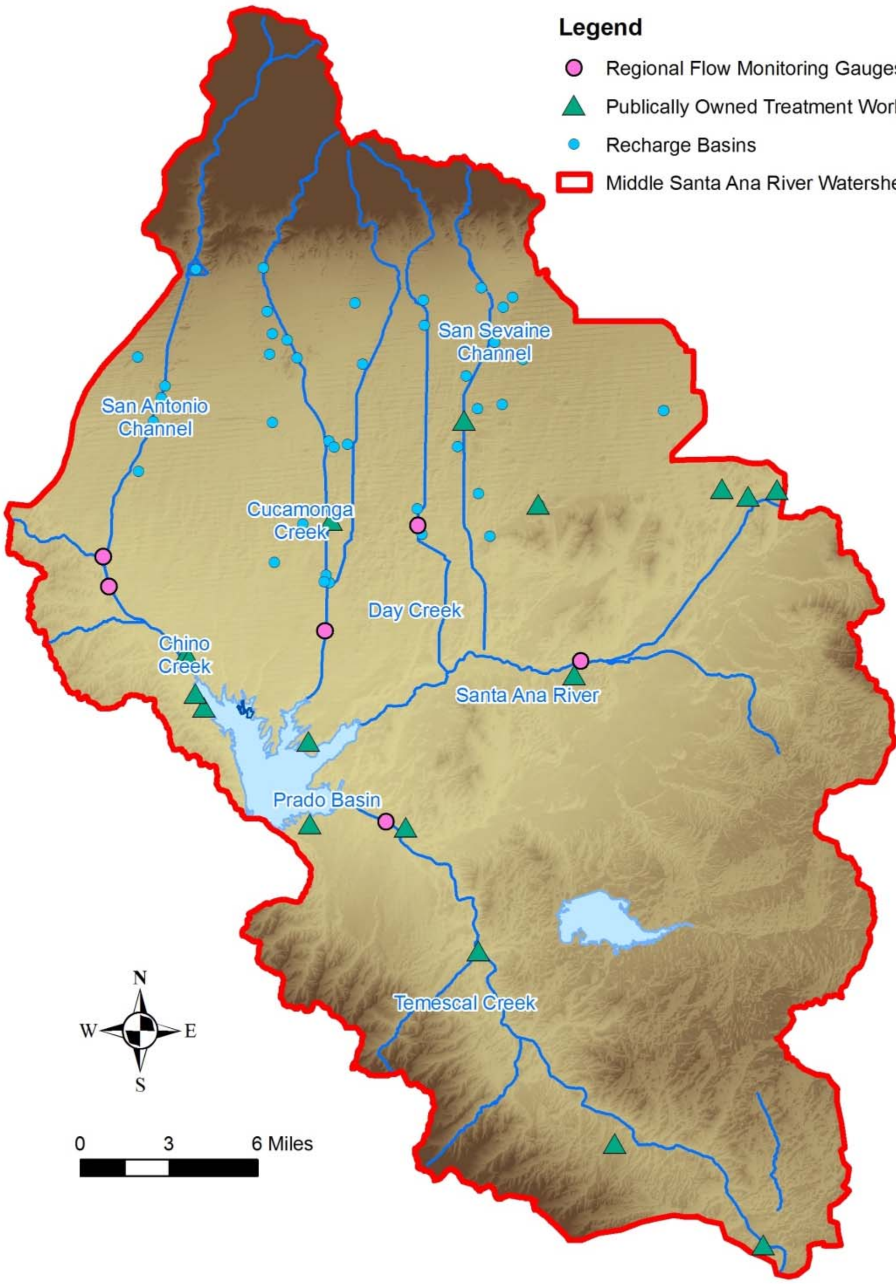


Figure 3-3. Location of recharge basins and publicly owned treatment works that influence instream flows in Middle Santa Ana River waterbodies.

Precipitation

Table 3-1 summarizes the precipitation statistics for a rainfall gauge located within the study area (Riverside Fire Station #3). The long-term 30-year average annual precipitation at this location is 10.06 inches/year. In comparison, the 2007-2008 sample period was very dry with only 5.39 inches of precipitation recorded. Figure 3-4 shows the monthly precipitation received during this project in comparison to long-term monthly averages.

Table 3-1. Average Annual Precipitation in the Study Area as Measured at Riverside Fire Station #3 as Compared to with 2007-2008 Study Period

Measurement	Precipitation (inches)
Average Annual Precipitation	10.06
Maximum Recorded Annual Precipitation	22.72
Minimum Recorded Annual Precipitation	1.07
Precipitation - July 2007 to June 2008	5.39

Temperature

Figure 3-5 provides the long-term average, maximum, and minimum monthly temperatures for the study area. Superimposed on this figure are the monthly average temperatures recorded during the 2007-2008 study period. These data show that the 2007-2008 period was warmer than normal during most months.

Water Quality

Bacterial indicator water quality data have been collected for many years in the MSAR watershed. Two studies completed in recent years include:

- *Regional Water Quality Control Board Study* – In 2002-2004 the RWQCB and the TMDL Taskforce (historically known as the MSAR Bacteria Indicator Workgroup), collected fecal coliform and *E. coli* data from several locations that were also sampled during this study. The data collected by the RWQCB during this period supported the impairment finding for Chino Creek, Mill Creek, and Reach 3 of the MSAR. Data from this study were obtained from the RWQCB for comparison with this study's sample results.

- *Chino Creek Watershed Study* – From 2004 to 2006, OCWD conducted a bacterial indicator and microbial source tracking study in the Chino Creek Watershed (Leddy 2007). The study effort included 14 sample locations in the watershed. Of these locations, three sites were at or near locations sampled in this study.

The findings from the above studies can be compared to the current study findings to evaluate how bacterial indicator concentrations have changed over time. This comparison is provided in Section 5.1.

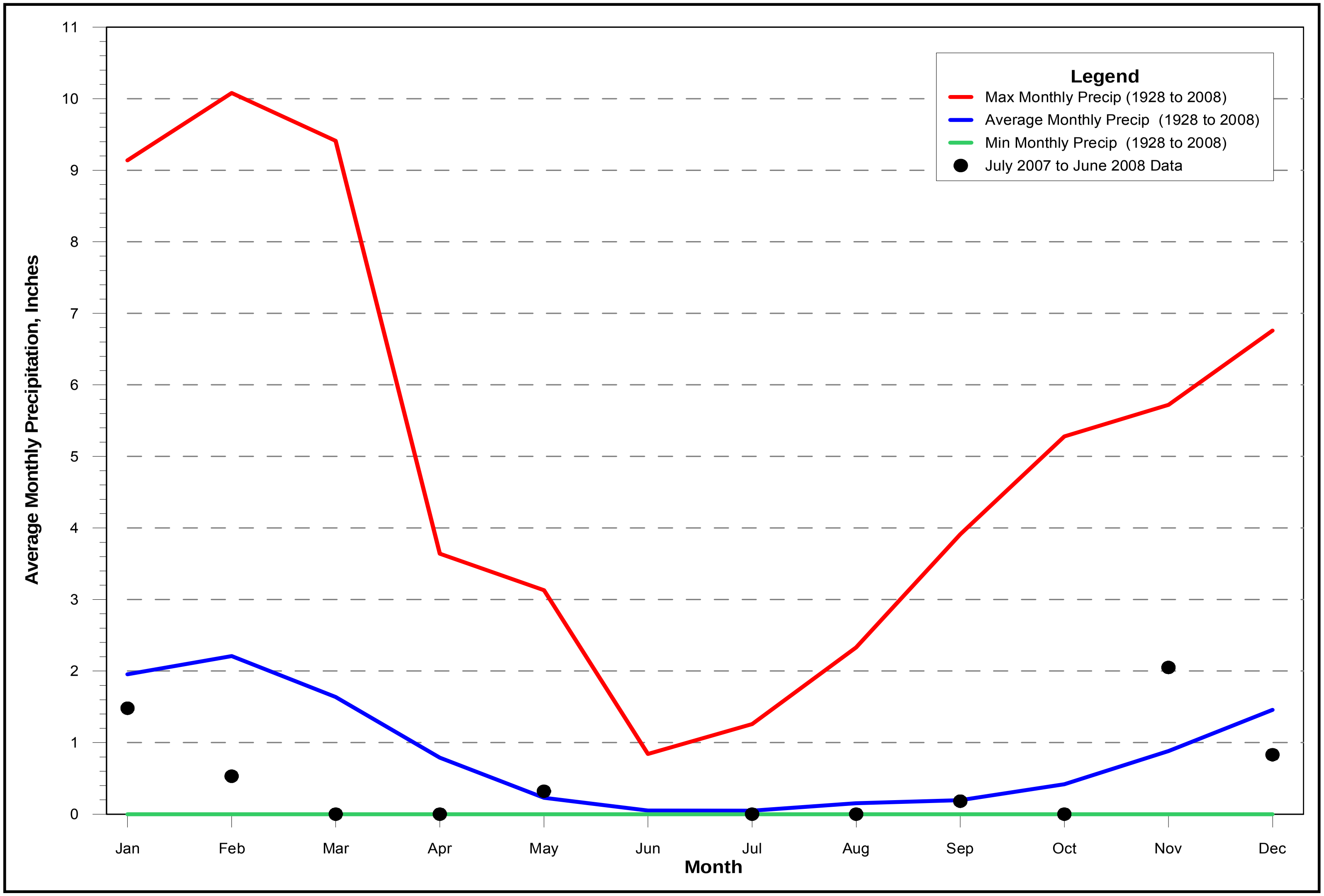


Figure 3-4. Average monthly precipitation at the Riverside Fire Station #3 rain gauge (blue line). The black dots show the comparative monthly precipitation received during the project study period (2007-2008).

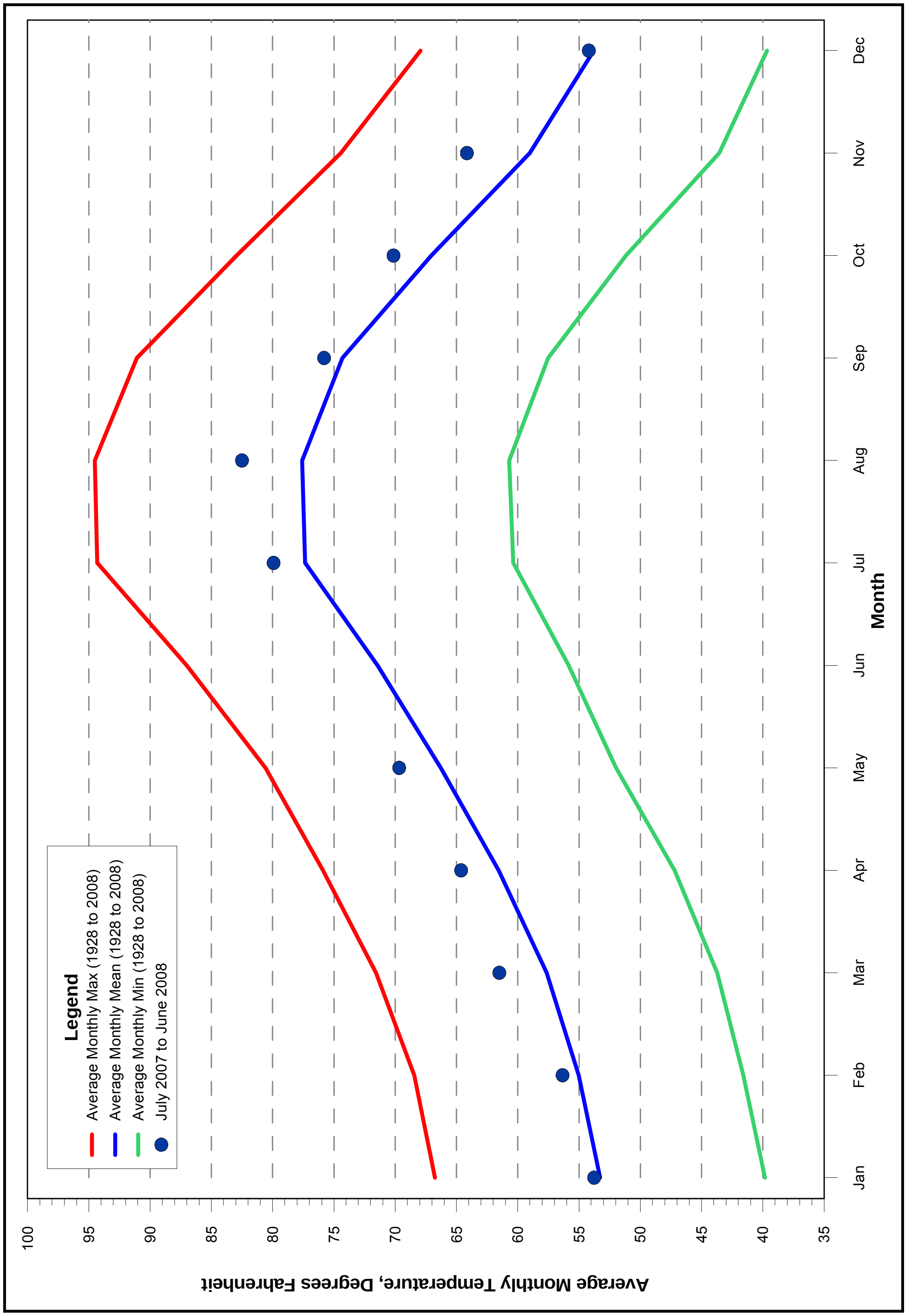


Figure 3-5. Average monthly temperatures in the study area (blue line). Black dots show the monthly average temperature that occurred during the study period.

3.2 Water Quality Sampling Program

The 2007-2008 water quality sampling supported the water quality monitoring programs established to support TMDL implementation (see Section 2): (1) Watershed-Wide Compliance Monitoring Program; and (2) Urban Source Evaluation Monitoring Program. The following sections provide a summary of each monitoring program. Complete information regarding each program is available in the approved Monitoring Plan[4] and Quality Assurance Project Plan[5].

3.2.1 Watershed-Wide Compliance Monitoring Program

The purpose of the Watershed-Wide Monitoring Program is to measure compliance with numeric targets established by the MSAR Bacterial Indicator TMDL. These numeric targets are derived from Basin Plan objectives established to protect the REC-1 beneficial use. Compliance sites were selected based on two key criteria:

- The sites should be located on waterbodies that are impaired and subject to TMDL compliance requirements; and

- The sites should be located in reaches of the impaired waterbodies where REC-1 activity is likely to occur, i.e., there is an increased risk from exposure to pathogens.

Based on these criteria, the MSAR Task Force established six Watershed-Wide (WW) sites as TMDL water quality compliance sites (Table 3-2, Figure 3-6). Specific information regarding each sample site may be found in the Monitoring Plan (see footnote 3).

3.2.2 Urban Source Evaluation Monitoring Program

The primary goal of the Urban Source Evaluation Monitoring Program is to guide efforts to reduce bacteria sources derived from discharges covered by MS4 NPDES permits. For 2007-2008, the following criteria provided the basis for sample site selection:

Table 3-2. Watershed-Wide Compliance Monitoring Program Sample Locations

Waterbody	Sample Location	Site Code
Icehouse Canyon Creek	Near Icehouse Canyon Trailhead Parking Lot	WW-C1
Chino Creek	Central Avenue	WW-C7
Mill Creek	Chino-Corona Road	WW-M5
Santa Ana River	MWD Crossing	WW-S1
Santa Ana River	Pedley Avenue	WW-S4
Prado Lake	Prado Lake Outlet	WW-C3

[4] Middle Santa Ana River Monitoring Plan, SAWPA 2008a. See the Santa Ana Regional Water Quality Control Board: http://www.waterboards.ca.gov/santaana/water_issues/programs/tmdl/msar_tmdl.shtml
[5] Quality Assurance Project Plan for the Middle Santa Ana River Pathogen TMDL – BMP Implementation Project, SAWPA 2008b. See the Santa Ana Regional Water Quality Control Board: http://www.waterboards.ca.gov/santaana/water_issues/programs/tmdl/msar_tmdl.shtml

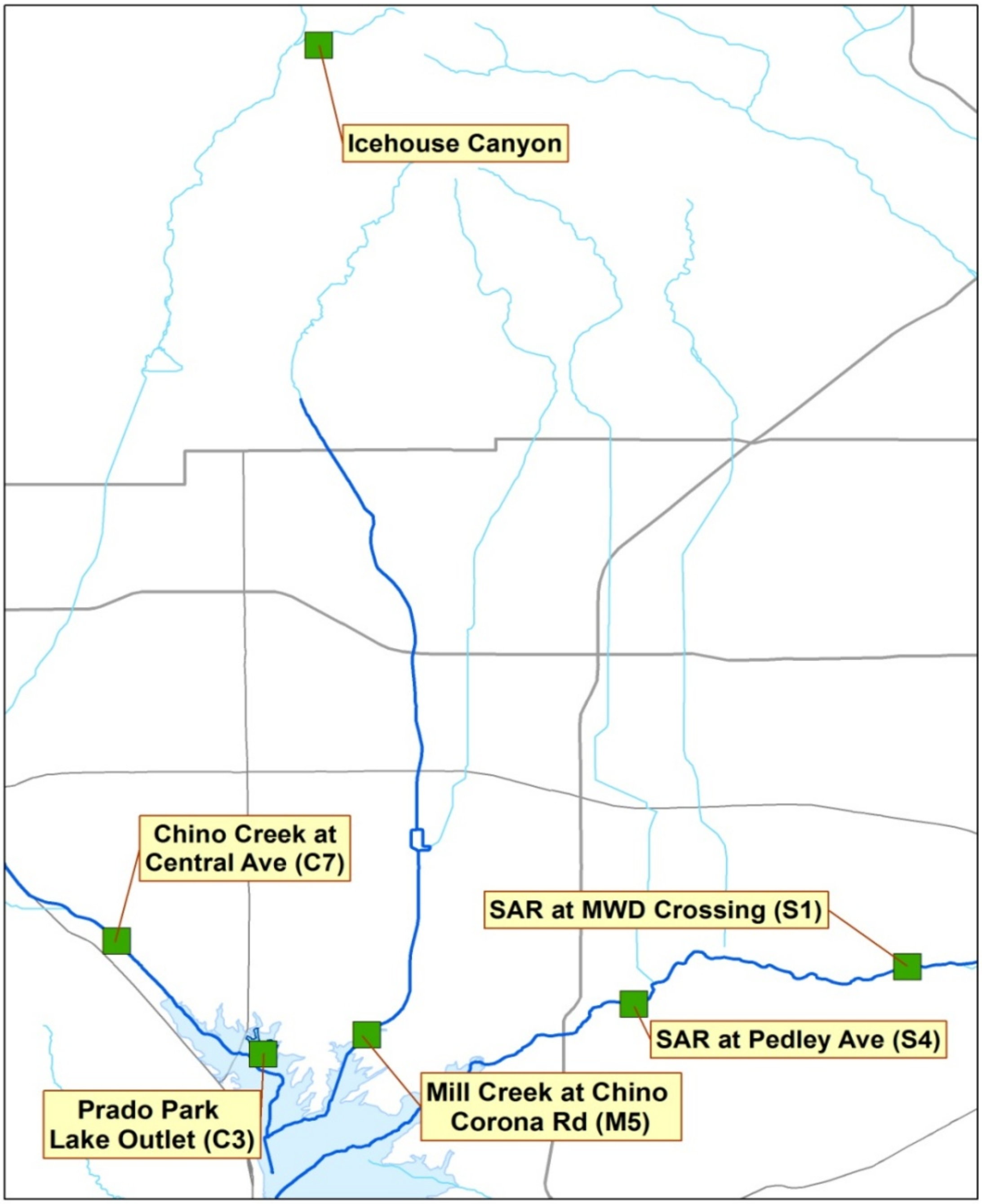


Figure 3-6. Location of Watershed-Wide Compliance Monitoring Program sample locations in the MSAR Watershed.

- Sample site is in a waterbody that is tributary to an impaired water
- Sample site has the potential to contribute a high percentage of the flow (volumetrically) to an impaired water
- Sample site should be close to the base of its watershed so that it characterizes the majority of flow reaching the impaired water from the site's watershed
- Flow at the selected sample site should not include any permitted effluent discharge
- Flow at the selected sample site should generally occur under both dry and wet weather conditions

Based on these criteria, Table 3-3 identifies the USEP sites selected for sampling in 2007-2008 and their relationship to the 303(d) listed waterbodies. Figure 3-7 shows the USEP sample sites in relation to the WW compliance sites. Specific information regarding each sample site may be found in the Monitoring Plan (see footnote 3).

Table 3-3. Urban Source Evaluation Monitoring Program Sample Locations

MSAR Waterbody	Waterbody Reach[1]	Sample Location	Site Code
Santa Ana River	Reach 3	Santa Ana River (SAR) at La Cadena Drive	US-SAR
		Box Springs Channel at Tequesquite Avenue	US-BXSP
		Sunnyslope Channel near confluence with SAR	US-SNCH
		Anza Drain near confluence with Riverside effluent channel	US-ANZA
		San Sevaine Channel in Riverside near confluence with SAR	US-SSCH
		Day Creek at Lucretia Avenue	US-DAY
		Temescal Wash at Lincoln Avenue	US-TEM
Chino Creek	Reach 1	Cypress Channel at Kimball Avenue	US-CYP
	Reach 2	San Antonio Channel at Walnut Ave	US-SACH
		Carbon Canyon Creek Channel at Pipeline Avenue	US-CCCH
Mill-Cucamonga Creek	Prado Area	Chris Basin Outflow (Lower Deer Creek)	US-CHRIS
		County Line Channel near confluence with Cucamonga Creek	US-CLCH
	Reach 1	Cucamonga Creek at Highway 60 (Above RP1)	US-CUC

[1] Reaches are defined in the Basin Plan.

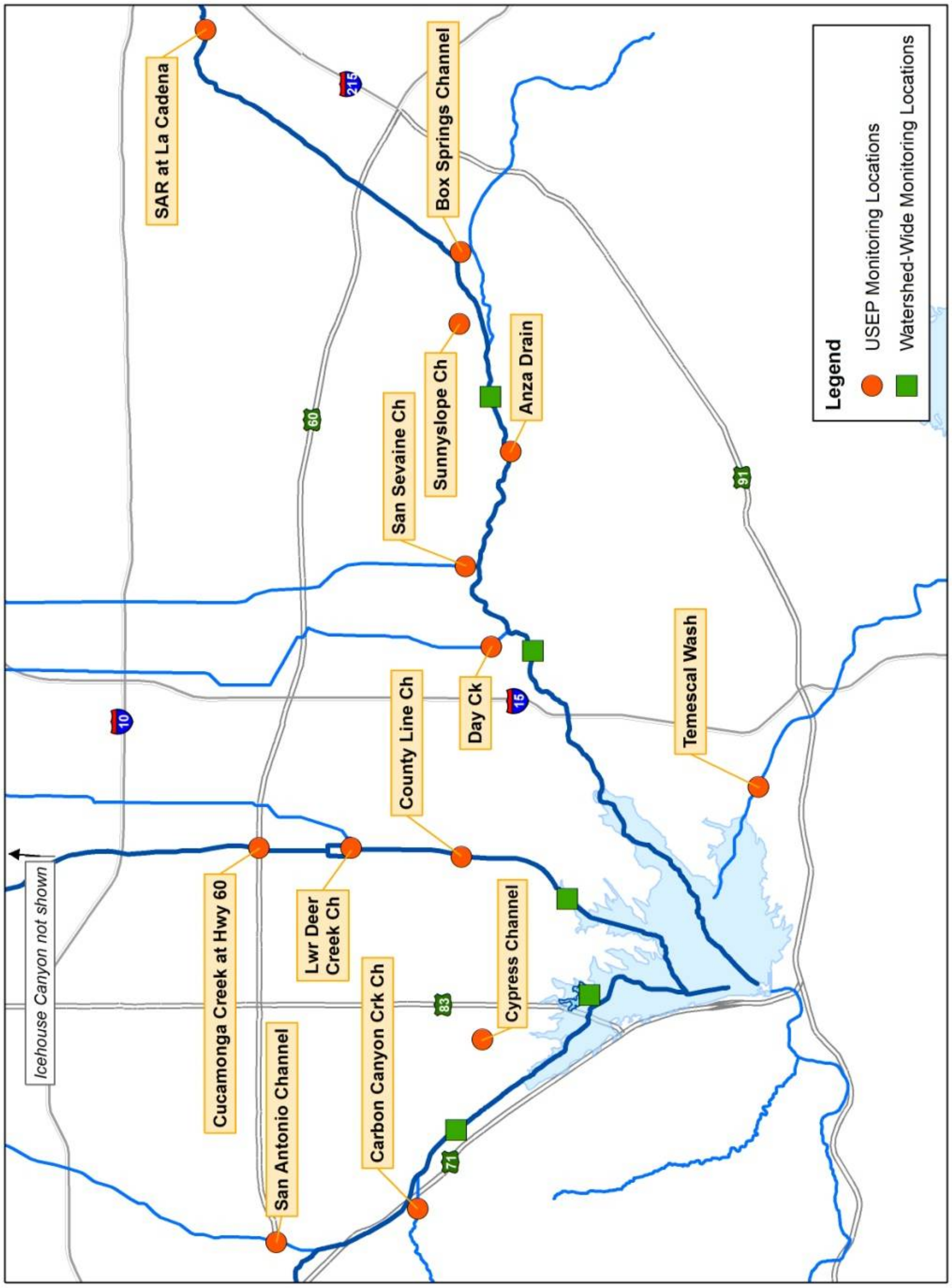


Figure 3-7. Location of Watershed-wide Compliance Monitoring Program sample locations in the MSAR Watershed.

3.3 Watershed Characteristics of Sample Sites

The following sections provide information on the watershed characteristics associated with each sample site.

3.3.1 Watershed Area

Figure 3-8 illustrates the areal coverage of the subwatersheds associated with each USEP and WW site. Table 3-4 provides the total acreage of each individual watershed. As a whole, the subwatersheds associated with the WW and USEP sites comprise 90.7 percent of the entire MSAR Watershed.

The acreage summarized in Table 3-4 assumes that all water originating from any point in the MSAR watershed can reach the base of the MSAR watershed at any time. However, because of the numerous dams and diversions (particularly along the base of the various mountain ranges), during dry weather, runoff at these higher elevation locations is likely to be captured and prevented from moving downstream. Accordingly, the effective watershed area from the standpoint of dry weather flow is smaller for some subwatersheds. Table 3-5 provides the effective watershed acreage taking into account the acreage where dry weather flows are unlikely to contribute to downstream waters.

3.3.2 Land Use

The primary land uses in the MSAR watershed include urban, agriculture, and open space. Incorporated cities in the MSAR watershed include Chino, Chino Hills, Claremont, Corona, Fontana, Montclair, Norco, Ontario, Pomona, Rancho Cucamonga, Rialto, Riverside, and Upland. In addition, there are several pockets of urbanized unincorporated areas. Open space areas include National Forest lands and State Park lands.

Land use data for the watershed were obtained from Southern California Association of Governments (SCAG). This organization breaks out land use into numerous categories, which may be recombined into the following four major categories:

- Agricultural
- Commercial/Industrial
- Natural/Vacant
- Residential

Figure 3-9 illustrates the areal coverage of these four land use types in the MSAR Watershed. Table 3-4 provides the total acreage and percent of total acreage for these land use types in the entire watershed. Table 3-5 revises the land use numbers by only considering the portions of the watershed likely to contribute to dry weather flow. This effectively removed many of the large areas of land classified as "natural/vacant" in the upper portions of the watershed, e.g., San Gabriel Mountains.

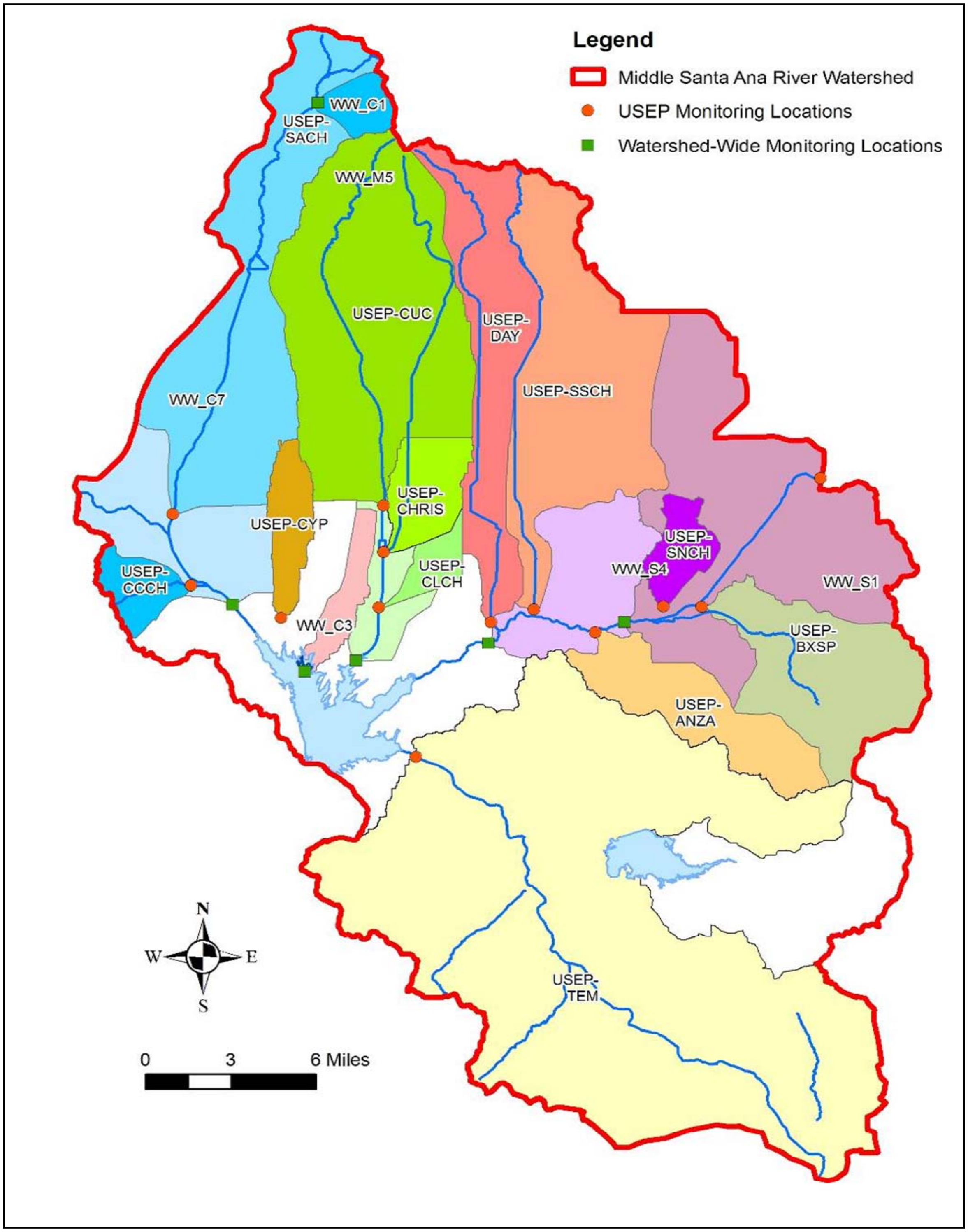


Figure 3-8. Watershed area associated with each Watershed-wide and Urban Source Evaluation sample site. See Tables 3-2 and 3-3 for site codes.

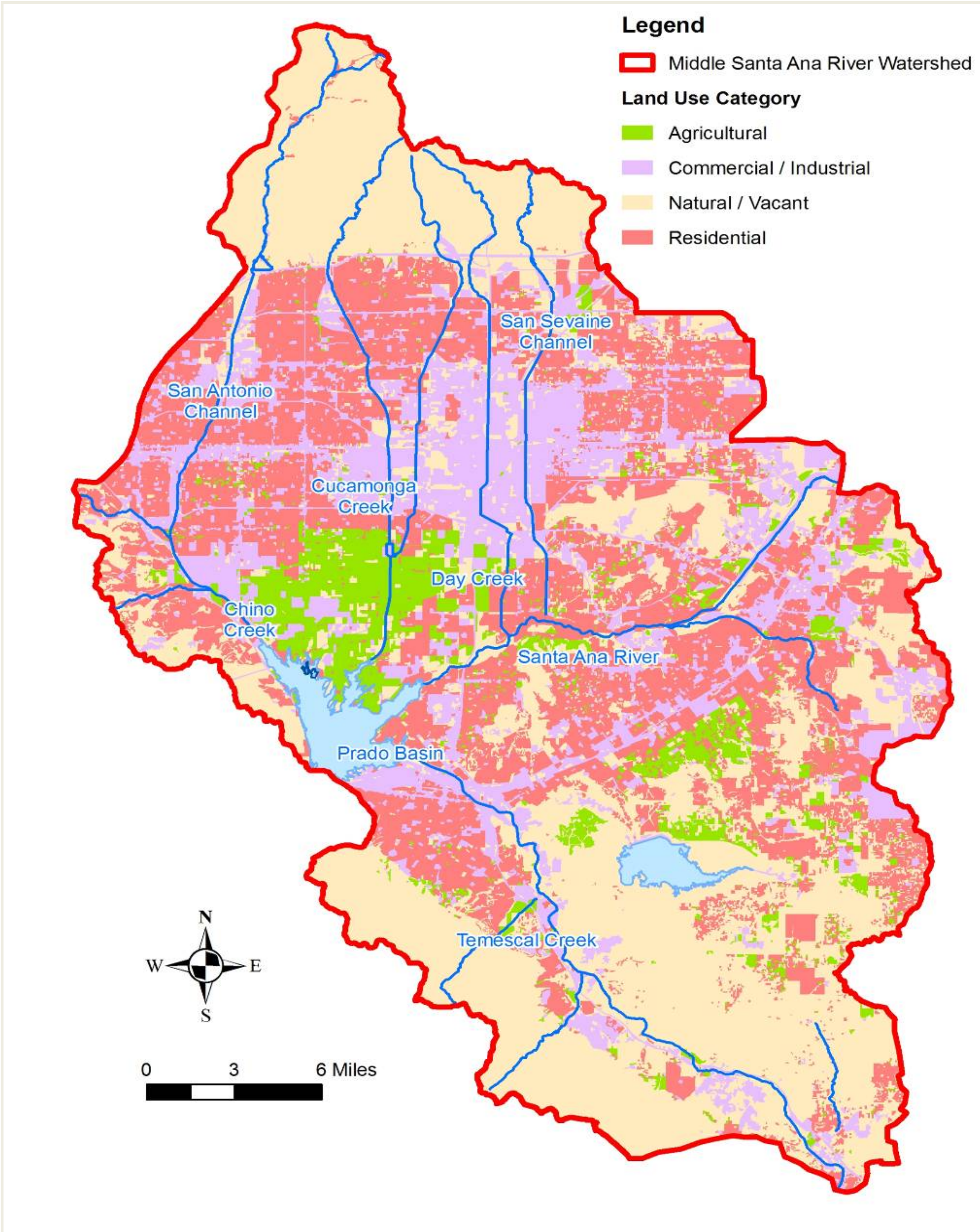


Figure 3-9. Major categories of land use in the MSAR Watershed.

Table 3-4. Acreage of major land use categories in each subwatershed sampled in the MSAR watershed[1]. Acreage based on entire subwatershed without regard for elevation and potential to contribute dry weather flows (contrast with Table 3-5, see text for discussion)

Site Type	Site	Watershed Area (Acres)	Number of Acres				Percent of Watershed Acreage			
			Agricultural	Commercial/ Industrial	Natural/Vacant	Residential	Agricultural	Commercial/ Industrial	Natural/Vacant	Residential
Watershed Wide Compliance	Icehouse Canyon Creek	2,861	0	1	2,826	34	0%	0%	99%	1%
	Prado Park Lake	3,738	2,274	521	512	432	61%	14%	14%	12%
	Chino Creek	57,877	1,463	12,402	22,644	21,368	3%	21%	39%	37%
	Mill Creek	58,854	5,067	16,408	18,243	19,137	9%	28%	31%	33%
	SAR @ MWD Crossing	64,640	2,539	15,996	18,632	27,473	4%	25%	29%	43%
	SAR @ Pedley Ave.	145,384	6,254	39,070	44,092	55,968	4%	27%	30%	38%
Urban Source Evaluation	Anza Drain	13,274	1,533	2,485	2,876	6,379	12%	19%	22%	48%
	Box Springs Channel	19,905	657	4,496	6,067	8,685	3%	23%	30%	44%
	Carbon Canyon Creek	3,960	162	229	1,903	1,666	4%	6%	48%	42%
	Chris Basin	6,241	393	3,782	1,027	1,039	6%	61%	16%	17%
	County Line Channel	4,059	1,833	1,270	696	260	45%	31%	17%	6%
	Cucamonga Creek	44,973	296	11,561	15,971	17,145	1%	26%	36%	38%
	Cypress Channel	4,952	1,270	790	90	2,802	26%	16%	2%	57%
	Day Creek	21,419	449	7,737	9,243	3,991	2%	36%	43%	19%
	San Antonio Channel	39,142	296	7,021	18,903	12,922	1%	18%	48%	33%
	Sunnyslope Channel	32,612	804	11,116	9,177	11,515	5%	14%	39%	42%
	San Sevaine Channel	132,605	6,021	14,421	85,157	27,006	2%	34%	28%	35%
	Temescal Creek	13,274	1,533	2,485	2,876	6,379	5%	11%	64%	20%
Total Acres/Percent of Total		465,754	30,810	91,358	198,743	144,842	7%	20%	43%	31%
MSAR Acreage/Percentage not sampled		47,602	5,363	2,321	25,162	14,756	11%	5%	53%	31%

[1] USEP site SAR at La Cadena (US-SAR) is not included because its entire watershed is located upstream of the MSAR watershed.

