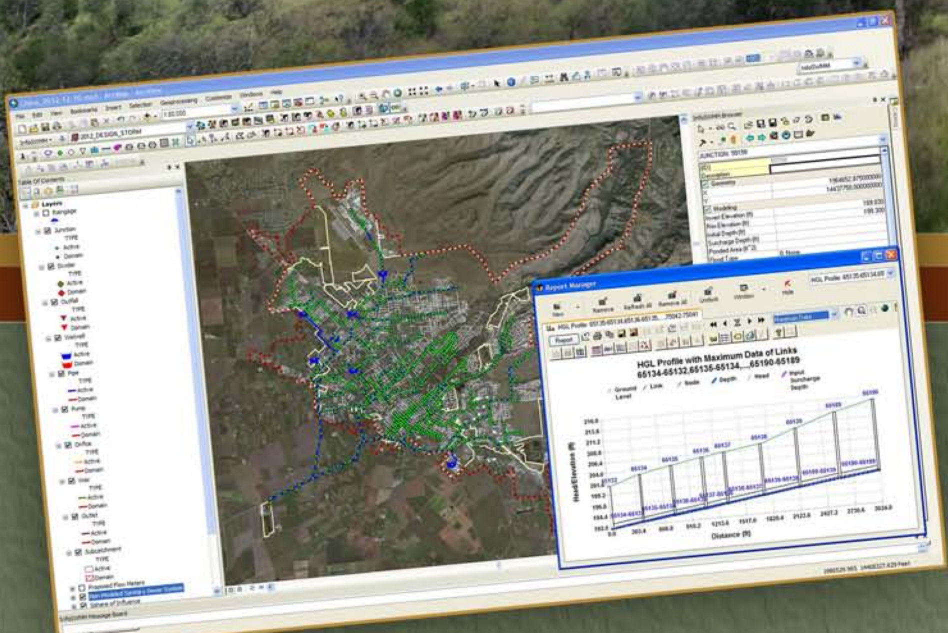
CITY OF CHICO
INC. 1872

FINAL

Sanitary Sewer MASTER PLAN Update

June 2013



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SANITARY SEWER MASTER PLAN UPDATE

FINAL

June 2013

06/18/2013

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City of Chico

SANITARY SEWER MASTER PLAN UPDATE

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SEWER COLLECTION SYSYEM MASTER PLAN

This executive summary presents a brief background of the City of Chico (City) sanitary sewer collection system, the need for this master plan, proposed improvements to mitigate existing system deficiencies, and proposed expansion projects. A summary of capital improvement project costs is included at the end of this chapter.

ES.1 INTRODUCTION

The City of Chico (City) was founded in 1860 by General John Bidwell and incorporated in 1872. The City has since grown to over 33 square miles with a population of 87,500 in the incorporated area. The City maintains a special sense of community and small-town living as it has developed into a vibrant regional center for business, recreation, and cultural activities. There are also many recreational opportunities in and around Chico.

The City is located in the Northern Sacramento Valley of California in Butte County, on State Highway Route 99, approximately 90 miles north of the City of Sacramento.

The City owns, maintains, and operates gravity sewer pipelines, force mains, sewer lift stations, and the Water Pollution Control Plant (WPCP). The City collects wastewater from residential, commercial, institutional, and industrial customers within its service area.

ES.2 STUDY AREA

The area serviced by the City is characterized as a growing and dynamic residential community with a significant number of students or employees of California State University, Chico (CSUC). There are varieties of residential neighborhoods ranging from rural residential to very high density residential in the downtown commercial district.

There are also several open space areas within the City, including Bidwell Park, California Park Lake, and the Chico Cemetery. The primary water bodies flow east to west through the City service area, and include Big Chico Creek, Little Chico Creek, Lindo Channel, Comanche Creek, and Sycamore Creek. The Sierra Nevada Mountains are located just east of the City. The Sacramento River is located roughly 5 miles west of the current City limits.

There are two major highways that run through the City. State Route 32 and 99 comprise the City's regional transportation network and serve much of the population in Butte County. State Route 32 connects Chico residents to Glenn and Plumas counties to the west and east, respectively. State Route 99 connects residents to Tehama and Sutter counties to the north and south, respectively. Figure ES.1 shows the study area boundary and the current City limits.

Land use assumptions used in this study are consistent with the 2030 General Plan. Since the land use assumptions forecast the type of growth within the study area, this association to the Master Plan should ensure that the wastewater generation projections and facilities required to serve future growth are consistent with the City's guiding document on development.

ES.3 SEWER SERVICE AREA OVERVIEW

The City's collection system consists of sewer mains, trunk sewers, lift stations, and flow diversions that collect and convey wastewater to the City's WPCP, which is located west of the City on Chico River Road. The City's existing sanitary sewer collection system is comprised of roughly 266 miles of gravity collection system pipes up to 66-inches in diameter. Figure ES.2 presents the existing City's collection system, including sewer diameters and lift station locations.

ES.4 WASTEWATER FLOWS

The average dry weather flow (ADWF) is the average flow that occurs on a daily basis during the dry weather season. The ADWF includes the base wastewater flow (BWF) generated by the City's users, plus dry weather groundwater infiltration (GWI).

Peak wet weather flow (PWWF) is the highest observed hourly flow that occurs following the design storm event. The City's sewers and lift stations were evaluated based on their capacity to convey the "design flow ("design flow" is synonymous to PWWF in this study).

A summary of the existing and build-out ADWF and the Design Flow is presented in Table ES.1. The City's ADWF is projected to roughly double from 6.9 mgd to 13.9 mgd by build out, whereas the PWWF is projected to increase from 20.5 mgd to about 35.3 mgd by build out (an increase of approximately 72-percent). Therefore, the City's PWWF to ADWF peaking factor is projected to decrease from roughly 3.0 to 2.5, which is typical for sanitary sewer collection systems.

Table ES.1 Current and Projected Wastewater Flow Summary
Sanitary Sewer Master Plan Update
City of Chico

Year	Average Dry Weather Flow (mgd)	Design Flow (mgd)	Peaking Factor
Existing	6.9	20.5	3.0
Build-Out	13.9	35.3	2.5

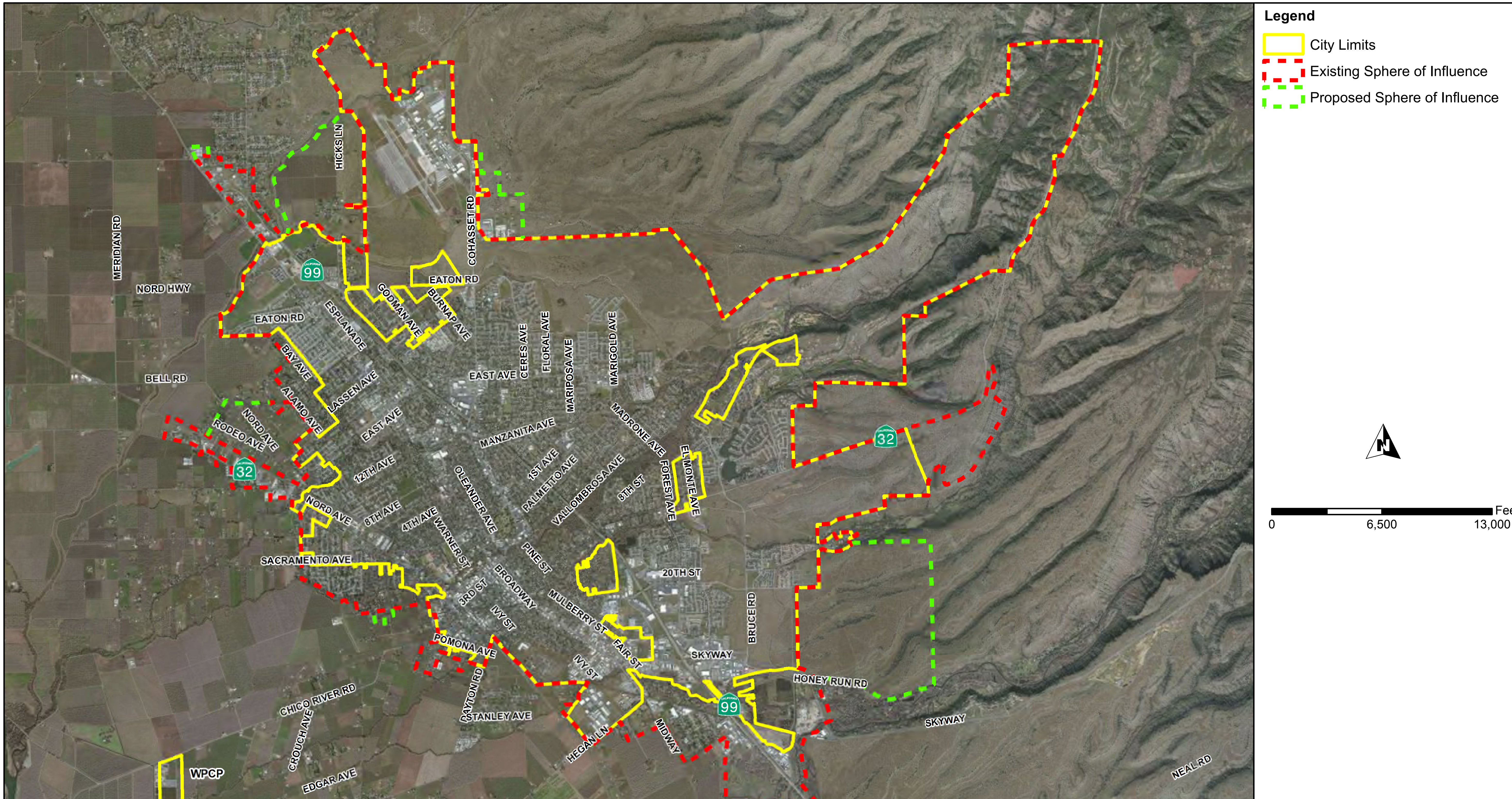

Figure ES.1
Study Area
Sanitary Sewer Master Plan Update
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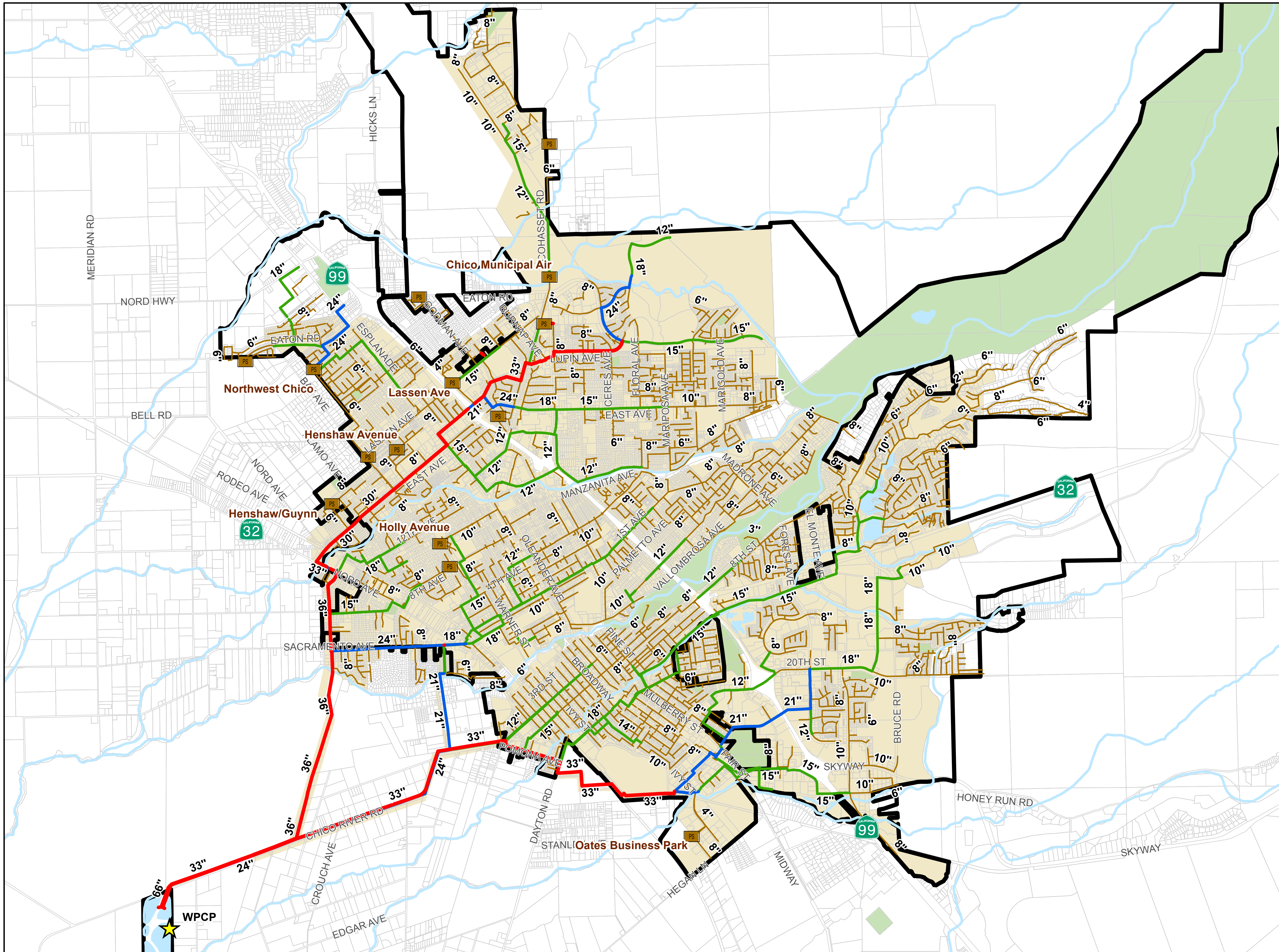

Legend

Existing Sanitary Sewer System

- Lift Station
- WPCP

Pipelines

- 10" and Smaller
- 12" - 18"
- 21" - 27"
- 30" and Larger
- Sanitary Sewer Service Area
- City Limits
- Parks
- Water Body
- Parcels

0 5,000 10,000 Feet

Figure ES.2
Existing Sanitary Sewer Collection System
Sanitary Sewer Master Plan Update
City of Chico

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ES.5 CAPACITY EVALUATION AND PROPOSED IMPROVEMENTS

The capacity analysis identified areas in the sewer system where flow restrictions occur or where pipe capacity is insufficient to convey design flows. Sewers that lack sufficient capacity to convey design flows create bottlenecks in the collection system that can potentially cause sanitary sewer overflows (SSOs).

For the existing sewer collection system, the PWWF was routed through the hydraulic model. In accordance with the established flow depth criteria for existing sewers, manholes where the hydraulic grade line (HGL) encroached within a distance halfway between the manhole rim and the pipe crown, or five feet of the manhole rim, were identified.

Note that the pipelines with an HGL that encroached within five feet of the manhole rim are not necessarily capacity deficient. In many cases, a surcharged condition within a given pipeline segment is due to backwater effects created by a downstream bottleneck. For this reason, the hydraulic model was analyzed to identify the pipeline segments that are the cause of the surcharged conditions.

In general, the City's collection system has sufficient capacity to convey current PWWFs without exceeding the established flow depth criterion. However, there are a few areas where capacity restrictions lead to flow depths that exceed allowable levels. Following the completion of the existing system analysis, improvement projects and alternatives were identified in order to mitigate existing system pipeline capacity deficiencies.

The build out system analysis was performed in a manner similar to the existing system analysis. The purpose of the build out system evaluation is to verify that the existing system improvements were appropriately sized to convey build out PWWFs, and to identify the locations of sewers that are adequately sized to convey existing PWWFs, but cannot convey build out PWWFs. Additionally, new trunk sewers were added to the hydraulic model and sized to service major growth areas beyond the current City sewer service area.

At build out, the City's wastewater flows are expected to double. As such, there are some areas of the existing collection system that cannot convey the build out PWWF without flows backing up above allowable levels.

Figure ES.3 illustrates the improvements recommended to mitigate capacity deficiencies in the existing sewer collection system and improvements to accommodate future growth as identified by the hydraulic analysis. Details of each improvement are also provided in Table ES.2.

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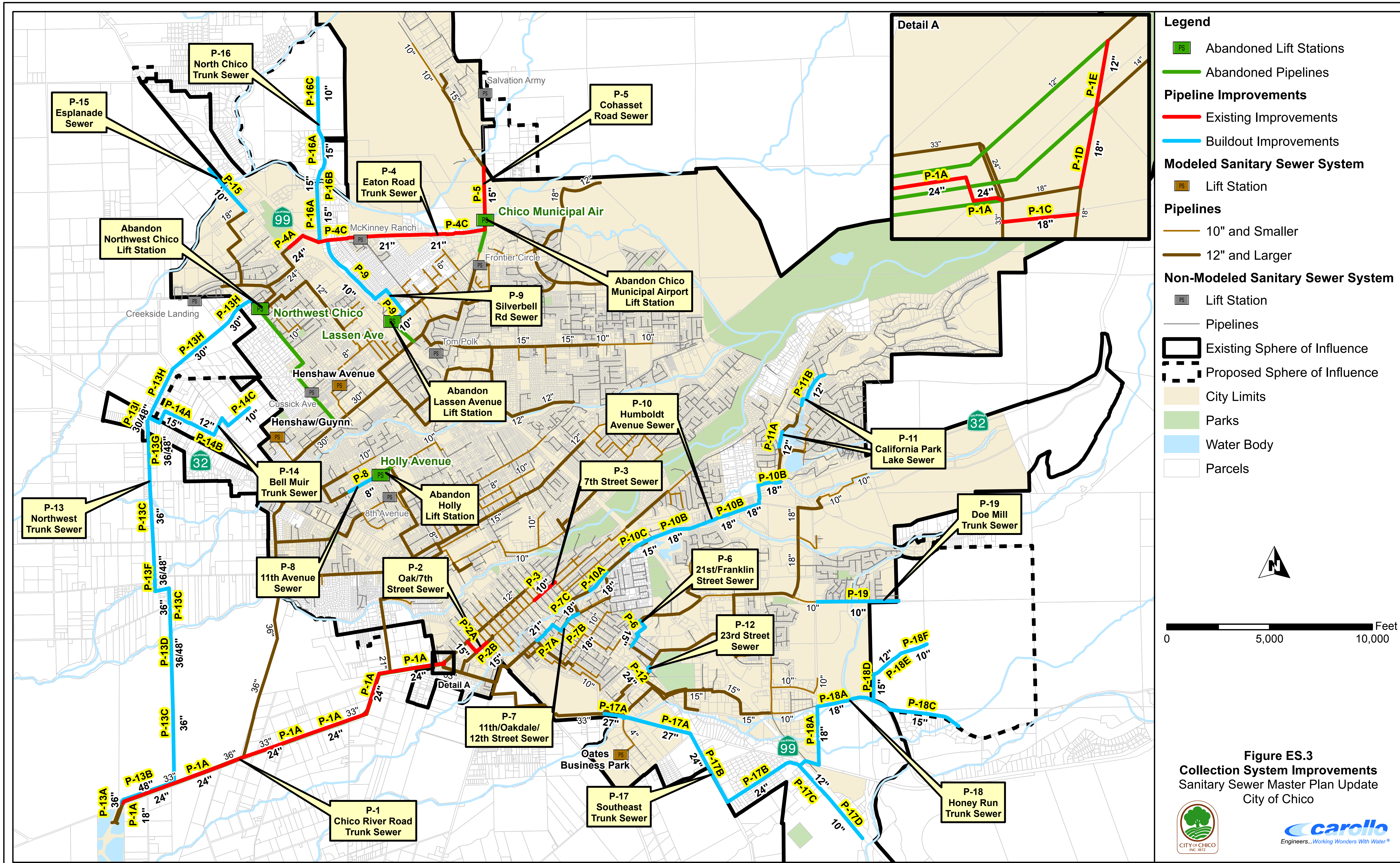

Figure ES.3
Collection System Improvements
Sanitary Sewer Master Plan Update
City of Chico

Table ES.2 **Proposed Improvements**
Sewer System Master Plan Update
City of Chico

Project Description				Project Size				Project Phasing			
Improv. ID	**Type of Improv.**	**Description/Street**	**Description/Limits**	**Existing Size (in.)**	**Proposed Size (in)**	**Replace/ New**	**Length (ft)**	**Phase 1 (2013-2015)**	**Phase 2 (2016-2020)**	**Phase 3 (2021-2025)**	**Phase 4 (2026-2030)**
Project 1 - Chico River Road Trunk Sewer											
P-1A	Gravity	Chico River Road	W. 5th Street to WPCP	12-24	24	Replace	17,800	x			
P-1B	Gravity	Near WPCP Junction Box	Dual 18-inch Pipes Near WPCP Junction Box	18	18	Replace	150	x			
P-1C	Gravity	Chico River Road	At W. 5th Street	--	18	New	50	x			
P-1D	Gravity	Chico River Road	At W. 5th Street	--	18	New	50	x			
P-1E	Gravity	Chico River Road	At W. 5th Street	--	12	Mew	30	x			
Project 2 - Oak/7th Street Sewer											
P-2A	Gravity	Oak Street/W. 7th Street	Walnut Street to W. 5th Street	10	15	Replace	990	x			
P-2B	Gravity	W. 7th Street	Cedar Street to Walnut Street	10	12	Replace	340	x			
Project 3 - 7th Street Sewer											
P-3	Gravity	E. 7th Street	Olive Street to Main Street	8	10	Replace	1,350	x			
Project 4 - Eaton Road Trunk Sewer											
P-4A	Gravity	Eaton Road	Hicks Lane to West of Highway 99	--	24	New	1,460		x		
P-4B	Casing	Eaton Road	Highway 99 Crossing	--	24/42	New	200		x		
P-4C	Gravity	Eaton Road	Cohasset Road to Hicks Lane	--	21	New	8,170		x		
P-4D	Gravity	Cohasset Road	CMA Lift Station to Eaton Road	--	18	New	540		x		
Project 5 - Cohasset Road Sewer											
P-5	Gravity	Cohasset Road	North of Thorntree Drive to CMA Lift Station	12	15	Replace	2,610		x		
Project 6 - 21st/Franklin Street Sewer											
P-6	Gravity	Franklin/E. 21st Street	E. 20th Street to Mulberry Street	12	15	Replace	1,700		x		
Project 7 - 11th/Oakdale/12th Street Sewer											
P-7A	Gravity	W. 11th/Oakdale Street	W. 12th Street to Chestnut Street Alley	15	21	Replace	1,600		x		
P-7B	Gravity	W. 12th Street	Park Avenue to Oakdale Street	--	18	Parallel	300		x		
P-7C	Gravity	W. 12th Street	Connect Existing 18-inch Sewer	18	18	In Ground	950		x		
Project 8 - 11th Avenue Sewer											
P-8	Gravity	W. 11th Avenue	Holley Avenue to West of Cecelia Lane	--	8	New	1,750			x	
Project 9 - Silverbell Road Sewer											
P-9	Gravity	Joshua Tree Rd/Silverbell Rd.	Lassen Ave. Lift Station to Eaton Road	--	10	New	6,560			x	
Project 10 - Humboldt Avenue Sewer											
P-10A	Gravity	Humboldt Avenue	Linden Street to Poplar Street	15	18	Replace	1,230				x
P-10B	Gravity	Humboldt Avenue	Bruce Road to West of Highway 99	15	18	Replace	8,110				x
P-10C	Casing	Humboldt Avenue	Highway 99 Crossing	12	18/30	Replace	300				x
Project 11 - California Park Lake Sewer											
P-11A	Gravity	Near California Lake Park	North of Bruce Road to Bruce Road	10	12	Replace	750				x
P-11B	Gravity	Near California Lake Park	Yosemite Drive to Upper Lake Court	10	12	Replace	2,070				x
Project 12 - 23rd Street Sewer											
P-12	Gravity	E. 23rd Street	At Fair Street	15	24	Replace	270				x
Project 13 - Northwest Trunk Sewer											
P-13A	Gravity	Near WPCP Junction Box	Dual 36-inch Pipes Near WPCP Junction Box	--	36	New	460		x		
P-13B	Gravity	Chico River Road	East of Alberton Avenue to WPCP	--	48	New	2,590		x		
P-13C	Gravity	E. of Alberton Ave./Muir Ave.	Railroad at Muir Ave. to Chico River Road	--	36	New	18,380		x		
P-13D	Casing	E. of Alberton Ave.	Creek Crossing	--	36/48	New	80		x		
P-13E	Casing	West Sacramento Avenue	Creek Crossing	--	36/48	New	70		x		

Table ES.2		Proposed Improvements Sewer System Master Plan Update City of Chico										
Project Description				**Project Size**				**Project Phasing**				
Improv. ID	**Type of Improv.**	**Description/Street**	**Description/Limits**	**Existing Size (in.)**	**Proposed Size (in)**	**Replace/ New**	**Length (ft)**	**Phase 1 (2013-2015)**	**Phase 2 (2016-2020)**	**Phase 3 (2021-2025)**	**Phase 4 (2026-2030)**
P-13F	Casing	Muir Avenue	Creek Crossing	--	36/48	New	30		x		
P-13G	Casing	Muir Avenue	Highway 32 Crossing	--	36/48	New	60		x		
P-13H	Gravity	N. of Muir Ave./Carmack Dr.	Northwest Chico LS to Railroad at Muir Ave.	--	30	New	8,480		x		
P-13I	Casing	Muir Avenue	Railroad Crossing	--	30/48	New	80		x		
Project 14 - Bell Muir Trunk Sewer											
P-14A	Gravity	Rodeo Avenue	E. of Muir Ave. to the Northwest Trunk Sewer	--	15	New	2,550			x	
P-14B	Gravity	Rodeo Avenue	East of Muir Avenue	--	12	New	1,320			x	
P-14C	Gravity	Near Rodeo Avenue	Nord to South Rodeo Avenue	--	10	New	2,740			x	
Project 15 - Esplanade Sewer											
P-15	Gravity	Esplanade	Garner Lane to Nord	--	10	New	2,720				x
Project 16 - North Chico Trunk Sewer											
P-16A	Gravity	Hicks Lane	Cabello Way to Eaton Road	--	15	New	4,630				x
P-16B	Casing	Hicks Lane	Creek Crossing	--	15/30	New	420				x
P-16C	Gravity	Hicks Lane	North of Cabello Way to Cabello Way	--	10	New	3,030				x
Project 17 - Southeast Trunk Sewer											
P-17A	Gravity	Greenbelt near Comanche Creek	Midway to West of Otterson Drive	--	27	New	4,420			x	
P-17B	Gravity	Midway/Entler Avenue	Highway 99 to Greenbelt	--	24	New	7,860			x	
P-17C	Gravity	Entler Avenue	Southgate Avenue to North of Northfield Avenue	--	12	New	2,160			x	
P-17D	Gravity	Entler Avenue	South of Southgate Avenue	--	10	New	2,500			x	
Project 18 - Honey Run Trunk Sewer											
P-18A	Gravity	Cramer Lane/Skyway Road	Potter Road to Highway 99	--	18	New	6,450				x
P-18B	Casing	Near Cramer Lane	Highway 99 Crossing	--	18/30	New	200				x
P-18C	Gravity	Honey Run Road	East of Skyway Road to Skyway Road	--	15	New	4,440				x
P-18D	Gravity	Potter Road	North of Skyway Road to Skyway Road	--	15	New	1,010				x
P-18E	Gravity	Field North of Skyway Road	Field North of Skyway Road	--	12	New	1,470				x
P-18F	Gravity	Field North of Skyway Road	Field North of Skyway Road	--	10	New	1,540				x
Project 19 - Doe Mill Trunk Sewer											
P-19	Gravity	Doe Mill Road	East of Potter Road to Bruce Road	--	10	New	3,960			x	

ES.5.1 Existing Versus Future Improvement

An existing deficiency is one where the existing facility's capacity is insufficient to meet the planning criteria (e.g., pipeline upgrades required to prevent severe surcharging during the design wet weather event) for existing users. If a project was proposed to correct an existing deficiency exclusively, then existing users were assigned 100 percent of the project's benefit, and therefore, 100 percent of the costs.

The majority of the Master Plan improvements will serve future users, even when an improvement calls for the upgrade of an existing facility. In these cases, an existing sewer or lift station may have sufficient capacity to convey current PWWFs, but as growth continues and more users are added to the system, the increased flow results in capacity deficiencies. These projects, as well as new trunk sewers to extend wastewater collection system service to future growth areas, are future improvements. Future users were assigned 100 percent of the future project's benefit and 100 percent of the costs.

In some cases, a project is needed to correct an existing capacity deficiency, but is sized to accommodate additional flows from future development. In these cases, the hydraulic modeling results were used to determine the cost breakdown between existing and future users based on the ratio of existing and build out average dry weather flows.

ES.5.2 Project Prioritization

The majority of improvements listed in Table ES.2 are driven by future development, which consist of new sewers that serve future growth or improvements to existing facilities that are needed to serve future growth. When fully implemented, the capital projects will allow the conveyance of PWWFs to the WPCP during build out conditions.

Prioritizing the required capital improvements for the City's sewer system is an important aspect of this study. The improvement projects were prioritized based on the following factors:

- Upgrading existing facilities to mitigate current capacity deficiencies and to serve future users
- Building the new trunks necessary to serve future users

Improvements to existing facilities will provide sufficient capacity to mitigate existing issues and to convey increased flows resulting from future growth. Future development will require the construction of sewers to serve new users. The projects were grouped into the following phases:

- Phase 1: Years 2013 through 2015
- Phase 2: Years 2016 through 2020
- Phase 3: Years 2021 through 2025
- Phase 4: Years 2026 through 2030

The projects were phased based on the best available information for how the City will develop moving forward. The actual implementation of the improvements serving future users ultimately depends on growth. The priorities presented below are estimates, and changes in the City's planning assumptions or growth projections could increase or decrease the priority of each improvement.

- **Phase 1 Projects (2013-2015)**. The highest priority project for the existing system is the Chico River Road Trunk Sewer Replacement (Project 1). City staff indicates that this sewer is in extremely poor shape and is in need of replacement as soon as possible. Therefore, this project is targeted for the first implementation phase.

  Other projects targeted for the first phase include the Oak/7th Street Sewer (Project 2) and the 7th Street Sewer (Project 3). These are existing capacity deficient sewers, and should be targeted for replacement in the early stages of the City capital improvement plan (CIP).

- **Phase 2 Projects (2016-2020)**. The second phase targets lower priority existing system improvements, as well as additional growth related improvements which could potentially be required in the relatively near term. Because Phase 1 is the shortest of the four CIP phases, and because the Chico River Road Trunk Sewer Replacement project represents a significant expense to the City in Phase 1, Project 4 (Eaton Road Trunk Sewer) and Project 5 (Cohasset Road Sewer) are targeted for construction in Phase 2. In addition, targeting this project in Phase 2 would allow the City time to perform additional flow monitoring and I/I mitigation measures upstream of the Chico Municipal Airport Lift Station to better isolate and potentially reduce or eliminate the major sources of I/I that represent the need for this project.

  Other growth related projects targeted for implementation in Phase 2 are the 21st/Franklin Street Sewer (Project 6), the 11th/Oakdale/12th Street Sewer (Project 7), and the Northwest Trunk Sewer. As previously noted, the actual rate of growth within the City will dictate when these improvements will be constructed.

- **Phase 3 and 4 Projects (2021-2025 and 2026-2030)**. Project 8 (West 11th Avenue Sewer) and Project 9 (Silverbell Road Sewer) are recommended in order to abandon two existing lift stations (the Holly Lift Station and the Lassen Avenue Lift Station). These projects are targeted for Phase 3 because they do not specifically address a capacity deficiency, and are therefore assigned a lower priority than the build out system improvements targeted in Phase 2.

  For the purposes of prioritization, the Phase 3 and 4 growth projects are viewed as longer-term projects driven by development at the outer edges of the planning area, and will be grouped together. The Phase 3 and 4 growth projects include the following:

  - Project 10 – Humbolt Avenue Sewer
  - Project 11 – California Lake Park Sewer

- Project 12 – 23rd Street Sewer
- Project 14 – Bell Muir Trunk Sewer
- Project 15 – Esplanade Sewer
- Project 16 – North Chico Trunk Sewer
- Project 17 – Southeast Trunk Sewer
- Project 18 – Honey Run Trunk Sewer
- Project 19 – Doe Mill Trunk Sewer

ES.6 CAPITAL IMPROVEMENT PLAN

The cost estimates presented in the capital improvement plan (CIP) have been prepared for general master planning purposes and for guidance in project evaluation and implementation. Final costs of a project will depend on actual labor and material costs, competitive market conditions, final project scope, implementation schedule, and other variable factors such as preliminary alignment generation, investigation of alternative routings, and detailed utility and topography surveys.

The Association for the Advancement of Cost Engineering (AACE) defines an Order of Magnitude Estimate, deemed appropriate for master plan studies, as an approximate estimate made without detailed engineering data. It is normally expected that an estimate of this type would be accurate within plus 50 percent to minus 30 percent. This section presents the assumptions used in developing order of magnitude cost estimates for recommended facilities.

The CIPs are prioritized based on their urgency to mitigate existing deficiencies and for servicing anticipated growth. It is recommended that improvements to mitigate existing deficiencies be constructed as soon as possible. The deficiencies in the future system have a significant total capital cost that is best distributed based on the order in which the City develops.

The improvements proposed in this study either benefit existing users, or are required to service new development and future users. A summary of the existing and future user cost share for the proposed projects by phase is summarized in Table ES.3.

Table ES.3 Summary of Capital Improvement Costs
Sanitary Sewer Master Plan Update
City of Chico

	Implementation Phase				
Reimbursement Category	**2013-15 ($, mill.)**	**2016-20 ($, mill.)**	**2021-25 ($, mill.)**	**2026-30 ($, mill.)**	**Total ($, mill.)**
Existing User	9.04	1.83	1.23	0.00	12.10
Future User	0.04	24.92	11.26	14.26	50.48
Total	**9.08**	**26.75**	**12.50**	**14.26**	**62.58**

Notes:
(1) Costs are based on ENR CCI 20-City Average of 9,351 (August 2012).

Chapter 1

BACKGROUND

This chapter presents a brief summary of the sanitary sewer system service area, the need for this Sanitary Sewer Master Plan Update (Master Plan) and the objectives of the study. A list of abbreviations is also provided to assist the reader in understanding the information presented.

1.1 INTRODUCTION

The City of Chico (City) was founded in 1860 by General John Bidwell and incorporated in 1872. The City has since grown to over 33 square miles with a population of 87,500 in the incorporated area[1]. The City maintains a special sense of community and small-town living as it has developed into a vibrant regional center for business, recreation, and cultural activities. There are also many recreational opportunities in and around Chico.

The City is located in the Northern Sacramento Valley of California in Butte County, on State Highway Route 99, approximately 90 miles north of the City of Sacramento. Figure 1.1 presents a location map of the City.

Modern-day Chico began with a 290-acre street grid pattern that is now Downtown. Early development included the California State University, Chico (CSUC) campus, the Downtown core, and the surrounding neighborhoods. The landscape, resources, topography, and amenities in and around Chico have helped shape the community over time. Chico has come to be recognized as a regional center for recreation, education, shopping, employment, and health services affording Chico residents an excellent quality of life[2].

The City owns, maintains, and operates gravity sewer pipelines, force mains, sewer lift stations, and the Water Pollution Control Plant (WPCP). The City collects wastewater from residential, commercial, institutional, and industrial customers within its service area.

1.2 SEWER SERVICE AREA

Figure 1.2 illustrates the City's current sewer service area. The City manages and maintains approximately 266 miles of gravity sewer lines up to 66-inches in diameter, 13 lift stations, and associated force mains. All wastewater generated within the sewer service area is conveyed to the City's WPCP for treatment.

The land use assumptions in this Master Plan were based on the Chico 2030 General Plan (2030 General Plan) and projected future developments within the City's proposed Sphere

[1] www.chico.ca.us
[2] Source: Chico 2030 General Plan, April 2011

of Influence (SOI), as defined by the 2030 General Plan. Should future planning conditions change from the assumptions stated in this Master Plan (i.e., accelerated growth, more intense developments, etc.), revisions and adjustments to the Master Plan recommendations would be necessary.

1.3 PREVIOUS MASTER PLAN

The City's original Sanitary Sewer Master Plan was developed in 1985 by Brown and Caldwell. More recently, the City's Sanitary Sewer Master Plan was updated by Carollo Engineers in 2003. The objective of the 2003 Sanitary Sewer Master Plan Update was to evaluate the capacity of the City's collection system during peak wet weather flows and to develop a capital improvement program to provide the City with a reliable and economic wastewater collection system for the future.

A major component of the 2003 Sanitary Sewer Master Plan Update was the development of a hydraulic model of the City's sanitary sewer collection system. The hydraulic model was created in Version 6.1 of the HYDRA hydraulic modeling software application, developed by Pizer, Inc. (Pizer). The model was assembled using the City's Geographic Information System (GIS) data, lift station drawings, supplemental survey work, and input from City Staff, and calibrated to both dry and wet weather flows.

Upon completion of the dry and wet weather flow calibration, a capacity analysis of the modeled collection system was performed for both existing and build out peak wet weather flows. Capital projects were then developed to mitigate the model simulated capacity deficiencies. In total, the 2003 Sanitary Sewer Master Plan Update recommended $44,193,000 in capital improvements (in September 2002 dollars) to the collection system, of which $1,733,000 was allocated to existing customers.

1.4 SCOPE AND AUTHORIZATION

The purpose of this Master Plan is to update the 2003 Master Plan and to identify capacity deficiencies in the sanitary sewer system, develop feasible alternatives to correct these deficiencies, and plan the infrastructure that will serve future development projected by the Chico 2030 General Plan. In October 2011, the City approved a professional service agreement with Carollo Engineers, Inc. (Carollo), to prepare this Master Plan Update for the sanitary sewer. The professional services agreement, which was amended in February 2012, included the following main tasks:

- Task 1 - Project Management
- Task 2 - System Modeling and Capacity Needs Determination
- Task 3 - Capital Improvement Program
- Task 4 - Master Plan Report

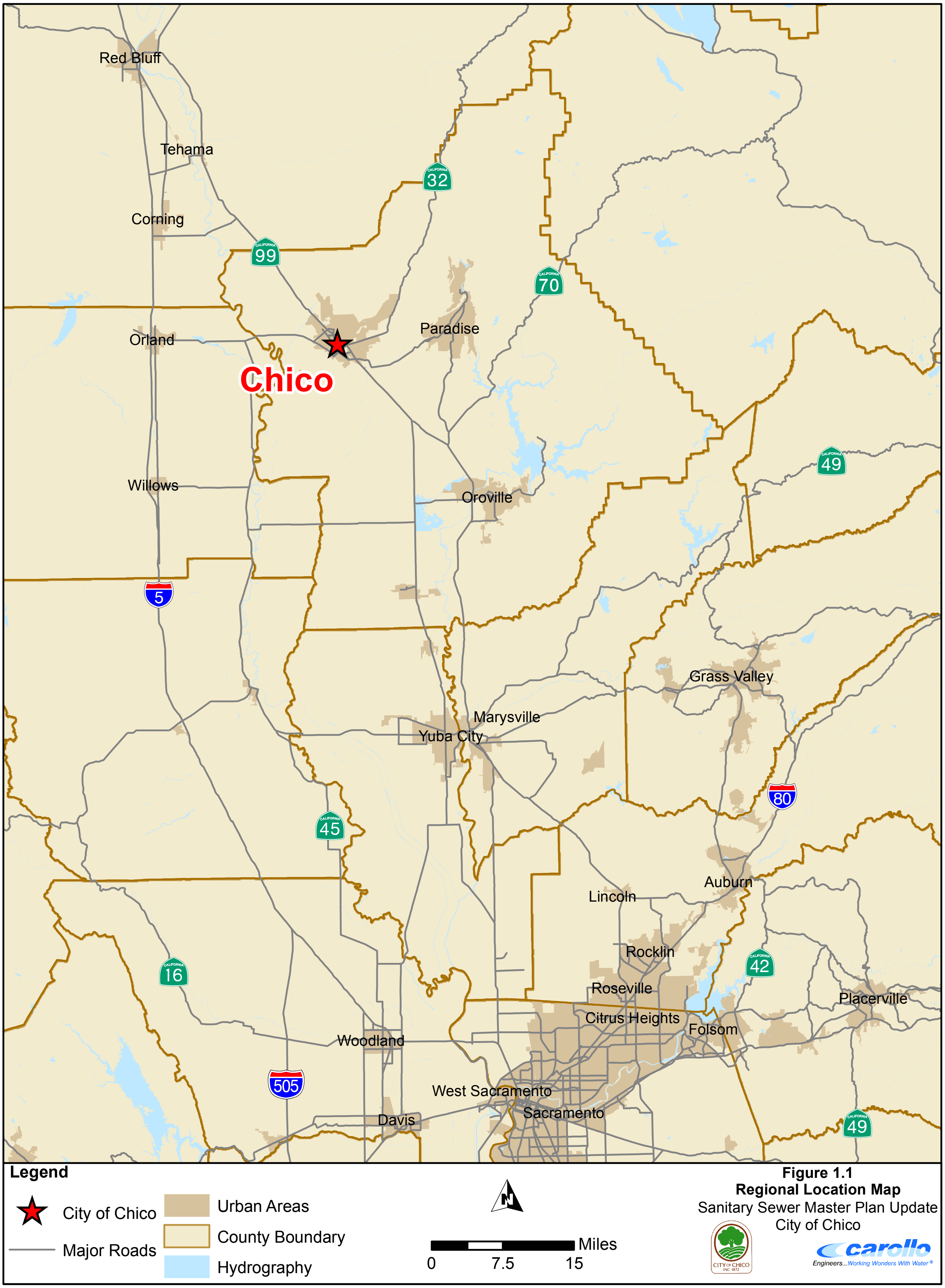

Figure 1.1
Regional Location Map
Sanitary Sewer Master Plan Update
City of Chico

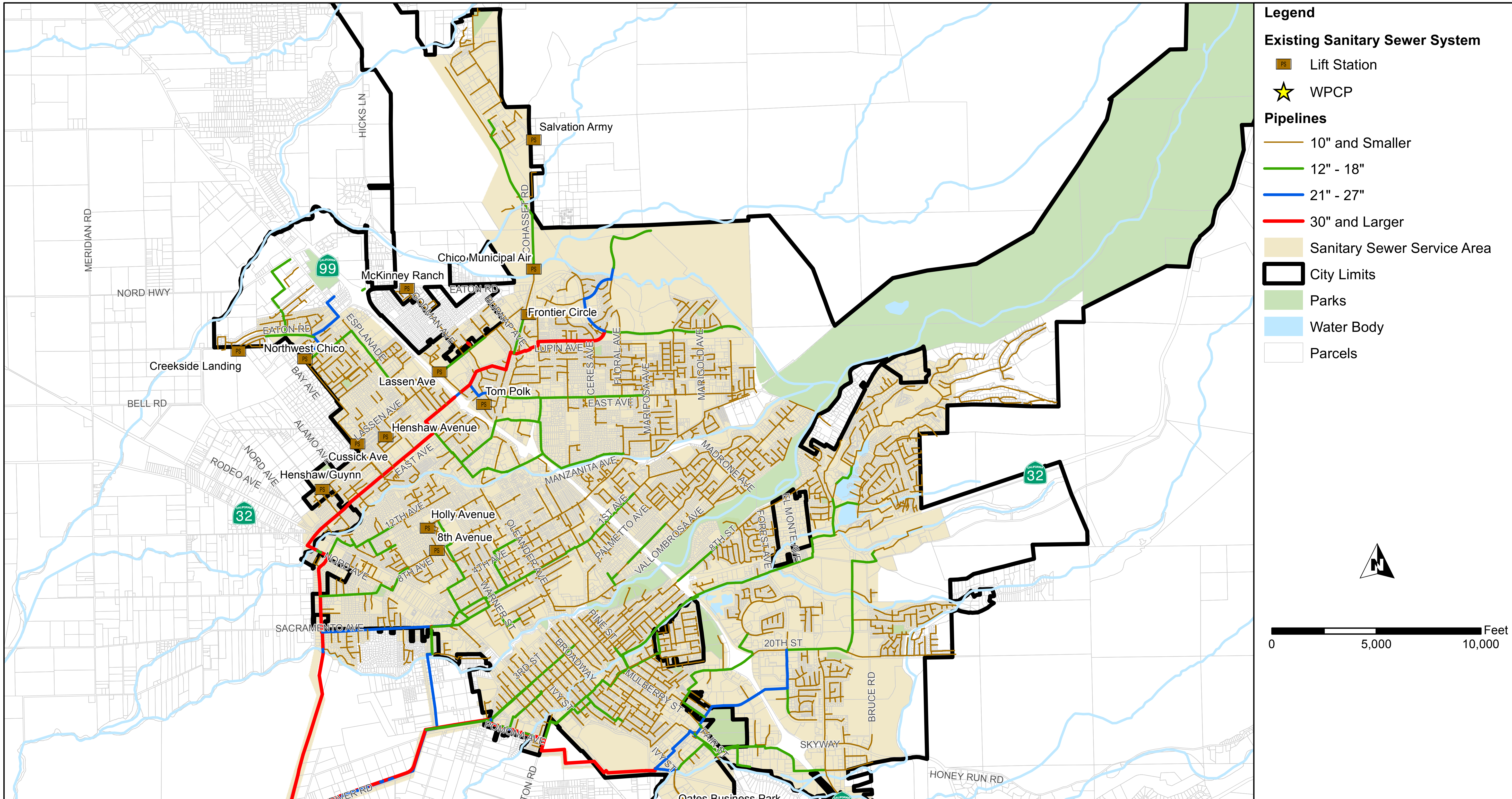

Figure 1.2
Sanitary Sewer Service Area
Sanitary Sewer Master Plan Update
City of Chico

1.5 REPORT ORGANIZATION

The Master Plan report contains seven chapters, followed by appendices that provide supporting documentation for the information presented in the report. The chapters are briefly described below:

Chapter 1 - Introduction. This chapter presents the need for this Master Plan and the objectives of the study. Lists of abbreviations and reference materials are also provided to assist the reader in understanding the information presented.

Chapter 2 - Study Area Description. This chapter presents a description of the study area, defines the planning horizon for this study, and summarizes the land use classifications.

Chapter 3 - Flow Monitoring Program. This chapter defines the typical components of wastewater in a collection system and the temporary flow monitoring program conducted as part of this study. The data and results from the flow monitoring program are summarized and discussed.

Chapter 4 - Collection System Facilities and Hydraulic Model. This chapter describes the development and calibration of the City's collection system hydraulic model. A description of the City's previous hydraulic model, the advantages of the newer modeling software being used for this Master Plan, and an outline of the steps used to build the model are provided. A detailed summary of the hydraulic model calibration steps, standards, and results for both dry weather and wet weather conditions is also provided.

Chapter 5 - Planning Criteria and Design Flows. The capacity of the City's sanitary sewer collection system was evaluated based on the planning criteria defined in this chapter. The planning criteria address the collection system capacity, gravity sewer pipe slopes, and maximum allowable depth of flow within a sewer. This chapter also summarizes the existing and build out design flows.

Chapter 6 - Capacity Evaluation and Proposed Improvements. This chapter discusses the hydraulic evaluation of the sewer collection system and the proposed projects that correct capacity deficiencies and serve future users.

Chapter 7 - Capital Improvement Plan. This chapter presents the capital improvement projects, a summary of the capital costs, and a basic assessment of the possible financial impacts on the City. This chapter presents the recommended capital improvement plan (CIP) for the City collection system and a summary of the capital costs.

1.6 ACKNOWLEDGMENTS

Carollo Engineers wishes to acknowledge and thank Mr. Fritz McKinley, former Building and Development Services Director; Mr. Ruben Martinez, General Services Director; Ms. Quene Hansen, former Capital Project Services Project Manager; Mr. Marc Sulik, Wastewater Treatment Plant Manager; Mr. Matt Thompson, Senior Civil Engineer; Mr. Rich Burgi, Associate Civil Engineer; Mr. Kirby White, Public Works Manager; and Mr. Brendan Vieg, Principal Planner. Their cooperation and courtesy in obtaining a variety of necessary information were valuable components in completing and producing this report.

1.7 ABBREVIATIONS AND DEFINITIONS

To conserve space and to improve readability, the following abbreviations are used in this report.

°F	Degrees Fahrenheit
2030 General Plan	Chico 2030 General Plan
AACE	Association for the Advancement of Cost Engineering
AAF	Average Annual Flow
ADWF	Average Dry Weather Flow
BWF	Base Wastewater Flow
Carollo	Carollo Engineers, Inc.
CCTV	Closed-Circuit Television
CEQA	California Environmental Quality Act
cfs	Cubic Feet Per Second
CIP	Capital Improvement Plan
City	City of Chico
CSUC	California State University, Chico
d/D	Flow Depth To Pipe Diameter Ratio
DWF	Dry Weather Flow
ENR CCI	Engineering News Record Construction Cost Index
EPA	United States Environmental Protection Agency

ft/s	Feet Per Second
ft^2	Square Feet
GIS	Geographic Information System
gpd	Gallons Per Day
gpd/ac	Gallons Per Day Per Acre
gpm	Gallons Per Minute
GUI	Graphical User Interface
GWI	Groundwater Infiltration
HGL	Hydraulic Grade Line
HP	Horsepower
I/I	Infiltration and Inflow
IDW	Inverse Distance Weighting
Master Plan	Sanitary Sewer Master Plan Update
mgd	Million Gallons Per Day
MSL	Mean Sea Level
n	Manning Friction Coefficient
NRCS	Natural Resources Conservation Service
PWWF	Peak Wet Weather Flow
RDII	Rainfall Derived Infiltration and Inflow
ROW	Right Of Way
SOI	Sphere of Influence
SPA	Special Planning Area
SSO	Sanitary Sewer Overflow
SWMM	Stormwater Management Model
V&A	V&A Consulting Engineers, Inc.
WaPUG	Wastewater Planning Users Group

WPCP	Water Pollution Control Plant
WWF	Wet Weather Flow

1.8 REFERENCE MATERIAL

The following documents were referenced in the preparation of this Master Plan:

- *Chico 2030 General Plan*, PMC, April 2011.
- *Chico 2030 General Plan Update Draft Environmental Impact Report*, PMC, September 2010
- *City of Chico Sanitary Sewer Master Plan Update Report*, Final, Carollo Engineers, May 2003.
- *City of Chico Sewer System Management Plan*, 1st Audit, RMC Water and Environment, July 2011.

STUDY AREA DESCRIPTION

This chapter presents a description of the study area, defines the planning horizon for the study, and summarizes the land use classifications.

2.1 STUDY AREA

The area serviced by the City of Chico (City) is characterized as a growing and dynamic residential community with a significant number of students or employees of California State University, Chico (CSUC). There are a variety of residential neighborhoods ranging from rural residential to very high density residential in the downtown commercial district.

There are also several open space areas within the City, including Bidwell Park, California Park Lake, and the Chico Cemetery. The primary water bodies flow east to west through the City service area, and include Big Chico Creek, Little Chico Creek, Lindo Channel, Comanche Creek, and Sycamore Creek. The Sierra Nevada Mountains are located just east of the City. The Sacramento River is located roughly 5 miles west of the current City limits.

There are two major highways that run through the City. State Route 32 and 99 comprise the City's regional transportation network and serve much of the population in Butte County. State Route 32 connects Chico residents to Glenn and Plumas counties to the west and east, respectively. State Route 99 connects residents to Tehama and Sutter counties to the north and south, respectively[1].

The City's proposed Sphere of Influence (SOI), as defined in Chico 2030 General Plan (2030 General Plan) is the study area boundary for this Sanitary Sewer Master Plan Update (Master Plan). The Master Plan study area boundary and the SOI are synonymous and will be used interchangeably throughout this report. The SOI extends beyond the current sewer service area and is approximately 28,094 acres (43.9 square miles). This Master Plan is intended as the guiding document to plan and implement sewer system improvements to accommodate future growth within the SOI. Figure 2.1 shows the study area boundary and the current City limits.

2.2 PLANNING PERIOD

The Master Plan study area is intended to include the existing City limits and development that could occur through build out of the City's proposed SOI. Existing and build out land uses within the study area are discussed in this chapter.

[1] Chico 2030 General Plan Update Draft Environmental Impact Report, September 2010.

2.3 CLIMATE

The City's study area is characterized by a Mediterranean-type climate with wet, mild winters, and warm, dry summers. Table 2.1 summarizes the maximum and minimum monthly temperatures as well as the average monthly precipitation. January is the City's coldest and wettest month, with an average high temperature of 53.9 degrees Fahrenheit (°F), an average low temperature of 35.6 °F, and 5.3 inches of precipitation. July is the City's hottest month, with an average high temperature of 96.4 °F and an average low temperature of 60.3 °F. Approximately 80 percent of the annual rainfall occurs between November and April, with an average annual rainfall of 25.66 inches.[2]

Table 2.1 Study Area Climate
Sanitary Sewer Master Plan Update
City of Chico

Month	Average Maximum Temperature (ºF)	Average Minimum Temperature (ºF)	Average Monthly Rainfall (inches)
January	53.9	35.6	5.30
February	60.2	38.6	4.44
March	65.6	40.9	3.43
April	72.8	44.6	1.85
May	81.2	50.5	0.98
June	89.7	56.4	0.45
July	96.4	60.3	0.02
August	94.8	58.0	0.09
September	89.5	54.2	0.44
October	78.6	47.1	1.38
November	64.9	40.1	2.92
December	54.9	35.9	4.38
Annual	**75.2**	**46.8**	**25.66**

Notes:
(1) Source: Western Regional Climate Center, Chico Experiment Station 041715, www.wrcc.dri.edu.

[2] Source: Historical data from Western Regional Climate Center, Chico Experiment Station 041715. www.wrcc.dri.edu

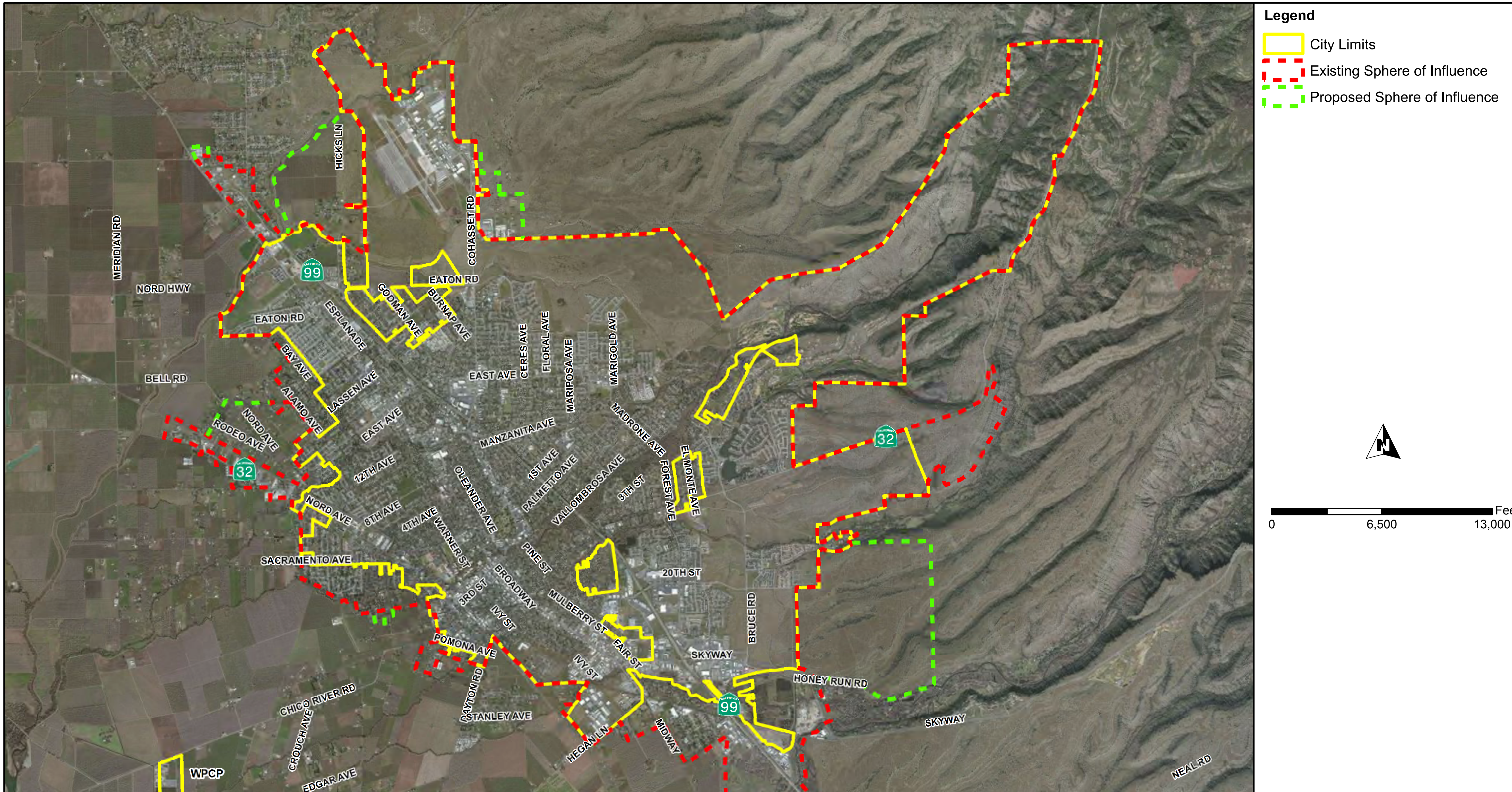

Figure 2.1
Study Area
Sanitary Sewer Master Plan Update
City of Chico

2.4 TOPOGRAPHY

The City is located on the Sacramento Valley floor near the base of the Sierra/ Nevada Mountains. The majority of the City is relatively flat and sloping to the southwest, but elevations increase on the eastern side of the City limits approaching the foothills. The City ranges in elevation from about 132 feet above mean sea level (MSL) in the west to about 1,666 feet above MSL in the hills in the east. The average elevation throughout the City is approximately 230 above MSL. Figure 2.2 shows the general topography of the study area.

2.5 LAND USE

The 2030 General Plan guides development within the City's planning boundary and establishes the long-range development policies. The 2030 General Plan also provides land use projections. Land use information is an integral component in determining the amount of wastewater generation within the City. The type of land use in an area will affect the volume and character of the wastewater generation. Adequately estimating the generation of wastewater from various land use types is important in sizing and maintaining effective sewer system facilities.

Land use assumptions used in this study are consistent with the 2030 General Plan. Since the land use assumptions forecast the type of growth within the study area, this association to the Master Plan should ensure that the wastewater generation projections and facilities required to serve future growth are consistent with the City's guiding document on development. Figure 2.3 illustrates the different land uses found in the General Plan. The study area's land use designation and respective acreage totals are summarized in Table 2.2. As can be seen in Table 2.2, the City is expected to grow from approximately 12,000 acres of currently developed lands to approximately 28,000 acres or approximately 135 percent. Appendix A provides a description of the different land uses. The descriptions are excerpts from the General Plan.

2.5.1 Existing Wastewater Service Area Land Use

The City provides wastewater collection service to residents, businesses, and other institutions within its City limits. Table 2.2 provides the acreage totals by land use classification within the proposed SOI. Also included in Table 2.2 are the land use totals for the current service area, and the breakdown between developed land, which generates wastewater flow, and undeveloped land that will be developed in the future. The City's current sewer service area consists of approximately 14,390 acres (includes developed and undeveloped land) or 22.5 square miles.

The largest land use category is residential (very low density, low density, medium density, medium-high density, high density, and residential mixed use), which accounts for approximately 44 percent of the total current sewer service area.

Commercial and industrial land uses (neighborhood commercial, commercial mixed use, commercial services, office mixed use, industrial/office mixed use, and manufacturing and warehousing) make up approximately 16 percent of the total. Other land uses such as public facilities and services, primary and secondary open space, streets, and other miscellaneous land uses account for approximately 40 percent of the total service area.

2.5.2 Build Out Wastewater Service Area Land Use

At build out of the proposed SOI, the City will encompass approximately 28,094 acres. Build out is defined as development of all land within the proposed SOI. Figure 2.3 and Table 2.2 include three different types of new growth within the City's proposed SOI that include special consideration due to the significant impacts that growth or development within these areas could mean to wastewater flows and the potential impacts to the collection system. These include:

- **Special Planning Areas (SPAs)**. This designation identifies areas with significant new growth potential and carries a requirement for subsequent planning prior to development. Within each SPA, the City has identified a mix of desired land uses in the form of a conceptual land plan. The 2030 General Plan identifies five separate SPAs, which are shown in gray on Figure 2.3:
  - Bell Muir
  - Barber Yard
  - Doe Mill/Honey Run
  - North Chico
  - South Entler
- **Opportunity Sites**. This designation identifies areas that provide a greater opportunity for change or improvement within the General Plan planning horizon. These Opportunity Sites have parcel-specific land use designations as well as special policy considerations. Opportunity Sites are shown on Figure 2.3 with a purple outline with a purple diagonal hatch fill pattern and labeled with numbers. There are a total of 15 Opportunity Sites.
- **Resource Constraint Overlays**. The Land Use Diagram identifies three areas with sensitive biological resources that will constrain development. Resource Constraint Overlay areas are identified on Figure 2.3 by a brown outline with a brown diagonal fill pattern.

These areas were considered separately during the development of the wastewater flow projections. Chapter 5 summarizes the methods used for the development of flows within these planning areas.

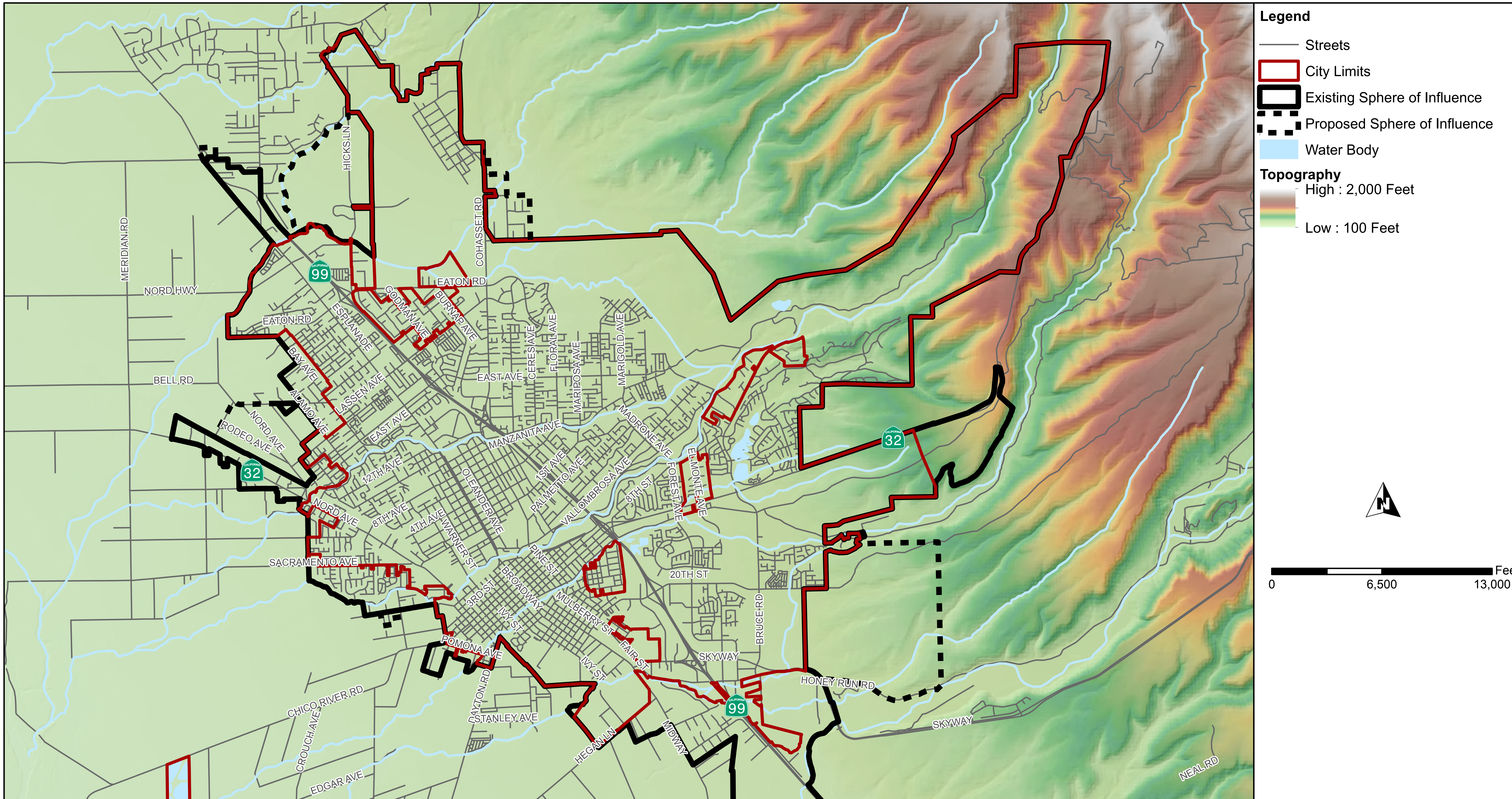

Figure 2.2
Study Area Topography
Sanitary Sewer Master Plan Update
City of Chico

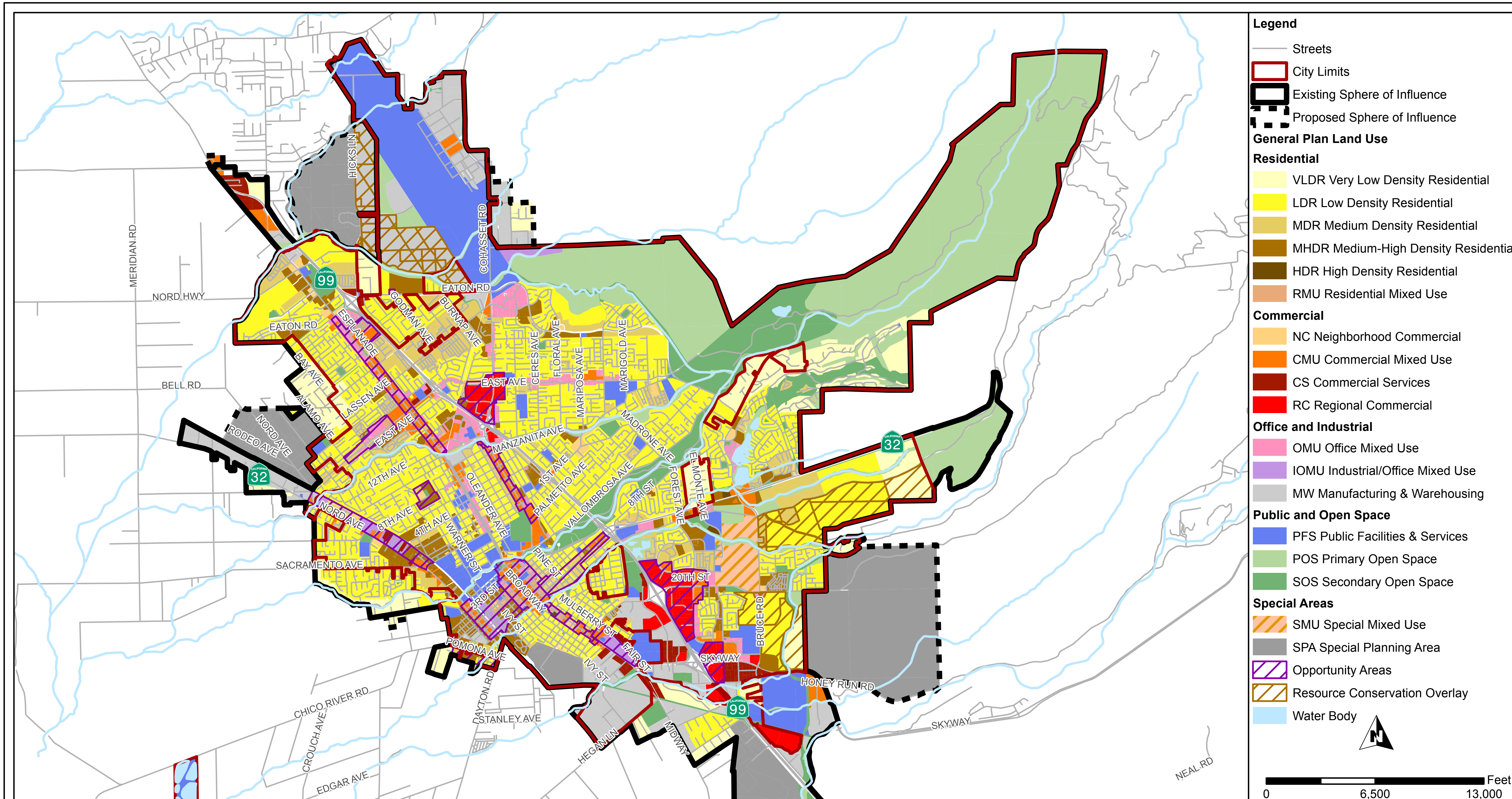

Figure 2.3
General Plan Land Use
Sanitary Sewer Master Plan Update
City of Chico

Table 2.2 General Plan Land Use
Sewer System Master Plan Update
City of Chico

Land Use Category	Existing Sewer Service Area							Build Out Sewer Service Area			
	Developed Area			Vacant Area							
	Non-Opportunity Area (acres)	Opportunity Area (acres)	Developed Area Subtotal (acres)	Non-Opportunity Area (acres)	Opportunity Area (acres)	Vacant Area Subtotal (acres)	Total Area (acres)	Non-RCO/ Opportunity Area (acres)	Resource Constraint Overlay (acres)	Opportunity Area (acres)	Total Buildout Area (acres)
VLDR Very Low Density Residential	214.9	0.0	214.9	89.8	0.0	89.8	304.7	1,545.6	186.3	0.0	1,731.9
LDR Low Density Residential	3,718.1	22.1	3,740.1	578.3	1.1	579.4	4,319.5	5,018.0	551.3	23.2	5,592.5
MDR Medium Density Residential	640.5	77.8	718.3	212.7	13.7	226.4	944.6	1,005.7	41.9	91.5	1,139.0
MHDR Medium-High Density Residential	481.3	88.2	569.4	102.0	4.4	106.3	675.7	680.8	24.5	92.5	797.9
HDR High Density Residential	4.7	1.6	6.3	4.4	0.0	4.4	10.6	9.0	0.0	1.6	10.6
CS Commercial Services	109.3	5.7	115.0	13.6	4.5	18.2	133.2	194.0	0.0	10.2	204.2
NC Neighbhorhood Commerical	26.7	16.4	43.2	22.3	5.0	27.3	70.5	73.3	0.0	21.5	94.7
RC Regional Commercial	71.3	242.3	313.6	67.5	36.0	103.5	417.1	138.9	0.0	278.3	417.2
MW Manufacturing and Warehousing	448.2	3.1	451.3	219.8	0.0	219.8	671.2	1,301.1	482.3	3.1	1,786.5
IOMU Industrial/Office Mixed Use	0.0	70.0	70.0	60.5	2.1	62.6	132.6	41.6	0.0	91.0	132.6
OMU Office Mixed Use	280.0	55.7	335.8	49.3	7.0	56.2	392.0	324.3	5.0	62.7	392.0
CMU Commercial Mixed Use	199.4	260.3	459.7	52.3	15.5	67.8	527.5	336.2	3.3	275.8	615.3
RMU Residential Mixed Use	0.5	49.2	49.7	0.0	18.9	18.9	68.6	0.1	0.0	68.1	68.2
SMU Special Mixed Use	4.3	0.0	4.3	192.5	0.0	192.5	196.8	196.8	0.0	0.0	196.8
PFS Public Facilities and Services	665.3	15.0	680.3	296.1	0.0	296.1	976.4	2,037.3	0.0	15.0	2,052.3
SPA Special Planning Area	11.0	0.0	11.0	133.8	0.0	133.8	144.8	2,733.4	0.0	0.0	2,733.4
POS Primary Open Space	1,112.5	3.7	1,116.2	0.2	0.0	0.2	1,116.4	5,202.0	0.0	3.7	5,205.7
SOS Secondary Open Space	401.0	8.4	409.4	31.5	0.4	32.0	441.3	1,704.8	0.0	8.8	1,713.6
Streets, Canals, etc.	2,369.5	300.7	2,670.2	0.0	0.0	0.0	2,670.2	2,909.1	0.0	300.7	3,209.8
Agriculture	175.5	0.0	175.5	0.0	0.0	0.0	175.5	0.0	0.0	0.0	0.0
Total	**10,934.0**	**1,220.3**	**12,154.2**	**2,126.7**	**108.5**	**2,235.2**	**14,389.5**	**25,451.9**	**1,294.7**	**1,347.7**	**28,094.2**

FLOW MONITORING PROGRAM

This chapter defines the typical components of wastewater in a collection system and the temporary flow monitoring program conducted as part of this study. The data and results from the flow monitoring program are summarized and discussed.

3.1 FLOW MONITORING SITES AND RAIN GAUGES

As part of the Scope of Services for this Sewer System Master Plan Update, Carollo Engineers, Inc. (Carollo) contracted with V&A Consulting Engineers (V&A) to conduct a temporary flow monitoring program within the City of Chico (City) sanitary sewer collection system. The purpose of the flow monitoring program was to assist in the development of design flow criteria, and to correlate actual collection system flows to the hydraulic model predicted flows. Flow monitoring data was also used to calibrate the collection system hydraulic model for dry weather and wet weather flow, and to help to identify areas of the system with the highest rates of infiltration/inflow (I/I). The temporary flow monitoring program was conducted for a period of approximately 10.5 weeks from February 23, 2012 to May 7, 2012.

The “Sanitary Sewer Flow Monitoring and Inflow/Infiltration Study, August 2012” prepared by V&A summarizes the flow monitoring program and was submitted to the City of Chico (City) as a stand-alone report. A copy of the report is included in Appendix B.

3.1.1 Flow Monitoring Sites and Tributary Areas

A total of seventeen (17) open-channel flow meters were installed at locations selected by Carollo and the City. The meter sites were selected to best isolate and model the critical areas and subareas within the sewer system. The 17 flow monitoring locations, as well as the area tributary to each site, are shown on Figure 3.1. Table 3.1 lists the flow monitoring locations and the diameters for the sewers where the meters were installed. Figure 3.2 provides a schematic illustration of the flow monitoring locations.

3.1.2 Flow Meter Installation and Flow Calculation

A mixture of Teledyne Isco 2150, Hach Sigma 910, and Marsh-McBirney Flo-Dar flow meters were used for this project. Isco 2150 and Sigma 910 meters use a pressure transducer to collect depth readings and ultrasonic Doppler sensors on the probe to determine the average fluid velocity. A Flo-Dar flow meter is a non-contact flow meter that uses radar to measure velocity and a down-looking ultrasonic sensor to measure depth. V&A selected the optimal type of flow meter to use on a site-to-site basis based on the hydraulic characteristics at each site, as well as other factors. For example, the Flo-Dar flow meter is commonly used in high velocity, small diameter pipes.

Table 3.1 Flow Monitoring Locations
Sanitary Sewer Master Plan Update
City of Chico

Monitor Site	Manhole ID	Pipe Diameter (in.)	Location
1	54002	30	460 W. East Avenue
4	35012	36	1190 Glenwood Avenue
5	45045	15	1042 Nord Avenue
6A	45024	18	1000 W Sacramento Avenue
6B	45010A	18	1000 W Sacramento Avenue
7	66003	15	150 feet from E 10th Street on Humboldt Avenue
8	35050	24	Intersection of W Sacramento Avenue and Westmont Court
9	46040	21	Intersection of Rose Avenue and Santa Clara Avenue
10	47014	18	Intersection of Pomona Avenue and Dayton Road
11	47015	33	Dayton Rd between Poppy Street and McIntosh Avenue
12	46149	14	Intersection of Hickory Street and W 5th Street
13	46097	12	Intersection of Maple Street and W 5th Street
14	47013	18	Intersection of Pomona Avenue and Dayton Road
15	57040	27	2309 Park Avenue
16	64016	33	600 El Varano Way
17	64073	24	Intersection of Tom Polk Avenue and Lynnwood Court
18	46075	10	Intersection of Warner Street and La Vista Way

In order to ensure that each meter was accurate and calibrated, manual level and velocity measurements were taken by V&A when each meter was installed and again when they were removed. These manual measurements were compared to simultaneous level and velocity readings from the flow meters. The pipe diameter was also verified, because the pipe diameter is needed to calculate flow rate in a pipe based on the velocity and level measurements. In addition, the depth of sediment, if any, was measured as this affects the cross sectional area of flow within a pipe.

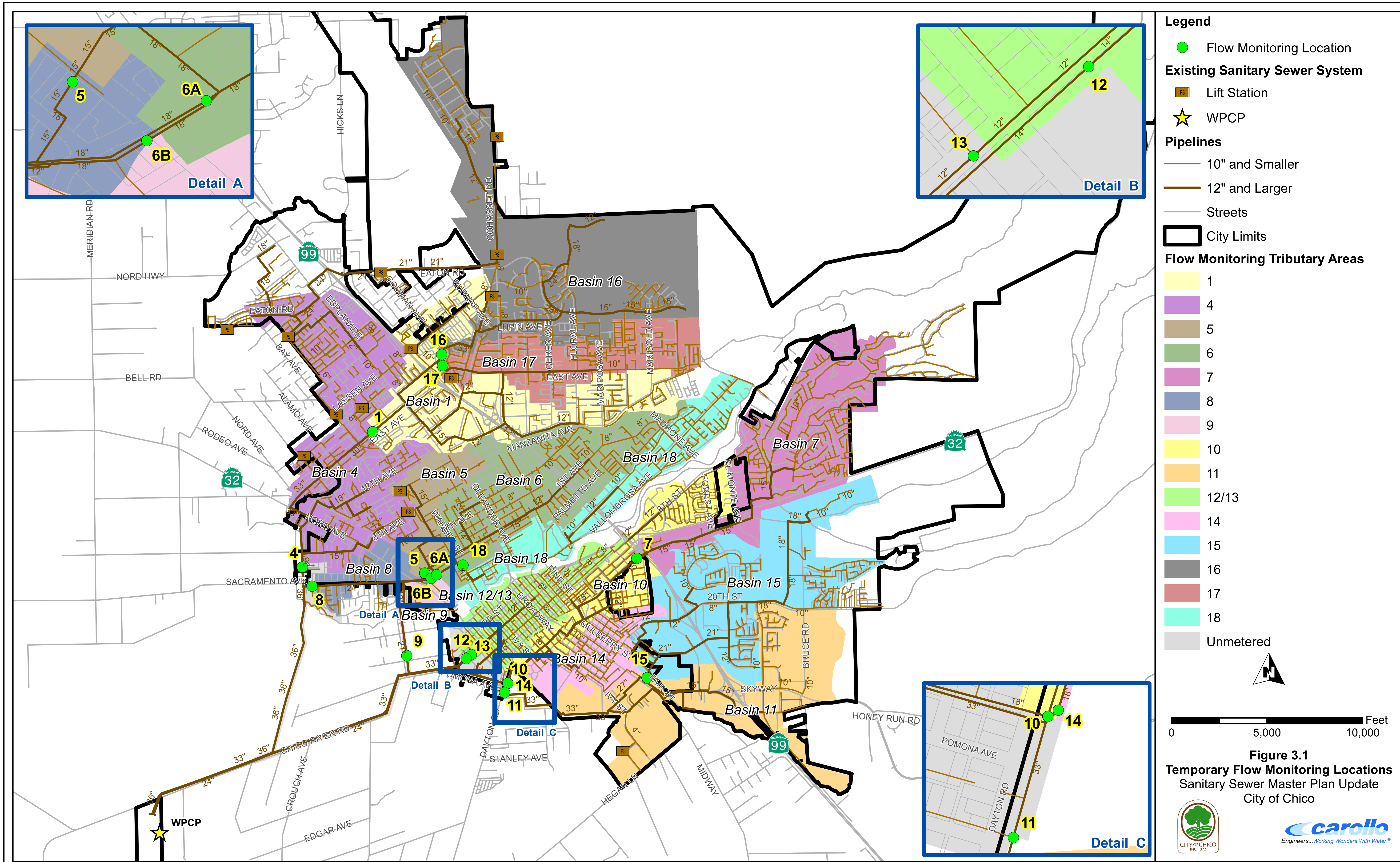

Figure 3.1
Temporary Flow Monitoring Locations
Sanitary Sewer Master Plan Update
City of Chico

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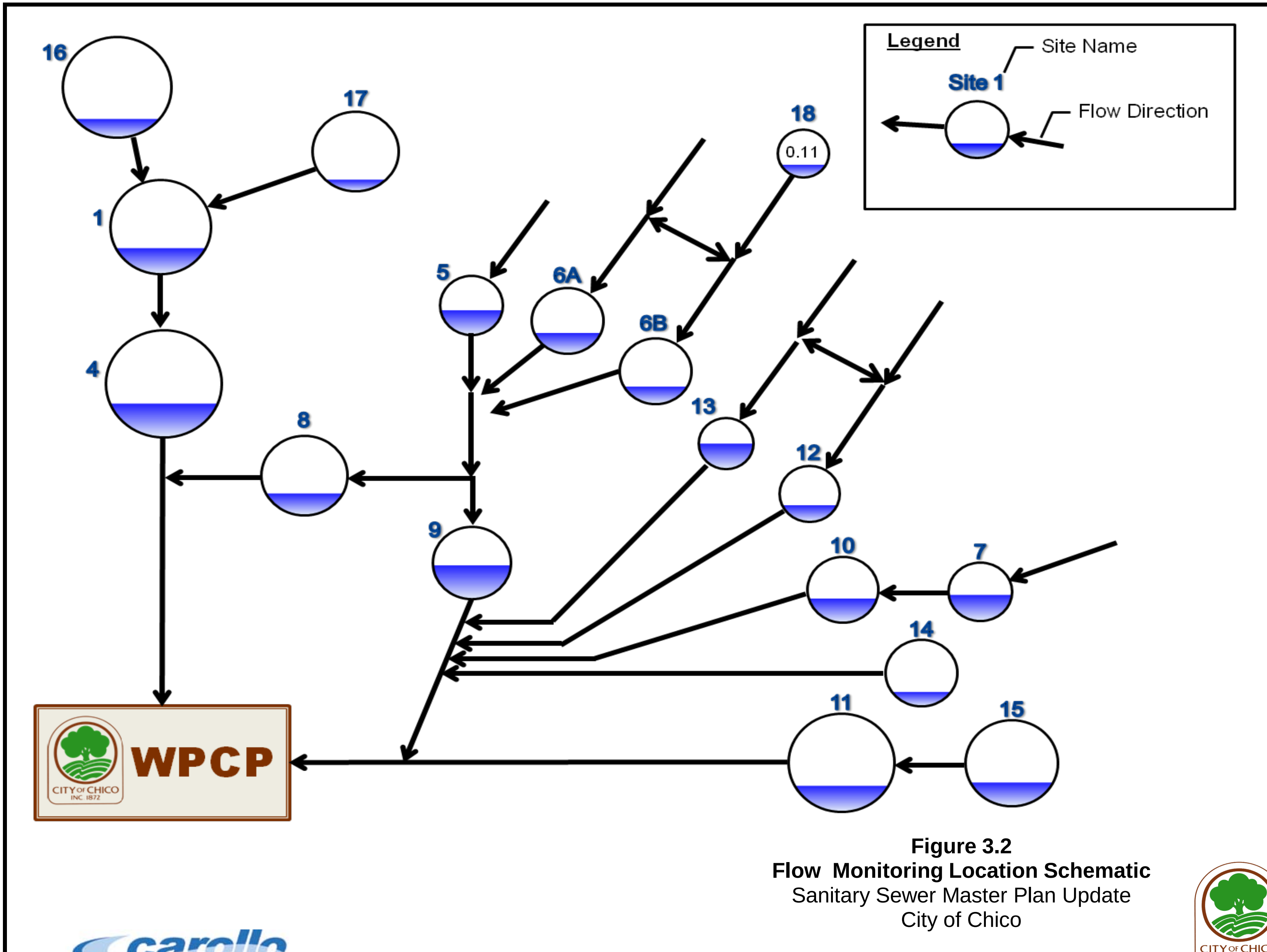

Figure 3.2
Flow Monitoring Location Schematic
Sanitary Sewer Master Plan Update
City of Chico

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V&A conducted an analysis of the data retrieved from each flow meter, and made adjustments as needed for calibration based on the field measurements, and to account for any sediment build up. The flow at each meter was then calculated at 5-minute intervals based on the continuity equation:

$$Q = V \times A$$

where,

Q = Pipeline flow rate, cfs

V = Average velocity, ft/s

A = Cross sectional flow area, ft^2

Finally, the 5-minute flow, velocity, and level data were aggregated into 15-minute increments.

3.1.3 Rain Gauges

Two rain gauges were installed by V&A as part of the flow monitoring program to capture rainfall that occurred throughout the study area. The location of each rain gauge is shown on Figure 3.3 and summarized in Table 3.2. Additional rainfall data was obtained from three additional rain gauges located throughout the City, which are maintained by local weather enthusiasts. The location of each of these rain gauges is also shown on Figure 3.3. V&A performed a quality assurance, quality control review of the data from these three rain gauges and it appeared to be valid and appropriate to use for the purposes of this study.

3.2 WASTEWATER FLOW COMPONENTS

As a way to help the reader understand the wastewater flow components, this section describes and provides definitions of commonly used terminology in the wastewater collection system analysis and evaluations conducted as part of this project. In general, wastewater consists of dry weather flow (DWF) and wet weather flow (WWF). DWF (or base flow) is flow generated by routine water usage in the residential, commercial, business and industrial sectors of the collection system.

Table 3.2 Rain Gauge Locations Sanitary Sewer Master Plan Update City of Chico		
Rain Gauge Number	**Installed**	**Location** **Col 4**
RG1	V&A	Rosedale Elementary School
RG2	V&A	Parkview Elementary School
Chico 14	Local Weather Enthusiast	Skyway Road between Park Avenue and Highway 99
Chico 26	Local Weather Enthusiast	Cohasset Road near Kovak Court
Chico 29	Local Weather Enthusiast	Just south of Canyon Oaks Golf Course

The other component of DWF is the contribution of dry weather groundwater infiltration (GWI) into the collection system. Dry weather GWI will enter the sewer system when the relative depth of the groundwater table is higher than the depth of the pipeline and when the susceptibility of the sanitary sewer pipe allows infiltration through defects such as cracks, misaligned joints, and broken pipelines.

WWF includes storm water inflow, trench infiltration, and GWI. The storm water inflow and trench infiltration comprise the WWF component termed I/I. The response in the sewer system to rainfall is seen immediately (as with inflow) or within hours after the storm (as with infiltration).

The third element of WWF is GWI, which is not specific to a single rainfall event, but rather to the effects on the sewer system over the entire wet weather season. The depth of the groundwater table rising above the pipe invert elevation causes GWI. Sewer pipes within close proximity to a body of water can be greatly influenced by groundwater effects. As the groundwater table fluctuates over the wet weather season, this fluctuation is seen as a mounding effect in flow monitoring data. Figure 3.4 illustrates the various flow components, which are described in detail in the following sections.

3.2.1 Base Wastewater Flow

The base wastewater flow (BWF) is the flow generated by the City's customers. The flow has a diurnal pattern that varies depending on the type of use. Commercial and industrial patterns, though they vary depending on the type of use, typically have more consistent higher flows during business hours and lower flows at night. Furthermore, the diurnal flow pattern experienced during a weekend may vary from the diurnal flow experienced during a weekday.

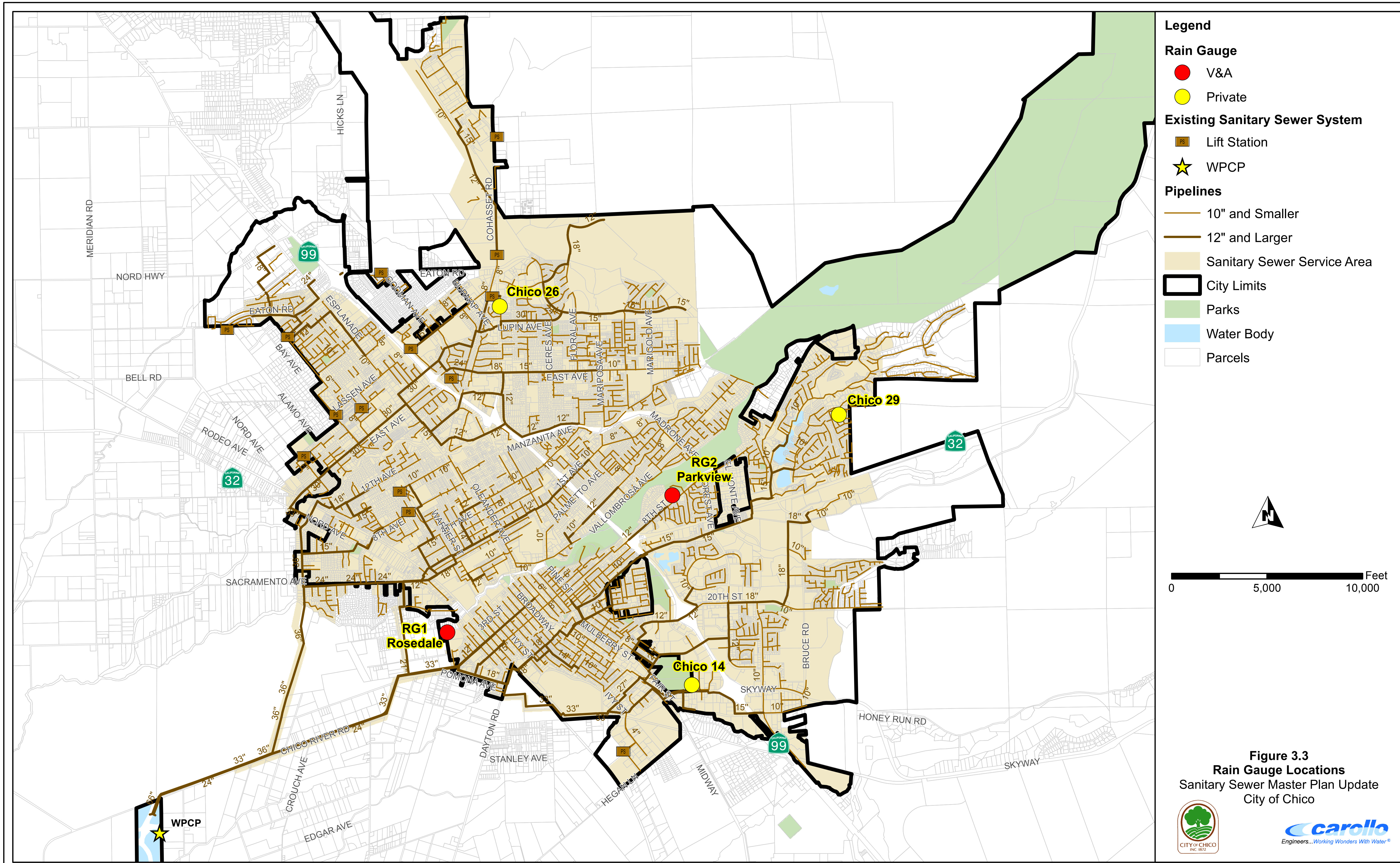
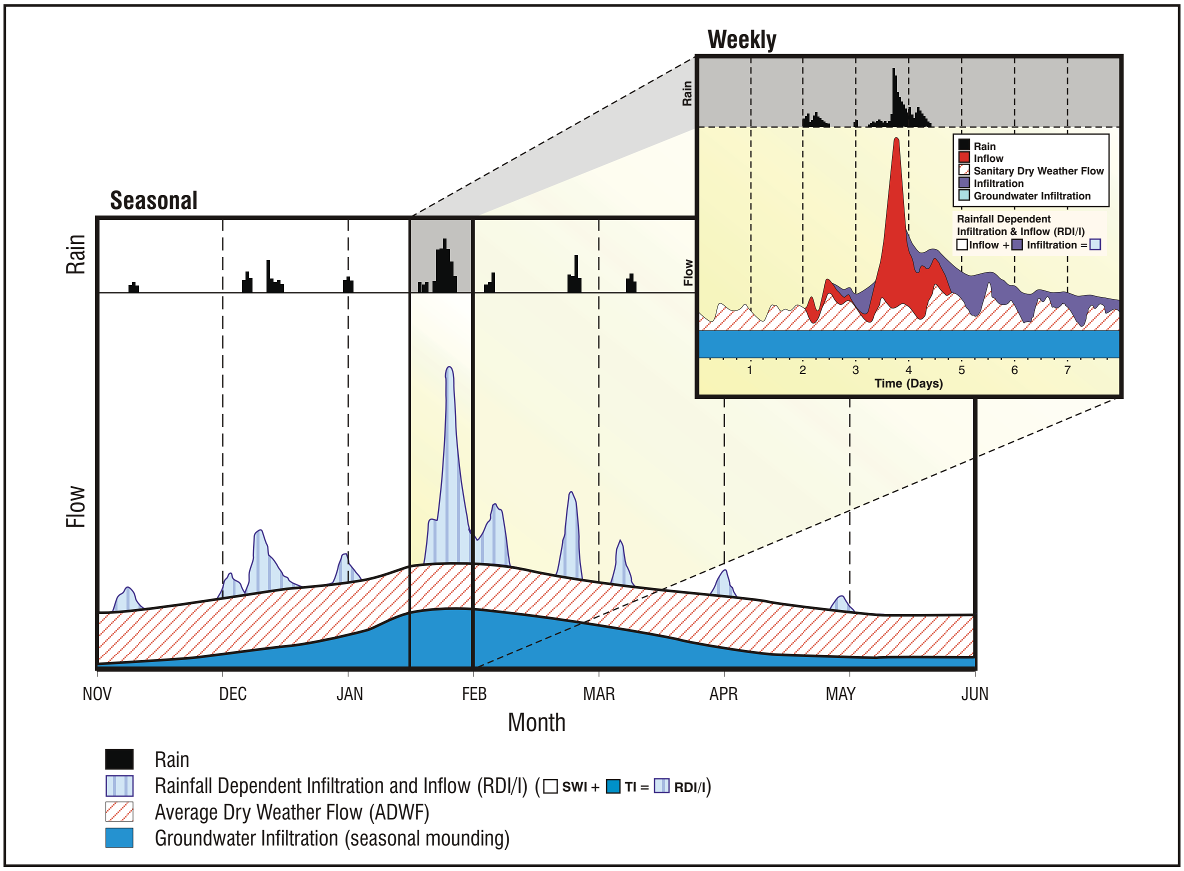
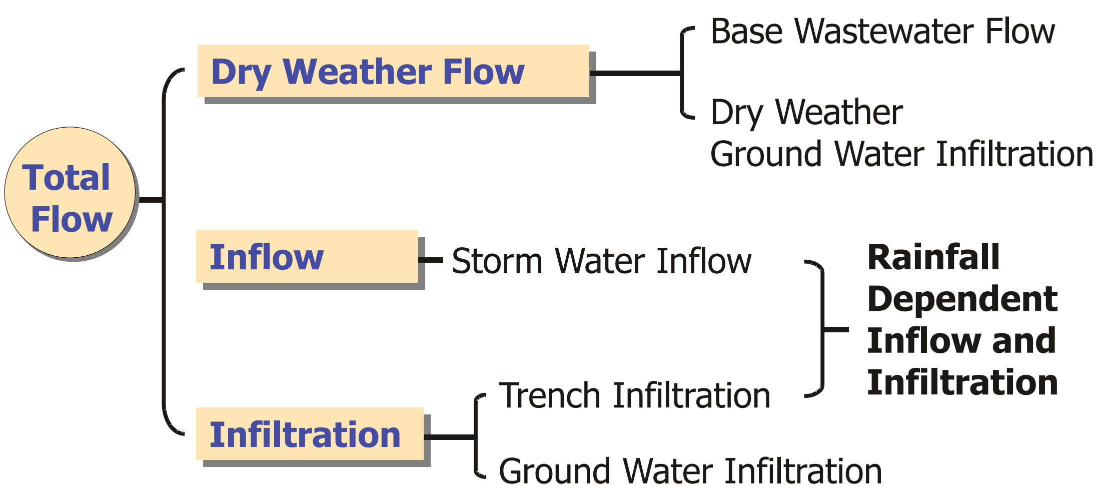


Figure 3.3
Rain Gauge Locations
Sanitary Sewer Master Plan Update
City of Chico





Note: This figure is not based on flow data specific to the City or this Master Plan

Figure 3.4
Typical Wastewater Flow Components
Sanitary Sewer Master Plan Update
City of Chico

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3.2.2 Average Annual Flow

The average annual flow (AAF) is the average flow that occurs on a daily basis throughout the year, including both periods of dry and wet weather conditions.

3.2.3 Average Dry Weather Flow

The Average Dry Weather Flow (ADWF) is the average flow that occurs on a daily basis during the dry weather season. The ADWF includes the BWF generated by the City's residential, commercial, and industrial users, plus the dry weather GWI component. For the City, the ADWF was estimated throughout the service area based on the historical influent flow data from the City's Water Pollution Control Plant (WPCP), and from the flow monitoring program.

3.2.4 Groundwater Infiltration

GWI, one of the components of I/I, is associated with extraneous water entering the sewer system through defects in pipes and manholes. GWI is related to the condition of the sewer pipes, manholes, and groundwater levels. GWI may occur throughout the year, although rates are typically higher in the late winter and early spring. Dry weather GWI (or base infiltration) cannot easily be separated from BWF by flow measurement techniques. Therefore, dry weather GWI is typically grouped with BWF.

3.2.5 Infiltration and Inflow

All wastewater collection systems have some I/I, although the characteristics and severity vary by region and individual collection system. Some of the most common sources of I/I are shown on Figure 3.5. Infiltration is defined as storm water flows that enter the sewer system by percolating through the soil and then through defects in pipelines, manholes, and joints. Examples of infiltration entry points are cracks in pipelines, misaligned joints, and root penetration. Inflow is defined as storm water that enters the sewer system via a storm drain cross connections, leaky manhole covers, or cleanouts. Examples of inflow entry points are roof drain and downspout connections, leaky manhole covers, and illegal storm drain connections.

The adverse effects of I/I entering the sewer system is that it increases both the flow volume and peak flows, as illustrated on Figure 3.6. If too much I/I enters the sewer system such that the sewer system is operating at or above its capacity, sanitary sewer overflows (SSOs) could occur.

3.2.6 Peak Wet Weather Flow (Design Flow)

Peak wet weather flow (PWWF) is the highest observed flow that occurs following a design storm event. Wet weather I/I cause flows in the collection system to increase. PWWF is typically used for designing sewers and lift stations. Therefore, the PWWF and the "Design Flow" are synonymous and will be used interchangeably throughout this report.

3.3 FLOW MONITORING RESULTS

This section summarizes the results of the flow monitoring program, including dry weather flow data, rainfall data, and wet weather flow data. Data collected from Meter 17 is presented throughout this and other chapters as an example of the type of data and the results from the flow monitoring program. Refer to Appendix B for additional data summaries and other information associated with the remaining meter sites.

3.3.1 Dry Weather Flow Data

During the flow monitoring period, depth and velocity data were collected at each meter at 5-minute intervals. The 5-minute data was then aggregated to 15-minute data by V&A. Carollo aggregated the 15-minute data to hourly data for use in the hydraulic model. Characteristic dry weather 24 hour diurnal flow patterns for each site were developed based on the hourly data. This hourly flow data was then used to calibrate the hydraulic model for the observed dry weather flows during the flow monitoring period.

Hourly patterns for weekday and weekend flows vary and are separated to better understand dry weather flow. V&A used the data from days least affected by rainfall to estimate the weekday and weekend dry weather flows. In addition, V&A provided estimates for the average weekday and weekend levels and velocities at each site, which are used in dry weather flow calibration. Figure 3.7 illustrates a typical variation of weekday and weekend flow in the City, which is based on the data collection from Meter 17. Similar graphics associated with the remaining sites are included in Appendix B. Table 3.3 summarizes the dry weather flows at each meter. Figure 3.8 provides a schematic illustration of the information presented in Table 3.3.

3.3.2 Rainfall Data

There were three main rainfall events that occurred during the course of the flow monitoring period, as well as a few other relatively minor events. Figure 3.9 illustrates the total accumulation of rainfall over the course of the flow monitoring period for each of the five rain gauges. Table 3.4 summarizes the total rainfall recorded at each of the five rain gauges during the three main rainfall events, as well as over the entire flow monitoring period. The flow monitoring report prepared by V&A (Appendix B) classifies each of the three main rainfall events as less than 2-year, 24-hour events for all five rain gauges.

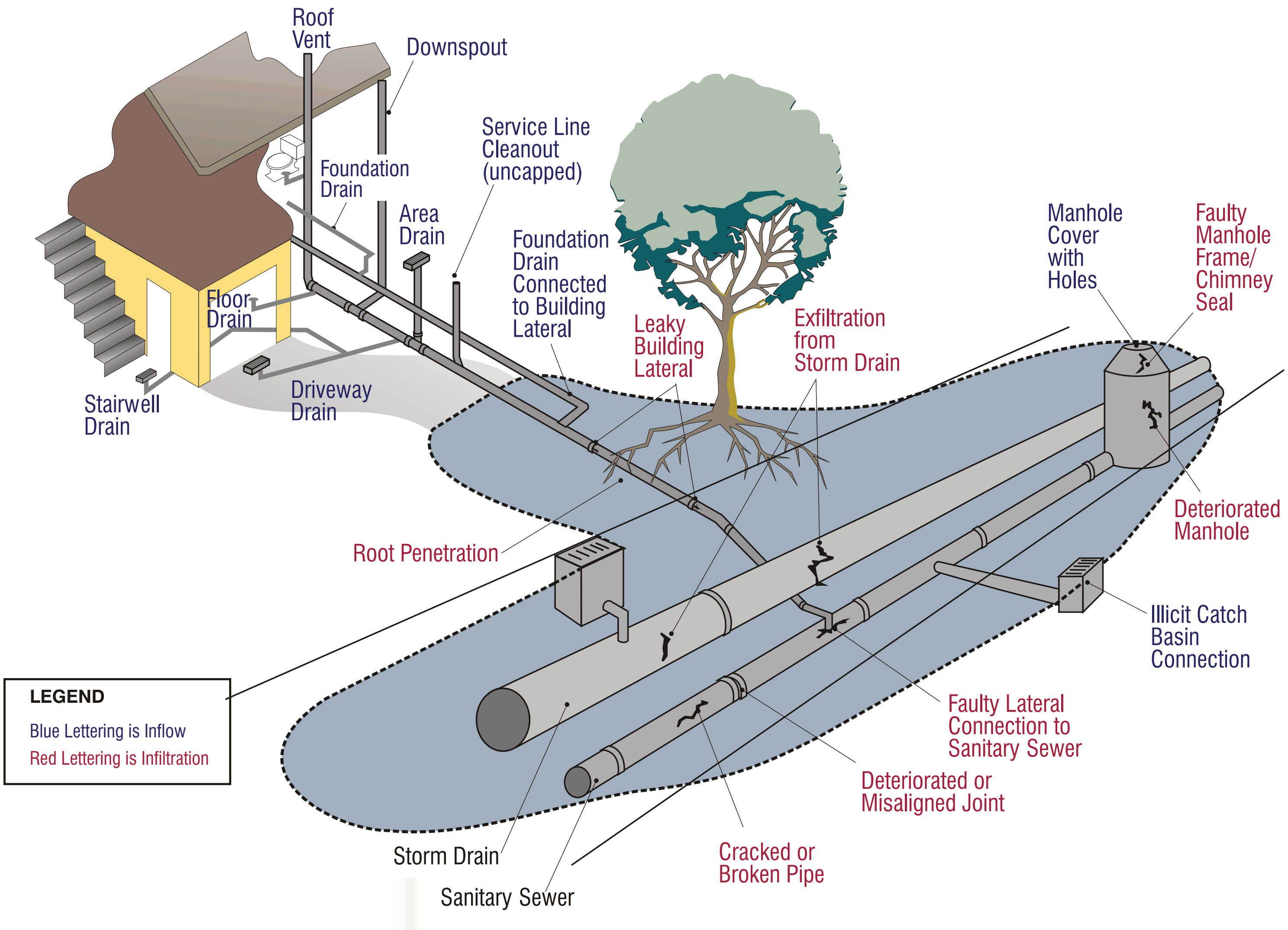

Figure 3.5
Typical Sources of Infiltration and Inflow
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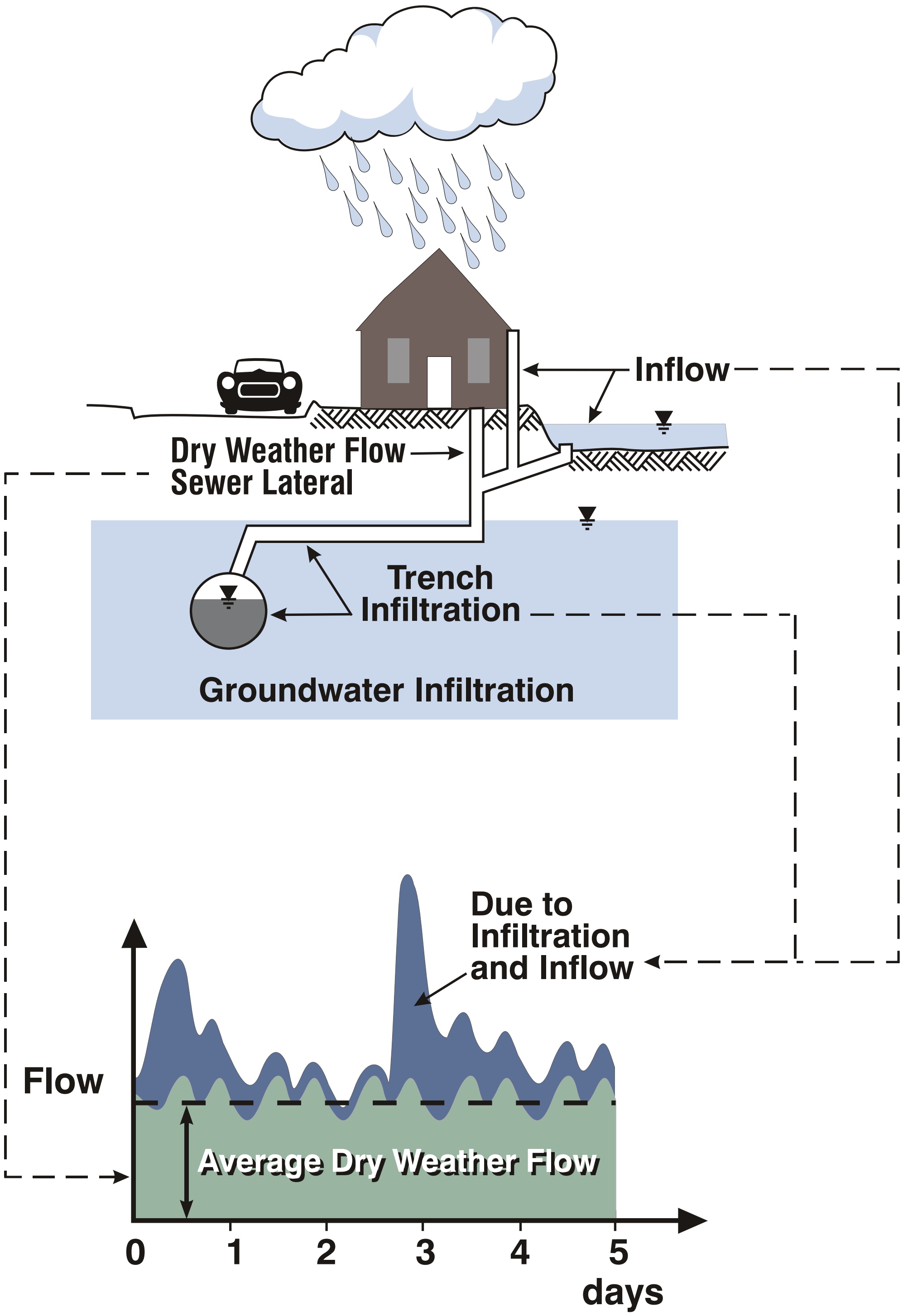

Figure 3.6
Typical Effects of Infiltration and Inflow
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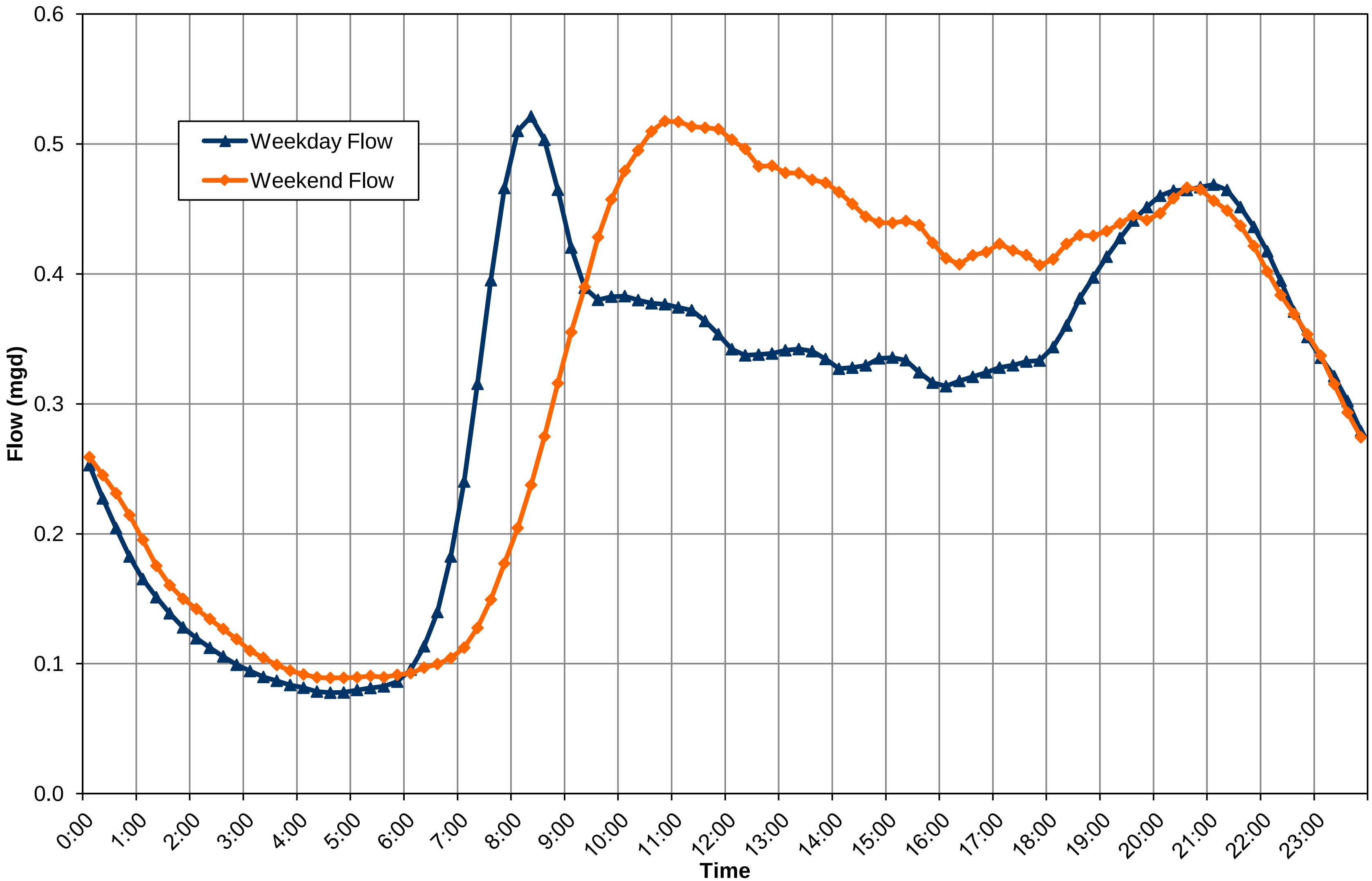

Figure 3.7
Typical Weekday vs. Weekend Dry Weather Flow Variation (Meter 17)
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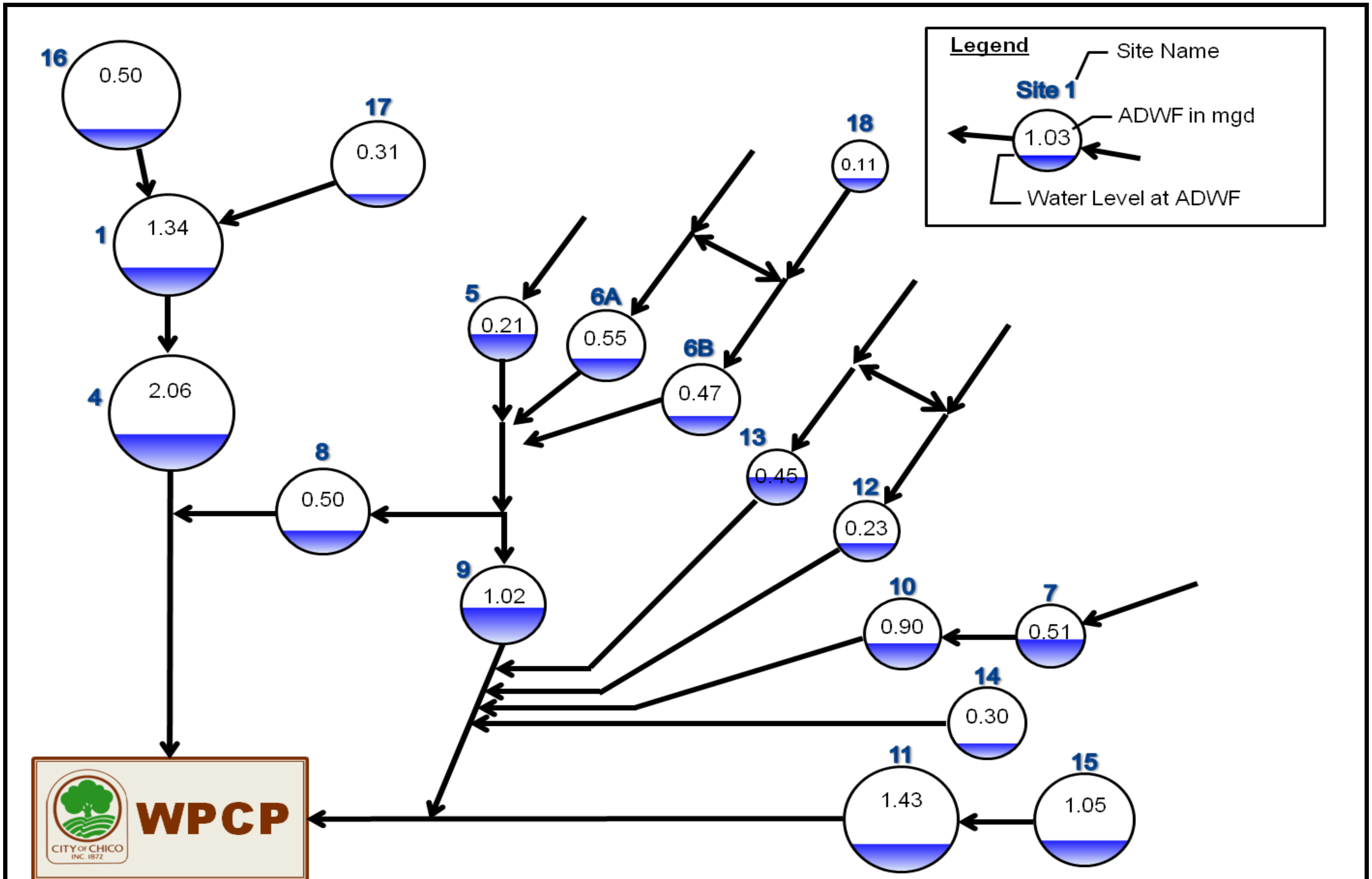

Figure 3.8
Dry Weather Flow Schematic
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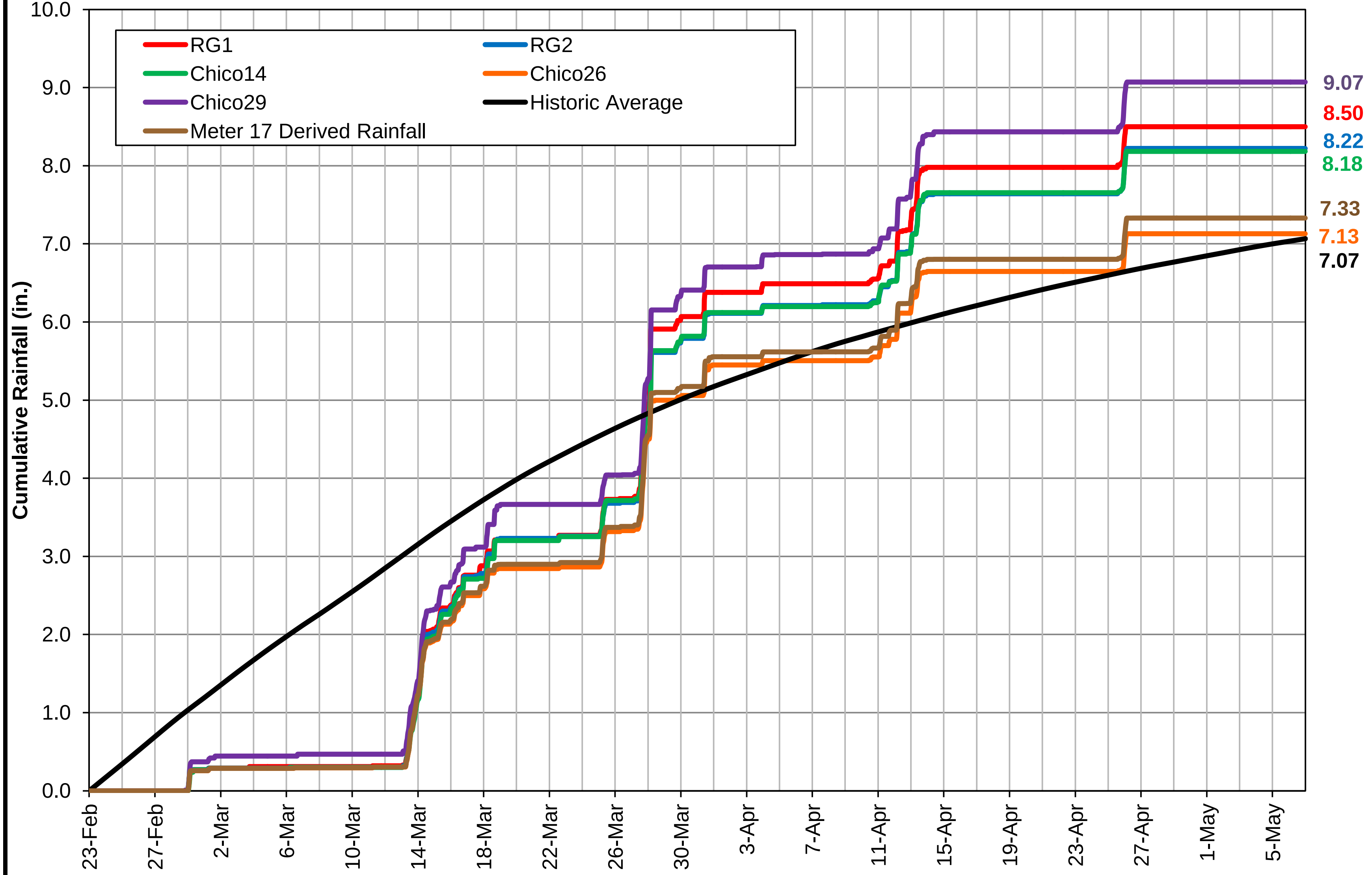

Figure 3.9
Rainfall Accumulation Plot
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Table 3.3	Dry Weather Flow Summary Sanitary Sewer Master Plan Update City of Chico			
Monitor Site	**Weekday Dry Weather Flow (mgd)**	**Weekend Dry Weather Flow (mgd)**	**Overall Dry Weather Flow (mgd)**	**Weekend Weekday Ratio**
1	1.33	1.36	1.34	1.02
4	2.05	2.1	2.06	1.03
5	0.21	0.22	0.21	1.07
6A	0.57	0.5	0.55	0.87
6B	0.47	0.47	0.47	1.01
7	0.5	0.51	0.51	1.02
8	0.51	0.5	0.5	0.98
9	1.03	1	1.02	0.97
10	0.9	0.9	0.9	1
11	1.46	1.38	1.43	0.95
12	0.23	0.22	0.23	0.94
13	0.46	0.43	0.45	0.93
14	0.3	0.32	0.3	1.06
15	1.06	1.03	1.05	0.97
16	0.5	0.51	0.5	1.03
17	0.3	0.33	0.31	1.08
18	0.12	0.11	0.11	0.92

Notes:
1. Source: Sanitary Sewer Flow Monitoring and Inflow/Infiltration Study, August 2012
2. Overall Dry Weather Flow = (5 x Weekday + 2 x Weekend)/7.

Table 3.4	Rainfall Event Summary Sanitary Sewer Master Plan Update City of Chico				
Rainfall Event	**Measured Rainfall (in.)**				
	RG 1	**RG 2**	**Chico 1**	**Chico 2**	**Chico 3**
Event 1: 3/13/12 – 3/19/12	2.90	2.93	2.90	2.52	3.19
Event 2: 3/27/12 – 4/1/12	1.64	2.43	2.40	2.11	2.66
Event 3: 4/10/12 – 4/14/12	1.49	1.42	1.46	1.14	1.53
Total for Monitoring Period	8.50	8.22	8.18	7.13	9.07

However, the storms did present valuable data in terms of the collection system's I/I response to wet weather flow events, and is therefore appropriate for I/I analysis and model calibration purposes.

The total rainfall recorded over the duration of the flow monitoring period ranged from 7.13-inches to 9.07-inches. The historical average rainfall for the flow-monitoring period is roughly 7.07-inches. Therefore, the measured rainfall totals ranged from roughly 101 percent to 128 percent of the historical average for the Chico area.

In order to perform I/I analysis and to aid in model calibration, the amount of rainfall that affected the individual flow monitoring basins (i.e., tributary areas) was calculated by V&A based on their proximity to the five rain gauge locations. The individual rainfall hyetographs were generated using the Inverse Distance Weighting (IDW) method, which is an interpolation method that assumes the influence of each rain gauge location diminishes with distance. For more detailed information related to this calculation, refer to Appendix B. Figure 3.10 illustrates the rainfall hyetograph generated for Meter 17 using this method. Figure 3.9 shows the accumulated rainfall over the flow monitoring program for Meter 17 as well. Similar graphics for each of the remaining flow monitoring sites are provided in Appendix B for reference.

3.3.3 Wet Weather Flow Data

The flow monitoring data was also evaluated to determine how the collection system responds to wet weather events. As mentioned above, the flow monitoring program captured three main rainfall events. The rainfall events that occurred between March 27, 2012 and April 1, 2012 (Event 2) were associated with the largest I/I response during the flow monitoring period, and are the most appropriate to be used for I/I analysis. However, the model was calibrated to all three of the main rainfall events (see Chapter 4 for further detail).

Figure 3.11 shows an example of the wet weather response at Meter 17 during the March 27, 2012 through April 1, 2012 rainfall events. Figure 3.11 illustrates the volume of I/I that entered the system from the collection system upstream of Site 17. The light blue area is the base sanitary flow while the gray area is the measured flow from the flow monitoring period. As can be seen in the figure, discernible amounts of I/I do enter the system during wet weather events. Similar graphs were generated for the remaining monitoring sites can be found in Appendix B.

The metric typically used to quantify the severity of the system's I/I is the R-value. The R-value is defined as the percentage of rainfall volume that makes it into the collection system as I/I. Table 3.5 summarizes the results for the March 27 to April 1, 2012 rainfall event (Event 2). As shown in Table 3.5, the R-Values vary from 0.2-percent in basins 1 and 4 to 9.4 percent in Basin 14. The City's overall R-Value for Event 2 was roughly 2.4 percent. In general, an R-Value of 5 percent or more is usually considered indicative of an I/I response.

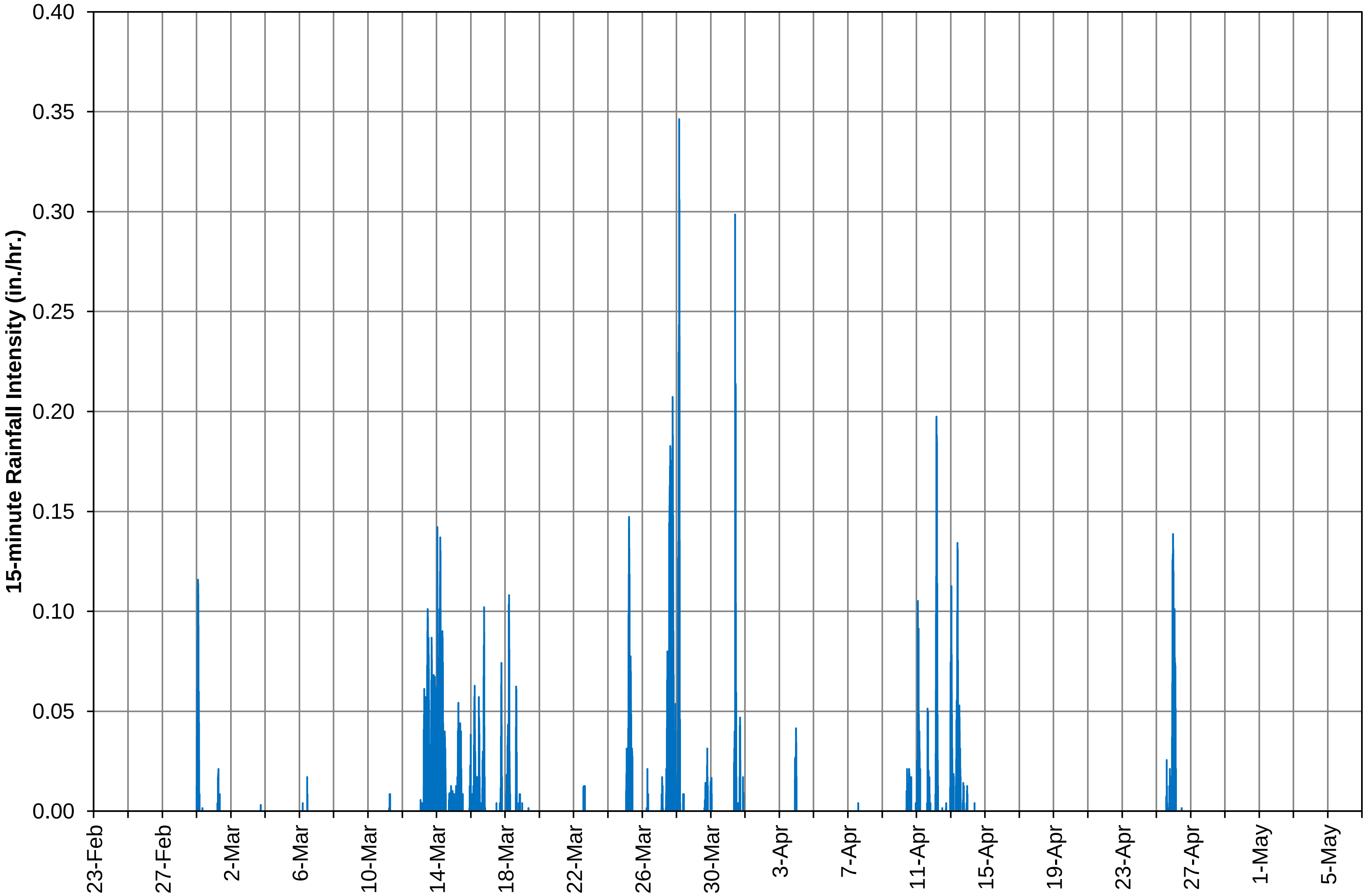

Figure 3.10
Rainfall Activity Over Flow
Monitoring Period (Meter 17)
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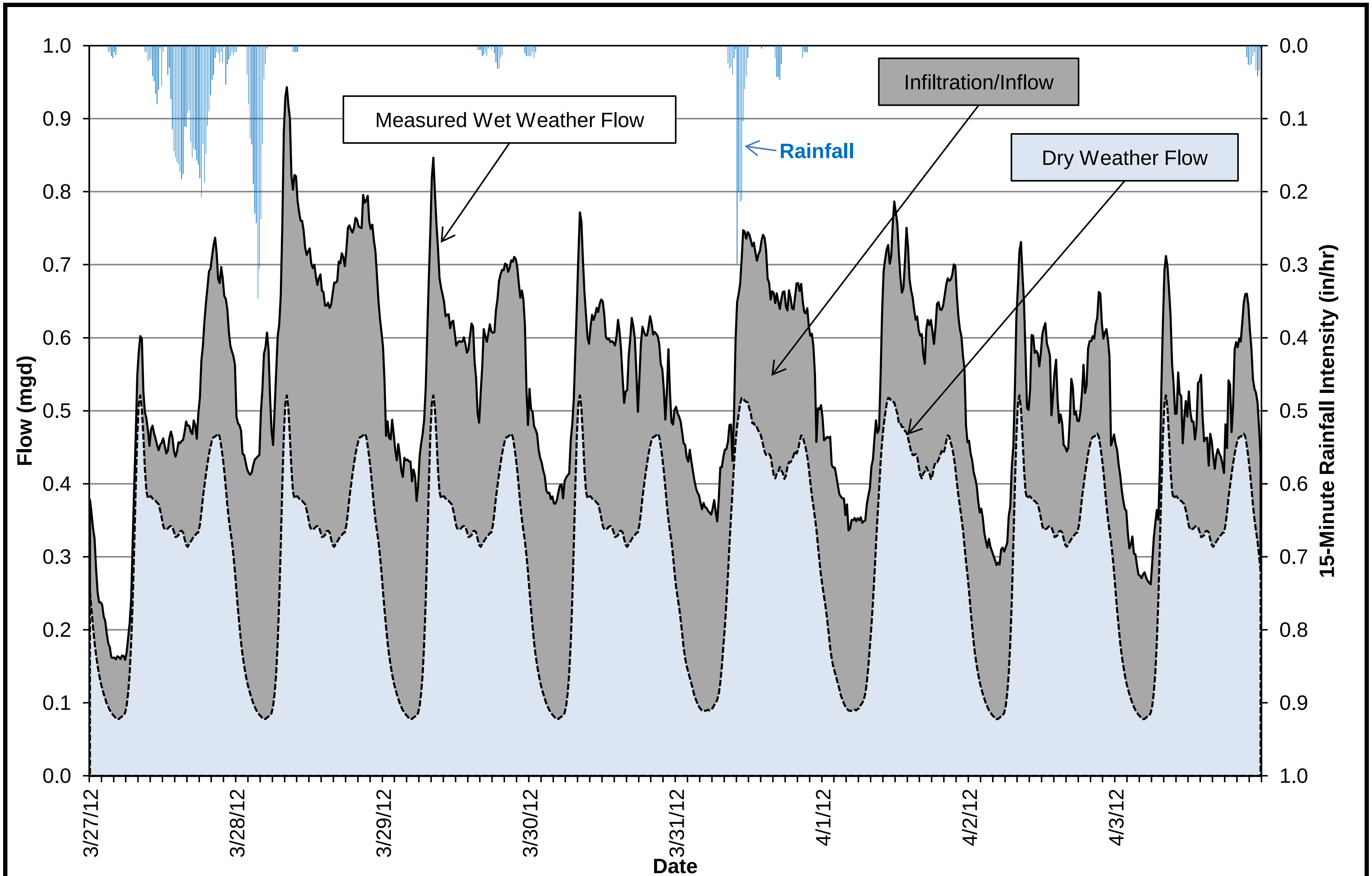

Figure 3.11
Example Wet Weather
Flow Response (Meter 17)
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The R-Value for each basin is determined by isolating I/I associated with individual flow monitoring basins (i.e., excluding flow rates from upstream flow monitors) and calculating the ratio of the volume of water that enters the system as I/I versus the volume of rainfall that fell over the flow monitoring basin tributary area. In some cases, flow splits and/or overflows affect the calculated R-Value for certain flow monitoring tributaries and can skew the results. In these cases, tributary areas that cannot be isolated are combined for the purposes of Table 3.5.

Another important metric to quantify the severity of the system's I/I response is the peak measured I/I rate, which was calculated by subtracting the baseline flow from the peak measured flow during Event 2. As shown in Table 3.5 the measured peak I/I rate to dry weather flow ratio ranged from 0.75 in Basin 1 to 4.18 in Basin 11. Citywide, the peak I/I rate to dry weather flow ratio from Event 2 was 1.17. It should be noted, however, that the peak I/I rates presented in Table 3.5 are for Event 2 only, which as previously mentioned, is classified as less than a 2-year event. Therefore, the peak I/I rate during the design storm event will be higher.

Table 3.5 I/I Analysis Summary
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City of Chico

Basin	Dry Weather Flow (mgd)	Estimated Total I/I (gallons)	R-Value (%)	Peak I/I Rate (mgd)	Peak I/I to DWF Ratio
1	0.53	127,000	0.2	0.40	0.75
4	0.72	191,000	0.2	1.15	1.59
5	0.21	166,000	0.7	0.12	0.59
6	0.90	2,131,000	2.8	1.14	1.27
7	0.51	2,632,000	3.0	1.29	2.54
8/9	0.30	29,000	0.1	0.35	1.15
10	0.40	1,643,000	4.0	0.48	1.22
11	0.38	2,110,000	2.5	1.59	4.18
12/13	0.68	846,000	2.3	1.08	1.59
14	0.30	2,438,000	9.4	0.80	2.61
15	1.05	3,124,000	3.2	1.93	1.84
16	0.50	4,255,000	3.3	2.03	4.05
17	0.31	1,840,000	4.3	0.53	1.70
18	0.11	509,000	1.1	0.38	3.35
City Total	**7.01**	**21,726,000**	**2.4**	**8.23**	**1.17**

Notes:
1. Source: Sanitary Sewer Flow Monitoring and Inflow/Infiltration Study, August 2012.
2. Results are taken from the March 27, 2012 to April 1, 2012 rainfall event (Event 2).

COLLECTION SYSTEM FACILITIES AND HYDRAULIC MODEL

This chapter describes the development and calibration of the City of Chico's (City's) collection system hydraulic model. A description of the City's previous hydraulic model, the advantages of the newer modeling software being used for the Master Plan, and an outline of the steps used to build the model are provided. A detailed summary of the hydraulic model calibration steps, standards, and results for both dry weather and wet weather conditions is also provided.

4.1 COLLECTION SYSTEM FACILITIES

The City's collection system consists of sewer mains, trunk sewers, lift stations, and flow diversions that collect and convey wastewater to the City's Water Pollution Control Plant (WPCP), which is located west of the City on Chico River Road.

Figure 4.1 presents the City's collection system. The oldest part of the City's collection system was constructed around 1903. The major trunks along Chico River Road and extending to different parts of the City were constructed in the 1920's. Expansion of the collection system has continued on to the present day.

4.1.1 Gravity Collection System

The City's existing sanitary sewer collection system is comprised of roughly 266 miles of gravity collection system pipe up to 66-inches in diameter. Table 4.1 presents a summary by diameter of the known sewers in the collection system. As shown in Table 4.1, roughly 70 percent of the system is 8-inches in diameter and smaller, with the majority of the system (roughly 47.2 percent) being 8-inches in diameter.

Some areas in the City are within very close proximity to the rivers, creeks, and California Park Lake. According to the City, the groundwater table in these areas can be within three to ten feet of the ground surface. Therefore, groundwater infiltration can be a significant source of flow into the collection system in these areas.

The age and condition of the collection system facilities will impact the quantity of inflow and infiltration allowed to enter the system. Typically, older sewer pipes have a greater potential of allowing significant infiltration and inflow into the collection system. Older pipelines should be a priority when considering pipelines for rehabilitation.

Table 4.1	Collection System Gravity Pipeline Summary Sanitary Sewer Master Plan Update City of Chico				
Diameter (inches)	Length (feet)	Percent of System (by length)	Diameter (inches)	Length (feet)	Percent of System (by length)
6 and Smaller	316,693	22.6	24	29,133	2.1
8	662,353	47.2	27	3,276	0.2
10	102,655	7.3	30	12,696	0.9
12	76,963	5.5	33	42,007	3.0
14	9,111	0.6	36	13,887	1.0
15	65,418	4.7	42	92	0.0
16	133	0.0	48	428	0.0
18	52,680	3.8	66	1,166	0.1
21	13,516	1.0	**Total (feet)**	**1,402,207**	**100.0**
			Total (miles)	**265.6**	**100.0**

Notes:
(1) Source: City of Chico GIS database

4.1.2 Lift Stations and Force Mains

The City operates and maintains wastewater lift stations throughout the City. Figure 4.2 shows the locations of each lift station and the area that it services. Figure 4.3 is a schematic representation of the City's lift stations and provides an overview of how flow from each lift station is ultimately routed through the collection system to the WPCP. Table 4.2 summarizes the available design data for the City's lift stations. A brief summary of each lift station is presented below:

- **Chico Municipal Airport**: The Chico Municipal Airport lift station was constructed in 1994 and is located just north of the intersection of Cohasset Road and Eaton Road. The lift station consists of a 6 foot diameter, 32.4 feet deep wet well and two 20 horsepower (hp), 958 gallon per minute (gpm) pumps. The lift station's firm capacity is 958 gpm, or 1.38 million gallons per day (mgd). The Chico Municipal Airport lift station conveys raw wastewater south via an 8-inch diameter force main approximately 1,455 feet to a manhole downstream of the lift station. Standby power is not available at this lift station.

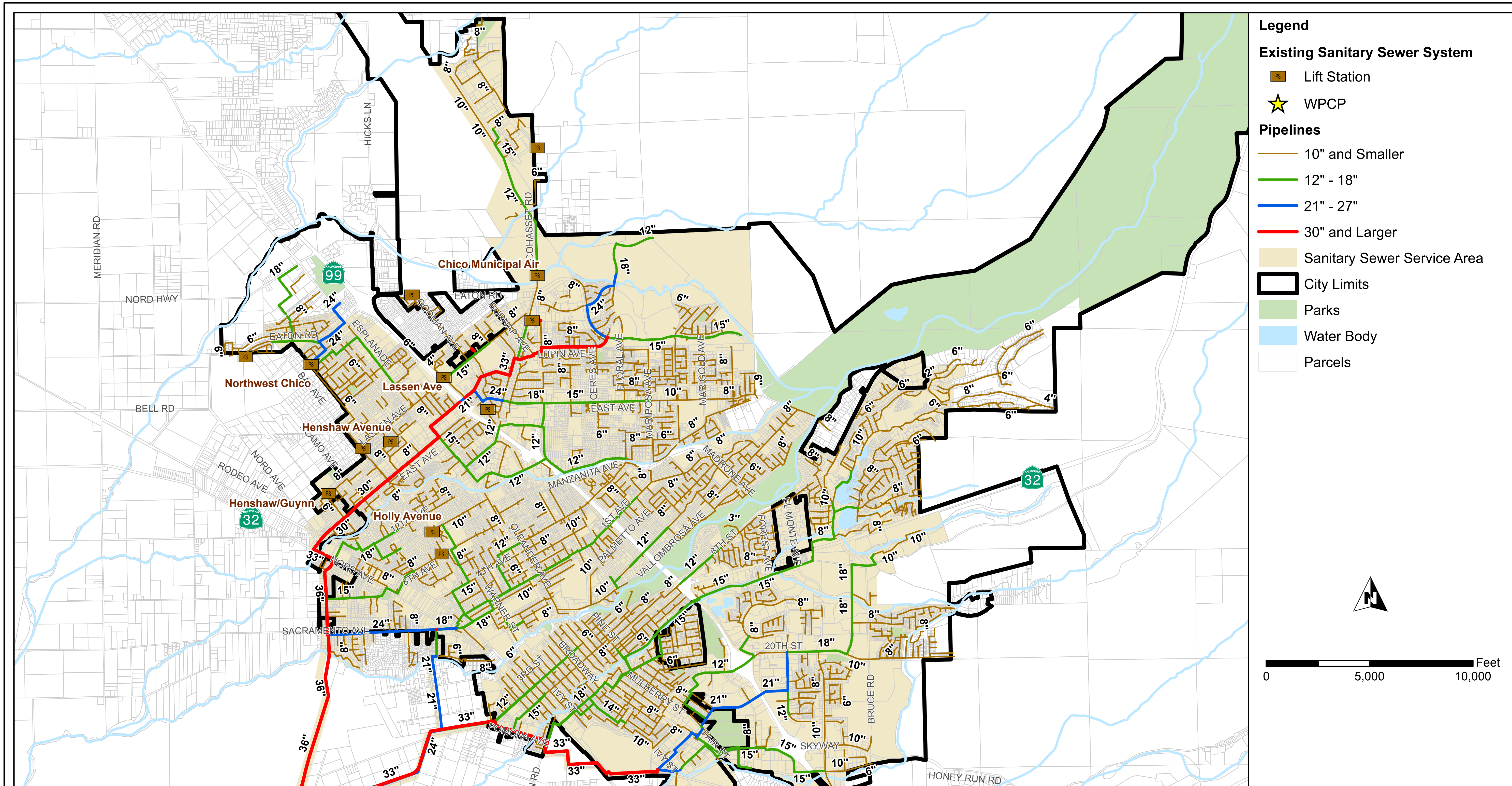

Figure 4.1
Existing Sanitary Sewer Collection System
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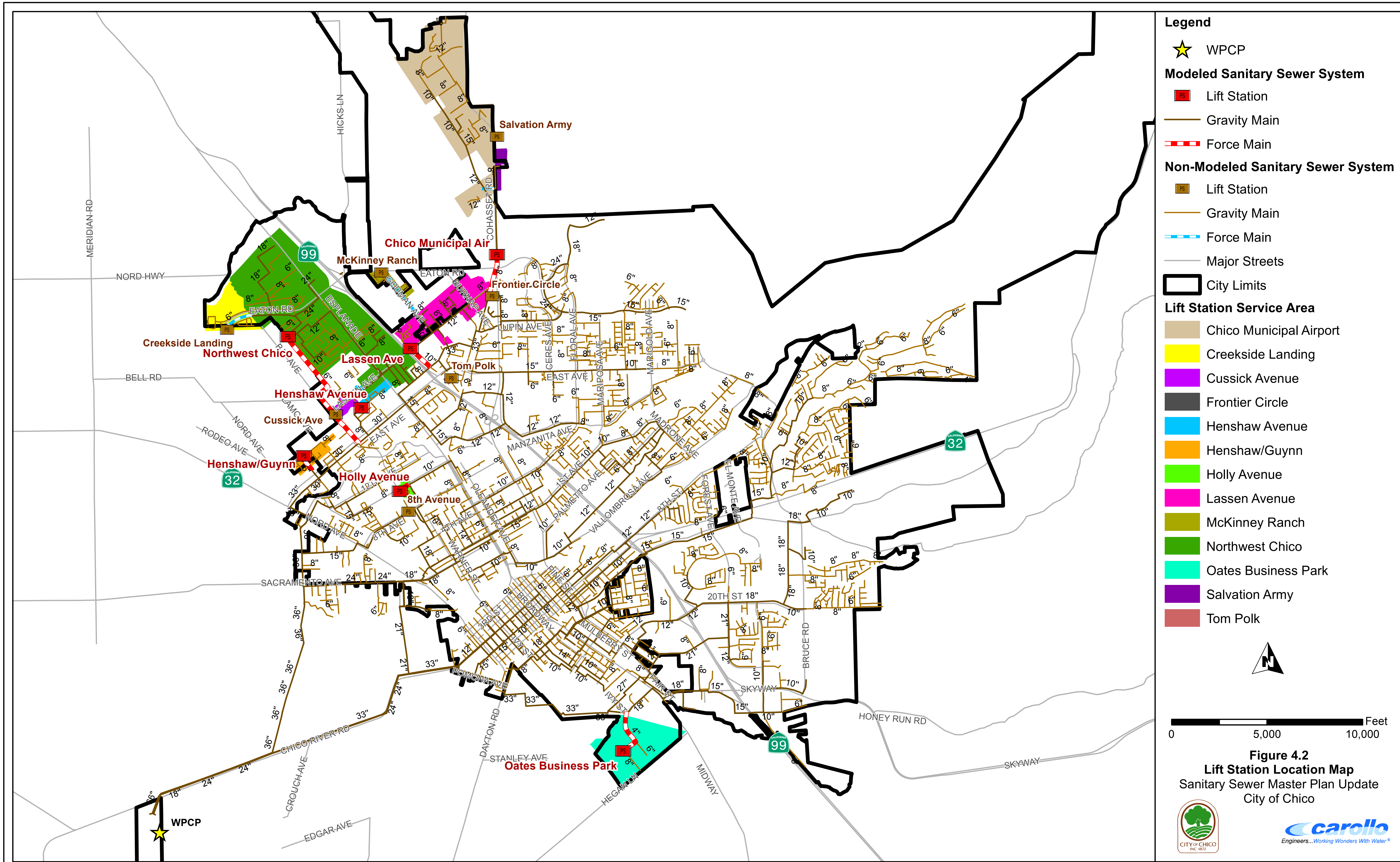

Figure 4.2
Lift Station Location Map
Sanitary Sewer Master Plan Update
City of Chico

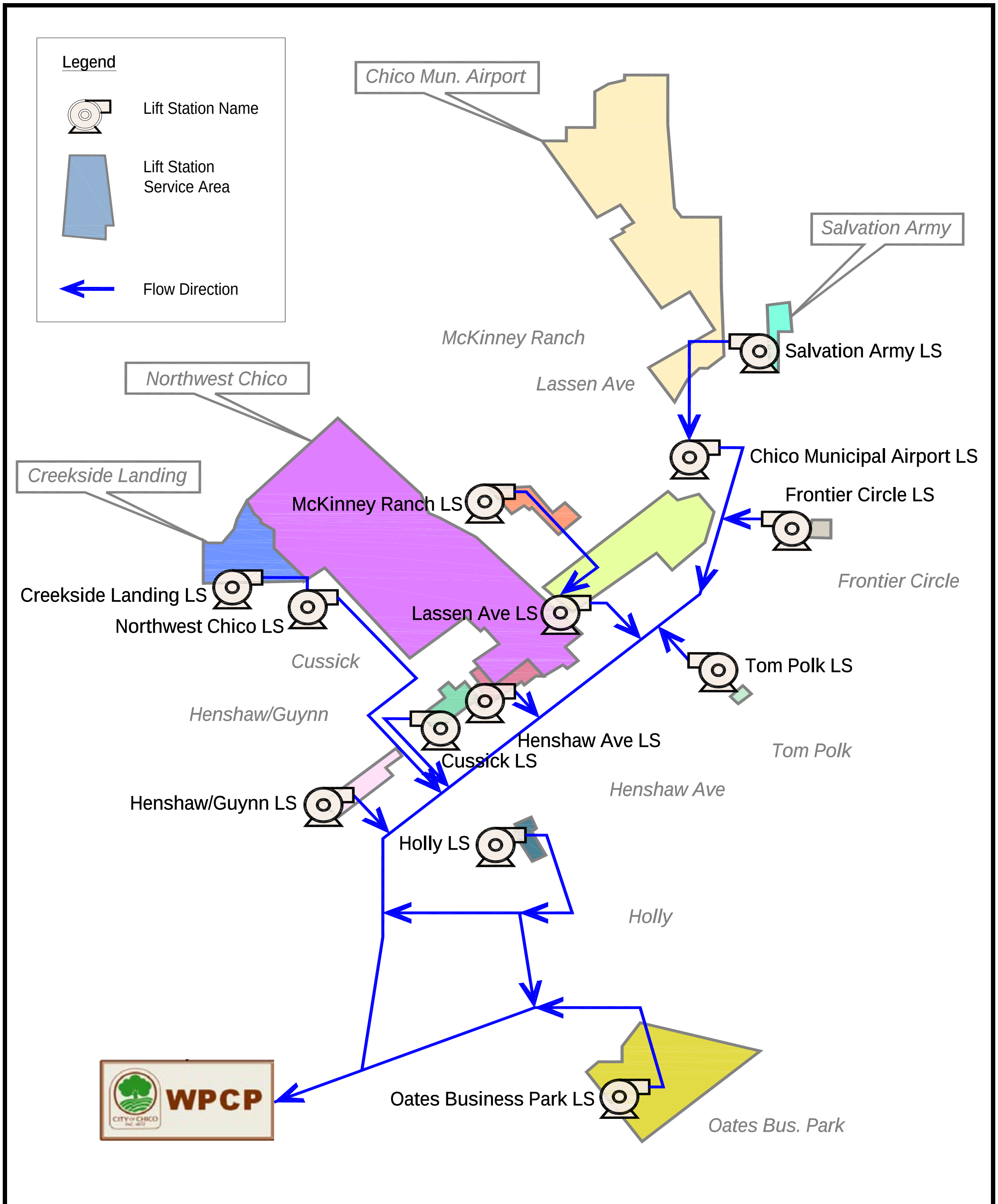

Figure 4.3
Lift Station Schematic
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Table 4.2 Lift Station Information
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City of Chico

Lift Station Name	General Information: Location	Year Built	Pump Data: Pump No.	hp	Pump Capacity (gpm)	Firm Capacity (gpm)	Firm Capacity (mgd)	Force Main Data: Diameter (in.)	Length (feet)
Chico Municipal Airport	Cohasset Road and	1994	1	20	958	958	1.38	8	1,455
	Eaton Road		2	20	958				
Creekside Landing	Burnt Ranch Road near	2007	1	n/a	n/a	n/a	n/a	6	1,553
	Catherine Court		2	n/a	n/a				
Cussick Avenue	Cussick Avenue and	2007	1	7.5	579	579	0.83	6	93
	Lassen Avenue		2	7.5	579				
Frontier Circle	Frontier Circle and	2009	1	n/a	35	35	0.05	4	415
	Cohasset Road		2	n/a	35				
Henshaw Avenue	Henshaw Avenue west of	1993	1	2.4	236	236	0.34	4	236
	Autumn Gold Drive		2	2.4	236				
Henshaw/Guynn	Henshaw Avenue and	1996	1	3	270	270	0.39	6	967
	Guynn Avenue		2	3	270				
Holly	Holly Avenue and	1989	1	1.6	223	223	0.32	4	619
	West 11th Avenue		2	1.6	223				
Lassen Avenue	Lassen Avenue and	2000	1	35	1,795	1,795	2.58	10	2,395
	Highway 99		2	35	1,795				
McKinney Ranch	Eaton Road and	2006	1	5	218	218	0.31	6	2,835
	Godman Avenue		2	5	218				
Northwest Chico	Lagacy Lane west of	1993/	1	35	1,492	1,492	2.15	12	7,419
	Sierra Springs Drive	2008	2	35	1,492				
Oates Business Park	Huss Lane and	1990	1	10	185	185	0.27	8	2,542
	Aztec Drive		2	10	185				
Salvation Army	Cohasset Road	2008	1	3	90	90	0.13	4	685
			2	3	90				
Tom Polk	Tom Polk Avenue near	2008	1	2	32	32	0.05	1.25	20
	East Avenue		2	2	32				

Notes:
1. Source: Data provided by City Staff.

- **Creekside Landing**: The Creekside Landing lift station was constructed in 2007 and is located on Burnt Ranch Road near Catherine Court. The lift station consists of an 8-foot diameter wet well with a depth of 25.7 feet (the pump horsepower and pumping capacity were not available for this lift station). The Creekside Landing lift station conveys raw wastewater east via a 6-inch diameter force main approximately 1,553 feet to a manhole downstream of the lift station. Standby power is available via a 50 kilowatt (kW) natural gas generator at this lift station.
- **Cussick Avenue**: The Cussick Avenue lift station was constructed in 2007 and is located at the intersection of Cussick Avenue and Henshaw Avenue. The lift station consists of an 8-foot diameter wet well with a depth of 19.8 feet and two 7.5 hp, 579 gpm pumps. The firm capacity of this lift station is 0.83 mgd. The Cussick Avenue lift station conveys raw wastewater approximately 93 feet through a 6-inch diameter force main where it connects to the existing 6-inch diameter force main that used to be used by the Northwest Chico lift station.
- **Frontier Circle**: The Frontier Circle lift station was constructed in 2009 and is located at the intersection of Frontier Circle and Cohasset Road. The lift station consists of a 4-foot diameter, 11.4 feet deep wet well and two 3-hp pumps (pumping capacity was not available for this lift station). The Frontier Circle lift station conveys raw wastewater via a 4-inch diameter force main approximately 415 feet to a manhole downstream of the lift station. Standby power is not available at this lift station.
- **Henshaw Avenue**: The Henshaw Avenue Lift Station was constructed in 1993 and is located on Henshaw Avenue west of Autumn Gold Drive. The lift station consists of a 6-foot diameter, 12.4 feet deep wet well and two 1.5-hp pumps (pumping capacity was not available for this lift station). The Henshaw Avenue lift station conveys raw wastewater via a 4-inch diameter force main approximately 236 feet to a manhole downstream of the lift station. Standby power is not available at this lift station.
- **Henshaw/Guynn**: The Henshaw/Guynn lift station was constructed in 1996 and is located at the intersection of Henshaw Avenue and Guynn Avenue. The lift station consists of an 8-foot diameter, 17.7 feet deep wet well and two 3-hp pumps, 270 gpm pumps. The lift station’s firm capacity is 270 gpm, or 0.39 mgd. The Henshaw/Guynn lift station conveys raw wastewater via a 6-inch diameter force main approximately 967 feet to a manhole downstream of the lift station. Standby power is not available at this lift station.
- **Holly**: The Holly lift station was constructed in 1989 and is located at the intersection of Holly Avenue and West 11th Avenue. The lift station consists of a 6-foot diameter, 15.7 feet deep wet well and two 1.6-hp pumps, 223 gpm pumps. The lift station’s firm capacity is 223 gpm, or 0.32 mgd. The Holly lift station conveys raw wastewater via a 4-inch diameter force main approximately 619 feet to a manhole downstream of the lift station. Standby power is not available at this lift station.

- **Lassen Avenue**: The Lassen Avenue lift station was constructed in 2000 and is located just northeast of the intersection of East Lassen Avenue and Highway Route 99. The lift station consists of a 10-foot diameter, 20.5 foot deep wet well and two 35 hp pumps, 1,795 gpm pumps. The lift station's firm capacity is 1,795 gpm, or 2.58 mgd. The Lassen Avenue lift station conveys raw wastewater approximately 2,395 feet via a 10-inch diameter force main to the manhole downstream of Lassen Avenue. Standby power is not available at this lift station.
- **McKinney Ranch**: The McKinney Ranch lift station was constructed in 2006 and is located at the intersection of Eaton Road and Godman Avenue. The lift station consists of an 8-foot diameter, 24.5 foot deep wet well and two 5 hp pumps, 218 gpm pumps. The lift station's firm capacity is 218 gpm, or 0.31 mgd. The McKinney Ranch lift station conveys raw wastewater approximately 2,835 feet via a 6-inch diameter force main to the manhole downstream of the lift station. Standby power is not available at this lift station.
- **Northwest Chico Lift Station**: The Northwest Chico lift station was constructed in 1993 and is located near Legacy Lane west of Sierra Springs Drive. There are two wet wells in the lift station, both of which are 8-feet in diameter. There are two 35 hp pumps in the lift station, each with a capacity of 1,492 gpm. The lift station's firm capacity is 1,492 gpm, or 2.15 mgd. There is currently no standby power available at this lift station. The Northwest Chico lift station conveys raw wastewater approximately 7,419 feet, via a 12-inch diameter force main to a manhole downstream of the lift station. An existing parallel 6-inch force main is currently not in use.
- **Oates Business Park Lift Station**: The Oates Business Park lift station was constructed in 1990 and is located in the Oates Business Park in the south of the City. The lift station consists of 6-foot diameter, 19.5 foot deep wet well and two 10 hp, 185 gpm pumps. The lift station's firm capacity is 185 gpm, or 0.27 mgd. The Oates Business Park lift station conveys raw wastewater approximately 2,542 feet through a 4-inch diameter force main to a manhole downstream of the lift station. Standby power is not available at this lift station.
- **Salvation Army**: The Salvation Army lift station was constructed in 2008 and is located on Cohasset Road. The lift station consists of a 6-foot diameter, 14.4 foot deep wet well and two 3 hp, 90 gpm pumps. The lift station's firm capacity is 90 gpm, or 0.13 mgd. The Salvation Army lift station conveys raw wastewater approximately 685 feet through a 4-inch diameter force main to a manhole downstream of the lift station. Standby power is available via a 35 hp natural gas generator at this lift station.
- **Tom Polk**: The Tom Polk lift station was constructed in 2008 and is located on Tom Polk Avenue near East Avenue. The lift station consists of a 3-foot diameter, 13 foot deep wet well and two 2 hp, 30 gpm pumps. The lift station's firm capacity is 30 gpm,

or 0.04 mgd. The Tom Polk lift station conveys raw wastewater approximately 20 feet through a 1.25-inch diameter force main to a manhole downstream of the lift station. Standby power is not available at this lift station.

4.2 HYDRAULIC MODEL DEVELOPMENT

A sewer collection system model is a simplified representation of the real sewer system. Sewer system models can assess the conveyance capacity for a collection system. In addition, sewer system models can perform “what if” scenarios to assess the impacts of future developments and land use changes. The City’s collection system hydraulic model was constructed using a multi-step process utilizing data from a variety of sources. This section summarizes the hydraulic model development process, including a summary of the modeling software selection, a description of the modeled collection system, the hydraulic model elements, and the model creation process.

4.2.1 Previous Hydraulic Computer Model

The City’s previous collection system hydraulic model was developed using the HYDRA Version 6.1 hydraulic modeling software package, developed by Pizer Inc. (Pizer). The HYDRA model routes flow through the collection system to evaluate the capacity of existing pipes and to determine where capacity constraints occur using the Kinematic Wave, standard step method. This method is a simplified version of the Saint Venant, one dimensional equations of fluid flow.

The HYDRA model was assembled as part of the 2003 Sanitary Sewer Master Plan Update project using the City’s Geographic Information System (GIS) data, lift station drawings, supplemental survey work, and input from City Staff.

4.2.2 Selected Hydraulic Modeling Software

In the decade since the previous hydraulic model was originally developed, significant improvements have been made to the hydraulic modeling software available on the market. Some examples of the improvements that have been made include modifications to the hydraulic routing engine as well as an enhanced graphical user interface (GUI), model output reports, and GIS compatibility. This Master Plan Update provided the City an opportunity to reexamine the software available on the market today and make a decision about continuing the use of HYDRA or converting the model to one of the newer software packages.

In the early stages of this Master Plan, Carollo conducted an evaluation of the major sanitary sewer hydraulic modeling software applications on the market today. The results of the evaluation are presented in a technical memorandum, which is provided in Appendix C for reference. This technical memorandum summarizes the major software vendors, briefly explains software features, compares the advantages and disadvantages of each software program, and provides a software program recommendation for the City.

Based on the results of the evaluation, it was agreed that InfoSWMM, by Innovyze (formerly MWH Soft), would be used to assemble the City's hydraulic model. InfoSWMM is a fully dynamic, geospatial wastewater and stormwater modeling and management software application, which is built to run within the ESRI ArcGIS software platform. The hydraulic modeling engine for the InfoSWMM software package uses the Environmental Protection Agency's (EPA) Storm Water Management Model (SWMM), which is widely used throughout the world for planning, analysis, and design related to stormwater runoff, combined sewers, sanitary sewers, and other drainage systems. InfoSWMM routes flows through the model using the Dynamic Wave method, which solves the complete Saint Venant, one dimensional equations of fluid flow.

The latest version (v 12.0) of InfoSWMM was used to assemble the InfoSWMM hydraulic model (InfoSWMM model).

4.2.3 Modeled Collection System and Skeletonization

Skeletonization is the process by which sewer systems are stripped of pipelines not considered essential for the intended analysis purpose. The purpose of skeletonizing a system is to develop a model that accurately simulates the hydraulics of a collection system, while at the same time reducing the complexity of a large model.

It is common practice in sewer system master planning to exclude small diameter sewers when developing a hydraulic computer model. The City's hydraulic model includes pipelines that are 10-inches in diameter and larger. Some smaller diameter sewers (8-inches in diameter and smaller) are also included in the City's hydraulic model where needed for connectivity.

The modeled sewer system consists of approximately 93.5 miles of sanitary sewer pipelines ranging in diameter from 4-inches to 66-inches, and seven sanitary sewer lift stations.

Figure 4.4 presents the City's modeled wastewater collection system. The larger trunk sewers range in diameter from 10-inches to 66-inches. Table 4.3 presents a summary of the modeled sewer system by diameter and length of pipe. Not included in these totals are the smaller sewer mains that were excluded during model skeletonization and therefore are not modeled.

Table 4.3	Modeled System Gravity Pipeline Summary Sanitary Sewer Master Plan Update City of Chico				
Diameter (inches)	**Length (feet)**	**Percent of Modeled System (by length)**	**Diameter (inches)**	**Length (feet)**	**Percent of Modeled System (by length)**
6 and Smaller	17,214	22.6	24	29,133	2.1
8	54,764	47.2	27	3,276	0.2
10	102,579	7.4	30	12,696	0.9
12	75,781	5.5	33	42,007	3.0
14	9,111	0.6	36	13,887	1.0
15	65,418	4.7	42	92	0.0
16	133	0.0	48	428	0.0
18	52,680	3.8	66	1,166	0.1
21	13,516	1.0	Total (feet)	493,880	100.0
			Total (miles)	93.5	100.0

Notes:
(1) Source: City of Chico GIS database

Of the City's thirteen total sanitary sewer lift stations, seven are connected to the modeled trunk system, and are therefore included in the hydraulic model. The modeled lift stations are:

- Chico Municipal Airport Lift Station
- Henshaw Avenue Lift Station
- Henshaw/Guynn Lift Station
- Holly Lift Station
- Lassen Avenue Lift Station
- Northwest Chico Lift Station
- Oates Business Park Lift Station

The remaining lift stations, which service smaller localized areas of the collection system and are located on the smaller 8-inch diameter and smaller pipes, were excluded from the model during the skeletonization process. Exclusion of very small lift stations is common in collection system master planning, because the flows pumped through these lift stations is insignificant and does not affect model accuracy for the trunk sewer system.

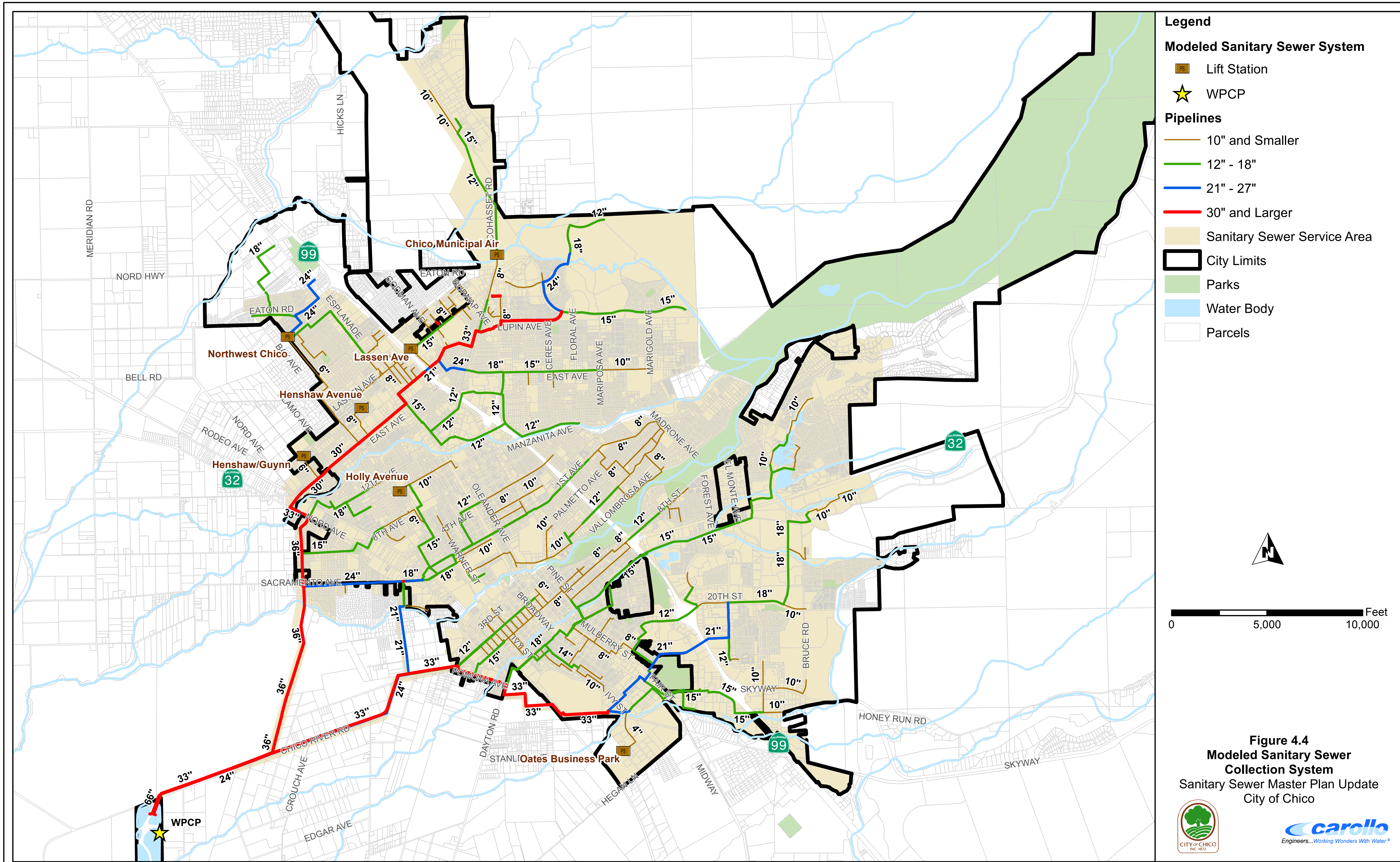

Figure 4.4
Modeled Sanitary Sewer Collection System
Sanitary Sewer Master Plan Update
City of Chico

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4.2.4 Elements of the Hydraulic Model

The following provides a brief overview of the major elements of the hydraulic model and the required input parameters associated with each:

- **Junctions**: Sewer manholes, cleanouts, as well as other locations where pipe sizes change or where pipelines intersect are represented by junctions in the hydraulic model. Required inputs for junctions include rim elevation, invert elevation, and surcharge depth (used to represent pressurized systems). Junctions are also used to represent locations where flows are split or diverted between two or more downstream links.

- **Pipes**: Gravity sewers and force mains are represented as pipes in the hydraulic model. Input parameters for pipes include length, friction factor (e.g., Manning's n for gravity mains, Hazen Williams C for force mains), invert elevations, diameter, and whether or not the pipe is a force main.

- **Storage Nodes**: For sewer system modeling, storage nodes typically are used to represent lift station wet wells (although other storage basins, etc. can be modeled as storage nodes). Input parameters for storage nodes include invert elevation, wet well depth, and wet well cross section.

- **Pumps**: Pumps are included in the hydraulic model as links. Input parameters for pumps include pump curves and operational controls.

- **Outfalls**: Outfalls represent areas where flow leaves the system. For sewer system modeling, an outfall typically represents the connection to the influent pump station at a wastewater treatment plant.

- **Rain Gauges**: Rain gauges are input into the hydraulic model to simulate historical or theoretical hourly rainfall events.

- **Inflows**: The following are the three types of wastewater flow sources that can be injected into individual model junctions (and storage nodes):
  - <u>External</u>. External inflows can represent any number of flows into the collection system, such as metered flow data or groundwater inflow. External inflows are applied to a specific model junction by applying a baseline flow value and a pattern that varies the flow by hour, day, or month of the year.
  - <u>Dry Weather</u>. Dry weather inflows simulate base sanitary wastewater flows and represent the average flow. The dry weather flows can be multiplied by up to four patterns that vary the flow by month, day, hour, and day of the week (e.g., weekday or weekend). The dry weather diurnal patterns are adjusted during the dry weather calibration process.
  - <u>RDII</u>. Rainfall Derived Infiltration and Inflows (RDII) are applied in the model by assigning a unit hydrograph and a corresponding tributary area to a given

junction. The unit hydrographs consists of several parameters that are used to adjust the volume of RDII that enters the system at a given location. These parameters are adjusted during the wet weather calibration process.

4.2.5 Wastewater Load Allocation

Determining the quantity of dry weather wastewater flows generated by a municipality and how they are distributed throughout the collection system is an important component of the hydraulic modeling process. Various techniques can be used to assign wastewater flows to individual model junctions, depending on the type of data that is available. Adequate estimates of the volume of wastewater are important in maintaining and sizing sewer system facilities, both for present and future conditions. Baseline wastewater loads were allocated (assigned to specific nodes) in the hydraulic model based on land use data provided by the City and wastewater flow coefficients developed for each land use type (these are described in detail in Chapter 5). The flow coefficients and land use data provides a means to transform a specific land use category into an average dry weather flow, as described below:

- **Step 1**: The City's service area was broken up into 758 individual loading polygons. Each loading polygon represents the geographic area that contributes flows into a single model node (i.e., trunk system manhole). In an all pipe model, however, a loading polygon could be as small as a few parcels. In a skeletonized model, such as the City's hydraulic model, a loading polygon will usually encompass a particular subdivision or grouping of lots.
- **Step 2**: The loads were calculated for each loading polygon using GIS by multiplying the appropriate flow coefficient by the land use acreage.
- **Step 3**: The hydraulic model's load allocation assigned the calculated average dry weather flow to the appropriate node in the sewer system model.
- **Step 4**: The allocated loads were adjusted as necessary during the dry weather flow calibration process (see Section 4.3) to closely match the actual measured dry weather flows recorded during the flow monitoring period.

4.2.6 Model Construction

The City's hydraulic model combines information on the physical and operational characteristics of the wastewater collection system, and performs calculations to solve a series of mathematical equations to simulate flows in pipes.

The model construction process consisted of eight steps, as described below:

- **Step 1**: The first step involved in the model conversion process was to extract relevant data from the City's existing HYDRA model (developed as part of the 2003 Sanitary Sewer Master Plan Update). This was accomplished using the "Transfer

Wizard" feature of the HYDRA software program, which converts the modeled HYDRA pipelines, junctions, etc. to GIS shapefiles.

- **Step 2**: Once the HYDRA model data were successfully extracted, the GIS shapefiles were reviewed for possible data errors and formatted to match the format accepted by the InfoSWMM software.
- **Step 3**: The Collection System layer shapefiles were then imported into InfoSWMM using the "GIS Exchange" functionality of InfoSWMM.
- **Step 4**: Due to certain differences in how the two modeling software platforms are configured, converting from one model to the other is not a one-to-one process. In other words, some of the physical and operational data associated with the HYDRA model is incompatible with the data input requirements of InfoSWMM.

  As an example, the computational engine of the HYDRA model requires that locations where flows are split between two downstream pipelines (e.g., overflows) be modeled as "diversions". A diversion is modeled in HYDRA as a node with an associated curve that relates the total node inflow to the rate of flow diverted to a particular sewer. InfoSWMM, on the other hand, uses a more robust computational engine that calculates the amount of flow in each downstream sewer based on the physical attributes of each downstream sewer (e.g., pipe inverts, diameter, slope, roughness) without the need of a user defined diversion curve. For this reason, flow diversions from the HYDRA model were simply modeled as manholes (or junctions) in the InfoSWMM model.

  Another example of the differences between the two modeling software applications is how lift stations are represented. In HYDRA, lift stations are represented as a single node in the model. The input data required for a lift station is the pump type (i.e., constant speed or variable speed), a wet well volume for the pump to turn on and off, and the pump discharge for up to three pumps. In InfoSWMM, by contrast, a lift station is represented by a storage node representing the wet well and links representing each of the lift station pumps. The input data required for wet wells are the wet well dimensions (e.g., cross sectional area, wet well depth) and the bottom elevation (invert) of the wet well. For each lift station, pump curves and operational controls (set points) are required. These parameters were input manually based on the lift station data provided by the City.
- **Step 5**: The City has constructed new sanitary sewer facilities throughout the collection system since the previous master plan was completed. In addition, the City has abandoned some lift stations. The City's sewer system GIS was reviewed to identify new facilities that needed to be included in the hydraulic model, and the new facilities were imported into the hydraulic model. Additionally, markups from City staff of the modeled collection system map were also reviewed and incorporated in the hydraulic model.

- **Step 6**: Once all the relevant data was input into the hydraulic model, the model was reviewed to verify that the model data was input correctly and that the flow direction, size, and layout of the modeled pipelines were logical. Additionally, the modeled lift stations were also checked to verify that they operated correctly.
- **Step 7**: Dry weather wastewater flows were then allocated to the appropriate model junctions.
- **Step 8**: The hydraulic model contains certain run parameters that need to be set by the user at the beginning of the project. These include run dates, time steps, reporting parameters, output units, and flow routing method. Once the run parameters were established, the model was debugged to ensure that it ran without errors or warnings.

4.3 HYDRAULIC MODEL CALIBRATION

Hydraulic model calibration is a crucial component of the hydraulic modeling effort. Calibrating the model to match data collected during the flow-monitoring program ensures the most accurate results possible. The calibration process consists of calibrating to both dry and wet weather conditions.

For this project, both dry and wet weather flow monitoring were conducted at 17 meter sites for a period of approximately 10.5 weeks in early 2012. Dry weather flow (DWF) calibration ensures an accurate depiction of base wastewater flow generated within the study area. The wet weather flow (WWF) calibration consists of calibrating the hydraulic model to a specific storm event or events to accurately simulate the peak and volume of infiltration/inflow (I/I) into the sewer system. The amount of I/I is essentially the difference between the WWF and DWF components.

4.3.1 Calibration Standards

The hydraulic model was calibrated in accordance with international modeling standards. The Wastewater Planning Users Group (WaPUG), a section of the Chartered Institution of Water and Environmental Management, has established generally agreed upon principles for model verification. The dry weather and wet weather calibration focused on meeting the recommendations on model verification contained in the “Code of Practice for the Hydraulic Modeling of Sewer Systems,” published by the WaPUG (WaPUG 2002), as summarized below:

- **Dry Weather Calibration Standards**: Dry weather calibration should be carried out for two dry weather days and the modeled flows and depths should be compared to the field measured flows and depths. Both the modeled and field measured flow hydrographs should closely follow each other in both shape and magnitude.

  In addition to the shape, the flow hydrographs should also meet the following criteria as a general guide:

  - The timing of flow peaks and troughs should be within one hour.

- The peak flow rate should be within the range of ±10 percent
- The volume of flow (or the average rate of flow) should be within the range of ±10 percent. If applicable, care should be taken to exclude periods of missing or inaccurate data.

- **Wet Weather Calibration Standards**: For at least two storm events from the flow monitoring period, the model simulated flows and depths should be compared to the field measured flows and depths. The flow hydrographs for both events should closely follow each other in both shape and magnitude, until the flow has substantially returned to dry weather flow rates.

  In addition to the shape, the flow hydrographs should also meet the following criteria as a general guide:

  - The timing of the peaks and troughs should be similar with regard to the duration of the events.
  - The peak flow rates at significant peaks should be in the range of +25 percent to 15 percent and should be generally similar throughout.
  - The volume of flow (or the average flow rate) should be within the range of +20 percent to -10 percent.

  The WaPUG recommends that for wet weather calibration, the use of a single calibration period incorporating a number of rainfall events should be considered whenever possible. In other words, if the flow monitoring program captured several back to back storms, it may be preferable to use the back to back storms events as the calibration storms, as opposed to calibrating to two separate storms that have occurred weeks or months apart.

4.3.2 Dry Weather Flow Calibration

The DWF calibration process consists of several elements, as outlined below:

- **Divide the system into areas tributary to each flow meter**. The first step in the calibration process was to divide the City into flow meter tributary areas. Fifteen tributary areas were created, one for each flow meter from the temporary flow monitoring program. There were actually seventeen meters installed during the flow monitoring program, but four meters (6A and 6B, 10 and 11) were installed on parallel pipelines that shared a common tributary area. A map showing the locations of each flow monitoring site and their associated tributary area are provided in Chapter 3 along with a schematic of the flow meters.

- **Define flow volumes within each area**. The next step was to define the flow volumes within each area, which was accomplished in the flow allocation step.

- **Create diurnal patterns to match the temporal distribution of flow**. A diurnal curve is a pattern of hourly multipliers that are applied to the base flow to simulate the variation in flow that occurs throughout the day. Two diurnal curves were developed for each flow monitoring tributary area, one representing weekday flow and one representing weekend flow. The diurnal patterns were initially developed based on the flow monitoring data and adjusted as part of the calibration process until the model simulated flows closely matched the field measured flows. Figure 4.5 shows the calibrated weekday and weekend diurnal patterns for the area tributary to Site 17. Similar diurnal curves were developed for each of the meters and its tributary area. These additional curves are available in Appendix D.

- **Adjust model variables to match field measured velocity and flow depths**. Once the model simulated flows acceptably matched the field measured flows, the model simulated velocity and flow depth were compared to the field measured velocity and flow depth. Adjustments were made to various model parameters until the modeled and measured velocity and depth closely matched one another. The primary varied parameters for this process are pipeline roughness (Manning's n) and sediment build up in the pipe, although other parameters can also be adjusted as calibration results are generated.

  Manning's roughness coefficients, or n values, have industry accepted ranges based on a number of variables. Roughness coefficients increase over time depending on the construction methods, installation quality, system maintenance, and other environmental factors. There can be certain factors within the City's collection system that can result in roughness coefficients which differ from the typical range. For example, pipeline bellies, joint misalignment, cracks, and debris (e.g., root intrusion, etc.) lead to increased turbulence in a pipe, as well as the apparent Manning's n factor.

  If the model is unable to reasonably match the field measured flow depth and velocity without leaving the acceptable range of Manning's roughness coefficients, further investigation is conducted to help determine the cause of the discrepancy. Some issues that could cause such a discrepancy can include errors in the slope or diameter of a pipeline, downstream blockages, pipeline sags, and, in some cases, influences from downstream lift station operations.

Table 4.4 provides a summary of the dry weather flow calibration using the average and daily peak flow results for both weekday and weekend conditions. As shown on Table 4.4, with a few exceptions, the model simulated average and peak flows for both weekday and weekend DWF were all within 10-percent. In general, the percent difference between the overall modeled and measured DWF ranged between 0.0 and 8.6 percent.

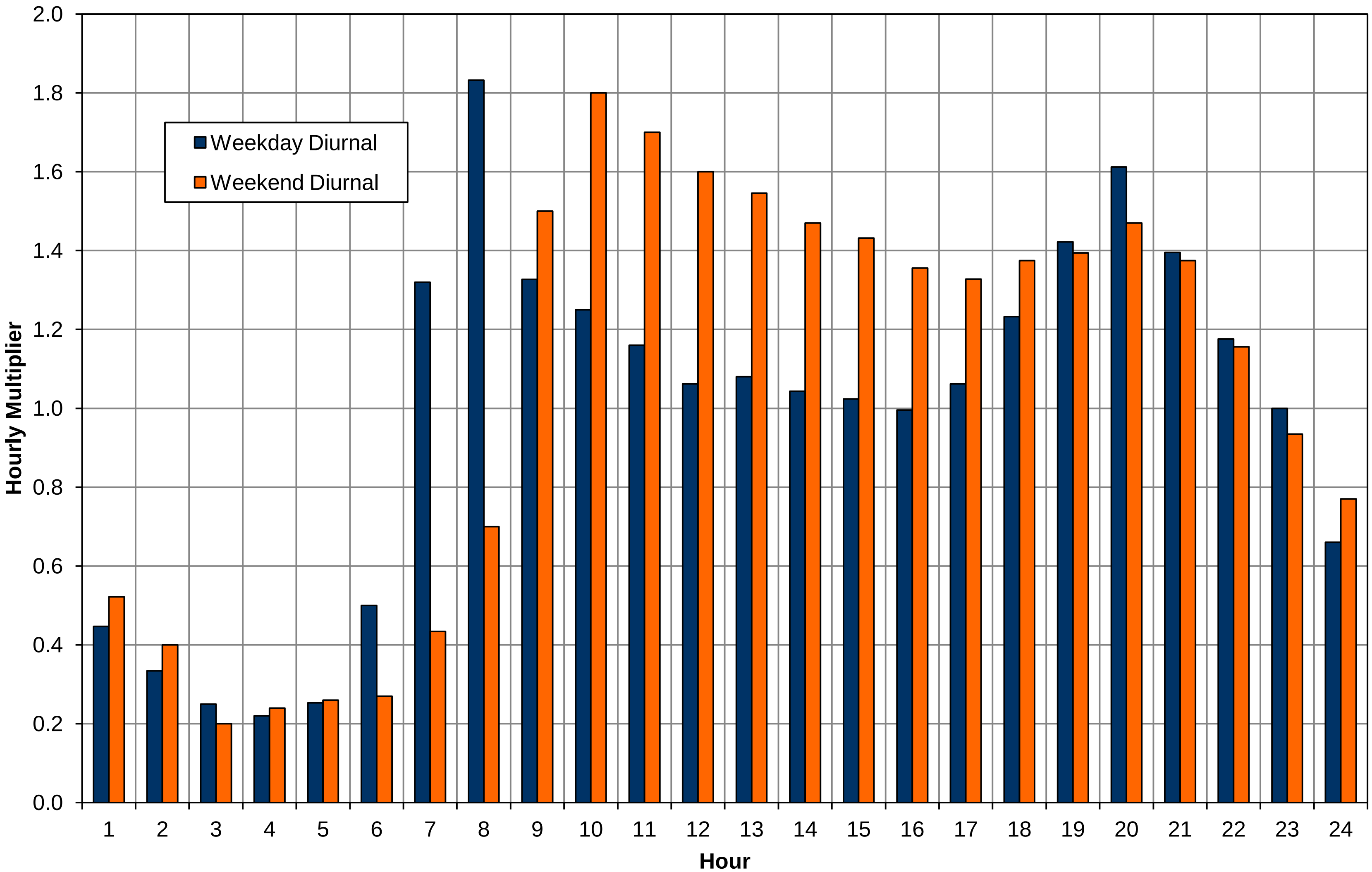

Figure 4.5
Example Diurnal Patterns (Meter 17)
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Table 4.4	Dry Weather Flow Calibration Summary Sanitary Sewer Master Plan Update City of Chico			
Monitor Site	**Pipe Diameter (in.)**	**Measured Dry Weather Flow[1],[2] (mgd)**	**Modeled Dry Weather Flow (mgd)**	**Percent Difference[3]**
Site 1	30	1.338	1.377	2.9
Site 4	36	2.164	2.169	0.2
Site 5	15	0.211	0.211	0.0
Site 6A	18	0.547	0.538	-1.8
Site 6B	18	0.467	0.472	1.3
Site 7	15	0.506	0.506	0.0
Site 8	24	0.504	0.461	-8.6
Site 9	21	1.021	1.059	3.7
Site 10	18	0.902	0.915	1.4
Site 11	33	1.433	1.415	-1.3
Site 12	14	0.227	0.217	-4.2
Site 13	12	0.453	0.458	1.2
Site 14	18	0.304	0.297	-2.4
Site 15	24	1.053	1.050	-0.3
Site 16	33	0.501	0.501	0.0
Site 17	23.5	0.309	0.309	0.0
Site 18	10	0.113	0.113	-0.3

Notes:

(1) Source: Sanitary Sewer Flow Monitoring and Inflow/Infiltration Study, August 2012
(2) Dry Weather Flow = (5 x Weekday Average + 2 x Weekend Average)/7
(3) Percent Difference = (Modeled – Measured)/Measured x 100

Appendix D contains a detailed dry weather flow calibration summary sheet for each of the 17 meter sites. Each calibration sheet provides plots that compare the model simulated and field measured flow, velocity, and level data for both weekday and weekend conditions. An example of the dry weather calibration for Site 17 is shown on Figure 4.6. As shown on Figure 4.6 and in Appendix D, there is excellent overall correlation of the field measured data to the model output results. However, there were a few sites where the modeled flows, levels, or velocities were slightly outside of the generally accepted calibration tolerances. The majority of these sites were only marginally outside of the acceptable tolerances, and therefore the model was considered calibrated.

4.3.3 Wet Weather Flow Calibration

The WWF calibration enables the hydraulic model to accurately simulate I/I entering the collection system during a large storm. As outlined below, the WWF calibration process consists of several elements:

- **Identify calibration rainfall events**. The WWF calibration process consists of running model simulations of historic rainfall events based on data collected as part of the temporary flow monitoring program. The goal of any wet weather flow monitoring program is to capture and characterize a system's response to a significant rainfall event, preferably during wet antecedent moisture conditions.

  The selection of a particular calibration storm or group of storms is based on a review of the flow and rainfall data. For WWF calibration, the model was run from March 11, 2012 to April 21, 2012, and calibrated to the three main rainfall events that occurred during the course of the flow monitoring period.

  In order to run a model simulation for the March 11, 2012 to April 21, 2012 rainfall events, the hourly rainfall data were input into the model for these events. Each flow monitoring tributary area, or basin, was assigned a specific rainfall hyetograph, which was calculated for each basin based on the rainfall data collected at the rain gauges installed as part of the temporary flow monitoring program. Refer to Chapter 3 and Appendix B for more detail on how this computation was performed.

- **Define RDII tributary areas**. For the WWF calibration, RDII flows are superimposed on top of the DWF. The model calculates RDII by assigning "RDII Inflows" to each node in the model. RDII inflows consist of both a unit hydrograph and the total area that is tributary to the model node. The RDII tributary areas were calculated in GIS using the loading polygons, excluding any large vacant, open space, or other areas in the system which are not expected to contribute to I/I into the collection system. The tributary area provides a means to transform hourly rainfall depth from the rainfall hyetographs into a rainfall volume. The rainfall volume is transformed into actual RDII flows using the unit hydrograph, as described in the next step.

- **Create I/I parameter database and modify to match field measured flows**. The main step in the WWF calibration process involves creating custom unit hydrographs for each flow monitoring tributary area using the "RTK Method," which is widely used in collection system master planning. Using the RTK Method, the RDII unit hydrograph is the summation of three separate triangular hydrographs (short term, medium term, and long term), which are each defined by three parameters: R, T, and K. R represents the fraction of rainfall over the sewer shed that enters the collection system; T represents the time to peak of the hydrograph; and K represents the ratio of time to recession to the time to peak. Therefore, there are a total of nine separate variables associated with each unit hydrograph. Figure 4.7 shows the shape of an example unit hydrograph.

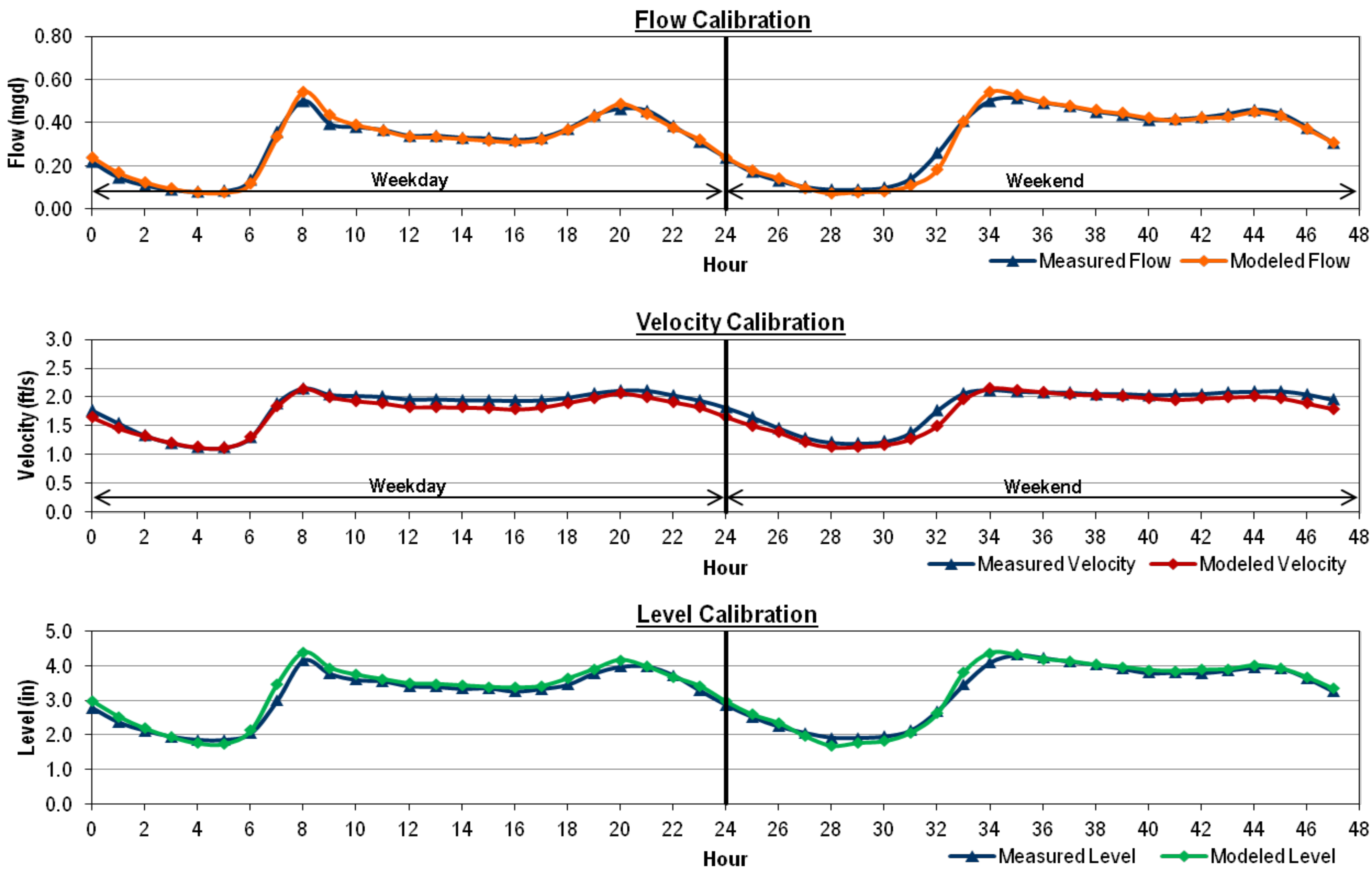

Figure 4.6
Example Dry Weather
Flow Calibration (Meter 17)
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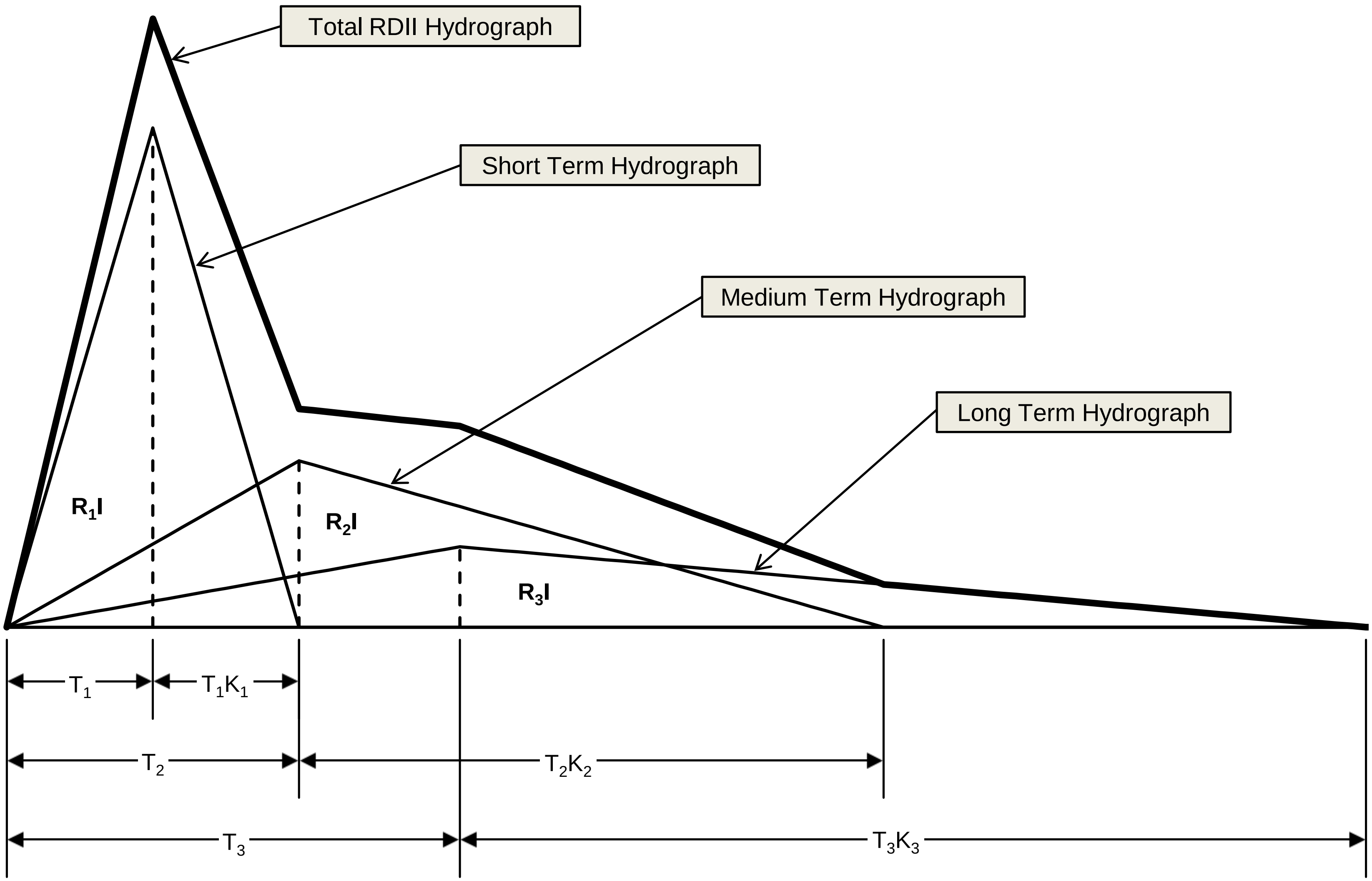

Figure 4.7
Example RDII Hydrograph
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The hydrographs utilize the R-Values (percent of rainfall that enters the collection system) calculated for each basin to simulate I/I. The nine variables in each unit hydrograph were initially set based on engineering judgment and then adjusted until the model simulated flows (both peak flows and average flows) matched closely with the field measured flows.

As with the dry weather calibration, the wet weather calibration process compared the meter data with the model output. Comparisons were made for average and peak flows as well as the temporal distribution of flow until flows returned to their baseline levels. According to the WaPUG, a hydraulic model is generally considered to be satisfactorily calibrated to WWF conditions if the modeled peak flows are within +25 percent to -15 percent of the field measured data, and if the average modeled flows are within +20 percent to -10 percent of the field measured data.

- **Refine model variables to match field measured velocity and flow depths**. After the model was considered to be satisfactorily calibrated for wet weather flows, the model simulated velocities and flow depths were checked against the field measured velocities and flow depths during the calibration storms. Refinements were made to the various model parameters so that the modeled and measured velocity and depth closely matched one another. If any adjustments were made to Manning's n-values or other parameters, the DWF calibration was rechecked as well to make sure that the flow depth and velocities still matched well under DWF conditions.

Appendix E contains a detailed wet weather flow calibration summary sheet for each of the 17 meter sites. Each calibration sheet provides plots that compare the model simulated and field measured flow, velocity, and level data for the calibration storms. An example of the wet weather calibration for Site 17 is shown on Figure 4.8. Table 4.5 provides a summary of the wet weather flow calibration using the average and peak flow results. As shown on Table 4.5, the model simulated average and peak flows at all meter sites were within the acceptable tolerances for at least two of the three calibration storms, and therefore the model was considered calibrated and ready to use for capacity analysis purposes.

Table 4.5 Wet Weather Flow Calibration Summary
Sanitary Sewer Master Plan Update
Chico of Chico

Monitor Site	Pipe Diameter (in)	Storm 1 (3/13/2012-3/24/2012) Avg. Flow (%)	Storm 1 Peak Flow (%)	Storm 1 Avg. Velocity (%)	Storm 1 Ave. Level (%)	Storm 2 (3/27/2012-4/4/2012 Avg. Flow (%)	Storm 2 Peak Flow (%)	Storm 2 Avg. Velocity (%)	Storm 2 Ave. Level (%)	Storm 3 (4/10/2012-4/17-2012) Avg. Flow (%)	Storm 3 Peak Flow (%)	Storm 3 Avg. Velocity (%)	Storm 3 Ave. Level (%)
1	30	4.3	7.0	-3.9	6.1	2.5	16.2	-4.6	5.3	5.9	7.7	-1.2	5.0
4	36	5.5	-2.2	3.9	1.3	2.5	0.1	3.1	-0.3	3.0	-5.0	3.5	-0.3
5	15	6.4	-5.	9.5	-1.6	-2.2	-9.9	3.7	-4.1	-3.8	-7.7	3.0	-4.7
6A	18	4.5	-6.5	1.8	2.2	4.8	16.4	0.3	3.6	-9.6	-35.5	-4.0	-2.6
6B	18	27.3	-9.4	10.2	14.5	-5.1	-14.5	1.5	-3.3	17.4	-20.3	13.7	8.8
7	15	-4.6	10.8	-3.5	-1.3	-2.3	9.2	-4.5	1.9	-4.9	12.5	-0.4	-4.0
8	24	10.5	6.5	3.9	1.7	-4.7	14.5	-4.7	-2.8	18.5	34.4	12.1	0.6
9	21	11.7	-1.6	13.7	-1.3	5.7	5.2	8.8	-2.3	1.7	-5.8	-0.3	2.1
10	18	13.5	13.6	-3.5	12.9	-2.3	8.8	-8.0	4.7	-4.3	18.3	-7.8	2.3
11	33	-0.6	6.2	-0.3	-0.1	-2.8	5.8	-1.5	-1.1	-3.1	12.4	-2.1	-0.4
12	14	5.6	16.1	-5.4	5.5	-7.7	14.9	-8.5	-1.8	-9.8	-6.3	-11.7	-0.5
13	12	20.8	2.8	5.9	11.6	-0.3	-11.7	1.3	-0.7	-0.7	-14.3	0.1	-0.4
14	18	5.7	2.3	0.0	4.5	2.1	14.1	2.8	0.0	6.9	-9.4	5.7	3.3
15	24	0.4	-5.3	0.7	-0.8	-2.8	-7.9	-3.4	0.0	-2.7	8.0	-5.1	1.4
16	33	1.0	-1.4	-4.4	3.6	-3.4	-2.1	-2.2	-0.4	3.4	13.7	-6.5	7.3
17	23.5	0.4	13.4	-4.3	1.8	-4.0	10.4	-4.1	-1.2	-5.1	-0.7	-6.1	-0.7
18	10	14.0	-3.8	0.1	10.7	0.1	6.5	-3.3	3.8	-5.2	-36.0	2.7	-4.9

Notes:
(1) Source: City of Chico 2012 Temporary Flow Monitoring Program, V&A Consulting Engineers.
(2) Percent Difference = Modeled – Measured/Measured*100.

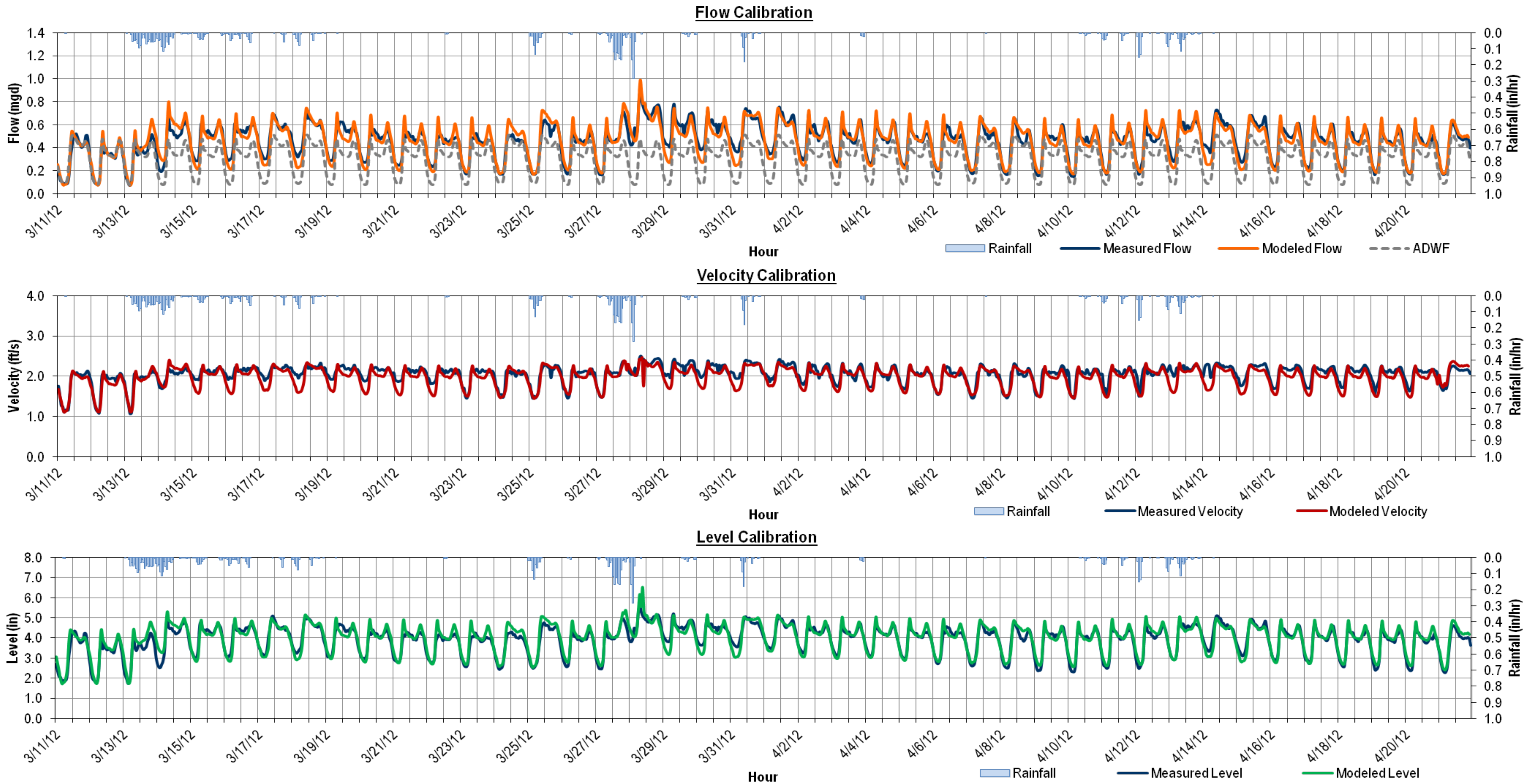

Figure 4.8
Example Wet Weather
Flow Calibration (Meter 17)
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PLANNING CRITERIA AND DESIGN FLOWS

The capacity of the City of Chico's (City's) sanitary sewer collection system was evaluated based on the planning criteria defined in this chapter. The planning criteria address the collection system capacity, gravity sewer pipe slopes, and maximum allowable depth of flow within a sewer. This chapter also summarizes the existing and build out design flows.

5.1 GRAVITY SEWERS

Gravity sewer pipe capacities are dependent on many factors. The factors include roughness of the pipe, the chosen maximum allowable depth of flow downstream flow conditions, and limiting velocity and slope. The following sections describe the factors that account for the determination of existing and future pipeline capacities in the City's collection system.

5.1.1 Manning Coefficient (n)

The manning coefficient 'n' is a friction coefficient that varies with respect to pipe material, size of pipe, depth of flow, smoothness of joints, root intrusion, and other factors. For sewer pipes, the manning coefficient typically ranges between 0.011 and 0.017, with 0.013 being a representative value used for system planning purposes. For this study, a manning "n" factor of 0.013 was assigned to all existing sewer collection system lines in the hydraulic model, and then refined as necessary during model calibration to accurately simulated field measured levels and velocities.

5.1.2 Flow Depth Criteria (d/D)

The primary criterion used to identify capacity deficient sewers or to size new sewer improvements is the maximum flow depth to pipe diameter ratio (d/D). The d/D value is defined as the depth of flow (d) in a pipe during peak (design) flow conditions divided by the pipe's diameter (D). Based on Carollo Engineers, Inc's (Carollo's) experience, City staff input, and industry standards, the following criteria were used:

5.1.2.1 <u>Flow Depth for Existing Sewers</u>

Maximum flow depth criteria for existing sanitary sewers are established based on a number of factors, including the acceptable risk tolerance of the utility, local standards and codes, and other factors. Using a conservative d/D ratio when evaluating existing sewers may lead to unnecessary replacement of existing pipelines. Conversely, lenient flow depth criteria could increase the risk of sanitary sewer overflows (SSOs). Ultimately, the maximum allowable flow depth criteria should be established to be as cost effective as possible while at the same time reducing the risk of SSOs to the greatest extent possible.

For Chico, water levels (hydraulic grade line) were allowed to rise to a distance halfway between the manhole rim and the pipe crown, or up to five feet below the manhole rim during peak wet weather flow (PWWF) conditions, whichever is more conservative.

A capacity deficient sewer (i.e., system bottleneck) raises the hydraulic grade line of upstream sewers, leading to backwater conditions. The greater the capacity deficiency, the higher water levels will surcharge upstream of the bottleneck pipeline (or pipelines). The hydraulic model is used to determine "backwater" pipelines in order to specify which specific pipelines are the actual root causes of the capacity deficiency. Capital projects are proposed to provide greater flow capacity for the deficient sewers, which eliminates the backwater conditions that cause surcharging.

5.1.2.2 Flow Depth for New Sewers

When designing sewer pipelines, it is common practice to adopt variable flow depth criteria for various pipe sizes. Design d/D ratios typically range from 0.5 to 0.92, with the lower values typically used for smaller pipes, which may experience flow peaks greater than design flow or blockages from debris, paper, or rags. Table 5.1 summarizes the criteria for the evaluation of existing sewers and for sizing new trunk lines. For pipelines less than 12-inches in diameter the max d/D value is 0.5 or 50 percent of the pipeline depth. Pipelines 12- to 18-inches in diameter, the max d/D is 0.67, and for pipelines larger than 18-inches in diameter the maximum d/D value is 0.75.

Table 5.1 Maximum Flow Depth Criteria
Sewer System Master Plan Update
City of Chico

Maximum Flow Depth for Existing Sewers	
Peak Wet Weather Flow:	Surcharge to halfway between manhole rim and pipe crown, or Surcharge to 5 ft below manhole rim
Maximum d/D for New Sewers	
Pipe Diameter (inches)	Maximum d/D Ratio (during Peak Flows)
Less than 12	0.50
12 to 18	0.67
Larger than 18	0.75

5.1.3 Design Velocities and Minimum Slopes

In order to minimize the settlement of sewage solids, it is standard practice in the design of gravity sewers to specify that a minimum velocity of 2 feet per second (ft/s) be maintained when the pipeline is half-full. At this velocity, the sewer flow will typically provide self cleaning for the pipe. Due to hydraulics of a circular conduit, velocity of half-full flow in pipes approaches the velocity of nearly full flow in pipes.

Table 5.2 lists the recommended minimum slopes and their corresponding maximum flows for maintaining self-cleaning velocities (equal to or greater than 2 ft/s) when the pipe is flowing at its maximum depth (d/D ratio).

Table 5.2 Minimum Slope for New Pipes
Sewer System Master Plan Update
City of Chico

Pipe Diameter (inches)	Minimum Slope[(1)(2)] (feet/feet)	Calculated Flow at Maximum d/D[(2)(3)]	
		d/D	Maximum Flow (mgd)
6	0.0050	0.50	0.127
8	0.0033	0.50	0.226
10	0.0025	0.50	0.353
12	0.0019	0.67	0.796
15	0.0014	0.67	1.24
18	0.0011	0.67	1.79
21	0.0009	0.75	2.84
24	0.0008	0.75	3.70
27	0.0007	0.75	4.68
30	0.0006	0.75	5.79
36	0.0006	0.75	9.65
42	0.0006	0.75	14.56

Notes:

(1) Recommended minimum slope for flows at a velocity greater than or equal to 2 ft/s.

(2) Manning's n = 0.013

(3) Calculated flow is determined using the minimum slope and maximum allowable d/D from Table 3.1.

5.1.4 Changes in Pipe Size

When a smaller sewer joins a large one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient. An approximate method for securing these results is to place the 0.8 depth point of both sewers at the same elevation. For planning purposes and designing new pipes, and in the absence of field data, sewer crowns were matched at the manholes.

5.2 LIFT STATIONS AND FORCE MAINS

Industry standard practice is to require that sewage lift stations have sufficient capacity to pump the PWWF with the largest pump out of service (firm capacity).

Force main piping should be sized to provide a minimum velocity of 3 ft/s at the design flow rate of the lift station and no more than 8 ft/s. For the determination of head loss, the Hazen Williams Equation is used with a C-factor of 120. These factors are typical for sewer system master planning purposes.

5.3 DESIGN FLOWS

This section summarizes the historic flows measured at the City's Water Pollution Control Plant (WPCP) and presents the calculation of the design flows used to model the existing and future sewer collection system.

5.3.1 Historic WPCP Flows

In addition to the flow monitoring program (summarized in Chapter 3), this project reviewed historical influent flow data at the WPCP from 2005 to 2010 (the last year in which a full years worth of data was available) to help establish wastewater flow criteria.

Flow data from January 2005 through December 2010 are summarized in Table 5.3. Table 5.3 lists the average flow at the WPCP for each month from 2005 through 2010. In addition, Table 5.3 summarizes the annual average flow (i.e., the average day flow) and the average dry weather flow (ADWF) for each of those years. As shown in Table 5.3, the annual average flow ranged from 7.08 million gallons per day (mgd) in 2010 to 7.96 mgd in 2006, with a six year average of 7.40 mgd. The ADWF (defined as the average flow during the months of July, August, and September) ranged from 6.16 mgd in 2010 to 7.11 mgd in 2007, with a six year average of 6.86 mgd. For this study, the existing average dry weather flow was defined as the six year ADWF, which is equal to 6.86 mgd.

5.3.2 Wastewater Flow Coefficients

In order to develop wastewater flow projections and allocate future flows to the collection system, relationships between land use and wastewater generation were developed. These relationships, called wastewater flow coefficients are established based on the average wastewater flow generated for each existing land use type. The land use flow coefficients were established to project the estimated average dry weather flow through build out of the City's sphere of influence (SOI).

Average wastewater flow coefficients are rates, usually expressed in gallons per day per acre (gpd/ac), applied to land use acreage to calculate the ADWF generated from a particular land use. A flow coefficient was developed for each land use classification. The flow coefficient provides a means to transform a land use category from acreage into wastewater flow. The resulting flow can be used to estimate the ADWF associated with development of existing vacant land areas. Wastewater flow coefficients for residential areas can range between 200 to 5,000 gpd/ac, and commercial and industrial areas might range from 500 to 2,500 gpd/ac. Land uses designated as open space and agriculture are assumed to generate negligible amounts of sewage flow, and as a result have a flow coefficient of zero.

Table 5.3 Historical UPCP Flows
Sanitary Sewer Master Plan Update
City of Chico

	WPCP Influent Flow(1) (mgd)						
Month	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2005-10 Average.**
January	8.18	9.12	7.16	8.41	7.05	8.55	8.08
February	7.14	8.19	8.43	8.77	9.05	8.76	8.39
March	7.25	10.20	7.43	7.46	8.09	7.39	7.97
April	7.17	9.71	7.51	7.32	7.06	7.78	7.76
May	7.65	7.51	7.19	7.11	7.13	6.39	7.16
June	7.04	6.81	6.72	6.67	6.38	6.01	6.61
July	6.77	6.71	6.67	6.67	6.21	5.90	6.49
August	7.22	7.20	7.08	6.99	6.67	6.08	6.87
September	7.45	7.40	7.59	7.32	7.05	6.52	7.22
October	7.45	7.45	7.57	7.41	7.14	6.87	7.32
November	7.50	7.52	7.28	7.39	6.86	6.74	7.22
December	8.78	7.72	7.70	7.19	7.01	8.10	7.75
Annual Average	**7.47**	**7.96**	**7.35**	**7.39**	**7.13**	**7.08**	**7.40**
ADWF(2)	**7.15**	**7.10**	**7.11**	**6.99**	**6.65**	**6.16**	**6.86**

Notes:
(1) Source: City influent metering records.
(2) ADWF is defined as the average flow during the months of July, August, and September.

The coefficients are developed using the following procedure:

- Average flows for each isolated flow metering tributary area were derived from the flow monitoring data (described in detail in Chapter 3).
- Using geographic information system (GIS), the acres for each land use type contained in each flow monitoring tributary area were calculated.
- Preliminary coefficients for each land use type are estimated based on values that are typical for the approximate number of dwelling units per acre and the typical number of people per dwelling unit for each land use type.
- The coefficients for each isolated flow metering tributary are then adjusted up or down (balanced) so that the calculated average flows from each tributary area match what was measured during the flow monitoring period.

- Once the coefficients for the isolated flow meter tributary areas were balanced, the weighted average of the coefficients for each land use type is calculated based on the acreage contribution from each isolated metering tributary area.
- The weighted average coefficients were then adjusted for the entire sewer collection system to match the existing ADWF of 6.86 mgd. The adjusted weighted average coefficients are considered representative of the wastewater generation by land use for the City as a whole, and are used to project future average wastewater flows.

The calibrated wastewater flow coefficients developed for this Master Plan range from 200 gpd/ac to 3,600 gpd/ac, and are summarized in Table 5.4.

5.3.3 Existing and Projected Average Dry Weather Flow

Developing an accurate estimate of the future quantity of wastewater generated at build out of the collections system is an important step in maintaining and sizing sewer system facilities, for both existing conditions and future developments. In general, the future ADWF for build out of the study area was determined by multiplying the wastewater flow coefficients by the projected land use acreage.

As noted in Chapter 2, the City's 2030 General Plan identifies three types of new growth within the SOI. These are special planning areas, opportunity sites, and resource constraint overlay sites. As shown in Table 5.4, an average wastewater flow coefficient of 1,200 gpd/ac was assumed to be representative of the future wastewater flows associated with the special planning areas. The 2030 General Plan assumes that 13 to 15 percent of the developed land within the opportunity sites will redevelop in the future. To account for this, the existing wastewater flows for existing developed areas within the opportunity sites were increased by 15 percent. In addition, there are existing vacant parcels within the opportunity areas. To provide a level of conservatism in the flow projections for these areas, future wastewater flows for vacant land within the opportunity sites were calculated assuming 115 percent of the ADWF coefficients listed in Table 5.4. Areas within the defined resource constraint overlay areas were assumed to not develop due to the sensitive biological resources in these areas.

Using this method, the build out ADWF is approximately 13.91 mgd, as summarized in Table 5.4.

Table 5.4 Wastewater Flow Coefficients and Projected ADWF
Sewer System Master Plan Update
City of Chico

	Existing Sewer Service Area							Build Out Sewer Service Area				Average Dry Weather Flow		
	Developed Area			Vacant Area										
Land Use Category	Non-Opportunity Area (acres)	Opportunity Area (acres)	Developed Area Subtotal (acres)	Non-Opportunity Area (acres)	Opportunity Area (acres)	Vacant Area Subtotal (acres)	Total Area (acres)	Non-RCO/ Opportunity Area (acres)	Resource Constraint Overlay (acres)	Opportunity Area (acres)	Total Buildout Area (acres)	ADWF Coefficient (gpd/acre)	Existing ADWF (mgd)	Buildout ADWF (mgd)
VLDR Very Low Density Residential	214.9	0.0	214.9	89.8	0.0	89.8	304.7	1,545.6	186.3	0.0	1,731.9	200	0.04	0.309
LDR Low Density Residential	3,718.1	22.1	3,740.1	578.3	1.1	579.4	4,319.5	5,018.0	551.3	23.2	5,592.5	800	2.99	4.036
MDR Medium Density Residential	640.5	77.8	718.3	212.7	13.7	226.4	944.6	1,005.7	41.9	91.5	1,139.0	1,050	0.75	1.166
MHDR Medium-High Density Residential	481.3	88.2	569.4	102.0	4.4	106.3	675.7	680.8	24.5	92.5	797.9	2,000	1.14	1.574
HDR High Density Residential	4.7	1.6	6.3	4.4	0.0	4.4	10.6	9.0	0.0	1.6	10.6	3,600	0.02	0.039
CS Commercial Services	109.3	5.7	115.0	13.6	4.5	18.2	133.2	194.0	0.0	10.2	204.2	900	0.10	0.185
NC Neighbhorhood Commerical	26.7	16.4	43.2	22.3	5.0	27.3	70.5	73.3	0.0	21.5	94.7	1,200	0.05	0.118
RC Regional Commercial	71.3	242.3	313.6	67.5	36.0	103.5	417.1	138.9	0.0	278.3	417.2	1,000	0.31	0.459
MW Manufacturing and Warehousing	448.2	3.1	451.3	219.8	0.0	219.8	671.2	1,301.1	482.3	3.1	1,786.5	400	0.18	0.522
IOMU Industrial/Office Mixed Use	0.0	70.0	70.0	60.5	2.1	62.6	132.6	41.6	0.0	91.0	132.6	700	0.05	0.102
OMU Office Mixed Use	280.0	55.7	335.8	49.3	7.0	56.2	392.0	324.3	5.0	62.7	392.0	800	0.27	0.317
CMU Commercial Mixed Use	199.4	260.3	459.7	52.3	15.5	67.8	527.5	336.2	3.3	275.8	615.3	1,000	0.46	0.653
RMU Residential Mixed Use	0.5	49.2	49.7	0.0	18.9	18.9	68.6	0.1	0.0	68.1	68.2	1,200	0.06	0.094
SMU Special Mixed Use	4.3	0.0	4.3	192.5	0.0	192.5	196.8	196.8	0.0	0.0	196.8	1,200	0.01	0.236
PFS Public Facilities and Services	665.3	15.0	680.3	296.1	0.0	296.1	976.4	2,037.3	0.0	15.0	2,052.3	600	0.41	0.815
SPA Special Planning Area	11.0	0.0	11.0	133.8	0.0	133.8	144.8	2,733.4	0.0	0.0	2,733.4	1,200	0.01	3.280
POS Primary Open Space	1,112.5	3.7	1,116.2	0.2	0.0	0.2	1,116.4	5,202.0	0.0	3.7	5,205.7	0	0.00	0.000
SOS Secondary Open Space	401.0	8.4	409.4	31.5	0.4	32.0	441.3	1,704.8	0.0	8.8	1,713.6	0	0.00	0.000
Streets, Canals, etc.	2,369.5	300.7	2,670.2	0.0	0.0	0.0	2,670.2	2,909.1	0.0	300.7	3,209.8	0	0.00	0.000
Agriculture	175.5	0.0	175.5	0.0	0.0	0.0	175.5	0.0	0.0	0.0	0.0	0	0.00	0.000
Total	10,934.0	1,220.3	12,154.2	2,126.7	108.5	2,235.2	14,389.5	25,451.9	1,294.7	1,347.7	28,094.2	--	6.86	13.91

5.3.4 Design Storm

Design storms are rainfall events used to analyze the performance of a collection system under extreme wet weather events. The first step in the development of the design storm is to define its recurrence interval and rainfall duration. The recurrence interval is based on the probability that a given rainfall event will occur or be exceeded in any given year. For example, a “100-year storm” means there is a 1 in 100 chance that a storm as large as or larger than this event will occur at a specific location in any year.

