Middle Santa Ana River Bacterial Indicator TMDL 2009 Dry Season Report

December 31, 2009

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

Table of Contents

List of Figures

Section 2

Section 4

List of Tables

Section 2

Section 3

Section 4

Section 1
Introduction

Various waterbodies in the Middle Santa Ana River (MSAR) watershed are listed on the state 303(d) list of impaired waters due to high levels of fecal coliform bacterial indicators. The Santa Ana Regional Water Quality Control Board (RWQCB) adopted the MSAR Bacterial Indicator Total Maximum Daily Load (TMDL) in 2005 (RWQCB 2005) to address the fecal coliform bacterial indicator impairments. Following approval by the State Water Resources Control Board, the Environmental Protection Agency (EPA) Region 9 approved the TMDL on May 16, 2007 making the TMDL effective.

The TMDL requires implementation of a watershed-wide compliance monitoring program for bacterial indicators. This program was initiated in July 2007. This report summarizes the findings from water quality monitoring conducted during the 2009 dry season and, where appropriate, compares results to previous sample periods.

1.1 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% of the samples exceed 400 organisms/100 mL for any 30-day period.*

The EPA published new bacterial indicator guidance in 1986 (EPA 1986). This guidance advised that for freshwaters *Escherichia coli* (*E. coli*) is a better bacterial indicator than fecal coliform. Specifically, 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), comprised of representatives from various stakeholder interests, including the Santa Ana Watershed Protection Authority (SAWPA), the counties of Orange, Riverside, and San Bernardino, Orange County Coastkeeper, Inland Empire Waterkeeper, 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 the following waterbodies in the MSAR watershed to the state 303(d) list of impaired waters:

- 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 2005 RWQCB-adopted 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% 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% of the samples exceed 212 organisms/100 mL for any 30-day period.

To focus TMDL implementation efforts, the MSAR Watershed TMDL Task Force ("Task Force") was established. This Task Force, which meets regularly to coordinate water quality management activities, includes representation by key watershed stakeholders, including urban stormwater dischargers, agricultural operators, and the RWQCB.

1.2 Watershed-Wide Compliance Monitoring

The MSAR Bacterial Indicator TMDL requires urban and agricultural dischargers to implement a watershed-wide bacterial indicator monitoring program by November 2007 (RWQCB 2005). The dischargers worked collaboratively through the TMDL Task Force to develop this program and prepare a Monitoring Plan (SAWPA 2008a) and Quality Assurance Project Plan (SAWPA 2008b)[1]. The TMDL Task Force implemented the monitoring program in July 2007 following RWQCB approval of program documents.

SAWPA (2009a) summarizes the findings from the first year of dry and wet season monitoring (2007-2008). SAWPA (2009b) and SAWPA (2009c) summarize the findings from the 2008 dry and 2008-2009 wet seasons, respectively. This report provides the results from the 2009 dry season.

[1] The Middle Santa Ana River Monitoring Plan and Quality Assurance Project Plan are available at hhttp://www.waterboards.ca.gov/santaana/water_issues/programs/tmdl/msar_tmdl.shtml

Section 2
Study Area

This section describes the study area and identifies the watershed-wide compliance monitoring locations sampled during the 2009 dry season. SAWPA (2009a) provides a more detailed characterization of the watershed.

2.1 Middle Santa Ana River Watershed

2.1.1 General Description

The Santa Ana River watershed, located in southern California, is approximately 2800 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 2-1).

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 sources of surface water flows vary, 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. A number of major tributaries to the MSAR exist, many of which have been modified for flood control purposes.

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

- *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.

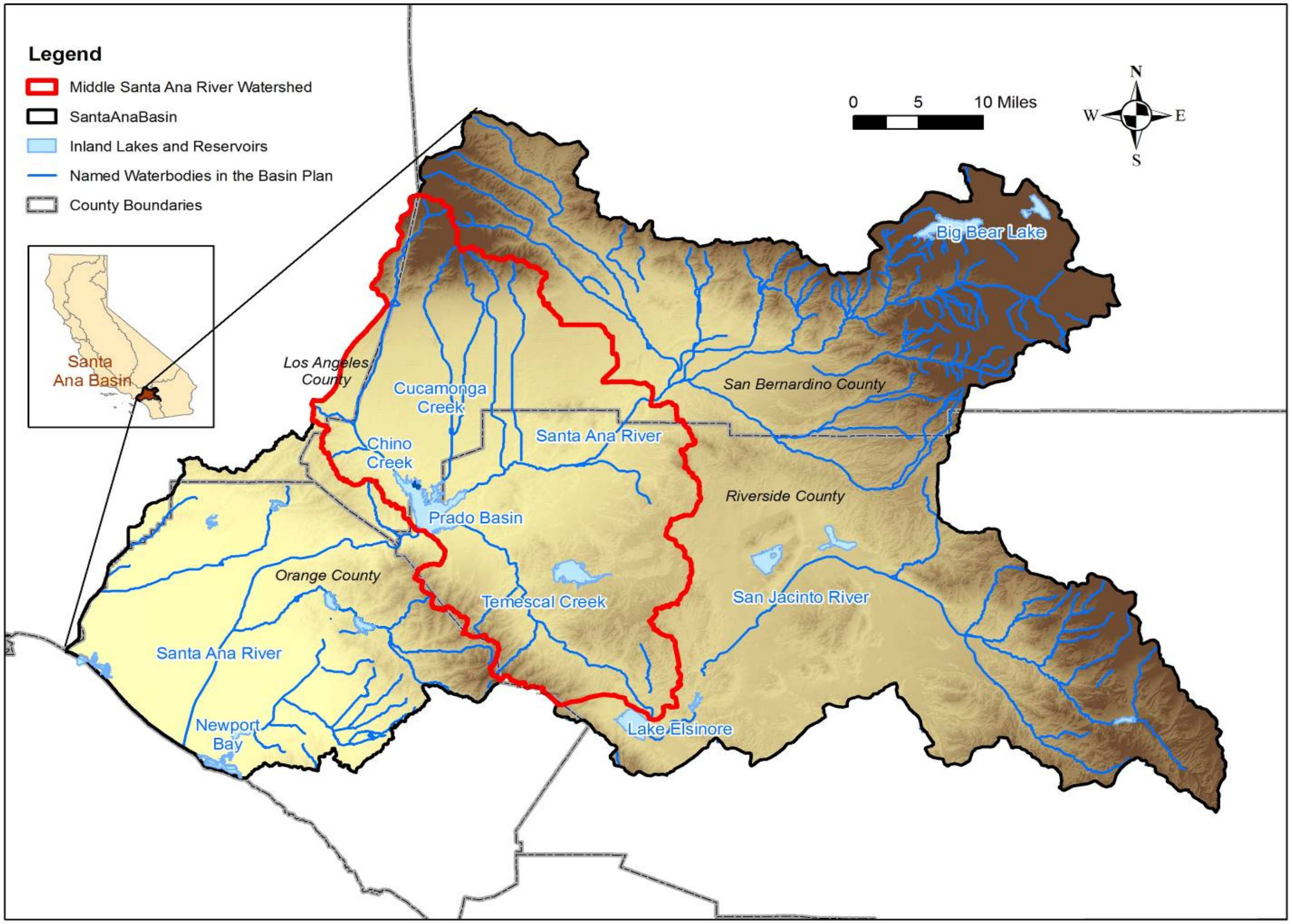

Figure 2-1. Location of the Middle Santa Ana River watershed (red outline) within the Santa Ana River watershed in southern California