Table 3-5. Acreage of major land use categories in each subwatershed sampled in the MSAR watershed1, 2. Acreage based on portion of each subwatershed which is likely to contribute dry weather flows to the sample location (i.e., higher elevation areas such as the San Gabriel Mountains were excluded) (contrast with Table 3-4; see text for discussion)

Site Type	Site	Watershed Area (Acres)	Number of Acres				Percent of Watershed Acreage			
			Agricultural	Commercial/ Industrial	Natural/Vacant	Residential	Agricultural	Commercial/ Industrial	Natural/Vacant	Residential
Watershed Wide Compliance	Prado Park Lake Outlet	3,738	3,738	2,274	521	512	61%	14%	14%	12%
	Chino Creek	40,324	40,324	1,460	12,272	5,627	4%	30%	14%	52%
	Mill Creek	47,185	47,185	5,067	16,348	6,633	11%	35%	14%	41%
	SAR @ MWD Crossing	64,640	64,640	2,539	15,996	18,632	4%	25%	29%	43%
	SAR @ Pedley Ave.	136,168	136,168	6,254	38,979	34,968	5%	29%	26%	41%
Urban Source Evaluation	Anza Drain	13,274	1,533	2,485	2,876	6,379	12%	19%	22%	48%
	Box Springs Channel	19,905	657	4,496	6,067	8,685	3%	23%	30%	44%
	Carbon Canyon Creek	3,934	162	229	1,885	1,659	4%	6%	48%	42%
	Chris Basin	6,241	393	3,782	1,027	1,039	6%	61%	16%	17%
	County Line Channel	4,059	1,833	1,270	696	260	45%	31%	17%	6%
	Cucamonga Creek	33,303	296	11,502	4,361	17,144	1%	35%	13%	51%
	Cypress Channel	4,952	1,270	790	90	2,802	26%	16%	2%	57%
	Day Creek	15,893	449	7,676	3,778	3,991	3%	48%	24%	25%
	San Antonio Channel	21,615	294	6,891	1,903	12,527	1%	32%	9%	58%
	Sunnyslope Channel	4,090	222	585	1,582	1,701	5%	14%	39%	42%
	San Sevaine Channel	28,923	804	11,086	5,518	11,515	3%	38%	19%	40%
	Temescal Creek	107,834	6,012	14,415	60,406	27,001	6%	13%	56%	25%
Total Acres/Study Area		402,593	30,798	91,073	136,284	144,438	8%	23%	34%	36%
Additional MSAR Acreage		47,602	5,363	2,321	25,162	14,756	11%	5%	53%	31%

[1] Icehouse Canyon Creek not included in this analysis; entire watershed in higher elevation area.
[2] USEP site SAR at La Cadena (US-SAR) is not included because its entire watershed is located upstream of the MSAR watershed.

Section 4
Methods

The collection and analysis of field data and water quality samples was governed by the RWQCB-approved Monitoring Plan and Quality Assurance Project Plan prepared for the Watershed-Wide Compliance and Urban Source Evaluation Monitoring Programs (see footnotes 3 and 4). The following sections provide a summary of the field and laboratory methods used to collect data for this project. Details regarding specific methods may be reviewed in the Monitoring Plan and Quality Assurance Project Plan

4.1 Water Quality Measurements

At all WW and USEP sites water quality measurements included the collection of data for field parameters and the collection of water samples for laboratory analysis:

- *Field Measurement:* Flow, temperature, conductivity, pH, dissolved oxygen, and turbidity.

- *Laboratory Analysis:* Fecal coliform, *E. coli*, and total suspended solids (TSS).

4.2 Microbial Source Tracking

At all USEP sites water samples were collected for the analysis of *Bacteroidales* host-specific markers for human, bovine, and domestic canine sources of bacterial indicators. The methodology provides a semi-quantitative estimate of the relative abundance of these markers in the water sample. The Urban Source Evaluation Plan, Monitoring Plan, and Quality Assurance Project Plan provide additional details regarding the selection and implementation of this microbial source tracking methodology.

Orange County Water District Laboratory and University of California Davis Laboratory (Department of Civil Engineering) each analyzed approximately half of the samples for *Bacteroidales* host-specific markers. Because differences exist in how these two laboratories test for the host-specific markers, a laboratory comparability study was conducted using a single blind test study design. Appendix C provides the methodology for this study and a summary of the results that were obtained.

4.3 Sample Frequency

Sample teams collected samples at each WW and USEP sample location according to the schedule established in the Monitoring Plan. This plan divided sampling into three types of events:

- *Warm Dry Weather* – defined by the TMDL as the warm period between April 1 and October 31st. Twenty and ten samples were planned for collection from each WW and USEP site, respectively. During the warm period, sampling occurred weekly with at least 5 weeks collected consecutively (to allow for calculation of a 5-sample geometric mean).

- *Cool Dry Weather* – defined by the TMDL as the cool period between November 1 and March 31st. Eleven and six samples were planned for collection from each WW and USEP site, respectively. During the cool period, sampling occurred weekly with at least 5 weeks collected consecutively (to allow for calculation of a 5-sample geometric mean).

- *Wet Weather* – defined as a four-sample event that takes place over a 5-day period that is initiated by the occurrence of a rain-induced runoff event. The first sample was collected on the day of the rain event. Subsequent samples were collected at approximately 48, 72, and 96 hours after the collection of the first sample.

Table 4-1 provides a summary of the number and timing of all sample events planned for 2007-2008 sample period. Table 4-2 summarizes the results of the sampling effort and provides information on when samples were missed and the reason for no sample.

Table 4-1. Number data collection activities planned for at each site in 2007-2008

Monitoring Program	Samples Planned/Site		Summer Dry Weather Schedule	Winter Dry Weather Schedule	Wet Weather Schedule
	Dry	Wet			
WW	30	4	15 weeks: July 9 – October 14, 2007 5 weeks: May 11 - June 8, 2008	10 weeks: December 16, 2007 – February 17, 2008	4 samples collected during 5 day period
USEP	16	4	5 weeks: July 9 to August 5, 2007; 5 weeks: August 26 to September 16, 2007	6 weeks: January 13 to February 17, 2007	4 samples collected during 5 day period

Table 4-2. Summary of samples actually collected

Monitoring Program	Sample Type	Planned	Collected	Site Dry	Samples Missed (Cause)
WW	Summer Dry Weather	120	104	16[2]	0
	Winter Dry Weather	60	50	10[2]	0
	Wet Weather[1]	24	20	4[2]	0
	Total	**204**	**174**	**30**	0
USEP	Summer Dry Weather	130	111	18	1 (access problem)
	Winter Dry Weather	78	63	15	0
	Wet Weather[1, 3]	52	44	4	4 (access problem)
	Total	**260**	**218**	**37**	5

1 Wet weather event occurred during week of December 7th.
2 Icehouse Canyon was dry on all sample dates except four in spring 2008.
3 Samples collected during wet weather event were potentially reclassified to dry weather for analysis purposes (see Section 4.7)

4.4 Data Collection

Two sampling teams collected field measurements and water quality samples during 2007-2008: (1) WW sites – San Bernardino County Flood Control District staff; (2) USEP sites – Brown & Caldwell, Inc. staff. CDM coordinated the activities of the sample teams and the submittal of samples to the appropriate laboratories for analysis.

Sample team staff participated in a field training prior to the initiation of the monitoring programs. Details regarding methods for field measurements and water quality sample collection are fully described in the Monitoring Plan and Quality Assurance Project Plan (see footnotes 3 & 4).

4.5 Sample Handling

Samples 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. Orange County Water District Laboratory and University of California Davis Laboratory (Department of Civil Engineering) each analyzed approximately half of the samples for *Bacteroidales* host-specific markers. The Quality Assurance Project Plan provides information regarding sample handling details (see footnote 4).

4.6 Data Handling

CDM and SAWPA maintained a file of all laboratory and field data records (e.g., data sheets, chain of custody forms) as required by the projects Quality Assurance Project Plan. CDM entered all field measurements and laboratory analysis results into a project database that is compatible with guidelines and formats established by the California SWAMP program. This database was periodically submitted to SAWPA for incorporation into the Santa Ana Watershed Data Management System (SAWDMS). Prior to submittal to SAWPA, CDM completed a QA/QC review of the data, as required by the project Quality Assurance Project Plan (see footnote 4).

4.7 Data Analysis

Data analysis relied on a combination of descriptive and hypothesis testing statistics to evaluate the data from various spatial, temporal and hydrological perspectives. These analyses were completed using statistical and graphical software packages including SYSTAT, @RISK, EXCEL, and GRAPHER. Prior to conducting hypothesis-based statistical tests, the data sets were evaluated for normality as needed to determine the appropriateness of using parametric or non-parametric tests. To the extent possible, after evaluating the nature of the data distribution, data were normalized (e.g., by using a natural log transformations) to allow for the use of more robust parametric statistical tests. If normalization was not possible, or there was some uncertainty in the data distribution, then non-parametric tests were applied.

Data analyses based on seasonal or flow characteristics were defined as follows:

- *Seasonal:* Samples were divided into two groups for seasonal analysis:
  - Warm Season: Samples collected between April 1st and October 31st.
  - Cool Season: Samples collected between November 1st and March 31st.

- *Flow Conditions:* A storm on December 7, 2007 was selected to collect wet weather samples using the guidelines identified in the Monitoring Plan. While this storm resulted in a stormwater runoff event at all WW and USEP study sites on the first day of sampling for the storm event (Figure 4-1), only some sites were influenced by wet weather flow two days after the storm when the second day of sampling occurred (December 9, 2007).

  In addition to this planned wet weather sampling event, other rain events occurred in parts of the MSAR watershed within days prior to the collection of routine weekly samples. Some of these samples had the potential to be collected during wet weather conditions, e.g., during elevated flows.

  Given these different possible scenarios for collection of a wet weather sample, the following data sources/criteria were evaluated to provide a basis for classifying a sample as having been collected during wet or dry 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; and

  - Comparison of the flow measurement taken at the time of sample collection to the typical site baseflow observed during the 2007-2008 sample period (See Section 5.7.3 for discussion of how baseflow conditions were estimated at each site).

Table 4-3 summarizes the sample results classified as being influenced by a wet weather flow condition. All remaining samples were classified as dry weather.

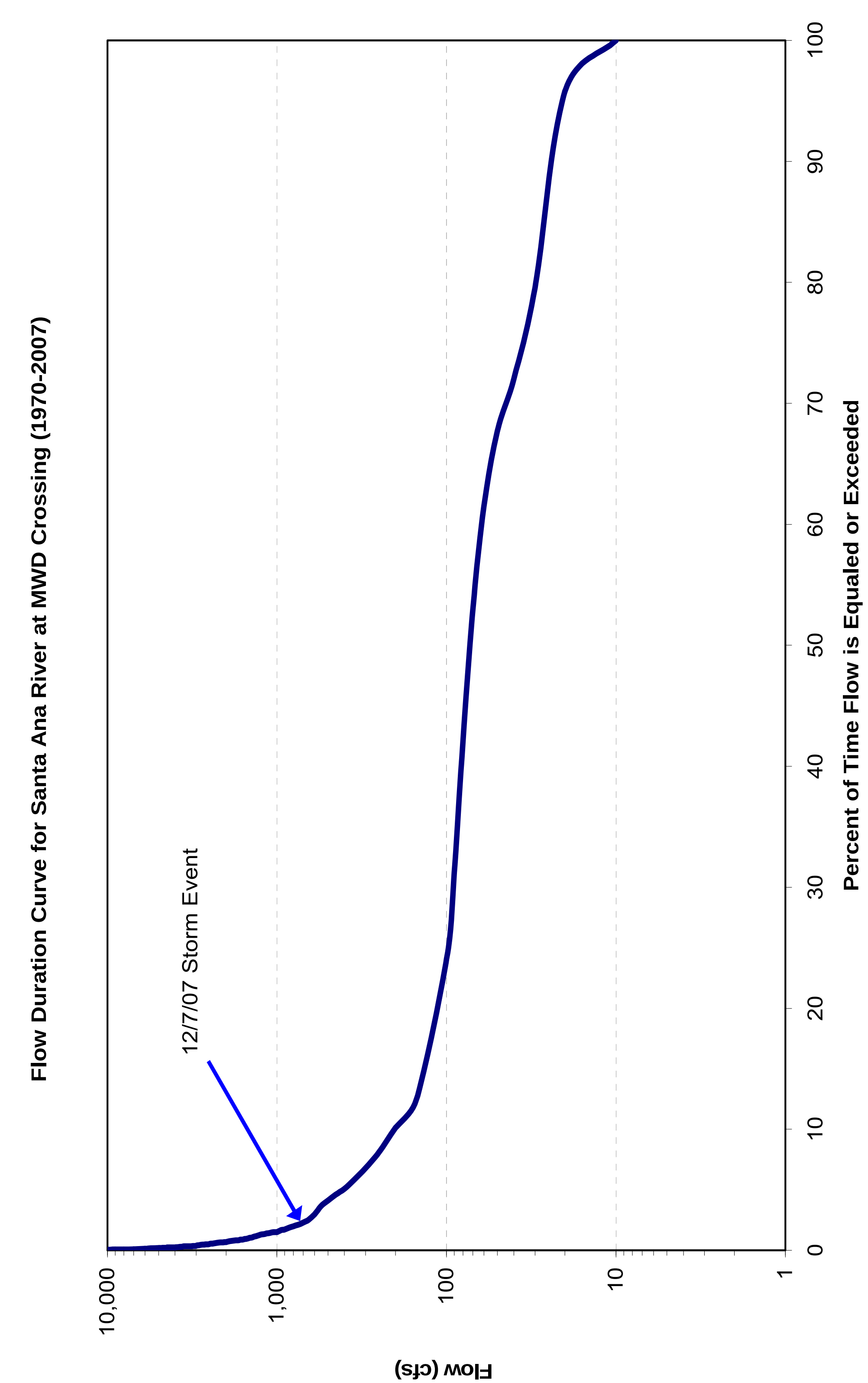


Figure 4-1. Long-term flow duration curve for the Santa Ana River at MWD crossing flow gauge (1970-2007). Note where the December 2007 wet weather sample event falls on the curve.

Table 4-3. Summary of samples classified as wet weather samples

Site	Sample Date	Preceding 3-Day Rainfall (inches)	Measured Flow (cfs)	Approximate Baseflow (cfs)
US-ANZA	12/7/2007	0.30	59	7
US-ANZA	12/9/2007	0.30	73	7
US-BXSP	12/7/2007	0.30	50	5
US-BXSP	12/9/2007	0.30	156	5
US-CCCH	12/7/2007	0.68	55	8
US-CHRIS	1/29/2008	1.42	10	2
US-CHRIS	12/7/2007	0.31	3	2
US-CUC	12/7/2007	0.31	19	5
US-CYP	12/7/2007	0.68	18	1
US-CYP	12/9/2007	0.63	4	1
US-DAY	12/7/2007	0.63	234	7
US-DAY	12/9/2007	0.63	250	7
US-SACH	12/7/2007	0.68	9	1
US-SAR	12/7/2007	0.30	250	9
US-SAR	12/9/2007	0.30	41	9
US-SNCH	12/7/2007	0.30	22	5
US-SSCH	12/7/2007	0.63	150	4
US-SSCH	12/9/2007	0.63	36	4
US-TEM	12/7/2007	0.30	58	27
WW-C3	12/7/2007	0.68	12	11
WW-C7	12/7/2007	0.68	130	38
WW-M5	12/7/2007	0.31	409	114
WW-M5	12/19/07	0.35	596	114
WW-S1	12/7/2007	0.30	639	56
WW-S1	12/9/2007	0.30	138	56
WW-S4	12/7/2007	0.30	1,267	230
WW-S4	12/9/2007	0.30	543	230
WW-S4	12/19/2007	0.20	1,221	230

Section 5 Results and Analysis

This section provides a summary of the results of data analyses applied to the 2007-2008 data set. Prior to conducting these analyses, categorical questions were developed to organize data analyses from various spatial, temporal, and hydrological perspectives. In the following sections, the relevant data questions are presented and the subsequent discussion describes the findings from the data analysis. The Executive Summary provides a synthesis of these data results and conclusions or recommendations for future monitoring activities.

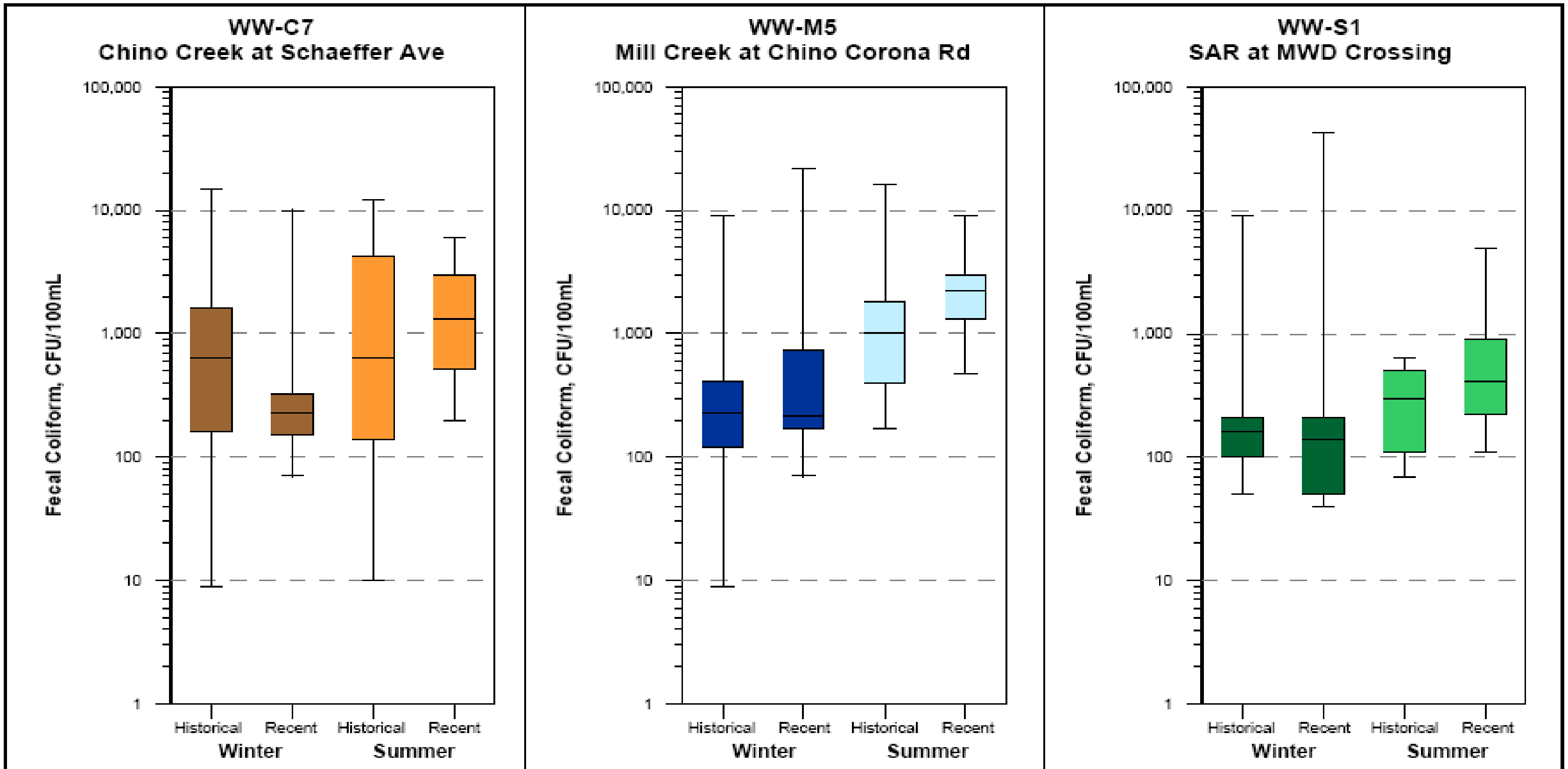
5.1 Data Results Summary

Appendix A, Tables A-1 through A-7, summarizes the data results (median and range of values) for each field measurement and laboratory analysis conducted at each site[6]. Appendix B, Tables B-1 through B-3, provides the actual bacterial indicator laboratory results obtained from each sample.

With only one exception, all bacterial indicator data were included in statistical analyses. The exception is the fecal coliform/*E. coli* sample result from Temescal Creek on September 5, 2007. The fecal coliform and *E. coli* concentrations were 1,800,000 and 410,000 cfu/100 mL, respectively, which were 2-log greater than any other observations obtained during this study. While the laboratory confirmed the result, it was removed from subsequent data analyses given that such a concentration was determined to be an atypical and unrepresentative outlier.

This study included a few sample locations where bacterial indicator water quality data have been collected previously. Figures 5-1 and 5-2 provide a comparison between the 2007-2008 bacterial indicator results and selected results observed during the RWQCB 2002-2004 study (data provided by the RWQCB - the findings from this study supported the impairment decision for MSAR watershed waterbodies). For fecal coliform, with the exception of the cool weather (winter) samples collected in 2007-2008 at the SAR MWD Crossing site, bacterial indicator concentrations were generally higher during 2007-2008 than during 2002-2004. *E. coli* concentrations were similar at Chino Creek, Schaeffer Avenue (nearby Central Avenue location) during warm and cool seasons, and during the cool weather season at SAR MWD Crossing. *E. coli* concentrations were higher in 2007-2008 at Mill Creek during all seasons and higher at SAR MWD Crossing during the warm summer season.

[6] The raw data used to generate these tables is available from SAWPA.



WW-C7 Chino Creek at Schaeffer Ave

	Winter		Summer	
	Historical	*Recent*	*Historical*	*Recent*
Start Date	2/5/2002	7/14/2007	2/5/2002	7/14/2007
End Date	4/14/2004	6/14/2008	4/14/2004	6/14/2008
n	30	14	15	20
Geo Mean	500	365	737	1,269
Median	635	230	640	1,300
Max	15,000	10,000	12,000	6,000
Min	9	70	10	200

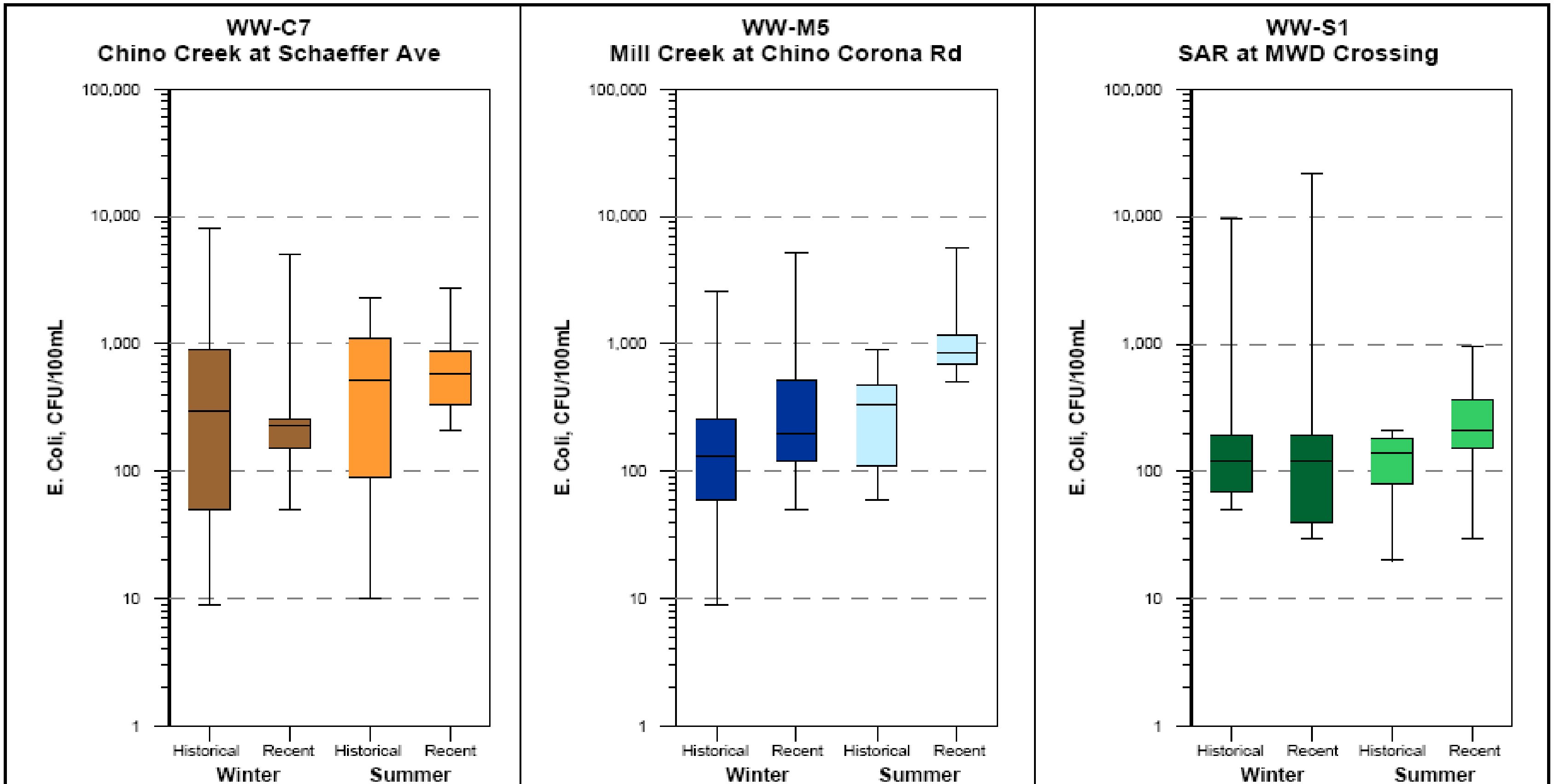
WW-M5 Mill Creek at Chino Corona Rd

	Winter		Summer	
	Historical	*Recent*	*Historical*	*Recent*
Start Date	2/5/2002	7/14/2007	2/5/2002	7/14/2007
End Date	4/14/2004	6/14/2008	4/14/2004	6/14/2008
n	30	14	15	20
Geo Mean	246	431	1,017	2,010
Median	225	215	1,000	2,250
Max	9,000	22,000	16,000	9,000
Min	9	70	170	480

WW-S1 SAR at MWD Crossing

	Winter		Summer	
	Historical	*Recent*	*Historical*	*Recent*
Start Date	2/5/2002	7/14/2007	2/5/2002	7/14/2007
End Date	4/14/2004	6/14/2008	4/14/2004	6/14/2008
n	29	14	15	20
Geo Mean	180	196	239	509
Median	160	140	300	405
Max	9,100	43,000	640	4,900
Min	50	40	70	110

Figure 5-1. Seasonal fecal coliform concentrations from 2002-2004 (historical) and 2007-2008 (recent) at three Middle Santa Ana River watershed locations. Note: Chino Creek at Schaeffer Avenue is nearby the WW site, Chino Creek at Central Avenue.



WW-C7 Chino Creek at Schaeffer Ave

	Winter		Summer	
	Historical	*Recent*	*Historical*	*Recent*
Start Date	2/5/2002	7/14/2007	2/5/2002	7/14/2007
End Date	4/14/2004	6/14/2008	4/14/2004	6/14/2008
n	30	14	15	20
Geo Mean	247	311	332	582
Median	300	225	510	585
Max	8,100	5,100	2,300	2,700
Min	9	50	10	210

WW-M5 Mill Creek at Chino Corona Rd

	Winter		Summer	
	Historical	*Recent*	*Historical*	*Recent*
Start Date	2/5/2002	7/14/2007	2/5/2002	7/14/2007
End Date	4/14/2004	6/14/2008	4/14/2004	6/14/2008
n	30	14	15	20
Geo Mean	125	323	255	962
Median	130	200	330	845
Max	2,600	5,200	910	5,700
Min	9	50	60	500

WW-S1 SAR at MWD Crossing

	Winter		Summer	
	Historical	*Recent*	*Historical*	*Recent*
Start Date	2/5/2002	7/14/2007	2/5/2002	7/14/2007
End Date	4/14/2004	6/14/2008	4/14/2004	6/14/2008
n	29	14	15	20
Geo Mean	137	165	102	207
Median	120	120	140	210
Max	9,700	22,000	210	960
Min	50	30	20	30

Figure 5-2. Seasonal E. coli concentrations from 2002-2004 (historical) and 2007-2008 (recent) at three Middle Santa Ana River watershed locations. Chino Creek at Schaeffer Avenue is nearby the WW site, Chino Creek at Central Avenue.

Table 5-1 summarizes the findings from selected sites sampled during the Chino Creek Watershed Study – Icehouse Canyon Creek (WW-C1), Chino Creek at Central Avenue (WW-C7), and Cypress Channel (US-CYP) (Leddy 2007). Geomeans were calculated for both sample type (dry weather, wet weather, recessional period following wet weather) and for all samples combined. Keeping in mind that the sample size for the Chino Study was much lower than the current study, a comparison of the Chino Study results with the current study finds similar bacterial indicator concentrations occurred at Icehouse Canyon, *E. coli* was higher during this study in Cypress Channel and Chino Creek, and fecal coliform was higher at Cypress Channel, but lower at Chino Creek. It should be noted, however, that climate, geomorphic, and other conditions at the Icehouse Canyon site are significantly different than any other site in the study area. Direct comparisons of water quality sample results from this location to other regional water quality data may not be appropriate.

Appendix A, Tables A-8 and A-9, summarize the *Bacteroidales* microbial source tracking data results from University of California Davis and Orange County Water District laboratories, respectively. Sections 5.9 and 5.11 provide additional discussion on site-to-site comparisons. As noted in Section 4.2, two laboratories were used for the *Bacteroidales* analysis. To evaluate comparability of results between laboratories, a laboratory comparability study was conducted. Appendix B provides details on the methodology and results of the study.

5.2 General Data Characterization

The first set of data questions characterized the statistical distribution of the fecal coliform and *E. coli* bacteria data collected in 2007-2008 under the Grant Project for the watershed as a whole (all samples from all locations) and spatially by sample location.

5.2.1 What is the overall statistical distribution of bacterial indicator concentrations without regard for location, flow conditions, or season?

Table 5-2 summarizes the distribution of the fecal coliform and *E. coli* data collected from all sites over all sample dates. The distribution provides the bacterial indicator concentrations at various percentiles of the data set. For example, the 50th percentile represents the median of the data set. For this data set, 50 percent of the observed *E. coli* and fecal coliform concentrations are below 300 and 520 (cfu/100 mL), respectively.

Table 5-1. Comparative bacterial indicator results from sites sampled in the Chino Creek Study, 2004-2006

Sample Location	Sample Type	Sample Date	Average Fecal Coliform[1]	Geomean – Fecal Coliform		Average *E. coli*[1]	Geomean – *E. coli*	
				Sample Type	All		Sample Type	All
Icehouse Canyon Creek[2]	Dry	7/18/2005	2	5	8	2.5	8	9
		8/29/2005	<9			25		
		5/15/2006	5.5			<9		
		6/19/2006	9			<9		
	Recessional	12/6/2004	<9	9		<9	9	
		1/24/2005	<9			<9		
		3/15/2005	<9			<9		
		4/25/2005	<9			<9		
	Storm	12/29/2004	<9	9		<9	9	
		2/11/2005	<9			<9		
		10/19/2005	<9			<9		
Chino Creek at Central Avenue	Dry	7/19/2005	3550	1,822	1,051	1100	314	341
		8/30/2005	2550			225		
		5/17/2006	290			90		
		6/21/2006	4200			435		
	Recessional	12/7/2004	115	114		70	68	
		1/21/2005	85			89.5		
		3/14/2005	85			35		
		5/2/2005	205			100		
	Storm	2/11/2005	19000	29,563		6700	1025	
		10/18/2005	46000			15000		
Cypress Channel at Kimball Ave.	Dry	7/19/2005	640	2,847	1,936	590	1,628	1,325
		8/30/2005	2850			1745		
		5/17/2006	7750			3250		
		6/21/2006	4650			2100		
	Recessional	12/7/2004	405	450		160	306	
		1/21/2005	185			195		
		3/14/2005	1275			500		
		4/26/2005	900			735		
		5/2/2005	215			235		
	Storm	12/28/2004	4700	13,168		4800	11,905	
		2/11/2005	7250			7400		
		10/18/2005	67000			47500		

[1] – Average of two samples collected during sampling event.
[2] – For Icehouse Canyon Creek, geomeans by using less than values as the actual value.

Table 5-2. Statistical distribution (cfu/100 mL) of bacterial indicator data (cfu/100 mL) for all sites without regard to location, season, or flow conditions

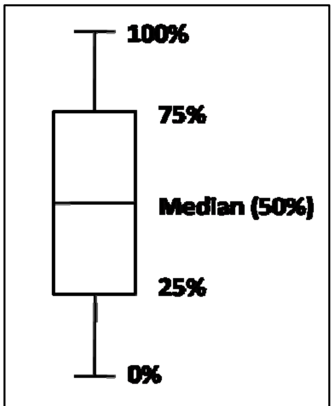
Statistic	*E. coli*	Fecal coliform
Sample Size (n)	391	391
Geometric Mean	352	716
10th Percentile	50	80
25th Percentile	130	190
50th Percentile (median)	300	520
75th Percentile	925	3,300
90th Percentile	3,800	9,000

Analysis of the bacterial indicator data showed that the data set had a log-normal distribution (Table 5-3, "all data"). The results of three statistical tests, Chi-Square, Anderson-Darling, and Kolmogorov-Smirov confirmed that the data had a log-normal distribution (a p-value of less than 0.05 indicates that the fitted distribution is significant). Figures 5-3 and 5-4 illustrate the fitted data distributions following the natural log transformation.

Based on these findings, prior to conducting statistical analyses a natural logarithm transformation was applied to the following data sets: All data, dry weather, warm weather and cool weather. Transformation of the data allowed for the use of parametric statistical tests. For the wet weather data, no distribution was identified (see below). Accordingly, statistical analyses involving these data relied on non-parametric tests. The sample collected from the US-TEM site on 9/4/07 was determined to be an outlier, because its concentration was 2-log greater than the site median for both *E. coli* and fecal coliform

5.2.2 What is the statistical distribution of bacterial indicator concentrations by location without regard for flow conditions or season?

Tables 5-4 and 5-5 summarize the data distribution for the fecal coliform and *E. coli* data for each WW and USEP site. Bacterial indicator concentrations varied greatly at individual sites. The highest variability, as measured by the coefficient of variation (calculated from natural log transformed data) at USEP sites, occurred at Cucamonga Creek and County Line Channel. For the WW sites, the Santa Ana River sites (MWD Crossing and Pedley Avenue) showed the highest variability.



Box & Whisker Plot

Figure 5-5 summarizes fecal coliform and concentrations for each sample site using Box and Whisker box plots (see text box for explanation of the box plots). The substantial breadth of the "whiskers" at most sites is indicative of the high variability of bacterial indicator concentrations observed.

Table 5-3. Analysis of the data distributions associated with different groupings of the bacterial indicator data.

Bacterial Indicator	Data Group	Sample Size (n)	Distribution Type	Chi-Square (p-value)	Anderson-Darling (p-value)	Kolmogorov-Smirnov (p-value)	Correlation Coefficient (r^2)
E. coli	All Data	391	Log-Normal	0.002	< 0.005	0.01 ≤ p ≤ 0.025	0.992
	Warm	214	Log-Normal	0.0175	< 0.005	< 0.01	0.993
	Cool	177	Log-Normal	< 0.001	< 0.005	< 0.01	0.961
	Dry	363	Log-Normal	< 0.002	< 0.005	0.025 ≤ p ≤ 0.05	0.996
	Wet	28	None				
Fecal coliform	All Data	391	Log-Normal	0.001	< 0.005	< 0.01	0.987
	Warm	214	Log-Normal	0.002	0.05 ≤ p ≤ 0.1	0.05 ≤ p ≤ 0.1	0.995
	Cool	177	Log-Normal	< 0.001	< 0.005	< 0.01	0.951
	Dry	363	Log-Normal	< 0.001	< 0.005	< 0.01	0.988
	Wet	28	None				

Table 5-4. Summary of fecal coliform concentrations (cfu/100 mL) and data variability by sample location.

Site Type	Site	N	Geomean	Median	Coefficient of Variation[2]
Watershed Wide Compliance	Icehouse Canyon Creek	4	9[1]	9[1]	0.00
	Prado Park Lake	34	115	99	0.20
	Chino Creek	34	759	645	0.21
	Mill Creek	34	1,066	1,400	0.20
	SAR @ MWD Crossing	34	344	275	0.26
	SAR @ Pedley Ave.	34	393	410	0.27
Urban Source Evaluation	Anza Drain	20	939	500	0.26
	Box Springs Channel	20	4,059	4,950	0.23
	Carbon Canyon Creek	20	197	145	0.28
	Chris Basin	20	2,162	2,300	0.17
	County Line Channel	7	1,014	1,300	0.36
	Cucamonga Creek	20	647	520	0.36
	Cypress Channel	14	5,852	5,950	0.15
	Day Creek	15	952	870	0.20
	San Antonio Channel	19	1,685	4,000	0.29
	SAR @ La Cadena	7	2,452	3,900	0.29
	Sunnyslope Channel	20	541	280	0.25
	San Sevaine Channel	16	1,254	2,300	0.29
	Temescal Creek	19	1,276	2,700	0.25

[1] - Actual results less than detection level of 9 cfu/100 mL
[2] - Coefficient of variation was calculated using natural log-transformed data

Table 5-5. Summary of *E. coli* concentrations (cfu/100 mL) and data variability by sample location.

Site Type	Site	N	Geomean	Median	Coefficient of Variation[2]
Watershed Wide Compliance	Icehouse Canyon Creek	4	9[1]	9[1]	0.00
	Prado Park Lake	34	100	105	0.21
	Chino Creek	34	450	385	0.16
	Mill Creek	34	614	725	0.18
	SAR @ MWD Crossing	34	188	165	0.25
	SAR @ Pedley Ave.	34	195	150	0.23
Urban Source Evaluation	Anza Drain	20	414	325	0.23
	Box Springs Channel	20	1,315	960	0.22
	Carbon Canyon Creek	20	122	130	0.33
	Chris Basin	20	1,225	2,050	0.17
	County Line Channel	7	776	1,160	0.37
	Cucamonga Creek	20	223	200	0.41
	Cypress Channel	14	3,061	2,700	0.14
	Day Creek	15	448	410	0.20
	San Antonio Channel	19	448	610	0.32
	SAR @ La Cadena	7	1,000	1,250	0.26
	Sunnyslope Channel	20	170	145	0.29
	San Sevaine Channel	16	539	440	0.31
	Temescal Creek	19	425	310	0.19

[1] - Actual results less than detection level of 9 cfu/100 mL
[2] - Coefficient of variation was calculated using natural log-transformed data

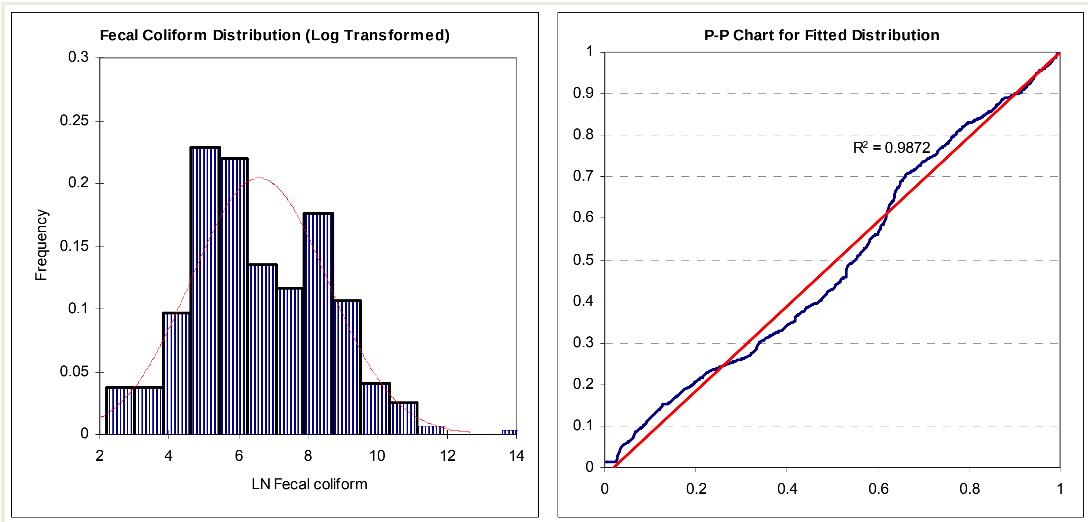


Figure 5-3. Log-normal distribution of all fecal coliform data, using all data regardless of location, season or flow conditions.