Duration is the length of time in which the rainfall occurs. It is industry standard in California to use the 10-year, 24-hour design storm for analyzing wastewater collection system performance during PWWF conditions. The 10-year, 24-hour design storm was also used as part of the previous master plan. For this reason, this study defines the design storm as a 10-year, 24-hour rainfall event. The 10-year, 24-hour design storm volume was developed as part of the previous master plan based on a statistical analysis of 52 years of rainfall, which revealed that a 10-year storm would have a total volume of 3.75-inches.

Once the design storm recurrence interval, duration, and associated rainfall volume have been determined, the next step in defining the design storm is to distribute the total rainfall over duration of the storm. This can be accomplished either by using a synthetic rainfall distribution (developed by the Natural Resource Conservation Service (NRCS)) or using the rainfall distribution for a large historic event of similar volume and duration. The City’s design storm was distributed using a rainfall pattern similar to that of the October 11, 1962 storm event. The October 11, 1962 event had a total volume and peak intensity similar to that of the statistically derived 10-year design storm. Figure 5.1 shows the 10-year, 24-hour design storm.

5.3.5 Existing and Projected Peak Wet Weather Flow

The PWWF is the highest observed hourly flow that occurs following the design storm event. Wet weather infiltration and inflow (I/I), which occurs during and after rainfall events, increases flows in the collection system. PWWF is typically used for designing sewers and lift stations. Therefore, the PWWF is the design flow for the purposes of this study. The City’s sewers and lift stations were evaluated based on their capacity to convey the PWWF.

The existing PWWF was derived throughout the system based on the hydraulic modeling results. This was accomplished by routing the 10-year, 24-hour design storm through the hydraulic model, which was calibrated to both dry weather and wet weather conditions. Detailed information regarding the calibration of the City’s hydraulic model is provided in Chapter 4.

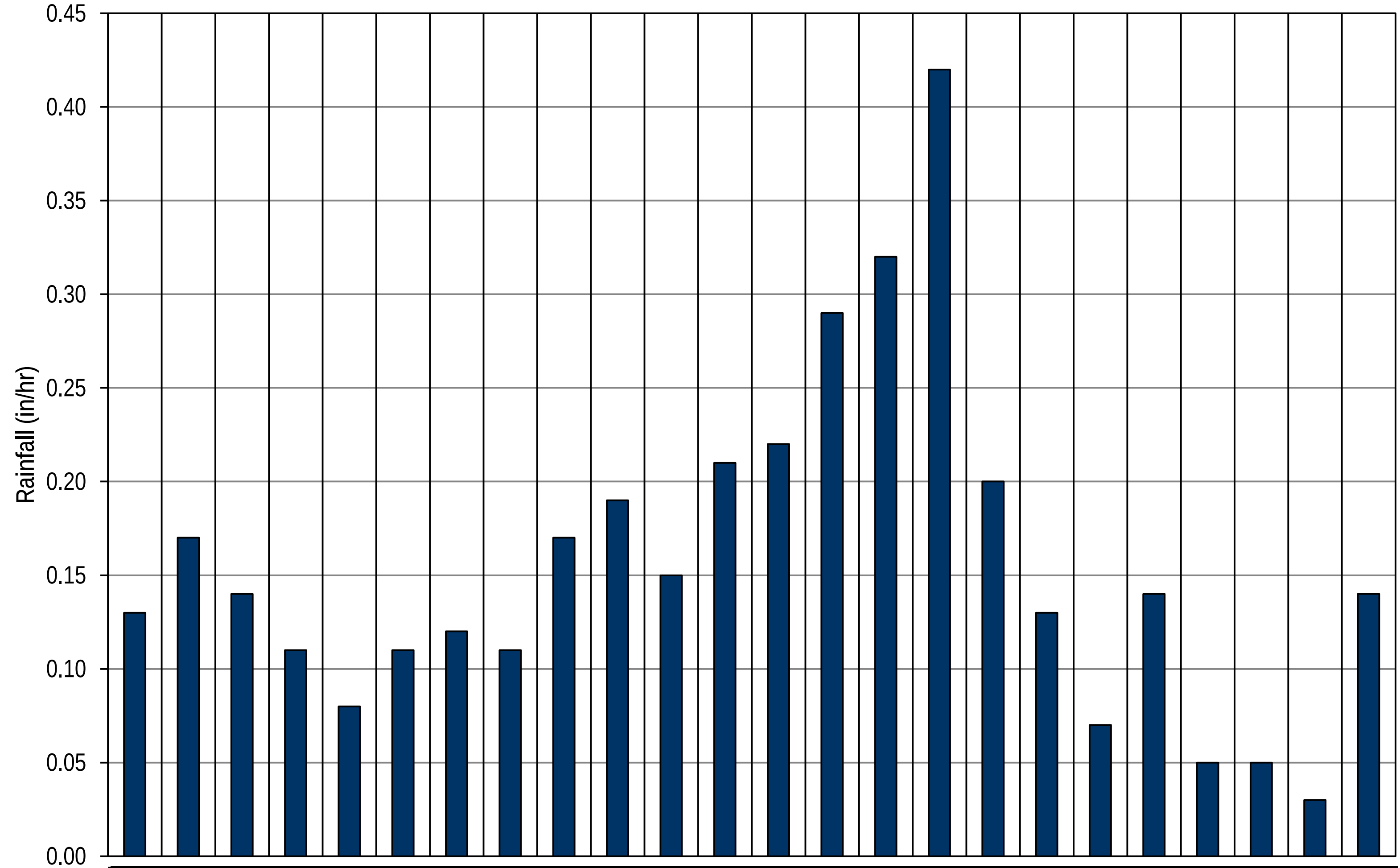
Similar to the existing PWWF, the build out PWWF was derived by routing a 10-year, 24 hour design storm through the hydraulic model. Peak I/I rates for future growth areas (e.g., vacant areas within the existing service area, growth areas outside of the current service area, etc.) were developed based on a peak I/I rate of 750 gallons per day per acre (gpd/ac).

Table 5.5 presents a summary of the existing and build out ADWF. In addition to the build out ADWF, Table 5.5 includes the existing and build out PWWFs. As shown in Table 5.5, City's ADWF is projected to roughly double from 6.9 mgd to 13.9 mgd by build out, whereas the PWWF is projected to increase from 20.5 mgd to about 35.3 mgd by build out (an increase of approximately 72-percent). Therefore, the City's PWWF to ADWF peaking factor is projected to decrease from roughly 3.0 to 2.5, which is typical for sanitary sewer collection systems. Newer sewers tend to have less I/I response than older areas of the system, primarily due to better construction methods. Furthermore, flow attenuation also tends to dampen out flow peaks as collection systems expand.

Table 5.5 Current and Projected Wastewater Flows
Sanitary Sewer Master Plan Update
City of Chico

Year	ADWF(1)	PWWF(2)	Peaking Factor
Existing	6.9	20.5	3.0
Build Out	13.9	35.3	2.5

Notes:
(1) ADWF = Average Dry Weather Flow.
(2) PWWF = Peak Wet Weather Flow.



Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Rainfall (in/hr)	0.13	0.17	0.14	0.11	0.08	0.11	0.12	0.11	0.17	0.19	0.15	0.21	0.22	0.29	0.32	0.42	0.20	0.13	0.07	0.14	0.05	0.05	0.03	0.14

Figure 5.1
10-Year, 24-Hour Design Storm
Sanitary Sewer Master Plan Update
City of Chico

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CAPACITY EVALUATION AND PROPOSED IMPROVEMENTS

This chapter discusses the hydraulic evaluation of the sewer collection system and the proposed projects that correct capacity deficiencies and serve future users.

6.1 CAPACITY EVALUATION

This section summarizes the results of the capacity evaluation of the City of Chico's (City's) sewer collection system, which includes a gravity pipeline capacity evaluation, as well as a lift station capacity evaluation. The evaluation considers both current and projected peak wet weather flow (PWWF) conditions.

6.1.1 Gravity Collection System Evaluation

Following the dry and wet weather flow calibration, which is summarized in detail in Chapter 4, a capacity analysis of the existing and future collection system was performed. The capacity analysis entailed identifying areas in the sewer system where flow restrictions occur or where pipe capacity is insufficient to convey PWWFs. Sewers that lack sufficient capacity to convey PWWFs create bottlenecks in the collection system that can potentially cause sanitary sewer overflows (SSOs). The sewer system was evaluated based on planning criteria presented in Chapter 5.

This section discusses the locations of current and projected hydraulic deficiencies resulting from flows exceeding the maximum flow depth criteria.

- **Existing System**. For the existing sewer collection system, the PWWF was routed through the hydraulic model. In accordance with the established flow depth criteria for existing sewers, manholes where the hydraulic grade line (HGL) encroached within a distance halfway between the manhole rim and the pipe crown, or five feet of the manhole rim, were identified.

  Note that the pipelines with an HGL that encroached within five feet of the manhole rim are not necessarily capacity deficient. In many cases, a surcharged condition within a given pipeline segment is due to backwater effects created by a downstream bottleneck. An illustration of backwater effects is shown in Figure 6.1. For this reason, the hydraulic model was analyzed to identify the pipeline segments that are the cause of the surcharged conditions.

  In general, the City's collection system has sufficient capacity to convey current PWWFs without exceeding the established flow depth criterion. However, there are a few areas where capacity restrictions lead to flow depths that exceed allowable levels. The location of these capacity deficient pipelines for current PWWF conditions are shown on Figure 6.2 in red.

Following the completion of the existing system analysis, improvement projects and alternatives were identified in order to mitigate existing system pipeline capacity deficiencies. The recommended improvement projects are discussed in greater detail in Section 6.2. In accordance with the established planning criteria, new sewer pipelines were sized such that the maximum flow depth to pipe diameter ratio (d/D) did not exceed the values summarized in Chapter 5. In other words, flows in recommended improvements were not allowed to surcharge during PWWF conditions.

- **Build Out**. The build out system analysis was performed in a manner similar to the existing system analysis. The purpose of the build out system evaluation is to verify that the existing system improvements were appropriately sized to convey build out PWWFs, and to identify the locations of sewers that are adequately sized to convey existing PWWFs, but cannot convey build out PWWFs. Additionally, new trunk sewers were added to the hydraulic model and sized to service major growth areas beyond the current City sewer service area.

  At build out, the City's wastewater flows are expected to double. As such, there are some areas of the existing collection system that cannot convey the build out PWWF without flows backing up above allowable levels. These pipelines are shown on Figure 6.3 in blue. The locations of new trunk sewers to service future growth are also shown on Figure 6.3 in orange.

6.1.2 Lift Station Evaluation

The City's hydraulic model includes lift stations that service the major trunk system (typically pipes 10-inches in larger). Lift stations that serve smaller 8-inch diameter and smaller pipes are not included in the hydraulic model. In accordance with the established planning criteria, the City's existing modeled lift stations were evaluated to determine if each one has available capacity to convey existing and future PWWF. Lift stations with an influent PWWF above the existing firm capacity were flagged as deficient. Table 6.1 summarizes the results of the lift station evaluation.

- **Existing System**. As shown in Table 6.1, the majority of the City's lift stations are adequately sized to convey the existing model simulated PWWFs. However, one of the seven modeled lift stations was flagged as deficient under existing PWWF conditions:
  - *Chico Municipal Airport Lift Station*. As shown in Table 6.1, the modeled existing PWWF into the Chico Municipal Airport Lift Station was 1.40 million gallons per day (mgd), which slightly exceeds its firm capacity (1.38 mgd). City staff indicated that much of the collection system upstream of this lift station (i.e., the collection system in the vicinity of the Chico Municipal Airport) was installed around the 1940's and 1950's, and that there is a good possibility that there are direct connections to the sanitary sewer system in this area.

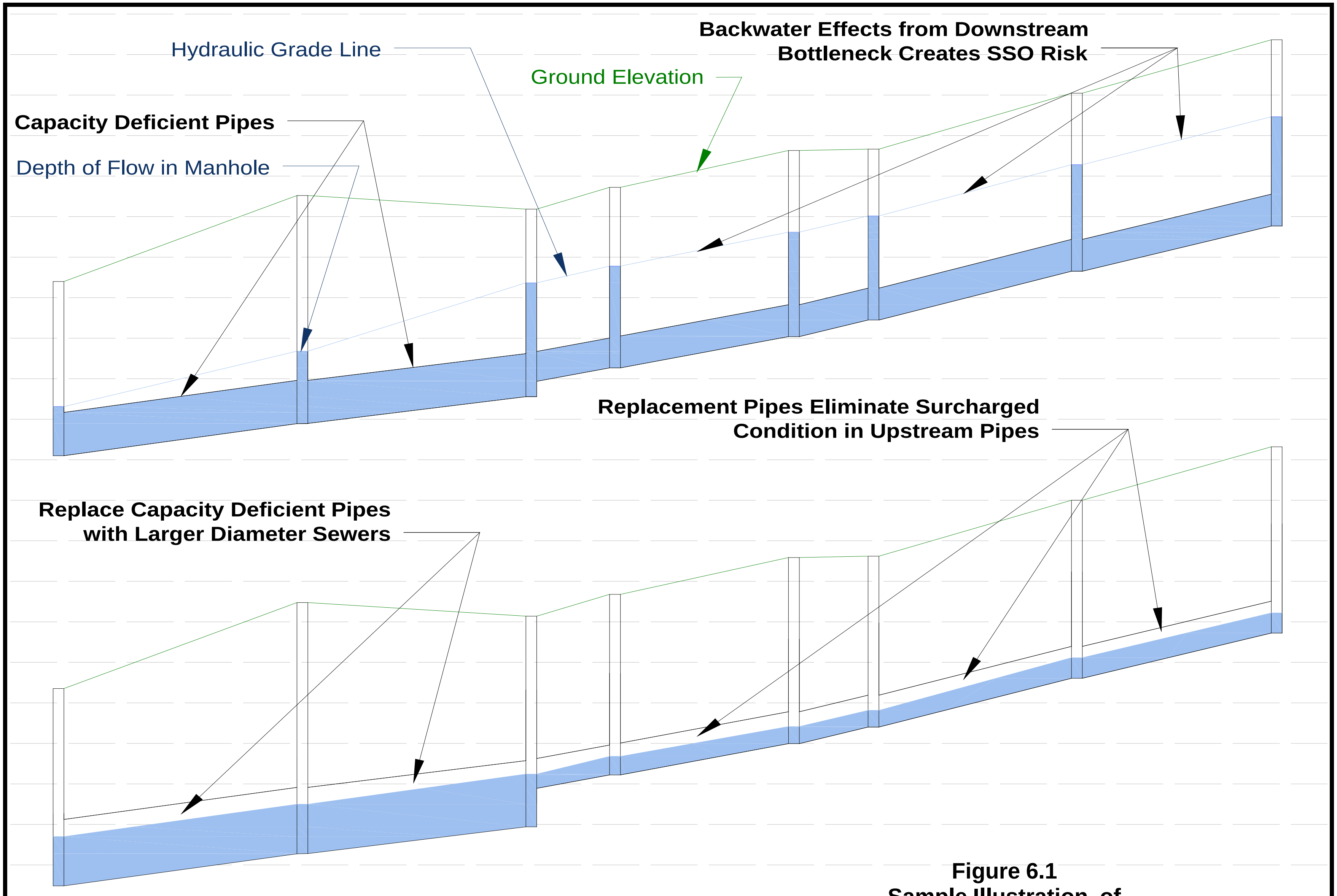

Figure 6.1
Sample Illustration of
Backwater Effects in a Sewer
Sanitary Sewer Master Plan Update
City of Chico

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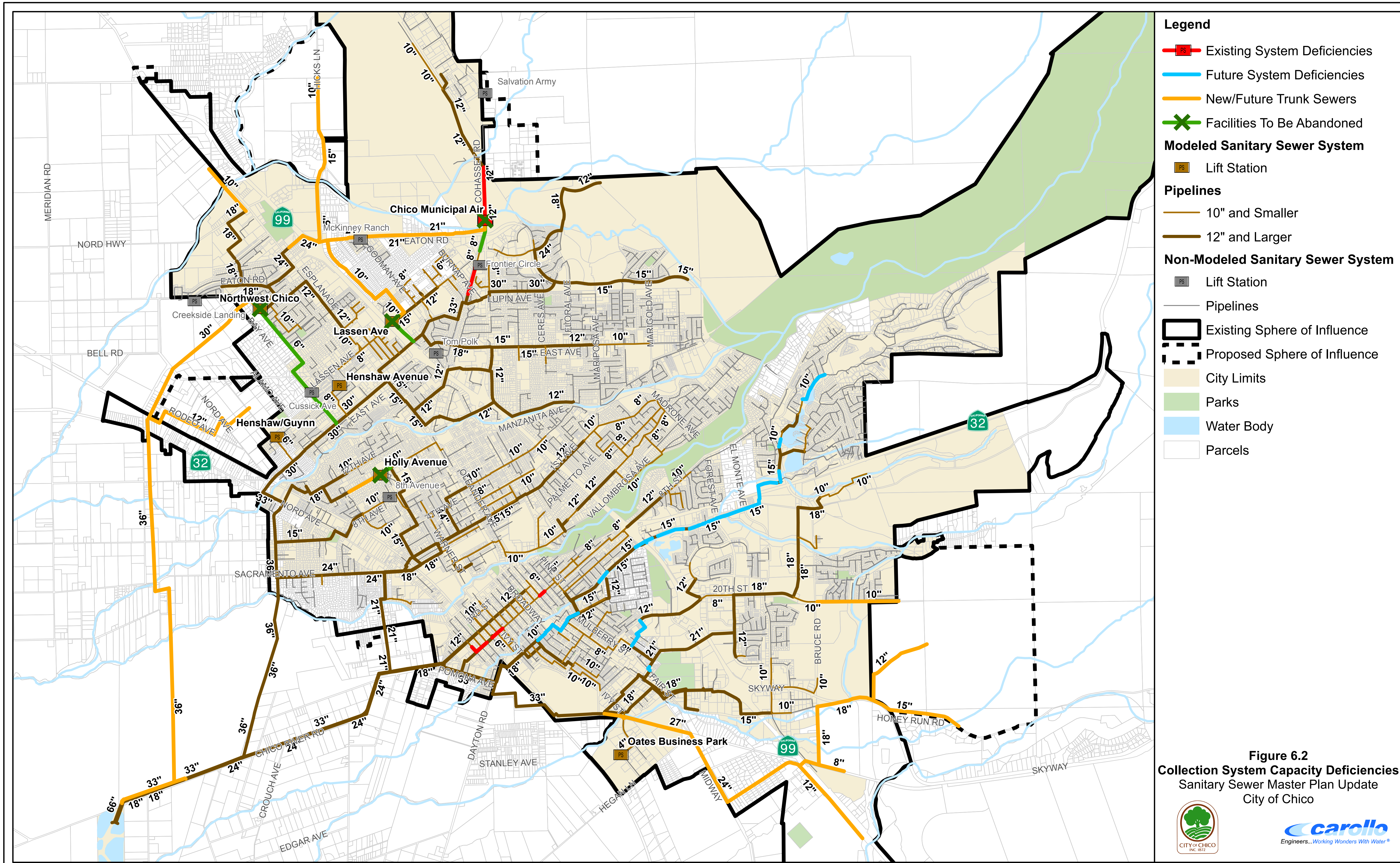


Figure 6.2
Collection System Capacity Deficiencies
Sanitary Sewer Master Plan Update
City of Chico

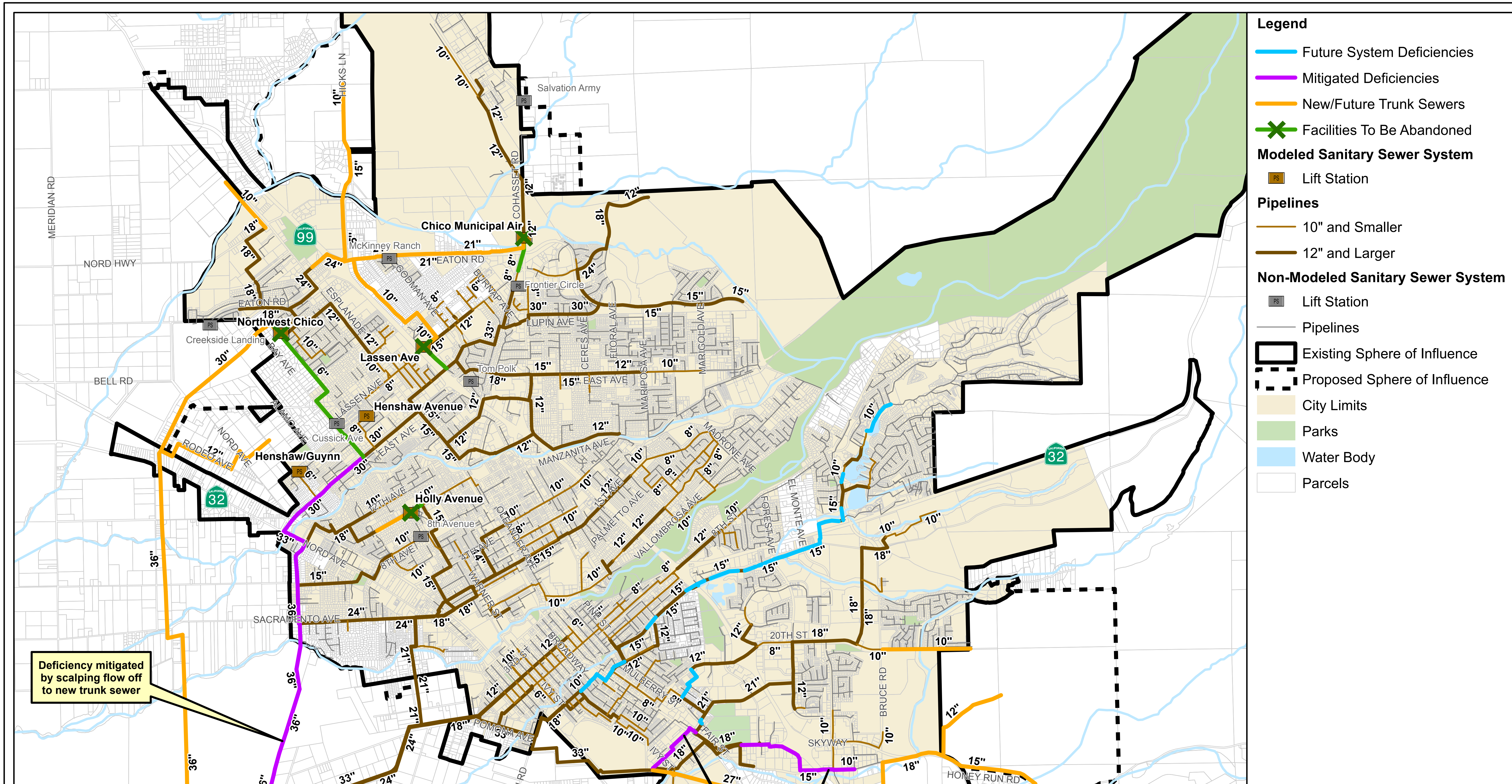


Figure 6.3
Build-Out Collection System
Capacity Deficiencies
Sanitary Sewer Master Plan Update
City of Chico

Table 6.1 Lift Station Evaluation
Sanitary Sewer Master Plan Update
City of Chico

	Pump Data					Existing Capacity Evaluation			Buildout Capacity Evaluation		
Lift Station Name	Pump	hp	Pump Capacity (gpm)	Firm Capacity (gpm)	Firm Capacity (mgd)	Existing PWWF (mgd)	Capacity Deficiency (Yes/No)	Capacity Deficiency (mgd)	Buildout PWWF (mgd)	Capacity Deficiency (Yes/No)	Capacity Deficiency (mgd)
Chico Municipal Airport	1	20	958	958	1.38	1.42	Yes	0.04	Abandoned	--	--
	2	20	958								
Henshaw Avenue	1	2.4	236	236	0.34	0.05	No	0.00	0.05	No	0.00
	2	2.4	236								
Henshaw/Guynn	1	3	270	270	0.39	0.04	No	0.00	0.08	No	0.00
	2	3	270								
Holly	1	1.6	223	223	0.32	0.02	No	0.00	Abandoned	--	--
	2	1.6	223								
Lassen Avenue	1	35	1,795	1,795	2.58	0.13	No	0.00	Abandoned	--	--
	2	35	1,795								
Northwest Chico	1	35	1,492	1,492	2.15	0.71	No	0.00	Abandoned	--	--
	2	35	1,492								
Oates Business Park	1	10	185	185	0.27	0.17	No	0.00	0.25	No	0.00
	2	10	185								

For this reason, the City plans to install City-owned flow meters in this area, and collect flow data during the next rainy seasons. The City also plans to conduct a smoke testing study during to further refine and isolate the major sources of inflow contributed by storm drains directly connected to the sewer system. Elimination of direct connections could potentially reduce or eliminate the existing capacity deficiency at this lift station.

- **Build Out**. Similar to the existing system analysis, the City's modeled lift stations were checked against the build out PWWF conditions, and no additional modeled lift stations were flagged as deficient for build out flow conditions.

  The City has had plans to construct the Eaton Road Trunk Sewer, the 11th Avenue Sewer, the Silverbell Road Sewer, and the Northwest Trunk Sewer. Construction of these trunk improvement projects will allow the City to abandon the Chico Municipal Airport Lift Station, the Northwest Chico Lift Station, the Lassen Avenue Lift Station, and the Holly Lift Station. Due to this fact, no build out PWWFs are presented in Table 6.1 for these lift stations. Section 6.2 below provides further detail regarding the proposed sewer trunk improvement projects that allow for these lift stations to be abandoned.

6.2 COLLECTION SYSTEM IMPROVEMENTS

Figure 6.4 illustrates the proposed sewer improvements required to correct existing deficiencies and to serve future users. Detail maps for each of the proposed improvements are provided in Chapter 8 for clarity. Table 6.2 provides more detail of each improvement. Both Figure 6.4 and Table 6.2 should be used together to locate the proposed improvement and to gain details of the improvement (length, diameter, street location, etc.). The improvement identification number links the figure and table. The improvements summarized in Table 6.2 use a cross-referenced number system. The columns used in Table 6.2 refer to the following:

- **Improvement ID**: Assigned unique identifier associated with each improvement project. This is an alphanumeric number that starts with one letter indicating the type of improvement P= Pipe, LS = Lift Station and continues with a number and a letter.
- **Type of improvement**: Pipelines, lift stations, force mains, and jacked steel casings.
- **Street Description**: Street in which the improvement is proposed.
- **Limits**: Description of the beginning and end of a proposed pipeline project.
- **Existing Size**: This is the size of the existing pipeline/facility. It represents the diameter of the existing pipelines (inches), and the total capacity of lift stations (mgd).
- **Proposed Size**: This is the size of the proposed improvement. It represents the diameter of the proposed pipelines (inches), and the total capacity of lift stations (mgd). Additionally, for jacked steel casings, the size of the casing as well as the carrier pipe are indicated (inches).

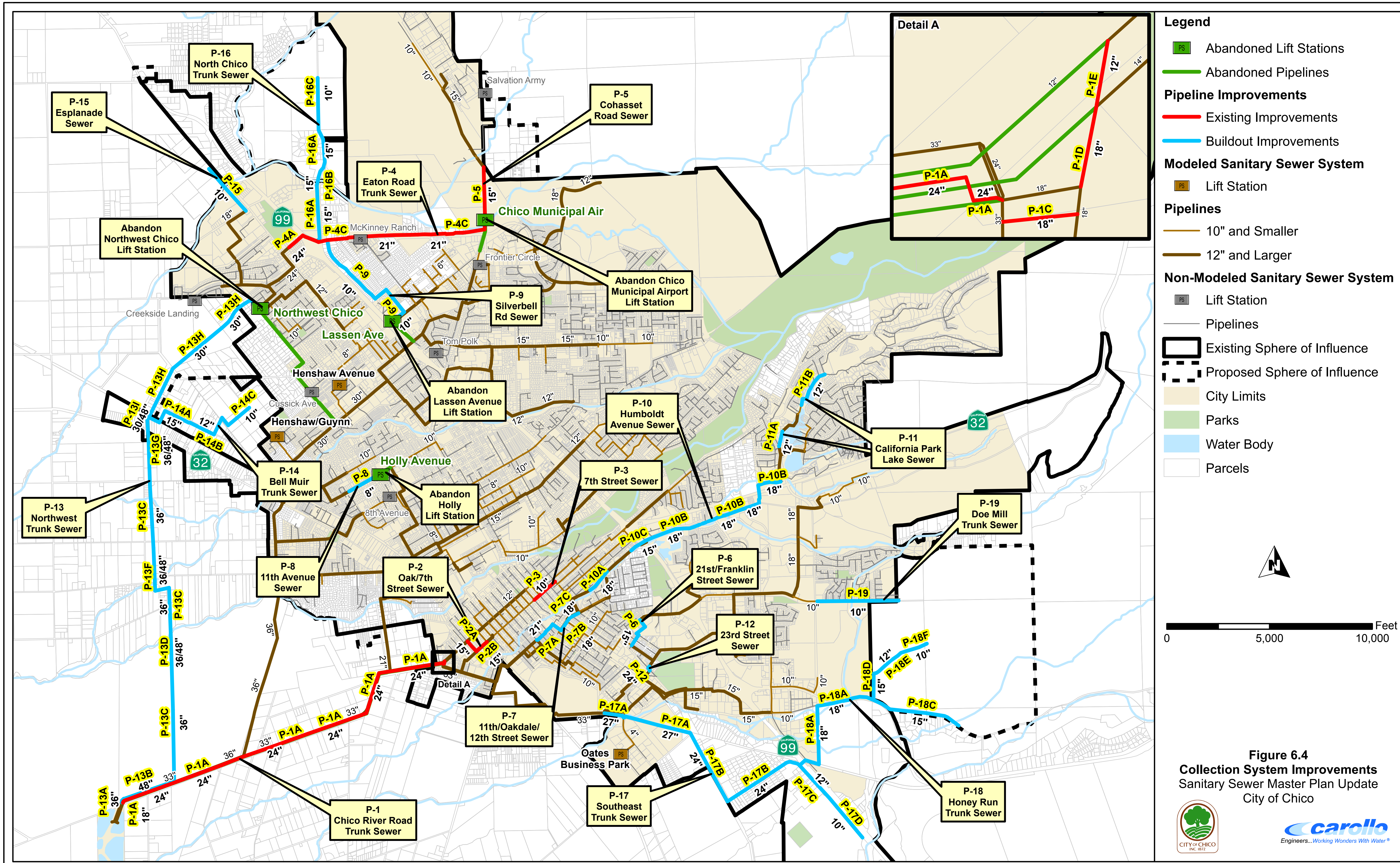


Figure 6.4
Collection System Improvements
Sanitary Sewer Master Plan Update
City of Chico

Table 6.2 Proposed Improvements
Sewer System Master Plan Update
City of Chico

Project Description				Project Size				Project Phasing			
Improv. ID	**Type of Improv.**	**Description/Street**	**Description/Limits**	**Existing Size (in.)**	**Proposed Size (in)**	**Replace/ New**	**Length (ft)**	**Phase 1 (2013-2015)**	**Phase 2 (2016-2020)**	**Phase 3 (2021-2025)**	**Phase 4 (2026-2030)**
Project 1 - Chico River Road Trunk Sewer											
P-1A	Gravity	Chico River Road	W. 5th Street to WPCP	12-24	24	Replace	17,800	x			
P-1B	Gravity	Near WPCP Junction Box	Dual 18-inch Pipes Near WPCP Junction Box	18	18	Replace	150	x			
P-1C	Gravity	Chico River Road	At W. 5th Street	--	18	New	50	x			
P-1D	Gravity	Chico River Road	At W. 5th Street	--	18	New	50	x			
P-1E	Gravity	Chico River Road	At W. 5th Street	--	12	Mew	30	x			
Project 2 - Oak/7th Street Sewer											
P-2A	Gravity	Oak Street/W. 7th Street	Walnut Street to W. 5th Street	10	15	Replace	990	x			
P-2B	Gravity	W. 7th Street	Cedar Street to Walnut Street	10	12	Replace	340	x			
Project 3 - 7th Street Sewer											
P-3	Gravity	E. 7th Street	Olive Street to Main Street	8	10	Replace	1,350	x			
Project 4 - Eaton Road Trunk Sewer											
P-4A	Gravity	Eaton Road	Hicks Lane to West of Highway 99	--	24	New	1,460		x		
P-4B	Casing	Eaton Road	Highway 99 Crossing	--	24/42	New	200		x		
P-4C	Gravity	Eaton Road	Cohasset Road to Hicks Lane	--	21	New	8,170		x		
P-4D	Gravity	Cohasset Road	CMA Lift Station to Eaton Road	--	18	New	540		x		
Project 5 - Cohasset Road Sewer											
P-5	Gravity	Cohasset Road	North of Thorntree Drive to CMA Lift Station	12	15	Replace	2,610		x		
Project 6 - 21st/Franklin Street Sewer											
P-6	Gravity	Franklin/E. 21st Street	E. 20th Street to Mulberry Street	12	15	Replace	1,700		x		
Project 7 - 11th/Oakdale/12th Street Sewer											
P-7A	Gravity	W. 11th/Oakdale Street	W. 12th Street to Chestnut Street Alley	15	21	Replace	1,600		x		
P-7B	Gravity	W. 12th Street	Park Avenue to Oakdale Street	--	18	Parallel	300		x		
P-7C	Gravity	W. 12th Street	Connect Existing 18-inch Sewer	18	18	In Ground	950		x		
Project 8 - 11th Avenue Sewer											
P-8	Gravity	W. 11th Avenue	Holley Avenue to West of Cecelia Lane	--	8	New	1,750			x	
Project 9 - Silverbell Road Sewer											
P-9	Gravity	Joshua Tree Rd/Silverbell Rd.	Lassen Ave. Lift Station to Eaton Road	--	10	New	6,560			x	
Project 10 - Humboldt Avenue Sewer											
P-10A	Gravity	Humboldt Avenue	Linden Street to Poplar Street	15	18	Replace	1,230				x
P-10B	Gravity	Humboldt Avenue	Bruce Road to West of Highway 99	15	18	Replace	8,110				x
P-10C	Casing	Humboldt Avenue	Highway 99 Crossing	12	18/30	Replace	300				x
Project 11 - California Park Lake Sewer											
P-11A	Gravity	Near California Lake Park	North of Bruce Road to Bruce Road	10	12	Replace	750				x
P-11B	Gravity	Near California Lake Park	Yosemite Drive to Upper Lake Court	10	12	Replace	2,070				x
Project 12 - 23rd Street Sewer											
P-12	Gravity	E. 23rd Street	At Fair Street	15	24	Replace	270				x
Project 13 - Northwest Trunk Sewer											
P-13A	Gravity	Near WPCP Junction Box	Dual 36-inch Pipes Near WPCP Junction Box	--	36	New	460		x		
P-13B	Gravity	Chico River Road	East of Alberton Avenue to WPCP	--	48	New	2,590		x		
P-13C	Gravity	E. of Alberton Ave./Muir Ave.	Railroad at Muir Ave. to Chico River Road	--	36	New	18,380		x		
P-13D	Casing	E. of Alberton Ave.	Creek Crossing	--	36/48	New	80		x		
P-13E	Casing	West Sacramento Avenue	Creek Crossing	--	36/48	New	70		x		

Table 6.2 Proposed Improvements
Sewer System Master Plan Update
City of Chico

Project Description				Project Size				Project Phasing			
Improv. ID	Type of Improv.	Description/Street	Description/Limits	Existing Size (in.)	Proposed Size (in)	Replace/ New	Length (ft)	Phase 1 (2013-2015)	Phase 2 (2016-2020)	Phase 3 (2021-2025)	Phase 4 (2026-2030)
P-13F	Casing	Muir Avenue	Creek Crossing	--	36/48	New	30		x		
P-13G	Casing	Muir Avenue	Highway 32 Crossing	--	36/48	New	60		x		
P-13H	Gravity	N. of Muir Ave./Carmack Dr.	Northwest Chico LS to Railroad at Muir Ave.	--	30	New	8,480		x		
P-13I	Casing	Muir Avenue	Railroad Crossing	--	30/48	New	80		x		
Project 14 - Bell Muir Trunk Sewer											
P-14A	Gravity	Rodeo Avenue	E. of Muir Ave. to the Northwest Trunk Sewer	--	15	New	2,550			x	
P-14B	Gravity	Rodeo Avenue	East of Muir Avenue	--	12	New	1,320			x	
P-14C	Gravity	Near Rodeo Avenue	Nord to South Rodeo Avenue	--	10	New	2,740			x	
Project 15 - Esplanade Sewer											
P-15	Gravity	Esplanade	Garner Lane to Nord	--	10	New	2,720				x
Project 16 - North Chico Trunk Sewer											
P-16A	Gravity	Hicks Lane	Cabello Way to Eaton Road	--	15	New	4,630				x
P-16B	Casing	Hicks Lane	Creek Crossing	--	15/30	New	420				x
P-16C	Gravity	Hicks Lane	North of Cabello Way to Cabello Way	--	10	New	3,030				x
Project 17 - Southeast Trunk Sewer											
P-17A	Gravity	Greenbelt near Comanche Creek	Midway to West of Otterson Drive	--	27	New	4,420			x	
P-17B	Gravity	Midway/Entler Avenue	Highway 99 to Greenbelt	--	24	New	7,860			x	
P-17C	Gravity	Entler Avenue	Southgate Avenue to North of Northfield Avenue	--	12	New	2,160			x	
P-17D	Gravity	Entler Avenue	South of Southgate Avenue	--	10	New	2,500			x	
Project 18 - Honey Run Trunk Sewer											
P-18A	Gravity	Cramer Lane/Skyway Road	Potter Road to Highway 99	--	18	New	6,450				x
P-18B	Casing	Near Cramer Lane	Highway 99 Crossing	--	18/30	New	200				x
P-18C	Gravity	Honey Run Road	East of Skyway Road to Skyway Road	--	15	New	4,440				x
P-18D	Gravity	Potter Road	North of Skyway Road to Skyway Road	--	15	New	1,010				x
P-18E	Gravity	Field North of Skyway Road	Field North of Skyway Road	--	12	New	1,470				x
P-18F	Gravity	Field North of Skyway Road	Field North of Skyway Road	--	10	New	1,540				x
Project 19 - Doe Mill Trunk Sewer											
P-19	Gravity	Doe Mill Road	East of Potter Road to Bruce Road	--	10	New	3,960			x	

- **Replace/New**: Indicates whether the proposed improvement is a replacement pipeline, parallel pipeline, or a new facility.
- **Length**: Estimated length of the proposed improvement (in feet). It should be noted that the length estimates do not account for re-routing the alignment to avoid unknown conditions.

When an increase to capacity is required, existing sewers can be upgraded or a parallel or relief sewer can be constructed. For the purposes of this study, unless otherwise stated, we assumed that a capacity deficient sewer would be upgraded to a larger diameter. The upgraded pipeline generally followed the same slope as the existing pipeline, with the exception where survey data revealed negative or flat slopes in an existing alignment.

In essence, there are two alternatives for every trunk sewer project, but the decision to replace or construct a parallel sewer should be made during the preliminary design phase.

During the preliminary design phase, the existing sewer should be inspected by closed circuit television (CCTV) to determine its structural condition. If severely deteriorated, the existing sewer should be upgraded. If moderately deteriorated, slip lining or cured-in-place pipe lining can rehabilitate the existing sewer.

The proposed improvements that will serve future users are sized for build-out conditions. As the City continues to grow, it is recommended that the proposed pipeline diameters be constructed so that the facilities have sufficient capacity for build out conditions. Building a smaller interim project with the plans of upsizing in the future to account for further growth is not recommended due to the extended useful life of the improvements proposed herein. The proposed pipe diameter represents the ultimate diameter for build out conditions.

6.2.1 Existing versus Future Improvement

An existing deficiency is one where the existing facility's capacity is insufficient to meet the planning criteria (e.g., pipeline upgrades required to prevent severe surcharging during the design wet weather event) for existing users. If a project was proposed to correct an existing deficiency exclusively, then existing users were assigned 100 percent of the project's benefit, and therefore, 100 percent of the costs.

The majority of the Master Plan improvements will serve future users, even when an improvement calls for the upgrade of an existing facility. In these cases, an existing sewer or lift station may have sufficient capacity to convey current PWWFs, but as growth continues and more users are added to the system, the increased flow results in capacity deficiencies. These projects, as well as new trunk sewers to extend wastewater collection system service to future growth areas, are future improvements. Future users were assigned 100 percent of the future project's benefit and 100 percent of the costs.

In some cases, a project is needed to correct an existing capacity deficiency, but is sized to accommodate additional flows from future development. In these cases, the hydraulic modeling results were used to determine the cost breakdown between existing and future users based on the ratio of existing and build out average dry weather flows. More information on the breakdown in cost split between existing and future users and whether a proposed improvement is intended to correct an existing deficiency, to serve a future user, or both, is provided in Chapter 7.

6.2.2 Existing System Improvements

For the majority of the City, the existing wastewater collection system contains sufficient capacity to convey the PWWF without exceeding the capacity criteria discussed Chapter 5. There are a few exceptions where existing sewers will need to be replaced by larger diameter sewers, or parallel sewers will need to be constructed to bypass flow around hydraulically deficient sewers. These projects are discussed in this section and details for each are provided in Appendix 7.

- **Project 1 – Chico River Road Trunk Sewer**. The existing Chico River Road Trunk Sewer has been reported to be in poor conditions and the City has determined that it should be replaced with a new trunk sewer located in the center of Chico River Road. In 2010, Carollo was retained to evaluate the appropriate replacement diameter and to assess the feasibility of alternative connection options. The results of this evaluation are summarized in a Project Memorandum dated March 2, 2010, which is included in Appendix F for reference.

  The Project Memorandum concluded that the most cost effective approach for downstream connection should occur by splitting the proposed 24-inch trunk sewer into two parallel 18 inch pipelines for reconnection into the existing junction box located within the City's Water Pollution Control Plant (WPCP) fence line. At the upstream terminus in the vicinity of Miller Avenue, the existing 12-, 14-, and 18-inch sewers would be recombined into a single 24-inch trunk sewer.

  As part of the collection system capacity evaluation (Section 6.1), the proposed diameter and configuration of the Chico River Road Trunk Sewer Replacement were reexamined with the revised current and build out PWWFs developed as part of this Master Plan and it was determined that the proposed 24-inch diameter replacement sewer and associated connections are adequate to service build out PWWFs.

- **Project 2 – Oak/7th Street Sewer**. This project consists of replacing approximately 1,330 feet of existing 10-inch diameter sewer on 7th Street and Oak Street from Cedar Street to West 5th Street with a new 12 inch diameter sewer from Cedar Street to Walnut Street, and a 15-inch diameter sewer from Walnut Street to West 5th Street. This project is required to mitigate surcharged conditions on West 7th Street for existing PWWFs.

- **Project 3 – 7th Street Sewer**. This project consists of replacing the existing 8-inch diameter sewer on 7th Street from Olive Street to Main Street with a new 10-inch diameter sewer. This project is required to mitigate surcharged conditions on West 7th Street for existing PWWFs.

- **Project 4 – Eaton Road Trunk Sewer**. This project is required to mitigate existing capacity deficiencies in the existing 12-inch diameter gravity sewer immediately downstream of the Chico Municipal Airport Lift Station and to service future growth in the north Chico area. In addition, this improvement project allows for the Chico Municipal Airport Lift Station to be abandoned.

  A new 540 foot long, 18-inch diameter sewer would divert flow from the manhole immediately upstream of the Chico Municipal Airport Lift Station on Cohasset Road to a new 21-inch diameter sewer on Eaton Road that extends 8,170 feet from Cohasset Road to Hicks Lane. At Hicks Lane, the 21-inch diameter sewer would flow into a new, 1,660 foot long reach of 24-inch diameter sewer that flows along Eaton Road from Hicks Lane and crosses Highway 99 to the existing 24-inch diameter sewer just west of Highway 99.

- **Project 5 – Cohasset Road Sewer**. This project mitigates existing capacity deficiencies in the sewer immediately upstream of the Chico Municipal Airport Lift Station, and consists of replacing approximately 2,610 feet of 12-inch diameter pipeline with a new 15-inch diameter sewer on Cohasset Road north of Thorntree Drive to the Chico Municipal Airport Lift Station.

6.2.3 Build Out System Improvements

The following discussion summarizes the new trunk sewers that will serve future users, as well as the locations of existing pipelines that would need to be replaced in order to accommodate build out PWWFs. The locations of the new trunk sewers are conceptual and are likely to change during the design phase. The locations shown are possible alignments based on available information and are intended to assist in the development of probable construction costs. No investigation into the feasibility of these alignments has been conducted. However, an attempt was made to place new trunk sewer alignments within existing streets or other feasible pipeline alignments.

- **Project 6 – 21st/Franklin Street Sewer**. The hydraulic evaluation indicated that the existing 12-inch diameter sewer on Franklin Street and East 21st Street from East 20th Street to Mullberry Street experienced minor surcharging under current PWWFs. However, the surcharged conditions did not exceed the maximum allowable flow depth criteria, and therefore no improvement is required for current PWWFs.

  However, the hydraulic evaluation indicates that during build out PWWF conditions, the existing 12-inch diameter sewer is not capable of conveying the PWWF without exceeding the allowable flow depth criteria, and should be replaced with a 15-inch diameter sewer.

- **Project 7 – 11th/Oakdale/12th Street Sewer**. Under current PWWF conditions, the existing 15-/18-inch diameter sewers on West 12th Street, Oakdale Street, and West 11th Street from Olive Street to the alley between Chestnut Street and Normal Street experienced surcharging. However, the surcharged conditions did not exceed the allowable flow depth criteria and therefore no improvement is required for current PWWFs.

  At build out, however, a capacity increase in this location is required. On West 12th Street, there is an existing 18-inch diameter relief sewer, which was constructed in 1989 from Manhole 57254 to Manhole 57345. The 18-inch pipe parallels the capacity deficient 15-inch diameter sewer from Olive Street to Main Street. At present, the 18-inch relief sewer does not connect back to system. In order to utilize this existing pipeline, a new 18-inch diameter parallel sewer should be constructed to connect the existing 18-inch sewer from Manhole 57345 to Manhole 57234.

  In addition, this project consists of replacing the existing 15-inch diameter sewer on Olive Street and West 11th Street from West 12th Street to Manhole 56000 in the alley northeast of Chestnut Street with a new 21-inch diameter sewer.

- **Project 8 – 11th Avenue Sewer**. With the construction of a new 8-inch diameter sewer on West 11th Avenue, the Holly Lift Station can be abandoned. The new 8-inch diameter sewer would divert flow from the manhole immediately upstream of the Holly Lift Station and convey it southwest along West 11th Avenue to the existing 15-inch diameter sewer west of Cecelia Lane.

- **Project 9 – Silverbell Avenue Sewer**. The City has indicated the existing Lassen Avenue Lift Station will be abandoned in the future. To accomplish this, a new 6,560 foot long reach of 10-inch diameter sewer would be constructed to convey flows northwest along Joshua Tree Road and Silverbell Road, where it would tie into the proposed Eaton Road Trunk Sewer.

- **Project 10 – Humbolt Avenue Sewer**. The hydraulic analysis indicated that several reaches of the existing 15-inch diameter sewers located along Humbolt Avenue from Bruce Road to Poplar Street are not capable of conveying build out PWWFs and should be replaced with a new 18-inch diameter sewer. There are some portions of the existing 15-inch diameter sewer that have a steeper slope than the majority of this reach of sewers. The hydraulic evaluation suggests that these steeper reaches of 15-inch diameter sewer do not need to be replaced.

- **Project 11 – California Lake Park Sewer**. The hydraulic analysis indicated that certain reaches of the existing 10-inch diameter sewers located near California Lake Park from Yosemite Drive to Bruce Road are not capable of conveying build out PWWFs and should be replaced with a new 12-inch diameter sewer. Similar to Project 10, there are some portions of the existing 10-inch diameter sewer that have a steeper slope than the majority of this reach of sewers, and do not need to be replaced. In addition, some reaches of sewers along this alignment are already 12-inch in diameter and would not need to be replaced.

- **Project 12 – 23rd Street Sewer**. Similar to Project 6, the hydraulic evaluation indicated that a short 270 foot reach of existing 15-inch diameter sewer located at the intersection of East 23rd Street and Fair Street experienced surcharging under current PWWFs. However, the surcharged conditions did not exceed the maximum allowable flow depth criteria, and therefore no improvement is required for current PWWFs.

  During build out of the PWWFs, however, the existing 15-inch diameter sewer is not capable of conveying the PWWF without exceeding the allowable flow depth criteria, and should be replaced with a 24-inch diameter sewer.

- **Project 13 – Northwest Trunk Sewer**. As part of the hydraulic evaluation for build out flow conditions, an analysis was conducted to determine whether additional growth in the northwest area of the City could be routed through the existing 30- and 36-inch diameter trunk sewer located on East Avenue, Glenwood Avenue, and down to Chico River Road. The analysis indicated that this major trunk sewer is not capable of conveying PWWFs and would need to be replaced.

  In lieu of replacing the existing trunk sewer, it is recommended that the City plan to construct the new Northwest Trunk Sewer, as indicated in the City's previous Master Plan. The new trunk sewer would consist of a new 30-inch diameter trunk sewer from the Northwest Chico Lift Station southwest to the railroad at Muir Avenue, a new 36-inch diameter sewer from Muir Avenue south to Chico River Road, and a new 48-inch diameter sewer to the WPCP. The City's junction box at the WPCP is currently configured to accommodate two new 36-inch pipelines for the Northwest Trunk Sewer. Therefore, just upstream of the junction box, the 48-inch sewer would be split into two 36-inch pipes.

  There are several benefits associated with construction of the new Northwest Trunk Sewer, including:

  – Allows for the abandonment of the Northwest Chico Lift Station (which the City has viewed as a temporary lift station), which ultimately saves the City in maintenance costs and power usage.

  – Eliminates the need to construct new lift stations to serve the Bell Muir specific plan growth area in the western portion of the City.

  – Would likely be easier to construct, and require significantly less public impacts than the replacement project required to continue to convey the flows through the existing trunk system.

  Site specific knowledge is limited in the master planning phase. For this reason, it is recommended that the City conduct a corridor study to examine the feasibility of constructing the planned Northwest Trunk Sewer prior to the design phase.

- **Project 14 – Bell Muir Trunk Sewer**. In order to serve the planned Bell Muir specific plan area, it is recommended that a new 10-, 12-, and 15-inch diameter trunk sewer be installed.
- **Project 15 – Esplanade Sewer**. This 10-inch diameter sewer is recommended to provide sanitary sewer service to a strip of commercial and manufacturing land uses next to Esplanade in the northern portions of the City.
- **Project 16 – North Chico Trunk Sewer**. This project consists of a new 10-inch through 15-inch diameter sewer to service primarily the North Chico specific plan area, as well as other land uses in the vicinity. This new trunk sewer would connect to the downstream end of the proposed Eaton Road Trunk Sewer.
- **Project 17 – Southeast Trunk Sewer**. As part of the hydraulic evaluation for build out flow conditions, an analysis was conducted to determine whether additional growth in the eastern area of the planning area (primarily associated with the Honey Run/Doe Mill specific planning area) could be routed through the existing 15-inch diameter sewer that crosses Highway 99 on Morrow Lane and continues west along Skyway Boulevard before splitting into a 15-inch and 18-inch diameter sewer at Scott Street. The analysis indicated that the increase in flows cannot be conveyed through the existing sewers, which would need to be replaced.

  Further analysis revealed that a more cost effective approach would be to route the flows associated with the areas to the planned Southeast Trunk Sewer, which would also serve specific plan and growth areas in the extreme southern end of the planning area. With this taken into consideration, the recommended Southeast Trunk Sewer would begin as a 10 inch and 12-inch sewer located adjacent to Highway 99 on the west. Near Northfield Avenue, the 12-inch sewer would flow into a 24-inch and then a 27-inch diameter trunk sewer that flows southwest and then northwest to the existing 33-inch diameter trunk sewer on Estes Road.
- **Project 18 – Honey Run Trunk Sewer**. The Honey Run Trunk Sewer consists of a network of 10-inch to 18-inch diameter sewers to service the majority of the Honey Run/Doe Mill specific planning area, as well some additional land use types near Highway 99. The Honey Run Trunk Sewer would connect to the Southeast Trunk Sewer through a Highway 99 crossing near Speedway Lane.
- **Project 19 – Doe Mill Trunk Sewer**. The Doe Mill Trunk Sewer consists of a new 10-inch diameter trunk sewer to service the northern portion of the Honey Run/Doe Mill specific plan area. The new trunk would connect to the existing 10-inch diameter sewer at Bruce Road.

6.2.4 Project Prioritization

The majority of improvements listed in Table 6.2 are driven by future development, which consist of new sewers that serve future growth or improvements to existing facilities that are needed to serve future growth. When fully implemented, the capital projects will allow the conveyance of PWWFs to the WPCP during build out conditions.

Prioritizing the required capital improvements for the City's sewer system is an important aspect of this study. The improvement projects were prioritized based on the following factors:

- Upgrading existing facilities to mitigate current capacity deficiencies and to serve future users
- Building the new trunks necessary to serve future users

Improvements to existing facilities will provide sufficient capacity to mitigate existing issues and to convey increased flows resulting from future growth. Future development will require the construction of sewers to serve new users. The projects were grouped into the following phases:

- Phase 1: Years 2013 through 2015
- Phase 2: Years 2016 through 2020
- Phase 3: Years 2021 through 2025
- Phase 4: Years 2026 through 2030

The projects were phased based on the best available information for how the City will develop moving forward. The actual implementation of the improvements serving future users ultimately depends on growth. The priorities presented below are estimates, and changes in the City's planning assumptions or growth projections could increase or decrease the priority of each improvement.

- **Phase 1 Projects (2013-2015)**. The highest priority project for the existing system is the Chico River Road Trunk Sewer Replacement (Project 1). City staff indicates that this sewer is in extremely poor shape and is in need of replacement as soon as possible. Therefore, this project is targeted for the first implementation phase.

  Other projects targeted for the first phase include the Oak/7th Street Sewer (Project 2) and the 7th Street Sewer (Project 3). These are existing capacity deficient sewers, and should be targeted for replacement in the early stages of the City capital improvement plan (CIP).

- **Phase 2 Projects (2016-2020)**. The second phase targets lower priority existing system improvements, as well as additional growth related improvements which could potentially be required in the relatively near term. Because Phase 1 is the shortest of the four CIP phases, and because the Chico River Road Trunk Sewer Replacement project represents a significant expense to the City in Phase 1, Project 4 (Eaton Road Trunk Sewer) and Project 5 (Cohasset Road Sewer) are targeted for construction in Phase 2. In addition, targeting this project in Phase 2 would allow the City time to perform additional flow monitoring and I/I mitigation measures upstream of the Chico Municipal Airport Lift Station to better isolate and potentially reduce or eliminate the major sources of I/I that represent the need for this project.

Other growth related projects targeted for implementation in Phase 2 are the 21st/Franklin Street Sewer (Project 6), the 11th/Oakdale/12th Street Sewer (Project 7), and the Northwest Trunk Sewer. As previously noted, the actual rate of growth within the City will dictate when these improvements will be constructed.

- **Phase 3 and 4 Projects (2021-2025 and 2026-2030)**. Project 8 (West 11th Avenue Sewer) and Project 9 (Silverbell Road Sewer) are recommended in order to abandon two existing lift stations (the Holly Lift Station and the Lassen Avenue Lift Station). These projects are targeted for Phase 3 because they do not specifically address a capacity deficiency, and are therefore assigned a lower priority than the build out system improvements targeted in Phase 2.

  For the purposes of prioritization, the Phase 3 and 4 growth projects are viewed as longer-term projects driven by development at the outer edges of the planning area, and will be grouped together. The Phase 3 and 4 growth projects include the following:

  - Project 10 – Humbolt Avenue Sewer
  - Project 11 – California Lake Park Sewer
  - Project 12 – 23rd Street Sewer
  - Project 14 – Bell Muir Trunk Sewer
  - Project 15 – Esplanade Sewer
  - Project 16 – North Chico Trunk Sewer
  - Project 17 – Southeast Trunk Sewer
  - Project 18 – Honey Run Trunk Sewer
  - Project 19 – Doe Mill Trunk Sewer

CAPITAL IMPROVEMENT PLAN

This chapter presents the recommended capital improvement plan (CIP) for the City of Chico (City) collection system and a summary of the capital costs. This chapter is organized to assist the City in making financial decisions, and is based on the evaluation of the City's sewer system.

7.1 CAPITAL IMPROVEMENT PROJECT COSTS

The capacity upgrades set the foundation for the City's capacity related sewer system CIP. The cost estimates presented in this study are opinions developed from bid tabulations, cost curves, information obtained from previous studies, and Carollo Engineers, Inc. (Carollo) experience on other projects. The costs are based on an Engineering News Record Construction Cost Index (ENR CCI) 20-City Average of 9,351 (August 2012).

7.2 COST ESTIMATING ACCURACY

The cost estimates presented in the CIP have been prepared for general master planning purposes and for guidance in project evaluation and implementation. Final costs of a project will depend on actual labor and material costs, competitive market conditions, final project scope, implementation schedule, and other variable factors such as preliminary alignment generation, investigation of alternative routings, and detailed utility and topography surveys.

The Association for the Advancement of Cost Engineering (AACE) defines an Order of Magnitude Estimate, deemed appropriate for master plan studies, as an approximate estimate made without detailed engineering data. It is normally expected that an estimate of this type would be accurate within plus 50 percent to minus 30 percent. This section presents the assumptions used in developing order of magnitude cost estimates for recommended facilities.

7.3 CONSTRUCTION UNIT COSTS

The construction costs are representative of sewer system facilities under normal construction conditions and schedules. Costs have been estimated for public works construction.

7.3.1 Gravity Sewer Unit Costs

Sewer pipeline improvements range in size from 10-inches to 24-inches in diameter in this study. Pipe casings up to 30-inches in diameter are included for major crossings (e.g., creeks, canals, highways, and railroad) of the trunk sewers. Unit costs for the construction of pipelines and appurtenances (e.g., manholes) are shown in Table 7.1.

Table 7.1	Gravity Pipeline Unit Costs Sanitary Sewer Master Plan Update City of Chico
Pipe Diameter (inches)	**Unit Cost ($/linear foot)[1]**
8	162
10	176
12	190
15	213
18	234
21	264
24	294
27	322
30	352
33	382
36	410
39	440
42	477
45	491
48	514
Pipeline Casing for Major Crossings[2]	
15/30	1,204
18/30	1,204
21/42	1,685
24/42	1,685
27/48	1,926
30/48	1,926
36/48	1,926

Notes:

(1) ENR CCI 20 City average used for estimating (August 2012) = 9,351

(2) Size represents pipeline diameter and associated casing size.

The construction cost estimates are based upon these unit costs. The unit costs are for "typical" field conditions with construction in stable soil at a depth ranging between 10 feet to 15 feet.

7.4 PROJECT COSTS AND CONTINGENCIES

Project cost estimates are calculated based on elements, such as the project location, size, length, land acquisition needs, and other factors. Allowances for project contingencies consistent with an “Order of Magnitude” estimate are also included in the project costs prepared as part of this study, as outlined in this section.

7.4.1 Baseline Construction Cost

This is the total estimated construction cost, in dollars, of the proposed improvement for pipelines and lift stations. Baseline construction costs were calculated by multiplying the estimated length by the unit cost.

7.4.2 Estimated Construction Cost

Contingency costs must be reviewed on a case-by-case basis because they will vary considerably with each project. Consequently, it is appropriate to allow for uncertainties associated with the preliminary layout of a project. Such factors as unexpected construction conditions, the need for unforeseen mechanical items, and variations in final quantities are a few of the items that can increase project costs for which it is wise to make allowances in preliminary estimates. To assist the City in making financial decisions for these future construction projects, contingency costs will be added to the planning budget as percentages of the total construction cost, divided into two categories: Estimated Construction Cost and Capital Improvement Cost.

Since knowledge about site-specific conditions of each proposed project is limited at the master planning stage, a 25 percent contingency was applied to the Baseline Construction Cost to account for unforeseen events and unknown conditions. This contingency accounts for unknown site conditions such as poor soils, unforeseen conditions, environmental mitigations, and other unknowns and is typical for master planning projects. The Estimated Construction Cost for the proposed sewer system improvement consists of the Baseline Construction Cost plus the 25 percent construction contingency.

7.4.3 Capital Improvement Cost

Other project construction contingency costs include costs associated with project engineering, construction phase professional services, and project administration. Engineering services associated with new facilities include preliminary investigations and reports, Right of Way (ROW) acquisition, foundation explorations, preparation of drawings and specifications during construction, surveying and staking, sampling of testing material, and start-up services. Construction phase professional services cover such items as construction management, engineering services, materials testing, and inspection during construction. Finally, there are project administration costs, which cover such items as legal fees, environmental/California Environmental Quality Act (CEQA) compliance requirements, financing expenses, administrative costs, and interest during construction.

The cost of these items can vary, but for the purpose of this study, it is assumed that the other project contingency costs will equal approximately 25 percent of the Estimated Construction Cost.

As shown in the following sample calculation of the capital improvement cost, the total cost of all project construction contingencies (construction, engineering services, construction management, and project administration) is 56.3 percent of the baseline construction cost. Calculation of the 56.3 percent is the overall mark-up on the baseline construction cost to arrive at the capital improvement cost. It is not an additional contingency.

Example:

Baseline Construction Cost	**$1,000,000**
Construction Contingency (25%)	$250,000
Estimated Construction Cost	**$1,250,000**
Engineering Cost + Construction Management + Project Administration (25%)	$312,500
Capital Improvement Cost	**$1,562,500**

A summary of the capital project costs is presented in Table 7.2. This table identifies the projects, provides a brief description of the project, identifies facility size (e.g., pipe diameter and length), and the capital improvement cost. The table also shows the probable phase in which the project would be implemented. The implementation timeframe was based on the priority of each project to correct existing deficiencies or to serve future users.

7.4.4 Capital Improvement Implementation

As discussed in Chapter 6, the capital improvement implementation (CIPs) are prioritized based on their urgency to mitigate existing deficiencies and for servicing anticipated growth. It is recommended that improvements to mitigate existing deficiencies be constructed as soon as possible. The deficiencies in the future system have a significant total capital cost that is best distributed based on the order in which the City develops.

The implementation phases are separated into 5-year increments, except for the first phase, which runs from 2013 through 2015. Each project is itemized by phase in Table 7.2 and a summary by phase is provided in Table 7.3.

7.4.5 Existing Versus Future Users Cost Share

The improvements proposed in this study either benefit existing users, or are required to service new development and future users. Some of the projects provide benefit to both existing and future users. An opinion of benefit to future users, based on preliminary project information, is included in Table 7.2. A summary of the existing and future user cost share for the proposed projects by phase is summarized in Table 7.3.

Table 7.2 Capital Improvement Plan
Sewer System Master Plan Update
City of Chico

Project Description				Project Size and Cost								Project Phasing				Existing vs. Future Users Cost Share		
Improv. ID	Type of Improv.	Description/Street	Description/Limits	Existing Size (in.)	Proposed Size (in)	Replace/ New	Length (ft)	Unit Cost[1] ($/LF)	Baseline Construction Cost[2] ($)	Estimated Construction Cost[3] ($)	Capital Improvement Cost[2],(3),(4) ($)	Phase 1 (2013-2015) ($)	Phase 2 (2016-2020) ($)	Phase 3 (2021-2025) ($)	Phase 4 (2026-2030) ($)	Future Users Benefit (%)	Existing Improvements ($)	Future Improvements ($)
Project 1 - Chico River Road Trunk Sewer																		
P-1A	Gravity	Chico River Road	W. 5th Street to WPCP	12-24	24	Replace	17,800	$ 294	$ 5,233,200	$ 6,541,500	$ 8,177,000	$ 8,177,000				0%	$ 8,177,000	$ -
P-1B	Gravity	Near WPCP Junction Box	Dual 18-inch Pipes Near WPCP Junction Box	18	18	Replace	150	$ 234	$ 35,100	$ 43,900	$ 55,000	$ 55,000				0%	$ 55,000	$ -
P-1C	Gravity	Chico River Road	At W. 5th Street	--	18	New	50	$ 234	$ 11,700	$ 14,600	$ 18,000	$ 18,000				0%	$ 18,000	$ -
P-1D	Gravity	Chico River Road	At W. 5th Street	--	18	New	50	$ 234	$ 11,700	$ 14,600	$ 18,000	$ 18,000				0%	$ 18,000	$ -
P-1E	Gravity	Chico River Road	At W. 5th Street	--	12	New	30	$ 190	$ 5,700	$ 7,100	$ 9,000	$ 9,000				0%	$ 9,000	$ -
								Project 1 Subtotal	**$ 5,297,400**	**$ 6,621,700**	**$ 8,277,000**	**$ 8,277,000**	**$ -**	**$ -**	**$ -**		**$ 8,277,000**	**$ -**
Project 2 - Oak/7th Street Sewer																		
P-2A	Gravity	Oak Street/W. 7th Street	Walnut Street to W. 5th Street	10	15	Replace	990	$ 213	$ 210,900	$ 263,600	$ 330,000	$ 330,000				5%	$ 313,000	$ 17,000
P-2B	Gravity	W. 7th Street	Cedar Street to Walnut Street	10	12	Replace	340	$ 190	$ 64,600	$ 80,800	$ 101,000	$ 101,000				5%	$ 96,000	$ 5,000
								Project 2 Subtotal	**$ 275,500**	**$ 344,400**	**$ 431,000**	**$ 431,000**	**$ -**	**$ -**	**$ -**		**$ 409,000**	**$ 22,000**
Project 3 - 7th Street Sewer																		
P-3	Gravity	E. 7th Street	Olive Street to Main Street	8	10	Replace	1,350	$ 176	$ 237,600	$ 297,000	$ 371,000	$ 371,000				5%	$ 353,000	$ 18,000
								Project 3 Subtotal	**$ 237,600**	**$ 297,000**	**$ 371,000**	**$ 371,000**	**$ -**	**$ -**	**$ -**		**$ 353,000**	**$ 18,000**
Project 4 - Eaton Road Trunk Sewer																		
P-4A	Gravity	Eaton Road	Hicks Lane to West of Highway 99	--	24	New	1,460	$ 294	$ 429,200	$ 536,500	$ 671,000		$ 671,000			84%	$ 108,000	$ 563,000
P-4B	Casing	Eaton Road	Highway 99 Crossing	--	24/42	New	200	$ 1,685	$ 337,000	$ 421,300	$ 527,000		$ 527,000			84%	$ 85,000	$ 442,000
P-4C	Gravity	Eaton Road	Cohasset Road to Hicks Lane	--	21	New	8,170	$ 264	$ 2,156,900	$ 2,696,100	$ 3,370,000		$ 3,370,000			69%	$ 1,047,000	$ 2,323,000
P-4D	Gravity	Cohasset Road	CMA Lift Station to Eaton Road	--	18	New	540	$ 234	$ 126,400	$ 158,000	$ 198,000		$ 198,000			52%	$ 94,000	$ 104,000
								Project 4 Subtotal	**$ 3,049,500**	**$ 3,811,900**	**$ 4,766,000**	**$ -**	**$ 4,766,000**	**$ -**	**$ -**		**$ 1,334,000**	**$ 3,432,000**
Project 5 - Cohasset Road Sewer																		
P-5	Gravity	Cohasset Road	North of Thorntree Drive to CMA Lift Station	12	15	Replace	2,610	$ 213	$ 555,900	$ 694,900	$ 869,000		$ 869,000			43%	$ 497,000	$ 372,000
								Project 5 Subtotal	**$ 555,900**	**$ 694,900**	**$ 869,000**	**$ -**	**$ 869,000**	**$ -**	**$ -**		**$ 497,000**	**$ 372,000**
Project 6 - 21st/Franklin Street Sewer																		
P-6	Gravity	Franklin/E. 21st Street	E. 20th Street to Mulberry Street	12	15	Replace	1,700	$ 213	$ 362,100	$ 452,600	$ 566,000		$ 566,000			100%	$ -	$ 566,000
								Project 6 Subtotal	**$ 362,100**	**$ 452,600**	**$ 566,000**	**$ -**	**$ 566,000**	**$ -**	**$ -**		**$ -**	**$ 566,000**
Project 7 - 11th/Oakdale/12th Street Sewer																		
P-7A	Gravity	W. 11th/Oakdale Street	W. 12th Street to Chestnut Street Alley	15	21	Replace	1,600	$ 264	$ 422,400	$ 528,000	$ 660,000		$ 660,000			100%	$ -	$ 660,000
P-7B	Gravity	W. 12th Street	Park Avenue to Oakdale Street	--	18	Parallel	300	$ 234	$ 70,200	$ 87,800	$ 110,000		$ 110,000			100%	$ -	$ 110,000
P-7C	Gravity	W. 12th Street	Connect Existing 18-inch Sewer	18	18	In Ground	950	$ -	$ -	$ -	$ -		$ -			100%	$ -	$ -
								Project 7 Subtotal	**$ 492,600**	**$ 615,800**	**$ 770,000**	**$ -**	**$ 770,000**	**$ -**	**$ -**		**$ -**	**$ 770,000**
Project 8 - 11th Avenue Sewer																		
P-8	Gravity	W. 11th Avenue	Holley Avenue to West of Cecelia Lane	--	8	New	1,750	$ 162	$ 283,500	$ 354,400	$ 443,000			$ 443,000		26%	$ 328,000	$ 115,000
								Project 8 Subtotal	**$ 283,500**	**$ 354,400**	**$ 443,000**	**$ -**	**$ -**	**$ 443,000**	**$ -**		**$ 328,000**	**$ 115,000**
Project 9 - Silverbell Road Sewer																		
P-9	Gravity	Joshua Tree Rd/Silverbell Rd.	Lassen Ave. Lift Station to Eaton Road	--	10	New	6,560	$ 176	$ 1,154,600	$ 1,443,300	$ 1,804,000			$ 1,804,000		50%	$ 906,000	$ 898,000
								Project 9 Subtotal	**$ 1,154,600**	**$ 1,443,300**	**$ 1,804,000**	**$ -**	**$ -**	**$ 1,804,000**	**$ -**		**$ 906,000**	**$ 898,000**
Project 10 - Humboldt Avenue Sewer																		
P-10A	Gravity	Humboldt Avenue	Linden Street to Poplar Street	15	18	Replace	1,230	$ 234	$ 287,800	$ 359,800	$ 450,000				$ 450,000	100%	$ -	$ 450,000
P-10B	Gravity	Humboldt Avenue	Bruce Road to West of Highway 99	15	18	Replace	8,110	$ 234	$ 1,897,700	$ 2,372,100	$ 2,965,000				$ 2,965,000	100%	$ -	$ 2,965,000
P-10C	Casing	Humboldt Avenue	Highway 99 Crossing	12	18/30	Replace	300	$ 1,204	$ 361,200	$ 451,500	$ 564,000				$ 564,000	100%	$ -	$ 564,000
								Project 10 Subtotal	**$ 2,546,700**	**$ 3,183,400**	**$ 3,979,000**	**$ -**	**$ -**	**$ -**	**$ 3,979,000**		**$ -**	**$ 3,979,000**
Project 11 - California Park Lake Sewer																		
P-11A	Gravity	Near California Lake Park	North of Bruce Road to Bruce Road	10	12	Replace	750	$ 190	$ 142,500	$ 178,100	$ 223,000				$ 223,000	100%	$ -	$ 223,000
P-11B	Gravity	Near California Lake Park	Yosemite Drive to Upper Lake Court	10	12	Replace	2,070	$ 190	$ 393,300	$ 491,600	$ 615,000				$ 615,000	100%	$ -	$ 615,000
								Project 11 Subtotal	**$ 535,800**	**$ 669,700**	**$ 838,000**	**$ -**	**$ -**	**$ -**	**$ 838,000**		**$ -**	**$ 838,000**
Project 12 - 23rd Street Sewer																		
P-12	Gravity	E. 23rd Street	At Fair Street	15	24	Replace	270	$ 294	$ 79,400	$ 99,300	$ 124,000				$ 124,000	100%	$ -	$ 124,000
								Project 12 Subtotal	**$ 79,400**	**$ 99,300**	**$ 124,000**	**$ -**	**$ -**	**$ -**	**$ 124,000**		**$ -**	**$ 124,000**
Project 13 - Northwest Trunk Sewer																		
P-13A	Gravity	Near WPCP Junction Box	Dual 36-inch Pipes Near WPCP Junction Box	--	36	New	460	$ 410	$ 188,600	$ 235,800	$ 295,000		$ 295,000			100%	$ -	$ 295,000
P-13B	Gravity	Chico River Road	East of Alberton Avenue to WPCP	--	48	New	2,590	$ 514	$ 1,331,300	$ 1,664,100	$ 2,080,000		$ 2,080,000			100%	$ -	$ 2,080,000
P-13C	Gravity	E. of Alberton Ave./Muir Ave.	Railroad at Muir Ave. to Chico River Road	--	36	New	18,380	$ 410	$ 7,535,800	$ 9,419,800	$ 11,775,000		$ 11,775,000			100%	$ -	$ 11,775,000
P-13D	Casing	E. of Alberton Ave.	Creek Crossing	--	36/48	New	80	$ 1,926	$ 154,100	$ 192,600	$ 241,000		$ 241,000			100%	$ -	$ 241,000
P-13E	Casing	West Sacramento Avenue	Creek Crossing	--	36/48	New	70	$ 1,926	$ 134,800	$ 168,500	$ 211,000		$ 211,000			100%	$ -	$ 211,000
P-13F	Casing	Muir Avenue	Creek Crossing	--	36/48	New	30	$ 1,926	$ 57,800	$ 72,300	$ 90,000		$ 90,000			100%	$ -	$ 90,000
P-13G	Casing	Muir Avenue	Highway 32 Crossing	--	36/48	New	60	$ 1,926	$ 115,600	$ 144,500	$ 181,000		$ 181,000			100%	$ -	$ 181,000
P-13H	Gravity	N. of Muir Ave./Carmack Dr.	Northwest Chico LS to Railroad at Muir Ave.	--	30	New	8,480	$ 352	$ 2,985,000	$ 3,731,300	$ 4,664,000		$ 4,664,000			100%	$ -	$ 4,664,000

Table 7.2 Capital Improvement Plan
Sewer System Master Plan Update
City of Chico

Project Description				Project Size and Cost								Project Phasing				Existing vs. Future Users Cost Share		
Improv. ID	Type of Improv.	Description/Street	Description/Limits	Existing Size (in.)	Proposed Size (in)	Replace/ New	Length (ft)	Unit Cost[1] ($/LF)	Baseline Construction Cost[2] ($)	Estimated Construction Cost[3] ($)	Capital Improvement Cost[2],(3),(4) ($)	Phase 1 (2013-2015) ($)	Phase 2 (2016-2020) ($)	Phase 3 (2021-2025) ($)	Phase 4 (2026-2030) ($)	Future Users Benefit (%)	Existing Improvements ($)	Future Improvements ($)
P-13I	Casing	Muir Avenue	Railroad Crossing	--	30/48	New	80	$ 1,926	$ 154,100	$ 192,600	$ 241,000		$ 241,000			100%	$ -	$ 241,000
							Project 13 Subtotal		**$ 12,657,100**	**$ 15,821,500**	**$ 19,778,000**	**$ -**	**$ 19,778,000**	**$ -**	**$ -**		**$ -**	**$ 19,778,000**
Project 14 - Bell Muir Trunk Sewer																		
P-14A	Gravity	Rodeo Avenue	E. of Muir Ave. to the Northwest Trunk Sewer	--	15	New	2,550	$ 213	$ 543,200	$ 679,000	$ 849,000			$ 849,000		100%	$ -	$ 849,000
P-14B	Gravity	Rodeo Avenue	East of Muir Avenue	--	12	New	1,320	$ 190	$ 250,800	$ 313,500	$ 392,000			$ 392,000		100%	$ -	$ 392,000
P-14C	Gravity	Near Rodeo Avenue	Nord to South Rodeo Avenue	--	10	New	2,740	$ 176	$ 482,200	$ 602,800	$ 754,000			$ 754,000		100%	$ -	$ 754,000
							Project 14 Subtotal		**$ 1,276,200**	**$ 1,595,300**	**$ 1,995,000**	**$ -**	**$ -**	**$ 1,995,000**	**$ -**		**$ -**	**$ 1,995,000**
Project 15 - Esplanade Sewer																		
P-15	Gravity	Esplanade	Garner Lane to Nord	--	10	New	2,720	$ 176	$ 478,700	$ 598,400	$ 748,000				$ 748,000	100%	$ -	$ 748,000
							Project 15 Subtotal		**$ 478,700**	**$ 598,400**	**$ 748,000**	**$ -**	**$ -**	**$ -**	**$ 748,000**		**$ -**	**$ 748,000**
Project 16 - North Chico Trunk Sewer																		
P-16A	Gravity	Hicks Lane	Cabello Way to Eaton Road	--	15	New	4,630	$ 213	$ 986,200	$ 1,232,800	$ 1,541,000				$ 1,541,000	100%	$ -	$ 1,541,000
P-16B	Casing	Hicks Lane	Creek Crossing	--	15/30	New	420	$ 1,204	$ 505,700	$ 632,100	$ 790,000				$ 790,000	100%	$ -	$ 790,000
P-16C	Gravity	Hicks Lane	North of Cabello Way to Cabello Way	--	10	New	3,030	$ 176	$ 533,300	$ 666,600	$ 833,000				$ 833,000	100%	$ -	$ 833,000
							Project 16 Subtotal		**$ 2,025,200**	**$ 2,531,500**	**$ 3,164,000**	**$ -**	**$ -**	**$ -**	**$ 3,164,000**		**$ -**	**$ 3,164,000**
Project 17 - Southeast Trunk Sewer																		
P-17A	Gravity	Greenbelt near Comanche Creek	Midway to West of Otterson Drive	--	27	New	4,420	$ 322	$ 1,423,200	$ 1,779,000	$ 2,224,000			$ 2,224,000		100%	$ -	$ 2,224,000
P-17B	Gravity	Midway/Entler Avenue	Highway 99 to Greenbelt	--	24	New	7,860	$ 294	$ 2,310,800	$ 2,888,500	$ 3,611,000			$ 3,611,000		100%	$ -	$ 3,611,000
P-17C	Gravity	Entler Avenue	Southgate Avenue to North of Northfield Avenue	--	12	New	2,160	$ 190	$ 410,400	$ 513,000	$ 641,000			$ 641,000		100%	$ -	$ 641,000
P-17D	Gravity	Entler Avenue	South of Southgate Avenue	--	10	New	2,500	$ 176	$ 440,000	$ 550,000	$ 688,000			$ 688,000		100%	$ -	$ 688,000
							Project 17 Subtotal		**$ 4,584,400**	**$ 5,730,500**	**$ 7,164,000**	**$ -**	**$ -**	**$ 7,164,000**	**$ -**		**$ -**	**$ 7,164,000**
Project 18 - Honey Run Trunk Sewer																		
P-18A	Gravity	Cramer Lane/Skyway Road	Potter Road to Highway 99	--	18	New	6,450	$ 234	$ 1,509,300	$ 1,886,600	$ 2,358,000				$ 2,358,000	100%	$ -	$ 2,358,000
P-18B	Casing	Near Cramer Lane	Highway 99 Crossing	--	18/30	New	200	$ 1,204	$ 240,800	$ 301,000	$ 376,000				$ 376,000	100%	$ -	$ 376,000
P-18C	Gravity	Honey Run Road	East of Skyway Road to Skyway Road	--	15	New	4,440	$ 213	$ 945,700	$ 1,182,100	$ 1,478,000				$ 1,478,000	100%	$ -	$ 1,478,000
P-18D	Gravity	Potter Road	North of Skyway Road to Skyway Road	--	15	New	1,010	$ 213	$ 215,100	$ 268,900	$ 336,000				$ 336,000	100%	$ -	$ 336,000
P-18E	Gravity	Field North of Skyway Road	Field North of Skyway Road	--	12	New	1,470	$ 190	$ 279,300	$ 349,100	$ 436,000				$ 436,000	100%	$ -	$ 436,000
P-18F	Gravity	Field North of Skyway Road	Field North of Skyway Road	--	10	New	1,540	$ 176	$ 271,000	$ 338,800	$ 424,000				$ 424,000	100%	$ -	$ 424,000
							Project 18 Subtotal		**$ 3,461,200**	**$ 4,326,500**	**$ 5,408,000**	**$ -**	**$ -**	**$ -**	**$ 5,408,000**		**$ -**	**$ 5,408,000**
Project 19 - Doe Mill Trunk Sewer																		
P-19	Gravity	Doe Mill Road	East of Potter Road to Bruce Road	--	10	New	3,960	$ 176	$ 697,000	$ 871,300	$ 1,089,000			$ 1,089,000		100%	$ -	$ 1,089,000
							Project 19 Subtotal		**$ 697,000**	**$ 871,300**	**$ 1,089,000**	**$ -**	**$ -**	**$ 1,089,000**	**$ -**		**$ -**	**$ 1,089,000**
Capital Improvement Plan Total																		
							Capital Improvement Plan Total		**$ 40,050,400**	**$ 50,063,400**	**$ 62,584,000**	**$ 9,079,000**	**$ 26,749,000**	**$ 12,495,000**	**$ 14,261,000**		**$ 12,104,000**	**$ 50,480,000**

Notes:
(1) ENR CCI = 9,351 (20-City Average, August 2012).
(2) Baseline Construction Costs = Length x Unit Cost
(3) Estimated Construction Cost includes a 25% construction contingency applied to the Baseline Construction Cost to account for unforseen events and unknown conditions.
(4) Capital Improvement Cost includes a 25% contingency applied to the Estimated Contruction Cost to account for engineering services, construction management, and project administration.

Table 7.3 Summary of Capital Improvement Costs
Sewer System Master Plan Update
City of Chico

Reimbursement Category	Implementation Phase				Total ($,M)
	2013-15 ($,M)	2016-20 ($,M)	2021-25 ($,M)	2026-30 ($,M)	
Existing User	9.04	1.83	1.23	0.00	**12.10**
Future User	0.04	24.92	11.26	14.26	**50.48**
Total	**9.08**	**26.75**	**12.50**	**14.26**	**62.58**

Notes:
(1) Costs are based on ENR CCI 20-City Average of 9,351 (August 2012).

Chapter 8

CAPITAL IMPROVEMENT PROJECT DETAIL SUMMARY SHEETS

This chapter presents the detail summary sheets for the nineteen projects described in Chapter 6. The project summary sheet includes capital improvement costs, project location and details, and a project detail map.

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 1

Project ID: **Project 1**
Description: **Chico River Road Trunk Sewer**
Improvements: **P-1A through P-1E**

Project Type: Existing System

Project Benefit
Existing Customers: 100%
Future Development: 0%

Implementation Phase

Phase 1 (2013 - 2015)	x
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	

Project Location
Chico River Road from West 5th Street to the WPCP.

Project Vicinity Map

Capital Improvement Costs

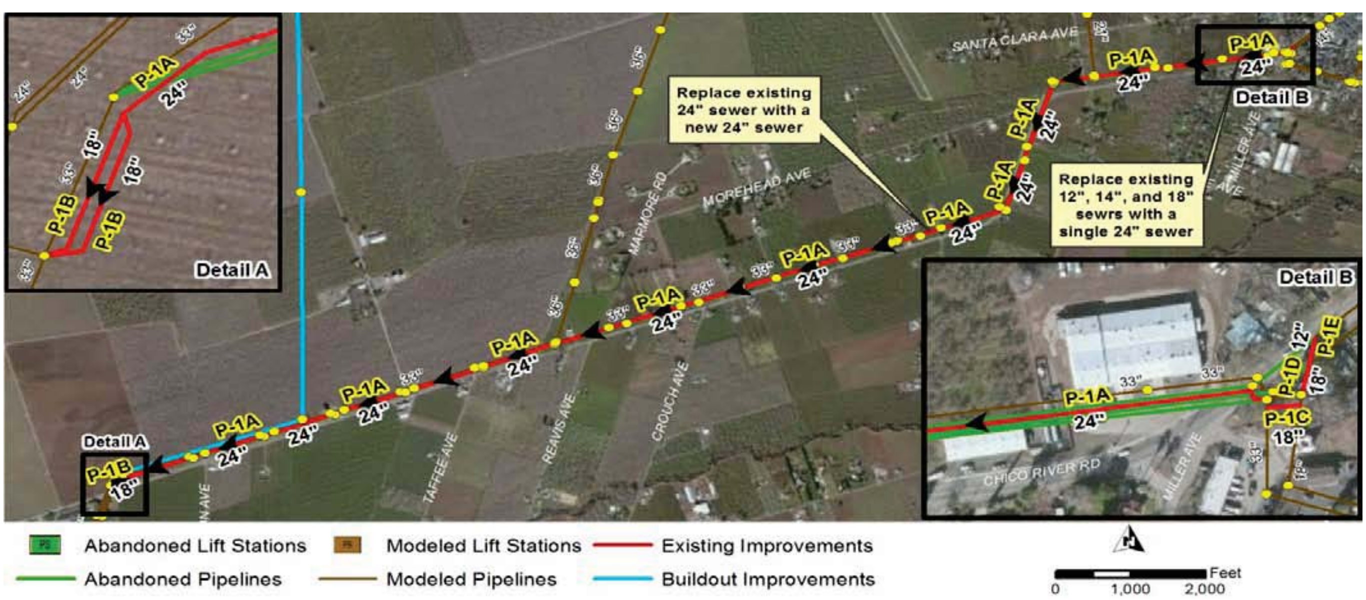
Baseline Construction Cost	$	5,297,400
Construction Contingency	$	1,324,300
Estimated Construction Cost	$	6,621,700
Engineering Services, Construction Management and Project Administration	$	1,655,300
Total Capital Improvement Cost	**$**	**8,277,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Replace the existing 12-inch, 14-inch, and 18-inch diameter sewers on Chico River Road from West 5th Street to Moorehead Avenue, and the existing 24-inch sewer from Moorehead Avenue to the WPCP with a new, 17,800 foot long reach of 24-inch diameter sewer. Connect existing sewers on the upstream end of the proposed 24-inch sewer with new 12-inch and 18-inch connections. Connect to existing WPCP junction box with new parallel 18-inch pipelines.

Project Justification
The existing Chico River Road Trunk Sewer has been reported to be in poor condition and the City has determined that it should be replaced with a new trunk sewer located in the center of Chico River Road. As part of the collection system capacity evaluation it was determined that a 24-inch diameter replacement sewer and associated connections are adequate to service build out PWWFs.

Project Detail Map



City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 2

Project ID: **Project 2**
Description: **Oak/7th Street Sewer**
Improvements: **P-2A through P-2B**

Project Type: Existing System

Project Benefit
Existing Customers: 95%
Future Development: 5%

Implementation Phase

Phase 1 (2013 - 2015)	x
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	

Project Location
Oak Street/W. 7th Street from Cedar Street to W. 5th Street

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	275,500
Construction Contingency	$	68,900
Estimated Construction Cost	$	344,400
Engineering Services, Construction Management and Project Administration	$	86,600
Total Capital Improvement Cost	**$**	**431,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Replace approximately 1,330 feet of existing 10-inch diameter sewer on 7th Street and Oak Street from Cedar Street to West 5th Street with a new 12 inch diameter sewer from Cedar Street to Walnut Street, and a 15-inch diameter sewer from Walnut Street to West 5th Street.

Project Justification
This project is required to mitigate surcharged conditions on West 7th Street for existing PWWFs.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 3

Project ID: **Project 3**
Description: **7th Street Sewer**
Improvements: **P-3**

Project Type: Existing System

Project Benefit
Existing Customers: 95%
Future Development: 5%

Implementation Phase

Phase 1 (2013 - 2015)	x
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	

Project Location
E. 7th Street from Olive Street to Main Street

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	237,600
Construction Contingency	$	59,400
Estimated Construction Cost	$	297,000
Engineering Services, Construction Management and Project Administration	$	74,000
Total Capital Improvement Cost	**$**	**371,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Replace approximately 1,350 feet of existing 8-inch diameter sewer on 7th Street from Olive Street to Main Street with a new 10-inch diameter sewer.

Project Justification
This project is required to mitigate surcharged conditions on West 7th Street for existing PWWFs.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 4

Project ID: **Project 4**
Description: **Eaton Road Trunk Sewer**
Improvements: **P-4A through P-4D**

Project Type: Existing System

Project Benefit

Existing Customers: 28%
Future Development: 72%

Project Vicinity Map

Implementation Phase

Phase	
Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	x
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	

Capital Improvement Costs

Baseline Construction Cost	$	3,049,500
Construction Contingency	$	762,400
Estimated Construction Cost	$	3,811,900
Engineering Services, Construction Management and Project Administration	$	954,100
Total Capital Improvement Cost	**$**	**4,766,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Location

Eaton Road from the Chico Municipal Airport Lift Station to west of Highway 99

Project Details

Construct a new 540 foot long, 18-inch diameter sewer to divert flow from the manhole immediately upstream of the Chico Municipal Airport Lift Station on Cohasset Road to a new 21-inch diameter sewer on Eaton Road that would extend 8,170 feet from Cohasset Road to Hicks Lane. At Hicks Lane, the 21-inch diameter sewer would flow into a new, 1,660-foot long reach of 24-inch diameter sewer that flows along Eaton Road from Hicks Lane and crosses Highway 99 to the existing 24-inch diameter sewer just west of Highway 99.

Project Justification

This project is required to mitigate existing capacity deficiencies in the existing 12-inch diameter gravity sewer immediately downstream of the Chico Municipal Airport Lift Station and to service future growth in the north Chico area. In addition, this improvement project allows for the Chico Municipal Airport Lift Station to be abandoned.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 5

Project ID: **Project 5**
Description: **Cohasset Road Sewer**
Improvements: **P-5**

Project Type: Existing System

Project Vicinity Map

Project Benefit

Existing Customers: 28%
Future Development: 72%

Implementation Phase

Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	x
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	

Capital Improvement Costs

Baseline Construction Cost	$	555,900
Construction Contingency	$	139,000
Estimated Construction Cost	$	694,900
Engineering Services, Construction Management and Project Administration	$	174,100
Total Capital Improvement Cost	**$**	**869,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Location

Cohasset Road north of Thorntree Drive to the Chico Municipal Airport Lift Station

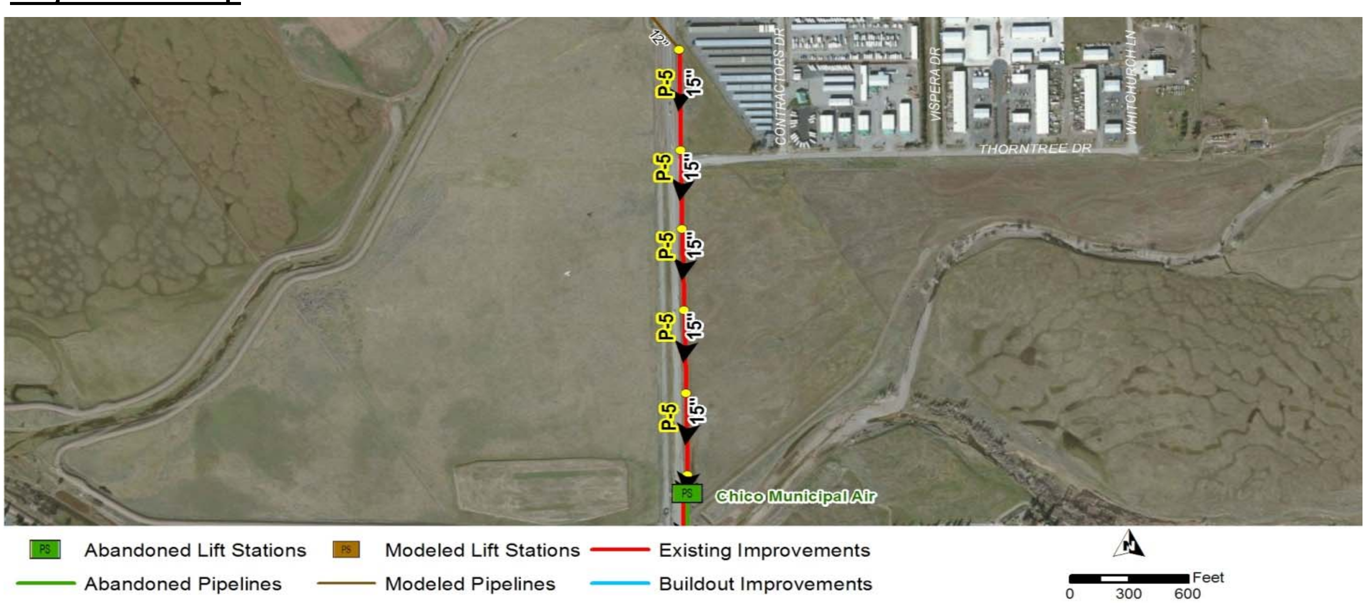
Project Details

Replace approximately 2,610 feet of 12-inch diameter pipeline with a new 15-inch diameter sewer on Cohasset Road north of Thorntree Drive to the Chico Municipal Airport Lift Station.

Project Justification

This project mitigates existing capacity deficiencies in the sewer immediately upstream of the Chico Municipal Airport Lift Station.

Project Detail Map



City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 6

Project ID: **Project 6**
Description: **21st/Franklin Street Sewer**
Improvements: **P-6**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase
Phase 1 (2013 - 2015) ___
Phase 2 (2016 - 2020) x
Phase 3 (2021 - 2025) ___
Phase 4 (2026 - 2030) ___

Project Location
Franklin/East 21st Street from East 20th Street to Mulberry Street

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	362,100
Construction Contingency	$	90,500
Estimated Construction Cost	$	452,600
Engineering Services, Construction Management and Project Administration	$	113,400
Total Capital Improvement Cost	**$**	**566,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Replace approximately 1,700 feet of existing 12-inch diameter sewer with a new 15-inch diameter sewer.

Project Justification
The existing 12-inch diameter sewer on Franklin Street and East 21st Street from East 20th Street to Mullberry Street experienced minor surcharging under current PWWFs, but did not exceed the maximum allowable flow depth criteria. However, the hydraulic evaluation indicates that during build out PWWF conditions, the existing 12-inch diameter sewer is not capable of conveying the PWWF without exceeding the allowable flow depth criteria.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 7

Project ID: **Project 7**
Description: **11th/Oakdale/12th Street Sewer**
Improvements: **P-7A through P-7C**

Project Type: Build Out System

Project Vicinity Map

Project Benefit

Existing Customers: 0%
Future Development: 100%

Implementation Phase

Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	x
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	

Capital Improvement Costs

Baseline Construction Cost	$	492,600
Construction Contingency	$	123,200
Estimated Construction Cost	$	615,800
Engineering Services, Construction Management and Project Administration	$	154,200
Total Capital Improvement Cost	**$**	**770,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Location

W. 11th Street/Oakdale Street/E. 12th Street from Park Avenue to Chestnut Street Alley

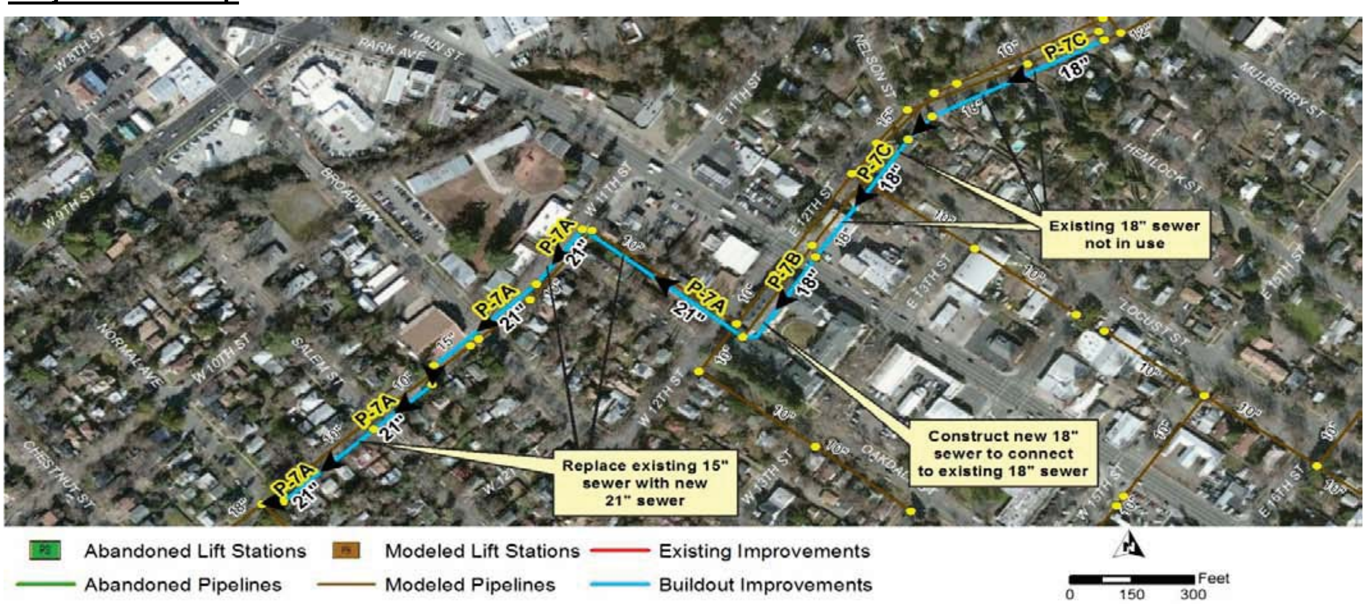
Project Details

On West 12th Street, there is an existing 18-inch diameter relief sewer, which parallels the capacity deficient 15-inch diameter sewer. At present, the 18-inch relief sewer does not connect back to system. Therefore, a new 18-inch diameter parallel sewer should be constructed to connect the existing 18-inch sewer. In addition, this project consists of replacing the existing 15-inch diameter sewer on Olive Street and West 11th Street from West 12th Street to the alley northeast of Chestnut Street with a new 21-inch diameter sewer.

Project Justification

Under current PWWF conditions, the existing 15-inch/18-inch diameter sewers on West 12th Street, Oakdale Street, and West 11th Street from Olive Street to the alley between Chestnut Street and Normal Street experienced surcharging, but did not exceed the allowable flow depth criteria. At build out, however, a capacity increase in this location is required.

Project Detail Map



City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 8

Project ID: **Project 8**
Description: **11th Avenue Sewer**
Improvements: **P-8**

Project Type: Build Out System

Project Benefit
Existing Customers: 74%
Future Development: 26%

Implementation Phase

Phase	
Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	x
Phase 4 (2026 - 2030)	

Project Location
W. 11th Avenue from Holley Avenue to west of Cecelia Lane

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	283,500
Construction Contingency	$	70,900
Estimated Construction Cost	$	354,400
Engineering Services, Construction Management and Project Administration	$	88,600
Total Capital Improvement Cost	**$**	**443,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Construct a new 8-inch diameter sewer to divert flow from the manhole immediately upstream of the Holly Lift Station and convey it southwest along West 11th Avenue to the existing 15-inch diameter sewer west of Cecelia Lane.

Project Justification
With the construction of a new 8-inch diameter sewer on West 11th Avenue, the Holly Lift Station can be abandoned.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 9

carollo

Project ID: **Project 9**
Description: **Silverbell Road Sewer**
Improvements: **P-9**

Project Type: Build Out System

Project Benefit
Existing Customers: 50%
Future Development: 50%

Implementation Phase
Phase 1 (2013 - 2015) ___
Phase 2 (2016 - 2020) ___
Phase 3 (2021 - 2025) x
Phase 4 (2026 - 2030) ___

Project Location
Joshua Tree Road.Silverbell Road from the Lassen Avenue Lift Station to Eaton Road.

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	1,154,600
Construction Contingency	$	288,700
Estimated Construction Cost	$	1,443,300
Engineering Services, Construction Management and Project Administration	$	360,700
Total Capital Improvement Cost	**$**	**1,804,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Construct a new 6,560 foot long reach of 10-inch diameter sewer to convey flows northwest along Joshua Tree Road and Silverbell Road, where it would tie into the proposed Eaton Road Trunk Sewer.

Project Justification
The City has indicated the existing Lassen Avenue Lift Station will be abandoned in the future.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 10

Project ID: **Project 10**
Description: **Humbolt Avenue Sewer**
Improvements: **P-10A through P-10C**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase

Phase 1 (2013 - 2015)	___
Phase 2 (2016 - 2020)	___
Phase 3 (2021 - 2025)	___
Phase 4 (2026 - 2030)	x

Project Location
Humbolt Avenue from Bruce Road to Poplar Street

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	2,546,700
Construction Contingency	$	636,700
Estimated Construction Cost	$	3,183,400
Engineering Services, Construction Management and Project Administration	$	795,600
Total Capital Improvement Cost	**$**	**3,979,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Replace apprximately 9,640 feet of existing 15-inch diameter sewers with a new 18-inch diameter sewer.

Project Justification
The hydraulic analysis indicated that several reaches of the existing 15-inch diameter sewers located along Humbolt Avenue from Bruce Road to Poplar Street are not capable of conveying build out PWWFs and should be replaced with a larger diameter sewer. There are some portions of the existing 15-inch diameter sewer that have a steeper slope than the majority of this reach of sewers. The hydraulic evaluation shows that these steeper reaches of 15-inch diameter sewer do not need to be replaced.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 11

Project ID: **Project 11**
Description: **California Lake Park Sewer**
Improvements: **P-11A through P-11B**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase
Phase 1 (2013 - 2015) ____
Phase 2 (2016 - 2020) ____
Phase 3 (2021 - 2025) ____
Phase 4 (2026 - 2030) x

Project Location
Near California Lake Park

Project Vicinity Map

Capital Improvement Costs

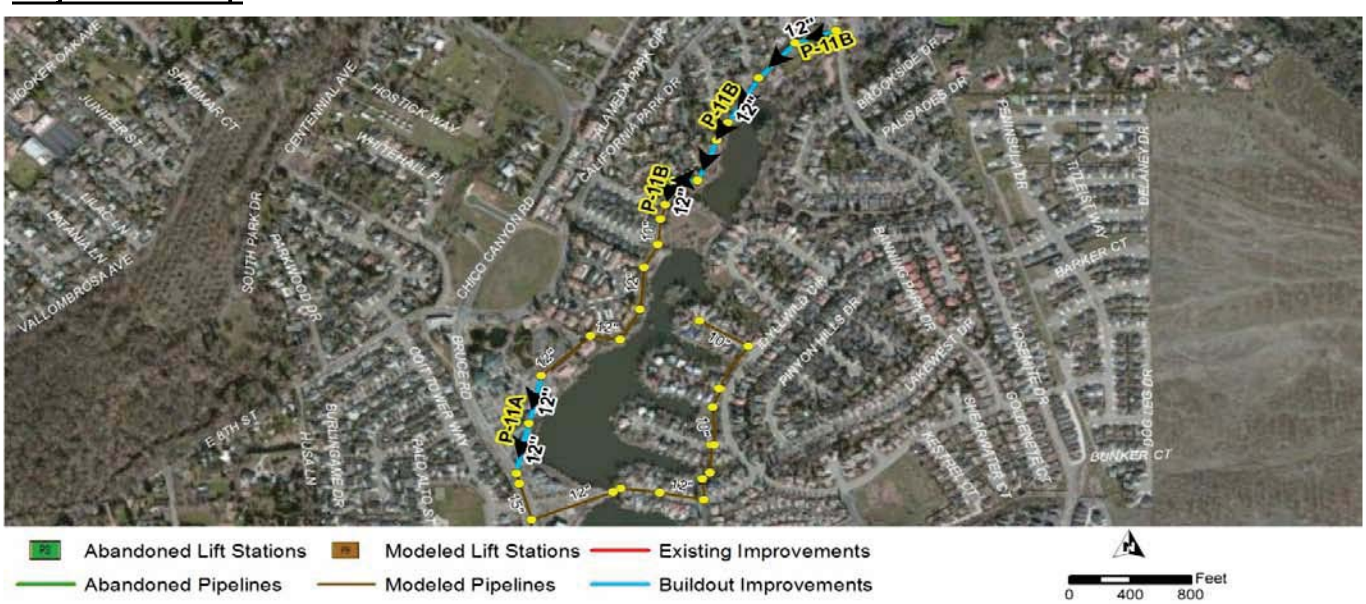
Baseline Construction Cost	$	535,800
Construction Contingency	$	133,900
Estimated Construction Cost	$	669,700
Engineering Services, Construction Management and Project Administration	$	168,300
Total Capital Improvement Cost	**$**	**838,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Replace certain reaches of the existing 10-inch diameter sewers located near California Lake Park from Yosemite Drive to Bruce Road with a new 12-inch diameter sewer.

Project Justification
The hydraulic analysis indicated that certain reaches of the existing 10-inch diameter sewers located near California Lake Park from Yosemite Drive to Bruce Road are not capable of conveying build out PWWFs and should be replaced. Similar to Project 10, there are some portions of the existing 10-inch diameter sewer that have a steeper slope than the majority of this reach of sewers, and do not need to be replaced. In addition, some reaches of sewers along this alignment are already 12-inch in diameter and would not need to be replaced.

Project Detail Map



City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 12

Project ID: **Project 12**
Description: **23rd Street Sewer**
Improvements: **P-12**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase
Phase 1 (2013 - 2015) ___
Phase 2 (2016 - 2020) ___
Phase 3 (2021 - 2025) ___
Phase 4 (2026 - 2030) x

Project Location
E. 23rd Street at Fair Street

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	79,400
Construction Contingency	$	19,900
Estimated Construction Cost	$	99,300
Engineering Services, Construction Management and Project Administration	$	24,700
Total Capital Improvement Cost	**$**	**124,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Replace 270 feet of existing 15-inch diameter sewer with a new 24-inch diameter sewer.

Project Justification
The hydraulic evaluation indicated that a short 270 foot reach of existing 15-inch diameter sewer located at the intersection of East 23rd Street and Fair Street experienced surcharging under current PWWFs, but the surcharged conditions did not exceed the maximum allowable flow depth criteria. During build out PWWFs, however, the existing 15-inch diameter sewer is not capable of conveying the PWWF without exceeding the allowable flow depth criteria, and should be replaced.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 13

Project ID: **Project 13**
Description: **Northwest Trunk Sewer**
Improvements: **P-13A through P-13I**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase

Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	x
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	

Project Location
West of Chico from the Northwest Chico Lift Station to the WPCP.

Project Vicinity Map

Capital Improvement Costs

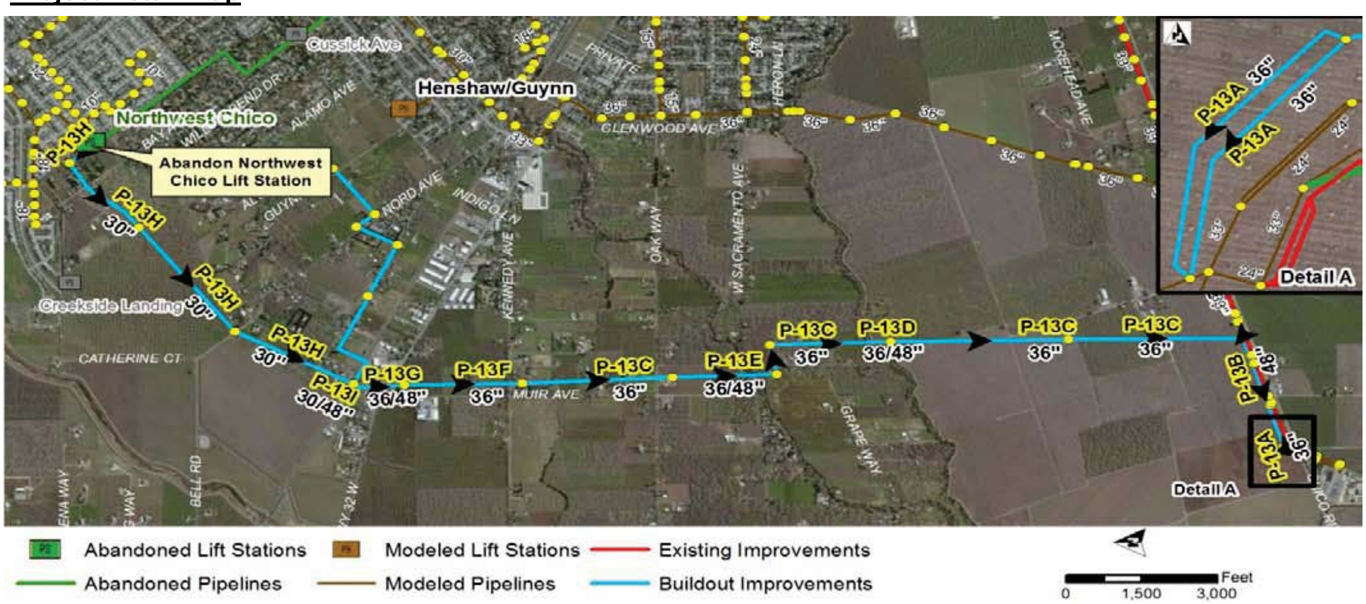
Baseline Construction Cost	$ 12,657,100
Construction Contingency	$ 3,164,400
Estimated Construction Cost	$ 15,821,500
Engineering Services, Construction Management and Project Administration	$ 3,956,500
Total Capital Improvement Cost	**$ 19,778,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
The new trunk sewer would consist of a new 30-inch diameter trunk sewer from the Northwest Chico Lift Station southwest to the railroad at Muir Avenue, a new 36-inch diameter sewer from Muir Avenue south to Chico River Road, and a new 48-inch diameter sewer to the WPCP. The City's junction box at the WPCP is currently configured to accommodate two new 36-inch pipelines for the Northwest Trunk Sewer. Therefore, just upstream of the junction box, the 48-inch sewer would be split into two 36-inch pipes.

Project Justification
For build out flow conditions, an analysis was conducted to determine whether growth in northwest Chico could be routed through the existing 30-inch and 36-inch diameter trunk sewer located on East Avenue, Glenwood Avenue, and down to Chico River Road. The analysis indicated that this major trunk sewer would need to be replaced. In lieu of replacing the existing trunk sewer, it is recommended that the City plan to construct the new Northwest Trunk Sewer.

Project Detail Map



City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 14

Project ID:	**Project 14**
Description:	**Bell Muir Trunk Sewer**
Improvements:	**P-14A through P-14C**
Project Type:	Build Out System

Project Vicinity Map

Project Benefit

Existing Customers: 0%
Future Development: 100%

Implementation Phase

Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	x
Phase 4 (2026 - 2030)	

Project Location

Near Rodeo Avenue to the Northwest Trunk Sewer

Capital Improvement Costs

Baseline Construction Cost	$ 1,276,200
Construction Contingency	$ 319,100
Estimated Construction Cost	$ 1,595,300
Engineering Services, Construction Management and Project Administration	$ 399,700
Total Capital Improvement Cost	**$ 1,995,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details

Construct a new 10-inch, 12-inch, and 15-inch diameter trunk sewer to serve the Bell Muir specific plan area.

Project Justification

Pipeline constructed to serve as the backbone sewer for the planned Bell Muir specific plan area.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 15

Project ID: **Project 15**
Description: **Esplanade Sewer**
Improvements: **P-15**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase

Phase	
Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	x

Project Location
Esplanade from Garner Lane to Nord

Project Vicinity Map

Capital Improvement Costs

Baseline Construction Cost	$	478,700
Construction Contingency	$	119,700
Estimated Construction Cost	$	598,400
Engineering Services, Construction Management and Project Administration	$	149,600
Total Capital Improvement Cost	**$**	**748,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Construct approximately 2,720 feet of new 10-inch diameter sewer.

Project Justification
This sewer is recommended to provide sanitary sewer service to a strip of commercial and manufacturing land uses next to Esplanade in the northern portions of the City.

Project Detail Map

Project ID: Project 16
Description: North Chico Trunk Sewer
Improvements: P-16A through P-16C

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase
Phase 1 (2013 - 2015) ___
Phase 2 (2016 - 2020) ___
Phase 3 (2021 - 2025) ___
Phase 4 (2026 - 2030) x

Project Location
Hicks Lane from north of Cabello Way to Eaton Road.

Project Vicinity Map

Capital Improvement Costs

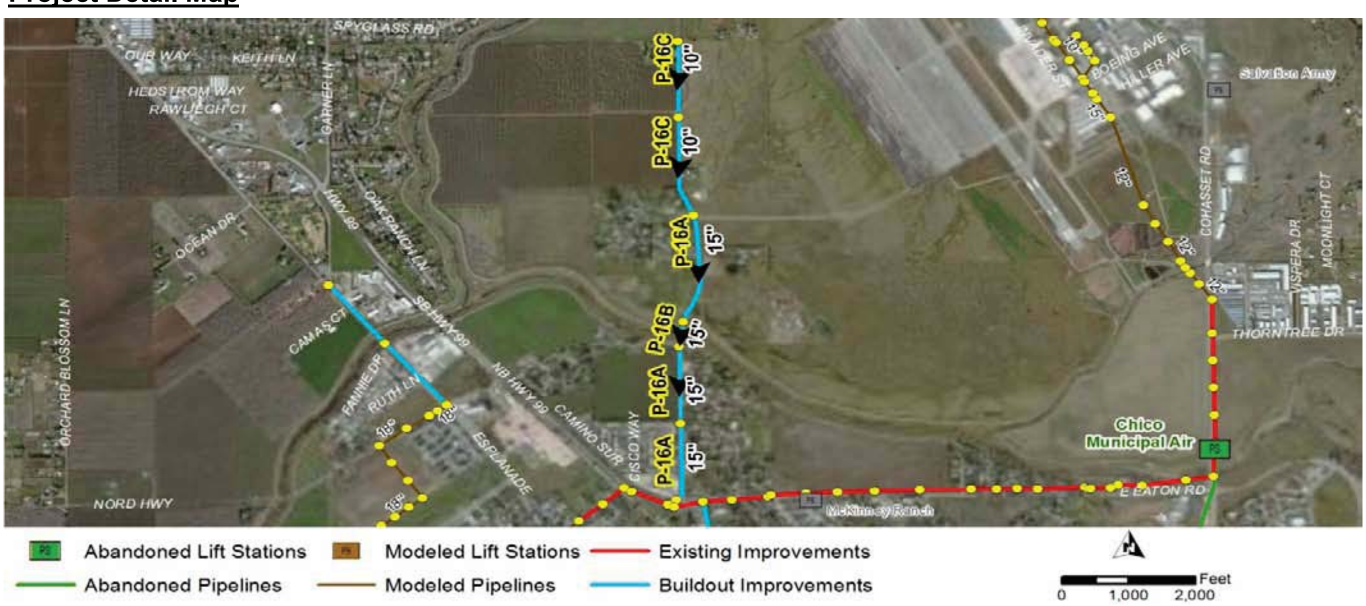
Baseline Construction Cost	$	2,025,200
Construction Contingency	$	506,300
Estimated Construction Cost	$	2,531,500
Engineering Services, Construction Management and Project Administration	$	632,500
Total Capital Improvement Cost	**$**	**3,164,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Construct a new 10-inch through 15-inch diameter trunk sewer that would connect to the downstream end of the proposed Eaton Road Trunk Sewer.

Project Justification
This project consists of a trunk sewer to service the North Chico specific plan area, as well as other land uses in the vicinity.

Project Detail Map



City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 17

Project ID: Project 17
Description: Southeast Trunk Sewer
Improvements: P-17A through P-17D

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Implementation Phase

Phase	
Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	x
Phase 4 (2026 - 2030)	

Project Location
Located in the vicinity of the South Entler specific plan area.

Project Vicinity Map

Capital Improvement Costs

Item	Cost
Baseline Construction Cost	$ 4,584,400
Construction Contingency	$ 1,146,100
Estimated Construction Cost	$ 5,730,500
Engineering Services, Construction Management and Project Administration	$ 1,433,500
Total Capital Improvement Cost	**$ 7,164,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
The recommended Southeast Trunk Sewer would begin as a 10 inch and 12-inch sewer located adjacent to Highway 99 on the west. Near Northfield Avenue, the 12-inch sewer would flow into a 24-inch and then a 27-inch diameter trunk sewer that flows southwest and then northwest to the existing 33-inch diameter trunk sewer on Estes Road.

Project Justification
This project is required to service future development in the southern area of the City, including the South Entler specific plan area. In addition, this trunk sewer would also convey flows from the future Honey Run Trunk Sewer, which would service the majority of the Honey Run/Doe Mill specific plan areas.

Project Detail Map

City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 18

Project ID: **Project 18**
Description: **Honey Run Trunk Sewer**
Improvements: **P-18A through P-18F**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Project Vicinity Map

Implementation Phase

Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	
Phase 4 (2026 - 2030)	x

Project Location
Located in the vicinity of Honey Run Road and Potter Road.

Capital Improvement Costs

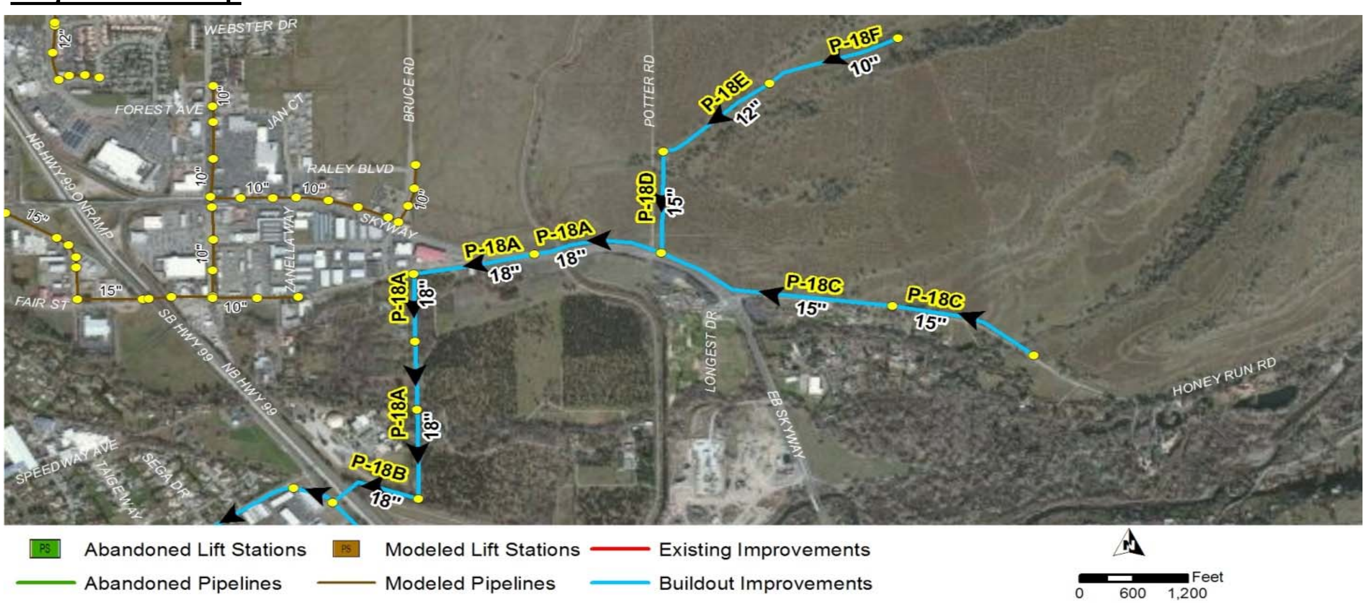
Baseline Construction Cost	$	3,461,200
Construction Contingency	$	865,300
Estimated Construction Cost	$	4,326,500
Engineering Services, Construction Management and Project Administration	$	1,081,500
Total Capital Improvement Cost	**$**	**5,408,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Details
Construct a backbown network of 10-inch to 18-inch diameter sewers to connect to the future Southeast Trunk Sewer.

Project Justification
The Honey Run Trunk Sewer would service the majority of the Honey Run/Doe Mill specific planning area, as well some additional land use types near Highway 99. The Honey Run Trunk Sewer would connect to the Southeast Trunk Sewer through a Highway 99 crossing near Speedway Lane.

Project Detail Map



City of Chico
Sanitary Sewer Master Plan Update
CAPITAL IMPROVEMENT PLAN PROJECT 19

Project ID: **Project 19**
Description: **Doe Mill Trunk Sewer**
Improvements: **P-19**

Project Type: Build Out System

Project Benefit
Existing Customers: 0%
Future Development: 100%

Project Vicinity Map

Implementation Phase

Phase 1 (2013 - 2015)	
Phase 2 (2016 - 2020)	
Phase 3 (2021 - 2025)	x
Phase 4 (2026 - 2030)	

Capital Improvement Costs

Baseline Construction Cost	$	697,000
Construction Contingency	$	174,300
Estimated Construction Cost	$	871,300
Engineering Services, Construction Management and Project Administration	$	217,700
Total Capital Improvement Cost	**$**	**1,089,000**

ENR CCI = 9,351 20-City Average, August 2012

Project Location
Doe Mill Road from east of Potter Road to Bruce Road.

Project Details
Construct a new 10-inch diameter trunk sewer and connect to the existing collection system at Bruce Road.

Project Justification
The Doe Mill Trunk Sewer cwould service the northern portion of the Honey Run/Doe Mill specific plan area. The new trunk would connect to the existing 10-inch diameter sewer at Bruce Road.

Project Detail Map

APPENDIX A – LAND USE DESCRIPTIONS (EXCERPTS FROM THE CHICO 2030 GENERAL PLAN)

CHICO 2030
GENERAL PLAN

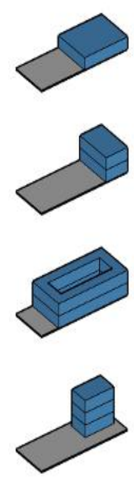
CITY OF CHICO
INC. 1872

APRIL 2011

LAND USE DESIGNATIONS AND DIAGRAM

LAND USE DESIGNATIONS

State planning law requires that the land use element of a general plan include a statement of the standard population density, building intensity, and allowed uses for the various land use designations in the plan (Government Code Section 65302(a)). The City's land use designations are generally described below and mapped on the Land Use Diagram (**Figure LU-1**). **Table LU-2** includes a representative land use image and typical density ranges and floor area ratios for each designation. The City Municipal Code provides detailed land use and development standards for development.



Floor Area Ratio: floor area ratio (FAR) expresses the intensity of use on a lot. The FAR represents the ratio between the total gross floor area of all buildings on a lot and the total land area of that lot. For example, a 20,000 square foot building on a 40,000 square foot lot yields a FAR of 0.50. A 0.50 FAR describes a single-story building that covers half of the lot, or a two-story building covering approximately one-quarter of the lot.

With this General Plan, a variety of new land use designations have been established to reflect the more mixed and, in some cases, more intense land uses envisioned for Chico. New mixed-use designations provide the opportunity for a combination of residential, commercial, and office uses on a single site, depending on the designation.

TABLE LU-2: LAND USE DESIGNATIONS AND DEVELOPMENT STANDARDS

Land Use Image	Land Use Designation Description	Allowed Density (Dwelling Units/Acre)		Suggested Floor Area Ratio (FAR)	
		Minimum DU/AC	Maximum DU/AC	Minimum FAR	Maximum FAR
Residential Designations					
	**Very Low Density Residential (VLDR)**	0.2	2.0	N/A	N/A
	This designation can provide a smooth transition between the rural areas and more densely developed neighborhoods, or be in "pockets" of development in carefully selected locations.				
	**Low Density Residential (LDR)**	2.1	7.0	N/A	N/A
	This designation represents the traditional single-family neighborhood with a majority of single-family detached homes and some duplexes. This is the predominant land use category of the City's existing neighborhoods.				
	**Medium Density Residential (MDR)**	7.1	14.0	N/A	N/A
	This designation is generally characterized by duplexes, small apartment complexes, single-family attached homes such as town homes and condominiums, and single-family detached homes on small lots.				
	**Medium-High Density Residential (MHDR)**	14.1	22.0	N/A	N/A
	This designation provides a transition between traditional single-family neighborhoods and high density residential, and major activity or job centers. Dwelling types may include townhouses, garden apartments, and other forms of multi-family housing.				
	**High Density Residential (HDR)**	20.0	70.0	N/A	N/A
	This designation represents the most urban residential category. The predominant style of development is larger, multi-family housing complexes, including apartments and condominiums.				
	**Residential Mixed Use (RMU)**	10.0 (1)	20.0 (1)	N/A	2.5 (1)
	This designation is characterized by predominantly residential development at medium to high densities. It allows for commercial or office uses to be located on the same property, either vertically or horizontally. It does not preclude development that is entirely residential, but rather encourages a mix of uses. Additionally, other primary uses may be allowed by right or with approval of a Use Permit, as outlined in the Municipal Code.				
Commercial Designations					
	**Neighborhood Commercial (NC)**	6.0 (2)	22.0	0.20	1.5
	This designation accommodates a mix of business, office, and residential uses that support the needs of residents living in the surrounding neighborhoods. Allowable uses include small grocery or drug stores, retail shops, and small-scale financial, business, personal services, and restaurants. Horizontal or vertical mixed use is required on larger sites with this designation, as specified in the Municipal Code.				

Land Use Image	Land Use Designation Description	Allowed Density (Dwelling Units/Acre)		Suggested Floor Area Ratio (FAR)	
		Minimum DU/AC	Maximum DU/AC	Minimum FAR	Maximum FAR
	**Commercial Mixed Use (CMU)**	6.0 (2)	22.0 (3)	0.25 (3)	1.0 (3)
	This designation encourages the integration of retail and service commercial uses with office and/or residential uses. In mixed-use projects, commercial use is the predominant use on the ground floor. This designation may also allow hospitals and other public/quasi-public uses. Other uses may be allowed by right or with approval of a Use Permit, as outlined in the Municipal Code.				
	**Commercial Service (CS)**	N/A	N/A	0.20	0.5
	This designation provides sites for commercial businesses not permitted in other commercial areas because they attract high volumes of vehicle traffic and may have adverse impacts on other commercial uses. Allowable uses include automobile repair and services, building materials, nurseries, equipment rentals, contractors' yards, wholesaling, storage, and similar uses. Other retail and offices uses may be allowed, as outlined in the Municipal Code.				
	**Regional Commercial (RC)**	6.0 (2)	50.0	0.20	2.0
	This designation provides sites for larger retail and service businesses that serve residents from the City and the region. Mixed-use projects integrating office or residential uses are allowed.				
Office Mixed Use and Industrial Designations					
	**Office Mixed Use (OMU)**	6.0 (2,4)	20.0 (4)	0.30	2.0 (4)
	This designation is characterized by predominantly office uses, but allows the integration of commercial and/or residential uses. Other primary uses may be allowed by right or with approval of a Use Permit, as outlined in the Municipal Code..				
	**Industrial Office Mixed Use (IOMU)**	7.0 (2)	14.0	0.25	1.5
	This designation provides for a wide range and combination of light industrial and office development. The designation is intended for the seamless integration of light industrial and office uses with supporting retail and service uses. Offices may be developed in an office park setting, but most office and light industrial development stands alone. Commercial and other support services may be integrated vertically or horizontally, but the predominant use is light industrial or office. Live-work uses may be permitted with special consideration for compatibility with predominant uses.				
	**Manufacturing and Warehouse (M&W)**	N/A	N/A	0.20	0.75
	This designation provides for the full range of manufacturing, agricultural and industrial processing, general service, and distribution uses. Other complimentary uses may be allowed by right or with approval of a Use Permit, as outlined in the Municipal Code.				
Public and Open Space Designations					
	**Public Facilities and Services (PFS)**	N/A	N/A	0	1.0
	This designation includes sites for schools, hospitals, governmental offices, airports, and other facilities that have a unique public character.				

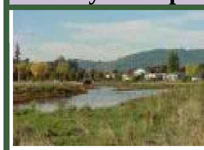
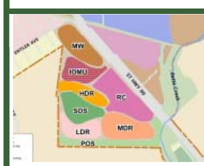
Land Use Image	Land Use Designation Description	Allowed Density (Dwelling Units/Acre)		Suggested Floor Area Ratio (FAR)	
		Minimum DU/AC	Maximum DU/AC	Minimum FAR	Maximum FAR
	**Primary Open Space (POS)**	N/A	N/A	N/A	N/A
	This designation is intended to protect, in perpetuity, areas with sensitive habitats including oak woodlands, riparian corridors, wetlands, creekside greenways, and other habitat for highly sensitive species, as well as groundwater recharge areas and areas subject to flooding that are not used for agriculture.				
	**Secondary Open Space (SOS)**	N/A	N/A	N/A	N/A
	This designation includes land used for both intensive and non-intensive recreational activities, such as parks, lakes, golf courses, and trails. Land within this category may also be used for resource management, detention basins, agriculture, grasslands and other similar uses.				
Overlay and Special Designations					
	**Resource Constraint Overlay (RCO)**	(5)	(5)	(5)	(5)
	This is an overlay designation that identifies areas with significant environmental resources that result in development constraints. The RCO requires subsequent studies to determine the exact location and the intensity of development that can take place in light of identified constraints.				
	**Special Mixed Use (SMU)**	7.0	35.0	N/A	N/A
	This designation provides for development of walkable neighborhoods with a mix of residential and nonresidential uses subject to approval of a regulating plan and circulation plan consistent with the Traditional Neighborhood Development zoning district.				
	**Special Planning Area (SPA)**	(6)	(6)	(6)	(6)
	This designation identifies areas for significant new growth that require subsequent comprehensive planning. Horizontal or vertical mixed-use is required (except for the Bell-Muir SPA). The General Plan includes a conceptual land plan for each SPA. Subsequent planning efforts for each area shall be found to be in substantial compliance with relevant SPA provisions and policies in the General Plan.				

Table Notes:

1. *When located Downtown or within a Corridor Opportunity Site, Residential Mixed Use has a minimum density of 15 dwelling units/acre, a maximum of 70 dwelling units per acre, and a maximum floor area ratio of 5.0.*
2. *If residential uses are incorporated horizontally, this minimum density should be met, but if integrated vertically, there is no minimum density requirement.*
3. *When located Downtown or within a Corridor Opportunity Site, Commercial Mixed Use has a maximum of 60 dwelling units per acre, and a maximum floor area ratio of 5.0.*
4. *When located Downtown or within a Corridor Opportunity Site, Office Mixed Use has a maximum of 60 dwelling units per acre, and a maximum floor area ratio of 5.0.*
5. *Allowable density and floor area ratio for the Resource Conservation Overlay designation shall be consistent with the standards of the underlying land use designation.*
6. *Allowable density and floor area ratio in the Special Planning Areas shall be consistent with the standards of the final land use designations identified for each site through subsequent master planning.*

LAND USE DIAGRAM

The Land Use Diagram (**Figure LU-1**) illustrates the distribution of the land use designations described above. In addition to identifying the land use designations, the Diagram highlights three types of land as follows:

1. **Special Planning Areas.** The Land Use Diagram includes five Special Planning Areas (SPAs). This designation identifies areas with significant new growth potential and carries a requirement for subsequent planning prior to development. Within each SPA, the City has identified a mix of desired land uses in the form of a conceptual land plan. The conceptual land plans do not represent precise proportions or locations for particular land uses. Detailed land use plans will be developed and refined as part of subsequent, comprehensive planning of each area. SPAs are shown on the Land Use Diagram with a dark outline, cross hatch lines, and labeled SPA-1 through SPA-5.

2. **Opportunity Sites**. The Land Use Diagram identifies 15 sites that provide a greater opportunity for change or improvement within the General Plan planning horizon. These Opportunity Sites have parcel-specific land use designations as well as special policy considerations. Opportunity Sites are shown on the Land Use Diagram with a dark outline and labeled with numbers 1 through 15.

3. **Resource Constraint Overlay**. The Land Use Diagram identifies three areas with sensitive biological resources that will constrain development. For these areas, the City has applied an "overlay" designation to acknowledge the existence of the identified constraints and set special policy requirements for subsequent study prior to development. Resource Constraint Overlay areas are identified on the Land Use Diagram by a dark outline with a dot fill pattern and labeled A through C.

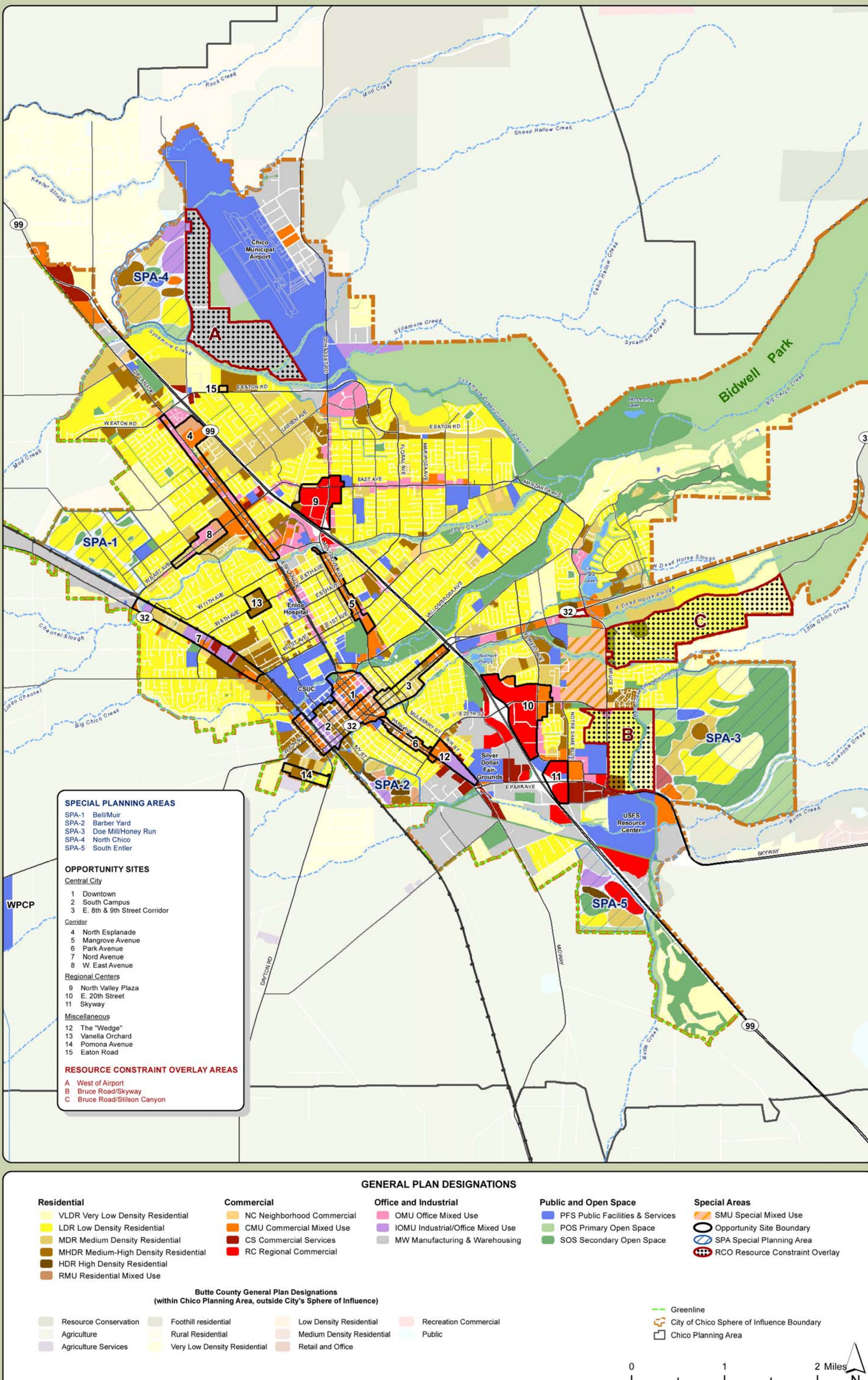


Figure LU-1 Land Use Diagram

CHICO 2030
GENERAL PLAN

APPENDIX B – CITY OF CHICO SANITARY SEWER FLOW MONITORING AND I/I STUDY

In order to conserve paper, this appendix has not been printed. The enclosed compact disc contains an electronic copy of this appendix.

SANITARY SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

City of Chico

August 2012

V&A

SANITARY SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

Prepared for

Prepared by

August 2012

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ABBREVIATIONS, TERMS AND DEFINITIONS USED IN THIS REPORT

Table i.
Abbreviations

Abbreviation	Term
ADWF	average dry weather flow
CCTV	closed-circuit television
CIP	capital improvement plan
CO	carbon monoxide
d/D	depth/diameter ratio
FM	flow monitor
gpd	gallons per day
gpm	gallons per minute
GWI	groundwater infiltration
H_2S	hydrogen sulfide
I/I	inflow and infiltration
IDM	inch-diameter-mile (miles of pipeline multiplied by the diameter of the pipeline in inches)
IDW	inverse distance weighting
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
Attenuation	Flow attenuation in a sewer collection system is the natural process of the reduction of the peak flow rate through redistribution of the same volume of flow over a longer period of time. This occurs as a result of friction (resistance), internal storage and diffusion along the sewer pipes. As the flows from the basins combine within the trunk sewer lines, the peaks from each basin will (a) not necessarily coincide at the same time, and (b) due to the length and time of travel through the trunk sewers, peak flows will ***attenuate*** as the peak flows move downstream. The sum of the peak flows of individual basins upstream will generally be greater than the measured peak flows observed at points downstream. Additional information on this concept is presented on page 16.
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.
Design storm	A theoretical storm event of a given duration and intensity that aligns with historical frequency records of rainfall events. For example, a 10-year, 24-hour design storm is a storm event wherein the volume of rain that falls in a 24-hour period would historically occur once every 10 years. Design storm events are used to predict I/I response and are useful for modeling how a collection system will react to a given set of storm event scenarios.
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

Term	Definition
	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 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.

Term	Definition
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 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.
Synthetic hydrograph	A set of algorithms has been developed to approximate the actual I/I hydrograph. The synthetic hydrograph is developed strictly using rainfall data and response parameters representing response time, recession coefficient and soil saturation.
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.

EXECUTIVE SUMMARY

Scope and Purpose

V&A has completed sanitary sewer flow monitoring and rainfall monitoring with inflow and infiltration (I/I) analysis within the City of Chico (City). Monitoring was performed over a period of approximately 6 weeks between February 23, 2012 and May 7, 2012 at 17 open-channel flow monitoring sites and two rain gauge locations. The purpose of this study was to measure sanitary sewer flows at the flow monitoring sites, estimate available sewer capacity and conduct analyses pertaining to infiltration and inflow (I/I) occurring in the basins upstream from the flow monitoring sites.

Site Flow Monitoring and Capacity Results

Peak measured flows and the flow level (depth) at peak flow times are important factors to consider in understanding the capacity and hydraulic performance within a collection system. Table 1 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 1.
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	1.34	3.74	2.80	30	12.67	0.42	-
Site 4	2.06	5.18	2.51	36	17.79	0.49	-
Site 5	0.21	0.41	1.93	15	8.30	0.55	-
Site 6A	0.55	1.48	2.70	18	7.89	0.44	-
Site 6B	0.47	1.32	2.82	18	8.32	0.46	-
Site 7	0.51	1.64	3.23	15	11.69	0.78	-
Site 8	0.50	1.30	2.57	24	10.37	0.43	-
Site 9	1.02	1.64	1.61	21	13.83	0.66	-
Site 10	0.90	2.25	2.49	18	10.07	0.56	-
Site 11	1.43	3.63	2.53	33	14.14	0.43	-
Site 12	0.23	0.51	2.27	14	6.24	0.45	-
Site 13	0.45	0.89	1.97	12	8.74	0.73	-
Site 14	0.30	0.88	2.88	18	6.06	0.34	-
Site 15	1.05	2.49	2.36	24	11.57	0.48	-
Site 16	0.50	2.55	5.08	33	12.60	0.38	-
Site 17	0.31	0.94	3.05	23.5	5.76	0.25	-
Site 18	0.11	0.49	4.30	10	5.16	0.52	-

The following capacity analysis results are noted:

- **Peaking Factor:** Sites 7, 16, 17 and 18 had peaking factors that exceeded typical design threshold limits for peak flow to average dry weather flow ratio.
- ***d/D* Ratio:** Only Site 7 had a *d/D* ratios that exceeded common threshold value for *d/D* ratio. None of the 17 sites reached a surcharged condition during the study.

Figure 1 shows a bar graph summarizing the site by site d/D ratios. Figure 2 shows a schematic diagram of the peak measured flows with peak flow levels.

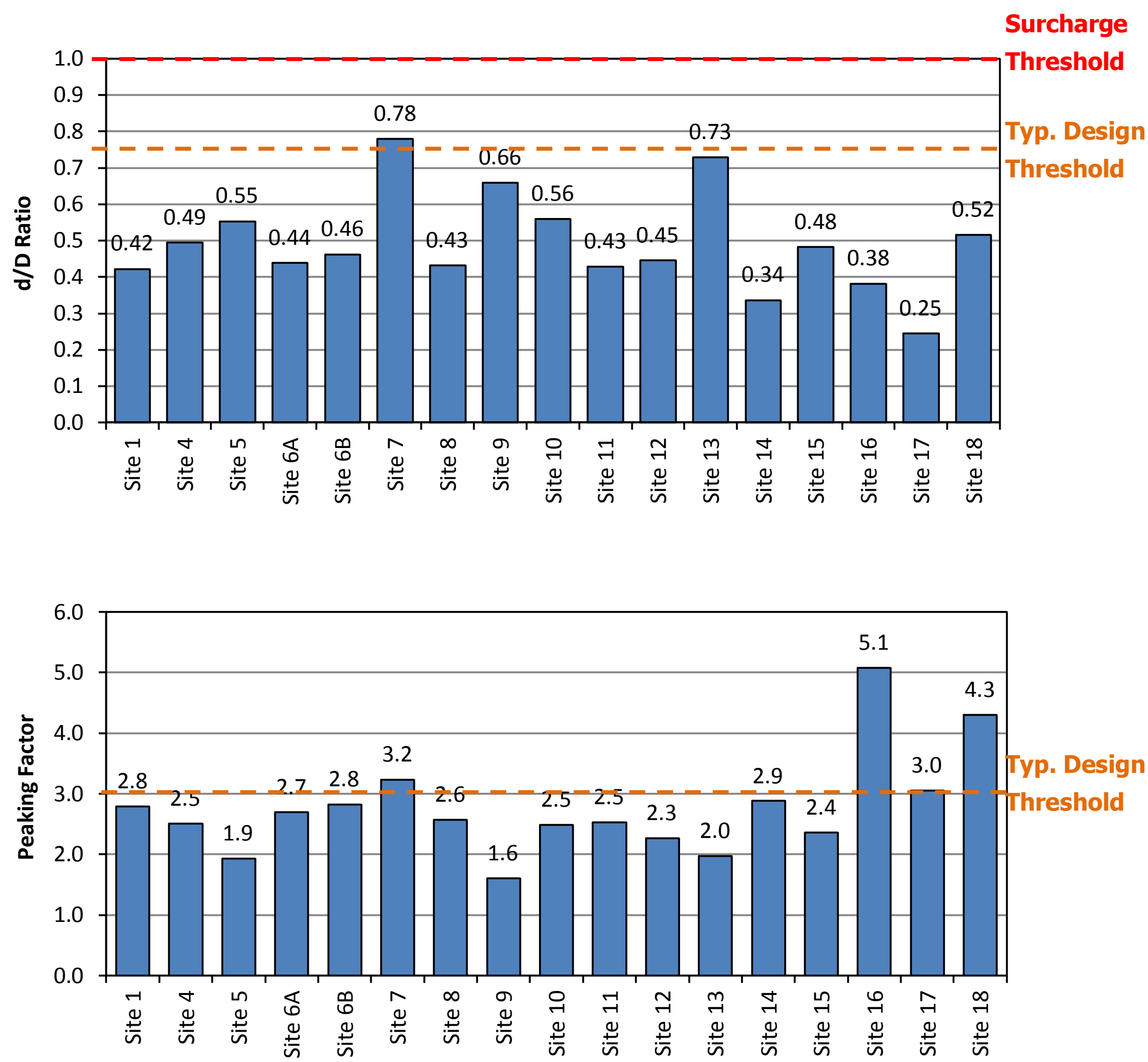


Figure 1. Capacity Summary Bar Graphs: d/D Ratios & Peaking Factor

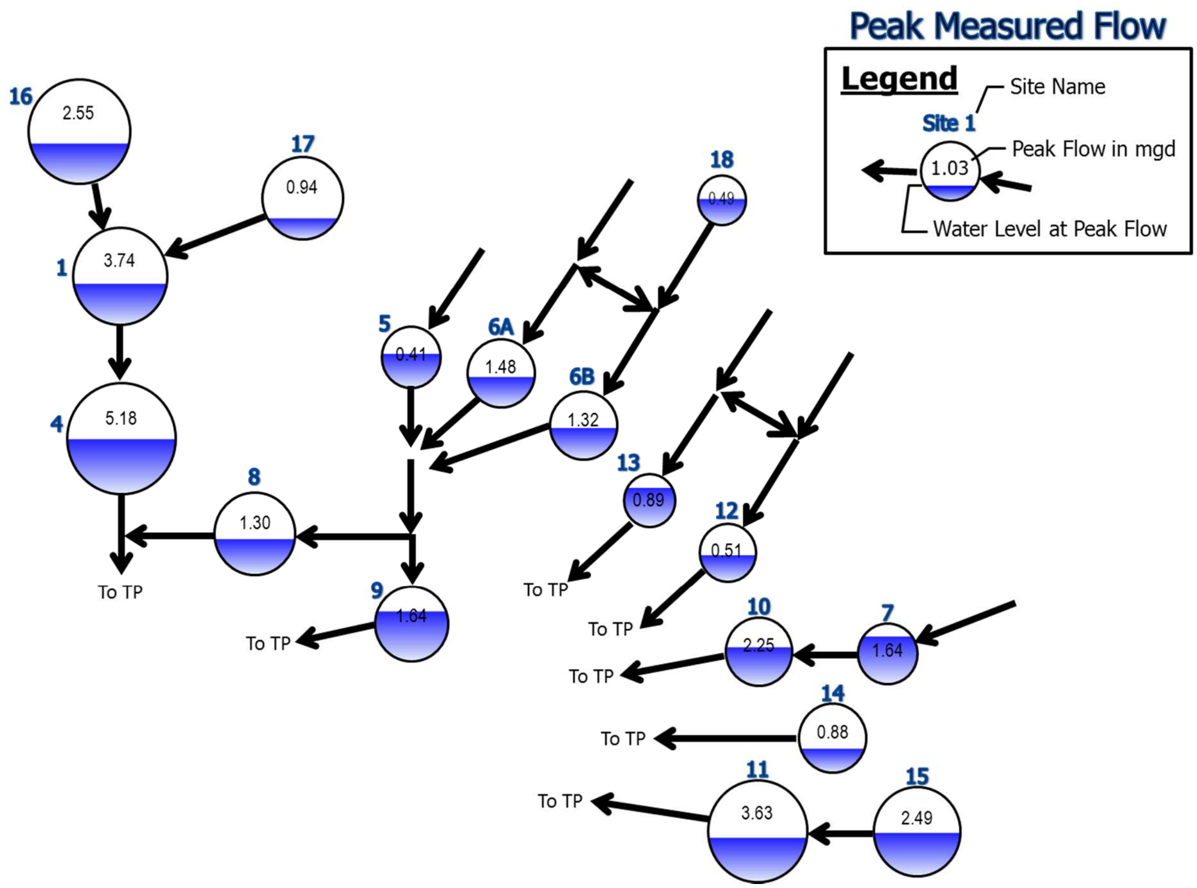


Figure 2. Peak Measured Flow Schematic

Basin Inflow and Infiltration Analysis Results

Table 2 summarizes the flow monitoring and I/I results for the flow monitoring basins that were isolated during this study. Infiltration and inflow rankings are shown such that 1 represents the highest infiltration or inflow contribution and 14 represents the least. The final I/I values and I/I analysis data were taken from the March 27 through April 1, 2012 rainfall event. Please refer to the I/I Methods section for more information on inflow analysis methods. Figure 3, Figure 4, Figure 5 and Figure 6 show temperature basin maps of the overall inflow and infiltration rankings. Figure 7 shows an illustrative map summary of the "Top 5" ranked basins for each I/I Analysis component.

Table 2.
I/I Analysis Summary

Basin	ADWF (mgd)	Peak I/I Rate (mgd)	Inflow Ranking	RDI Ranking	Evidence of High GWI?	Combined I/I Ranking
Basin 1	0.53	0.40	14	12	Yes	12
Basin 4	0.72	1.15	11	14	No	13
Basin 5	0.21	0.12	13	9	No	11
Basin 6	0.90	1.14	8	8	No	8
Basin 7	0.51	1.29	5	7	No	6
Basin 8/9	0.30	0.35	10	13	No	14
Basin 10	0.40	0.48	12	4	Yes	7
Basin 11	0.38	1.59	1	2	No	5
Basin 12/13	0.68	1.08	6	10	Yes	10
Basin 14	0.30	0.80	2	1	No	1
Basin 15	1.05	1.93	4	6	Yes	4
Basin 16	0.50	2.03	3	5	No	2
Basin 17	0.31	0.53	9	3	No	3
Basin 18	0.11	0.38	7	11	Yes	9
Total	7.01	8.23				

Ranking of 1 represents most inflow after normalization.

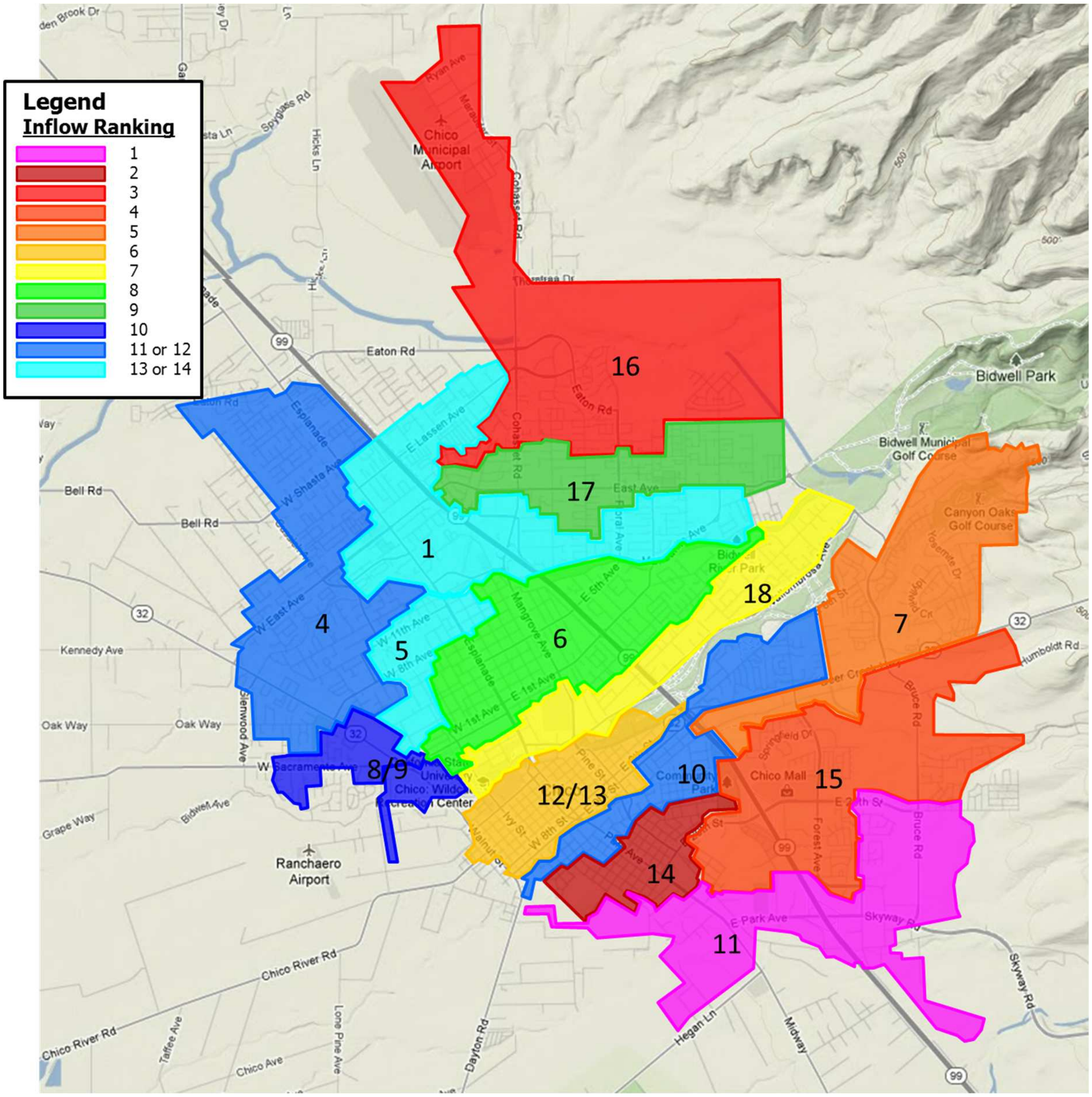


Figure 3. Inflow Temperature Map (by rank)

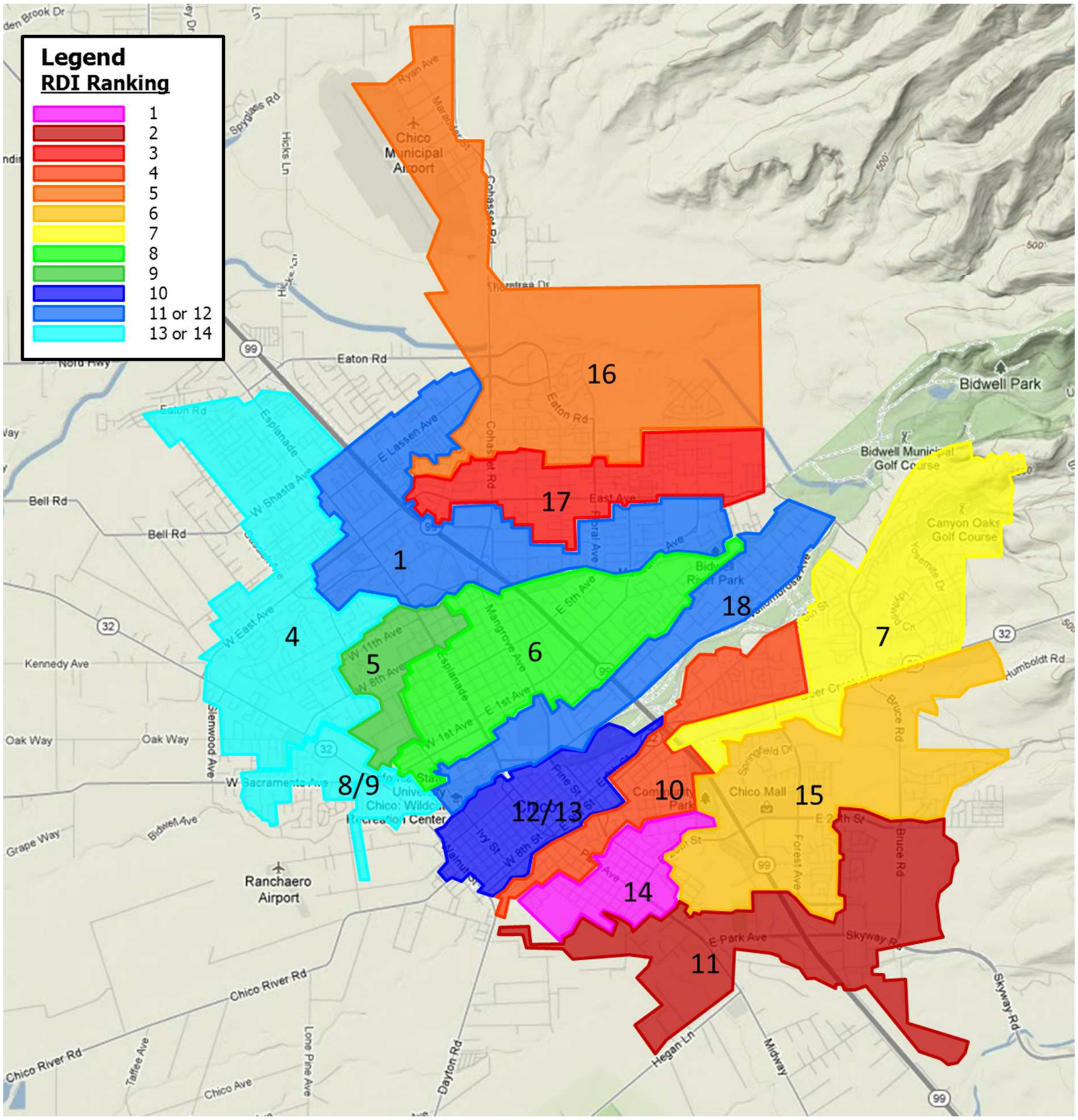


Figure 4. RDI Temperature Map (by rank)

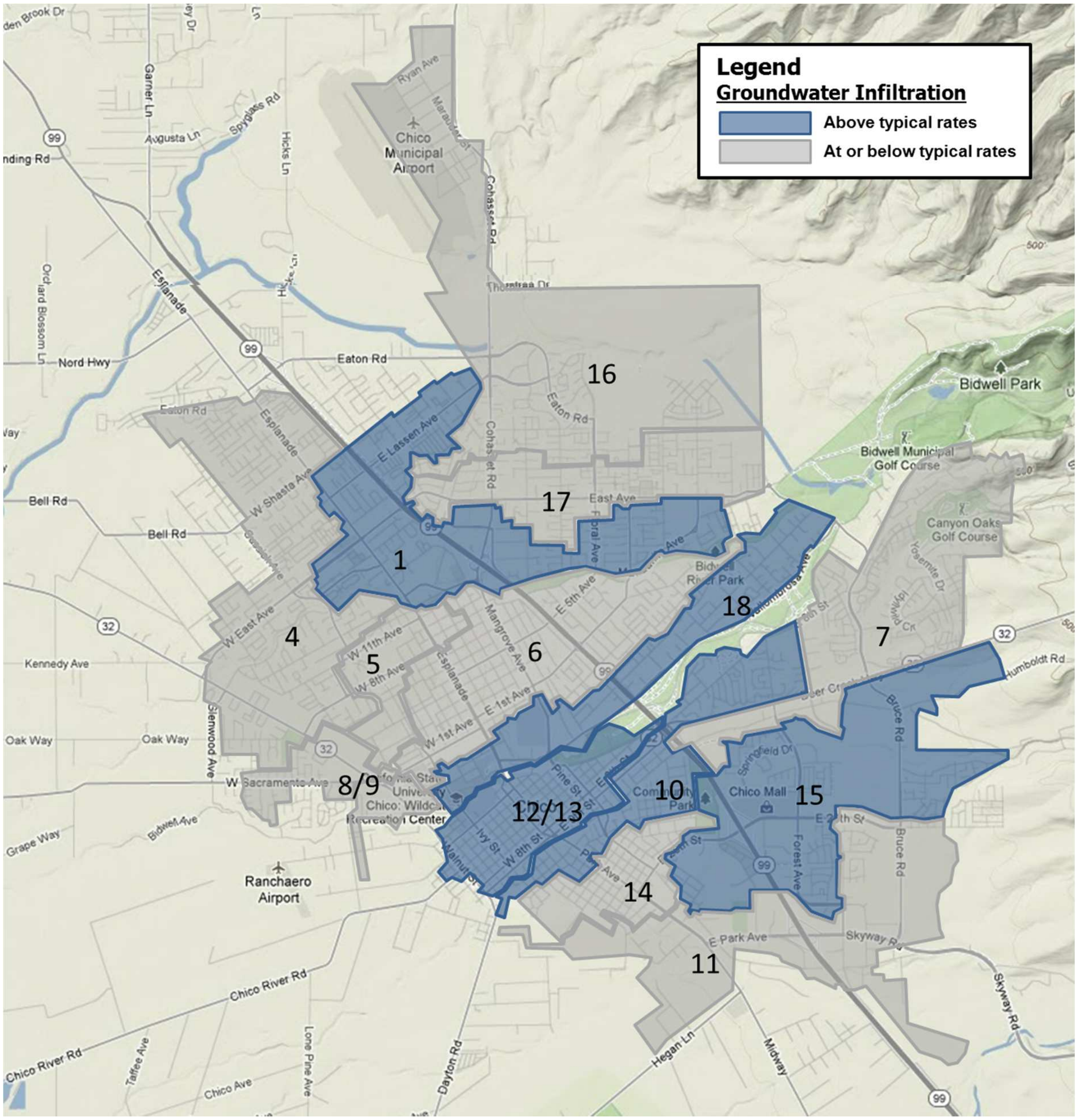


Figure 5. Basins with High Groundwater Rates

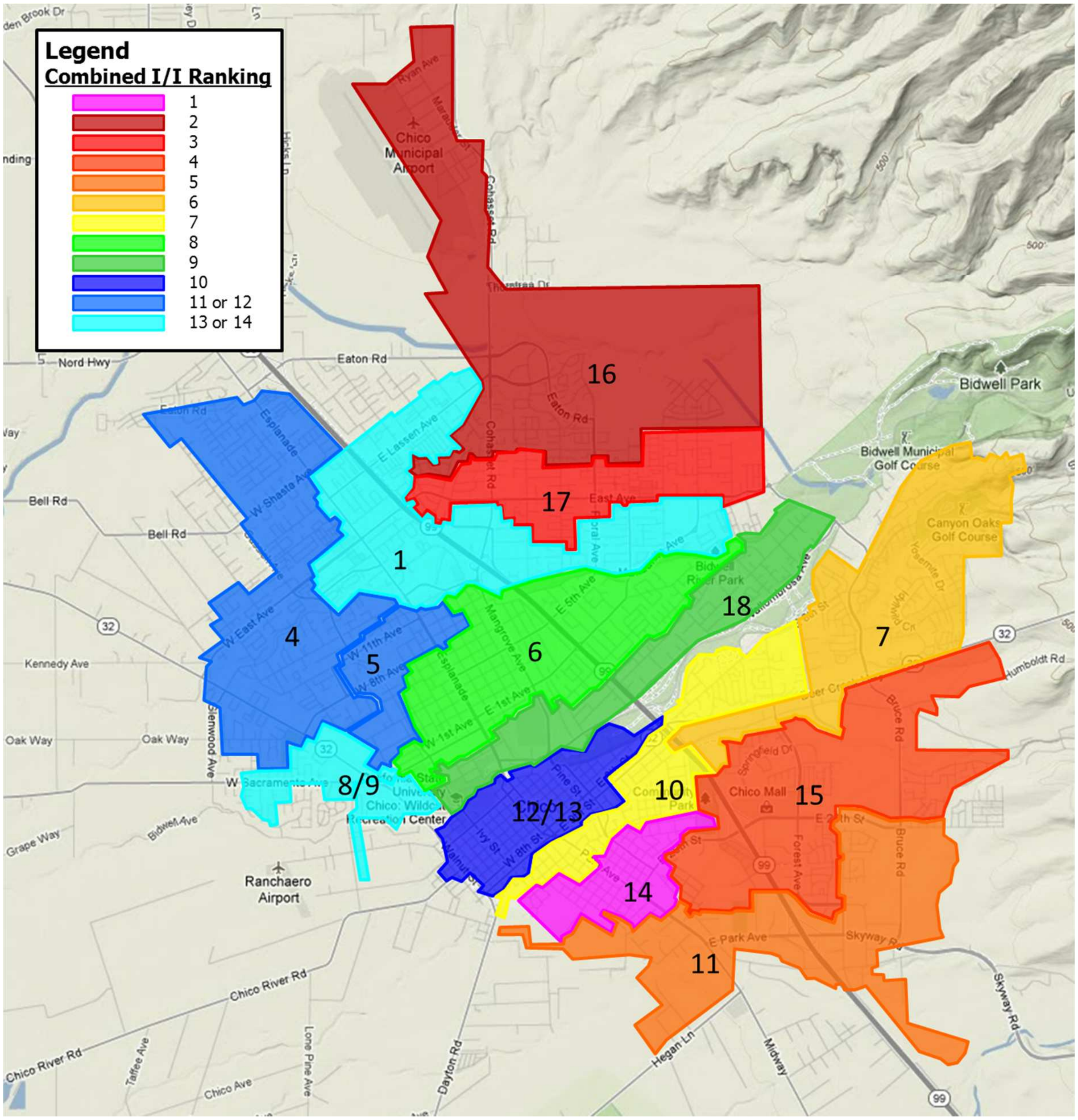


Figure 6. Combined I/I Temperature Map (by rank)

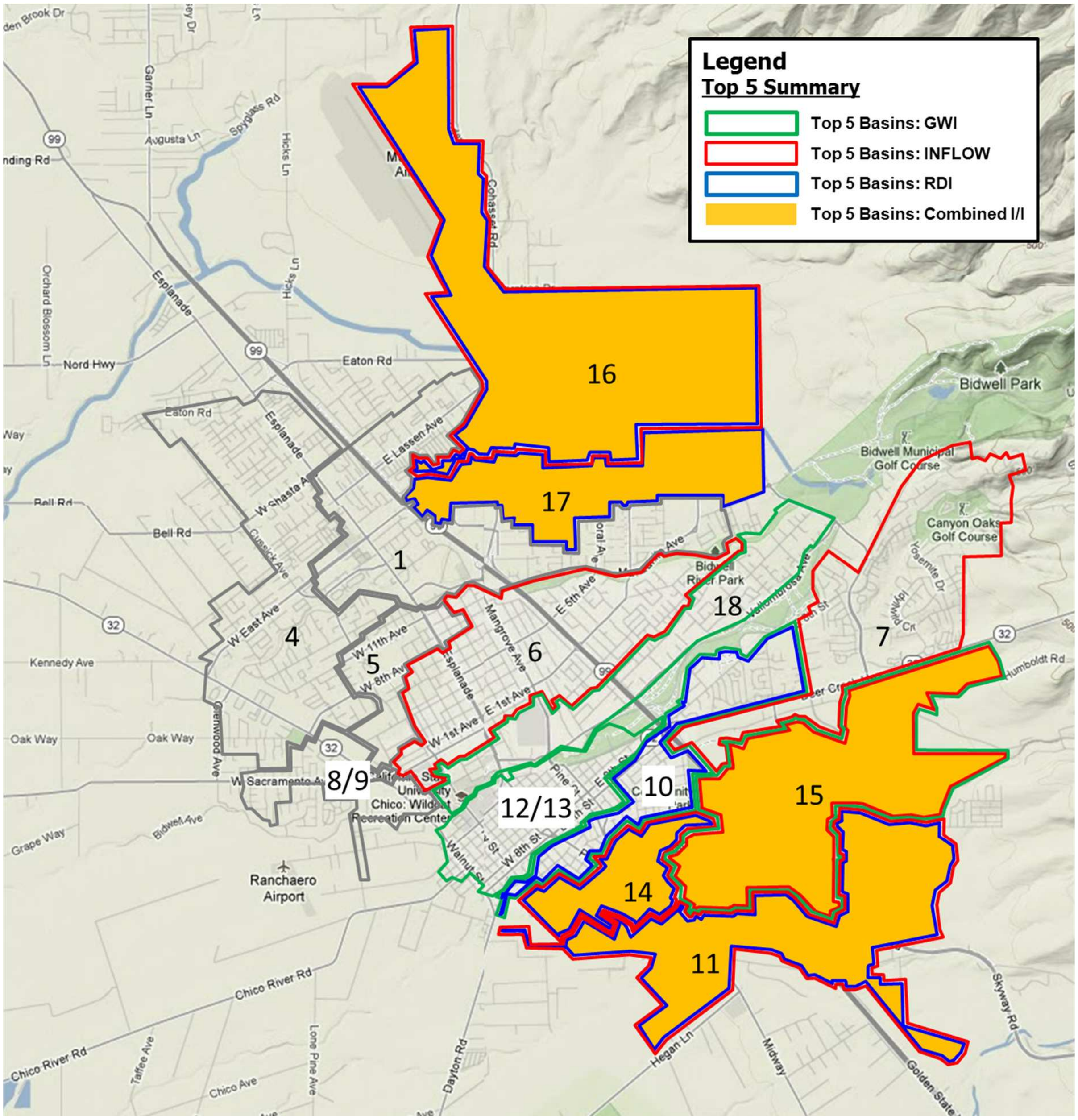


Figure 7. Temperature Map Summary: Top Five Basins, All I/I Analyses

Recommendations

V&A advises that future I/I reduction plans consider the following recommendations:

1. **Determine I/I Reduction Program:** The City should examine its I/I reduction needs to determine 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 greatest inflow problems. The highest inflow occurred in Basins 7, 11, 14, 15 and 16.
    b. If total 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 greatest infiltration problems.
        i. The highest normalized rainfall-dependent infiltration occurred in Basins 10, 11, 14, 16 and 17.
        ii. The highest groundwater infiltration occurred in Basins 1, 10, 12/13, 15 and 18.
2. **I/I Investigation Methods:** Potential I/I investigation methods include the following:
    a. Smoke testing
    b. Mini-basin flow monitoring
    c. Nighttime reconnaissance work to (1) investigate and determine direct point sources of inflow and (2) determine the areas and pipe reaches responsible for high levels of infiltration contribution.
3. **I/I Reduction Cost-Effectiveness Analysis:** The City should conduct a study to determine which is more cost-effective: (1) locating the sources of inflow and infiltration and systematically rehabilitating or replacing the faulty pipelines or (2) continued treatment of the additional rainfall-dependent I/I flow.

INTRODUCTION

Preface

The City of Chico was founded in 1860 by General John Bidwell and was incorporated in 1872. The City encompasses over 33 square miles with a population of approximately 87,500 in the incorporated area. The City of Chico operates and maintains a modern 12 million gallon per day (mgd) capacity, secondary treatment, activated sludge, wastewater treatment plant with future expandability to 15 MGD capacity. The plant operates under strict waste discharge requirements permitted by the California Water Resources Control Board. The discharge location for the treated wastewater (effluent) is the Sacramento River.

Scope and Purpose

V&A has completed sanitary sewer flow monitoring and rainfall monitoring with inflow and infiltration (I/I) analysis within the City. Flow and rainfall monitoring was performed from February 23, 2012 to May 7, 2012 at 17 open-channel flow monitoring sites and two rain gauge locations. V&A also used data from three rain gauges located throughout the City that were maintained by local weather enthusiasts.

The purpose of this study was to measure sanitary sewer flows at the flow monitoring sites, estimate available sewer capacity and conduct analyses pertaining to infiltration and inflow (I/I) occurring in the basins upstream from the flow monitoring sites.

Flow Monitoring Sites and Rain Gauges

Flow monitoring sites are the locations where the flow monitors were placed. Flow monitoring site data may include the flows of one or many drainage basins. To isolate a flow monitoring basin, an addition or subtraction of flows may be required[2]. Capacity and flow rate information is presented on a site-by-site basis. The flow monitoring and rain gauge locations are listed in Table 3 and shown in Figure 8.

[2] There is error inherent in flow monitoring. Adding and subtracting flows increases error on an additive basis. For example, if Site A has error ±10% and Site B has error ±10%, then the resulting flow when subtracting Site A from Site B would be ±20%.

Table 3.
List of Flow Monitoring Sites

Monitoring Site	Pipe Diameter (in)	Location
Site 1	30	460 W East Avenue
Site 4	36	1190 Glenwood Avenue
Site 5	15	1042 Nord Avenue
Site 6A	18	1000 W Sacramento Avenue
Site 6B	18	1000 W Sacramento Avenue
Site 7	15	150 feet from E 10th Street on Humboldt Avenue
Site 8	24	Intersection of W Sacramento Avenue and Westmont Court
Site 9	21	Intersection of Rose Avenue and Santa Clara Avenue
Site 10	18	Intersection of Pomona Avenue and Dayton Road
Site 11	33	Dayton Rd between Poppy Street and McIntosh Avenue
Site 12	14	Intersection of Hickory Street and W 5th Street
Site 13	12	Intersection of Maple Street and W 5th Street
Site 14	18	Intersection of Pomona Avenue and Dayton Road
Site 15	27	2309 Park Avenue
Site 16	33	600 El Varano Way
Site 17	24	Intersection of Tom Polk Avenue and Lynnwood Court
Site 18	10	Intersection of Warner Street and La Vista Way
Rain Gauges		
RG 1	Rosedale Elementary School	
RG 2	Parkview Elementary School	

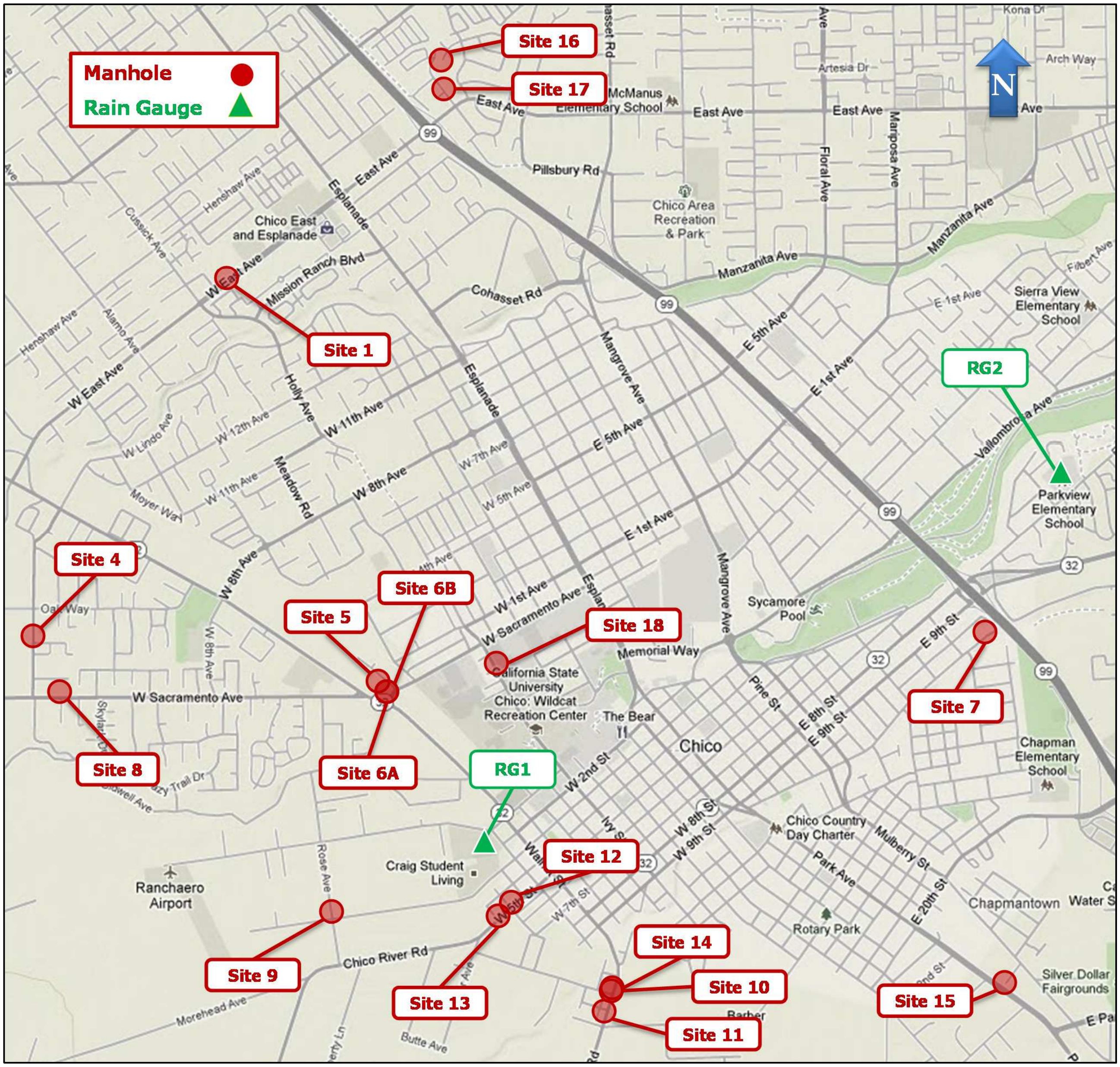


Figure 8. Flow Monitoring Site Map

Flow Monitoring Basins

Flow monitoring basins are localized areas of a sanitary sewer collection system upstream of a given location (often a flow meter), including all pipelines, inlets, and appurtenances. The basin 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 may exclude separately monitored basins upstream. I/I analysis in this report will be conducted on a basin-by-basin basis.

Within the City, there are several locations with cross-connections between trunk sewers or overflow bypass sewers to help equalize basins and prevent sanitary sewer overflows during peak rain events. However, unless the inter-basin connections are plugged, the behavior of flows may not be known with certainty. Table 4 lists the basins that were definitively isolated and thus utilized for I/I analysis. Figure 9 illustrates the basins utilized for I/I analysis.

Table 4.
List of Isolated Basins for I/I Analysis

Basin	Area (acres)	Pipe Length (IDM[3])	Basin Flow Calculation
Basin 1	1,317	218.0	$= Q_1 - (Q_{16} + Q_{17})$
Basin 4	1,475	342.6	$= Q_4 - Q_1$
Basin 5	338	54.6	$= Q_5$
Basin 6	1,142	205.7	$= Q_{6A} + Q_{6B} - Q_{18}$
Basin 7	1,218	206.0	$= Q_7$
Basin 8/9	335	86.5	$= Q_8 + Q_9 - (Q_5 + Q_{6A} + Q_{6B})$
Basin 10	602	147.3	$= Q_{10} - Q_7$
Basin 11	1,292	165.4	$= Q_{11} - Q_{15}$
Basin 12/13	553	130.6	$= Q_{12} + Q_{13}$
Basin 14	397	83.8	$= Q_{14}$
Basin 15	1,489	220.6	$= Q_{15}$
Basin 16	2,240	242.0	$= Q_{16}$
Basin 17	732	146.2	$= Q_{17}$
Basin 18	690	108.6	$= Q_{18}$
Total[4]	**13,820**	**2,357.8**	$= Q_4 + Q_8 + Q_9 + Q_{10} + Q_{11} + Q_{12} + Q_{13} + Q_{14}$

[3] Inch-diameter-mile (miles of pipeline multiplied by the diameter of the pipeline in inches). This is the industry standard unit of measurement for stating length of pipe within a sanitary drainage basin.
[4] The total flow encapsulates most of the flow that is conveyed to the treatment facility and should be generally representative of the overall Chico collection system. It is noted that the total sum per the basin flow calculation is not 100% of the flow that reaches the treatment facility.

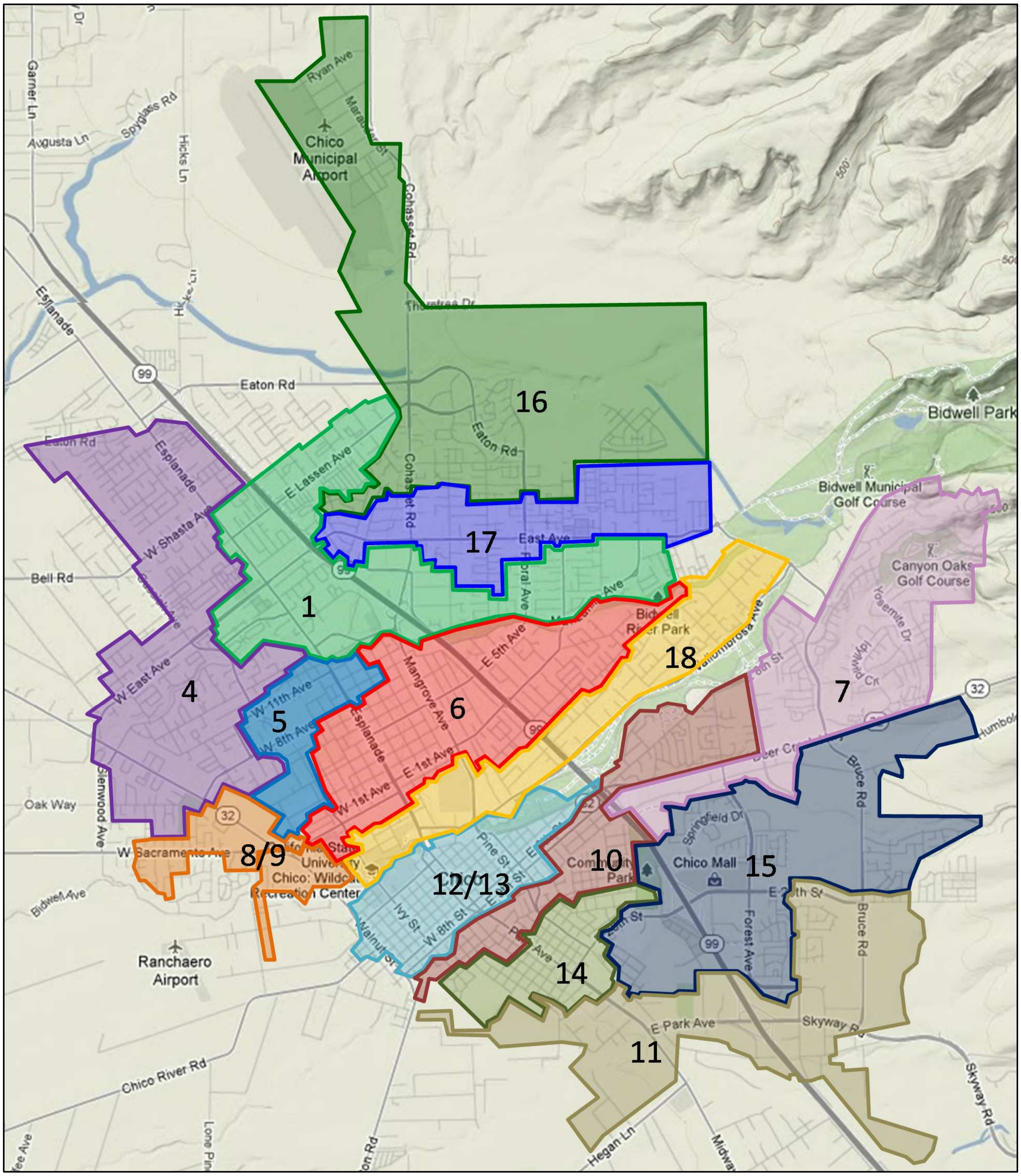


Figure 9. Basin Map for I/I Analysis

Attenuation

Flow attenuation in a sewer collection system is the natural process of the reduction of the peak flow rate through redistribution of the same volume of flow over a longer period of time. This occurs as a result of friction (resistance), internal storage and diffusion along the sewer pipes. Fluids are constantly working towards equilibrium. For example, a volume of fluid poured into a static vessel with no outside turbulence will eventually stabilize to a static state, with a smooth fluid surface without peaks and valleys. Attenuation within a sanitary sewer collection system is based upon this concept. A flow profile with a strong peak will tend to stabilize towards equilibrium, shown in Figure 10.

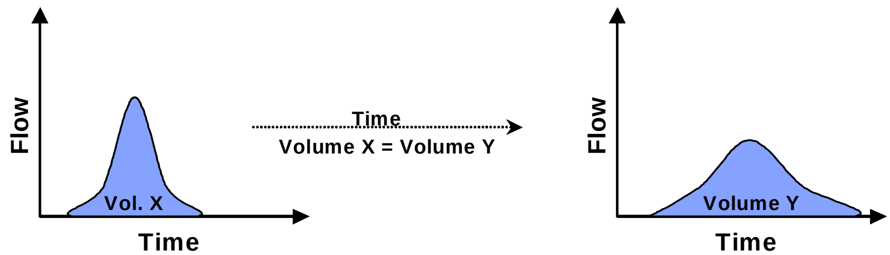


Figure 10. Attenuation Illustration

Within a sanitary sewer collection system, each individual basin will have a specific flow profile. As the flows from the basins combine within the trunk sewer lines, the peaks from each basin will (a) not necessarily coincide at the same time, and (b) due to the length and time of travel through the trunk sewers, peak flows will attenuate prior to reaching the treatment facility. The sum of the peak flows of the individual basins within a collection system will usually be greater than the peak flows observed at the treatment facility.

Due to attenuation and especially the difficulties of synching flows from basins with different travel times, when subtracting flows between basins, the accuracy in reported peak flows decreases. Per the basin equations listed in Table 4, it should be expected that the "level of confidence" of reported peak flows within basins requiring subtraction of flows would be less. Basin 1 required the subtraction of two flow meters, Basin 8/9 required the subtraction of 3 flow meters and the possibility for error at these locations is henceforth noted[5].

[5] Note: calculations made based on flows that are not "instantaneous" will not be as affected by attenuation (peak flow measurements are an instantaneous measurement whereas average daily flows are not). There is less confidence when reviewing peak instantaneous flows within a basin requiring subtraction from upstream basins. RDI calculations and Total I/I calculations are made over a longer period of time and are not subject to attenuation.

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 23.0%), 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

A mixture of Teledyne Isco 2150, Hach Sigma 910 and Marsh-McBirney Flo-Dar flow meters were installed by V&A in the sewer lines listed in Table 1. Isco 2150 and Sigma 910 meters use a pressure transducer to collect depth readings and ultrasonic Doppler sensors on the probe to determine the average fluid velocity. A Flo-Dar flow meter is a non-contact flow meter that uses radar to measure velocity and a down-looking ultrasonic sensor to measure depth.

Figure 11 shows a typical installation for a flow meter with a submerged sensor. Figure 12 shows illustrations of a typical Flo-Dar installation.

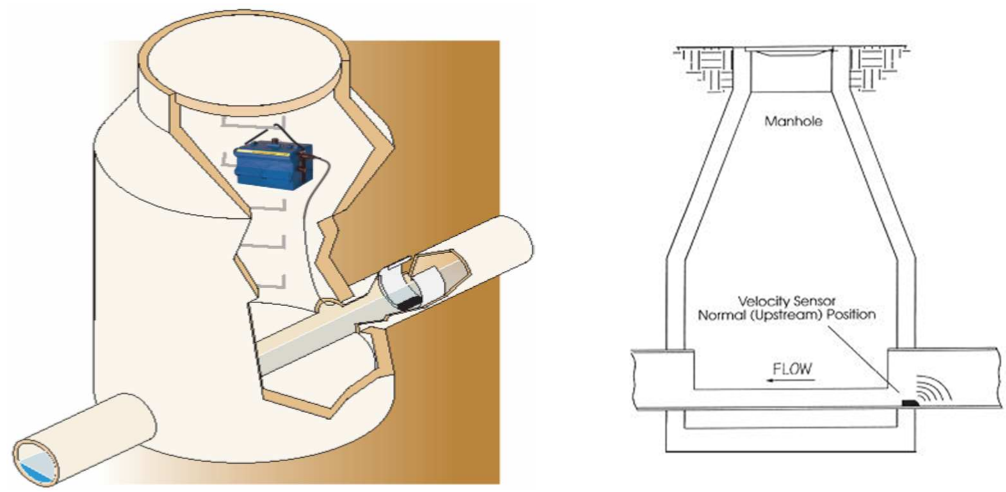


Figure 11. Typical Installation for Flow Meter with Submerged Sensor

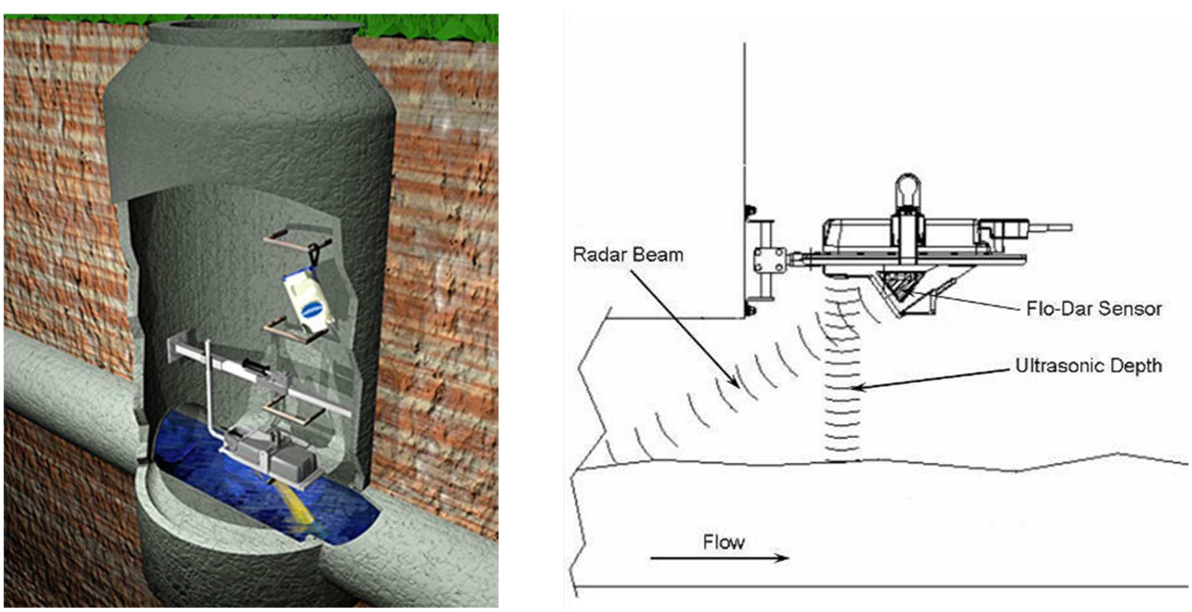


Figure 12. Typical Hach Marsh-McBirney Flo-Dar Installation

Manual level and velocity measurements were taken during installation of the flow meters and again when they were removed. These manual measurements 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.

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:

$$Q = V \cdot A$$

where Q is the volume flow rate, V is the average velocity as determined by the ultrasonic sensor, and A is the cross-sectional area of flow as determined from the depth of flow. For circular pipe:

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

where D is the pipe diameter and d is the depth of flow.

RESULTS AND ANALYSIS

Rainfall: Rain Gauge Data

V&A installed two rain gauges for the duration of the study to capture rainfall across the limits of the City boundary, illustrated in Figure 13. V&A also used data from three rain gauges located throughout the City that are maintained by local weather enthusiasts. It is noted that V&A had no control over these three rain gauges and ultimately takes no responsibility for the accuracy of the data presented for these three rain gauges. However, V&A did perform a QAQC review of the data and it appears to be valid.

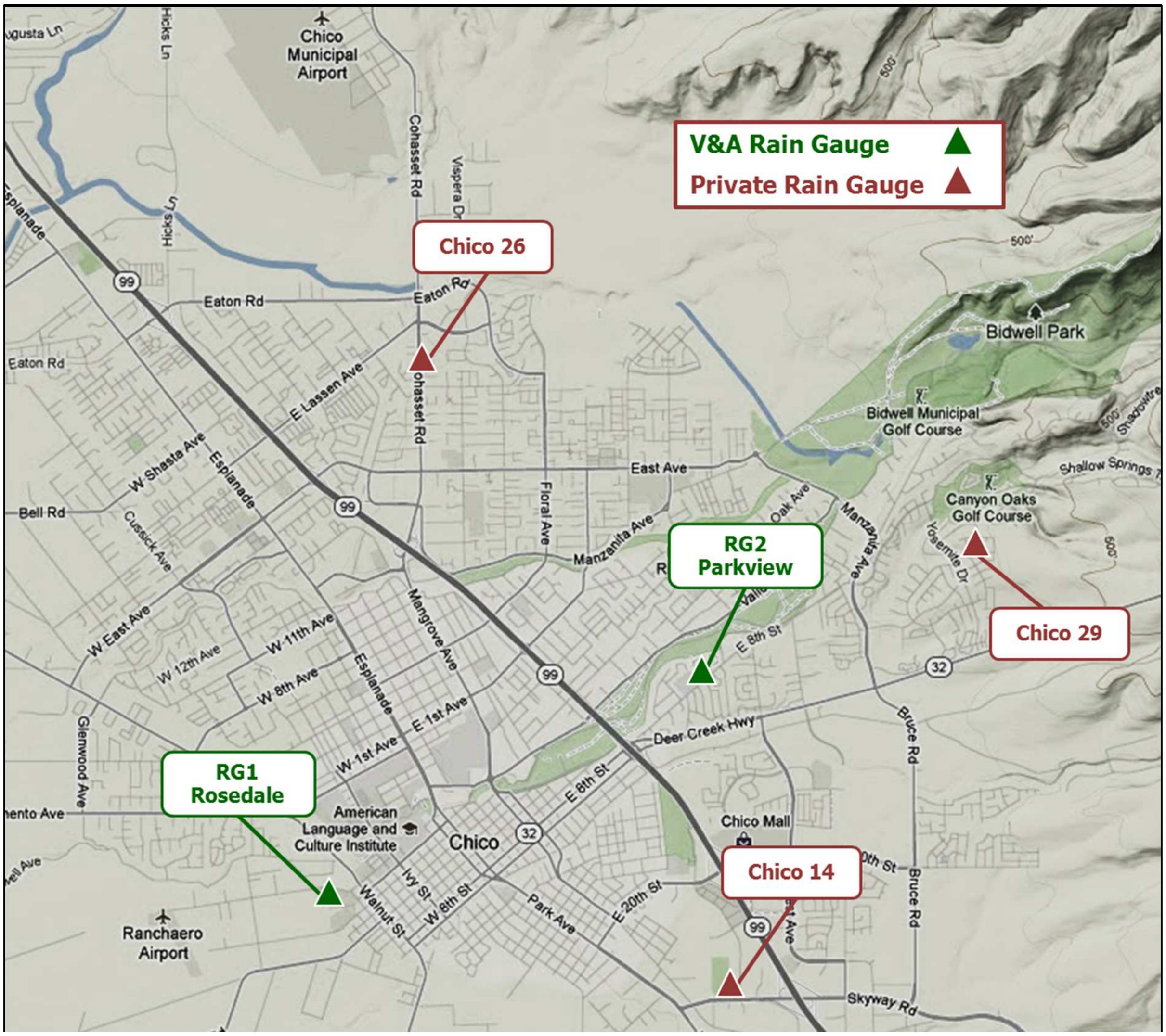


Figure 13. Rain Gauge Locations

There were three main rainfall events that occurred over the course of the flow monitoring period, summarized in Table 5. Figure 14 graphically displays the rainfall activity recorded over the flow monitoring period (an average of the five rain gauges is shown).

Table 5.
Rainfall Events Used for I/I Analysis

Rainfall Event	RG 1 (in)	RG 2 (in)	Chico 14 (in)	Chico 26 (in)	Chico 29 (in)
Event 1: March 13 – 19, 2012	2.90	2.93	2.90	2.52	3.19
Event 2: March 27 – April 1, 2012	2.64	2.43	2.40	2.11	2.66
Event 3: April 10 – 14, 2012	1.49	1.42	1.46	1.14	1.53
Total over Monitoring Period	*8.50*	*8.22*	*8.18*	*7.13*	*9.07*

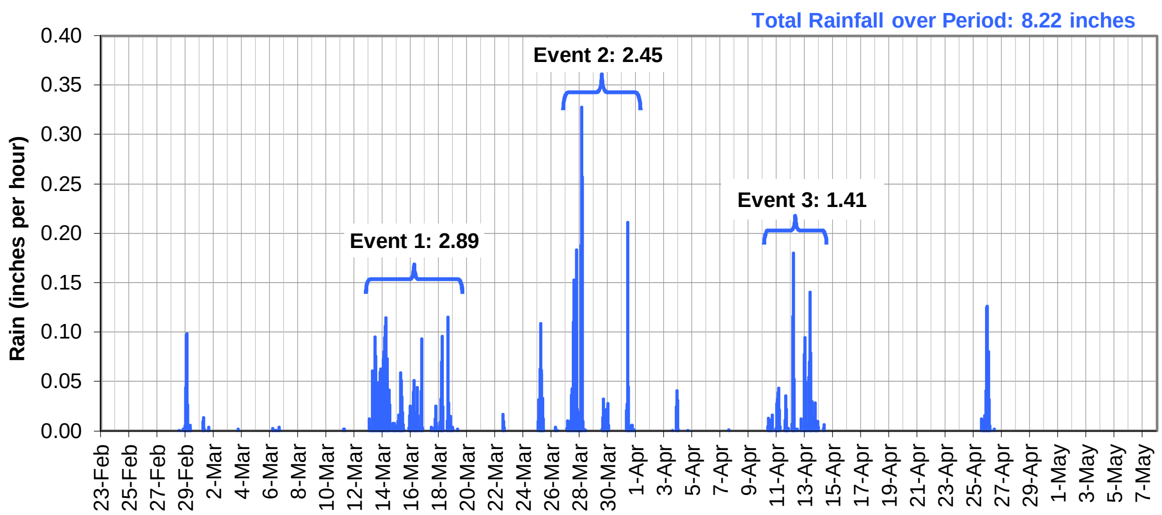


Figure 14. Rainfall Activity over Flow Monitoring Period

Figure 15 shows the rain accumulation plot of the period rainfall, as well as the historical average rainfall[6] in the City during this project duration. Rainfall totals for the RG1, RG2, Chico14, Chico26 and Chico29 rain gauges were 120%, 116%, 116%, 101% and 128% above the historical normal levels during this time period, respectively.

[6] Historical data taken from the WRCC (Station 41715 in Chico): http://www.wrcc.dri.edu/summary/climsmnca.html

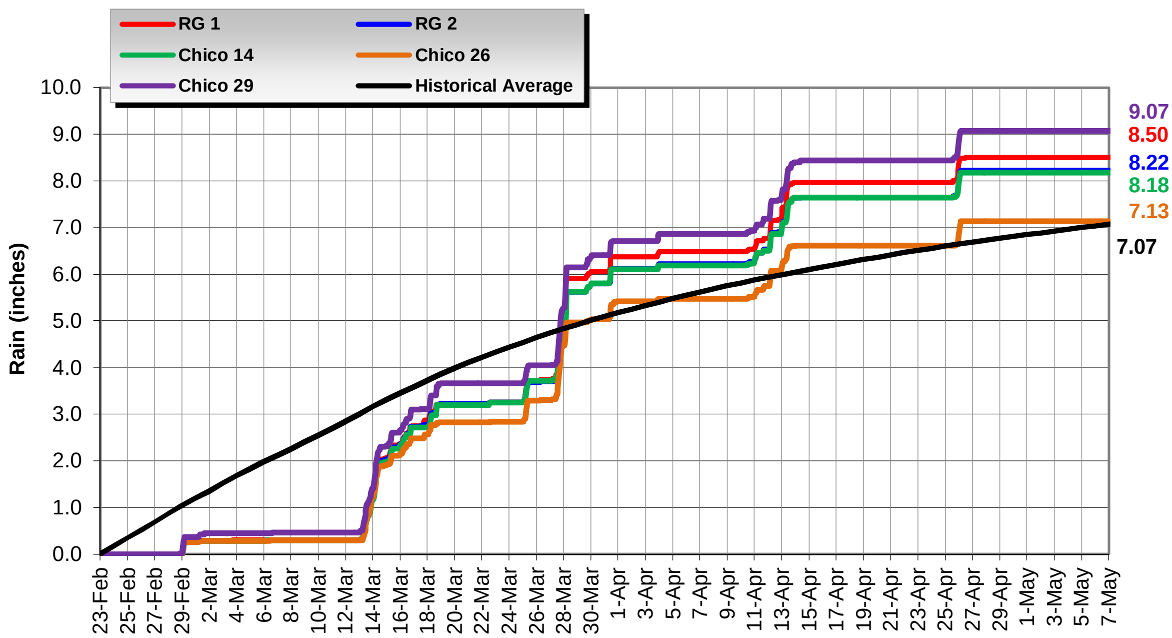


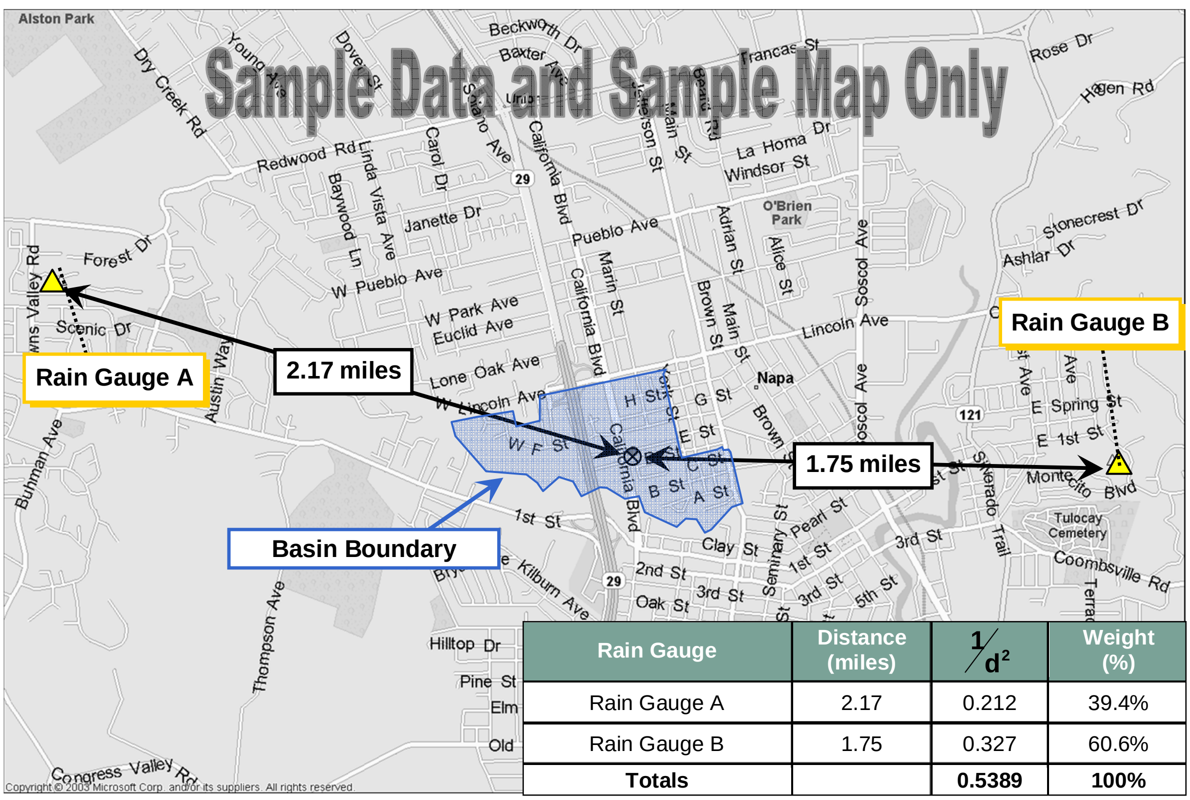
Figure 15. Rainfall Accumulation Plot

Rainfall: Rain Gauge Triangulation

The rainfall affecting the sanitary sewer collection system basins must be calculated based on the proximity to the rain gauge locations. The mean precipitation for the sanitary sewer collection system was calculated by taking data from five local rain gauges and using the Inverse Distance Weighting (IDW) method. The IDW is an interpolation method that assumes the influence of each rain gauge location diminishes with distance. The center of a sanitary sewer collection system was identified and a weighted average was taken of the precipitation data from nearby rain gauge locations. The IDW function is as follows:

$$weight(d) = \frac{1/d^{p}}{\sum 1/d^{p}},$$ where: d = distance p = power ($p > 0$)

The value of *p* is user defined. The most common choice for hydrological studies of watershed areas is *p* = 2. Figure 16 illustrate the IDW method (sample data). The rain gauge distribution as calculated for each flow monitoring site is shown in Table 6.



Rain Gauge	Distance (miles)	$1/d^2$	Weight (%)
Rain Gauge A	2.17	0.212	39.4%
Rain Gauge B	1.75	0.327	60.6%
Totals		**0.5389**	**100%**

Figure 16. Rainfall Inverse Distance Weighting Method

Table 6.
Rain Gauge Distribution by Basin

Monitoring Site	RG 1	RG 2	Chico 14	Chico 26	Chico 29
Basin 1	2.1%	4.8%	0.0%	93.1%	0.0%
Basin 4	7.4%	10.2%	0.0%	82.4%	0.0%
Basin 5	74.6%	25.4%	0.0%	0.0%	0.0%
Basin 6 (A+B)	30.7%	69.3%	0.0%	0.0%	0.0%
Basin 7	1.0%	6.5%	0.0%	0.0%	92.5%
Basin 8	41.9%	58.1%	0.0%	0.0%	0.0%
Basin 9	33.9%	66.1%	0.0%	0.0%	0.0%
Basin 10	1.1%	98.9%	0.0%	0.0%	0.0%
Basin 11	3.8%	11.5%	84.8%	0.0%	0.0%
Basin 12/13	1.4%	98.6%	0.0%	0.0%	0.0%
Basin 14	1.4%	98.6%	0.0%	0.0%	0.0%
Basin 15	4.5%	16.1%	79.4%	0.0%	0.0%
Basin 16	6.7%	46.2%	47.1%	0.0%	0.0%
Basin 17	1.7%	3.5%	0.0%	94.8%	0.0%
Basin 18	4.0%	10.3%	0.0%	85.7%	0.0%

Rainfall: Storm 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[7]. Storm 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 National Oceanic and Atmospheric Administration (NOAA) for all areas within the continental United States. For example, the NOAA Rainfall Frequency Atlas[8] classifies a 10-year, 24-hour storm event in at the Latitude/Longitude coordinates of the Rain Gauge 1 location as 4.24 inches (Figure 17). This means that in any given year, at this specific location, there is a 10% chance that 4.24 inches of rain will fall in any 24-hour period.

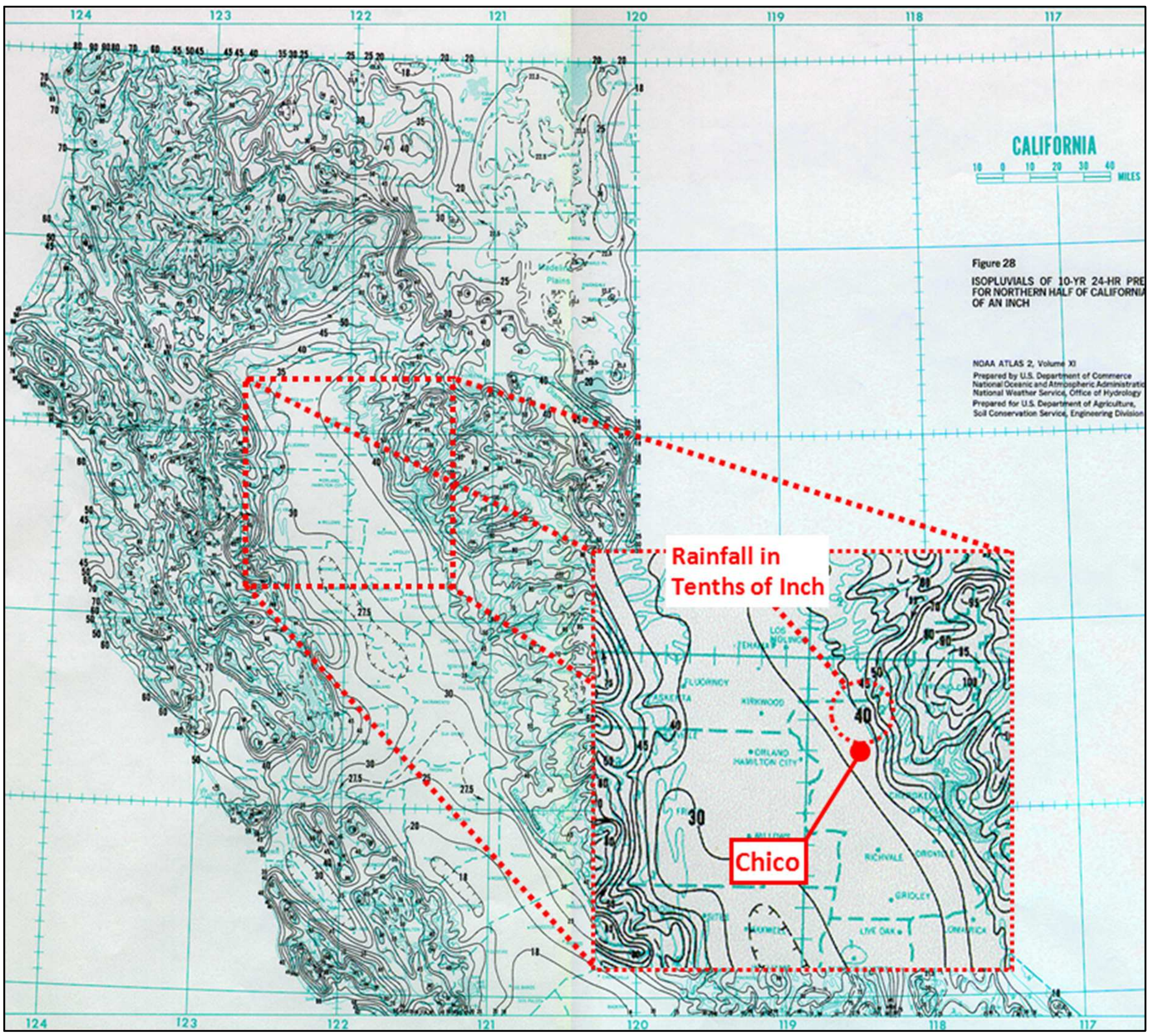


Figure 17. NOAA Northern California Rainfall Frequency Map

[7] Sanitary sewers are often designed to withstand I/I contribution to sanitary flows for specific-sized "design" storm events.

[8] NOAA Western U.S. Precipitation Frequency Maps Atlas 2, 1973: http://www.wrcc.dri.edu/pcpnfreq.html

From the NOAA frequency maps, for a specific latitude and longitude, the rainfall densities for period durations ranging from 15 minutes to 60 days are known for rain events ranging from 1-year to 100-year intensities. These are plotted to develop a rain event frequency map specific to each rainfall monitoring site. Superimposing the peak measured densities for Events 1, 2 and 3 on the rain event frequency plot determines the classification of the storm event, shown in Figure 18 for RG 1, Figure 19 for RG 1, Figure 20 for Chico14, Figure 21 for Chico26, and Figure 22 for Chico29.

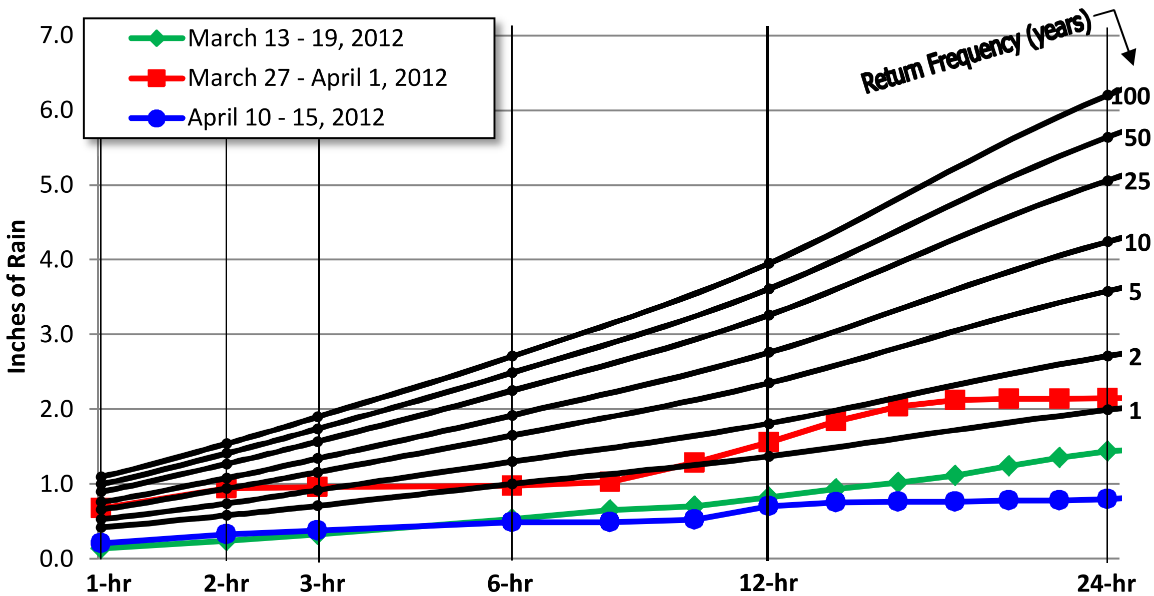


Figure 18. Storm Event Classification – RG 1

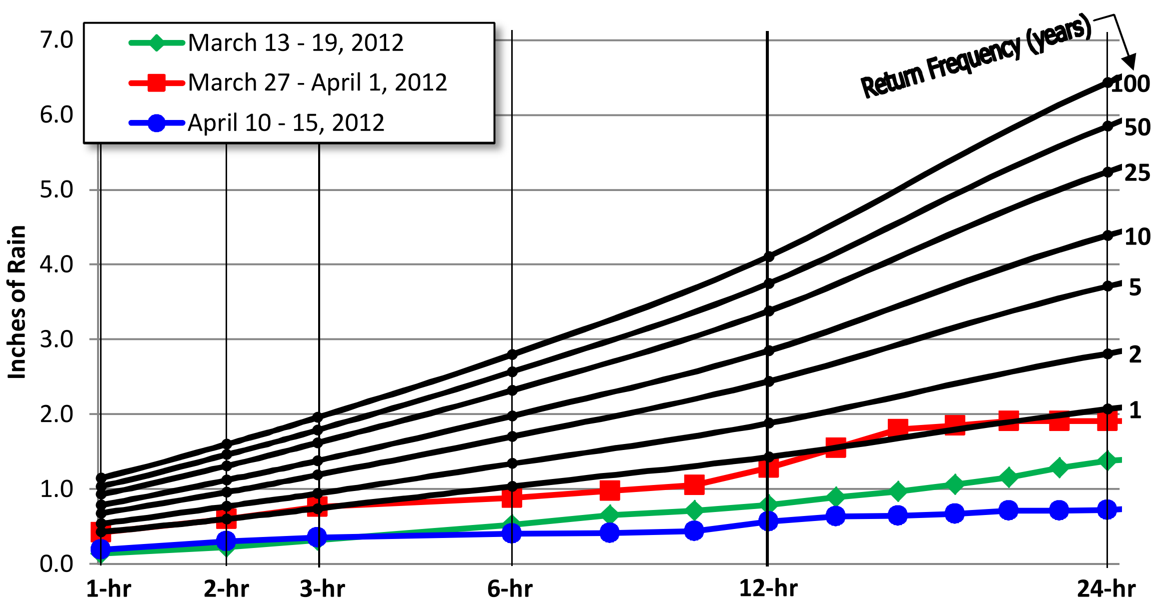


Figure 19. Storm Event Classification – RG 2

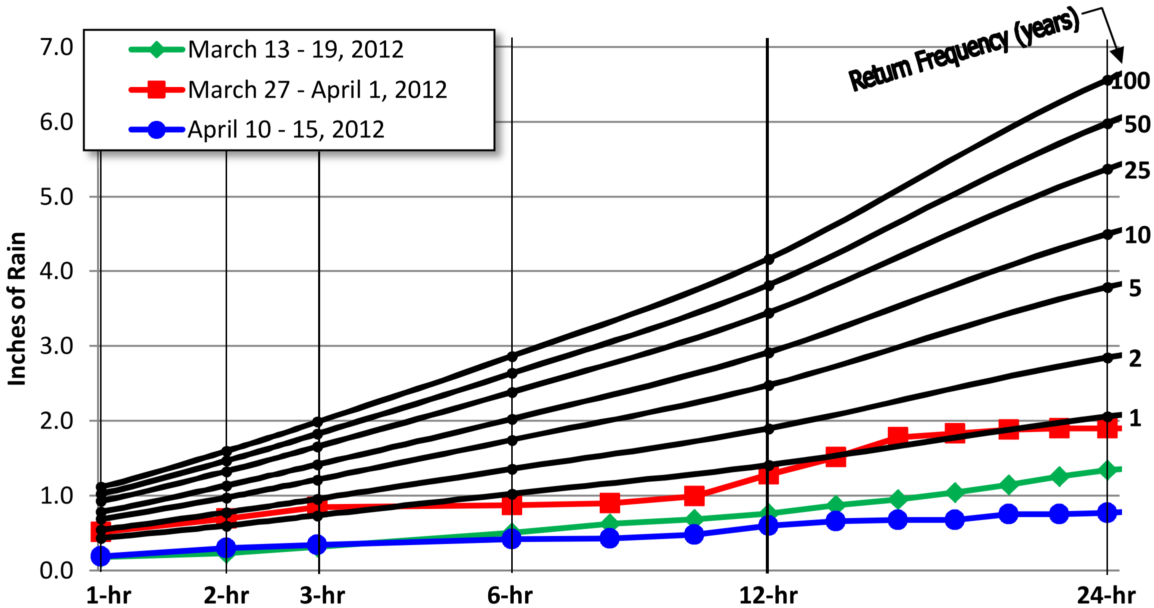


Figure 20. Storm Event Classification – Chico14

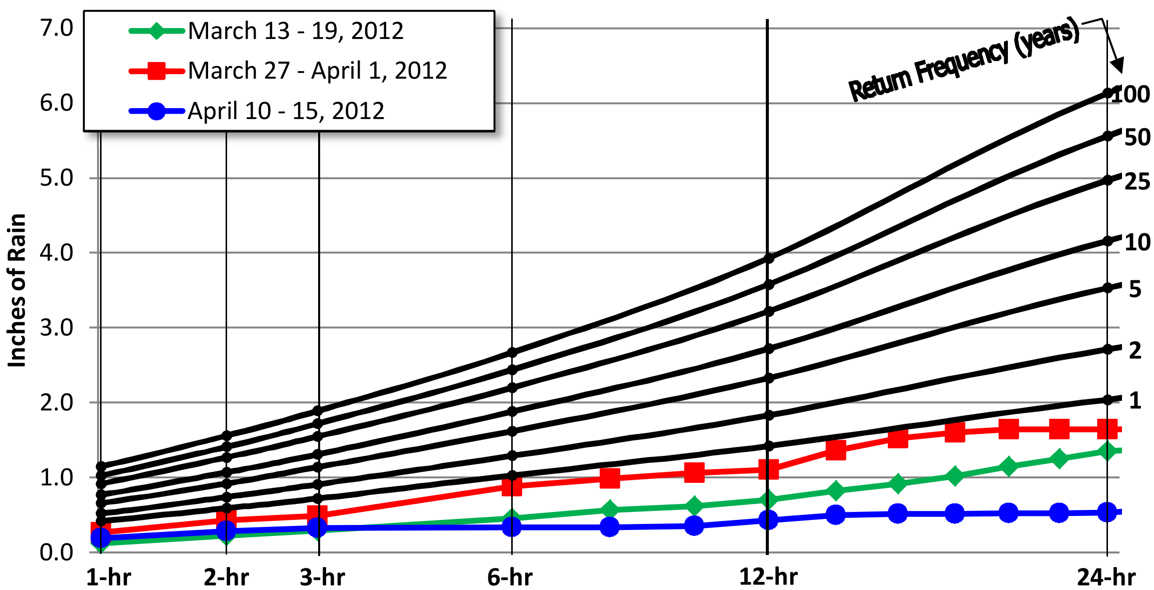


Figure 21. Storm Event Classification – Chico26

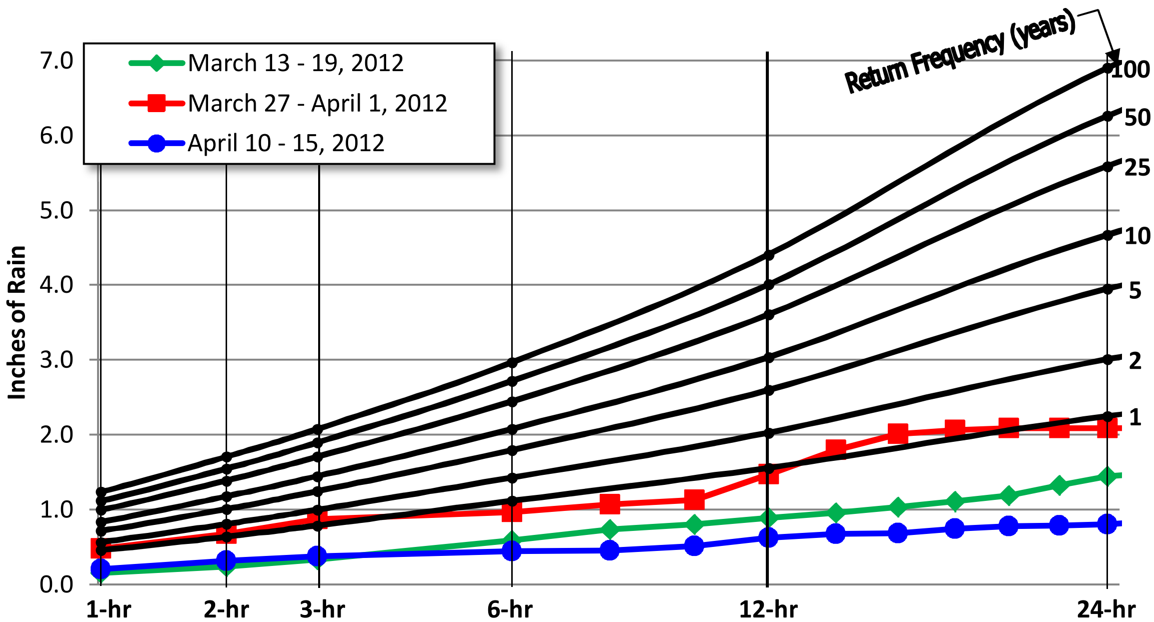


Figure 22. Storm Event Classification – Chico29

Table 5 summarizes the classification of the rainfall events that occurred during the flow monitoring period.

