TEMPORARY FLOW MONITORING PROGRAM

4.1 INTRODUCTION

Temporary flow meters and rain gauges were installed in order to correlate actual collection system flows with the estimated flows in the hydraulic model. The temporary flow monitoring and rain gauge data is used to calibrate the collection system hydraulic model for DWF and WWF, as well as perform an I/I analysis.

Carollo Engineers, Inc. (Carollo) contracted V&A Consulting Engineers for the flow monitoring effort. The report entitled "Sanitary Sewer Flow Monitoring and Inflow/Infiltration Study," dated August 2007, presents the flow results for each temporary flow meter and rain gauge. This chapter serves to summarize the V&A flow monitoring effort. The V&A report is located in Appendix A.

4.2 FLOW MONITORING OF SEWER BASINS

Four rain gauges and twelve flow meters were used for the flow monitoring effort. Flow monitoring was conducted for approximately three months during the 2006-2007 wet weather season. The temporary flow meters were installed by V&A on February 7, 2007, and removed on May 9, 2007. During flow monitoring, depth and velocity data were collected at each meter and translated into 60-minute intervals to assist the modeling effort and I/I analysis. In addition to the flow meters installed by V&A, flow data from permanent meters were available. Locations of the permanent meters included the City’s Airport and 5th meters as well as SC-OR’s Ruddy Creek Pump Station, Feather River Pump Station, and the WWTP.

The City’s service area was divided into unique sewer basins based on the topographical layout of the sewer system and the location of major sewer pump stations. The temporary flow meters were installed at the terminus of each sewer basin to measure DWF and WWF from each sewer basin. Figure 4.1 presents the flow monitoring and rain gauge locations as well as the sewer basin layout for the City.

Each unique sewer basin is defined by a combination of flow meters that measure the wastewater flowing in and out of the basin. A simplified schematic illustrating the direction of flow and connection between the basins is presented in Figure 4.2.

