TABLE 15 – (continued)

Structural Point Repair Project Recommendations

Problem Number	Severity	Description	Project Type	Ref.	Estimated Cost
5-171-80.9	Heavy	Heavy mineral deposits at lateral connection joint, lateral approximately 50 percent blocked	Side Sewer Tee Repair	TV-513	$11,580
5-185-81.6	Heavy	Heavy mineral deposits within lateral; unable to determine if it is active; stones visible	Side Sewer Tee Repair	TV-620	$11,580
5-67.1-43.9	Heavy	Large offset joint in lateral	Side Sewer Tee Repair	TV-641	$11,580
5-76-26.0	Heavy	Heavy broken joint- visible soil- large offset joint in lateral	Side Sewer Tee Repair	TV-658	$11,580
3-52-102	Medium	Pipe damage at lateral connection w/ main-lateral has dropped or shifted down; light infiltration	Side Sewer Tee Repair	TV-10	$11,580
5-77.1-0	Heavy	Heavily grouted joint- survey abandoned	Side Sewer Point Repair	TV-665	$8,400
5-77.1-21.4	Heavy	Large separated joint	Side Sewer Point Repair	TV-666	$8,400
5-77.1-21.4	Heavy	Visible soil through joint separation- infiltration runner	Side Sewer Point Repair	TV-667	$8,400
5-77.1-21.4	Heavy	Survey abandoned	Side Sewer Point Repair	TV-668	$8,400
5-196-8.8	Heavy	Break in concrete pipe, soil is visible through break	Side Sewer Point Repair	TV-675	$8,400
5-188-24.3	Heavy	Heavy mineral deposits	Side Sewer Point Repair	TV-692	$8,400
5-183-13.9	Heavy	Heavy mineral deposits	Side Sewer Point Repair	TV-707	$8,400

MULTIPLE PROBLEM AREA REPAIRS

Many of the problems identified as a part of this study were located adjacent to other problems in the same run of sewer pipe. Of the 847 problems identified as a part of this study, 444 of them are located in the 55 runs of sewer pipe containing five or more problems. Some of these runs of pipe with multiple problems are better suited for total line rehabilitation or replacement instead of individual repair projects. Table 16 shows project recommendations for repair or rehabilitation of the pipe runs with multiple problems.

TABLE 16

Multiple Problem Run Project Recommendations

Up-stream MH	Down-stream MH	# of Problems	Repair/ Rehabilitation Method	Notes	Project Cost
5-189	5-187	11	Open Cut	5 Heavy problems	$81,900
5-27	5-26	13	Open Cut/Cured-in-Place Pipe	Offset joints should be repaired prior to CIPP	$44,775
5-182	5-181	11	Cured-in-Place Pipe		$22,935
5-179	5-178	10	Cured-in-Place Pipe	Offset joints should be repaired prior to CIPP	$48,180
5-184	5-183	9	Cured-in-Place Pipe		$42,075
5-41.1	5-40	16	Cured-in-Place Pipe	Offset joints can be repaired prior to CIPP	$66,990
5-42	5-41.1	9	Cured-in-Place Pipe	Cracks and holes in pipe	$66,000
5-89	5-88	11	Pipe Grouting	Numerous leaking pipe joints	$ 9,675
5-15	5-14	18	Pipe Grouting	Numerous leaking pipe joints	$6,925
5-67.1	5-67	13	Pipe Grouting	Does not necessarily repair leaking lateral connections	$7,500
5-67	5-44	19	Pipe Grouting	Offset joint should be repaired and roots removed prior to grouting	$8,700
5-28	5-26	9	Pipe Grouting	Infiltration of pipe joints	$10,750
5-25	5-24	8	Pipe Grouting	Infiltration and mineral deposits at pipe joints	$10,050
5-10	5-9	8	Pipe Grouting	Infiltration of pipe joints	$10,100

Table 17 above gives some recommendations for multiple pipe run repair or rehabilitation projects. Open cut repair was recommended for pipe runs which have a large number of offset joints and other structural problems. Cured-in-place pipe rehabilitation was recommended for pipe runs which have numerous cracks or holes in the pipe and can benefit from a new pipe liner. Some projects recommended for cured-in-place pipe rehabilitation include offset joints that should be repaired before the pipe is lined. Pipe grouting rehabilitation was recommended for pipe runs which have larger numbers of leaky joints. However, this technique does not provide any structural properties. Fold and Form Pipe rehabilitation can be used interchangeably with cured-in-

place pipe rehabilitation, but, CIPP is the more commonly used technique. Sliplining was not recommended for any projects because it reduces the diameter and capacity of the pipe. Pipe bursting was not recommended for any projects. If the City determines a pipe line needs to be upsized, pipe bursting should be considered for repair if the soils are suitable. Pipe runs in vicinity to each other and using the same repair/rehabilitation method can be combined as projects to lower costs.

For budgeting purposes, we used a cost of $225 per lineal foot for open cut pipe replacement, $165 per lineal foot for cured-in-place pipe repair, and $25 per lineal foot for pipe grouting repair. Project specifics such as number of side sewer connections, temporary pumping requirements, traffic control, and surface restoration will vary with each pipe repair/rehabilitation project. Exact project costs should be re-examined prior to construction.

CITY CODE

Inflow influenced I/I was measured at 15.00 MGD or an increase of 532 percent over the average base sanitary sewer flow. The largest source of inflow entering the sanitary sewer system located during this study was the illicit connections of roof drains, gutters, and yard drains. The City code currently states in Section 14.12.060 that "*No person shall discharge or cause to be discharged any storm water, surface water, ground water, roof runoff, subsurface drainage, cooling water or untreated industrial process waters into any sanitary sewer*." Although illicit stormwater connections to sewer system are prohibited, the City code does not lay out a clear approach for enforcement. An analysis of the City's code regarding illicit connections to the sanitary sewer system and code from other City's and County's in Washington State can be seen in Appendix I.

We recommend the City review their code regarding illicit connections to the sanitary sewer system and develop a strategy for enforcement of the code and removal of sources identified. A number of City's codes regarding illicit connections to the sanitary sewer system as well as a discussion of options for the enforcement and removal of illicit connections can be found in Appendix I.

APPENDIX A

FLOW MONITORING

BACKGROUND

The first phase of the I/I study consisted of flow monitoring. Flow monitoring was used to determine the extent and general locations of the I/I and to identify areas for further investigation.

FLOW METER LOCATIONS

Twelve flow meters were installed simultaneously throughout the City. The City was divided up into eleven drainage basins with the twelfth flow meter placed on 76th Avenue before the sewer enters the WWTP. The period of flow monitoring began on December 23, 2008, and ended on March 16, 2009. The locations of the flow meters can be seen in Figure A-1. A schematic representation of the City's sewer system showing each of the flow meter basins can be seen in Figure A-2. More detailed information on the installation and location of each of the flow meters can be seen at the end of Appendix A. Table A-1 summarizes information about each of the flow meters.

TABLE A-1

Flow Meter Locations

Flow Meter	Manhole	Area (acres)	Drainage Basin
1	16-91	338	Lift Station #8
2	16-3	367	Lift Station #10
3	3-3	346	Lift Station #10
4	3-2	520	Lift Station #10
5	4-45	247	Lift Station #10
6	3-106.1	726	Lift Station #10
7	1-25	280	Lift Station #12
8	11-2	420	Lift Station #12
9	7-117	464	NE Gravity
10	7-1	296	NW Gravity
11	6-38.1	110	W Gravity
12	8-10	4,900	To WWTP

PRECIPITATION DATA

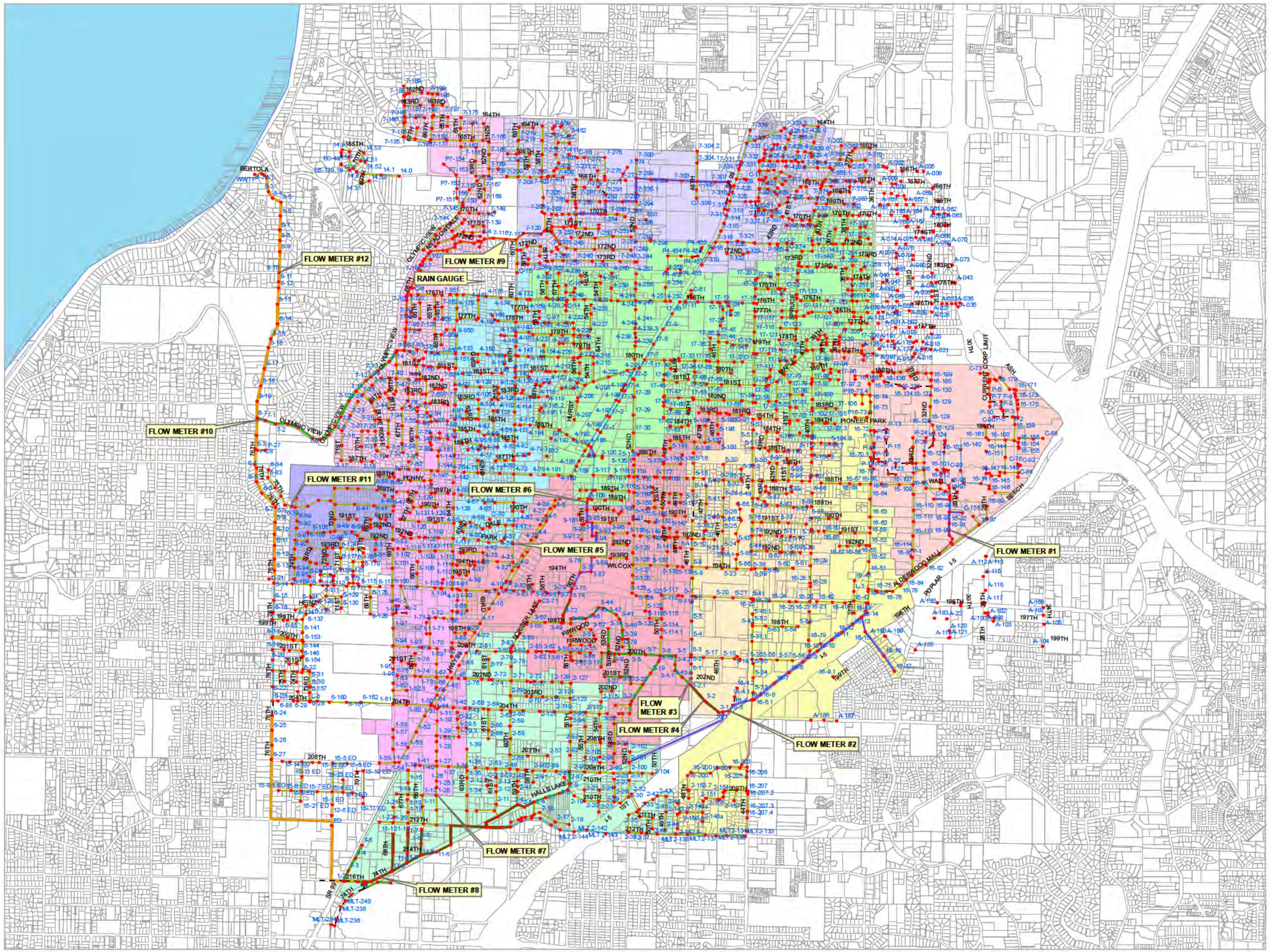
The Maple Park rain gauge data was used to measure precipitation during the flow monitoring period. This rain gauge is located off 62nd Avenue West just north of 176th Street SW and can be seen in Figure A-1. The rain gauge is a part of a personal weather station operated by the Cascade and Pacific Railway and linked through King 5 weather. The weather station measures the precipitation every 5 minutes. We also installed two rain gauges during the flow monitoring period, at the City Shop and in a storm drainage pond located off 172nd Street. In addition, we received precipitation information from the

rain gauge located at the Wastewater Treatment Plant (WWTP). These additional sources of rain gauge data were used to compare with the Maple Park rain gauge. The Maple Park rain gauge data was used in our analysis because it provided a more complete record of precipitation before the flow monitoring period. Figure A-3 shows the daily precipitation during the flow monitoring period.

Based on the results shown in Figure A-3, only 4 days during the monitoring period exceeded 0.3 inch of rain, 23 days ranged from 0.1 to 0.3 inch of rain, and the remaining 57 days had less than 0.1 inch of rain. The flow monitoring period had a significant period of dry weather and 47 days had no rain. The only significant precipitation event during the flow monitoring period took place during January 7th and 8th, 2009 with daily precipitation of 0.91 and 0.13 inch, respectively. We compared the January 7th, 2009 rain event of 0.91 inches with rain gauge information from March 2007 through March 2009 and it was seen to be the 4th largest rain event in the 2-year period. The largest event was a 3.21-inch rain event on December 3, 2007, following a 1.71-inch rain event on December 2, 2007. The December 2007 rain events caused significant flooding in western Washington and the closure of Interstate 5 south of Olympia for 2 weeks.

PIPE MATERIALS

The Lynnwood wastewater collection system is comprised of a number of types of pipe materials including concrete, polyvinyl chloride (PVC), high density polyethylene (HDPE), and ductile iron. The majority of the system constructed in the 1960s and 1970s is concrete pipe. Concrete pipe is rarely used for sewer anymore with PVC being the standard construction material. Older concrete pipe is known to have problems with I/I. The pipe materials in each of the flow meter basins are summarized below in Table A-2 and Figure A-4. Also shown is the percentage of each type of material in the basins.