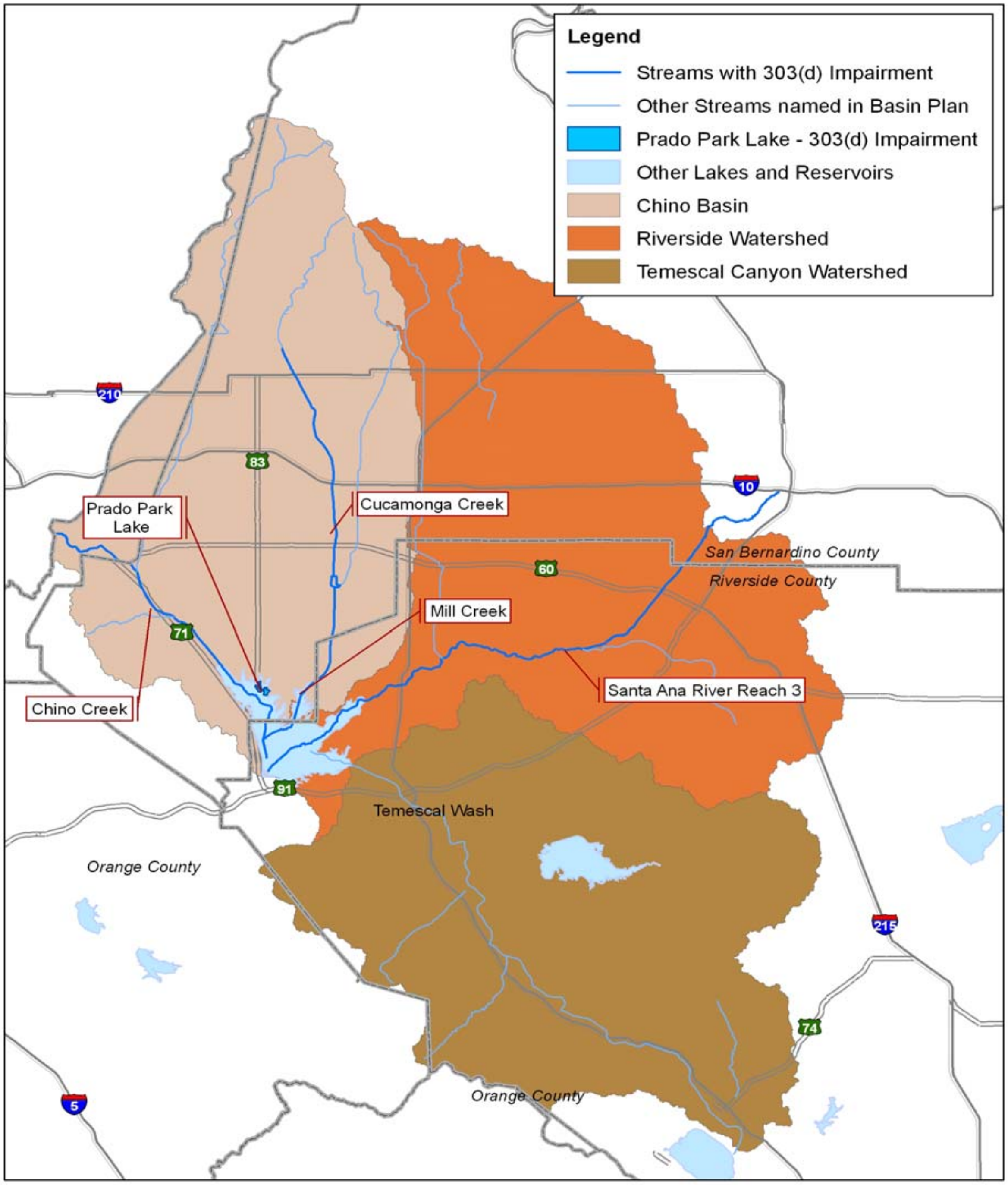

Figure 2-2. Major geographic areas of the Middle Santa Ana River watershed

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. This area is located in the south central part of the Chino Basin subwatershed. At the time of TMDL development the area contained approximately 300,000 cows (RWQCB 2005). As of January 2009, this number was down to about 138,500 (email communication, Ed Kashak [RWQCB] to Pat Boldt, December 8, 2009). In recent years, 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).

2.1.2 Physical Description

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

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, 2009a). Instream flows in the watershed are influenced by the following (Figure 2-3):

- 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 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.

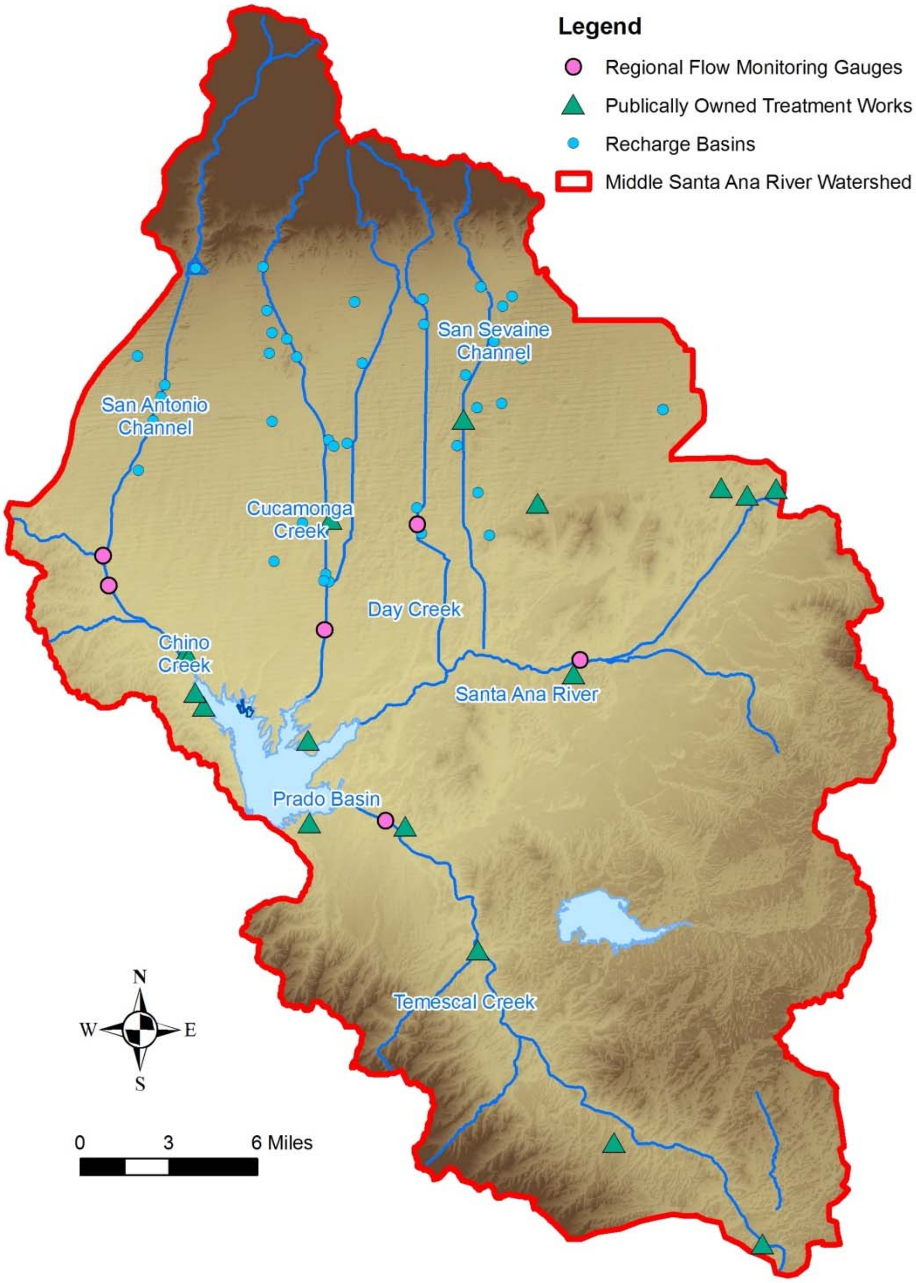

Figure 2-3. Location of recharge basins and publicly owned treatment works that influence instream flows in Middle Santa Ana River waterbodies

Precipitation

Table 2-1 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.

Table 2-1. Average annual precipitation in the study area as measured at Riverside Fire Station #3

Measurement	Precipitation (inches)
Average Annual Precipitation	10.06
Maximum Recorded Annual Precipitation	22.72
Minimum Recorded Annual Precipitation	1.07

Water Quality

Bacterial indicator water quality data have been collected for many years in the MSAR watershed. SAWPA (2009a) references and summarizes the findings from MSAR watershed studies conducted prior to 2007. SAWPA 2009a, 2009b and 2009c report bacterial indicator data collected since 2007.

2.2 Watershed-Wide Compliance Monitoring Sites

The TMDL Task Force established the watershed-wide compliance monitoring sites in the MSAR watershed. Table 2-2 and Figure 2-4 identify the location of each site sampled in 2009[2]. Attachment A of the Monitoring Plan (see footnote 1) provides additional information about each sample location.

Table 2-2. Watershed-wide compliance monitoring program sample locations

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

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

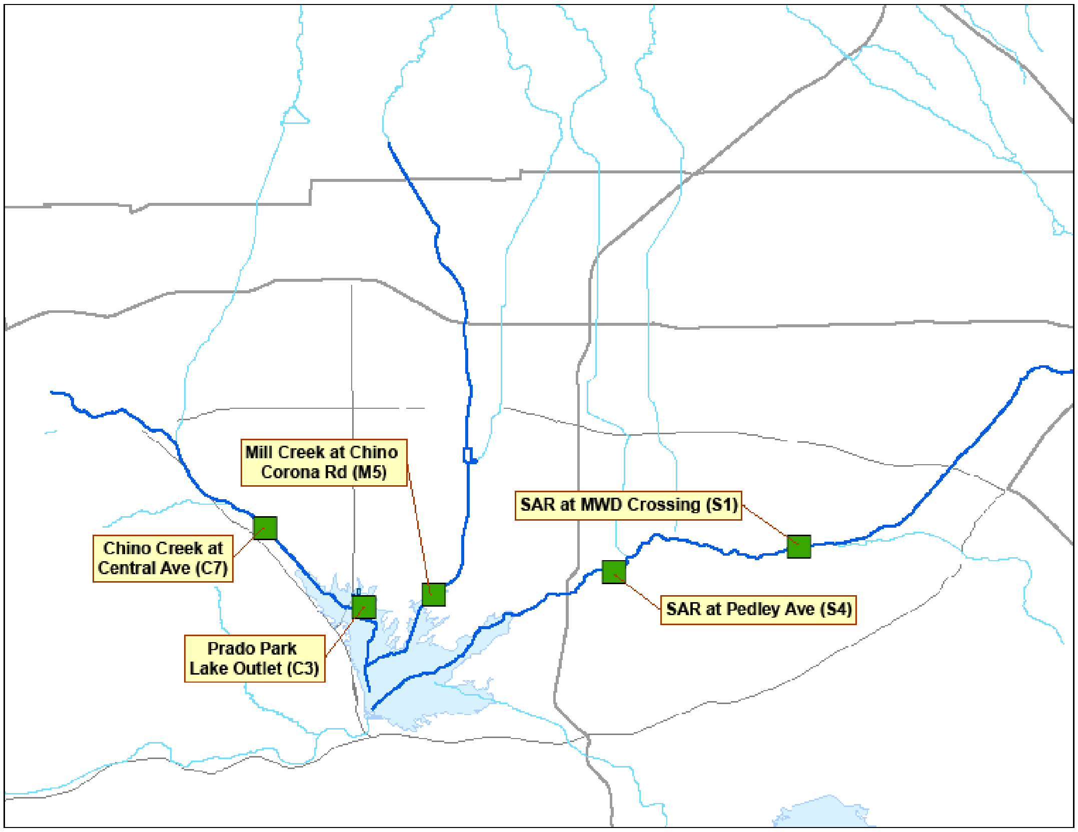

Figure 2-4. Location of watershed-wide compliance monitoring program sample locations in the Middle Santa Ana River watershed

Section 3
Methods

The RWQCB-approved Monitoring Plan and Quality Assurance Project Plan (see footnote 1) provide detailed information regarding the collection and analysis of field data and water quality samples. The following sections provide a summary of these methods.

