This document is released for the purpose of information exchange review and planning only under the authority of Hugh Steve McDonald, December 2015, State of California, PE No. 44074 and Tracy Anne Clinton, December 2015, State of California, PE No. 48199

City Of Oxnard

Public Works Integrated Master Plan

WASTEWATER

PROJECT MEMORANDUM 3.11
FLOW MONITORING

FINAL DRAFT
December 2015

2700 YGNACIO VALLEY ROAD, SUITE 300 • WALNUT CREEK, CALIFORNIA 94598 • P. 925.932.1710 • F. 925.930.0208

City Of Oxnard

Public Works Integrated Master Plan

WASTEWATER

PROJECT MEMORANDUM 3.11
FLOW MONITORING

TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1
1.1 Project Memorandums (PMs) Used for Reference 1
2.0 DRY WEATHER FLOW MONITORING FINDINGS 1
2.1 Pipeline Capacity Analysis During Dry Weather Flow Monitoring 1
3.0 WET WEATHER FLOW MONITORING FINDINGS 2
3.1 Rainfall Data 2
3.2 Baseline Flow Analysis 2
3.3 Pipeline Capacity Analysis During Wet Weather Flow Monitoring 3
3.4 Inflow Results 4
3.5 Infiltration Results 5

APPENDIX A – DRY WEATHER SANITARY SEWER FLOW MONITORING STUDY
APPENDIX B – WET WEATHER SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

LIST OF TABLES

Table 1 Capacity Analysis Summary for Dry Weather Flow Monitoring 2
Table 2 Baseline Flow Summary 3
Table 3 Capacity Analysis Summary for Wet Weather Flow Monitoring 4
Table 4 Inflow and Infiltration Analysis Summary 4

FLOW MONITORING

1.0 INTRODUCTION

V&A Incorporated (V&A) was contracted to conduct both dry and wet weather sanitary sewer flow monitoring within the City of Oxnard. V&A conducted dry weather flow monitoring at 10 open-channel flow monitoring sites from August 2, 2014 to August 24, 2014 and the results can be seen in Appendix A. V&A performed wet weather flow monitoring at 10 open-channel flow monitoring sites from December 9, 2014 to February 25, 2015. Except for one location, the wet weather monitoring sites were at the same locations as the dry weather study. The flow monitoring for Site 4A was performed one manhole upstream from Site 4 as the new site had better hydraulic conditions for flow monitoring. Rainfall data for five rainfall recording sites was obtained from the Ventura County Watershed Protection District Hydrologic Data Server. The results of the wet weather flow monitoring can be seen in Appendix B.

1.1 Project Memorandums (PMs) Used for Reference

The wastewater flow monitoring outlined in this PM was made in concert with recommendations and analyses from other related PMs:

- PM 3.1 - Wastewater System - Background Summary.
- PM 3.2 - Wastewater System - Flow and Load Projections.
- PM 3.3 - Wastewater System - Infrastructure Modeling and Alternatives.
- PM 3.4 - Wastewater System - Treatment Plant Performance and Capacity.

2.0 DRY WEATHER FLOW MONITORING FINDINGS

2.1 Pipeline Capacity Analysis During Dry Weather Flow Monitoring

Table 1 summarizes the peak recorded flows, levels, d/D ratios, and peaking factors per site during the flow monitoring period. The capacity analysis is presented on a site-by-site basis and represents the hydraulic conditions only at the flow monitoring conditions. Hydraulic conditions in other areas of the collection system will differ.

Peaking factor is defined as the peak measured flow divided by the average dry weather flow (ADWF). All flow monitoring sites had dry weather peaking factors below the typical design threshold value of 3.0.

Table 1 Capacity Analysis Summary for Dry Weather Flow Monitoring Public Works Integrated Master Plan City of Oxnard						
Site	**ADWF (mgd)**	**Peak Measured Flow (mgd)**	**Peaking Factor**	**Diameter (in)**	**Peak Level (in)**	**d/D Ratio**
Site 1	5.14	8.44	1.64	41.5	19.8	0.48
Site 2	2.70	3.83	1.42	36	16.1	0.45
Site 3	7.13	13.53	1.90	60	21.5	0.36
Site 4	4.30	7.06	1.64	33	14.5	0.44
Site 5	1.34	2.85	2.13	36	14.0	0.39
Site 6	1.35	2.38	1.76	24	15.1	0.63
Site 7	0.31	0.53	1.71	24	5.9	0.25
Site 8	1.84	2.96	1.61	27	11.6	0.43
Site 9	2.04	3.34	1.64	42	8.5	0.20
Site 10	1.91	3.46	1.81	37	16.3	0.44

The d/D Ratio is the peak measured depth of flow (d) divided by the pipe diameter (D). All flow monitoring sites also had dry weather d/D ratios below the typical design threshold value of 0.75.

3.0 WET WEATHER FLOW MONITORING FINDINGS

3.1 Rainfall Data

During the wet weather flow monitoring period, there were two notable rainfall events observed from the five rainfall recording sites. Rainfall Event 1 occurred from December 11, 2014 to December 12, 2014; the amount of rainfall was between 1.89 to 2.55 inches for the five rainfall recording sites. Rainfall Event 2 occurred from January 10, 2015 to January 11, 2015; the amount of rainfall was between 1.46 to 2.26 inches for the five rainfall recording sites. Rainfall Event 1 had a return frequency greater than a 5-year storm event for a 6-hour duration. If longer durations are considered, Rainfall Event 1 was greater than a 2-year storm event for a 12-hour duration and greater than a 1-year storm event for a 2-day duration. Rainfall Event 2 was less than a 1-year storm event for all durations.

3.2 Baseline Flow Analysis

Table 2 summarizes the baseline flow data measured during both the dry and wet weather flow monitoring. The baseline flows compare well with each other except for Site 2 and Site 4.

The flow patterns measured at Site 2 were not indicative of residential flow contributions, but more industrial or retail flows. If the service area is mostly industrial, then flows may be expected to be sporadic. The sporadic flows could account for the discrepancy between the ADWFs observed during the dry weather and wet weather flow monitoring.

Table 2 Baseline Flow Summary
Public Works Integrated Master Plan
City of Oxnard

Site	Overall ADWF (mgd)[(1)]	Dry Weather ADWF (mgd)[(2)]
Site 1	4.823	5.142
Site 2	2.194	2.702
Site 3	6.988	7.134
Site 4A	3.153	4.301[(3)]
Site 5	1.408	1.341
Site 6	1.197	1.351
Site 7	0.333	0.311
Site 8	1.638	1.840
Site 9	2.306	2.041
Site 10	2.128	1.913

Notes:
(1) ADWF observed during wet weather flow monitoring.
(2) ADWF observed during dry weather flow monitoring.
(3) Refers to data from Site 4. There was no dry weather flow monitoring conducted for Site 4A.

As mentioned previously, all the wet weather flow monitoring sites were at the same locations as the dry weather study except for one location. Site 4, which was monitored during the dry weather study, had inconsistent hydraulics. Additionally, Site 4 had turbulent conditions and was not an ideal site to capture accurate flow monitoring data. Based on discussions between V&A and the City of Oxnard, the wet weather monitoring for Site 4 was relocated to a different location with suitable hydraulic conditions to ensure accuracy and repeatability. The new flow monitoring location, labeled Site 4A, was placed one manhole upstream from Site 4.

3.3 Pipeline Capacity Analysis During Wet Weather Flow Monitoring

Table 3 summarizes the peak recorded flows, levels, d/D ratios, and peaking factors per site during the flow monitoring period. The capacity analysis is presented on a site-by-site basis and represents the hydraulic conditions only at the flow monitoring conditions. Hydraulic conditions in other areas of the collection system will differ. All sites had peaking factors and d/D ratios that were lower than the typical design threshold. No surcharging was observed at any of the flow monitoring sites.

Table 3	Capacity Analysis Summary for Wet Weather Flow Monitoring Public Works Integrated Master Plan City of Oxnard					
Site	**ADWF (mgd)**	**Peak Measured Flow (mgd)**	**Peaking Factor**	**Diameter (in)**	**Peak Level (in)**	**d/D Ratio**
Site 1	4.823	8.312	1.7	41.5	20.0	0.48
Site 2	2.194	6.002	2.7	36	21.2	0.59
Site 3	6.988	14.352	2.1	60	24.1	0.40
Site 4	3.153	5.729	1.8	33	23.1	0.70
Site 5	1.408	3.074	2.2	36	13.5	0.37
Site 6	1.197	2.292	1.9	24	11.0	0.46
Site 7	0.333	0.620	1.9	24	5.9	0.25
Site 8	1.638	4.540	2.8	27	15.5	0.57
Site 9	2.306	4.053	1.8	42	9.5	0.23
Site 10	2.128	4.024	1.9	37	14.9	0.40

3.4 Inflow Results

Inflow results were obtained from Rainfall Event 1 since it was the most intensive short-term rainfall event observed. Table 4 summarizes the peak measured I/I flows and inflow analysis results. The inflow component of inflow and infiltration (I/I) often causes a peak flow problem in the sewer system and often dictates the required capacity of downstream pipes and transport facilities to carry these peak instantaneous flows.

Table 4	Inflow and Infiltration Analysis Summary Public Works Integrated Master Plan City of Oxnard		
Site	**ADWF (mgd)**	**Peak I/I Rate (mgd)**	**Peak I/I per ADWF**
Site 1	4.823	3.468	0.7
Site 2	2.194	3.242	1.5
Site 3	6.988	5.545	0.8
Site 4A	3.153	4.512	1.4
Site 5	1.408	2.044	1.5
Site 6	1.197	1.081	0.9
Site 7	0.333	0.248	0.7
Site 8	1.638	3.725	2.3
Site 9	2.306	1.884	0.8
Site 10	2.128	1.052	0.5

3.5 Infiltration Results

Based on the data, the rain dependent infiltration (RDI) rates for all the flow monitoring sites in the City of Oxnard were minimal or negligible. RDI analysis would typically be run 24-hours after the conclusion of a rainfall event; however, within 8 hours or so, the flow rates had already returned to baseline levels. Although the RDI rates were negligible, there are many sewers that travel through perched aquifers that have infiltration regardless of rainfall.

APPENDIX A – DRY WEATHER SANITARY SEWER FLOW MONITORING STUDY

SANITARY SEWER FLOW MONITORING STUDY

City of Oxnard

October 2014

V&A

CITY OF OXNARD
SANITARY SEWER FLOW MONITORING STUDY

Prepared for

Carollo Engineers
89 Newbury Street, Suite 104
Danvers, MA 01923

Prepared by

October 2014

TABLE OF CONTENTS

ABBREVIATIONS, TERMS AND DEFINITIONS ii

INTRODUCTION 1
Scope and Purpose 1
Flow Monitoring Sites 1
METHODS AND PROCEDURES 3
Confined Space Entry 3
Flow Meter Installation 4
Flow Calculation 5
RESULTS AND ANALYSIS 6
Observation of Sediment 6
Average Dry Weather Flow 6
Peak Measured Flows and Pipeline Capacity Analysis 8

TABLES

Table 1. List of Flow Monitoring Locations 1
Table 3. Summary of Sediment Condition 6
Table 4. Average Dry Weather Flow Summary 7
Table 3. Capacity Analysis Summary 8

FIGURES

Figure 1. Flow Monitoring Site Map 2
Figure 2. Typical Installation for Flow Meter with Submerged Sensor 4
Figure 5. Sample ADWF Diurnal Flow Patterns 6
Figure 3. Average Dry Weather Flow Schematic 7
Figure 4. Capacity Summary Bar Graphs: Peaking Factors 9
Figure 5. Capacity Summary Bar Graphs: d/D Ratios 9
Figure 6. Peak Measured Flow Schematic 10

APPENDICES

Appendix A: Flow Monitoring Sites: Data, Graphs, Information

ABBREVIATIONS USED IN THIS REPORT

Abbreviation	Term
ADWF	average dry weather flow
BL	Baseline
CO	carbon monoxide
d/*D*	depth/diameter ratio
FM	flow monitor
H_2S	hydrogen sulfide
LEL	lower explosive limit
mgd	million gallons per day
Q	flow rate
SSO	sanitary sewer overflow
WWTP	Wastewater Treatment Plant

INTRODUCTION

Scope and Purpose

V&A Consulting Engineers, Inc. (V&A) was retained by Carollo Engineers to perform a sanitary sewer flow monitoring study within the City of Oxnard, California (City). Flow monitoring was performed over a period of approximately three weeks from August 2, 2014 to August 24, 2014 at 10 open-channel flow monitoring sites. The purpose of this study was to measure sanitary sewer flows at the flow monitoring sites and estimate available sewer capacity.

Flow Monitoring Sites

Flow monitoring sites are the locations where the flow monitors were placed. Capacity and flow rate information is presented on a site-by-site basis. The flow monitoring locations are listed in Table 1 and shown in Figure 1.

Table 1. List of Flow Monitoring Locations

Site	Pipe Diameter (in)	Location
Site 1	41.5	McWane Boulevard, east of Perkins Road Latitude: 34.140102°; Longitude: -119.183253°
Site 2	36	Magellan Avenue Latitude: 34.144846°; Longitude: -119.183017°
Site 3	60	J Street and E Port Hueneme Road Latitude: 34.148103°; Longitude: -119.1862°
Site 4	33	J Street and W Hueneme Road Latitude: 34.147435°; Longitude: -119.186003°
Site 5	36	S Rice Avenue and East of Emerson Avenue Latitude: 34.181916°; Longitude: -119.142732°
Site 6	24	S Rose Avenue and E Wooley Road Latitude: 34.189341°; Longitude: -119.160081°
Site 7	24	E Gonzales Road and Bahia Drive Latitude: 34.219168°; Longitude: -119.17503°
Site 8	27	J Street, between Spruce Street and Teakwood Street Latitude: 34.171606°; Longitude: -119.185694°
Site 9	42	N Ventura Road, between Devonshire Drive and Doris Avenue Latitude: 34.210324°; Longitude: -119.194643°
Site 10	37	West of W Hemlock Street and Jetty Street Latitude: 34.181227°; Longitude: -119.211645°

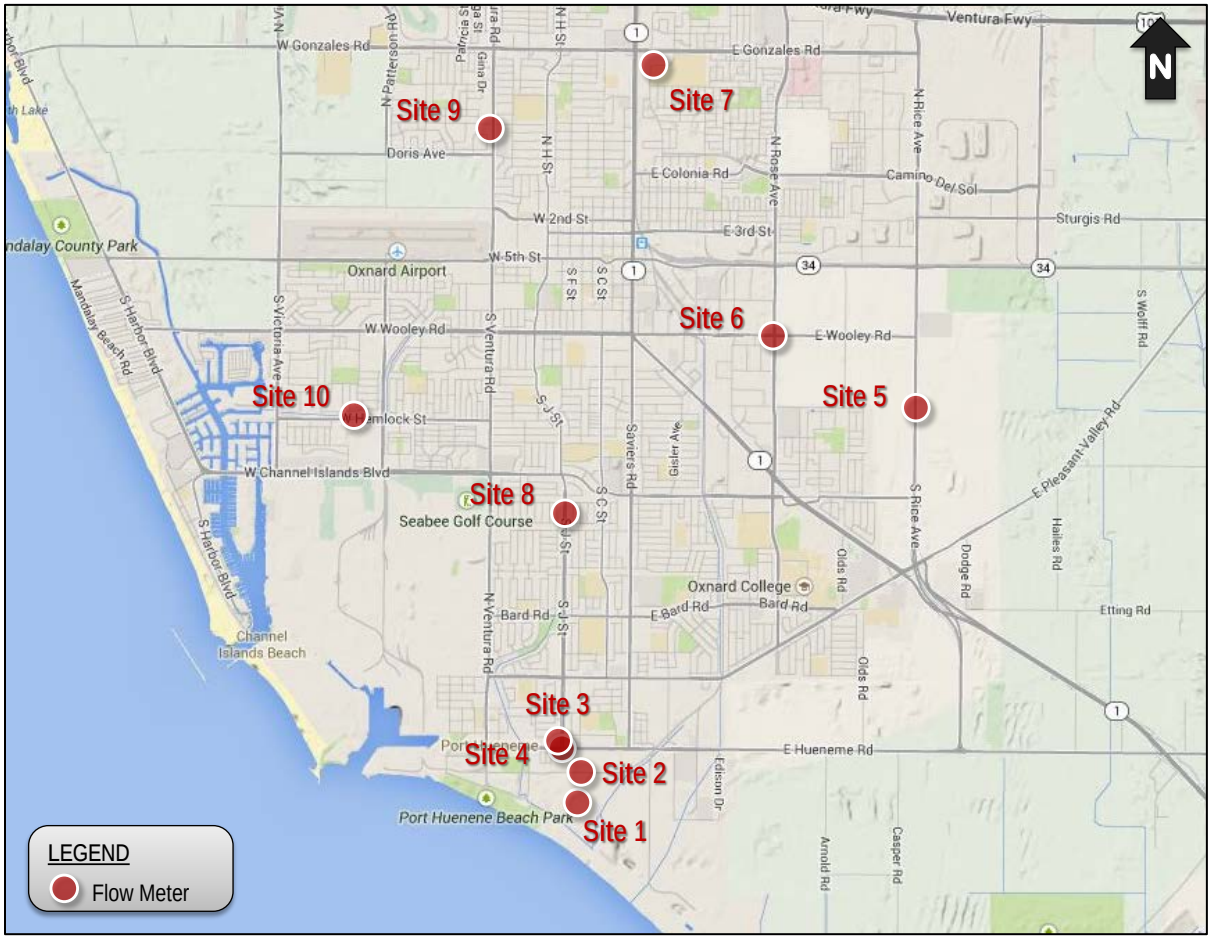


Figure 1. Flow Monitoring Site Map

METHODS AND PROCEDURES

Confined Space Entry

A confined space (Photo 1) is defined as any space that is large enough and so configured that a person can bodily enter and perform assigned work, has limited or restricted means for entry or exit and is not designed for continuous employee occupancy. In general, the atmosphere must be constantly monitored for sufficient levels of oxygen (19.5% to 23.5%), and the absence of hydrogen sulfide (H_2S) gas, carbon monoxide (CO) gas, and lower explosive limit (LEL) levels. A typical confined space entry crew has members with OSHA-defined responsibilities of Entrant, Attendant and Supervisor. The Entrant is the individual performing the work. He or she is equipped with the necessary personal protective equipment needed to perform the job safely, including a personal four-gas monitor (Photo 2). If it is not possible to maintain line-of-sight with the Entrant, then more Entrants are required until line-of-sight can be maintained. The Attendant is responsible for maintaining contact with the Entrants to monitor the atmosphere using another four-gas monitor and maintaining records of all Entrants, if there are more than one. The Supervisor is responsible for developing the safe work plan for the job at hand prior to entering.

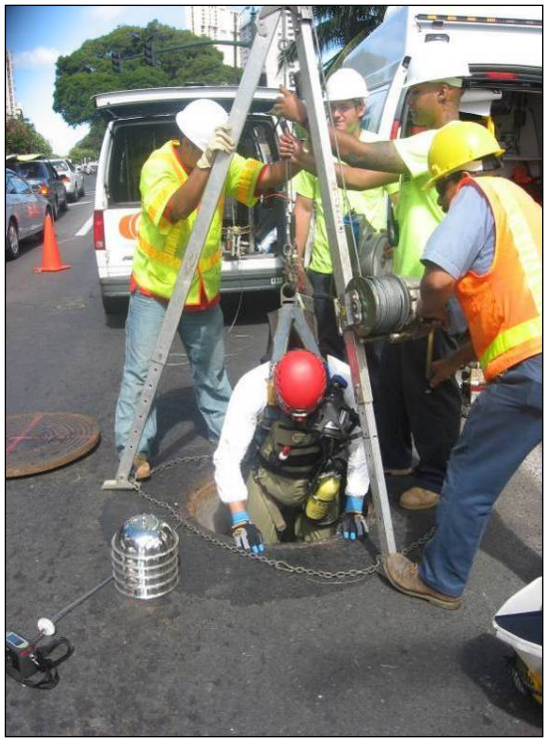


Photo 1. Confined Space Entry

Photo 2. Typical Personal Four-Gas Monitor

Flow Meter Installation

Teledyne Isco 2150 meters were installed by V&A in the sewer lines listed in Table 1. Isco 2150 meters use submerged sensors with a pressure transducer to collect depth readings and an ultrasonic Doppler sensor to determine the average fluid velocity. The ultrasonic sensor emits high-frequency sound waves, which are reflected by air bubbles and suspended particles in the flow. The sensor receives the reflected signal and determines the Doppler frequency shift, which indicates the estimated average flow velocity. The sensor is typically mounted at a manhole inlet to take advantage of smoother upstream flow conditions. The sensor may be offset to one side to lessen the chances of fouling and sedimentation where these problems are expected to occur. Manual level and velocity measurements were taken during installation of the flow meters and again when they were removed and were compared to simultaneous level and velocity readings from the flow meters to ensure proper calibration and accuracy. Figure 2 shows a typical installation for a flow meter with a submerged sensor.

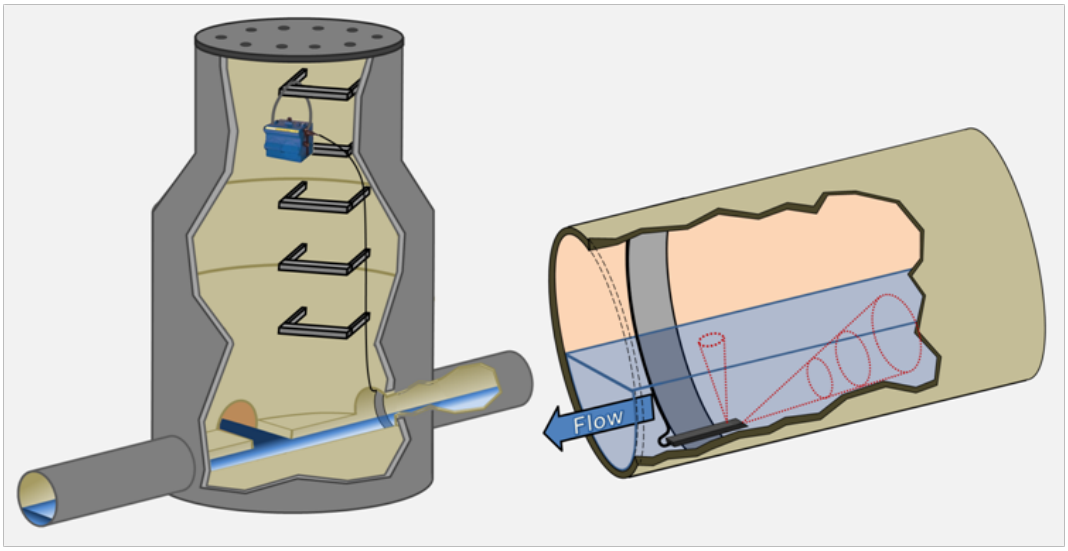


Figure 2. Typical Installation for Flow Meter with Submerged Sensor

Flow Calculation

Data retrieved from the flow meter was placed into a spreadsheet program for analysis. Data analysis includes data comparison to field calibration measurements, as well as necessary geometric adjustments as required for sediment (sediment reduces the pipe's wetted cross-sectional area available to carry flow). Area-velocity flow metering uses the continuity equation,

$$Q = v \cdot A = v \cdot (A_T - A_S)$$

where Q : Volume flow rate
v: Average velocity as determined by the ultrasonic sensor
A: Cross-sectional area available to carry flow
A_T: Total cross-sectional area for both wastewater and sediment
A_S: Cross-sectional area of sediment.

For circular pipe,

$$A_T = \left[\frac{D^2}{4}\cos^{-1}\left(1-\frac{2d_W}{D}\right)\right] - \left[\left(\frac{D}{2}-d_W\right)\left(\frac{D}{2}\right)\sin\left(\cos^{-1}\left(1-\frac{2d_W}{D}\right)\right)\right]$$

$$A_S = \left[\frac{D^2}{4}\cos^{-1}\left(1-\frac{2d_S}{D}\right)\right] - \left[\left(\frac{D}{2}-d_S\right)\left(\frac{D}{2}\right)\sin\left(\cos^{-1}\left(1-\frac{2d_S}{D}\right)\right)\right]$$

where d_W: Distance between wastewater level and pipe invert
d_S: Depth of sediment
D: Pipe Diameter

RESULTS AND ANALYSIS

Observation of Sediment

During flow meter installation and removal, sediment was observed from three sites (Table 3). No sediment was found at the other monitoring sites.

Table 2. Summary of Sediment Condition

Monitoring Site	Depth of Sediment (in.)
Site 1	1.25
Site 3	0.50
Site 5	6.00

Average Dry Weather Flow

Days least affected by rainfall were used to estimate dry weather flows. Typically within a given week, there are four distinct diurnal flow curves that can be established:

- **Mondays through Thursdays:** morning peaks between 8:00 am and 9:00 am, evening peaks between 9:00 pm and 10:00 pm.
- **Fridays:** similar to the Mondays-Thursdays flow curve, but with decreased evening flows from 7:00 pm to midnight.
- **Saturdays:** morning peaks between 11:00 am and 1:00 pm, and a flattened evening peak flow similar to Friday evenings.
- **Sundays:** similar to the Sundays flow curve, but with increased evening flows from 7:00 pm to midnight as people prepare for the work week. The evening flow patterns are similar to the Mondays through Thursdays flow curve.

Figure 5 illustrates the varying flow patterns within a work week (sample data, not from this study).

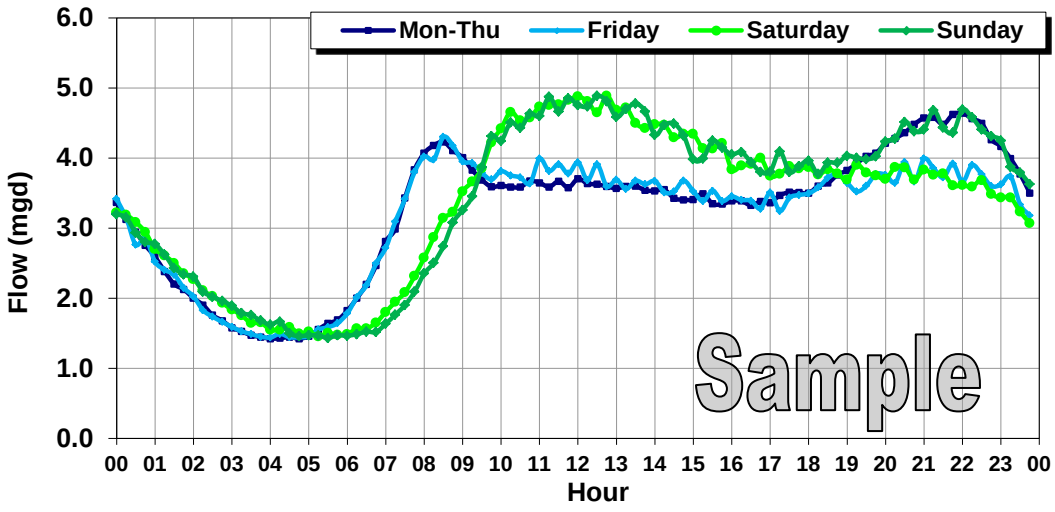


Figure 3. Sample ADWF Diurnal Flow Patterns

This distinction could be important for inflow and infiltration (I/I) analysis, were a storm event to occur during the evening hours on a Friday, Saturday or Sunday. The ADWF curves for this study were taken from the dry days from August 2 through August 24, 2014. The overall average dry weather flow (ADWF) is calculated per the following equation:

$$ADWF = \left(ADWF_{Mon-Thu} \times \frac{4}{7} \right) + \left(ADWF_{Fri} \times \frac{1}{7} \right) + \left(ADWF_{Sat} \times \frac{1}{7} \right) + \left(ADWF_{Sun} \times \frac{1}{7} \right),$$

Table 4 lists the average dry weather flow (ADWF) recorded during this study for the flow monitoring sites. Figure 6 shows a schematic diagram of the overall ADWF and flow levels. Detailed graphs of the ADWF data on a site-by-site basis are included in *Appendix A*.

Table 3. Average Dry Weather Flow Summary

Monitoring Site	Monday - Thursday (mgd)	Friday (mgd)	Saturday (mgd)	Sunday (mgd)	Overall Average (mgd)
Site 1	5.39	5.18	4.71	4.55	5.14
Site 2	2.76	2.86	2.66	2.35	2.70
Site 3	7.03	7.09	7.23	7.51	7.13
Site 4	4.28	4.29	4.39	4.30	4.30
Site 5	1.48	1.38	1.11	0.97	1.34
Site 6	1.44	1.40	1.17	1.13	1.35
Site 7	0.31	0.31	0.31	0.32	0.31
Site 8	1.82	1.86	1.89	1.84	1.84
Site 9	2.01	2.01	2.11	2.11	2.04
Site 10	1.88	1.85	2.00	2.04	1.91

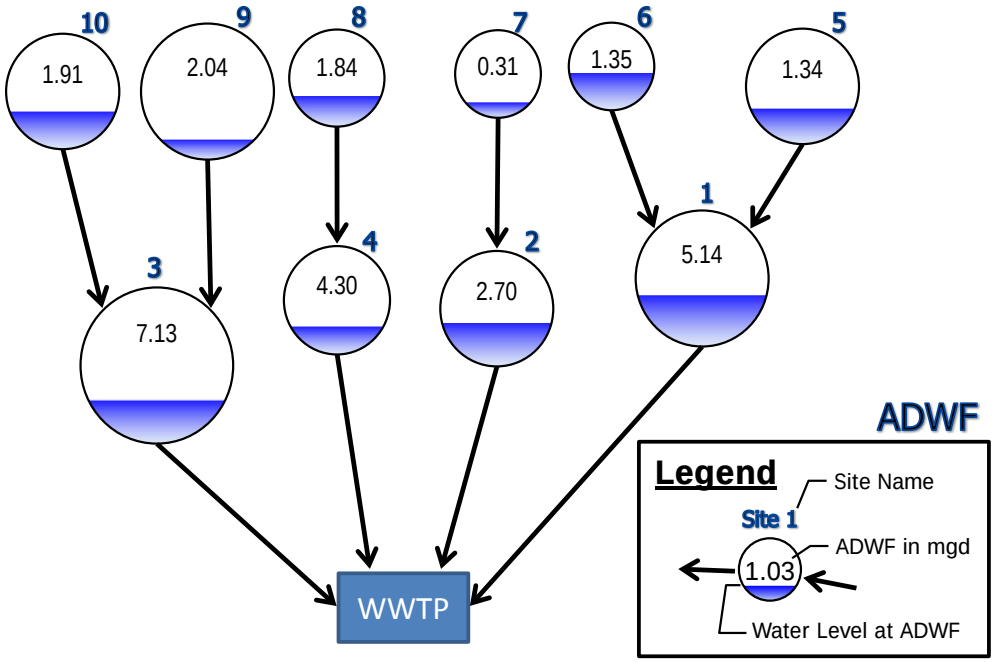


Figure 4. Average Dry Weather Flow Schematic

Peak Measured Flows and Pipeline Capacity Analysis

It is necessary to determine peak measured flows and the flow level (depths) at the peak flow in order to understand the capacity of the collection system. The peak flows and flow levels reported are from the peak measurements as taken across the entirety of the flow monitoring period. Peak flows and levels may not correspond to a rainfall event, but instead may be caused due to blockages, grease or roots that cause a backflow condition. The following capacity analysis terms are defined as follows:

- **Peaking Factor:** Peaking factor is defined as the peak measured flow divided by the average dry weather flow (ADWF). A peaking factor threshold value of 3.0 is commonly used for sanitary sewer design.
- ***d*/*D* Ratio:** The *d*/*D* ratio is the peak measured depth of flow (*d*) divided by the pipe diameter (*D*). A threshold value of 0.75 is commonly used for sanitary sewer design.

Table 3 summarizes the peak recorded flows, levels, *d*/*D* ratios, and peaking factors per site during the entire flow monitoring period. Capacity analysis data is presented on a site-by-site basis and represents the hydraulic conditions only at the point site locations. Hydraulic conditions in other areas of the collection system will differ. In this study, all flow monitoring sites had peaking factors and d/D ratios lower than the design threshold values.

Table 4. Capacity Analysis Summary

Site	ADWF (mgd)	Peak Measured Flow (mgd)	Peaking Factor	Diameter (in)	Peak Level (in)	*d*/*D* Ratio
Site 1	5.14	8.44	1.64	41.5	19.8	0.48
Site 2	2.70	3.83	1.42	36	16.1	0.45
Site 3	7.13	13.53	1.90	60	21.5	0.36
Site 4	4.30	7.06	1.64	33	14.5	0.44
Site 5	1.34	2.85	2.13	36	14.0	0.39
Site 6	1.35	2.38	1.76	24	15.1	0.63
Site 7	0.31	0.53	1.71	24	5.9	0.25
Site 8	1.84	2.96	1.61	27	11.6	0.43
Site 9	2.04	3.34	1.64	42	8.5	0.20
Site 10	1.91	3.46	1.81	37	16.3	0.44

The following capacity analysis items are noted:

- **Peaking Factor:** All sites had dry weather peaking factors below typical threshold values.
- **d/D Ratio:** All sites had dry weather d/D ratios below typical threshold values.

Figure 4 and Figure 5 show bar graphs summarizing the site-by-site peaking factors and d/D ratios, respectively.

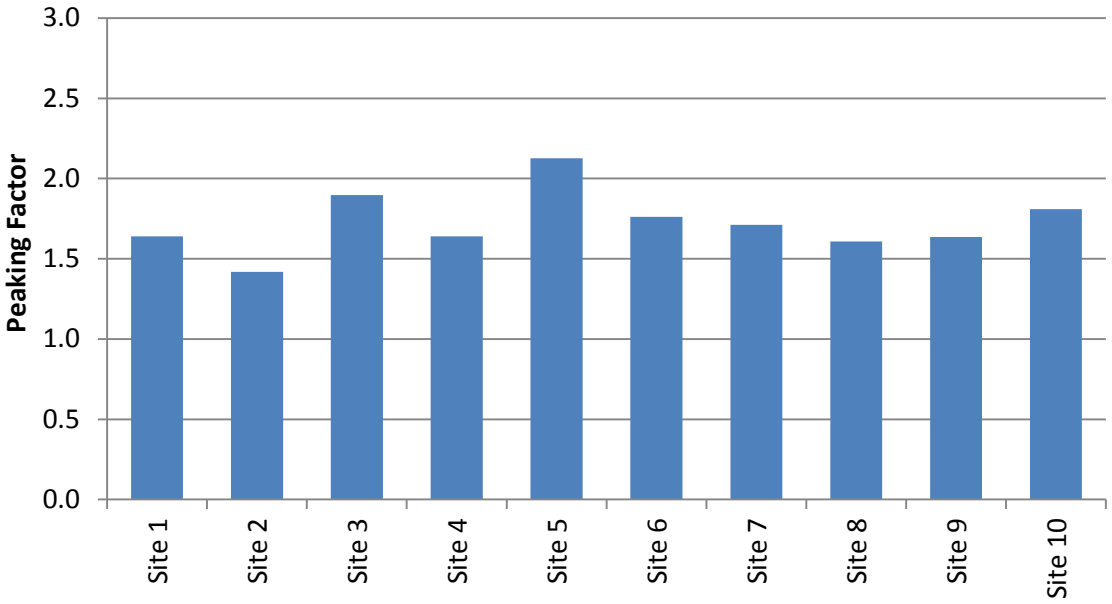


Figure 5. Capacity Summary Bar Graphs: Peaking Factors

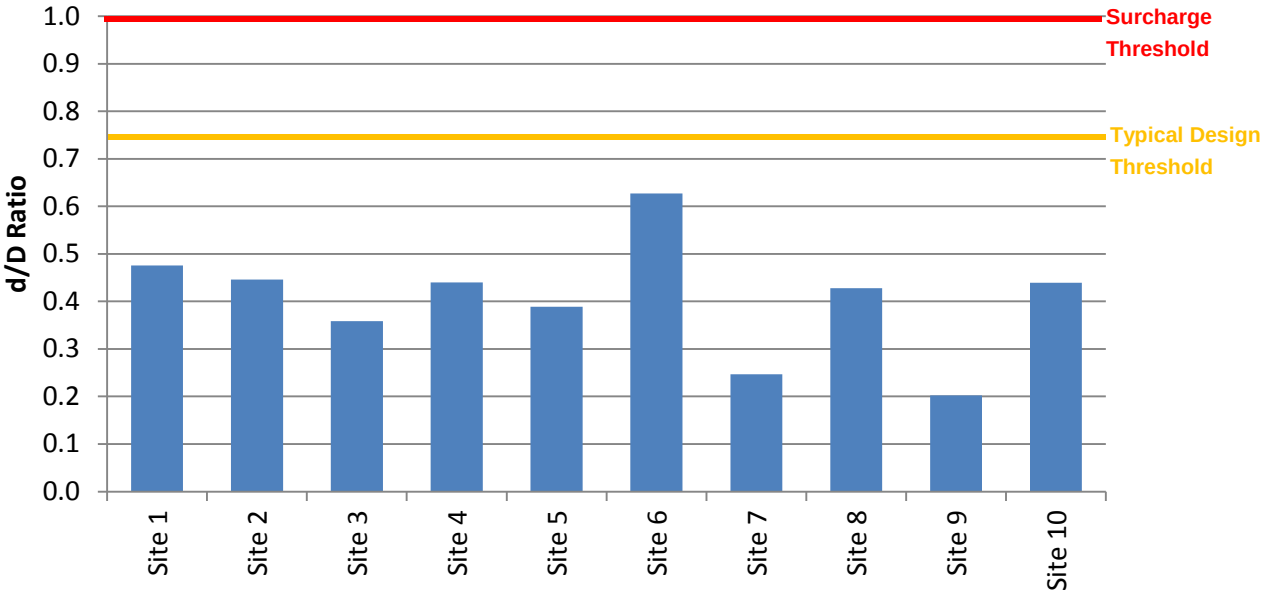


Figure 6. Capacity Summary Bar Graphs: d/D Ratios

Figure 6 shows the schematic diagram of the monitoring sites and the peak measured flows with peak flow levels. However, it is not valid to perform a flow balance when looking at peak measured flows through a collection system due to flow attenuation.

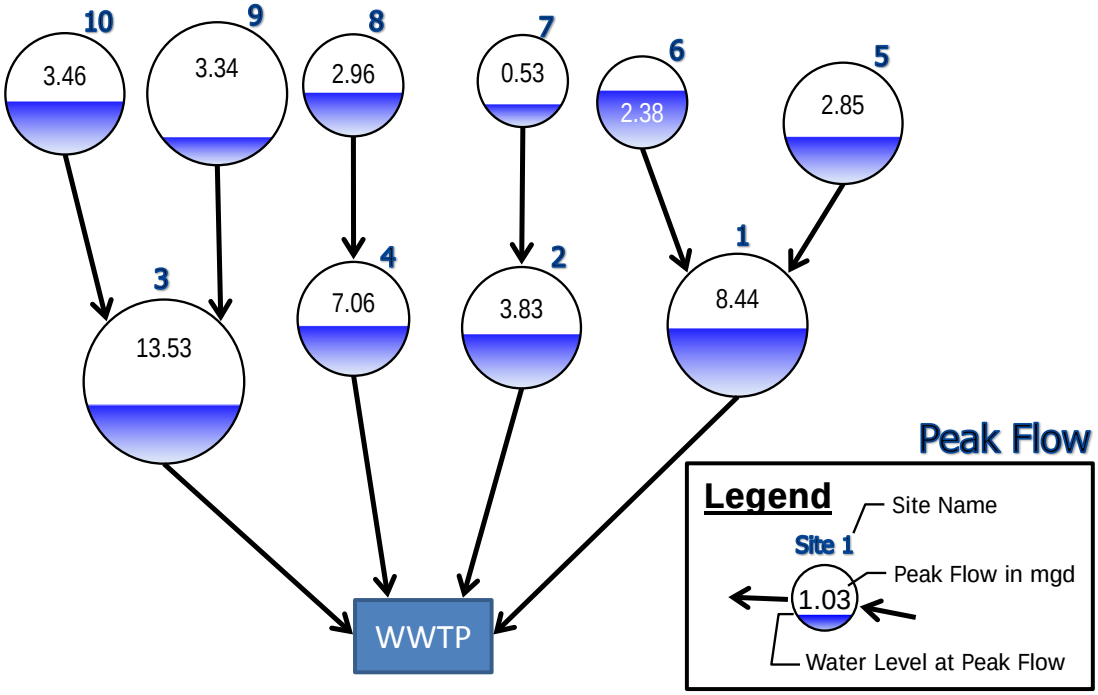


Figure 7. Peak Measured Flow Schematic

APPENDIX A

FLOW MONITORING SITES: DATA, GRAPHS, INFORMATION

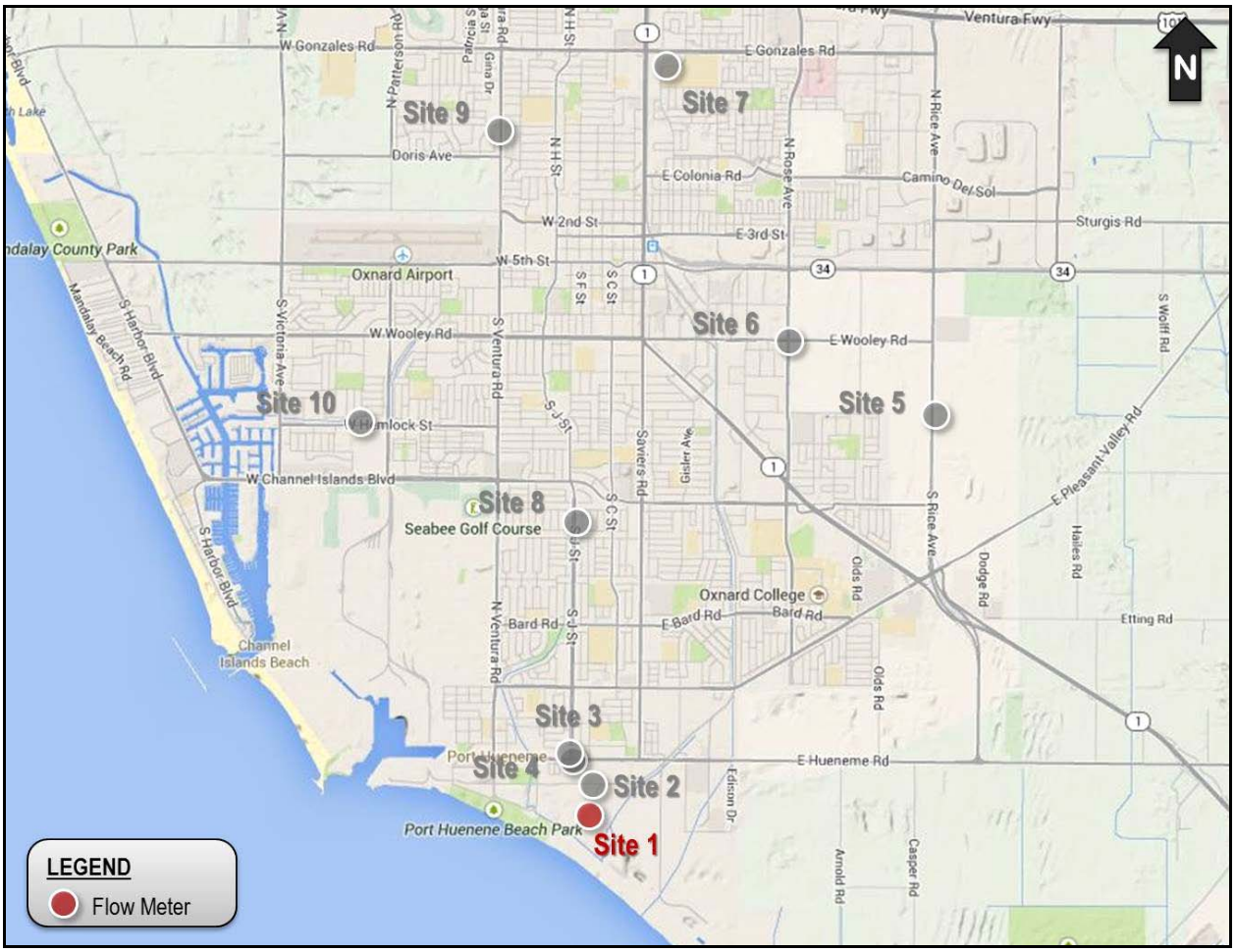
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 1

Location: McWane Boulevard, east of Perkins Road

Data Summary Report



Vicinity Map: Site 1

SITE 1

Site Information

Location: McWane Boulevard, east of Perkins Road

Coordinates: 119.1833° W, 34.1401° N

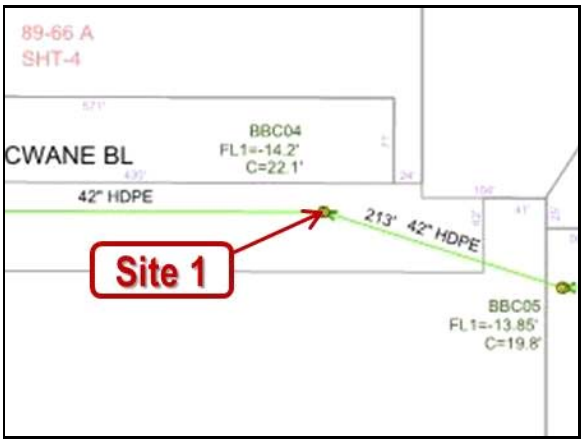
Rim Elevation: 10 feet

Pipe Diameter: 41.5 inches

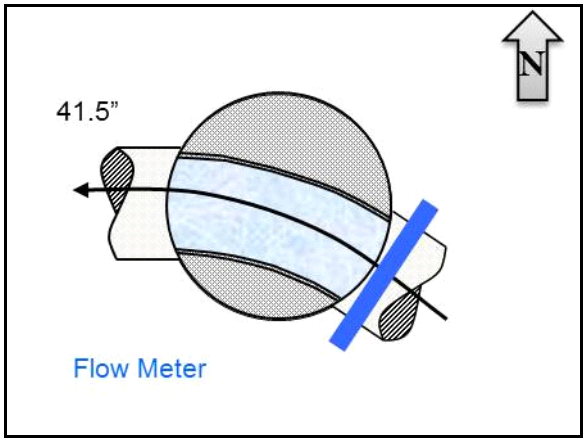
Baseline Flow: 5.142 mgd

Peak Measured Flow: 8.438 mgd

Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 1

Additional Site Photos

Effluent Pipe

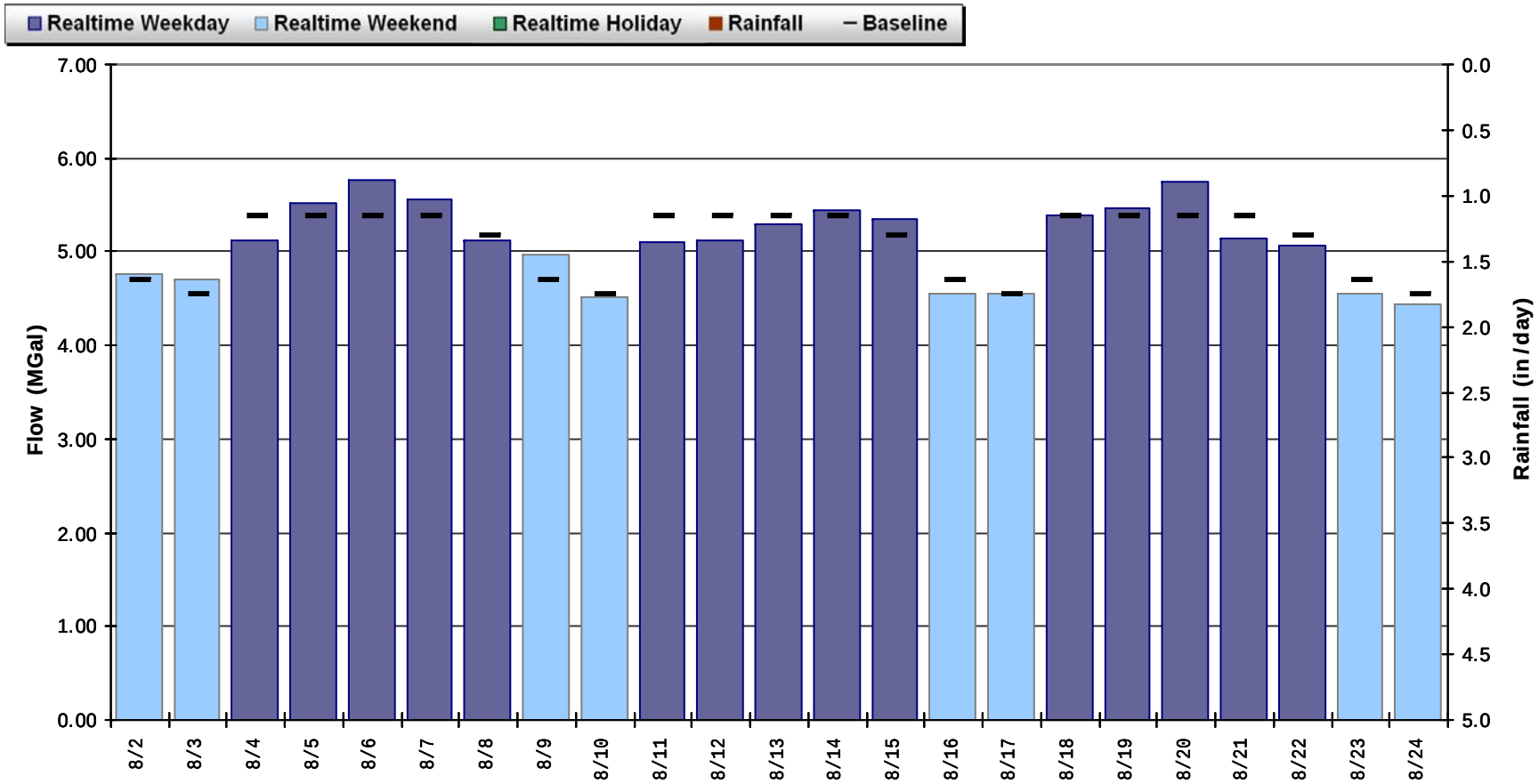
Influent Pipe

SITE 1

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 5.098 MGal **Peak Daily Flow: 5.768 MGal** **Min Daily Flow: 4.436 MGal**

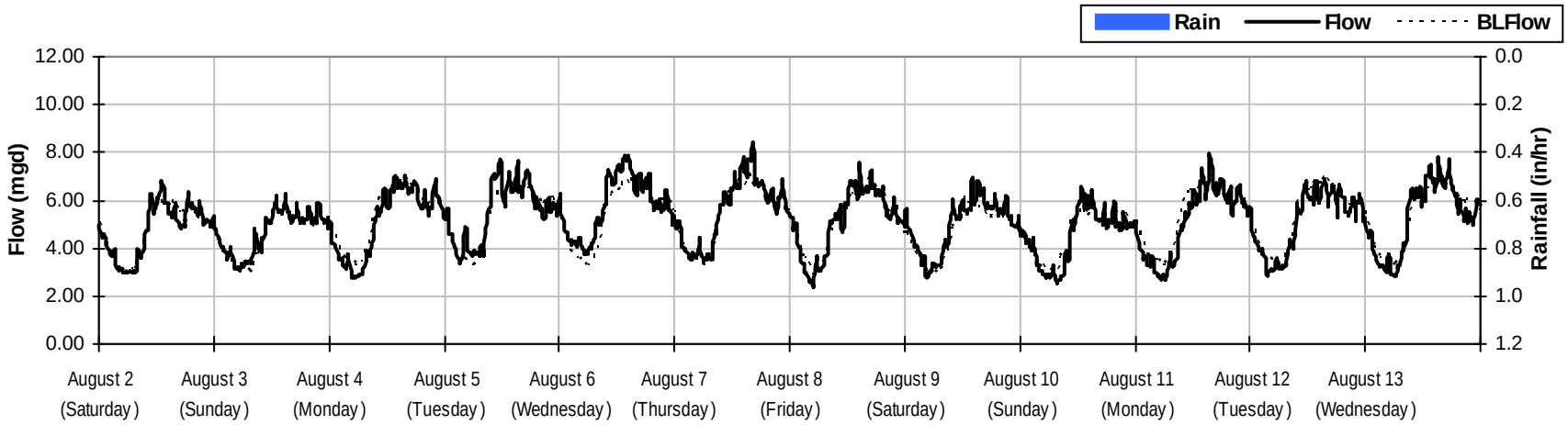
Total Monthly Rainfall: 0.00 inches

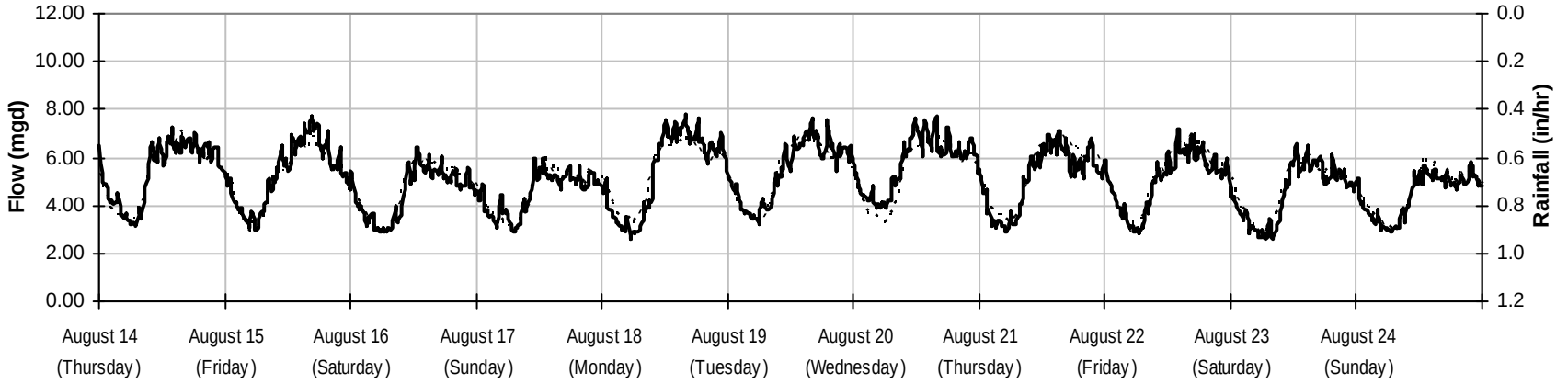


SITE 1

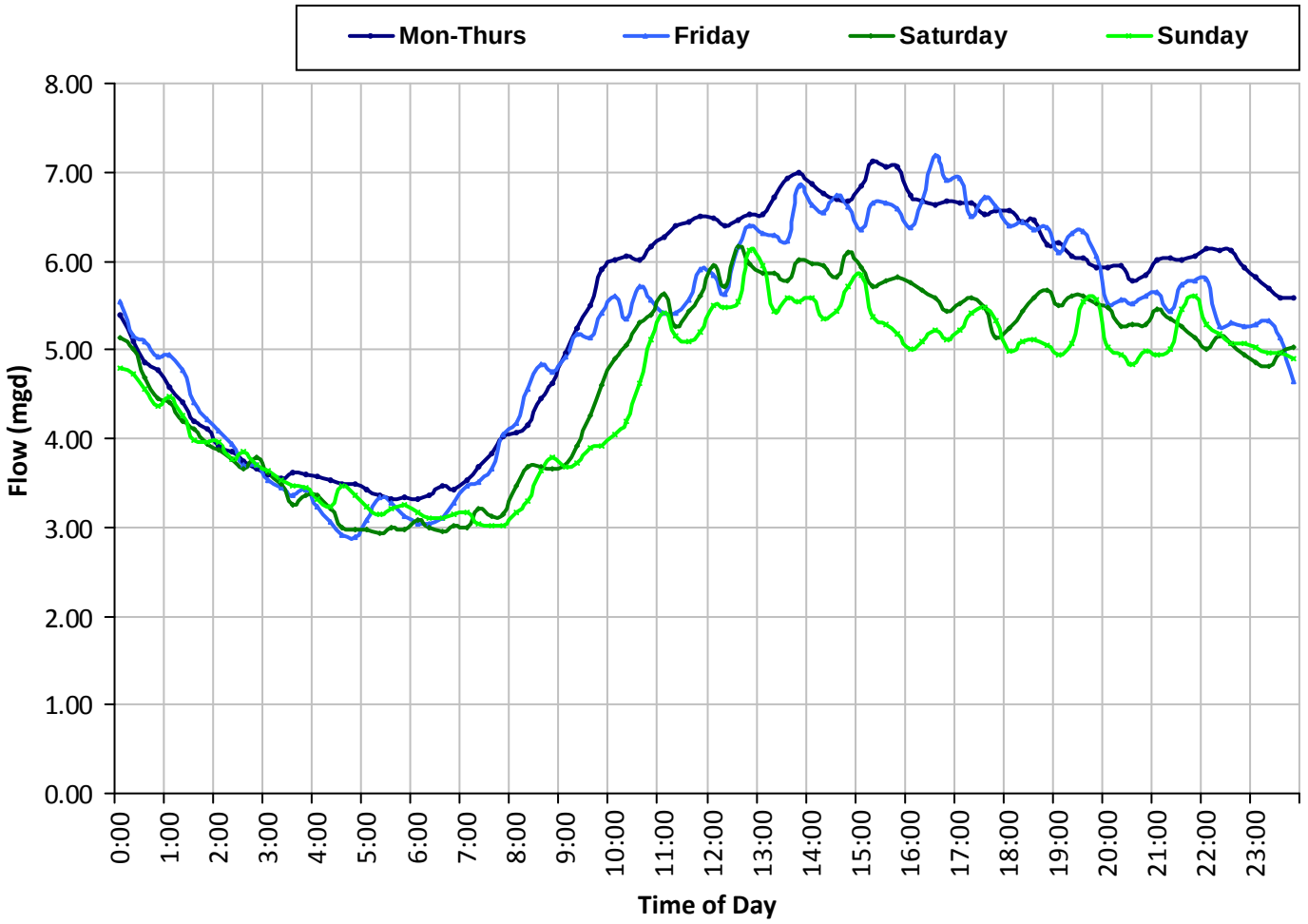
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 5.098 mgd** **Peak Flow: 8.438 mgd** **Min Flow: 2.386 mgd**



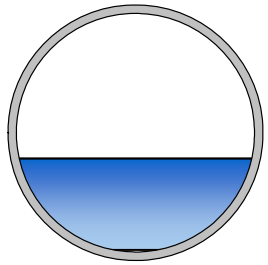


SITE 1
Baseline Flow Hydrographs



Baseline Flow:

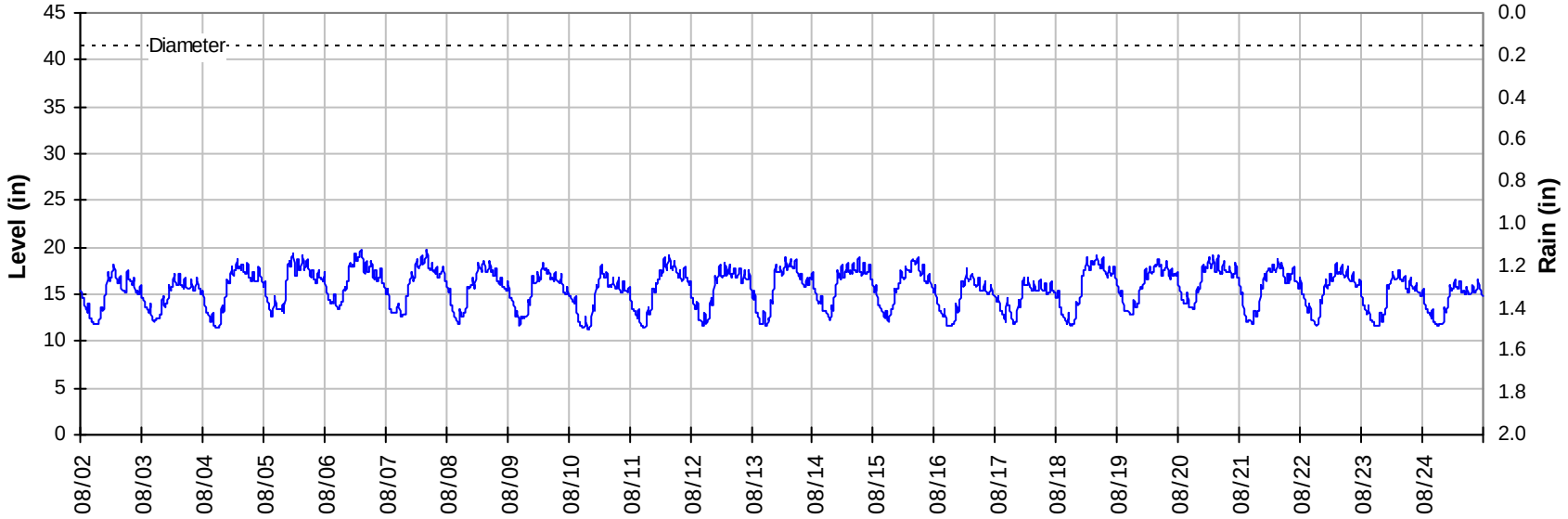
5.142 *mgd*

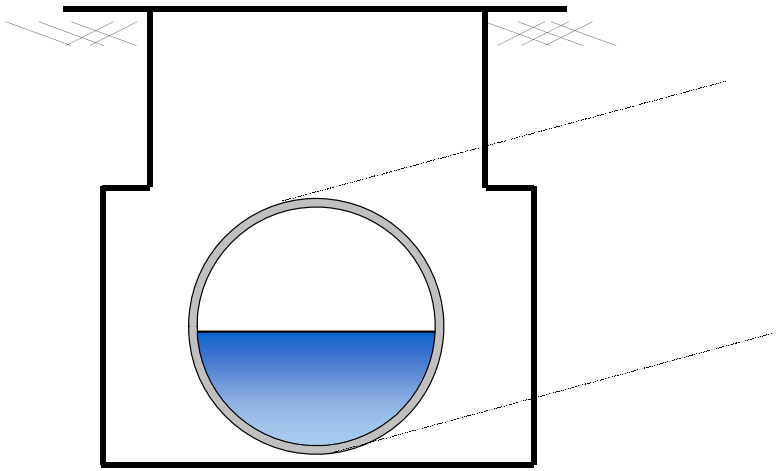


SITE 1

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period



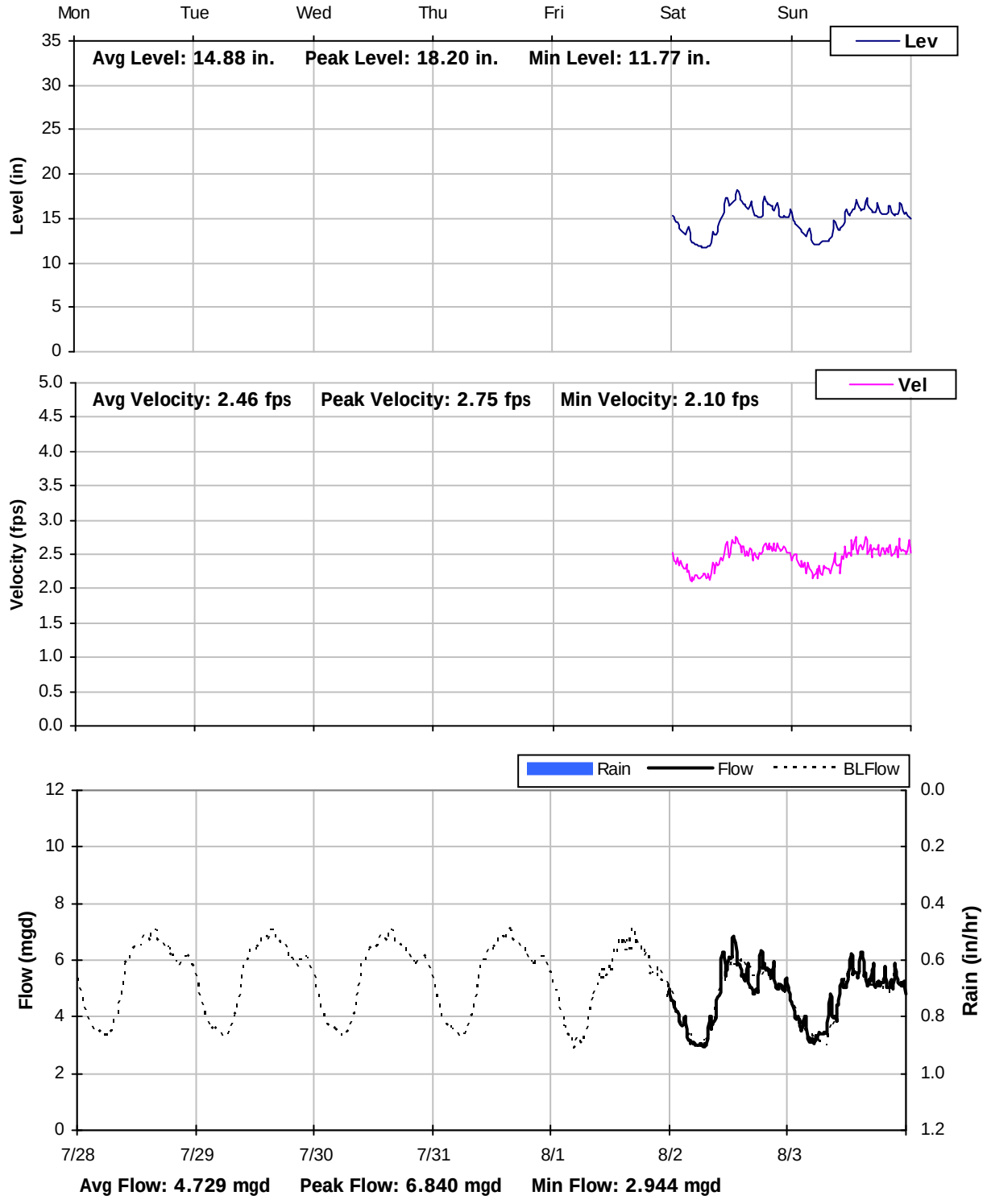


Pipe Diameter:	41.5	*inches*
Peak Measured Level:	19.8	*inches*
Peak d/D Ratio:	0.48	

SITE 1

Weekly Level, Velocity and Flow Hydrographs

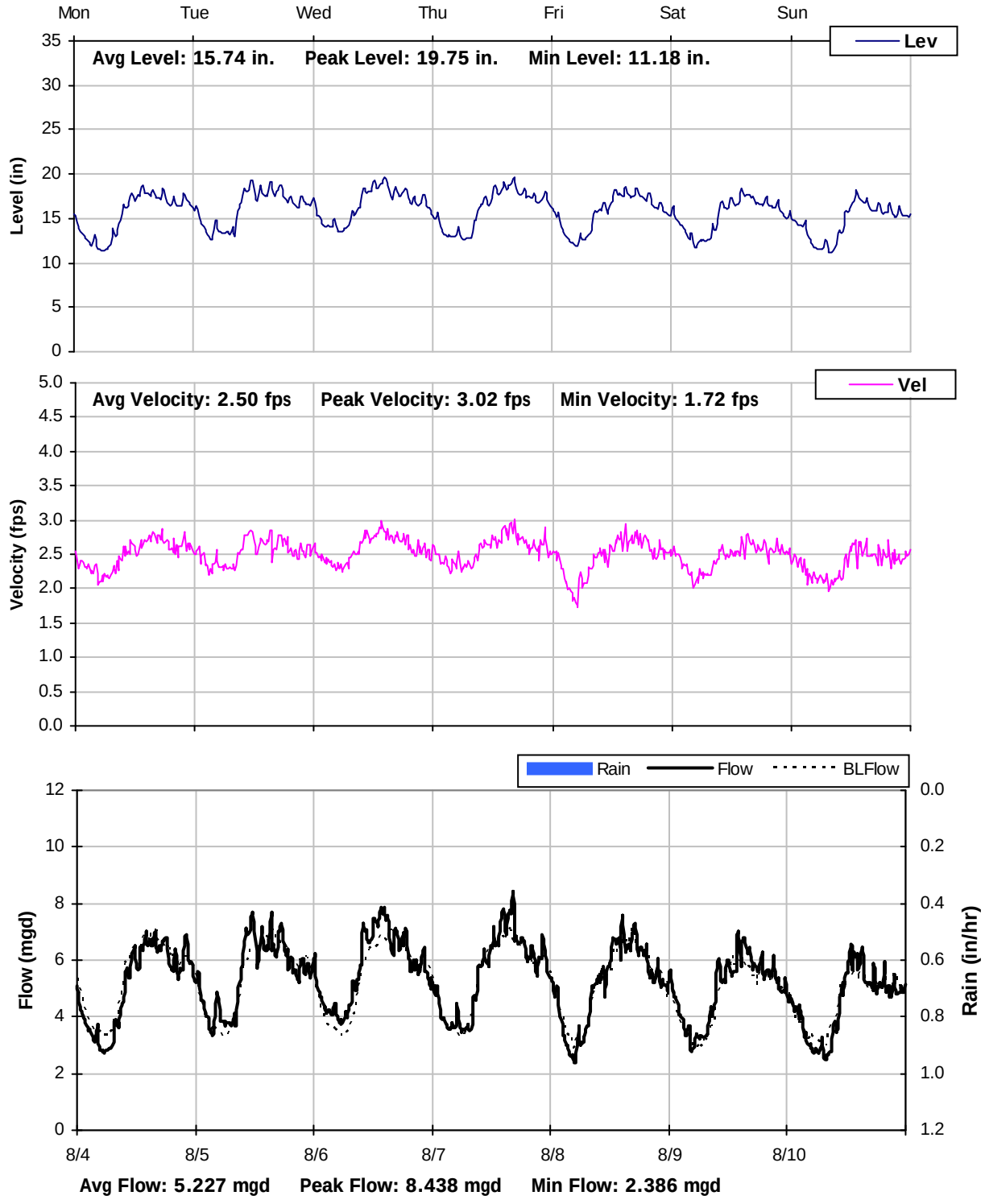
7/28/2014 to 8/4/2014



SITE 1

Weekly Level, Velocity and Flow Hydrographs

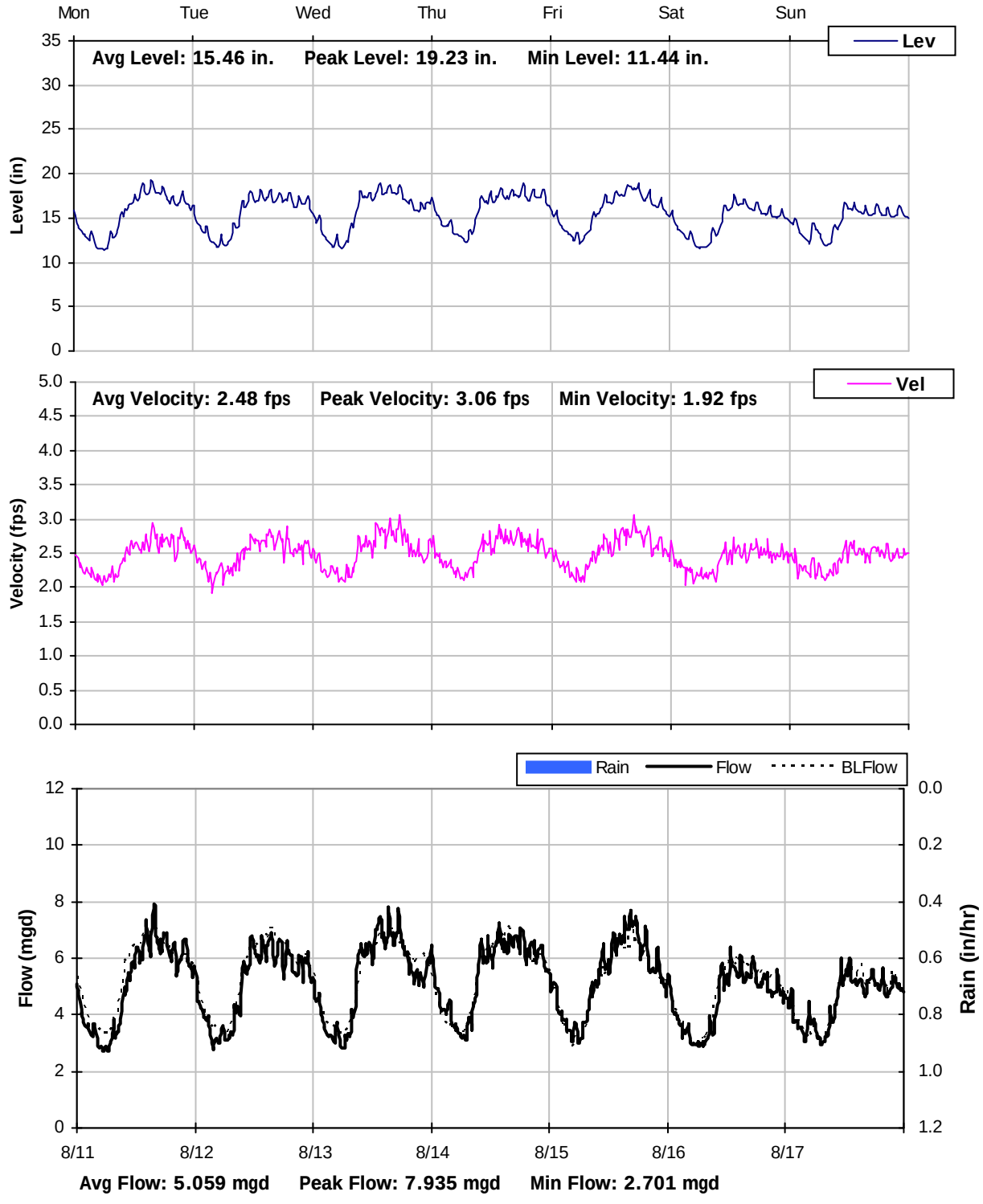
8/4/2014 to 8/11/2014



SITE 1

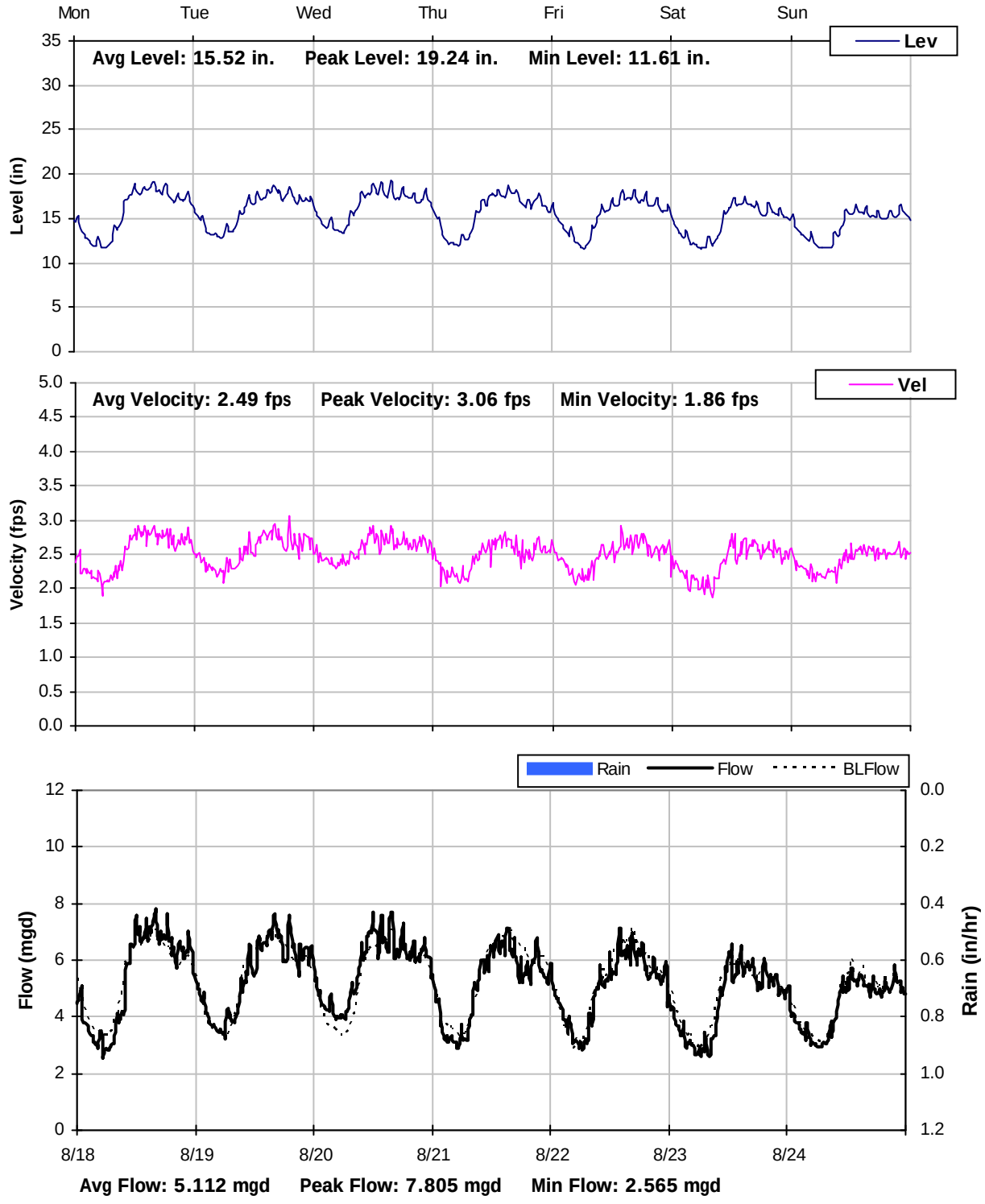
Weekly Level, Velocity and Flow Hydrographs

8/11/2014 to 8/18/2014



SITE 1

Weekly Level, Velocity and Flow Hydrographs
8/18/2014 to 8/25/2014



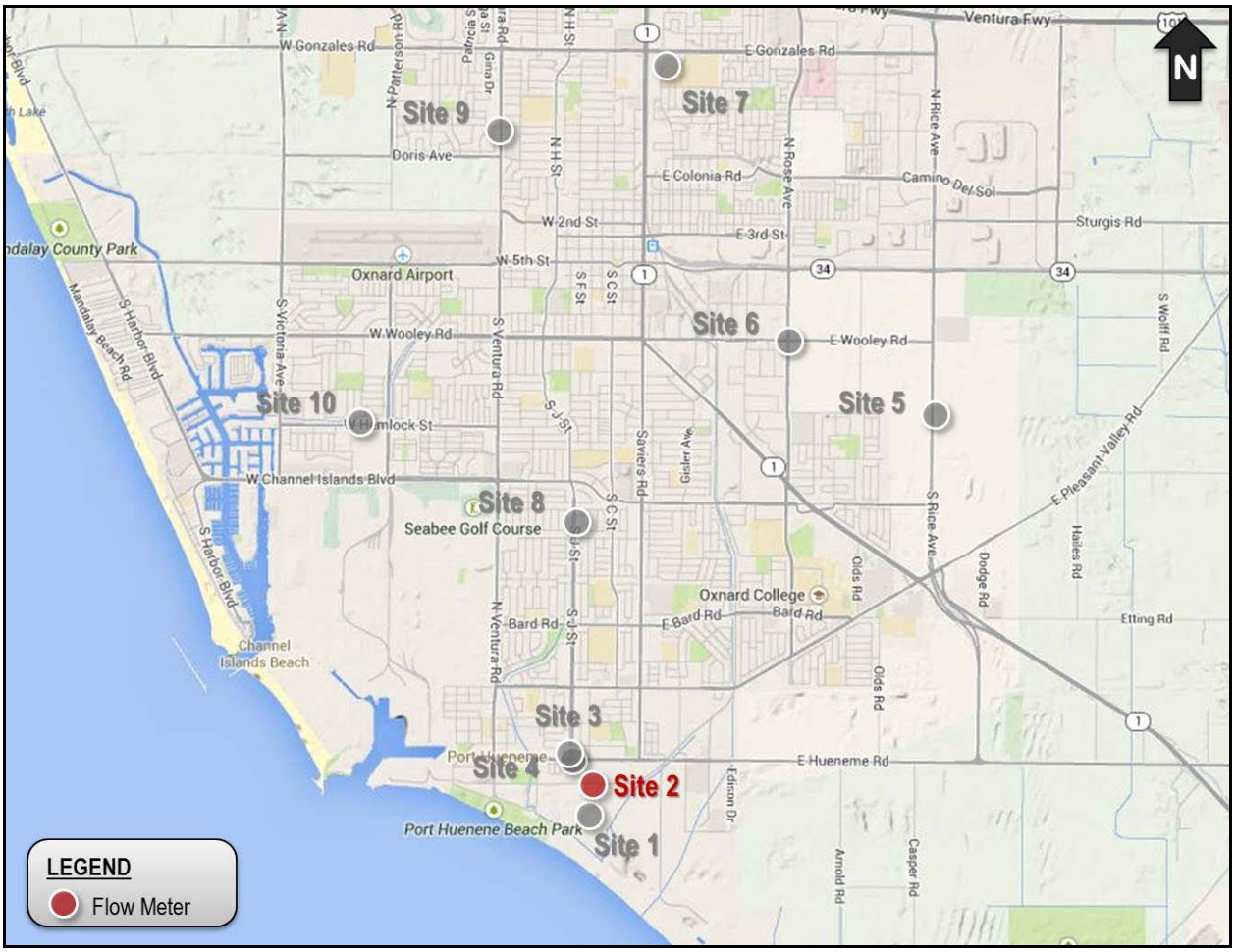
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 2

Location: Magellan Avenue

Data Summary Report



Vicinity Map: Site 2

SITE 2

Site Information

Location: Magellan Avenue

Coordinates: 119.1830° W, 34.1448° N

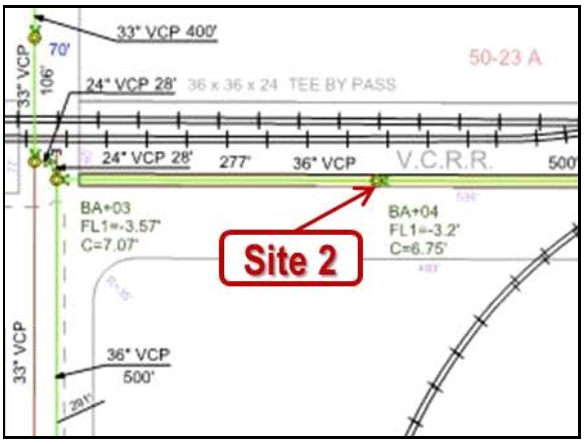
Rim Elevation: 13 feet

Pipe Diameter: 36 inches

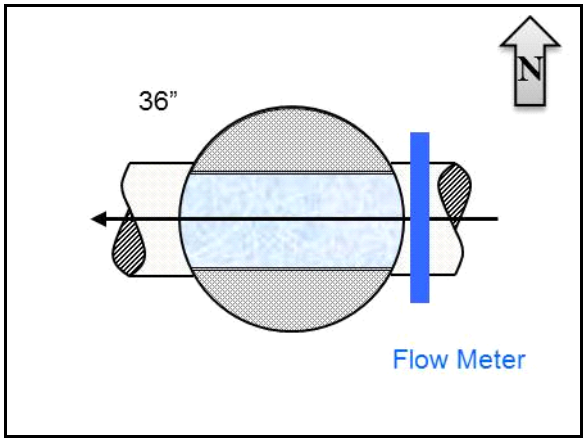
Baseline Flow: 2.702 mgd

Peak Measured Flow: 3.833 mgd

Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 2

Additional Site Photos

Effluent Pipe

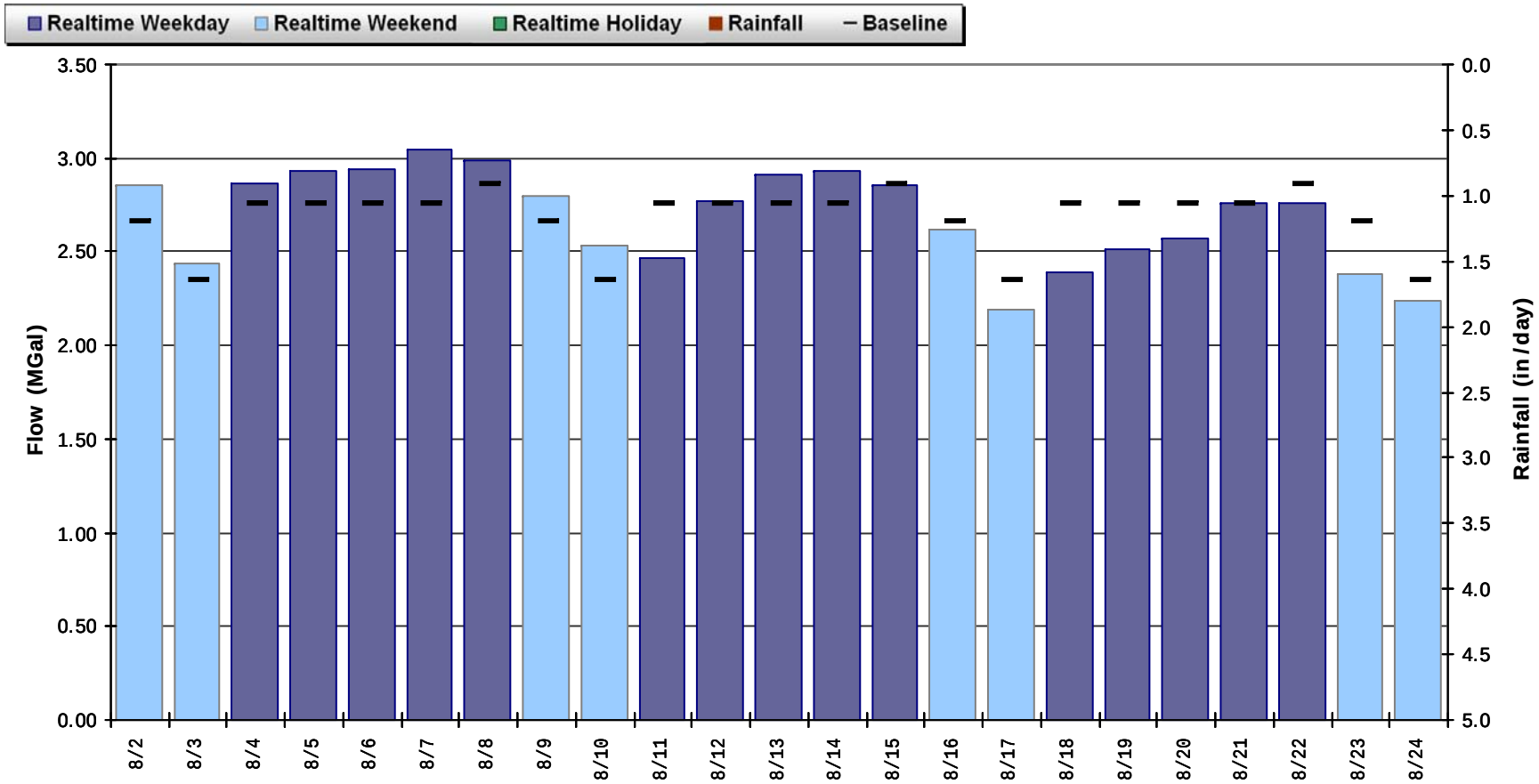
Influent Pipe

SITE 2

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 2.685 MGal **Peak Daily Flow: 3.043 MGal** **Min Daily Flow: 2.192 MGal**

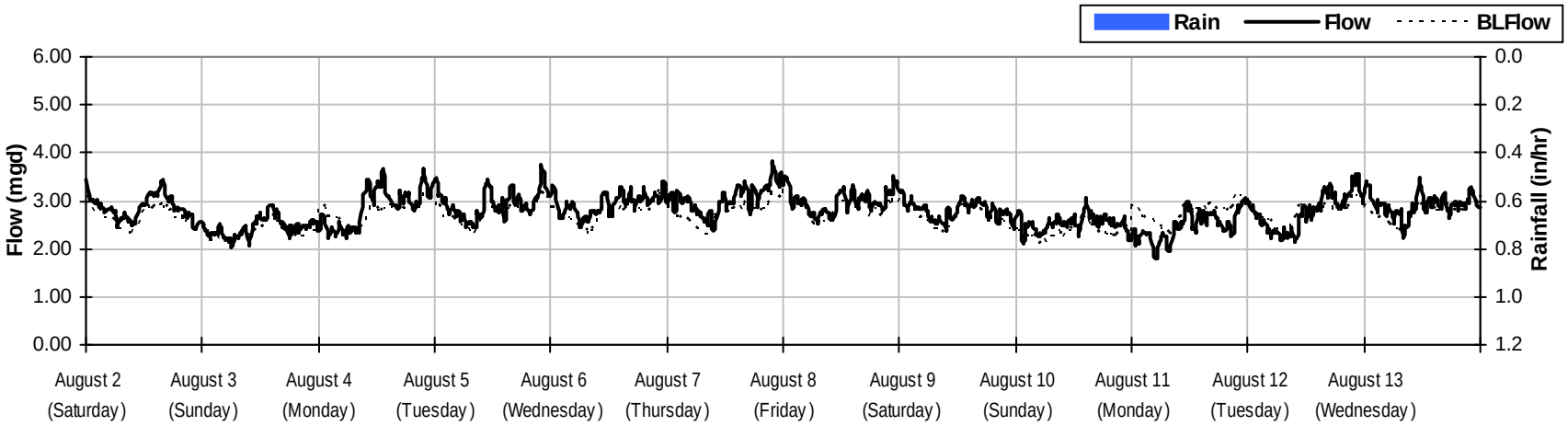
Total Monthly Rainfall: 0.00 inches

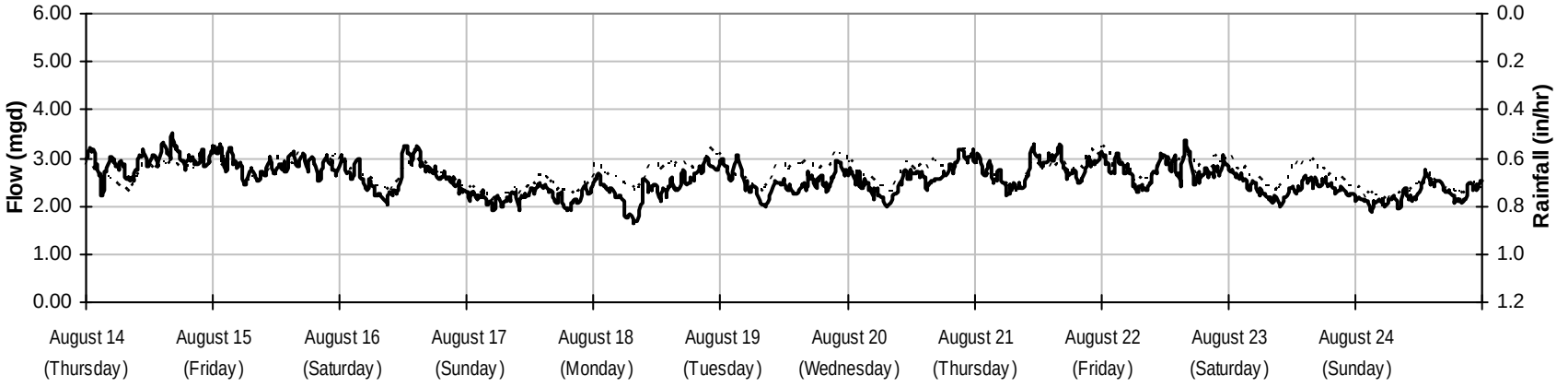


SITE 2

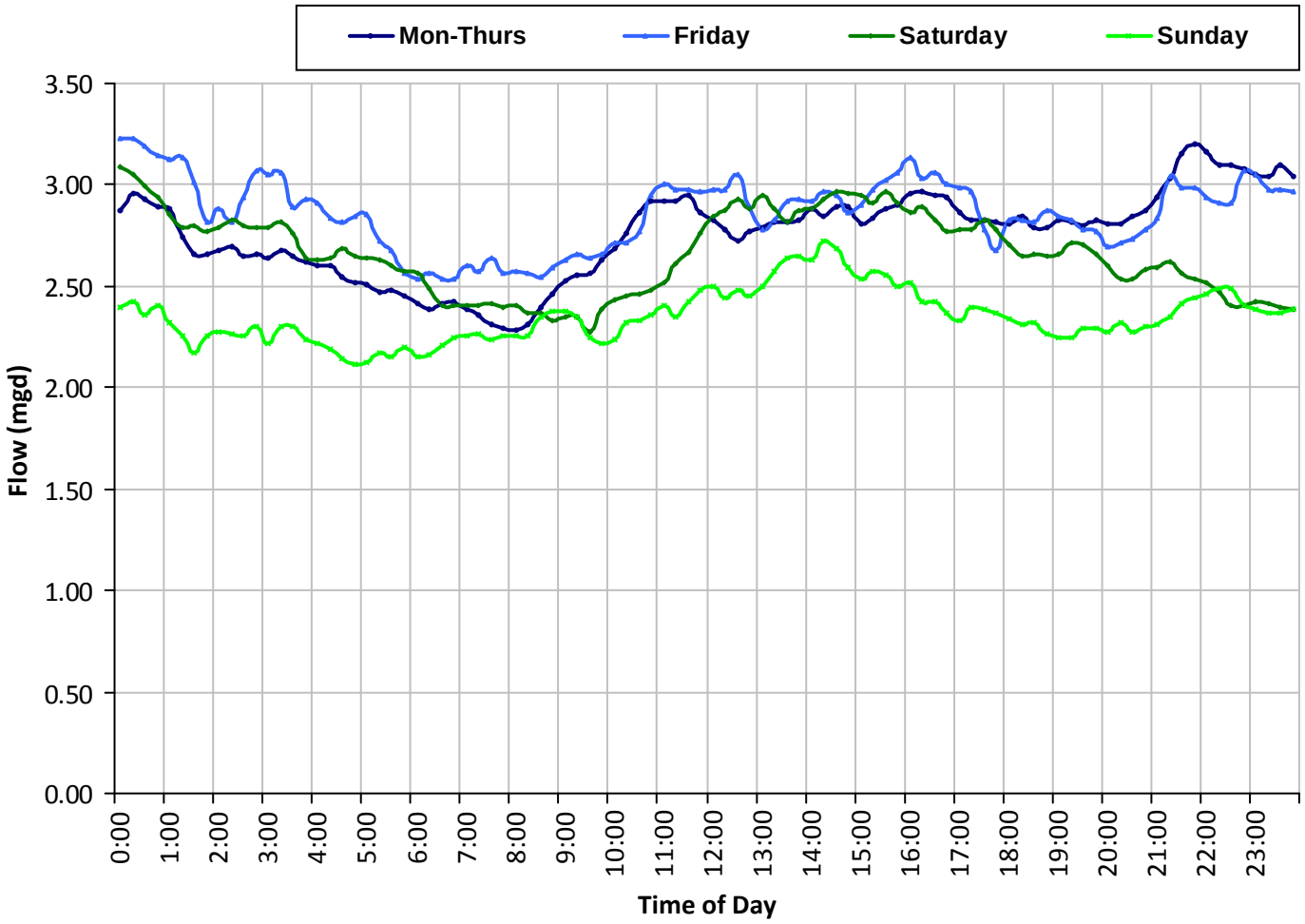
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 2.685 mgd** **Peak Flow: 3.833 mgd** **Min Flow: 1.657 mgd**



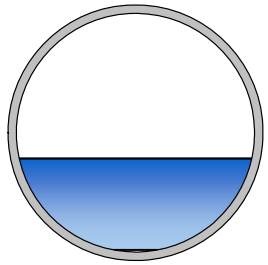


SITE 2
Baseline Flow Hydrographs



Baseline Flow:

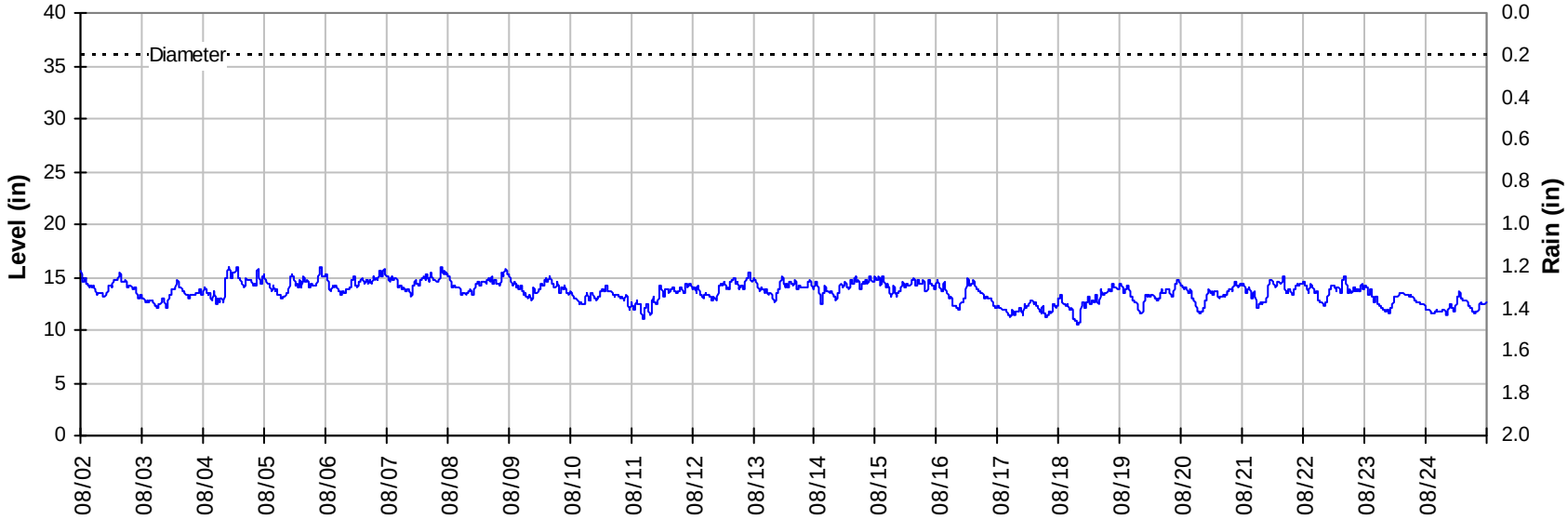
2.702 *mgd*

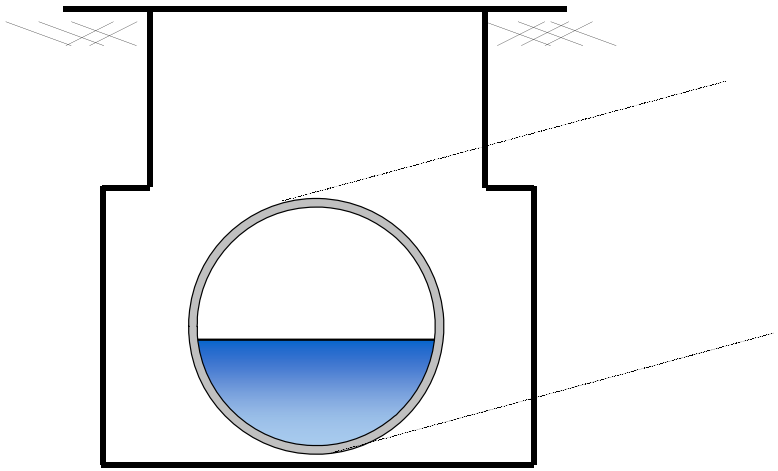


SITE 2

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period



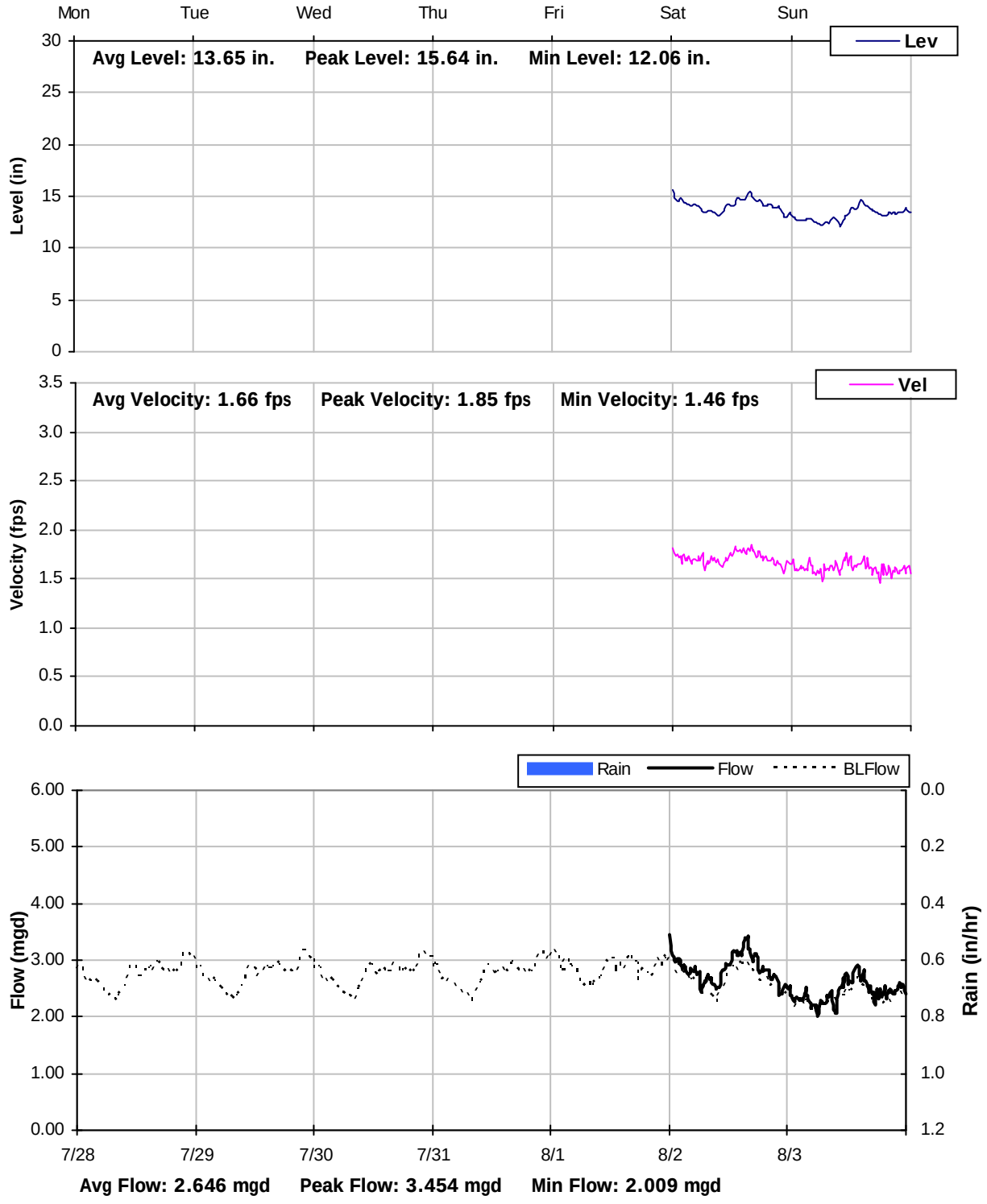


Pipe Diameter:	36	*inches*
Peak Measured Level:	16.1	*inches*
Peak d/D Ratio:	0.45	

SITE 2

Weekly Level, Velocity and Flow Hydrographs

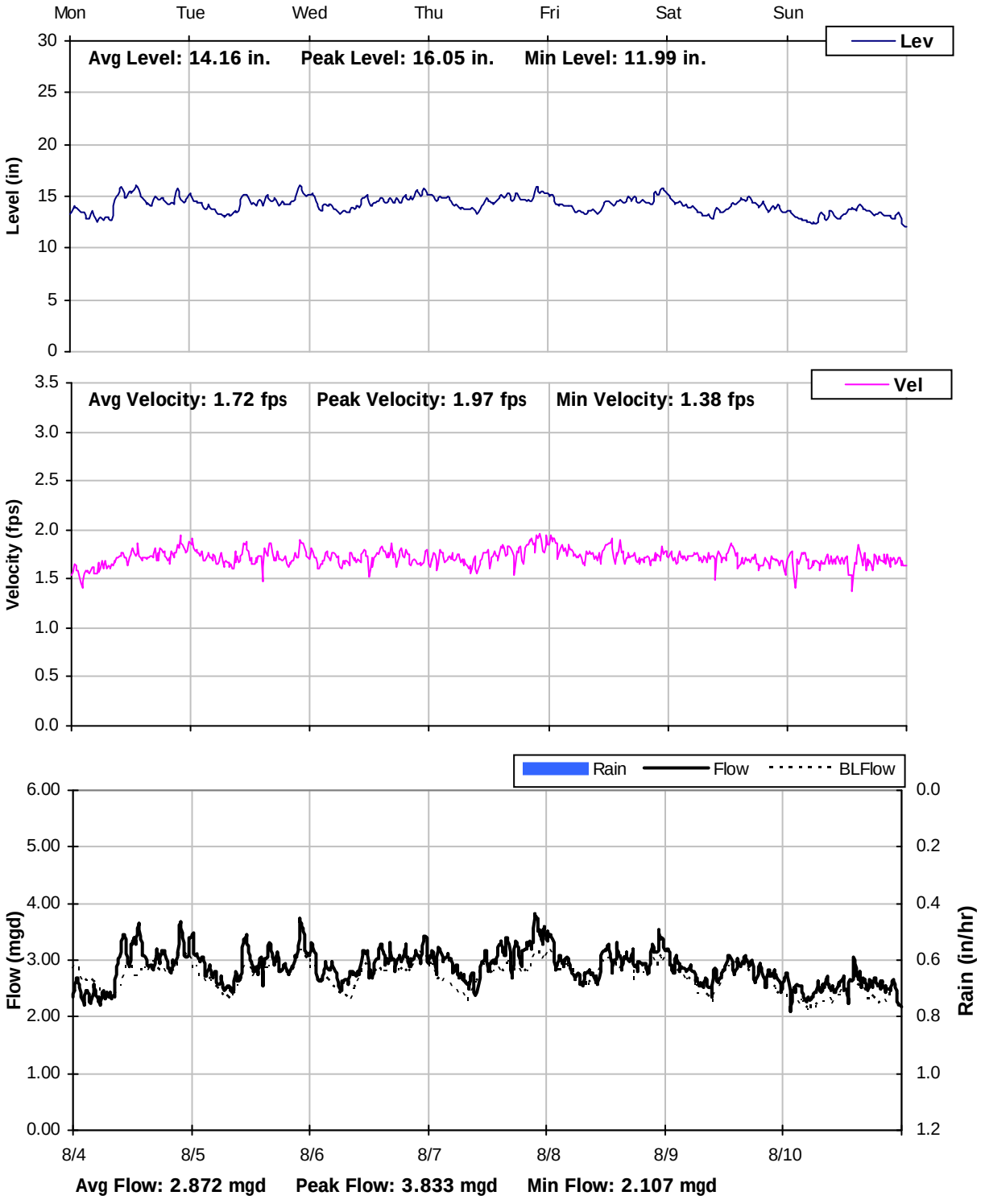
7/28/2014 to 8/4/2014



SITE 2

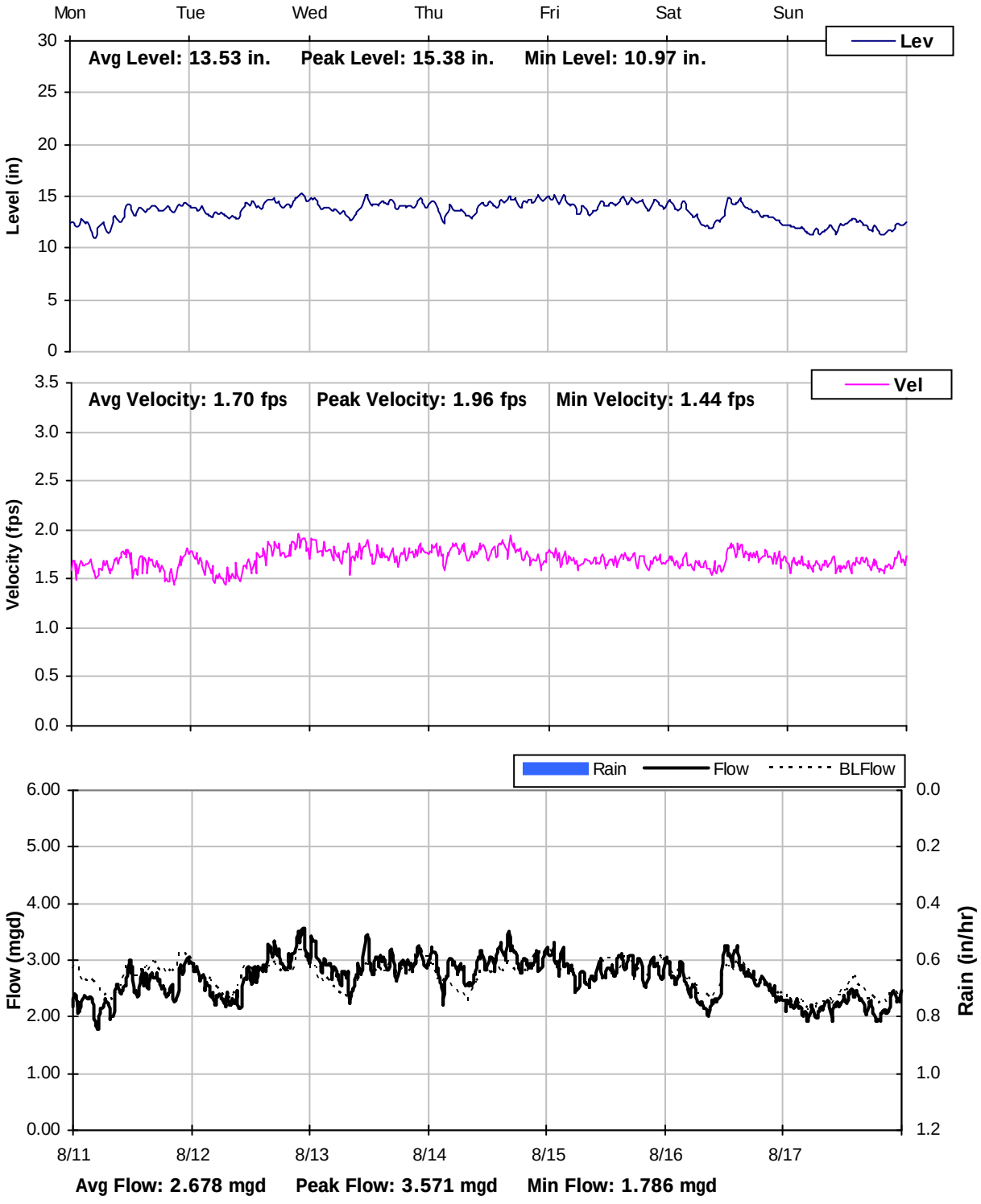
Weekly Level, Velocity and Flow Hydrographs

8/4/2014 to 8/11/2014



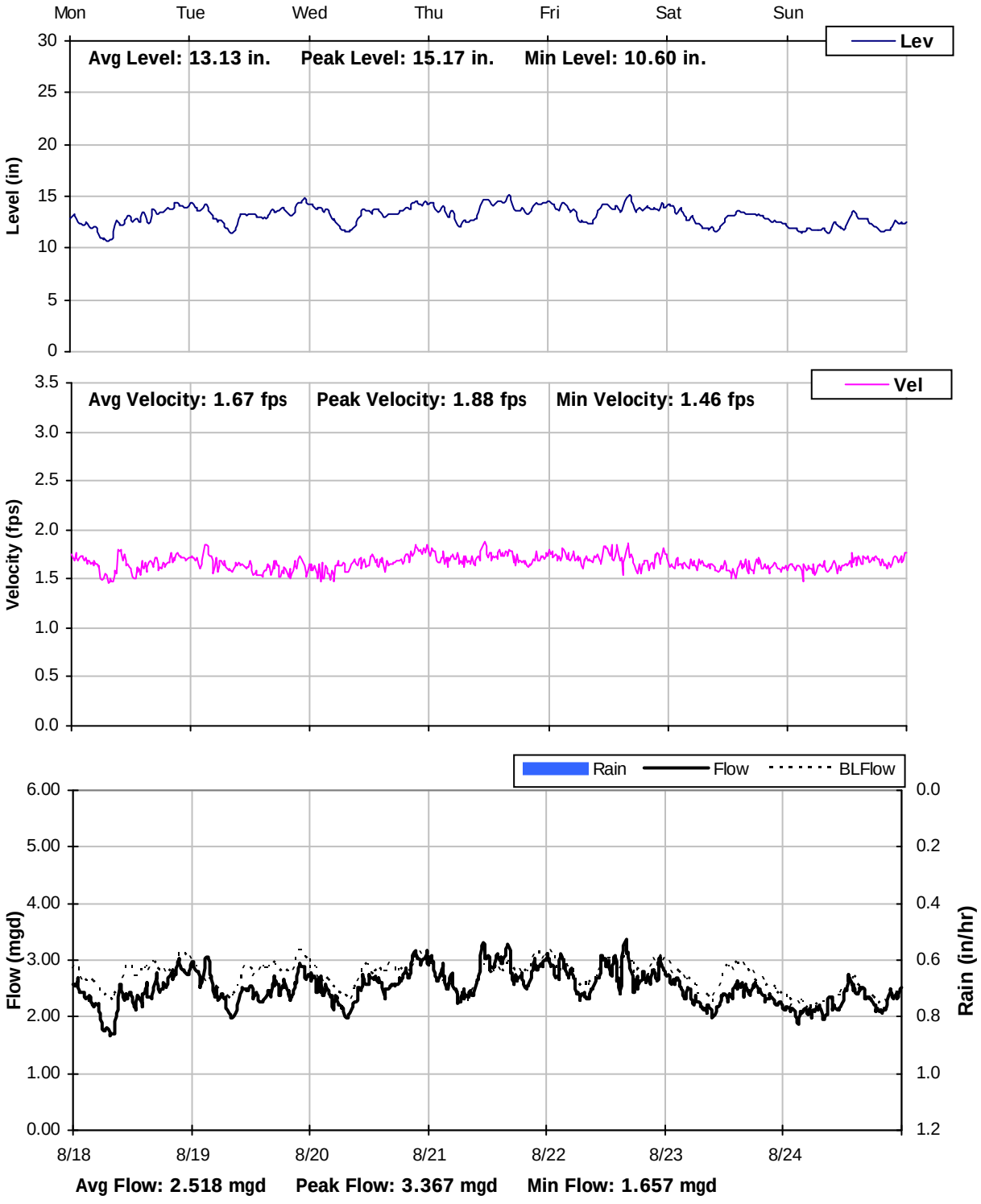
SITE 2

Weekly Level, Velocity and Flow Hydrographs
8/11/2014 to 8/18/2014



SITE 2

Weekly Level, Velocity and Flow Hydrographs
8/18/2014 to 8/25/2014



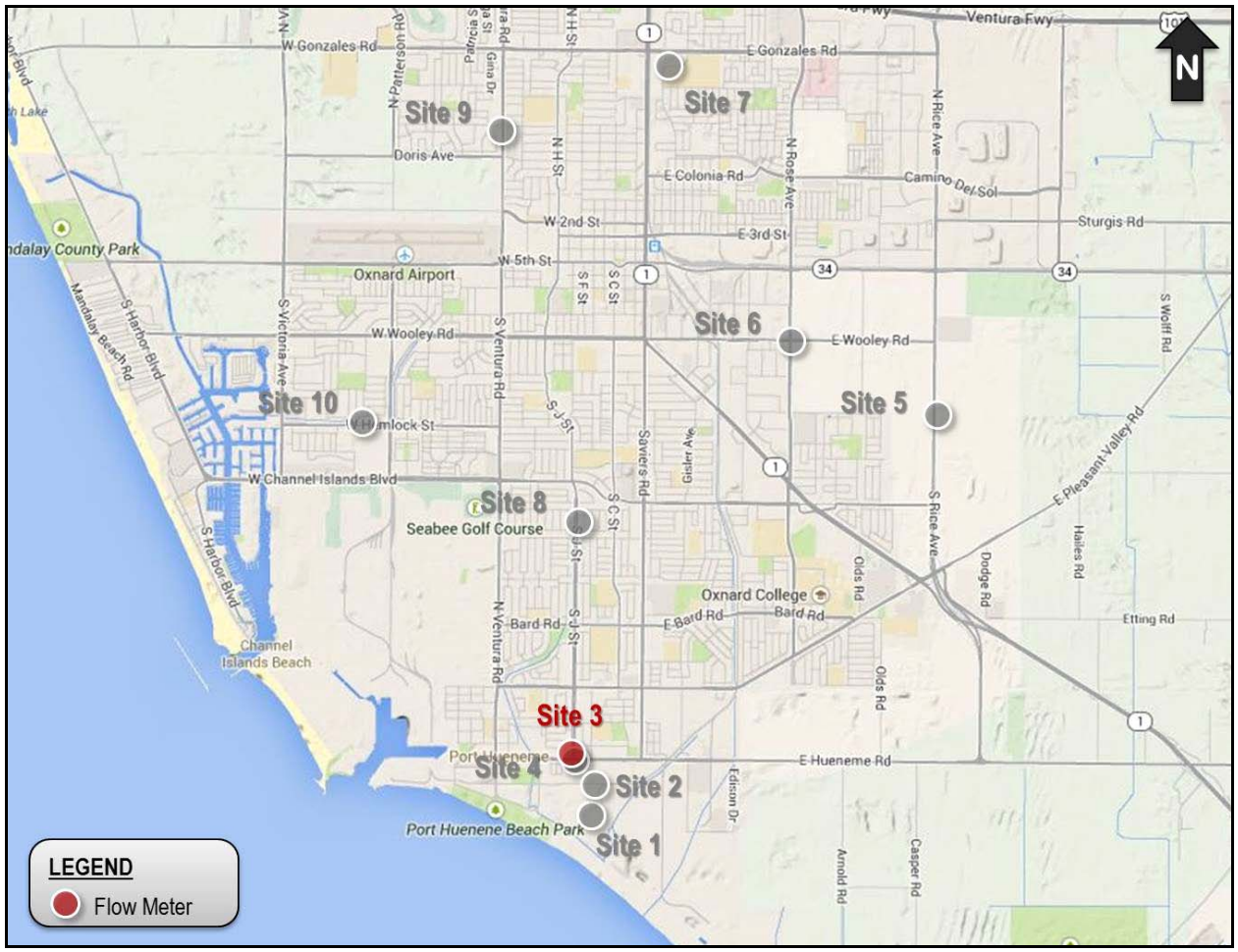
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 3

Location: J Street and E Port Hueneme Road

Data Summary Report



Vicinity Map: Site 3

SITE 3

Site Information

Location: J Street and E Port Hueneme Road

Coordinates: 119.1862° W, 34.1481° N

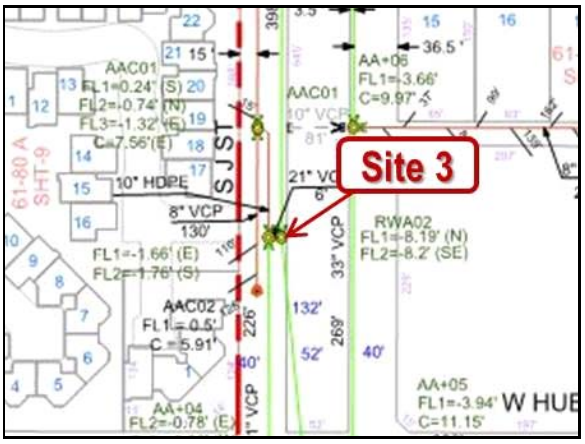
Rim Elevation: 13 feet

Pipe Diameter: 60 inches

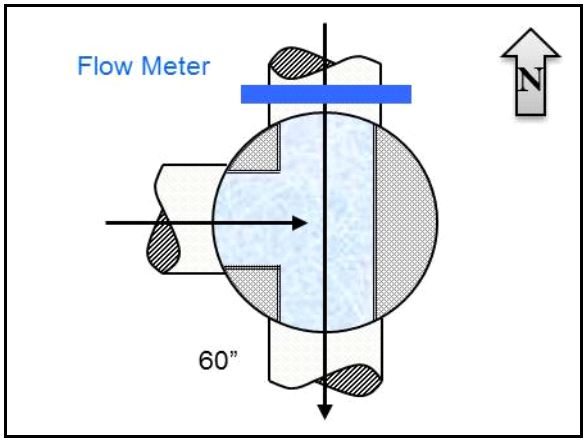
Baseline Flow: 7.134 mgd

Peak Measured Flow: 13.534 mgd

Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 3

Additional Site Photos

Effluent Pipe

Influent Pipe

SITE 3

Additional Site Photos

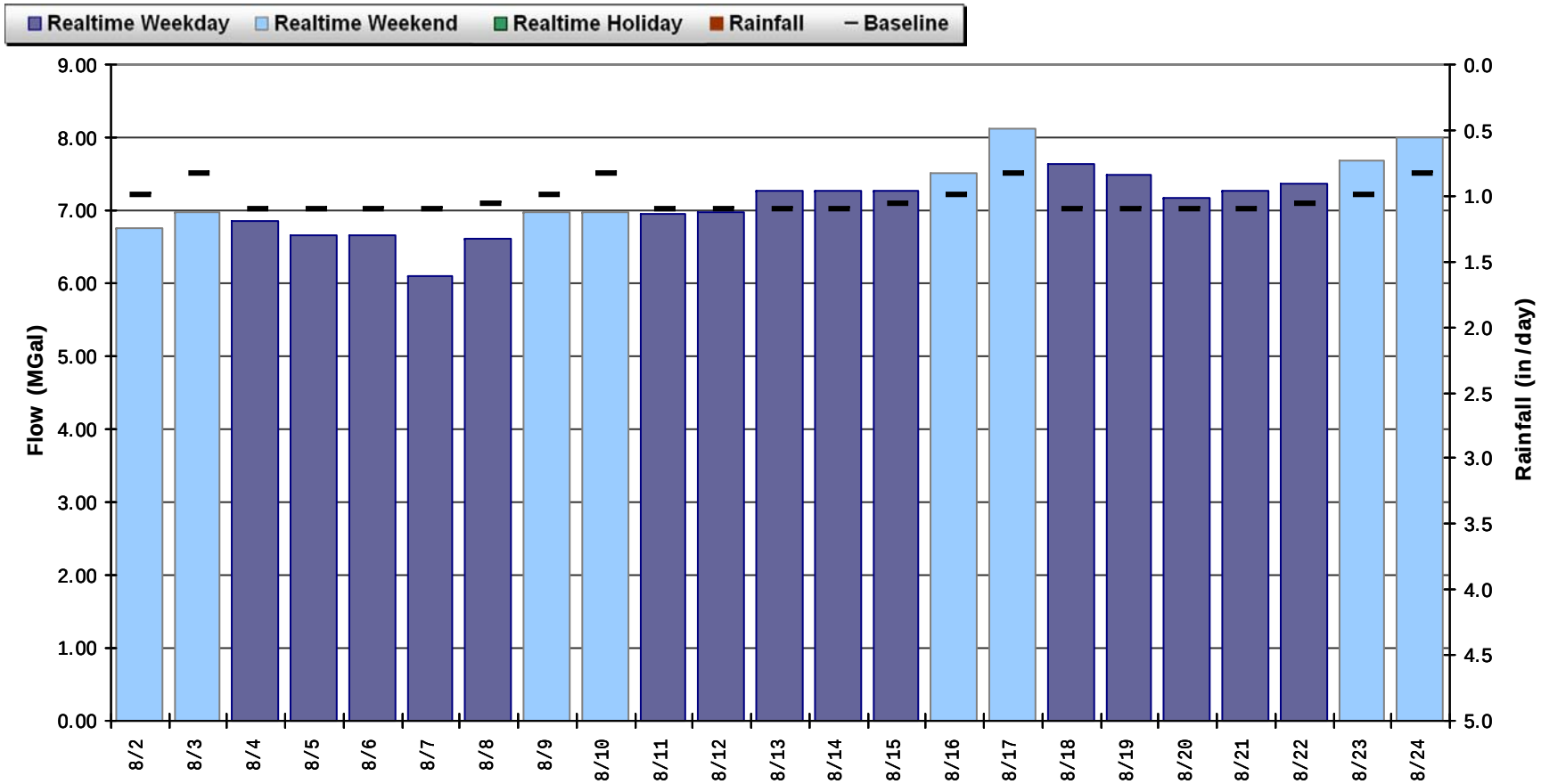
Lateral Pipe

SITE 3

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 7.155 MGal **Peak Daily Flow: 8.119 MGal** **Min Daily Flow: 6.109 MGal**

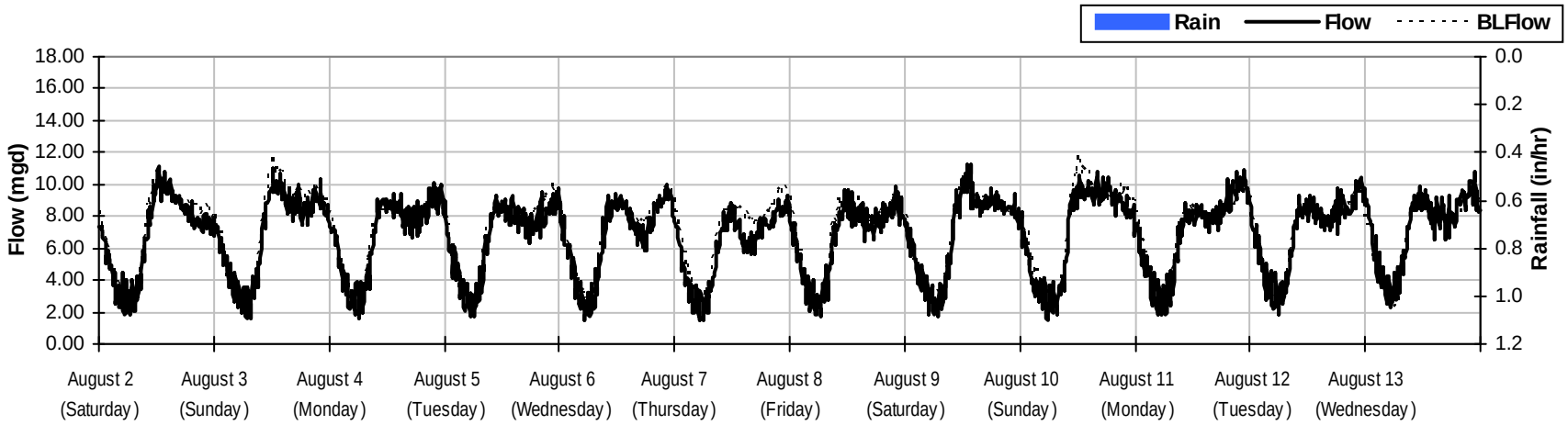
Total Monthly Rainfall: 0.00 inches

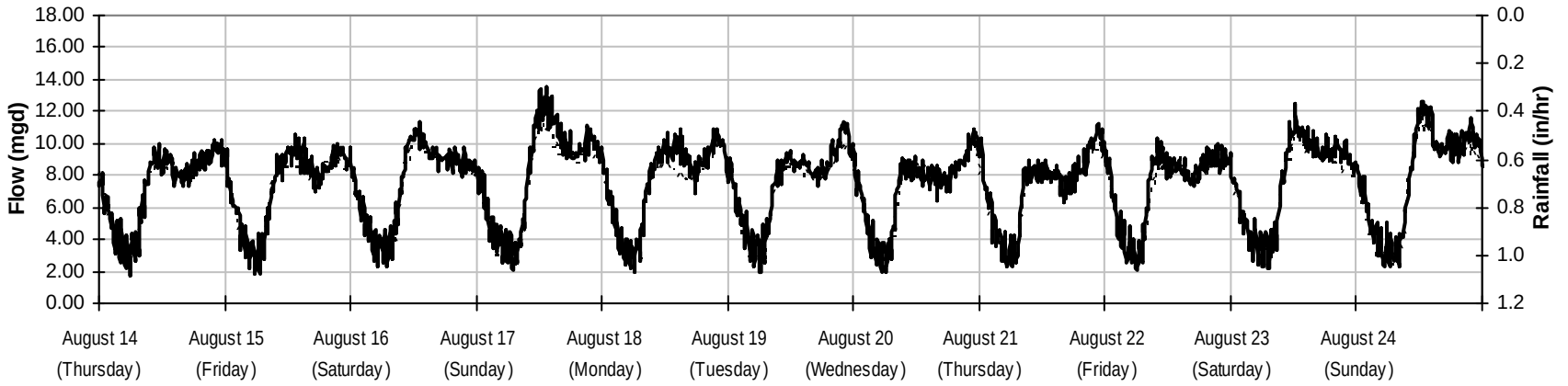


SITE 3

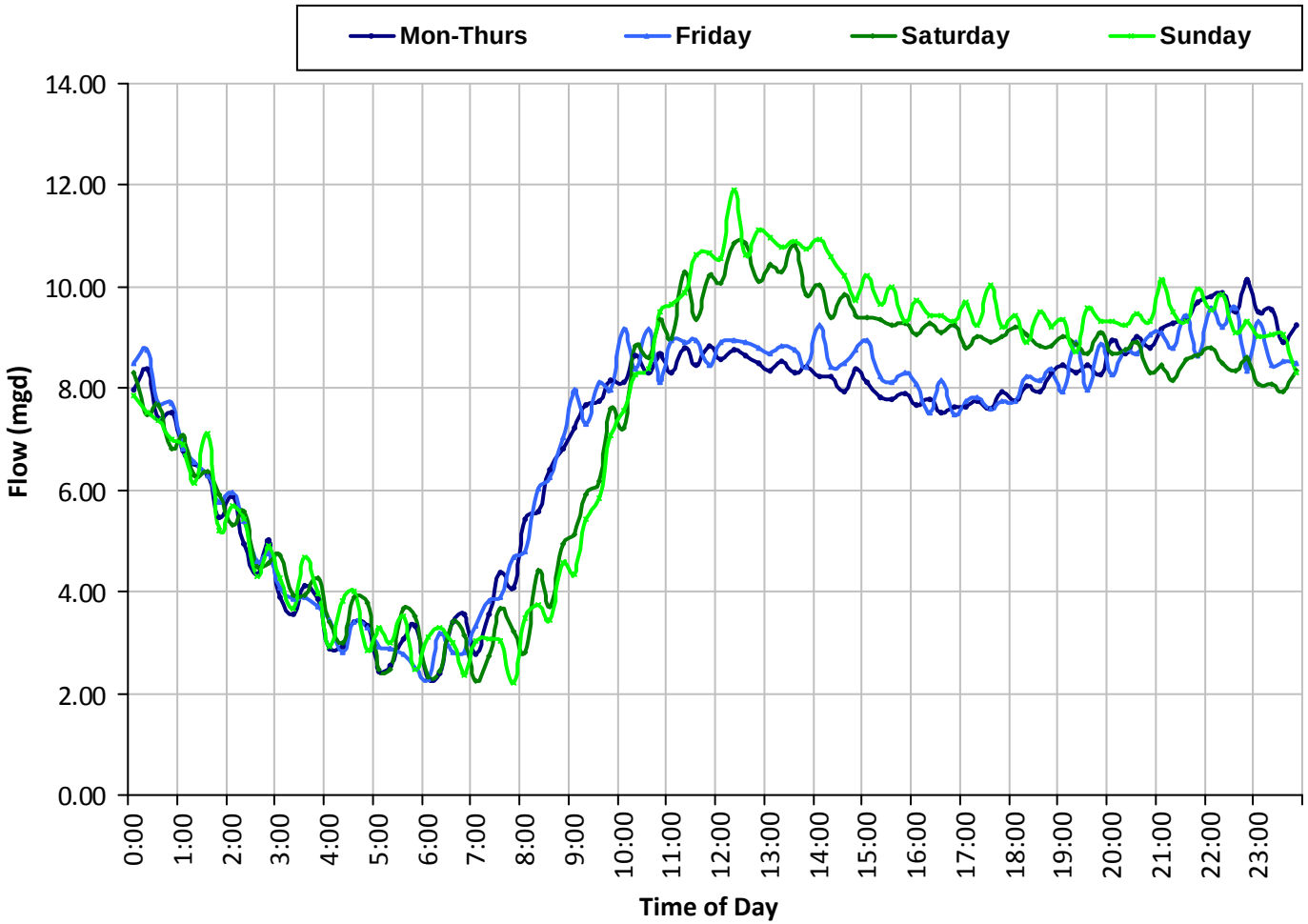
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 7.155 mgd** **Peak Flow: 13.534 mgd** **Min Flow: 1.478 mgd**



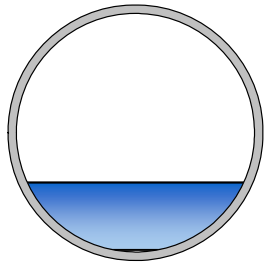


SITE 3
Baseline Flow Hydrographs



Baseline Flow:

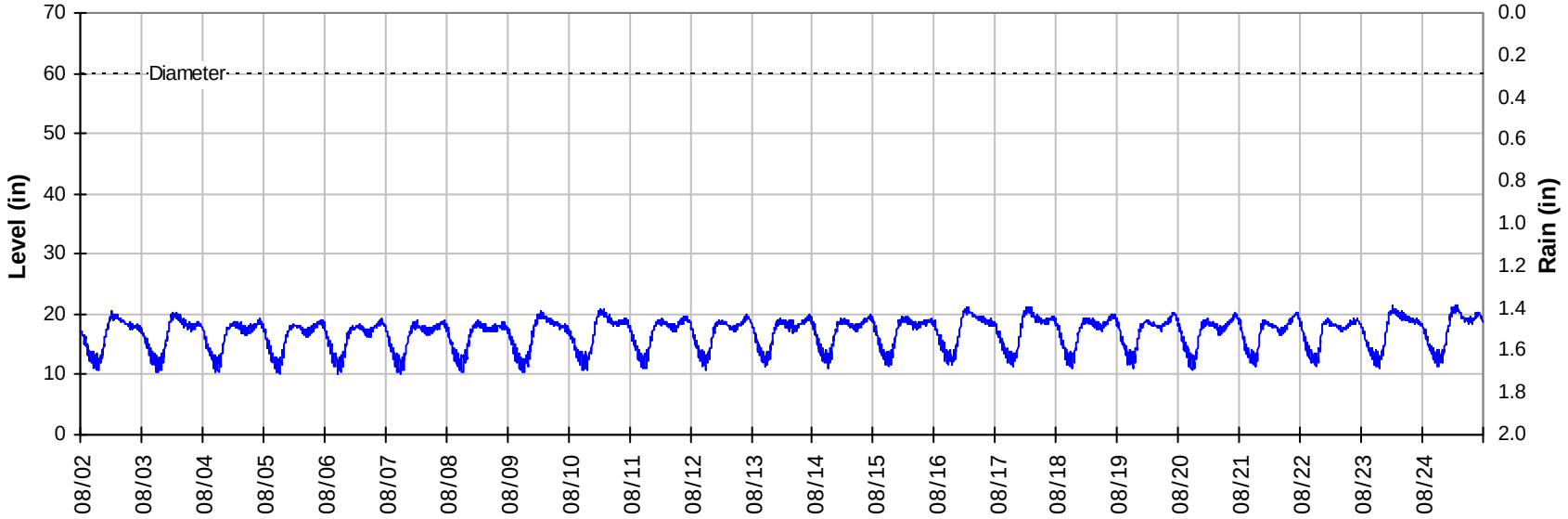
7.134 *mgd*

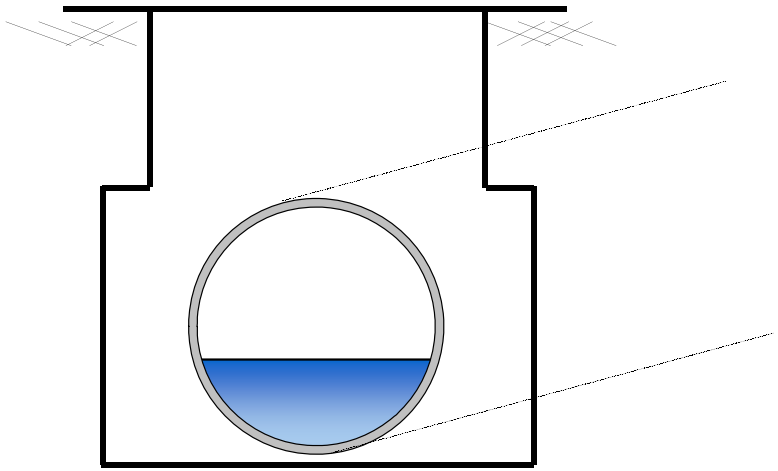


SITE 3

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period



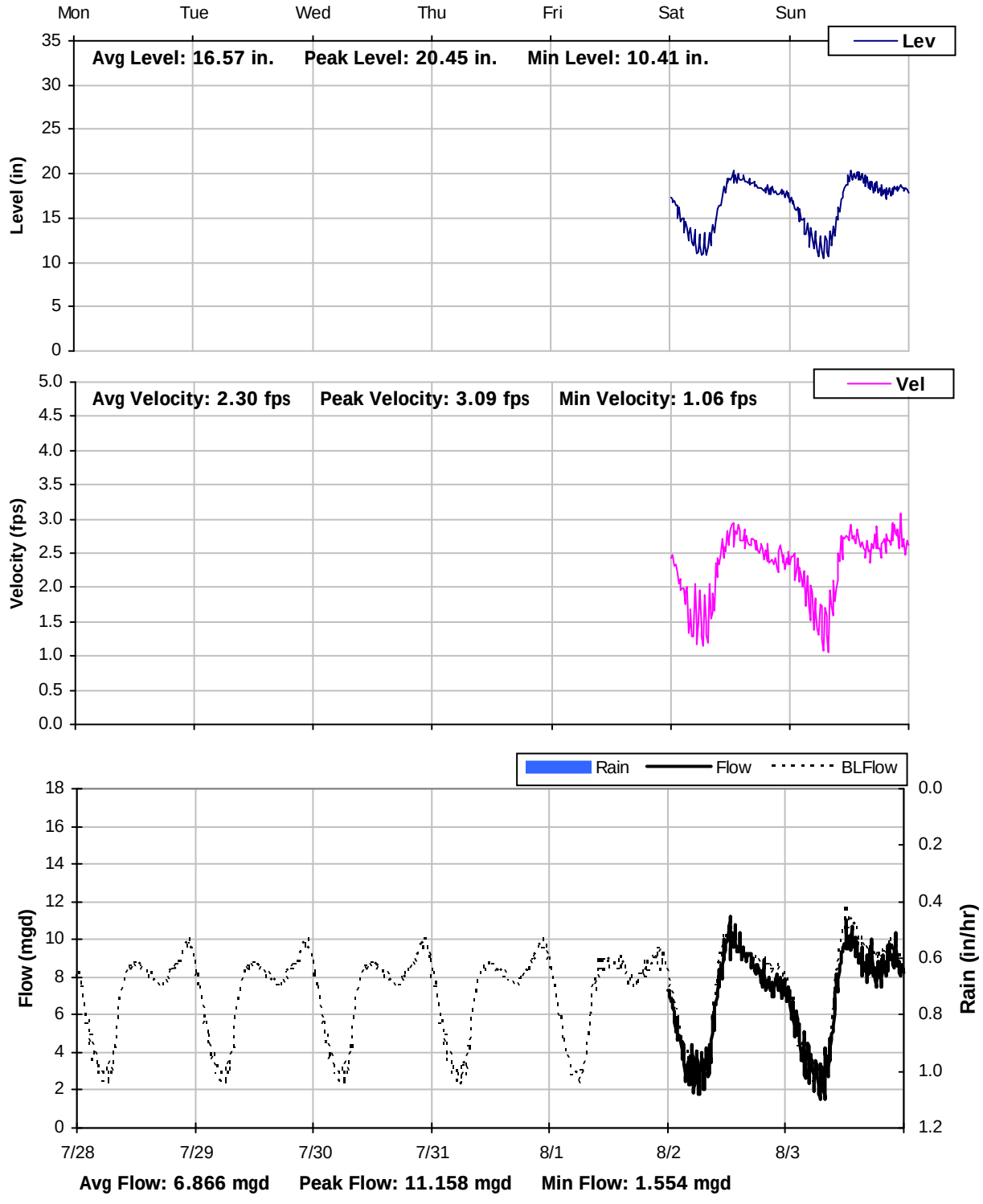


Pipe Diameter:	60	*inches*
Peak Measured Level:	21.5	*inches*
Peak d/D Ratio:	0.36	

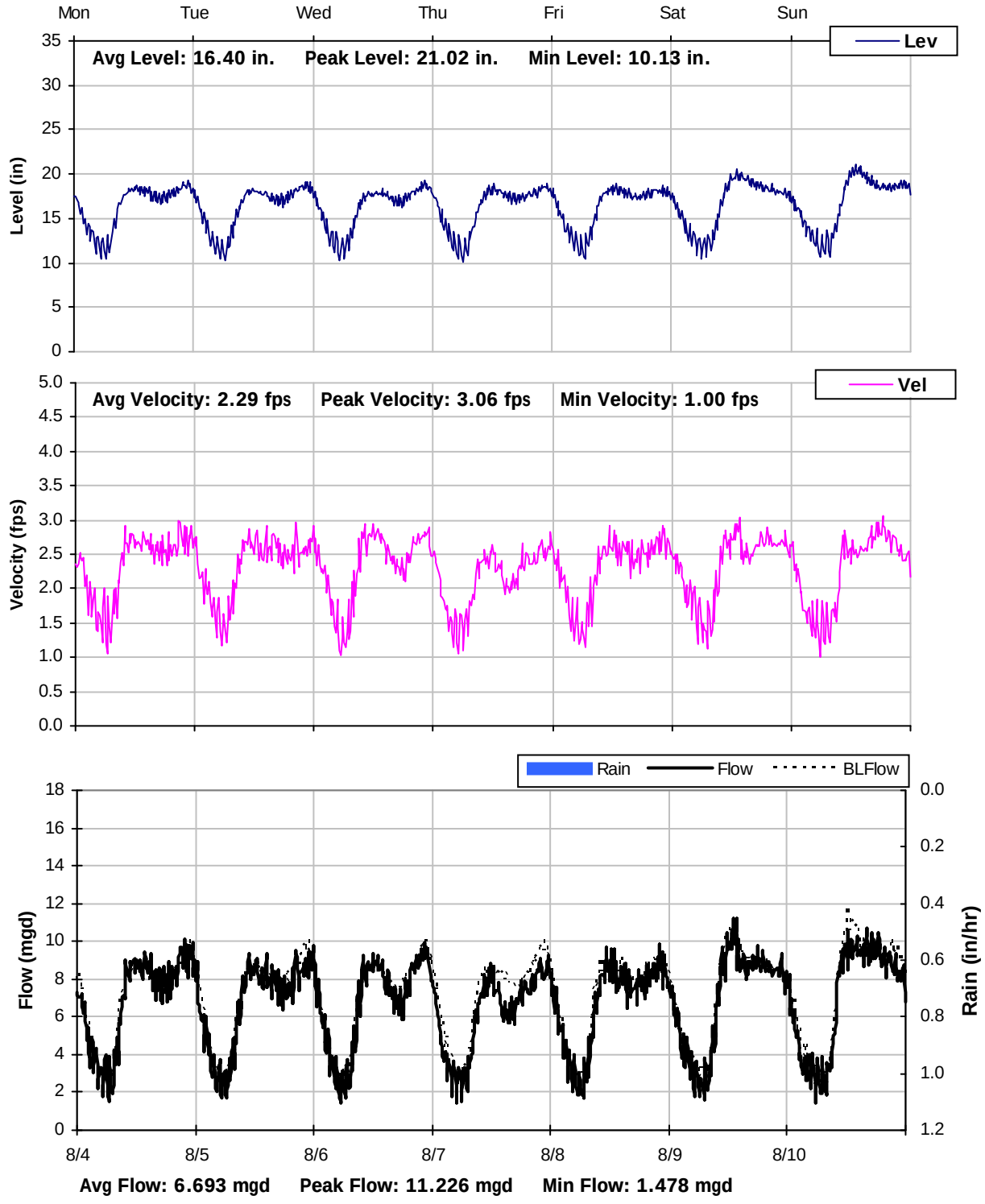
SITE 3

Weekly Level, Velocity and Flow Hydrographs

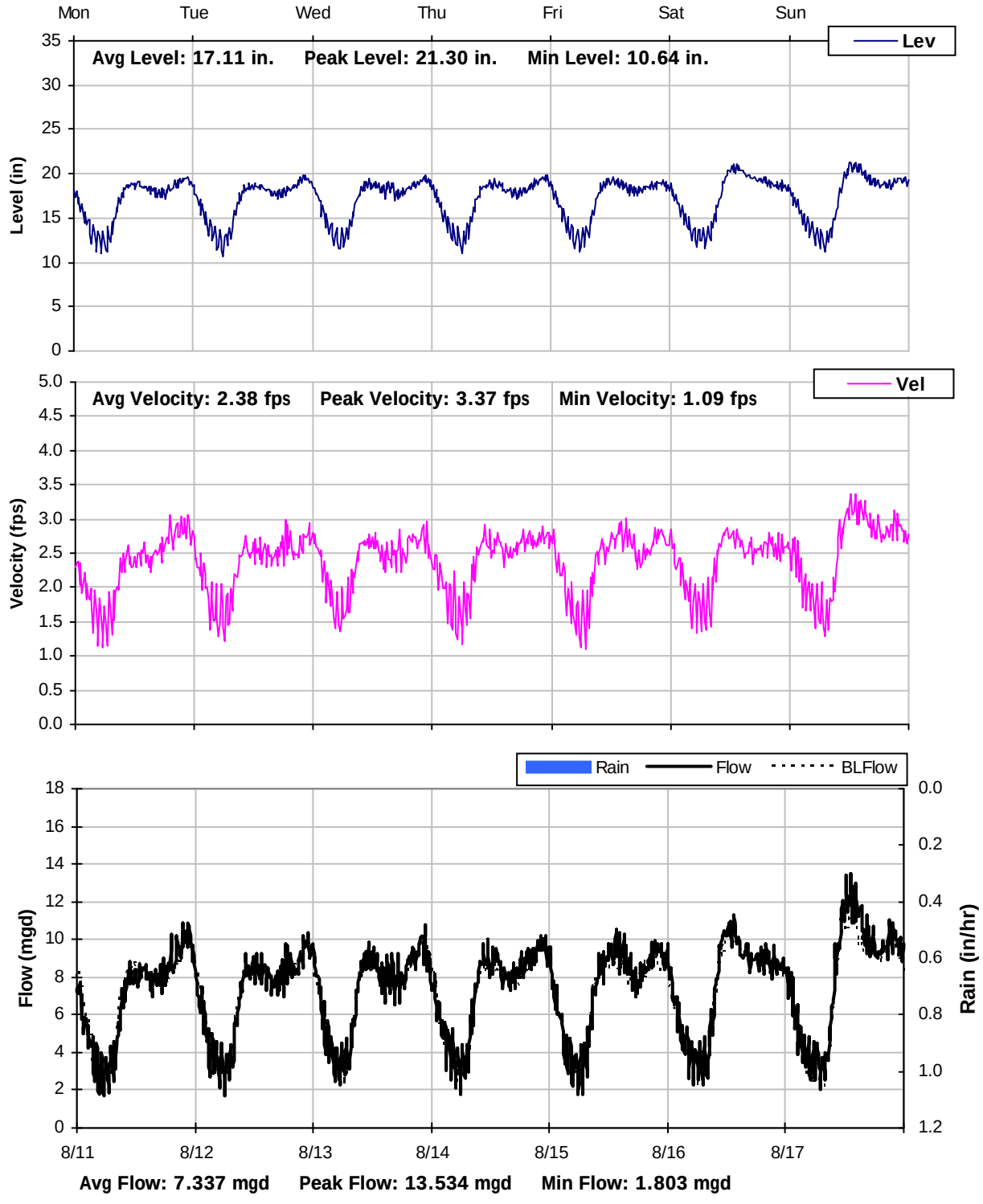
7/28/2014 to 8/4/2014



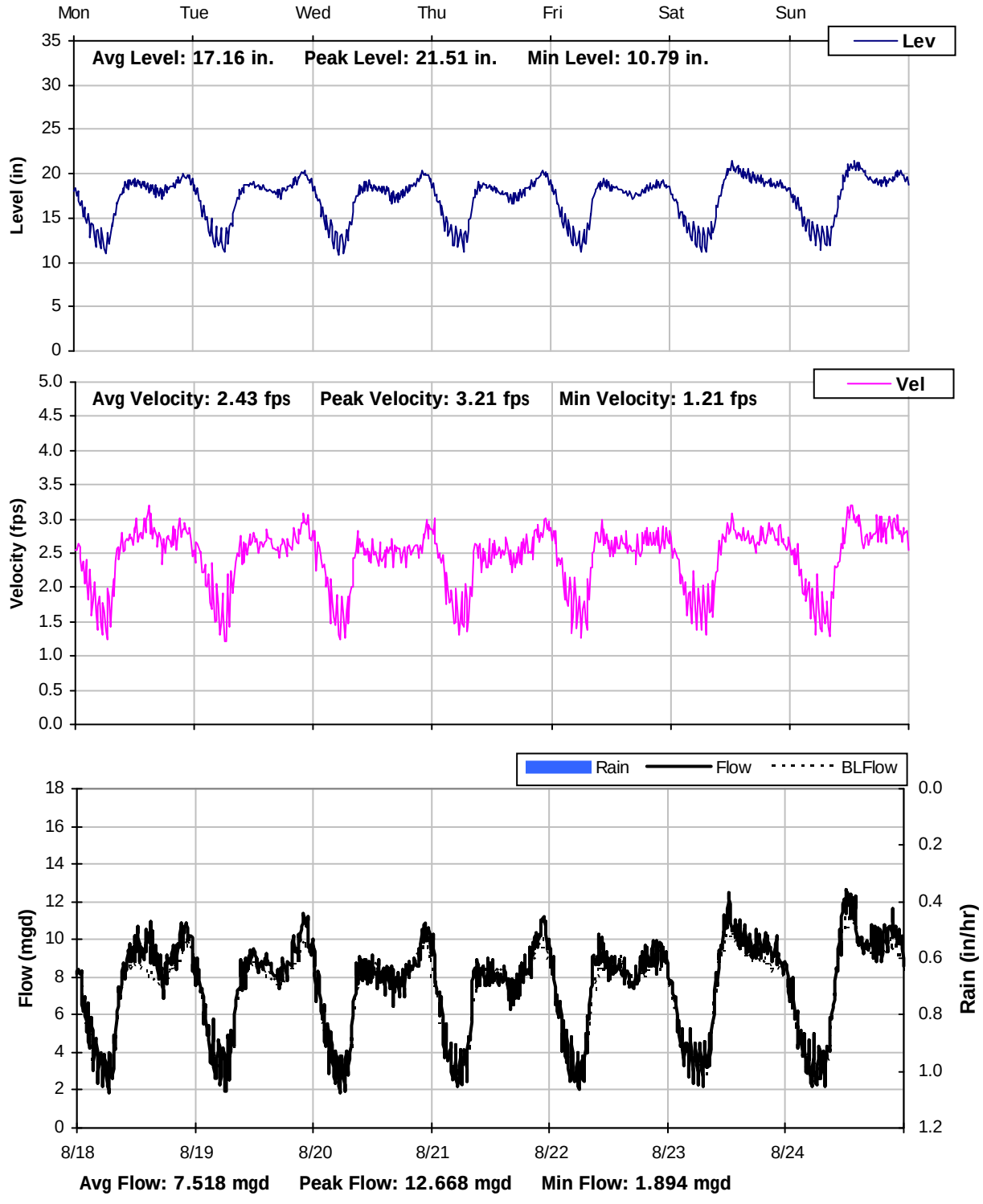
SITE 3
Weekly Level, Velocity and Flow Hydrographs
8/4/2014 to 8/11/2014



SITE 3
Weekly Level, Velocity and Flow Hydrographs
8/11/2014 to 8/18/2014



SITE 3
Weekly Level, Velocity and Flow Hydrographs
8/18/2014 to 8/25/2014



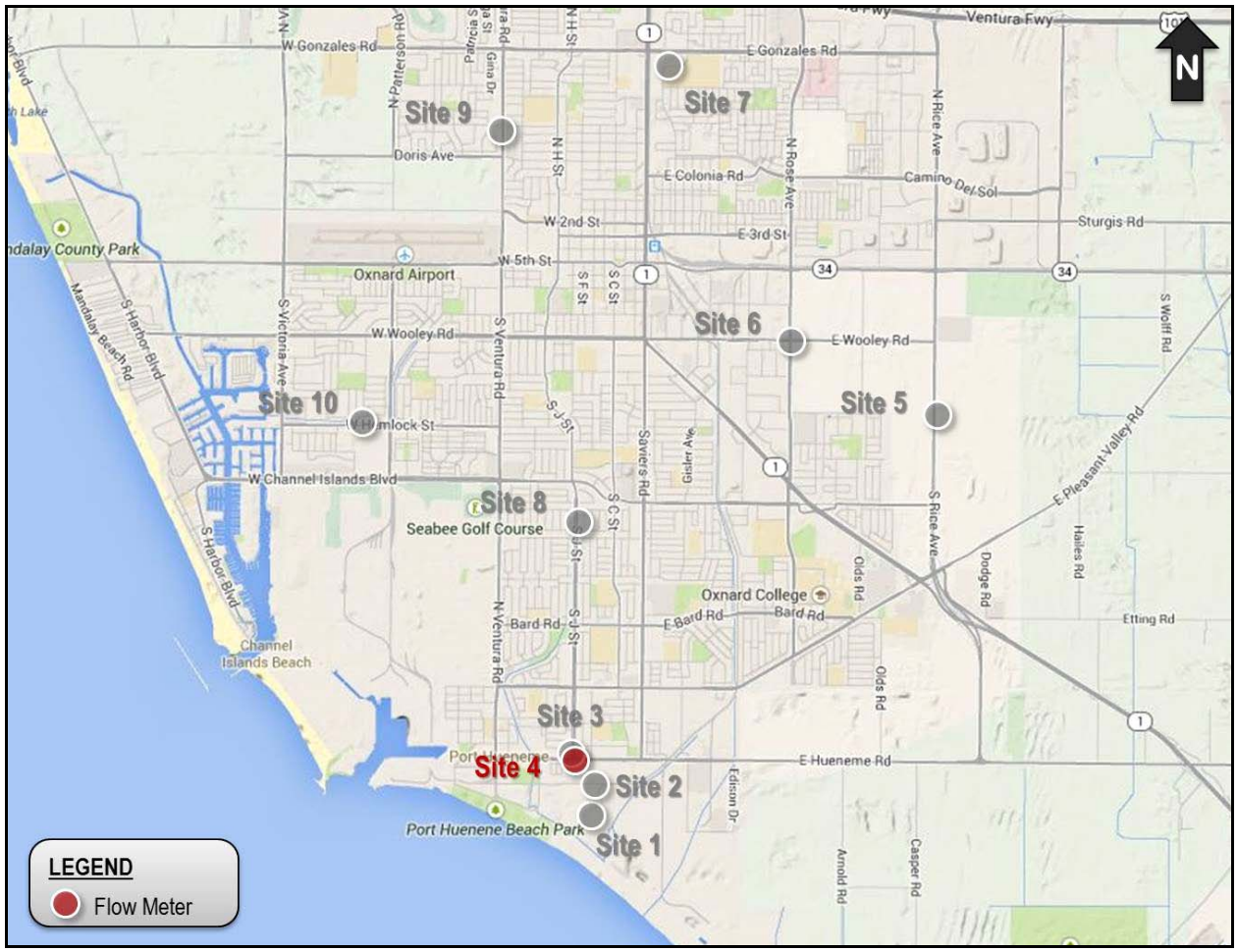
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 4