LEGEND:

- SEWER MANHOLES

SEWERLINES:

- unknown
- 6 in
- 8 in
- 10 in
- 12 in
- 15 in
- 18 in
- 21 in
- 24 in
- PARCELS

FLOW METER BASINS:

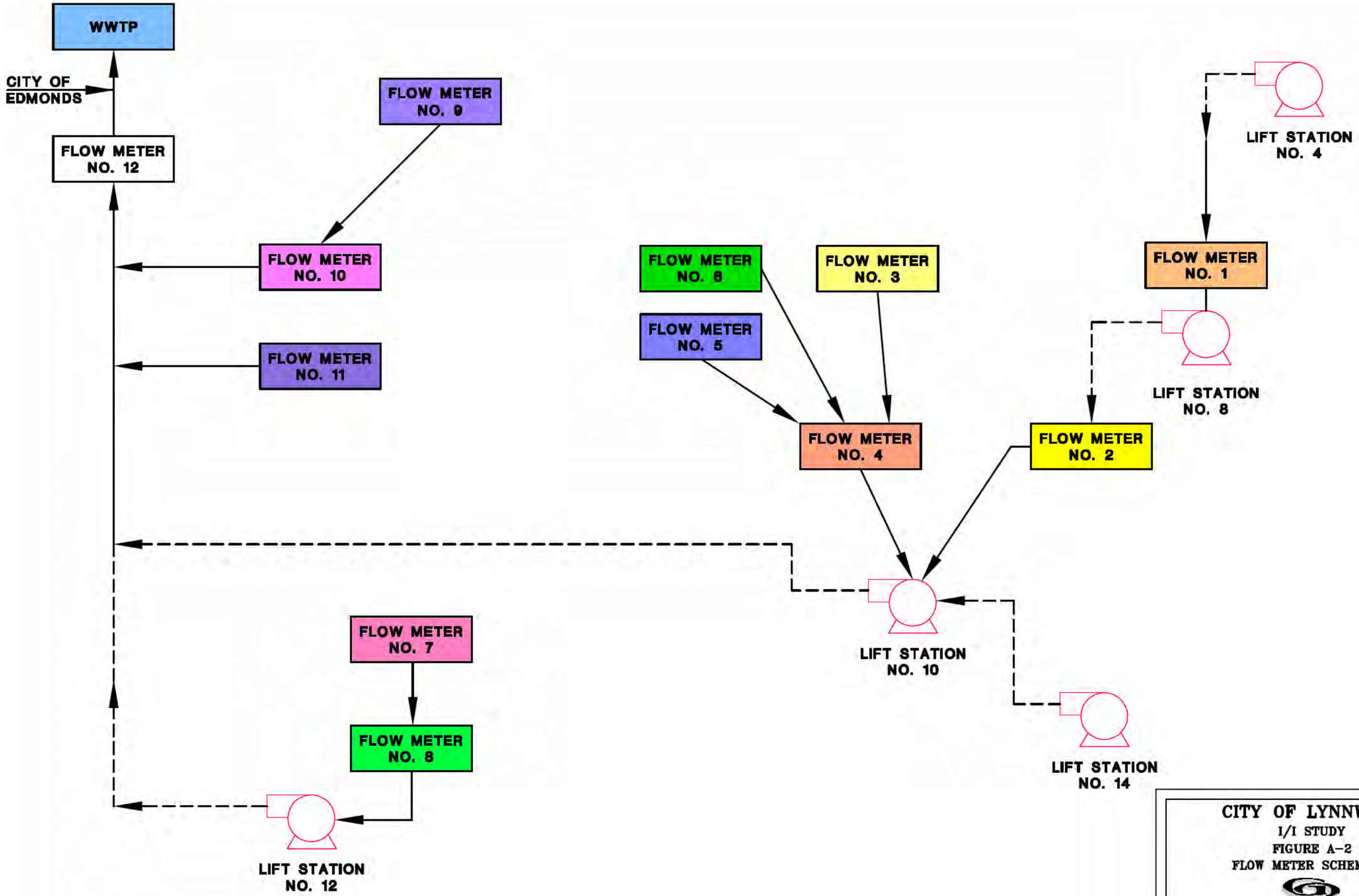
- BASIN #1 - 338 ACRES
- BASIN #2 - 356 ACRES
- BASIN #3 - 320 ACRES
- BASIN #4 - 511 ACRES
- BASIN #5 - 250 ACRES
- BASIN #6 - 722 ACRES
- BASIN #7 - 285 ACRES
- BASIN #8 - 463 ACRES
- BASIN #9 - 464 ACRES
- BASIN #10 - 295 ACRES
- BASIN #11 - 110 ACRES

CITY OF LYNNWOOD

FIGURE A-1
FLOWMETER LOCATIONS
WASTEWATER COLLECTION SYSTEM

Gray & Osborne, Inc.
CONSULTING ENGINEERS

L:\Lynnwood\09624 I&I Study\GIS\FIGURE_A-1.mxd



CITY OF LYNNWOOD
I/I STUDY
FIGURE A-2
FLOW METER SCHEMATIC

Gray & Osborne, Inc.
CONSULTING ENGINEERS

L:\LYNNWOOD\08624 I&I STUDY\REPORT\APPENDIX A_FLOW MONITORING RESULTS REPORT\FIGURES\SCHEMATIC.DWG, FIGURE A-2, 2/7/2011 7:51:26 AM, I:I, BY: MSEIDEL

Figure A-3

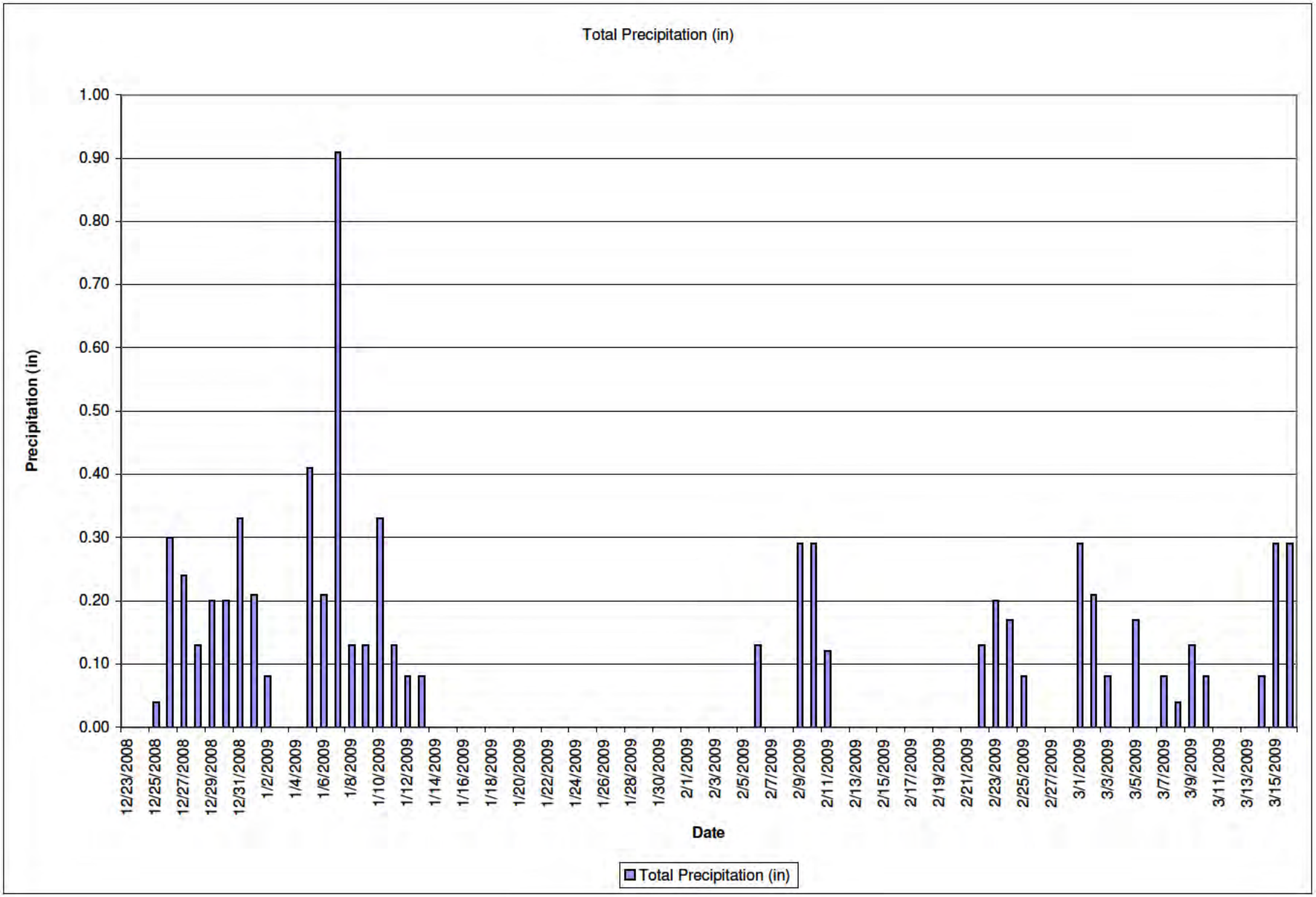

Total Precipitation (in)
Precipitation (in)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
12/23/2008
12/25/2008
12/27/2008
12/29/2008
12/31/2008
1/2/2009
1/4/2009
1/6/2009
1/8/2009
1/10/2009
1/12/2009
1/14/2009
1/16/2009
1/18/2009
1/20/2009
1/22/2009
1/24/2009
1/26/2009
1/28/2009
1/30/2009
2/1/2009
2/3/2009
2/5/2009
2/7/2009
2/9/2009
2/11/2009
2/13/2009
2/15/2009
2/17/2009
2/19/2009
2/21/2009
2/23/2009
2/25/2009
2/27/2009
3/1/2009
3/3/2009
3/5/2009
3/7/2009
3/9/2009
3/11/2009
3/13/2009
3/15/2009
Date
Total Precipitation (in)

Figure A-4

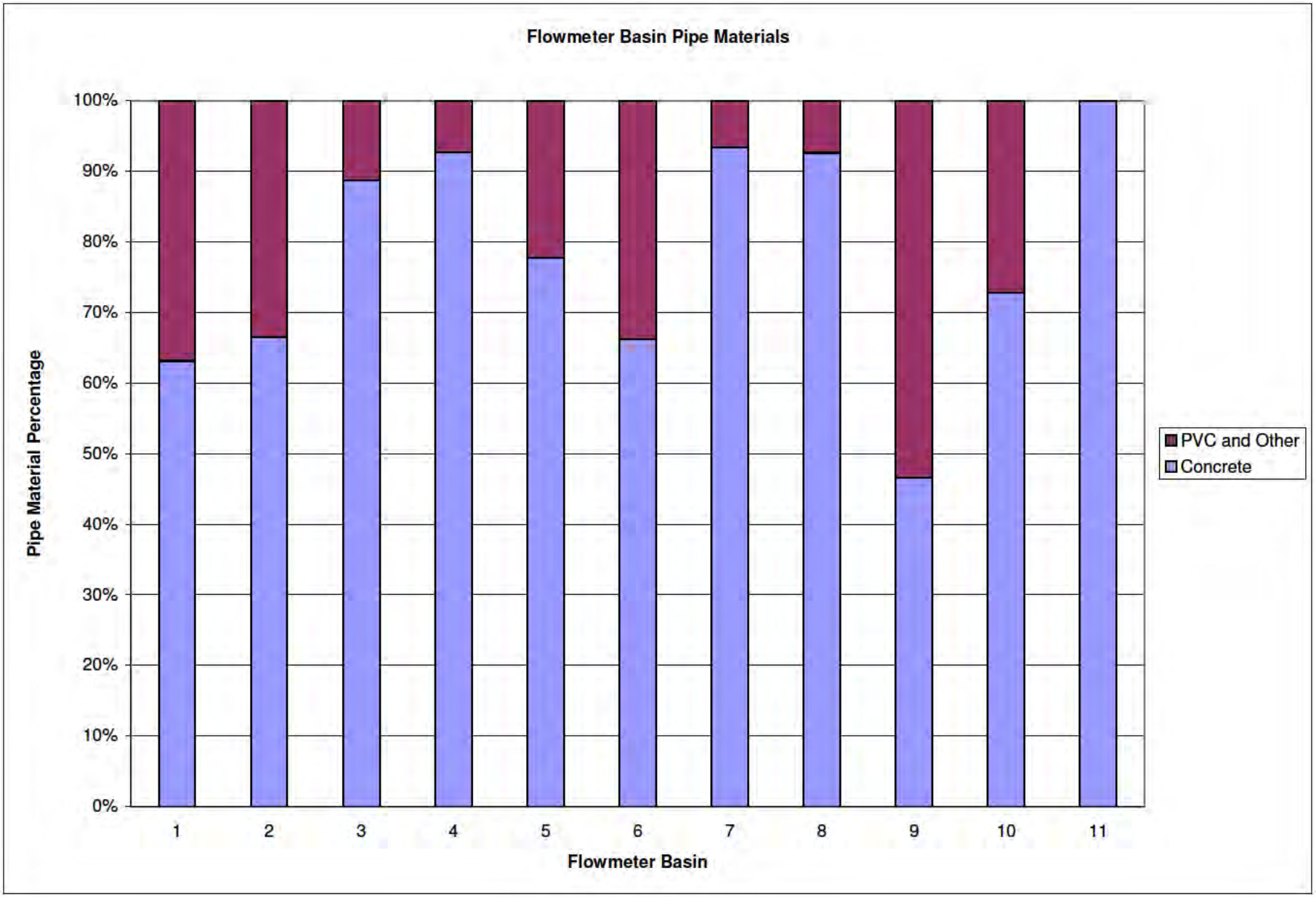

Flowmeter Basin Pipe Materials
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pipe Material Percentage
1
2
3
4
5
6
7
8
9
10
11
Flowmeter Basin
PVC and Other
Concrete

TABLE A-2

Flow Meter Basin Pipe Materials

Flow Meter Basin	Pipe Material	Length	% of System
1	Concrete	22,421	63.1%
	PVC	6,837	19.2%
	Other	6,291	17.7%
	Total =	35,549	
2	Concrete	16,911	66.5%
	PVC	8,144	32.0%
	Other	377	1.5%
	Total =	25,432	
3	Concrete	34,304	88.7%
	PVC	3,765	9.7%
	Other	620	1.6%
	Total =	38,689	
4	Concrete	53,750	92.7%
	PVC	3,433	5.9%
	Other	808	1.4%
	Total =	57,991	
5	Concrete	26,565	77.7%
	PVC	7,609	22.3%
	Other	0	0.0%
	Total =	34,174	
6	Concrete	56,506	66.2%
	PVC	28,275	33.1%
	Other	518	0.6%
	Total =	85,299	
7	Concrete	36,500	93.3%
	PVC	2,154	5.5%
	Other	464	1.2%
	Total =	39,118	
8	Concrete	48,948	92.6%
	PVC	3,906	7.4%
	Other	0	0.0%
	Total =	52,854	
9	Concrete	27,591	46.6%
	PVC	30,565	51.7%
	Other	1,006	1.7%
	Total =	59,162	
10	Concrete	35,675	72.8%
	PVC	13,318	27.2%
	Other	30	0.1%
	Total =	49,022	
11	Concrete	15,029	100.0%
	PVC	0	0.0%
	Other	0	0.0%
	Total =	15,029	

FLOW MONITORING ANALYSIS

Flow monitoring began on December 23, 2008, and concluded on March 16, 2009. The flow meters recorded readings every 15 minutes. Each of the twelve flow meter basins have been analyzed for I/I using data from the flow meters and precipitation records. Flow meter data has been summarized for both the peak day I/I and the instantaneous I/I. Graphs of I/I values for each flow meter are shown as follows.