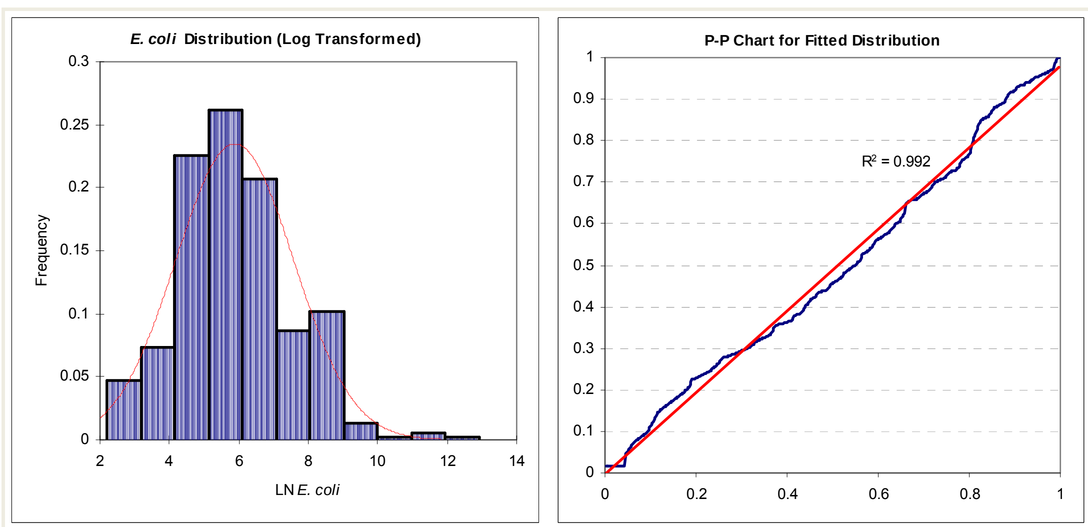


Figure 5-4. Log-normal distribution of all *E. coli* data, using all data regardless of location, season or flow conditions.

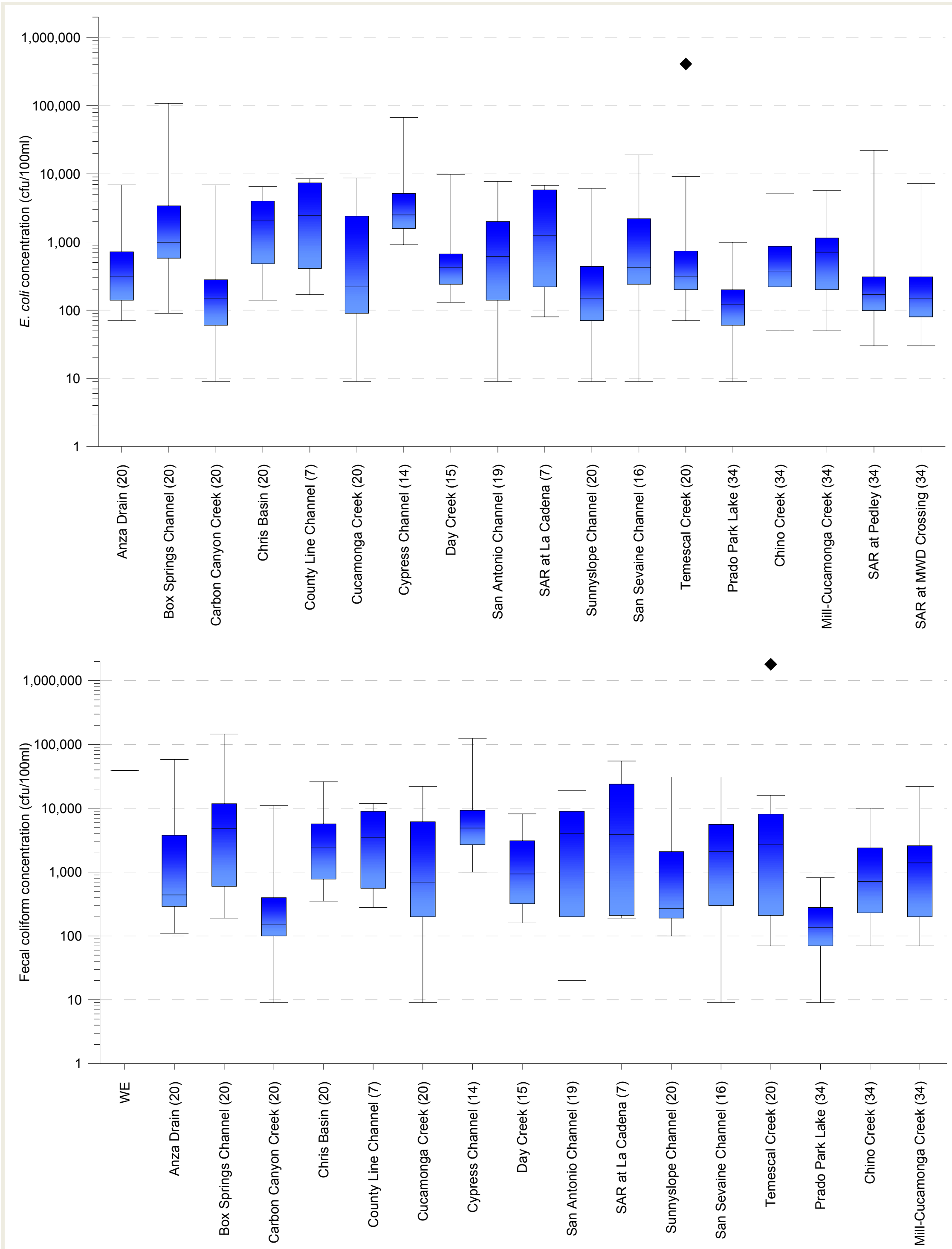


Figure 5-5. Statistical distribution of bacterial indicator data by location (fecal coliform, lower figure; *E. coli*, upper figure) illustrated using Box & Whisker box plots (see Section 5.2.2 for explanation of how to interpret Box & Whisker box plots). These figures illustrate the one data point that was treated an outlier for Temescal Creek(♦)

For the WW sites, median *E. coli* concentrations were lowest at Prado Park Lake Outlet (105 cfu/100 mL) and highest at Mill Creek (725 cfu/100 mL) (Figure 5-5). In general, if one assumes that sites with higher bacterial concentrations should be investigated before locations with lower bacterial concentrations, then it is also preferable to prioritize those locations with the lowest variability because the consistently strong signal makes it easier to perform source tracking studies. The probability of successful source identification and/or control is expected to diminish as bacterial concentrations decline and statistical variability increases.

5.3 Compliance Analysis

The compliance analysis compared the bacterial indicator data for fecal coliform and *E. coli* to the existing fecal coliform objectives and the REC-1 *E. coli* objectives being developed by the SWQSTF (see Section 2). Compliance was evaluated for the geomean of bacterial indicator concentrations and the single sample exceedance frequency. Geomeans were calculated only when at least five sample results were available from the previous five week period. The calculated geomeans were compared to the following fecal coliform Basin Plan objective and proposed *E. coli* objective:

- Fecal coliform: log mean less than 200 organisms/100 mL based on five or more samples/30 day period.
- *E. coli*: log mean less than 126 organisms/100 mL based on five or more samples/30 day period.

The single sample exceedance frequency analysis was completed by calculating the frequency that all fecal coliform and *E. coli* sample results exceeded the following single sample objectives:

- Fecal coliform: 400 cfu/100 mL.
- *E. coli*: 235 cfu/100 mL.

Using the above compliance criteria, the following questions were evaluated.

5.3.1 What is the frequency of compliance with the current and proposed bacterial indicator objectives at each sampling location during dry weather conditions?

Tables 5-6 and 5-7 summarize the percent compliance for each USEP and WW site. During dry weather, the fecal coliform single sample exceedance frequency ranged from 32% at Carbon Canyon Creek to 100% at Cypress Channel and Chris Basin. The *E. coli* single sample exceedance frequency at USEP sites ranged from 26% at Carbon Canyon Creek and Sunnyslope Channel to 100% at Cypress Channel.

Table 5-6. Bacterial indicator compliance frequency for fecal coliform.

Site Type	Site	Single Sample Criterion Exceedance Frequency (%)		Geomean (cfu/100 mL)				Geomean Exceedance Frequency (%)
		Dry	Wet	Warm 2007 (7/14 – 8/11)	Warm 2007 (9/1 – 9/29)	Cool 2008 (1/19 – 2/16)	Cool 2008 (1/26 – 2/23)	
Watershed Wide Compliance	Icehouse Canyon Creek	0	n/a[1]	See Figure 5-6 for time series plot of rolling geomeans				n/a[2]
	Prado Park Lake	21	100					10
	Chino Creek	73	100					93
	Mill Creek	75	100					97
	SAR @ MWD Crossing	50	100					70
	SAR @ Pedley Ave.	55	100					73
Urban Source Evaluation	Anza Drain	78	100	577	3,808	261	457	100
	Box Springs Channel	94	100	12,990	23,077	607	858	100
	Carbon Canyon Cr.	32	100	126	257	205	122	50
	Chris Basin	100	100	4,705	1,520	1,758	1,404	100
	County Line Channel	86	n/a[2]	1,476	n/a[2]	n/a[2]	n/a[2]	100
	Cucamonga Cr.	58	100	261	1,624	271	884	100
	Cypress Channel	100	100	11,366	4,949	n/a[2]	n/a[2]	100
	Day Creek	77	100	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	San Antonio Channel	72	100	n/a[2]	9,026	2,038	1,630	100
	SAR @ La Cadena	60	100	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Sunnyslope Channel	63	100	332	776	270	523	100
	San Sevaine Channel	86	100	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Temescal Cr.	74	100	5,912	13,232	172	170	50

[1] – Site was dry during wet weather event
[2] – Insufficient data to calculate geomean (see text)

Table 5-7. Bacterial indicator compliance frequency for *E. coli*.

Site Type	Site	Single Sample Criterion Exceedance Frequency (%)		Geomean (cfu/100 mL)				Geomean Exceedance Frequency (%)
		Dry	Wet	Warm 2007 (7/14 – 8/11)	Warm 2007 (9/1 – 9/29)	Cool 2008 (1/19 – 2/16)	Cool 2008 (1/26 – 2/23)	
Watershed Wide Compliance	Icehouse Canyon Creek	0	n/a[1]	See Figure 5-7 for time series plot of rolling geomeans				n/a[2]
	Prado Park Lake	15	0					53
	Chino Creek	73	100					100
	Mill Creek	75	100					100
	SAR @ MWD Crossing	28	100					73
	SAR @ Pedley Ave.	23	100					63
Urban Source Evaluation	Anza Drain	56	100	380	638	177	341	100
	Box Springs Channel	83	100	1,149	4,793	655	939	100
	Carbon Canyon Cr.	26	100	44	84	200	177	50
	Chris Basin	89	100	1,758	429	1,530	1,447	100
	County Line Channel	71	n/a[2]	1,194	n/a[2]	n/a[2]	n/a[2]	100
	Cucamonga Cr.	42	100	74	262	176	356	75
	Cypress Channel	100	100	4,745	1,981	n/a[2]	n/a[2]	100
	Day Creek	69	100	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	San Antonio Channel	67	100	n/a[2]	718	2,085	1,394	100
	SAR @ La Cadena	60	100	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Sunnyslope Channel	26	100	165	204	72	207	75
	San Sevaine Channel	79	100	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Temescal Cr.	68	100	491	3,127	162	143	100

[1] – Site was dry during wet weather event
[2] – Insufficient data to calculate geomean (see text)

For the USEP sites four 5-sample/30 day intervals were sampled allowing calculation of four geomeans. If insufficient data were available from a specific site, no geomean was calculated. Tables 5-6 and 5-7 summarize median *E. coli* and fecal concentrations and the percent non-compliance. The percent non-compliance was 100% for all USEP sites except Carbon Canyon Creek (50%) and Sunnyslope Channel and Cucamonga Creek with 75% non-compliance.

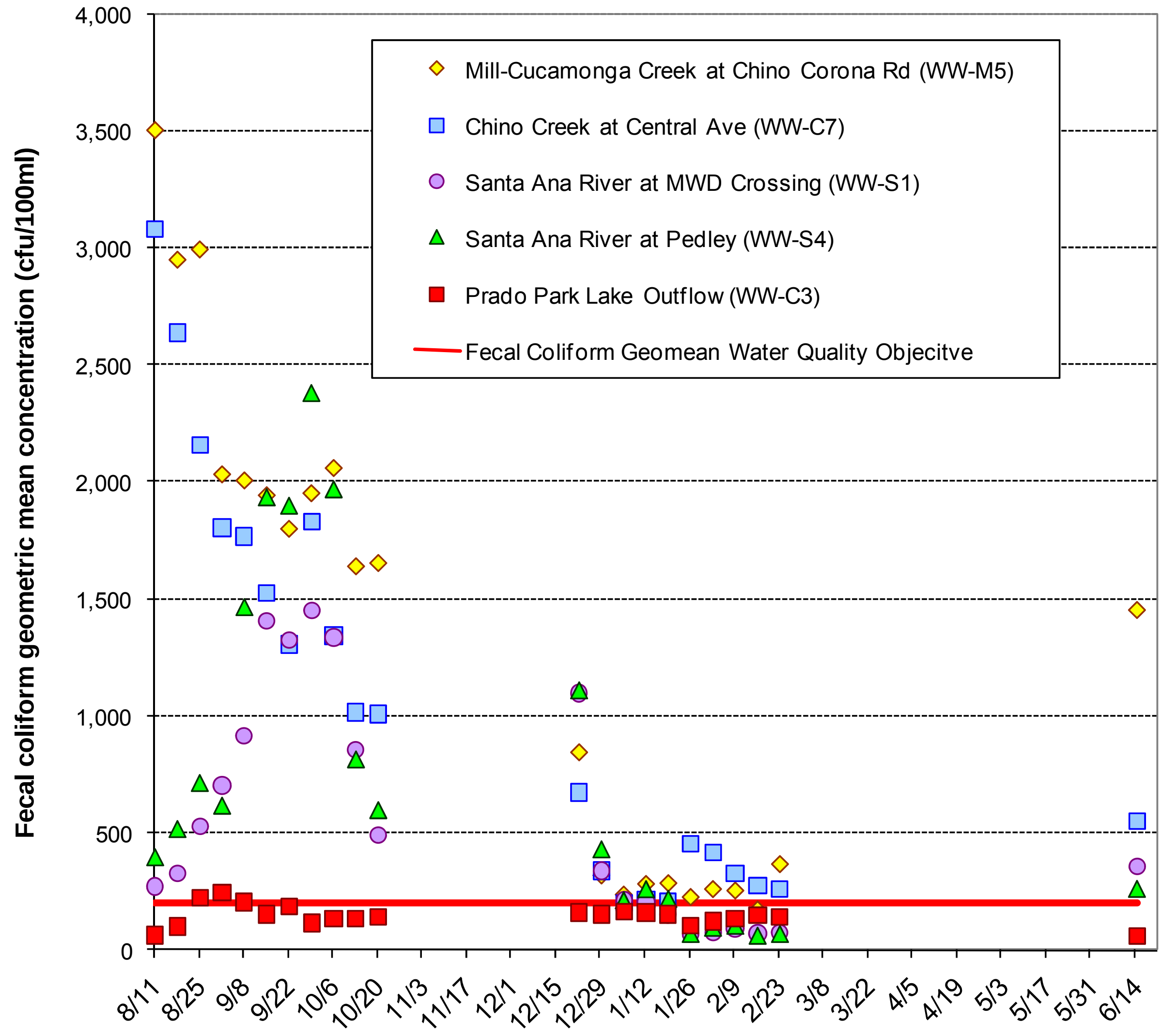
At WW sites no *E. coli* or fecal coliform single sample exceedances occurred at Icehouse Canyon Creek (this site was dry during most of the study; only four samples were collected for analysis). Among other WW sites, fecal coliform exceedance frequency ranged from 21% at Prado Park Lake to 75% at Mill Creek. For *E. coli*, the single sample exceedance frequency ranged from 15% at Prado Park Lake Outlet to 75% at Mill Creek.

For the WW sites rolling geomeans were calculated for samples collected during the 2007 warm season sample period, samples collected during the 2007-2008 cool season sample period, and the 2008 warm season sample period (5-week sample period in May/June only). Figures 5-6 and 5-7 show the rolling geomean concentrations for each site for 2007-2008.

5.3.2 What is the frequency of compliance with the current and proposed bacterial indicator objectives at each sampling location during wet weather conditions?

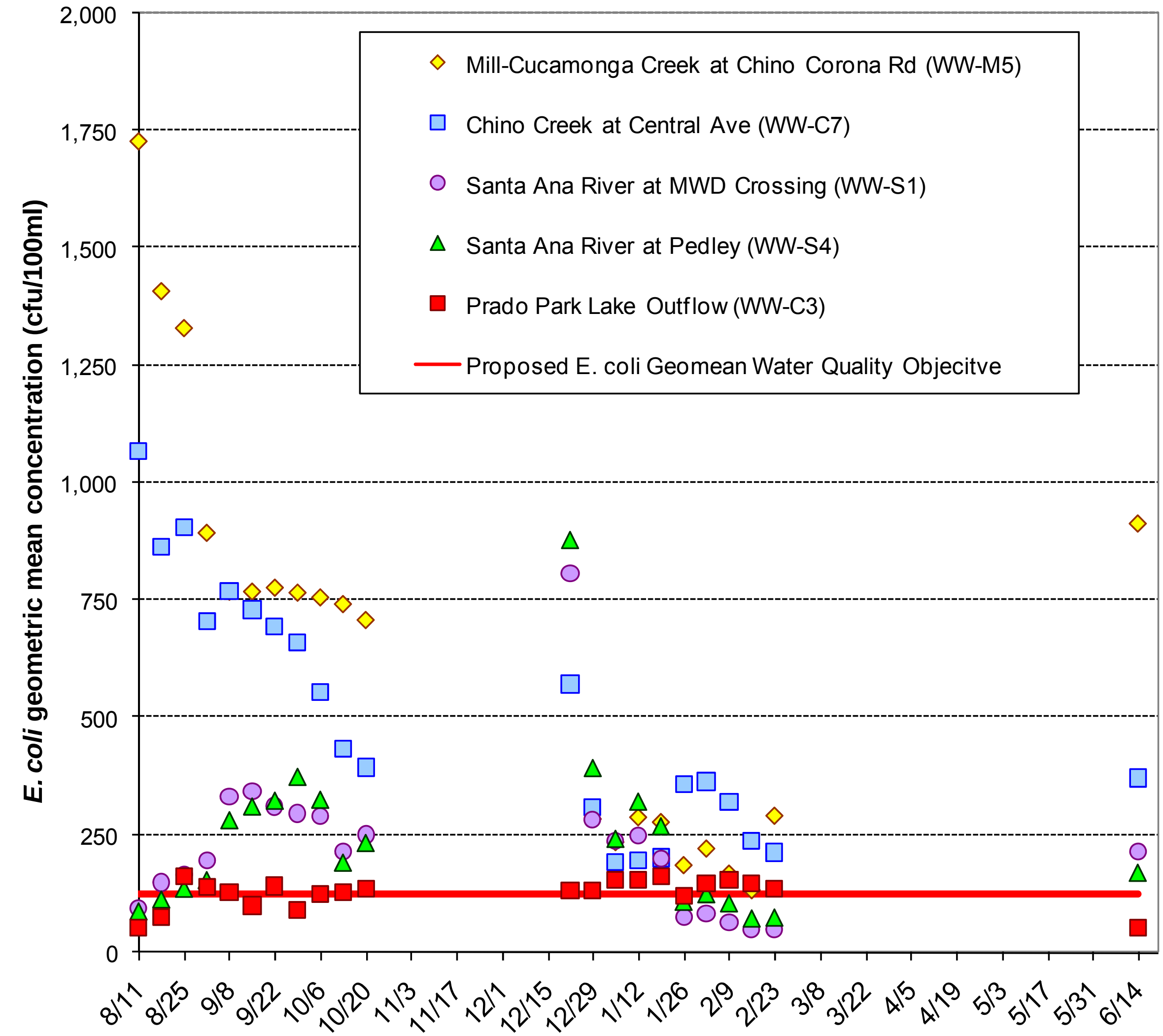
A total of 28 samples were classified as wet weather samples (See Section 4-7 for process used to classify a sample as being influenced by wet weather runoff conditions). Tables 5-6 and 5-7 summarize the single sample exceedance frequency for *E. coli* and fecal coliform during this period. No geomeans were calculated for wet weather samples because five samples were not collected within a 30-day period. Regardless of site type (USEP or WW) or bacterial indicator type (fecal coliform or *E. coli*), the single sample exceedance frequency for wet weather samples was 100%.

The fact that the rate of non-compliance is much higher during wet weather conditions than during dry weather conditions suggests that changes in flow may be a significant factor contributing to water quality impairment. It also implies that it would be more cost effective to prioritize the search for dry weather sources and solution than it would be to focus on wet weather conditions. First, although the rate of compliance is higher during dry weather, the prevalence of such conditions in sunny southern California means that there are a great many more days of non-compliance occurring during dry weather than during wet weather. Second, given the relative difference in flows, it is much easier to design appropriate mitigation strategies for the low-flow, dry-weather condition. Third, due to actual and perceived safety hazards, the likelihood that recreation will occur during or immediately after wet weather conditions is highly unlikely.



5-Week Period End Date	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
8/11/2007	65	3,078	3,501	272	398
8/18/2007	103	2,637	2,947	326	518
8/25/2007	224	2,157	2,991	531	715
9/1/2007	248	1,802	2,031	703	618
9/8/2007	207	1,765	2,005	915	1,466
9/15/2007	156	1,524	1,942	1,405	1,934
9/22/2007	190	1,304	1,799	1,323	1,898
9/29/2007	118	1,830	1,951	1,449	2,379
10/6/2007	136	1,343	2,058	1,337	1,968
10/13/2007	136	1,013	1,639	856	816
10/20/2007	145	1,007	1,653	489	599
12/22/2007	163	672	845	1,097	1,111
12/29/2007	156	338	320	338	432
1/5/2008	167	201	238	211	214
1/12/2008	163	213	283	204	262
1/19/2008	156	205	286	153	220
1/26/2008	104	451	227	69	71
2/2/2008	125	415	261	75	97
2/9/2008	136	327	255	93	106
2/16/2008	150	275	174	70	63
2/23/2008	142	259	368	73	71
6/14/2008	63	549	1,452	359	263

Figure 5-6. Time series plot of fecal coliform geometric means for Watershed-Wide Compliance Sites, 2007-2008. Each geomean is calculated from the previous five sample results collected over a five week period.



5-Week Period End Date	WW-C3	WW-C7	WW-M5	WW-S1	WW-S4
8/11/2007	53	1,069	1,726	97	89
8/18/2007	75	865	1,407	151	114
8/25/2007	163	907	1,329	168	137
9/1/2007	142	706	893	197	155
9/8/2007	130	771	768	332	283
9/15/2007	100	731	768	346	312
9/22/2007	143	697	776	313	325
9/29/2007	92	662	765	297	375
10/6/2007	126	556	755	292	327
10/13/2007	130	436	741	217	193
10/20/2007	138	395	707	252	234
12/22/2007	132	573	571	807	880
12/29/2007	134	311	283	285	394
1/5/2008	157	194	234	239	243
1/12/2008	157	198	287	251	322
1/19/2008	163	203	277	201	270
1/26/2008	122	360	185	77	109
2/2/2008	149	366	220	84	126
2/9/2008	156	322	167	66	106
2/16/2008	147	239	132	52	74
2/23/2008	138	214	290	52	76
6/14/2008	54	373	912	218	171

Figure 5-7. Time series plot of *E. coli* geometric means for Watershed-Wide Compliance Sites, 2007-2008. Each geomean is calculated from the previous five sample results collected over a five week period.

5.4 Location Analysis

The following sections summarize the results of analyses conducted to evaluate between site comparisons of bacterial indicator concentrations. For these analyses the sample size was relatively small, which limited the ability to transform the data so that it was normally distributed. Accordingly, the following analyses relied on the use of non-parametric statistical tests.

5.4.1 Is there a statistically-significant difference in *E. coli* concentrations among sample locations during warm, dry weather conditions?

The non-parametric Kruskal-Wallis statistical test demonstrated that significantly different *E. coli* concentrations existed among sites during warm, dry conditions (N= 214; K-statistic = 115; p-value < 0.001). This result indicates that at least one site is significantly different from the others. This analysis was followed up with a Games-Howell Means Comparison test ("means test") which identifies which paired sites have significantly different *E. coli* concentrations.

The means test showed that Icehouse Canyon Creek *E. coli* concentrations differed significantly from all other sites. This is an expected outcome since all four sample results from this location were < 9 cfu/100 mL. Table 5-8 summarizes all other paired means tests where a significant difference was observed. If the delta was positive, then the concentration at Site 1 was significantly higher than the concentration at Site 2. If the delta was negative, then the Site 1 concentration was significantly lower than the Site 2 concentration. Of note in the results:

- Carbon Canyon Creek had significantly lower *E. coli* concentrations than several USEP and WW sites. It is just as important to know which, if any, sites are significantly lower in bacterial concentrations as it is to identify locations with excessively high concentrations. The fact that *E. coli* concentrations at Carbon Canyon Creek were so much lower than other nominally similar locations in the watershed suggests that more effective BMPs may have been installed in that more-recently developed area. Thus, it merits for detailed investigation.

- Prado Park Lake had significantly lower *E. coli* concentrations than Chino and Mill Creeks. This indicates that the original 303(d) listing for the lake may have been in error and should be reevaluated. It also suggests that impounded waters may behave differently from flowing creek. Perhaps slowing the water reduces the probability of resuspending bacteria from the sediment. Or, perhaps the ponds act as settling basins that allow the bacteria-laden sediments to fall out of suspension. Or, perhaps the ambient sunlight is able to provide more effective disinfection effectively in still waters. In any event, this knowledge may aid planners in developing better BMP strategies.

Table 5-8. Results of Games-Howell means comparison statistical test. Table shows which paired sites had significantly diffferent *E. coli* concentrations during the warm season under dry weather conditions. Test results of paired comparisions with Icehouse Canyon Creek (WW-C1) are not shown as most sites had significantly higher *E. coli* concentrations than WW-C1.

Site 1	Site 2	Delta[1]	p-value
US-ANZA	WW-C3	314	0.034
US-BXSP	WW-C3	1215	0.006
	US-CCCH	1193	0.007
US-CCCH	US-CYP	-2939	< 0.001
	WW-M5	-492	0.007
	US-TEM	-303	0.025
	US-CHRIS	-1103	0.029
	WW-C7	-328	0.03
US-CHRIS	WW-C3	1125	0.012
US-CYP	WW-C3	2961	< 0.001
	US-SNCH	2891	0.001
	WW-S4	2866	0.001
	WW-S1	2872	0.002
US-SNCH	WW-M5	-444	0.005
US-TEM	WW-C3	325	< 0.001
	WW-S4	230	0.037
WW-C3	WW-C7	-350	< 0.001
	WW-M5	-514	< 0.001
WW-C7	WW-S1	262	0.003
	WW-S4	255	0.003
WW-M5	WW-S1	425	< 0.001
	WW-S4	419	< 0.001

[1] – Positive value indicates that Site 1 had significantly greater *E. coli* concentrations; a negative value indicates that Site 1 had significantly lower *E. coli* concentrations.

- Mill and Chino Creeks had significantly higher *E. coli* concentrations than the Santa Ana River sample sites. Because there are far fewer outfalls to Mill Creek and Chino Creek, and the signal strength is higher, it should be easier to identify the bacterial sources in these streams than it would be to do so in the Santa Ana River mainstem. This is especially true given that the bacterial concentrations in Carbon Canyon Creek (which flows into Chino Creek) are so much lower. Finally, because these streams are so much smaller there is a higher likelihood of engineering a cost-effective solution than for the Santa Ana River.

5.4.2 Is there a statistically-significant difference in *E. coli* concentrations among sample locations during cool, dry weather conditions?

The same types of statistical analyses described under Section 5.4.1 were also applied to the cool, dry weather data. The non-parametric Kruskal-Wallis test demonstrated that significantly different bacterial indicator concentrations existed among sites during cool, dry conditions (N = 149; K-statistic = 41; p-value = 0.01).

Icehouse Canyon Creek was dry during the cool months so no comparisons were made between this site and other sites. Table 5-9 summarizes paired means tests where a significant difference was observed.

Table 5-9. Results of Games-Howell means comparison statistical test. Table shows which paired sites had significantly diffferent *E. coli* concentrations during the cool season under dry weather conditions.

Site 1	Site 2	Delta[1]	p-value
US-CCCH	US-CHRIS	-1103	0.030
US-CHRIS	WW-S4	1030	0.002
	WW-C3	1125	0.006
	WW-S1	1036	0.006
	US-TEM	800	0.025
US-CYP	WW-C3	2866	< 0.001

[1] – Positive value indicates that Site 1 had significantly greater *E. coli* concentrations; a negative value indicates that Site 1 had significantly lower *E. coli* concentrations.

Of note in the results:

- Carbon Canyon Creek had significantly lower *E. coli* concentrations than Chris Basin.

- Chris Basin had significantly higher *E. coli* concentrations than Prado Park Lake, both Santa Ana River sites, and Temescal Creek.

- Cypress Creek had significantly higher *E. coli* concentrations than Prado Park Lake.

It appears that seasonality effects various locations in different ways. The significant disparities that were discovered between sites during warm weather (see Section 5.4.1 above) were different from the disparities identified during cooler winter months. The next section will explore the issue of seasonality in greater detail.

5.5 Seasonal Analysis

The sample results were divided into two groups: (1) samples collected during the warm weather months of April through October; and (2) samples collected during the cool weather months of November through March. The following sections summarize the results of various statistical analyses applied to these data groups.

5.5.1 What is the statistical distribution of bacterial indicator concentrations during warm weather months without regard for location or flow conditions?

Table 5-10 summarizes the data distribution for fecal coliform and *E. coli* data collected during the warm weather months. The median concentrations for these bacterial indicators during the warm weather months were 365 and 1,125 cfu/100 mL, respectively. Analysis of the data set showed that the warm weather bacterial indicator data set had a log-normal distribution (see Table 5-3, "warm"); accordingly, prior to conducting statistical analyses a natural logarithm transformation was applied to the data. Figures 5-8 and 5-9 illustrate the data distribution following transformation.

5.5.2 What is the statistical distribution of bacterial indicator concentrations during cool weather months without regard for location or flow conditions?

Table 5-11 summarizes the data distribution for fecal coliform and *E. coli* data collected during the cool weather months. The median concentrations for the bacterial indicators (particularly for fecal coliform) were lower during the cool weather months (240 and 310 cfu/100 mL, respectively) than during the warm weather months (see previous section). Analysis of the data set showed that the cool weather bacterial indicator data set had a log-normal distribution (see Table 5-3, "cool"); accordingly, prior to conducting statistical analyses a natural logarithm transformation was applied to the data. Figures 5-10 and 5-11 illustrate the data distribution following transformation.

Table 5-10. Statistical distribution (cfu/100 mL) of bacterial indicator data for all sites during the warm months (April through October) without regard for location or flow conditions

Statistic	*E. coli*	Fecal coliform
Sample Size (n)	214	214
Geometric Mean	355	1,021
10th Percentile	40	93
25th Percentile	150	280
50th Percentile (median)	365	1,125
75th Percentile	920	4,500
90th Percentile	2,700	9,210

Table 5-11. Statistical distribution (cfu/100 mL) of bacterial indicator data for all sites during the cool weather months (November through March) without regard for location or flow conditions

Statistic	*E. coli*	Fecal coliform
Sample Size (n)	177	177
Geometric Mean	348	467
10th Percentile	60	70
25th Percentile	100	133
50th Percentile (median)	240	310
75th Percentile	930	1,000
90th Percentile	5,040	7,280

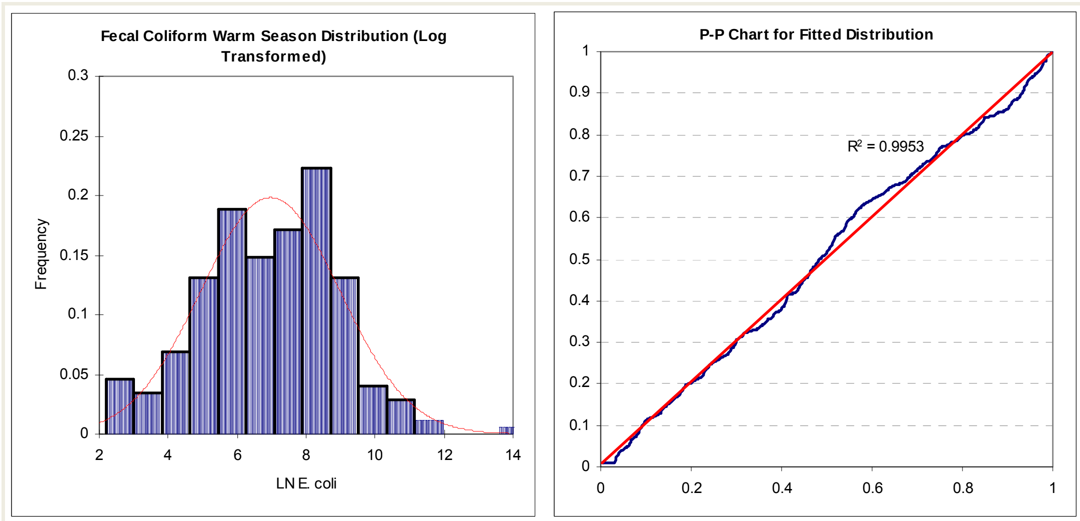


Figure 5-8. Log-normal distribution of all fecal coliform data collected during warm weather months.

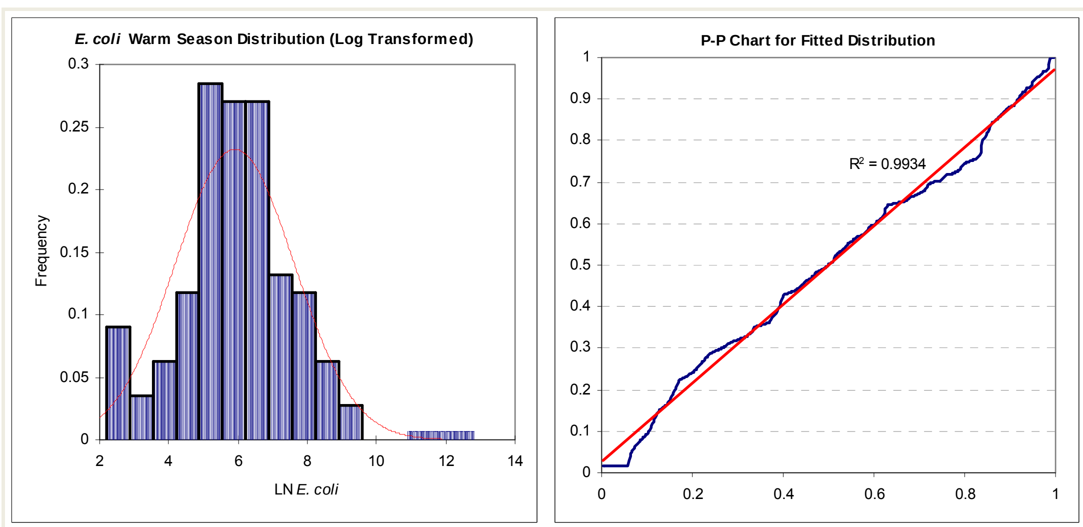


Figure 5-9. Log-normal distribution of all *E. coli* data collected during warm weather months.

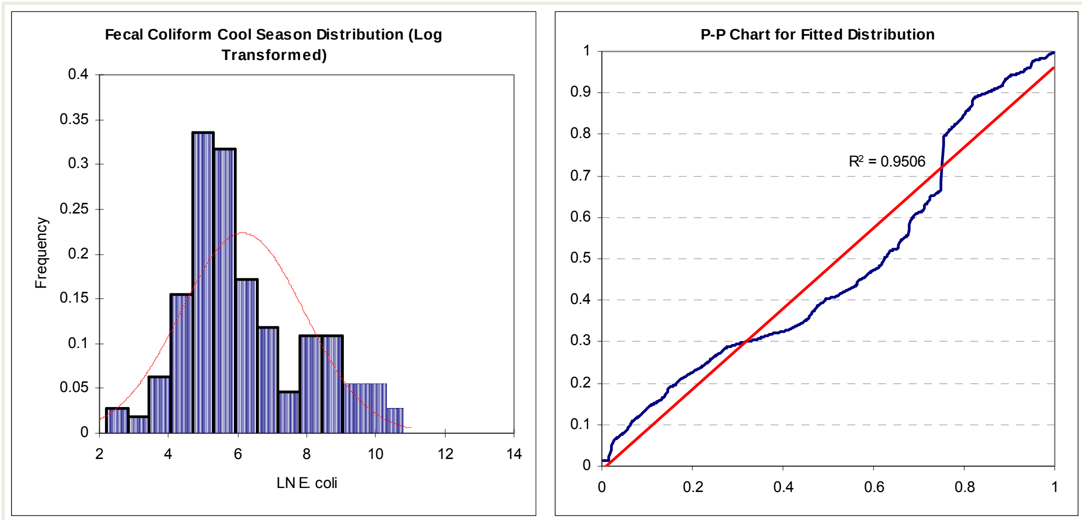


Figure 5-10. Log-normal distribution of all fecal coliform data collected during cool weather months

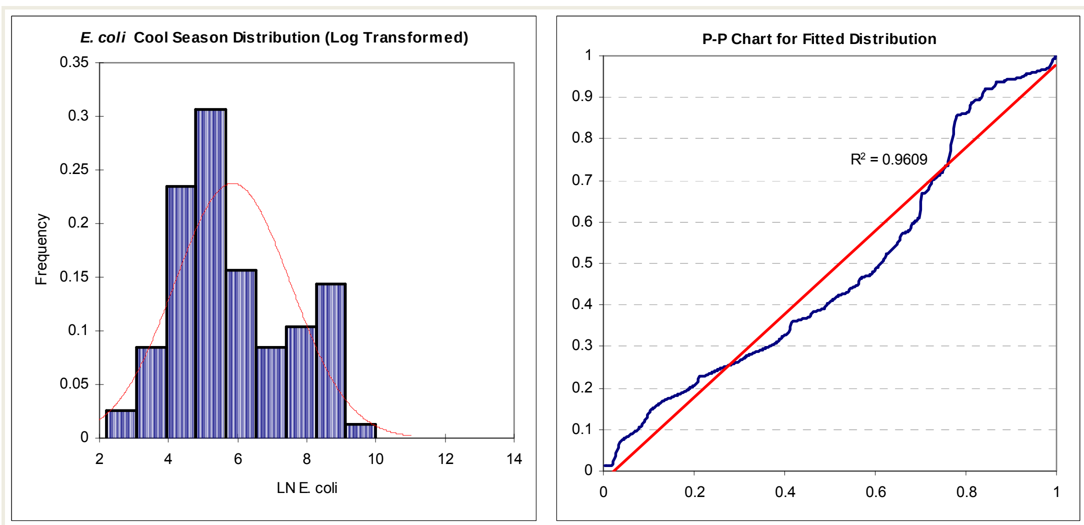


Figure 5-11. Log-normal distribution of all *E. coli* data collected during the cool weather months

5.5.3 Is there a statistically significant difference in bacterial indicator concentrations between warm and cool weather months (excluding the storm event sample) without controlling for location?