Table 7.
Classification of Rainfall Events

Rainfall Event	RG 1	RG 2	Chico 14	Chico 26	Chico 29
Event1: January 19 – 23, 2012	< 1 year	< 1 year	< 1 year	< 1 year	< 1 year
Event 2: March 13 – 18, 2012	1 year, 24 hour	1 year, 18 hour	1 year, 18 hour	< 1 year	1 year, 18 hour
Event 3: March 24 – 26, 2012	< 1 year	< 1 year	< 1 year	< 1 year	< 1 year

Flow Monitoring: Average Dry Weather Flows

Weekday and weekend flow patterns differ and must be separated when determining average dry weather flows. Days least affected by rainfall were used to estimate weekend and weekday average flows. Table 8 lists the average dry weather flow (ADWF) recorded during this study for the flow monitoring sites. Figure 23 shows a schematic diagram of the average dry weather flows and flow levels. Detailed graphs of the flow monitoring data on a site-by-site basis are included in *Appendix A*.

Table 8.
Dry Weather Flow Summary

Monitoring Site	Weekday ADWF (mgd)	Weekend ADWF (mgd)	Overall ADWF (mgd)	Weekend/ Weekday Ratio
Site 1	1.33	1.36	1.34	1.02
Site 4	2.05	2.10	2.06	1.03
Site 5	0.21	0.22	0.21	1.07
Site 6A	0.57	0.50	0.55	0.87
Site 6B	0.47	0.47	0.47	1.01
Site 7	0.50	0.51	0.51	1.02
Site 8	0.51	0.50	0.50	0.98
Site 9	1.03	1.00	1.02	0.97
Site 10	0.90	0.90	0.90	1.00
Site 11	1.46	1.38	1.43	0.95
Site 12	0.23	0.22	0.23	0.94
Site 13	0.46	0.43	0.45	0.93
Site 14	0.30	0.32	0.30	1.06
Site 15	1.06	1.03	1.05	0.97
Site 16	0.50	0.51	0.50	1.03
Site 17	0.30	0.33	0.31	1.08
Site 18	0.12	0.11	0.11	0.92

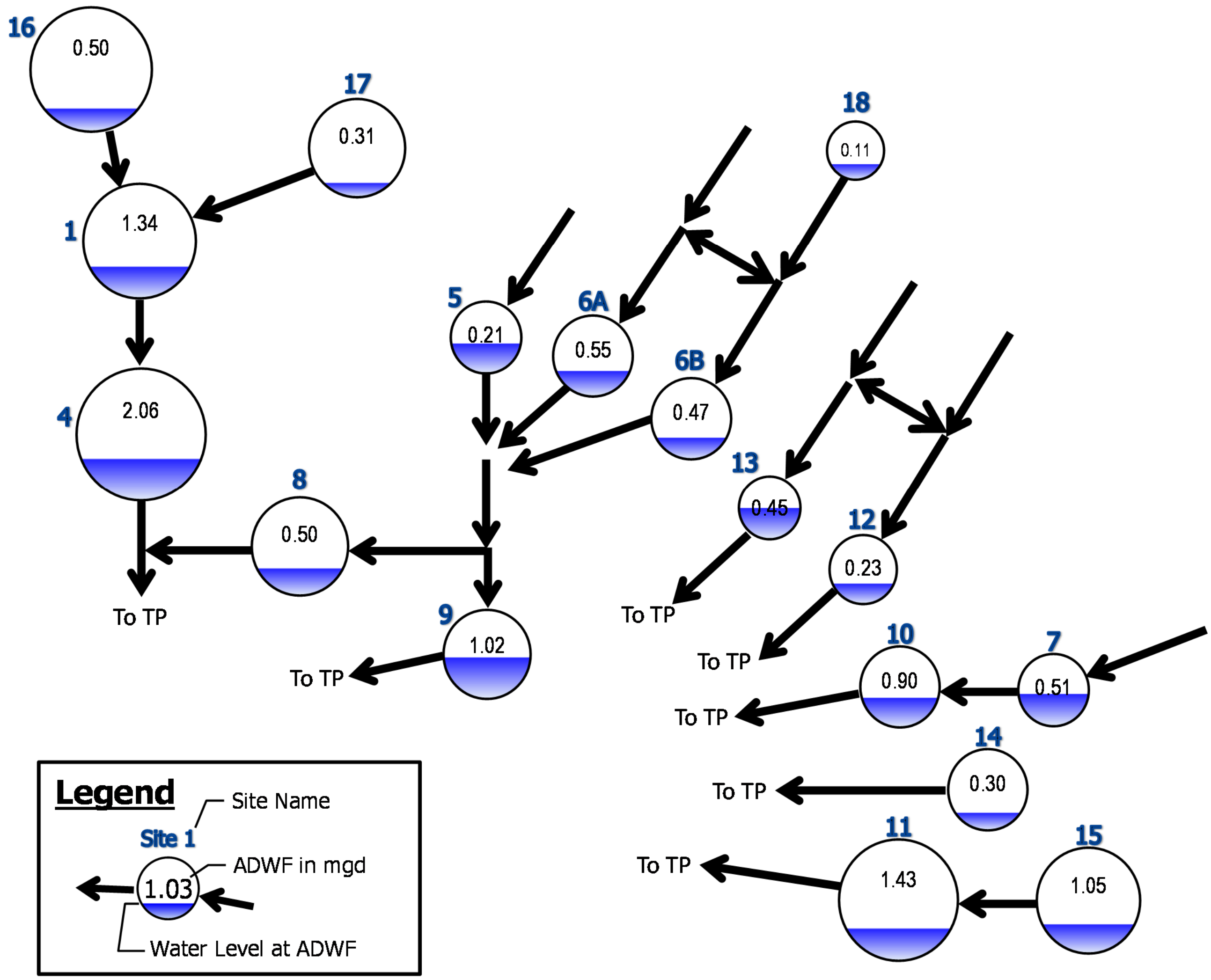


Figure 23. Average Dry Weather Flow Schematic

Flow Monitoring: 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 understanding the capacity and hydraulic performance within a collection 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. 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 *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.

Table 9 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 9.
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	1.34	3.74	2.80	30	12.67	0.42	-
Site 4	2.06	5.18	2.51	36	17.79	0.49	-
Site 5	0.21	0.41	1.93	15	8.30	0.55	-
Site 6A	0.55	1.48	2.70	18	7.89	0.44	-
Site 6B	0.47	1.32	2.82	18	8.32	0.46	-
Site 7	0.51	1.64	3.23	15	11.69	0.78	-
Site 8	0.50	1.30	2.57	24	10.37	0.43	-
Site 9	1.02	1.64	1.61	21	13.83	0.66	-
Site 10	0.90	2.25	2.49	18	10.07	0.56	-
Site 11	1.43	3.63	2.53	33	14.14	0.43	-
Site 12	0.23	0.51	2.27	14	6.24	0.45	-
Site 13	0.45	0.89	1.97	12	8.74	0.73	-
Site 14	0.30	0.88	2.88	18	6.06	0.34	-
Site 15	1.05	2.49	2.36	24	11.57	0.48	-
Site 16	0.50	2.55	5.08	33	12.60	0.38	-
Site 17	0.31	0.94	3.05	23.5	5.76	0.25	-
Site 18	0.11	0.49	4.30	10	5.16	0.52	-

The following capacity analysis results are noted:

- **Peaking Factor:** Sites 7, 16, 17 and 18 had peaking factors that exceeded typical design threshold limits for peak flow to average dry weather flow ratio.
- ***d*/*D* Ratio:** Only Site 7 had a *d*/*D* ratios that exceeded common threshold value for *d*/*D* ratio. None of the 17 sites reached a surcharged condition during the study.

Figure 24 and Figure 25 show bar graphs summarizing the site by site peaking factors and d/D ratios, respectively. Figure 26 shows a schematic diagram of the peak measured flows with peak flow levels.

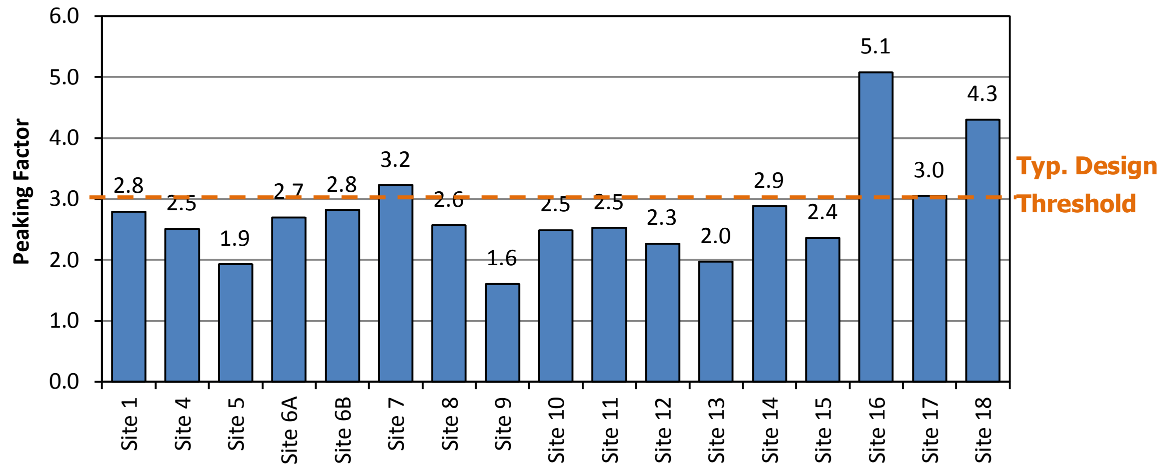


Figure 24. Capacity Summary Bar Graphs: Peaking Factors

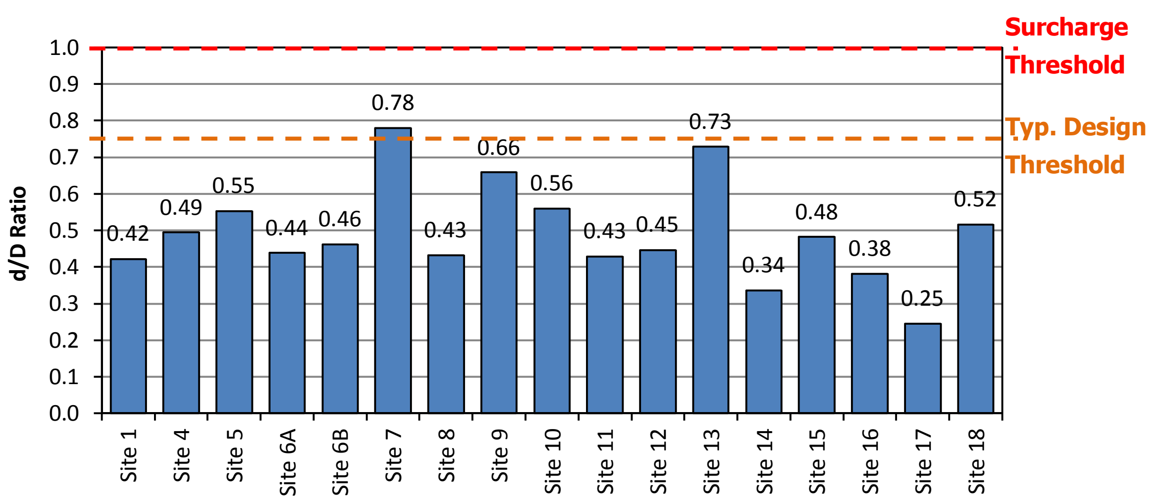


Figure 25. Capacity Summary Bar Graphs: d/D Ratios

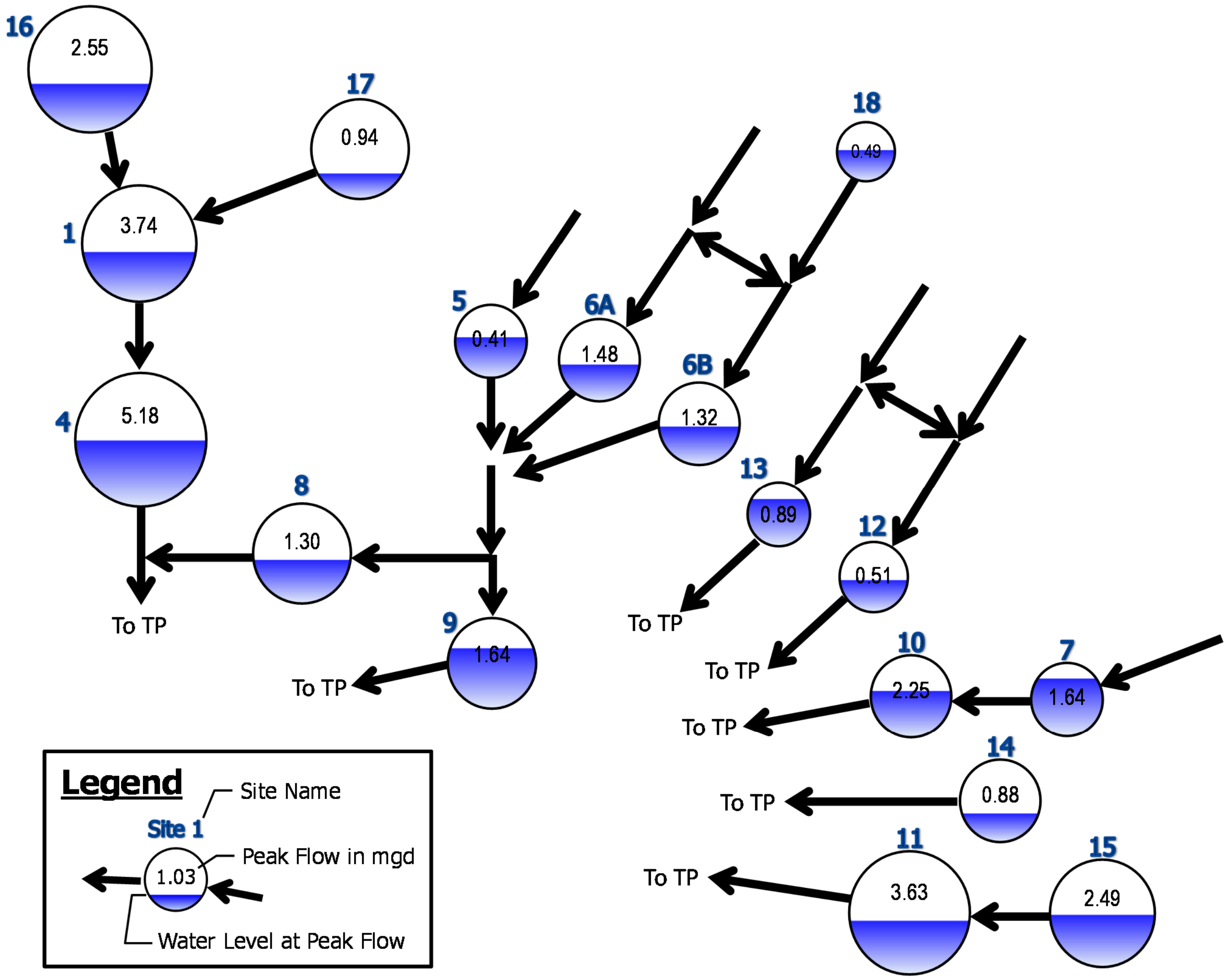


Figure 26. Peak Measured Flow Schematic

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:

Inflow Definition

- **Definition:** 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.
- **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.
- **Graphical Identification:** Inflow is usually recognized graphically by large-magnitude, short-duration spikes immediately following a rain event.

Infiltration Definition

- **Definition:** 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.
- **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.
- **Graphical Identification:** 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.

Figure 27 shows sample graphs indicating the typical graphical response patterns for inflow and infiltration.

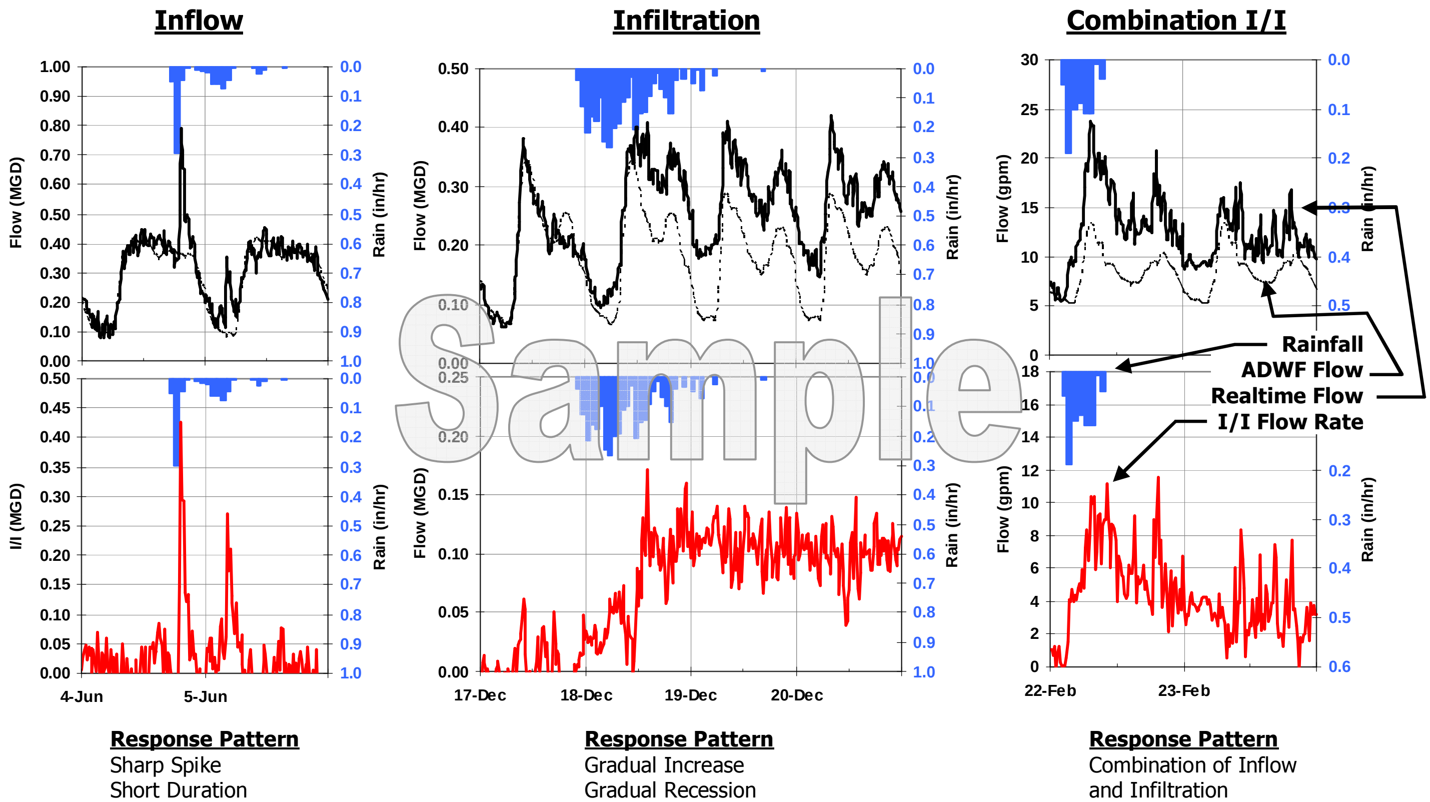


Figure 27. Inflow and Infiltration: Graphical Response Patterns

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.

Figure 28 illustrates the possible sources and components of I/I.

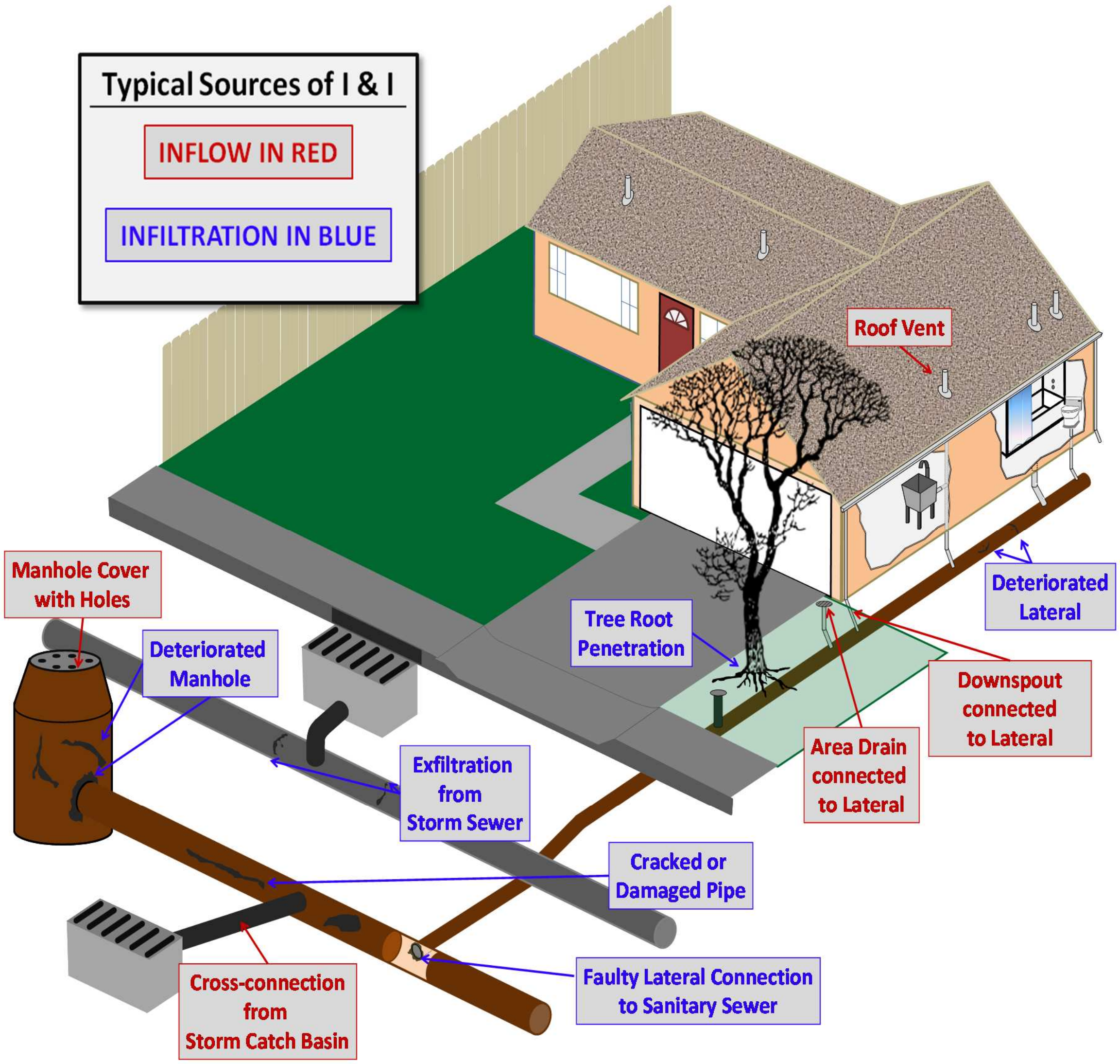


Figure 28. Typical Sources of Infiltration and Inflow

Inflow / Infiltration: Analysis Methods

After differentiating I/I flows from ADWF flows, various calculations can be made to: (1) determine which I/I component (inflow or infiltration) is more prevalent at a particular site, and (2) to compare the relative magnitude of the I/I components between drainage basins and between storm events. Some analysis methods are shown as follows:

Inflow Indicators

Peak I/I Flow Rate: Inflow is characterized by sharp, direct spikes occurring during a rainfall event. Peak I/I rates are used for inflow analysis[9]. After determining the peak I/I flow rate for a given site, and for a given storm event, there are three ways to *normalize* the peak I/I rates for an "apples-to-apples" comparison amongst the different drainage basins:

- **Peak I/I Flow Rate per IDM:** Peak measured I/I rate divided by length of pipe within the drainage basin, expressed in units of inch-diameter-mile (IDM) (miles of pipeline multiplied by the diameter of the pipeline in inches). Final units are gallons per day (gpd) per IDM.
- **Peak I/I Flow Rate per Acre:** Peak measured I/I rate divided by the geographic area of the upstream basin in acres. Units are gpd per acre.
- **Peak I/I Flow Rate to ADWF Ratio:** Peak measured I/I rate divided by average dry weather flow (ADWF). This is a ratio and is expressed without units.

Infiltration Indicators

Dry Weather Groundwater Infiltration: GWI analysis is conducted by looking at minimum dry weather flow to average dry weather flow ratios and comparing them to established standards to quantify the rate of excess groundwater infiltration. As with inflow, GWI infiltration rates can be normalized by means of pipe length (IDM), basin area (acres), and dry weather flow rates (ADWF). These methods are discussed in further detail in the *Groundwater Analysis* section later in this report.

Rainfall-Dependent Infiltration: Infiltration occurring after the conclusion of a storm event is classified as rainfall-dependent infiltration. Analysis is conducted by looking at the infiltration rates at set periods after the conclusion of a storm event. Depending on the system and the time required for flows to return to ADWF levels, different set periods may be examined to determine the basins with the greatest or most sustained rainfall-dependent infiltration rates.

Combined I/I Indicators

Total Infiltration: The total inflow and infiltration is measured in gallons per site and per storm event. Because it is based on total I/I volume, it is an indicator of combined inflow and infiltration and is used to identify the overall volumetric influence of I/I within the monitoring basin. As with inflow, pipe length, basin area, and dry weather flow are used to normalize combined I/I for basin comparison:

[9] I/I flow rate is the realtime flow less the estimated average dry weather flow rate. It is an estimate of flows attributable to rainfall. By using peak measured flow rates (inclusive of ADWF), the I/I flow rate would be skewed higher or lower depending on whether the storm event I/I response occurs during low flow or high flow hours.

- **Combined I/I Flow Rate per IDM:** Total infiltration (gallons) divided by length of pipe (IDM) and divided by storm event rainfall (inches of rain). Final units are gallons per day (gpd) per IDM per inch-rain.
- **R-Value:** Total infiltration (gallons) divided by the total rainfall that fell within the acreage of a particular basin (gallons of rainfall). This is expressed as a percentage and is explained as "the percent of rain that falls that enters the sanitary sewer collection system." Systems with R-values less than 5%[10] are often considered to be performing well.
- **Combined I/I Flow Rate per ADWF:** Total infiltration (gallons) divided by the ADWF (gpd) and divided by storm event rainfall (inches of rain). Final units are million gallons per MGD of ADWF per inch-rain.

Realtime flows were plotted against ADWF flows to analyze the I/I response to rainfall events. Figure 29 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*.

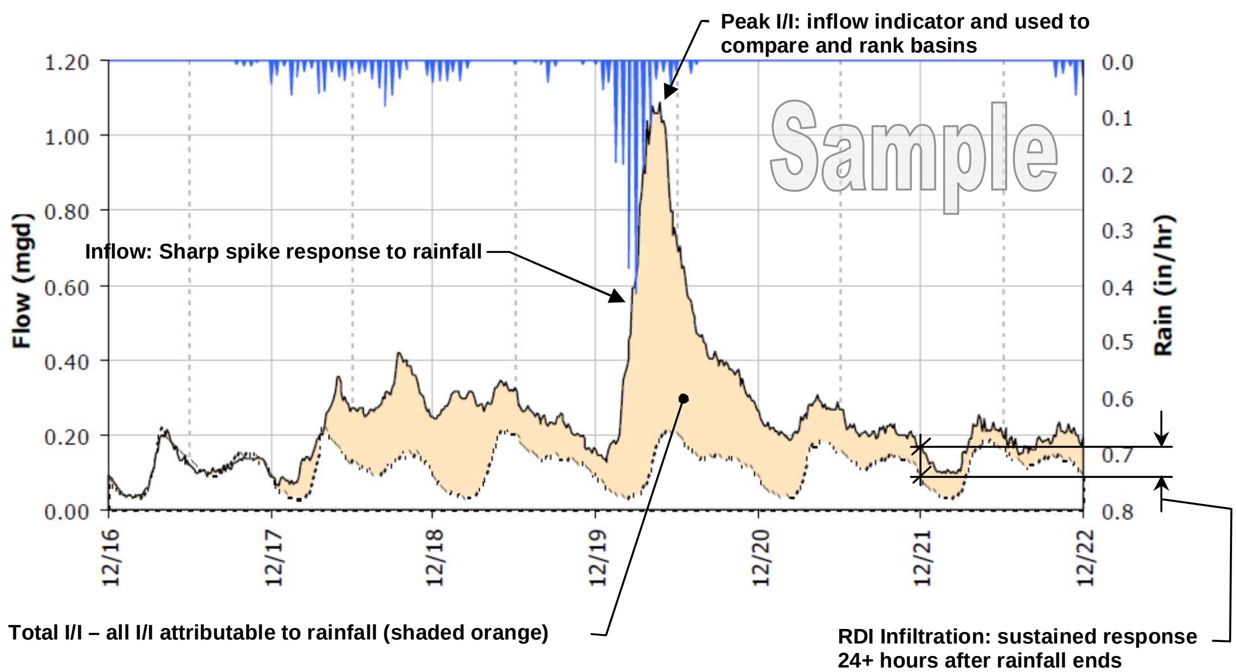


Figure 29. Sample Infiltration and Inflow Isolation Graph

The infiltration and inflow indicators were normalized by the per-IDM, per-ACRE and per-ADWF methods in this report. Final rankings were determined by weighting the per-IDM, per-ACRE and per-ADWF normalization methods by 50%, 15% and 35%, respectively, with ties broken by the per-IDM method. The per-IDM method is given a higher weight including the tie-break because, for this study, future I/I rehabilitation and/or reduction efforts are typically budgeted per unit length of pipe. Additionally, the IDM measurement typically has a higher level of accuracy than drainage watershed area and low-flow ADWF.

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

Inflow and Infiltration: Results

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.

Table 10 summarizes the peak measured I/I flows and inflow analysis results. Peak I/I flow rates were taken from Event 2 (March 27 through April 1, 2012 – refer to the *I/I Methods* section for more information on inflow analysis methods and ranking procedures). Figure 30, Figure 31 and Figure 32 show bar graph summaries of the inflow analysis, and Figure 33 shows a temperature map summary of the inflow analysis results per basin.

Table 10.
Basins Inflow Analysis Summary

Basin	ADWF (mgd)	Peak I/I Rate (mgd)	Peak I/I to IDM (gpd/IDM)	Peak I/I per Acre (GPAD)	Peak I/I per ADWF	Inflow Ranking
Basin 1	0.53	0.40	1,827	302	0.75	14
Basin 4	0.72	1.15	3,350	778	1.59	11
Basin 5	0.21	0.12	2,276	368	0.59	13
Basin 6	0.90	1.14	5,565	1,002	1.27	8
Basin 7	0.51	1.29	6,248	1,056	2.54	5
Basin 8/9	0.30	0.35	4,010	1,035	1.15	10
Basin 10	0.40	0.48	3,273	801	1.22	12
Basin 11	0.38	1.59	9,598	1,229	4.18	1
Basin 12/13	0.68	1.08	8,268	1,954	1.59	6
Basin 14	0.30	0.80	9,503	2,007	2.61	2
Basin 15	1.05	1.93	8,763	1,298	1.84	4
Basin 16	0.50	2.03	8,374	905	4.05	3
Basin 17	0.31	0.53	3,606	720	1.70	9
Basin 18	0.11	0.38	3,484	548	3.35	7
Total	7.01	8.23	3,490	595	1.17	

Ranking of 1 represents most inflow after normalization.

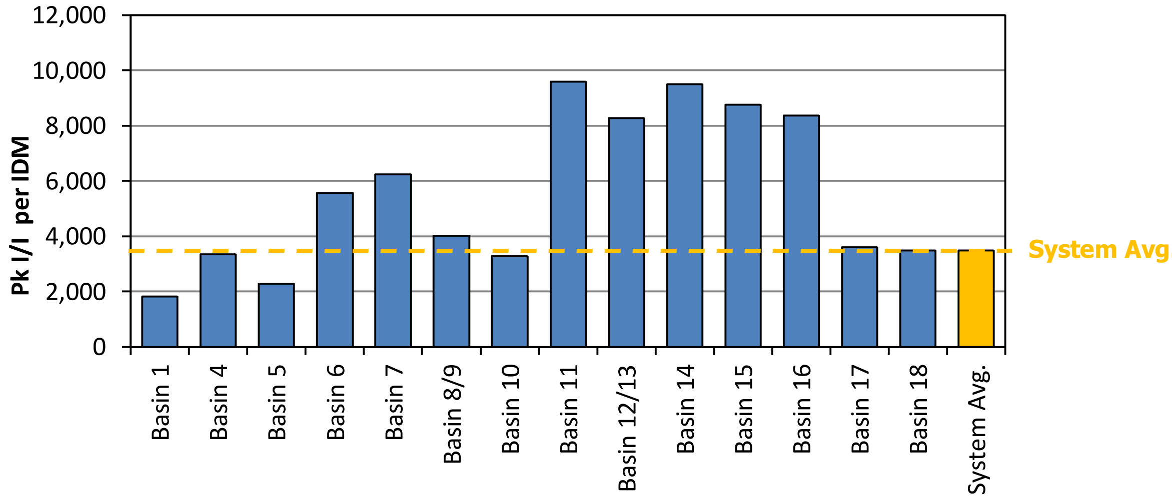


Figure 30. Bar Graphs: Inflow Analysis Summary – Peak I/I to IDM

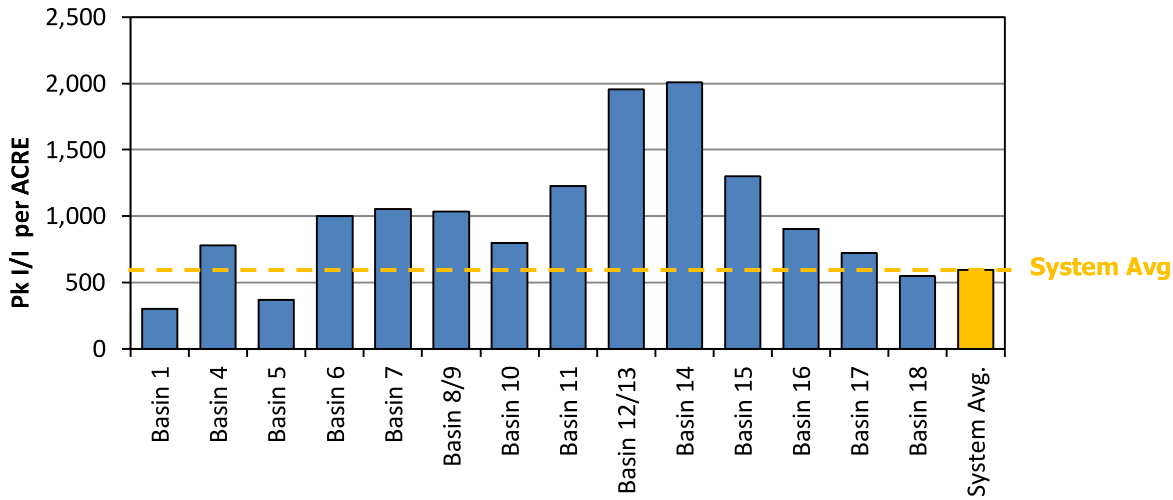


Figure 31. Bar Graphs: Inflow Analysis Summary – Peak I/I to ACRE

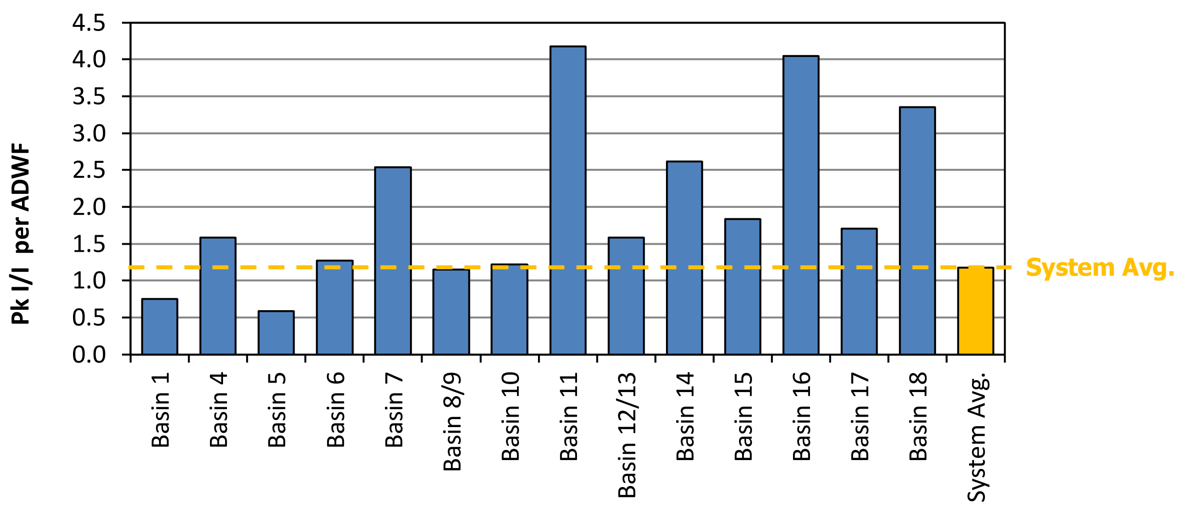


Figure 32. Bar Graphs: Inflow Analysis Summary – Peak I/I to ADWF

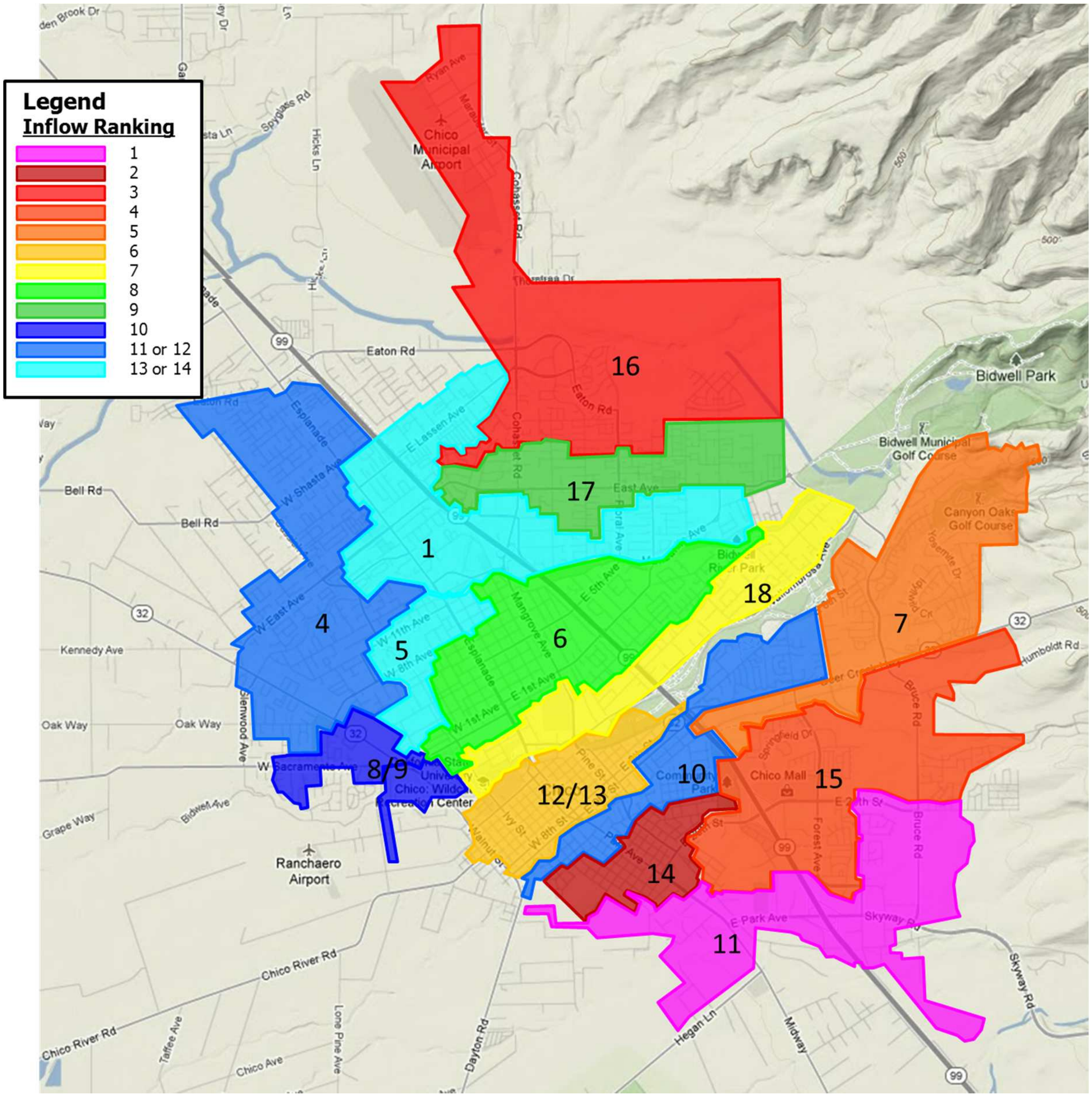


Figure 33. Inflow Temperature Map (by rank)

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 drop off 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).

Table 11 summarizes the RDI analysis results. The RDI rate was taken as the average I/I rate on April 2, approximately 24 hours after the conclusion of Storm Event 2 (refer to the *I/I Methods* section for more information on inflow analysis methods and ranking procedures). Figure 34, Figure 35 and Figure 36 shows bar graph summaries of the RDI analysis, and a temperature map by overall ranking is shown in Figure 37.

Table 11.
Basins RDI Analysis Summary

Basin	ADWF (mgd)	RDI Rate (mgd)	RDI per IDM (gpd/IDM)	RDI per Acre (GPAD)	RDI per ADWF	RDI Ranking
Basin 1	0.53	0.029	134	22	6%	12
Basin 4	0.72	0.011	33	8	2%	14
Basin 5	0.21	0.036	657	106	17%	9
Basin 6	0.90	0.175	850	153	19%	8
Basin 7	0.51	0.214	1,039	176	42%	7
Basin 8/9	0.30	0.005	58	15	2%	13
Basin 10	0.40	0.182	1,239	303	46%	4
Basin 11	0.38	0.248	1,501	192	65%	2
Basin 12/13	0.68	0.069	532	126	10%	10
Basin 14	0.30	0.235	2,809	593	77%	1
Basin 15	1.05	0.265	1,203	178	25%	6
Basin 16	0.50	0.283	1,170	126	57%	5
Basin 17	0.31	0.194	1,324	264	63%	3
Basin 18	0.11	0.020	187	29	18%	11
Total	7.01	1.903	807	138	27%	

Ranking of 1 represents most RDI after normalization.

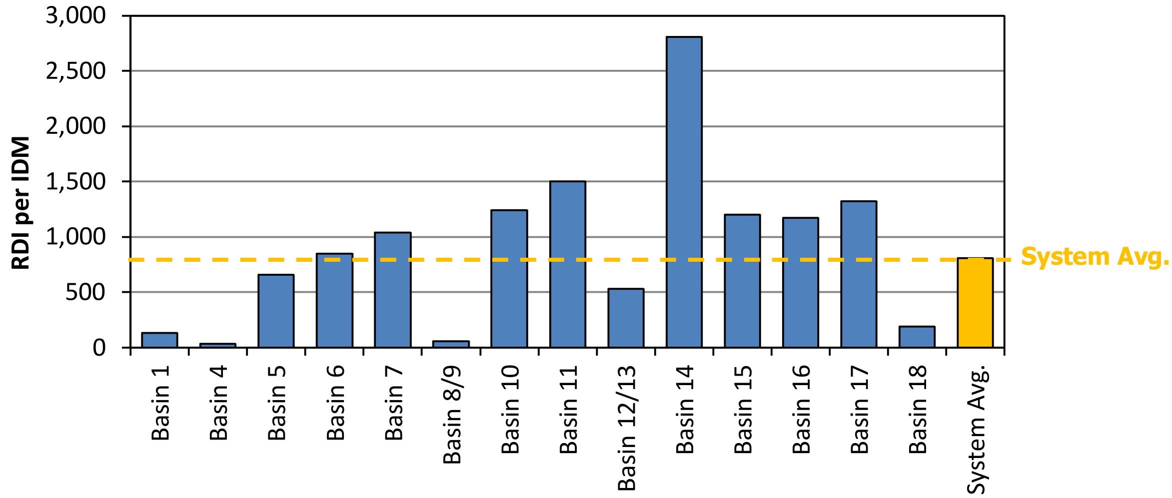


Figure 34. Bar Graphs: RDI Analysis Summary – RDI Rate to IDM

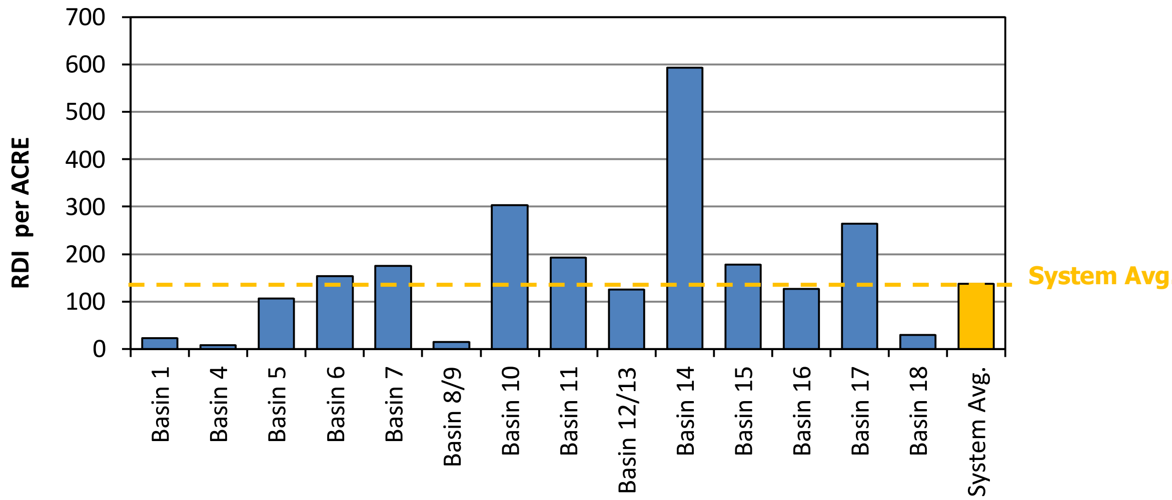


Figure 35. Bar Graphs: RDI Analysis Summary – RDI Rate to ACRE

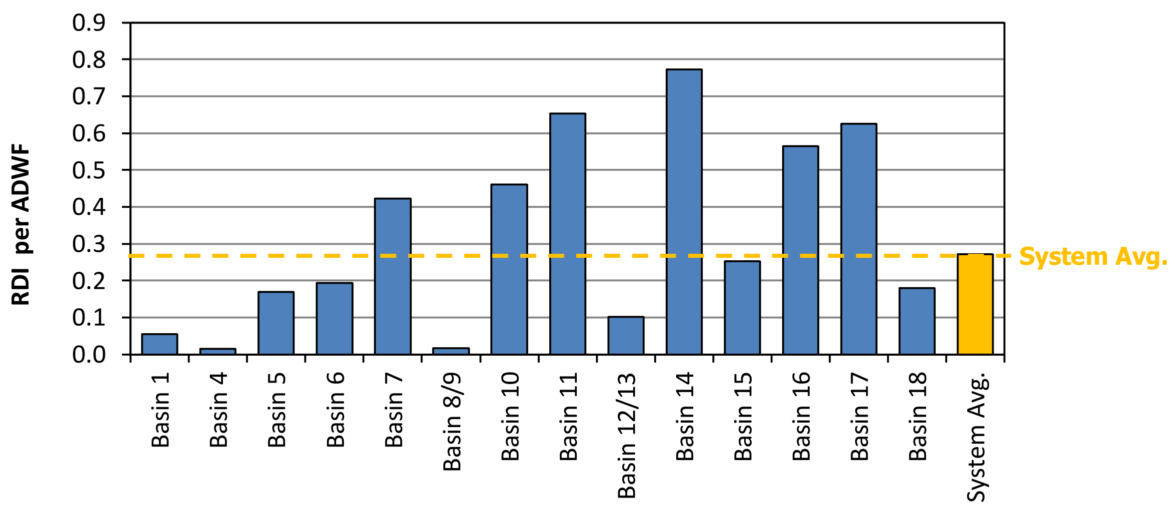


Figure 36. Bar Graphs: RDI Analysis Summary – RDI Rate to ADWF

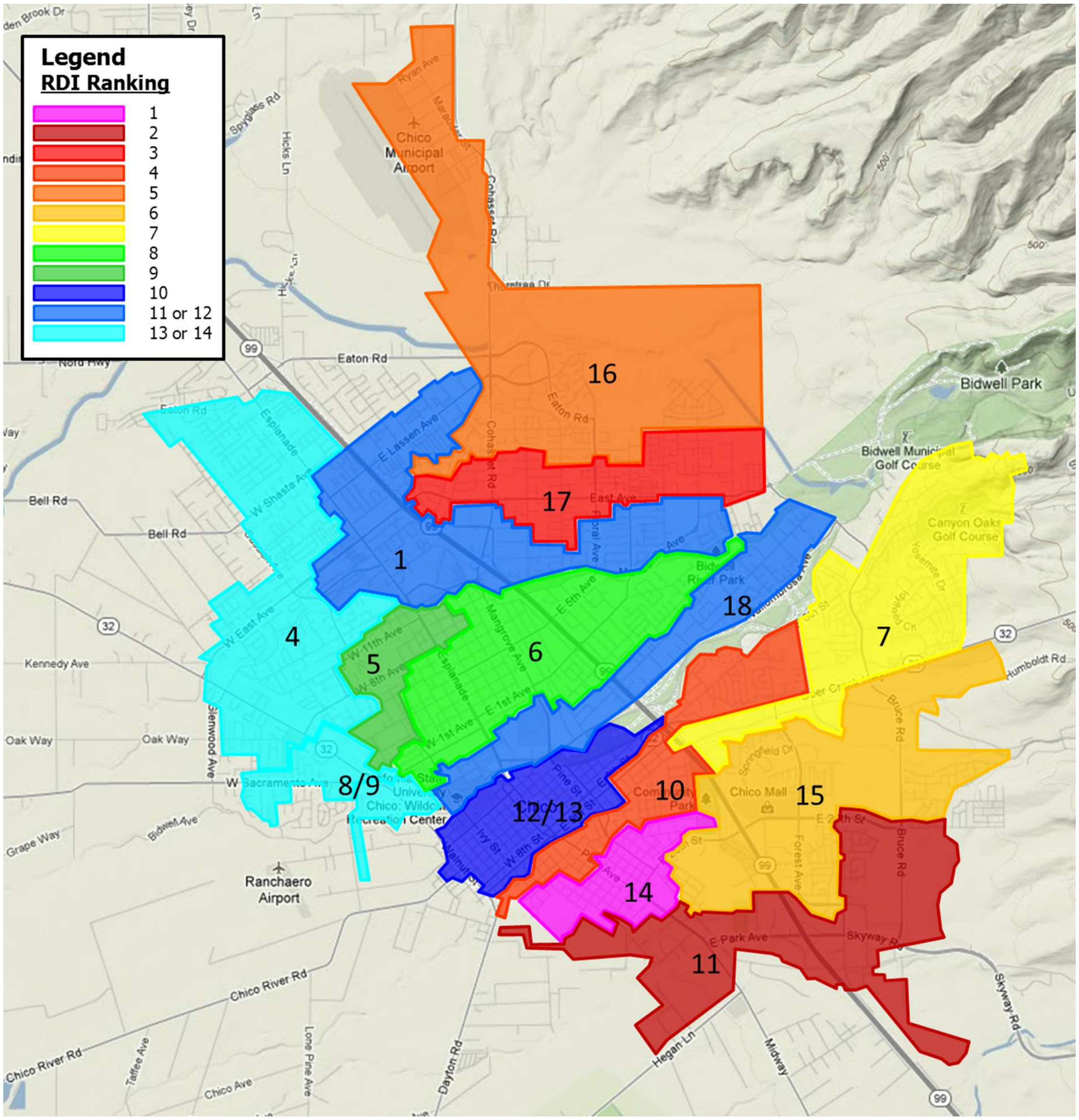


Figure 37. RDI Temperature Map (by rank)

Groundwater Infiltration Results Summary

Dry weather (ADWF) flow can be expected to have a predictable diurnal flow pattern. While each site is unique, experience has shown that, given a reasonable volume of flow and typical loading conditions, the daily flows fall into a predictable range when compared to the daily average flow. If a site has a large percentage of groundwater infiltration occurring during the periods of dry weather flow measurement, the amplitudes of the peak and low flows will be dampened[11]. Figure 38 shows a sample of two flow monitoring sites, both with nearly the same average daily flow, but with considerably different peak and low flows. In this *sample* case, Site B1 may have a considerable volume of groundwater infiltration.

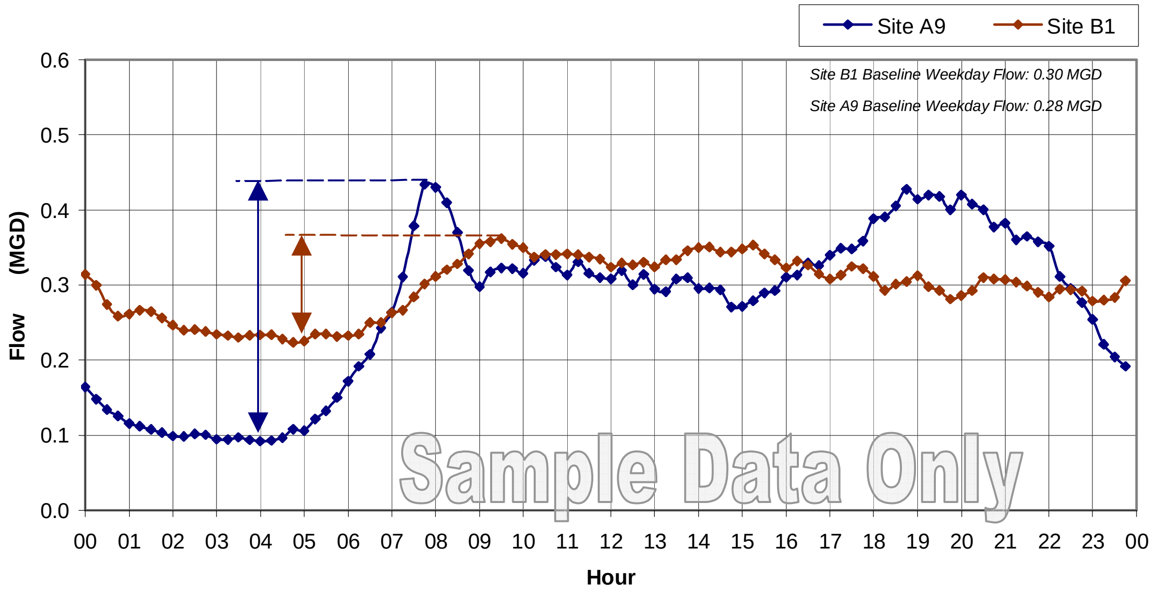


Figure 38. Groundwater Infiltration Sample Figure

It can be useful to compare the low-to-ADWF ratios for the flow metering sites. A site with abnormal ratios, and with no other reason to suspect abnormal flow patterns (such as proximity to pump station, treatment facilities, etc.), has a possibility of higher levels of groundwater infiltration in comparison to the rest of the collection system. Figure 39 plots the low-to-ADWF ratios against the ADWF flows for the sites monitored during this study. The dotted line shows “typical” low-to-ADWF ratios per the Water Environment Federation (WEF)[12].

[11] Theoretically imagining an extreme case, if there were 0.2 mgd of ADWF flow and 2.0 mgd of groundwater infiltration, the peaks and lows would be barely recognizable; the ADWF flow would be nearly a straight line.

[12] WEF Manual of Practice No. 9, “Design and Construction of Sanitary and Storm Sewers.”

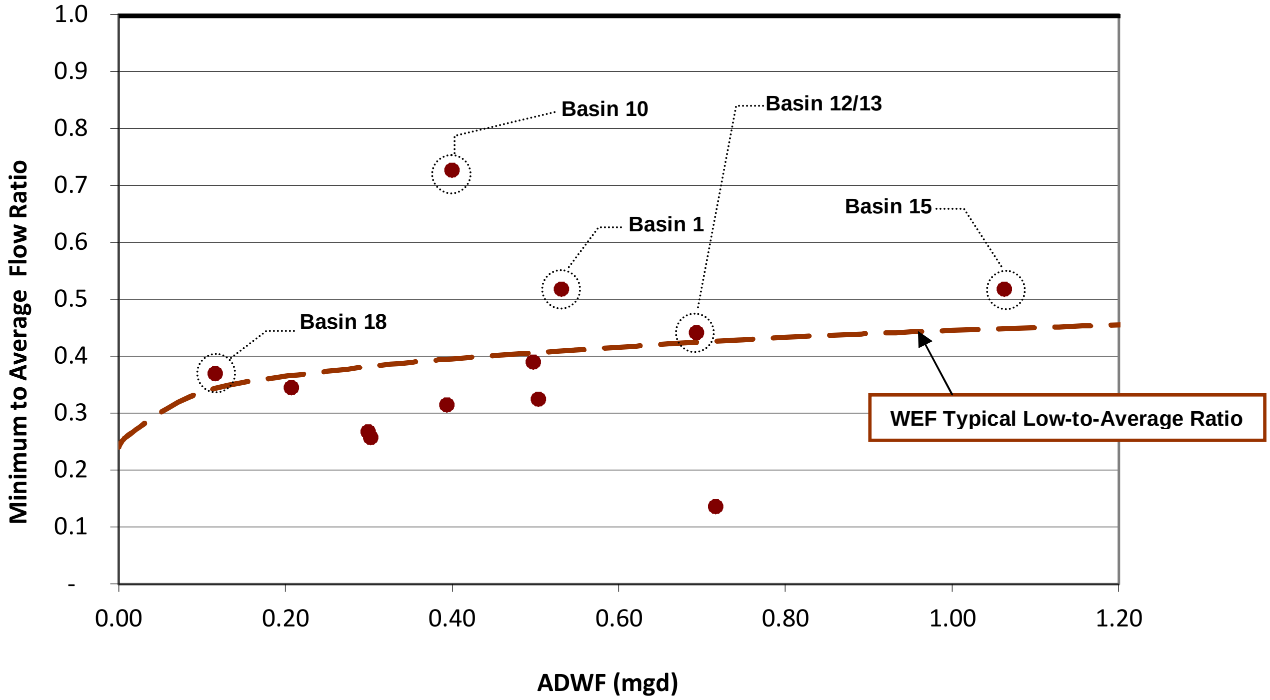


Figure 39. Minimum Flow Ratios vs. ADWF[13]

The following GWI results are noted:

- Basins 1, 10, 12/13, 15 and 18 show evidence of higher than normal GWI rates; the GWI rates for these basins were **above** the WEF typical Low-to-Average Ratio, indicating the possibility of excessive groundwater infiltration.

Figure 40 shows a color-coded map of the basins with rates of groundwater infiltration above typical groundwater infiltration standards (as set forth by WEF).

[13] Due to attenuation, it should be expected that sites with larger flow volumes should not have quite the peak-to-average and low-to-average flow ratios as sites with lesser flow volumes, which is why the WEF typical trend lines slope closer to 1.0 as the ADWF increases, as shown in the figure.

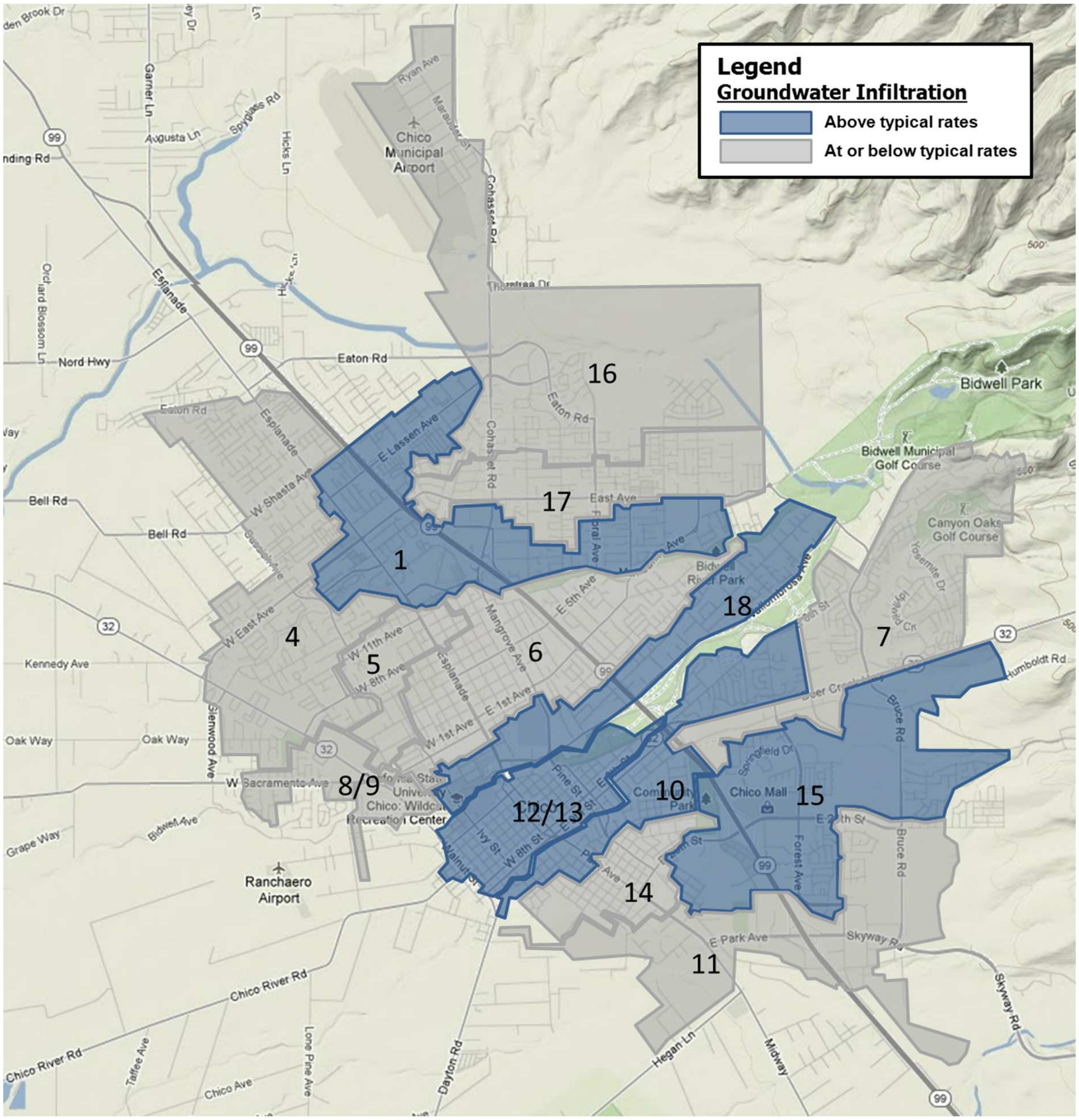


Figure 40. Basins with High Groundwater Rates

Combined I/I Results Summary

Combined I/I analysis considers the totalized volume (in gallons) of both inflow and rainfall-dependent infiltration over the course of a storm event.

Table 12 summarizes the combined I/I flow results. Combined I/I results were taken from Event 2 (March 27 through April 1, 2012) (refer to the *I/I Methods* section for more information on inflow analysis methods). Combined I/I flows were normalized by the IDM and acreage methods, with ties broken by the IDM ranking. Figure 41, Figure 42 and Figure 43 show bar graph summaries of the combined I/I analysis, and Figure 44 shows a temperature map summary of the combined I/I analysis results per basin. Figure 45 shows an illustrative map summary of the top 5 ranked basins for each I/I analysis component.

Table 12.
Basins Combined I/I Analysis Summary

Basin	ADWF (mgd)	Total I/I (gallons)	Total I/I per IDM	R-Value (%)	Total I/I per ADWF	Combined I/I Ranking
Basin 1	0.53	127,000	271.7	0.2%	0.11	12
Basin 4	0.72	191,000	258.1	0.2%	0.12	13
Basin 5	0.21	166,000	1,176.1	0.7%	0.30	11
Basin 6	0.90	2,131,000	4,202.2	2.8%	0.96	8
Basin 7	0.51	2,632,000	4,846.1	3.0%	1.97	6
Basin 8/9	0.30	29,000	132.8	0.1%	0.04	14
Basin 10	0.40	1,643,000	4,409.7	4.0%	1.64	7
Basin 11	0.38	2,110,000	5,276.6	2.5%	2.30	5
Basin 12/13	0.68	846,000	2,672.8	2.3%	0.51	10
Basin 14	0.30	2,438,000	12,066.1	9.4%	3.32	1
Basin 15	1.05	3,124,000	5,841.5	3.2%	1.22	4
Basin 16	0.50	4,255,000	8,248.6	3.3%	3.98	2
Basin 17	0.31	1,840,000	5,813.5	4.3%	2.75	3
Basin 18	0.11	509,000	1,918.1	1.1%	1.84	9
Total	7.01	21,726,000	3,740.7	2.4%	1.26	

Ranking of 1 represents most combined I/I after normalization.

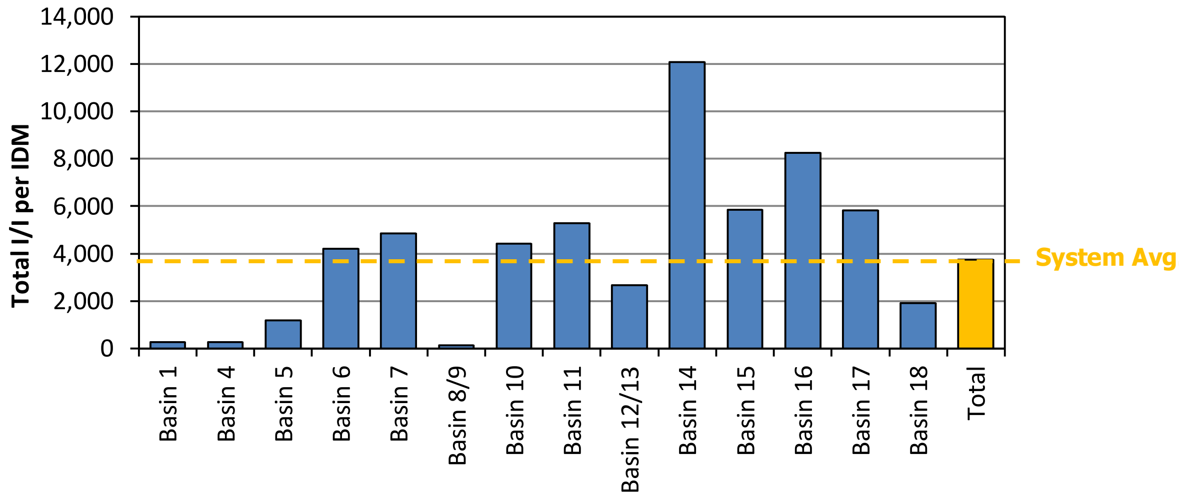


Figure 41. Bar Graphs: Combined I/I Analysis Summary – Total I/I to IDM

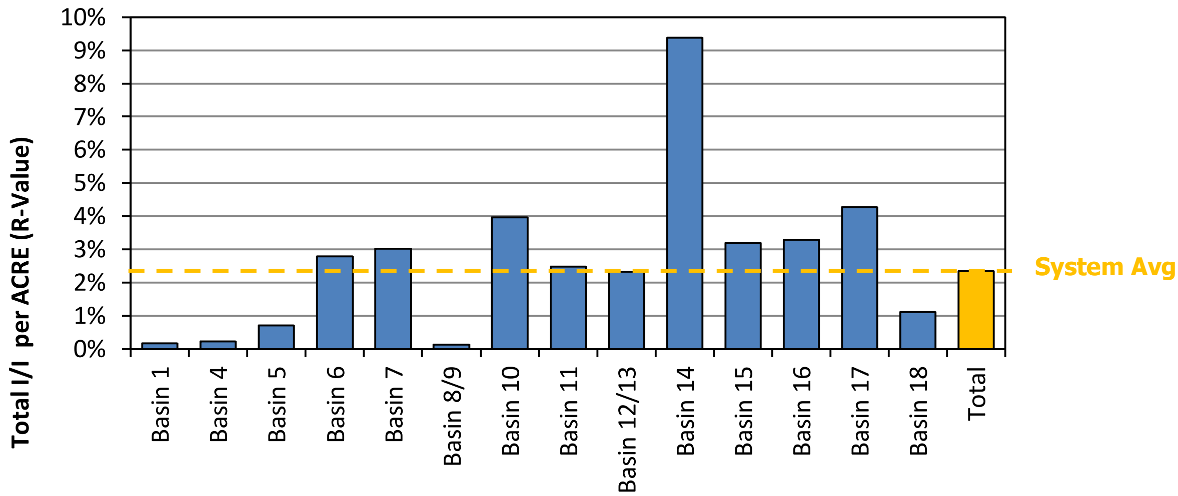


Figure 42. Bar Graphs: Combined I/I Analysis Summary – Total I/I to ACRE (R-Value)

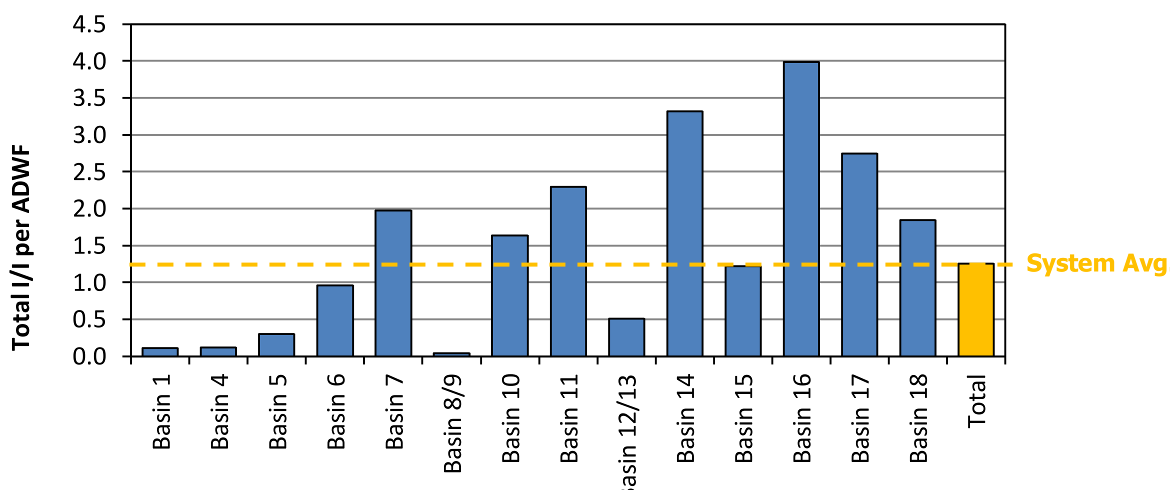


Figure 43. Bar Graphs: Combined I/I Analysis Summary – Total I/I to ADWF

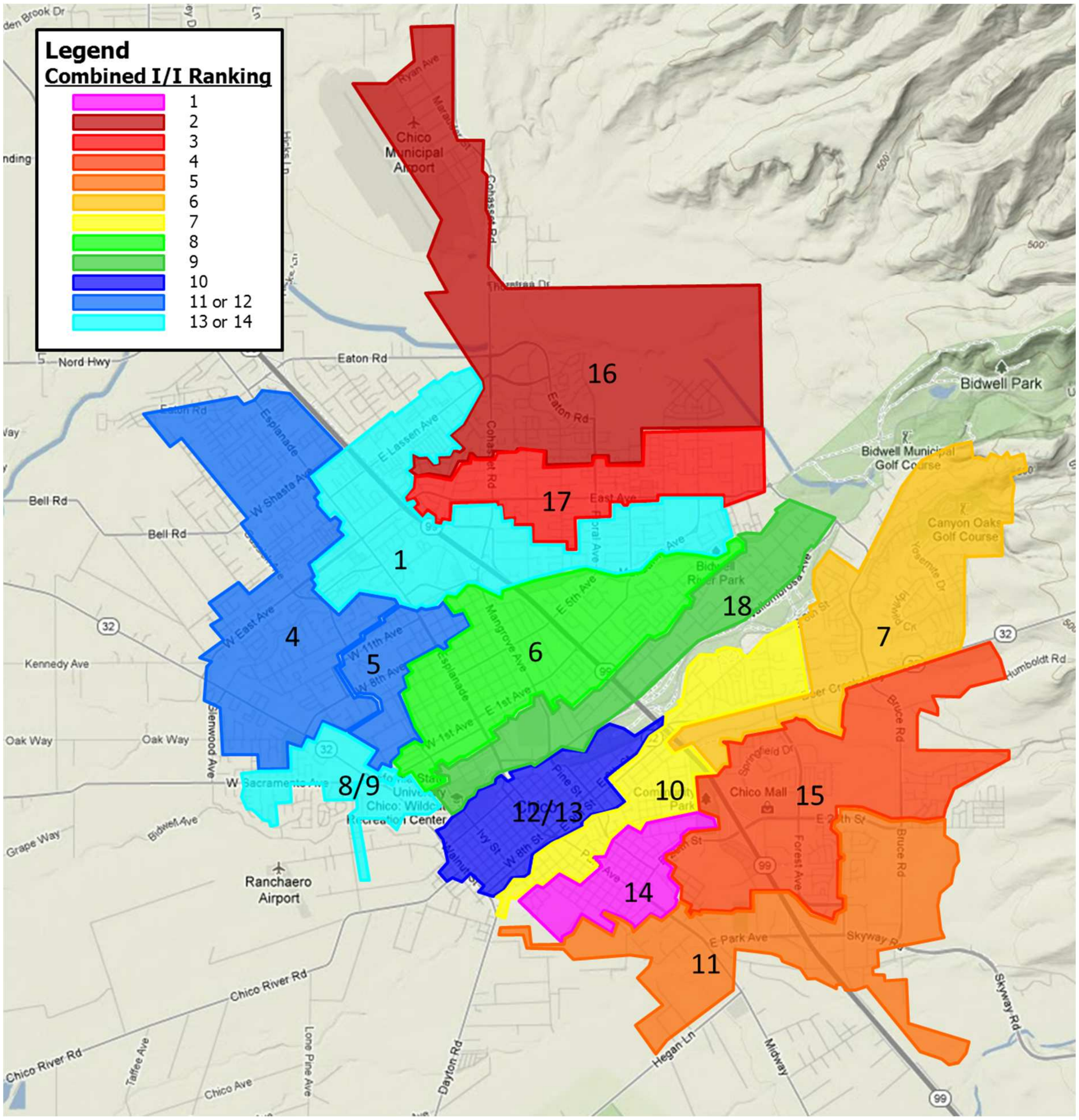


Figure 44. Combined I/I Temperature Map (by rank)

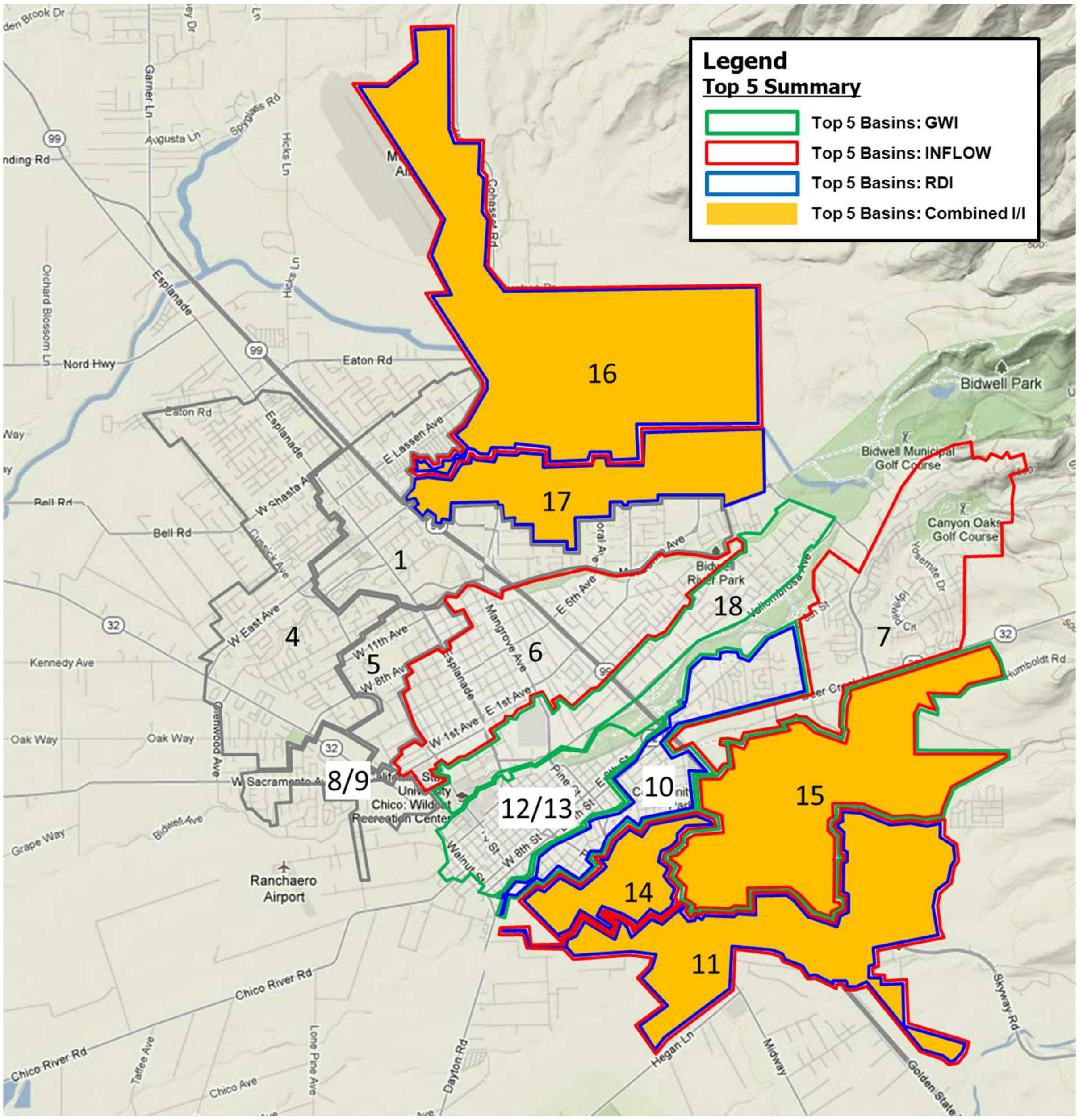


Figure 45. Temperature Map Summary: Top Five Basins by Each Method

Recommendations

V&A advises that future I/I reduction plans consider the following recommendations:

1. **Determine I/I Reduction Program:** The City should examine its I/I reduction needs to determine 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 greatest inflow problems. The highest inflow occurred in Basins 7, 11, 14, 15 and 16.
    b. If total 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 greatest infiltration problems.
        i. The highest normalized rainfall-dependent infiltration occurred in Basins 10, 11, 14, 16 and 17.
        ii. The highest groundwater infiltration occurred in Basins 1, 10, 12/13, 15 and 18.
2. **I/I Investigation Methods:** Potential I/I investigation methods include the following:
    a. Smoke testing
    b. Mini-basin flow monitoring
    c. Nighttime reconnaissance work to (1) investigate and determine direct point sources of inflow and (2) determine the areas and pipe reaches responsible for high levels of infiltration contribution.
3. **I/I Reduction Cost-Effectiveness Analysis:** The City should conduct a study to determine which is more cost-effective: (1) locating the sources of inflow and 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 Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

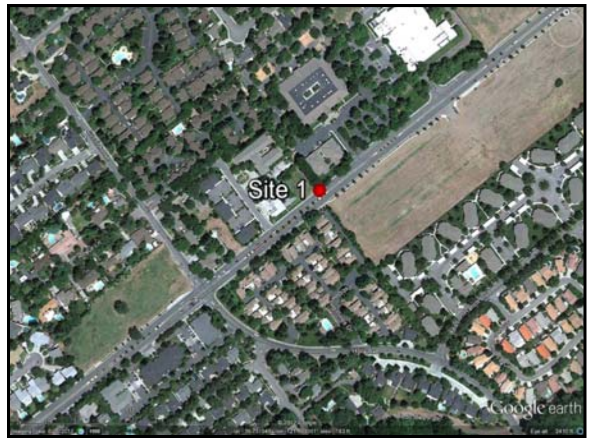
Monitoring Site: Site 1

Location: W East Avenue, northeast of Cussick Avenue

Vicinity Map:

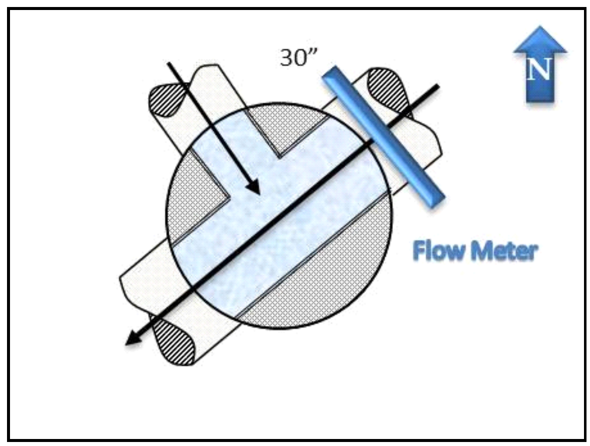
SITE 1
Site Information Report

Location:	W East Avenue, northeast of Cussick Avenue
Coordinates:	121.8690° W, 39.7523° N
Elevation:	183 feet
Diameter:	30 inches
Baseline Flow:	1.338 mgd
Peak Measured Flow:	3.740 mgd



Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

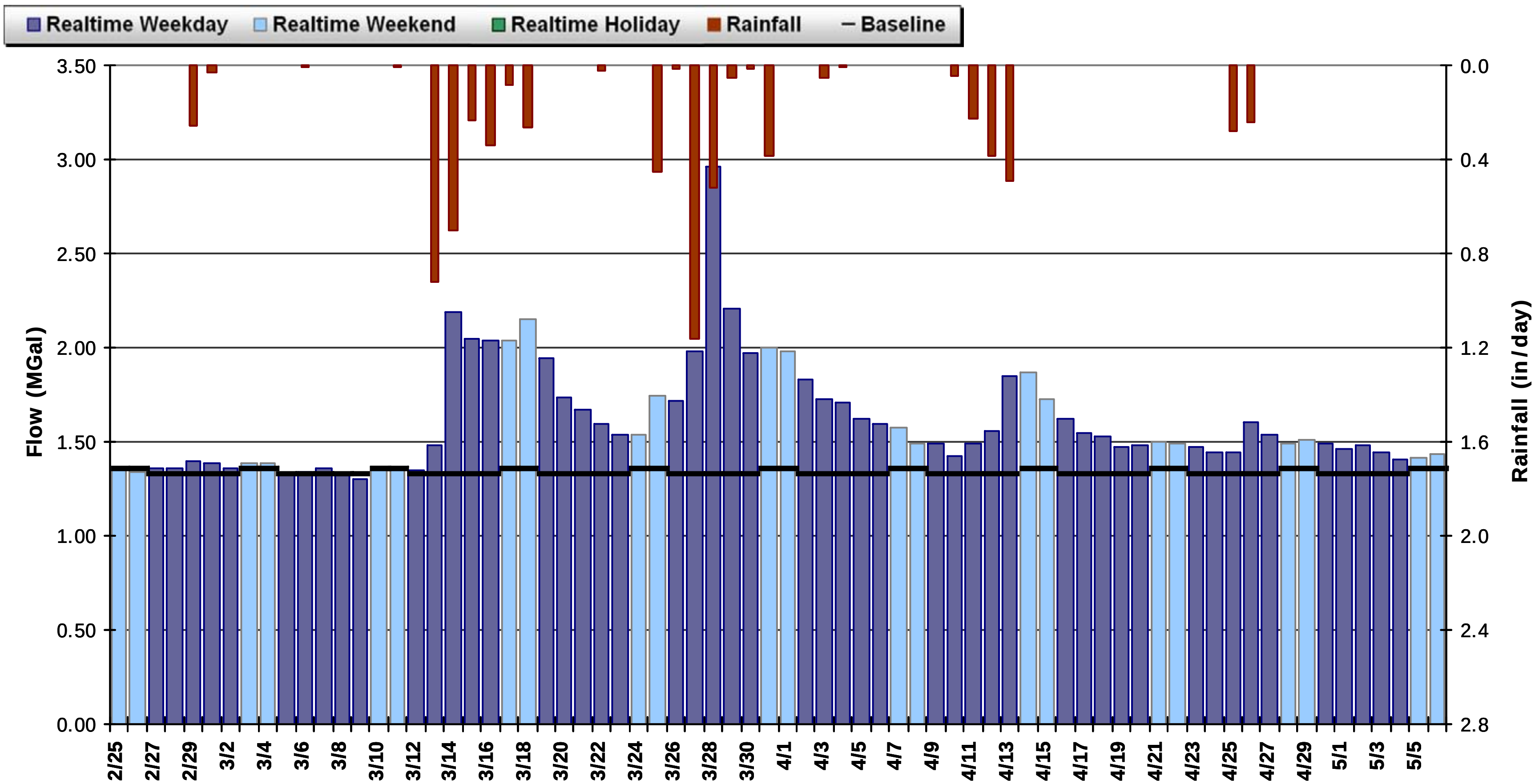
Plan View

SITE 1

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.608 MGal **Peak Daily Flow: 2.961 MGal** **Min Daily Flow: 1.305 MGal**

Total Period Rainfall: 7.21 inches

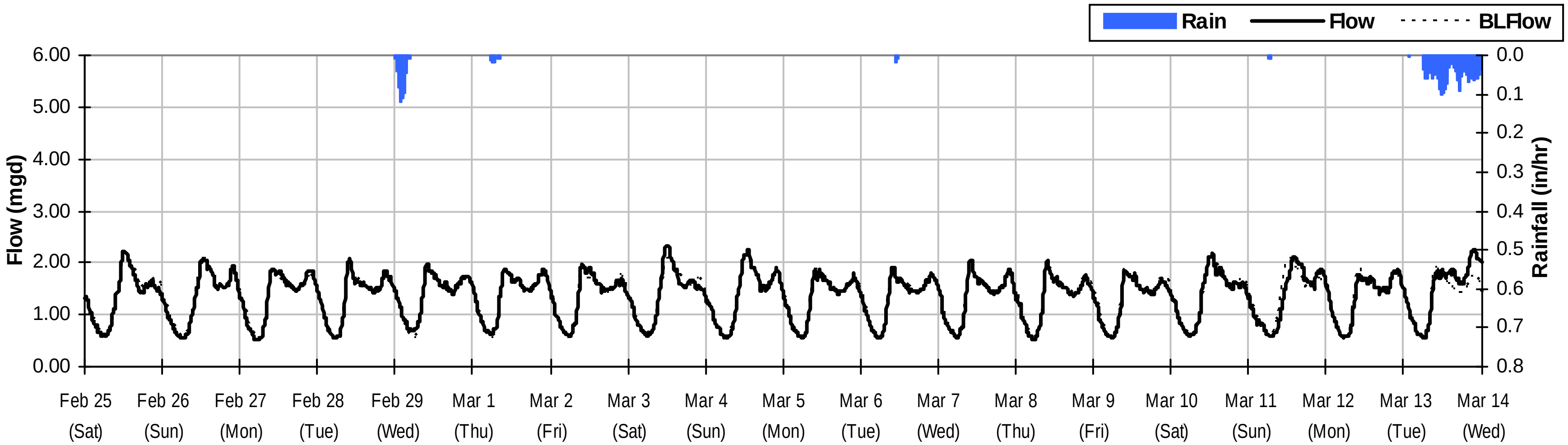


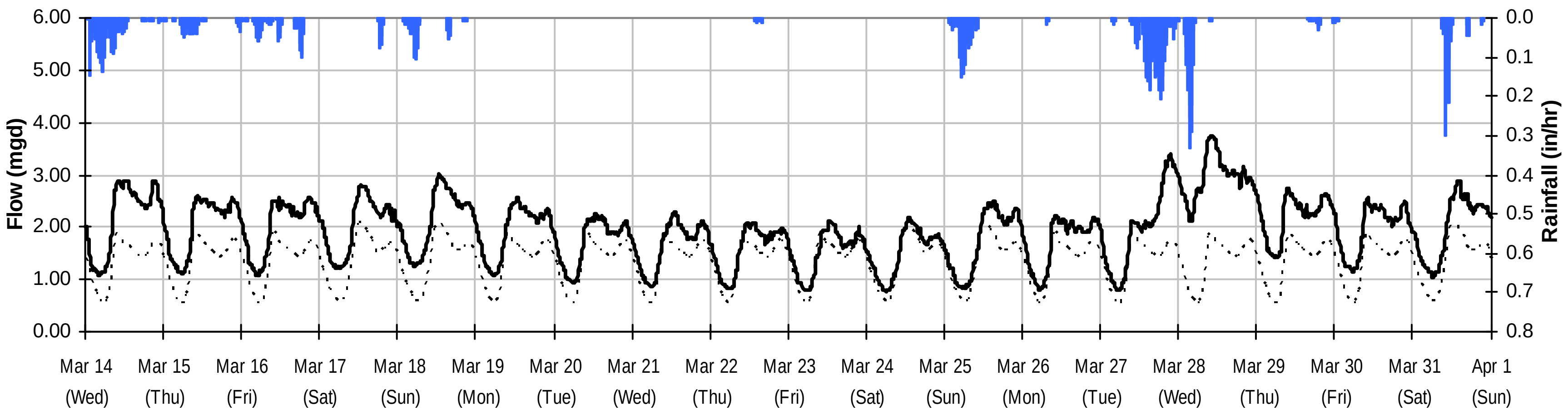
SITE 1

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 1.656 mgd **Peak Flow: 3.740 mgd** **Min Flow: 0.510 mgd**

Total Period Rainfall: 5.47 inches



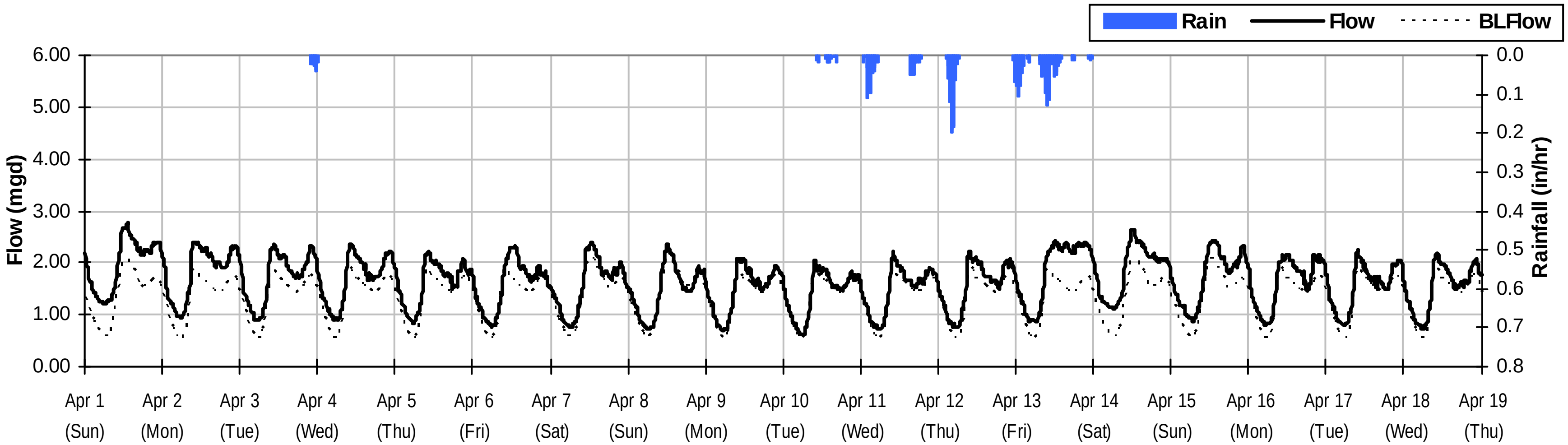


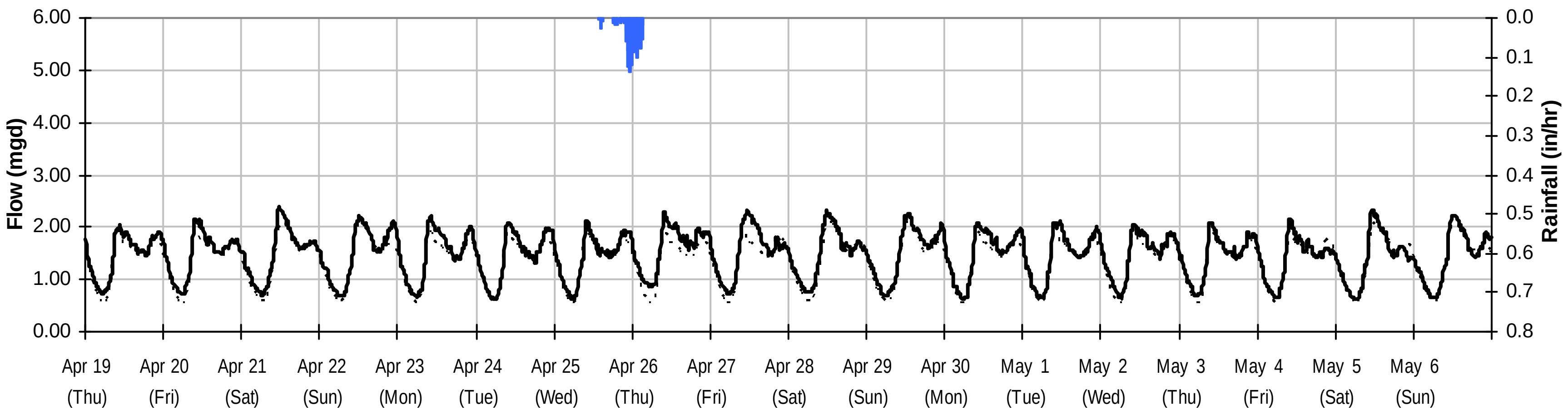
SITE 1

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 1.561 mgd **Peak Flow: 2.766 mgd** **Min Flow: 0.611 mgd**

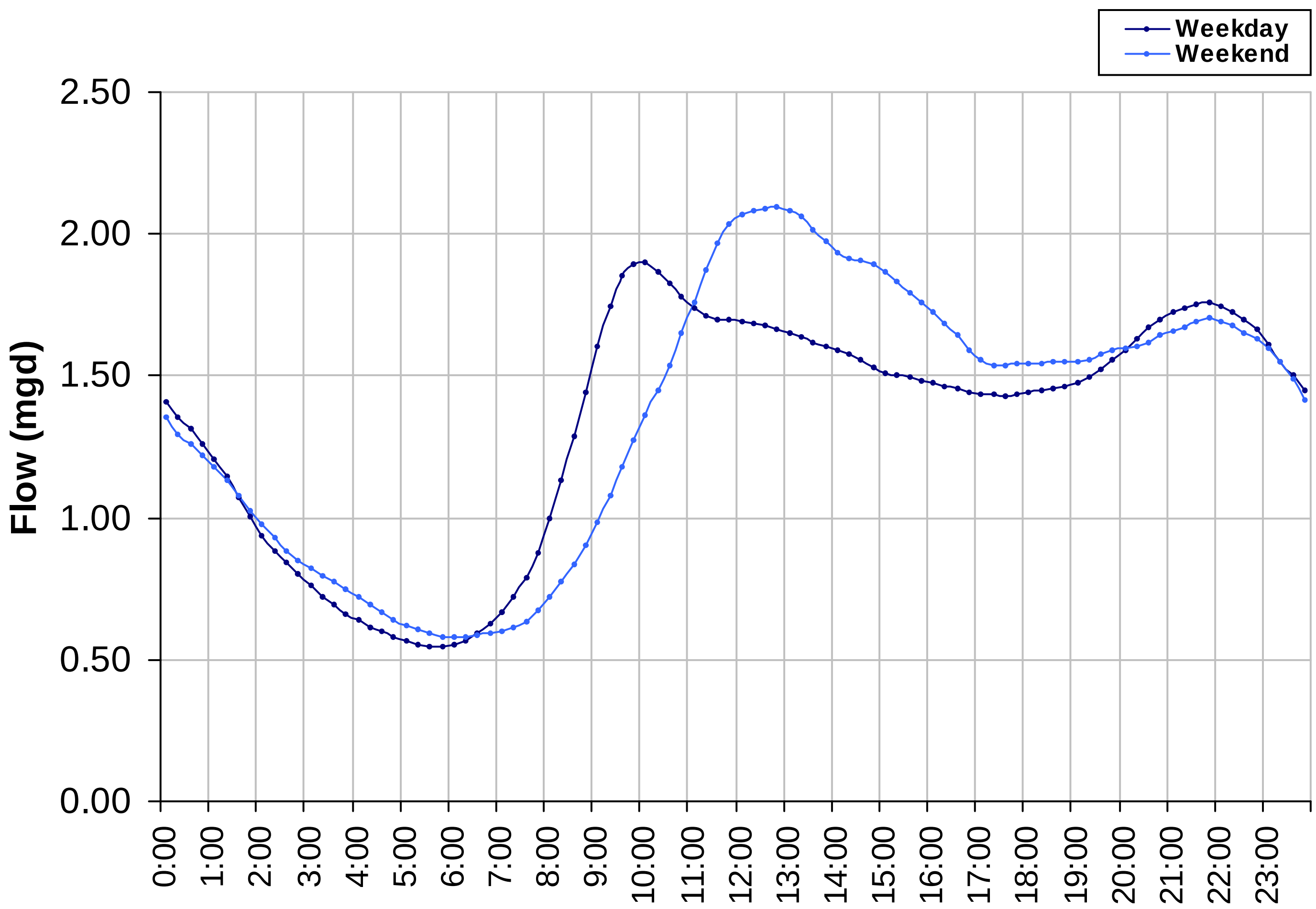
Total Period Rainfall: 1.74 inches





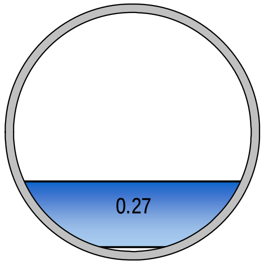
SITE 1

Baseline Flow Hydrographs



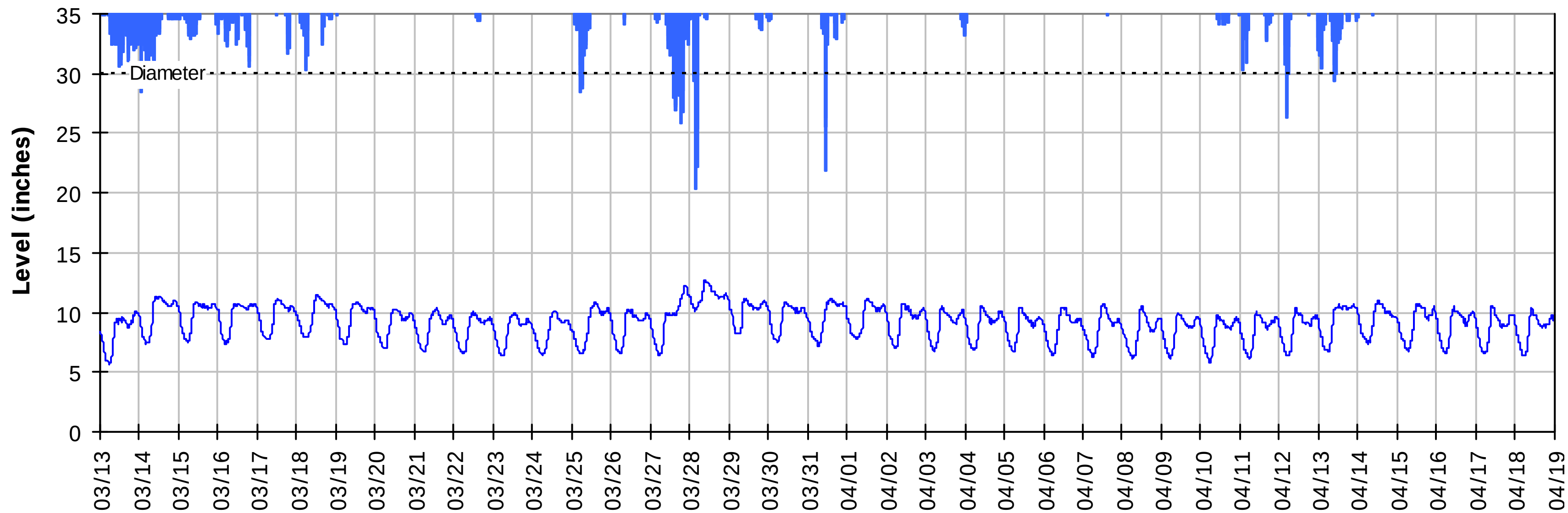
Baseline Flow:

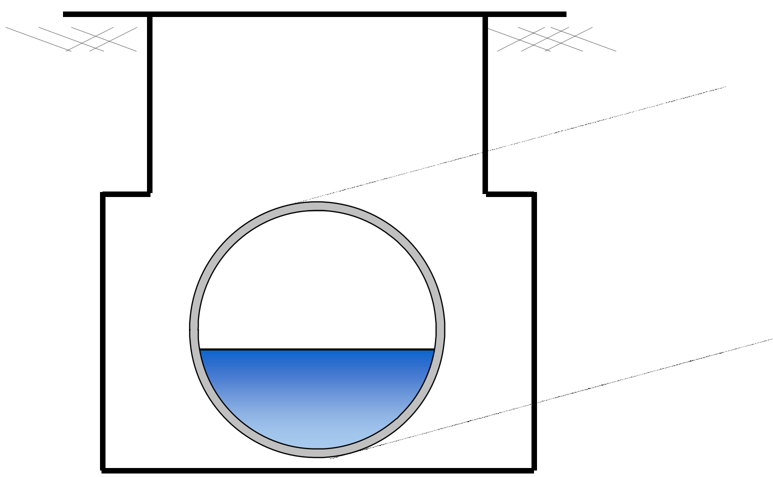
1.338 *mgd*



SITE 1
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





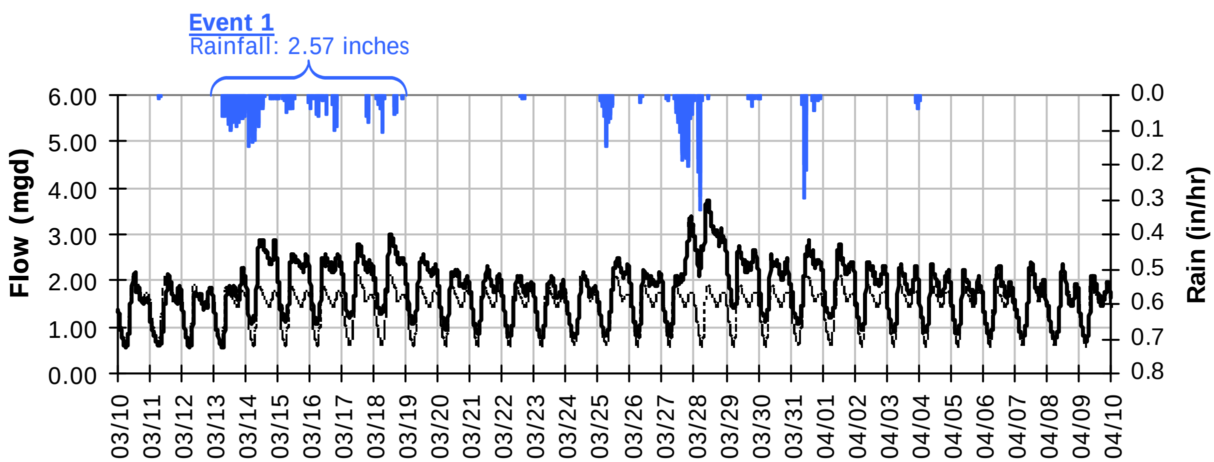
Pipe Diameter: 30 *inches*

Peak Measured Level: 12.7 *inches*

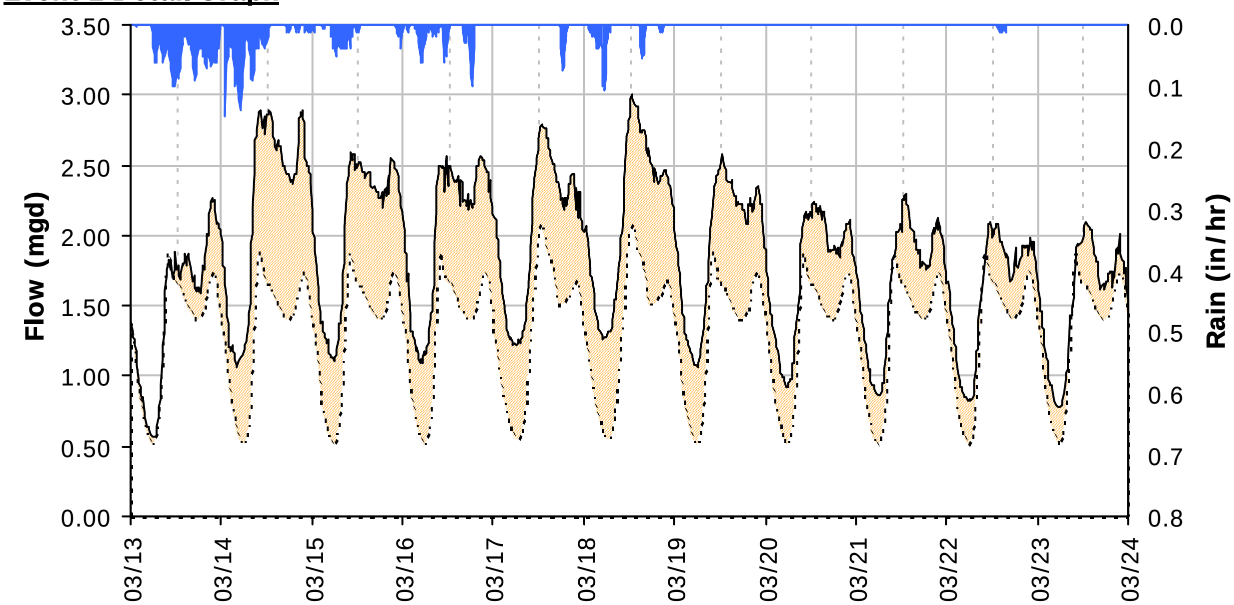
Peak d/D Ratio: 0.42

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 = 2.57 inches)

Capacity

Peak Flow: 3.01 *mgd*
PF: 2.25
Peak Level: 11.46 *in*
d/D Ratio: 0.38

Inflow

Peak I/I Rate: 1.24 *mgd*
PkI/I:IDM: 2,044 *gpd/IDM*
PkI/I:Acre: 289 *gpd/acre*
Pk I/I:ADWF: 0.93

RDI (infiltration)

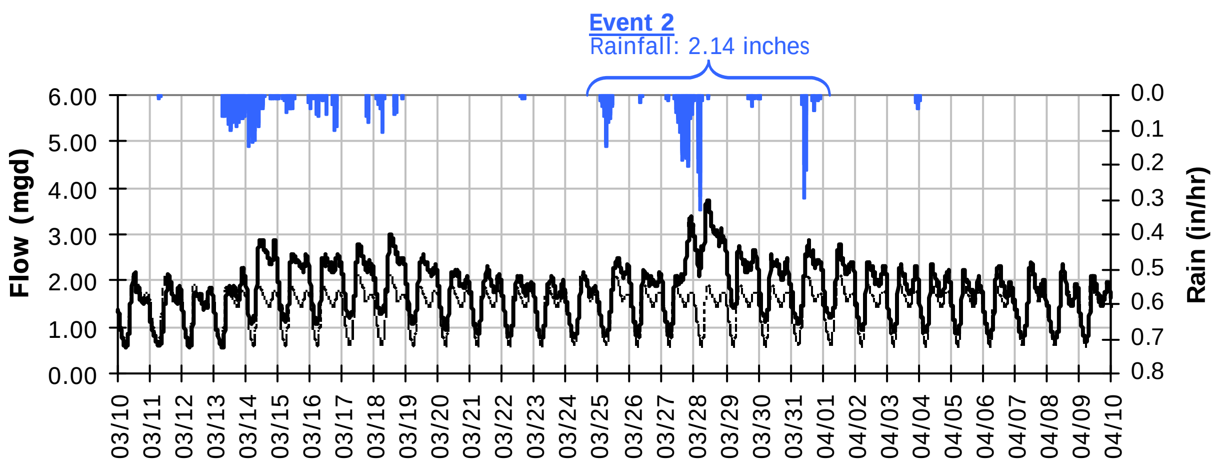
Infiltration Rate: 0.404 *mgd*
(3/20/2012)
RDI:IDM: 666 *gpd/IDM*
RDI:Acre: 94 *gpd/acre*
RDI (% of BL): 30%

Combined I/I

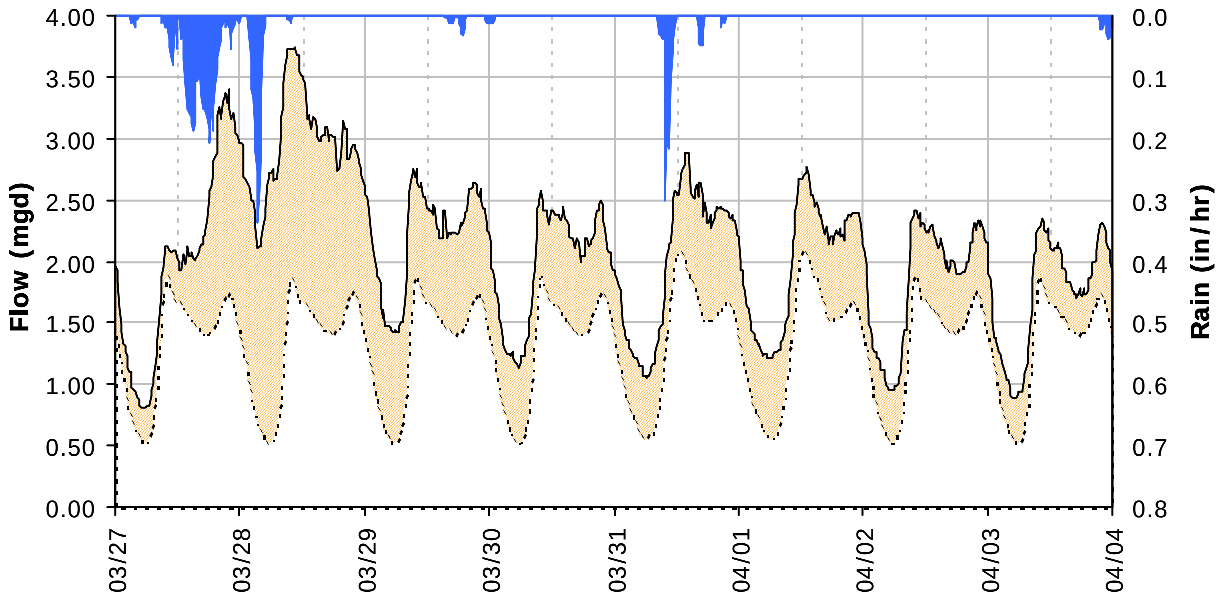
Total I/I: 6,061,000 *gallons*
Total I/I:IDM: 3,890 *gal/IDM/in*
R-Value: 2.0%
Total I/I:ADWF: 1.76 *per in-rain*

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 = 2.14 inches)

Capacity

Peak Flow: 3.74 *mgd*
PF: 2.80
Peak Level: 12.67 *in*
d/D Ratio: 0.42

Inflow

Peak I/I Rate: 2.19 *mgd*
PkI/I:IDM: 3,606 *gpd/IDM*
PkI/I:Acre: 510 *gpd/acre*
Pk I/I:ADWF: 1.63

RDI (infiltration)

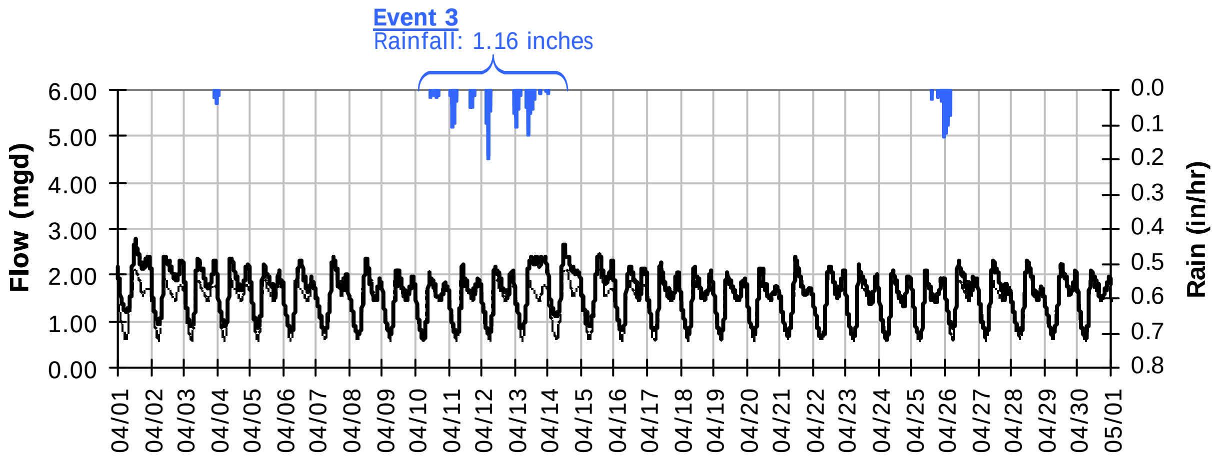
Infiltration Rate: 0.506 *mgd* (4/2/2012)
RDI:IDM: 835 *gpd/IDM*
RDI:Acre: 118 *gpd/acre*
RDI (% of BL): 38%

Combined I/I

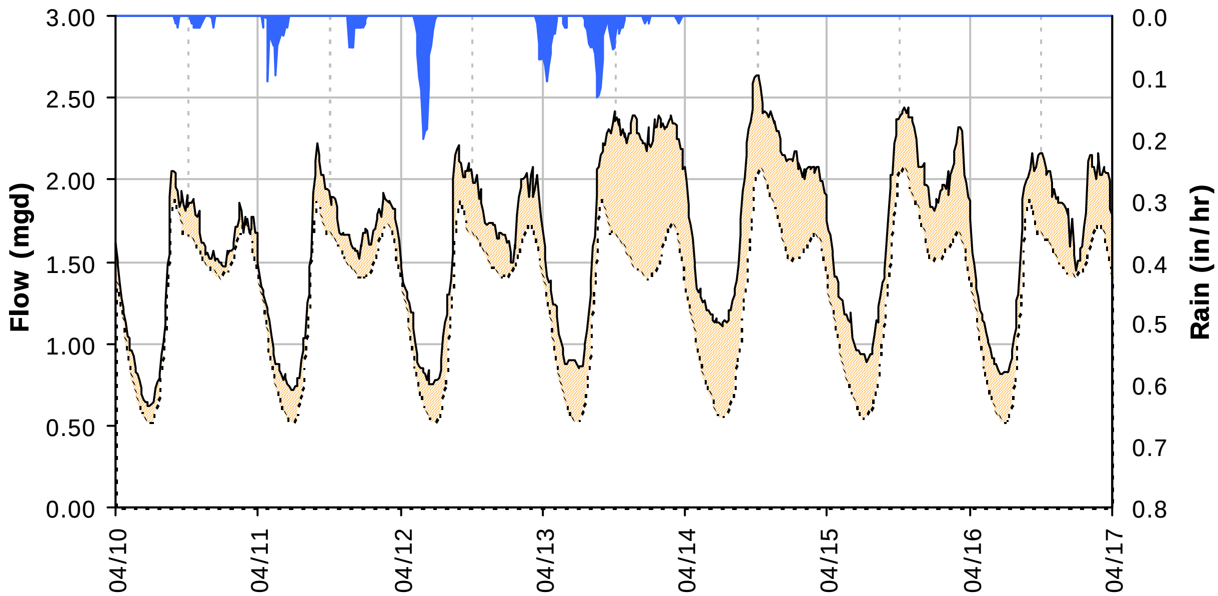
Total I/I: 6,222,000 *gallons*
Total I/I:IDM: 4,802 *gal/IDM/in*
R-Value: 2.5%
Total I/I:ADWF: 2.18 *per in-rain*

SITE 1
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.16 inches)

Capacity

Peak Flow: 2.64 *mgd*
PF: 1.97
Peak Level: 11.05 *in*
d/D Ratio: 0.37

Inflow

Peak I/I Rate: 0.90 *mgd*
PkI/I:IDM: 1,489 *gpd/IDM*
PkI/I:Acre: 210 *gpd/acre*
Pk I/I:ADWF: 0.67

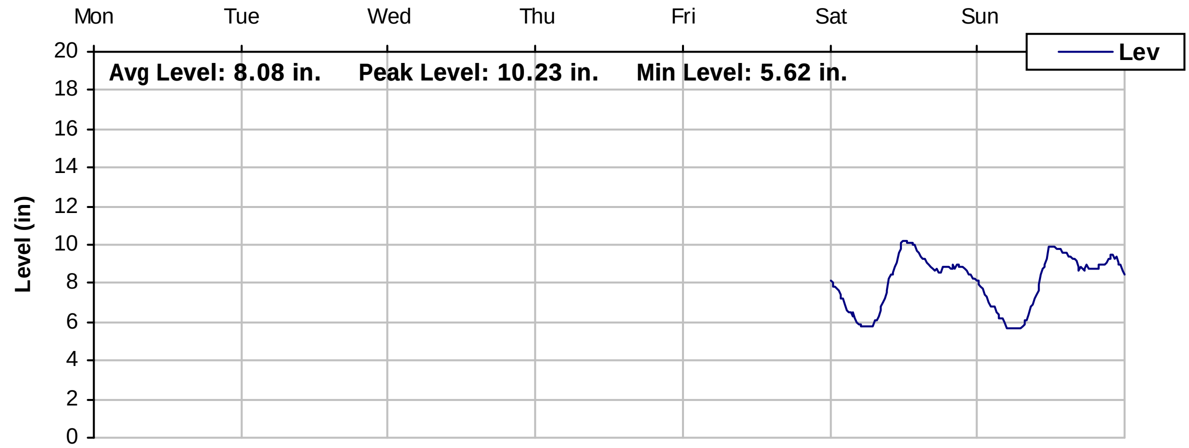
RDI (infiltration)

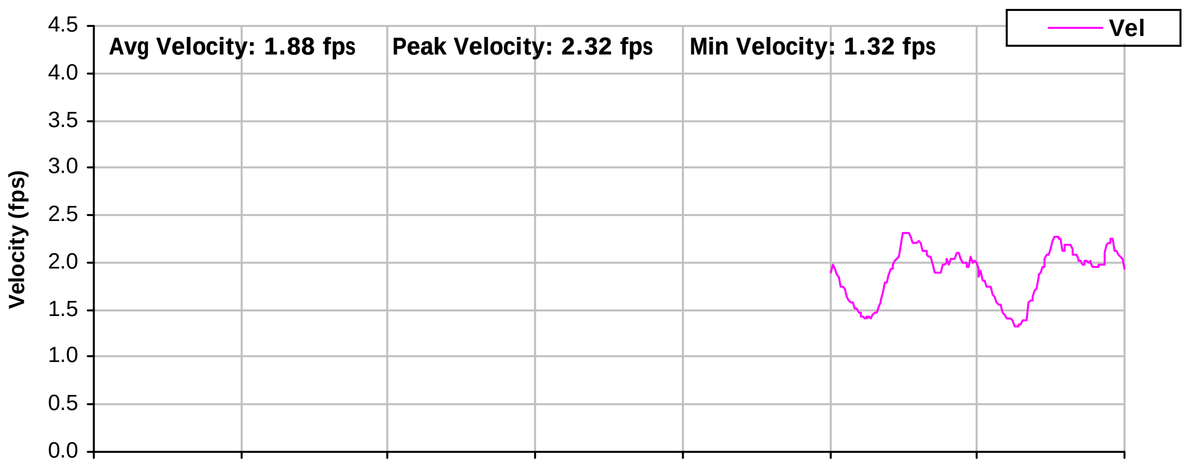
Infiltration Rate: 0.367 *mgd*
(4/15/2012)
RDI:IDM: 605 *gpd/IDM*
RDI:Acre: 85 *gpd/acre*
RDI (% of BL): 27%

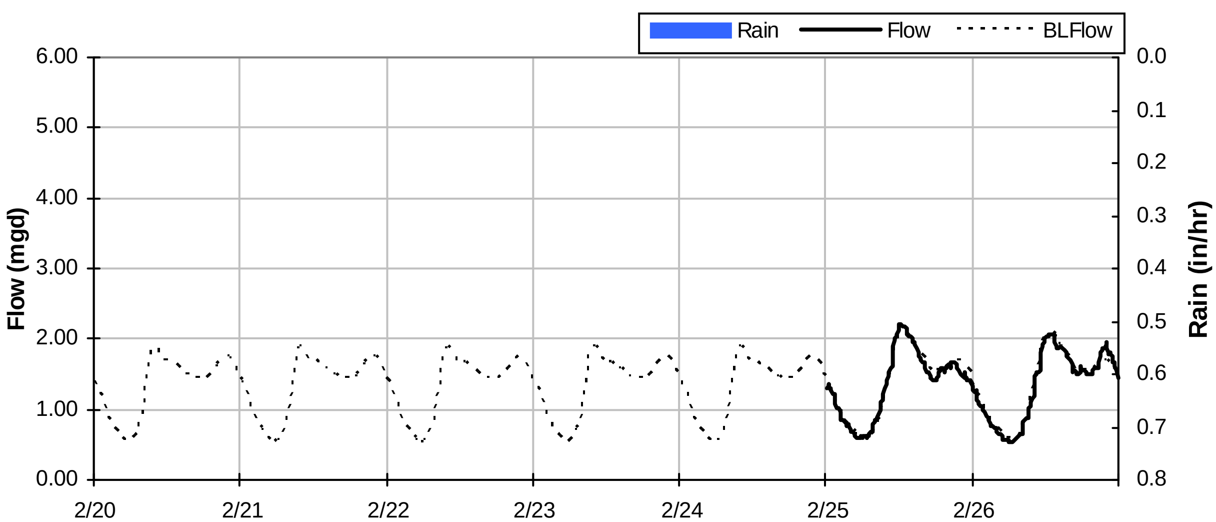
Combined I/I

Total I/I: 2,383,000 *gallons*
Total I/I:IDM: 3,403 *gal/IDM/in*
R-Value: 1.8%
Total I/I:ADWF: 1.54 *per in-rain*

SITE 1
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

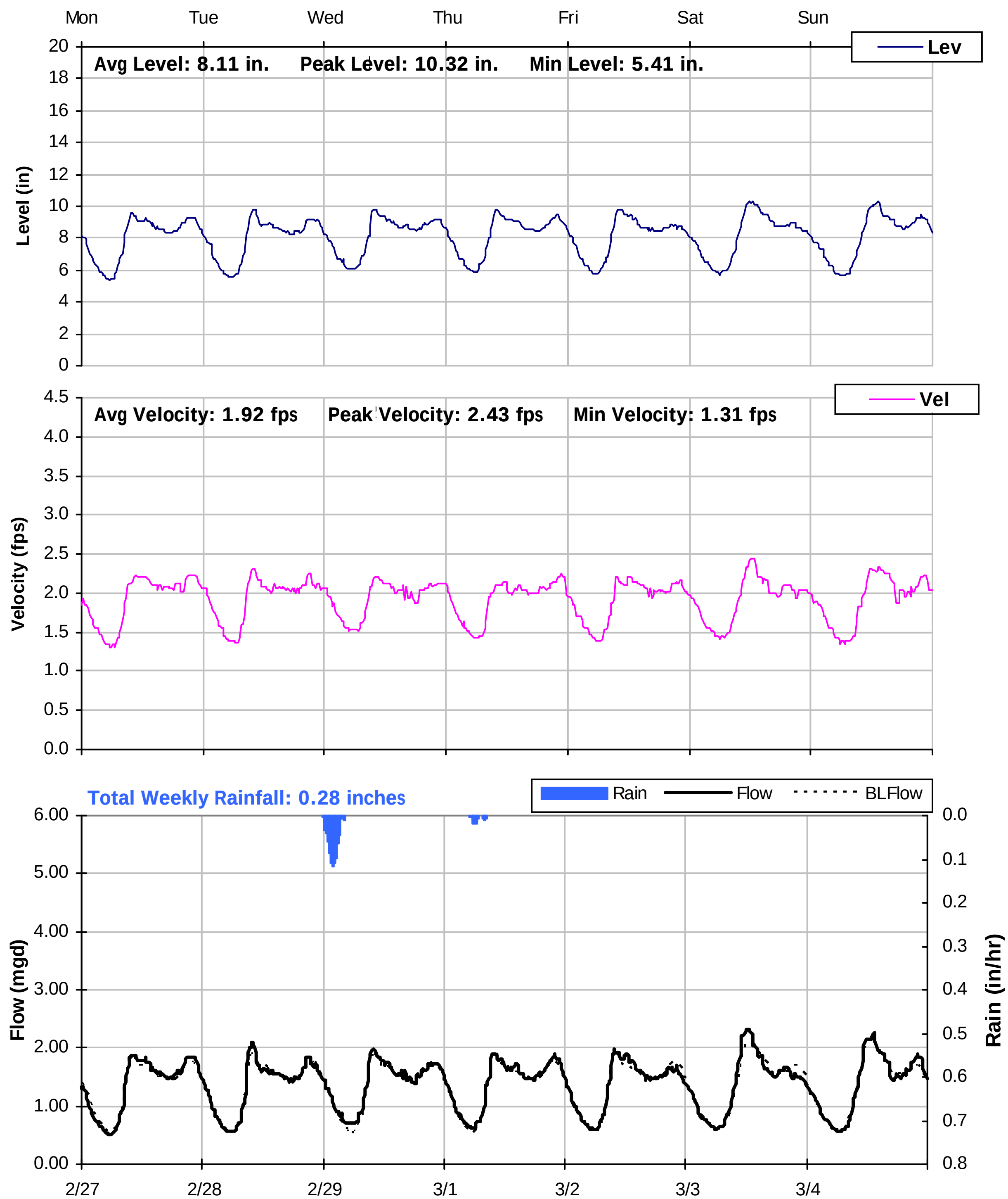






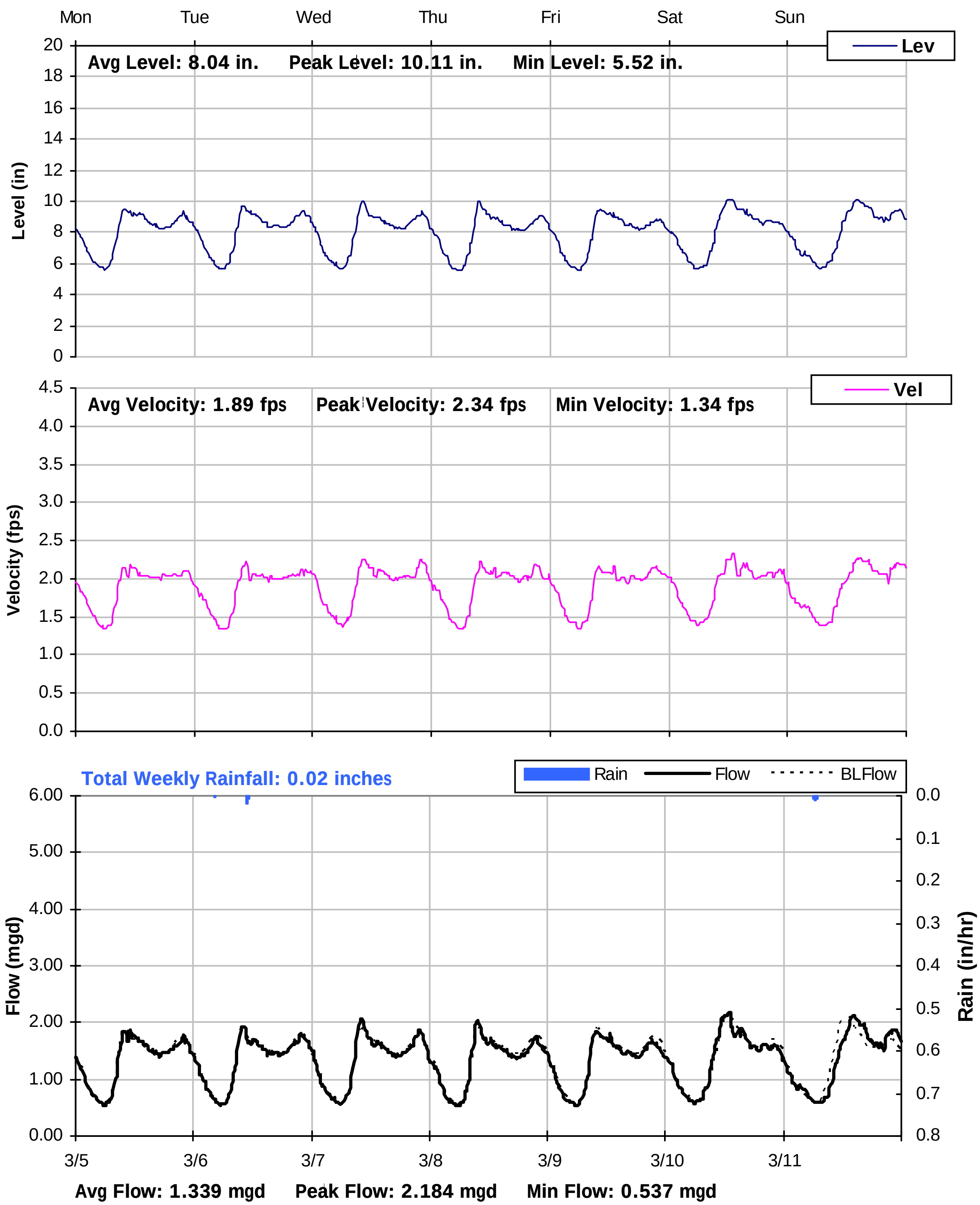
Avg Flow: 1.348 mgd **Peak Flow: 2.216 mgd** **Min Flow: 0.543 mgd**

SITE 1
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012

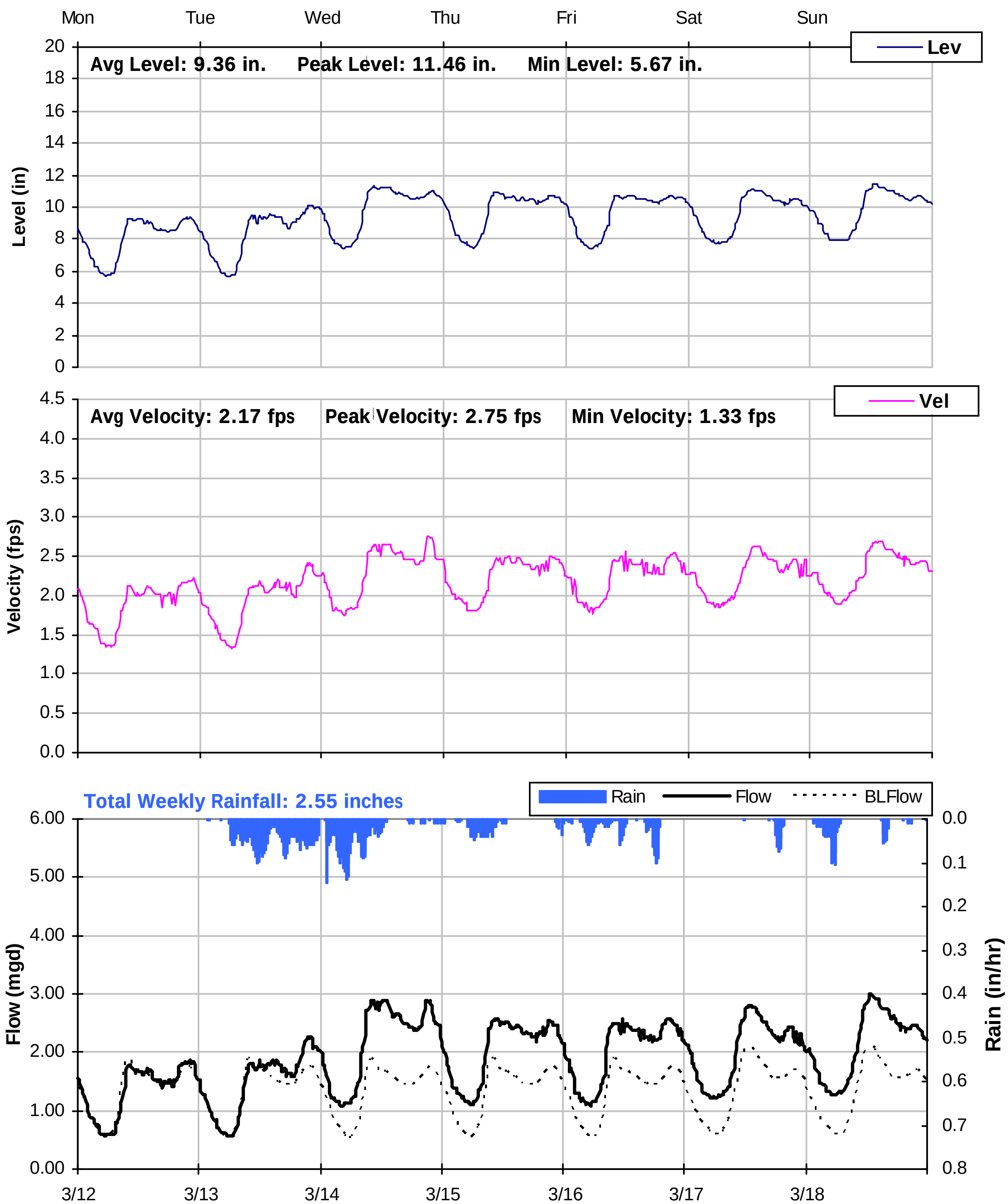


Avg Flow: 1.377 mgd **Peak Flow: 2.333 mgd** **Min Flow: 0.510 mgd**

SITE 1
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012

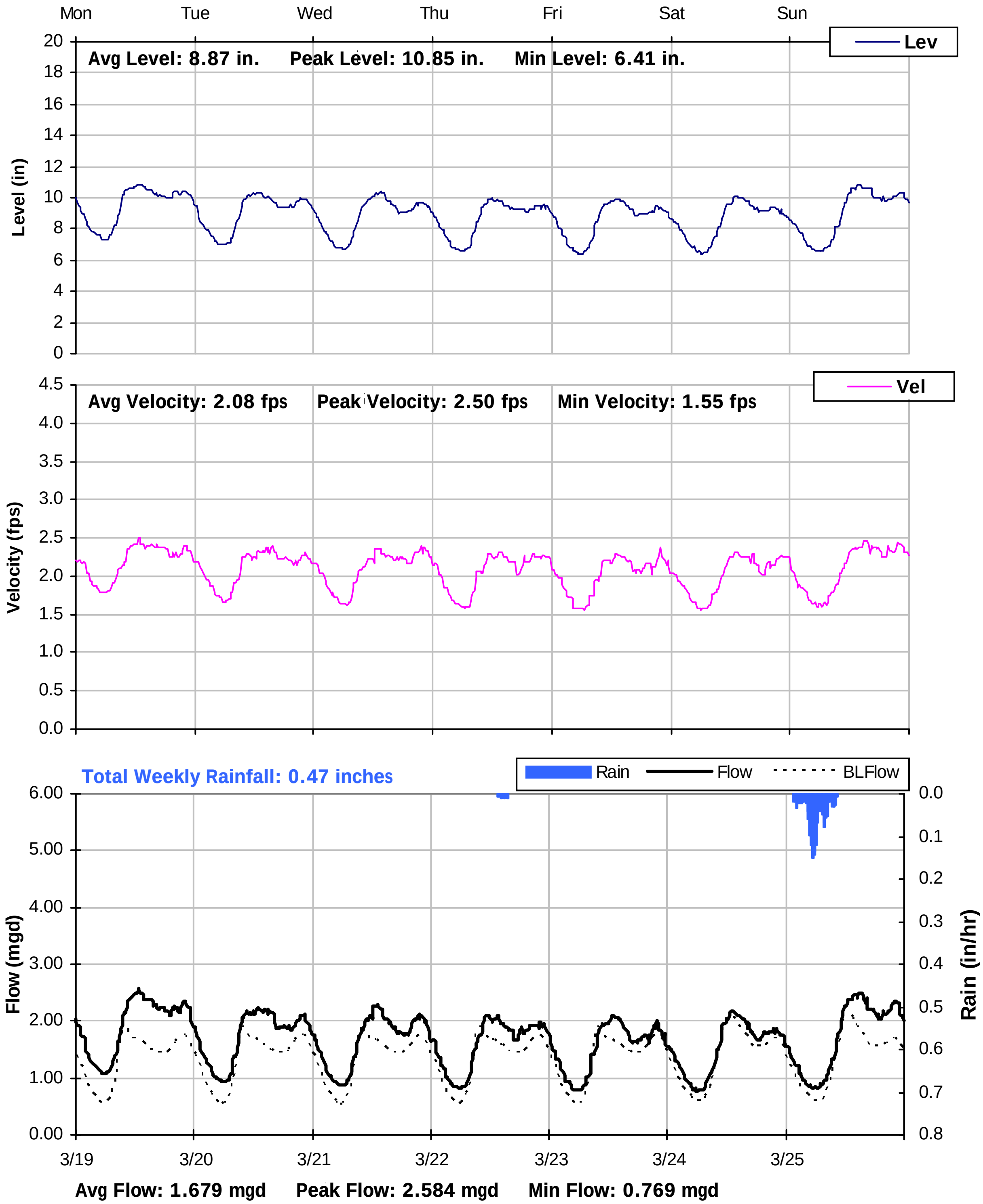


SITE 1
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012

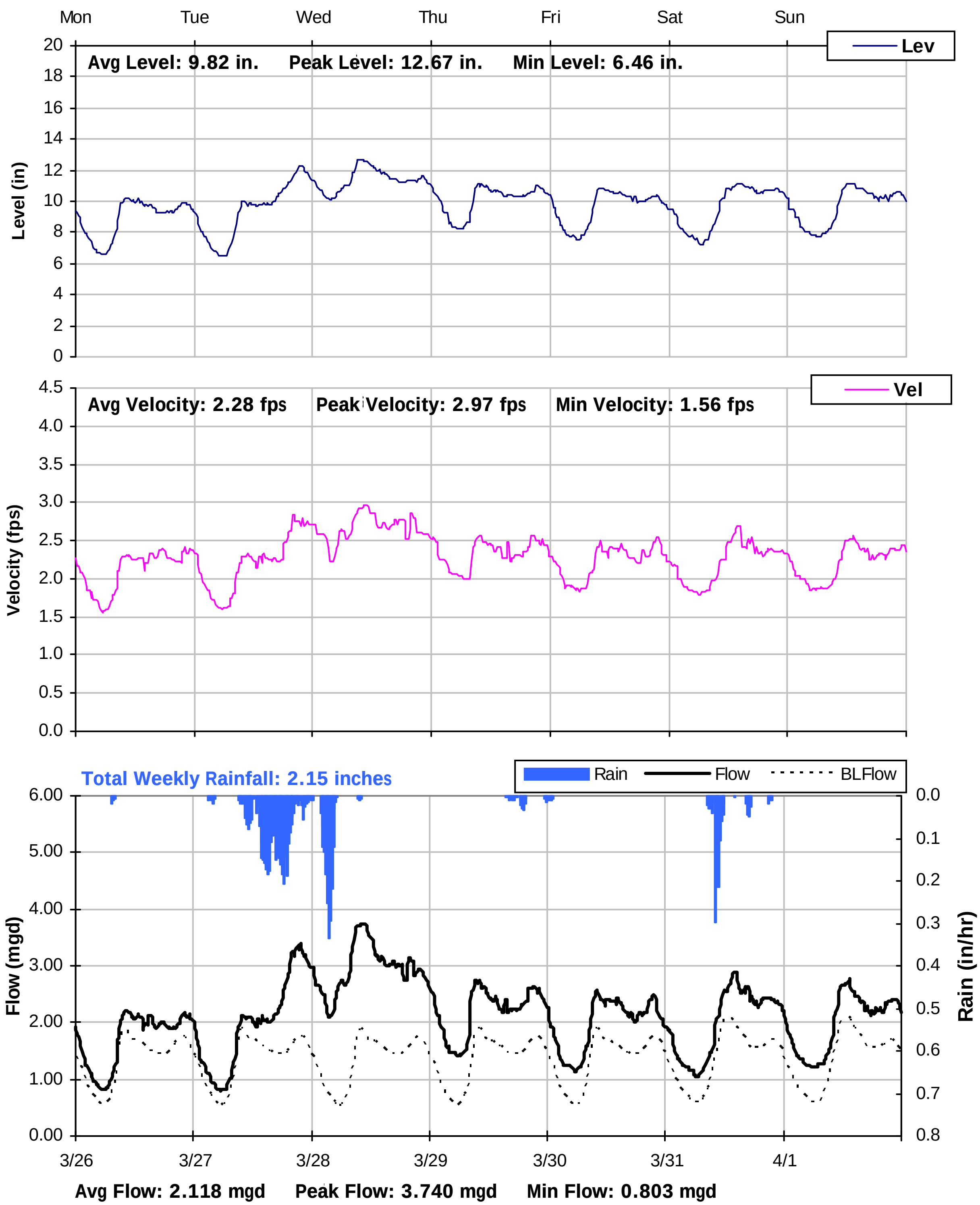


Avg Flow: 1.899 mgd Peak Flow: 3.008 mgd Min Flow: 0.562 mgd

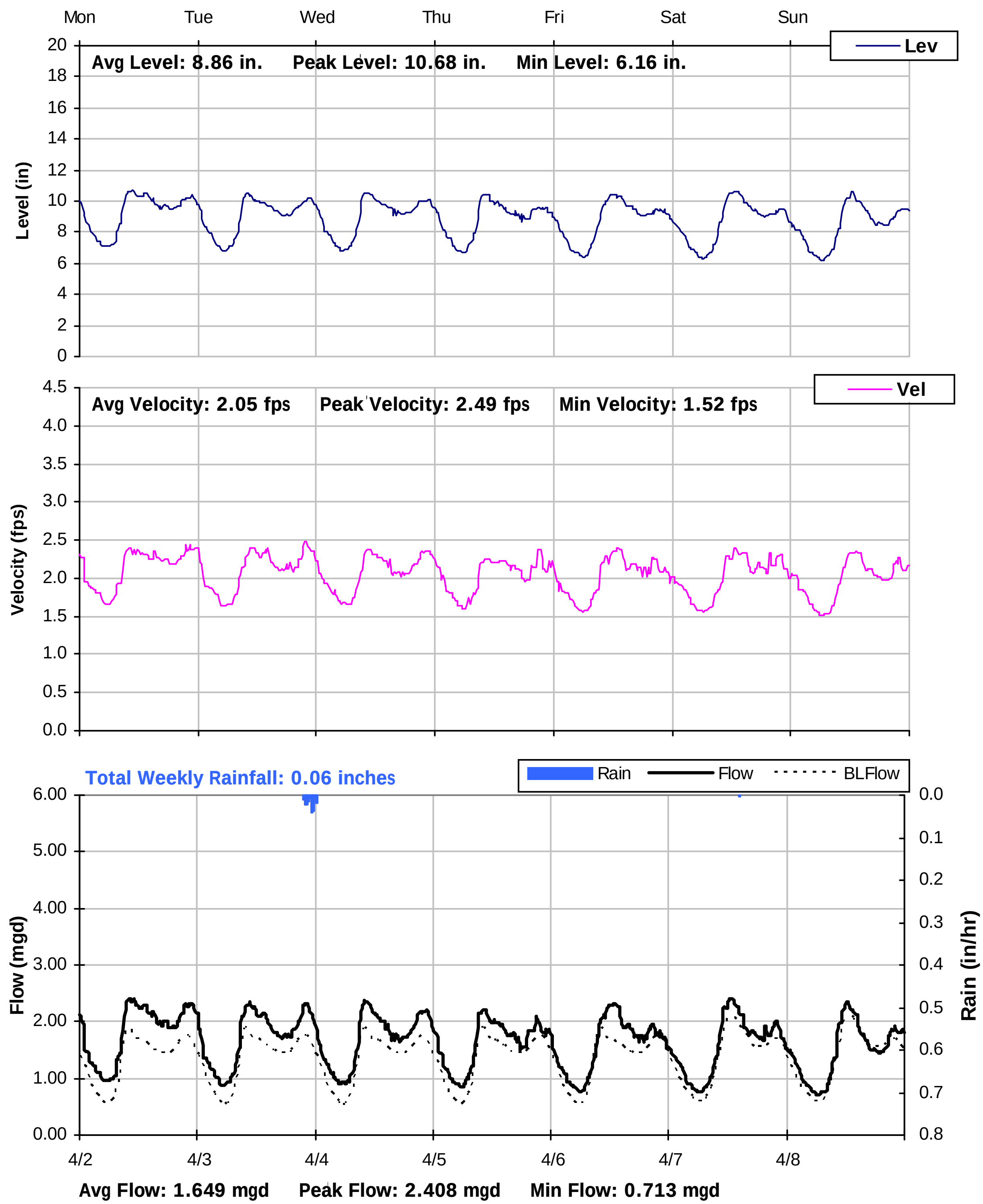
SITE 1
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



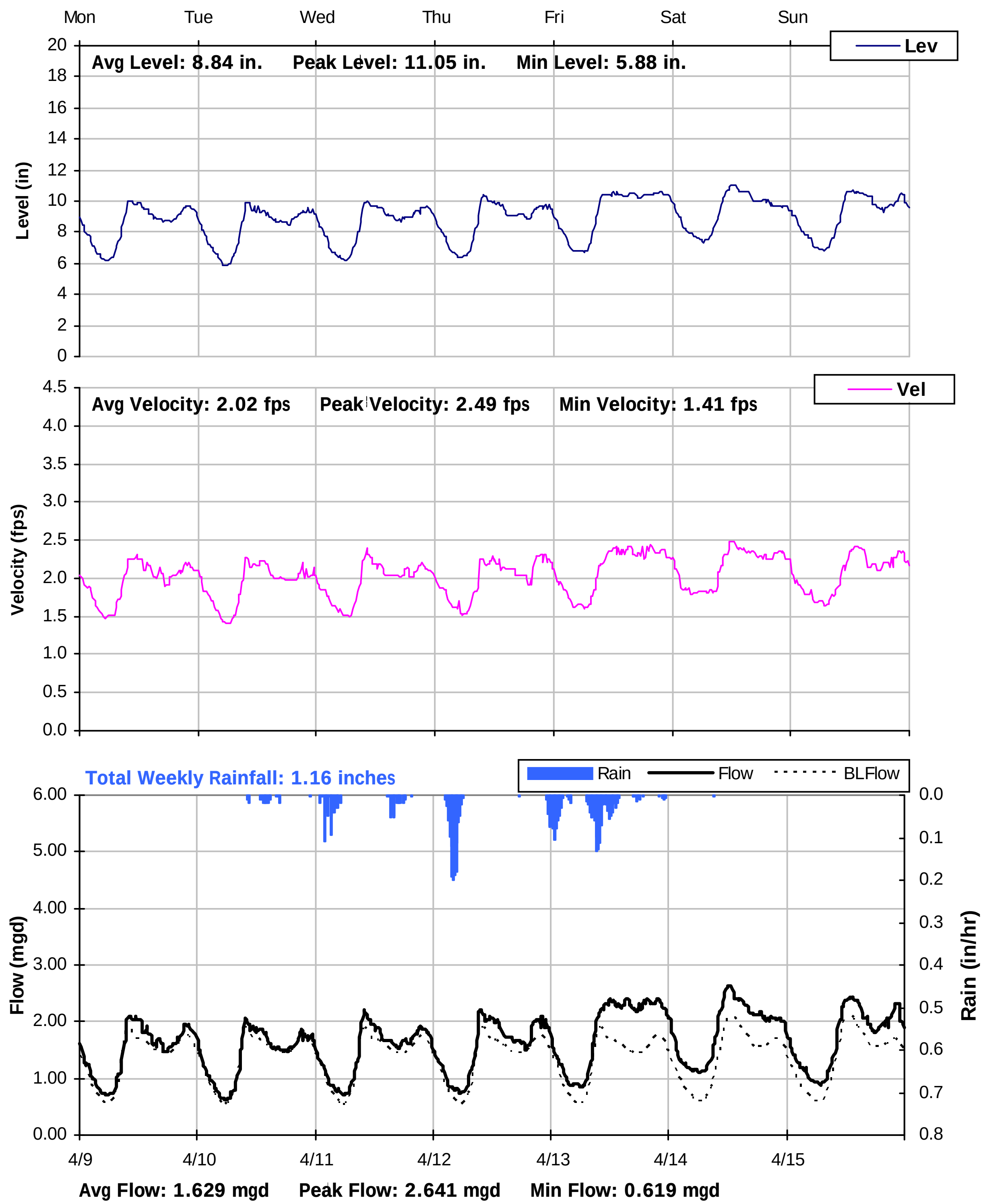
SITE 1
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



SITE 1
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



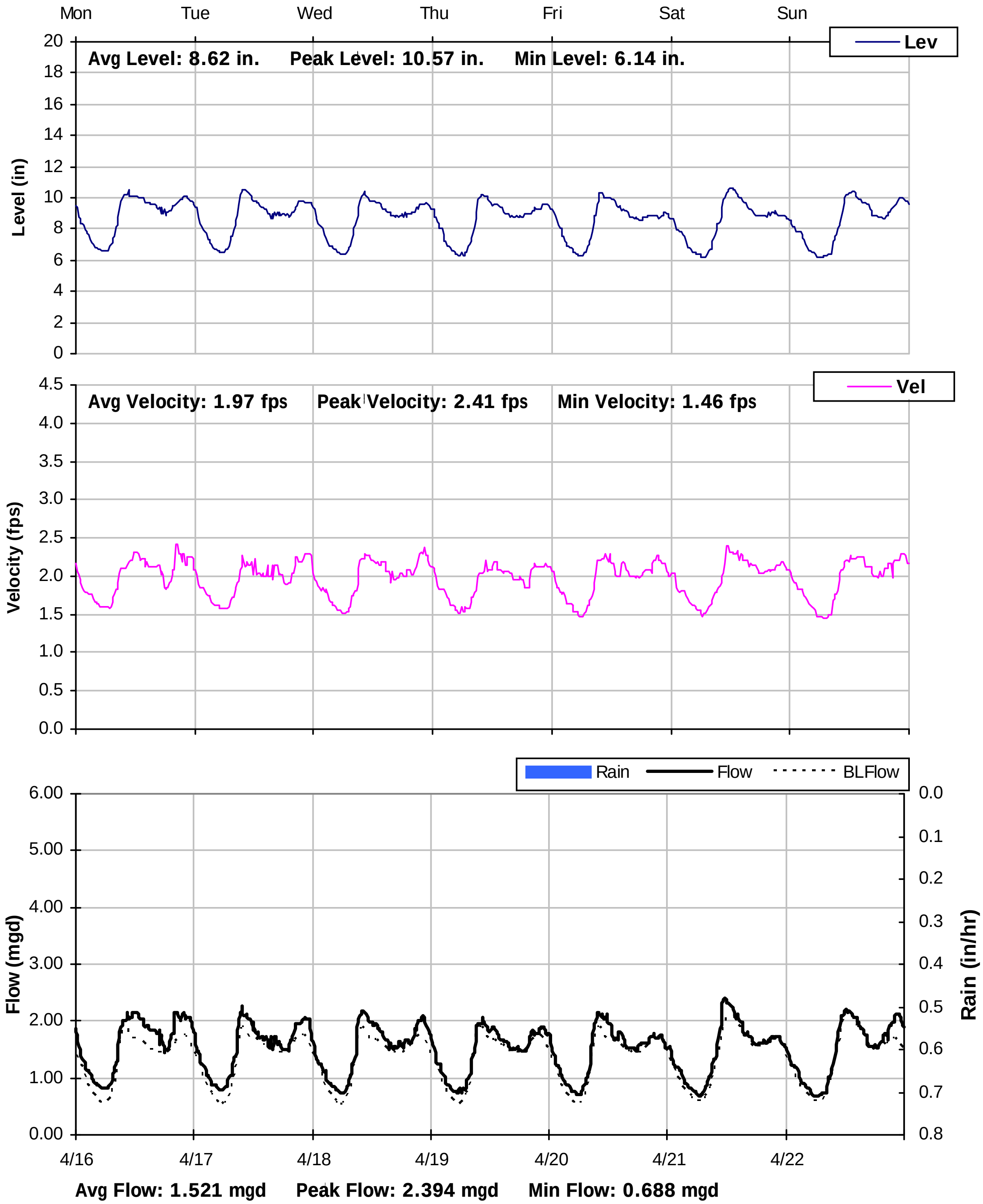
SITE 1
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



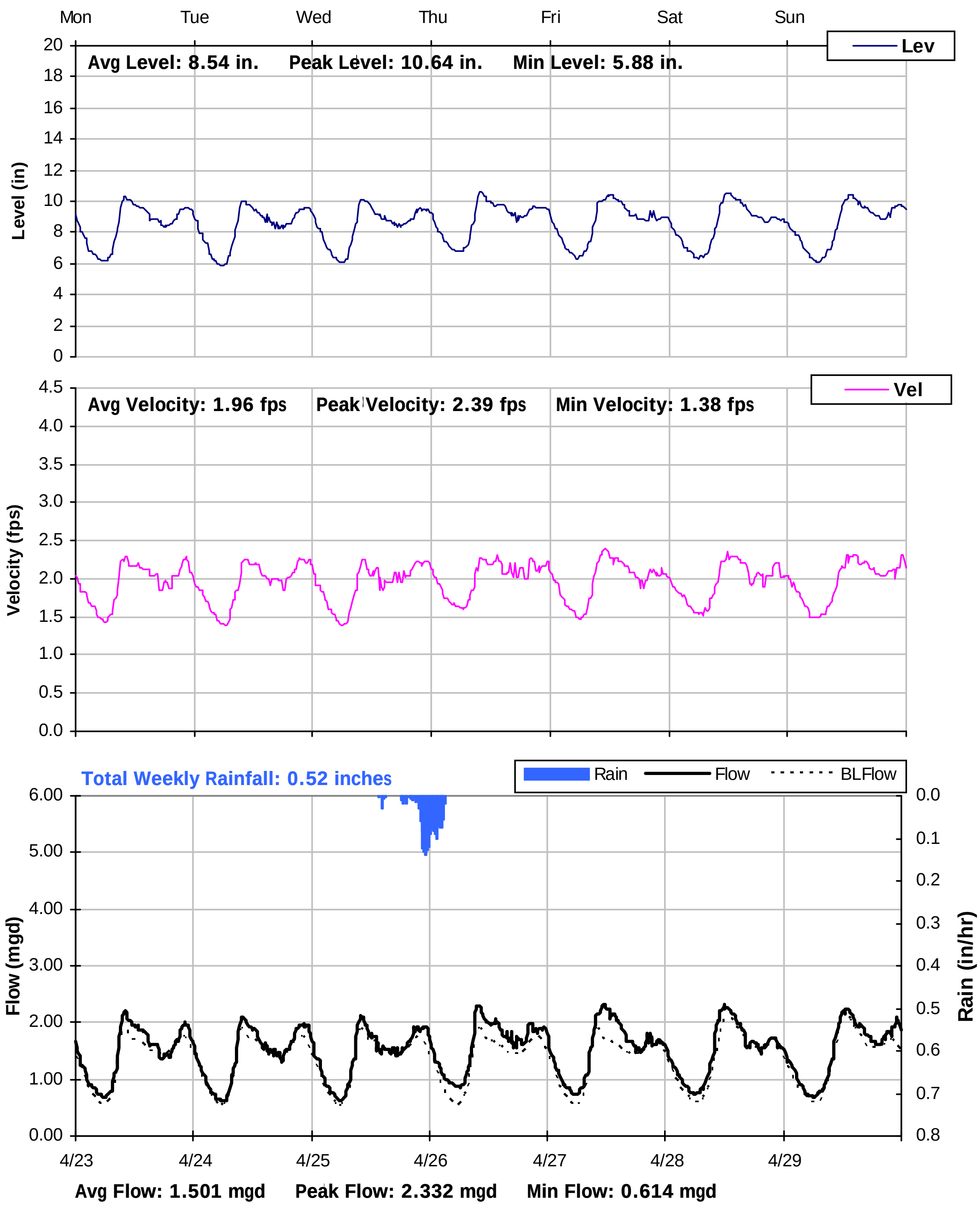
SITE 1

Weekly Level, Velocity and Flow Hydrographs

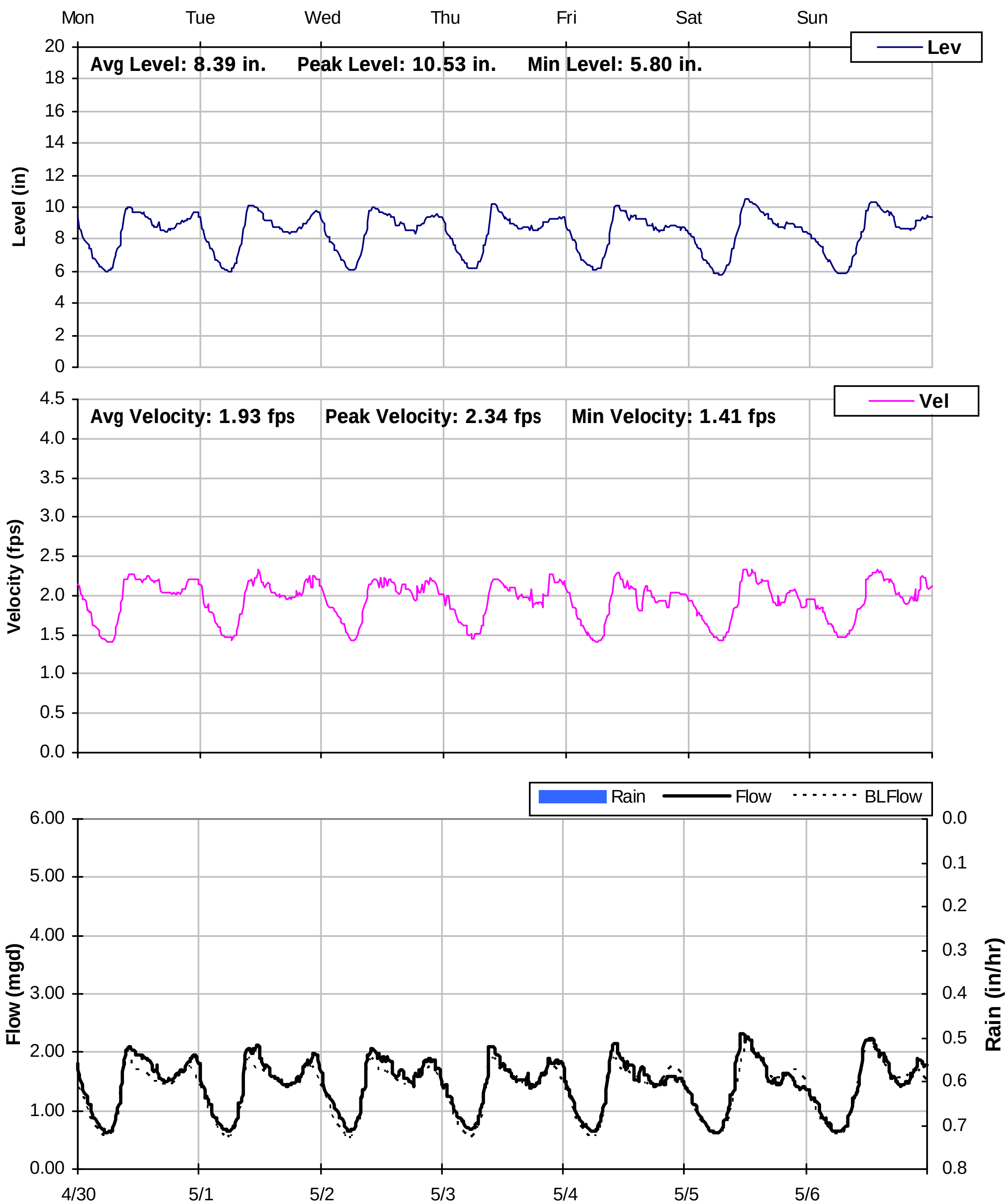
4/16/2012 to 4/23/2012



SITE 1
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 1
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



Avg Flow: 1.447 mgd **Peak Flow: 2.325 mgd** **Min Flow: 0.611 mgd**

City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 4

Location: Glenwood Avenue between W Sacramento Avenue and Oak Way

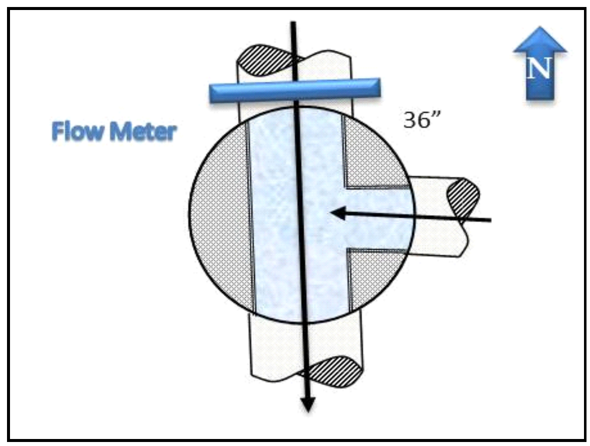
Vicinity Map:

SITE 4
Site Information Report

Location:	Glenwood Avenue between W Sacramento Avenue and Oak Way
Coordinates:	121.8818° W, 39.7338° N
Elevation:	167 feet
Diameter:	36 inches
Baseline Flow:	2.061 mgd
Peak Measured Flow:	5.176 mgd

Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

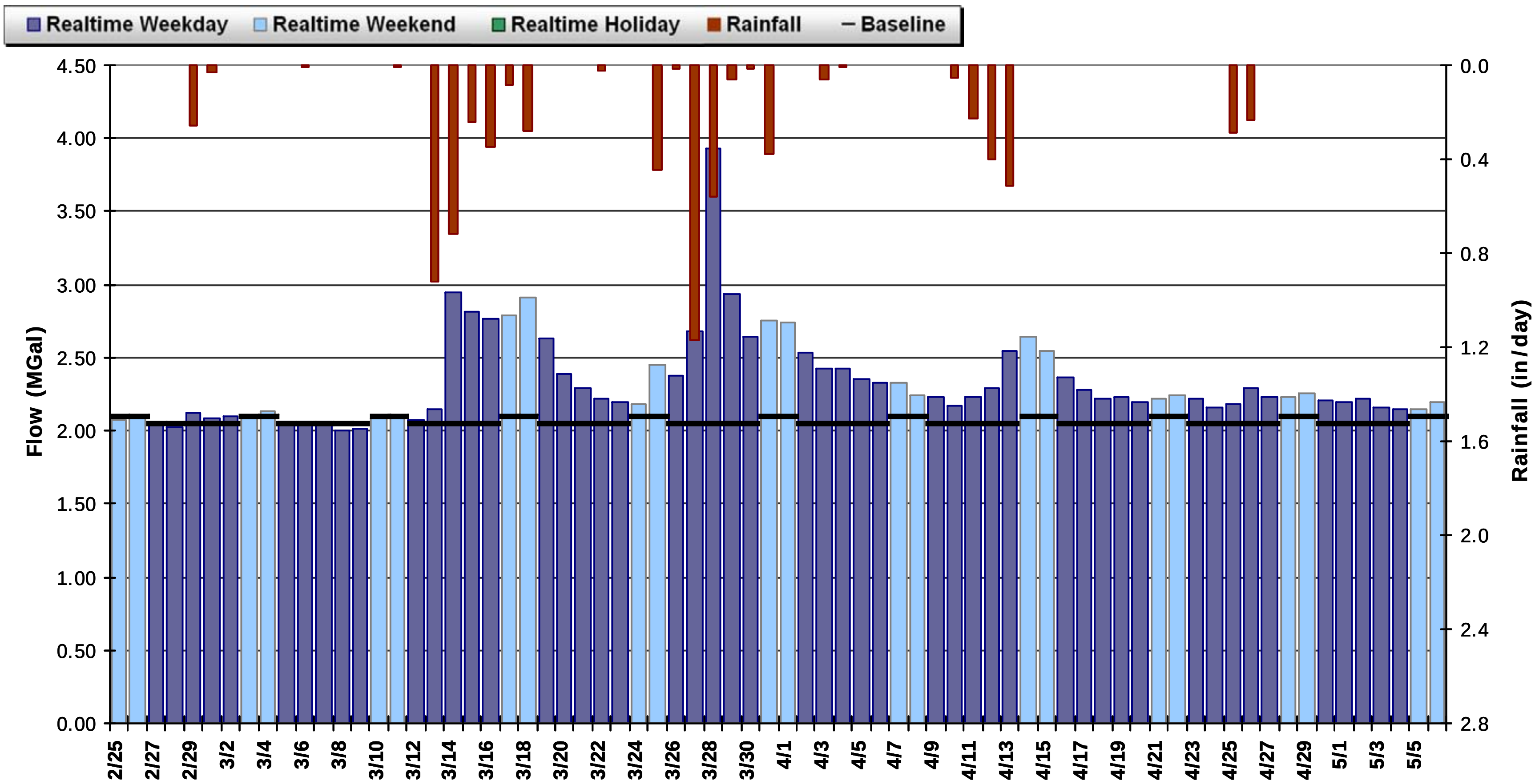
Plan View

SITE 4

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 2.333 MGal **Peak Daily Flow: 3.925 MGal** **Min Daily Flow: 2.005 MGal**

Total Period Rainfall: 7.34 inches

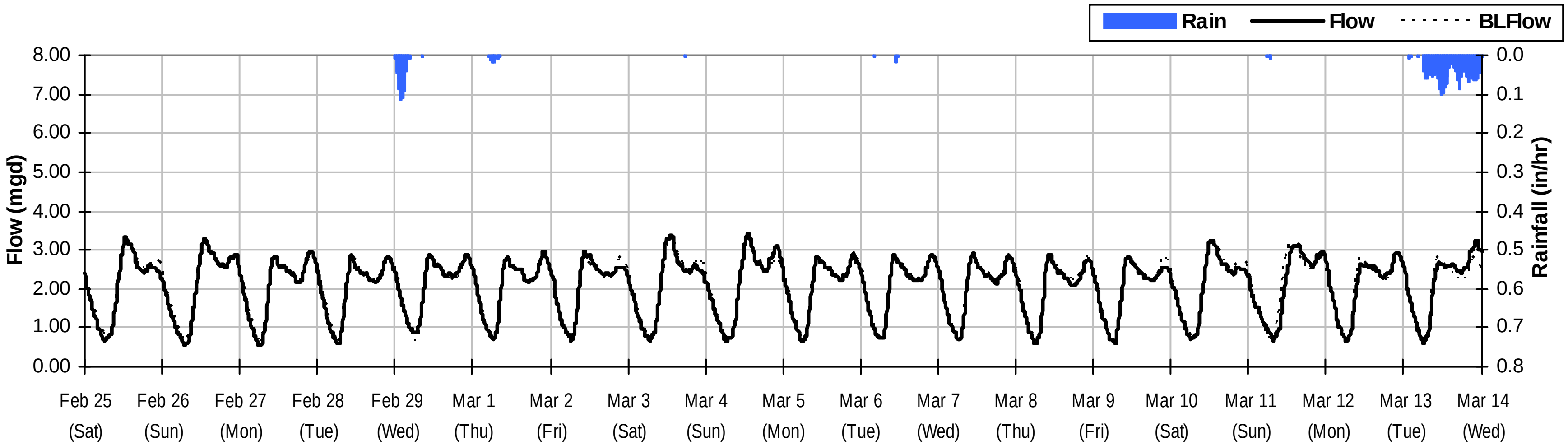


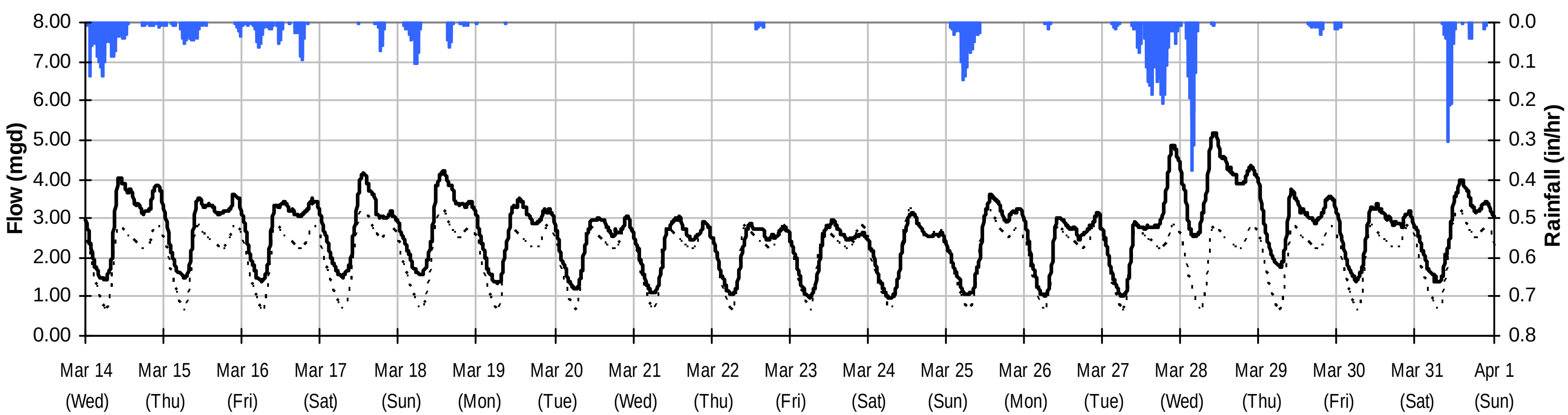
SITE 4

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 2.369 mgd **Peak Flow: 5.176 mgd** **Min Flow: 0.540 mgd**

Total Period Rainfall: 5.56 inches



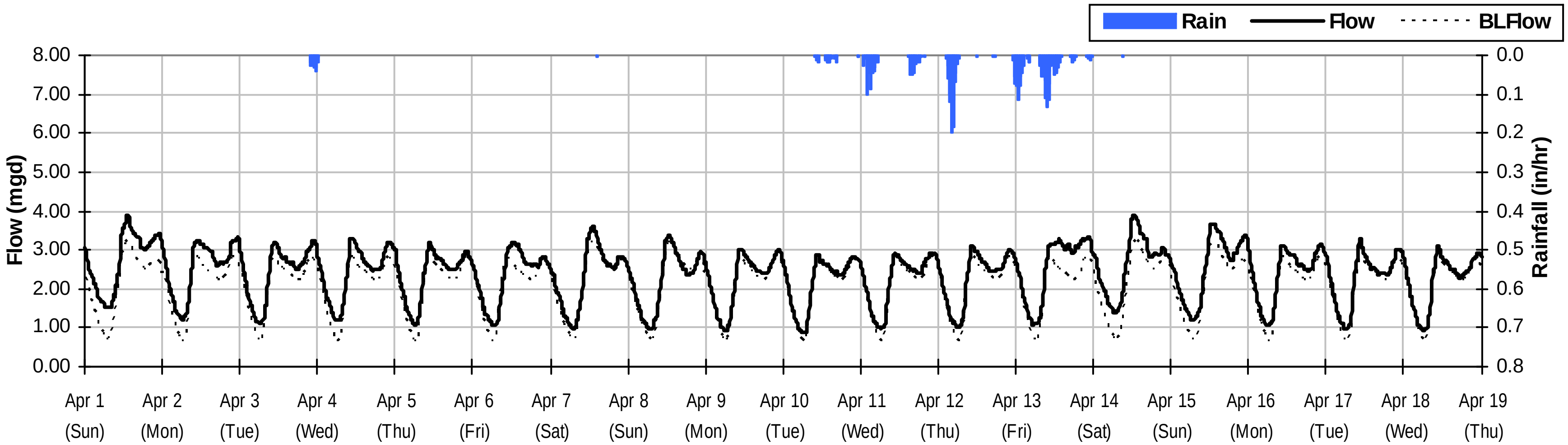


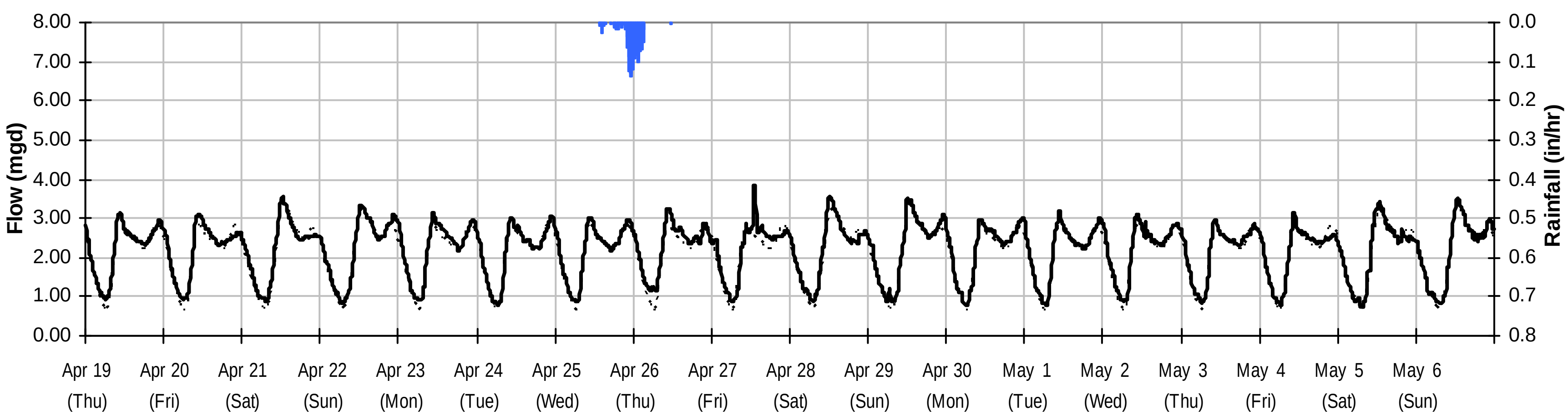
SITE 4

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 2.296 mgd **Peak Flow: 3.903 mgd** **Min Flow: 0.756 mgd**

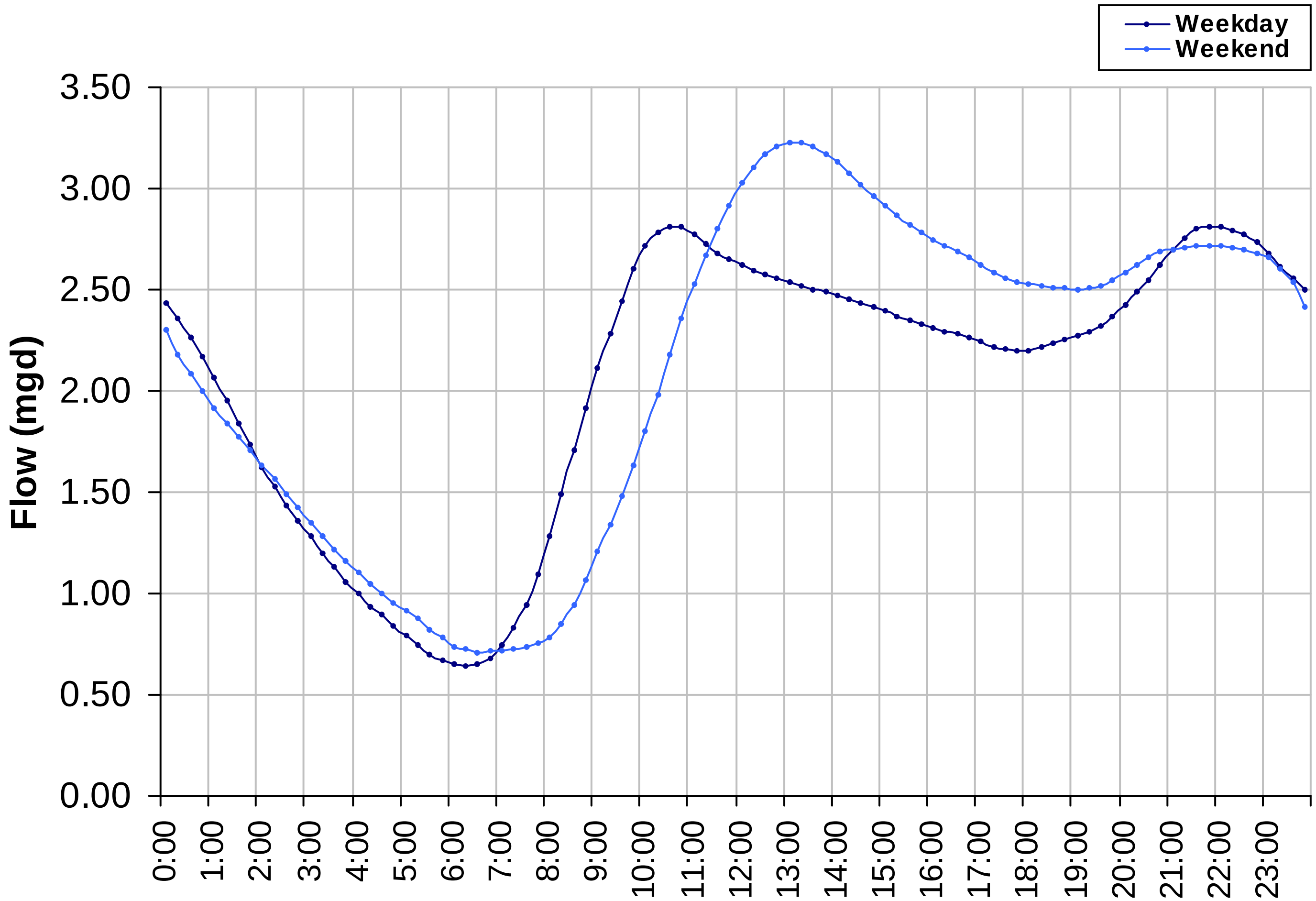
Total Period Rainfall: 1.78 inches





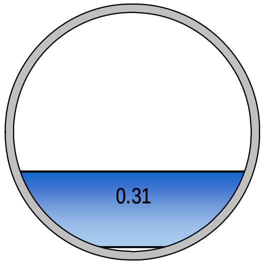
SITE 4

Baseline Flow Hydrographs



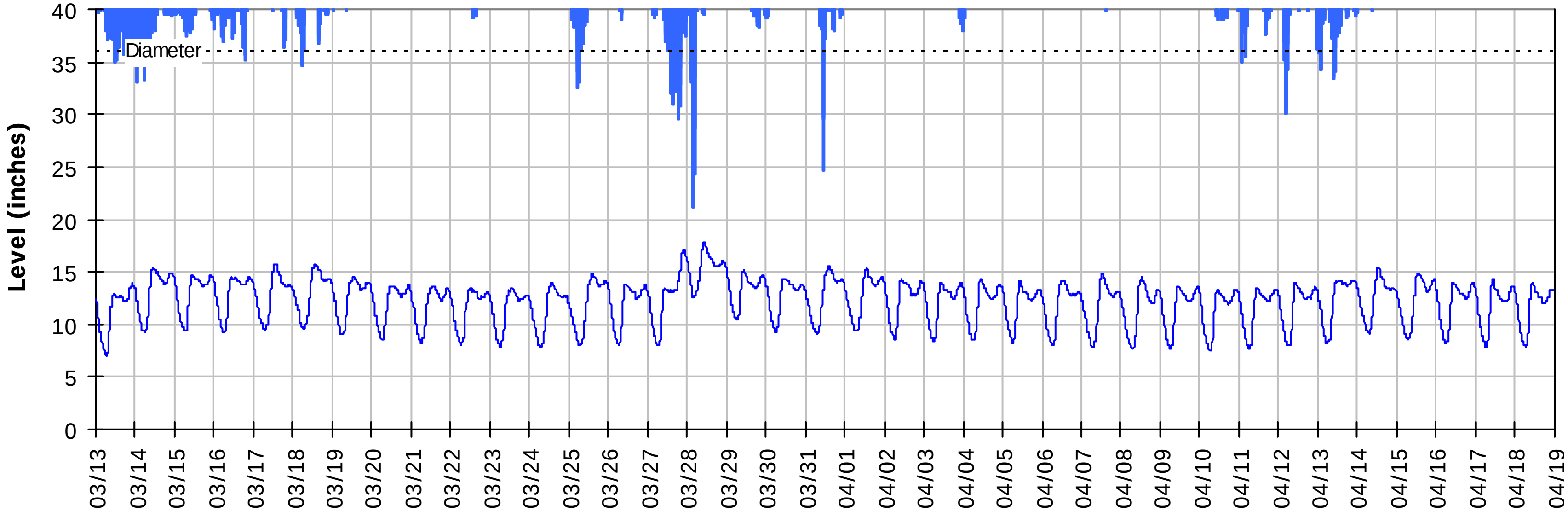
Baseline Flow:

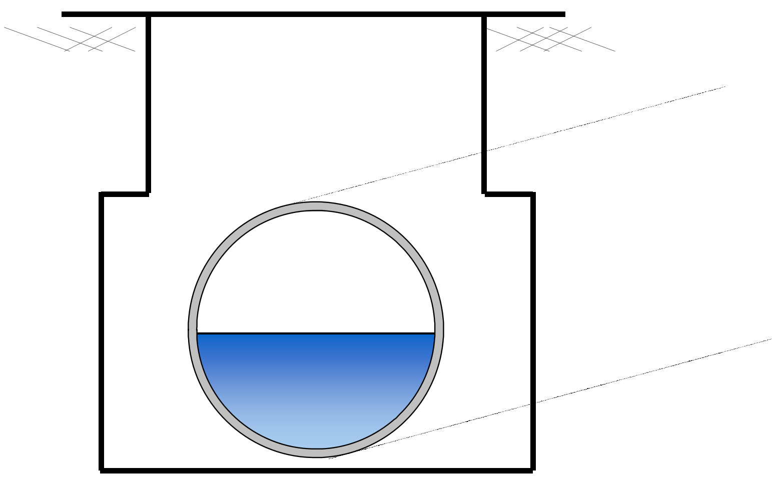
2.061 *mgd*



SITE 4
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

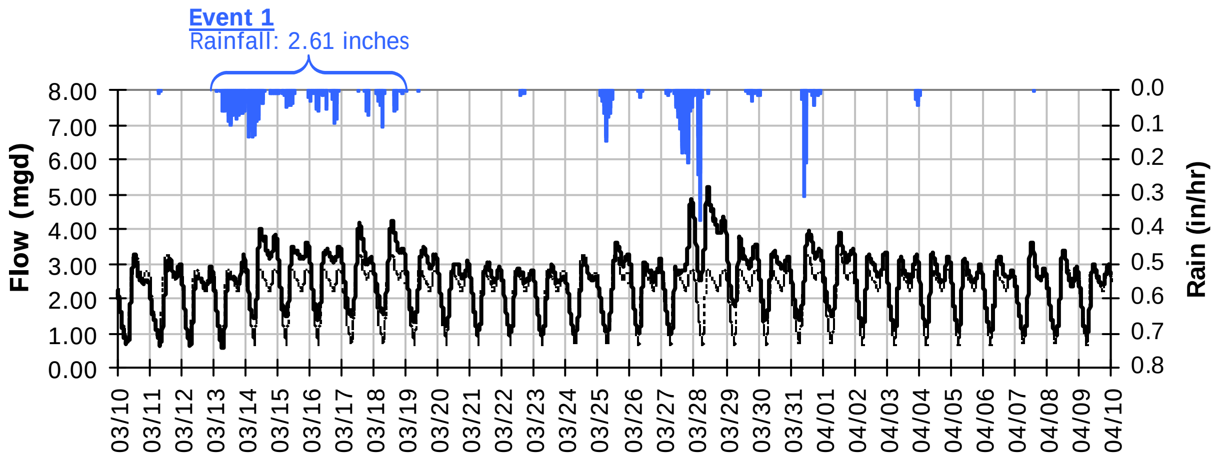




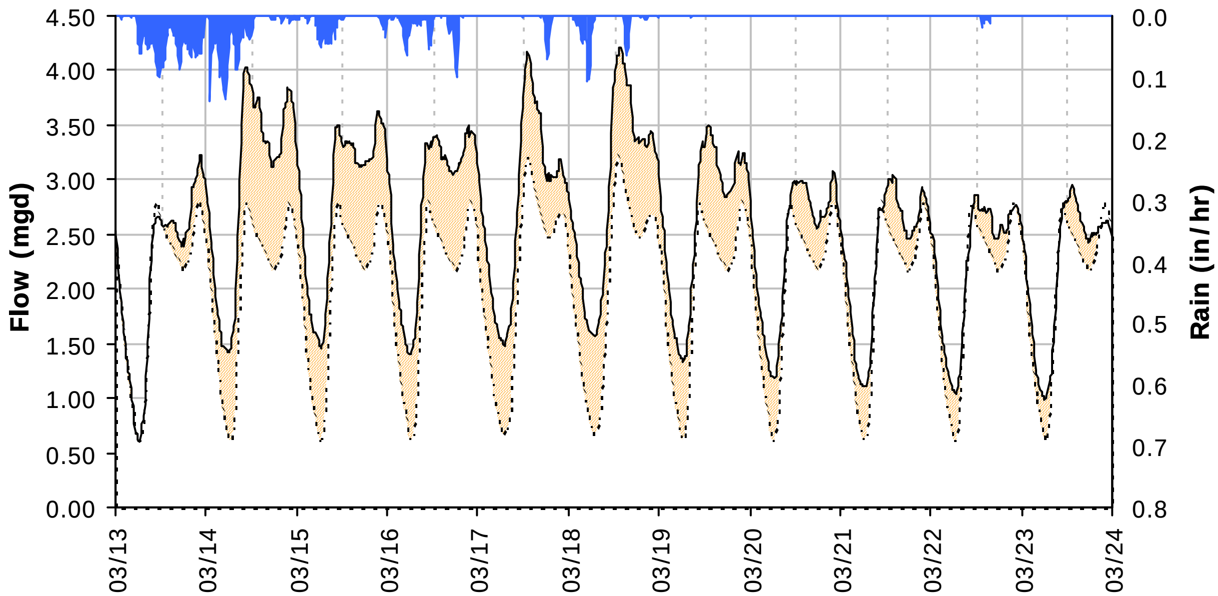
Pipe Diameter:	36	*inches*
Peak Measured Level:	17.8	*inches*
Peak d/D Ratio:	0.49	

SITE 4
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 = 2.61 inches)

Capacity

Peak Flow: 4.21 *mgd*
PF: 2.04
Peak Level: 15.77 *in*
d/D Ratio: 0.44

Inflow

Peak I/I Rate: 1.29 *mgd*
PkI/I:IDM: 1,359 *gpd/IDM*
PkI/I:Acre: 224 *gpd/acre*
Pk I/I:ADWF: 0.63

RDI (infiltration)

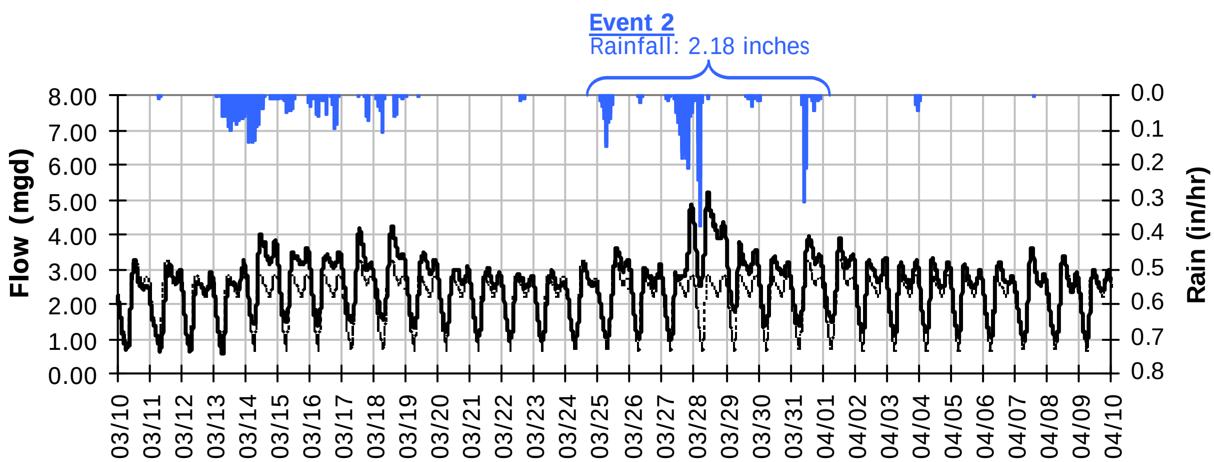
Infiltration Rate: 0.337 *mgd* (3/20/2012)
RDI:IDM: 355 *gpd/IDM*
RDI:Acre: 58 *gpd/acre*
RDI (% of BL): 16%

Combined I/I

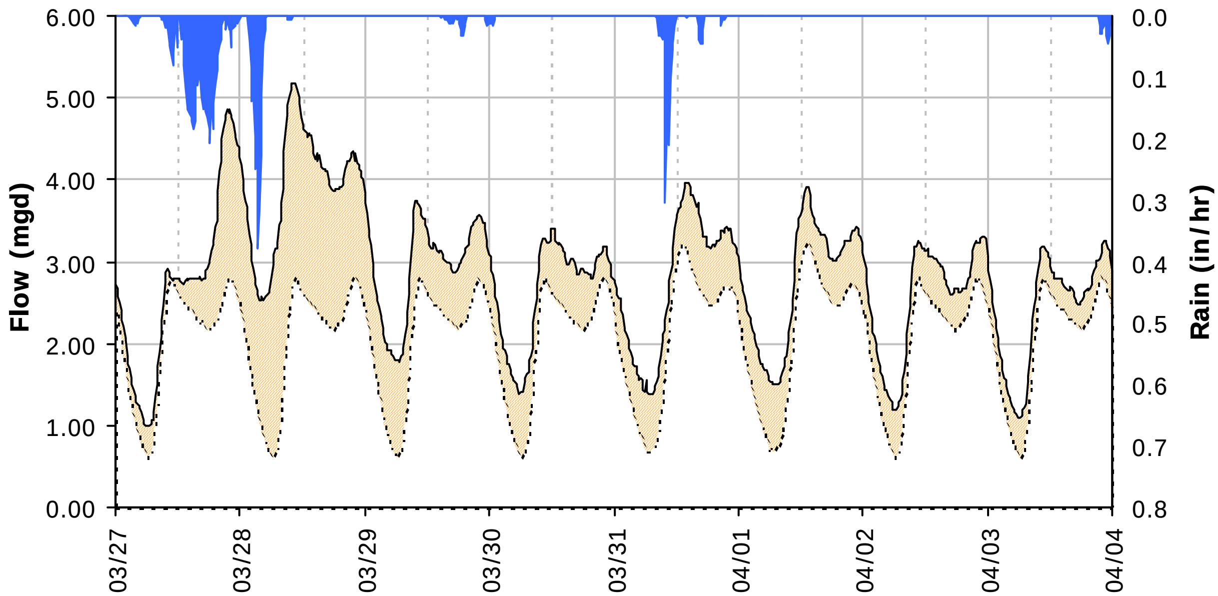
Total I/I: 5,819,000 *gallons*
Total I/I:IDM: 2,346 *gal/IDM/in*
R-Value: 1.4%
Total I/I:ADWF: 1.08 *per in-rain*

SITE 4
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 = 2.18 inches)

Capacity

Peak Flow: 5.18 *mgd*
PF: 2.51
Peak Level: 17.79 *in*
d/D Ratio: 0.49

Inflow

Peak I/I Rate: 2.68 *mgd*
PkI/I:IDM: 2,822 *gpd/IDM*
PkI/I:Acre: 465 *gpd/acre*
Pk I/I:ADWF: 1.30

RDI (infiltration)

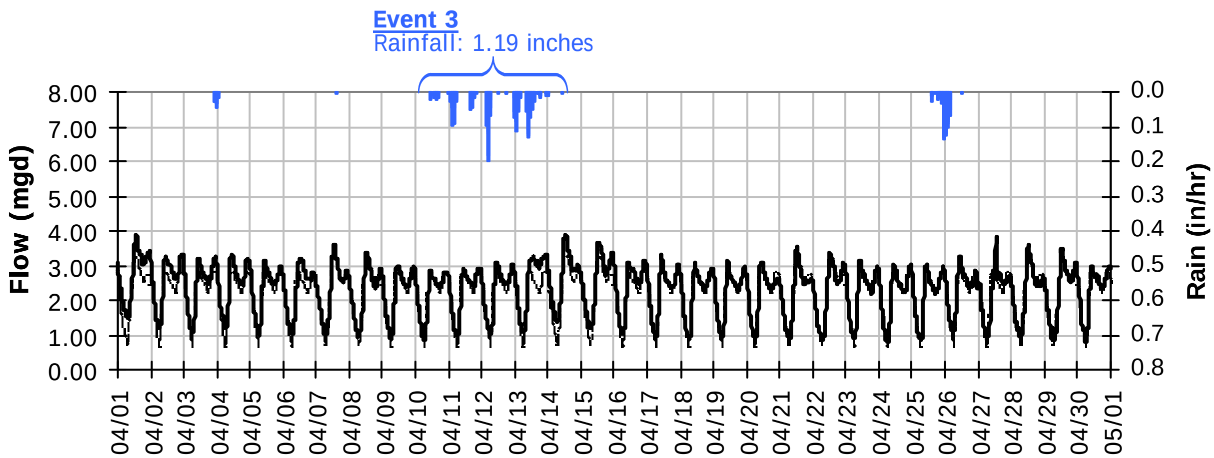
Infiltration Rate: 0.487 *mgd*
(4/2/2012)
RDI:IDM: 514 *gpd/IDM*
RDI:Acre: 85 *gpd/acre*
RDI (% of BL): 24%

Combined I/I

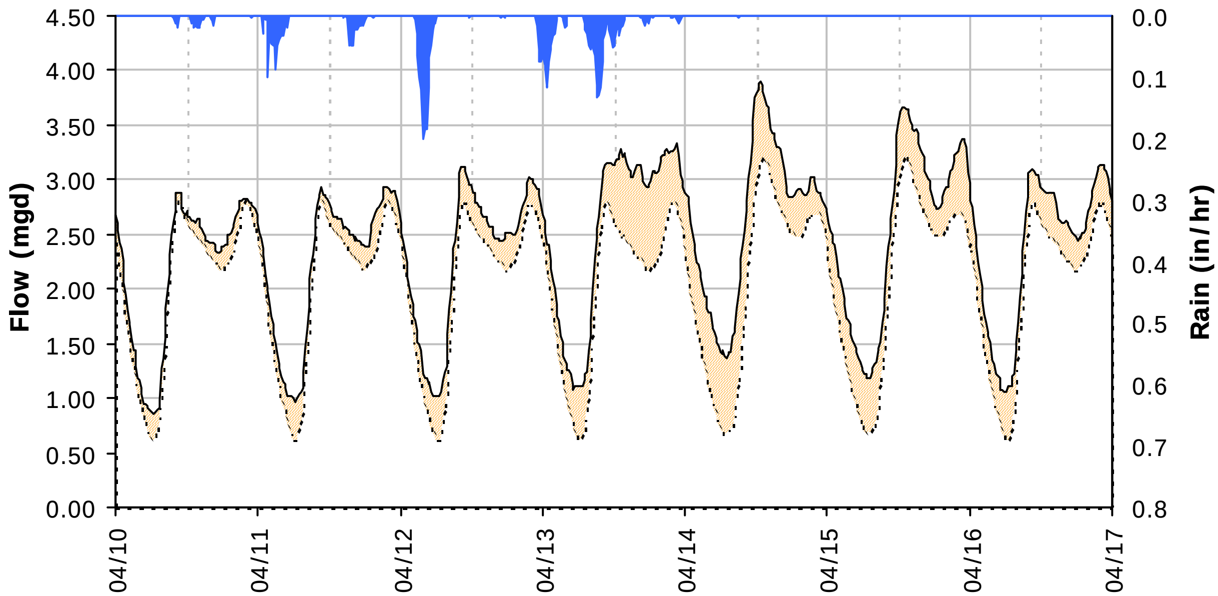
Total I/I: 6,413,000 *gallons*
Total I/I:IDM: 3,097 *gal/IDM/in*
R-Value: 1.9%
Total I/I:ADWF: 1.43 *per in-rain*

SITE 4
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.19 inches)

Capacity

Peak Flow: 3.90 *mgd*
PF: 1.89
Peak Level: 15.34 *in*
d/D Ratio: 0.43

Inflow

Peak I/I Rate: 0.85 *mgd*
PkI/I:IDM: 901 *gpd/IDM*
PkI/I:Acre: 148 *gpd/acre*
Pk I/I:ADWF: 0.41

RDI (infiltration)

Infiltration Rate: 0.450 *mgd*
(4/15/2012)
RDI:IDM: 474 *gpd/IDM*
RDI:Acre: 78 *gpd/acre*
RDI (% of BL): 21%

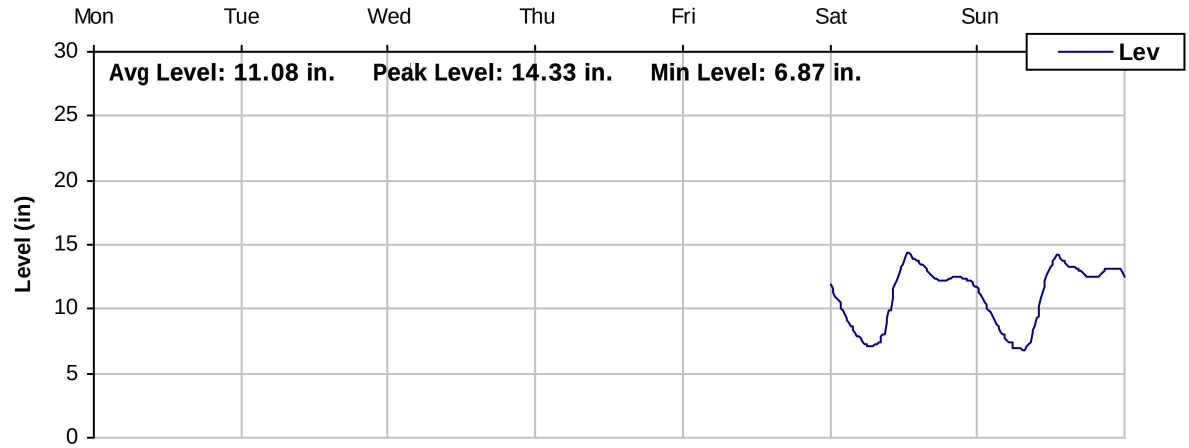
Combined I/I

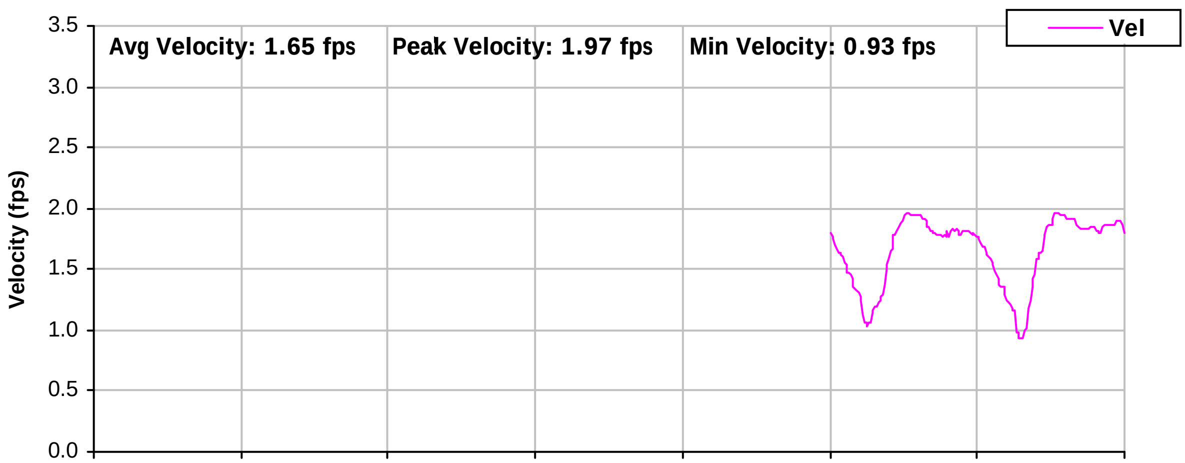
Total I/I: 2,603,000 *gallons*
Total I/I:IDM: 2,307 *gal/IDM/in*
R-Value: 1.4%
Total I/I:ADWF: 1.06 *per in-rain*

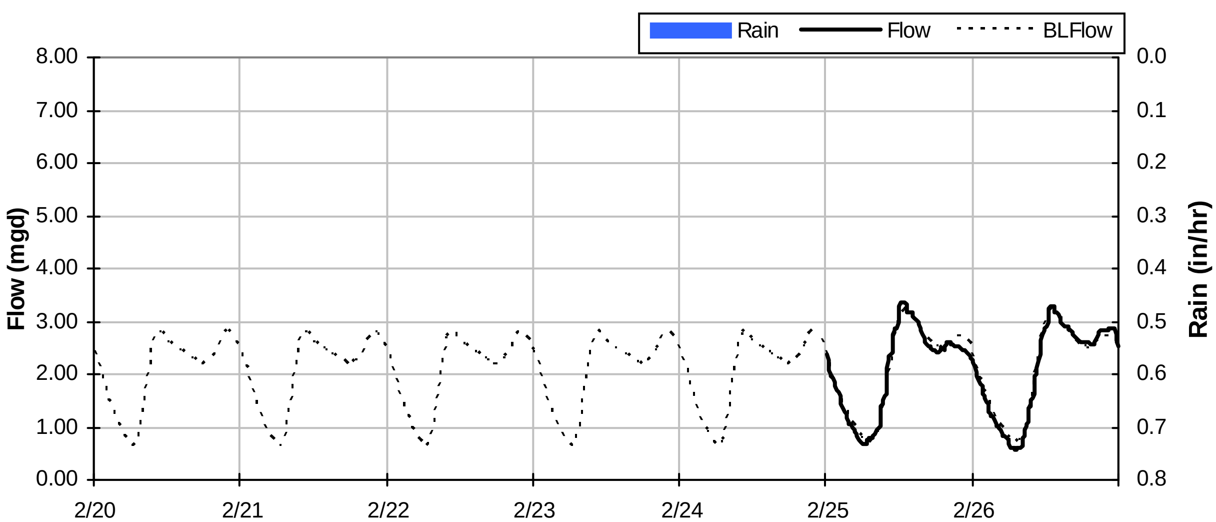
SITE 4

Weekly Level, Velocity and Flow Hydrographs

2/20/2012 to 2/27/2012





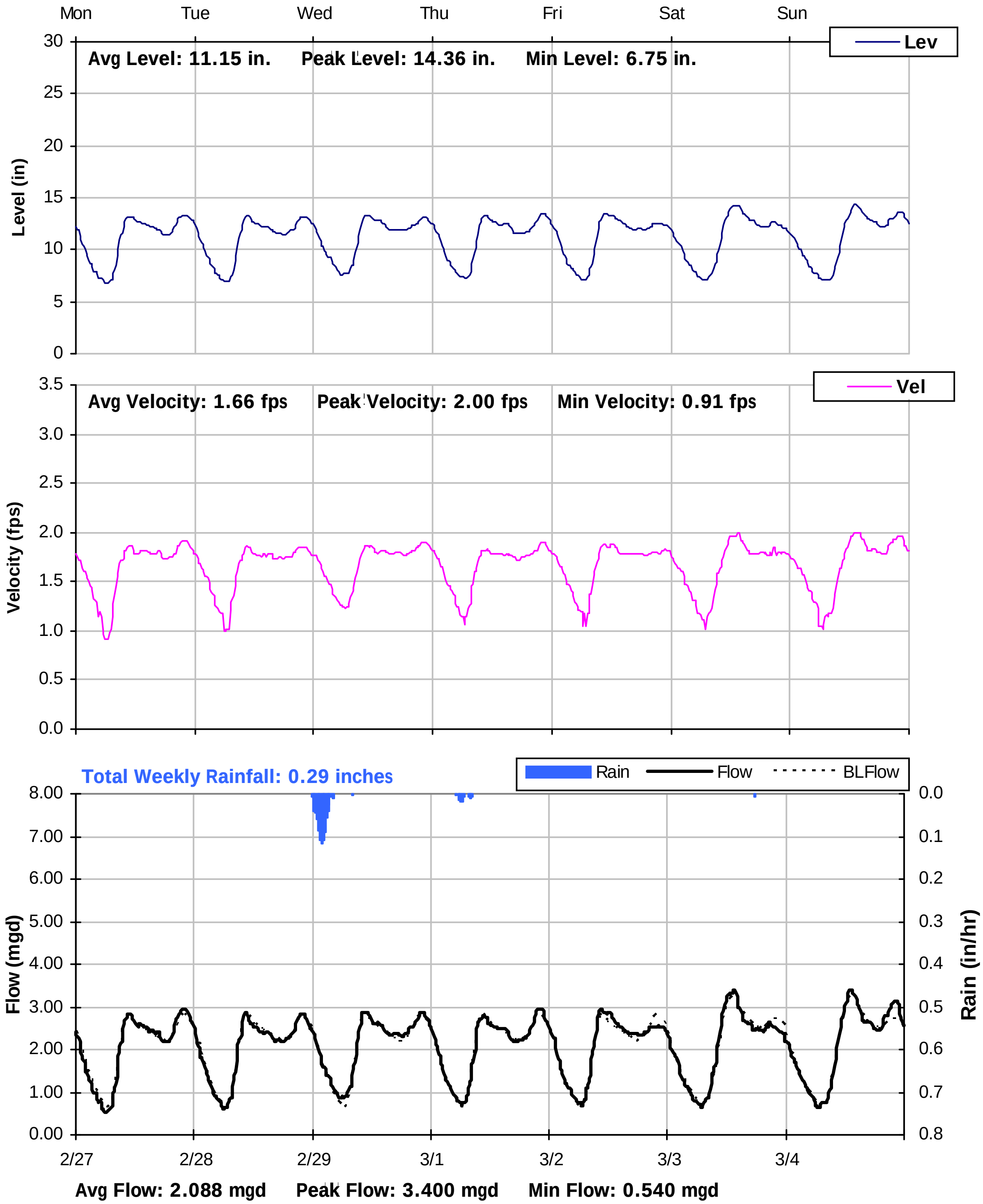


Avg Flow: 2.086 mgd **Peak Flow: 3.340 mgd** **Min Flow: 0.566 mgd**

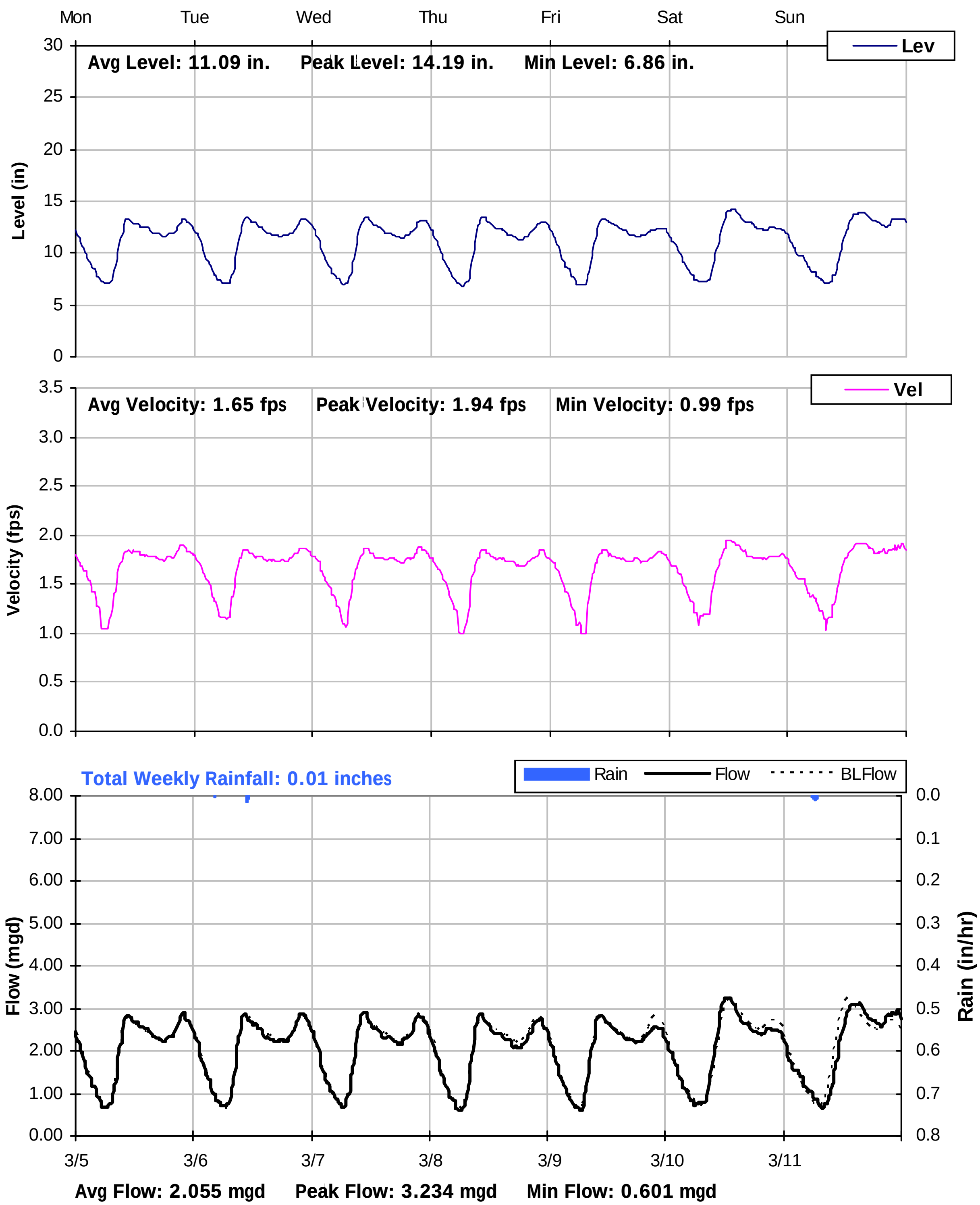
SITE 4

Weekly Level, Velocity and Flow Hydrographs

2/27/2012 to 3/5/2012



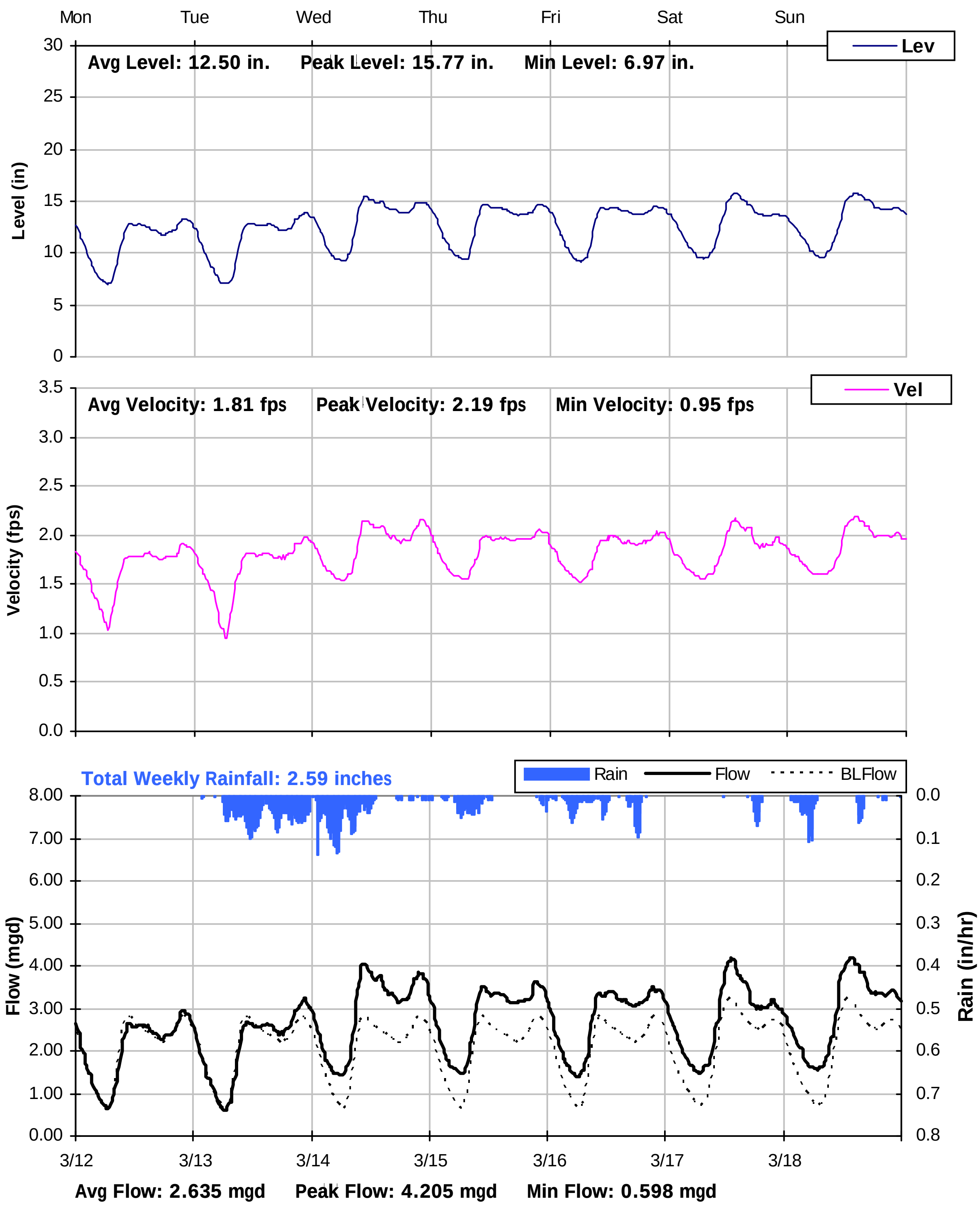
SITE 4
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