PEAK DAY INFILTRATION

The peak day analysis was used to analyze the infiltration component of I/I. Infiltration is groundwater entering a sewer pipe by means of defective pipes, pipe joints, or manhole walls. Infiltration quantities exhibit seasonal variation in response to groundwater levels. Storm events trigger a rise in the groundwater levels and increase infiltration. The greatest infiltration is observed following significant storm events with prolonged periods of precipitation. After a careful review of the records, we determined the best time to look at infiltration for the flow monitoring period was January 11, 2009. This day follows several days of continued precipitation after the large January 7, 2009 storm event as seen in Figure A-3. Flow monitoring data was obtained for eight of the twelve flow meters for this precipitation event.

Daily flow meter data has been compiled and graphed for each basin with precipitation records shown as an overlay. Also shown on the graph is the average dry weather flow through each flow meter for the entire flow monitoring period. The basis for the average dry weather flow is for days with at least 3 prior days without any rain. The peak day I/I has been calculated by comparing the difference between the daily flow for the January 11, 2009 rain event with the average dry weather flow.

INSTANTANEOUS INFLOW

The instantaneous analysis was used to analyze the inflow component of I/I. Inflow is the surface water entering the sewer system from yard, roof, and footing drains, from cross connections with storm drains, through holes in manhole covers, and through illicit connections to the sanitary sewer system. Peak inflow occurs during heavy storm events when storm sewer systems are taxed beyond their capacity, resulting in hydraulic backups and local ponding. As discussed earlier, the only significant precipitation event during the flow monitoring period took place during January 7th and 8th, 2009 with daily precipitation of 0.91 and 0.13 inch, respectively. Because of difficulties installing the flow meters due to snow only four of the twelve flow meters had been installed and were operating during the January 7th and 8th storm event.

The January 7th and 8th I/I occurrences are shown in graph form as hourly flow versus hourly precipitation. Also shown on each graph is a dry weather diurnal curve established from the flow meter data collected during the study period of this project. The dry weather diurnal curve was established using flow from days with at least 3 days

prior without any rain. The hourly flows of each of these dry weather days were averaged to produce this diurnal curve. The peak instantaneous I/I has been calculated by comparing the difference between the peak instantaneous flow for the January 7th and 8th rain event and the dry weather diurnal curves previously described.

FLOW METERS

Flow Meter #1

Flow Meter #1 measures the flows that are received by Lift Station No. 8 and includes the flow from the Alderwood Mall area. Figures A-5 and A-6 are used to compare the Peak Day I/I and Instantaneous I/I for Flow Meter #1 respectively. As seen in Figure A-5, the total flows in this basin are low. The flows are seen to be higher on the weekends when the Alderwood Mall has more use. Based on the graphs shown in Figure A-5, there is no clear indication of infiltration or inflow during rain events. The highest daily flow event on January 31, 2009 is during a dry weather period and is also likely associated with higher use at the Alderwood Mall. Figure A-6 shows the instantaneous flows for the basin compared to the January 7th and 8th rain event. The flow during this period is similar to the dry weather diurnal flows, indicating minor I/I concerns.

Flow Meter #2

Flow Meter #2 measures the flows from Lift Station No. 8 force main and also from a gravity portion of the City's older sewer system from 36th Avenue and 40th Avenue. Flow Meter #2 sits upstream of Lift Station No. 10. Figure A-7 shows the daily flows compared to the daily precipitation through this flow meter. As seen in Figure A-7, the higher flow days do no correlate to the rain events. The I/I for this flow meter cannot be calculated and compared to other basins since neither the January 7th and 8th inflow influenced or January 11th infiltration influenced rain events were not captured.

Flow Meter #3

Flow Meter #3 measures the flows from a portion of the City's older sewer system that flows down 48th Avenue. Figures A-8 and A-9 are used to compare the Peak Day I/I and Instantaneous I/I for Flow Meter #3, respectively. Figure A-8 shows a clear sign of infiltration and inflow. The highest daily flows follow the larger rain events. The daily flows are particularly high after the early January rain events. Figure A-9 shows the instantaneous flows for the basin compared to the January 7th and 8th rain event. The flow during this period is significantly higher than the dry weather diurnal flow. This indicates that inflow into the sewer system was occurring during this storm event.

Flow Meter #4

Flow Meter #4 measures the flow from a large area that feeds into Lift Station No. 10 and includes the flows measured by Flow Meters #3, #5, and #6. Flow Meter #4 sits downstream from the sewer line that goes through the Scriber Lake area. Figure A-10 shows the daily flows compared to the daily precipitation through this flow meter. The I/I for this flow meter cannot be calculated and compared to other basins since the early January rain events were not captured.

Flow Meter #5

Flow Meter #5 measures the flow from a portion of the City's older sewer system that flows down 60th Avenue before crossing under Highway 99 and flowing to Lift Station No. 10. Figures A-11 and A-12 are used to compare the Peak Day I/I and Instantaneous I/I for Flow Meter #5, respectively. The flows through this basin are fairly small. Figure A-11 shows a clear sign of infiltration and inflow in this basin. The flows after the rain event slowly trend back towards the dry weather flows indicating the presence of both infiltration and inflow. Figure A-12 shows the instantaneous flows for the basin compared to the January 7th and 8th rain event. The flow during this period is significantly higher than the dry weather diurnal flow. The peak flow follows the end of the January 7th and 8th rain event indicating the presence of inflow.

Flow Meter #6

Flow Meter #6 measures the flow from a portion of the City's older sewer system the majority of which comes from the pipes around Highway 99. This basin flows downstream and is measured by Flow Meter #4 and eventually flows into Lift Station No. 10. Figure A-13 shows the daily flows compared to the daily precipitation through this flow meter. The I/I for this flow meter cannot be calculated and compared to other basins since very little data was captured.

Flow Meter #7

Flow Meter #7 measures the flows that come down 66th Avenue SW and flows into Lift Station No. 12. Figure A-14 shows the daily flows compared to the daily precipitation through this flow meter. Figure A-14 shows infiltration and inflow with the daily flows increasing slightly after all of the rain events. However, the I/I for this flow meter cannot be quantified and compared to other basins since the January 7th and 8th inflow influenced and January 11th infiltration influenced rain events were not captured.

Flow Meter #8

Flow Meter #8 measures the majority of the flows that come into Lift Station No. 12. Figure A-15 shows the daily flows for Flow Meter #8 compared to the daily precipitation. Figure A-15 shows infiltration and inflow with the daily flows increasing after all of the

Figure A-5

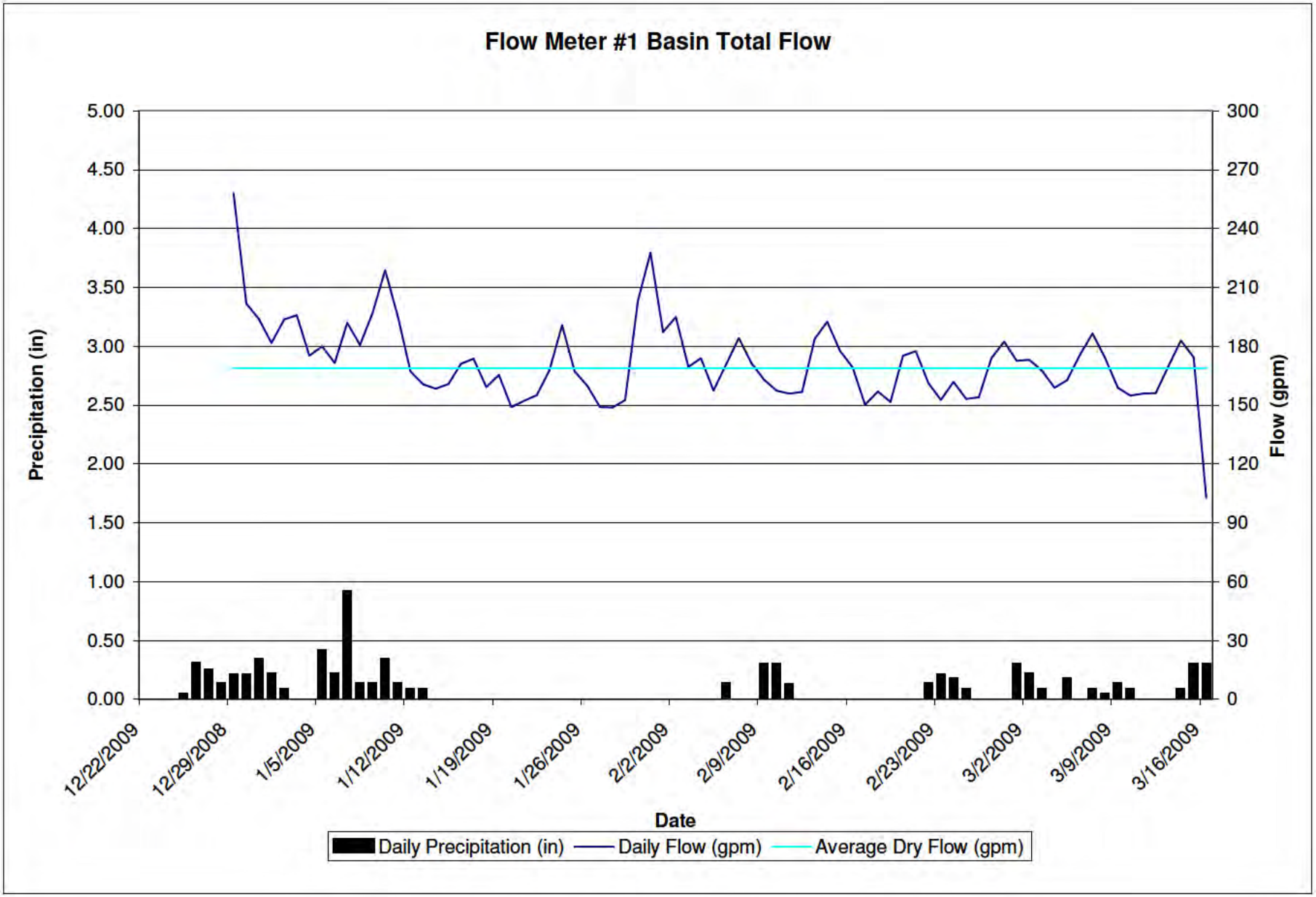

Flow Meter #1 Basin Total Flow
Precipitation (in)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Flow (gpm)
300
270
240
210
180
150
120
90
60
30
0
12/22/2009
12/29/2008
1/5/2009
1/12/2009
1/19/2009
1/26/2009
2/2/2009
2/9/2009
2/16/2009
2/23/2009
3/2/2009
3/9/2009
3/16/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-6

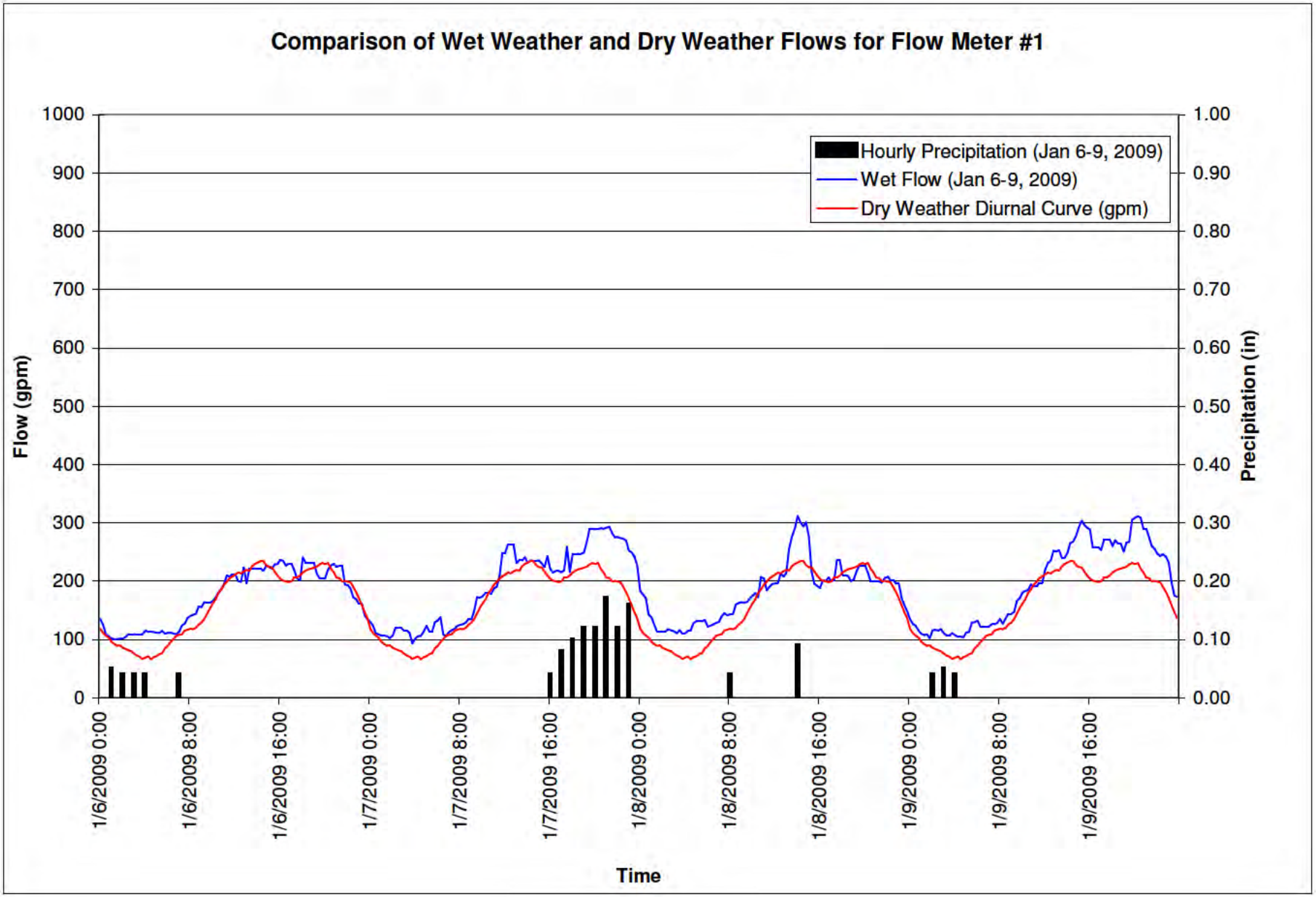

Comparison of Wet Weather and Dry Weather Flows for Flow Meter #1
Hourly Precipitation (Jan 6-9, 2009)
Wet Flow (Jan 6-9, 2009)
Dry Weather Diurnal Curve (gpm)
Flow (gpm)
Precipitation (in)
Time
1000
900
800
700
600
500
400
300
200
100
0
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1/6/2009 0:00
1/6/2009 8:00
1/6/2009 16:00
1/7/2009 0:00
1/7/2009 8:00
1/7/2009 16:00
1/8/2009 0:00
1/8/2009 8:00
1/8/2009 16:00
1/9/2009 0:00
1/9/2009 8:00
1/9/2009 16:00