Location: J Street and W Hueneme Road

Data Summary Report



Vicinity Map: Site 4

SITE 4

Site Information

Location: J Street and W Hueneme Road

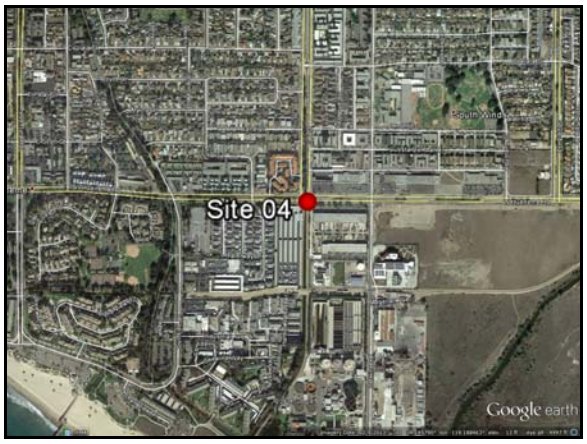
Coordinates: 119.1860° W, 34.1474° N

Rim Elevation: 12 feet

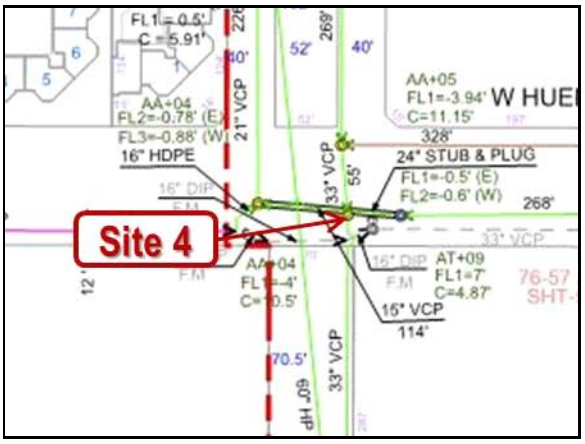
Pipe Diameter: 33 inches

Baseline Flow: 4.301 mgd

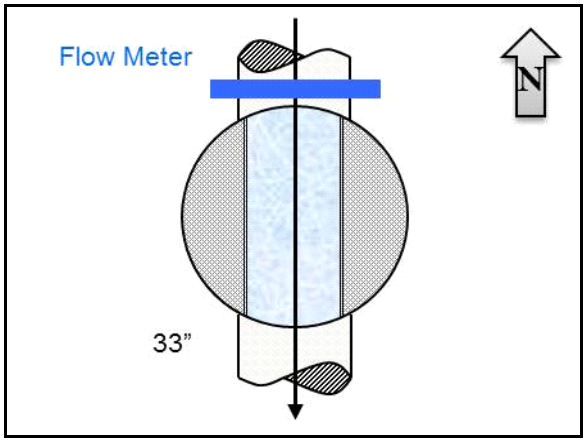
Peak Measured Flow: 7.057 mgd



Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 4

Additional Site Photos

Effluent Pipe

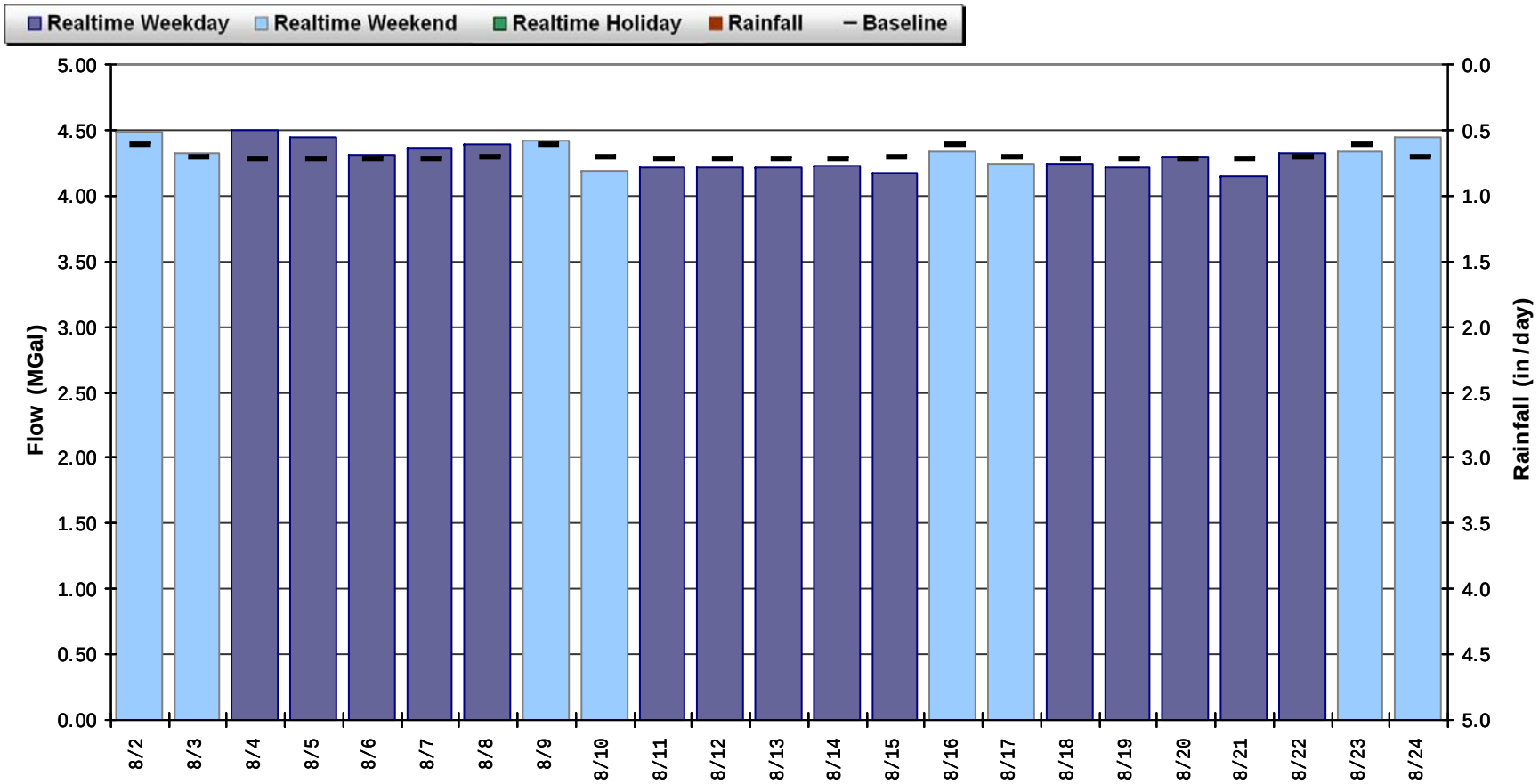
Influent Pipe

SITE 4

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 4.305 MGal **Peak Daily Flow: 4.503 MGal** **Min Daily Flow: 4.141 MGal**

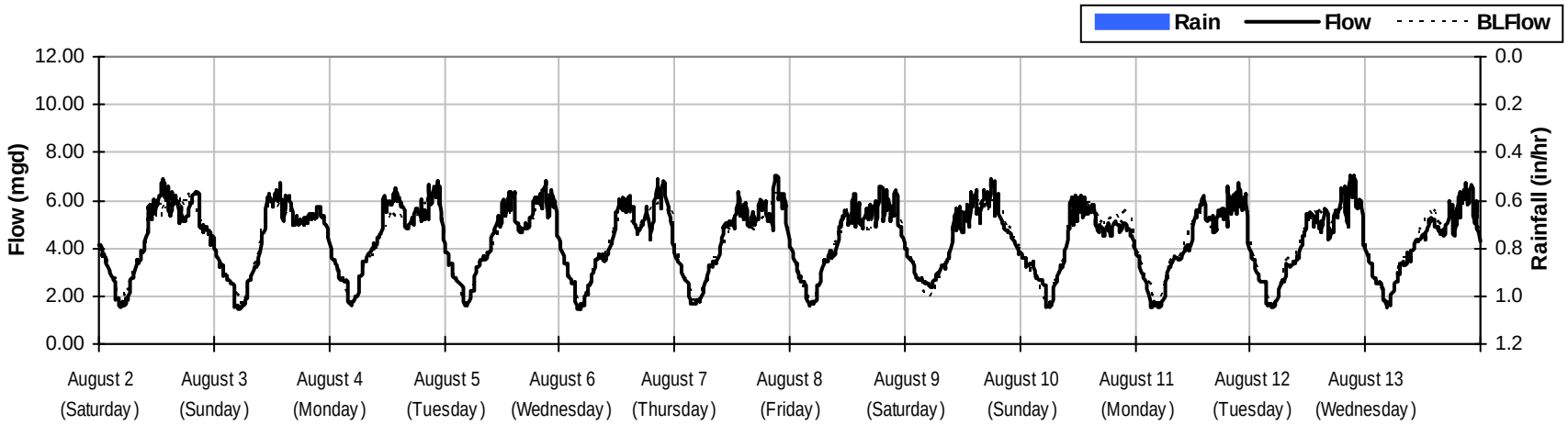
Total Monthly Rainfall: 0.00 inches

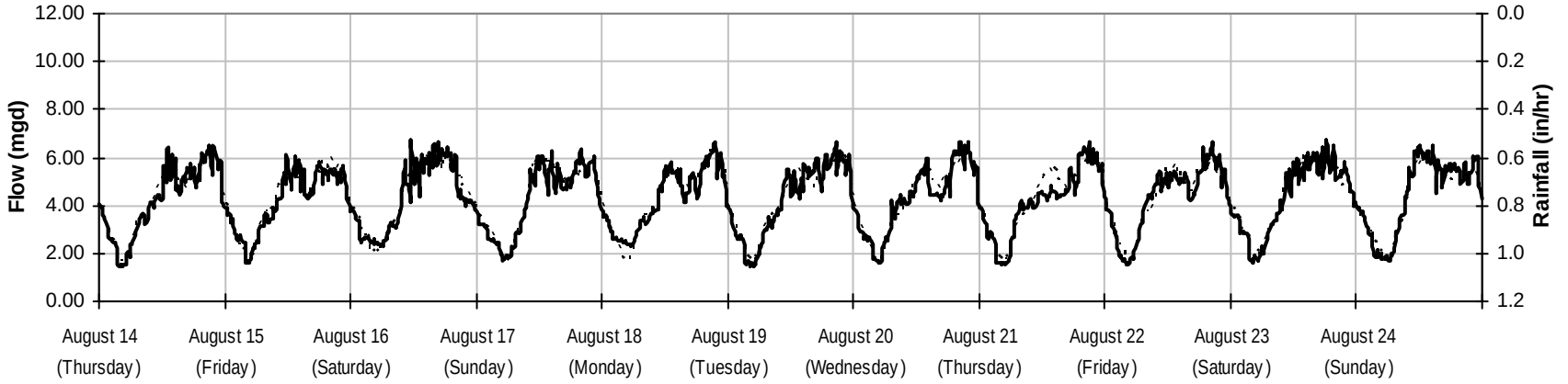


SITE 4

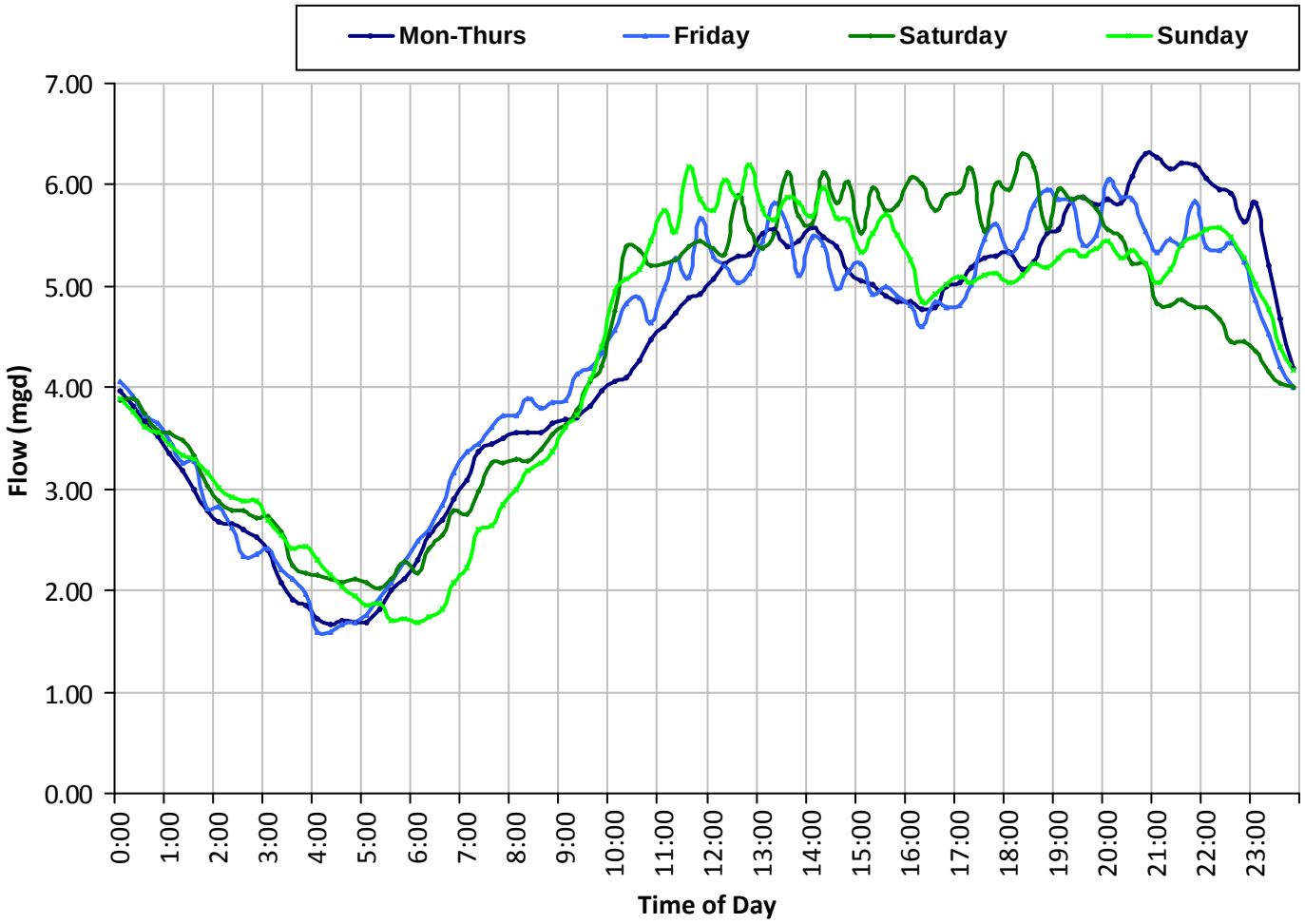
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 4.305 mgd** **Peak Flow: 7.057 mgd** **Min Flow: 1.427 mgd**



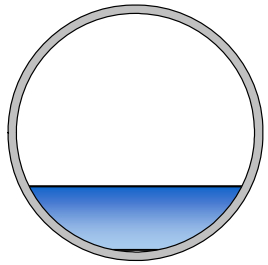


SITE 4
Baseline Flow Hydrographs



Baseline Flow:

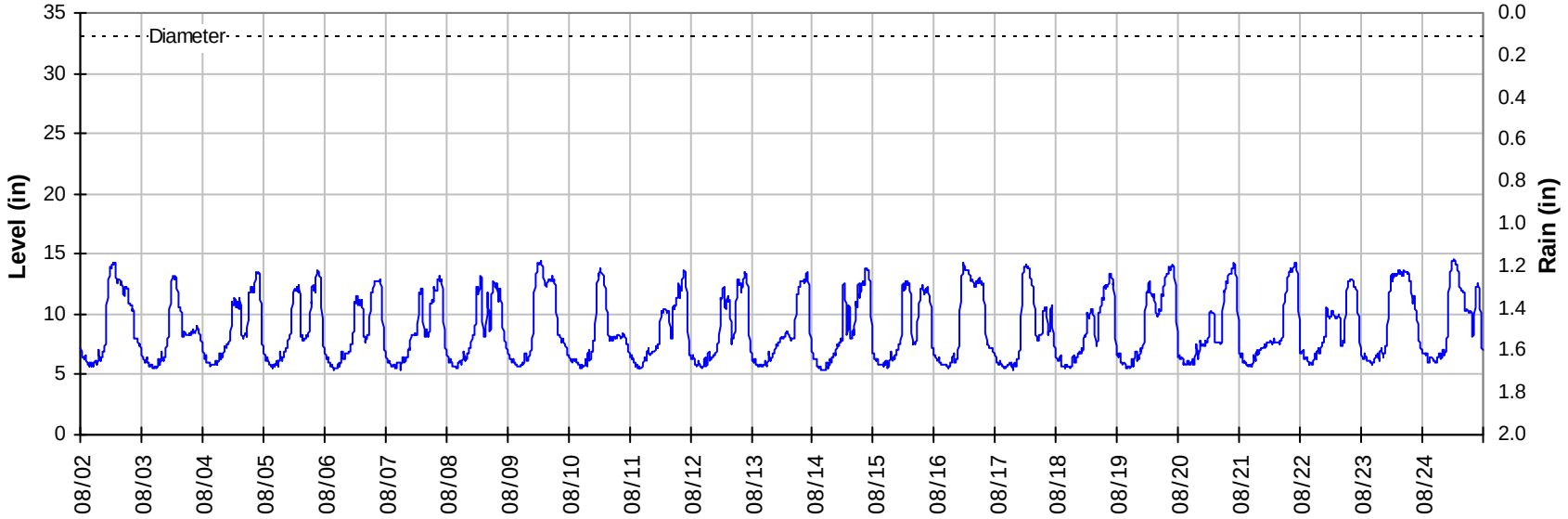
4.301 *mgd*

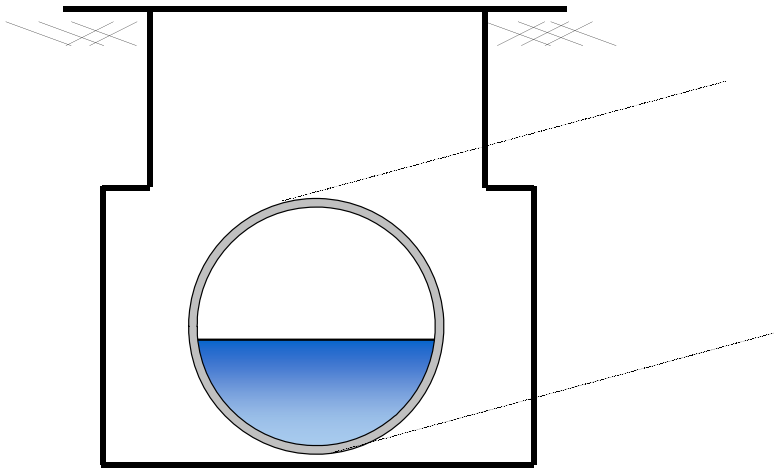


SITE 4

Site Capacity and Surcharge Summary

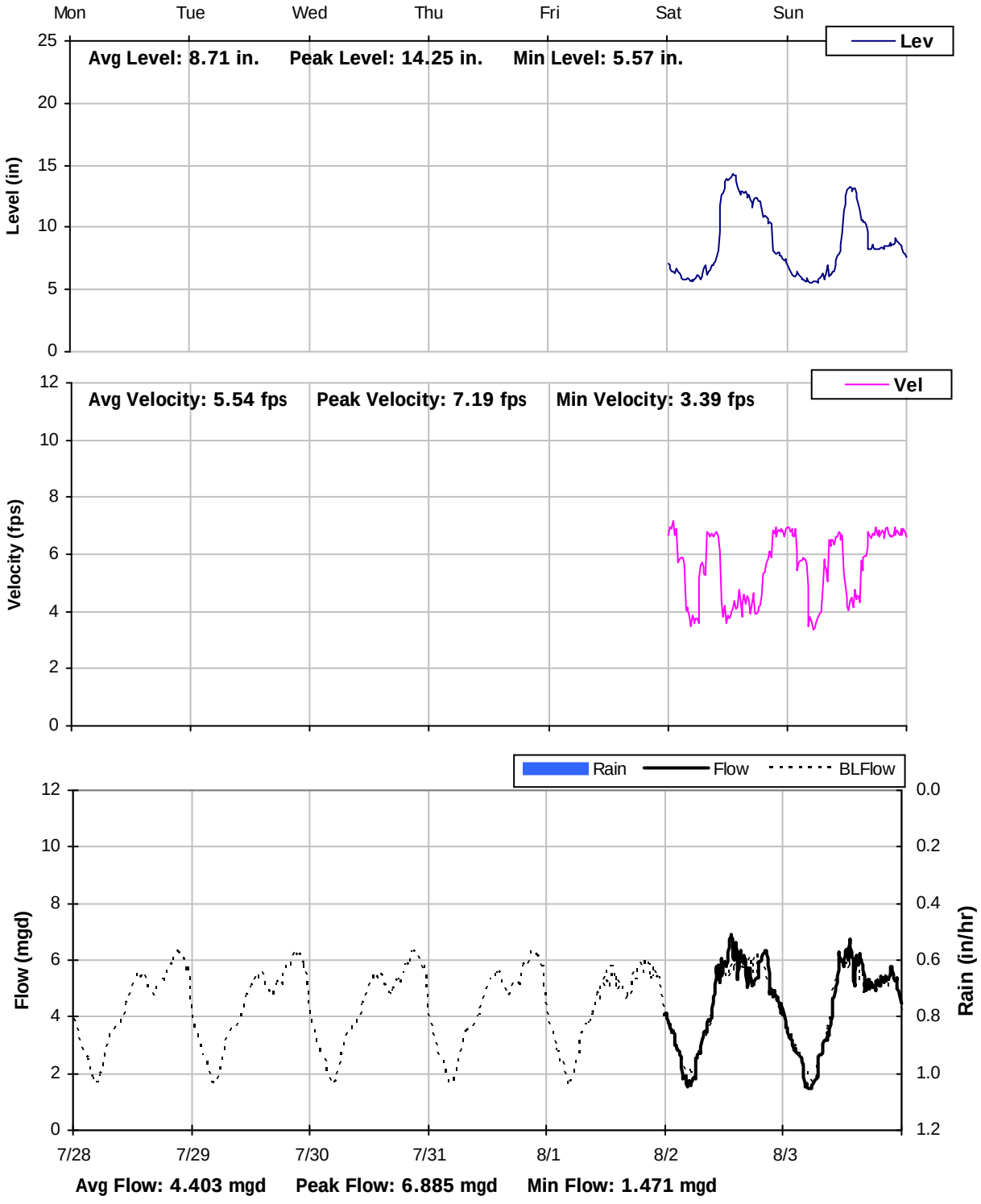
Realtime Flow Levels with Rainfall Data over Monitoring Period



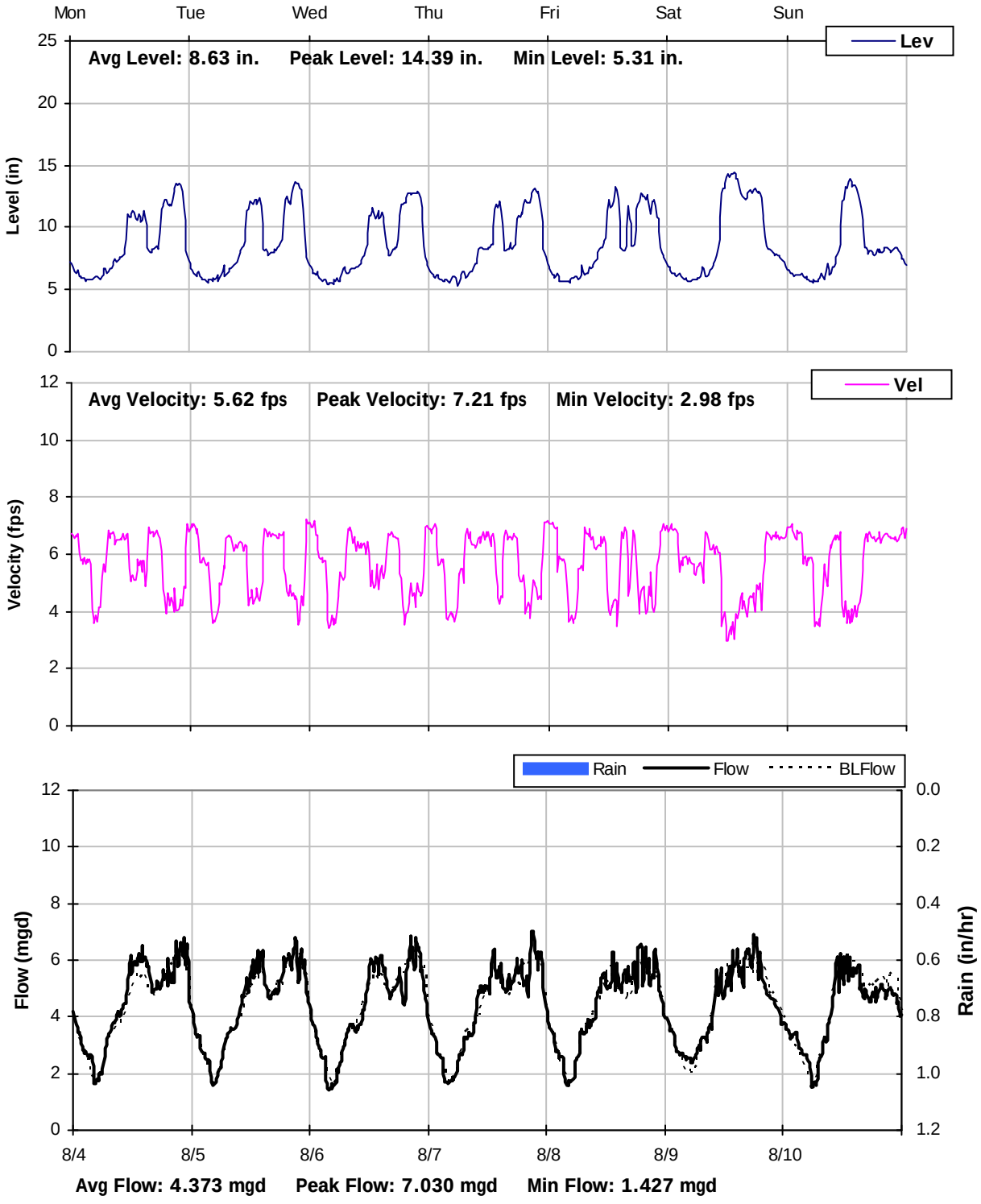


Pipe Diameter:	33	*inches*
Peak Measured Level:	14.5	*inches*
Peak d/D Ratio:	0.44	

SITE 4
Weekly Level, Velocity and Flow Hydrographs
7/28/2014 to 8/4/2014



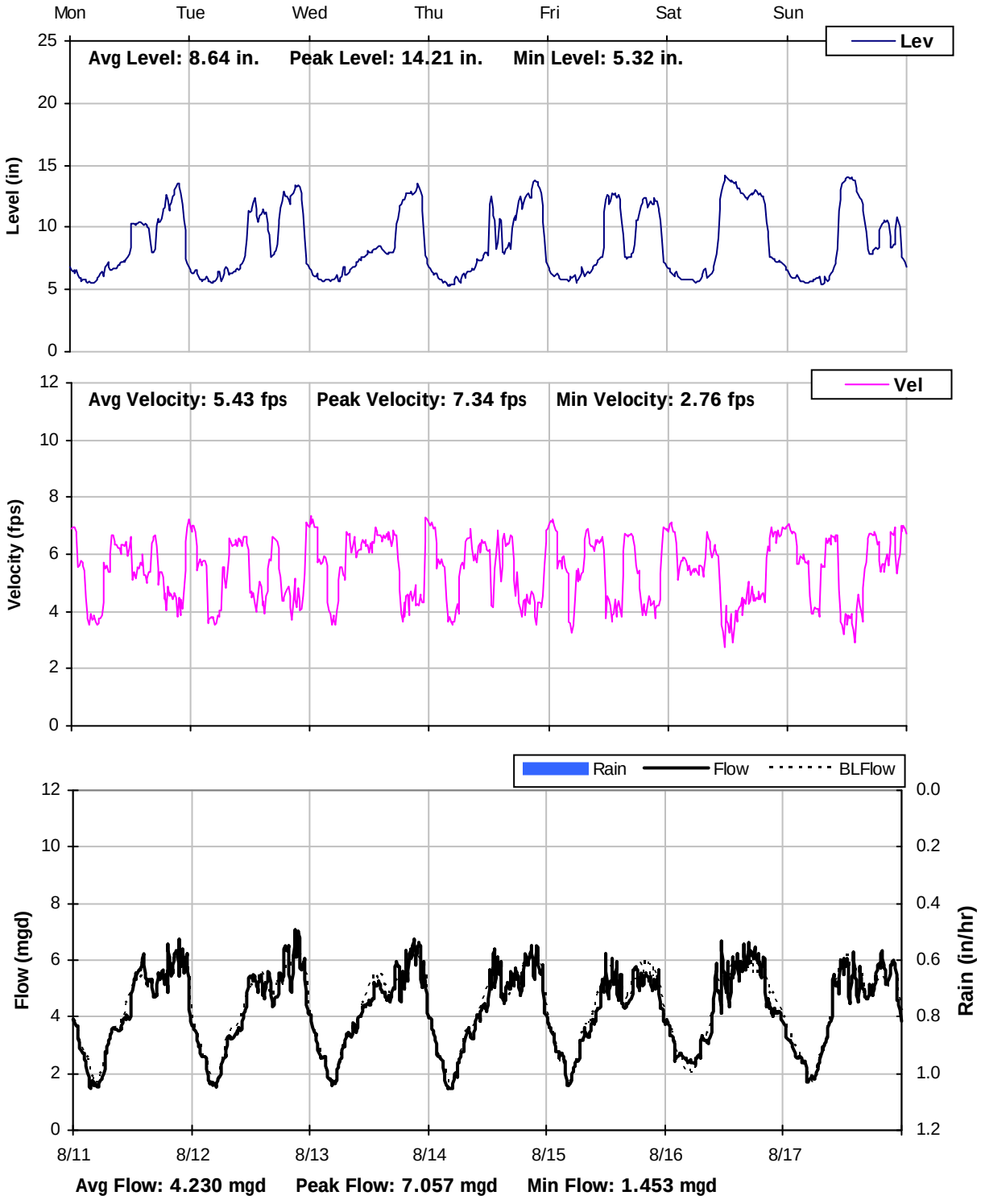
SITE 4
Weekly Level, Velocity and Flow Hydrographs
8/4/2014 to 8/11/2014



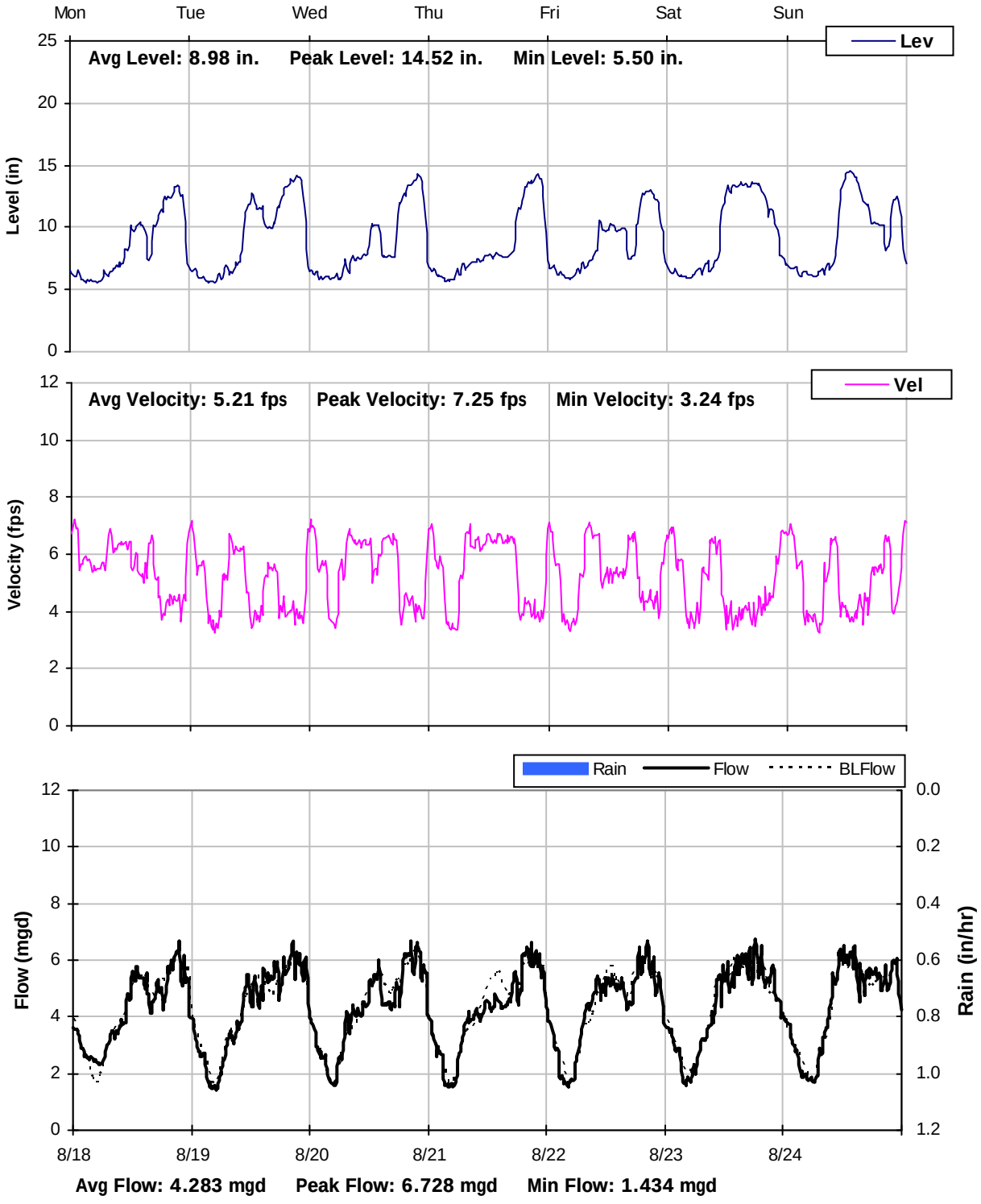
SITE 4

Weekly Level, Velocity and Flow Hydrographs

8/11/2014 to 8/18/2014



SITE 4
Weekly Level, Velocity and Flow Hydrographs
8/18/2014 to 8/25/2014



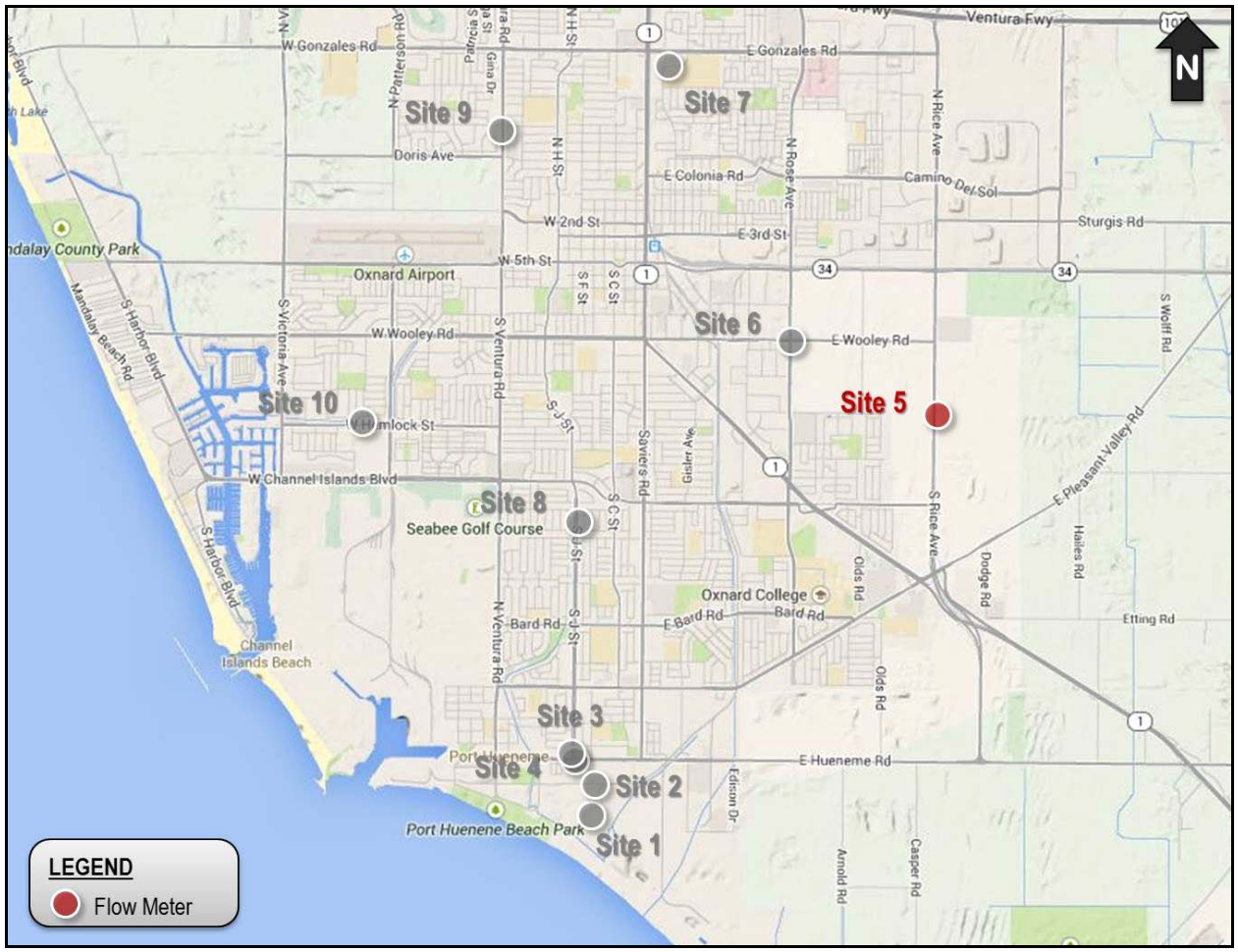
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 5

Location: S Rice Avenue and East of Emerson Avenue

Data Summary Report



Vicinity Map: Site 5

SITE 5

Site Information

Location: S Rice Avenue and East of Emerson Avenue

Coordinates: 119.1427° W, 34.1819° N

Rim Elevation: 44 feet

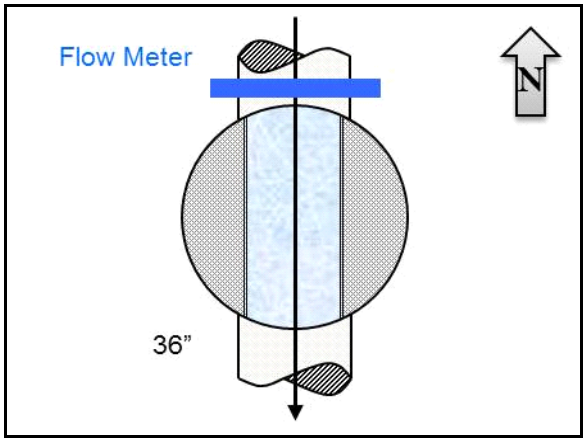
Pipe Diameter: 36 inches

Baseline Flow: 1.341 mgd

Peak Measured Flow: 2.852 mgd

Satellite Map

Sanitary Map



Flow Diagram

Street View

Plan View

SITE 5

Additional Site Photos

Effluent Pipe

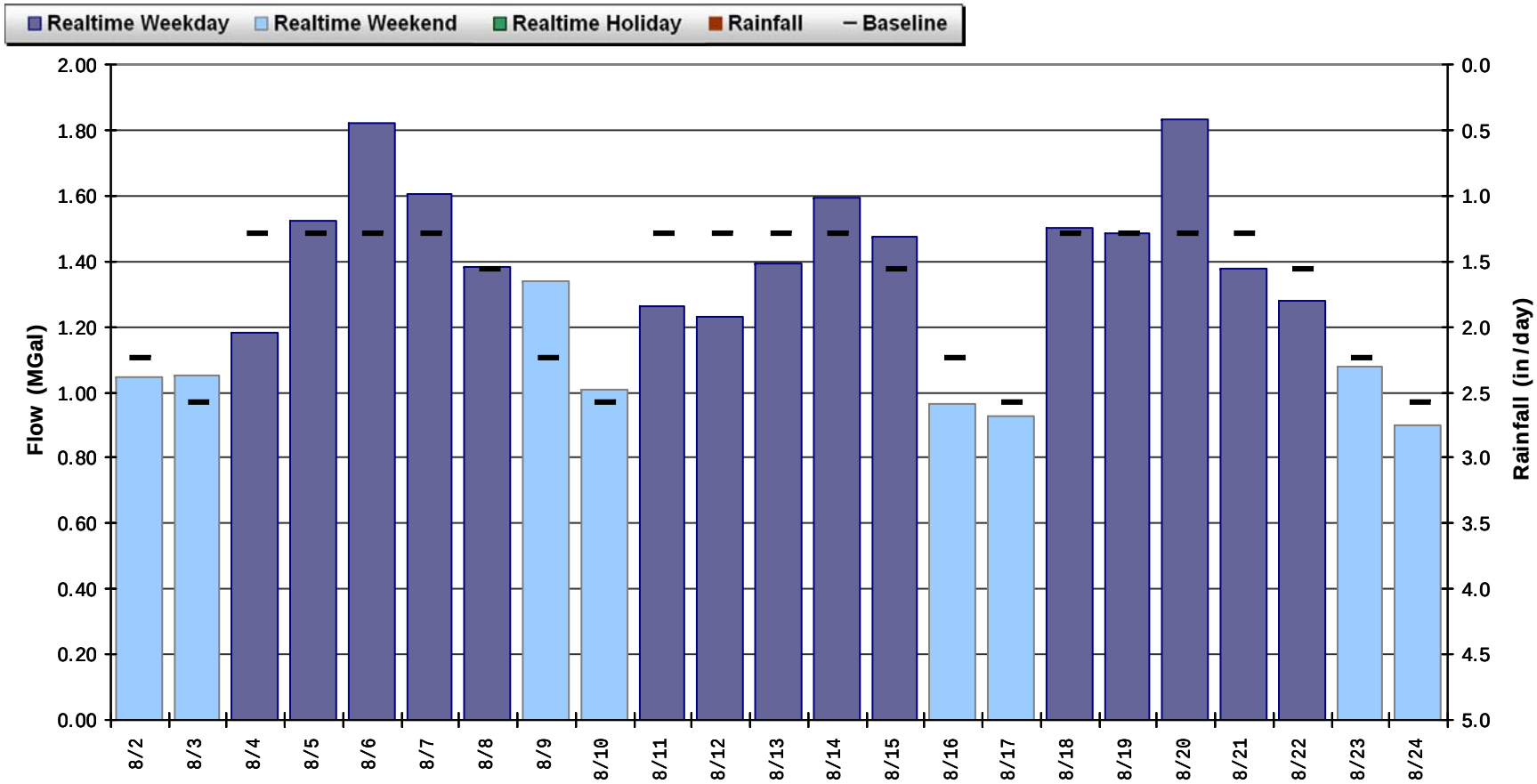
Influent Pipe

SITE 5

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 1.315 MGal **Peak Daily Flow: 1.831 MGal** **Min Daily Flow: 0.898 MGal**

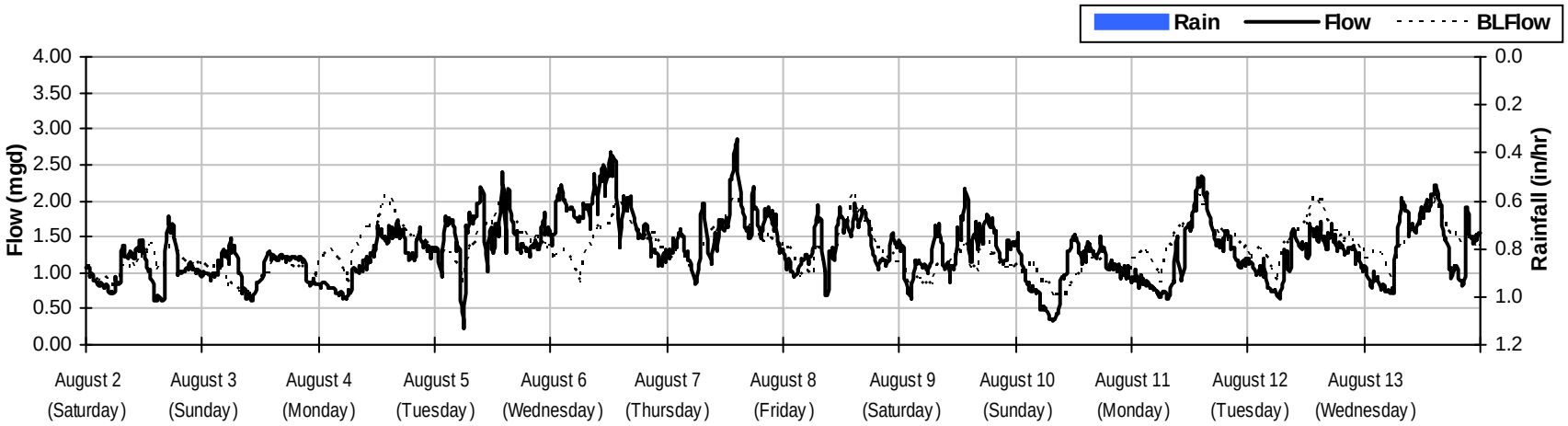
Total Monthly Rainfall: 0.00 inches

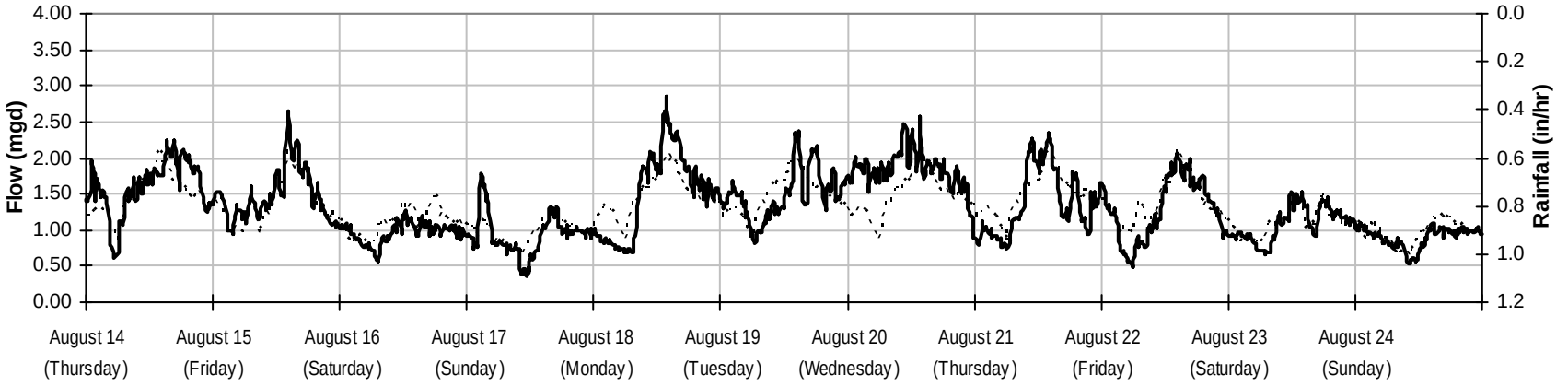


SITE 5

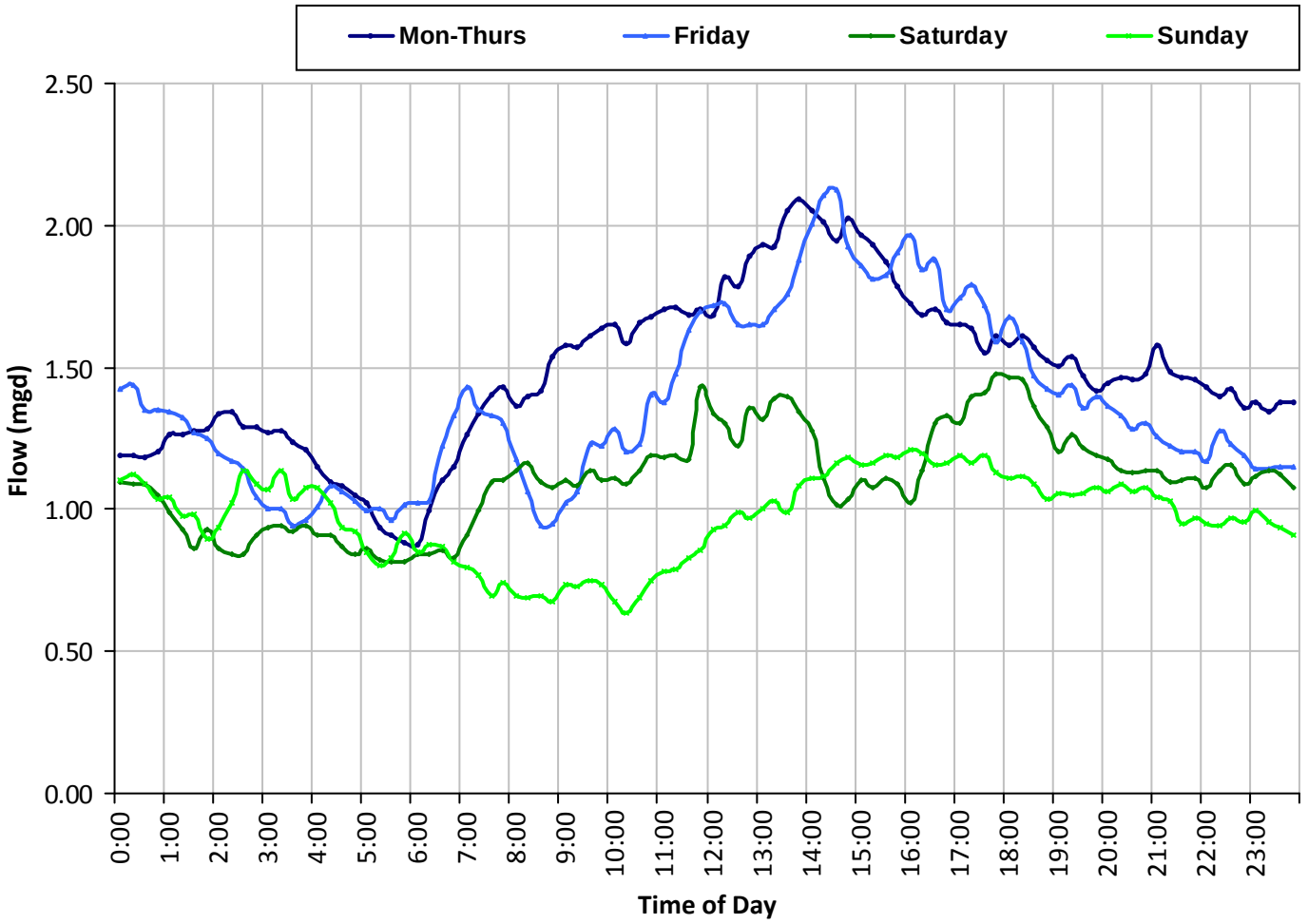
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 1.315 mgd** **Peak Flow: 2.852 mgd** **Min Flow: 0.233 mgd**



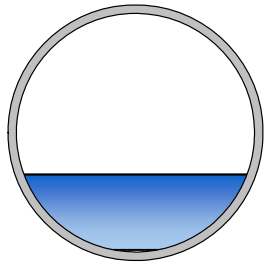


SITE 5
Baseline Flow Hydrographs



Baseline Flow:

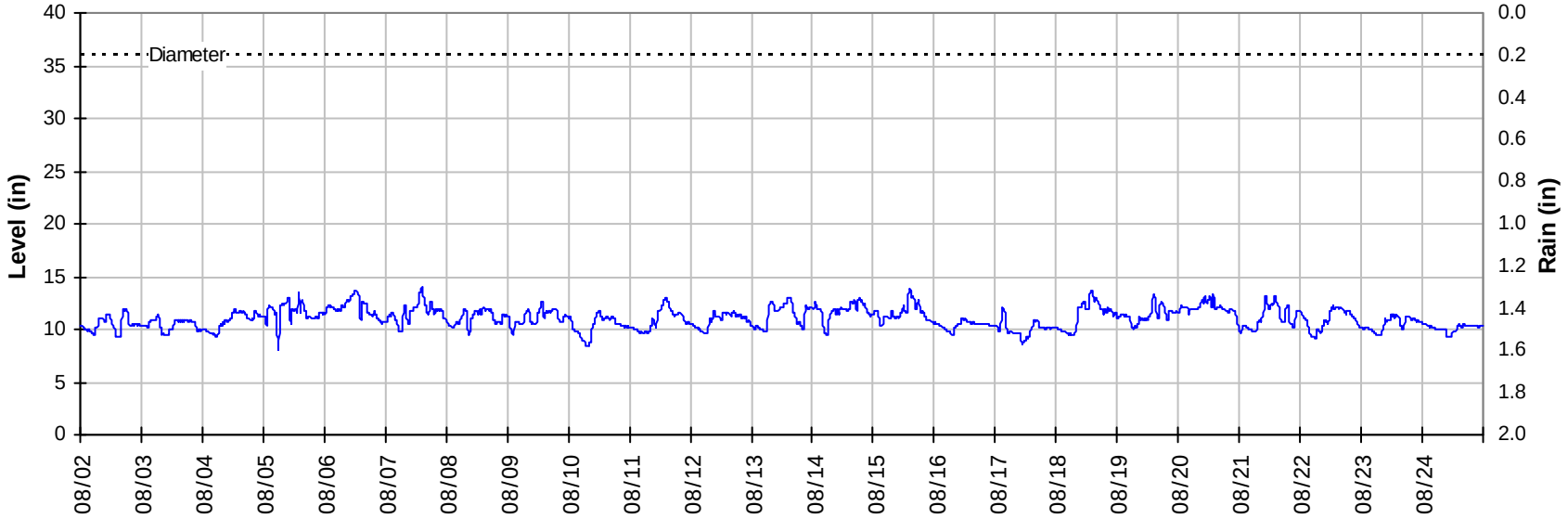
1.341 *mgd*

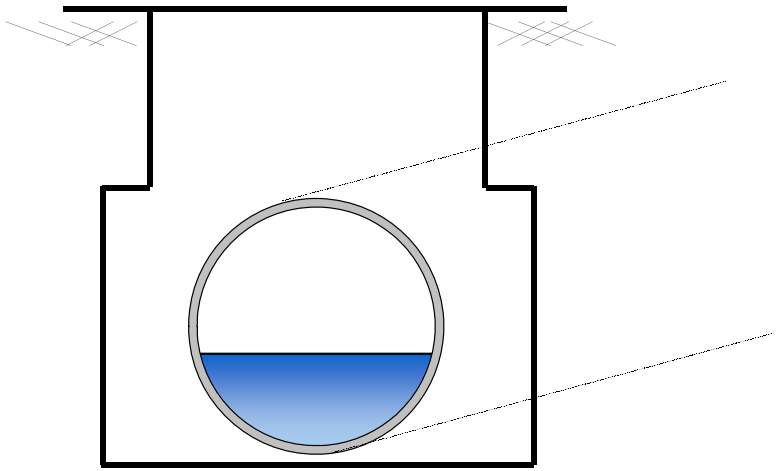


SITE 5

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period



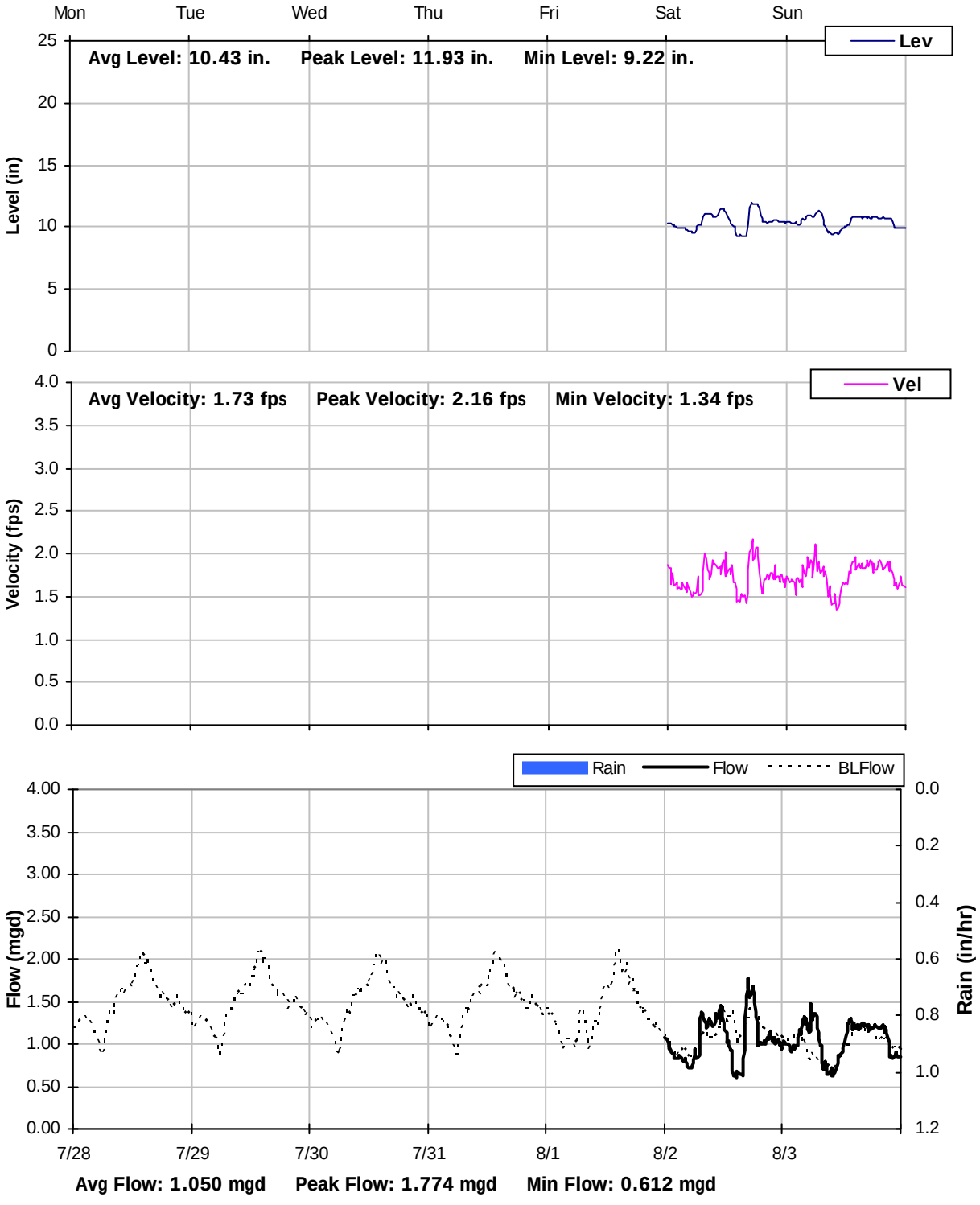


Pipe Diameter:	36	*inches*
Peak Measured Level:	14	*inches*
Peak d/D Ratio:	0.39	

SITE 5

Weekly Level, Velocity and Flow Hydrographs

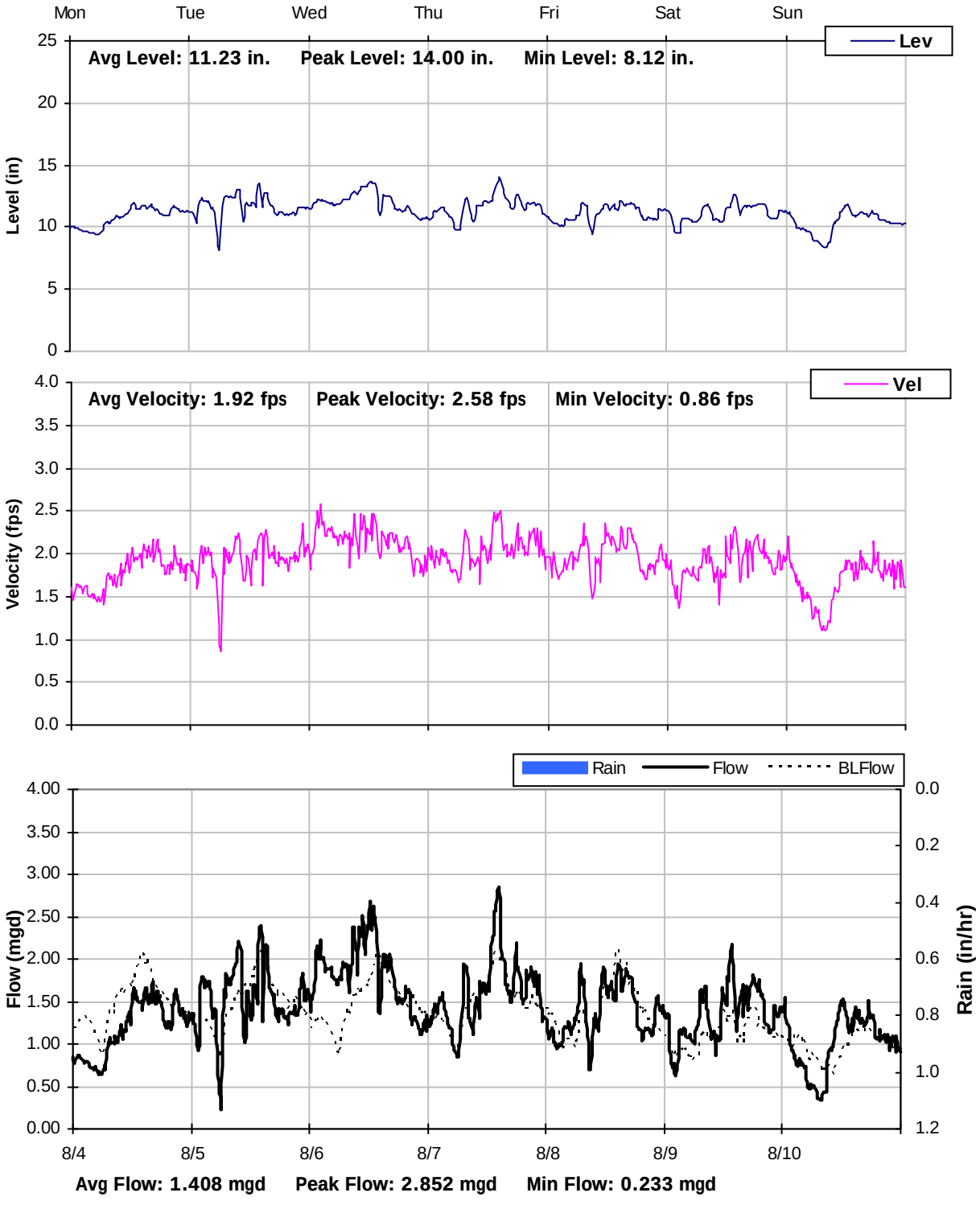
7/28/2014 to 8/4/2014



SITE 5

Weekly Level, Velocity and Flow Hydrographs

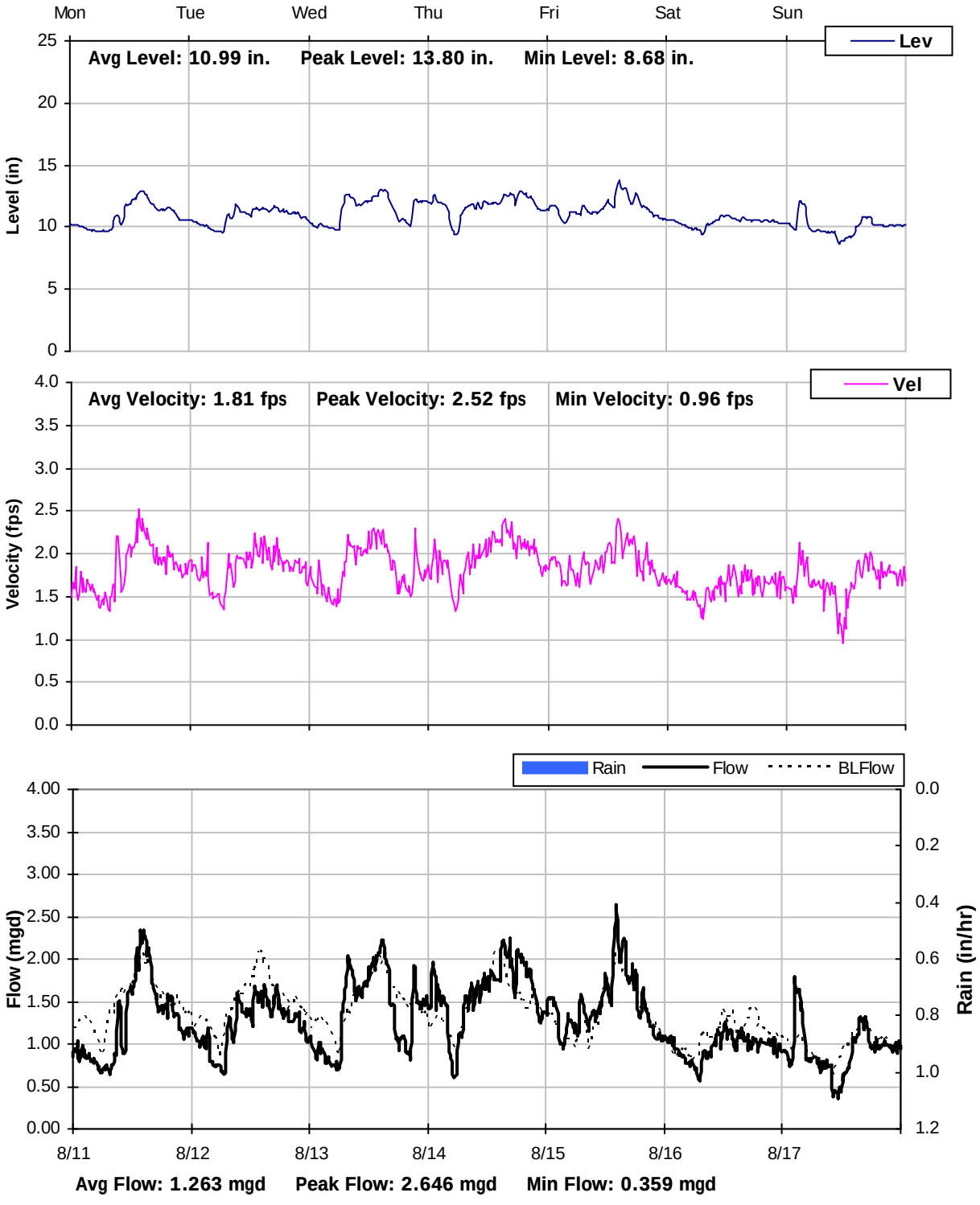
8/4/2014 to 8/11/2014



SITE 5

Weekly Level, Velocity and Flow Hydrographs

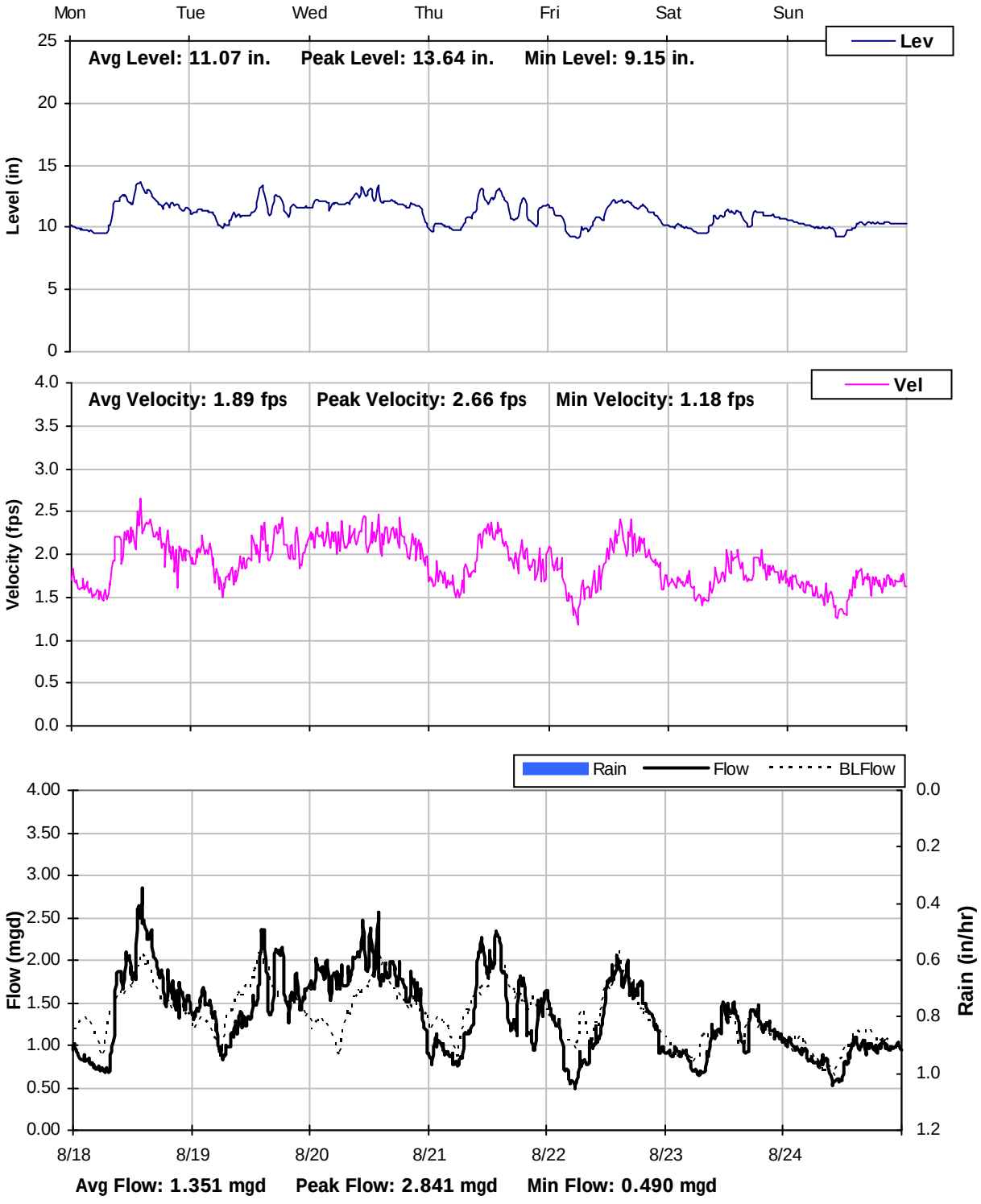
8/11/2014 to 8/18/2014



SITE 5

Weekly Level, Velocity and Flow Hydrographs

8/18/2014 to 8/25/2014



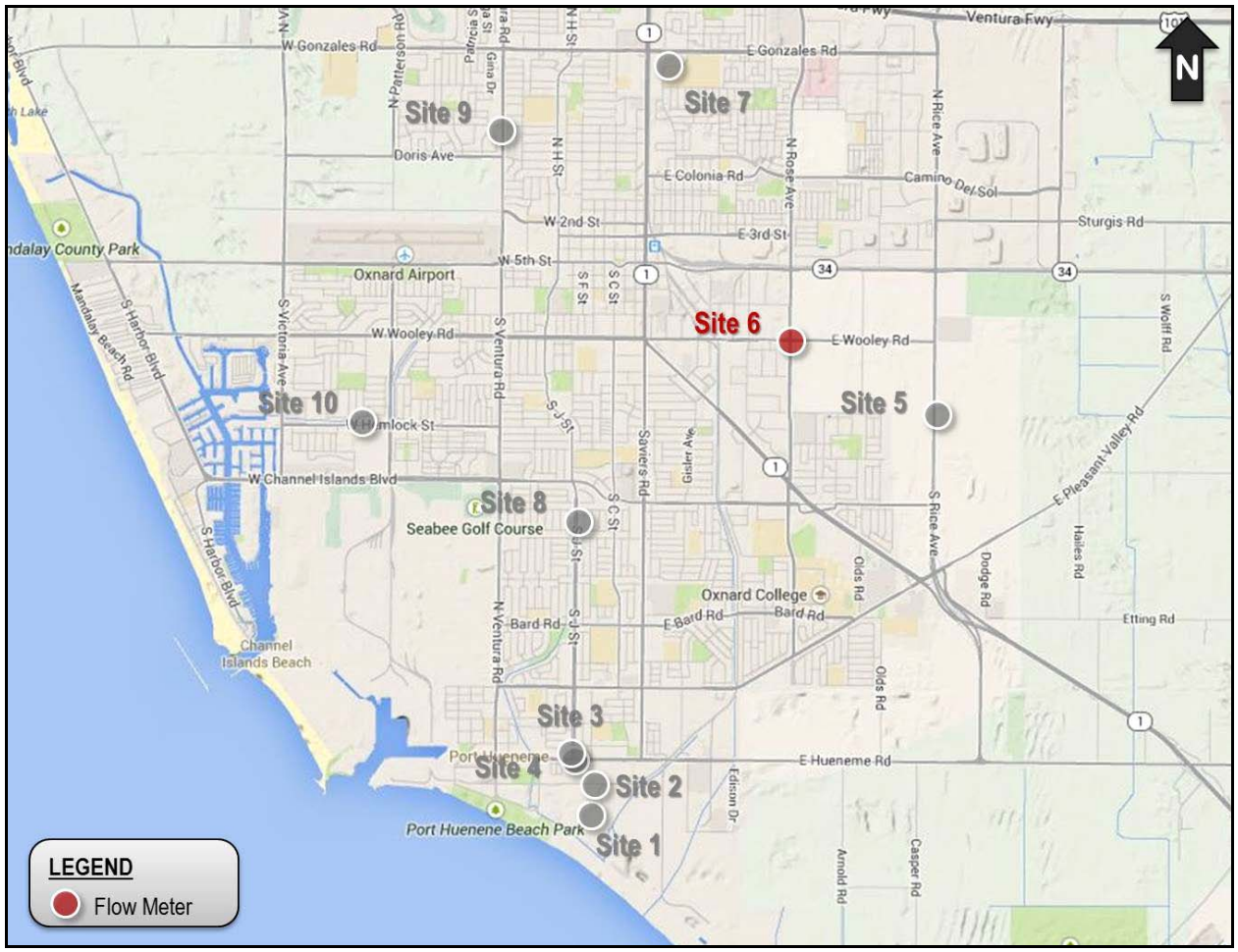
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 6

Location: S Rose Avenue and E Wooley Road

Data Summary Report



Vicinity Map: Site 6

SITE 6

Site Information

Location: S Rose Avenue and E Wooley Road

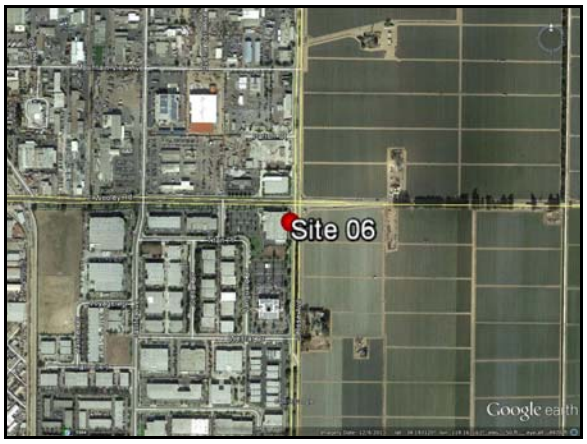
Coordinates: 119.1601° W, 34.1893° N

Rim Elevation: 49 feet

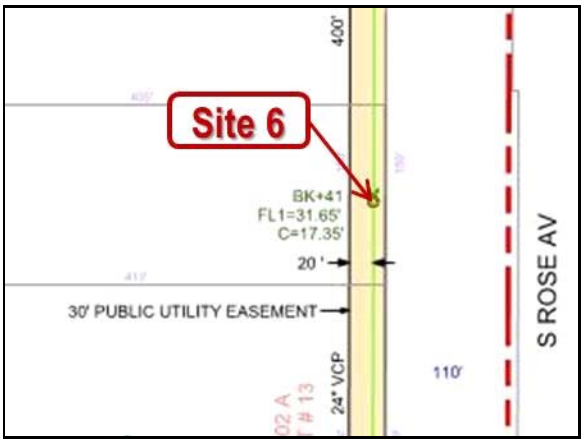
Pipe Diameter: 24 inches

Baseline Flow: 1.351 mgd

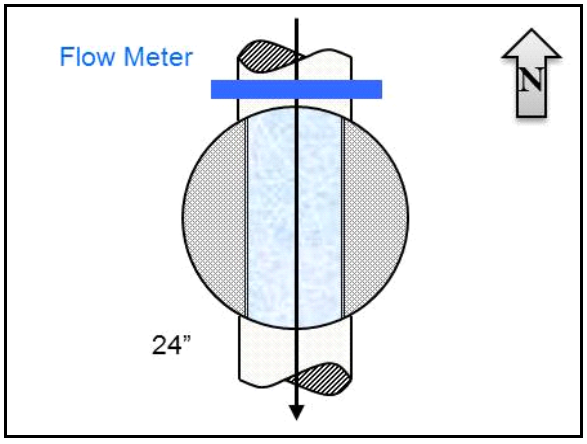
Peak Measured Flow: 2.381 mgd



Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 6

Additional Site Photos

Effluent Pipe

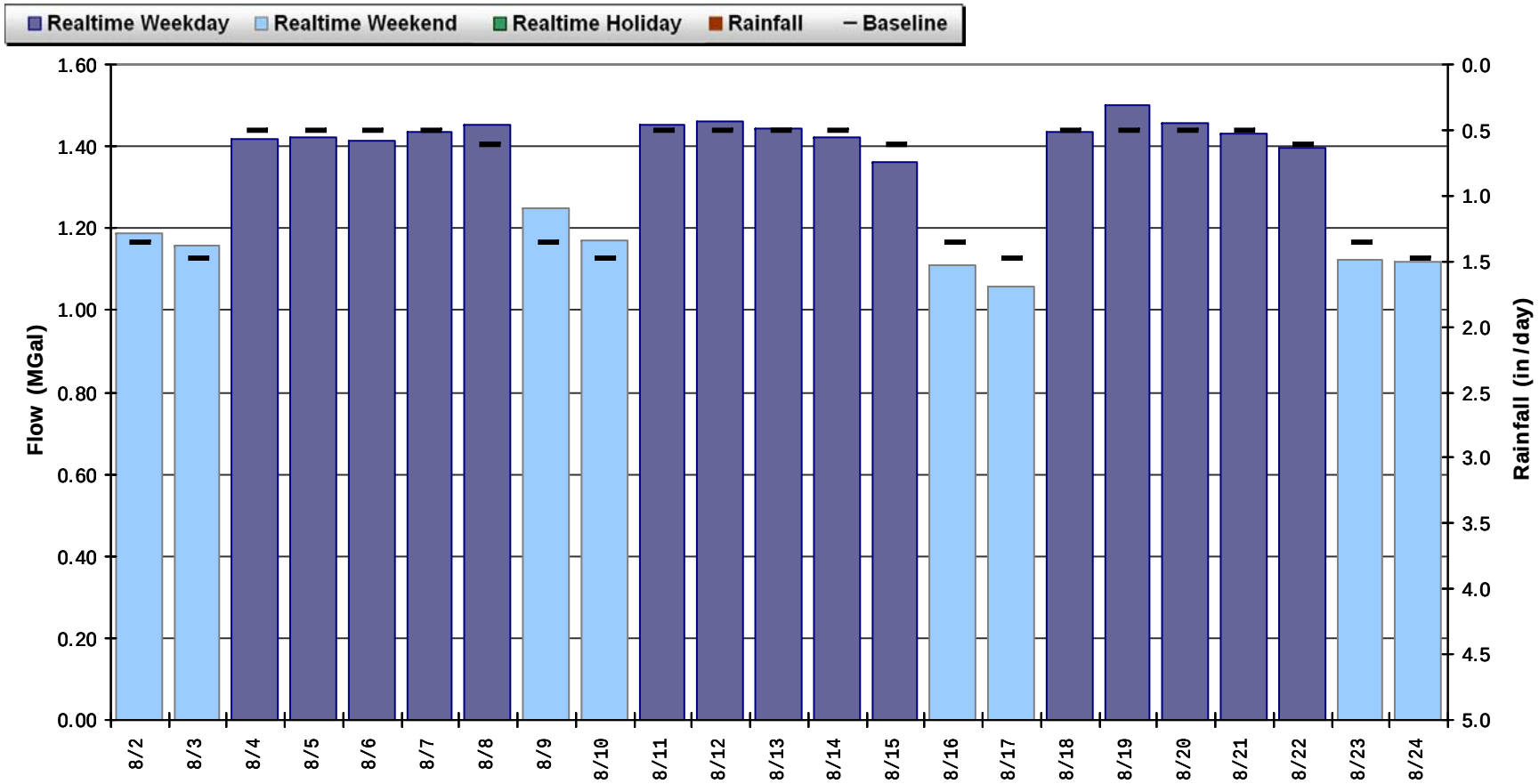
Influent Pipe

SITE 6

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 1.333 MGal **Peak Daily Flow: 1.502 MGal** **Min Daily Flow: 1.058 MGal**

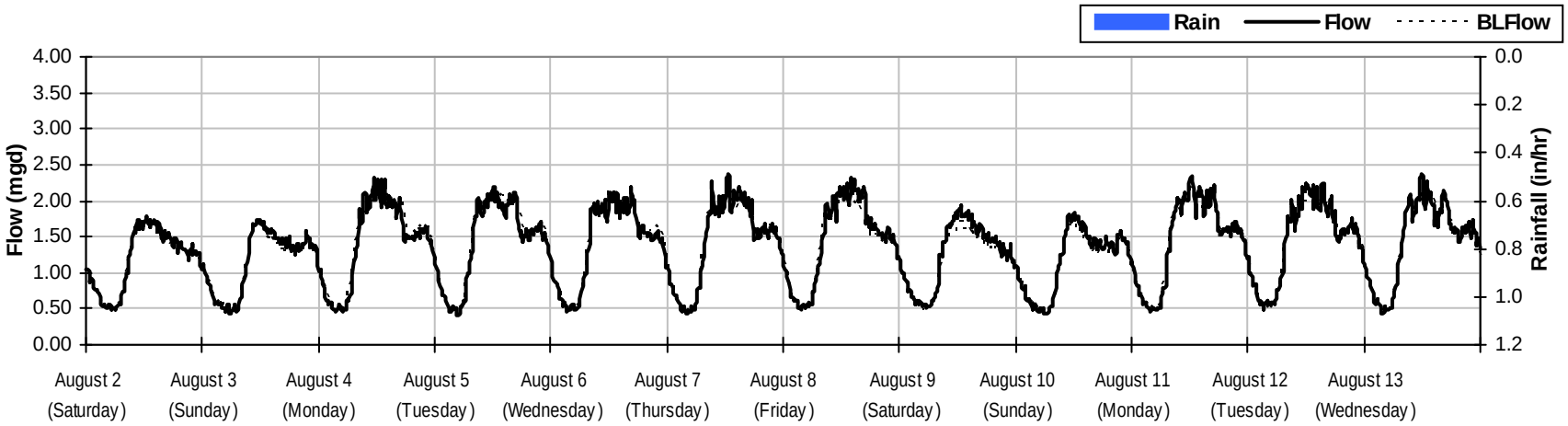
Total Monthly Rainfall: 0.00 inches

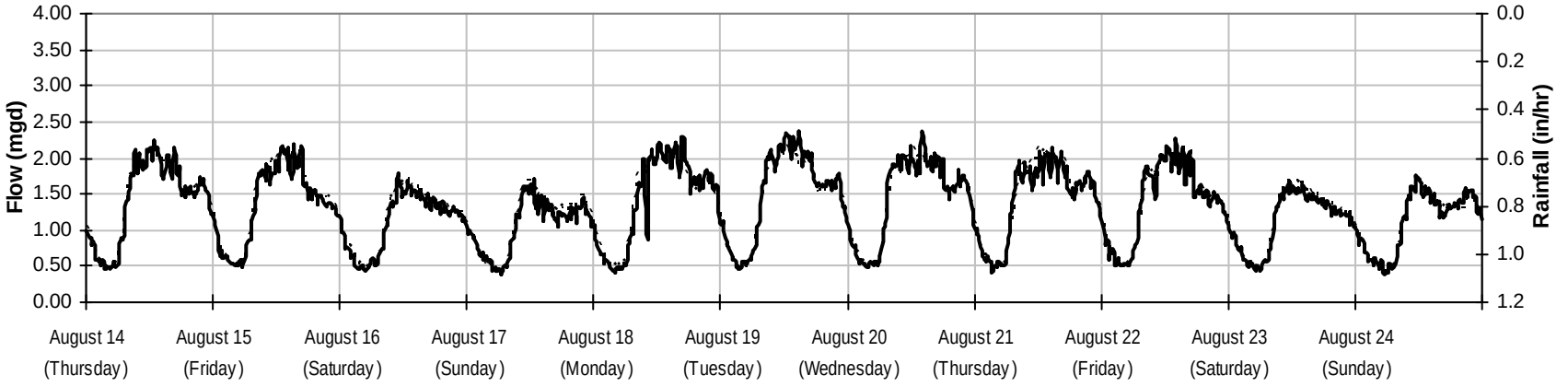


SITE 6

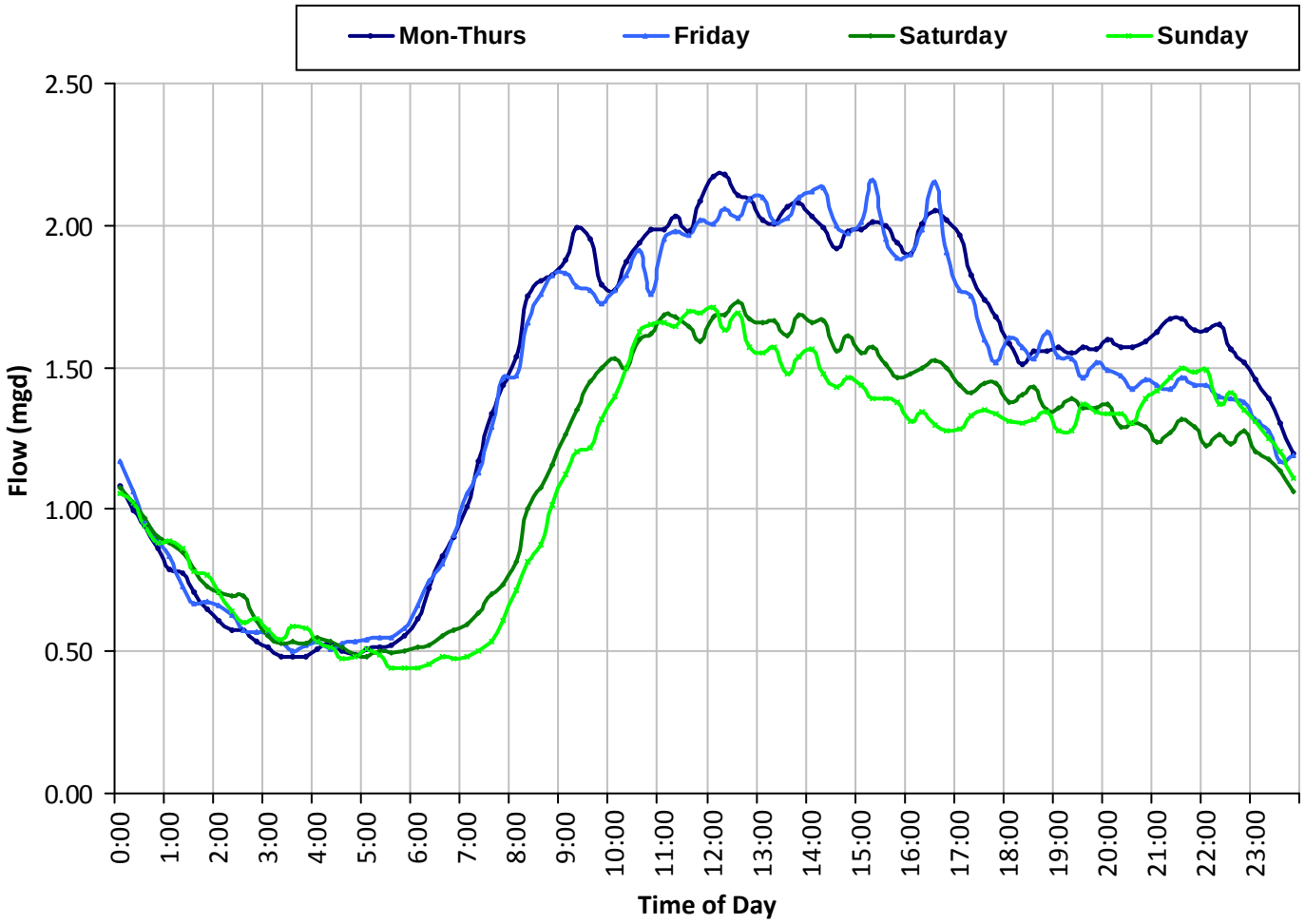
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 1.333 mgd** **Peak Flow: 2.381 mgd** **Min Flow: 0.375 mgd**



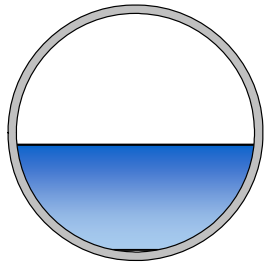


SITE 6
Baseline Flow Hydrographs



Baseline Flow:

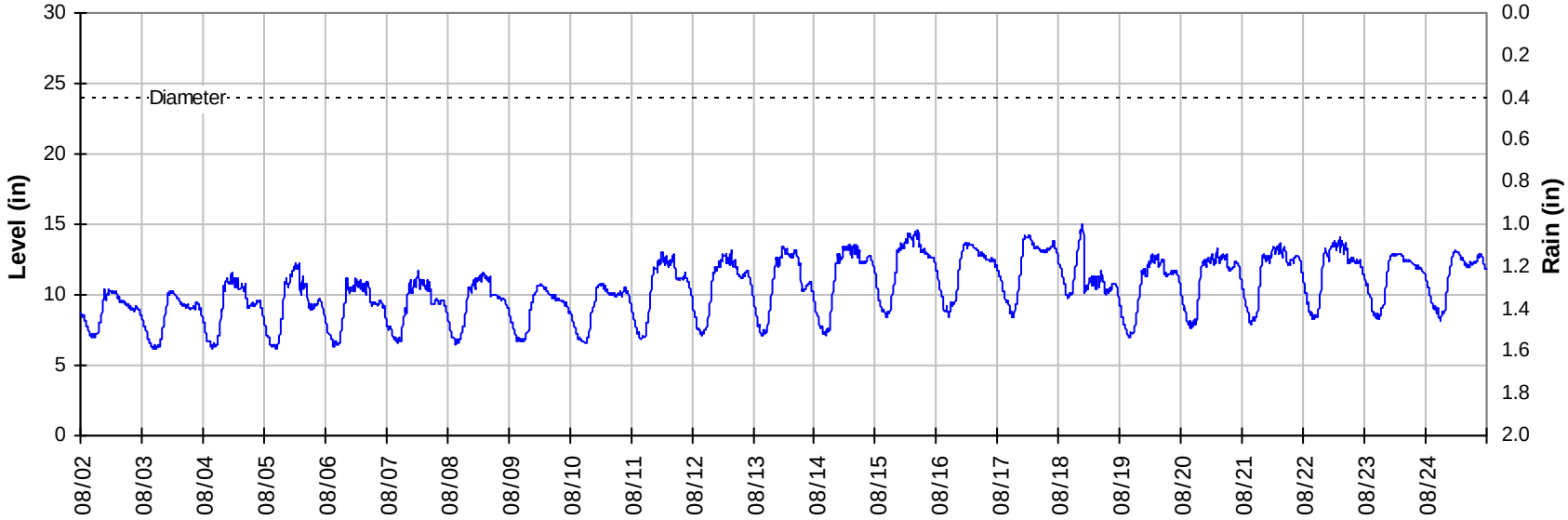
1.351 *mgd*

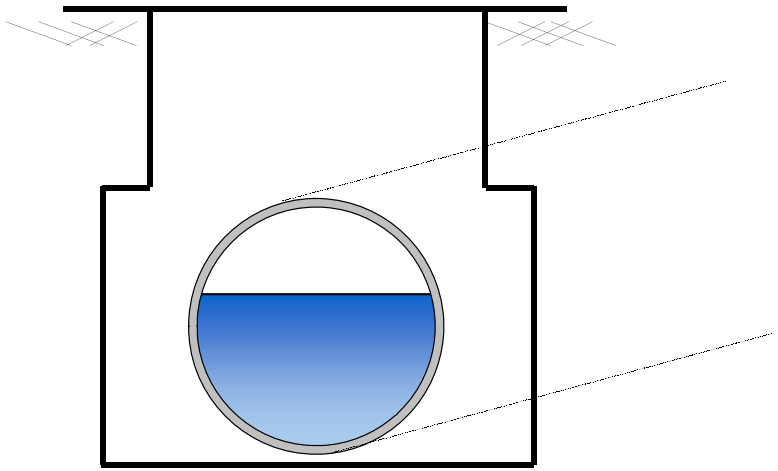


SITE 6

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period



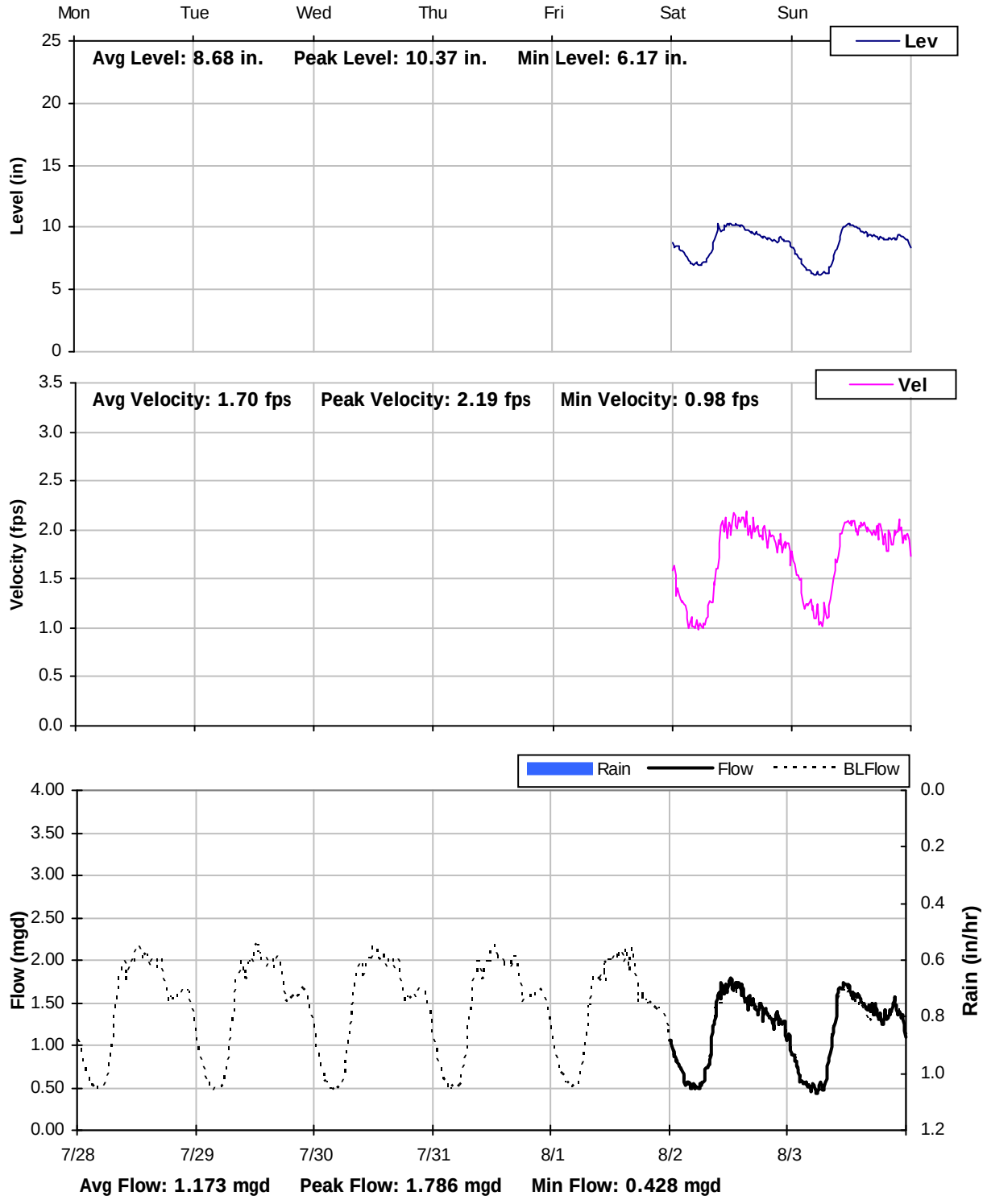


Pipe Diameter:	24	*inches*
Peak Measured Level:	15.1	*inches*
Peak d/D Ratio:	0.63	

SITE 6

Weekly Level, Velocity and Flow Hydrographs

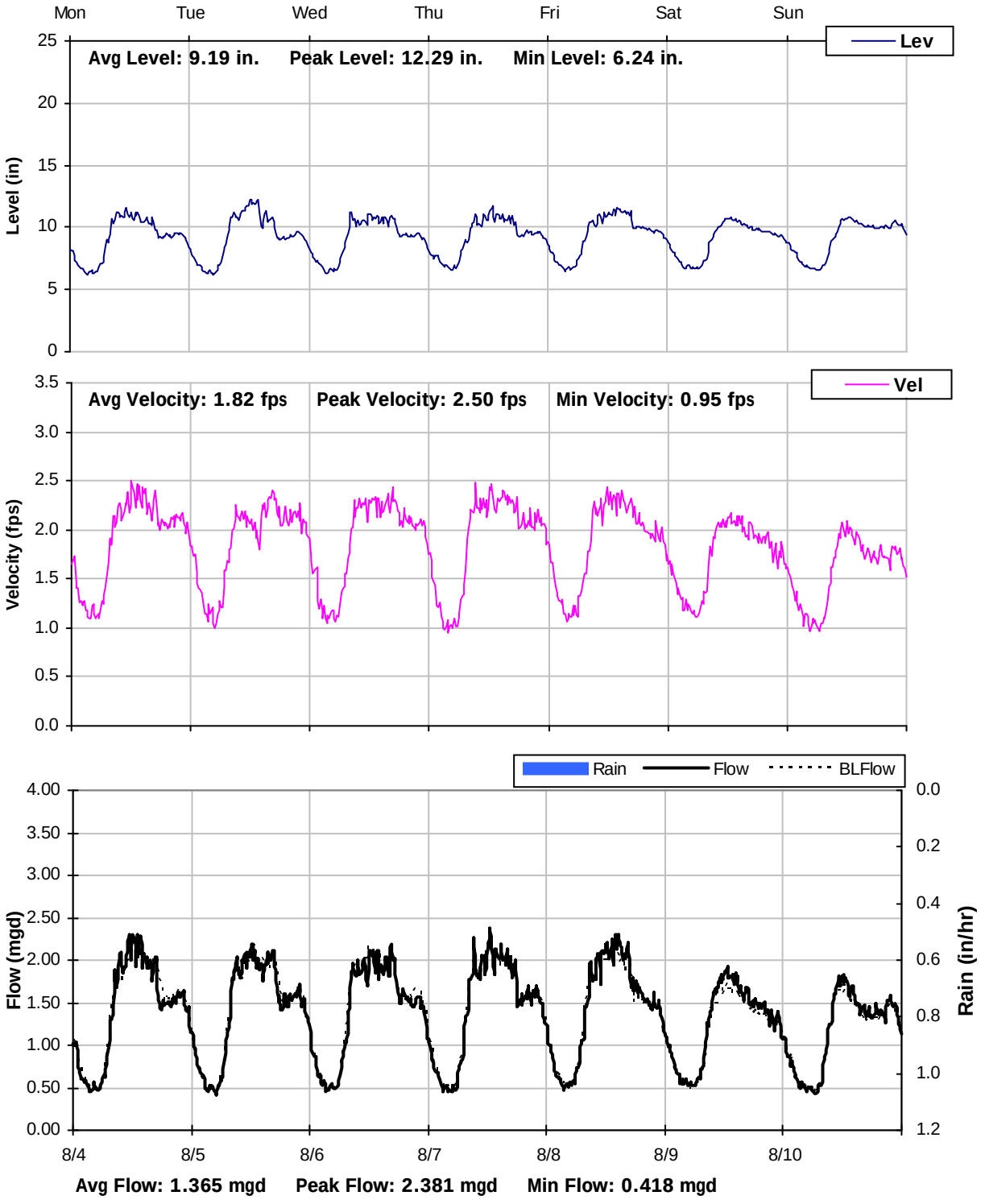
7/28/2014 to 8/4/2014



SITE 6

Weekly Level, Velocity and Flow Hydrographs

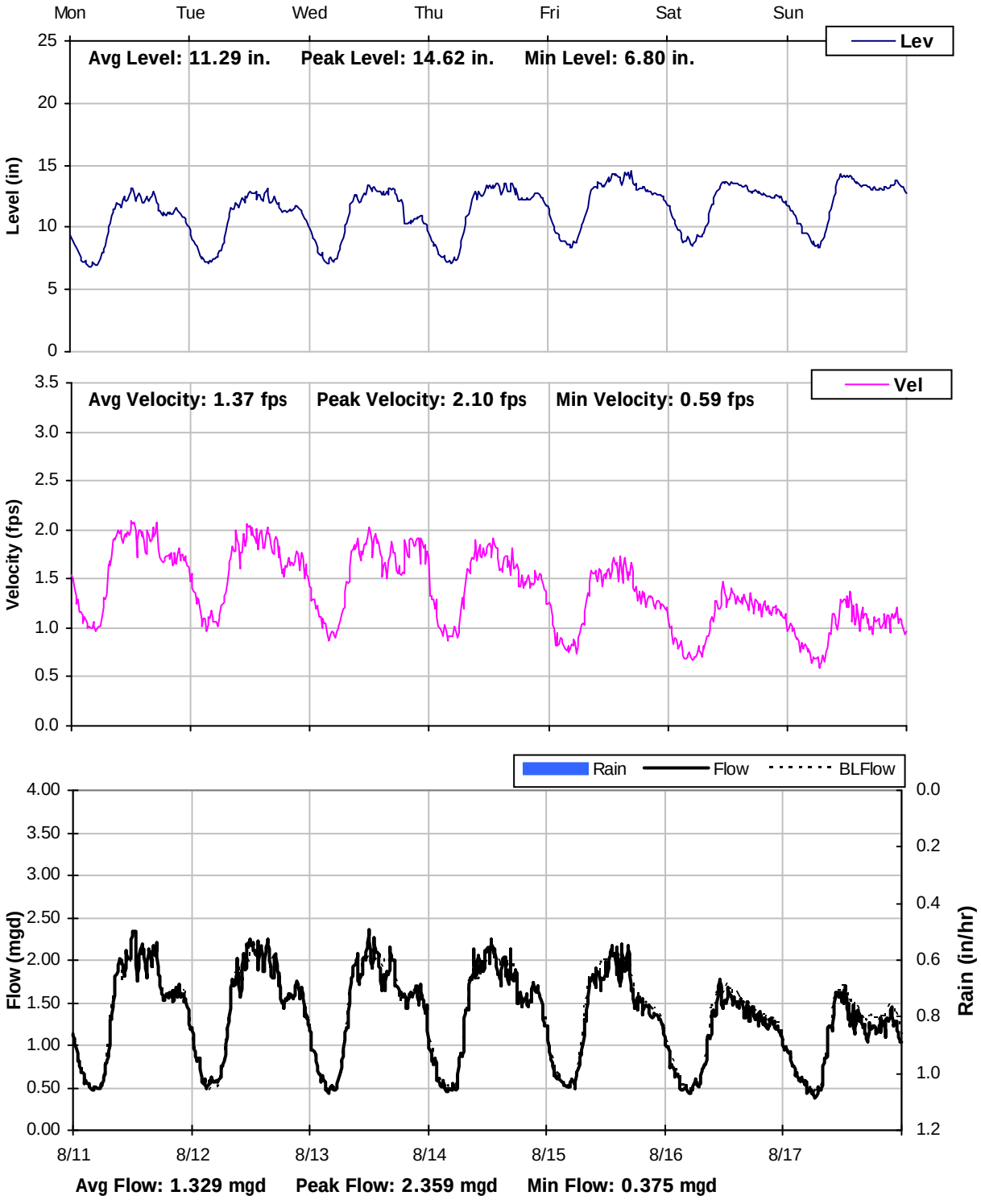
8/4/2014 to 8/11/2014



SITE 6

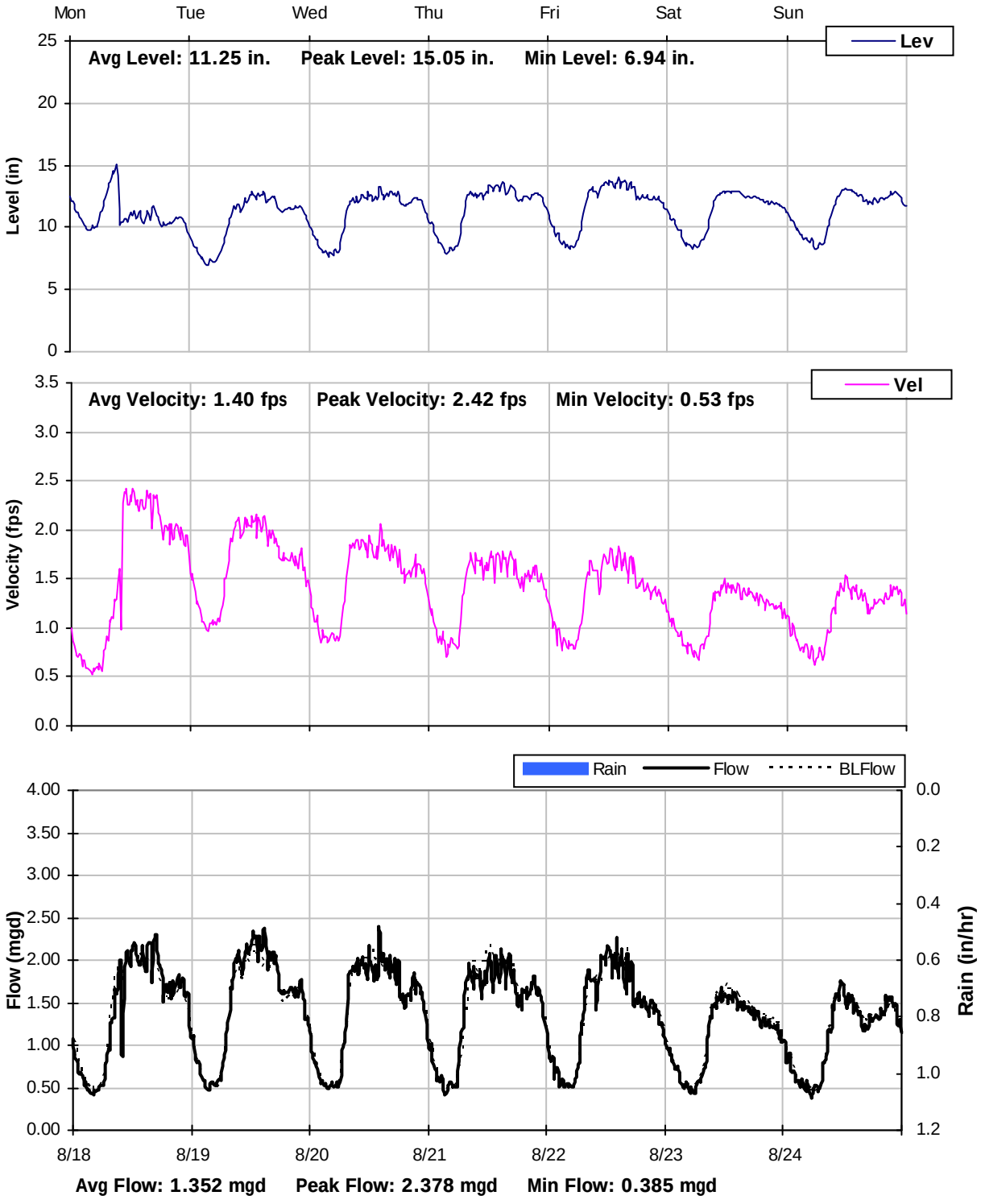
Weekly Level, Velocity and Flow Hydrographs

8/11/2014 to 8/18/2014



SITE 6

Weekly Level, Velocity and Flow Hydrographs
8/18/2014 to 8/25/2014



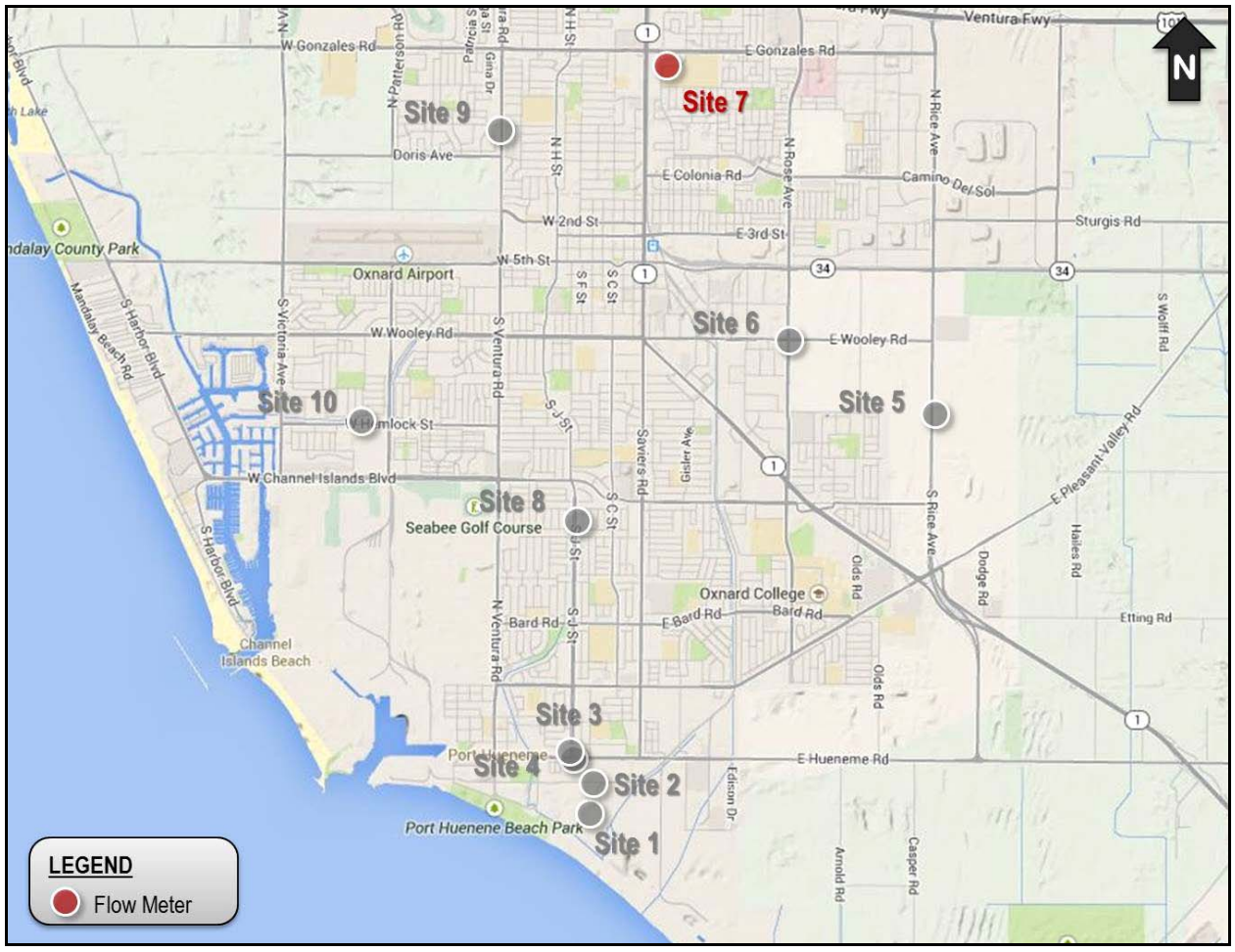
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 7

Location: E Gonzales Road and Bahia Drive

Data Summary Report



Vicinity Map: Site 7

SITE 7

Site Information

Location: E Gonzales Road and Bahia Drive

Coordinates: 119.1750° W, 34.2192° N

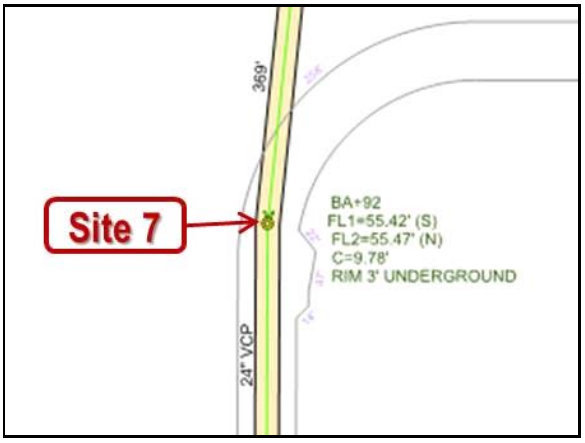
Rim Elevation: 74 feet

Pipe Diameter: 24 inches

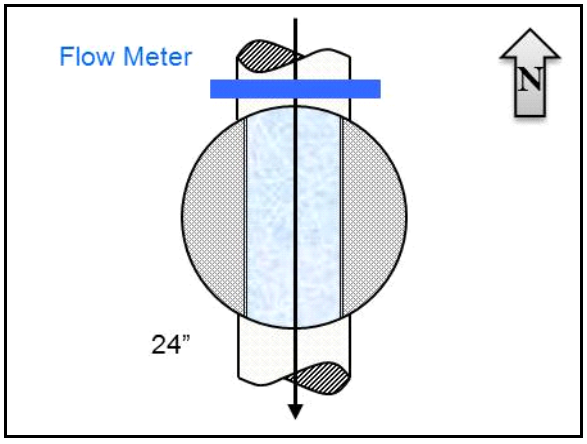
Baseline Flow: 0.311 mgd

Peak Measured Flow: 0.532 mgd

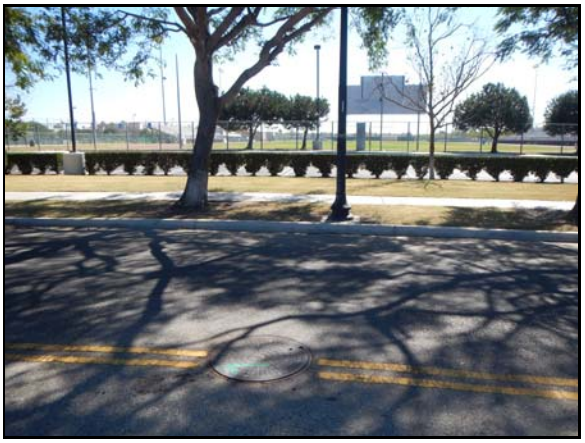
Satellite Map



Sanitary Map



Flow Diagram



Street View

Plan View

SITE 7

Additional Site Photos

Effluent Pipe

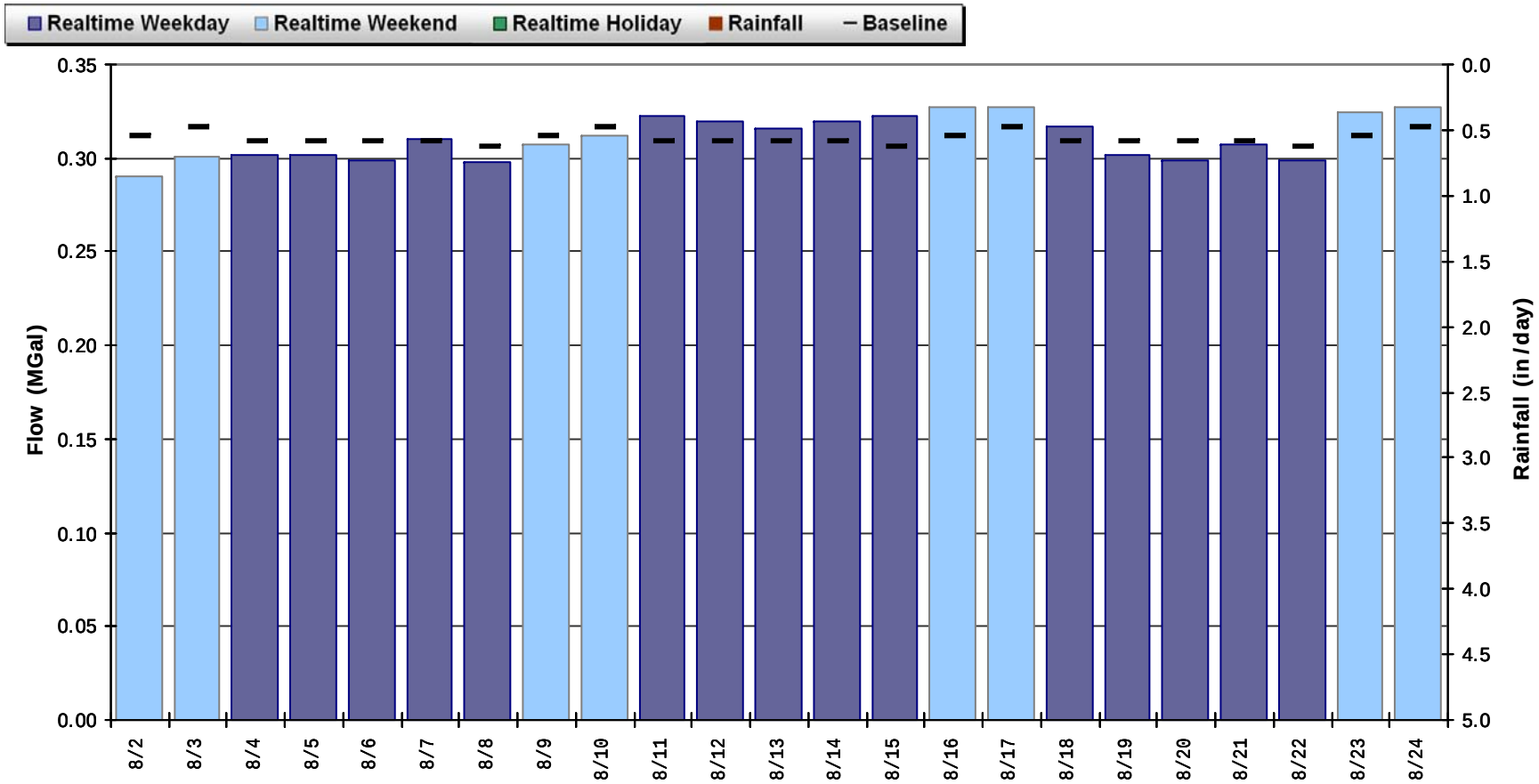
Influent Pipe

SITE 7

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 0.311 MGal **Peak Daily Flow: 0.327 MGal** **Min Daily Flow: 0.290 MGal**

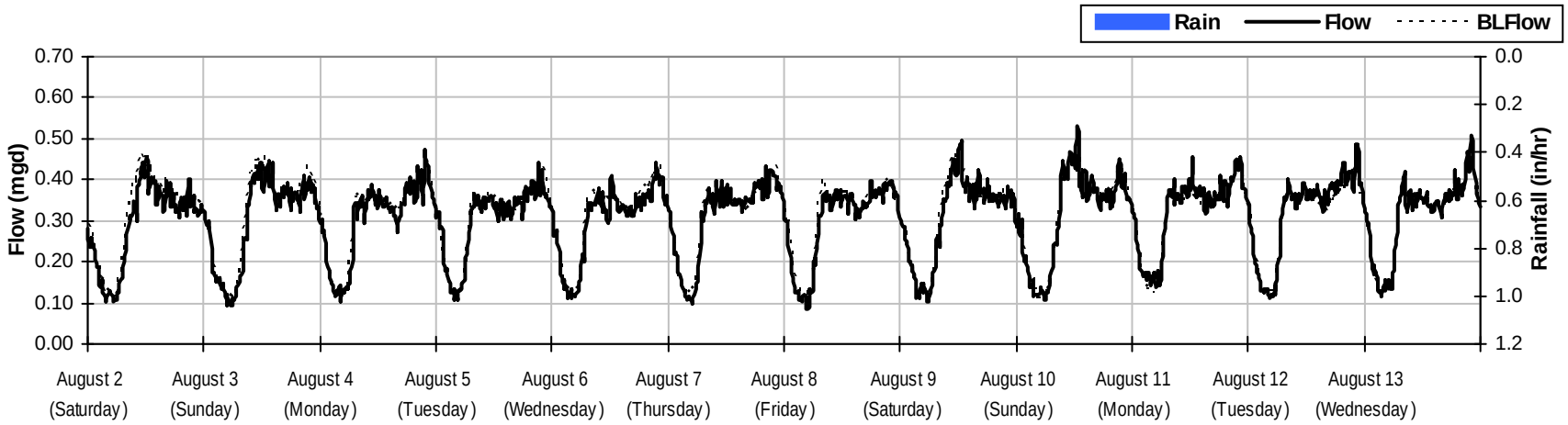
Total Monthly Rainfall: 0.00 inches

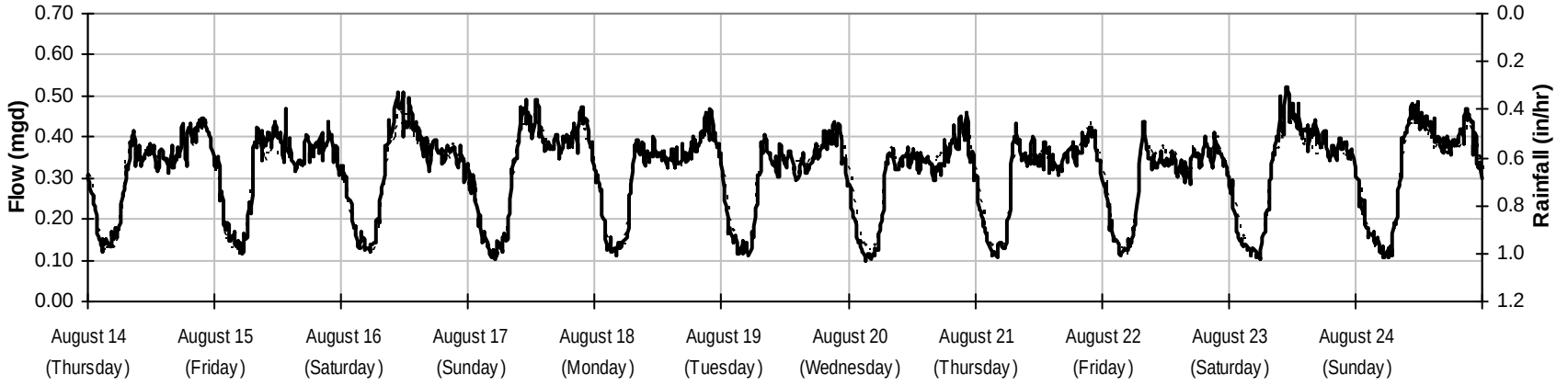


SITE 7

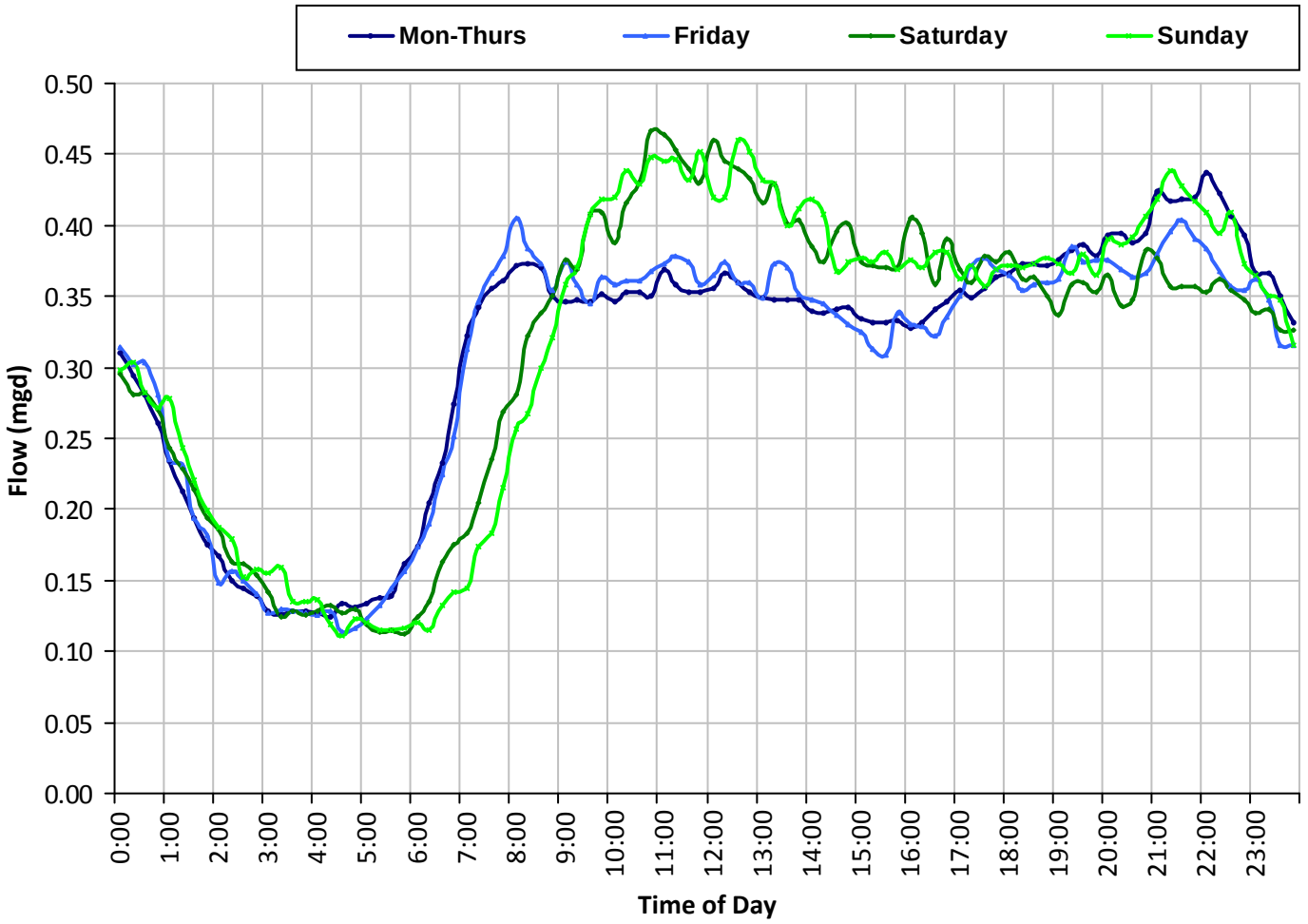
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 0.311 mgd** **Peak Flow: 0.532 mgd** **Min Flow: 0.085 mgd**



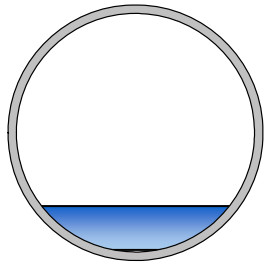


SITE 7
Baseline Flow Hydrographs



Baseline Flow:

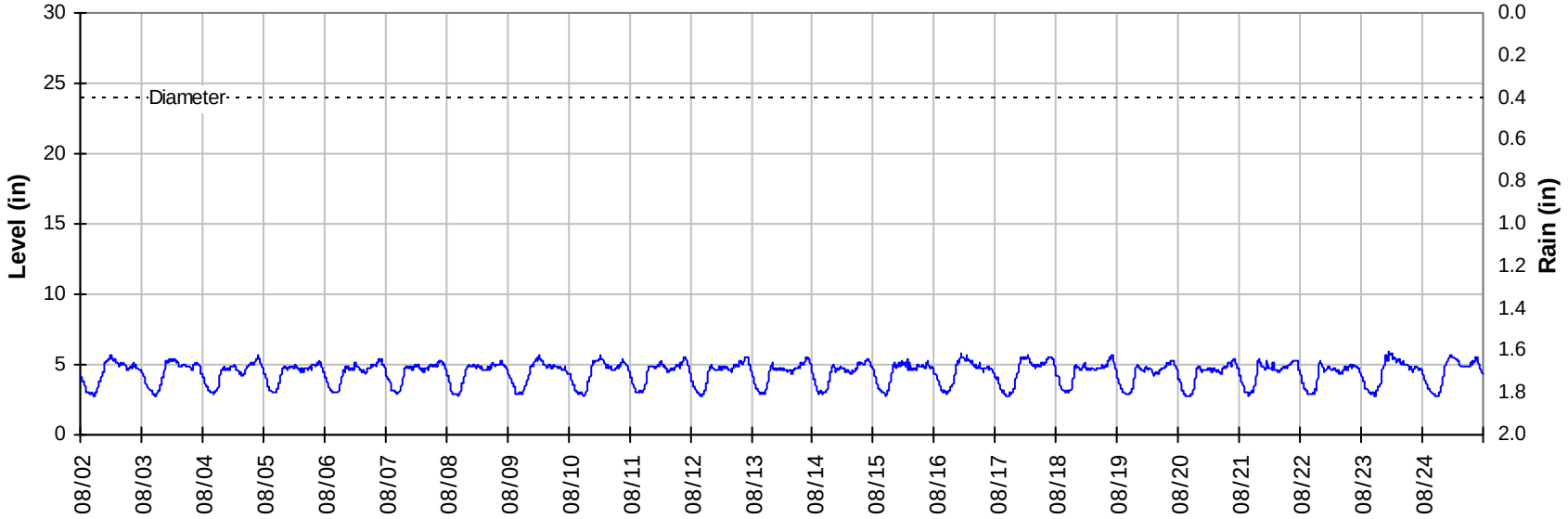
0.311 *mgd*

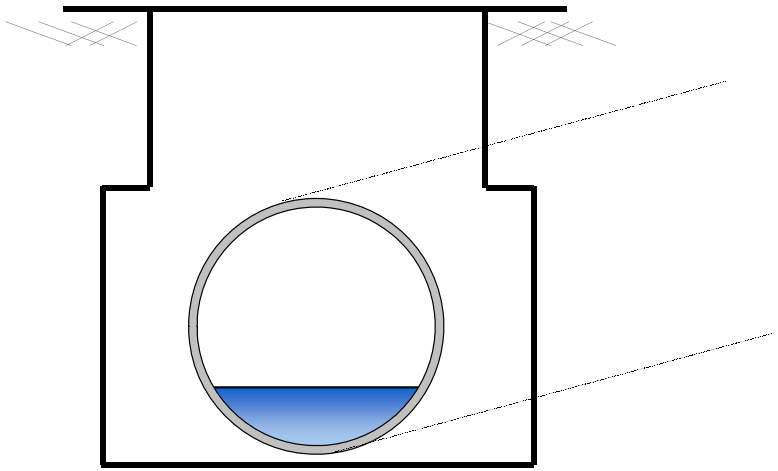


SITE 7

Site Capacity and Surcharge Summary

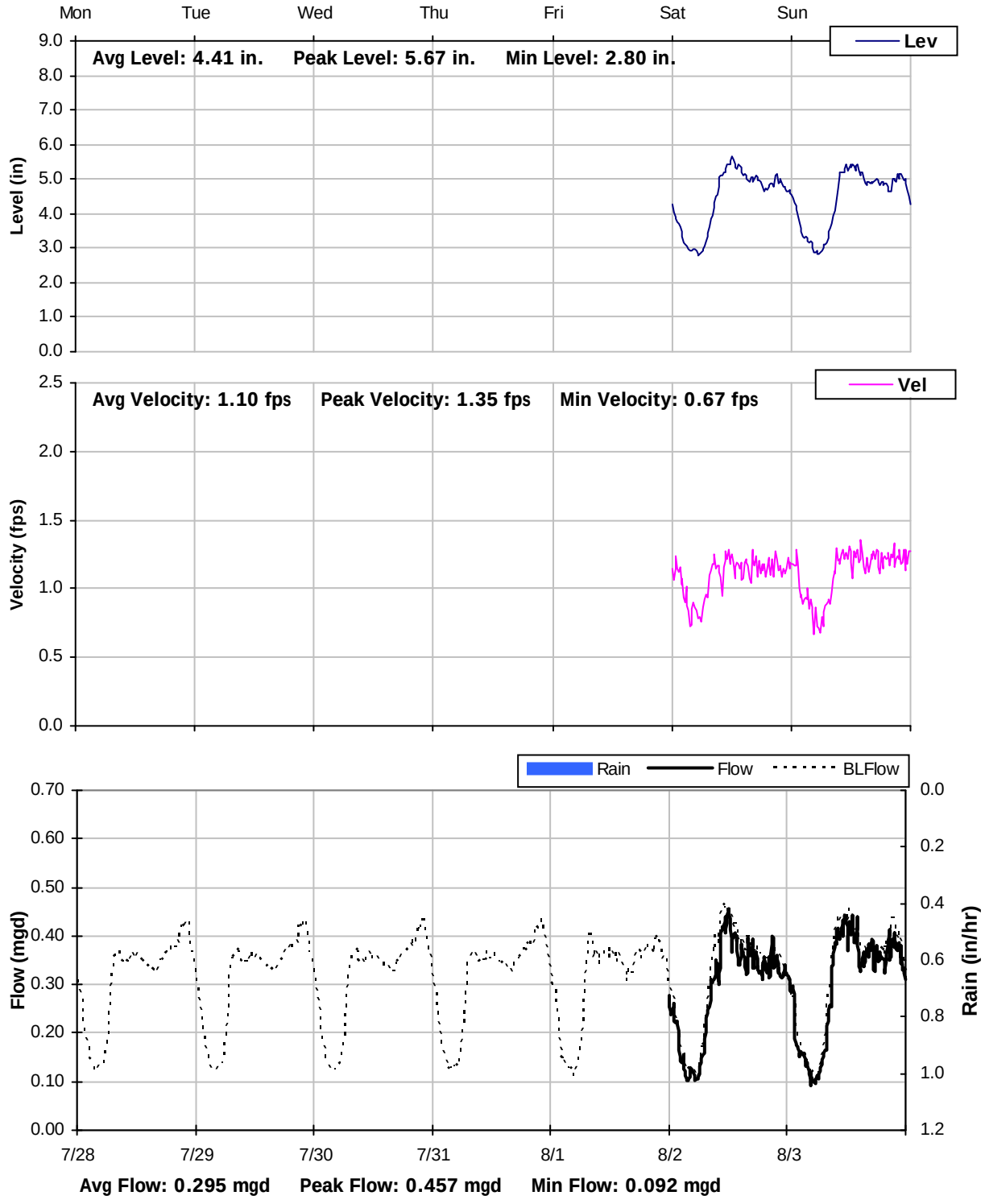
Realtime Flow Levels with Rainfall Data over Monitoring Period





Pipe Diameter:	24	*inches*
Peak Measured Level:	5.93	*inches*
Peak d/D Ratio:	0.25	

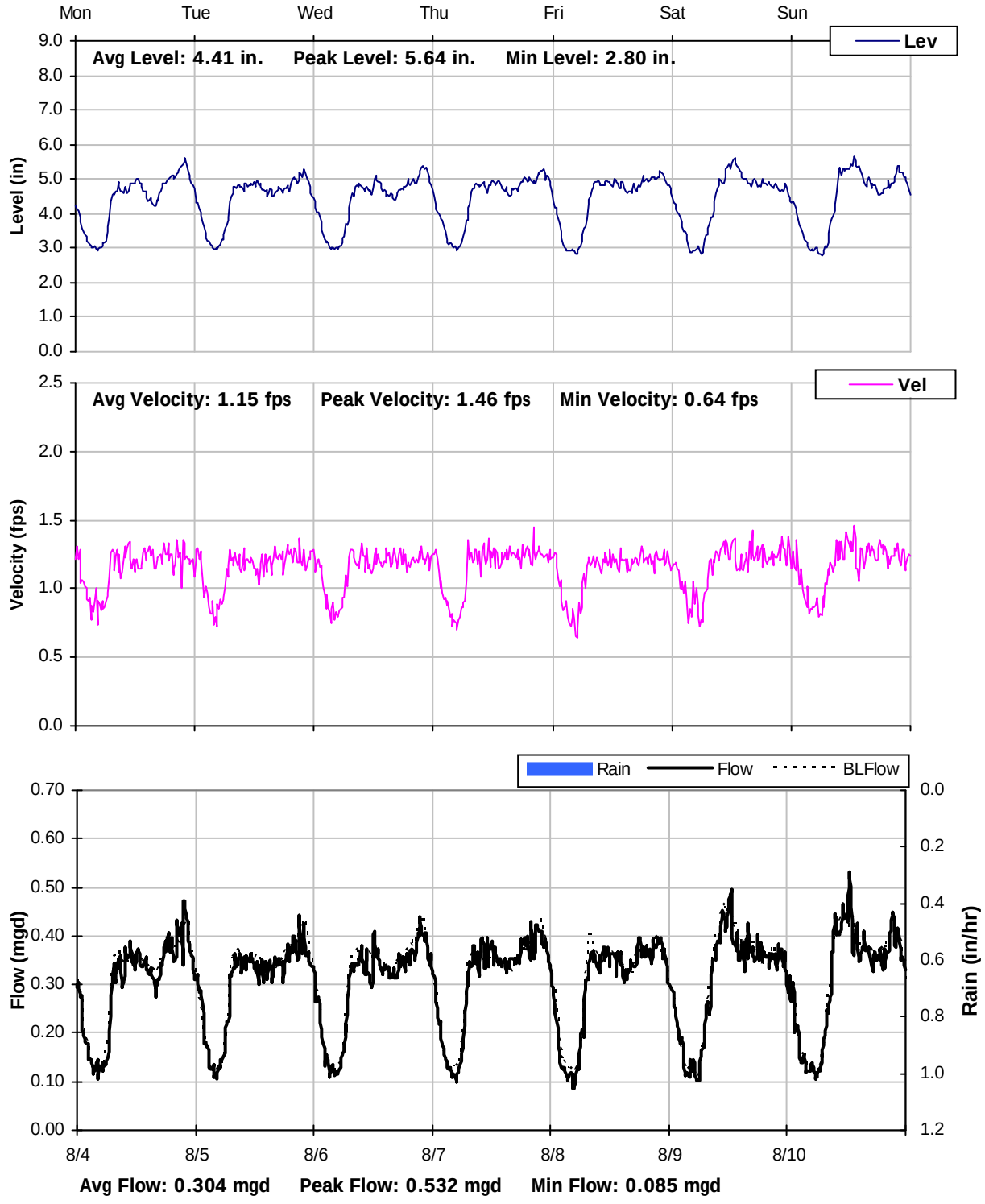
SITE 7
Weekly Level, Velocity and Flow Hydrographs
7/28/2014 to 8/4/2014



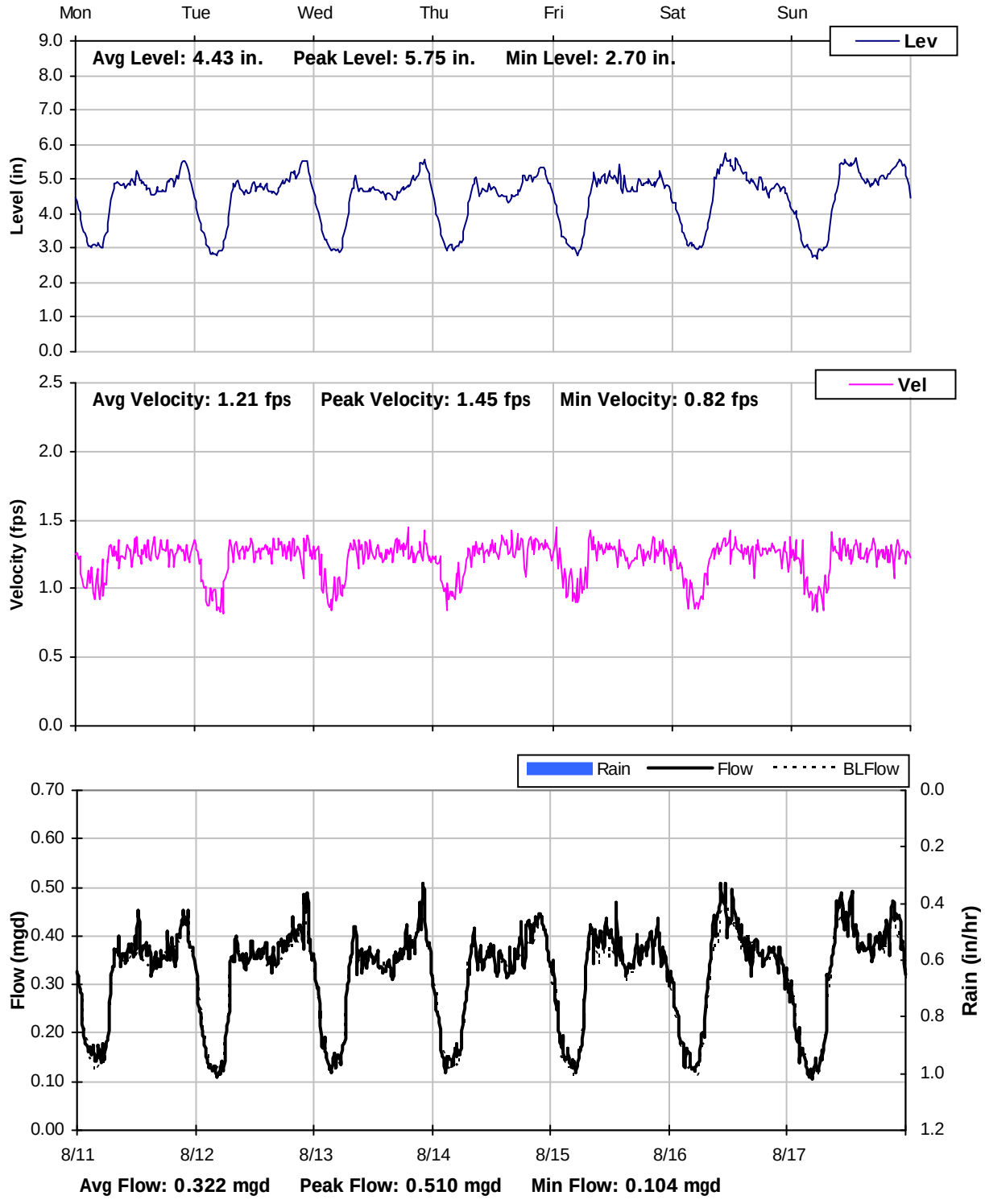
SITE 7

Weekly Level, Velocity and Flow Hydrographs

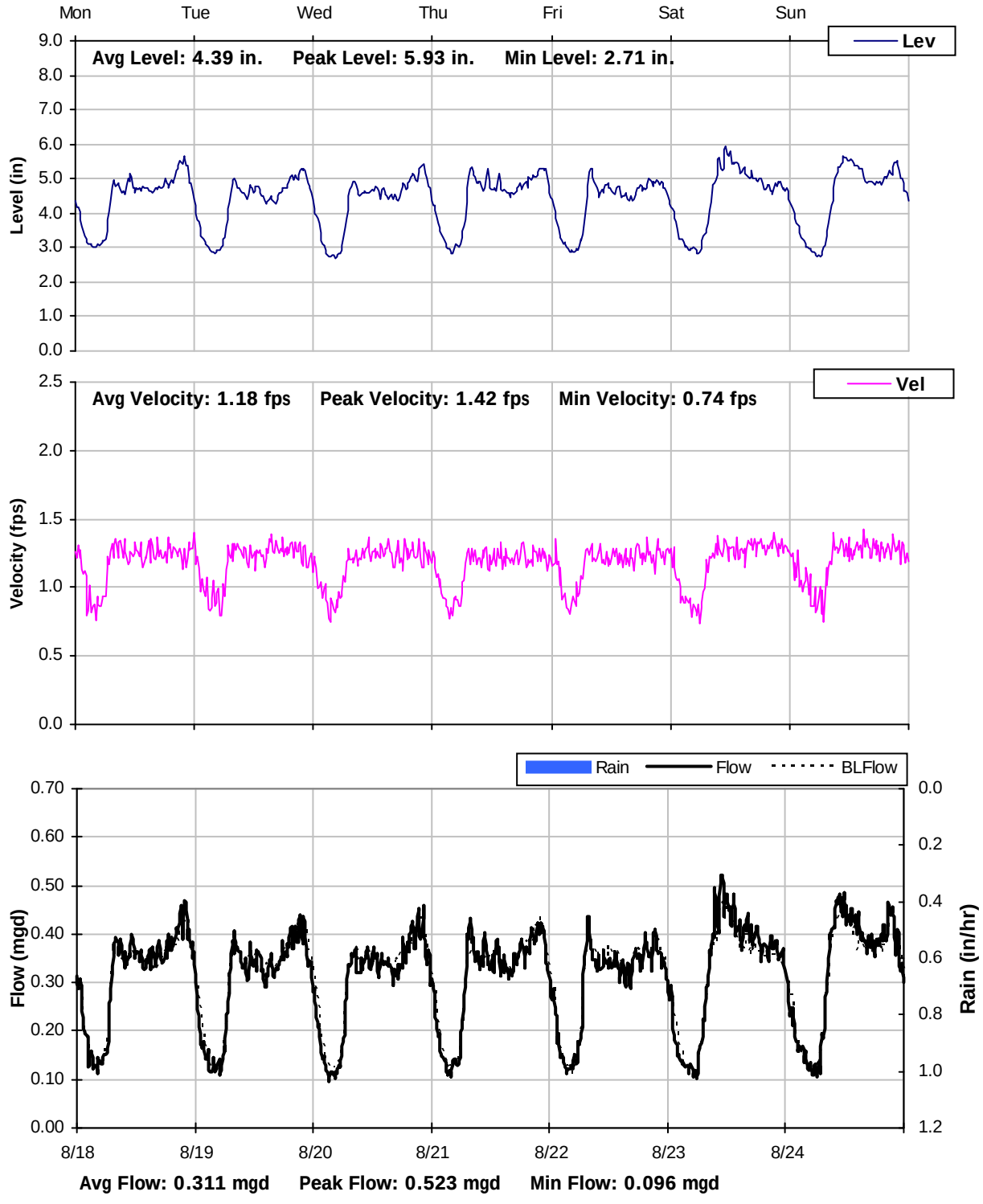
8/4/2014 to 8/11/2014



SITE 7
Weekly Level, Velocity and Flow Hydrographs
8/11/2014 to 8/18/2014



SITE 7
Weekly Level, Velocity and Flow Hydrographs
8/18/2014 to 8/25/2014



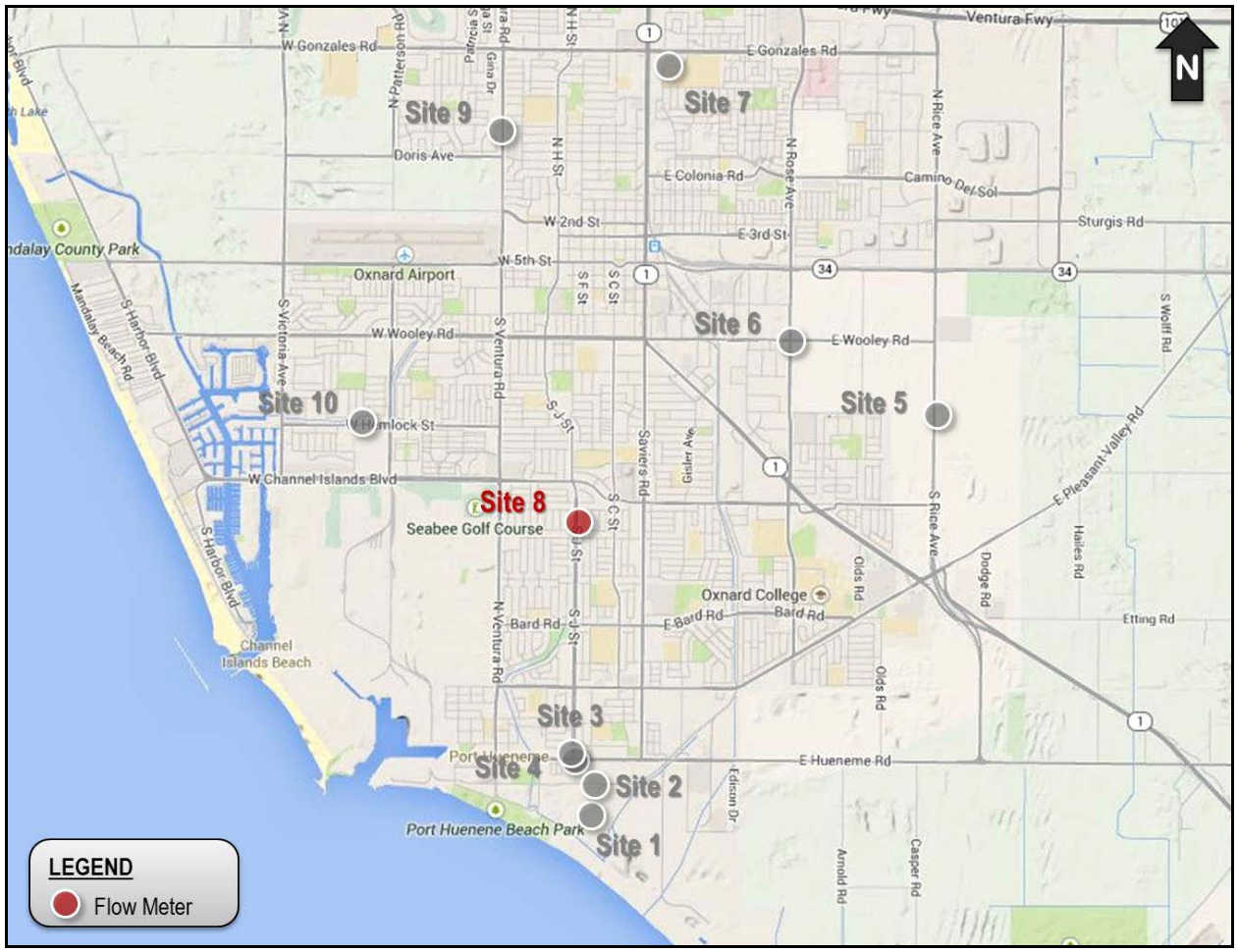
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 8

Location: J Street, between Spruce Street and Teakwood Street

Data Summary Report



Vicinity Map: Site 8

SITE 8

Site Information

Location: J Street, between Spruce Street and Teakwood Street

Coordinates: 119.1857° W, 34.1716° N

Rim Elevation: 25 feet

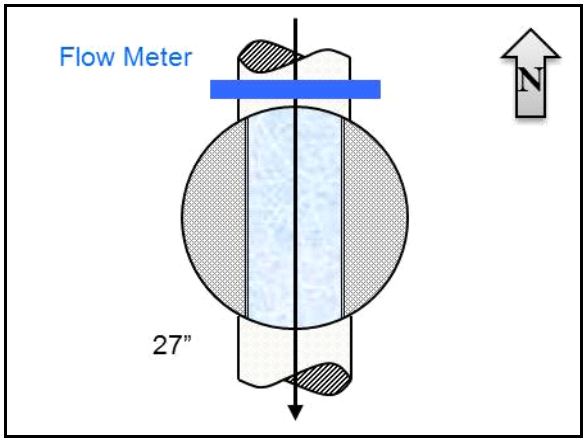
Pipe Diameter: 27 inches

Baseline Flow: 1.840 mgd

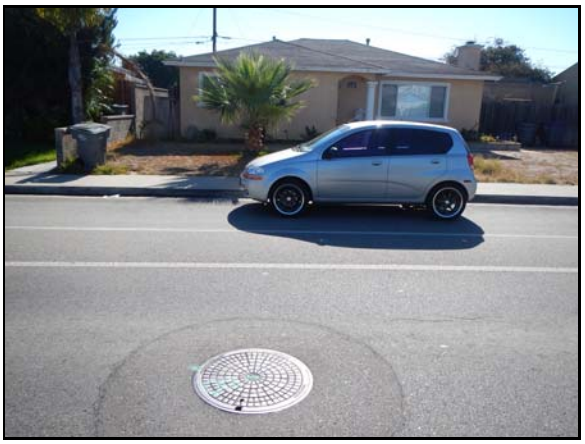
Peak Measured Flow: 2.958 mgd

Satellite Map

Sanitary Map



Flow Diagram



Street View

Plan View

SITE 8

Additional Site Photos

Effluent Pipe

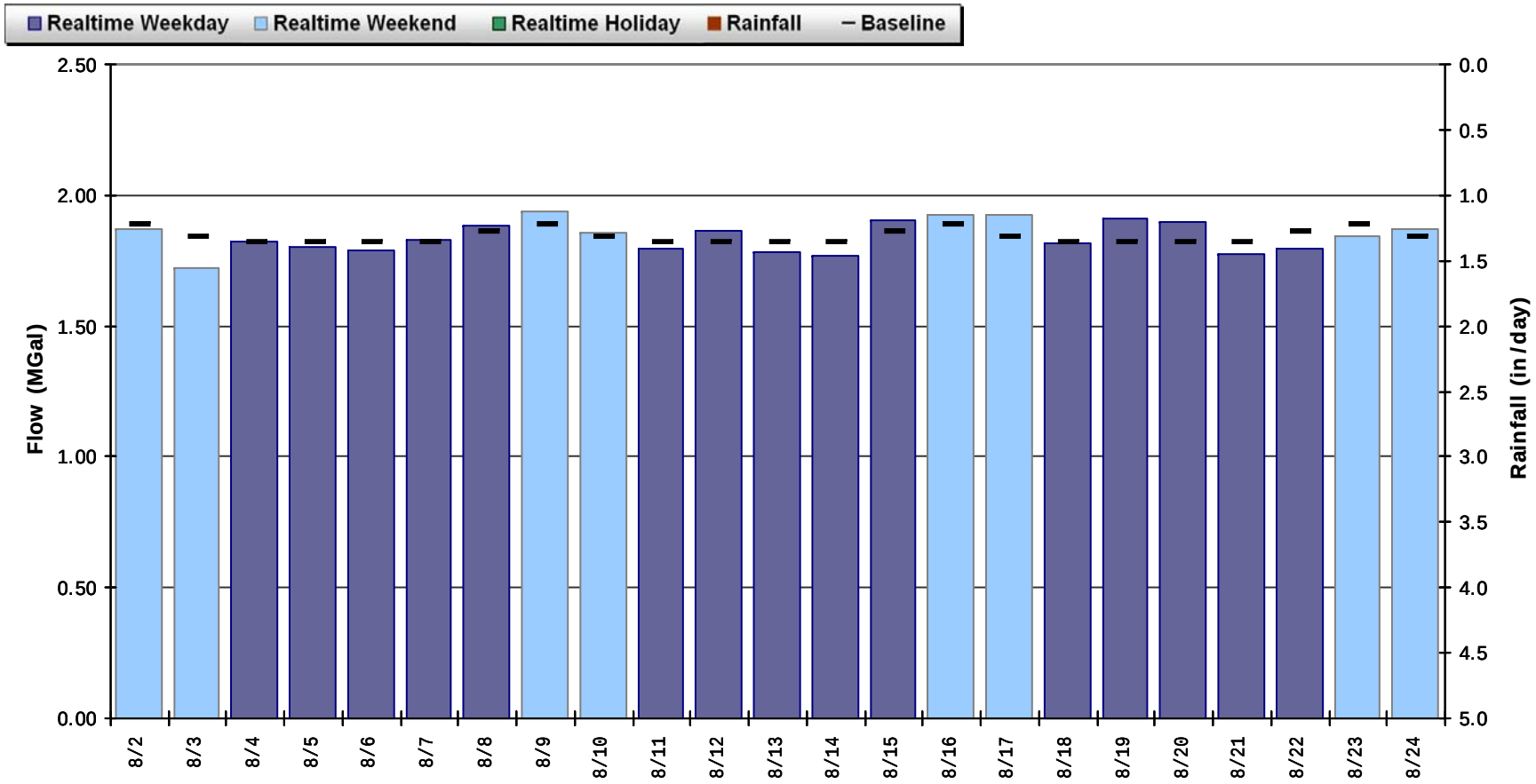
Influent Pipe

SITE 8

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 1.842 MGal **Peak Daily Flow: 1.937 MGal** **Min Daily Flow: 1.721 MGal**