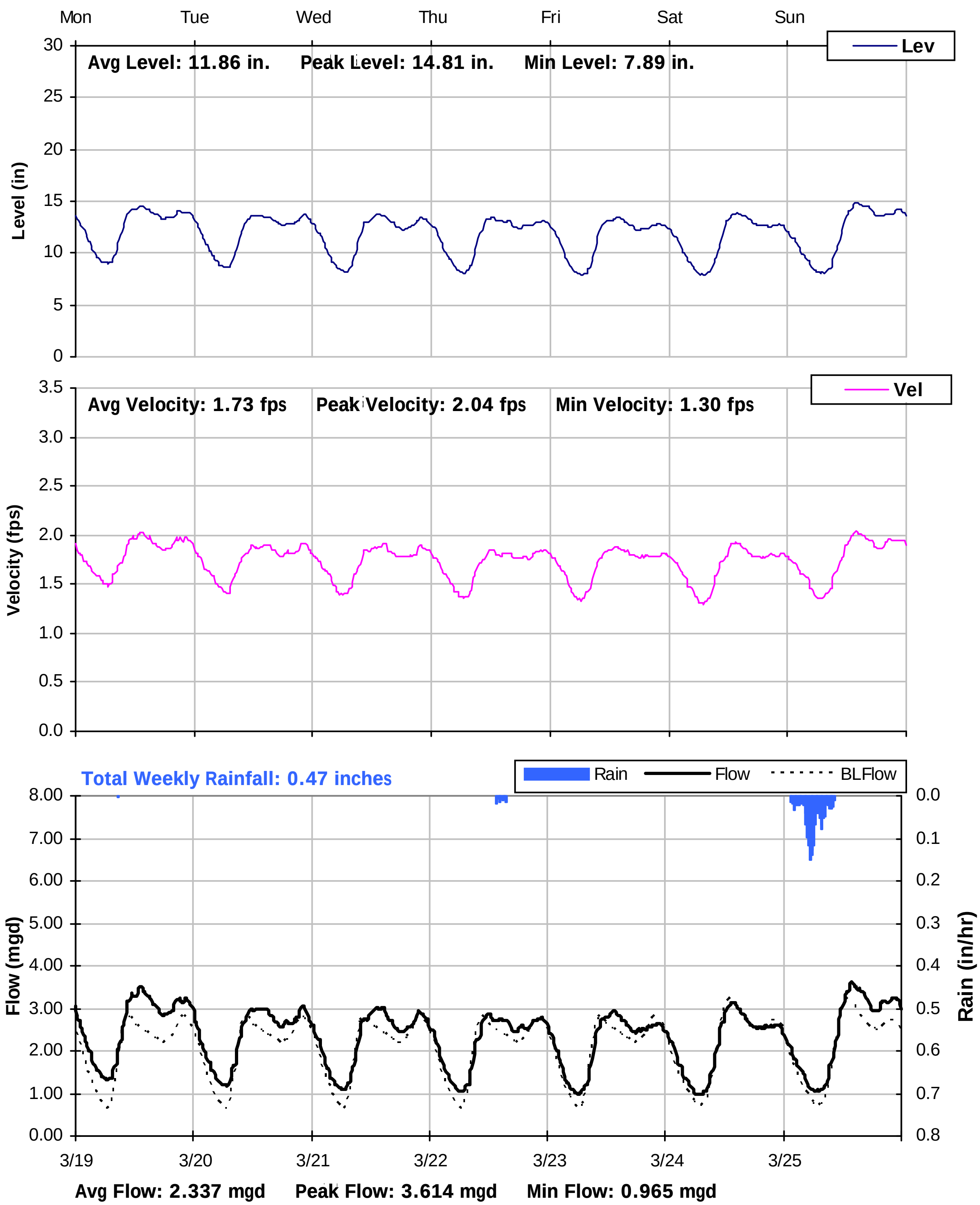
SITE 4

Weekly Level, Velocity and Flow Hydrographs

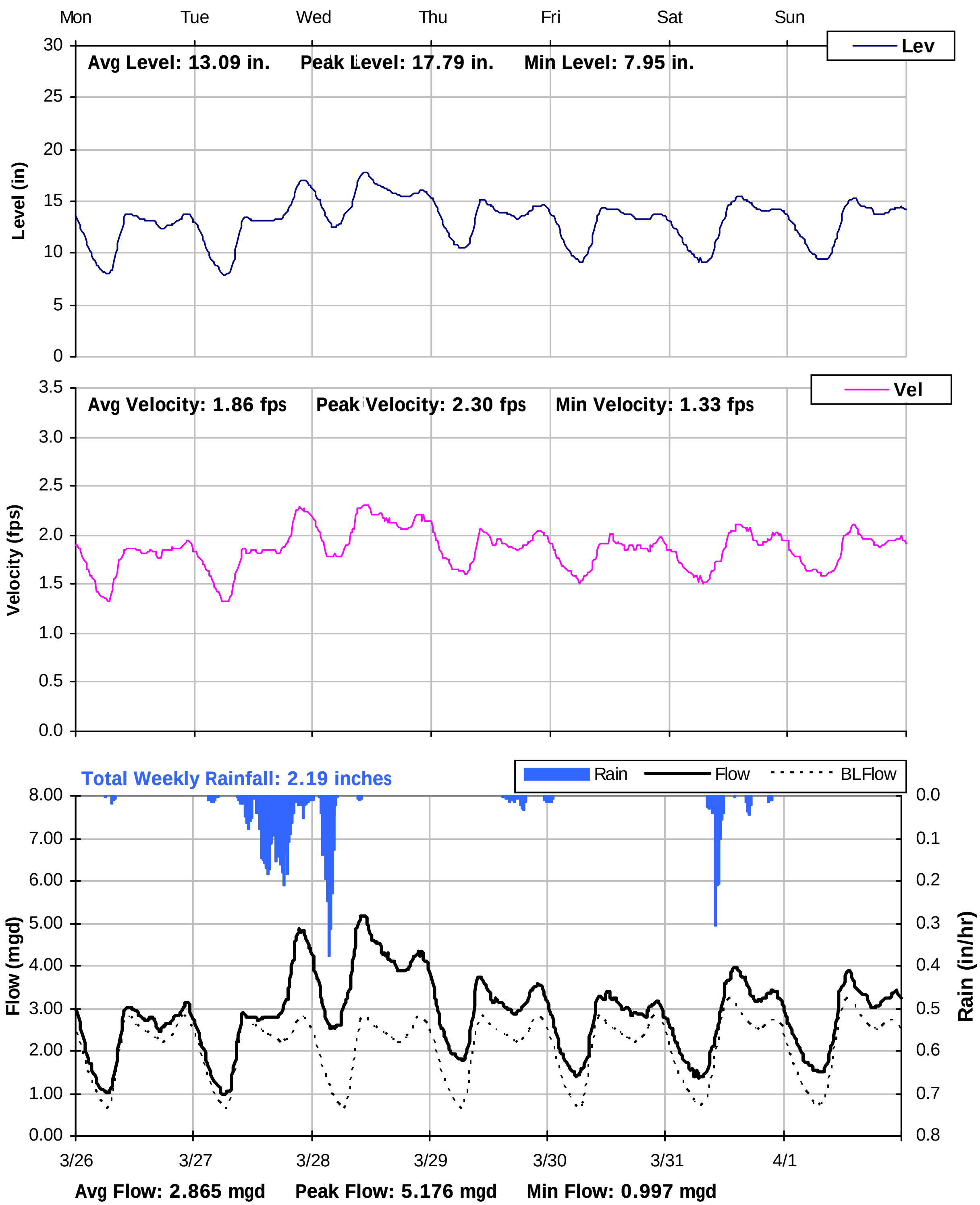
3/12/2012 to 3/19/2012



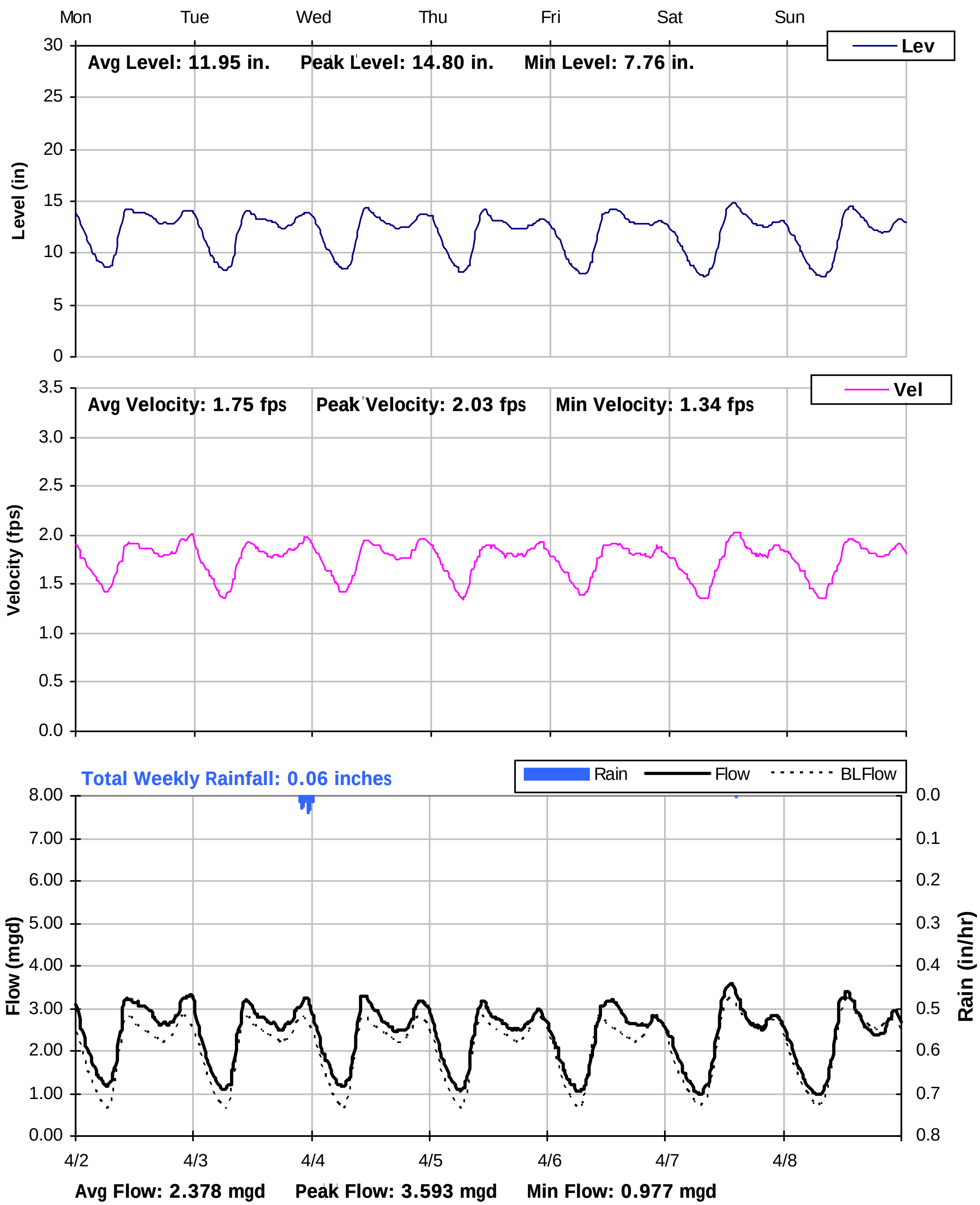
SITE 4
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



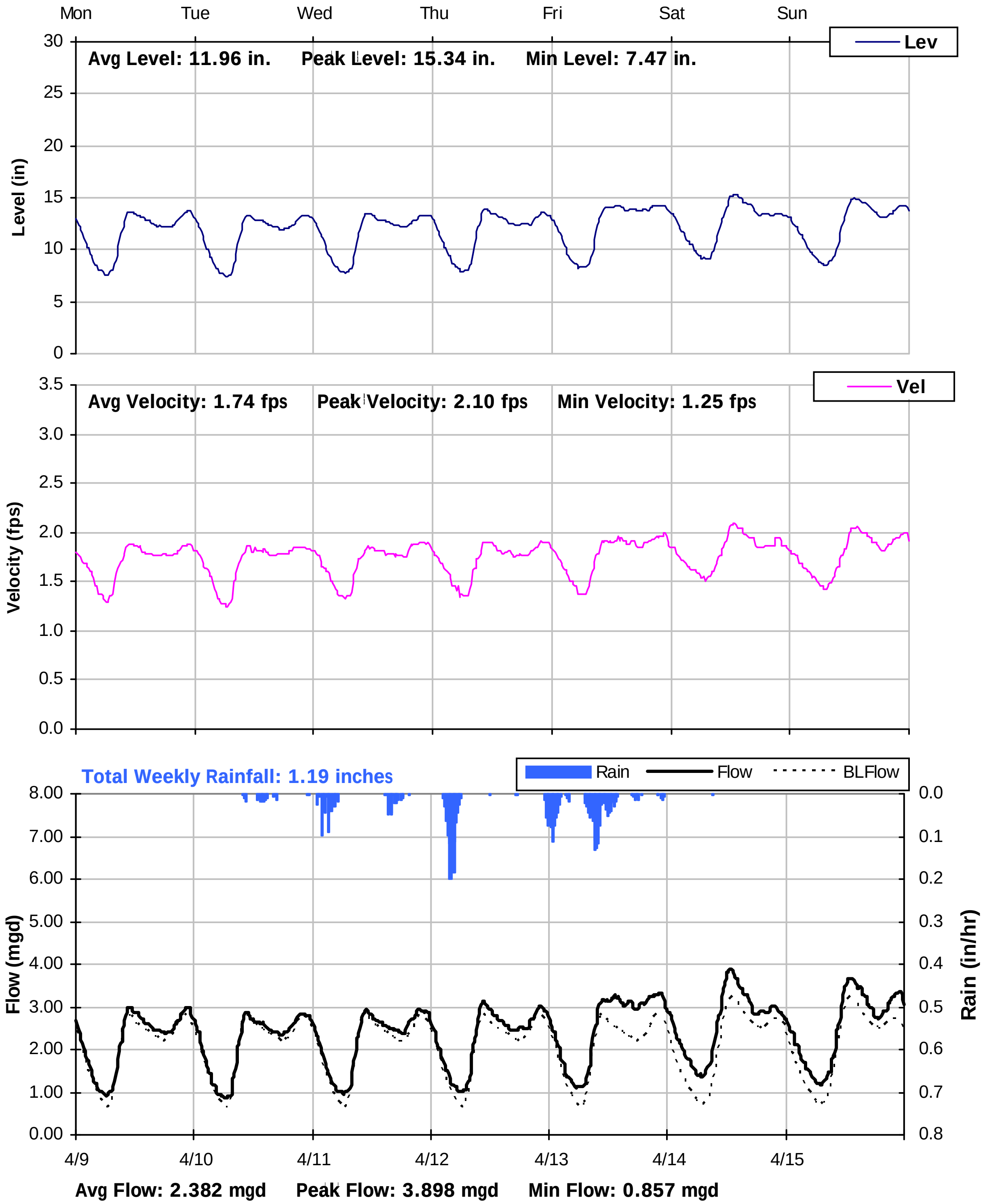
SITE 4
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



SITE 4
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



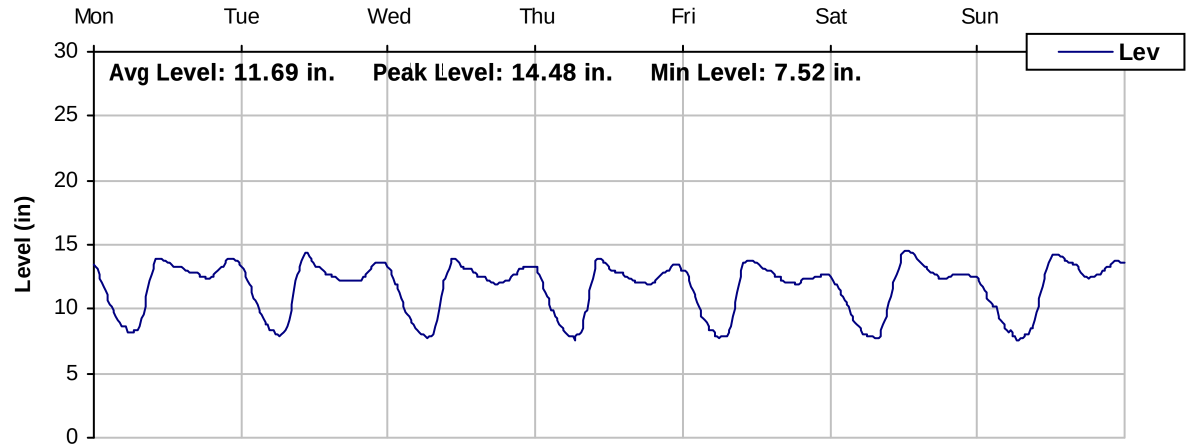
SITE 4
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012

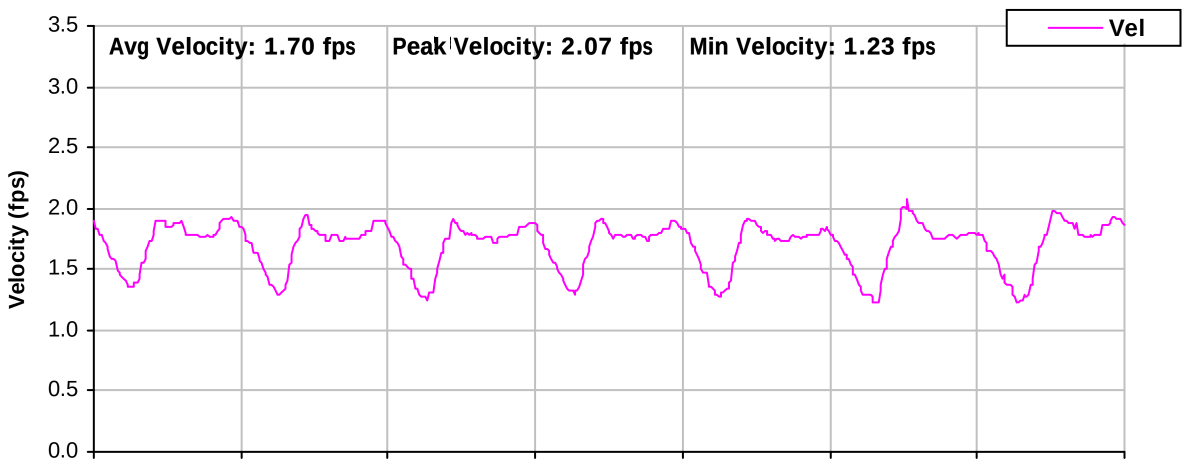


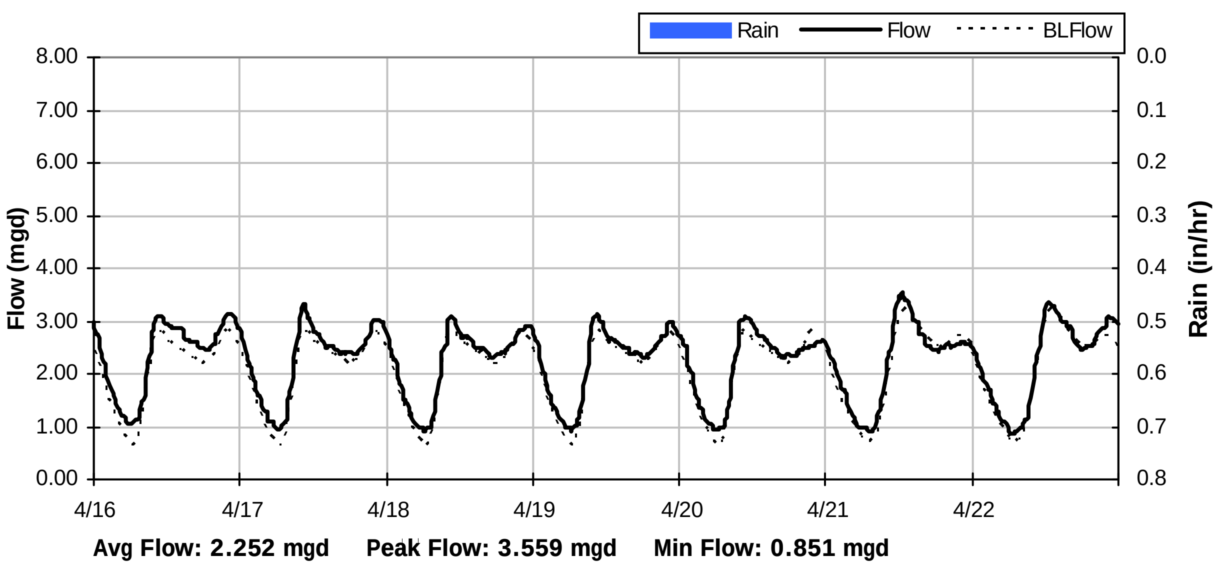
SITE 4

Weekly Level, Velocity and Flow Hydrographs

4/16/2012 to 4/23/2012



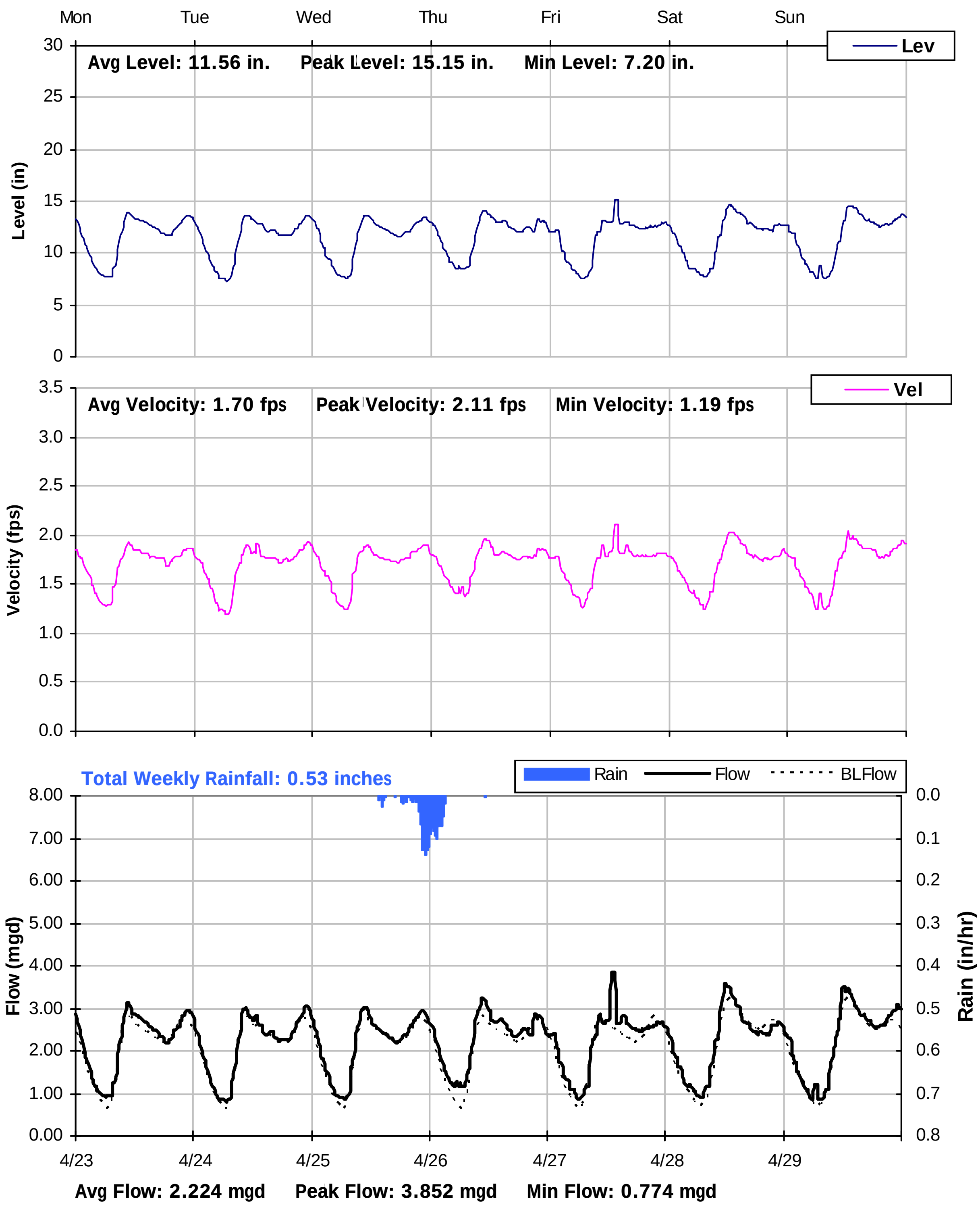




SITE 4

Weekly Level, Velocity and Flow Hydrographs

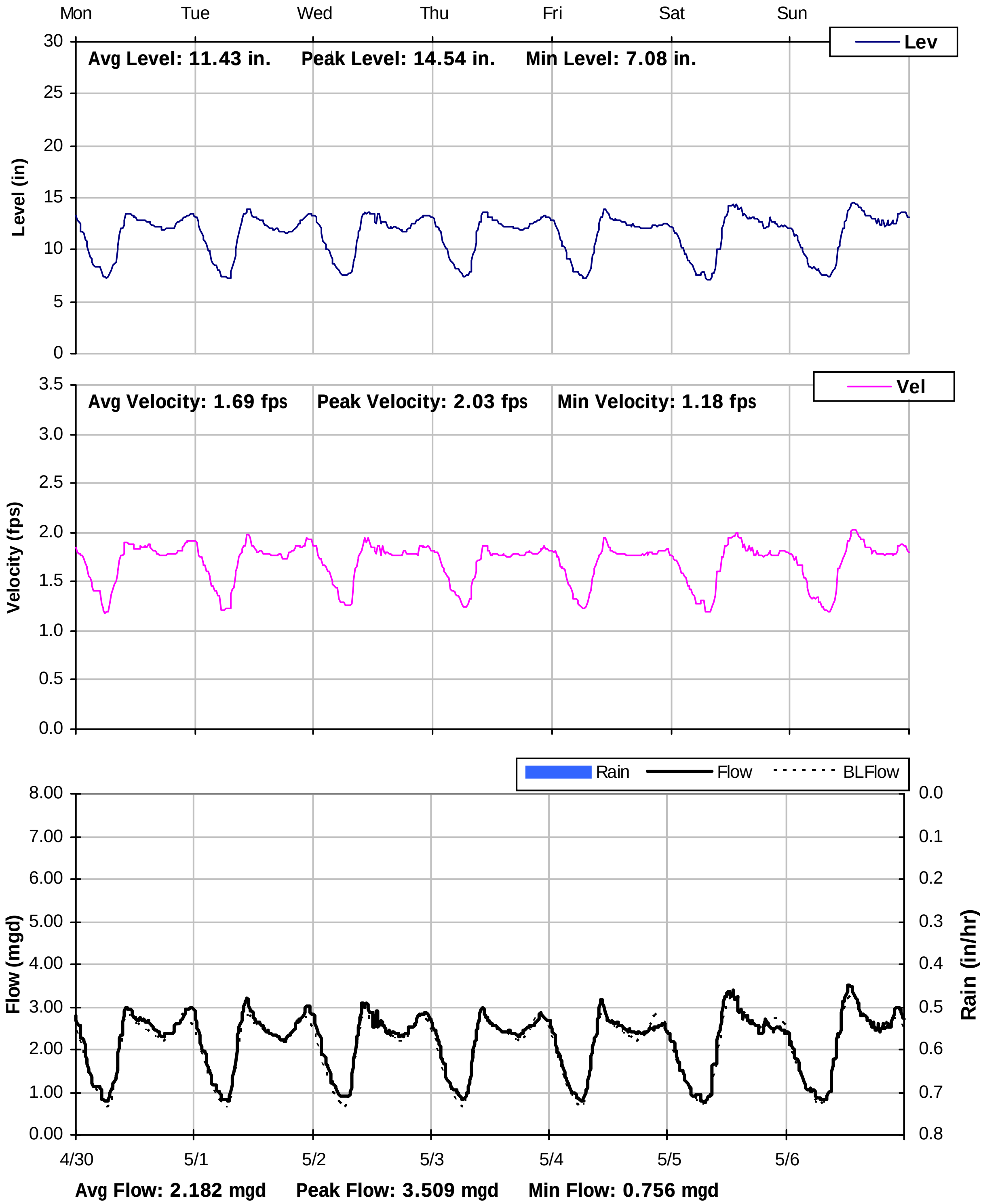
4/23/2012 to 4/30/2012



SITE 4

Weekly Level, Velocity and Flow Hydrographs

4/30/2012 to 5/7/2012



City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

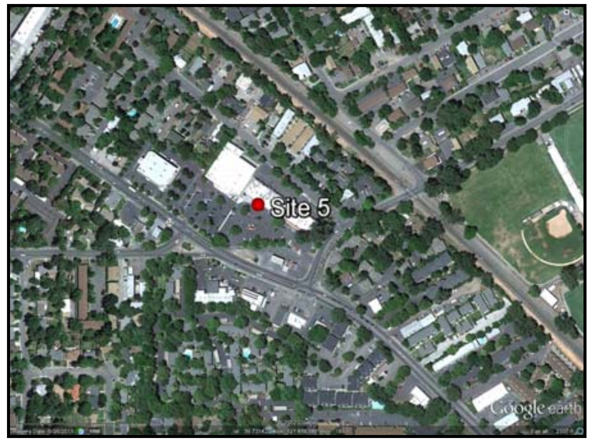
Monitoring Site: Site 5

Location: California 32 at West Sacramento Avenue (in Parking Lot near Safeway)

Vicinity Map:

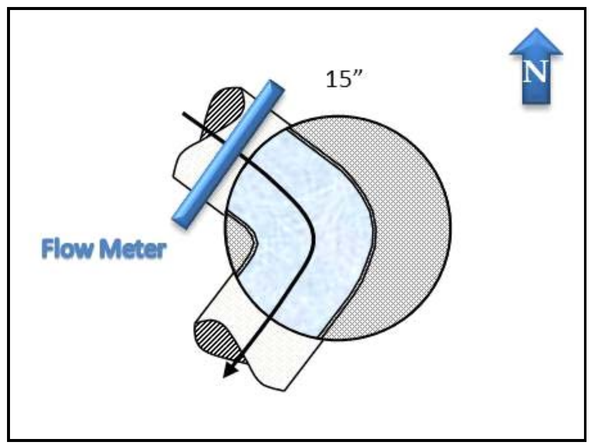
SITE 5
Site Information Report

Location:	California 32 at West Sacramento Avenue (in Parking Lot near Safeway)
Coordinates:	121.8590° W, 39.7316° N
Elevation:	184 feet
Diameter:	15 inches
Baseline Flow:	0.211 mgd
Peak Measured Flow:	0.457 mgd



Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

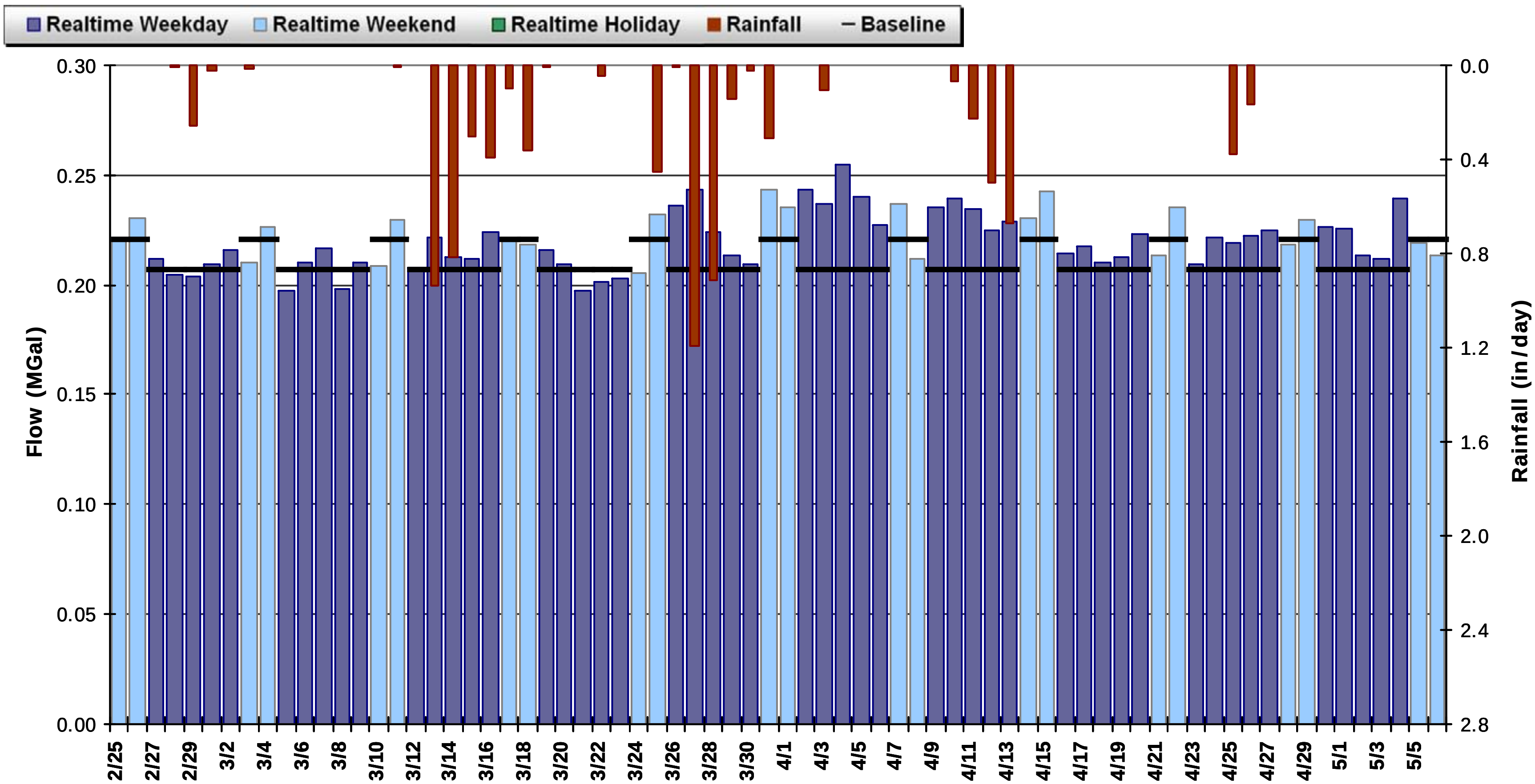

Plan View

SITE 5

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.221 MGal **Peak Daily Flow: 0.255 MGal** **Min Daily Flow: 0.197 MGal**

Total Period Rainfall: 8.43 inches

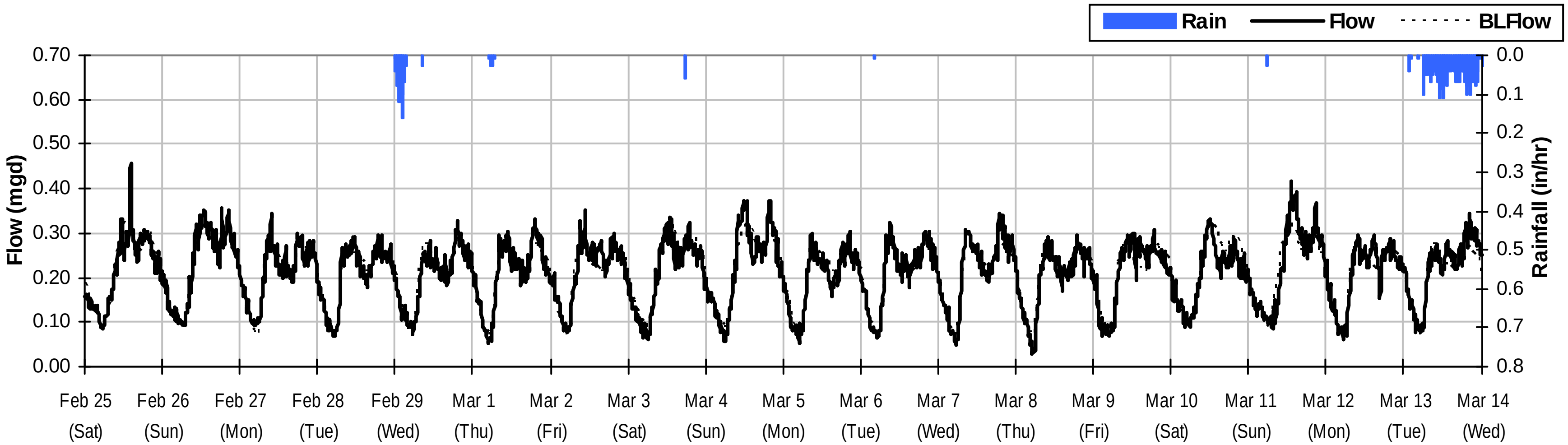


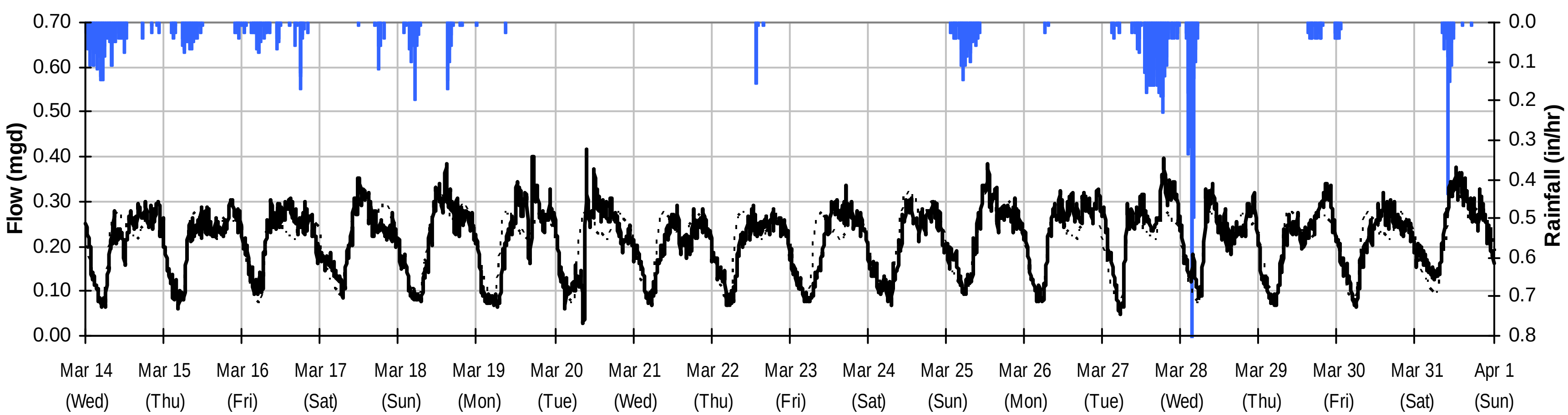
SITE 5

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.215 mgd **Peak Flow: 0.457 mgd** **Min Flow: 0.027 mgd**

Total Period Rainfall: 6.31 inches



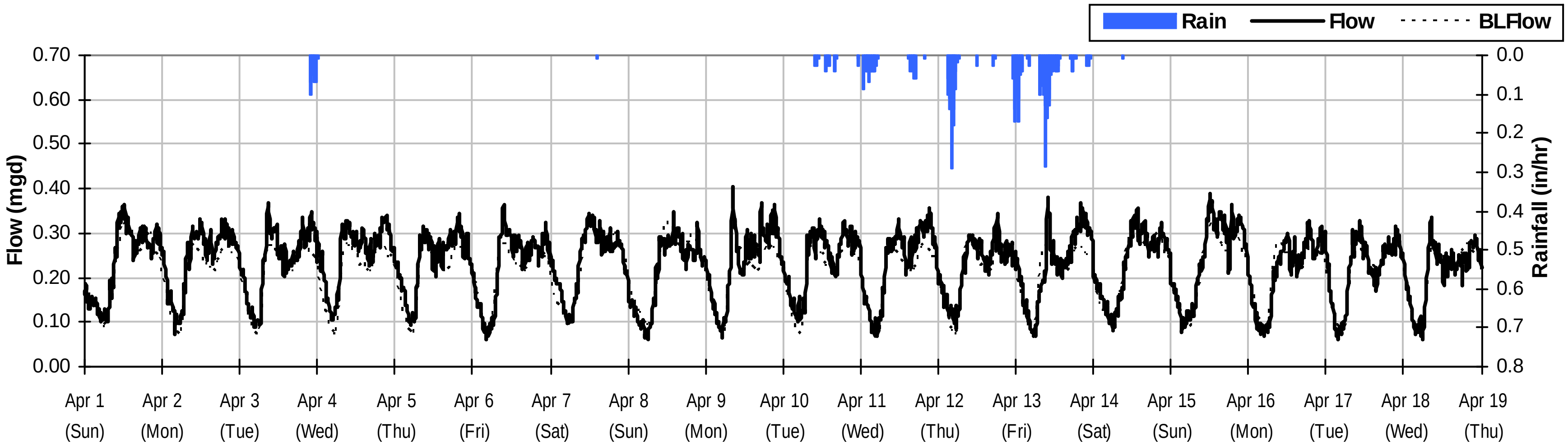


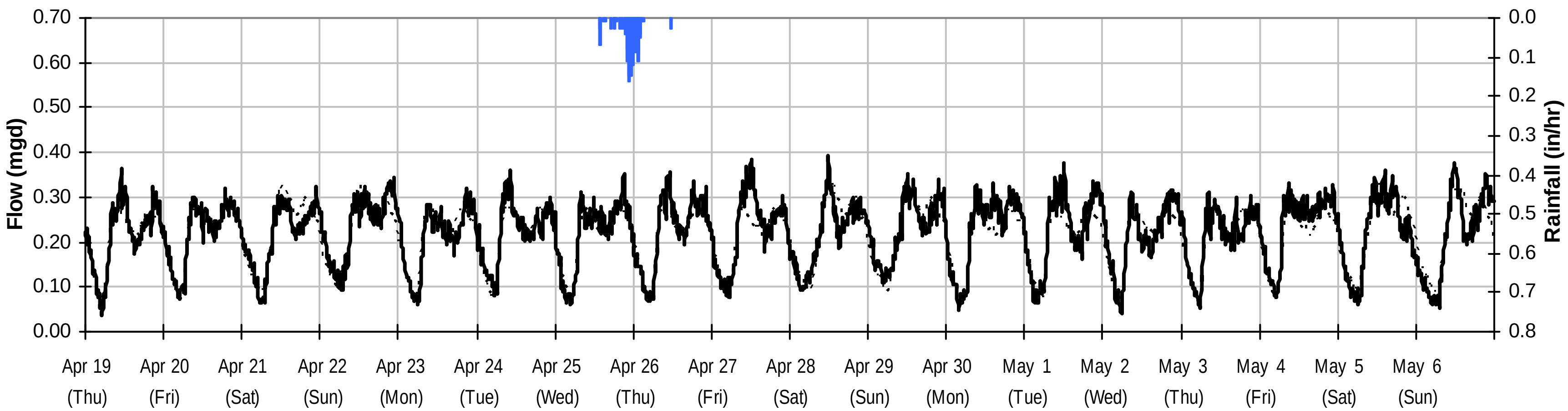
SITE 5

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.226 mgd **Peak Flow: 0.405 mgd** **Min Flow: 0.035 mgd**

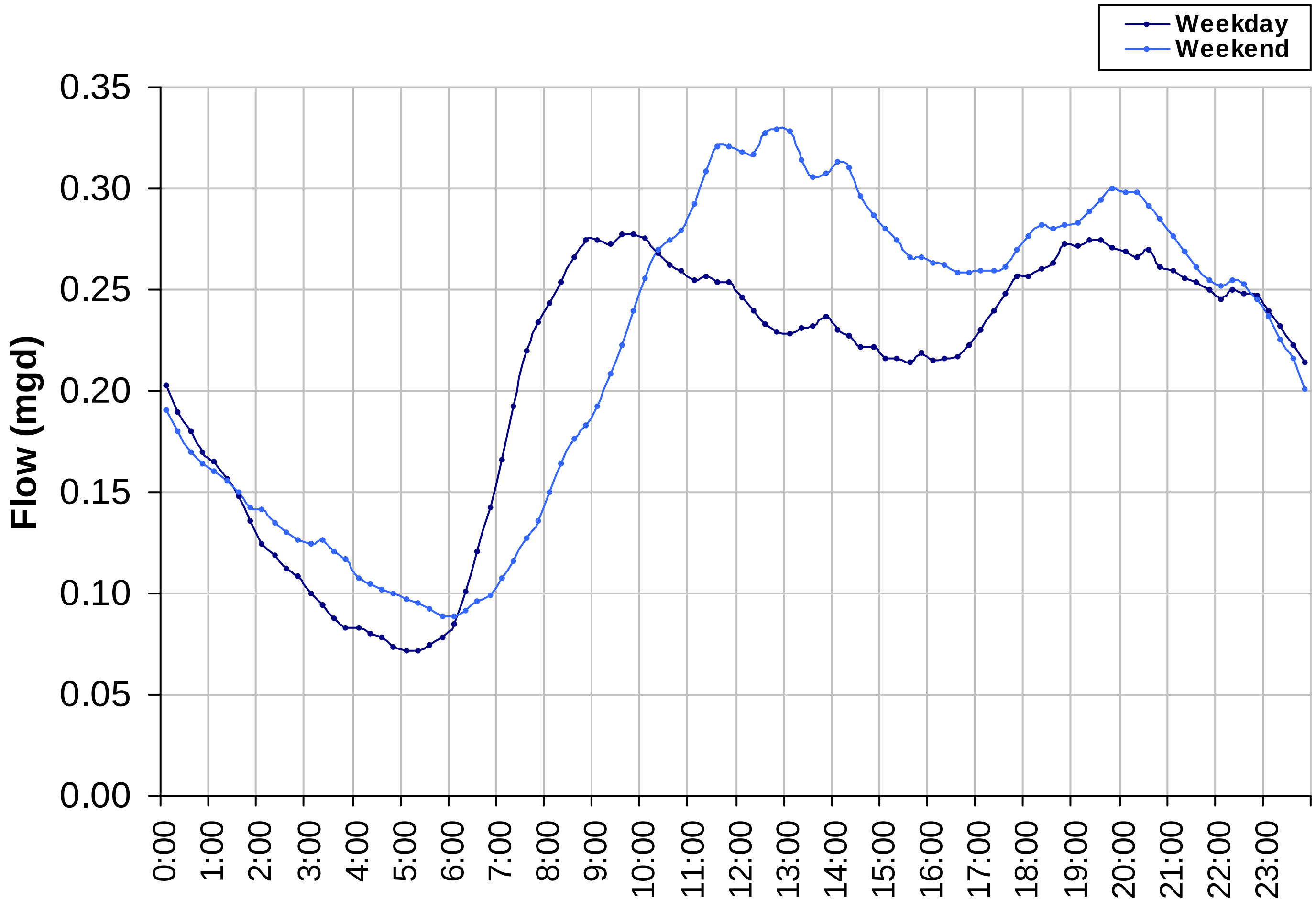
Total Period Rainfall: 2.12 inches





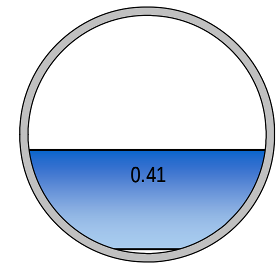
SITE 5

Baseline Flow Hydrographs



Baseline Flow:

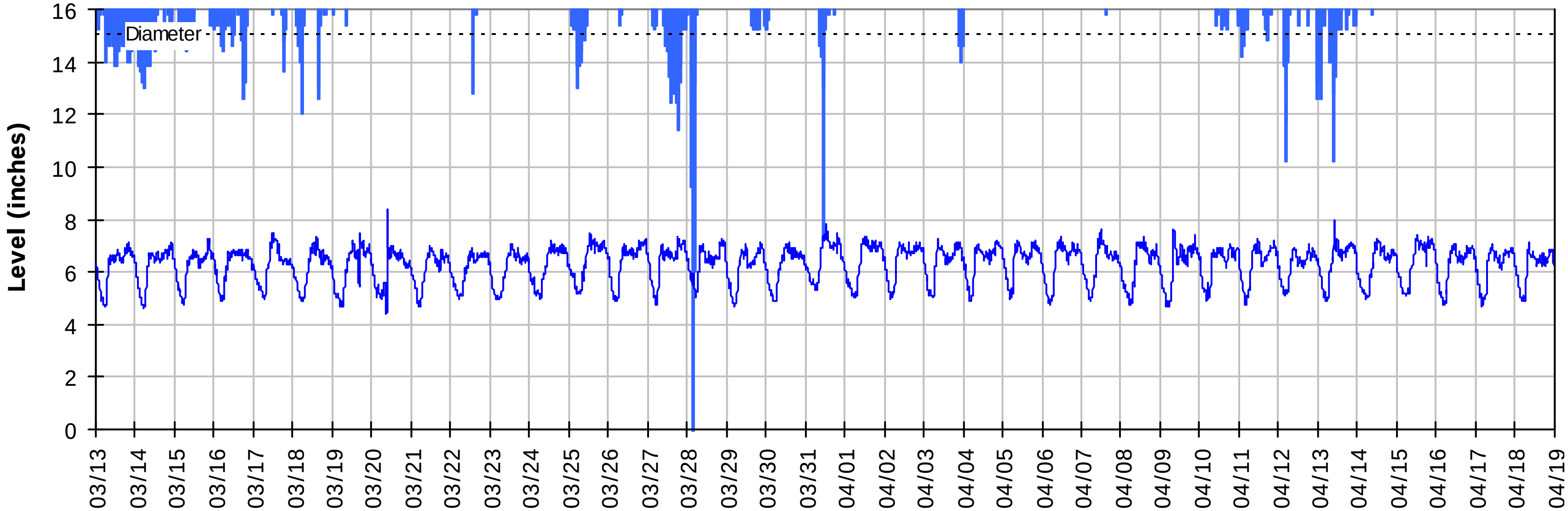
0.211 *mgd*

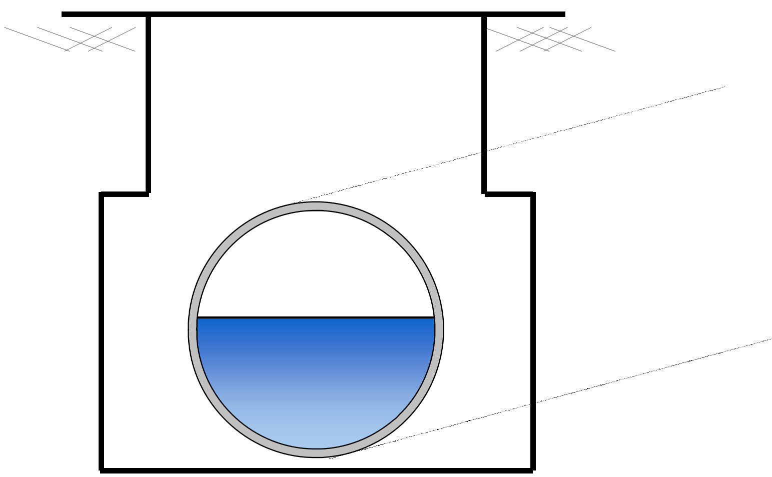


SITE 5

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





Pipe Diameter: 15 *inches*

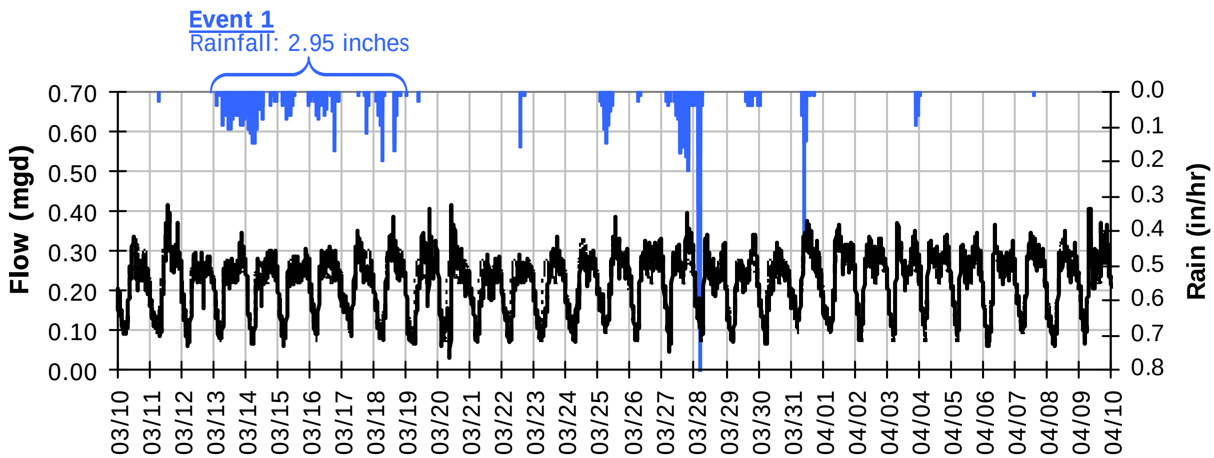
Peak Measured Level: 8.3 *inches*

Peak d / D Ratio: 0.55

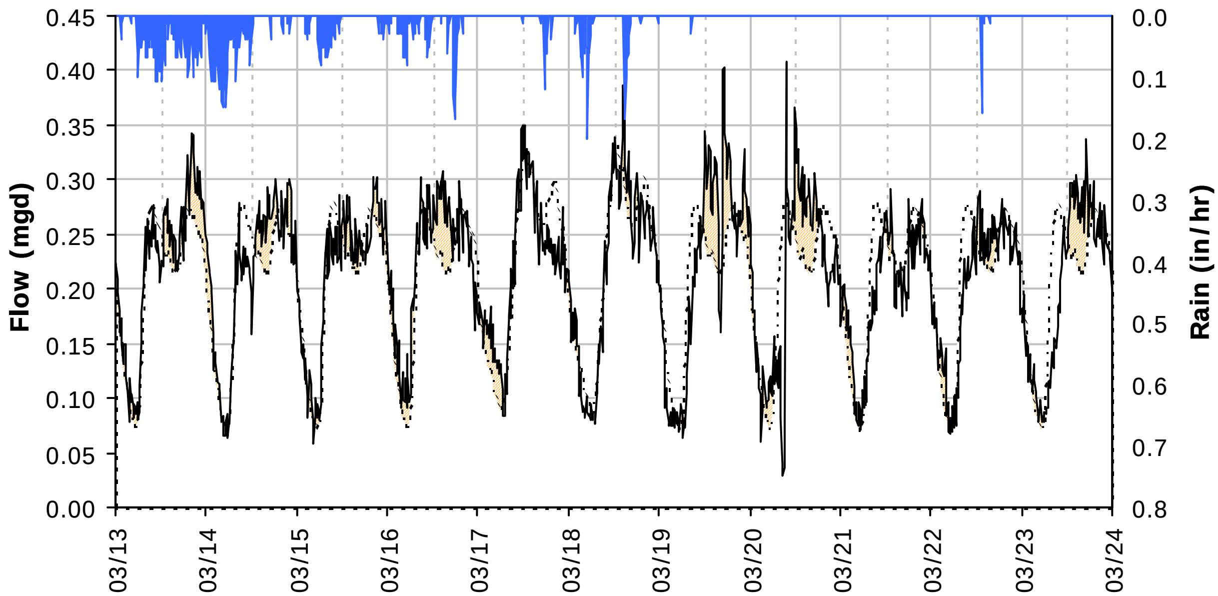
SITE 5

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 = 2.95 inches)

Capacity

Peak Flow:	0.41 *mgd*
PF:	1.93
Peak Level:	8.30 *in*
d/D Ratio:	0.55

Inflow

Peak I/I Rate:	0.17 *mgd*
PkI/I:IDM:	3,138 *gpd/IDM*
PkI/I:Acre:	507 *gpd/acre*
Pk I/I:ADWF:	0.81

RDI (infiltration)

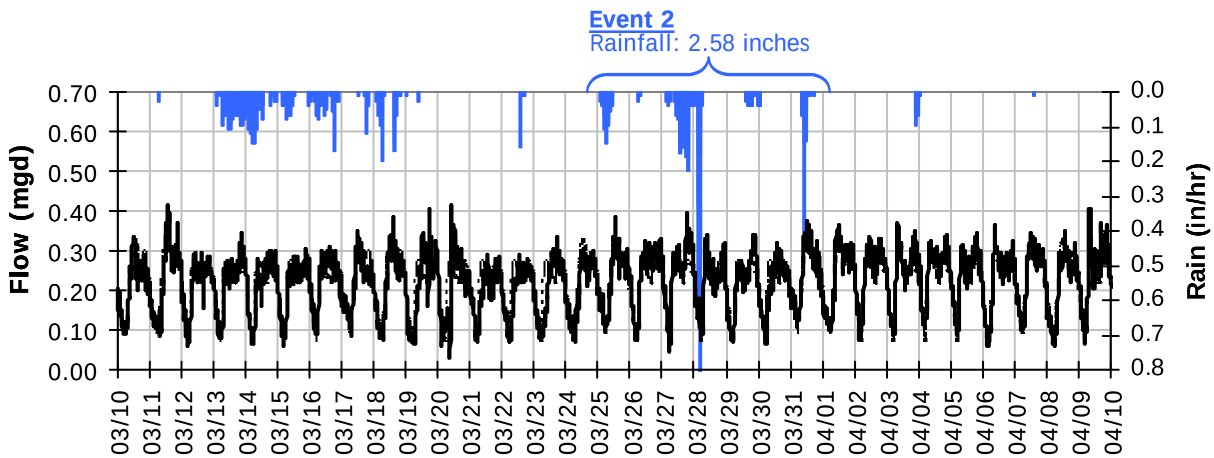
Infiltration Rate: (3/20/2012)	0.002 *mgd*
RDI:IDM:	38 *gpd/IDM*
RDI:Acre:	6 *gpd/acre*
RDI (% of BL):	1%

Combined I/I

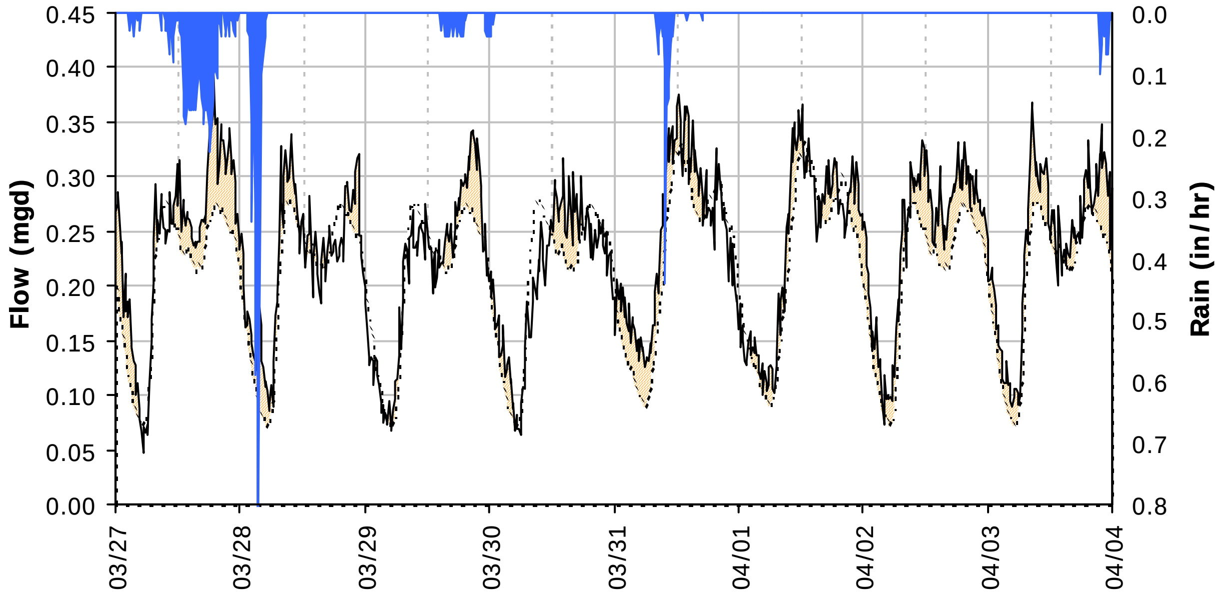
Total I/I:	29,000 *gallons*
Total I/I:IDM:	182 *gal/IDM/in*
R-Value:	0.1%
Total I/I:ADWF:	0.05 *per in-rain*

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 = 2.58 inches)

Capacity

Peak Flow: 0.40 *mgd*
PF: 1.88
Peak Level: 7.81 *in*
d/D Ratio: 0.52

Inflow

Peak I/I Rate: 0.12 *mgd*
PkI/I:IDM: 2,276 *gpd/IDM*
PkI/I:Acre: 368 *gpd/acre*
Pk I/I:ADWF: 0.59

RDI (infiltration)

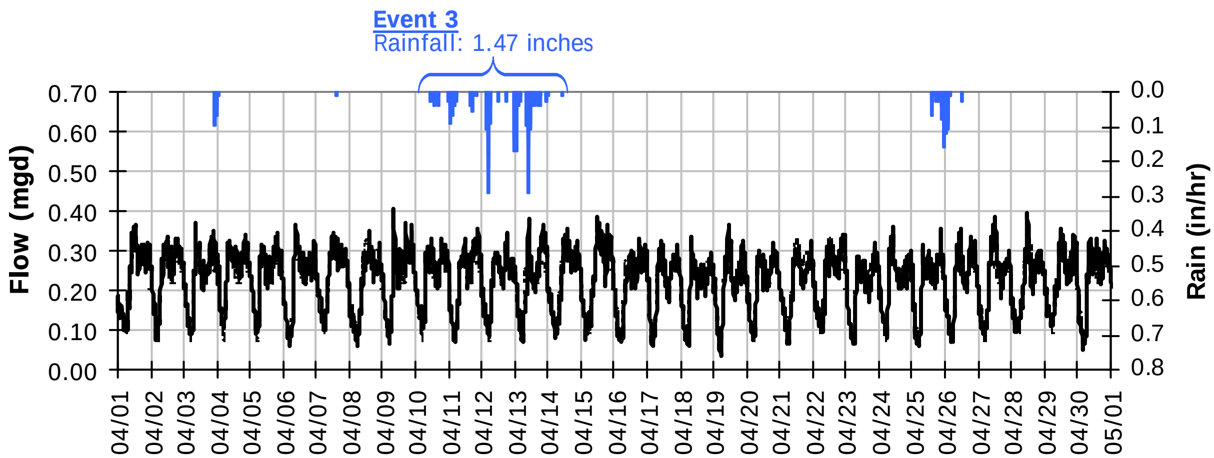
Infiltration Rate: 0.036 *mgd*
(4/2/2012)
RDI:IDM: 657 *gpd/IDM*
RDI:Acre: 106 *gpd/acre*
RDI (% of BL): 17%

Combined I/I

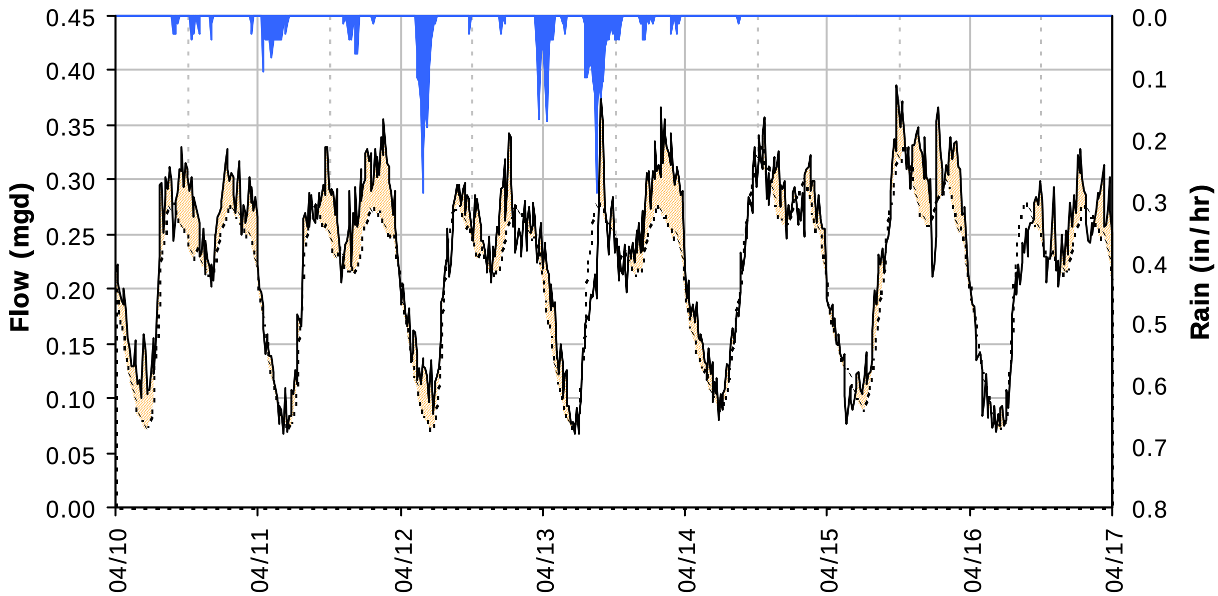
Total I/I: 166,000 *gallons*
Total I/I:IDM: 1,173 *gal/IDM/in*
R-Value: 0.7%
Total I/I:ADWF: 0.30 *per in-rain*

SITE 5
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.47 inches)

Capacity

Peak Flow:	0.39 *mgd*
PF:	1.83
Peak Level:	7.98 *in*
d/D Ratio:	0.53

Inflow

Peak I/I Rate:	0.10 *mgd*
PkI/I:IDM:	1,818 *gpd/IDM*
PkI/I:Acre:	294 *gpd/acre*
Pk I/I:ADWF:	0.47

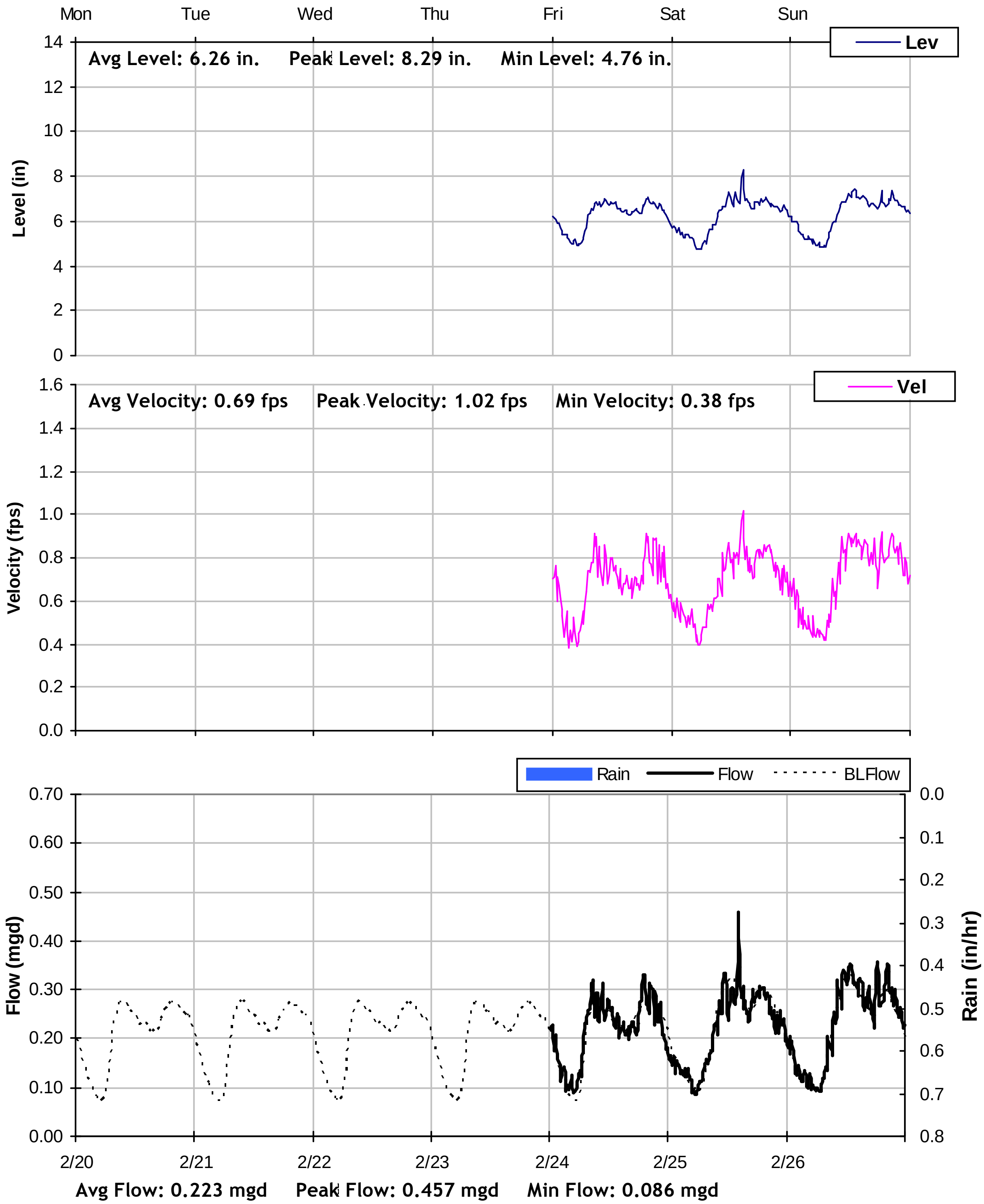
RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.022 *mgd*
RDI:IDM:	397 *gpd/IDM*
RDI:Acre:	64 *gpd/acre*
RDI (% of BL):	10%

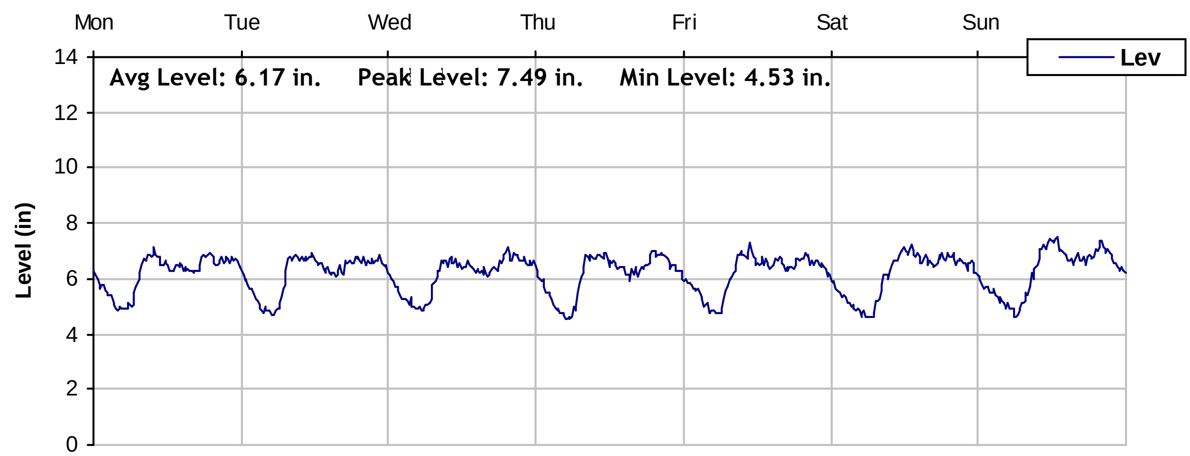
Combined I/I

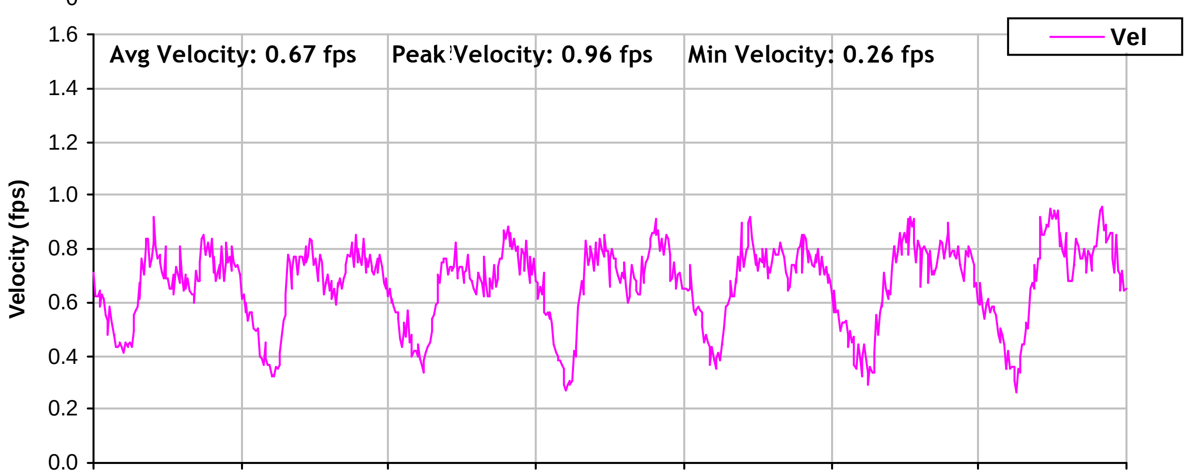
Total I/I:	138,000 *gallons*
Total I/I:IDM:	1,720 *gal/IDM/in*
R-Value:	1.0%
Total I/I:ADWF:	0.45 *per in-rain*

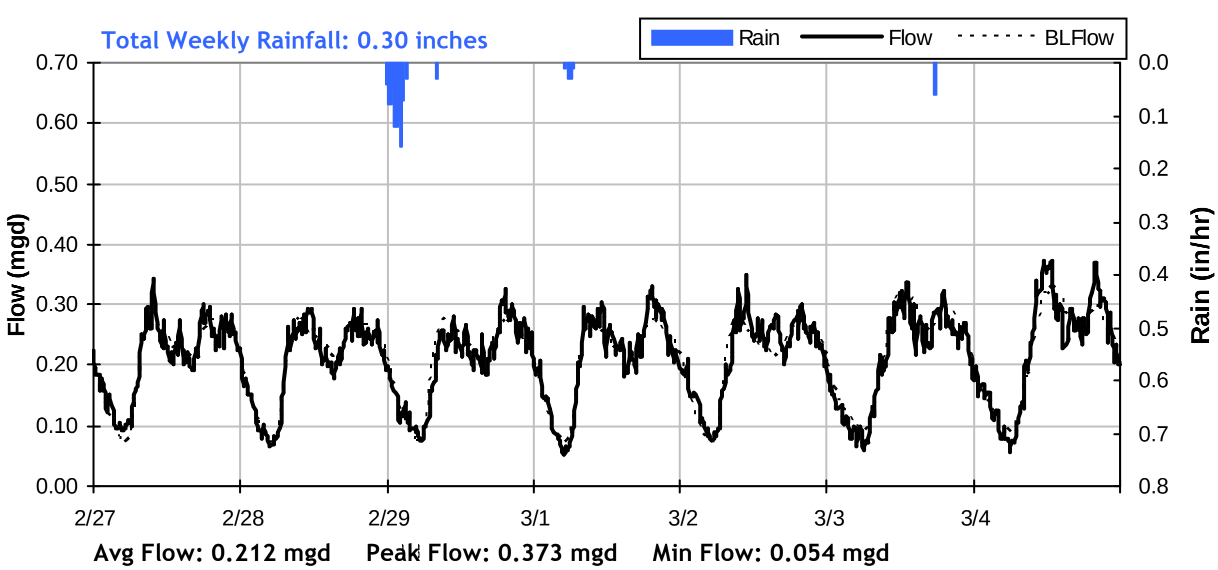
SITE 5
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



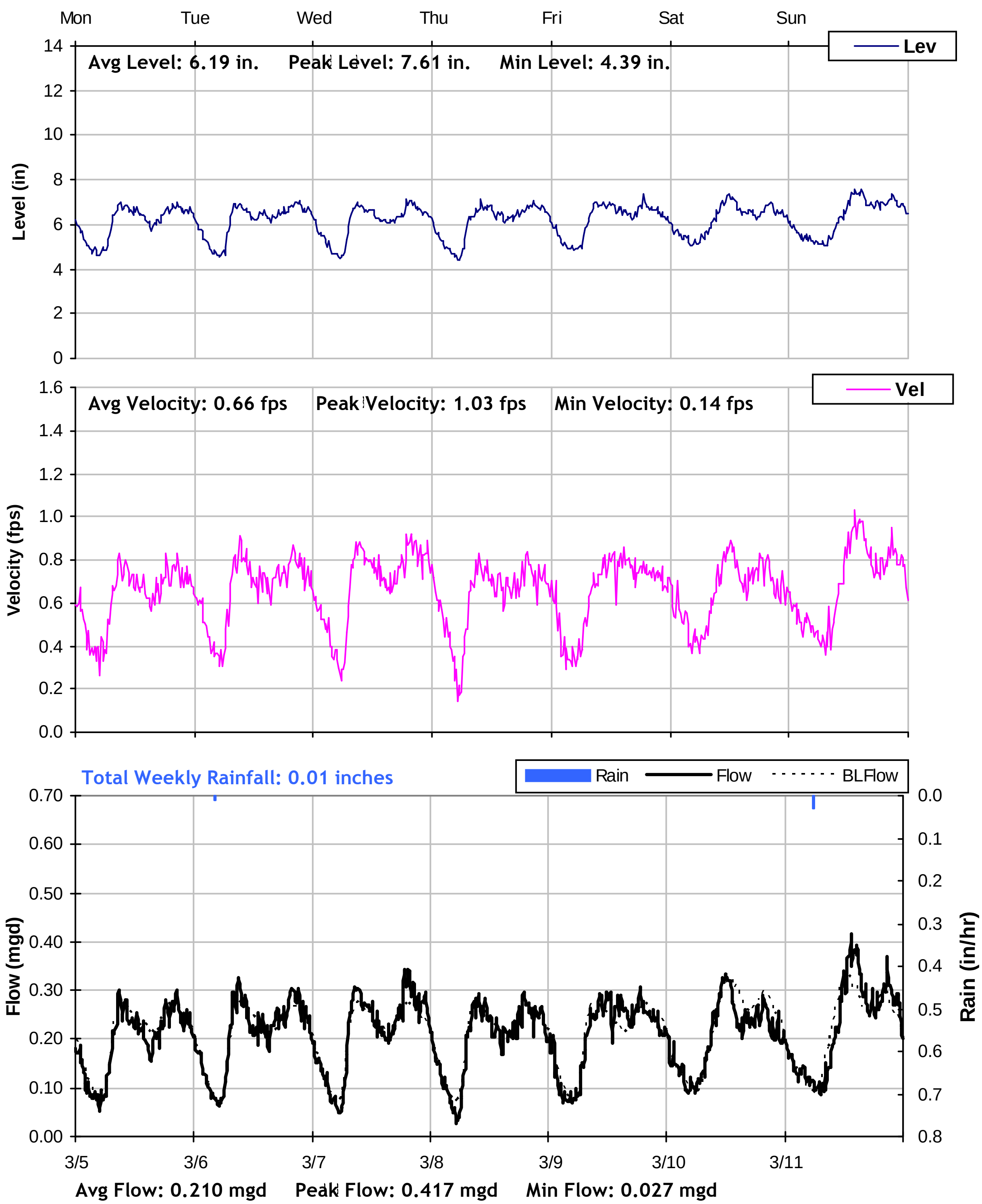
SITE 5
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012







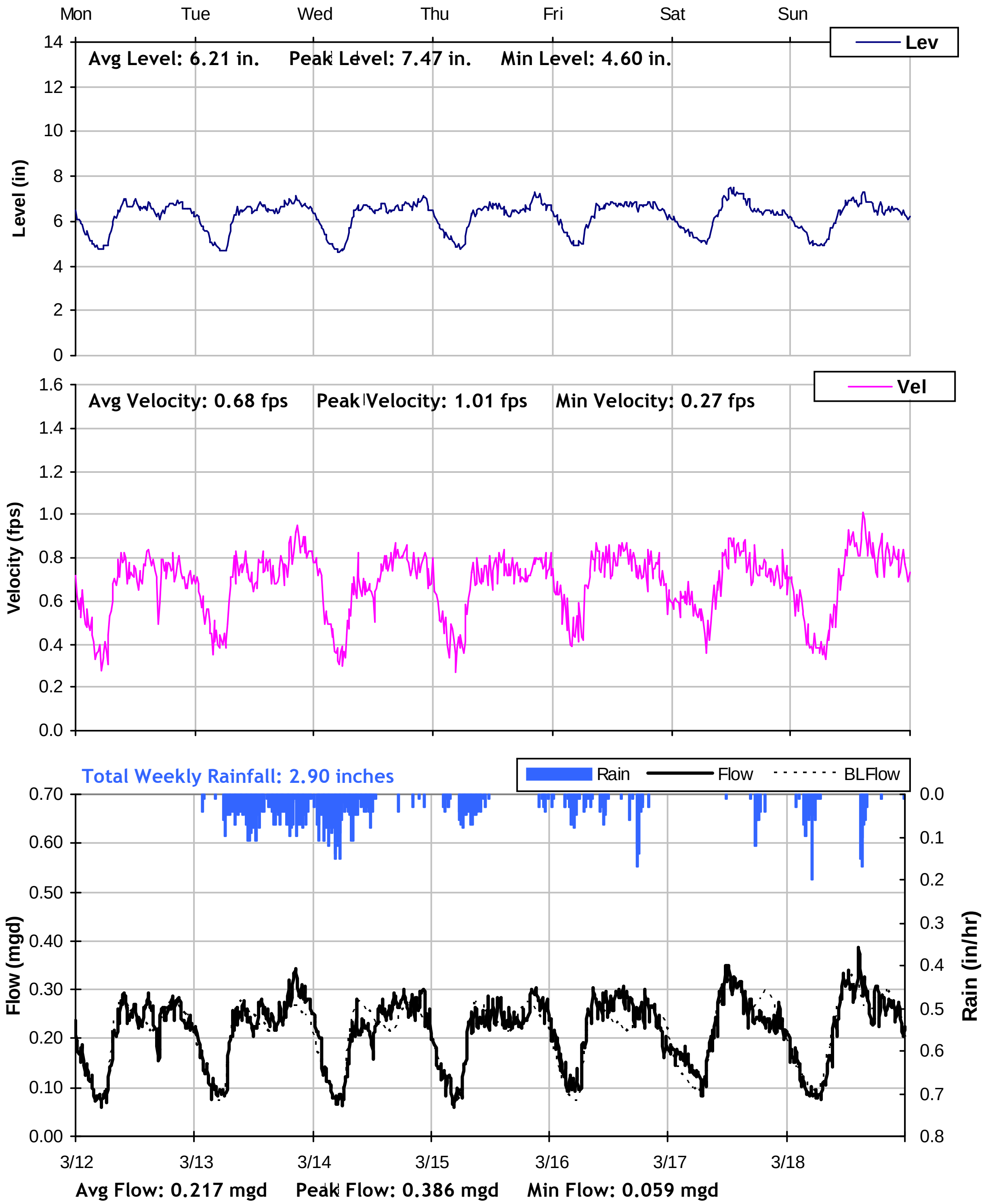
SITE 5
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



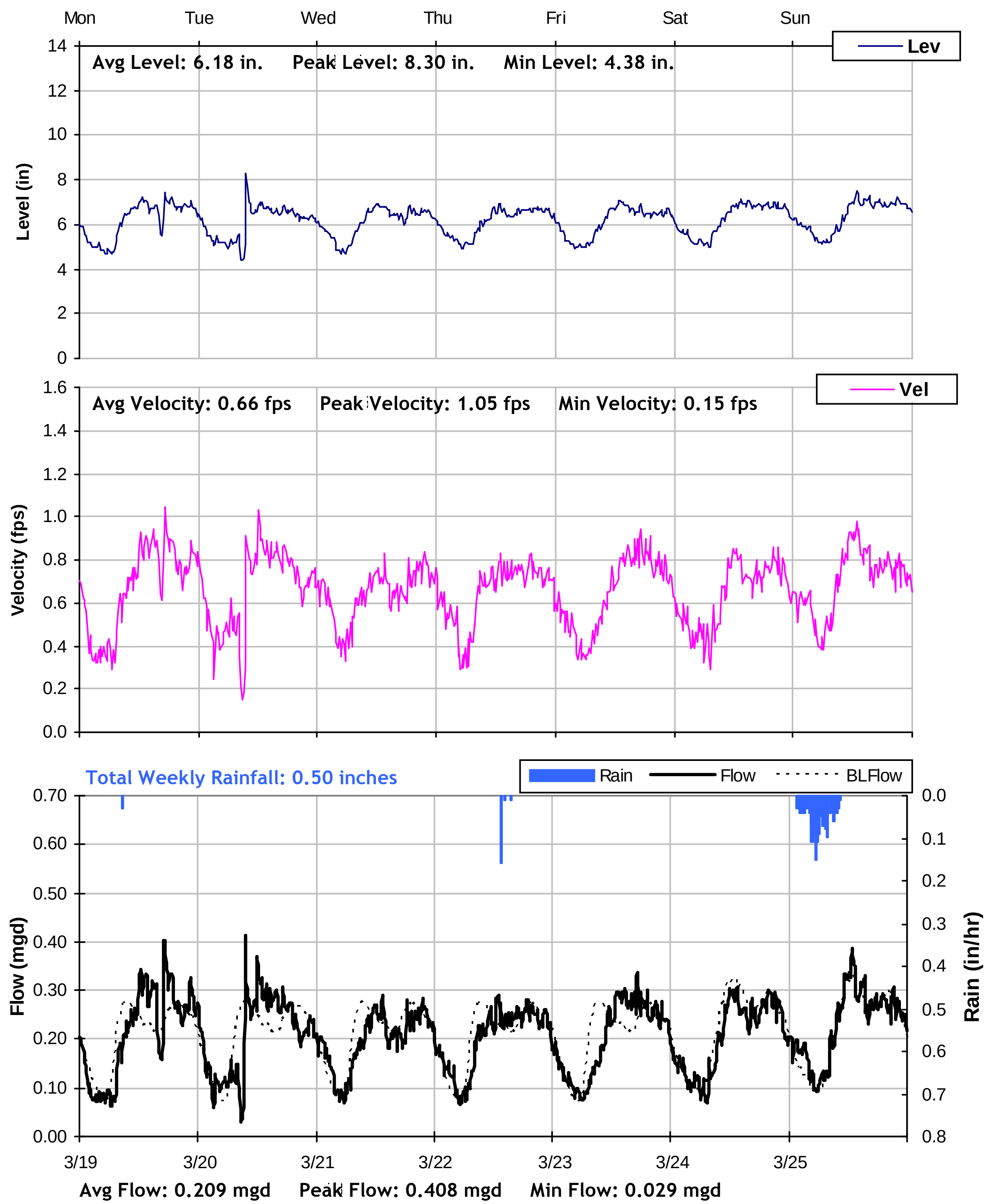
SITE 5

Weekly Level, Velocity and Flow Hydrographs

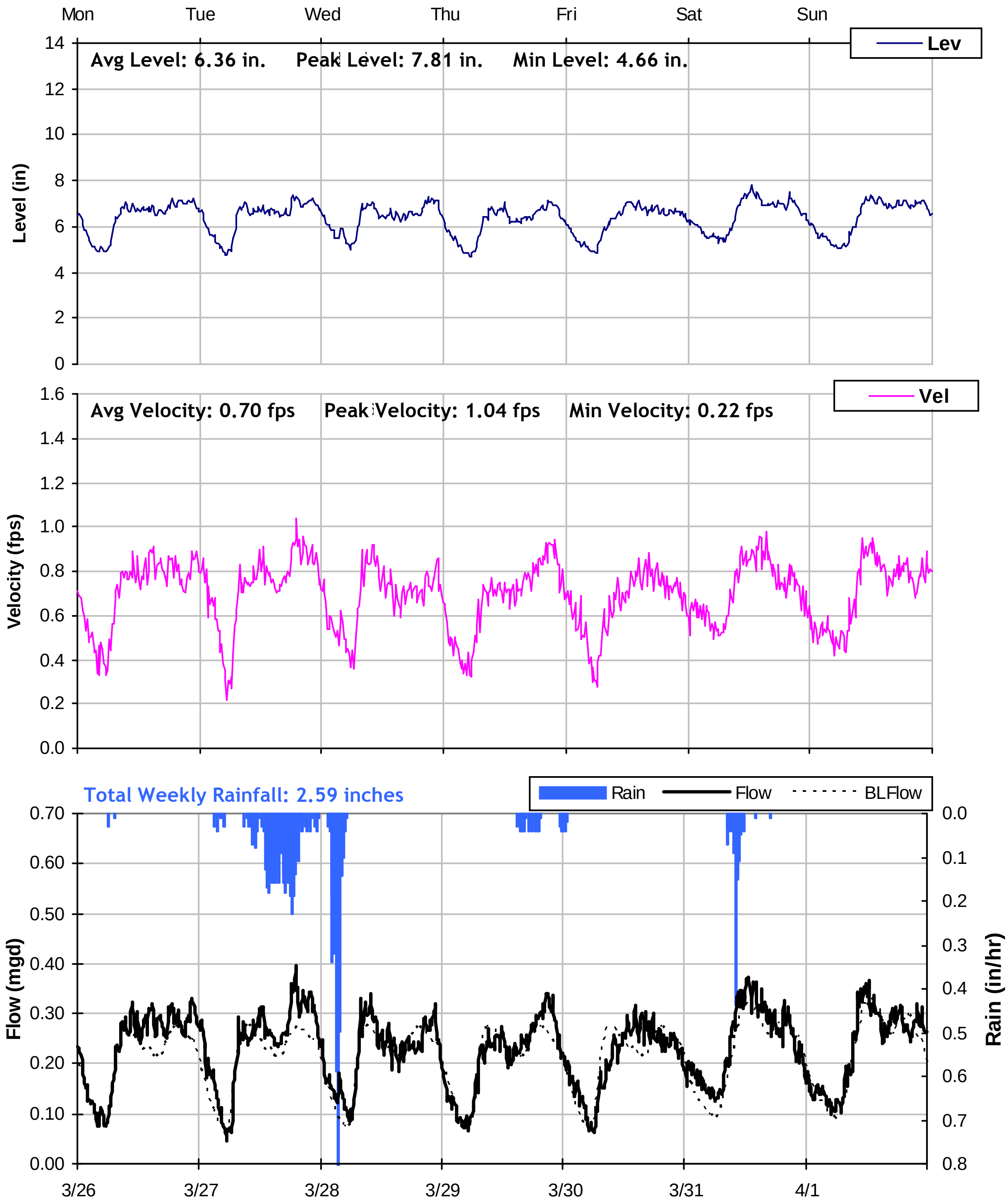
3/12/2012 to 3/19/2012



SITE 5
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012

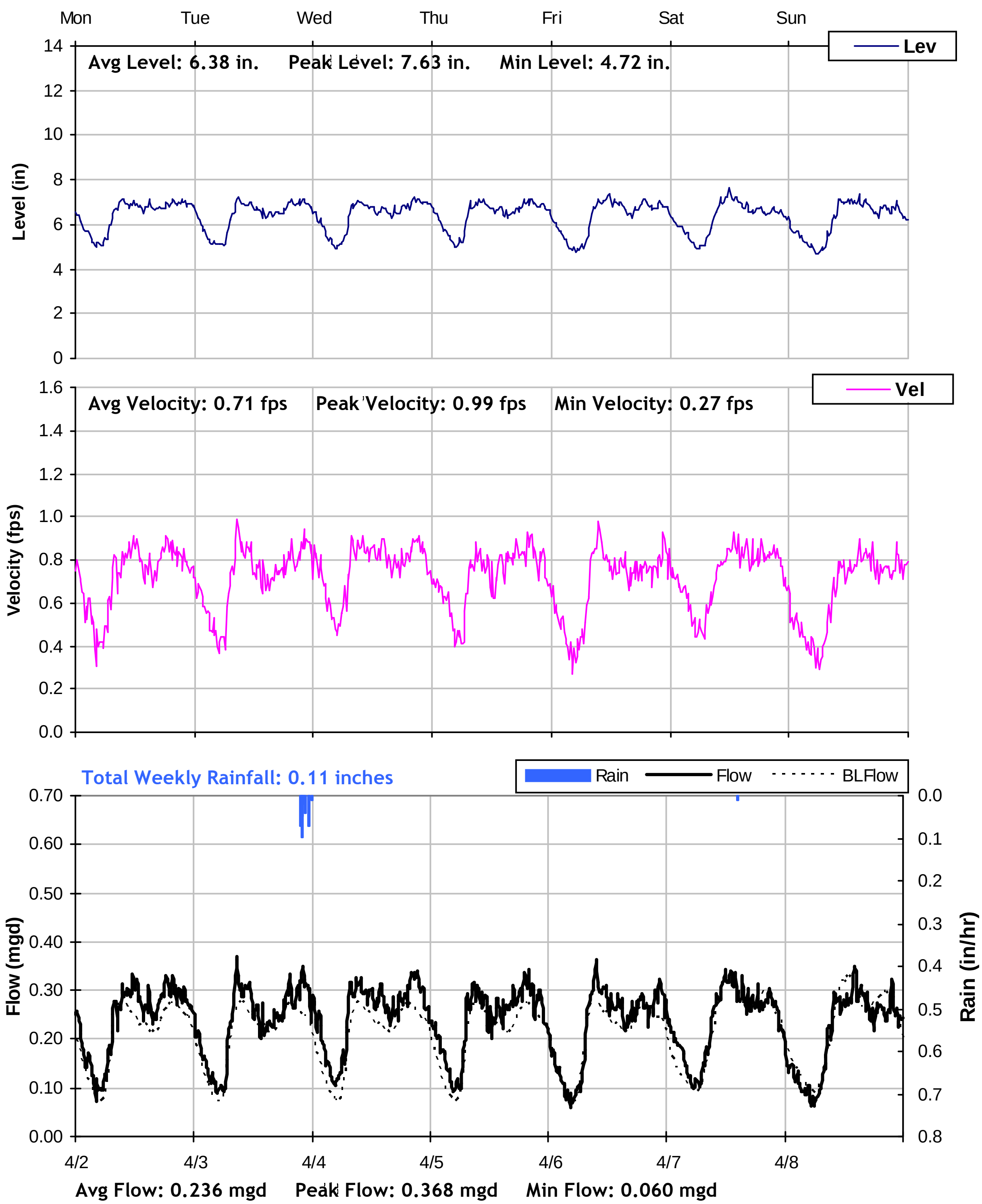


SITE 5
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012

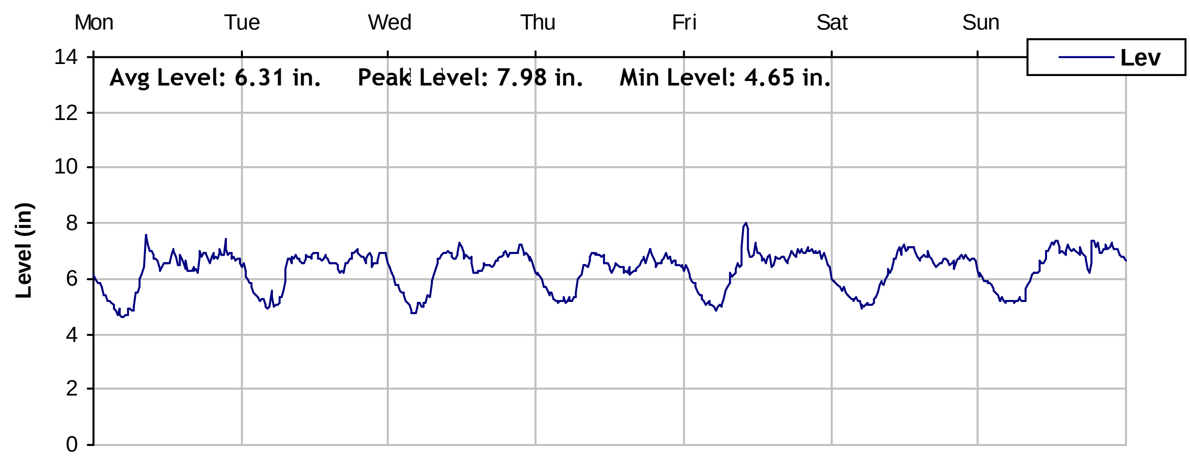


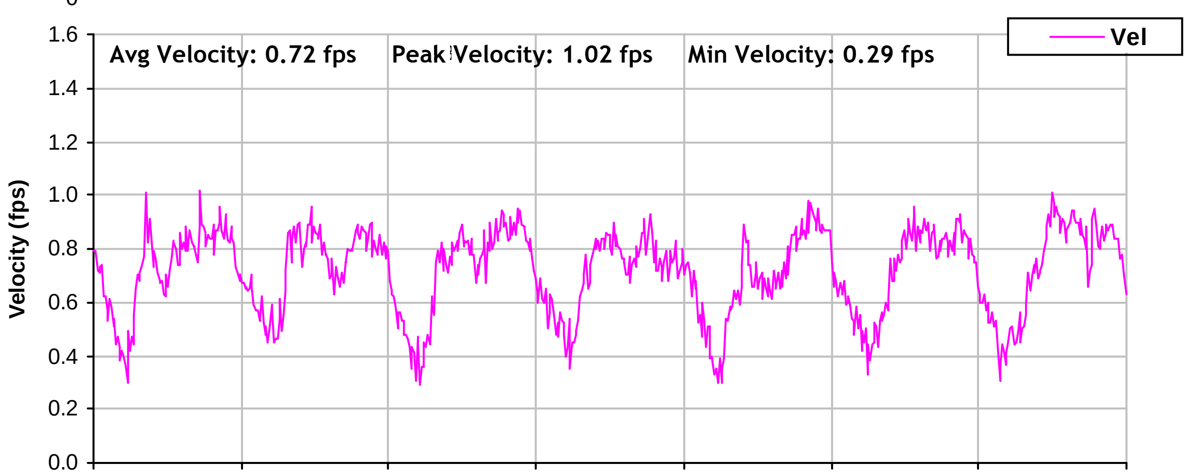
Avg Flow: 0.229 mgd   Peak Flow: 0.396 mgd   Min Flow: 0.047 mgd

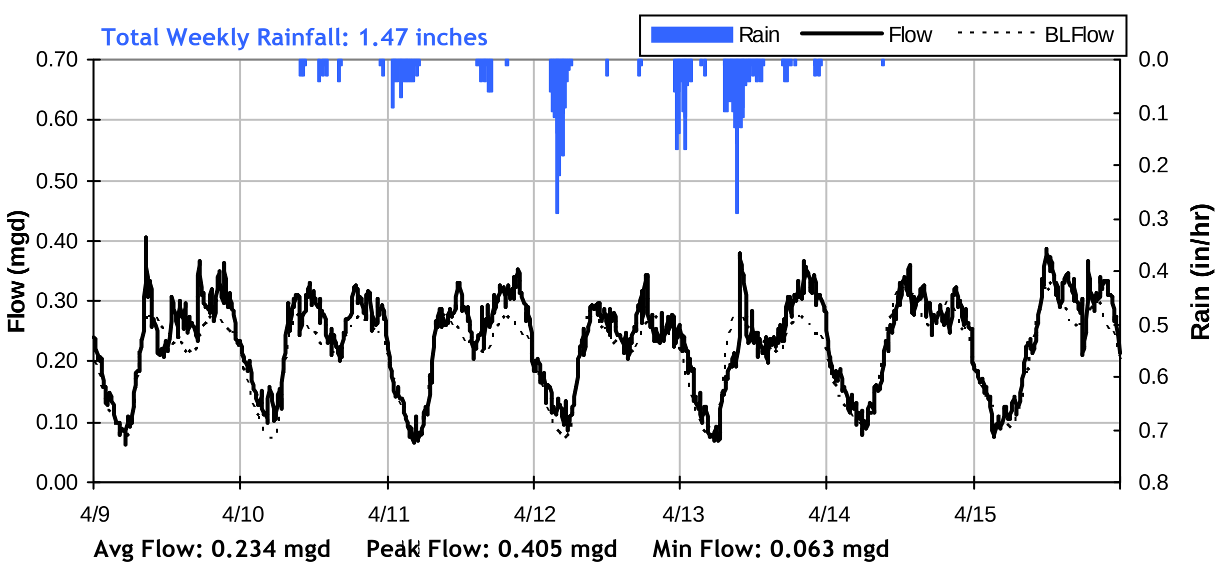
SITE 5
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



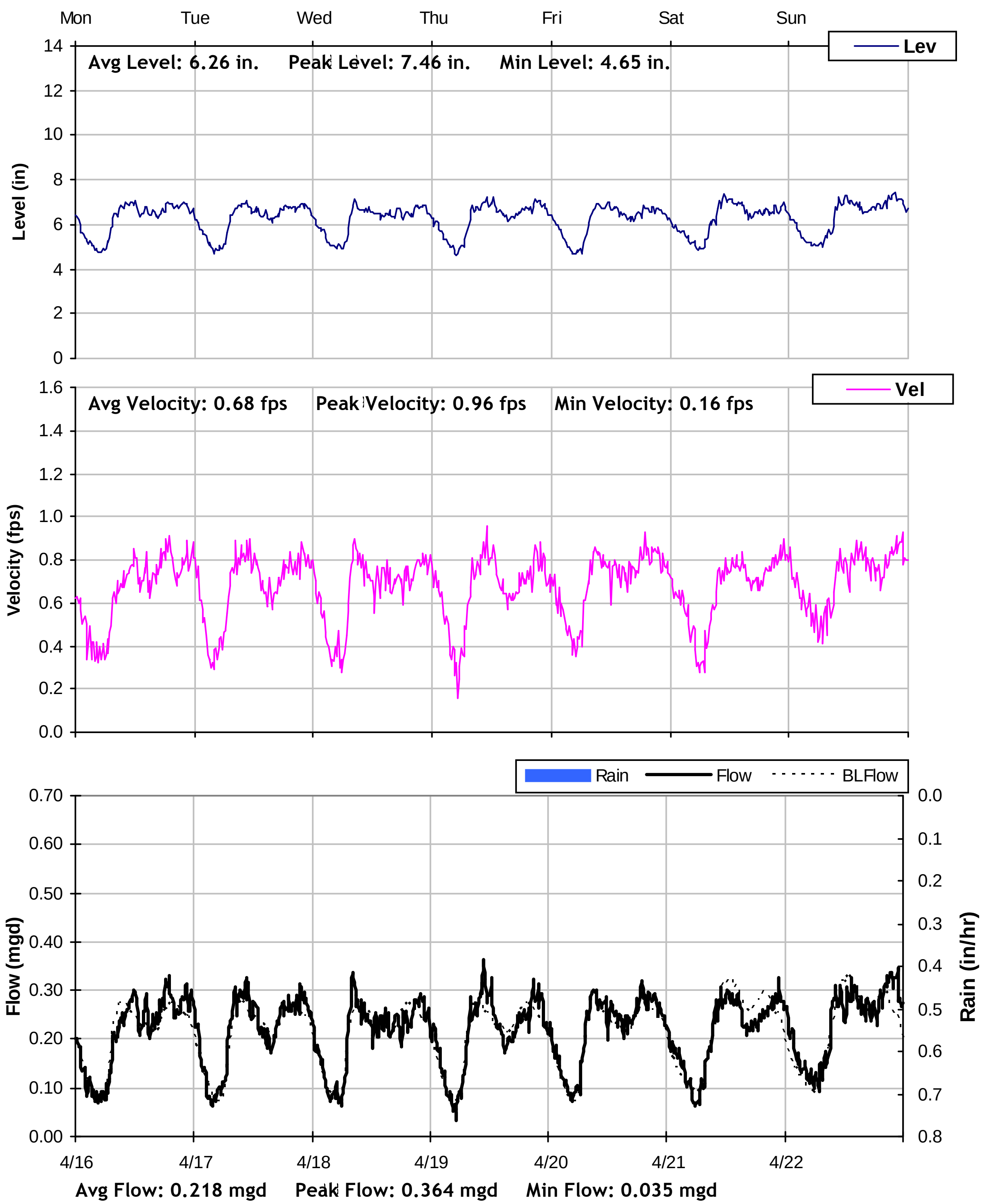
SITE 5
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



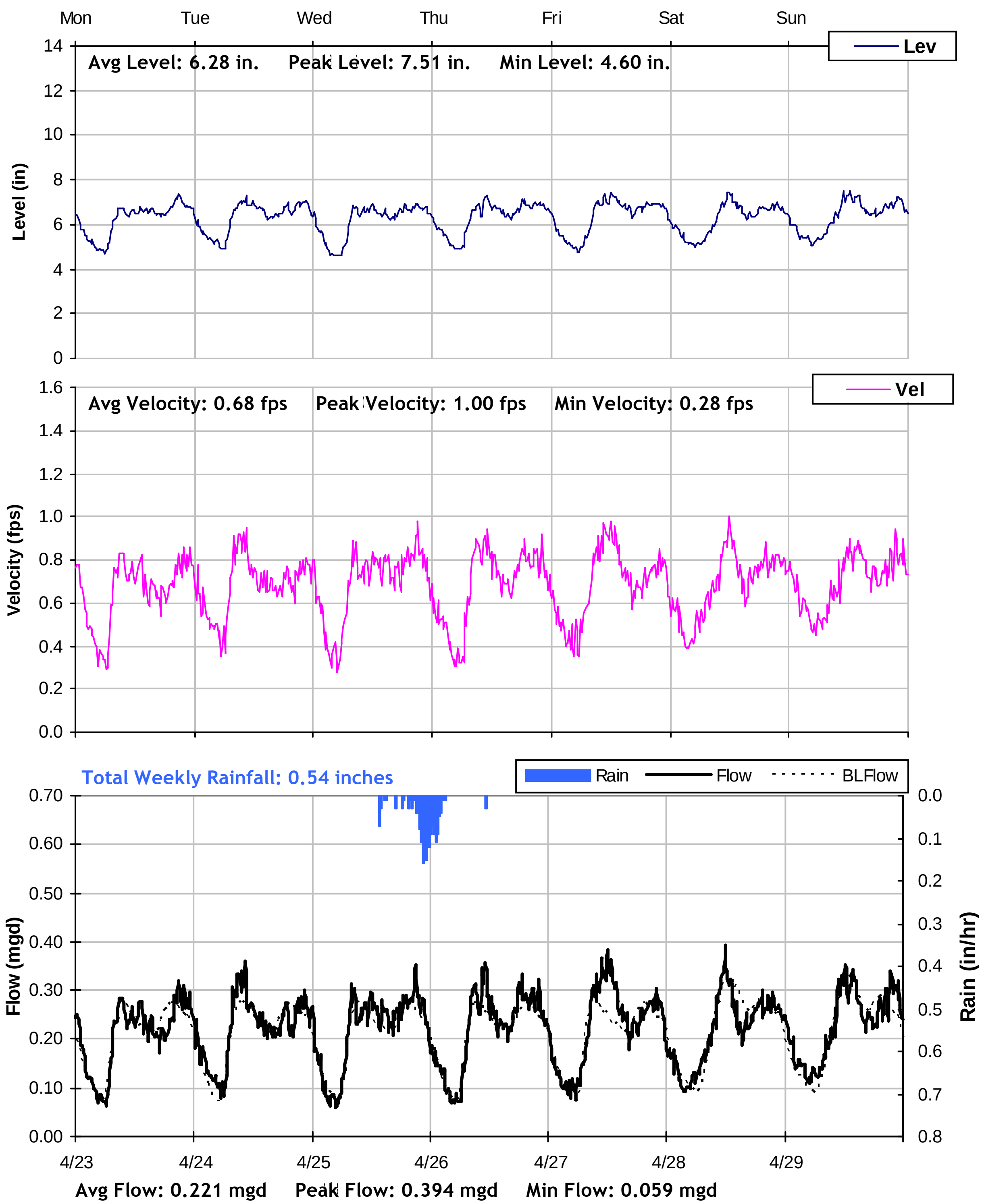




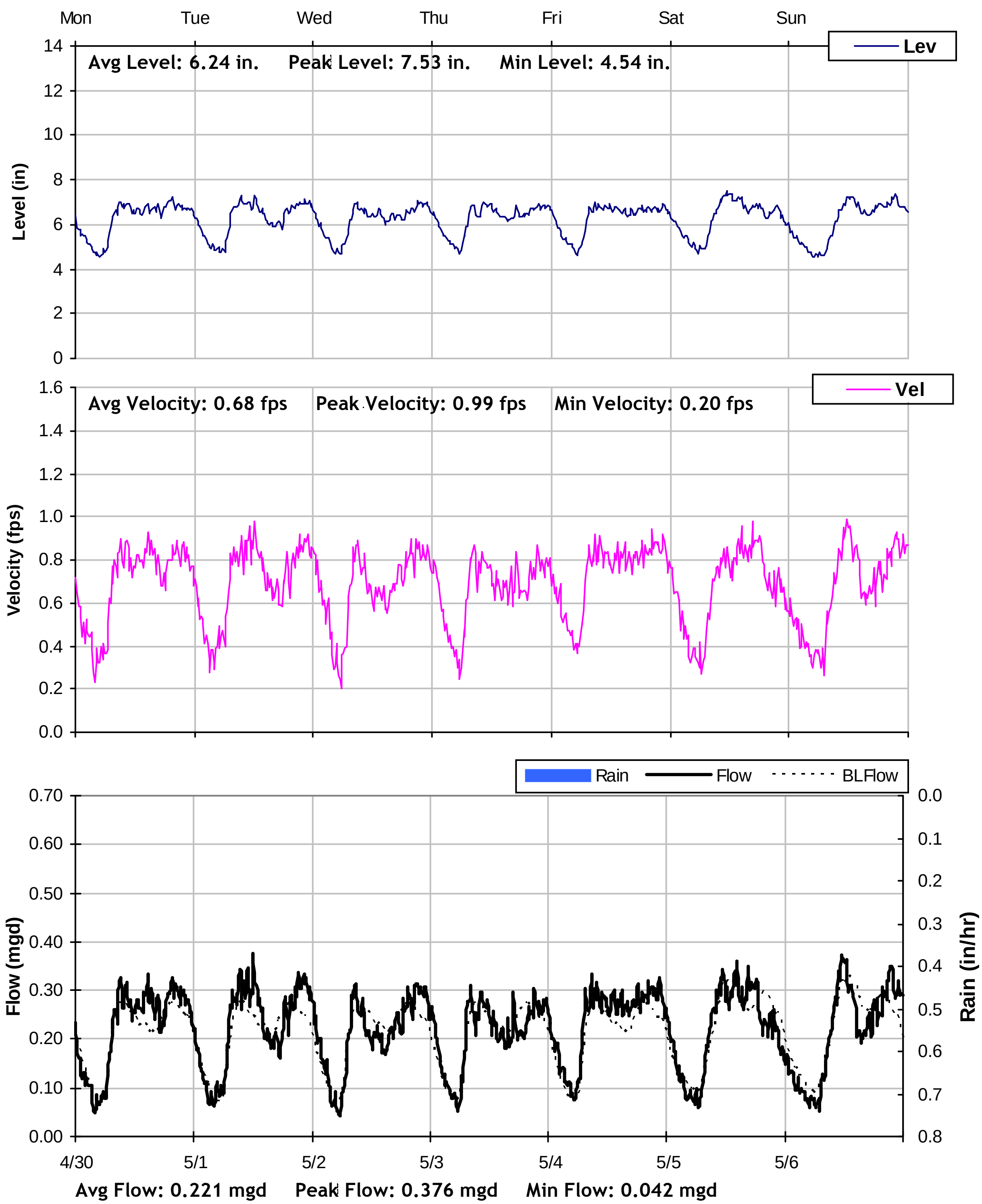
SITE 5
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012



SITE 5
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 5
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

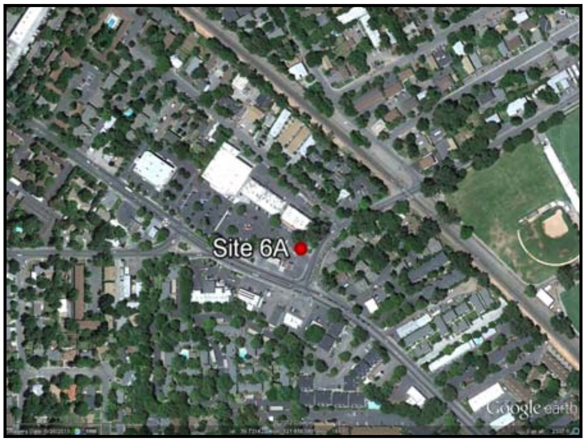
Monitoring Site: Site 6A

Location: California 32 at West Sacramento Avenue (in Parking Lot near Subway)

Vicinity Map:

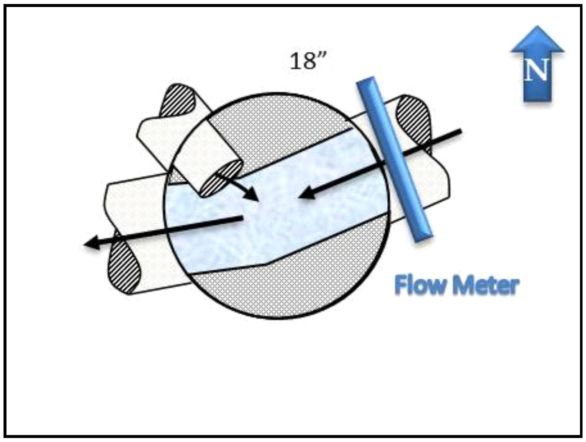
SITE 6A
Site Information Report

Location:	California 32 at West Sacramento Avenue (in Parking Lot near Subway)
Coordinates:	121.8583° W, 39.7311° N
Elevation:	185 feet
Diameter:	18 inches
Baseline Flow:	0.547 mgd
Peak Measured Flow:	1.477 mgd



Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

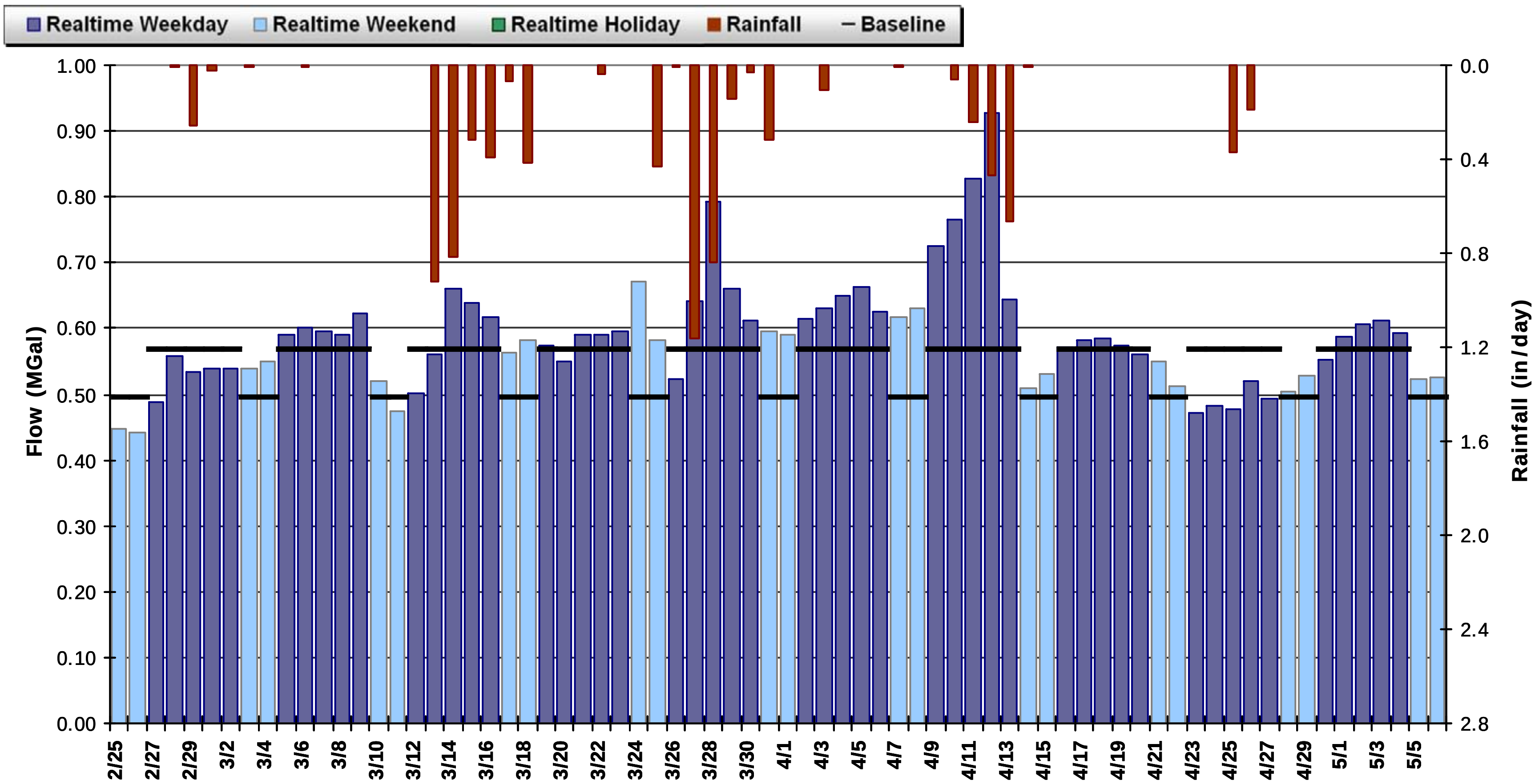
Plan View

SITE 6A

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.585 MGal **Peak Daily Flow: 0.928 MGal** **Min Daily Flow: 0.441 MGal**

Total Period Rainfall: 8.30 inches

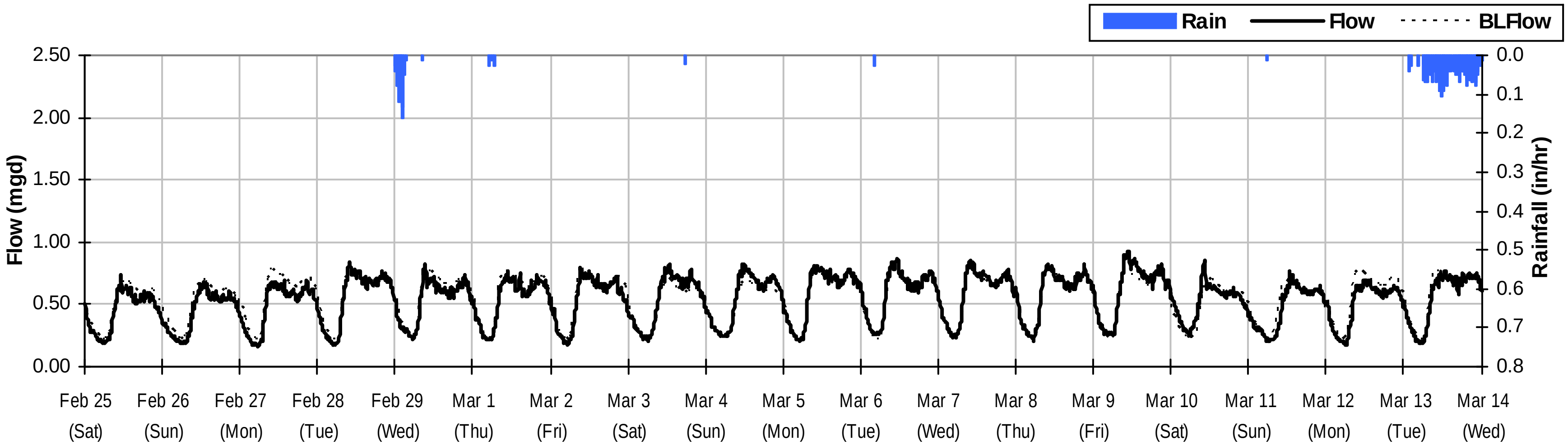


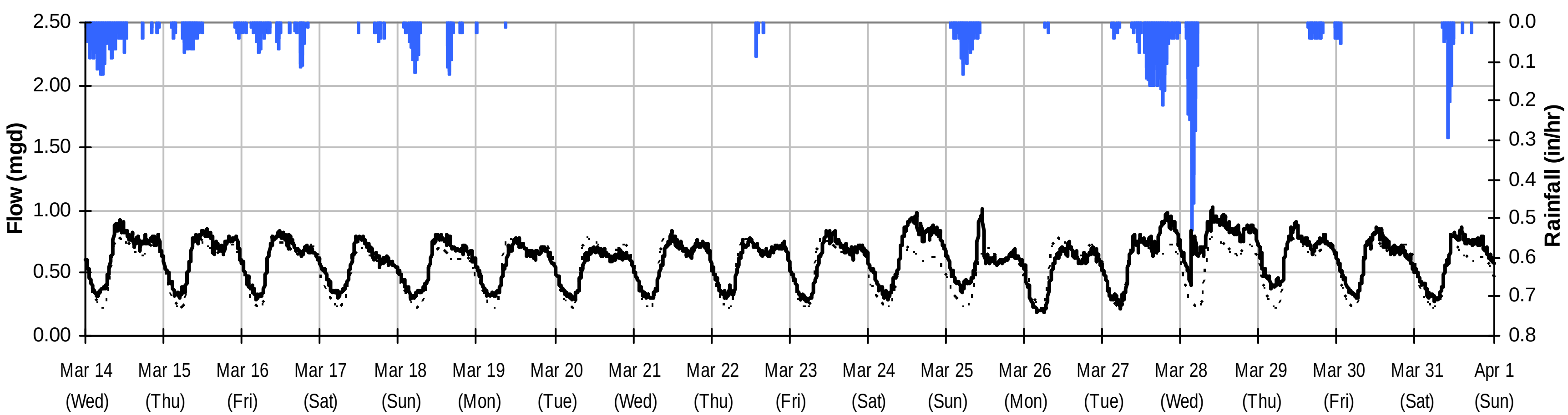
SITE 6A

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.576 mgd **Peak Flow: 1.028 mgd** **Min Flow: 0.162 mgd**

Total Period Rainfall: 6.19 inches



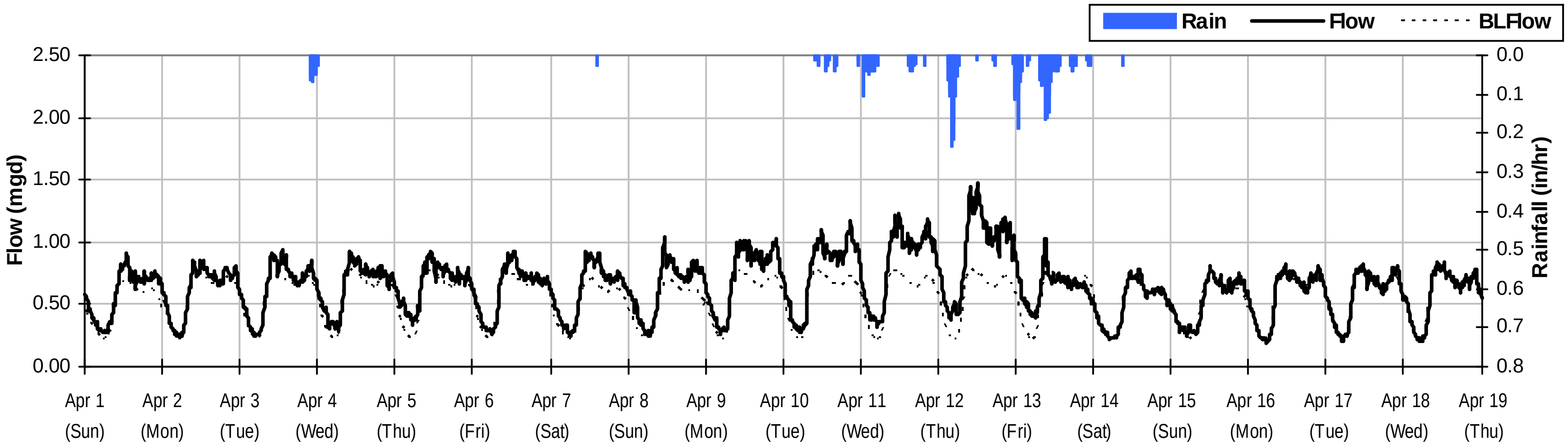


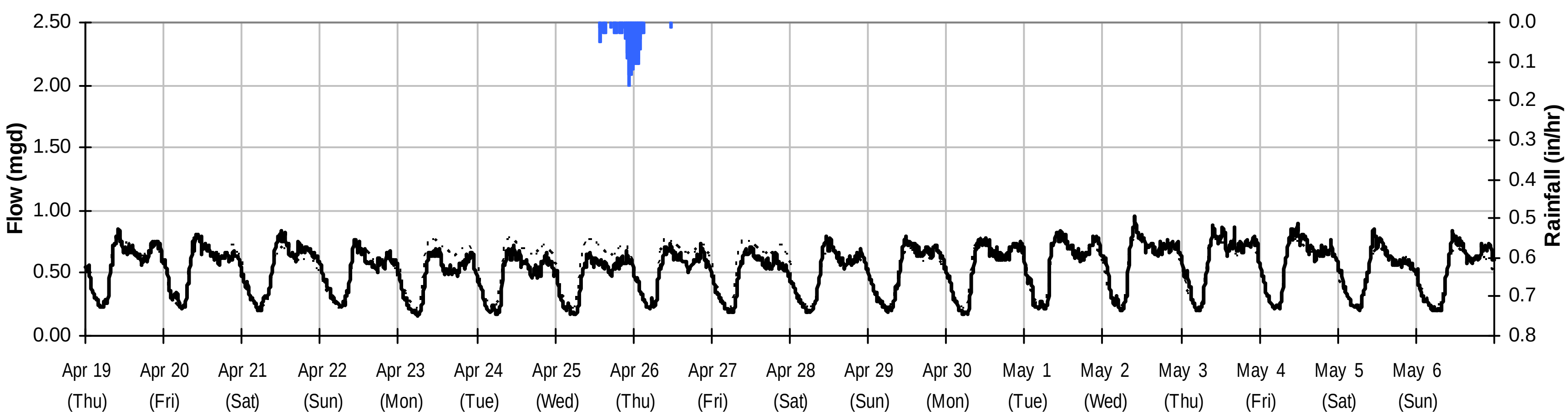
SITE 6A

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.593 mgd **Peak Flow: 1.477 mgd** **Min Flow: 0.158 mgd**

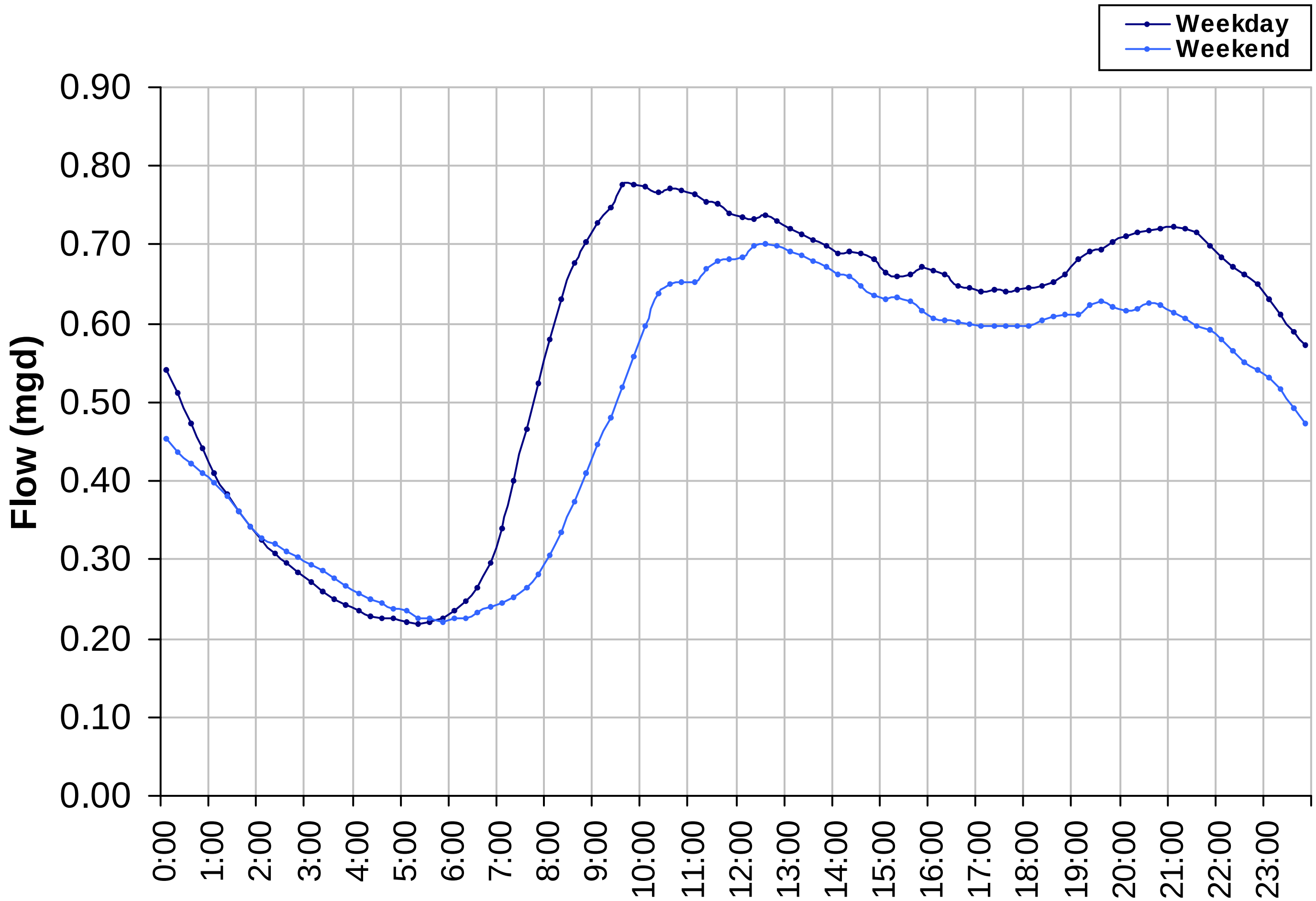
Total Period Rainfall: 2.11 inches





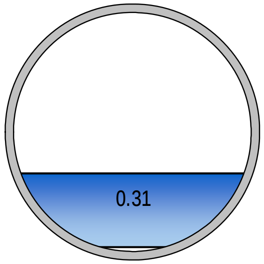
SITE 6A

Baseline Flow Hydrographs



Baseline Flow:

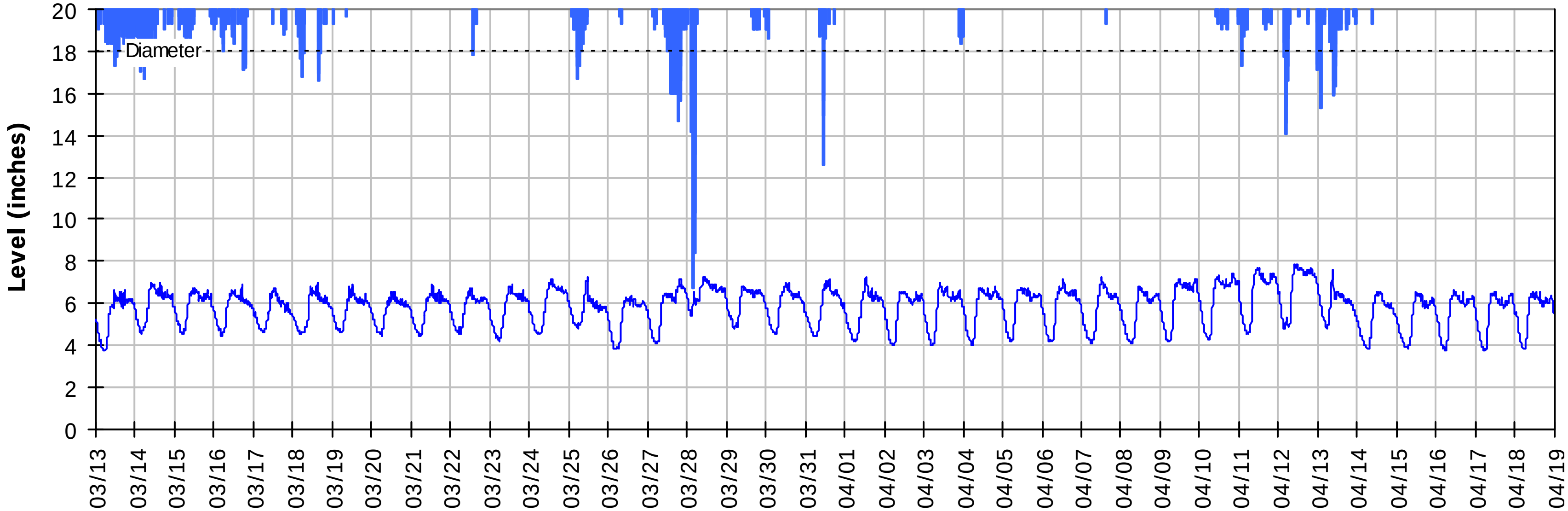
0.547 *mgd*

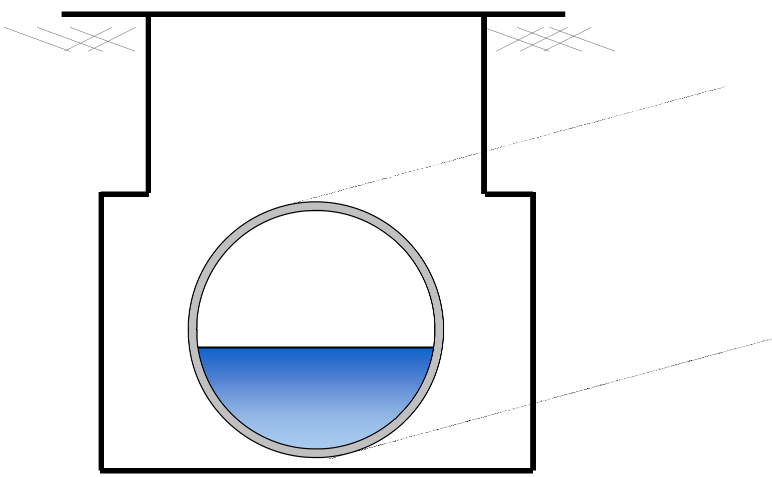


SITE 6A

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





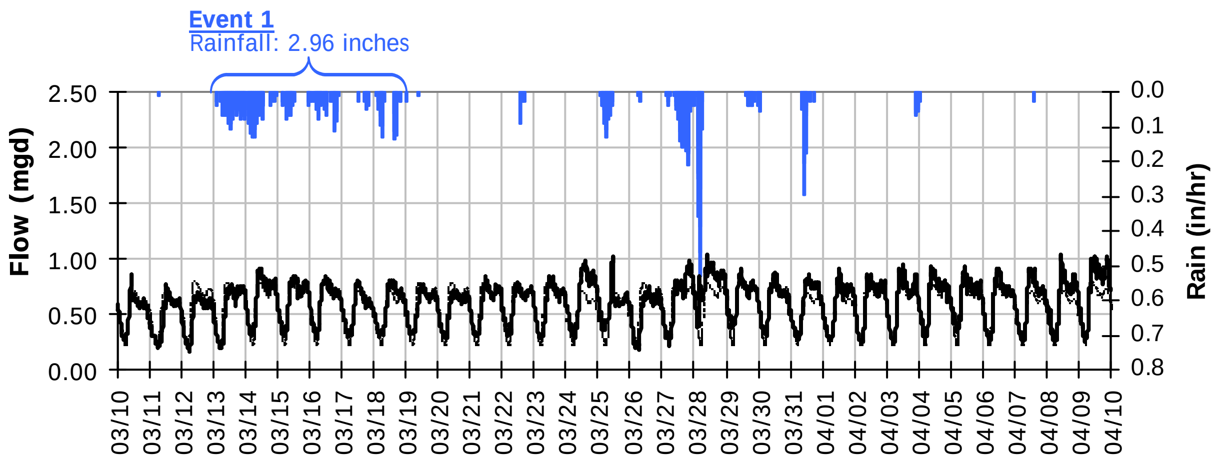
Pipe Diameter: 18 *inches*

Peak Measured Level: 7.89 *inches*

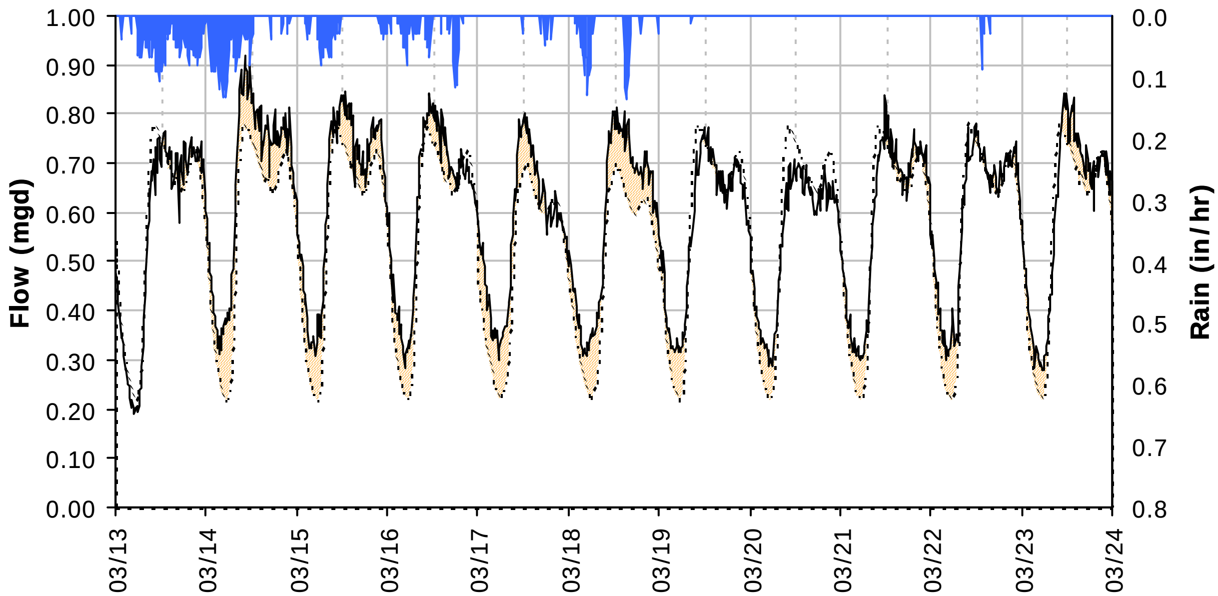
Peak d/D Ratio: 0.44

SITE 6A
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 = 2.96 inches)

Capacity

Peak Flow: 0.92 *mgd*
PF: 1.68
Peak Level: 7.02 *in*
d/D Ratio: 0.39

Inflow

Peak I/I Rate: 0.18 *mgd*
Pk I/I:ADWF: 0.32

RDI (infiltration)

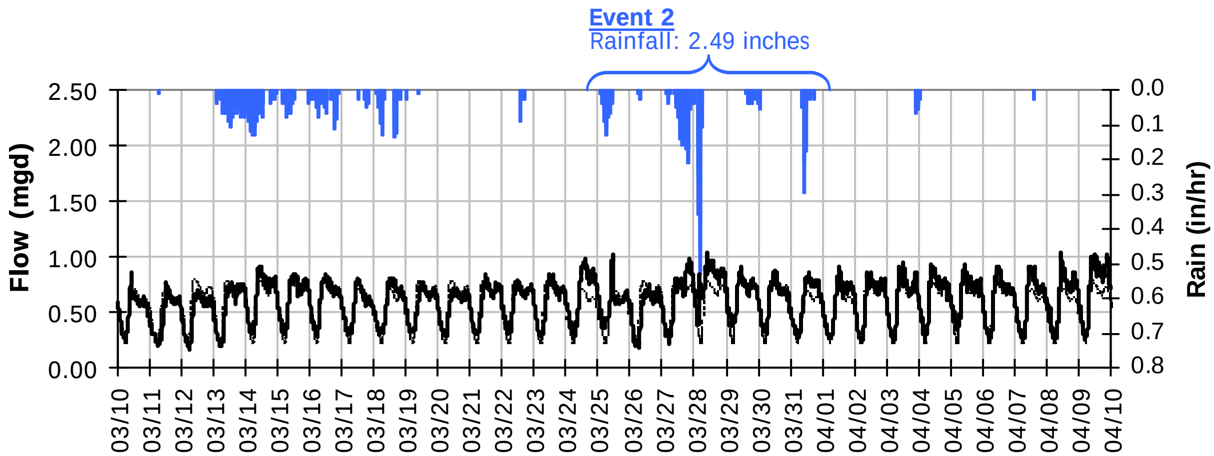
Infiltration Rate: 0.000 *mgd*
(3/20/2012)
RDI (% of BL): 0%

Combined I/I

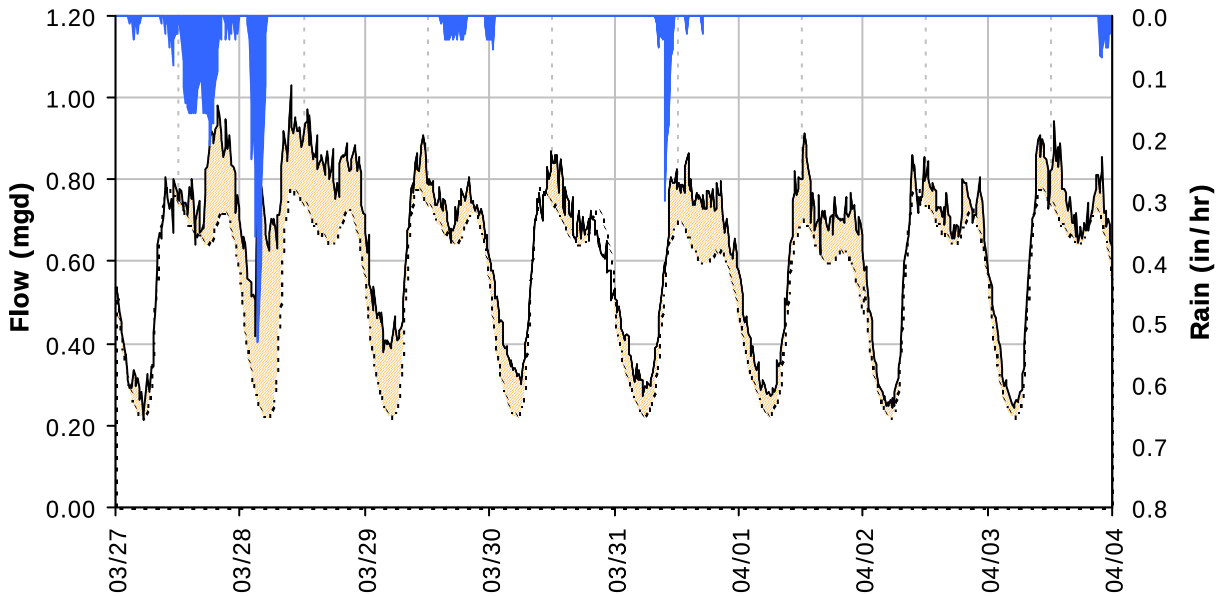
Total I/I: 425,000 *gallons*
Total I/I:ADWF: 0.26 *per in-rain*

SITE 6A
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph

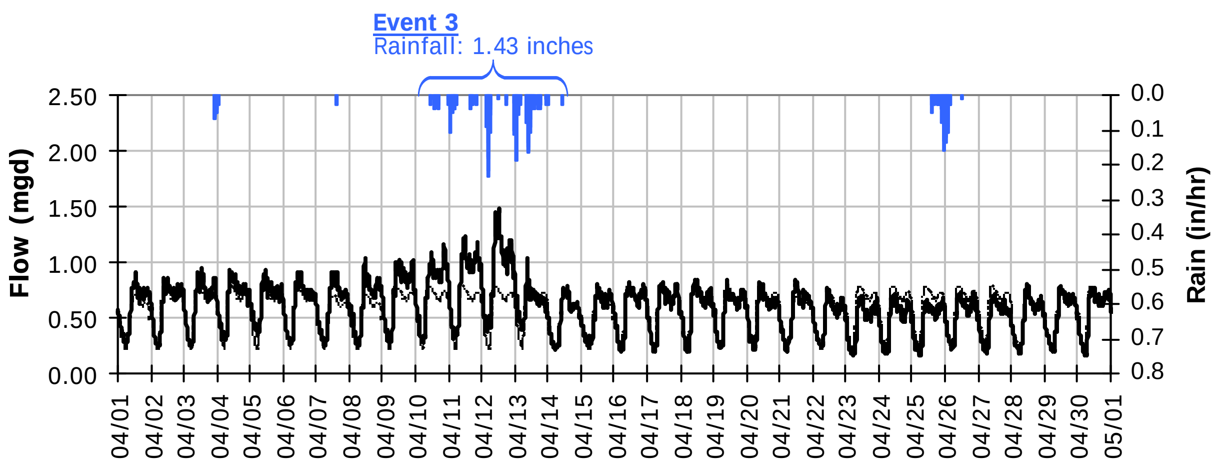


Storm Event I/I Analysis (Rain = 2.49 inches)

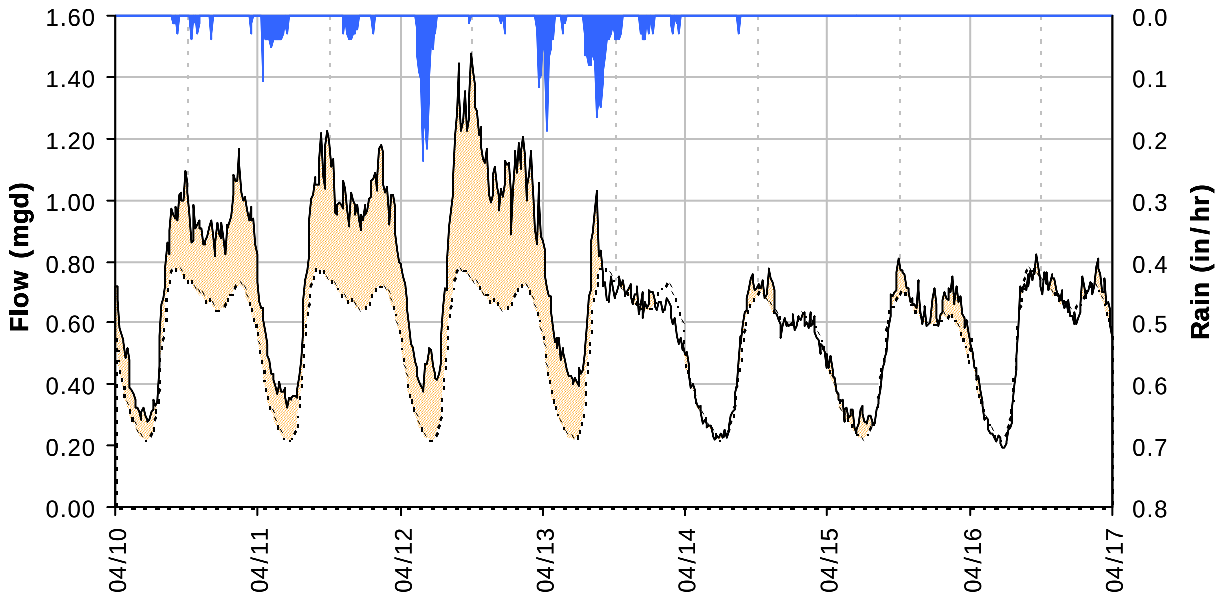
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	1.03 *mgd*	**Peak I/I Rate:**	0.58 *mgd*	**Infiltration Rate:** (4/2/2012)	0.047 *mgd*	**Total I/I:**	740,000 *gallons*
PF:	1.88	**Pk I/I:ADWF:**	1.05	**RDI (% of BL):**	8%	**Total I/I:ADWF:**	0.54 *per in-rain*
Peak Level:	7.24 *in*						
d/D Ratio:	0.40						

SITE 6A
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.43 inches)

Capacity

Peak Flow: 1.48 *mgd*
PF: 2.70
Peak Level: 7.89 *in*
d/D Ratio: 0.44

Inflow

Peak I/I Rate: 0.74 *mgd*
Pk I/I:ADWF: 1.35

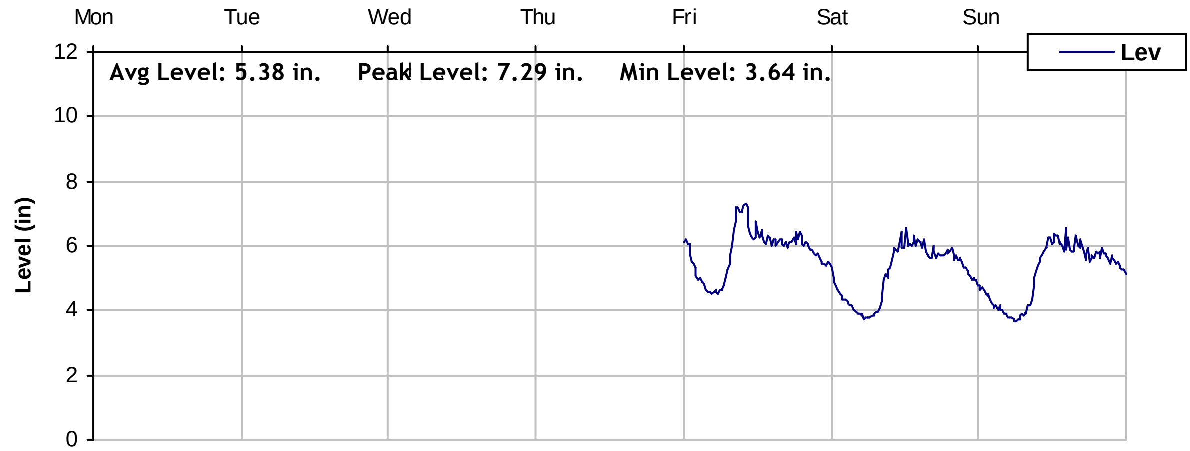
RDI (infiltration)

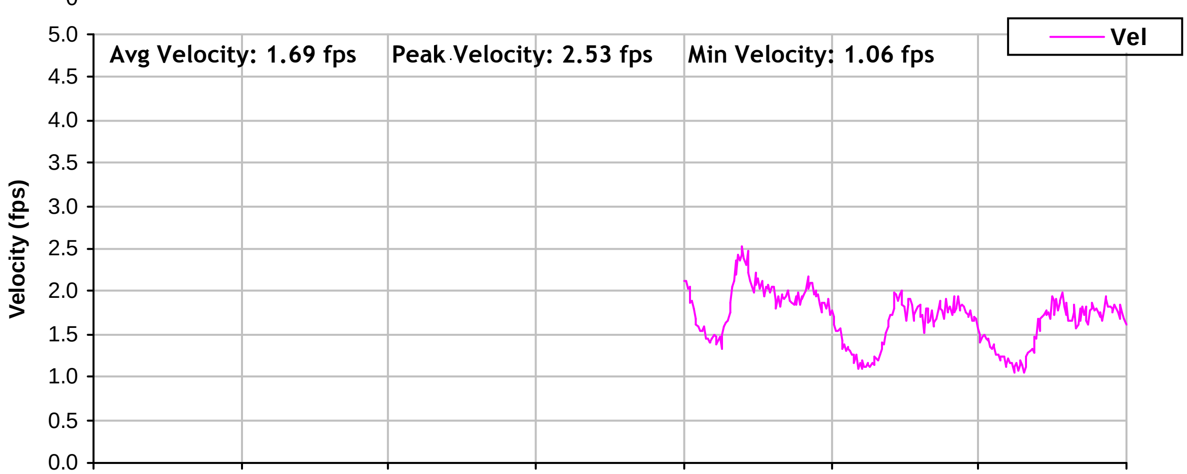
Infiltration Rate: 0.036 *mgd*
(4/15/2012)
RDI (% of BL): 7%

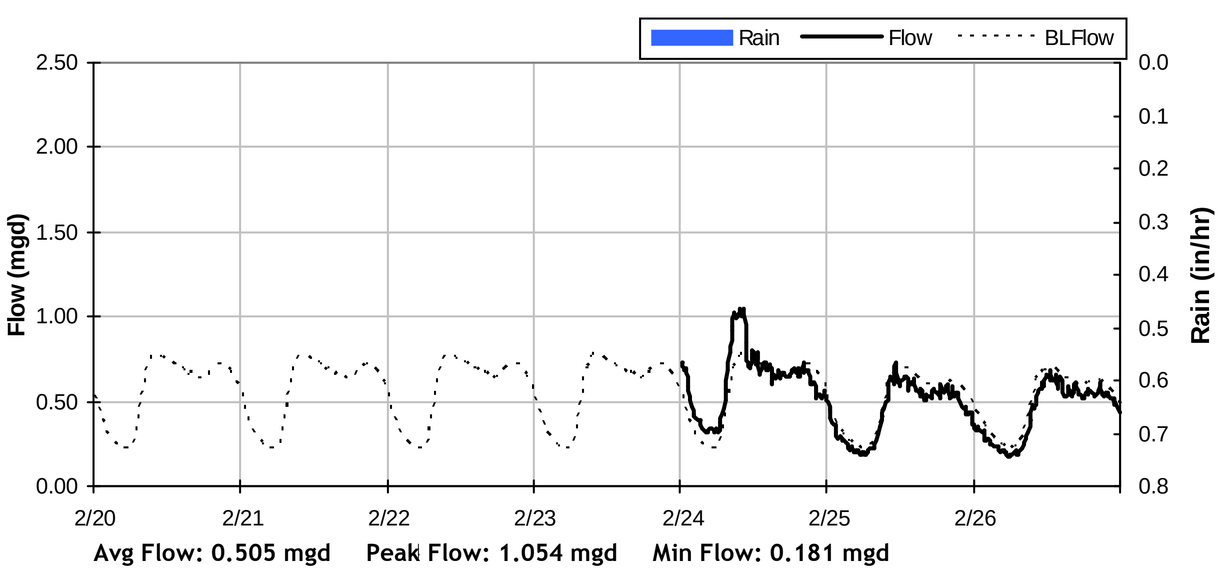
Combined I/I

Total I/I: 945,000 *gallons*
Total I/I:ADWF: 1.20 *per in-rain*

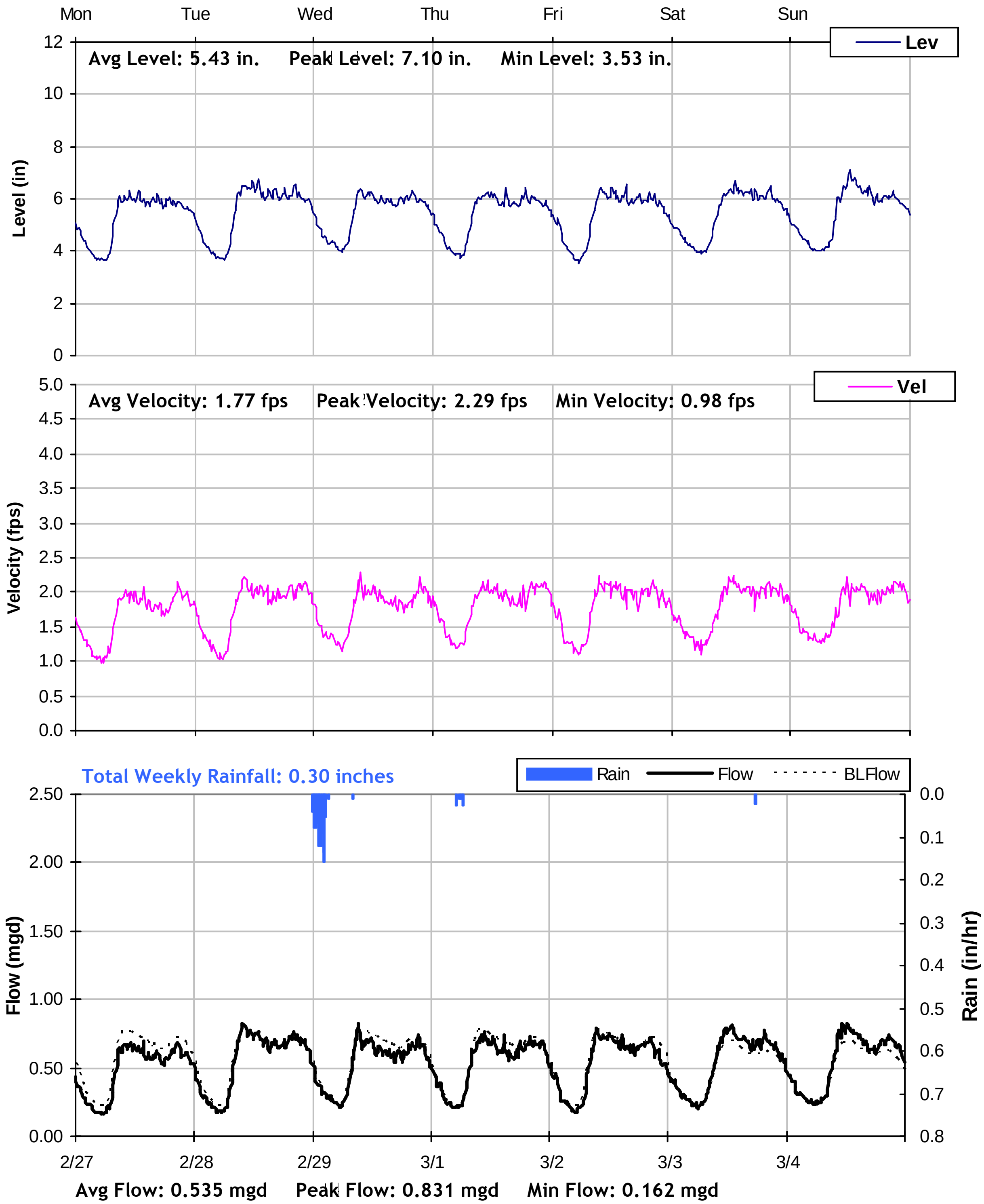
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



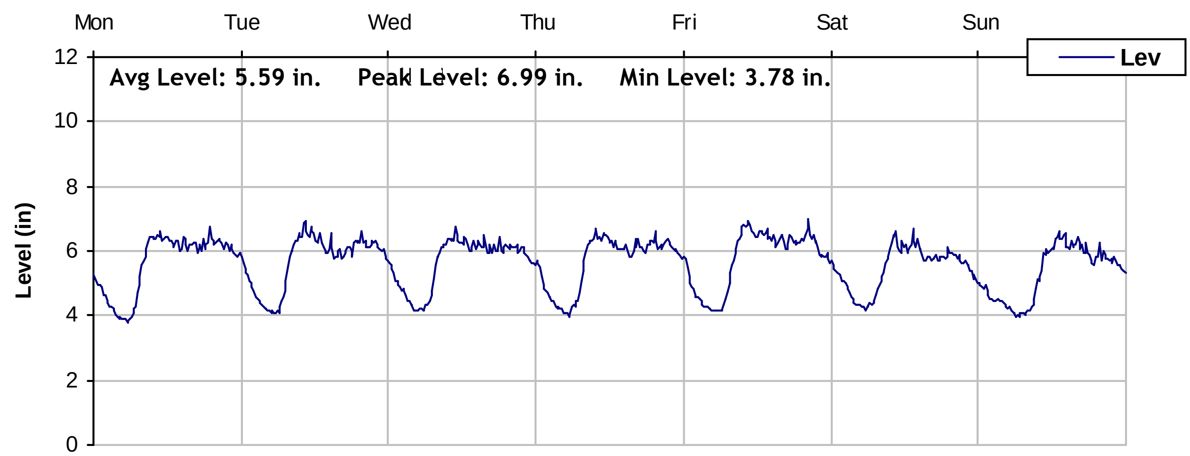


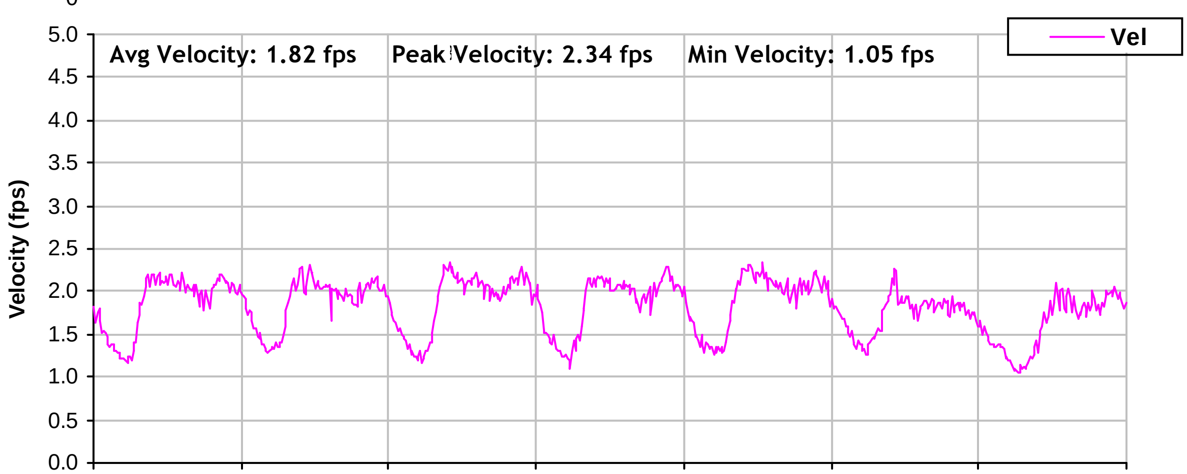


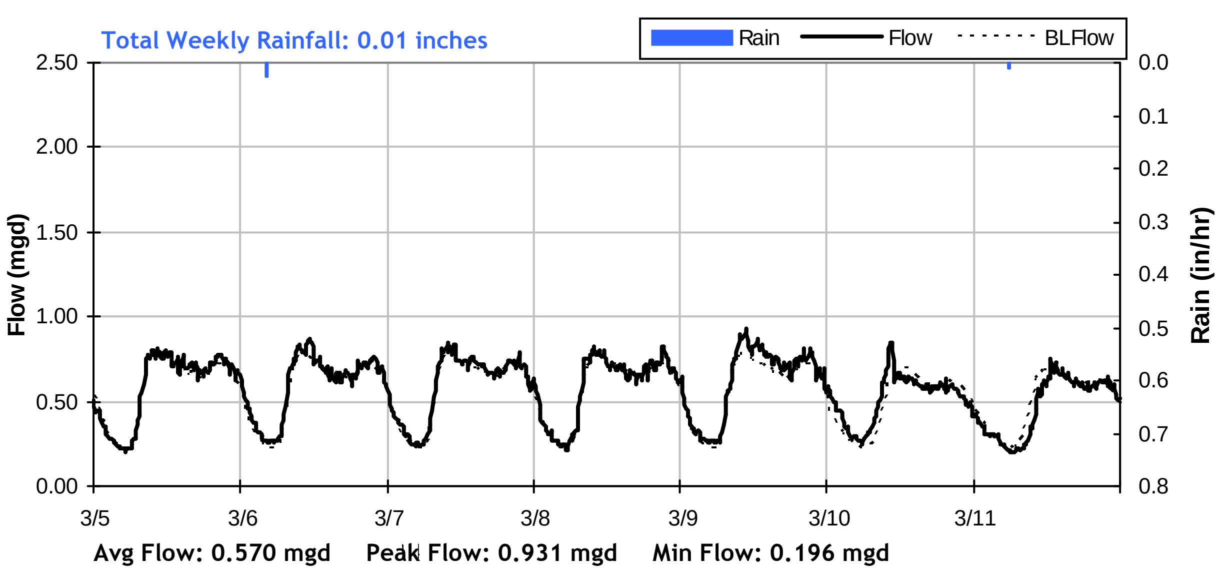
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



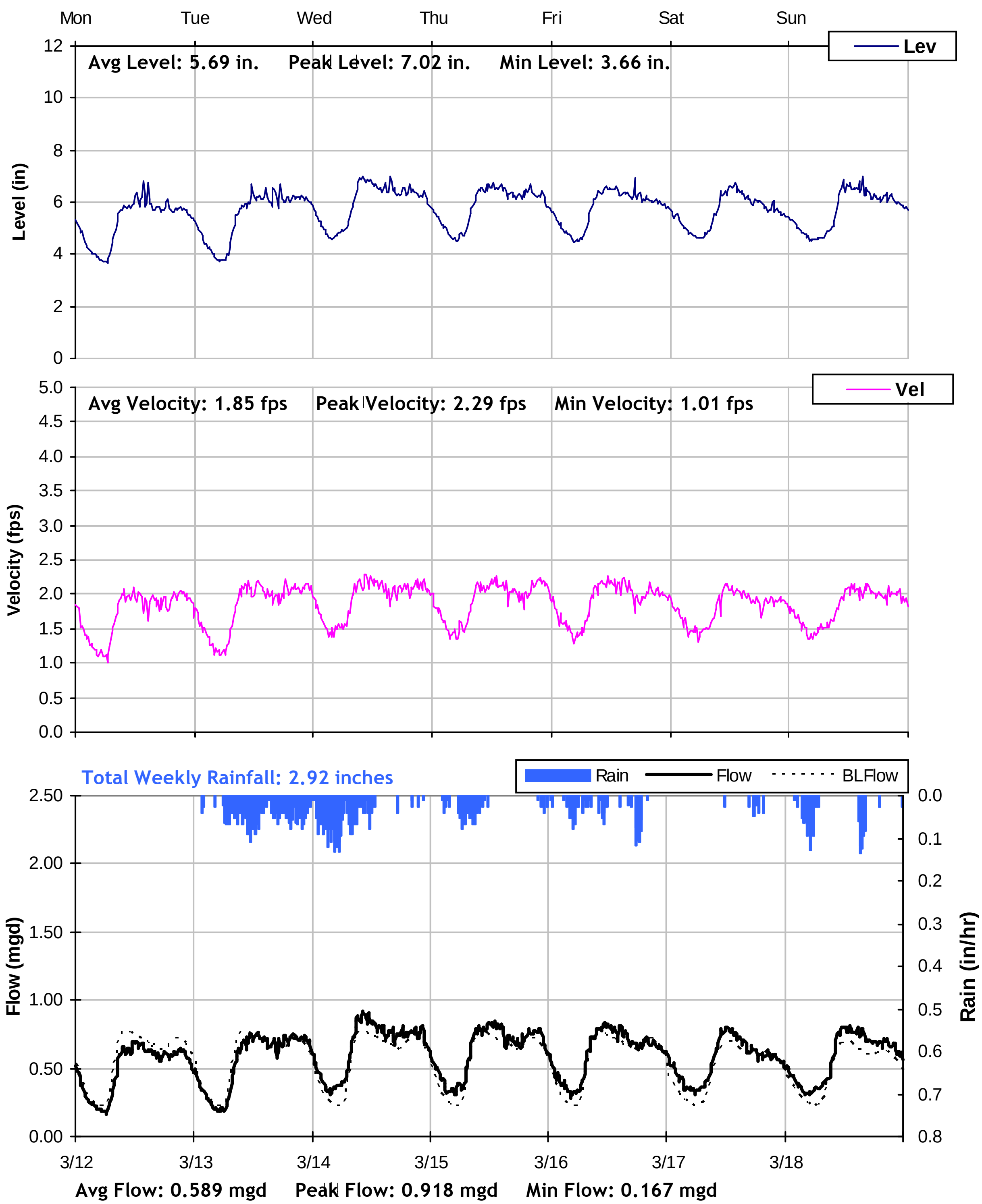
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



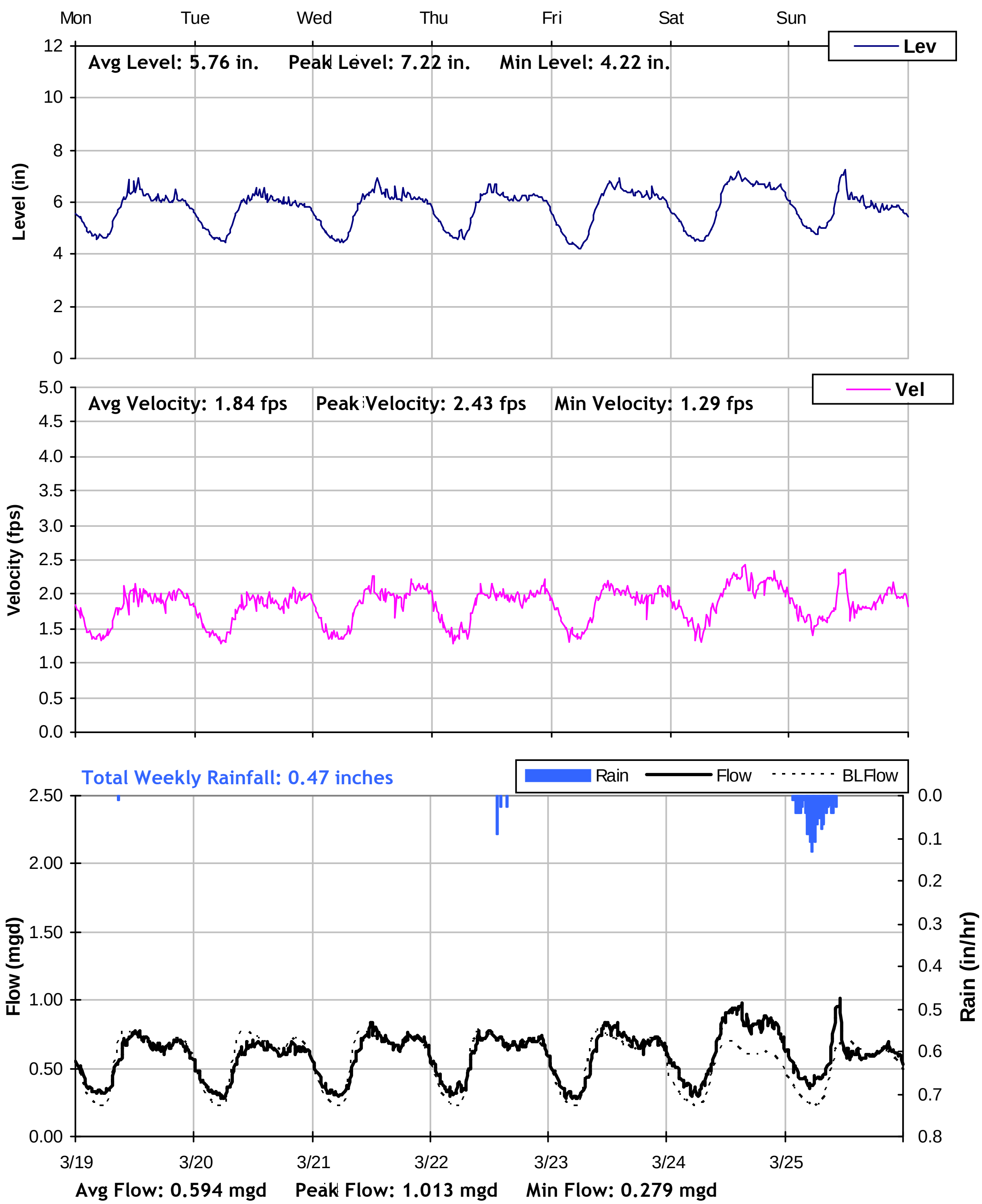




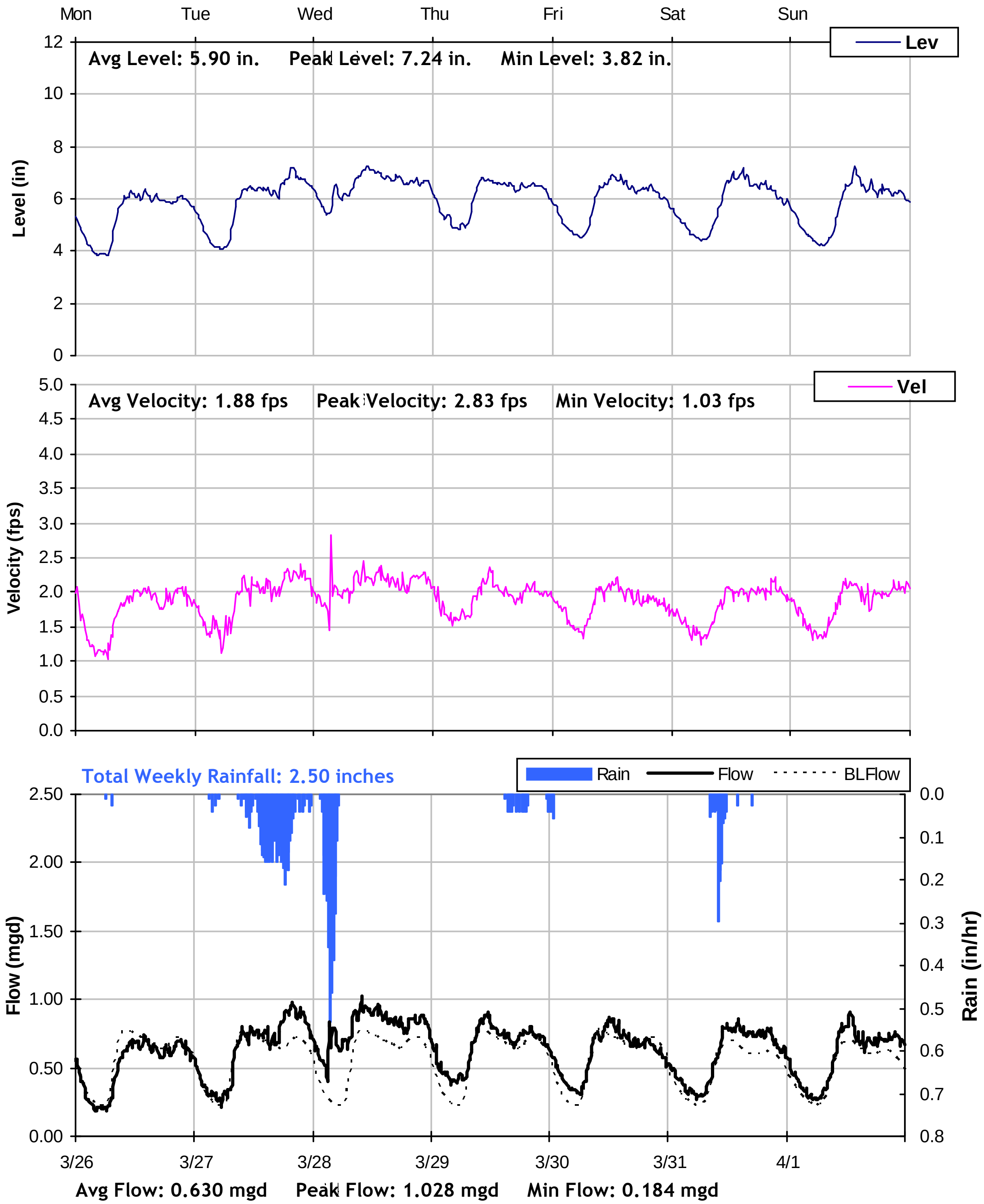
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



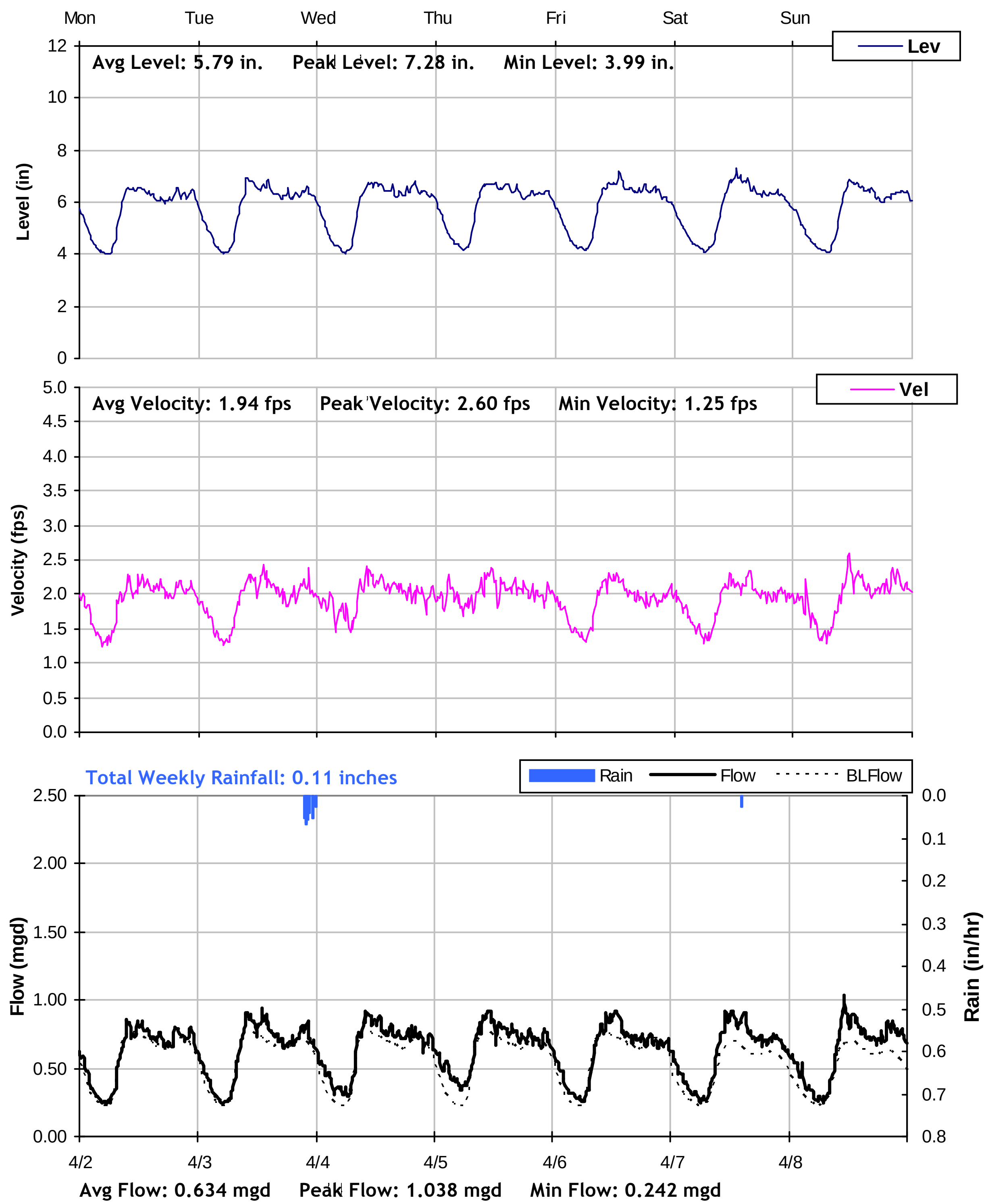
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



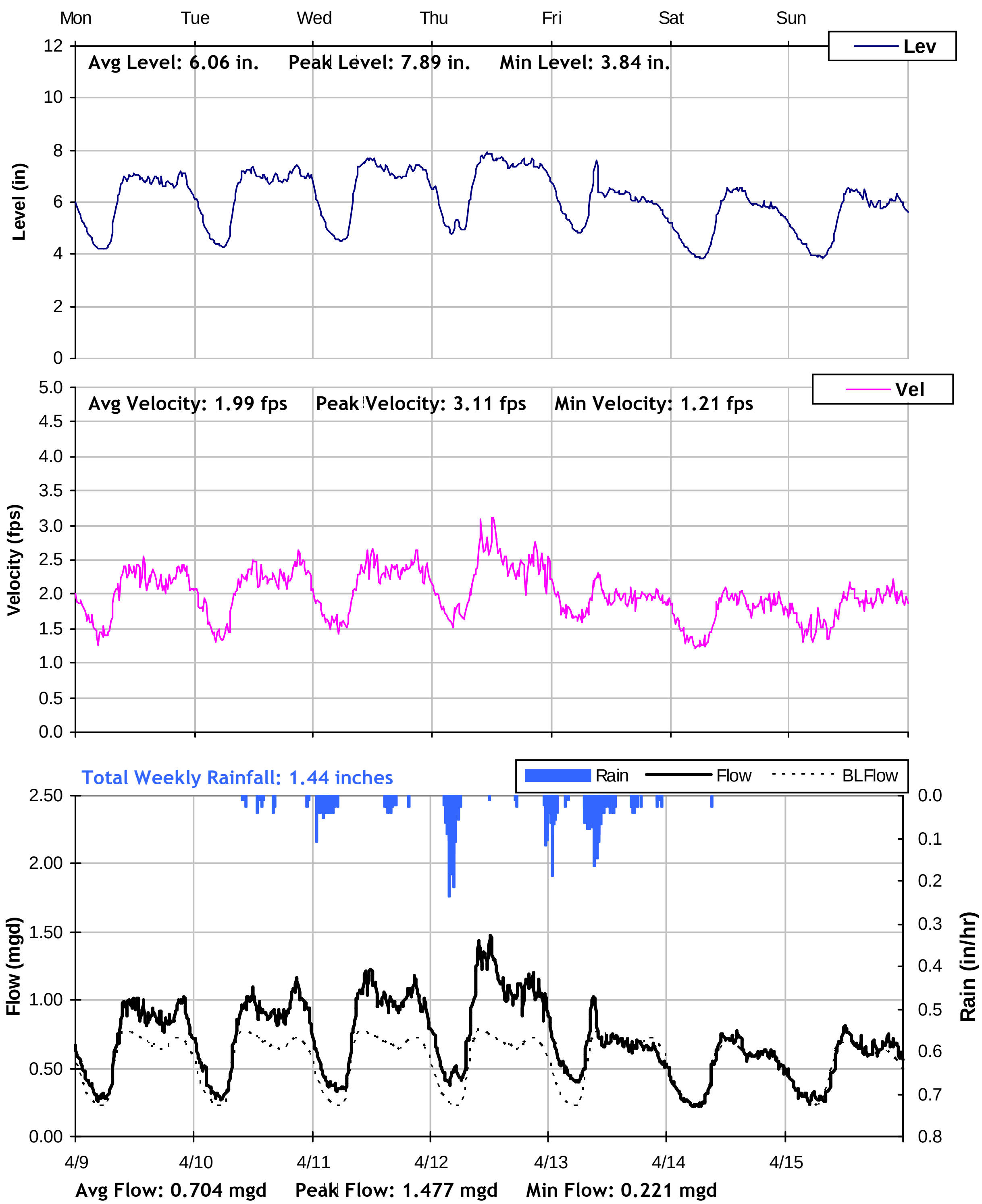
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



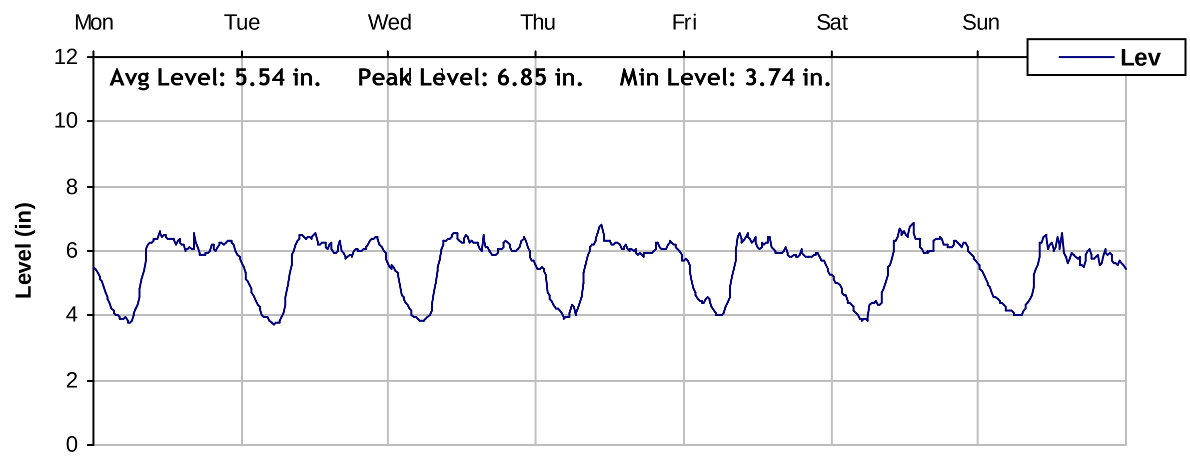
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012

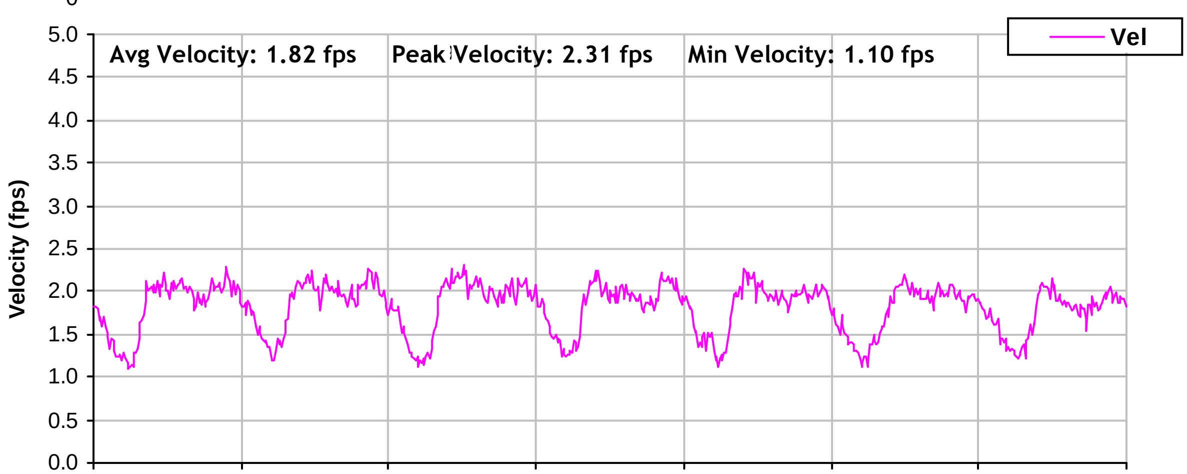


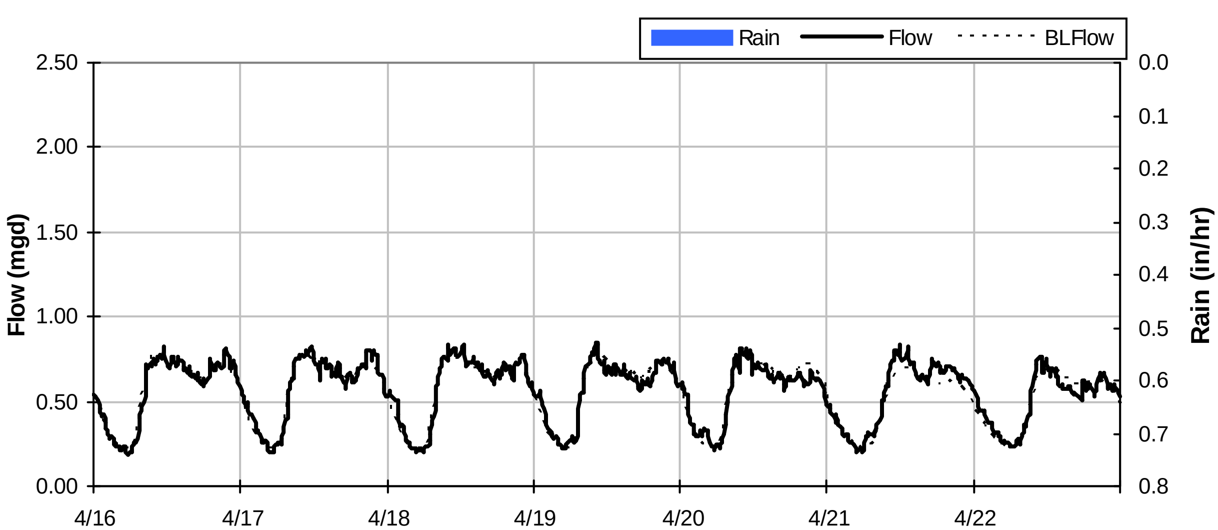
SITE 6A
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



SITE 6A
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012

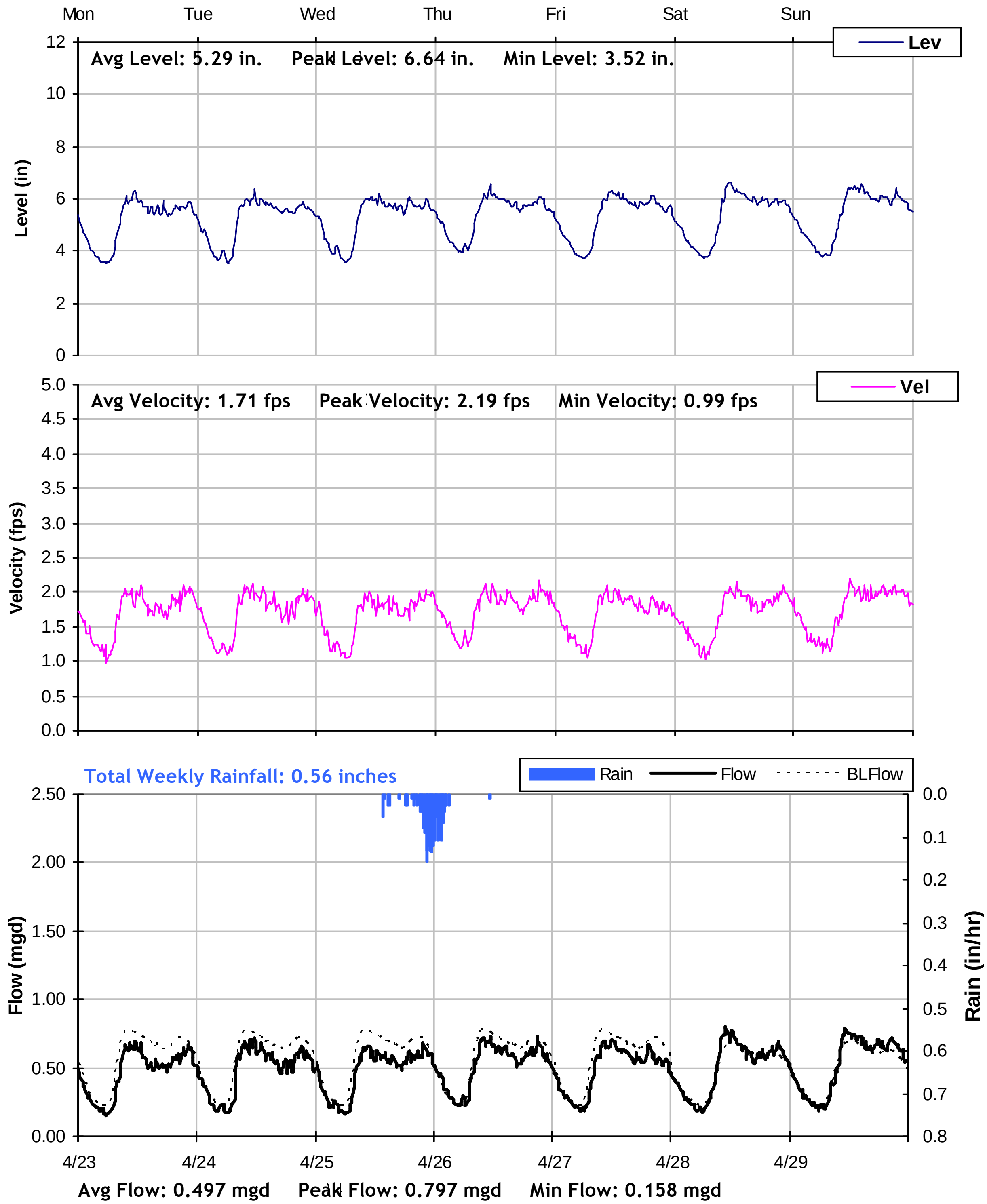




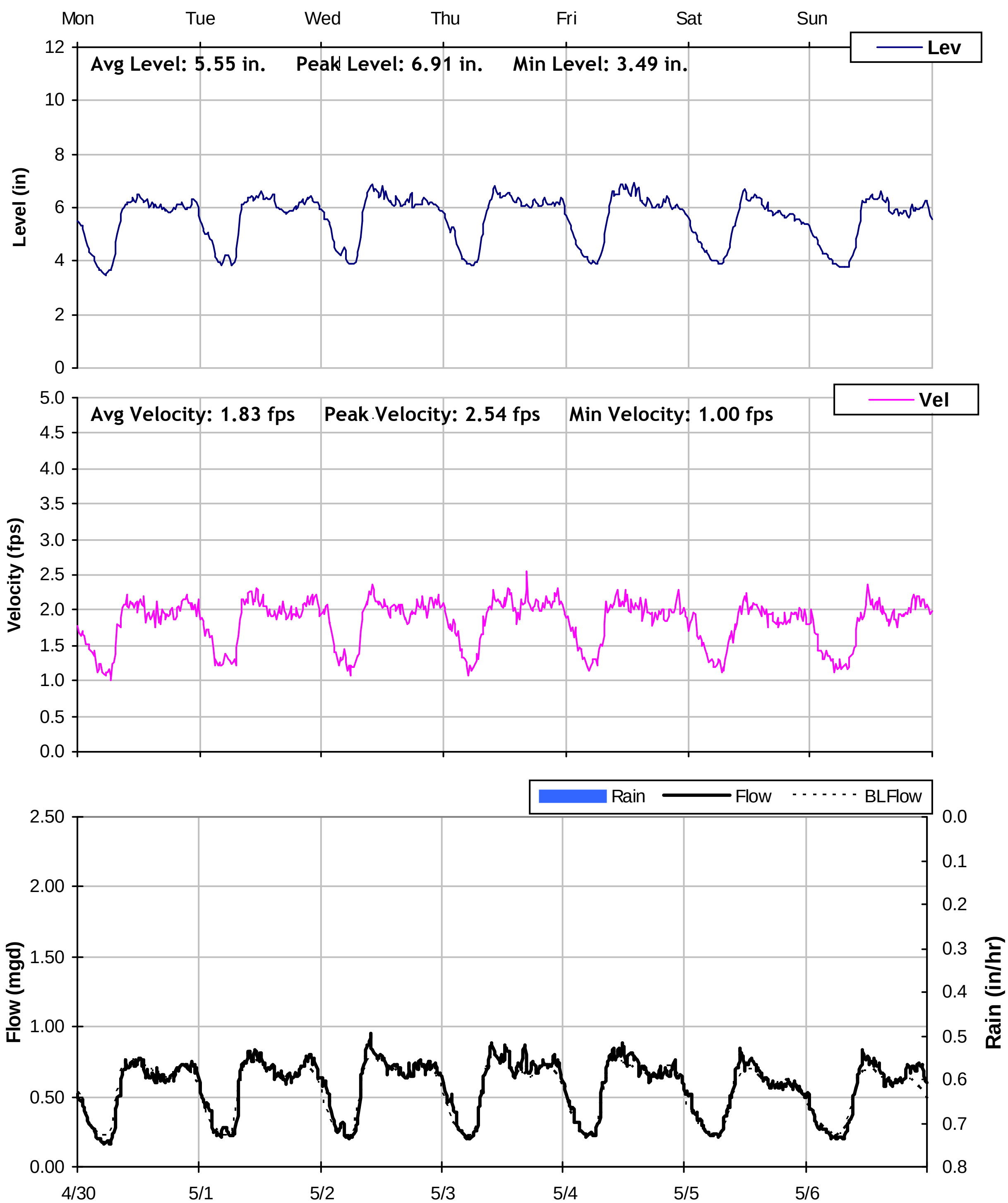


Avg Flow: 0.562 mgd **Peak Flow: 0.848 mgd** **Min Flow: 0.193 mgd**

SITE 6A
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 6A
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



Avg Flow: 0.571 mgd **Peak Flow: 0.951 mgd** **Min Flow: 0.168 mgd**

City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 6B

Location: California 32 at West Sacramento Avenue (in Parking Lot near Subway)

Vicinity Map:

SITE 6B
Site Information Report

Location: California 32 at West Sacramento Avenue (in Parking Lot near Subway)

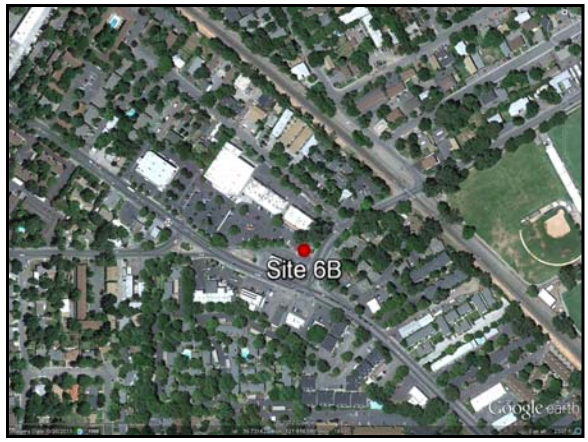
Coordinates: 121.8583° W, 39.7311° N

Elevation: 185 feet

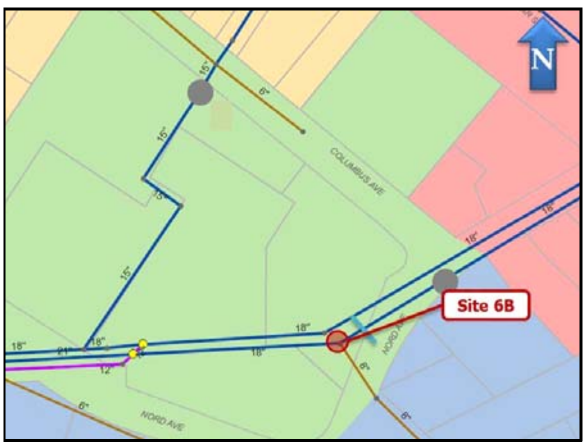
Diameter: 18 inches

Baseline Flow: 0.467 mgd

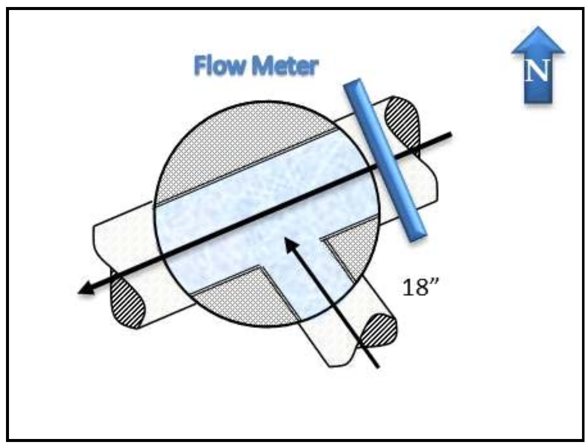
Peak Measured Flow: 1.315 mgd



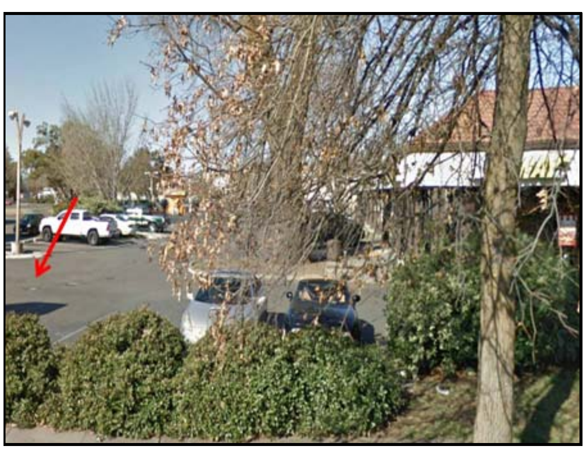
Satellite Map



Sanitary Sewer Map



Flow Sketch


View from Street

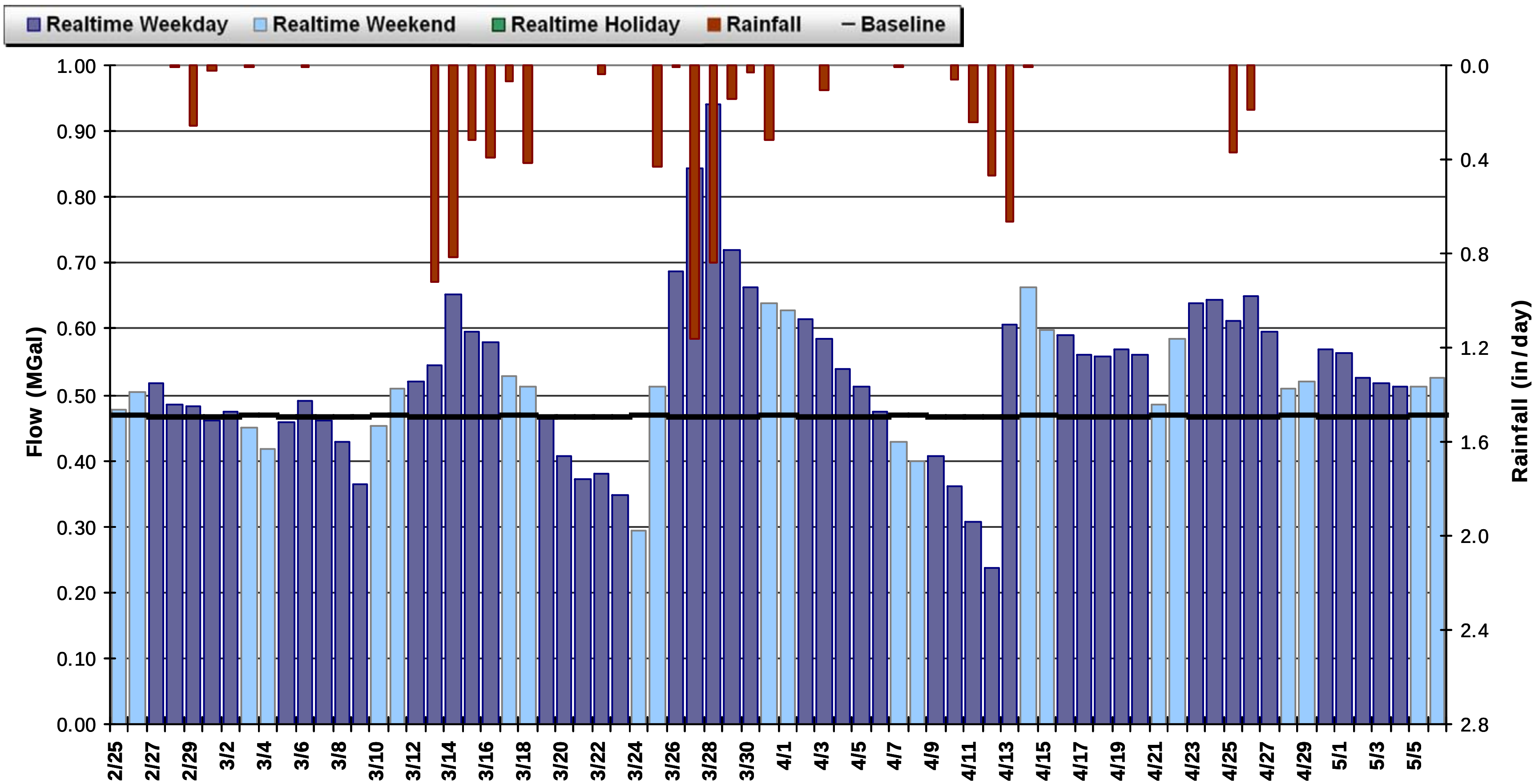

Plan View

SITE 6B

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.525 MGal **Peak Daily Flow: 0.942 MGal** **Min Daily Flow: 0.238 MGal**

Total Period Rainfall: 8.30 inches

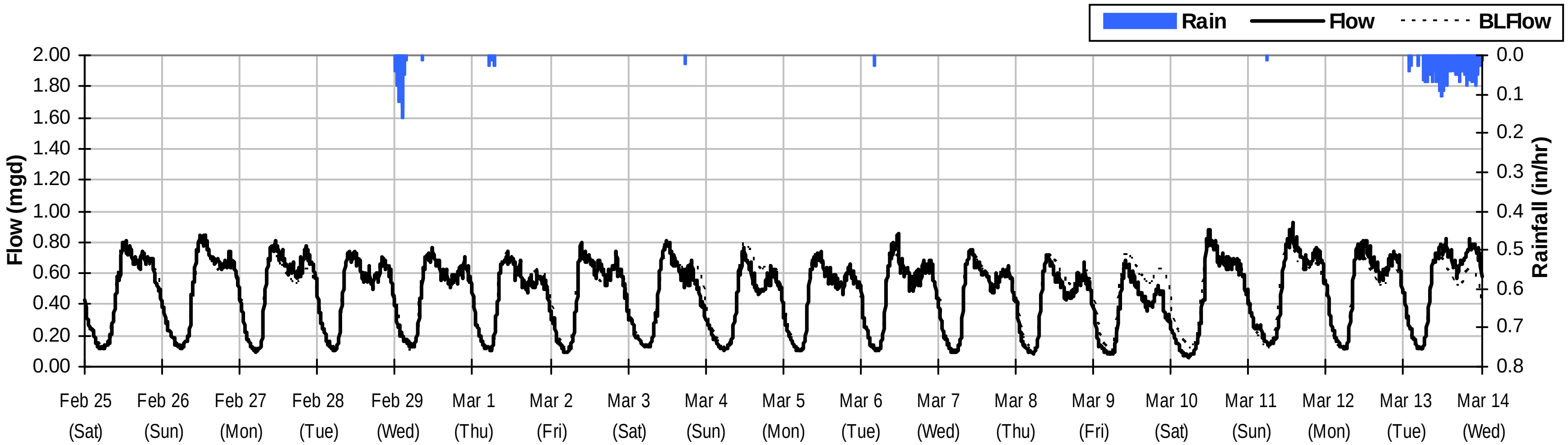


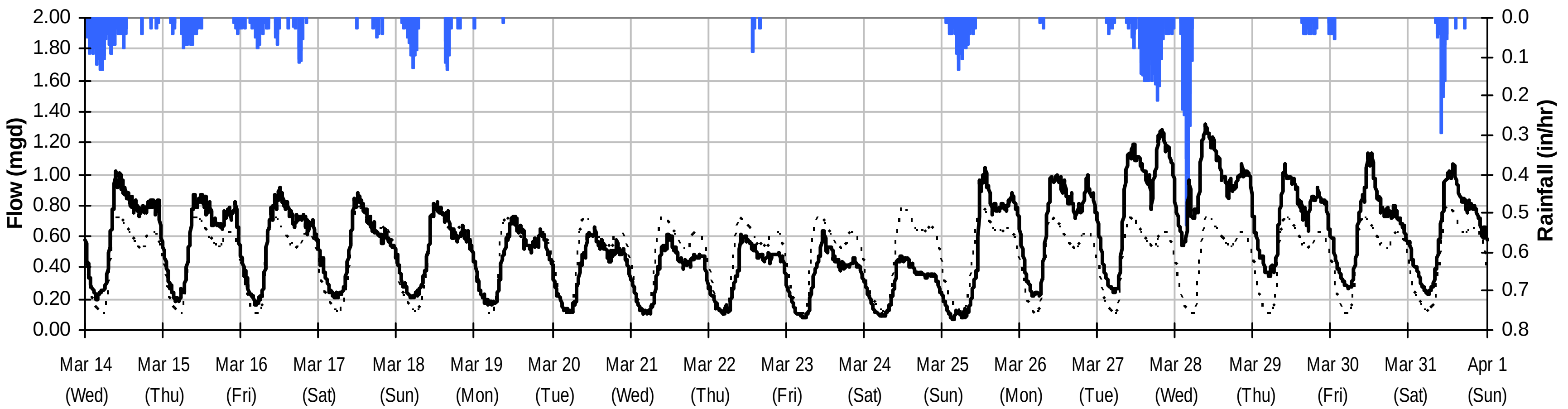
SITE 6B

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.518 mgd **Peak Flow: 1.315 mgd** **Min Flow: 0.058 mgd**

Total Period Rainfall: 6.19 inches



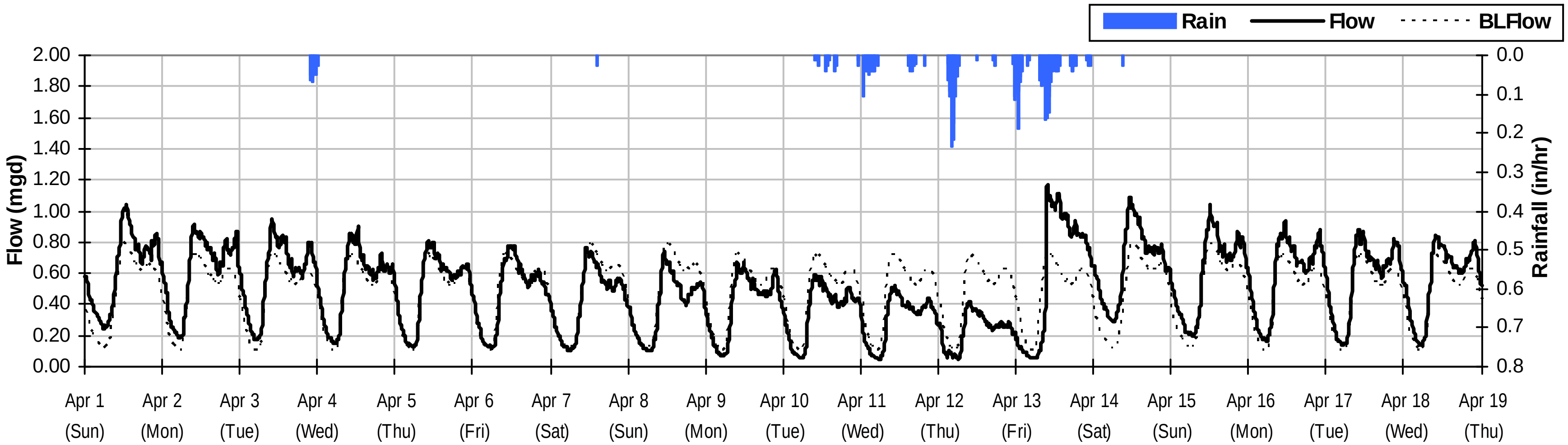


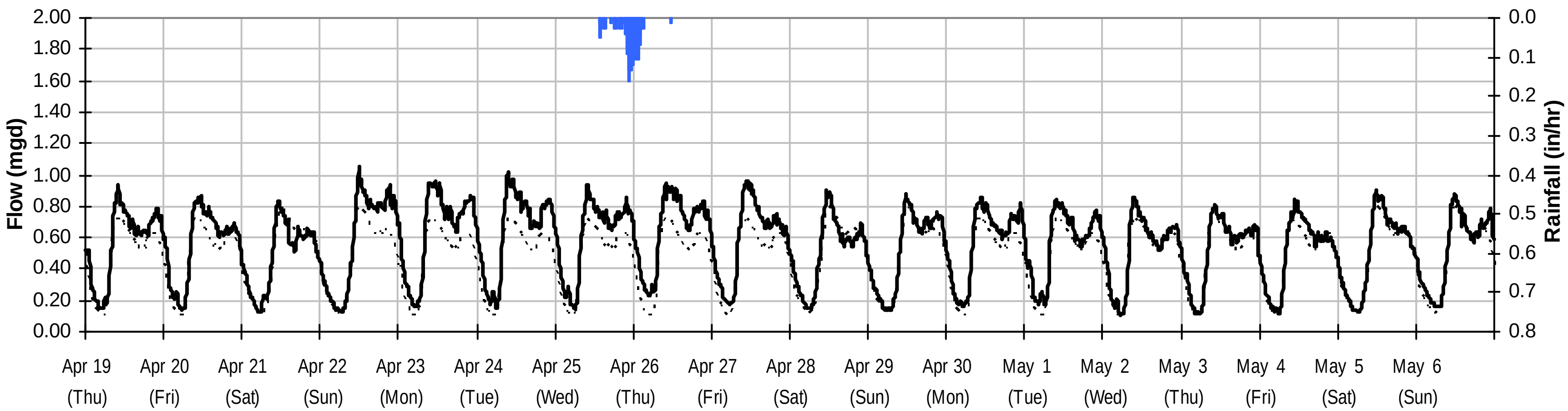
SITE 6B

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.532 mgd **Peak Flow: 1.169 mgd** **Min Flow: 0.050 mgd**

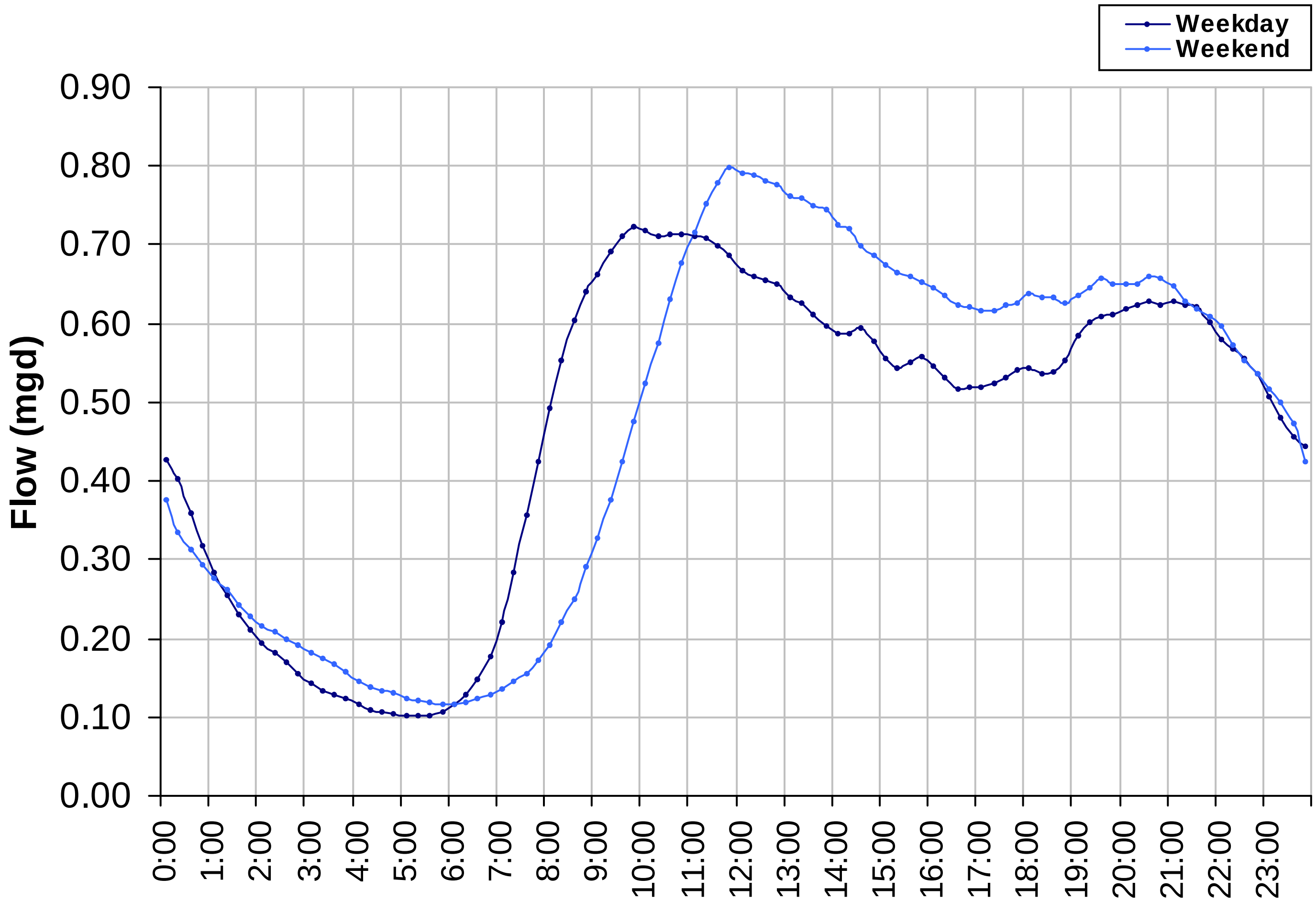
Total Period Rainfall: 2.11 inches





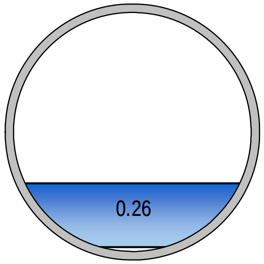
SITE 6B

Baseline Flow Hydrographs



Baseline Flow:

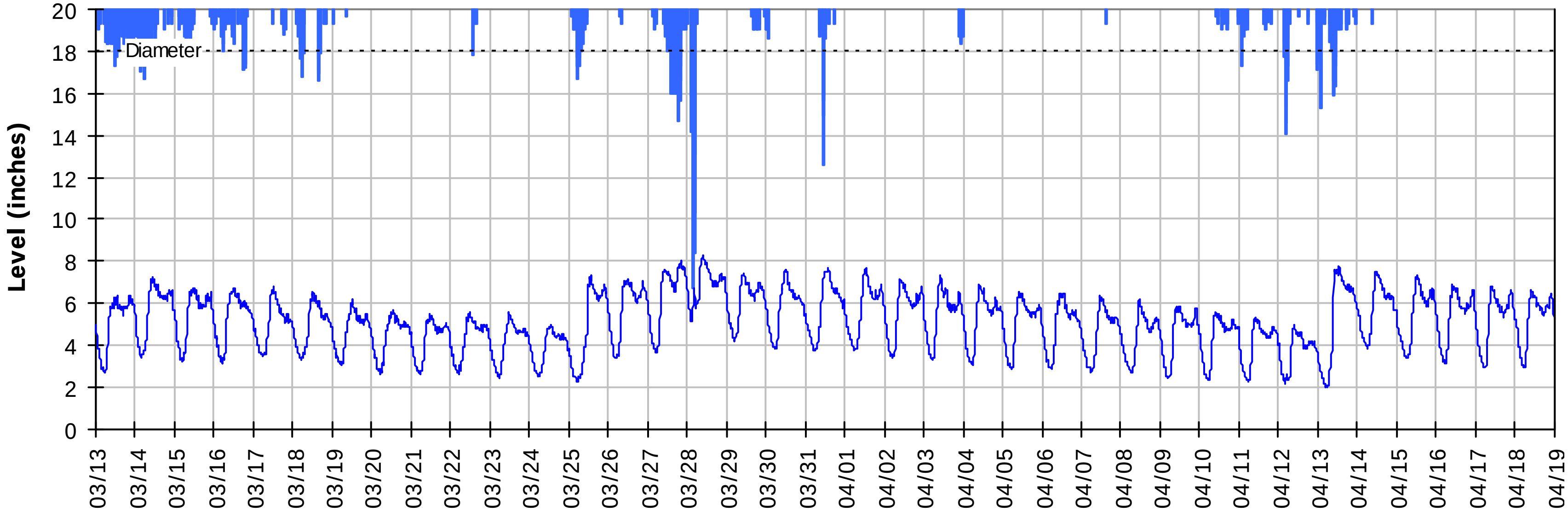
0.467 *mgd*

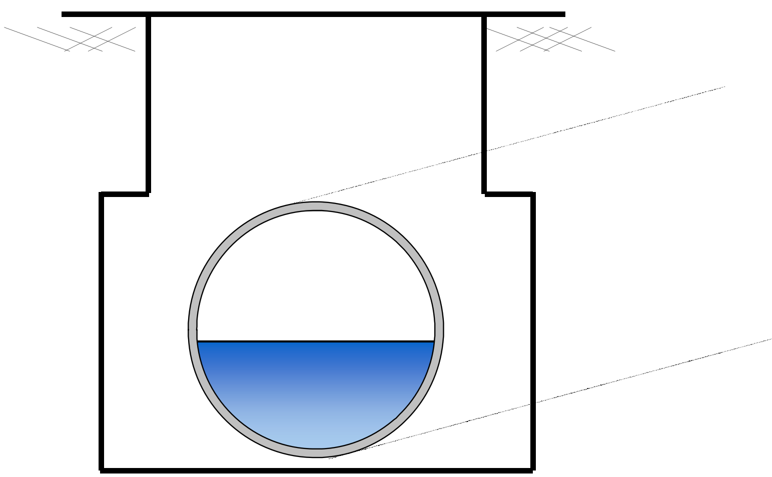


SITE 6B

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

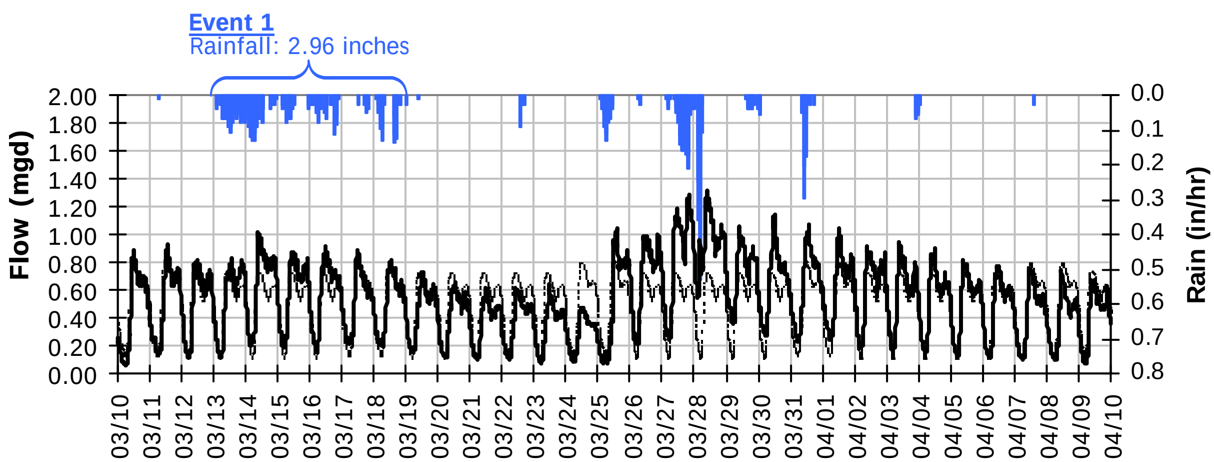




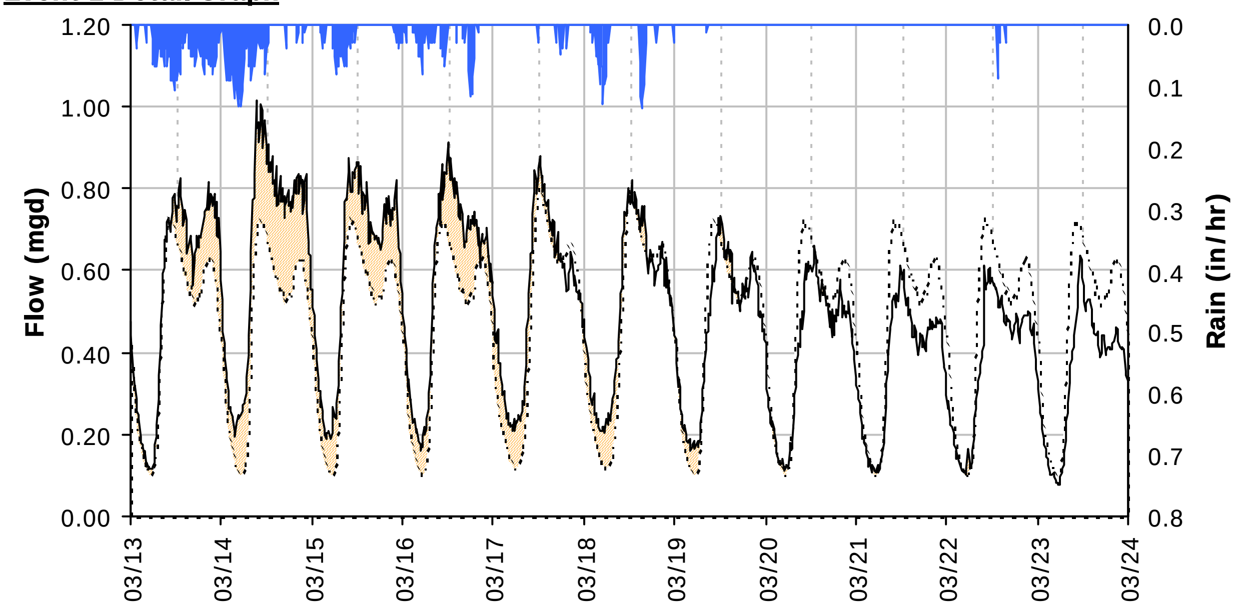
Pipe Diameter:	18	*inches*
Peak Measured Level:	8.32	*inches*
Peak d/D Ratio:	0.46	