3.1 Water Quality Measurements

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

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

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

3.2 Sample Frequency

The Monitoring Plan established sample collection dates for each year of the monitoring program. During 2009, the dry season sample dates were planned as follows: Collect weekly samples over a 20 week period from the week ending May 30, 2009 to the week ending October 10, 2009. Table 3-1 summarizes the results of the 2009 dry season sampling effort. All planned water quality samples were successfully collected.

3.3 Data Collection

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

Table 3-1. Summary of water sample collection activity during 2009 dry season

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

[1] – Number of planned samples depends on the number of sample weeks per month times the number of sites planned for sampling. For example, in June five sites were planned for sampling during each of five available sample weeks for a total of 25 samples.

3.4 Sample Handling

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

3.5 Data Handling

CDM and SAWPA maintain a file of all laboratory and field data records (e.g., data sheets, chain of custody forms) as required by the 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 Surface Water Ambient Monitoring Program. CDM periodically submits to SAWPA updates of this for incorporation into the Santa Ana Watershed Data Management System (SAWDMS), which SAWPA manages. Prior to a data submittal to SAWPA, CDM completes a QA/QC review of the data.

3.6 Data Analysis

Data analysis relied primarily on the use of descriptive and correlation statistics. For any statistical analyses, the bacterial indicator data were assumed to be log-normally distributed as was observed in previous studies (SAWPA 2009a). Accordingly, prior to conducting statistical analyses, the bacterial indicator data were log transformed.

Section 4
Sample Results

This section summarizes the results of data analyses applied to the 2009 dry season dataset. Where appropriate to provide context, data results are compared to water quality results previously reported (SAWPA 2009a, 2009b, 2009c).

4.1 Water Quality Observations

Table 4-1 provides the median value and range of observations for each sampled water quality constituent. Tables 4-2 and 4-3 summarize the fecal coliform and *E. coli* concentrations, respectively, observed during each sample event. No data outliers were identified in the data set.

4.2 Characterization of Bacterial Indicators

Table 4-4 summarizes the distribution of the fecal coliform and *E. coli* data collected from all sites over all sample dates during the 2009 dry season. Tables 4-5 and 4-6 summarize the geometric mean, median, and coefficient of variation of the fecal coliform and *E. coli* data, respectively, for all samples collected at each site during the 2009 dry season.

In general the 2009 dry season fecal coliform and *E. coli* geometric mean concentrations were lower than observed during previous dry season sample periods in 2007 and 2008 (Tables 4-5 and 4-6). Lowest bacterial indicator concentrations were observed at the Prado Park Lake outlet and Santa Ana River sites. Highest concentrations were observed at the Chino Creek and Mill-Cucamonga Creek sample locations.

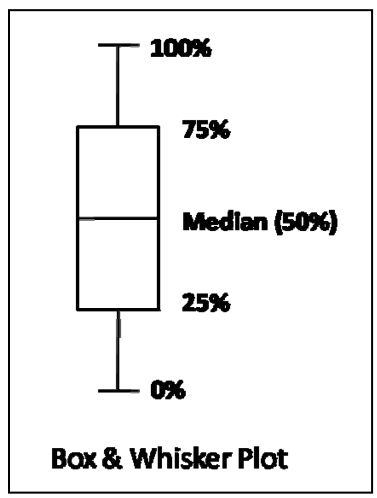

Figure 4-1 summarizes fecal coliform and *E. coli* concentrations, respectively, for each sample site using Box and Whisker box plots (see text box for explanation of the box plots). The Mill-Cucamonga Creek and Chino Creek sites had the highest observed median bacterial indicator concentrations (fecal coliform: 405 cfu/100 mL and 250 cfu/100 mL, respectively; *E. coli*: 620 cfu/100 mL and 215 cfu/100 mL, respectively) (see Tables 4-5 and 4-6). The lowest median fecal coliform and *E. coli* concentrations were observed at Prado Park Lake (fecal coliform: 105 cfu/100 mL; *E. coli*: 50 cfu/100 mL). The Santa Ana River sites had similar median concentrations (fecal coliform: 125 - 140 cfu/100 mL; *E. coli*: 130 cfu/100 mL) (see Figure 4-1; Tables 4-5 and 4-6).

Table 4-1. Summary of water quality monitoring data collected during 2009 dry season

Constituent	Prado Park Lake Outflow (WW-C3)	Chino Creek at Central Ave (WW-C7)	Mill-Cucamonga Creek (WW-M5)	Santa Ana River at MWD Crossing (WW-S1)	Santa Ana River at Pedley (WW-S4)
Fecal coliform (cfu/100 mL)					
N	20	20	20	20	20
Median	105	250	465	125	140
Range	8 - 790	70 – 2,200	150 – 4,300	40 - 240	50 - 460
E. coli **(cfu/100 mL)**					
n	20	20	20	20	20
Median	50	215	620	130	130
Range	9 - 730	40 - 740	320 – 4,600	40 - 320	40 - 240
Total Suspended Solids (mg/L)					
n	19	19	19	19	19
Median	14.6	6.3	6.4	4.6	8.2
Range	7.4 – 180.0	3.7 – 10.7	3.2 – 14.2	2.6 – 9.9	5.4 – 13.1
Dissolved Oxygen (mg/L)					
n	20	20	20	20	20
Median	7.9	8.5	7.8	9.0	8.0
Range	5.0 – 10.9	6.5 – 10.2	3.2 – 10.6	7.3 – 11.3	5.8 – 10.2
pH (Standard Units)					
n	20	20	20	20	20
Median	8.55	8.65	8.15	7.90	7.90
Range	8.00 – 9.20	6.20 – 9.10	7.00 – 8.90	6.90 – 8.30	7.06 – 8.40
Turbidity (NTU)					
n	15[1]	20	20	20	20
Median	9.6	5.1	4.1	3.4	4.7
Range	8.6 – 93.8	3.5 – 7.9	2.5 – 8.0	2.2 – 5.7	2.2 – 8.8
Water Temperature (°C)					
n	20	20	20	20	20
Median	25.6	26.4	20.9	19.6	20.6
Range	22.1 – 28.9	20.5 – 29.6	12.8 – 24.1	15.3 – 22.2	16.0 – 23.6
Flow (cfs)					
n	19[2]	19[2]	20	20	18[2]
Median	5.0	11.8	43.6	54.3	92.5
Range	3.4 – 11.8	2.9 – 49.4	16.8 – 134.7	36.9 – 186.0	36.9 -149.5
Conductivity (µS/cm)					
n	20	20	20	20	19[3]
Median	757	933	657	882	863
Range	569 – 846	603 – 1,060	420 – 834	529 – 1,040	609[3] - 990

[1] – Per field notes, water too turbid on several occasions to obtain a measurement
[2] – Flow could not be calculated from field notes for at least one site
[3] – Field notes for 6/2/09 listed conductivity at 94 uS/cm. Because this value was significantly lower than other measurements at this site, it was removed from calculation.

Table 4-2. Fecal coliform (cfu/100 mL) concentrations observed at watershed-wide compliance sites during the 2009 dry season

Sample Week	Prado Park Lake Outlet (WW-C3)	Chino Creek @ Central Avenue (WW-C7)	Mill-Cucamonga Creek @ Chino-Corona Rd (WW-M5)	SAR @ MWD Crossing (WW-S1)	SAR @ Pedley Avenue (WW-S4)
May 25	120	210	150	120	99
June 1	40	70	210	80	50
June 8	140	220	540	40	140
June 15	140	170	480	140	90
June 22	20	220	290	99	120
June 29	90	280	350	80	99
July 6	40	1,100	300	140	120
July 13	< 9	1,600	>= 220	120	160
July 20	40	250	280	150	170
July 27	80	320	1,500	160	220
August 3	70	280	280	120	220
August 10	99	>= 520	>= 560	170	140
August 17	250	200	270	130	140
August 24	200	>= 230	4300	140	90
August 31	>= 180	2200	500	240	460
September 7	120	>= 240	>= 450	99	230
September 14	>= 110	1000	3000	150	180
September 21	>= 790	>= 460	>= 840	110	90
September 28	150	250	850	180	220
October 5	80	210	580	70	200

Table 4-3. *E. coli* (cfu/100 mL) concentrations observed at watershed-wide compliance sites during the 2009 dry season

Sample Week	Prado Park Lake Outlet (WW-C3)	Chino Creek @ Central Avenue (WW-C7)	Mill-Cucamonga Creek @ Chino-Corona Rd (WW-M5)	SAR @ MWD Crossing (WW-S1)	SAR @ Pedley Avenue (WW-S4)
May 25	180	180	320	100	140
June 1	80	40	490	40	40
June 8	90	230	620	80	110
June 15	90	140	830	140	100
June 22	50	80	330	140	130
June 29	50	130	410	90	99
July 6	40	190	570	60	140
July 13	9	270	370	140	70
July 20	9	160	520	80	130
July 27	40	280	2,300	140	90
August 3	50	210	540	140	120
August 10	9	350	982	110	140
August 17	50	230	620	120	130
August 24	80	>= 410	4,600	320	>= 240
August 31	>= 50	740	1,350	>= 220	>= 210
September 7	110	370	950	180	210
September 14	>= 50	360	2,900	220	150
September 21	>= 730	220	700	210	120
September 28	40	140	690	110	140
October 5	30	110	620	100	110

Table 4-4. Statistical distribution of bacterial indicator data (cfu/100 mL) during the 2009 dry season

Statistic	2009 Dry Weather	
	E. coli	**Fecal coliform**
Sample Size (n)	100	100
Geometric Mean	164	193
10^{th} Percentile	49	79
25^{th} Percentile	90	118
50^{th} Percentile (median)	140	175
75^{th} Percentile	323	280
90^{th} Percentile	691	601

Table 4-5. Summary of fecal coliform concentrations (cfu/100 mL) and data variability by sample location during the 2007, 2008 and 2009 dry seasons

Site	2009				2008				2007			
	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]
Prado Park Lake	20	91	105	0.21	20	152	175	0.17	15	114	140	0.25
Chino Creek	20	339	250	0.14	20	1,116	720	0.20	15	1,678	1,800	0.11
Mill-Cucamonga Creek	20	505	405	0.14	20	1,334	1,400	0.18	15	2,240	2,300	0.09
SAR @ MWD Crossing	20	119	125	0.08	20	232	225	0.18	15	572	420	0.18
SAR @ Pedley Ave.	20	144	140	0.10	20	306	225	0.22	15	773	550	0.19