A parametric Student-t test was applied to the seasonal geometric mean results to determine if a significant difference exists between bacterial indicator concentrations observed under warm, dry and cool, dry weather conditions. The bacterial indicator data were natural log transformed prior to completing the statistical analysis. Table 5-12 summarizes the results of these tests. Both fecal coliform (p = 0.0001) and *E. coli* concentrations (p = 0.018) differed significantly between seasons.

Therefore, the data suggest that ambient air temperature may play an important role in stimulating bacterial growth. But, that should come as no great surprise to anyone who uses a refrigerator to store food. More detailed statistical analysis may allow us to account for, and adjust for this natural factor when the TMDL models are next updated.

5.6 Runoff Analysis

The section evaluates the data under both dry and wet weather conditions. Section 4.7 describes how data were classified as being collected during dry or wet weather conditions. Most of the wet weather samples were collected during the first two sample days associated with the wet weather sampling event (December 7-9, 2007; see Figure 4-1 which shows the relationship between the sampled storm event and the long term flow duration curve at the SAR MWD Crossing site).

5.6.1 What is the statistical distribution of bacterial indicator concentrations under dry weather conditions without regard for location or season?

Table 5-13 summarizes the data distribution for fecal coliform and *E. coli* data collected during dry weather conditions regardless of season. The median concentrations for these bacterial indicators during the dry conditions were 280 and 440 cfu/100 mL, respectively. Analysis of the data set showed that the dry weather conditions bacterial indicator data set had a log-normal distribution (see Table 5-3, "dry"); accordingly, prior to conducting statistical analyses a natural logarithm transformation was applied to the dataset. Figures 5-12 and 5-13 illustrate the data distribution following transformation.

5.6.2 What is the statistical distribution of bacterial indicator concentrations under wet weather conditions without regard for location or season?

Section 4.7 described how samples were classified as wet weather samples. Applying these criteria, 28 samples wet weather samples were collected during 2007-2008 (primarily December 7-9, 2007). Table 5-14 summarizes the data distribution for fecal coliform and *E. coli* bacterial indicators during wet weather conditions. Compared to dry weather conditions, the median bacterial indicator concentrations were substantially greater (e.g., for *E. coli*, dry weather = 280 [see Table 5-13]; wet weather = 4,750 cfu/100 mL).

Figures 5-14 and 5-15 illustrate the data distribution of the wet weather data without transformation. Statistical analysis could not fit a distribution to the data set (see Table 5-3, "wet"). Accordingly, no data transformation could be applied to the weather data to normalize it. Any statistical analyses using these data relied on non-parametric methods.

Table 5-12. Results of Student-t test comparing season geometric means for fecal coliform and *E. coli*

Statistic	N	Fecal coliform (cfu/100 mL)	*E. coli* (cfu/100 mL)
Geometric Mean – warm, dry weather	214	1,021	355
Geometric Mean- cool, dry weather	149	296	238
Student t-test p-value		0.0001	0.018

Table 5-13. Statistical distribution (cfu/100 mL) of bacterial indicator data for all sites during dry conditions regardless of season

Statistic	*E. coli*	Fecal coliform
Sample Size (n)	363	363
Geometric Mean	301	614
10th Percentile	42	70
25th Percentile	120	180
50th Percentile (median)	280	440
75th Percentile	800	2,700
90th Percentile	2,780	7,080

Table 5-14. Statistical distribution (cfu/100 mL) of bacterial indicator data for all sites during wet weather conditions[1] regardless of location

Statistic	*E. coli*	Fecal coliform
Sample Size (n)	28	28
Geometric Mean	2,635	5,248
10th Percentile	292	539
25th Percentile	2,580	4,144
50th Percentile (median)	4,750	7,500
75th Percentile	6,900	16,750
90th Percentile	8,570	24,700

[1] – See Section 4.7 for a discussion of how samples were classified as wet weather.

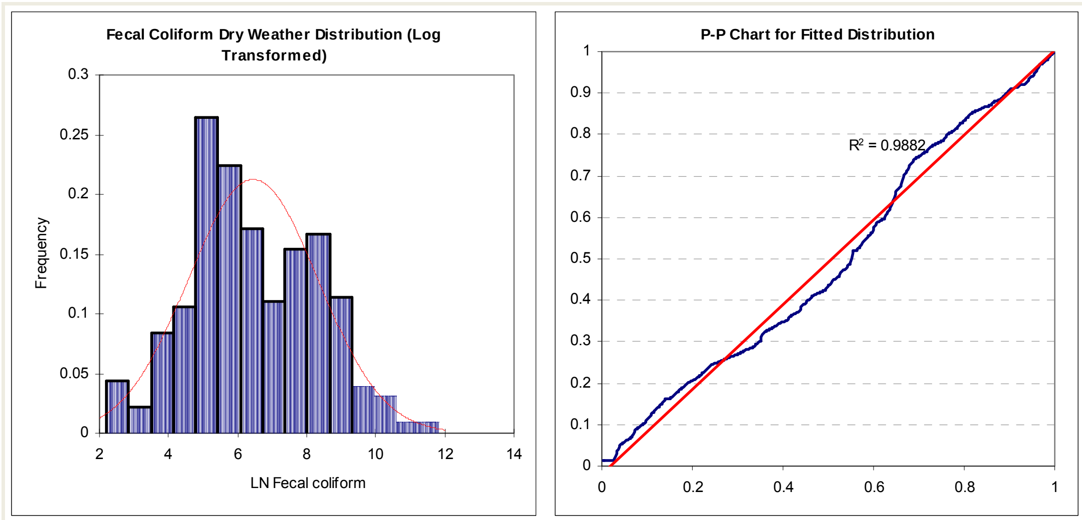


Figure 5-12. Log-normal distribution of all fecal coliform data collected during dry weather conditions, regardless of season.

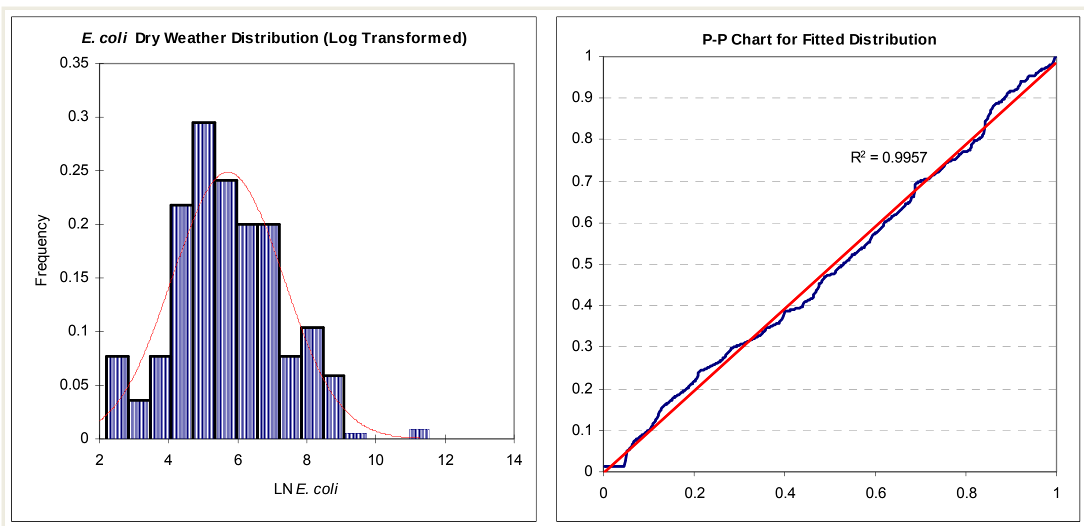


Figure 5-13. Log-normal distribution of all *E. coli* data collected during dry weather conditions, regardless of season.

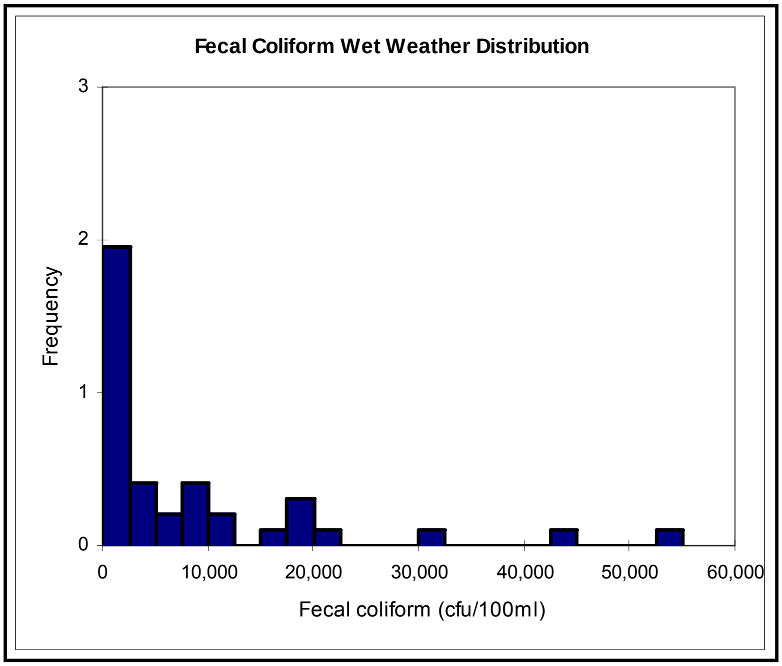


Figure 5-14. Distribution of fecal coliform data collected during wet weather conditions. No statistical data distribution was identified.

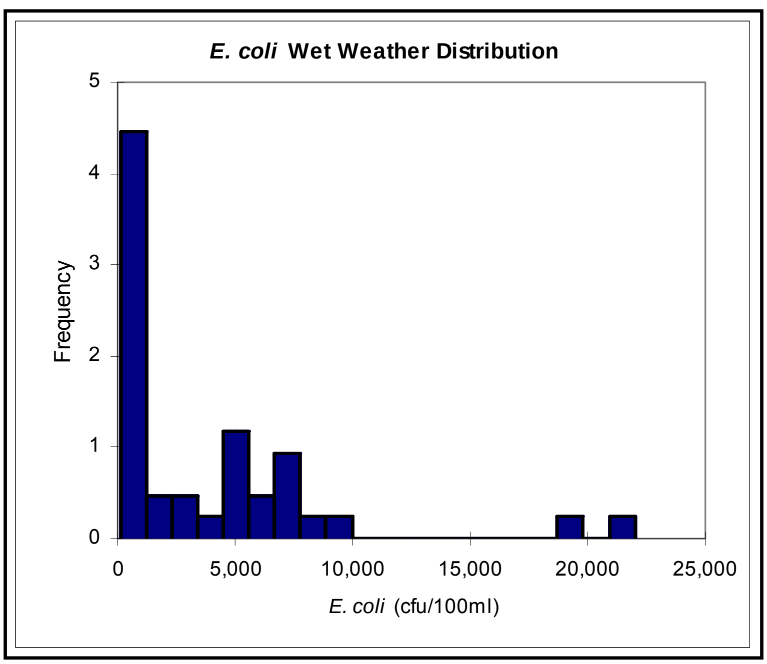


Figure 5-15. Distribution of all *E. coli* data collected during wet weather conditions. No statistical data distribution was identified.

5.6.3 Is there a statistically-significant difference in bacterial indicator concentrations during dry weather conditions vs. wet weather conditions without regard for location?

A non-parametric Mann-Whitney U Test was applied to the bacterial indicator results to determine if a significant difference exists between bacterial indicator concentrations observed under dry and wet weather conditions, regardless of location. Table 5-15 summarizes the results of the Mann-Whitney U Test. Fecal coliform and *E. coli* concentrations both differed significantly ($p < 0.001$) between dry and wet weather conditions, regardless of location.

Table 5-15. Results of Mann-Whitney U Test comparing fecal coliform and *E. coli* geometric mean concentrations under dry and wet weather conditions during the cool weather season

Statistic	N	Fecal coliform (cfu/100 mL)	*E. coli* (cfu/100 mL)
Geometric Mean – dry weather	149	296	238
Geometric Mean- wet weather	28	5,248	2,635
Test Statistic		374	489
p-value		<0.001	< 0.001

The fact that *E. coli* concentrations were, on average, nearly 17-times higher during wet weather conditions than during dry weather conditions is extremely important given that most wet weather events occur during cooler months. This would seem to contradict the finding in section 5.5.3 (above). More likely, it indicates that both air temperature and stream flows are important variables when seeking to predict in-stream bacteria concentrations.

5.6.4 Is there a statistically-significant difference in bacterial indicator concentrations during dry weather conditions vs. wet weather conditions during the cool weather season while controlling for location?

Figures 5-16 and 5-17 provide Box Whisker box plots to summarize for each sample location the range of fecal coliform and *E. coli* concentrations observed during warm weather conditions. Figures 5-18 and 5-19 provide additional box plots that summarize fecal coliform and *E. coli* under cool dry weather conditions. Superimposed (yellow dots) on the Box and Whisker box plots for the cool dry weather conditions (Figures 5-18 and 5-19) are the bacterial indicator concentrations observed in samples collected under wet weather conditions during the same season. For the most part, bacterial indicator concentrations were much higher (greater than the 75^{th} percentile) during wet weather conditions.

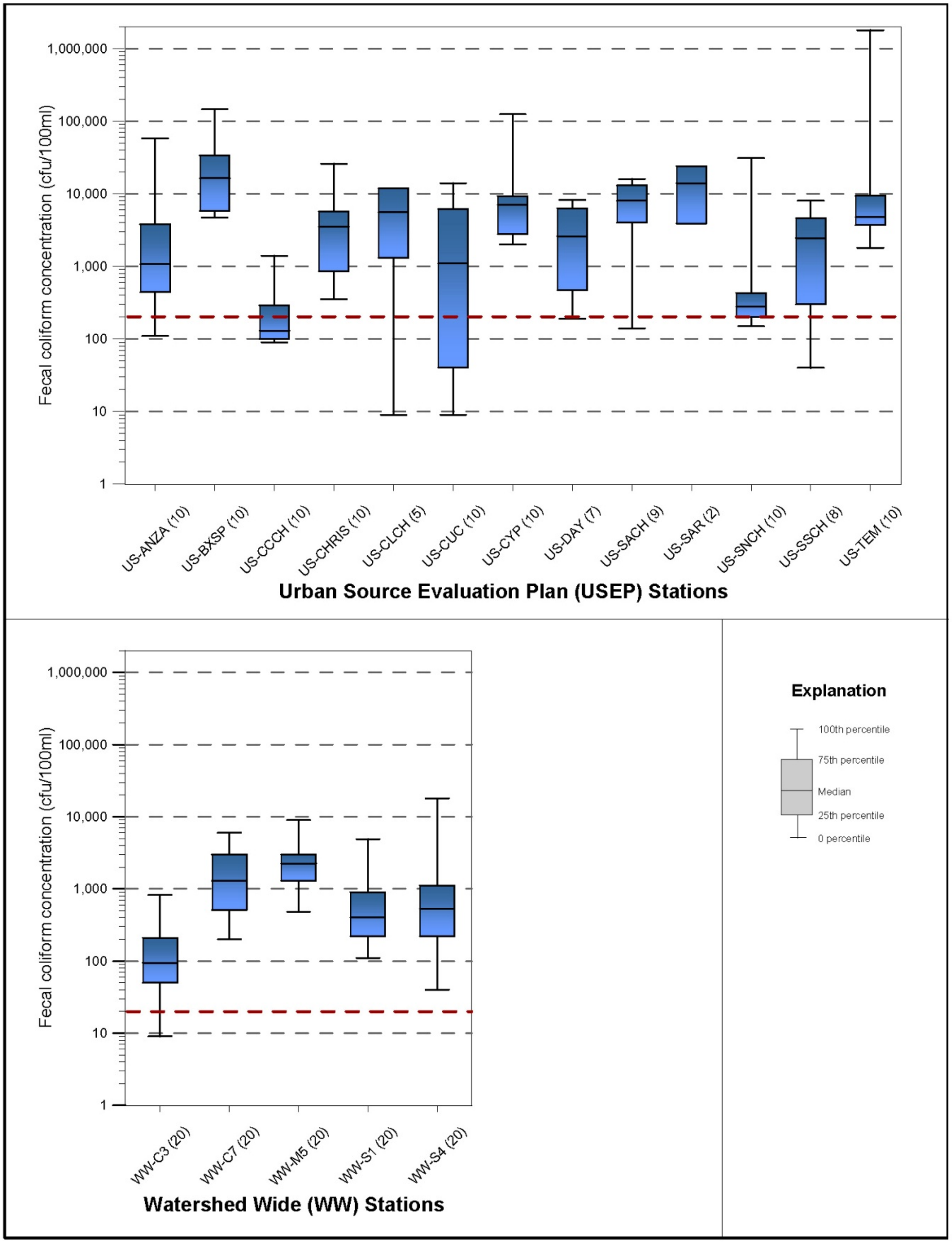


Figure 5-16. Box and Whisker box plots of fecal coliform concentrations during warm season dry weather conditions. Dashed line indicates the existing fecal coliform geometric mean water quality objective

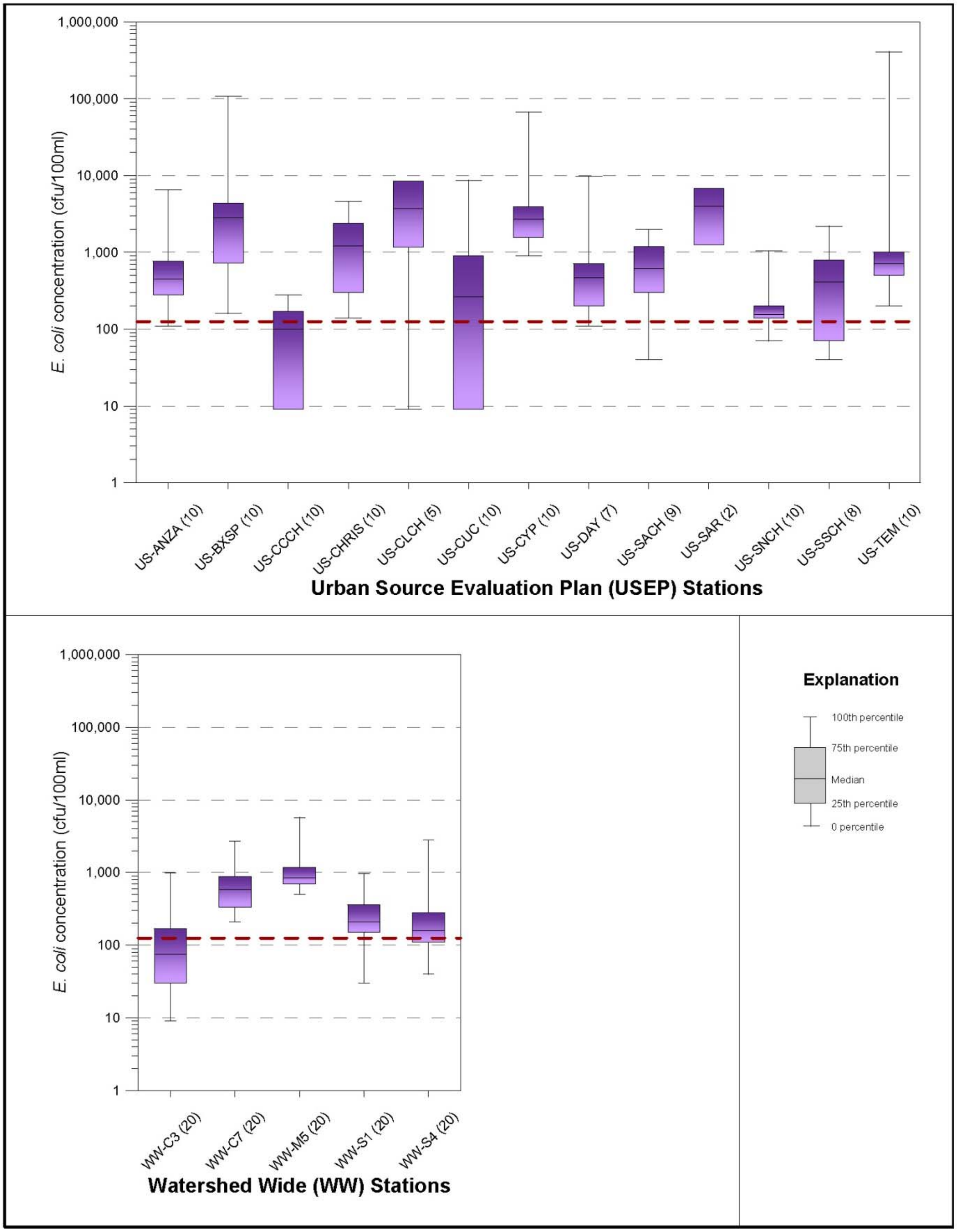


Figure 5-17. Box and Whisker box plots of *E. coli* concentrations during warm season dry weather conditions. Dashed line indicates the proposed *E. coli* geometric mean water quality objective

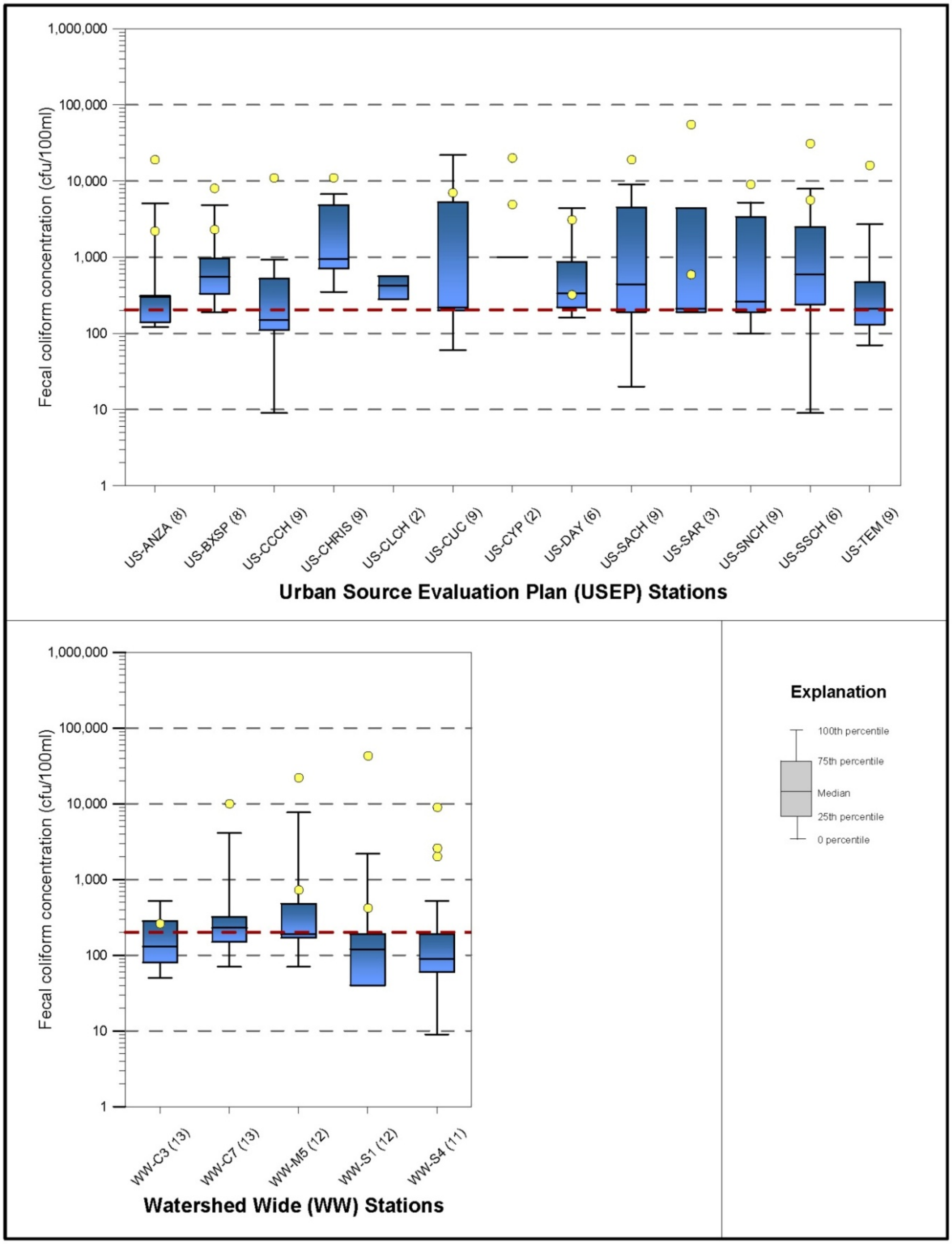


Figure 5-18. Box and Whisker box plots of fecal coliform concentrations during cool season dry weather conditions. Superimposed (yellow dots) are fecal coliform concentrations observed at each site under wet weather conditions during the same season. Dashed line indicates the existing fecal coliform geometric mean water quality objective.

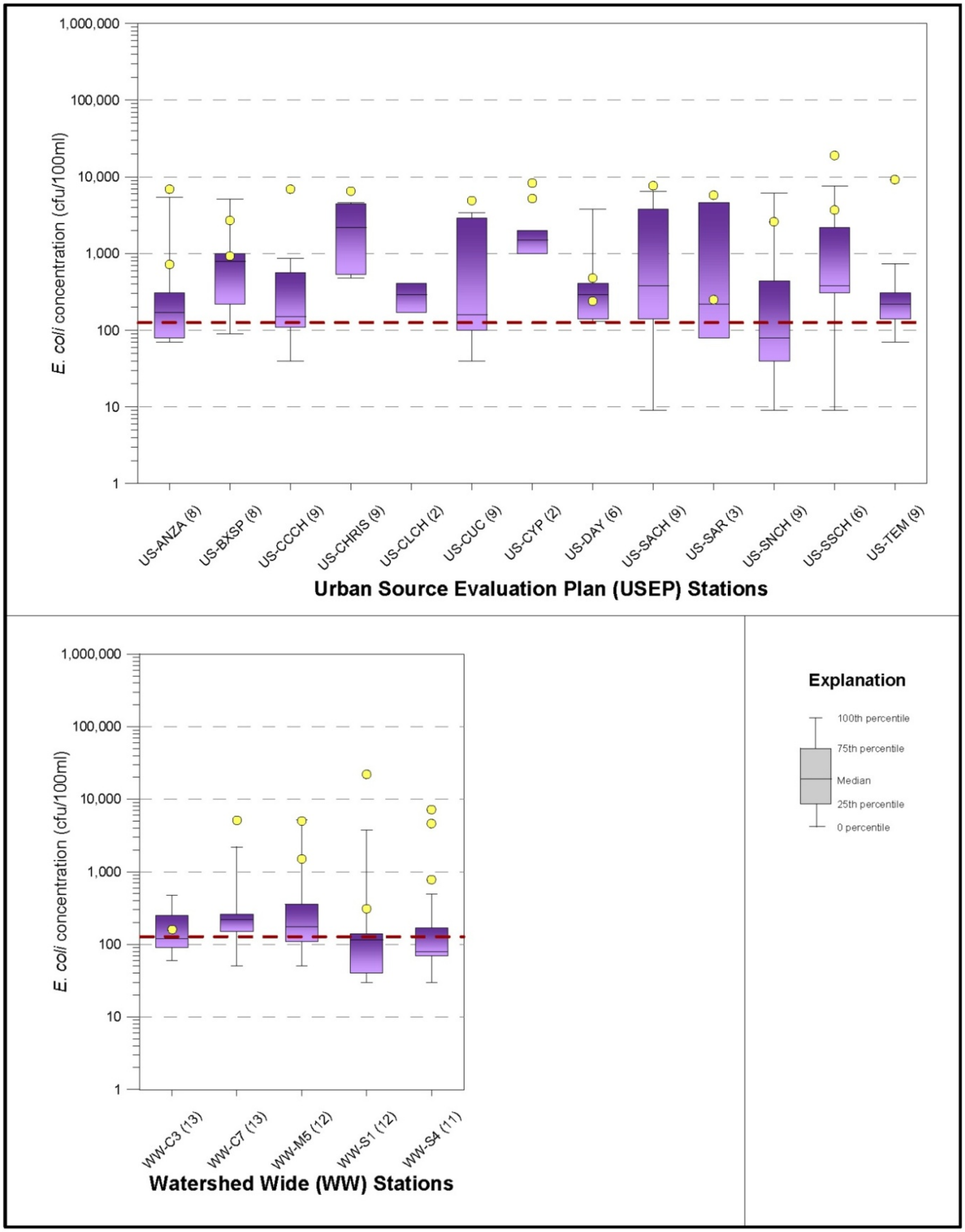


Figure 5-19. Box and Whisker box plots of *E. coli* concentrations during cool season dry weather conditions. Superimposed (yellow dots) are fecal coliform concentrations observed at each site under wet weather conditions during the same season. Dashed line indicates the proposed *E. coli* geometric mean water quality objective.

These data bear out the conclusion that increased flows that occur following wet weather events tend to increase *E. coli* concentrations even during cooler months when the overall bacterial concentrations are reduced by lower air temperatures. Therefore, temperature and flows are both important predictors of bacterial pollution and should be considered in future modeling efforts. In addition, the next phase of the investigation should include a multivariate statistical analysis to determine the relative importance of each factor.

5.7 Flow Analysis

Flow measurements were gathered during sample collection at each site. Statistical analysis of these data provided understanding regarding the relationship (if any) between flow and bacterial indicator concentrations. The response to the first few questions provides a summary of the flow characteristics associated with the sample sites. Subsequent questions evaluate the relationship between flow and bacterial indicators.

5.7.1 What is the statistical distribution of flow characteristics without regard for location or season?

Table 5-16 summarizes the data distribution for flow measurements collected from all sites regardless of season or weather conditions (dry or wet). Analysis of the data set showed that the flow data has an inverse Gaussian distribution (describes a data set of positively skewed non-negative data). Figure 5-20 illustrates the characteristics of this data distribution.

5.7.2 What is the statistical distribution of flow characteristics by location without regard to season?

Figure 5-21 uses Box and Whisker box plots to describe the range of flow conditions observed at each sample location during the entire sample period. Median flows at USEP sample locations were less than 10 cfs for all sites except Temescal Creek and Santa Ana River at La Cadena (however, flow at this site was uncommon and included a large wet weather flow). At the WW sites, median flows were relatively low at the Prado Park Lake outlet and Chino Creek (10 to 30 cfs). In contrast, median flows were greater than 100 cfs at Mill Creek and the two Santa Ana River sites.

Figure 5-22 provides time series plots of flow (cfs) at each USEP and WW site. This figure shows that higher flows tend to occur during the cool months when wet weather events are most likely to occur.

Table 5-16. Statistical distribution of flow data (cubic feet/second, cfs) for all sites under all weather conditions

Statistic	Flow (cfs)
Sample Size (n)	377
10th Percentile	1
25th Percentile	3
50th Percentile (median)	11
75th Percentile	66
90th Percentile	153

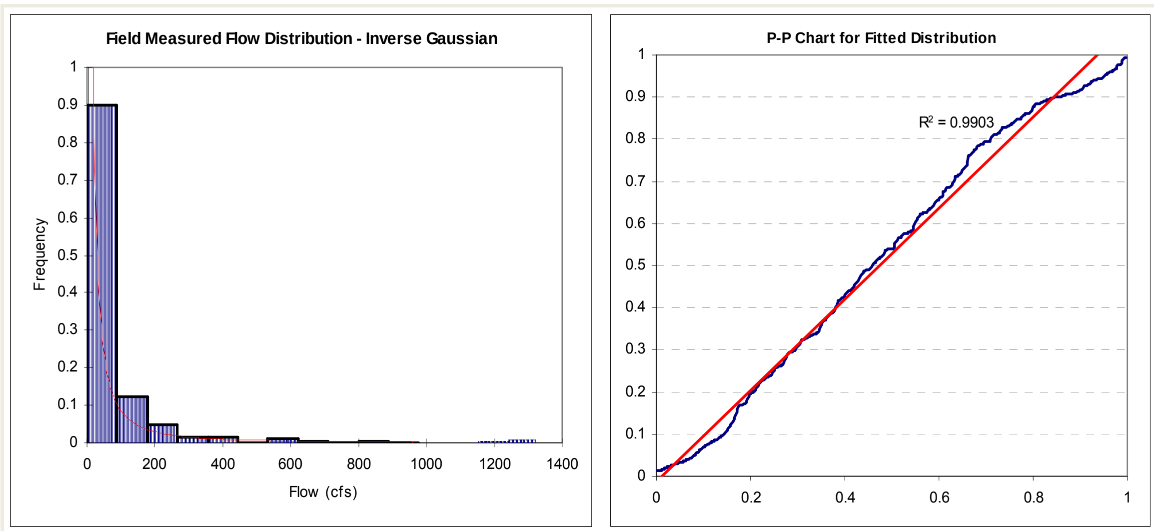


Figure 5-20. Distribution of flow data for all sites and seasons. Flow data fits an inverse Gaussian distribution.

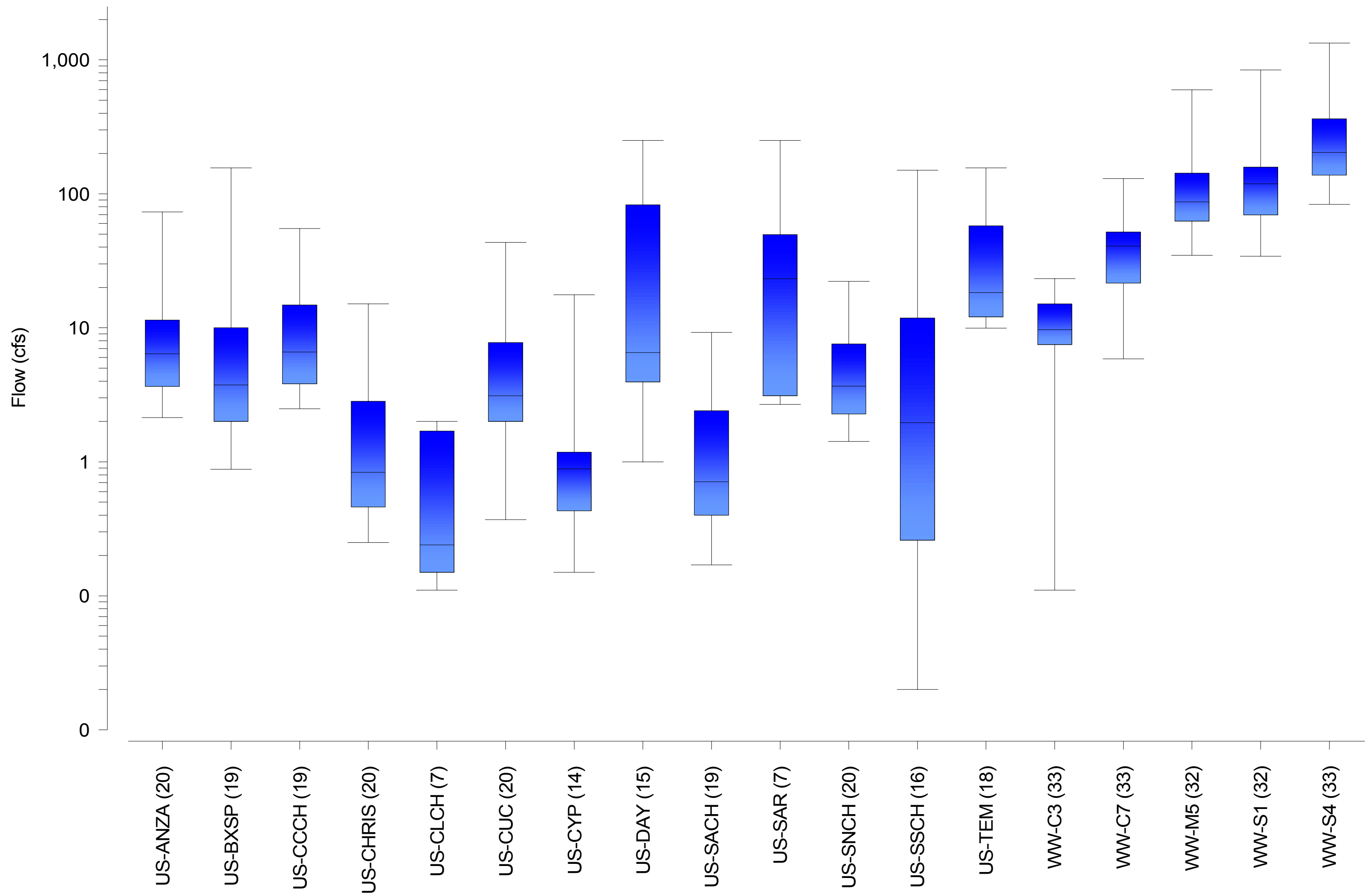


Figure 5-21. Box and Whisker box plots illustrating the range of flow conditions (cfs) observed at each site in 2007-2008. The number in parentheses following the site names is the number of flow observations collected for that site.