SITE 6B
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 = 2.96 inches)

Capacity

Peak Flow: 1.02 *mgd*
PF: 2.18
Peak Level: 7.25 *in*
d/D Ratio: 0.40

Inflow

Peak I/I Rate: 0.33 *mgd*
Pk I/I:ADWF: 0.70

RDI (infiltration)

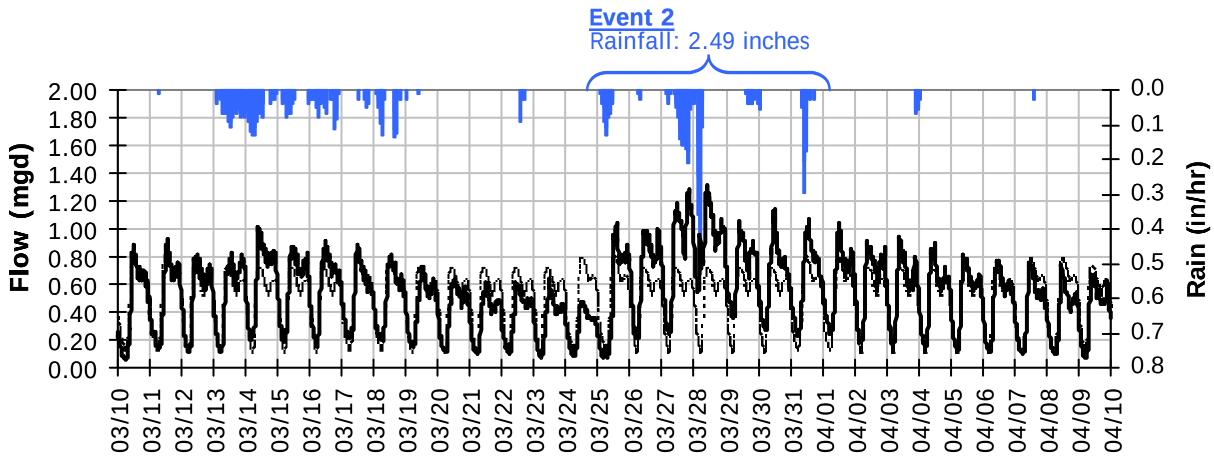
Infiltration Rate: 0.000 *mgd* (3/20/2012)
RDI (% of BL): 0%

Combined I/I

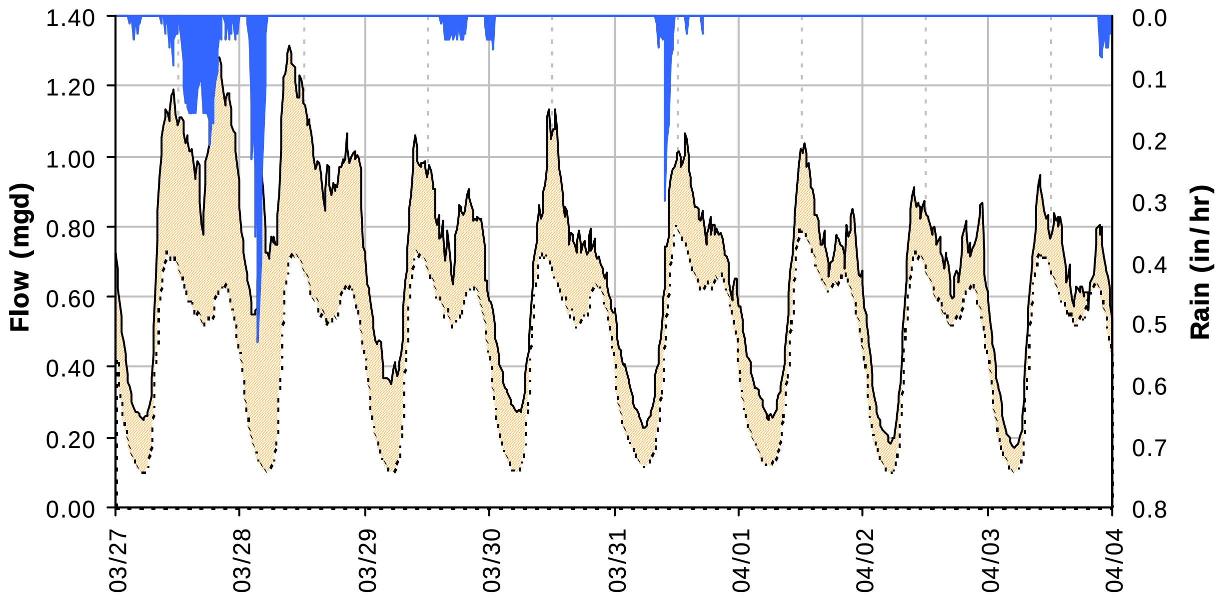
Total I/I: 250,000 *gallons*
Total I/I:ADWF: 0.18 *per in-rain*

SITE 6B
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 = 2.49 inches)

Capacity

Peak Flow: 1.32 *mgd*
PF: 2.82
Peak Level: 8.32 *in*
d/D Ratio: 0.46

Inflow

Peak I/I Rate: 0.85 *mgd*
Pk I/I:ADWF: 1.82

RDI (infiltration)

Infiltration Rate: 0.148 *mgd*
(4/2/2012)
RDI (% of BL): 32%

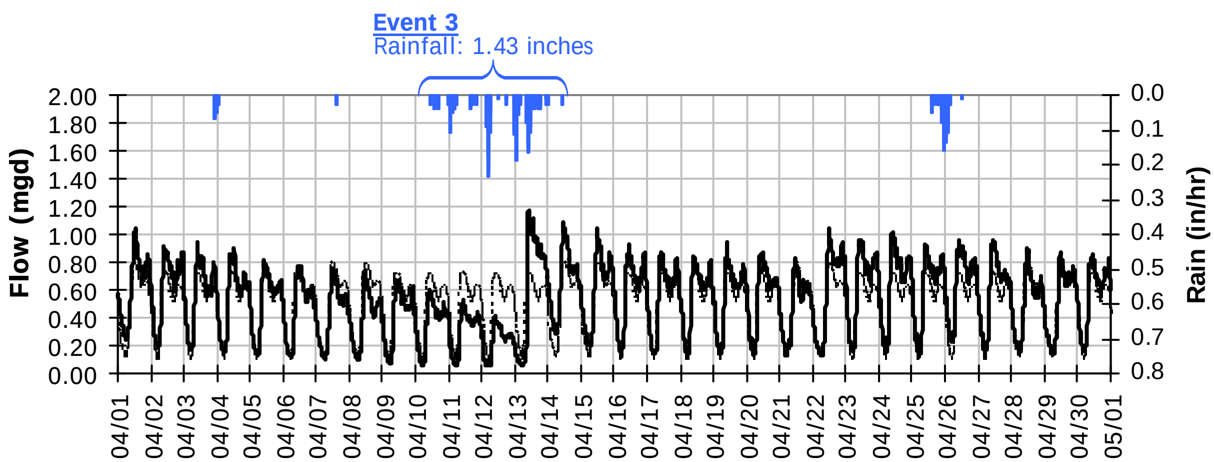
Combined I/I

Total I/I: 1,900,000 *gallons*
Total I/I:ADWF: 1.64 *per in-rain*

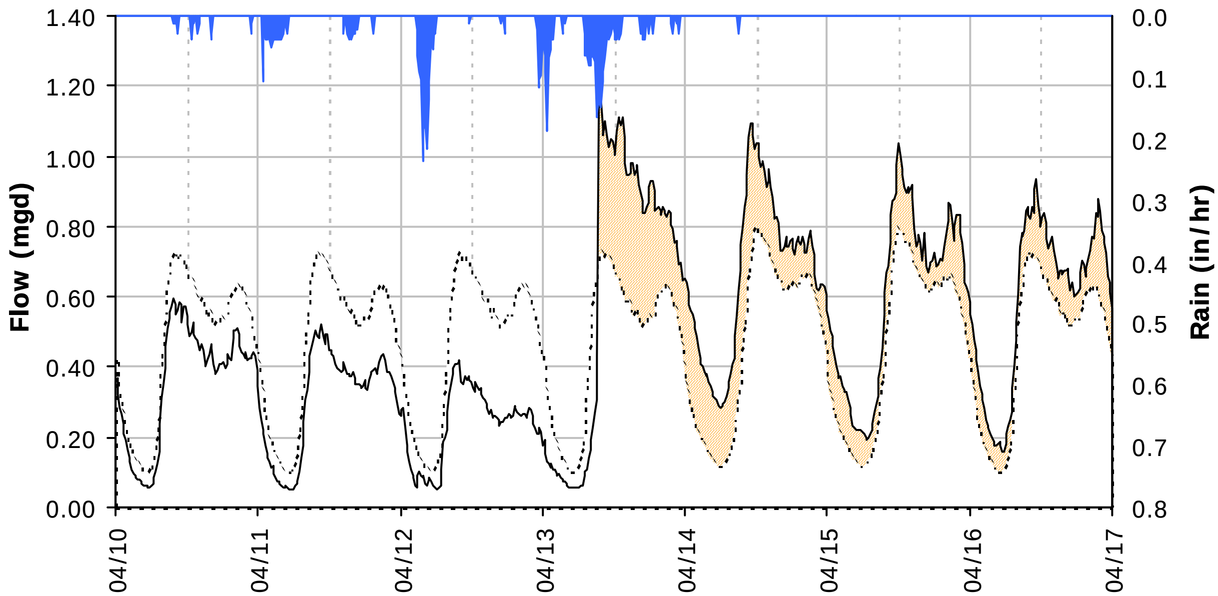
SITE 6B

I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



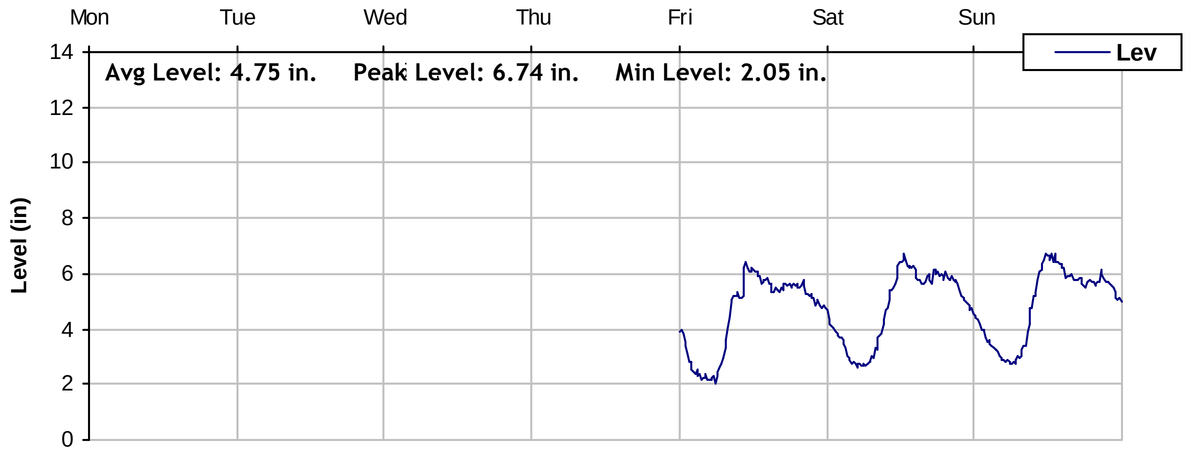
Event 3 Detail Graph

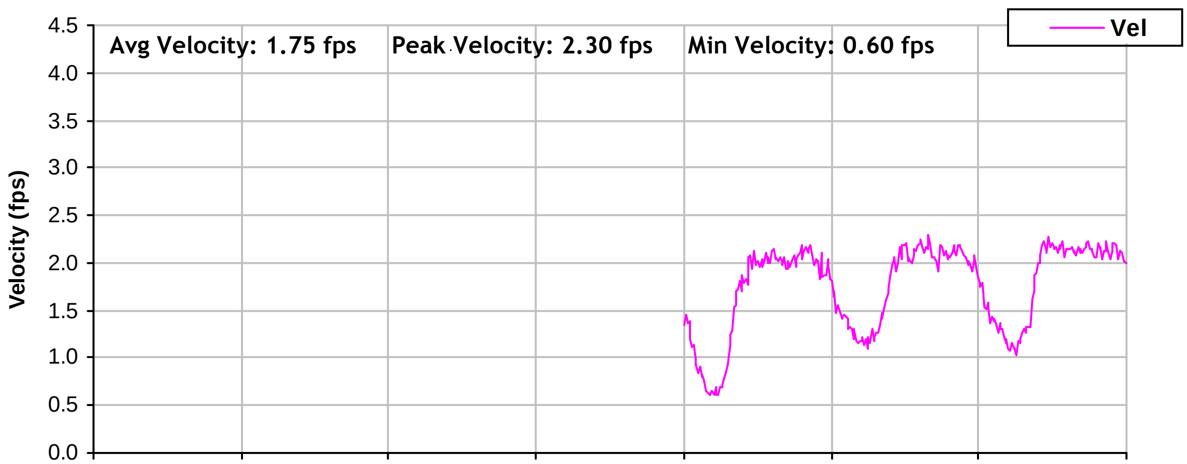


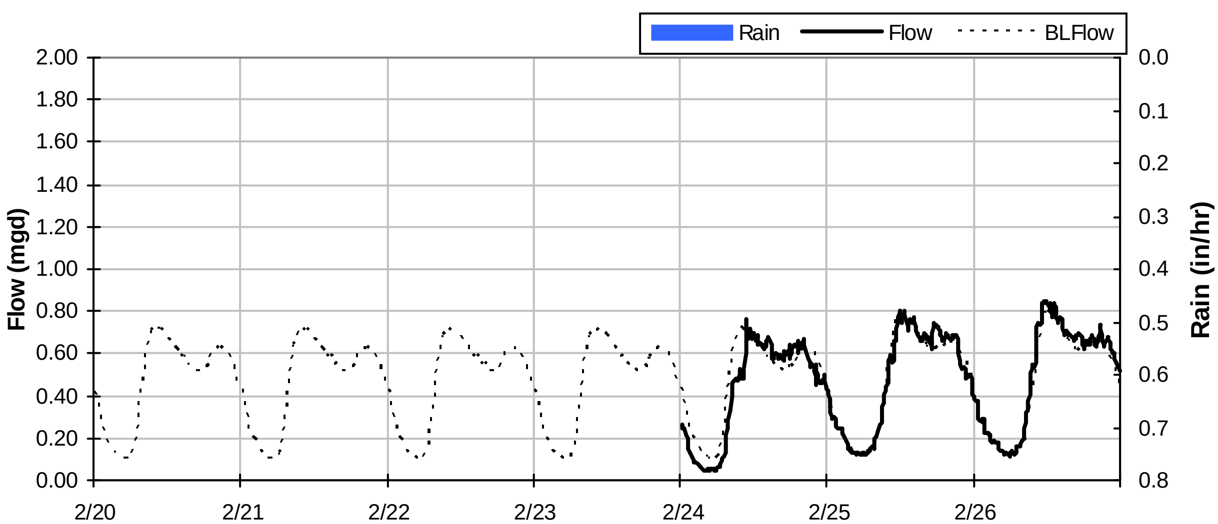
Storm Event I/I Analysis (Rain = 1.43 inches)

Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	1.17 *mgd*	**Peak I/I Rate:**	0.50 *mgd*	**Infiltration Rate:** (4/15/2012)	0.131 *mgd*	**Total I/I:**	99,000 *gallons*
PF:	2.51	**Pk I/I:ADWF:**	1.07	**RDI (% of BL):**	28%	**Total I/I:ADWF:**	0.15 *per in-rain*
Peak Level:	7.74 *in*						
d/D Ratio:	0.43						

SITE 6B
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012





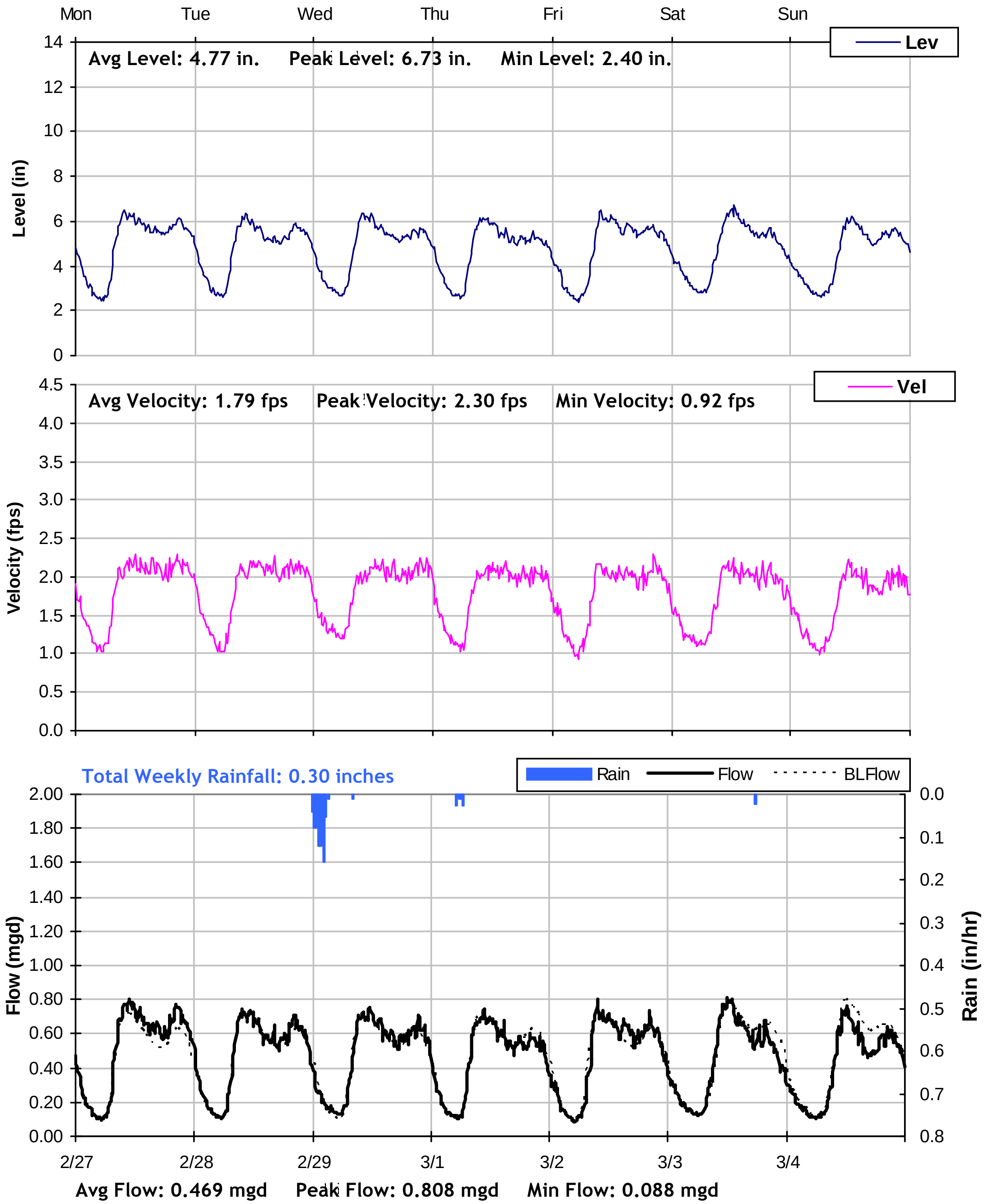


Avg Flow: 0.469 mgd Peak Flow: 0.846 mgd Min Flow: 0.047 mgd

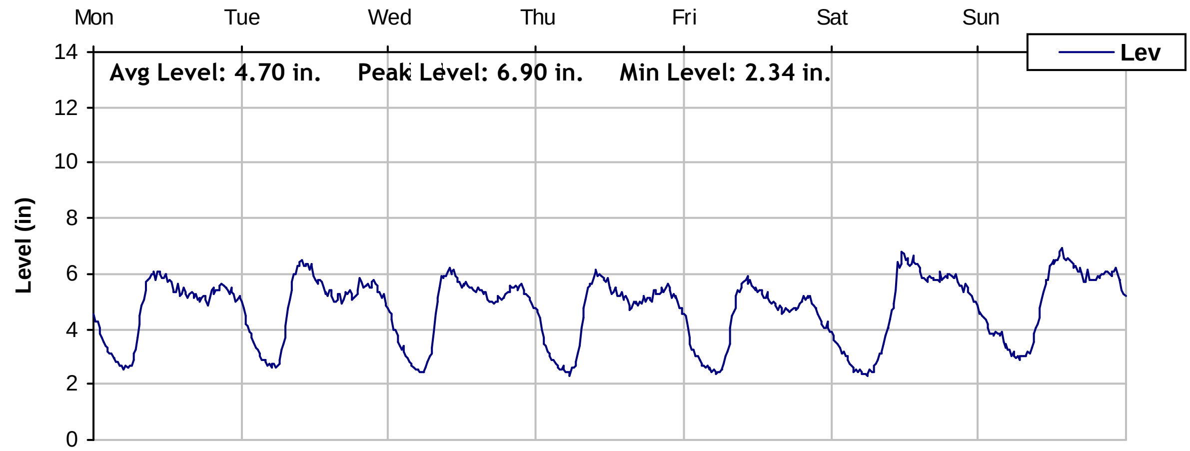
SITE 6B

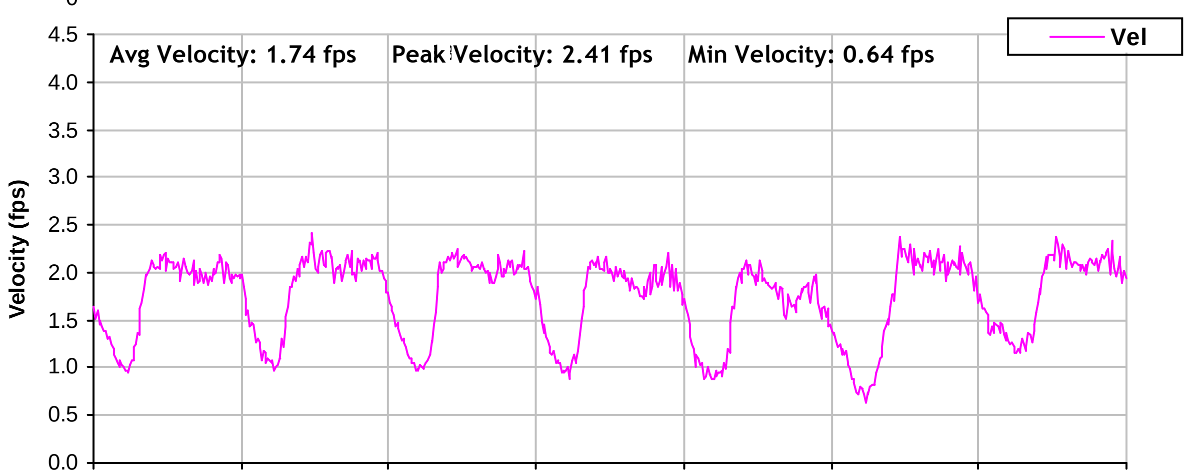
Weekly Level, Velocity and Flow Hydrographs

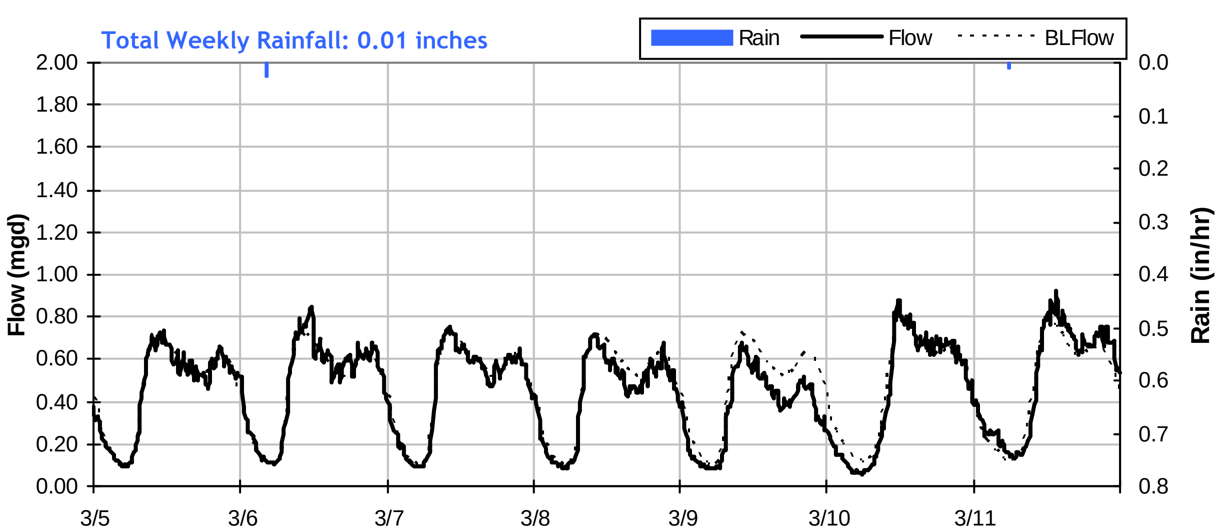
2/27/2012 to 3/5/2012



SITE 6B
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012





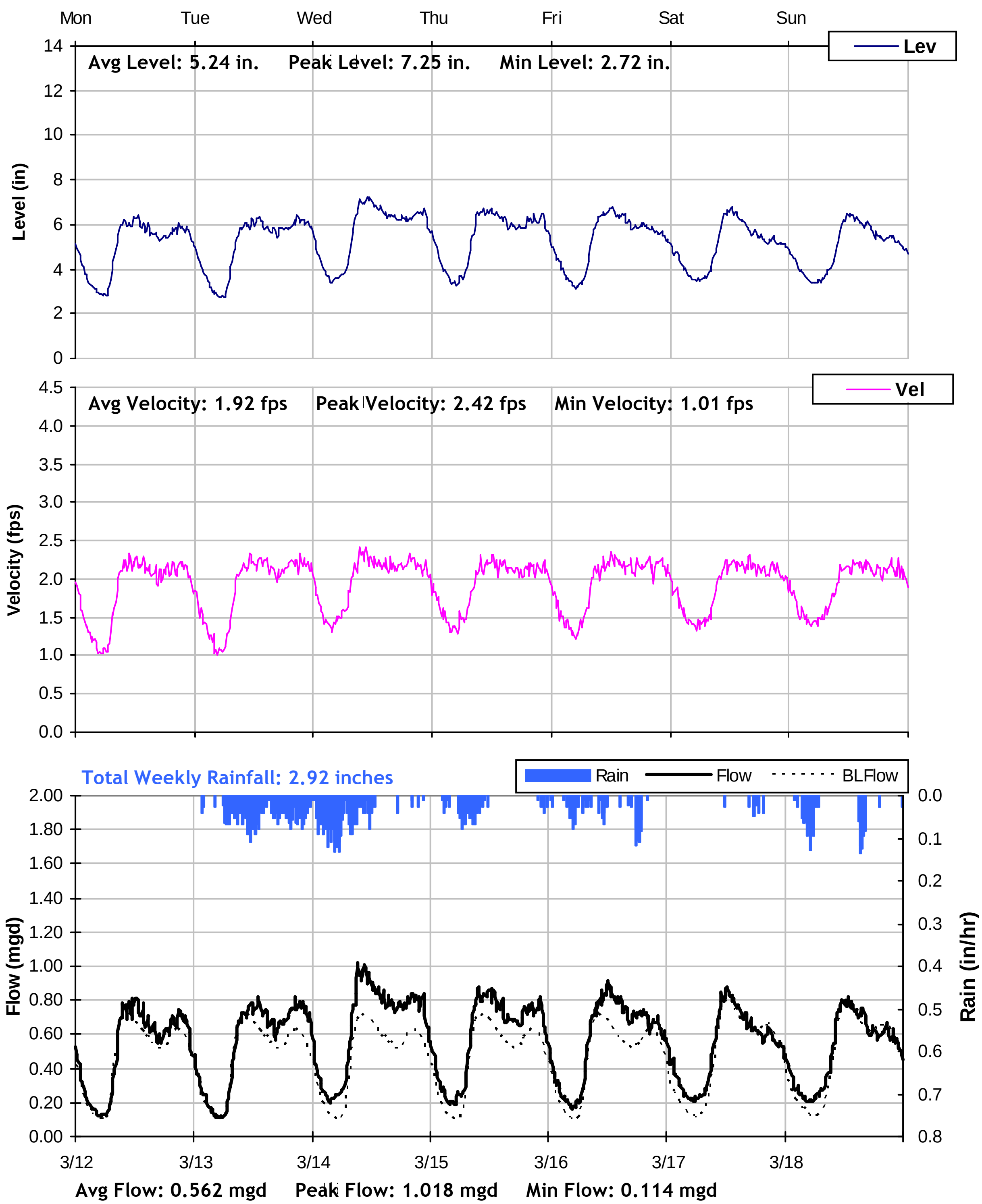


Avg Flow: 0.452 mgd   Peak Flow: 0.927 mgd   Min Flow: 0.058 mgd

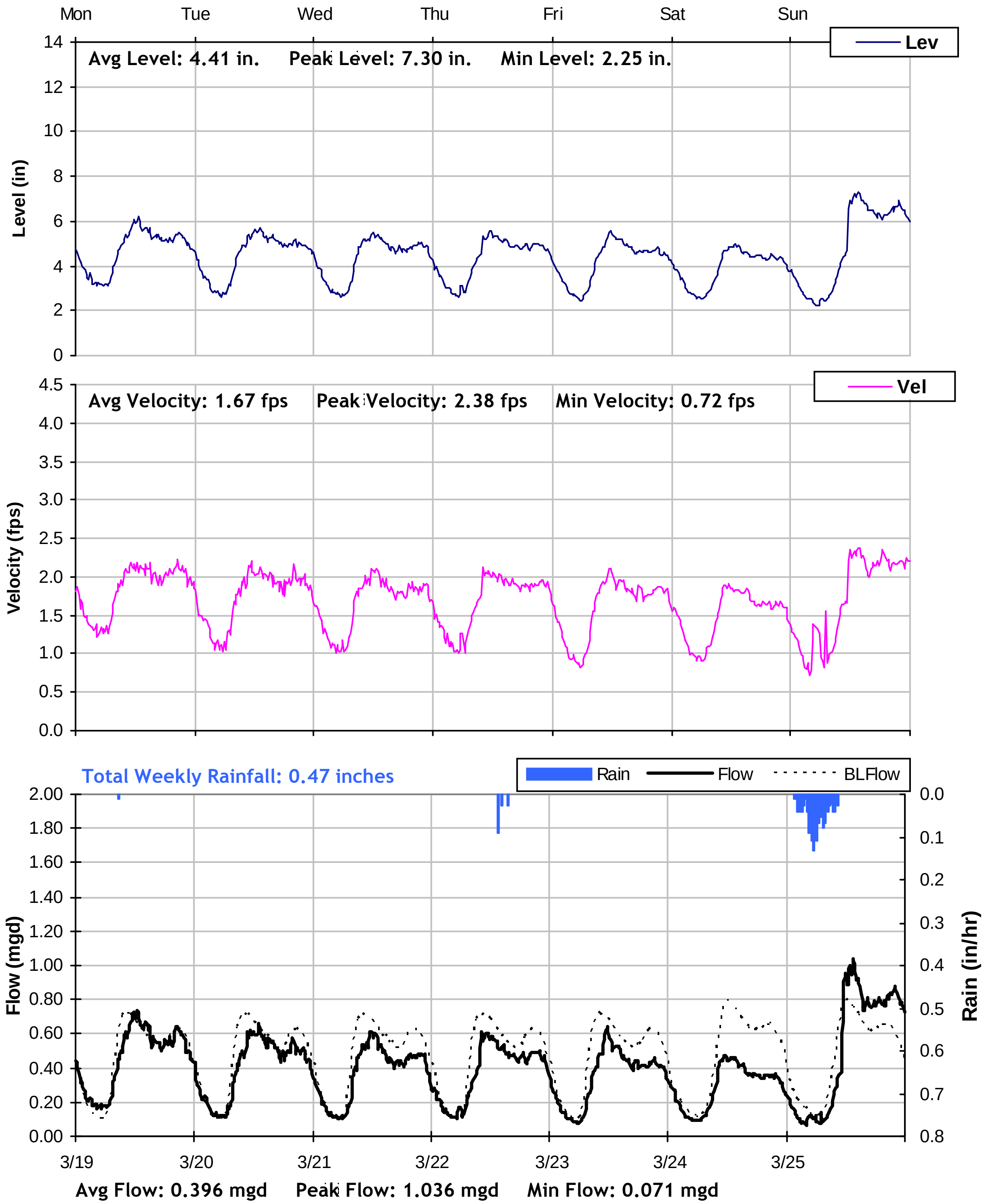
SITE 6B

Weekly Level, Velocity and Flow Hydrographs

3/12/2012 to 3/19/2012



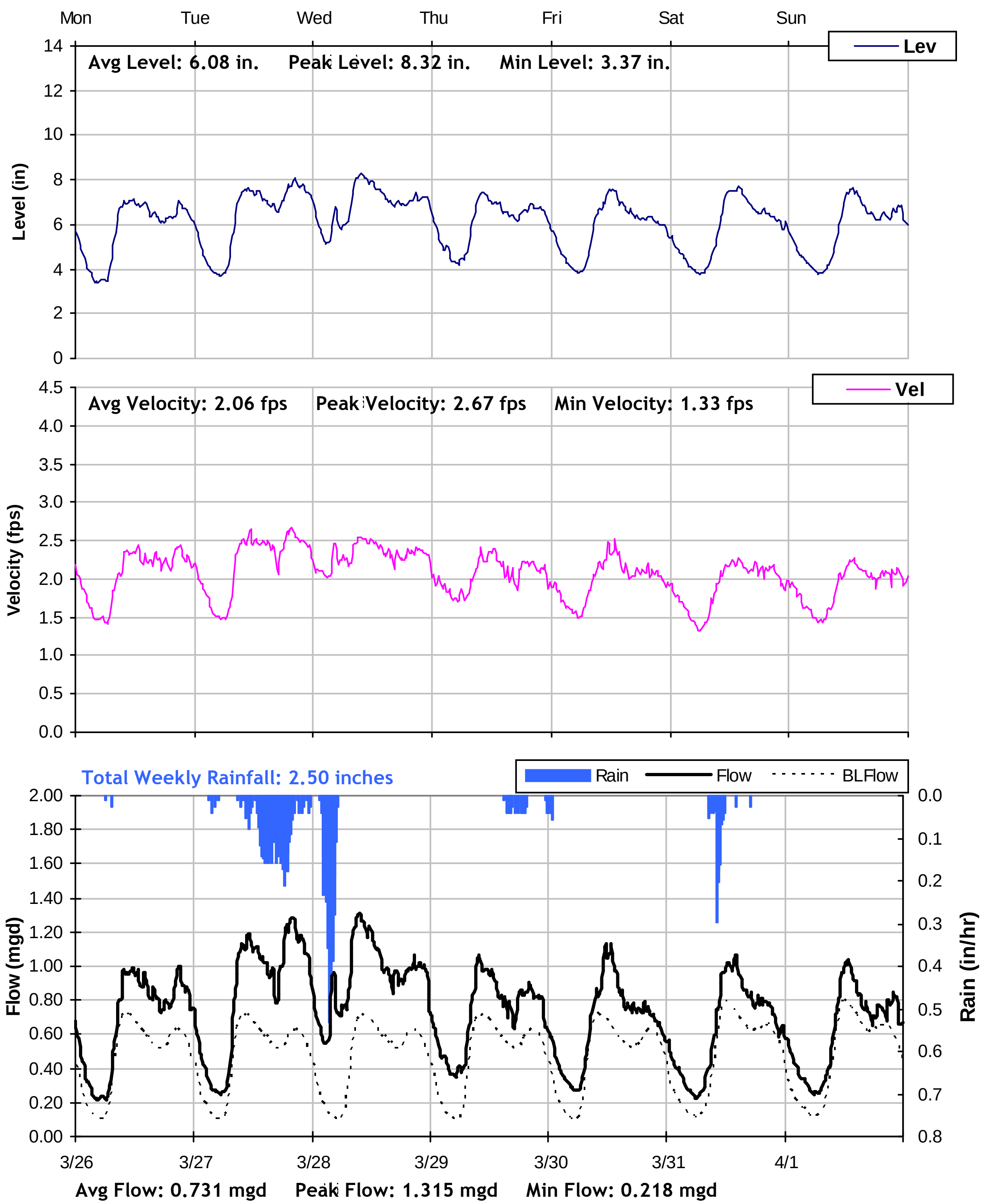
SITE 6B
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



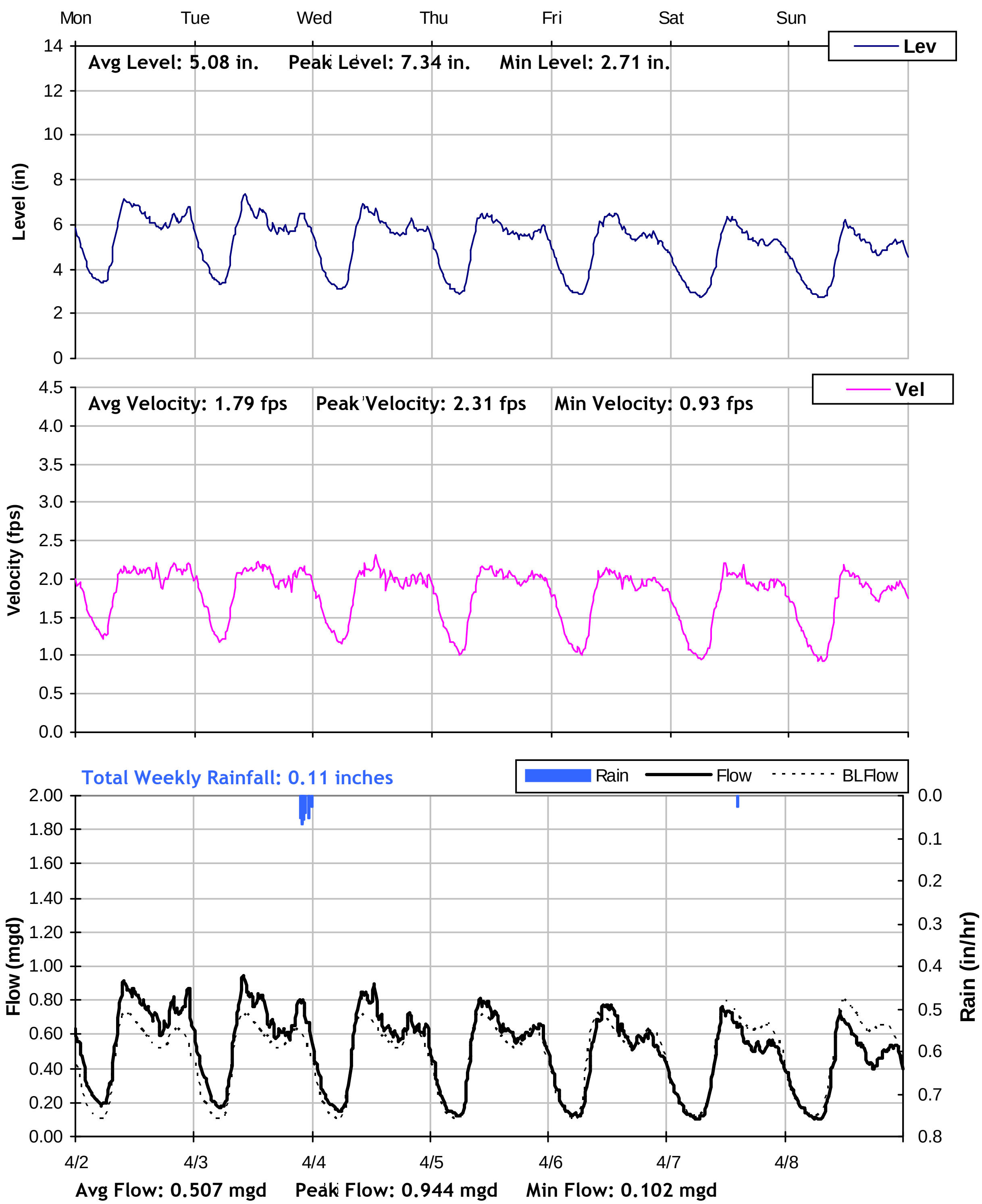
SITE 6B

Weekly Level, Velocity and Flow Hydrographs

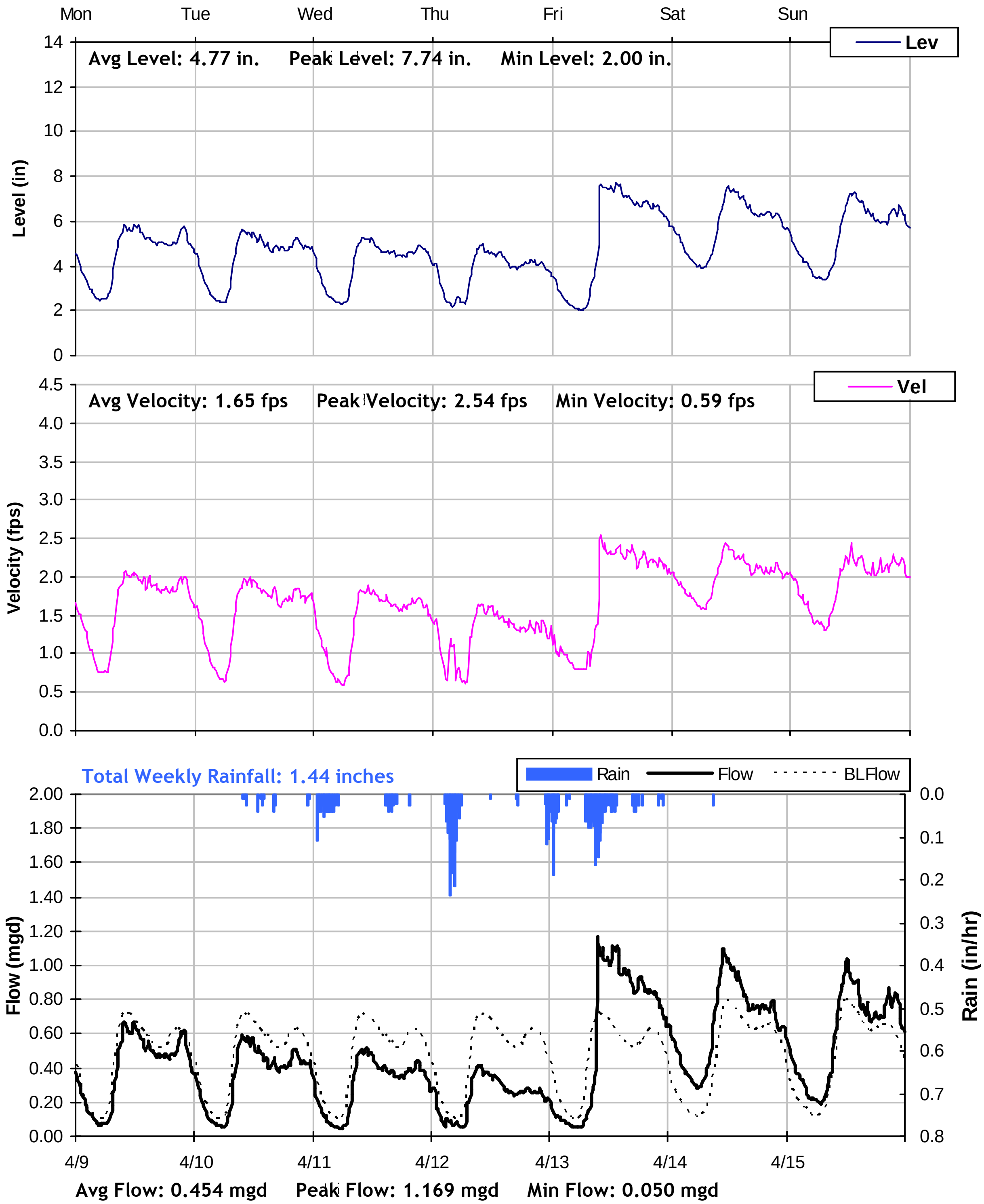
3/26/2012 to 4/2/2012



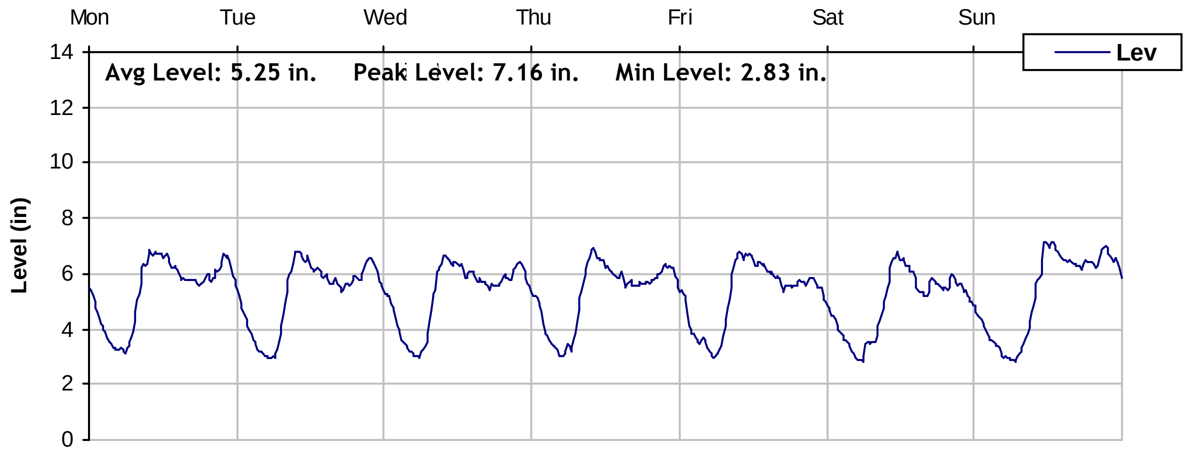
SITE 6B
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012

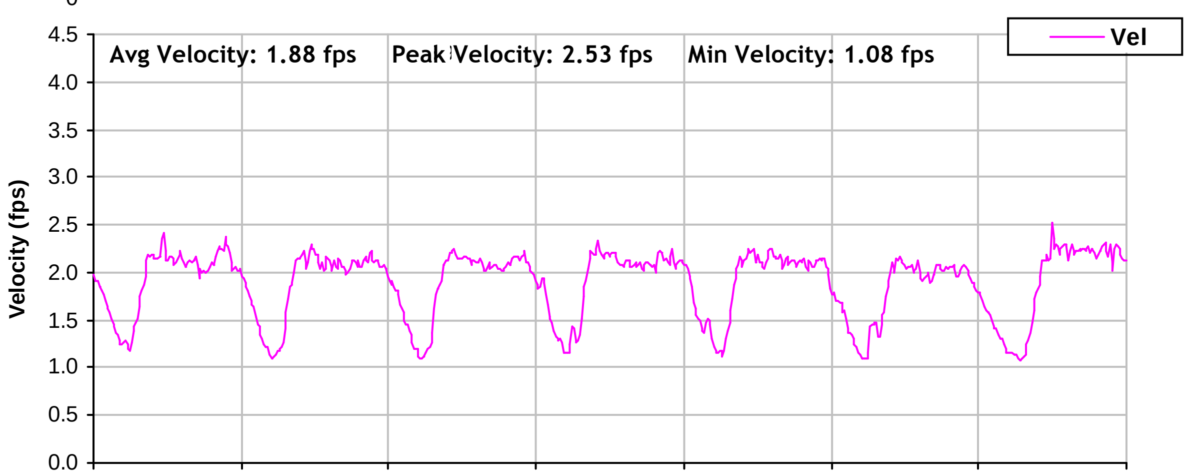


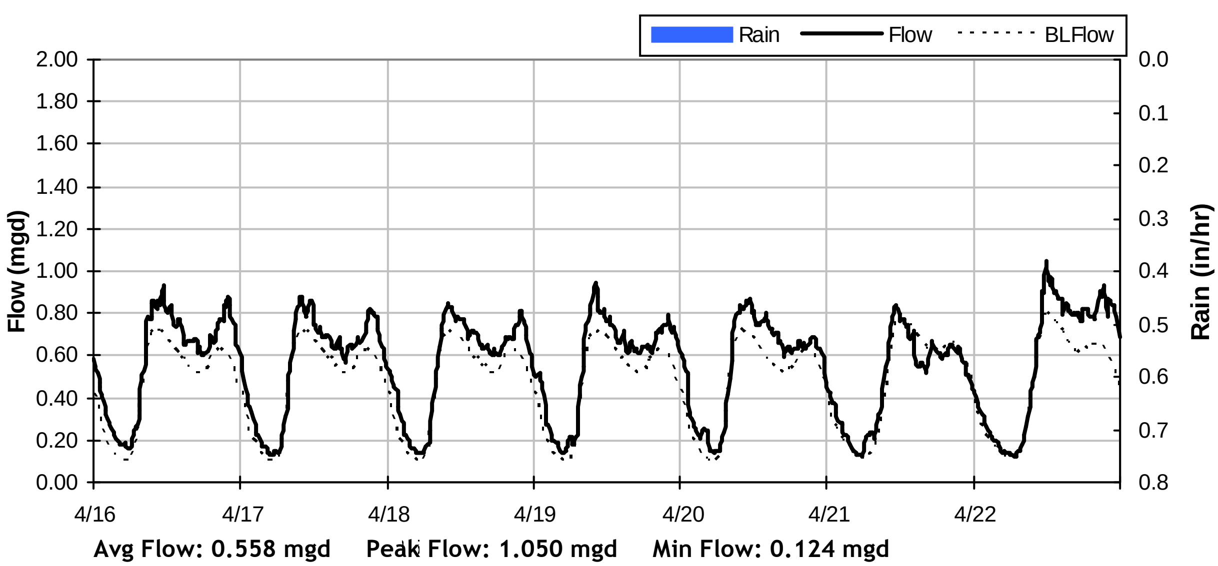
SITE 6B
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



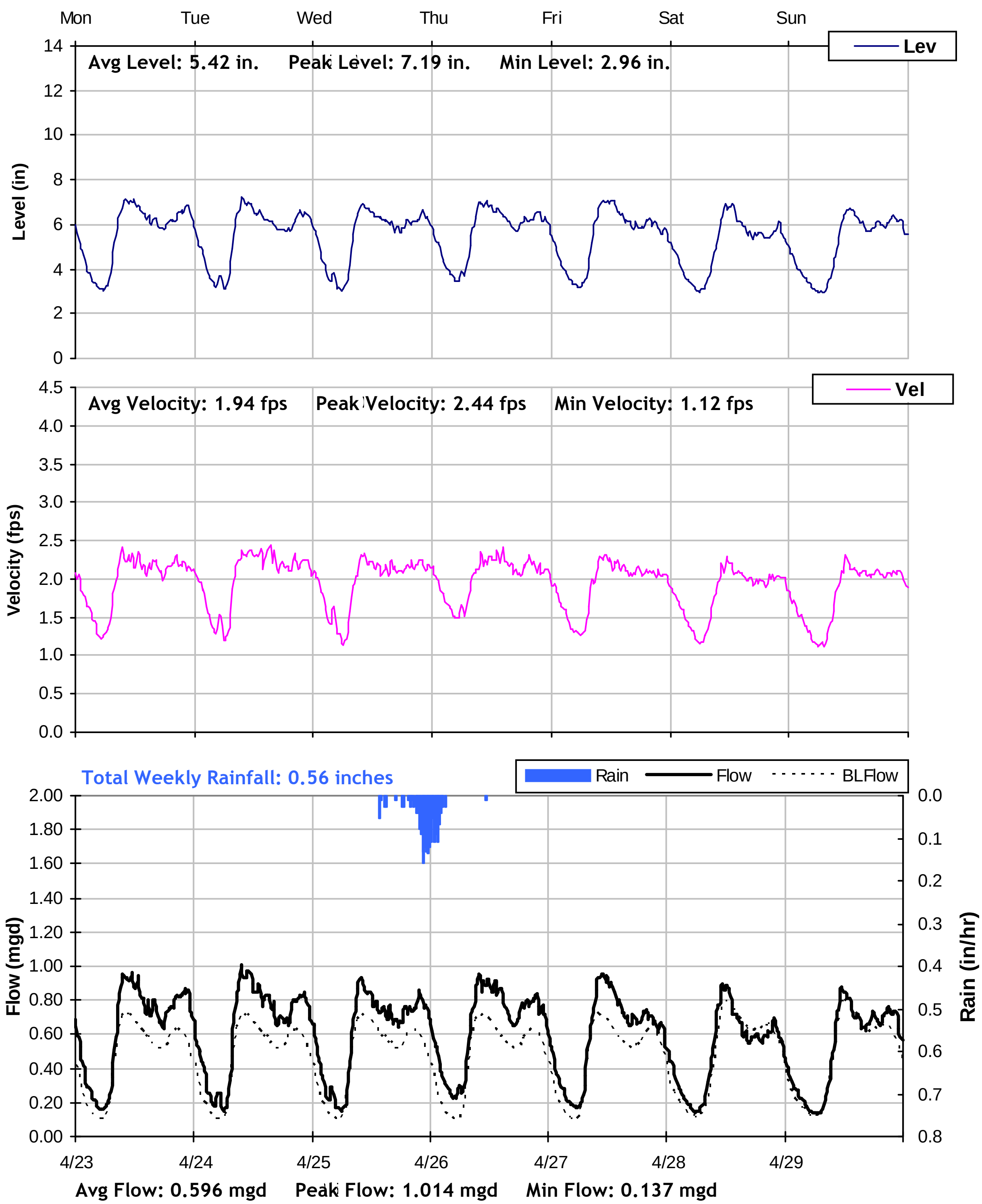
SITE 6B
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012



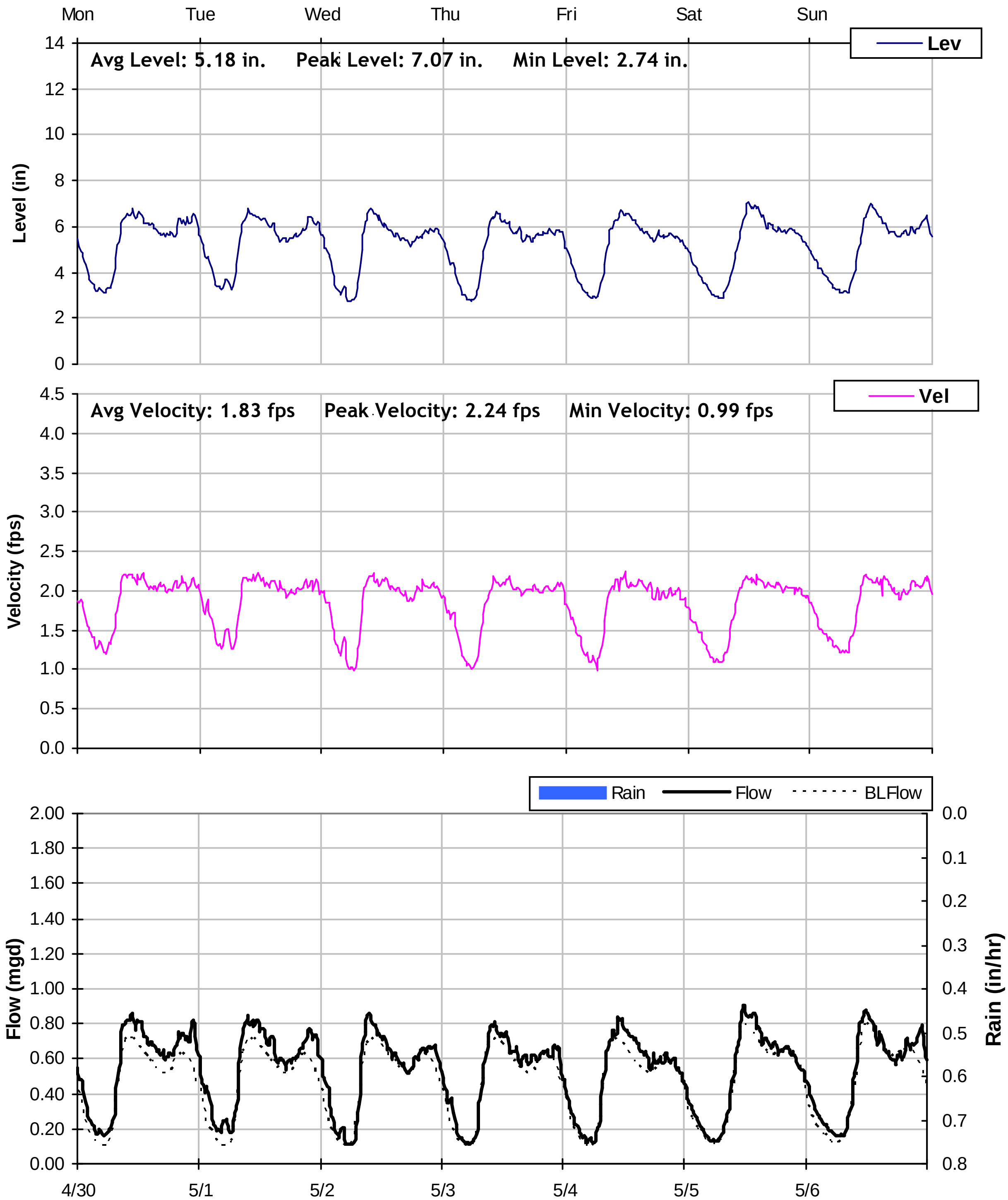




SITE 6B
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 6B
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



Avg Flow: 0.532 mgd Peak Flow: 0.901 mgd Min Flow: 0.109 mgd

City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 7

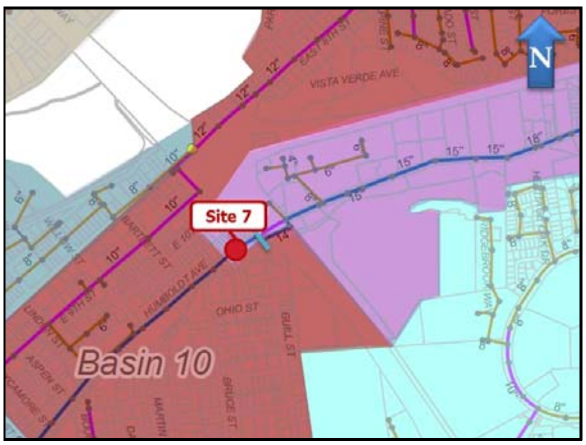
Location: Humboldt Avenue, northeast of Bartlett Street (towards the end of the street)

Vicinity Map:

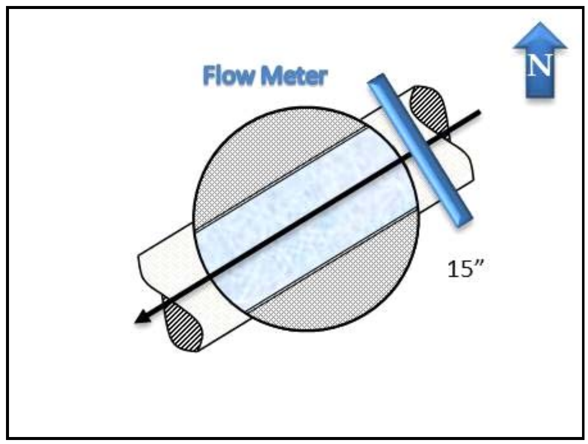
SITE 7
Site Information Report

Location:	Humboldt Avenue, northeast of Bartlett Street (towards the end of the street)
Coordinates:	121.8184° W, 39.7341° N
Elevation:	218 feet
Diameter:	15 inches
Baseline Flow:	0.506 mgd
Peak Measured Flow:	1.636 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

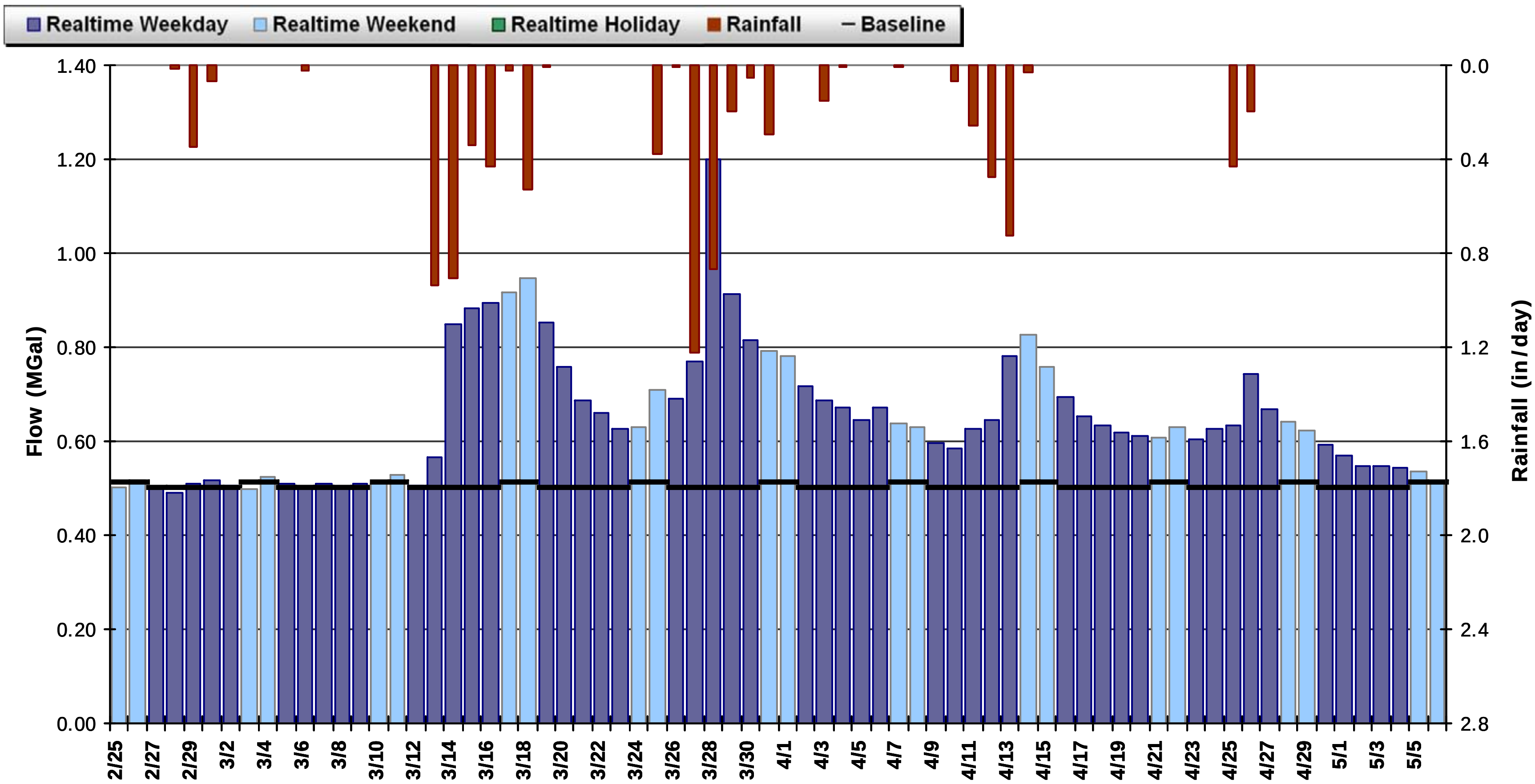
Plan View

SITE 7

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.651 MGal **Peak Daily Flow: 1.200 MGal** **Min Daily Flow: 0.489 MGal**

Total Period Rainfall: 9.00 inches

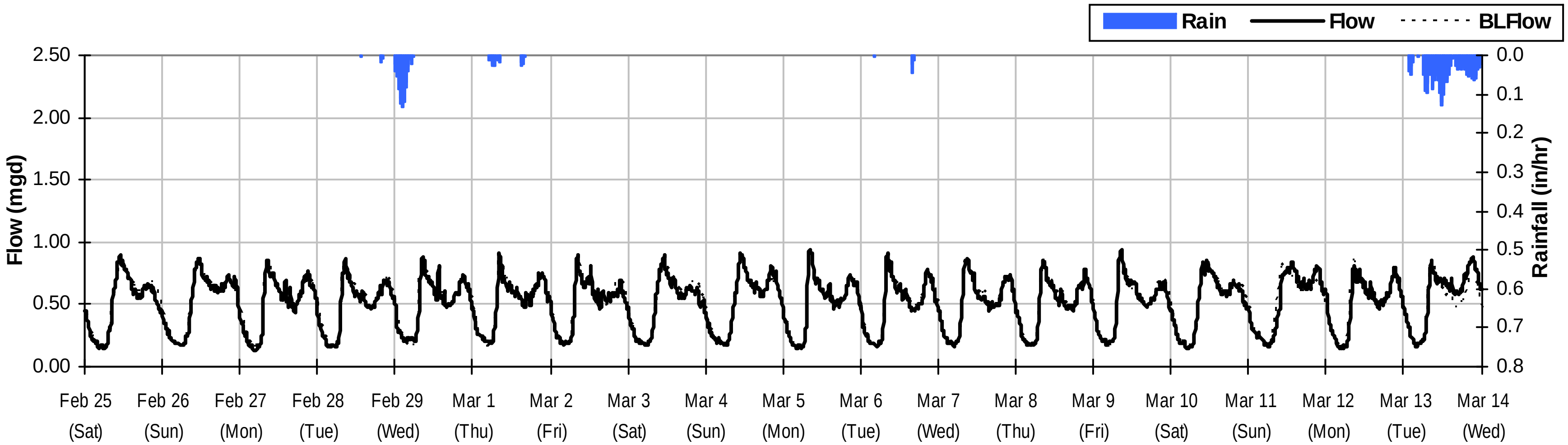


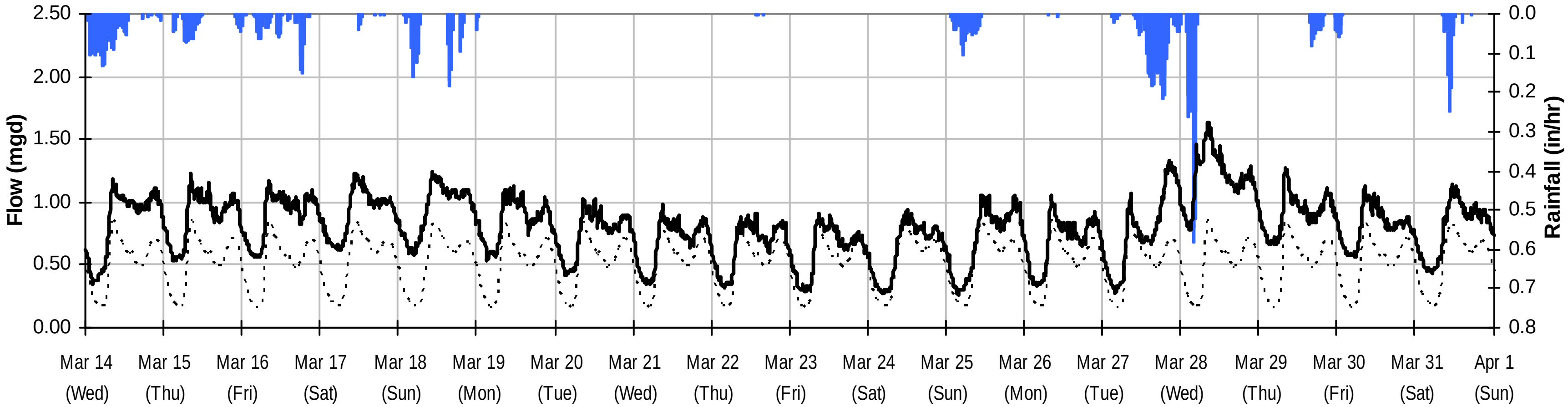
SITE 7

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.661 mgd **Peak Flow: 1.636 mgd** **Min Flow: 0.134 mgd**

Total Period Rainfall: 6.65 inches



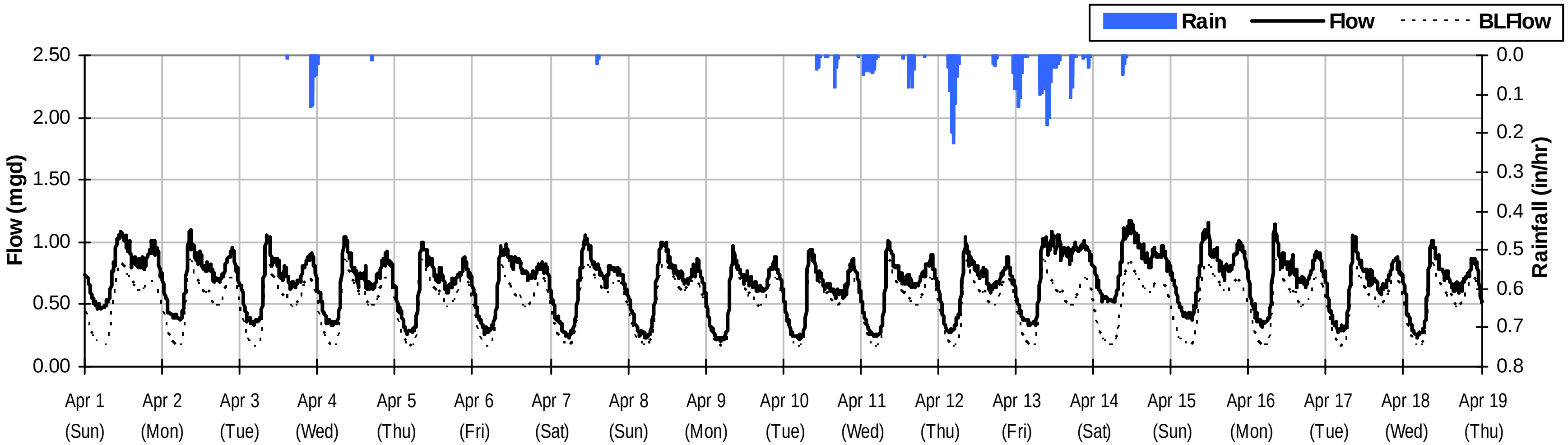


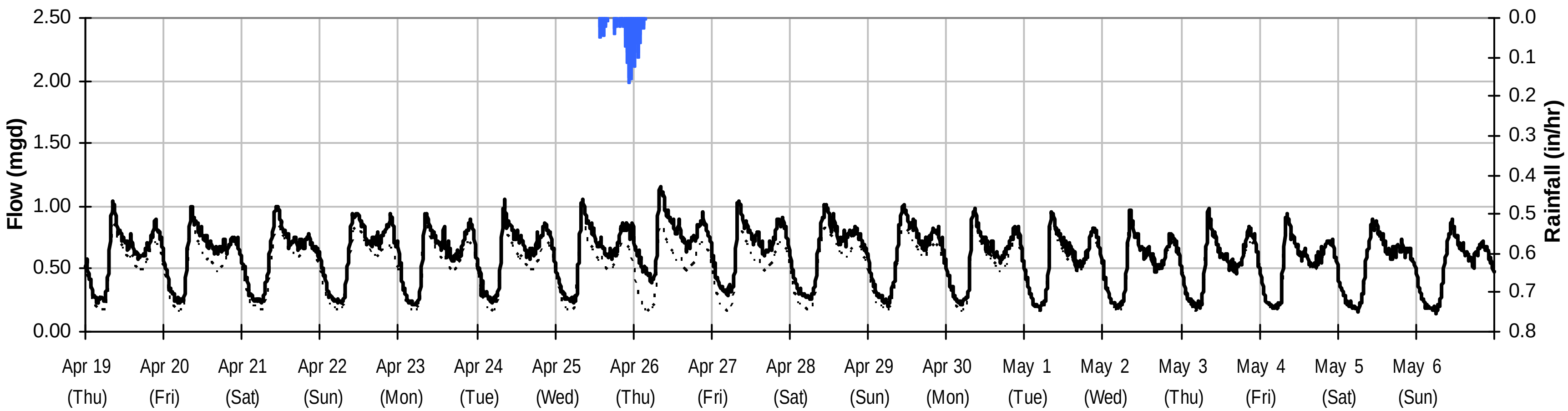
SITE 7

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.642 mgd **Peak Flow: 1.173 mgd** **Min Flow: 0.144 mgd**

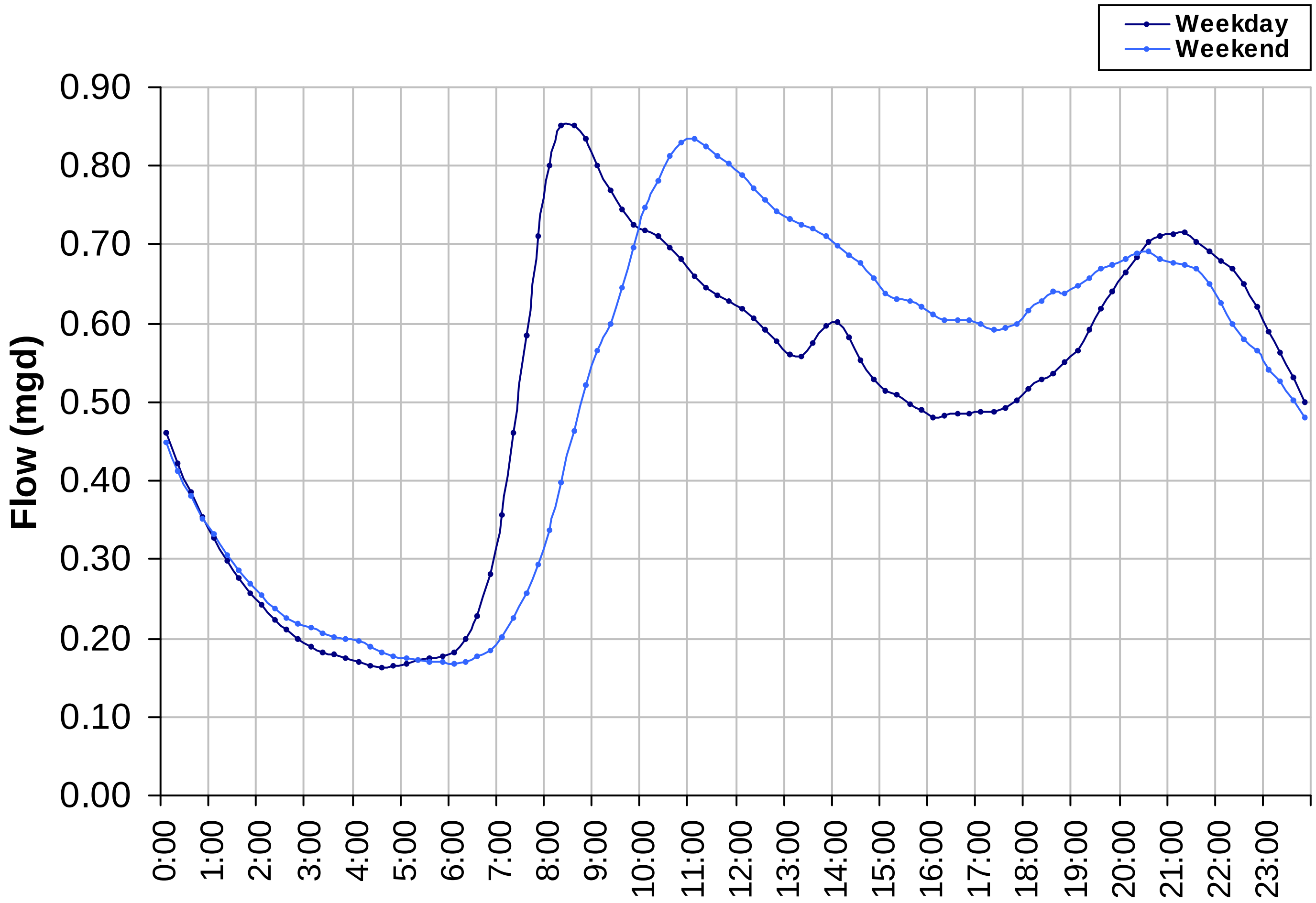
Total Period Rainfall: 2.34 inches





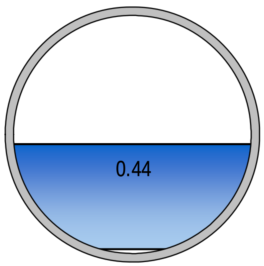
SITE 7

Baseline Flow Hydrographs



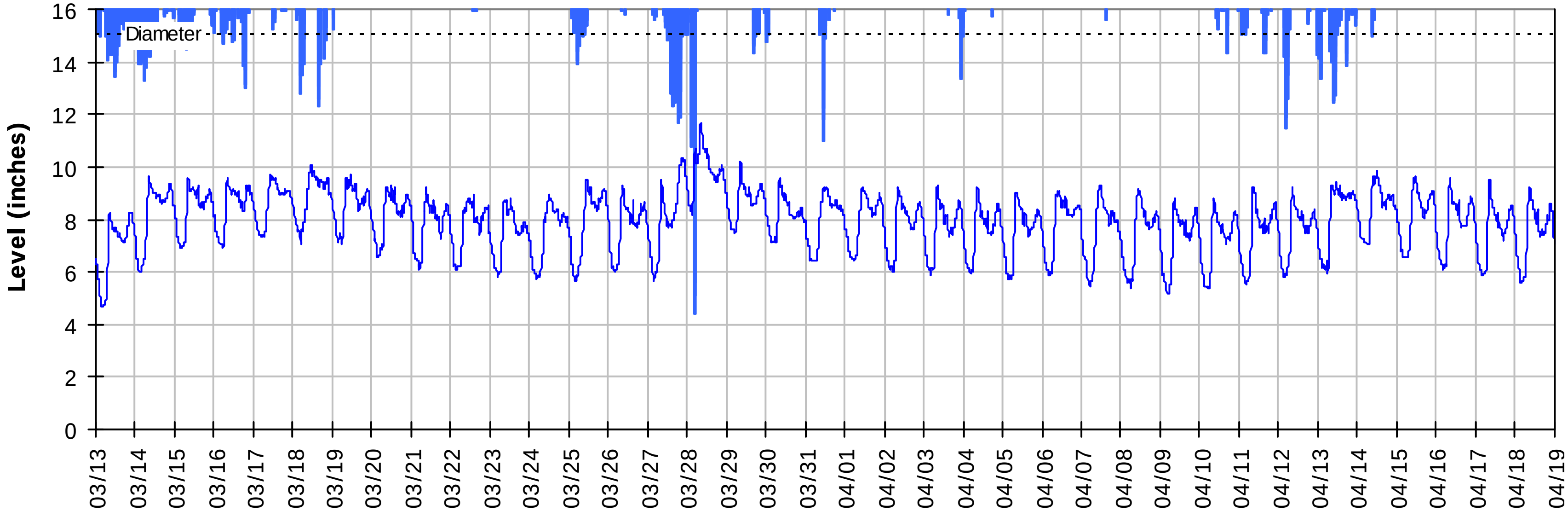
Baseline Flow:

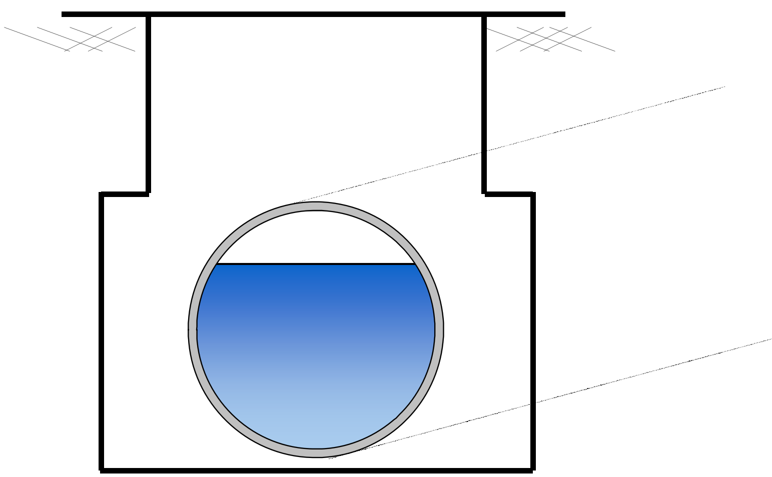
0.506 *mgd*



SITE 7
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





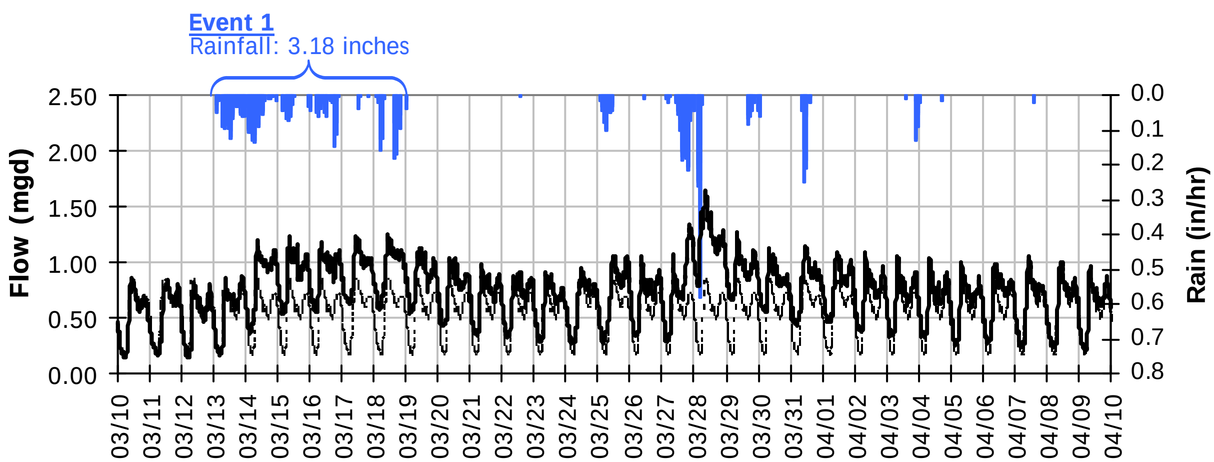
Pipe Diameter: 15 *inches*

Peak Measured Level: 11.7 *inches*

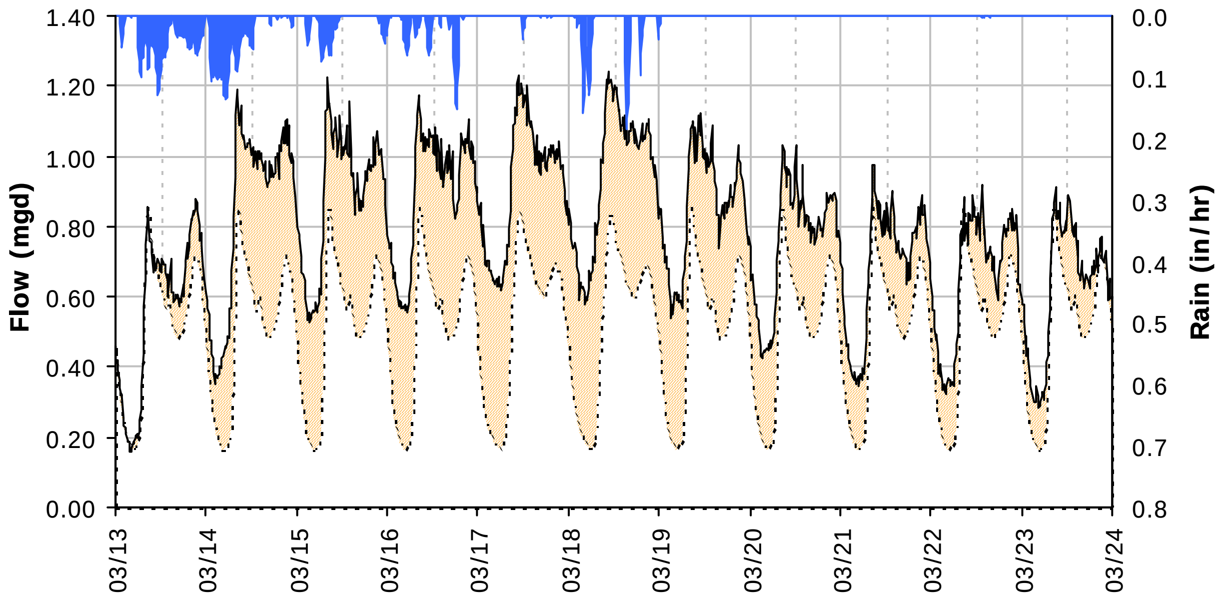
Peak d/D Ratio: 0.78

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 = 3.18 inches)

Capacity

Peak Flow:	1.24	*mgd*
PF:	2.45	
Peak Level:	10.08	*in*
d/D Ratio:	0.67	

Inflow

Peak I/I Rate:	0.61	*mgd*
PkI/I:IDM:	2,946	*gpd/IDM*
PkI/I:Acre:	498	*gpd/acre*
Pk I/I:ADWF:	1.20	

RDI (infiltration)

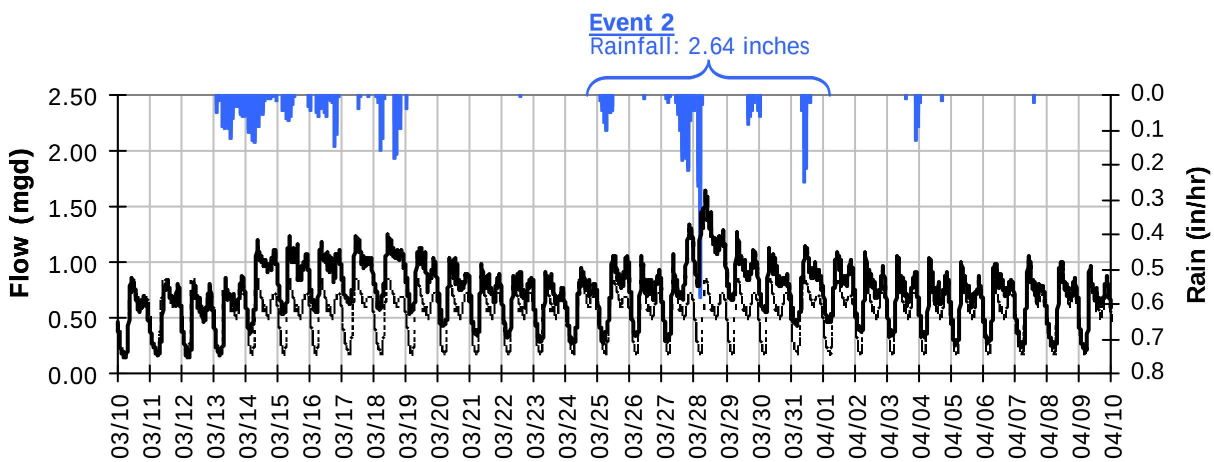
Infiltration Rate: (3/20/2012)	0.254	*mgd*
RDI:IDM:	1,236	*gpd/IDM*
RDI:Acre:	209	*gpd/acre*
RDI (% of BL):	51%	

Combined I/I

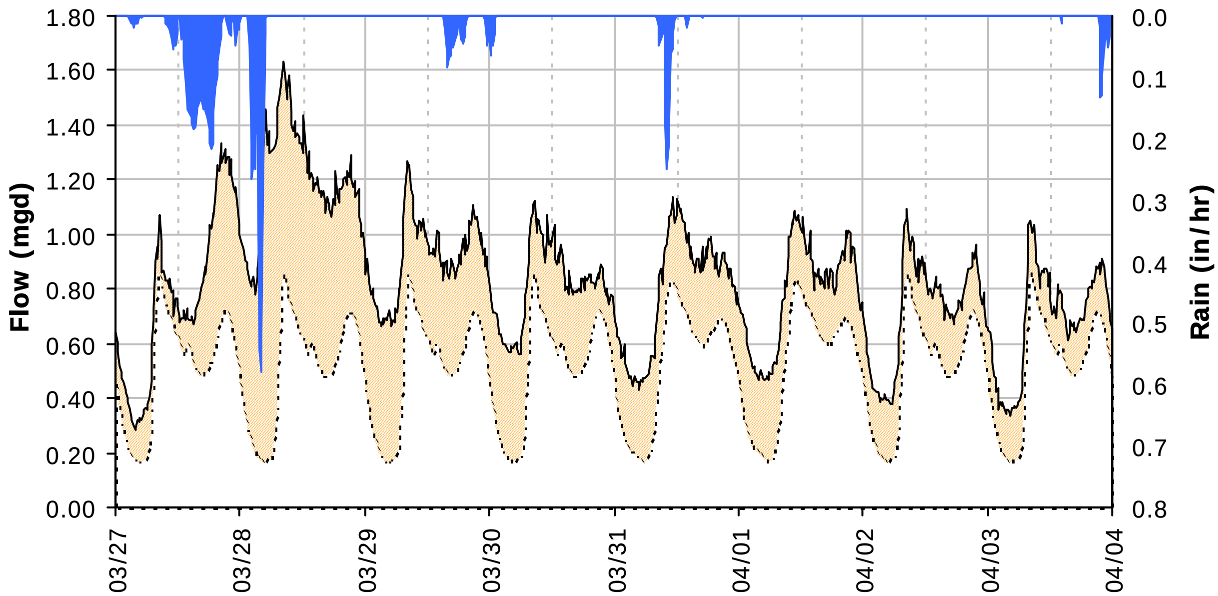
Total I/I:	3,083,000	*gallons*
Total I/I:IDM:	4,711	*gal/IDM/in*
R-Value:	2.9%	
Total I/I:ADWF:	1.92	*per in-rain*

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 = 2.64 inches)

Capacity

Peak Flow:	1.64	*mgd*
PF:	3.23	
Peak Level:	11.69	*in*
d/D Ratio:	0.78	

Inflow

Peak I/I Rate:	1.29	*mgd*
PkI/I:IDM:	6,248	*gpd/IDM*
PkI/I:Acre:	1,056	*gpd/acre*
Pk I/I:ADWF:	2.54	

RDI (infiltration)

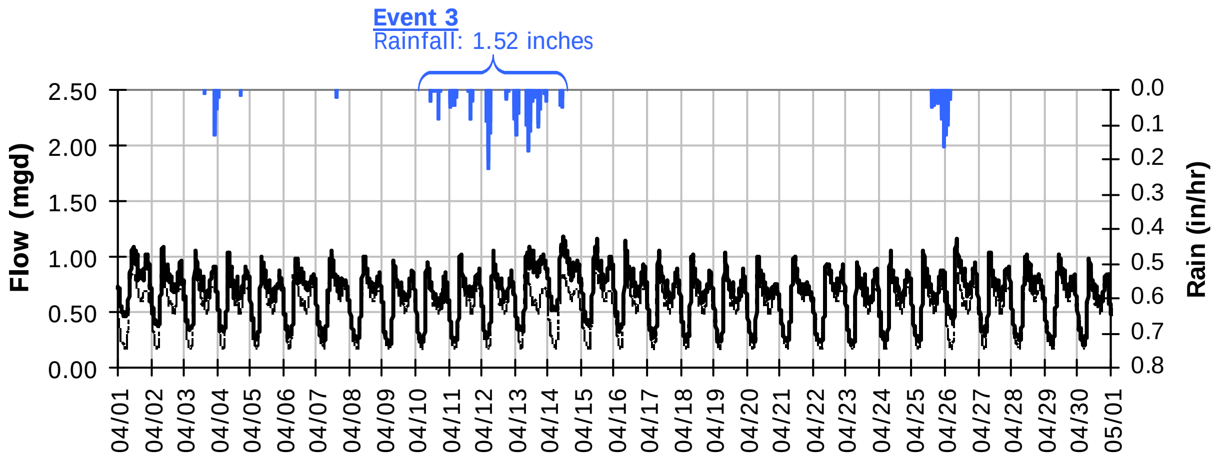
Infiltration Rate: (4/2/2012)	0.214	*mgd*
RDI:IDM:	1,039	*gpd/IDM*
RDI:Acre:	176	*gpd/acre*
RDI (% of BL):	43%	

Combined I/I

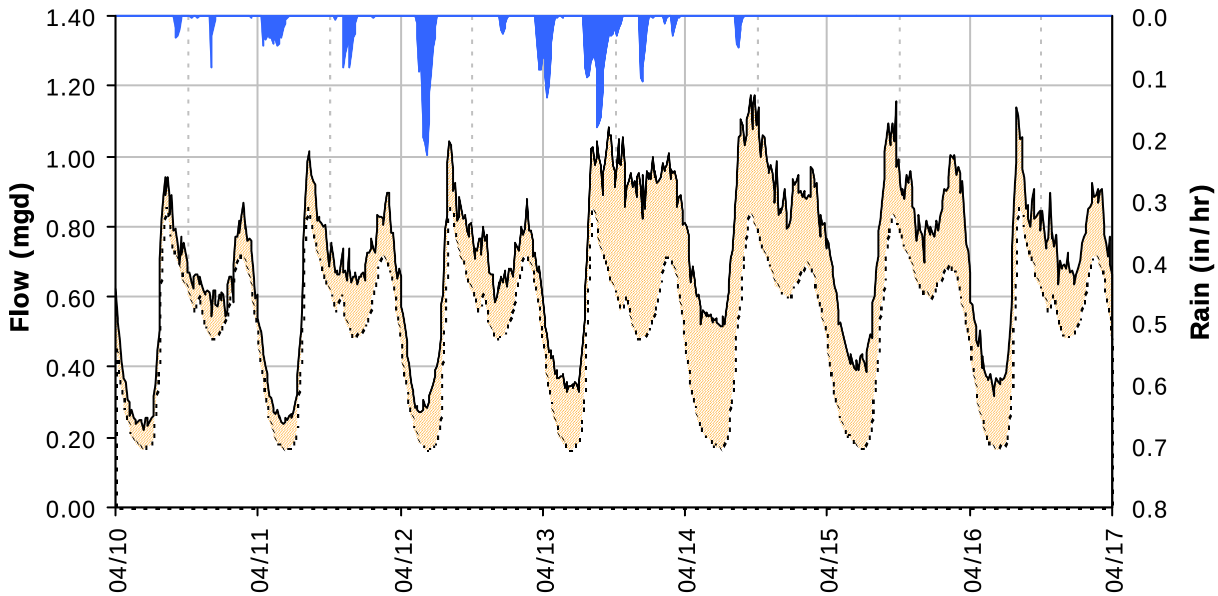
Total I/I:	2,632,000	*gallons*
Total I/I:IDM:	4,846	*gal/IDM/in*
R-Value:	3.0%	
Total I/I:ADWF:	1.97	*per in-rain*

SITE 7
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



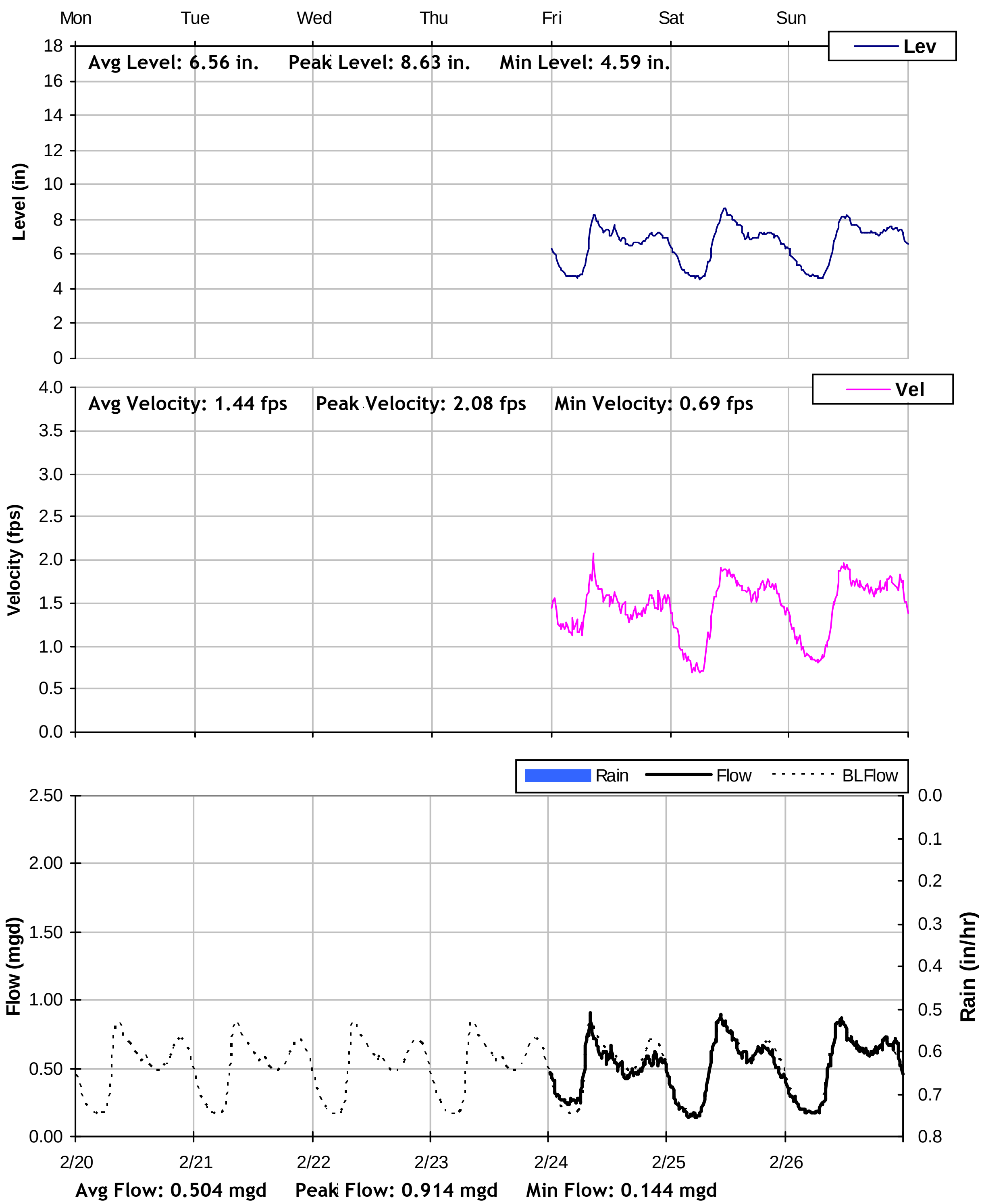
Storm Event I/I Analysis (Rain = 1.52 inches)

Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	1.17 *mgd*	**Peak I/I Rate:**	0.49 *mgd*	**Infiltration Rate:** (4/15/2012)	0.243 *mgd*	**Total I/I:**	1,378,000 *gallons*
PF:	2.32	**PkI/I:IDM:**	2,364 *gpd/IDM*	**RDI:IDM:**	1,180 *gpd/IDM*	**Total I/I:IDM:**	4,392 *gal/IDM/in*
Peak Level:	9.84 *in*	**PkI/I:Acre:**	400 *gpd/acre*	**RDI:Acre:**	199 *gpd/acre*	**R-Value:**	2.7%
d/D Ratio:	0.66	**Pk I/I:ADWF:**	0.96	**RDI (% of BL):**	47%	**Total I/I:ADWF:**	1.79 *per in-rain*

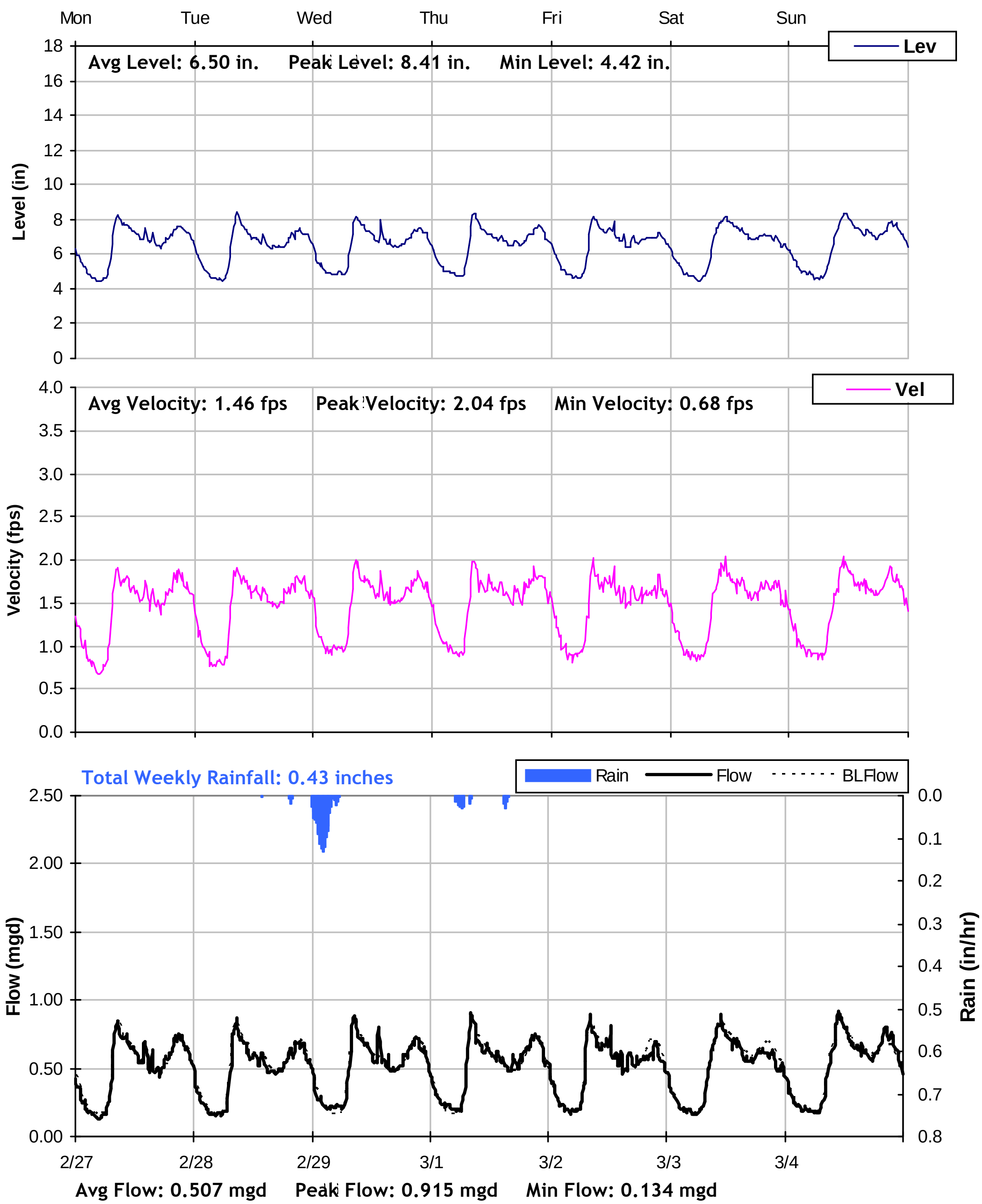
SITE 7

Weekly Level, Velocity and Flow Hydrographs

2/20/2012 to 2/27/2012



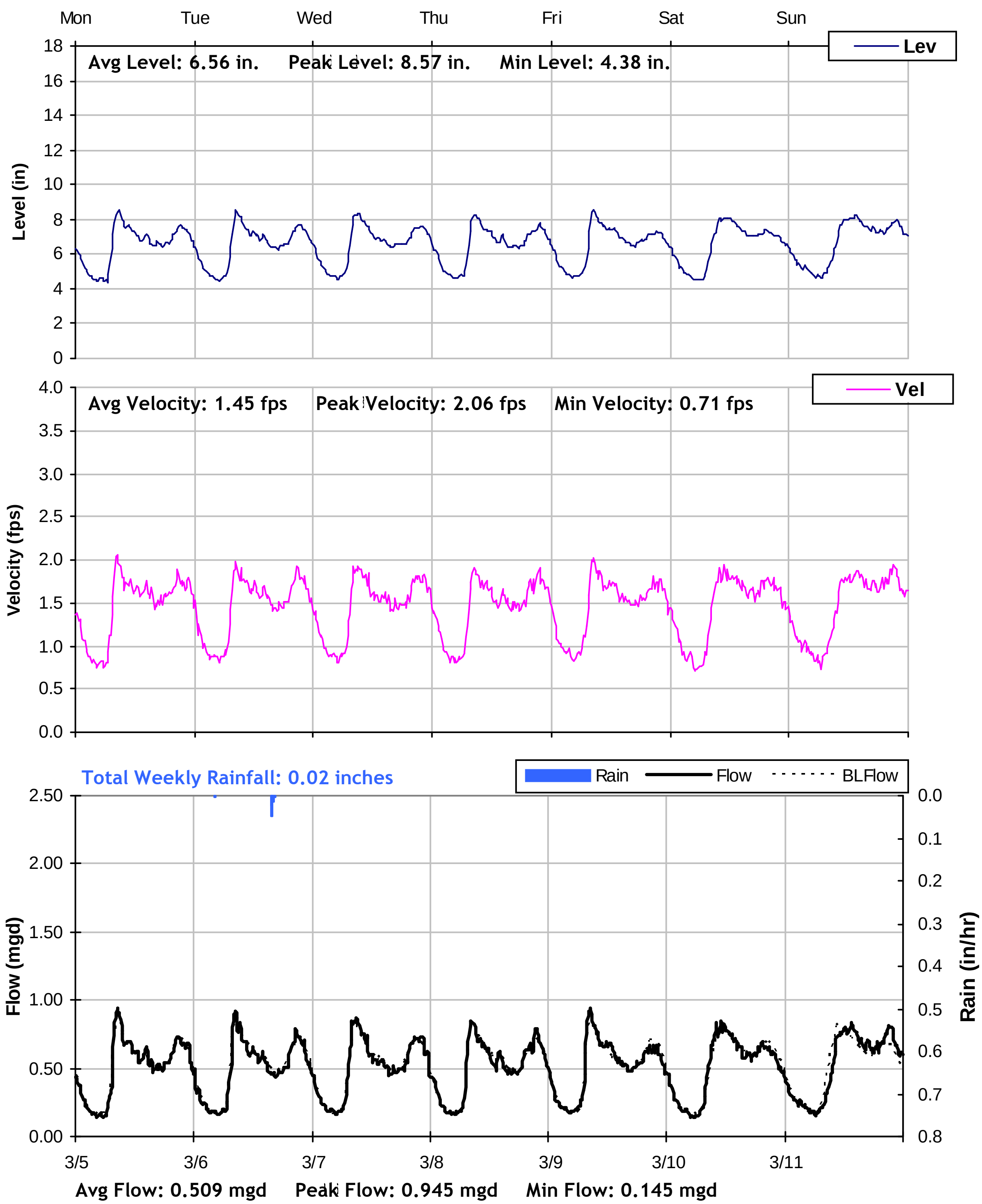
SITE 7
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



SITE 7

Weekly Level, Velocity and Flow Hydrographs

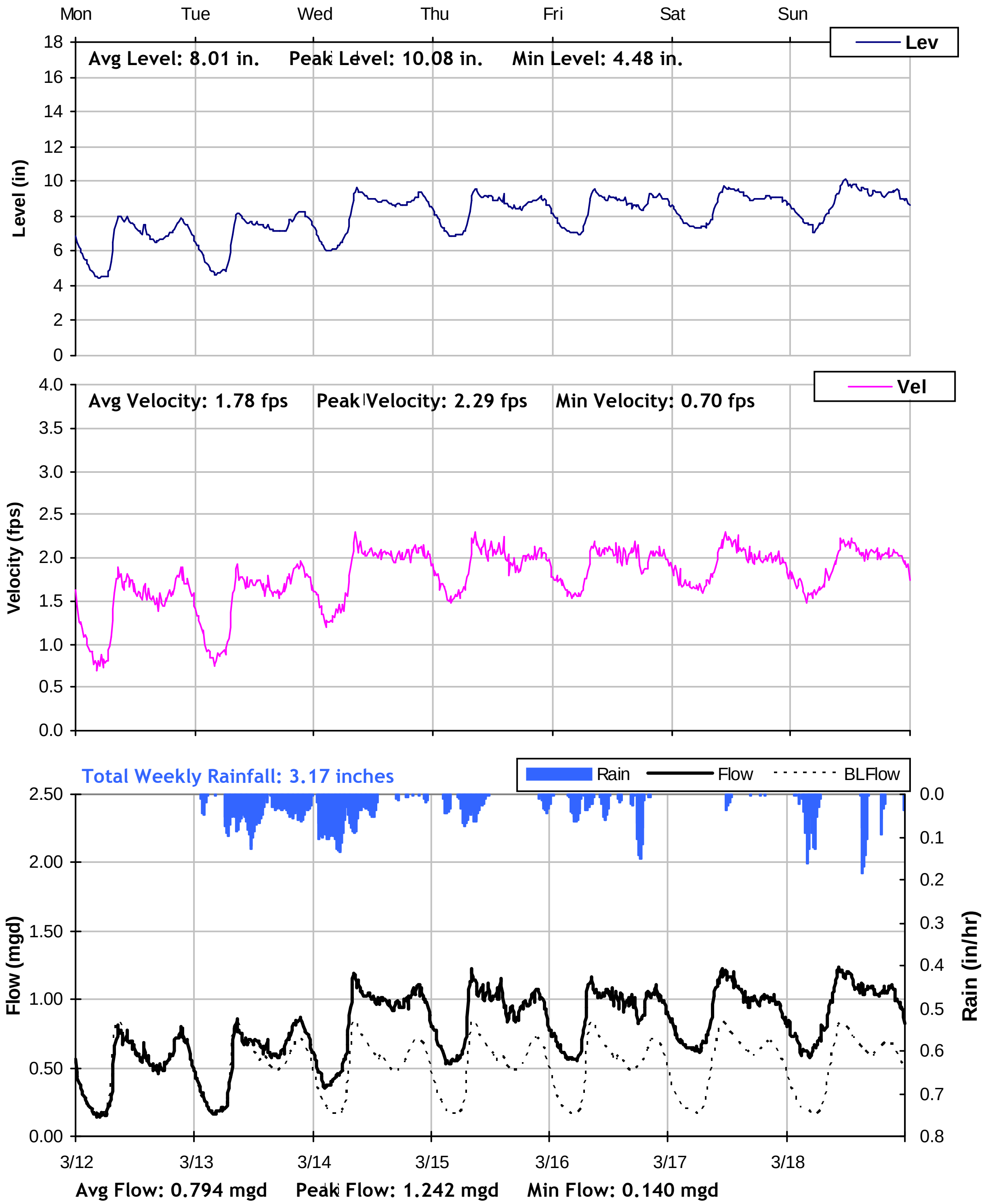
3/5/2012 to 3/12/2012



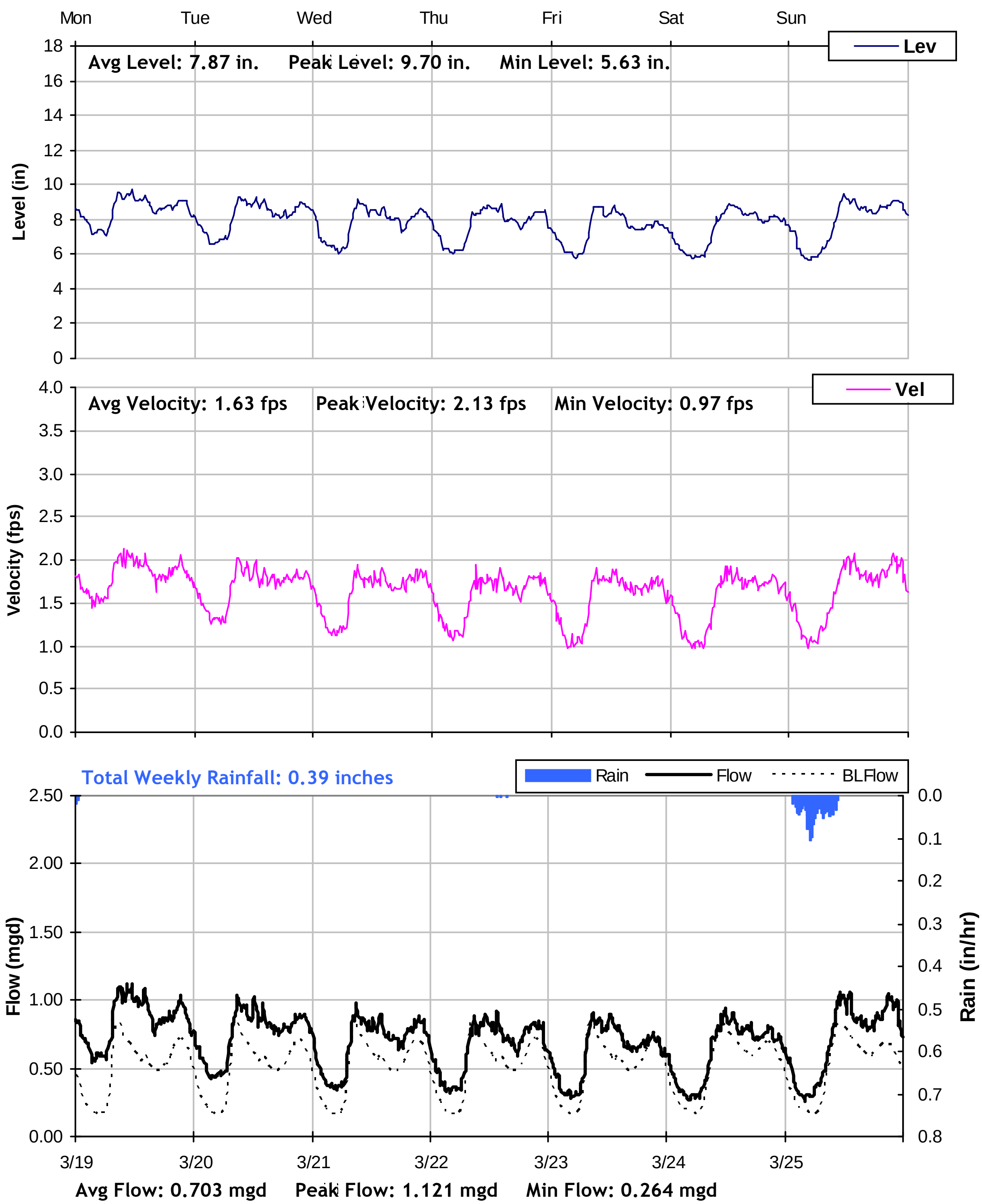
SITE 7

Weekly Level, Velocity and Flow Hydrographs

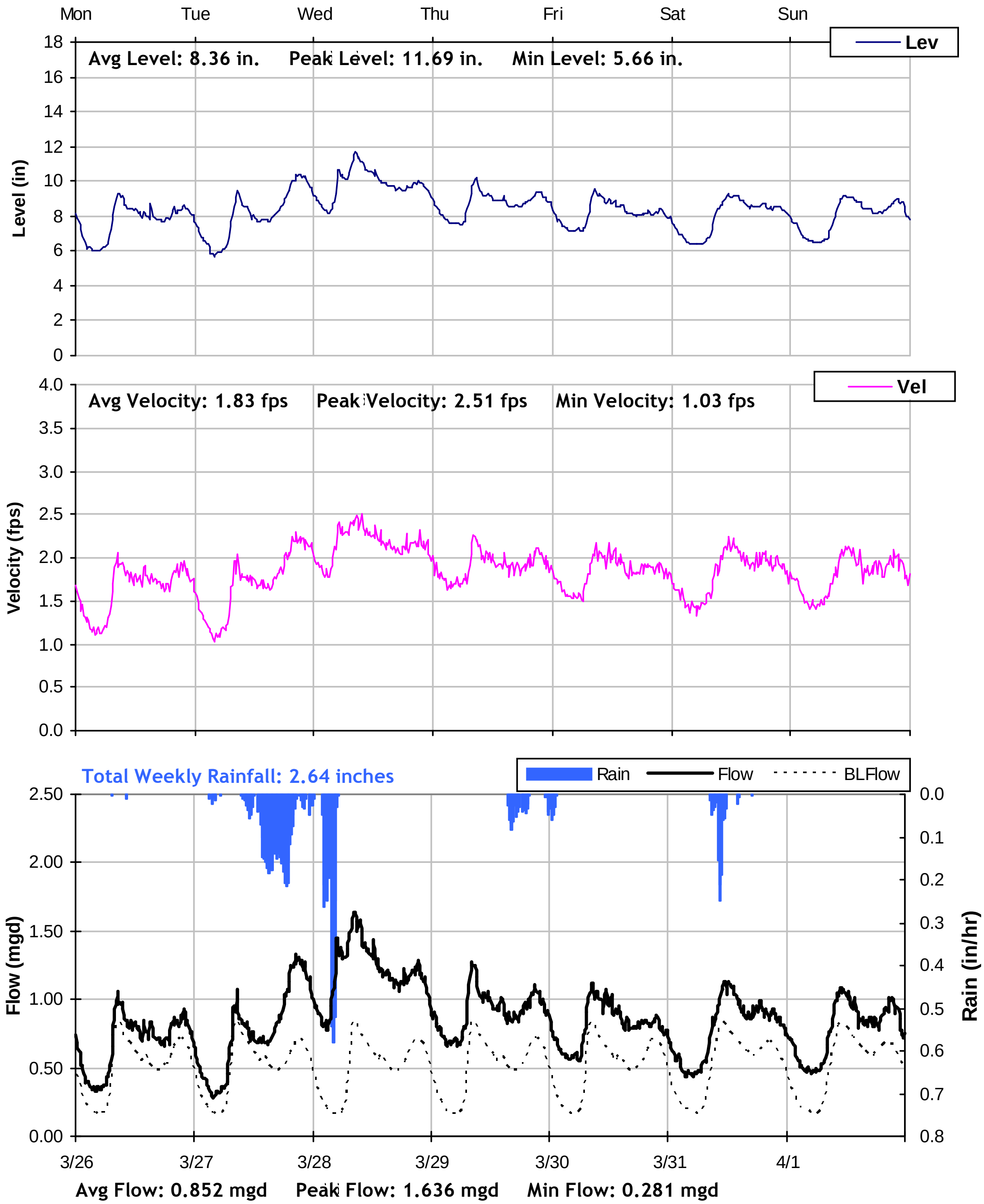
3/12/2012 to 3/19/2012



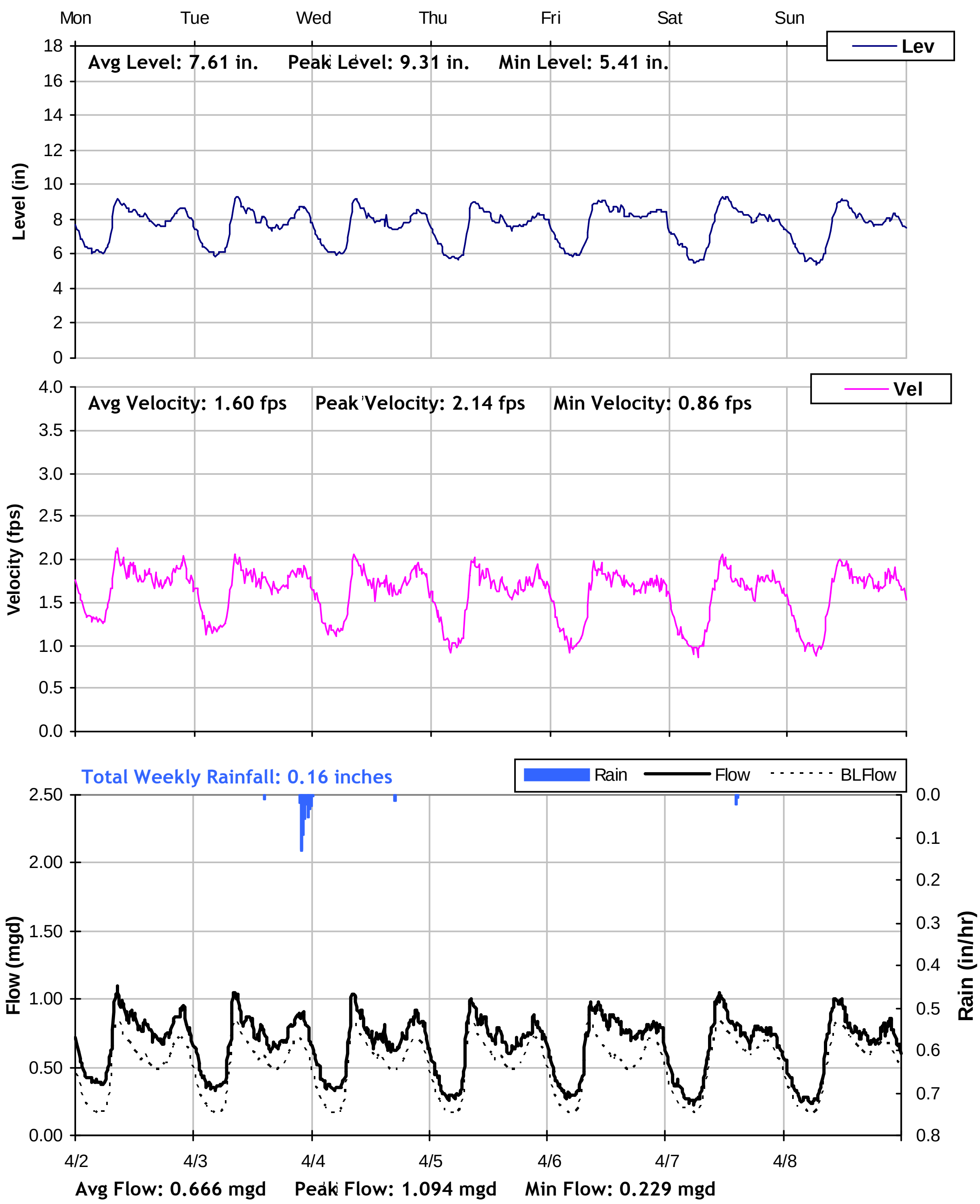
SITE 7
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



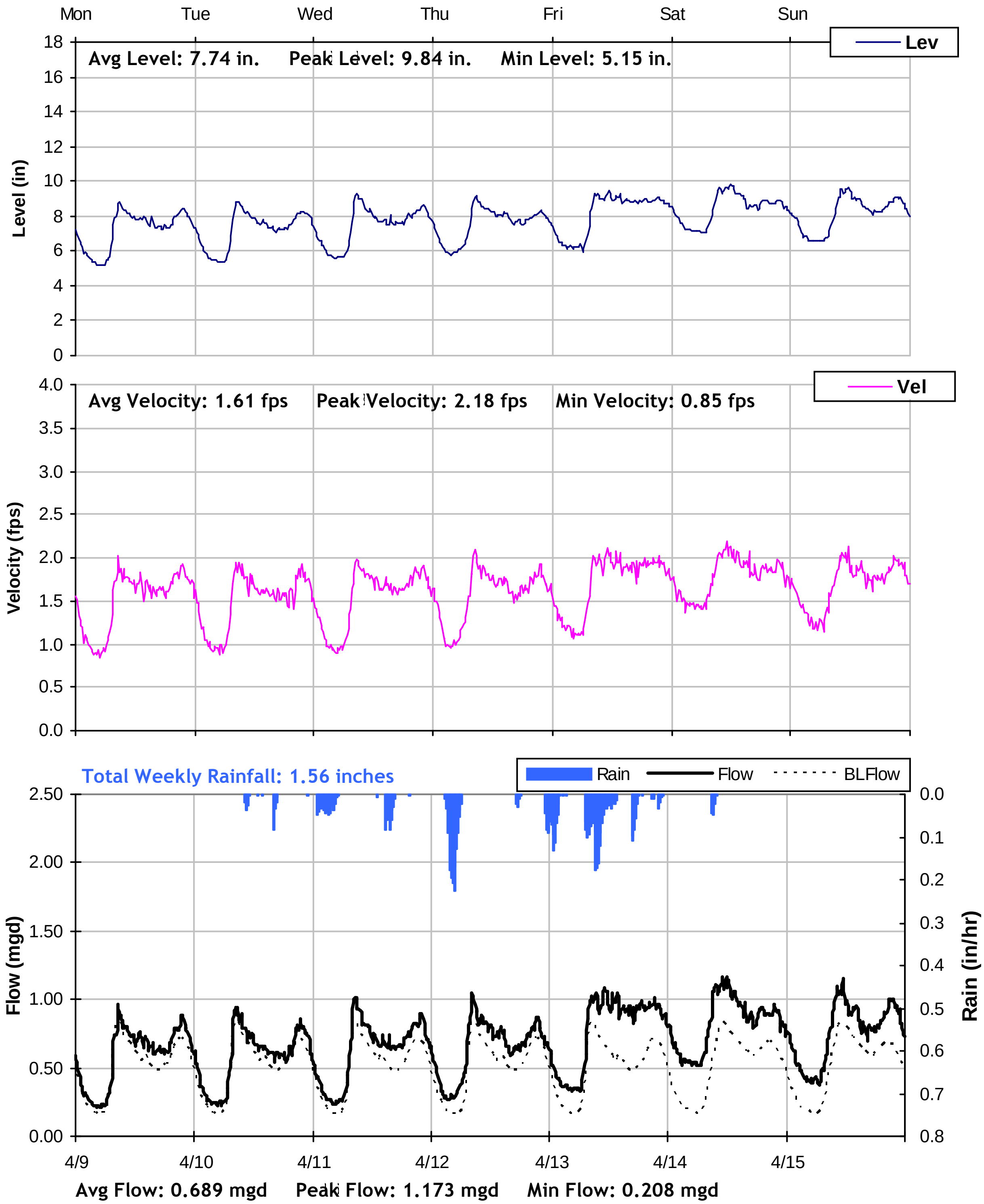
SITE 7
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



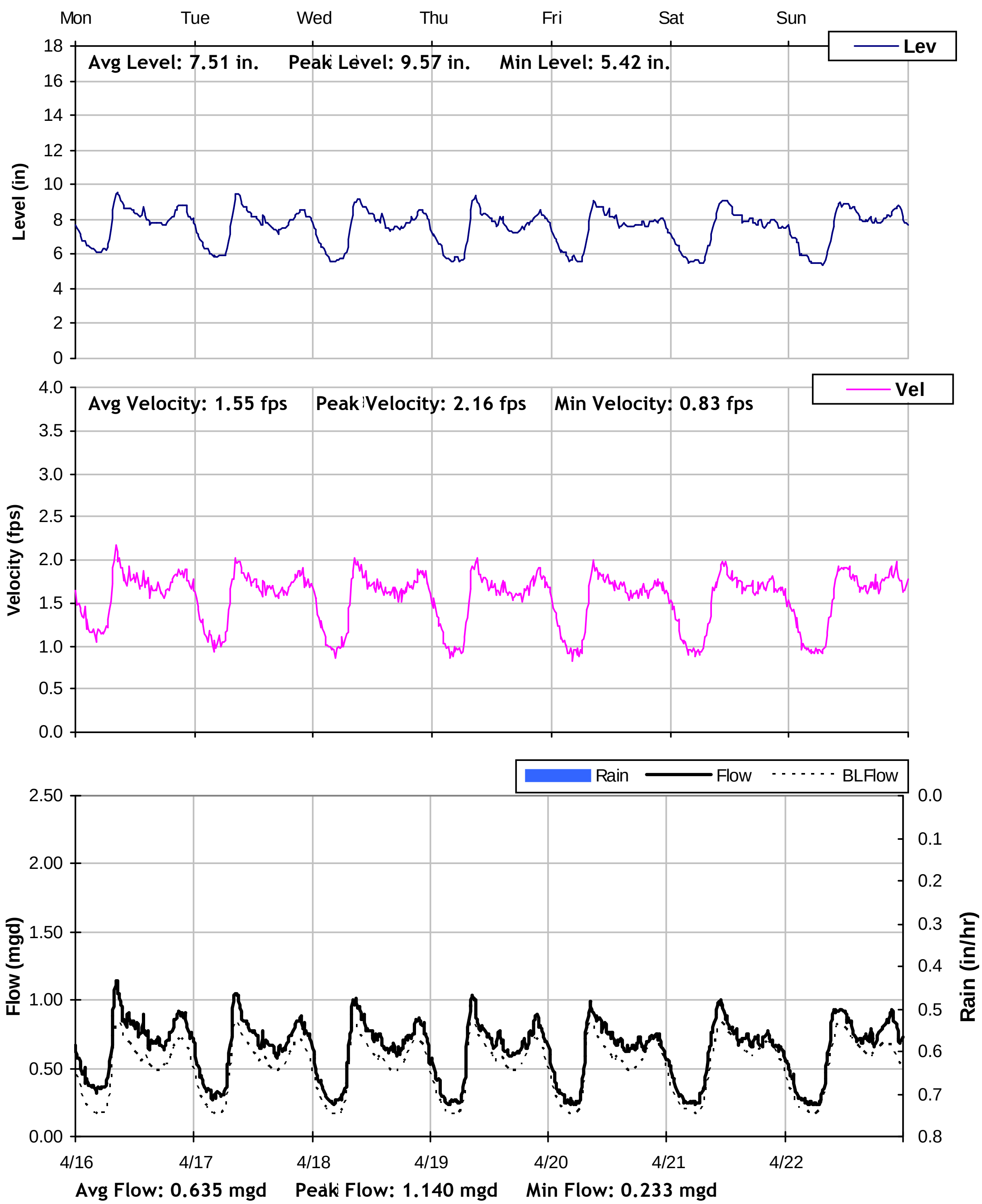
SITE 7
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



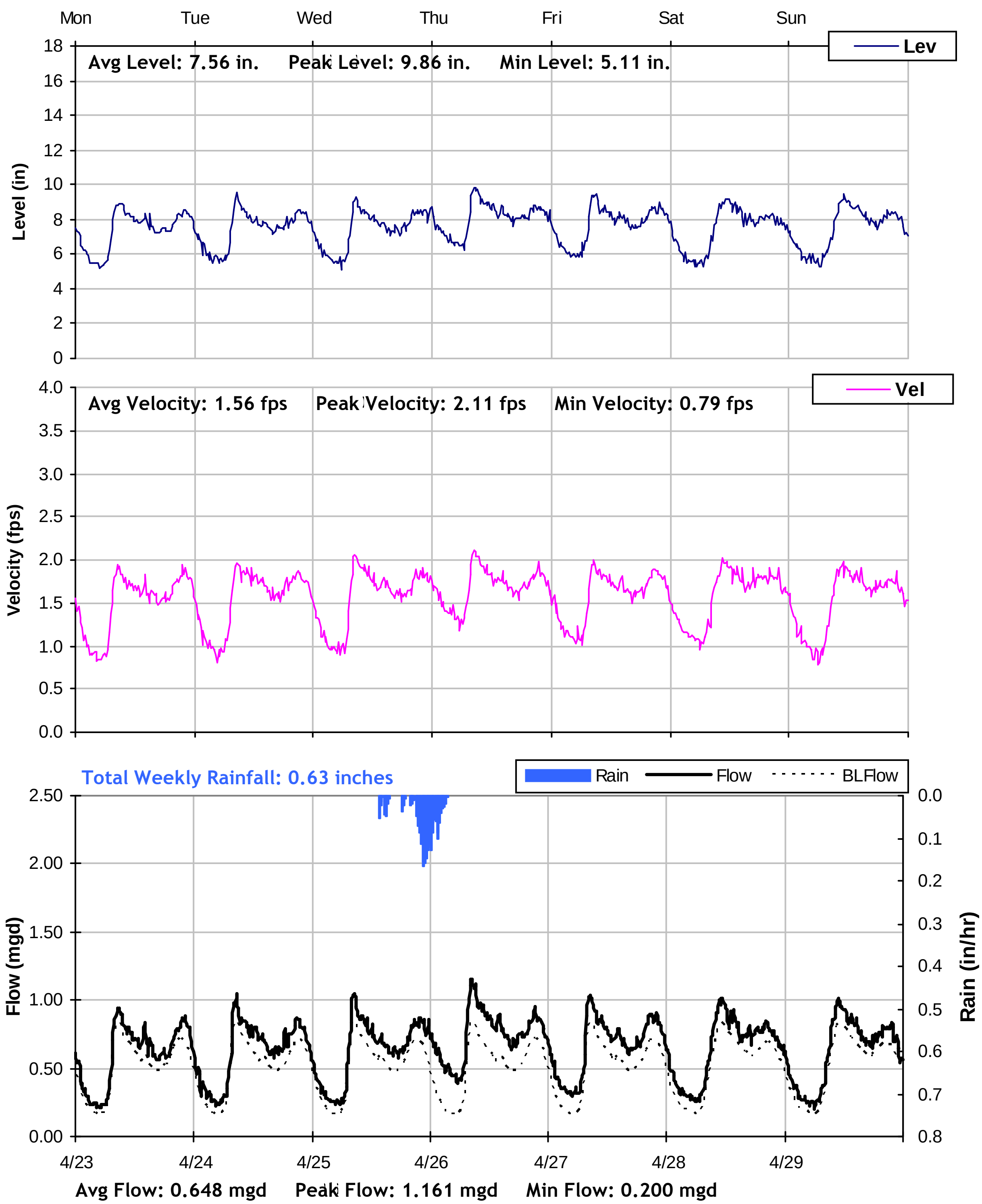
SITE 7
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



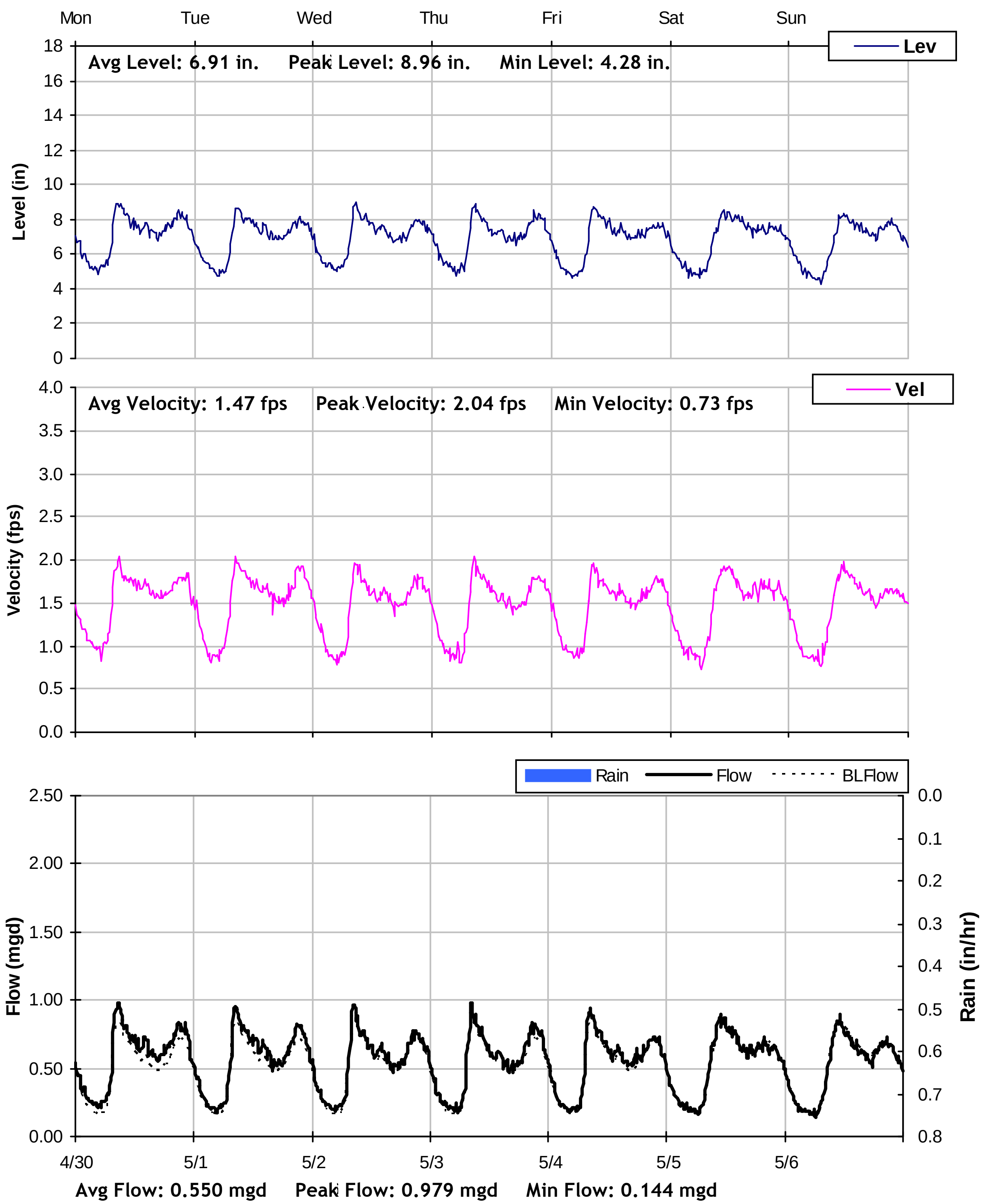
SITE 7
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012



SITE 7
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 7
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



City of Chico

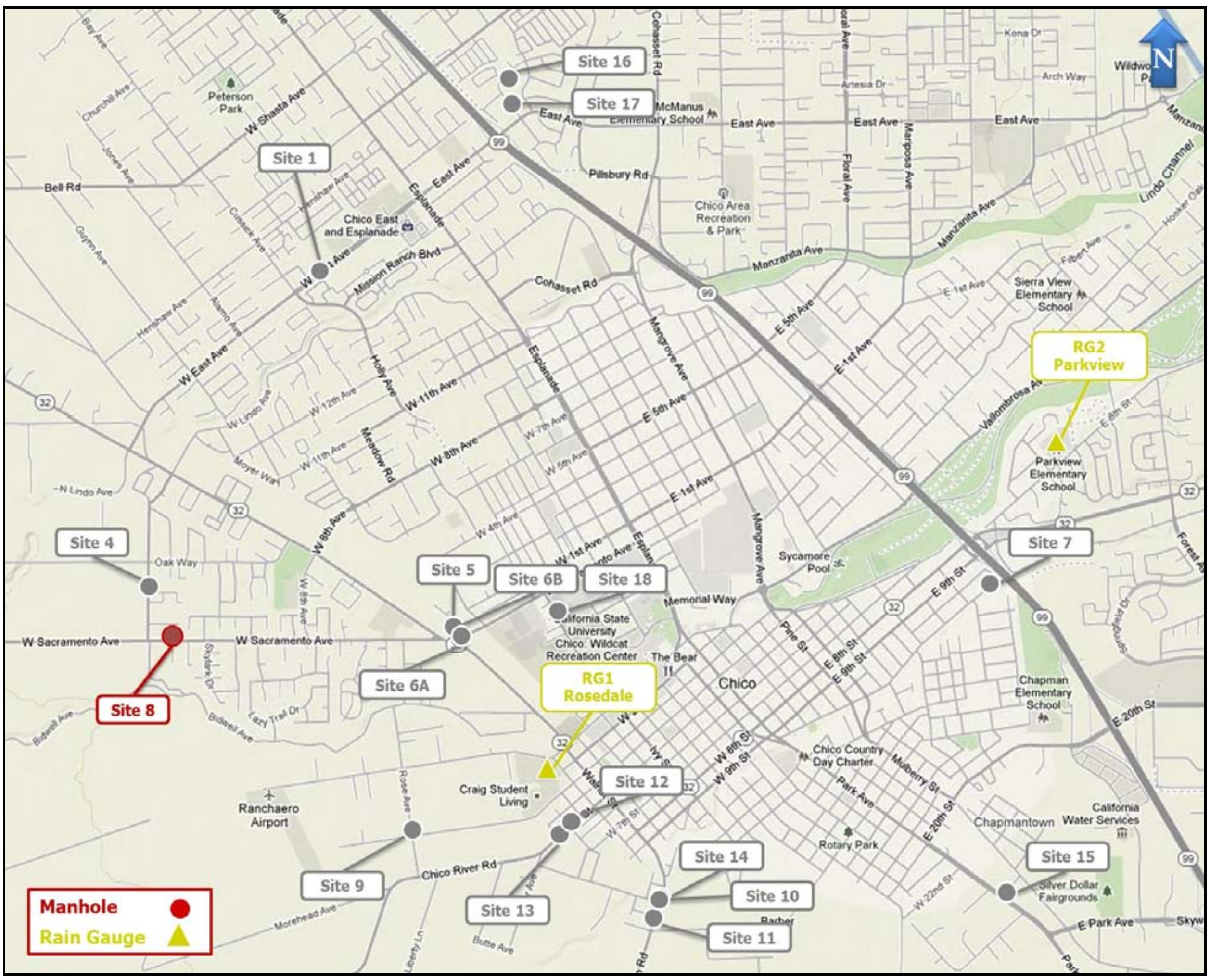
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 8

Location: W Sacramento Avenue at Woodmont Court

Vicinity Map:

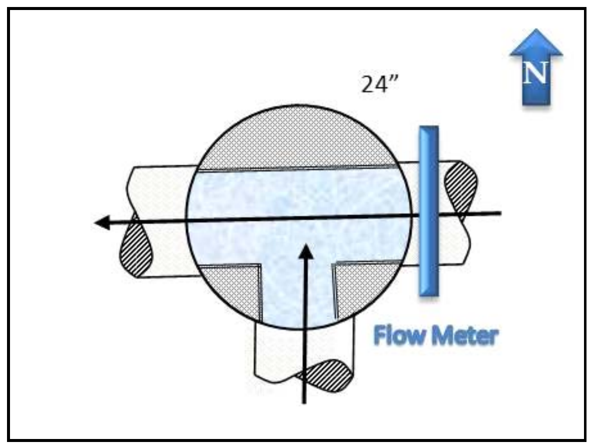


SITE 8
Site Information Report

Location:	W Sacramento Avenue at Woodmont Court
Coordinates:	121.8800° W, 39.7310° N
Elevation:	168 feet
Diameter:	24 inches
Baseline Flow:	0.504 mgd
Peak Measured Flow:	1.297 mgd

Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

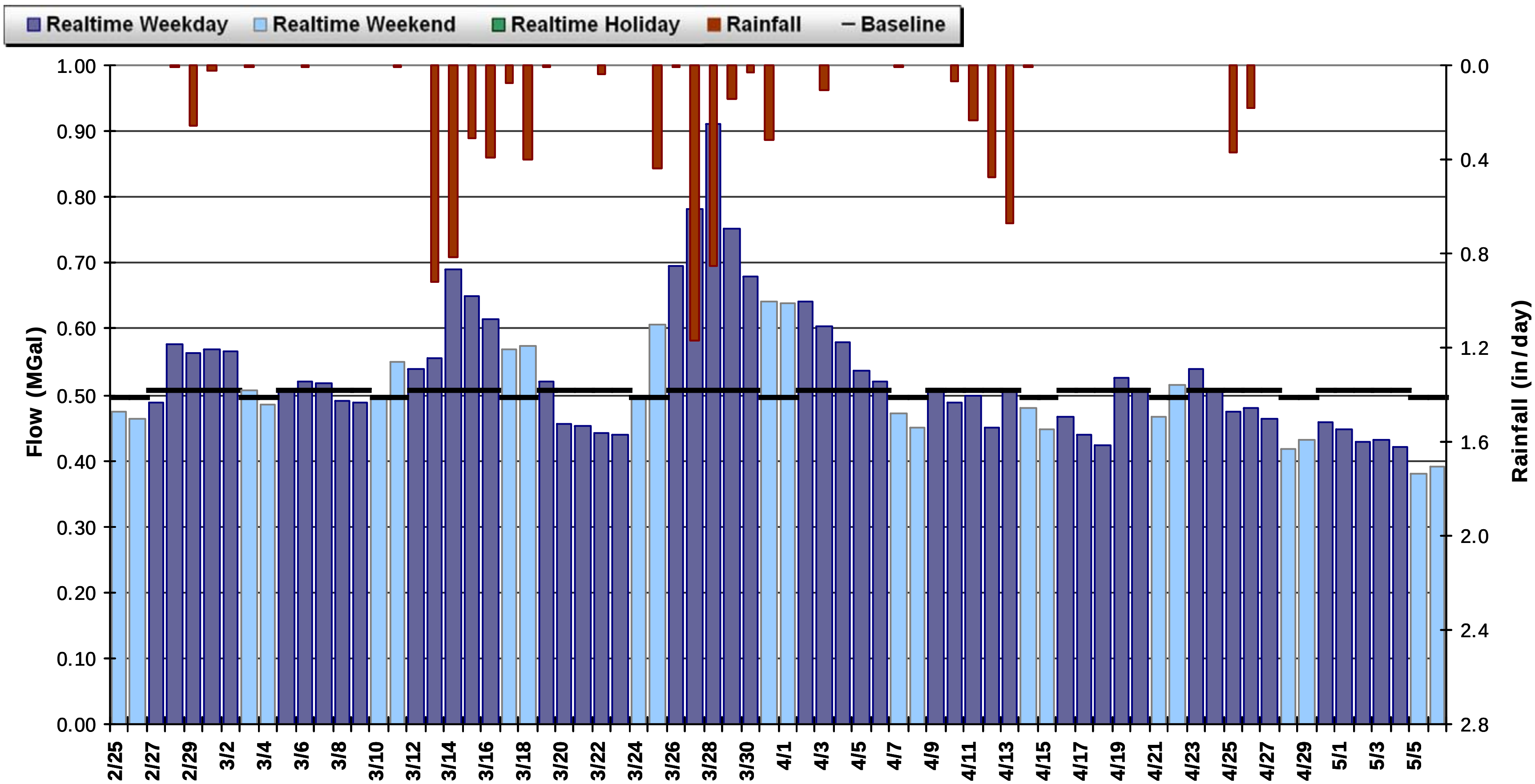
Plan View

SITE 8

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.524 MGal **Peak Daily Flow: 0.911 MGal** **Min Daily Flow: 0.380 MGal**

Total Period Rainfall: 8.34 inches

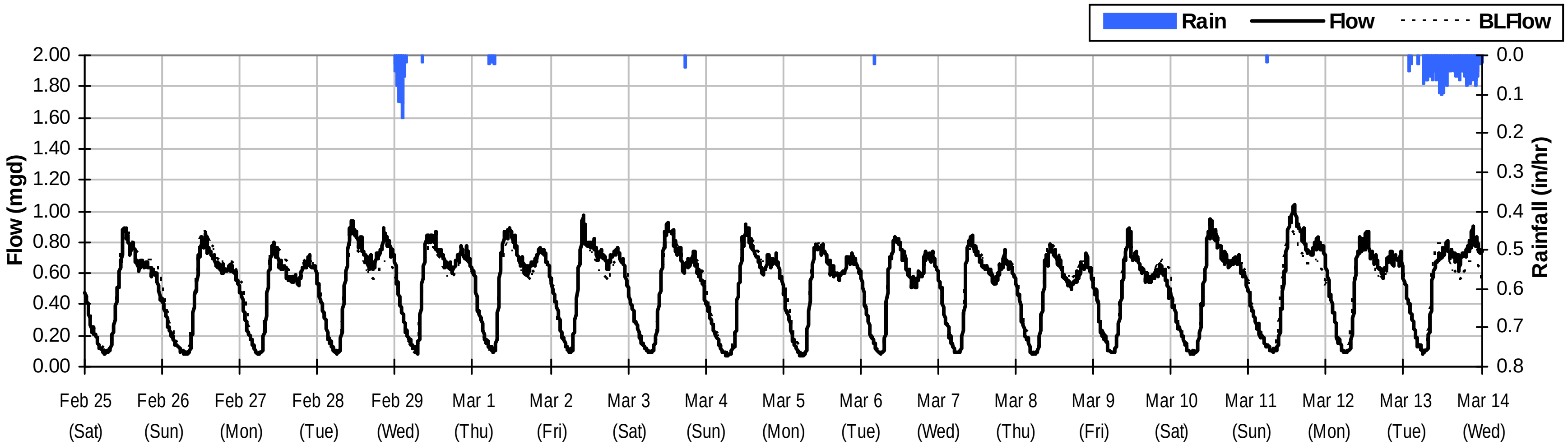


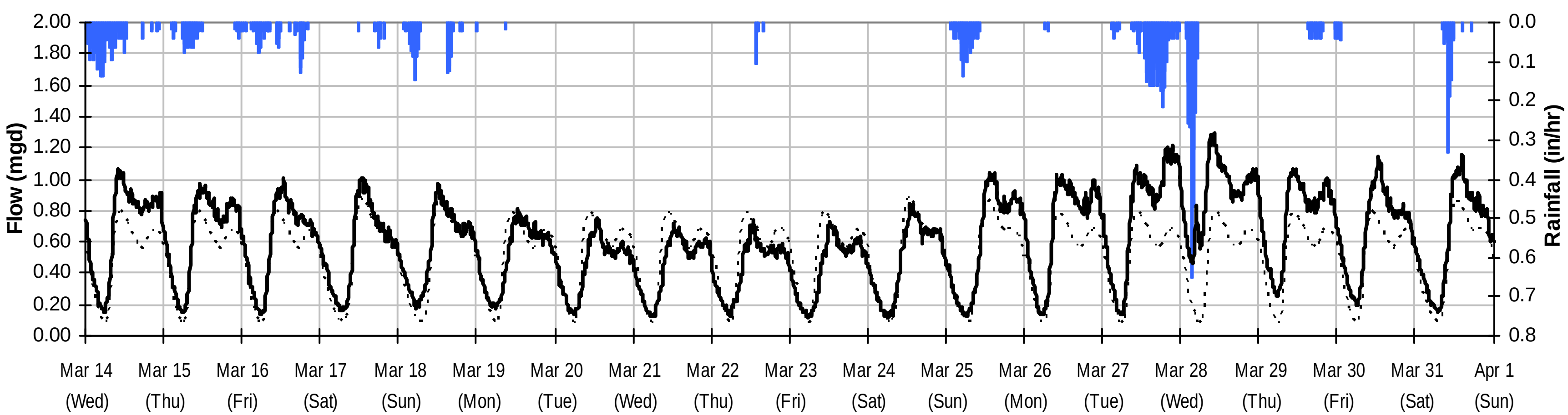
SITE 8

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.565 mgd **Peak Flow: 1.297 mgd** **Min Flow: 0.068 mgd**

Total Period Rainfall: 6.22 inches



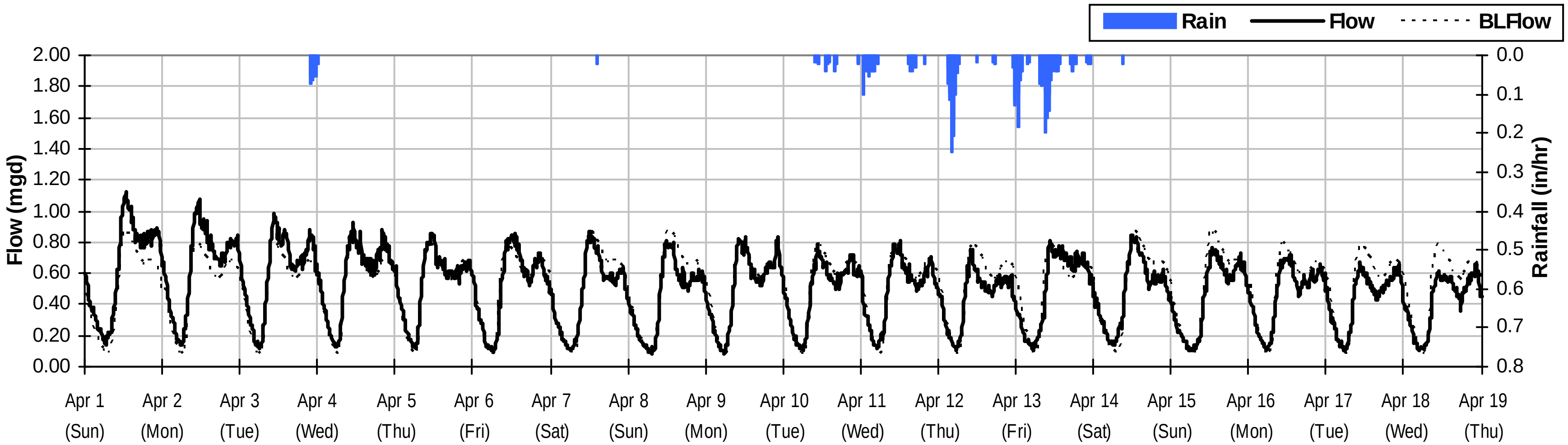


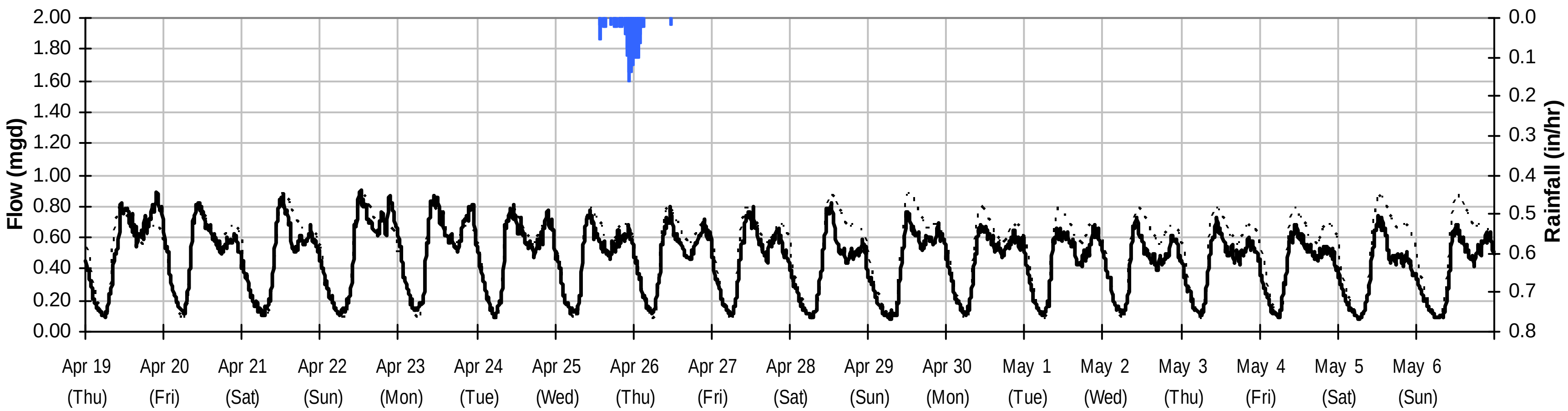
SITE 8

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.484 mgd **Peak Flow: 1.120 mgd** **Min Flow: 0.082 mgd**

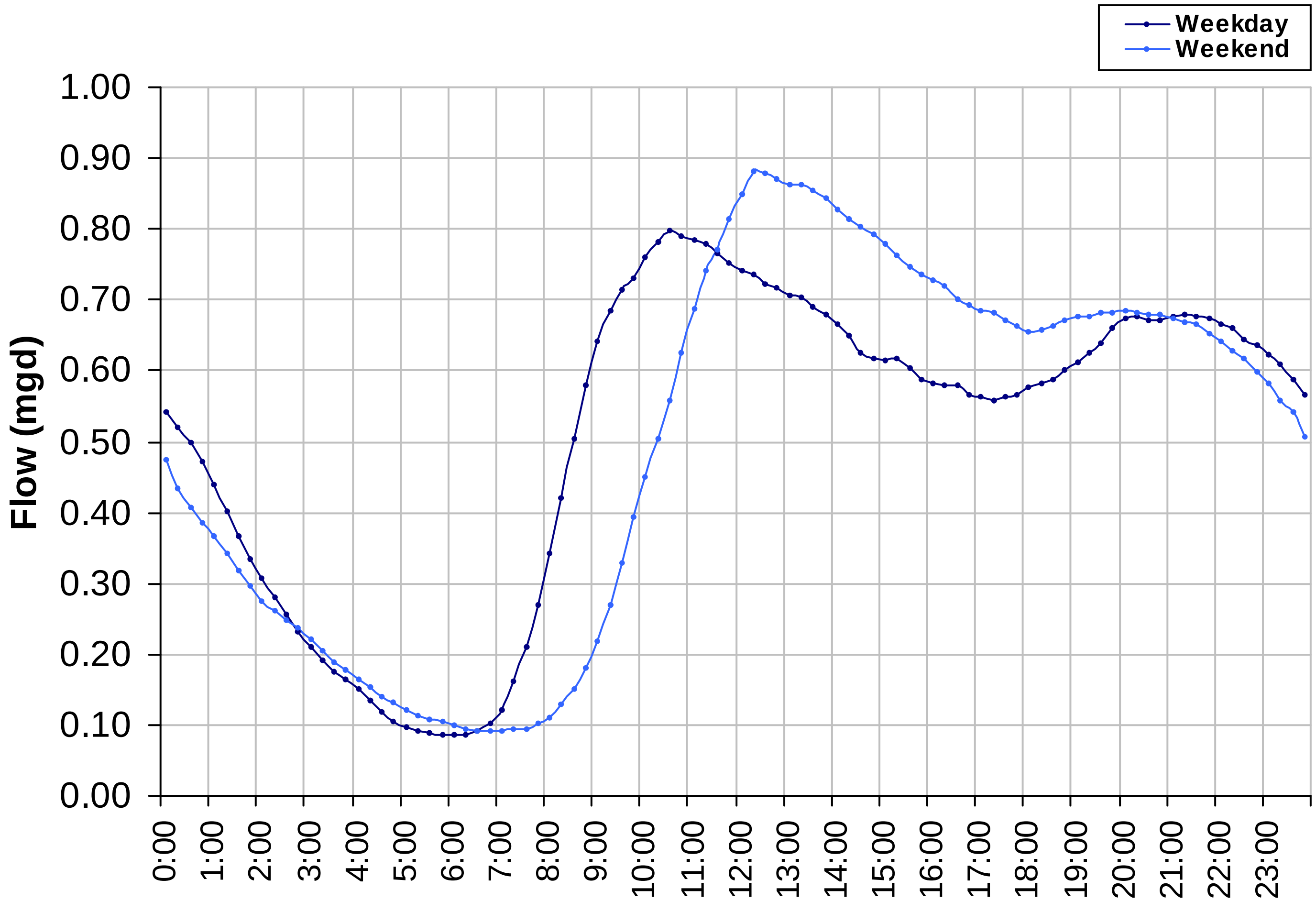
Total Period Rainfall: 2.11 inches





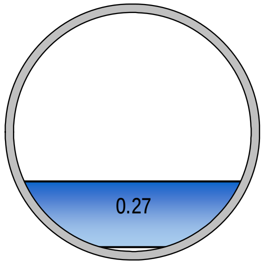
SITE 8

Baseline Flow Hydrographs



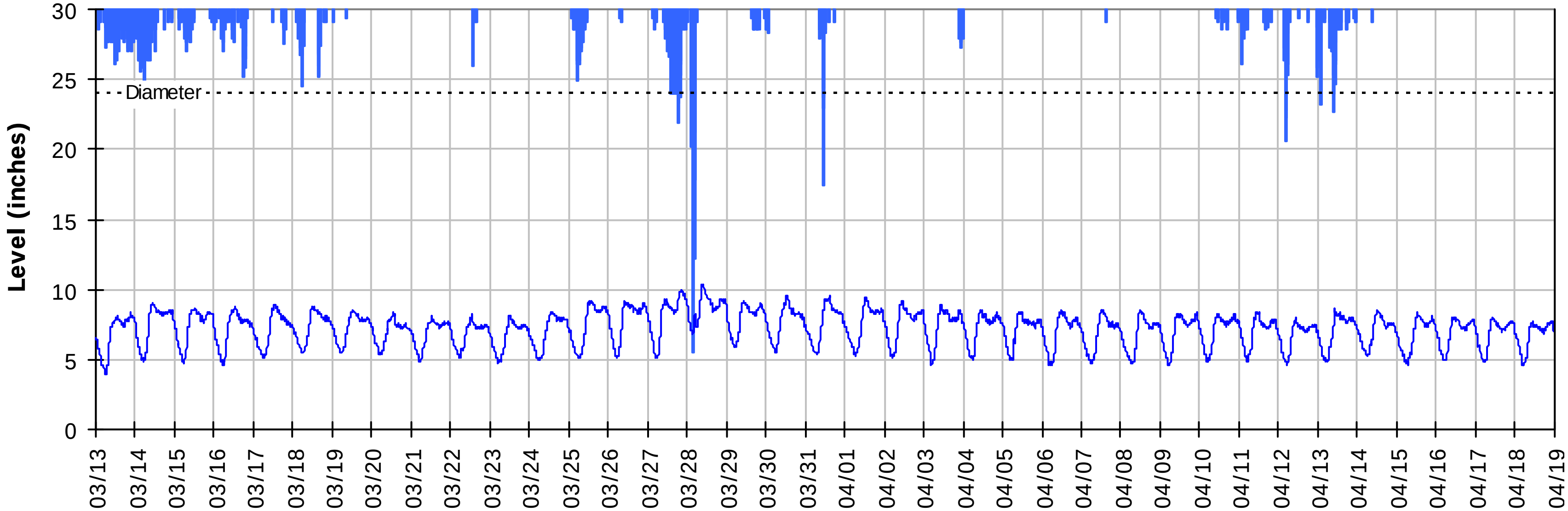
Baseline Flow:

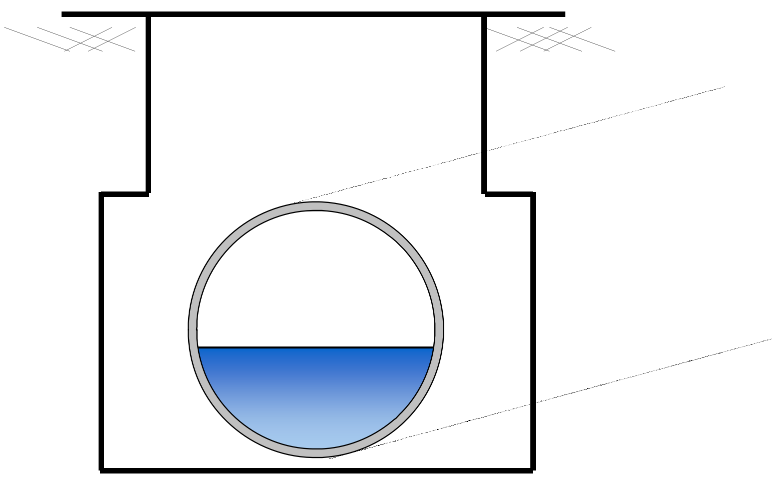
0.504 *mgd*



SITE 8
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





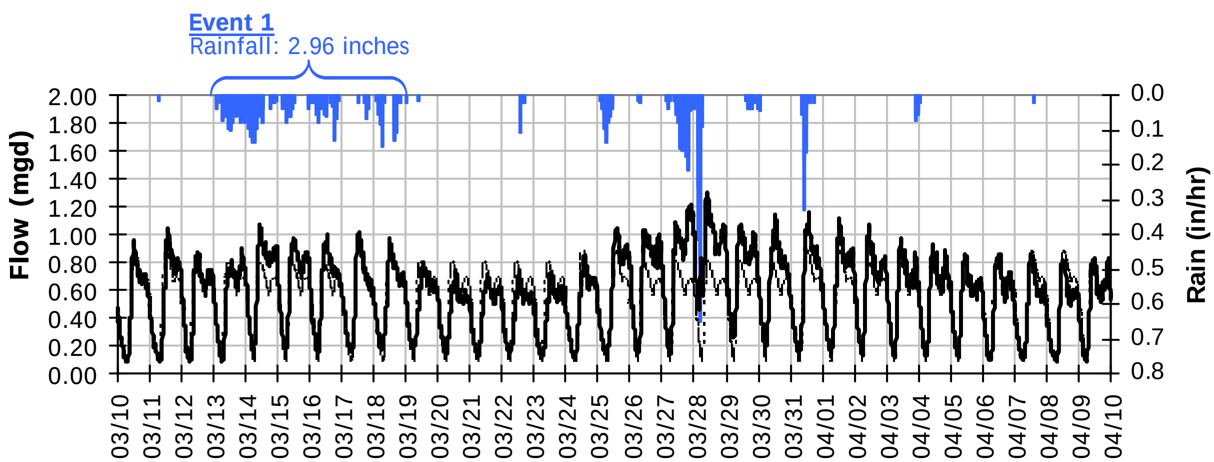
Pipe Diameter: 24 *inches*

Peak Measured Level: 10.4 *inches*

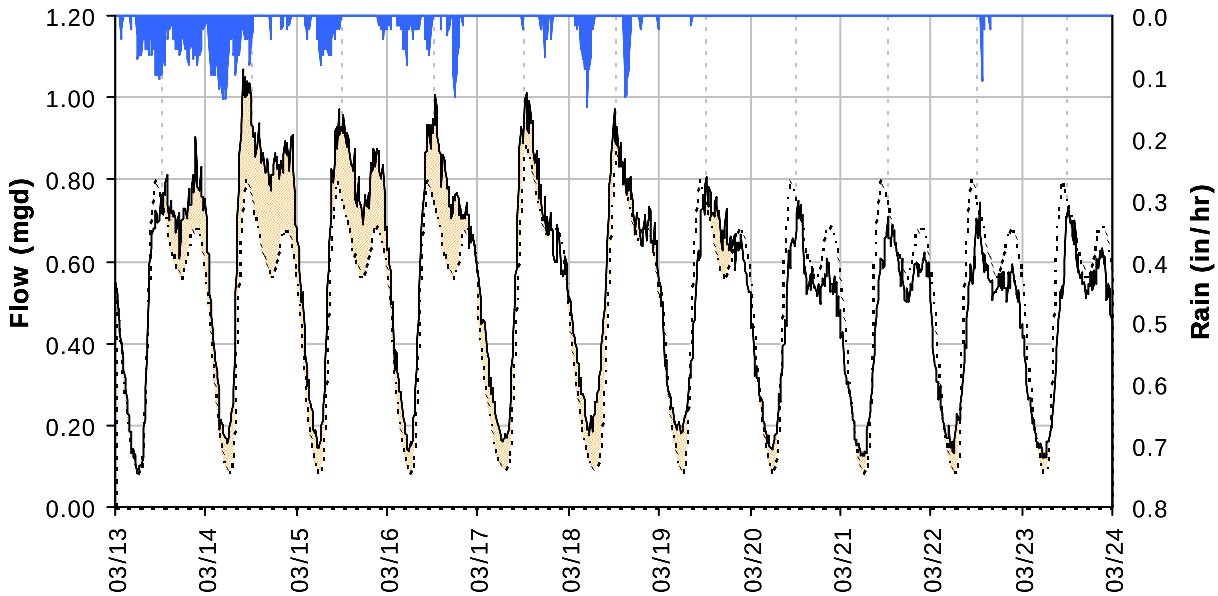
Peak d/D Ratio: 0.43

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 = 2.96 inches)

Capacity

Peak Flow: 1.07 *mgd*
PF: 2.12
Peak Level: 9.01 *in*
d/D Ratio: 0.38

Inflow

Peak I/I Rate: 0.34 *mgd*
Pk I/I:ADWF: 0.67

RDI (infiltration)

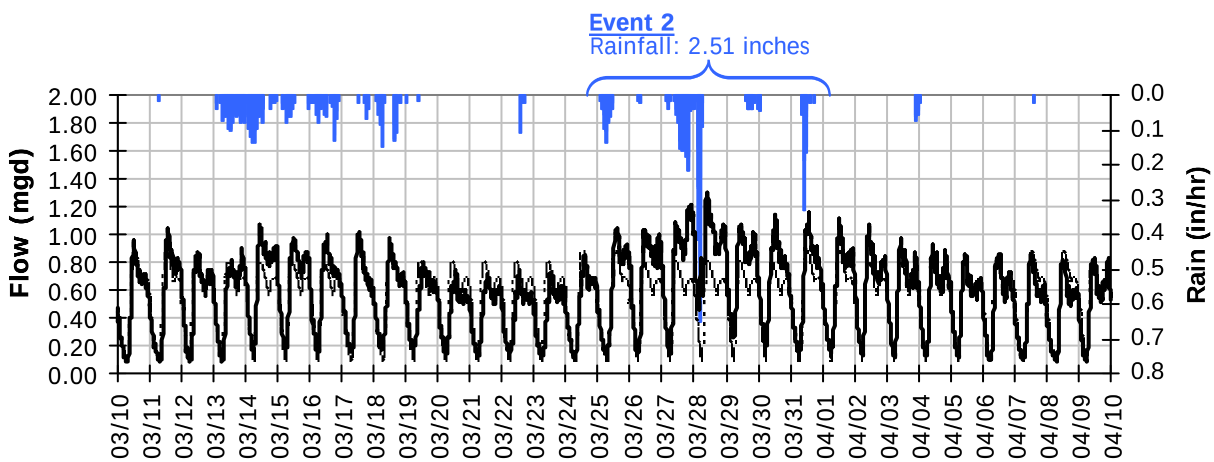
Infiltration Rate: 0.000 *mgd*
(3/20/2012)
RDI (% of BL): 0%

Combined I/I

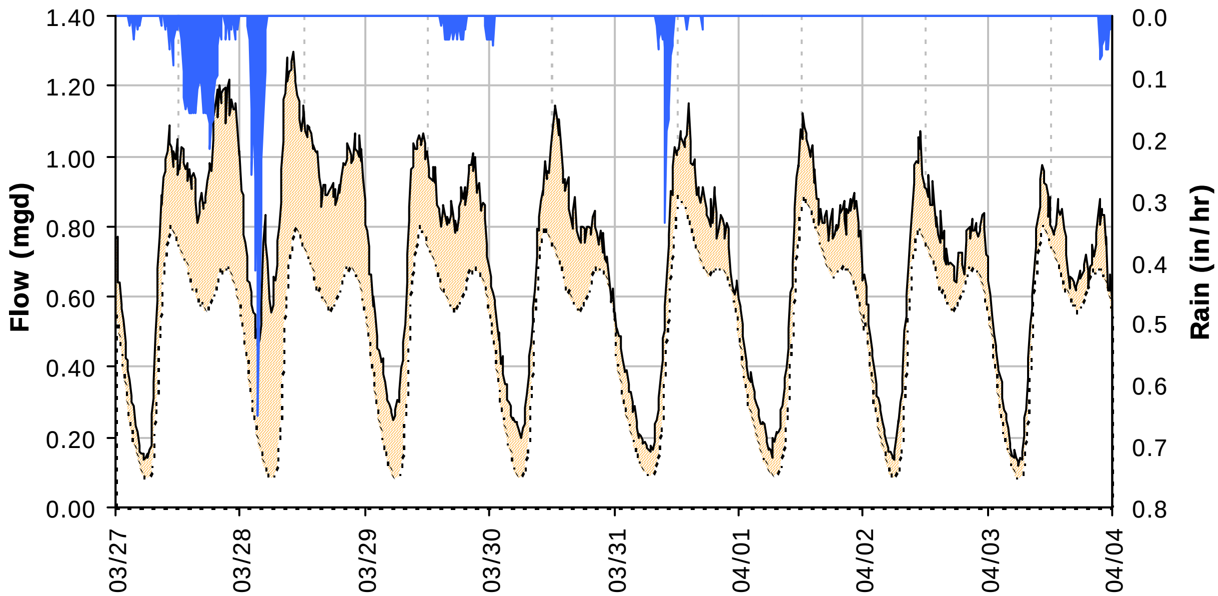
Total I/I: 401,000 *gallons*
Total I/I:ADWF: 0.27 *per in-rain*

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 = 2.51 inches)

Capacity

Peak Flow: 1.30 *mgd*
PF: 2.57
Peak Level: 10.37 *in*
d/D Ratio: 0.43

Inflow

Peak I/I Rate: 0.73 *mgd*
Pk I/I:ADWF: 1.45

RDI (infiltration)

Infiltration Rate: 0.133 *mgd* (4/2/2012)
RDI (% of BL): 26%

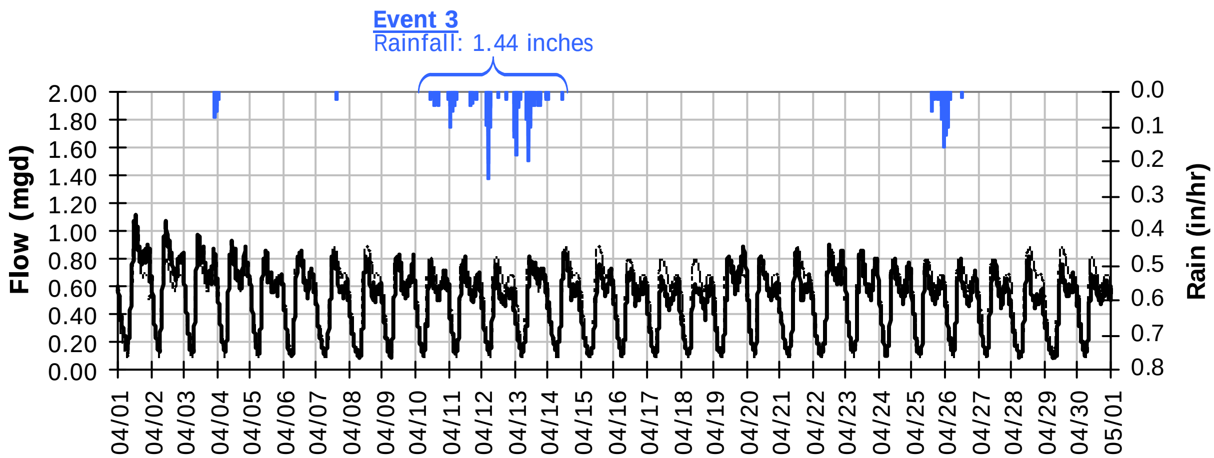
Combined I/I

Total I/I: 1,608,000 *gallons*
Total I/I:ADWF: 1.27 *per in-rain*

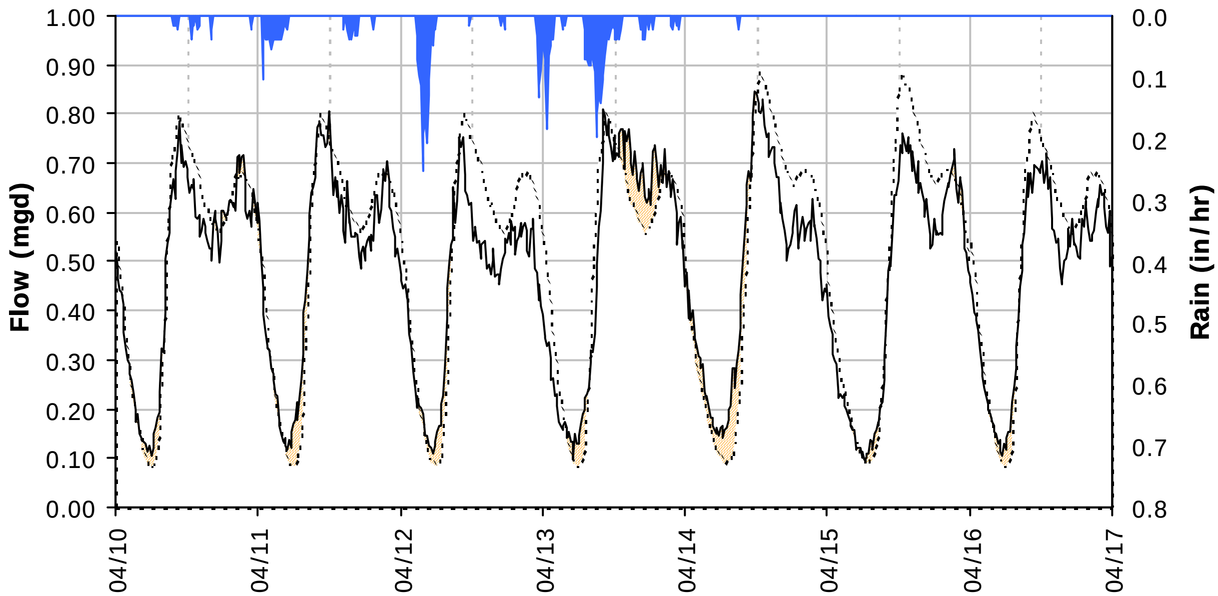
SITE 8

I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.44 inches)

Capacity

Peak Flow: 0.85 *mgd*
PF: 1.68
Peak Level: 8.59 *in*
d/D Ratio: 0.36

Inflow

Peak I/I Rate: 0.17 *mgd*
Pk I/I:ADWF: 0.34

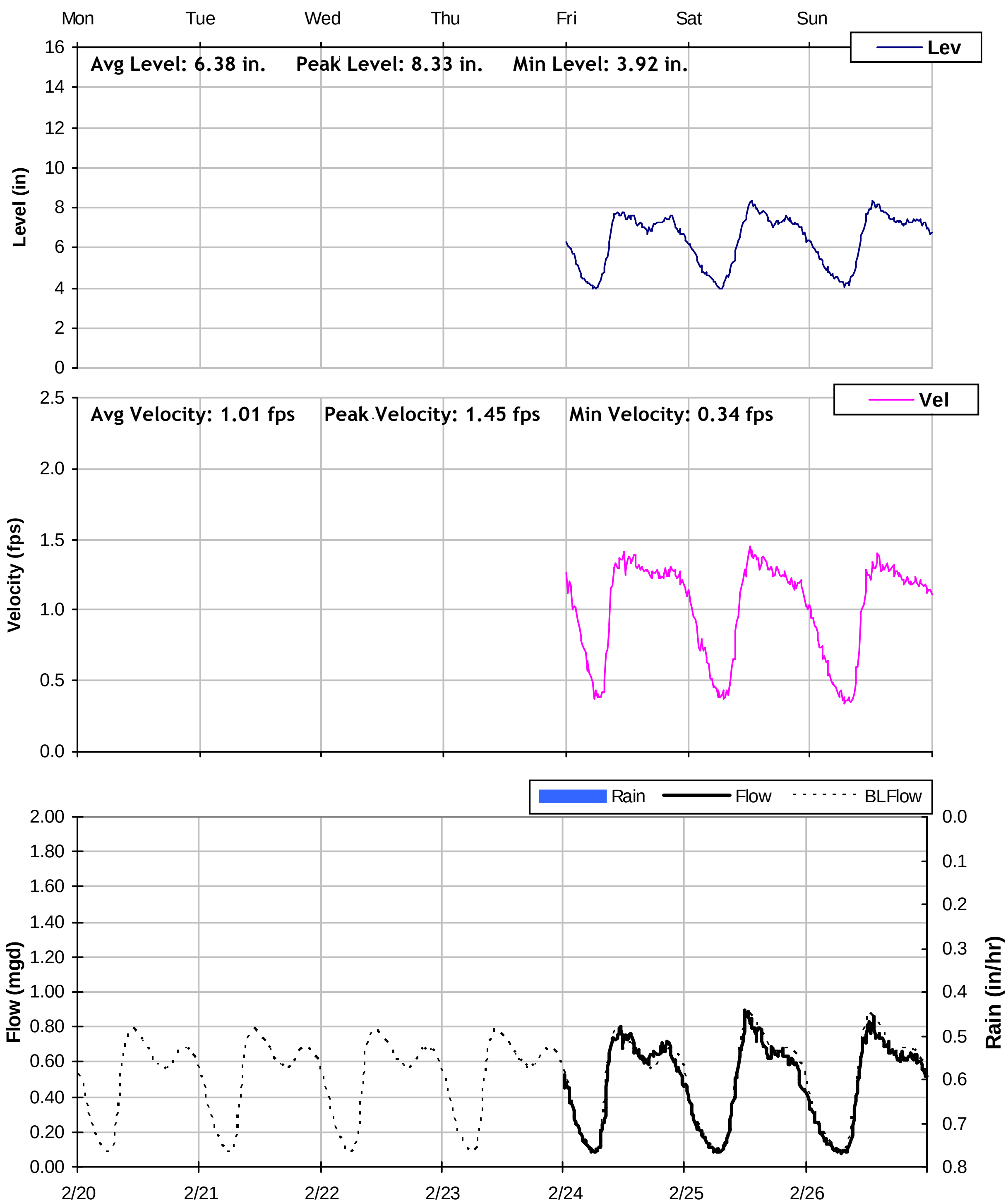
RDI (infiltration)

Infiltration Rate: 0.000 *mgd* (4/15/2012)
RDI (% of BL): 0%

Combined I/I

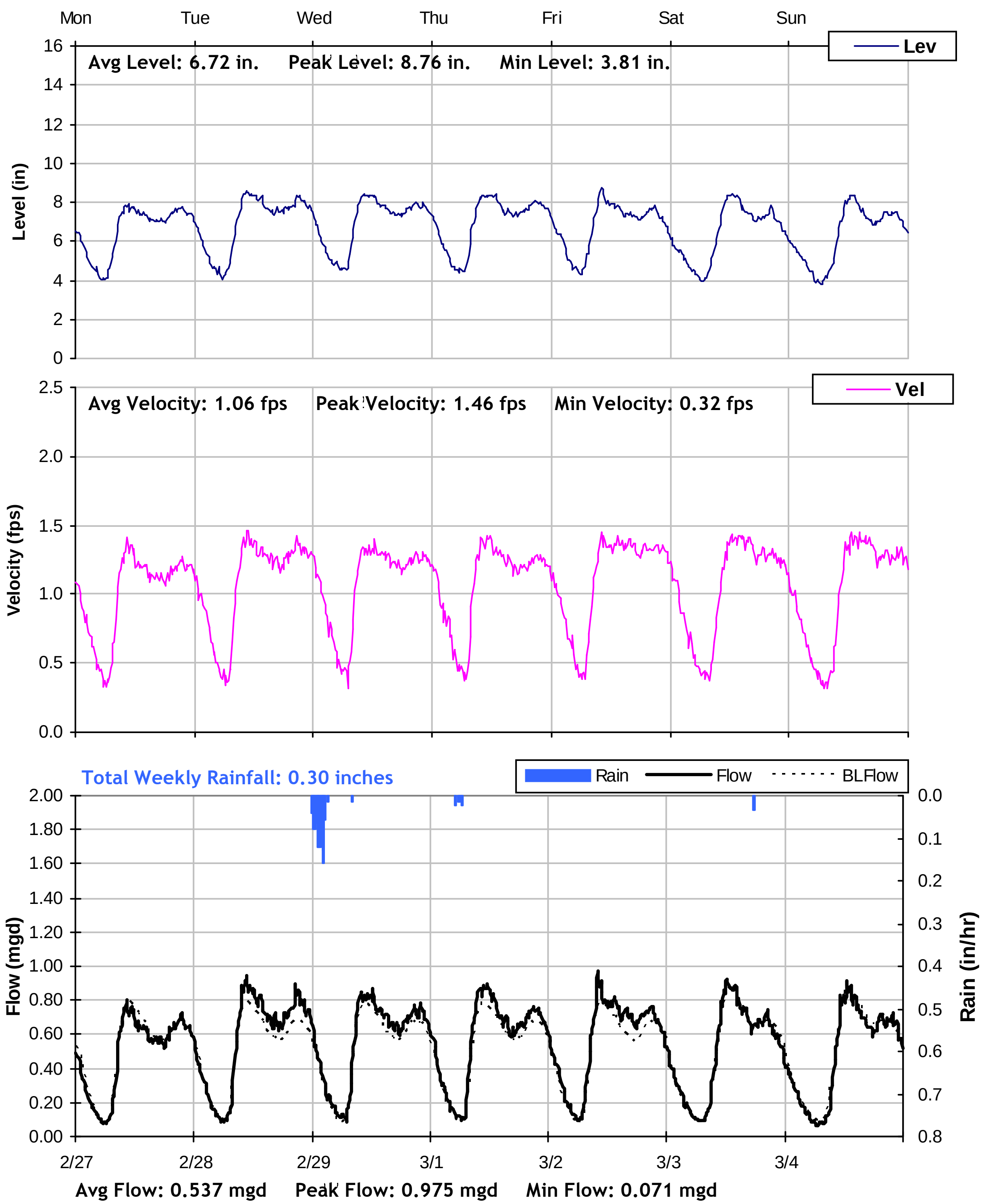
Total I/I: -193,000 *gallons*
Total I/I:ADWF: -0.27 *per in-rain*

SITE 8
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

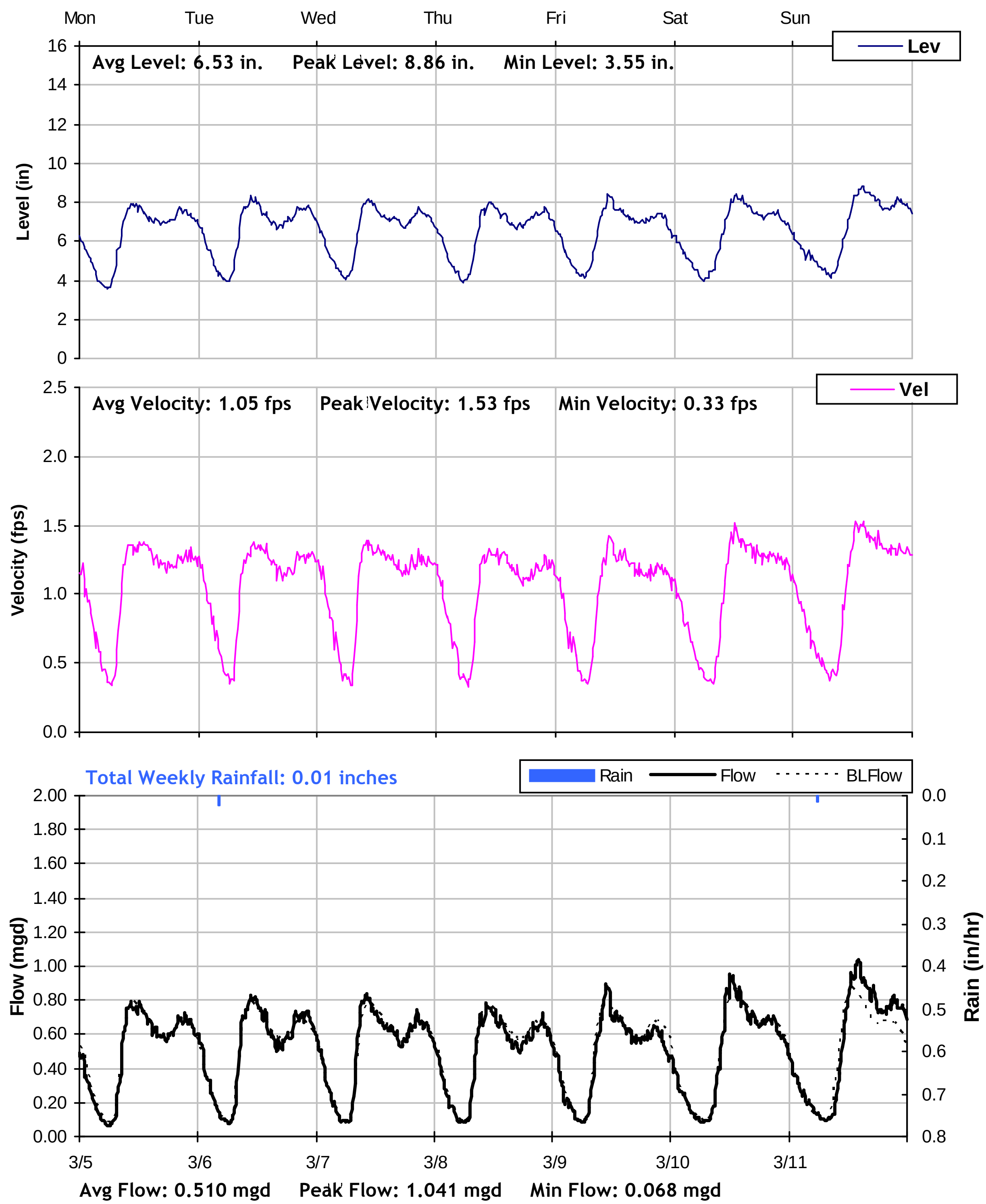


Avg Flow: 0.481 mgd Peak Flow: 0.895 mgd Min Flow: 0.078 mgd

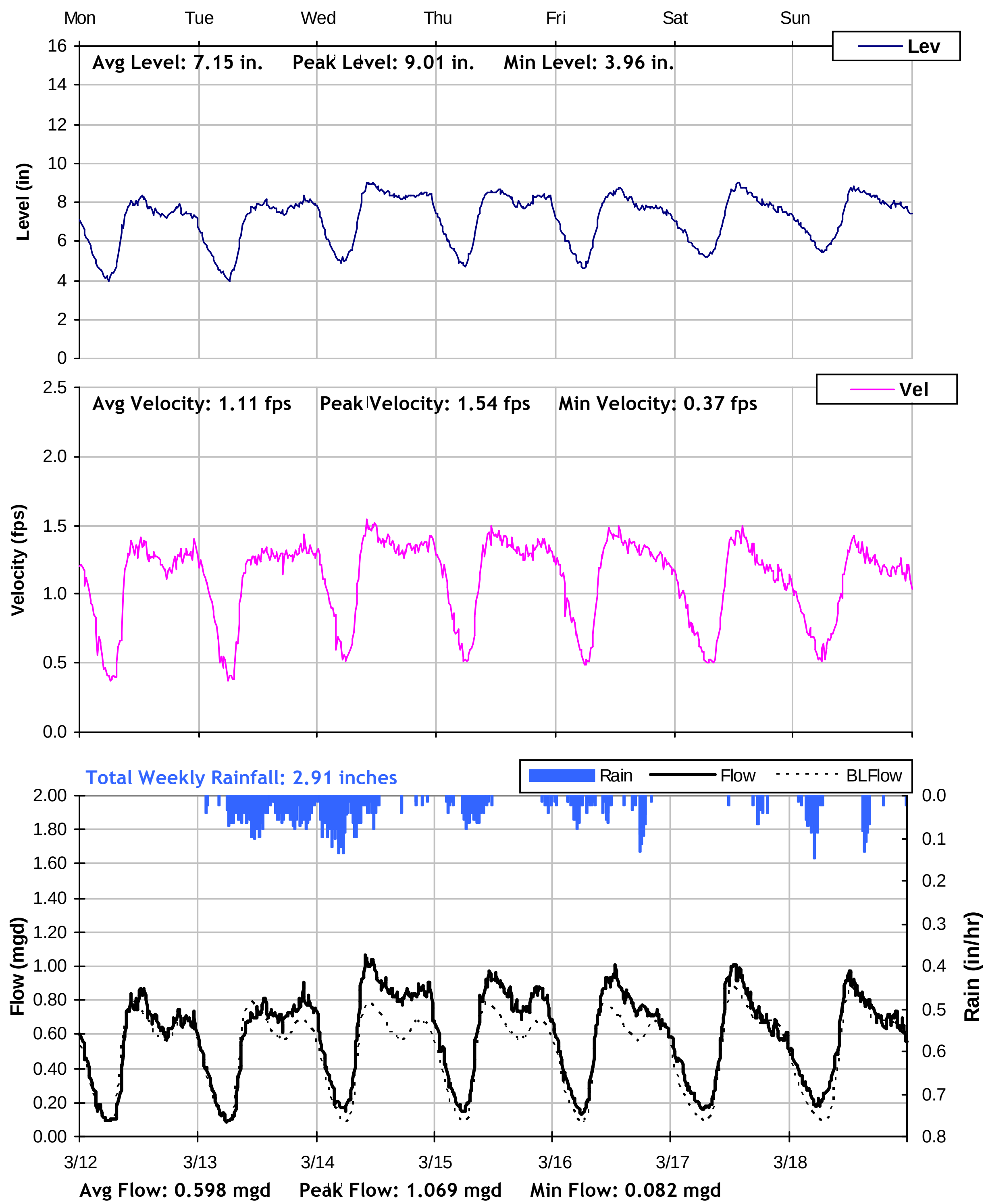
SITE 8
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



SITE 8
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



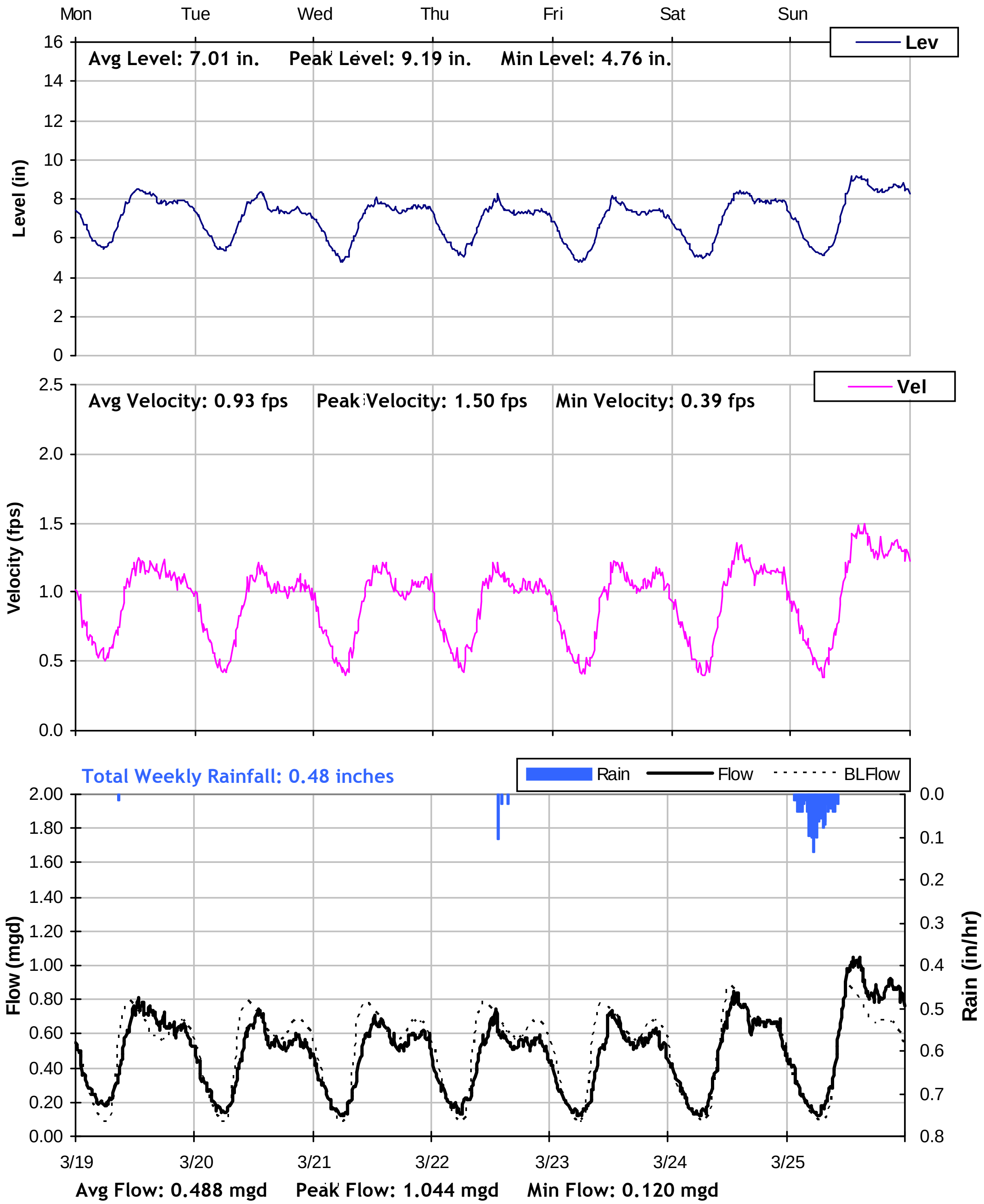
SITE 8
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



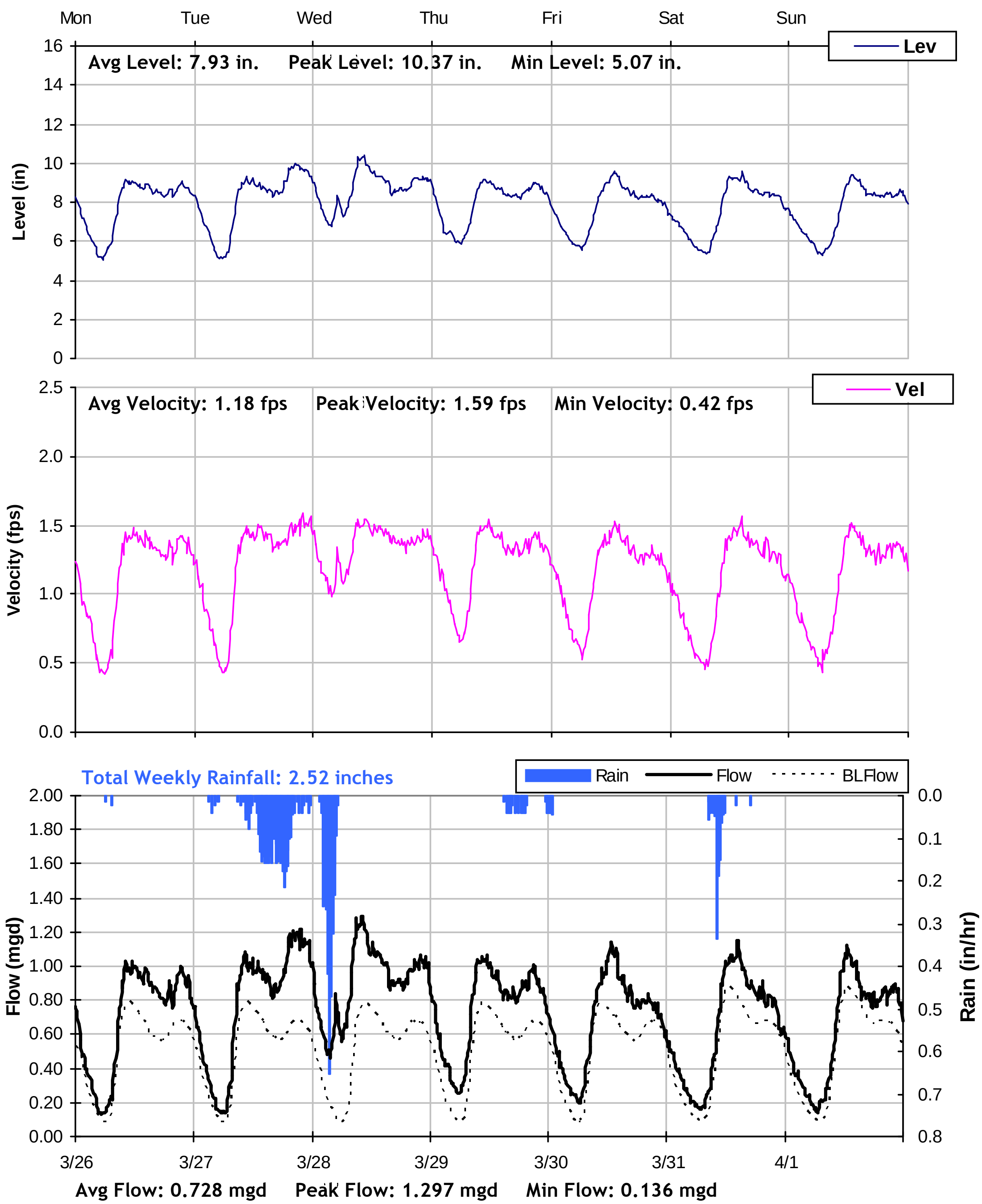
SITE 8

Weekly Level, Velocity and Flow Hydrographs

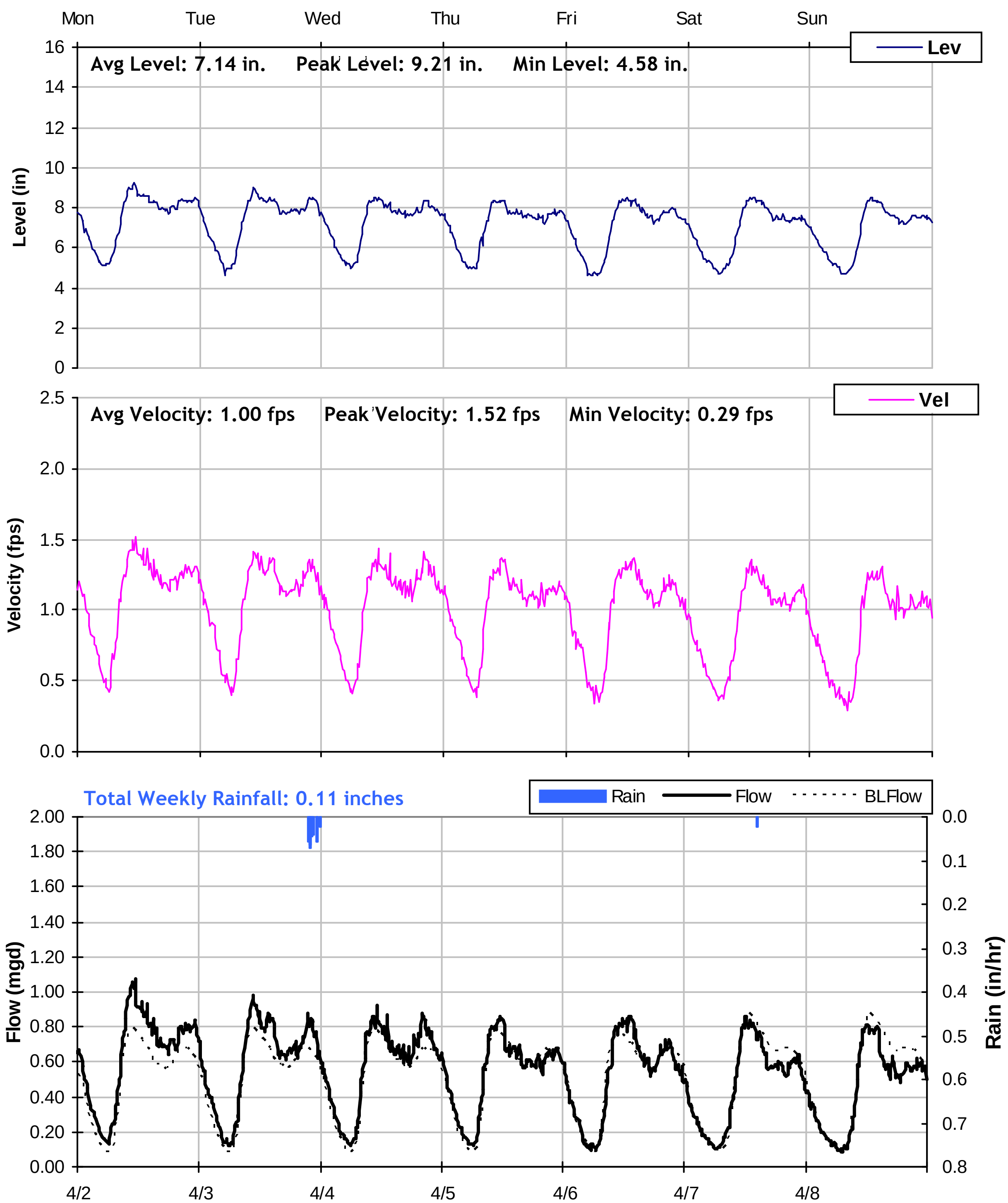
3/19/2012 to 3/26/2012



SITE 8
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012

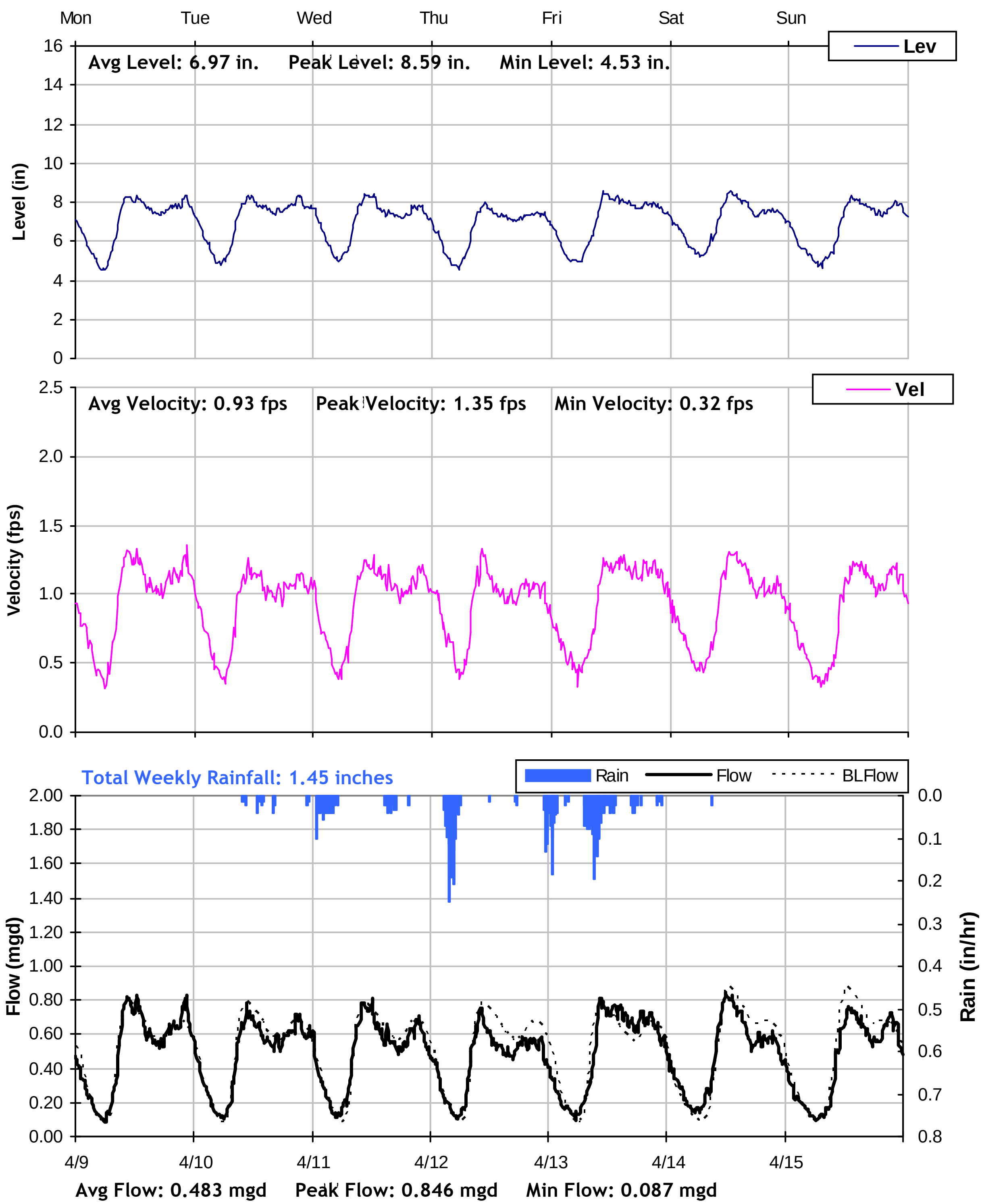


SITE 8
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012

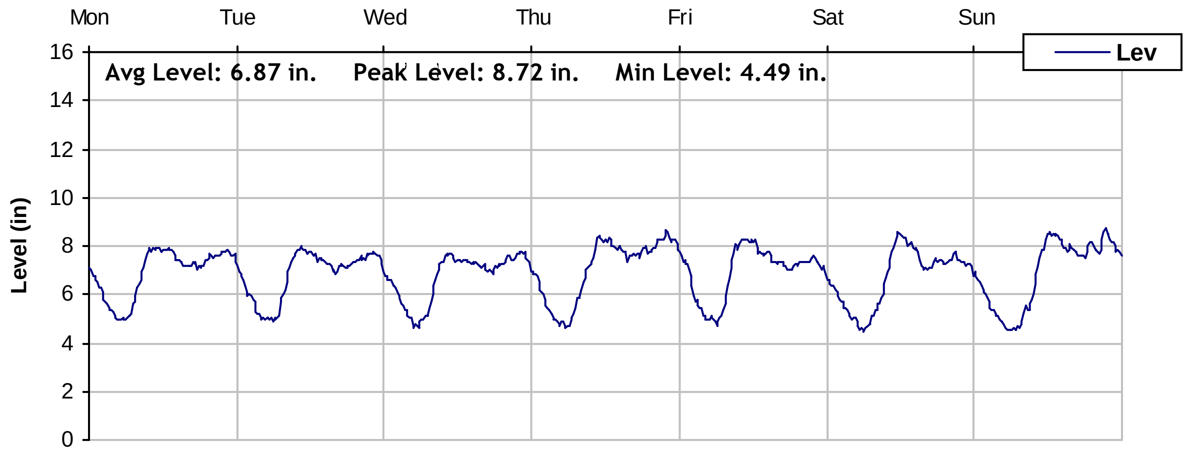


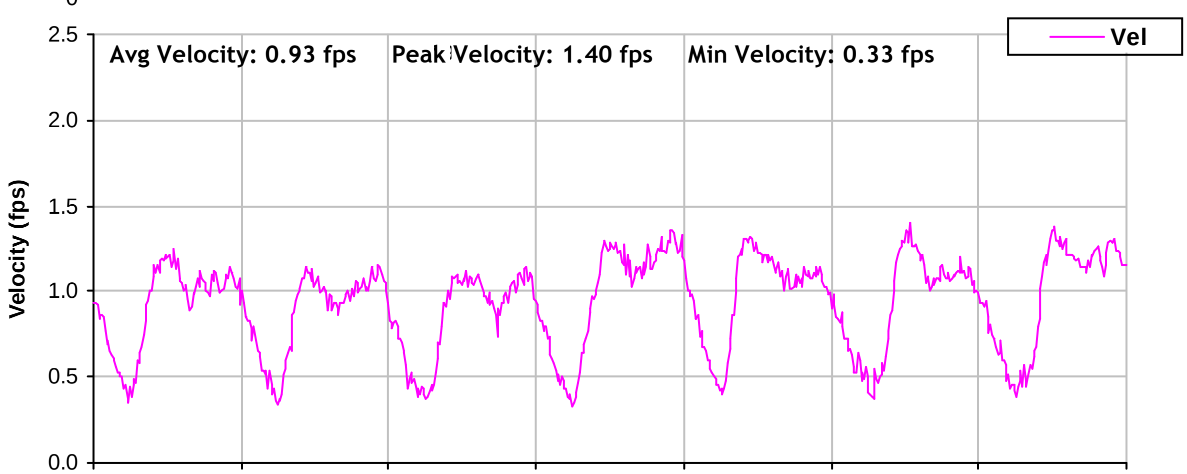
Avg Flow: 0.543 mgd Peak Flow: 1.074 mgd Min Flow: 0.084 mgd

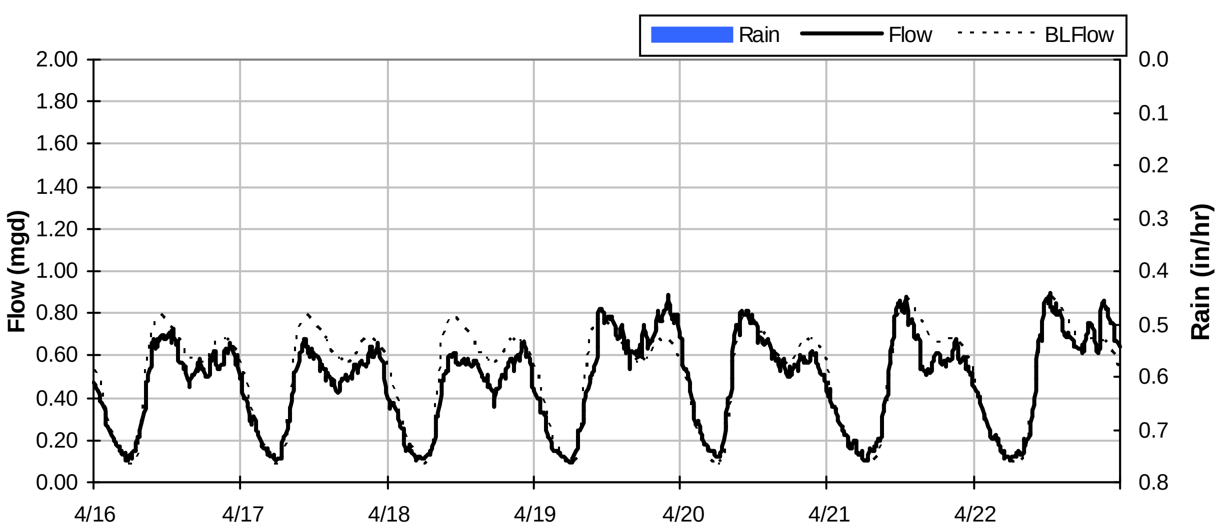
SITE 8
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



SITE 8
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012





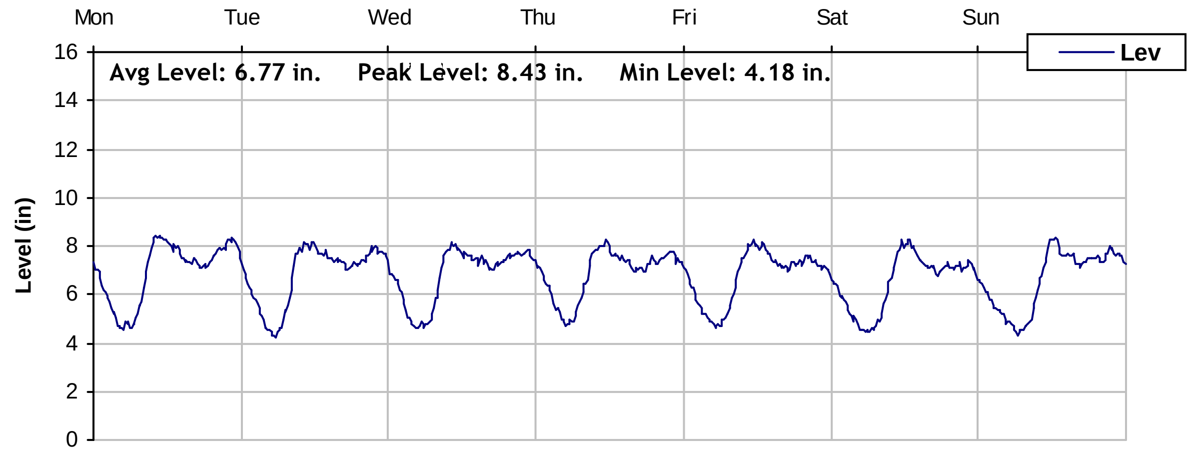


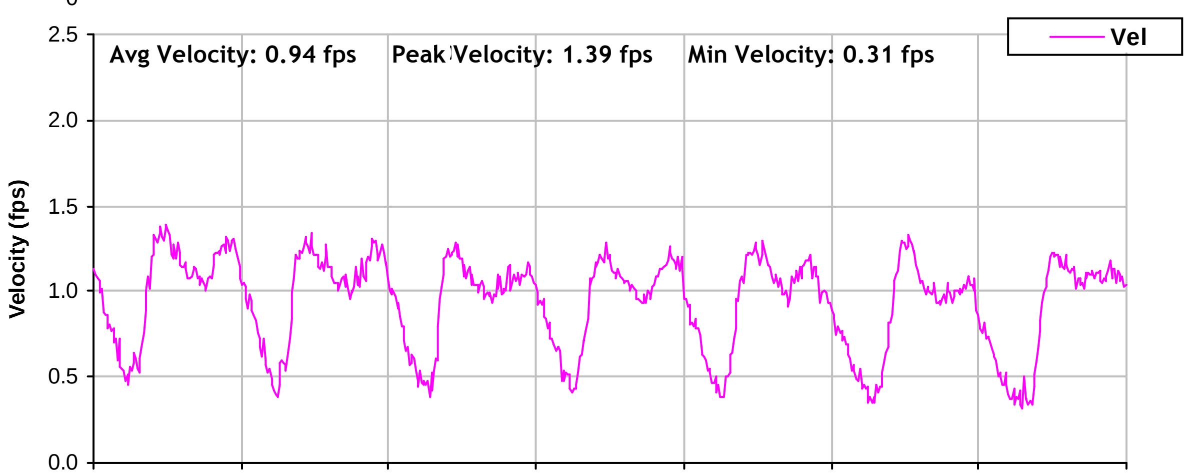
Avg Flow: 0.478 mgd   Peak Flow: 0.900 mgd   Min Flow: 0.094 mgd