[1] - Coefficient of variation was calculated using natural log-transformed data

Table 4-6. Summary of *E. coli* concentrations (cfu/100 mL) and data variability by sample location during the 2007, 2008 and 2009 dry seasons

Site	2009				2008				2007			
	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]	N	Geometric Mean	Median	Coefficient of Variation[1]
Prado Park Lake	20	51	50	0.26	20	124	120	0.19	15	90	110	0.27
Chino Creek	20	202	215	0.12	20	570	460	0.18	15	676	770	0.09
Mill-Cucamonga Creek	20	764	620	0.11	20	855	760	0.13	15	979	780	0.09
SAR @ MWD Crossing	20	123	130	0.08	20	148	155	0.14	15	204	220	0.18
SAR @ Pedley Ave.	20	123	130	0.10	20	162	145	0.11	15	187	150	0.19

[1] - Coefficient of variation was calculated using natural log-transformed data

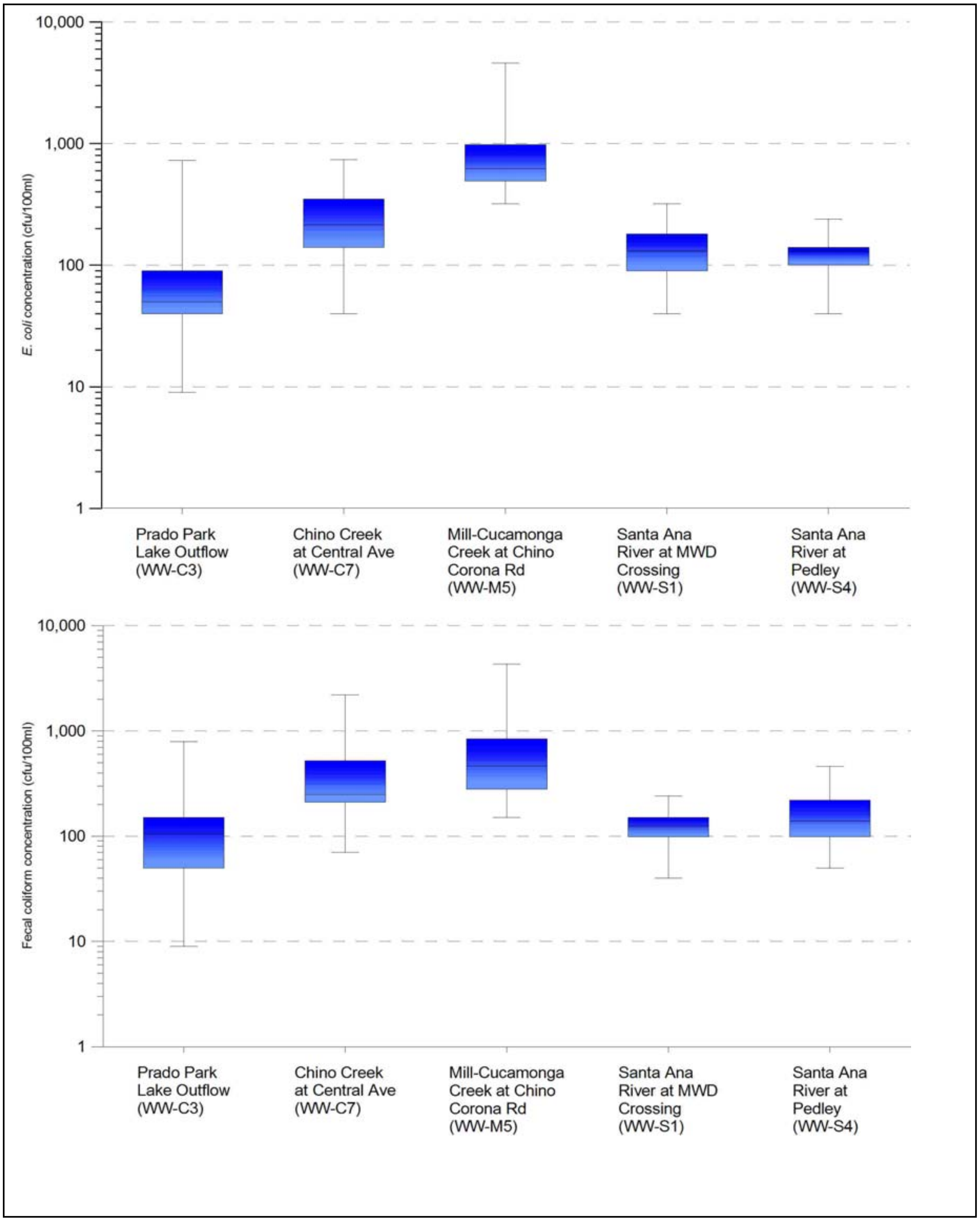

Figure 4-1. Statistical distribution of bacterial indicator data collected during the 2009 dry season illustrated using Box & Whisker box plots. Upper figure: *E. coli*; Lower figure: Fecal coliform.

4.3 Bacterial Indicator Compliance Analysis

The compliance analysis compared the bacterial indicator data for existing REC-1 fecal coliform and *E. coli* to the existing fecal coliform objectives and the proposed REC-1 *E. coli* objectives under development by the SWQSTF. Compliance was evaluated for the geometric mean and single sample exceedance frequency of bacterial indicator concentrations. Geometric means were calculated only when at least five sample results were available from the previous five week period.

The calculated geometric means 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

For the Prado Park Lake and Santa Ana River sites the single sample exceedance frequency for fecal coliform and *E. coli* was 0% or 5%. In contrast, at the Chino and Mill-Cucamonga Creek sites the single sample exceedance frequency ranged from 35 to 100% with the highest exceedance frequencies observed at Mill-Cucamonga Creek for *E. coli* (Tables 4-7 and 4-8).

The fecal coliform geometric mean exceedance frequency was very low at the Santa Ana River sites (0% to 6%) and Prado Park Lake (6%). For these same sites, the *E. coli* geometric mean exceedance frequency ranged from 44% for the Santa Ana River sites to 0% at the Prado Park Lake site. The fecal coliform and *E. coli* geometric mean exceedance frequencies were 88% for Chino Creek and 100% for Mill-Cucamonga Creek (Tables 4-7 and 4-8).

Figures 4-2 through 4-6 illustrate the variability in single sample results and rolling geometric mean values for fecal coliform for the period beginning with the 2007 dry season through the end of the 2009 dry season. Figures 4-7 through 4-11 illustrate comparable results for *E. coli* for the same period of record. The extended period of record illustrates how the bacterial indicator concentrations have varied over time.

Table 4-7. Bacterial indicator compliance frequency for fecal coliform during the 2009 dry season

Site	Single Sample Criterion Exceedance Frequency (%)	Geometric Mean Criterion Exceedance Frequency (%)
Prado Park Lake	5%	6%
Chino Creek	35%	88%
Mill-Cucamonga Creek	55%	100%
SAR @ MWD Crossing	5%	6%
SAR @ Pedley Ave.	0%	0%

Table 4-8. Bacterial indicator compliance frequency for *E. coli* during the 2009 dry season

Site	Single Sample Criterion Exceedance Frequency (%)*	Geometric Mean Criterion Exceedance Frequency (%)*
Prado Park Lake	5%	0%
Chino Creek	35%	88%
Mill-Cucamonga Creek	100%	100%
SAR @ MWD Crossing	5%	44%
SAR @ Pedley Ave.	5%	44%

* - Evaluation of compliance based on proposed water quality objectives. See Section 1.1