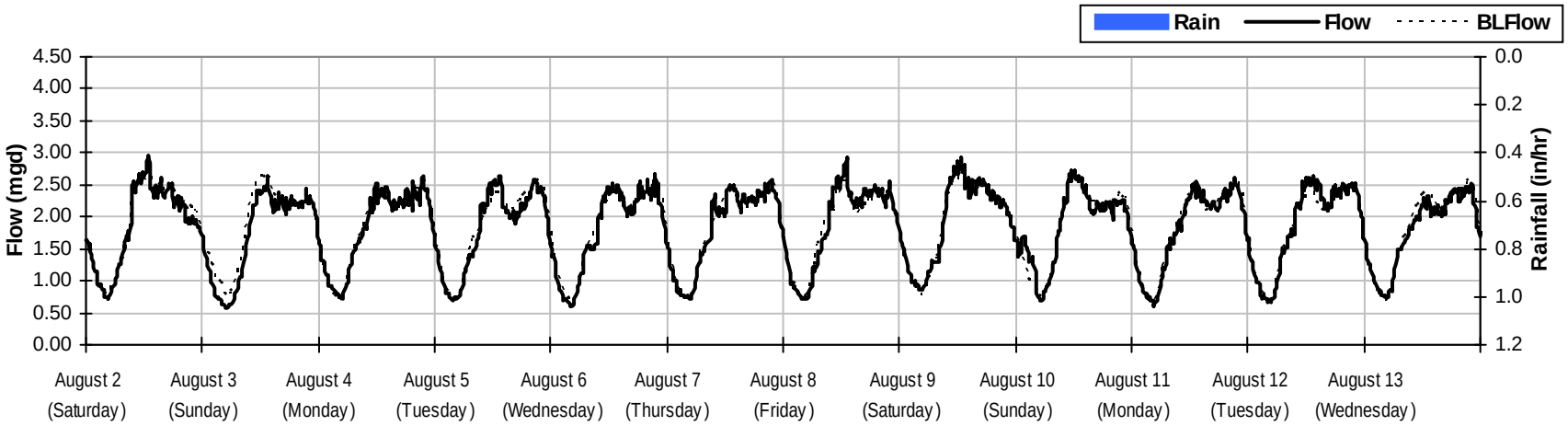
Total Monthly Rainfall: 0.00 inches

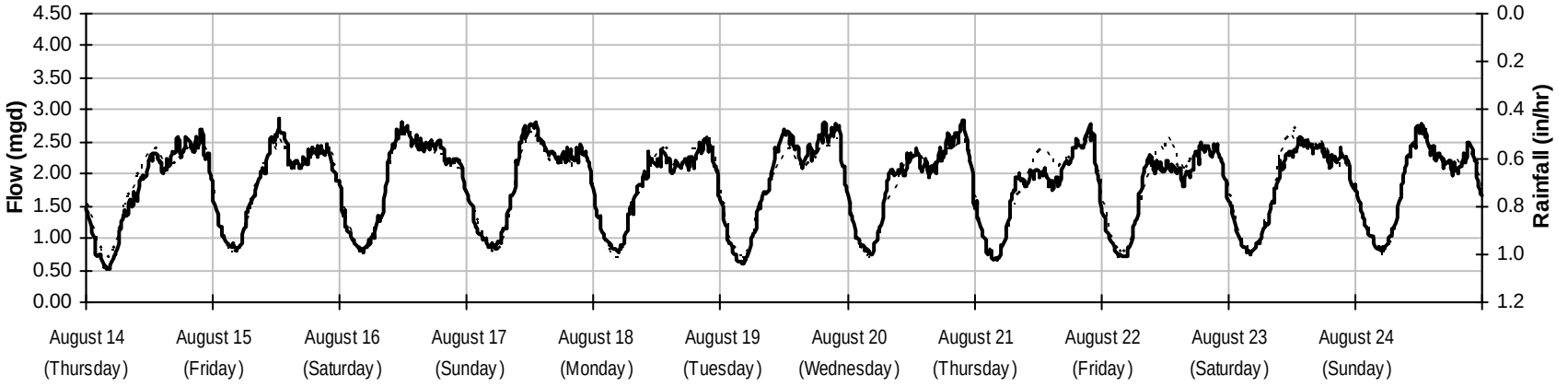


SITE 8

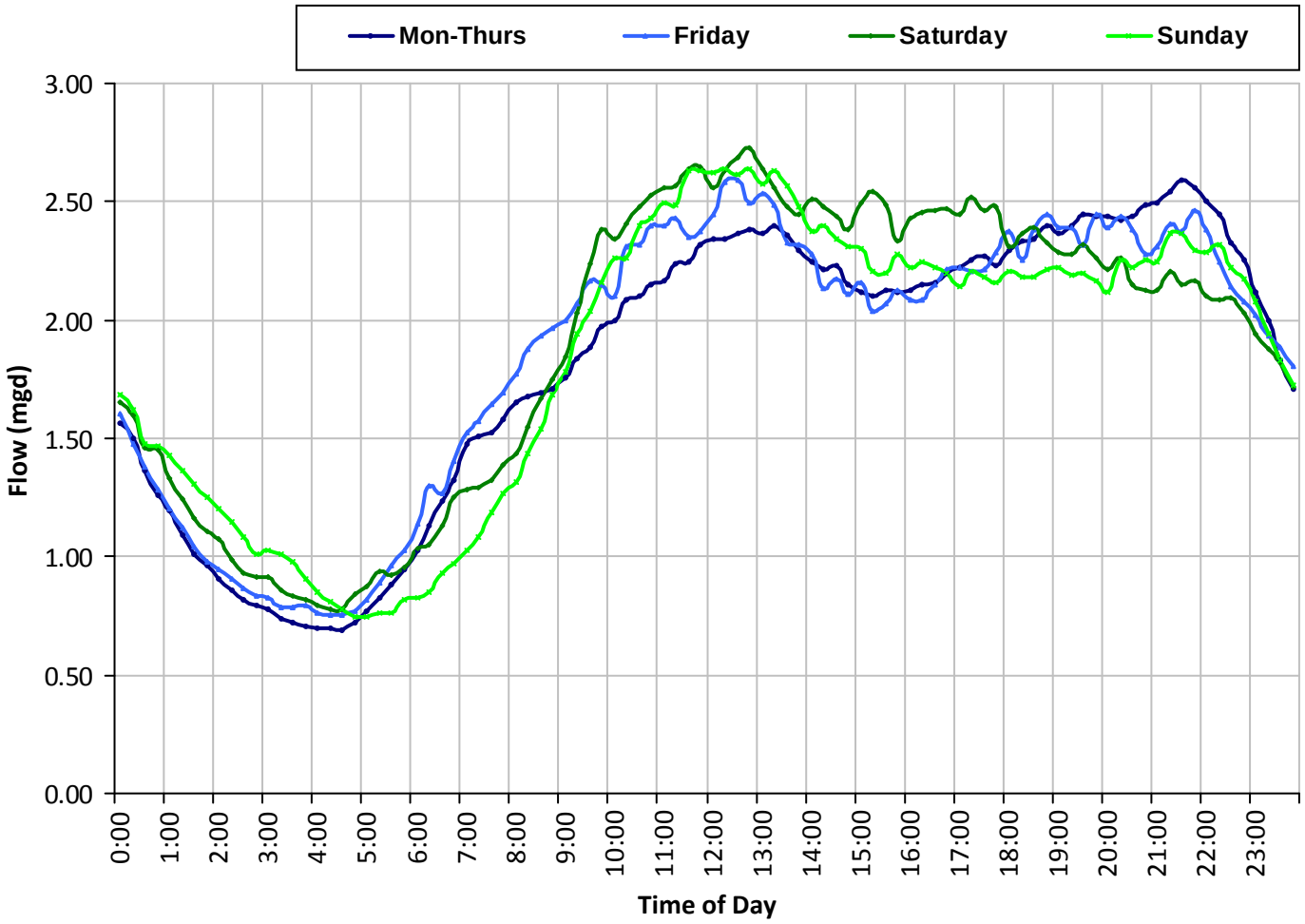
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 1.842 mgd** **Peak Flow: 2.958 mgd** **Min Flow: 0.525 mgd**



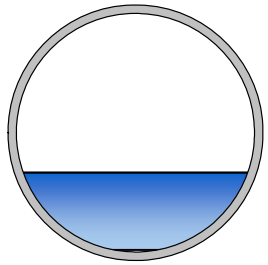


SITE 8
Baseline Flow Hydrographs



Baseline Flow:

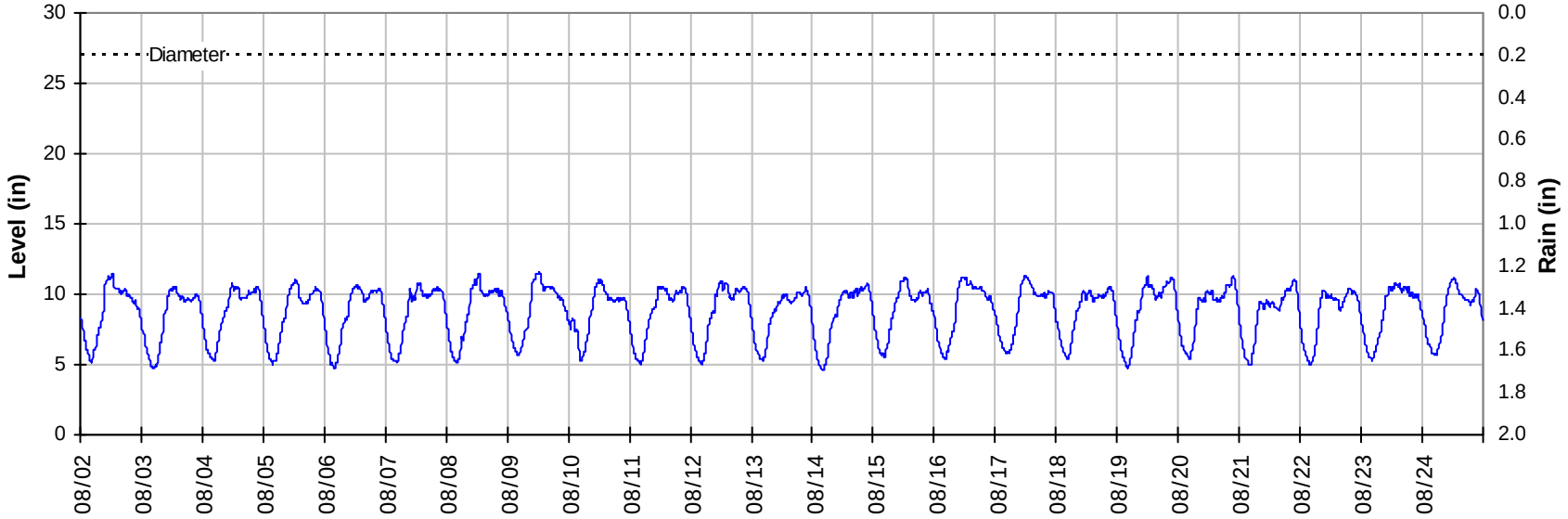
1.840 *mgd*

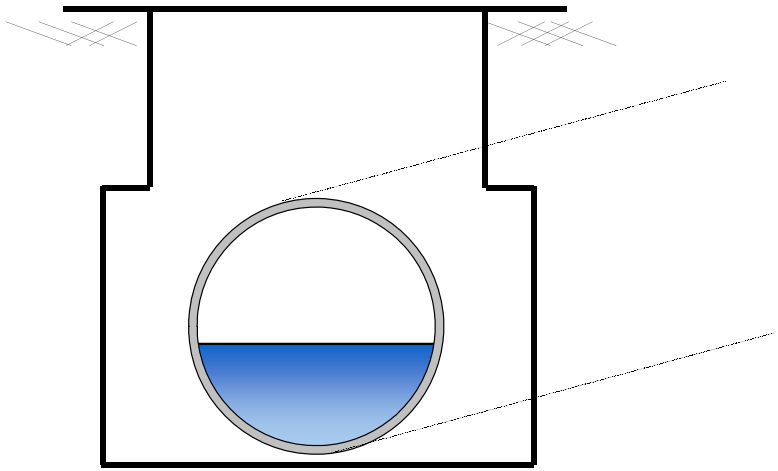


SITE 8

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period



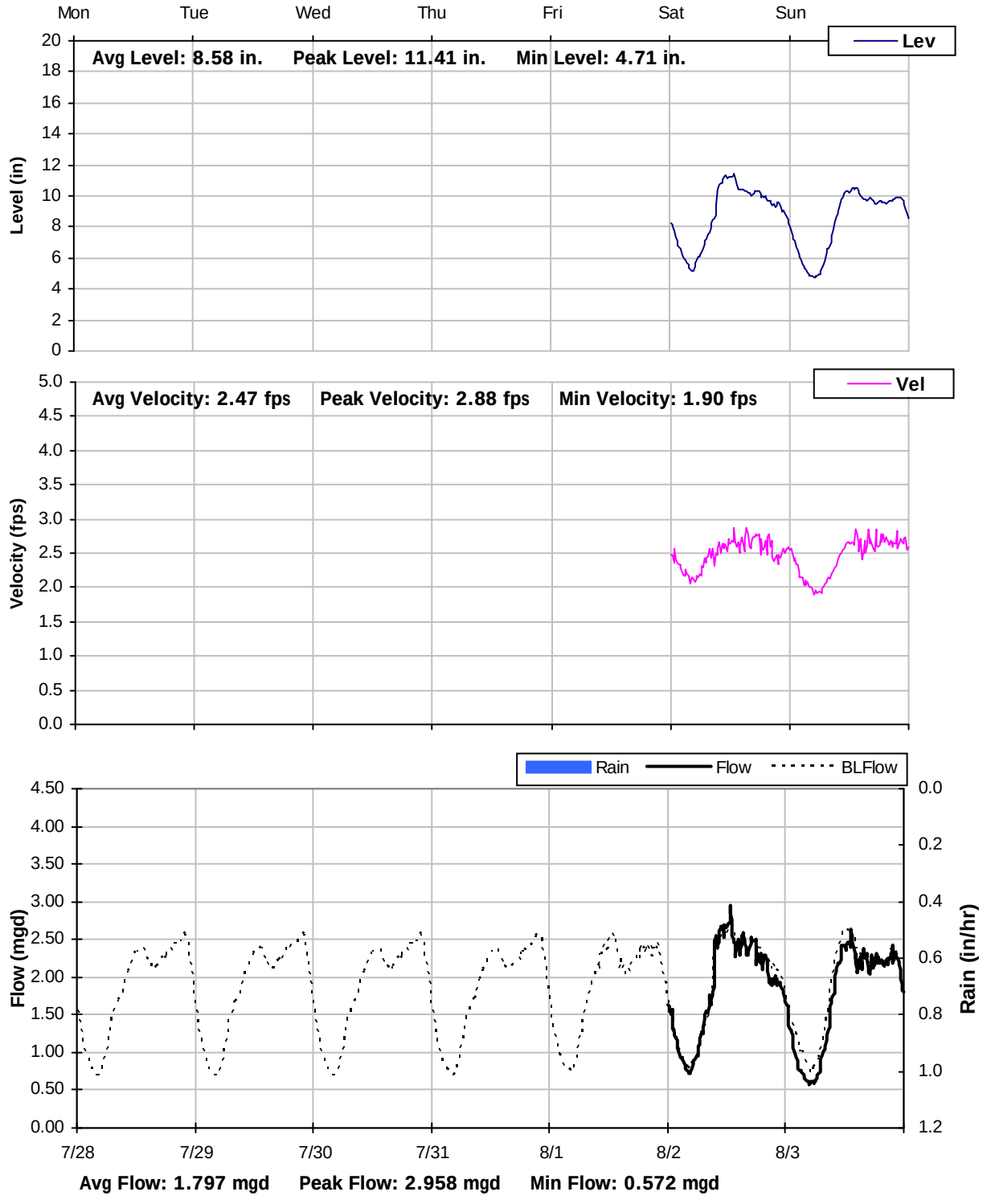


Pipe Diameter:	27	*inches*
Peak Measured Level:	11.6	*inches*
Peak d/D Ratio:	0.43	

SITE 8

Weekly Level, Velocity and Flow Hydrographs

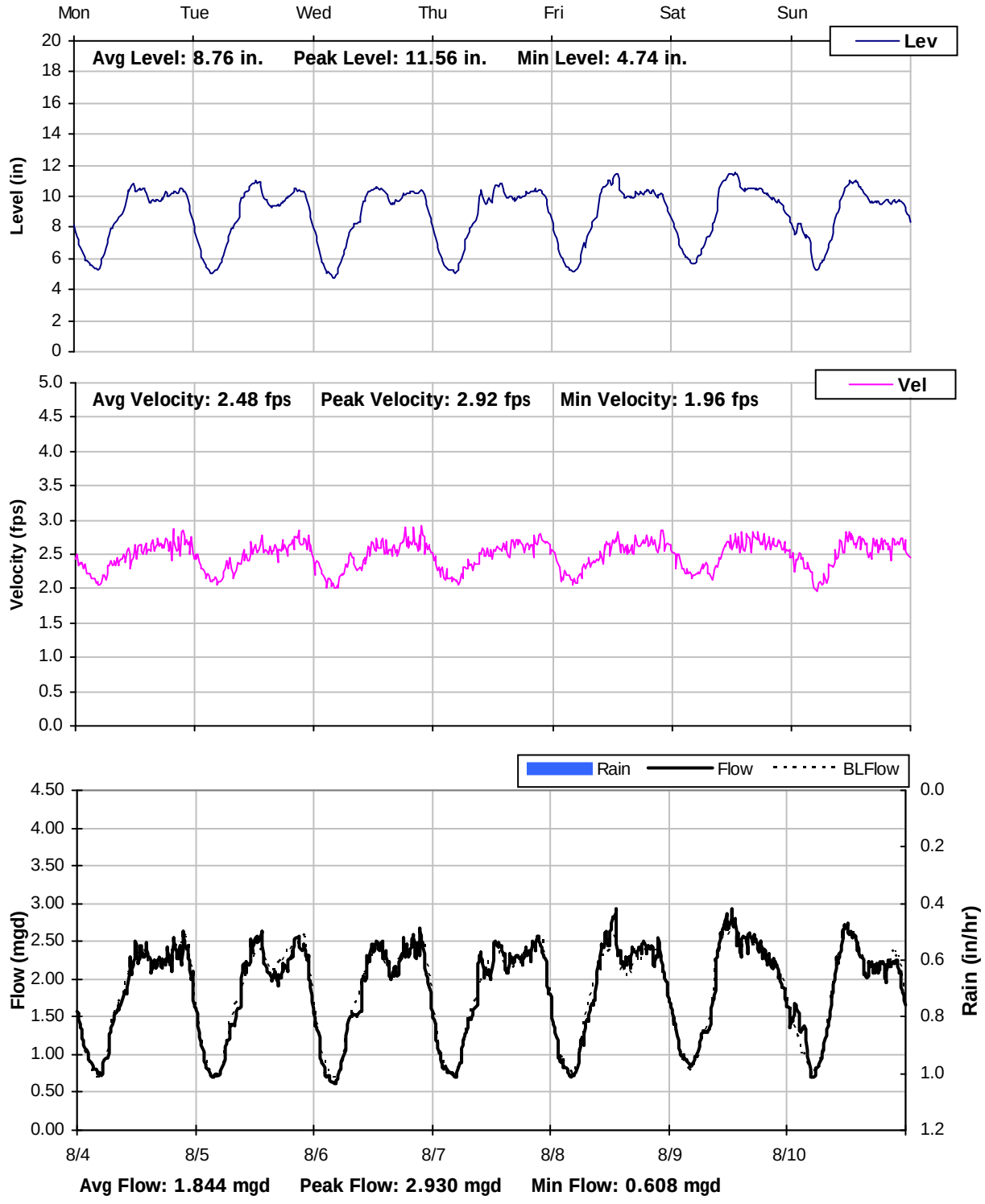
7/28/2014 to 8/4/2014



SITE 8

Weekly Level, Velocity and Flow Hydrographs

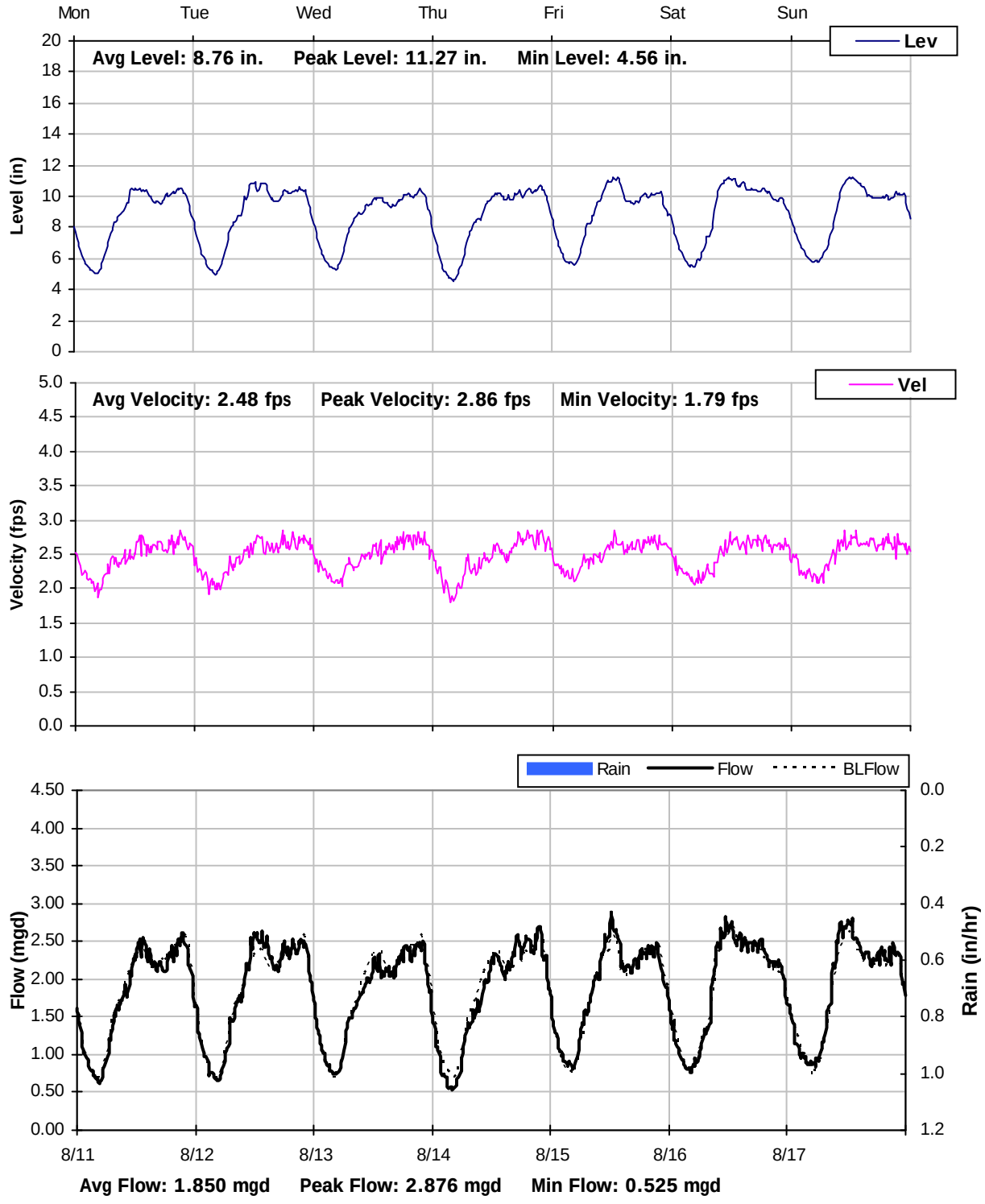
8/4/2014 to 8/11/2014



SITE 8

Weekly Level, Velocity and Flow Hydrographs

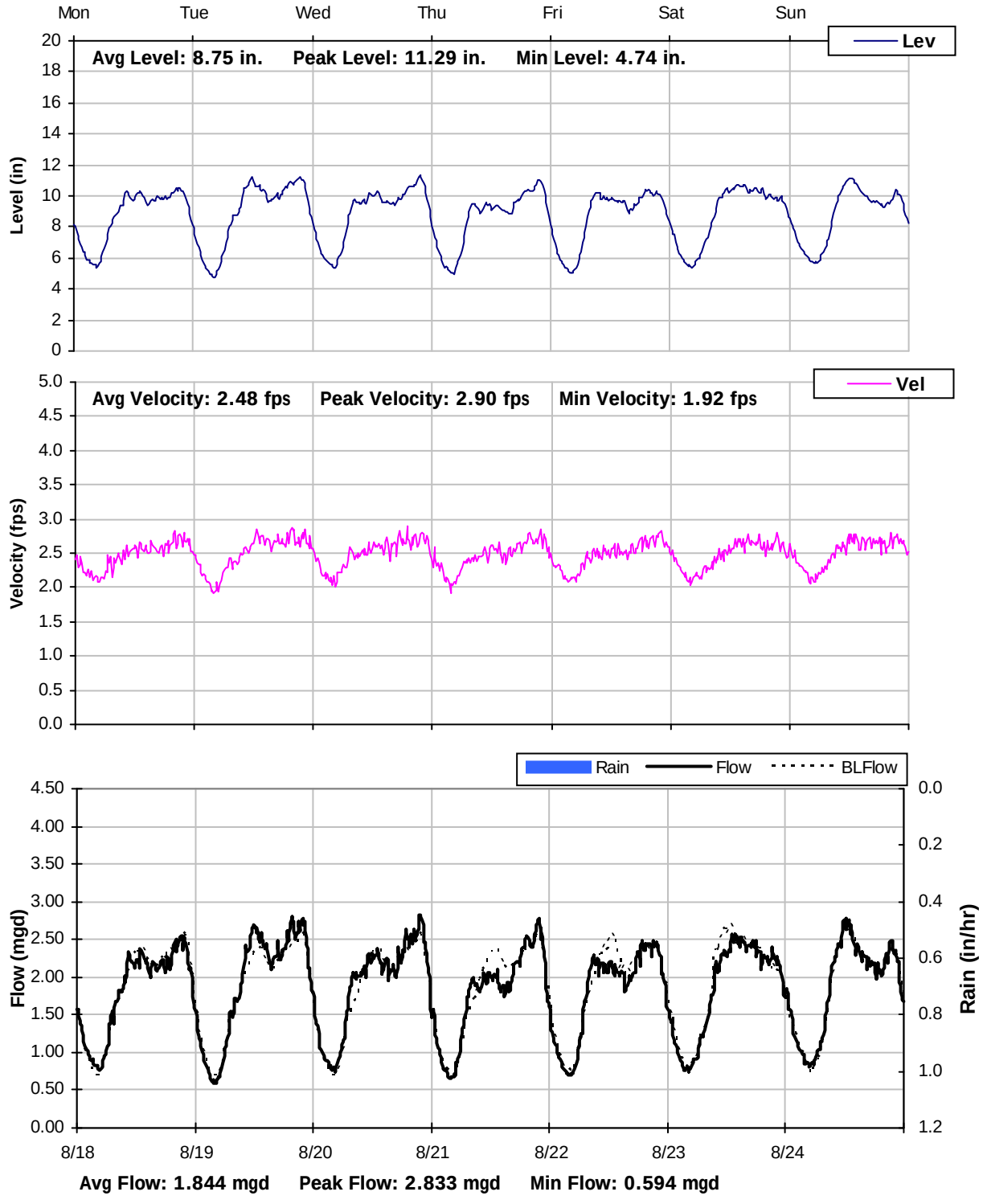
8/11/2014 to 8/18/2014



SITE 8

Weekly Level, Velocity and Flow Hydrographs

8/18/2014 to 8/25/2014



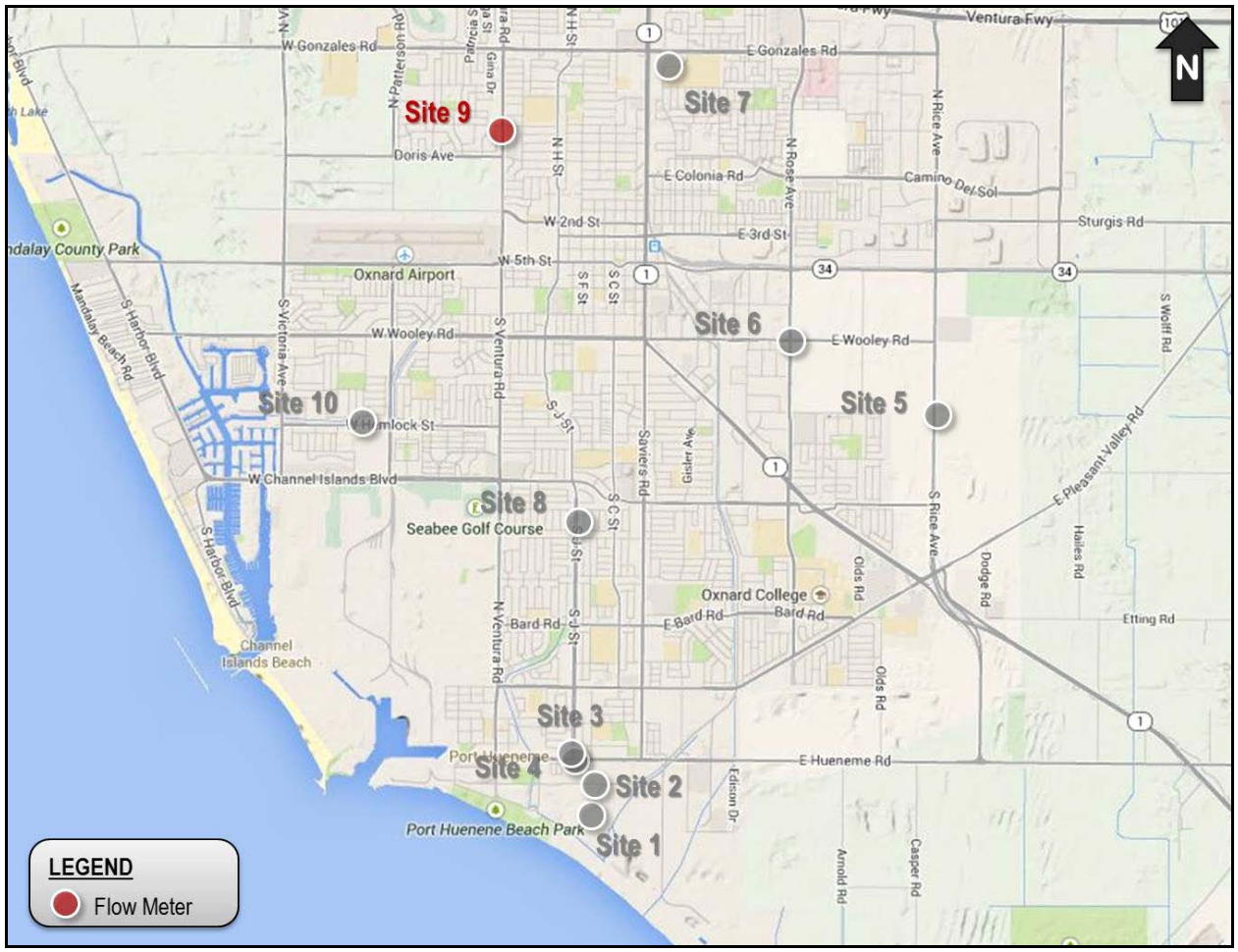
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 9

Location: N Ventura Road, between Devonshire Drive and Doris Avenue

Data Summary Report



Vicinity Map: Site 9

SITE 9

Site Information

Location: N Ventura Road, between Devonshire Drive and Doris Avenue

Coordinates: 119.1946° W, 34.2103° N

Rim Elevation: 54 feet

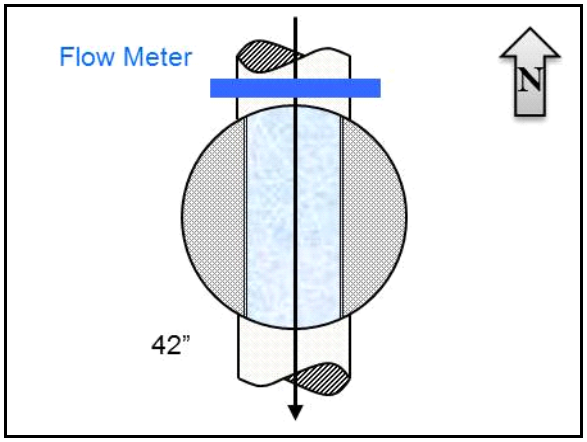
Pipe Diameter: 42 inches

Baseline Flow: 2.041 mgd

Peak Measured Flow: 3.340 mgd

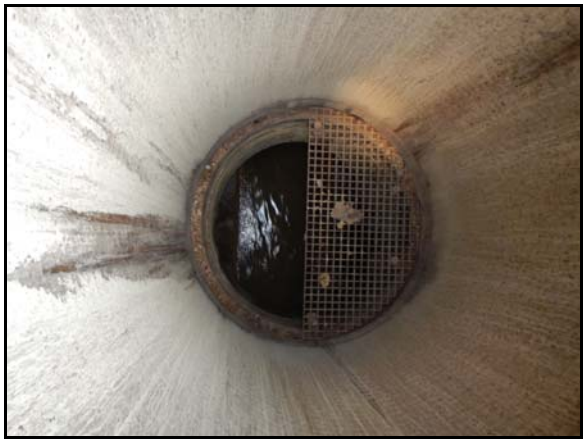
Satellite Map

Sanitary Map



Flow Diagram

Street View



Plan View

SITE 9

Additional Site Photos

Effluent Pipe

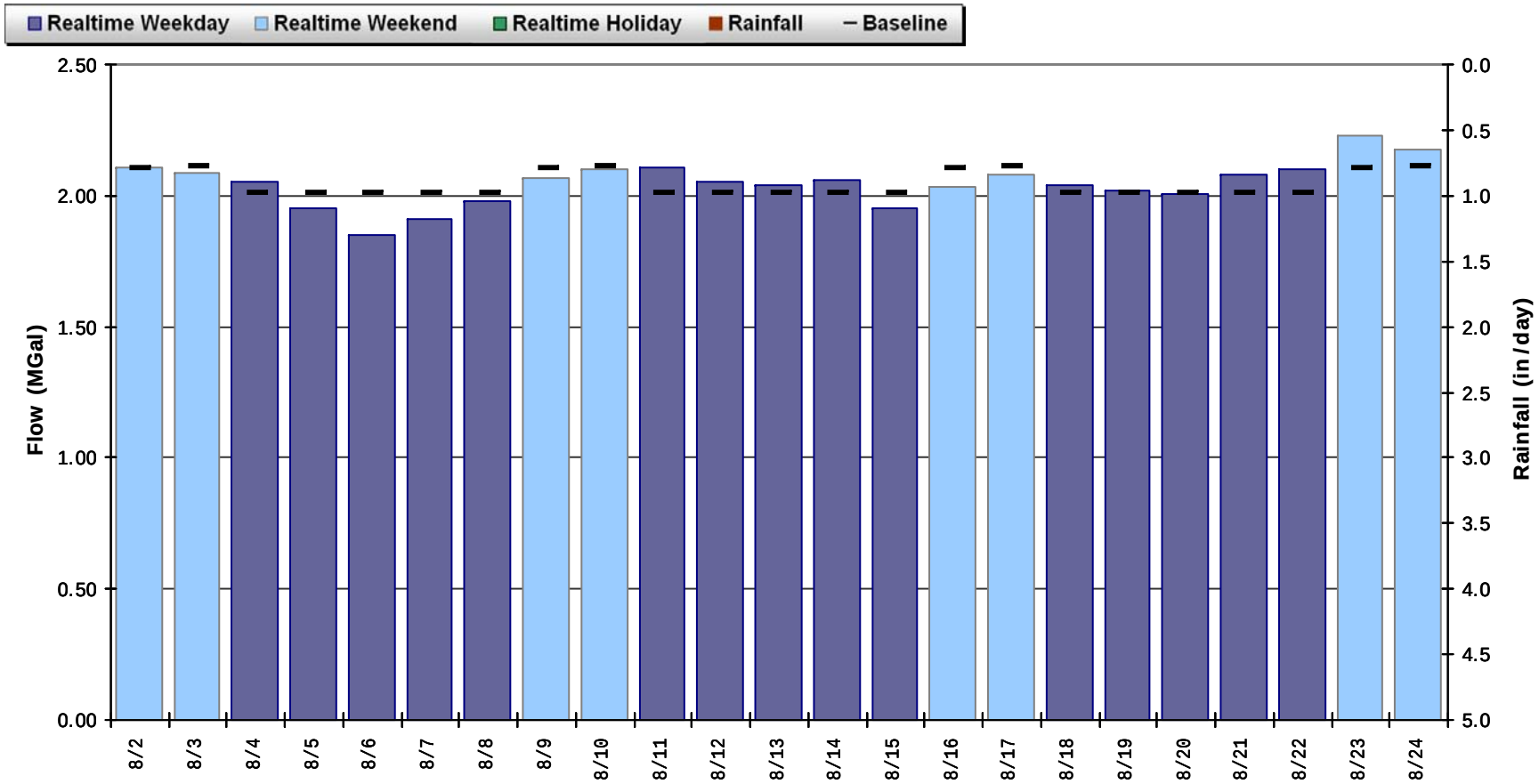
Influent Pipe

SITE 9

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 2.047 MGal **Peak Daily Flow: 2.231 MGal** **Min Daily Flow: 1.849 MGal**

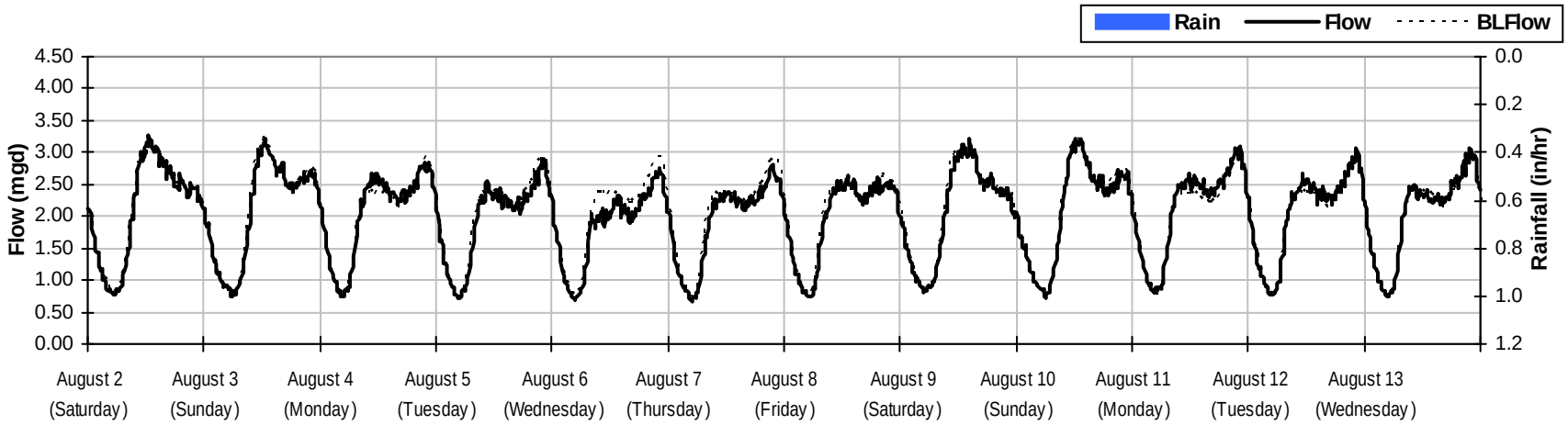
Total Monthly Rainfall: 0.00 inches

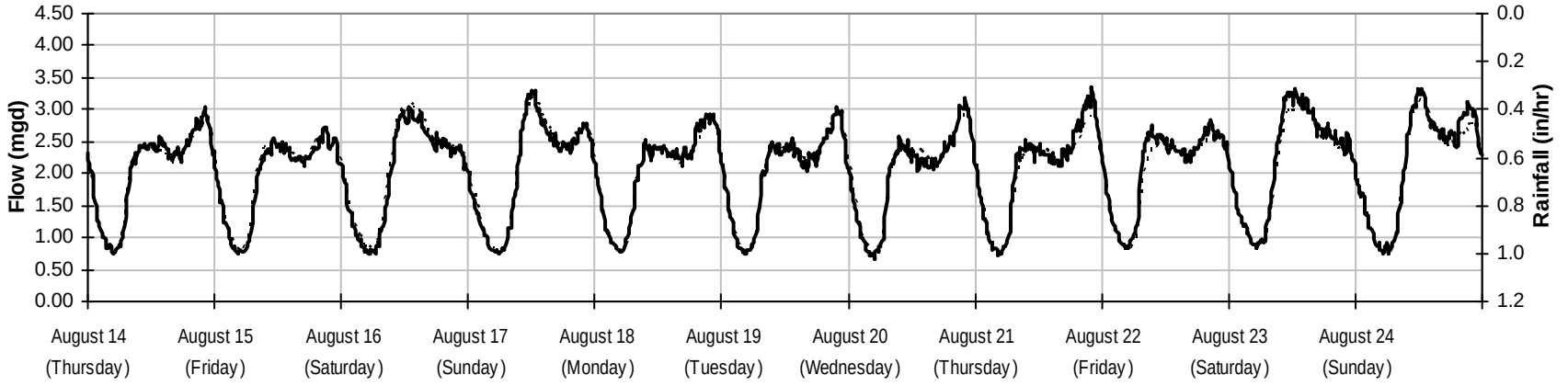


SITE 9

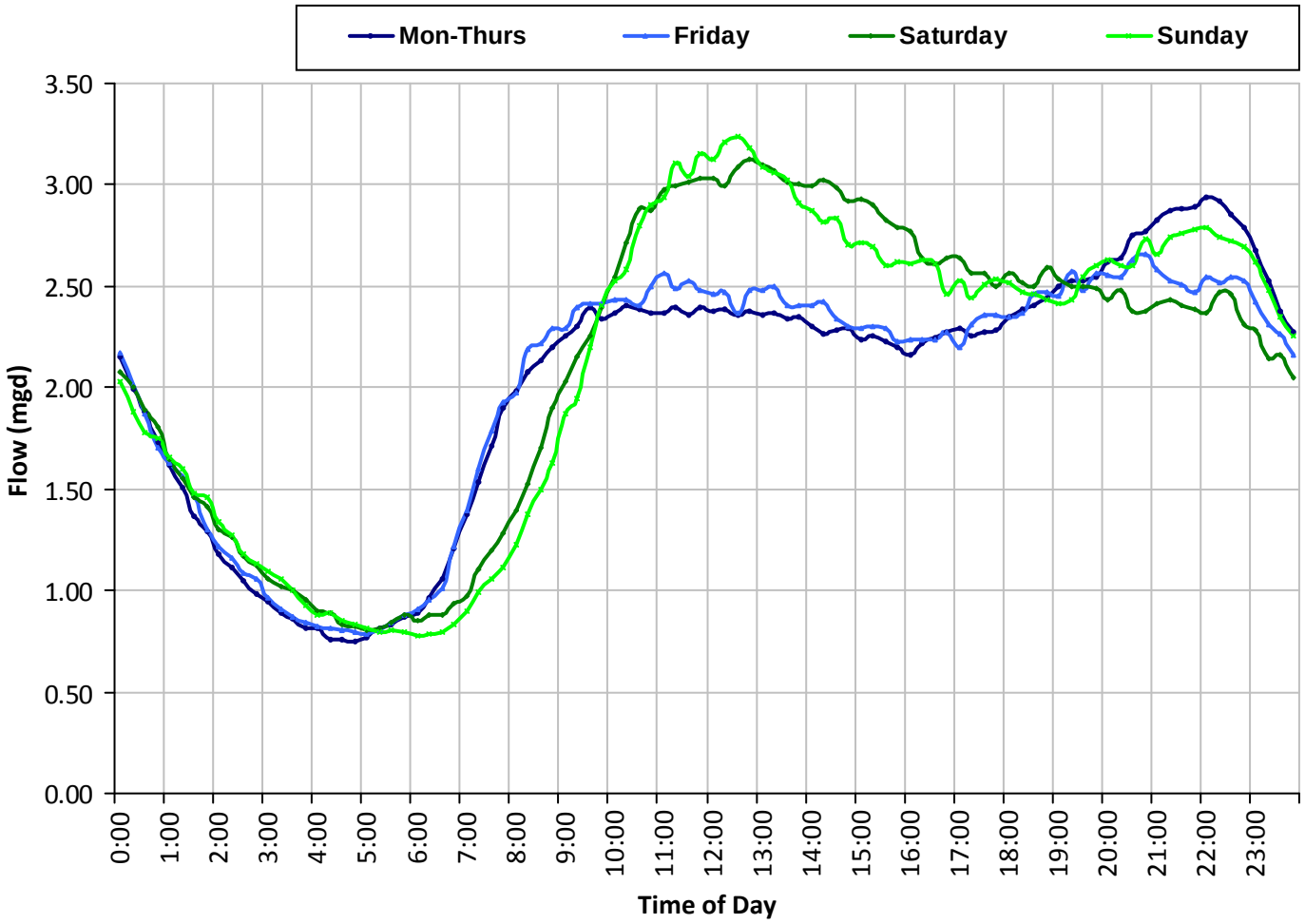
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 2.047 mgd** **Peak Flow: 3.340 mgd** **Min Flow: 0.661 mgd**



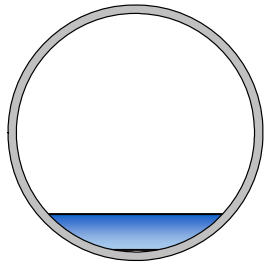


SITE 9
Baseline Flow Hydrographs



Baseline Flow:

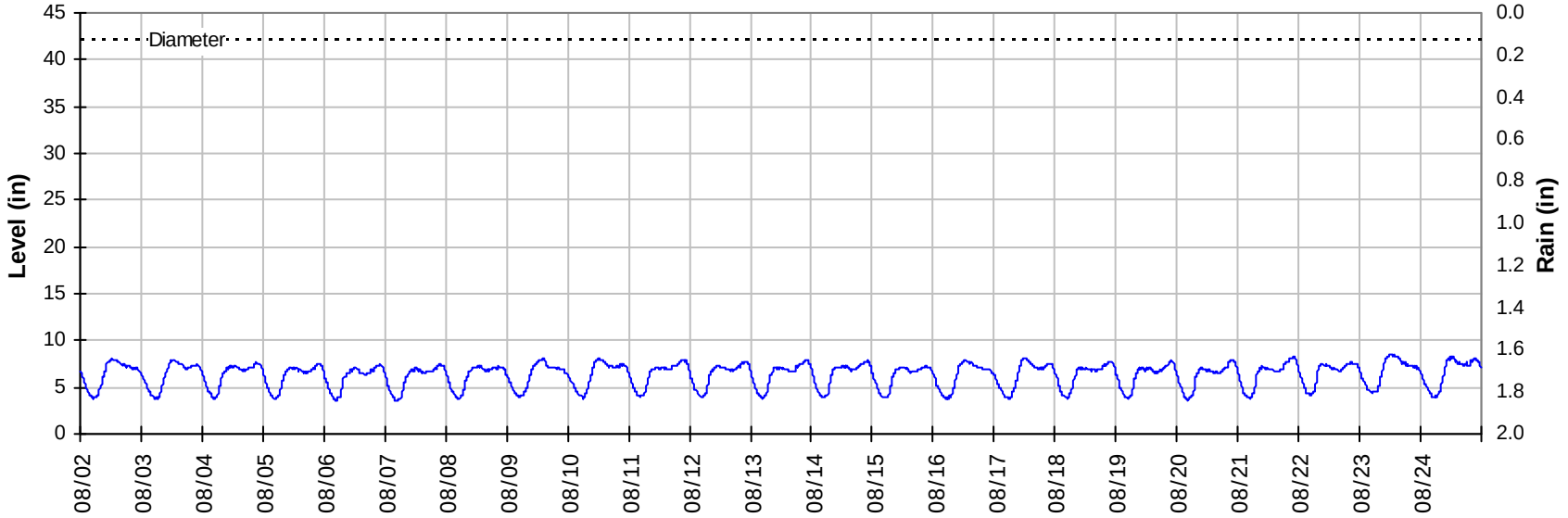
2.041 *mgd*

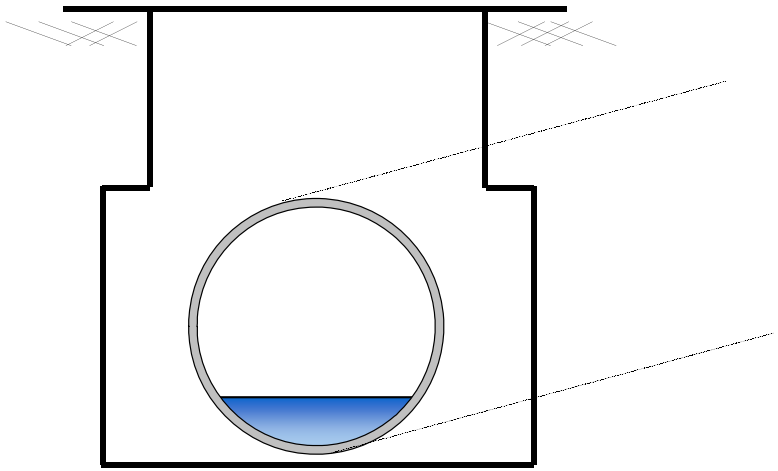


SITE 9

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period



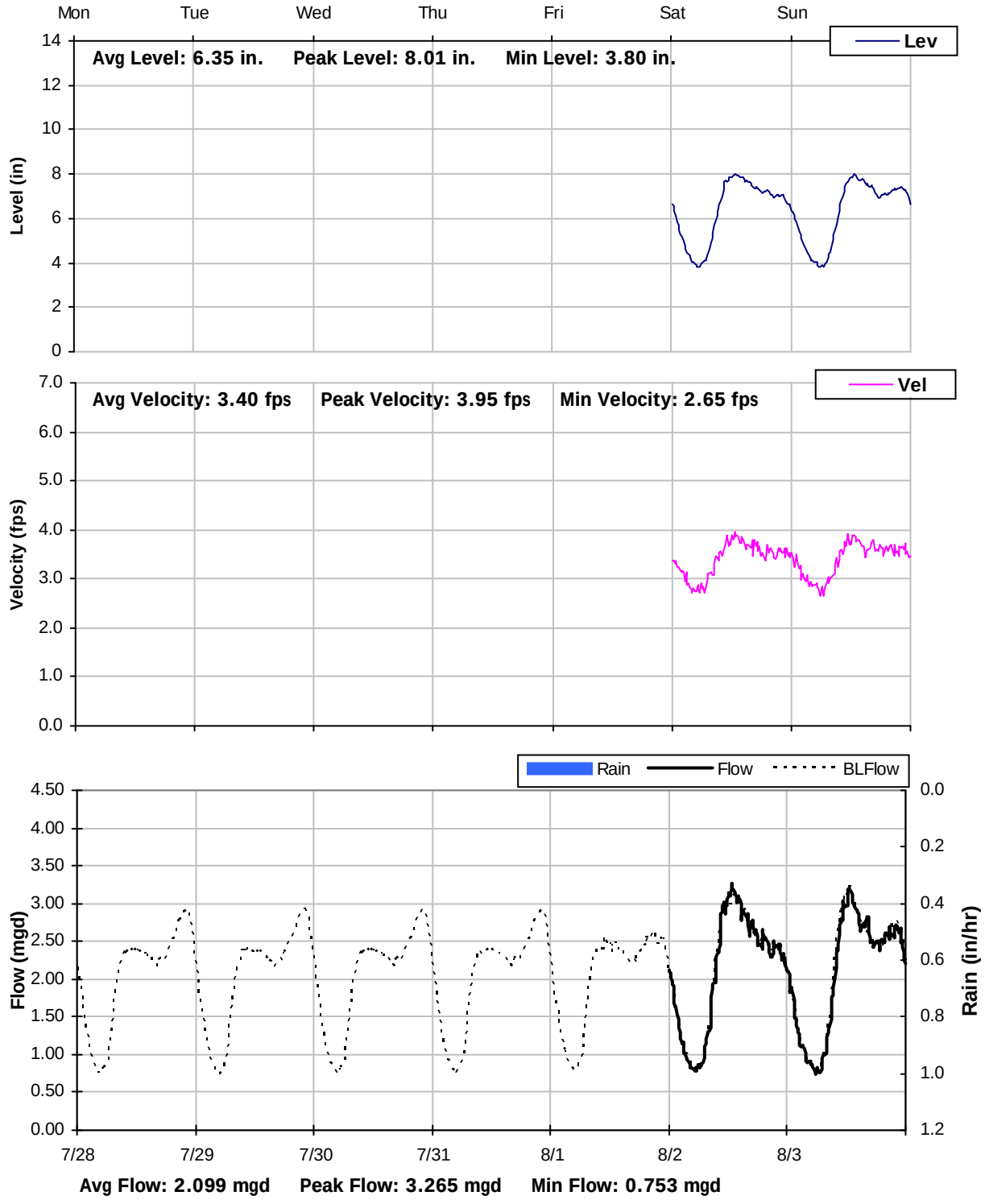


Pipe Diameter:	42	*inches*
Peak Measured Level:	8.49	*inches*
Peak d/D Ratio:	0.20	

SITE 9

Weekly Level, Velocity and Flow Hydrographs

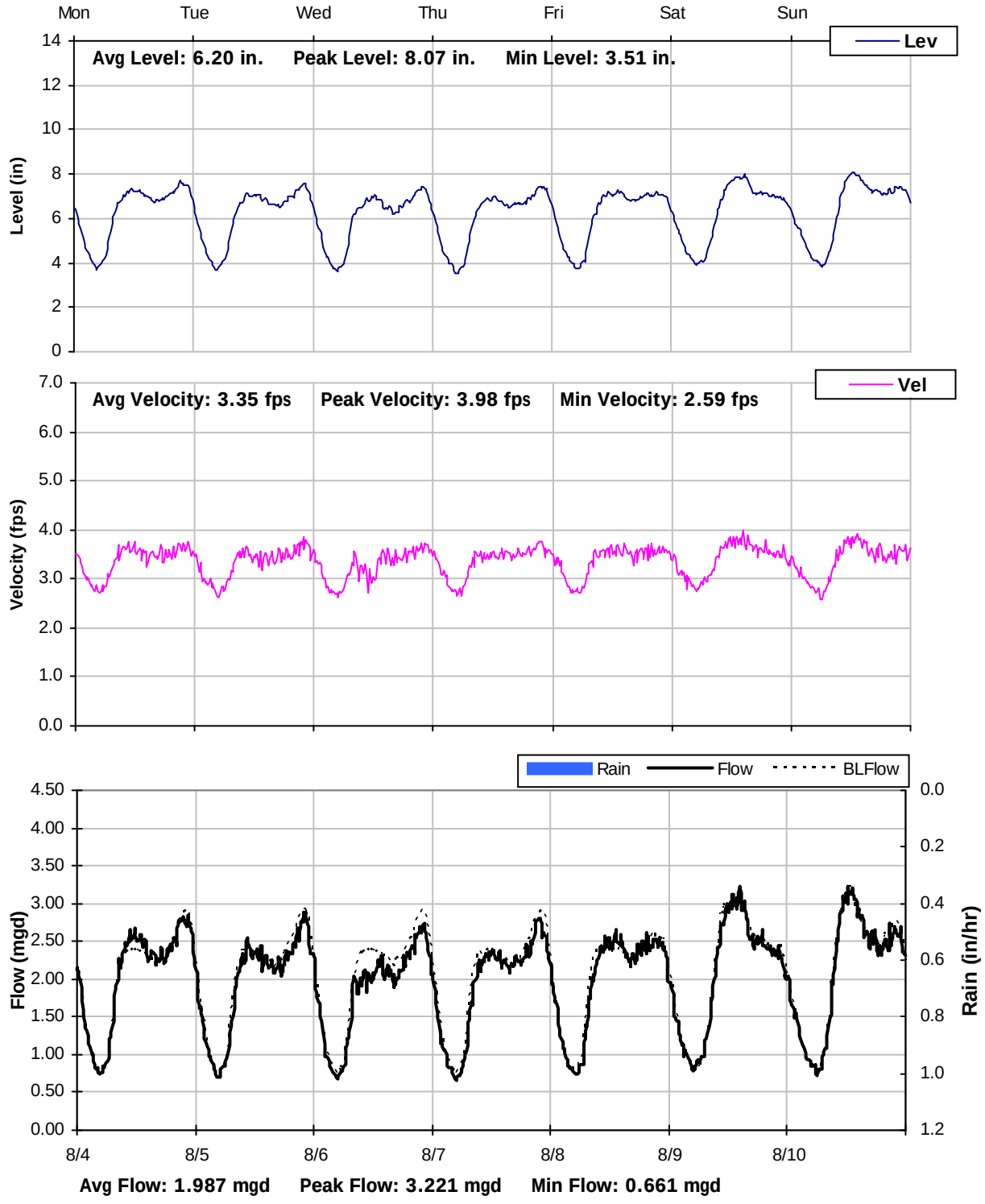
7/28/2014 to 8/4/2014



SITE 9

Weekly Level, Velocity and Flow Hydrographs

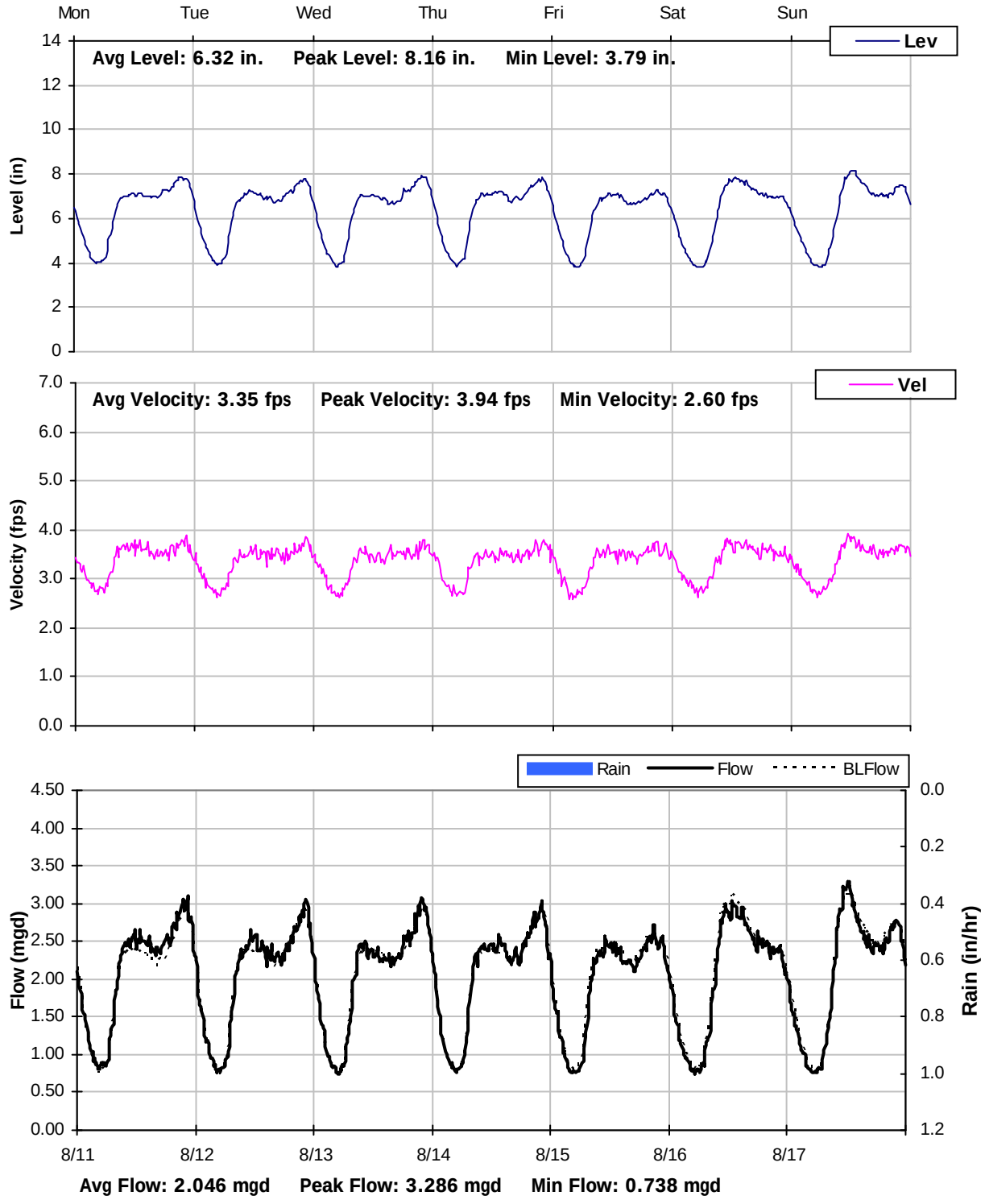
8/4/2014 to 8/11/2014



SITE 9

Weekly Level, Velocity and Flow Hydrographs

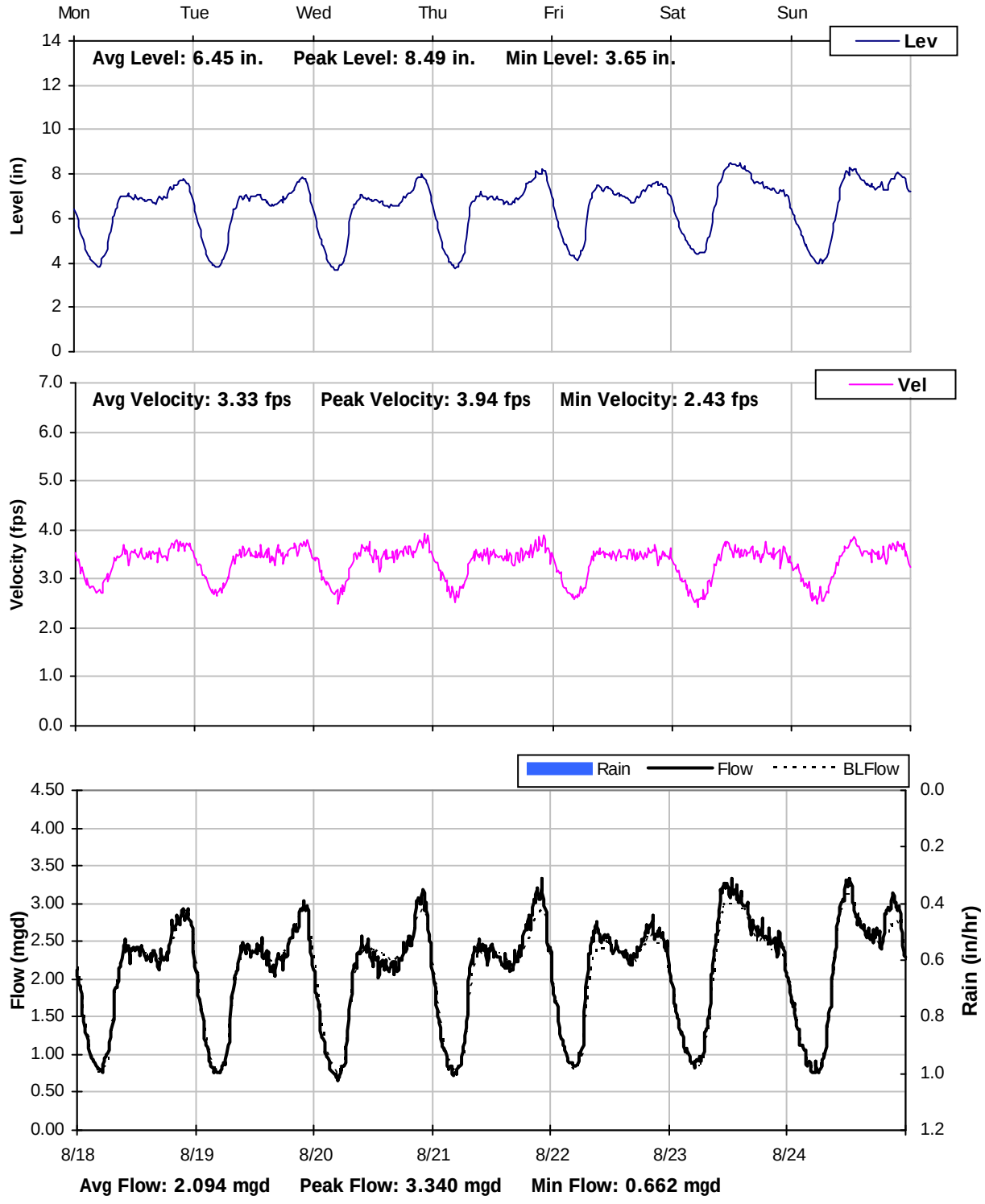
8/11/2014 to 8/18/2014



SITE 9

Weekly Level, Velocity and Flow Hydrographs

8/18/2014 to 8/25/2014



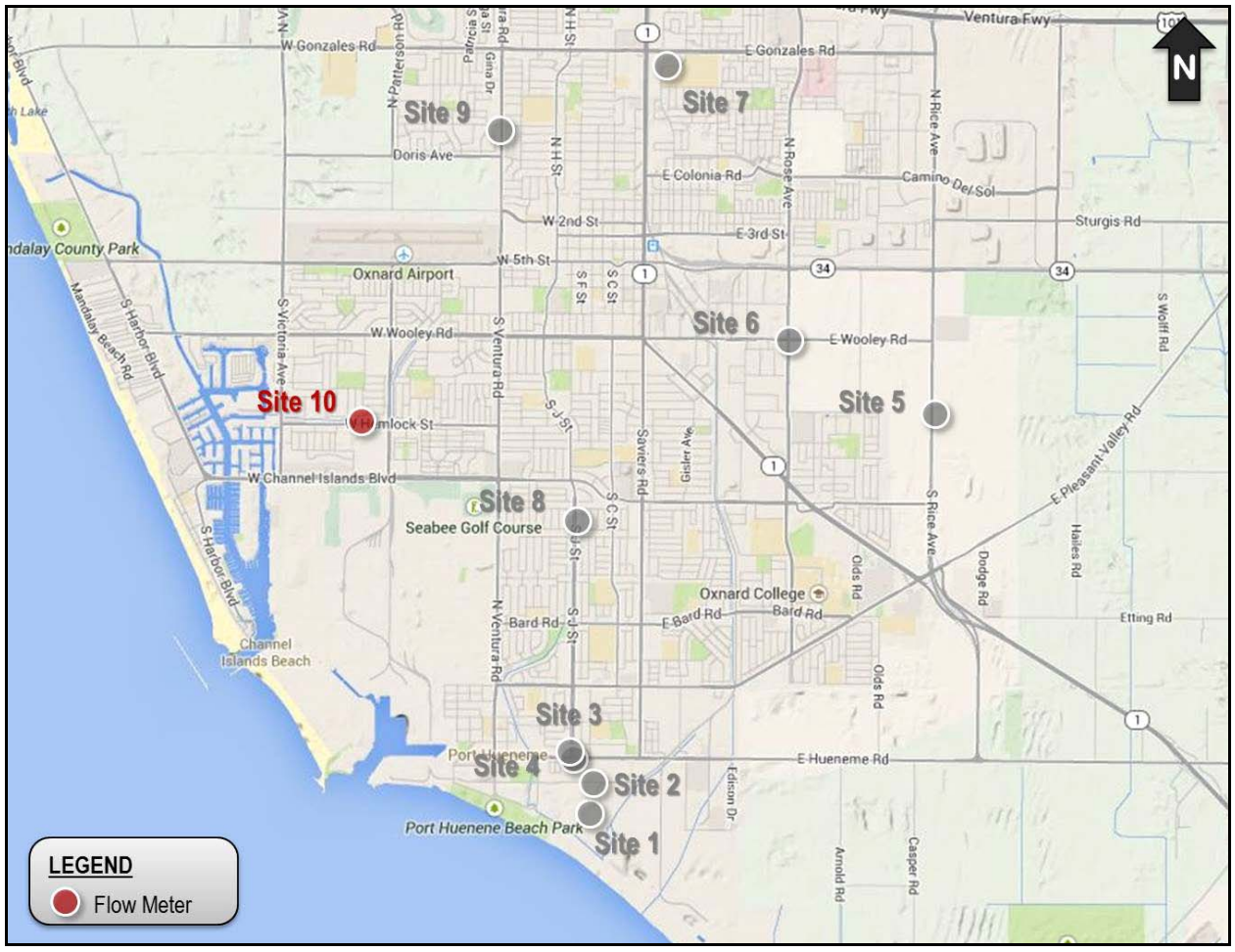
City of Oxnard

Sanitary Sewer Flow Monitoring
Temporary Monitoring: August, 2014

Monitoring Site: Site 10

Location: West of W Hemlock Street and Jetty Street

Data Summary Report



Vicinity Map: Site 10

SITE 10

Site Information

Location: West of W Hemlock Street and Jetty Street

Coordinates: 119.2116° W, 34.1812° N

Rim Elevation: 16 feet

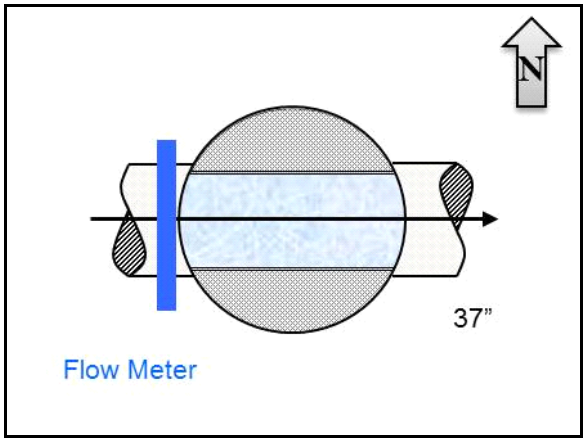
Pipe Diameter: 37 inches

Baseline Flow: 1.913 mgd

Peak Measured Flow: 3.460 mgd

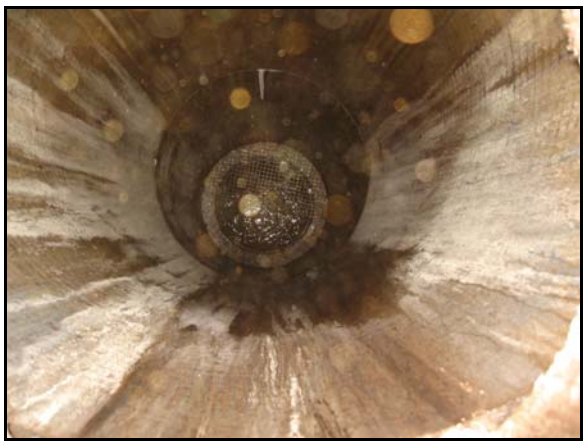
Satellite Map

Sanitary Map



Flow Diagram

Street View



Plan View

SITE 10

Additional Site Photos

Effluent Pipe

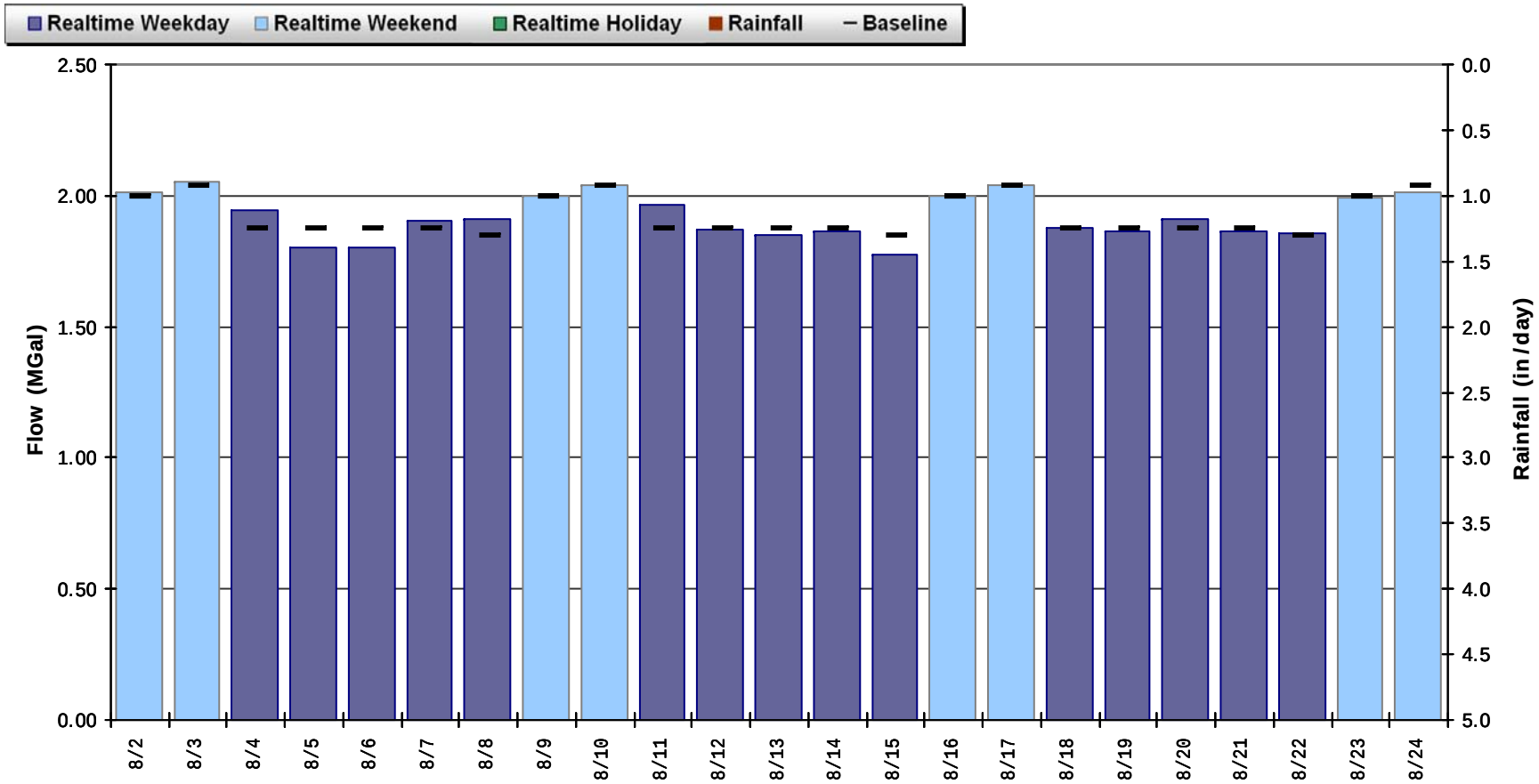
Influent Pipe

SITE 10

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 1.922 MGal **Peak Daily Flow: 2.052 MGal** **Min Daily Flow: 1.776 MGal**

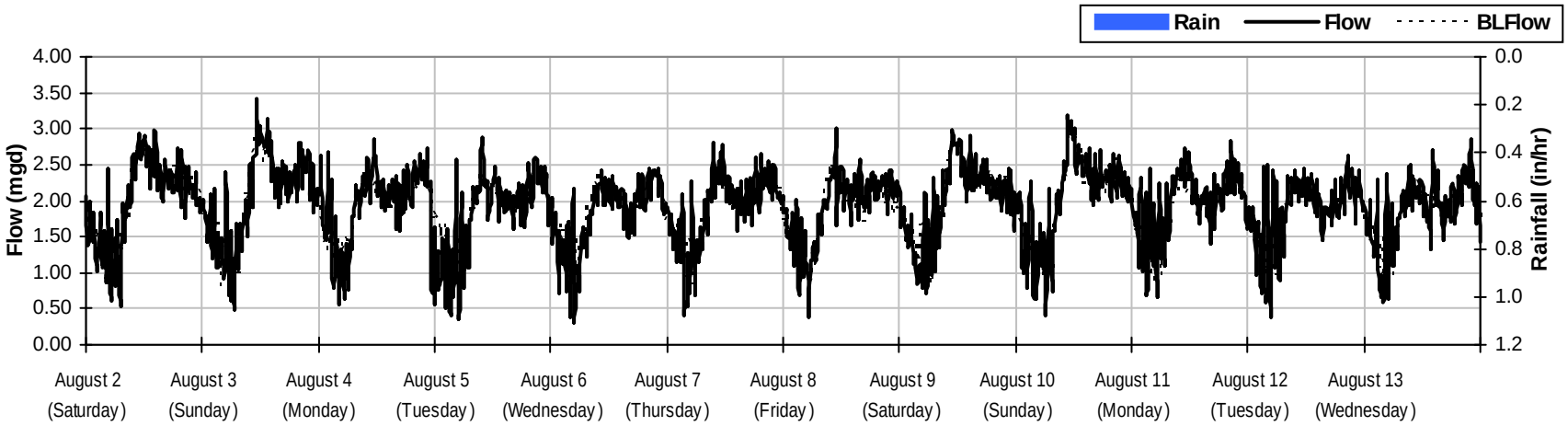
Total Monthly Rainfall: 0.00 inches

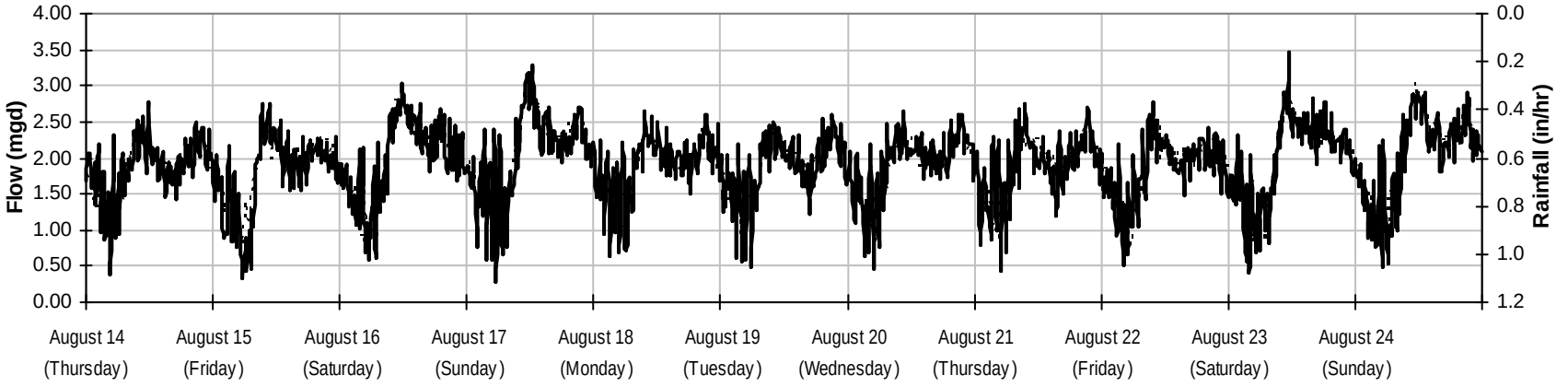


SITE 10

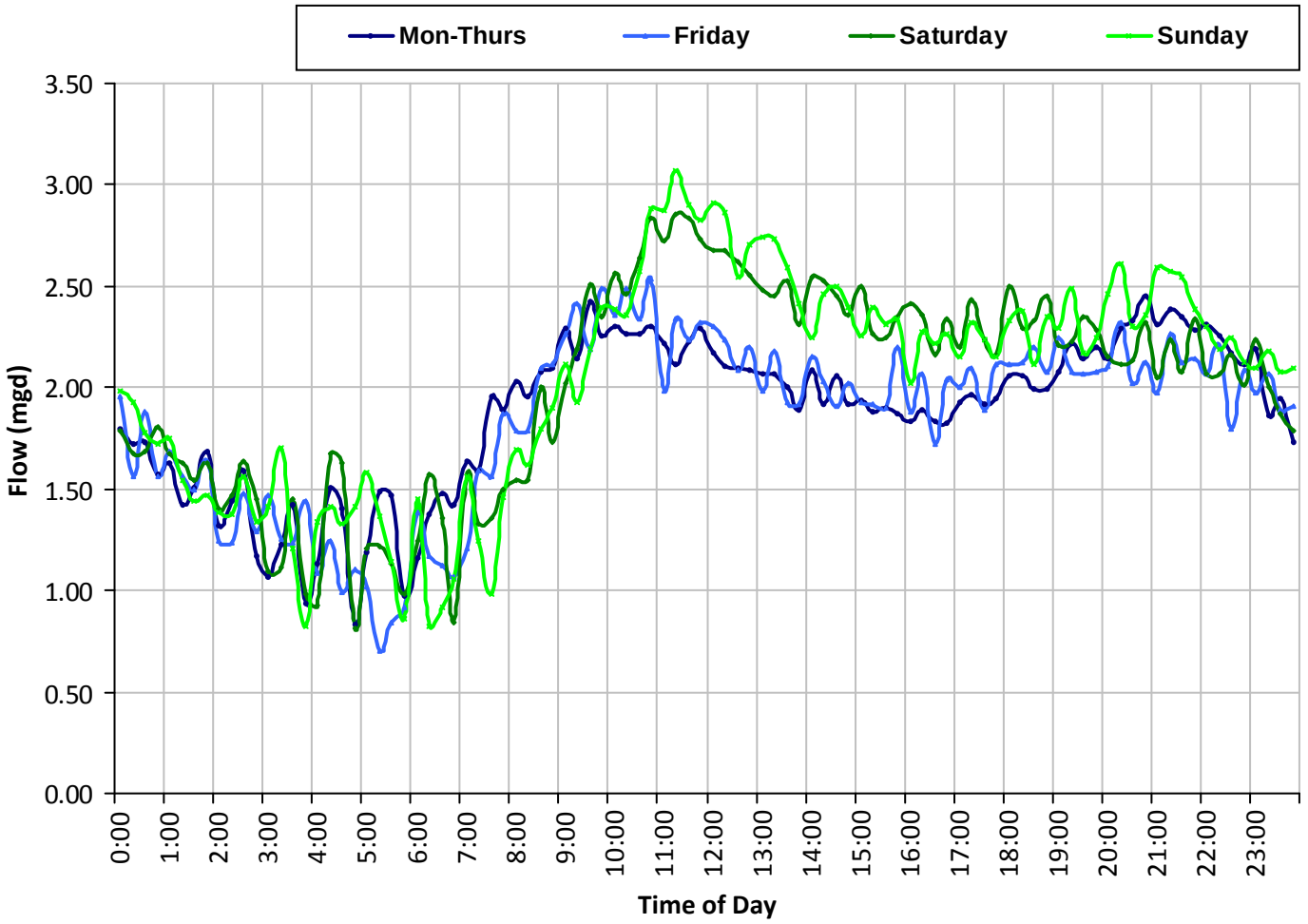
Flow Summary: 8/2/2014 to 8/24/2014

Total Period Rainfall: 0.00 inches **Avg Flow: 1.922 mgd** **Peak Flow: 3.460 mgd** **Min Flow: 0.288 mgd**



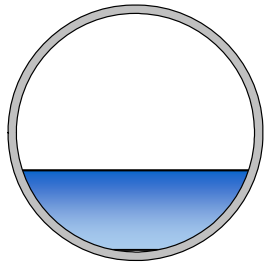


SITE 10
Baseline Flow Hydrographs



Baseline Flow:

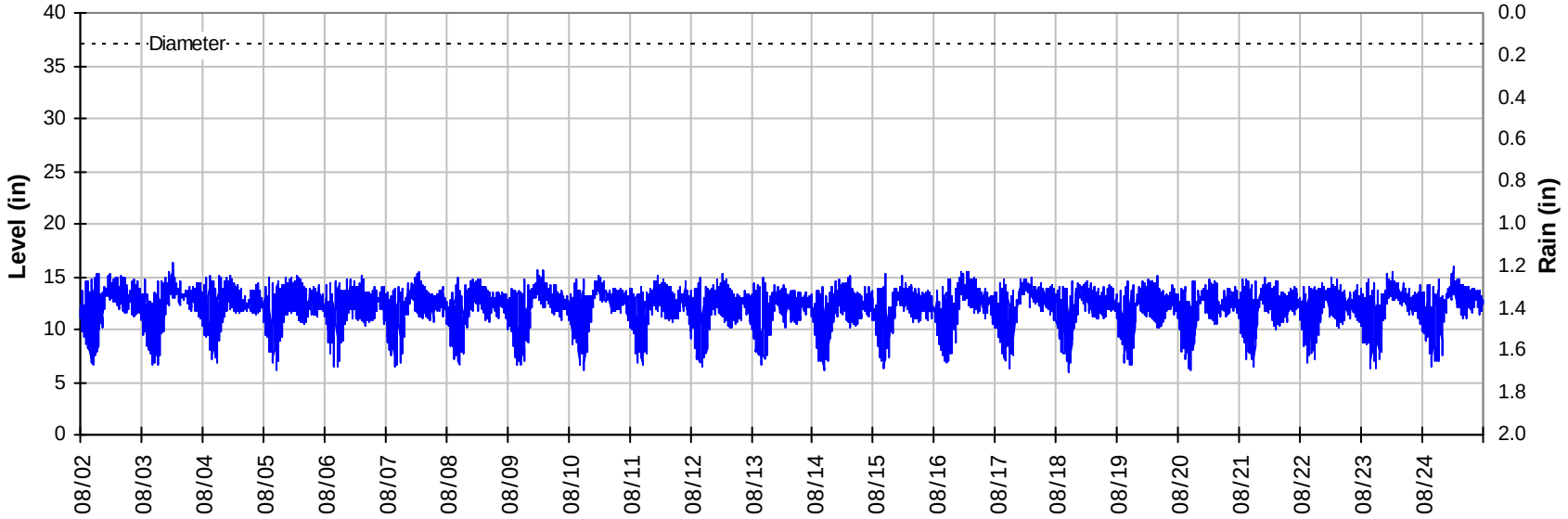
1.913 *mgd*

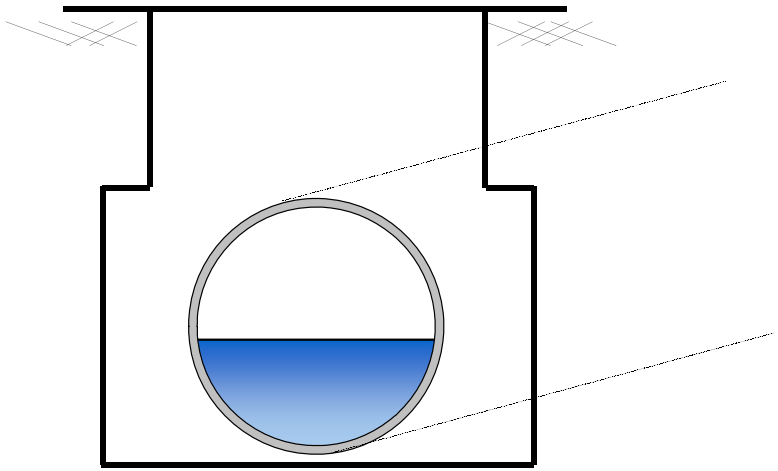


SITE 10

Site Capacity and Surcharge Summary

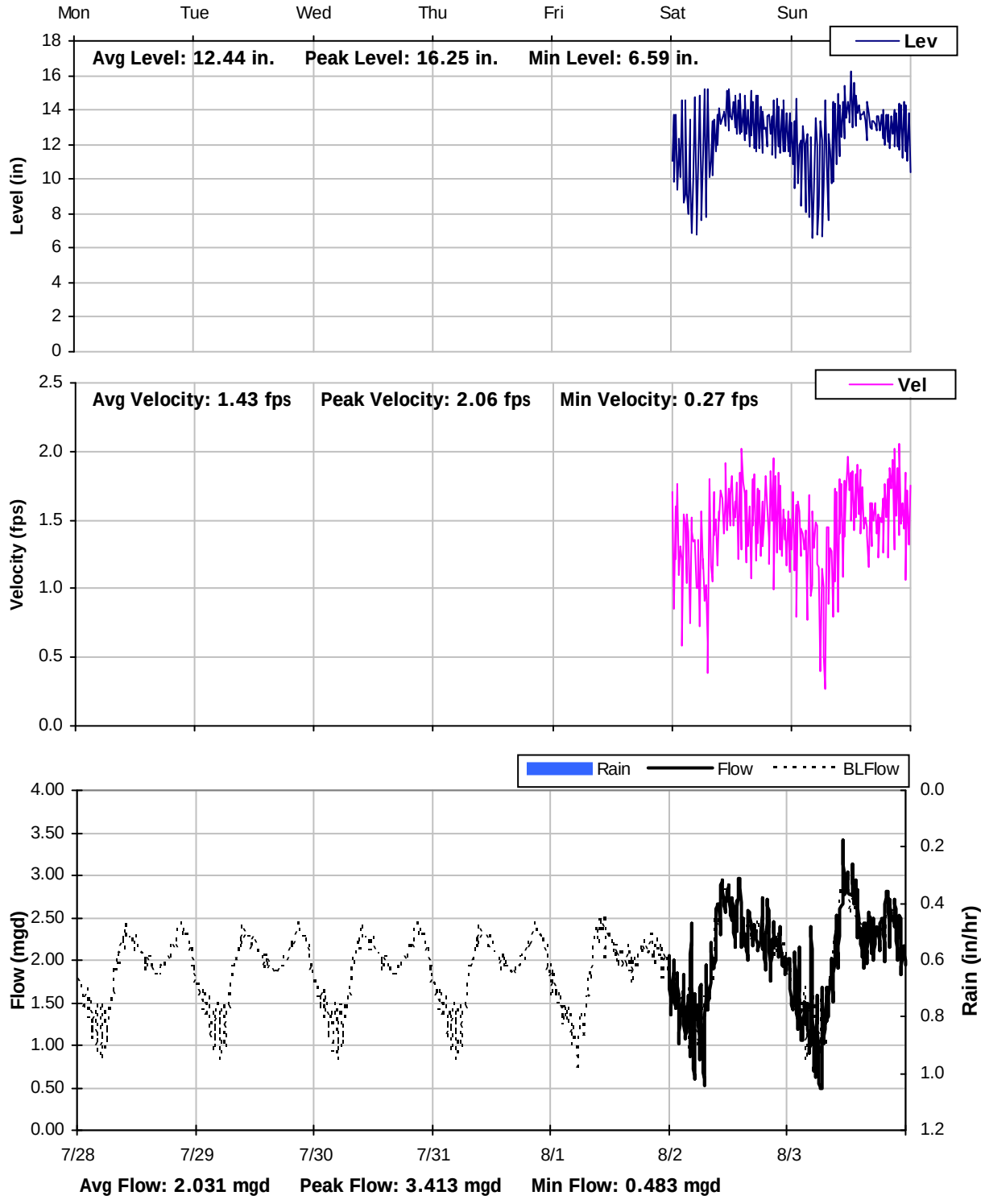
Realtime Flow Levels with Rainfall Data over Monitoring Period



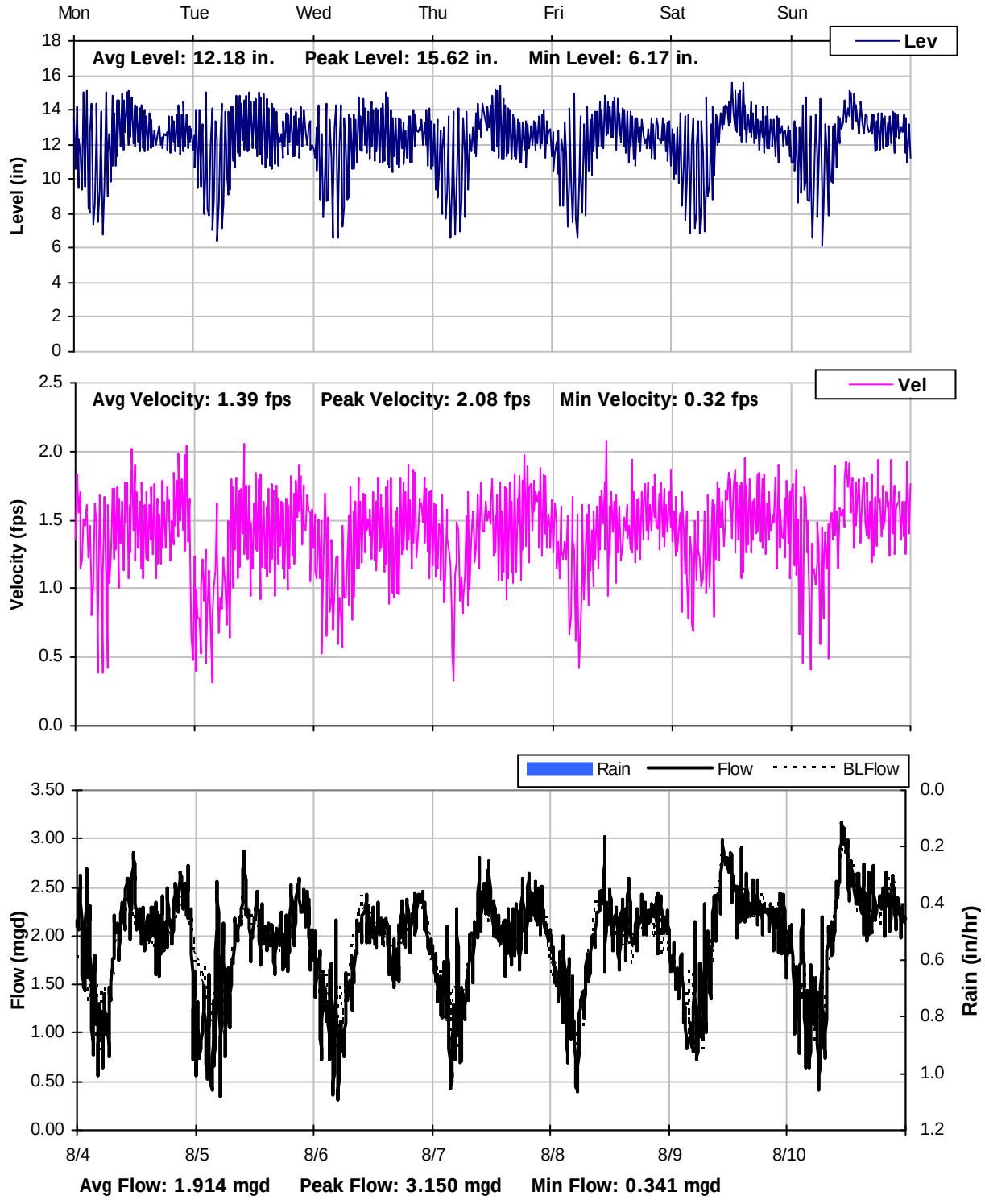


Pipe Diameter:	37	*inches*
Peak Measured Level:	16.3	*inches*
Peak d/D Ratio:	0.44	

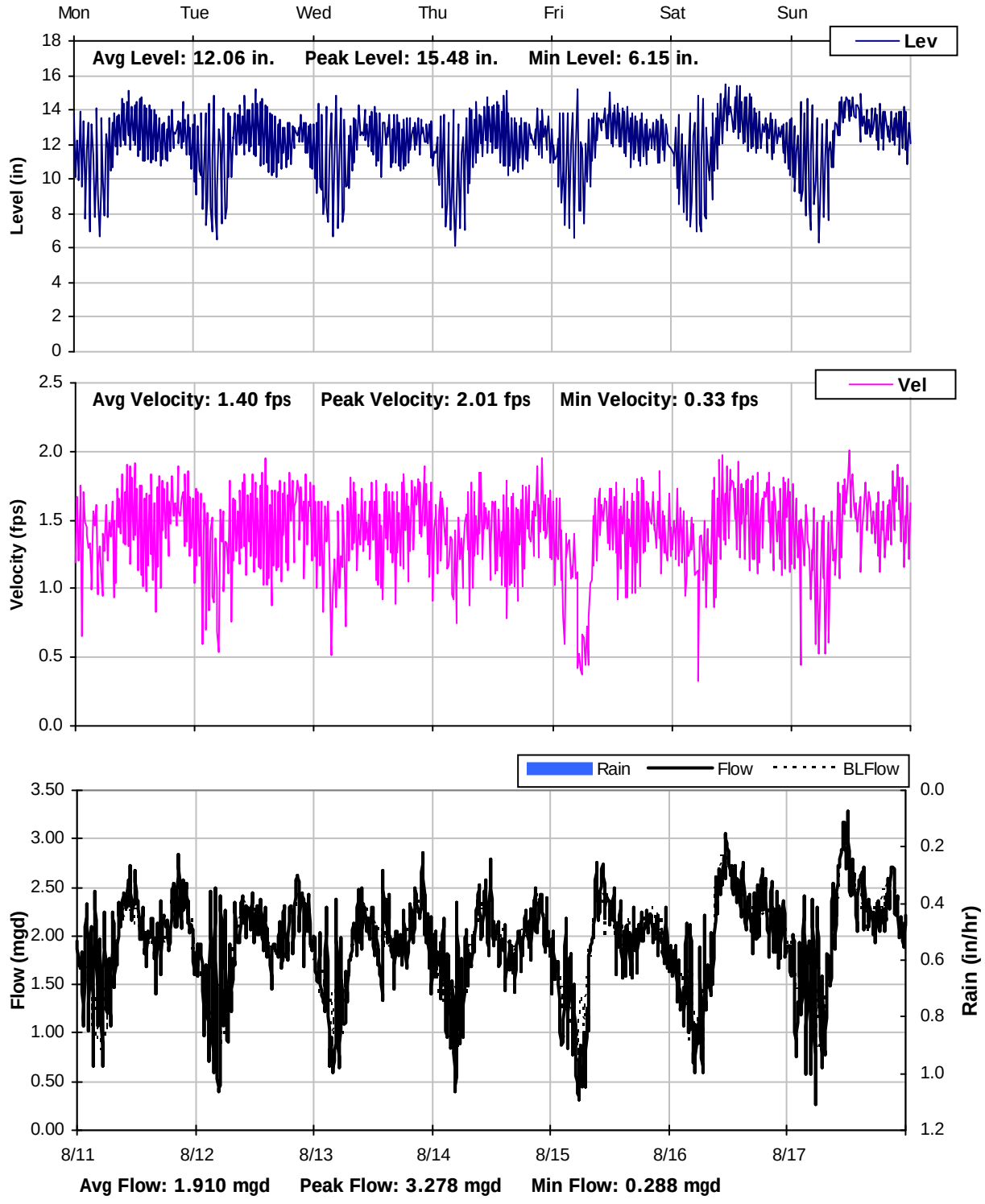
SITE 10
Weekly Level, Velocity and Flow Hydrographs
7/28/2014 to 8/4/2014



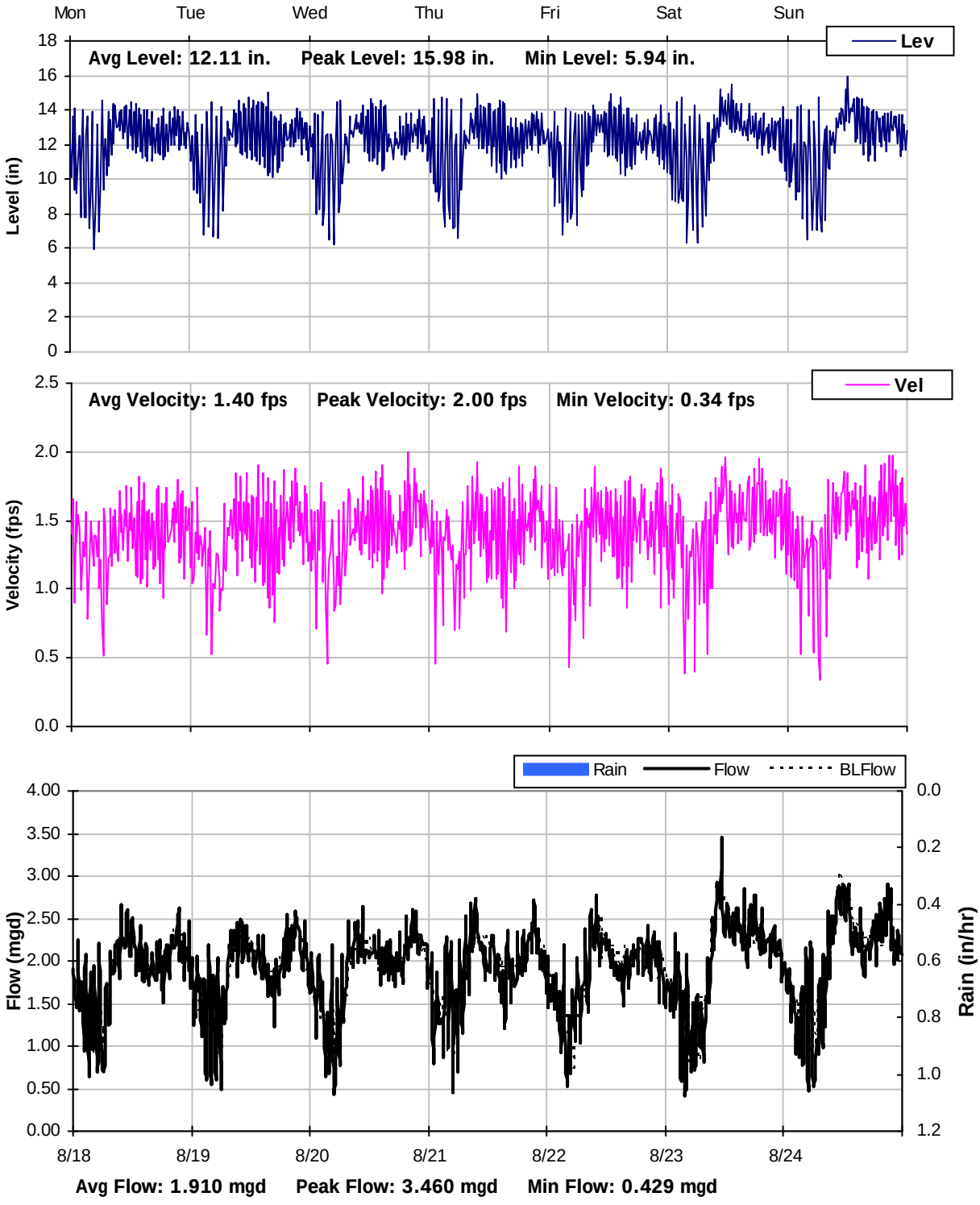
SITE 10
Weekly Level, Velocity and Flow Hydrographs
8/4/2014 to 8/11/2014

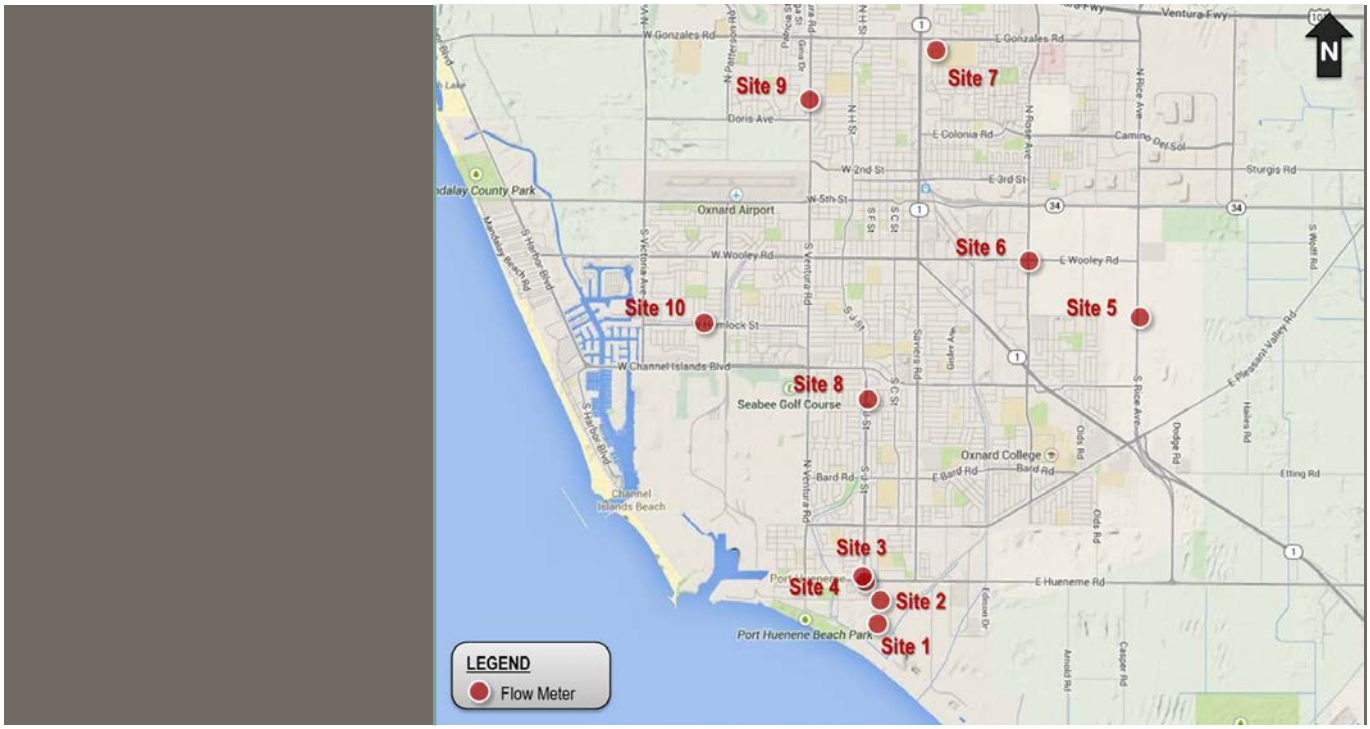


SITE 10
Weekly Level, Velocity and Flow Hydrographs
8/11/2014 to 8/18/2014



SITE 10
Weekly Level, Velocity and Flow Hydrographs
8/18/2014 to 8/25/2014





V&A

Oakland
155 Grand Avenue, Suite 700
Oakland, CA 94612
510.903.6600 **Tel**
510.903.6601 **Fax**

San Diego
11011 Via Frontera, Suite C
San Diego, CA 92127
858.576.0226 **Tel**

Houston
8220 Jones Road, Suite 500
Houston, TX 77065
713.568.9067 **Tel**

Las Vegas
3430 East Russell Road, Suite 316
Las Vegas, NV 89120
702.522.7967 **Tel**
702.553.4694 **Fax**

vaengineering.com

APPENDIX B – WET WEATHER SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

CITY OF OXNARD
SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

CITY OF OXNARD CALIFORNIA

May 2015

V&A

CITY OF OXNARD
SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

Prepared for: **Carollo Engineers**
89 Newbury Street, Suite 104
Danvers, MA 01923

Date: May 2015

Prepared by: V&A

V&A Project No. 14-0195

TABLE OF CONTENTS

ES EXECUTIVE SUMMARY 1
Scope and Purpose 1
Site Flow Monitoring and Capacity Results 1
Recommendations 2
1.0 INTRODUCTION 3
1.1 Introduction 3
2.0 METHODS AND PROCEDURES 5
2.1 Confined Space Entry 5
2.2 Flow Meter Installation 6
2.3 Flow Calculation 7
2.4 Inflow / Infiltration Analysis: Definitions and Identification 8
2.4.1 Definition and Typical Sources 8
2.4.2 Infiltration Components 9
2.4.3 Impact and Cost of Source Detection and Removal 9
2.4.4 Graphical Identification of I/I 10
2.4.5 Analysis Methods 11
3.0 RESULTS AND ANALYSIS 12
3.1 Rainfall Monitoring 12
3.1.1 Flow Study Rainfall Data 12
3.1.2 Regional Rainfall Event Classification 14
3.2 Flow Monitoring 16
3.2.1 Baseline Flow Analysis 16
3.2.2 Peak Measured Flows and Pipeline Capacity Analysis 18
3.3 Inflow and Infiltration: Results 20
3.3.1 Inflow Results Summary 20
3.3.2 Infiltration Results Summary 21
4.0 CONCLUSIONS AND RECOMMENDATIONS 23
4.1 Conclusions 23
4.2 Recommendations 23

TABLES

Table ES-1. Capacity Analysis Summary 1
Table 1-1. List of Flow Monitoring Sites 3
Table 1-2. List of Rainfall Recording Sites 4
Table 3-1. Rainfall Recorded for the Two Rainfall Events 13
Table 3-2. Baseline Flow Summary 17
Table 3-3. Capacity Analysis Summary 18
Table 3-4. Inflow Analysis Summary 20

FIGURES

Figure 1-1. Locations of Flow/Rainfall Monitoring Sites 4
Figure 2-1. Typical Installation for Flow Meter with Submerged Sensor 6
Figure 2-2. Typical Sources of Infiltration and Inflow 8
Figure 2-3. Sample Infiltration and Inflow Isolation Graph 10
Figure 2-4. Inflow and Infiltration: Graphical Response Patterns 11
Figure 3-1. Rainfall Events Recorded at Oxnard Civic Center 12
Figure 3-2. Rainfall Accumulation at Oxnard Civic Center 13
Figure 3-3. NOAA Southern California Rainfall Frequency Map 14
Figure 3-4. Rainfall Event Classification at Oxnard Civic Center 15
Figure 3-5. Sample ADWF Diurnal Flow Patterns 16
Figure 3-6. Capacity Summary: d/D Ratios 19
Figure 3-7. Capacity Summary: Peaking Factors 19
Figure 3-8. Inflow Analysis Summary – Peak I/I to ADWF 21
Figure 3-9. RDI Measurement, Site 1 22

APPENDICES

Appendix A. Flow Monitoring Sites: Data, Graphs, Information

ABBREVIATIONS, TERMS AND DEFINITIONS USED IN THIS REPORT

Table i. Abbreviations

Abbreviation	Term
ADWF	average dry weather flow
CO	carbon monoxide
d/D	depth/diameter ratio
FM	flow monitor
H_2S	hydrogen sulfide
I/I	inflow and infiltration
LEL	lower explosive limit
mgd	million gallons per day
NOAA	National Oceanic and Atmospheric Administration
Q	flow rate
RDI	rainfall-dependent infiltration
RRI	rainfall-responsive infiltration
RG	rain gauge
SSO	sanitary sewer overflow
WEF	Water Environment Federation
WRCC	Western Regional Climate Center

Table ii. Terms and Definitions

Term	Definition
Average dry weather flow (ADWF)	Average flow rate or pattern from days without noticeable inflow or infiltration response. ADWF usage patterns for weekdays and weekends differ and must be computed separately. ADWF can be expressed as a numeric average or as a curve showing the variation in flow over a day. ADWF includes the influence of normal groundwater infiltration (not related to a rain event).
Basin	Sanitary sewer collection system upstream of a given location (often a flow meter), including all pipelines, inlets, and appurtenances. Also refers to the ground surface area near and enclosed by pipelines. A basin may refer to the entire collection system upstream from a flow meter or exclude separately monitored basins upstream.
Depth/diameter (*d*/*D*) ratio	Depth of water in a pipe as a fraction of the pipe's diameter. A measure of fullness of the pipe used in capacity analysis.
Infiltration and inflow	Infiltration and inflow (I/I) rates are calculated by subtracting the ADWF flow curve from the instantaneous flow measurements taken during and after a storm event. Flow in excess of the baseline consists of inflow, rainfall-responsive infiltration, and rainfall-dependent infiltration. **Total I/I** is the total sum in gallons of additional flow attributable to a storm event.
Infiltration, *groundwater*	Groundwater infiltration (**GWI**) is groundwater that enters the collection system through pipe defects. GWI depends on the depth of the groundwater table above the pipelines as well as the percentage of the system that is submerged. The variation of groundwater levels and subsequent groundwater infiltration rates is seasonal by nature. On a day-to-day basis, groundwater infiltration rates are relatively steady and will not fluctuate greatly.
Infiltration, *rainfall-dependent*	Rainfall-dependent infiltration (**RDI**) is similar to groundwater infiltration but occurs as a result of storm water. The storm water percolates into the soil, submerges more of the pipe system, and enters through pipe defects. RDI is the slowest component of storm-related infiltration and inflow, beginning gradually and often lasting 24 hours or longer. The response time depends on the soil permeability and saturation levels.
Infiltration, *rainfall-responsive*	Rainfall-responsive infiltration (**RRI**) is storm water that enters the collection system through pipe defects, but normally in sewers constructed close to the ground surface such as private laterals. RRI is independent of the groundwater table and reaches defective sewers via the pipe trench in which the sewer is constructed, particularly if the pipe is placed in impermeable soil and bedded and backfilled with a granular material. In this case, the pipe trench serves as a conduit similar to a French drain, conveying storm drainage to defective joints and other openings in the system.
Inflow	**Inflow** is defined as water discharged into the sewer system, including private sewer laterals, from **direct** connections such as downspouts, yard and area drains, holes in manhole covers, cross-connections from storm drains, or catch basins. Inflow creates a peak flow problem in the sewer system and often dictates the required capacity of downstream pipes and transport facilities to carry these peak instantaneous flows. Overflows are often attributable to high inflow rates.
Normalization	To run an "apples-to-apples" comparison amongst different basins, calculated metrics must be **normalized**. Individual basins will have different runoff areas, pipe lengths and sanitary flows. There are three common methods of normalization. Depending on the information available, one or all methods can be applied to a given project: • Pipe Length: The metric is divided by the length of pipe in the upstream

Term	Definition
	basin expressed in units of inch-diameter-mile (IDM). • Basin Area: The metric is divided by the estimated drainage area of the basin in acres. • ADWF: The metric is divided by the average dry weather sanitary flow (ADWF).
Normalization, *inflow*	The peak I/I flow rate is used to quantify inflow. Although the instantaneous flow monitoring data will typically show an inflow peak, the inflow response is measured from the I/I flow rate (in excess of baseline flow). This removes the effect of sanitary flow variations and measures only the I/I response: • Pipe Length: The peak I/I flow rate is divided by the length of pipe (IDM) in the upstream basin. The result is expressed in gallons per day (gpd) per IDM (gpd/IDM). • Basin Area: The peak I/I flow rate is divided by the geographic area of the upstream basin. The result is expressed in gpd per acre. • ADWF: The peak I/I flow rate is divided by the average dry weather flow (ADWF). This is a ratio and is expressed without units.
Normalization, *GWI*	The estimated GWI rates are compared to acceptable GWI rates, as defined by the Water Environment Federation, and are used to identify basins with high GWI: • Pipe Length: The GWI flow rate is divided by the length of pipe (IDM) in the upstream basin. The result is expressed in gallons per day (gpd) per IDM (gpd/IDM). • Basin Area: The GWI flow rate is divided by the geographic area of the upstream basin. The result is expressed in gpd per acre. • ADWF: The GWI flow rate is divided by the average dry weather flow (ADWF). This is a ratio and is expressed without units.
Normalization, *RDI*	The estimated RDI rates at a period 24 hours or more after the conclusion of a storm event are used to identify basins with high RDI: • Pipe Length: The RDI flow rate is divided by the length of pipe (IDM) in the upstream basin. The result is expressed in gallons per day (gpd) per IDM (gpd/IDM). • Basin Area: The RDI flow rate is divided by the geographic area of the upstream basin. The result is expressed in gpd per acre. • ADWF: The RDI flow rate is divided by the average dry weather flow (ADWF). This is a ratio and is expressed without units.
Normalization, *total I/I*	The estimated totalized I/I in gallons attributable to a particular storm event is used to identify basins with high total I/I. Because this is a totalized value rather than a rate and can be attributable solely to an individual storm event, the volume of the storm event is also taken into consideration. This allows for a comparison not only between basins but also between storm events: • Pipe Length: Total gallons of I/I is divided by the length of pipe (IDM) in the upstream basin and the rainfall total (inches) of the storm event. The result is expressed in gallons per IDM per inch-rain. • Basin Area (R-Value): Total gallons of I/I is divided by total gallons of rainfall

Term	Definition
	water that fell within the acreage of the basin area. This is a ratio and is expressed as a percentage. R-Value is described as "the percentage of rainfall that enters the collection system." Systems with R-Values less than 5%[1] are often considered to be performing well. • ADWF: Total gallons of I/I is divided by the ADWF and the rainfall total of the storm event. The result is expressed in million gallons per MGD of ADWF per inch of rain.
Peaking factor	Ratio of peak measured flow to average dry weather flow. This ratio expresses the degree of fluctuation in flow rate over the monitoring period and is used in capacity analysis.
Surcharge	When the flow level is higher than the crown of the pipe, then the pipeline is said to be in a **surcharged** condition. The pipeline is surcharged when the *d/D* ratio is greater than 1.0.
Weekend/weekday ratio	The ratio of weekend ADWFs to weekday ADWFs. In residential areas, this ratio is typically slightly higher than 1.0. In business districts, depending on the type of service, this ratio can be significantly less than 1.0.

[1] Keefe, P.N. "Test Basins for I/I Reduction and SSO Elimination." 1998 WEF Wet Weather Specialty Conference, Cleveland.

ES EXECUTIVE SUMMARY

Scope and Purpose

V&A Consulting Engineers (V&A) has completed sanitary sewer flow monitoring within the City of Oxnard (City) under the wet weather conditions. During this study, the flow monitoring was performed from December 9, 2014 to February 25, 2015 at ten open-channel flow monitoring sites. The monitored sites were the same as the dry weather study except Site 4A. The dry weather study was performed in August, 2014 and the report was submitted in October, 2014.

The main purpose of this study was to establish the baseline sanitary flows and quantify the inflow/infiltration. The City can utilize the data for sewer hydraulic modeling analysis and sewer rehabilitation/replacement verification.

Site Flow Monitoring and Capacity Results

Table ES-1 summarizes the flow monitoring and I/I results for the flow monitoring sites. It should be noted that the flow rate and sewer capacity information is presented on a site-by-site basis.

Table ES-1. Capacity Analysis Summary

Monitoring Site	ADWF (mgd)	Peak Measured Flow (mgd)	Peaking Factor	d/D Ratio	Peak I/I Rate (mgd)	Peak I/I per ADWF
Site 1	4.823	8.312	1.7	0.48	3.468	0.7
Site 2	2.194	6.002	2.7	0.59	3.242	1.5
Site 3	6.988	14.352	2.1	0.40	5.545	0.8
Site 4A	3.153	5.729	1.8	0.70	4.512	1.4
Site 5	1.408	3.074	2.2	0.37	2.044	1.5
Site 6	1.197	2.292	1.9	0.46	1.081	0.9
Site 7	0.333	0.620	1.9	0.25	0.248	0.7
Site 8	1.638	4.540	2.8	0.57	3.725	2.3
Site 9	2.306	4.053	1.8	0.23	1.884	0.8
Site 10	2.128	4.024	1.9	0.40	1.052	0.5

The flow monitoring and I/I analyses show that:

1. **Inflow and Infiltration:** Most of the I/I within the collection system comes from INFLOW. There was negligible rain dependent infiltration observed during this flow monitoring study.
2. **Capacity:** The capacity analysis in this study shows that the sewer system is in good condition on a capacity basis during this monitoring study.

Recommendations

V&A advises that future I/I reduction plans consider the following recommendations if I/I is a concern to the City:

1. **Determine I/I Reduction Program:** The City should examine its I/I reduction needs to determine their strategy and goals for a future I/I reduction program.
   a. If peak flows, sanitary sewer overflows, and pipeline capacity issues are of greater concern, then priority can be given to investigate and reduce sources of inflow within the basins with the higher inflow/ADWF ratios. This would appear to be the greatest concern for the City collection system.
   b. If infiltration and general pipeline deterioration are of greater concern, then the program can be weighted to investigate and reduce sources of infiltration within the basins with the higher RDI/ADWF ratios. Infiltration does not appear to be an issues for the City collection system.
2. **I/I Investigation Methods:** Potential I/I investigation methods include the following:
   a. smoke testing
   b. mini-basin flow monitoring
   c. CCTV inspection
3. **I/I Reduction Cost Effective Analysis:** The City should conduct a study to determine which is more cost-effective: (1) locating the sources of inflow/infiltration and systematically rehabilitating or replacing the faulty pipelines; or (2) continued treatment of the additional rainfall dependent I/I flow.

1.0 INTRODUCTION

1.1 Introduction

V&A Consulting Engineers (V&A) has completed sanitary sewer flow monitoring within the City of Oxnard (City) under wet weather conditions. During this study, the flow monitoring was performed from December 9, 2014 to February 25, 2015 at ten open-channel flow monitoring sites. The monitored sites were the same as the dry weather study except Site 4A. The dry weather study was performed in August, 2014 and the report was submitted in October, 2014.

The main purpose of this study was to establish the baseline sanitary flows and quantify the inflow/infiltration. The City can utilize the data for sewer hydraulic modeling analysis and sewer rehabilitation/replacement verification. The flow monitoring locations are listed in Table 1-1. It should be noted that the flow rate and sewer capacity information is presented on a site-by-site basis.

Table 1-1. List of Flow Monitoring Sites

Monitoring Site	Measured Pipe Diameter (in)	Location
Site 1	41.5	McWane Boulevard, east of Perkins Road
Site 2	36	Magellan Avenue
Site 3	60	J Street and E Port Hueneme Road
Site 4A*	33	J Street and W Hueneme Road
Site 5	36	S Rice Avenue and East of Emerson Avenue
Site 6	24	S Rose Avenue and E Wooley Road
Site 7	24	E Gonzales Road and Bahia Drive
Site 8	27	J Street, between Spruce Street and Teakwood Street
Site 9	42	N Ventura Road, between Devonshire Drive and Doris Avenue
Site 10	37	West of W Hemlock Street and Jetty Street

*Site 4A was installed one manhole upstream from Site 4 in the dry weather study as the new site had a better hydraulic condition for flow monitoring.

The rainfall data was obtained from Ventura County Watershed Protection District Hydrologic Data Server and the sites are listed in Table 1-2. The flow monitoring sites and rainfall recording sites are shown together in Figure 1-1.

Table 1-2. List of Rainfall Recording Sites

Monitoring Site	Latitude (°)	Longitude (°)
Oxnard WWTP	34.142	-119.187
Oxnard Airport	34.202	-119.208
Oxnard Civic Center	34.200	-119.180
El Rio-UWCD Spreading Grounds	34.239	-119.153
Oxnard NWS	34.207	-119.137

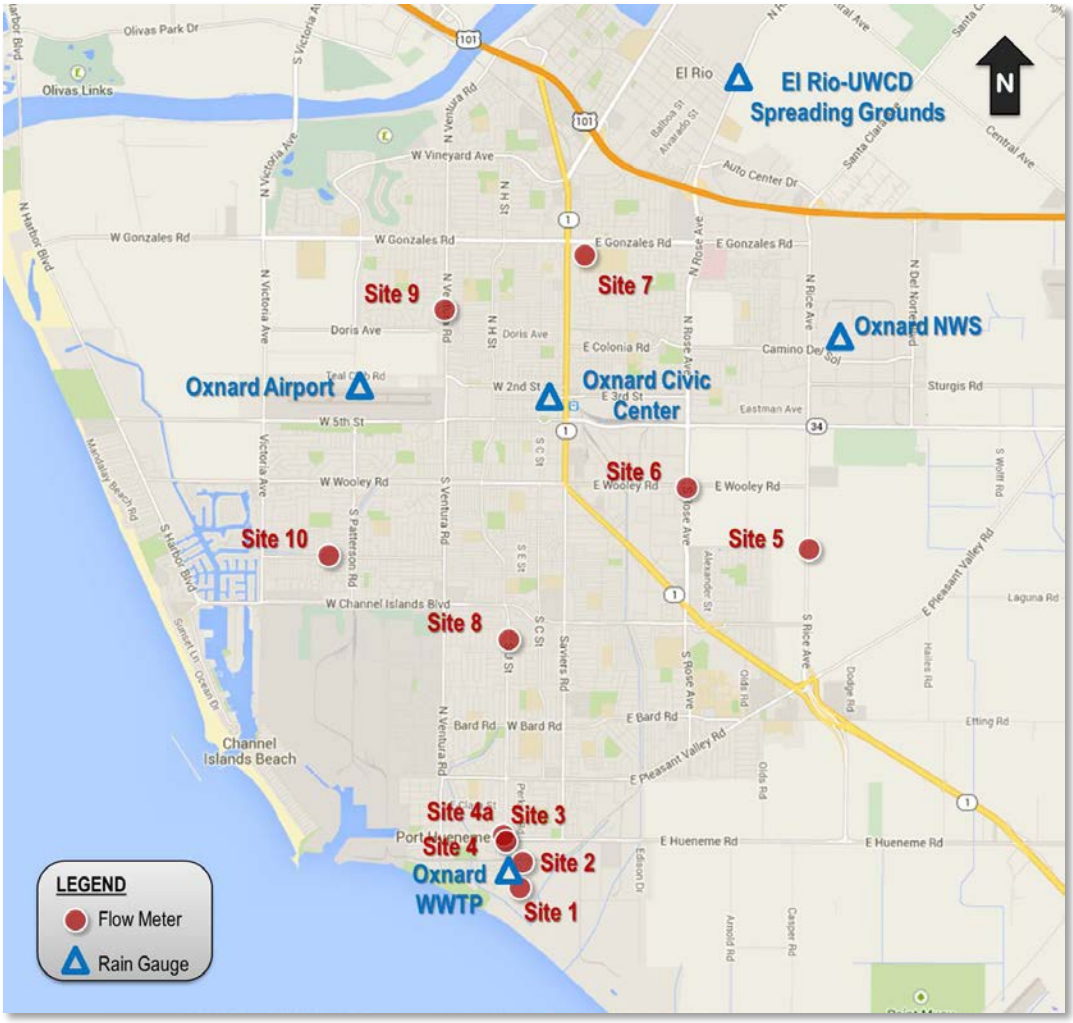


Figure 1-1. Locations of Flow/Rainfall Monitoring Sites

2.0 METHODS AND PROCEDURES

2.1 Confined Space Entry

A confined space (Photo 2-1) is defined as any space that is large enough and so configured that a person can bodily enter and perform assigned work, has limited or restricted means for entry or exit and is not designed for continuous employee occupancy. In general, the atmosphere must be constantly monitored for sufficient levels of oxygen (19.5% to 23.5%), and the absence of hydrogen sulfide (H_2S) gas, carbon monoxide (CO) gas, and lower explosive limit (LEL) levels. A typical confined space entry crew has members with OSHA-defined responsibilities of Entrant, Attendant and Supervisor. The Entrant is the individual performing the work. He or she is equipped with the necessary personal protective equipment needed to perform the job safely, including a personal four-gas monitor (Photo 2-2). If it is not possible to maintain line-of-sight with the Entrant, then more Entrants are required until line-of-sight can be maintained. The Attendant is responsible for maintaining contact with the Entrants to monitor the atmosphere using another four-gas monitor and maintaining records of all Entrants, if there are more than one. The Supervisor is responsible for developing the safe work plan for the job at hand prior to entering.

Photo 2-1. Confined Space Entry

Photo 2-2. Typical Personal Four-Gas Monitor

2.2 Flow Meter Installation

Teledyne Isco 2150 meters were installed by V&A in the sewer lines listed in Table 1-1. Isco 2150 meters use submerged sensors with a pressure transducer to collect depth readings and an ultrasonic Doppler sensor to determine the average fluid velocity. The ultrasonic sensor emits high-frequency sound waves, which are reflected by air bubbles and suspended particles in the flow. The sensor receives the reflected signal and determines the Doppler frequency shift, which indicates the estimated average flow velocity. The sensor is typically mounted at a manhole inlet to take advantage of smoother upstream flow conditions. The sensor may be offset to one side to lessen the chances of fouling and sedimentation where these problems are expected to occur. Manual level and velocity measurements were taken during installation of the flow meters and again when they were removed and were compared to simultaneous level and velocity readings from the flow meters to ensure proper calibration and accuracy. The pipe diameter was also verified in order to accurately calculate the flow cross-section. The continuous depth and velocity readings were recorded by the flow meters on 5-minute intervals. Figure 2-1 shows a typical installation for a flow meter with a submerged sensor.

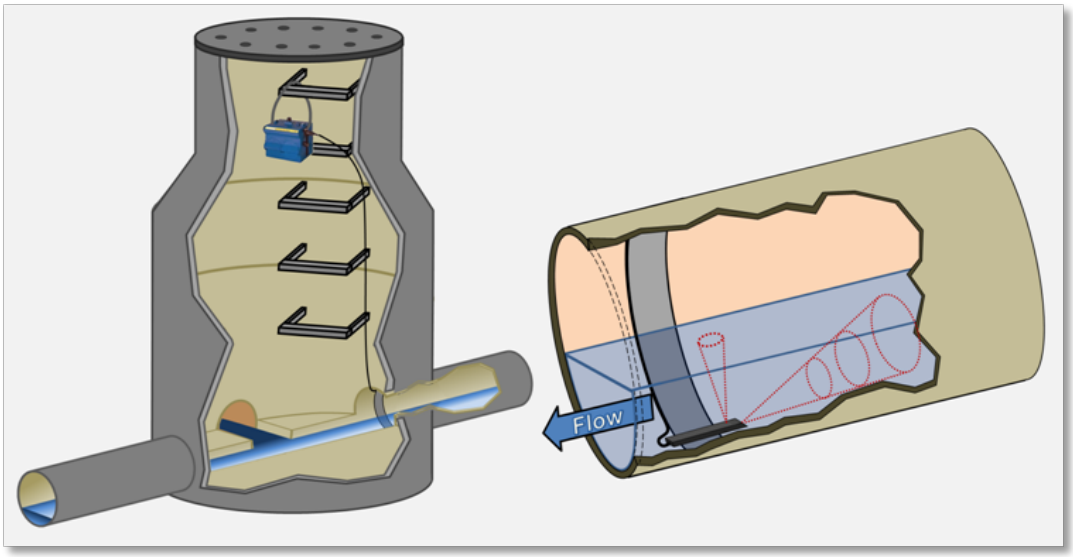


Figure 2-1. Typical Installation for Flow Meter with Submerged Sensor

2.3 Flow Calculation

Data retrieved from the flow meter was placed into a spreadsheet program for analysis. Data analysis includes data comparison to field calibration measurements, as well as necessary geometric adjustments as required for sediment (sediment reduces the pipe's wetted cross-sectional area available to carry flow). Area-velocity flow metering uses the continuity equation,

$$Q = v \cdot A = v \cdot (A_T - A_S)$$

where Q : volume flow rate
v: average velocity as determined by the ultrasonic sensor
A: cross-sectional area available to carry flow
A_T: total cross-sectional area with both wastewater and sediment
A_S: cross-sectional area of sediment.

For circular pipe,

$$A_T = \left[\frac{D^2}{4}\cos^{-1}\left(1-\frac{2d_W}{D}\right)\right] - \left[\left(\frac{D}{2}-d_W\right)\left(\frac{D}{2}\right)\sin\left(\cos^{-1}\left(1-\frac{2d_W}{D}\right)\right)\right]$$

$$A_S = \left[\frac{D^2}{4}\cos^{-1}\left(1-\frac{2d_S}{D}\right)\right] - \left[\left(\frac{D}{2}-d_S\right)\left(\frac{D}{2}\right)\sin\left(\cos^{-1}\left(1-\frac{2d_S}{D}\right)\right)\right]$$

where d_W: distance between wastewater surface level and pipe invert
d_S: depth of sediment
D: pipe diameter

2.4 Inflow / Infiltration Analysis: Definitions and Identification

Inflow and infiltration (I/I) consists of storm water and groundwater that enter the sewer system through pipe defects and improper storm drainage connections and is defined as follows:

2.4.1 Definition and Typical Sources

- Inflow: Storm water inflow is defined as water discharged into the sewer system, including private sewer laterals, from direct connections such as downspouts, yard and area drains, holes in manhole covers, cross-connections from storm drains, or catch basins.
- Infiltration: Infiltration is defined as water entering the sanitary sewer system through defects in pipes, pipe joints, and manhole walls, which may include cracks, offset joints, root intrusion points, and broken pipes.

Figure 2-2 illustrates the possible sources and components of I/I.

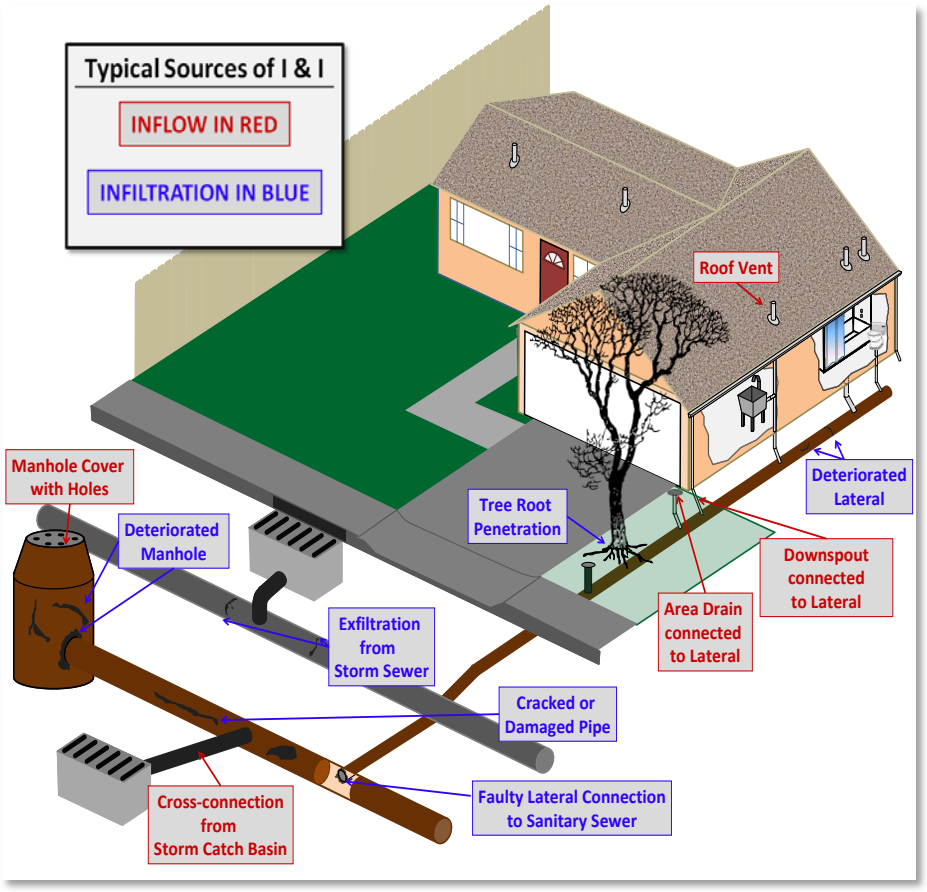


Figure 2-2. Typical Sources of Infiltration and Inflow

2.4.2 Infiltration Components

Infiltration can be further subdivided into components as follows:

- Groundwater Infiltration: Groundwater infiltration depends on the depth of the groundwater table above the pipelines as well as the percentage of the system submerged. The variation of groundwater levels and subsequent groundwater infiltration rates is seasonal by nature. On a day-to-day basis, groundwater infiltration rates are relatively steady and will not fluctuate greatly.
- Rainfall-Dependent Infiltration: This component occurs as a result of storm water and enters the sewer system through pipe defects, as with groundwater infiltration. The storm water first percolates directly into the soil and then migrates to an infiltration point. Typically, the time of concentration for rainfall-related infiltration may be 24 hours or longer, but this depends on the soil permeability and saturation levels.
- Rainfall-Responsive Infiltration is storm water which enters the collection system indirectly through pipe defects, but normally in sewers constructed close to the ground surface such as private laterals. Rainfall-responsive infiltration is independent of the groundwater table and reaches defective sewers via the pipe trench in which the sewer is constructed, particularly if the pipe is placed in impermeable soil and bedded and backfilled with a granular material. In this case, the pipe trench serves as a conduit similar to a French drain, conveying storm drainage to defective joints and other openings in the system. This type of infiltration can have a quick response and graphically can look very similar to inflow.

2.4.3 Impact and Cost of Source Detection and Removal

- Inflow:
  - Impact: This component of I/I creates a peak flow problem in the sewer system and often dictates the required capacity of downstream pipes and transport facilities to carry these peak instantaneous flows. Because the response and magnitude of inflow is tied closely to the intensity of the storm event, the short-term peak instantaneous flows may result in surcharging and overflows within a collection system. Severe inflow may result in sewage dilution, resulting in upsetting the biological treatment (secondary treatment) at the treatment facility.
  - Cost of Source Identification and Removal: Inflow locations are usually less difficult to find and less expensive to correct. These sources include direct and indirect cross-connections with storm drainage systems, roof downspouts, and various types of surface drains. Generally, the costs to identify and remove sources of inflow are low compared to potential benefits to public health and safety or the costs of building new facilities to convey and treat the resulting peak flows.

- **Infiltration:**
  - Impact: Infiltration typically creates long-term annual volumetric problems. The major impact is the cost of pumping and treating the additional volume of water, and of paying for treatment (for municipalities that are billed strictly on flow volume).
  - Cost of Source Detection and Removal: Infiltration sources are usually harder to find and more expensive to correct than inflow sources. Infiltration sources include defects in deteriorated sewer pipes or manholes that may be widespread throughout a sanitary sewer system.

2.4.4 Graphical Identification of I/I

Inflow is usually recognized graphically by large-magnitude, short-duration spikes immediately following a rain event. Infiltration is often recognized graphically by a gradual increase in flow after a wet-weather event. The increased flow typically sustains for a period after rainfall has stopped and then gradually drops off as soils become less saturated and as groundwater levels recede to normal levels. Realtime flows were plotted against ADWF to analyze the I/I response to rainfall events. Figure 2-3 illustrates a sample of how this analysis is conducted and some of the measurements that are used to distinguish infiltration and inflow. Similar graphs were generated for the individual flow monitoring sites and can be found in *Appendix A*.

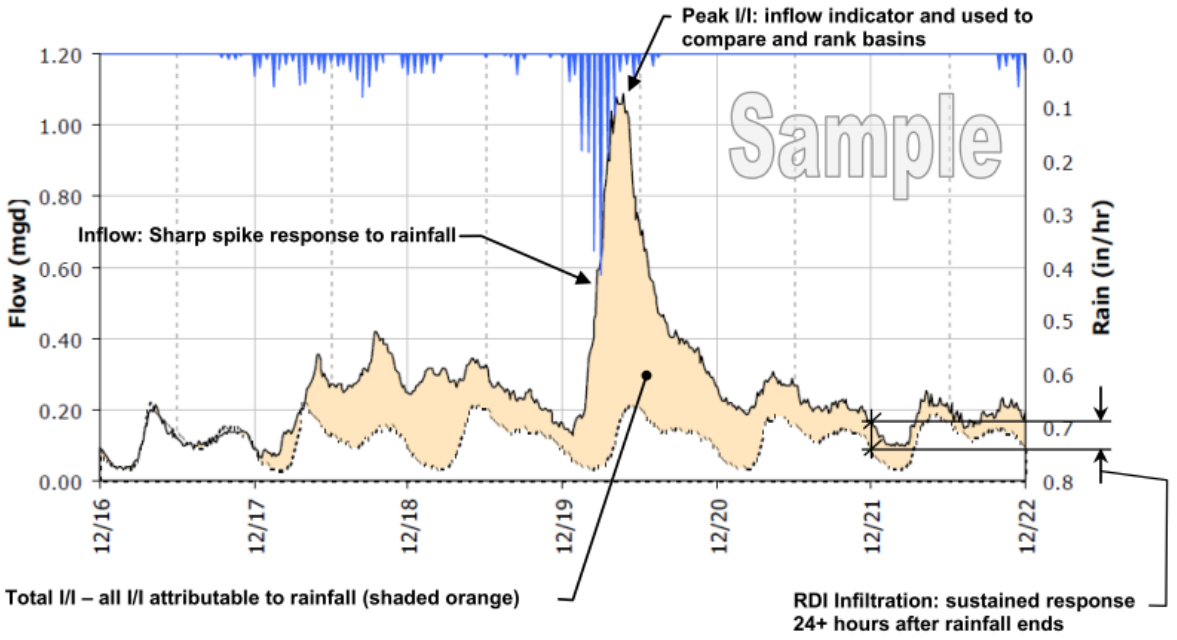


Figure 2-3. Sample Infiltration and Inflow Isolation Graph

Figure 2-4 shows sample graphs indicating the typical graphical response patterns for inflow and infiltration in a more detailed version.

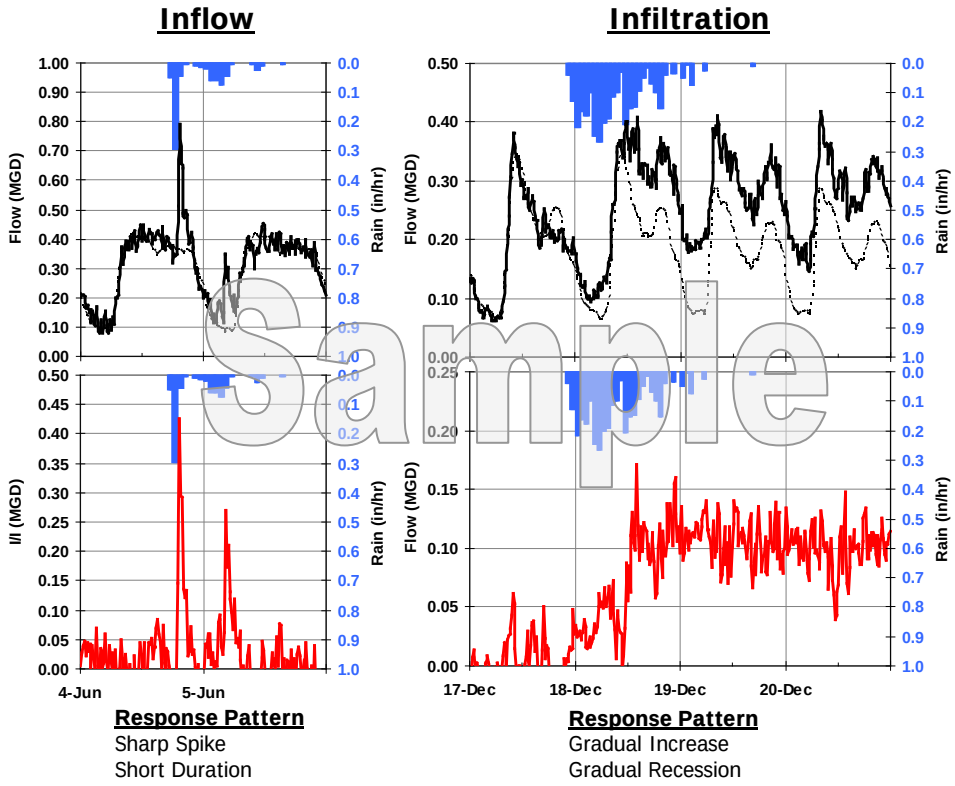


Figure 2-4. Inflow and Infiltration: Graphical Response Patterns

2.4.5 Analysis Methods

In this study, after differentiating I/I flows from ADWF flows, the peak inflow and RDI were normalized to ADWF for an "apples-to-apples" comparison amongst the different sites.

3.0 RESULTS AND ANALYSIS

3.1 Rainfall Monitoring

3.1.1 Flow Study Rainfall Data

The rainfall data was obtained from five locations from Ventura County Watershed Protection District Hydrologic Data Server and the sites are previously listed in Table 1-2 and shown in Figure 1-1.

There were several rainfall events during the flow monitoring period. Two notable rainfall events were defined and selected from all the five locations. For illustration purpose, Figure 3-1 shows the two rainfall events and other small rainfall events recorded at Oxnard Civic Center. The total rainfall over period was 5.24 inches. Rainfall Event 1 and Event 2 are 2.55 inches and 1.70 inches, respectively.

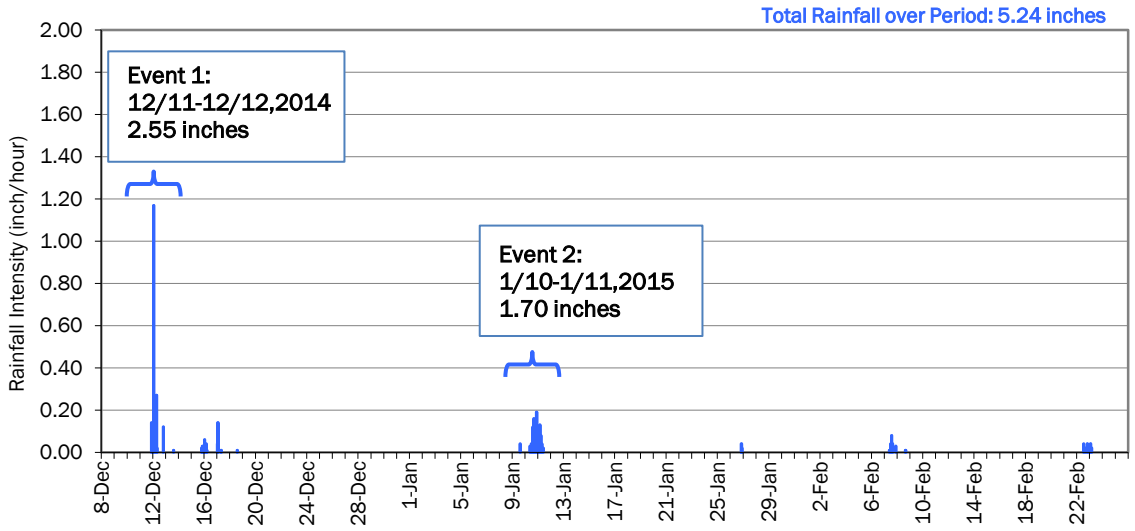


Figure 3-1. Rainfall Events Recorded at Oxnard Civic Center

The rainfall recorded at all the locations are listed in Table 3-1.

Table 3-1. Rainfall Recorded for the Two Rainfall Events

Monitoring Site	Event 1 Precipitation (in.)	Event 2 Precipitation (in.)	Total Precipitation (in.)
Oxnard WWTP	2.10	1.46	4.66
Oxnard Airport	2.10	1.60	4.70
Oxnard Civic Center	2.55	1.70	5.24
El Rio-UWCD Spreading Grounds	1.89	2.11	5.08
Oxnard NWS	2.50	2.26	6.05

Figure 3-2 shows the rainfall accumulation during the monitoring period, as well as the historical average rainfall in the City during this project duration. The historical data was taken from the WRCC (Station 046569 at Oxnard Civic Center[2]). The cumulative precipitation was approximately 38% lower than the historical precipitation for the time period shown.

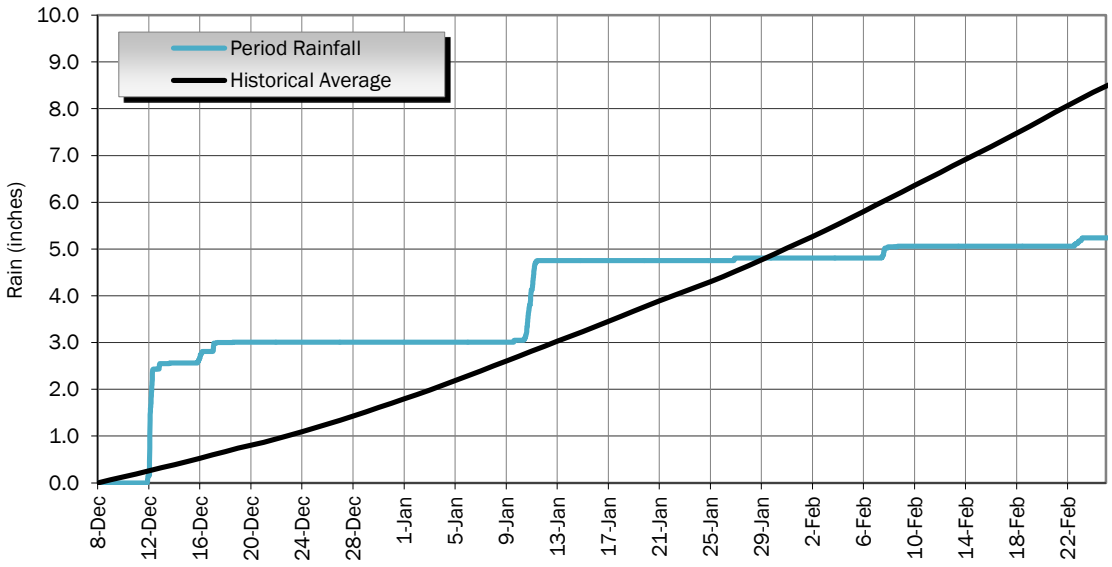


Figure 3-2. Rainfall Accumulation at Oxnard Civic Center

[2] http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?caoxna+sca

3.1.2 Regional Rainfall Event Classification

It is important to classify the relative size of a major storm event that occurs over the course of a flow monitoring period[3]. Rainfall events are classified by intensity and duration. Based on historical data, frequency contour maps for storm events of given intensity and duration have been developed by the NOAA for Southern California (Figure 3-3).

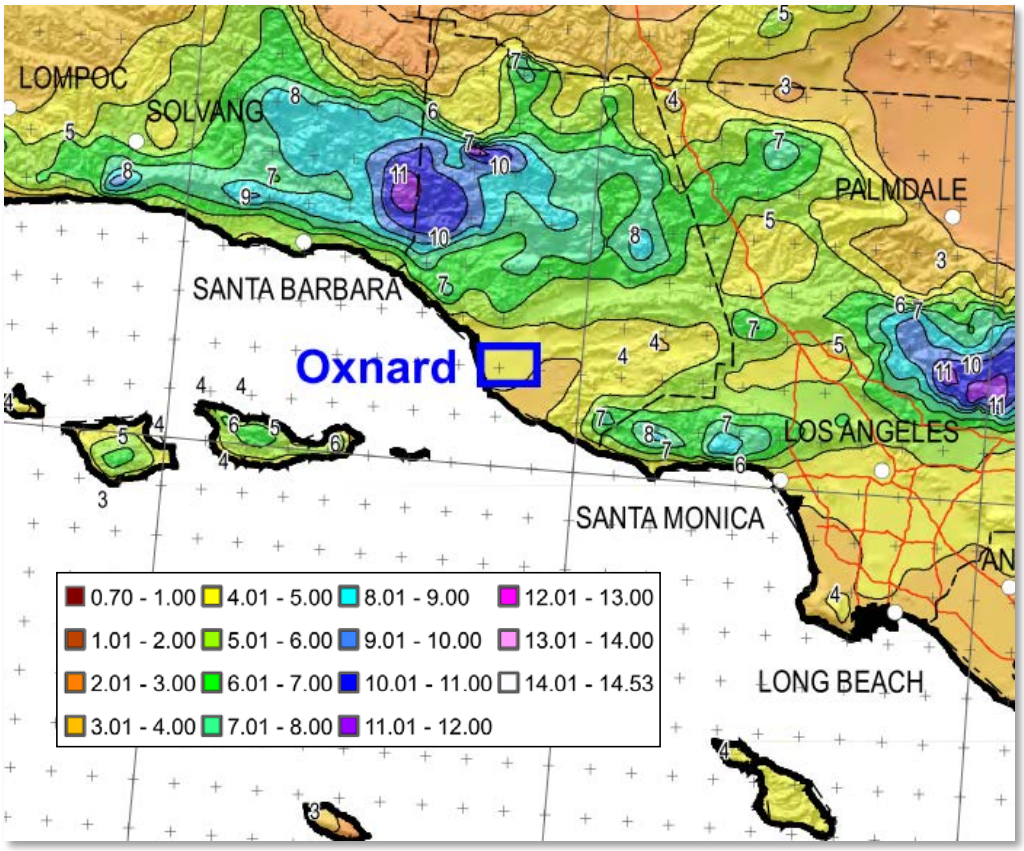


Figure 3-3. NOAA Southern California Rainfall Frequency Map

For example, the NOAA Rainfall Frequency Atlas[4] classifies a 10-year, 24-hour storm event at Oxnard as 4.3 inches. This means that in any given year, at this specific location, there is a 10% chance that 4.3 inches of rain will fall in any 24-hour period.

From the NOAA frequency maps, for a specific latitude and longitude, the rainfall densities for period durations ranging from 5 minutes to 60 days are known for rain events ranging from 1-year to 1000-year intensities. These can be plotted to develop a rain event frequency map specific to each rainfall

[3] Sanitary sewers are often designed to withstand I/I contribution to sanitary flows for specific-sized "design" storm events.
[4] NOAA Western U.S. Precipitation Frequency Maps Atlas 2, 1973: http://www.wrcc.dri.edu/pcpnfreq.html

monitoring site. Superimposing the peak measured densities for the rainfall events on the rain event frequency plot determines the classification of the rainfall event.

Figure 3-4 shows the classification curves for Rainfall Events 1 and 2 at Oxnard Civic Center. It can be seen from the figure that Event 2 was a less than a 1-year event for all durations. Event 1 was greater than a 5-year event for a 6-hour duration. If longer durations are considered, the event was a three-year event for a 12-hour duration and a 1-year event for a 2-day duration.

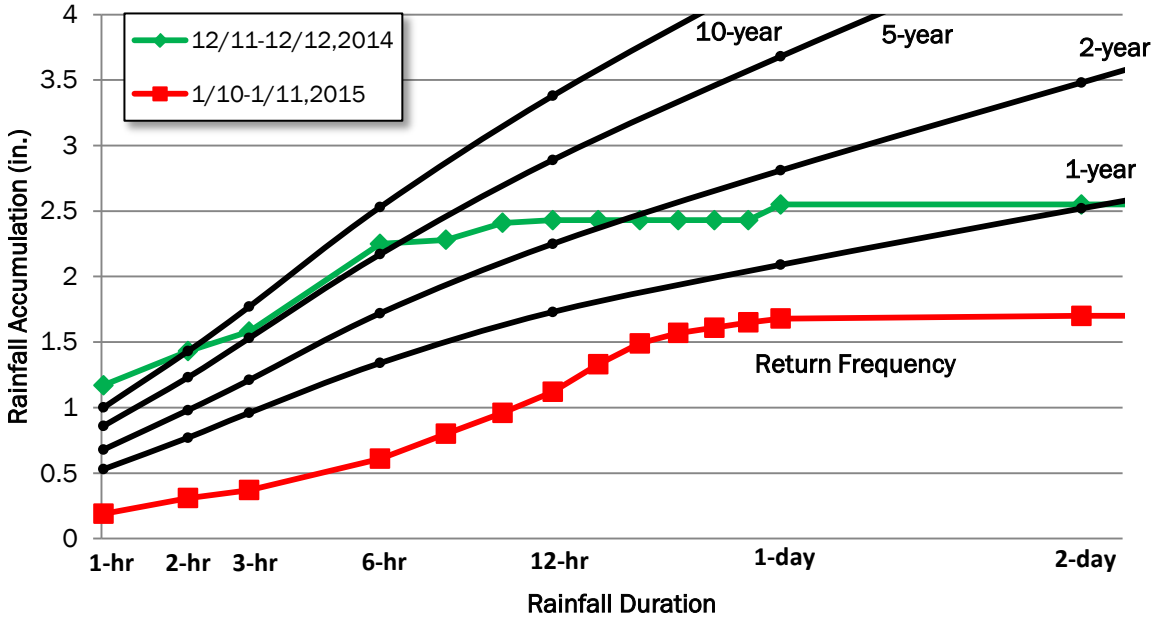


Figure 3-4. Rainfall Event Classification at Oxnard Civic Center

3.2 Flow Monitoring

3.2.1 Baseline Flow Analysis

The baseline flows used in this study to calculate inflow and infiltration were taken from "Dry Days" from January 20 through February 12, 2015 when RDI had the least impact. Similar to the dry weather study, four distinct average dry weather flow curves were established for each site location:

- Mondays – Thursdays
- Fridays
- Saturdays
- Sundays

Flows for many sites differ on Friday evenings compared to Mondays through Thursdays. Starting around 7 pm, the flows are often decreased (compared to Monday through Thursday). Similarly, flow patterns for Saturday and Sunday were also separated due to their unique evening flow pattern. This type of differentiation can be important when determining I/I response, especially if a rain event occurs on a Friday, Saturday or Sunday evening.

Figure 3-5 illustrates a sample of varying flow patterns within a typical dry week. Graphs of the ADWF (called *Baseline* in this study) flow patterns for each site can be found in *Appendix A*.

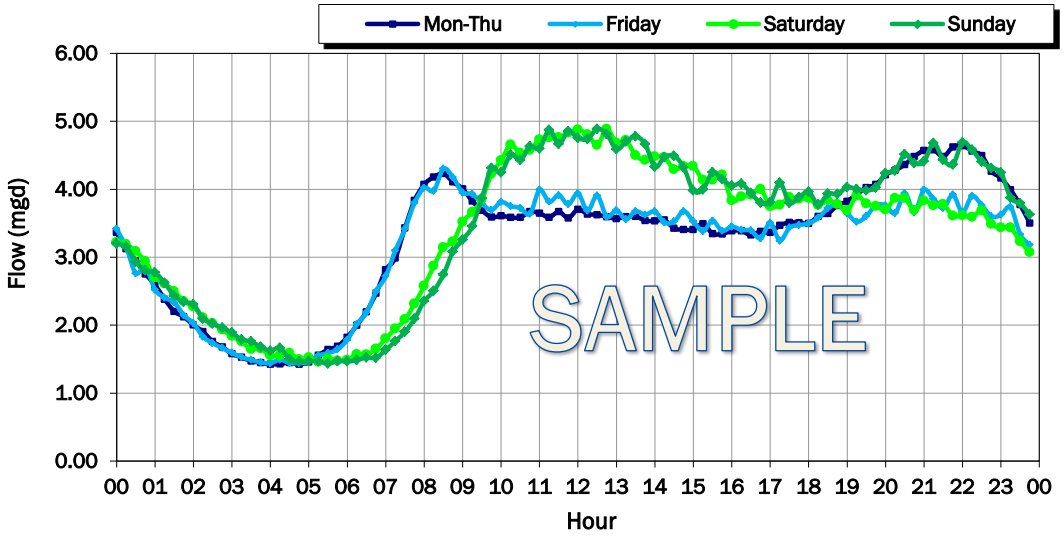


Figure 3-5. Sample ADWF Diurnal Flow Patterns

The overall average dry weather flow (ADWF) was calculated per the following equation:

$$ADWF = \left(ADWF_{Mon-Thu} \times \frac{4}{7} \right) + \left(ADWF_{Fri} \times \frac{1}{7} \right) + \left(ADWF_{Sat} \times \frac{1}{7} \right) + \left(ADWF_{Sun} \times \frac{1}{7} \right),$$

Table 3-2 summarizes the baseline flow data measured during this study. The baseline flows compare well with the dry weather study except Site 2 and Site 4.