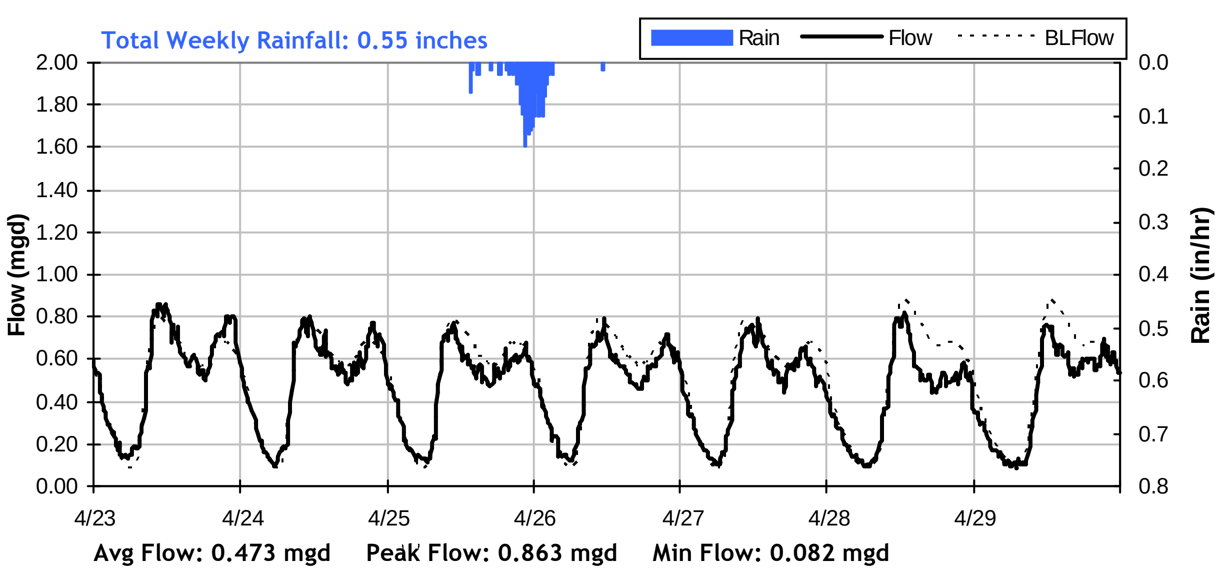
SITE 8

Weekly Level, Velocity and Flow Hydrographs

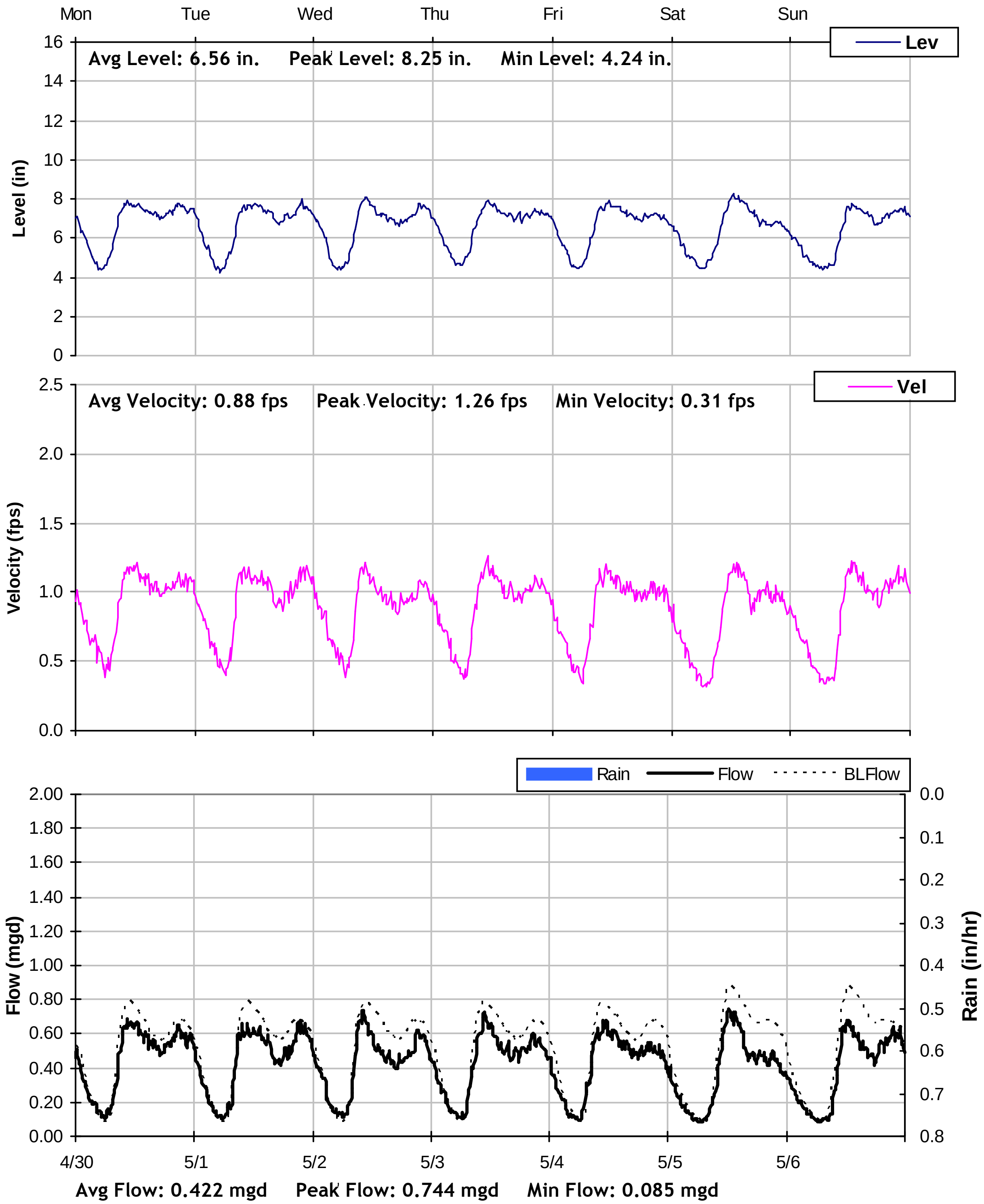
4/23/2012 to 4/30/2012







SITE 8
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



City of Chico

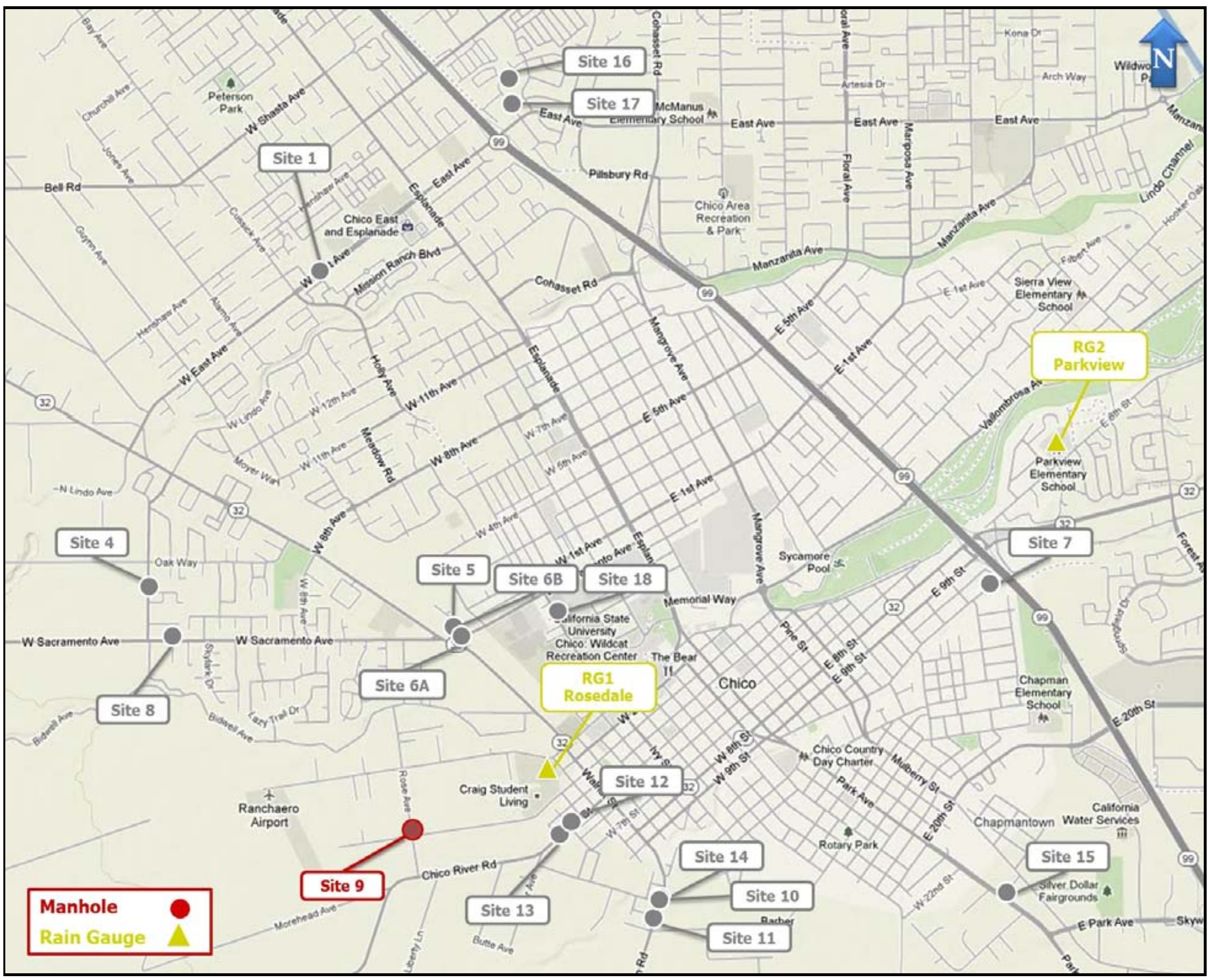
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 9

Location: Chico River Road at Ross Avenue

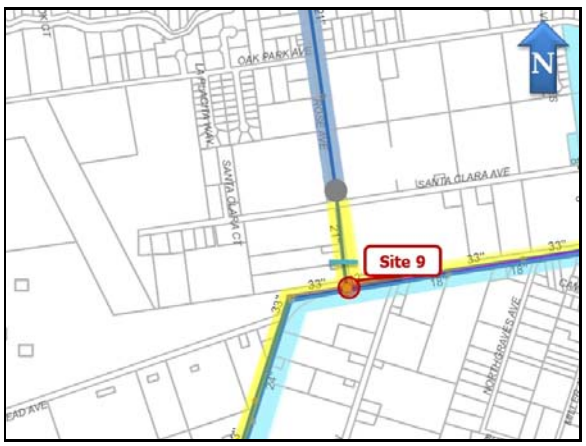
Vicinity Map:



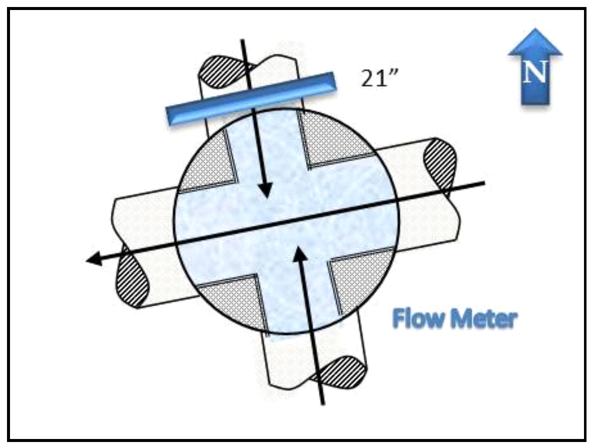
SITE 9
Site Information Report

Location:	Chico River Road at Ross Avenue
Coordinates:	121.8614° W, 39.7174° N
Elevation:	179 feet
Diameter:	21 inches
Baseline Flow:	1.021 mgd
Peak Measured Flow:	1.652 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch


View from Street

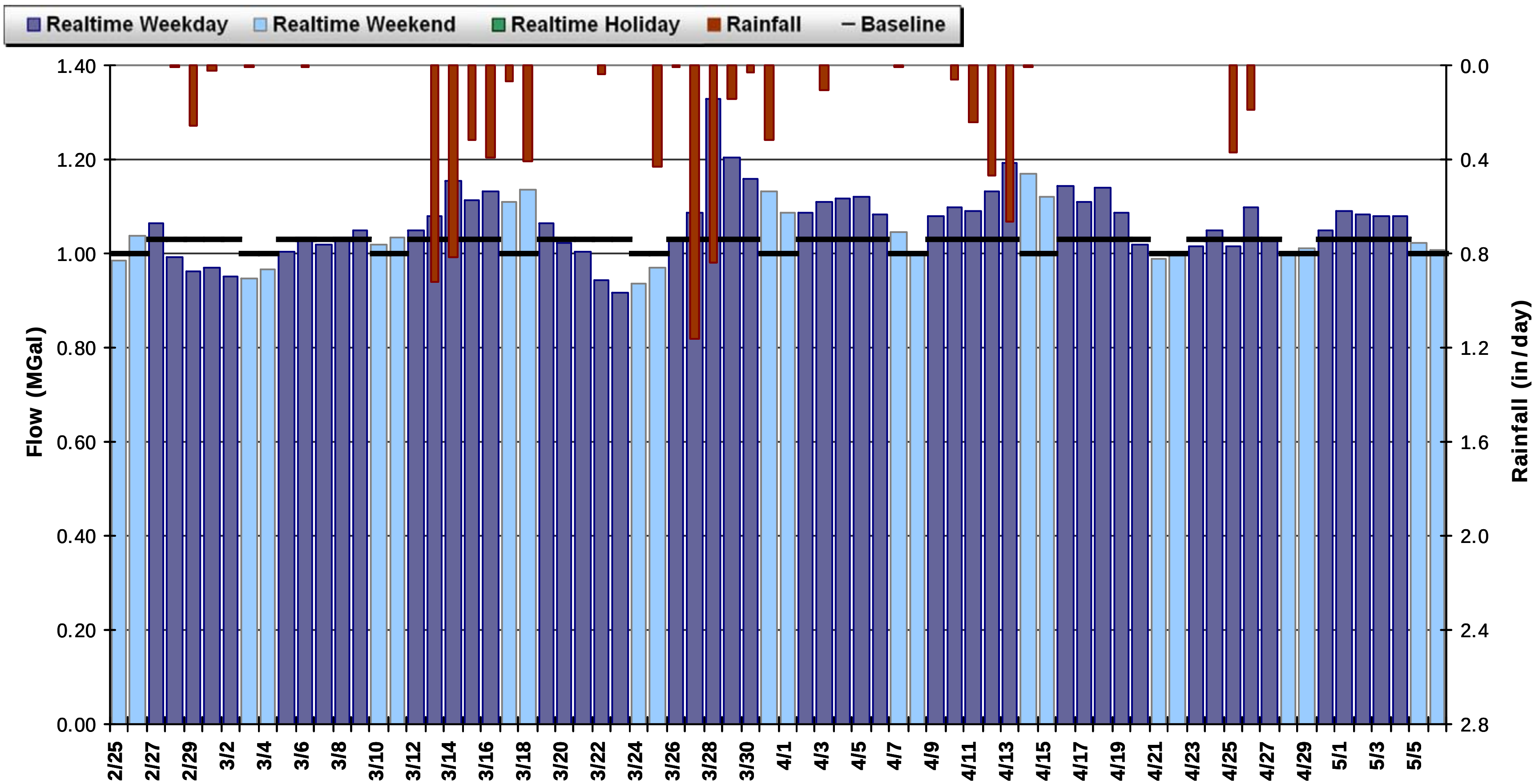

Plan View

SITE 9

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.060 MGal **Peak Daily Flow: 1.330 MGal** **Min Daily Flow: 0.916 MGal**

Total Period Rainfall: 8.31 inches

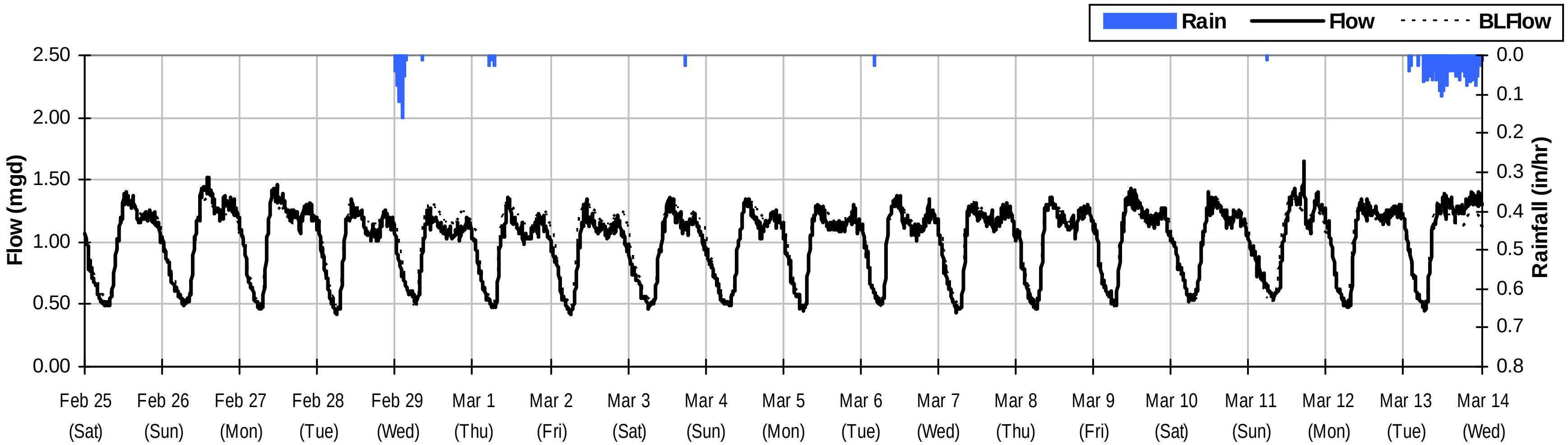


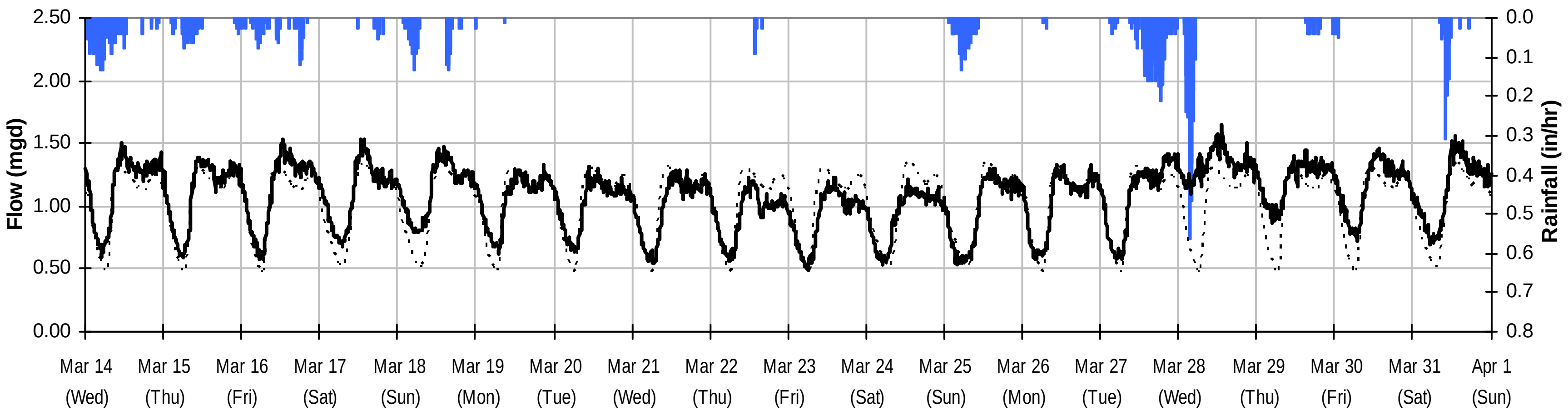
SITE 9

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 1.046 mgd **Peak Flow: 1.652 mgd** **Min Flow: 0.418 mgd**

Total Period Rainfall: 6.20 inches



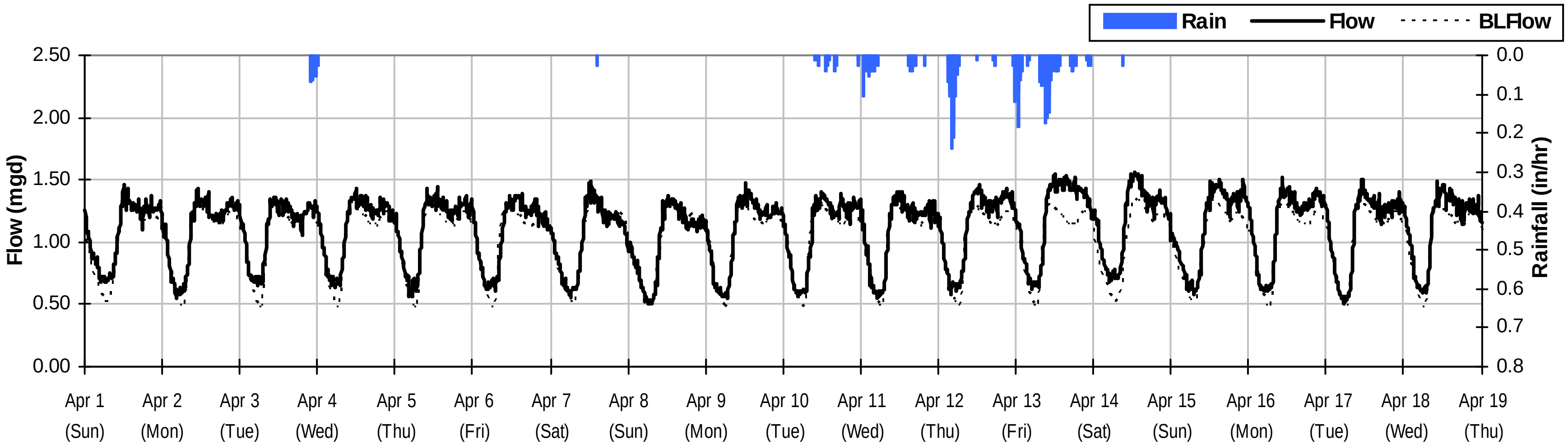


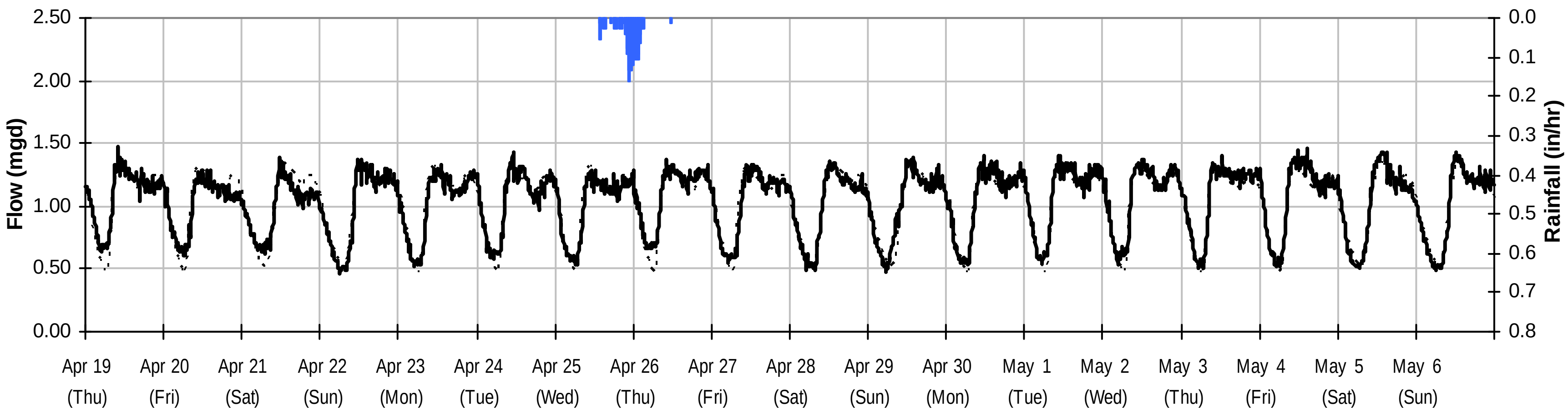
SITE 9

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 1.074 mgd **Peak Flow: 1.564 mgd** **Min Flow: 0.455 mgd**

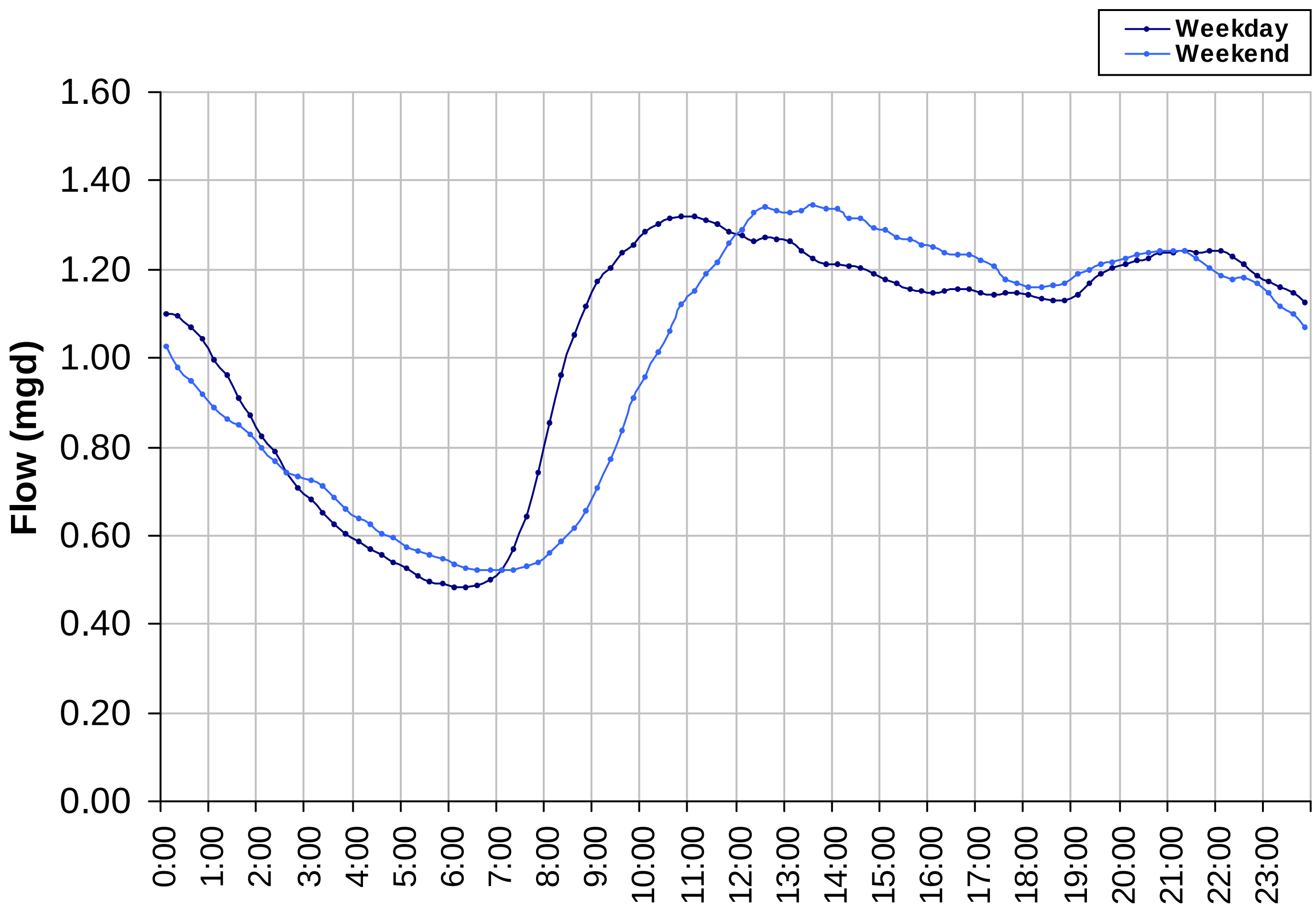
Total Period Rainfall: 2.11 inches





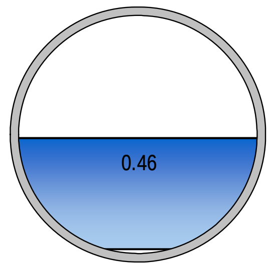
SITE 9

Baseline Flow Hydrographs



Baseline Flow:

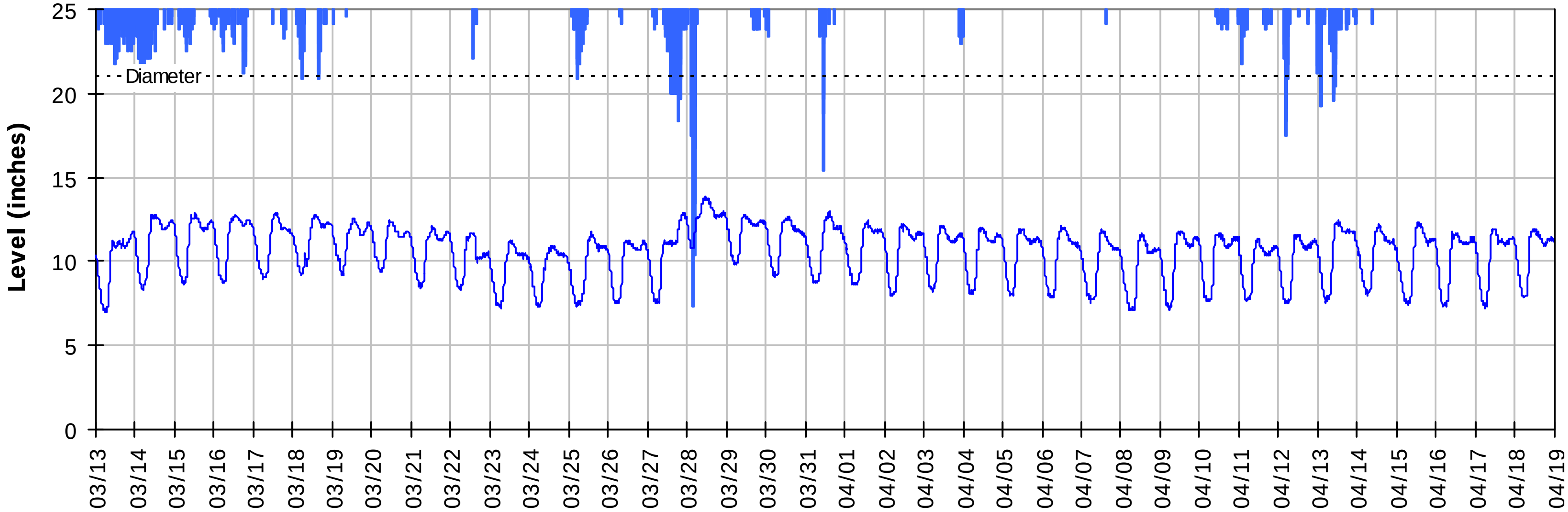
1.021 *mgd*

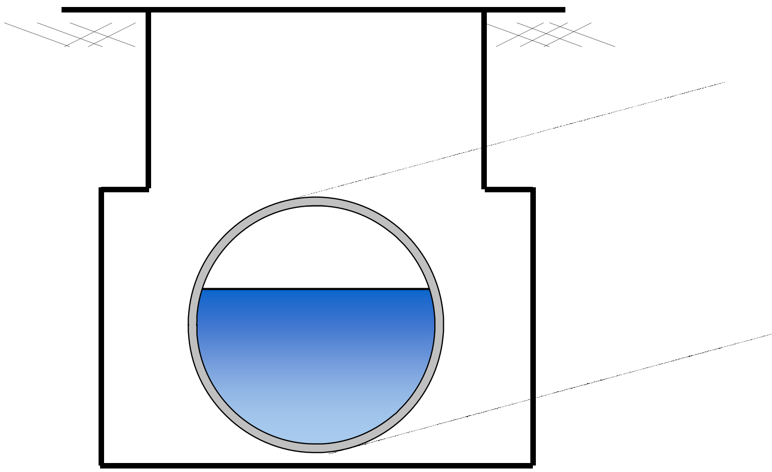


SITE 9

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





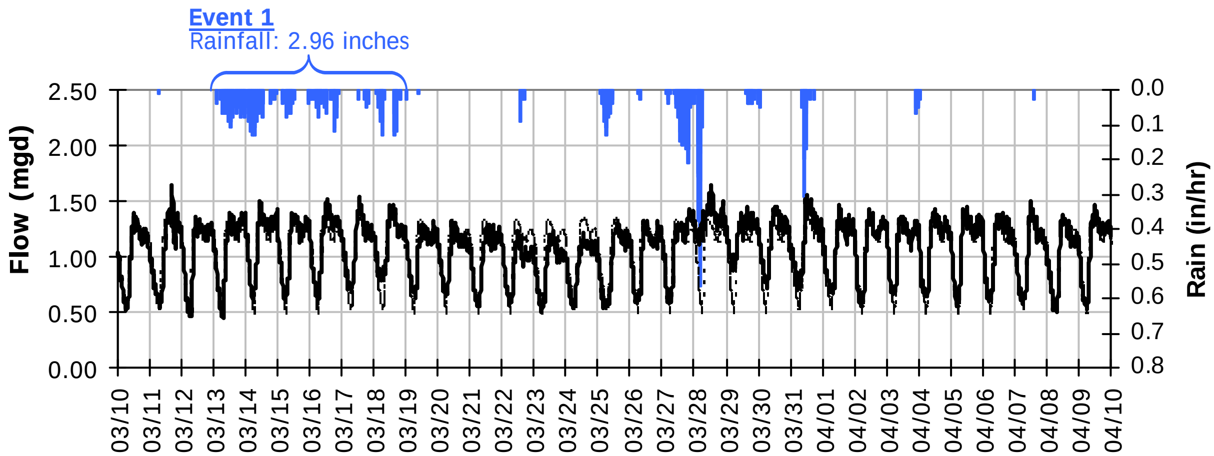
Pipe Diameter: 21 *inches*

Peak Measured Level: 13.8 *inches*

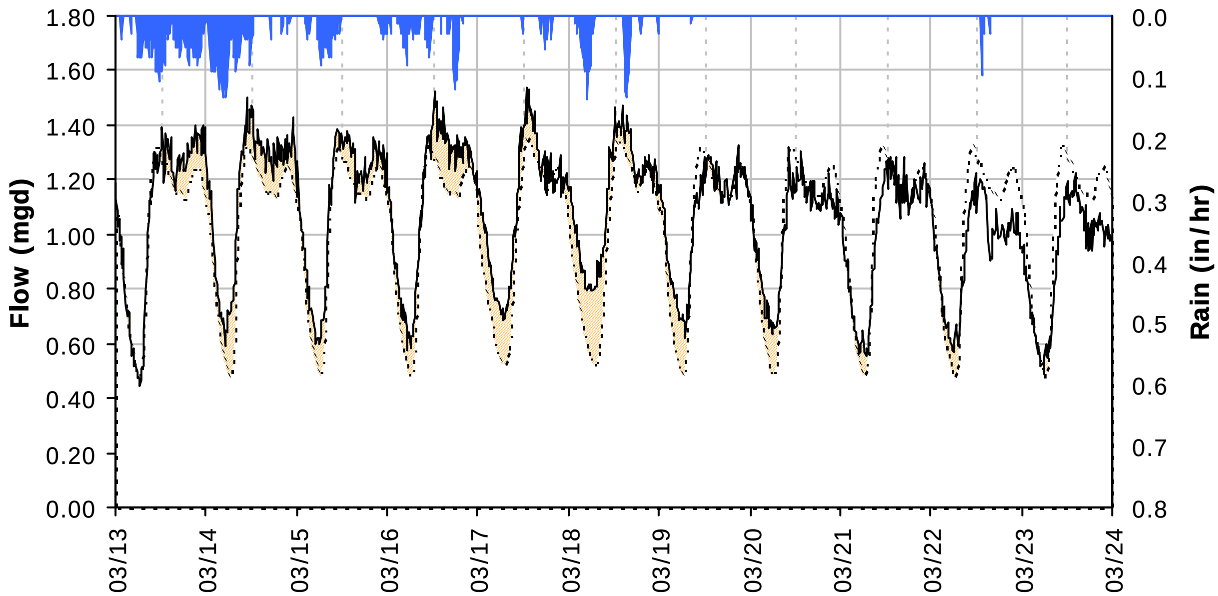
Peak d/D Ratio: 0.66

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 = 2.96 inches)

Capacity

Peak Flow: 1.53 *mgd*
PF: 1.50
Peak Level: 12.93 *in*
d/D Ratio: 0.62

Inflow

Peak I/I Rate: 0.37 *mgd*
Pk I/I:ADWF: 0.36

RDI (infiltration)

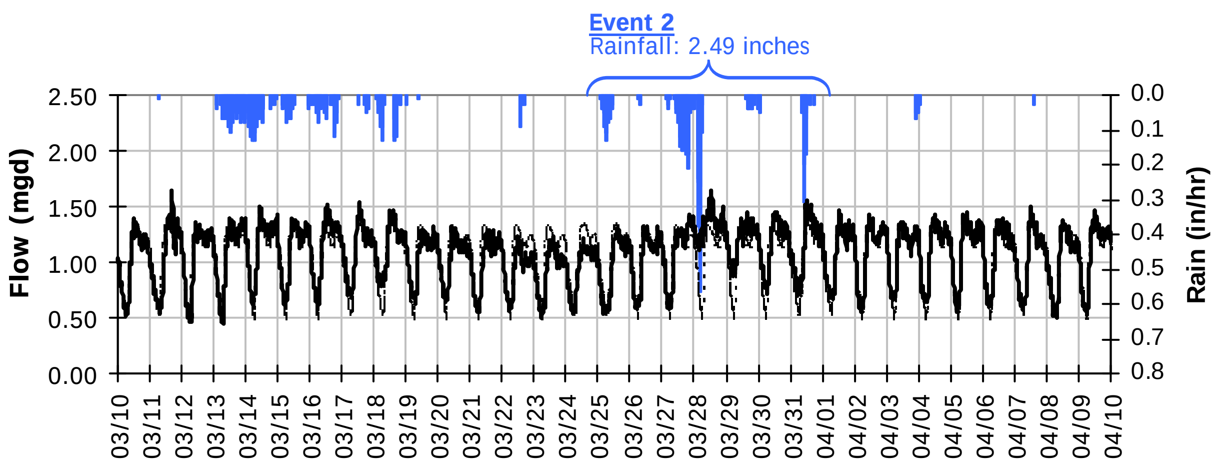
Infiltration Rate: 0.000 *mgd*
(3/20/2012)
RDI (% of BL): 0%

Combined I/I

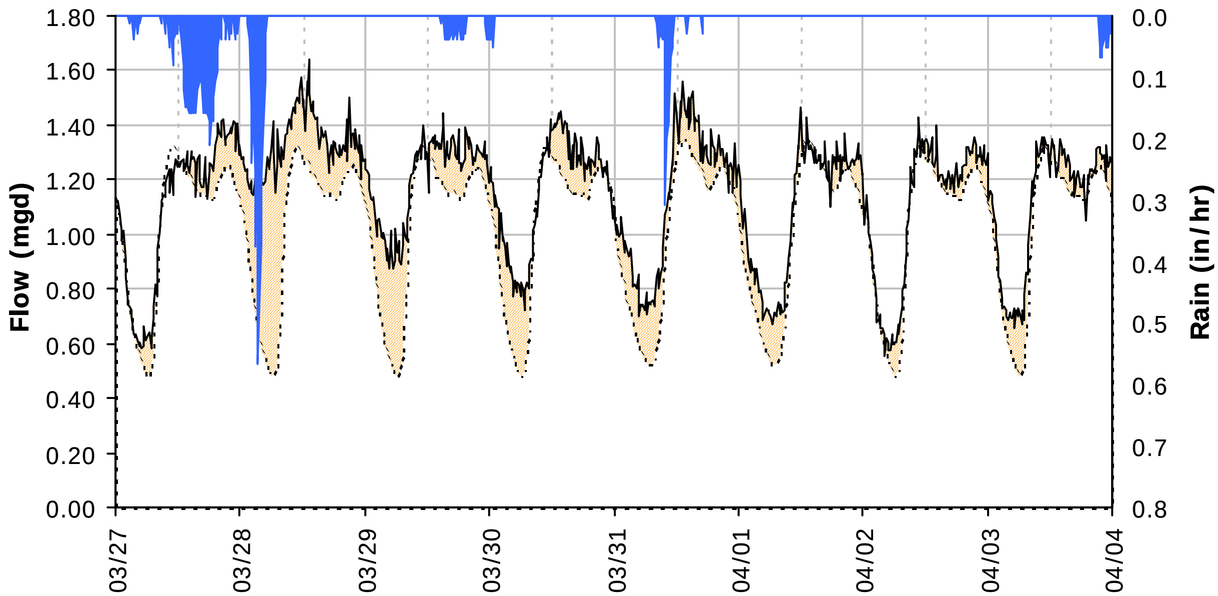
Total I/I: 406,000 *gallons*
Total I/I:ADWF: 0.13 *per in-rain*

SITE 9
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph

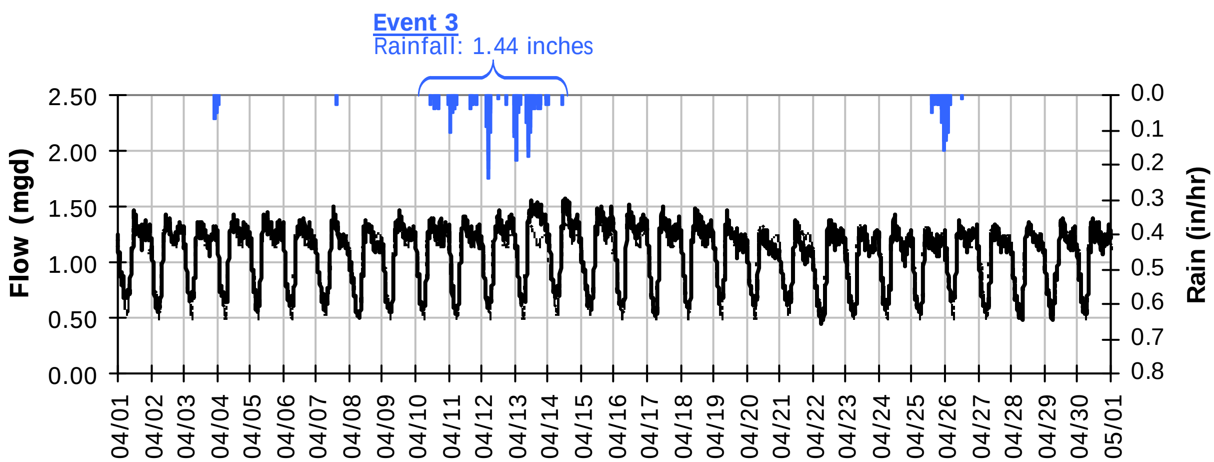


Storm Event I/I Analysis (Rain = 2.49 inches)

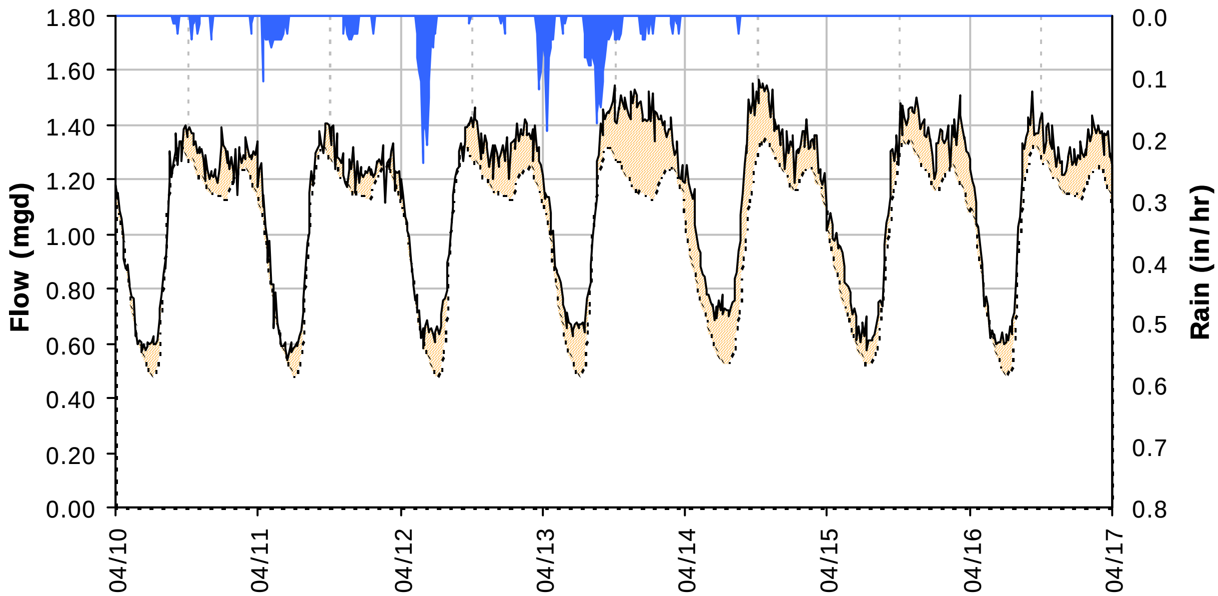
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	1.64 *mgd*	**Peak I/I Rate:**	0.93 *mgd*	**Infiltration Rate:** (4/2/2012)	0.056 *mgd*	**Total I/I:**	1,019,000 *gallons*
PF:	1.61	**Pk I/I:ADWF:**	0.91	**RDI (% of BL):**	5%	**Total I/I:ADWF:**	0.40 *per in-rain*
Peak Level:	13.83 *in*						
d/D Ratio:	0.66						

SITE 9
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.44 inches)

Capacity

Peak Flow: 1.56 *mgd*
PF: 1.53
Peak Level: 12.44 *in*
d/D Ratio: 0.59

Inflow

Peak I/I Rate: 0.39 *mgd*
Pk I/I:ADWF: 0.38

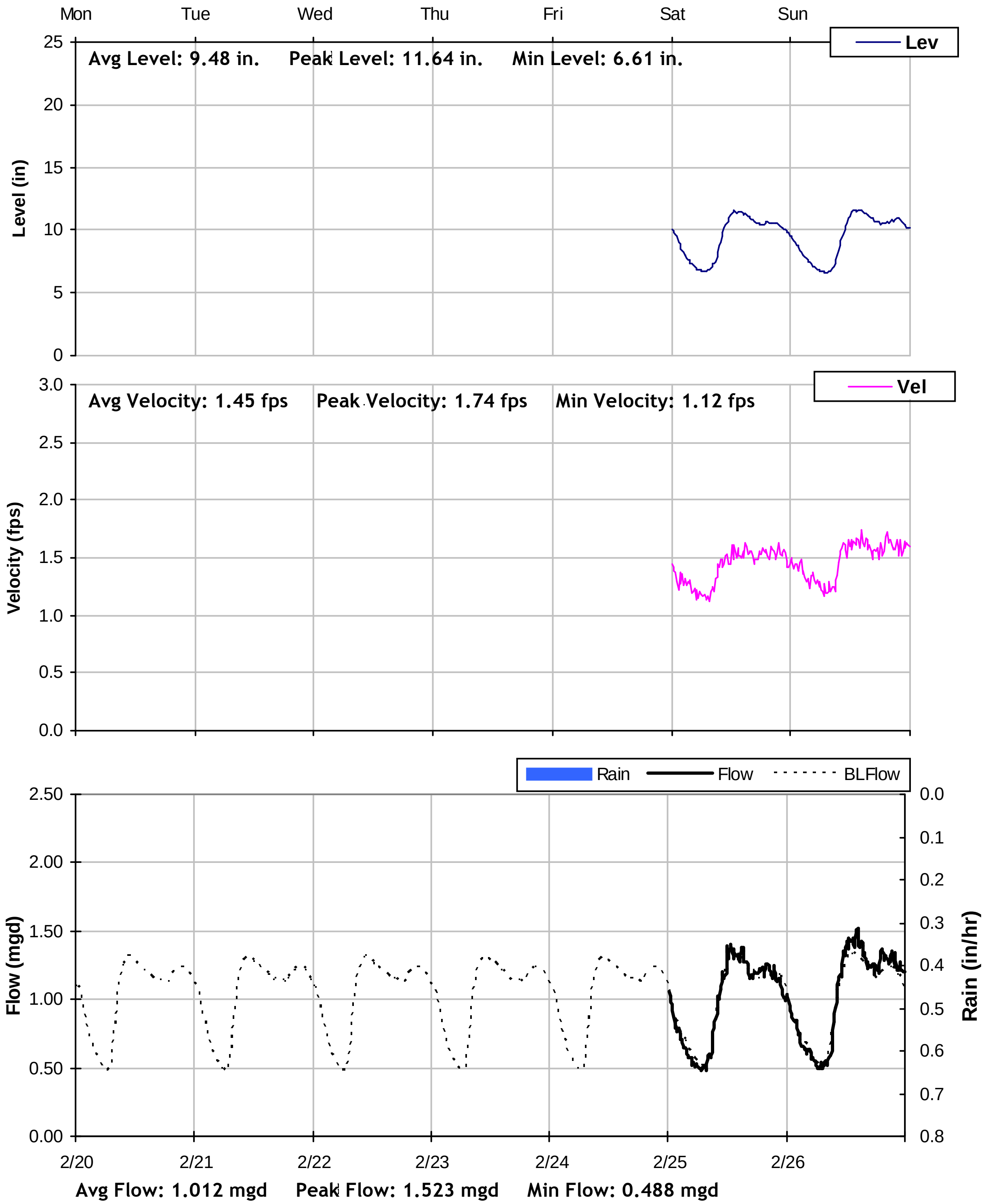
RDI (infiltration)

Infiltration Rate: 0.124 *mgd*
(4/15/2012)
RDI (% of BL): 12%

Combined I/I

Total I/I: 799,000 *gallons*
Total I/I:ADWF: 0.54 *per in-rain*

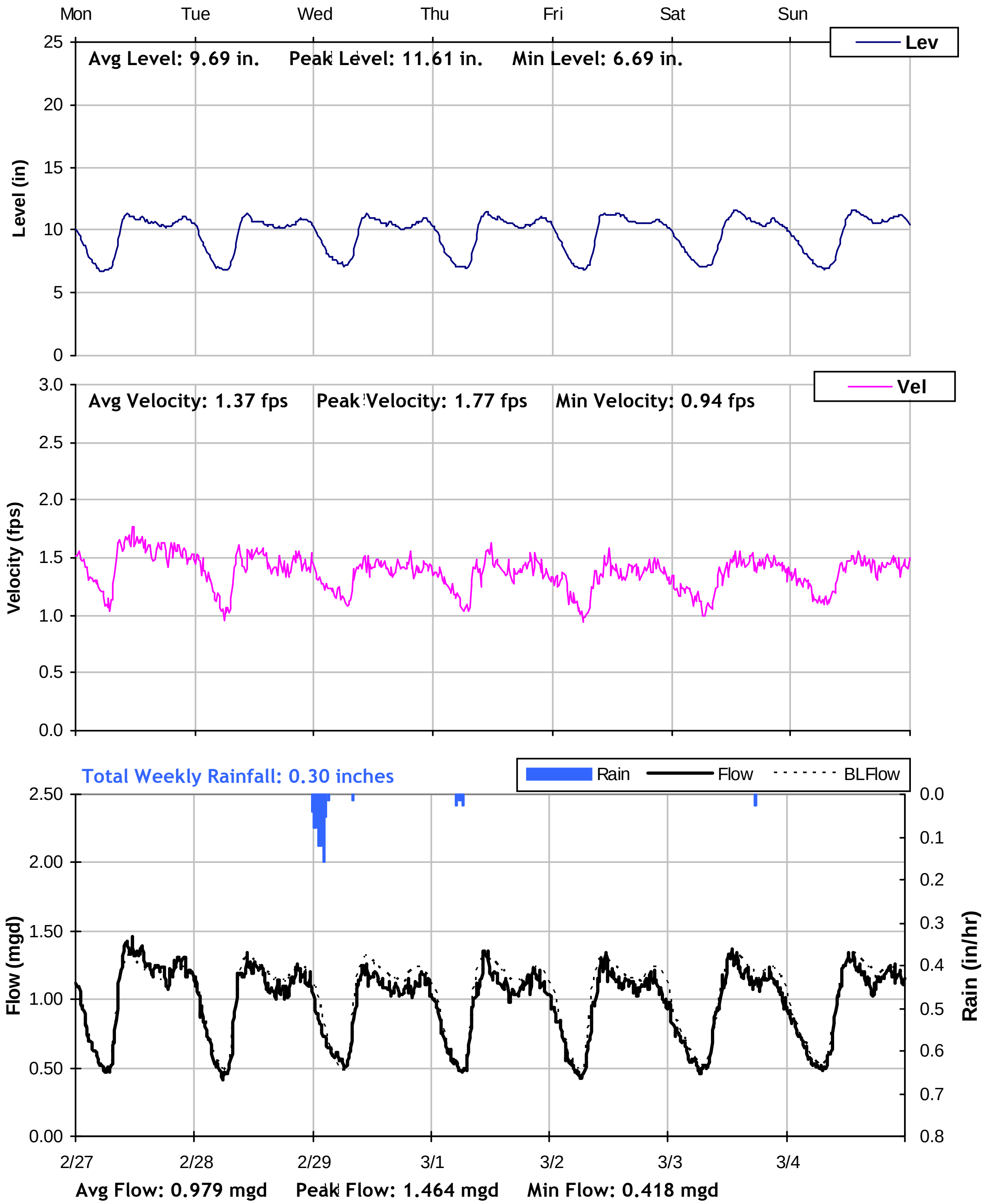
SITE 9
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



SITE 9

Weekly Level, Velocity and Flow Hydrographs

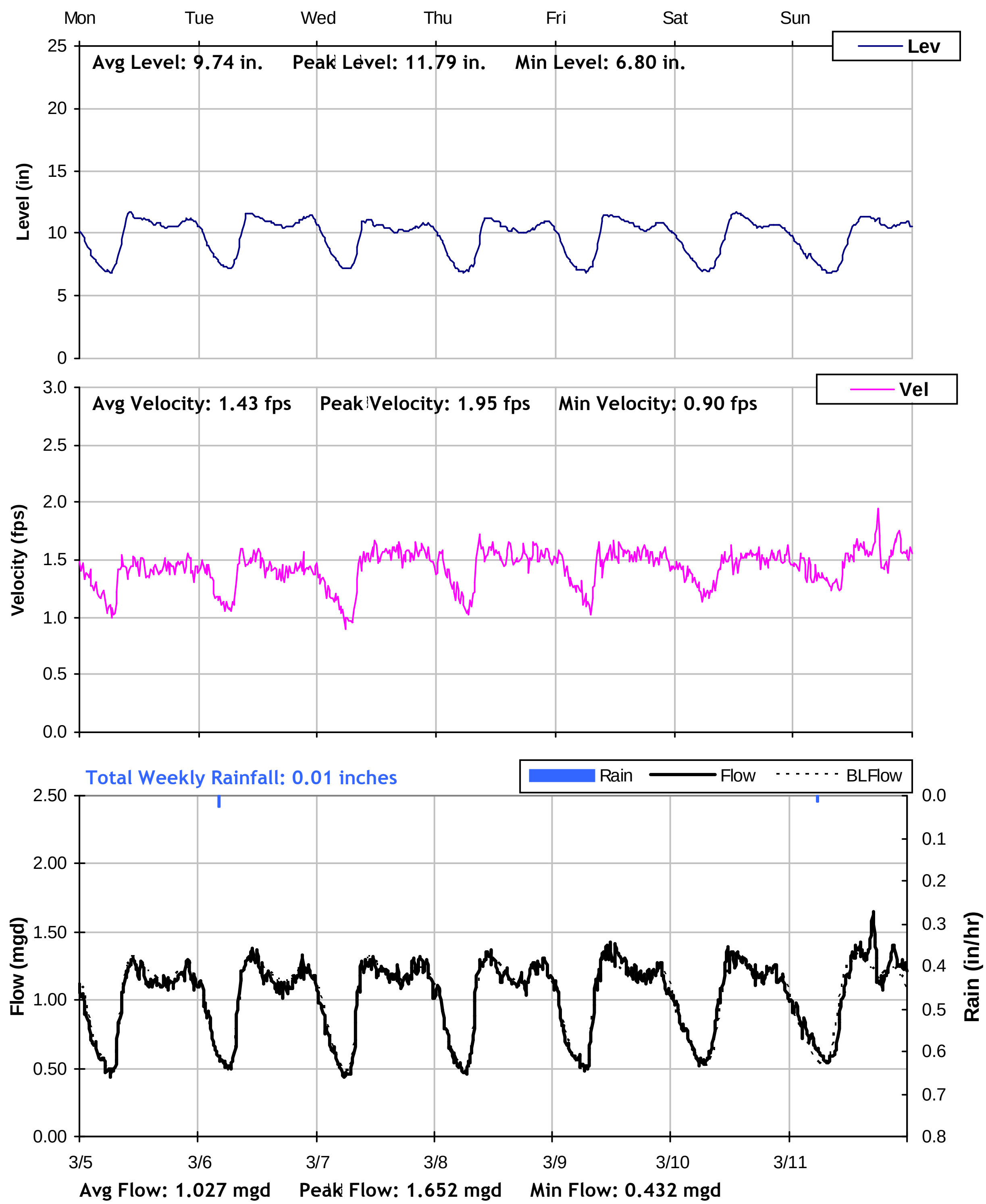
2/27/2012 to 3/5/2012



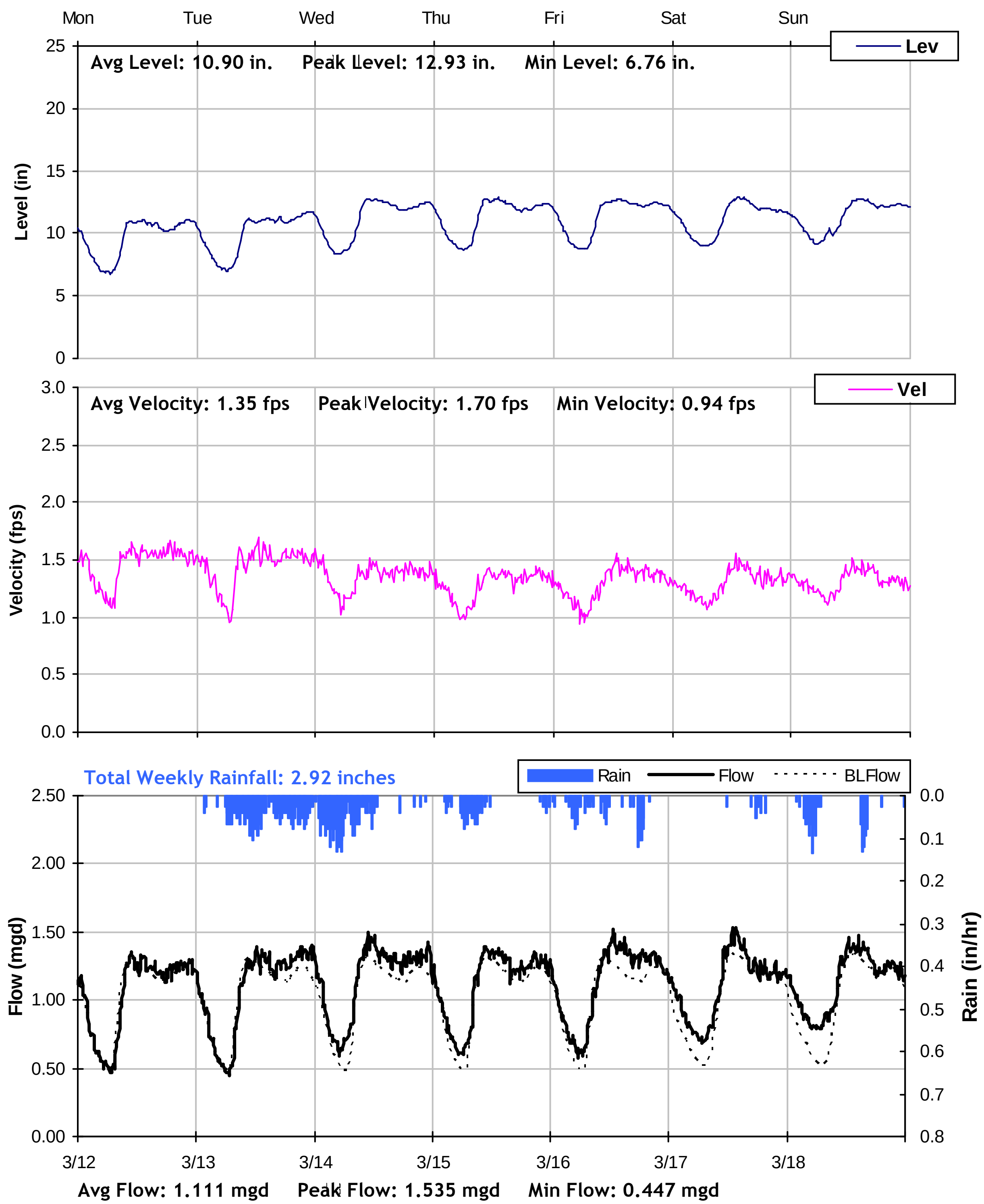
SITE 9

Weekly Level, Velocity and Flow Hydrographs

3/5/2012 to 3/12/2012



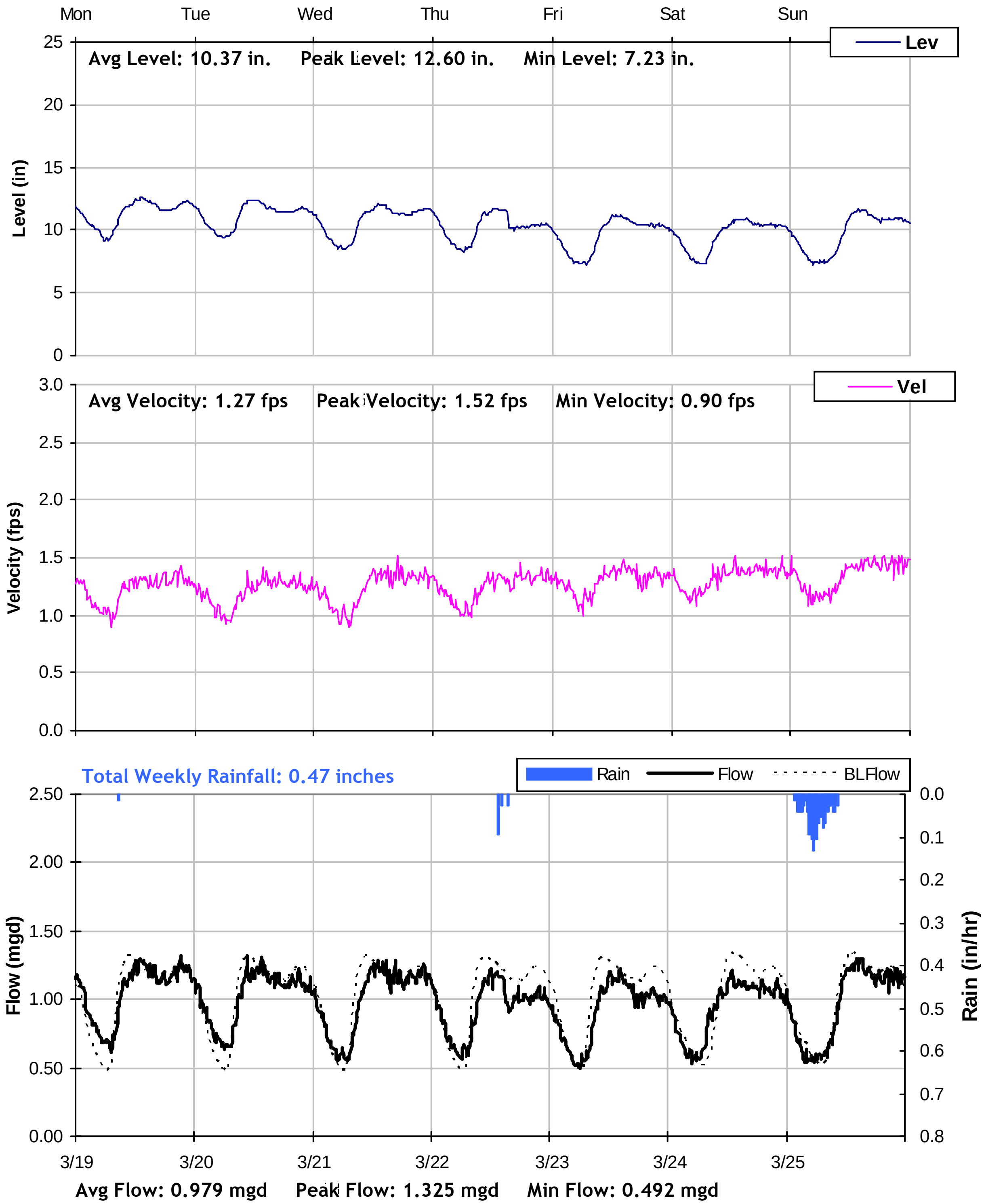
SITE 9
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



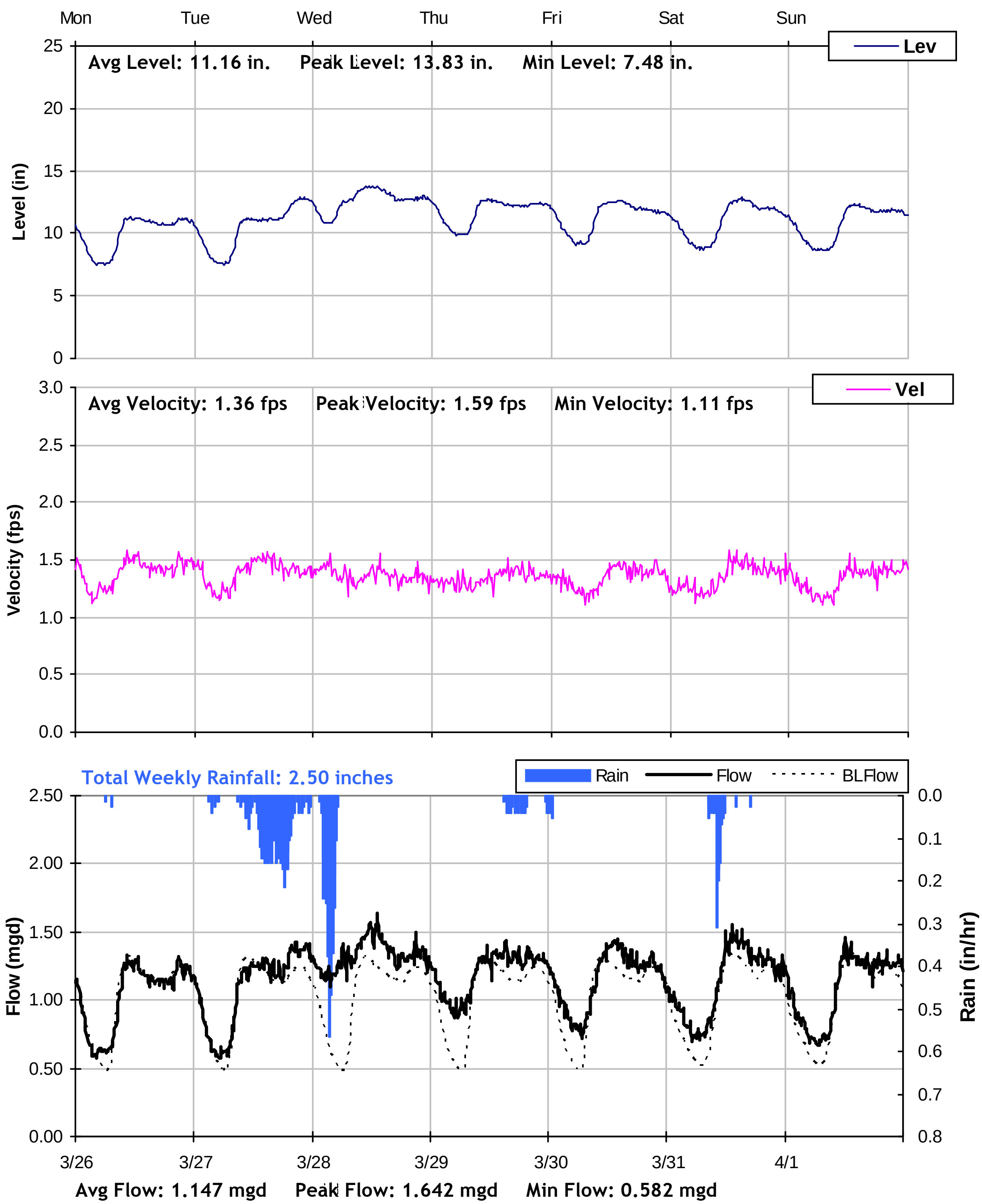
SITE 9

Weekly Level, Velocity and Flow Hydrographs

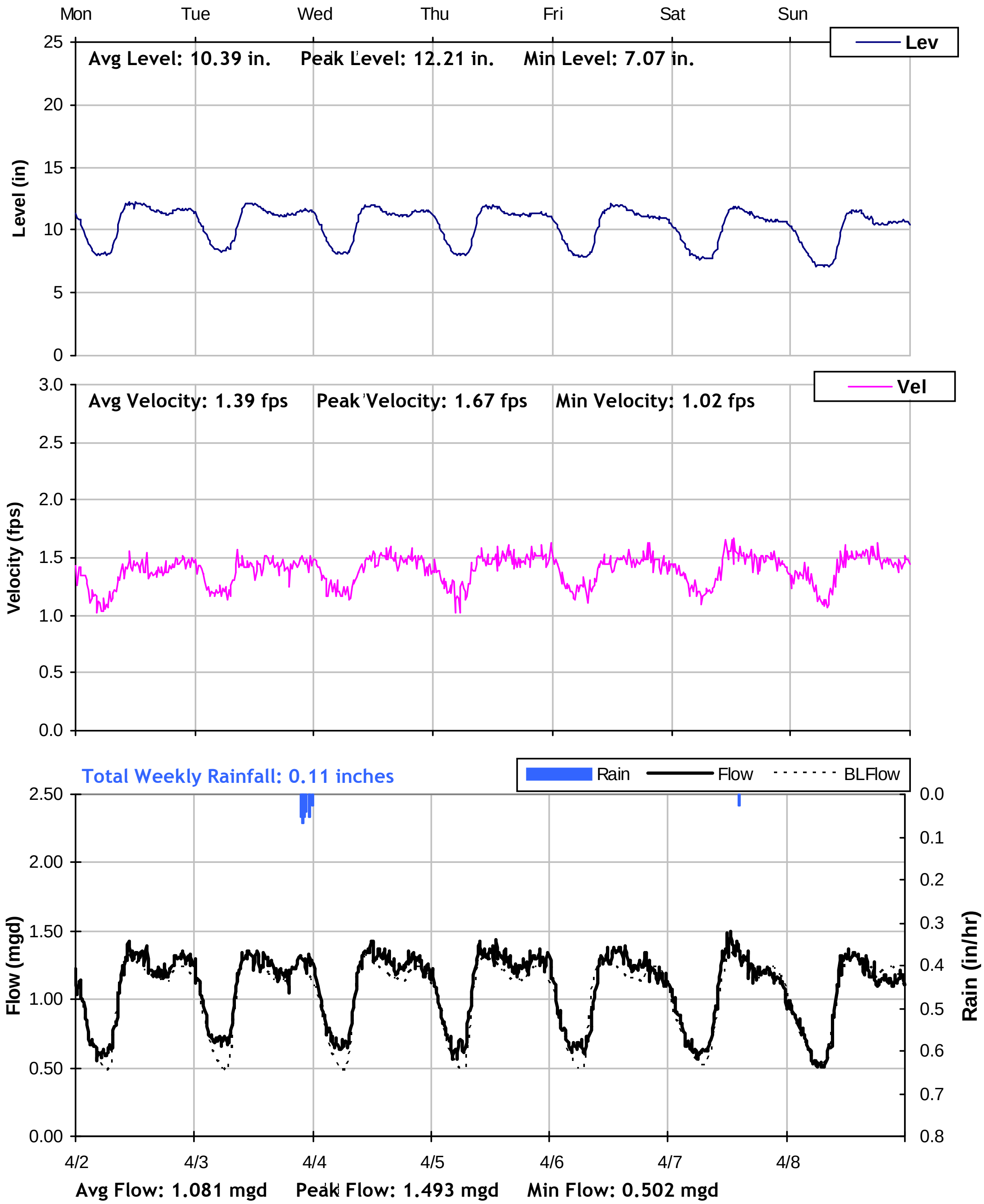
3/19/2012 to 3/26/2012



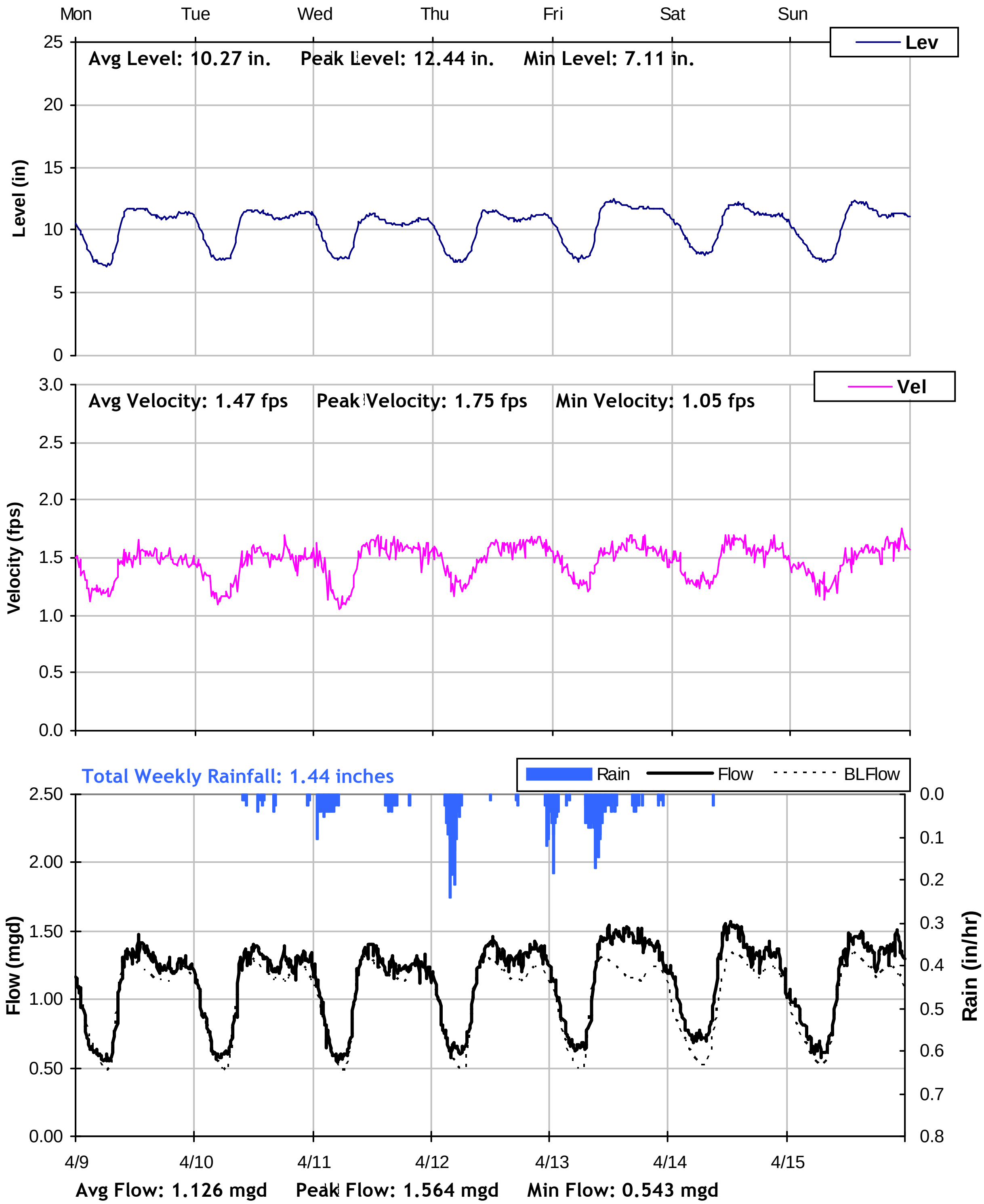
SITE 9
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



SITE 9
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



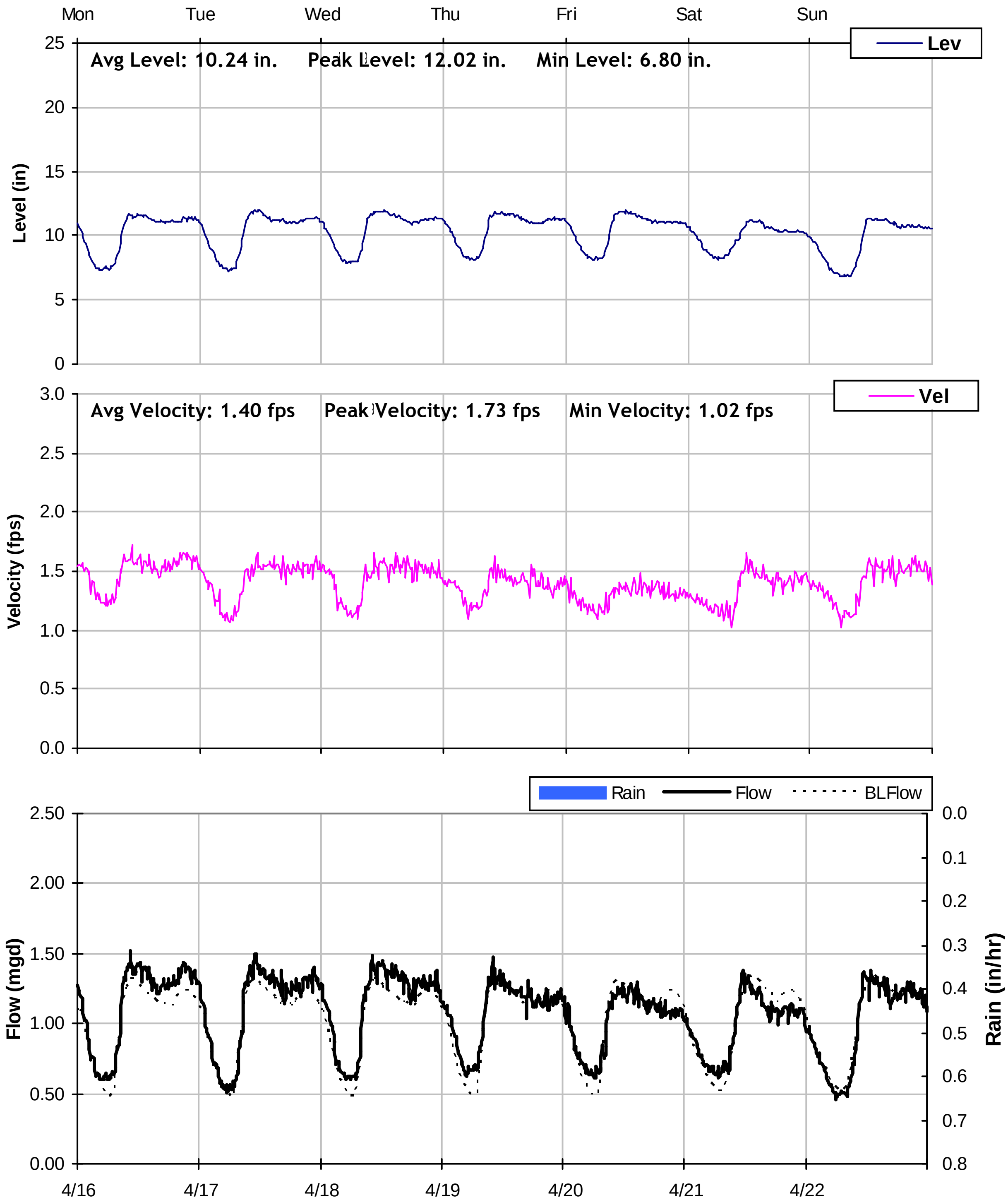
SITE 9
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



SITE 9

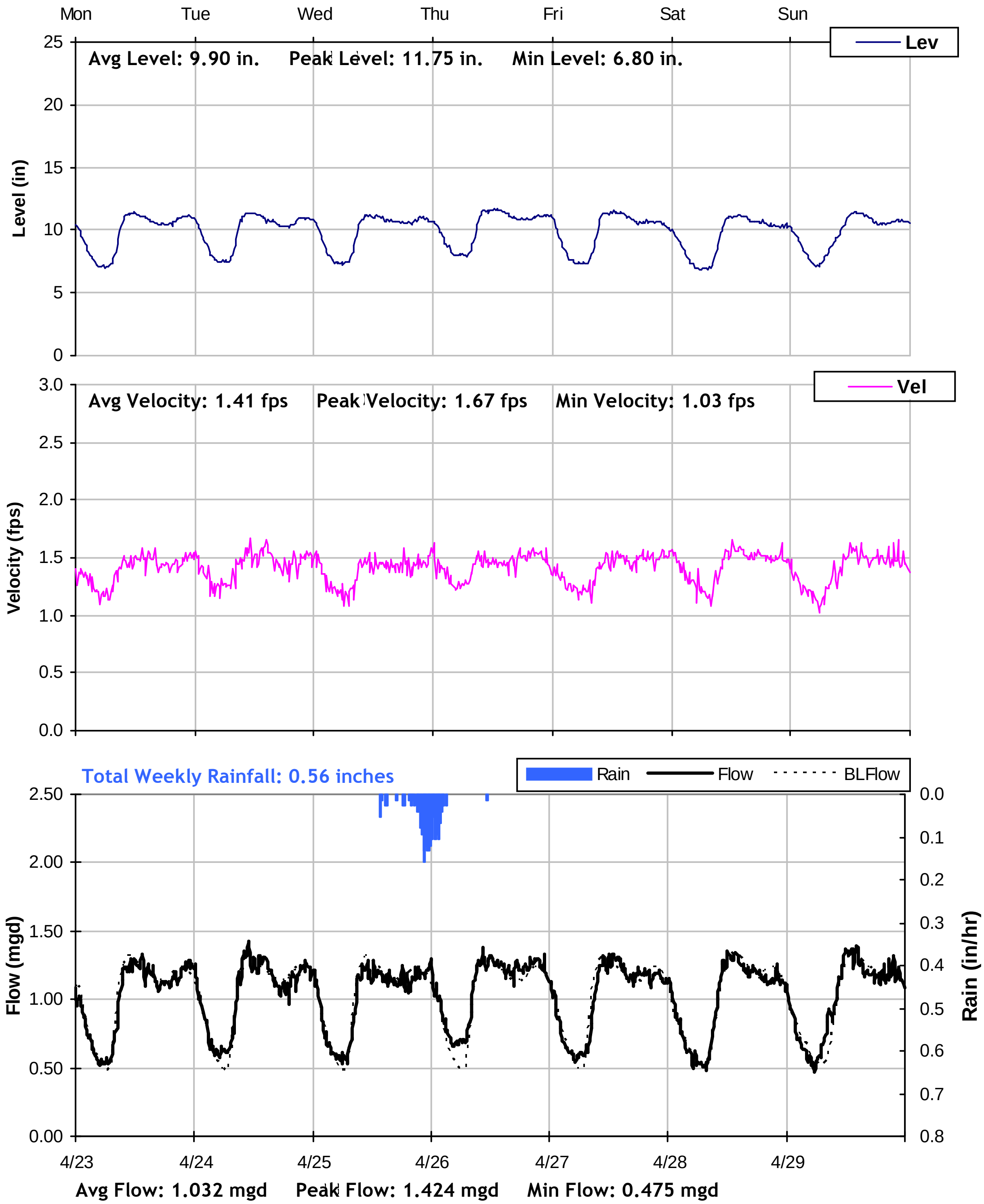
Weekly Level, Velocity and Flow Hydrographs

4/16/2012 to 4/23/2012



Avg Flow: 1.069 mgd Peak Flow: 1.523 mgd Min Flow: 0.455 mgd

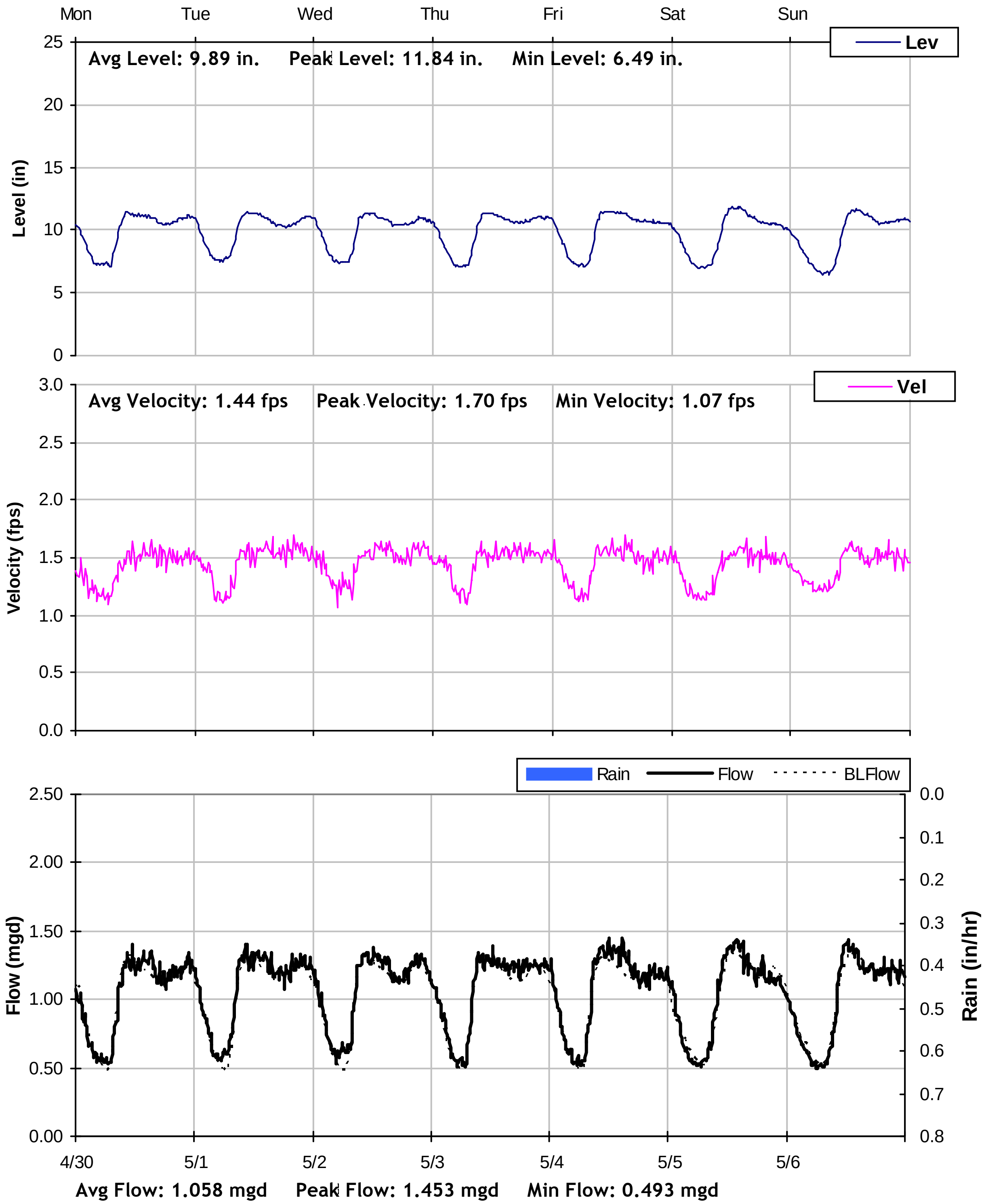
SITE 9
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 9

Weekly Level, Velocity and Flow Hydrographs

4/30/2012 to 5/7/2012



City of Chico

Sanitary Sewer Flow Monitoring and I/I Study
Year 2012

Monitoring Site: Site 10

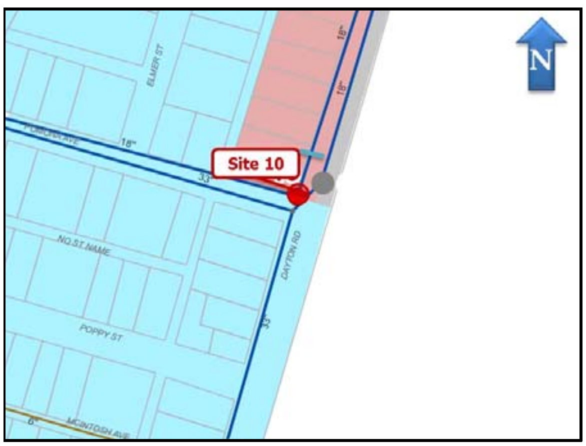
Location: Dayton Road at Pomona Avenue

Vicinity Map:

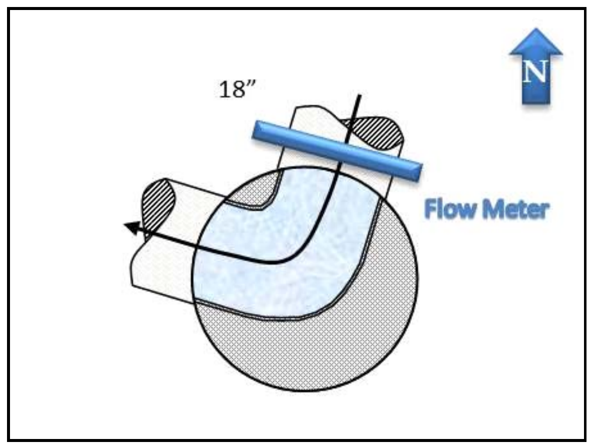
SITE 10
Site Information Report

Location:	Dayton Road at Pomona Avenue
Coordinates:	121.8433° W, 39.7159° N
Elevation:	184 feet
Diameter:	18 inches
Baseline Flow:	0.902 mgd
Peak Measured Flow:	2.246 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

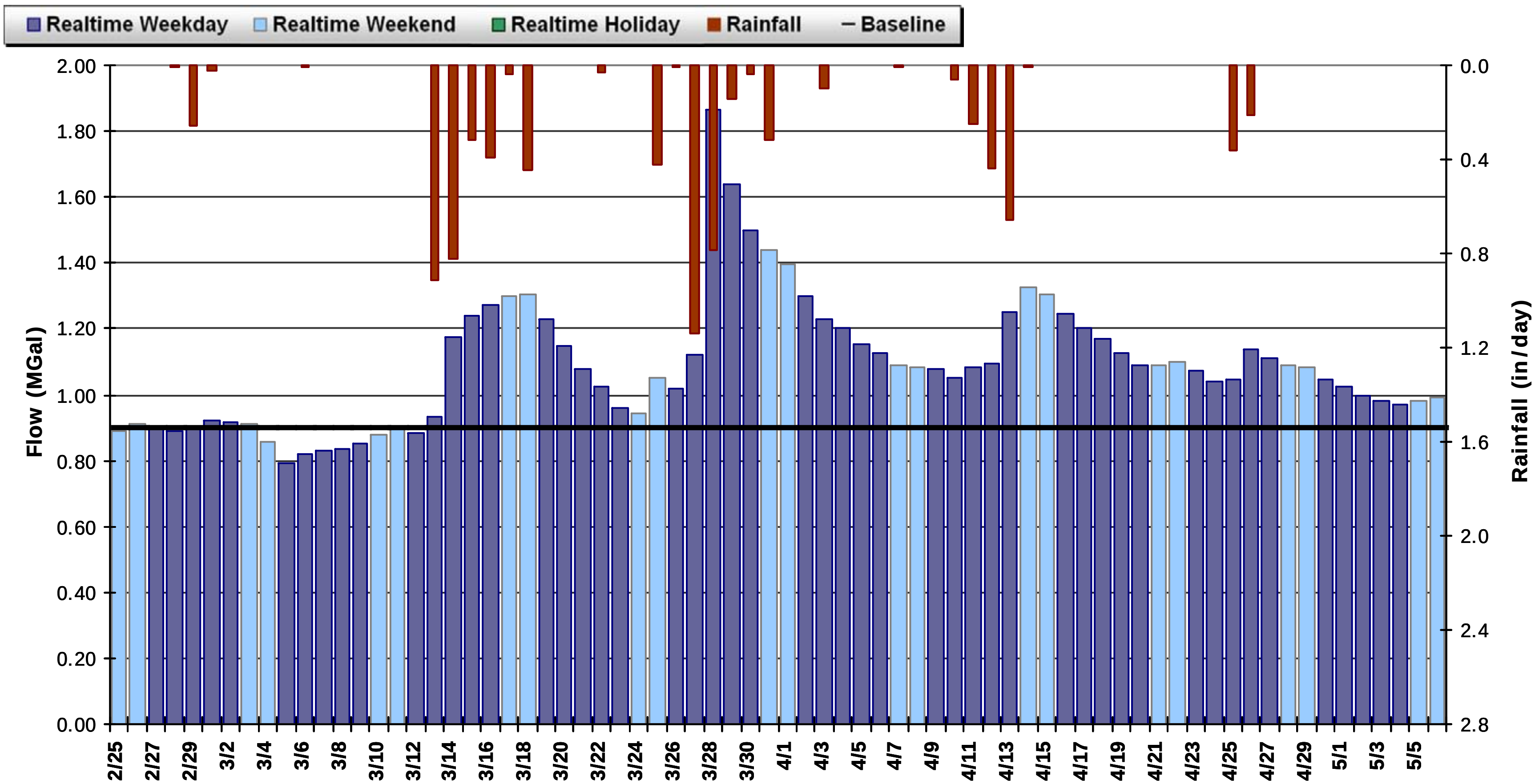
Plan View

SITE 10

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.090 MGal **Peak Daily Flow: 1.867 MGal** **Min Daily Flow: 0.791 MGal**

Total Period Rainfall: 8.21 inches

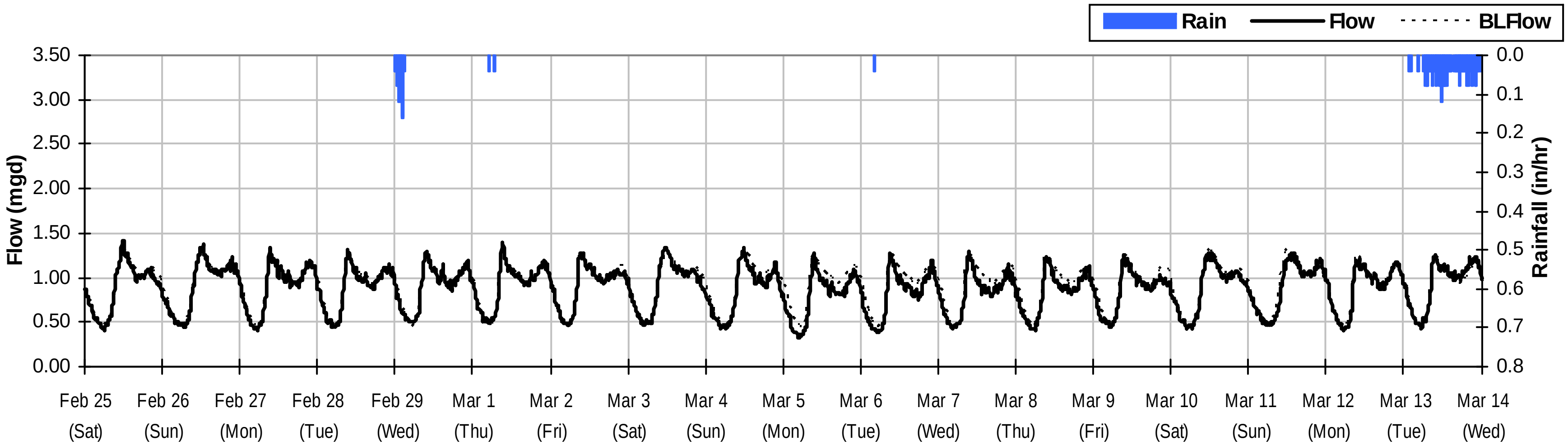


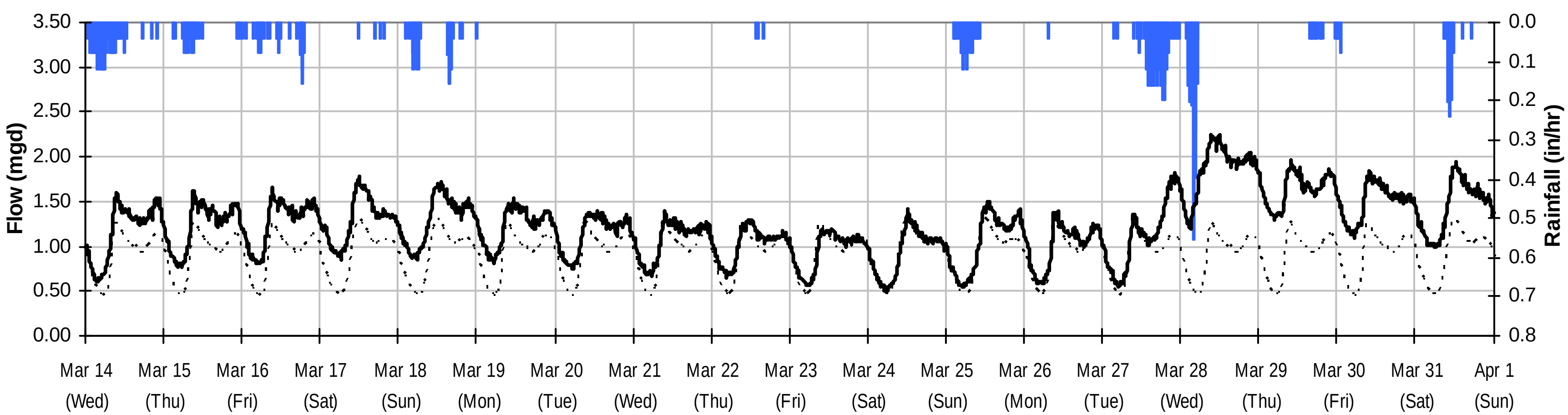
SITE 10

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 1.059 mgd **Peak Flow: 2.246 mgd** **Min Flow: 0.333 mgd**

Total Period Rainfall: 6.11 inches



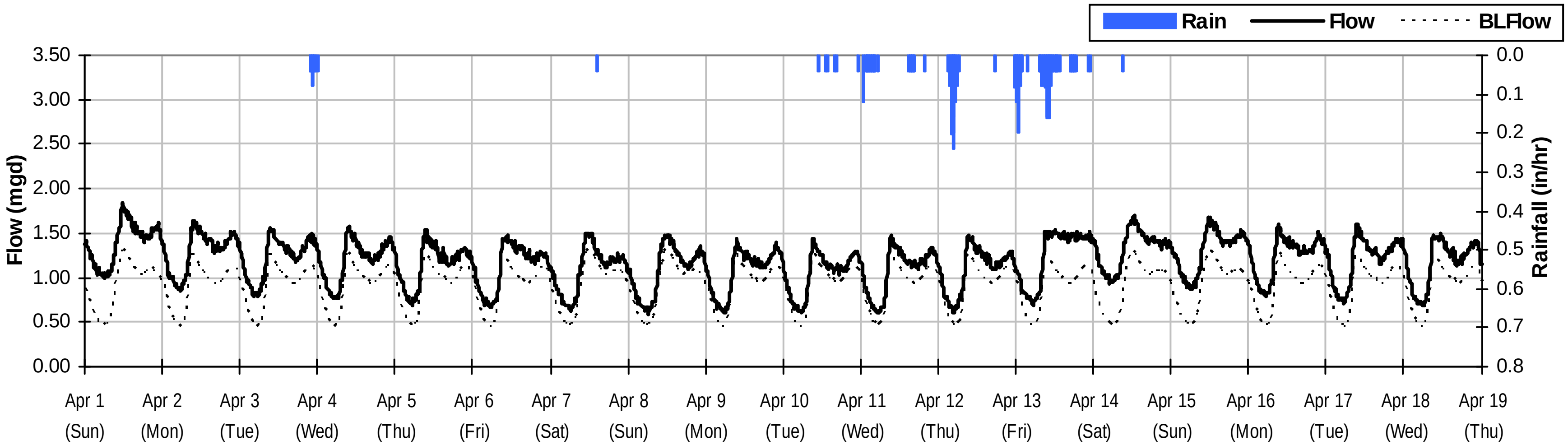


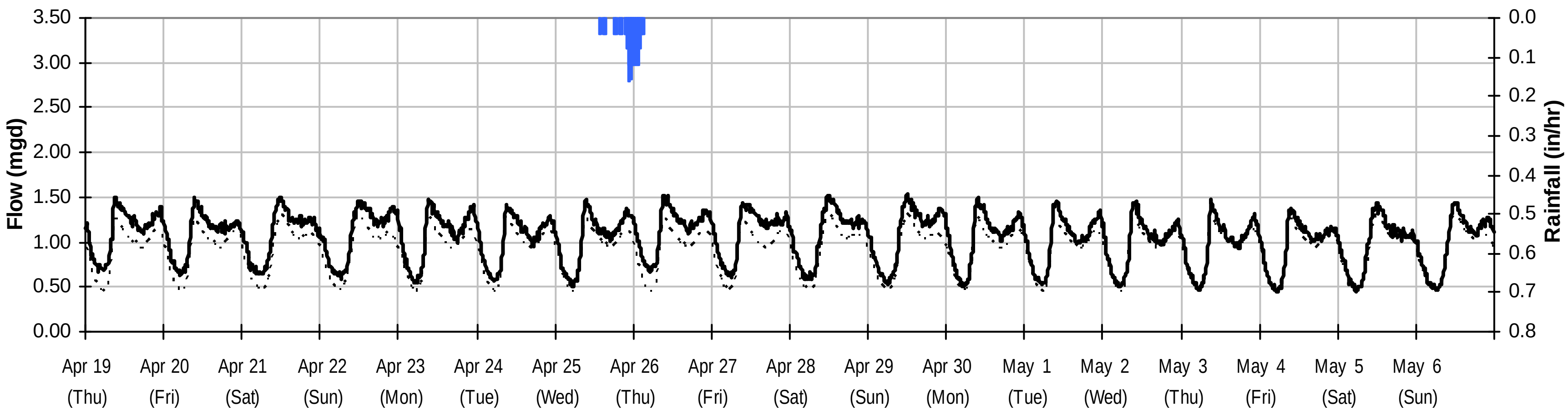
SITE 10

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 1.121 mgd **Peak Flow: 1.841 mgd** **Min Flow: 0.445 mgd**

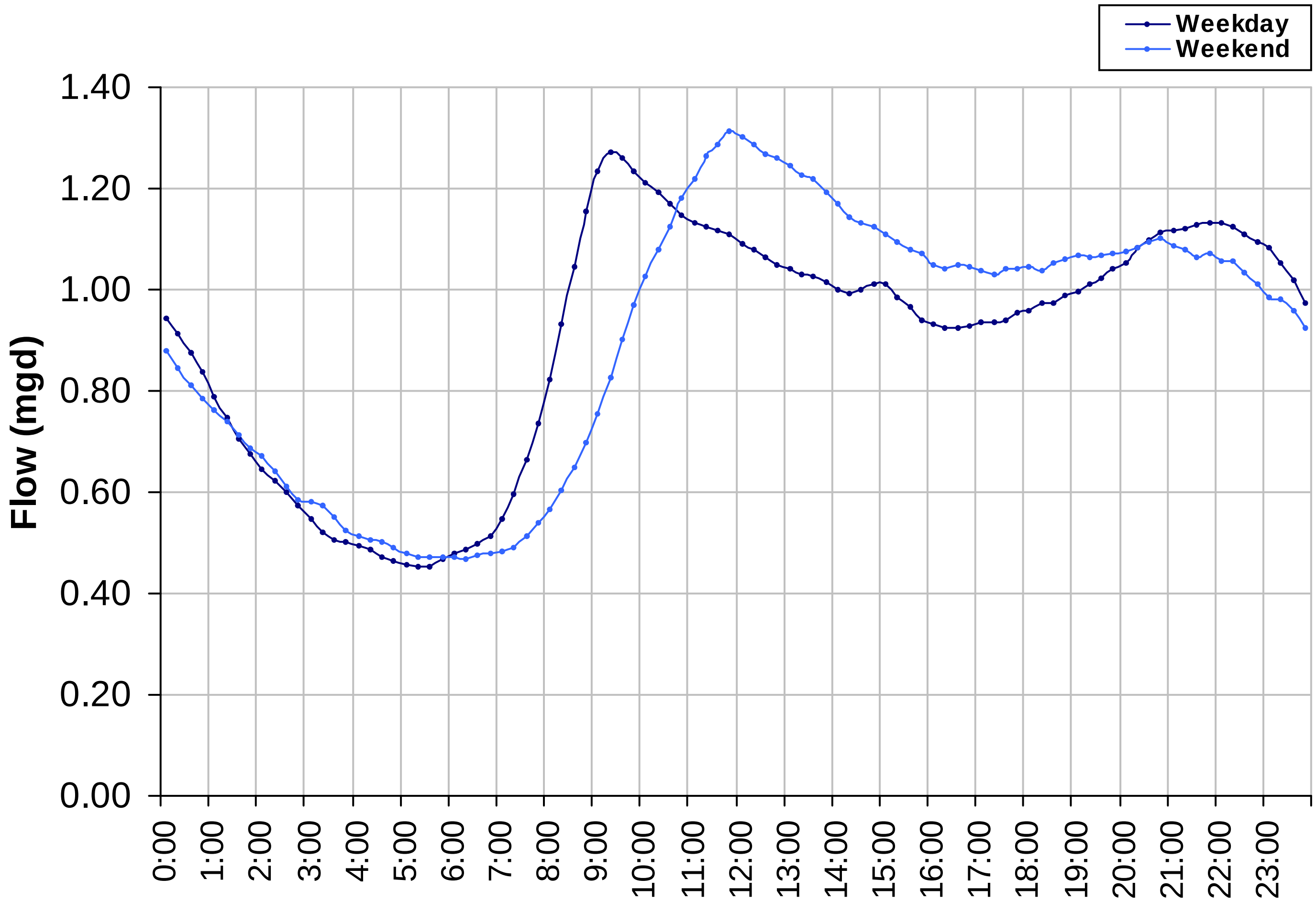
Total Period Rainfall: 2.10 inches





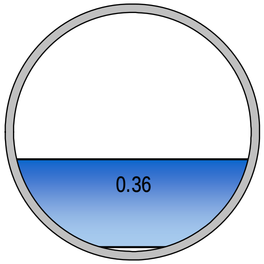
SITE 10

Baseline Flow Hydrographs



Baseline Flow:

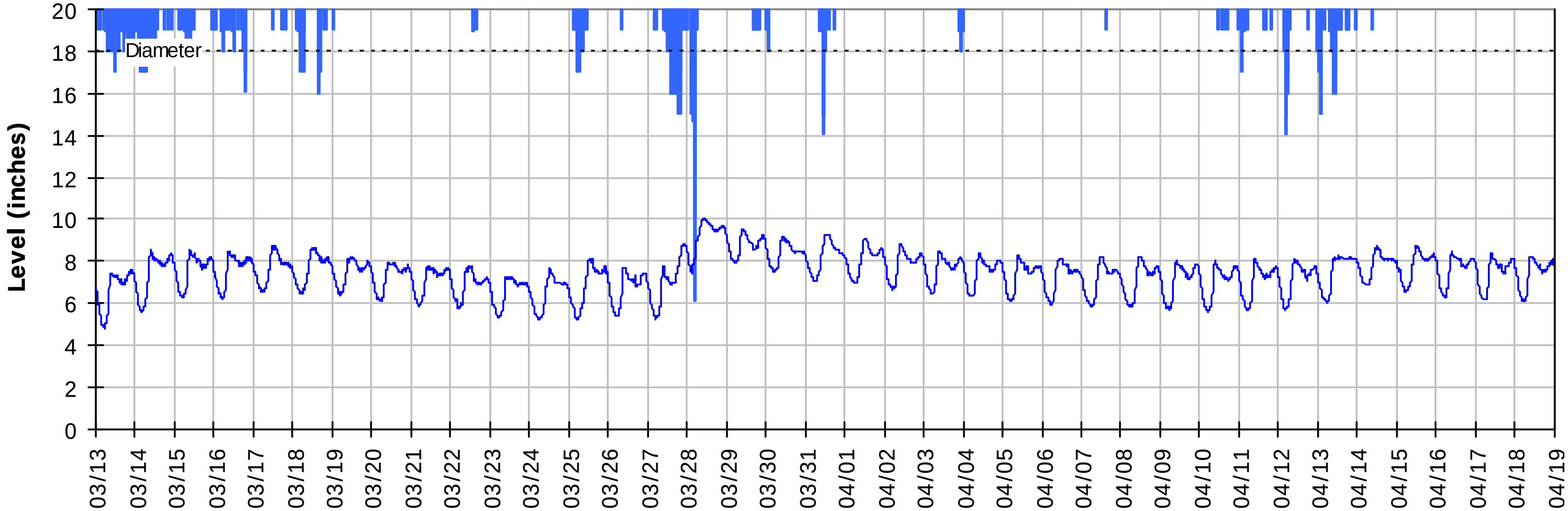
0.902 *mgd*

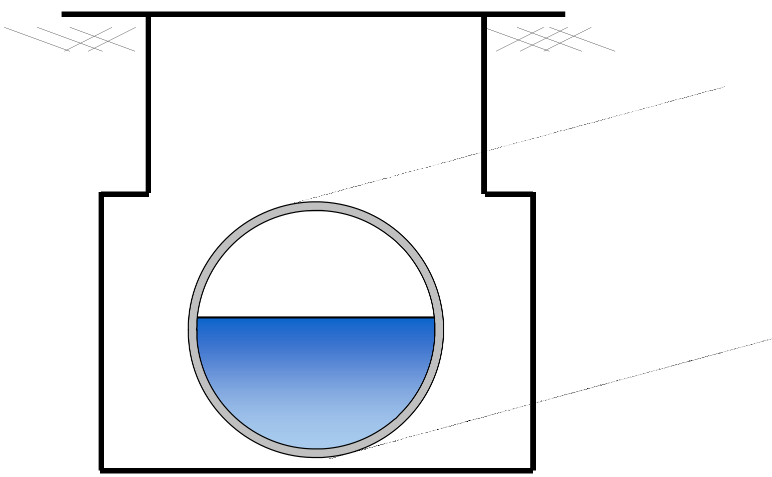


SITE 10

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





Pipe Diameter: 18 *inches*

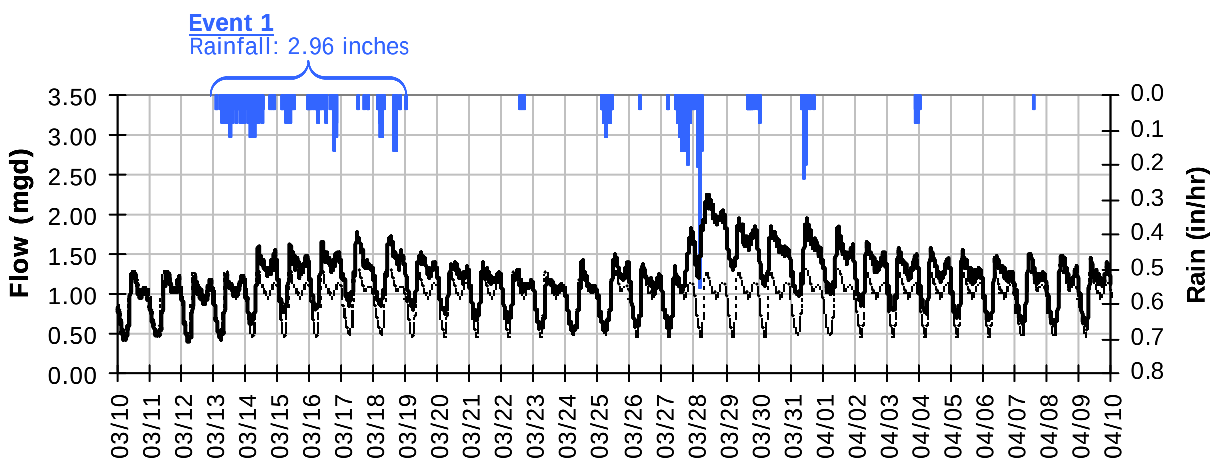
Peak Measured Level: 10.1 *inches*

Peak d/D Ratio: 0.56

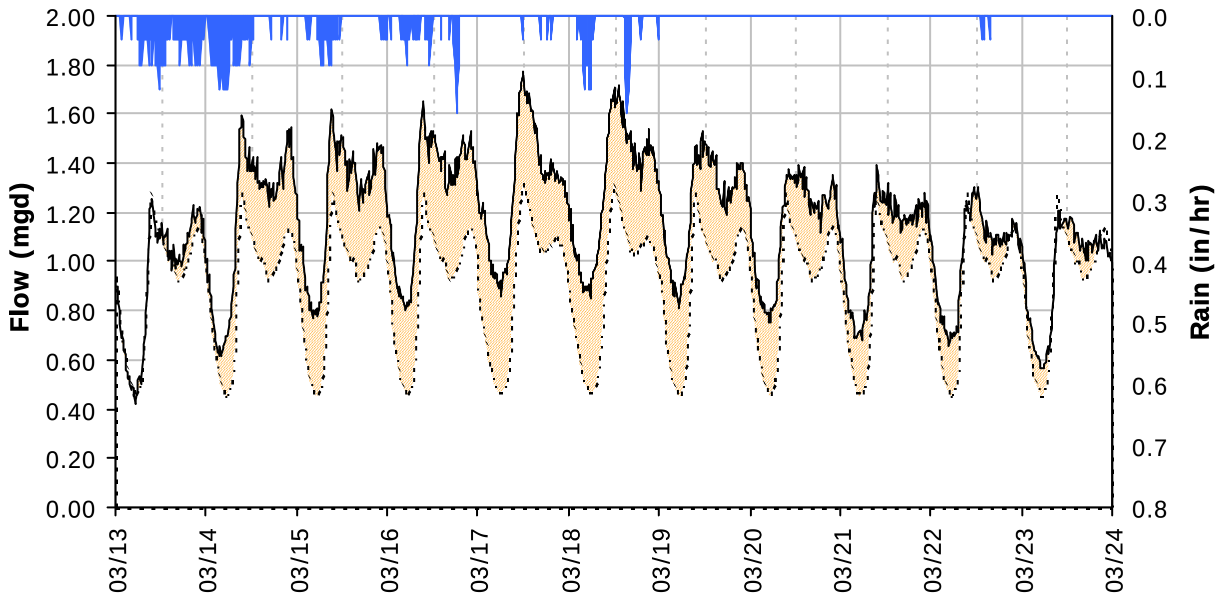
SITE 10

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 = 2.96 inches)

Capacity

Peak Flow:	1.77	*mgd*
PF:	1.97	
Peak Level:	8.75	*in*
d/D Ratio:	0.49	

Inflow

Peak I/I Rate:	0.52	*mgd*
PkI/I:IDM:	1,465	*gpd/IDM*
PkI/I:Acre:	284	*gpd/acre*
Pk I/I:ADWF:	0.57	

RDI (infiltration)

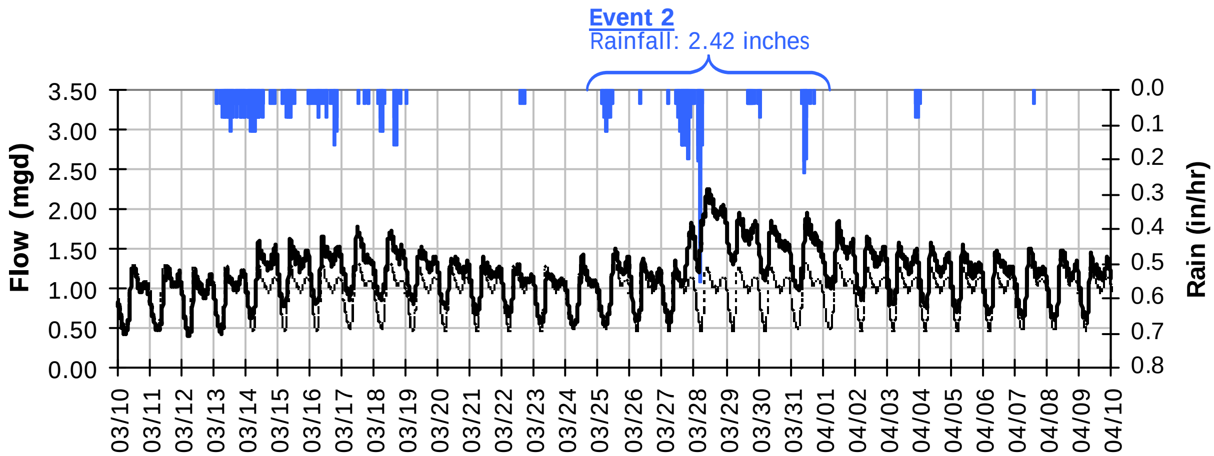
Infiltration Rate: (3/20/2012)	0.243	*mgd*
RDI:IDM:	688	*gpd/IDM*
RDI:Acre:	134	*gpd/acre*
RDI (% of BL):	27%	

Combined I/I

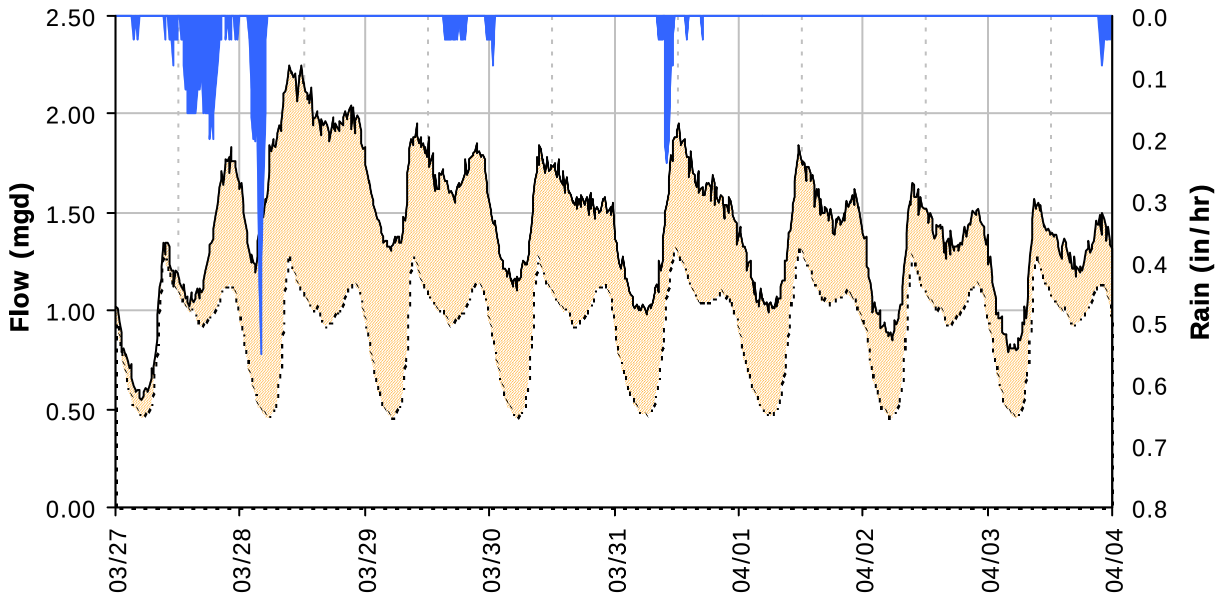
Total I/I:	2,733,000	*gallons*
Total I/I:IDM:	2,613	*gal/IDM/in*
R-Value:	1.9%	
Total I/I:ADWF:	1.02	*per in-rain*

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 = 2.42 inches)

Capacity

Peak Flow: 2.25 *mgd*
PF: 2.49
Peak Level: 10.07 *in*
d/D Ratio: 0.56

Inflow

Peak I/I Rate: 1.38 *mgd*
PkI/I:IDM: 3,915 *gpd/IDM*
PkI/I:Acre: 760 *gpd/acre*
Pk I/I:ADWF: 1.53

RDI (infiltration)

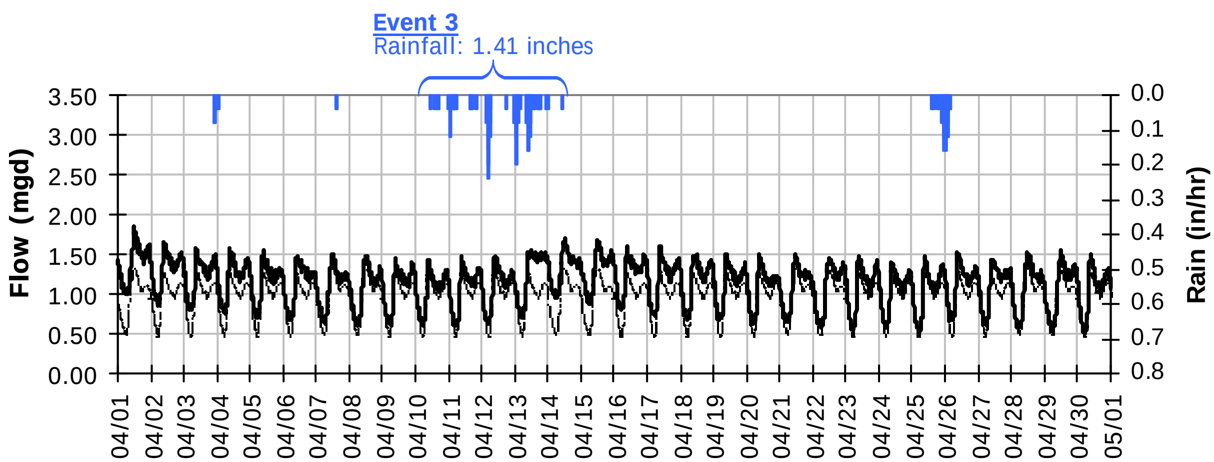
Infiltration Rate: 0.397 *mgd* (4/2/2012)
RDI:IDM: 1,122 *gpd/IDM*
RDI:Acre: 218 *gpd/acre*
RDI (% of BL): 44%

Combined I/I

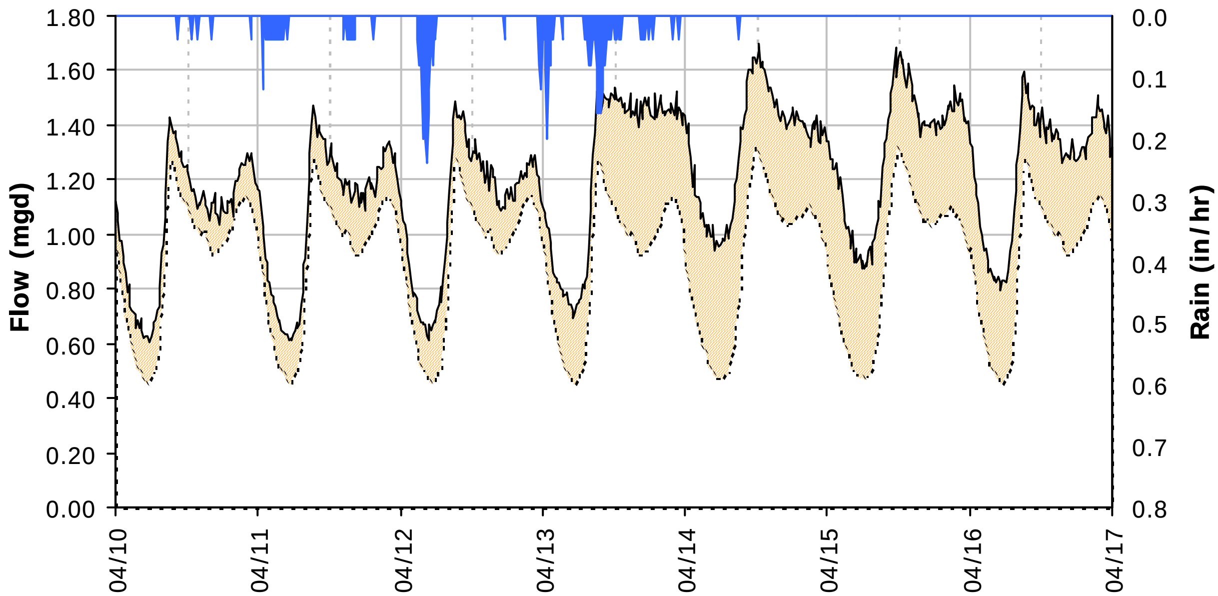
Total I/I: 4,275,000 *gallons*
Total I/I:IDM: 4,995 *gal/IDM/in*
R-Value: 3.6%
Total I/I:ADWF: 1.96 *per in-rain*

SITE 10
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.41 inches)

Capacity

Peak Flow: 1.70 *mgd*
PF: 1.88
Peak Level: 8.75 *in*
d/D Ratio: 0.49

Inflow

Peak I/I Rate: 0.60 *mgd*
PkI/I:IDM: 1,689 *gpd/IDM*
PkI/I:Acre: 328 *gpd/acre*
Pk I/I:ADWF: 0.66

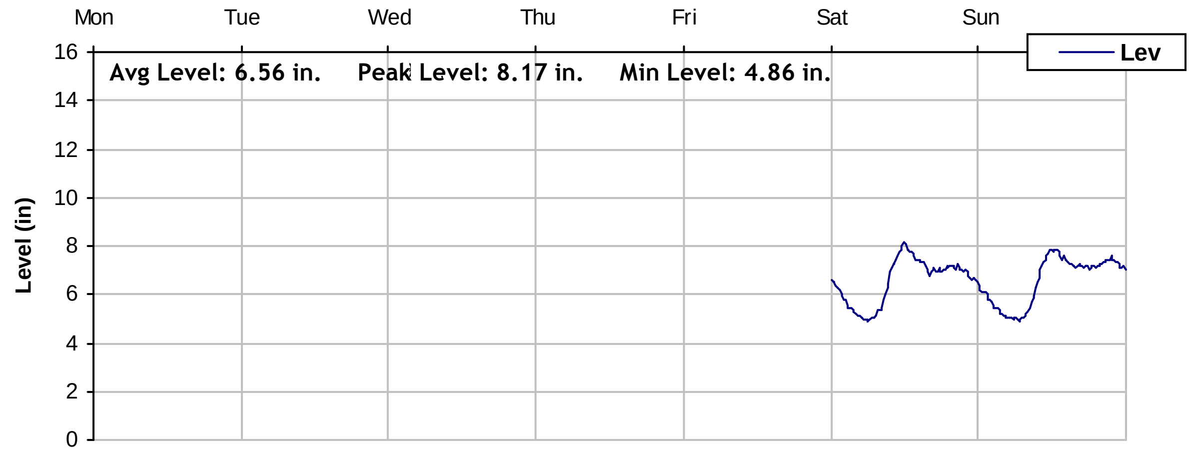
RDI (infiltration)

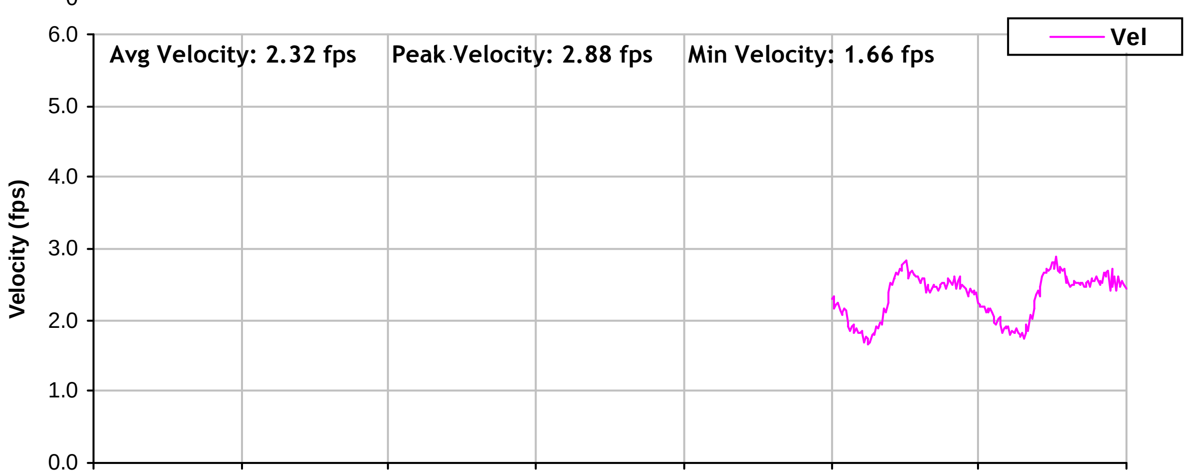
Infiltration Rate: 0.404 *mgd*
(4/15/2012)
RDI:IDM: 1,144 *gpd/IDM*
RDI:Acre: 222 *gpd/acre*
RDI (% of BL): 45%

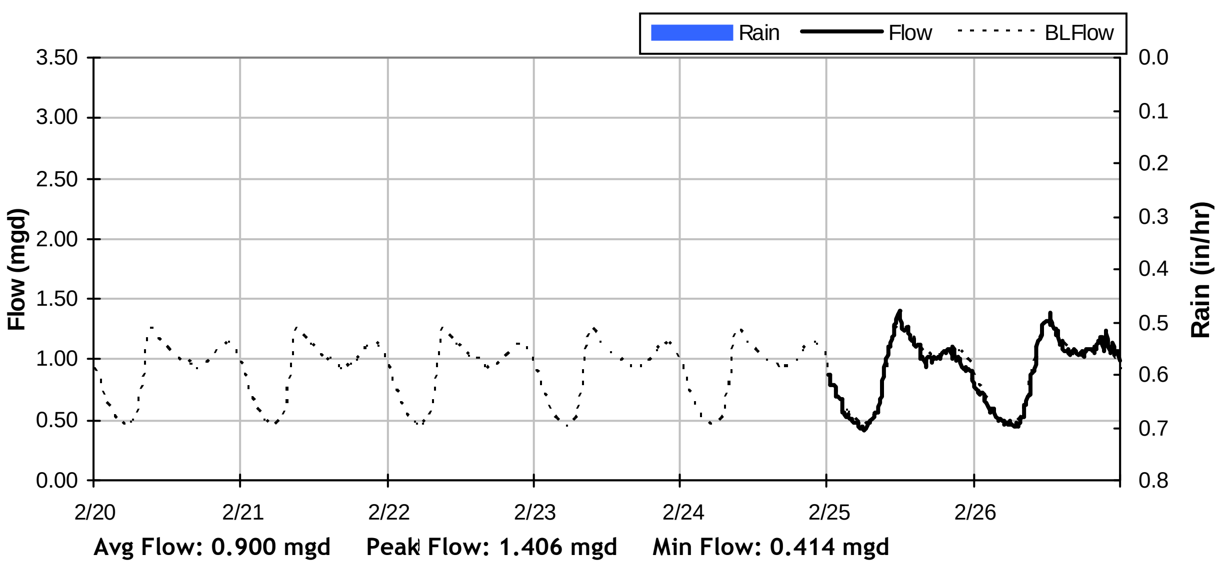
Combined I/I

Total I/I: 2,040,000 *gallons*
Total I/I:IDM: 4,093 *gal/IDM/in*
R-Value: 2.9%
Total I/I:ADWF: 1.60 *per in-rain*

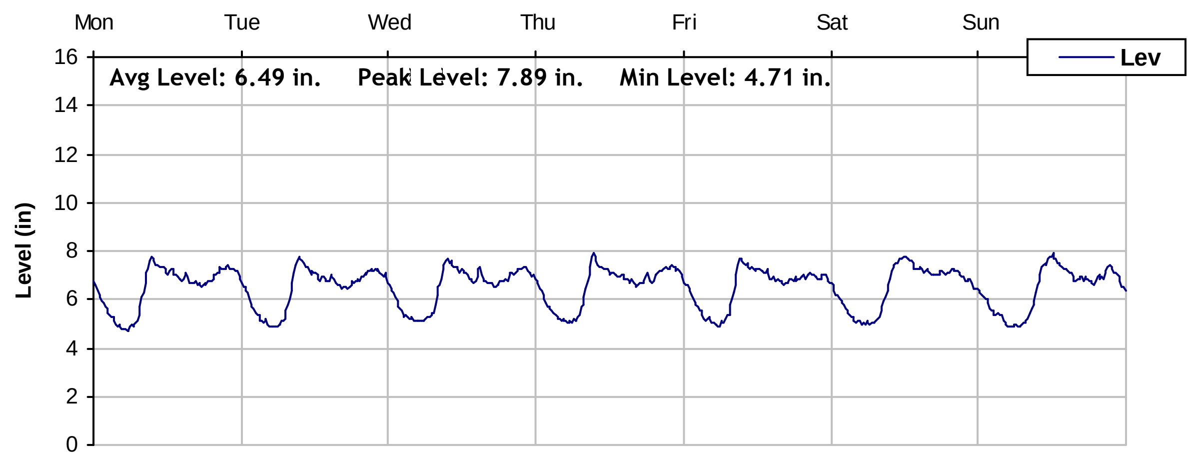
SITE 10
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

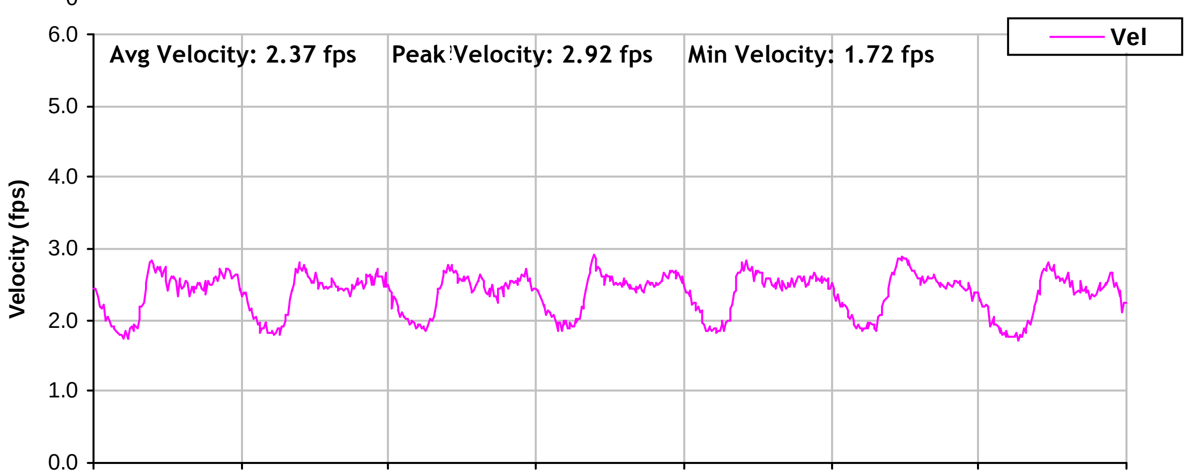


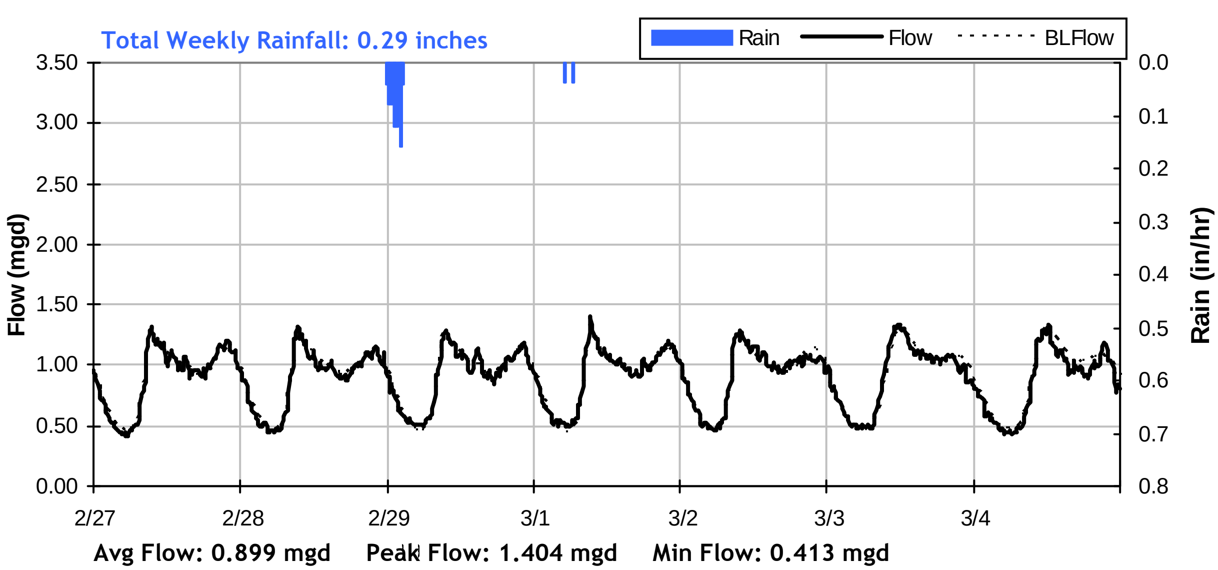




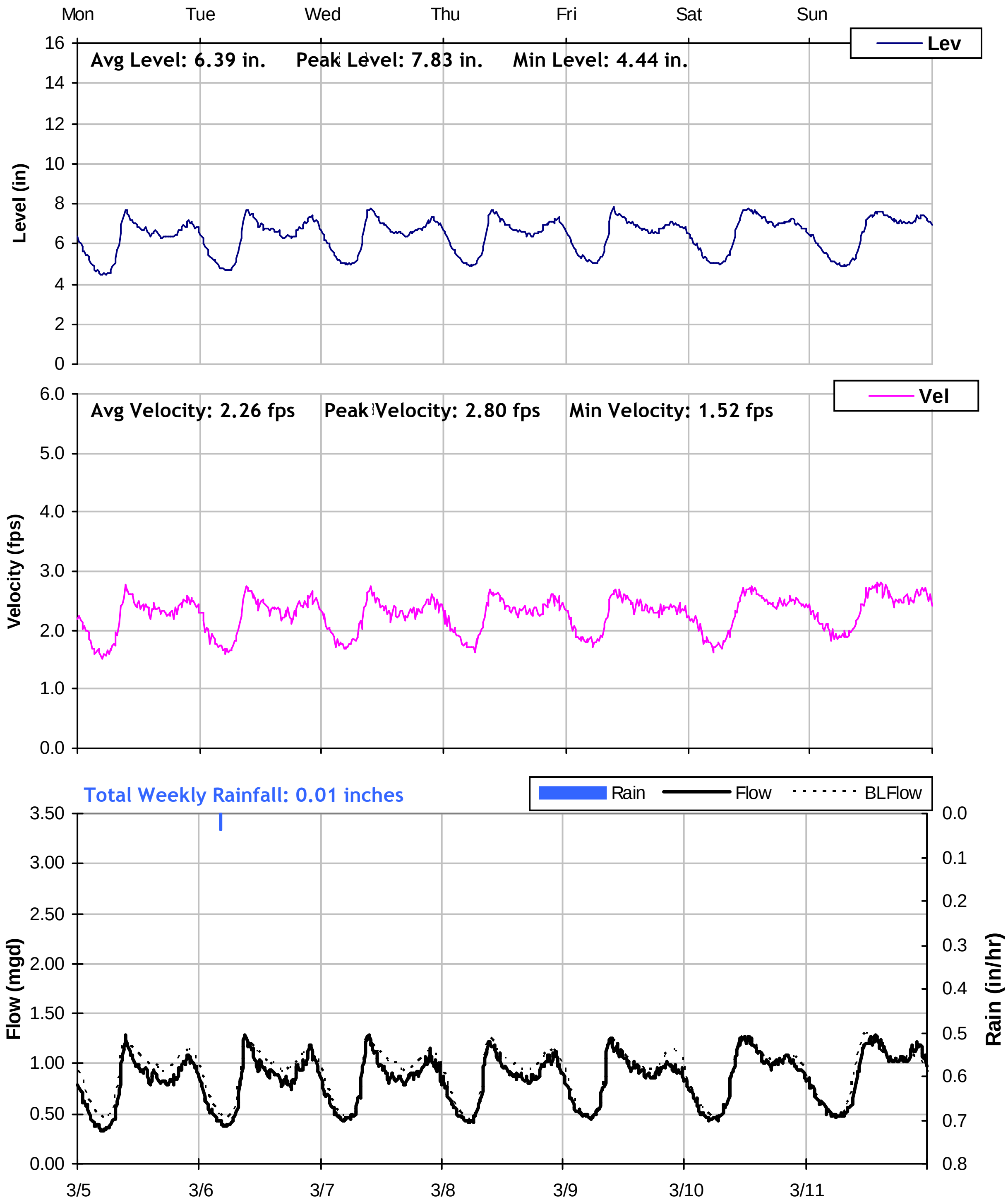
SITE 10
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012





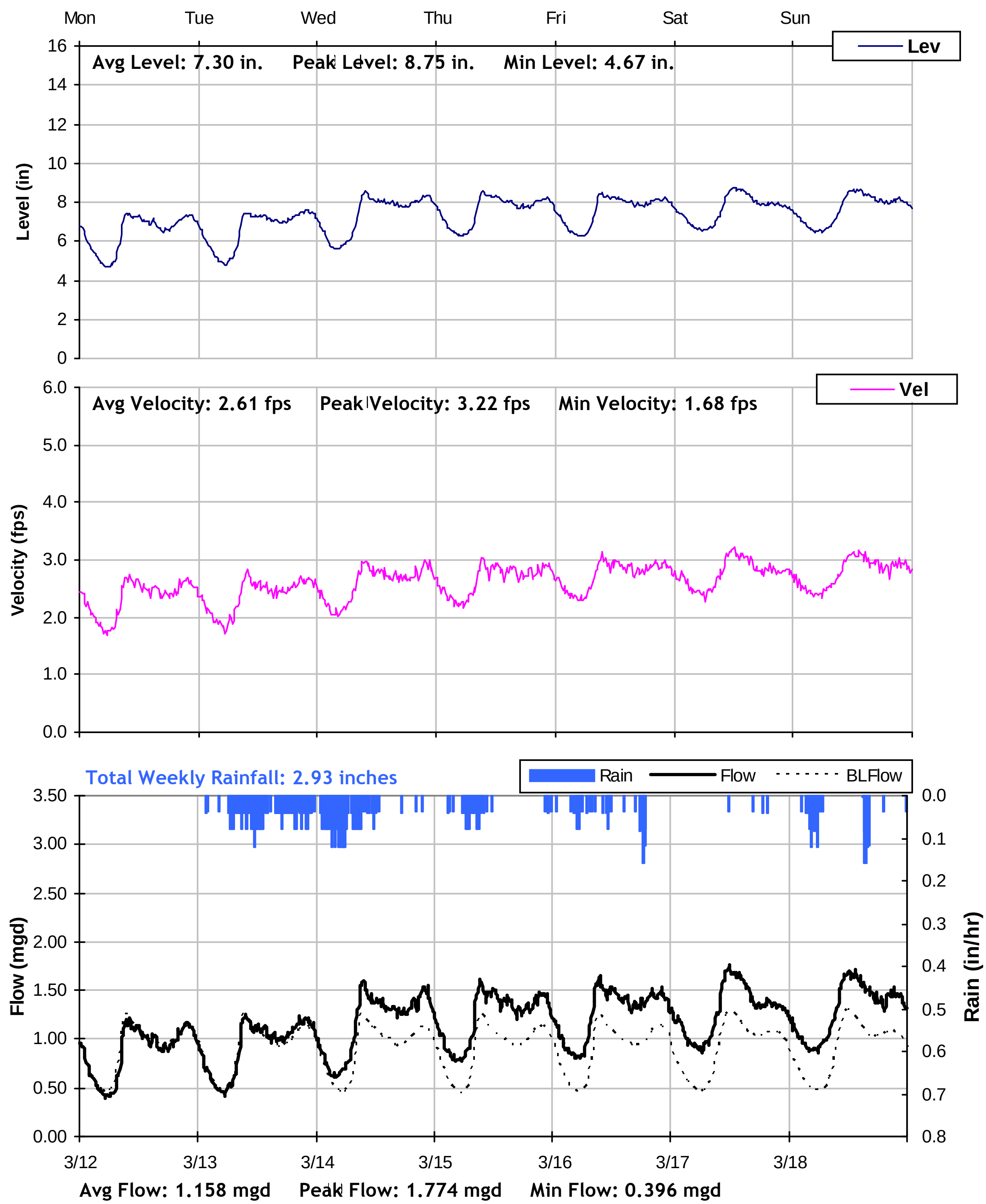


SITE 10
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012

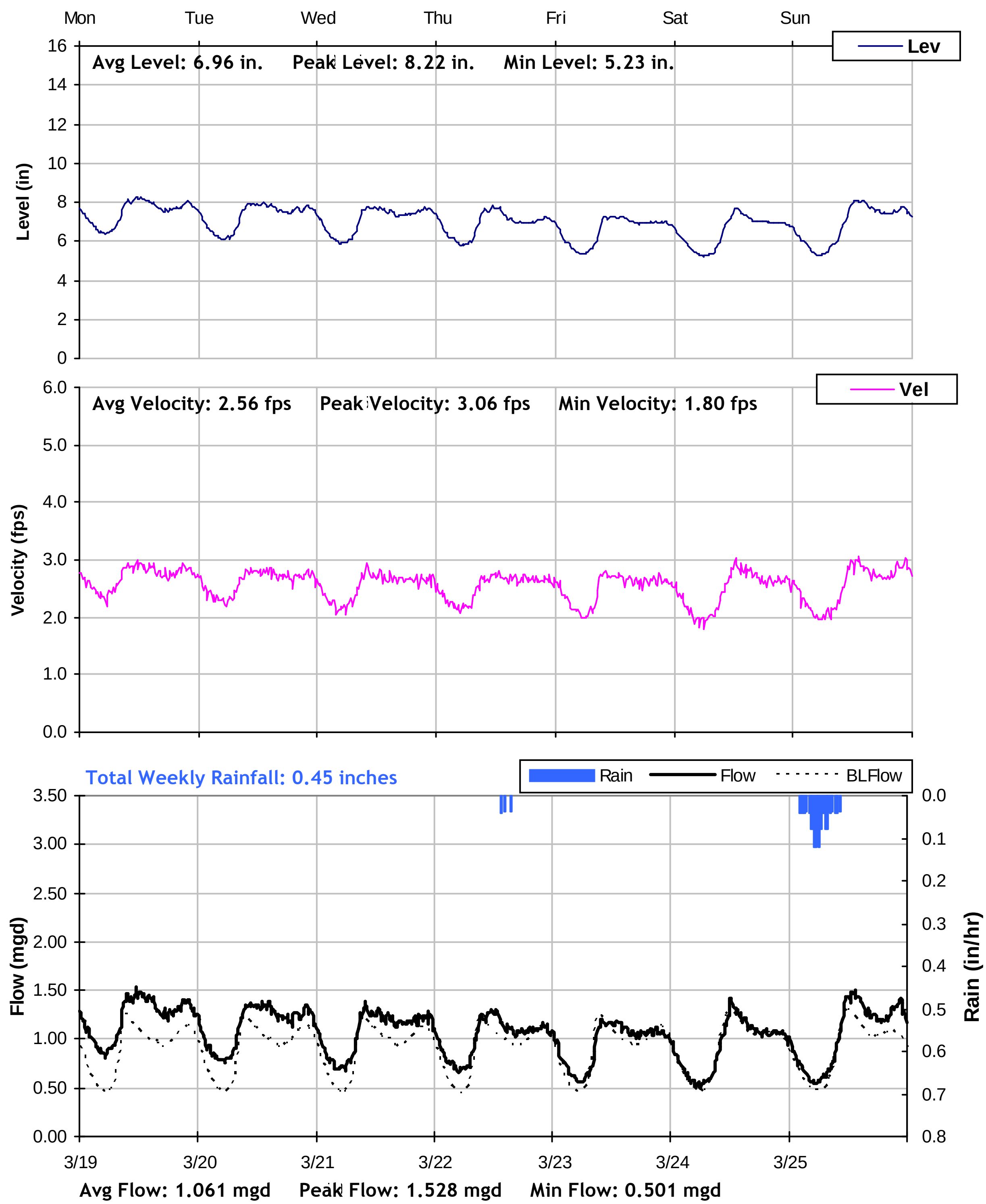


Avg Flow: 0.844 mgd Peak Flow: 1.292 mgd Min Flow: 0.333 mgd

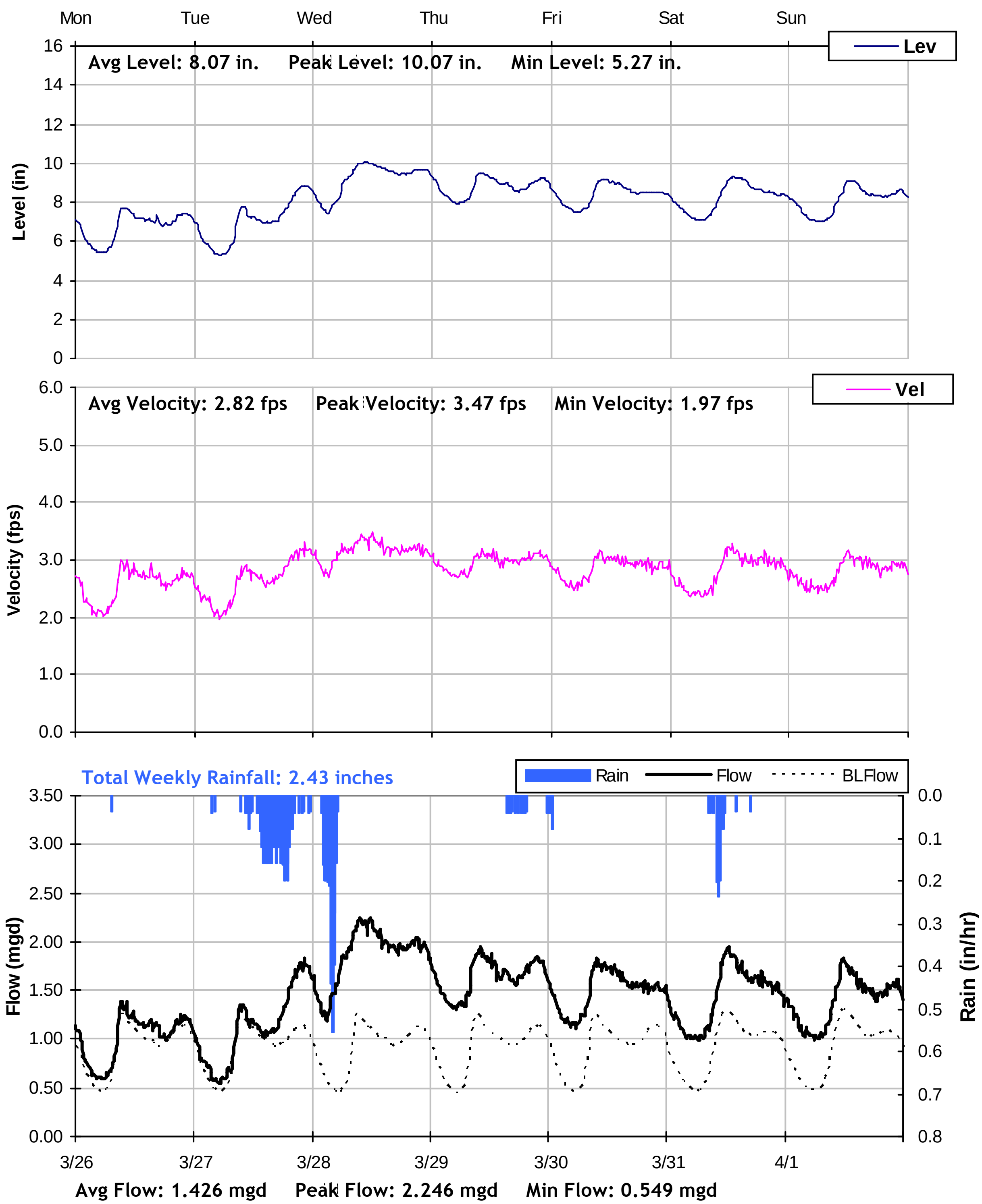
SITE 10
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



SITE 10
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



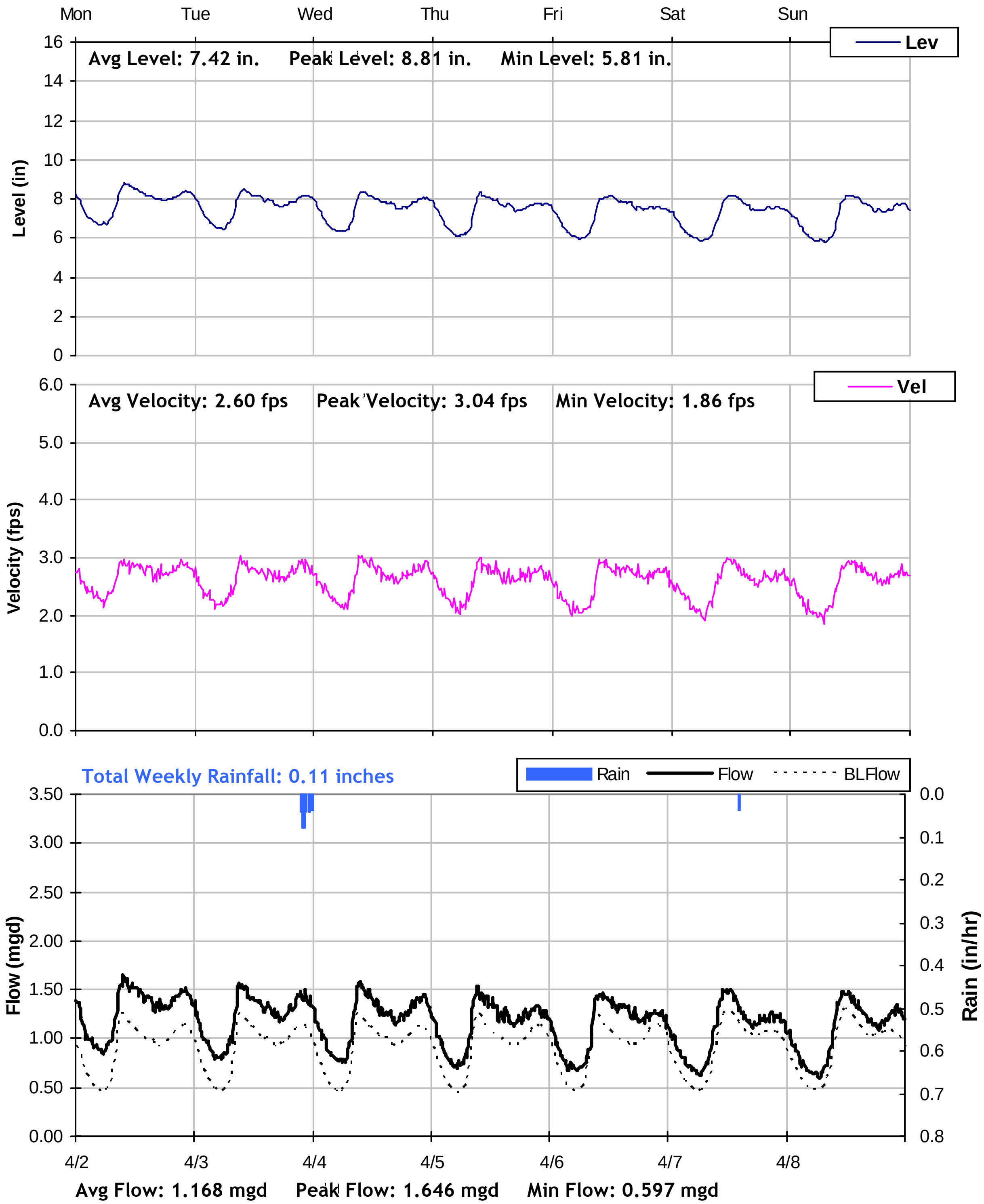
SITE 10
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



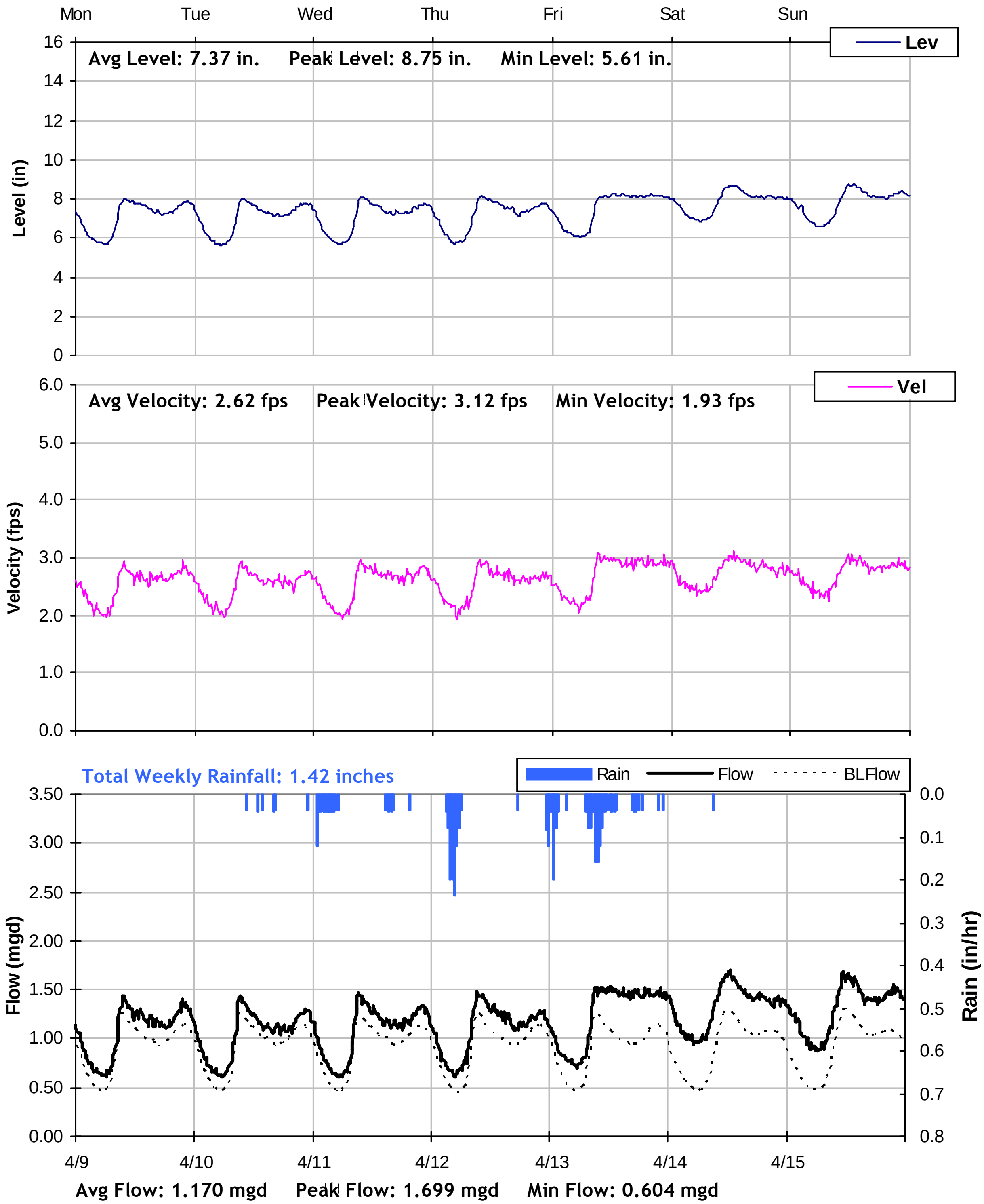
SITE 10

Weekly Level, Velocity and Flow Hydrographs

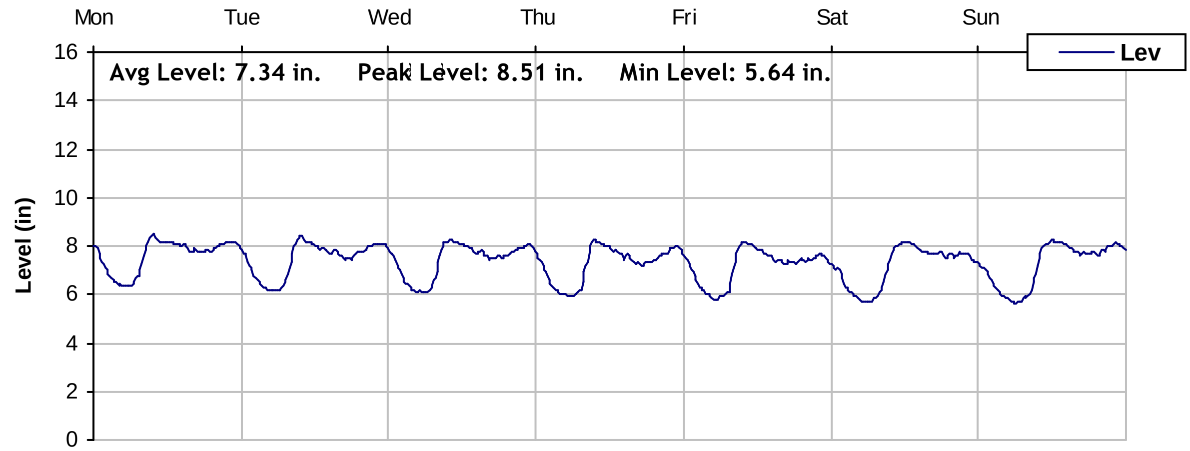
4/2/2012 to 4/9/2012

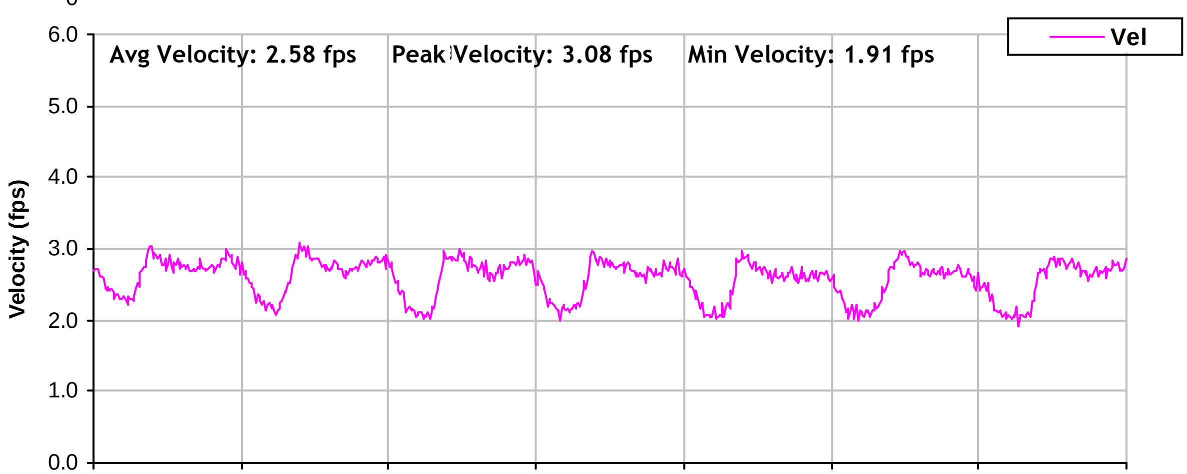


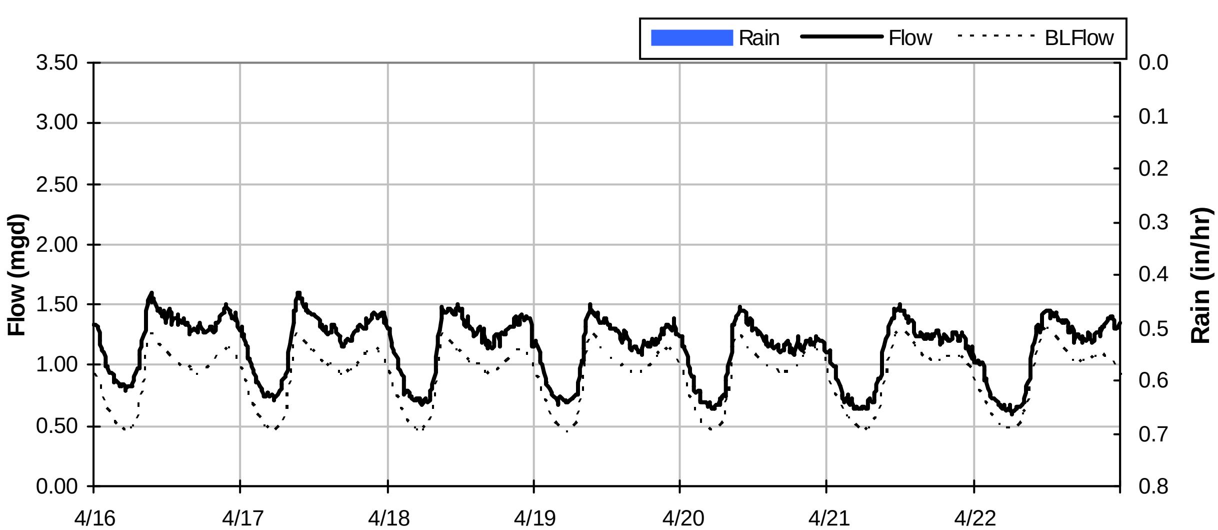
SITE 10
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



SITE 10
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012

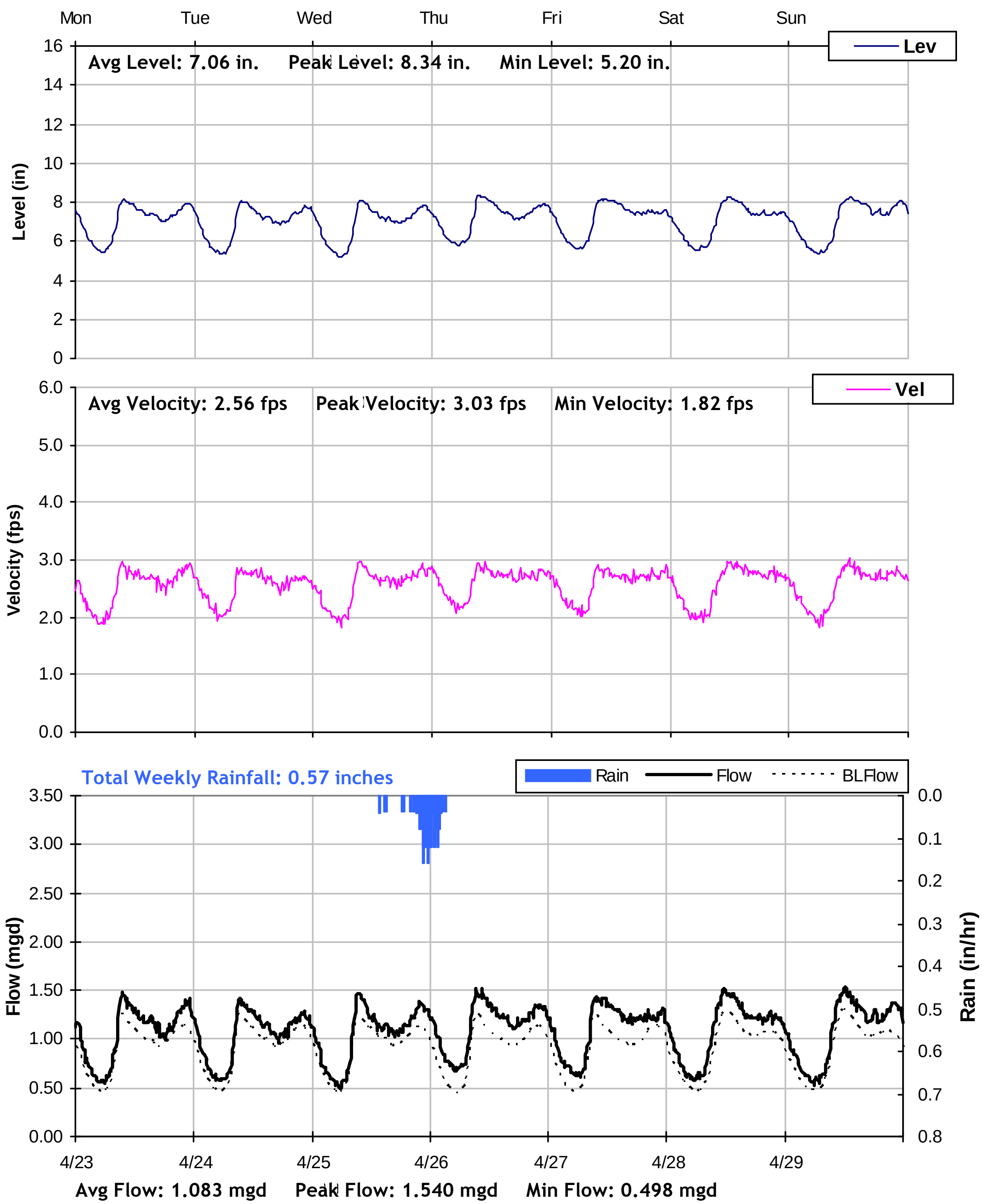




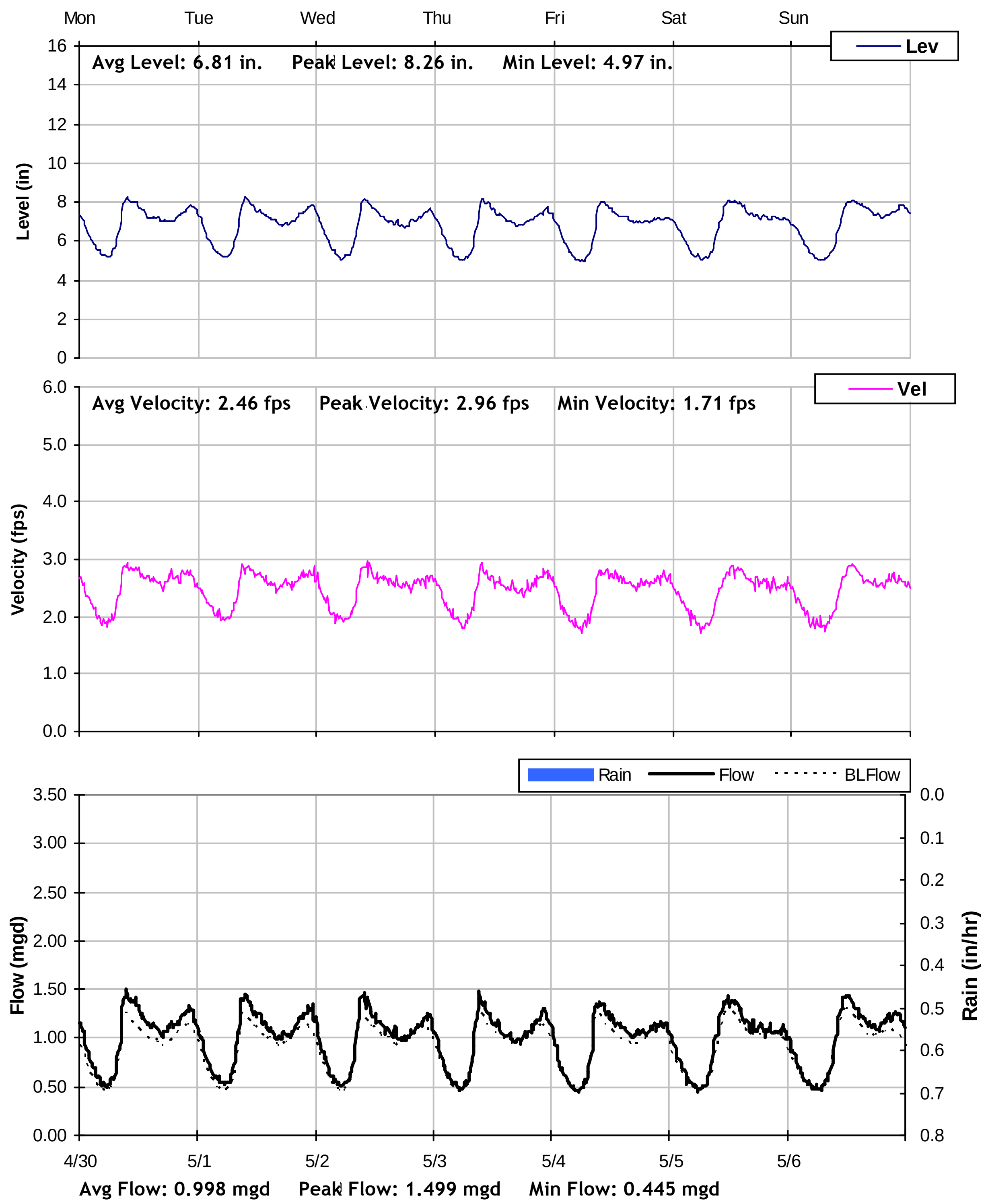


Avg Flow: 1.146 mgd   Peak Flow: 1.605 mgd   Min Flow: 0.587 mgd

SITE 10
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 10
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

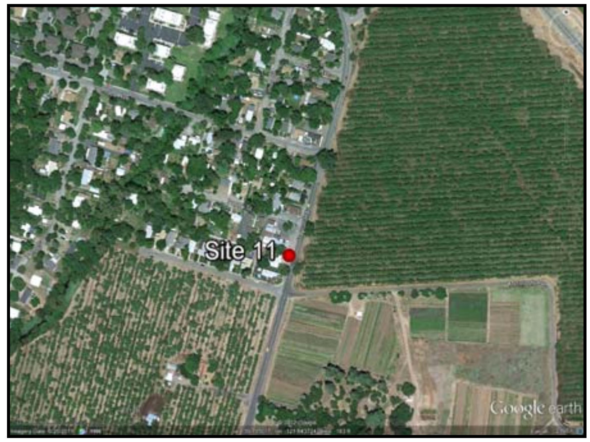
Monitoring Site: Site 11

Location: Dayton Road, southwest of Pomona Avenue

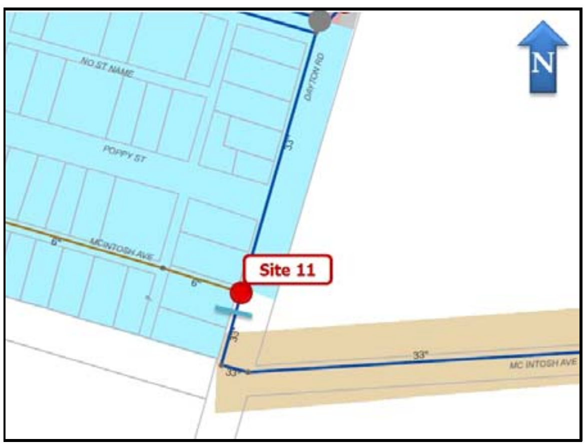
Vicinity Map:

SITE 11
Site Information Report

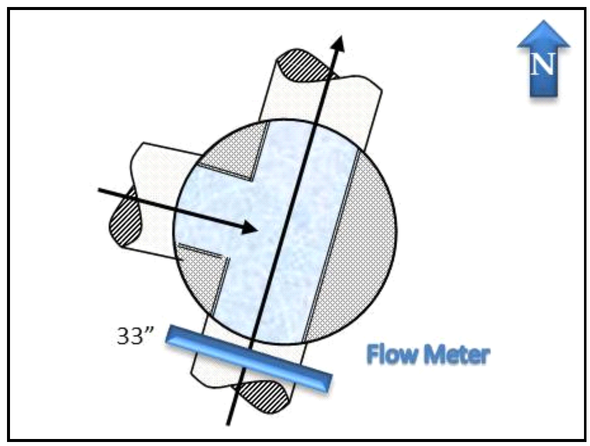
Location:	Dayton Road, southwest of Pomona Avenue
Coordinates:	121.8439° W, 39.7146° N
Elevation:	183 feet
Diameter:	33 inches
Baseline Flow:	1.433 mgd
Peak Measured Flow:	3.626 mgd



Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

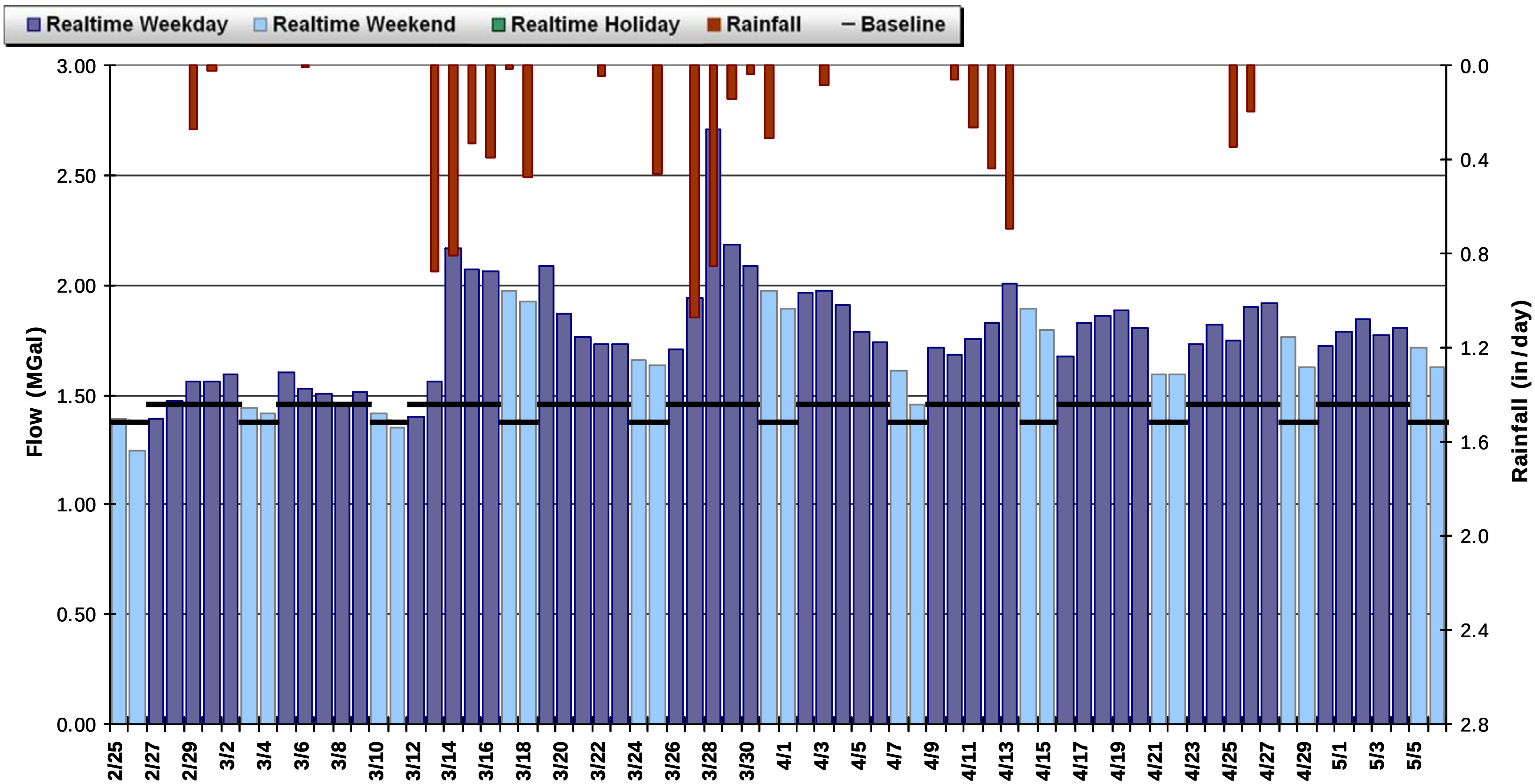
Plan View

SITE 11

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.745 MGal **Peak Daily Flow: 2.708 MGal** **Min Daily Flow: 1.248 MGal**

Total Period Rainfall: 8.20 inches

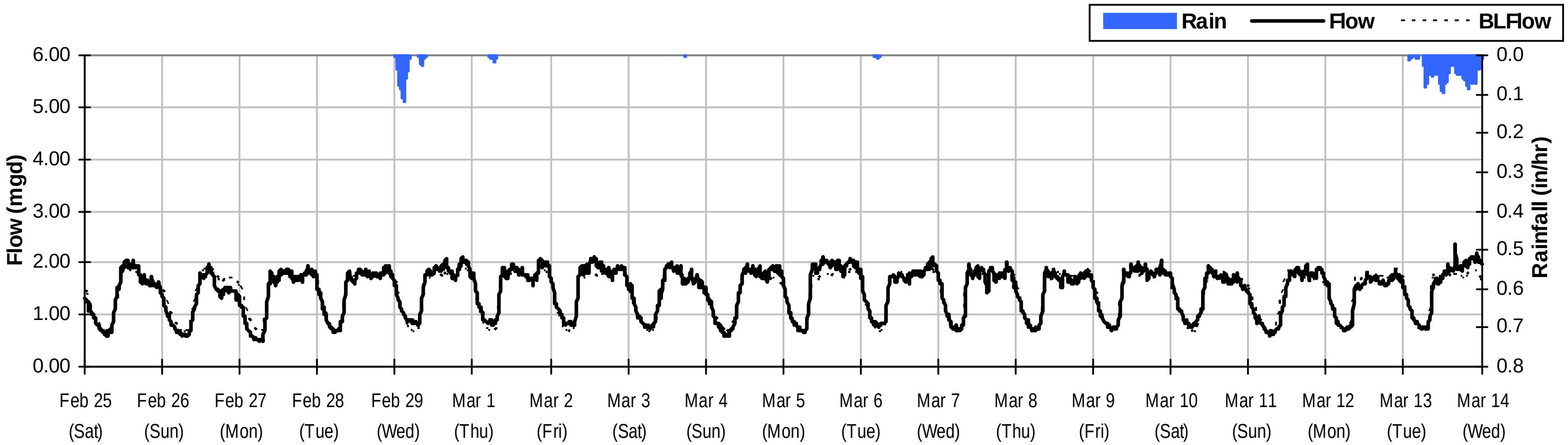


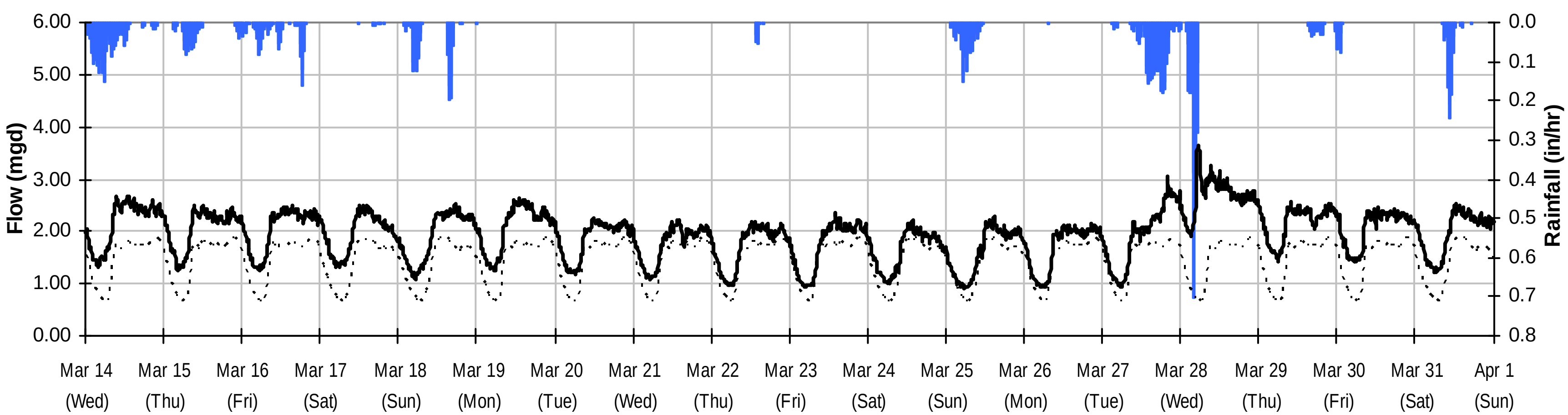
SITE 11

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 1.712 mgd **Peak Flow: 3.626 mgd** **Min Flow: 0.493 mgd**

Total Period Rainfall: 6.12 inches



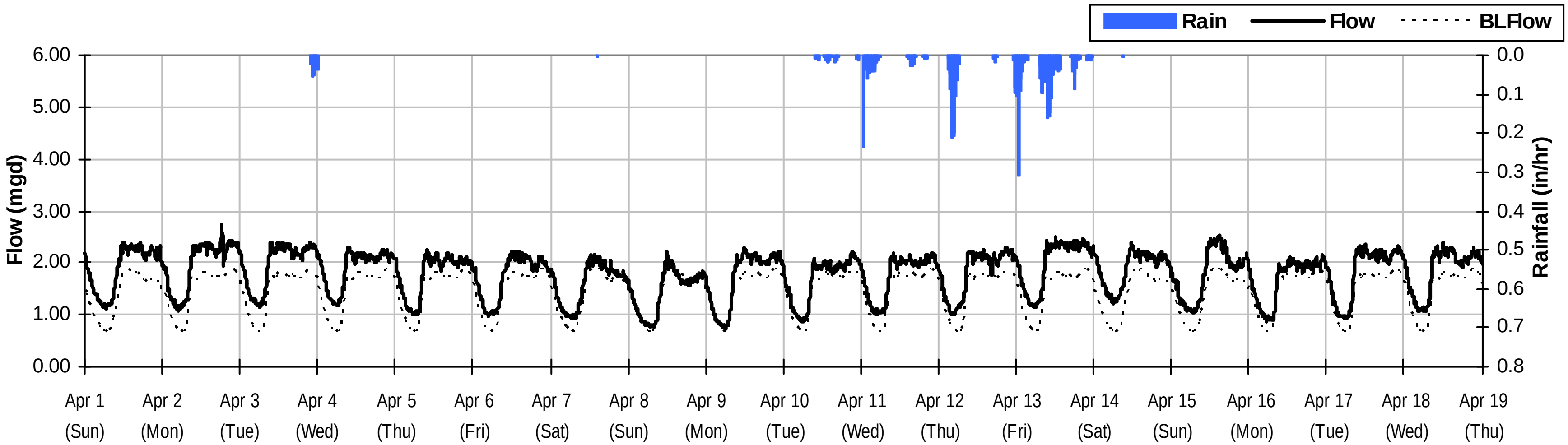


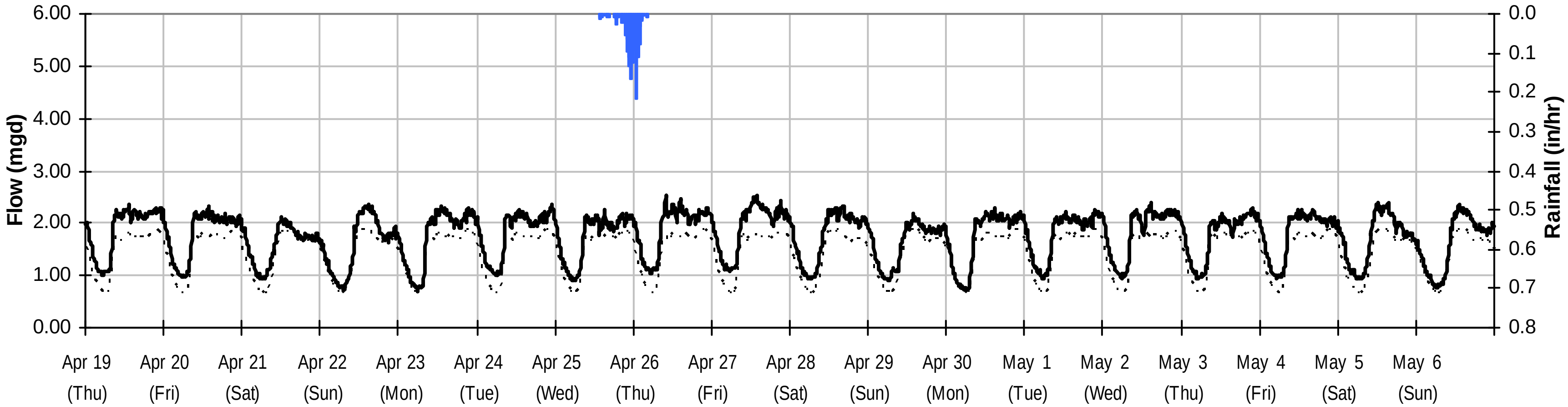
SITE 11

Period Flow Summary: April 1 to May 7, 2012

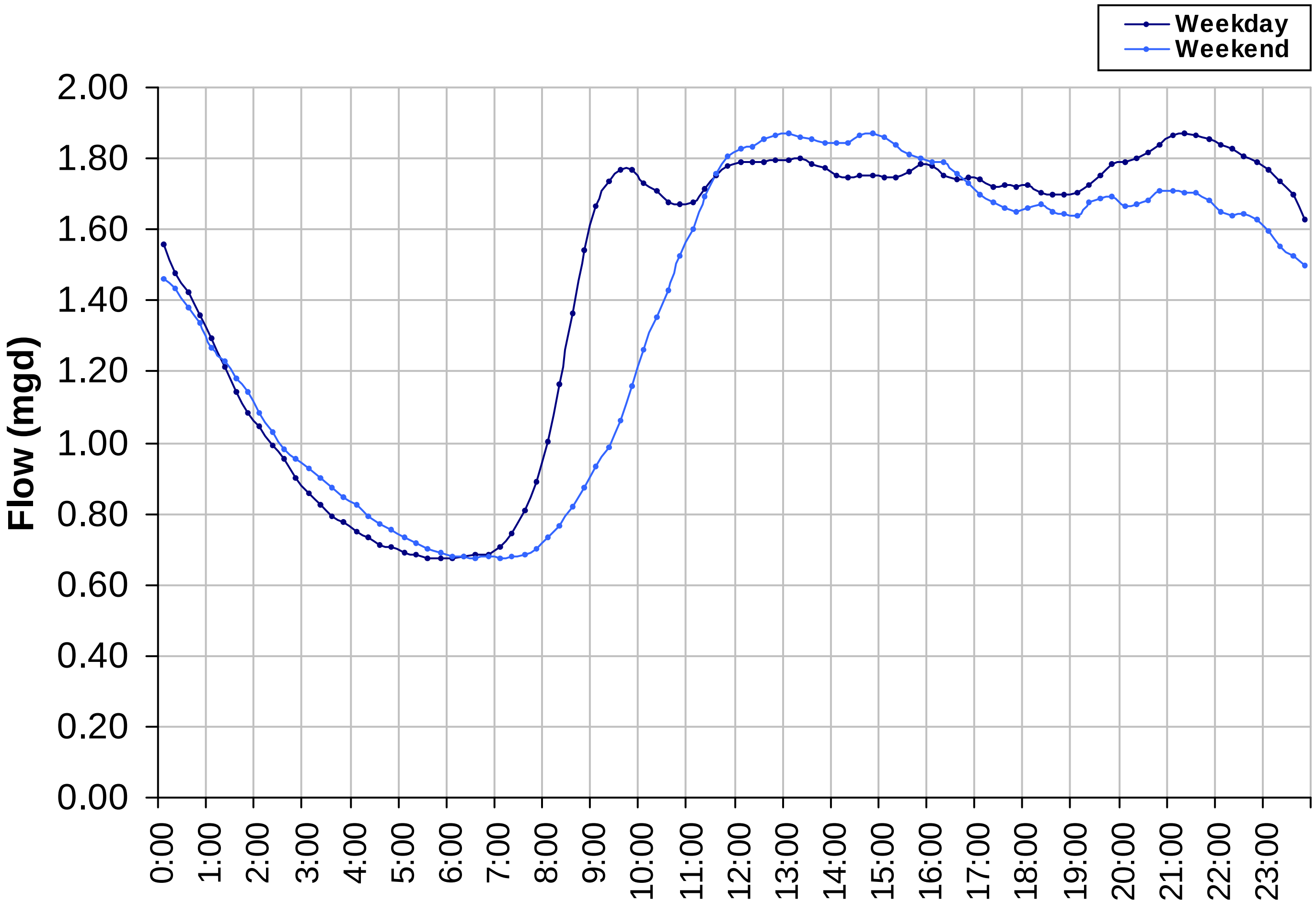
Avg Flow: 1.778 mgd **Peak Flow: 2.735 mgd** **Min Flow: 0.696 mgd**

Total Period Rainfall: 2.08 inches



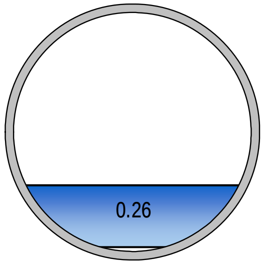


SITE 11
Baseline Flow Hydrographs



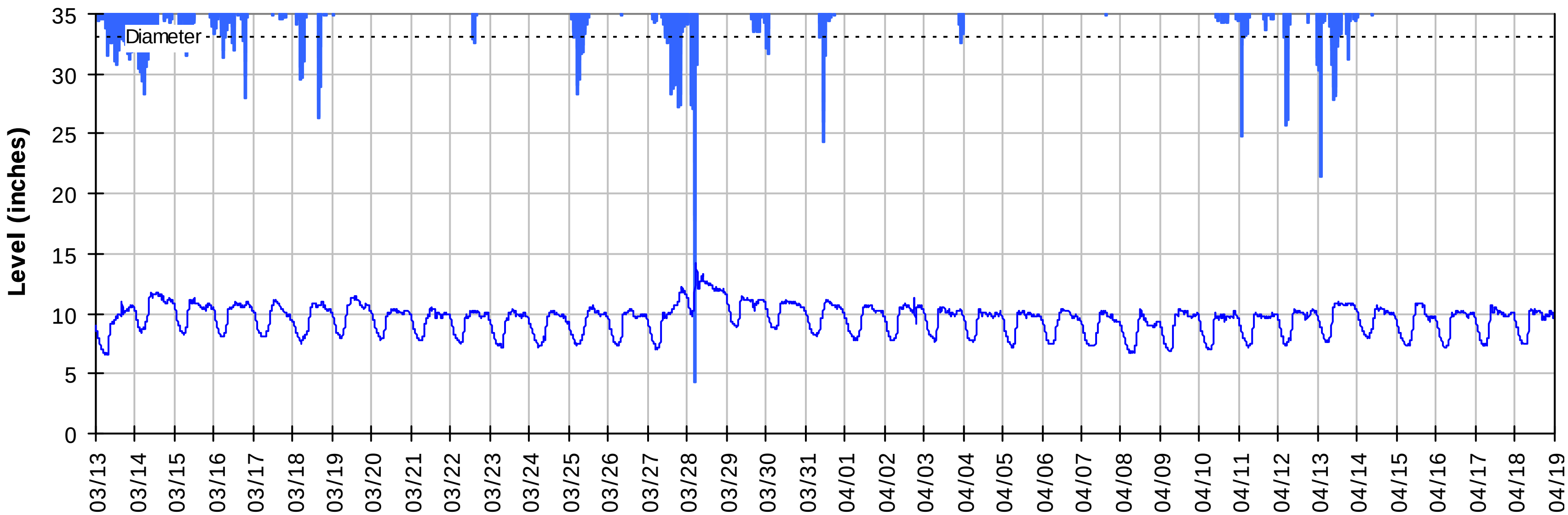
Baseline Flow:

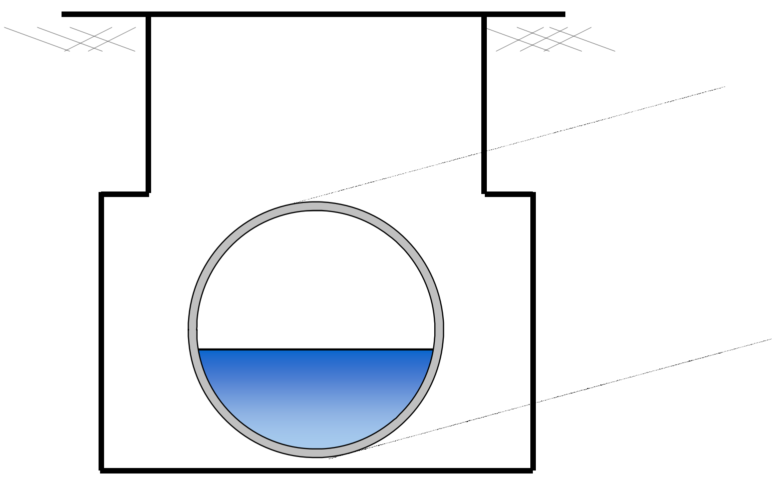
1.433 *mgd*



SITE 11
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





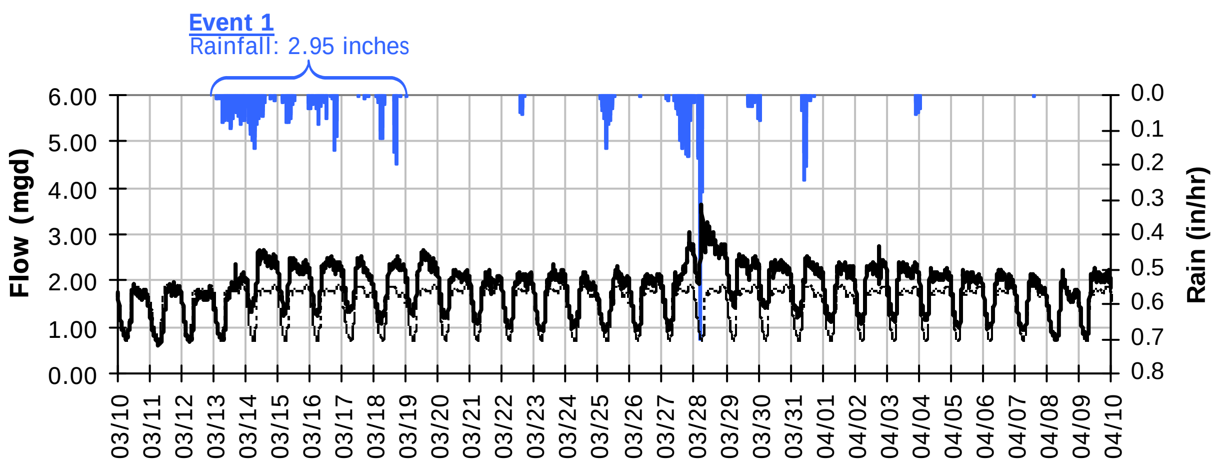
Pipe Diameter: 33 *inches*

Peak Measured Level: 14.1 *inches*

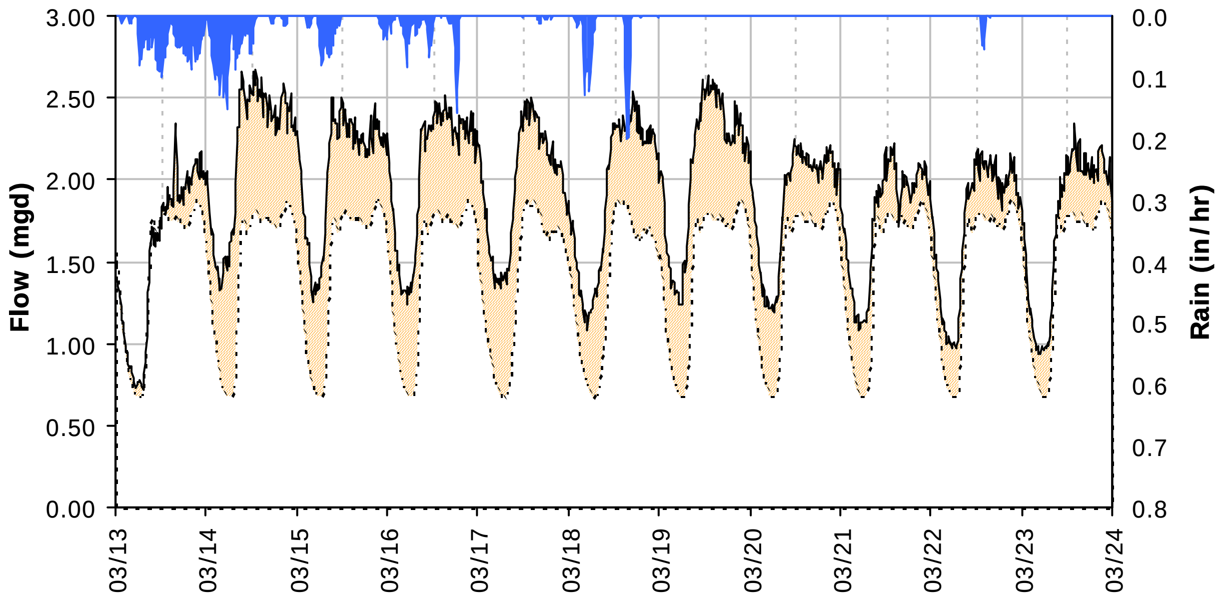
Peak d/D Ratio: 0.43

SITE 11
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 = 2.95 inches)

Capacity

Peak Flow: 2.67 *mgd*
PF: 1.86
Peak Level: 11.80 *in*
d/D Ratio: 0.36

Inflow

Peak I/I Rate: 1.07 *mgd*
PkI/I:IDM: 2,777 *gpd/IDM*
PkI/I:Acre: 385 *gpd/acre*
Pk I/I:ADWF: 0.75

RDI (infiltration)

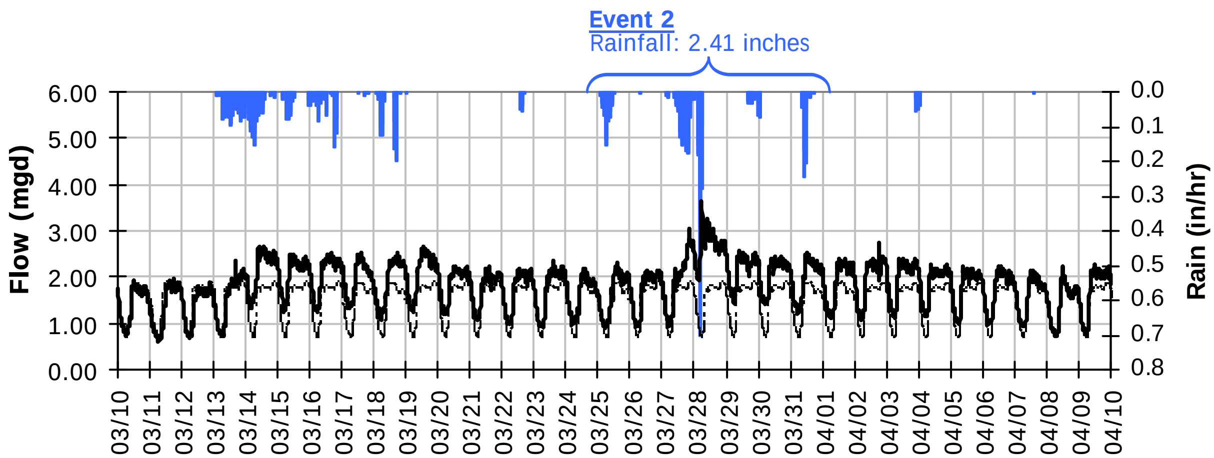
Infiltration Rate: 0.412 *mgd*
(3/20/2012)
RDI:IDM: 1,066 *gpd/IDM*
RDI:Acre: 148 *gpd/acre*
RDI (% of BL): 28%

Combined I/I

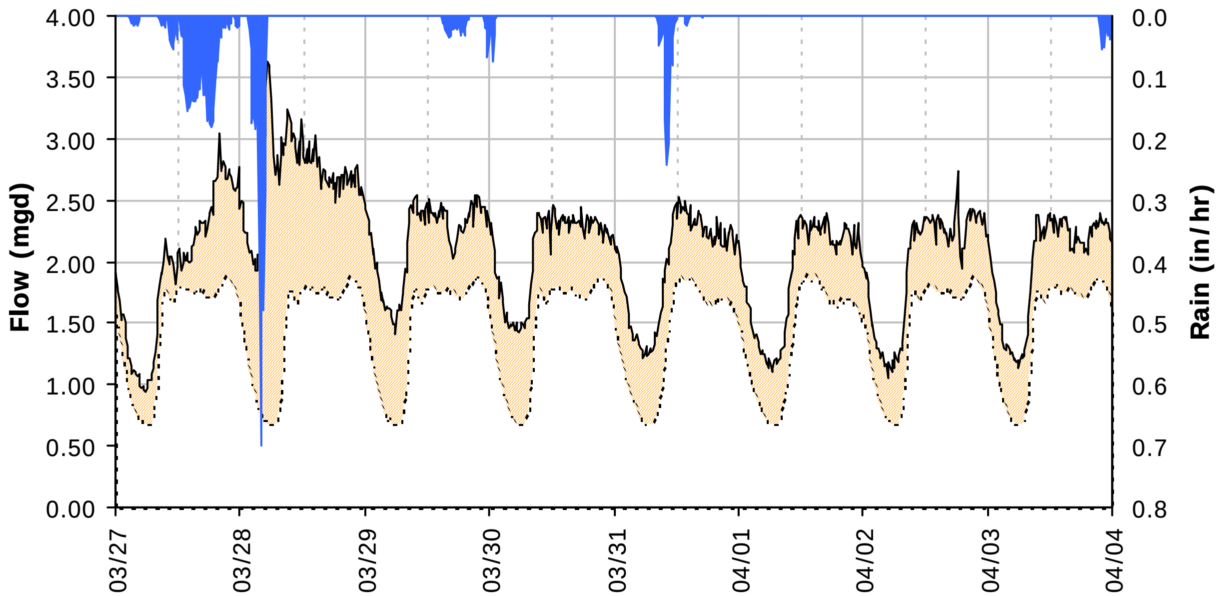
Total I/I: 5,083,000 *gallons*
Total I/I:IDM: 4,462 *gal/IDM/in*
R-Value: 2.3%
Total I/I:ADWF: 1.20 *per in-rain*

SITE 11
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 = 2.41 inches)

Capacity

Peak Flow:	3.63	*mgd*
PF:	2.53	
Peak Level:	14.14	*in*
d/D Ratio:	0.43	

Inflow

Peak I/I Rate:	2.94	*mgd*
PkI/I:IDM:	7,619	*gpd/IDM*
PkI/I:Acre:	1,057	*gpd/acre*
Pk I/I:ADWF:	2.05	

RDI (infiltration)

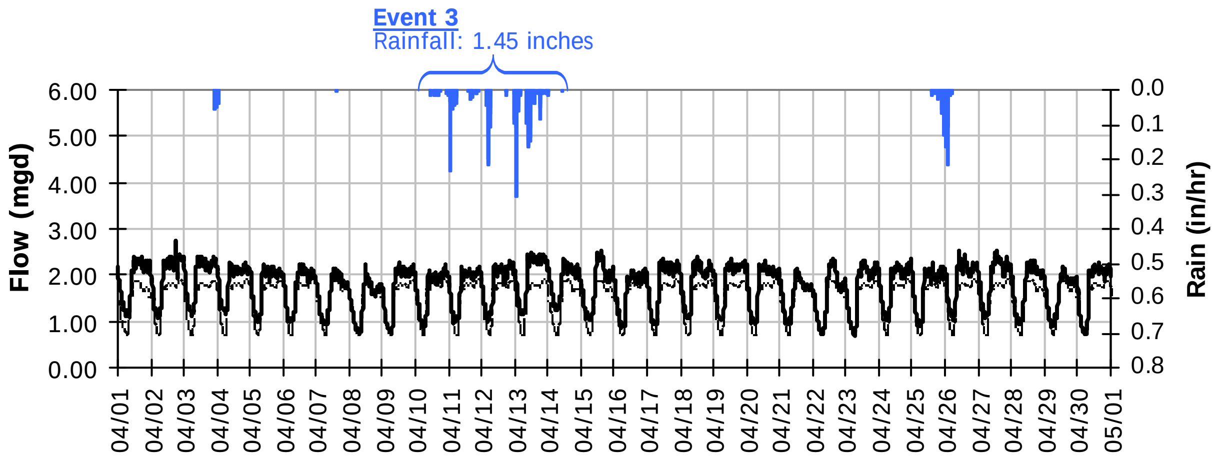
Infiltration Rate: (4/2/2012)	0.514	*mgd*
RDI:IDM:	1,331	*gpd/IDM*
RDI:Acre:	185	*gpd/acre*
RDI (% of BL):	35%	

Combined I/I

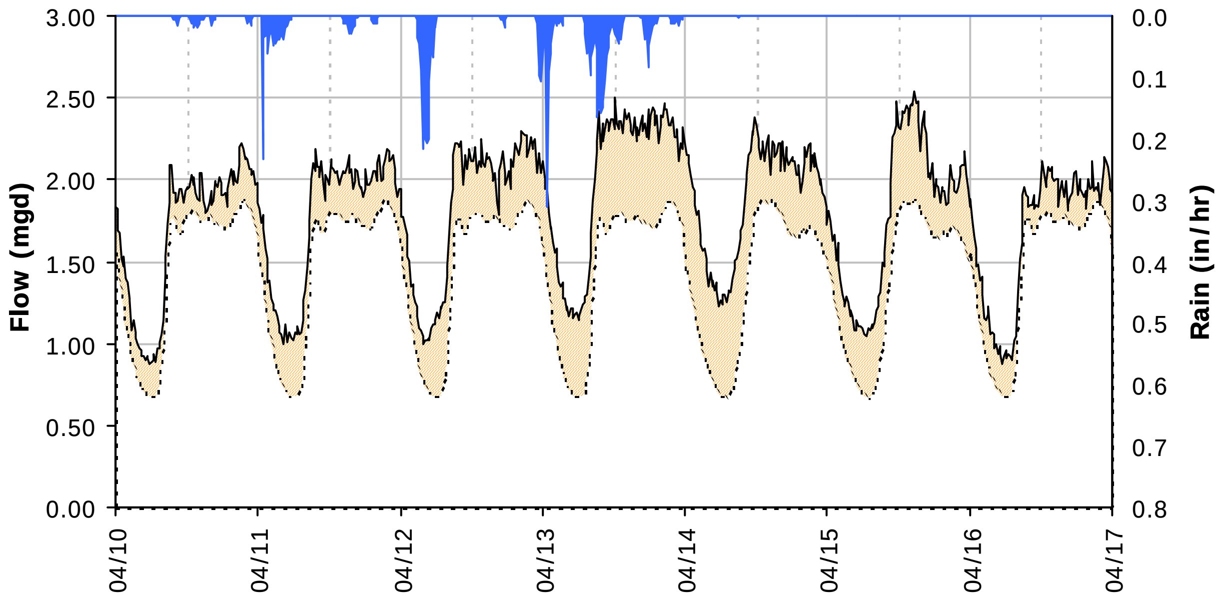
Total I/I:	5,234,000	*gallons*
Total I/I:IDM:	5,627	*gal/IDM/in*
R-Value:	2.9%	
Total I/I:ADWF:	1.52	*per in-rain*

SITE 11
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



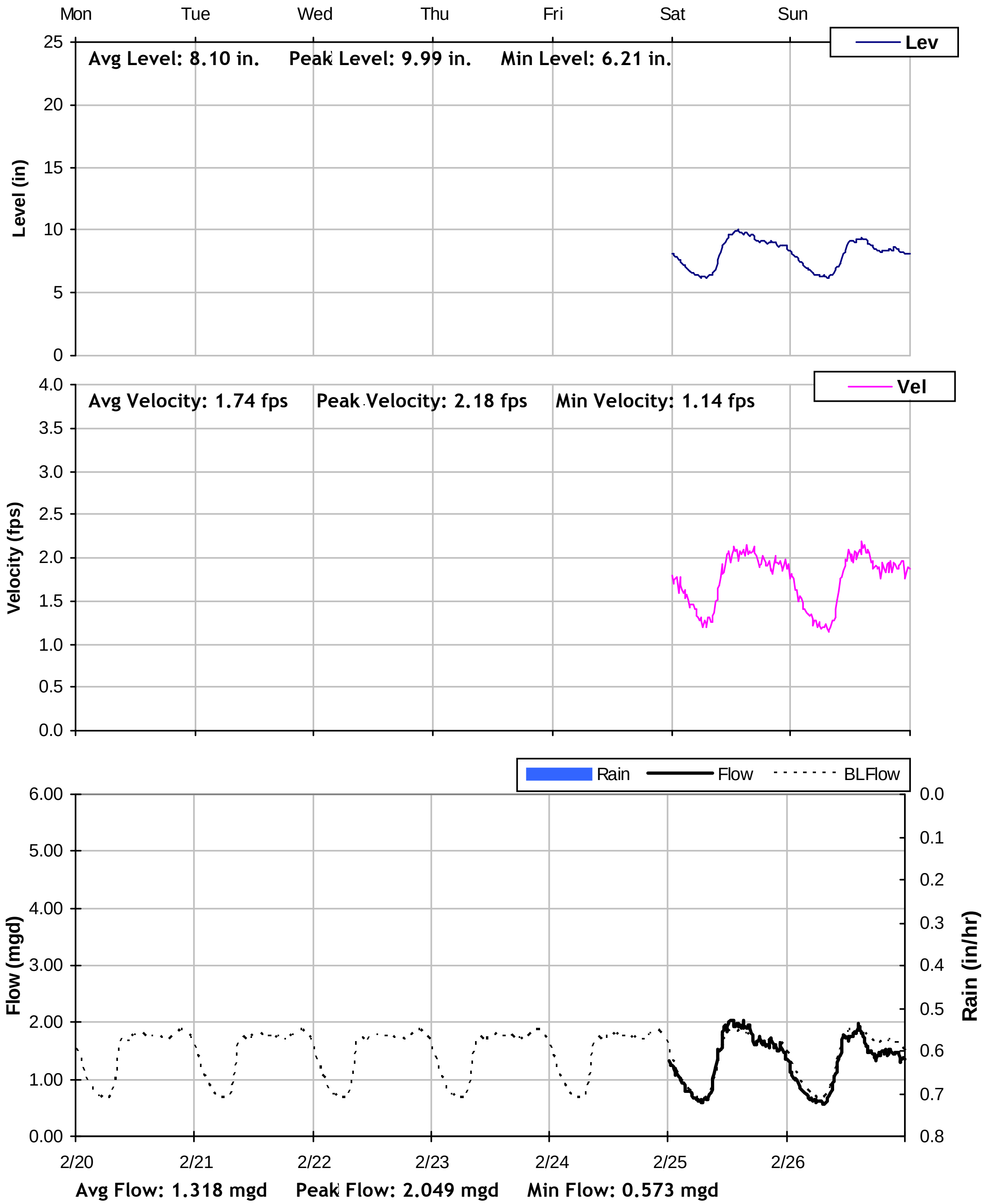
Event 3 Detail Graph



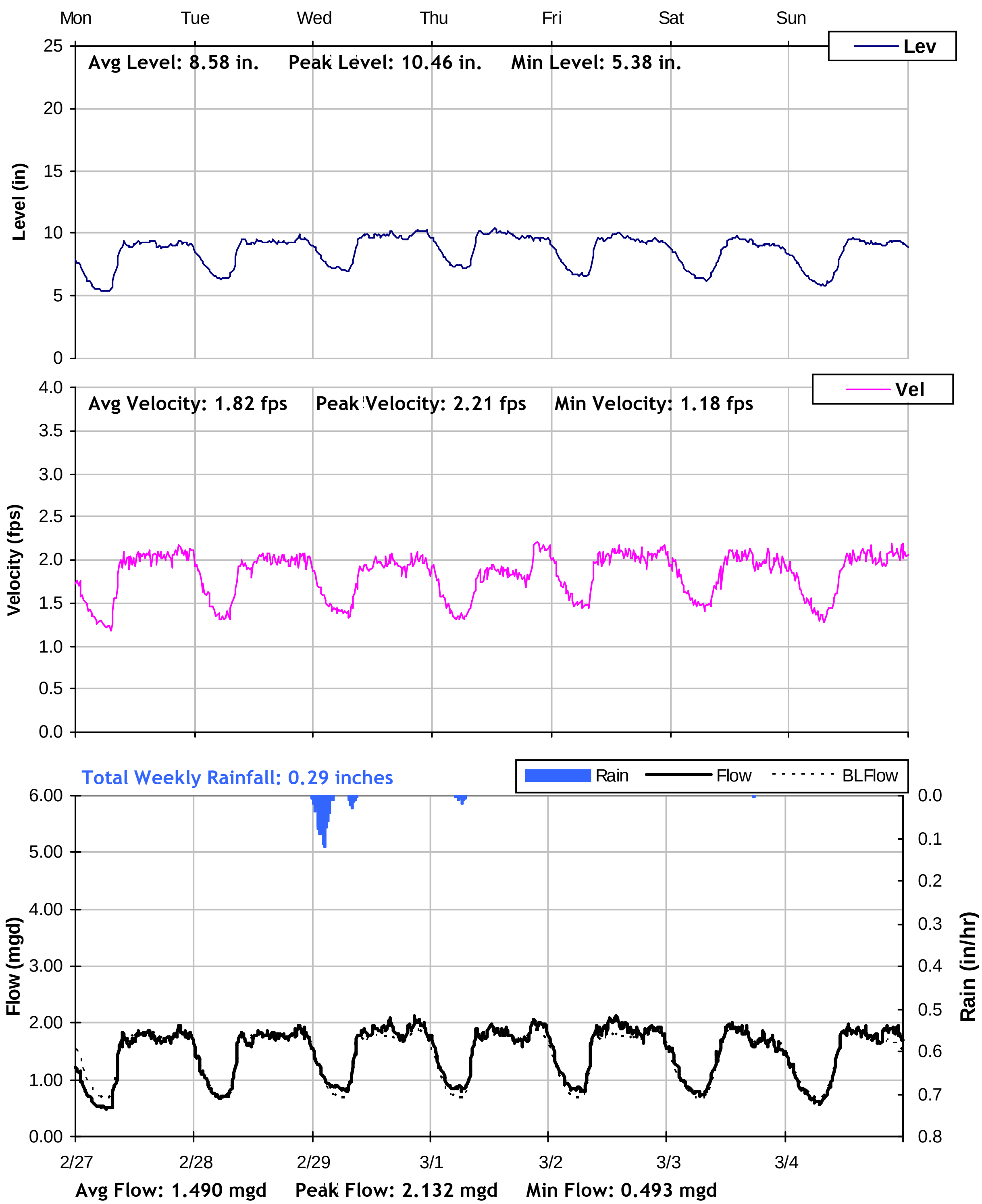
Storm Event I/I Analysis (Rain = 1.45 inches)

Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	2.54 *mgd*	**Peak I/I Rate:**	0.78 *mgd*	**Infiltration Rate:** (4/15/2012)	0.414 *mgd*	**Total I/I:**	2,605,000 *gallons*
PF:	1.77	**PkI/I:IDM:**	2,027 *gpd/IDM*	**RDI:IDM:**	1,071 *gpd/IDM*	**Total I/I:IDM:**	4,647 *gal/IDM/in*
Peak Level:	11.03 *in*	**PkI/I:Acre:**	281 *gpd/acre*	**RDI:Acre:**	149 *gpd/acre*	**R-Value:**	2.4%
d/D Ratio:	0.33	**Pk I/I:ADWF:**	0.55	**RDI (% of BL):**	30%	**Total I/I:ADWF:**	1.25 *per in-rain*

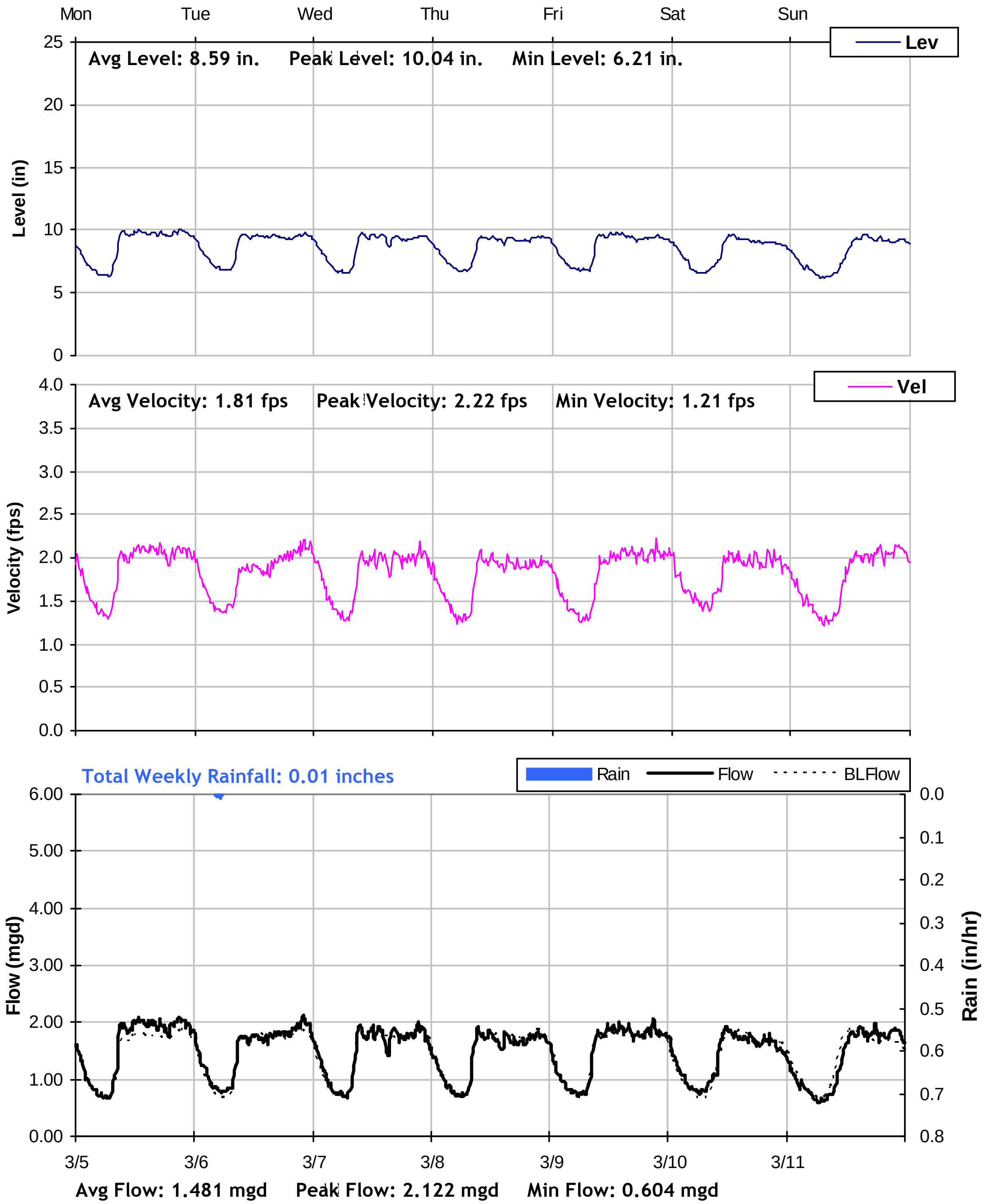
SITE 11
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