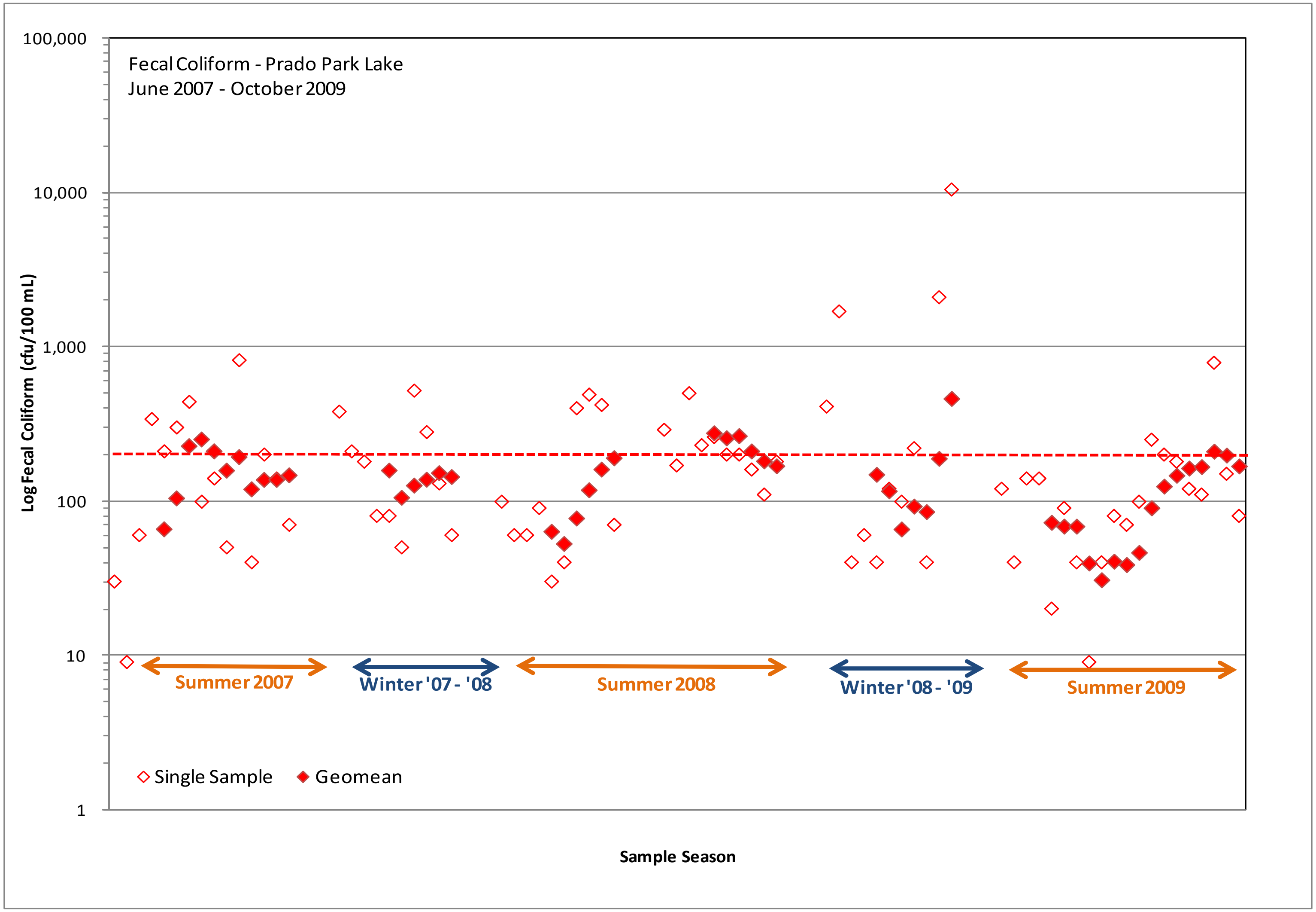

Figure 4-2. Time series plot of fecal coliform single sample results and geometric means for samples collected from Prado Park Lake from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates the geometric mean water quality objective).

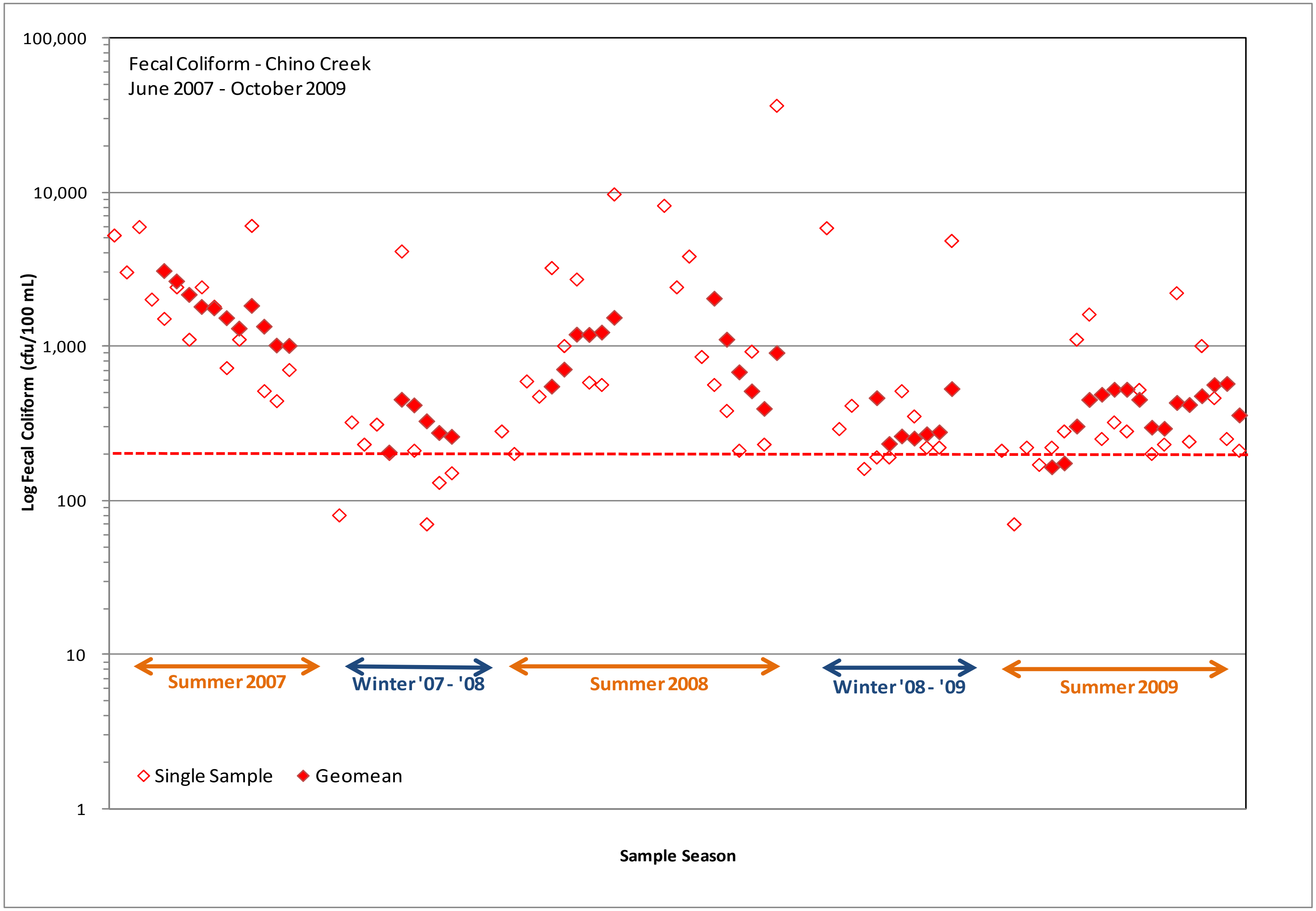

Figure 4-3. Time series plot of fecal coliform single sample results and geometric means for samples collected from Chino Creek from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates the geometric mean water quality objective).

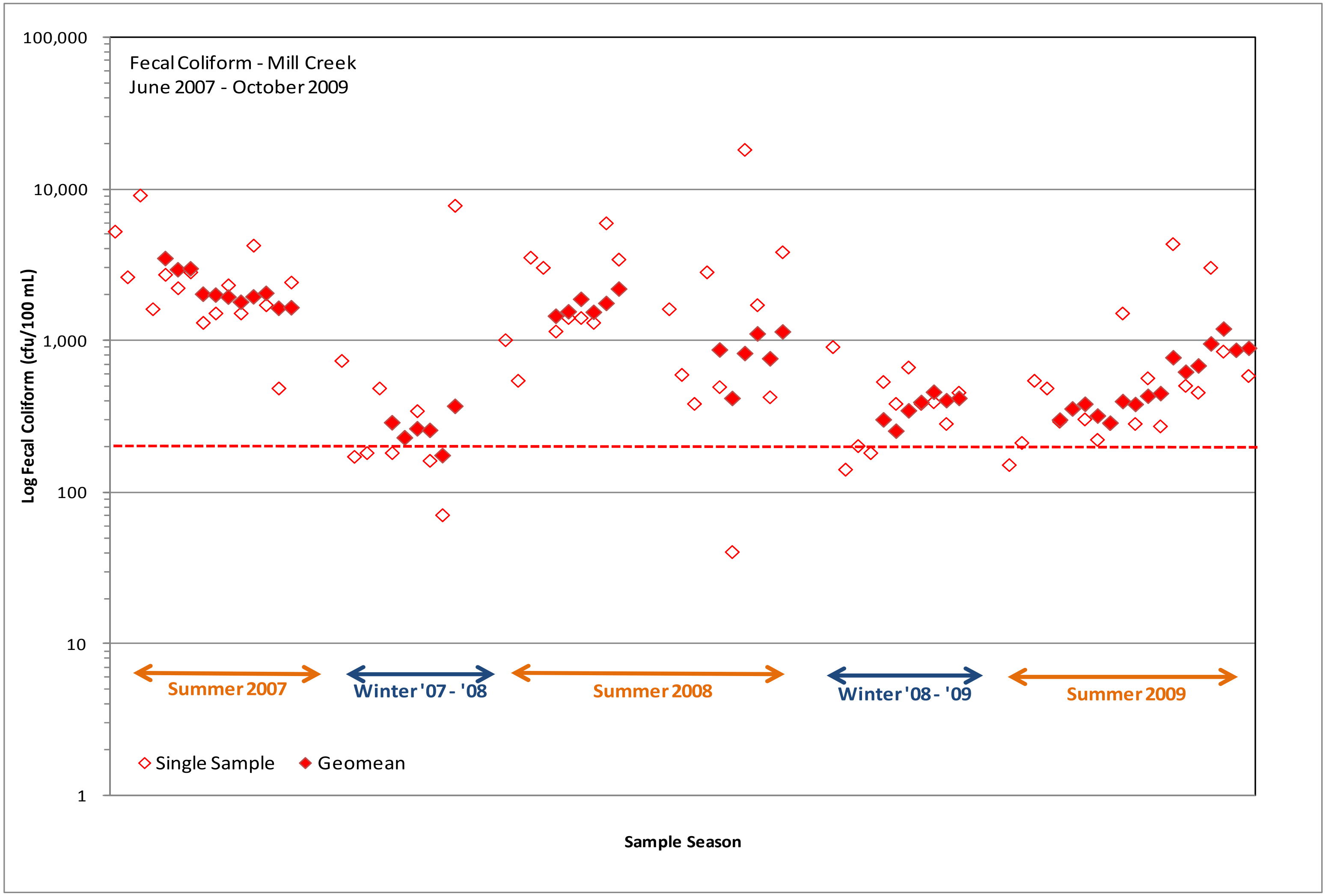

Figure 4-4. Time series plot of fecal coliform single sample results and geometric means for samples collected from Mill-Cucamonga Creek from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates the geometric mean water quality objective).