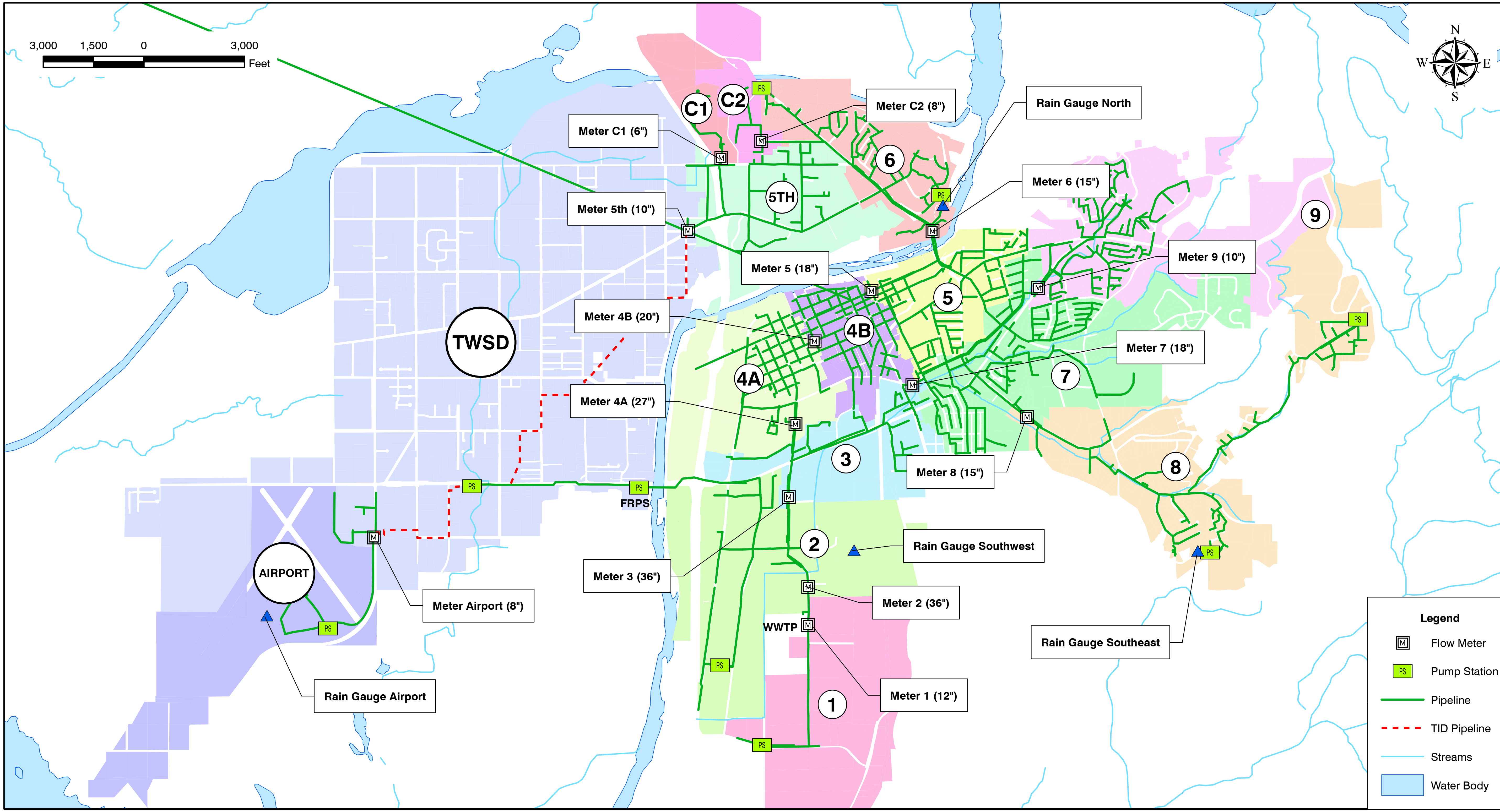
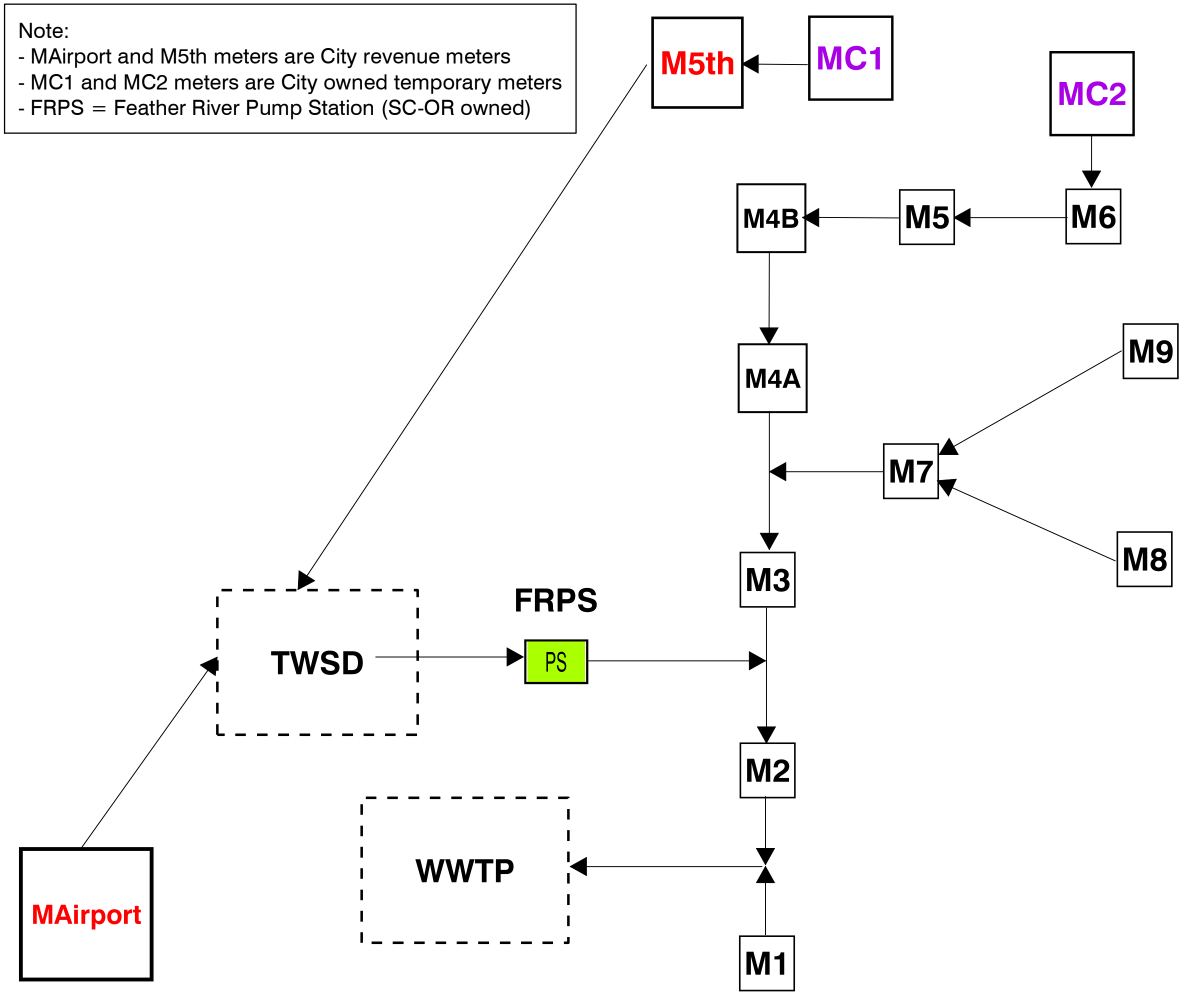