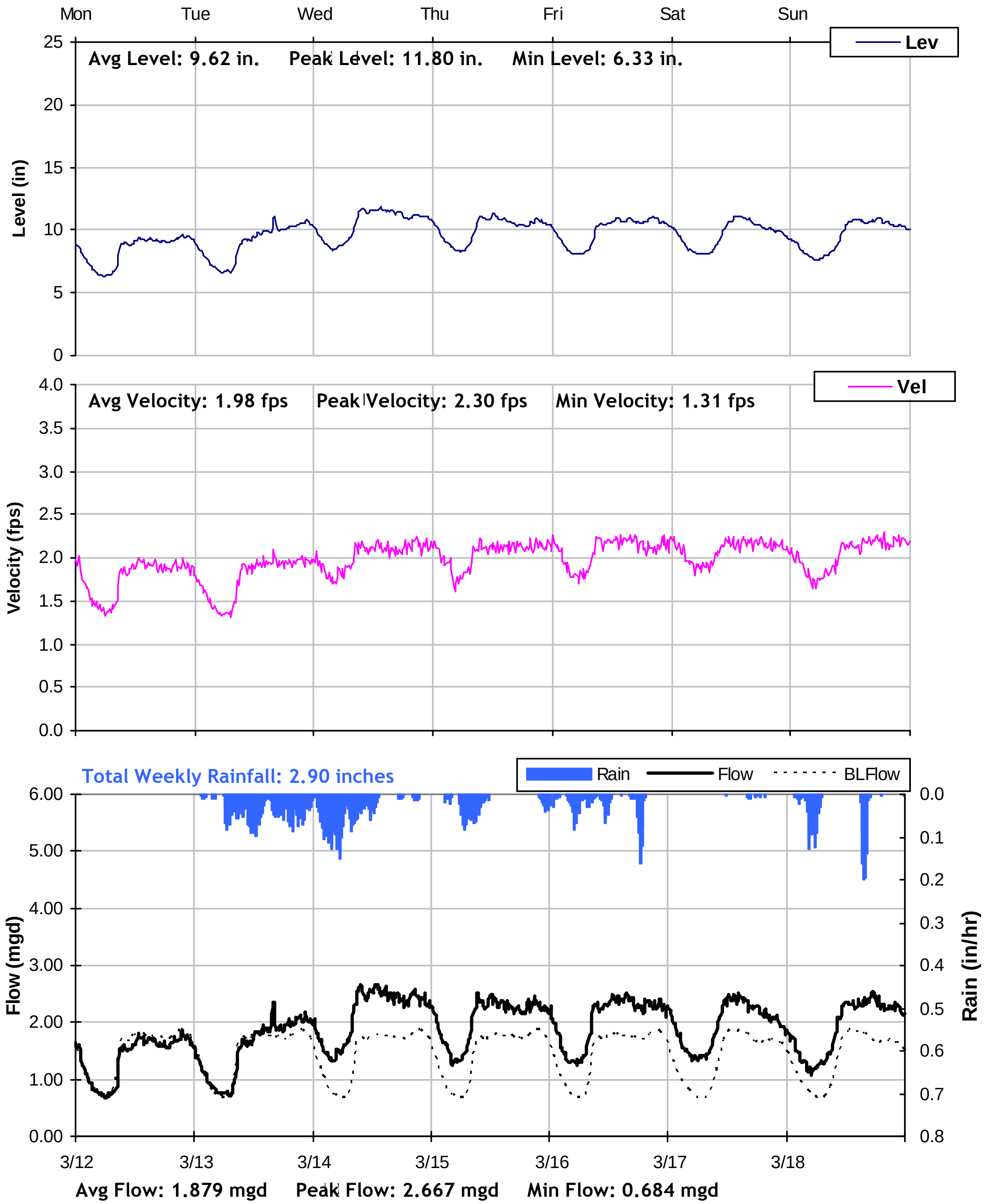
SITE 11
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



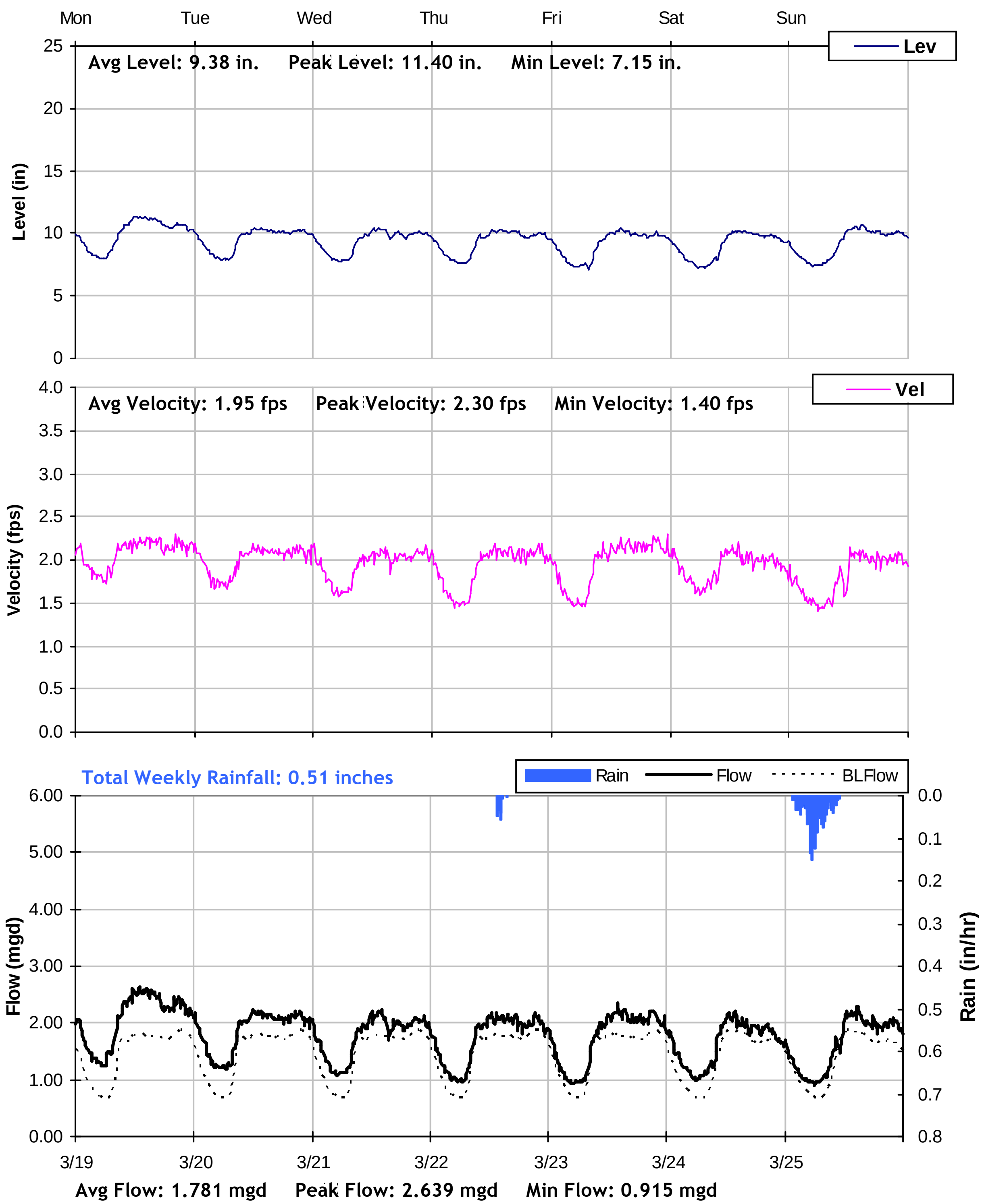
SITE 11
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



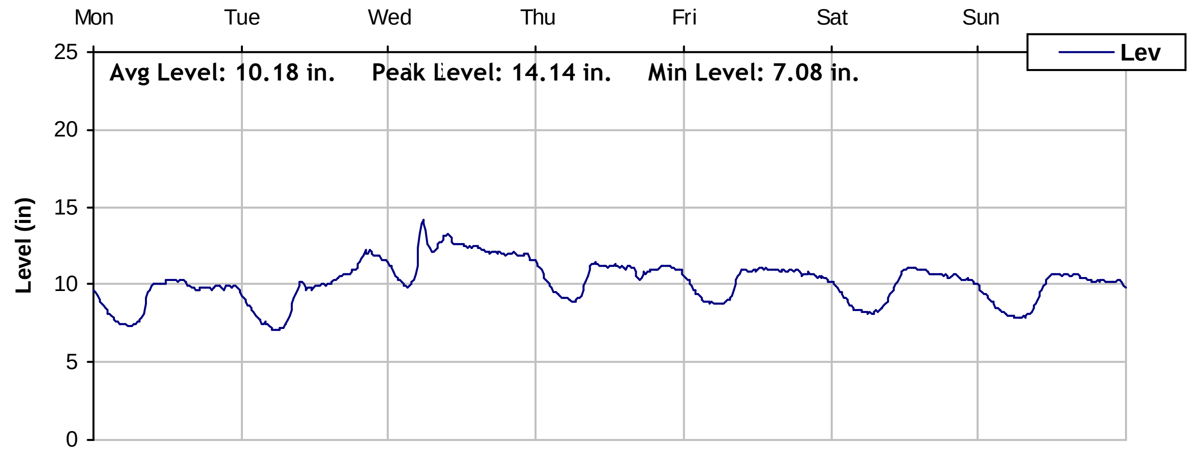
SITE 11
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012

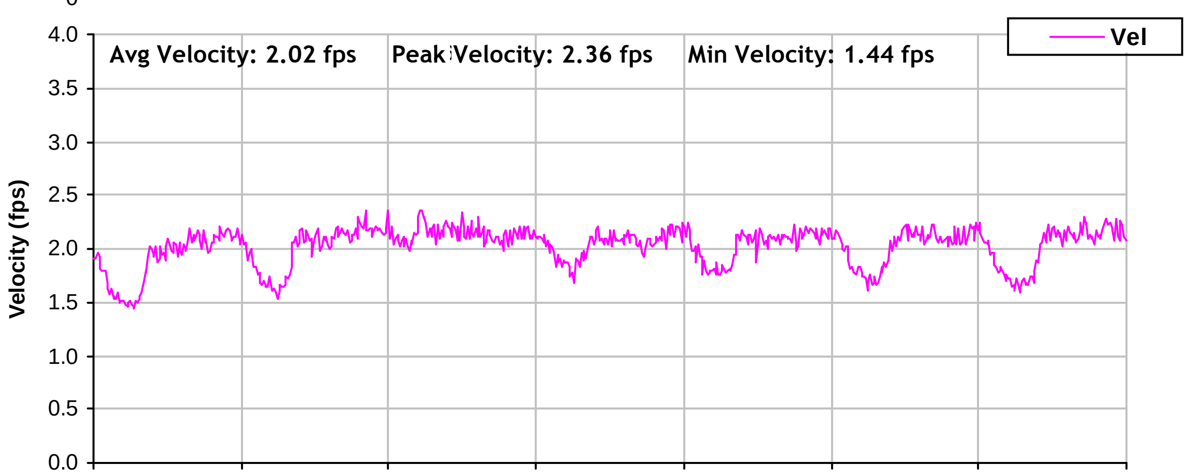


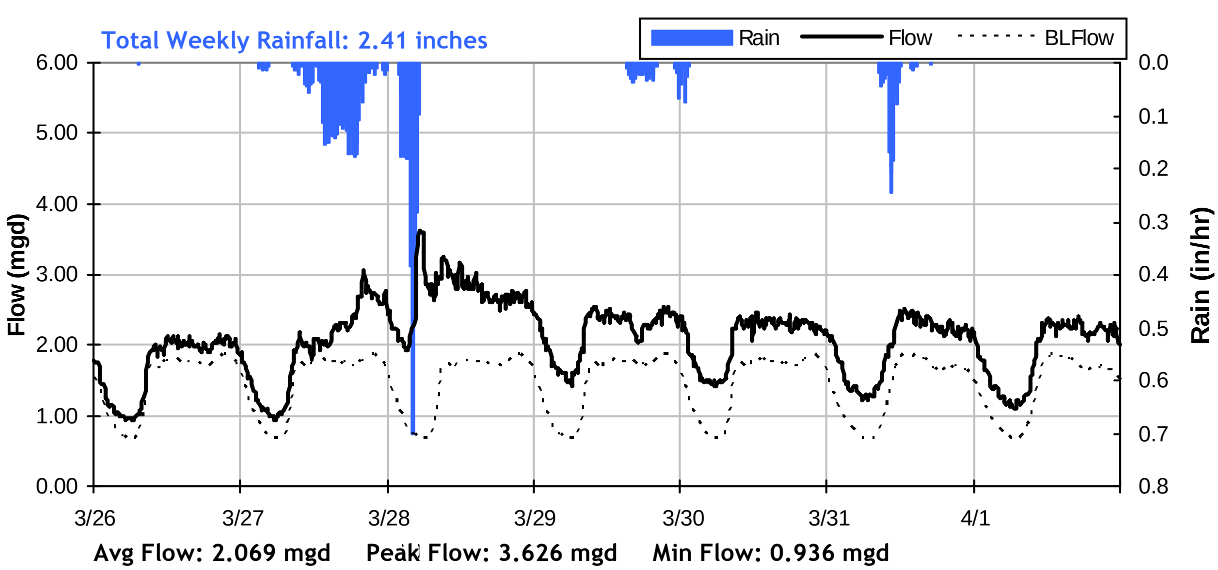
SITE 11
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



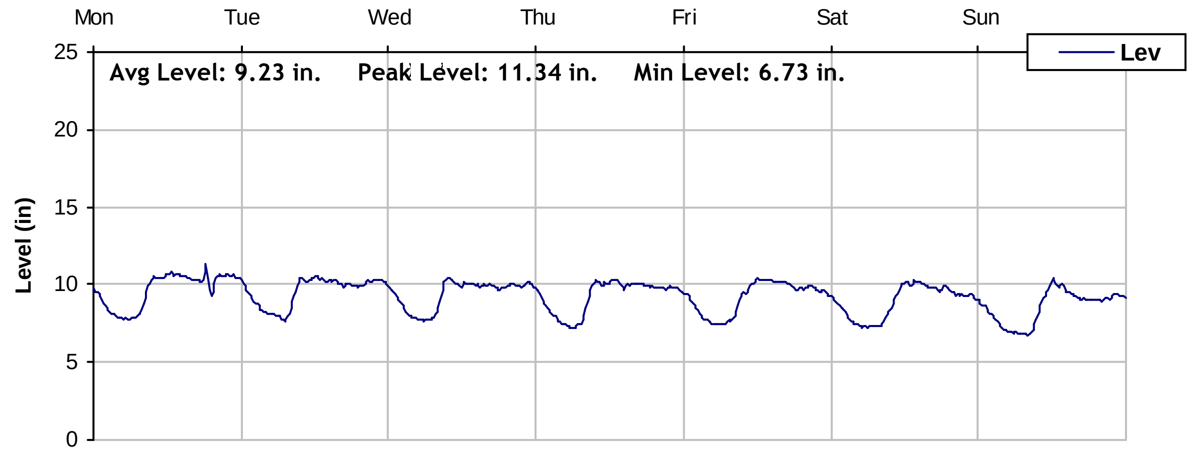
SITE 11
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012

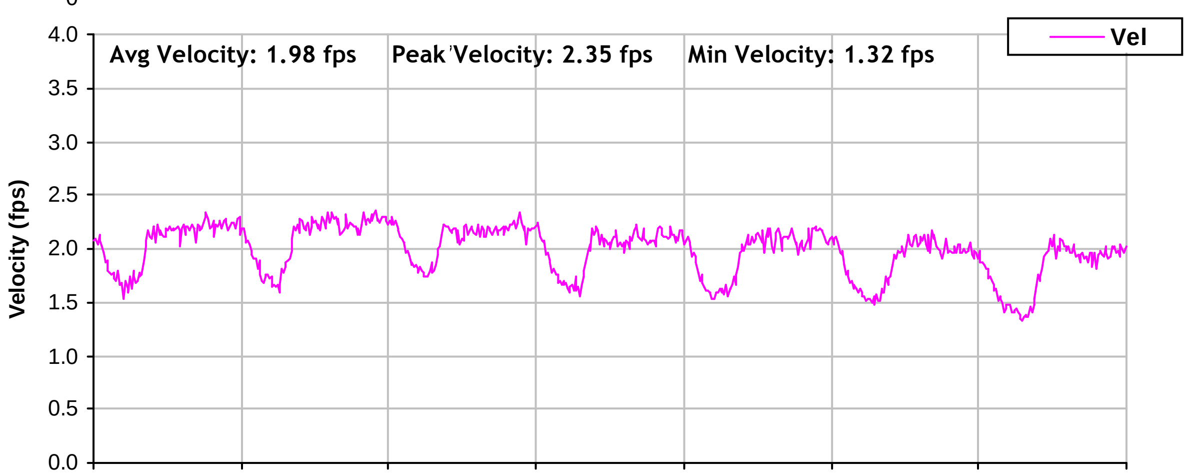


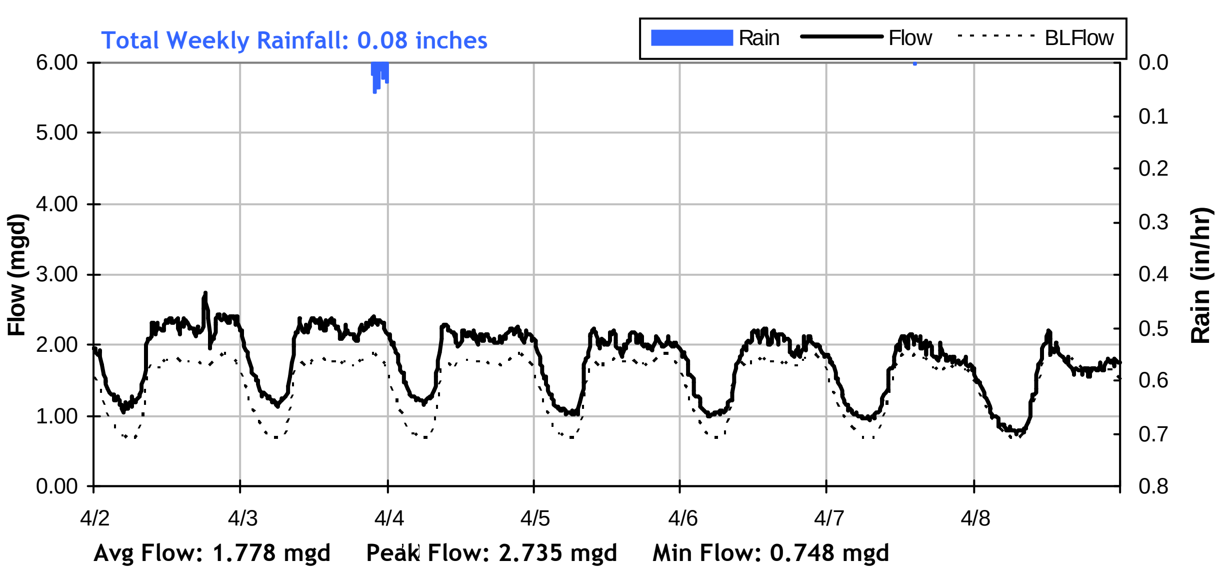




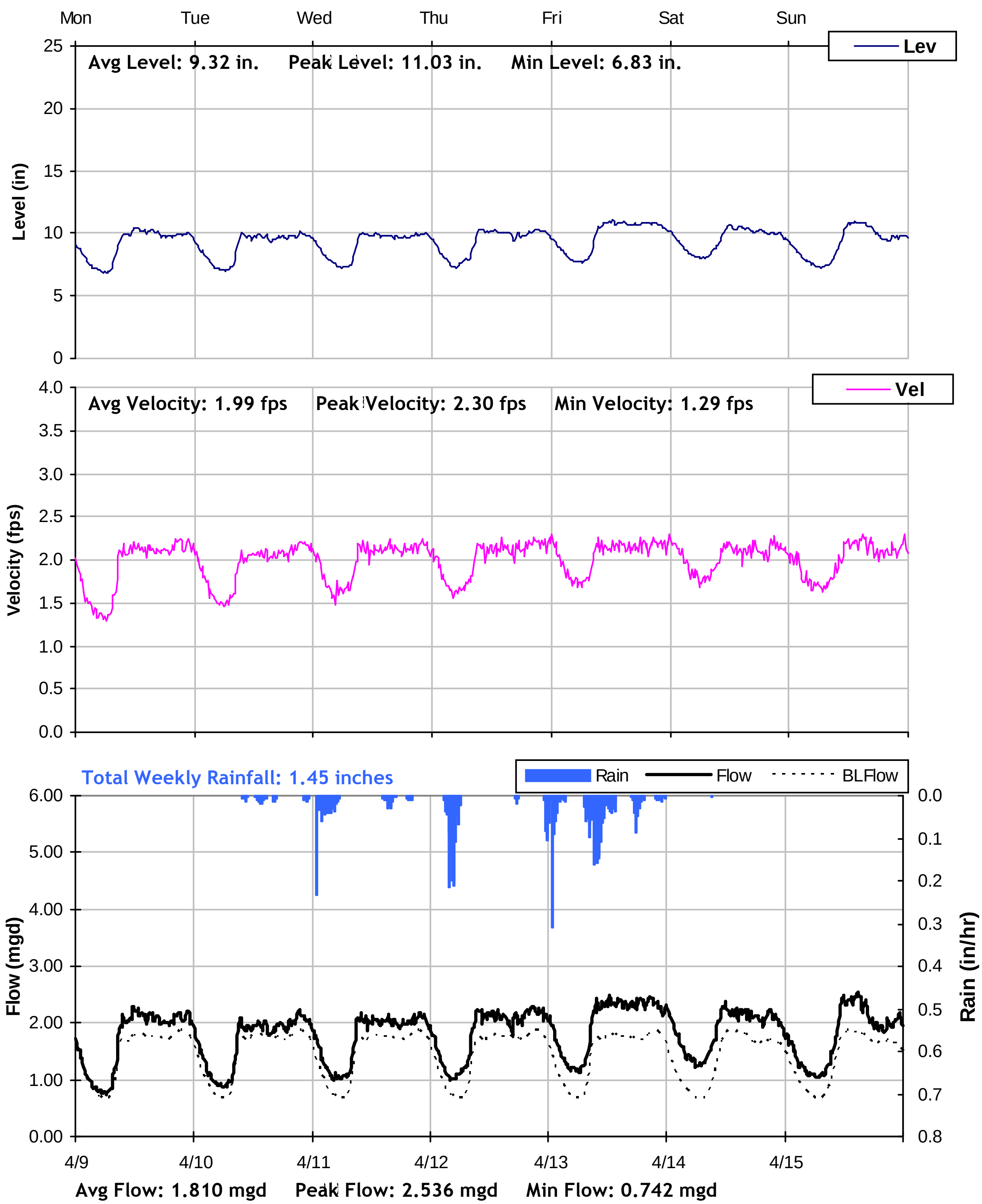
SITE 11
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



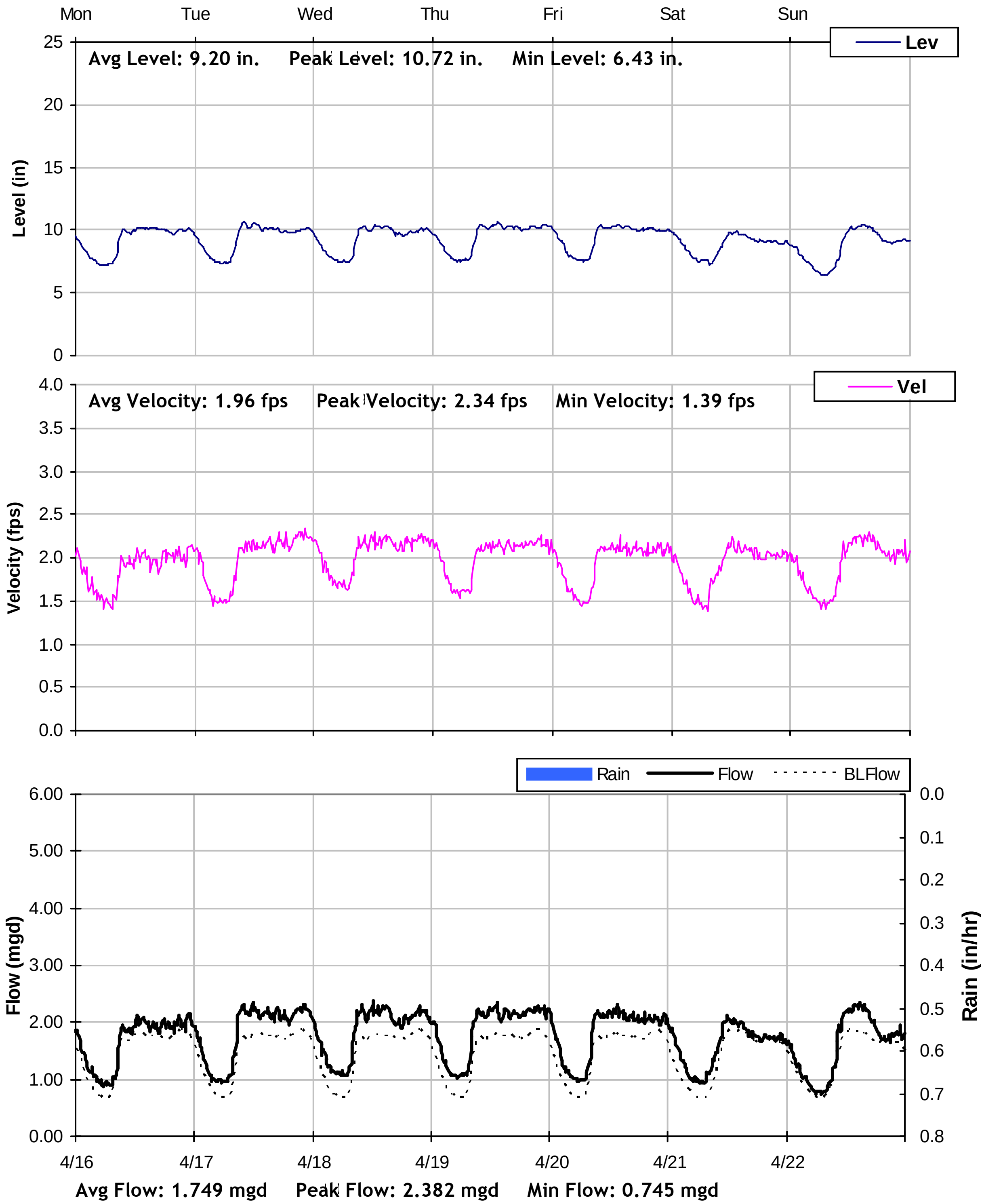




SITE 11
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



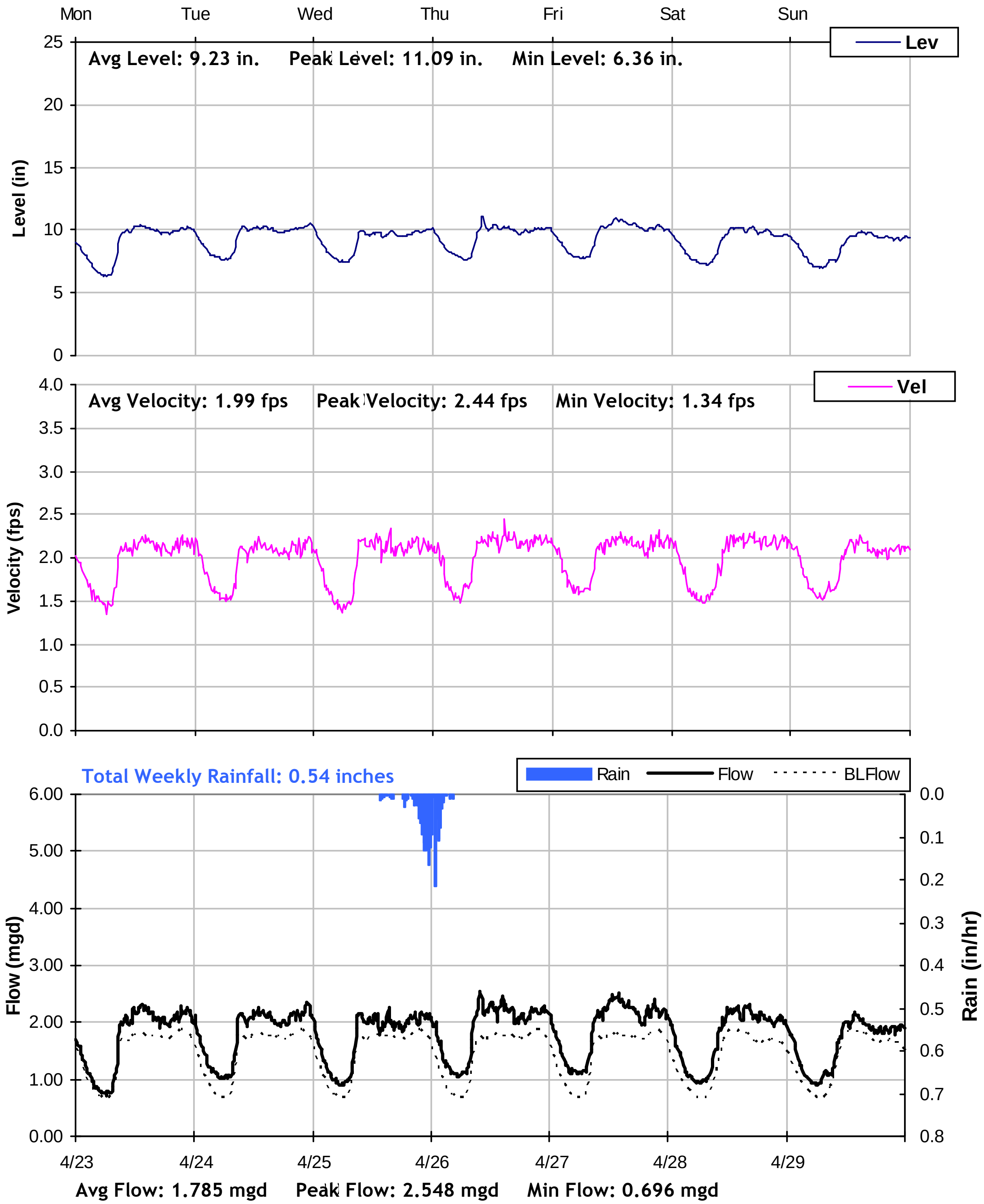
SITE 11
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012



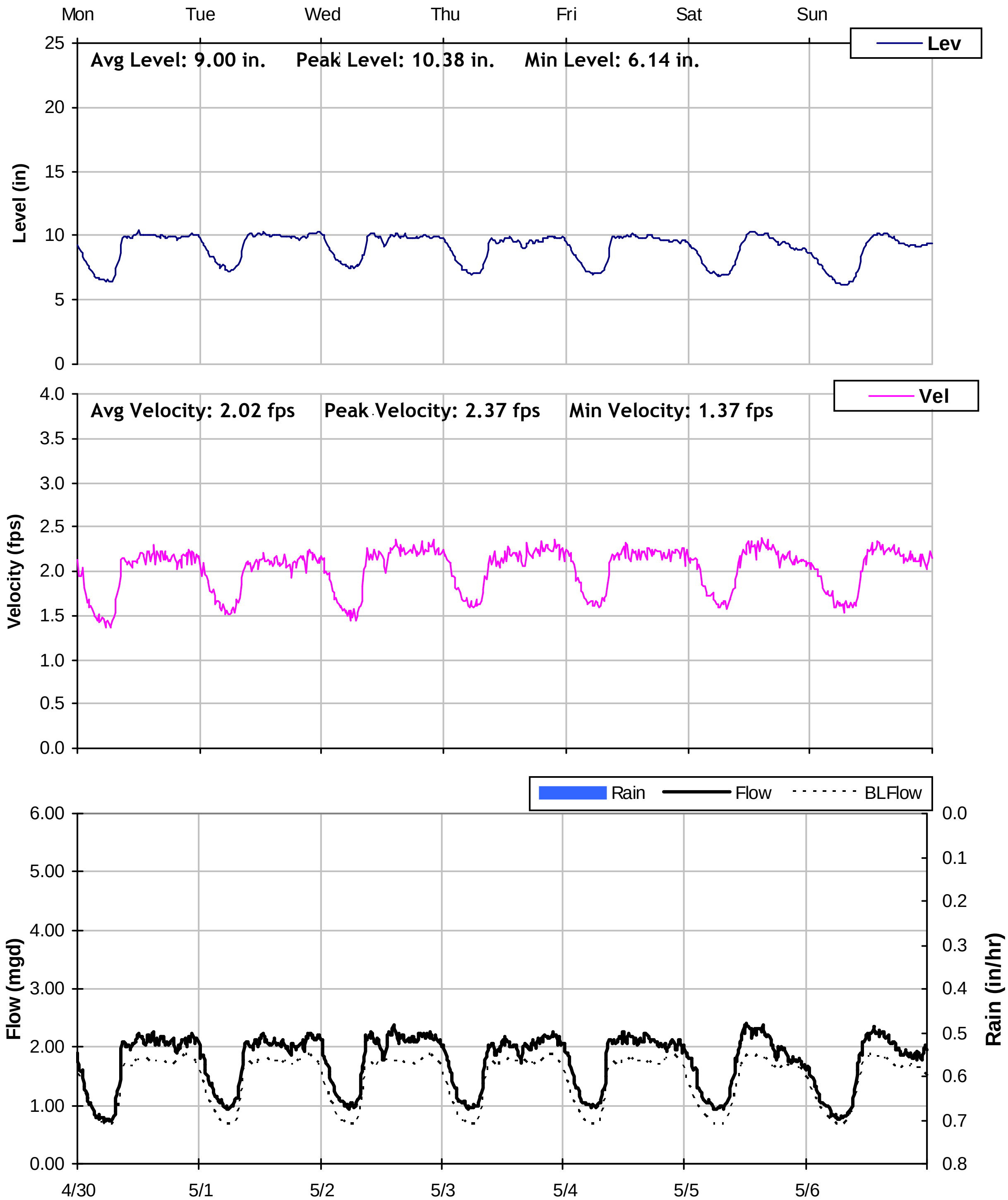
SITE 11

Weekly Level, Velocity and Flow Hydrographs

4/23/2012 to 4/30/2012



SITE 11
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



Avg Flow: 1.753 mgd Peak Flow: 2.392 mgd Min Flow: 0.722 mgd

City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 12

Location: West 5th Street at Hickory Street

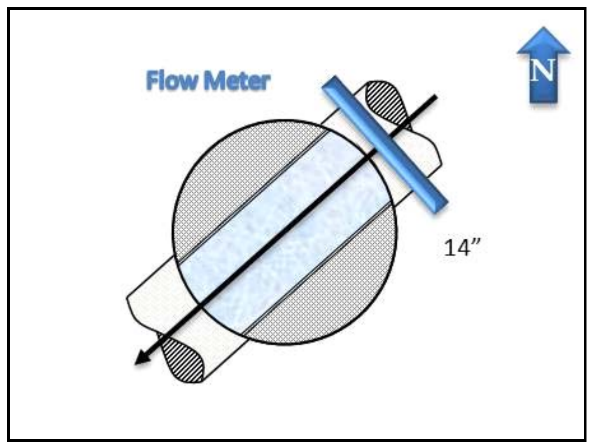
Vicinity Map:

SITE 12
Site Information Report

Location:	West 5th Street at Hickory Street
Coordinates:	121.8500° W, 39.7203° N
Elevation:	184 feet
Diameter:	14 inches
Baseline Flow:	0.227 mgd
Peak Measured Flow:	0.515 mgd

Satellite Map

Sanitary Sewer Map



Flow Sketch

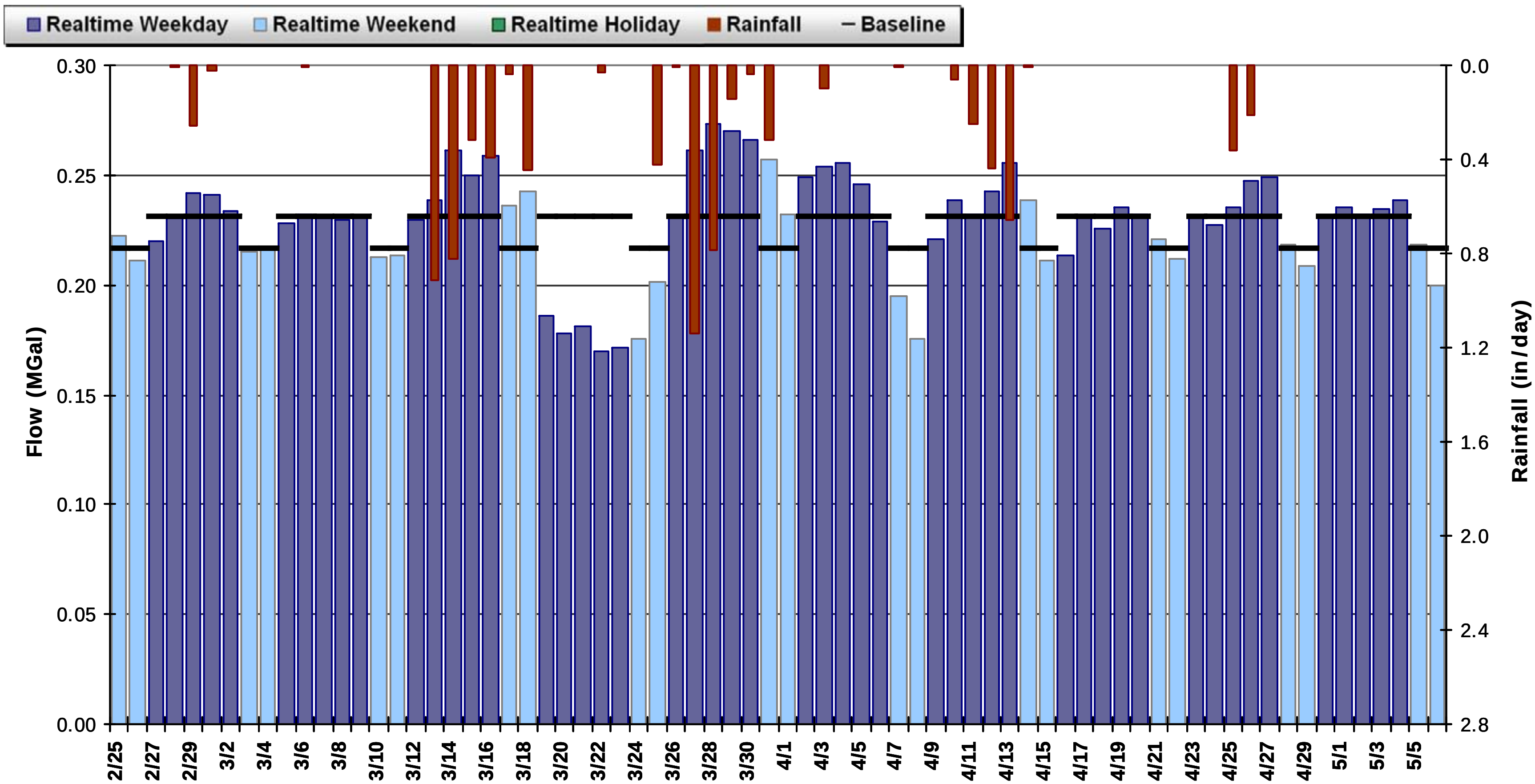
View from Street

Plan View

SITE 12
Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.228 MGal **Peak Daily Flow: 0.274 MGal** **Min Daily Flow: 0.170 MGal**

Total Period Rainfall: 8.21 inches

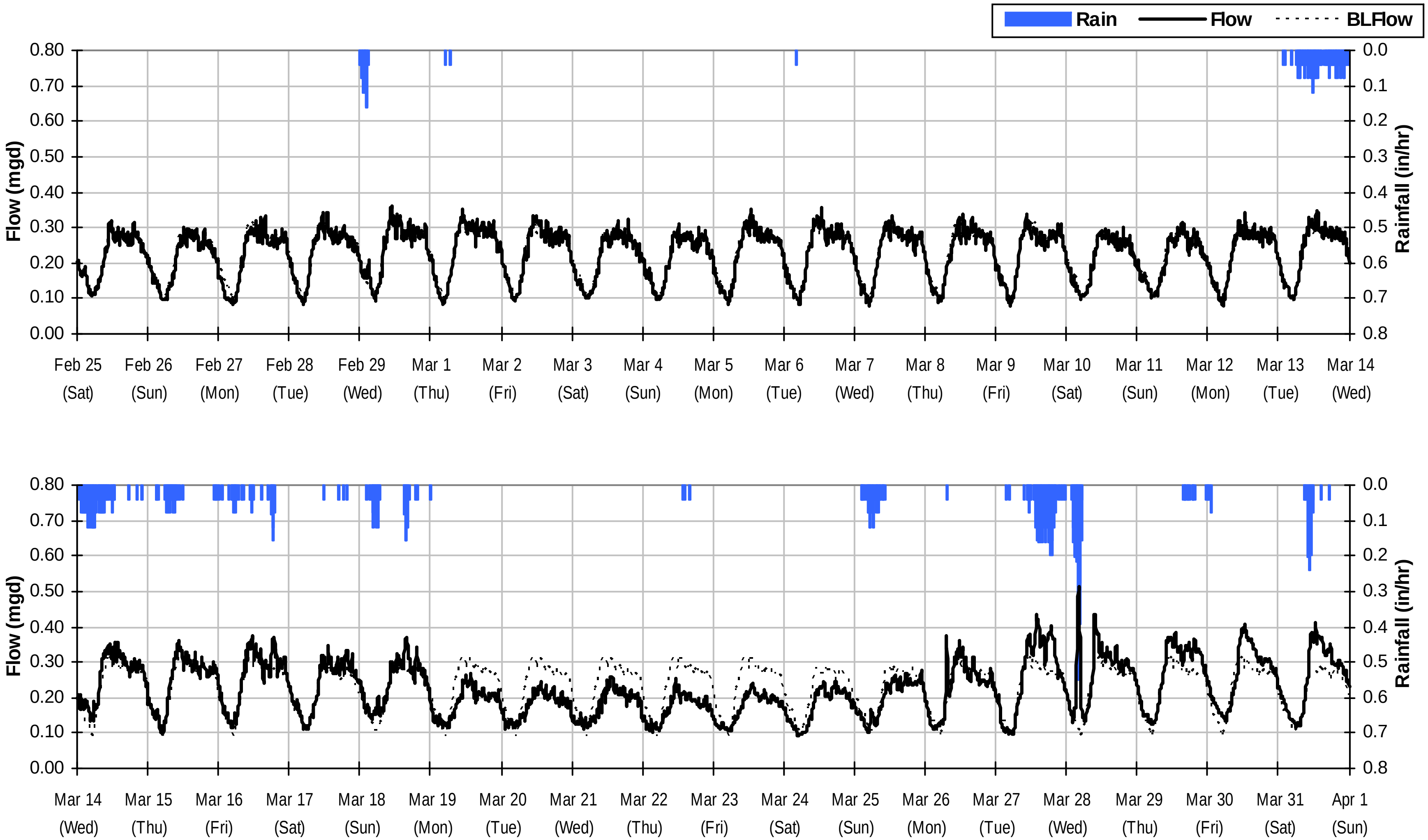


SITE 12

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.226 mgd **Peak Flow: 0.515 mgd** **Min Flow: 0.078 mgd**

Total Period Rainfall: 6.11 inches

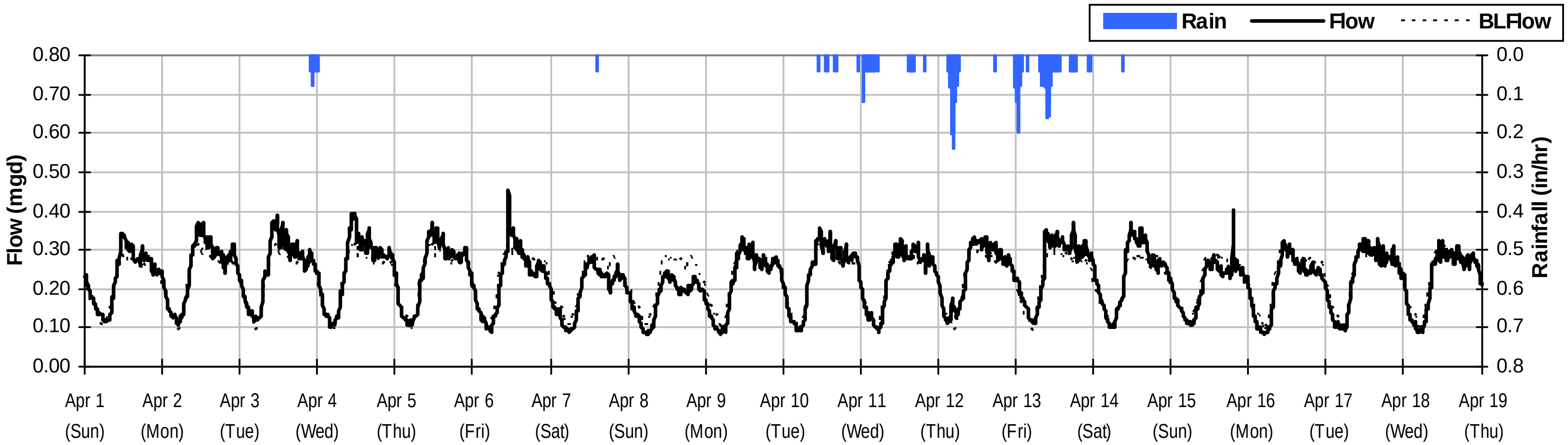


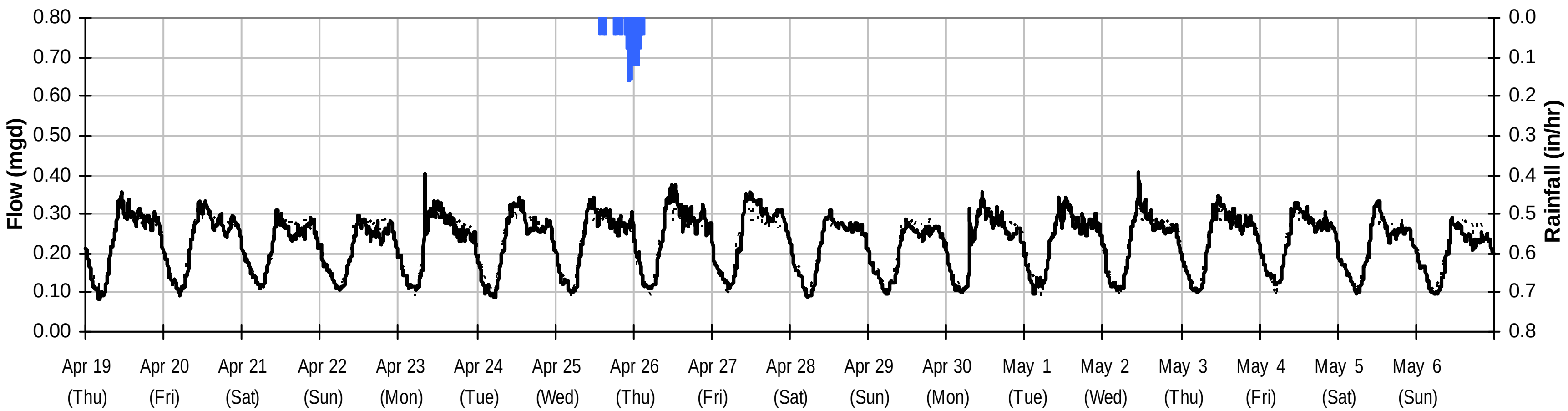
SITE 12

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.229 mgd   Peak Flow: 0.455 mgd   Min Flow: 0.081 mgd

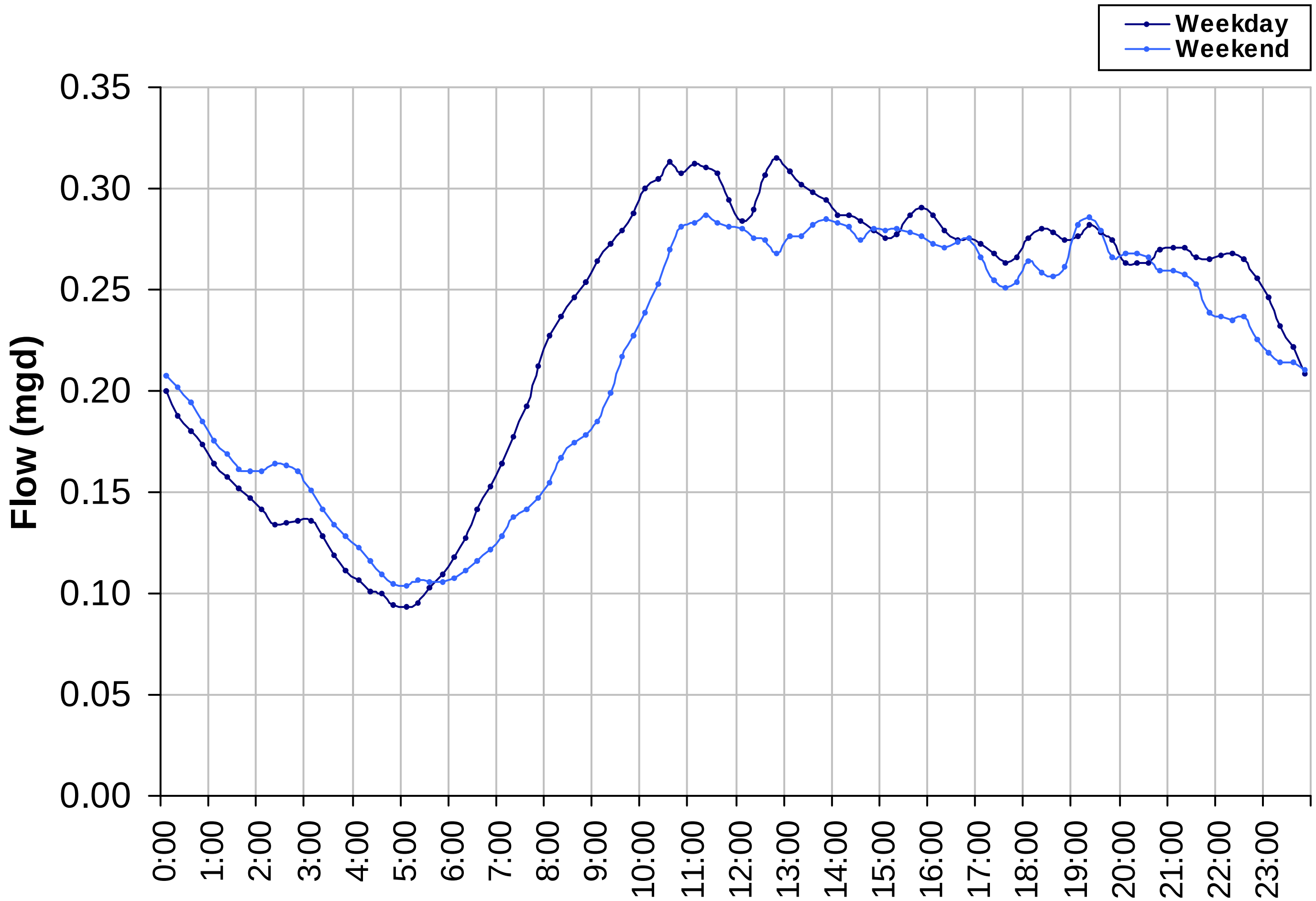
Total Period Rainfall: 2.10 inches





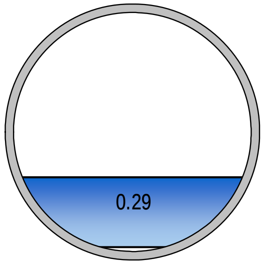
SITE 12

Baseline Flow Hydrographs



Baseline Flow:

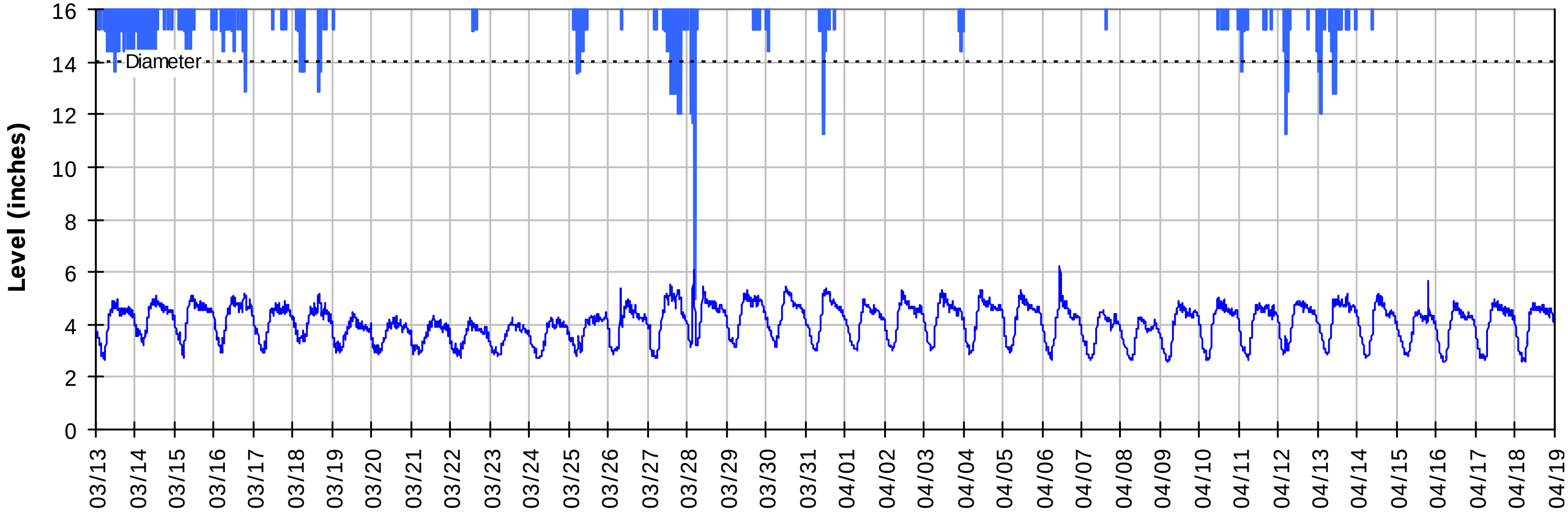
0.227 *mgd*

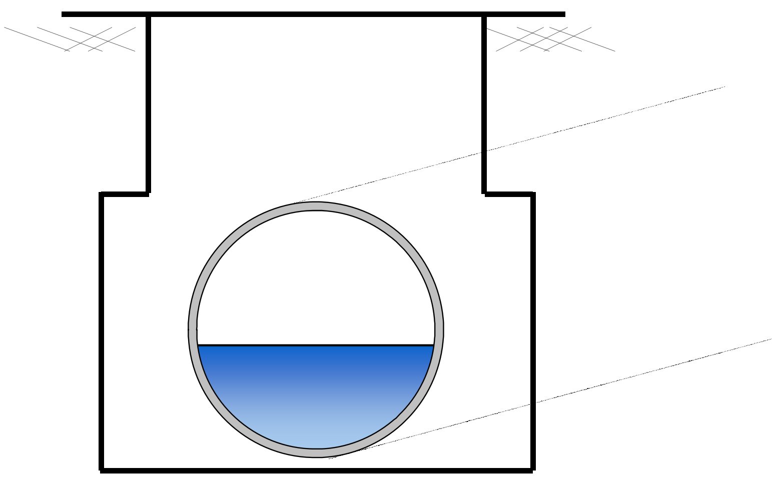


SITE 12

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





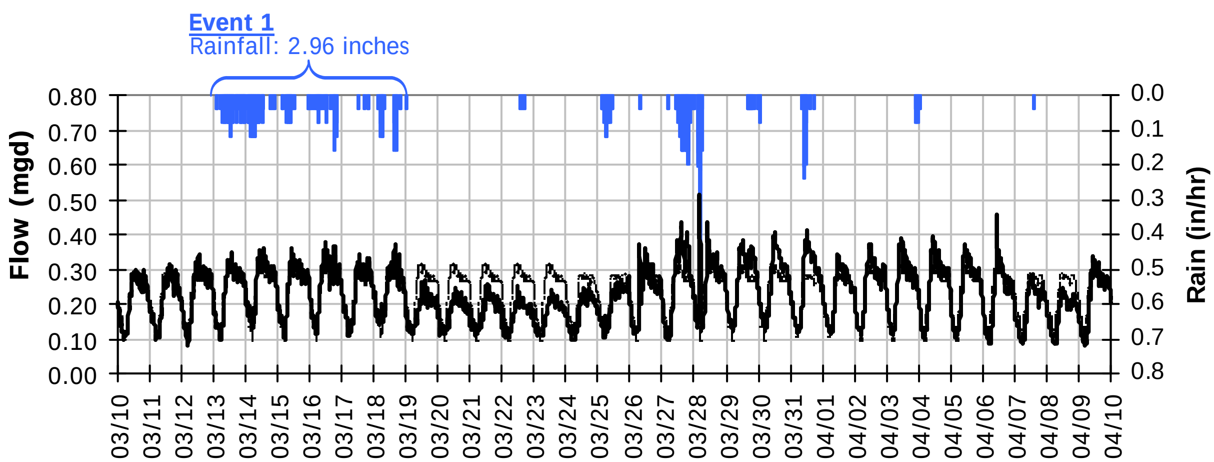
Pipe Diameter: 14 *inches*

Peak Measured Level: 6.24 *inches*

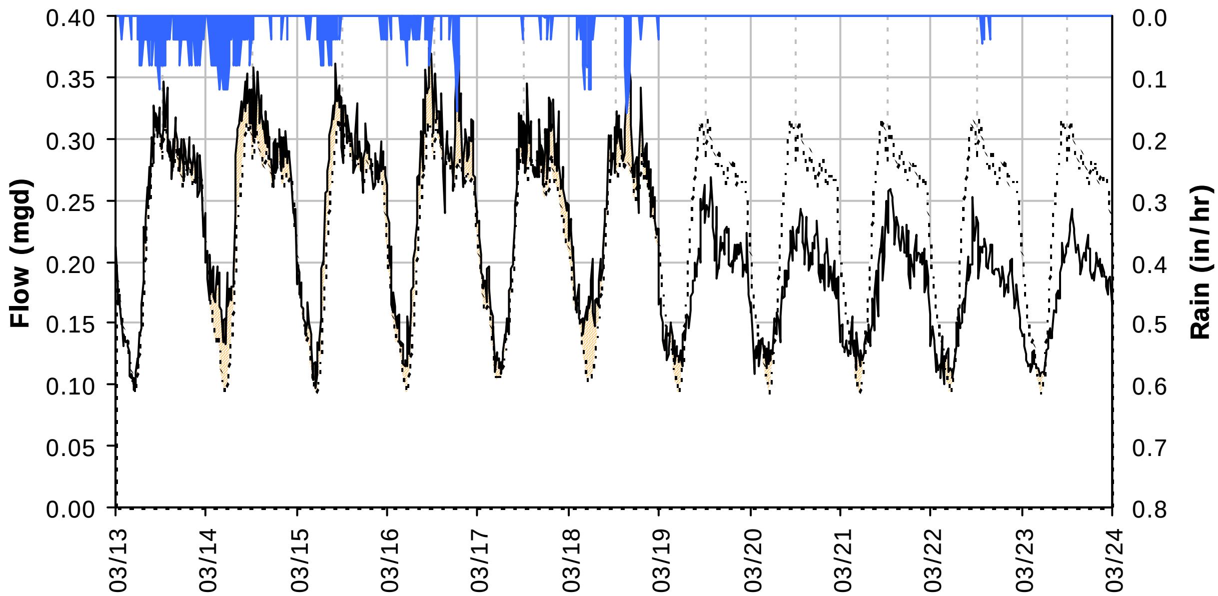
Peak d/D Ratio: 0.45

SITE 12
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 = 2.96 inches)

Capacity

Peak Flow: 0.37 *mgd*
PF: 1.65
Peak Level: 5.15 *in*
d/D Ratio: 0.37

Inflow

Peak I/I Rate: 0.09 *mgd*
Pk I/I:ADWF: 0.41

RDI (infiltration)

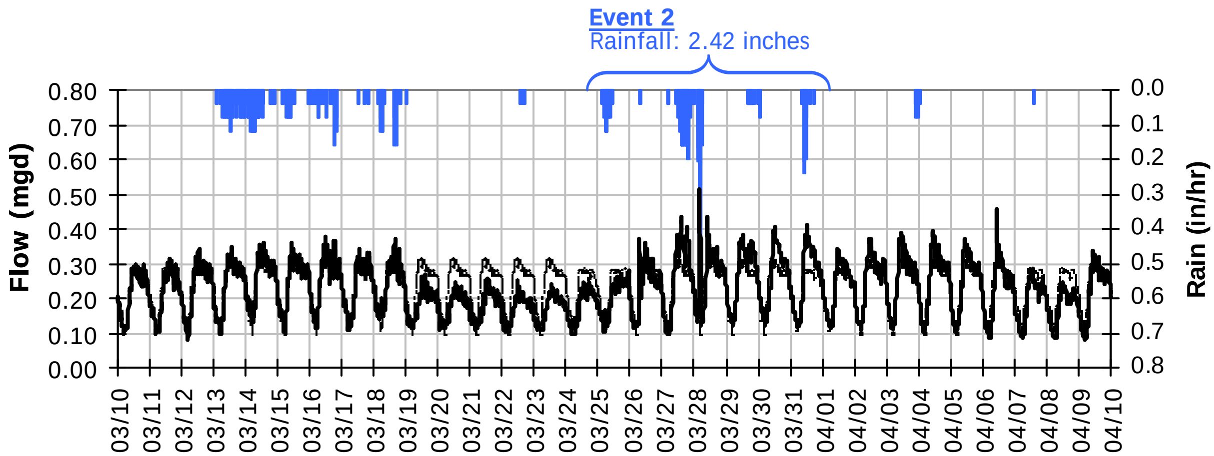
Infiltration Rate: 0.000 *mgd*
(3/20/2012)
RDI (% of BL): 0%

Combined I/I

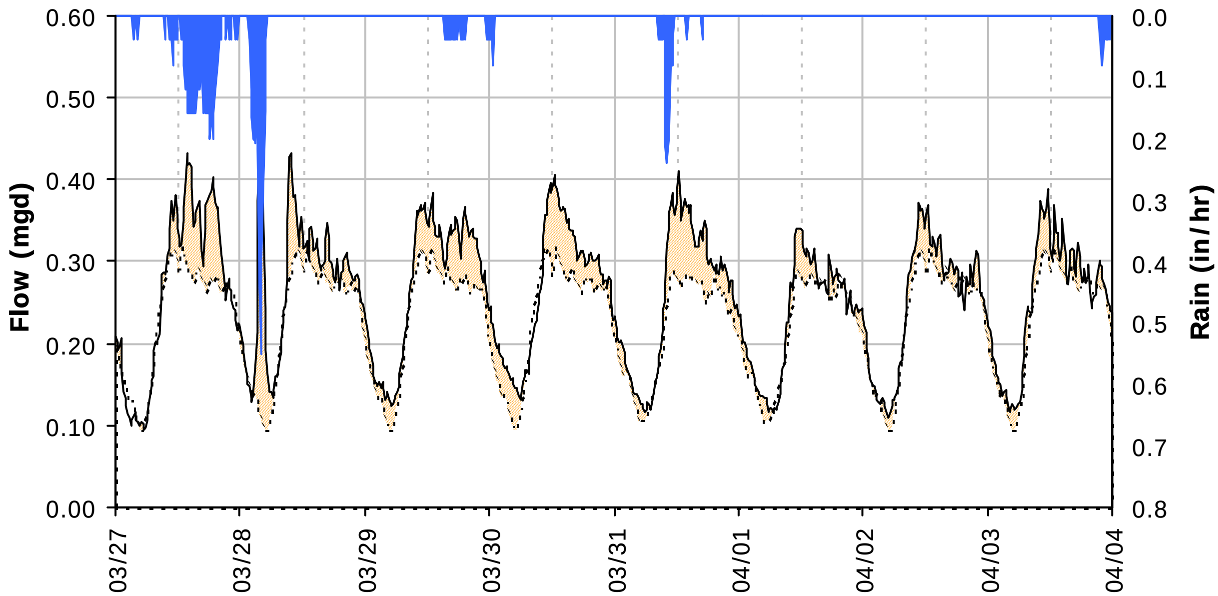
Total I/I: -139,000 *gallons*
Total I/I:ADWF: -0.21 *per in-rain*

SITE 12
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph

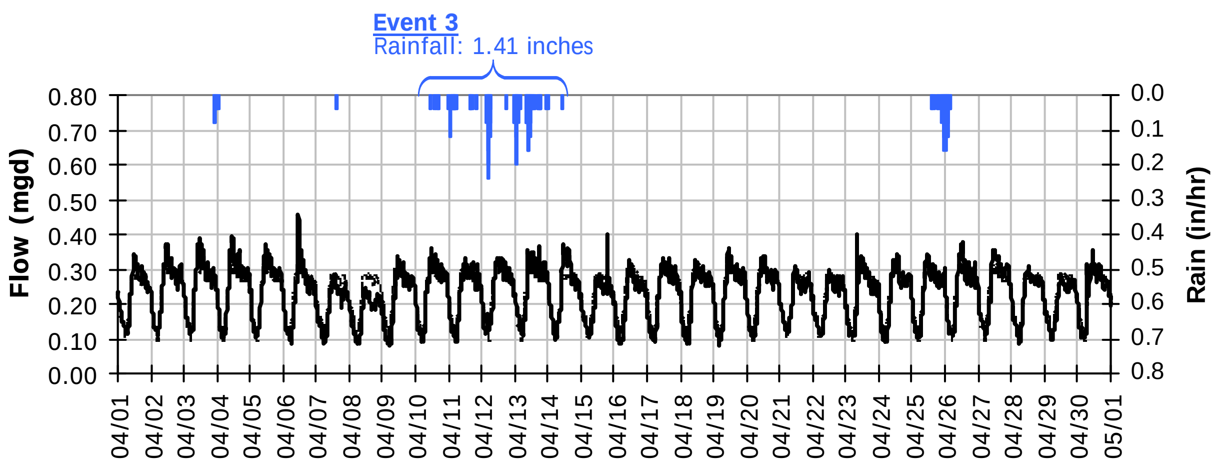


Storm Event I/I Analysis (Rain = 2.42 inches)

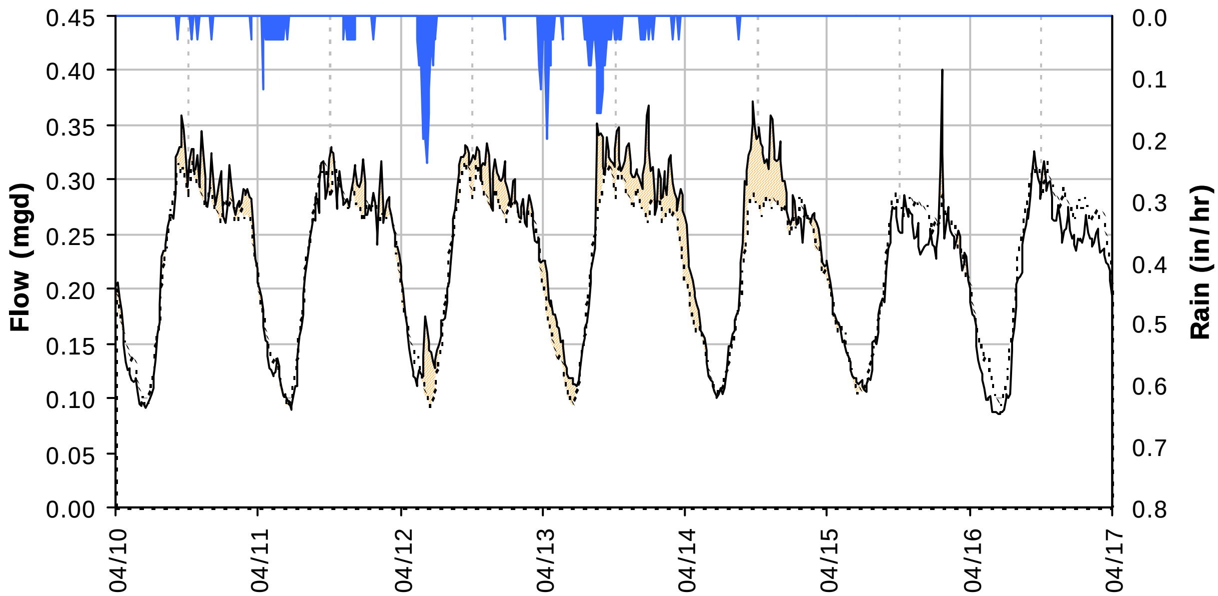
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.51 *mgd*	**Peak I/I Rate:**	0.41 *mgd*	**Infiltration Rate:** (4/2/2012)	0.018 *mgd*	**Total I/I:**	245,000 *gallons*
PF:	2.27	**Pk I/I:ADWF:**	1.80	**RDI (% of BL):**	8%	**Total I/I:ADWF:**	0.44 *per in-rain*
Peak Level:	6.08 *in*						
d/D Ratio:	0.43						

SITE 12
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.41 inches)

Capacity

Peak Flow: 0.40 *mgd*
PF: 1.77
Peak Level: 5.69 *in*
d/D Ratio: 0.41

Inflow

Peak I/I Rate: 0.11 *mgd*
Pk I/I:ADWF: 0.50

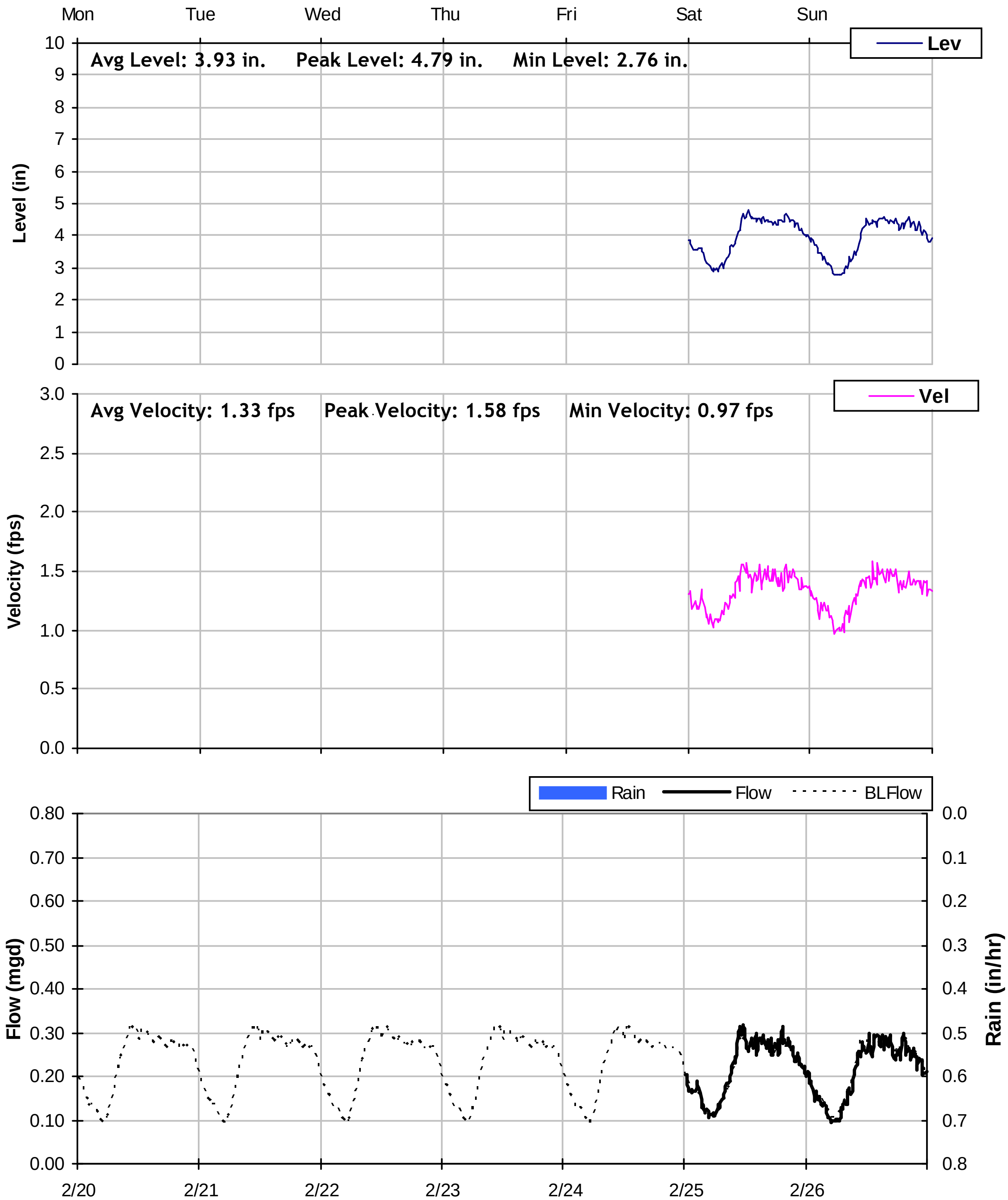
RDI (infiltration)

Infiltration Rate: 0.000 *mgd*
(4/15/2012)
RDI (% of BL): 0%

Combined I/I

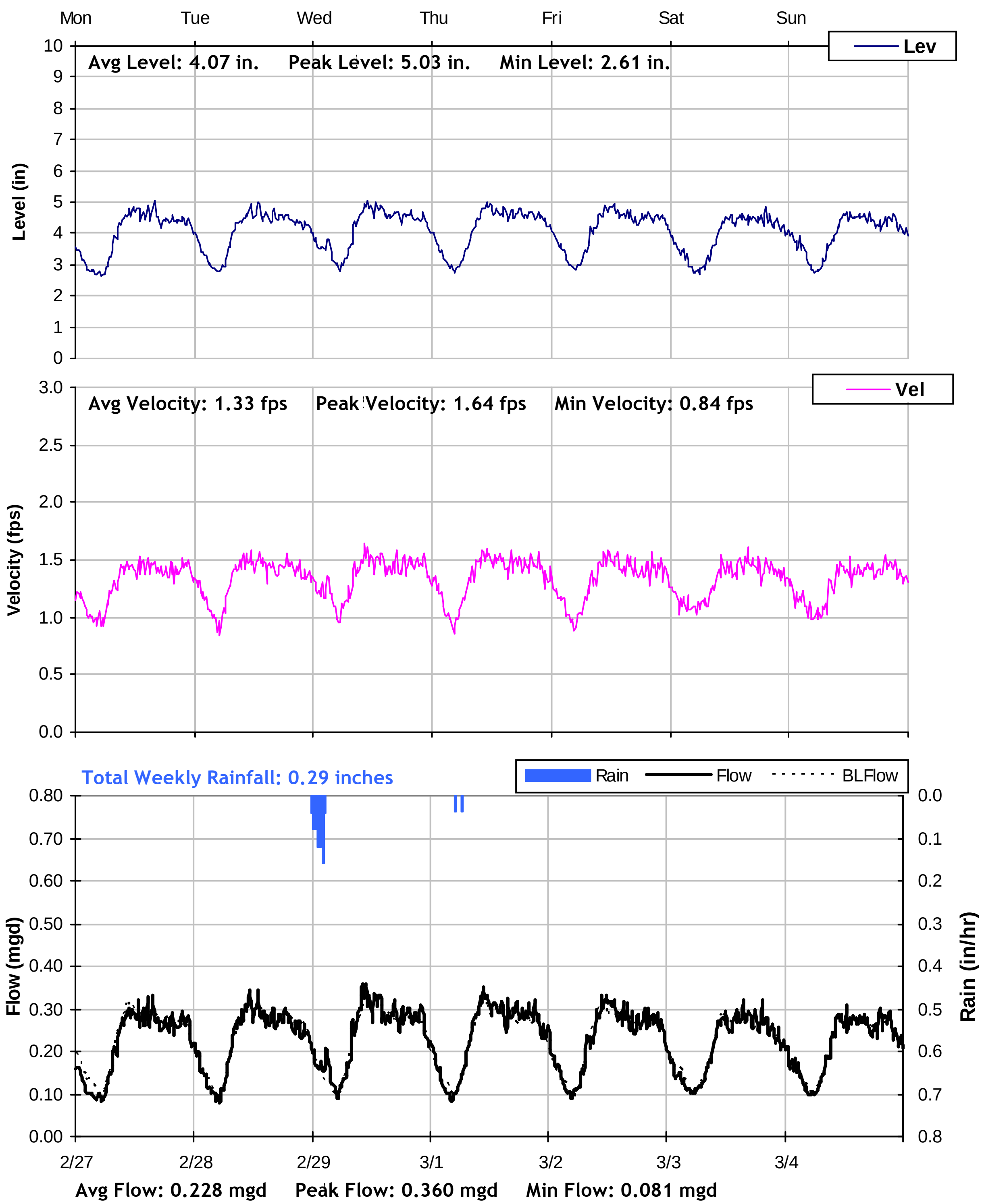
Total I/I: 44,000 *gallons*
Total I/I:ADWF: 0.14 *per in-rain*

SITE 12
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



Avg Flow: 0.217 mgd Peak Flow: 0.317 mgd Min Flow: 0.095 mgd

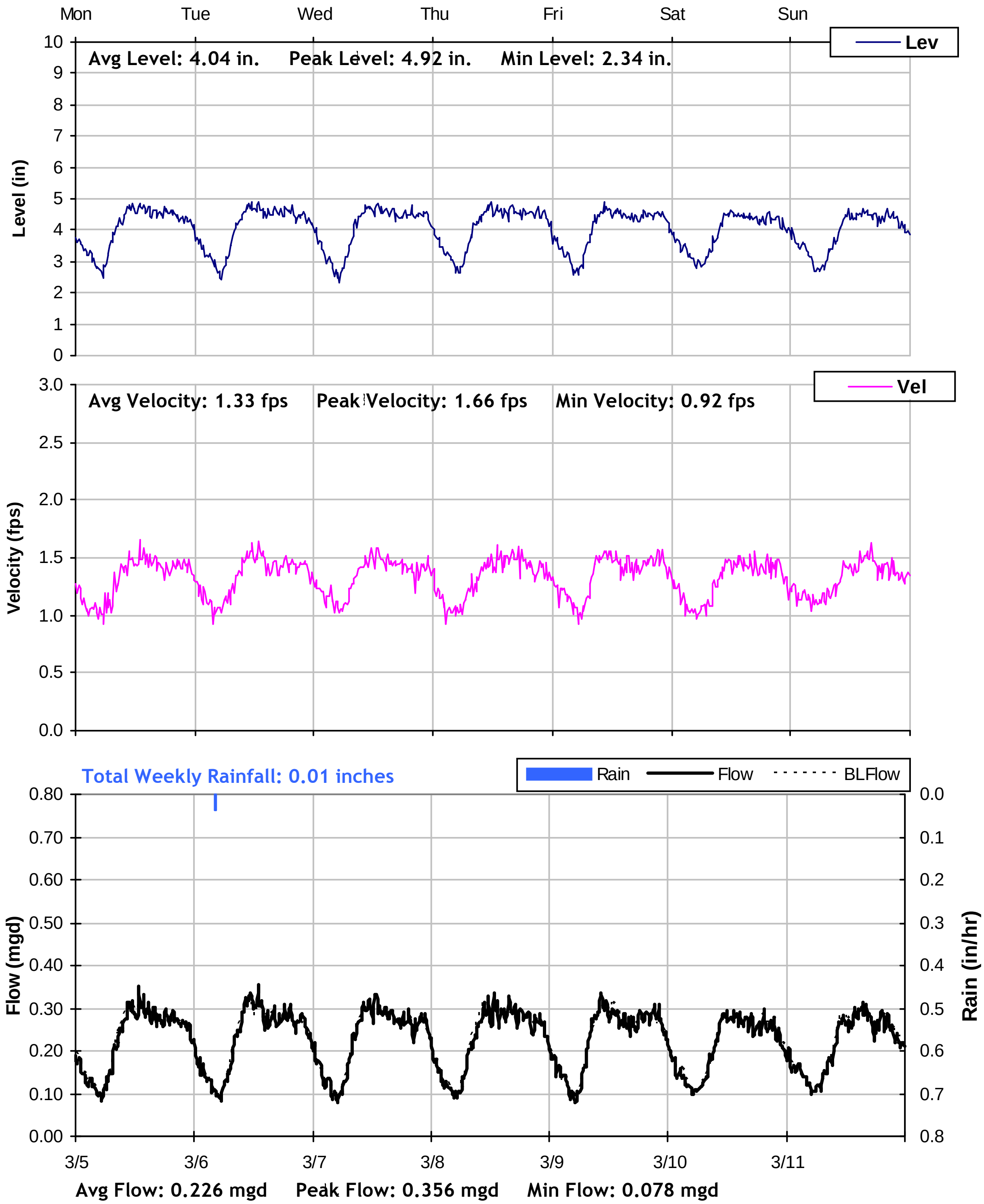
SITE 12
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



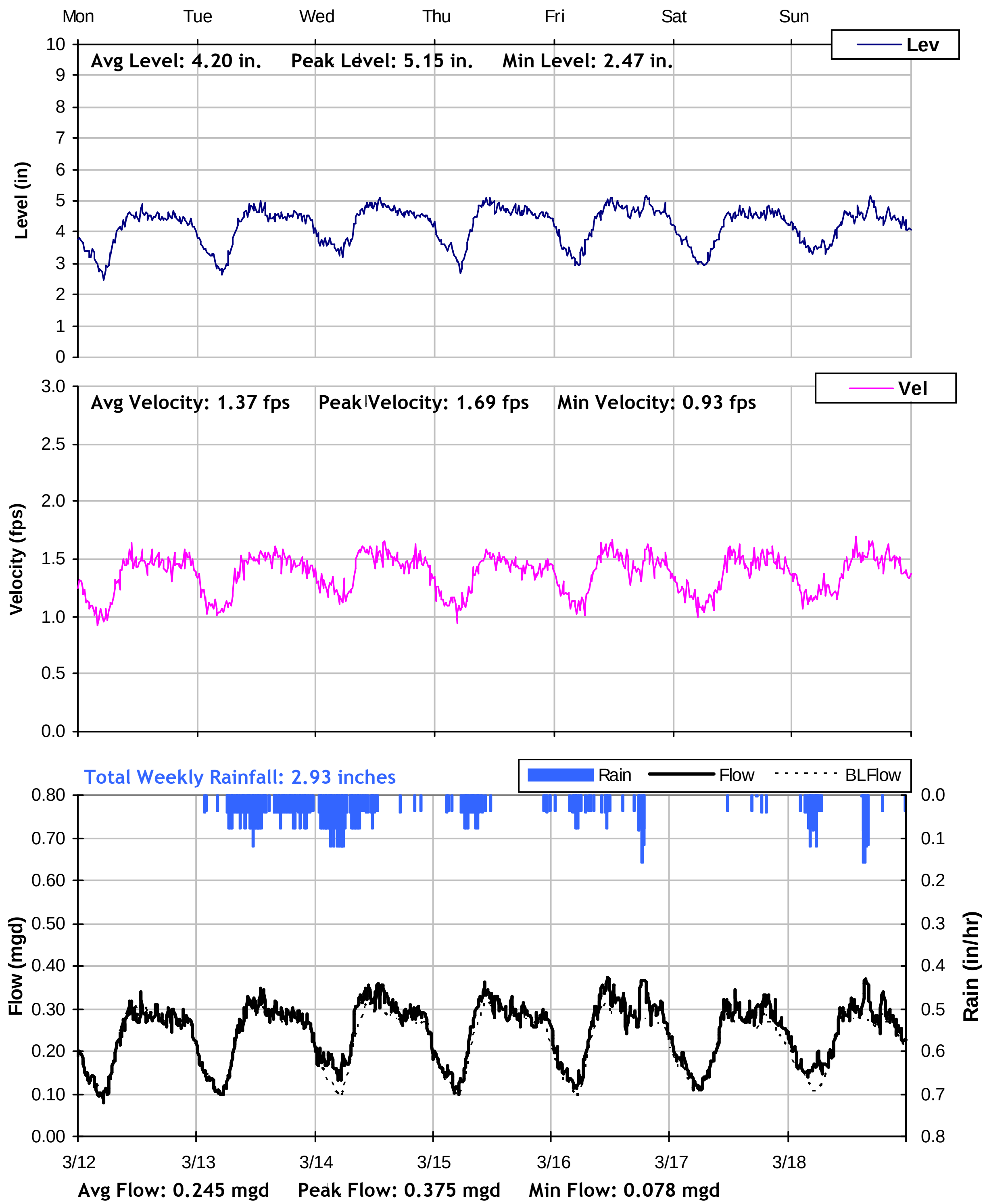
SITE 12

Weekly Level, Velocity and Flow Hydrographs

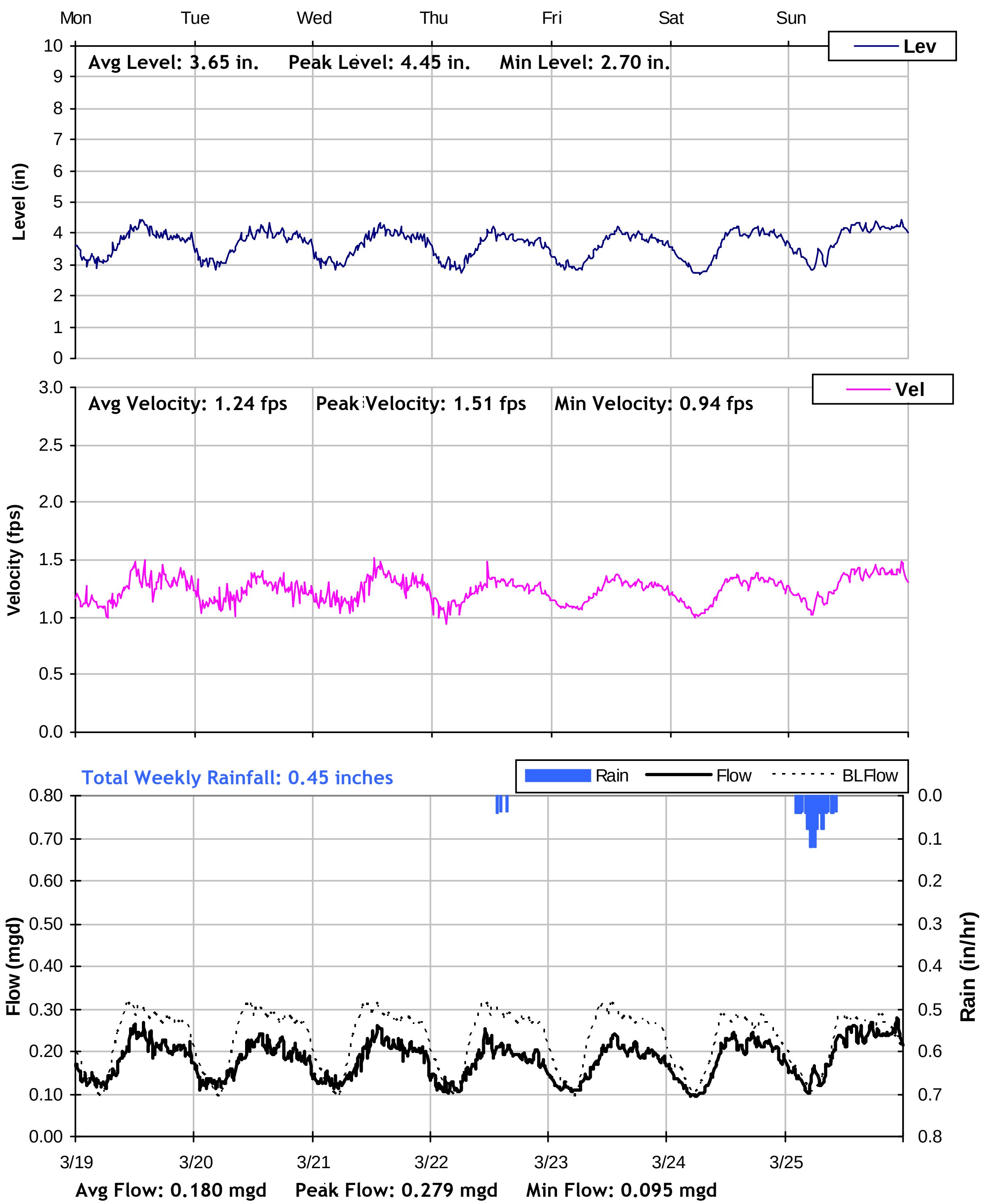
3/5/2012 to 3/12/2012



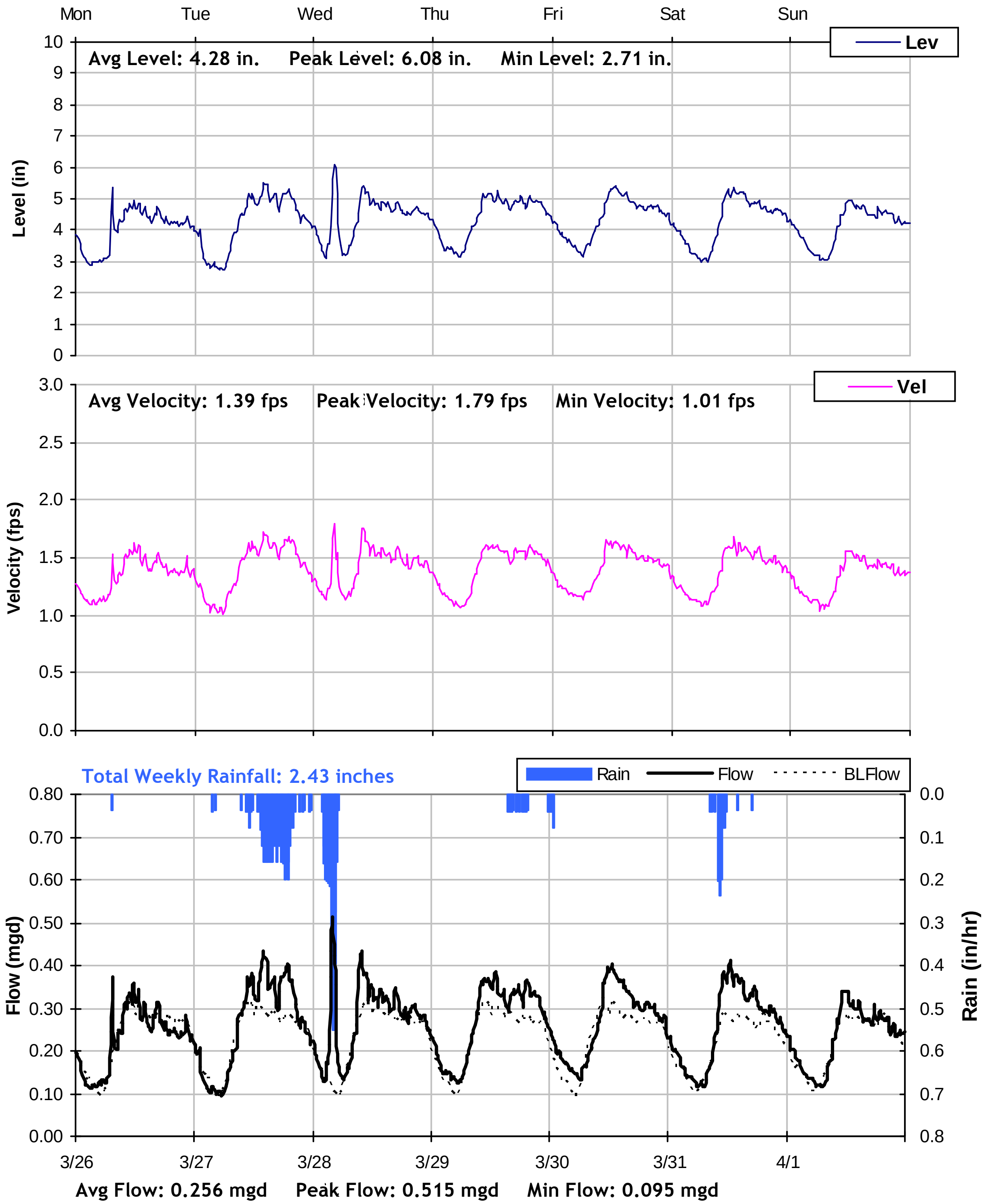
SITE 12
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



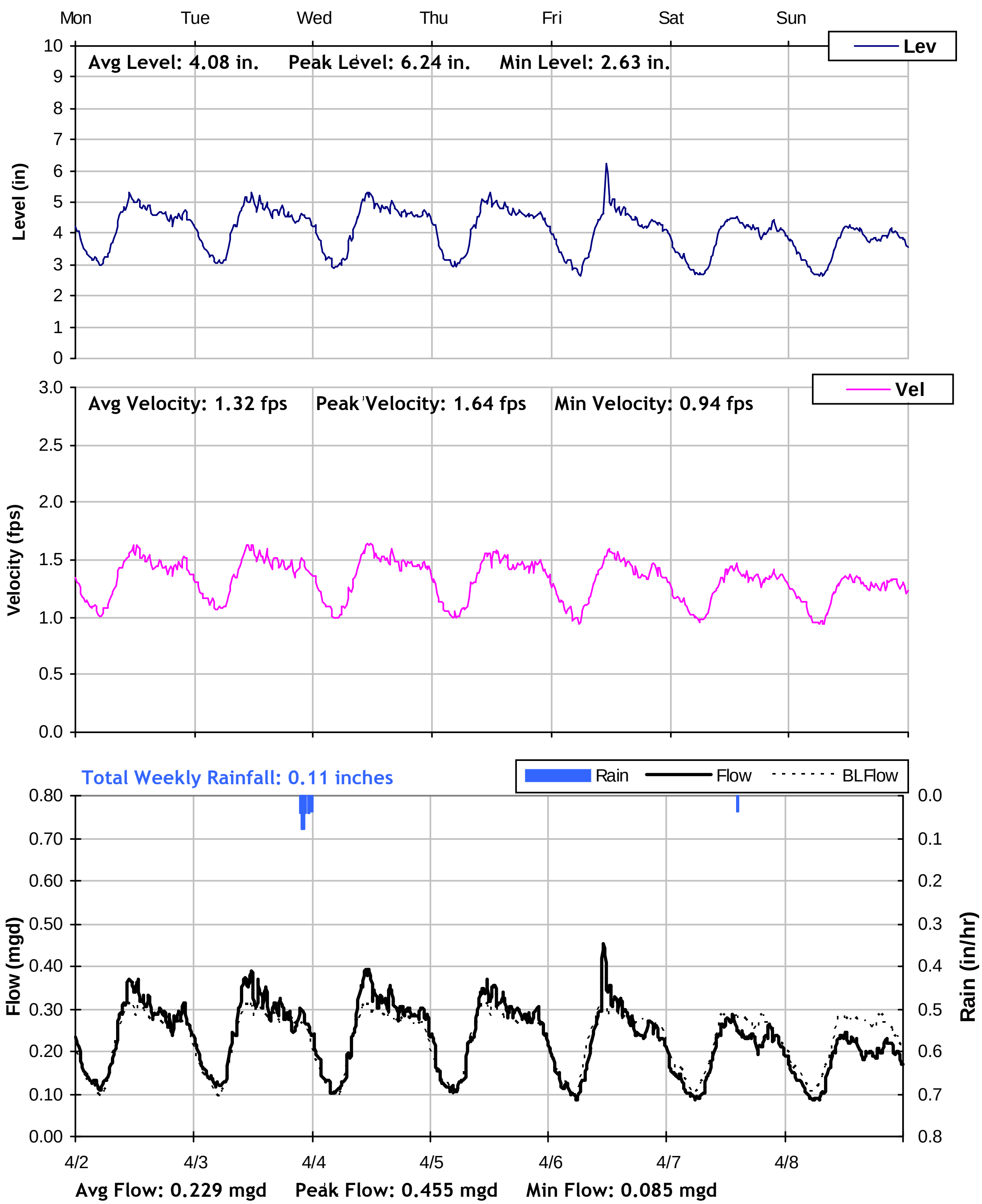
SITE 12
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



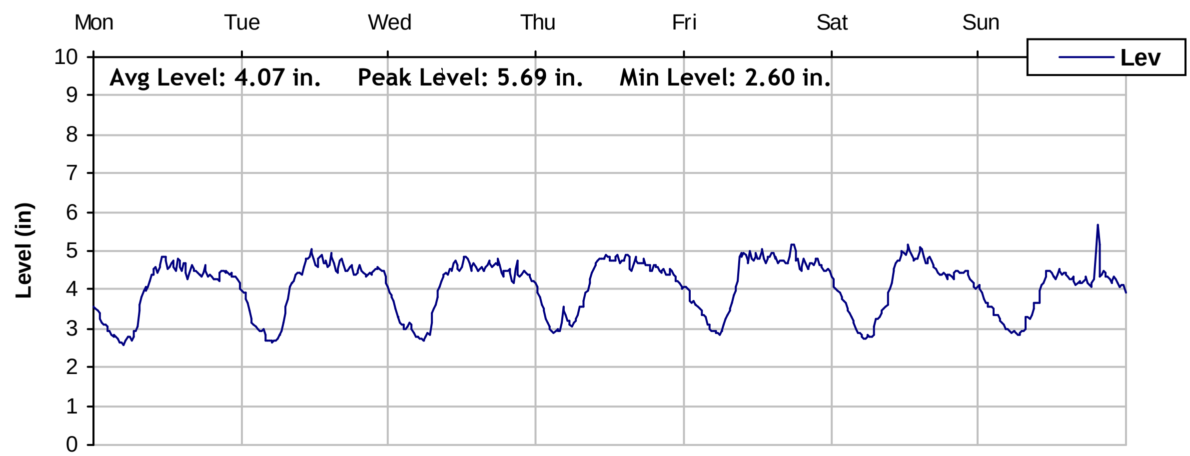
SITE 12
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012

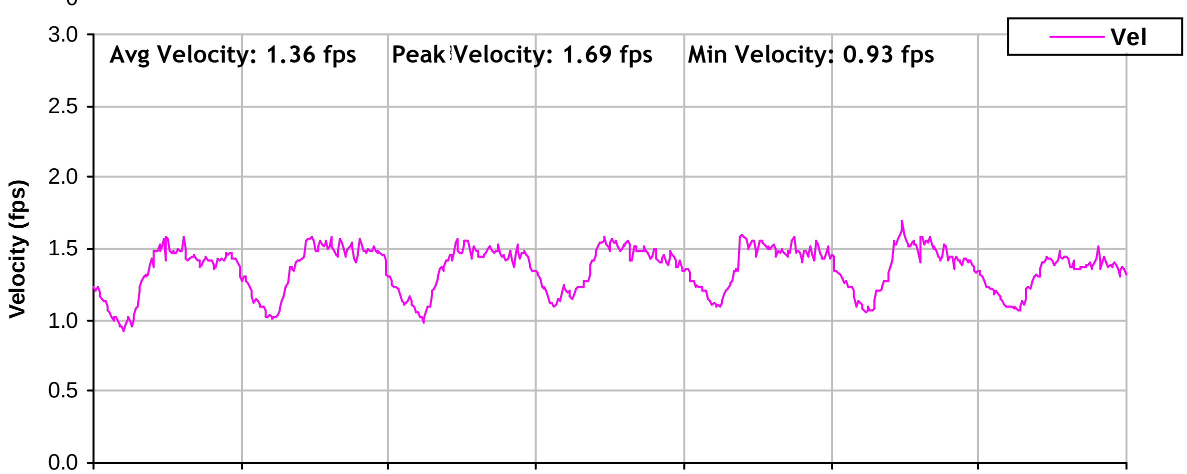


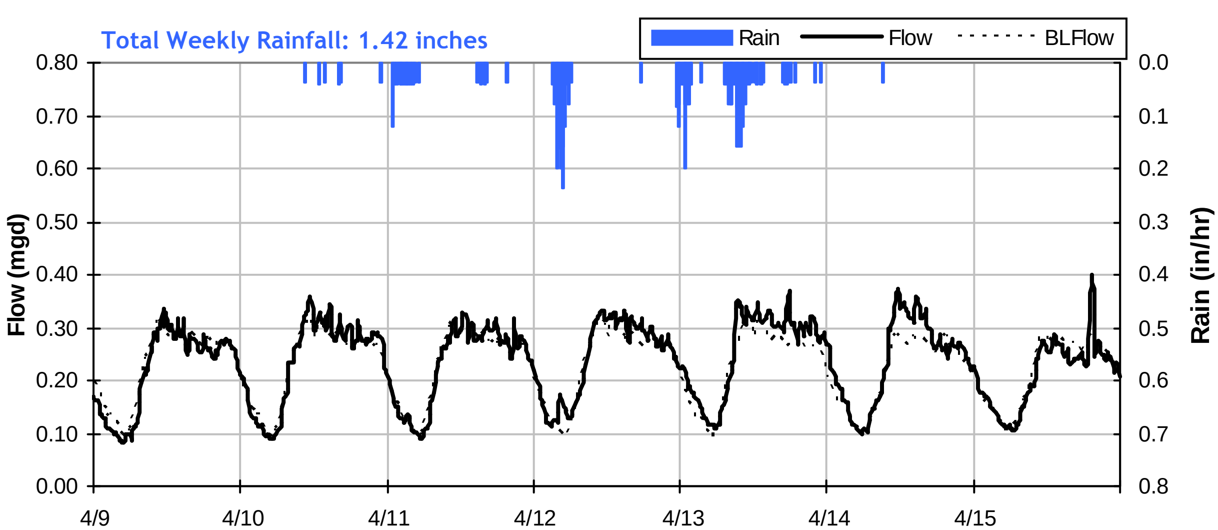
SITE 12
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



SITE 12
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012





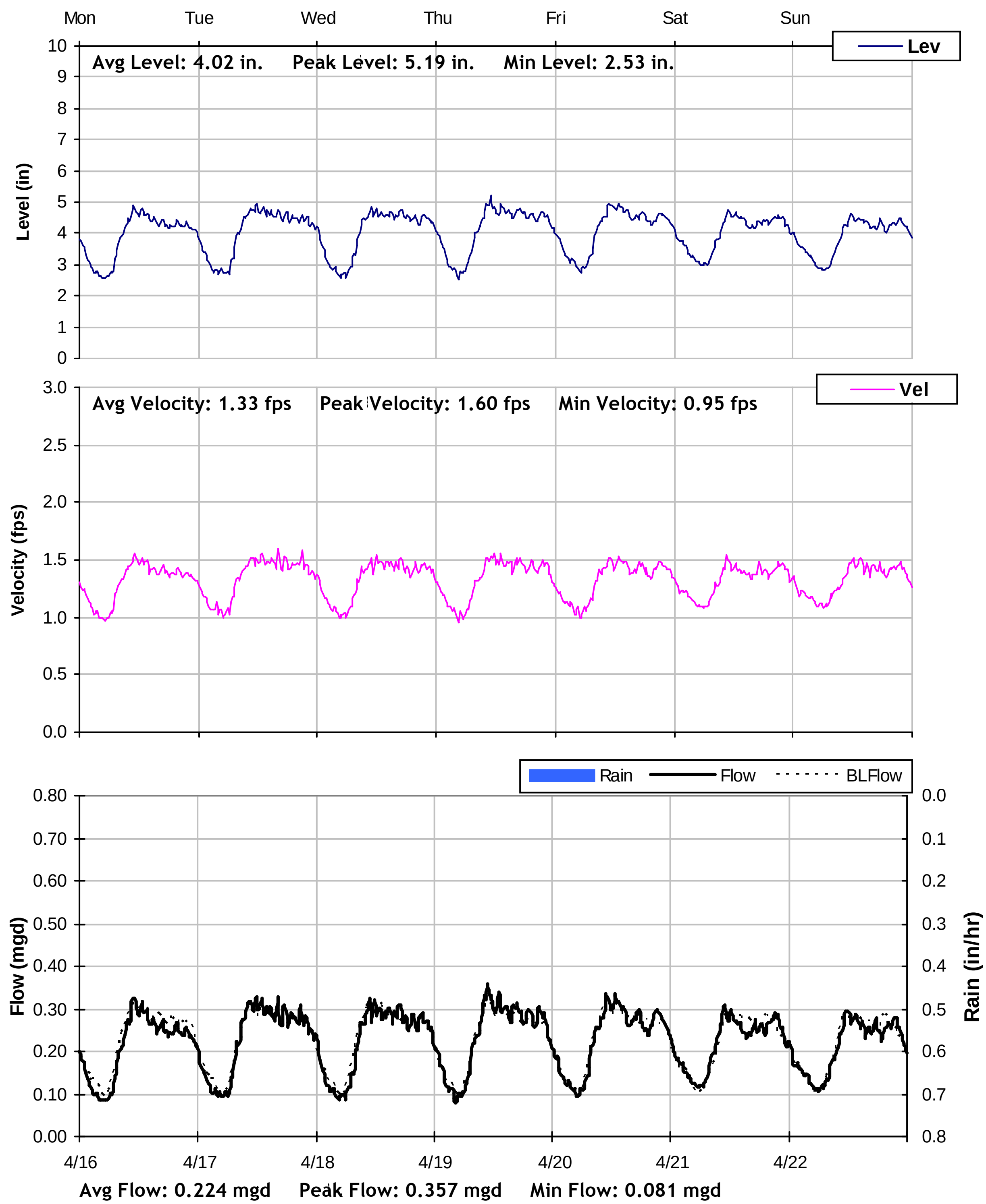


Avg Flow: 0.234 mgd Peak Flow: 0.401 mgd Min Flow: 0.082 mgd

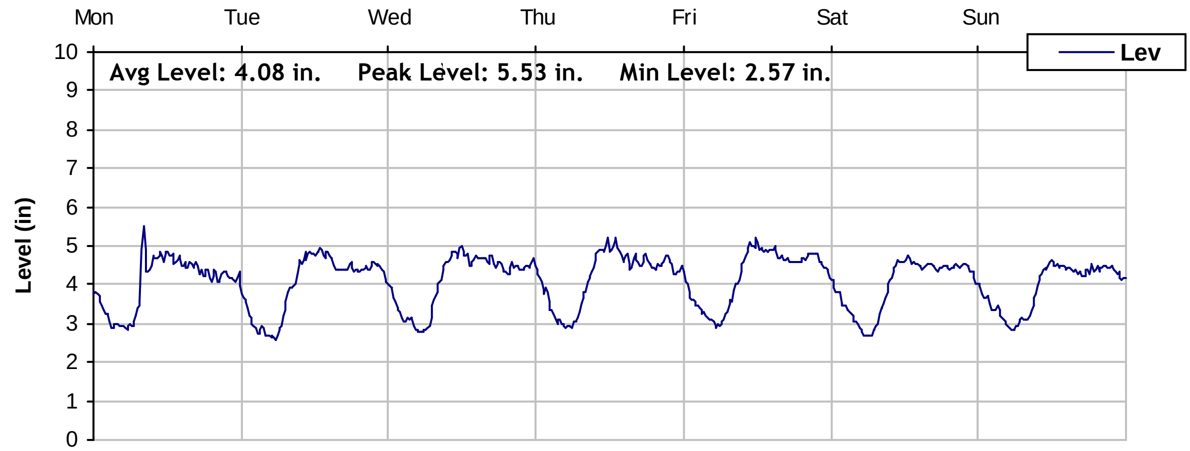
SITE 12

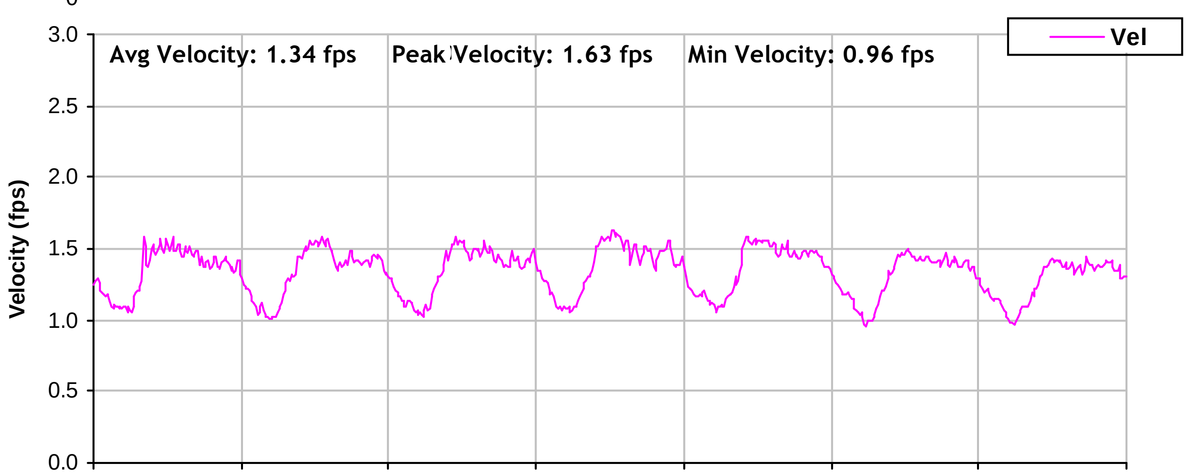
Weekly Level, Velocity and Flow Hydrographs

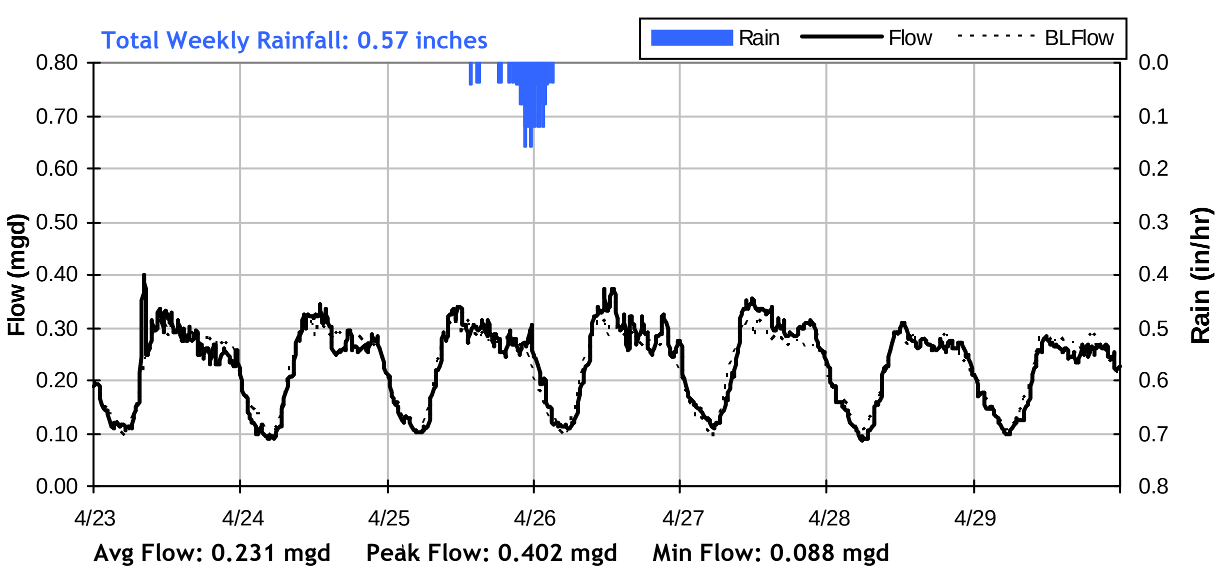
4/16/2012 to 4/23/2012



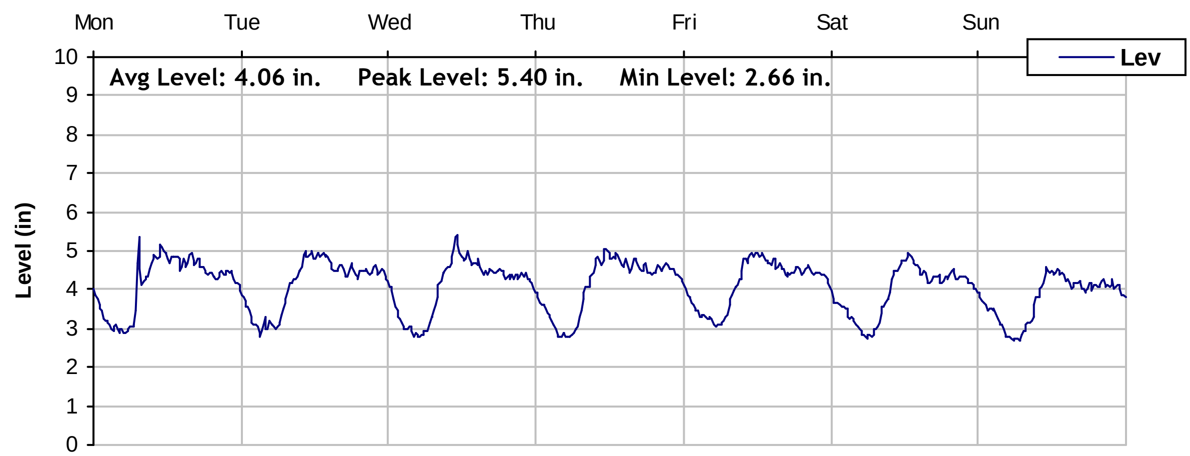
SITE 12
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012

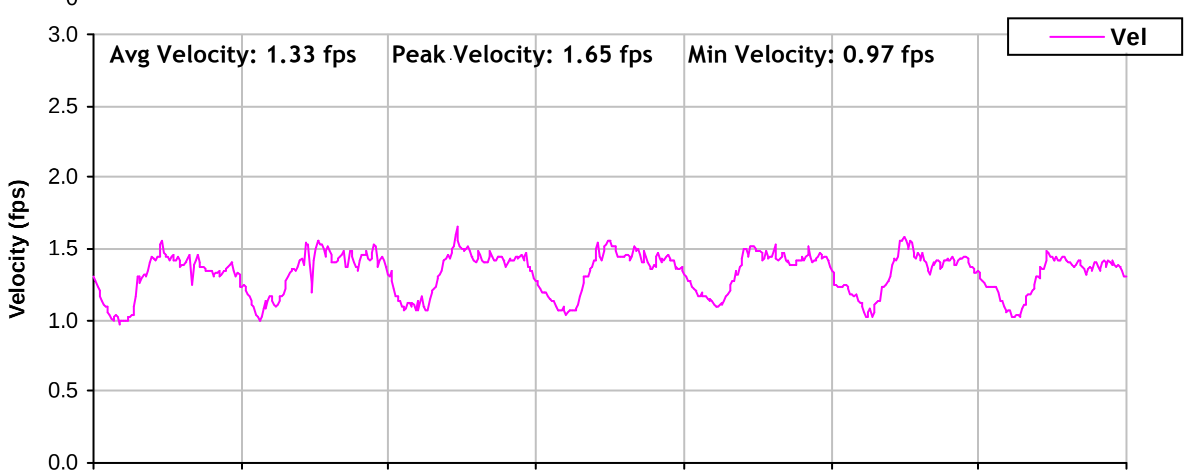


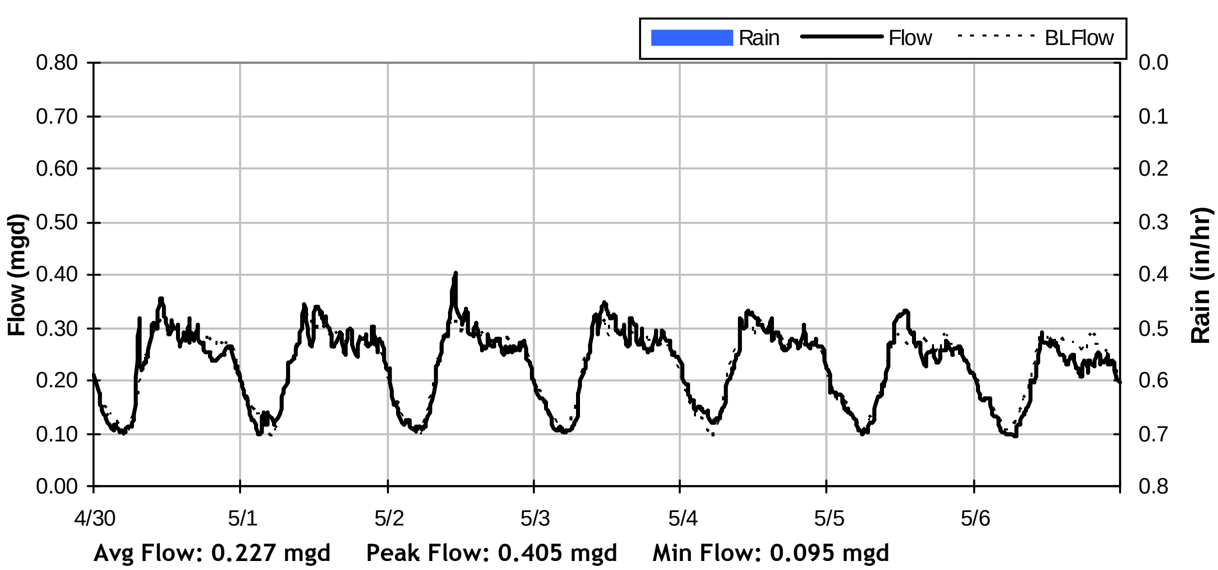




SITE 12
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012







City of Chico

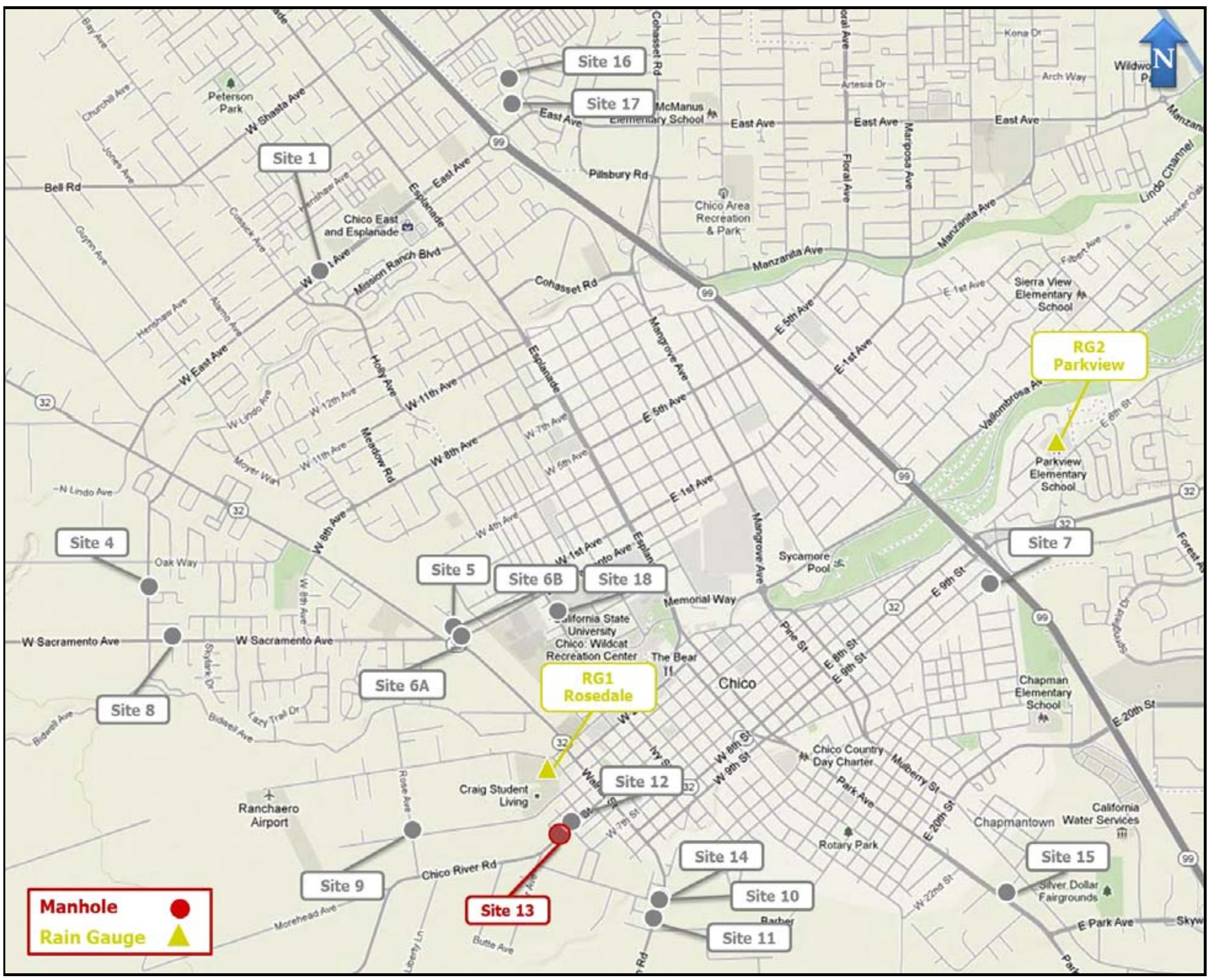
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 13

Location: West 5th Street at Maple Street

Vicinity Map:

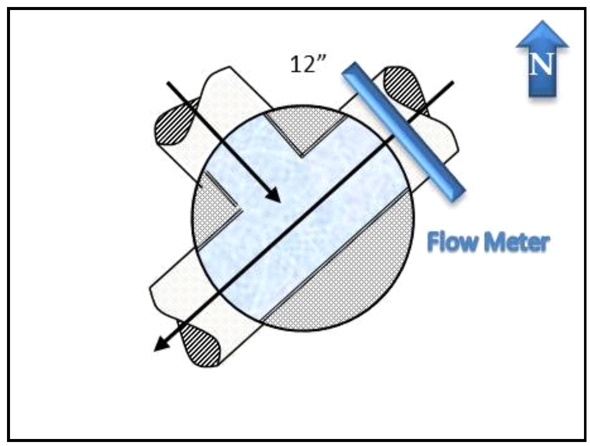


SITE 13
Site Information Report

Location:	West 5th Street at Maple Street
Coordinates:	121.8510° W, 39.7196° N
Elevation:	182 feet
Diameter:	12 inches
Baseline Flow:	0.453 mgd
Peak Measured Flow:	0.893 mgd

Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

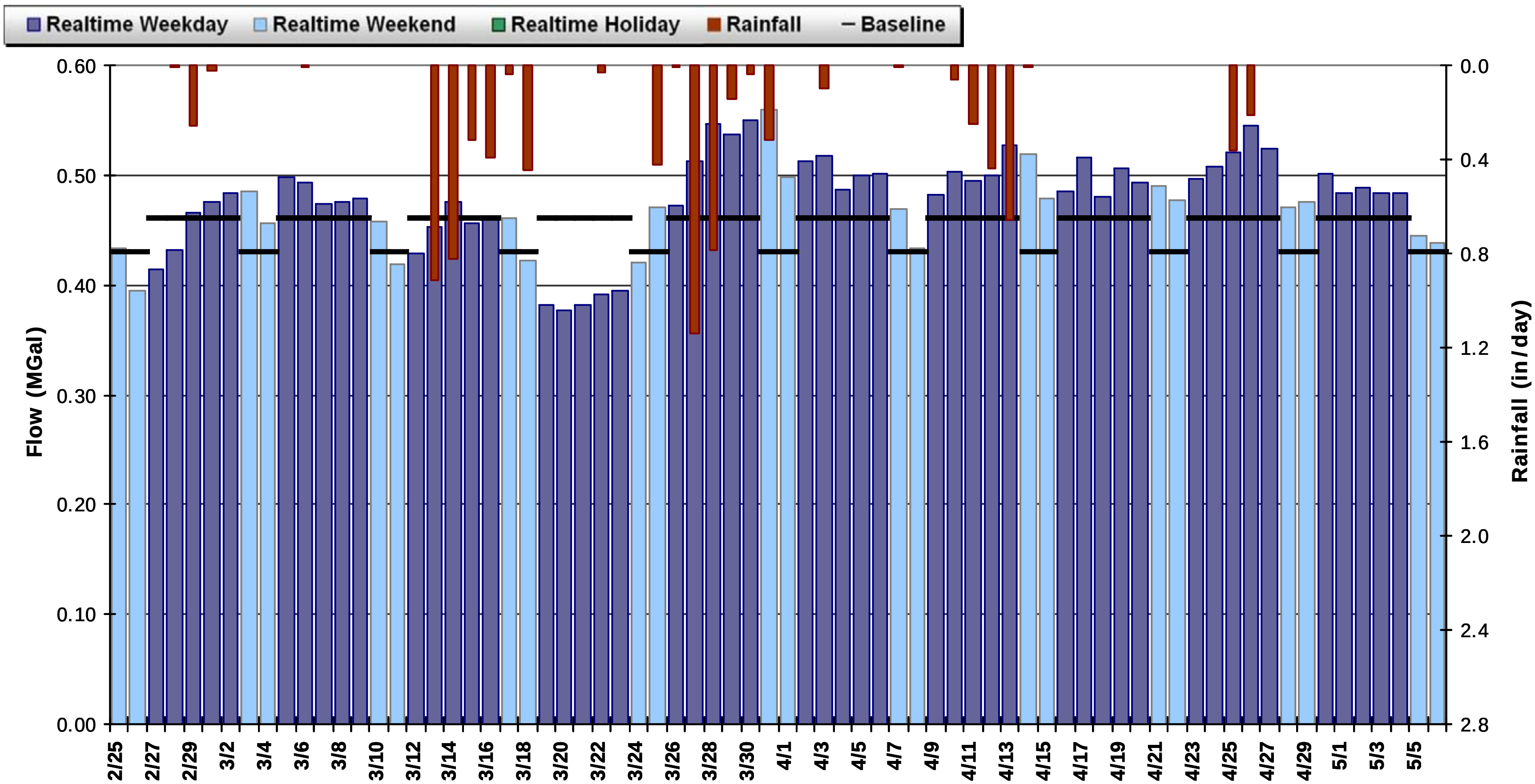
Plan View

SITE 13

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.475 MGal **Peak Daily Flow: 0.559 MGal** **Min Daily Flow: 0.378 MGal**

Total Period Rainfall: 8.21 inches

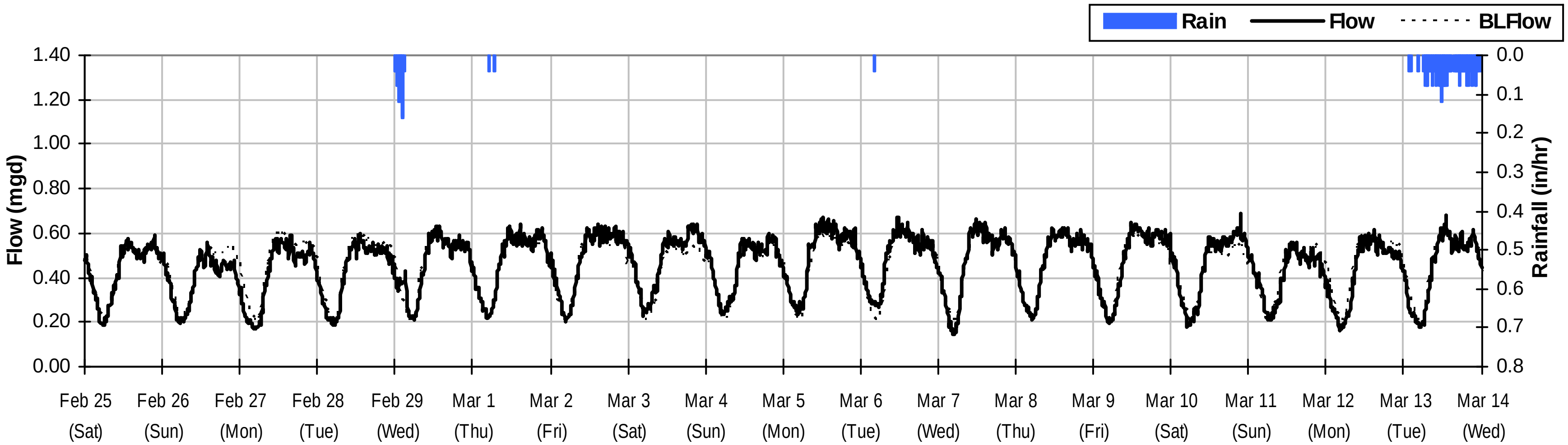


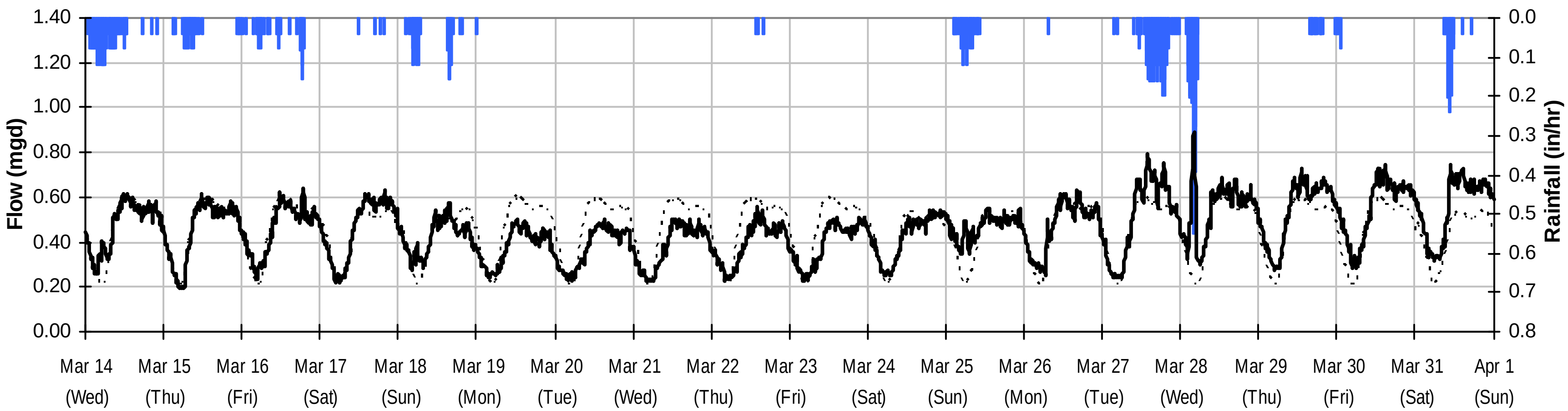
SITE 13

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.458 mgd **Peak Flow: 0.893 mgd** **Min Flow: 0.148 mgd**

Total Period Rainfall: 6.11 inches



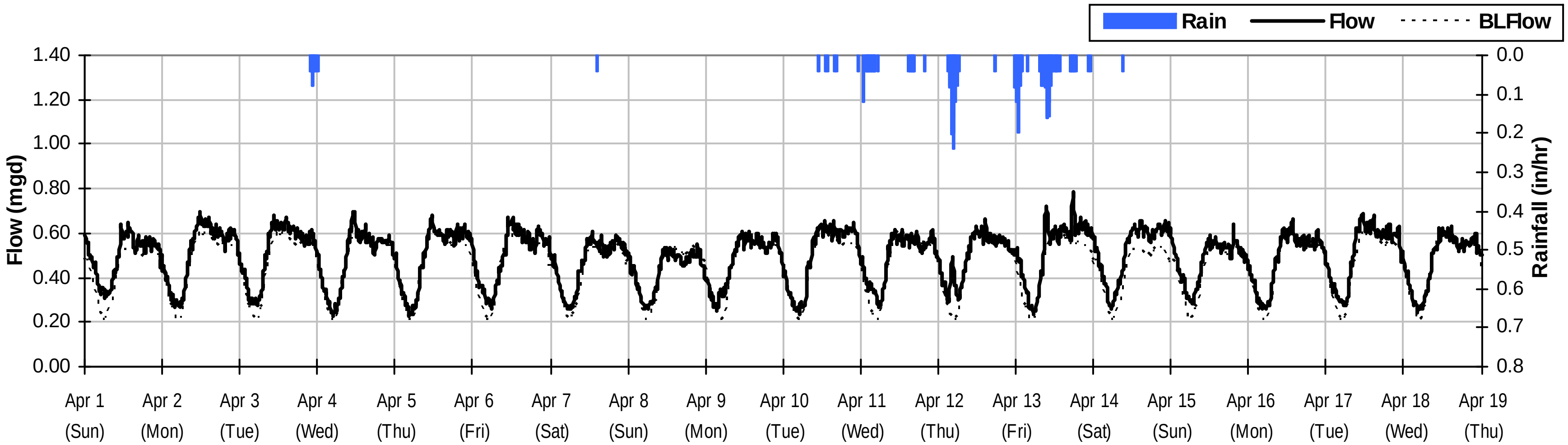


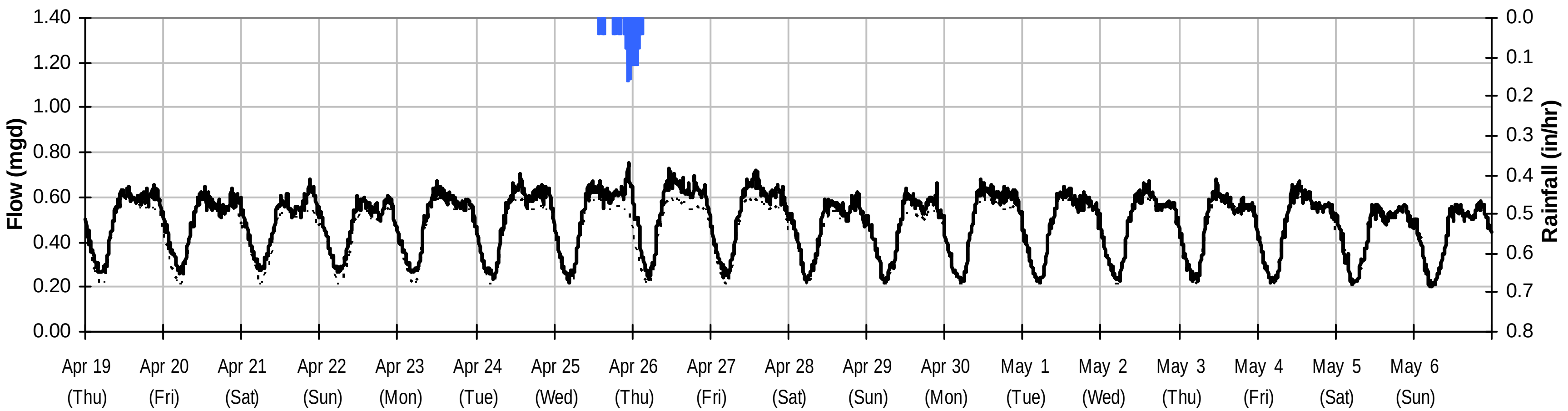
SITE 13

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.493 mgd **Peak Flow: 0.782 mgd** **Min Flow: 0.199 mgd**

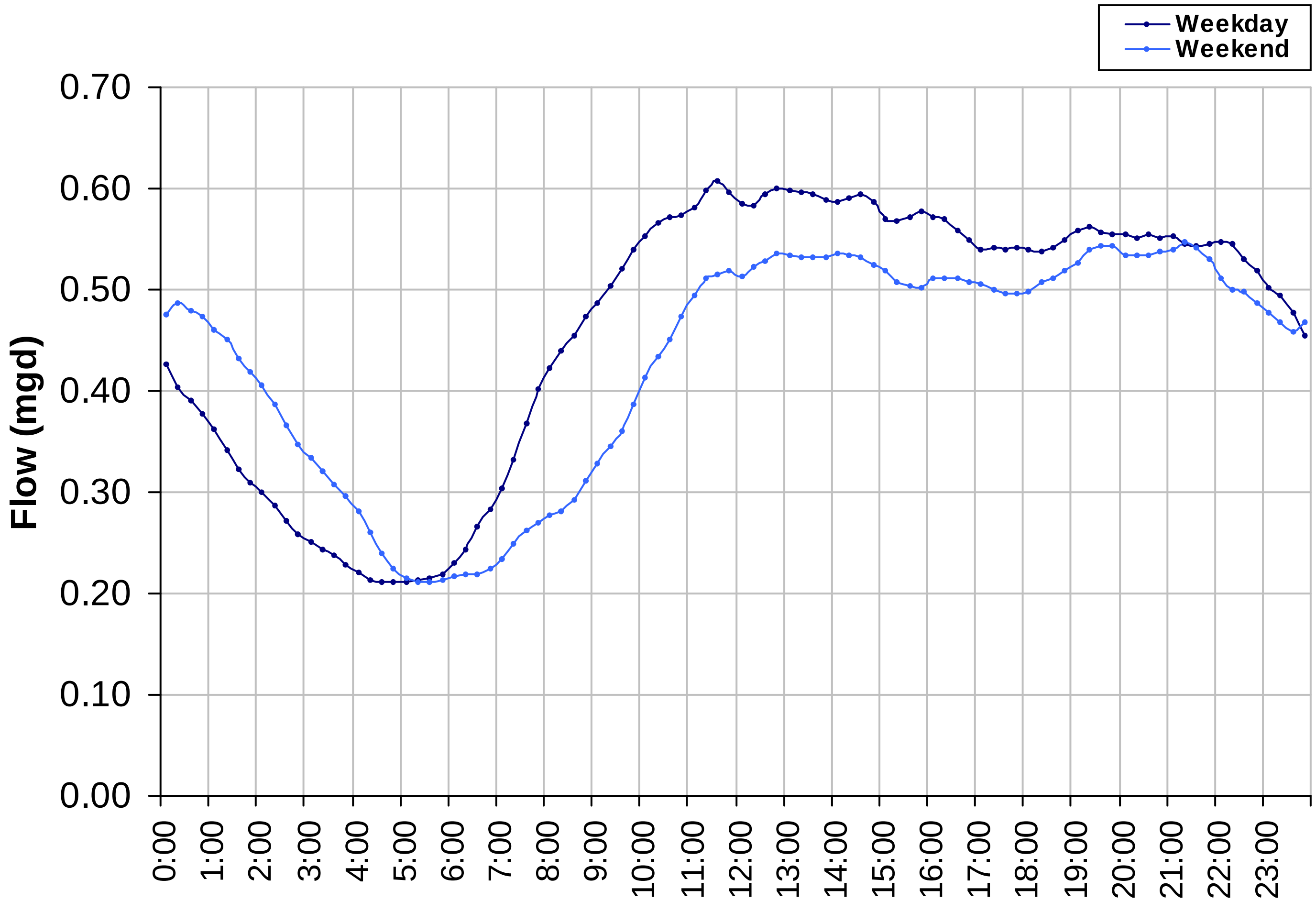
Total Period Rainfall: 2.10 inches





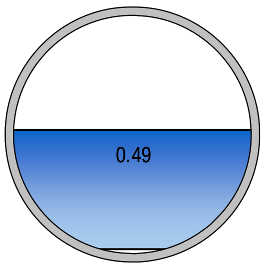
SITE 13

Baseline Flow Hydrographs



Baseline Flow:

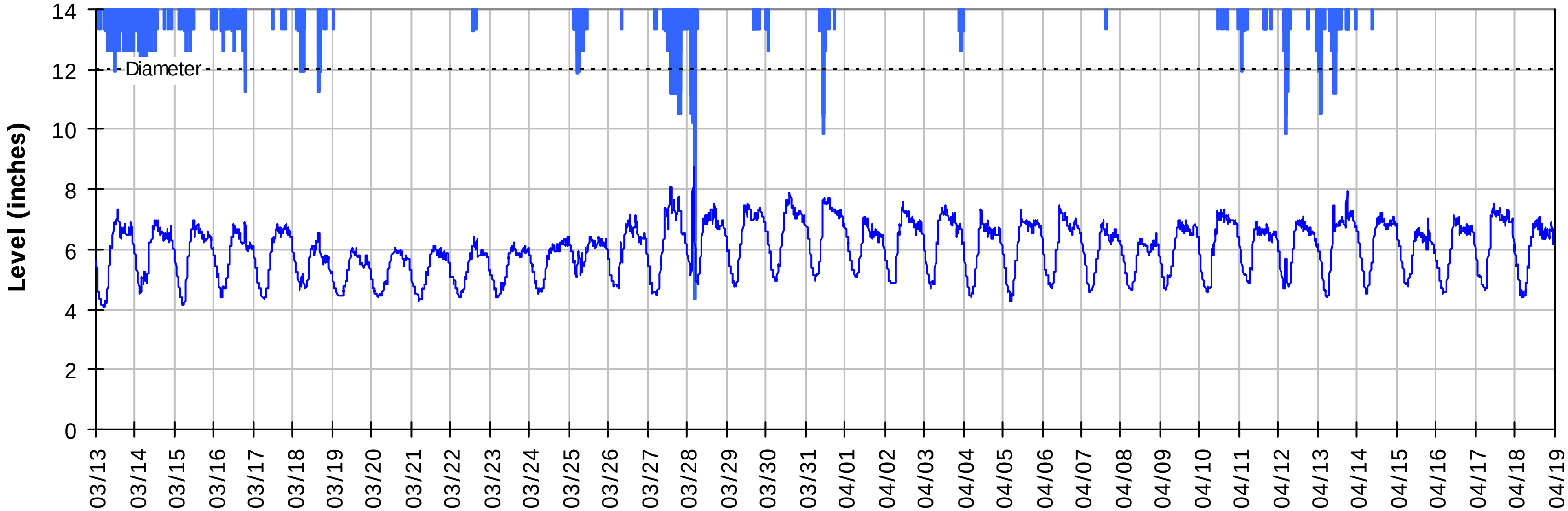
0.453 *mgd*

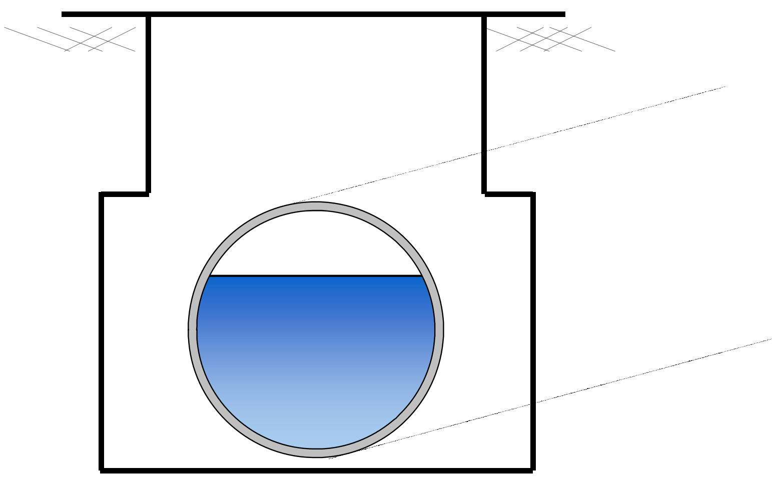


SITE 13

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





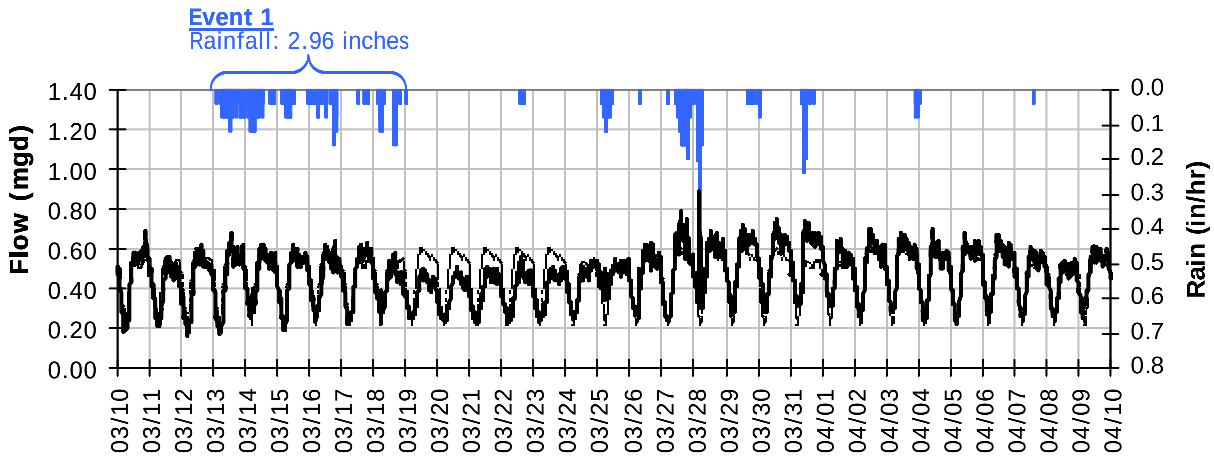
Pipe Diameter: 12 *inches*

Peak Measured Level: 8.74 *inches*

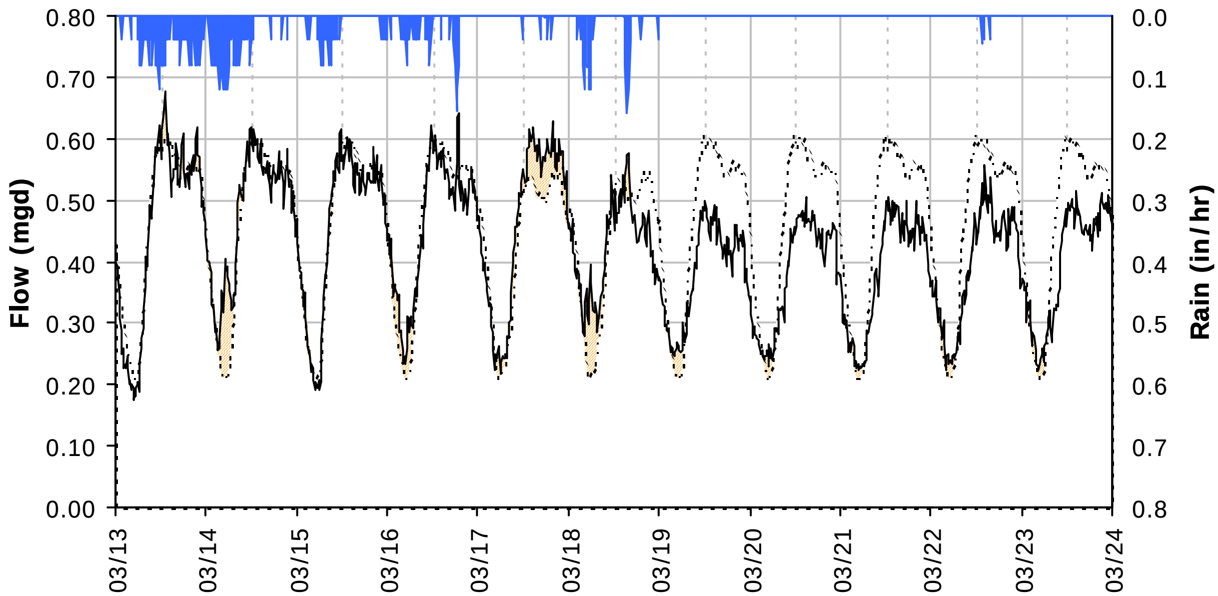
Peak d/D Ratio: 0.73

SITE 13
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 = 2.96 inches)

Capacity

Peak Flow: 0.68 *mgd*
PF: 1.49
Peak Level: 7.34 *in*
d/D Ratio: 0.61

Inflow

Peak I/I Rate: 0.19 *mgd*
Pk I/I:ADWF: 0.42

RDI (infiltration)

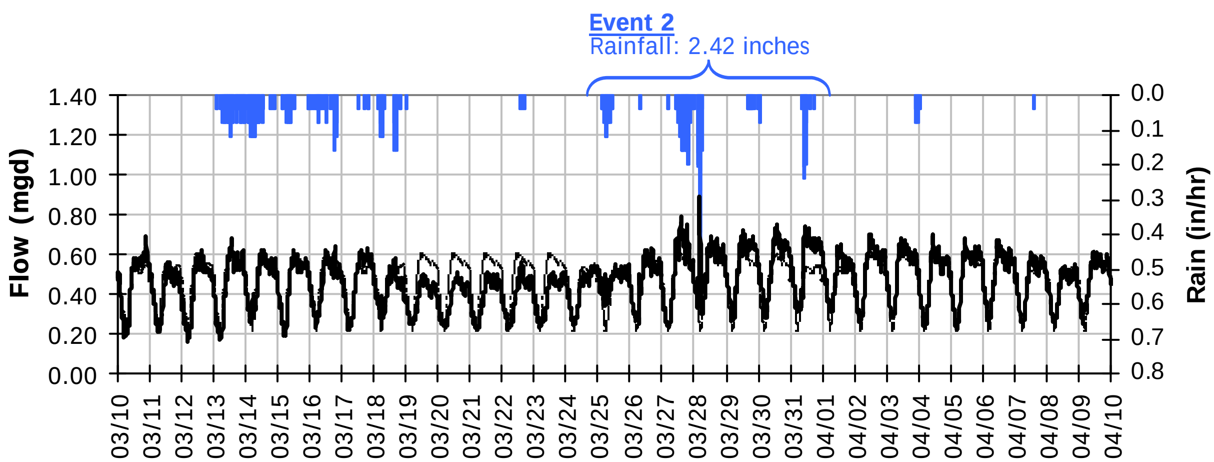
Infiltration Rate: 0.000 *mgd*
(3/20/2012)
RDI (% of BL): 0%

Combined I/I

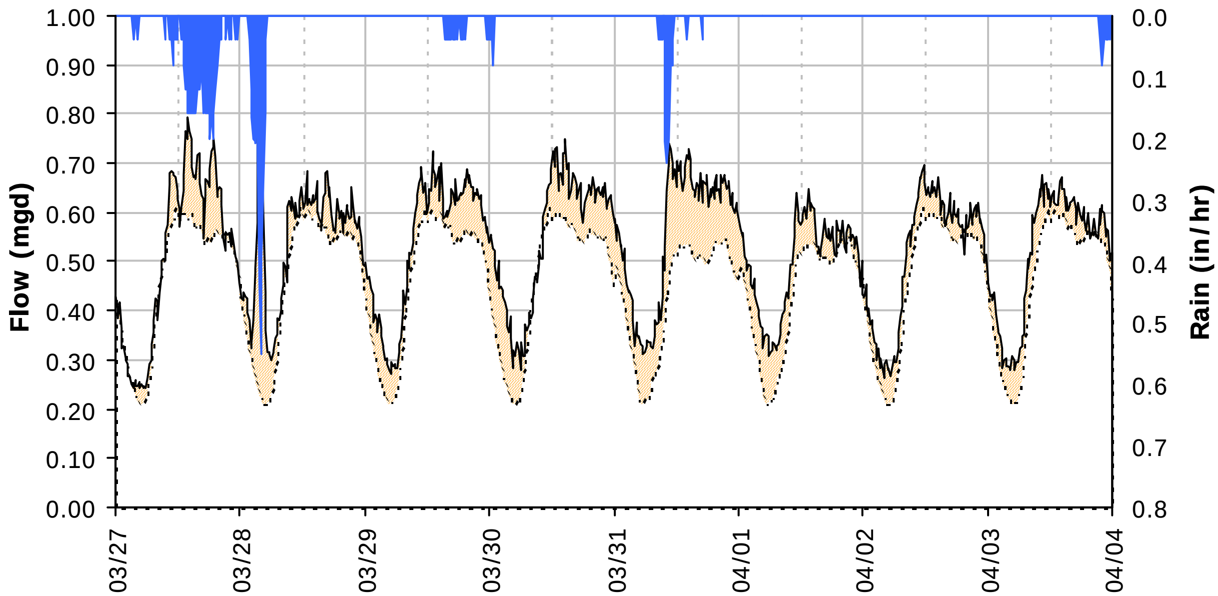
Total I/I: -359,000 *gallons*
Total I/I:ADWF: -0.27 *per in-rain*

SITE 13
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 = 2.42 inches)

Capacity

Peak Flow: 0.89 *mgd*
PF: 1.97
Peak Level: 8.74 *in*
d/D Ratio: 0.73

Inflow

Peak I/I Rate: 0.67 *mgd*
Pk I/I:ADWF: 1.48

RDI (infiltration)

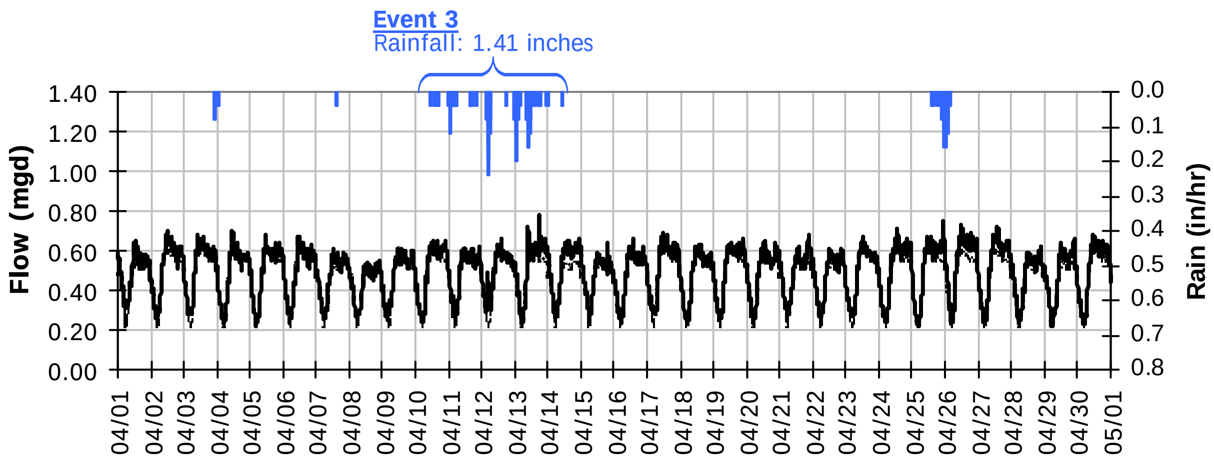
Infiltration Rate: 0.051 *mgd* (4/2/2012)
RDI (% of BL): 11%

Combined I/I

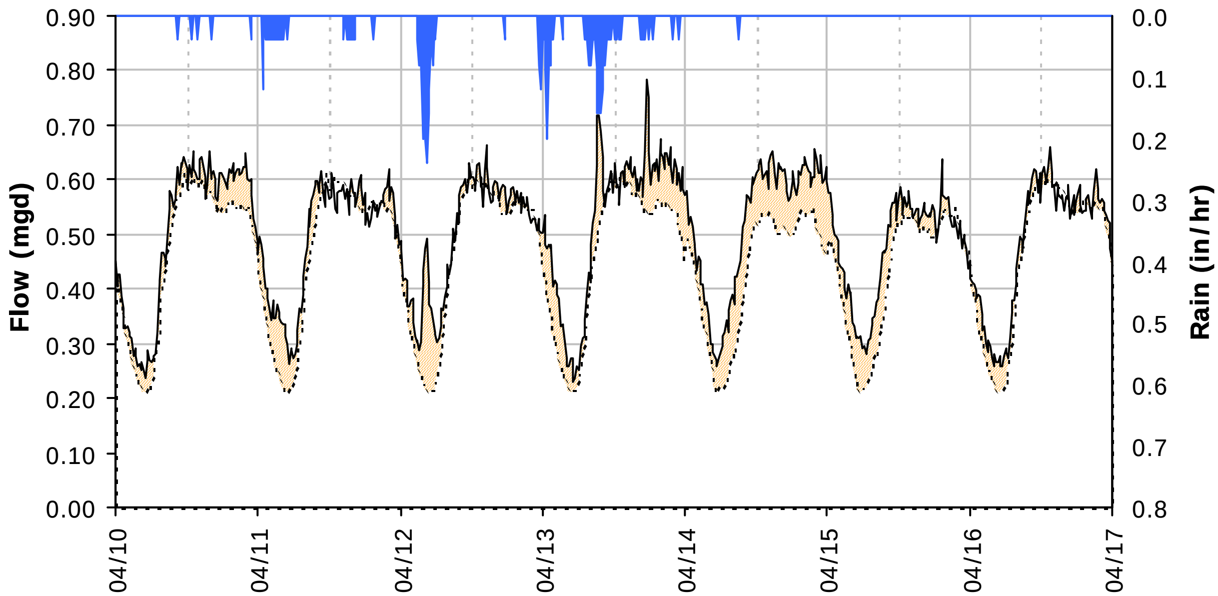
Total I/I: 602,000 *gallons*
Total I/I:ADWF: 0.55 *per in-rain*

SITE 13
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.41 inches)

Capacity

Peak Flow: 0.78 *mgd*
PF: 1.73
Peak Level: 7.96 *in*
d/D Ratio: 0.66

Inflow

Peak I/I Rate: 0.28 *mgd*
Pk I/I:ADWF: 0.62

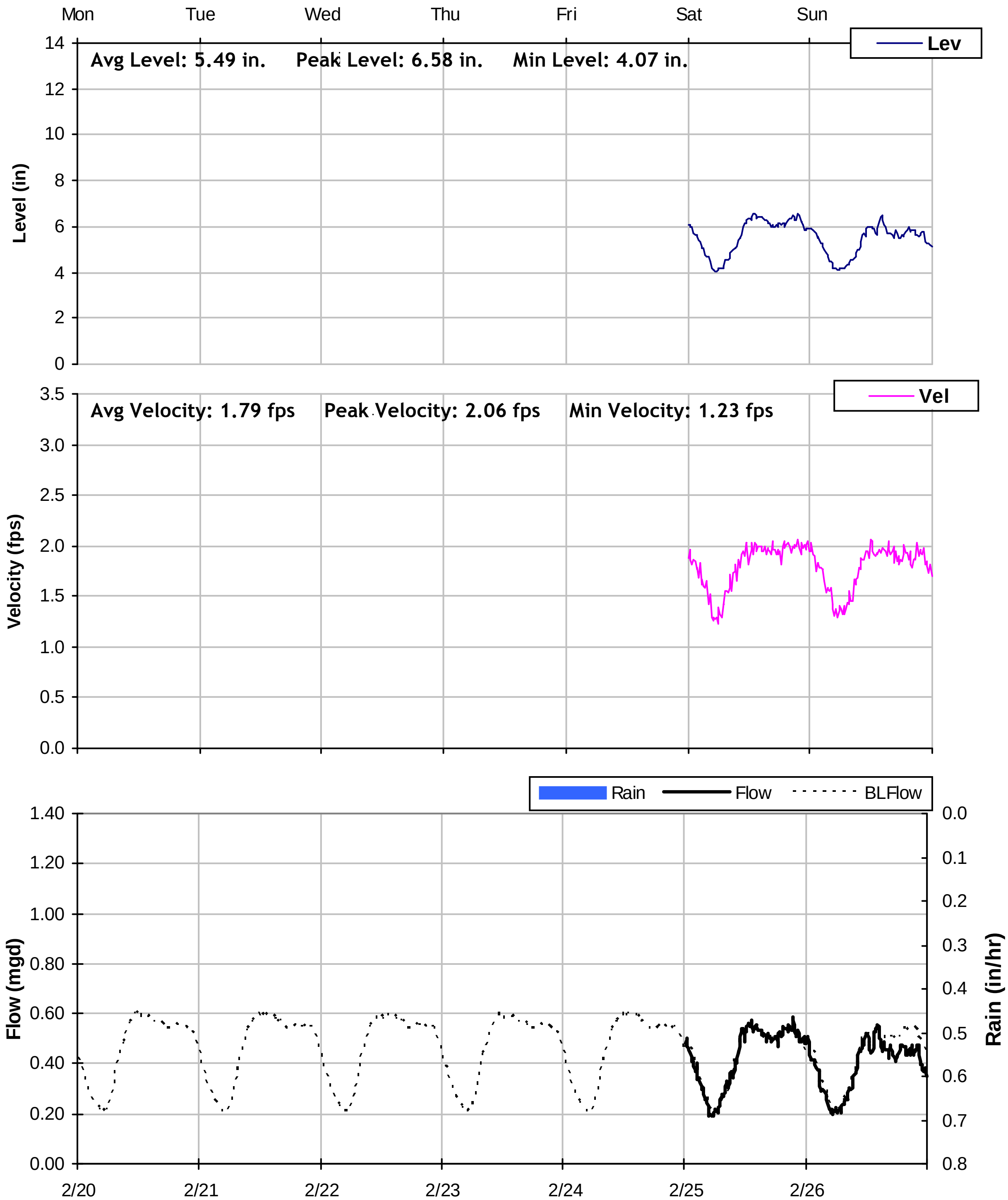
RDI (infiltration)

Infiltration Rate: 0.047 *mgd*
(4/15/2012)
RDI (% of BL): 11%

Combined I/I

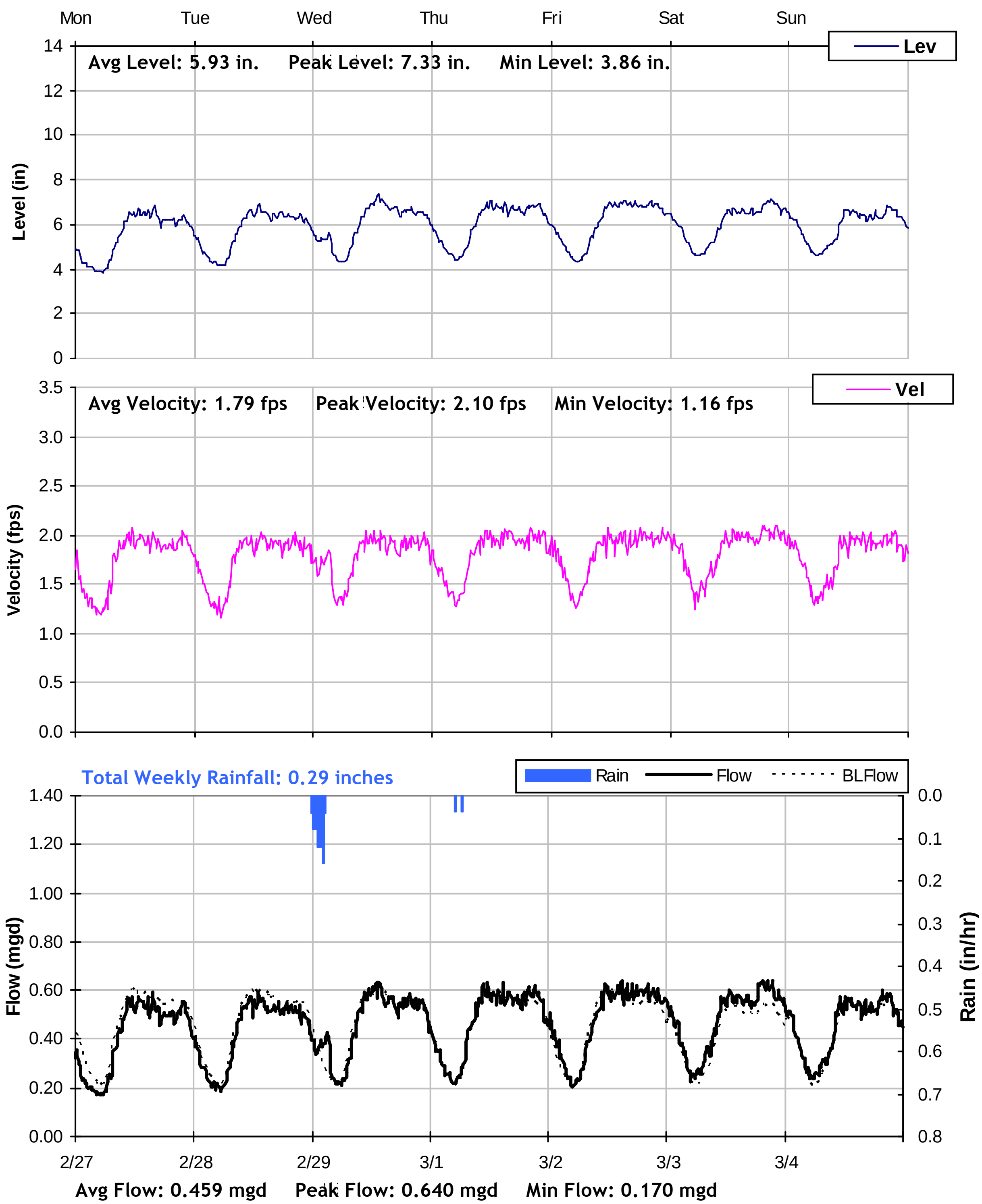
Total I/I: 337,000 *gallons*
Total I/I:ADWF: 0.53 *per in-rain*

SITE 13
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

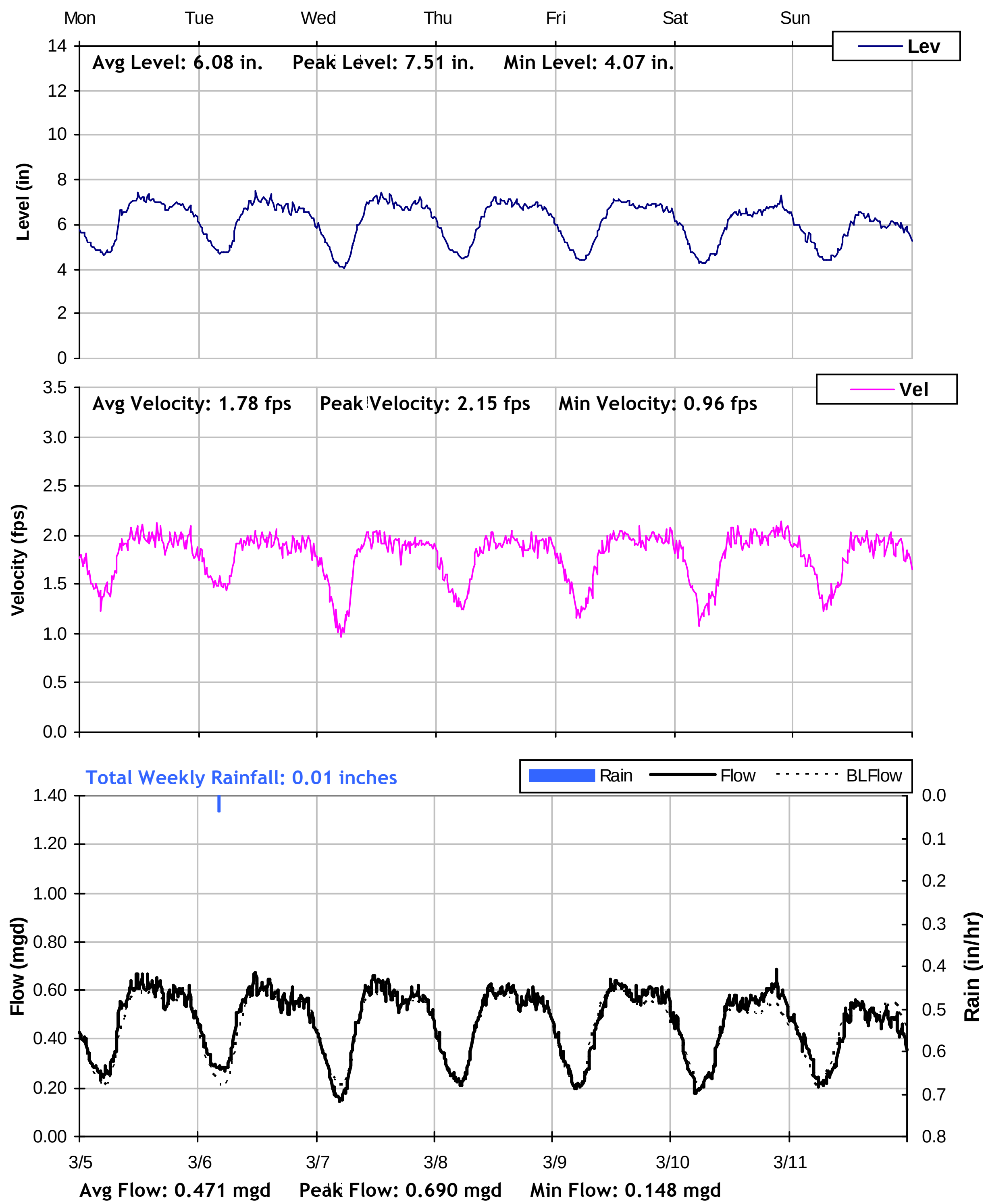


Avg Flow: 0.414 mgd **Peak Flow: 0.588 mgd** **Min Flow: 0.188 mgd**

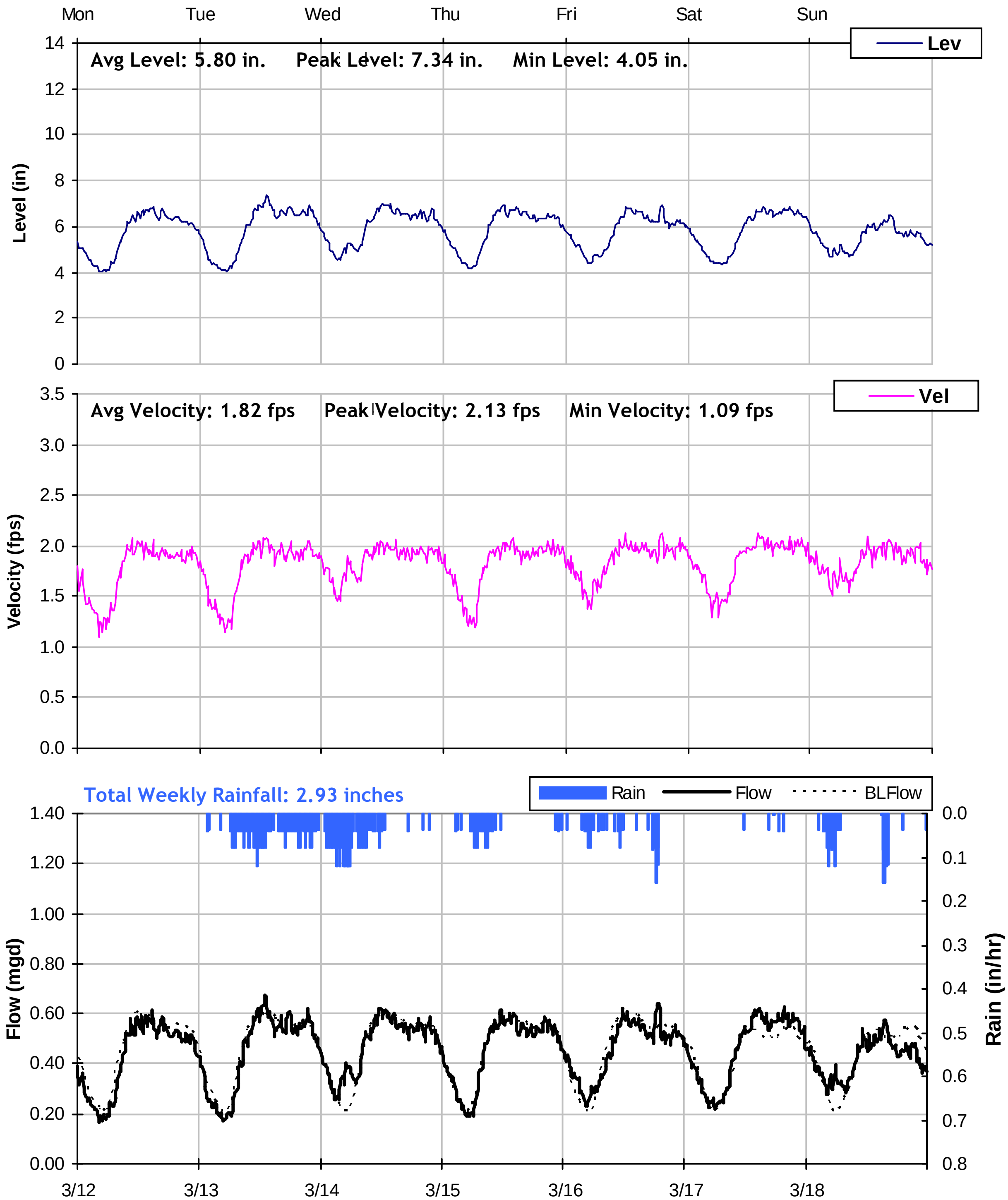
SITE 13
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



SITE 13
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012

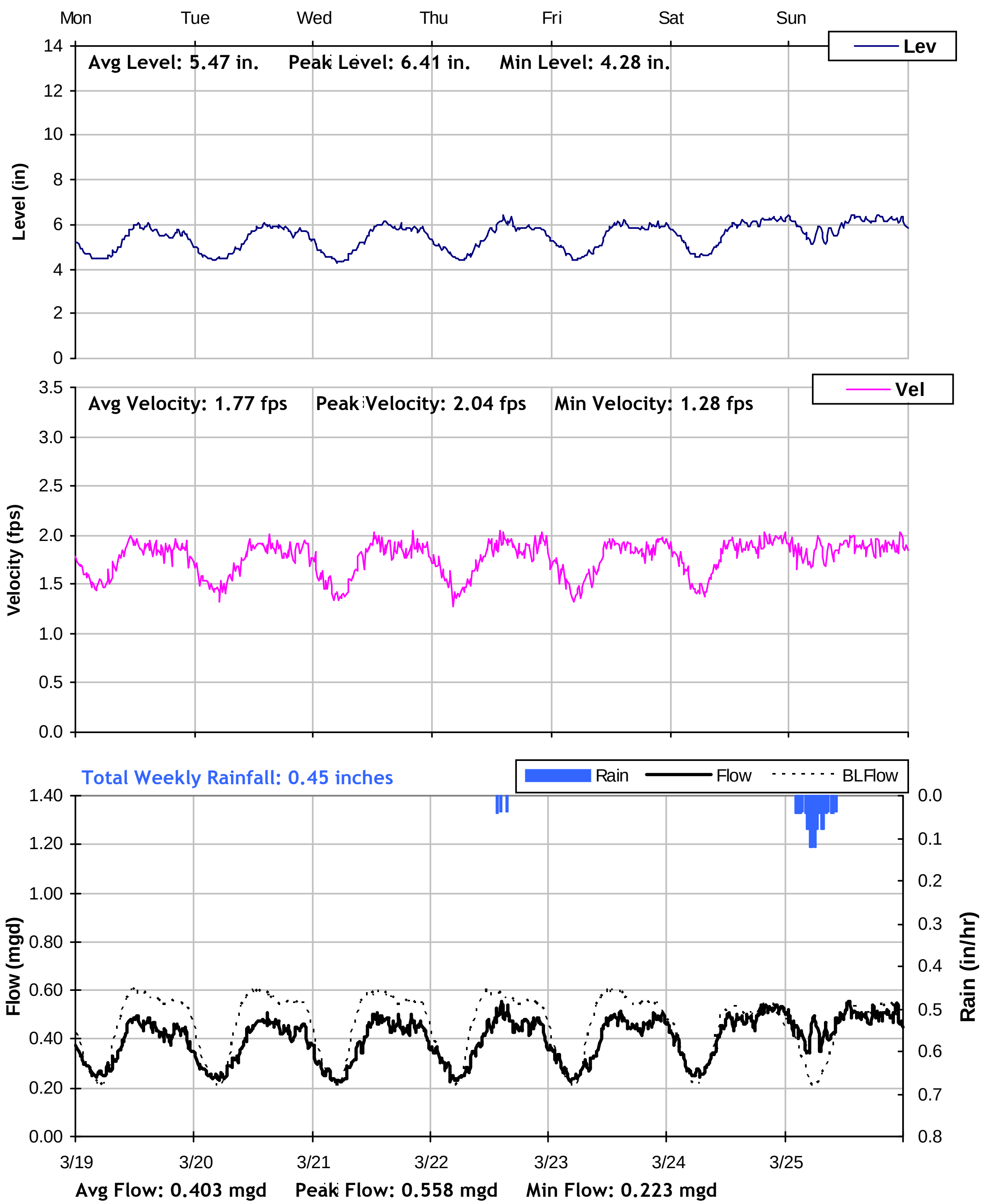


SITE 13
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012

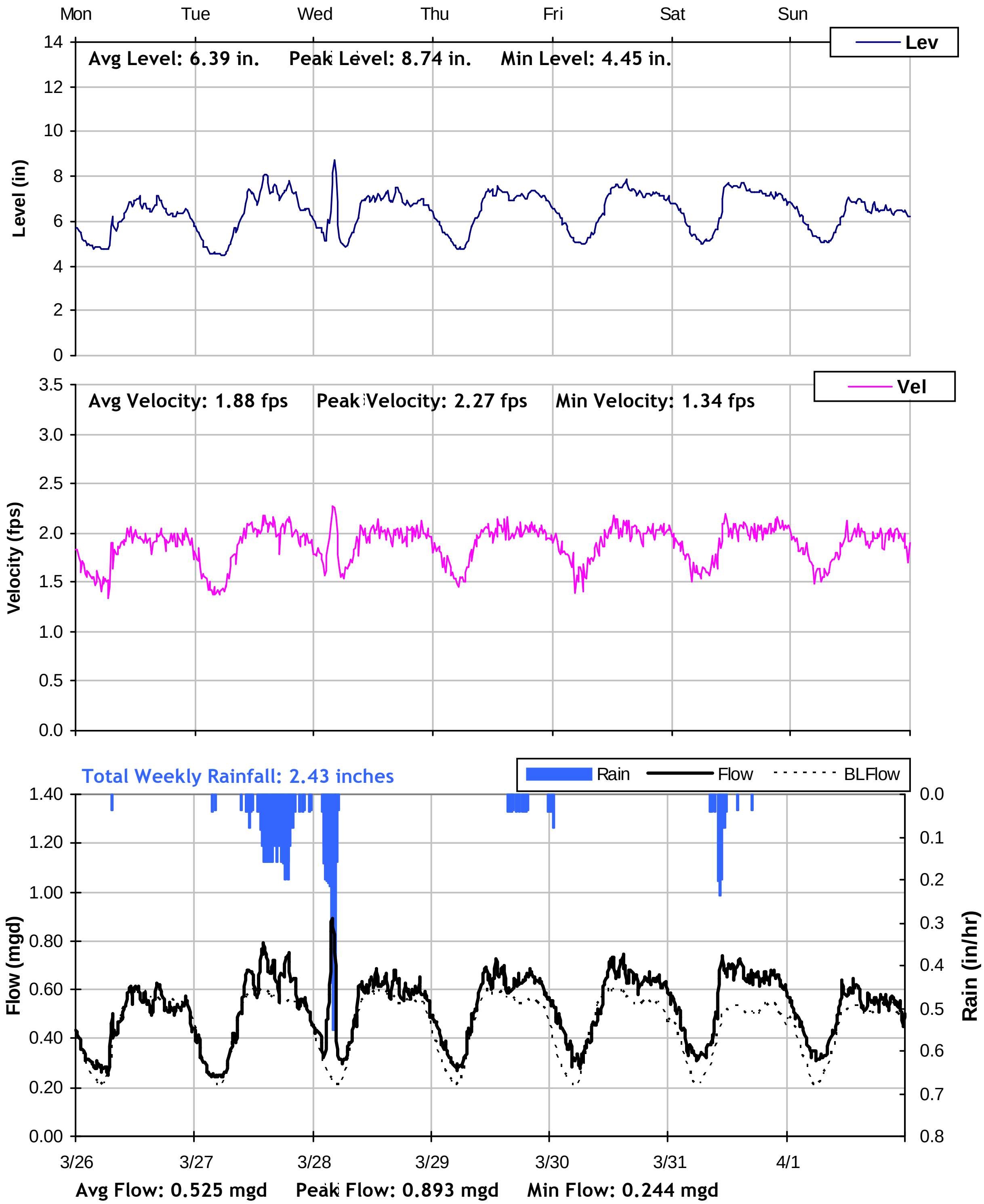


Avg Flow: 0.451 mgd Peak Flow: 0.676 mgd Min Flow: 0.164 mgd

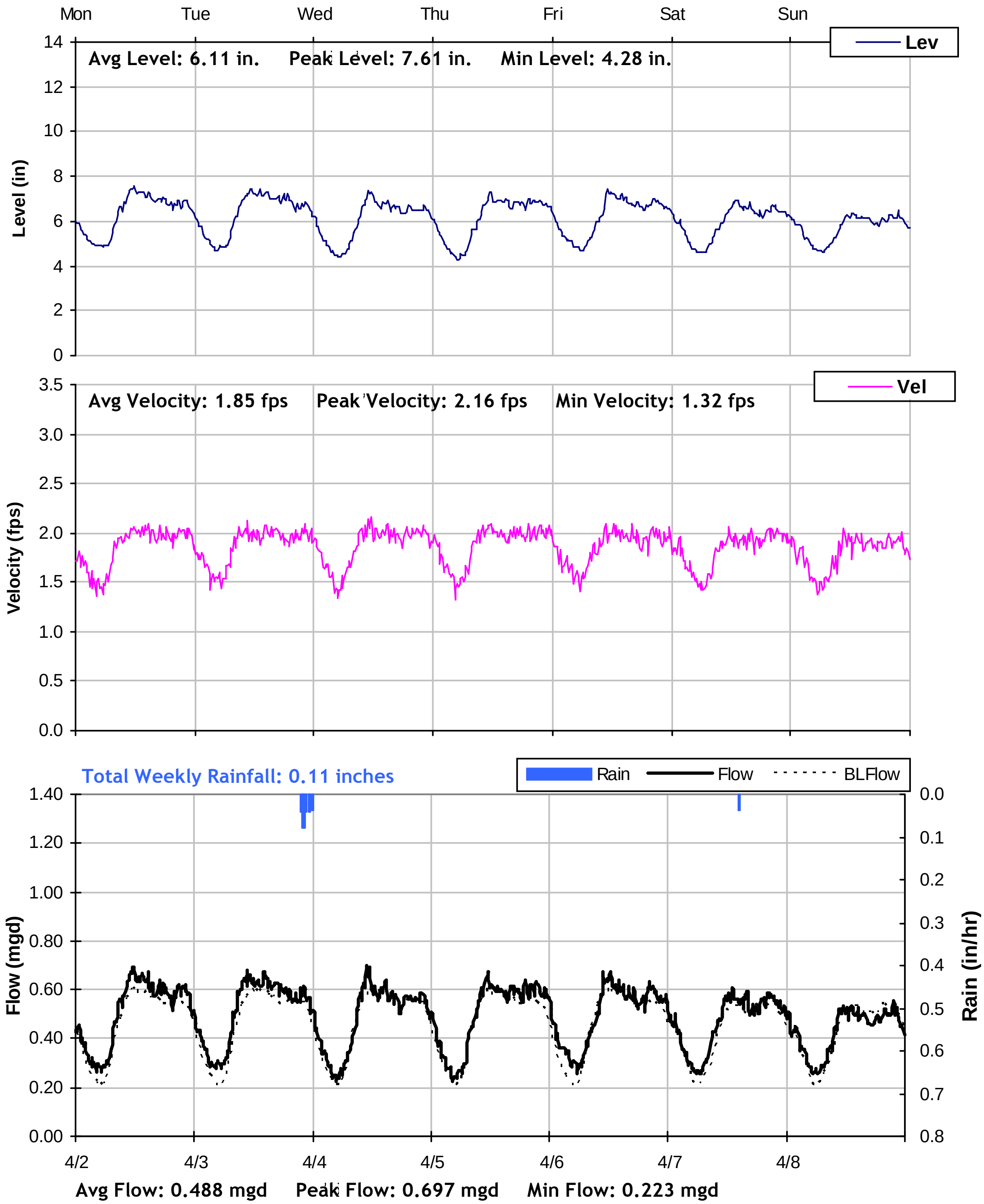
SITE 13
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



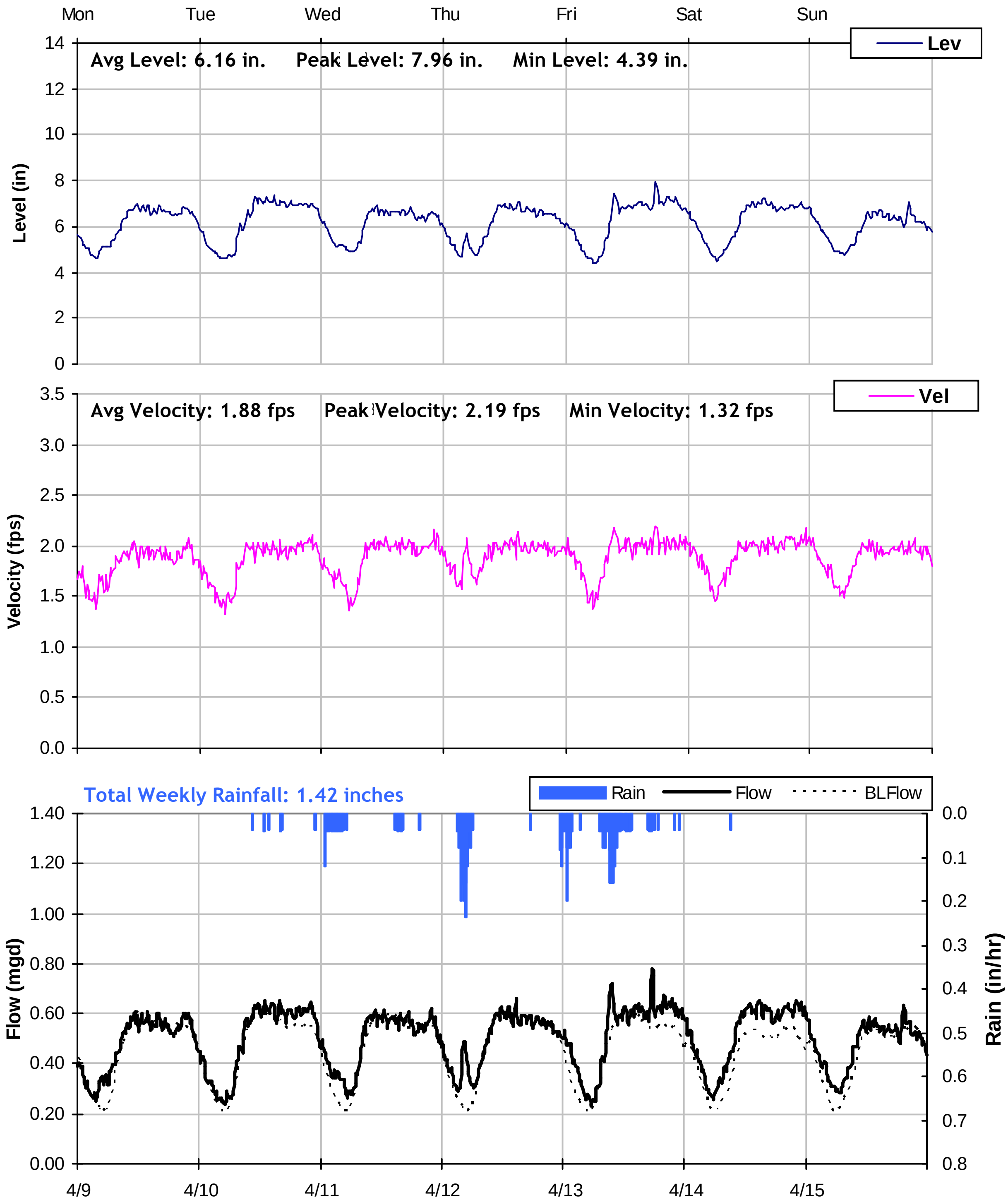
SITE 13
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



SITE 13
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012

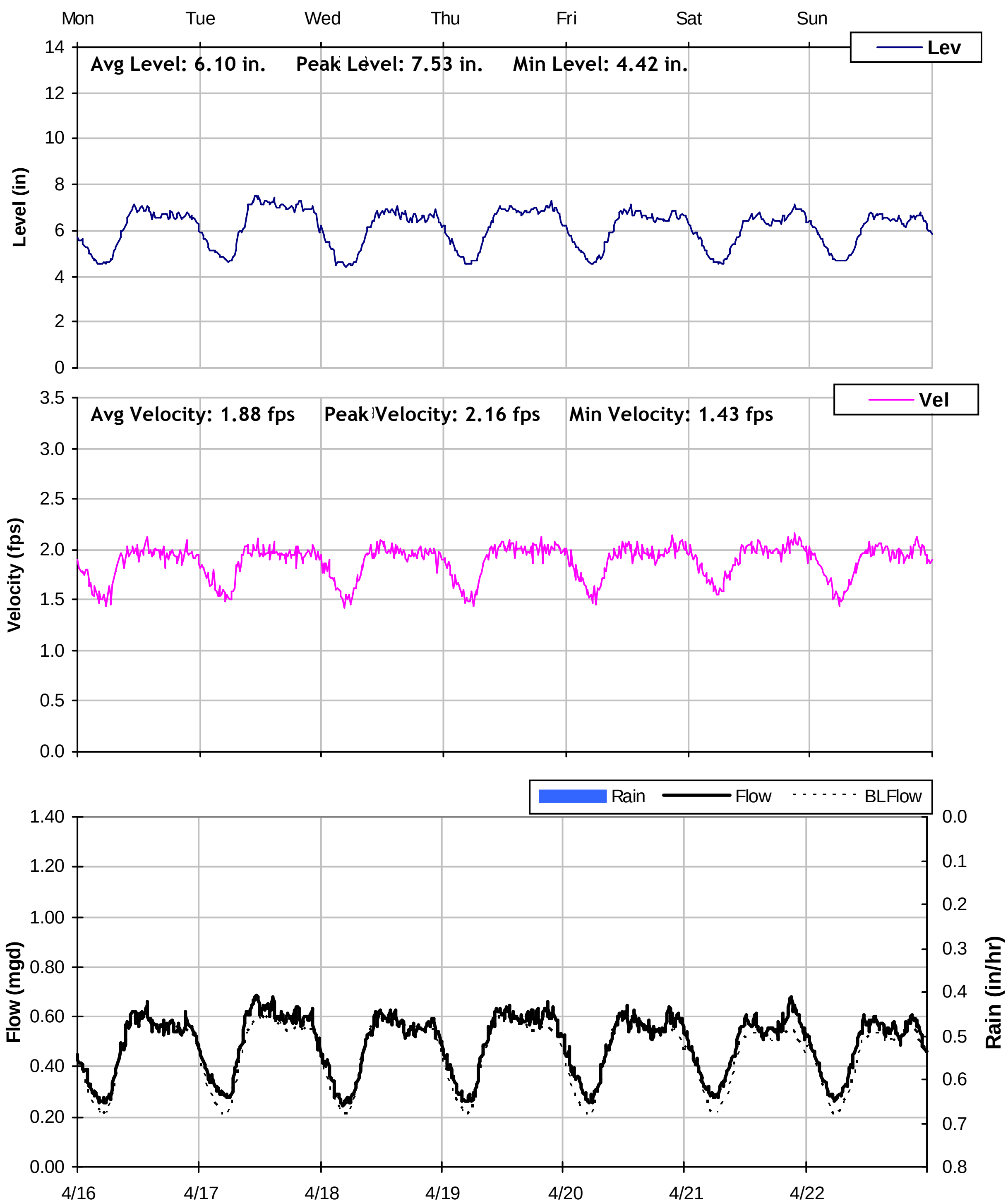


SITE 13
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



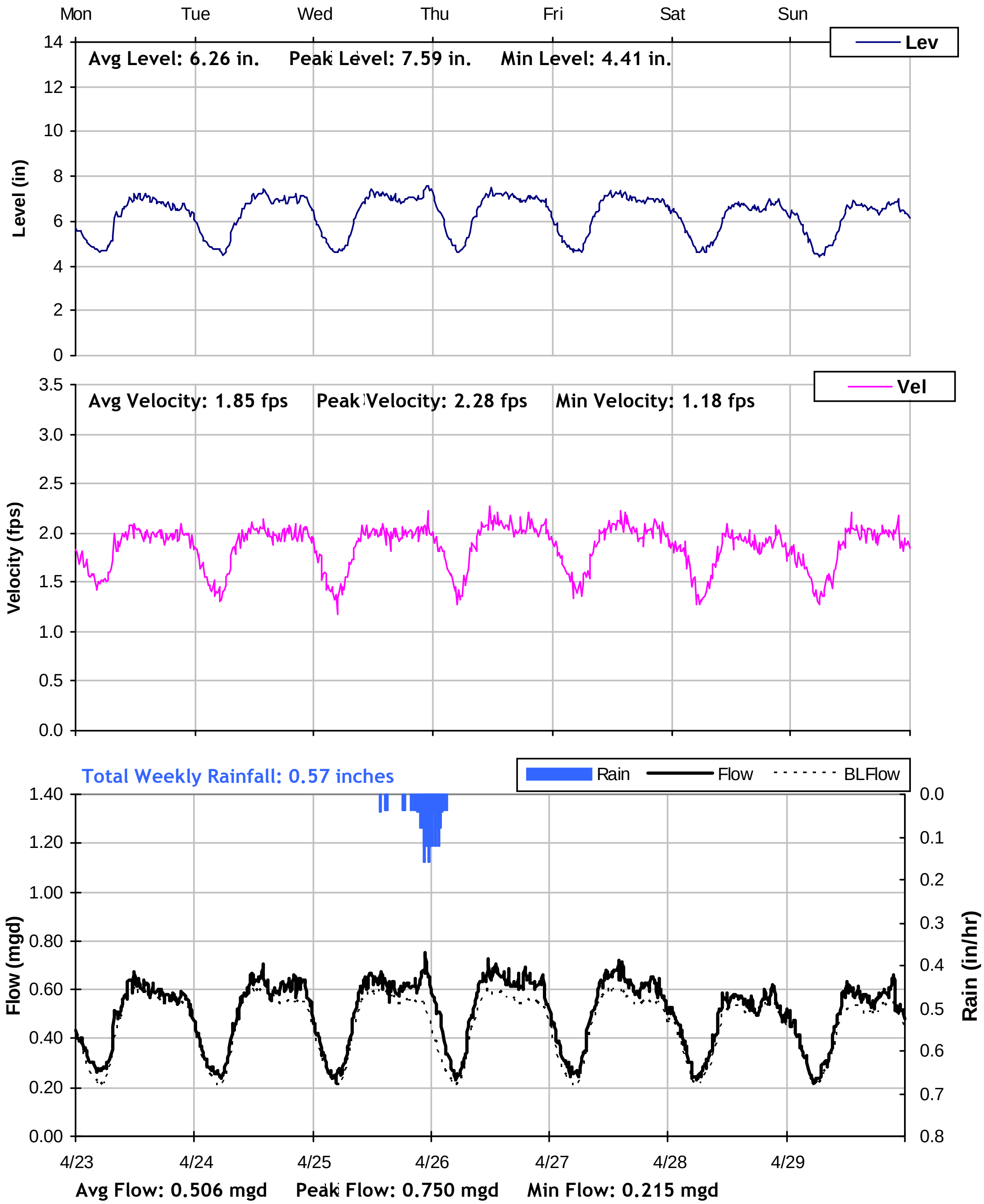
Avg Flow: 0.500 mgd **Peak Flow: 0.782 mgd** **Min Flow: 0.231 mgd**

SITE 13
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012

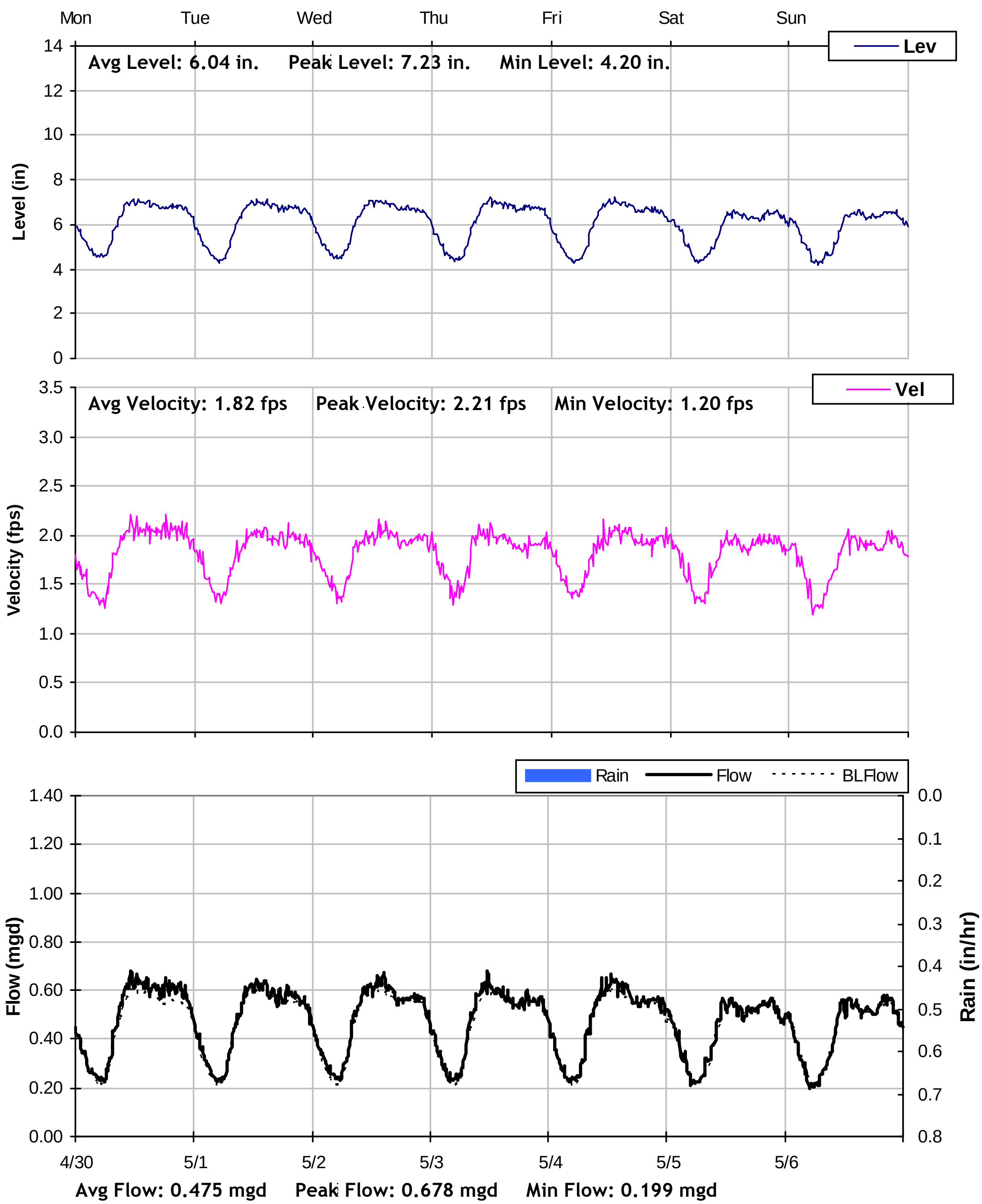


Avg Flow: 0.493 mgd Peak Flow: 0.686 mgd Min Flow: 0.247 mgd

SITE 13
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 13
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 14

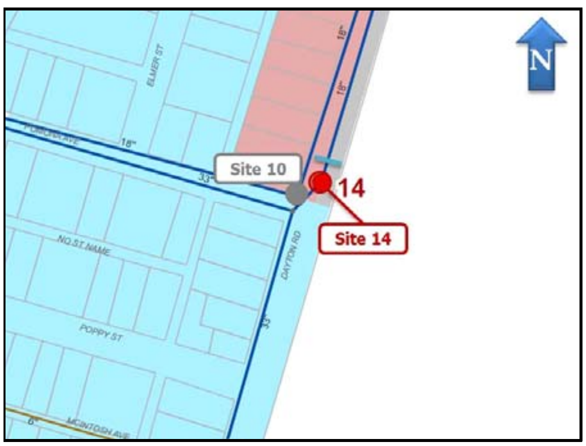
Location: Dayton Road, northeast of Pomona Avenue

Vicinity Map:

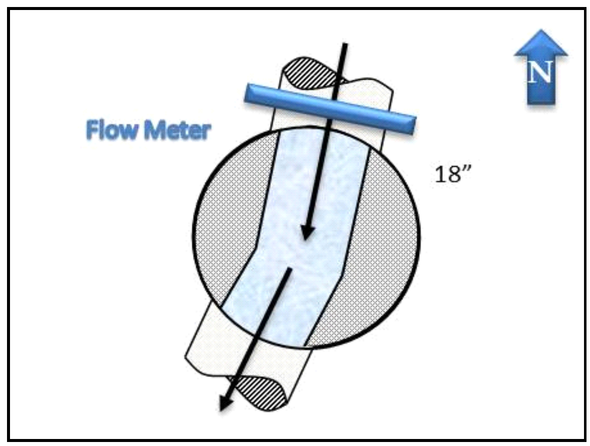
SITE 14
Site Information Report

Location:	Dayton Road, northeast of Pomona Avenue
Coordinates:	121.8431° W, 39.7161° N
Elevation:	185 feet
Diameter:	18 inches
Baseline Flow:	0.304 mgd
Peak Measured Flow:	0.877 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch


View from Street

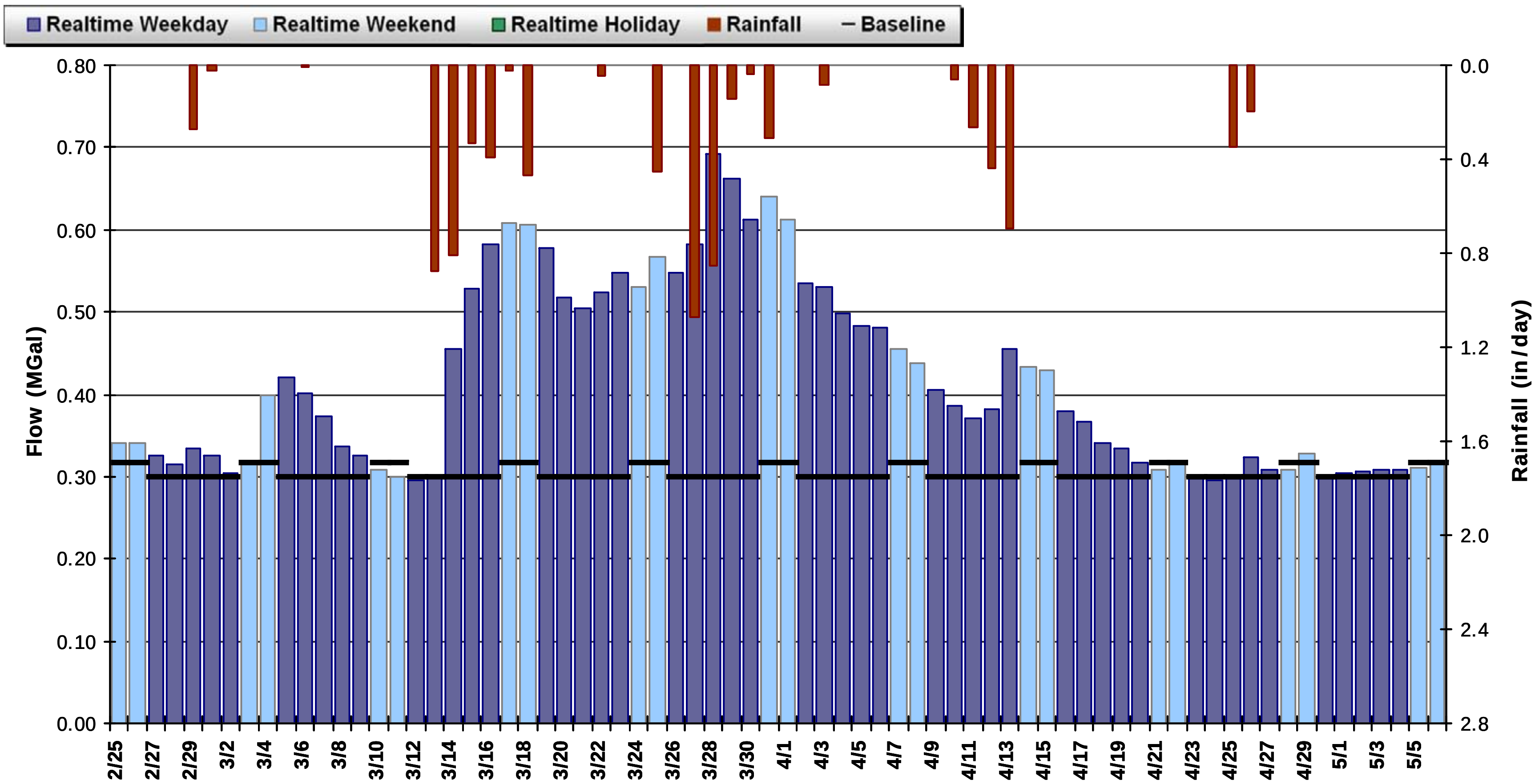

Plan View

SITE 14

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.415 MGal **Peak Daily Flow: 0.691 MGal** **Min Daily Flow: 0.295 MGal**

Total Period Rainfall: 8.20 inches

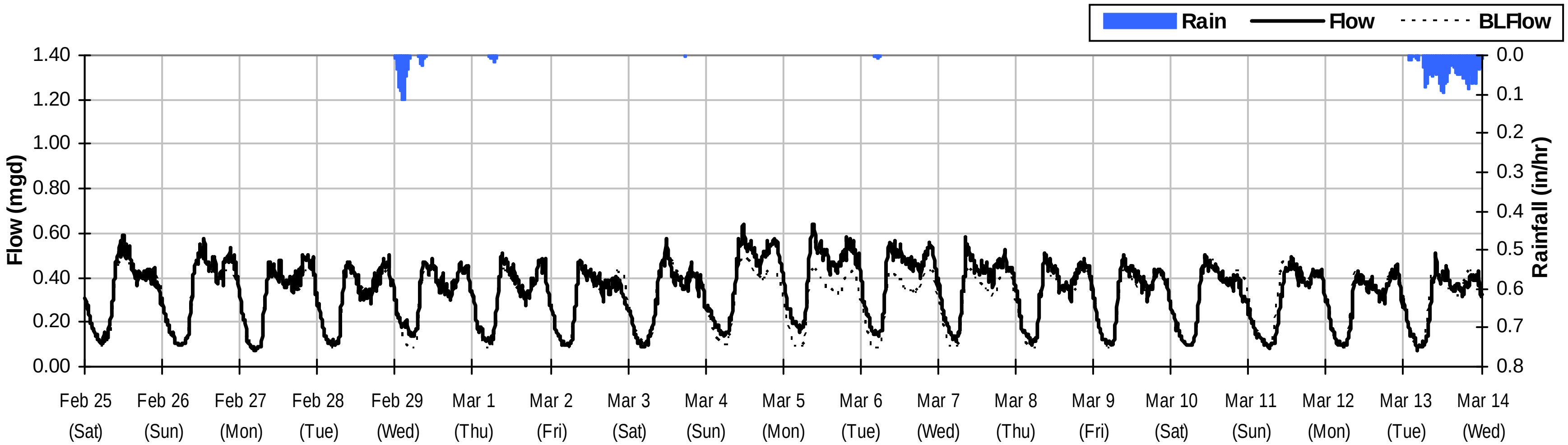


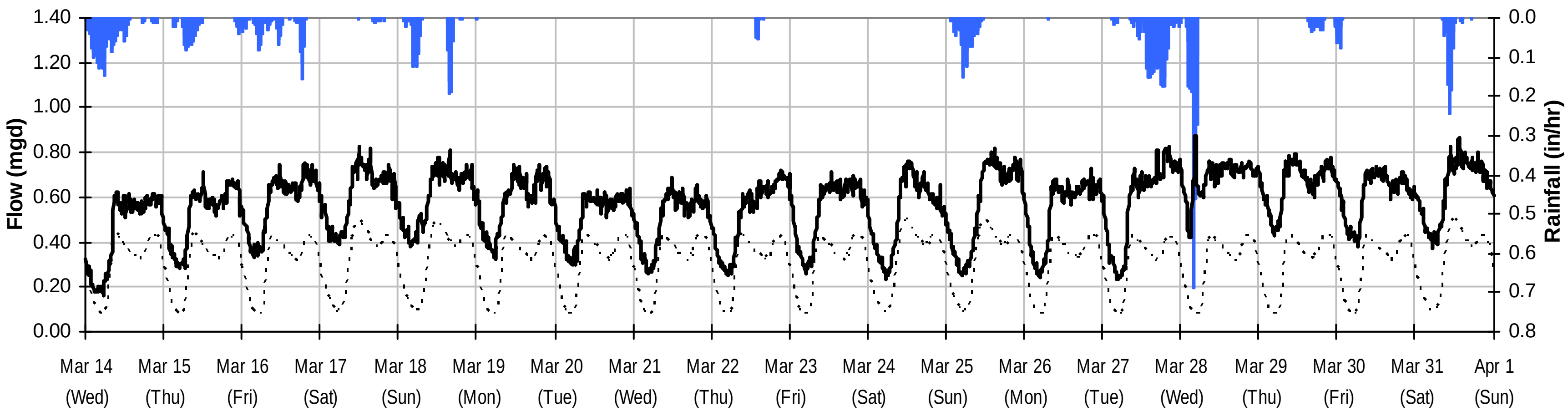
SITE 14

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.454 mgd **Peak Flow: 0.877 mgd** **Min Flow: 0.074 mgd**

Total Period Rainfall: 6.12 inches



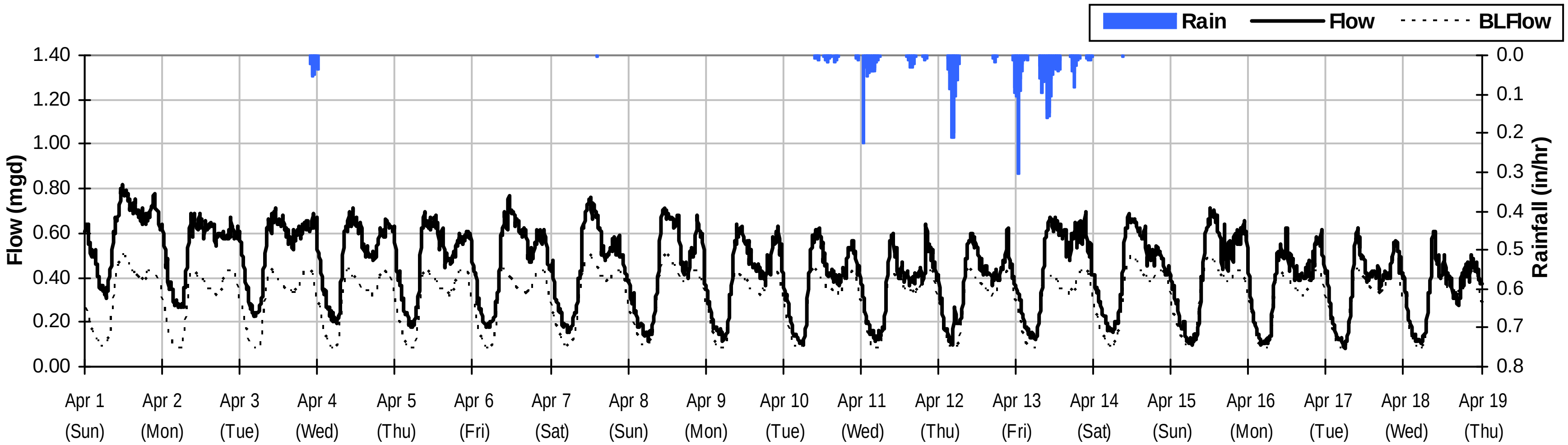


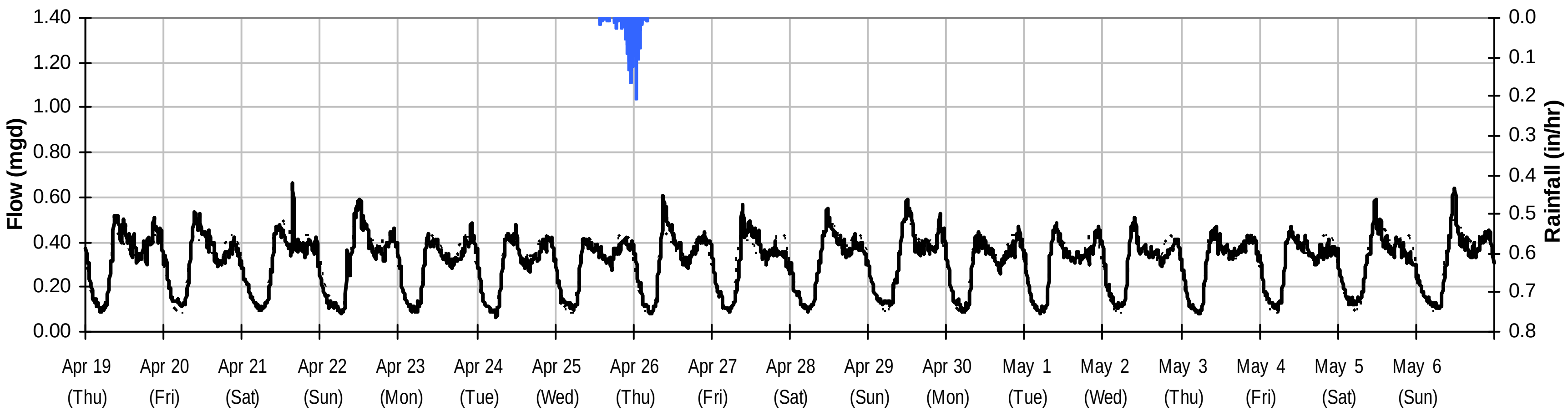
SITE 14

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.377 mgd **Peak Flow: 0.817 mgd** **Min Flow: 0.068 mgd**

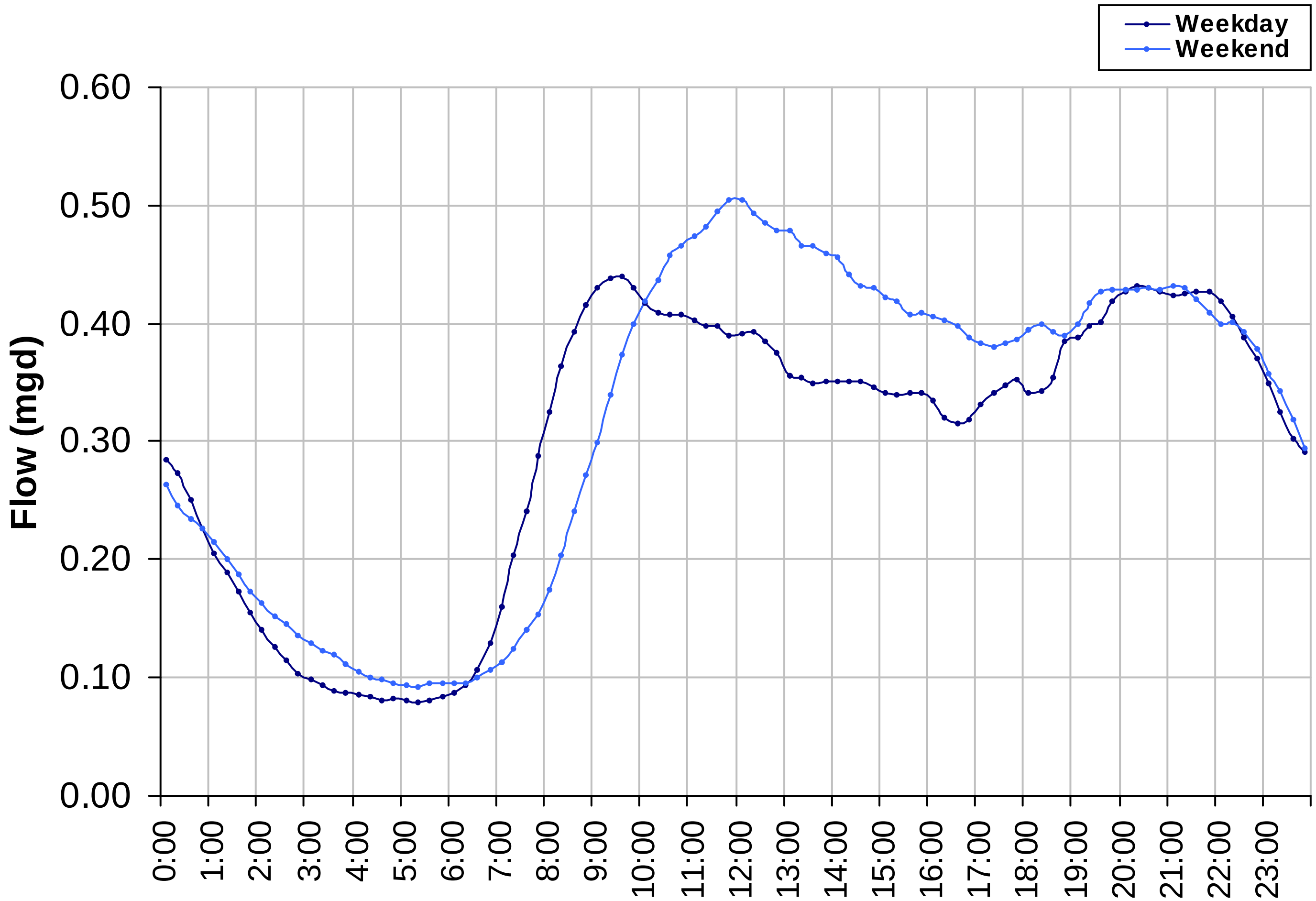
Total Period Rainfall: 2.08 inches



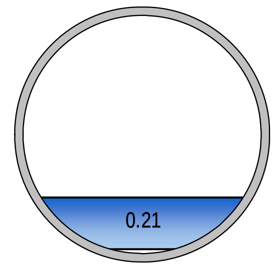


SITE 14

Baseline Flow Hydrographs

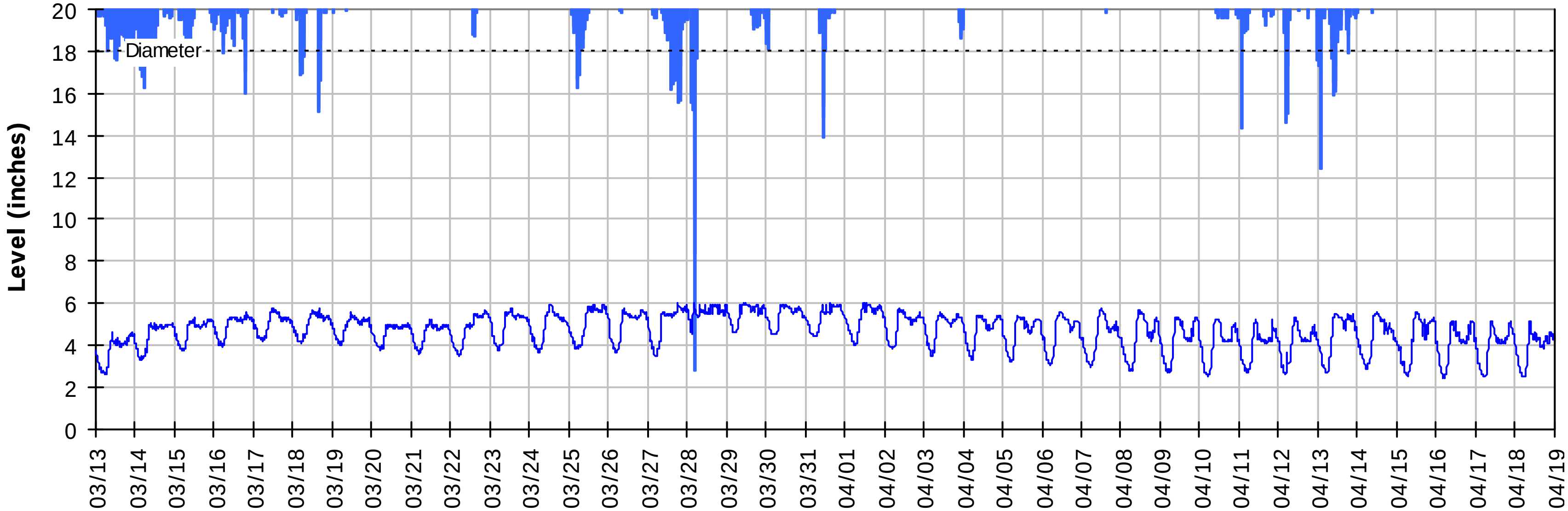


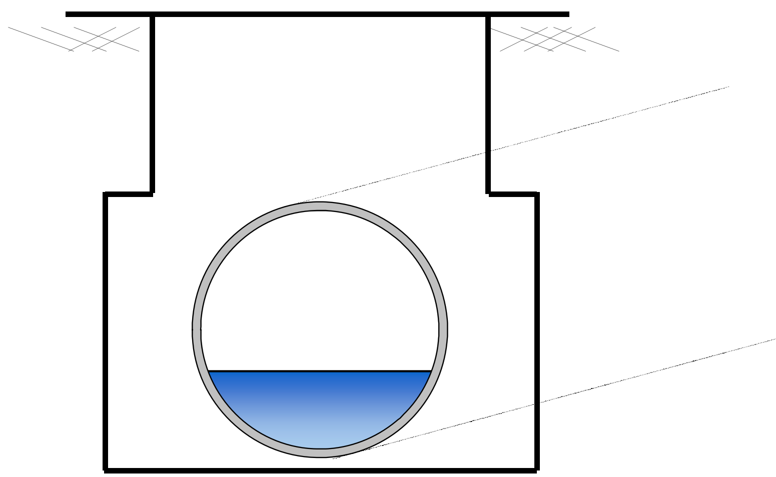
Baseline Flow:
0.304 *mgd*



SITE 14
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





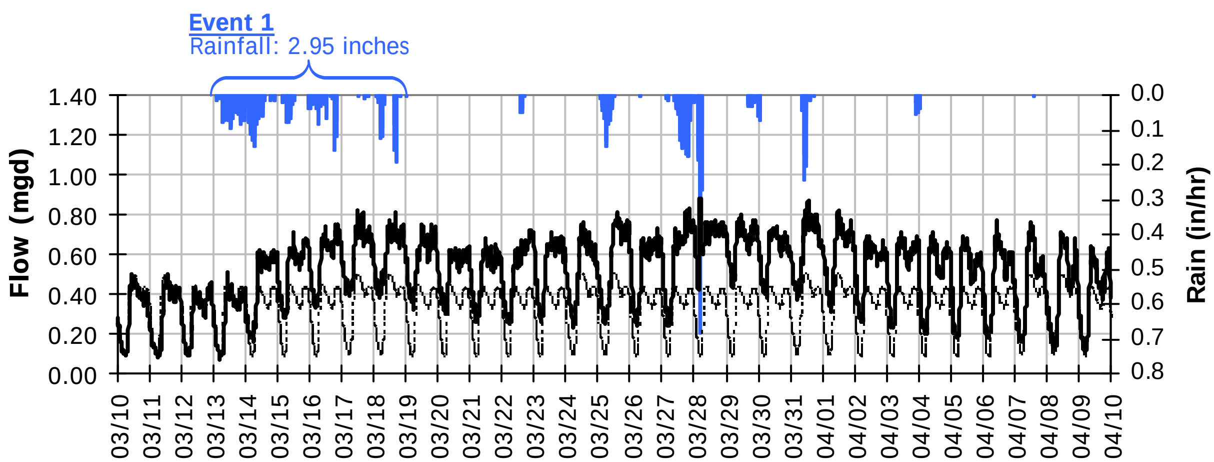
Pipe Diameter: 18 *inches*

Peak Measured Level: 6.06 *inches*

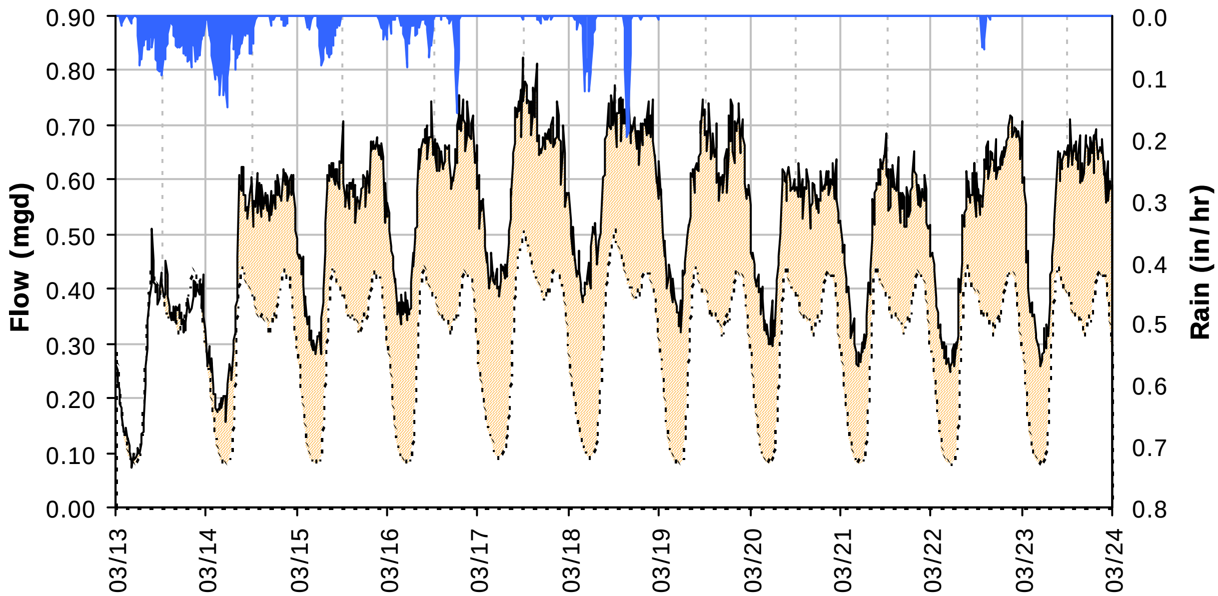
Peak d/D Ratio: 0.34

SITE 14
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 = 2.95 inches)