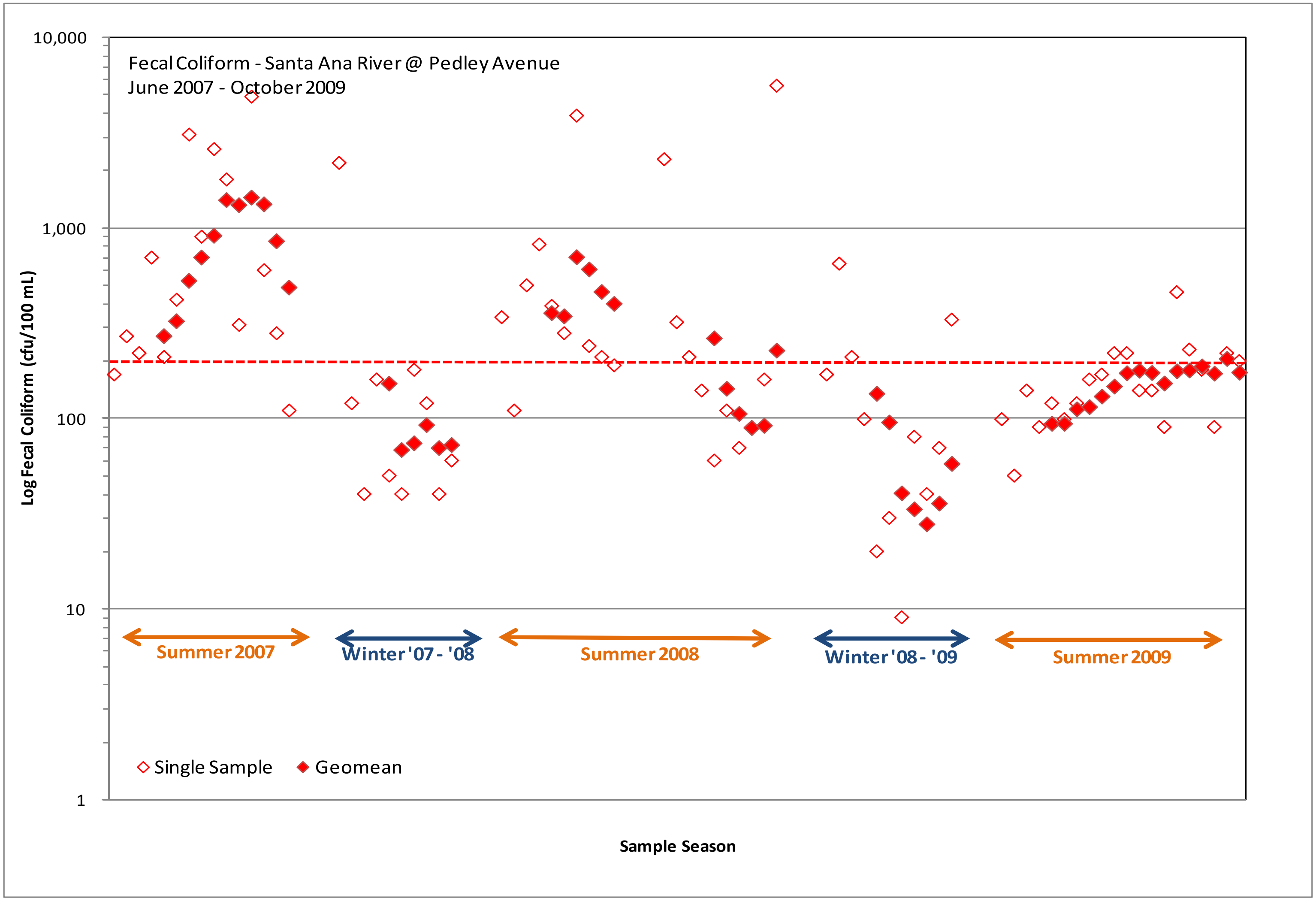

Figure 4-5. Time series plot of fecal coliform single sample results and geometric means for samples collected from Santa Ana River @ Pedley Avenue from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates the geometric mean water quality objective).

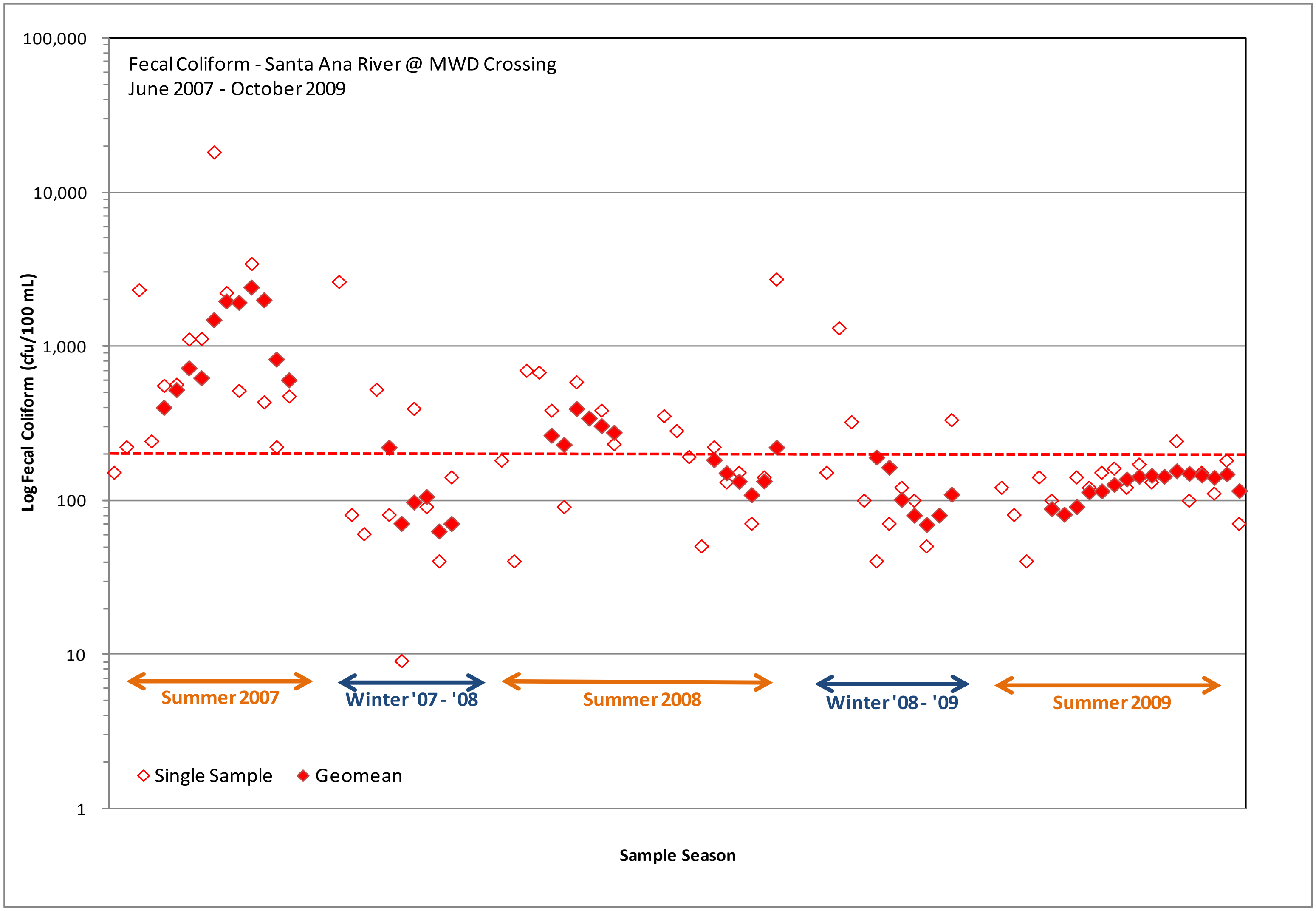

Figure 4-6. Time series plot of fecal coliform single sample results and geometric means for samples collected from Santa Ana River @ MWD Crossing from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates the geometric mean water quality objective).