Figure A-7

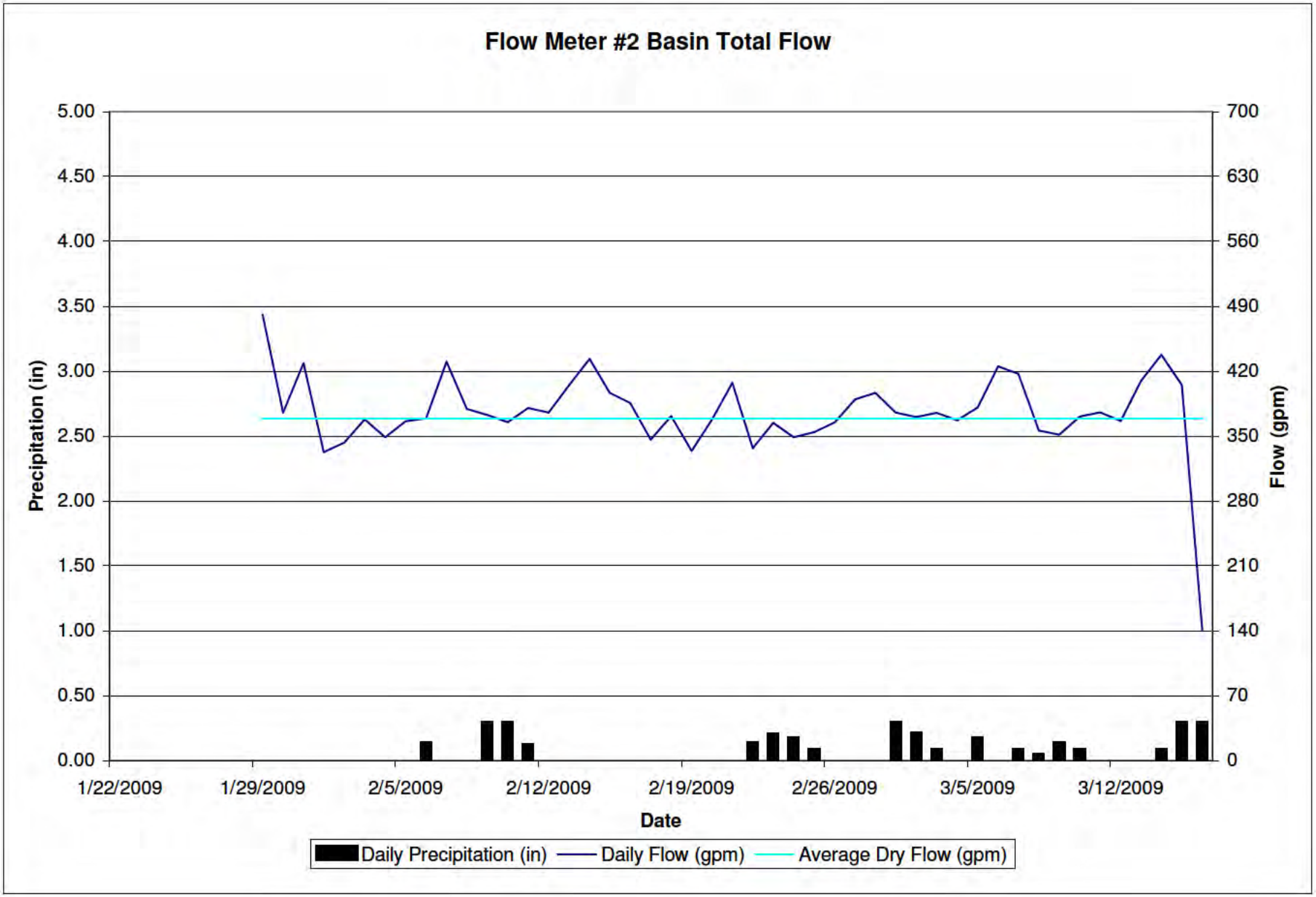

Flow Meter #2 Basin Total Flow
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Precipitation (in)
700
630
560
490
420
350
280
210
140
70
0
Flow (gpm)
1/22/2009
1/29/2009
2/5/2009
2/12/2009
2/19/2009
2/26/2009
3/5/2009
3/12/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-8

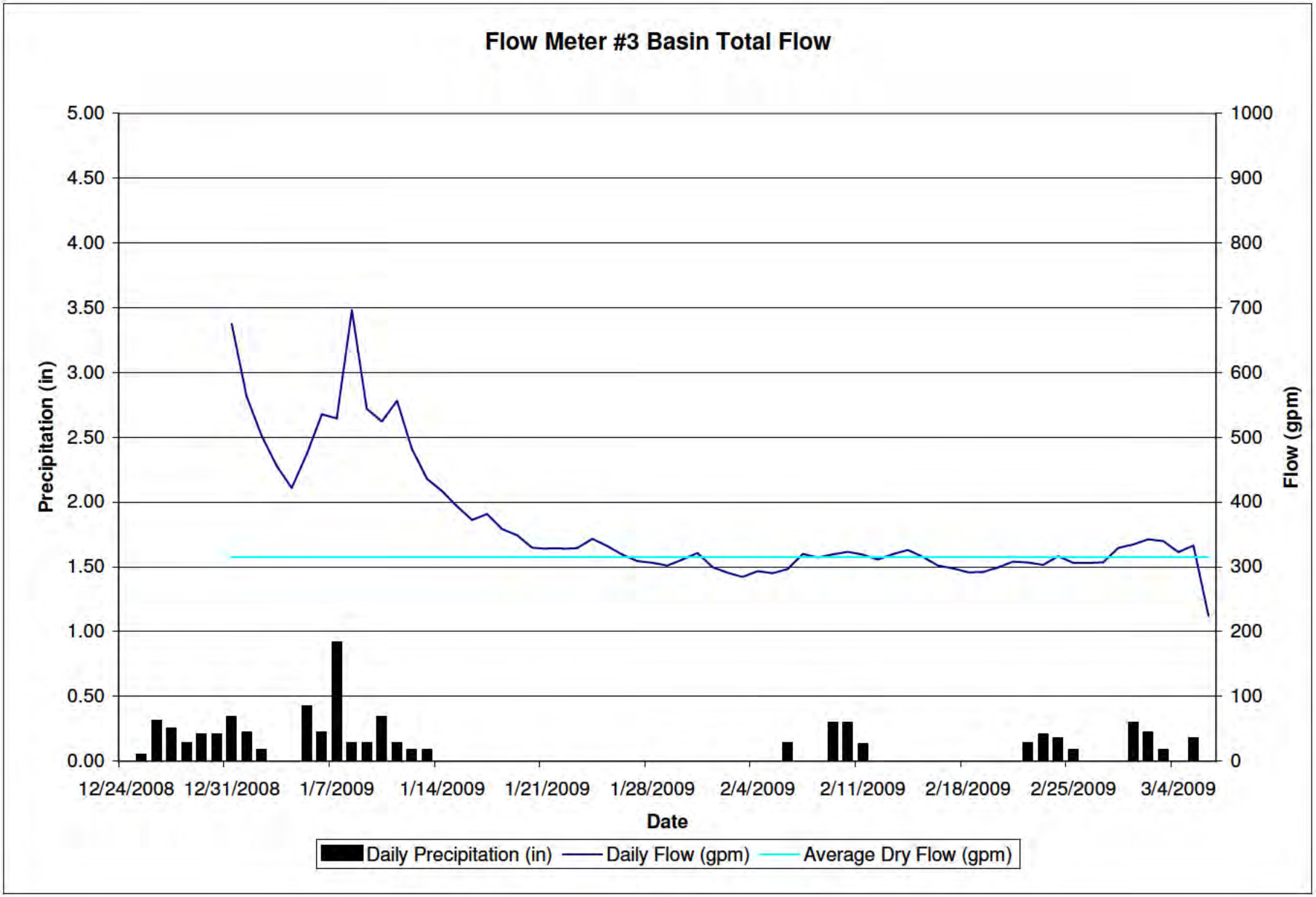

Flow Meter #3 Basin Total Flow
Precipitation (in)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Flow (gpm)
1000
900
800
700
600
500
400
300
200
100
0
12/24/2008
12/31/2008
1/7/2009
1/14/2009
1/21/2009
1/28/2009
2/4/2009
2/11/2009
2/18/2009
2/25/2009
3/4/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-9

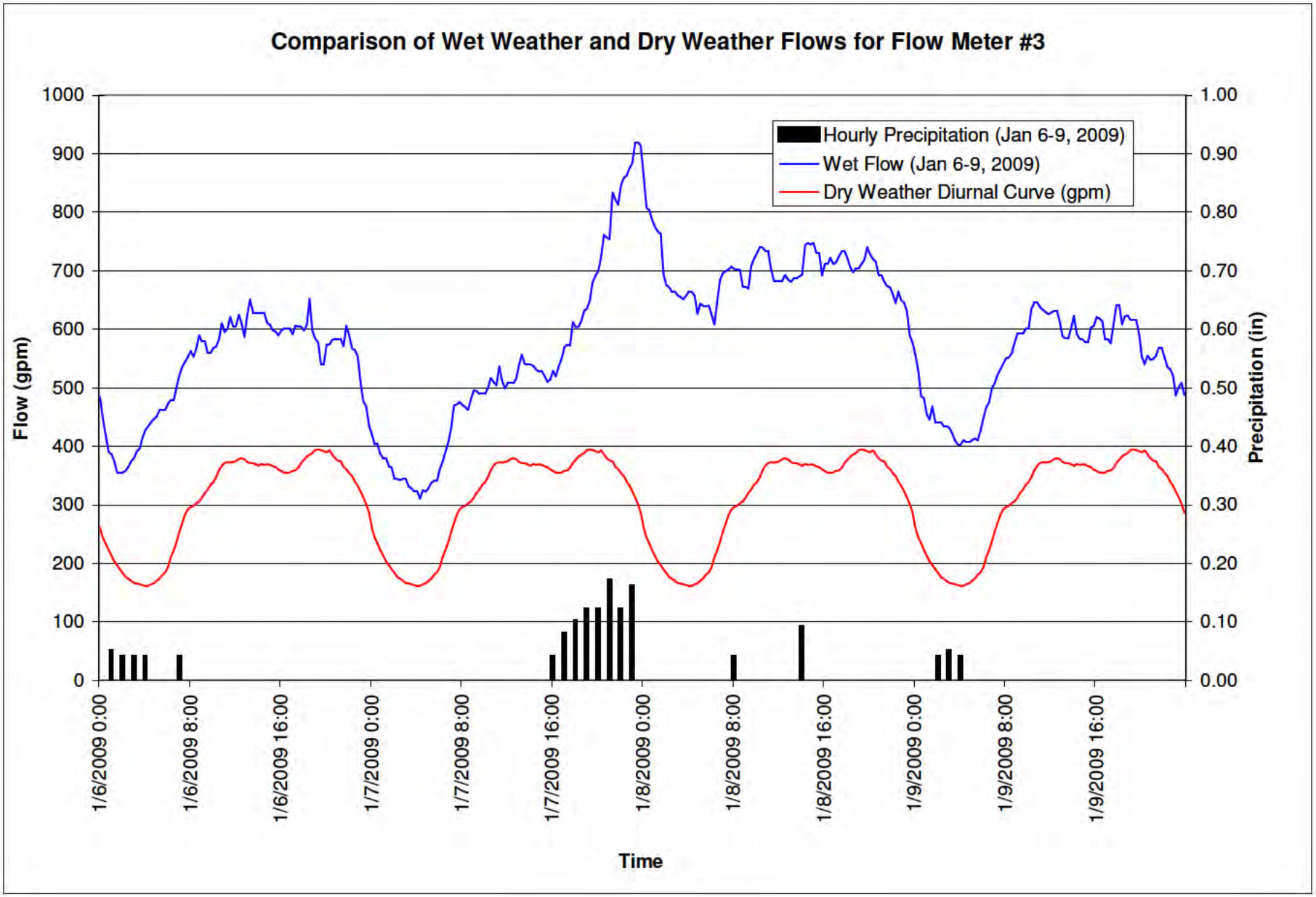

Comparison of Wet Weather and Dry Weather Flows for Flow Meter #3
Hourly Precipitation (Jan 6-9, 2009)
Wet Flow (Jan 6-9, 2009)
Dry Weather Diurnal Curve (gpm)
Flow (gpm)
Precipitation (in)
Time
1000
900
800
700
600
500
400
300
200
100
0
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1/6/2009 0:00
1/6/2009 8:00
1/6/2009 16:00
1/7/2009 0:00
1/7/2009 8:00
1/7/2009 16:00
1/8/2009 0:00
1/8/2009 8:00
1/8/2009 16:00
1/9/2009 0:00
1/9/2009 8:00
1/9/2009 16:00