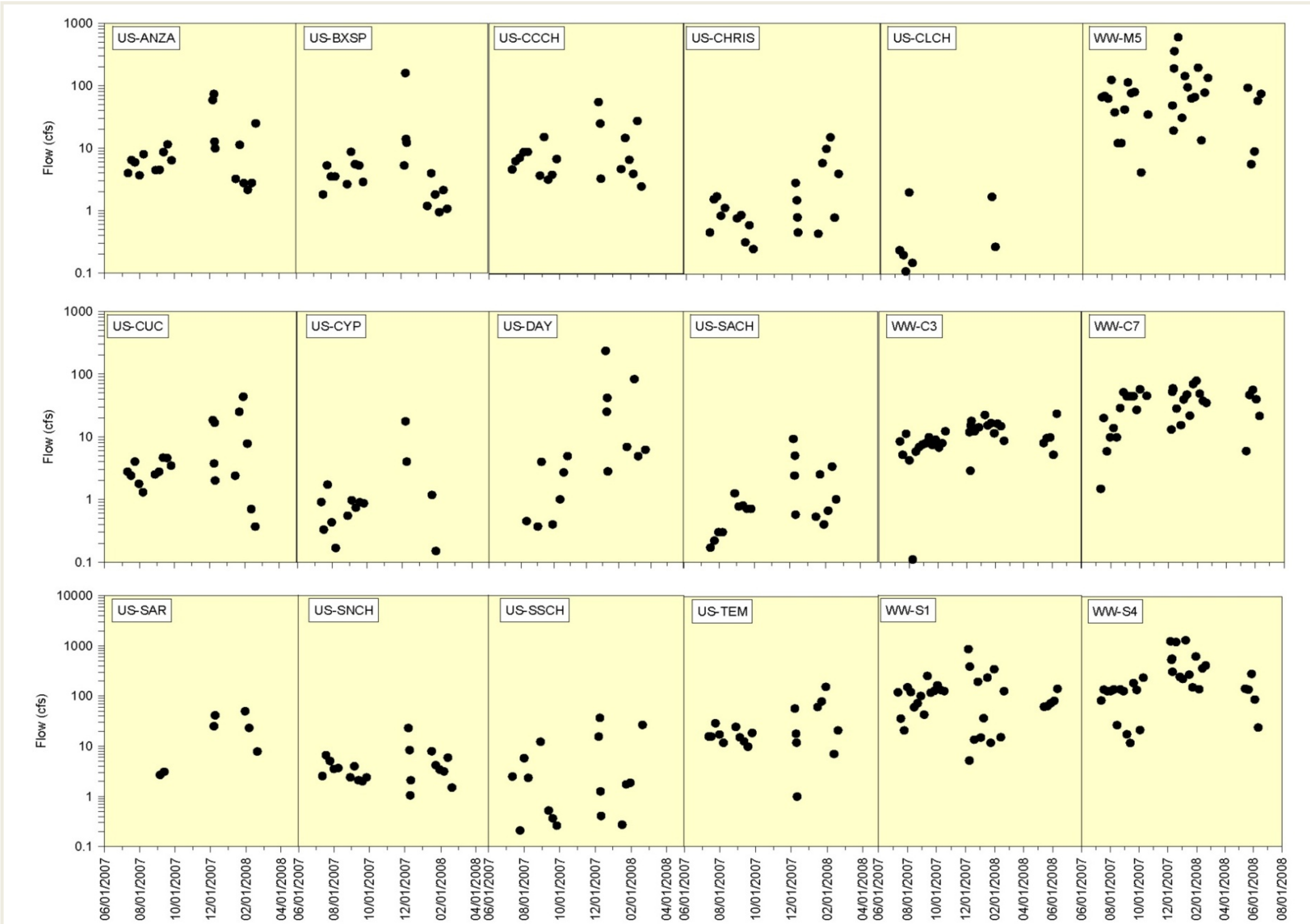


Figure 5-22. Time series plots for each sample location showing flow measured during each sample event (cfs) over the entire sample period.

To provide a means to directly compare flow variability among sites, each flow measurement from a site was normalized to the median flow for that site. The normalized or relative flow is the ratio of the flow measured at the time of sample collection to the median flow for the site calculated from all measurements collected over the course of the 2007-2008 monitoring period. For example, the flow measured at US-DAY on 2/20/07 was 6.2 cfs and the median flow rate measured at US-DAY for the entire sample period was 4.9 cfs. For this example, the relative flow is 6.2/4.9 or 1.27. Ultimately, a ratio <1.0 indicates that the measured flow was less than the median flow; a ratio >1.0 indicates that the measured flow was greater than the median flow.

Figure 5-23 shows the results of this data normalization process completed for all sites and flow measurements. Sites with high flow variability are those where substantive differences exist between low and high values along the y-axis (e.g., Day Creek – US-DAY and San Sevaine Channel – US-SSCH). Sites with low flow variability are those where the relative flow measurements cluster close to a 1.0 ratio (e.g., Prado Park Lake Outlet – WWC3).

5.7.3 What are the flow characteristics, by location, during dry weather conditions?

Figure 5-24 summarizes the estimated baseflow (cfs) for each USEP and WW site. With the exception of the Santa Ana River MWD Crossing site (WW-S1), where a continuous daily flow record was available from a USGS gauge, baseflow was estimated by calculating the average of all field flow measurements taken during dry weather flow conditions. For WW-S1, baseflow was estimated by applying the 5-day sliding interval baseflow separation method to daily flow measurements at the USGS gauge.

As would be expected given its relatively large watershed size, the Santa Ana River site at Pedley Avenue (WW-S4) had the highest baseflow for all WW locations. All USEP sites had baseflows of less than 10 cfs except Temescal Creek with a baseflow of 26.8 cfs. Figure 5-25 shows the relationship between watershed area (acres) and estimated baseflow (cfs). This relationship is shown in two ways: (1) entire watershed topographically; (2) portion of the watershed that is most likely to contribute to dry weather flows (and therefore, more likely to be a component of the baseflow).

5.7.4 Is there a general correlation between *E. coli* concentrations and flow regardless of location, season or flow conditions?

Figure 5-26 illustrates the relationship between flow measurements (cfs) and *E. coli* concentrations (cfu/100 mL). This relationship (1) shows the result from using all data regardless of location, season or flow condition (wet or dry weather); and (2) makes no attempt to normalize the flow data. The results show that throughout the watershed elevated *E. coli* concentrations (> 1,000 cfu/100 mL) occur regardless of whether flow is low or high. Figure 5-26 includes a trendline (estimated by Excel), but the R^2 value is close to zero ($R^2 = 0.003$), indicating that no significant relationship exists between flow and *E. coli* concentration.

As discussed in Section 5.7.2, the flow data were normalized by converting measured flow data into a ratio of measured site flow to median site flow. A correlation analysis between the natural log *E. coli* concentration and the relative flow values found a statistically significant relationship ($p < 0.001$) regardless of location, season or flow conditions (Table 5-17, "all samples").

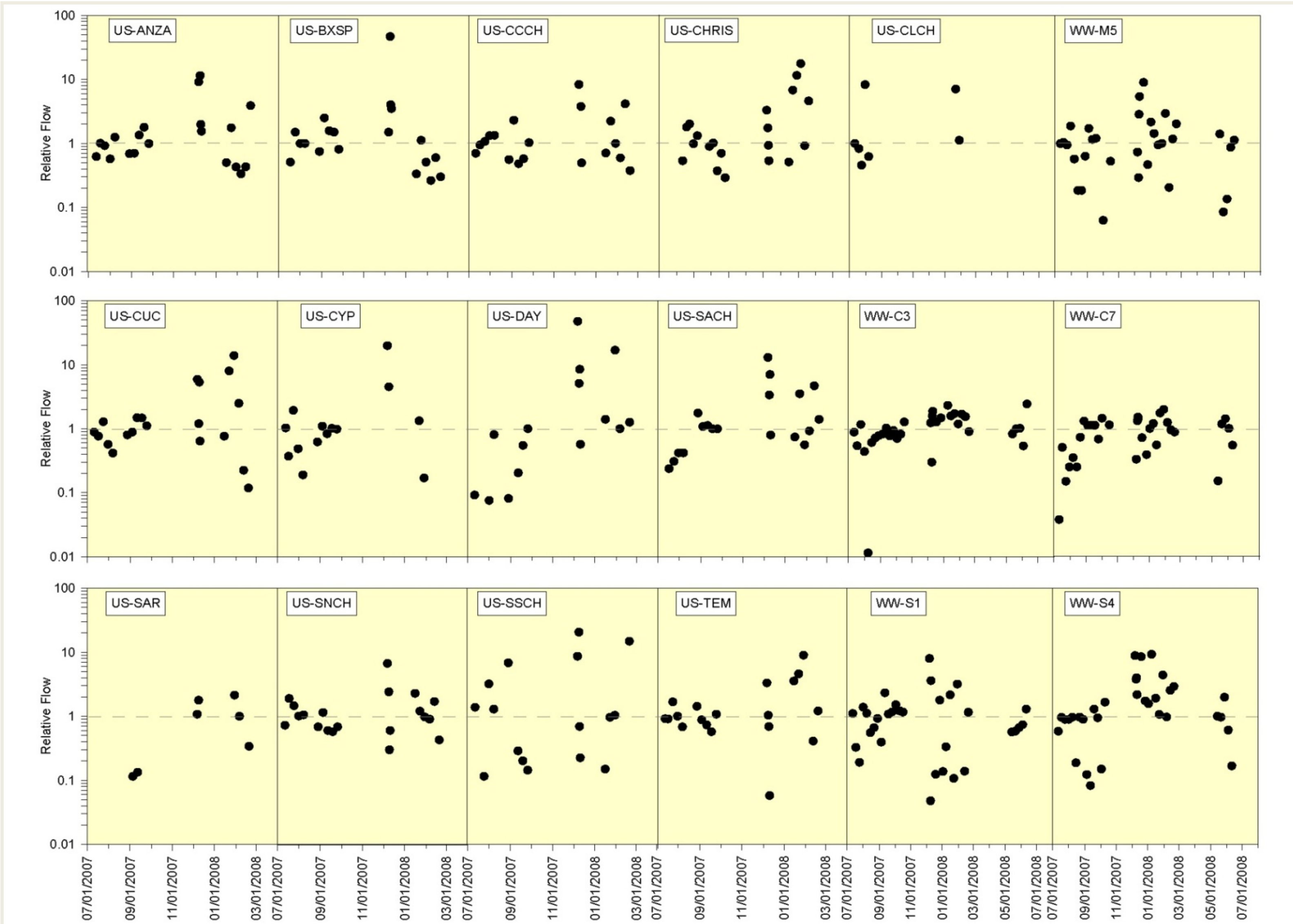


Figure 5-23. Time series plots showing a comparison of relative flow among sites. Increased scatter along the y-axis indicates increased flow variability at the site.

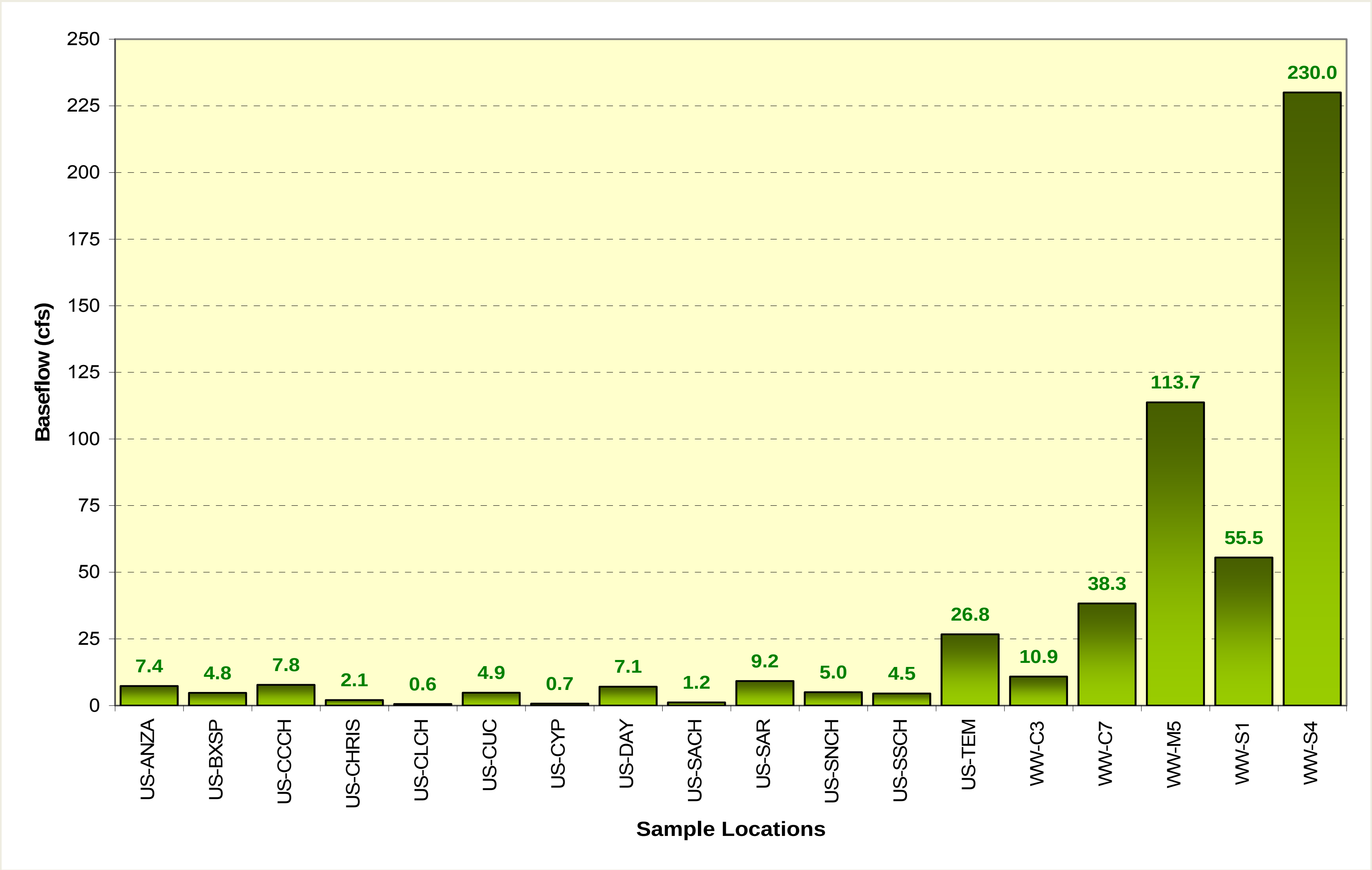


Figure 5-24. Estimated baseflow conditions during dry weather at all sample locations. See Section 5.7.3 for a description of how baseflow conditions were estimated.

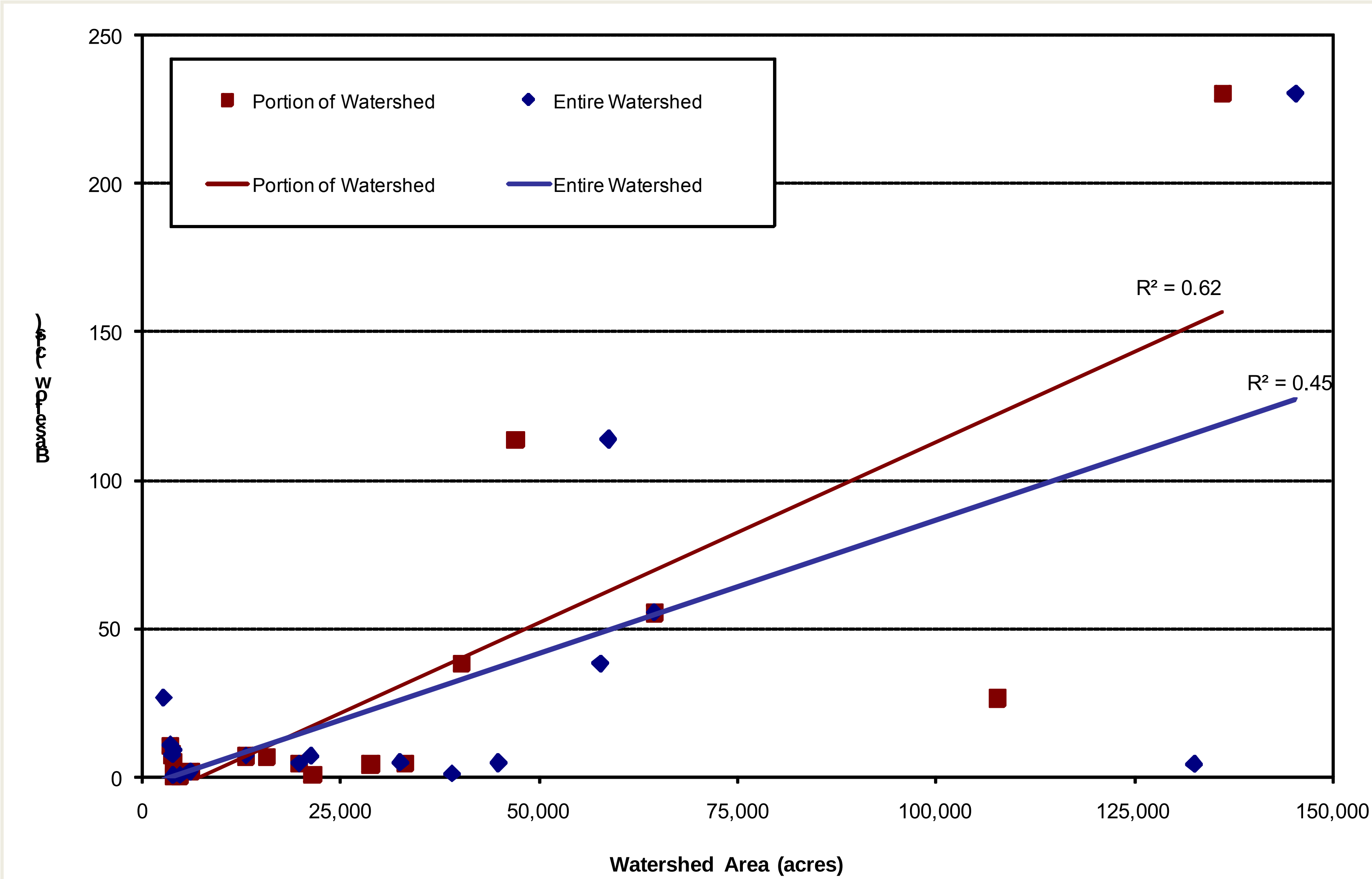


Figure 5-25. Relationship between baseflow (cfs) and watershed area. Watershed area is calculated in two ways: (1) Entire watershed topographically; and (2) portion of the watershed that is most likely to contribute to dry weather flows.

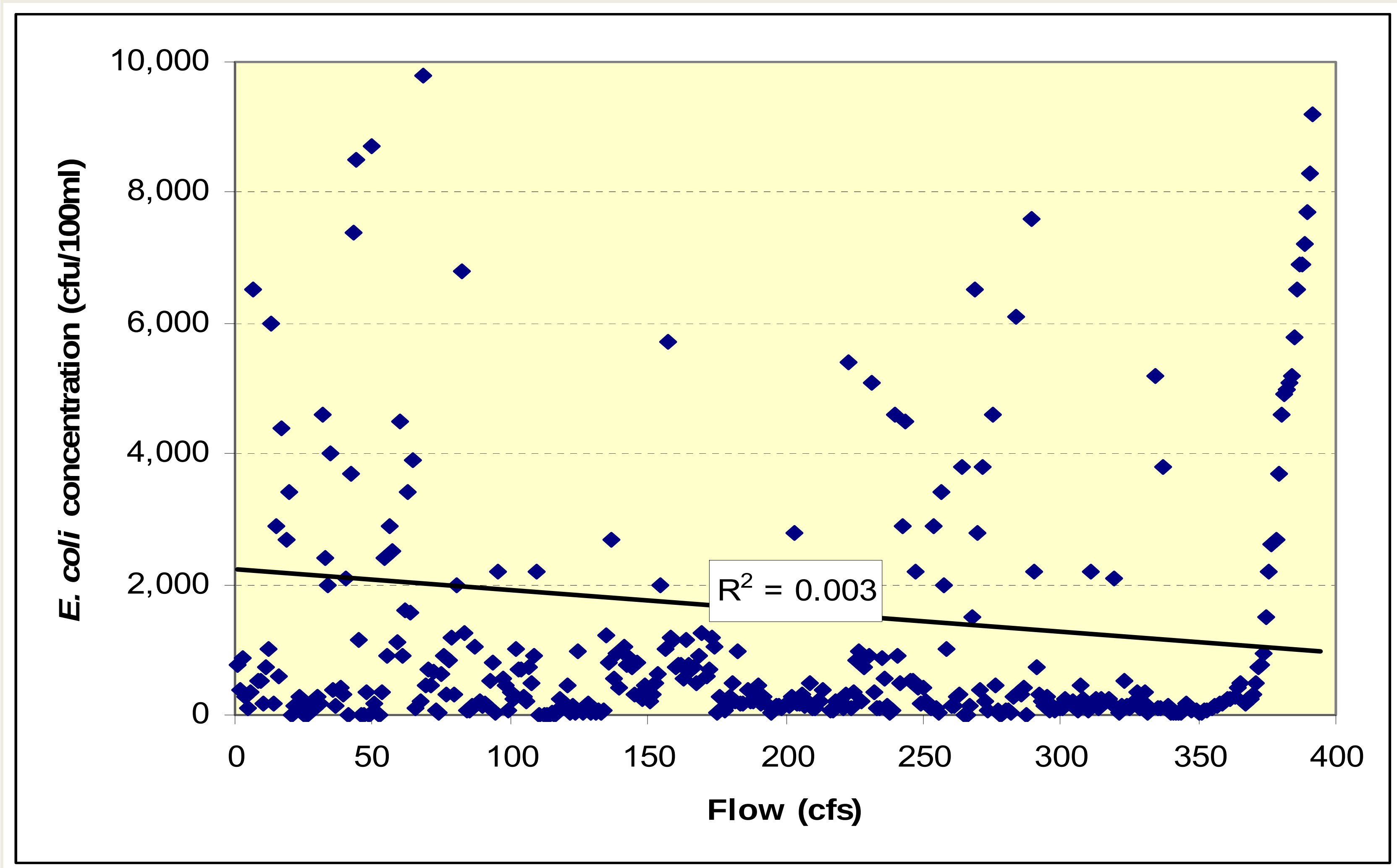


Figure 5-26. Scatterplot of flow data (cfs) and *E. coli* concentrations (cfu/100 mL) using all data regardless of location, season and flow condition. Non-significant linear trend line fit using Excel.

At first glance, it would appear that this analysis contradicts earlier findings that increased flows associated with wet weather resulted in higher bacterial concentrations. The normalized data shown in Table 5-17 clearly indicate that, regardless of how large a stream is during dry weather conditions, bacterial concentrations increase when flows increase significantly above those baseline levels (as happens when it rains).

Table 5-17. Correlation analysis between natural log *E. coli* concentration (cfu/100 mL) and relative flow (ratio of measured flow to median flow) for various data groupings.

Data Group	Pearson's r	Degrees of freedom (n - 2)	Student t-statistic	p-value
All Samples	0.18	375	3.48	0.001
Dry Weather Samples	0.05	349	1.01	0.313
Wet Weather Samples	0.02	26	0.10	0.921
Warm Season Samples	0.15	198	2.08	0.04
Cool Season Samples	0.27	177	3.73	< 0.001

5.7.5 Is there a correlation between *E. coli* concentrations and flow during dry weather conditions regardless of location or season?

Figure 5-27 illustrates the relationship between flow (cfs) and *E. coli* concentrations (cfu/100 mL). This relationship (1) shows the result of using only data collected during dry weather regardless of location or season; and (2) makes no attempt to normalize the flow data. As with Section 5.7.4, the results show that throughout the watershed elevated *E. coli* concentrations are elevated (> 1,000 cfu/100 mL) regardless of whether flow is low or high. Figure 5-27 includes a trendline (estimated by Excel), but the R^2 value, while better than observed for the previous analysis, is still close to zero ($R^2 = 0.0197$), indicating that no significant relationship exists between flow and *E. coli* concentration.

Similar to Section 5.7.4, the normalized flow data (ratio of measured site flow to median site flow) were further evaluated. A correlation analysis between the natural log *E. coli* concentration and the relative flow values found a non-significant statistical relationship between *E. coli* concentration and flow during dry conditions regardless of season (p-value = 0.313) (Table 5-17, "dry weather"). However, if samples are evaluated seasonally without regard to flow conditions, a significant relationship is observed for the warm (p-value = 0.04) and cool (p-value < 0.001) seasons (Table 5-17, "warm" or "cool").

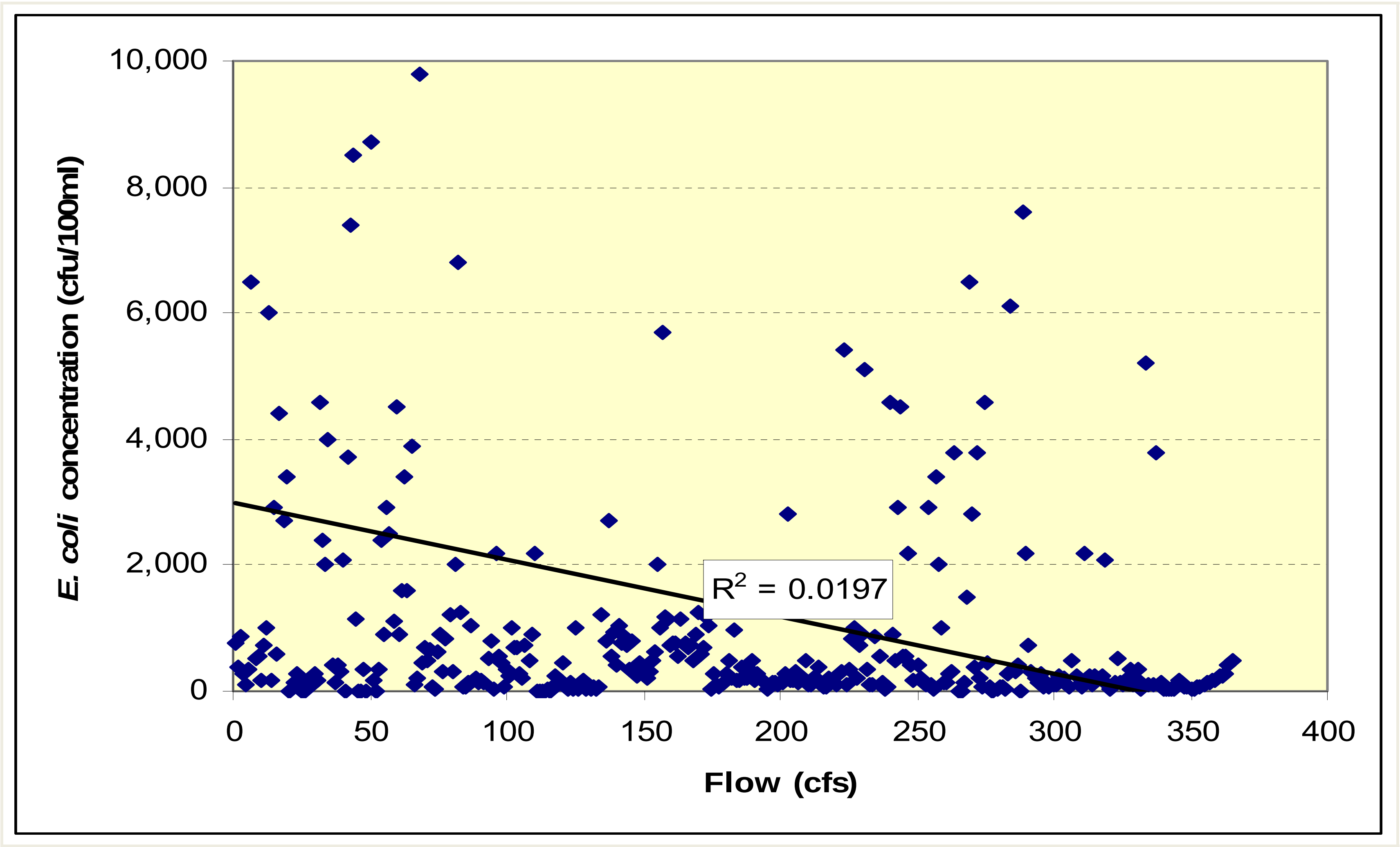


Figure 5-27. Scatterplot of flow data (cfs) and *E. coli* concentrations (cfu/100 mL) using data from all sites and seasons, but only for dry weather conditions. Non-significant linear trend line fit using Excel.

These data confirm that it is not the amount of flow, per se, that determines the number of bacteria present. Rather, it is the degree to which flow increases above its normal, dry-weather background levels that matters. This does not tell us, however, whether the higher *E. coli* concentrations result from the increased sediment scouring that occurs or whether the stormwater runoff is merely transporting larger bacterial loads that are being shed from the surrounding terrain. It is likely that this question has already been investigated by other scientists in other watersheds. Therefore, a detailed follow-on study is not recommended.

5.7.6 Is there a statistically significant correlation between *E. coli* concentrations and flow while controlling for location under varying flow conditions?

Tables 5-18 and 5-19 summarize the results of the following correlation analyses conducted for each sample location:

- Relationship between *E. coli* concentration and flow for all data regardless of season or flow; and
- Relationship between *E. coli* concentration and flow, but under dry weather conditions only.

Both analyses relied on Spearman's rho (ρ) non-parametric test that produces a correlation coefficient. A negative correlation coefficient indicates an inverse data relationship (e.g., increased flow resulted in lower *E. coli* concentrations); a positive correlation indicates that a direct relationship exists between *E. coli* concentration and flow (e.g., increased flow equals increased bacteria).

Table 5-18 shows that when all data are included, regardless of flow condition, a statistically significant <u>positive</u> correlation exists between the *E. coli* concentration and flow at the following USEP sites: Chris Basin ($p = 0.015$), Cypress Channel ($p = 0.022$), and San Sevaine Channel ($p < 0.001$). None of the WW sites had a statistically significant correlation between *E. coli* concentration and flow.

Table 5-19 shows that when only dry weather data are evaluated, statistically significant <u>positive</u> correlations exist between the *E. coli* concentration and flow for only Chris Basin ($p = 0.022$). A statistically significant <u>negative</u> correlation exists between the *E. coli* concentration and flow at Sunnyslope Channel ($p = 0.032$) and Santa Ana River at La Cadena ($p = 0.015$). For the WW sites, a statistically significant <u>negative</u> correlation exists between *E. coli* concentration and flow at Mill Creek ($p = 0.012$) and SAR MWD Crossing ($p = 0.013$).

Table 5-18. Correlation analysis between natural log *E. coli* concentration (cfu/100 mL) and natural log flow (cfs) for all sites, regardless of season or flow conditions

Site Type	Site	Spearman Rho (ρ)	Degrees of freedom (n - 2)	t-statistic	p-value	Significant?[1]
Watershed Wide Compliance	Icehouse Canyon Creek	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Prado Park Lake	-0.01	31	0.05	0.480	No
	Chino Creek	-0.14	31	0.78	0.221	No
	Mill Creek	-0.18	30	1.02	0.158	No
	SAR @ MWD Crossing	-0.29	30	1.68	0.052	No
	SAR @ Pedley Ave.	0.22	31	1.23	0.114	No
Urban Source Evaluation	Anza Drain	0.24	18	1.03	0.158	No
	Box Springs Channel	0.24	17	1.00	0.166	No
	Carbon Canyon Creek	0.38	17	1.70	0.054	No
	Chris Basin	0.49	18	2.36	0.015	Yes (+)
	County Line Channel	-0.07	5	0.16	0.440	No
	Cucamonga Creek	0.22	18	0.97	0.172	No
	Cypress Channel	0.55	12	2.26	0.022	Yes (+)
	Day Creek	-0.08	13	0.27	0.396	No
	San Antonio Channel	0.21	17	0.87	0.198	No
	SAR @ La Cadena	-0.54	5	1.42	0.107	No
	Sunnyslope Channel	-0.25	18	1.08	0.147	No
	San Sevaine Channel	0.84	14	5.86	< 0.001	Yes (+)
	Temescal Creek	-0.17	16	0.70	0.247	No

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation
[2] – Insufficient data from this site

Table 5-19. Correlation analysis between natural log *E. coli* concentration (cfu/100 mL) and natural log flow (cfs) for all sites during dry weather flow conditions only

Site Type	Site	Spearman Rho (ρ)	Degrees of freedom (n - 2)	t-statistic	p-value	Significant?[1]
Watershed Wide Compliance	Icehouse Canyon Creek	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Prado Park Lake	-0.02	31	0.09	0.464	No
	Chino Creek	-0.25	31	1.44	0.080	No
	Mill Creek	-0.40	30	2.38	0.012	Yes (+)
	SAR @ MWD Crossing	-0.39	30	2.33	0.013	Yes (+)
	SAR @ Pedley Ave.	-0.02	31	0.09	0.464	No
Urban Source Evaluation	Anza Drain	0.03	18	0.14	0.445	No
	Box Springs Channel	0.23	17	0.96	0.175	No
	Carbon Canyon Creek	0.27	17	1.17	0.129	No
	Chris Basin	0.45	18	2.16	0.022	Yes (+)
	County Line Channel	-0.07	5	0.16	0.440	No
	Cucamonga Creek	0.14	18	0.61	0.275	No
	Cypress Channel	0.30	12	1.09	0.149	No
	Day Creek	-0.10	13	0.36	0.362	No
	San Antonio Channel	0.07	17	0.27	0.395	No
	SAR @ La Cadena	-0.80	5	2.98	0.015	Yes (+)
	Sunnyslope Channel	-0.42	18	1.97	0.032	Yes (+)
	San Sevaine Channel	0.78	14	4.65	< 0.001	Yes (+)
	Temescal Creek	-0.26	16	1.08	0.148	No

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation
[2] – Insufficient data from this site

5.8 Temporal Analysis

This section provides an analysis of the variability of week to week *E. coli* concentrations within minimum 5-week periods (selected because this is the period used to calculate geomeans). The metric for measuring variability is the coefficient of variation. This was calculated for each site for various 5 or 6 week periods using natural log transformed data.

5.8.1 What is the temporal variability in *E. coli* concentrations during five week sample periods at all sites regardless of flow conditions during warm and cool seasons?

Table 5-20 provides the coefficient of variation for each WW site for four warm season periods and 2 cool season periods (5-week time periods are provided on the table). During the warm season, the Prado Park Lake Outlet site had the highest week to week variability within 5-week periods. Lowest variability occurred at the Chino Creek site. For the cool season, the Santa Ana River sites were the most variable during one 5-week period, but Mill and Chino Creeks had the highest variability during the second 5-week period.

Table 5-21 summarizes the coefficient of variation for each USEP site during two warm season periods and one cool season period (coefficient of variation based on six samples for this period). Highest variability during the warm season occurred at Cucamonga Channel; lowest variability occurred at Temescal Creek during the first 5-week period and Day Creek during the second 5-week period. For the cool season, San Sevaine Channel had the highest variability; lowest variability was observed at Cypress Channel.

As noted in section 5.2.2, it is generally easier to perform successful source tracking studies at those locations where data variability is lowest. Most source investigations rely principally on the analysis of single samples rather than the calculation of long-term geometric means to improve the odds of identifying the source before conditions change. Therefore, the stronger and more stable signals improve the efficiency and effectiveness of the source investigation effort.

5.9 Molecular Analysis

Appendix A, Tables A-8 and A-9 summarize the *Bacteroidales* results for all sites from all laboratories. The University of California Davis and Orange County Water District analyzed samples for the presence of *Bacteroidales* host specific markers for human, bovine, and domestic canine bacterial indicator sources. The University of California Davis also analyzed samples for a universal *Bacteroidales* marker, which represents all possible bacteria sources. Where the universal marker was measured, it was a quantified at levels much higher than the other measured markers, indicating the presence of many other sources of bacteria, e.g. birds, rodents, small mammals and reptiles. The following sections summarize the frequency of detection of the human, domestic canine and bovine markers at USEP sites.

Table 5-20. Within site variability of *E. coli* concentrations at WW sites. Variability based on coefficient of variation (using log-transformed data) calculated for each consecutive five week period during warm and cool seasons.

Site Type	Site	Warm Season (5 Week Periods, Week Ending)				Cool Season (5 Week Periods, Week Ending)	
		7/14 – 8/11	**8/18 – 9/15**	**9/22-10/20**	**5/17 -6/14**	**12/22 – 1/19**	**1/26 – 2/23**
Watershed Wide Compliance	Icehouse Canyon Creek	n/a[1]	n/a[1]	n/a[1]	0.00[2]	n/a[1]	n/a[1]
	Prado Park Lake	0.31	0.26	0.26	0.16	0.07	0.18
	Chino Creek	0.08	0.05	0.07	0.07	0.06	0.26
	Mill Creek	0.10	0.04	0.03	0.05	0.19	0.31
	SAR @ MWD Crossing	0.18	0.12	0.07	0.09	0.32	0.19
	SAR @ Pedley Ave.	0.13	0.22	0.09	0.11	0.32	0.18

[1] – Site was dry during the period
[2] – Site had flow 4 of 5 sample dates.

Table 5-21. Within site variability of *E. coli* concentrations at USEP sites. Variability based on coefficient of variation (using log-transformed data) calculated for three five week periods during warm and cool seasons.

Site Type	Site	Warm Season (5 Week Periods, Week Ending)		Cool Season (5 Week Periods Week Ending)
		7/14 – 8/11	9/1 – 9/29	1/19 – 2/16
Urban Source Evaluation	Anza Drain	0.14	0.21	0.25
	Box Springs Channel	0.20	0.23	0.15
	Carbon Canyon Creek	0.42	0.30	0.24
	Chris Basin	0.17	0.16	0.12
	County Line Channel	0.40	n/a[1]	0.11
	Cucamonga Creek	0.72	0.38	0.34
	Cypress Channel	0.18	0.08	0.07
	Day Creek	0.38	0.04	0.19
	San Antonio Channel	0.29	0.13	0.19
	SAR @ La Cadena	n/a[1]	0.15	0.35
	Sunnyslope Channel	0.22	0.10	0.39
	San Sevaine Channel	0.28	0.15	0.47
	Temescal Creek	0.11	0.09	0.12

[1] – Site was dry during the period
[2] – Site had flow 4 of 5 sample dates.

5.9.1 What is the frequency of detection of each of the molecular markers, by location, regardless of season or flow conditions?

Table 5-22 summarizes the frequency of *Bacteroidales* detections at each USEP site for human, bovine, and domestic canine host-specific markers. Figure 5-28 shows the frequency of detection of each of the *Bacteroidales* host-specific markers for each USEP site as a proportion of the number of samples analyzed at the site. For the smaller USEP watersheds (other than SAR - La Cadena), the sites with highest frequency of detection of host-specific markers included:

- Human marker - Box Springs Channel and Chris Basin;
- Bovine marker – Anza Drain, Cypress Channel and San Antonio Channel; and
- Domestic canine marker - Chris Basin, County Line Channel and Day Creek.