- **Site 2:** The flow patterns measured at this site are not indicative of residential flow contribution, but more industrial or retail flows. If the service area is mostly industrial, then flows may be expected to be sporadic.

  Both level and velocity dropped on January 17, 2015 but the general hydraulic condition stayed consistent and diagnostic and calibration data confirm the drop in flows to be correct. V&A believes the data submitted for both the dry weather and wet weather studies to be reliable data.

  V&A took care to consider the relative baseline flows at the time of the storm events when running the I/I analysis for this site.

- **Site 4A:** Site 4, which was monitored during the dry weather study, had inconsistent hydraulics, showing strange backflow conditions. No evidence of backflow was found during the wet weather study. Additionally Site 4 had turbulent conditions and was not an ideal site to capture accurate flow monitoring data. V&A consulted with the City and a decision was made to relocate Site 4 to a location with suitable hydraulic conditions to ensure data accuracy and repeatability. Data from Site 4 from the dry weather study is considered invalid. An additional meter was installed one manhole upstream from Site 4, labeled "Site 4A".

Table 3-2. Baseline Flow Summary

Monitoring Site	Sediment (in.)	Monday-Thursday ADWF (mgd)	Friday ADWF (mgd)	Saturday ADWF (mgd)	Sunday ADWF (mgd)	Overall ADWF (mgd)	Dry Weather ADWF (mgd)
Site 1	4	5.005	4.814	4.510	4.417	4.823	5.142
Site 2	-	2.262	2.316	2.145	1.844	2.194	2.702
Site 3	-	6.828	6.695	7.440	7.465	6.988	7.134
Site 4A	4	3.131	2.978	3.219	3.351	3.153	4.301
Site 5	-	1.509	1.448	1.216	1.157	1.408	1.341
Site 6	-	1.264	1.232	1.034	1.054	1.197	1.351
Site 7	-	0.332	0.327	0.336	0.342	0.333	0.311
Site 8	-	1.647	1.509	1.660	1.704	1.638	1.840
Site 9	-	2.299	2.216	2.329	2.402	2.306	2.041
Site 10	-	2.077	2.085	2.198	2.301	2.128	1.913

3.2.2 Peak Measured Flows and Pipeline Capacity Analysis

Peak measured flows and the flow level (depth) at peak flow times are important factors to consider in order to understand the capacity of the flow monitoring system. The peak flows and flow levels reported are from the peak measurements taken across the entirety of the flow monitoring period and may or may not correspond to a simultaneous event for all sites. There were several instances of backflow conditions due to capacity constraints and the inability of the local collection system to handle peak wet weather flows.

The following capacity analysis terms are defined as follows:

- d/D Ratio: The d/D ratio is the peak measured depth of flow (d) divided by the pipe diameter (D). A d/D ratio of 0.75 is a common maximum threshold value used for pipe design. The d/D ratio for each site was computed based on the maximum depth of flow for the flow monitoring study.
- Peaking Factor: Peaking factor is defined as the peak measured flow divided by the average dry weather flow (ADWF). A peaking factor threshold value of 3.0 is commonly used for sanitary sewer design; however, it is noted that this value is variable and subject to attenuation (see previous section) and the size of the upstream collector area. The District should follow its own standards and criteria when examining peaking factors.

Table 3-3 summarizes the peak recorded flows, levels, *d/D* ratios, and peaking factors per site during the flow monitoring period. Capacity analysis data is presented on a site-by-site basis and represents the hydraulic conditions only at the point site locations. Hydraulic conditions in other areas of the collection system will differ.

Table 3-3. Capacity Analysis Summary

Site	ADWF (mgd)	Peak Measured Flow (mgd)	Peaking Factor	Diameter (in)	Peak Level (in)	*d/D* Ratio	Level Surcharged above Crown (ft)
Site 1	4.823	8.312	1.7	41.5	20.0	0.48	-
Site 2	2.194	6.002	2.7	36	21.2	0.59	-
Site 3	6.988	14.352	2.1	60	24.1	0.40	-
Site 4A	3.153	5.729	1.8	33	23.1	0.70	-
Site 5	1.408	3.074	2.2	36	13.5	0.37	-
Site 6	1.197	2.292	1.9	24	11.0	0.46	-
Site 7	0.333	0.620	1.9	24	5.9	0.25	-
Site 8	1.638	4.540	2.8	27	15.5	0.57	-
Site 9	2.306	4.053	1.8	42	9.5	0.23	-
Site 10	2.128	4.024	1.9	37	14.9	0.40	-

The following capacity analysis results are noted:

- d/D Ratio: All sites had d/D ratios lower than the typical design threshold. No surcharging was found.
- Peaking Factor: All sites had peaking factors lower than the typical design threshold limits

Figure 3-6 and Figure 3-7 summarizes the site-by-site d/D ratios and peaking factors, respectively in descending order.

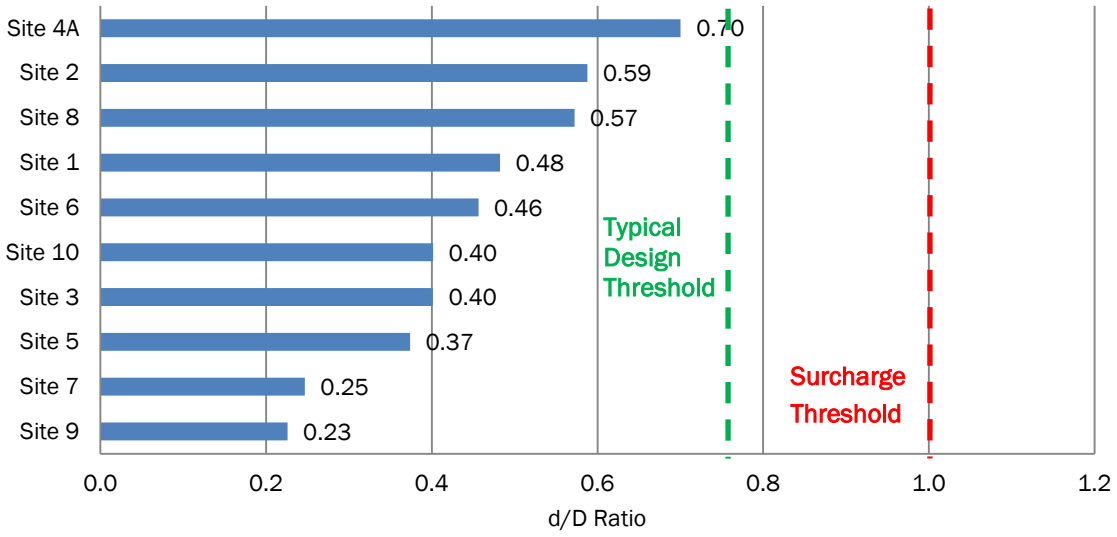


Figure 3-6. Capacity Summary: d/D Ratios

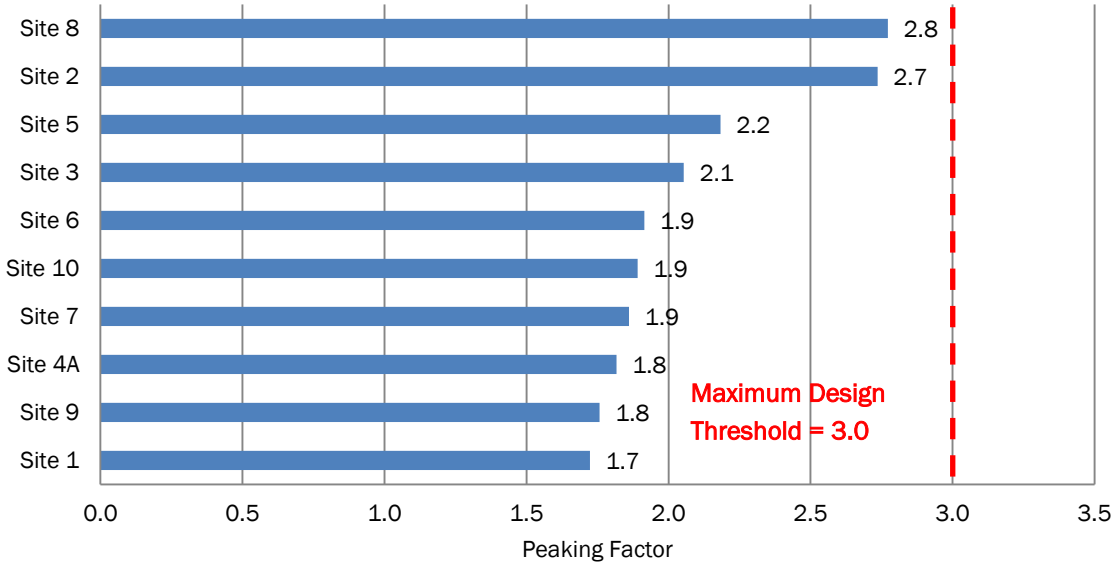


Figure 3-7. Capacity Summary: Peaking Factors

3.3 Inflow and Infiltration: Results

3.3.1 Inflow Results Summary

Inflow is storm water discharged into the sewer system through direct connections such as downspouts, area drains, cross-connections to catch basins, etc. These sources transport rain water directly into the sewer system and the corresponding flow rates are tied closely to the intensity of the storm. This component of I/I often causes a peak flow problem in the sewer system and often dictates the required capacity of downstream pipes and transport facilities to carry these peak instantaneous flows.

Inflow results were taken from Rainfall Event 1 (December 11 to 12, 2014). This is because this rainfall event is the most intensive short-term rainfall event. Table 3-4 summarizes the peak measured I/I flows and inflow analysis results for the storm events that occurred during the monitoring period.

Table 3-4. Inflow Analysis Summary

Monitoring Site	ADWF (mgd)	Peak I/I Rate (mgd)	Peak I/I per ADWF
Site 1	4.823	3.468	0.7
Site 2	2.194	3.242	1.5
Site 3	6.988	5.545	0.8
Site 4A	3.153	4.512	1.4
Site 5	1.408	2.044	1.5
Site 6	1.197	1.081	0.9
Site 7	0.333	0.248	0.7
Site 8	1.638	3.725	2.3
Site 9	2.306	1.884	0.8
Site 10	2.128	1.052	0.5

Figure 3-8 shows the summary of the inflow analysis in descending order. Site 8 had the highest Peak I/I per ADWF of 2.3. The other sites had ratios of 1.5 or less.

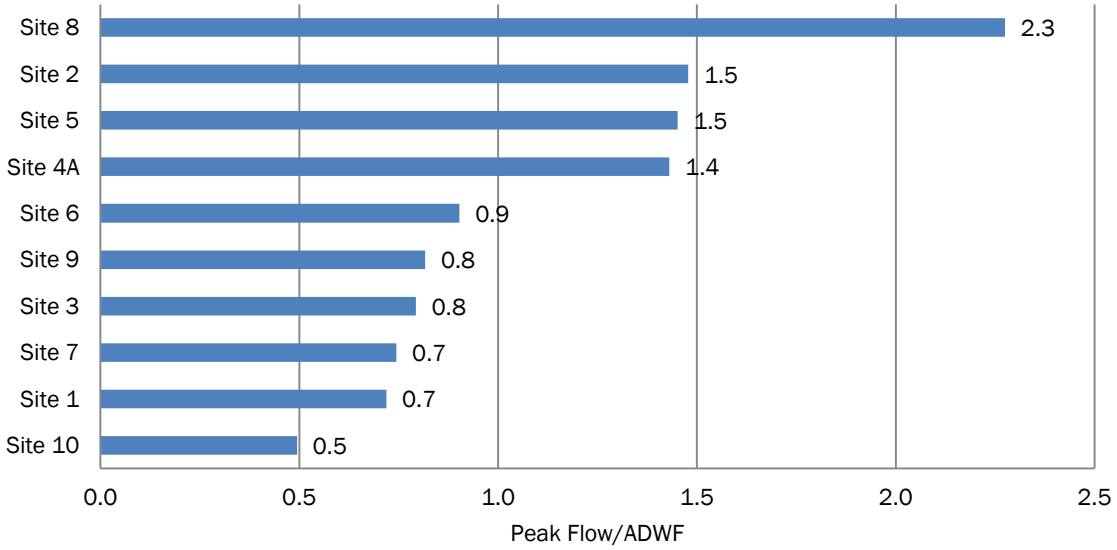


Figure 3-8. Inflow Analysis Summary – Peak I/I to ADWF

3.3.2 Infiltration Results Summary

Infiltration is defined as water entering the sanitary sewer system through defects in pipes, pipe joints, and manhole walls, which may include cracks, offset joints, root intrusion points, and broken pipes. Increased flows into the sanitary sewer system are usually tied to groundwater levels and soil saturation levels. Infiltration sources transport rain water into the system *indirectly*; flow levels in the sanitary system increase gradually, are typically sustained for a period after rainfall has stopped, and then gradually decrease as soils become less saturated and as groundwater levels recede to normal. Infiltration typically creates long-term annual volumetric problems. The major impact is the cost of pumping and treating the additional volume of water, and of paying for treatment (for municipalities that are billed strictly on flow volume).

The rain dependent infiltration rates for the monitoring sites in Oxnard were minimal or negligible and an RDI analysis could not be performed. For example, Figure 3-9 illustrates this I/I response graphic for Site 4 for Event 2. RDI analysis would typically be run 24-hours after the conclusion of the rainfall event; however, within 8 hours or so, the flow rates had returned to baseline levels. This was typical for all of the monitoring sites. For this study, rain dependent infiltration was considered negligible; generally, rain dependent infiltration does not appear to be an issue within the collection system.

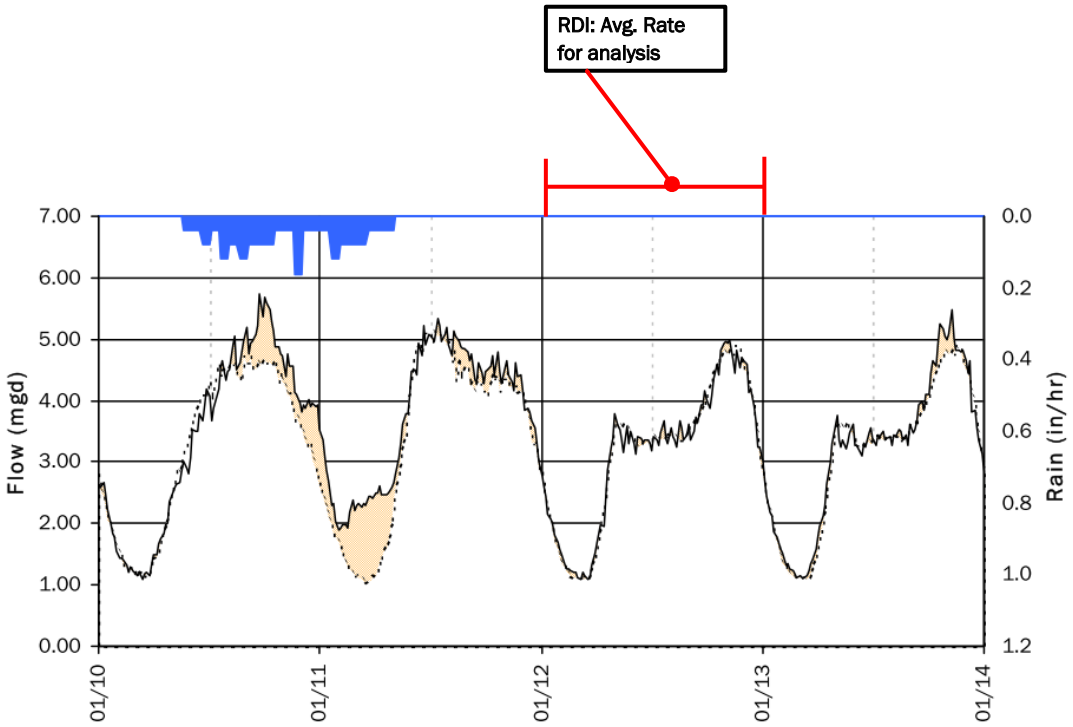


Figure 3-9. RDI Measurement, Site 1

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The flow monitoring and I/I analyses show that:

3. **Inflow and Infiltration:** Most of the I/I within the collection system comes from INFLOW. There was negligible rain dependent infiltration observed during this flow monitoring study.
4. **Capacity:** The capacity analysis in this study shows that the sewer system is in good condition on a capacity basis during this monitoring study.

4.2 Recommendations

V&A advises that future I/I reduction plans consider the following recommendations if I/I is a concern to the City:

4. **Determine I/I Reduction Program:** The City should examine its I/I reduction needs to determine their strategy and goals for a future I/I reduction program.
    a. If peak flows, sanitary sewer overflows, and pipeline capacity issues are of greater concern, then priority can be given to investigate and reduce sources of inflow within the basins with the higher inflow/ADWF ratios. This would appear to be the greatest concern for the City collection system.
    b. If infiltration and general pipeline deterioration are of greater concern, then the program can be weighted to investigate and reduce sources of infiltration within the basins with the higher RDI/ADWF ratios. Infiltration does not appear to be an issues for the City collection system.
5. **I/I Investigation Methods:** Potential I/I investigation methods include the following:
    a. smoke testing
    b. mini-basin flow monitoring
    c. CCTV inspection
6. **I/I Reduction Cost Effective Analysis:** The City should conduct a study to determine which is more cost-effective: (1) locating the sources of inflow/infiltration and systematically rehabilitating or replacing the faulty pipelines; or (2) continued treatment of the additional rainfall dependent I/I flow.

APPENDIX A. FLOW MONITORING SITES: DATA, GRAPHS, INFORMATION

City of Oxnard

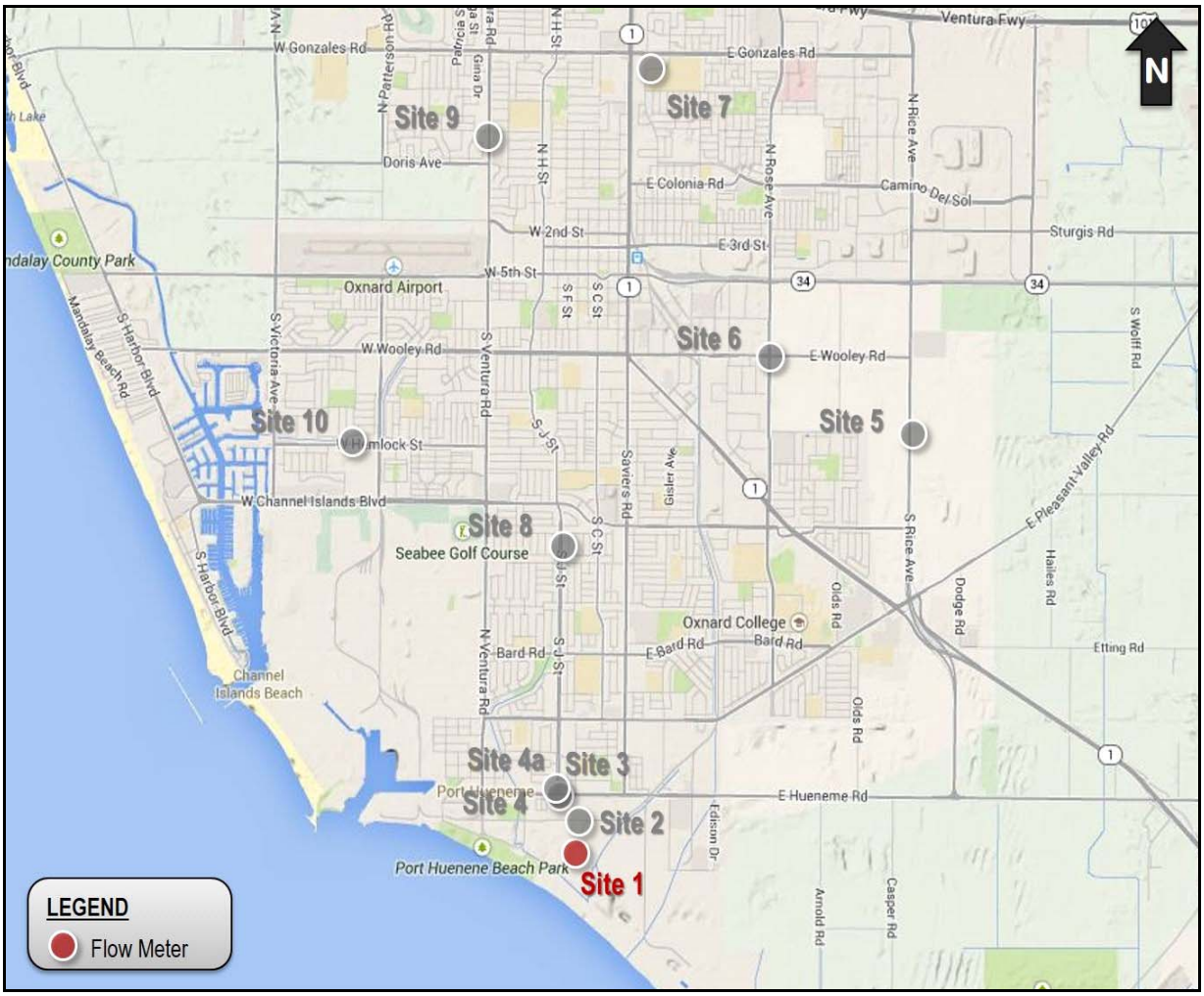
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 1

Location: McWane Boulevard, east of Perkins Road

Data Summary Report



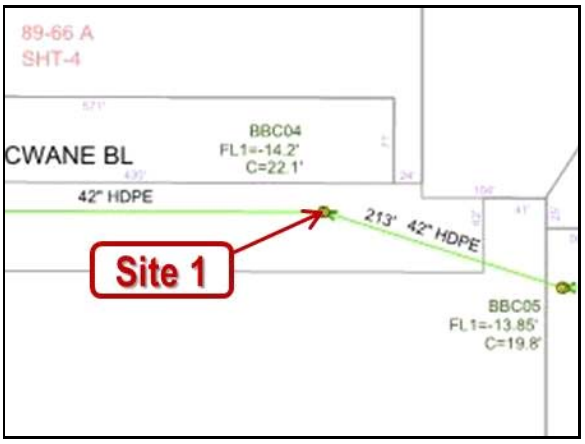
Vicinity Map: Site 1

SITE 1

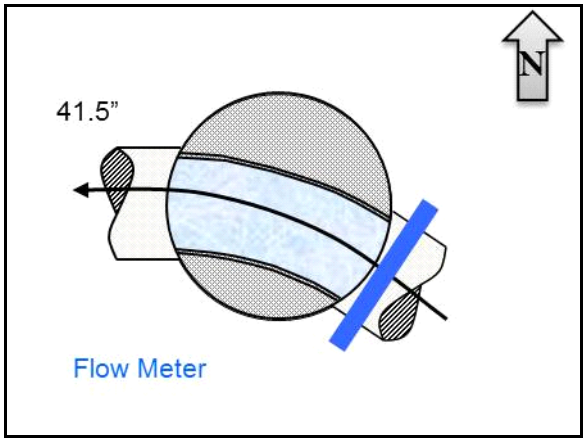
Site Information

Location:	McWane Boulevard, east of Perkins Road
Coordinates:	119.1833° W, 34.1401° N
Rim Elevation:	10 feet
Pipe Diameter:	41.5 inches
Baseline Flow:	4.823 mgd
Peak Measured Flow:	8.312 mgd

Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 1

Additional Site Photos

Effluent Pipe

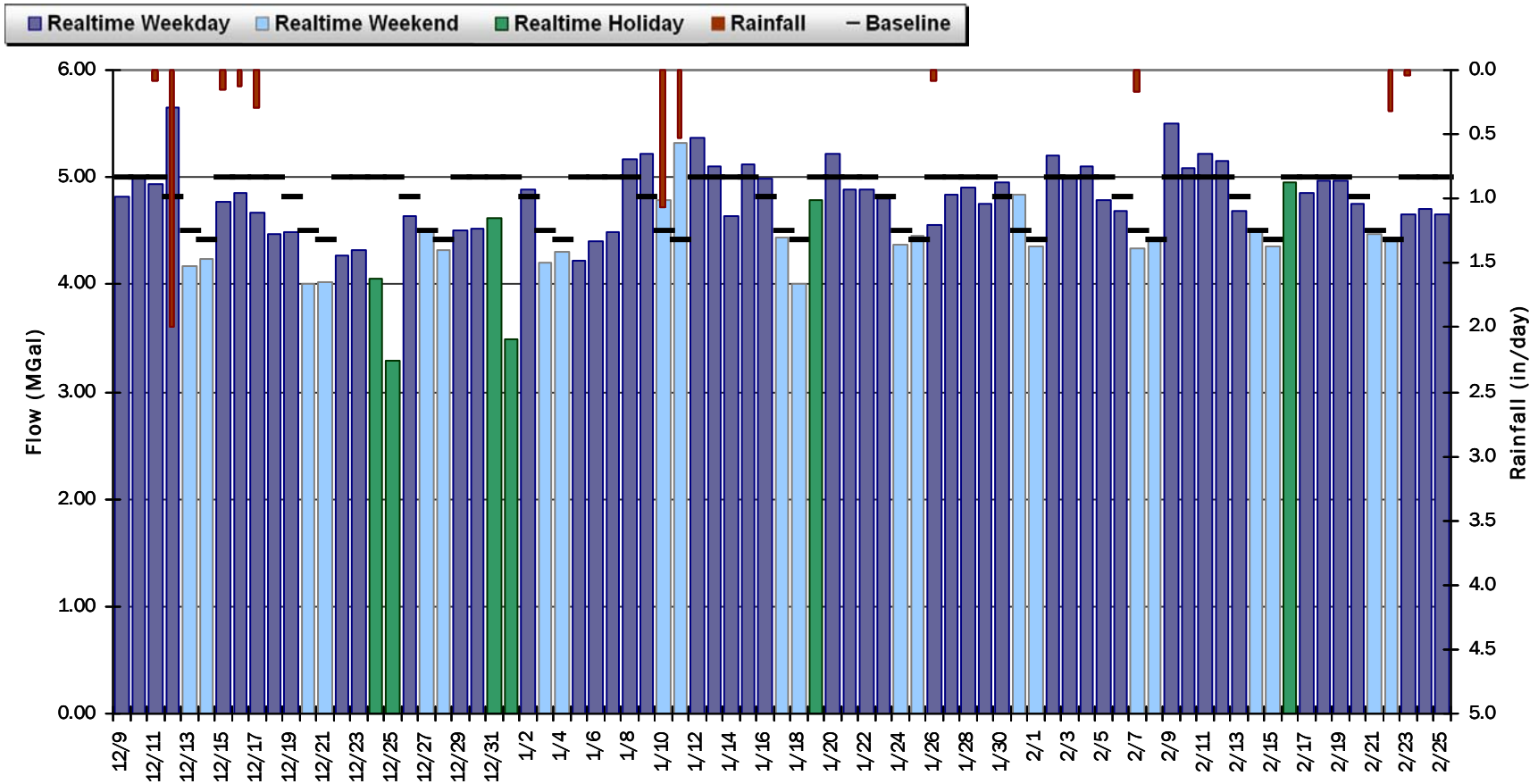
Influent Pipe

SITE 1

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 4.675 MGal **Peak Daily Flow: 5.646 MGal** **Min Daily Flow: 3.287 MGal**

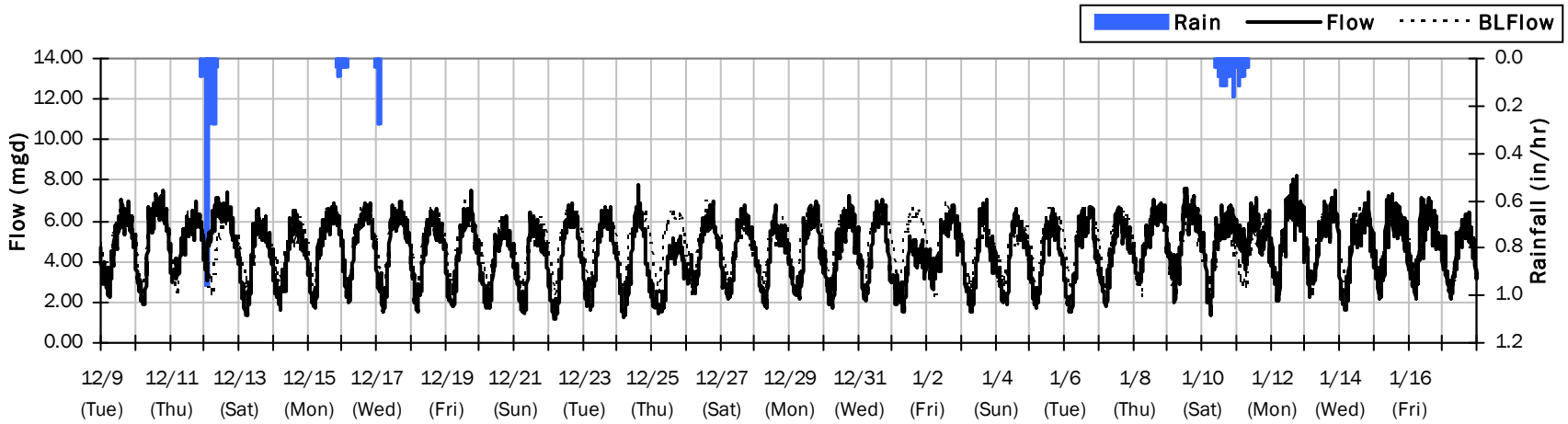
Total Period Rainfall: 4.84 inches

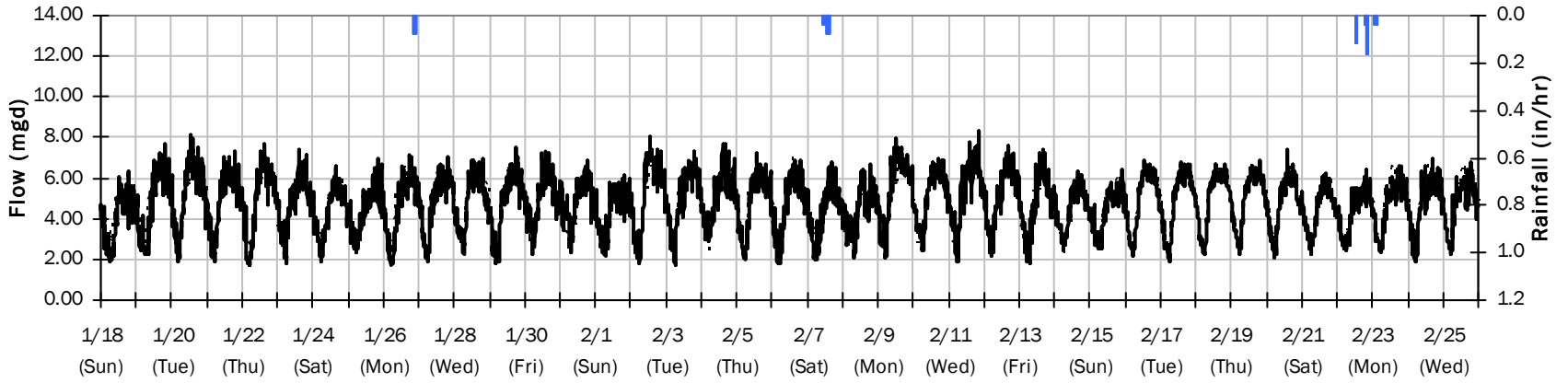


SITE 1

Flow Summary: 12/9/2014 to 2/25/2015

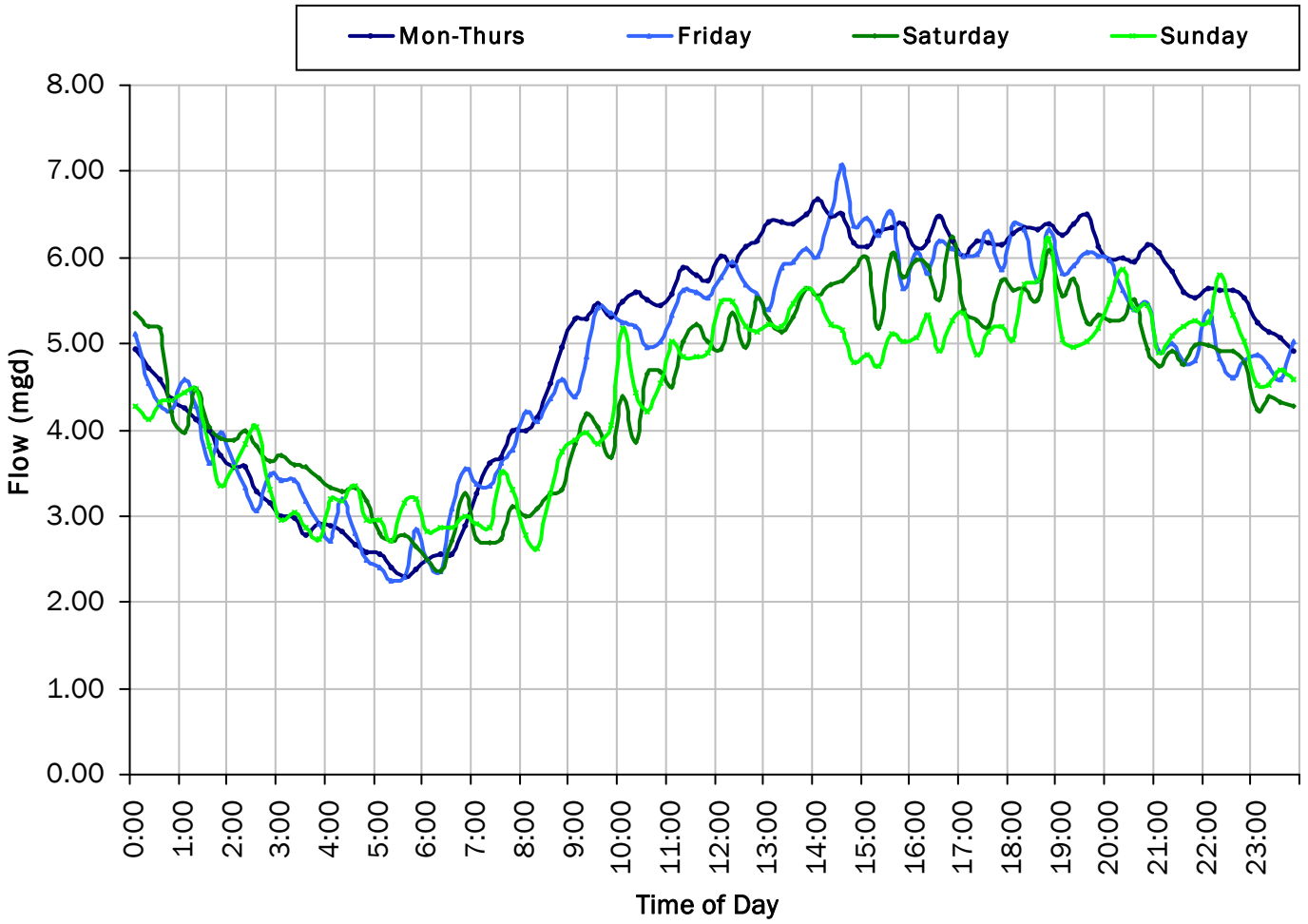
Total Period Rainfall: 4.84 inches **Avg Flow: 4.675 mgd Peak Flow: 8.312 mgd Min Flow: 1.176 mgd**





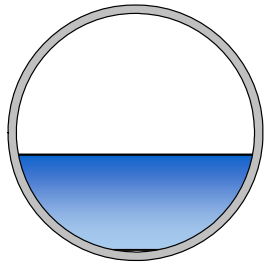
SITE 1

Baseline Flow Hydrographs



Baseline Flow:

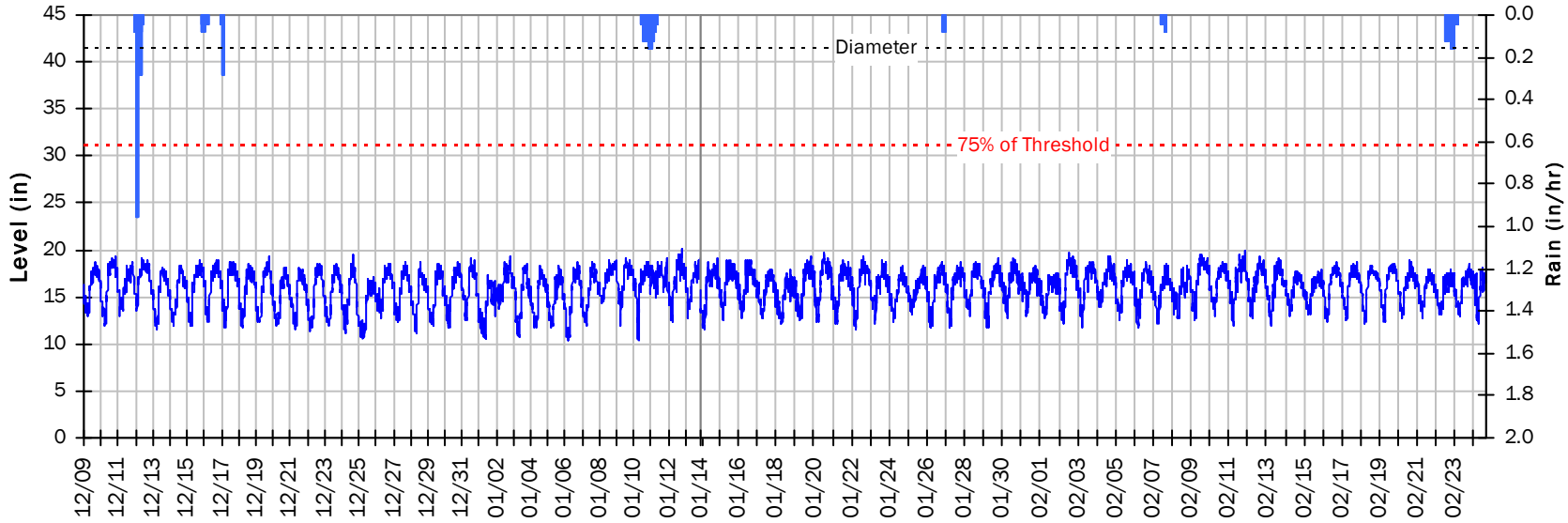
4.82 *mgd*

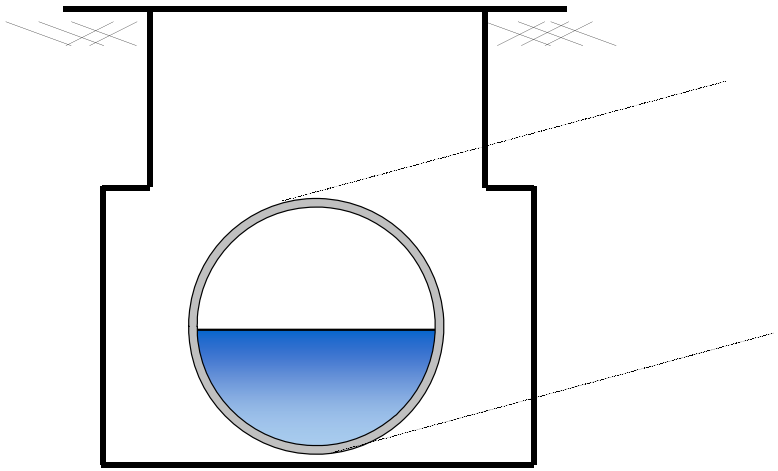


SITE 1

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

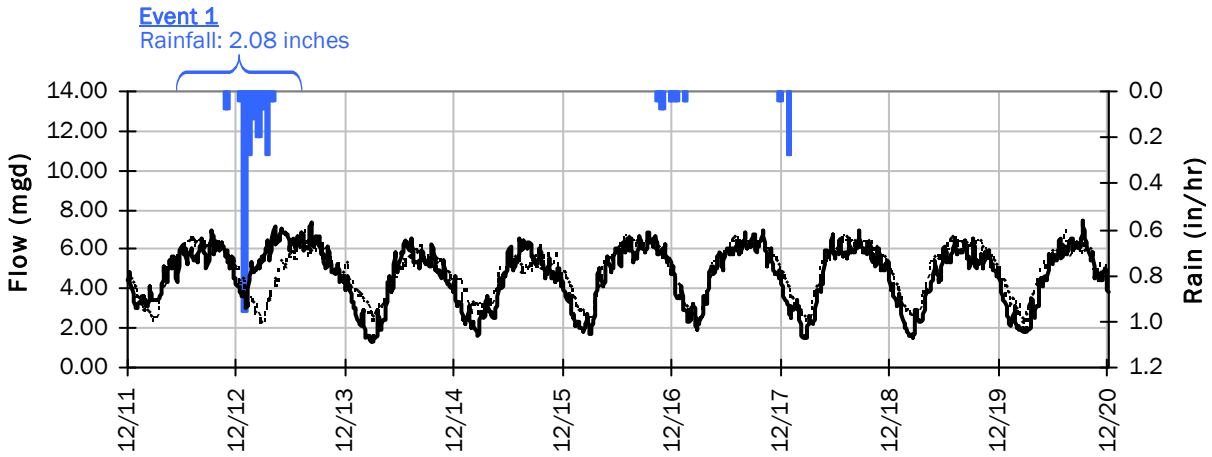




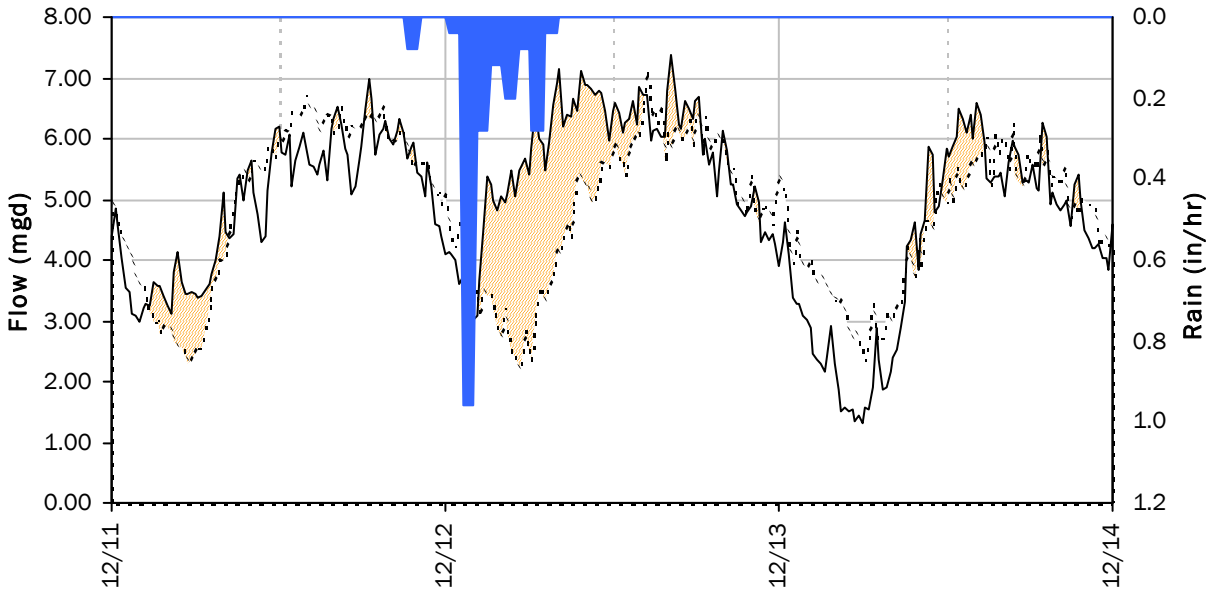
Pipe Diameter:	41.5 *inches*
Peak Measured Level:	20.0 *inches*
Peak d/D Ratio:	0.48

SITE 1
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

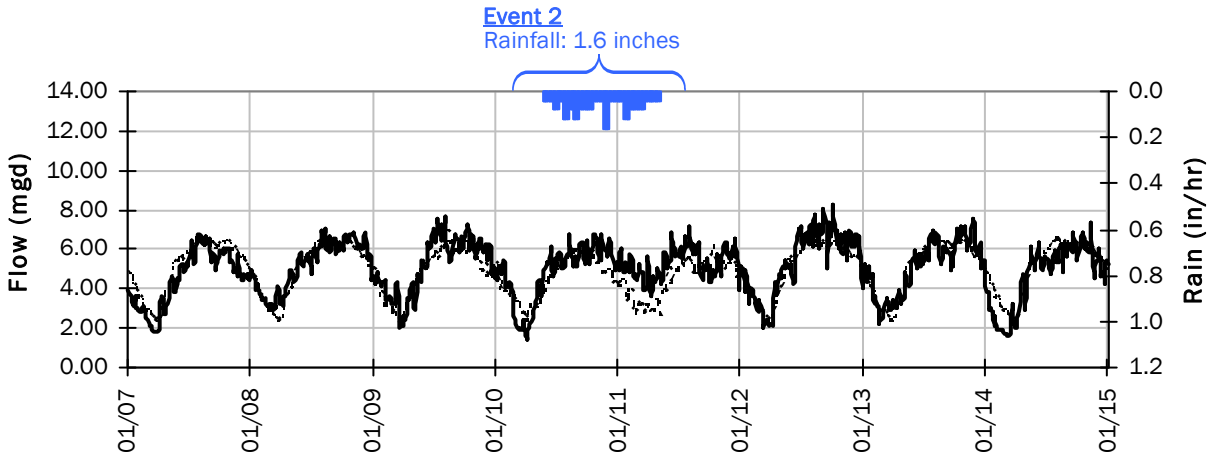


Storm Event I/I Analysis (Rain = 2.08 inches)

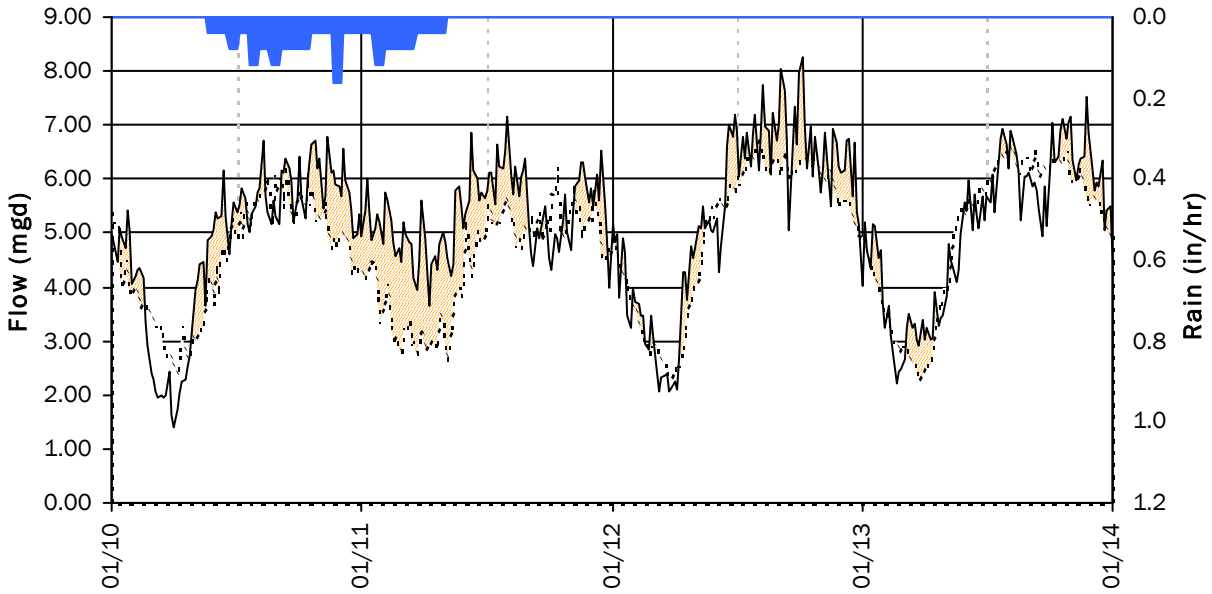
Capacity		Inflow / Infiltration	
Peak Flow:	7.38 *mgd*	**Peak I/I Rate:**	3.47 *mgd*
PF:	1.53	**Total I/I:**	474,000 *gallons*
Peak Level:	19.20 *in*		
d/D Ratio:	0.46		

SITE 1
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



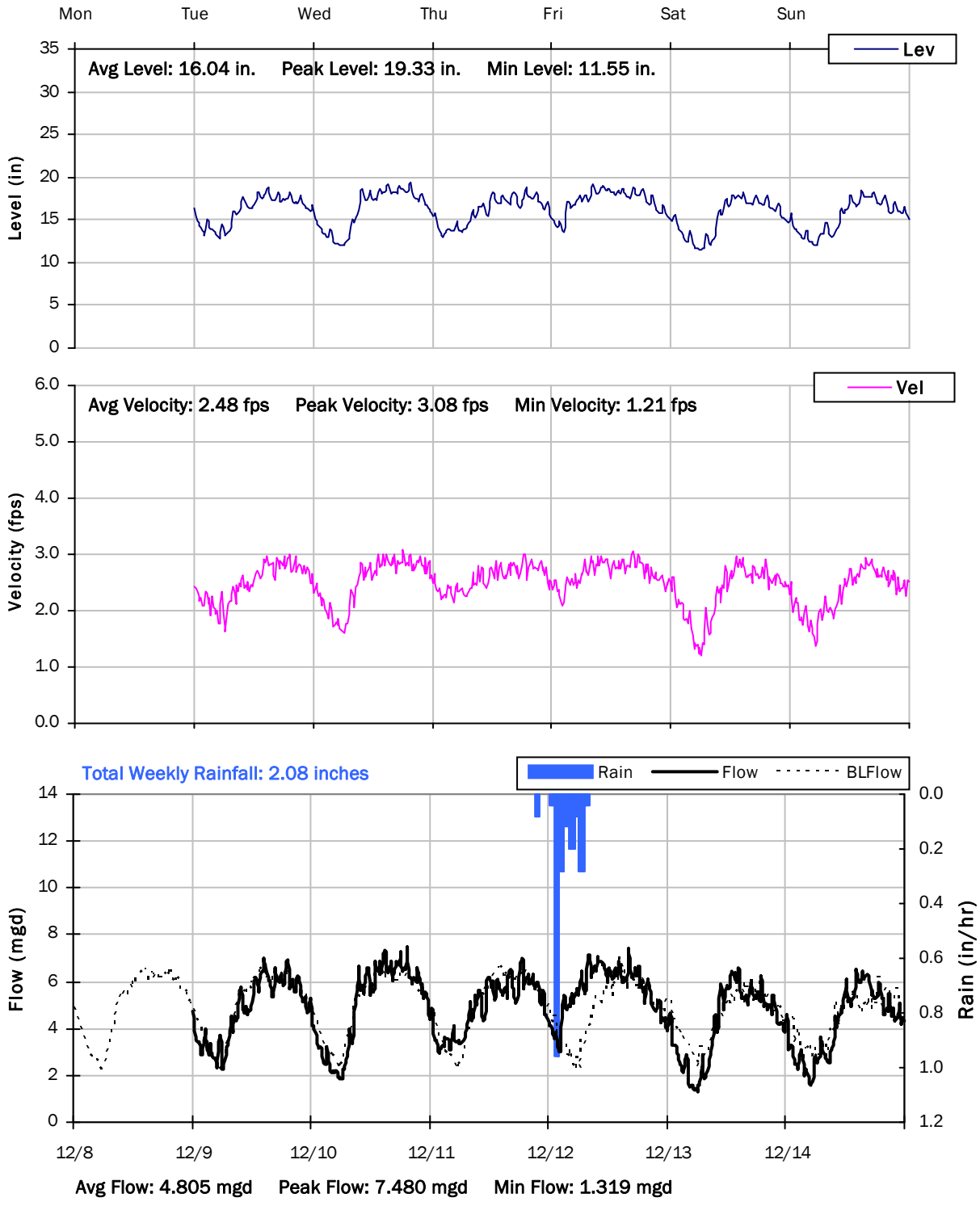
Storm Event I/I Analysis (Rain = 1.60 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	8.26 *mgd*	**Peak I/I Rate:**	2.64 *mgd*
PF:	1.71	**Total I/I:**	1,543,000 *gallons*
Peak Level:	20.02 *in*		
d/D Ratio:	0.48		

SITE 1

Weekly Level, Velocity and Flow Hydrographs

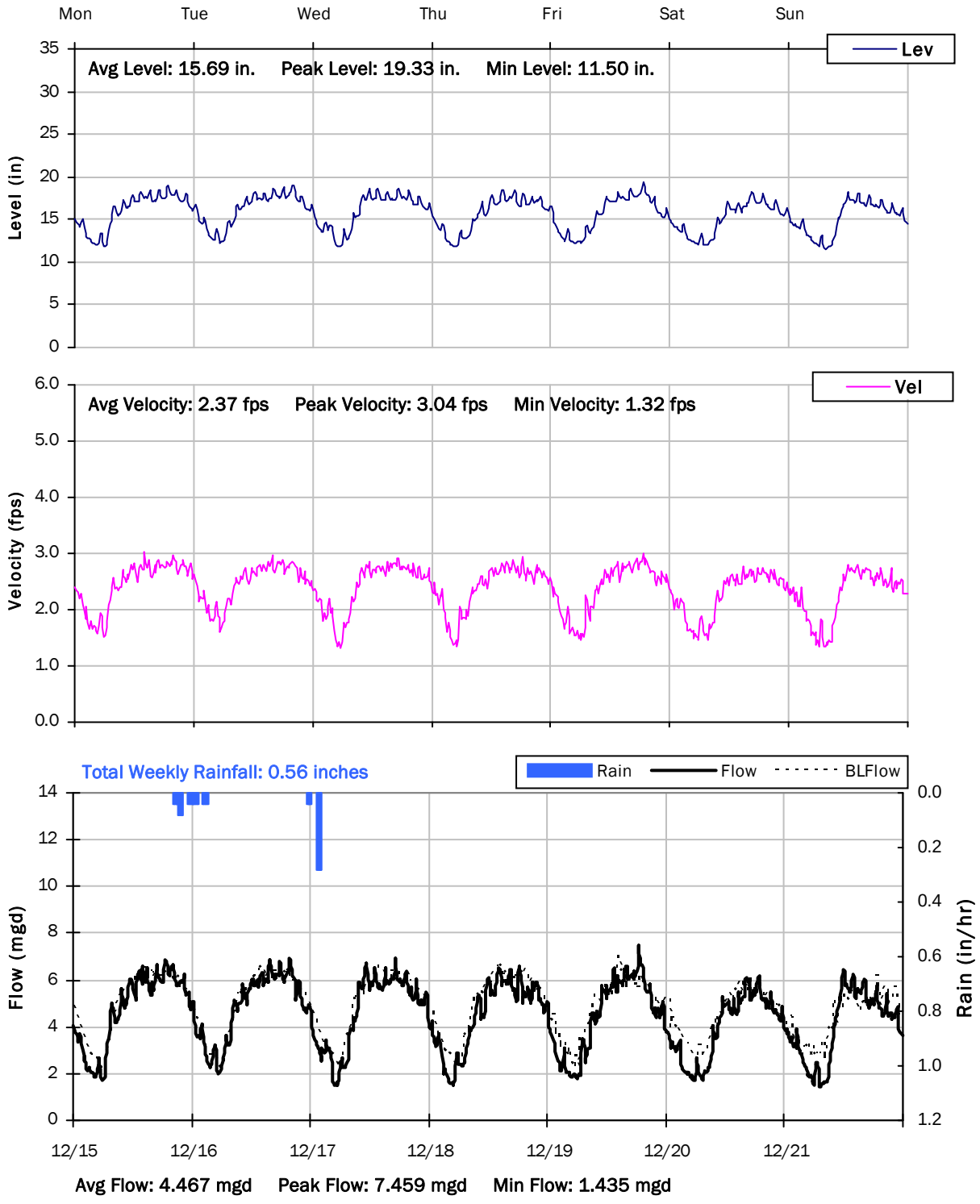
12/8/2014 to 12/15/2014



SITE 1

Weekly Level, Velocity and Flow Hydrographs

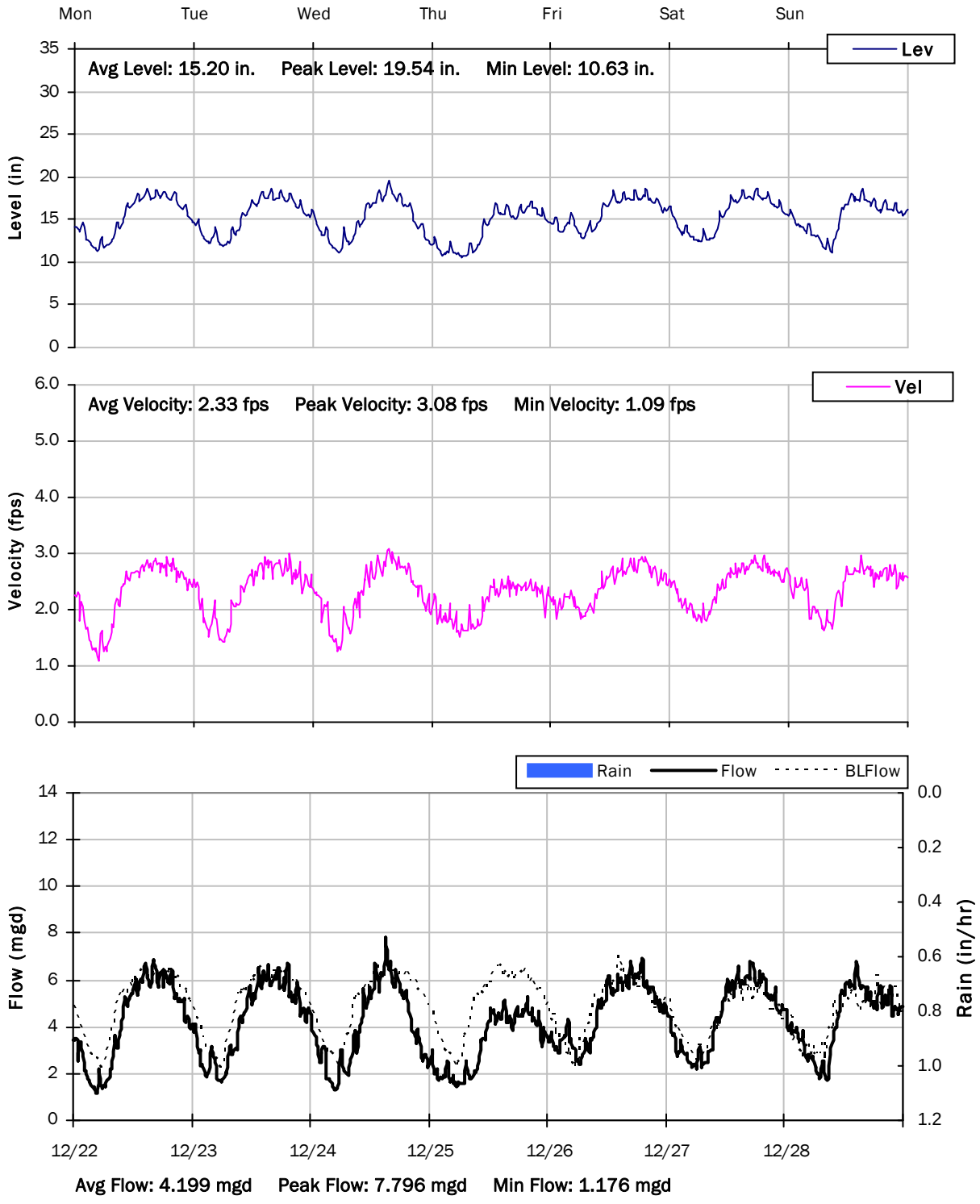
12/15/2014 to 12/22/2014



SITE 1

Weekly Level, Velocity and Flow Hydrographs

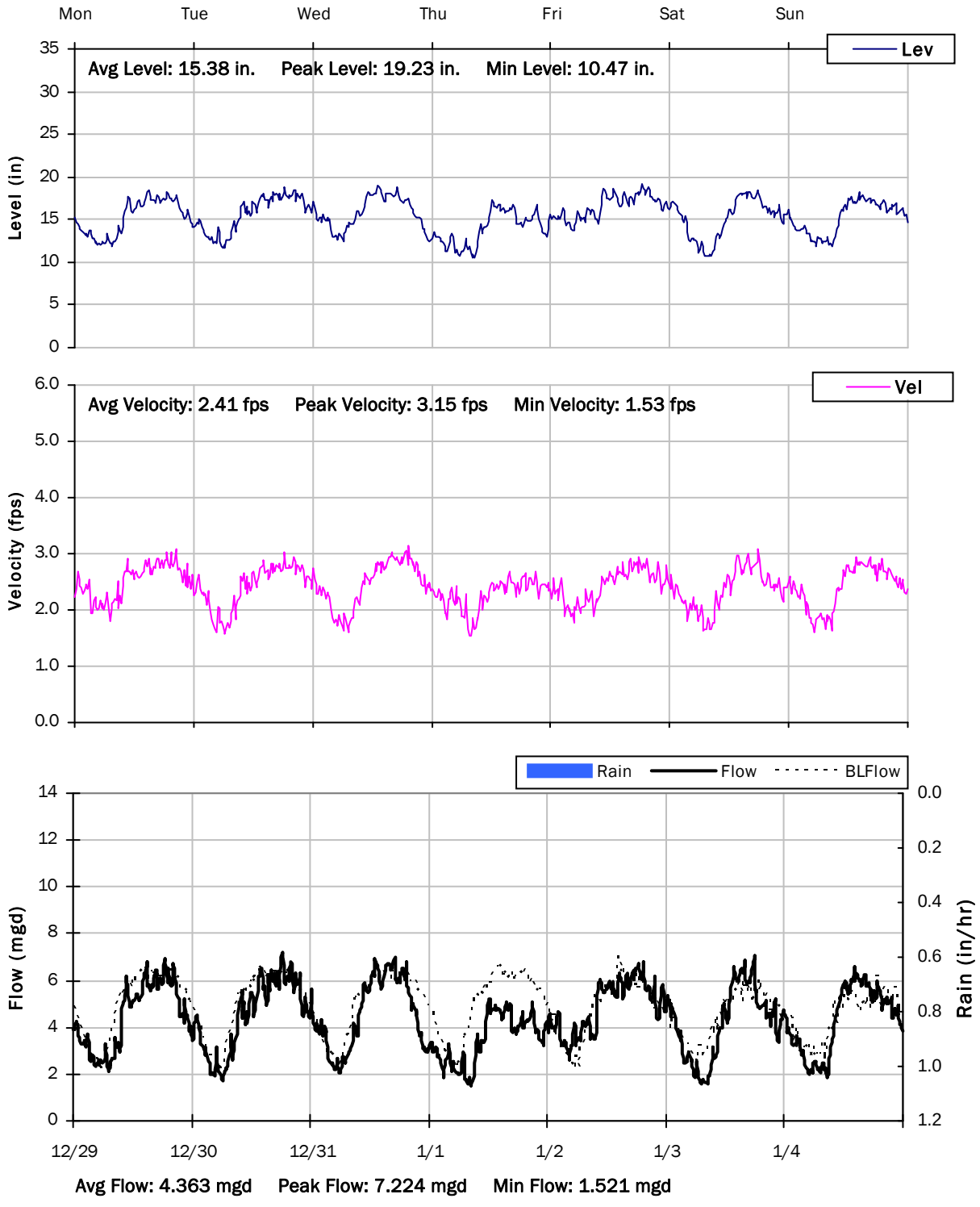
12/22/2014 to 12/29/2014



SITE 1

Weekly Level, Velocity and Flow Hydrographs

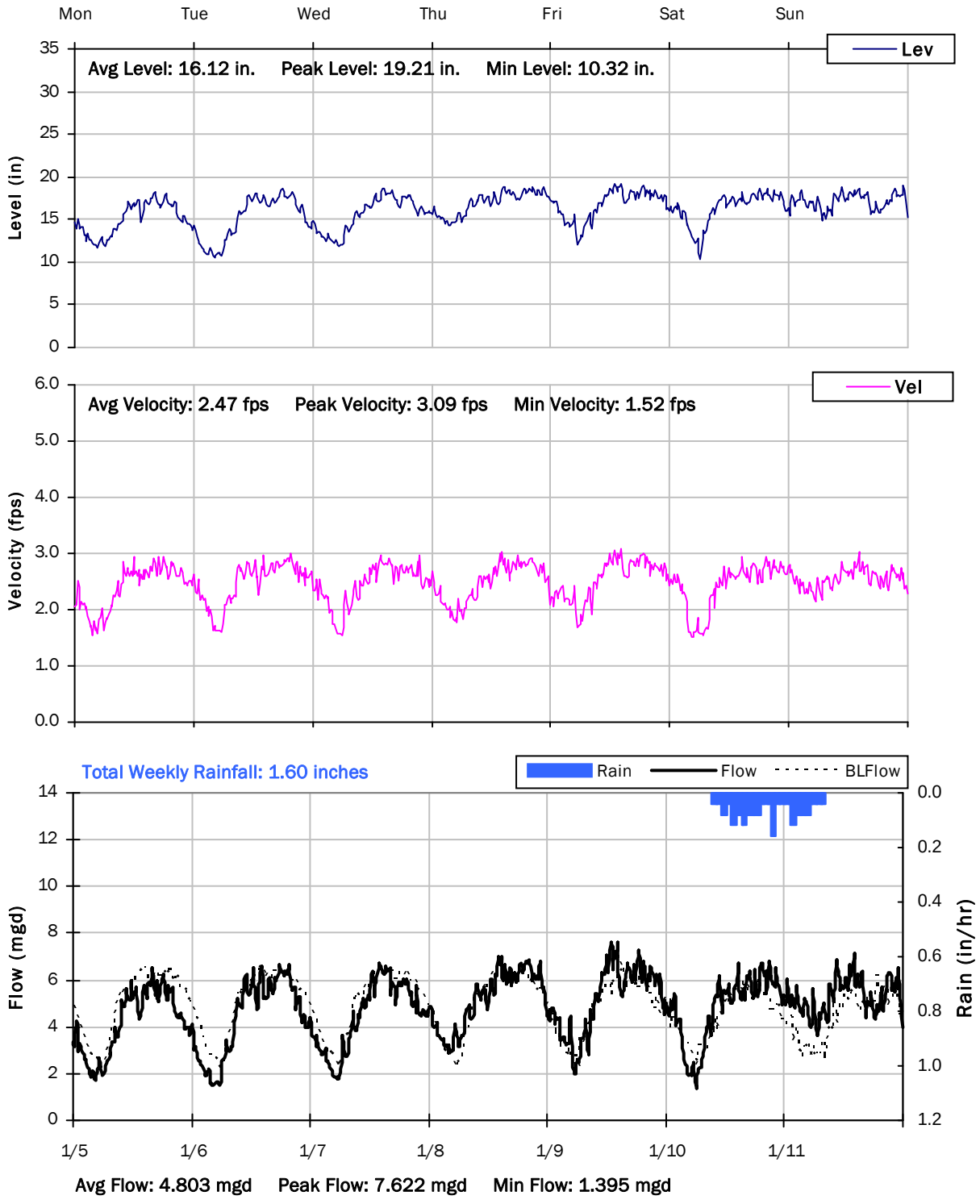
12/29/2014 to 1/5/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

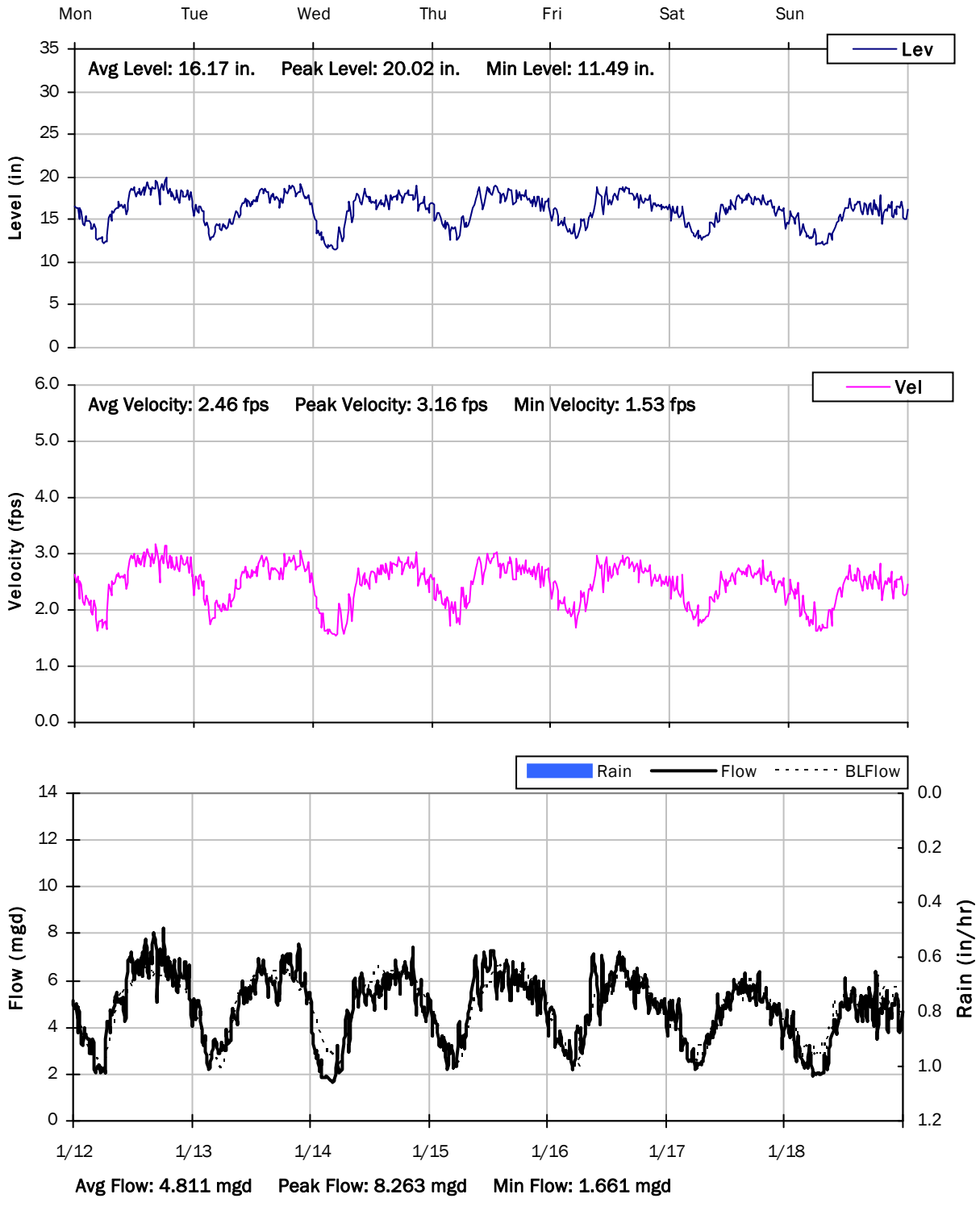
1/5/2015 to 1/12/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

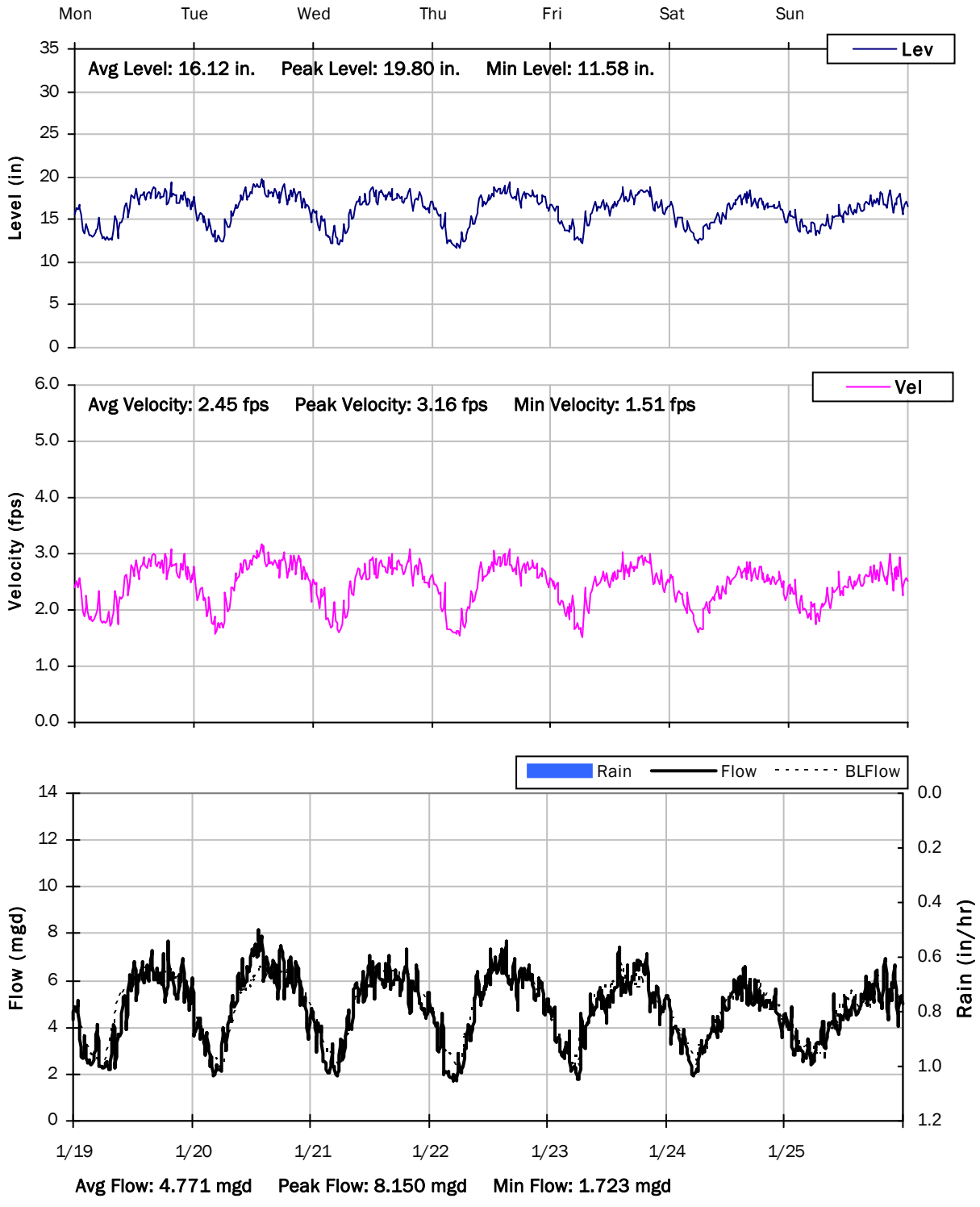
1/12/2015 to 1/19/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

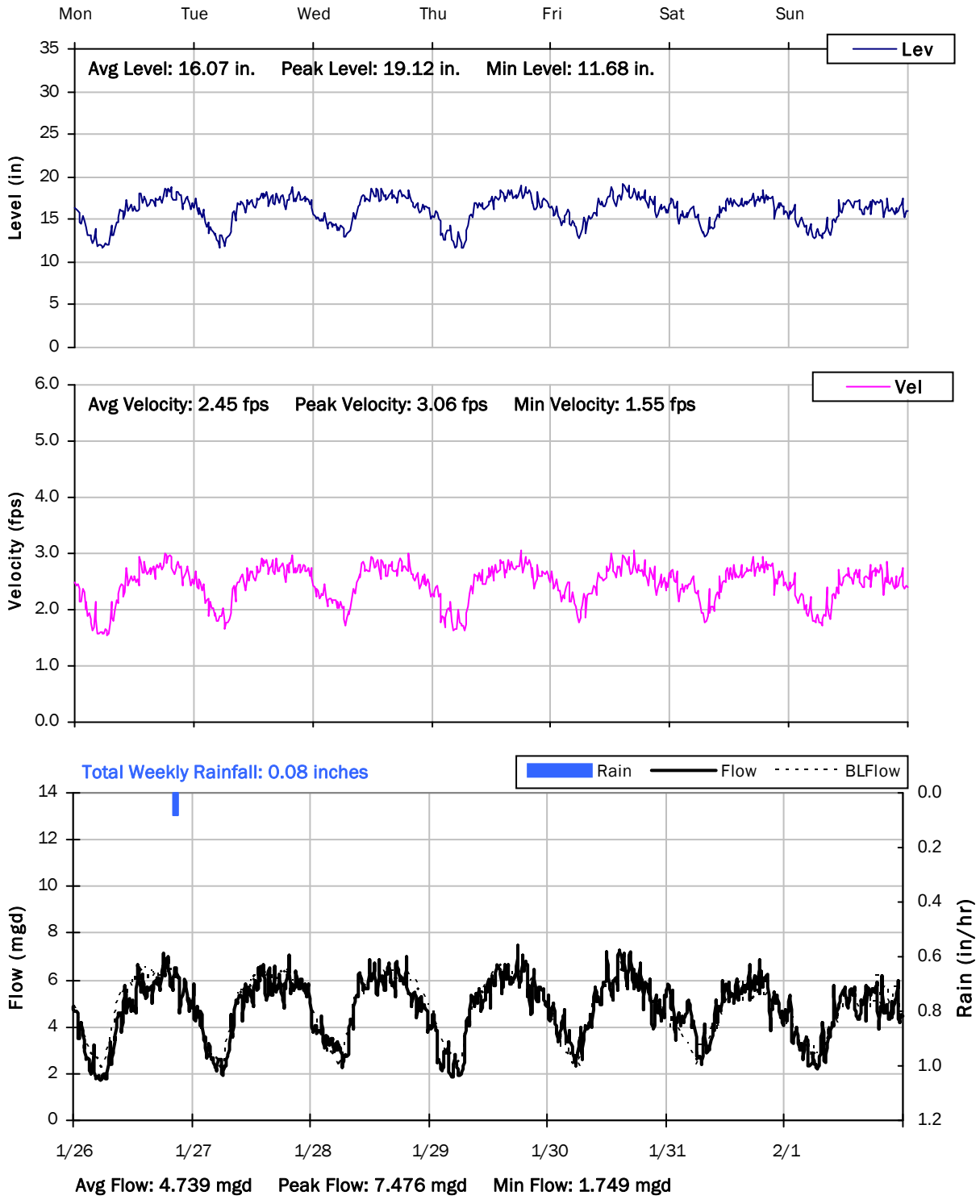
1/19/2015 to 1/26/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

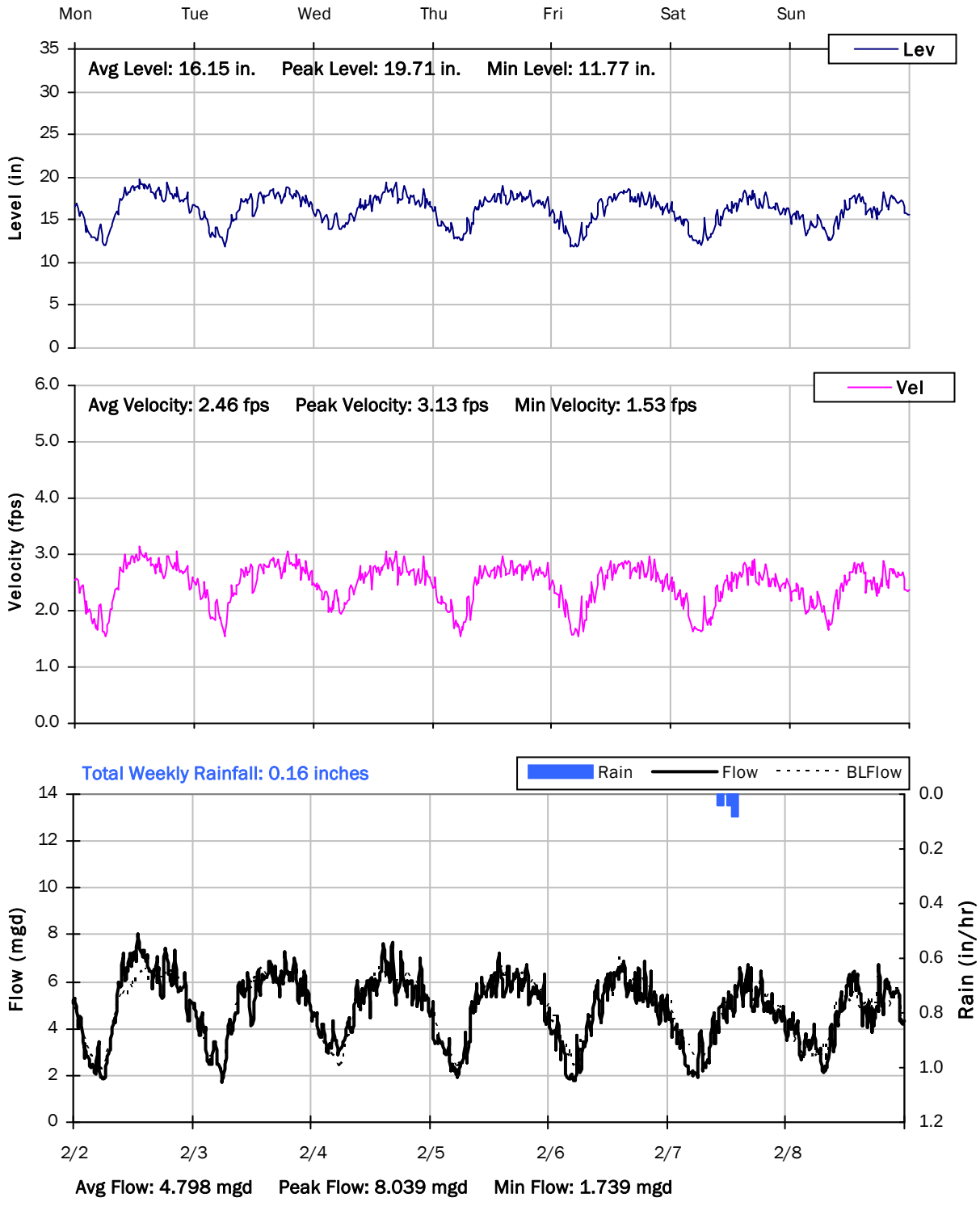
1/26/2015 to 2/2/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

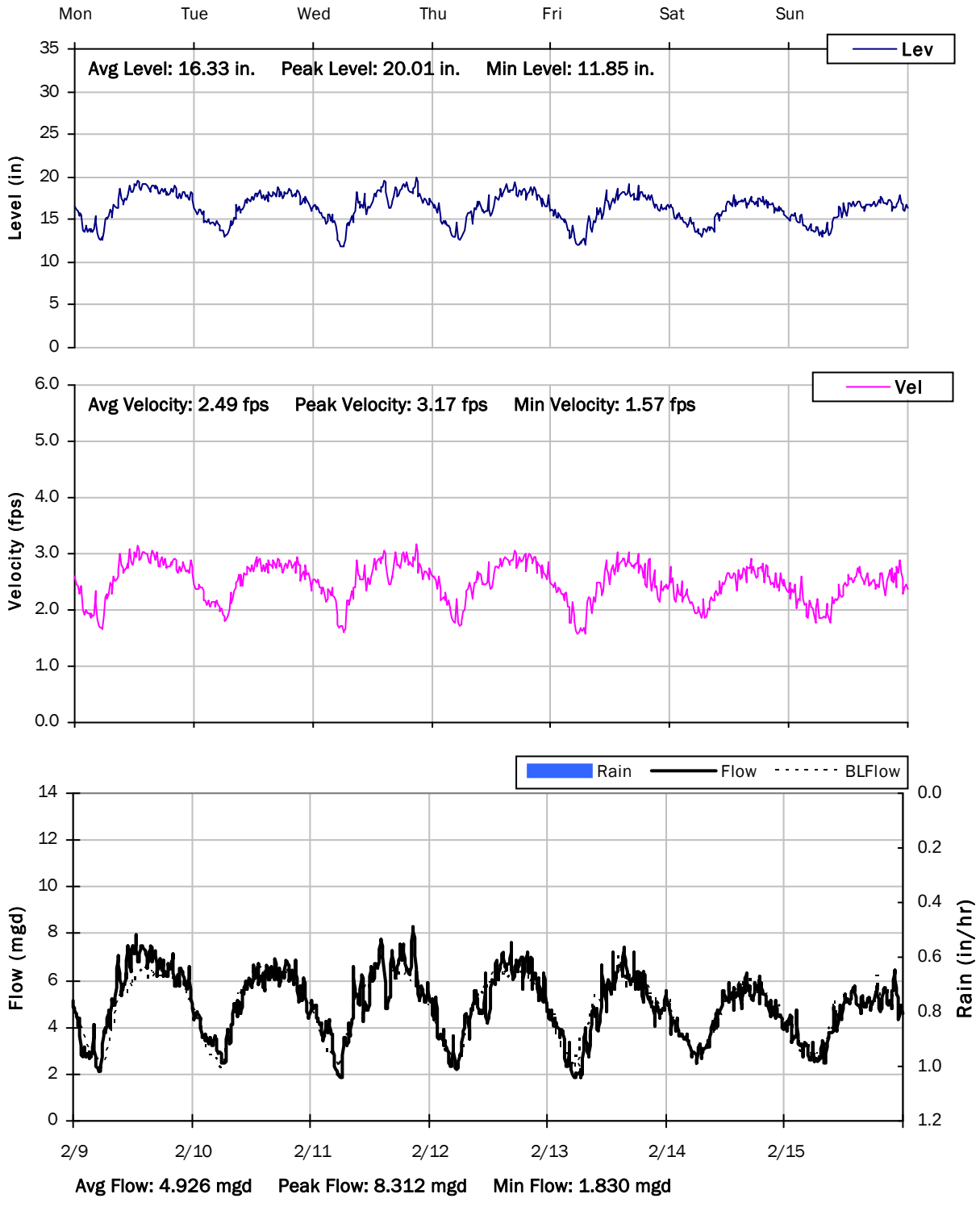
2/2/2015 to 2/9/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

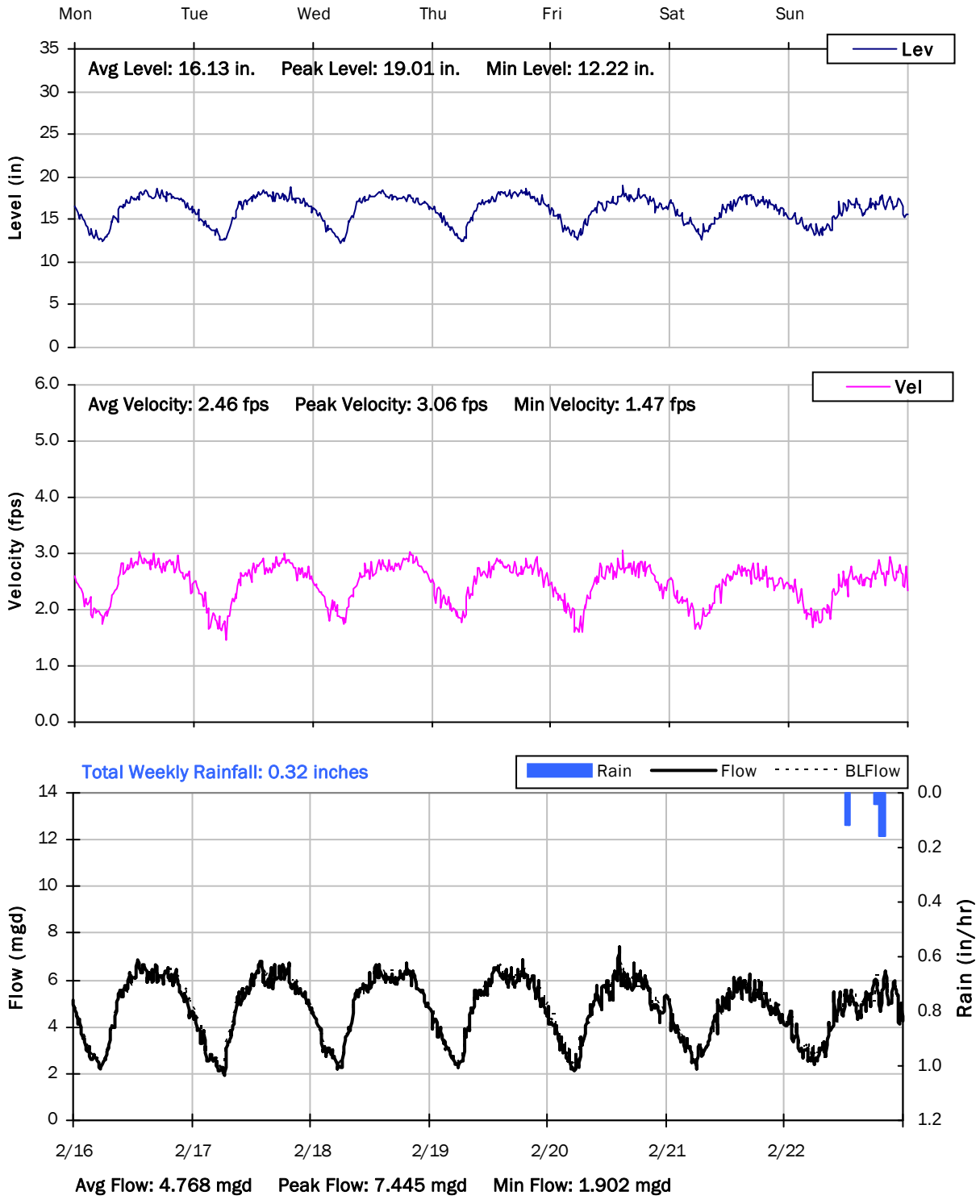
2/9/2015 to 2/16/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

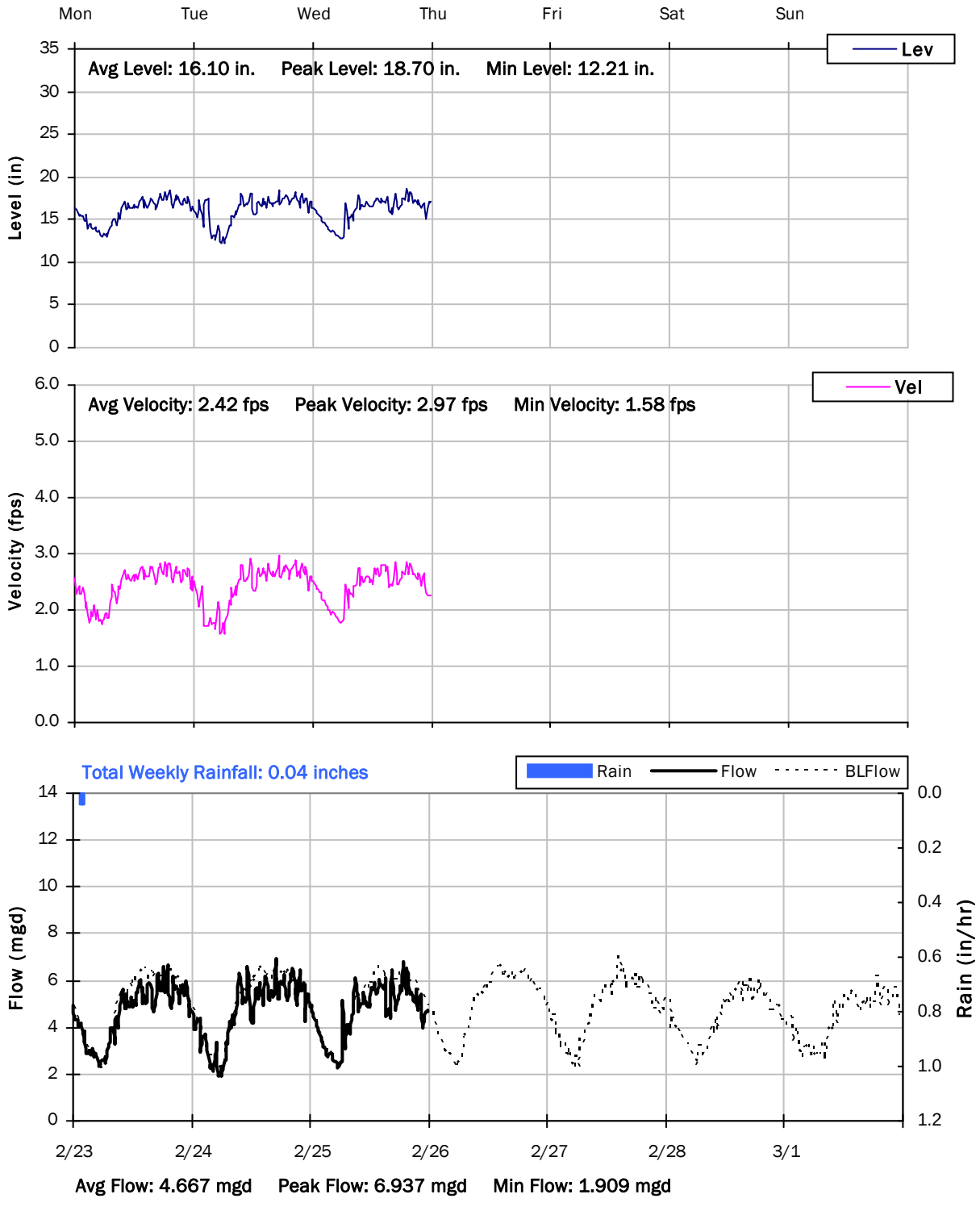
2/16/2015 to 2/23/2015



SITE 1

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

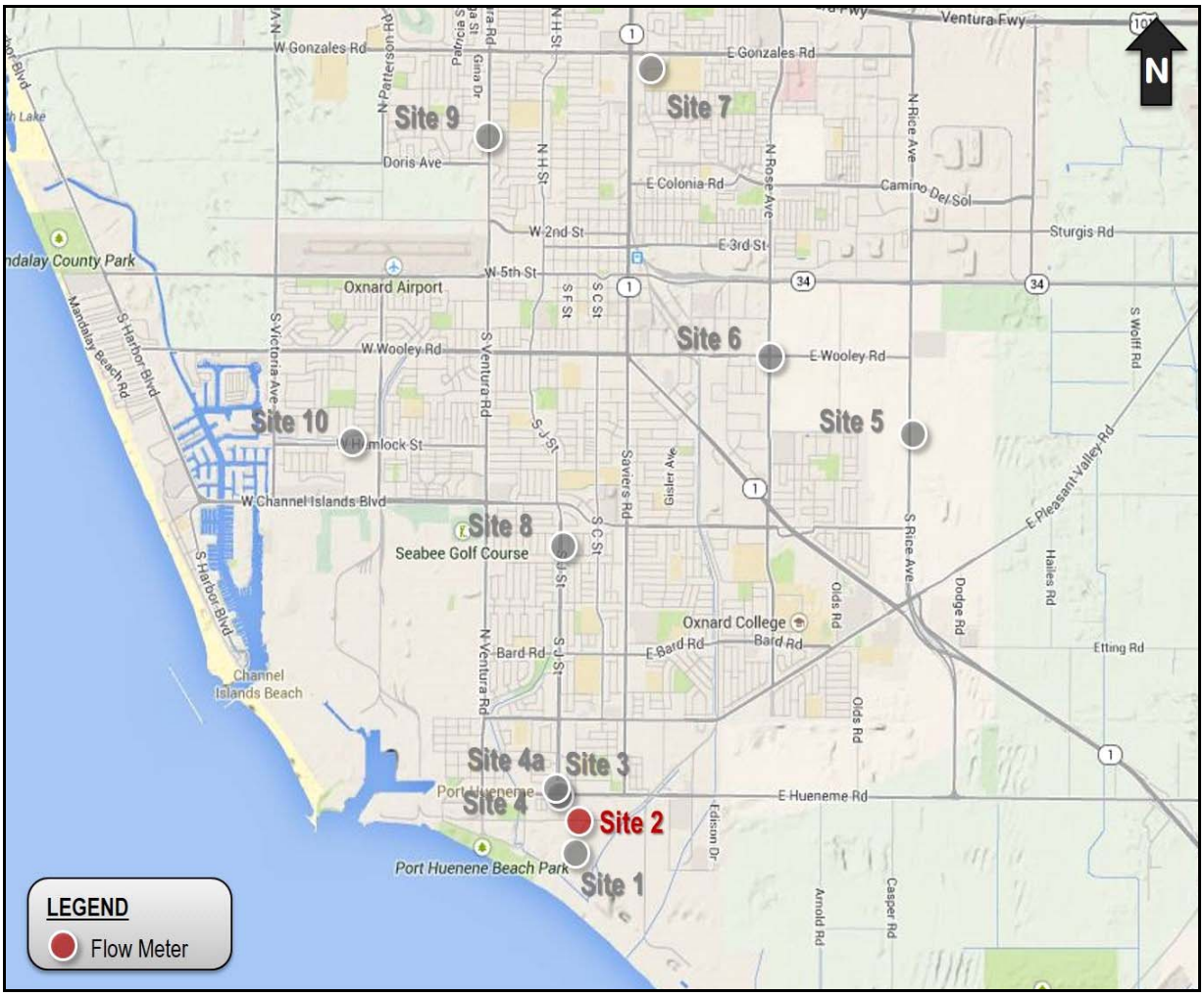
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 2

Location: Magellan Avenue

Data Summary Report



Vicinity Map: Site 2

SITE 2

Site Information

Location: Magellan Avenue

Coordinates: 119.1830° W, 34.1448° N

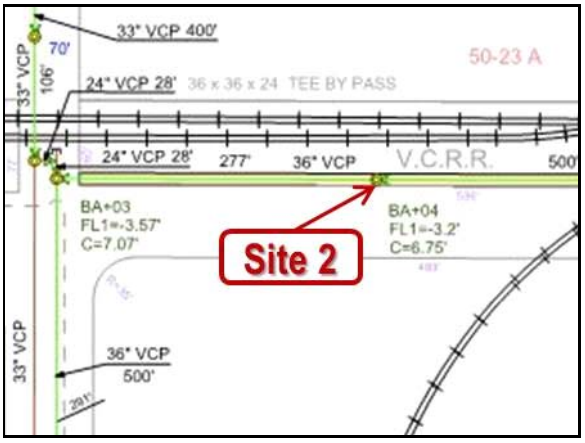
Rim Elevation: 13 feet

Pipe Diameter: 36 inches

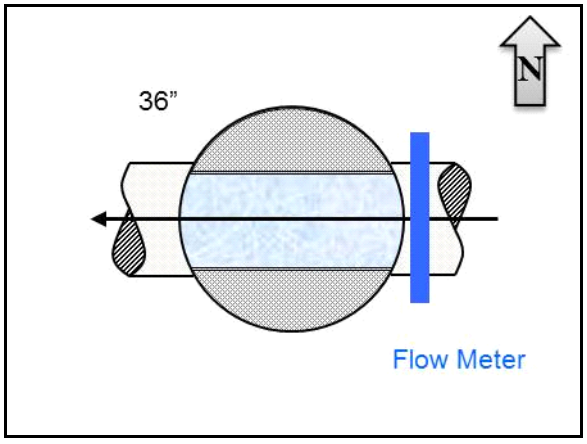
Baseline Flow: 2.194 mgd

Peak Measured Flow: 6.002 mgd

Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 2

Additional Site Photos

Effluent Pipe

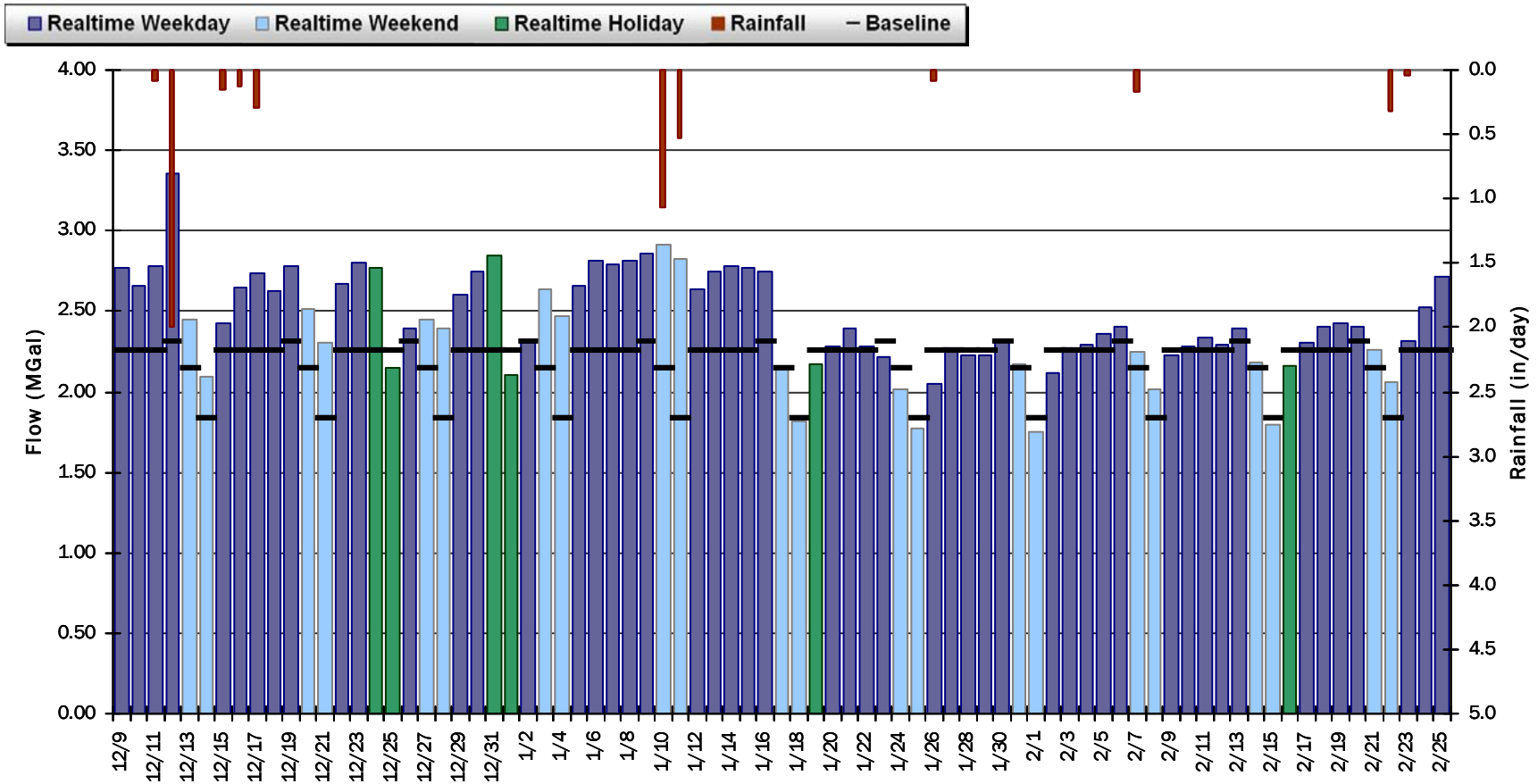
Influent Pipe

SITE 2

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 2.428 MGal **Peak Daily Flow: 3.359 MGal** **Min Daily Flow: 1.751 MGal**

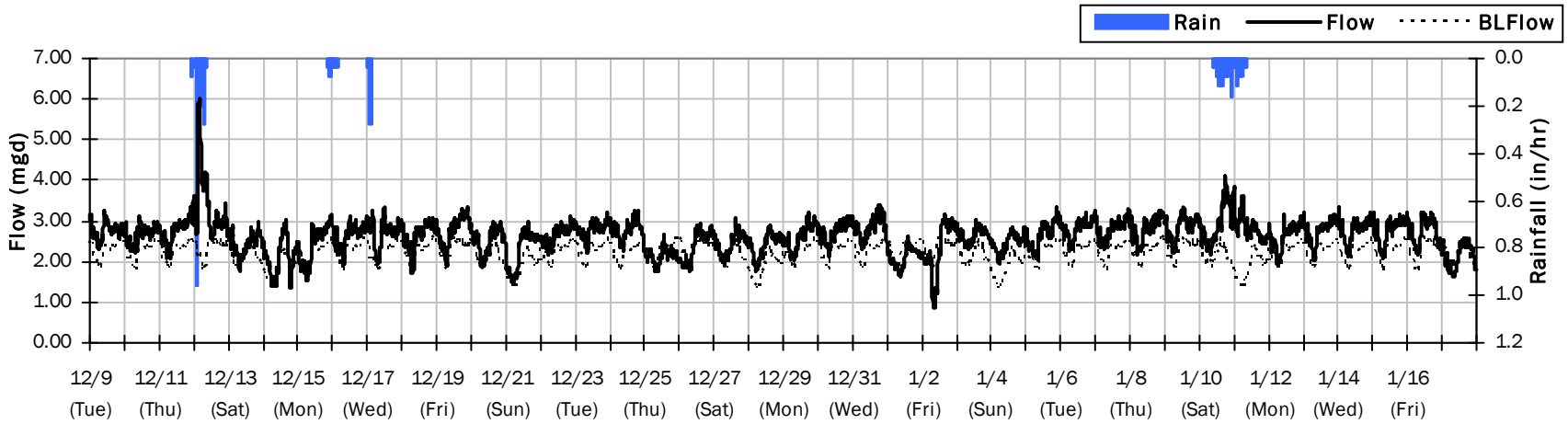
Total Period Rainfall: 4.84 inches

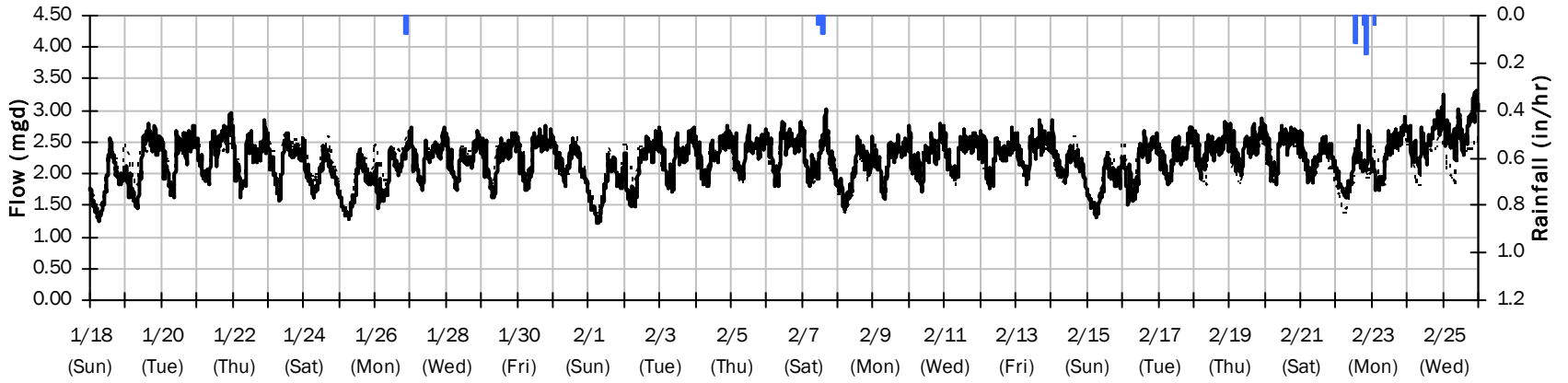


SITE 2

Flow Summary: 12/9/2014 to 2/25/2015

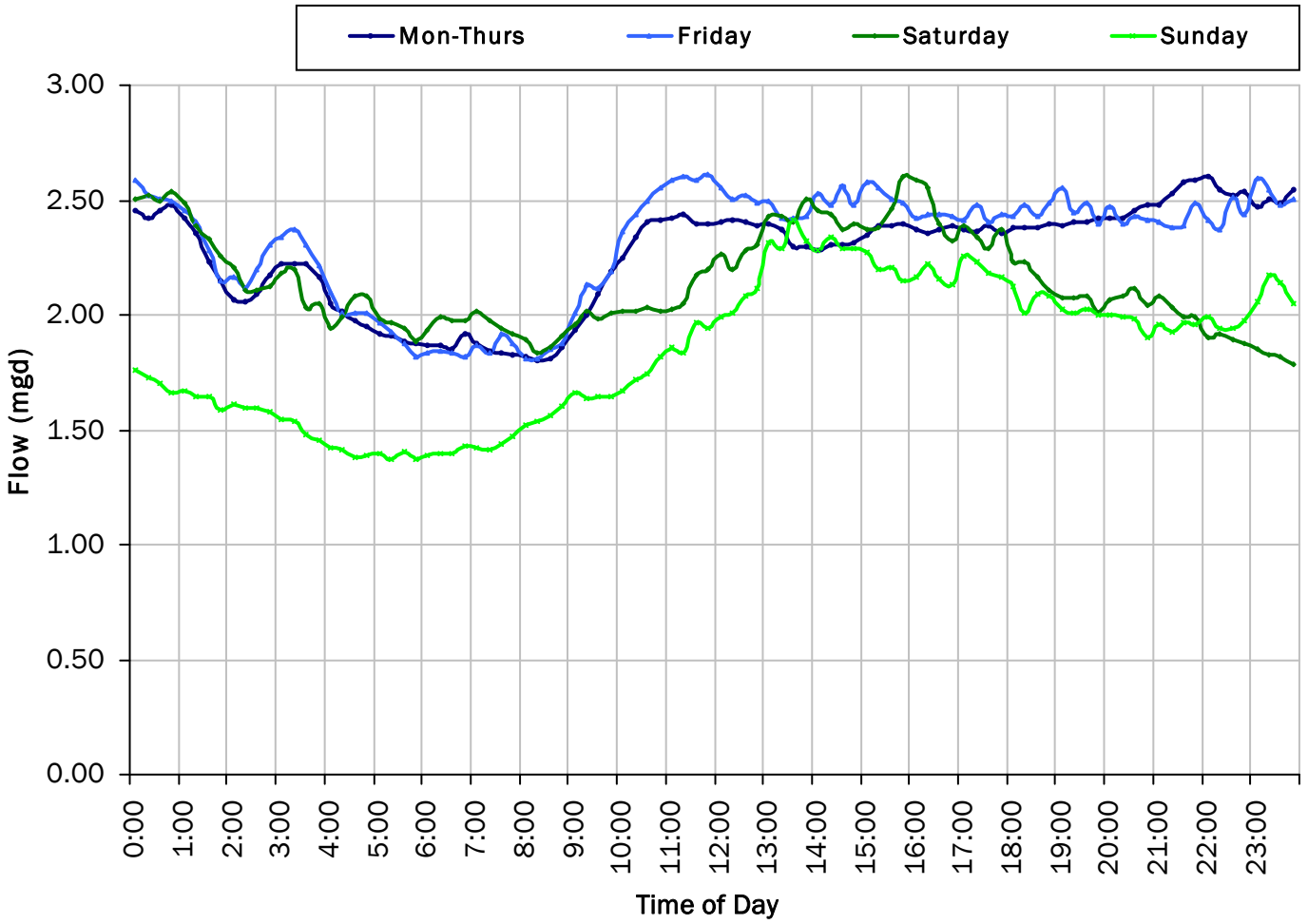
Total Period Rainfall: 4.84 inches Avg Flow: 2.428 mgd Peak Flow: 6.002 mgd Min Flow: 0.853 mgd





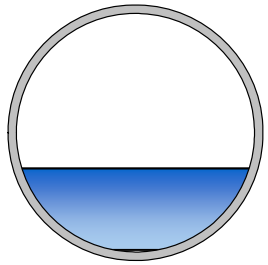
SITE 2

Baseline Flow Hydrographs



Baseline Flow:

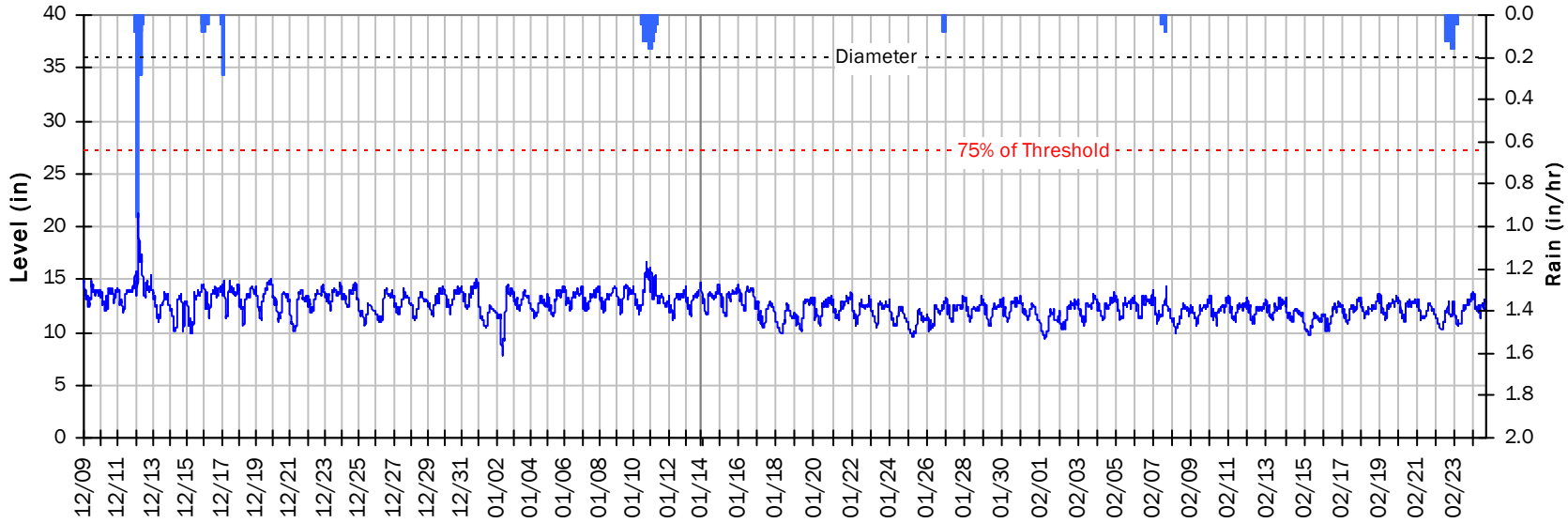
2.19 *mgd*

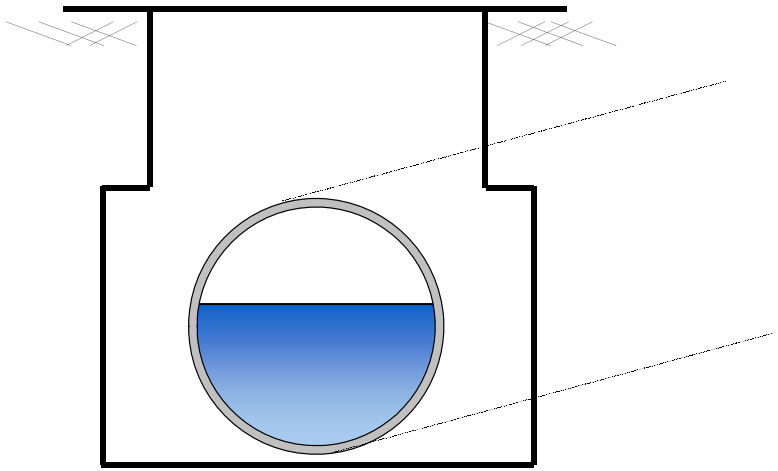


SITE 2

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

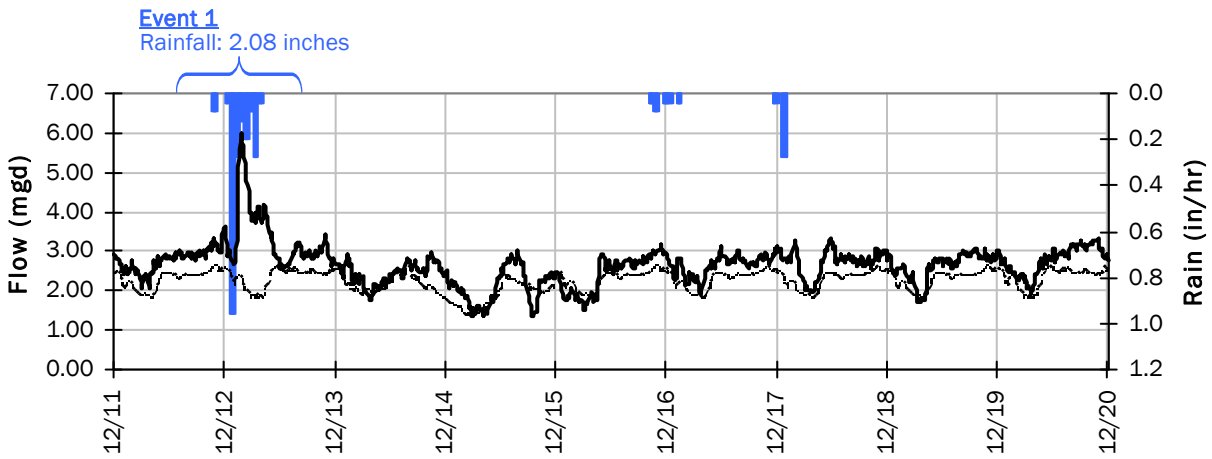




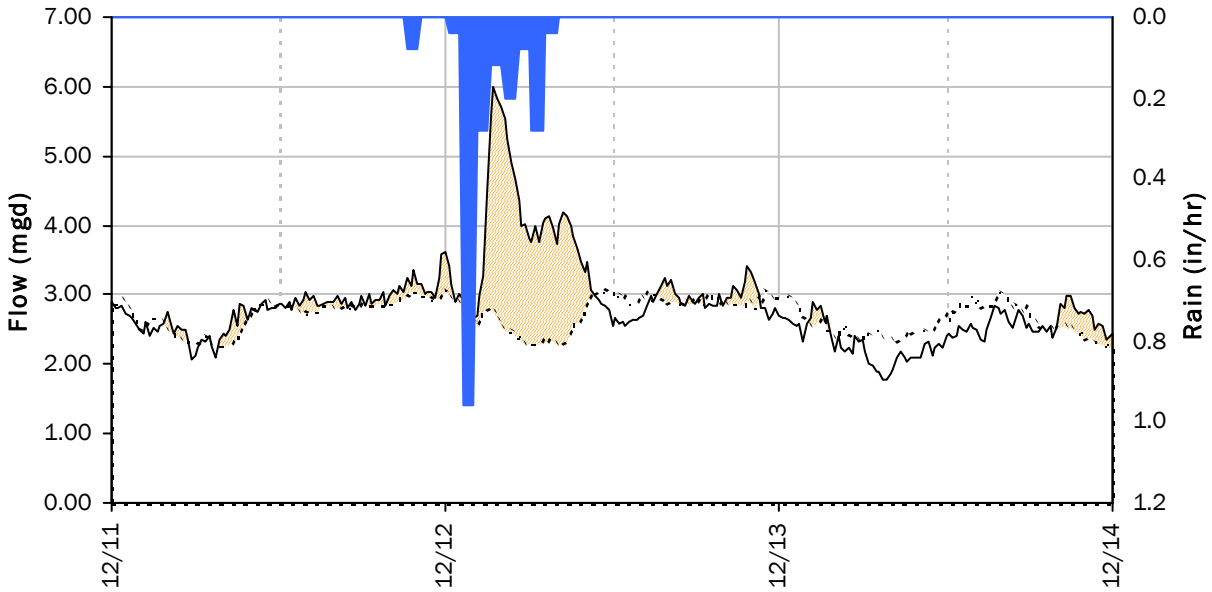
Pipe Diameter:	36	*inches*
Peak Measured Level:	21.2	*inches*
Peak d/D Ratio:	0.59	

SITE 2
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

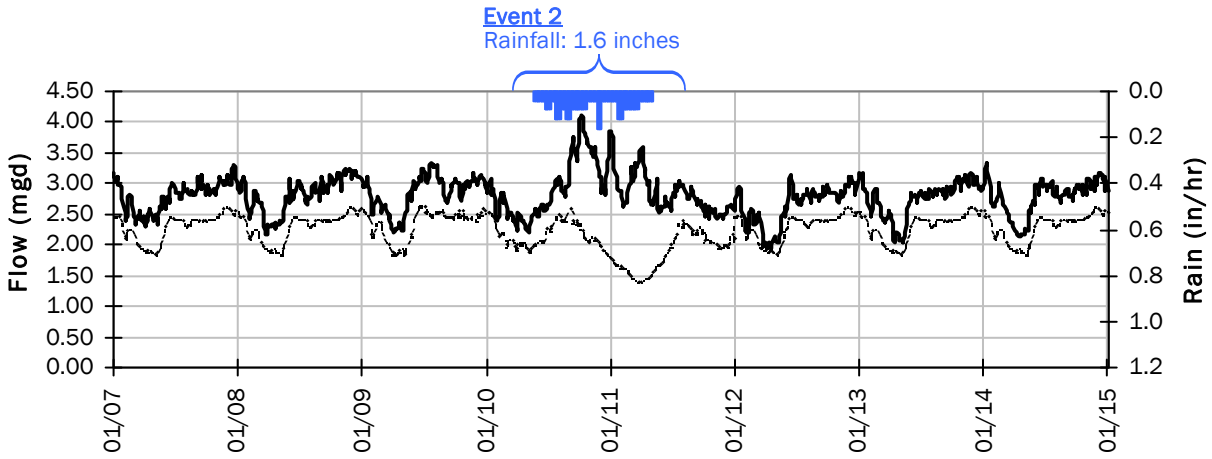


Storm Event I/I Analysis (Rain = 2.08 inches)

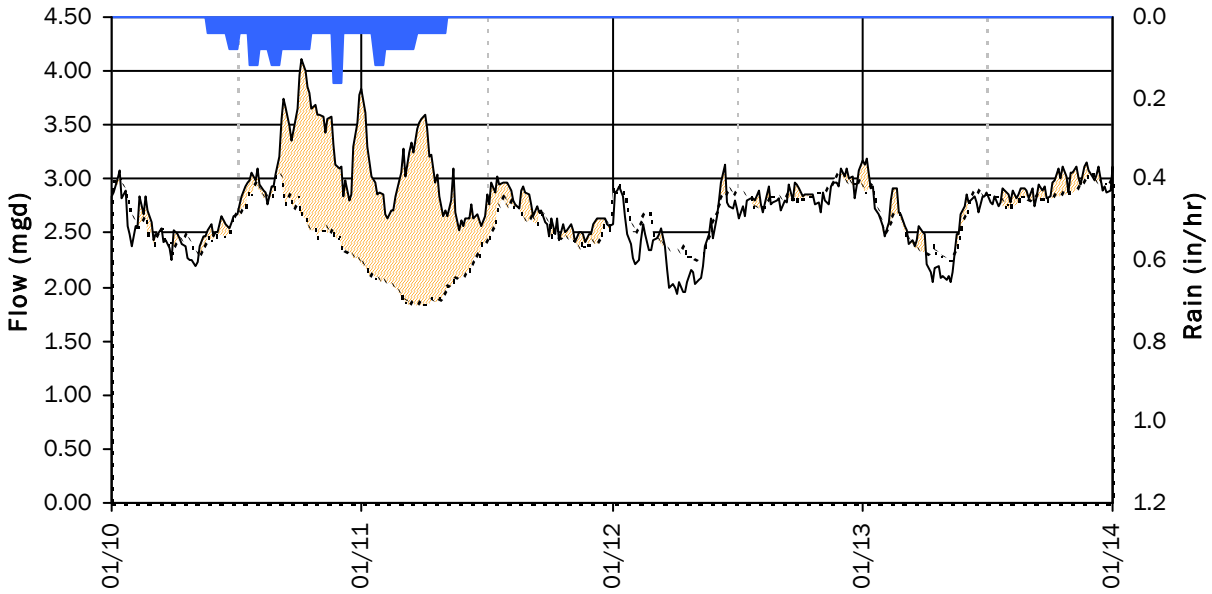
Capacity		Inflow / Infiltration	
Peak Flow:	6.00 *mgd*	**Peak I/I Rate:**	3.24 *mgd*
PF:	2.74	**Total I/I:**	460,000 *gallons*
Peak Level:	21.16 *in*		
d/D Ratio:	0.59		

SITE 2
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



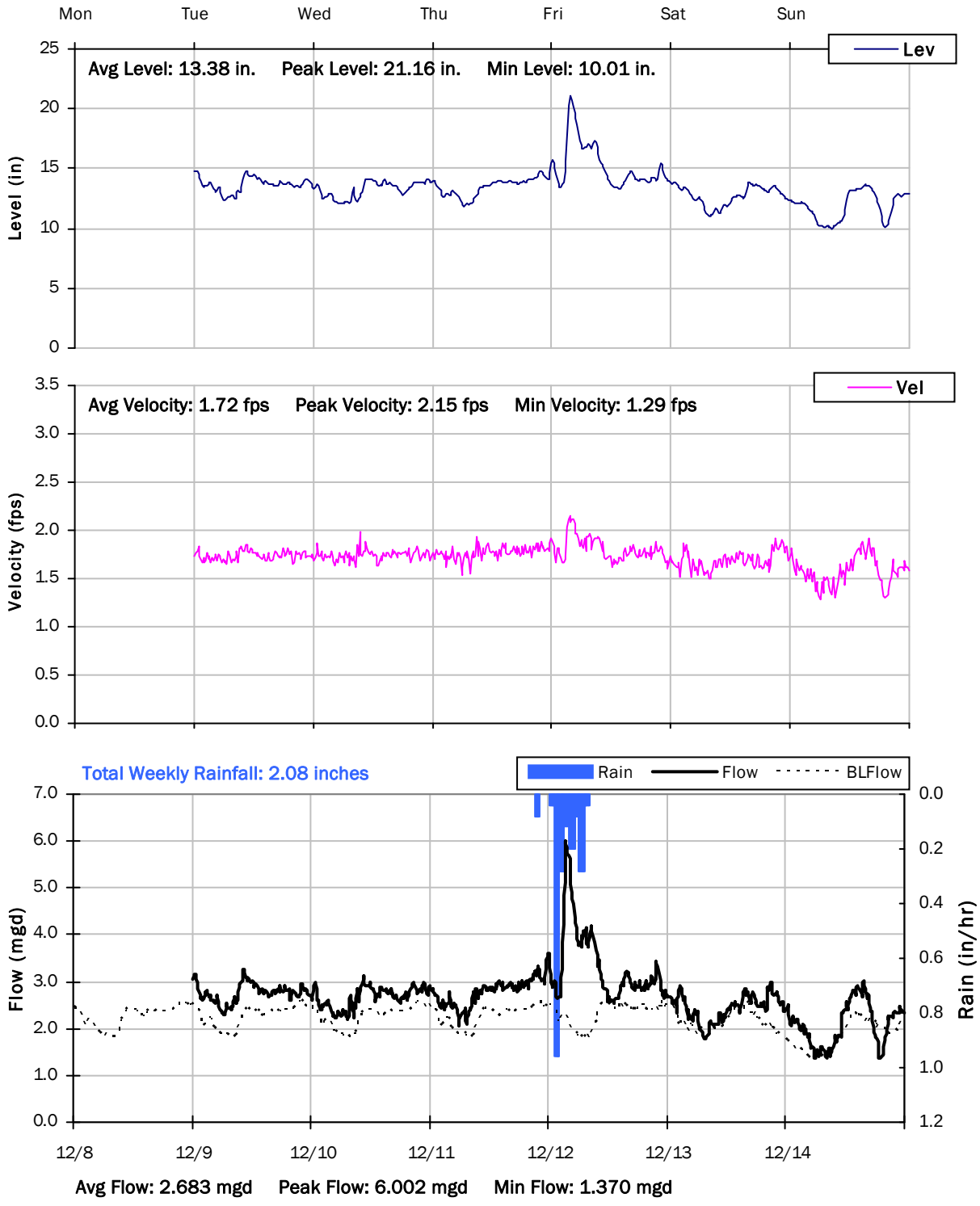
Storm Event I/I Analysis (Rain = 1.60 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	4.11 *mgd*	**Peak I/I Rate:**	1.76 *mgd*
PF:	1.87	**Total I/I:**	788,000 *gallons*
Peak Level:	16.68 *in*		
d/D Ratio:	0.46		

SITE 2

Weekly Level, Velocity and Flow Hydrographs

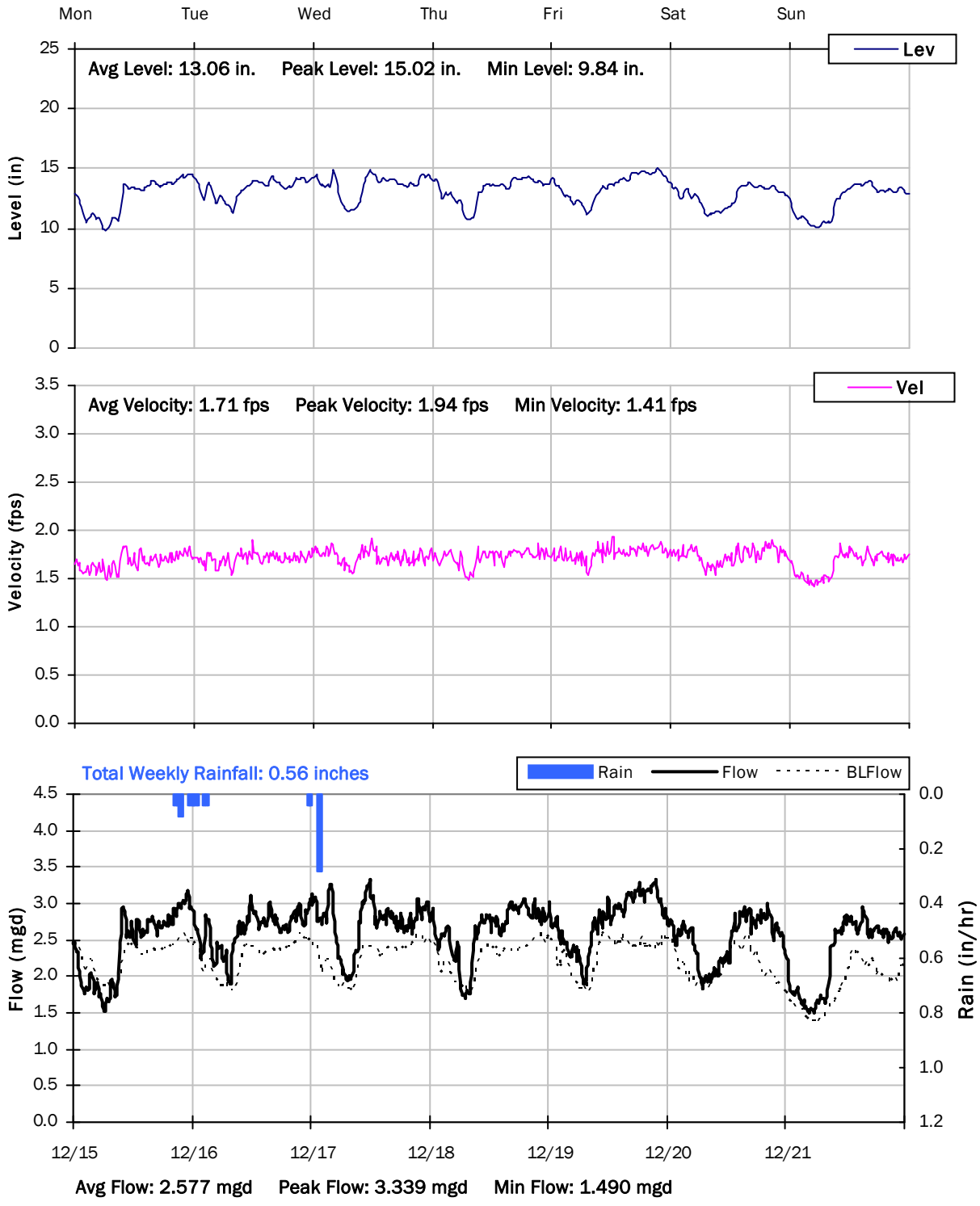
12/8/2014 to 12/15/2014



SITE 2

Weekly Level, Velocity and Flow Hydrographs

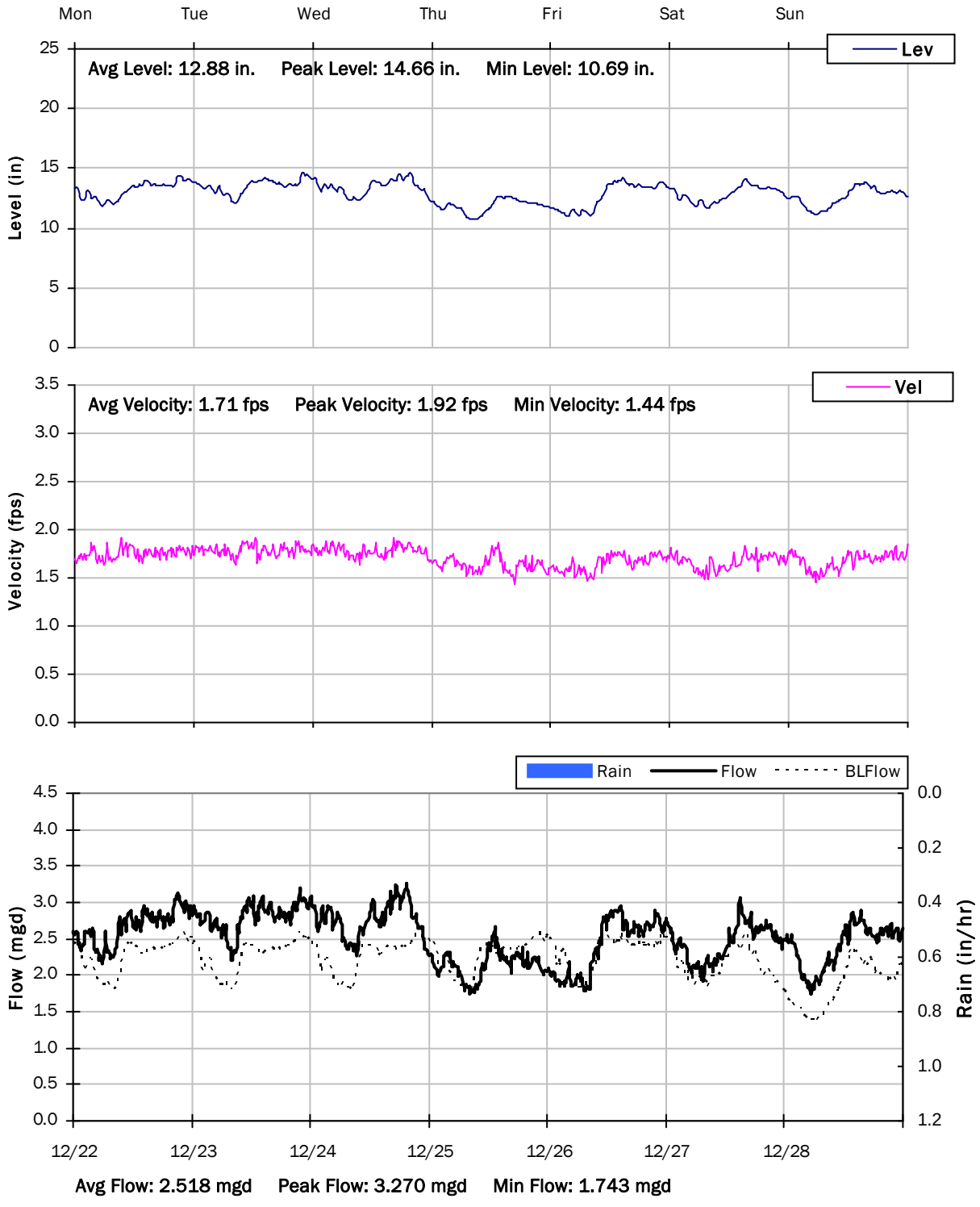
12/15/2014 to 12/22/2014



SITE 2

Weekly Level, Velocity and Flow Hydrographs

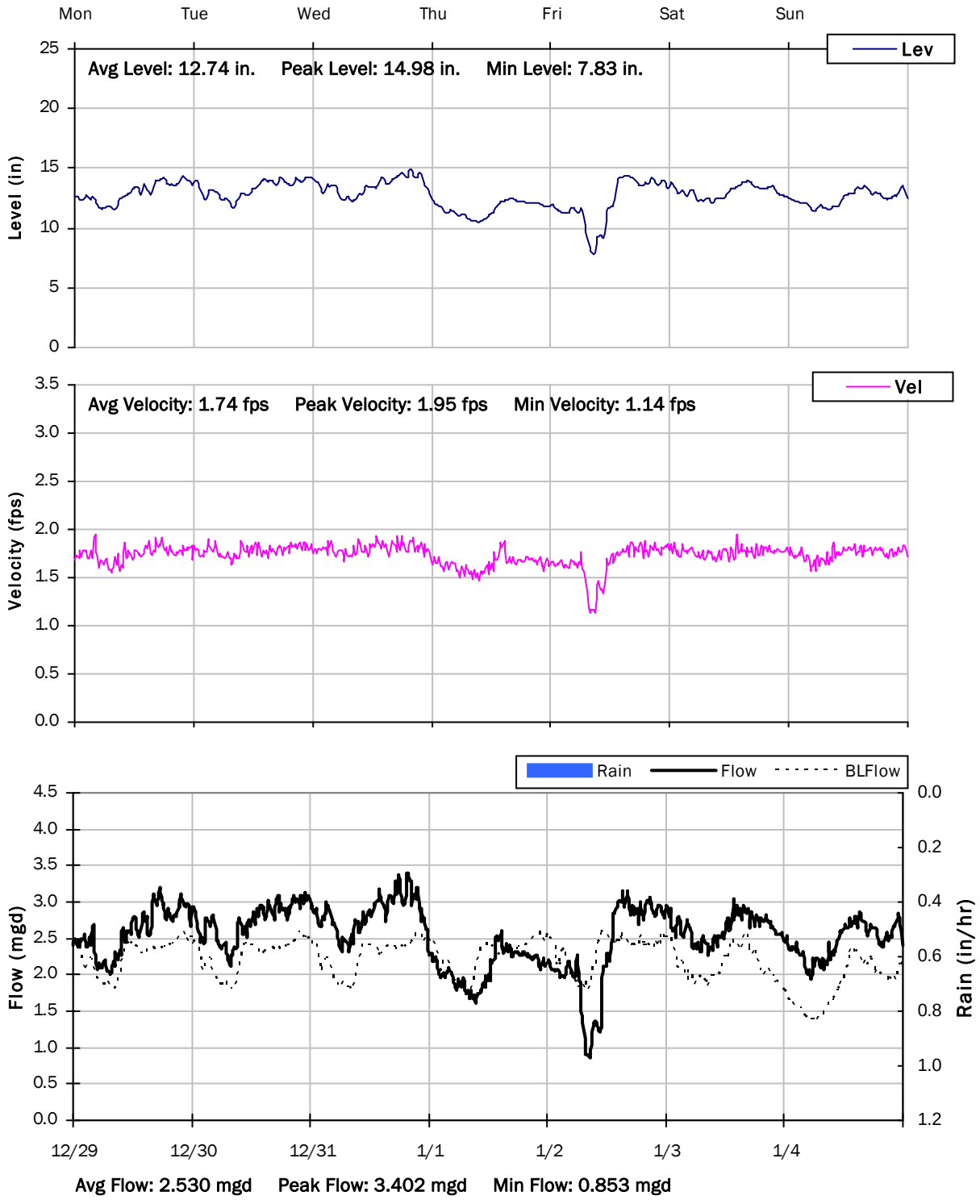
12/22/2014 to 12/29/2014



SITE 2

Weekly Level, Velocity and Flow Hydrographs

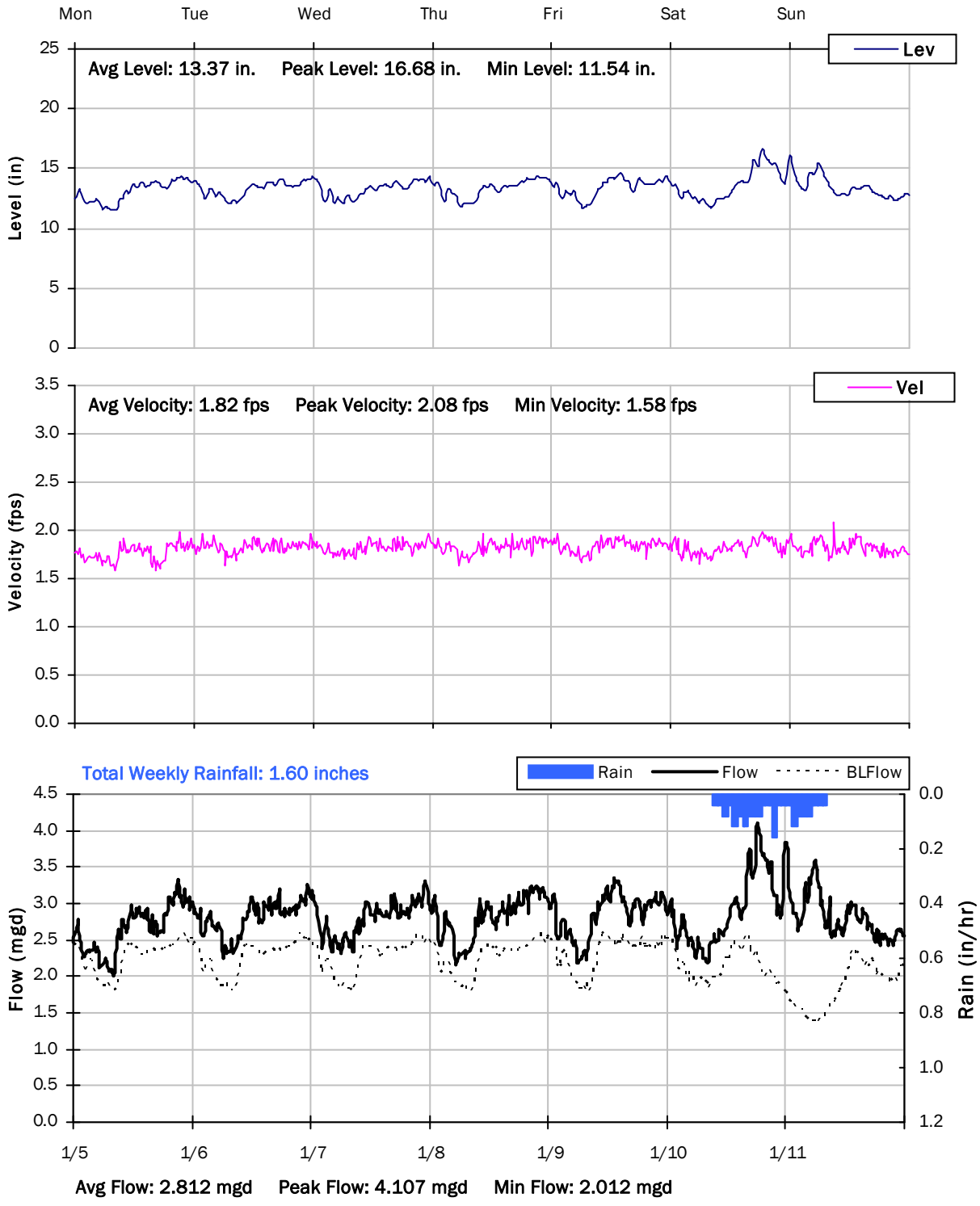
12/29/2014 to 1/5/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

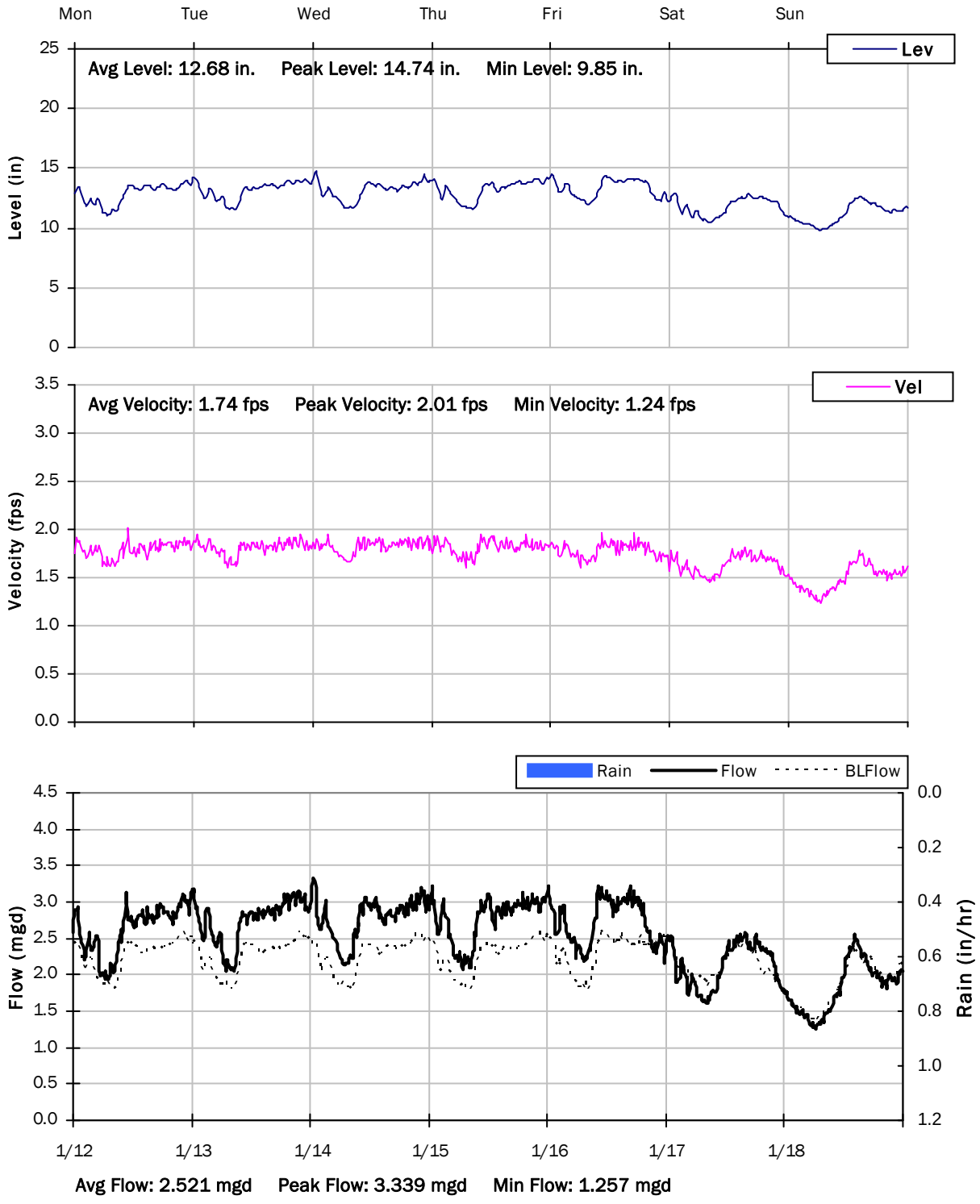
1/5/2015 to 1/12/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

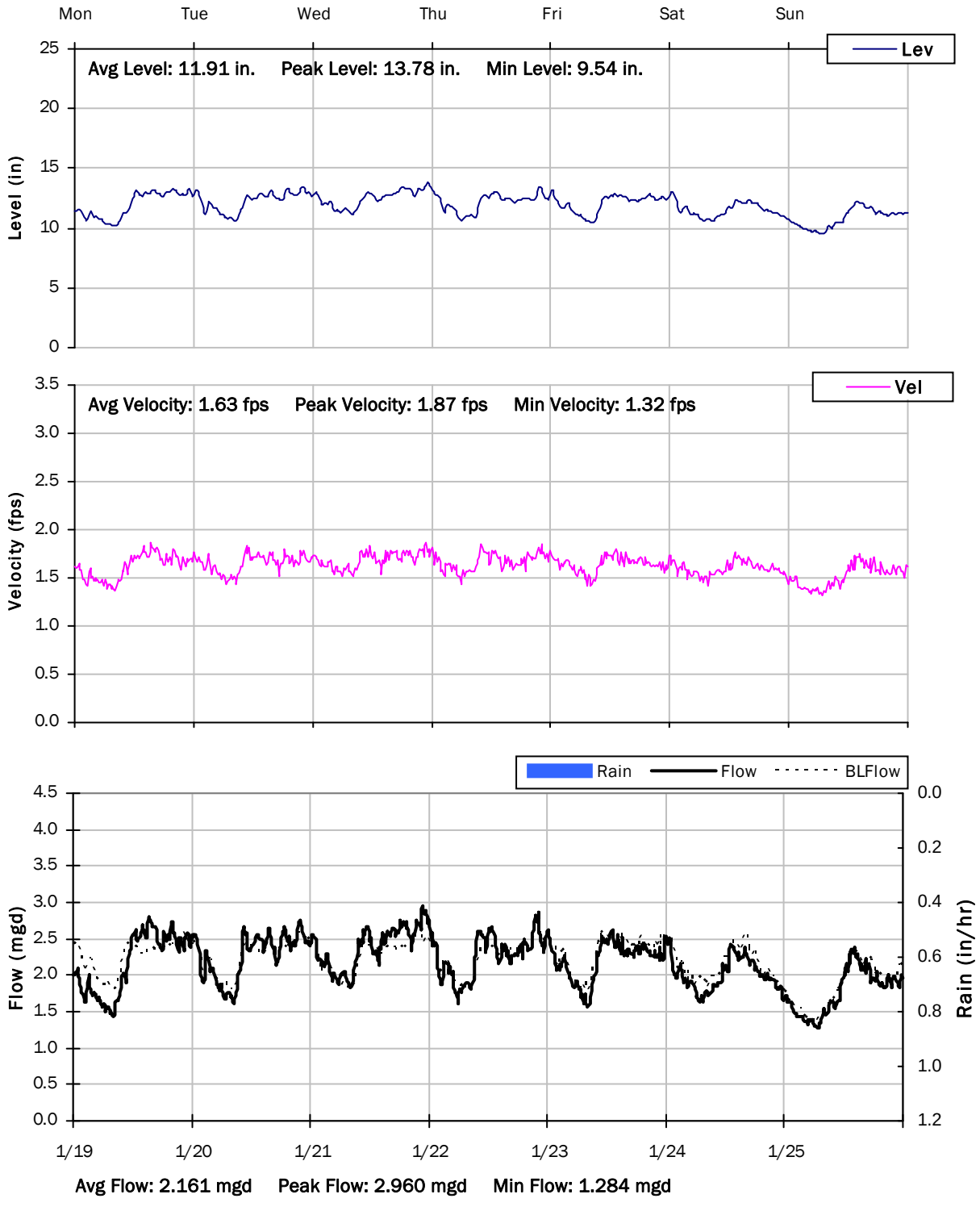
1/12/2015 to 1/19/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

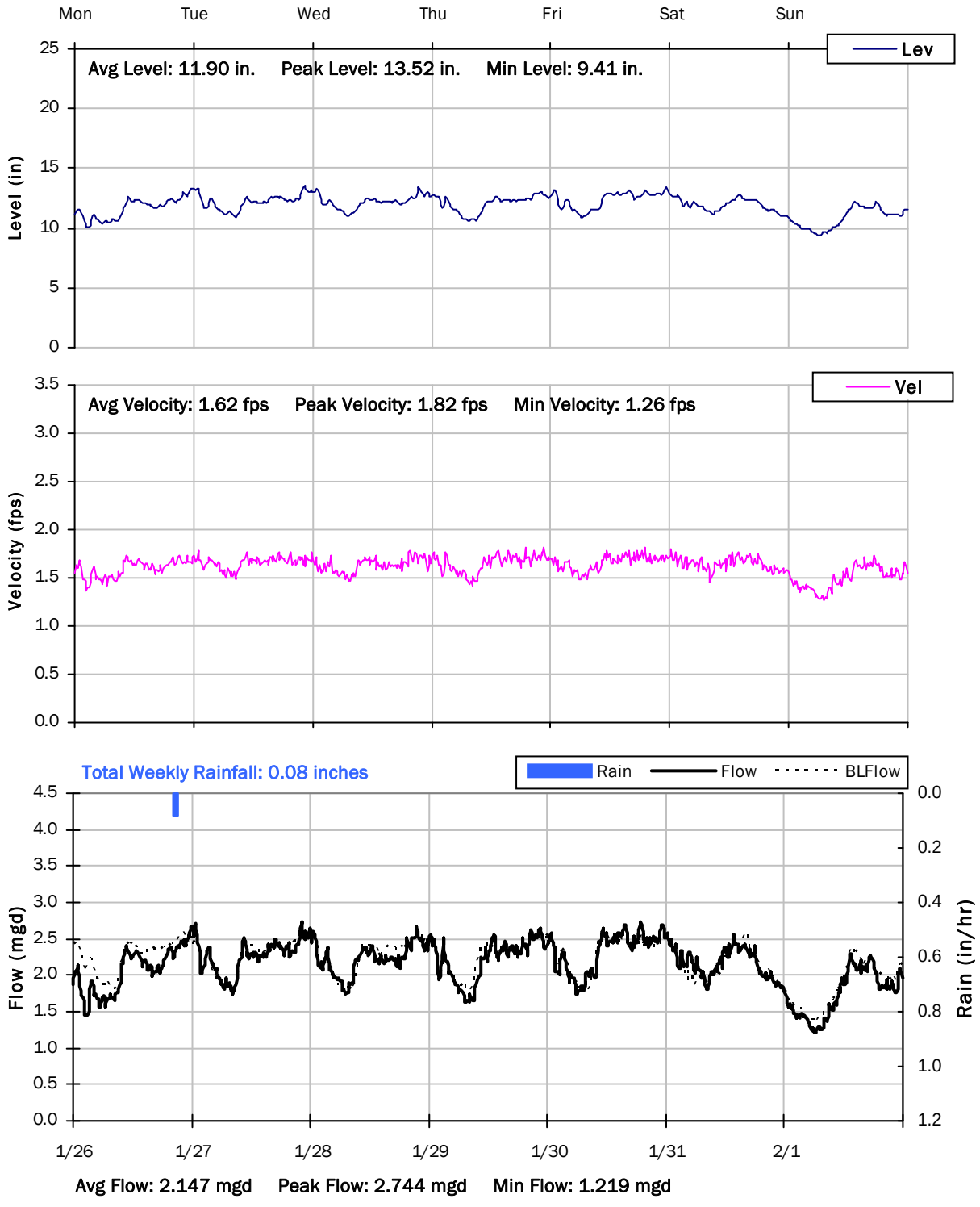
1/19/2015 to 1/26/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