Figure A-10

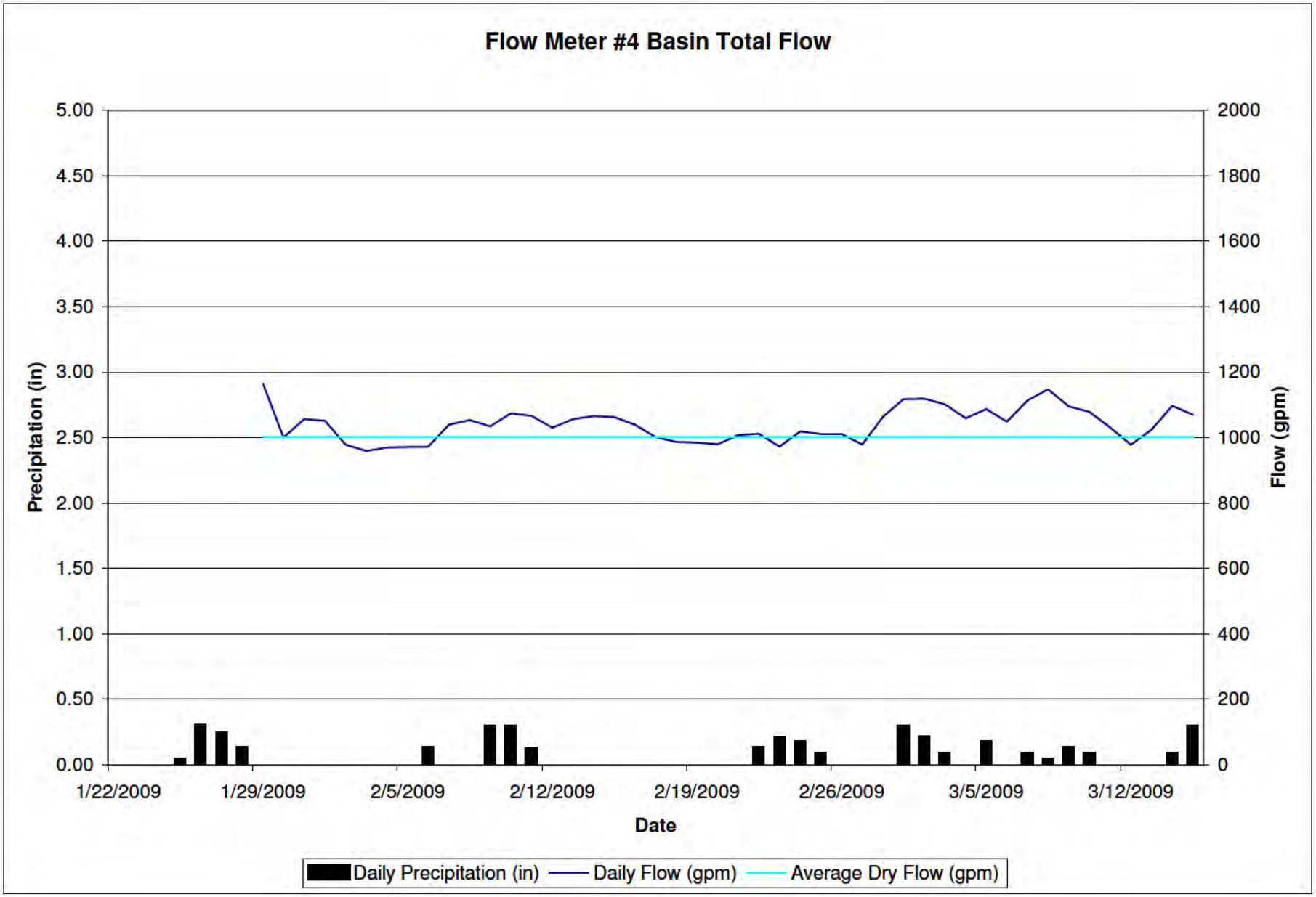

Flow Meter #4 Basin Total Flow
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Precipitation (in)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Flow (gpm)
1/22/2009
1/29/2009
2/5/2009
2/12/2009
2/19/2009
2/26/2009
3/5/2009
3/12/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-11

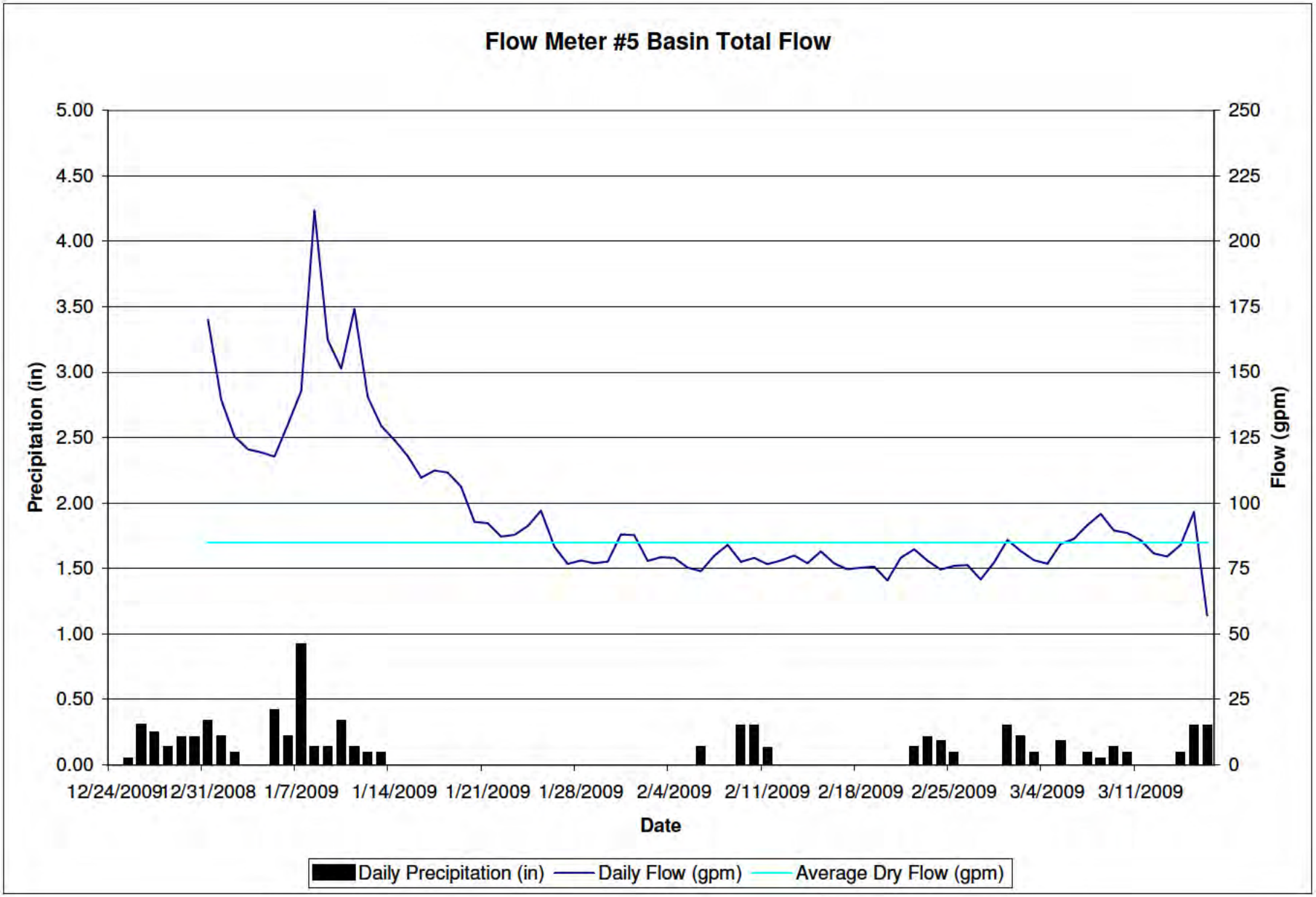

Flow Meter #5 Basin Total Flow
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Precipitation (in)
250
225
200
175
150
125
100
75
50
25
0
Flow (gpm)
12/24/2009
12/31/2008
1/7/2009
1/14/2009
1/21/2009
1/28/2009
2/4/2009
2/11/2009
2/18/2009
2/25/2009
3/4/2009
3/11/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-12

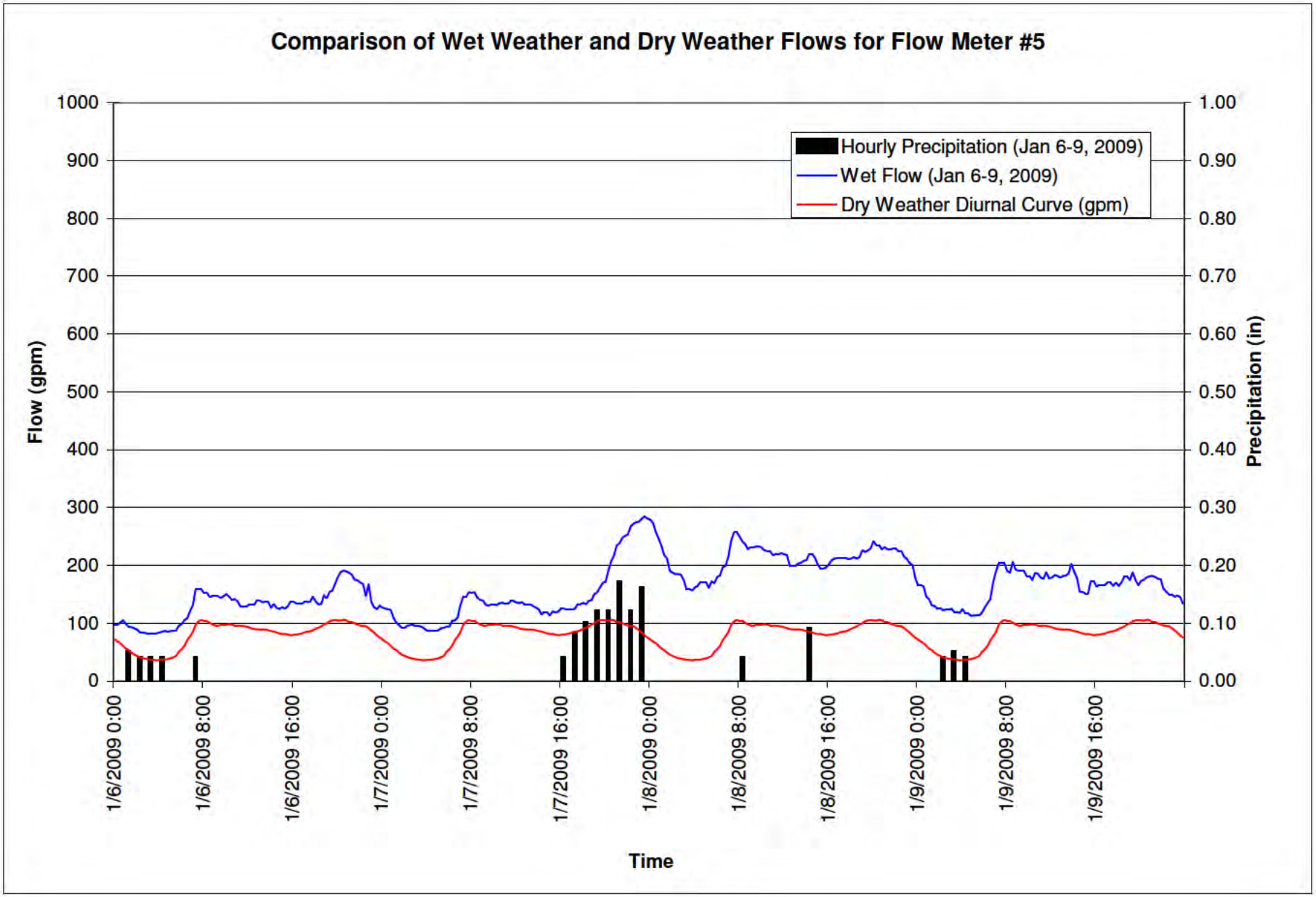

Comparison of Wet Weather and Dry Weather Flows for Flow Meter #5
Hourly Precipitation (Jan 6-9, 2009)
Wet Flow (Jan 6-9, 2009)
Dry Weather Diurnal Curve (gpm)
Flow (gpm)
Precipitation (in)
Time
1000
900
800
700
600
500
400
300
200
100
0
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1/6/2009 0:00
1/6/2009 8:00
1/6/2009 16:00
1/7/2009 0:00
1/7/2009 8:00
1/7/2009 16:00
1/8/2009 0:00
1/8/2009 8:00
1/8/2009 16:00
1/9/2009 0:00
1/9/2009 8:00
1/9/2009 16:00

Figure A-13

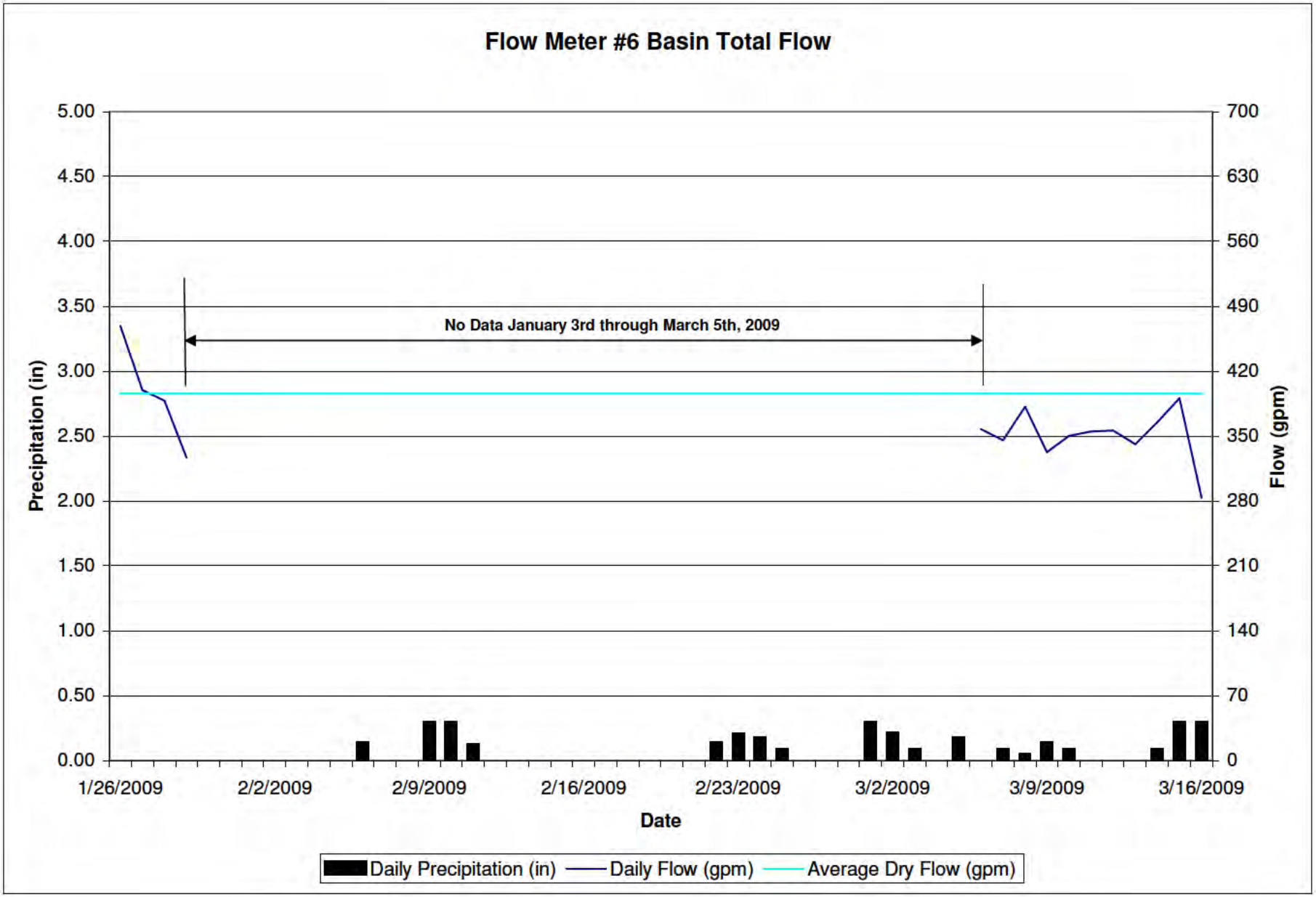

Flow Meter #6 Basin Total Flow
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Precipitation (in)
700
630
560
490
420
350
280
210
140
70
0
Flow (gpm)
No Data January 3rd through March 5th, 2009
1/26/2009
2/2/2009
2/9/2009
2/16/2009
2/23/2009
3/2/2009
3/9/2009
3/16/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-14