Table 5.22. Summary of number of *Bacteroidales* host-specific marker detections for all USEP sites, regardless of season and flow conditions

Description	N	Human	Domestic Canine	Bovine
Anza Drain	20	1	3	10
Box Springs Channel	20	18	4	4
Carbon Canyon Cr.	20	0	8	0
Chris Basin	20	5	16	2
County Line Channel	7	0	5	2
Cucamonga Cr.	20	1	6	0
Cypress Channel	14	1	2	10
Day Creek	15	1	5	0
San Antonio Channel	19	3	6	10
SAR @ La Cadena	7	3	5	0
Sunnyslope Channel	20	3	4	3
San Sevaine Channel	16	2	4	3
Temescal Cr.	20	1	3	1

Host-specific marker detection was high for human and domestic canine at the SAR-La Cadena site. However, this site integrates bacteria sources primarily from the upper Santa Ana River watershed and was sampled infrequently because it was dry. Accordingly, in regards to sources derived from within the MSAR Watershed the frequency of detection at this site has less meaning than other USEP sites.

Because it is difficult for pathogens to cross the species barrier, high concentrations of human markers signal increased risk of contagion to people engaged in water contact recreation. Consequently, these markers can be used to identify the highest priority sites as those that appear to be contaminated by human pathogens. It may be appropriate to perform more detailed sanitary surveys looking for leaking sewer or septic systems. Or, the elevated human *Bacteroidales* may originate from homeless persons or other temporary encampments.

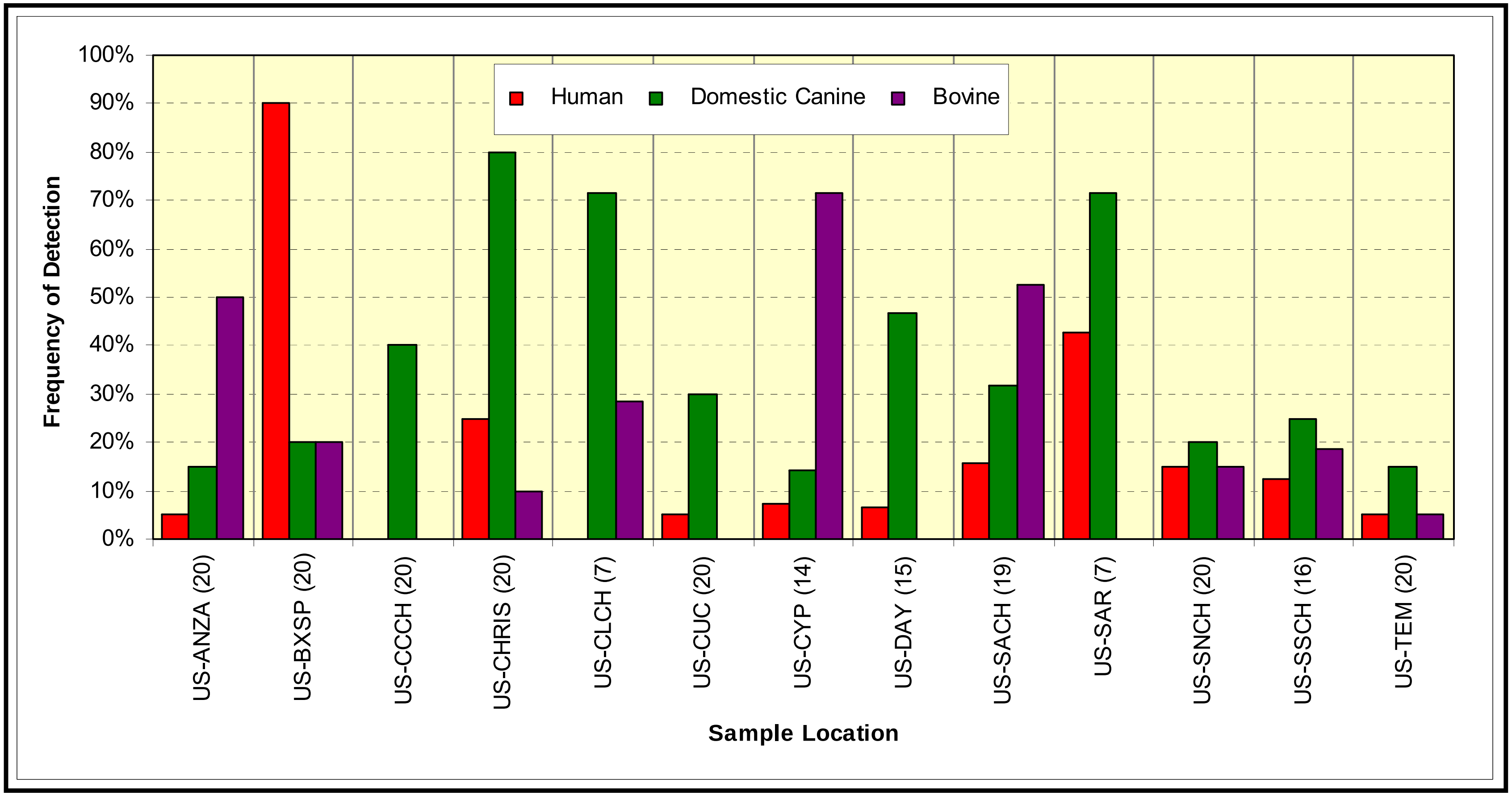


Figure 5-28. Frequency of detection of *Bacteroidales* host-specific markers for human, domestic canine and bovine. Numbers in parentheses next to site locations are the numbers of samples analyzed at that site during 2007-2008 sampling program.

5.9.2 Is there a statistical relationship between bacterial indicator concentrations and the detection of molecular markers?

USEP sample data were divided into two groups:

- Samples where at least one *Bacteroidales* host-specific marker was detected; and
- Samples where no *Bacteroidales* markers were detected.

The group where at least one marker was detected was further subdivided into three groups: (1) samples with a human detection; (2) samples with a bovine detection; and (3) samples with a domestic canine detection.

The grouped data were statistically evaluated to determine if any statistical relationship exists between host-specific marker detections and the geomean of bacterial indicator concentrations (Table 5-23). None of the tests was significant for either fecal coliform or *E. coli*. These results indicate no statistically significant relationship between the detection of a host-specific marker and instream bacterial indicator concentrations.

Table 5-23. Results of Student t-test comparing fecal coliform and *E. coli* geometric mean concentrations to detection of *Bacteroidales* host-specific markers (human, domestic canine, bovine)

Host-Specific Marker	Statistic	Measure	N	Fecal coliform (cfu/100 mL)	*E. coli* (cfu/100 mL)
Human	Geomean	Human marker detected	39	1,540	671
		Human marker not detected	178	1,121	440
	Student t-test	p-value		0.371	0.240
Domestic Canine	Geomean	Domestic canine marker detected	73	1,110	637
		Domestic canine marker not detected	144	1,228	428
	Student t-test	p-value		0.714	0.123
Bovine	Geomean	Bovine marker detected	45	1,703	690
		Bovine marker not detected	172	1,080	447
	Student t-test	p-value		0.165	0.170

It is disappointing that the host-specific *Bacteroidales* markers were not closely correlated with either *E. coli* or fecal coliform concentrations. This means the latter, less expensive methods cannot be used as surrogates for the former. Additional testing will be necessary in order to distinguish human bacteria from other common sources. These data also suggest that *E. coli* and fecal coliform are imperfect surrogates of human health risk. This is consistent with the results of epidemiological studies performed in San Diego's Mission Bay area. The combination of both *E. coli* data and *Bacteroidales* data provide a better strategy for prioritizing source investigations and BMP implementation based on risk reduction.

5.10 Bacterial Indicator Correlation Analysis

The following questions evaluate the relationship between fecal coliform and *E. coli* concentrations under a variety of conditions. A parametric correlation coefficient (Pearson's r) and corresponding p-value were obtained for each analysis. Prior to conducting the statistical analyses, the bacterial indicator data were normalized with a natural logarithm transformation. No site-specific analyses could be completed because of the small sample size.

5.10.1 Is there a correlation between fecal coliform and *E. coli* concentrations under any of the following conditions: (1) all sites without regard for location, season or flow conditions; (2) during warm or cool seasons without regard for location or flow conditions; or (3) during dry or wet weather conditions without regard to location or season?

Table 5-24 summarizes the results of all correlation analyses for various data groupings. Regardless of the conditions applied to the data, a highly significant positive correlation exists between fecal coliform and *E. coli* concentrations.

5.10.2 Is there a correlation between fecal coliform and *E. coli* concentrations, by location, without regard for season or flow conditions?

Table 5-25 summarizes the results of all correlation analyses conducted for each USEP and WW site regardless of season or flow conditions. A highly significant positive correlation exists between fecal coliform and *E. coli* concentrations for all sites.

5.10.3 Is there a correlation between fecal coliform and *E. coli* concentrations during dry weather while controlling for location?

Table 5-26 summarizes the results of all correlation analyses conducted for each USEP and WW site for samples collected during dry weather conditions. A significant positive correlation exists between fecal coliform and *E. coli* concentrations at all sites.

Table 5-24. Correlation analyses between natural log *E. coli* concentrations (cfu/100 mL) and natural log fecal coliform concentrations (cfu/ 100 mL) for various data groupings regardless of sample location

Data Grouping	Pearson's r coefficient	Degrees of freedom	t-statistic	p-value	Significant?[1]
All Samples	0.87	389	34.17	< 0.001	Yes (+)
Warm Season Samples	0.85	212	23.35	< 0.001	Yes (+)
Cool Season Samples	0.93	175	33.90	< 0.001	Yes (+)
Dry Weather Samples	0.85	363	30.68	< 0.001	Yes (+)
Wet Weather Samples	0.89	26	9.92	< 0.001	Yes (+)

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation

Table 5-25. Correlation analyses between natural log *E. coli* concentrations (cfu/100 mL) and natural log fecal coliform concentrations (cfu/ 100 mL) for each USEP and WW site regardless of season or flow conditions

Site Type	Site	Spearman Rho (ρ)	Degrees of freedom (n - 2)	Student t-statistic	p-value	Significant?[1]
Watershed Wide Compliance	Icehouse Canyon Creek	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Prado Park Lake	0.88	32	10.27	< 0.001	Yes (+)
	Chino Creek	0.92	32	12.92	< 0.001	Yes (+)
	Mill Creek	0.82	32	8.01	< 0.001	Yes (+)
	SAR @ MWD Crossing	0.71	32	5.77	< 0.001	Yes (+)
	SAR @ Pedley Ave.	0.79	32	7.19	< 0.001	Yes (+)
Urban Source Evaluation	Anza Drain	0.82	18	6.10	< 0.001	Yes (+)
	Box Springs Channel	0.63	18	3.48	0.003	Yes (+)
	Carbon Canyon Creek	0.73	18	4.49	0.003	Yes (+)
	Chris Basin	0.74	18	4.67	< 0.001	Yes (+)
	County Line Channel	0.89	5	4.44	0.007	Yes (+)
	Cucamonga Creek	0.91	18	9.25	< 0.001	Yes (+)
	Cypress Channel	0.73	12	3.73	0.003	Yes (+)
	Day Creek	0.94	13	9.59	< 0.001	Yes (+)
	San Antonio Channel	0.69	17	3.93	0.001	Yes (+)
	SAR @ La Cadena	0.96	5	8.11	0.001	Yes (+)
	Sunnyslope Channel	0.70	18	4.14	0.001	Yes (+)
	San Sevaine Channel	0.74	14	4.08	0.001	Yes (+)
	Temescal Creek	0.72	17	4.37	0.001	Yes (+)

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation
[2] – Insufficient data from this site

Table 5-26. Correlation analyses between natural log *E. coli* concentrations (cfu/100 mL) and natural log fecal coliform concentrations (cfu/ 100 mL) for each USEP and WW site under dry weather conditions

Site Type	Site	Pearson's r coefficient	Degrees of freedom (n - 2)	t-statistic	p-value	Significant?[1]
Watershed Wide Compliance	Icehouse Canyon Creek	n/a[2]	n/a[2]	n/a[2]	n/a[2]	n/a[2]
	Prado Park Lake	0.87	31	9.78	< 0.001	Yes (+)
	Chino Creek	0.91	31	12.07	< 0.001	Yes (+)
	Mill Creek	0.84	30	8.41	< 0.001	Yes (+)
	SAR @ MWD Crossing	0.69	30	5.19	< 0.001	Yes (+)
	SAR @ Pedley Ave.	0.73	29	5.80	< 0.001	Yes (+)
Urban Source Evaluation	Anza Drain	0.79	16	5.22	< 0.001	Yes (+)
	Box Springs Channel	0.65	16	3.38	0.004	Yes (+)
	Carbon Canyon Creek	0.68	17	3.83	< 0.001	Yes (+)
	Chris Basin	0.71	17	4.12	< 0.001	Yes (+)
	County Line Channel	0.89	5	4.44	0.007	Yes (+)
	Cucamonga Creek	0.91	17	8.99	< 0.001	Yes (+)
	Cypress Channel	0.73	10	3.37	0.007	Yes (+)
	Day Creek	0.94	11	9.14	< 0.001	Yes (+)
	San Antonio Channel	0.64	16	3.29	0.005	Yes (+)
	SAR @ La Cadena	1.00	3	38.70	< 0.001	Yes (+)
	Sunnyslope Channel	0.66	17	3.57	0.002	Yes (+)
	San Sevaine Channel	0.66	12	3.01	0.011	Yes (+)
	Temescal Creek	0.67	16	3.65	0.002	Yes (+)

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation
[2] – Insufficient data from this site

The fact that *E. coli* and fecal coliform concentrations are closely correlated is not surprising given that the former is merely a subset of the latter. However, because the correlation is so strong (r^2=65-90%), it may be possible to rely on fecal coliform measurements as surrogates for *E. coli* concentrations during source investigations if doing so provides substantial analytical savings or greater sampling flexibility. *E. coli* data should still be preferred over fecal coliform data when performing general characterization studies intended to establish system-wide priorities for follow-on source identification studies or general compliance evaluations.

5.11 Risk Analysis

This section uses the frequency and magnitude of bacterial indicator concentration exceedances (over proposed *E. coli* objectives) coupled with *Bacteroidales* host-specific marker detections (for USEP sites only) to rank the importance of sites for follow-up bacterial indicator management activities. This analysis focused on samples collected under dry weather conditions as it is under this condition that bacterial source control is most likely achieved.

Because public resources are inherently limited, available funds must be allocated in a manner which provides the most cost-effective reduction in human health risk. In general, risk increases in proportion to the frequency and magnitude of bacteria violations at any given site. In addition, risk to recreational swimmers is believed to be greater at those locations where elevated bacterial concentrations also appear to originate from human sources (Table 5-27). Therefore, using simple Bayesian constructs, it is possible to construct a rudimentary method for rank-ordering locations based on relative risk (Figure 5-29).

Table 5-27. Factors for rank-ordering waterbodies based on relative risk

Less Risk	Greater Risk
Fewer bacterial indicator exceedances	Frequent bacterial indicator exceedances
Smaller bacterial indicator exceedances	Larger bacterial indicator exceedances
Human microbial markers not detected	Human microbial markers detected
Cooler weather conditions	warmer weather conditions
Baseflow conditions	elevated flow conditions

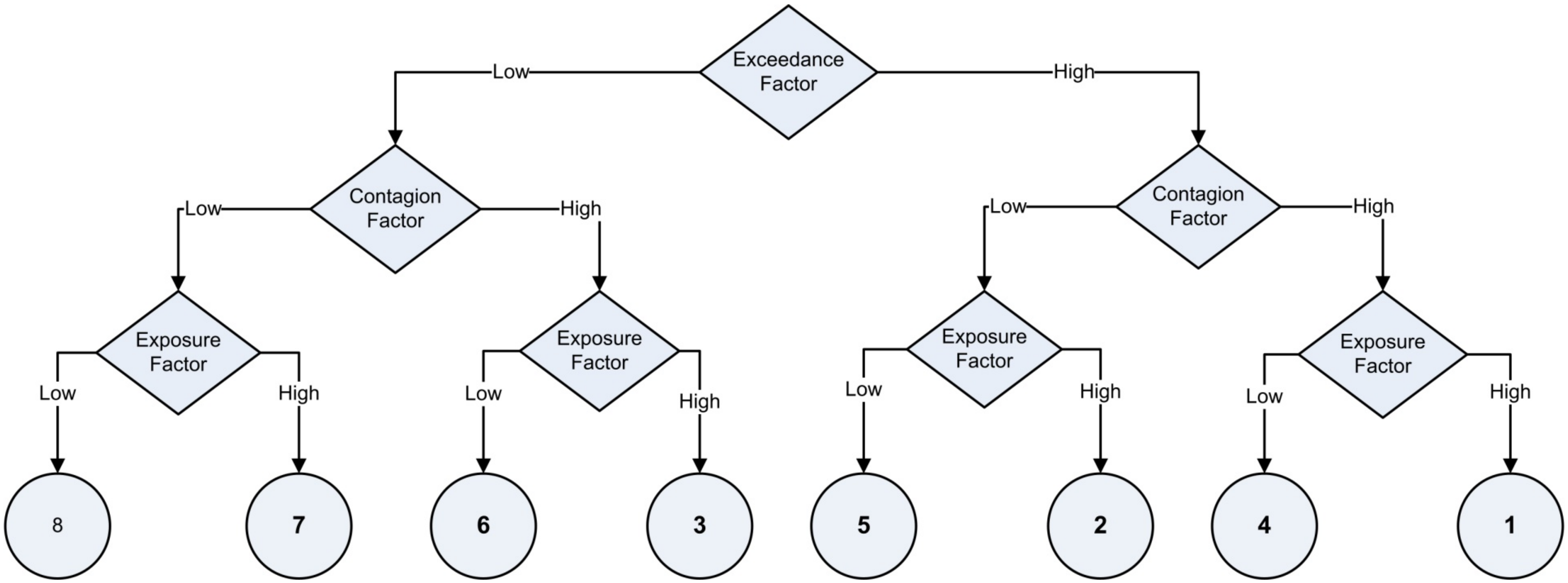


Figure 5-29. Method for rank-ordering waterbodies or sites based upon relative risk

5.11.1 What is the rank-order of WW sites based on the frequency and magnitude of exceedance of the proposed *E. coli* objective under dry weather conditions?

Table 5-28 ranks the WW sites independently by (1) frequency of single sample exceedance; and (2) magnitude of exceedances. The scores for each set of rankings are multiplied to obtain a site Bacteria Prioritization Score (BPS). The result of this analysis ranks Mill and Chino Creeks as the highest priority areas for focusing on compliance activities.

The frequency of exceedance and the magnitude of exceedance are independent measures of signal strength. This is important for evaluating risk to human health and for assessing the probability of successful source identification. Both of these factors are useful for developing appropriate priorities for follow-on investigations. Those sites that have a high rate of exceedance and a high level of exceedance represent the greatest potential threat. Therefore, Table 5-28 derives a BPS by multiplying the relative ranks for each indicator.

5.11.2 What is the rank-order of USEP sites based on the frequency and magnitude of exceedance of the *E. coli* objective and detection of the three *Bacteroidales* markers (human, bovine and domestic canine) under dry weather conditions?

Table 5-29 provides the results of independently ranking three factors for each USEP site: (1) frequency of single sample exceedance; (2) magnitude of exceedances; and (3) frequency of detection of the human *Bacteroidales* marker. The results of each ranking are multiplied together to obtain a BPS for each site. These scores are then normalized to scale them from 0 (lowest rank) to 100 (highest rank). Figure 5-30 illustrates the results for the human marker. The highest ranked sites are Box Springs Channel (BPS = 100), Chris Basin (BPS = 78) and Cypress Channel (BPS = 59). The lowest ranked sites are Carbon Canyon Creek (BPS = 0), Sunnyslope Channel (BPS = 1), and Cucamonga Creek (BPS = 2).

Table 5-30 provides the results of the same ranking process for USEP sites, but instead of ranking the human marker the detection frequency of the bovine marker is ranked. As before, the resulting BPS scores are normalized to scale them from 0 (lowest rank) to 100 (highest rank). Figure 5-31 illustrates the results for the bovine marker. The highest ranked sites are Cypress Channel (BPS = 100) and Box Springs Channel (BPS = 63). The lowest ranked sites are Carbon Canyon Creek (BPS = 0), Cucamonga Creek and Sunnyslope Channel (BPS = 1), and Day Creek and SAR at La Cadena (BPS = 2).

Table 5-31 provides the results of the same ranking process, except that it is focused on the domestic canine marker detection frequency. Figure 5-32 illustrates the results for this marker. The highest ranked sites are Chris Basin

Table 5-28. Ranking of WW sites based on the frequency and magnitude of bacterial indicator exceedances during dry weather (Lowest value = lowest degree of exceedance). Site score = result of multiplying columns (1) and (2).

Site	Relative Rank of Bacterial Indicator Water Quality		
	Frequency of Single Sample Exceedance (1)	Magnitude of Exceedance (2)	Bacteria Prioritization Score (1) * (2)
Icehouse Canyon Creek	1	1	1
Prado Park Lake	2	2	4
Chino Creek	5	5	25
Mill Creek	6	6	36
SAR @ MWD Crossing	4	4	16
SAR @ Pedley Ave.	3	3	9

Table 5-29. Ranking of USEP sites based on the frequency and magnitude of bacterial indicator exceedances and frequency of *Bacteroidales* human marker detections. Data are for dry weather conditions (Lowest value = lowest degree of exceedance). Bacteria Prioritization score = result of multiplying columns (1), (2) and (3). Normalized score result of scaling Bacteria Prioritization Scores to a range of 0 to 100.

Site	Relative Rank of Bacterial Indicator Water Quality			Bacteria Prioritization Score (1)*(2)*(3)	Normalized Score (4)
	Frequency of Single Sample Exceedance (1)	Magnitude of Exceedance (2)	Frequency of Human Detections (3)		
Anza Drain	4	5	5	100	5
Box Springs Channel	11	13	13	1859	100
Carbon Canyon Creek	1	1	1	1	0
Chris Basin	12	11	11	1452	78
County Line Channel	9	10	1	90	5
Cucamonga Creek	3	7	3	63	3
Cypress Channel	13	12	7	1092	59
Day Creek	8	6	6	288	15
San Antonio Channel	6	9	10	540	29
SAR @ La Cadena	5	8	12	480	26
Sunnyslope Channel	1	3	9	27	1
San Sevaine Channel	10	4	8	320	17
Temescal Creek	7	2	3	42	2

Table 5-30. Ranking of USEP sites based on the frequency and magnitude of bacterial indicator exceedances and frequency of *Bacteroidales* bovine marker detections. Data are for dry weather conditions (Lowest value = lowest degree of exceedance). Bacteria Prioritization score = result of multiplying columns (1), (2) and (3). Normalized score result of scaling Bacteria Prioritization Scores to a range of 0 to 100.

Site	Relative Rank of Bacterial Indicator Water Quality			Bacteria Prioritization Score	Normalized Score
	Frequency of Single Sample Exceedance (1)	Magnitude of Exceedance (2)	Frequency of Bovine Detections (3)	(1)*(2)*(3)	(4)
Anza Drain	4	5	11	220	11
Box Springs Channel	11	13	9	1287	63
Carbon Canyon Creek	1	1	1	1	0
Chris Basin	12	11	6	792	39
County Line Channel	9	10	10	900	44
Cucamonga Creek	3	7	1	21	1
Cypress Channel	13	12	13	2028	100
Day Creek	8	6	1	48	2
San Antonio Channel	6	9	12	648	32
SAR @ La Cadena	5	8	1	40	2
Sunnyslope Channel	1	3	7	21	1
San Sevaine Channel	10	4	8	320	16
Temescal Creek	7	2	5	70	3

Table 5-31. Ranking of USEP sites based on the frequency and magnitude of bacterial indicator exceedances and frequency of *Bacteroidales* domestic canine marker detections. Data are for dry weather conditions (Lowest value = lowest degree of exceedance). Bacteria Prioritization score = result of multiplying columns (1), (2) and (3). Normalized score result of scaling Bacteria Prioritization Scores to a range of 0 to 100.

Site	Relative Rank of Bacterial Indicator Water Quality			Bacteria Prioritization Score	Normalized Score
	Frequency of Single Sample Exceedance (1)	Magnitude of Exceedance (2)	Frequency of Domestic Canine Detections (3)	(1)*(2)*(3)	(4)
Anza Drain	4	5	2	40	2
Box Springs Channel	11	13	4	572	33
Carbon Canyon Creek	1	1	9	9	0
Chris Basin	12	11	13	1716	100
County Line Channel	9	10	12	990	58
Cucamonga Creek	3	7	7	147	9
Cypress Channel	13	12	1	156	9
Day Creek	8	6	10	480	28
San Antonio Channel	6	9	8	432	25
SAR @ La Cadena	5	8	11	440	26
Sunnyslope Channel	1	3	4	12	1
San Sevaine Channel	10	4	6	240	14
Temescal Creek	7	2	2	28	2

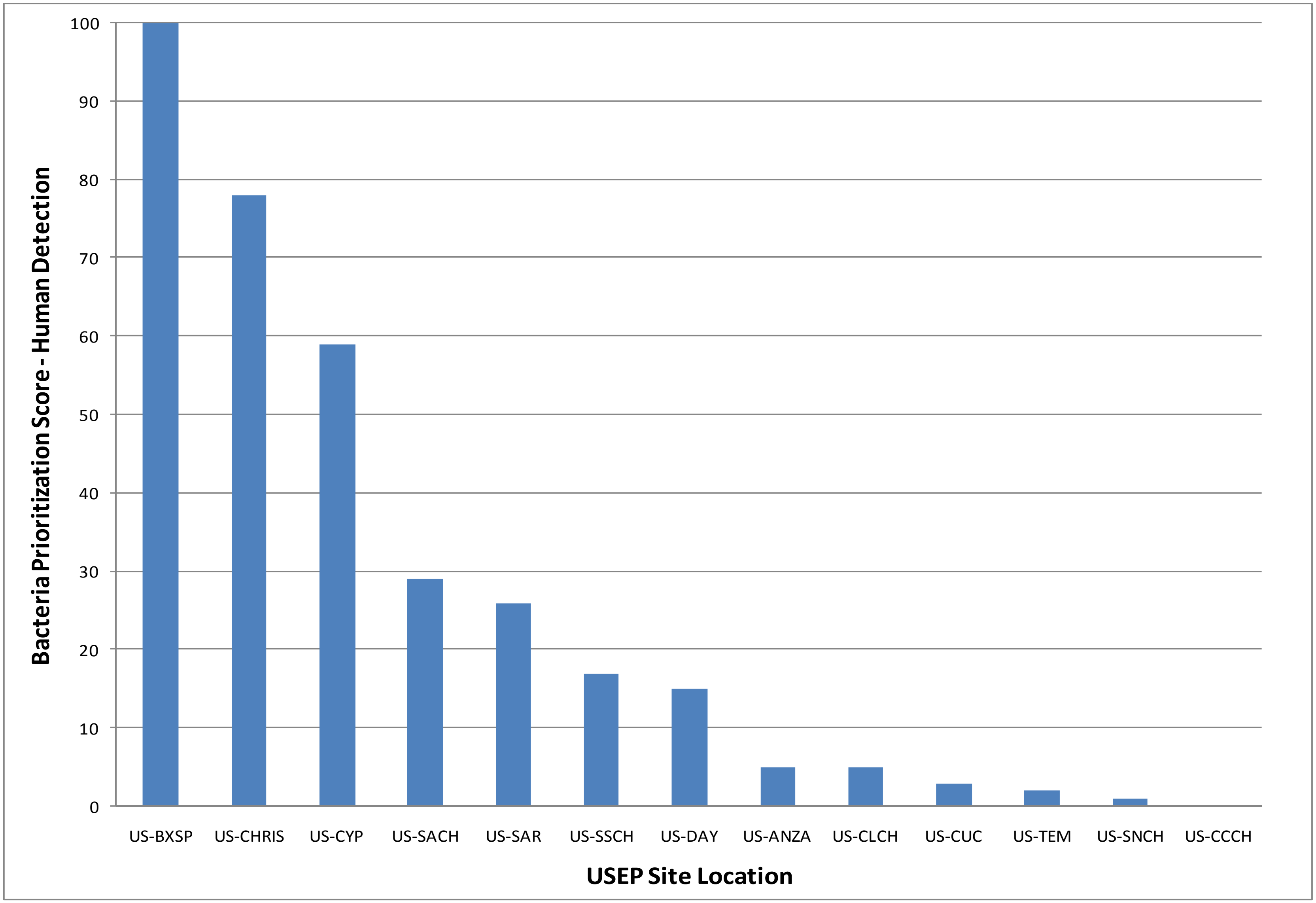


Figure 5-30. USEP sites ranked by their Bacteria Prioritization Score (BPS) based on the *Bacteroidales* host-specific marker for humans. See Section 5.11.2 and Table 5-26 for information on how the BPS is calculated.

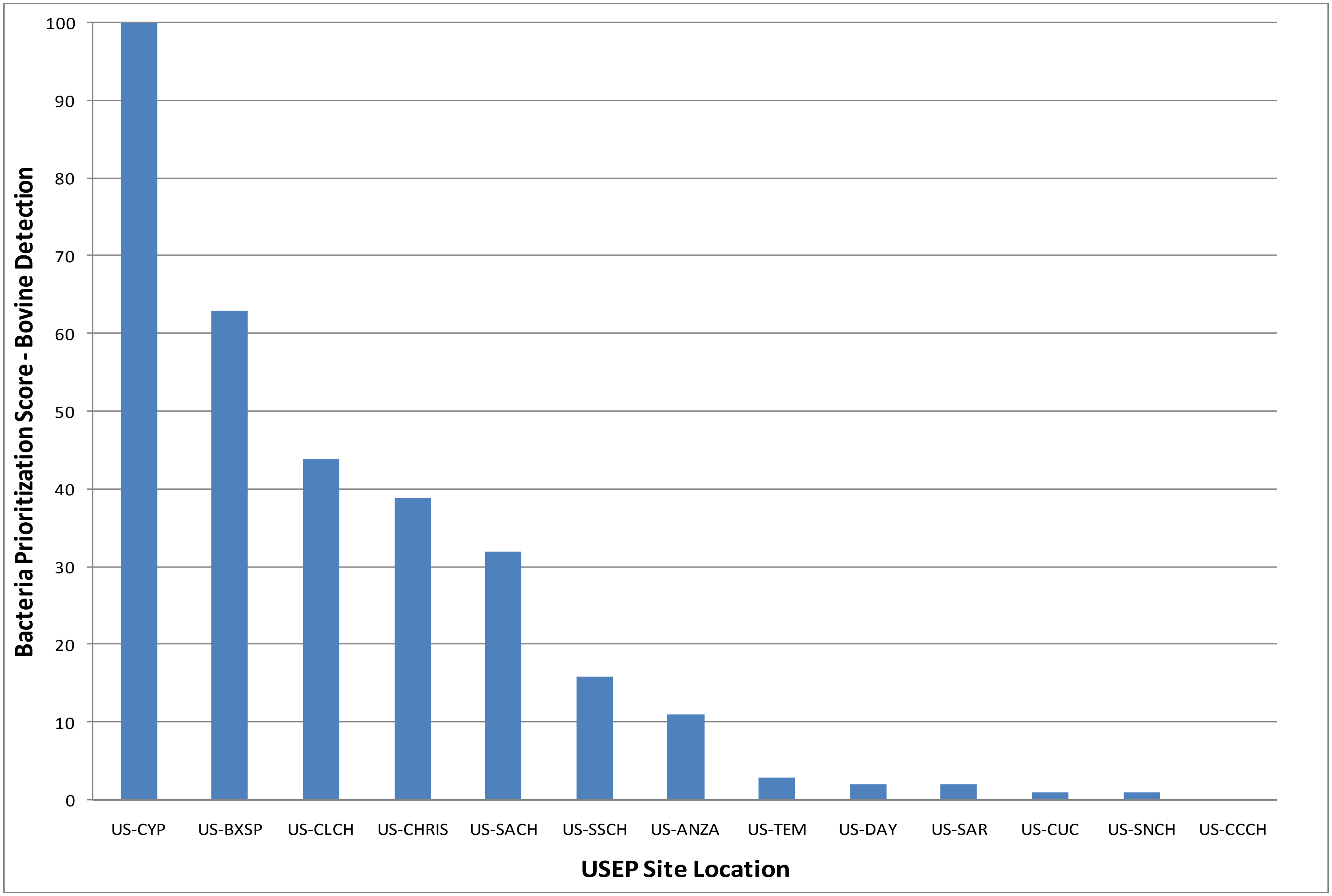


Figure 5-31. USEP sites ranked by their Bacteria Prioritization Score (BPS) based on the *Bacteroidales* host-specific marker for bovine. See Section 5.11.2 and Table 5-27 for information on how the BPS is calculated.

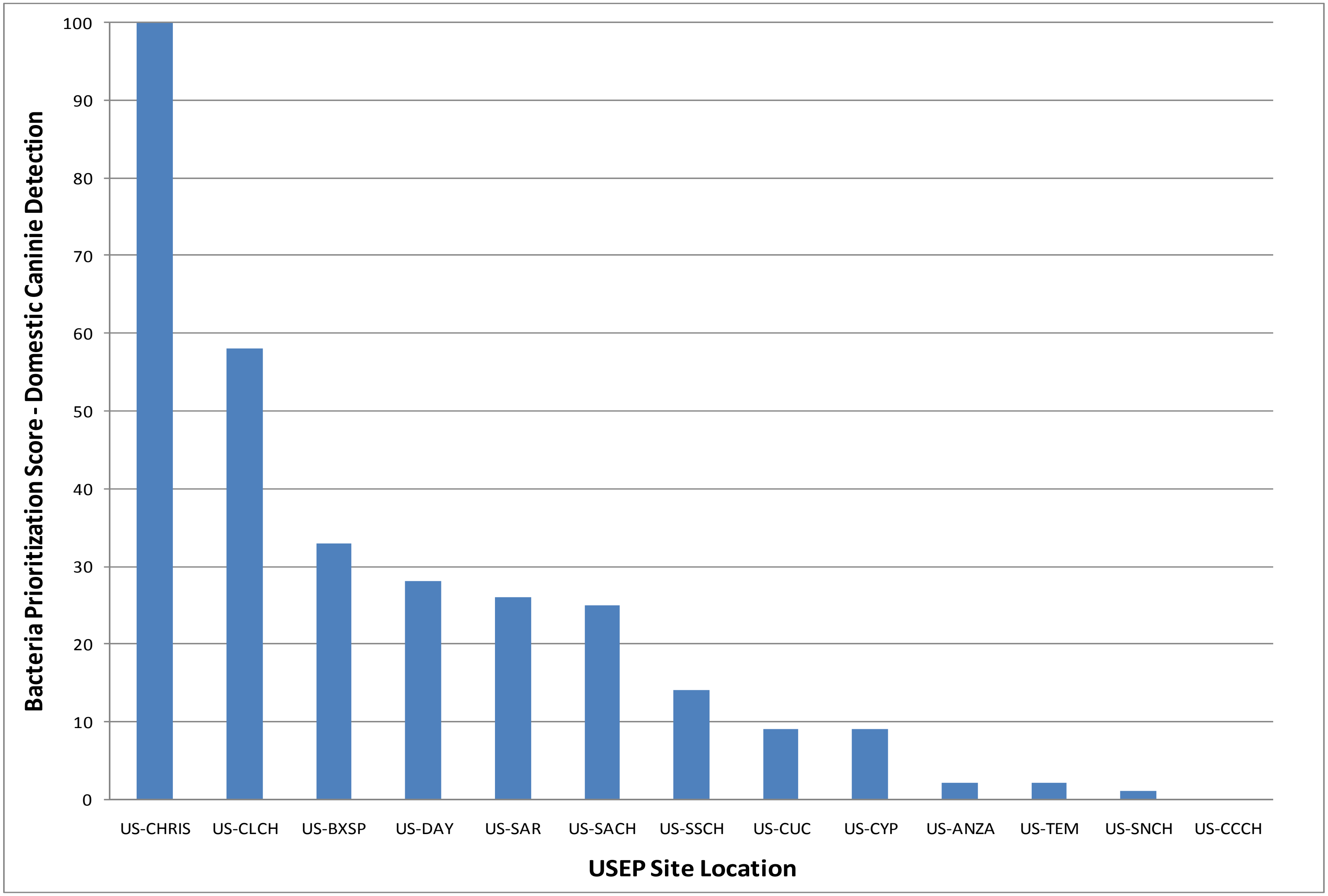


Figure 5-32 USEP sites ranked by their Bacteria Prioritization Score (BPS) based on the *Bacteroidales* host-specific marker for domestic canine. See Section 5.11.2 and Table 5-28 for information on how the BPS is calculated.

(BPS = 100) and County Line Channel (BPS = 58). The lowest ranked sites are Carbon Canyon Creek (BPS = 0) and Sunnyslope Channel (BPS = 1).

Just as the BPS provides a useful measure of signal strength, adding rank-ordered information regarding human markers helps insure available resources are allocated to identify and control sources that are most likely to impair recreational uses. Admittedly, this method is relatively crude compared to more sophisticated epidemiological studies, however it is also much faster and far less expensive. As such, it is a more practical alternative for making management and implementation decisions. However, one must be careful not to assume that the final product scores represent any proportional measure of absolute risk. They are simple measures of relative rank intended to suggest the order in which resources should be allocated among competing project priorities.

5.12 Miscellaneous Analysis

This section addresses a variety of questions that are not addressed by previous sections.

5.12.1 Are the bacterial indicator concentrations observed at the Carbon Canyon Creek USEP site (Chino Hills area), which has a predominantly residential land use in the watershed, significantly different from any other USEP sites where the upstream watershed is also predominantly residential?

Carbon Canyon Creek, which drains the Chino Hills and is tributary to Chino Creek, consistently had low bacterial indicator concentrations and detections of human, bovine or domestic canine *Bacteroidales* markers. The watershed is dominated by residential land use (see Tables 3-4 and 3-5). The site with the most similar land use, Sunnyslope Channel, was compared with the Carbon Canyon site to determine if bacterial indicator concentrations were similar or significantly different.

Table 5-32 summarizes the results of a parametric Student t-test that compared the geometric mean fecal coliform and *E. coli* concentrations between sites.