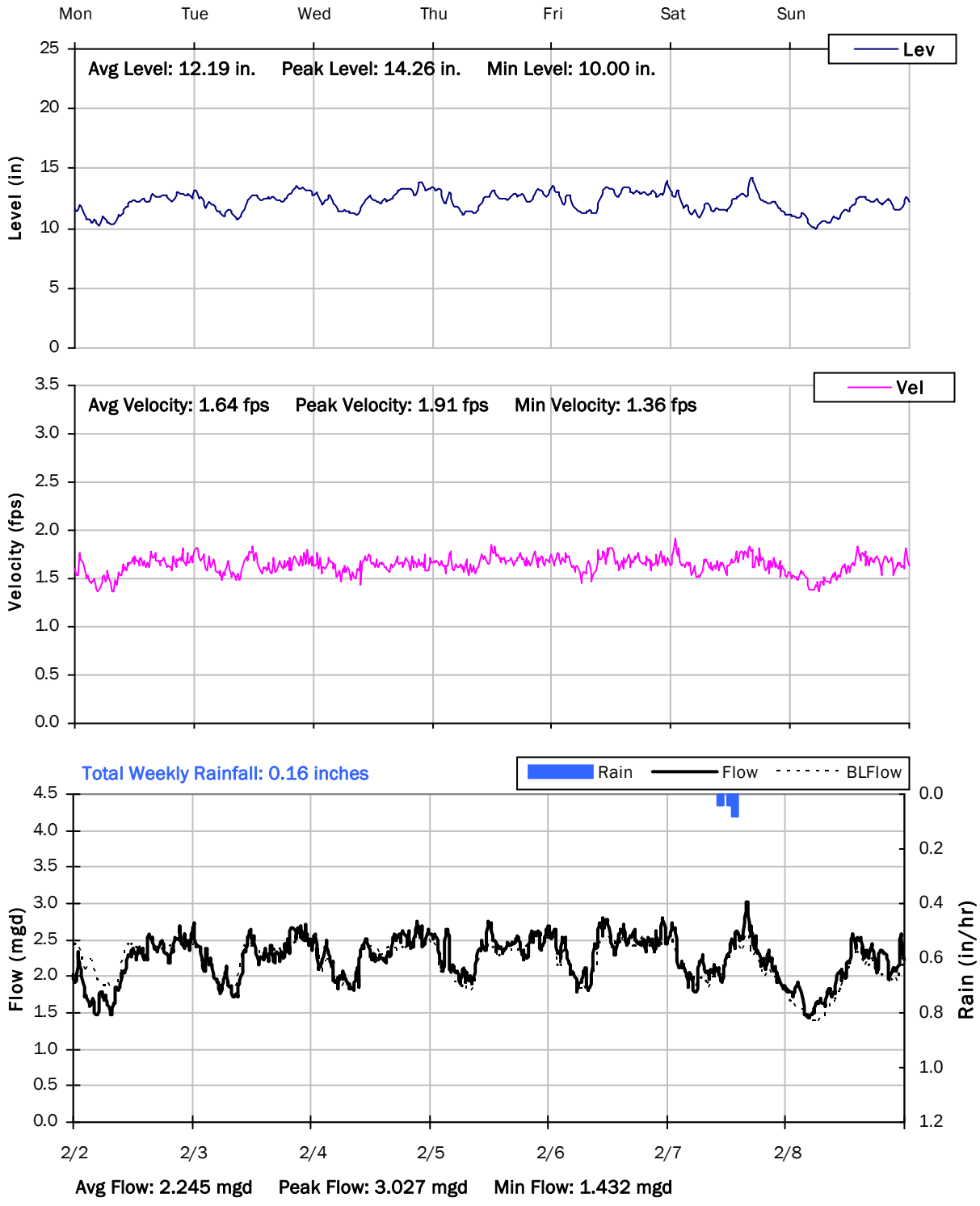
1/26/2015 to 2/2/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

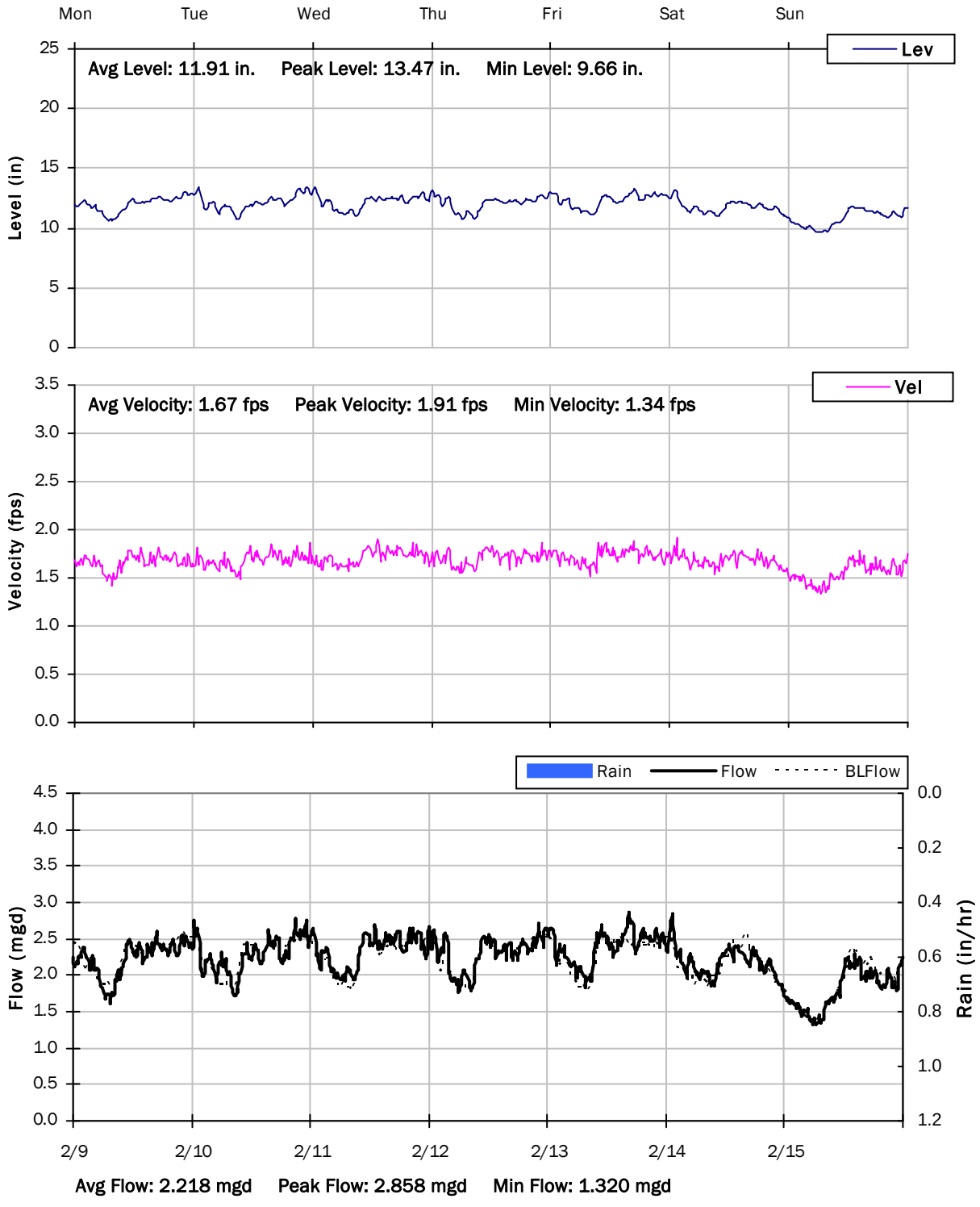
2/2/2015 to 2/9/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

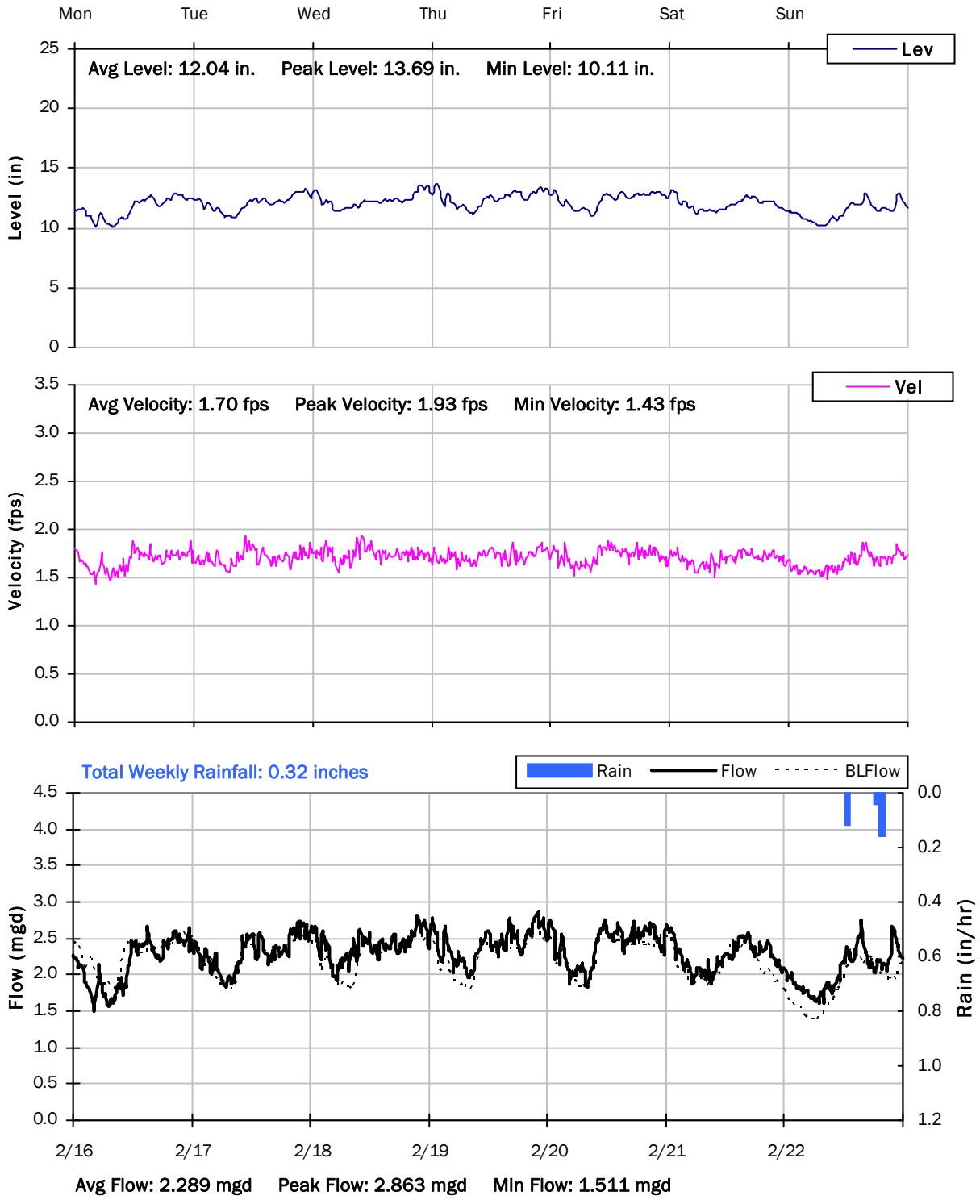
2/9/2015 to 2/16/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

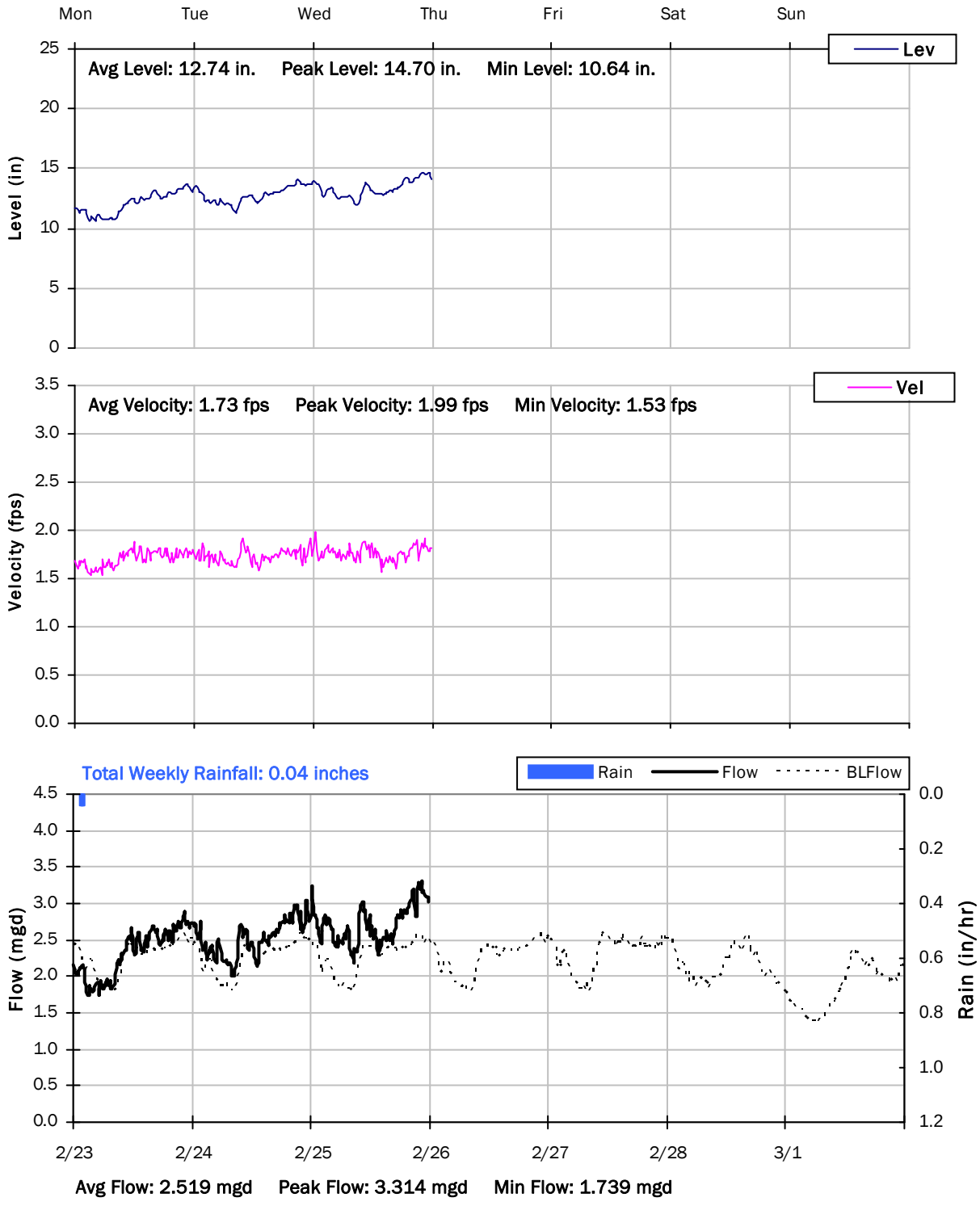
2/16/2015 to 2/23/2015



SITE 2

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

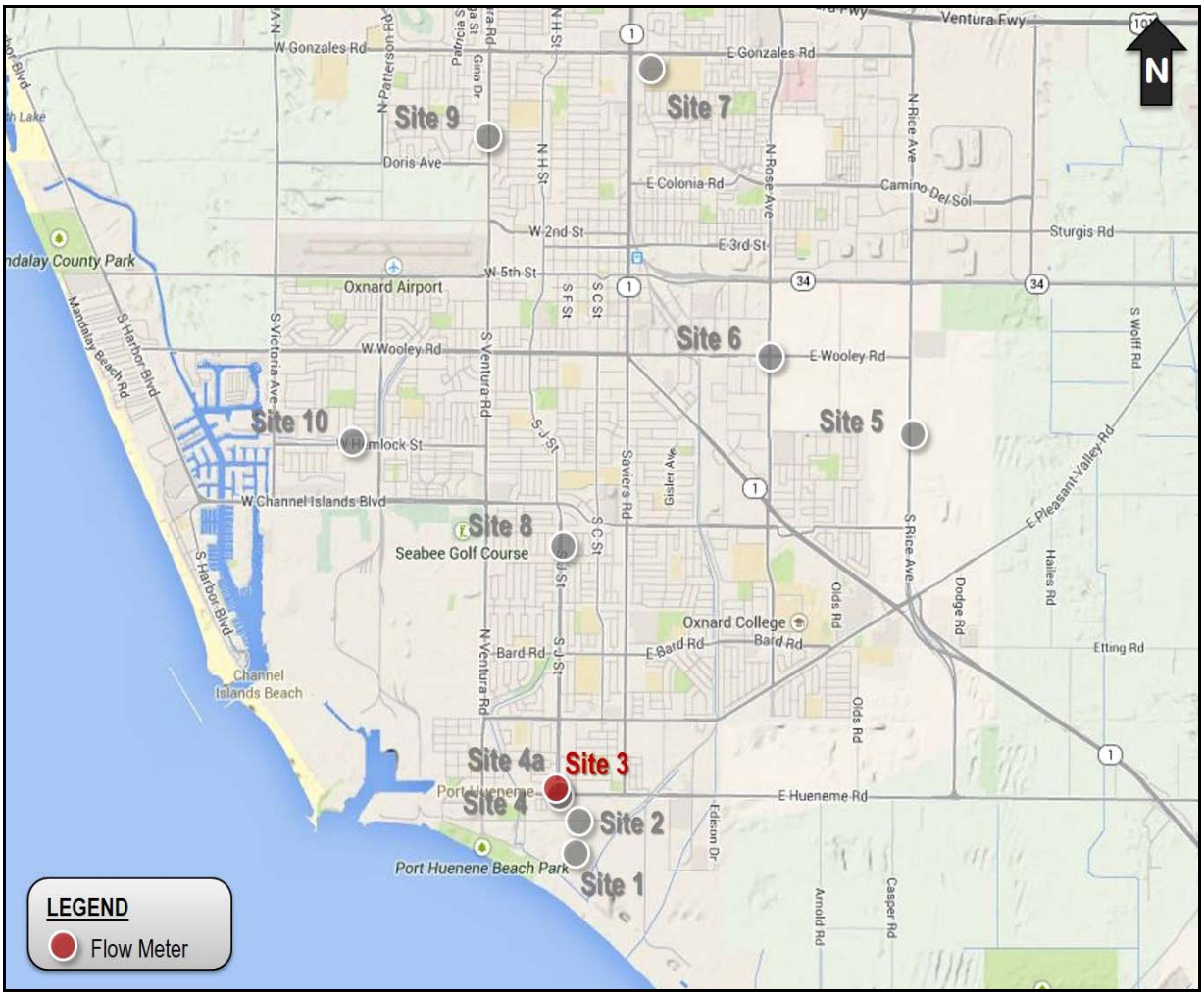
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 3

Location: J Street and E Port Hueneme Road

Data Summary Report



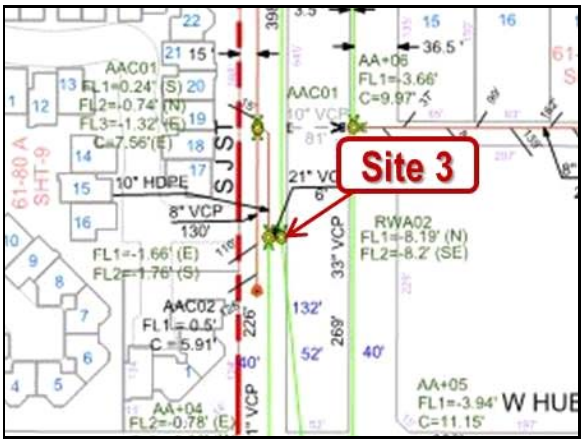
Vicinity Map: Site 3

SITE 3

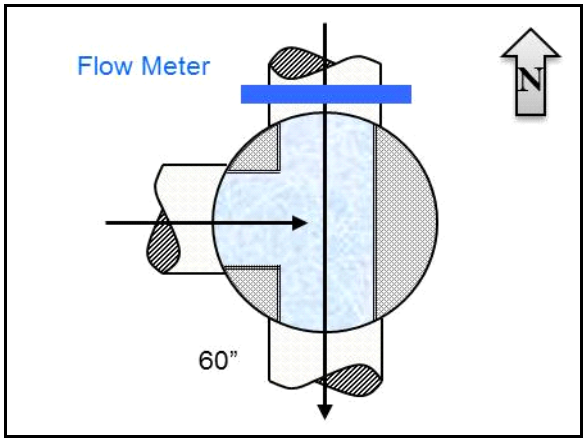
Site Information

Location:	J Street and E Port Hueneme Road
Coordinates:	119.1862° W, 34.1481° N
Rim Elevation:	13 feet
Pipe Diameter:	60 inches
Baseline Flow:	6.988 mgd
Peak Measured Flow:	14.352 mgd

Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 3

Additional Site Photos

Effluent Pipe

Influent Pipe

SITE 3

Additional Site Photos

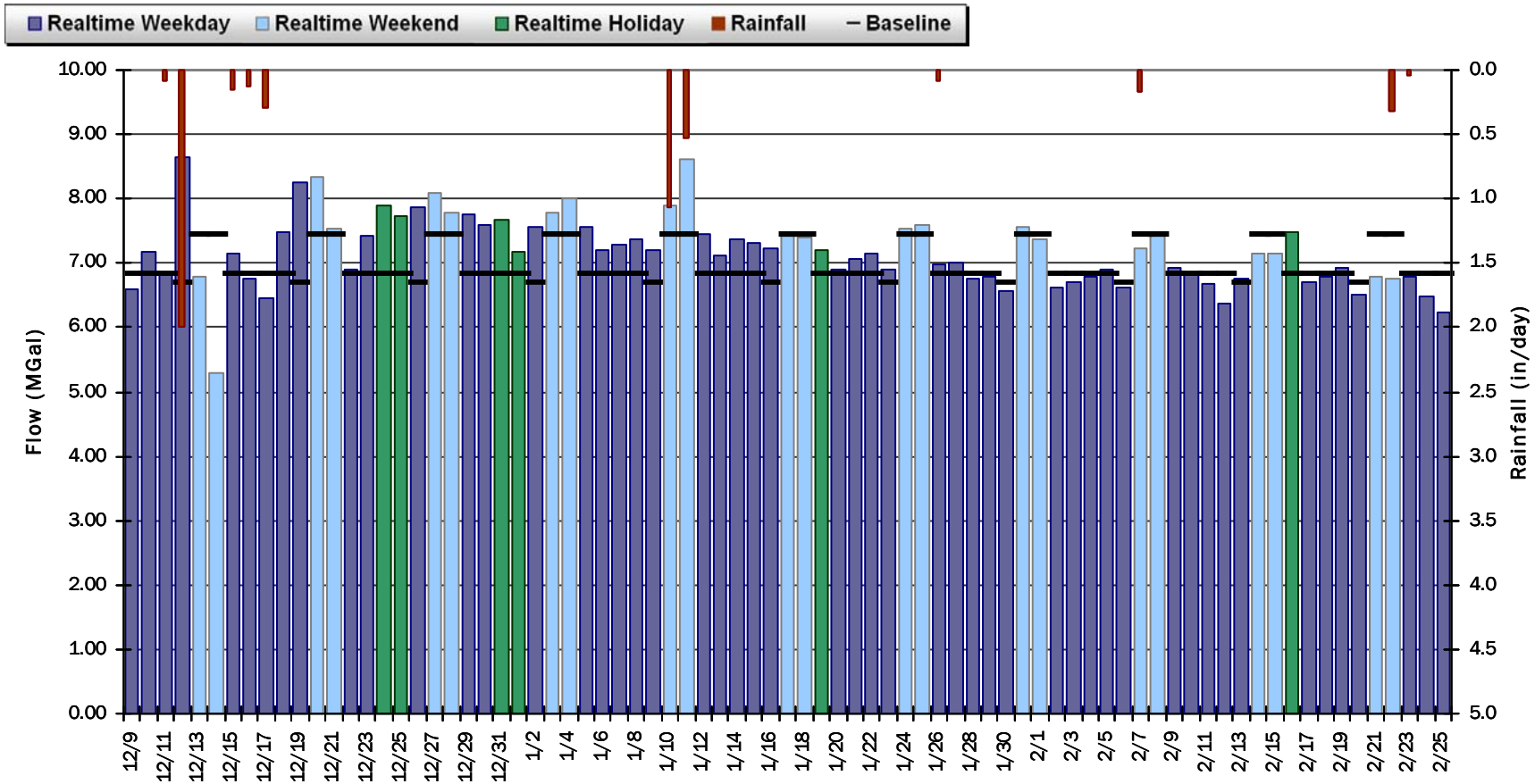
Lateral Pipe

SITE 3

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 7.189 MGal **Peak Daily Flow: 8.648 MGal** **Min Daily Flow: 5.294 MGal**

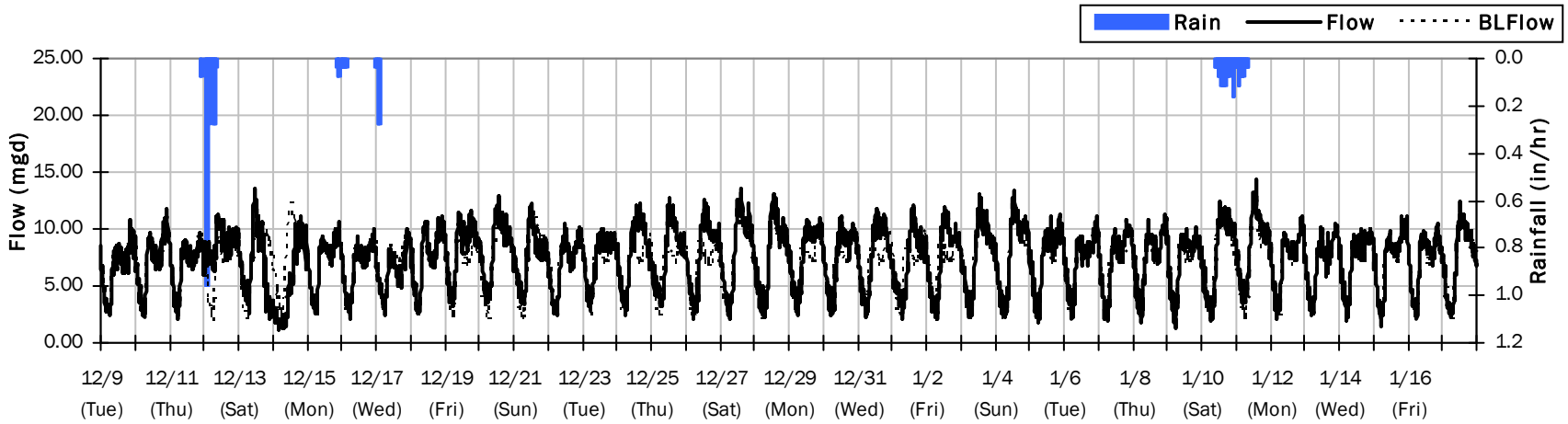
Total Period Rainfall: 4.84 inches

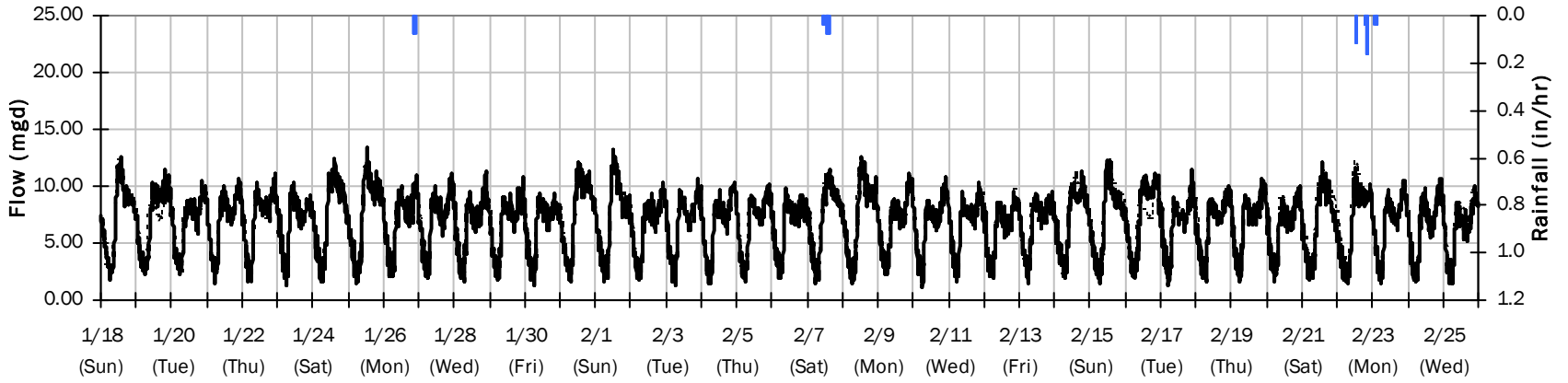


SITE 3

Flow Summary: 12/9/2014 to 2/25/2015

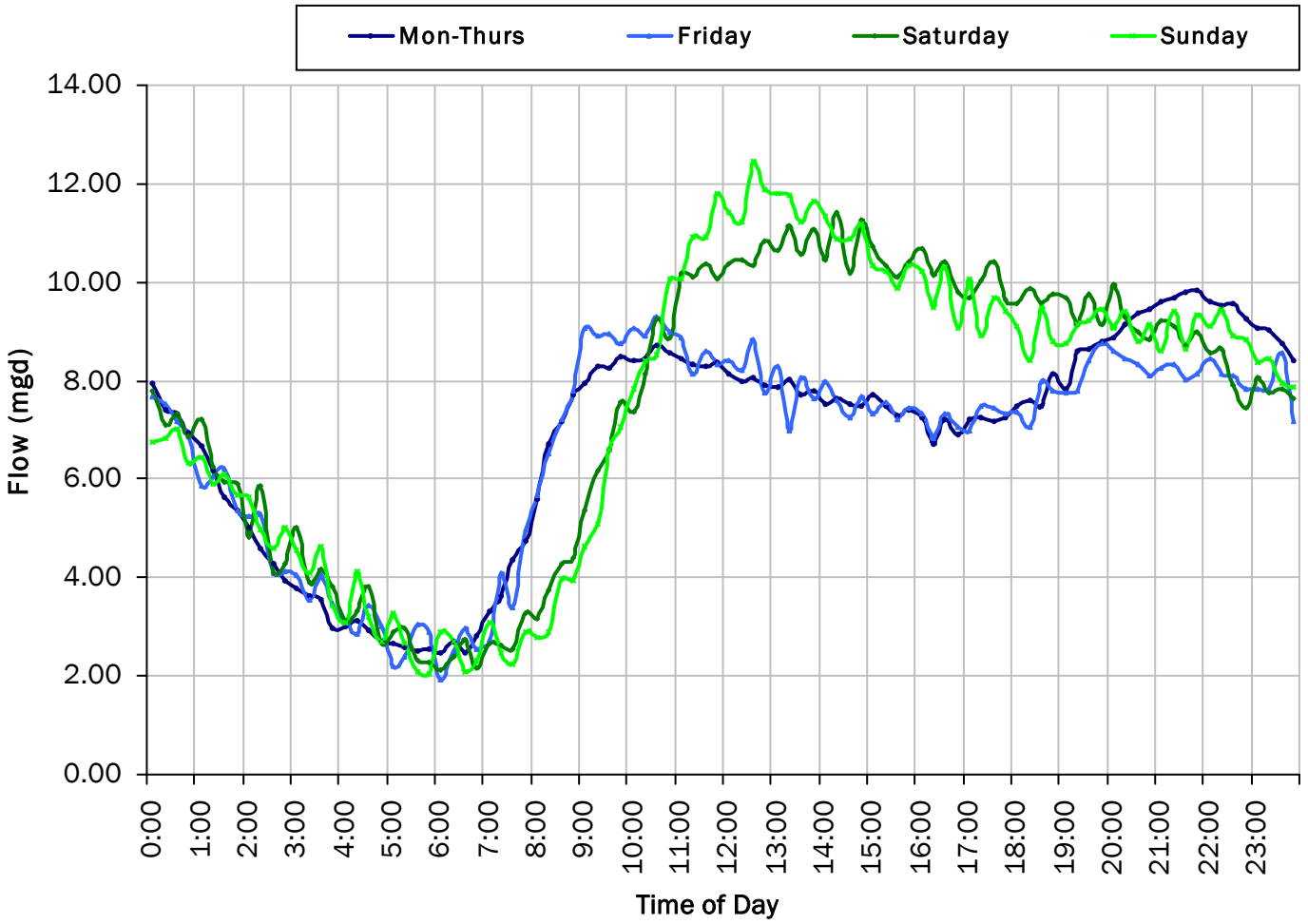
Total Period Rainfall: 4.84 inches Avg Flow: 7.189 mgd Peak Flow: 14.352 mgd Min Flow: 1.162 mgd





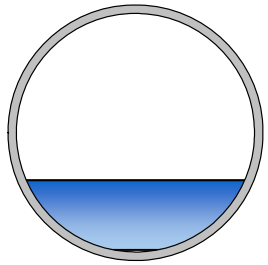
SITE 3

Baseline Flow Hydrographs



Baseline Flow:

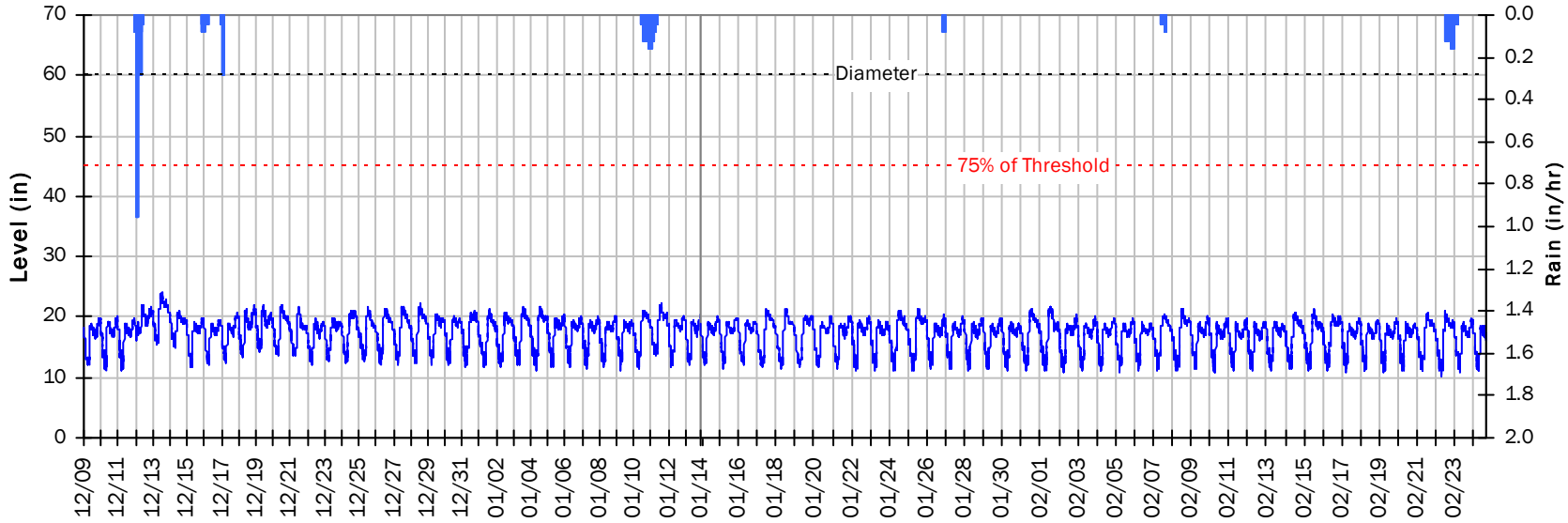
6.99 *mgd*

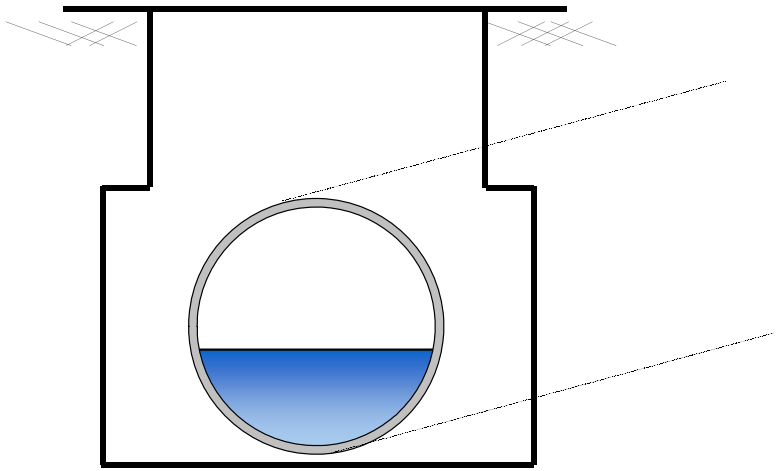


SITE 3

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

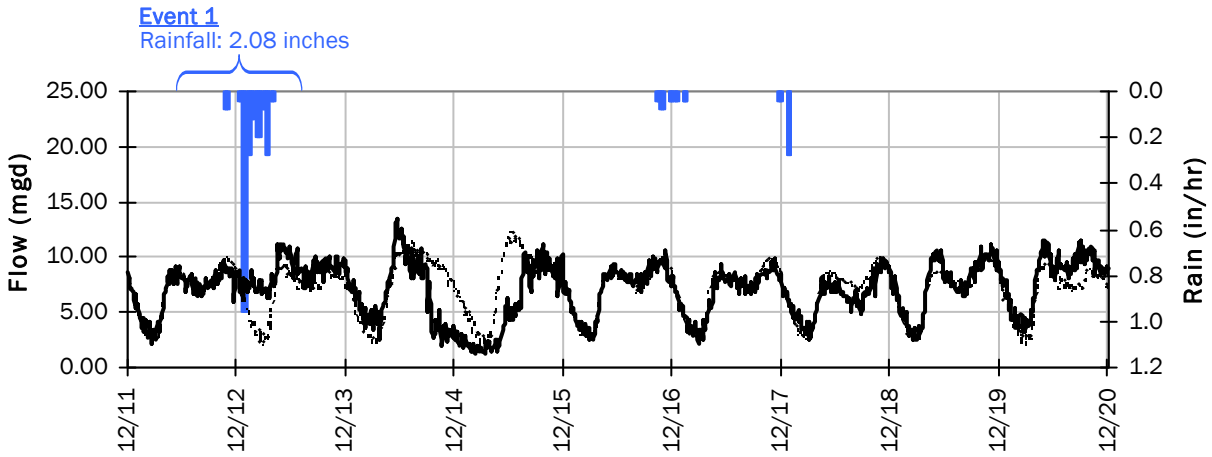




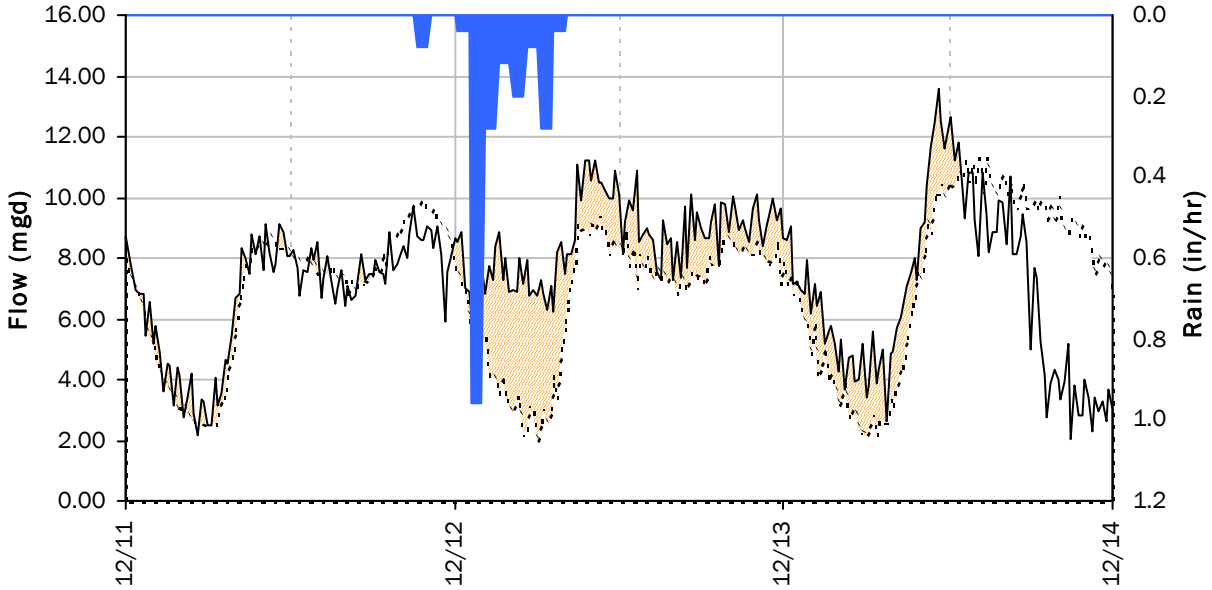
Pipe Diameter:	60	*inches*
Peak Measured Level:	24.1	*inches*
Peak d/D Ratio:	0.40	

SITE 3
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

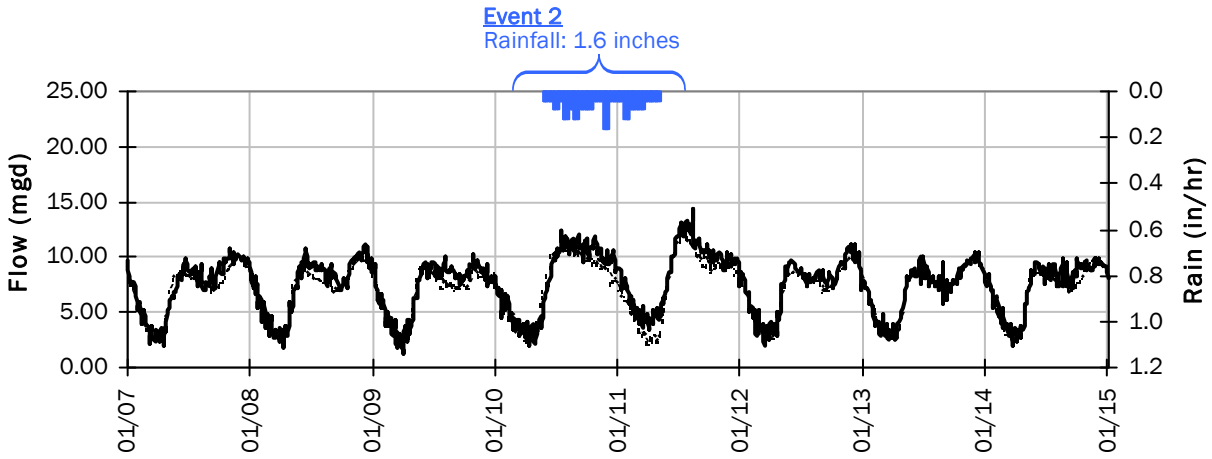


Storm Event I/I Analysis (Rain = 2.08 inches)

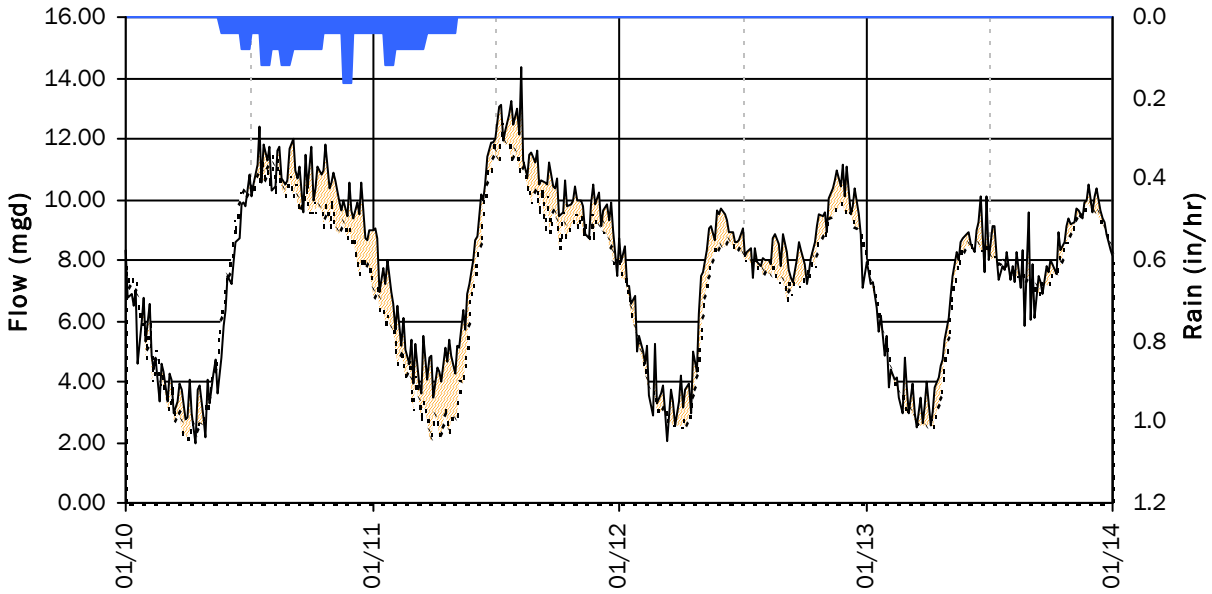
Capacity		Inflow / Infiltration	
Peak Flow:	13.55 *mgd*	**Peak I/I Rate:**	5.55 *mgd*
PF:	1.94	**Total I/I:**	1,174,000 *gallons*
Peak Level:	24.08 *in*		
d/D Ratio:	0.40		

SITE 3
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



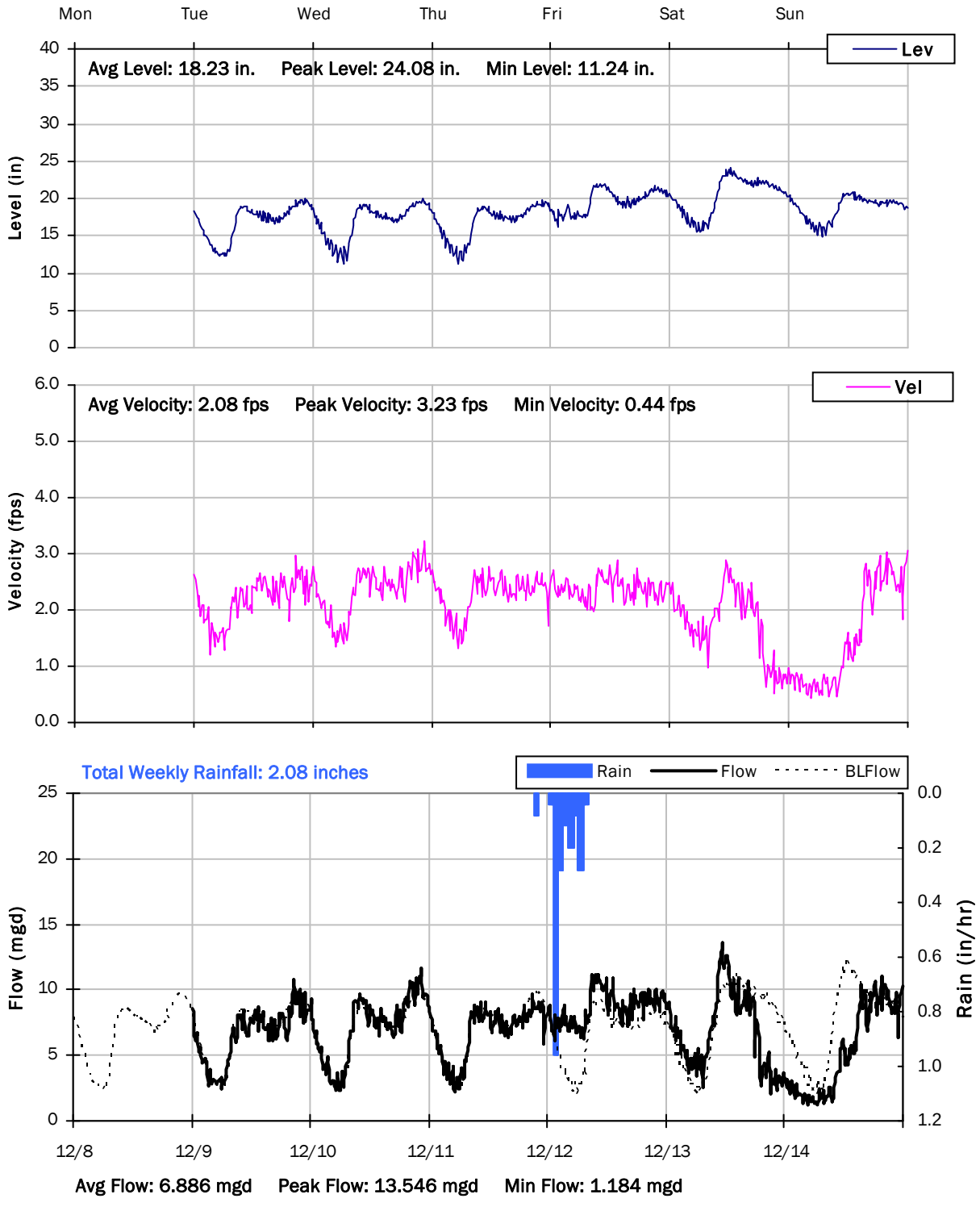
Storm Event I/I Analysis (Rain = 1.60 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	14.35 *mgd*	**Peak I/I Rate:**	3.46 *mgd*
PF:	2.05	**Total I/I:**	2,227,000 *gallons*
Peak Level:	22.27 *in*		
d/D Ratio:	0.37		

SITE 3

Weekly Level, Velocity and Flow Hydrographs

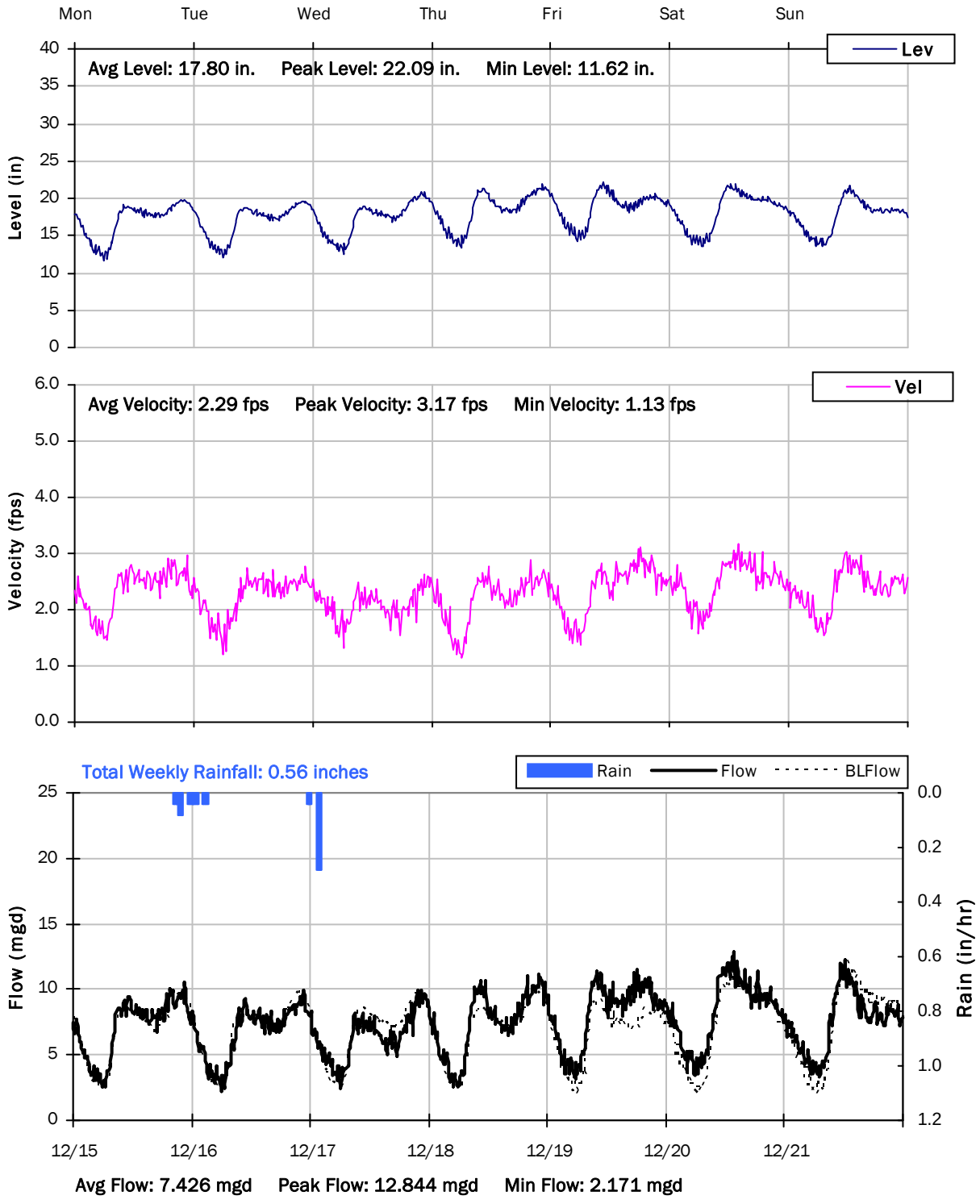
12/8/2014 to 12/15/2014



SITE 3

Weekly Level, Velocity and Flow Hydrographs

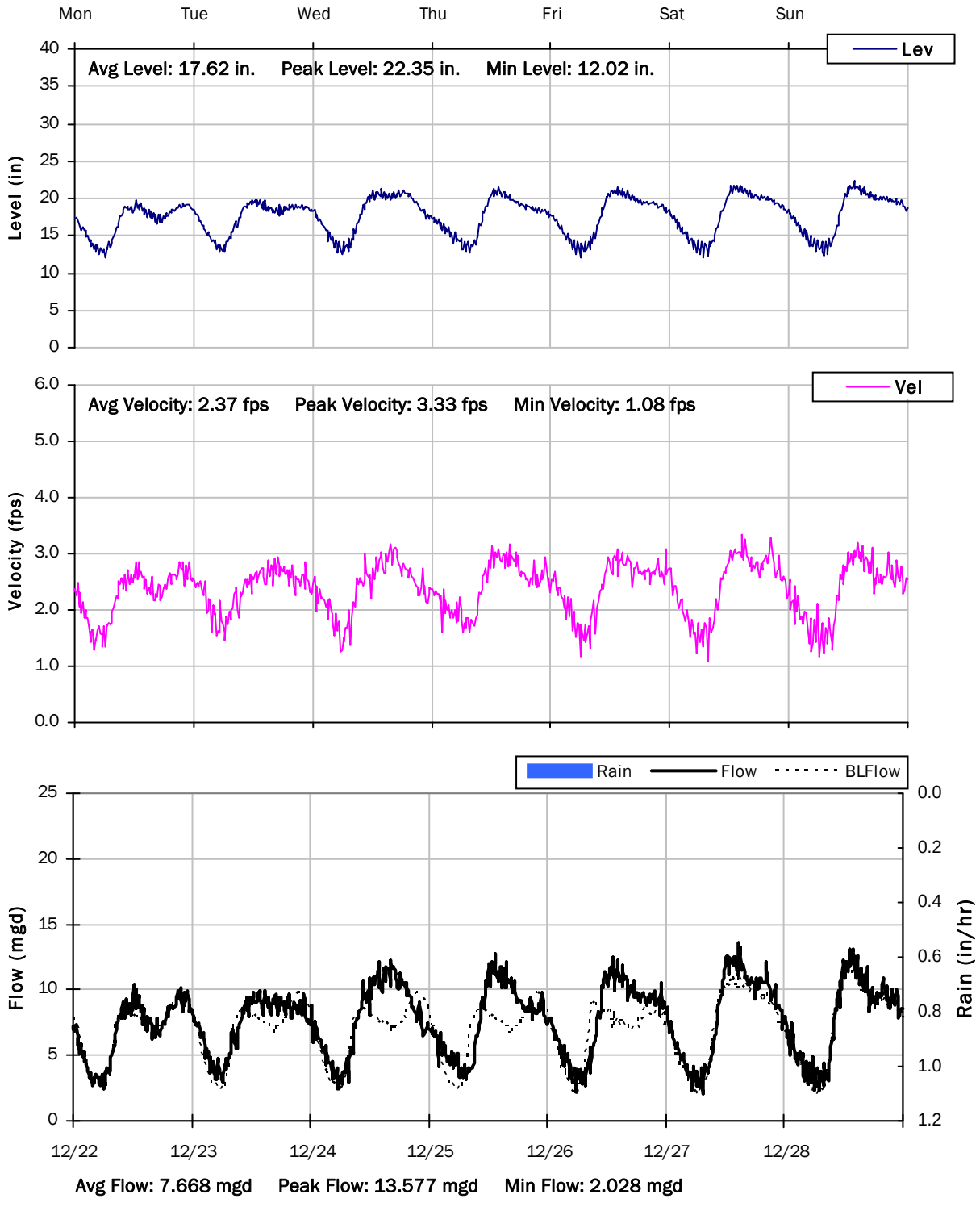
12/15/2014 to 12/22/2014



SITE 3

Weekly Level, Velocity and Flow Hydrographs

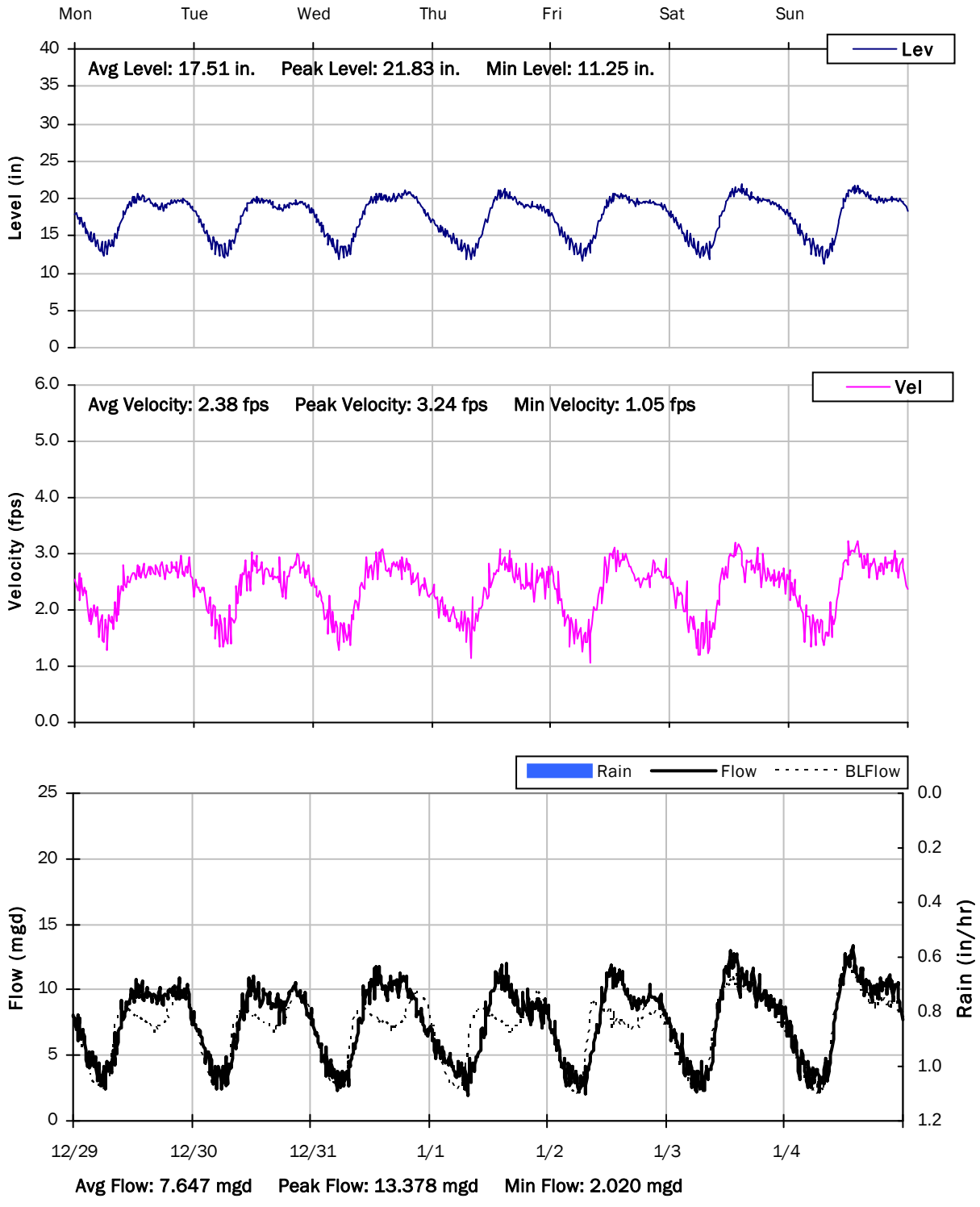
12/22/2014 to 12/29/2014



SITE 3

Weekly Level, Velocity and Flow Hydrographs

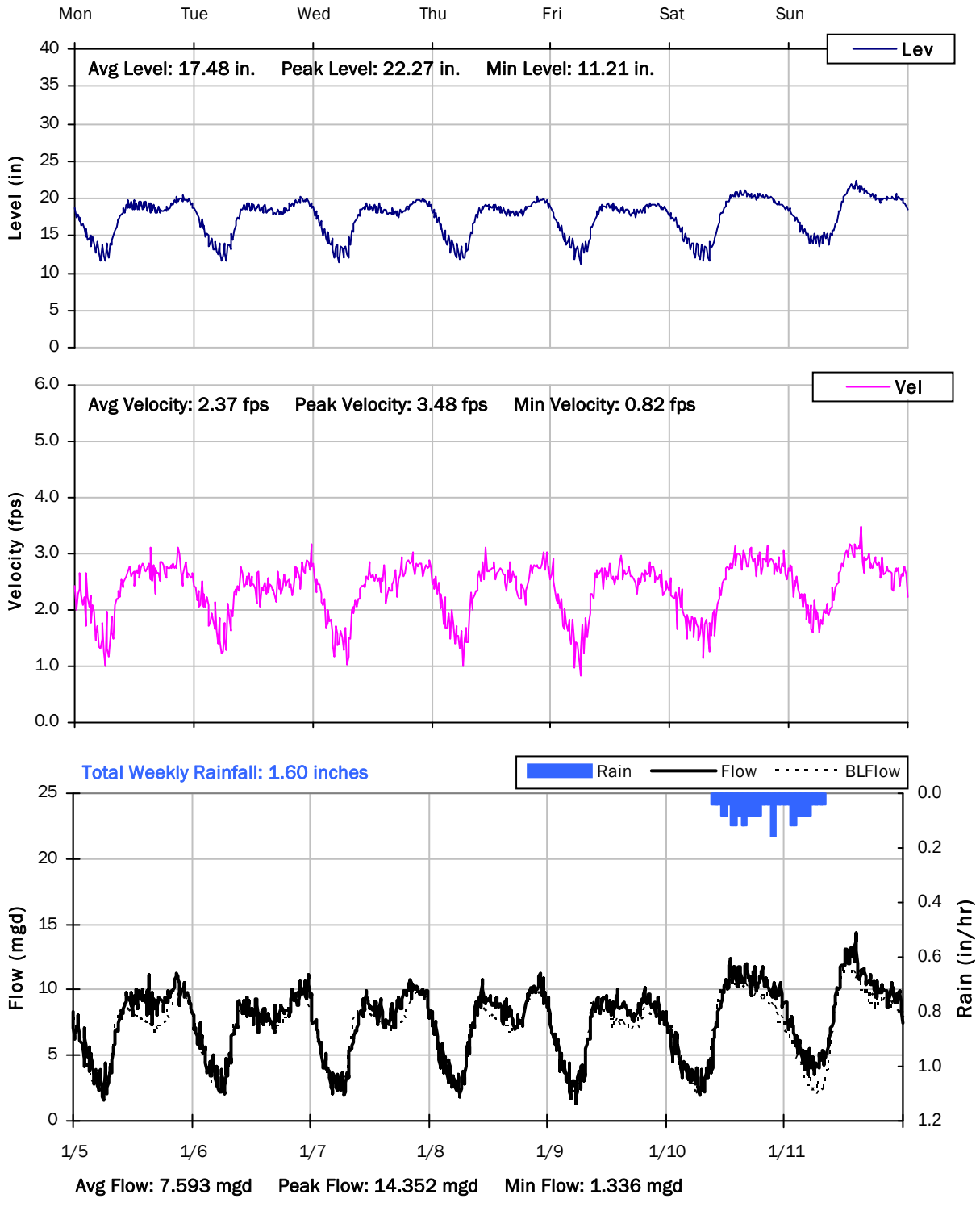
12/29/2014 to 1/5/2015



SITE 3

Weekly Level, Velocity and Flow Hydrographs

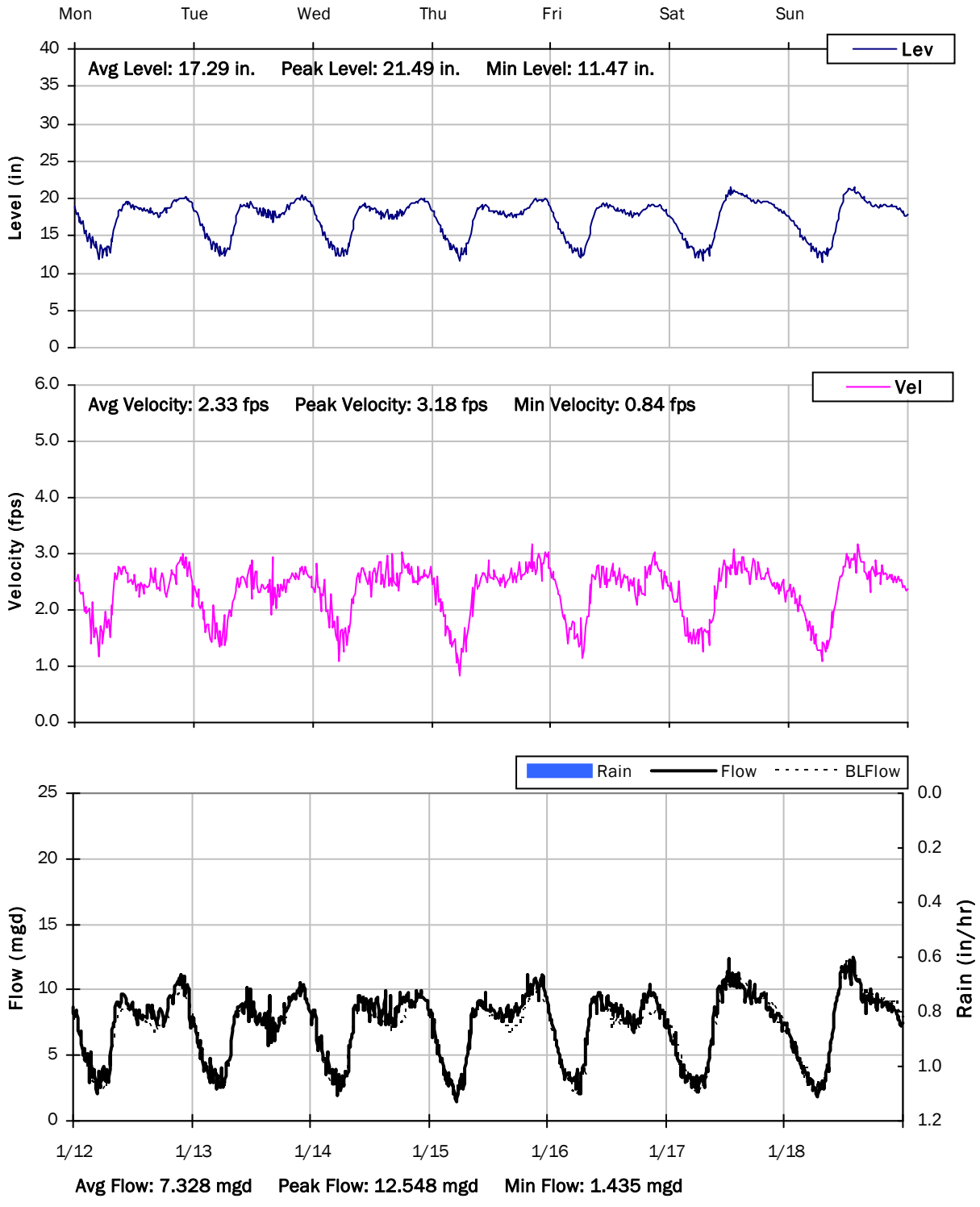
1/5/2015 to 1/12/2015



SITE 3

Weekly Level, Velocity and Flow Hydrographs

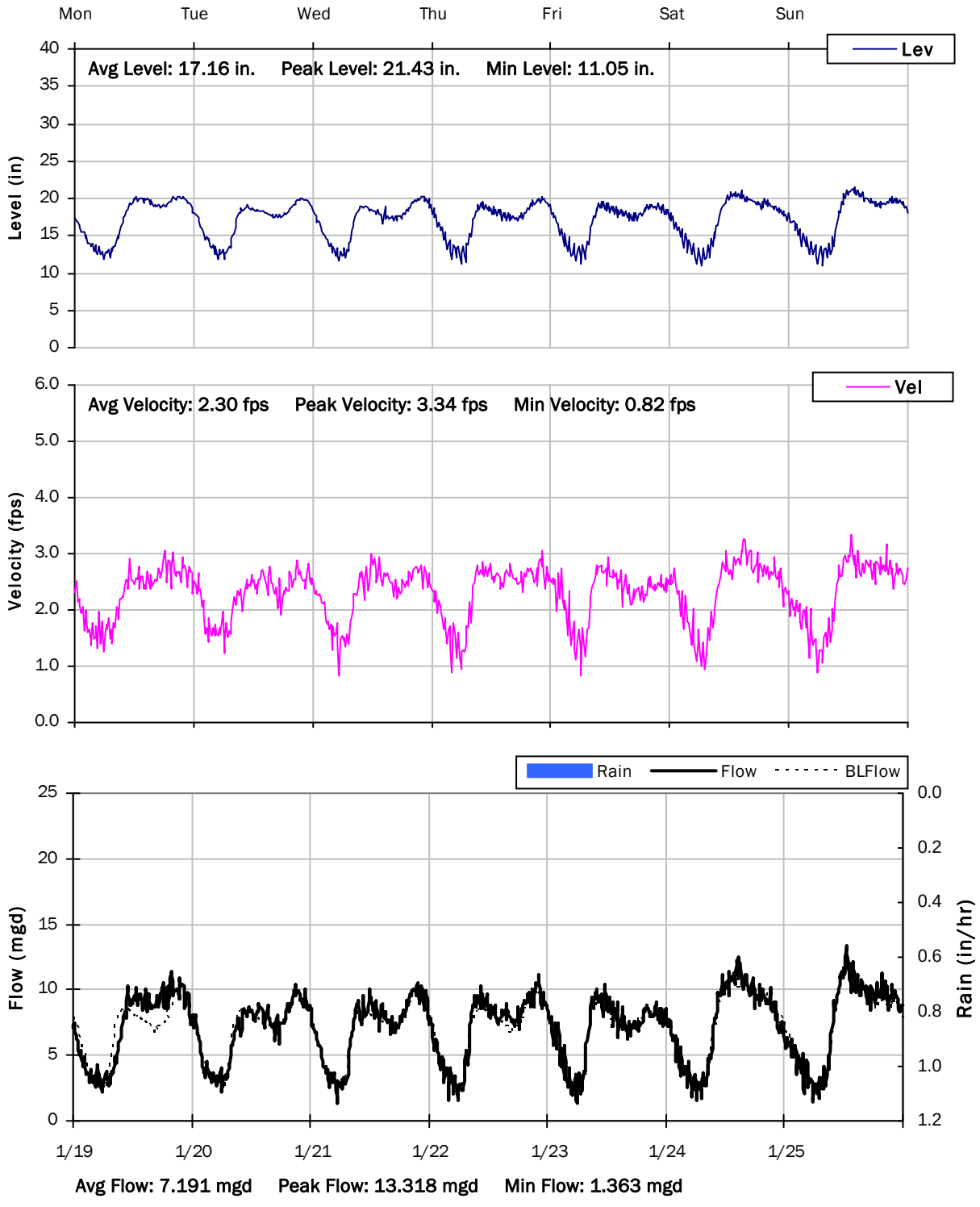
1/12/2015 to 1/19/2015



SITE 3

Weekly Level, Velocity and Flow Hydrographs

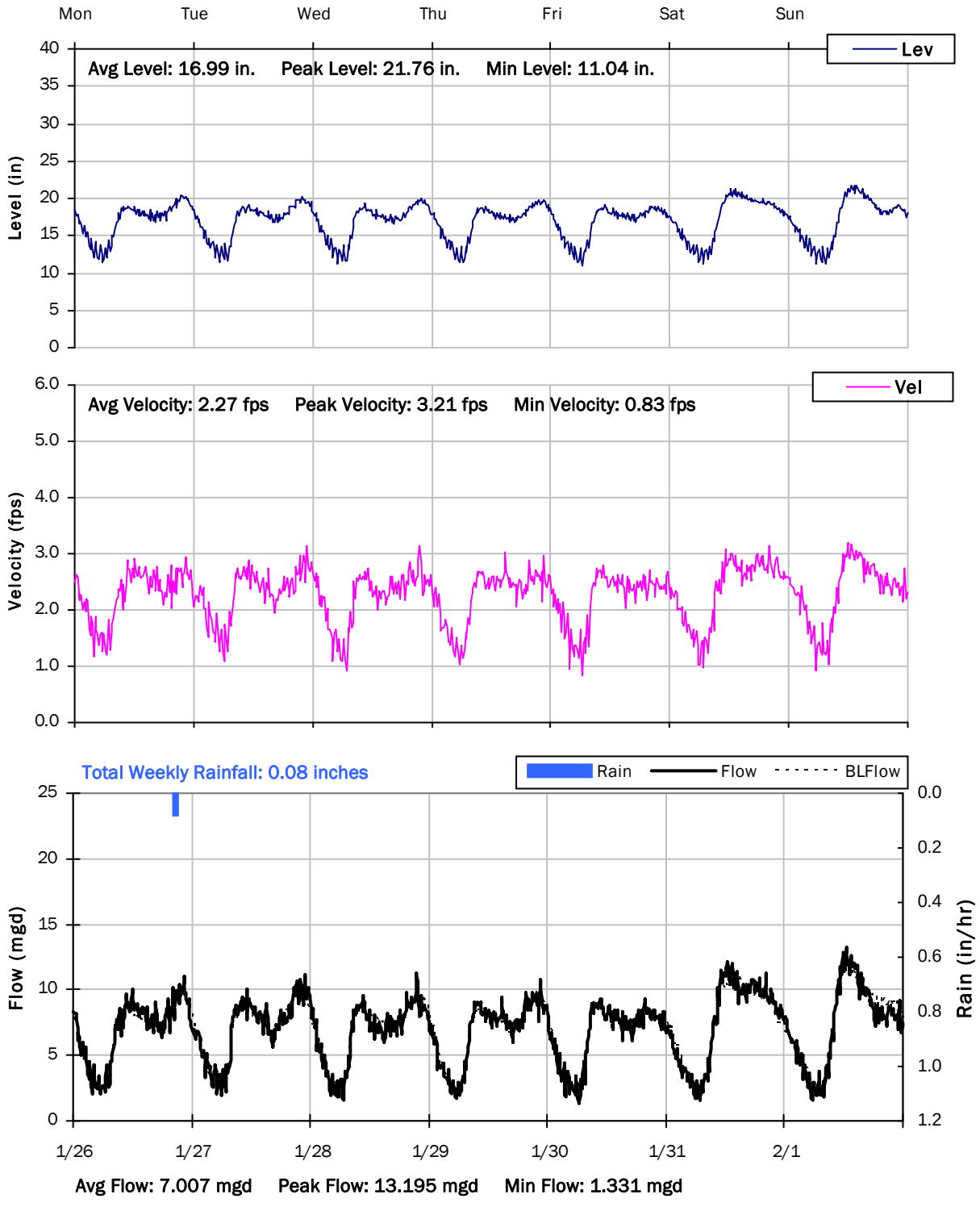
1/19/2015 to 1/26/2015



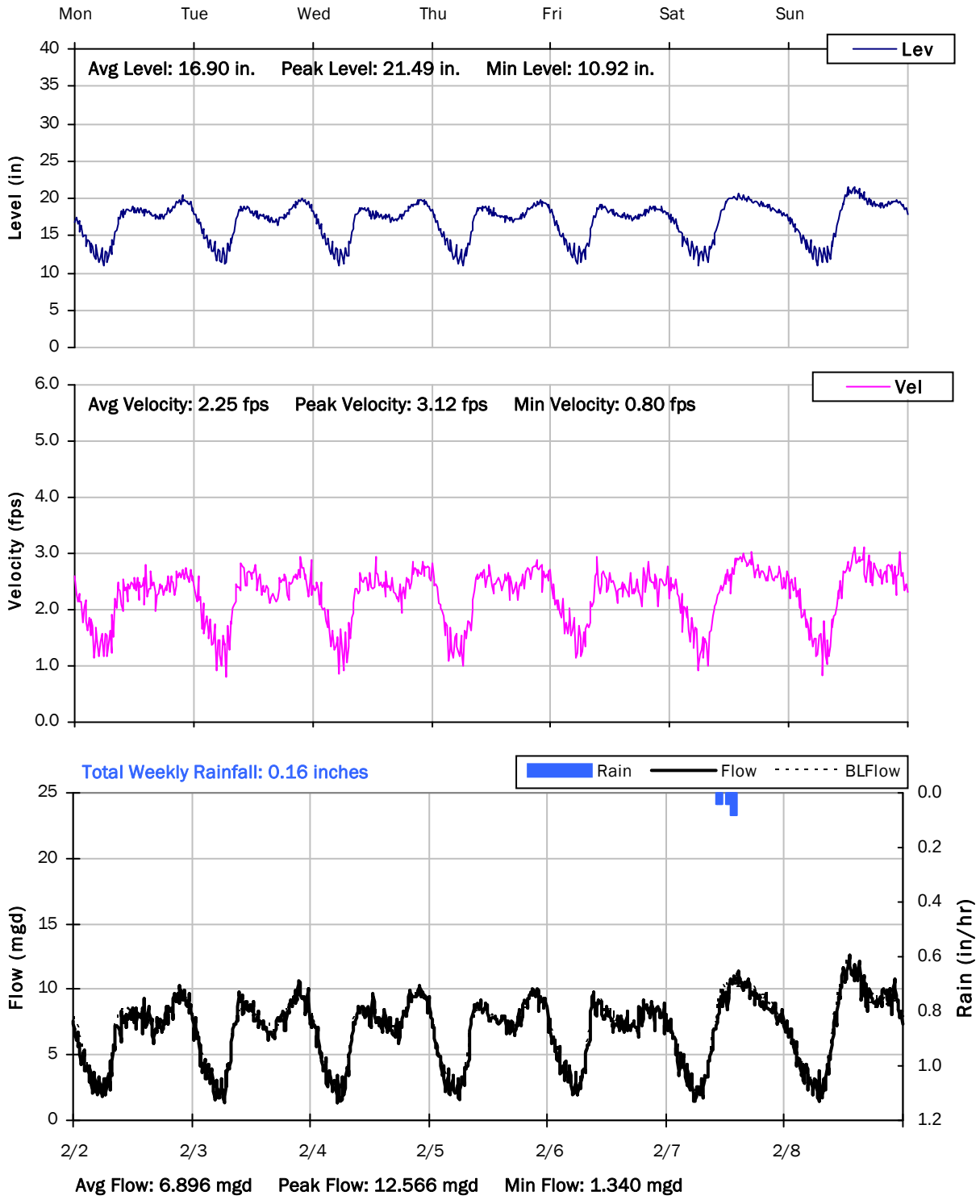
SITE 3

Weekly Level, Velocity and Flow Hydrographs

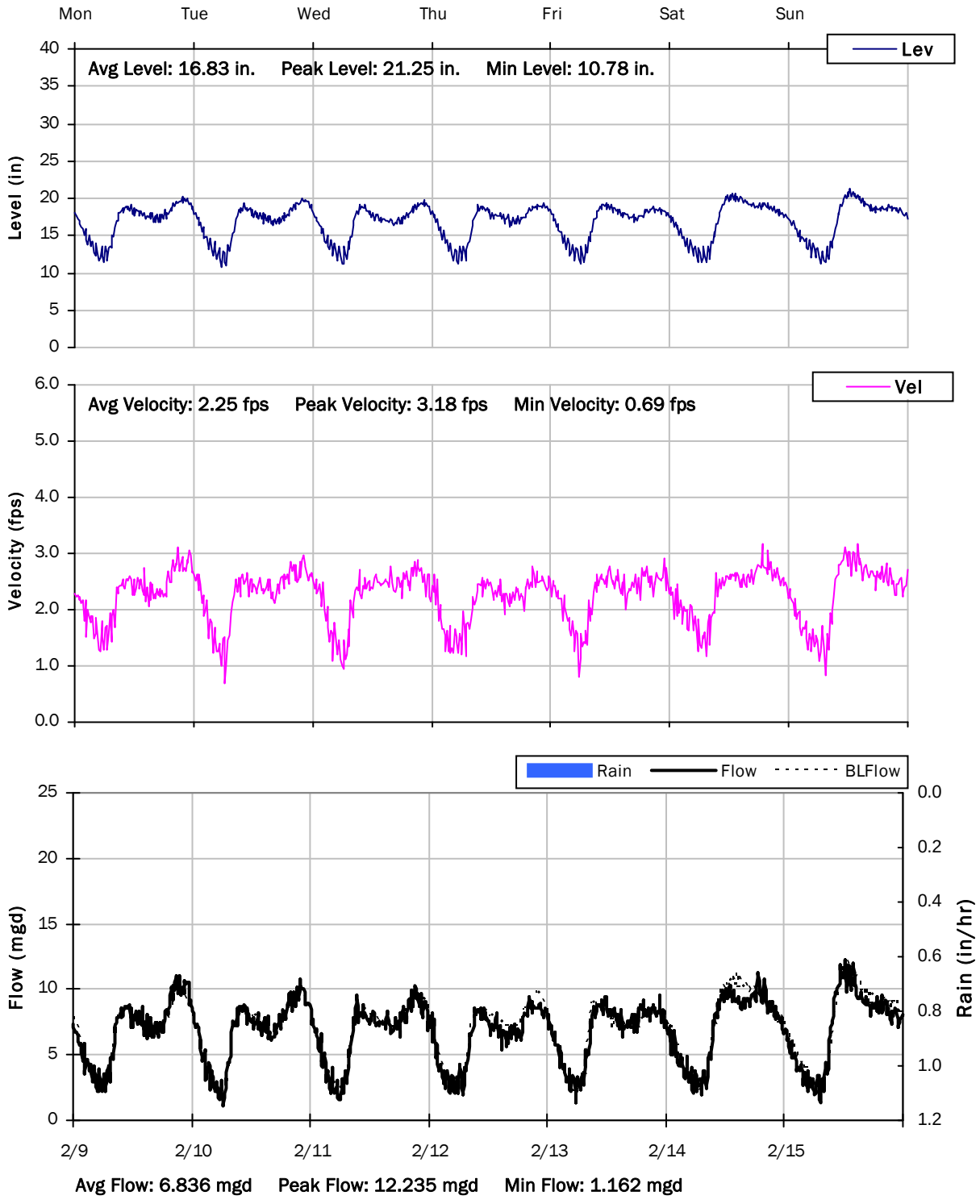
1/26/2015 to 2/2/2015



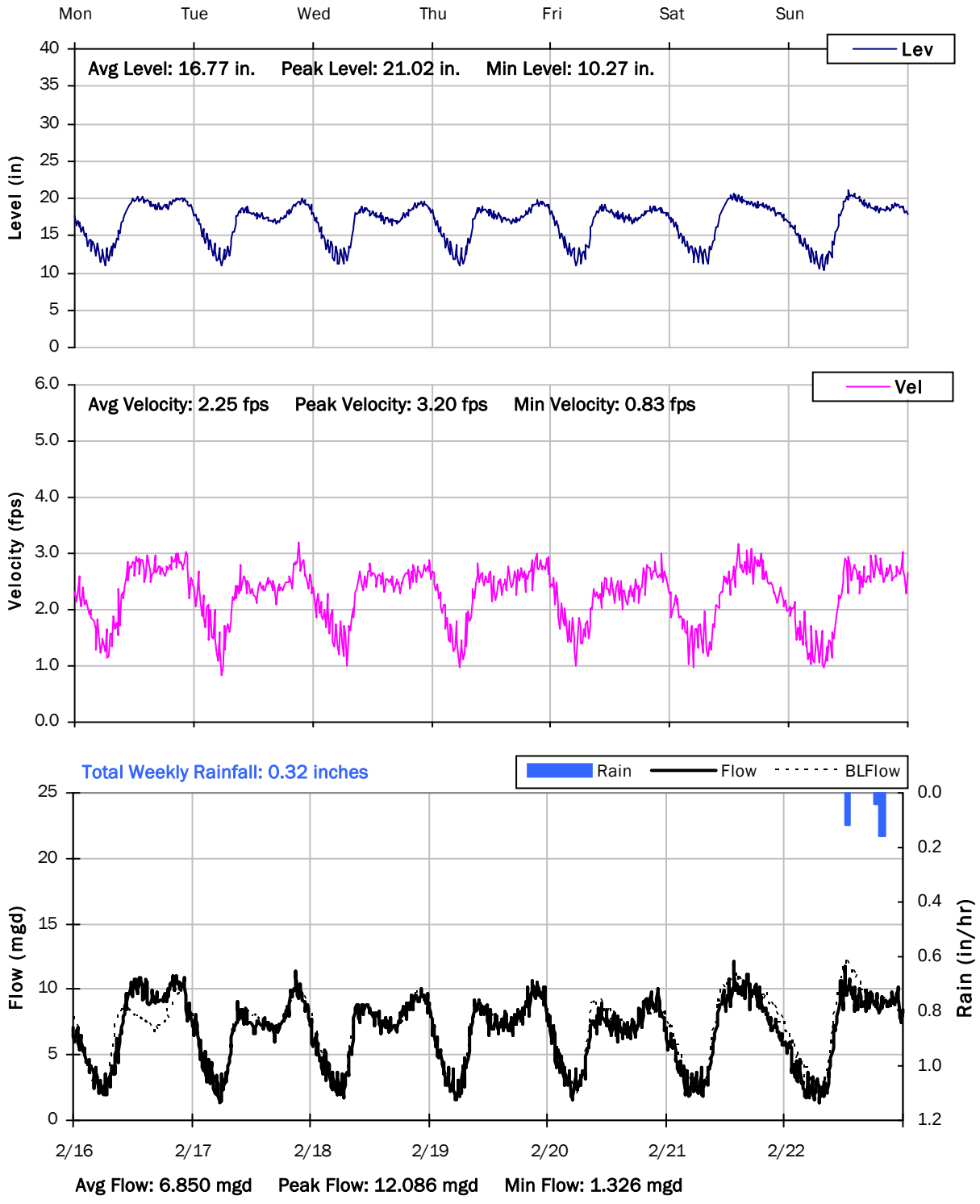
SITE 3
Weekly Level, Velocity and Flow Hydrographs
2/2/2015 to 2/9/2015



SITE 3
Weekly Level, Velocity and Flow Hydrographs
2/9/2015 to 2/16/2015



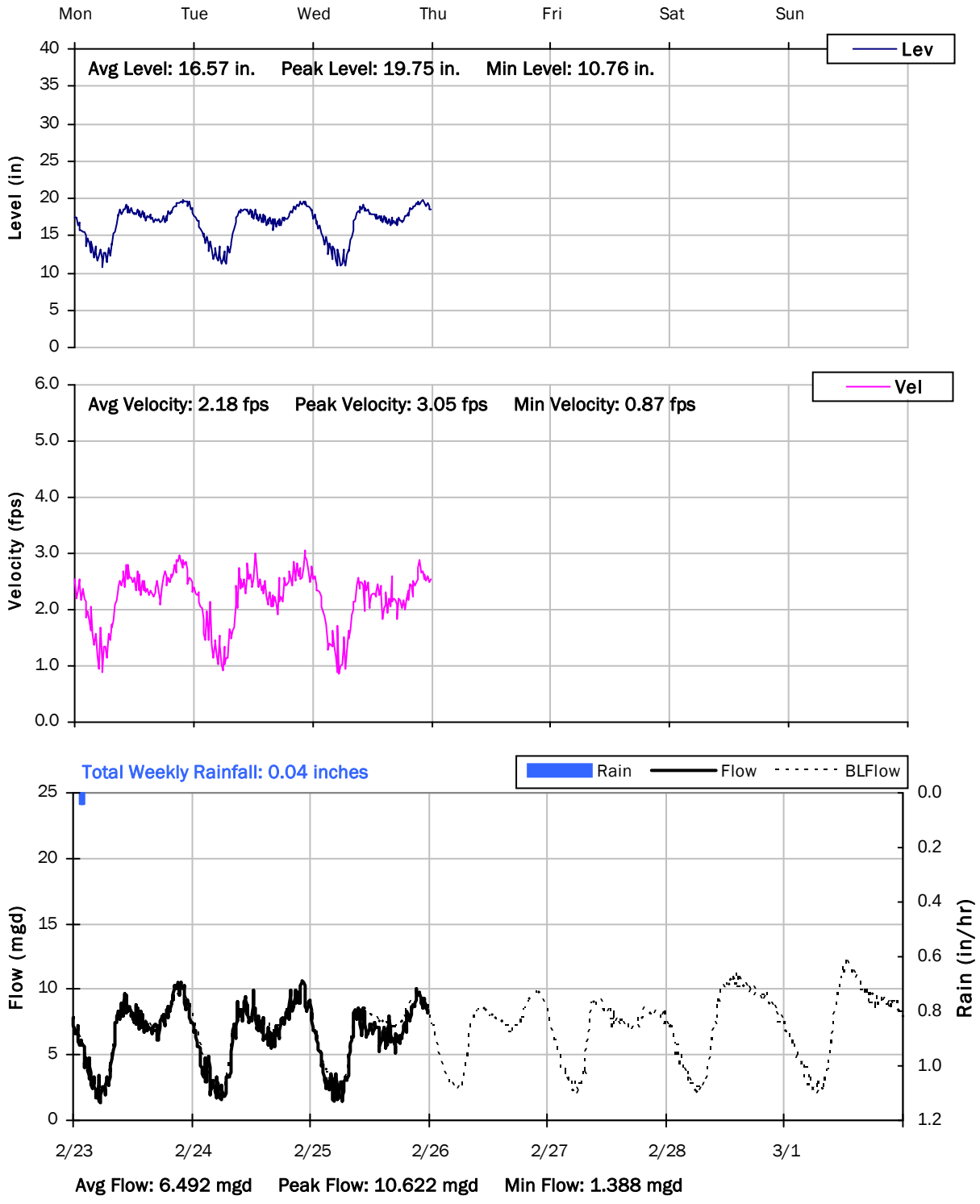
SITE 3
Weekly Level, Velocity and Flow Hydrographs
2/16/2015 to 2/23/2015



SITE 3

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

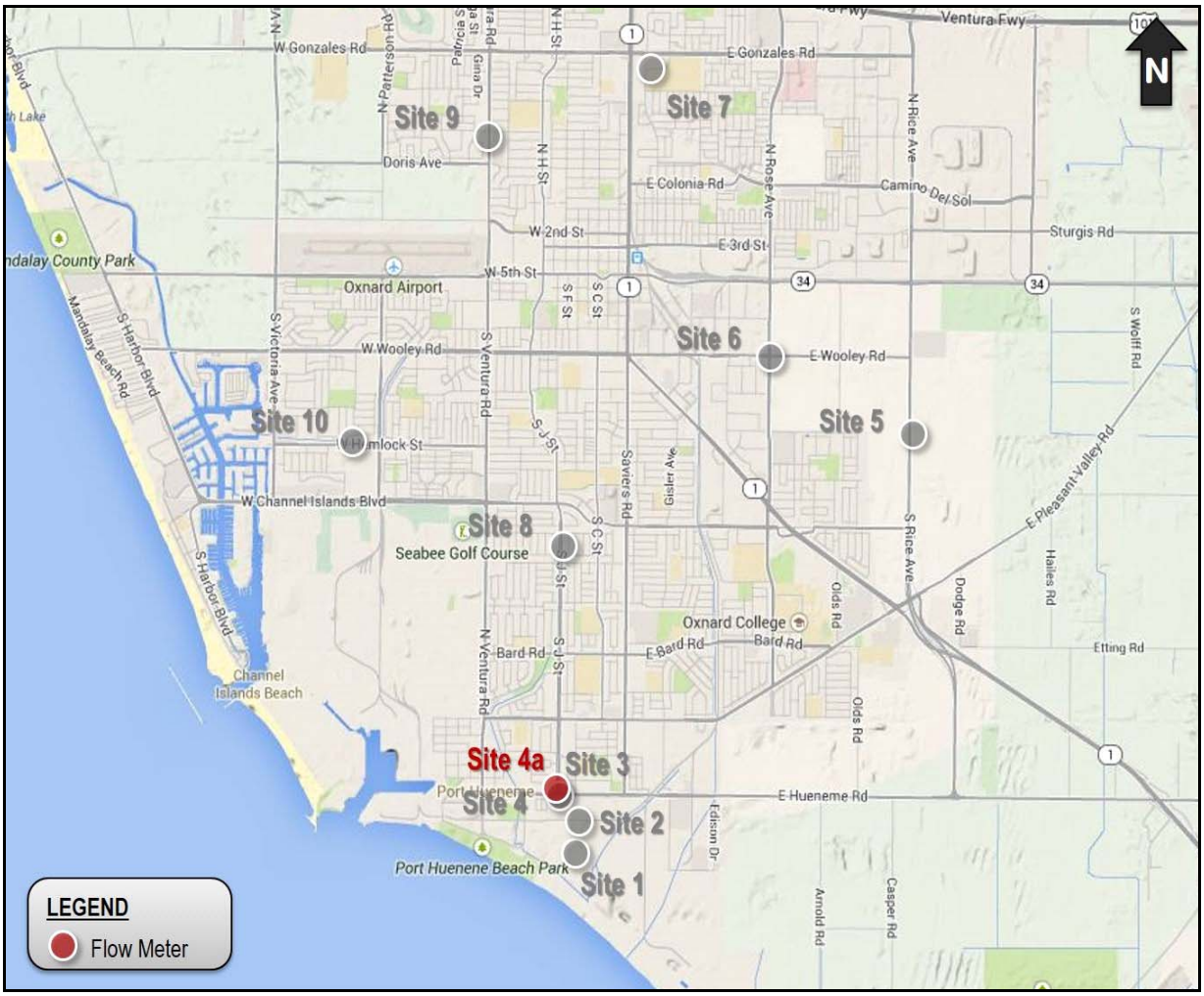
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 4A

Location: Northbound J Street south of Cuesta Del Mar Drive

Data Summary Report



Vicinity Map: Site 4A

SITE 4A

Site Information

Location: Northbound J Street south of Cuesta Del Mar Drive

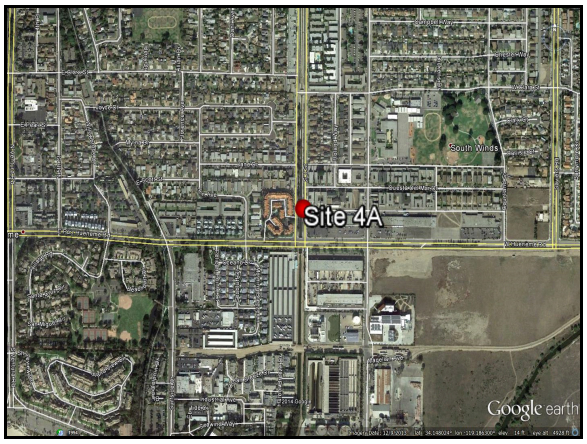
Coordinates: 119.1860° W, 34.1483° N

Rim Elevation: 13 feet

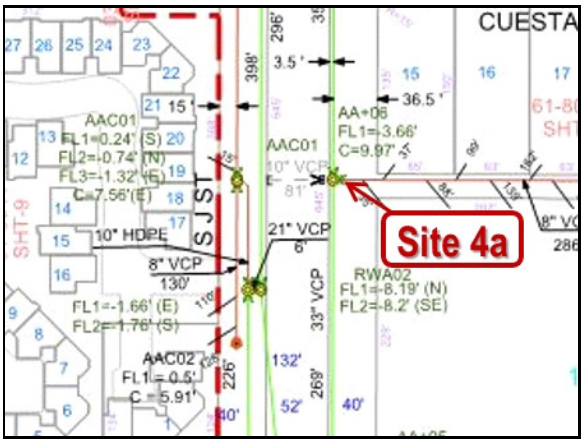
Pipe Diameter: 33 inches

Baseline Flow: 3.153 mgd

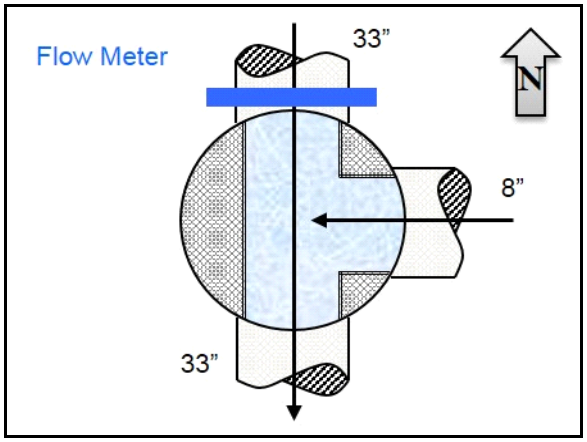
Peak Measured Flow: 5.729 mgd



Satellite Map



Sanitary Map



Flow Diagram

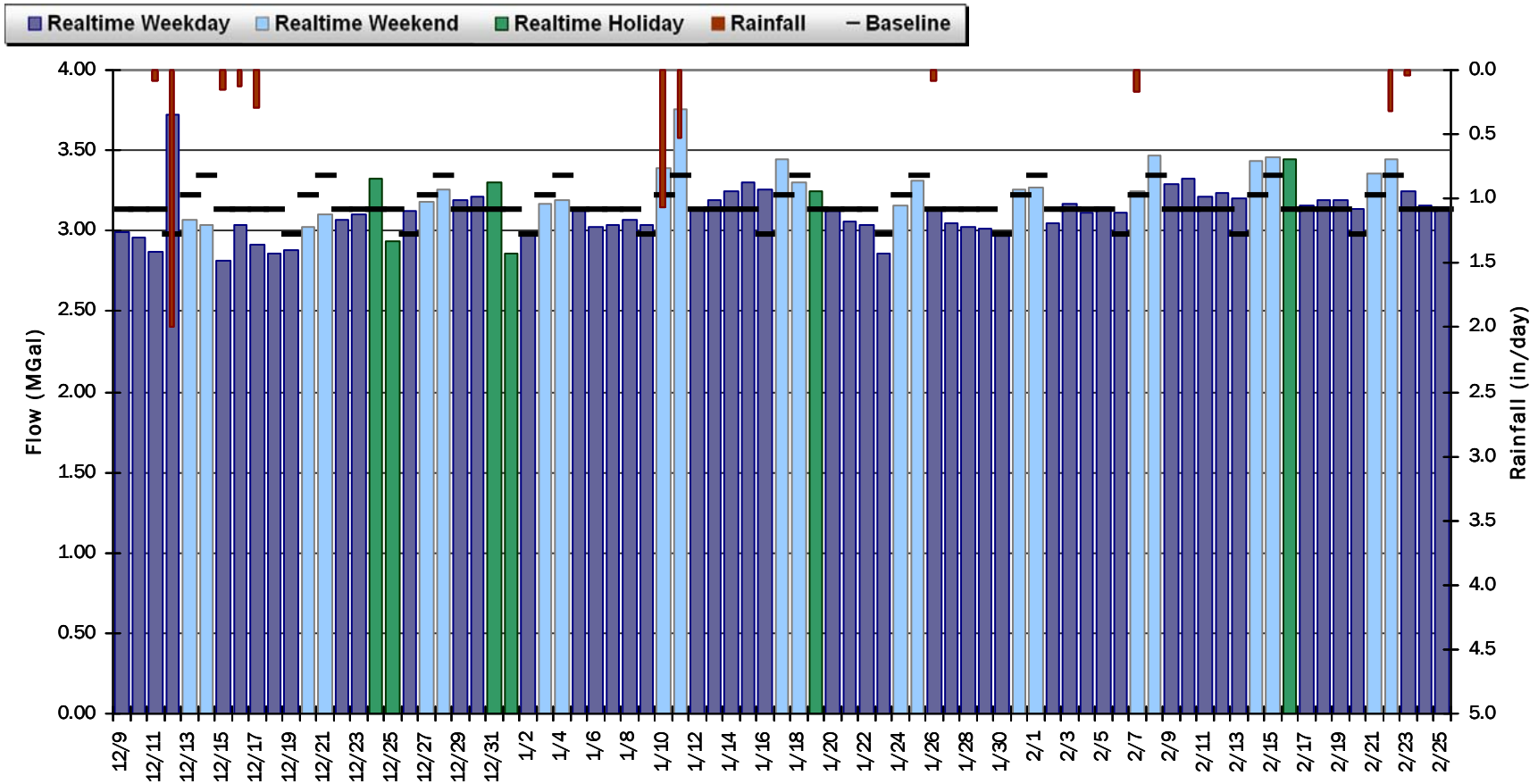
Street View

SITE 4A

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 3.164 MGal **Peak Daily Flow: 3.753 MGal** **Min Daily Flow: 2.815 MGal**

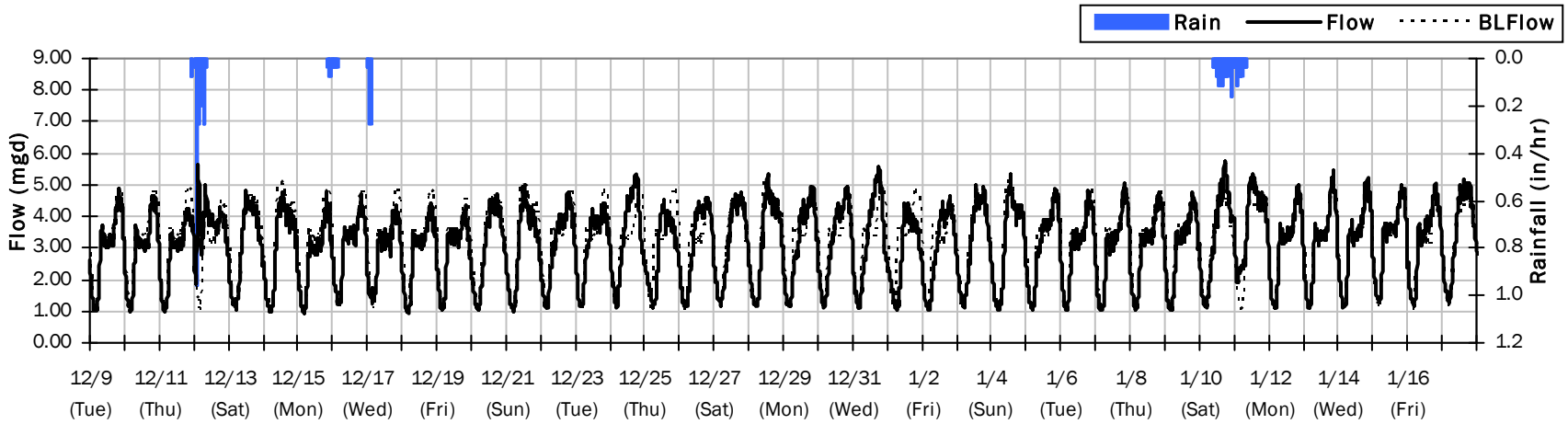
Total Period Rainfall: 4.84 inches

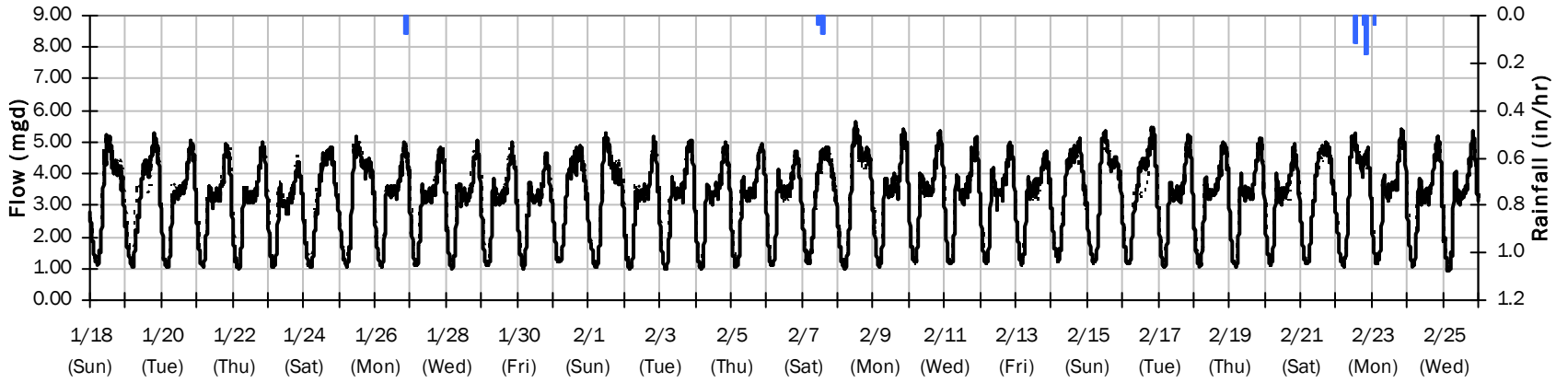


SITE 4A

Flow Summary: 12/9/2014 to 2/25/2015

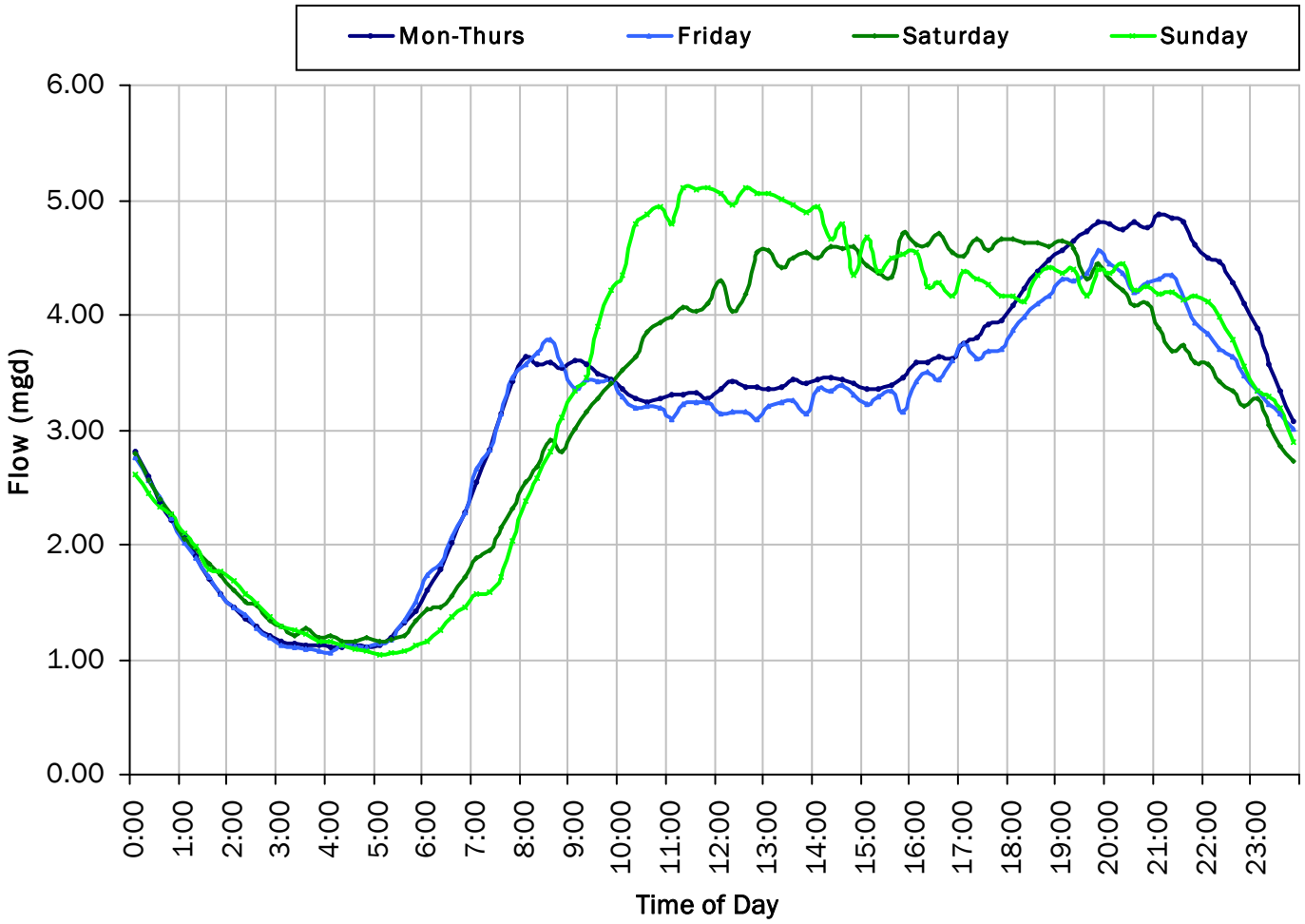
Total Period Rainfall: 4.84 inches Avg Flow: 3.164 mgd Peak Flow: 5.729 mgd Min Flow: 0.906 mgd





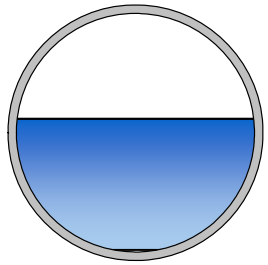
SITE 4A

Baseline Flow Hydrographs



Baseline Flow:

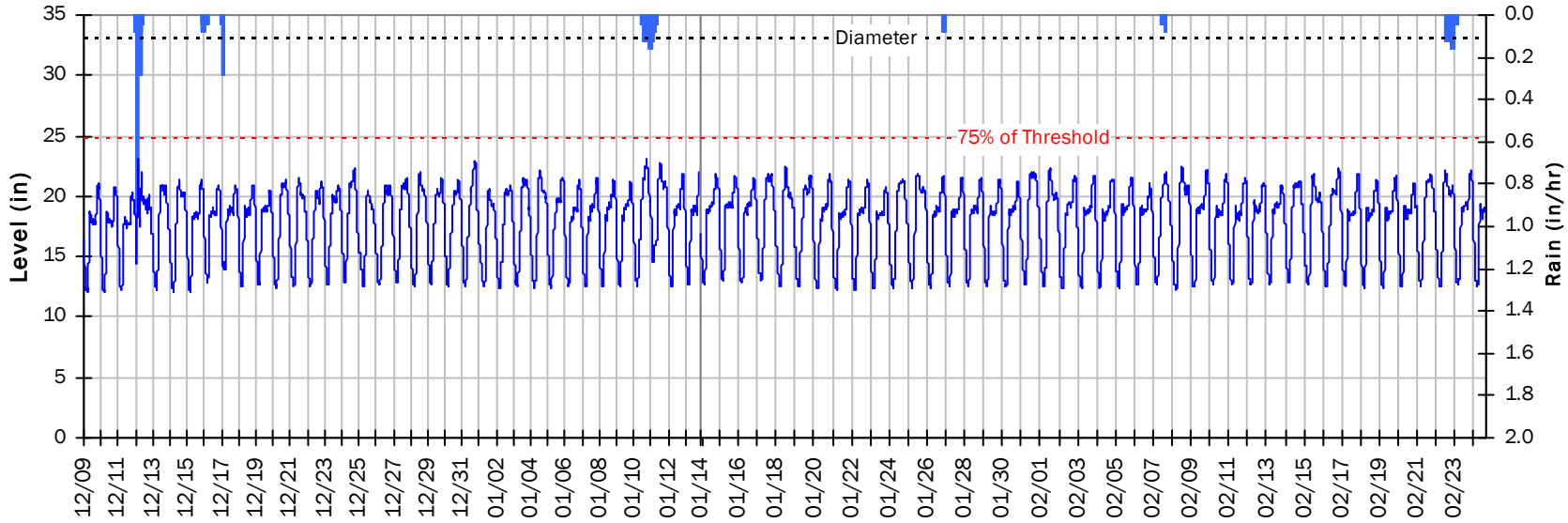
3.15 *mgd*

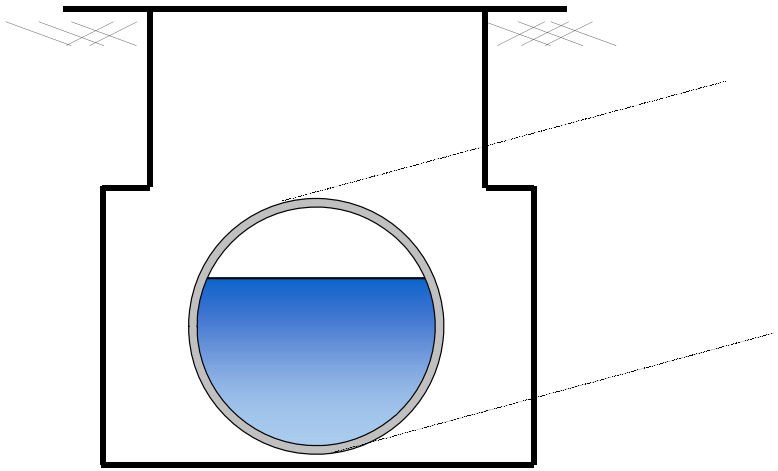


SITE 4A

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





Pipe Diameter: 33 *inches*

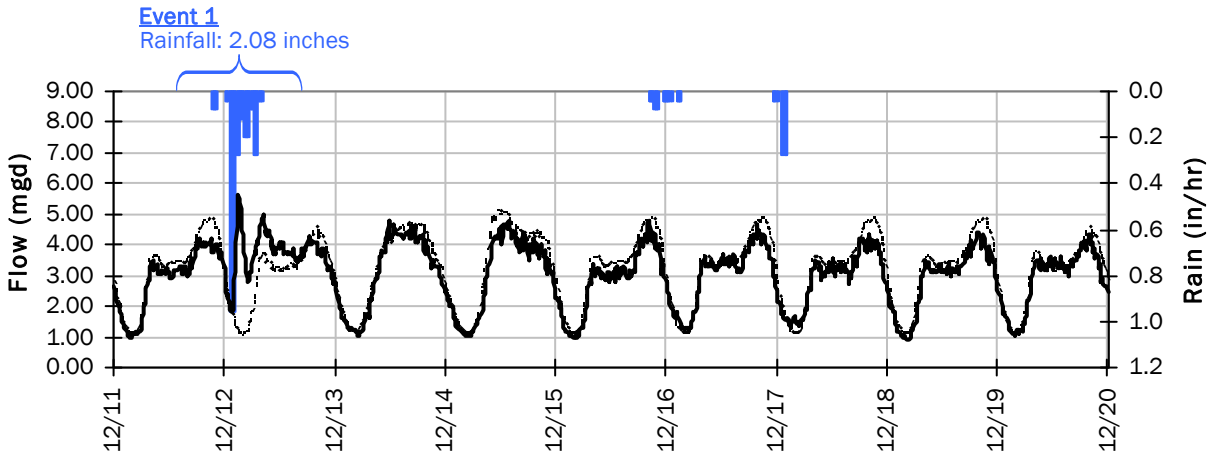
Peak Measured Level: 23.1 *inches*

Peak d/D Ratio: 0.70

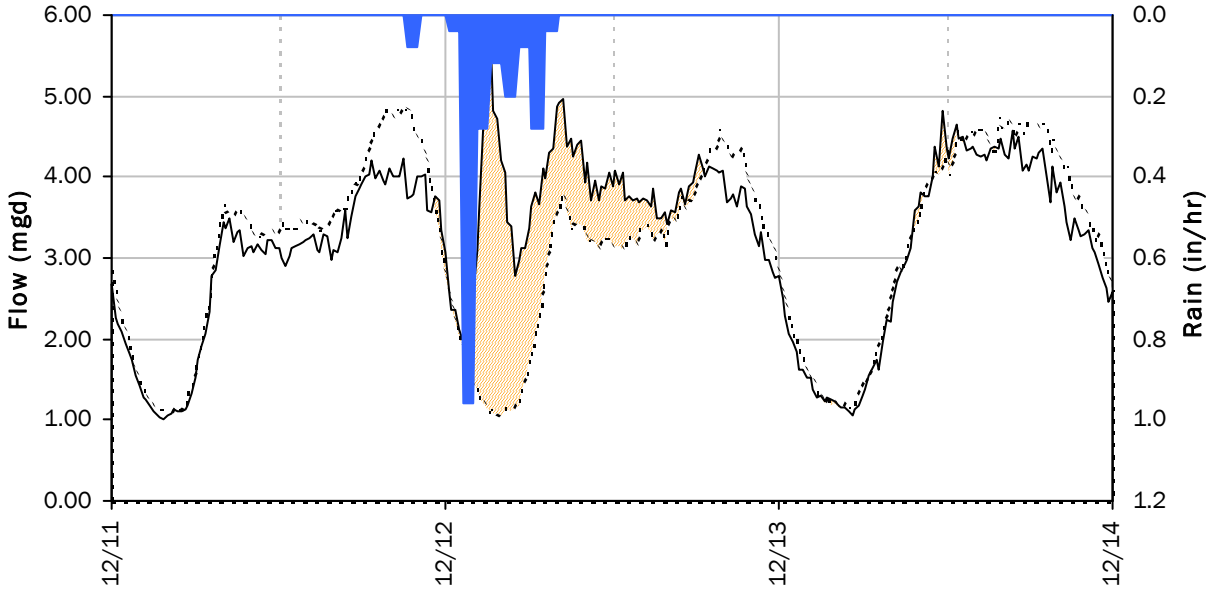
SITE 4A

I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

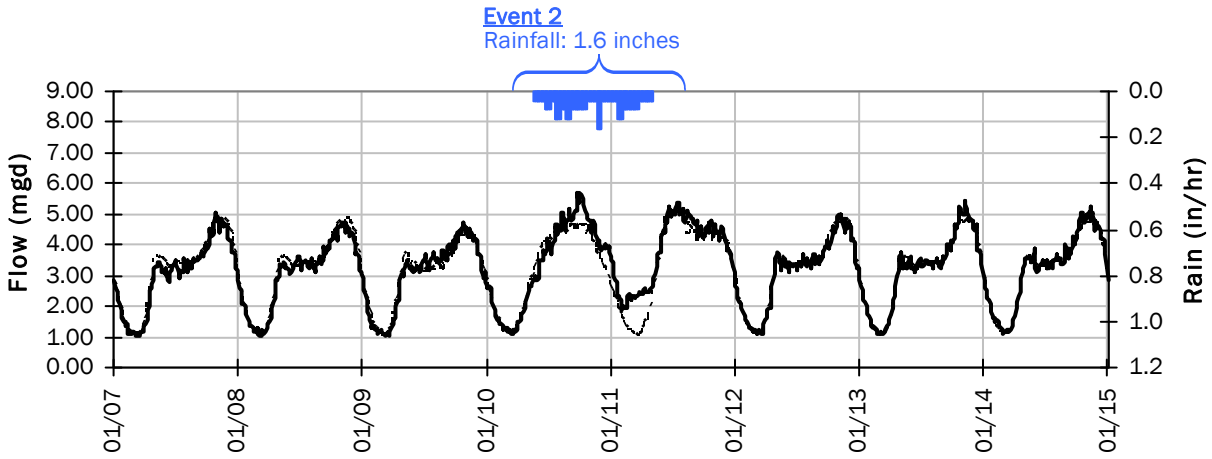


Storm Event I/I Analysis (Rain = 2.08 inches)

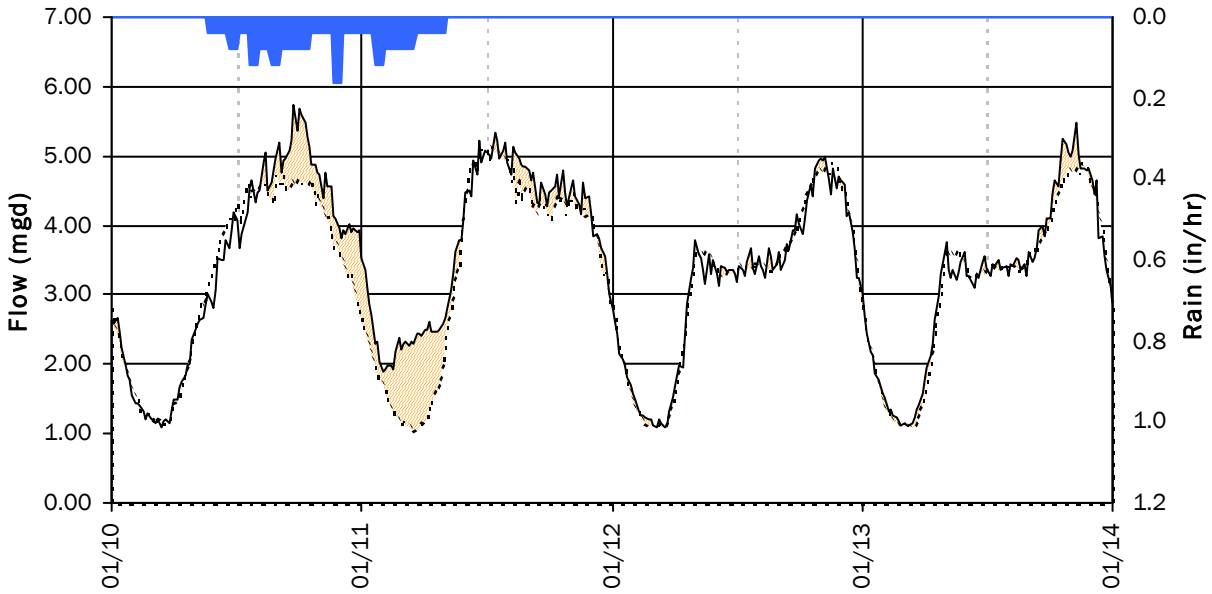
Capacity		Inflow / Infiltration	
Peak Flow:	5.63 *mgd*	**Peak I/I Rate:**	4.51 *mgd*
PF:	1.79	**Total I/I:**	577,000 *gallons*
Peak Level:	23.04 *in*		
d/D Ratio:	0.70		

SITE 4A
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



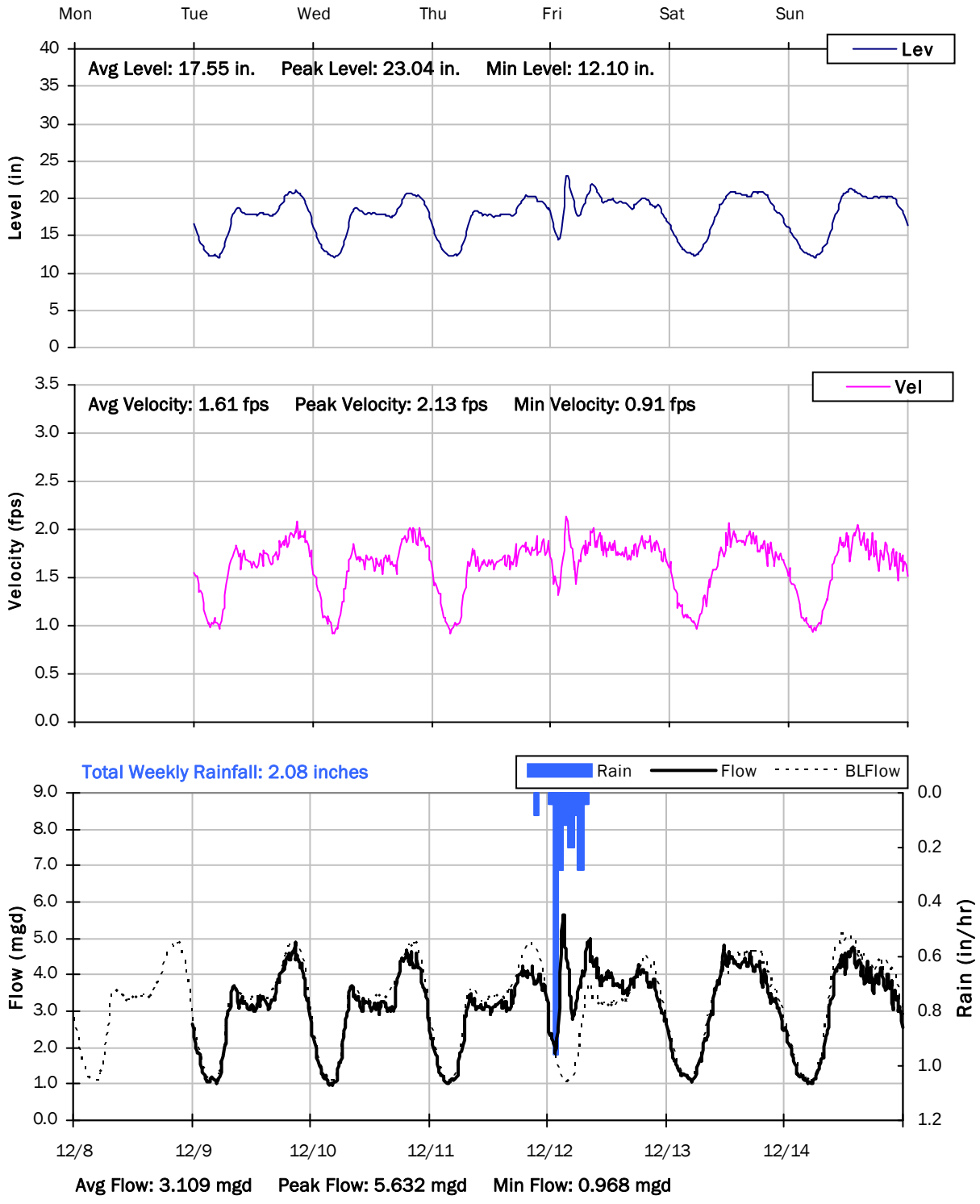
Storm Event I/I Analysis (Rain = 1.60 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	5.73 *mgd*	**Peak I/I Rate:**	1.37 *mgd*
PF:	1.82	**Total I/I:**	571,000 *gallons*
Peak Level:	23.11 *in*		
d/D Ratio:	0.70		

SITE 4A

Weekly Level, Velocity and Flow Hydrographs

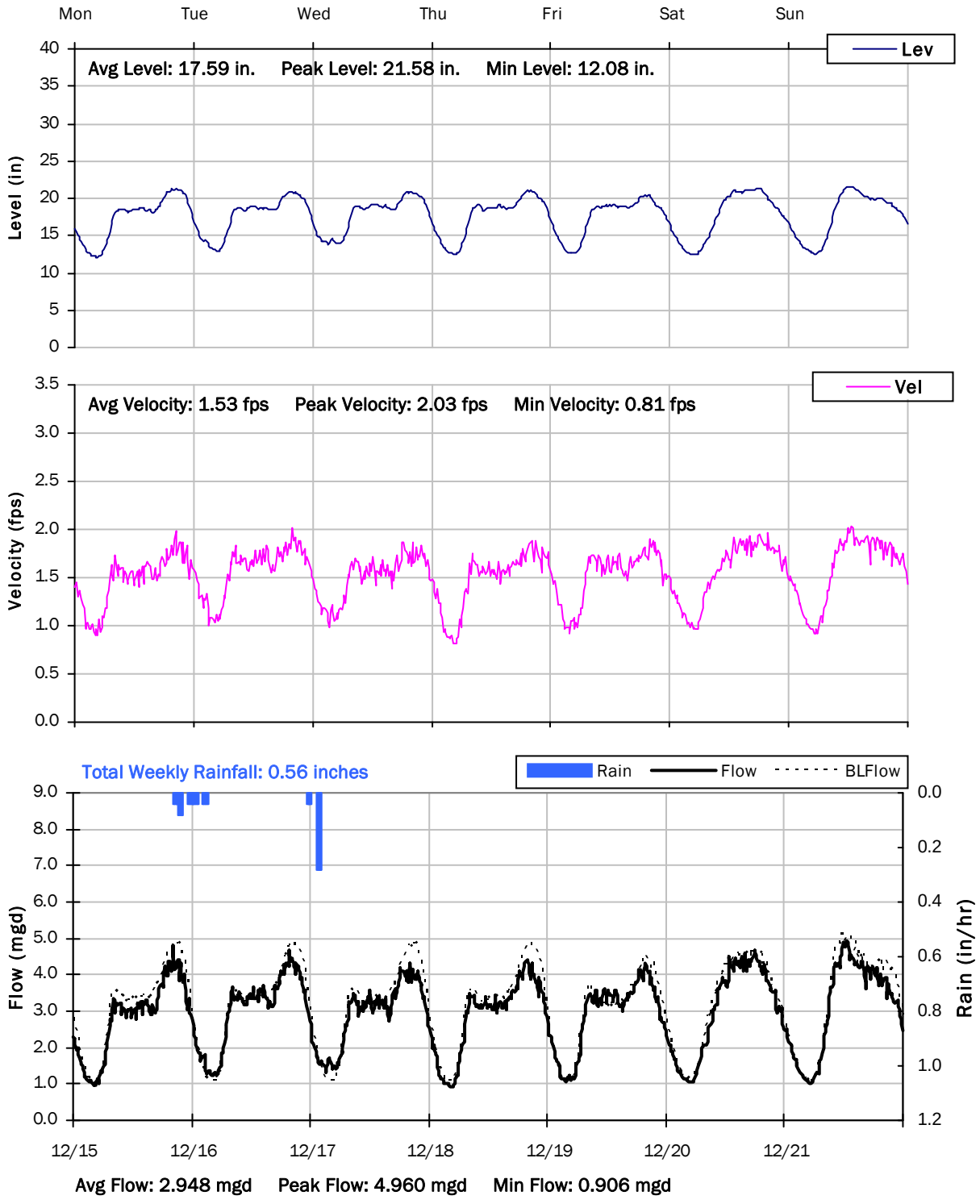
12/8/2014 to 12/15/2014



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

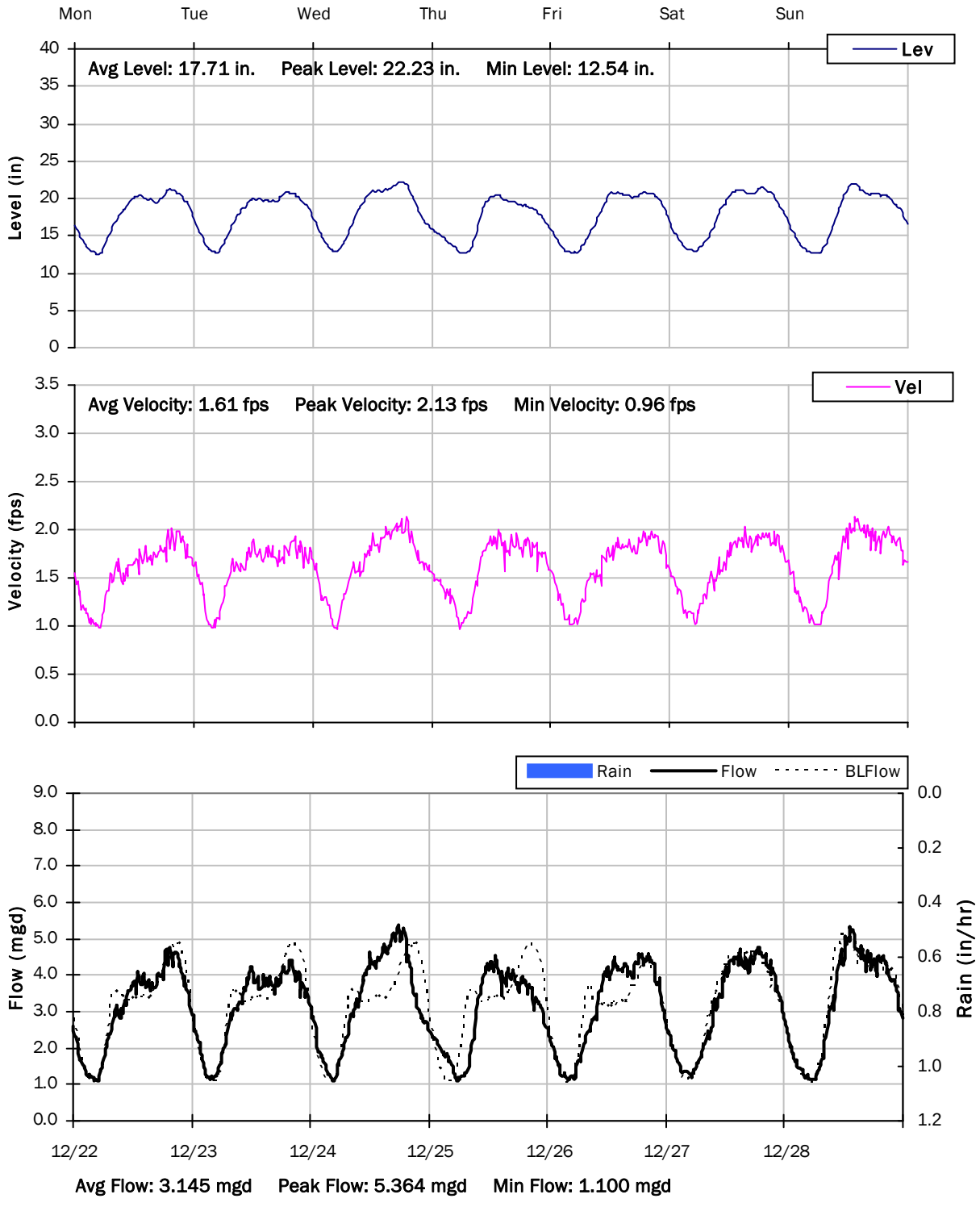
12/15/2014 to 12/22/2014



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

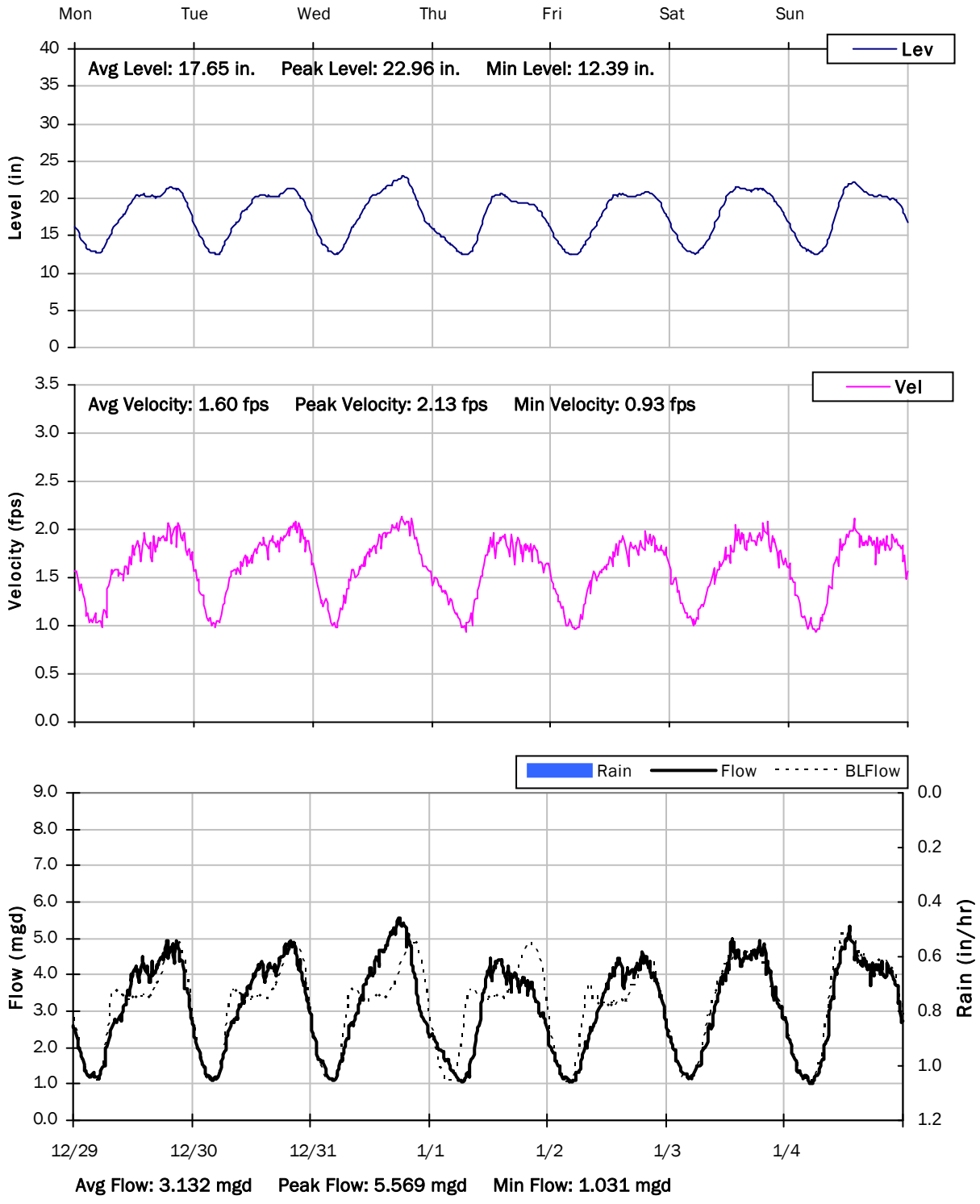
12/22/2014 to 12/29/2014



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

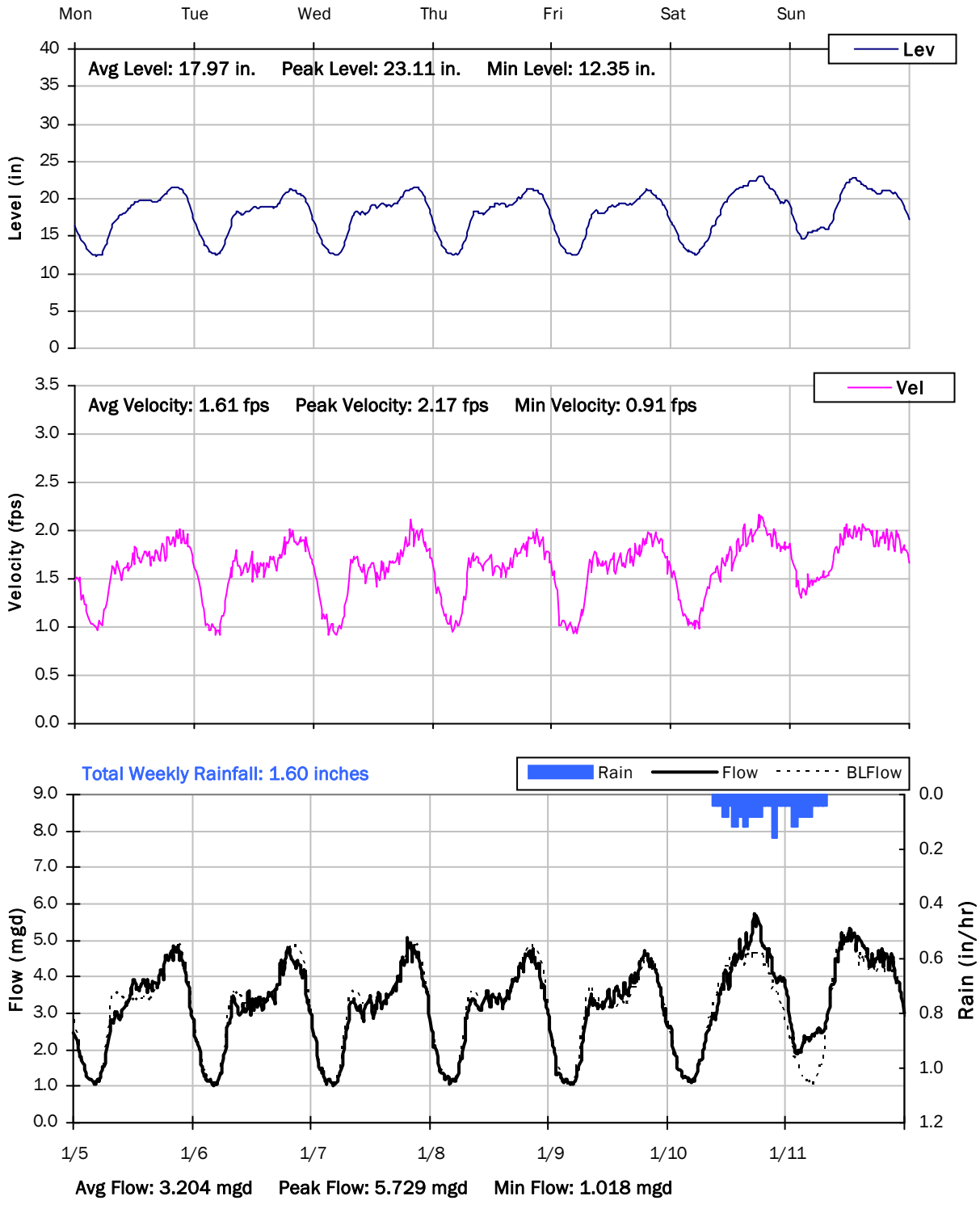
12/29/2014 to 1/5/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

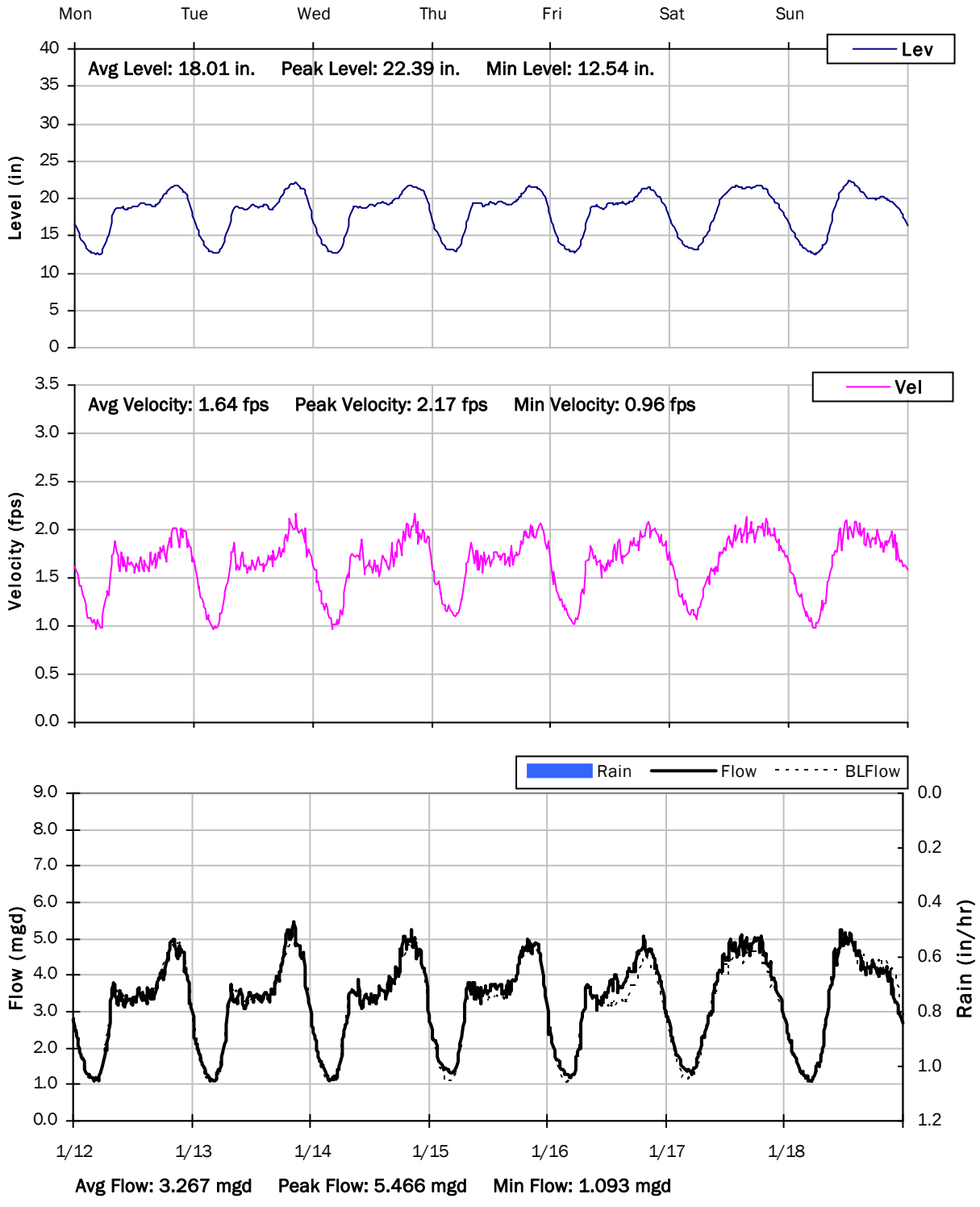
1/5/2015 to 1/12/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

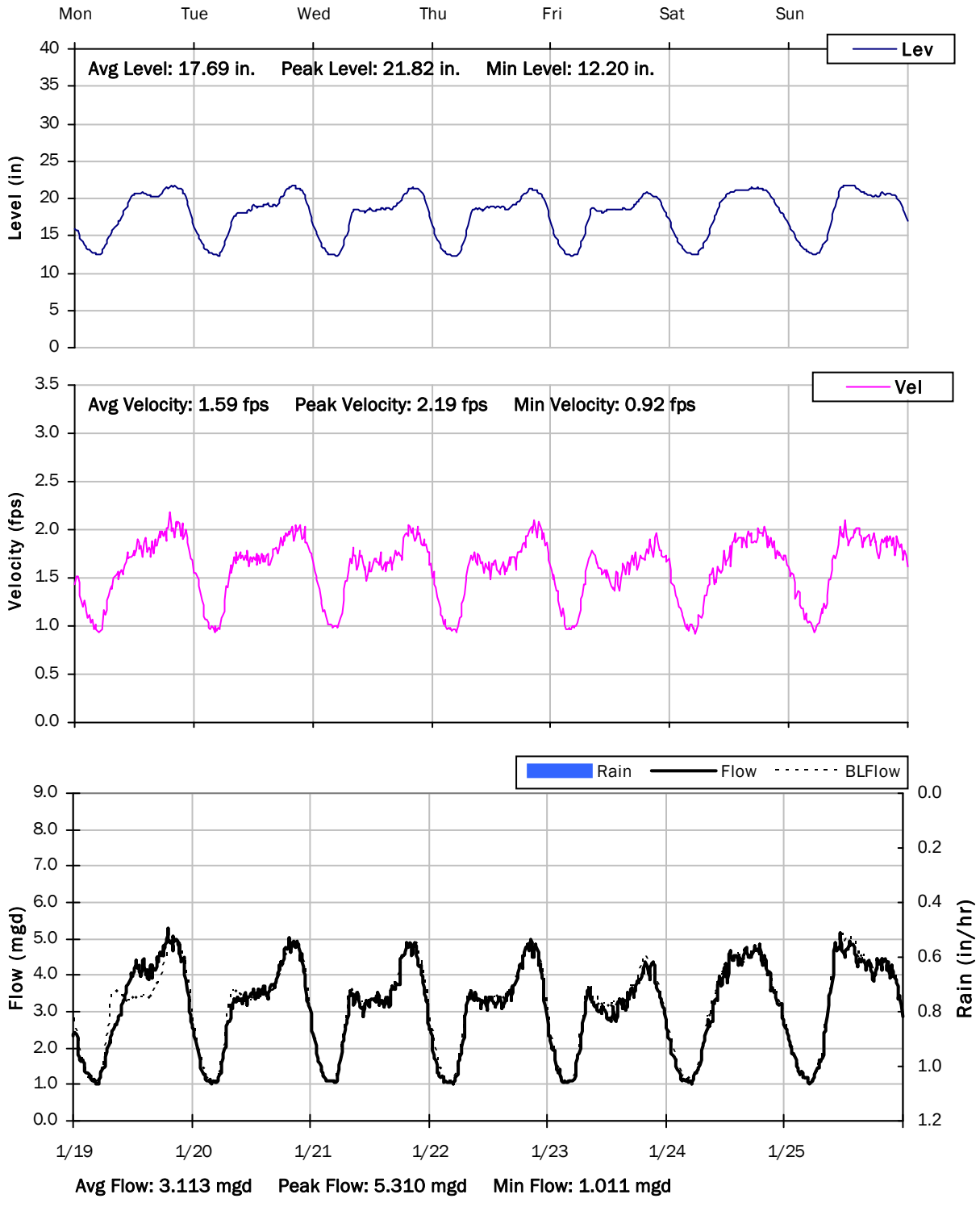
1/12/2015 to 1/19/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

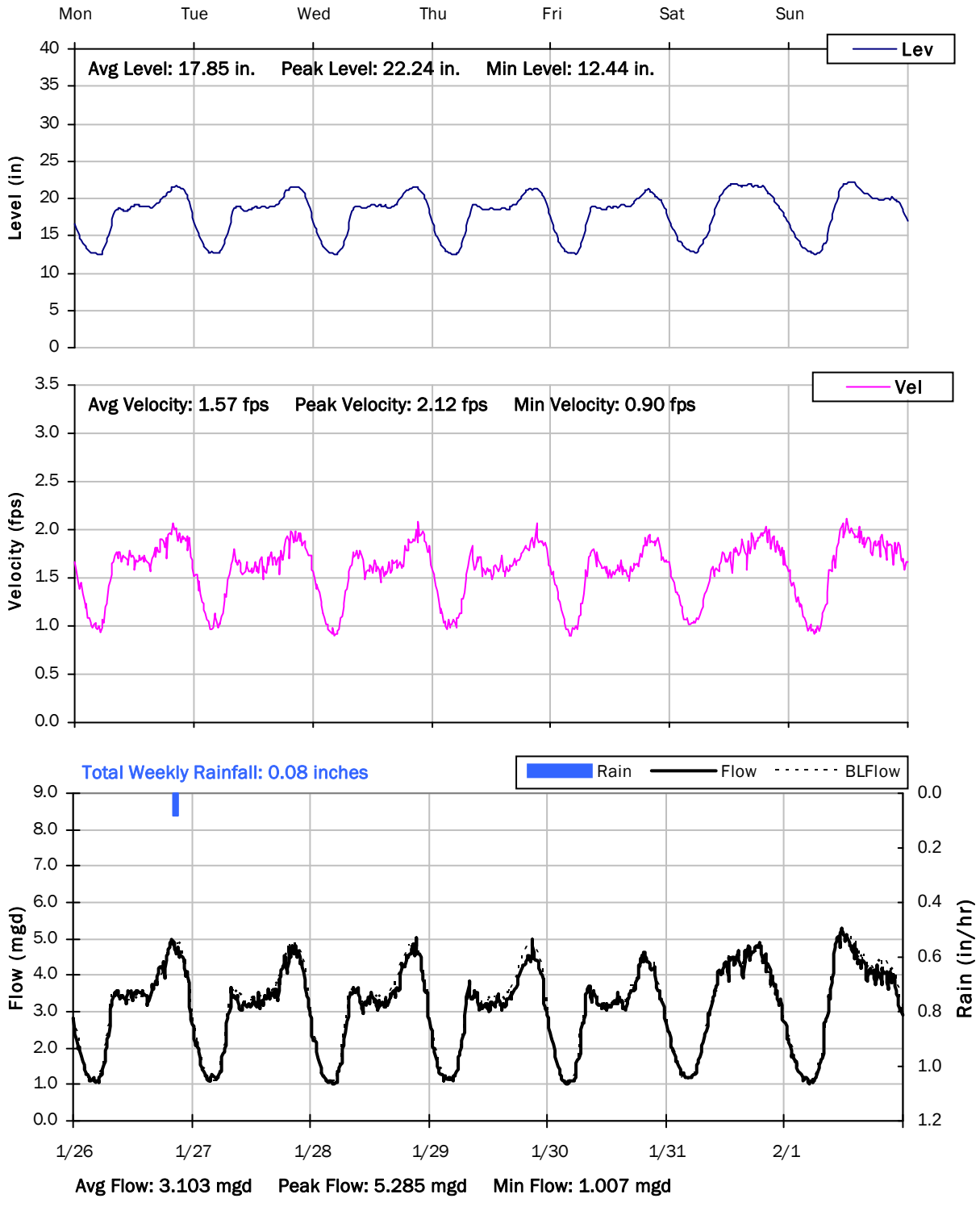
1/19/2015 to 1/26/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

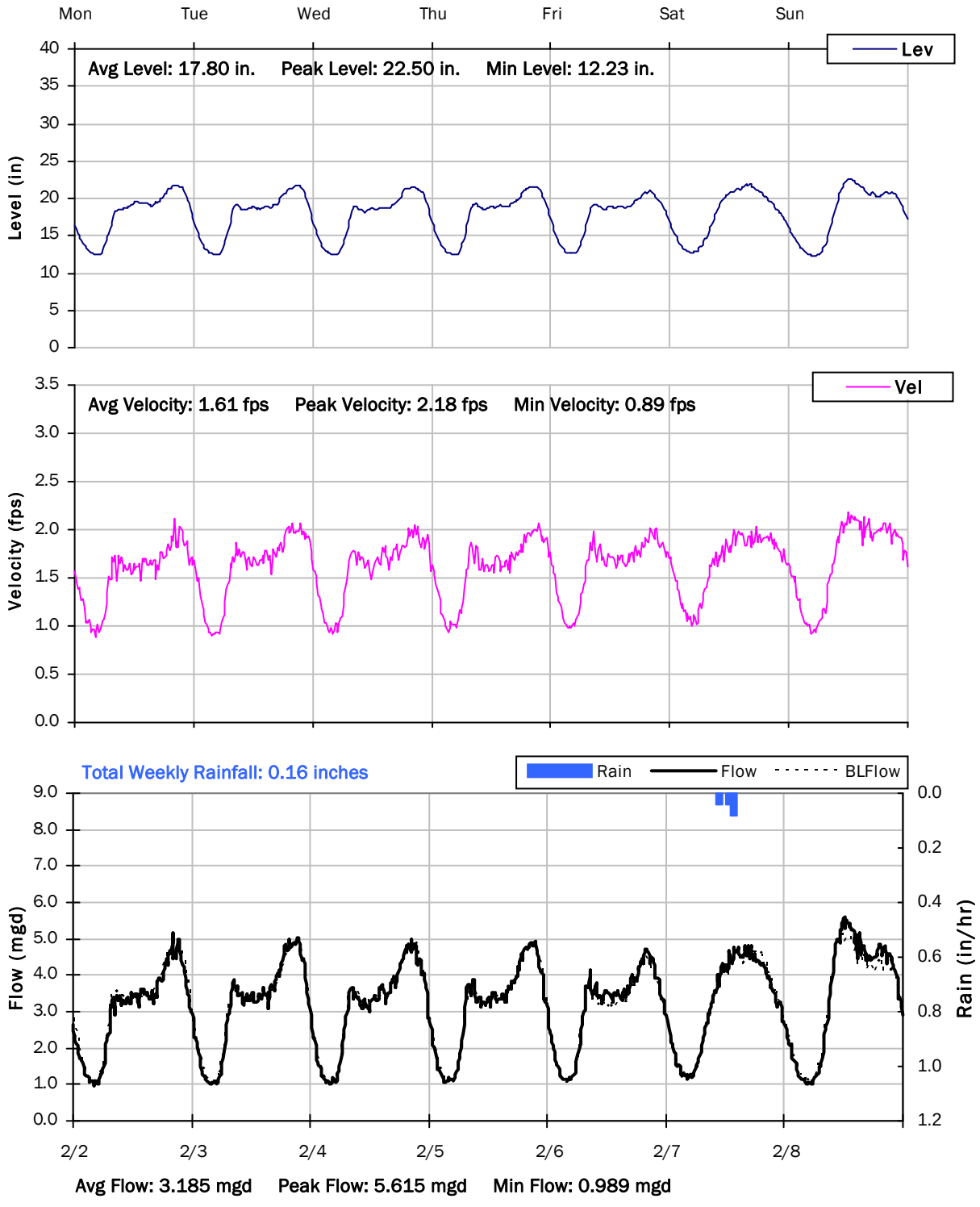
1/26/2015 to 2/2/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