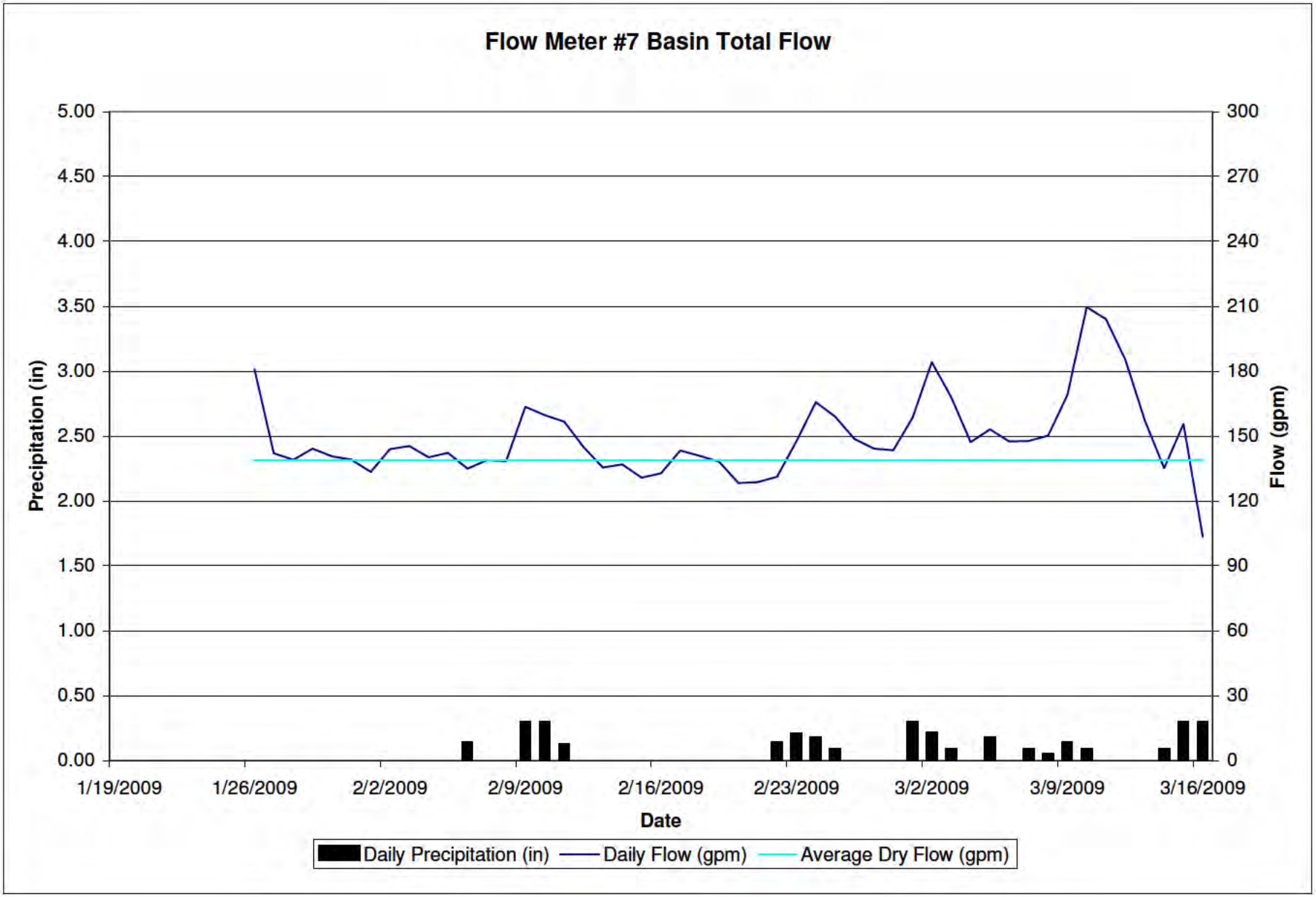
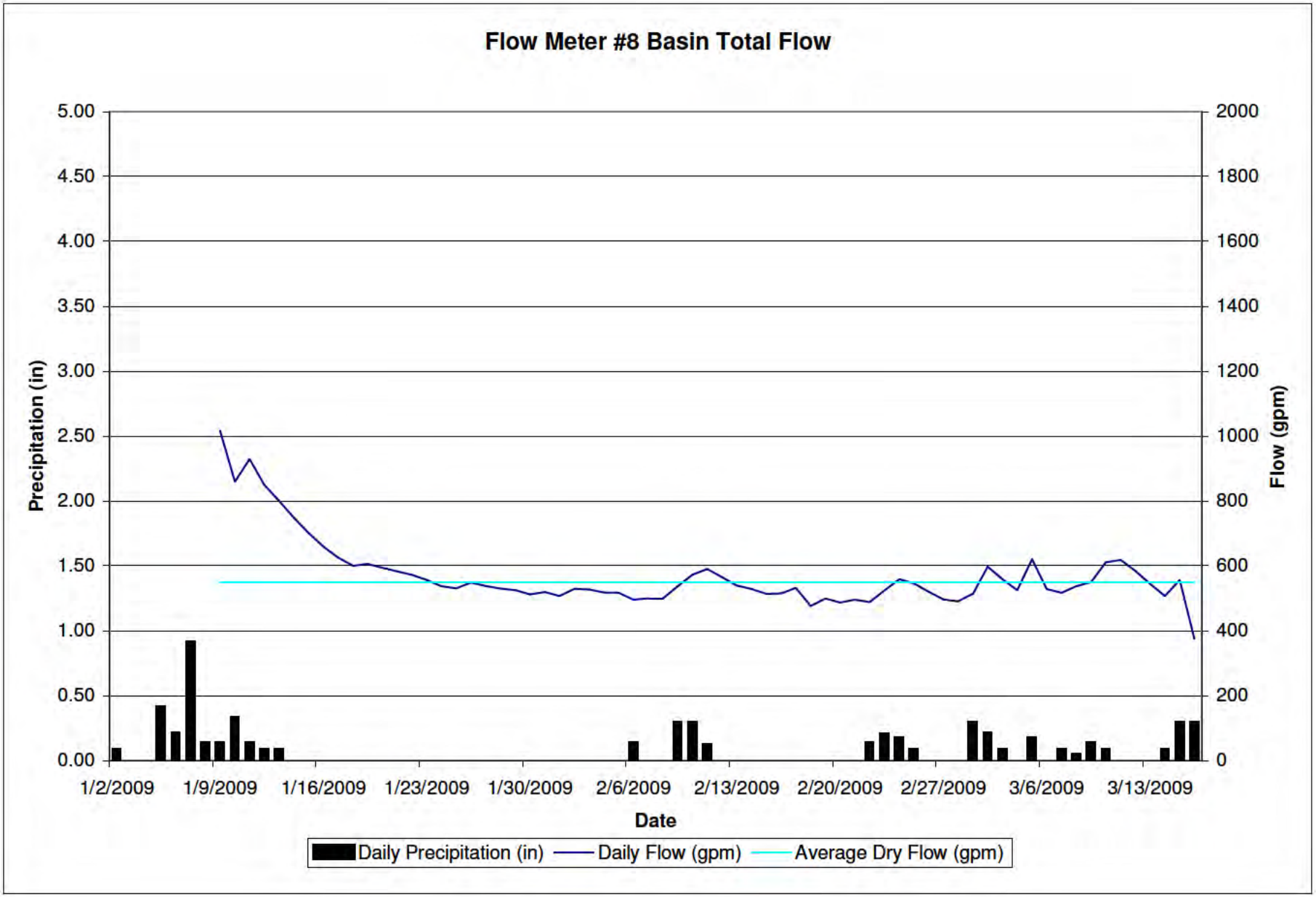

Flow Meter #7 Basin Total Flow
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Precipitation (in)
300
270
240
210
180
150
120
90
60
30
0
Flow (gpm)
1/19/2009
1/26/2009
2/2/2009
2/9/2009
2/16/2009
2/23/2009
3/2/2009
3/9/2009
3/16/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-15


Flow Meter #8 Basin Total Flow
Precipitation (in)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Flow (gpm)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1/2/2009
1/9/2009
1/16/2009
1/23/2009
1/30/2009
2/6/2009
2/13/2009
2/20/2009
2/27/2009
3/6/2009
3/13/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

rain events. The daily flow for January 11th shows the presence of infiltration in this flow meter basin. The Instantaneous I/I for this flow meter cannot be compared to other basins since the January 7th and 8th inflow influenced rain event was not captured.

Flow Meter #9

Flow Meter #9 measures flow from the north part of the City's sewer service area that eventually flows down Olympic View Drive and into the transmission line on 76th Street that flows into the WWTP. Figure A-16 shows the daily flow for Flow Meter #9 compared to the daily precipitation. This shows a small amount of I/I associated with the January 11th infiltration influenced rain event. The remainder of the analysis period does not show significant increases in flow associated with the smaller rain events. The Instantaneous I/I for this flow meter cannot be compared to other basins since the January 7th and 8th inflow influenced rain event was not captured.

Flow Meter #10

Flow Meter #10 also measures flow from the north part of the City's sewer service area and includes the flows from the Flow Meter #9 basin. The flow meter is located near the intersection of Olympic View Drive and 76th Street before the flow heads north on 76th Street to the WWTP. Figures A-17 and A-18 are used to compare the Peak Day I/I and Instantaneous I/I for Flow Meter #10, respectively. Figure A-17 clearly shows the daily flow increasing in response to the January 7th and 8th rain event indicating the presence of I/I in this basin. Figure A-18 shows the instantaneous flows for the basin compared to the January 7th and 8th rain event. The flow is shown to peak towards the end of this rain event and remain high for the next few days before decreasing. This indicates the presence of a moderate amount of both infiltration and inflow.

Flow Meter #11

Flow Meter #11 measures the flow from a small basin on the west side of the City that flows by gravity to the transmission line on 76th Street. This is the smallest flow meter basin used in this study and has low flows. Figure A-19 shows the daily flows for Flow Meter #11 compared to the daily precipitation. This shows that the highest daily flows appear to come several days after the January 7th and 8th rain event. This indicates that this basin is more influenced by infiltration than inflow. The Instantaneous I/I for this flow meter cannot be calculated and compared to other basins since the January 7th and 8th rain event was not captured.

Flow Meter #12

Flow Meter #12 measures the flow coming down the transmission line on 76th Street and includes all the flows from the City's sewer system. Flow Meter #12 includes all the flows seen at the WWTP except the flows from the City of Edmonds which come into a manhole just upstream of the WWTP. Figure A-20 shows the daily flow for Flow Meter

#12 compared to the daily precipitation. Figure A-20 shows that the highest daily flows appear to come following the early January rain events indicating the presence of I/I throughout the City. The data from Flow Meter #12 was compared to the flow meter at the WWTP. The flows seen through Flow Meter #12 were significantly smaller than the flows seen at the WWTP. Because of this the data can be used to show qualitatively that I/I is a problem in the City, but cannot be used quantitatively to calculate a value.

Wastewater Treatment Plant

The circular charts from the primary effluent flow meter at the WWTP were graphed against the daily precipitation for the entire flow monitoring period as shown in Figure A-21. From conversations with City staff, the primary effluent flow meter does not always provide accurate flow measurement. A project is in design to replace the primary effluent flow meter at the WWTP with a more accurate magnetic flow meter. In addition, the primary effluent flow meter does not measure the flow entering the WWTP, but measures the flow coming out of the primary clarifiers. However, as seen in Figure A-21, the flows through the primary effluent flow meter are shown to greatly increase after the early January rain events. Figure A-22 shows the instantaneous flows through the effluent flow meter compared to the January 7th and 8th rain event. The flow during this period is significantly higher than the dry weather diurnal flow which was calculated using the same dry weather days used to calculate the flow meter dry weather diurnal flows. This indicates that inflow into the sewer system was occurring during this storm event.

FLOW MONITORING RESULTS SUMMARY

Table A-3 presents the calculated infiltration influenced peak day I/I rate for each of the flow meter basins. The rates were calculated using the same day so the results could be compared for each of the flow meters. The date of January 11, 2009 was used because this was several days after a major storm event during a period of prolonged precipitation. Groundwater levels were higher meaning the I/I rates were heavily influenced by infiltration. The infiltration influenced peak day I/I has been calculated by comparing the difference between the daily flow with the dry weather average flow. The I/I rate has been expressed in a standard unit of measurement of gallons per acre per day (GPAD).

Figure A-16

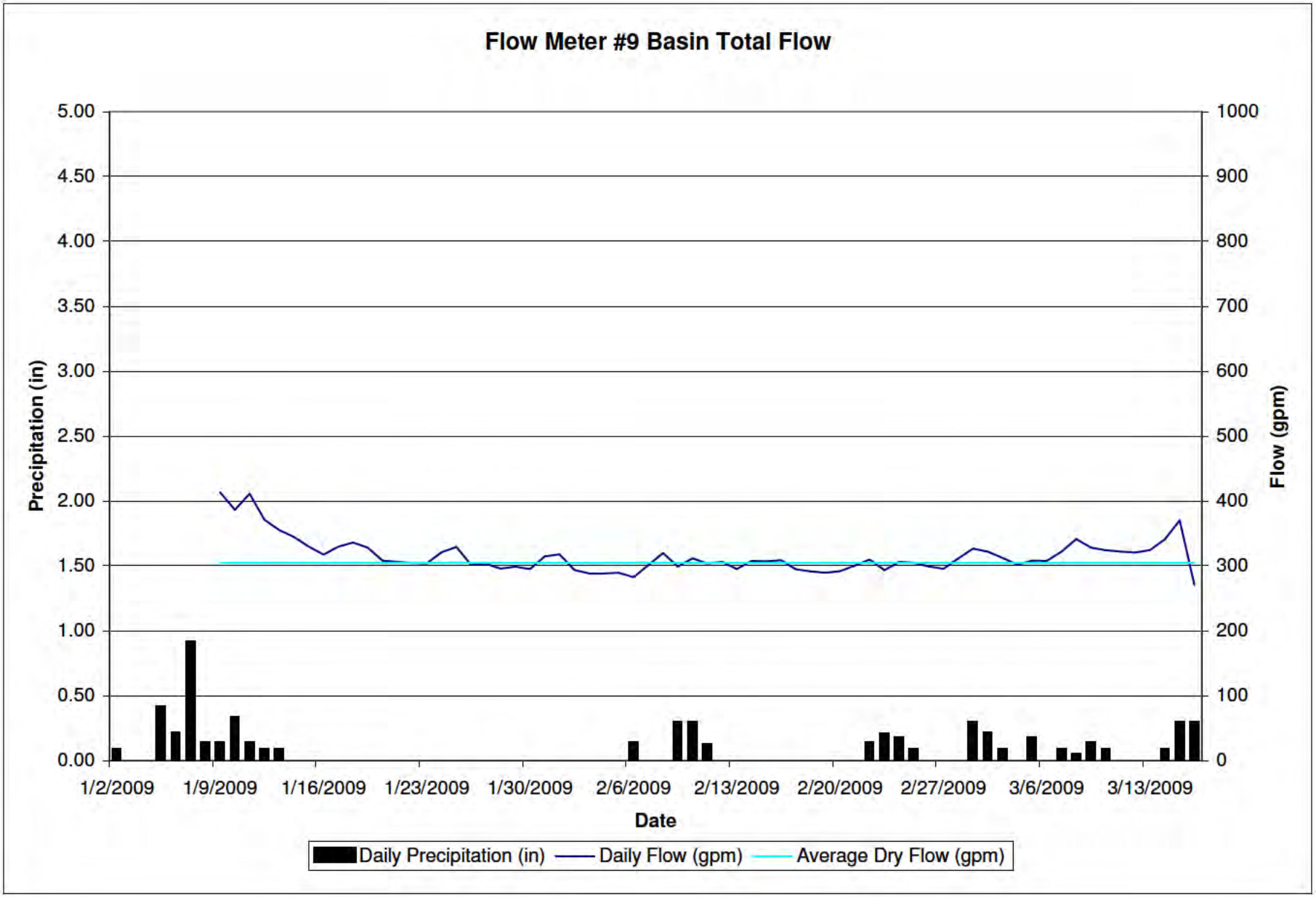

Flow Meter #9 Basin Total Flow
Precipitation (in)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Flow (gpm)
1000
900
800
700
600
500
400
300
200
100
0
1/2/2009
1/9/2009
1/16/2009
1/23/2009
1/30/2009
2/6/2009
2/13/2009
2/20/2009
2/27/2009
3/6/2009
3/13/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-17