FIGURE 4.1
FLOW METER AND RAIN GAUGE LOCATIONS
SANITARY SEWER MASTER PLAN
CITY OF OROVILLE



Basin Equations

Basin 1 = M1

Basin 2 = M2 - M3 - FRPS

Basin 3 = M3 - M4A - M7

Basin 4A = M4A - M4B

Basin 4B = M4B - M5

Basin 5 = M5 - M6

Basin 6 = M6

Basin 7 = M7 - M8 - M9

Basin 8 = M8

Basin 9 = M9

Basin Airport = MAirport

Basin 5th = M5th

Basin TWSD = FRPS - MAirport - M5th

WWTP = M1 + M2

Figure 4.2
BASIN FLOW SCHEMATIC
SANITARY SEWER MASTER PLAN
CITY OF OROVILLE

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4.3 RAINFALL MONITORING

Three rain gauges were installed during the temporary flow monitoring effort at various locations around the City to capture precipitation data while the flow monitoring was conducted. In addition to the three installed gauges, the existing gauge at the Oroville Airport was also monitored.

The locations of these four rain gauges in relation to the City service area are presented in Figure 4.1.

Four significant rainfall events occurred during the monitoring period. A summary of the four rainfall events captured during the flow monitoring period is presented in Table 4.1. The peak 24-hour duration storms extracted from the four events are characterized as having a frequency of less than 2 years (return period < 2 years). Rainfall can differ across the service area due to the varying topography. Rain gauges Airport and Southwest are located in low-lying areas, whereas rain gauges North and Southeast are in higher elevations.

For the purpose of the hydraulic modeling task, Event No. 2 was used for calibration, while Event No. 1 was used for verification.

Event No. 2 exhibited intense and consistent intensity rainfall over the event duration in slightly saturated soil conditions and is considered most appropriate for the calibration effort because of these characteristics. The other rainfall events were characterized with intermittent intensities.

Event No. 1, which had some intense rainfall and coincided with dry soils, was used to verify the hydraulic model calibration. Event No. 1 exhibits higher instantaneous peaks, but storm runoff volumes were less than Event No. 2.

Table 4.1	Rainfall Events Sanitary Sewer Master Plan City of Oroville						
				Rain Gauge Total (inches)			
Event No.	**Event Period**	**Event Description**	**Estimated Soil Condition**	**North**	**South West**	**South East**	**Airport**
1	Feb 7 - 12	Continuous and relatively intense rainfall.	Mostly dry	3.91	4.07	3.39	3.46
2	Feb 22 - 27	Continuous and relatively intense rainfall in saturated soil conditions.	Slightly Saturated	2.63	2.93	2.07	2.20
3	Mar 26	Light intensity late-season rainfall event.	Slightly Saturated	0.44	0.36	0.26	0.35
4	Apr 21	Light intensity late-season rainfall event.	Slightly Saturated	0.97	1.03	1.02	0.96

Note:
1. Adapted from Table 3 of Sanitary Sewer Flow Monitoring and I/I Report (V&A, August 2007).

4.4 DRY AND WET WEATHER FLOW RESULTS

Flow monitoring results are provided for each flow meter as well as each sewer basin. Each meter was placed in a strategic location that ensured that flow from the basins could be accurately calculated. Depending on the location of the particular meter, it measures flow from portions of, or multiple, sewer basins. The flow attributed to each basin is calculated using a combination of flow meters. A summary of the flow monitoring program, for both DWF and WWF, is presented in Table 4.2, listed by meter. Table 4.3 summarizes the flow monitoring program by basin. A characteristic dry weather period was chosen from the available two months of flow data to perform the DWF calibration. The later portion of the flow monitoring period provided the most characteristic DWF period because it did not include rainfall. The hourly data for the seven days were averaged to provide a typical 24-hour DWF pattern at each meter. This hourly flow data was then used to calibrate the hydraulic model for DWF.