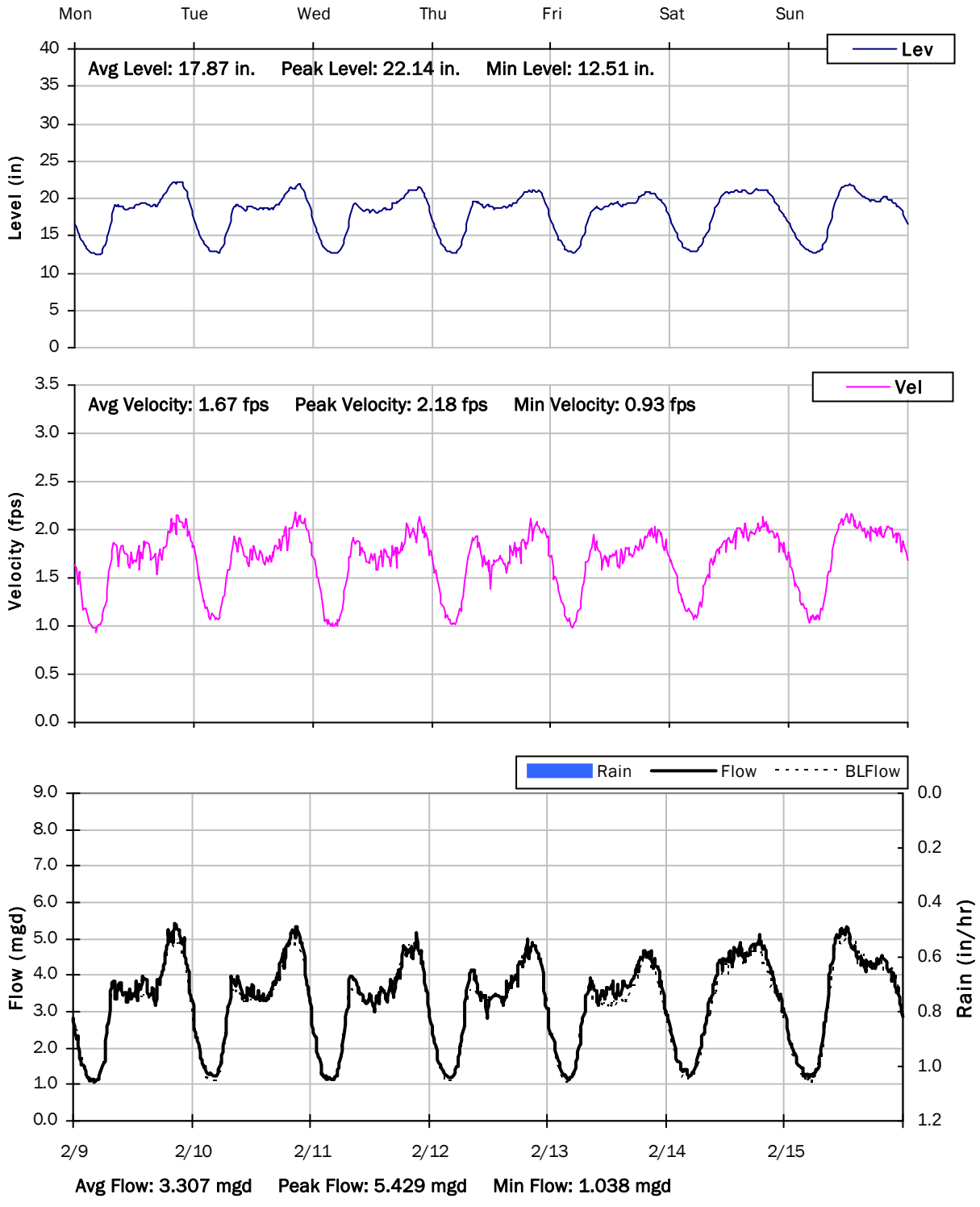
2/2/2015 to 2/9/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

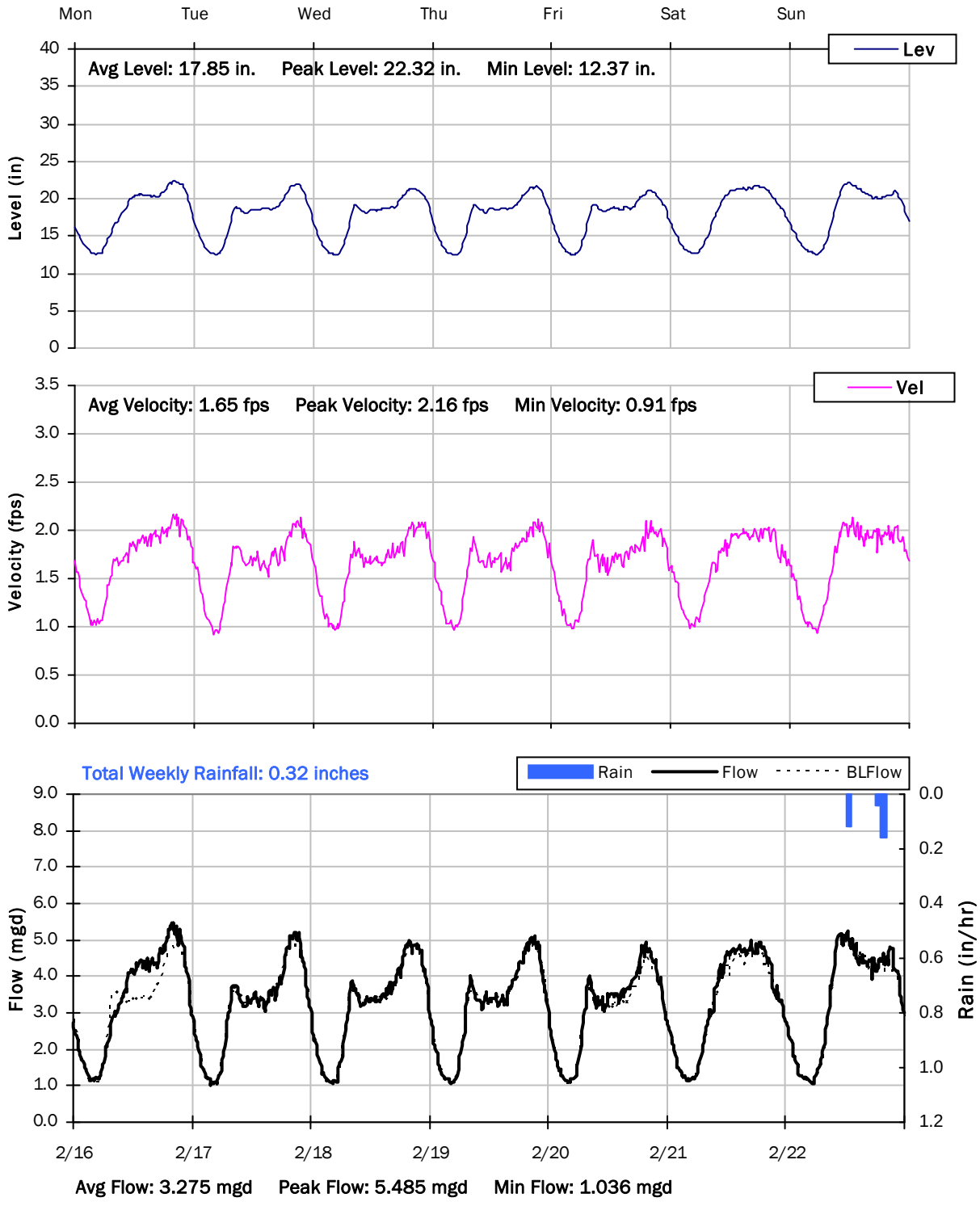
2/9/2015 to 2/16/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

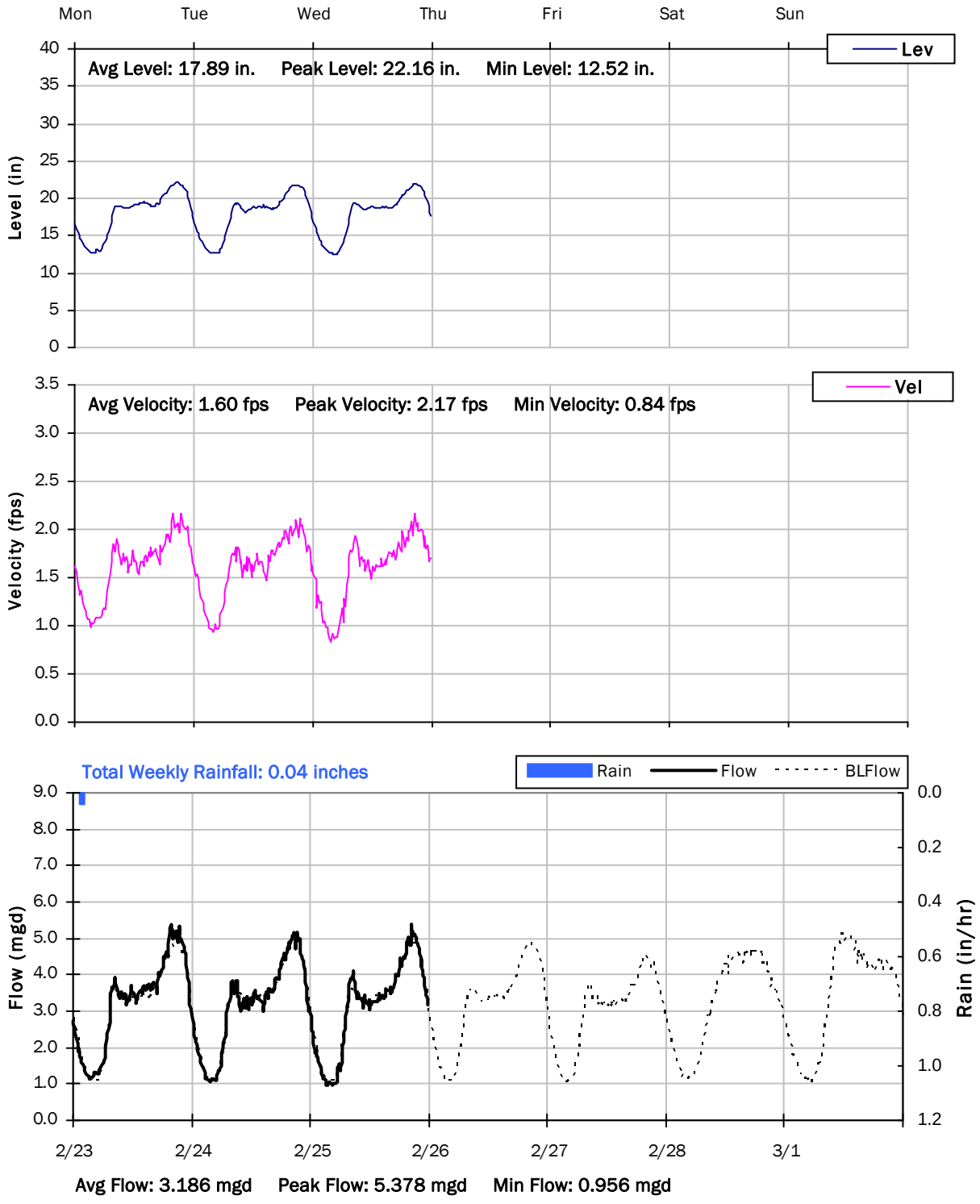
2/16/2015 to 2/23/2015



SITE 4A

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

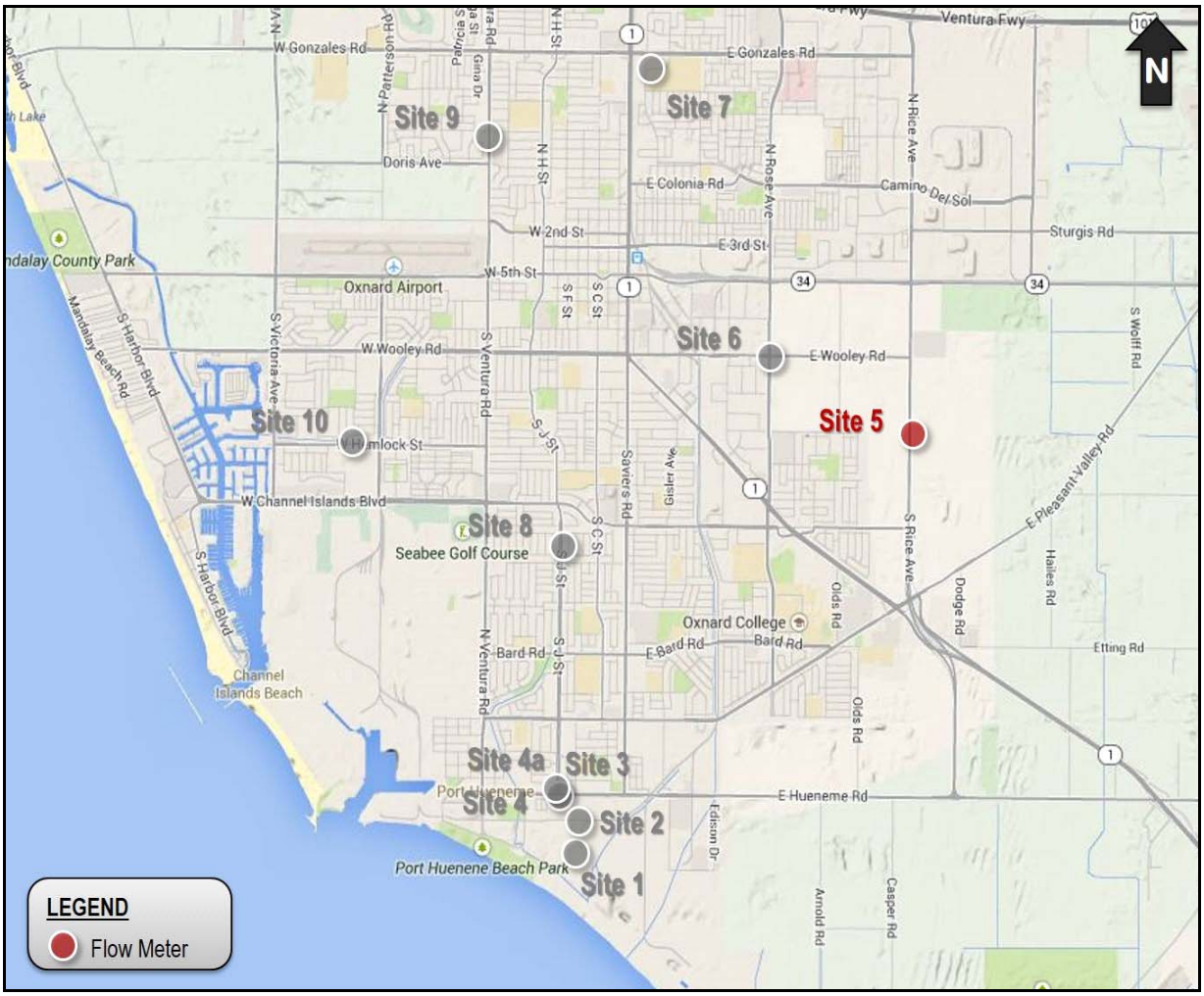
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 5

Location: S Rice Avenue and East of Emerson Avenue

Data Summary Report



Vicinity Map: Site 5

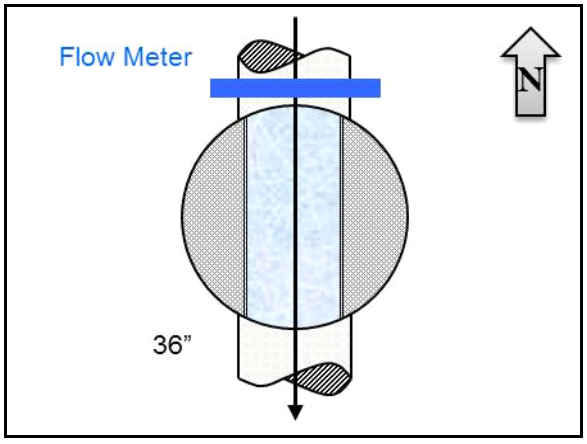
SITE 5

Site Information

Location:	S Rice Avenue and East of Emerson Avenue
Coordinates:	119.1427° W, 34.1819° N
Rim Elevation:	44 feet
Pipe Diameter:	36 inches
Baseline Flow:	1.408 mgd
Peak Measured Flow:	3.074 mgd

Satellite Map

Sanitary Map



Flow Diagram

Street View

Plan View

SITE 5

Additional Site Photos

Effluent Pipe

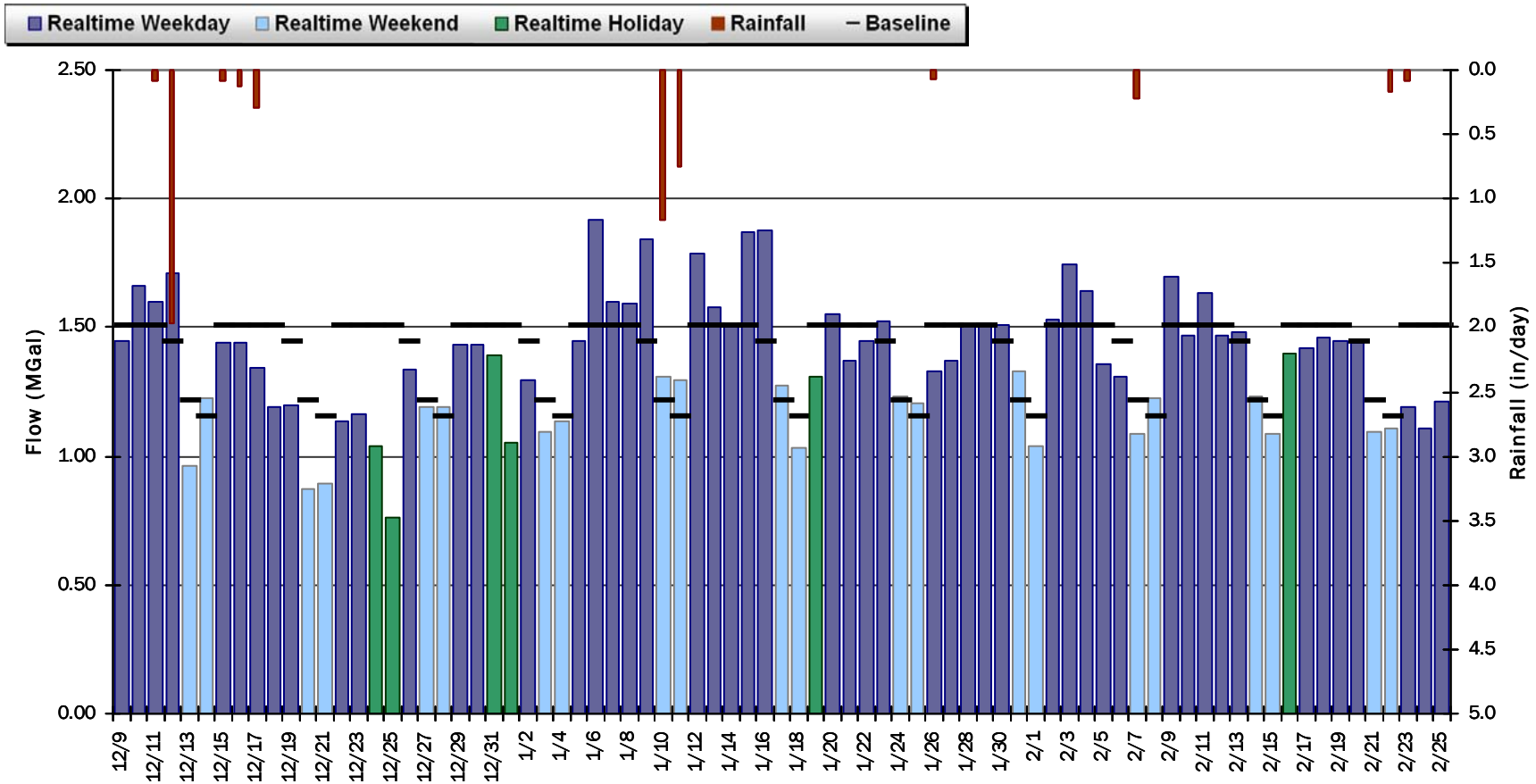
Influent Pipe

SITE 5

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 1.363 MGal **Peak Daily Flow: 1.916 MGal** **Min Daily Flow: 0.762 MGal**

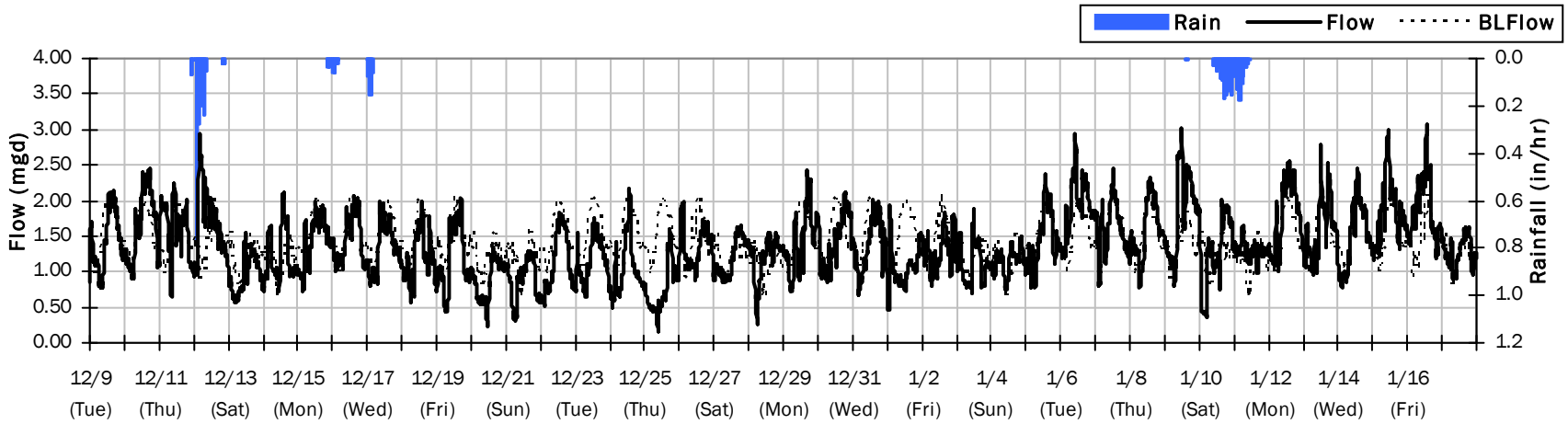
Total Period Rainfall: 5.00 inches

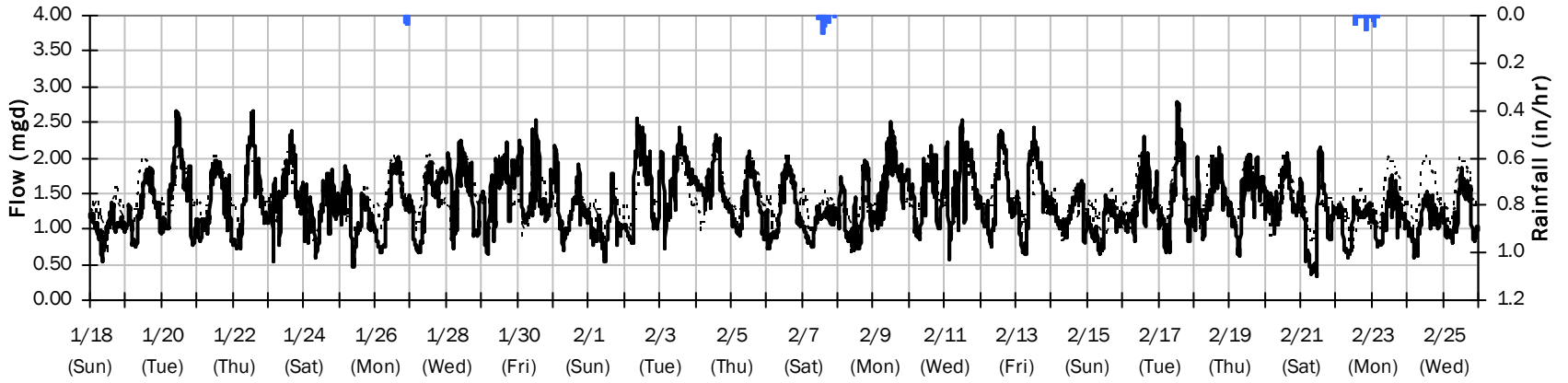


SITE 5

Flow Summary: 12/9/2014 to 2/25/2015

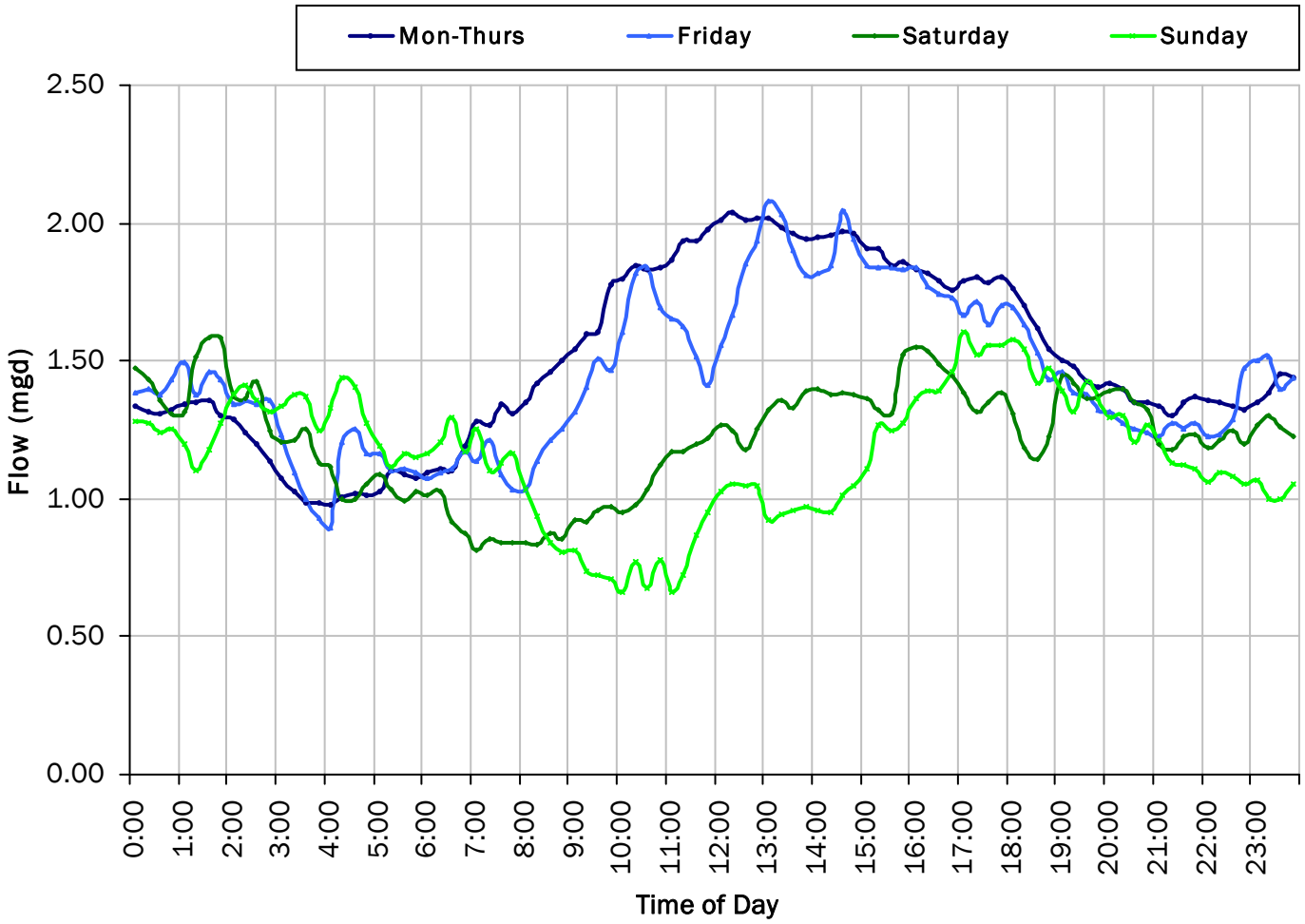
Total Period Rainfall: 5.00 inches Avg Flow: 1.363 mgd Peak Flow: 3.074 mgd Min Flow: 0.153 mgd





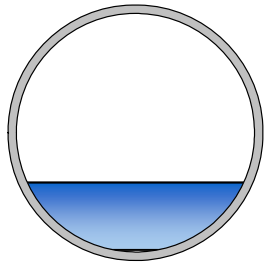
SITE 5

Baseline Flow Hydrographs



Baseline Flow:

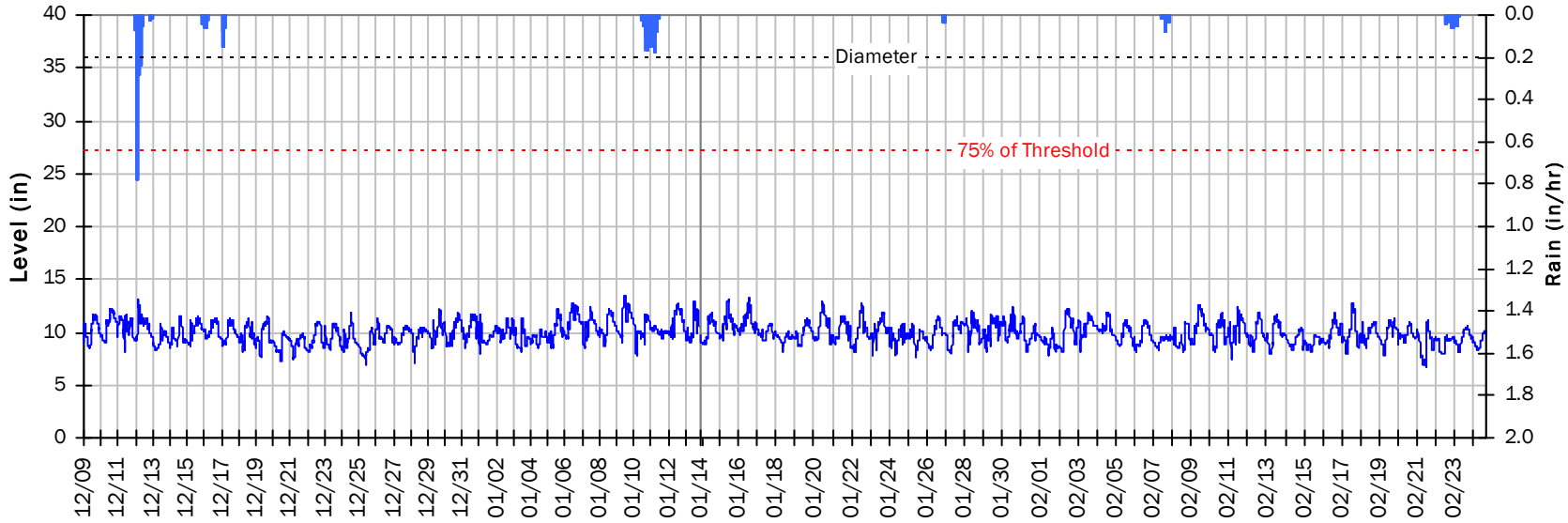
1.41 *mgd*

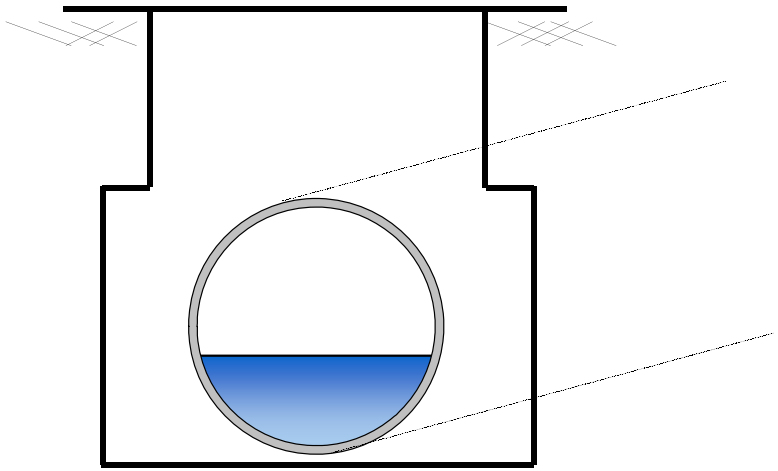


SITE 5

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

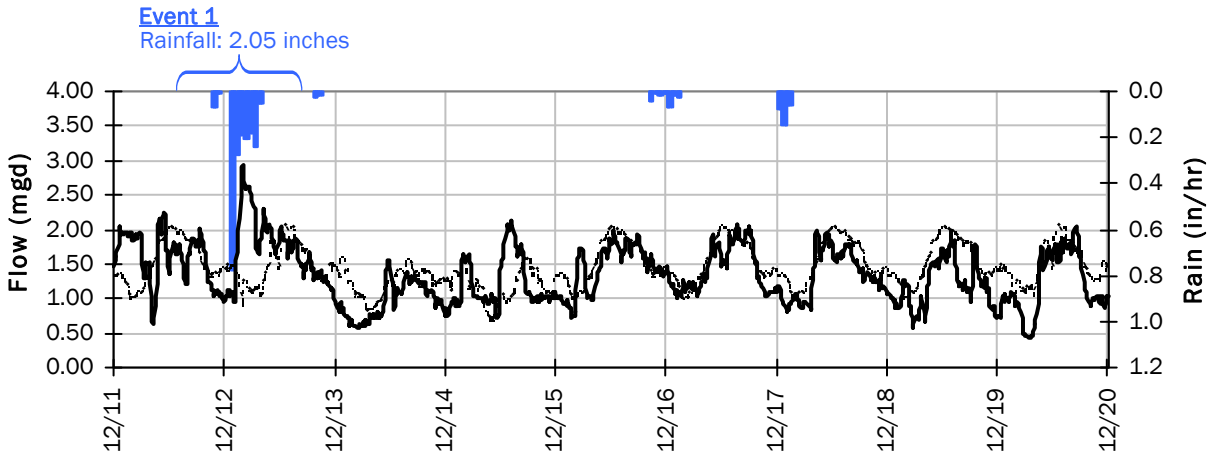




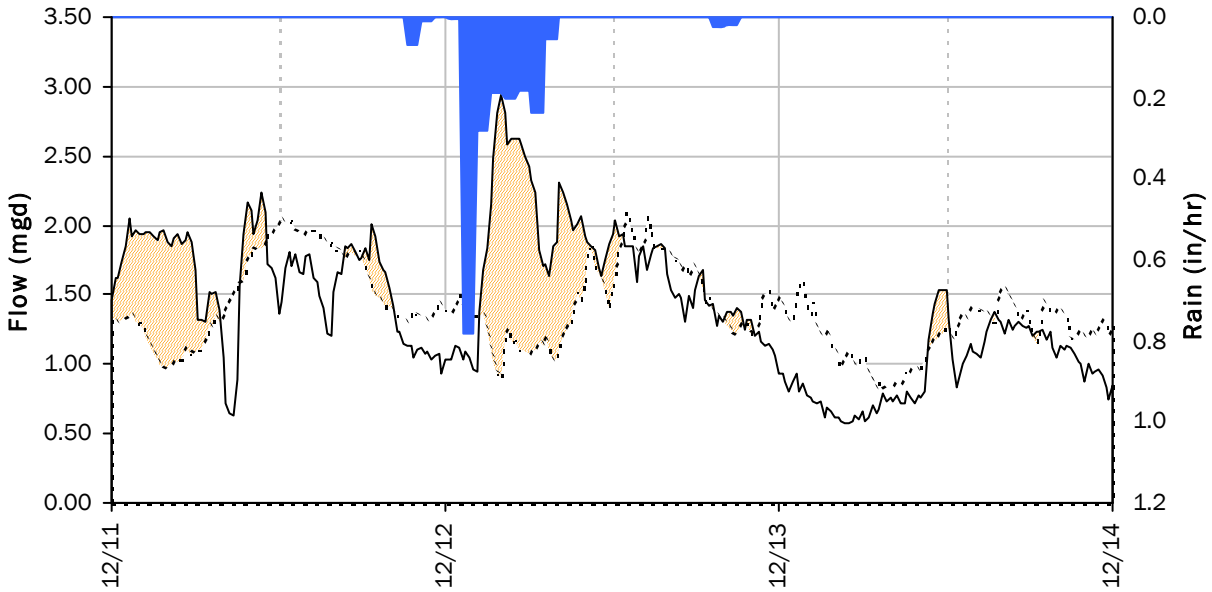
Pipe Diameter:	36	*inches*
Peak Measured Level:	13.5	*inches*
Peak d/D Ratio:	0.37	

SITE 5
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

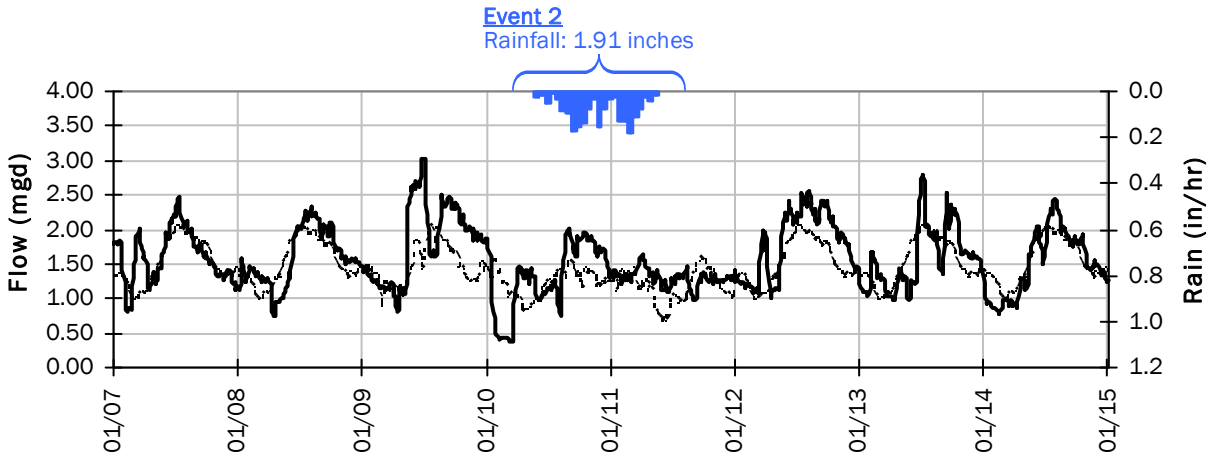


Storm Event I/I Analysis (Rain = 2.05 inches)

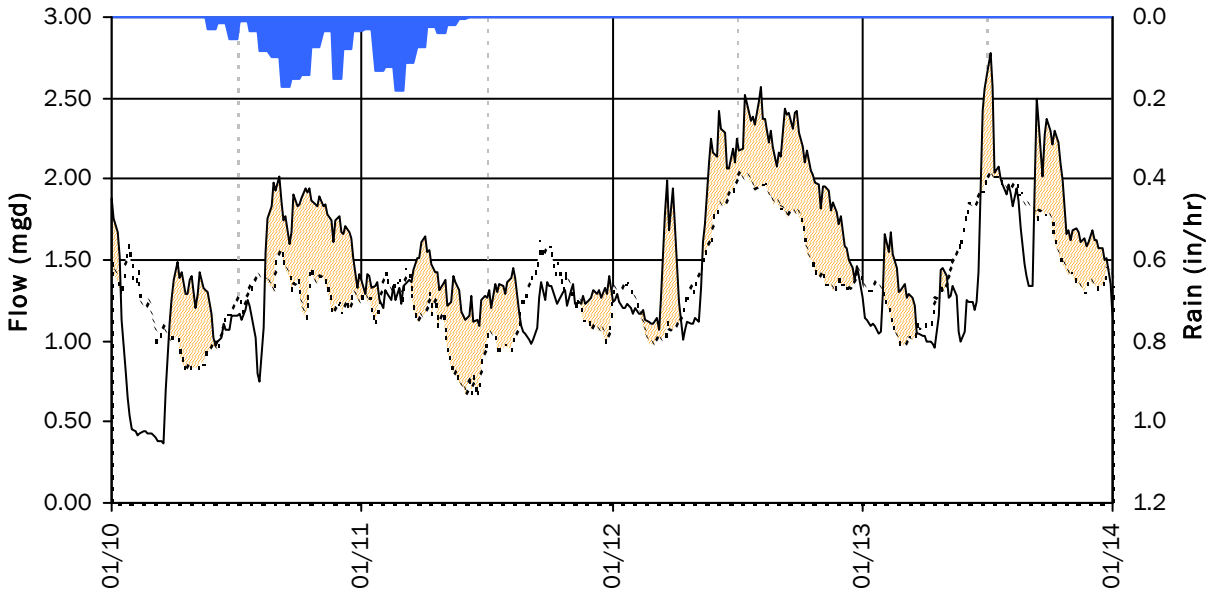
Capacity		Inflow / Infiltration	
Peak Flow:	2.94 *mgd*	**Peak I/I Rate:**	2.04 *mgd*
PF:	2.09	**Total I/I:**	-22,000 *gallons*
Peak Level:	13.10 *in*		
d/D Ratio:	0.36		

SITE 5
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



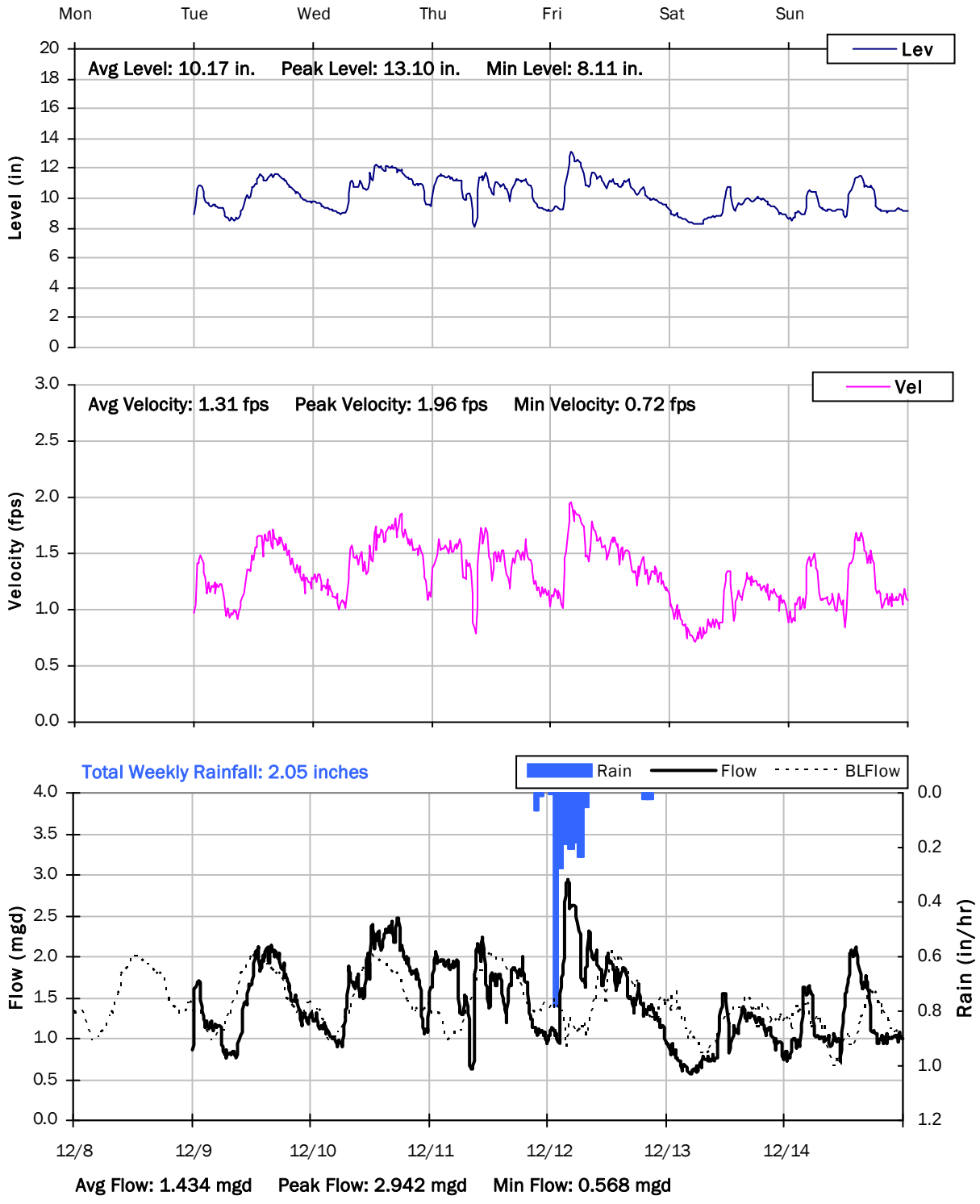
Storm Event I/I Analysis (Rain = 1.91 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	2.56 *mgd*	**Peak I/I Rate:**	0.89 *mgd*
PF:	1.82	**Total I/I:**	509,000 *gallons*
Peak Level:	12.78 *in*		
d/D Ratio:	0.36		

SITE 5

Weekly Level, Velocity and Flow Hydrographs

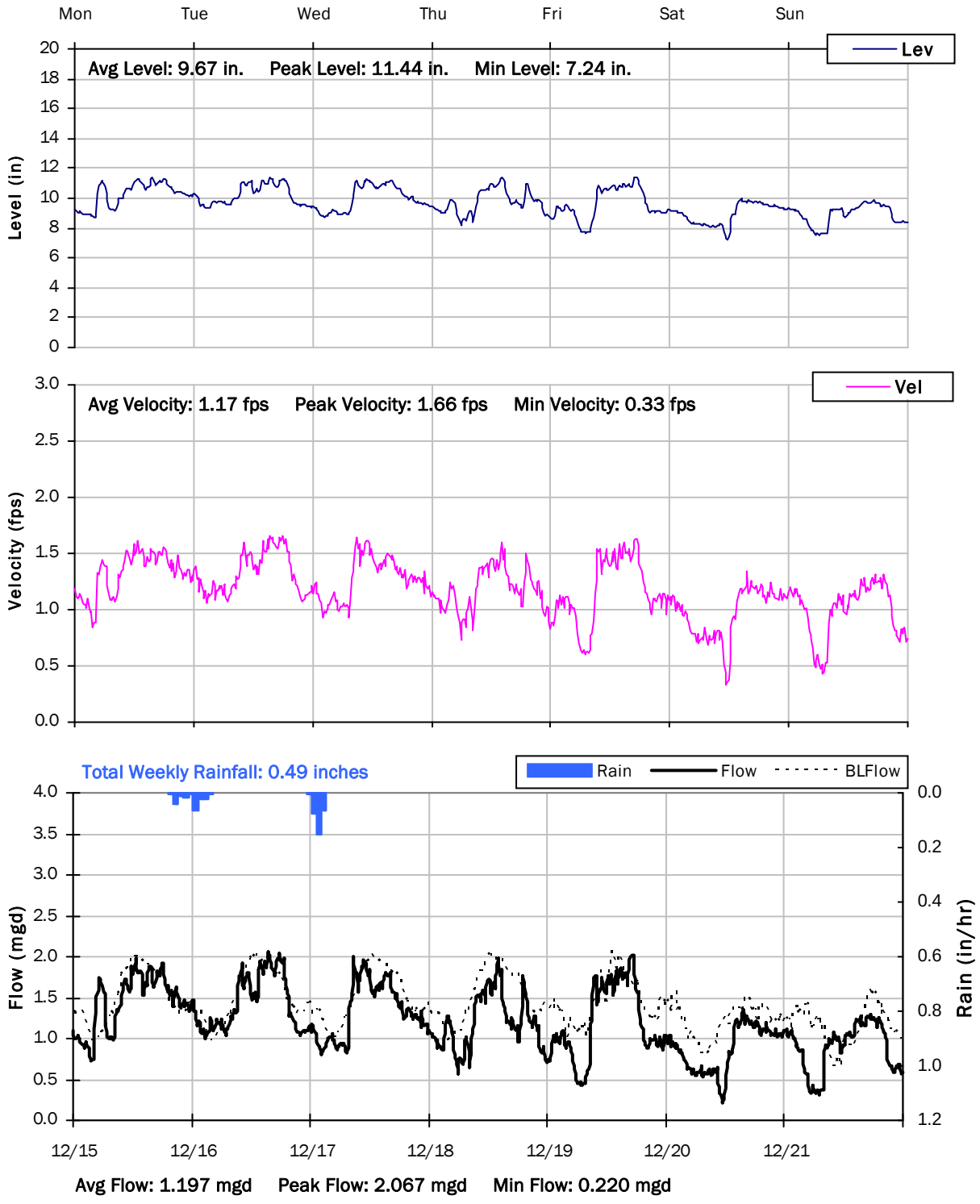
12/8/2014 to 12/15/2014



SITE 5

Weekly Level, Velocity and Flow Hydrographs

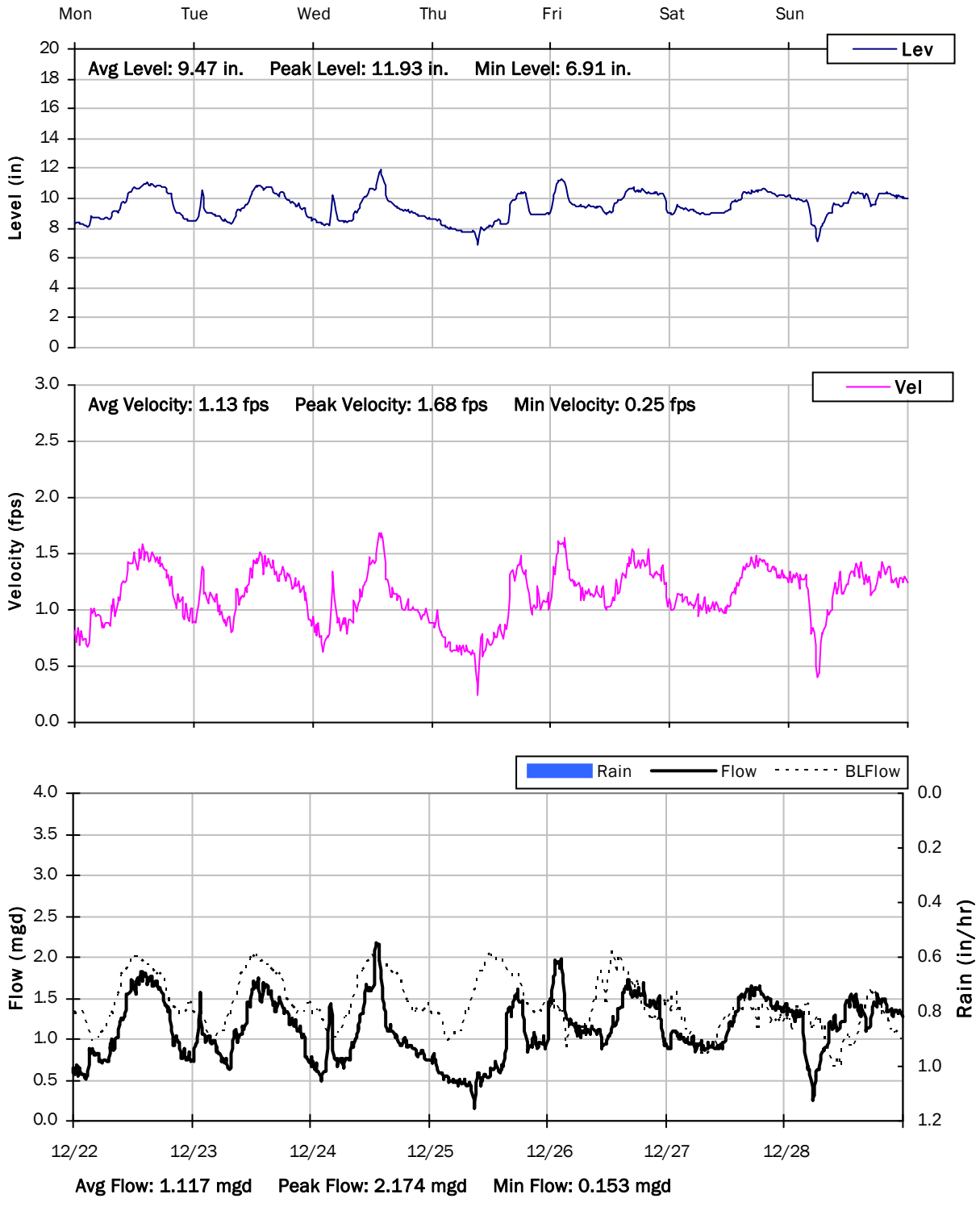
12/15/2014 to 12/22/2014



SITE 5

Weekly Level, Velocity and Flow Hydrographs

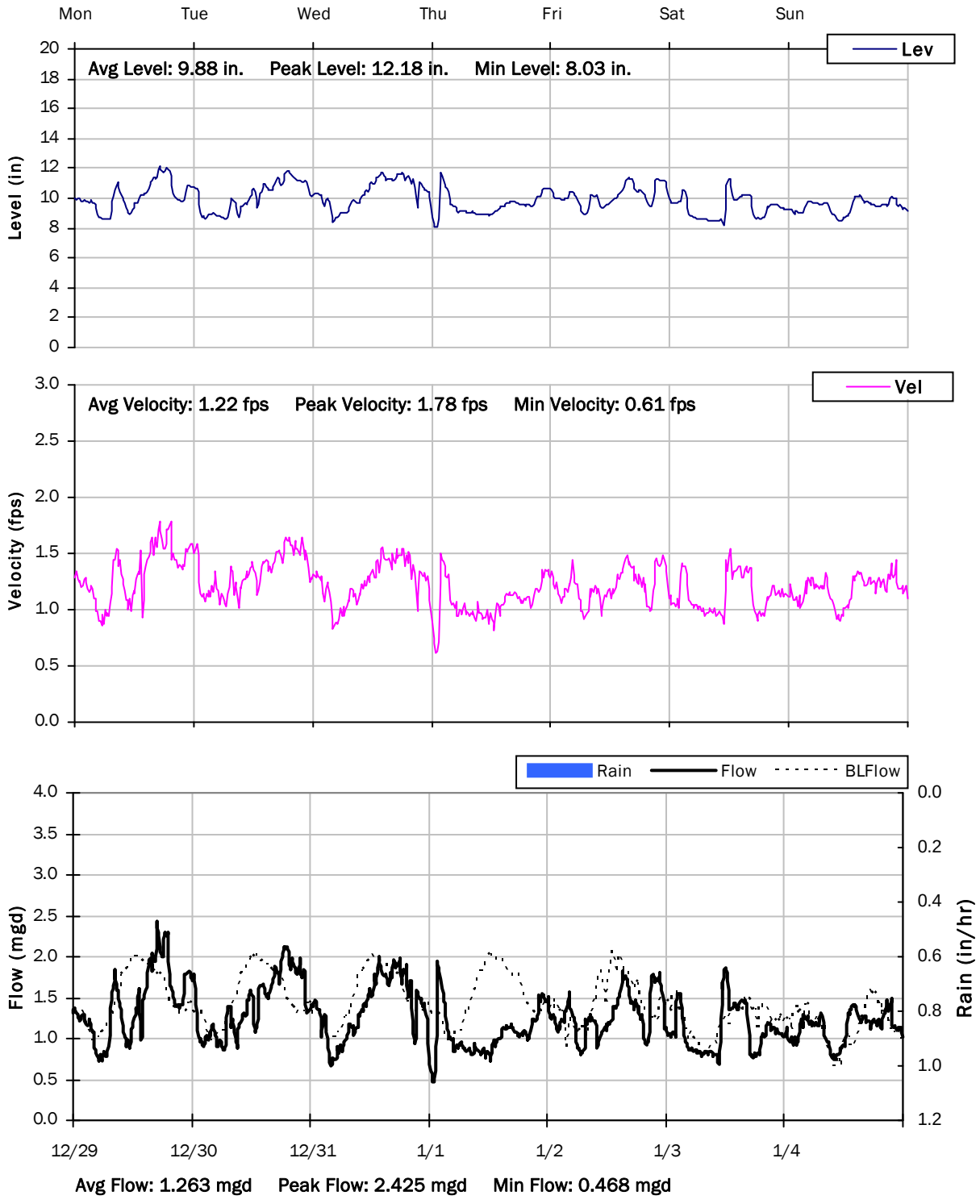
12/22/2014 to 12/29/2014



SITE 5

Weekly Level, Velocity and Flow Hydrographs

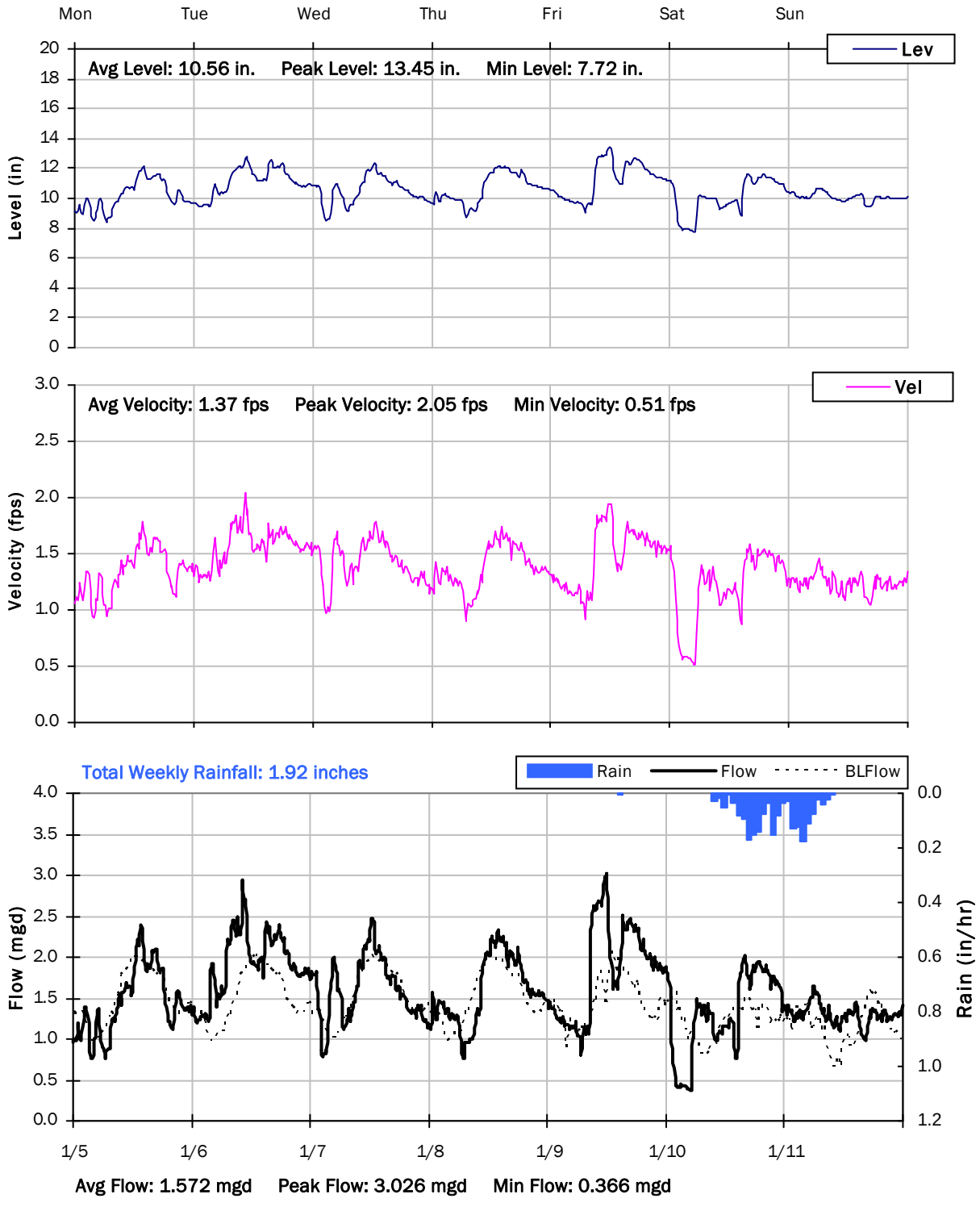
12/29/2014 to 1/5/2015



SITE 5

Weekly Level, Velocity and Flow Hydrographs

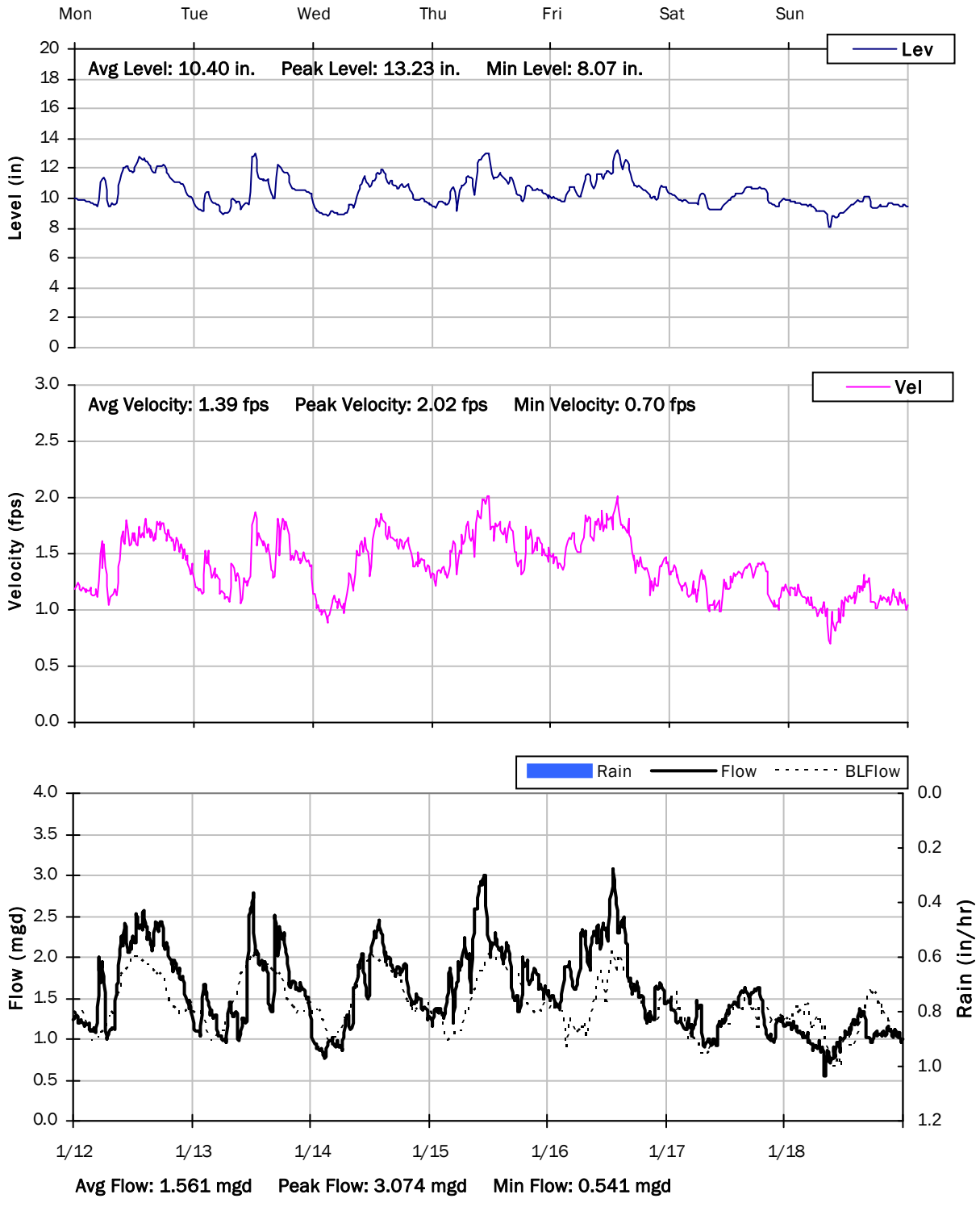
1/5/2015 to 1/12/2015



SITE 5

Weekly Level, Velocity and Flow Hydrographs

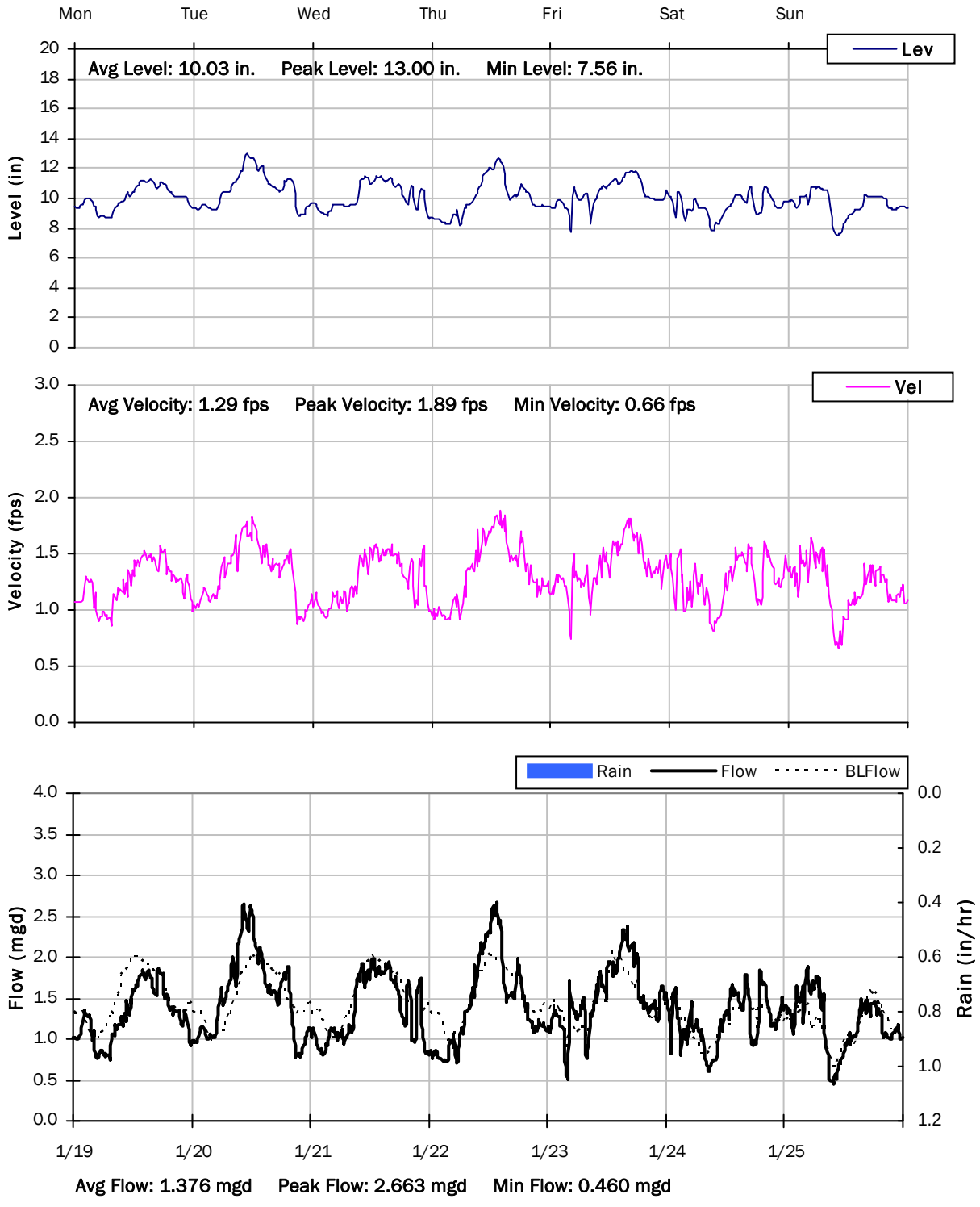
1/12/2015 to 1/19/2015



SITE 5

Weekly Level, Velocity and Flow Hydrographs

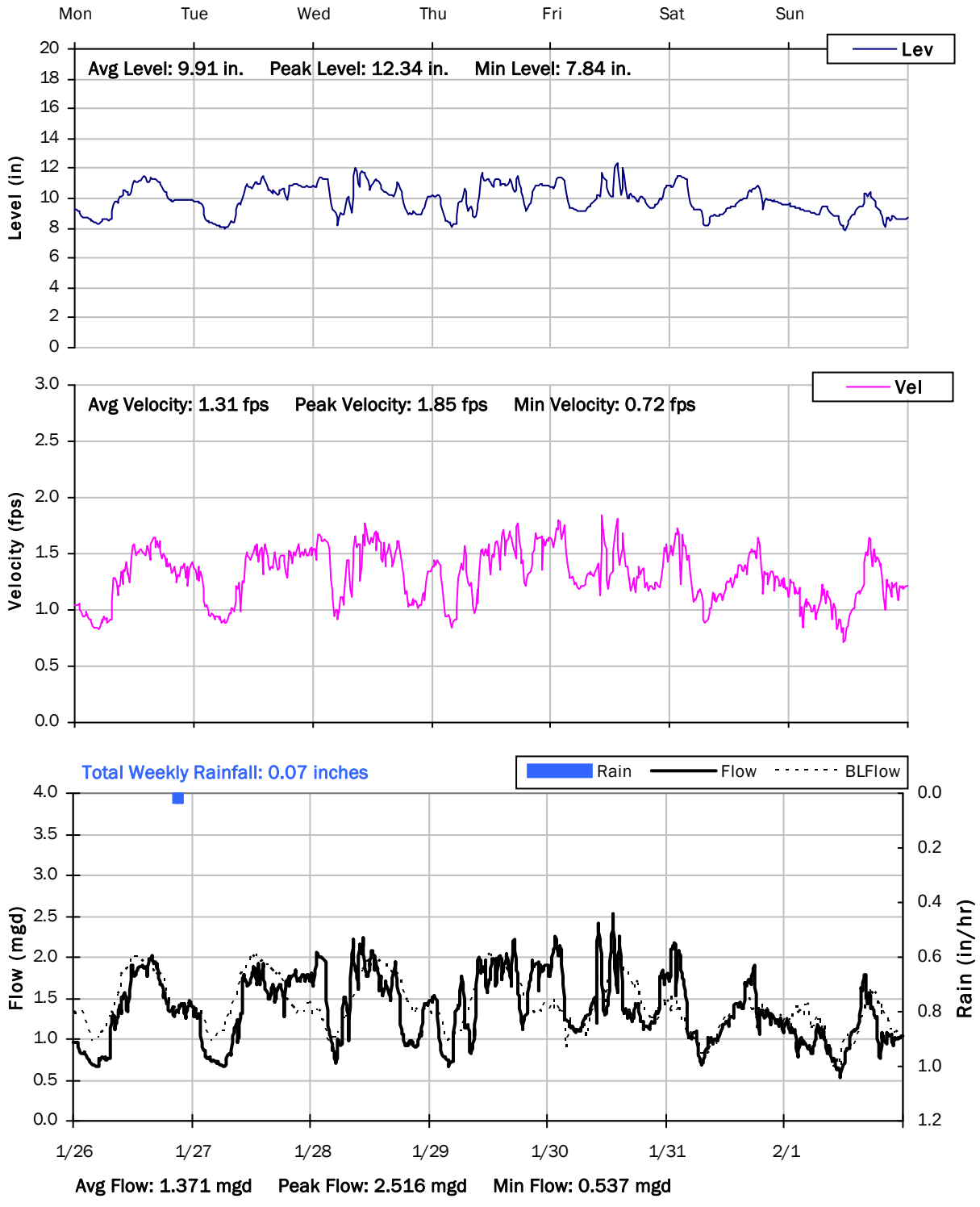
1/19/2015 to 1/26/2015



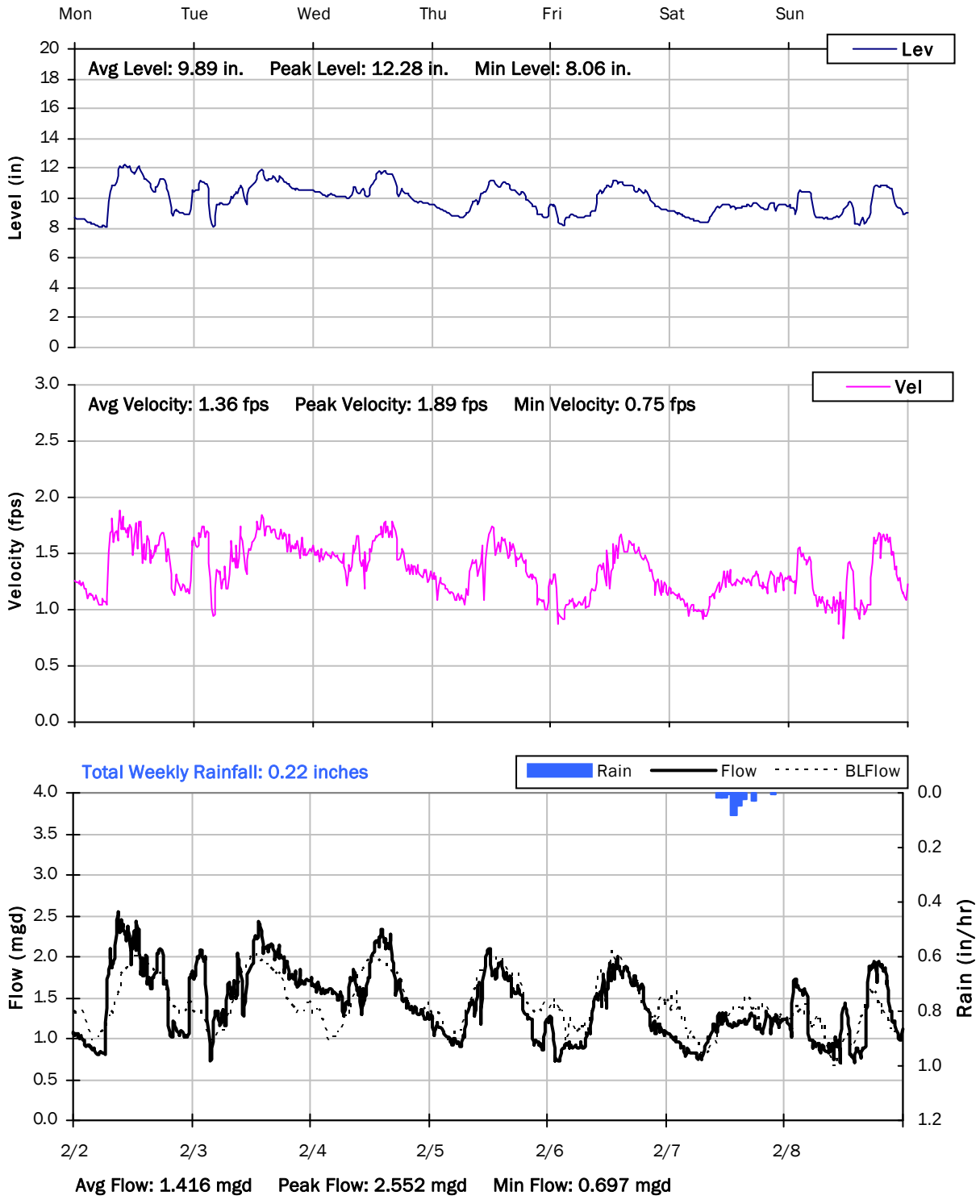
SITE 5

Weekly Level, Velocity and Flow Hydrographs

1/26/2015 to 2/2/2015



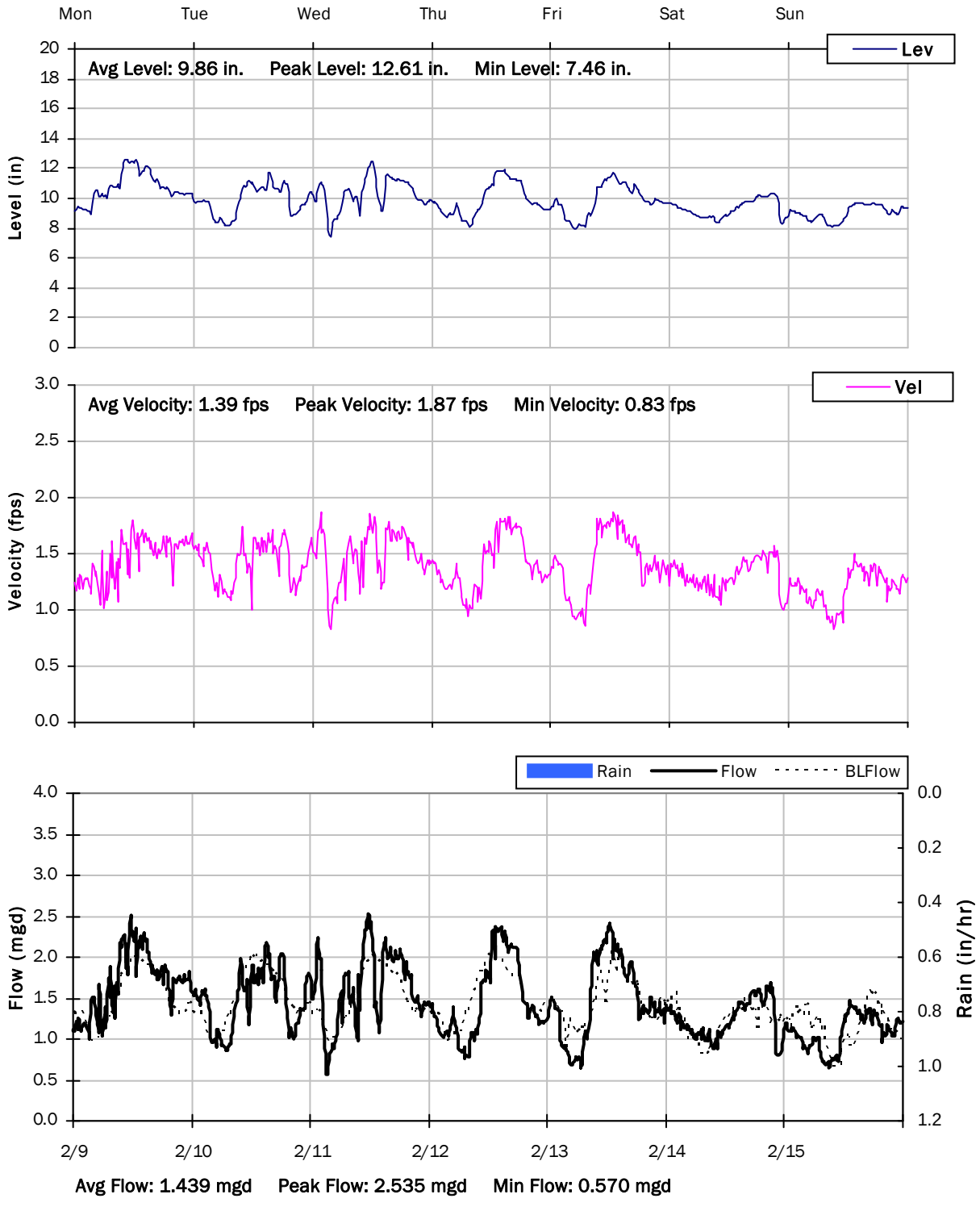
SITE 5
Weekly Level, Velocity and Flow Hydrographs
2/2/2015 to 2/9/2015



SITE 5

Weekly Level, Velocity and Flow Hydrographs

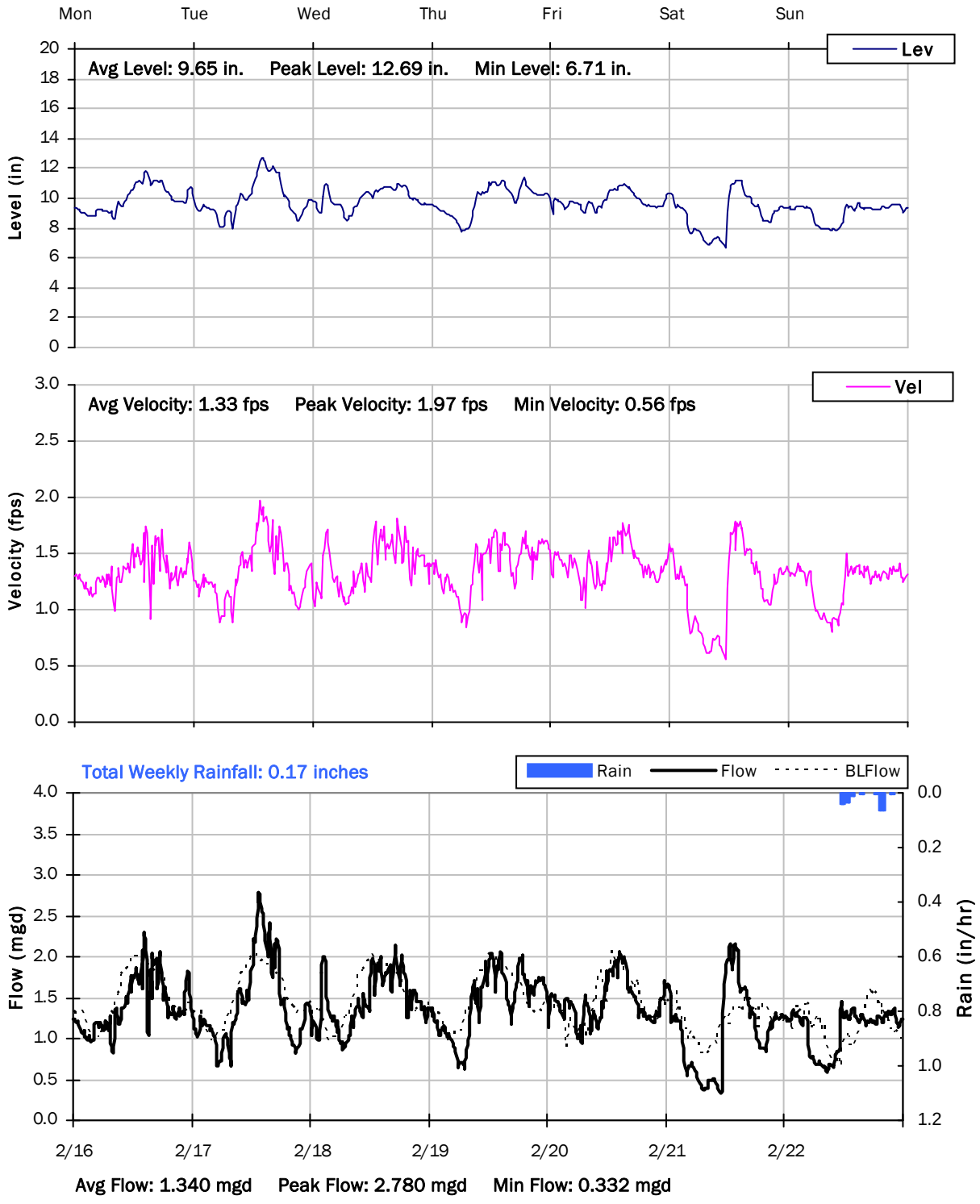
2/9/2015 to 2/16/2015



SITE 5

Weekly Level, Velocity and Flow Hydrographs

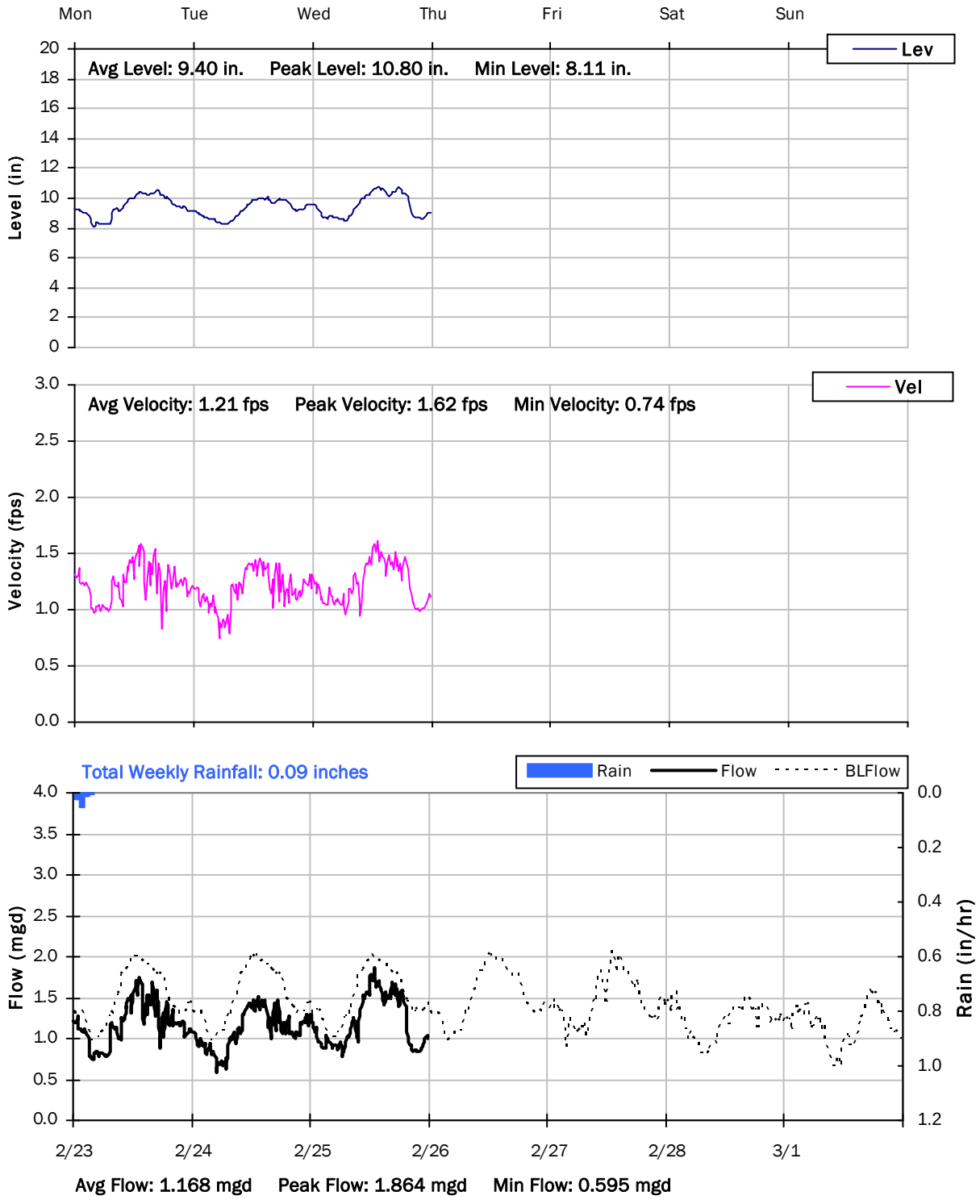
2/16/2015 to 2/23/2015



SITE 5

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

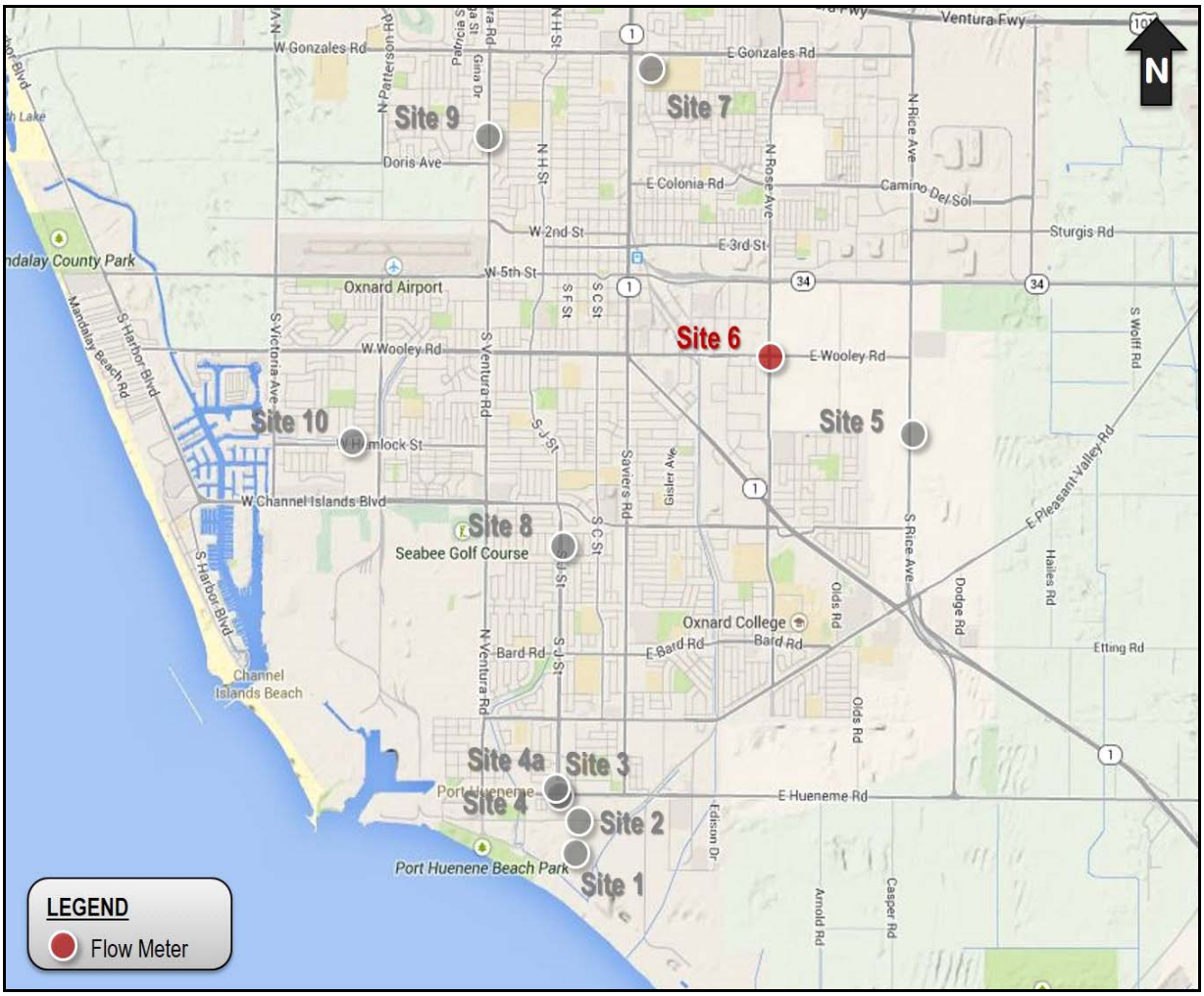
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 6

Location: S Rose Avenue and E Wooley Road

Data Summary Report

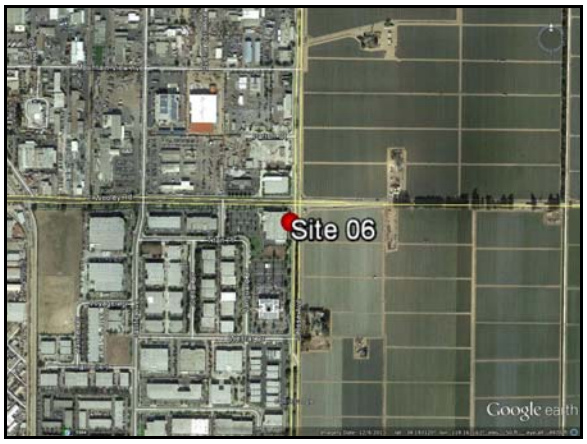


Vicinity Map: Site 6

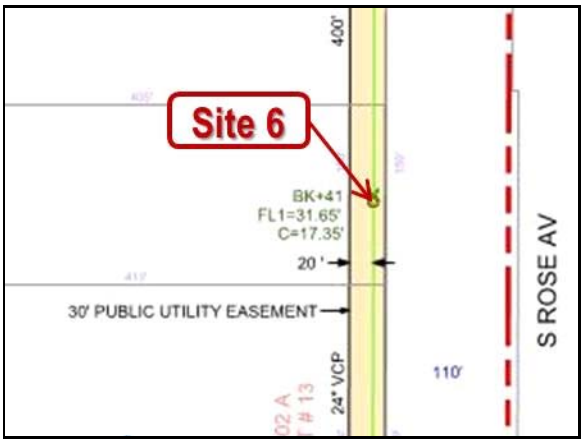
SITE 6

Site Information

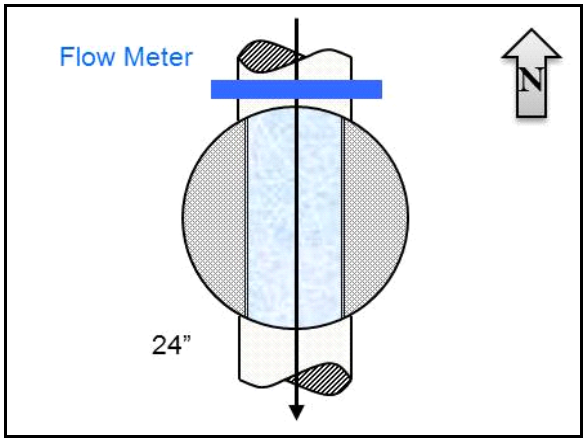
Location:	S Rose Avenue and E Wooley Road
Coordinates:	119.1601° W, 34.1893° N
Rim Elevation:	49 feet
Pipe Diameter:	24 inches
Baseline Flow:	1.197 mgd
Peak Measured Flow:	2.292 mgd



Satellite Map



Sanitary Map



Flow Diagram

Street View

Plan View

SITE 6

Additional Site Photos

Effluent Pipe

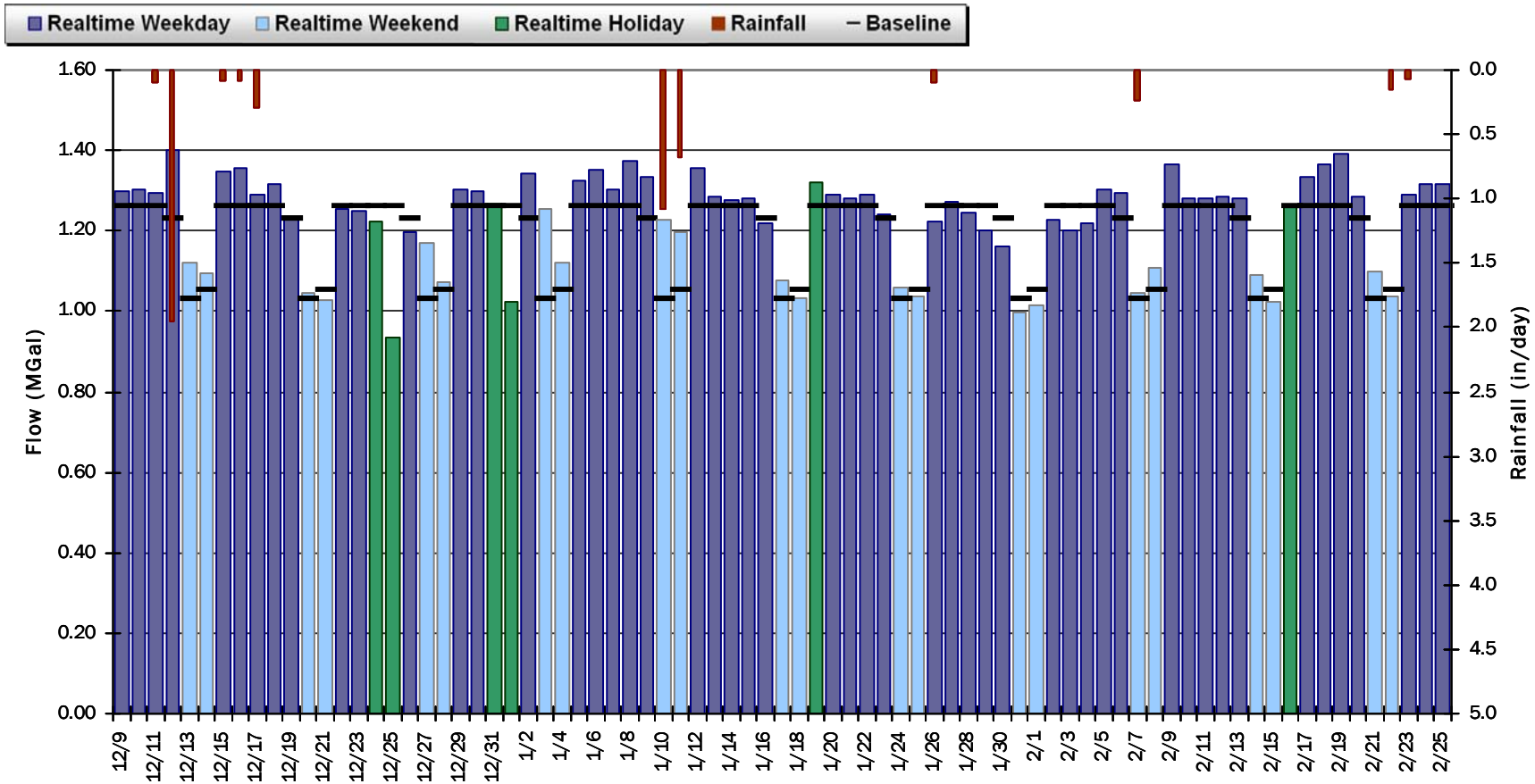
Influent Pipe

SITE 6

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 1.226 MGal **Peak Daily Flow: 1.403 MGal** **Min Daily Flow: 0.933 MGal**

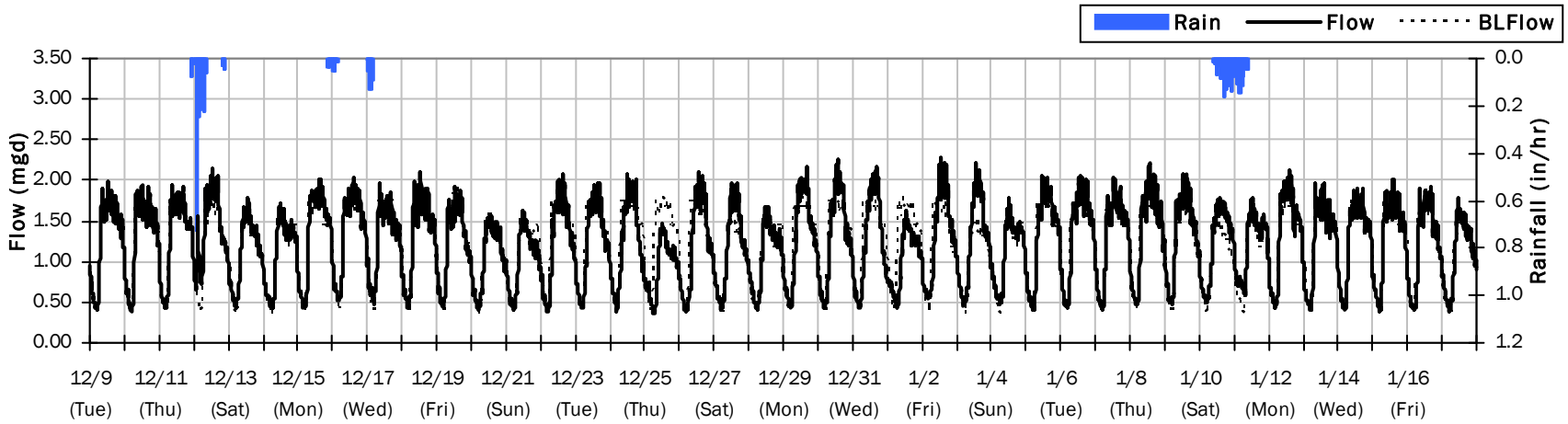
Total Period Rainfall: 4.81 inches

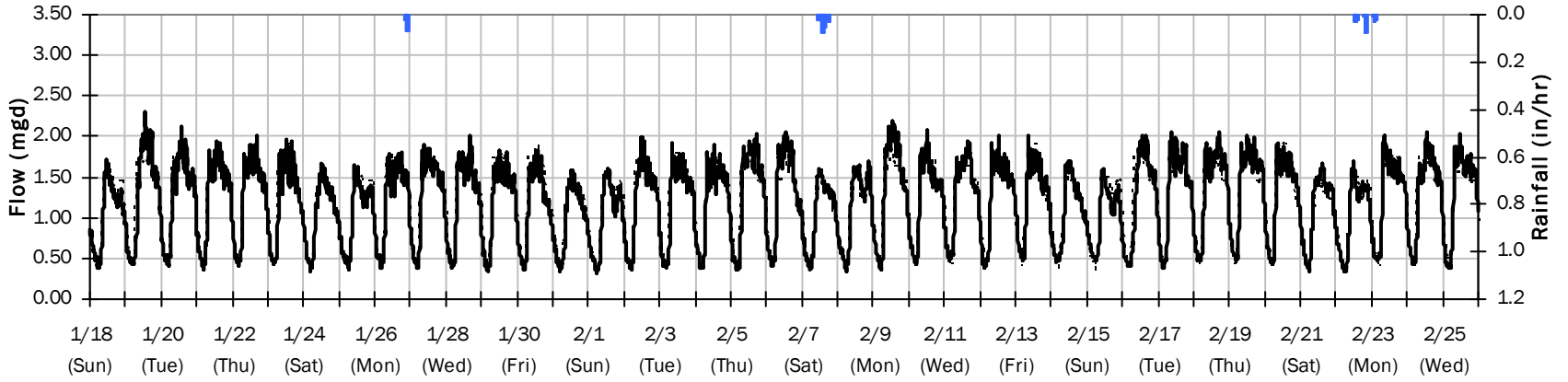


SITE 6

Flow Summary: 12/9/2014 to 2/25/2015

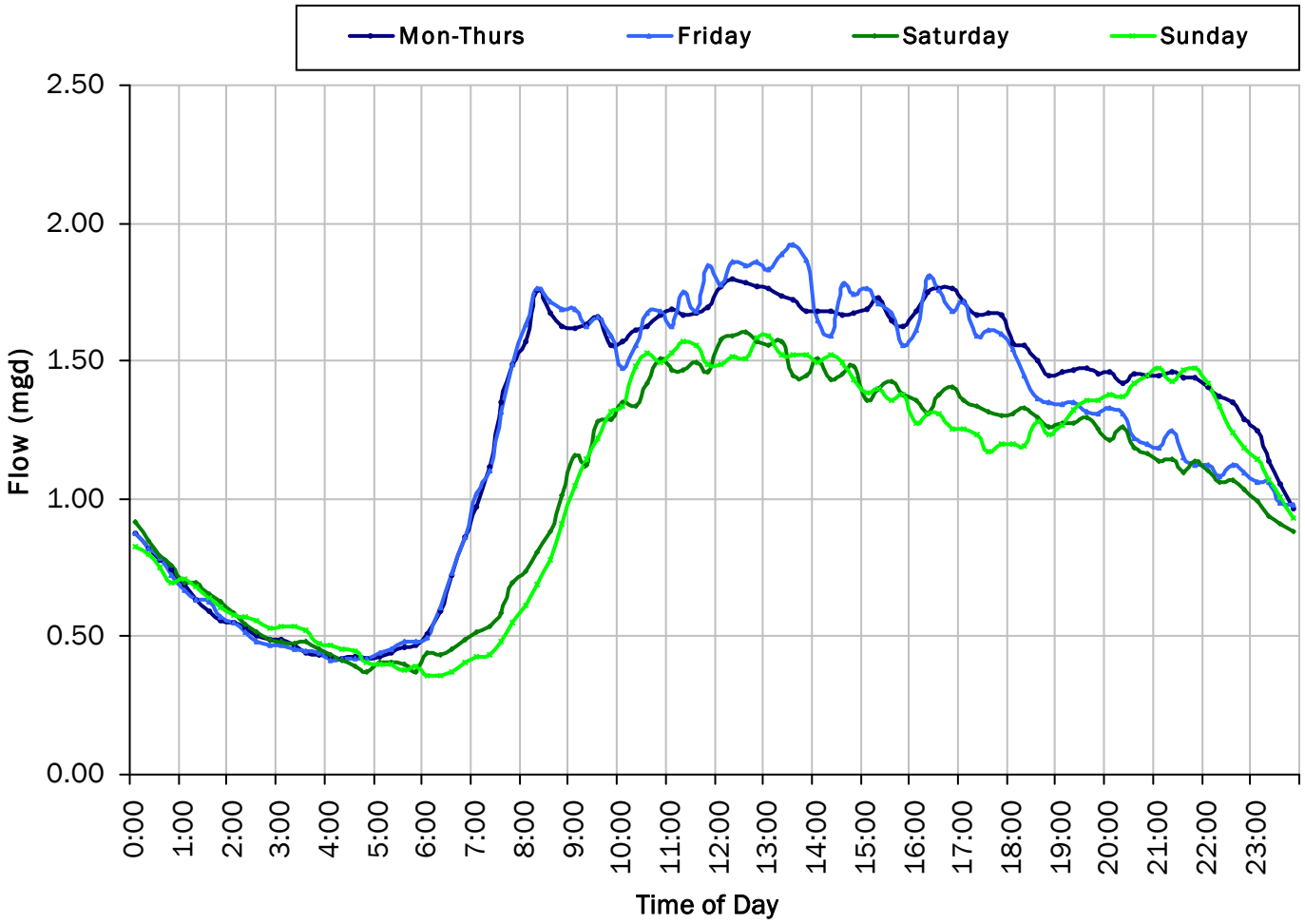
Total Period Rainfall: 4.81 inches Avg Flow: 1.226 mgd Peak Flow: 2.292 mgd Min Flow: 0.309 mgd





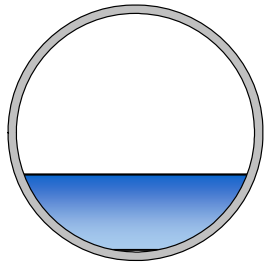
SITE 6

Baseline Flow Hydrographs



Baseline Flow:

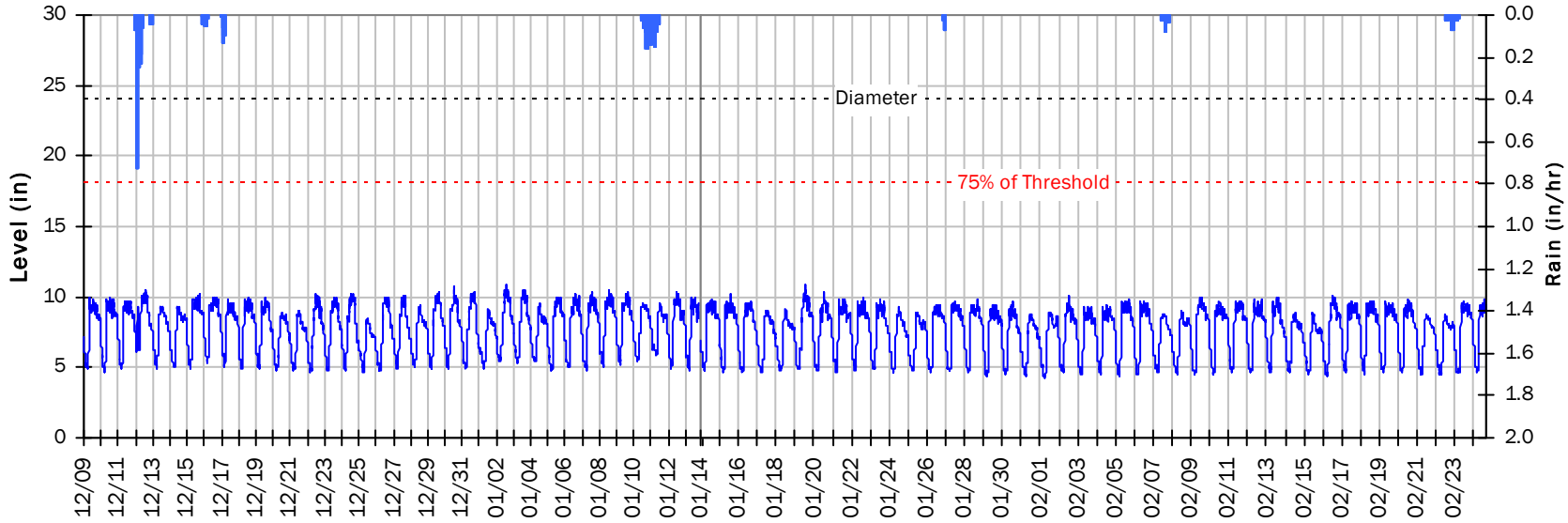
1.20 *mgd*

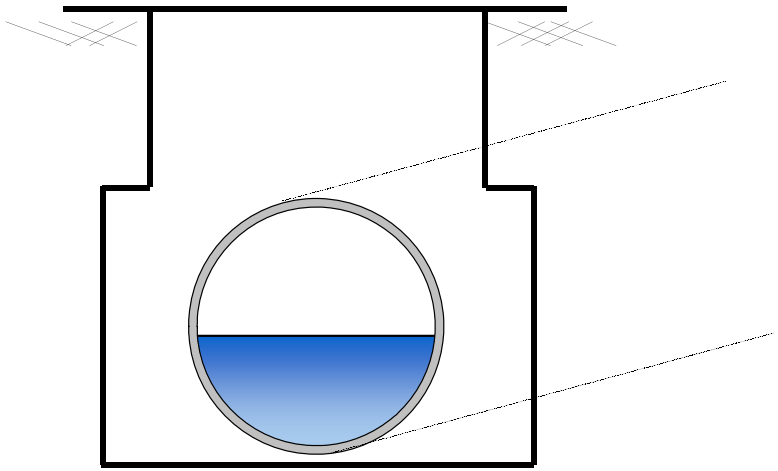


SITE 6

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





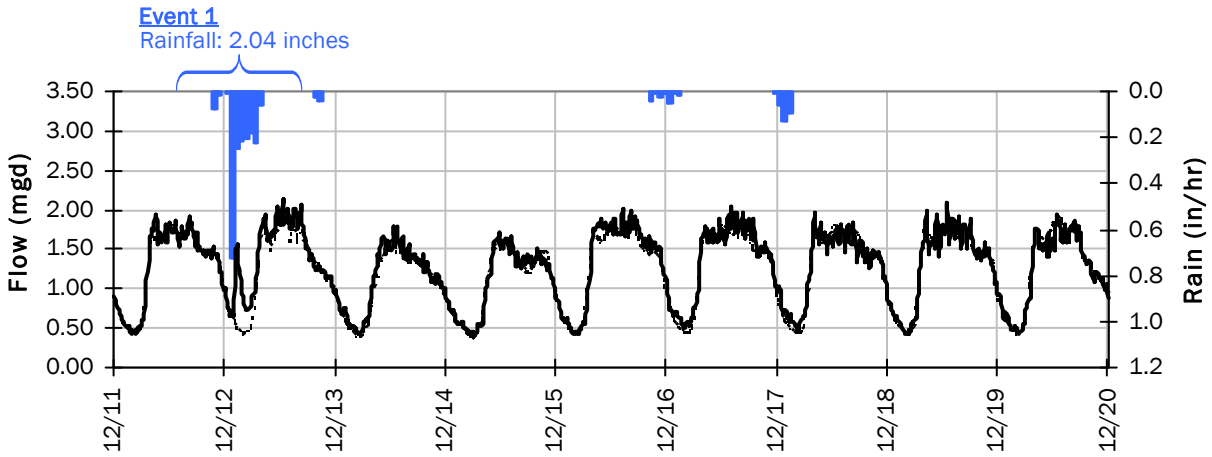
Pipe Diameter: 24 *inches*

Peak Measured Level: 11 *inches*

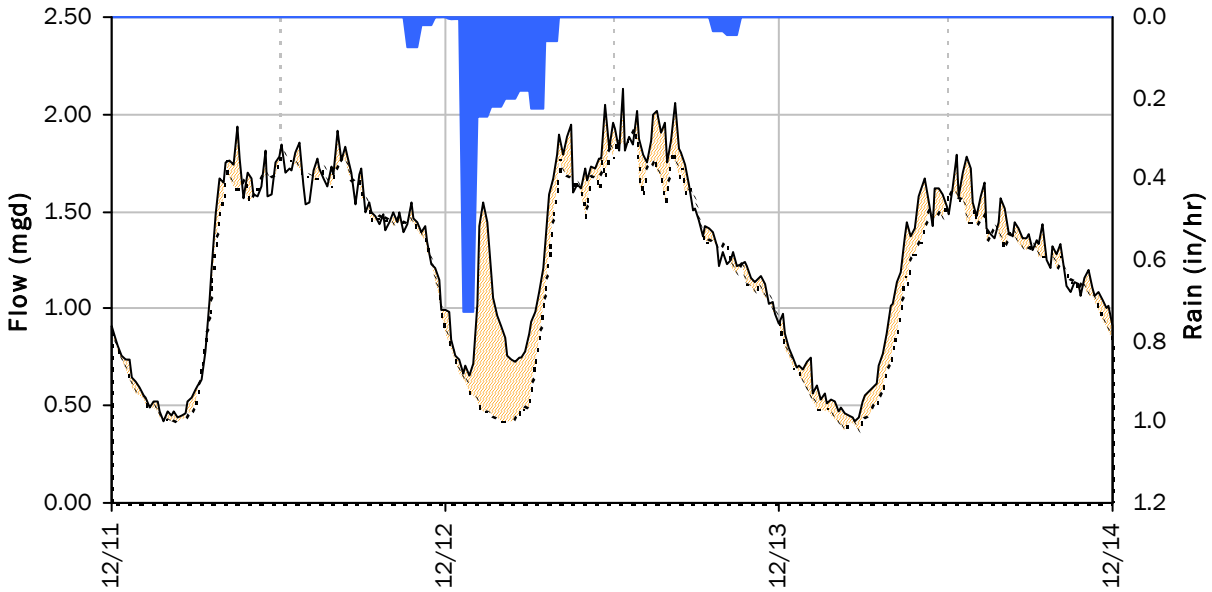
Peak d/D Ratio: 0.46

SITE 6
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

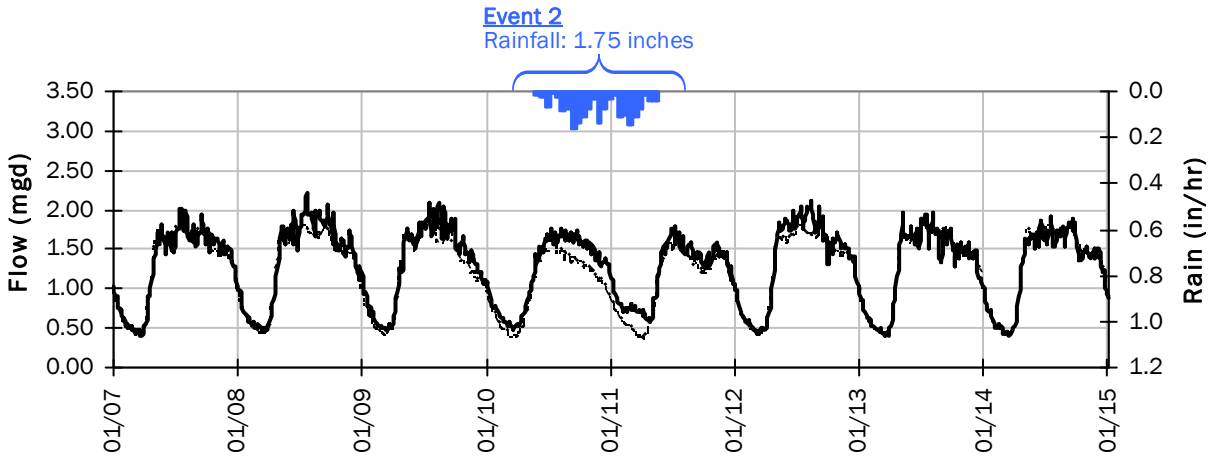


Storm Event I/I Analysis (Rain = 2.04 inches)

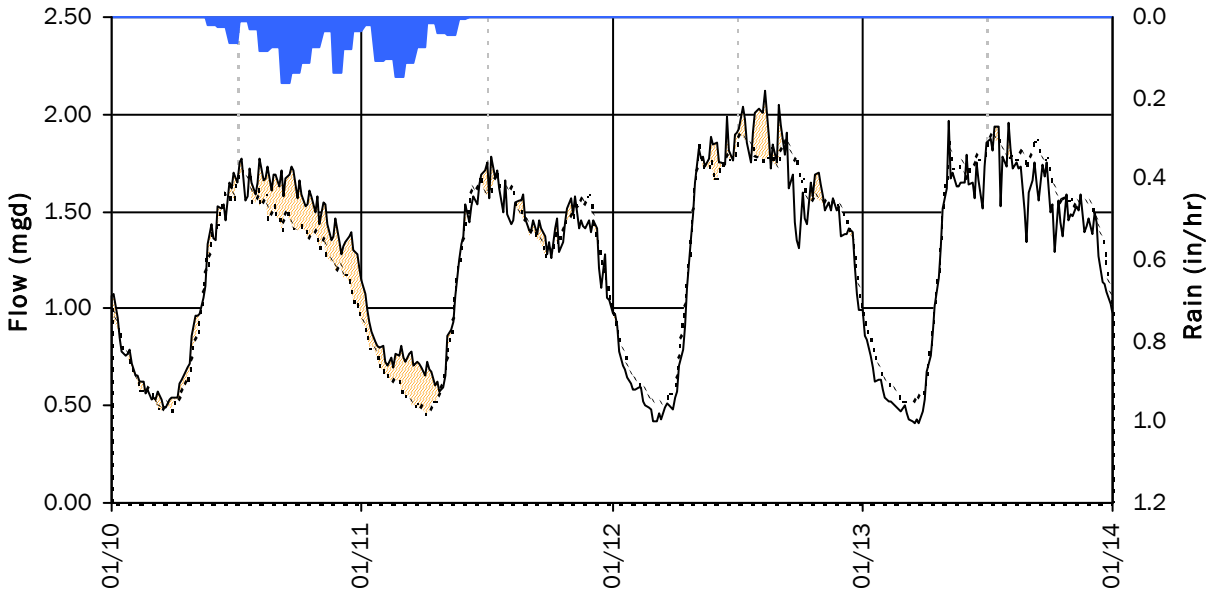
Capacity		Inflow / Infiltration	
Peak Flow:	2.13 *mgd*	**Peak I/I Rate:**	1.08 *mgd*
PF:	1.78	**Total I/I:**	264,000 *gallons*
Peak Level:	10.44 *in*		
d/D Ratio:	0.44		

SITE 6
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



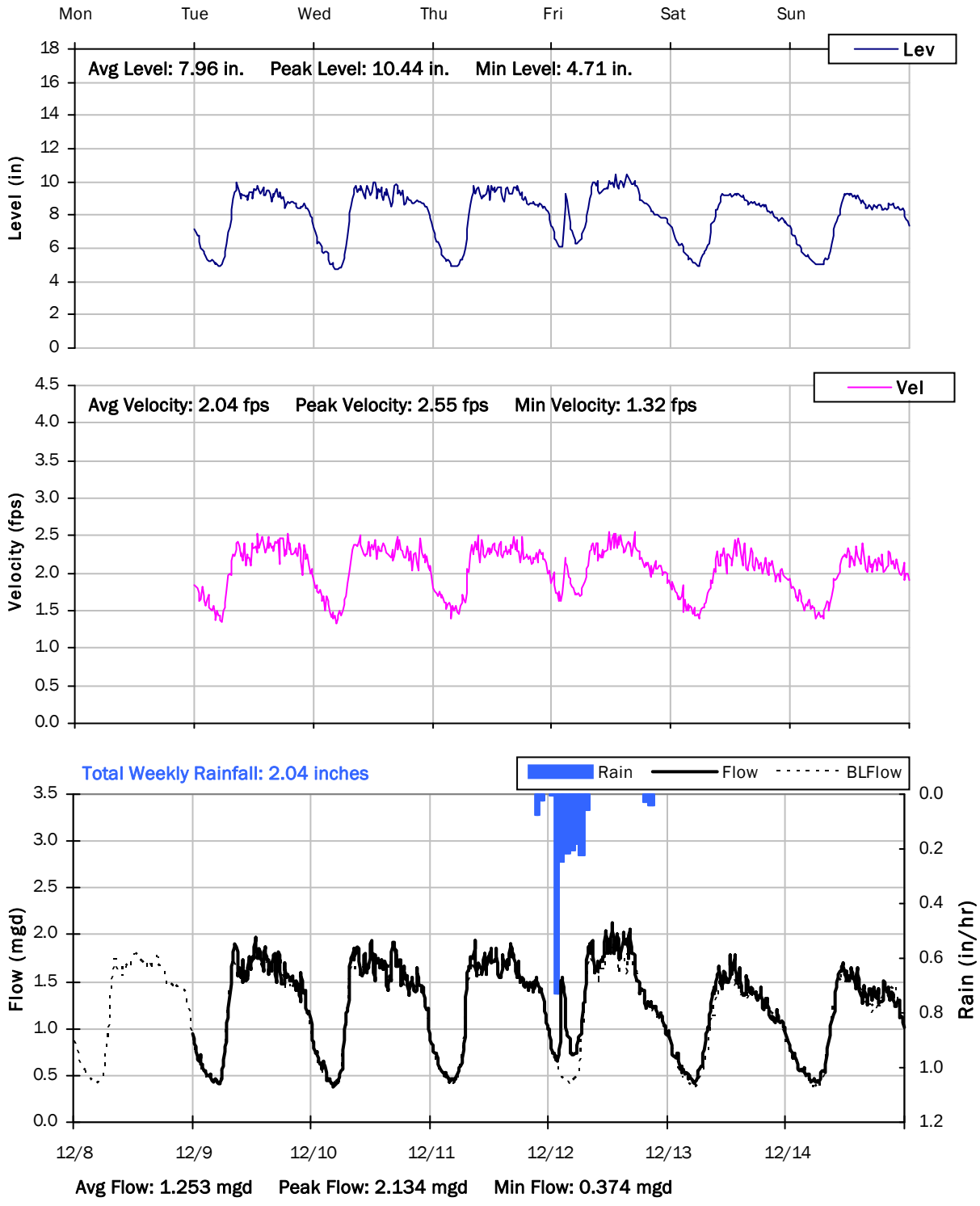
Storm Event I/I Analysis (Rain = 1.75 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	2.13 *mgd*	**Peak I/I Rate:**	0.36 *mgd*
PF:	1.78	**Total I/I:**	128,000 *gallons*
Peak Level:	10.40 *in*		
d/D Ratio:	0.43		

SITE 6

Weekly Level, Velocity and Flow Hydrographs

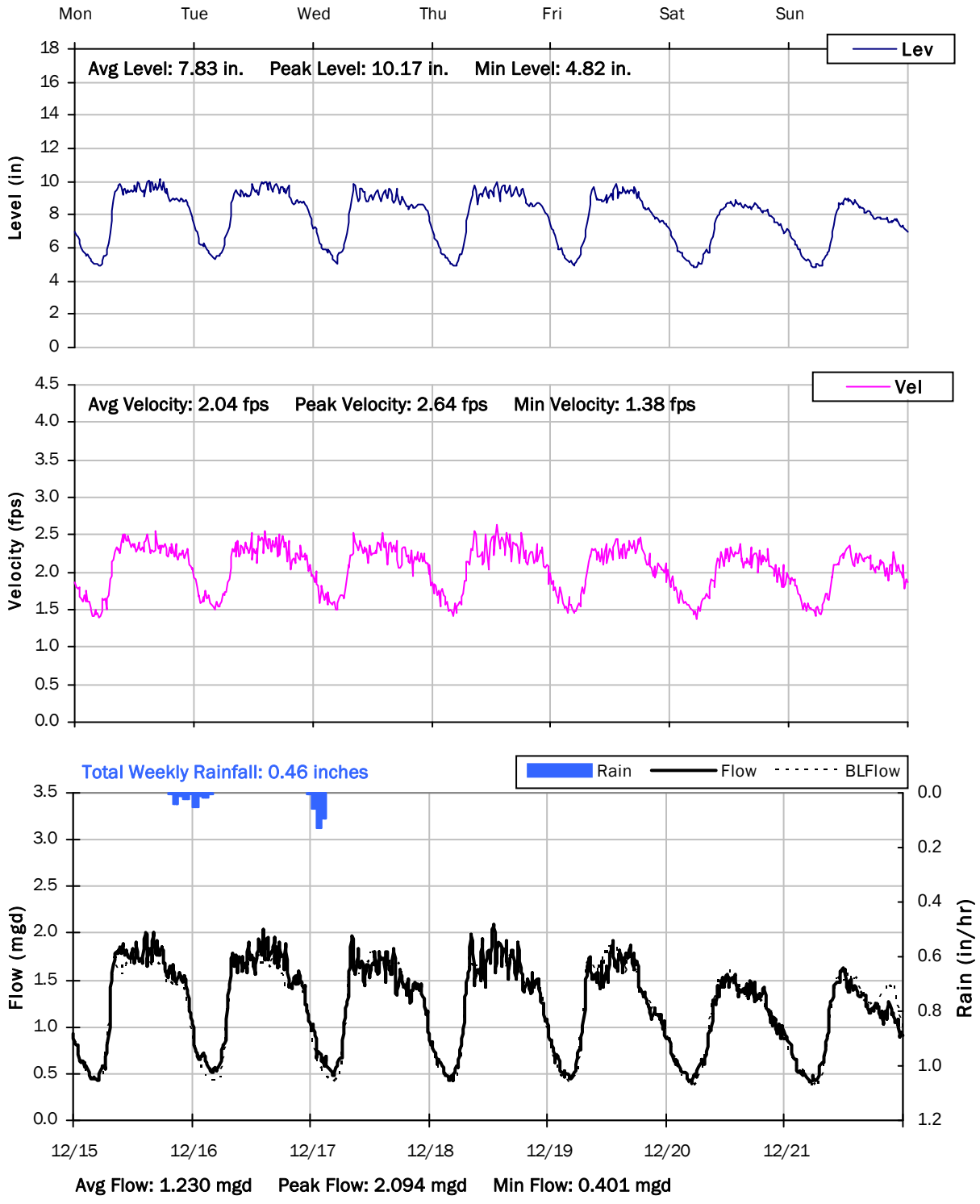
12/8/2014 to 12/15/2014



SITE 6

Weekly Level, Velocity and Flow Hydrographs

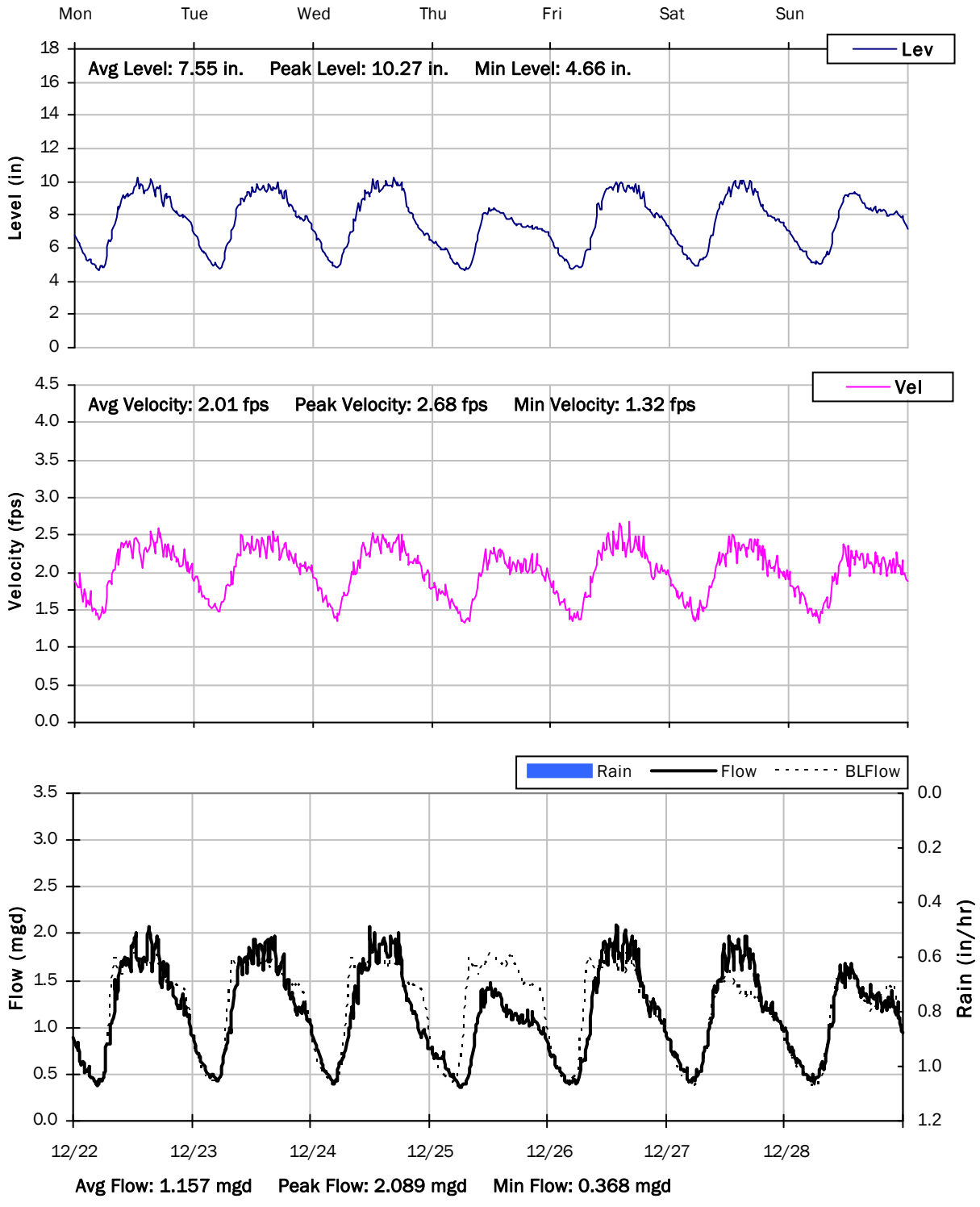
12/15/2014 to 12/22/2014



SITE 6

Weekly Level, Velocity and Flow Hydrographs

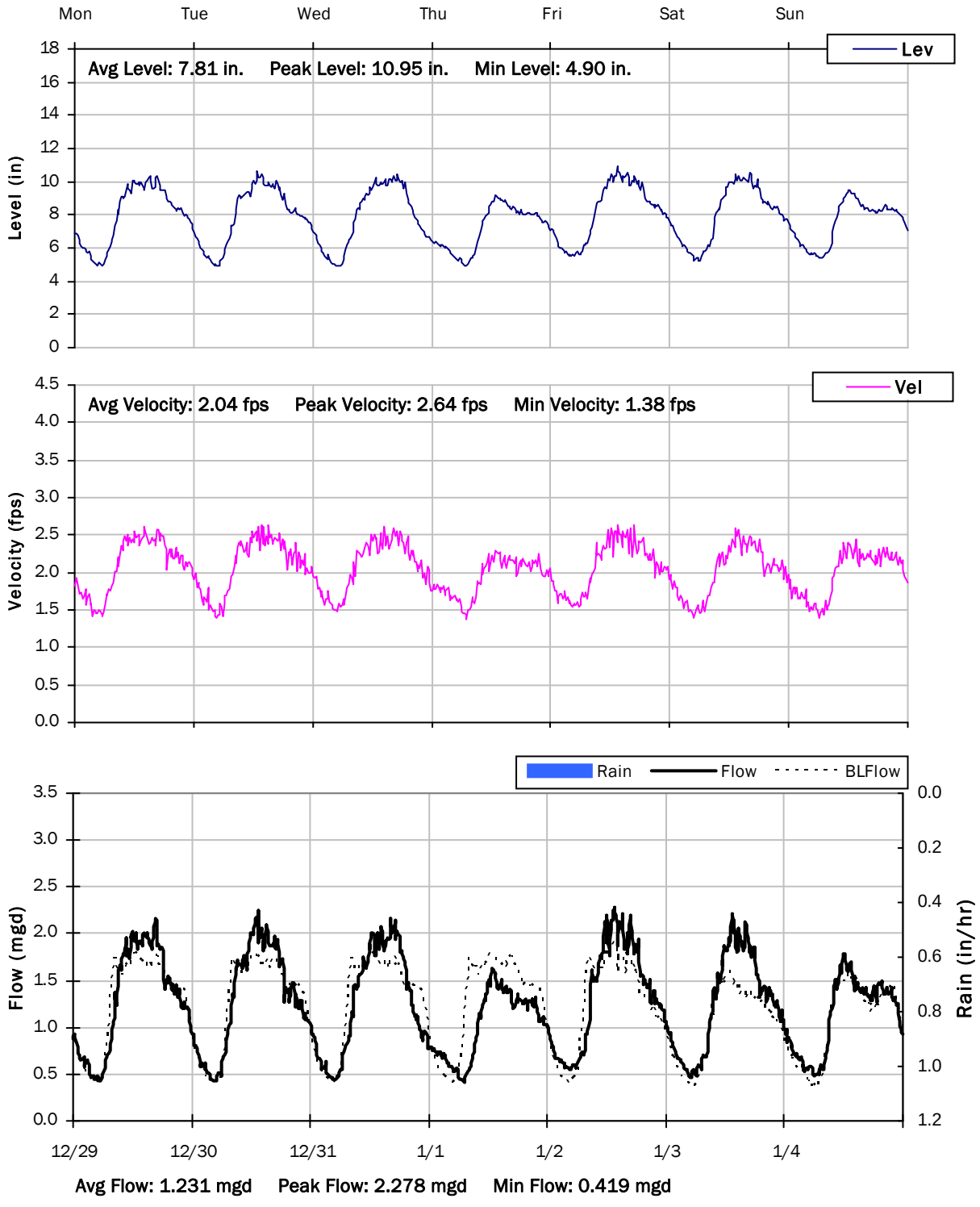
12/22/2014 to 12/29/2014



SITE 6

Weekly Level, Velocity and Flow Hydrographs

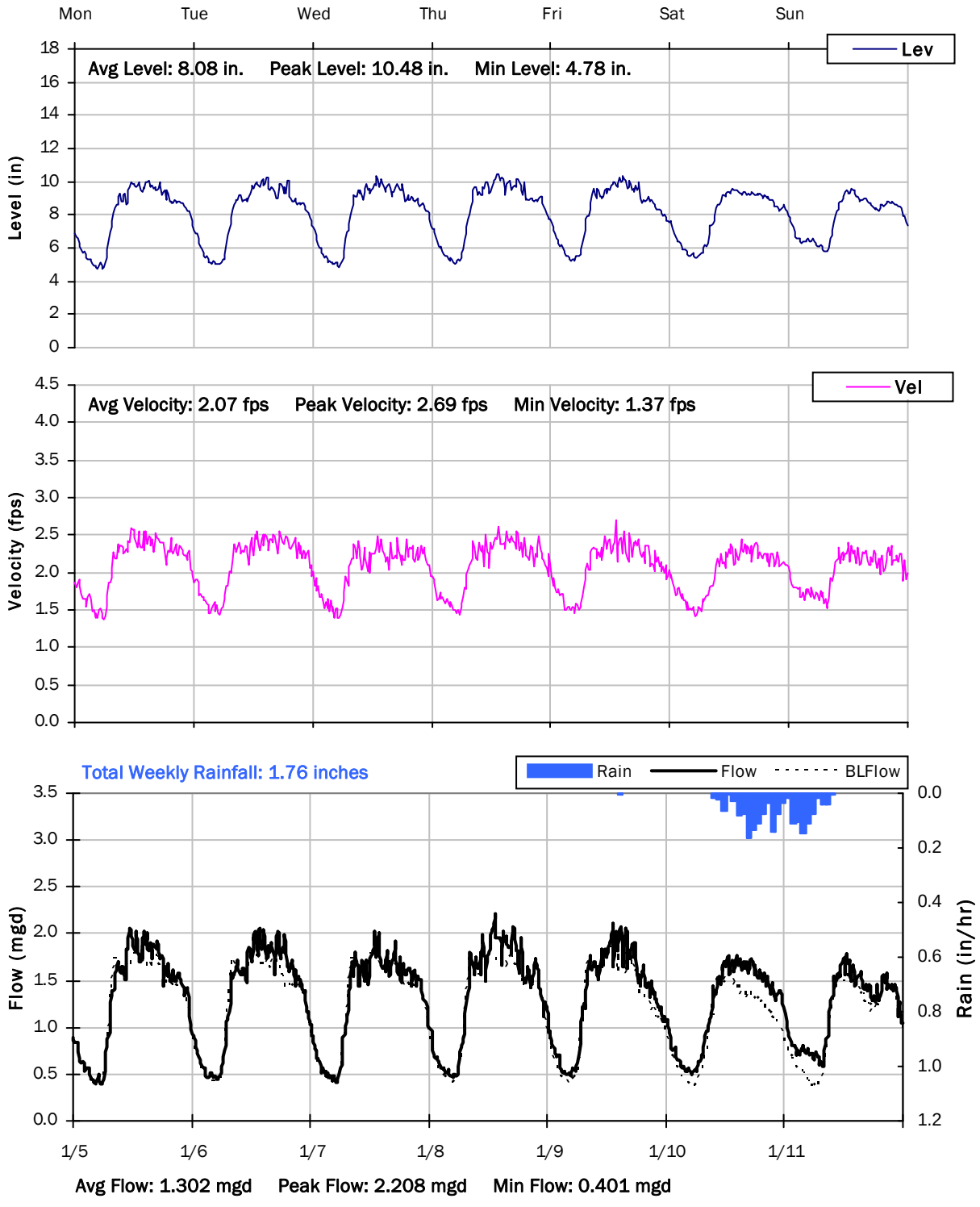
12/29/2014 to 1/5/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

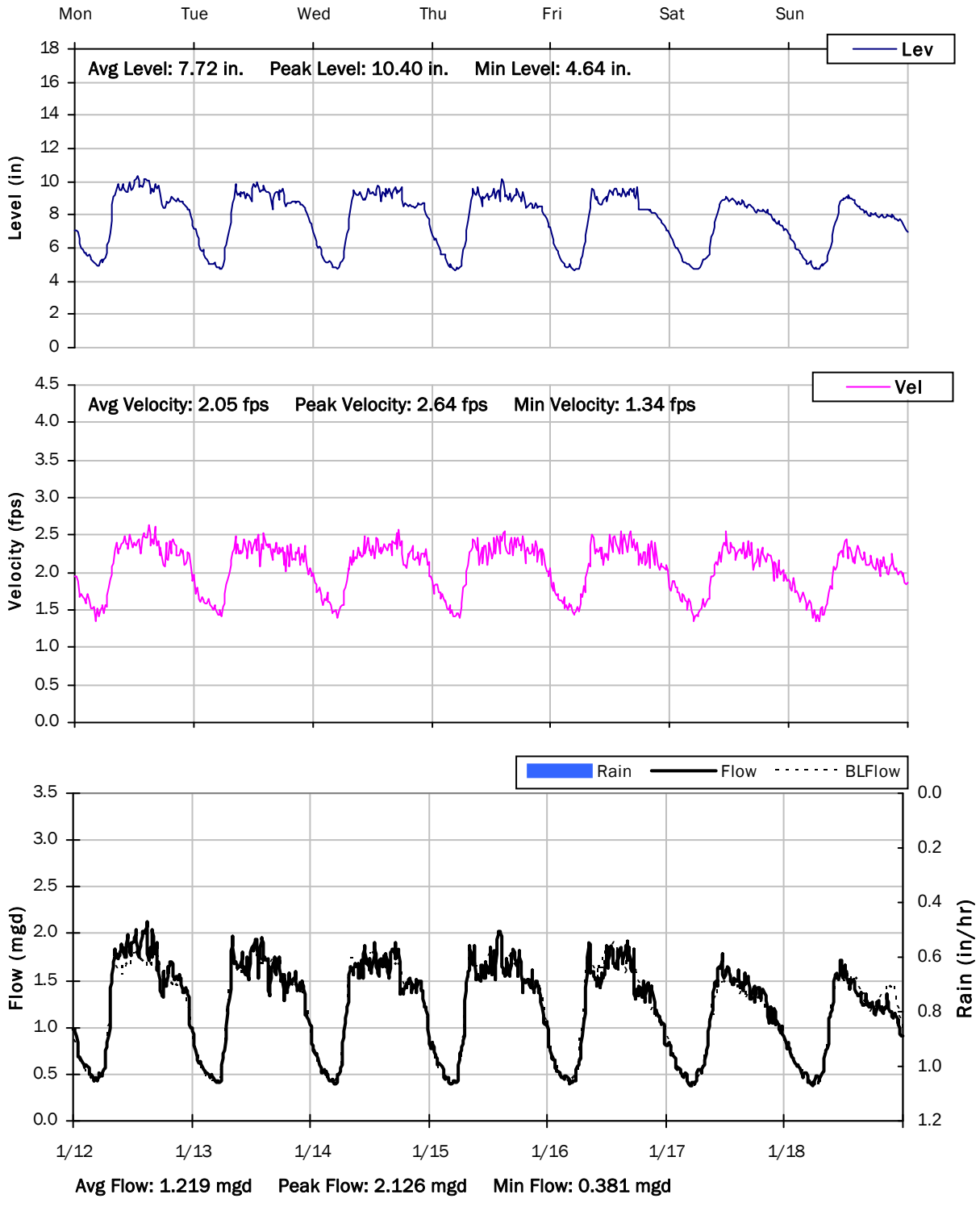
1/5/2015 to 1/12/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

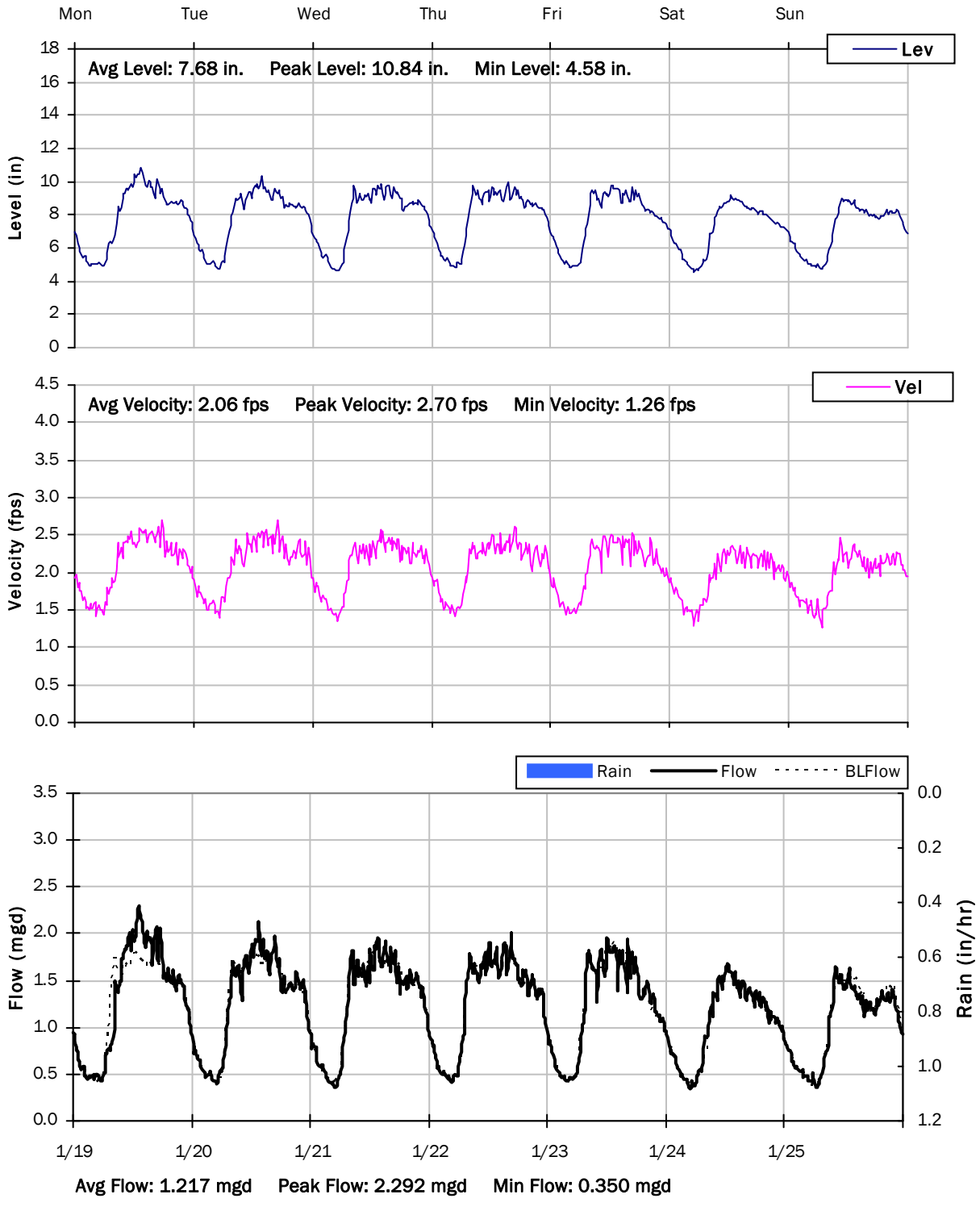
1/12/2015 to 1/19/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

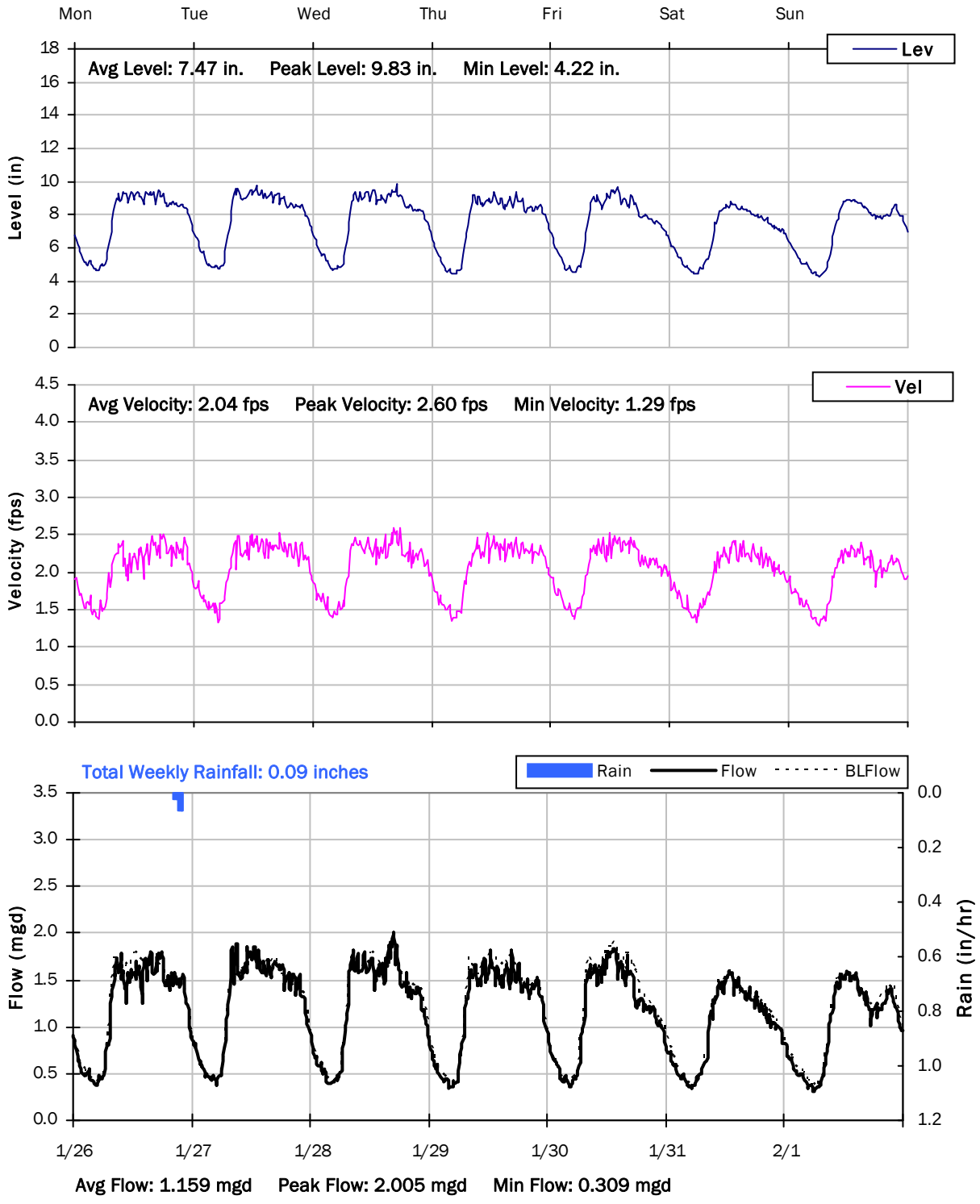
1/19/2015 to 1/26/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

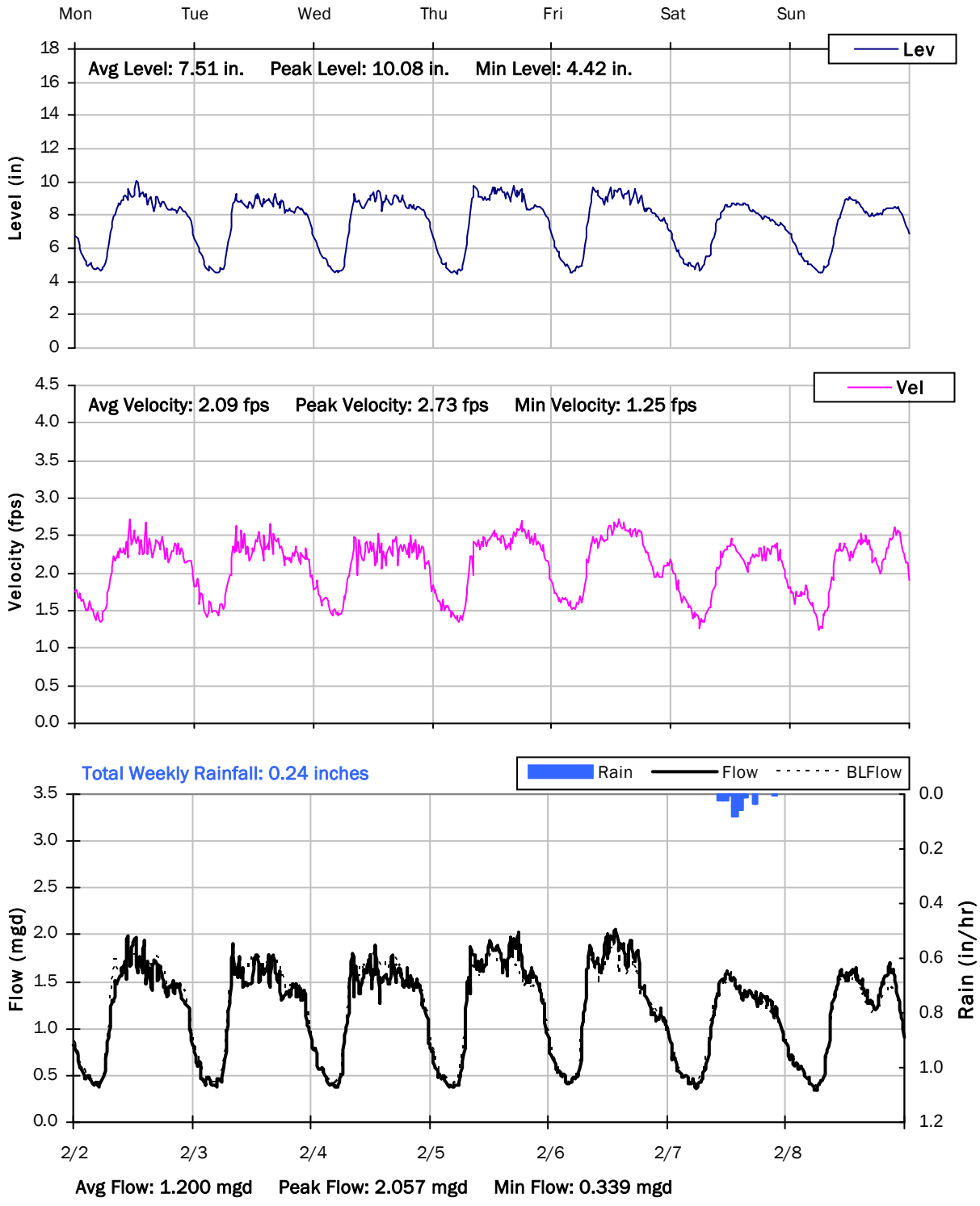
1/26/2015 to 2/2/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

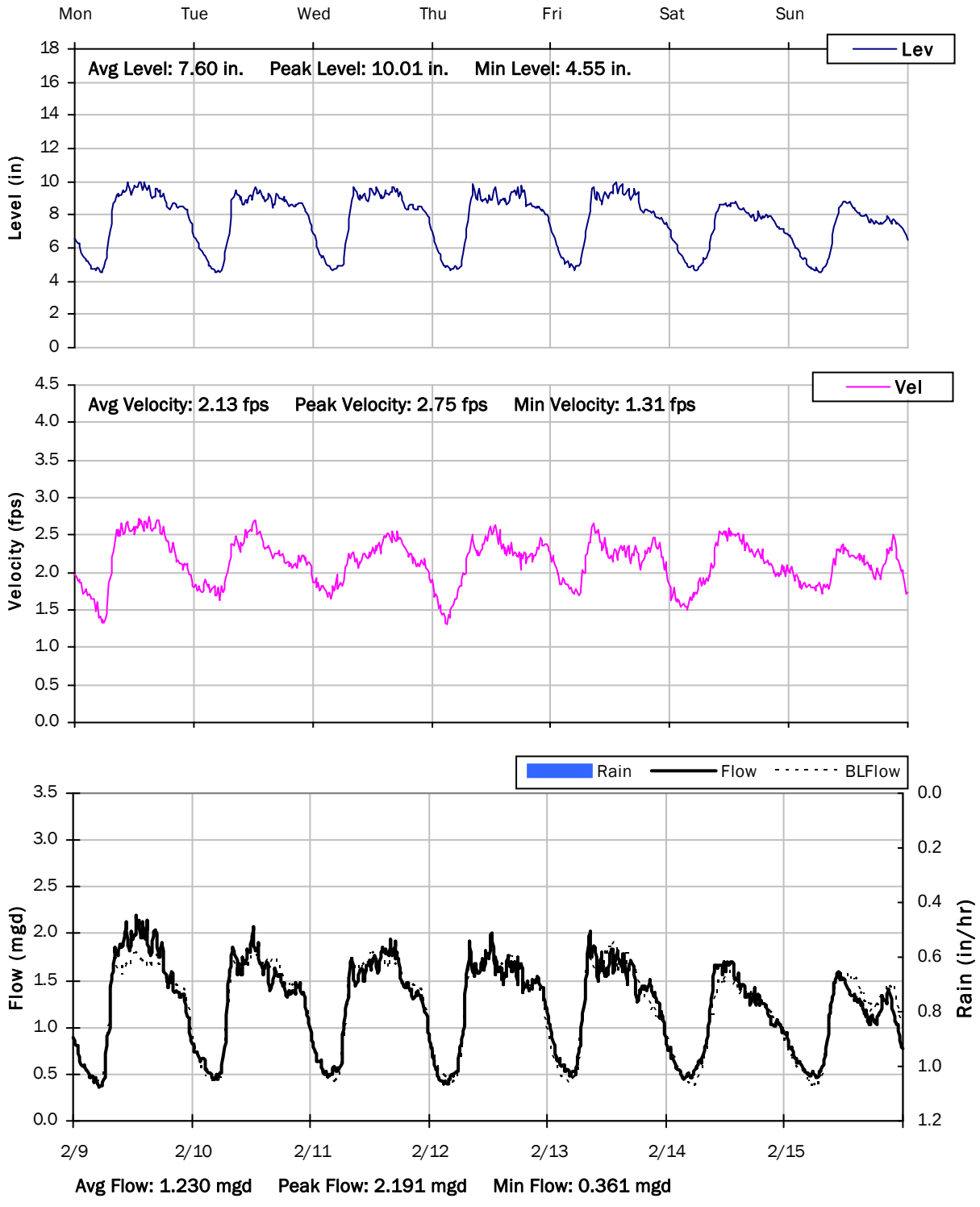
2/2/2015 to 2/9/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

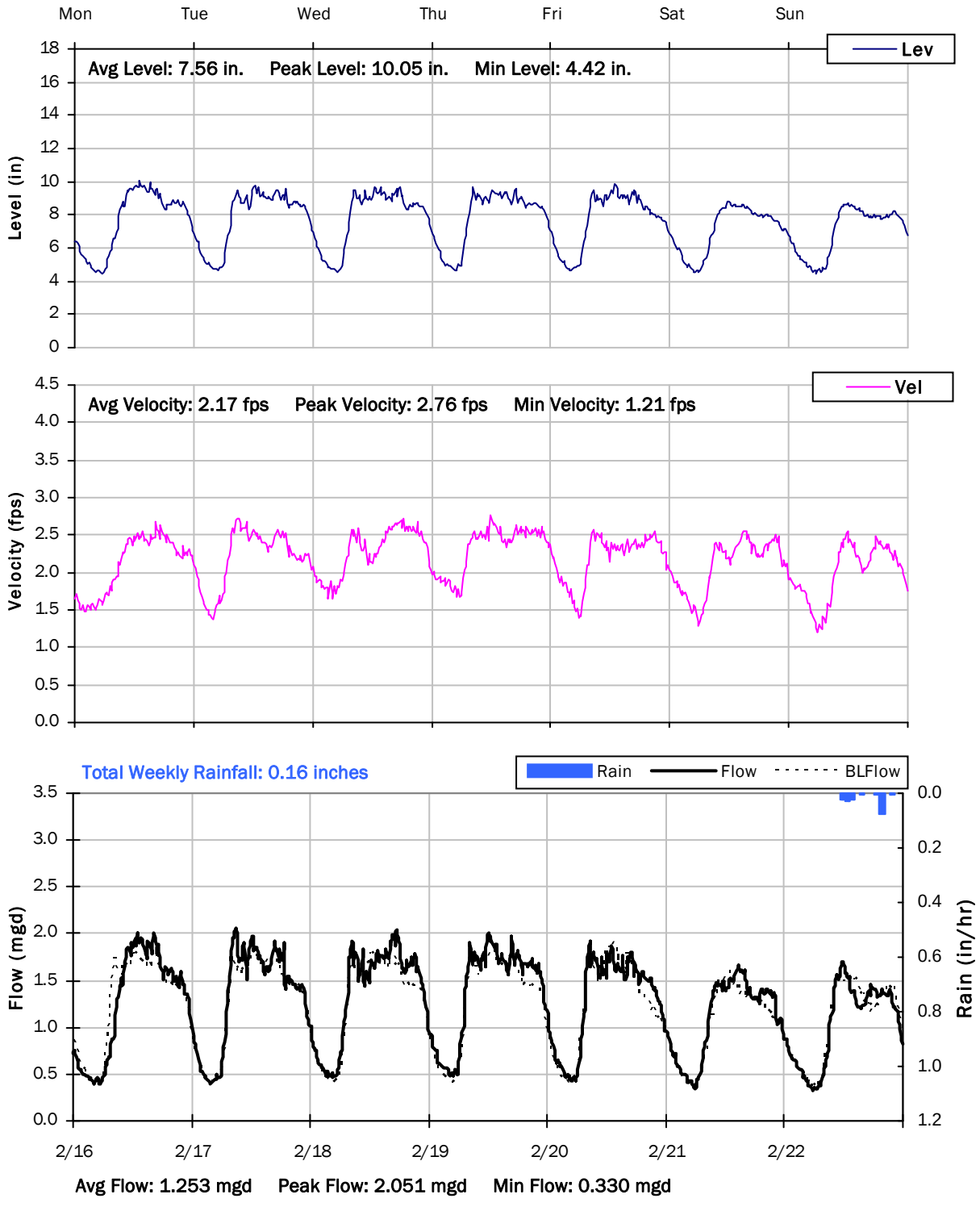
2/9/2015 to 2/16/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