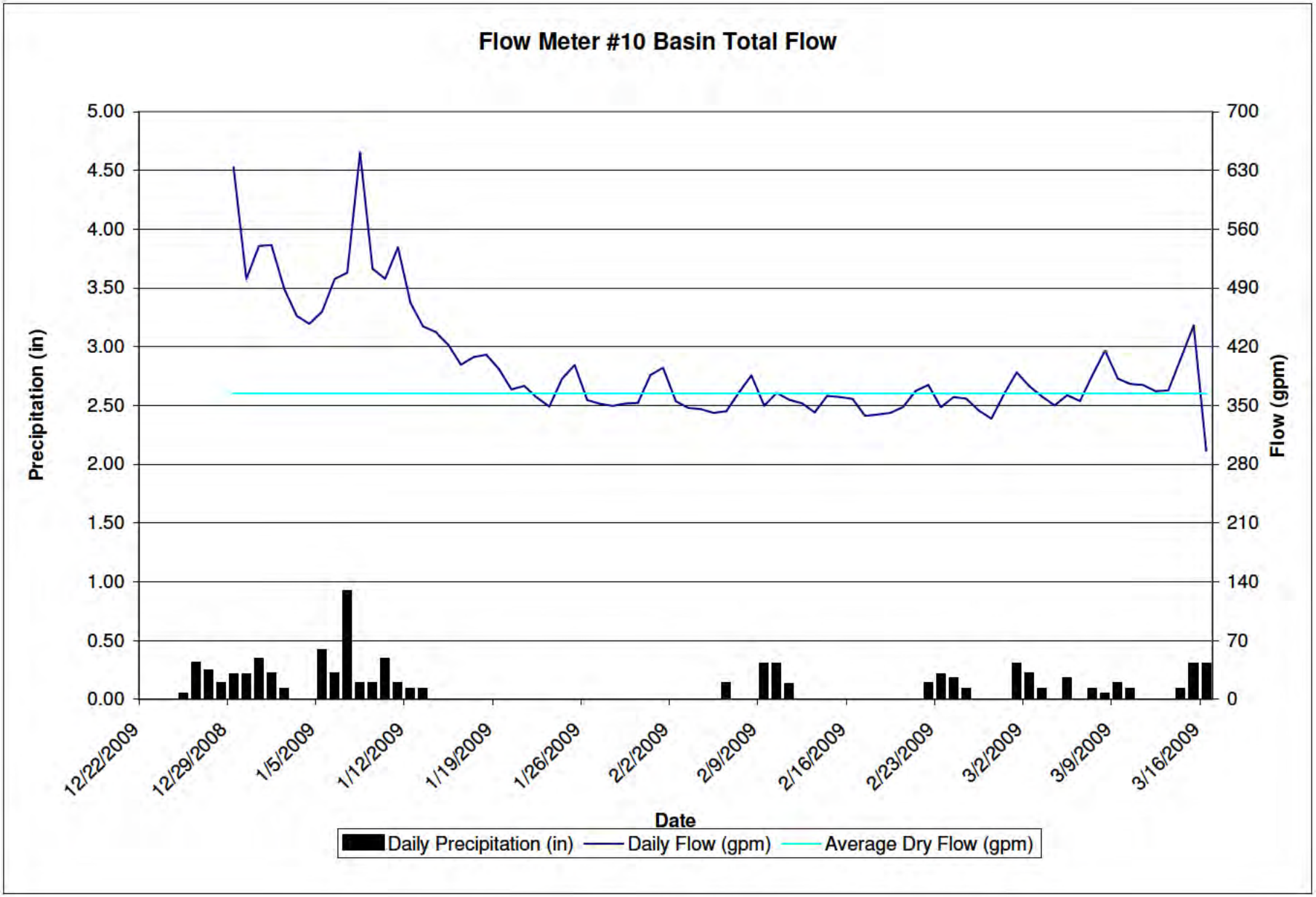

Flow Meter #10 Basin Total Flow
Precipitation (in)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Flow (gpm)
700
630
560
490
420
350
280
210
140
70
0
12/22/2009
12/29/2008
1/5/2009
1/12/2009
1/19/2009
1/26/2009
2/2/2009
2/9/2009
2/16/2009
2/23/2009
3/2/2009
3/9/2009
3/16/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-18

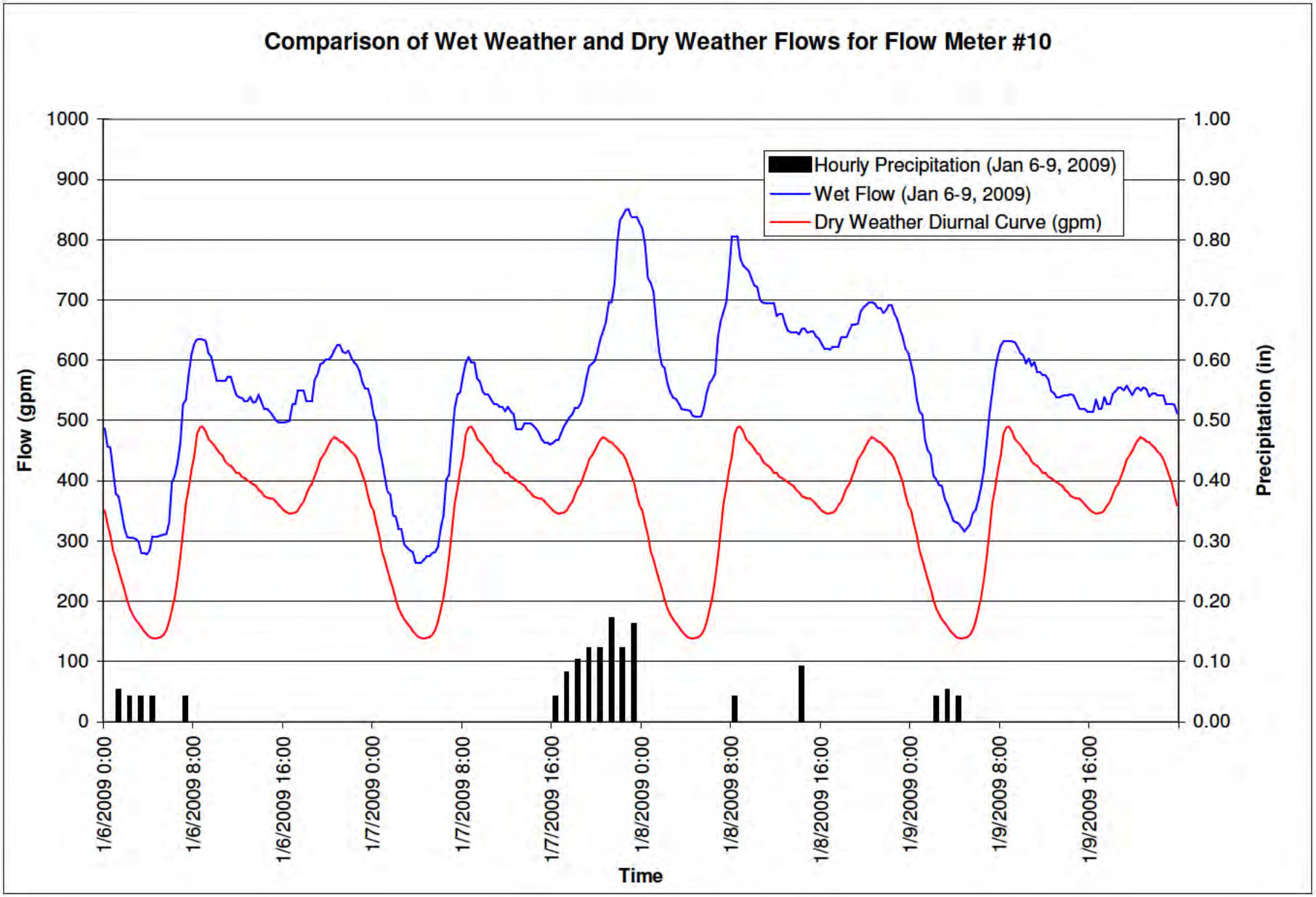

Comparison of Wet Weather and Dry Weather Flows for Flow Meter #10
Hourly Precipitation (Jan 6-9, 2009)
Wet Flow (Jan 6-9, 2009)
Dry Weather Diurnal Curve (gpm)
Flow (gpm)
Precipitation (in)
Time
1000
900
800
700
600
500
400
300
200
100
0
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1/6/2009 0:00
1/6/2009 8:00
1/6/2009 16:00
1/7/2009 0:00
1/7/2009 8:00
1/7/2009 16:00
1/8/2009 0:00
1/8/2009 8:00
1/8/2009 16:00
1/9/2009 0:00
1/9/2009 8:00
1/9/2009 16:00

Figure A-19

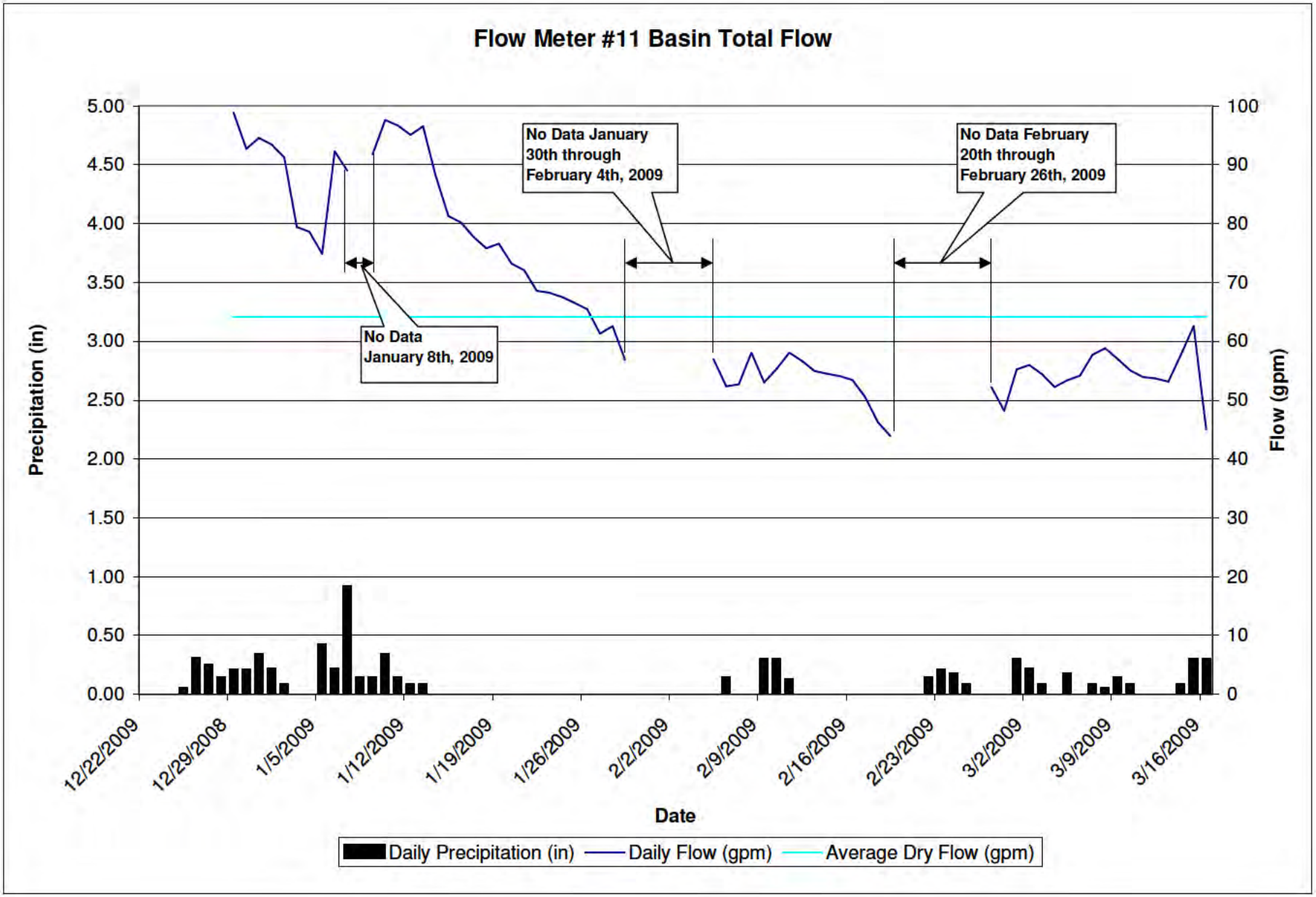

Flow Meter #11 Basin Total Flow
No Data January 30th through February 4th, 2009
No Data February 20th through February 26th, 2009
No Data January 8th, 2009
Precipitation (in)
Flow (gpm)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
100
90
80
70
60
50
40
30
20
10
0
12/22/2009
12/29/2008
1/5/2009
1/12/2009
1/19/2009
1/26/2009
2/2/2009
2/9/2009
2/16/2009
2/23/2009
3/2/2009
3/9/2009
3/16/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-20