Table 4.2 Flow Monitoring Program[1]
Sanitary Sewer Master Plan
City of Oroville

Meter I.D.	Manhole I.D.	Pipe Diameter (inches)	Dry Weather Flow: Average DWF[2] (mgd)	Dry Weather Flow: Minimum DWF (mgd)	Dry Weather Flow: Peak DWF (mgd)	Wet Weather Flow: PWWF[3] (mgd)	Wet Weather Flow: Flow Depth at PWWF (inches)	Wet Weather Flow: d/D[3]
M1	1A	12	0.0022	0.0013	0.0035	0.25	10.08	0.84
M2[5]	3	36	2.54	0.95	3.85	11.78	30.56	0.85
M3	10	36	1.34	0.66	1.86	4.67	19.71	0.55
M4A	14	27	0.59	0.26	0.84	1.83	10.96	0.41
M4B	27	20	0.36	0.16	0.52	2.43	9.21	0.46
M5	36	18	0.26	0.10	0.37	1.47	9.03	0.50
M6	S10E	15	0.17	0.048	0.26	1.21	4.84	0.32
M7	68	18	0.63	0.32	0.86	3.26	8.04	0.45
M8	102	15	0.10	0.048	0.16	0.64	6.22	0.41
M9	FF9	10	0.33	0.21	0.45	1.42	12.14	>1.0
MC1	PP33B	6	0.056	0.012	0.091	0.14	3.59	0.60
MC2	VV4	8	0.013	0.00072	0.039	0.19	1.85	0.23
Mairport[6]	AP8	8	0.003[7]	0.0013[8]	0.0045[8]	0.60	---	---
M5th[6]	PP2A	10	0.25[7]	0.11[8]	0.37[8]	0.063	---	---
FRPS	FRPS	21	0.68	0.29	0.91	2.20	---	---
WWTP	WWTP	36	2.54	1.12	4.00	9.36	---	---

Notes:
1. Flow monitoring conducted February 7 – May 9, 2007 by V&A.
2. DWF = dry weather flow.
3. PWWF = peak wet weather flow (hourly).
4. d/D = flow depth to pipe diameter ratio.
5. Meter 2 pulled approximately two weeks after installation due to conflicts with nearby construction.
6. Data unreliable due to blockages in channel.
7. Average DWF based on historical values per Rick Walls, Senior Civil Engineer.
8. Minimum and Peak DWF values estimated by multiplying ADWF by the average peaking factors for the other meters.

Table 4.3	Flow Monitoring by Basin Sanitary Sewer Master Plan City of Oroville			
Basin	**ADWF[1] (mgd)**	**Minimum DWF[2] (mgd)**	**Peak DWF (mgd)**	**PWWF[3] (mgd)**
1	0.0022	0.0013	0.0035	0.25
2[4]	0.14	---	---	---
3[5]	0.12	-0.080	0.22	0.77
4A	0.23	0.084	0.34	0.45
4B	0.09	0.042	0.15	0.27
5	0.10	0.047	0.14	0.83
6	0.15	0.042	0.25	0.86
7	0.20	0.052	0.32	1.59
8	0.10	0.048	0.16	0.64
9	0.33	0.21	0.45	1.42
C1	0.056	0.012	0.09	0.14
C2	0.013	0.00072	0.04	0.19
Airport	0.003	0.0013	0.045	0.60
5th[6]	0.19	---	---	---
City Total[7]	1.73	---	---	---

Notes:
1. ADWF = average dry weather flow.
2. DWF = dry weather flow.
3. PWWF = peak wet weather flow.
4. Basin 2 values may not be accurate due to the short two-week monitoring period of Meter 2. Basin 2 = WWTP (SEC) – FRPS – LOAPUD – Meter 1 – Meter 3.
5. Basin 3 Minimum DWF < 0 mgd due to differences between gravity flow of upstream meters and pumped flow at the Feather River Pump Station (FRPS).
6. Basin 5th data not accurate due to blockages at Meter 5th. Basin 5^{th} = Meter 5^{th} – Meter C1.
7. Totals may not add up due to temporal differences in flow due to differing travel times. TWSD not included.

4.5 INFLOW AND INFILTRATION ANALYSIS

There are numerous methods to quantify rainfall dependent infiltration. The initial methods that were used (based only on analysis of flow data), the R-Value method, and the peaking factor method.

The R-Value method is defined as the volume of I/I for the storm event divided by the total volume of rainfall over a basin and is calculated by the following equation:

R-Value Equation: $R = (I/I) / [A * Rain]$

Where:	I/I =	Volume of infiltration and inflow, $ft.^3$
	A =	Area of basin, $ft.^2$
	Rain =	Depth of rainfall, ft.