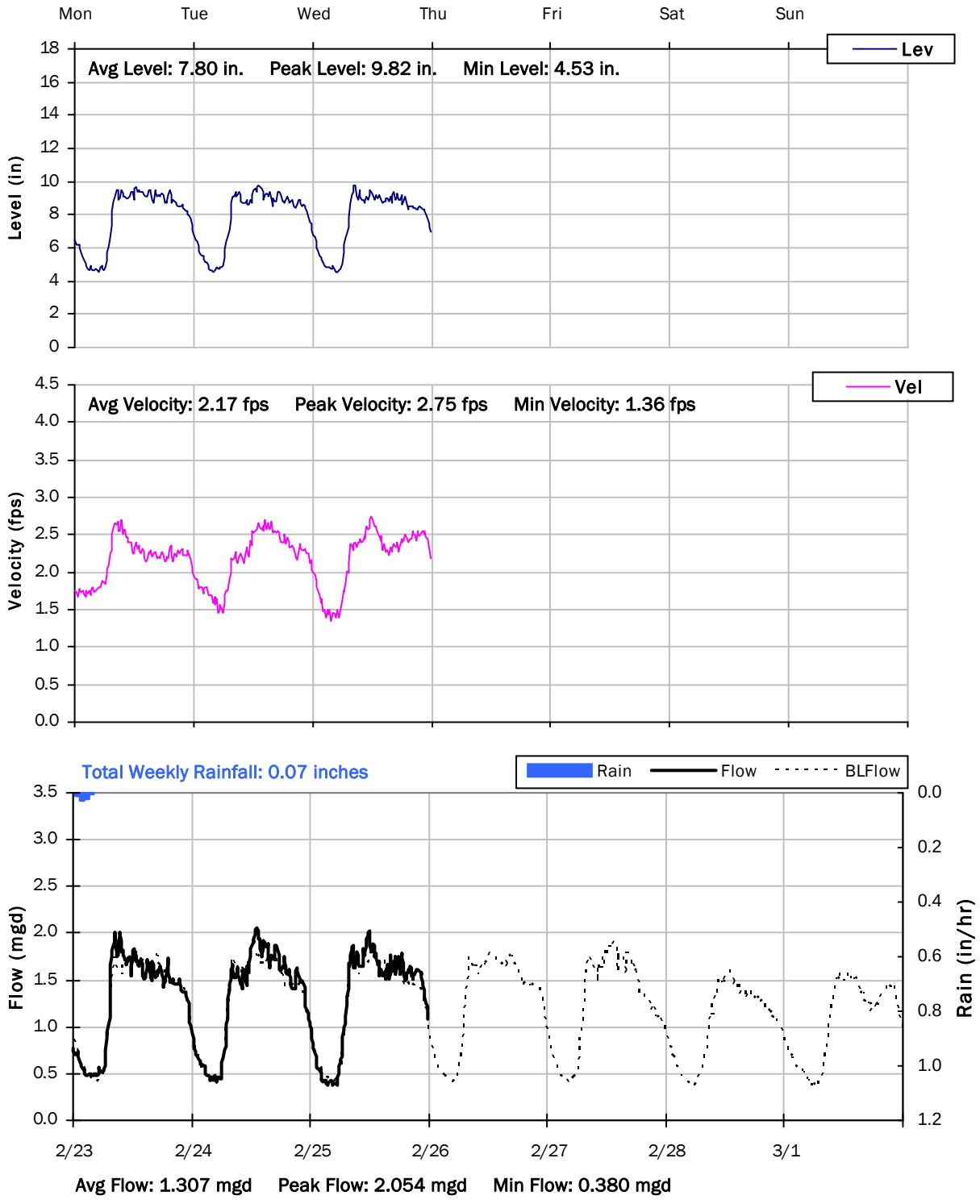
2/16/2015 to 2/23/2015



SITE 6

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

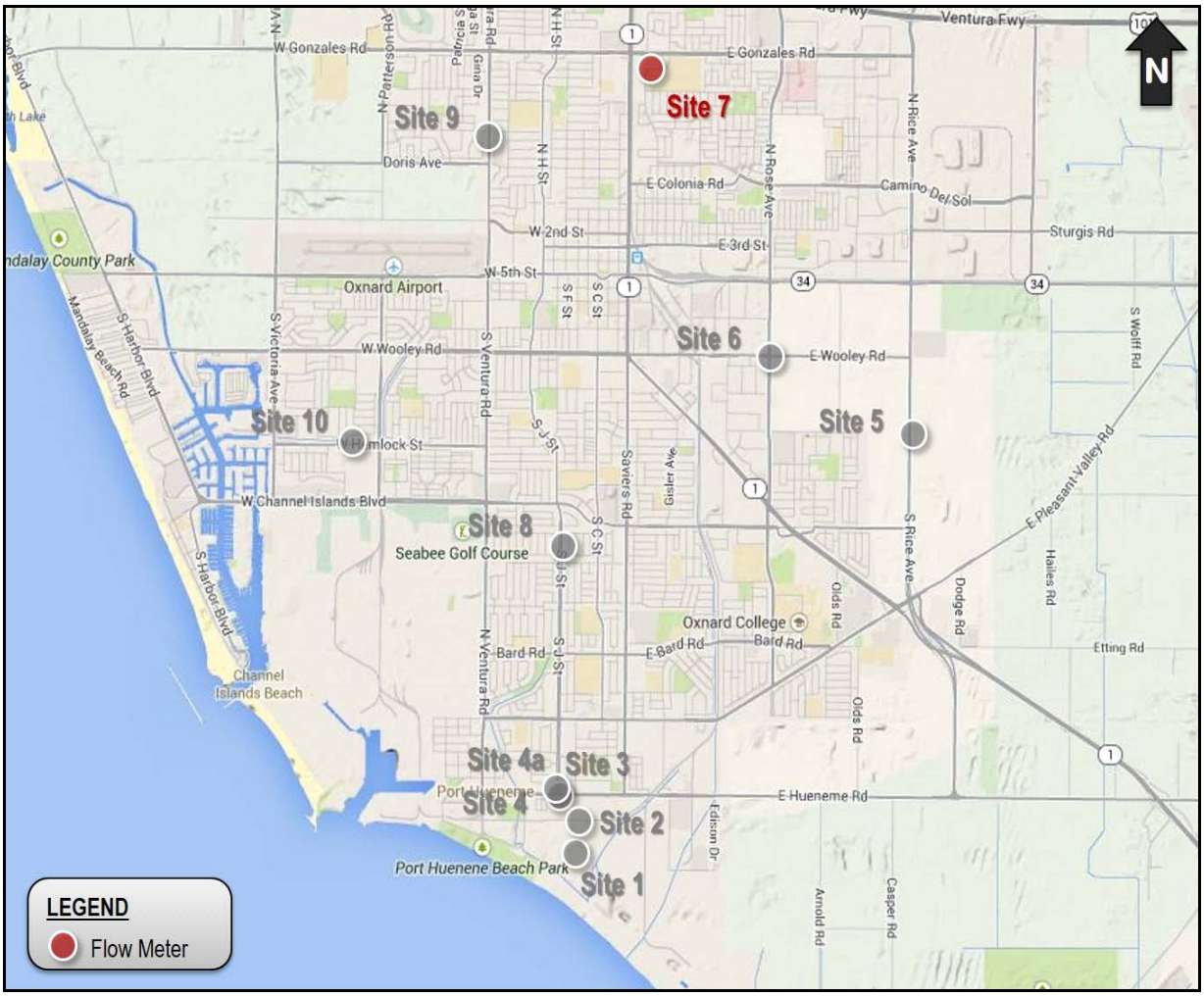
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 7

Location: E Gonzales Road and Bahia Drive

Data Summary Report



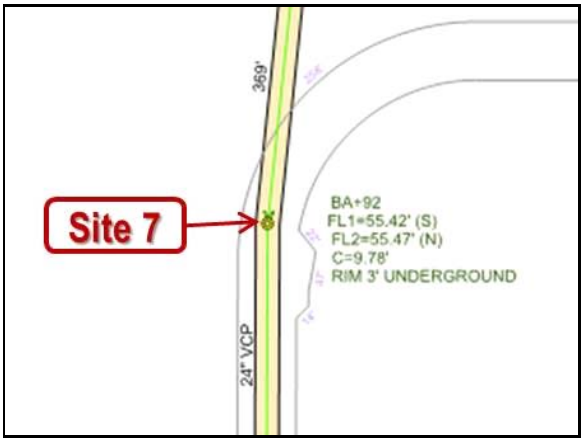
Vicinity Map: Site 7

SITE 7

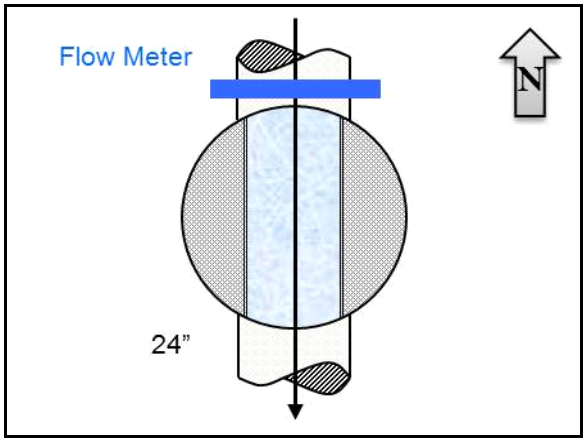
Site Information

Location:	E Gonzales Road and Bahia Drive
Coordinates:	119.1750° W, 34.2192° N
Rim Elevation:	74 feet
Pipe Diameter:	24 inches
Baseline Flow:	0.333 mgd
Peak Measured Flow:	0.620 mgd

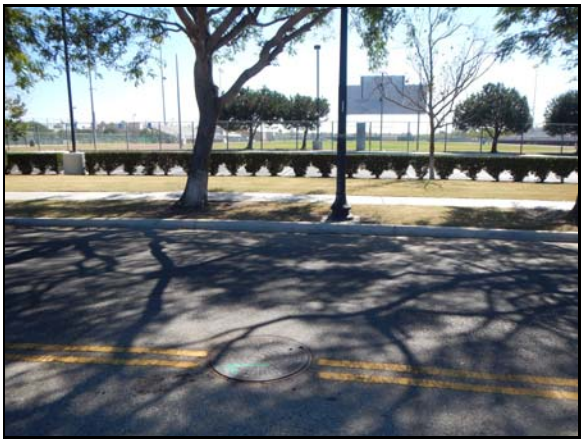
Satellite Map



Sanitary Map



Flow Diagram



Street View

Plan View

SITE 7

Additional Site Photos

Effluent Pipe

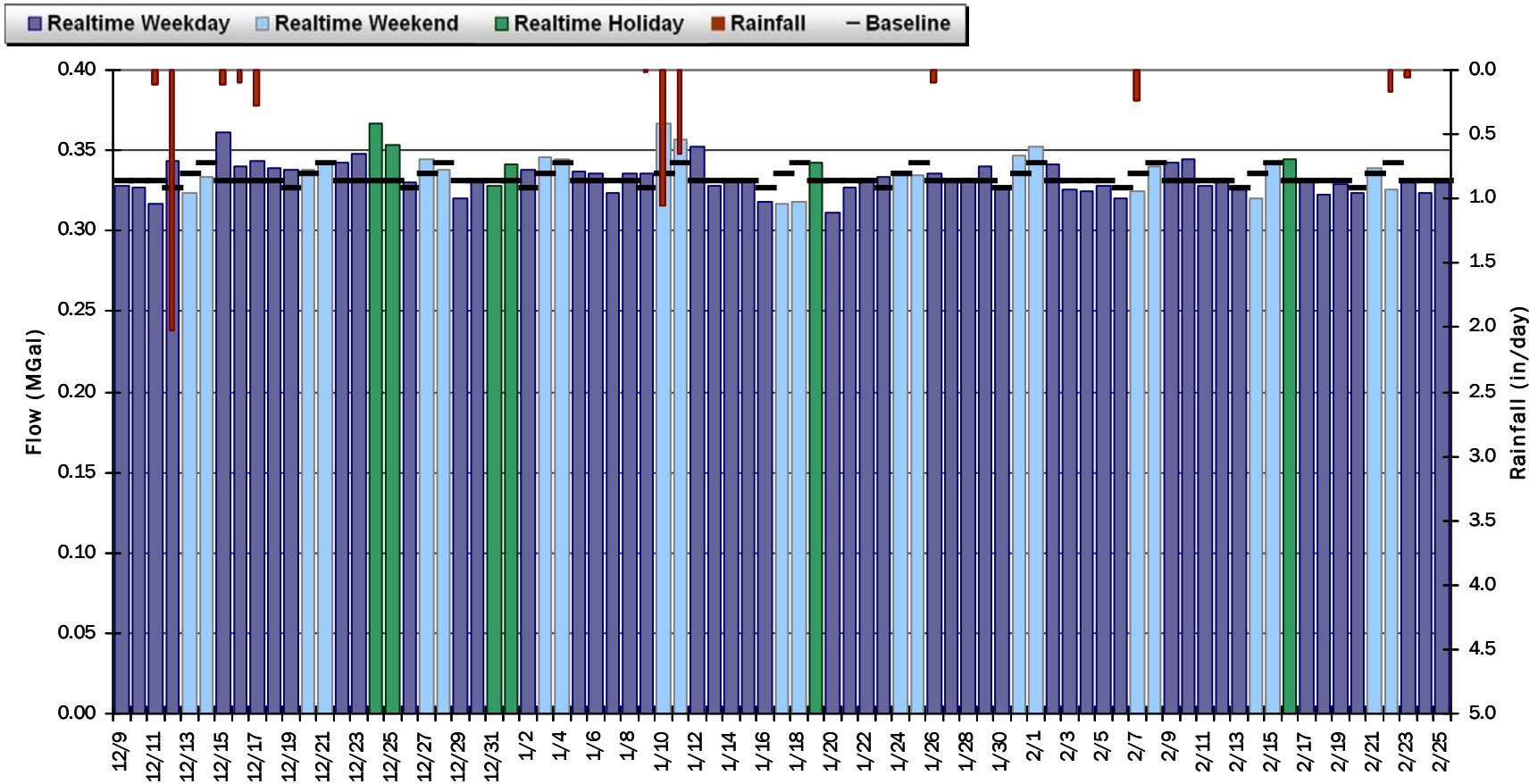
Influent Pipe

SITE 7

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 0.335 MGal **Peak Daily Flow: 0.367 MGal** **Min Daily Flow: 0.311 MGal**

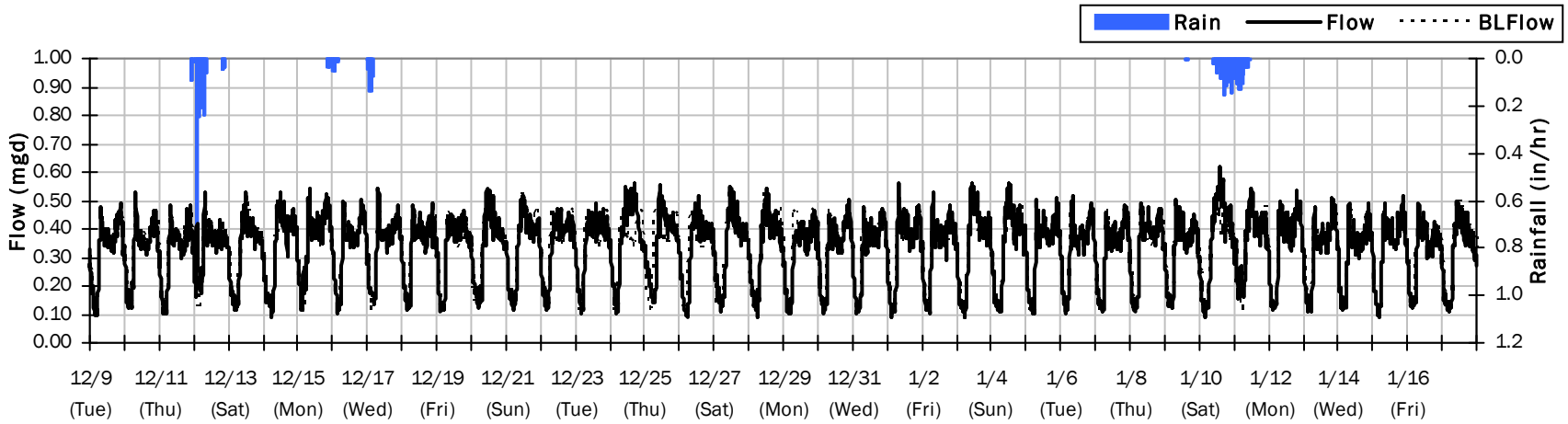
Total Period Rainfall: 4.88 inches

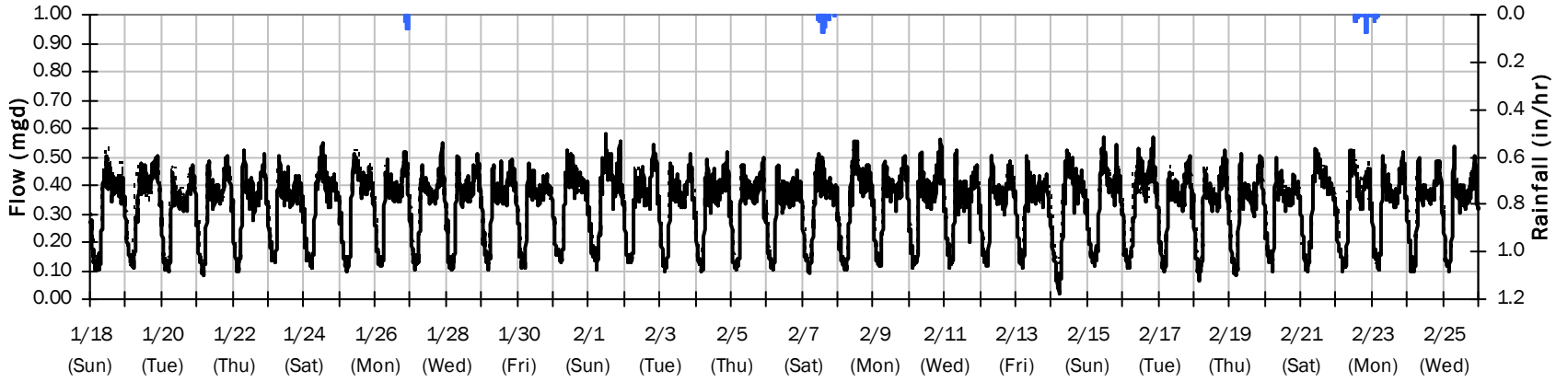


SITE 7

Flow Summary: 12/9/2014 to 2/25/2015

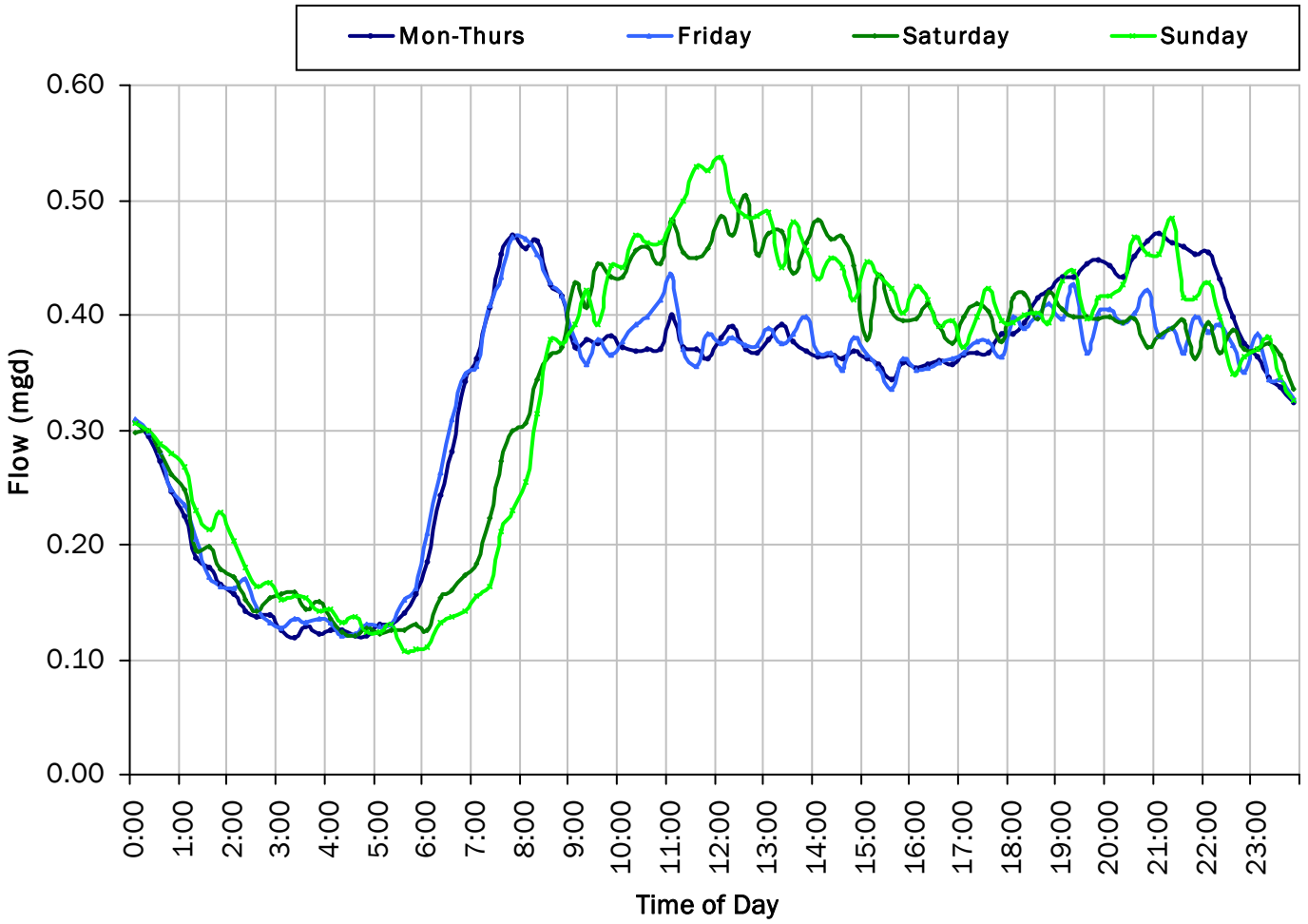
Total Period Rainfall: 4.88 inches Avg Flow: 0.335 mgd Peak Flow: 0.620 mgd Min Flow: 0.017 mgd





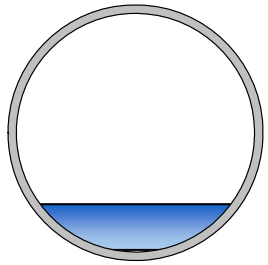
SITE 7

Baseline Flow Hydrographs



Baseline Flow:

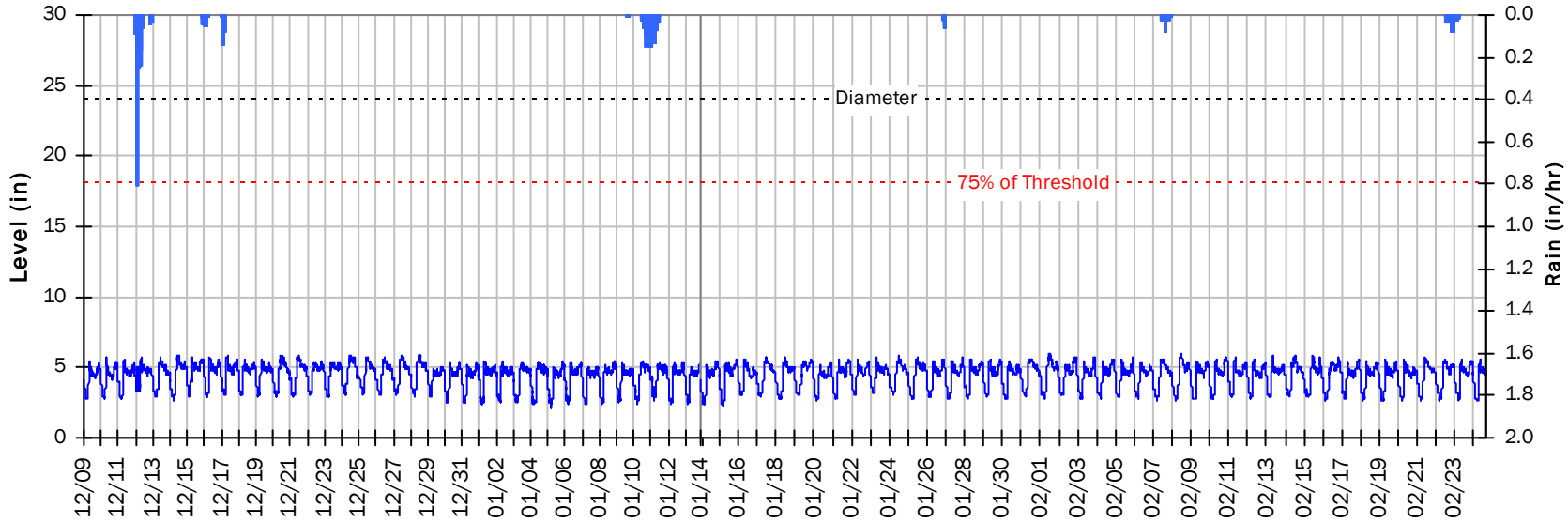
0.33 *mgd*

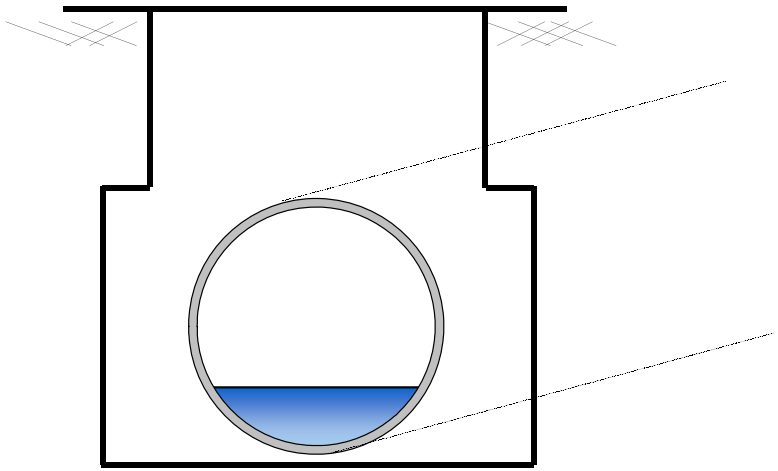


SITE 7

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





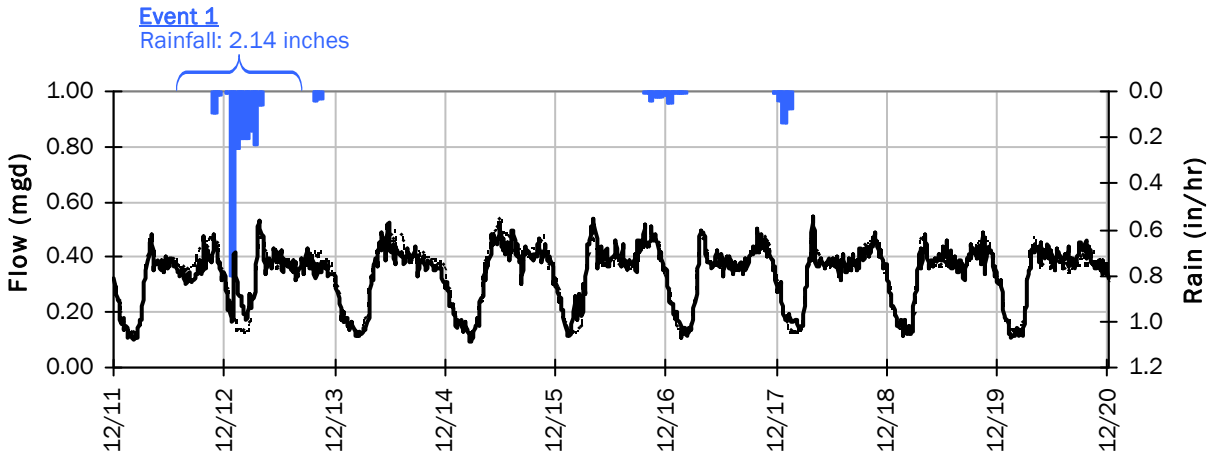
Pipe Diameter: 24 *inches*

Peak Measured Level: 5.92 *inches*

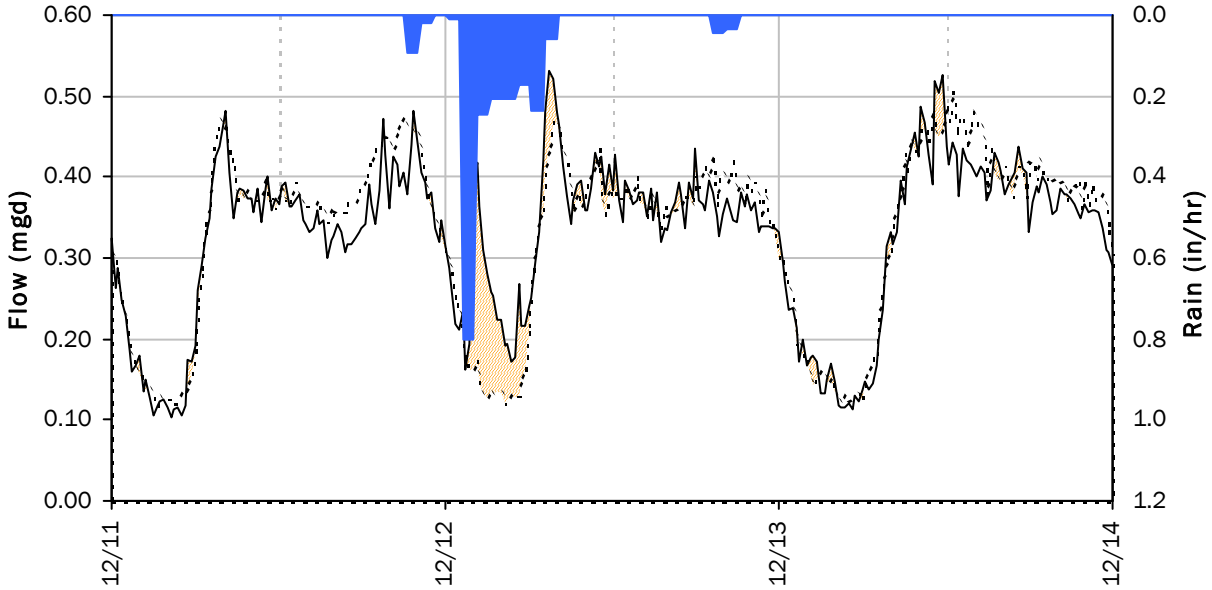
Peak d/D Ratio: 0.25

SITE 7
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

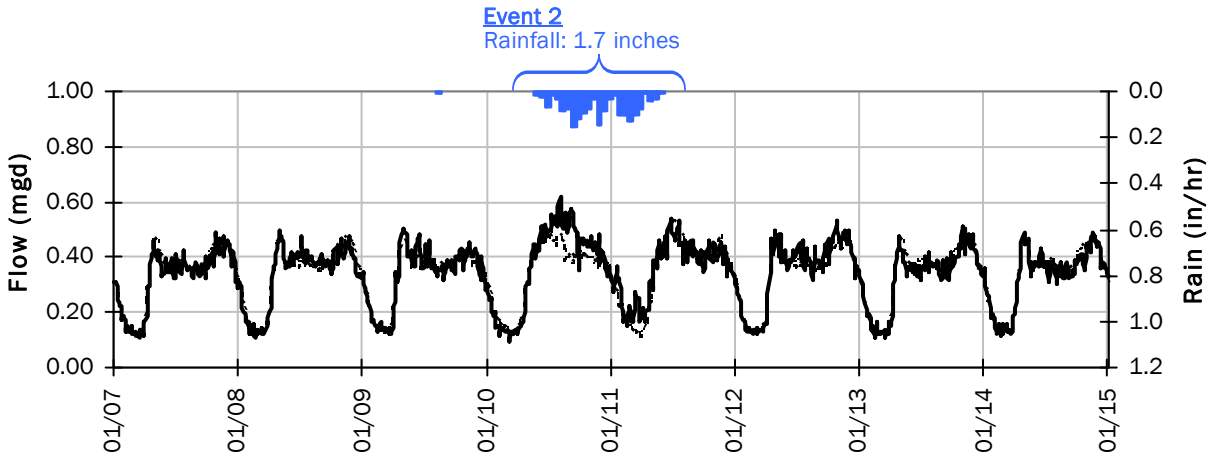


Storm Event I/I Analysis (Rain = 2.14 inches)

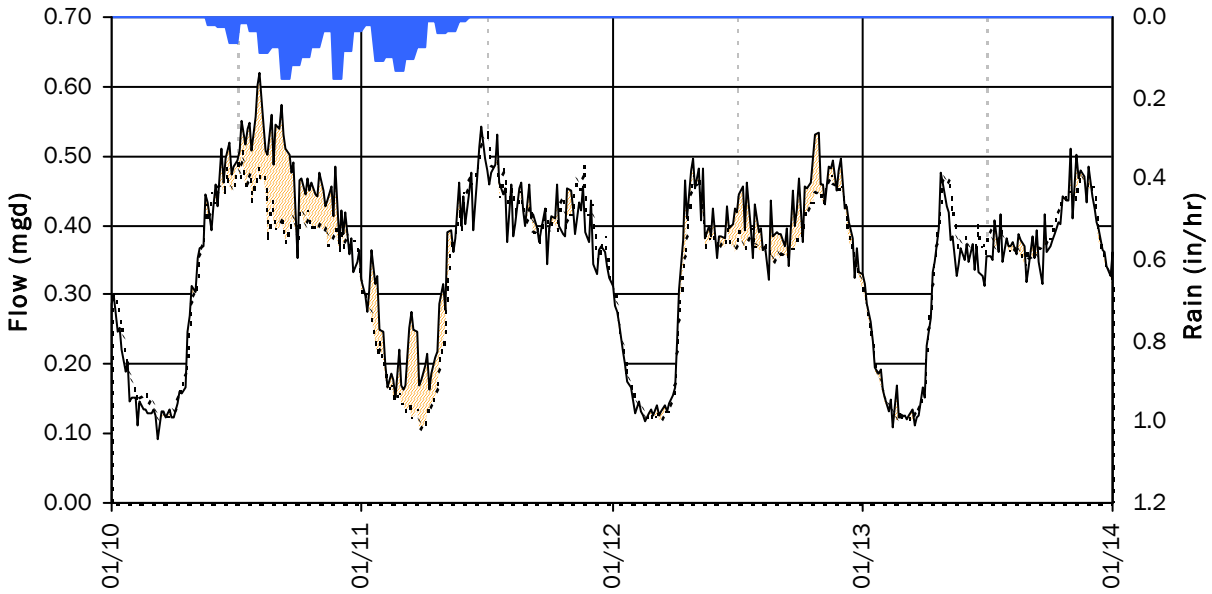
Capacity		Inflow / Infiltration	
Peak Flow:	0.53 *mgd*	**Peak I/I Rate:**	0.25 *mgd*
PF:	1.59	**Total I/I:**	4,000 *gallons*
Peak Level:	5.76 *in*		
d/D Ratio:	0.24		

SITE 7
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



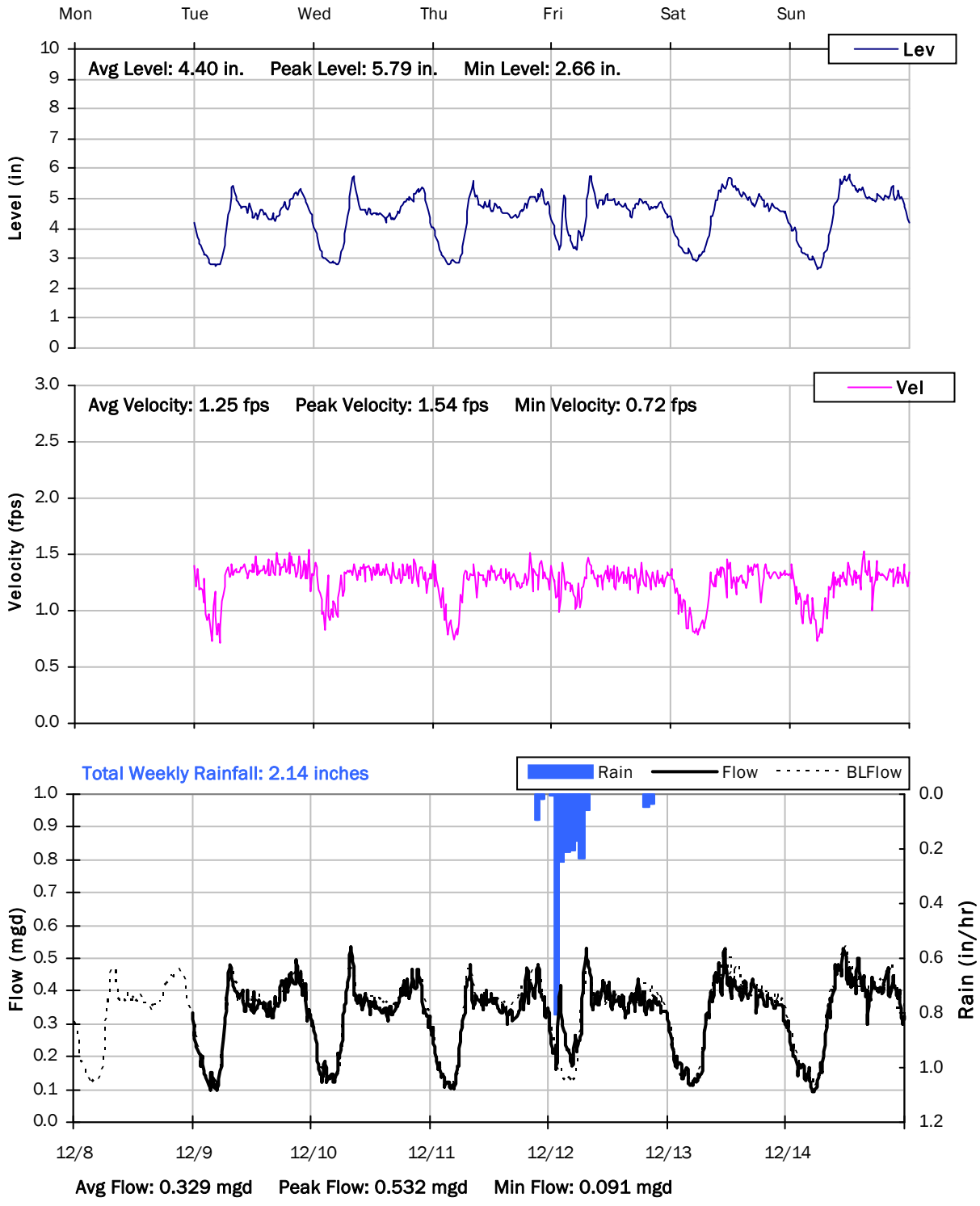
Storm Event I/I Analysis (Rain = 1.70 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	0.62 *mgd*	**Peak I/I Rate:**	0.16 *mgd*
PF:	1.86	**Total I/I:**	65,000 *gallons*
Peak Level:	5.40 *in*		
d/D Ratio:	0.23		

SITE 7

Weekly Level, Velocity and Flow Hydrographs

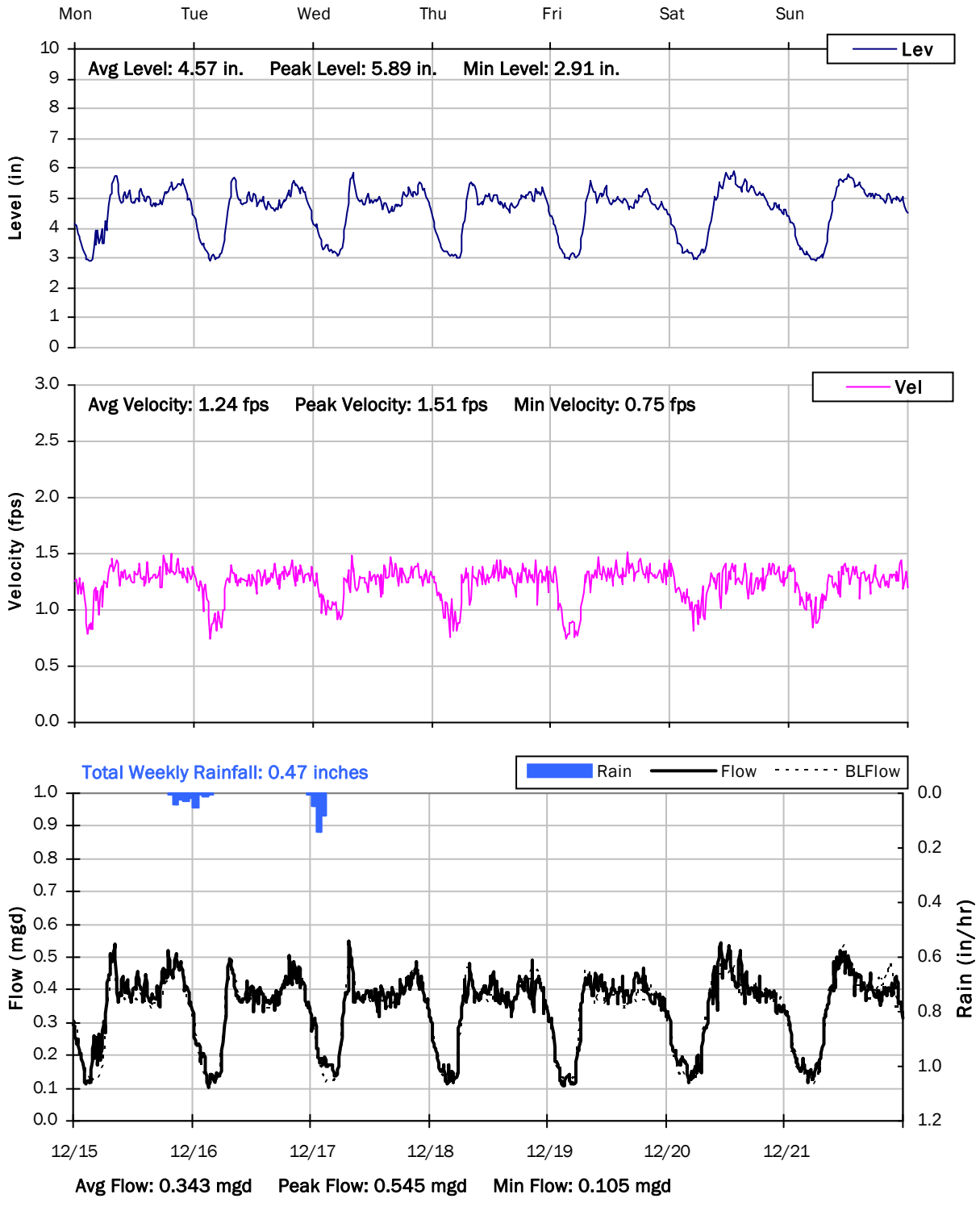
12/8/2014 to 12/15/2014



SITE 7

Weekly Level, Velocity and Flow Hydrographs

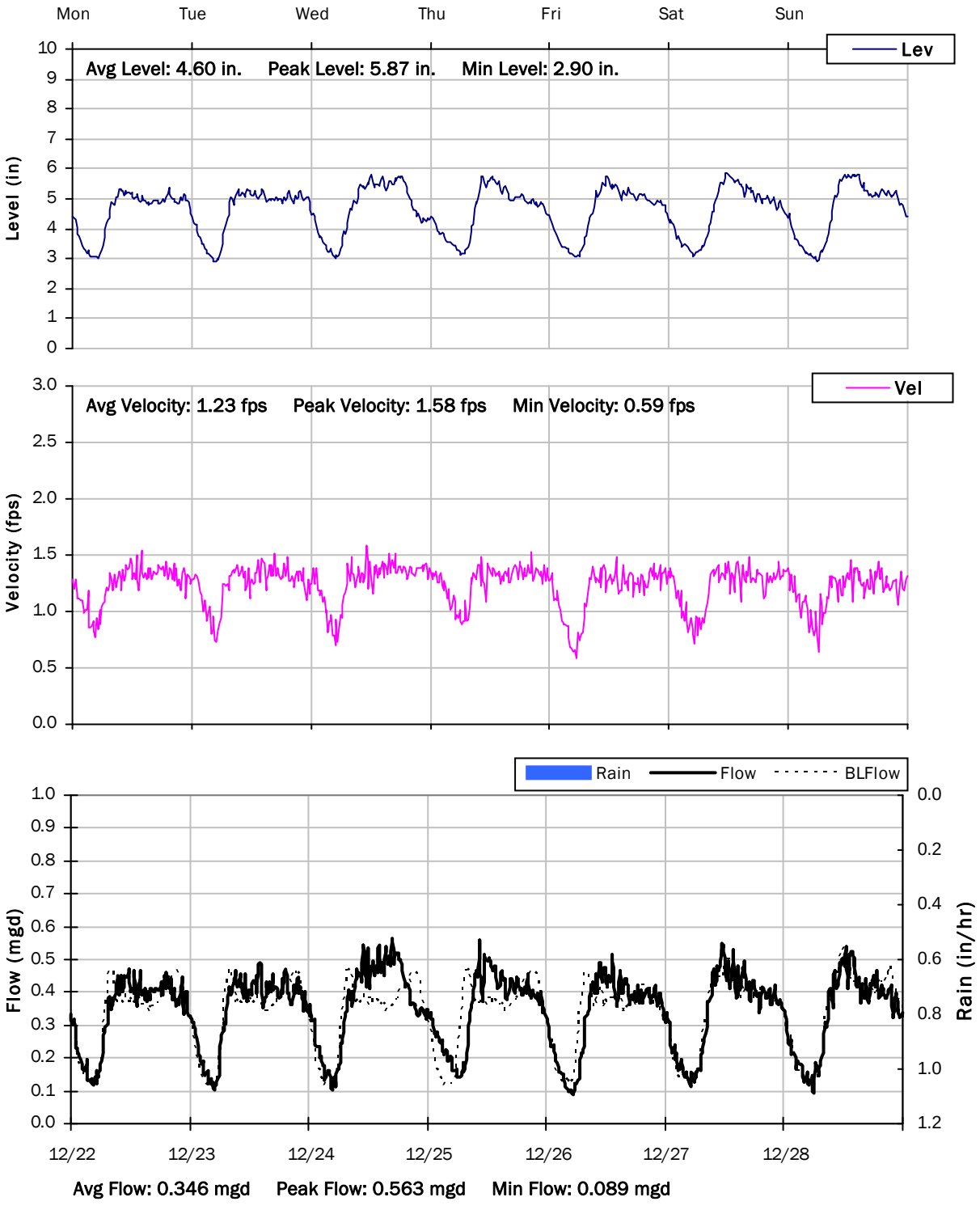
12/15/2014 to 12/22/2014



SITE 7

Weekly Level, Velocity and Flow Hydrographs

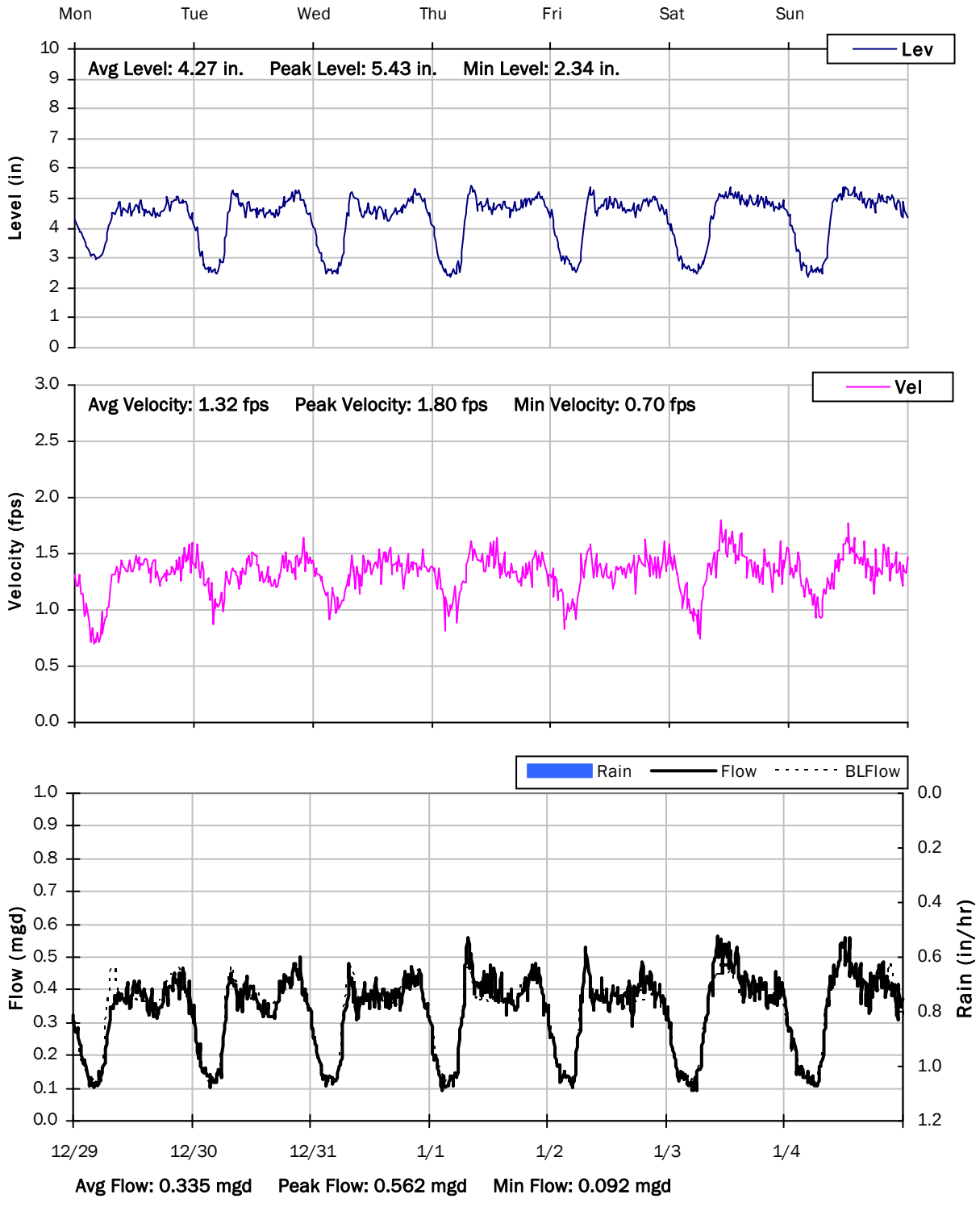
12/22/2014 to 12/29/2014



SITE 7

Weekly Level, Velocity and Flow Hydrographs

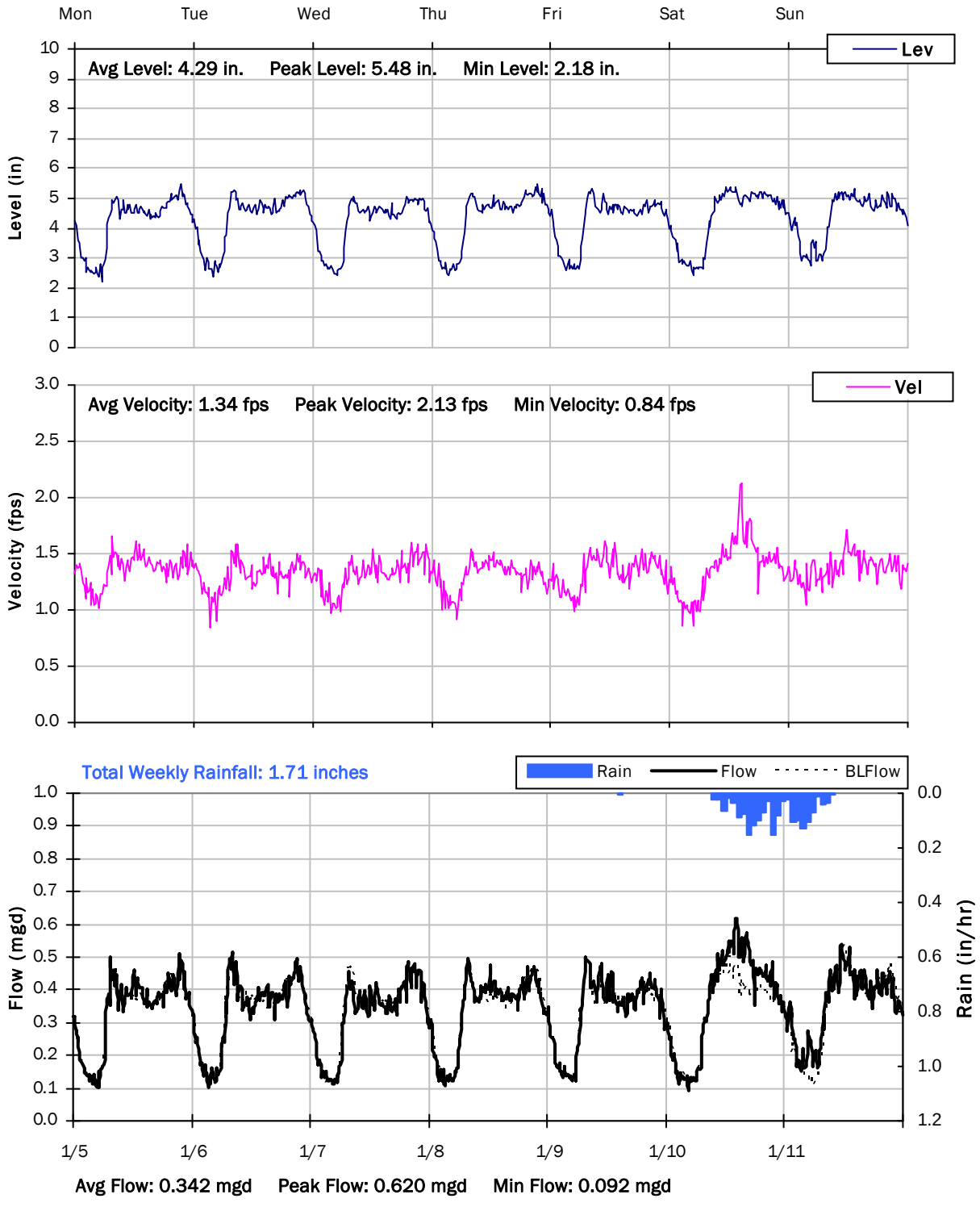
12/29/2014 to 1/5/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

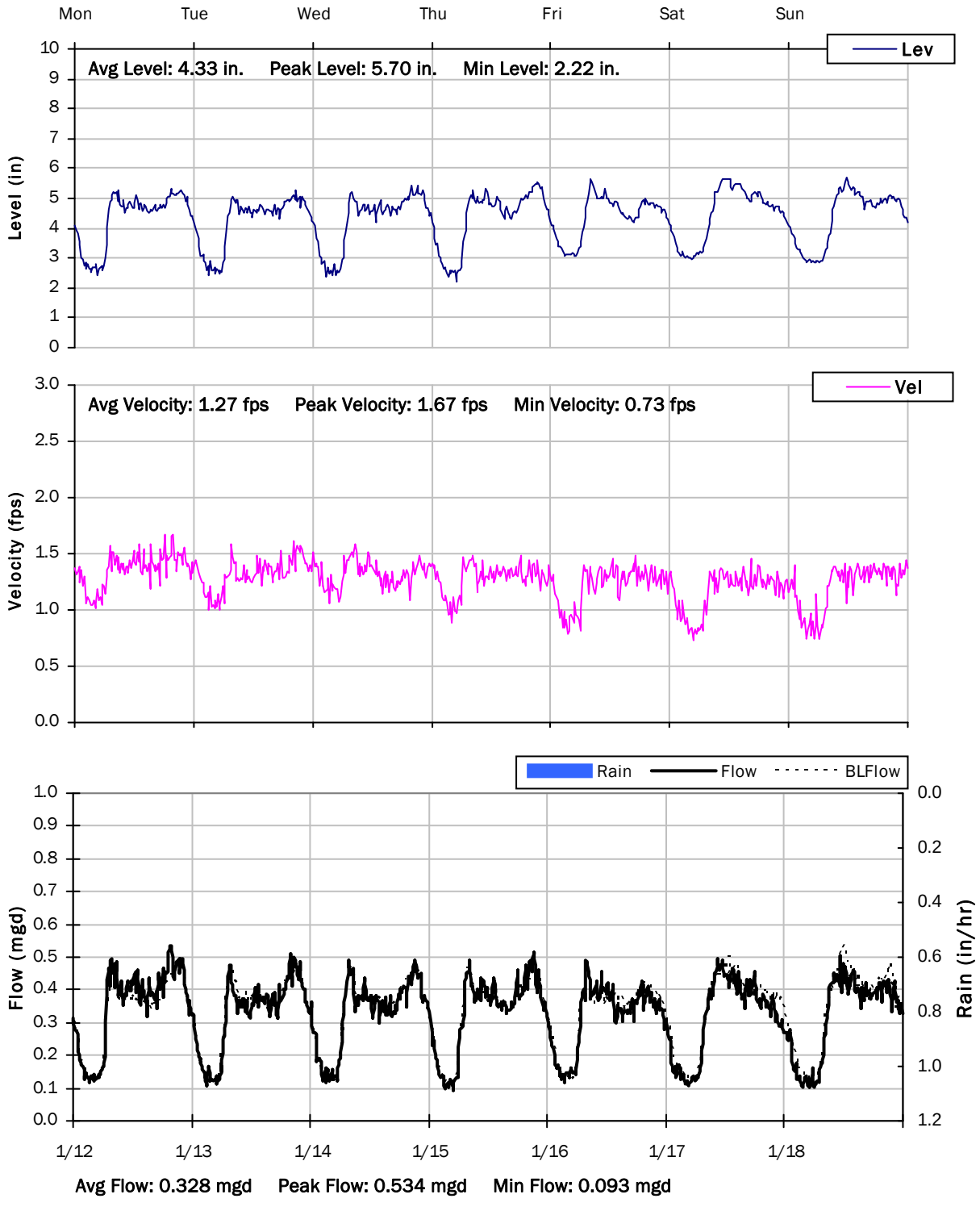
1/5/2015 to 1/12/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

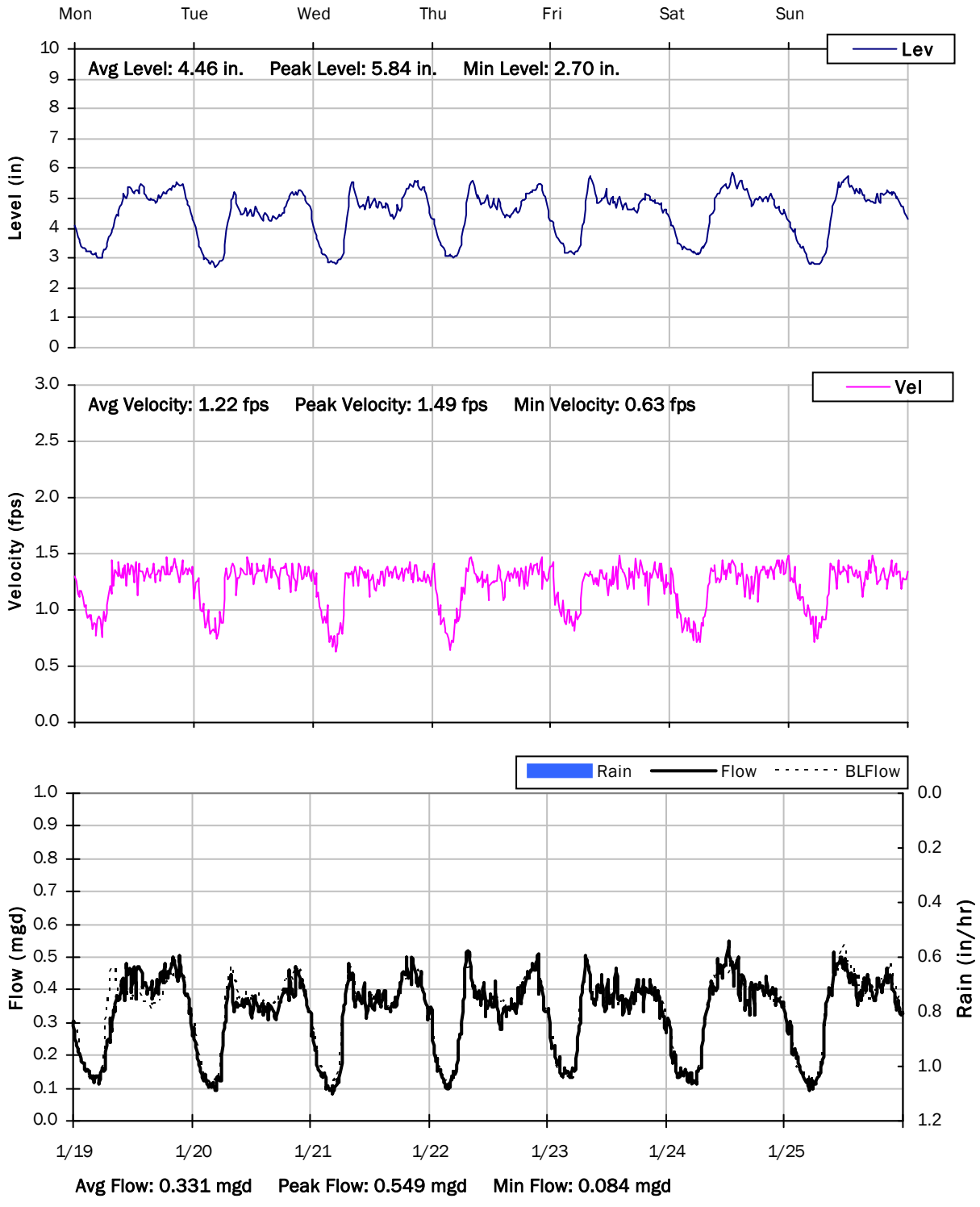
1/12/2015 to 1/19/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

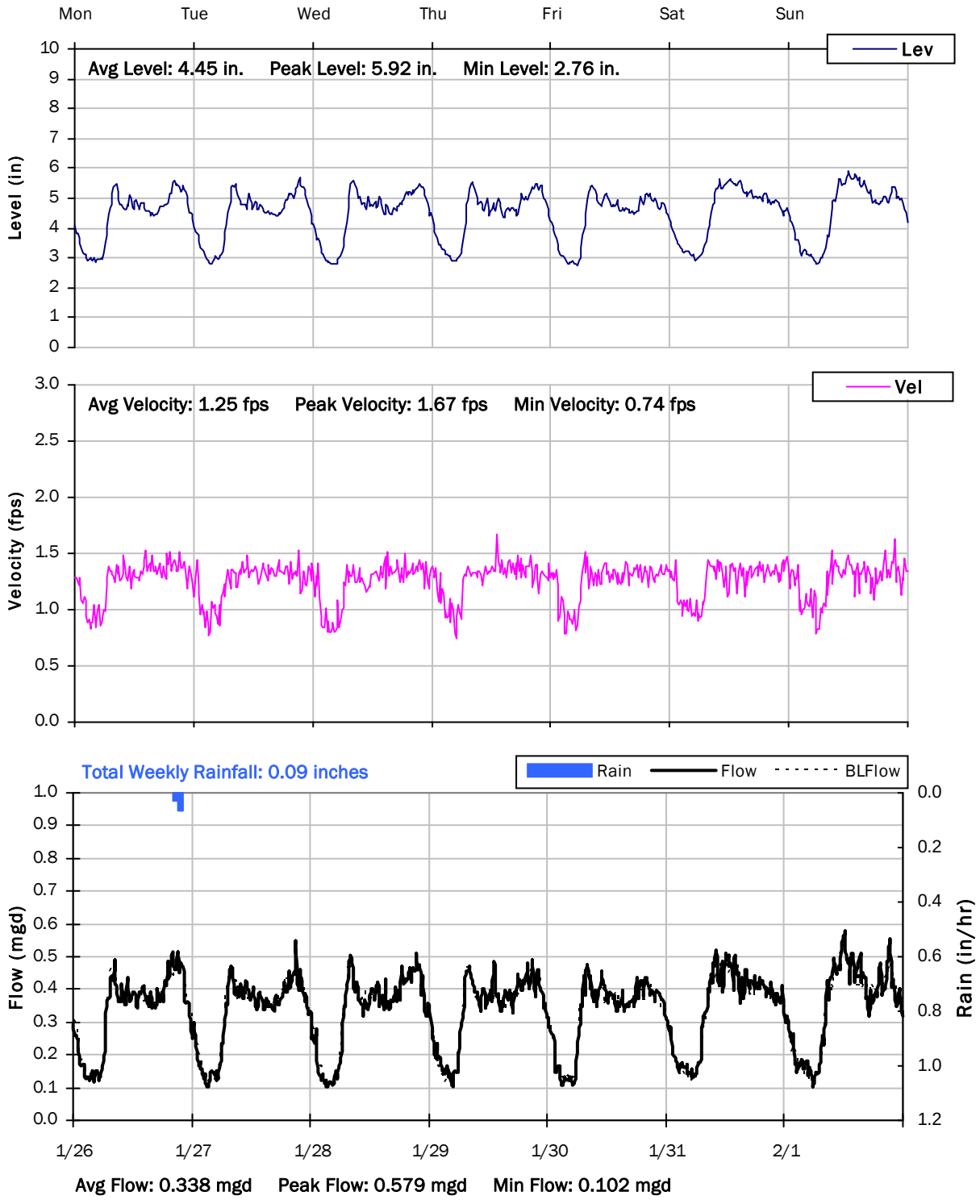
1/19/2015 to 1/26/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

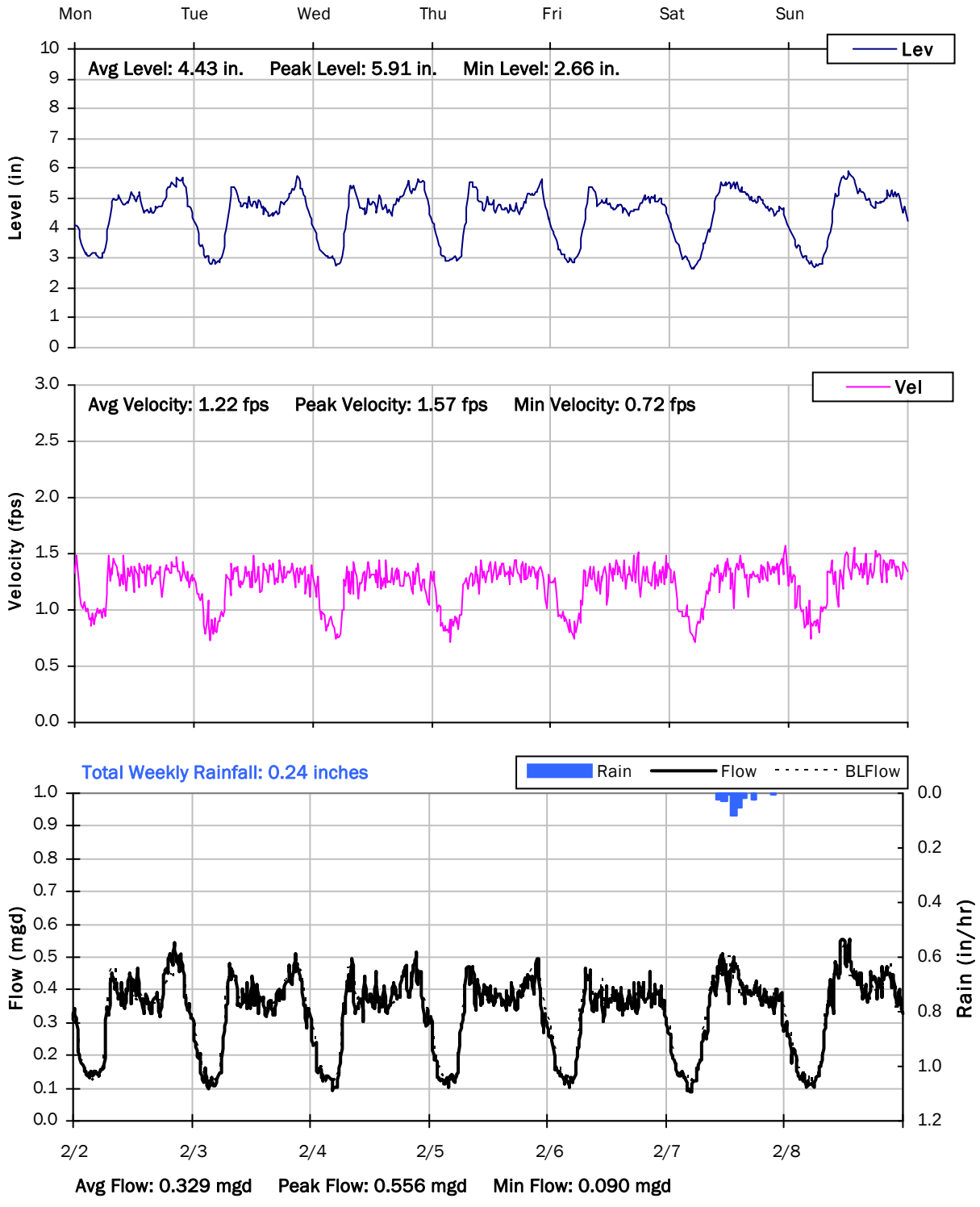
1/26/2015 to 2/2/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

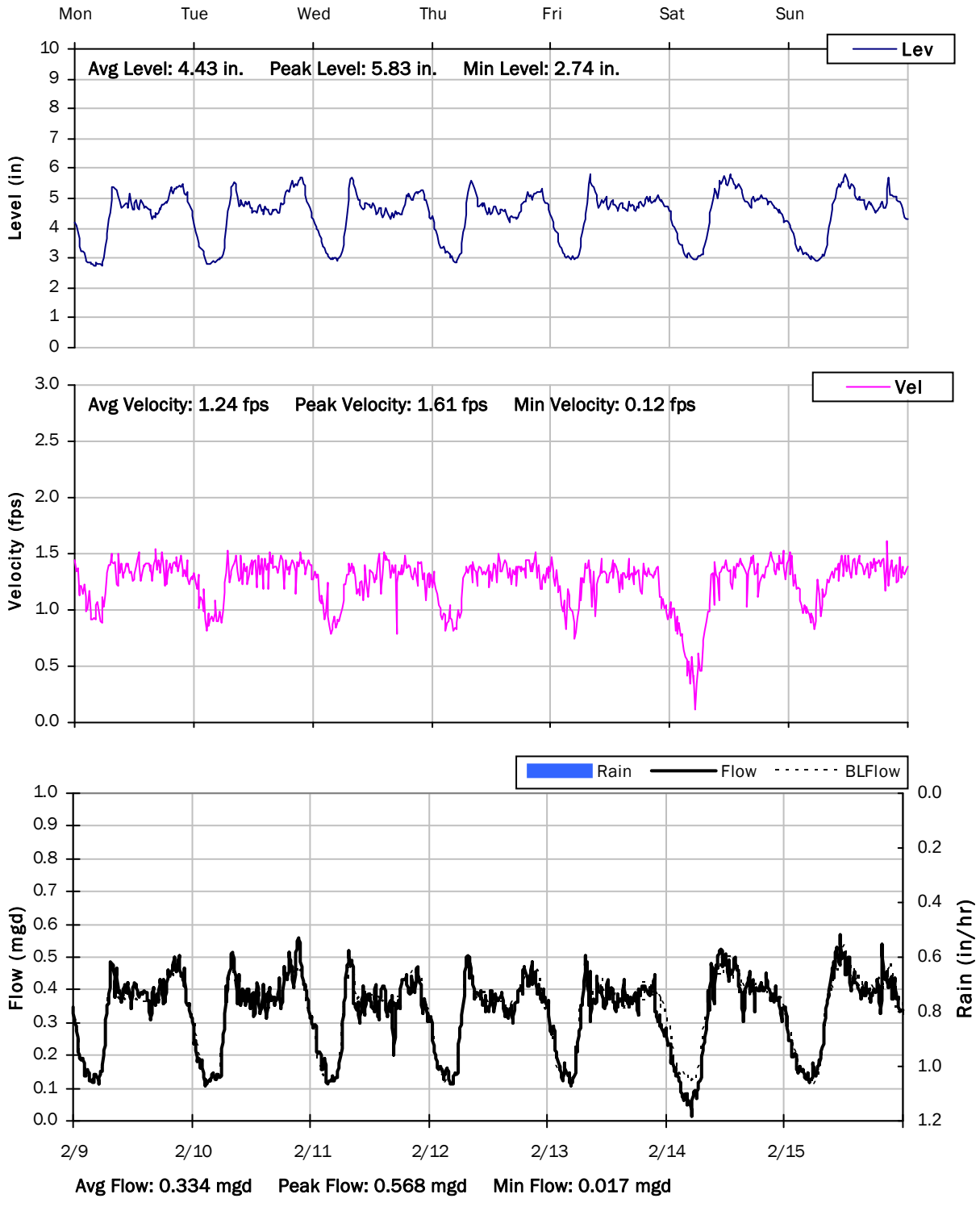
2/2/2015 to 2/9/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

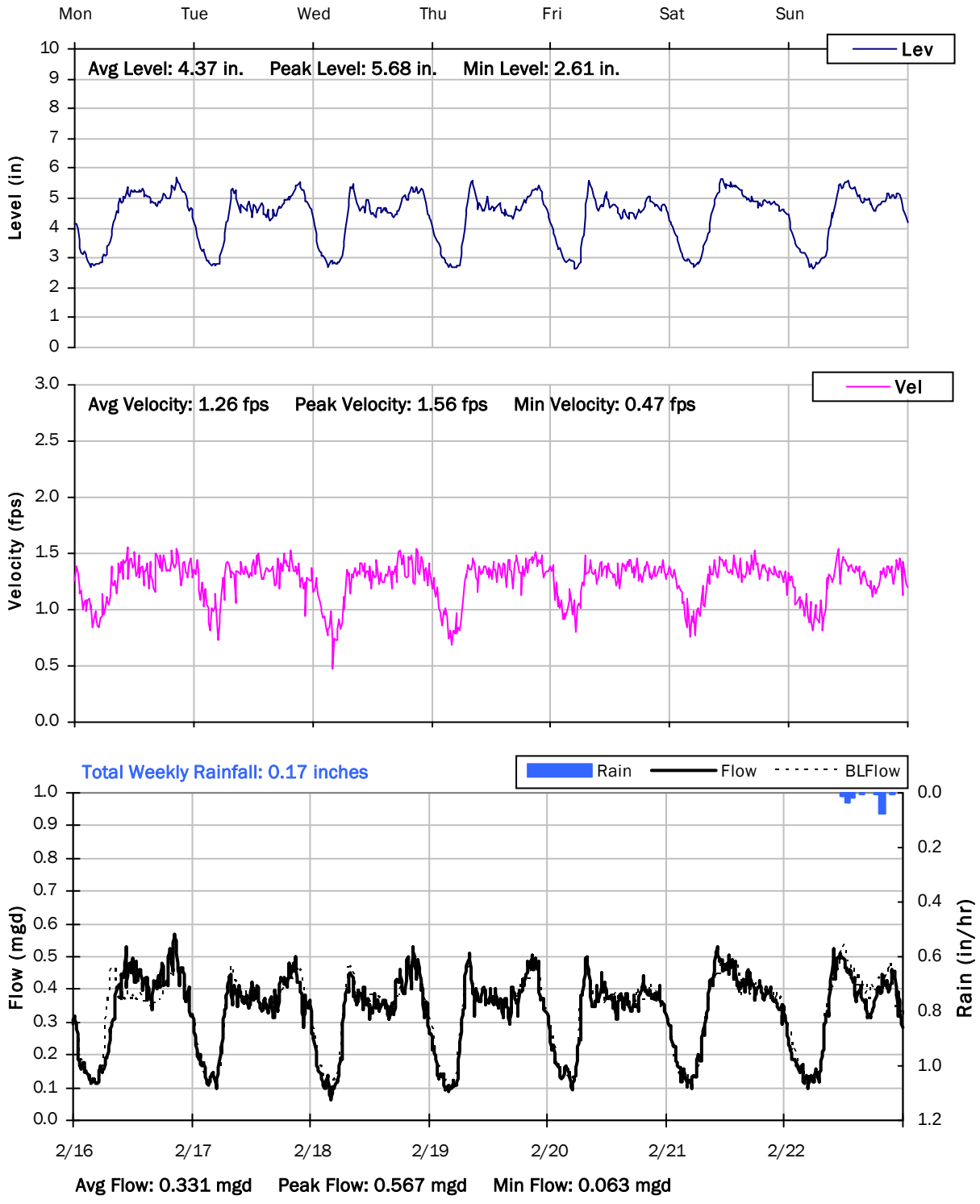
2/9/2015 to 2/16/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

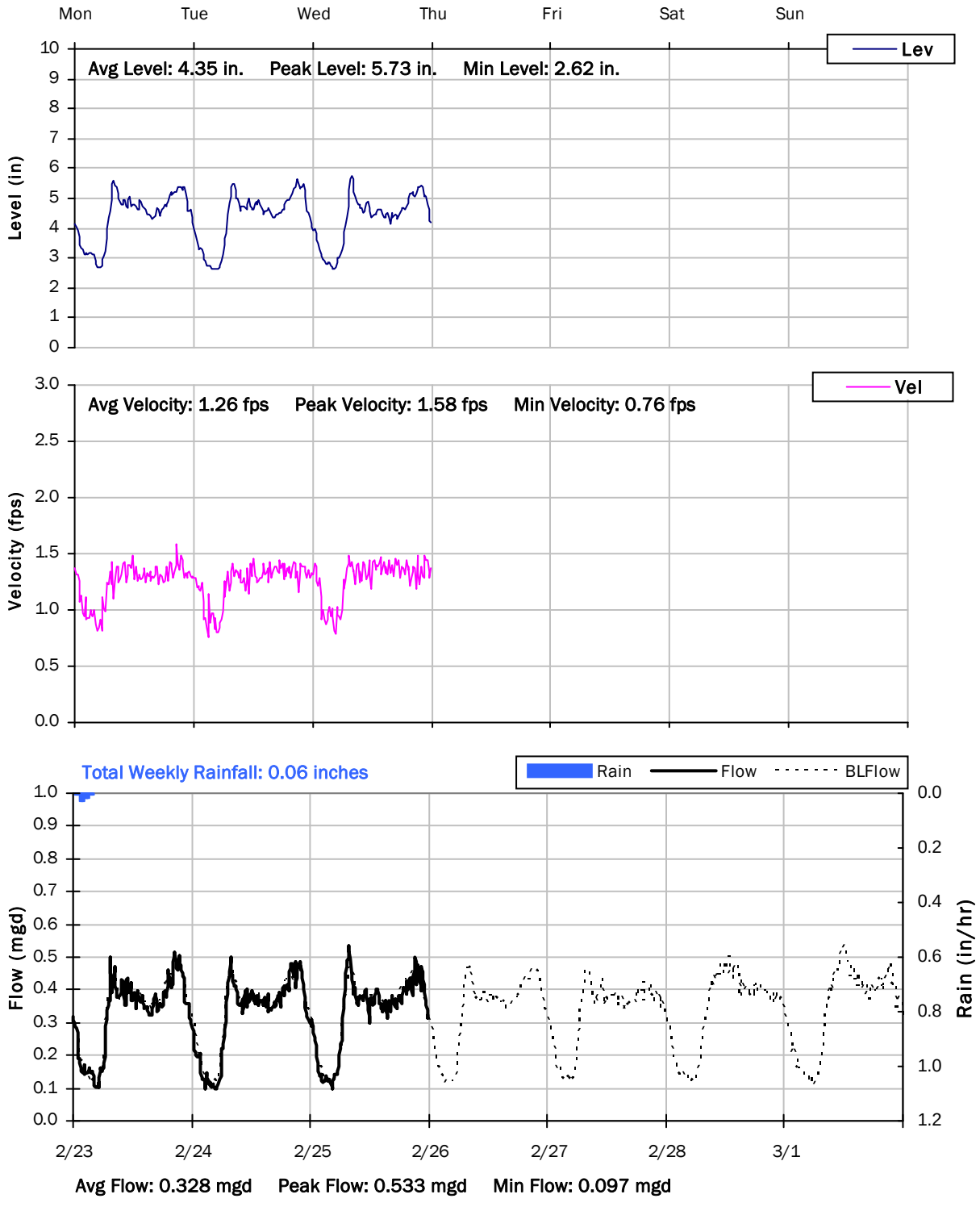
2/16/2015 to 2/23/2015



SITE 7

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

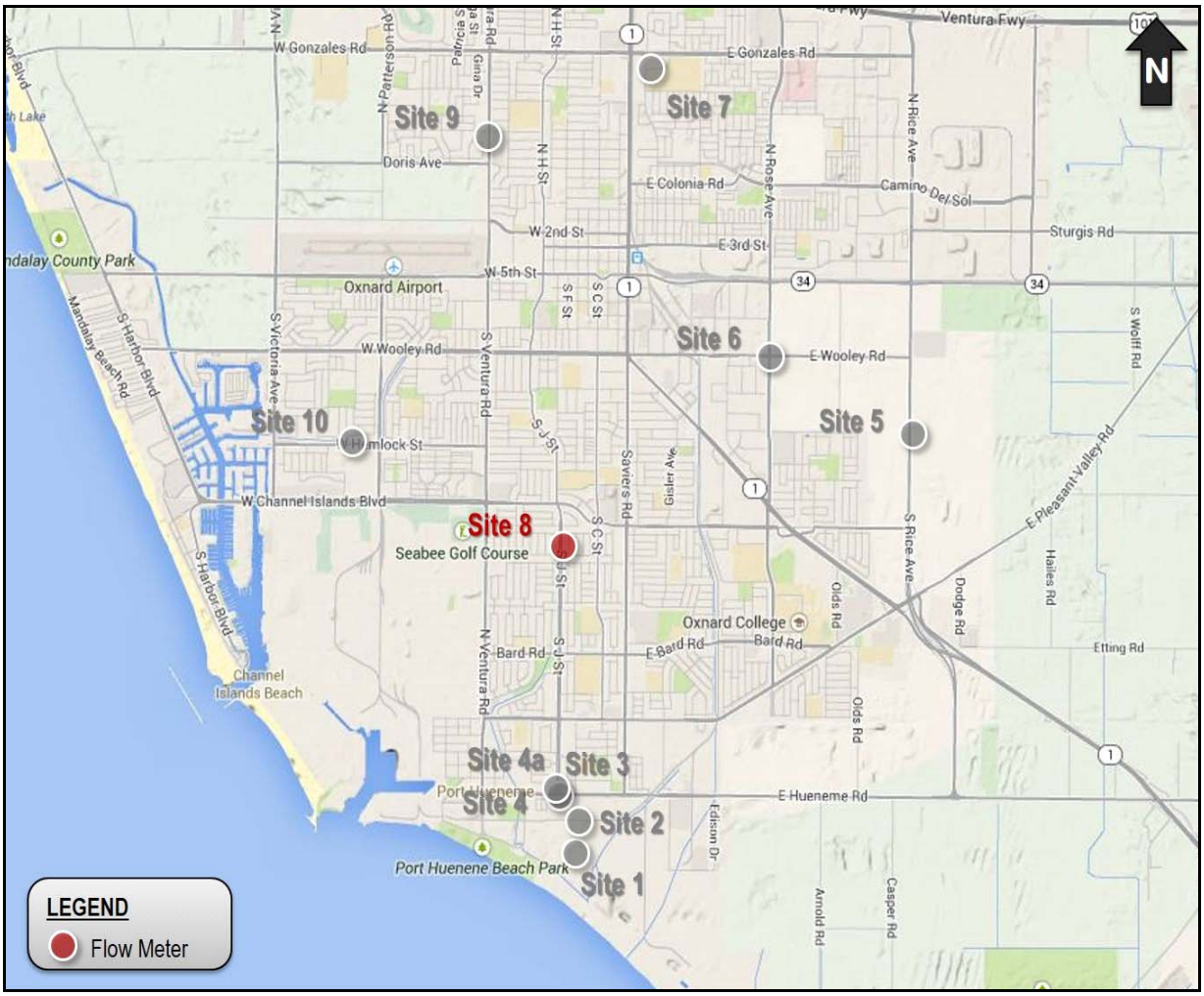
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 8

Location: J Street, between Spruce Street and Teakwood Street

Data Summary Report



Vicinity Map: Site 8

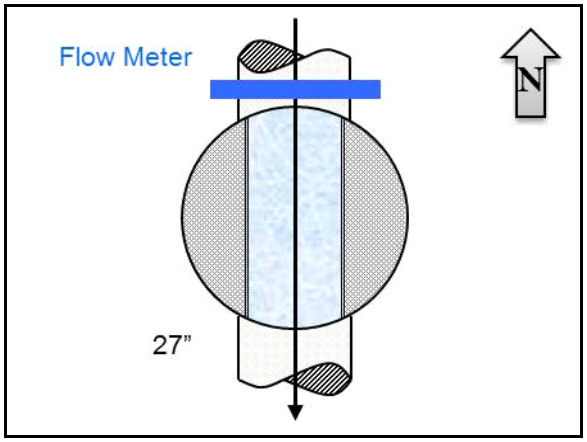
SITE 8

Site Information

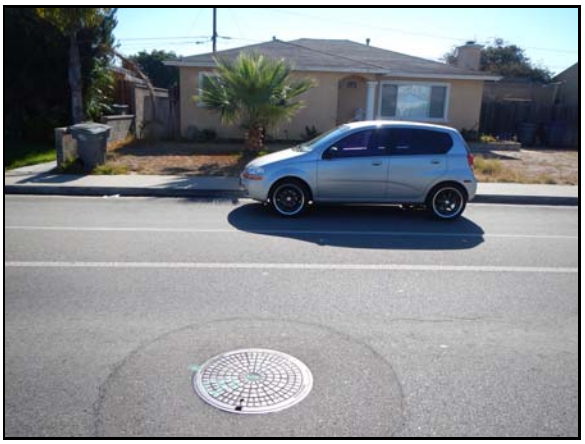
Location:	J Street, between Spruce Street and Teakwood Street
Coordinates:	119.1857° W, 34.1716° N
Rim Elevation:	25 feet
Pipe Diameter:	27 inches
Baseline Flow:	1.638 mgd
Peak Measured Flow:	4.540 mgd

Satellite Map

Sanitary Map



Flow Diagram



Street View

Plan View

SITE 8

Additional Site Photos

Effluent Pipe

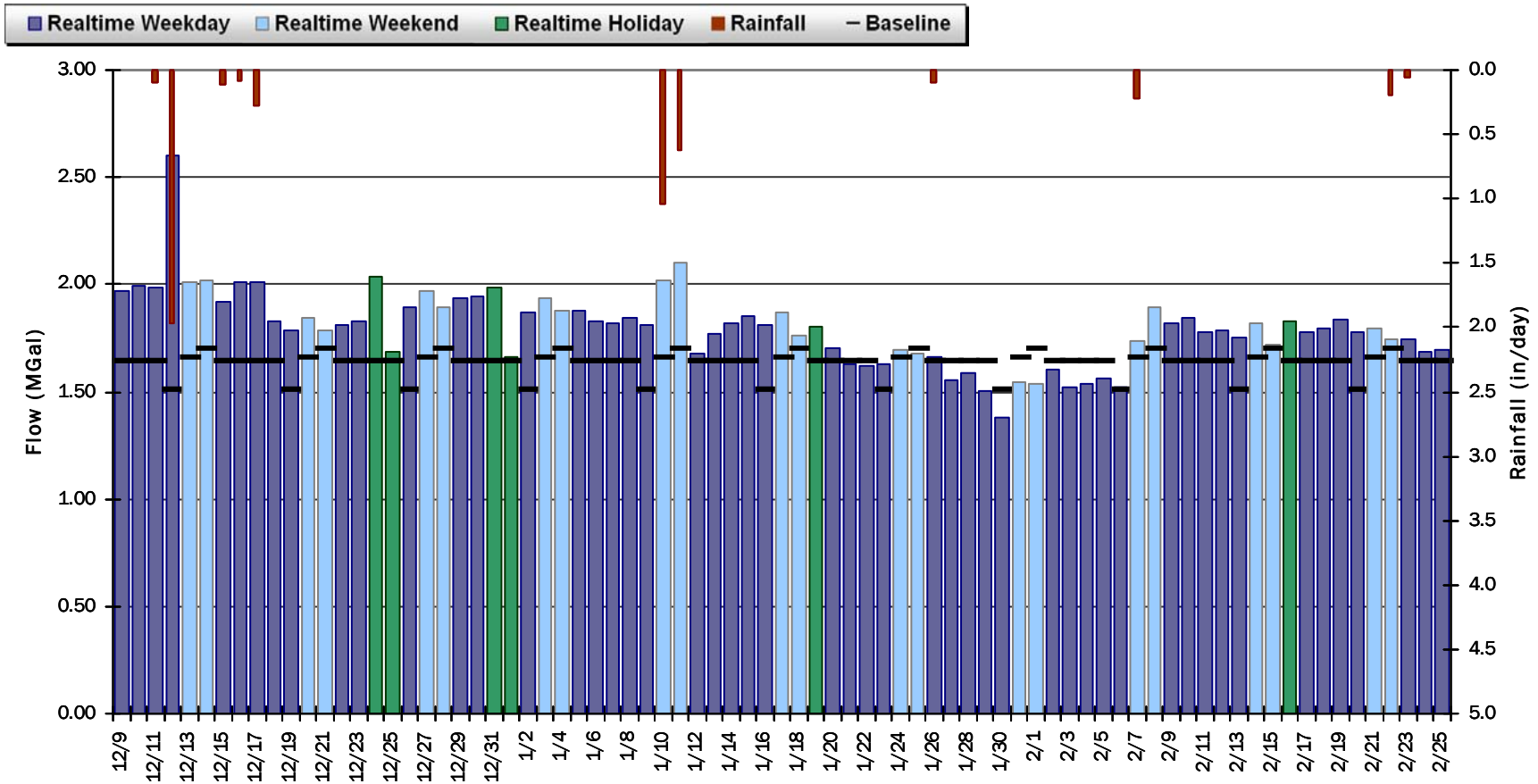
Influent Pipe

SITE 8

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 1.799 MGal **Peak Daily Flow: 2.602 MGal** **Min Daily Flow: 1.381 MGal**

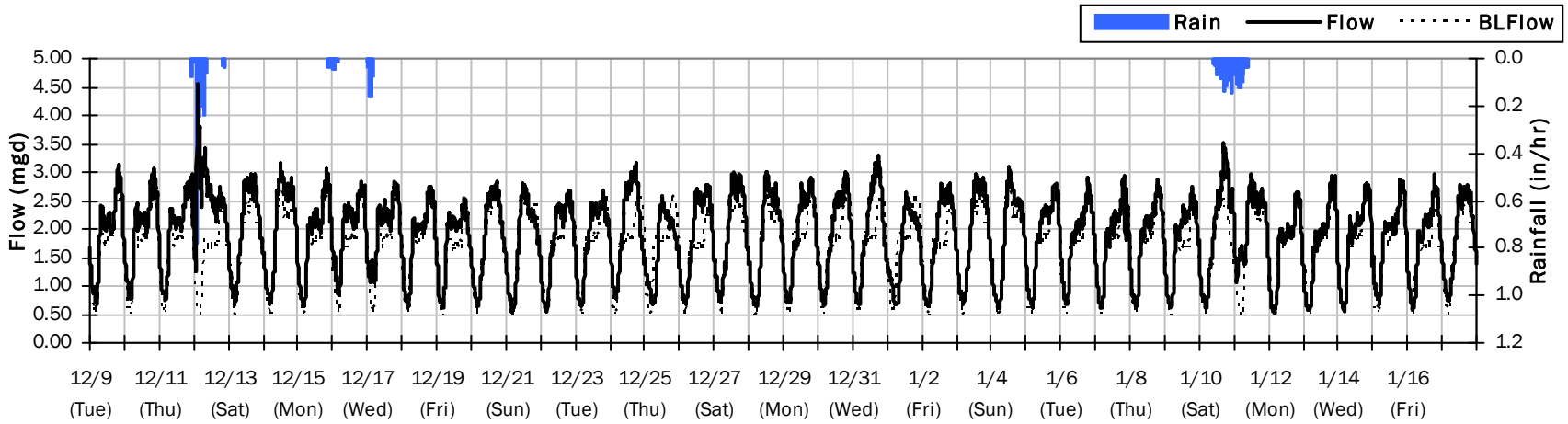
Total Period Rainfall: 4.78 inches

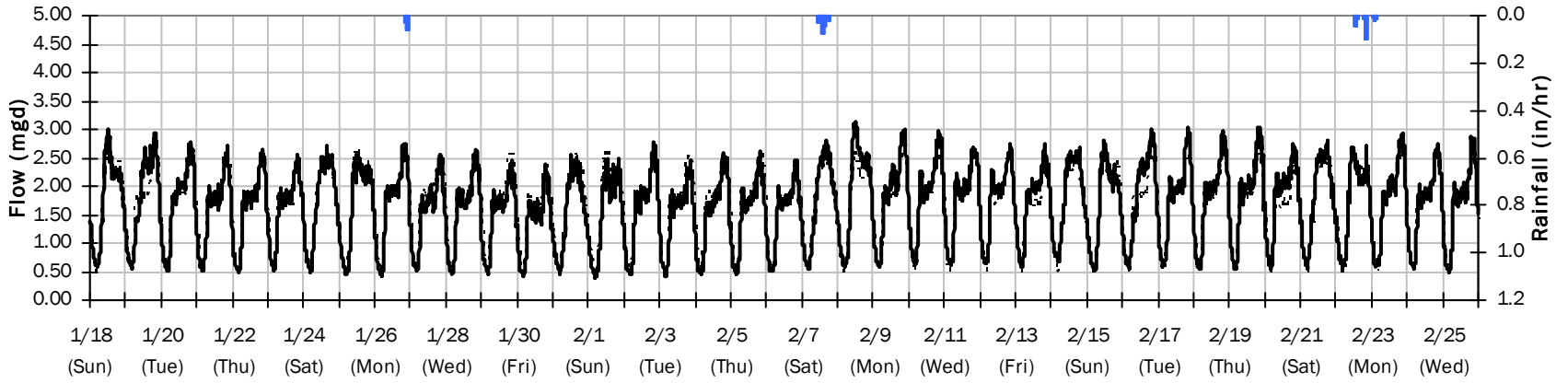


SITE 8

Flow Summary: 12/9/2014 to 2/25/2015

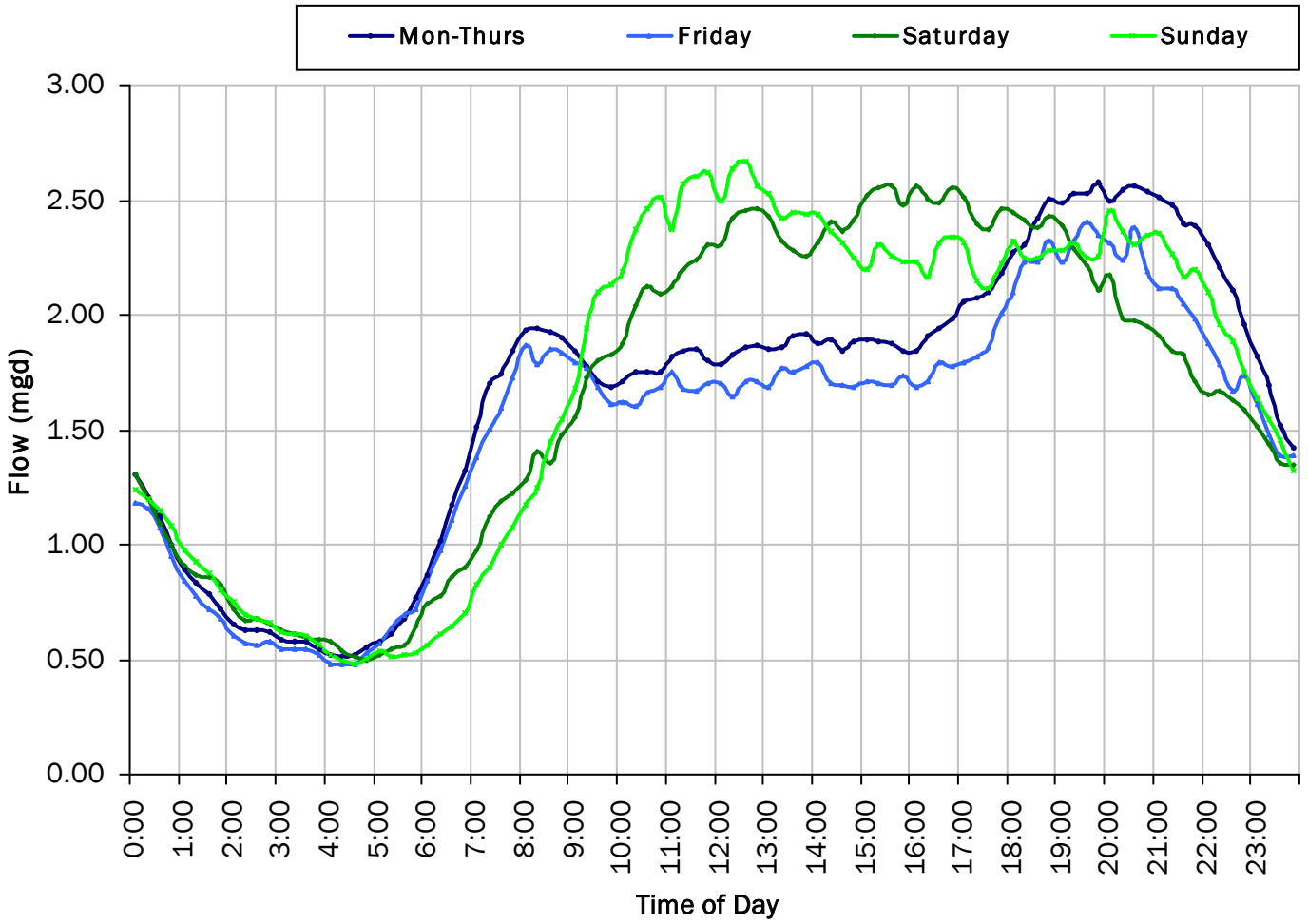
Total Period Rainfall: 4.78 inches Avg Flow: 1.799 mgd Peak Flow: 4.540 mgd Min Flow: 0.401 mgd





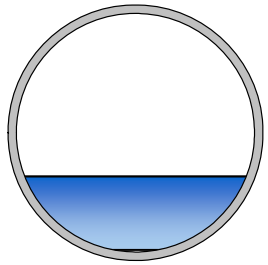
SITE 8

Baseline Flow Hydrographs



Baseline Flow:

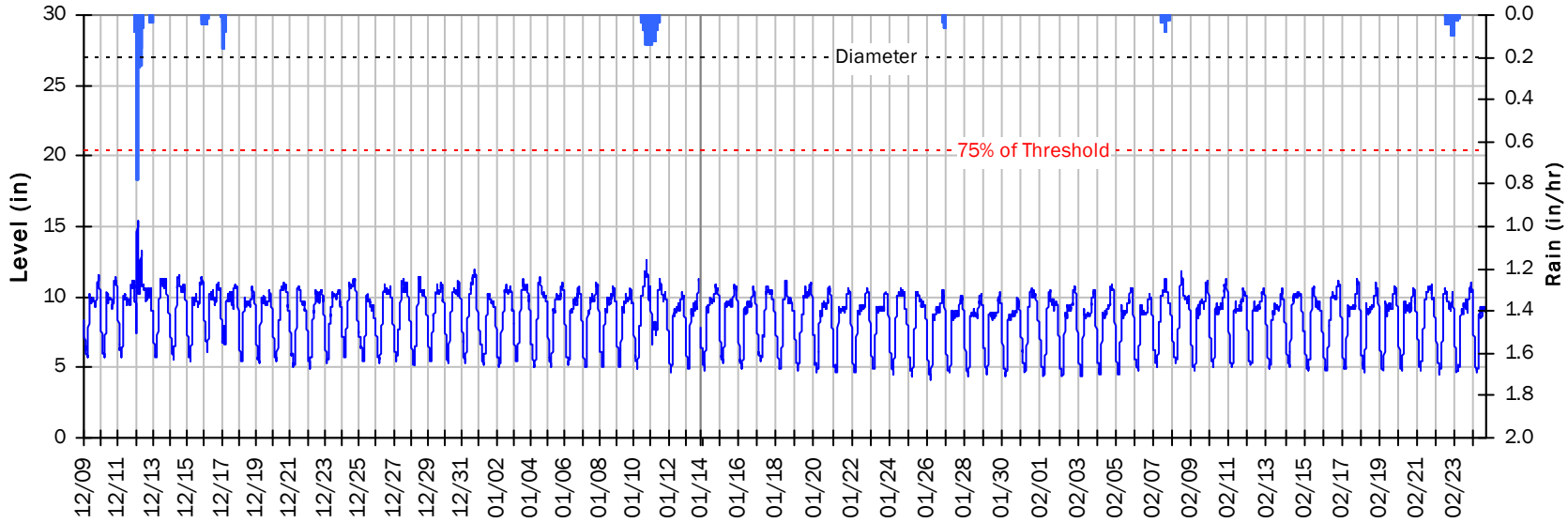
1.64 *mgd*

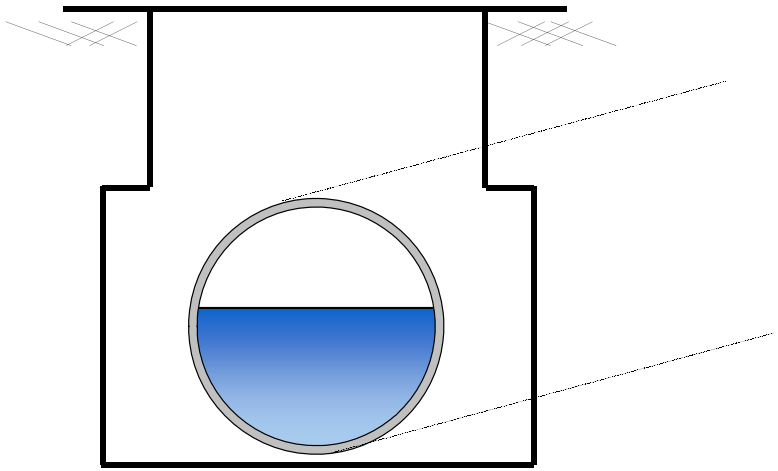


SITE 8

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





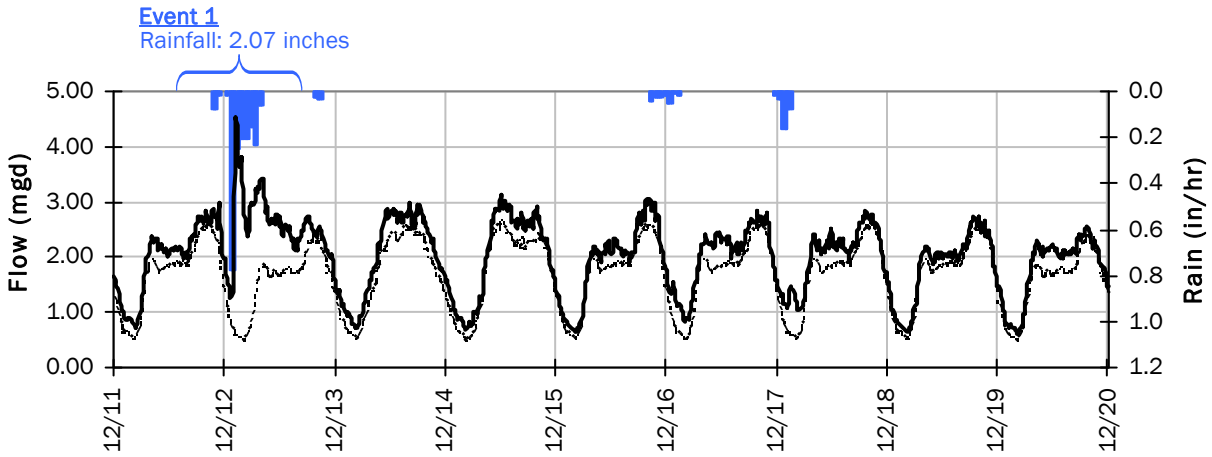
Pipe Diameter: 27 *inches*

Peak Measured Level: 15.5 *inches*

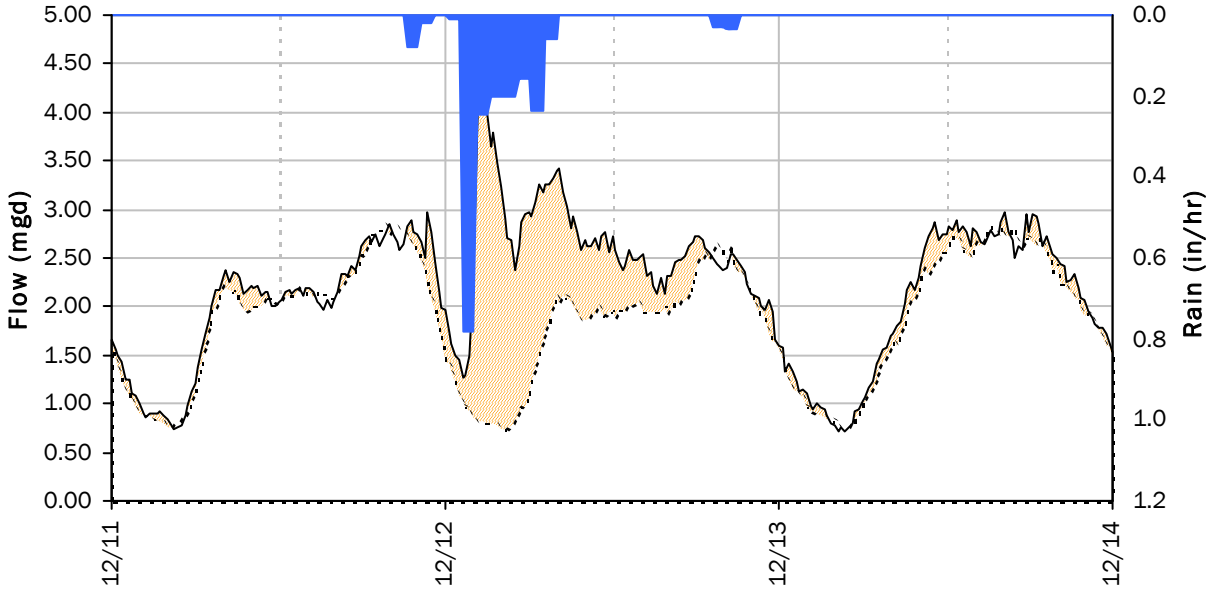
Peak d/D Ratio: 0.57

SITE 8
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

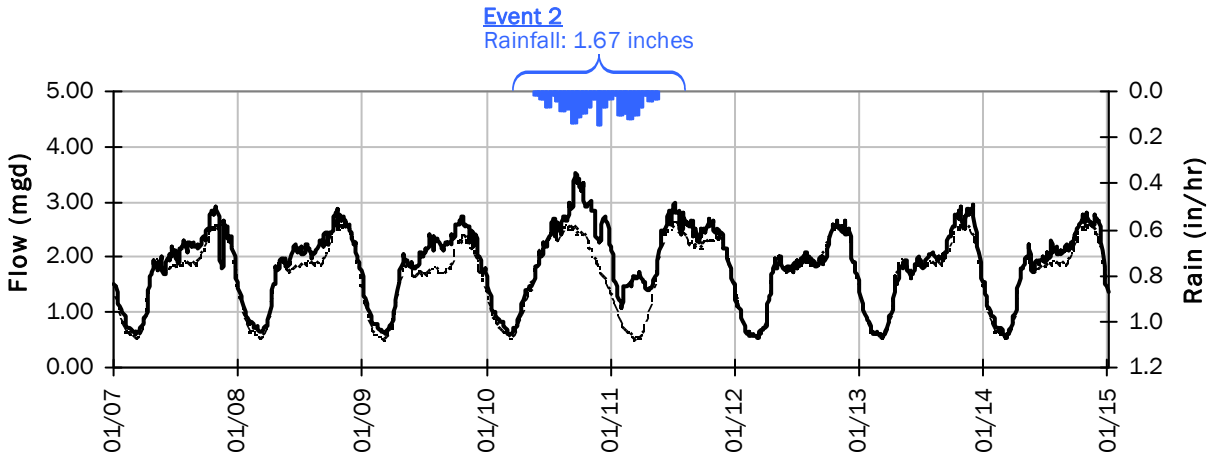


Storm Event I/I Analysis (Rain = 2.07 inches)

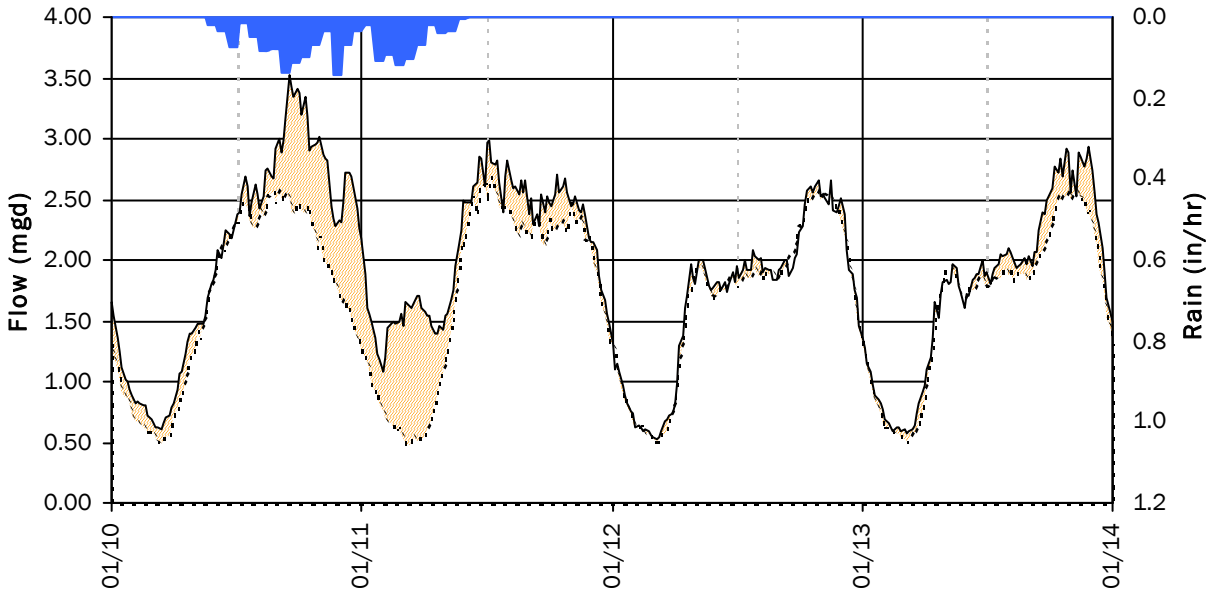
Capacity		Inflow / Infiltration	
Peak Flow:	4.54 *mgd*	**Peak I/I Rate:**	3.73 *mgd*
PF:	2.77	**Total I/I:**	981,000 *gallons*
Peak Level:	15.45 *in*		
d/D Ratio:	0.57		

SITE 8
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



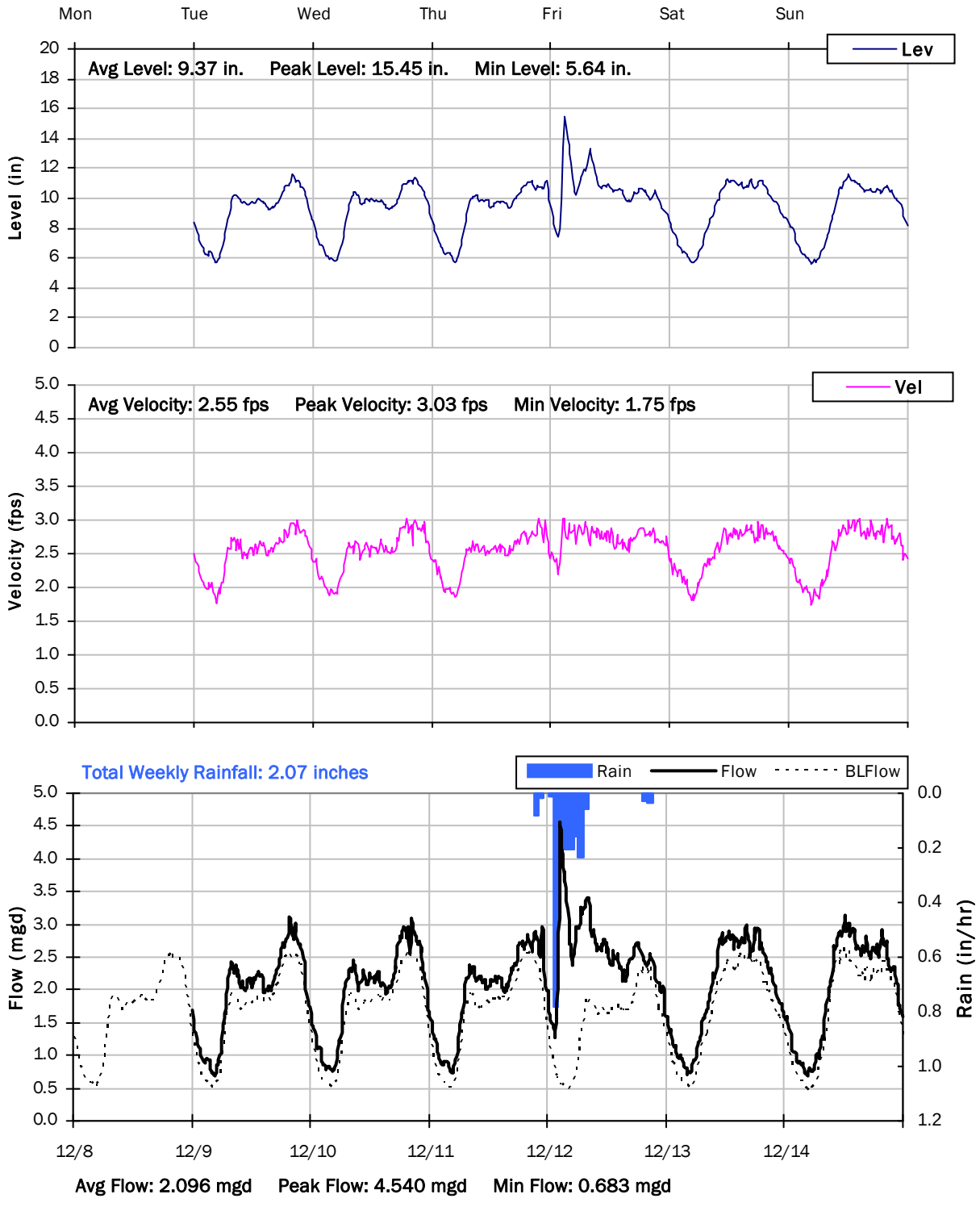
Storm Event I/I Analysis (Rain = 1.67 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	3.52 *mgd*	**Peak I/I Rate:**	1.20 *mgd*
PF:	2.15	**Total I/I:**	791,000 *gallons*
Peak Level:	12.65 *in*		
d/D Ratio:	0.47		

SITE 8

Weekly Level, Velocity and Flow Hydrographs

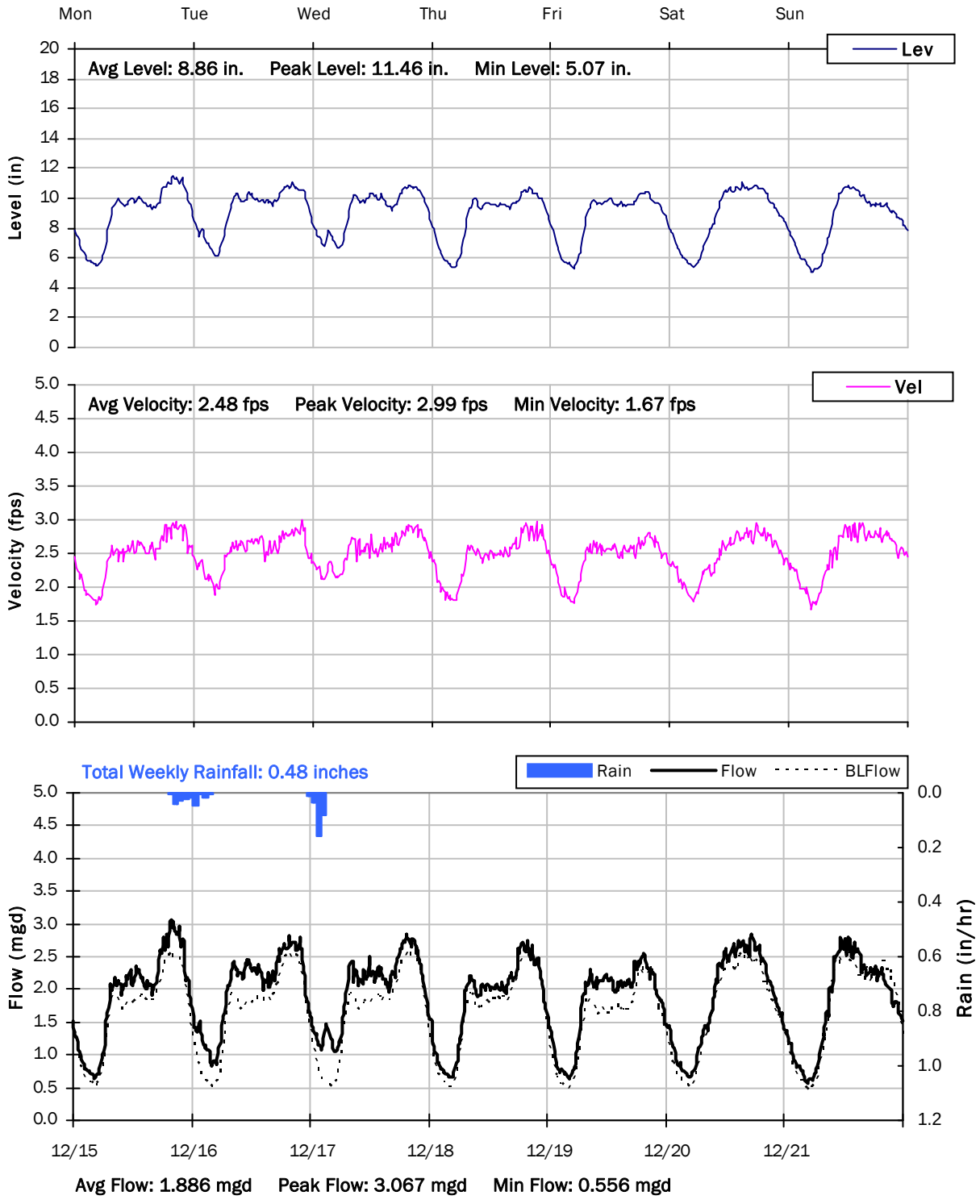
12/8/2014 to 12/15/2014



SITE 8

Weekly Level, Velocity and Flow Hydrographs

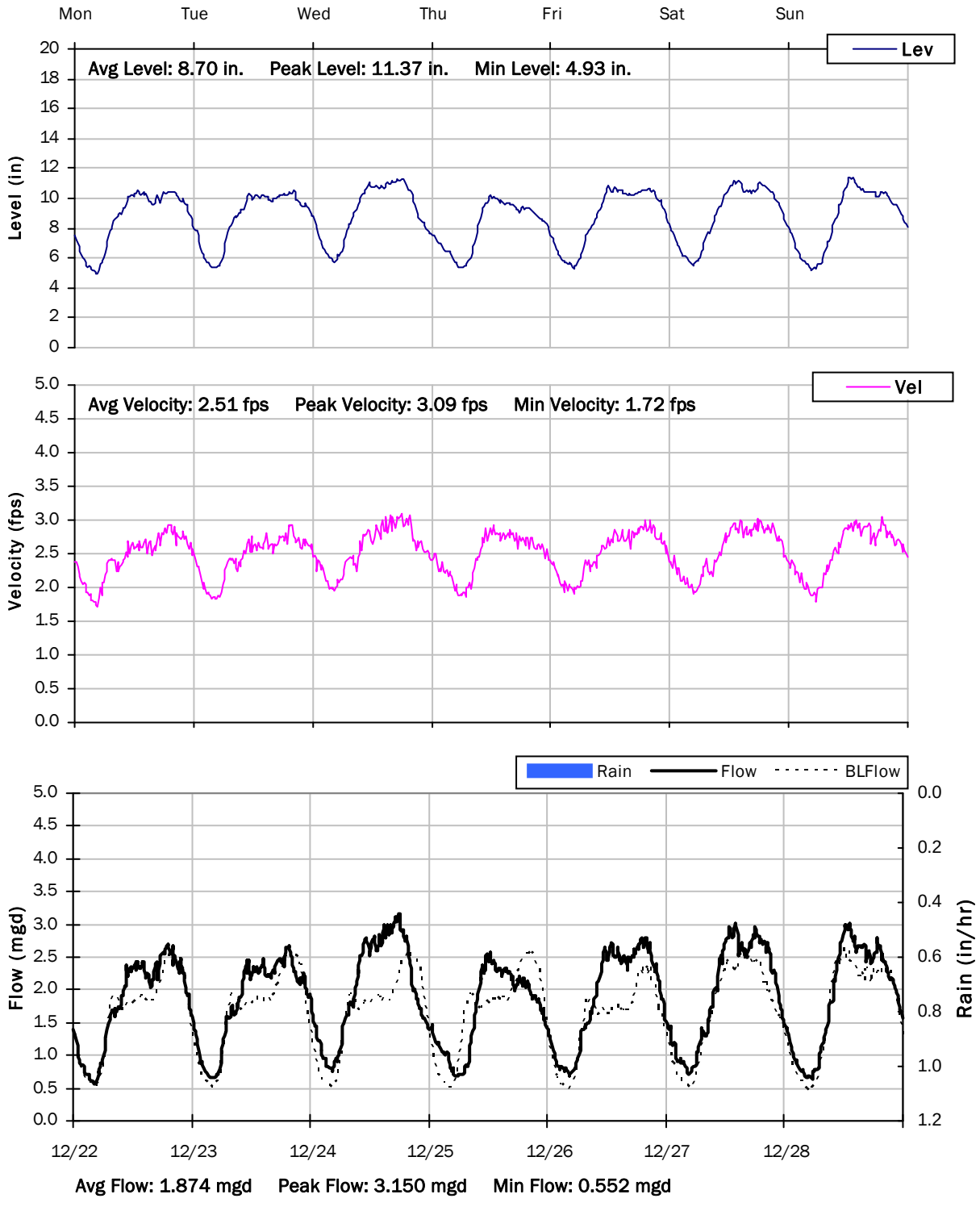
12/15/2014 to 12/22/2014



SITE 8

Weekly Level, Velocity and Flow Hydrographs

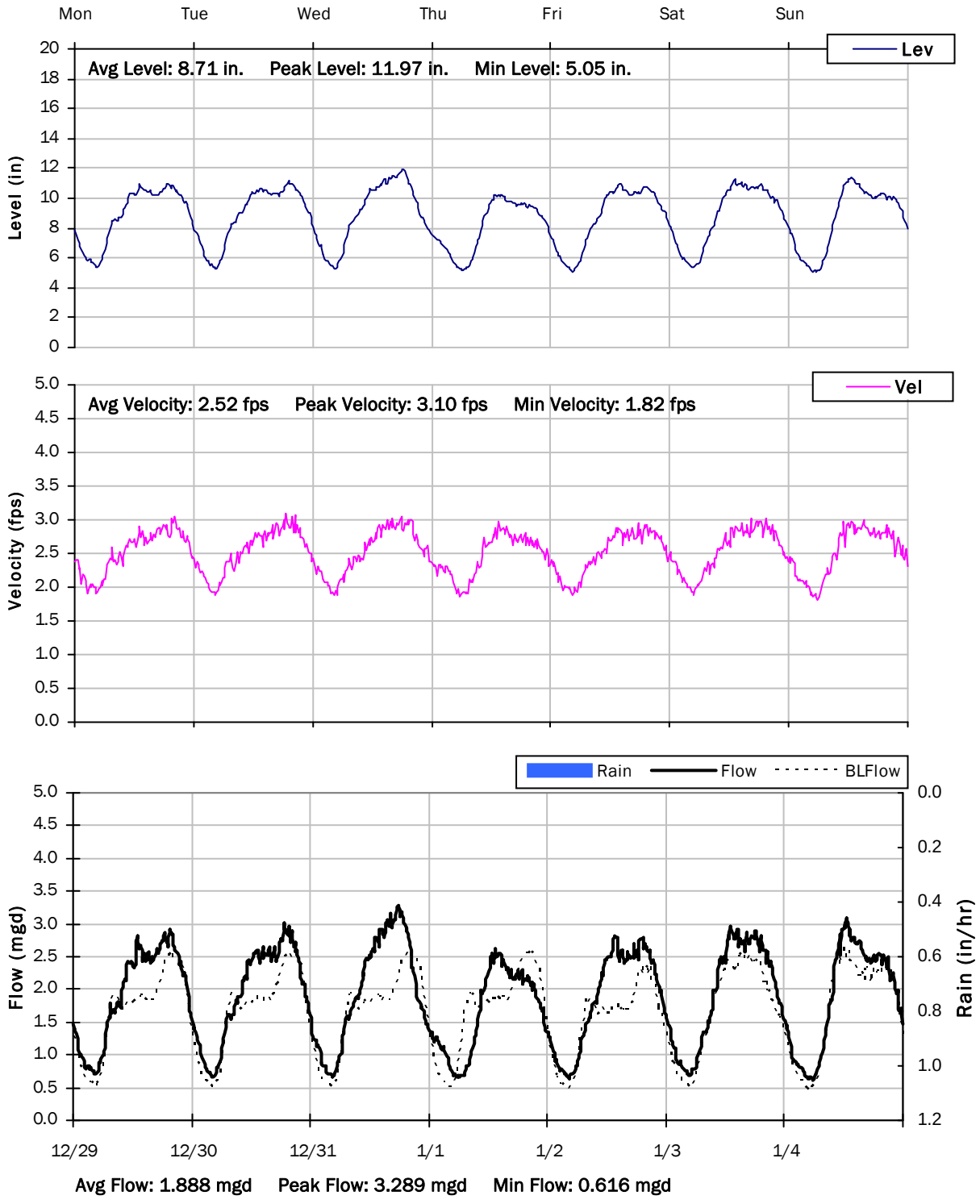
12/22/2014 to 12/29/2014



SITE 8

Weekly Level, Velocity and Flow Hydrographs

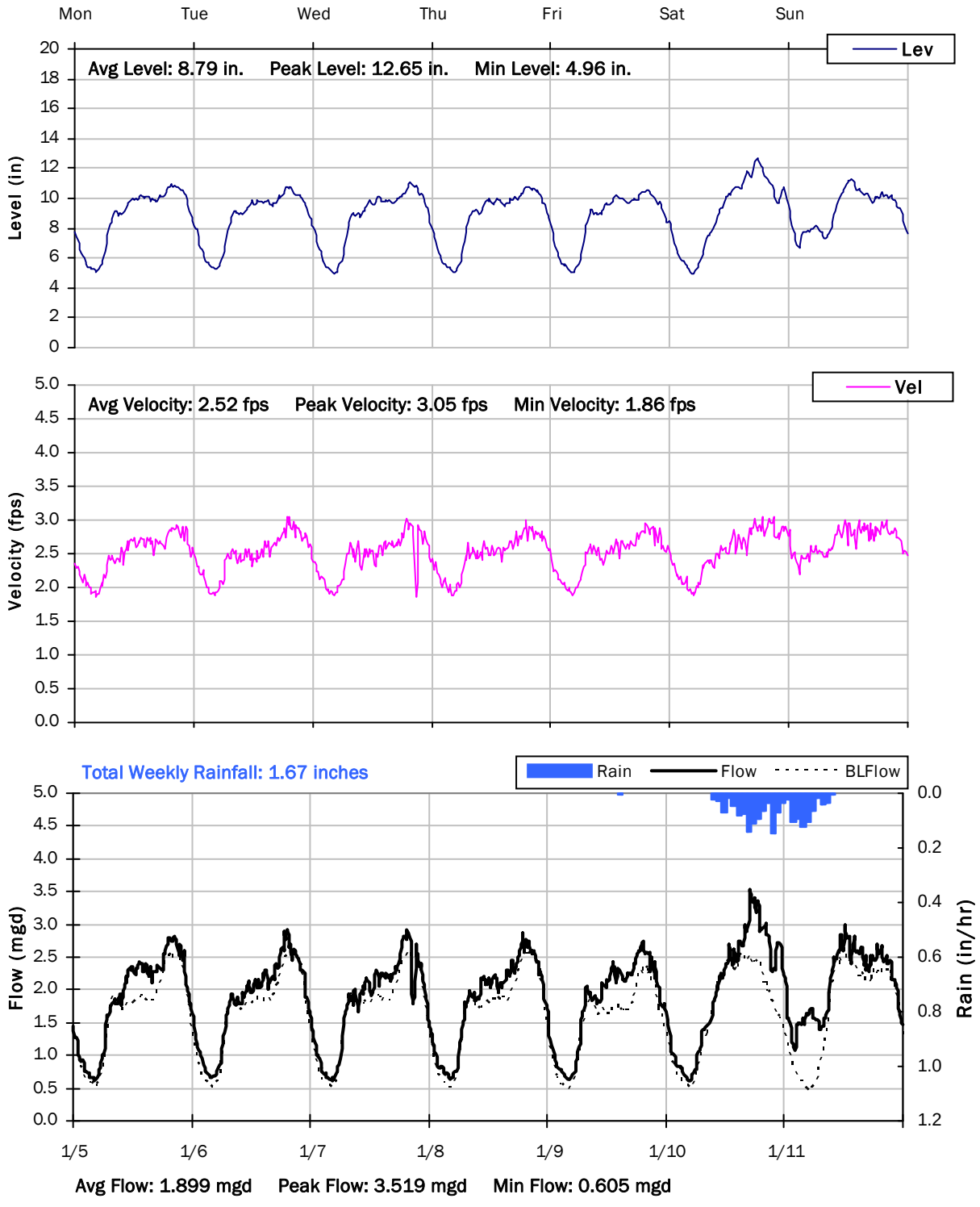
12/29/2014 to 1/5/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

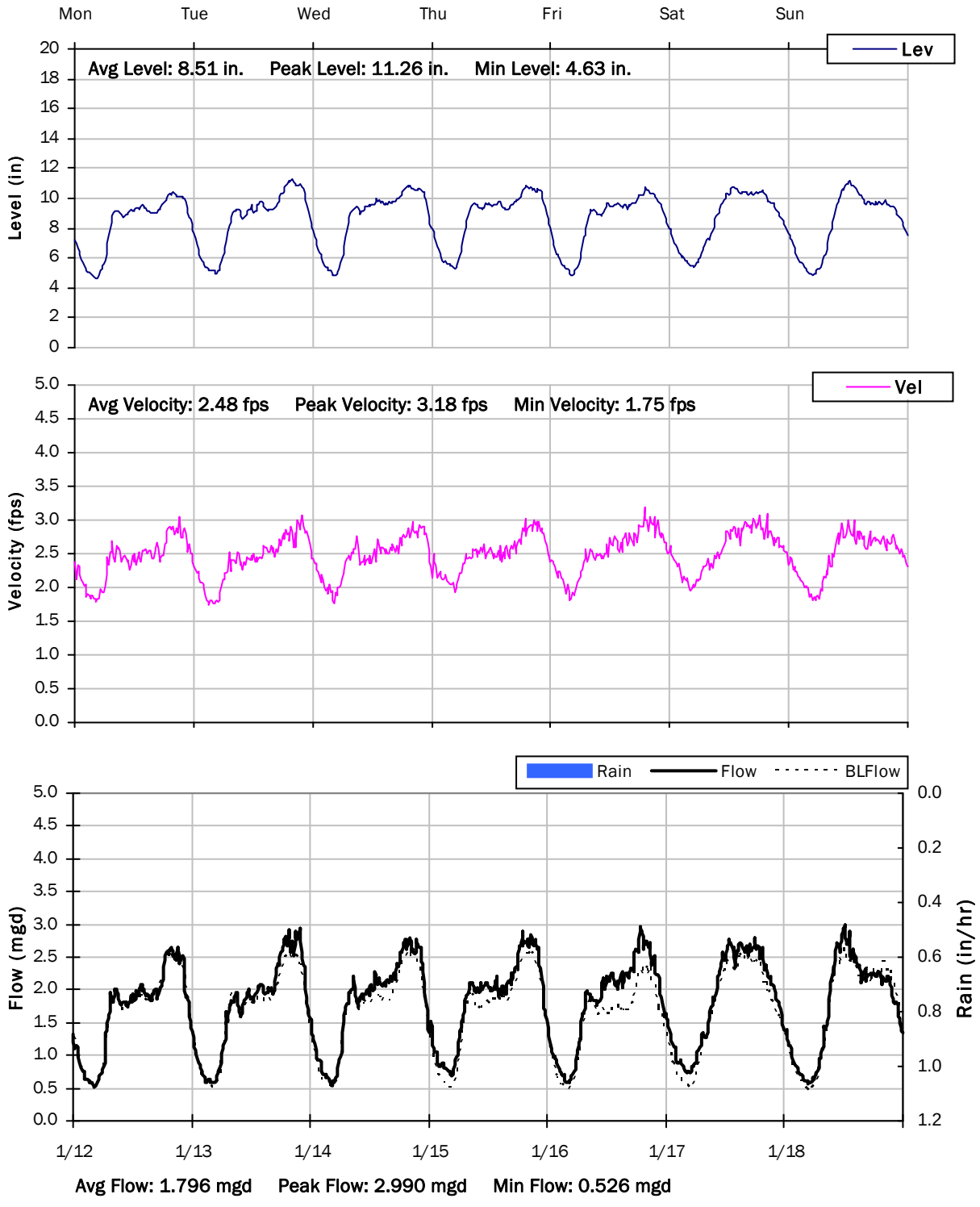
1/5/2015 to 1/12/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

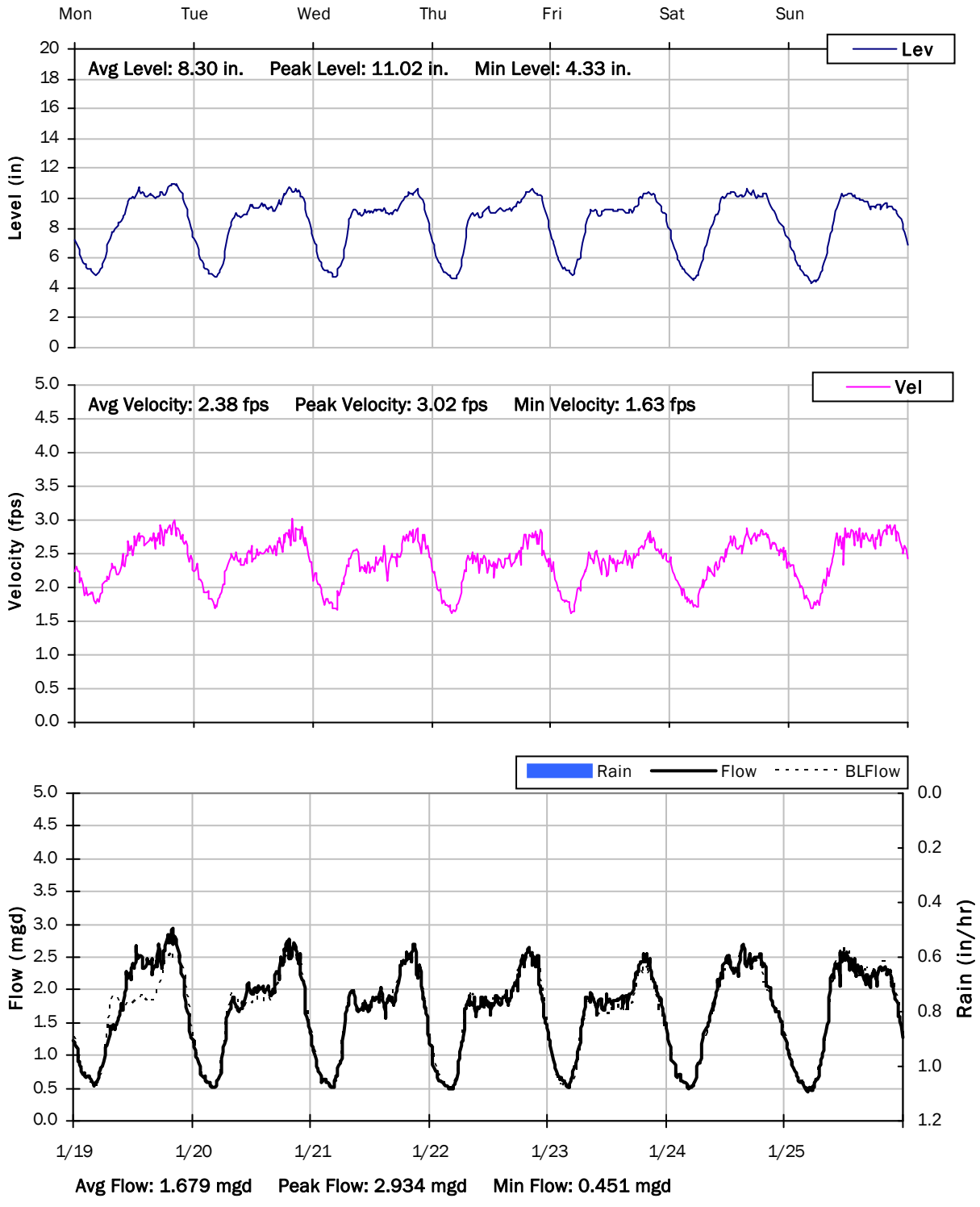
1/12/2015 to 1/19/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

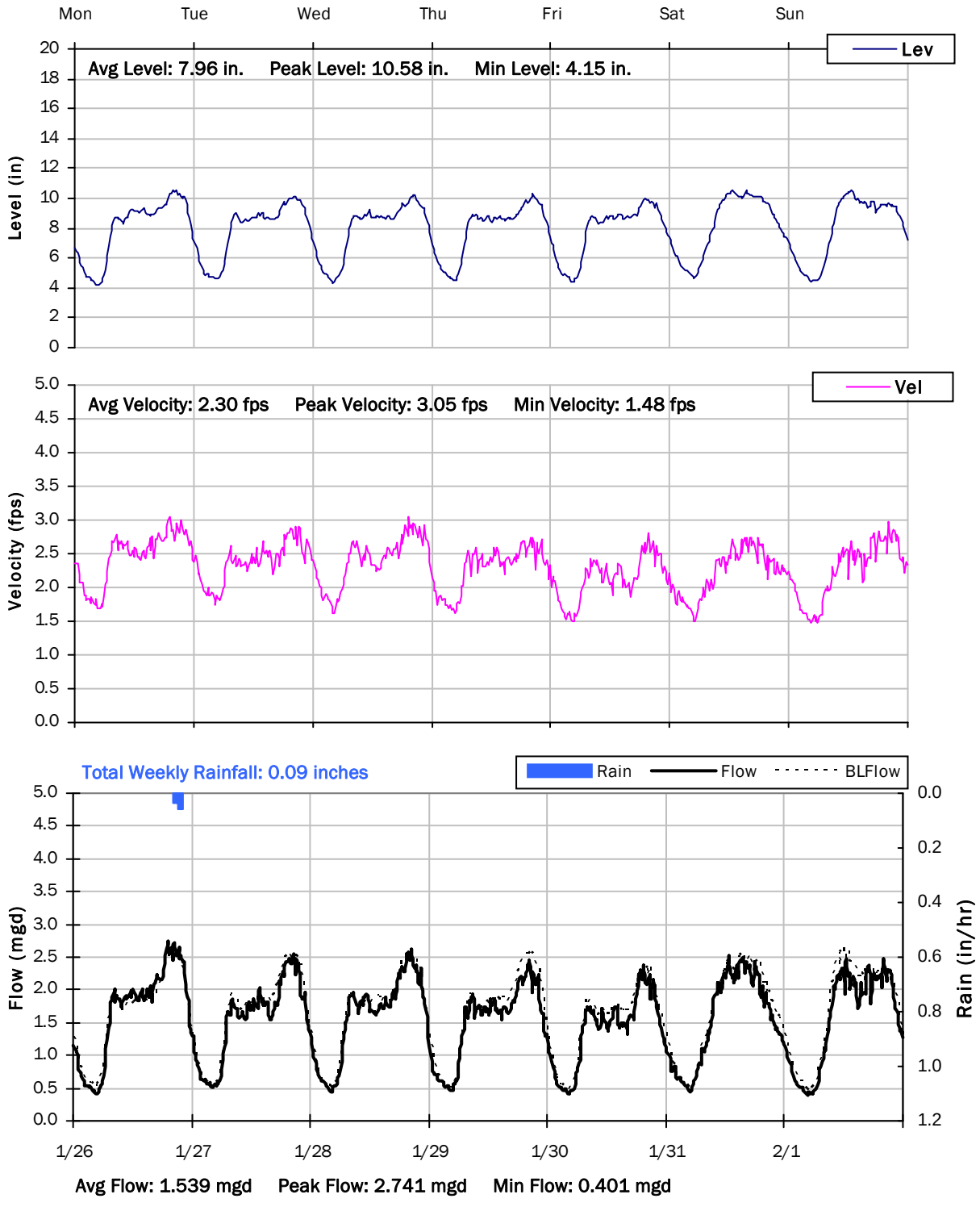
1/19/2015 to 1/26/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

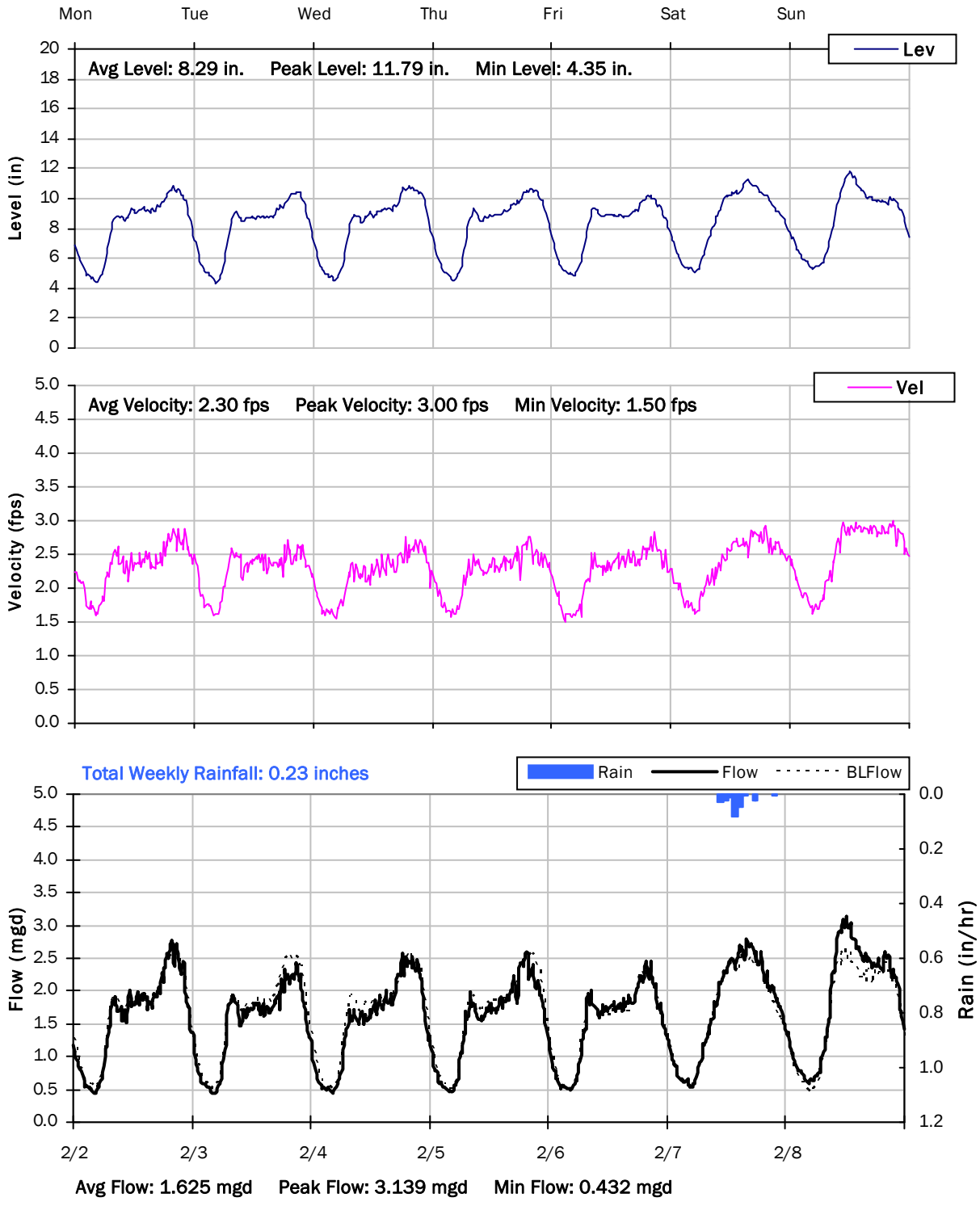
1/26/2015 to 2/2/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

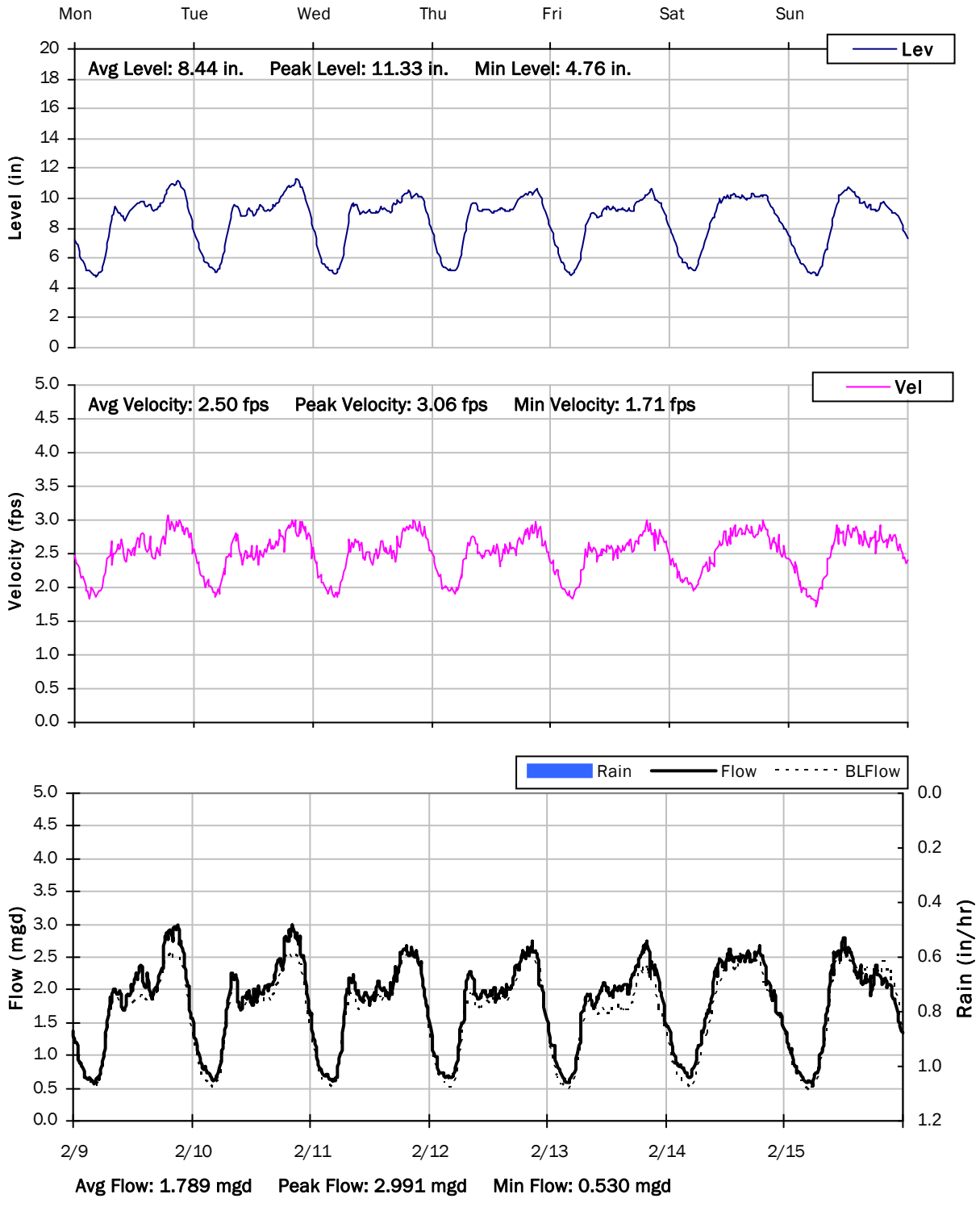
2/2/2015 to 2/9/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

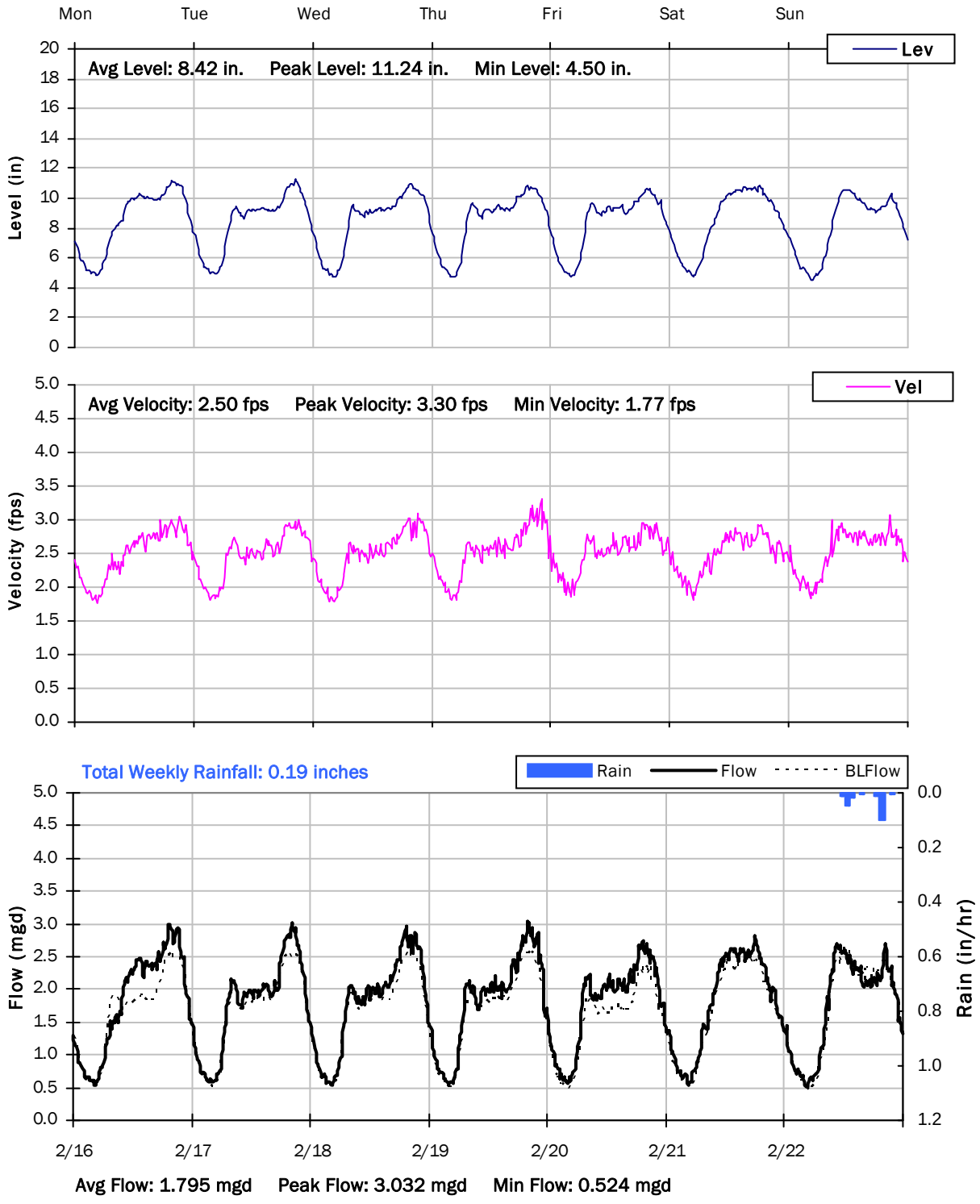
2/9/2015 to 2/16/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