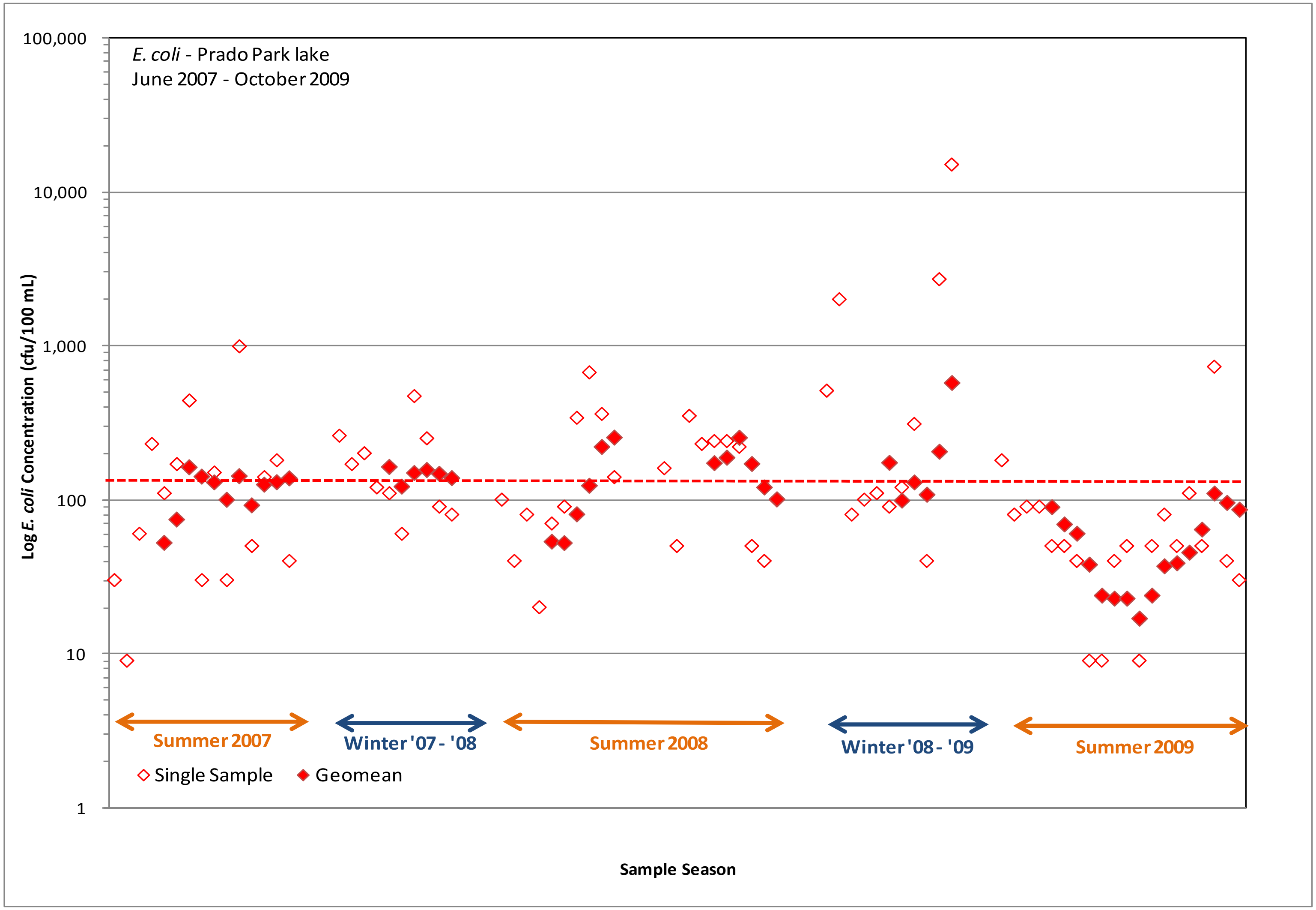

Figure 4-7. Time series plot of *E. coli* single sample results and geometric means for samples collected from Prado Park Lake from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates proposed geometric mean water quality objective).

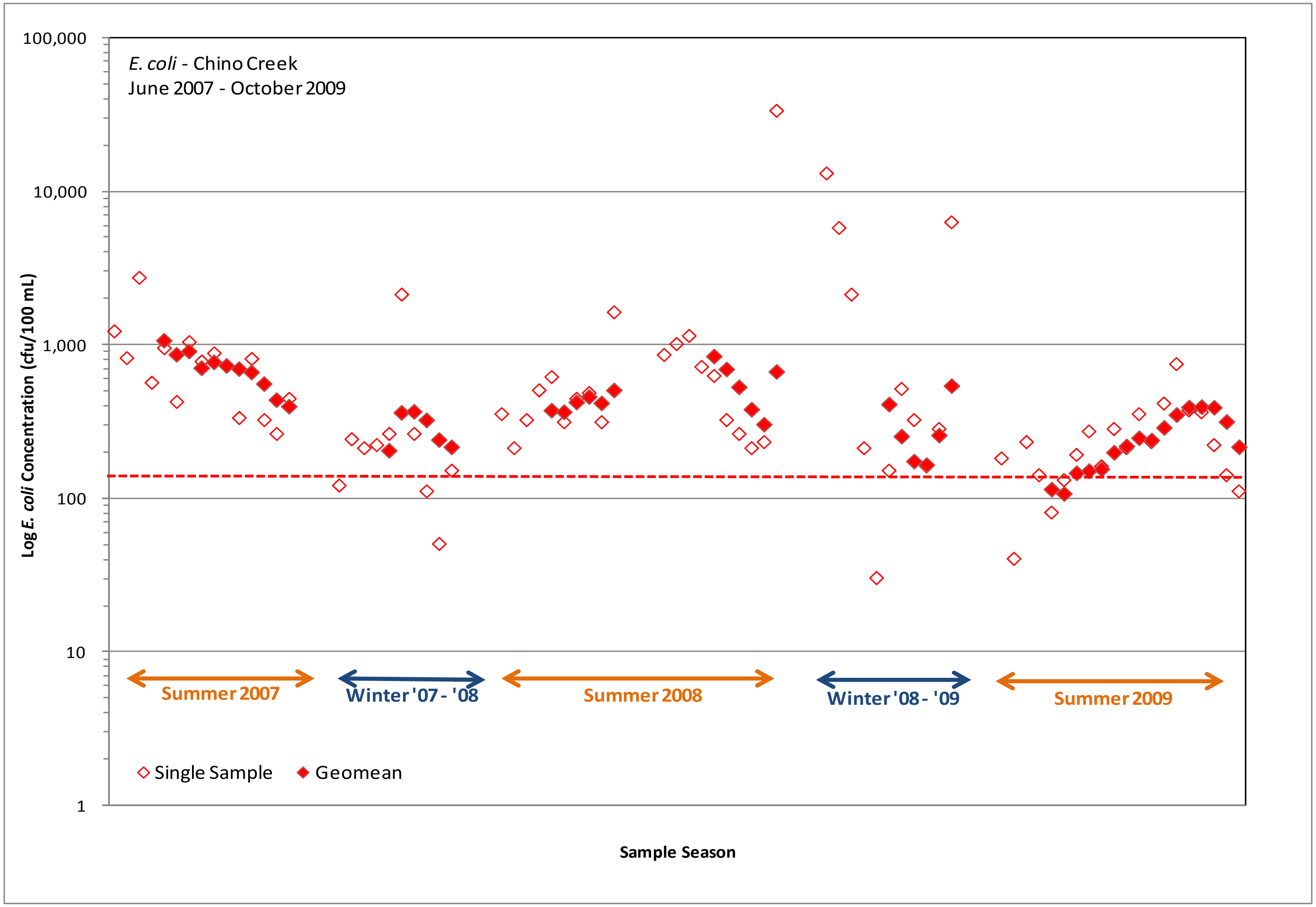

Figure 4-8. Time series plot of *E. coli* single sample results and geometric means for samples collected from Chino Creek from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates proposed geometric mean water quality objective).

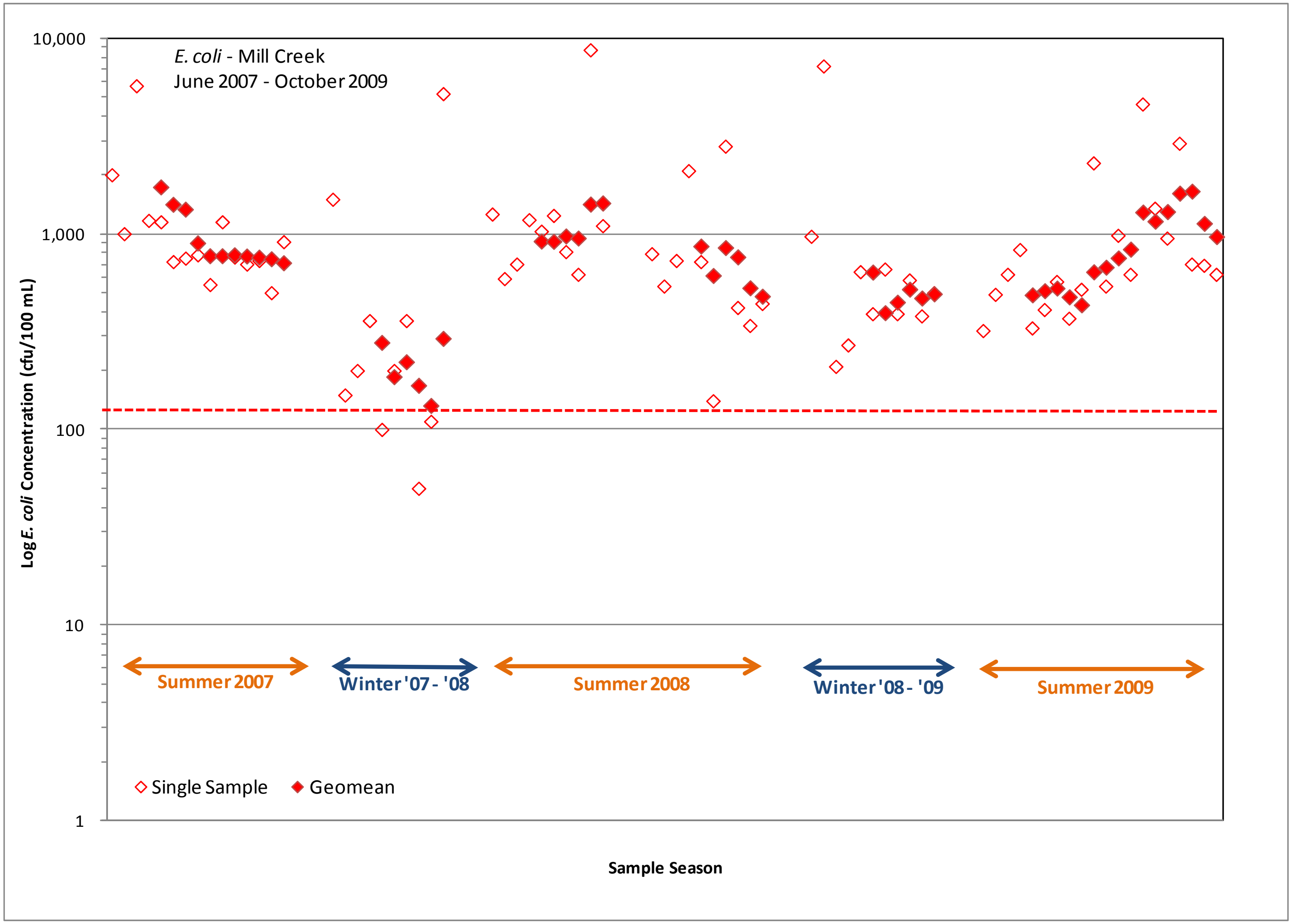

Figure 4-9. Time series plot of *E. coli* single sample results and geometric means for samples collected from Mill-Cucamonga Creek from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates proposed geometric mean water quality objective).