The calculated R-Values are specific to the storm event being quantified and thus different storm events will yield different values. Collection systems with R-Values less than 5 percent are generally considered to have acceptable infiltration.

The inflow component of rainfall dependent infiltration and inflow (RDI/I) is measured using peaking factors (PFs). PFs define the extent of peak flows in the collection system. The PF method is defined as the hourly PWWF divided by the average DWF. A PF of three is typically used in the design of new sewers. A PF greater than five usually indicates potential inflows into the sewer system. Table 4.4 summarizes the I/I methods used to assess the performance of the City's collection system for the four rainfall events.

Results from the I/I analysis show that the majority of the collection system facilities are displaying few deficiencies. R-Values and PFs include both I/I, however, R-Values tend to better express the severity of infiltration while PFs express the severity of inflow. The system-wide average R-Value was approximately 4.4 percent less than threshold value of 5 percent. Meters 6, 7, and C2 marginally exceeded the threshold, while Meter 9 greatly exceeded the threshold.

The system-wide PF was approximately 3.6, higher than the threshold value of three. However, this is still lower than a PF of five, which indicates more severe inflow problems. Meters 1, 5, 6, 7, 9, and C2 experienced PFs above three, in particular, Meter C2 had a significantly higher PF than the threshold value.

This initial I/I analysis was performed by analyzing flow data (not modeling) and is only an indicator of potential basin level I/I problems. Detailed hydraulic modeling, included in the next chapter, expands on this initial analysis and identifies potential capacity deficiencies on the project level.

Table 4.4 Inflow and Infiltration Analysis
Sanitary Sewer Master Plan
City of Oroville

		Event No. 1[1]			Event No. 2[2]			Event No. 3[3]			Event No. 4[4]		
Basin I.D.	ADWF[5] (mgd)[9]	PWWF[6] (mgd)	PF[7]	R-Value[8] (%)	PWWF (mgd)	PF	R-Value (%)	PWWF (mgd)	PF	R-Value (%)	PWWF (mgd)	PF	R-Value (%)
1	0.0022	0.0014	6.41	0.0	0.01	4.27	0.0	0.003	1.25	0.0	0.006	2.74	0.0
2[10]	2.54	12.36	4.87	2.6	8.79	3.47	4.1	4.76	1.87	0.3	5.03	1.98	0.8
3	1.34	5.23	3.89	2.6	4.43	3.30	4.4	2.37	1.76	0.6	2.49	1.85	0.7
4A	0.59	1.89	3.19	1.6	1.60	2.71	2.2	0.99	1.68	0.2	1.03	1.75	0.8
4B	0.36	1.51	4.17	2.3	1.34	3.70	3.2	0.74	2.03	0.5	0.70	1.93	0.8
5	0.26	1.55	5.91	3.1	1.21	4.61	3.6	0.50	1.91	0.3	0.56	2.14	0.7
6	0.17	1.01	6.09	4.1	0.66	3.97	5.7	0.40	2.40	0.5	0.58	3.45	1.1
7	0.63	3.46	5.47	4.6	2.62	4.14	5.7	1.19	1.88	0.6	1.11	1.76	0.7
8	0.10	0.72	7.07	0.9	0.31	3.00	1.1	0.27	2.67	0.2	0.31	3.08	0.3
9	0.33	1.48	4.54	9.5	1.32	4.05	17.2	0.66	2.01	0.9	0.79	2.43	4.1
C1	0.056	0.13	2.32	1.8	0.15	2.66	1.9	0.12	2.05	0.2	0.13	2.25	0.6
C2	0.013	0.27	20.99	6.0	0.19	14.47	6.0	0.09	6.64	1.3	0.17	13.16	3.1

Notes:
1. Event No. 1 occurred over a 6-day period from February 7-12, 2007.
2. Event No. 2 occurred over a 6-day period from February 22-27, 2007.
3. Event No. 3 occurred over a 6-hour period on March 26, 2007.
4. Event No. 3 occurred over a 36-hour period from April 21-22, 2007.
5. ADWF = Average Dry Weather Flow.
6. PWWF = Peak Wet Weather Flow (hourly).
7. PF = Peaking Factor = PWWF/ADWF.
8. R-Value is the percentage of rainfall that permeates into the sewer system.
9. mgd = millions gallons per day.
10. Values for Basin 2 may not be accurate since only two weeks of data was collected. The remaining data was synthesized.