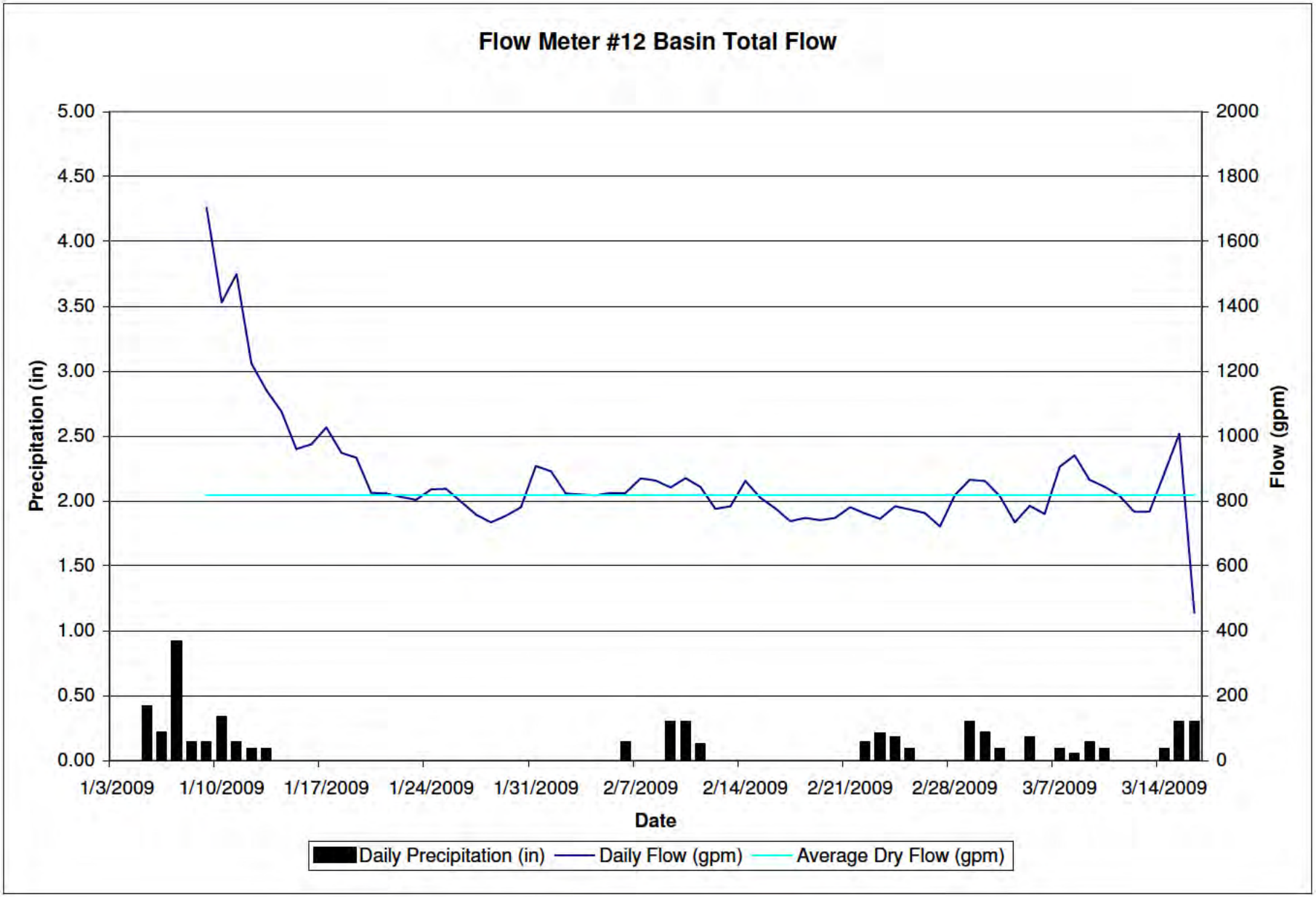

Flow Meter #12 Basin Total Flow
Precipitation (in)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Flow (gpm)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1/3/2009
1/10/2009
1/17/2009
1/24/2009
1/31/2009
2/7/2009
2/14/2009
2/21/2009
2/28/2009
3/7/2009
3/14/2009
Date
Daily Precipitation (in)
Daily Flow (gpm)
Average Dry Flow (gpm)

Figure A-21

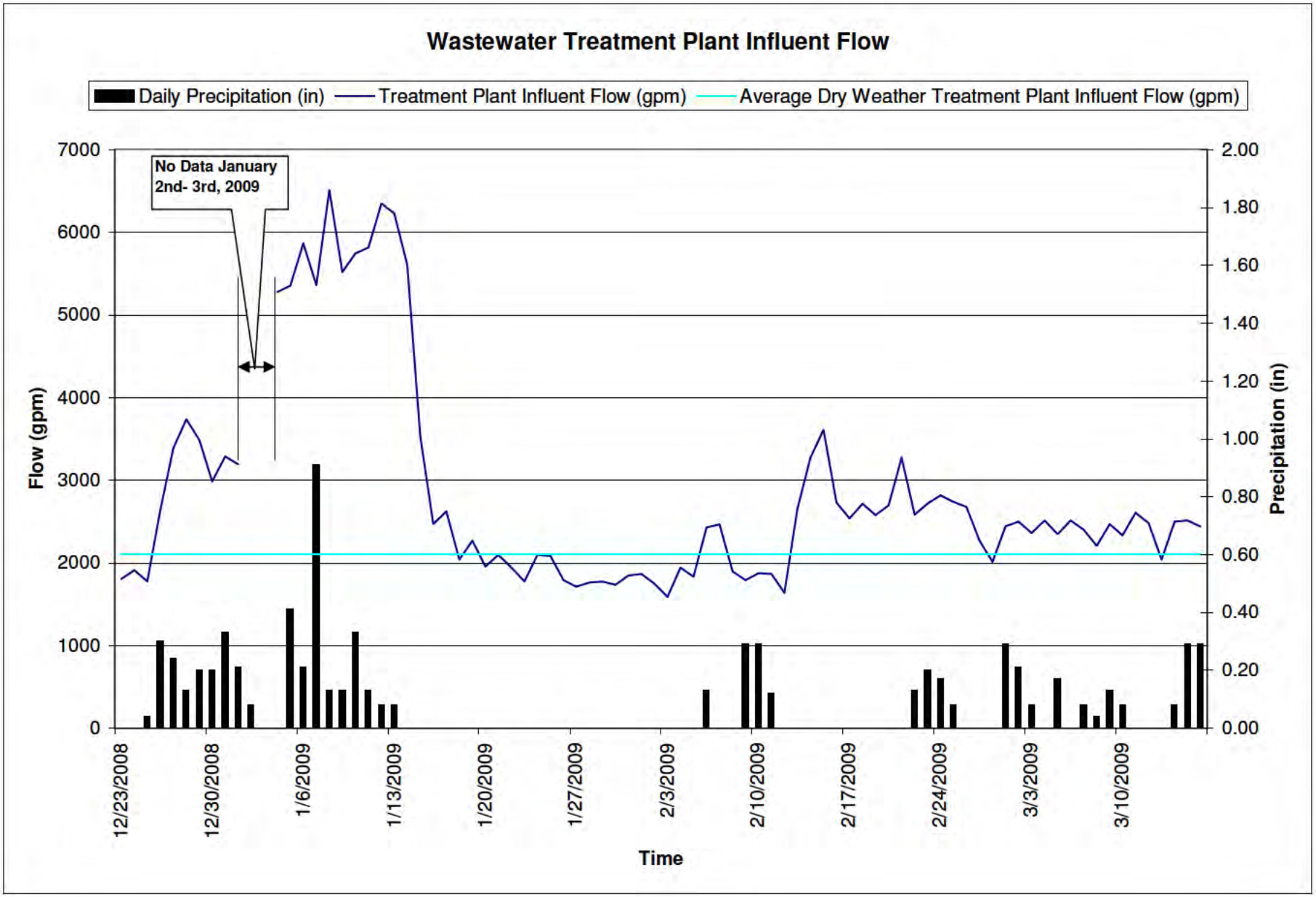

Wastewater Treatment Plant Influent Flow
Daily Precipitation (in)
Treatment Plant Influent Flow (gpm)
Average Dry Weather Treatment Plant Influent Flow (gpm)
No Data January 2nd- 3rd, 2009
Flow (gpm)
Precipitation (in)
Time
7000
6000
5000
4000
3000
2000
1000
0
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
12/23/2008
12/30/2008
1/6/2009
1/13/2009
1/20/2009
1/27/2009
2/3/2009
2/10/2009
2/17/2009
2/24/2009
3/3/2009
3/10/2009

Figure A-22

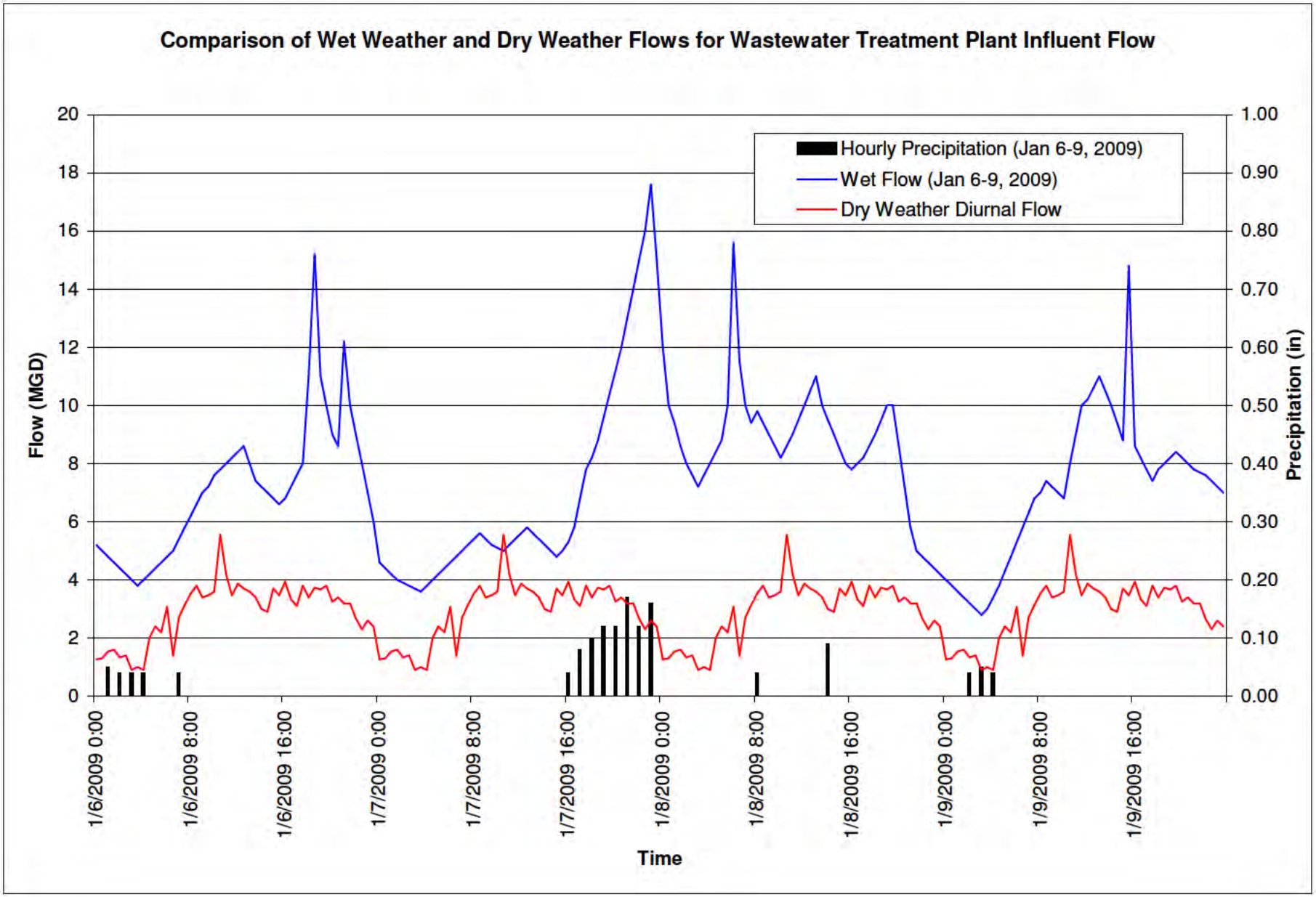

Comparison of Wet Weather and Dry Weather Flows for Wastewater Treatment Plant Influent Flow
Hourly Precipitation (Jan 6-9, 2009)
Wet Flow (Jan 6-9, 2009)
Dry Weather Diurnal Flow
Flow (MGD)
Precipitation (in)
Time
0
2
4
6
8
10
12
14
16
18
20
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1/6/2009 0:00
1/6/2009 8:00
1/6/2009 16:00
1/7/2009 0:00
1/7/2009 8:00
1/7/2009 16:00
1/8/2009 0:00
1/8/2009 8:00
1/8/2009 16:00
1/9/2009 0:00
1/9/2009 8:00
1/9/2009 16:00

TABLE A-3

Infiltration Influenced Peak Day I/I Values

Flow Meter	Peak Flow Day (gpm)	Infiltration Influenced I/I Flow (gpm)	Basin Area (Acre)	Total Upstream Basin Area (Acre)	Infiltration Influenced I/I Rate (GPAD)
1	1/11/2009	26.1	338	338	111
2	(1)	(1)	367	705	(1)
3	1/11/2009	240.9	346	346	1,002
4	(1)	(1)	520	1,839	(1)
5	1/11/2009	89.2	247	247	520
6	(1)	(1)	726	726	(1)
7	(1)	(1)	280	280	(1)
8	1/11/2009	380.1	420	700	782
9	1/11/2009	105.9	464	464	329
10	1/11/2009	174.2	296	760	330
11	1/11/2009	32.5	110	110	425
12	1/11/2009	(2)	4,900	4,900	(2)
WWTP	1/11/2009	3,722.2	6,100	6,100	879

(1) Unable to calculate due to insufficient data.
(2) Unable to calculate due to inaccurate flow meter readings.

Table A-4 presents the calculated inflow influenced peak instantaneous I/I rate for each of the flow meter basins. The rates were calculated using the same storm event so the results could be compared for each of the flow meters. The storm event of January 7, 2009 was used because this was the only major storm event of the flow monitoring period. The I/I rates during major storm events are more heavily influenced by inflow. The inflow influenced peak instantaneous I/I has been calculated by comparing the difference between the peak instantaneous flow and the dry weather diurnal curves previously described. The I/I rate has been expressed in a standard unit of measurement of gallons per acre per day (GPAD).