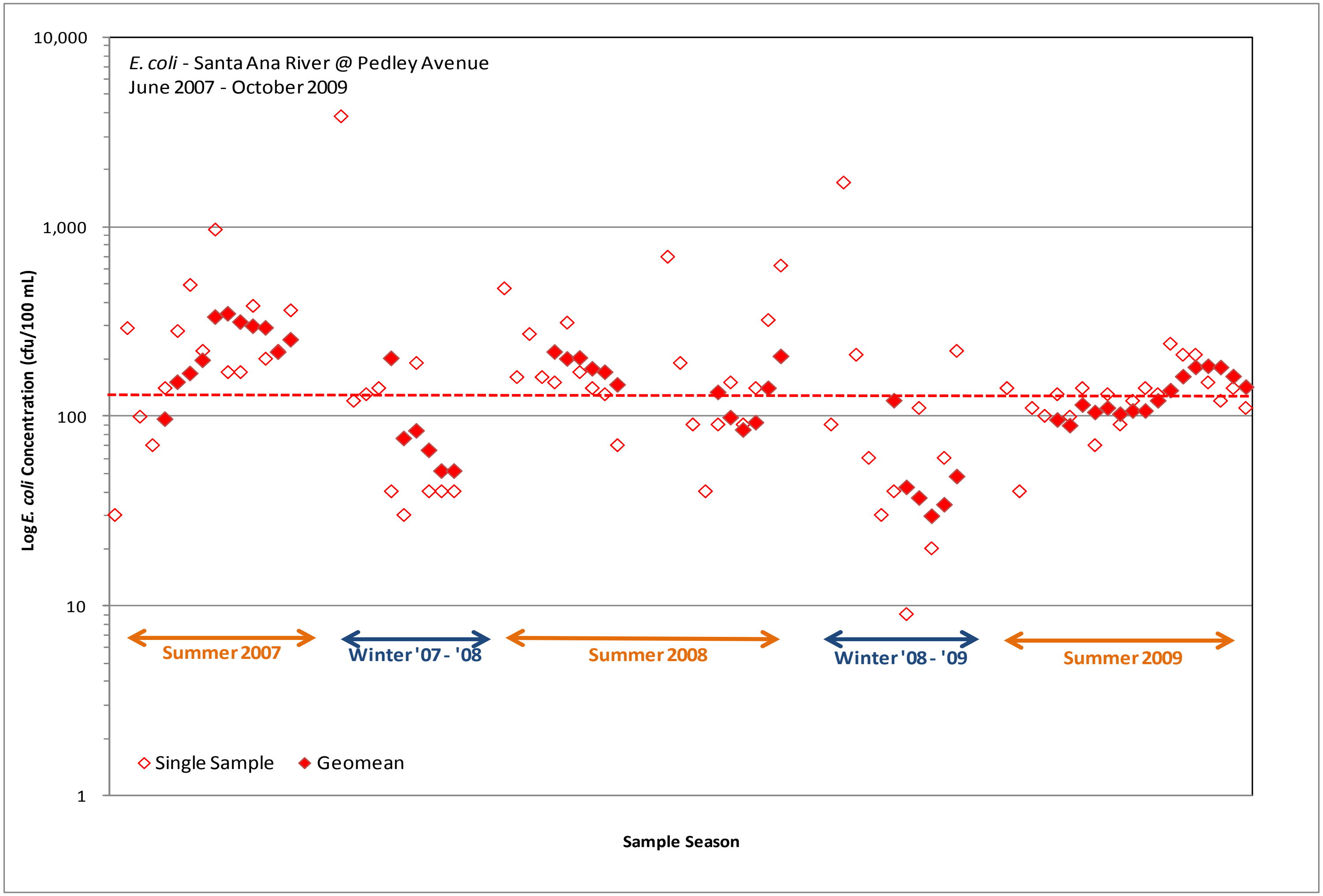

Figure 4-10. Time series plot of *E. coli* single sample results and geometric means for samples collected from Santa Ana River @ Pedley Avenue from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates proposed geometric mean water quality objective).

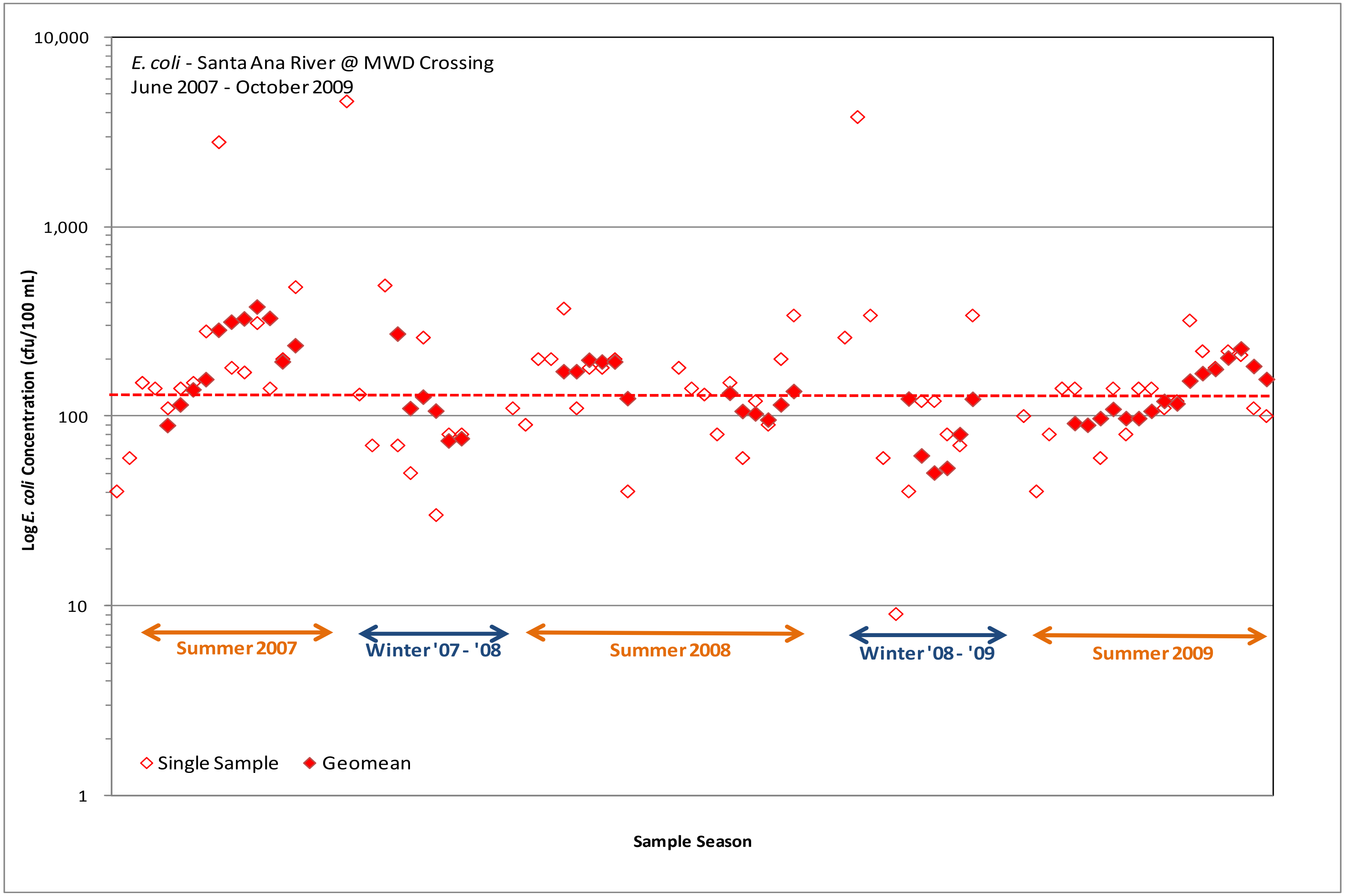

Figure 4-11. Time series plot of *E. coli* single sample results and geometric means for samples collected from Santa Ana River @ MWD Crossing from July 2007 through October 2009. A geometric mean was calculated only if five samples were collected during the previous five weeks (red line indicates proposed geometric mean water quality objective).

4.4 Correlation Analysis

Table 4-9 summarizes the results of a correlation analysis between fecal coliform and *E. coli* concentrations. A highly significant correlation was observed at three watershed-wide compliance sites, with the best correlation observed at Mill-Cucamonga Creek. The correlation was weak at the Santa River MWD crossing site and a non-significant correlation was observed at the Santa River Pedley Avenue site.

Table 4-10 summarizes the results of correlation analyses between bacterial indicators and field parameters measured during each sample event. Significant correlations were observed between (1) fecal coliform concentrations and TSS, turbidity and conductivity; and (2) *E. coli* concentrations and TSS, turbidity and conductivity.

Table 4-9. Correlation of natural log *E. coli* concentrations (cfu/100 mL) and natural log fecal coliform concentrations (cfu/ 100 mL) during the 2009 dry season

Site	Pearson's r coefficient	Degrees of freedom (n - 2)	t-statistic	p-value	Significant?[1]
Prado Park Lake	0.66	18	3.7	0.002	Yes
Chino Creek	0.67	18	3.9	0.001	Yes
Mill-Cucamonga Creek	0.91	18	9.3	< 0.001	Yes
SAR @ MWD Crossing	0.48	18	2.3	0.034	Yes
SAR @ Pedley Ave.	0.41	18	1.9	0.074	No

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

Table 4-10. Correlation analysis between bacterial indicator concentrations and field parameters during the 2009 dry season

Data Subset/Comparison	Pearson's r coefficient	Degrees of freedom (n - 2)	Student-t statistic	p-value[1]
Fecal Coliform vs.				
Conductivity	-0.38	118	4.5	< 0.001
Dissolved Oxygen	-0.1	118	0.7	0.49
pH	-0.14	118	1.6	0.11
Suspended Solids	0.21	113	2.3	0.02
Temperature	-0.05	117	0.5	0.62
Turbidity	0.40	113	4.7	< 0.001
***E. coli* vs.**				
Conductivity	-0.45	118	5.4	< 0.001
Dissolved Oxygen	0.0	118	0.0	0.99
pH	-0.14	118	1.5	0.14
Suspended Solids	0.23	113	2.6	0.01
Temperature	-0.15	117	1.7	0.09
Turbidity	0.44	113	5.2	< 0.001

[1] - Significance determined by a p-value < 0.05

Section 5
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