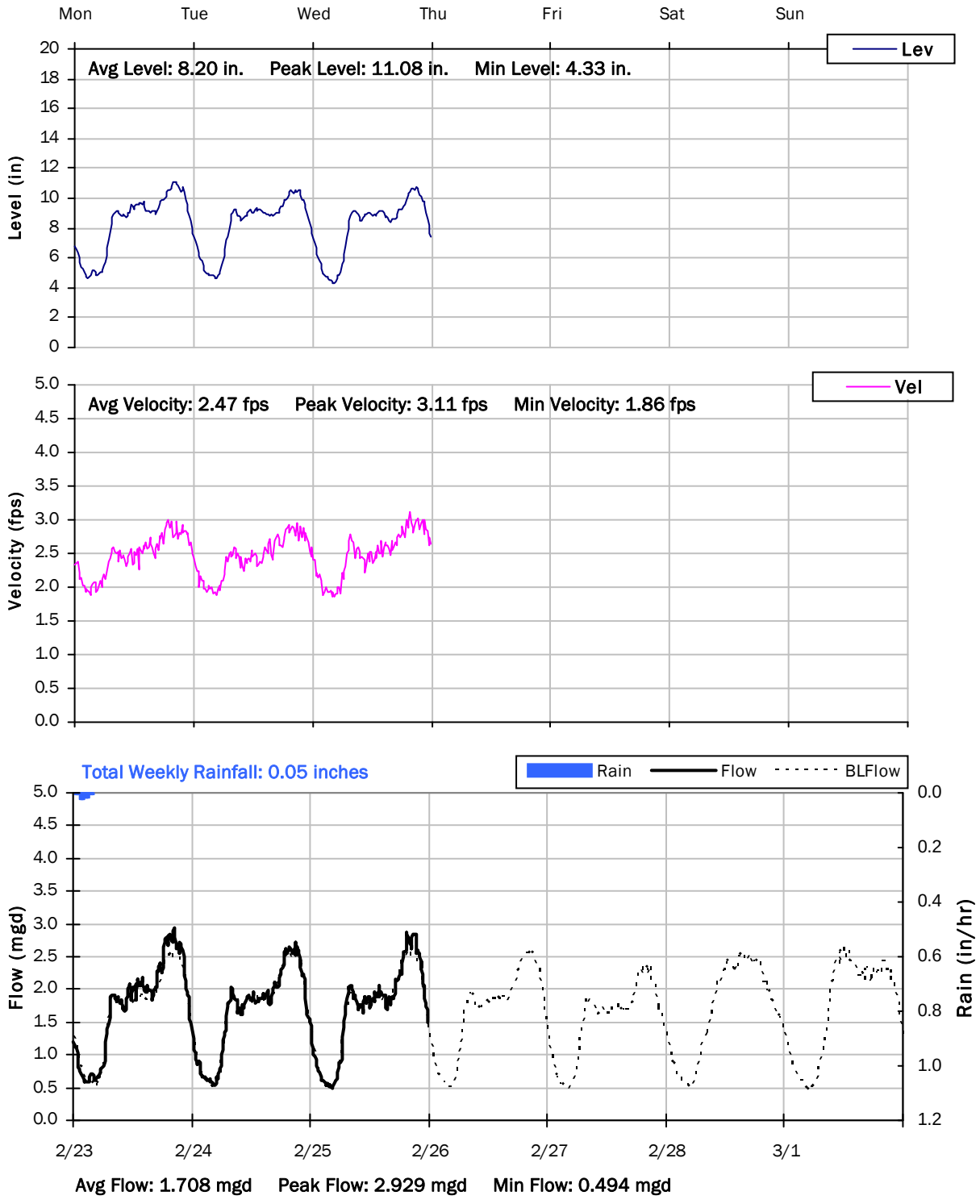
2/16/2015 to 2/23/2015



SITE 8

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015



City of Oxnard

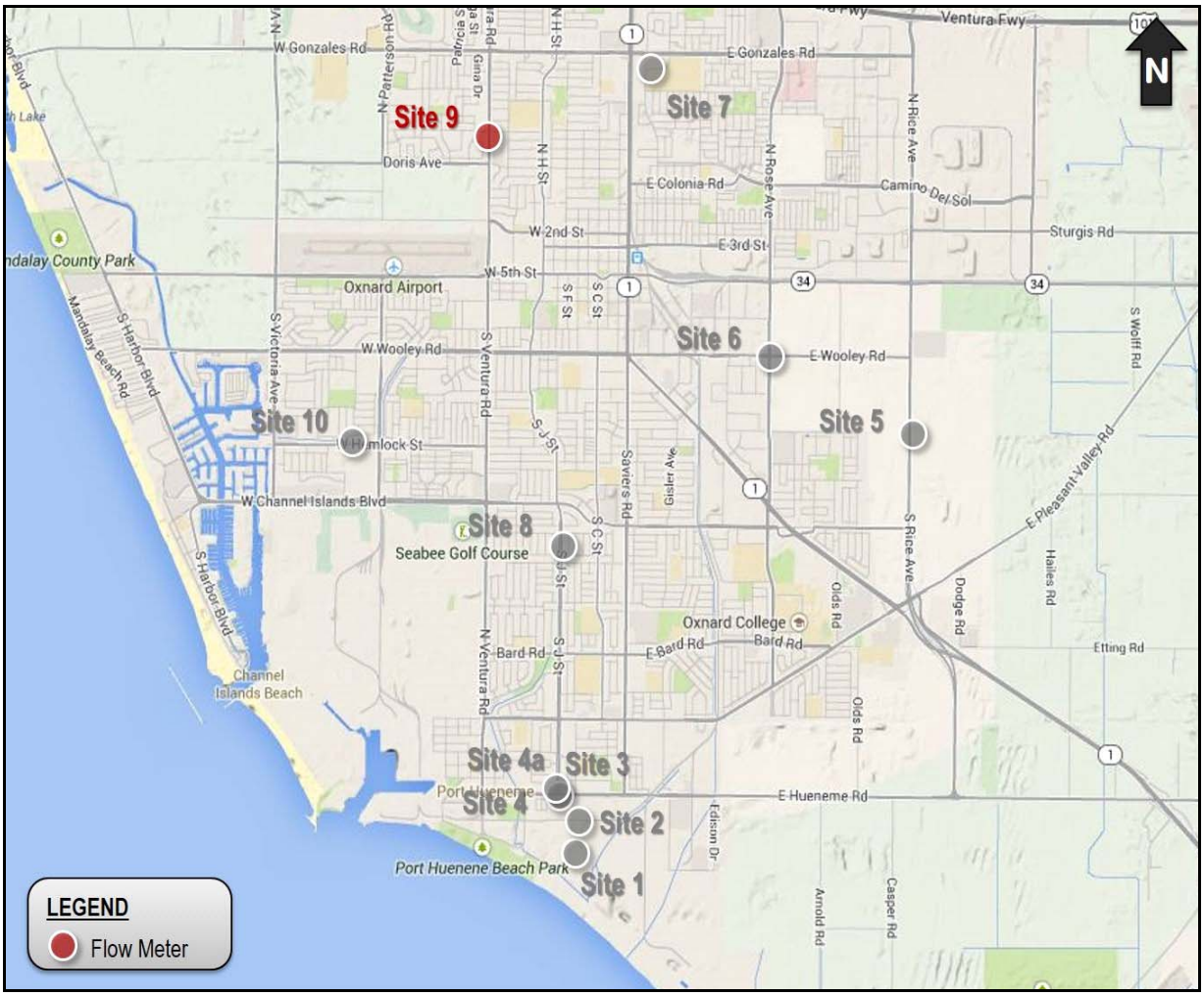
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 9

Location: N Ventura Road, between Devonshire Drive and Doris Avenue

Data Summary Report



Vicinity Map: Site 9

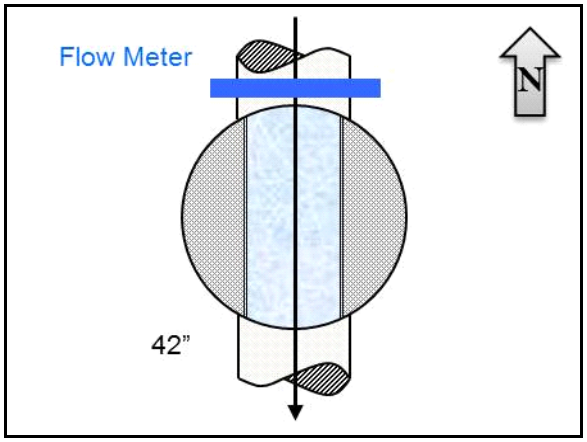
SITE 9

Site Information

Location:	N Ventura Road, between Devonshire Drive and Doris Avenue
Coordinates:	119.1946° W, 34.2103° N
Rim Elevation:	54 feet
Pipe Diameter:	42 inches
Baseline Flow:	2.306 mgd
Peak Measured Flow:	4.053 mgd

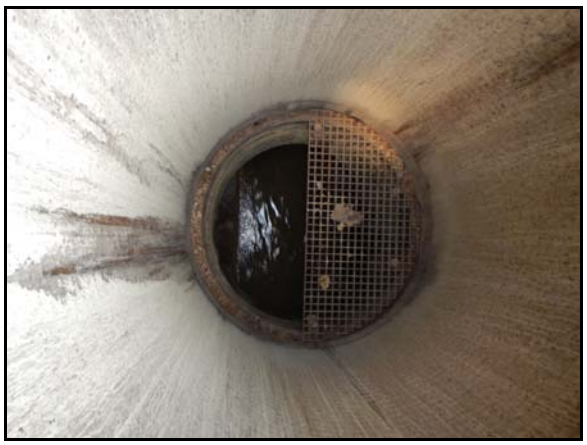
Satellite Map

Sanitary Map



Flow Diagram

Street View



Plan View

SITE 9

Additional Site Photos

Effluent Pipe

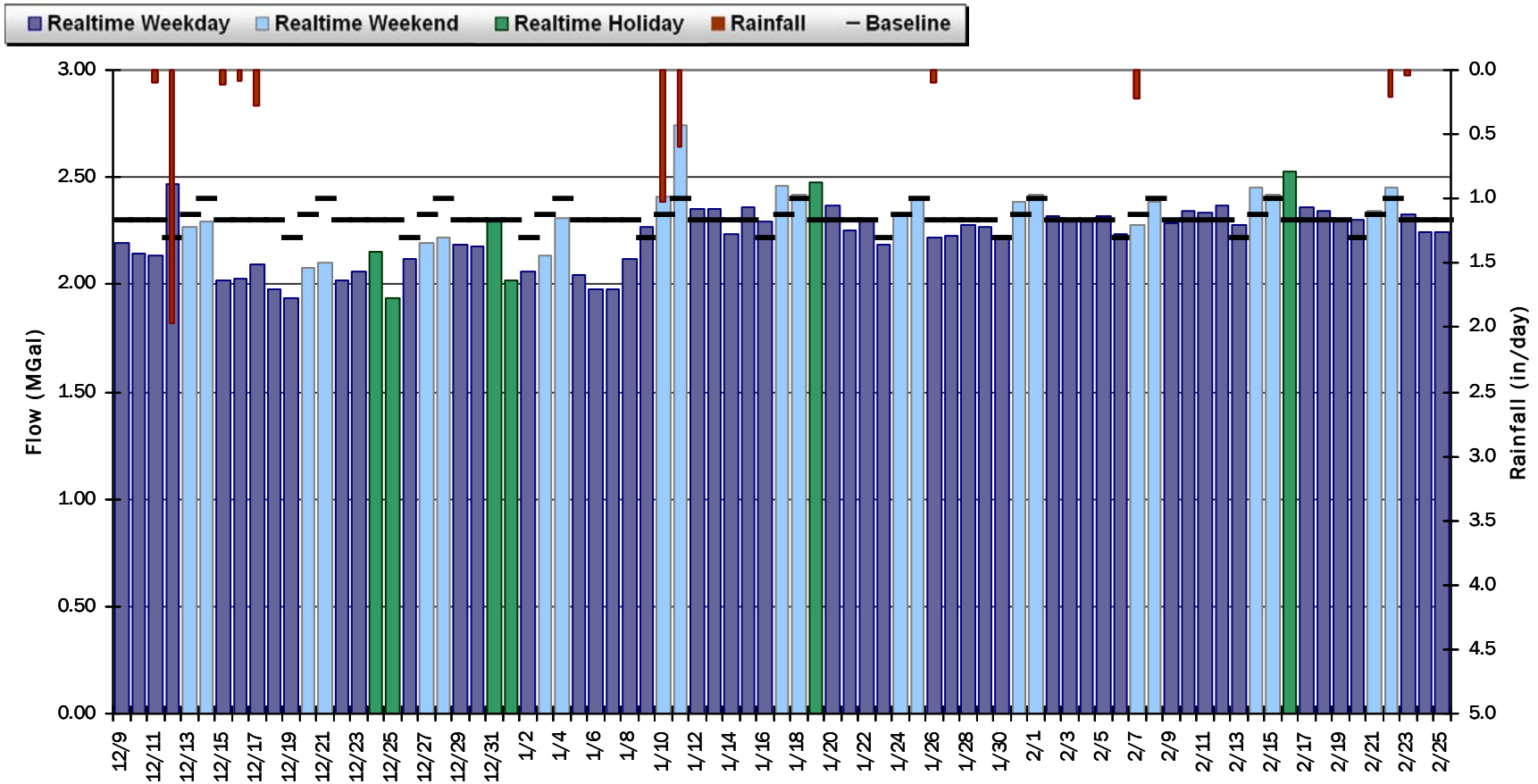
Influent Pipe

SITE 9

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 2.254 MGal **Peak Daily Flow: 2.741 MGal** **Min Daily Flow: 1.934 MGal**

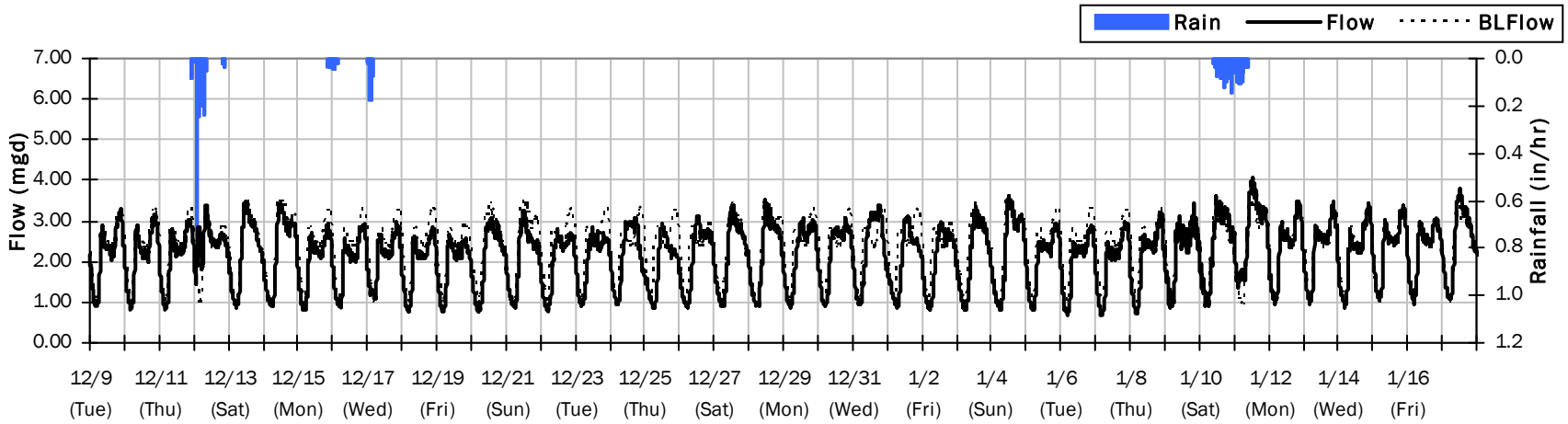
Total Period Rainfall: 4.74 inches

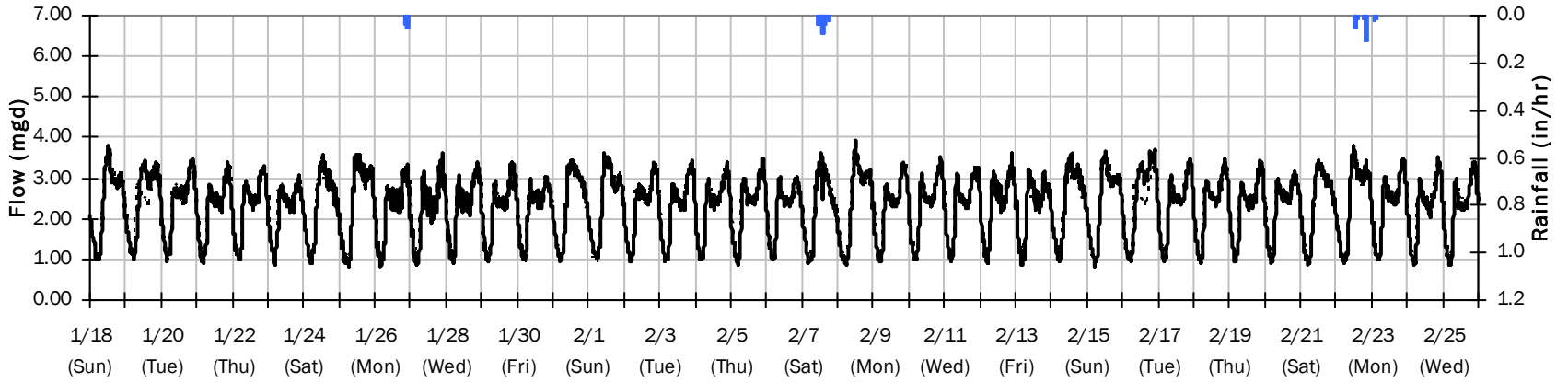


SITE 9

Flow Summary: 12/9/2014 to 2/25/2015

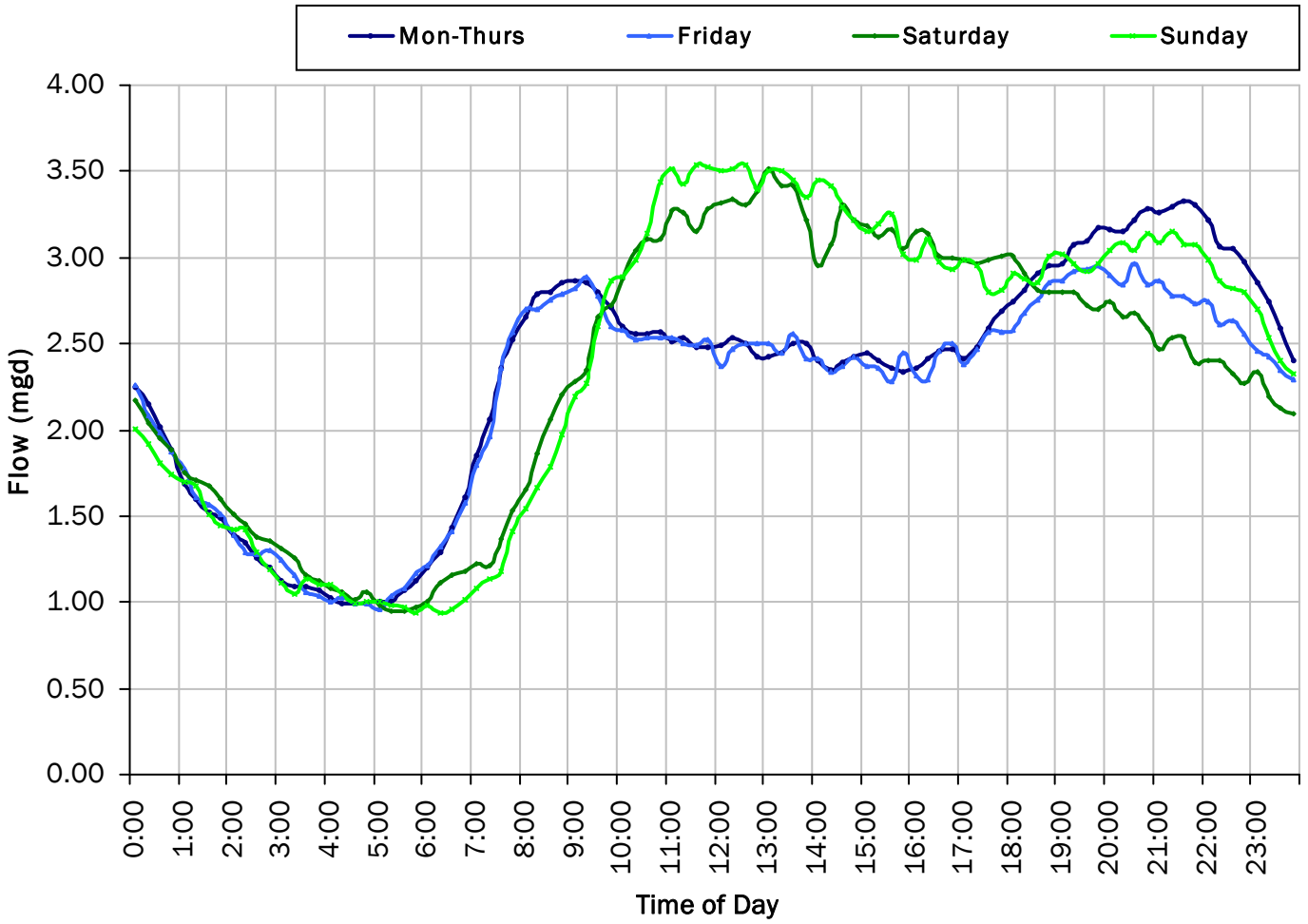
Total Period Rainfall: 4.74 inches Avg Flow: 2.254 mgd Peak Flow: 4.053 mgd Min Flow: 0.677 mgd





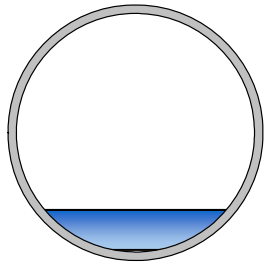
SITE 9

Baseline Flow Hydrographs



Baseline Flow:

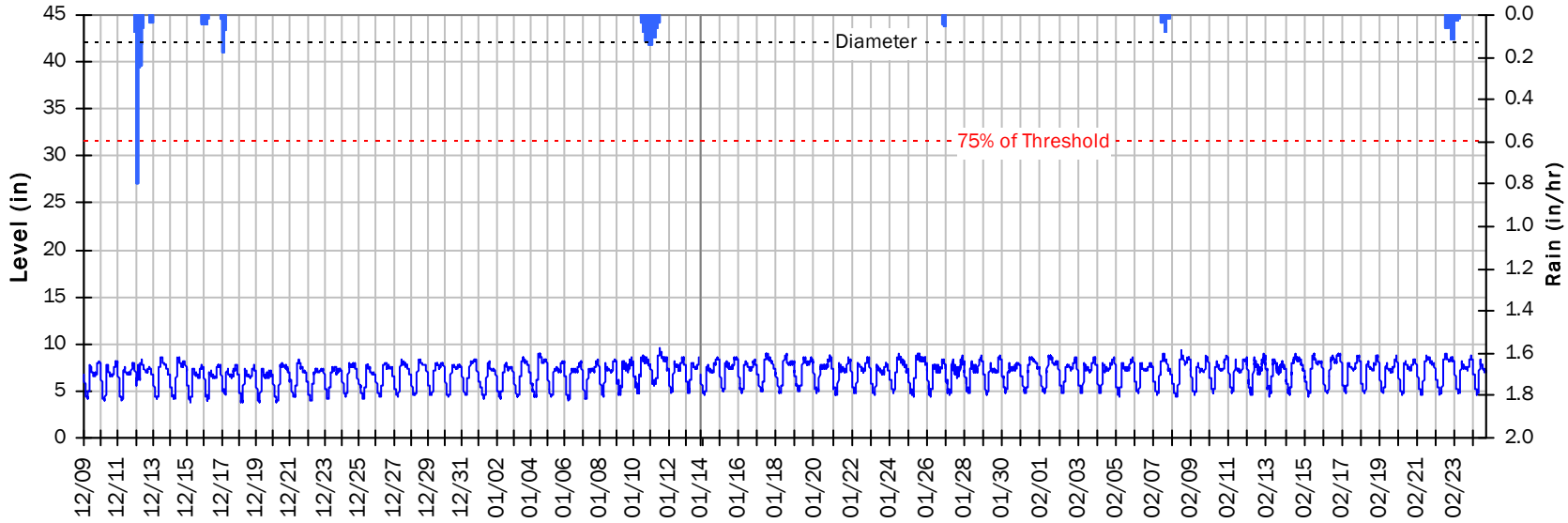
2.31 *mgd*

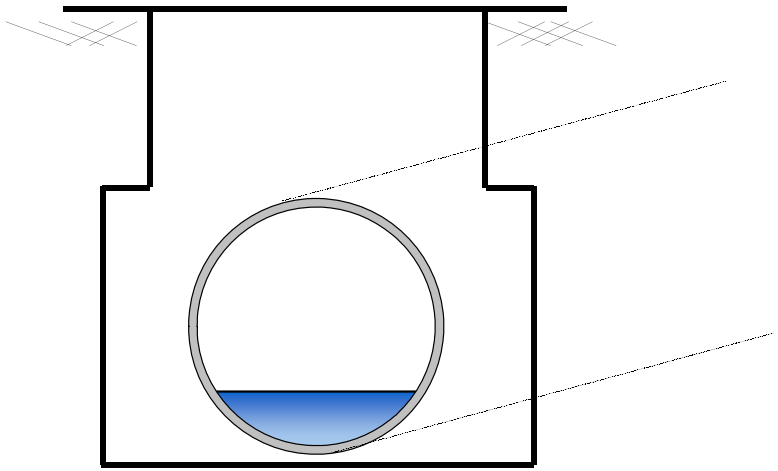


SITE 9

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

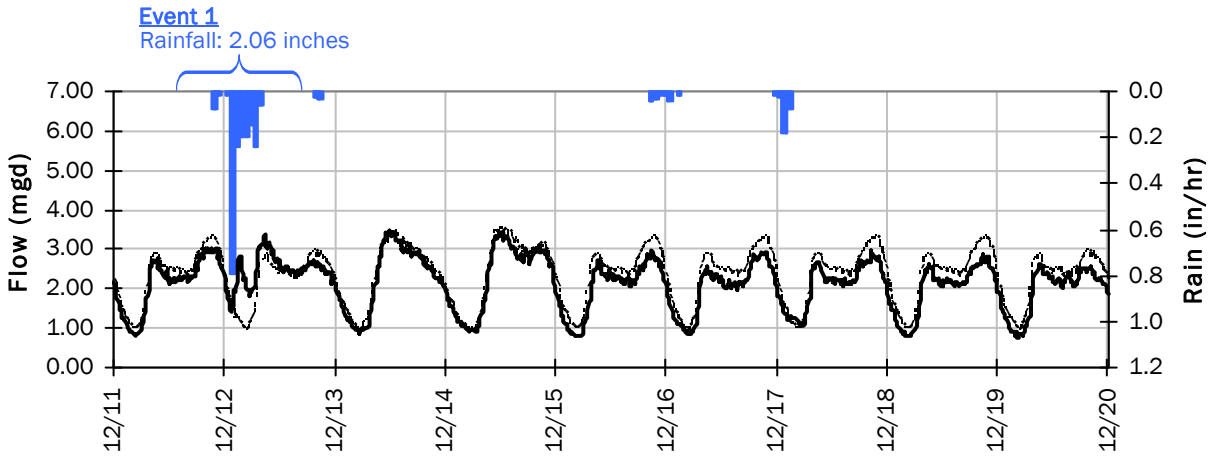




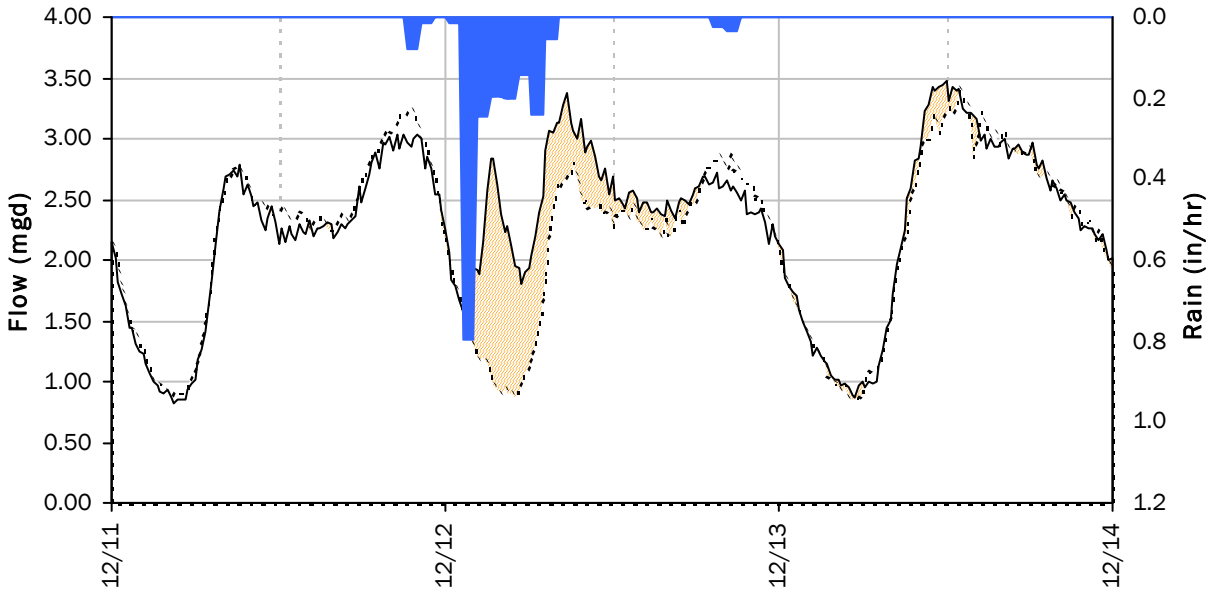
Pipe Diameter:	42	*inches*
Peak Measured Level:	9.48	*inches*
Peak d/D Ratio:	0.23	

SITE 9
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

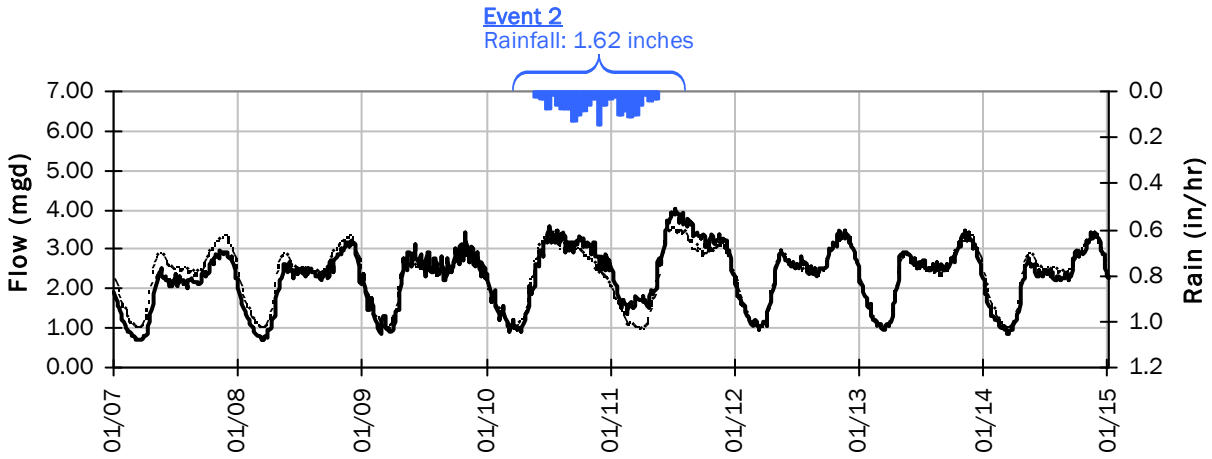


Storm Event I/I Analysis (Rain = 2.06 inches)

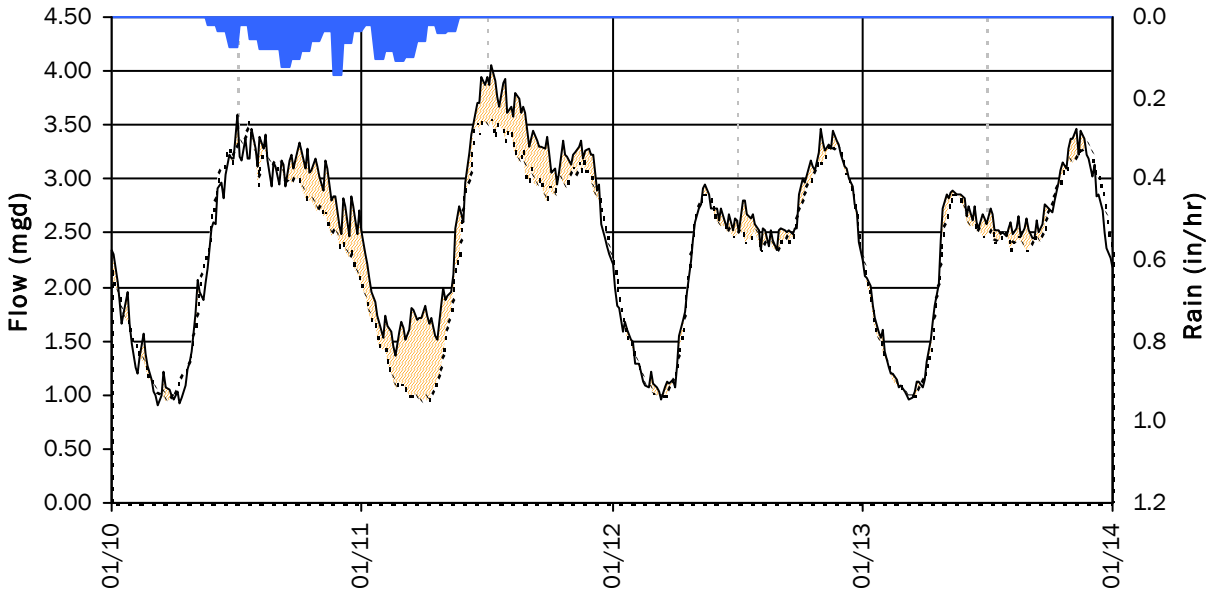
Capacity		Inflow / Infiltration	
Peak Flow:	3.47 *mgd*	**Peak I/I Rate:**	1.88 *mgd*
PF:	1.50	**Total I/I:**	386,000 *gallons*
Peak Level:	8.59 *in*		
d/D Ratio:	0.20		

SITE 9
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



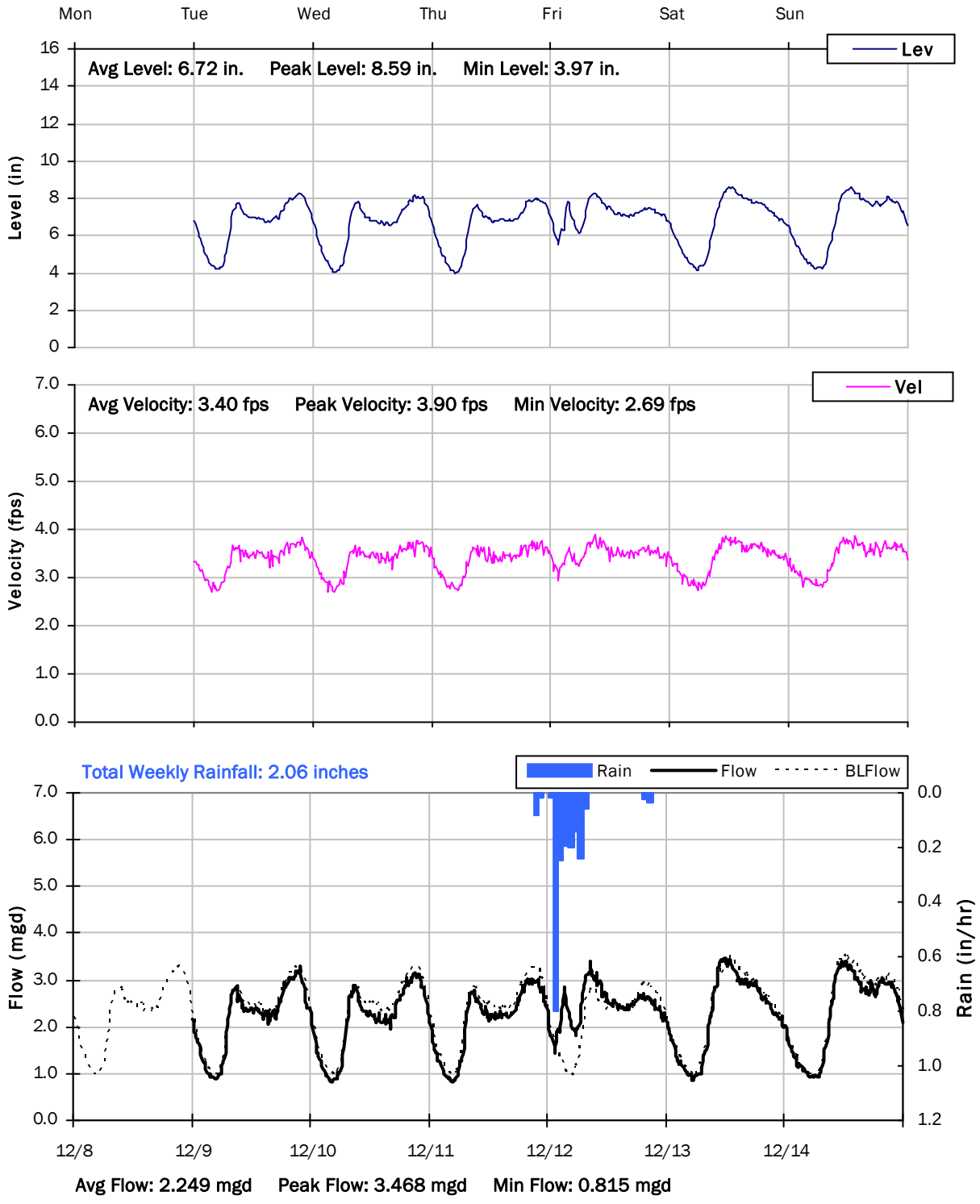
Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.62 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	4.05 *mgd*	**Peak I/I Rate:**	0.84 *mgd*
PF:	1.76	**Total I/I:**	475,000 *gallons*
Peak Level:	9.48 *in*		
d/D Ratio:	0.23		

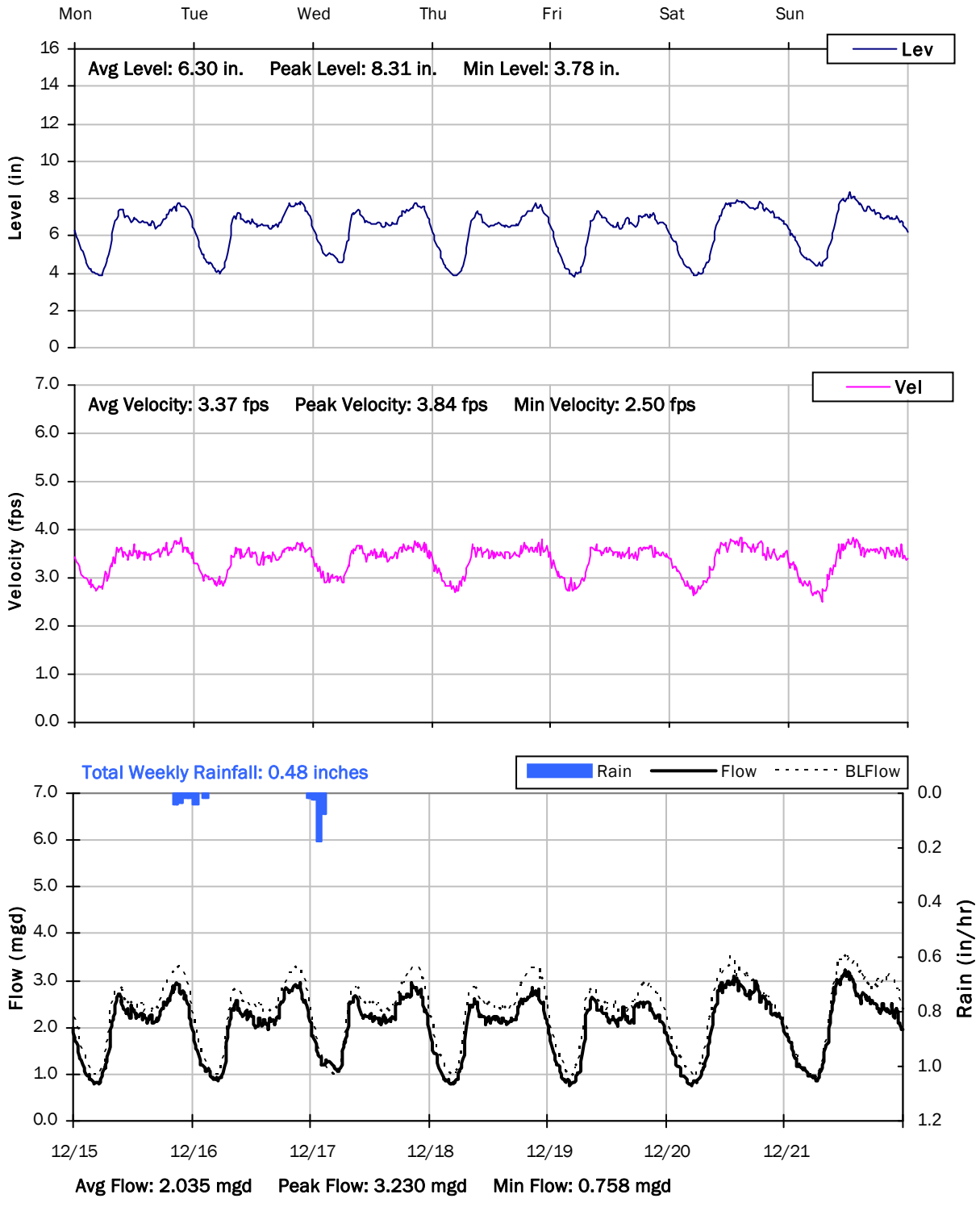
SITE 9
Weekly Level, Velocity and Flow Hydrographs
12/8/2014 to 12/15/2014



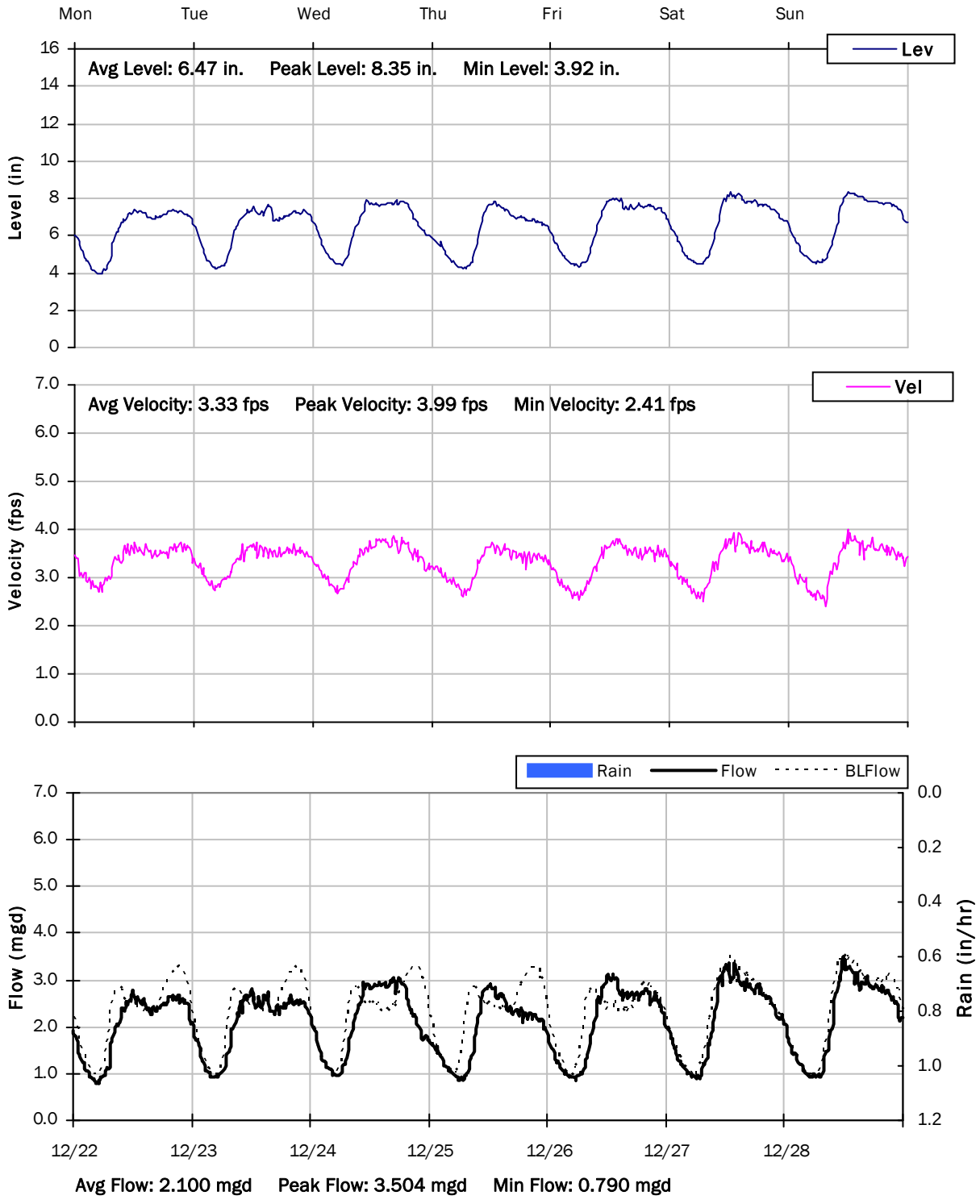
SITE 9

Weekly Level, Velocity and Flow Hydrographs

12/15/2014 to 12/22/2014



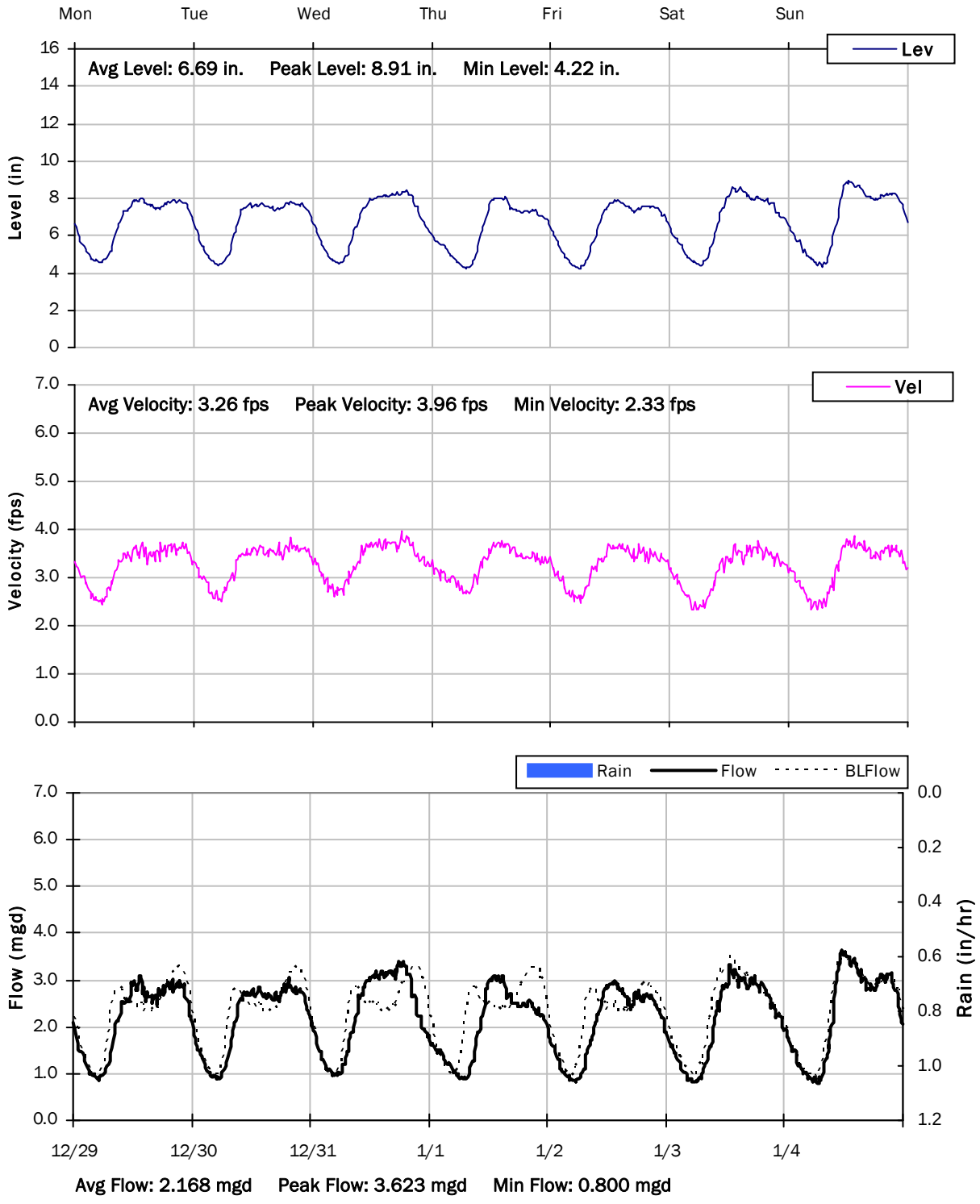
SITE 9
Weekly Level, Velocity and Flow Hydrographs
12/22/2014 to 12/29/2014



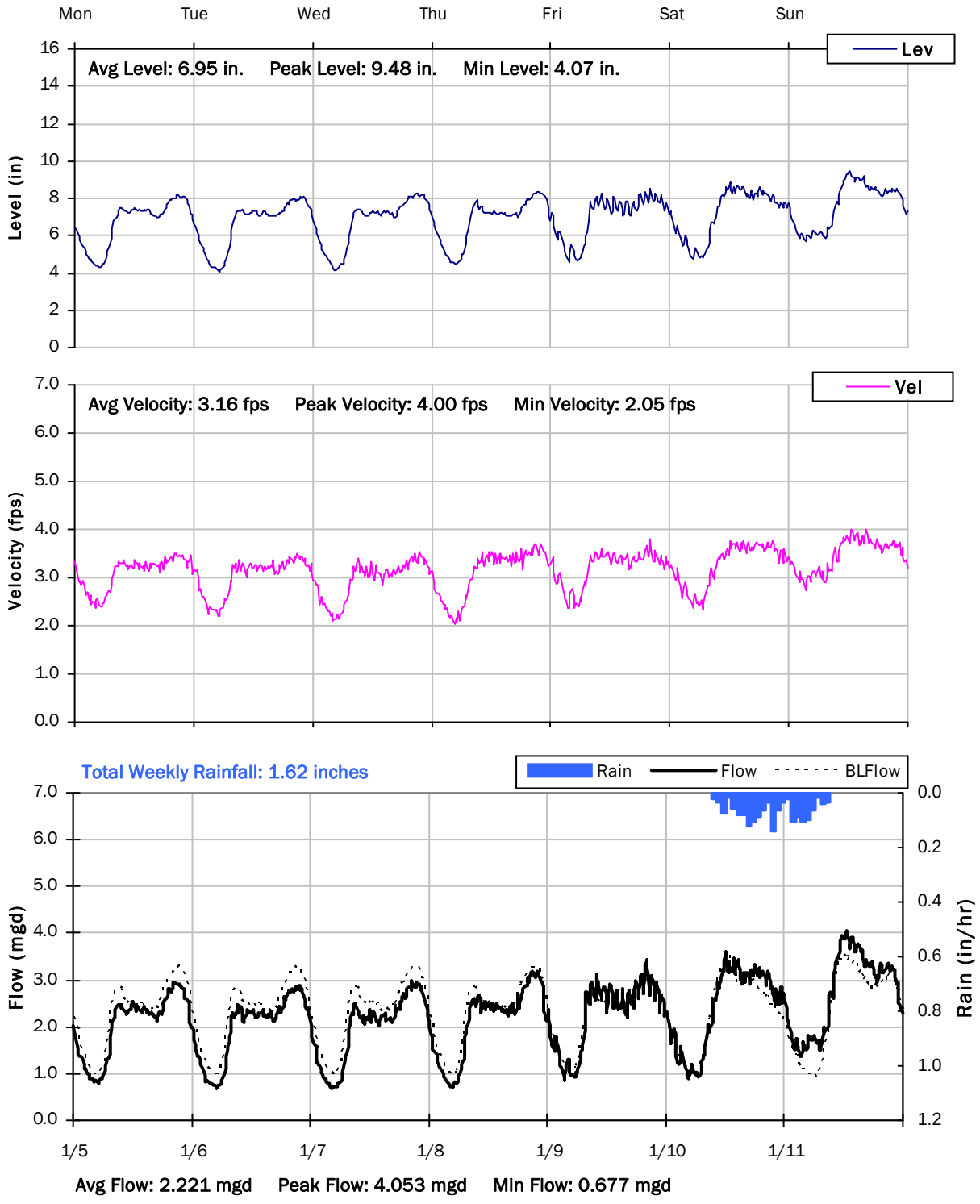
SITE 9

Weekly Level, Velocity and Flow Hydrographs

12/29/2014 to 1/5/2015



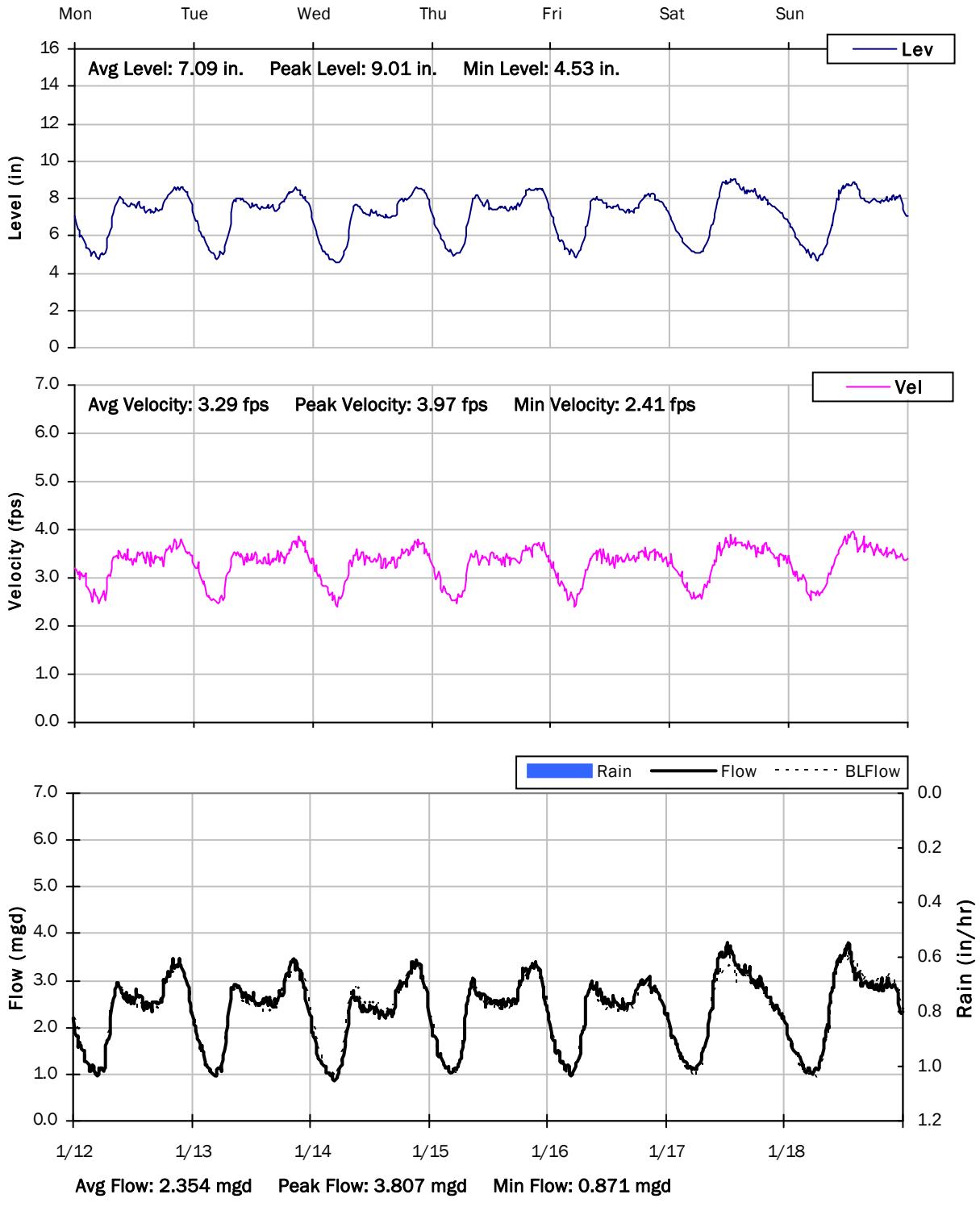
SITE 9
Weekly Level, Velocity and Flow Hydrographs
1/5/2015 to 1/12/2015



SITE 9

Weekly Level, Velocity and Flow Hydrographs

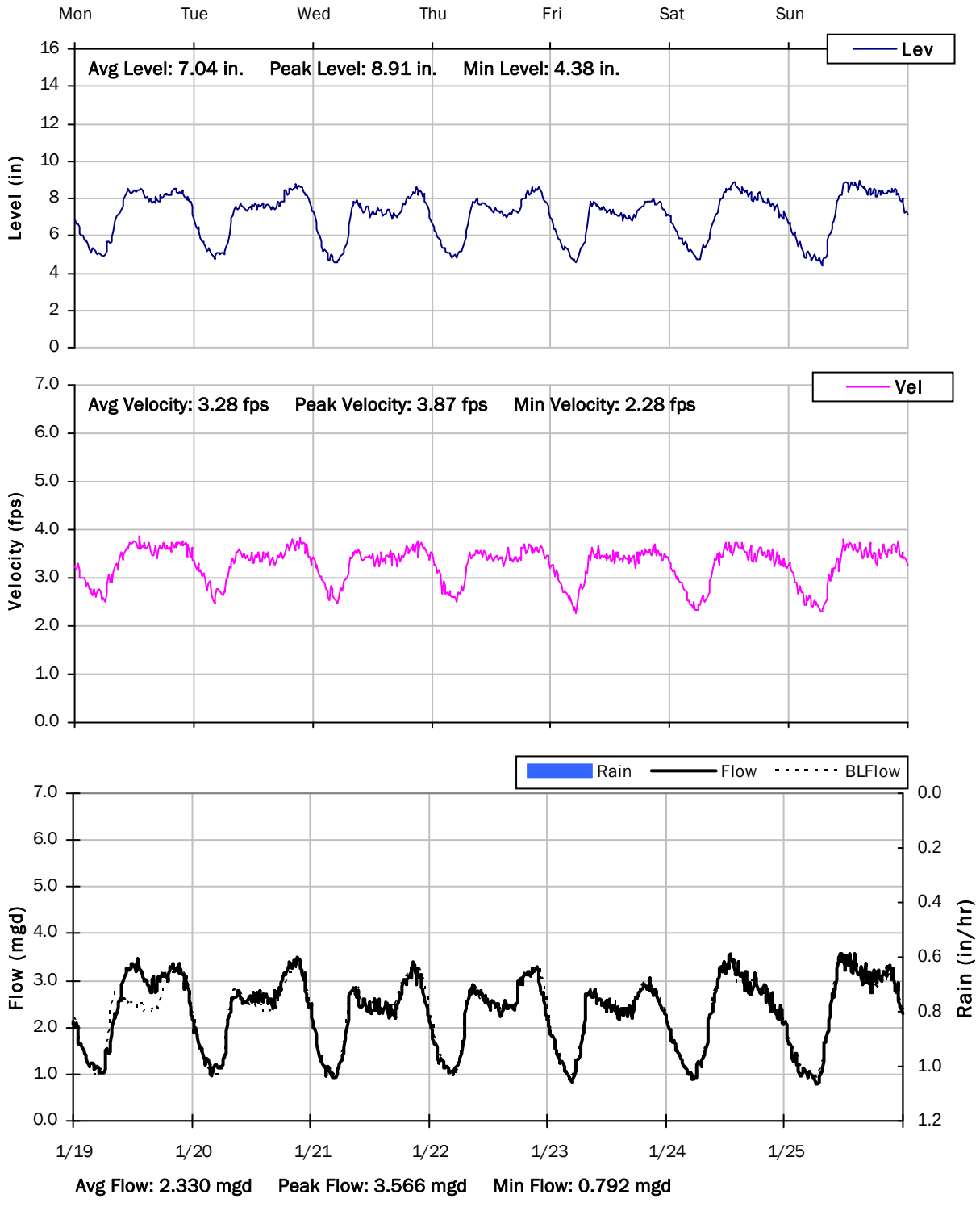
1/12/2015 to 1/19/2015



SITE 9

Weekly Level, Velocity and Flow Hydrographs

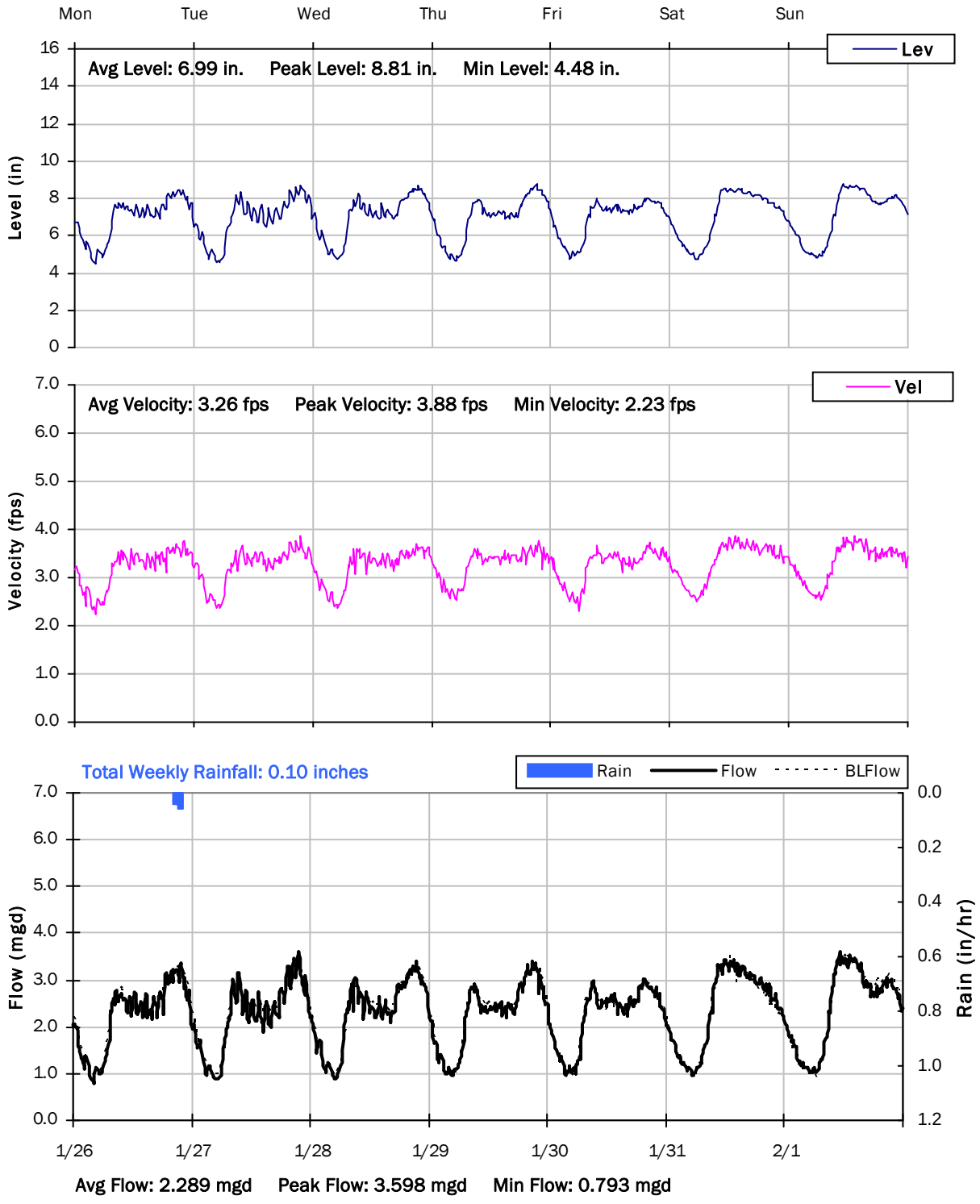
1/19/2015 to 1/26/2015



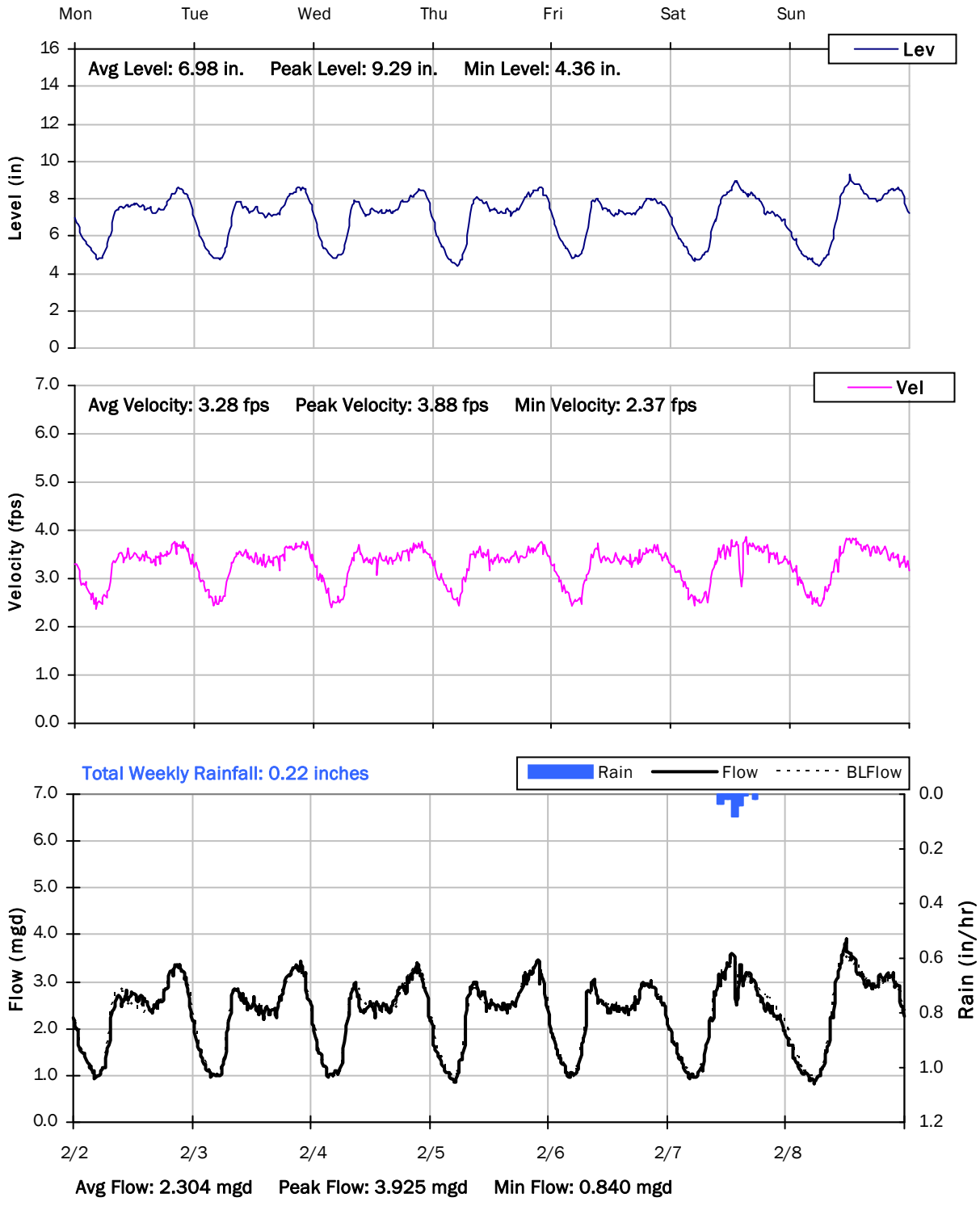
SITE 9

Weekly Level, Velocity and Flow Hydrographs

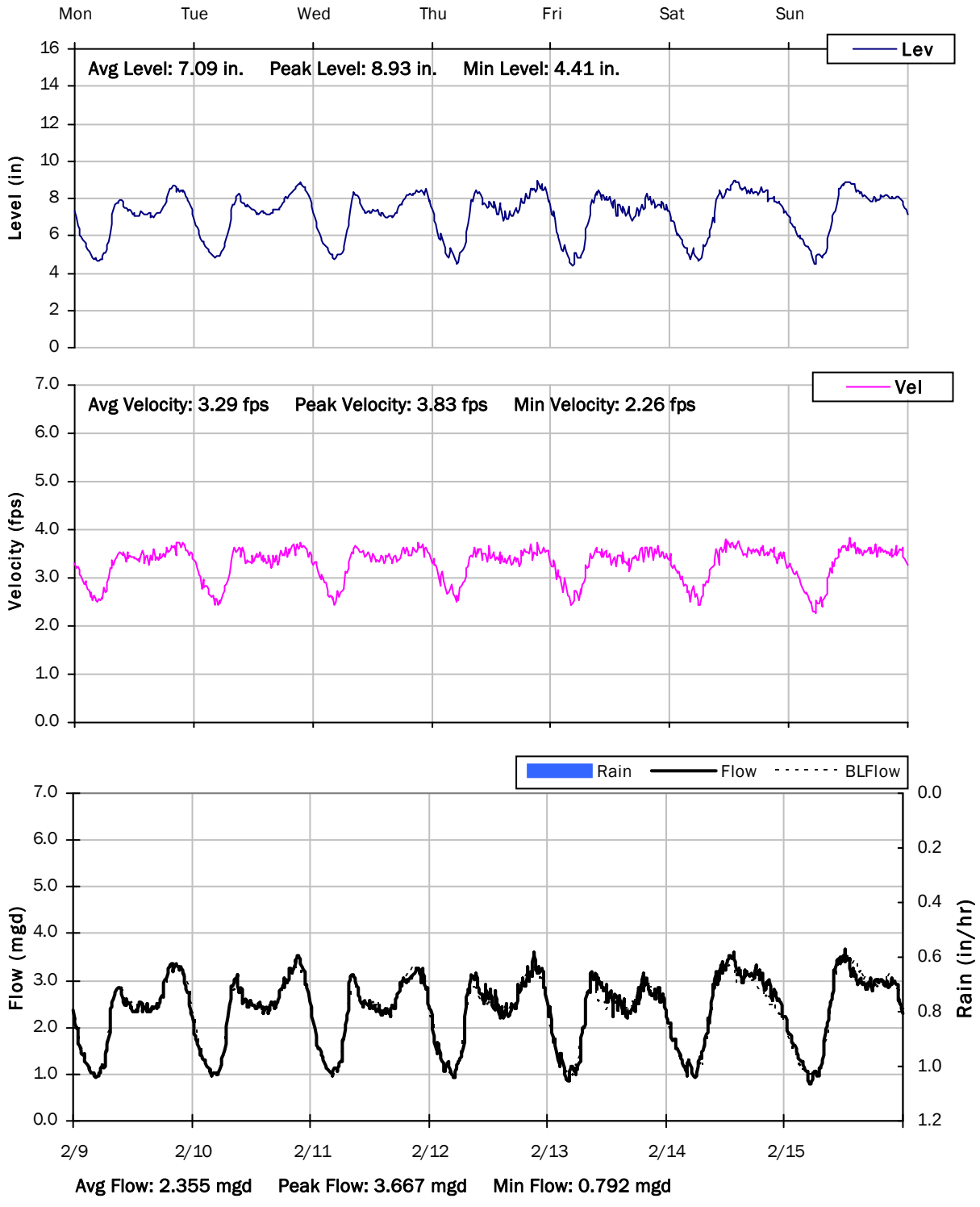
1/26/2015 to 2/2/2015



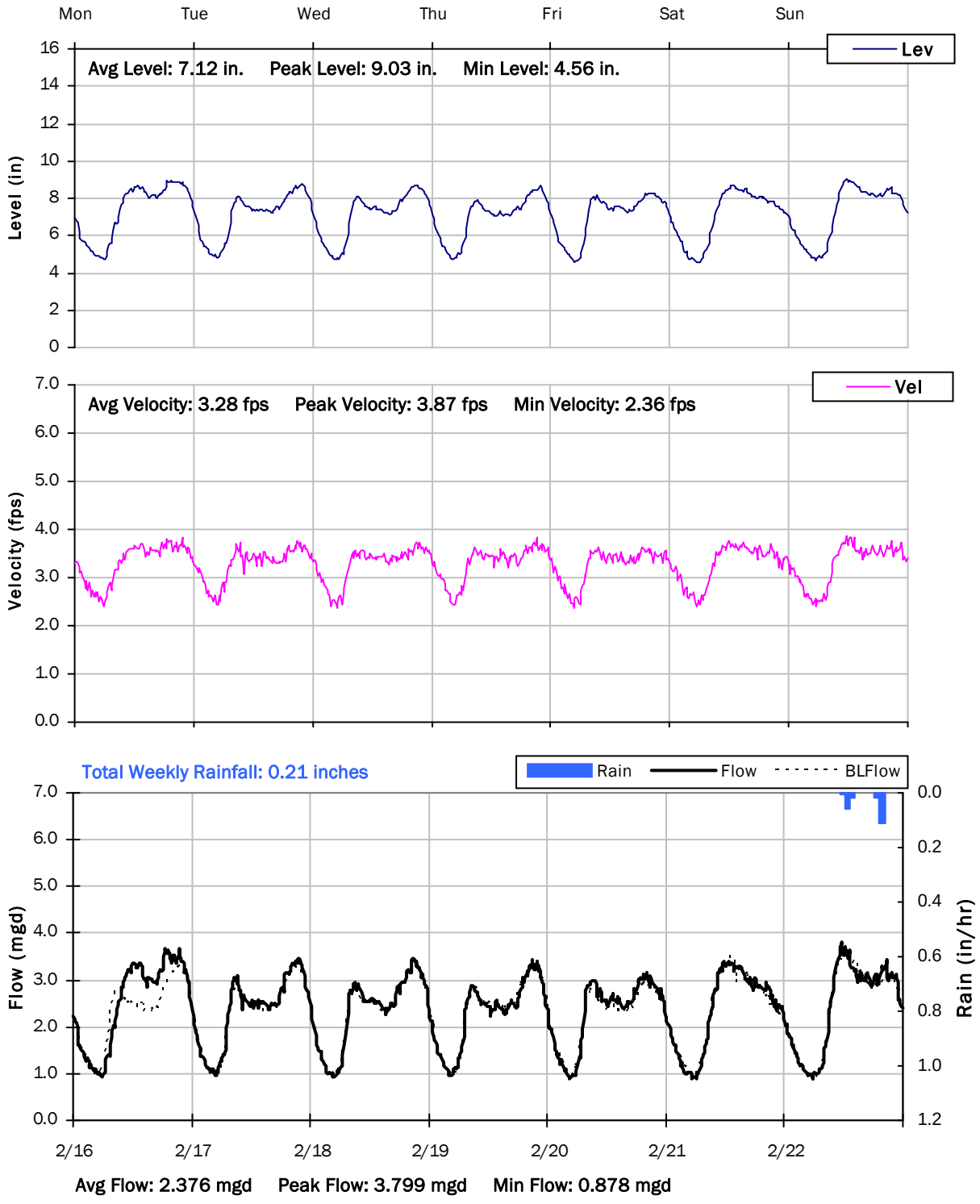
SITE 9
Weekly Level, Velocity and Flow Hydrographs
2/2/2015 to 2/9/2015



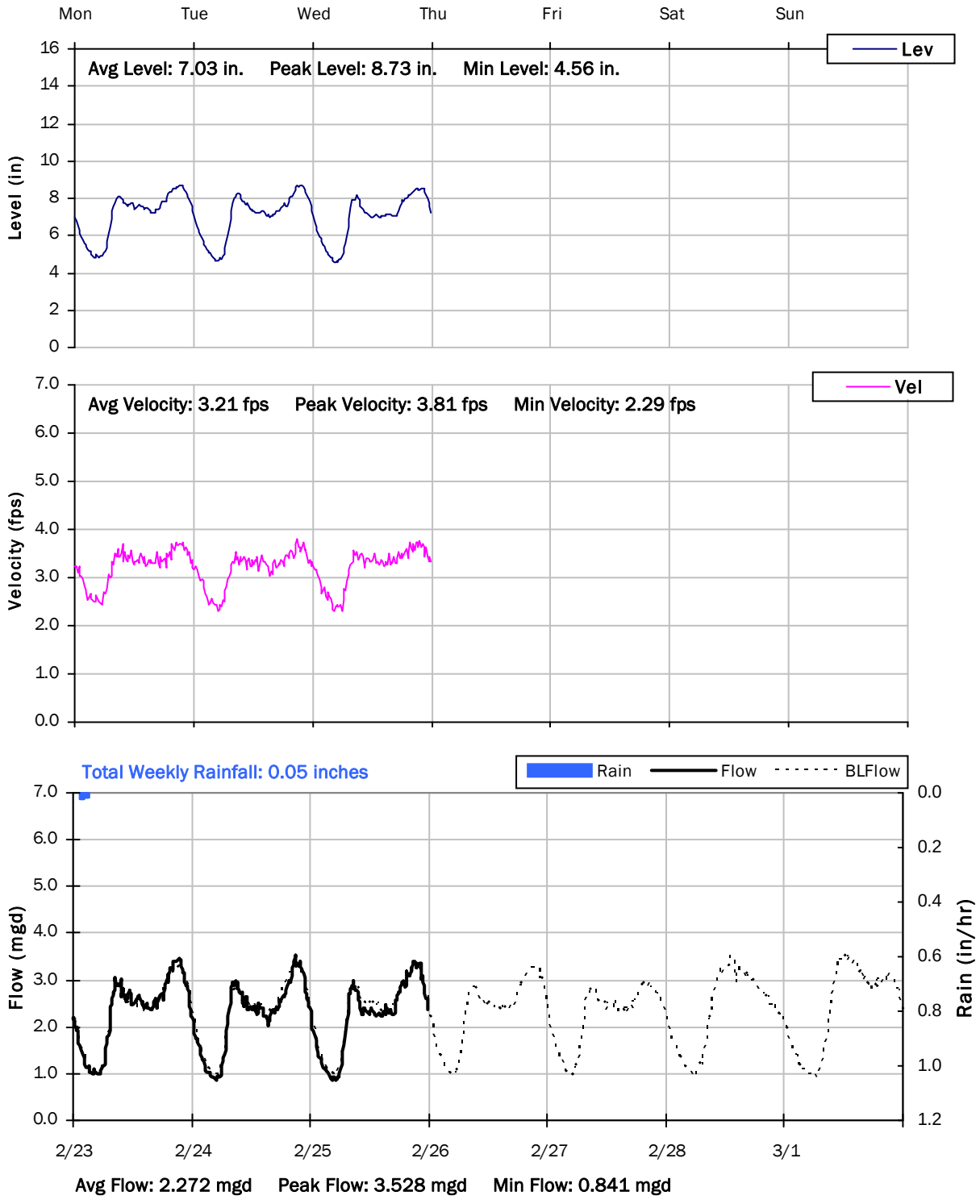
SITE 9
Weekly Level, Velocity and Flow Hydrographs
2/9/2015 to 2/16/2015



SITE 9
Weekly Level, Velocity and Flow Hydrographs
2/16/2015 to 2/23/2015



SITE 9
Weekly Level, Velocity and Flow Hydrographs
2/23/2015 to 3/2/2015



City of Oxnard

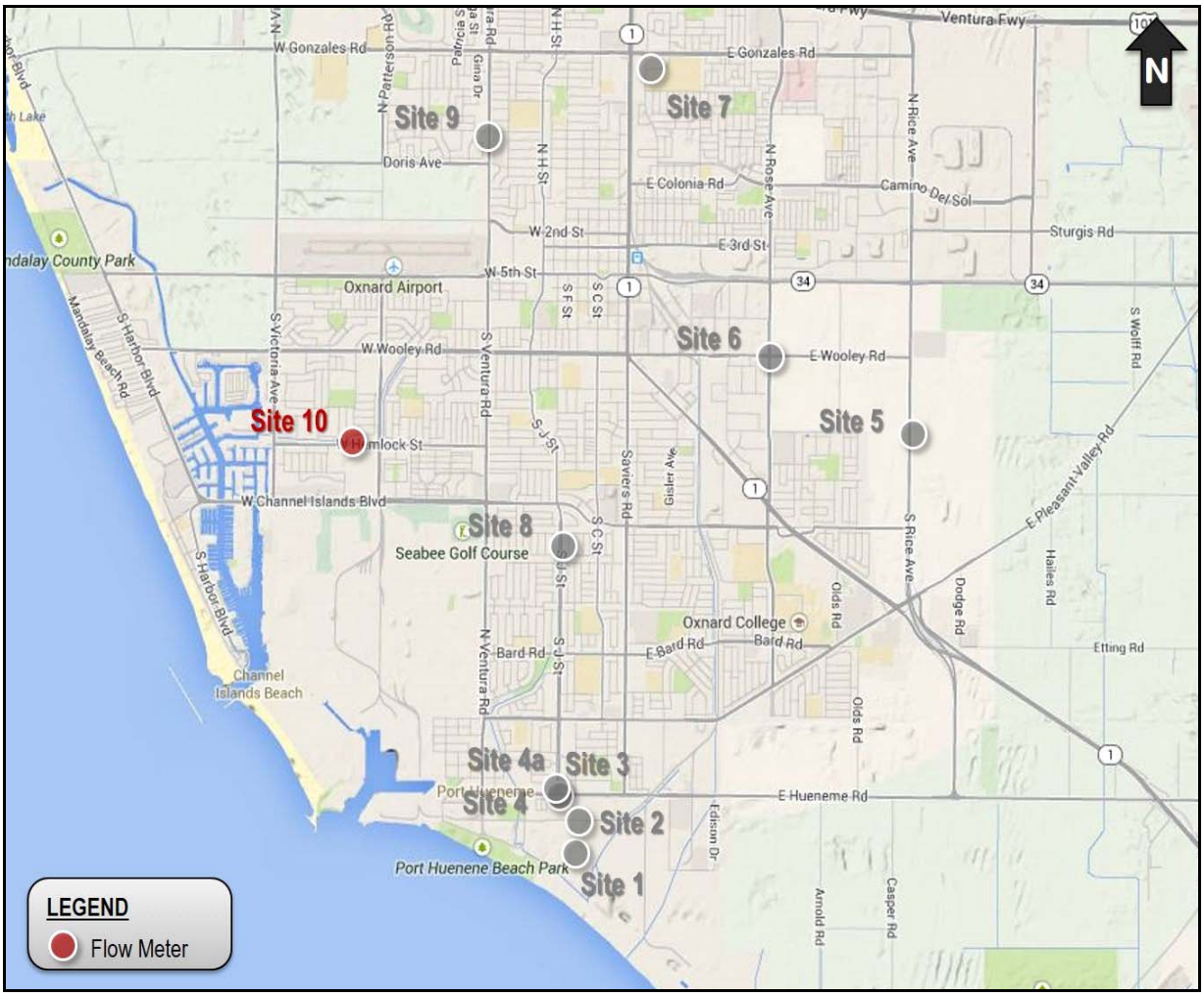
Sanitary Sewer Flow Monitoring

Temporary Monitoring: December, 2014 through February, 2015

Monitoring Site: Site 10

Location: West of W Hemlock Street and Jetty Street

Data Summary Report



Vicinity Map: Site 10

SITE 10

Site Information

Location: West of W Hemlock Street and Jetty Street

Coordinates: 119.2116° W, 34.1812° N

Rim Elevation: 16 feet

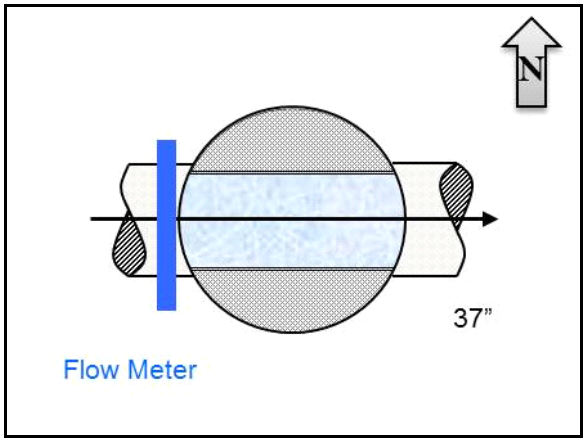
Pipe Diameter: 37 inches

Baseline Flow: 2.128 mgd

Peak Measured Flow: 4.024 mgd

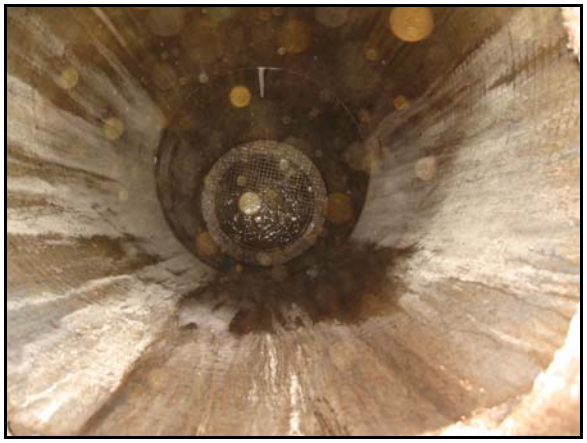
Satellite Map

Sanitary Map



Flow Diagram

Street View



Plan View

SITE 10

Additional Site Photos

Effluent Pipe

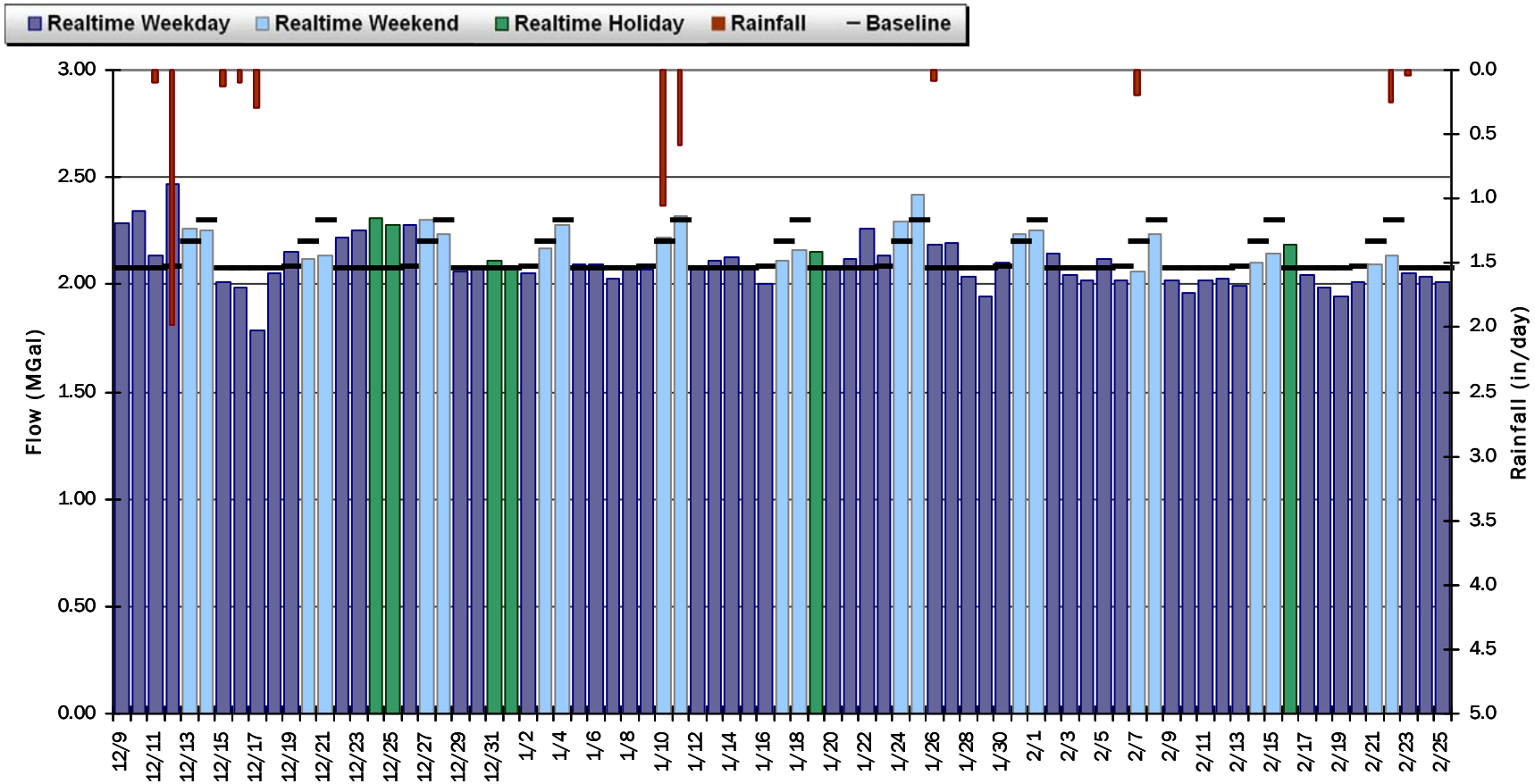
Influent Pipe

SITE 10

Period Flow Summary: Daily Flow Totals

Avg Period Flow: 2.128 MGal **Peak Daily Flow: 2.467 MGal** **Min Daily Flow: 1.786 MGal**

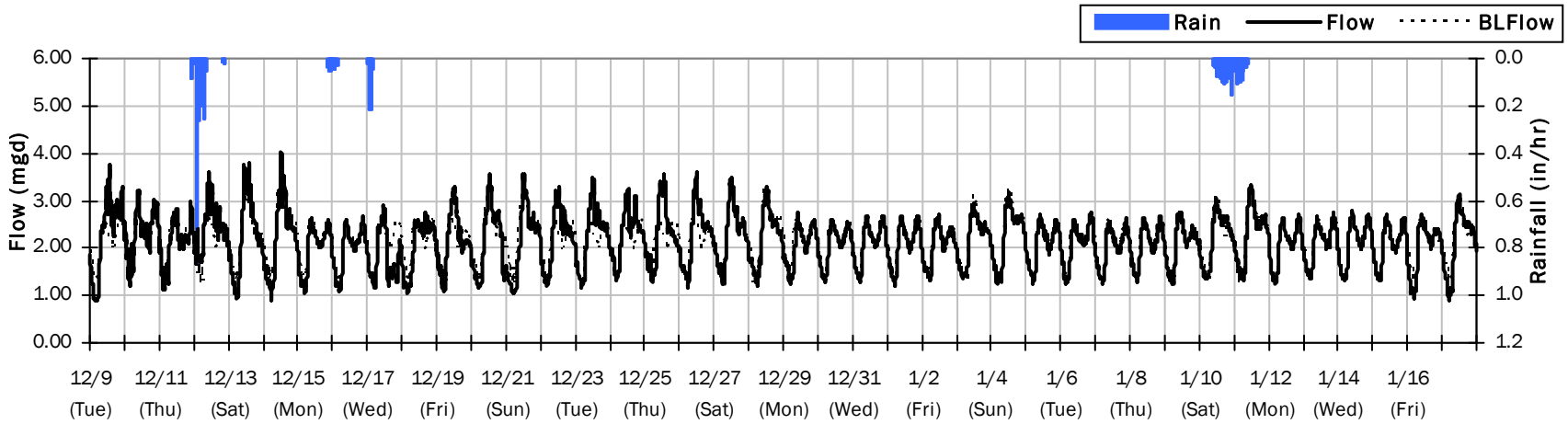
Total Period Rainfall: 4.81 inches

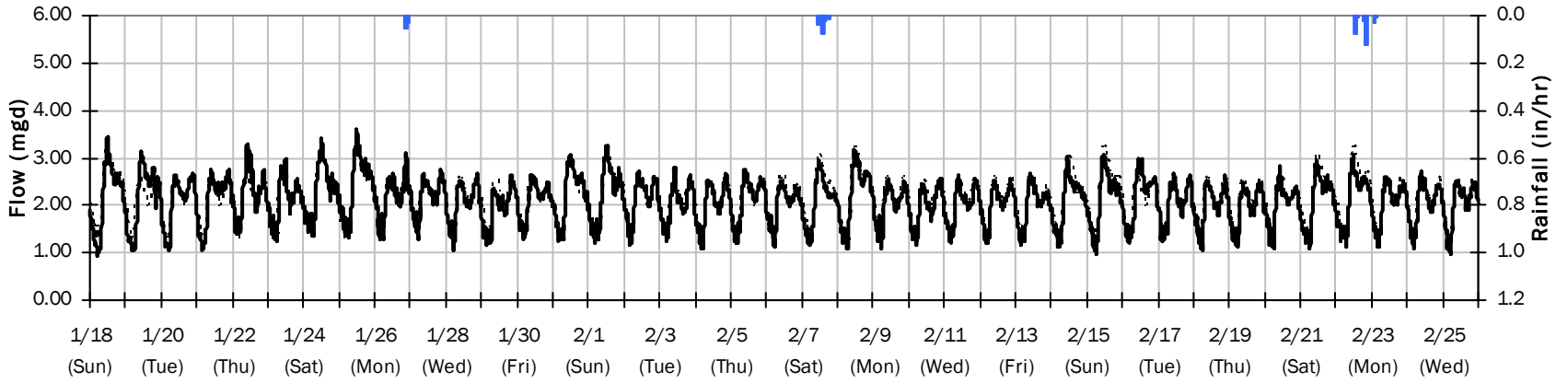


SITE 10

Flow Summary: 12/9/2014 to 2/25/2015

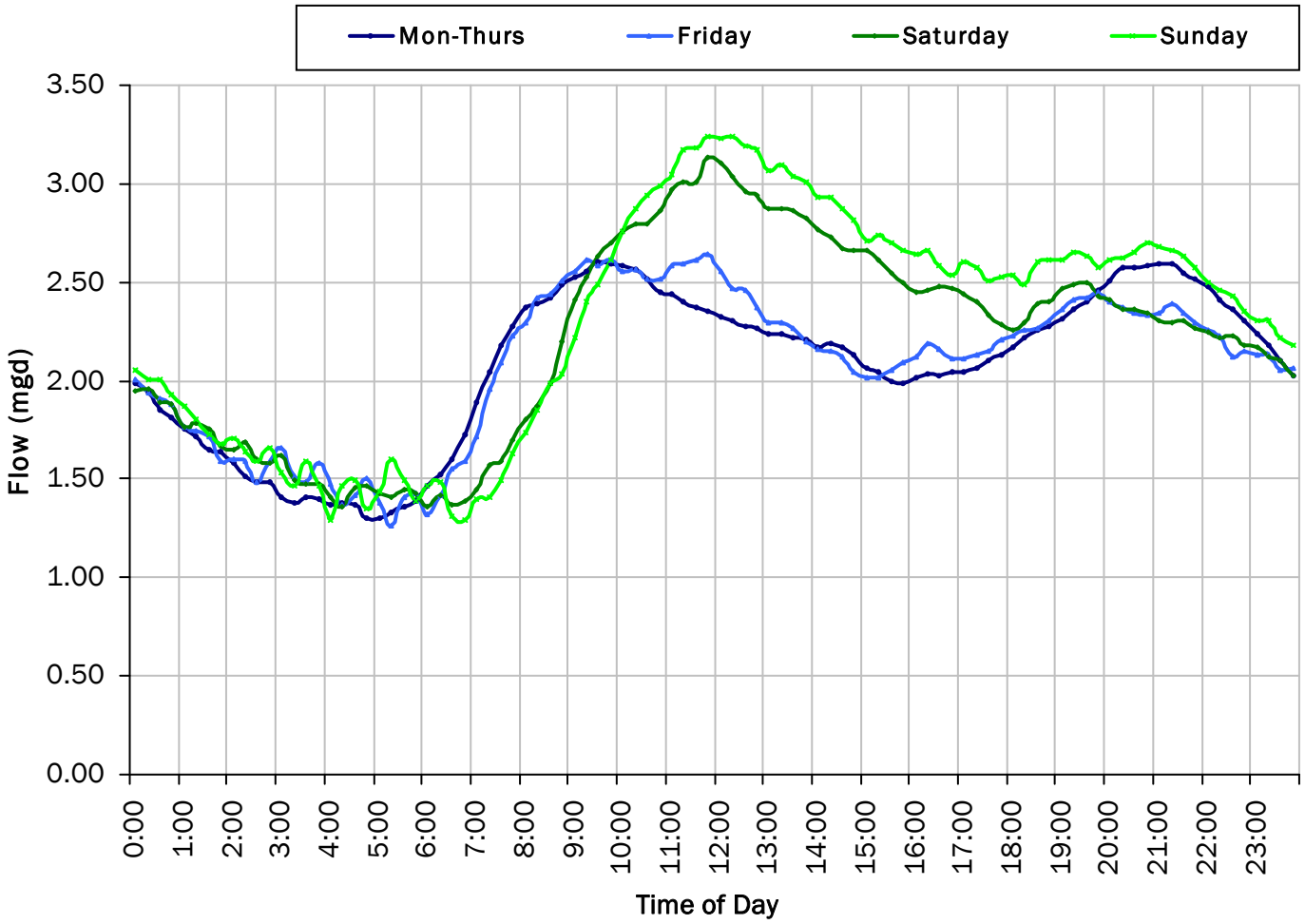
Total Period Rainfall: 4.81 inches Avg Flow: 2.128 mgd Peak Flow: 4.024 mgd Min Flow: 0.876 mgd





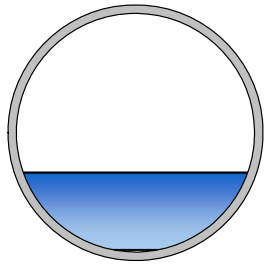
SITE 10

Baseline Flow Hydrographs



Baseline Flow:

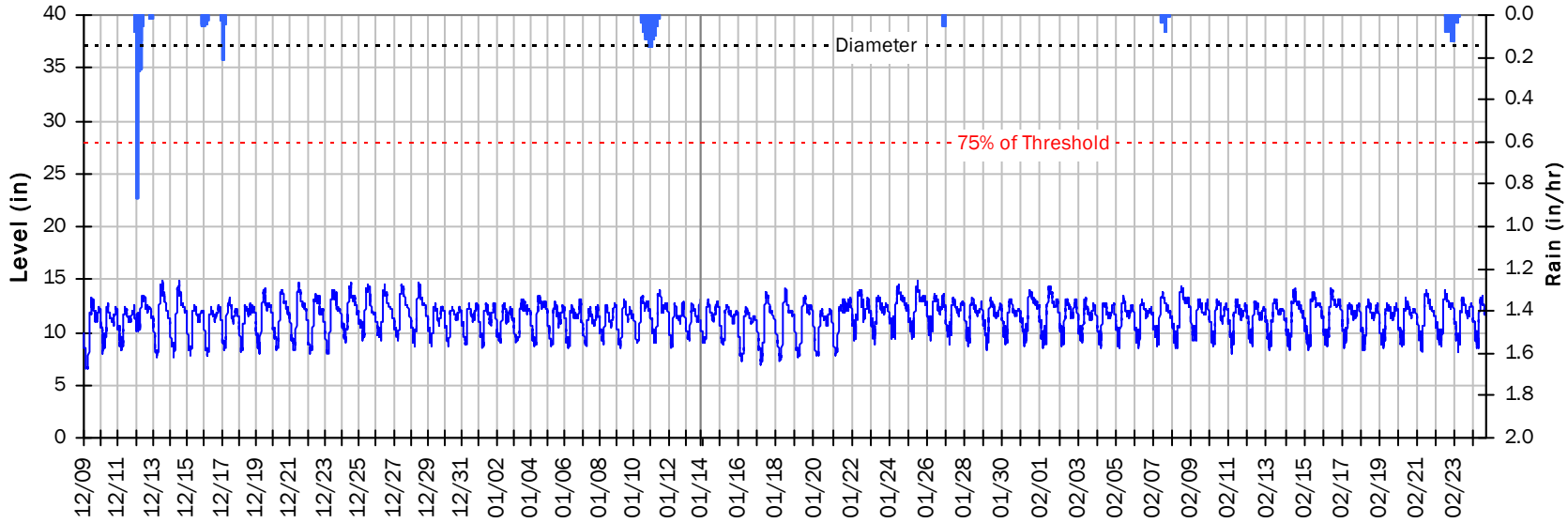
2.13 *mgd*

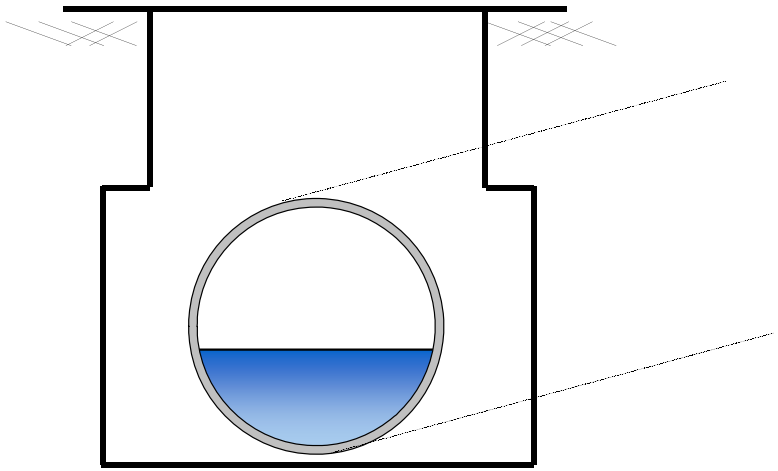


SITE 10

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

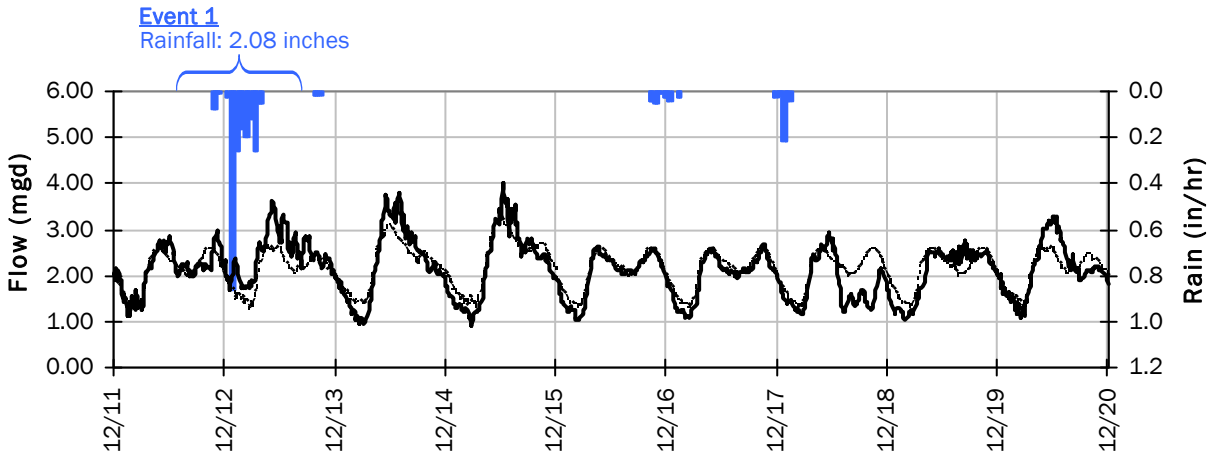




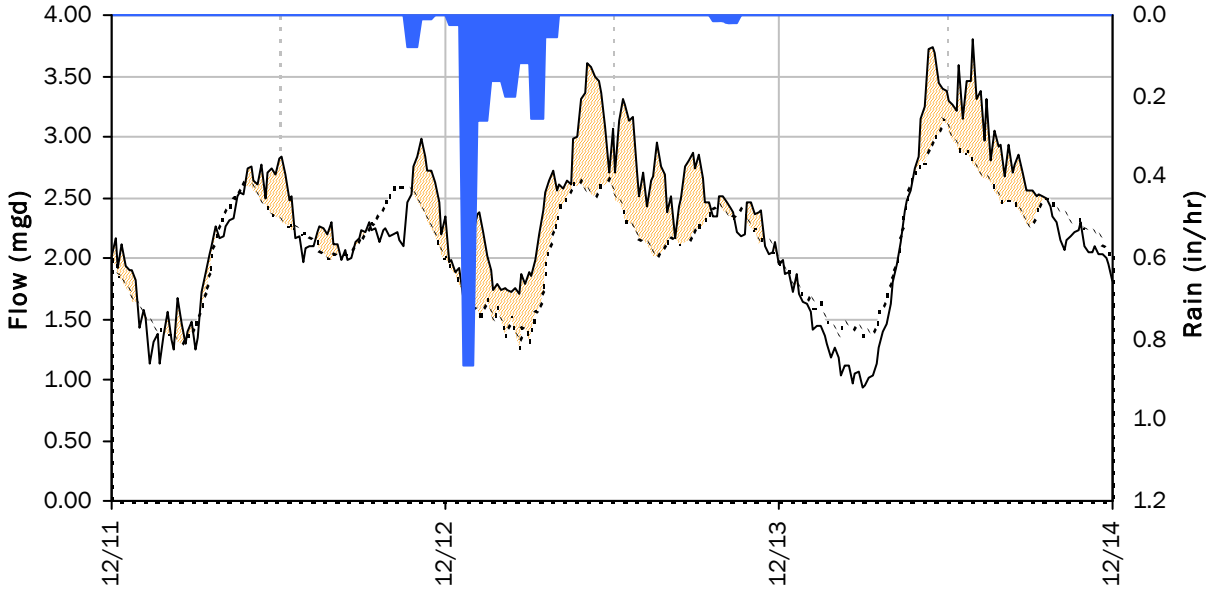
Pipe Diameter:	37	*inches*
Peak Measured Level:	14.9	*inches*
Peak d/D Ratio:	0.40	

SITE 10
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

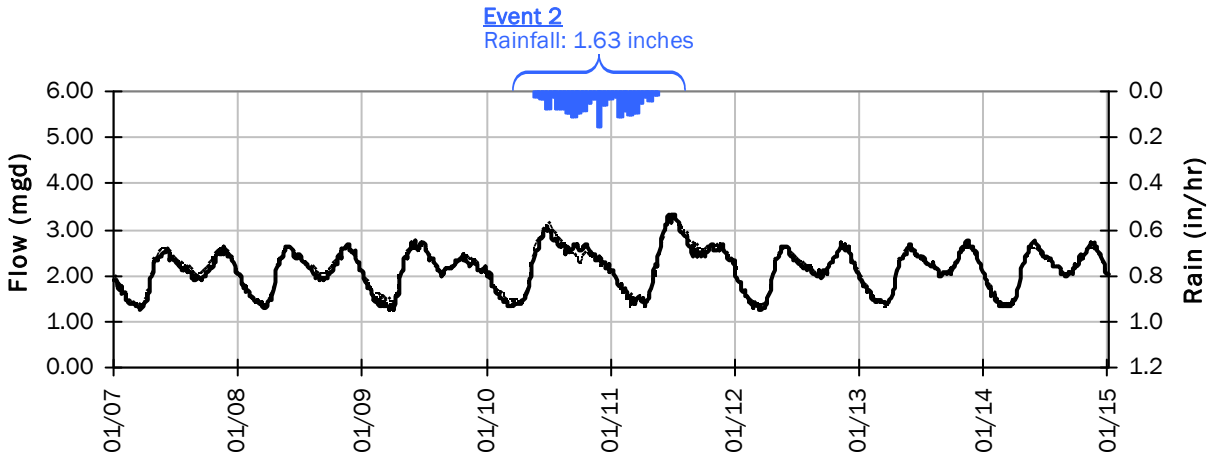


Storm Event I/I Analysis (Rain = 2.08 inches)

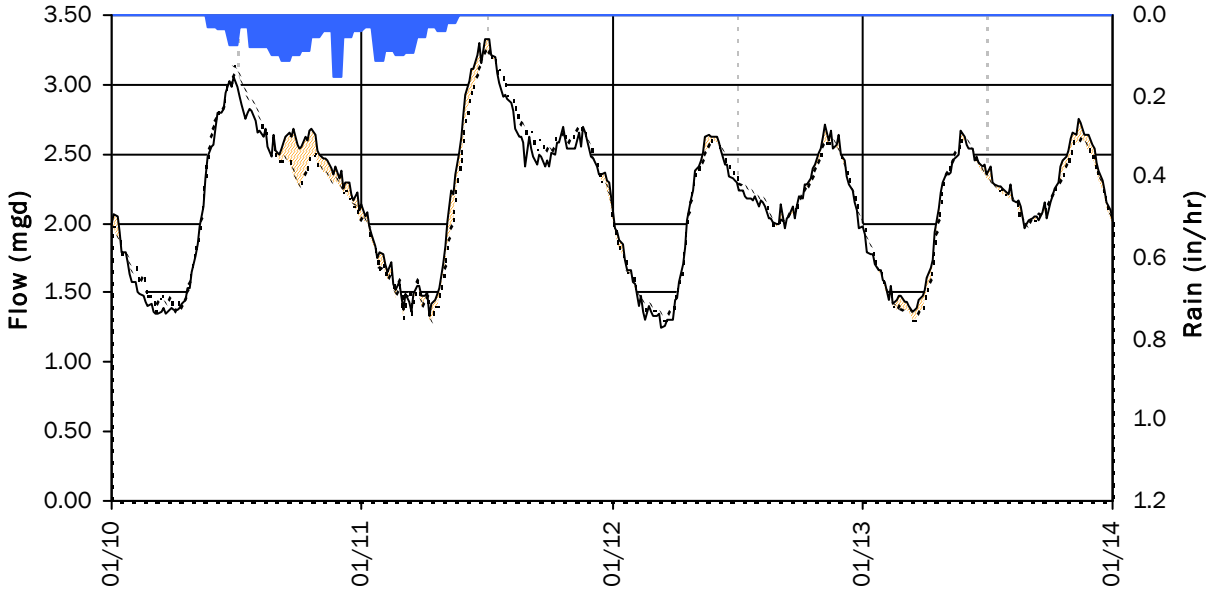
Capacity		Inflow / Infiltration	
Peak Flow:	3.80 *mgd*	**Peak I/I Rate:**	1.05 *mgd*
PF:	1.78	**Total I/I:**	477,000 *gallons*
Peak Level:	14.84 *in*		
d/D Ratio:	0.40		

SITE 10
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



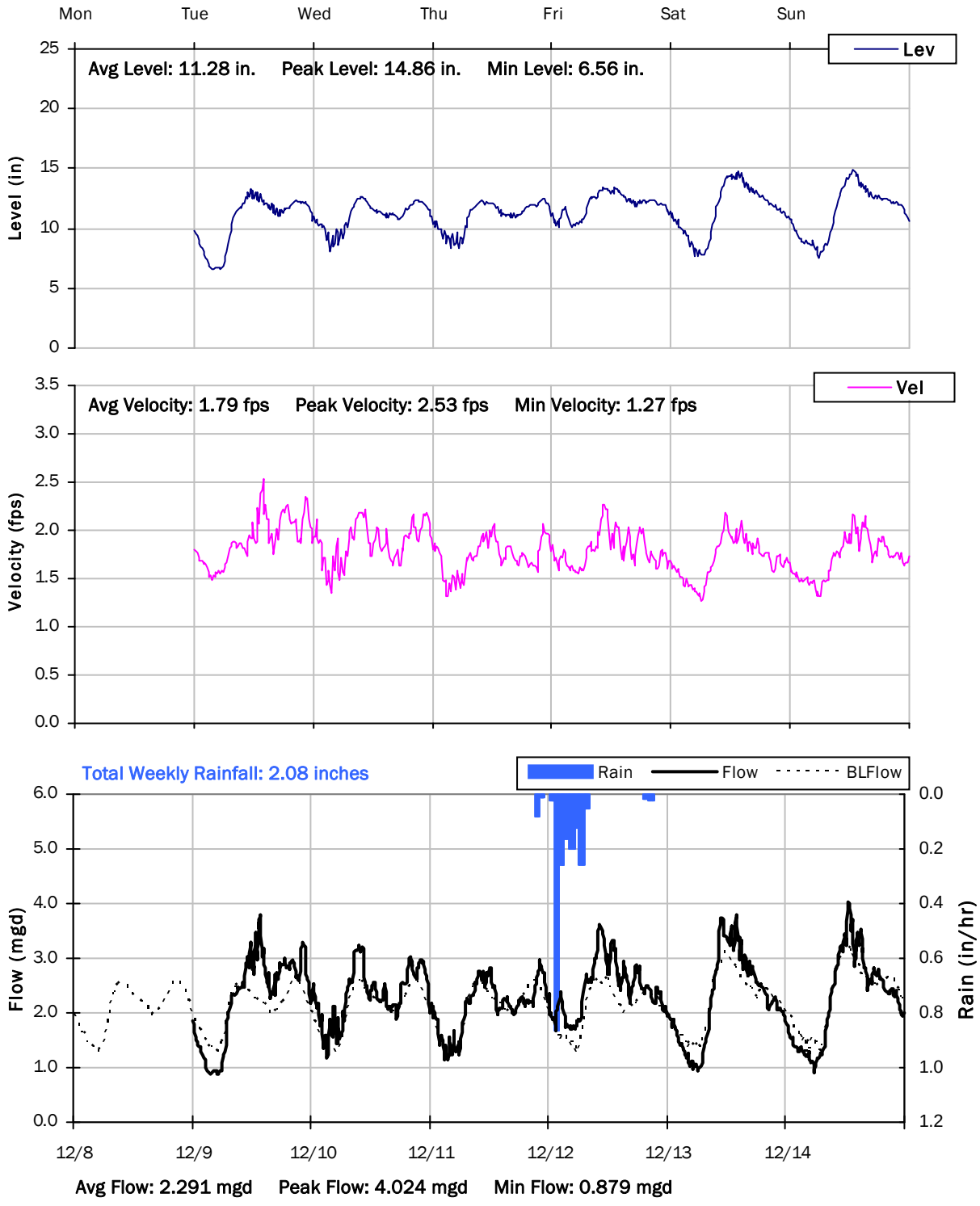
Storm Event I/I Analysis (Rain = 1.63 inches)

Capacity		Inflow / Infiltration	
Peak Flow:	3.33 *mgd*	**Peak I/I Rate:**	0.34 *mgd*
PF:	1.57	**Total I/I:**	31,000 *gallons*
Peak Level:	13.98 *in*		
d/D Ratio:	0.38		

SITE 10

Weekly Level, Velocity and Flow Hydrographs

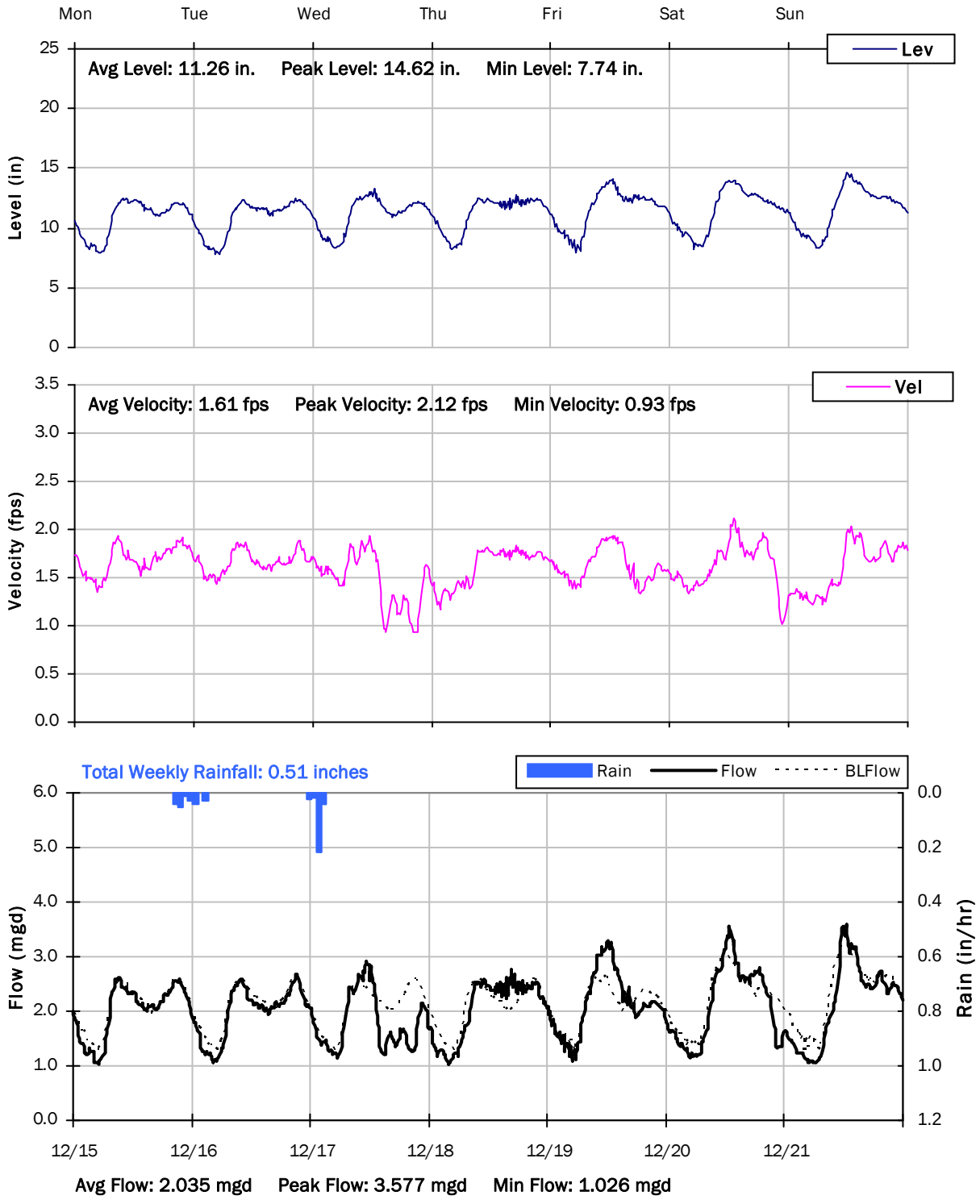
12/8/2014 to 12/15/2014



SITE 10

Weekly Level, Velocity and Flow Hydrographs

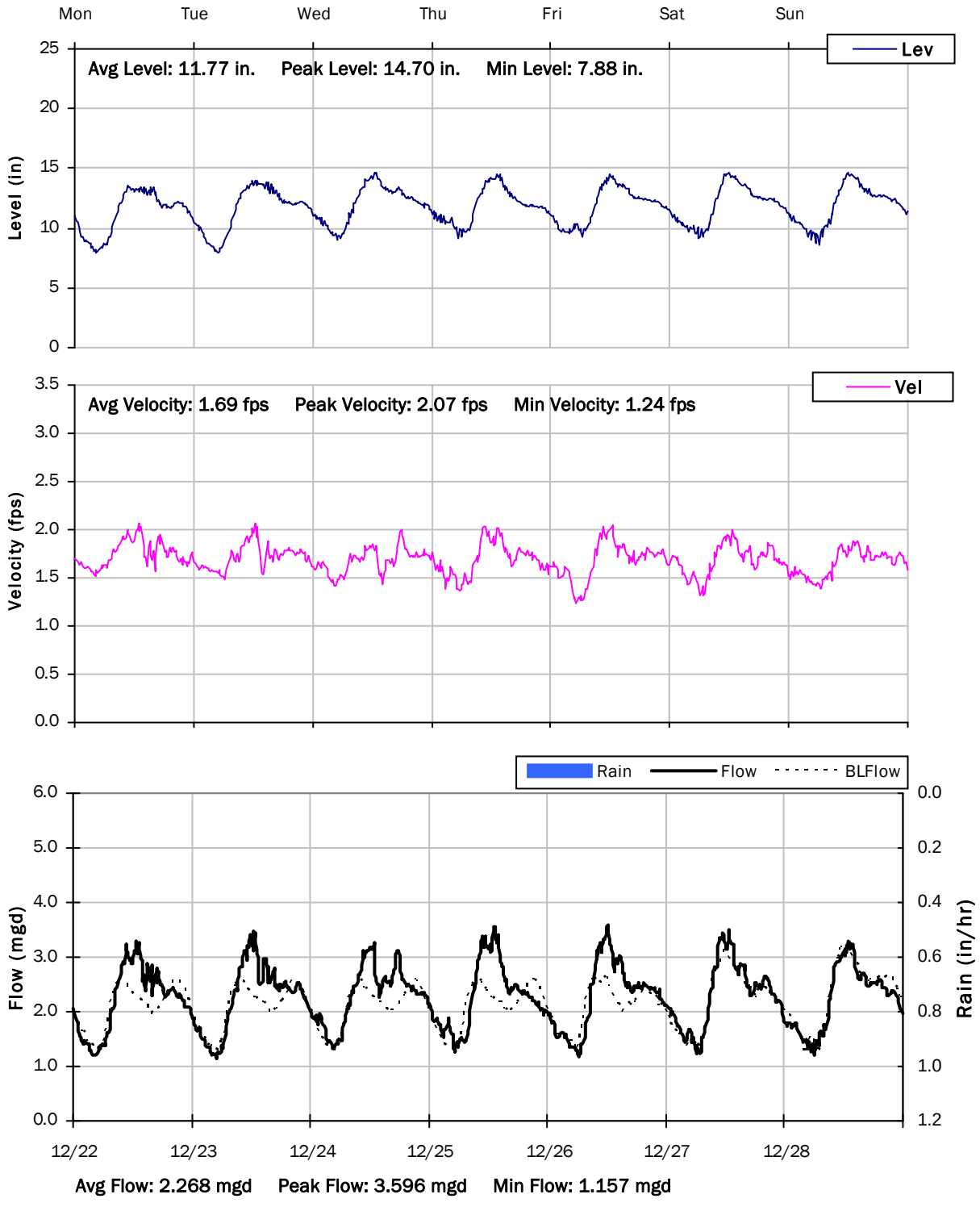
12/15/2014 to 12/22/2014



SITE 10

Weekly Level, Velocity and Flow Hydrographs

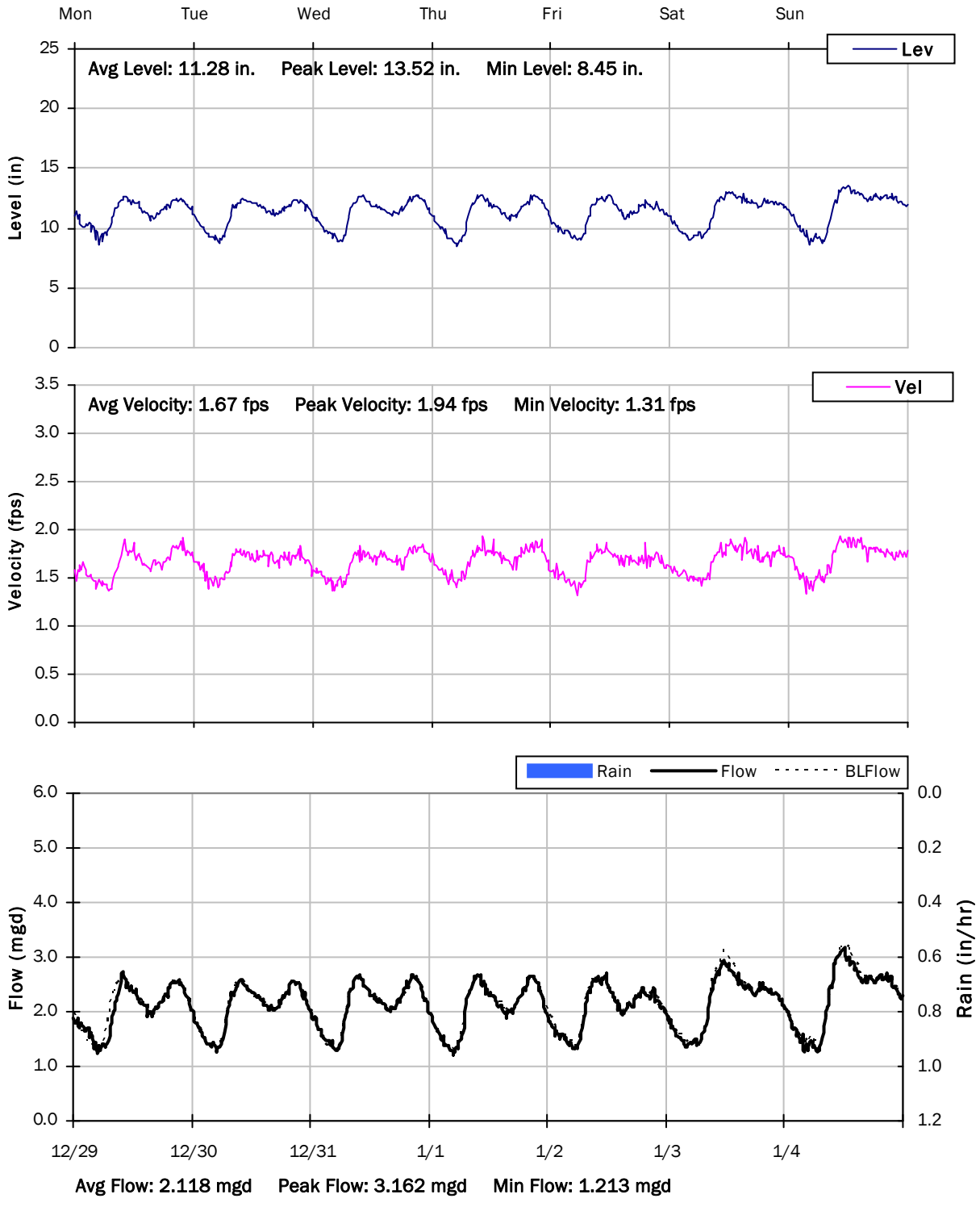
12/22/2014 to 12/29/2014



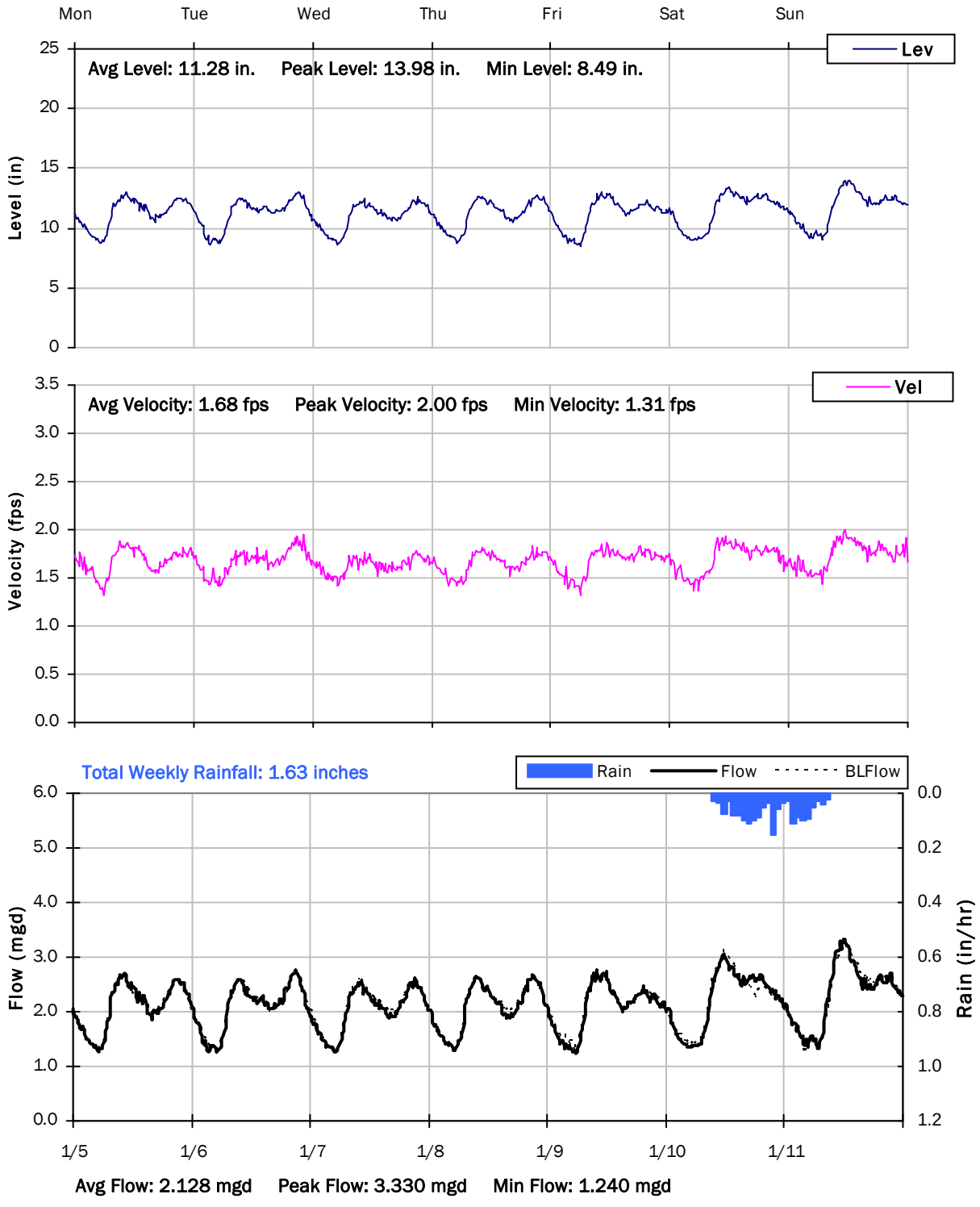
SITE 10

Weekly Level, Velocity and Flow Hydrographs

12/29/2014 to 1/5/2015



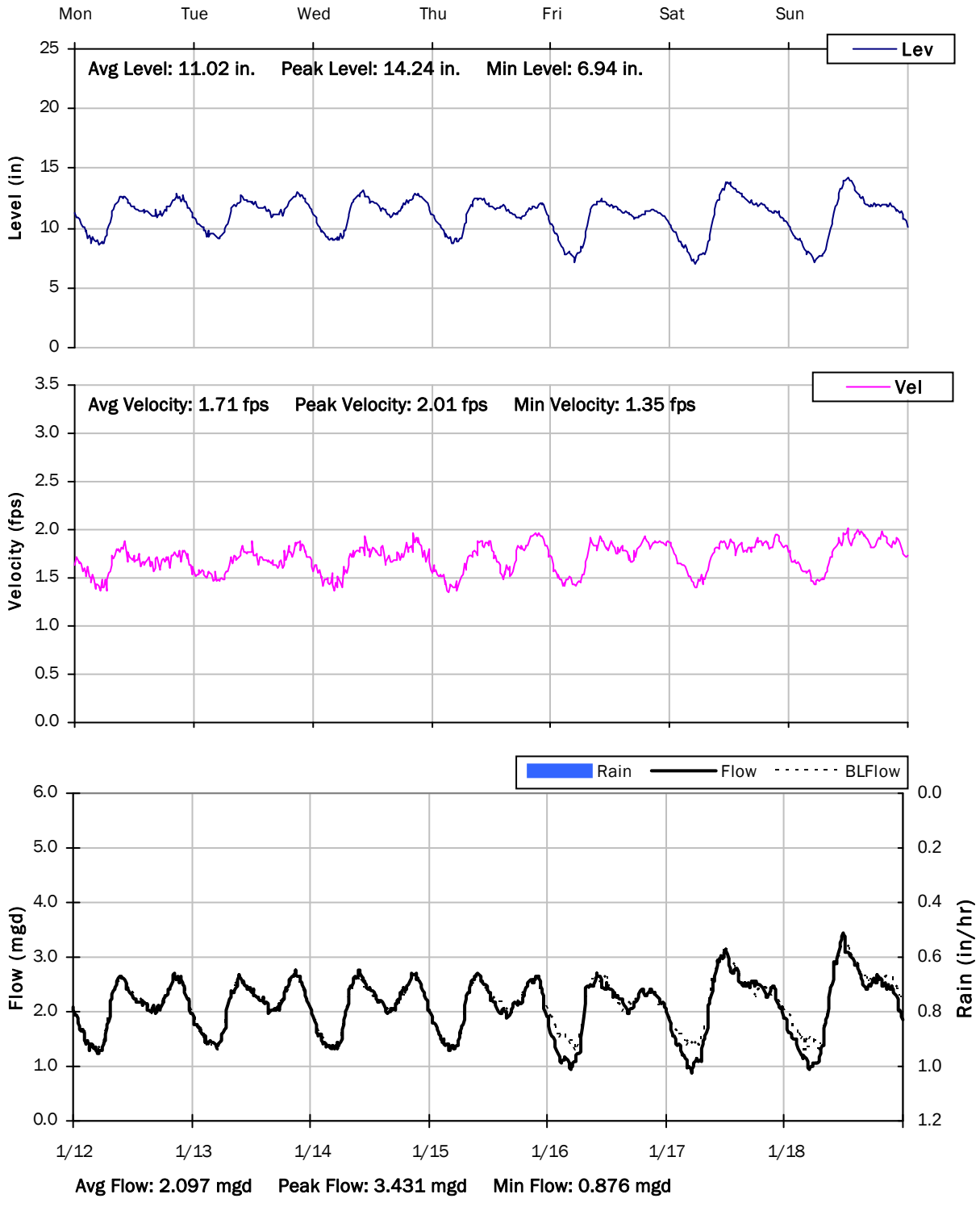
SITE 10
Weekly Level, Velocity and Flow Hydrographs
1/5/2015 to 1/12/2015



SITE 10

Weekly Level, Velocity and Flow Hydrographs

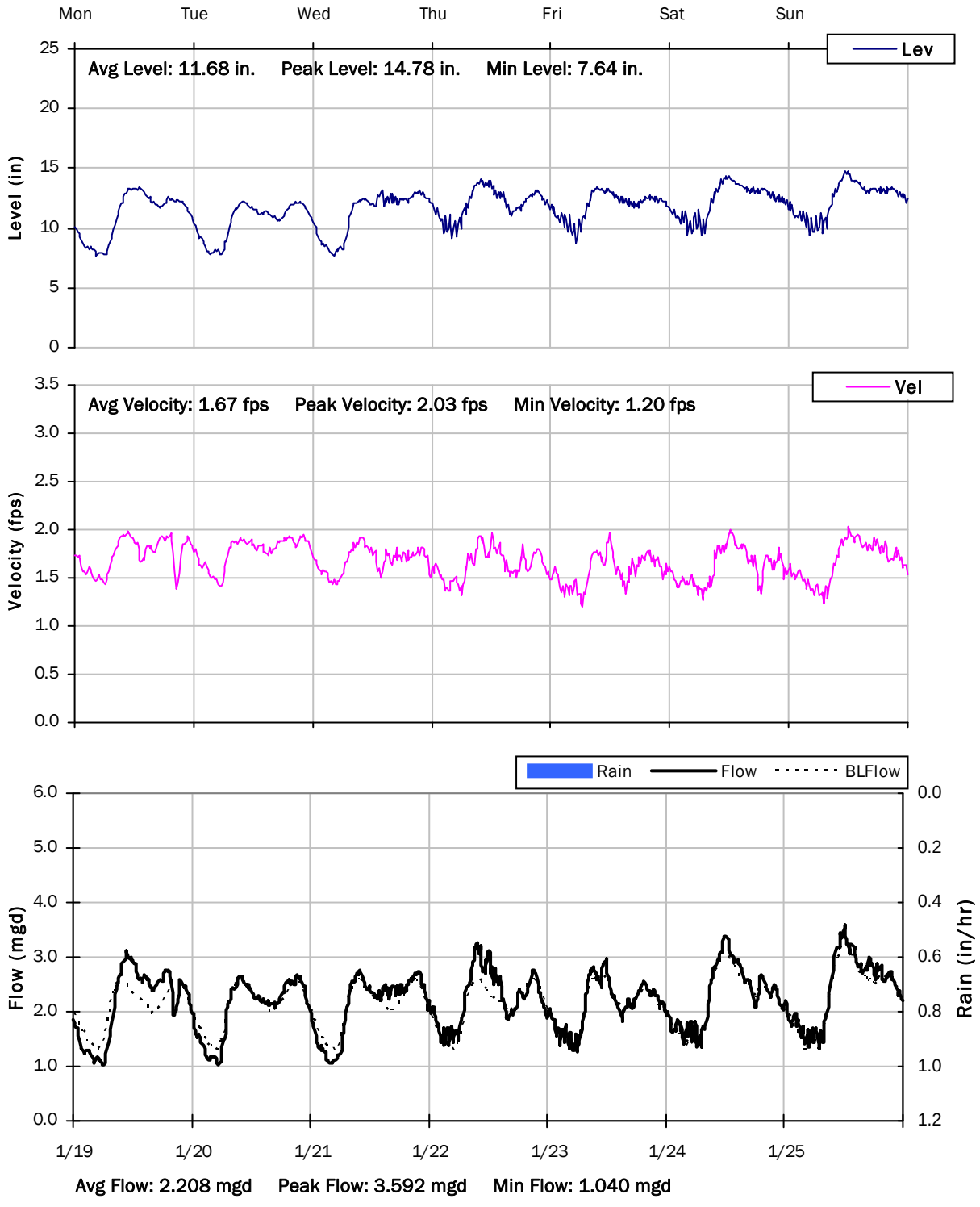
1/12/2015 to 1/19/2015



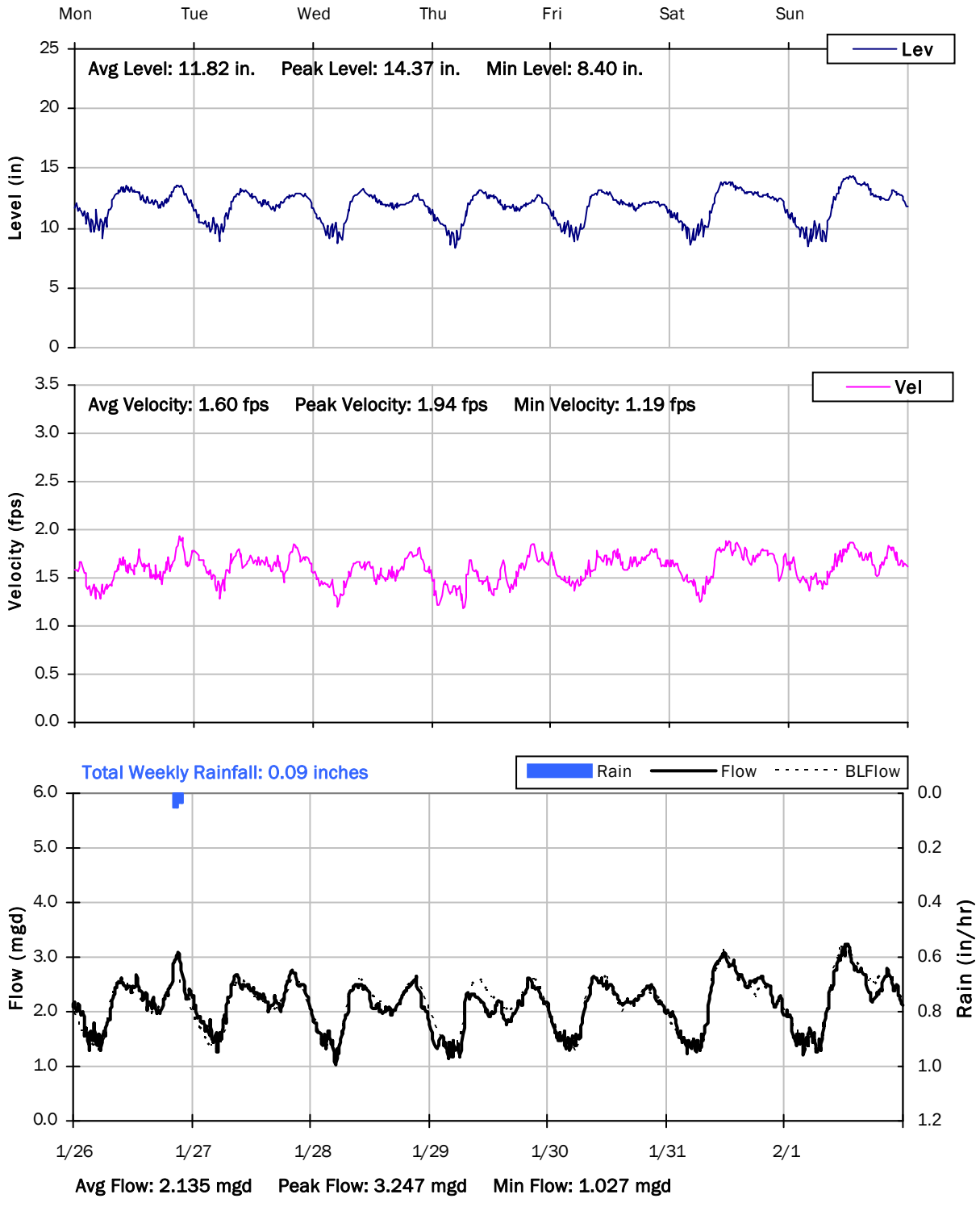
SITE 10

Weekly Level, Velocity and Flow Hydrographs

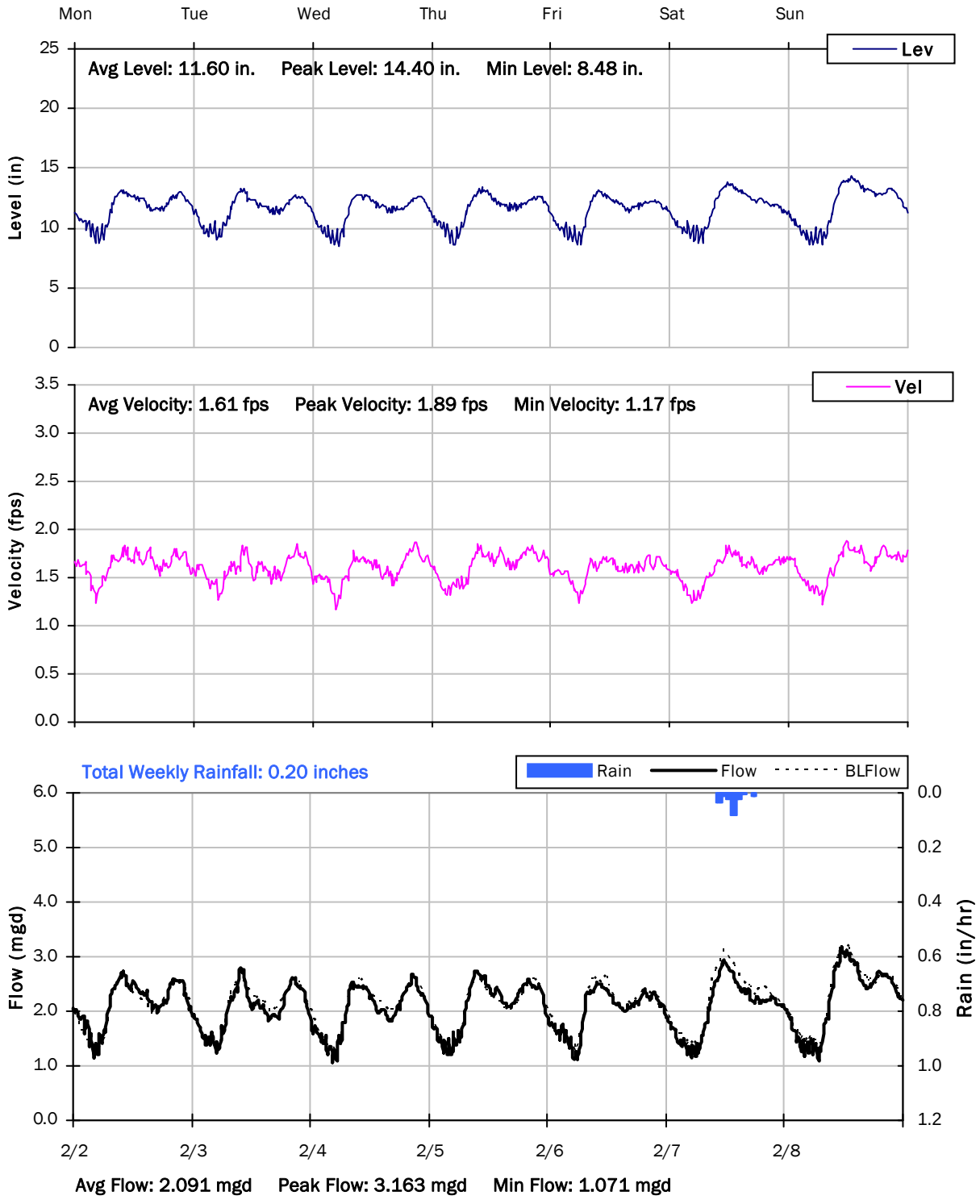
1/19/2015 to 1/26/2015



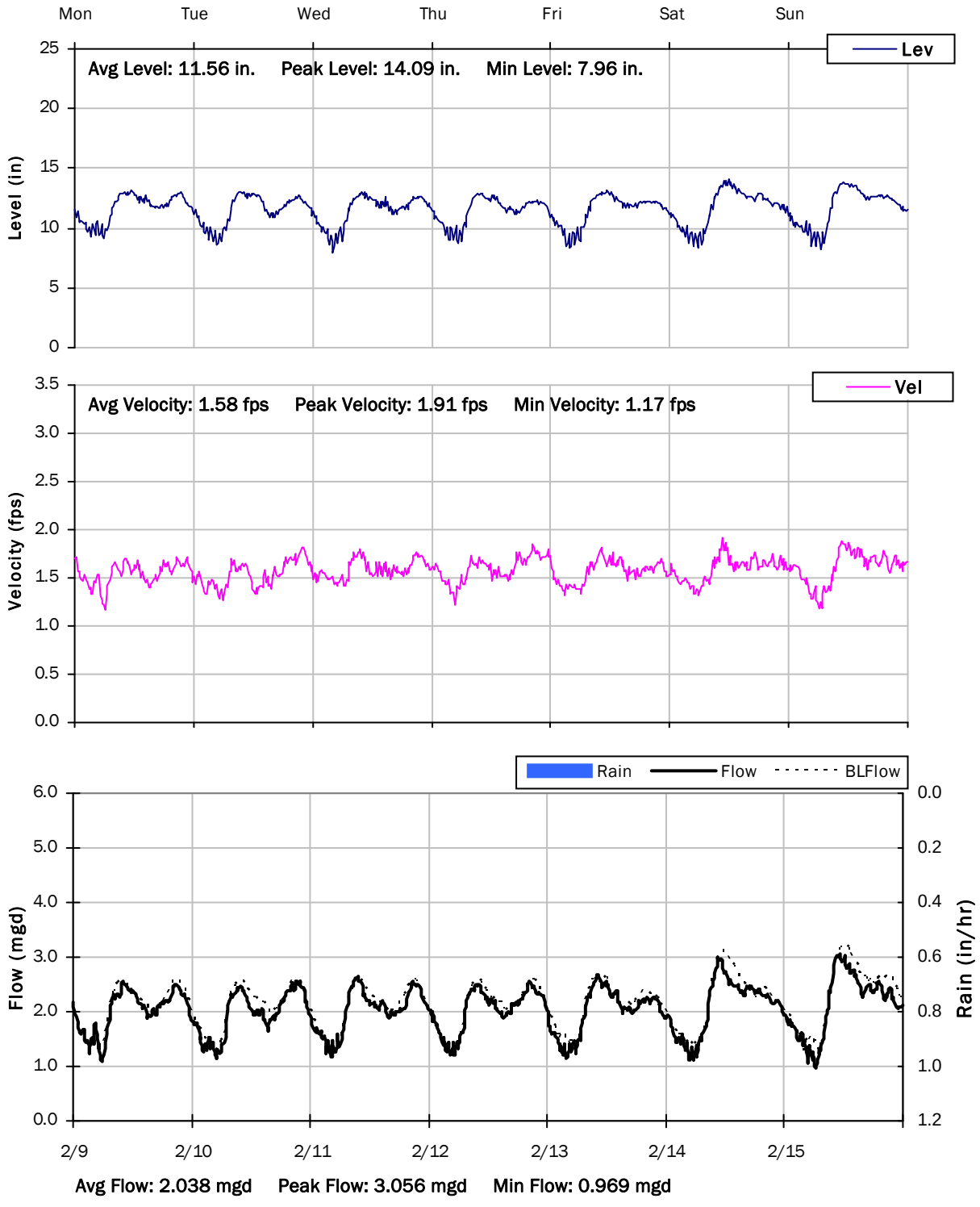
SITE 10
Weekly Level, Velocity and Flow Hydrographs
1/26/2015 to 2/2/2015



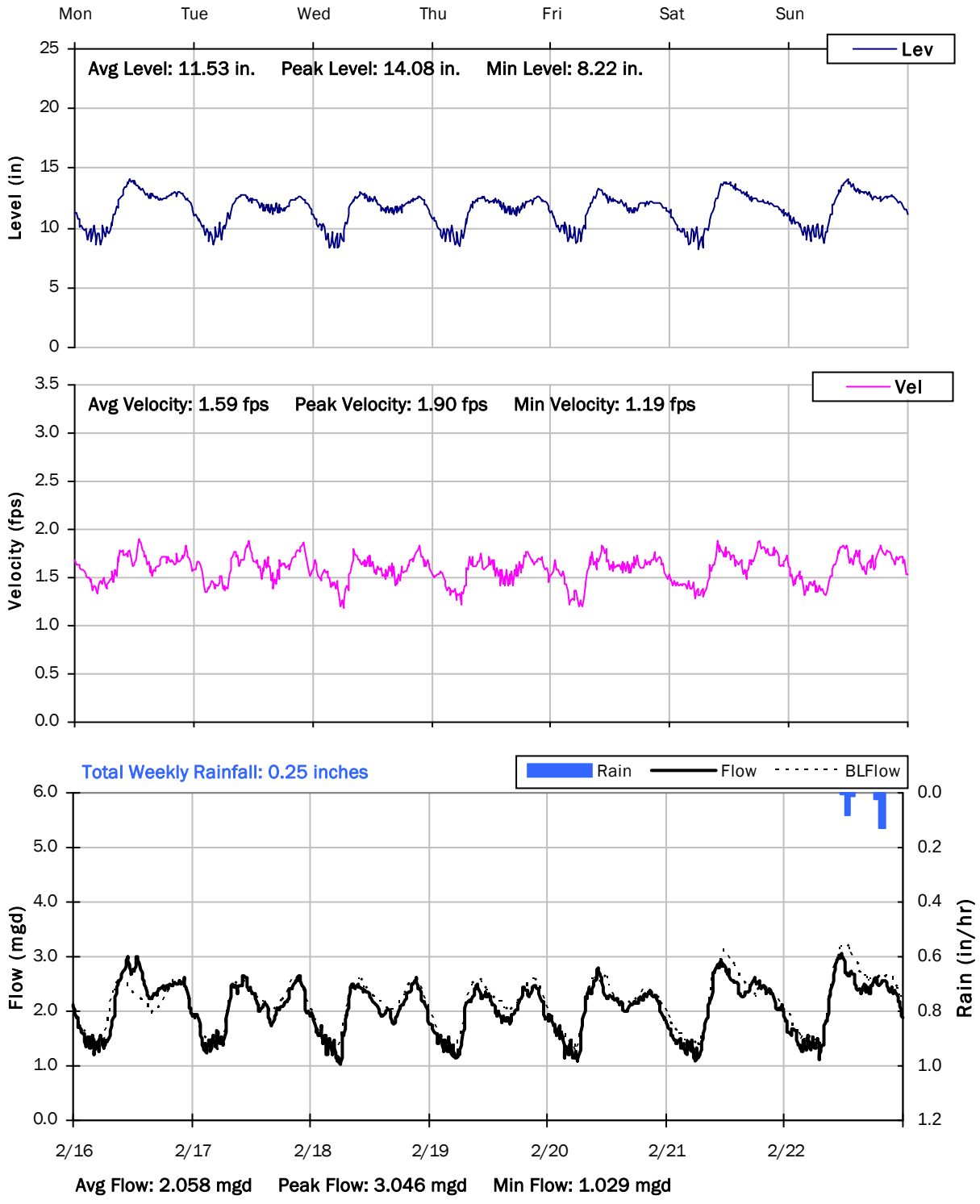
SITE 10
Weekly Level, Velocity and Flow Hydrographs
2/2/2015 to 2/9/2015



SITE 10
Weekly Level, Velocity and Flow Hydrographs
2/9/2015 to 2/16/2015



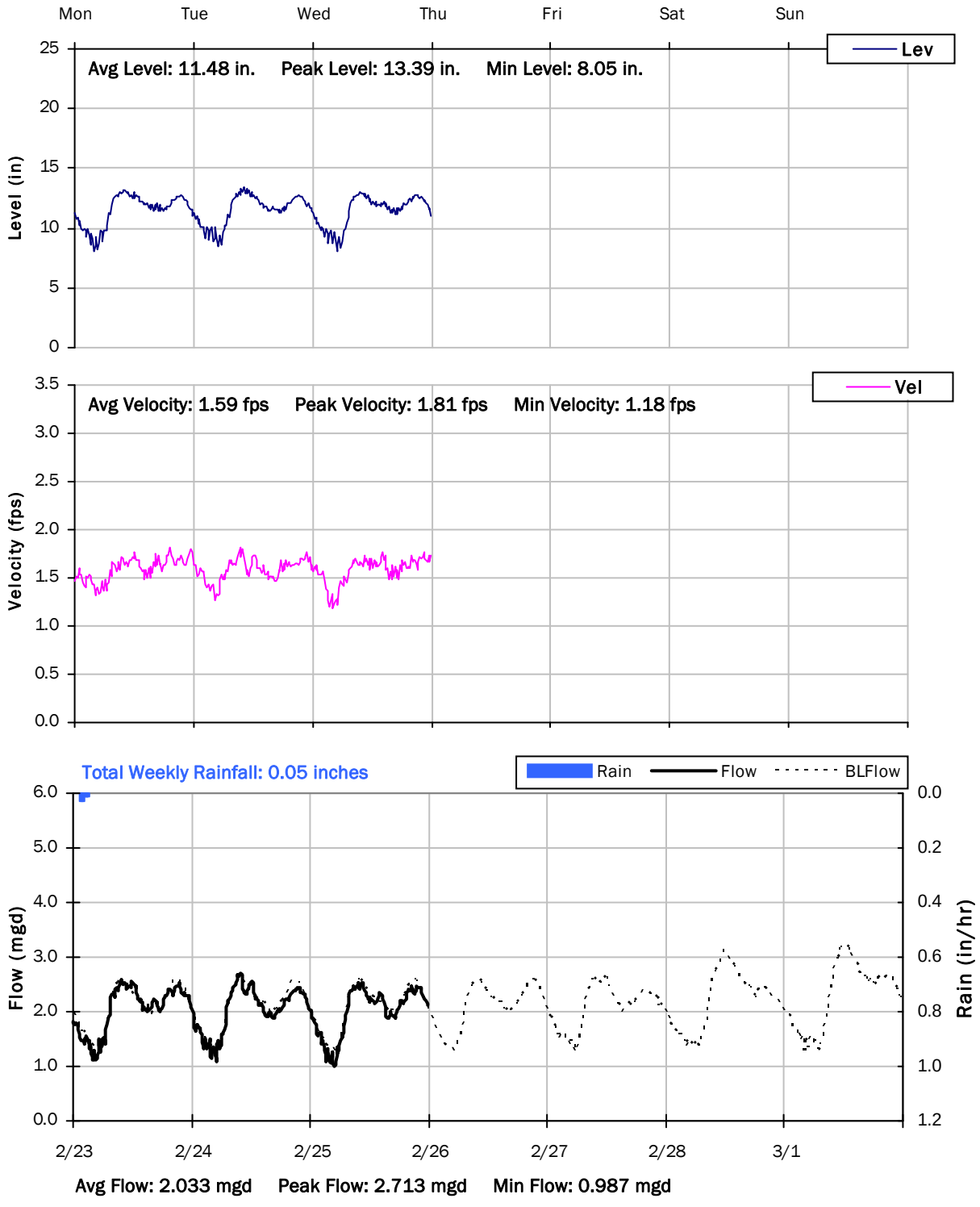
SITE 10
Weekly Level, Velocity and Flow Hydrographs
2/16/2015 to 2/23/2015

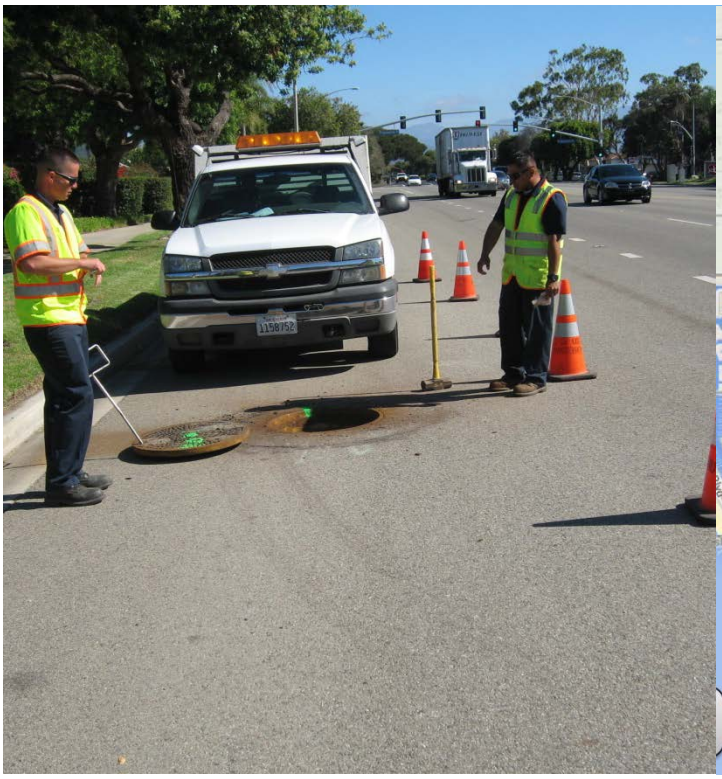


SITE 10

Weekly Level, Velocity and Flow Hydrographs

2/23/2015 to 3/2/2015





Oakland
155 Grand Avenue, Suite 700
Oakland, CA 94612
510.903.6600 Tel
510.903.6601 Fax

San Diego
11011 Via Frontera, Suite C
San Diego, CA 92127
858.576.0226 Tel

Houston
8220 Jones Road, Suite 500
Houston, TX 77065
713.568.9067 Tel

Las Vegas
3430 East Russell Road, Suite 316
Las Vegas, NV 89120
702.522.7967 Tel
702.553.4694 Fax

V&A

vaengineering.com