Table 5-32. Results of a parametric Student t test comparing the natural log transformed fecal coliform and *E. coli* geometric mean concentrations at Carbon Canyon Creek and Sunnyslope Channel using all samples, regardless of season or flow conditions

Sample Location	Statistic	N	Fecal coliform (cfu/100 mL)	*E. coli* (cfu/100 mL)
Carbon Canyon Creek	Geomean	20	197	122
Sunnyslope Channel	Geomean	20	541	170
		Test Statistic	2.102	0.675
		p-value	0.021	0.252

The statistical test was not significant for *E. coli* (p = 0.252), indicating similar bacteria concentrations. In contrast, the fecal coliform concentration was significantly higher at the Sunnyslope Channel site (p = 0.021).

As noted earlier, bacterial concentrations appeared to be significantly lower in Carbon Canyon Creek when compared to other locations throughout the watershed. However, when data from Carbon Canyon Creek is compared only to data from a watershed with relatively similar land use patterns (e.g. Sunnyslope Channel) the results are not so clear. Fecal coliform concentrations are significantly lower in Carbon Canyon Creek but *E. coli* concentrations are not. This is a puzzling result given that, in general, fecal coliform and *E. coli* correlate very closely with one another (see discussion in section 5.10). Therefore, further investigation is recommended for Carbon Canyon Creek in the next phase of the source identification study.

5.12.2 Does the relative proportion of land use types in a given watershed correlate with bacterial indicator concentrations?

Tables 3.4 and 3.5 summarized the land use (total acres and percent of total acreage) for each WW and USEP watershed. Land use acreage was calculated using two different methods:

- The entire watershed was included regardless of the limited potential for portions of the watershed to contribute to dry weather flows (e.g., because of the presence of a dam, diversion or recharge basin); and
- Only the portion of the watershed that was most likely to contribute dry weather flows was included in the land acreage calculations.

Table 5-33 summarizes the correlation analysis (non-parametric Spearman's rho correlation coefficient) results for the comparison between land use acreage or percent total land use to natural log transformed fecal coliform concentrations. When the analysis was conducted on the acreage calculated for the entire watershed significant positive correlations between land use and fecal coliform concentrations were observed for:

- Commercial/industrial land use (total acres and percent of total acreage); and
- Residential land use (percent of total acreage).

When only the portion of the watershed where dry weather flow contributions are likely to occur was considered, significant positive and negative correlations were observed for the following:

Table 5-33. Correlation analysis results for comparisons between natural log fecal coliform concentrations and land use in each subwatershed based on two measures: (1) relative acreage and (2) percent of total acreage. Analysis completed for two methods for calculating watershed area: (1) entire watershed without regard for elevation and potential to contribute dry weather flows, or (2) portion of watershed which is most likely to contribute dry weather flows.

Area	Measure	Land Use Type	Spearman Rho (ρ)	Degrees of Freedom (n - 2)	t-statistic	p-value	Significant?[1]
Entire Watershed	Relative Acreage	Agricultural	-0.07	382	1.35	0.178	No
		Commercial/Industrial	0.10	382	2.00	0.046	Yes (+)
		Natural/Vacant	0.05	382	0.88	0.379	No
		Residential	0.06	382	1.12	0.263	No
	Percent of Total Acreage	Agricultural	-0.08	382	1.59	0.113	No
		Commercial/Industrial	0.23	382	4.58	< 0.001	Yes (+)
		Natural/Vacant	0.02	382	0.41	0.682	No
		Residential	0.11	382	2.08	0.038	Yes (+)
Portion of Watershed Likely Contributing Dry Weather Flow	Relative Acreage	Agricultural	-0.11	378	2.11	0.036	Yes (-)
		Commercial/Industrial	0.07	378	1.42	0.156	No
		Natural/Vacant	0.03	378	0.62	0.536	No
		Residential	0.03	378	0.53	0.596	No
	Percent of Total Acreage	Agricultural	-0.13	378	2.45	0.015	Yes (-)
		Commercial/Industrial	0.25	378	5.04	< 0.001	Yes (+)
		Natural/Vacant	-0.06	378	1.21	0.227	No
		Residential	0.17	378	3.27	0.001	Yes (+)

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation

- Agricultural land use was negatively correlated (total acres and percent of total acreage);
- Commercial/industrial land use was positively correlated (percent of total acreage); and
- Residential land use was positively correlated (percent of total acreage).

Table 5-34 summarizes the findings from the correlation analysis (non-parametric Spearman's rho correlation coefficient) for the comparison between land use acreage or percent total land use to natural log transformed *E. coli* concentrations. When the analysis was conducted on the acreage calculated for the entire watershed significant positive correlations between land use and fecal coliform concentrations were observed for:

- Commercial/industrial land use (percent of total acreage).

When only the portion of the watershed where dry weather flow contributions are likely to occur was considered, significant positive and negative correlations were observed for the following:

- Natural/vacant land use was negatively correlated (percent of total acreage);

- Commercial/industrial land use was positively correlated (percent of total acreage); and
- Residential land use was positively correlated (percent of total acreage).

These data confirm that urbanization tends to increase bacterial indicator concentrations in stormwater runoff compared to that measured in natural/vacant land or agricultural lands. Such a conclusion is consistent with a number of similar studies throughout the United States. However, these data also suggest that knowing the relative proportion of each land use type provides very little predictive power. Only about 10% of the variation in *E. coli* concentrations can be attributed to changes in land use within a particular watershed. On the other hand, if some of the variation can be explained by changes in air temperature, and some by changes in stream flow, and some by changes in land use, it may be possible to construct a multivariate model that, collectively, is able to predict much of the overall variation in bacteria concentrations. However, prior to doing this the source of runoff, which varies from one subwatershed to another, will need to be better understood. For example, the USEP sites may receive well blow off, treated wastewater effluent, irrigation wastewater, or any of a number of other unique discharge sources or process waters that affect land use correlation analyses. Characterizing these inputs is necessary prior to further analysis, but doing so should be a high priority in the next phase of urban source evaluation study efforts.

Table 5-34. Correlation analysis results for comparisons between natural log *E. coli* concentrations and land use in each subwatershed based on two measures: (1) relative acreage and (2) percent of total acreage. Analysis completed for two methods for calculating watershed area: (1) entire watershed without regard for elevation and potential to contribute dry weather flows, or (2) portion of watershed which is most likely to contribute dry weather flows.

Area	Measure	Land Use Type	Spearman Rho (ρ)	Degrees of Freedom (n - 2)	t-statistic	p-value	Significant?[1]
Entire Watershed	Relative Acreage	Agricultural	-0.04	382	0.82	0.413	No
		Commercial/Industrial	0.08	382	1.55	0.122	No
		Natural/Vacant	-0.01	382	0.18	0.857	No
		Residential	0.01	382	0.18	0.857	No
	Percent of Total Acreage	Agricultural	-0.01	382	0.18	0.857	No
		Commercial/Industrial	0.24	382	4.81	< 0.001	Yes (+)
		Natural/Vacant	-0.04	382	0.72	0.472	No
		Residential	0.05	382	1.06	0.290	No
Portion of Watershed Likely Contributing Dry Weather Flow	Relative Acreage	Agricultural	-0.08	378	1.54	0.124	No
		Commercial/Industrial	0.05	378	0.97	0.333	No
		Natural/Vacant	-0.01	378	0.27	0.787	No
		Residential	-0.02	378	0.43	0.667	No
	Percent of Total Acreage	Agricultural	-0.04	378	0.86	0.390	No
		Commercial/Industrial	0.27	378	5.34	< 0.001	Yes (+)
		Natural/Vacant	-0.13	378	2.47	0.014	Yes (-)
		Residential	0.13	378	2.51	0.013	Yes (+)

[1] – Significance determined by p value < 0.05; (-) = negative correlation; (+) = positive correlation

5.12.3 Is there a correlation between any of the field parameters and the measured bacterial indicator concentrations?

Table 5-35 provides the results of correlation analyses between fecal coliform and *E. coli* concentrations and field parameters measured during each sample event. Bacterial indicator data were natural log-transformed; the field measurement data were assumed to be normally distributed.

Table 5-35 shows that dissolved oxygen, pH and suspended solids concentrations were all positively correlated with fecal coliform concentrations. For *E. coli*, the suspended solids concentration was the only field parameter correlated (positive) with *E. coli* concentrations.

Although statistically-significant, the correlation between TSS and bacterial concentrations provides very poor predictive power (<10%). Therefore, TSS will not serve as a useful surrogate for *E. coli* or fecal coliform in any follow-on investigations. However, the data do suggest that BMPs designed to reduce TSS may provide a small improvement in water quality by reducing bacterial concentrations at the margin. At this stage, it is still difficult to separate the relative effects of increased flow from increased turbidity when the latter is so closely correlated with the former.

Table 5-35. Correlation analysis results for comparisons between bacterial indicator concentrations and measured field parameters.

Data Subset/Comparison	Pearson's r coefficient	Degrees of freedom (n - 2)	Student-t statistic	p-value
Natural Log Fecal Coliform vs.				
Dissolved Oxygen	0.13	383	2.62	0.009
pH	0.13	383	2.67	0.008
Suspended Solids	0.20	380	3.98	< 0.001
Temperature	0.01	382	0.23	0.818
Turbidity	0.12	382	2.35	0.019
Natural Log *E. coli* vs.				
Dissolved Oxygen	0.03	383	0.56	0.576
pH	0.06	383	1.16	0.247
Suspended Solids	0.14	380	2.75	0.006
Temperature	0.02	382	0.47	0.639
Turbidity	0.03	382	0.63	0.529

5.12.4 Is the wet weather data sufficient to determine the time needed, after a storm event, for bacteria concentrations to return to ambient background levels for dry weather conditions during the same season?

A wet weather event was sampled December 7-11, 2007. The first sample was collected on the first day of the wet weather event. The second sample was collected 48 hours later. Third and fourth samples were collected at 72 and 96 hours after the first sample, respectively.

Several of the USEP and WW sites have flow gauges located near the sample location. As a result, the sample results obtained during the wet weather sampling event can be overlaid on the storm hydrograph. Figures 5-33 and 5-34 show the results for two WW sites (SAR MWD Crossing and Chino Creek at Central Avenue). Figures 5-35 to 5-37 show the results for three USEP sites (San Antonio Channel, Cucamonga Creek, and Temescal Creek). Based on these results, bacterial indicator concentrations appeared to return to ambient background levels as follows:

- SAR MWD Crossing – between 48 and 72 hours.
- Chino Creek – by 72 hours.
- San Antonio Channel – by 48 hours.
- Cucamonga Creek – between 48 and 72 hours.
- Temescal Creek - between 48 and 72 hours.

These data may be useful to demonstrate the practical effect of adopting a "high flow suspension" in the Santa Ana River Basin Plan. Previous analyses developed for the SWQSTF show that stream flows routinely return to normal baseline dry-weather levels approximately 24 hours after a rain event ends. And, these new data confirm that bacterial concentrations also return to pre-storm levels approximately 48-72 hours after it stops raining. Since *E. coli* and fecal coliform data were not collected at the 24 hours after the storm, it is not possible to discern just how closely bacterial concentrations are associated with changes in runoff. But, the data do suggest that the 24-hour termination rule presently being considered by the SWQSTF for the temporary high flow suspension, the period of time when flow conditions are unsafe for recreation, may provide significant public health protection from the most extreme water quality impairments.

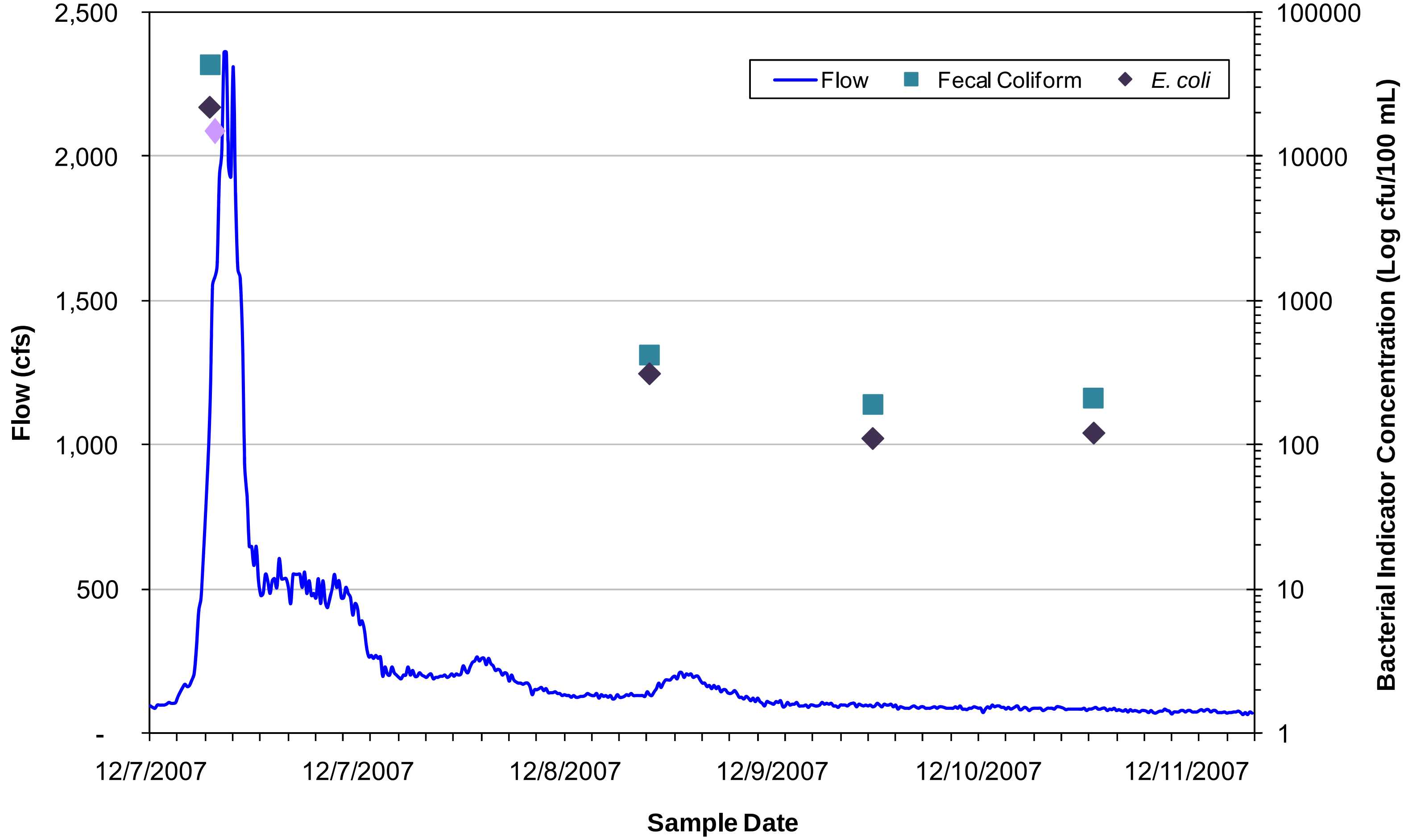


Figure 5-33. Bacterial indicator concentrations over four-day period during and following wet weather runoff event (December 7, 2007) at the Santa Ana River MWD Crossing sample location (WW-S1).

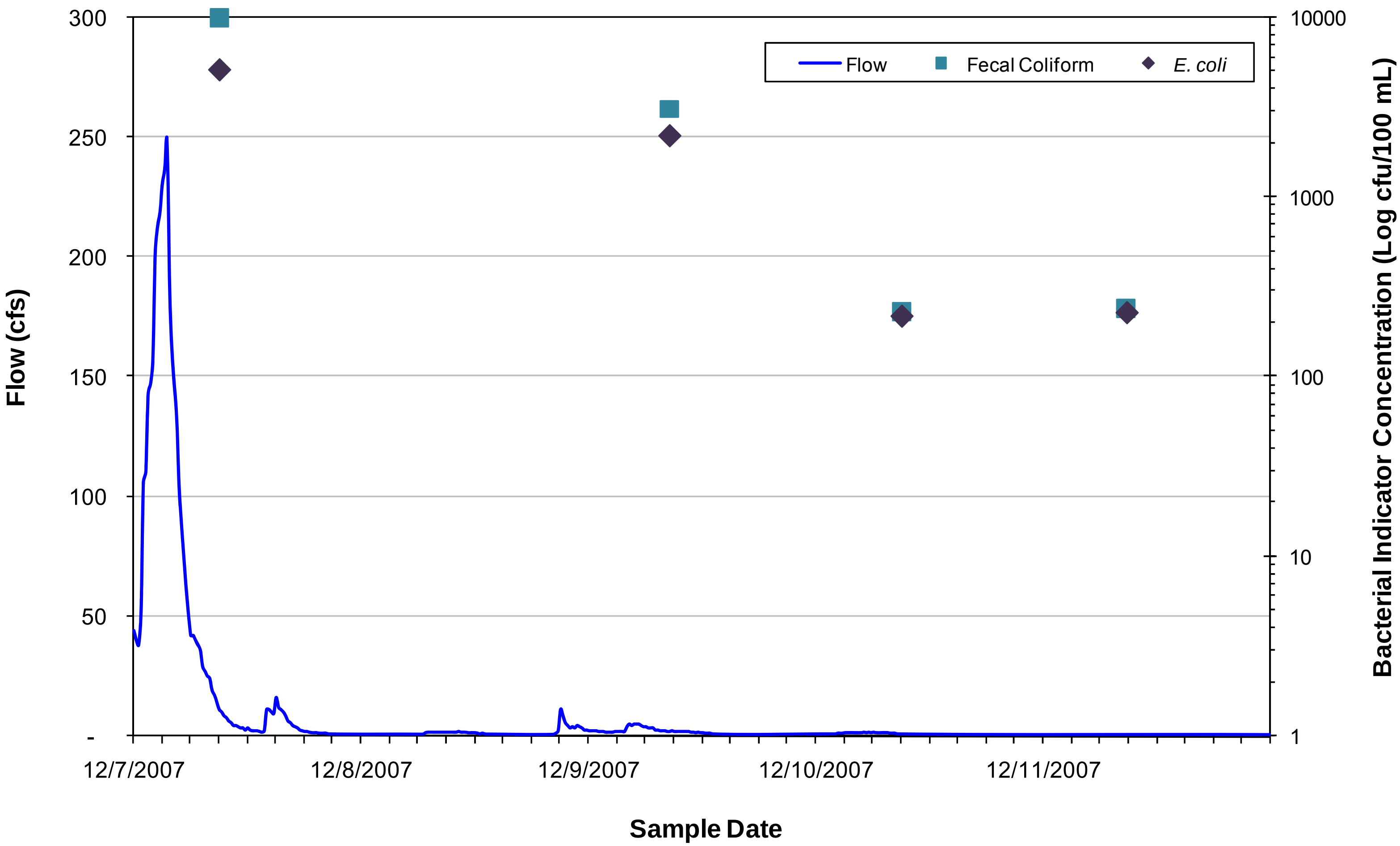


Figure 5-34. Bacterial indicator concentrations over four-day period during and following wet weather runoff event (December 7, 2007) at the Chino Creek at Central Avenue sample location (WW-C7).

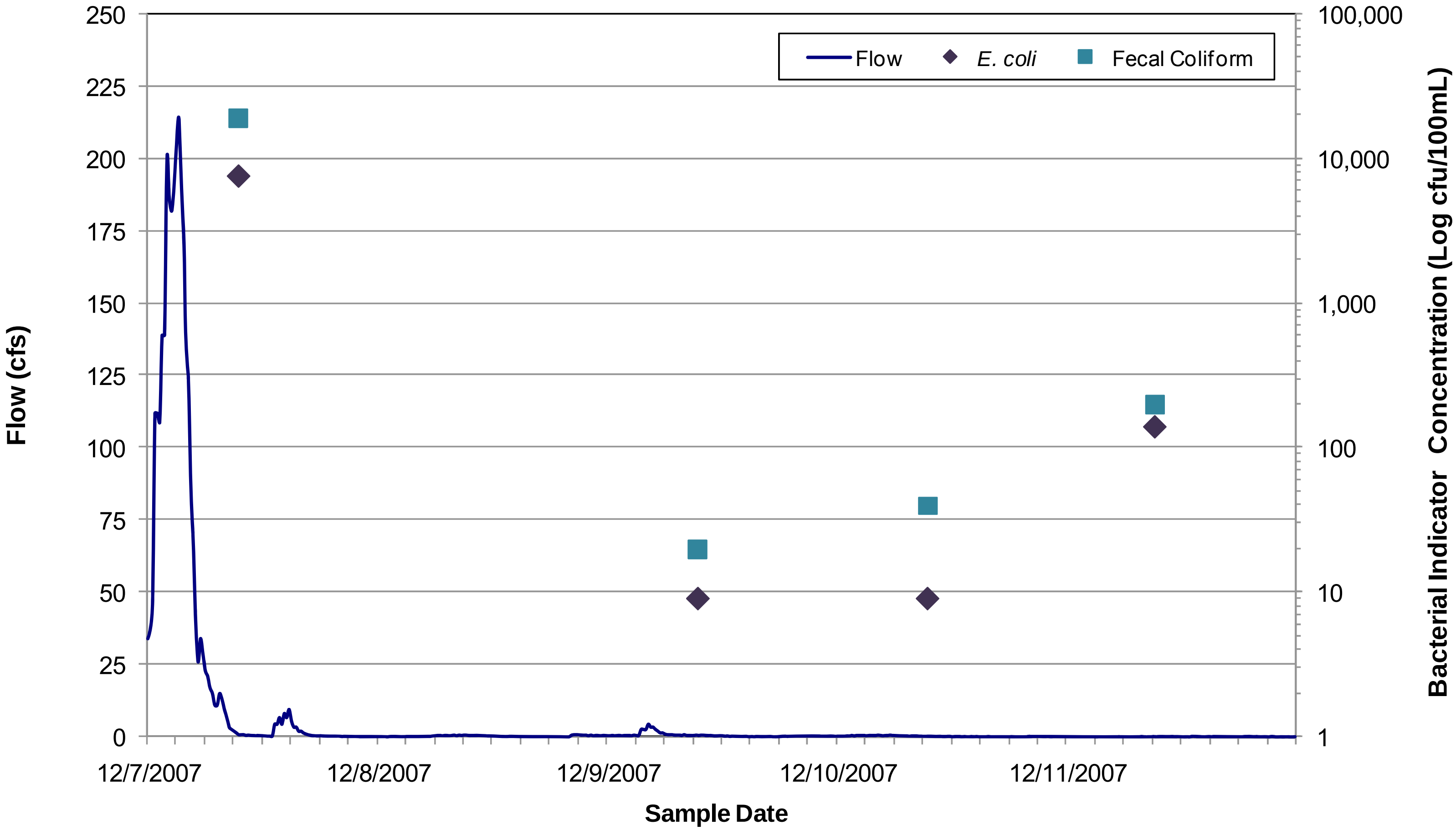


Figure 5-35. Bacterial indicator concentrations over four-day period during and following wet weather runoff event (December 7, 2007) at the San Antonio Channel sample location (US-SACH).

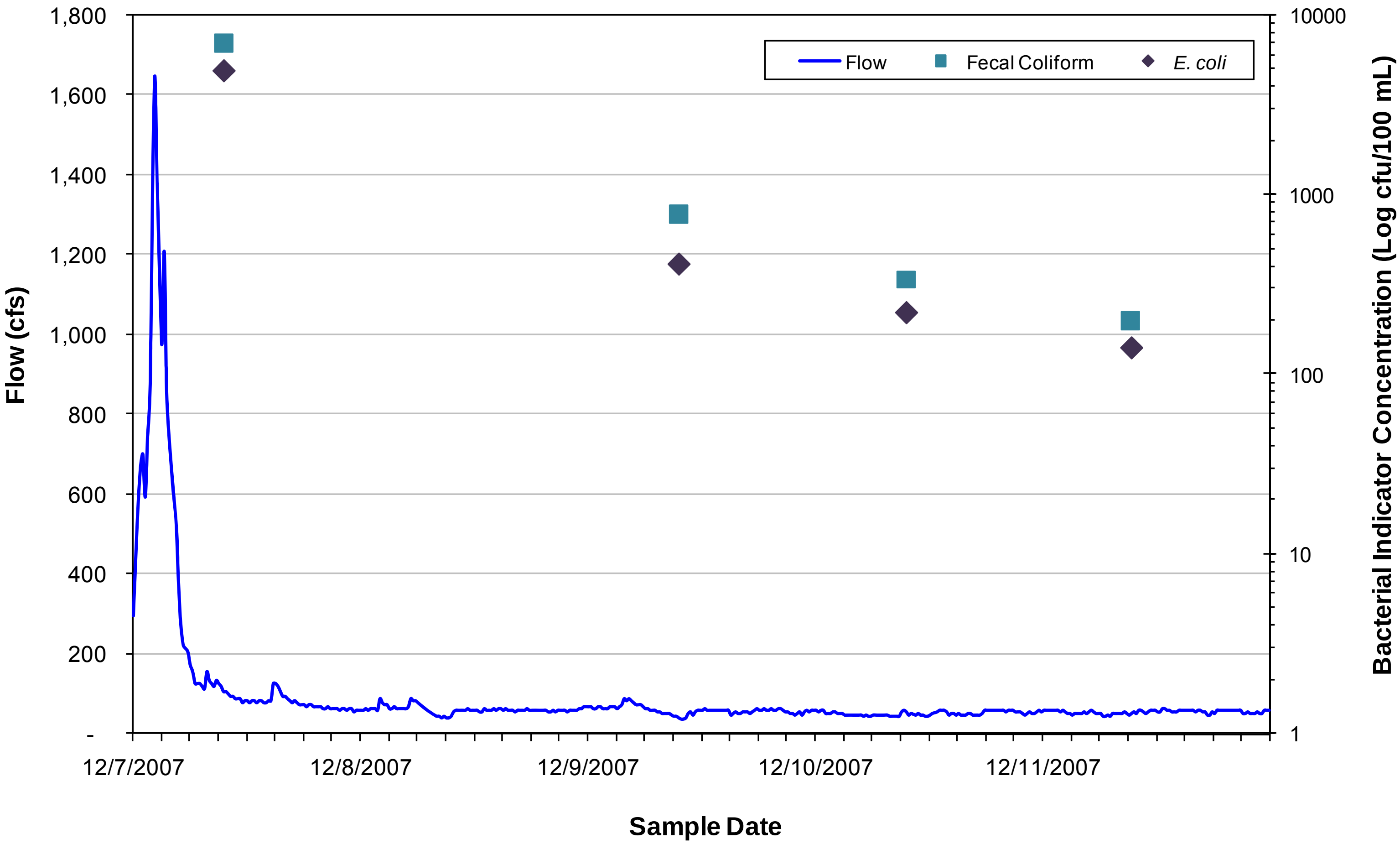


Figure 5-36. Bacterial indicator concentrations over four-day period during and following wet weather runoff event (December 7, 2007) at the Cucamonga Channel sample location (US-CUC).

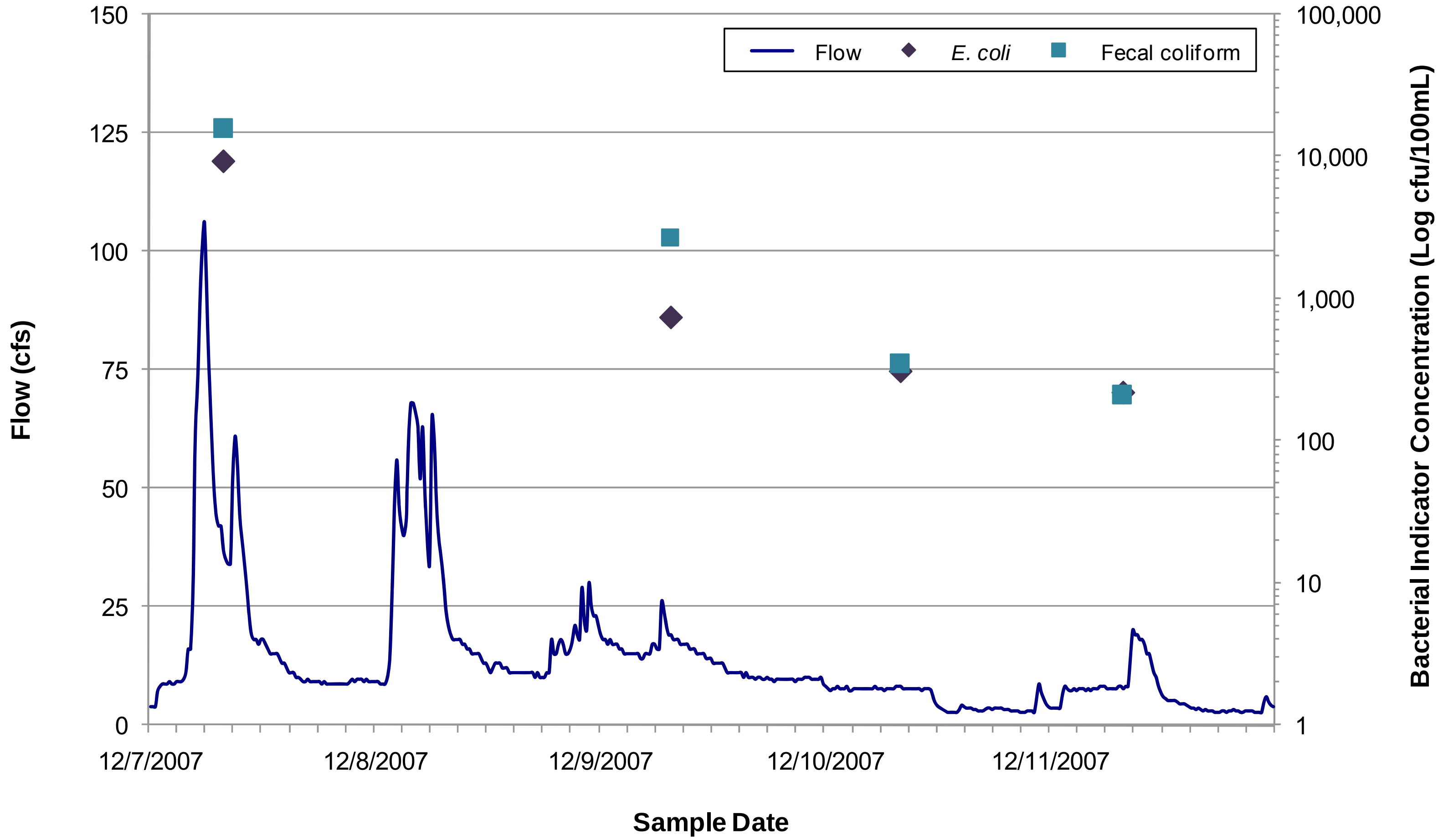


Figure 5-37. Bacterial indicator concentrations over four-day period during and following wet weather runoff event (December 7, 2007) at the Temescal Creek sample location (US-TEM).

Section 6
References

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Appendix A
Water Quality Summary

Table A-1. Summary of fecal coliform data (cfu/100 mL) for USEP and WW sites, 2007-2008

Sample Location	Warm Season - Dry				Cool Season - Dry				Wet Weather				
	N	Min	Max	Median	N	Min	Max	Median	N	12/7/07	12/9/07	12/19/07	1/29/08
US-ANZA	10	110	58,000	1,070	8	120	5,100	300	2	19,000	2,200		
US-BXSP	10	4,700	146,000	16,400	8	190	4,800	555	2	8,000	2,300		
US-CCCH	10	90	1,400	130	9	9	930	150	1	11,000			
US-CHRIS	10	350	26,000	3,500	8	350	6,700	860	2	11,000			4,200
US-CLCH	5	9	11,900	5,600	2	280	560	420					
US-CUC	10	9	14,000	1,100	9	60	22,000	220	1	7,000			
US-CYP	10	2,000	125,000	7,050	2	1,000	1,000	1,000	2	20,000	4,900		
US-DAY	7	190	8,200	2,600	6	160	4,400	335	2	3,100	320		
US-SACH	9	140	16,000	8,000	9	20	9,000	440	1	19,000			
US-SAR	2	3,900	24,000	13,950	3	190	4,400	210	2	590	55,000		
US-SNCH	10	150	31,000	280	9	100	5,200	260	1	9,000			
US-SSCH	8	40	8,000	2,450	6	9	7,900	590	2	31,000	5,600		
US-TEM	9	1,800	10,200	4,600	9	70	2,700	210	1	16,000			
WW-C1	4	9	9	9									
WW-C3	20	9	820	95	13	50	520	130	1	90			
WW-C7	20	200	6,000	1,300	13	70	4,100	230	1	10,000			
WW-M5	20	480	9,000	2,250	12	70	7,700	200	2	22,000		730	
WW-S1	20	110	4,900	405	12	40	2,200	120	2	43,000	420		
WW-S4	20	40	18,000	530	11	9	520	90	3	9,000	2,000	2,600	

Table A-2. Summary of *E. coli* data (cfu/100 mL) for USEP and WW sites, 2007-2008

Sample Location	Warm Season - Dry				Cool Season - Dry				Wet Weather				
	N	Min	Max	Median	N	Min	Max	Median	N	12/7/07	12/9/07	12/19/07	1/29/08
US-ANZA	10	110	6,500	450	8	70	5,400	170	2	6,900	720		
US-BXSP	10	160	108,000	2,800	8	90	5,100	785	2	2,700	930		
US-CCCH	10	9	280	100	9	40	860	150	1	6,900			
US-CHRIS	10	140	4,600	1,205	8	480	4,600	1,550	2	6,500			2,200
US-CLCH	5	9	8,500	3,700	2	170	410	290					
US-CUC	10	9	8,700	265	9	40	3,400	160	1	4,900			
US-CYP	10	910	67,000	2,700	2	1,000	2,000	1,500	2	8,300	5,200		
US-DAY	7	110	9,800	470	6	130	3,800	290	2	480	240		
US-SACH	9	40	2,000	610	9	9	6,500	380	1	7,700			
US-SAR	2	1,250	6,800	4,025	3	80	4,600	220	2	250	5,800		
US-SNCH	10	70	1,040	155	9	9	6,100	80	1	2,600			
US-SSCH	8	40	2,200	410	6	9	7,600	380	2	19,000	3,700		
US-TEM	9	200	2,200	710	9	70	740	220	1	9,200			
WW-C1	4	9	9	9									
WW-C3	20	9	990	75	13	60	470	120	1	140			
WW-C7	20	210	2,700	585	13	50	2,200	220	1	5,100			
WW-M5	20	500	5,700	845	12	50	5,200	175	2	5,000		1,500	
WW-S1	20	30	960	210	12	30	3,800	115	2	22,000	310		
WW-S4	20	40	2,800	160	11	30	490	80	3	7,200	780	4,600	

Table A-3. Summary of dissolved oxygen data (mg/L) for USEP and WW sites, 2007-2008

Sample Location	Warm Season - Dry				Cool Season - Dry				Wet Weather				
	N	Min	Max	Median	N	Min	Max	Median	N	12/7/07	12/9/07	12/19/07	1/29/08
US-ANZA	10	6.64	11.55	9.98	8	9.33	11.80	10.82	2	12.41	10.47		
US-BXSP	10	7.58	11.36	9.77	8	10.31	13.13	11.90	2	11.02	11.67		
US-CCCH	10	7.10	11.89	9.06	9	10.33	13.67	11.74	1	11.13			
US-CHRIS	10	6.71	11.02	8.94	8	9.87	14.61	12.61	2	10.72			12.54
US-CLCH	5	5.74	7.97	6.59	2	11.58	11.92	11.75					
US-CUC	10	6.56	10.71	7.66	9	10.01	12.37	11.26	1	10.91			
US-CYP	10	7.63	13.11	9.71	2	11.80	12.12	11.96	2	11.45	14.01		
US-DAY	7	6.30	11.98	10.80	6	9.80	13.23	12.49	2	10.79	10.54		
US-SACH	9	7.03	11.32	8.67	9	10.30	15.13	13.01	1	11.18			
US-SAR	2	8.34	9.56	8.95	3	10.16	11.88	11.11	2	11.57	11.94		
US-SNCH	10	7.29	11.55	10.04	9	9.35	11.60	9.65	1	11.20			
US-SSCH	8	7.21	11.70	10.43	6	11.58	14.33	12.61	2	12.23	12.41		
US-TEM	9	7.57	11.93	9.10	9	10.61	13.45	11.21	1	11.10			
WW-C1	4	9.25	9.90	9.72									
WW-C3	20	6.78	13.80	9.08	13	6.76	12.32	9.50	1	7.76			
WW-C7	20	8.57	12.01	9.51	13	9.90	11.82	10.63	1	10.29			
WW-M5	20	5.61	15.10	11.86	12	8.28	17.93	10.83	2	9.43		11.17	
WW-S1	20	7.80	9.57	8.38	12	7.55	11.20	9.27	2	8.10	7.48		
WW-S4	20	7.32	9.22	8.30	11	9.10	11.26	9.58	3	8.94	8.88	9.14	

Table A-4. Summary of pH data (standard units) for USEP and WW sites, 2007-2008

Sample Location	Warm Season - Dry				Cool Season - Dry				Wet Weather				
	N	Min	Max	Median	N	Min	Max	Median	N	12/7/07	12/9/07	12/19/07	1/29/08
US-ANZA	10	8.22	8.75	8.52	8	7.45	8.05	7.94	2	6.85	7.14		
US-BXSP	10	8.61	9.33	9.06	8	8.04	8.91	8.42	2	8.25	8.28		
US-CCCH	10	5.54	8.66	8.35	9	7.54	9.62	8.16	1	8.51			
US-CHRIS	10	8.96	10.84	10.15	8	6.98	9.04	8.74	2	7.91			8.14
US-CLCH	5	9.45	10.35	9.90	2	7.22	9.50	8.36					
US-CUC	10	7.67	11.55	10.76	9	7.57	10.22	8.73	1	7.89			
US-CYP	10	8.37	8.92	8.61	2	8.62	8.97	8.80	2	8.24	8.36		
US-DAY	7	8.60	9.81	8.67	6	8.12	8.78	8.53	2	7.12	7.53		
US-SACH	9	9.42	11.01	10.21	9	7.20	9.51	9.18	1	9.03			
US-SAR	2	9.11	9.39	9.25	3	8.18	8.94	8.21	2	8.33	8.28		
US-SNCH	10	8.06	9.06	8.48	9	7.01	8.36	8.09	1	7.15			
US-SSCH	8	8.56	9.41	8.99	6	7.90	8.71	8.45	2	6.90	6.67		
US-TEM	9	8.54	8.93	8.81	9	7.79	9.43	8.51	1	7.84			
WW-C1	4	6.1	7.7	6.8									
WW-C3	20	7.0	9.3	8.5	13	6.5	7.6	6.9	1	6.7			
WW-C7	20	7.2	8.3	7.8	13	6.5	7.7	7.2	1	6.7			
WW-M5	20	7.3	8.7	8.0	12	6.6	8.4	7.5	2	6.8		7.3	
WW-S1	20	6.9	8.2	7.6	12	6.4	7.7	7.3	2	6.9	6.6		
WW-S4	20	7.1	8.3	7.7	11	6.8	7.7	7.4	3	6.9	7.2	7.2	

Table A-5. Summary of Total Suspended Solids data (mg/L) for USEP and WW sites, 2007-2008

Sample Location	Warm Season - Dry				Cool Season - Dry				Wet Weather				
	N	Min	Max	Median	N	Min	Max	Median	N	12/7/07	12/9/07	12/19/07	1/29/08
US-ANZA	10	3.2	15.5	7.3	8	2.8	63.3	4.2	2	66.7	25.3		
US-BXSP	10	1.72	27.4	4.0	8	1.7	71	4.36	2	428	58		
US-CCCH	9	0.44	14.6	0.8	9	1.3	18.2	3	1	24			
US-CHRIS	10	3.0	84	8.8	8	9.6	151.7	33.8	2	18.7			48
US-CLCH	5	13.2	23	16.8	2	17	29	23					
US-CUC	10	4.0	20.8	11.1	9	2.25	149.7	9.3	1	137			
US-CYP	10	0.22	42	13.5	2	14.8	73.7	44.25	2	50.6	96		
US-DAY	7	0.20	11.4	1.8	6	5.1	75.5	8.6	2	10.6	6.4		
US-SACH	9	11.5	542	128	9	2.1	163.5	29.6	1	8.2			
US-SAR	2	650	1770	1210	3	160	508	205	2	1140	366		
US-SNCH	10	2.2	32.83	3.6	9	1.6	19.7	4.2	1	20			
US-SSCH	8	2.62	11	6.9	6	5	116.3	8.95	2	34	44.7		
US-TEM	7	8.3	19.4	10.8	9	2.4	36.6	13.2	1	50.4			
WW-C1	4	0.5	1.29	0.94									
WW-C3	19	8.4	90.1	19	13	7	653	15.3	1	25.6			
WW-C7	19	0	55.25	8.3	13	3	29.2	7.2	1	8.4			
WW-M5	18	4.5	25.8	10.8	12	5.2	111	10.05	2	101.6		19.6	
WW-S1	19	4.0	229.5	10.5	12	10.4	236	28.5	2	3108	92.3		
WW-S4	19	2.67	258.5	8.8	11	14.4	382	39.8	3	130.4	143.3	107	

Table A-6. Summary of turbidity data (nephalometric turbidity units) for USEP and WW sites, 2007-2008

Sample Location	Warm Season - Dry				Cool Season - Dry				Wet Weather				
	N	Min	Max	Median	N	Min	Max	Median	N	12/7/07	12/9/07	12/19/07	1/29/08
US-ANZA	10	3.17	6.03	4.46	8	2.57	33.2	4.08	2	52.5	30.5		
US-BXSP	10	0.7	34.8	2.14	8	2.72	83.3	3.90	2	306	151		
US-CCCH	10	0.03	3.93	0.63	9	0.07	6.21	2.34	1	8.56			
US-CHRIS	10	2.02	35.5	4.32	8	7.77	151	10.0	2	14.21			75.5
US-CLCH	5	3.13	10.84	3.90	2	35.7	110.3	73					
US-CUC	10	1.63	6.13	3.74	9	2.35	80.9	9.43	1	6.1			
US-CYP	10	7.29	23	10.76	2	15.3	26.1	20.7	2	10	12.24		
US-DAY	7	0.6	2.18	1.43	6	1.52	56.9	11.33	2	5.05	6.34		
US-SACH	9	9.21	95.5	26.30	9	10	62.4	28.0	1	12.29			
US-SAR	2	361	3242	1802	3	170	402	288	2	1394	352		
US-SNCH	10	0.24	10.9	0.54	9	0.67	22	2.22	1	25.6			
US-SSCH	8	1.43	6.48	3.67	6	5.25	64.5	12.59	2	19.4	34.3		
US-TEM	9	5.07	10.18	7.31	9	5.32	91.1	9.41	1	8.4			
WW-C1	4	0.51	0.82	0.67									
WW-C3	20	5.6	35.5	9.03	13	7.68	20.2	10.20	1	84.4			
WW-C7	20	2.02	12.8	3.80	13	2	147	3.51	1	14.5			
WW-M5	20	1.85	9.3	4.29	12	1.97	69.1	4.06	2	84.1		16.7	
WW-S1	20	2.6	330	3.91	12	5.96	919	14.80	1		82.4		
WW-S4	20	1.5	418	4.98	11	6.09	745	19.20	3	87.3	97.3	40.9	

Table A-7. Summary of water temperature data (celsius) for USEP and WW sites, 2007-2008

Sample Location	Warm Season - Dry				Cool Season - Dry				Wet Weather				
	N	Min	Max	Median	N	Min	Max	Median	N	12/7/07	12/9/07	12/19/07	1/29/08
US-ANZA	10	19.3	26.3	23.6	8	12.0	15.6	13.2	2	14.7	11.2		
US-BXSP	10	21.1	26.8	23.1	8	12.4	14.9	13.4	2	14.6	11.6		
US-CCCH	10	19.8	27.3	23.4	9	8.4	14.6	10.6	1	13.7			
US-CHRIS	10	20.0	33.3	26.7	8	9.3	16.5	13.3	2	14			12.4
US-CLCH	5	28.4	34.9	30.6	2	13.3	13.6	13.5					
US-CUC	10	21.3	34.4	29.6	9	12.1	18.8	12.8	1	13.9			
US-CYP	10	16.7	25.1	21.0	2	8.3	9.3	8.8	2	13.2	13.1		
US-DAY	7	18.4	33.0	19.6	6	6.7	13.9	11.6	2	15	12.4		
US-SACH	9	20.9	30.8	24.9	9	6.0	14.1	10.3	1	13.5			
US-SAR	2	28.2	30.3	29.3	3	14.4	15.7	15.3	2	14.2	11.5		
US-SNCH	10	20.1	26.2	22.6	9	13.9	16.8	15.2	1	16.5			
US-SSCH	8	20.0	29.7	21.4	6	8.9	13.4	10.1	2	14	8.9		
US-TEM	9	17.0	23.4	19.7	9	9.0	13.1	10.6	1	15			
WW-C1	4	8.4	10.4	9.4									
WW-C3	20	20.4	29.1	25.7	13	11.6	15.4	13.9	1	15.8			
WW-C7	20	21.0	29.4	24.1	13	12.3	20.2	16.8	1	16.5			
WW-M5	20	18.3	27.8	22.8	12	12.5	16.7	14.6	2	14.9		14.3	
WW-S1	20	0.0	27.0	20.1	11	8.1	16.3	12.5	2	15.9	14.4		
WW-S4	20	16.3	24.2	21.2	11	8.7	15.9	12.7	3	15.3	13.6	14.2	

Table A-8. *Bacteroidales* results from samples analyzed by University California, Davis

USEP Sample Location	Host-Specific Marker	Sample Date	Unit	Result	Method Detection Level
US-ANZA	Human	1/16/2008	gc/mL	385	47
US-BXSP	Dog	7/12/2007	gc/100mL	285	3
	Human	7/12/2007	gc/100mL	11,097	20
		7/18/2007	gc/100mL	91,783	93
		8/29/2007	gc/100mL	2,175	34
		9/5/2007	gc/100mL	6,221	10
		9/12/2007	gc/100mL	2,245	31
		12/11/2007	gc/mL	1,030	22
		1/16/2008	gc/mL	877,000	343
		2/13/2008	gc/mL	62,700	125
US-CCCH	Dog	1/29/2008	gc/mL	2	3
US-CHRIS	Bovine	7/12/2007	gc/100mL	20,015	50
		9/4/2007	gc/100mL	1,680	95
	Dog	7/12/2007	gc/100mL	472	8
		7/19/2007	gc/100mL	4,578	26,112
		9/11/2007	gc/100mL	15	2
		12/10/2007	gc/mL	6	2
		1/15/2008	gc/mL	1,750	41
		1/29/2008	gc/mL	13	4
		2/12/2008	gc/mL	11	3
	Human	7/12/2007	gc/100mL	3,369	47
		1/15/2008	gc/mL	141,000	256
		1/29/2008	gc/mL	265	24
US-CLCH	Bovine	7/11/2007	gc/100mL	188	27
	Dog	7/11/2007	gc/100mL	1,210	4
US-CUC	Dog	7/11/2007	gc/100mL	425	14
		12/10/2007	gc/mL	8	8
		1/29/2008	gc/mL	9	4
		2/12/2008	gc/mL	13	4
US-CUC	Human	7/11/2007	gc/100mL	3,902	86
US-CYP	Bovine	7/17/2007	gc/100mL	752	12
		1/29/2008	gc/mL	622	43
	Dog	8/28/2007	gc/100mL	12	4
		1/29/2008	gc/mL	191	6
	Human	1/29/2008	gc/mL	179	40
US-DAY	Dog	1/30/2008	gc/mL	34	4
	Human	1/30/2008	gc/mL	183	25

Table A-8. *Bacteroidales* results from samples analyzed by University California, Davis

USEP Sample Location	Host-Specific Marker	Sample Date	Unit	Result	Method Detection Level
US-SACH	Dog	12/11/2007	gc/mL	45	5
		1/15/2008	gc/mL	29	2
		1/29/2008	gc/mL	20	2
		2/12/2008	gc/mL	52	3
	Human	12/10/2007	gc/mL	359	2
		12/11/2007	gc/mL	1,640	31
		1/29/2008	gc/mL	400	11
US-SAR	Dog	9/12/2007	gc/100mL	37	10
	Human	1/30/2008	gc/mL	974	8
US-SNCH	Bovine	7/12/2007	gc/100mL	2,096	26
	Dog	7/12/2007	gc/100mL	514	4
	Human	7/12/2007	gc/100mL	1,442	24
		8/29/2007	gc/100mL	6	6
		1/30/2008	gc/mL	149	6
US-SSCH	Dog	8/29/2007	gc/100mL	12	1
		1/30/2008	gc/mL	22	4
US-SSCH	Human	7/12/2007	gc/100mL	689	33
		1/16/2008	gc/mL	323	4
US-TEM	Bovine	7/17/2007	gc/100mL	786	9
	Dog	1/29/2008	gc/mL	2	2

Table A-9. *Bacteroidales* results from samples analyzed by Orange County Water District

USEP Sample Location	Host-Specific Marker	Sample Date	Unit	Result	Qualifier
US-ANZA	Bovine	7/25/2007	cells/mL	1,000	=
		8/1/2007	cells/mL	100	=
		8/8/2007	cells/mL	1,000	=
		9/19/2007	cells/mL	1,000	=
		9/26/2007	cells/mL	10	>
		12/7/2007	cells/mL	10	>
		12/9/2007	cells/mL	10	>
		1/23/2008	cells/mL	1,000	=
		2/6/2008	cells/mL	100	=
		2/20/2008	cells/mL	100	=
	Dog	1/23/2008	cells/mL	1,000	=
		2/6/2008	cells/mL	1,000	=
		2/20/2008	cells/mL	1,000	=
US-BXSP	Bovine	7/25/2007	cells/mL	10	>
		8/8/2007	cells/mL	10	>
		1/23/2008	cells/mL	10	>
		2/20/2008	cells/mL	10	>
	Dog	7/25/2007	cells/mL	10	>
		1/23/2008	cells/mL	100	=
		2/20/2008	cells/mL	100	=
	Human	7/25/2007	cells/mL	27,000	=
		8/1/2007	cells/mL	1,000	=
		8/8/2007	cells/mL	20,000	=
		9/19/2007	cells/mL	27,000	=
		9/26/2007	cells/mL	27,000	=
		12/7/2007	cells/mL	20,000	=
		12/9/2007	cells/mL	20,000	=
		1/23/2008	cells/mL	1,000	=
		2/6/2008	cells/mL	20,000	=
		2/20/2008	cells/mL	20,000	=
US-CCCH	Dog	7/31/2007	cells/mL	100	=
		9/26/2007	cells/mL	1,000	=
		12/7/2007	cells/mL	1,000	=
		12/9/2007	cells/mL	10	>
		1/22/2008	cells/mL	10	>
		2/5/2008	cells/mL	1,000	=
		2/19/2008	cells/mL	100	=

Table A-9. *Bacteroidales* results from samples analyzed by Orange County Water District

USEP Sample Location	Host-Specific Marker	Sample Date	Unit	Result	Qualifier
US-CHRIS	Dog	7/24/2007	cells/mL	1,000	=
		7/31/2007	cells/mL	1,000	=
		8/7/2007	cells/mL	1,000	=
		9/18/2007	cells/mL	100	=
		9/25/2007	cells/mL	10	>
		12/7/2007	cells/mL	1,000	=
		12/9/2007	cells/mL	100	=
		1/22/2008	cells/mL	10	>
		2/19/2008	cells/mL	100	=
US-CHRIS	Human	1/22/2008	cells/mL	10	>
		2/5/2008	cells/mL	10	>
US-CLCH	Bovine	1/22/2008	cells/mL	100	=
	Dog	7/24/2007	cells/mL	1,000	=
		7/31/2007	cells/mL	1,000	=
		8/7/2007	cells/mL	1,000	=
		1/22/2008	cells/mL	100	=
US-CUC	Dog	1/22/2008	cells/mL	1,000	=
		2/5/2008	cells/mL	1,000	=
US-CYP	Bovine	7/24/2007	cells/mL	1,000	=
		7/31/2007	cells/mL	1,000	=
		8/7/2007	cells/mL	1,000	=
		9/18/2007	cells/mL	1,000	=
		9/25/2007	cells/mL	1,000	=
		12/7/2007	cells/mL	1,000	=
		12/9/2007	cells/mL	1,000	=
		1/22/2008	cells/mL	10	>
US-DAY	Dog	8/1/2007	cells/mL	1,000	=
		9/26/2007	cells/mL	1,000	=
		12/7/2007	cells/mL	10	>
		12/9/2007	cells/mL	10	>
		2/6/2008	cells/mL	10	>
		2/20/2008	cells/mL	10	>
US-SACH	Bovine	7/24/2007	cells/mL	100	=
		7/31/2007	cells/mL	100	=
		8/7/2007	cells/mL	100	=
		9/18/2007	cells/mL	1,000	=
		9/25/2007	cells/mL	100	=
		12/7/2007	cells/mL	1,000	=

Table A-9. *Bacteroidales* results from samples analyzed by Orange County Water District

USEP Sample Location	Host-Specific Marker	Sample Date	Unit	Result	Qualifier
US-SACH	Bovine	12/9/2007	cells/mL	100	=
		1/22/2008	cells/mL	1,000	=
		2/5/2008	cells/mL	10	>
		2/19/2008	cells/mL	100	=
	Dog	1/22/2008	cells/mL	10	>
		2/19/2008	cells/mL	10	>
US-SAR	Dog	12/7/2007	cells/mL	1,000	=
		12/9/2007	cells/mL	10	>
		2/6/2008	cells/mL	1,000	=
		2/20/2008	cells/mL	1,000	=
	Human	2/6/2008	cells/mL	20,000	=
		2/20/2008	cells/mL	20,000	=
US-SNCH	Bovine	8/1/2007	cells/mL	1,000	=
		1/23/2008	cells/mL	1,000	=
	Dog	1/23/2008	cells/mL	1,000	=
		2/6/2008	cells/mL	100	=
		2/20/2008	cells/mL	100	=
US-SSCH	Bovine	7/25/2007	cells/mL	100	=
		8/8/2007	cells/mL	1,000	=
		9/19/2007	cells/mL	1,000	=
	Dog	1/23/2008	cells/mL	1,000	=
		2/20/2008	cells/mL	100	=
US-TEM	Dog	1/22/2008	cells/mL	1,000	=
		2/5/2008	cells/mL	1,000	=
	Human	2/5/2008	cells/mL	1,000	=

Appendix B
Bacterial Indicator Data

Table B-1. Fecal coliform laboratory results, USEP sites, 2007-2008

Sample Week	Anza (US-ANZA)	Box Springs (US-BXSP)	Carbon Canyon (US-CCCH)	Chris Basin (US-CHRIS)	County Line Channel (US-CCLH)	Cucamonga Creek (US-CUC)	Cypress Channel (US-CYP)	Day Creek (US-DAY)	San Antonio Channel (US-SACH)	Santa Ana River @ La Cadena (US-SAR)	Sunnyslope Channel (US-SNCH)	San Sevaine Channel (US-SSCH)	Temescal Creek (US-TEM)
Dry Weather Sampling													
7/8/07	840	31,000	100	350	< 9	> 40	> 24,000	> 190	NS[2]	NS[1]	400	2,800	> 3,800
7/15/07	560	21,000	290	26,000	11,900	< 9	2,000	NS[1]	140	NS[1]	160	NS[1]	5,000
7/22/07	2,800	> 11,800	100	4,800	5,600	> 12,100	125,000	NS[1]	5,900	NS[1]	150	40	4,600
7/29/07	440	8,300	90	11,000	9,000	20	3,400	> 470	2,300	NS[1]	2,100	4,600	8,100
8/5/07	> 110	5,800	120	4,800	1,300	14,000	9,300	8,200	8,700	NS[1]	200	1,900	10,200
8/26/07	> 430	4,700	140	> 850	NS[1]	700	> 2,800	> 2,700	9,000	NS[1]	270	> 3,200	3,700
9/2/07	58,000	55,000	> 400	> 1,000	NS[1]	> 310	7,000	NS[1]	8,000	24,000	290	NS[1]	1,800,000[3]
9/9/07	3,800	146,000	> 160	> 2,200	NS[1]	1,500	> 7,100	2,600	16,000	3,900	430	> 300	> 1,800
9/16/07	1,300	34,000	90	760	NS[1]	6,200	2,700	> 1,000	> 4,000	NS[1]	270	2,100	3,600
9/23/07	6,500	5,100	1,400	5,700	NS[1]	5,600	7,900	6,300	13,000	NS[1]	31,000	> 8,000	9,400
1/13/08	310	850	120	2,400	NS[1]	60	NS[1]	290	580	NS[1]	190	240	140
1/20/08	140	960	930	6,700	560	5,300	1,000	NS[1]	9,000	NS[1]	220	< 9	300
1/27/0/	290	330	520	4,200	280	210	1,000	870	3,400	210	400	7,900	470
2/3/08	310	510	210	350	NS[1]	220	NS[1]	380	440	190	260	NS[1]	70
2/10/08	310	> 600	30	710	NS[1]	100	NS[1]	NS[1]	4,500	NS[1]	330	NS[1]	110
2/17/08	5,100	4,800	< 9	780	NS[1]	22,000	NS[1]	4,400	190	4,400	5,200	2,500	130
Wet Weather Sample event													
12/7/07	19,000	8,000	11,000	11,000	NS[2]	7,000	20,000	3,100	19,000	590	9,000	31,000	16,000
12/9/07	2,200	2,300	370	4,800	NS[2]	780	4,900	320	20	55,000	3,400	5,600	2,700
12/10/07	120	190	110	940	NS[2]	340	NS[1]	220	40	NS[1]	100	420	350
12/11/07	180	440	150	410	NS[2]	200	NS[1]	160	200	NS[1]	180	760	210

[1] – No sample, site dry
[2] – No sample, unable to access
[3] – Considered an outlier

Table B-2. *E. coli* laboratory results, USEP sites, 2007-2008

Sample Week	Anza (US-ANZA)	Box Springs (US-BXSP)	Carbon Canyon (US-CCCH)	Chris Basin (US-CHRIS)	County Line Channel (US-CCLH)	Cucamonga Creek (US-CUC)	Cypress Channel (US-CYP)	Day Creek (US-DAY)	San Antonio Channel (US-SACH)	Santa Ana River @ La Cadena (US-SAR)	Sunnyslope Channel (US-SNCH)	San Sevaine Channel (US-SSCH)	Temescal Creek (US-TEM)
Dry Weather Sampling													
7/8/07	770	> 720	9	190	< 9	< 9	> 2,900	> 110	NS[2]	NS[1]	70	800	> 1,000
7/15/07	380	1,000	150	> 4,600	> 3,700	< 9	2,500	NS[1]	> 80	NS[1]	70	NS[1]	690
7/22/07	> 880	> 6,000	> 280	2,400	7,400	> 350	67,000	NS[1]	40	NS[1]	140	40	> 710
7/29/07	280	160	50	2,000	8,500	< 9	1,100	> 200	610	NS[1]	1,040	> 2,200	> 290
8/5/07	110	2,900	9	4,000	> 1,160	8,700	4,500	9,800	> 920	NS[1]	170	560	> 200
8/26/07	340	580	9	400	NS[1]	180	> 910	440	> 300	NS[1]	200	460	> 720
9/2/07	6,500	4,400	170	> 140	NS[1]	9	1,600	NS[1]	> 830	6,500	140	NS[1]	410,000
9/9/07	> 520	108,000	> 90	> 410	NS[1]	> 350	> 3,400	> 710	> 1,200	> 1,250	160	70	> 500
9/16/07	540	> 2,700	> 110	300	NS[1]	2,400	> 1,580	470	> 320	NS[1]	150	360	> 920
9/23/07	170	> 3,400	> 280	2,100	NS[1]	> 900	3,900	> 670	2,000	NS[1]	> 520	240	> 2,200
1/13/08	200	840	110	2,900	NS[1]	100	NS[1]	280	1,150	NS[1]	30	420	150
1/20/08	140	990	860	4,500	410	2,900	2,000	NS[1]	6,500	NS[1]	80	< 9	270
1/27/0/	200	220	560	2,200	170	160	1,000	410	2,800	220	70	7,600	280
2/3/08	99	730	150	540	NS[1]	90	NS[1]	300	380	80	40	NS[1]	70
2/10/08	310	900	40	540	NS[1]	40	NS[1]	NS[1]	3,800	NS[1]	280	NS[1]	140
2/17/08	5,400	5,100	60	2,200	NS[1]	3,400	NS[1]	3,800	200	4,600	6,100	2,200	80
Wet Weather Sample event													
12/7/07	6,900	2,700	6,900	6,500	NS[2]	> 4,900	8,300	480	7,700	5,800	2,600	19,000	9,200
12/9/07	720	930	340	4,600	NS[2]	410	5,200	240	< 9	250	440	3,700	740
12/10/07	80	90	150	900	NS[2]	220	NS[1]	140	< 9	NS[1]	80	340	310
12/11/07	70	340	110	480	NS[2]	140	NS[1]	130	140	NS[1]	< 9	310	220

[1] – No sample, site dry
[2] – No sample, unable to access
[3] – Considered an outlier

Table B-3. Fecal coliform and *E. coli* laboratory results, WW sites, 2007-2008

Sample Week	Fecal coliform						*E. coli*					
	Icehouse Canyon (WW-C1)	Prado Park Lake (WW-C3)	Chino Creek (WW-C7)	Mill Creek (WW-M5)	Santa Ana River @ MWD Crossing (WW-S1)	Santa Ana River @ Pedley Avenue (WW-S4)	Icehouse Canyon (WW-C1)	Prado Park Lake (WW-C3)	Chino Creek (WW-C7)	Mill Creek (WW-M5)	Santa Ana River @ MWD Crossing (WW-S1)	Santa Ana River @ Pedley Avenue (WW-S4)
Dry Weather Sampling												
7/8/07	NS[1]	30	5,200	5,200	170	150	NS[1]	30	1,210	2,000	30	40
7/15/07	NS[1]	9	3,000	2,600	270	220	NS[1]	< 9	810	> 1,000	290	60
7/22/07	NS[1]	60	5,900	> 9,000	220	2,300	NS[1]	60	> 2,700	> 5,700	99	150
7/29/07	NS[1]	> 340	2,000	> 1,600	700	> 240	NS[1]	230	560	1,170	70	140
8/5/07	NS[1]	210	1,500	2,700	210	550	NS[1]	110	940	> 1,150	140	110
8/12/07	NS[1]	300	2,400	2,200	420	560	NS[1]	170	420	720	280	140
8/19/07	NS[1]	440	1,100	2,800	3,100	1,100	NS[1]	440	> 1,030	> 750	> 490	150
8/26/07	NS[1]	99	> 2,400	> 1,300	> 900	1,110	NS[1]	30	770	780	220	280
9/2/07	NS[1]	140	1,800	> 1,500	2,600	18,000	NS[1]	150	870	550	960	2,800
9/9/07	NS[1]	50	> 720	> 2,300	1,800	2,200	NS[1]	30	> 720	> 1,150	170	180
9/16/07	NS[1]	820	1,100	> 1,500	310	510	NS[1]	990	> 330	> 760	170	170
9/23/07	NS[1]	40	6,000	4,200	4,900	3,400	NS[1]	50	> 800	> 700	> 380	> 310
9/30/07	NS[1]	200	510	1,700	600	430	NS[1]	140	320	730	200	140
10/7/07	NS[1]	140	440	480	280	220	NS[1]	180	260	500	220	200
10/14/07	NS[1]	70	> 700	2,400	110	470	NS[1]	40	440	910	360	480
12/16/07	NS[1]	380	80	730	2,200	2,600	NS[1]	260	120	1,500	3,800	4,600
12/23/07	NS[1]	210	320	170	120	80	NS[1]	170	240	150	120	130
12/30/07	NS[1]	180	230	180	40	60	NS[1]	200	210	200	130	70
1/6/08	NS[1]	80	310	480	160	520	NS[1]	120	220	360	140	490
1/13/08	NS[1]	80	200	180	50	80	NS[1]	110	260	100	40	70
1/20/08	NS[1]	50	4,100	230	40	9	NS[1]	60	2,100	200	30	50
1/27/0/	NS[1]	520	210	340	180	390	NS[1]	470	260	360	190	260
2/3/08	NS[1]	280	70	160	120	90	NS[1]	250	110	50	40	30
2/10/08	NS[1]	130	130	70	40	40	NS[1]	90	50	110	40	80
2/17/08	NS[1]	60	150	7,700	60	140	NS[1]	80	150	5,200	40	80

Table B-3. Fecal coliform and *E. coli* laboratory results, WW sites, 2007-2008

Sample Week	Fecal coliform						*E. coli*					
	Icehouse Canyon (WW-C1)	Prado Park Lake (WW-C3)	Chino Creek (WW-C7)	Mill Creek (WW-M5)	Santa Ana River @ MWD Crossing (WW-S1)	Santa Ana River @ Pedley Avenue (WW-S4)	Icehouse Canyon (WW-C1)	Prado Park Lake (WW-C3)	Chino Creek (WW-C7)	Mill Creek (WW-M5)	Santa Ana River @ MWD Crossing (WW-S1)	Santa Ana River @ Pedley Avenue (WW-S4)
5/11/08	NS[1]	99	280	1,000	340	180	NS[1]	100	350	1,260	470	110
5/18/08	< 9	60	200	540	110	40	< 9	40	210	590	160	90
5/25/08	< 9	60	590	3,500	500	690	< 9	80	320	70	270	200
6/1/08	< 9	90	470	3,000	820	670	< 9	20	500	1,180	> 160	> 200
6/8/08	< 9	30	3,200	1,140	390	380	< 9	70	610	1,030	150	370
Wet Weather Sample Event												
12/7/07	NS[1]	260	10,000	22,000	43,000	9,000	NS[1]	160	5,100	> 5,000	22,000	7,200
12/9/07	NS[1]	130	3,100	790	420	2,000	NS[1]	90	2,200	520	310	780
12/10/07	NS[1]	90	230	200	190	190	NS[1]	120	200	130	110	120
12/11/07	NS[1]	99	240		210	190	NS[1]	90	230	120	120	170

[1] – No sample, site dry

Appendix C
Laboratory Comparability Study

Objectives

First year implementation of the Urban Source Evaluation Plan (USEP) for the Middle Santa Ana River Total Maximum Daily Load (TMDL) included the collection of water samples from 13 locations to evaluate urban sources of bacteria. Sample analysis for this USEP monitoring program included assays by two different laboratories: University of California at Davis (UCD) and the Orange County Water District (OCWD). Each laboratory uses its own microbial source tracking (MST) method for the extraction and analysis of human, bovine and dog *Bacteroidales/Bacteroides genetic* markers. The objective of this study was to evaluate the comparability of these laboratory methods for detecting and quantifying the presence of host-specific *Bacteroidales/Bacteroides* markers. This is of particular interest because of the potential differences that these methods may have in detection limits for target organisms. Method sensitivity is a common concern in the interpretation of laboratory results where substantively different methods are used, e.g., the most probable number (MPN) and membrane filtration (MF) methods for quantifying bacterial indicators in a water sample have differences in sensitivity.

Study Design

The laboratory comparability study used a single blind study design. A total of seven samples were analyzed by each laboratory: (1) 3 aqueous grab samples with no spike of *Bacteroidales*; (2) 3 aqueous grab samples spiked with various combinations of *Bacteroidales* markers (treatments); and (3) 1 aqueous blank sample. Aqueous grab samples were collected from three sites previously sampled under the USEP Monitoring Program. The actual sample locations, labeled A, B, and C, and the nature of the samples, e.g., spiked or not spiked, were unknown to the samplers. The general procedure for sampling at each site was as follows:

- *Aqueous Grab Sample, No Spike* – At least two liters of water were collected in a single container. After appropriate mixing, the collected water was split into two 1-liter bottles, labeled with a unique number, and submitted for *Bacteroidales* analysis. One bottle was submitted to UCD; the other to OCWD.

- *Aqueous Grab Sample, Spiked* – At least two liters of water was collected in a single container. The water in the holding container was spiked with one of the following treatments: (1) human fecal material; (2) bovine fecal material; or (3) mixture of human/bovine fecal material (methods for preparation of treatments and spiked samples are described below). After appropriate mixing, the collected/spiked water was split into two 1-liter bottles, labeled with a unique number, and submitted for *Bacteroidales* analysis. One bottle was submitted to UCD; the other to OCWD.

- *Sample Blank* - A blank sample with de-ionized water was prepared in a single container. This prepared sample was split into two 1-liter bottles, labeled with a unique number, and submitted for *Bacteroidales* analysis. One bottle was be submitted to UCD; the other to OCWD.

Fecal Solution Preparation

The fecal matter solutions needed for each treatment were prepared in the following manner (from Kildare et al. 2007):

Table C-1. Single blind study design schematic for collection/treatment of aqueous samples[1]

Location	Sample	Split	Laboratory	Treatment	Sample No.
A	1	A	UCD	None	UCD-K2B
		B	OCWD	None	OCWD-C3H
	2	A	UCD	Spiked w/ human fecal solution	UCD-P6S
		B	OWCD	Spiked w/ human fecal solution	OCWD-A7N
B	3	A	UCD	None	UCD-N7A
		B	OWCD	None	OCWD-B2O
	4	A	UCD	Spiked w/ bovine fecal solution	UCD-R4D
		B	OWCD	Spiked w/ bovine fecal solution	OCWD-D4R
C	5	A	UCD	None	UCD-Z5S
		B	OWCD	None	OCWD-S6P
	6	A	UCD	Spiked w/ human/bovine mixture	UCD-H3C
		B	OWCD	Spiked w/ human/bovine mixture	OCWD-D5A
Blank	7	A	UCD	None	UCD-L1B
		B	OWCD	None	OCWD-X1B

[1] All sample collection and handling methods were implemented as required by the Monitoring Plan and Quality Assurance Project Plan prepared for the Middle Santa Ana River TMDL BMP Implementation Project (SAWPA 2008a, b).

- *Human Fecal Solution*: One liter of screened primary influent was obtained from the Riverside Regional Water Quality Treatment Plant. The influent was collected in a clean glass bottle and stored in a dark refrigerator until preparation of the spiked aqueous grab sample.

- *Bovine Fecal Solution*: Fecal samples were collected from a dairy in the Chino, California area. A total of 10 samples were collected from individual cow ''pies''. A composite sample was prepared by placing roughly equal amounts of individual fecal samples into a clean Ziploc™ bag and thoroughly mixing them. Then 1.043 grams of the mixed material was diluted in 1-liter of de-ionized water and stored for less than 1 hour prior to being used to spike the aqueous grab samples.

Preparation of Spiked Samples (Treatments)

Spiked grab samples were prepared using site water collected from the selected sample locations:

- *Spiked with Human Source* - 30 mL of the human fecal solution was put into a clean sample bottle and then diluted to 1-liter total volume with water from the appropriate sample site (e.g., Location A, Sample 2 in Table C-1).

- *Spiked with Bovine Source* – 30 mL of the bovine fecal solution was put into a clean sample bottle and then diluted to 1-liter volume with water from the appropriate sample site (e.g., Location B, Sample 4 in Table C-1).

- *Spiked with a Human/Bovine Source* – 30 mL of the human fecal solution and 300 mL of the bovine fecal solution were put into a clean sample bottle. This mixture was diluted to 1-liter volume with water from the appropriate sample site (e.g., Location C, Sample 6 in Table C-1).

Laboratory Analysis and Reporting

Samples were collected on September 30, 2008, and delivered directly to OCWD and shipped overnight to UCD. To minimize differences in the time between sample collection/preparation and sample analysis, samples were analyzed at approximately the same time at each laboratory. Each laboratory submitted its results to CDM by providing the unique sample identification number (see Table C-1) coupled with its laboratory result.

Data Analysis

The results from each laboratory were tabulated and linked to the sample location and sample treatment information (see Table C-1). The three sample locations labeled A, B, and C were Box Springs Channel (US-BXSPR), Anza Drain (US-ANZA), and San Antonio Channel (US-SACH), respectively (see Table 3-3 and Figure 3-7 for location information).

Table C-2 summarizes the observed results. For comparison purposes, colors highlight similarities and differences between laboratories:

- Green – Laboratories obtained comparable results.

- Yellow – Minor differences between laboratories, where one laboratory detected the source, but had a very low detection of the source, while the other laboratory had no detection.

- Red – Substantive differences observed between laboratories, where one laboratory had a strong detection of the source and the other had no detection.

- Clear – Differences associated with the magnitude of detection. Both laboratories detected the source, but one laboratory had a stronger detection signal.

To highlight differences between laboratories with regards to the magnitude of detection, pluses (+) and minuses (-) are shown. For example, a difference between (+)

and (++) indicates that the detection signal at one laboratory was one order of magnitude higher than the other laboratory.

Table C-2 shows that the laboratories did not obtain identical results for all split samples. Of the 21 possible comparisons (7 samples, three source analyses), the following results were achieved:

- Green – 66% (14/21) were comparable in terms of signal detection and strength of the signal.
- Clear – 10% (2/21) were comparable in terms of signal detection, but had differences in the strength of the signal.
- Yellow – 10% (2/21) had minor detection differences; however, when detected the signal was very low.
- Red – 25% (3/21) had significant differences with strong differences in signal detection and magnitude of detection. These differences were observed in the following two samples:
    - Sample 5 – This sample, collected at San Antonio Channel, was untreated. UCD obtained a strong signal for the presence of bacteria from a human source; the OCWD result was no detection.
    - Sample 6 - This sample, collected at San Antonio Channel, was spiked with both human and bovine fecal material. UCD detected strong signals for both bacteria sources. In contrast, OCWD detected neither. However, based on these findings, OCWD identified an error in its original laboratory result. Upon re-analysis, similar results as UCD were obtained. Accordingly, the color coding of the pairing would have been changed from red to clear.

Discussion

Several key findings, evident from this study, should be considered when evaluating the microbial source tracking data obtained from the USEP sites and potentially future source analysis studies in the area.

- Combining the green and clear sample results, approximately 75% of the between laboratory analyses were comparable. In contrast, 25% of the results are not comparable. The laboratory researchers indicated that, based on other studies, this level of comparability is good. Published studies have routinely identified lower levels of inter-method comparability (personal communication with Dr. Stefan Wuertz, UCD, and Menu Leddy, OCWD, February 10, 2009).
- Twenty-five percent of the paired results differed in some manner, possibly due to differences in assay sensitivity. This finding has important implications from a compliance or regulatory perspective. These implications provide the basis for a

number of recommendations for how MST studies should be crafted and how results should be interpreted (including for this study):

- Studies that plan to use MST as tool for making water quality regulatory decisions should consider using at least two methodologies. These methods should have substantively different sensitivities to provide better understanding regarding the detection limit. Before implementation of MST studies, minimum detection limits should be established. As part of this effort, it is important to conduct a similar blind study to evaluate the degree of sensitivity of the different methods. For example, as was done in this study, when only one laboratory detected a signal in a spiked sample (see Sample 6), this information provided the basis for reanalyzing the sample and identifying an error in the original analysis.

- When a detection is obtained, regardless of the strength of the signal, it is important to collect a number of follow-up samples from the same location to determine if the signal can be repeatedly detected (e.g., OCWD's laboratory program requires the collection of 3 to 5 additional samples to verify the detection, especially with grab samples).

- Compliance activities should only be considered for implementation at sites where the signal is detected on multiple occasions. In addition, other measures of compliance should be considered simultaneously, e.g., magnitude of bacterial indicator concentrations and frequency of exceedance of water quality objectives. For this study, the recommendations contained in the Executive Summary (Section 1) take into account these considerations.

Table C-2. Results of analysis of blind study samples by OCWD and UCD laboratories[1, 2]

Location	Bottle No.	Sample	Split	Lab	Treatment	Human	Bovine	Dog
Box Springs	UCD-K2B	1	A	UCD	None	+	-	-
Box Springs	OCWD-C3H	1	B	OCWD	None	+	-	+
Box Springs	UCD-P6S	2	A	UCD	Human	+++	-	-
Box Springs	OCWD-A7N	2	B	OCWD	Human	++	-	-
Anza Drain	UCD-N7A	3	A	UCD	None	-	-	-
Anza Drain	OCWD-B20	3	B	OCWD	None	-	-	-
Anza Drain	UCD-R4D	4	A	UCD	Bovine	+	++	-
Anza Drain	OCWD-D4R	4[3]	B	OCWD	Bovine	-	+	-
San Antonio Channel	UCD-Z5S	5	A	UCD	None	++	-	-
San Antonio Channel	OCWD-S6P	5[3]	B	OCWD	None	-	-	-
San Antonio Channel	UCD-H3C	6	A	UCD	Human + Bovine	+++	++	-
San Antonio Channel	OCWD-D5A	6[3]	B	OCWD	Human + Bovine	-	-	-
Blank	UCD-L1B	7	A	UCD	None	-	-	-
Blank	OCWD-X1B	7	B	OCWD	None	-	-	-

1 (-) indicates source not detected; (+) indicates source detected. Number of pluses indicates difference in orders of magnitude from other laboratories results.

2 Green indicates laboratories obtained comparable results; yellow indicates disagreement between laboratories, but concentrations were low; red indicates significant difference between laboratories; clear indicates agreement, but strength of signal different by at least an order of magnitude.

3 After receiving a report on the results, OCWD reanalyzed these three samples with the following results: (1) Sample 4 = no change; Sample 5 = no change; Sample 6 = (+) for human, (+) for bovine, and no change for dog. These findings illustrate well the recommendations regarding the use of more than one MST method to provide insight into detection limits.