Capacity

Peak Flow: 0.82 *mgd*
PF: 2.70
Peak Level: 5.79 *in*
d/D Ratio: 0.32

Inflow

Peak I/I Rate: 0.42 *mgd*
PkI/I:IDM: 5,034 *gpd/IDM*
PkI/I:Acre: 1,063 *gpd/acre*
Pk I/I:ADWF: 1.38

RDI (infiltration)

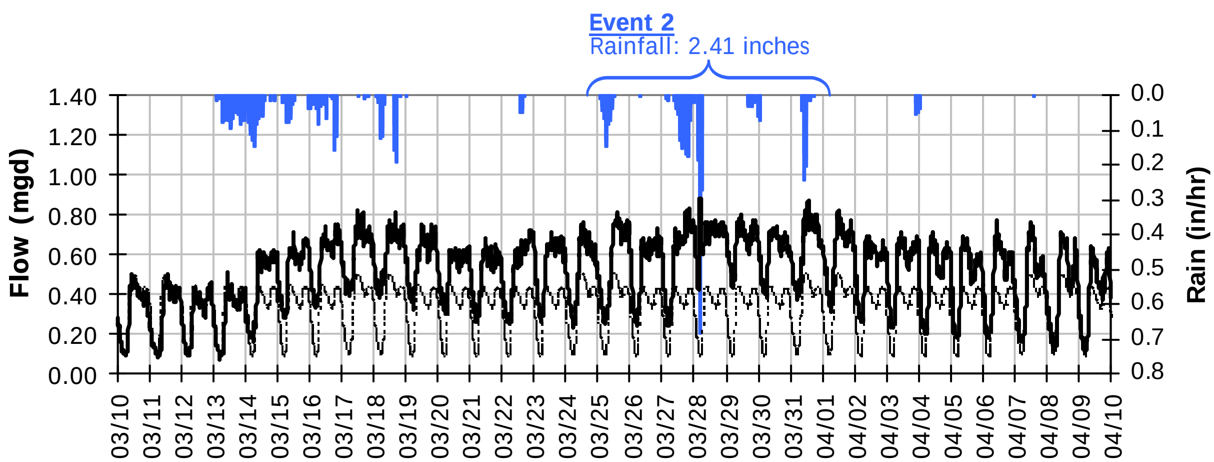
Infiltration Rate: 0.219 *mgd*
(3/20/2012)
RDI:IDM: 2,609 *gpd/IDM*
RDI:Acre: 551 *gpd/acre*
RDI (% of BL): 73%

Combined I/I

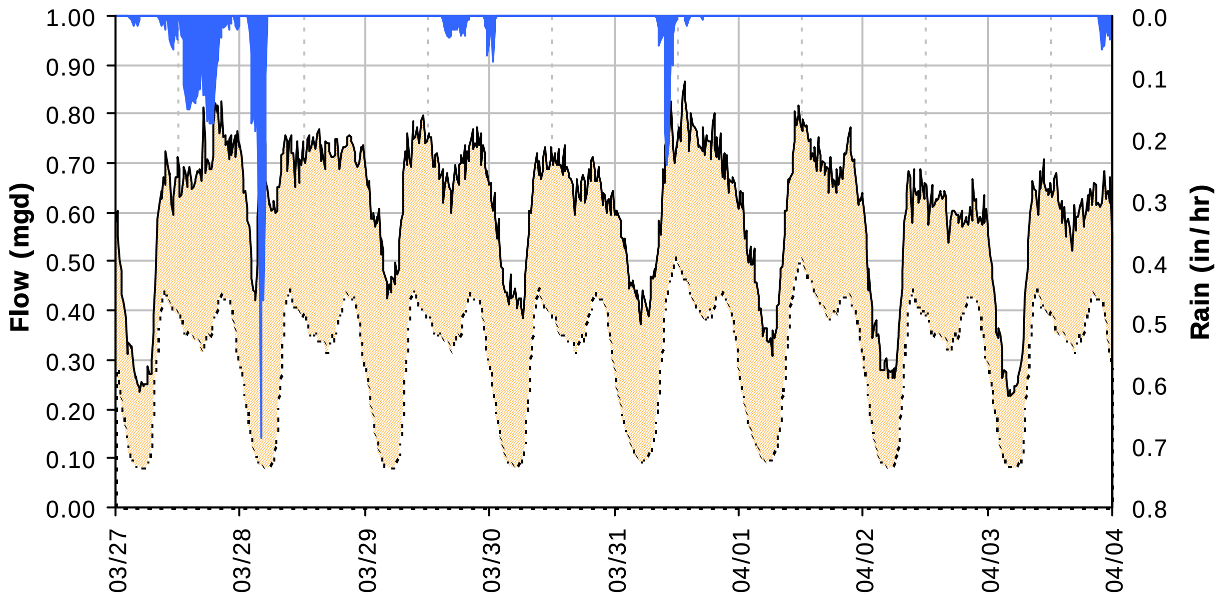
Total I/I: 2,423,000 *gallons*
Total I/I:IDM: 9,800 *gal/IDM/in*
R-Value: 7.6%
Total I/I:ADWF: 2.70 *per in-rain*

SITE 14
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph

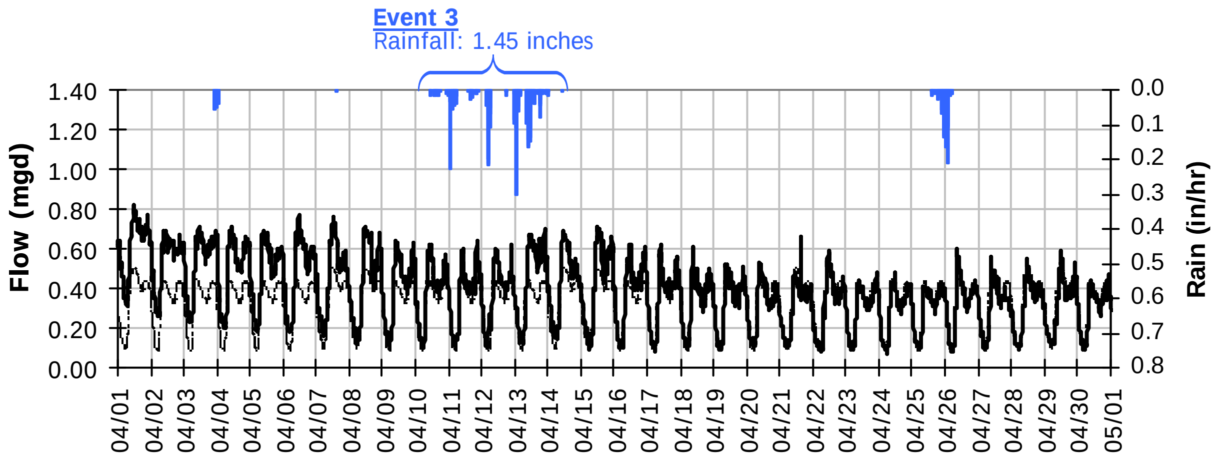


Storm Event I/I Analysis (Rain = 2.41 inches)

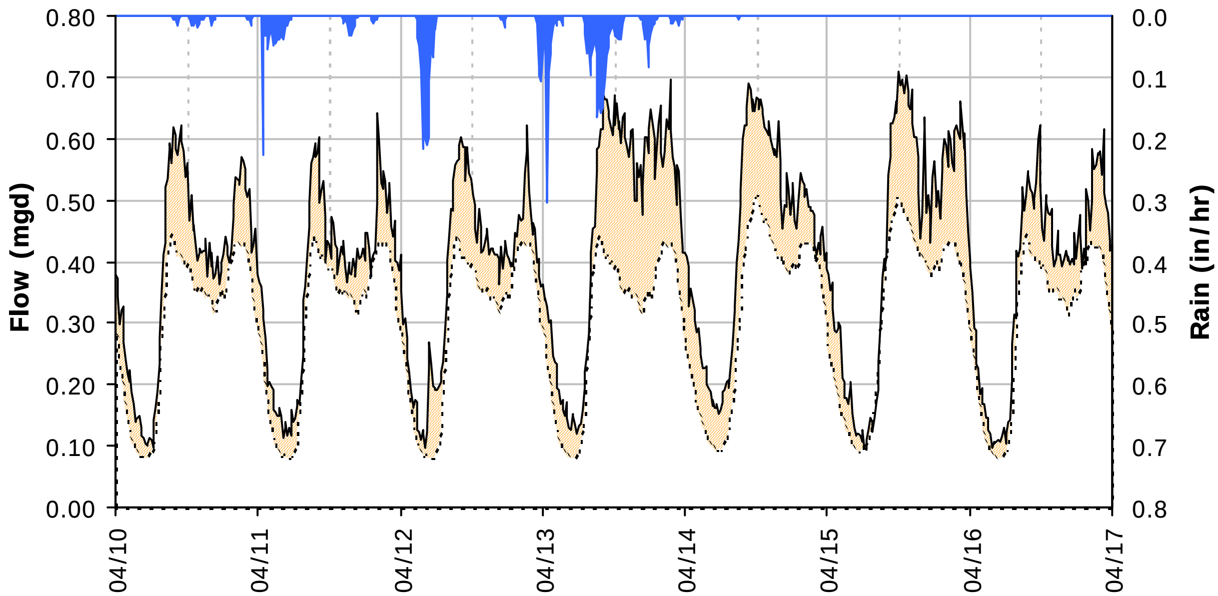
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.88 *mgd*	**Peak I/I Rate:**	0.80 *mgd*	**Infiltration Rate:** (4/2/2012)	0.235 *mgd*	**Total I/I:**	2,438,000 *gallons*
PF:	2.88	**PkI/I:IDM:**	9,503 *gpd/IDM*	**RDI:IDM:**	2,809 *gpd/IDM*	**Total I/I:IDM:**	12,064 *gal/IDM/in*
Peak Level:	6.06 *in*	**PkI/I:Acre:**	2,007 *gpd/acre*	**RDI:Acre:**	593 *gpd/acre*	**R-Value:**	9.4%
d/D Ratio:	0.34	**Pk I/I:ADWF:**	2.61	**RDI (% of BL):**	79%	**Total I/I:ADWF:**	3.32 *per in-rain*

SITE 14
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.45 inches)

Capacity

Peak Flow:	0.71 *mgd*
PF:	2.33
Peak Level:	5.56 *in*
d/D Ratio:	0.31

Inflow

Peak I/I Rate:	0.30 *mgd*
PkI/I:IDM:	3,640 *gpd/IDM*
PkI/I:Acre:	769 *gpd/acre*
Pk I/I:ADWF:	1.00

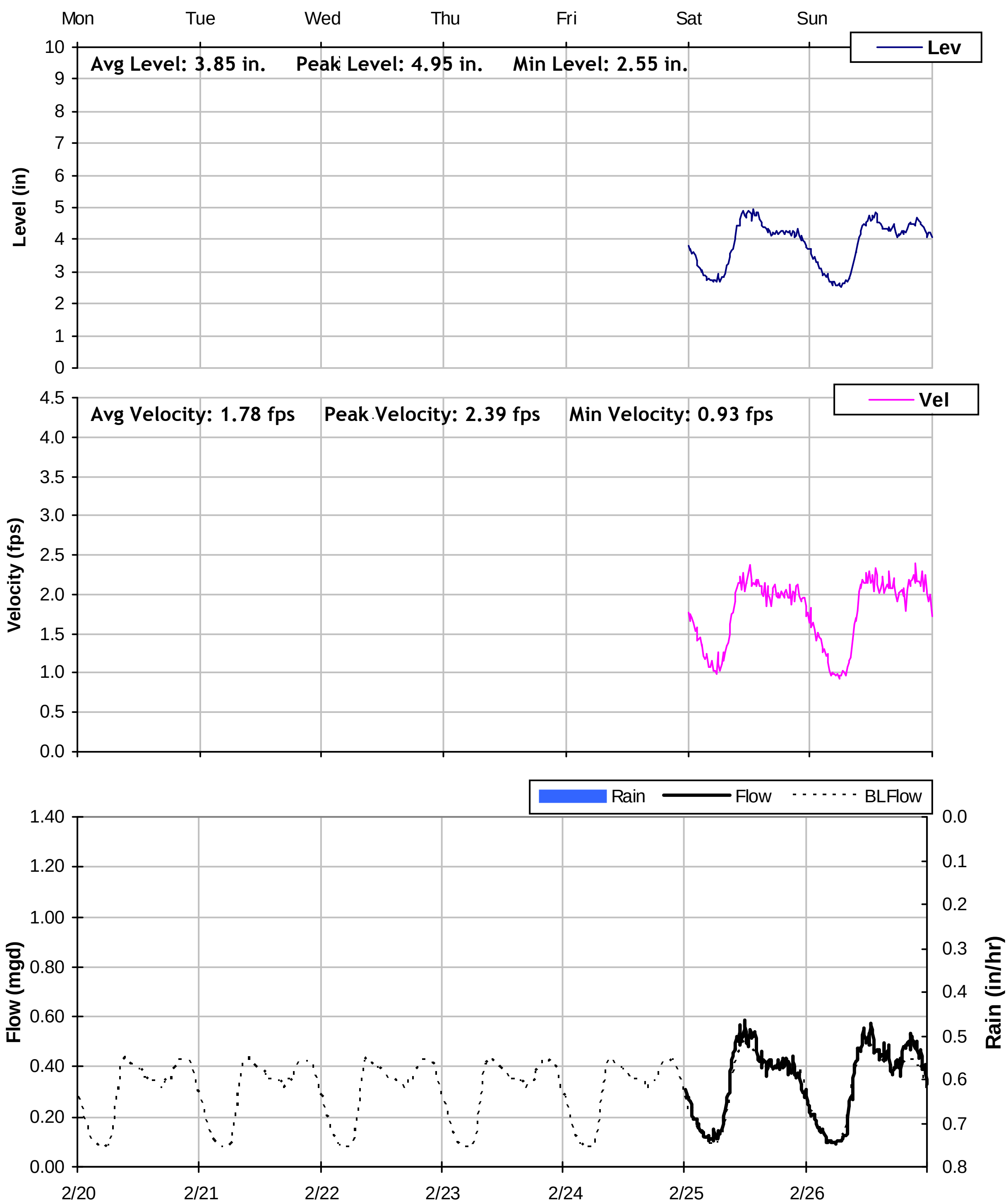
RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.112 *mgd*
RDI:IDM:	1,341 *gpd/IDM*
RDI:Acre:	283 *gpd/acre*
RDI (% of BL):	35%

Combined I/I

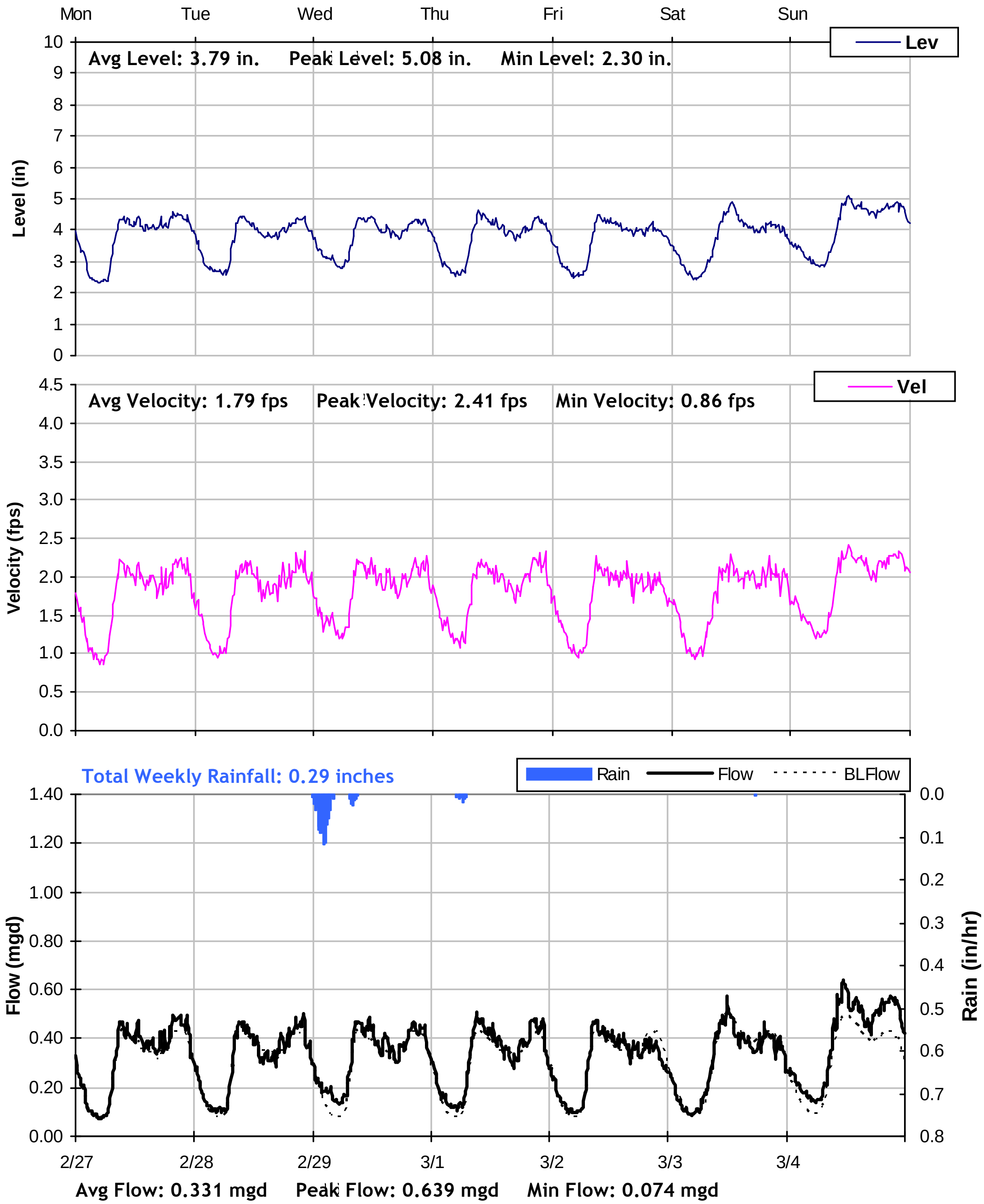
Total I/I:	706,000 *gallons*
Total I/I:IDM:	5,811 *gal/IDM/in*
R-Value:	4.5%
Total I/I:ADWF:	1.60 *per in-rain*

SITE 14
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



Avg Flow: 0.341 mgd Peak Flow: 0.588 mgd Min Flow: 0.095 mgd

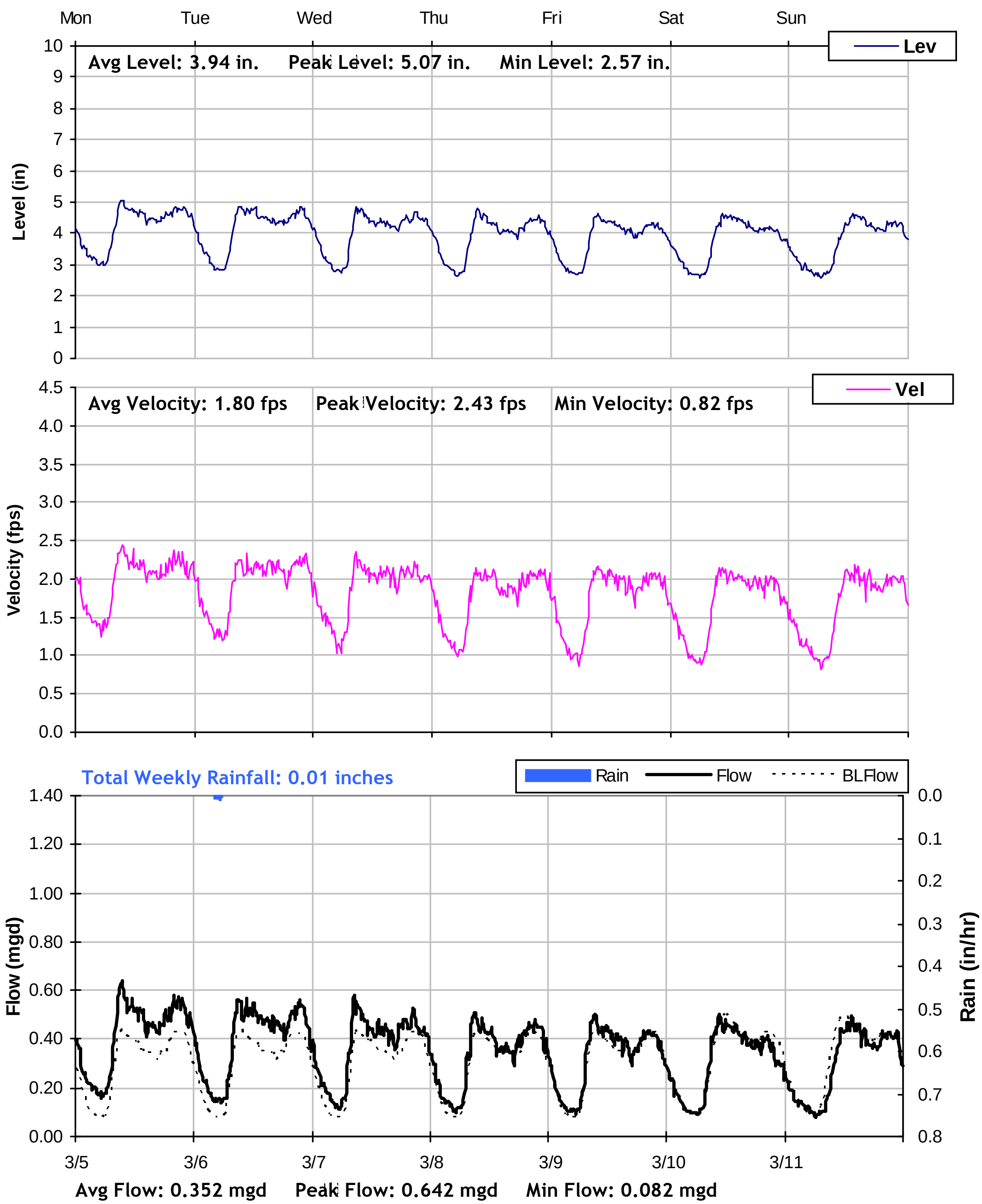
SITE 14
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



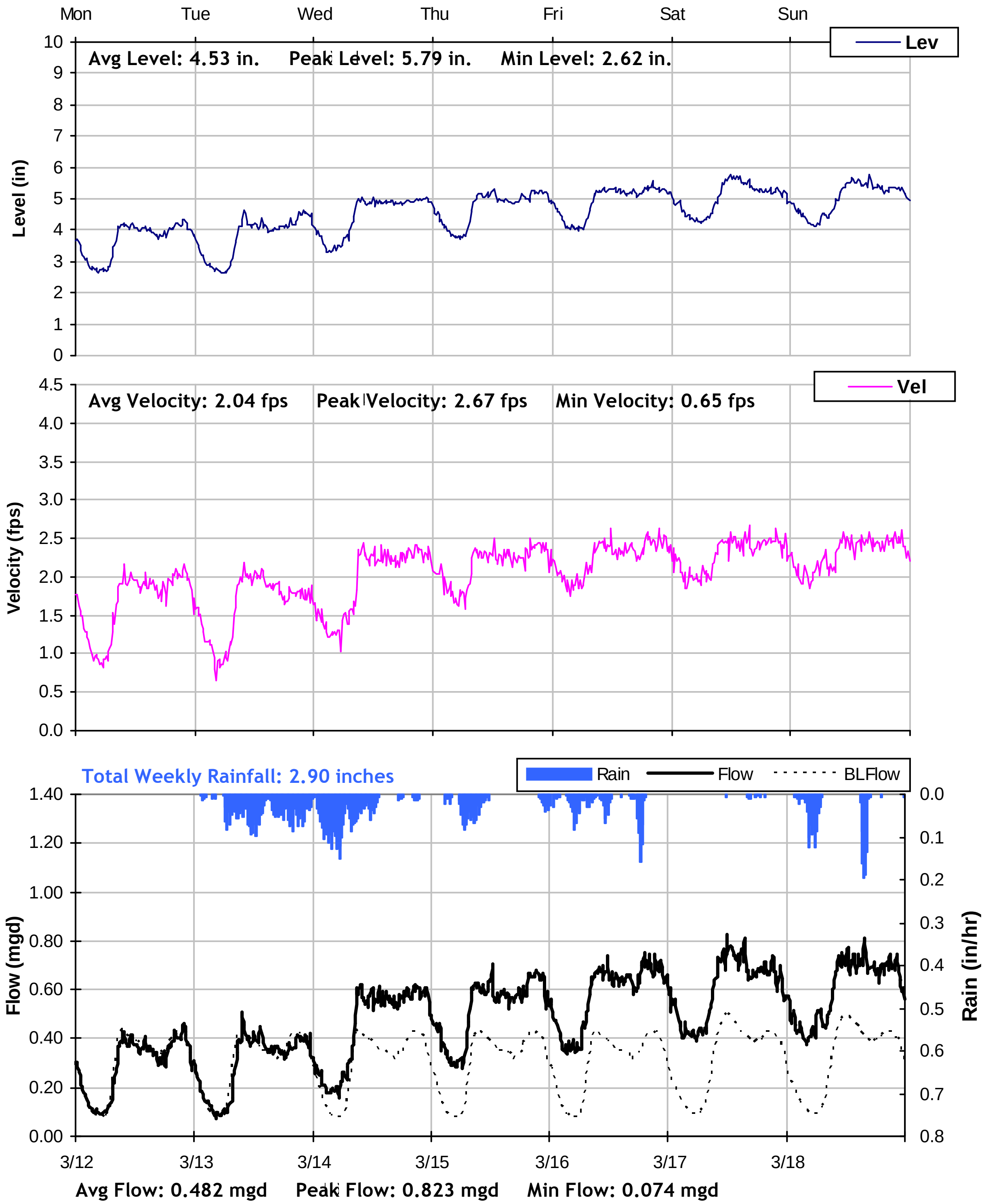
SITE 14

Weekly Level, Velocity and Flow Hydrographs

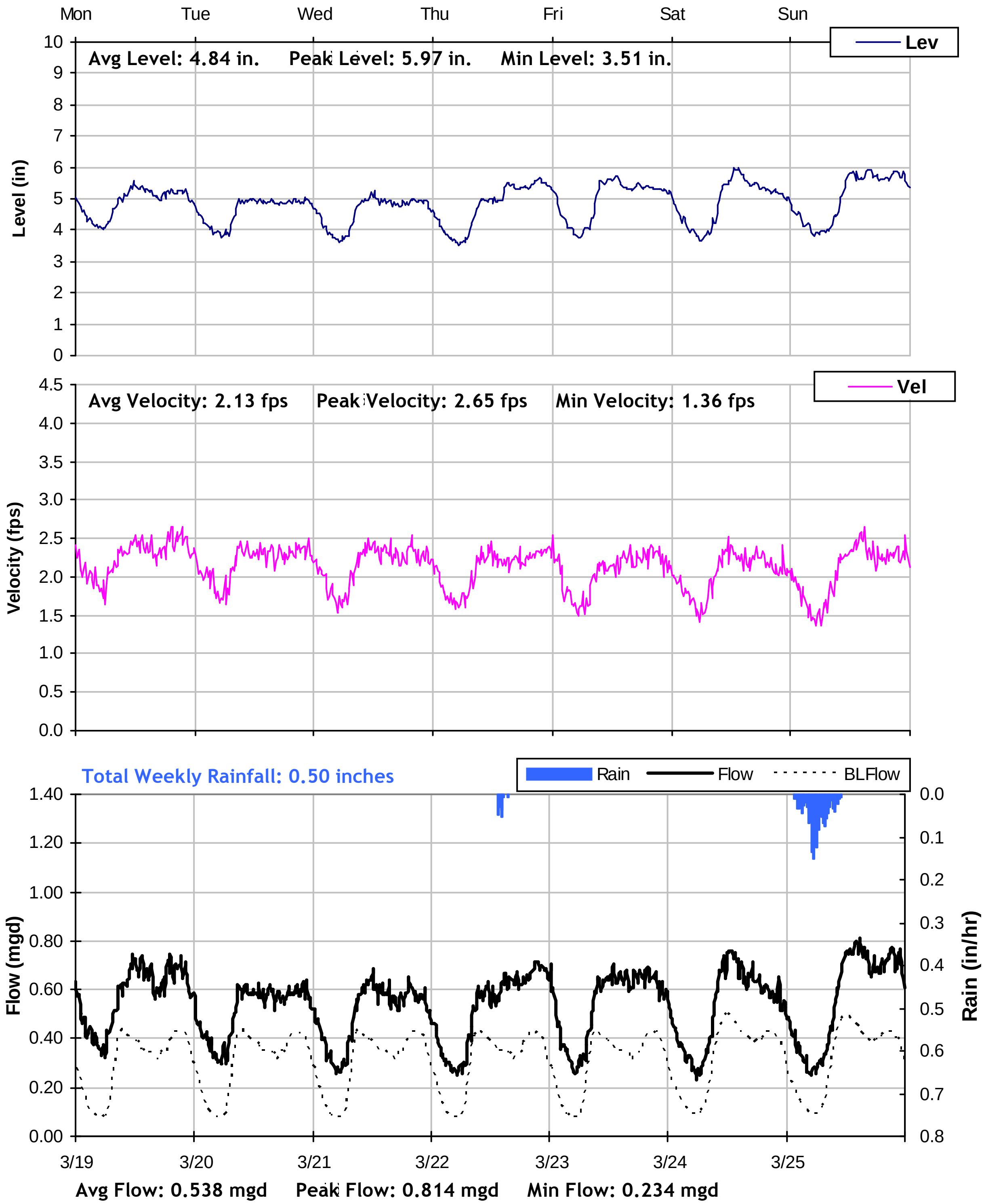
3/5/2012 to 3/12/2012



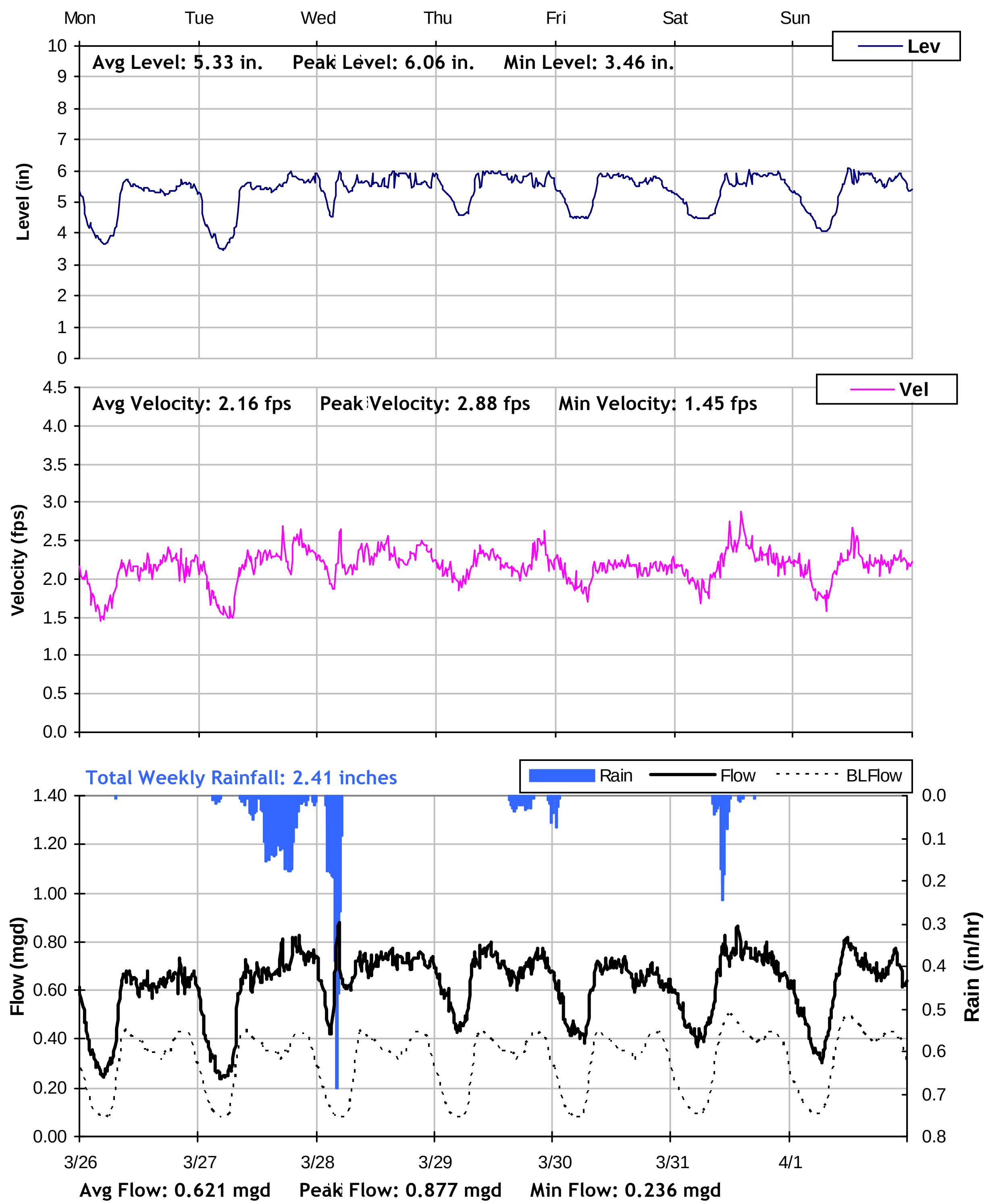
SITE 14
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



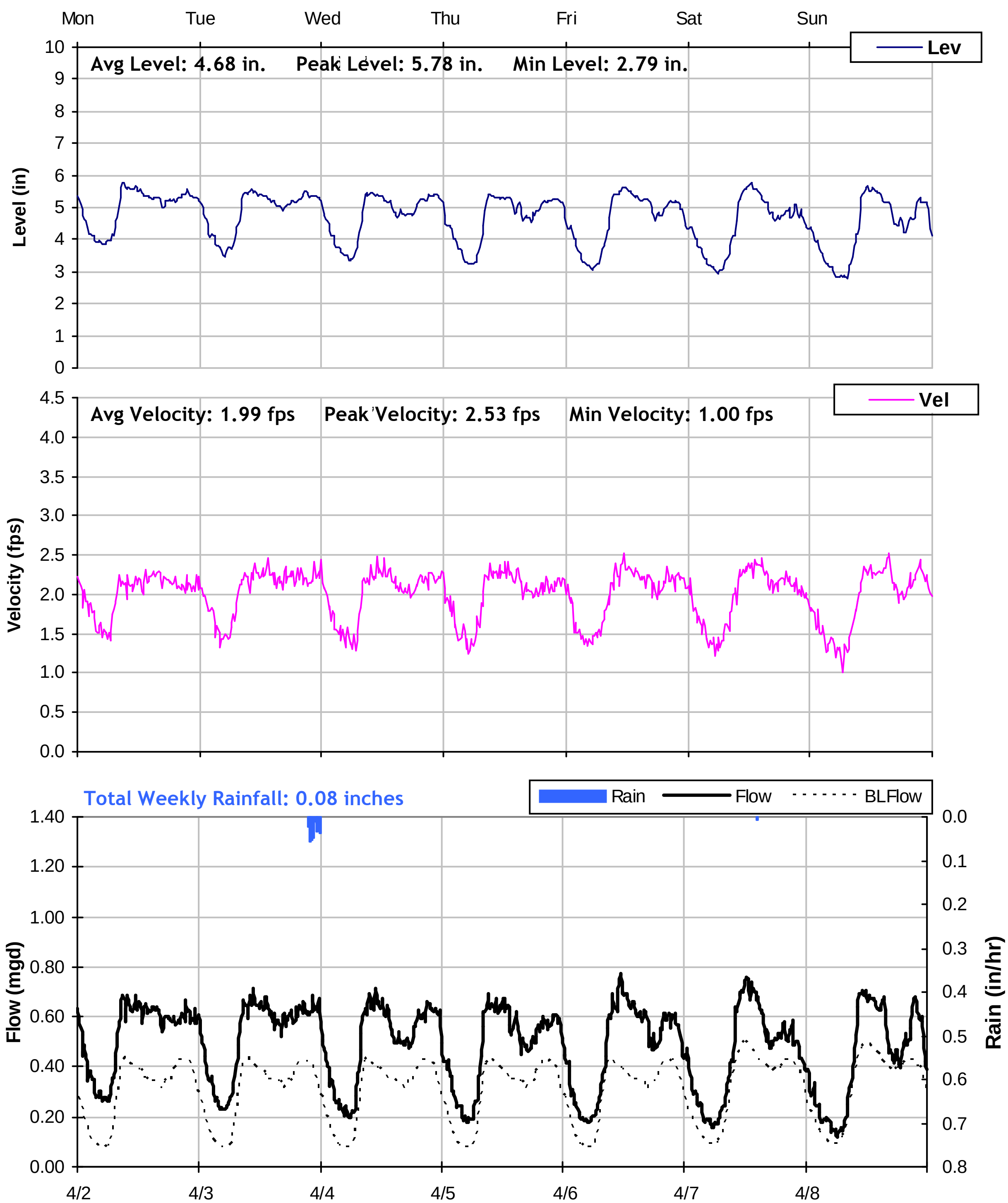
SITE 14
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



SITE 14
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012

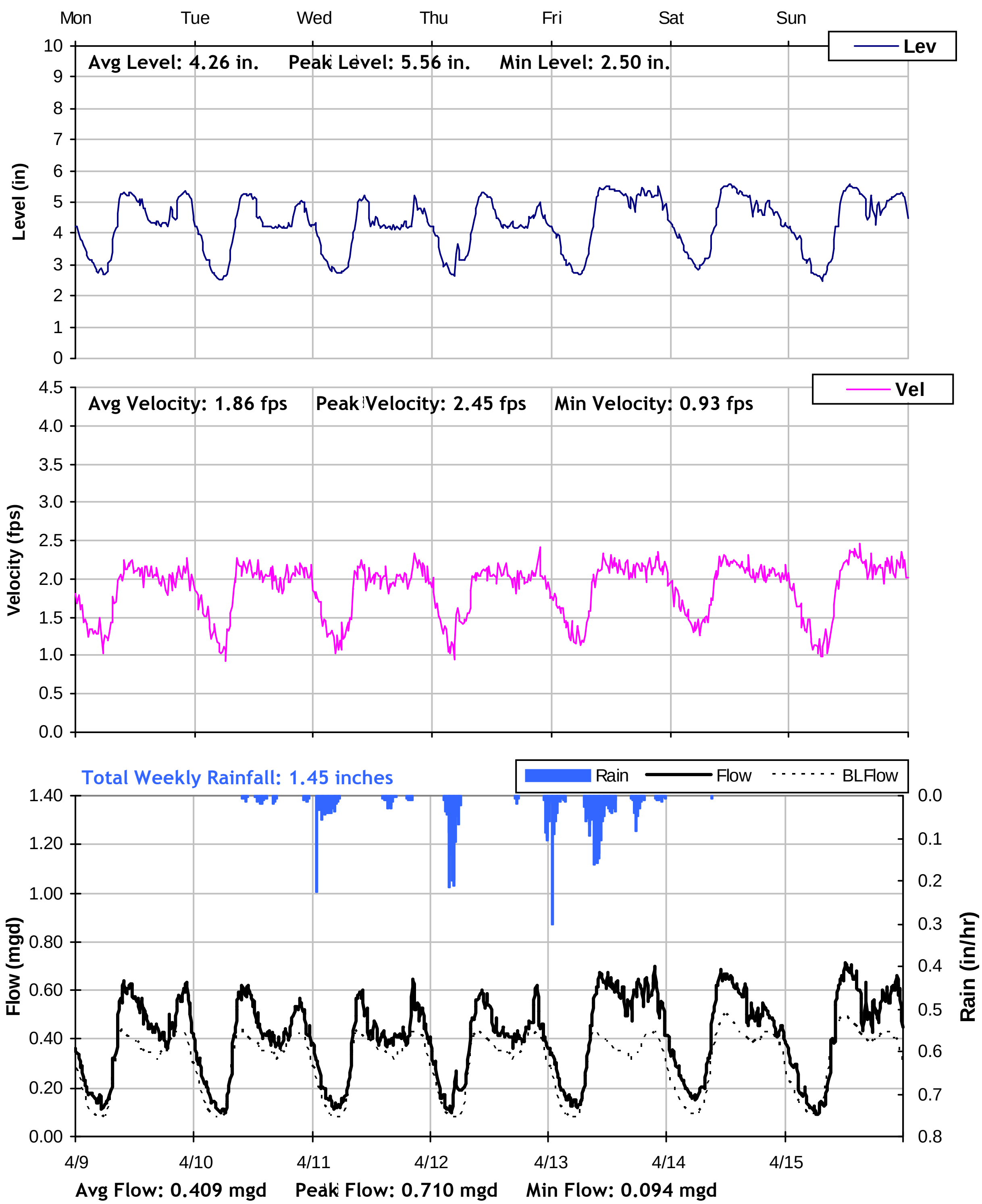


SITE 14
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012

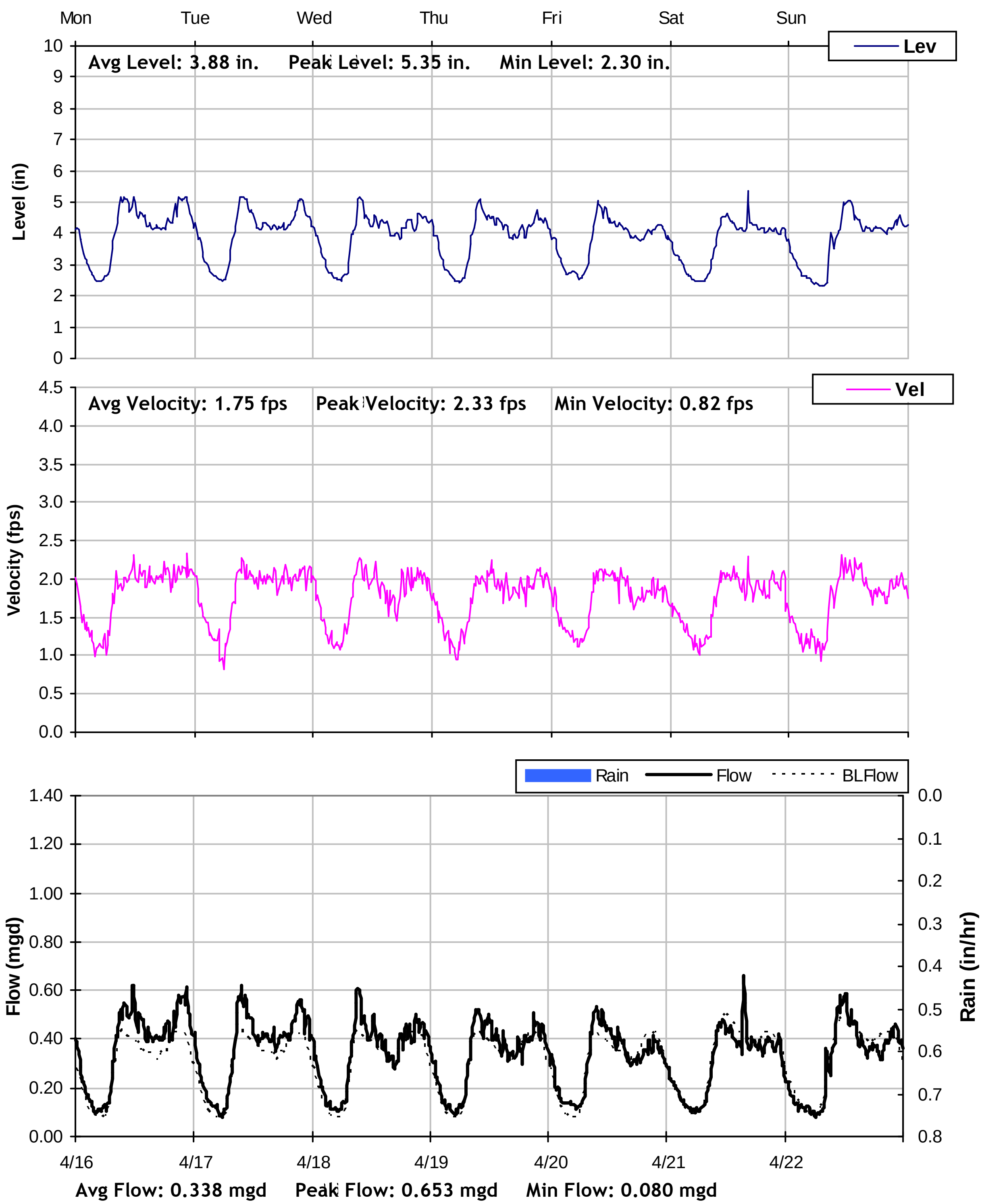


Avg Flow: 0.489 mgd Peak Flow: 0.770 mgd Min Flow: 0.117 mgd

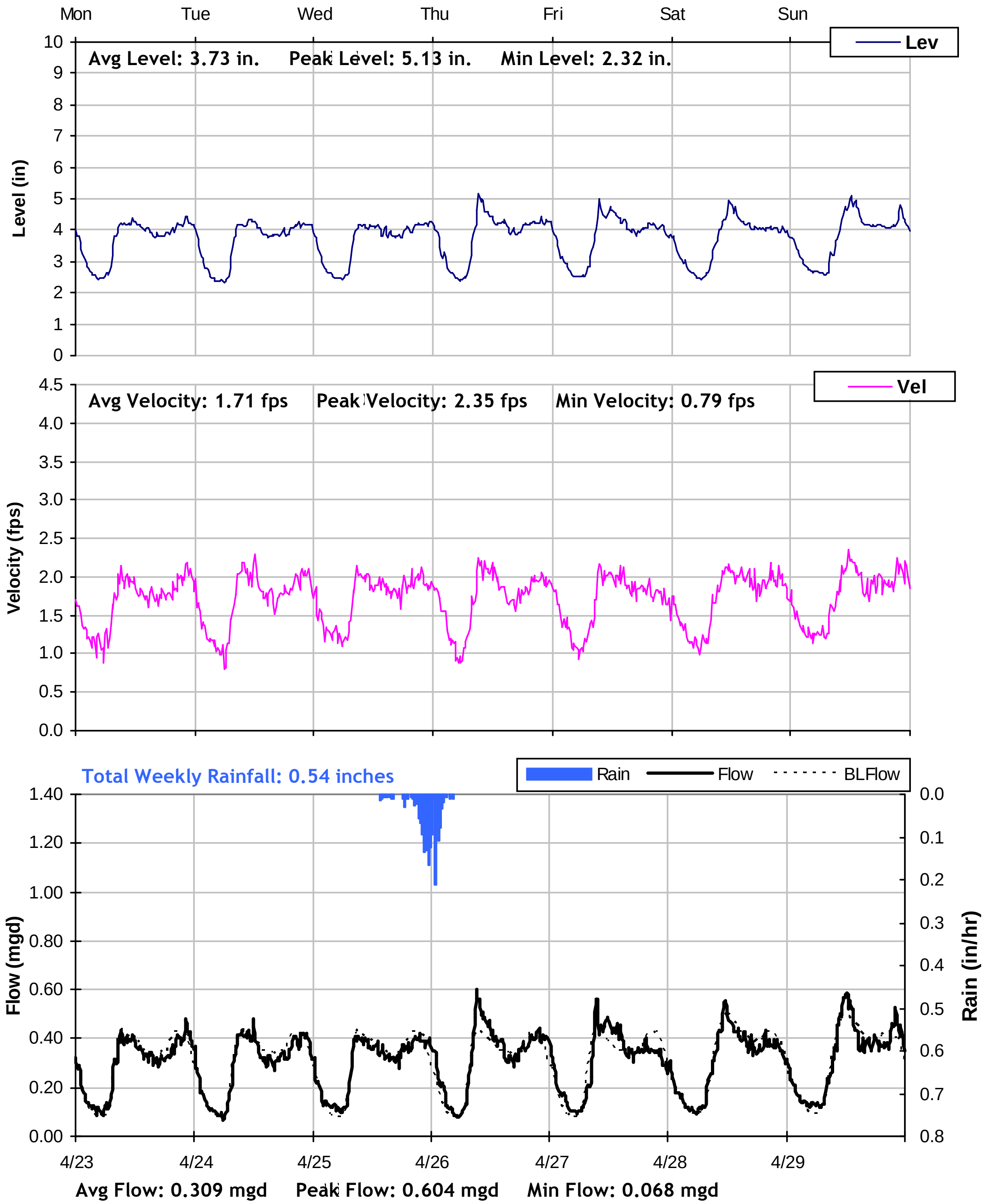
SITE 14
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



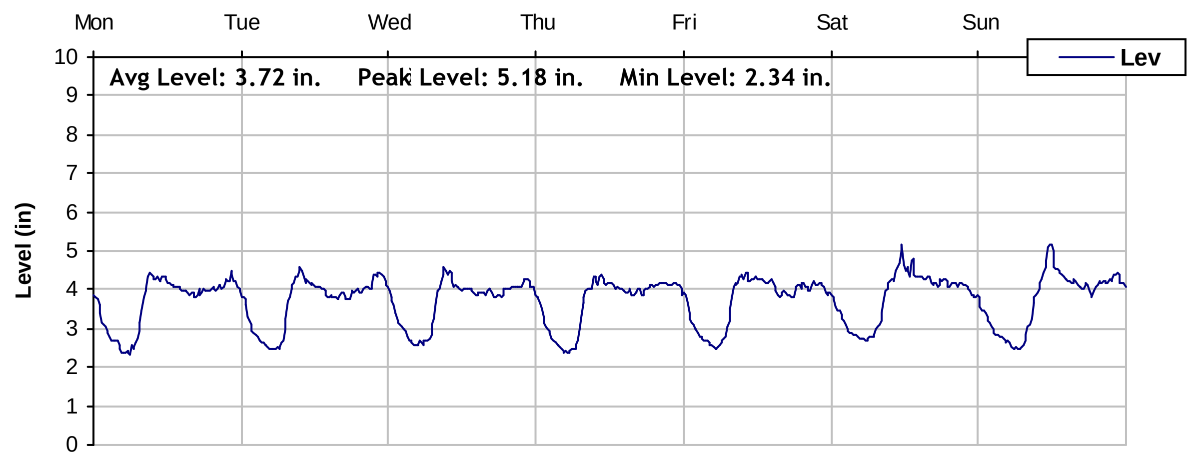
SITE 14
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012

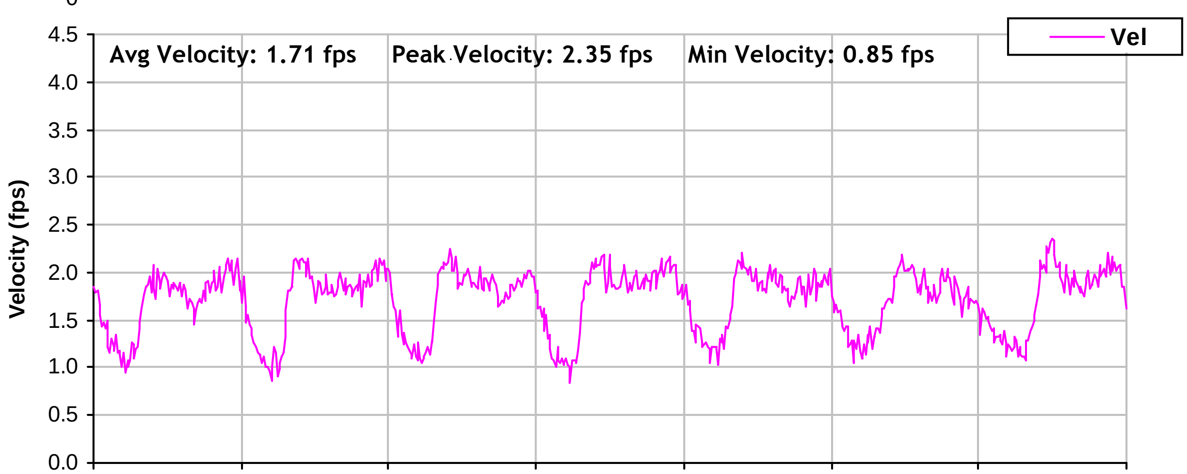


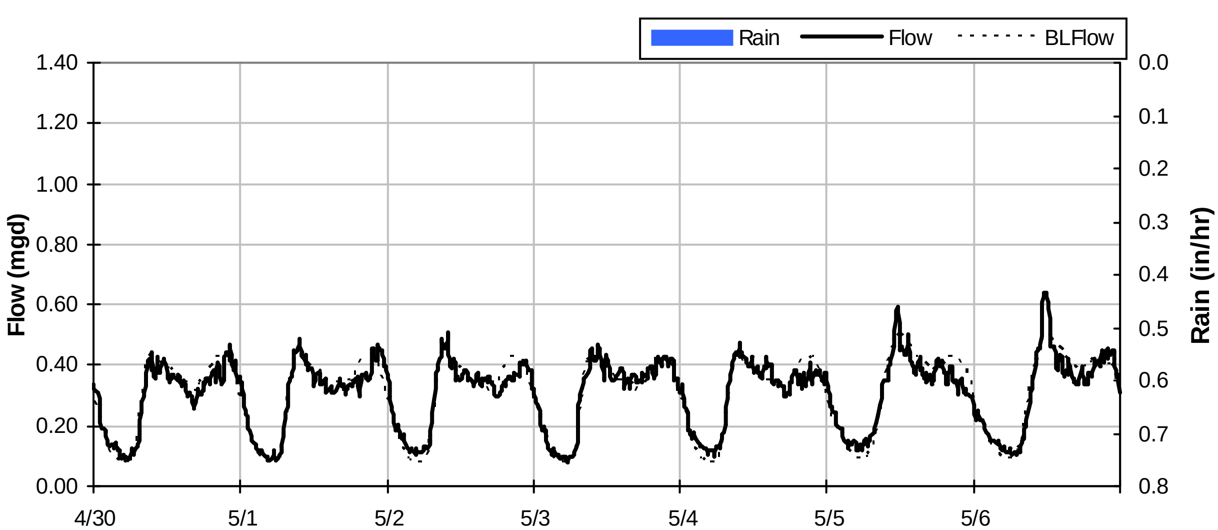
SITE 14
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 14
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012







Avg Flow: 0.307 mgd **Peak Flow: 0.639 mgd** **Min Flow: 0.077 mgd**

City of Chico

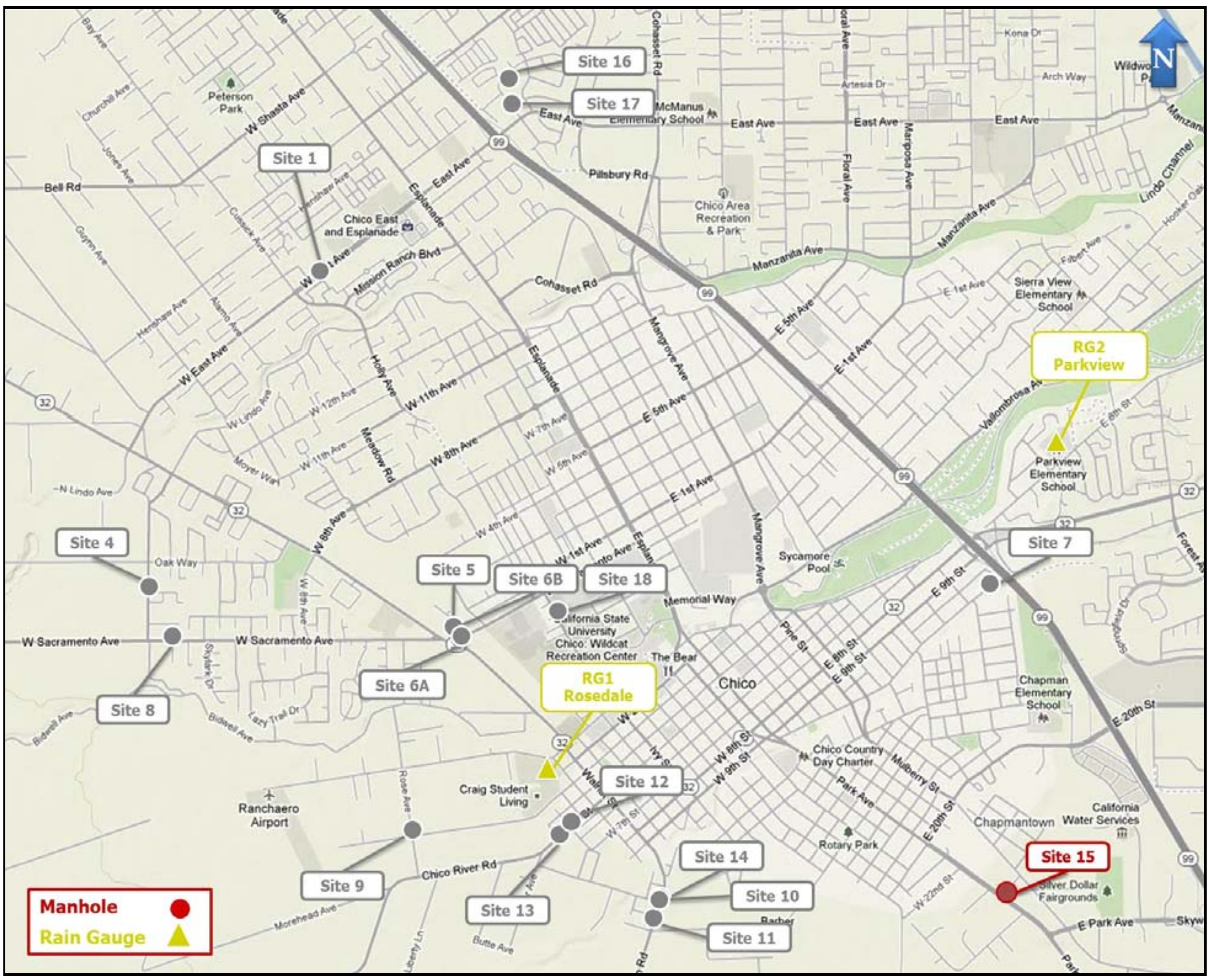
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 15

Location: Park Avenue between Westfield Lane and Meyers Street

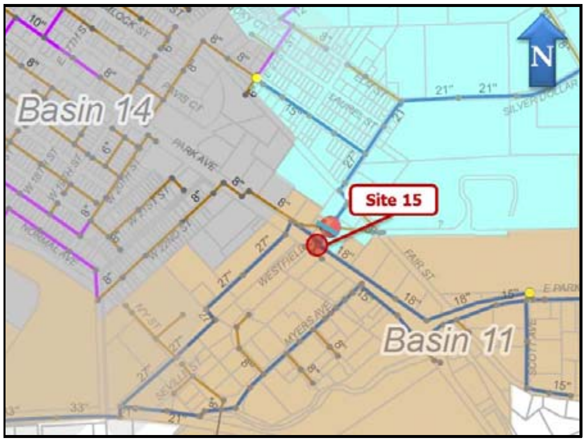
Vicinity Map:



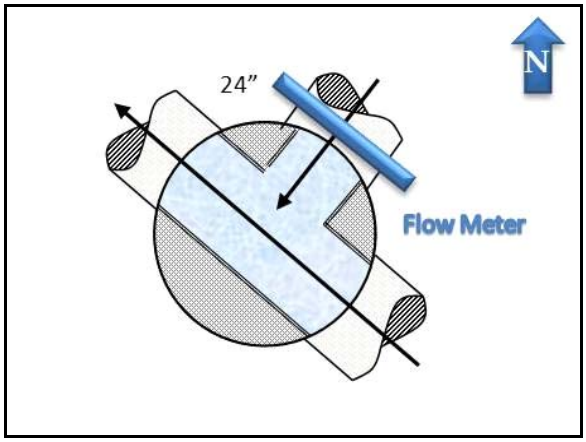
SITE 15
Site Information Report

Location:	Park Avenue between Westfield Lane and Meyers Street
Coordinates:	121.8173° W, 39.7162° N
Elevation:	203 feet
Diameter:	24 inches
Baseline Flow:	1.053 mgd
Peak Measured Flow:	2.488 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch


View from Street

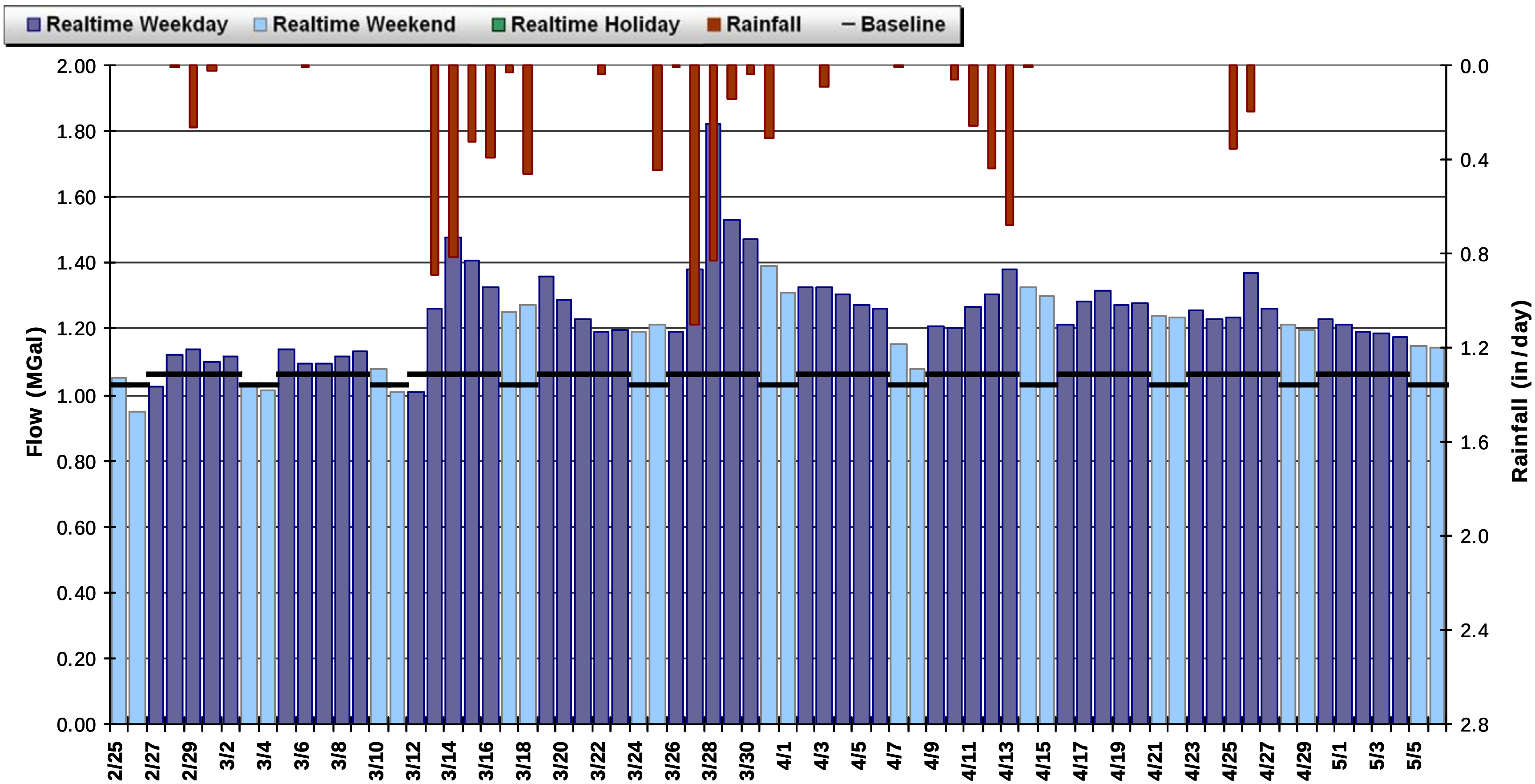

Plan View

SITE 15

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.230 MGal **Peak Daily Flow: 1.821 MGal** **Min Daily Flow: 0.949 MGal**

Total Period Rainfall: 8.22 inches

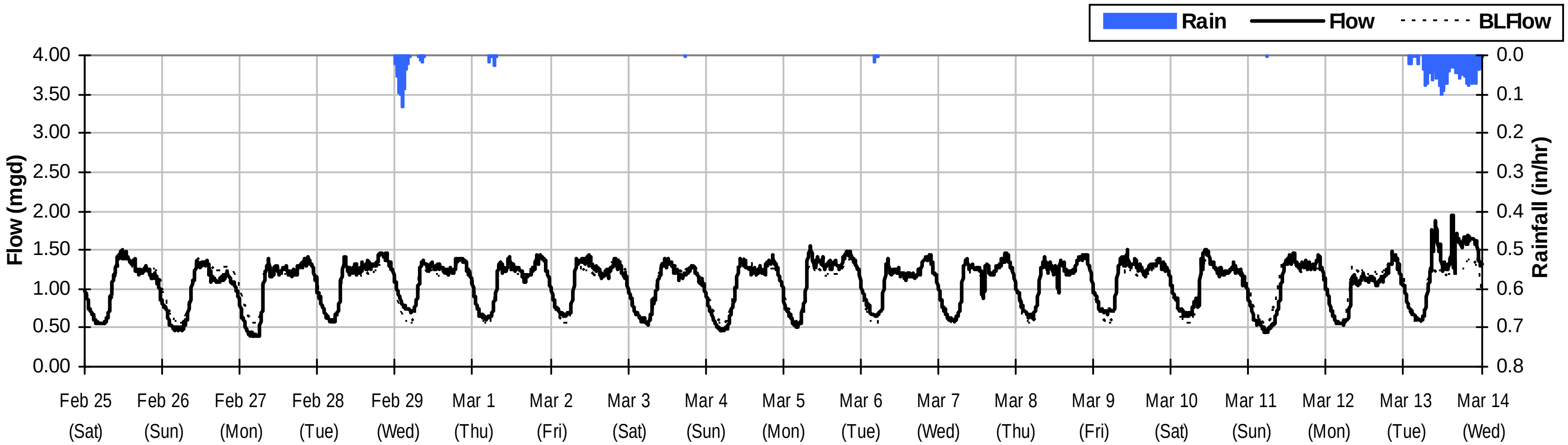


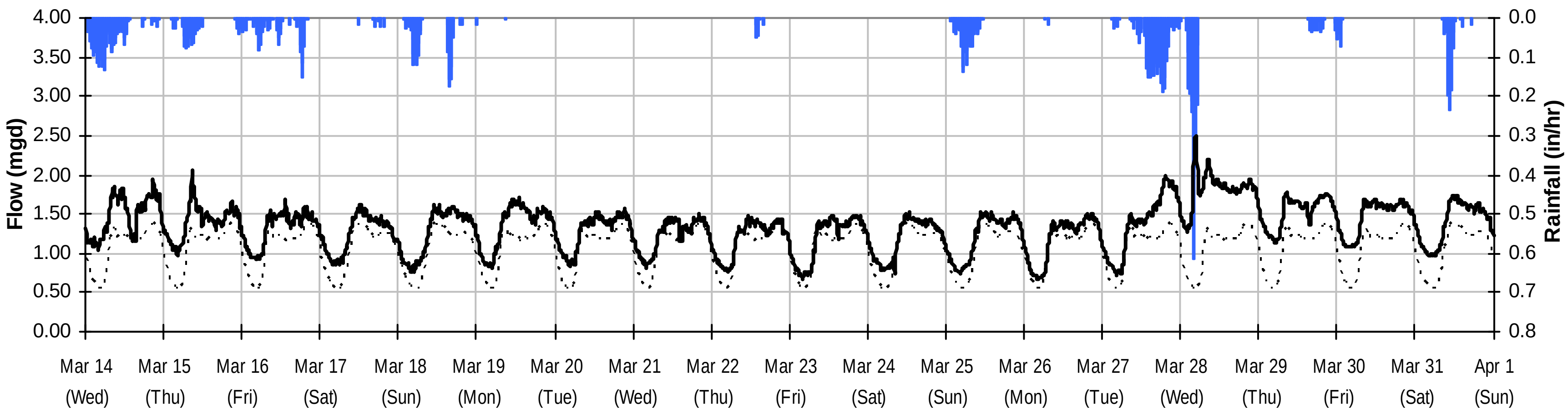
SITE 15

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 1.213 mgd **Peak Flow: 2.488 mgd** **Min Flow: 0.385 mgd**

Total Period Rainfall: 6.13 inches



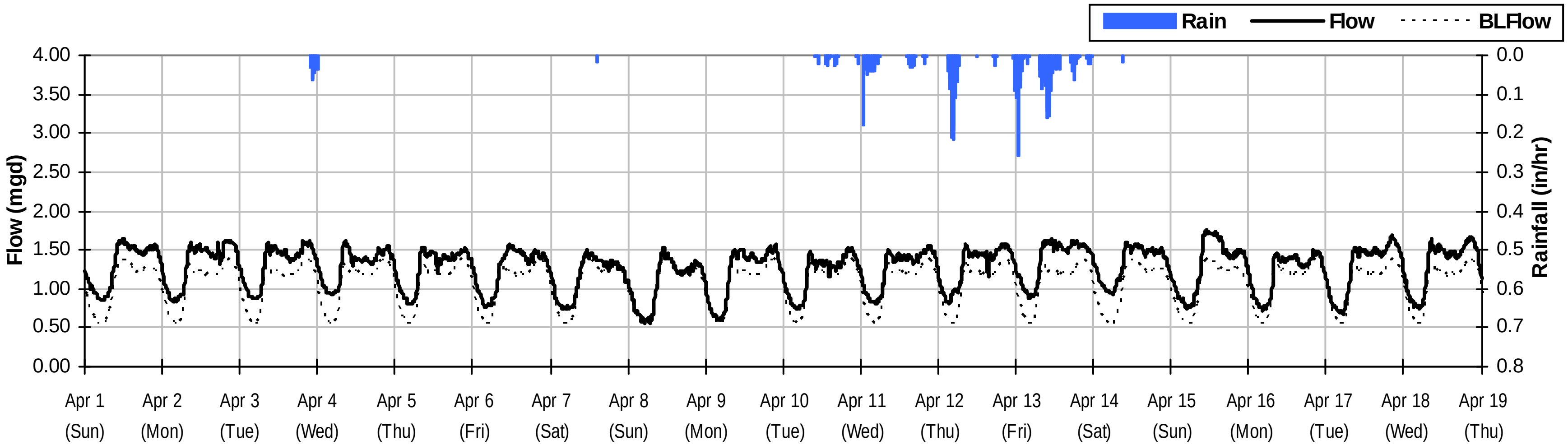


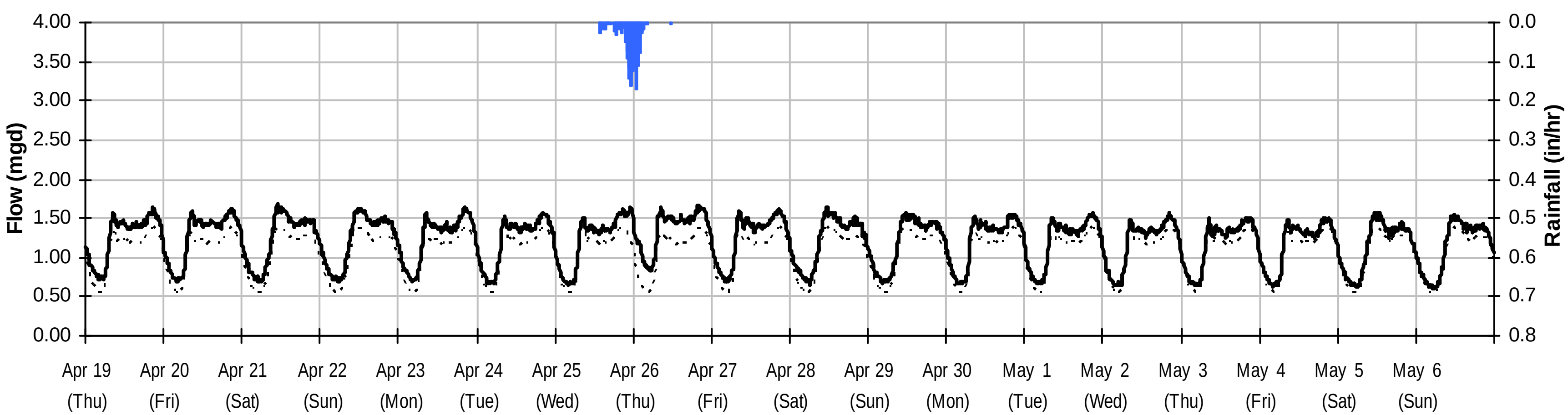
SITE 15

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 1.247 mgd **Peak Flow: 1.763 mgd** **Min Flow: 0.553 mgd**

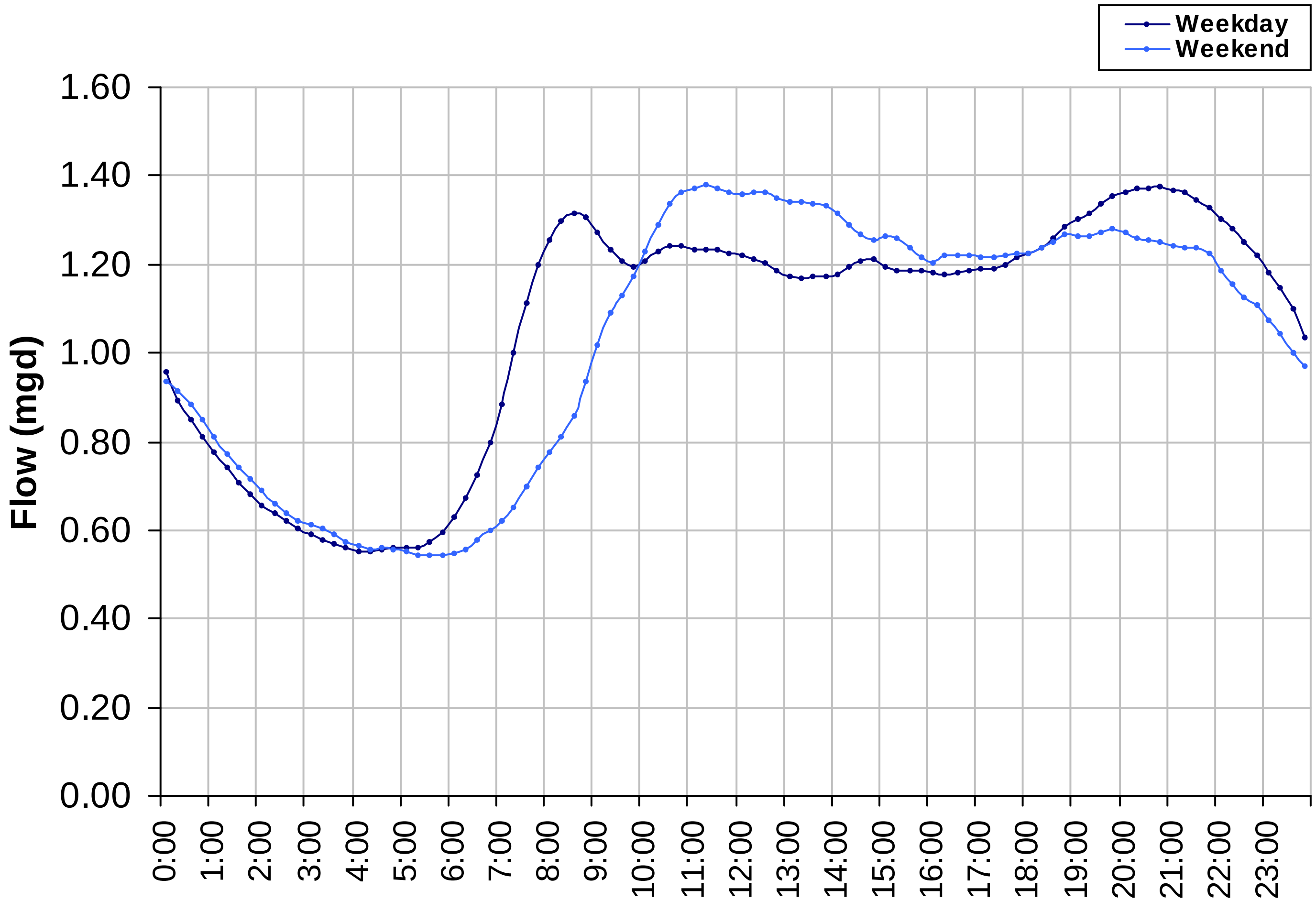
Total Period Rainfall: 2.09 inches





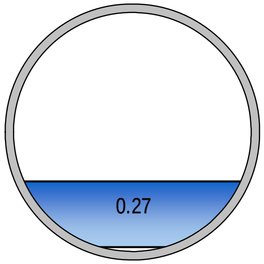
SITE 15

Baseline Flow Hydrographs



Baseline Flow:

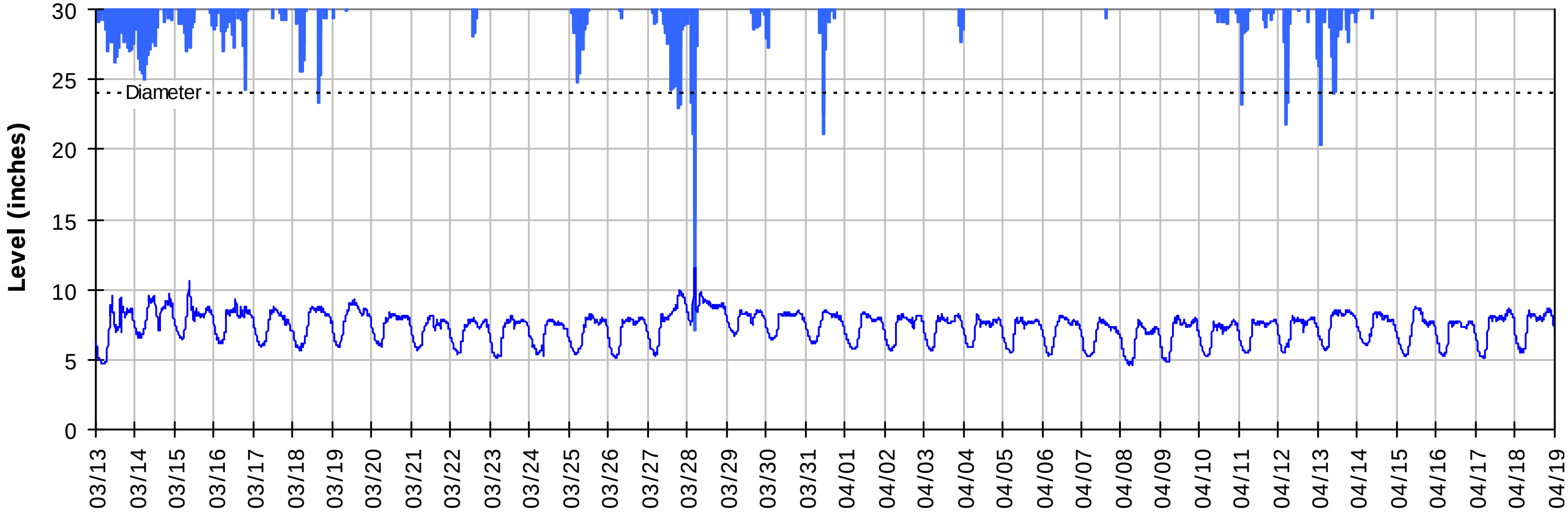
1.053 *mgd*

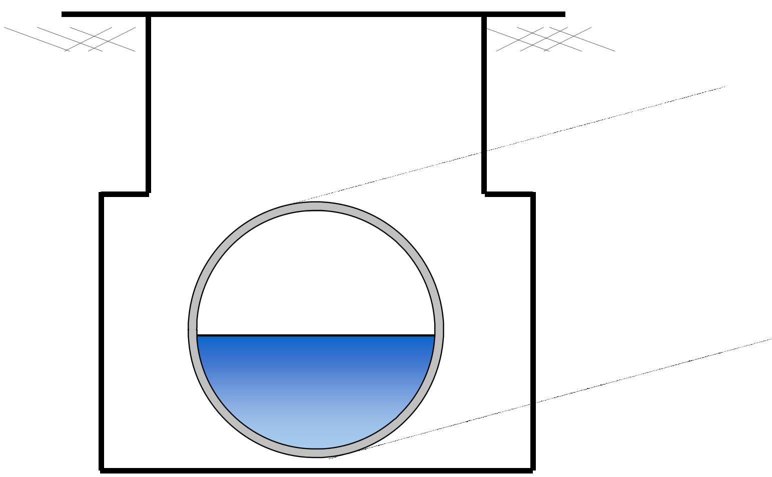


SITE 15

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





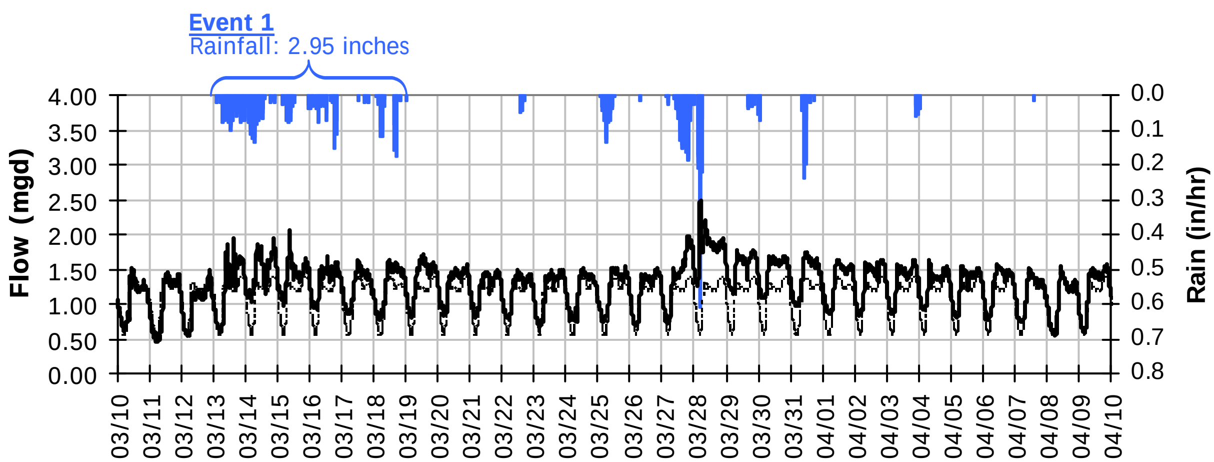
Pipe Diameter: 24 *inches*

Peak Measured Level: 11.6 *inches*

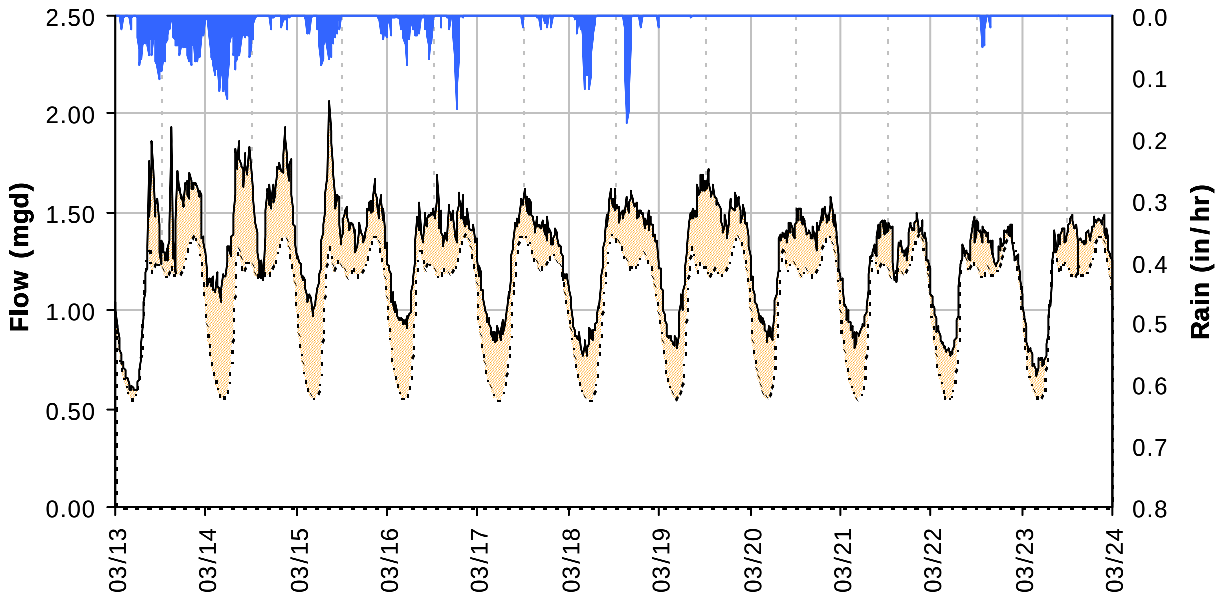
Peak d/D Ratio: 0.48

SITE 15
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 = 2.95 inches)

Capacity

- **Peak Flow:** 2.07 *mgd*
- **PF:** 1.96
- **Peak Level:** 10.62 *in*
- **d/D Ratio:** 0.44

Inflow

- **Peak I/I Rate:** 0.75 *mgd*
- **PkI/I:IDM:** 3,420 *gpd/IDM*
- **PkI/I:Acre:** 507 *gpd/acre*
- **Pk I/I:ADWF:** 0.72

RDI (infiltration)

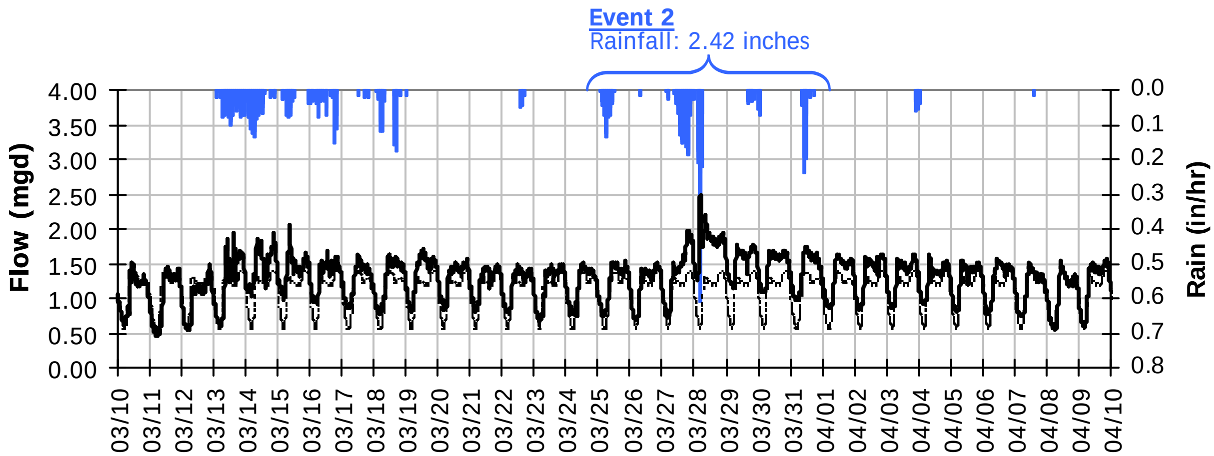
- **Infiltration Rate:** (3/20/2012) 0.227 *mgd*
- **RDI:IDM:** 1,029 *gpd/IDM*
- **RDI:Acre:** 152 *gpd/acre*
- **RDI (% of BL):** 21%

Combined I/I

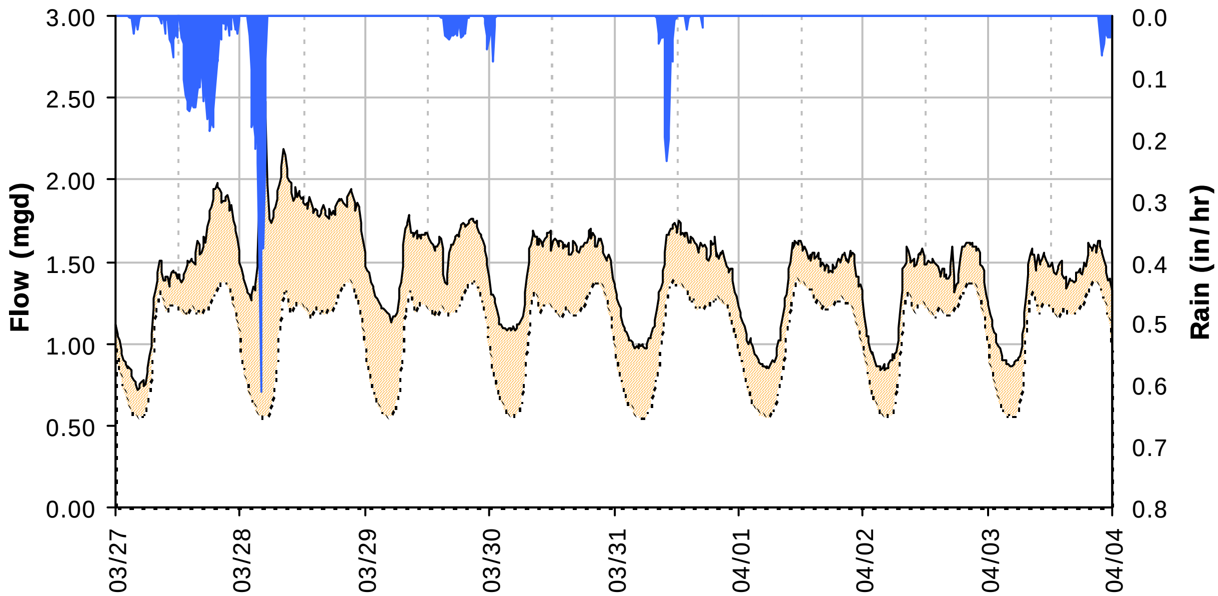
- **Total I/I:** 2,640,000 *gallons*
- **Total I/I:IDM:** 4,050 *gal/IDM/in*
- **R-Value:** 2.2%
- **Total I/I:ADWF:** 0.85 *per in-rain*

SITE 15
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 = 2.42 inches)

Capacity

Peak Flow:	2.49	*mgd*
PF:	2.36	
Peak Level:	11.57	*in*
d/D Ratio:	0.48	

Inflow

Peak I/I Rate:	1.93	*mgd*
PkI/I:IDM:	8,763	*gpd/IDM*
PkI/I:Acre:	1,298	*gpd/acre*
Pk I/I:ADWF:	1.84	

RDI (infiltration)

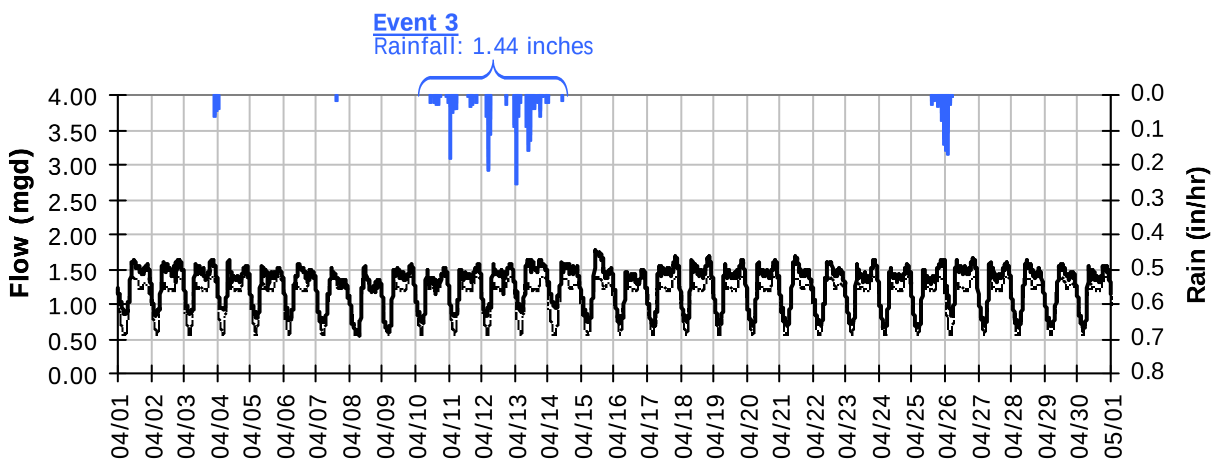
Infiltration Rate: (4/2/2012)	0.265	*mgd*
RDI:IDM:	1,203	*gpd/IDM*
RDI:Acre:	178	*gpd/acre*
RDI (% of BL):	25%	

Combined I/I

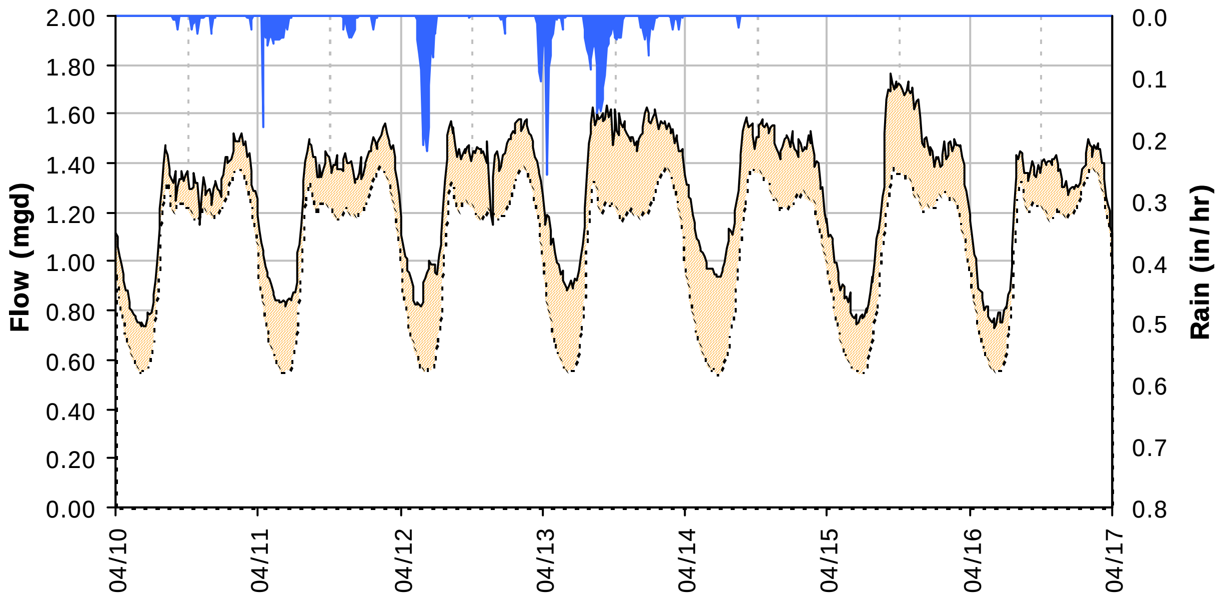
Total I/I:	3,124,000	*gallons*
Total I/I:IDM:	5,842	*gal/IDM/in*
R-Value:	3.2%	
Total I/I:ADWF:	1.22	*per in-rain*

SITE 15
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.44 inches)

Capacity

Peak Flow:	1.76	*mgd*
PF:	1.67	
Peak Level:	8.75	*in*
d/D Ratio:	0.36	

Inflow

Peak I/I Rate:	0.44	*mgd*
PkI/I:IDM:	2,005	*gpd/IDM*
PkI/I:Acre:	297	*gpd/acre*
Pk I/I:ADWF:	0.42	

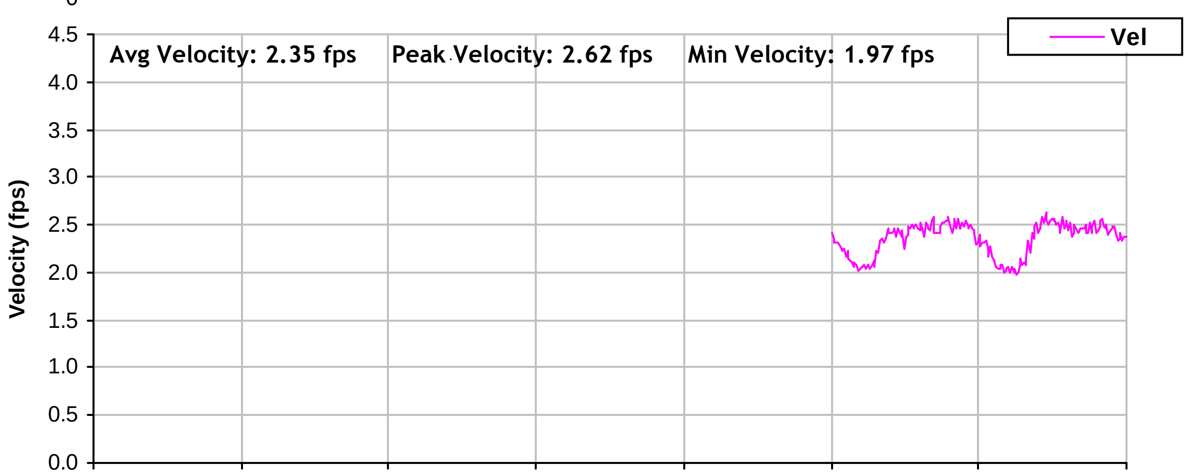
RDI (infiltration)

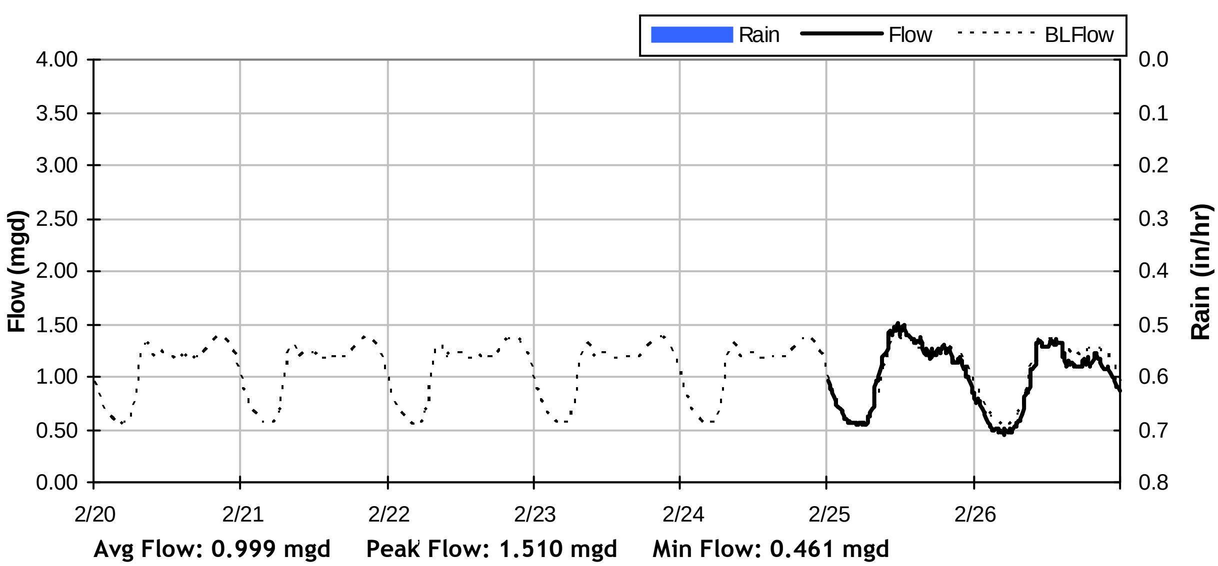
Infiltration Rate: (4/15/2012)	0.267	*mgd*
RDI:IDM:	1,210	*gpd/IDM*
RDI:Acre:	179	*gpd/acre*
RDI (% of BL):	26%	

Combined I/I

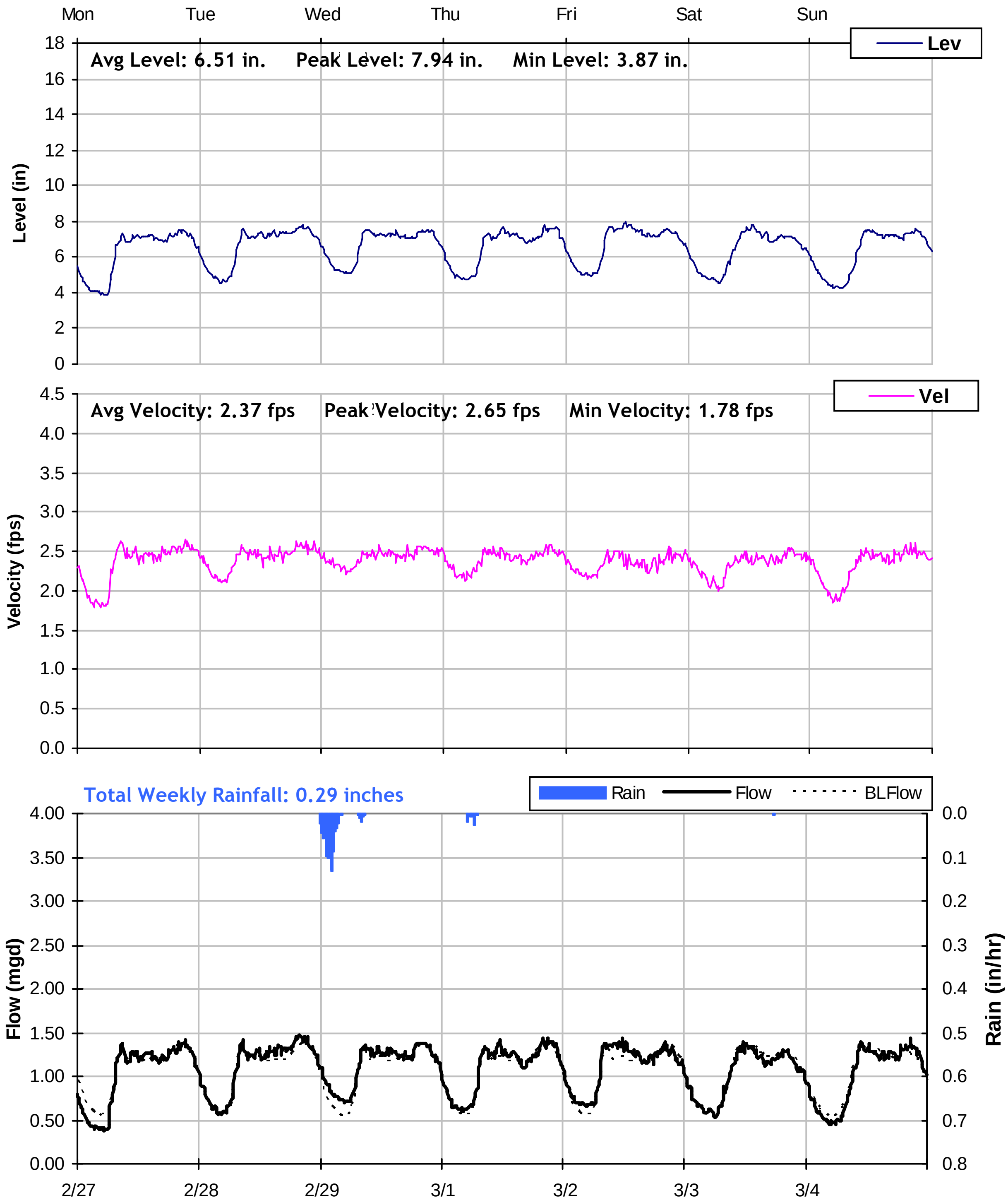
Total I/I:	1,619,000	*gallons*
Total I/I:IDM:	5,107	*gal/IDM/in*
R-Value:	2.8%	
Total I/I:ADWF:	1.07	*per in-rain*

SITE 15
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012





SITE 15
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012

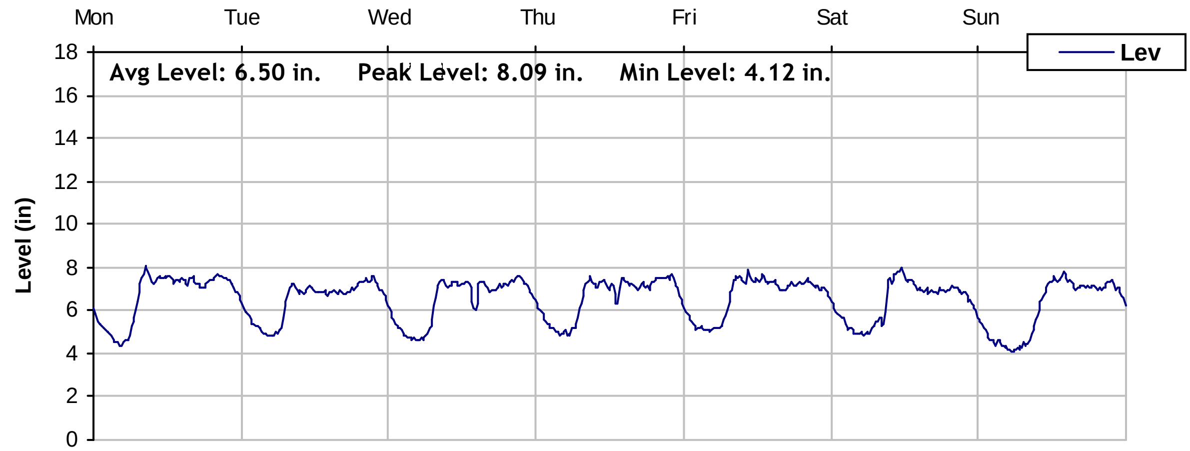


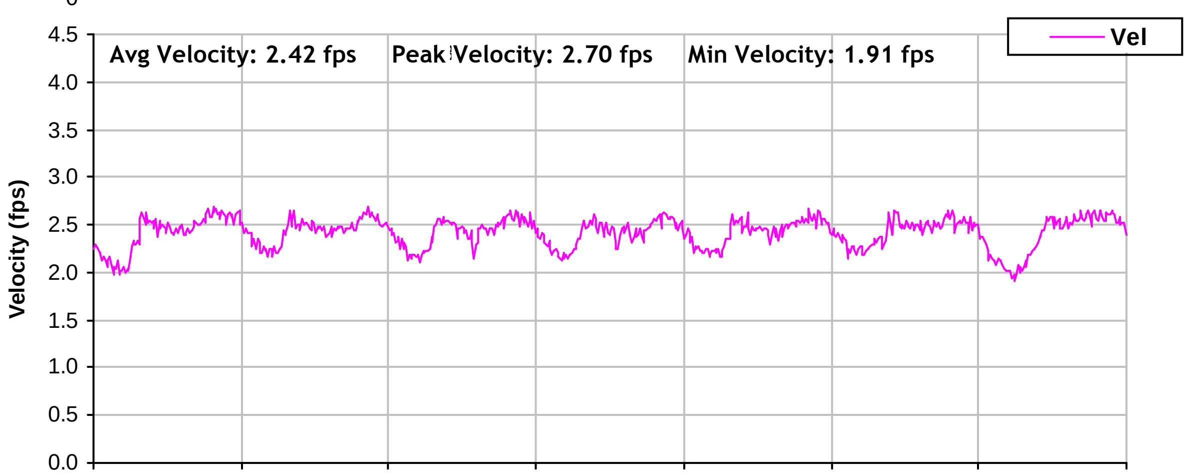
Avg Flow: 1.077 mgd Peak Flow: 1.462 mgd Min Flow: 0.385 mgd

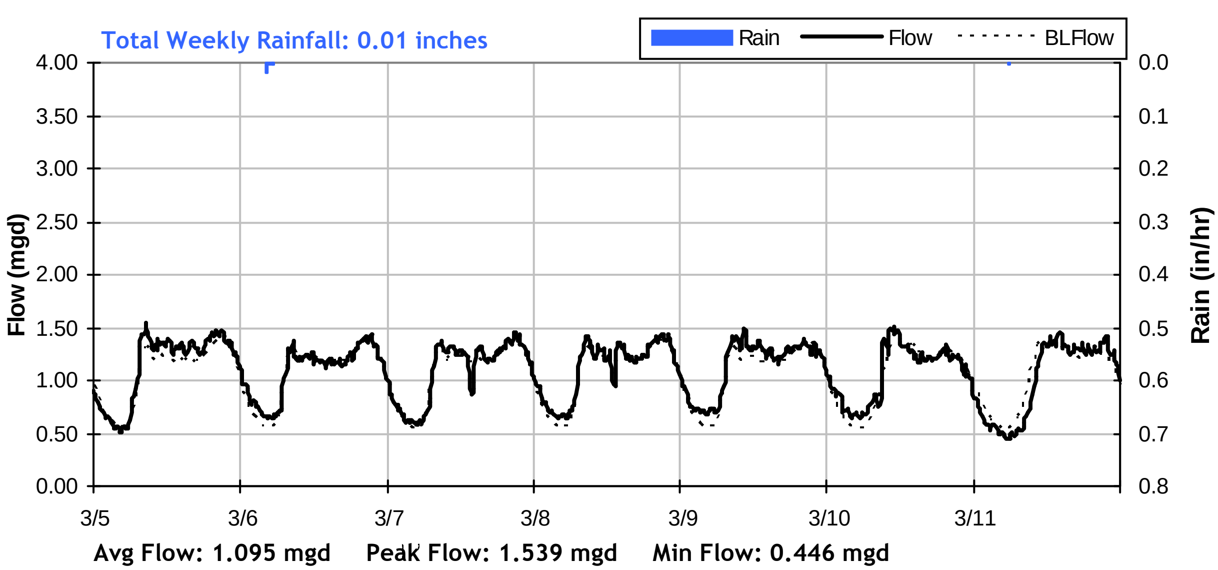
SITE 15

Weekly Level, Velocity and Flow Hydrographs

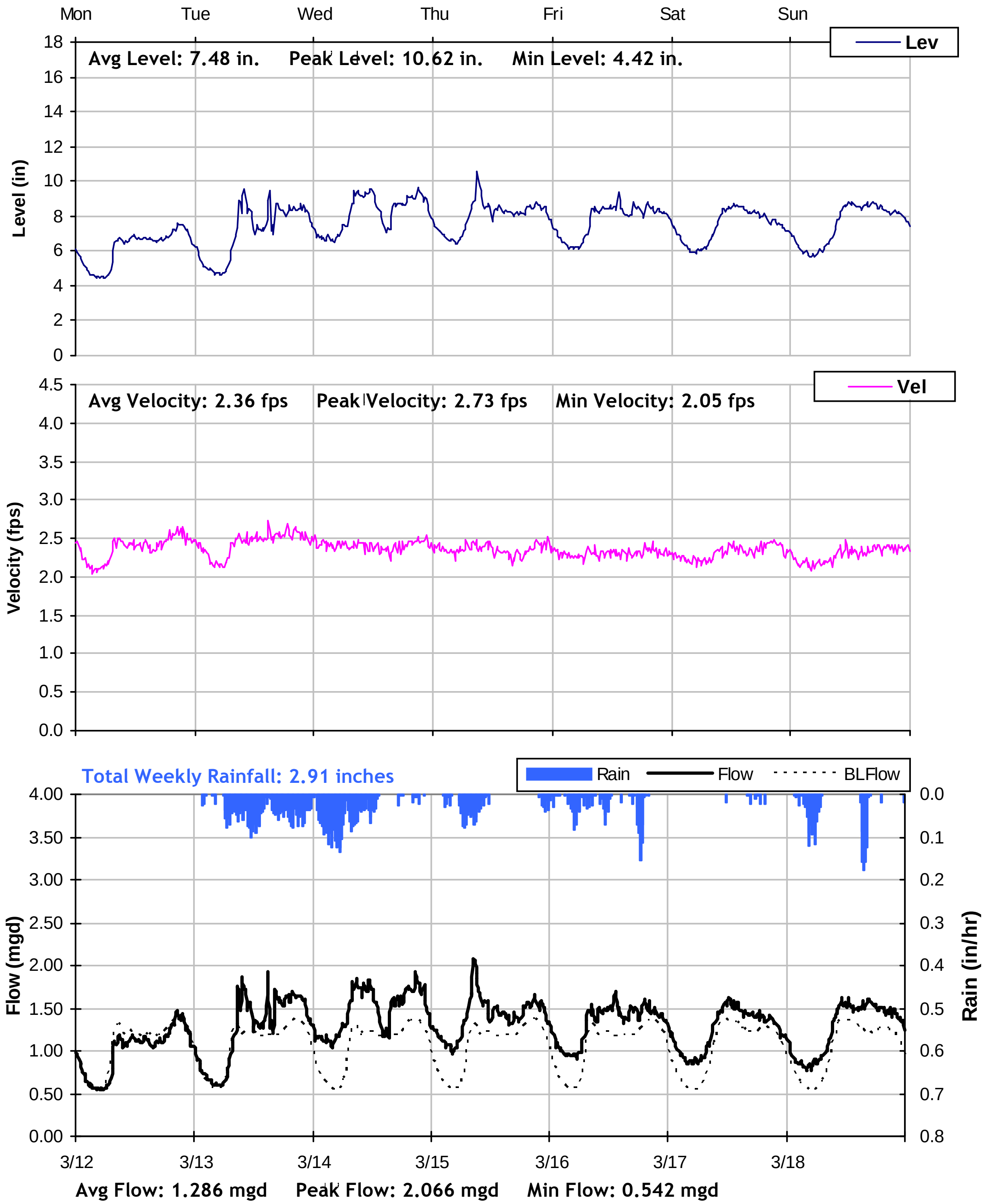
3/5/2012 to 3/12/2012



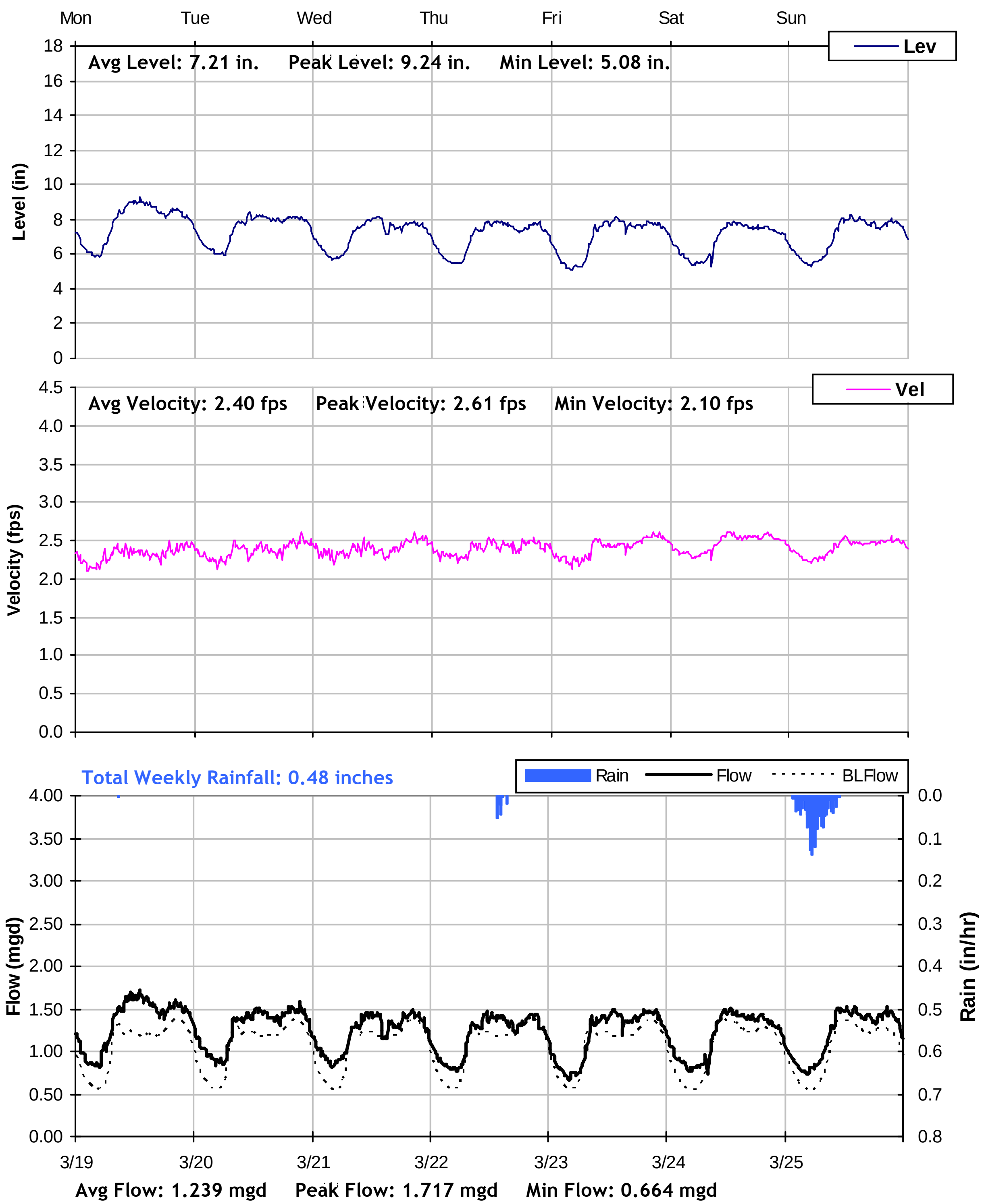




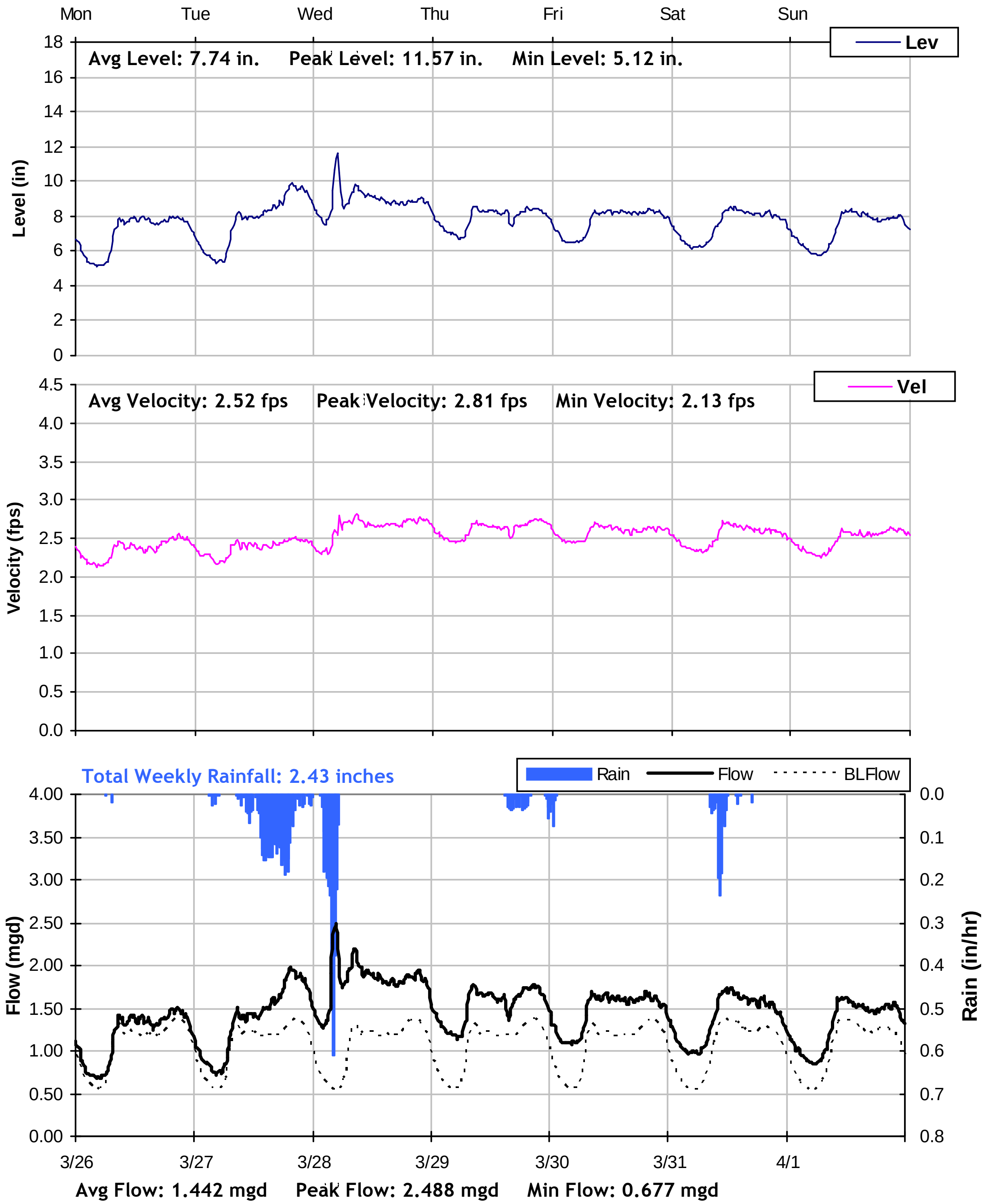
SITE 15
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



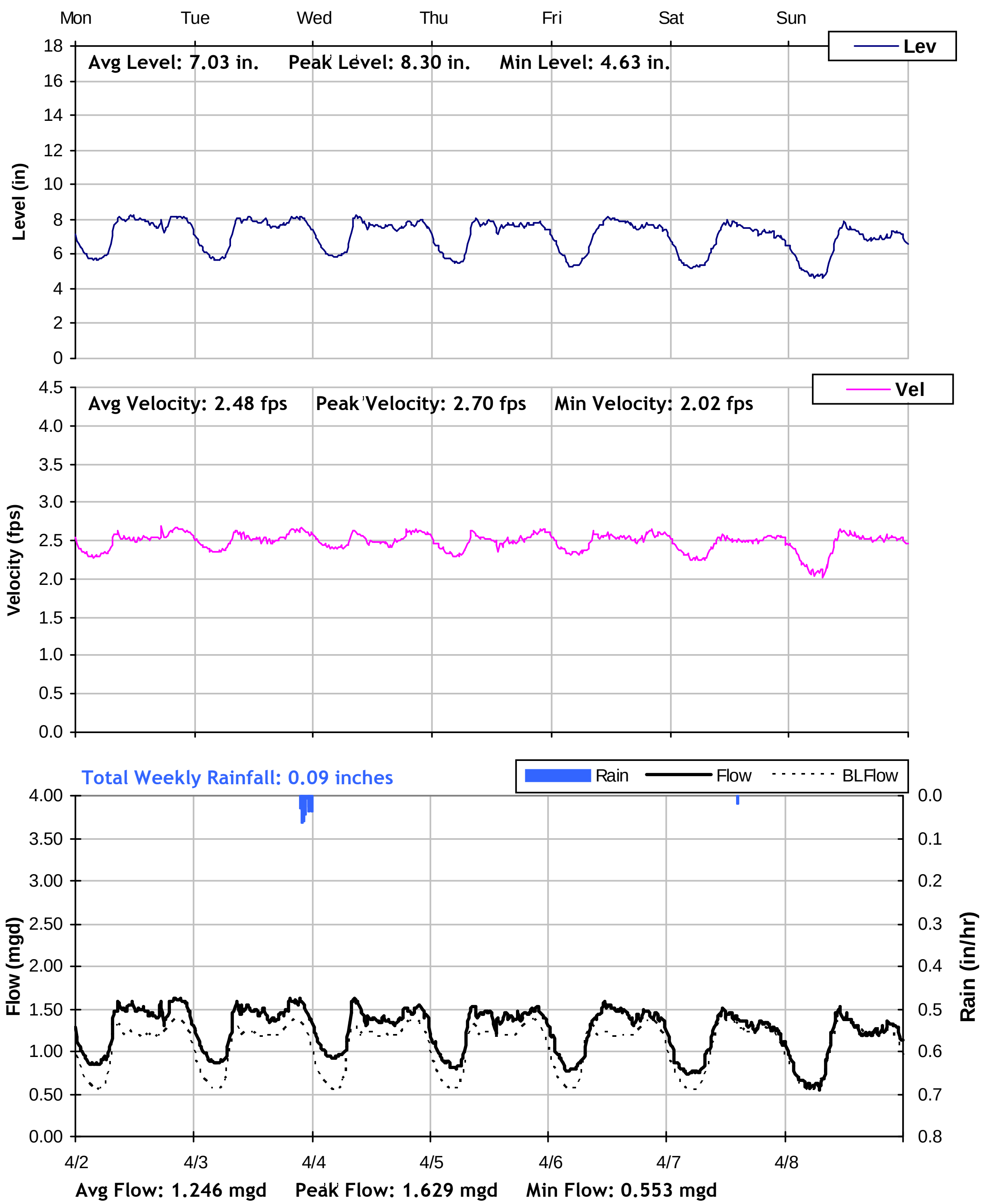
SITE 15
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



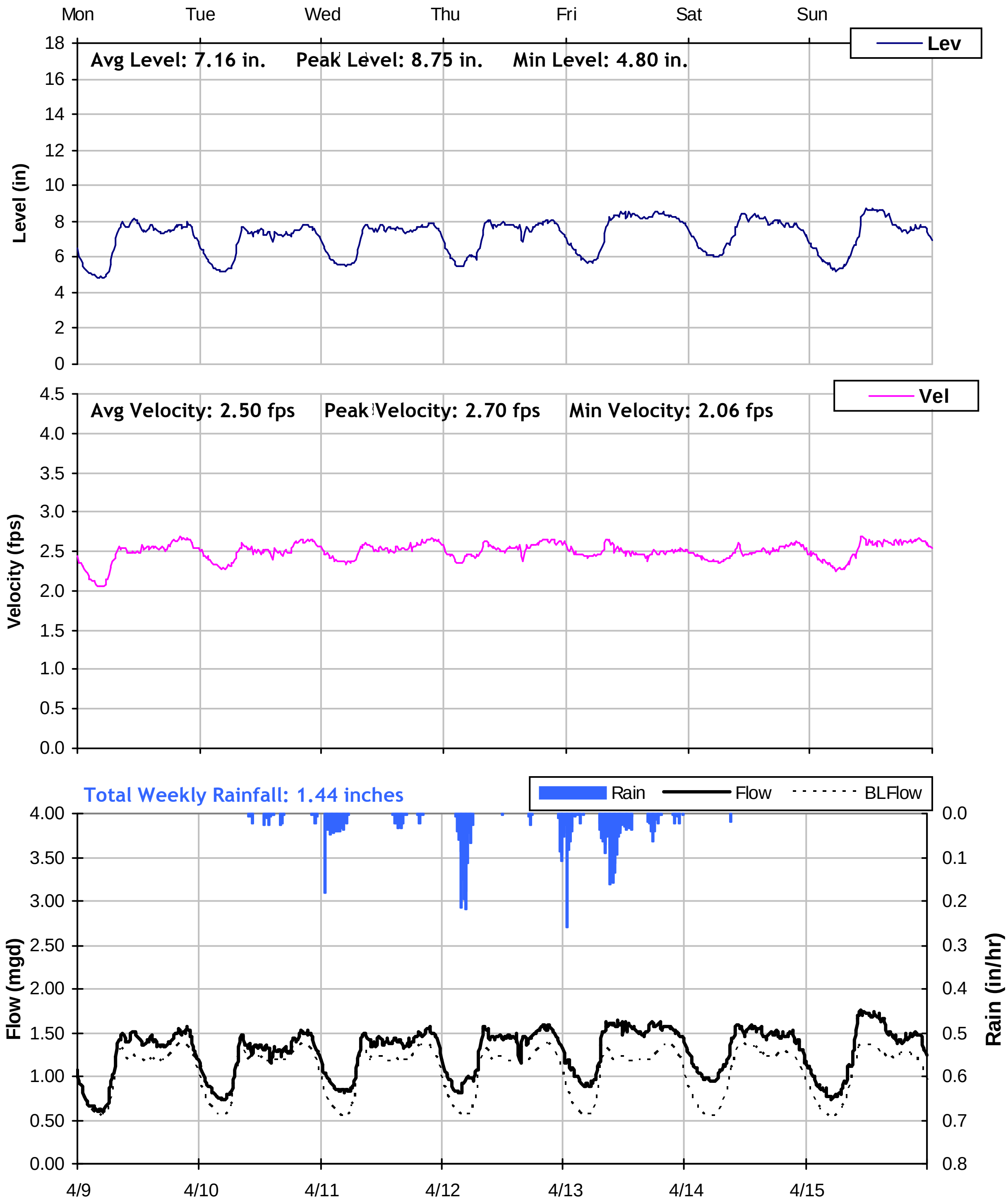
SITE 15
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



SITE 15
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012

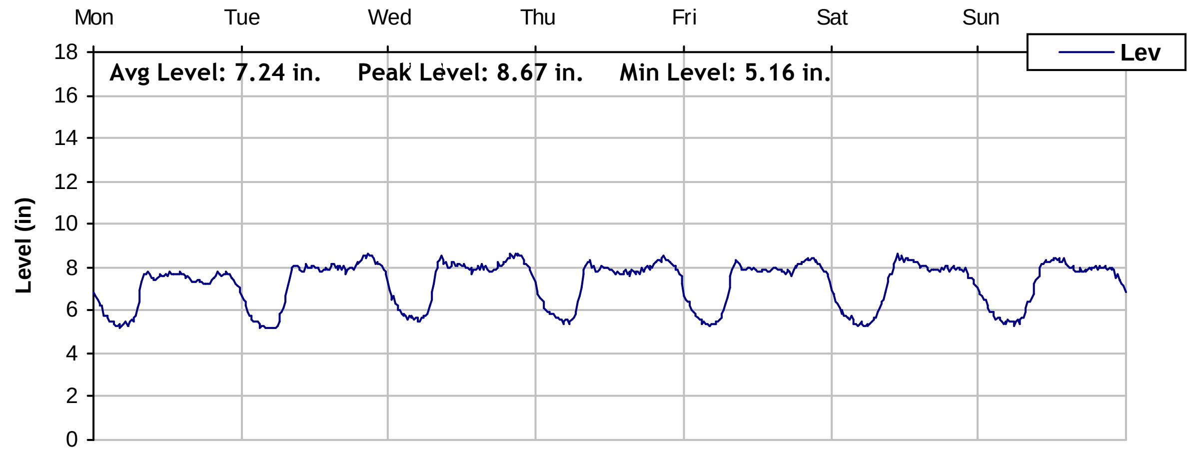


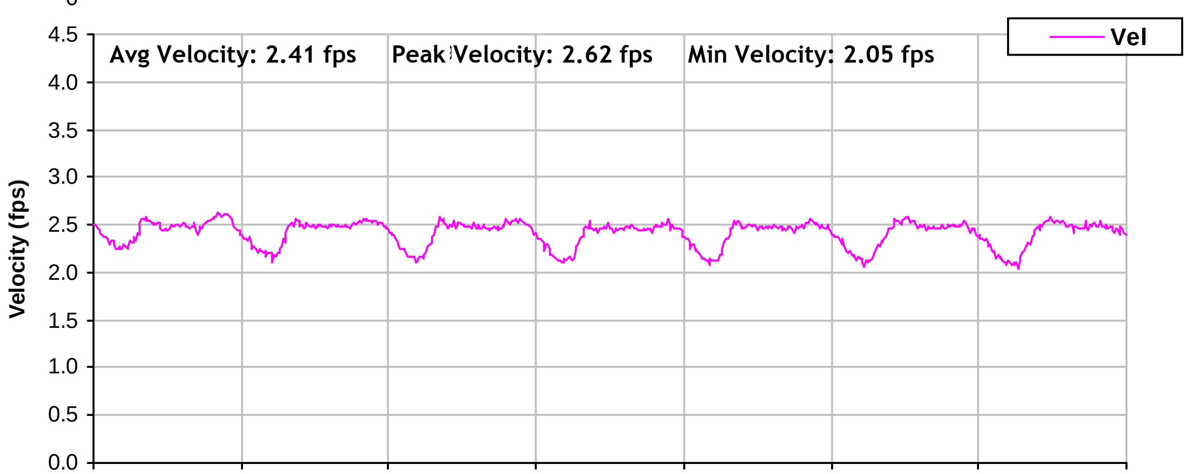
SITE 15
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012

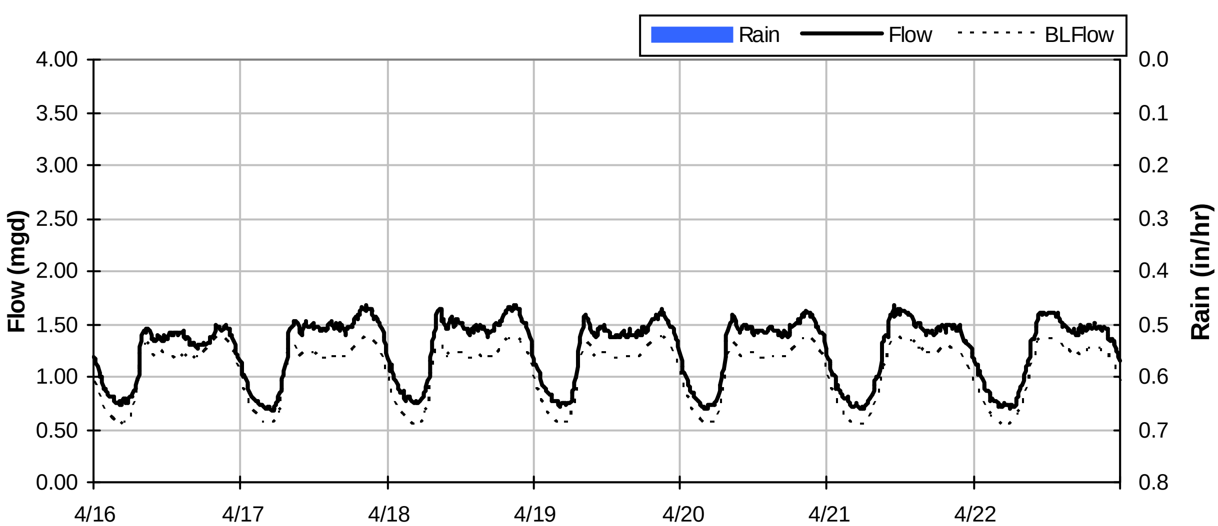


Avg Flow: 1.283 mgd Peak Flow: 1.763 mgd Min Flow: 0.597 mgd

SITE 15
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012

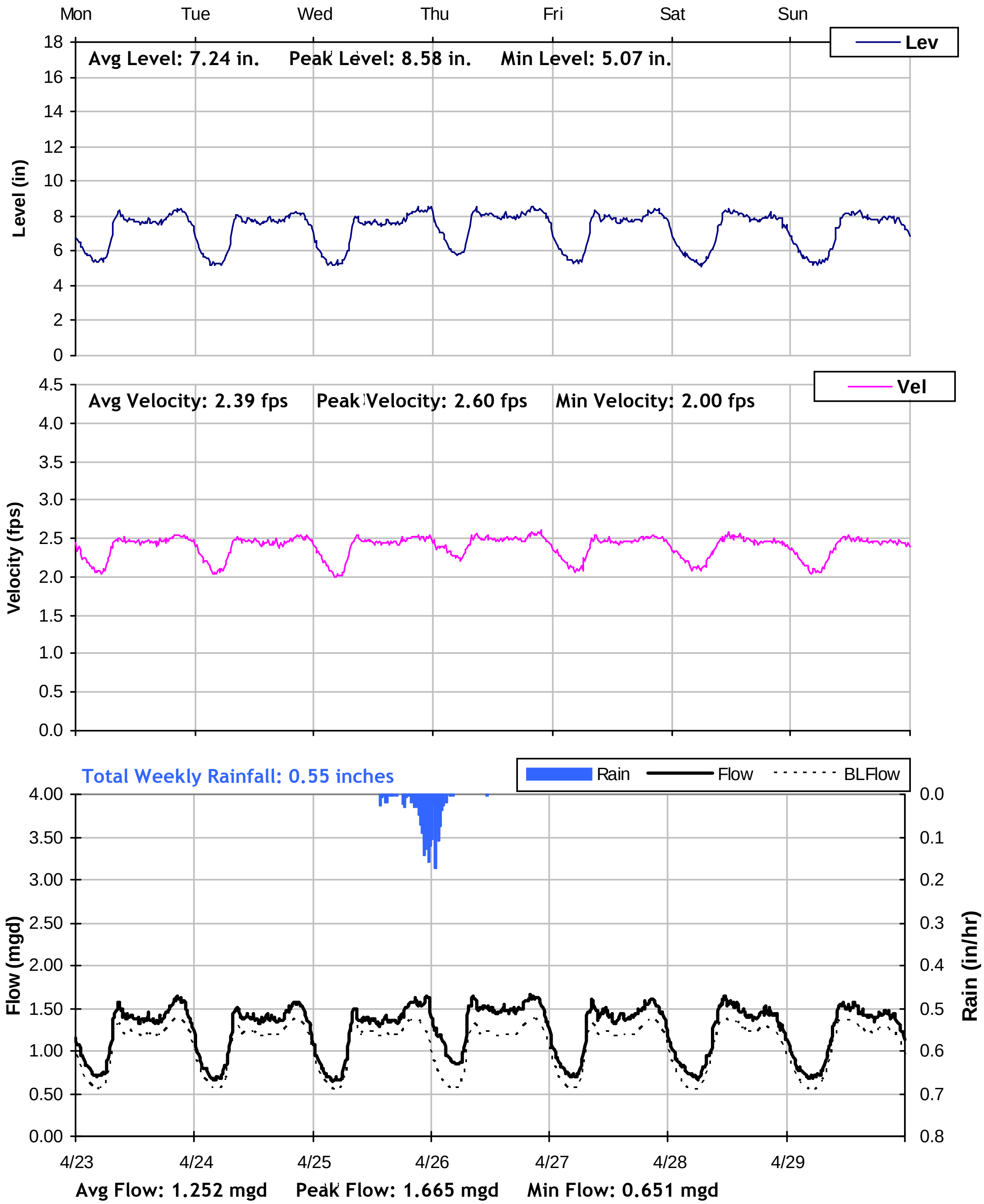




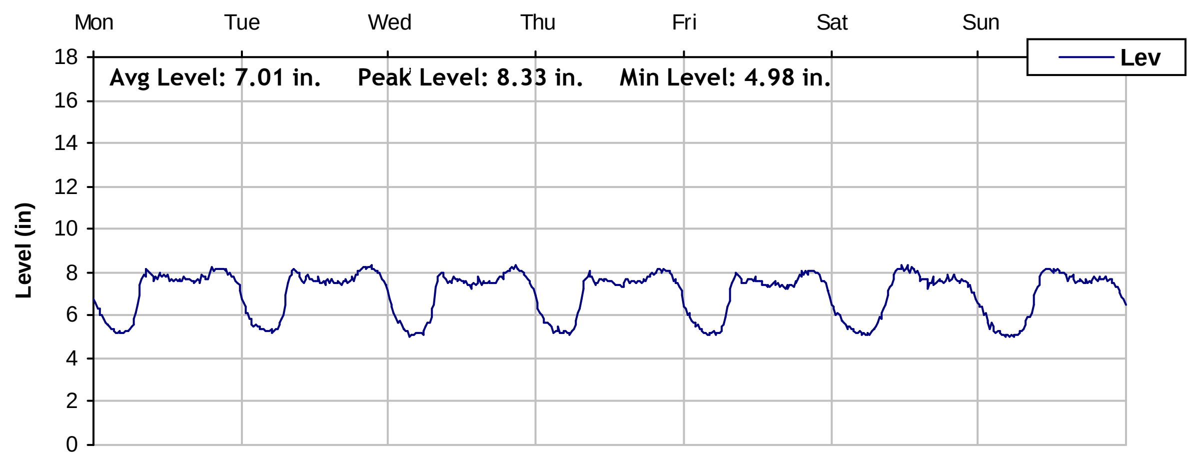


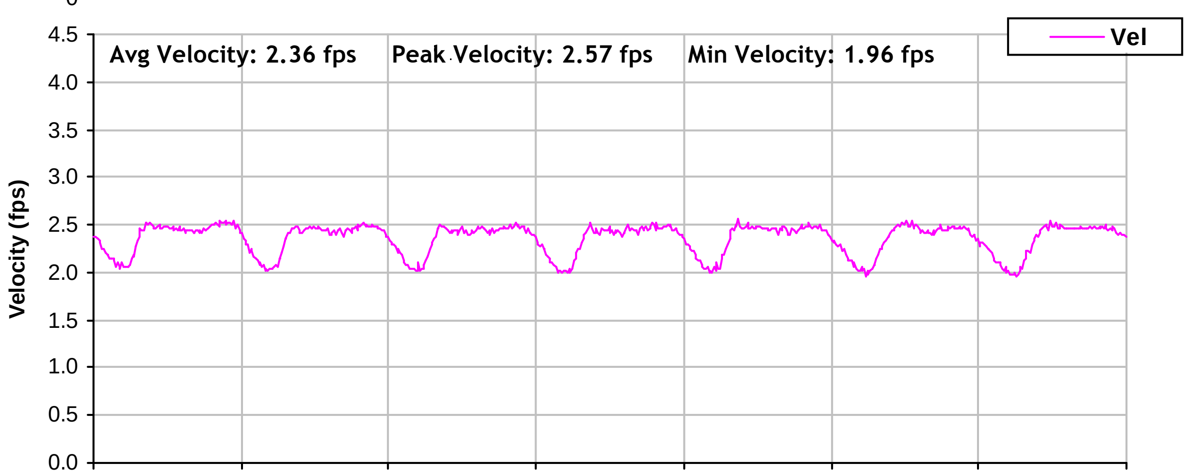
Avg Flow: 1.263 mgd **Peak Flow: 1.685 mgd** **Min Flow: 0.678 mgd**

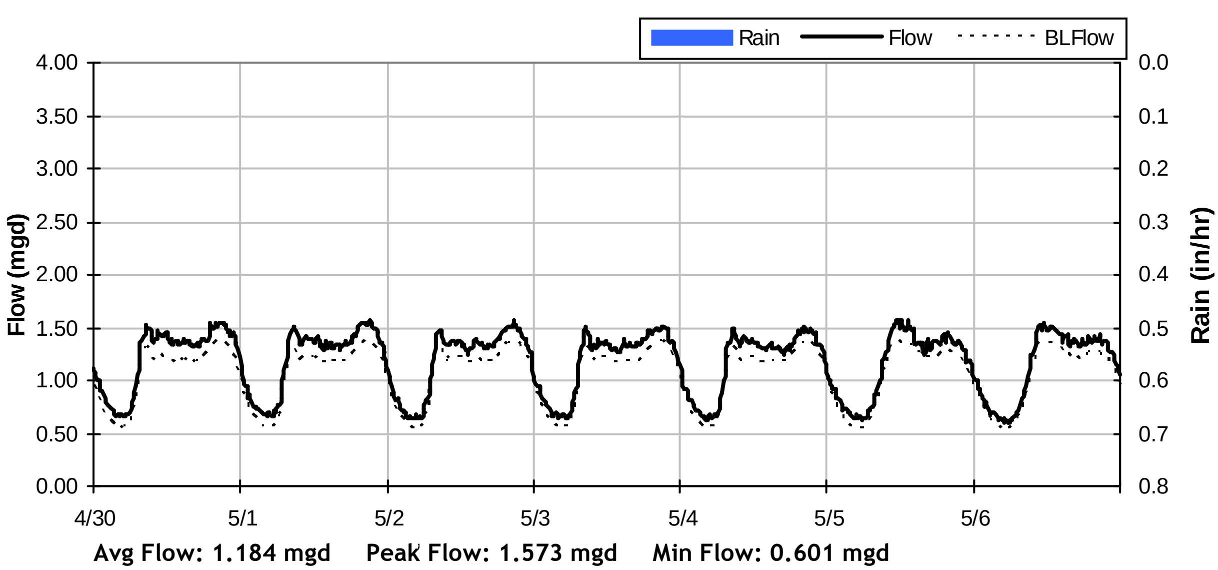
SITE 15
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 15
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012







City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

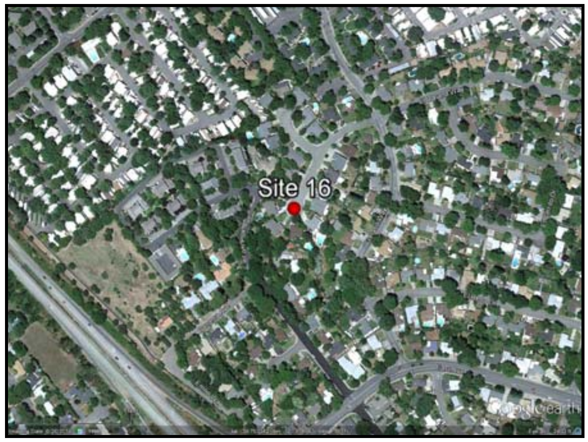
Monitoring Site: Site 16

Location: End of El Varano Way, west of El Passo Way

Vicinity Map:

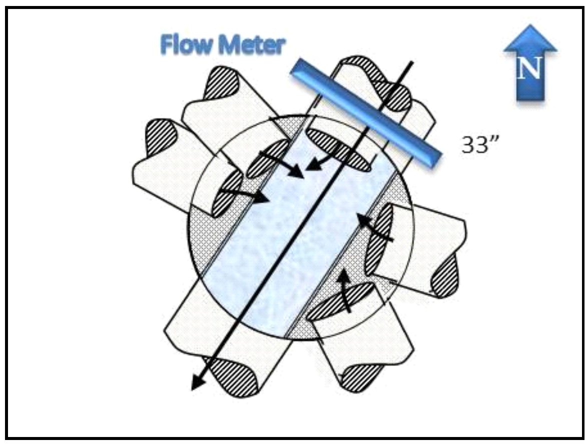
SITE 16
Site Information Report

Location:	End of El Varano Way, west of El Passo Way
Coordinates:	121.8547° W, 39.7635° N
Elevation:	193 feet
Diameter:	33 inches
Baseline Flow:	0.501 mgd
Peak Measured Flow:	2.546 mgd



Satellite Map

Sanitary Sewer Map



Flow Sketch


View from Street

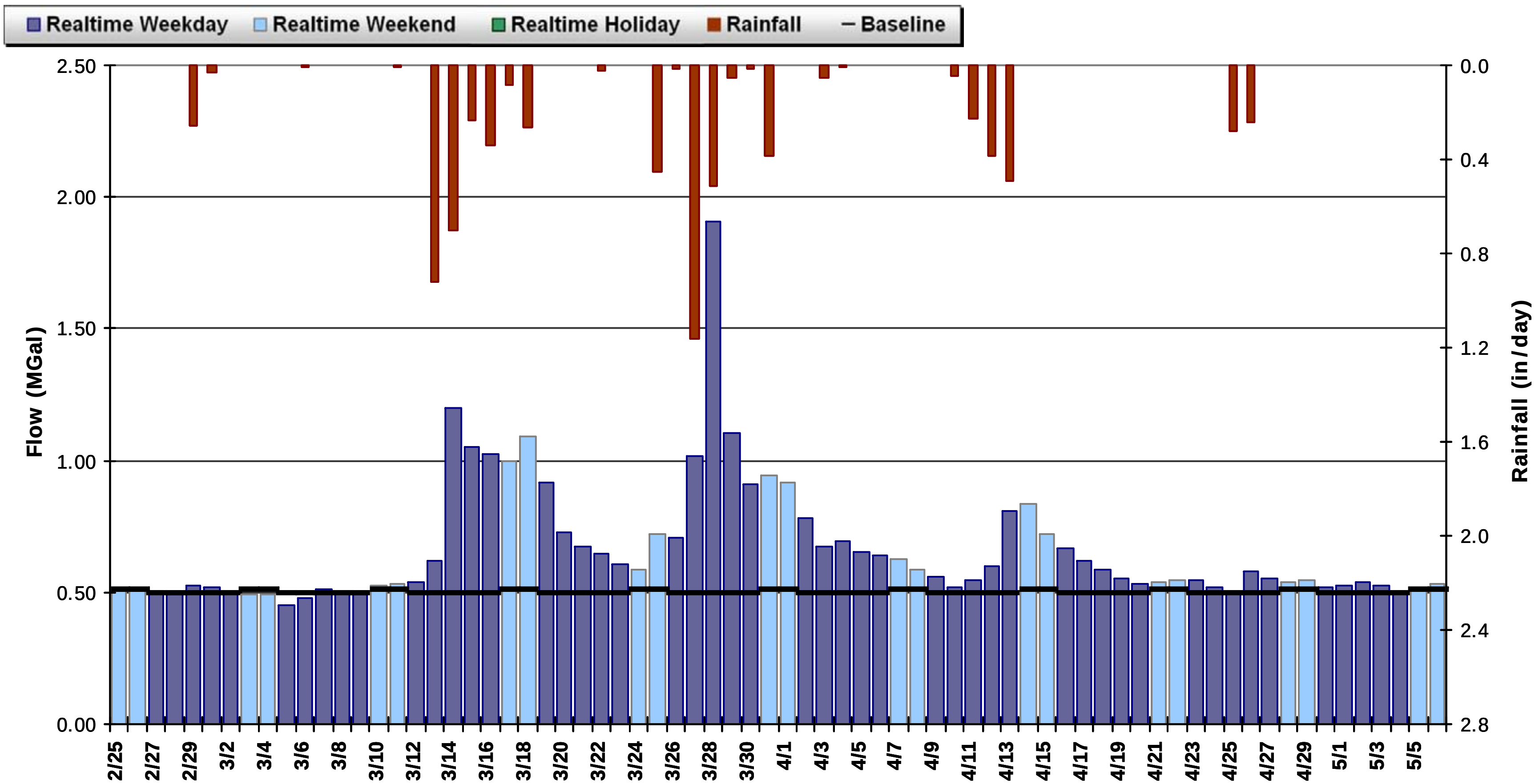

Plan View

SITE 16

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.663 MGal **Peak Daily Flow: 1.910 MGal** **Min Daily Flow: 0.451 MGal**

Total Period Rainfall: 7.19 inches

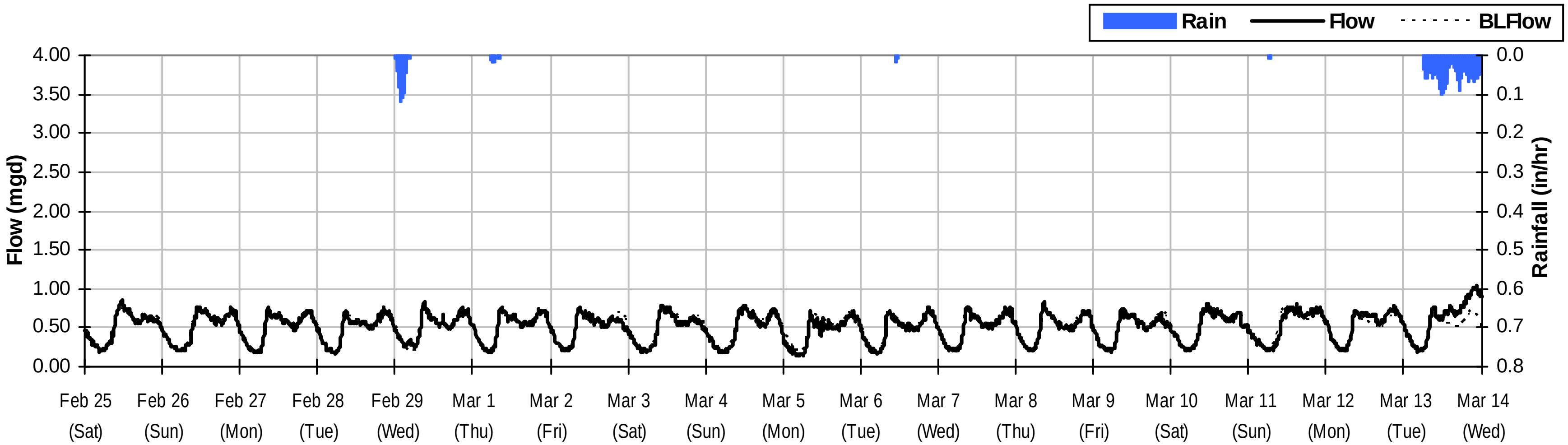


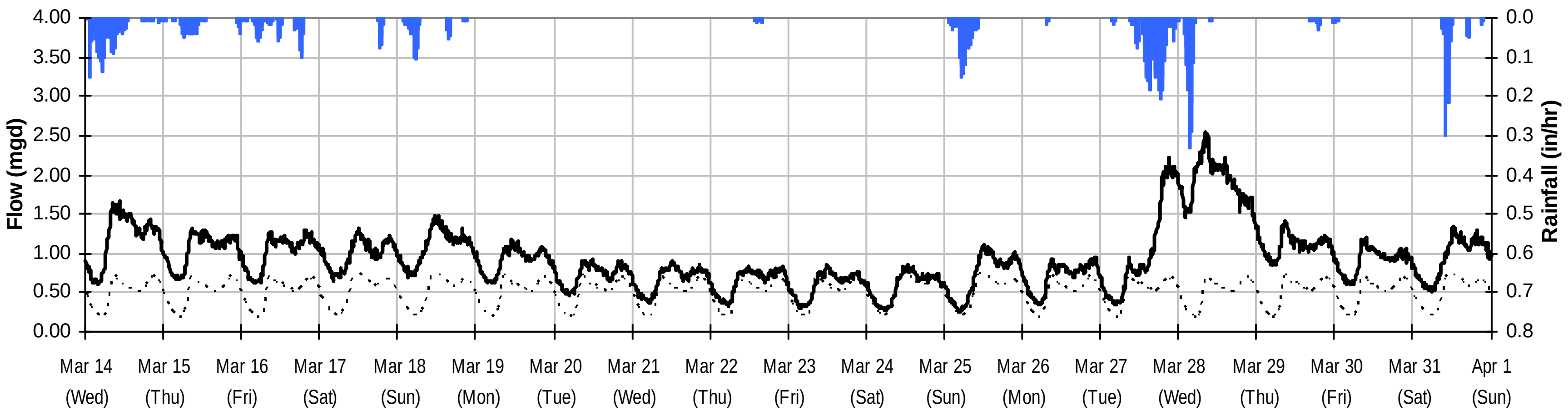
SITE 16

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.723 mgd Peak Flow: 2.546 mgd Min Flow: 0.146 mgd

Total Period Rainfall: 5.46 inches



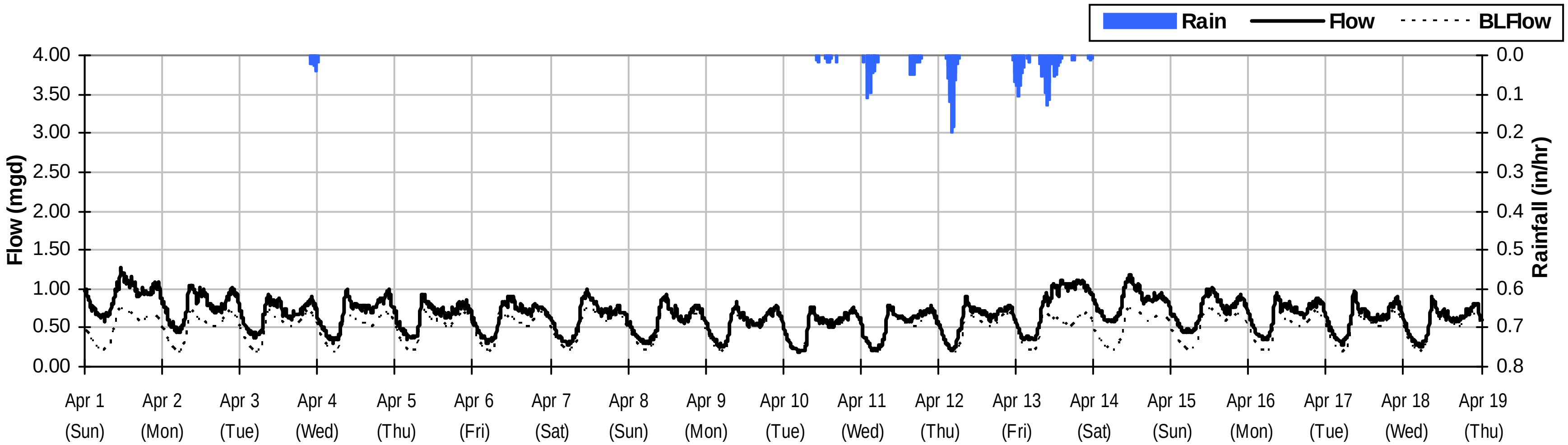


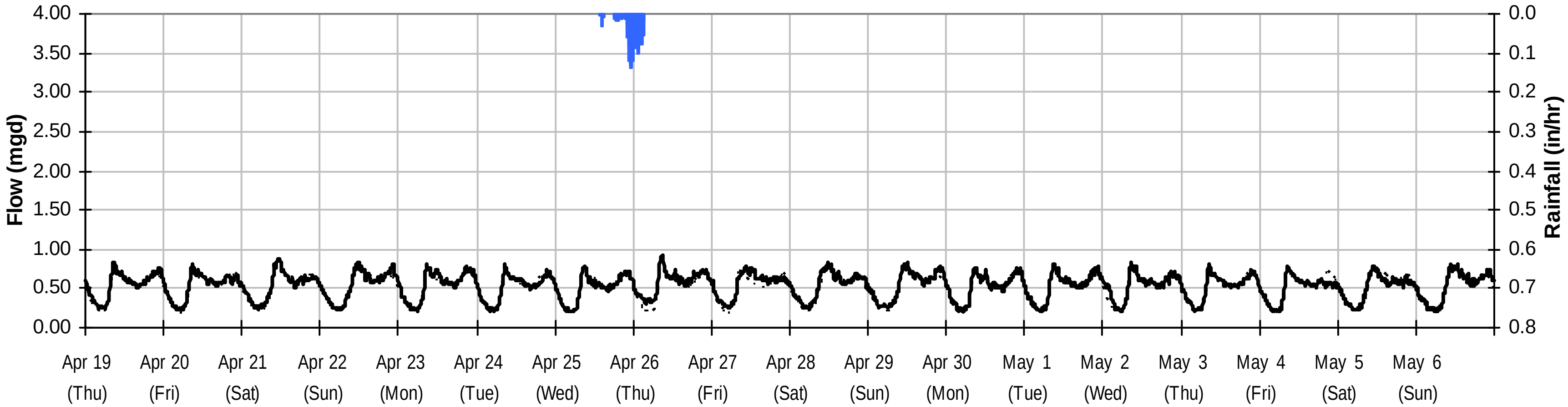
SITE 16

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.602 mgd **Peak Flow: 1.268 mgd** **Min Flow: 0.178 mgd**

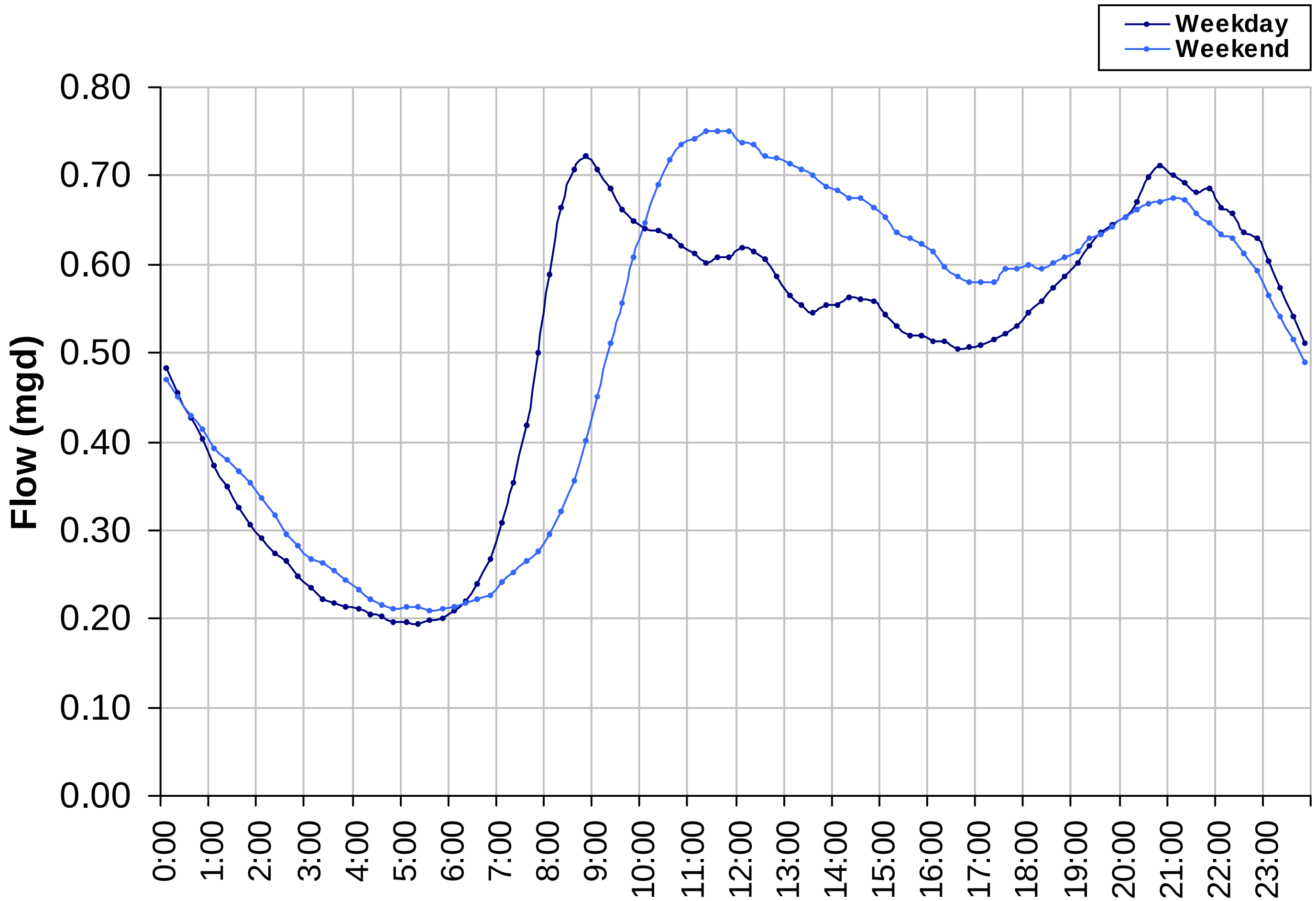
Total Period Rainfall: 1.73 inches





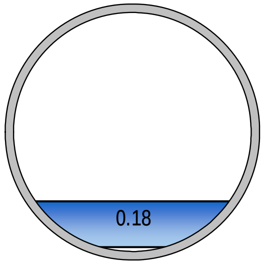
SITE 16

Baseline Flow Hydrographs



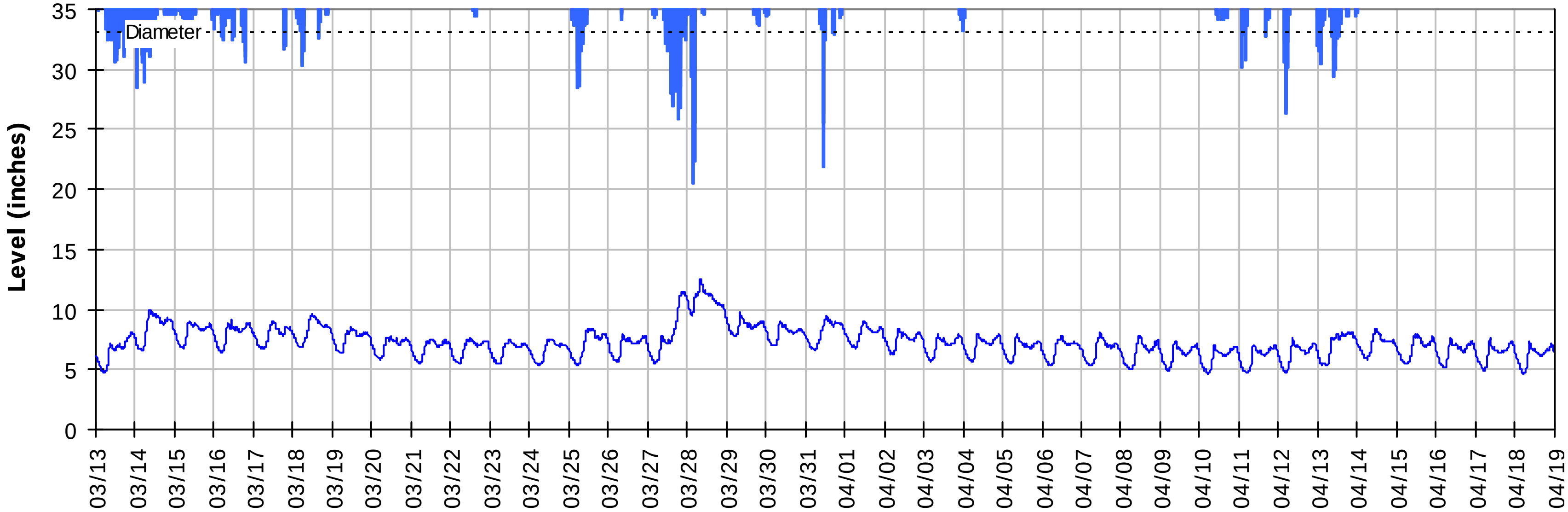
Baseline Flow:

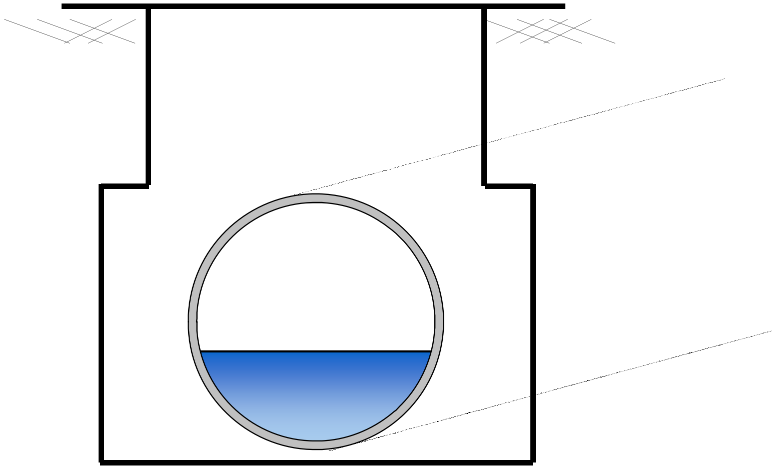
0.501 *mgd*



SITE 16
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





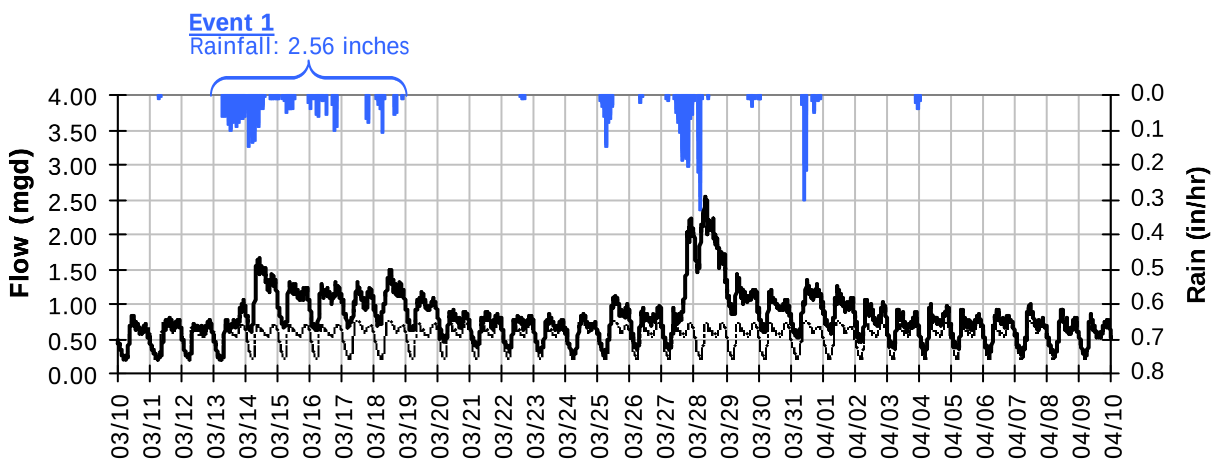
Pipe Diameter: 33 *inches*

Peak Measured Level: 12.6 *inches*

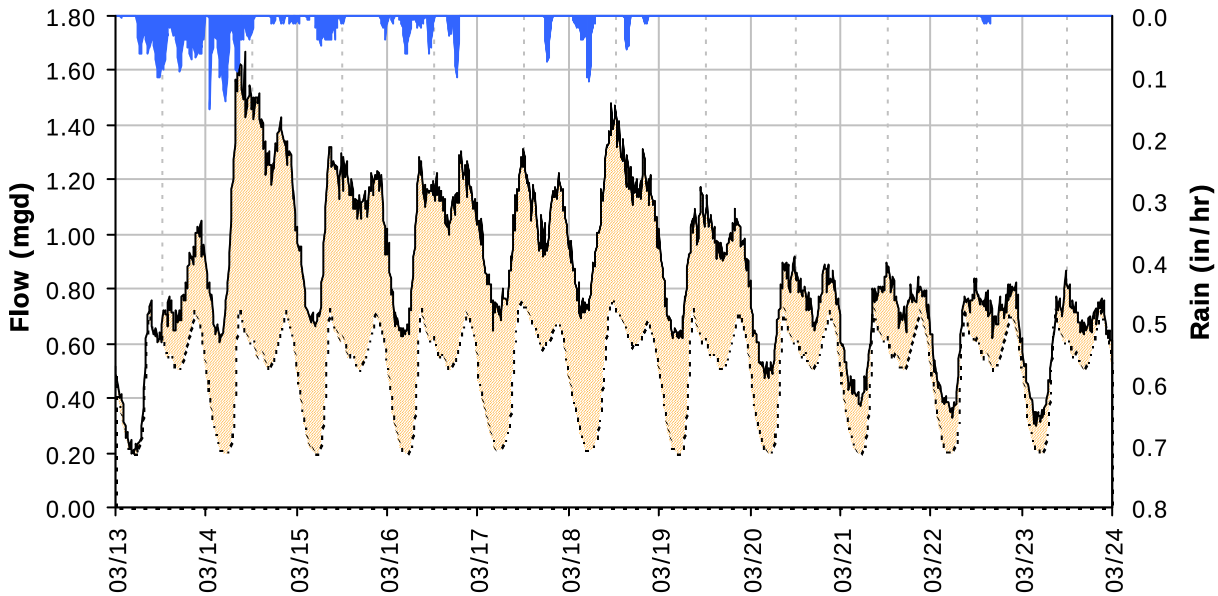
Peak d/D Ratio: 0.38

SITE 16
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 = 2.56 inches)

Capacity

Peak Flow: 1.67 *mgd*
PF: 3.33
Peak Level: 10.01 *in*
d/D Ratio: 0.30

Inflow

Peak I/I Rate: 1.03 *mgd*
PkI/I:IDM: 4,266 *gpd/IDM*
PkI/I:Acre: 461 *gpd/acre*
Pk I/I:ADWF: 2.06

RDI (infiltration)

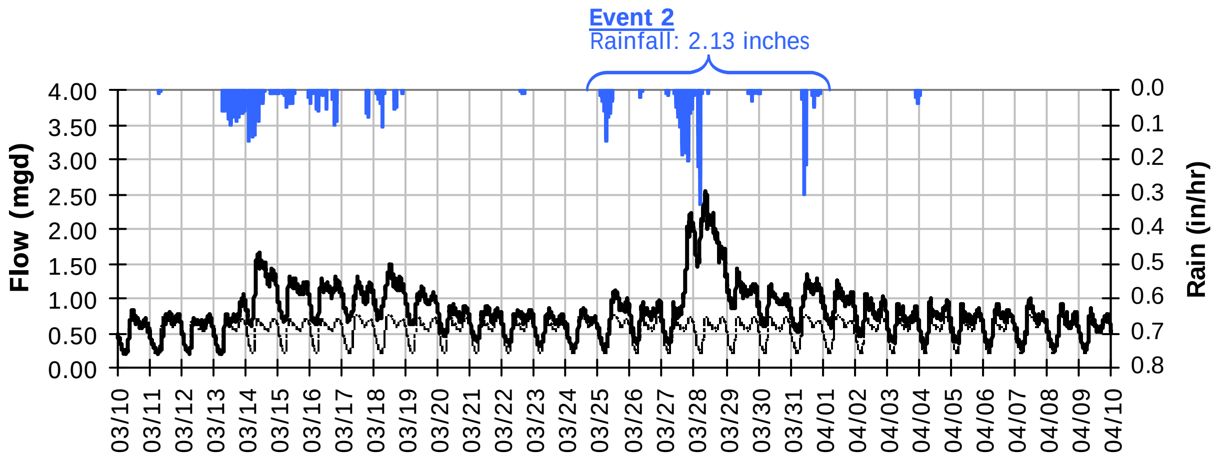
Infiltration Rate: 0.232 *mgd*
(3/20/2012)
RDI:IDM: 958 *gpd/IDM*
RDI:Acre: 104 *gpd/acre*
RDI (% of BL): 47%

Combined I/I

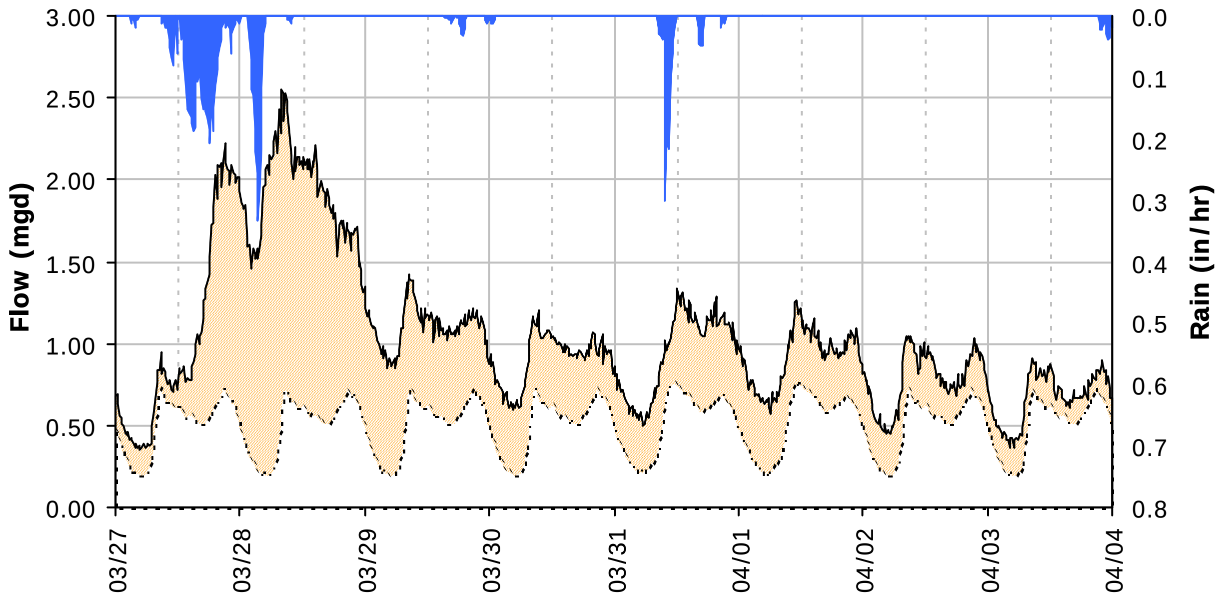
Total I/I: 4,054,000 *gallons*
Total I/I:IDM: 6,534 *gal/IDM/in*
R-Value: 2.6%
Total I/I:ADWF: 3.16 *per in-rain*

SITE 16
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 = 2.13 inches)

Capacity

Peak Flow: 2.55 *mgd*
PF: 5.08
Peak Level: 12.60 *in*
d/D Ratio: 0.38

Inflow

Peak I/I Rate: 2.03 *mgd*
PkI/I:IDM: 8,374 *gpd/IDM*
PkI/I:Acre: 905 *gpd/acre*
Pk I/I:ADWF: 4.05

RDI (infiltration)

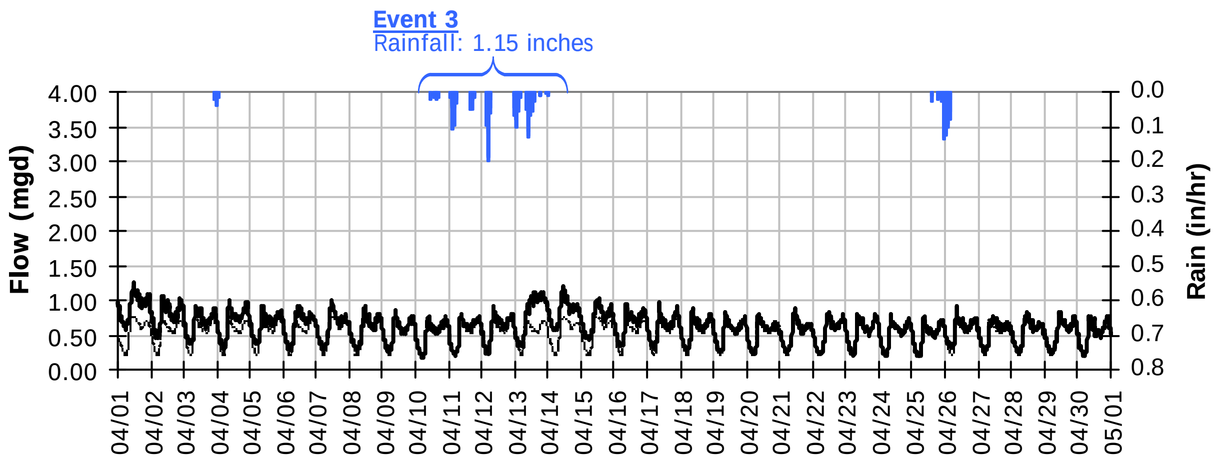
Infiltration Rate: 0.283 *mgd*
(4/2/2012)
RDI:IDM: 1,170 *gpd/IDM*
RDI:Acre: 126 *gpd/acre*
RDI (% of BL): 57%

Combined I/I

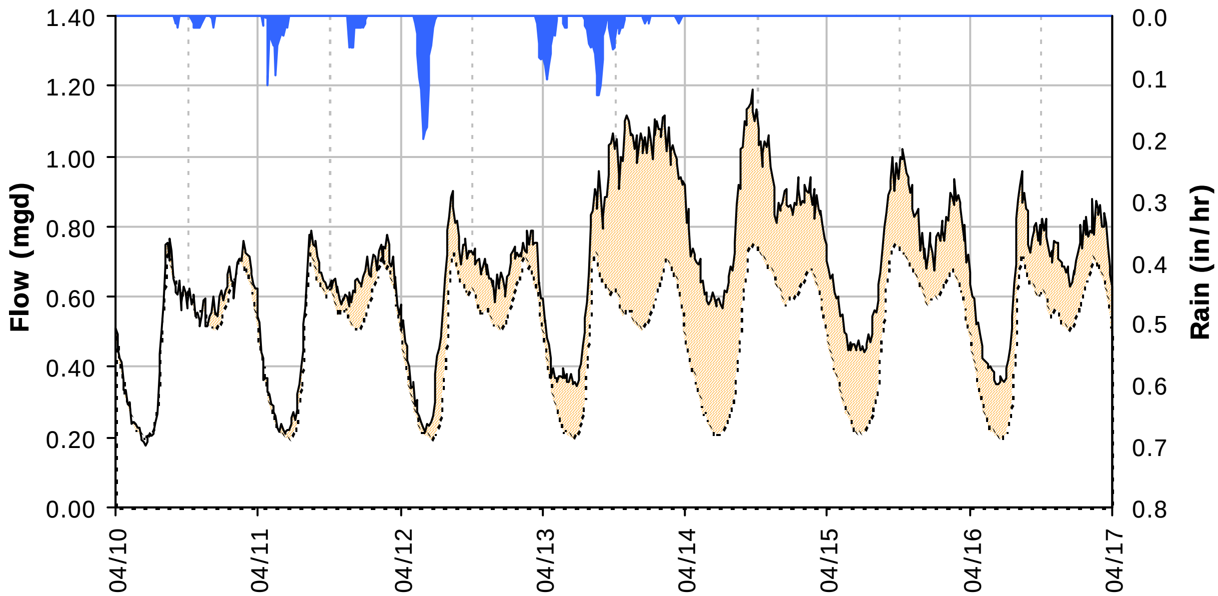
Total I/I: 4,255,000 *gallons*
Total I/I:IDM: 8,249 *gal/IDM/in*
R-Value: 3.3%
Total I/I:ADWF: 3.98 *per in-rain*

SITE 16
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.15 inches)

Capacity

Peak Flow:	1.19 *mgd*
PF:	2.37
Peak Level:	8.44 *in*
d/D Ratio:	0.26

Inflow

Peak I/I Rate:	0.56 *mgd*
PkI/I:IDM:	2,330 *gpd/IDM*
PkI/I:Acre:	252 *gpd/acre*
Pk I/I:ADWF:	1.13

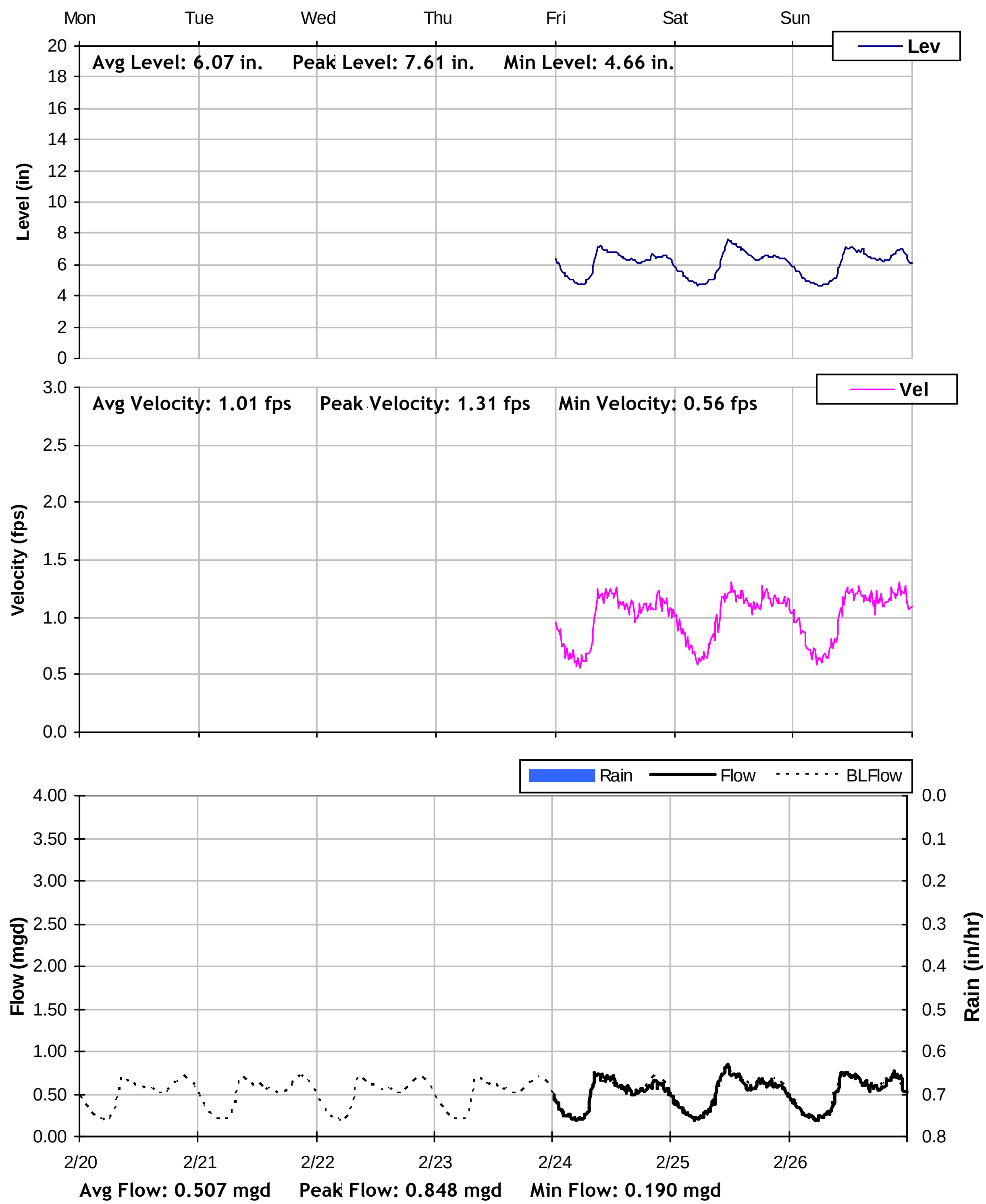
RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.212 *mgd*
RDI:IDM:	877 *gpd/IDM*
RDI:Acre:	95 *gpd/acre*
RDI (% of BL):	42%

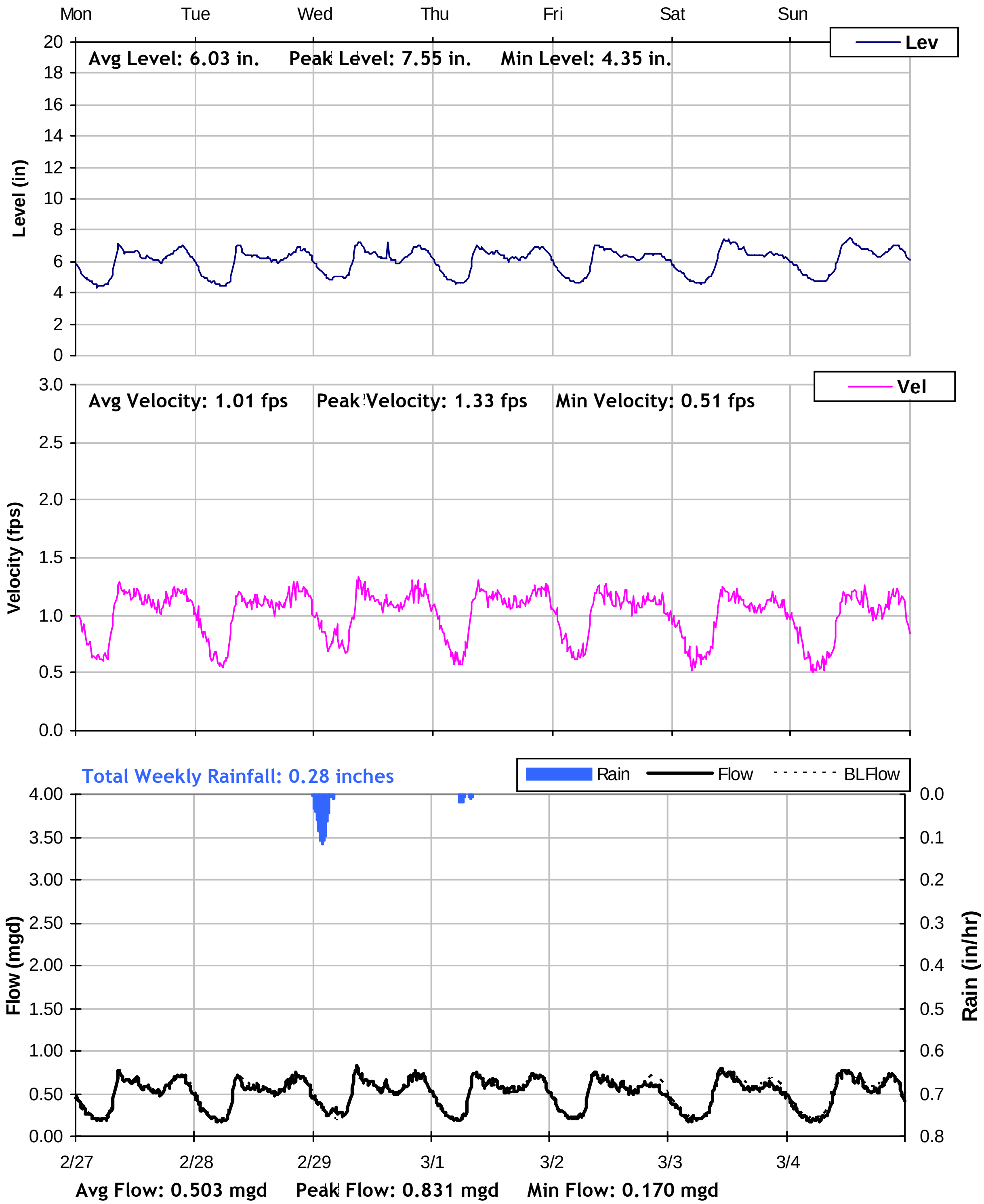
Combined I/I

Total I/I:	1,199,000 *gallons*
Total I/I:IDM:	4,308 *gal/IDM/in*
R-Value:	1.7%
Total I/I:ADWF:	2.08 *per in-rain*

SITE 16
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



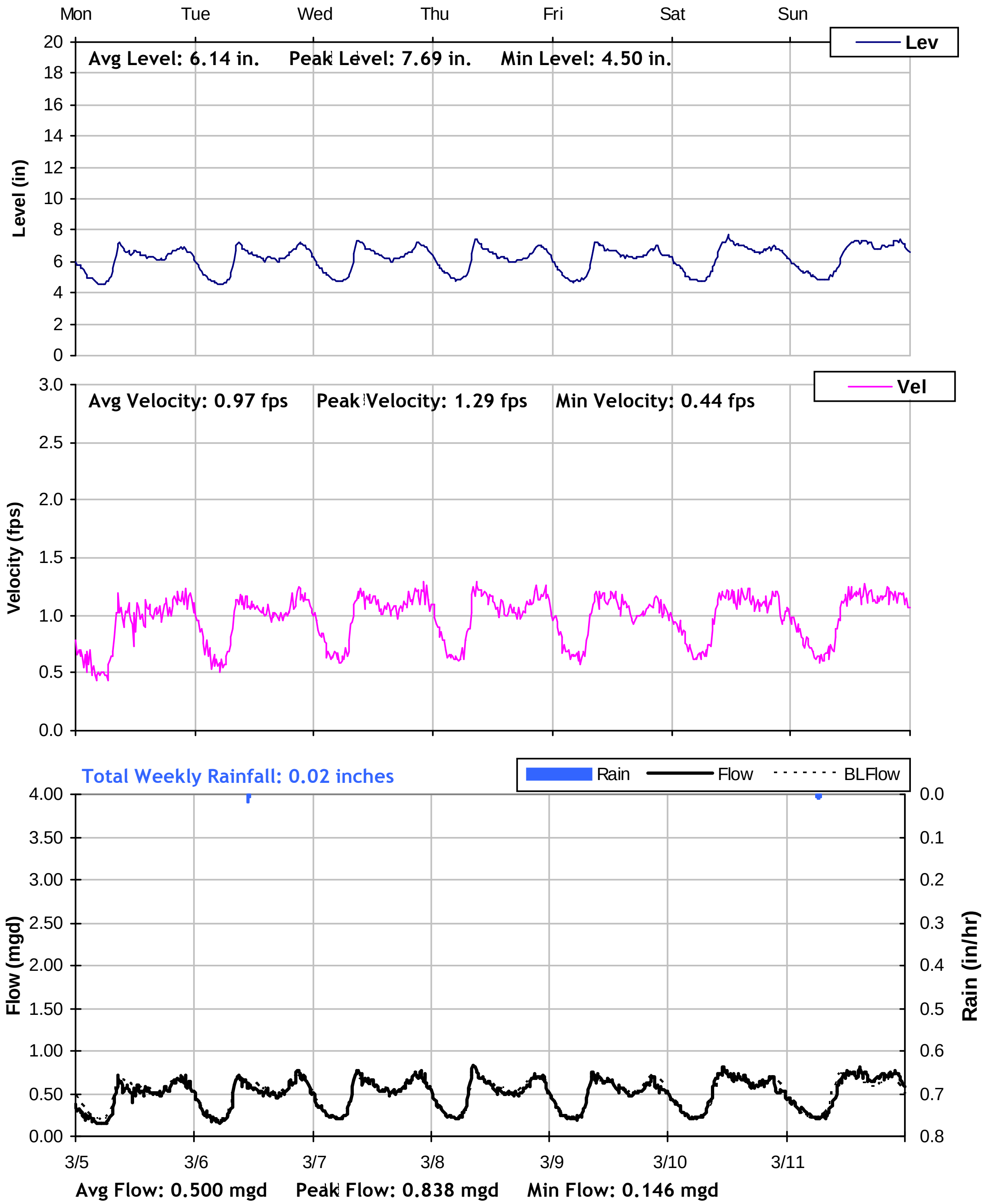
SITE 16
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



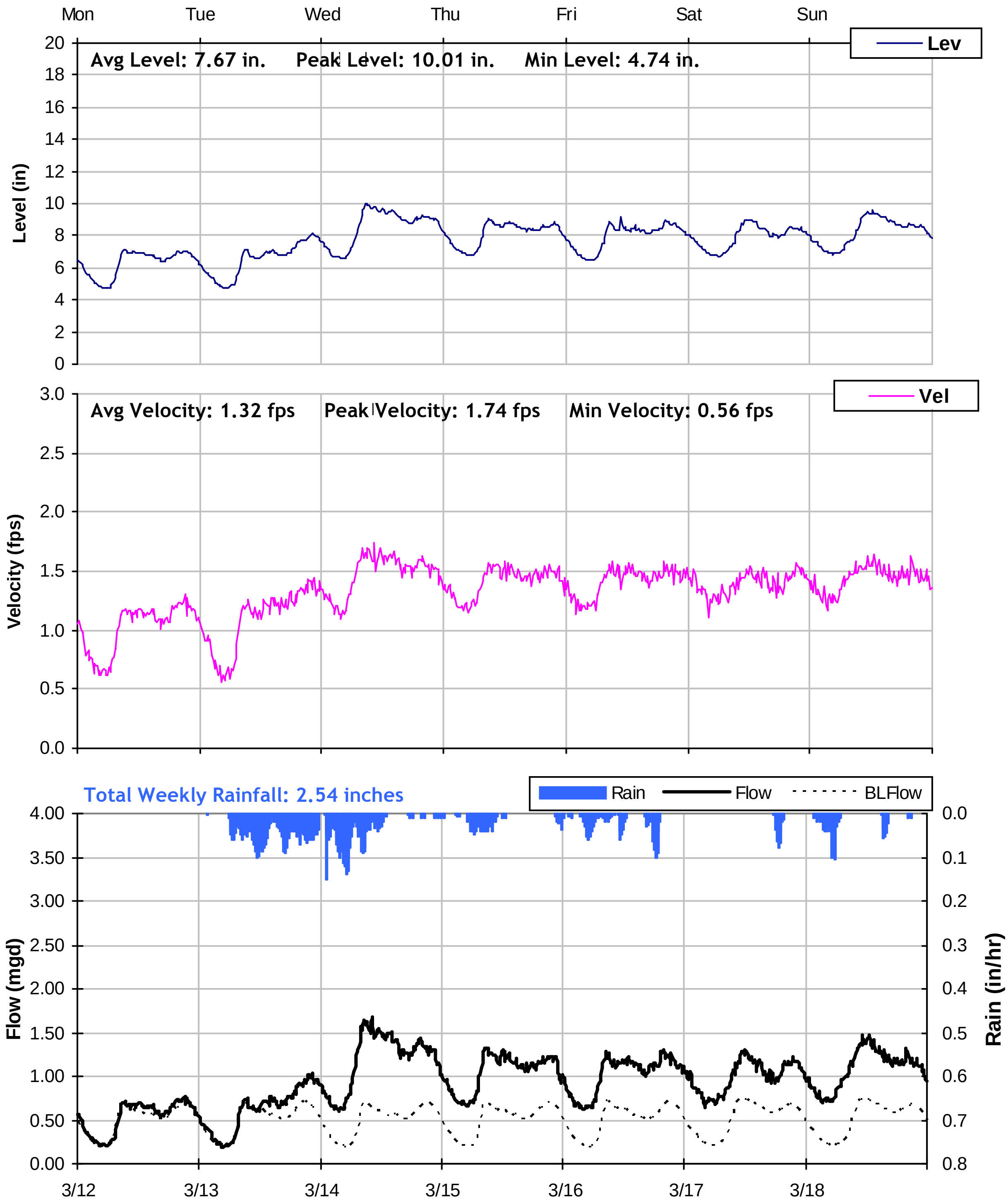
SITE 16

Weekly Level, Velocity and Flow Hydrographs

3/5/2012 to 3/12/2012

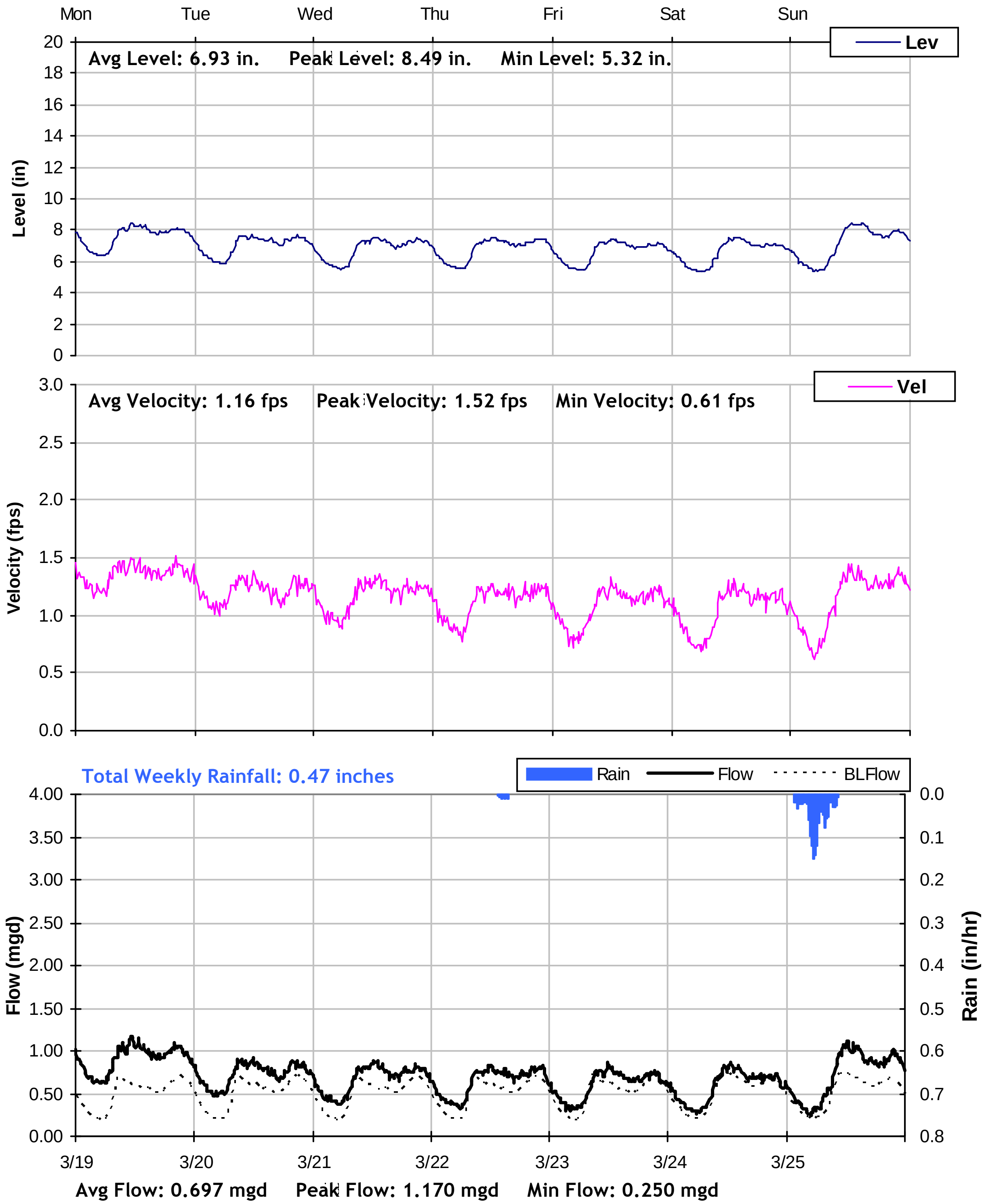


SITE 16
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012

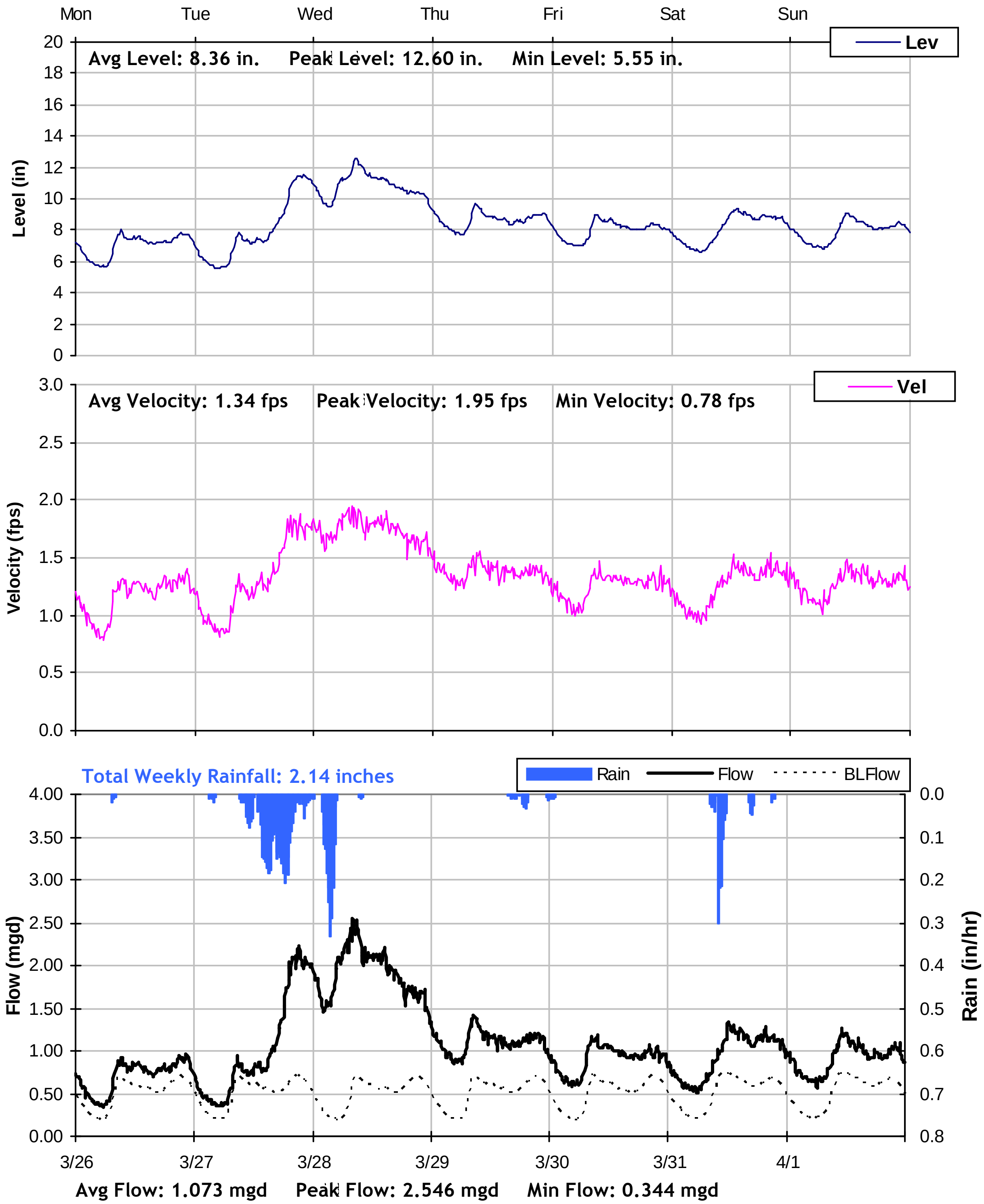


Avg Flow: 0.932 mgd Peak Flow: 1.670 mgd Min Flow: 0.195 mgd

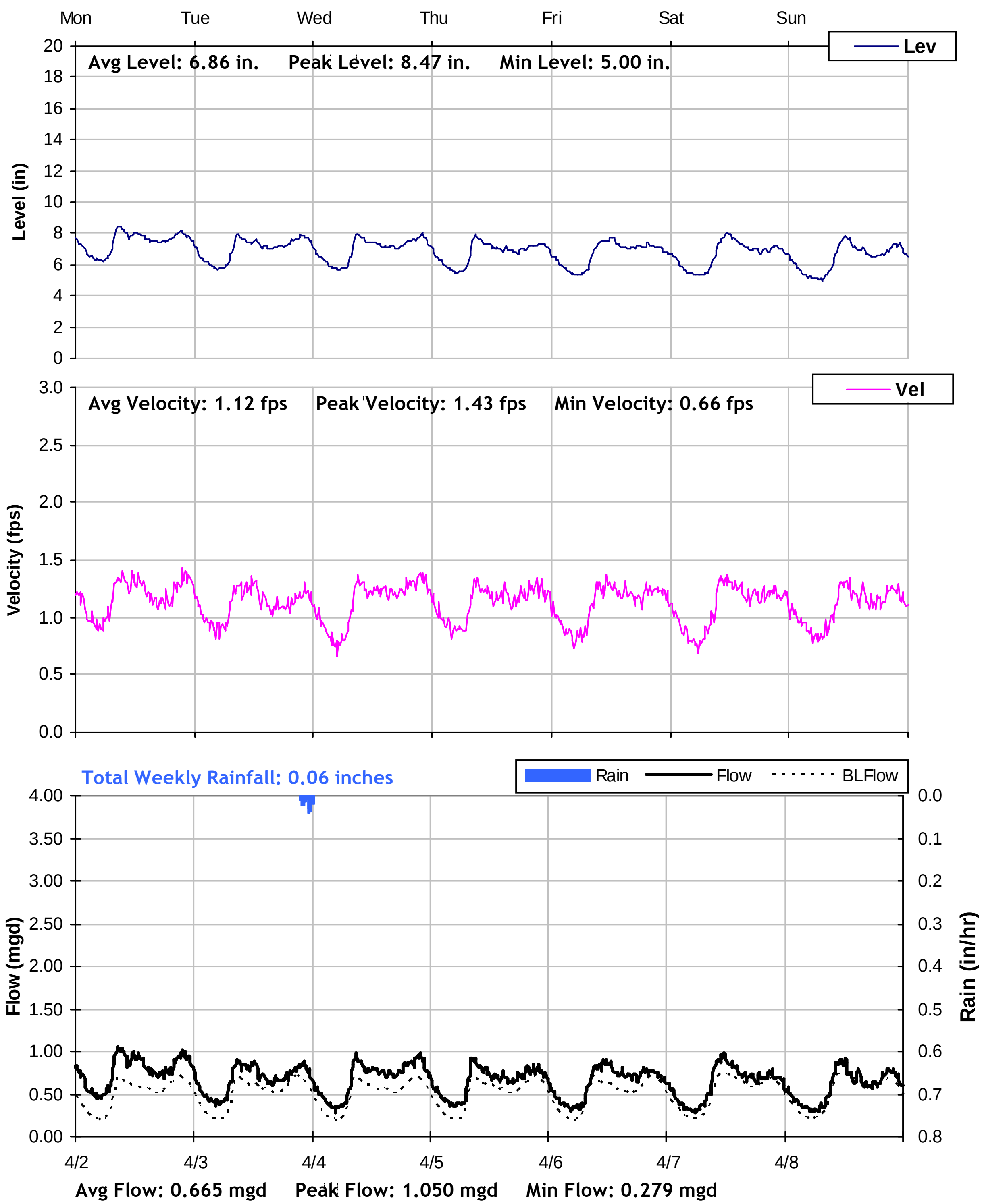
SITE 16
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



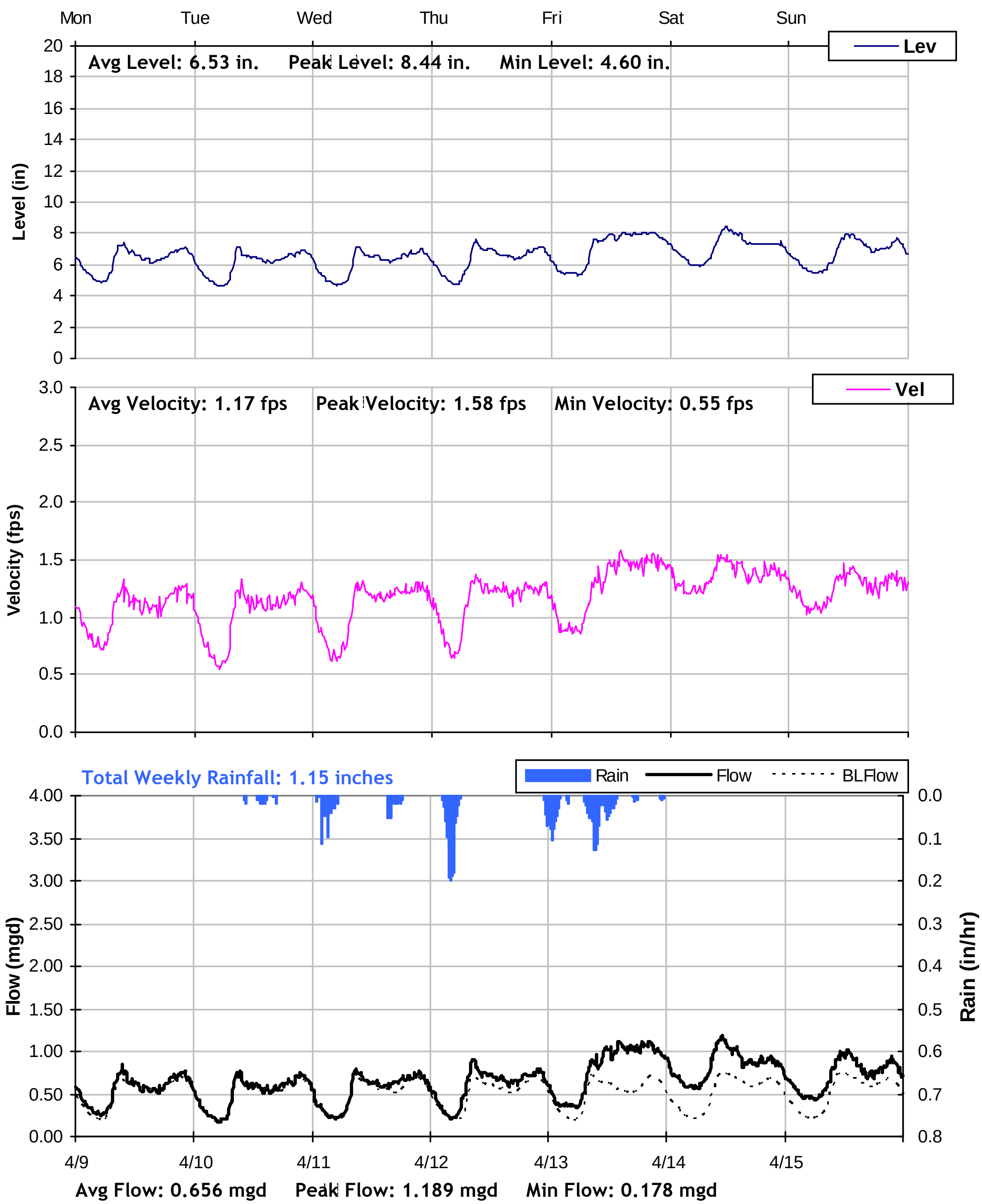
SITE 16
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



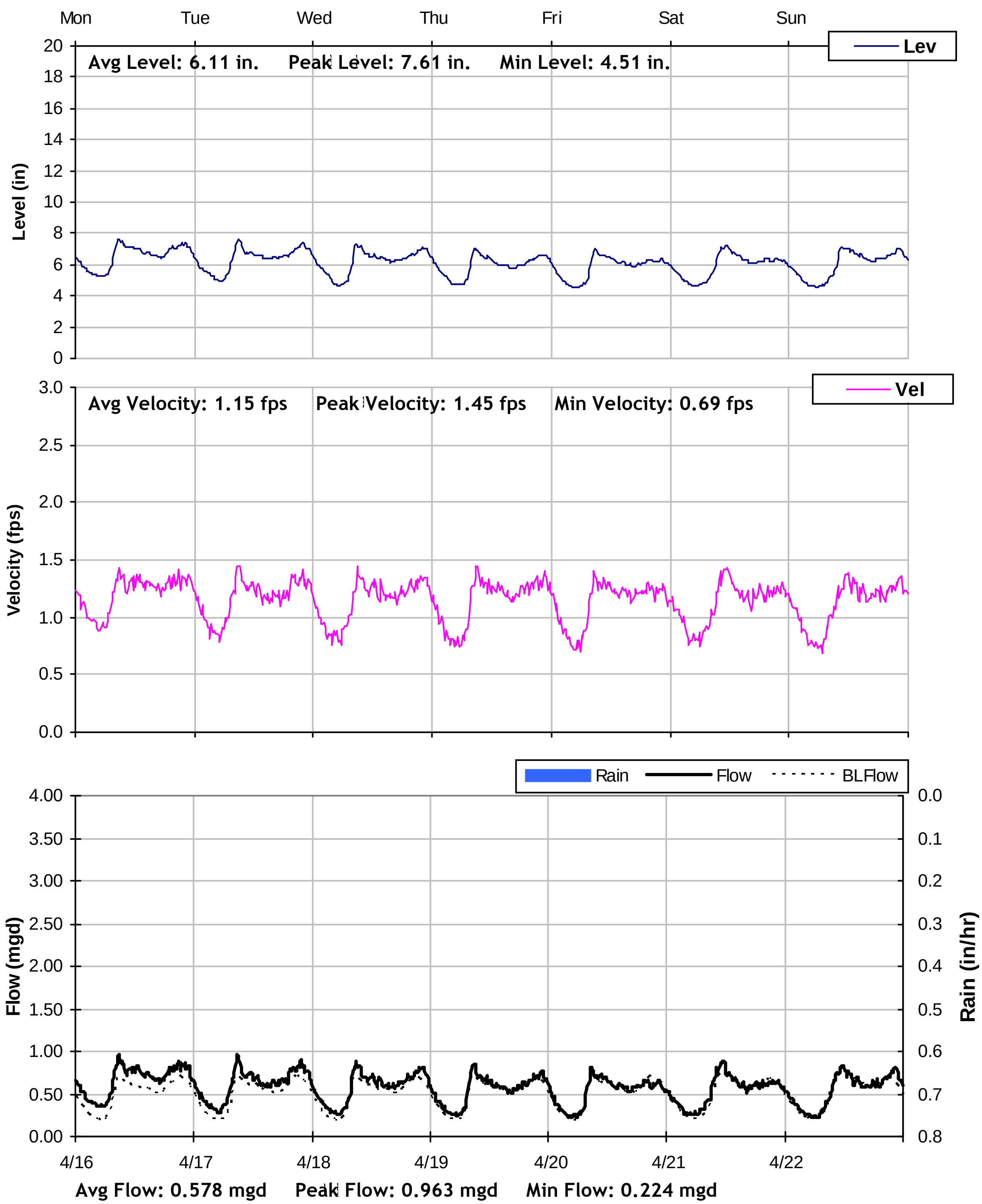
SITE 16
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



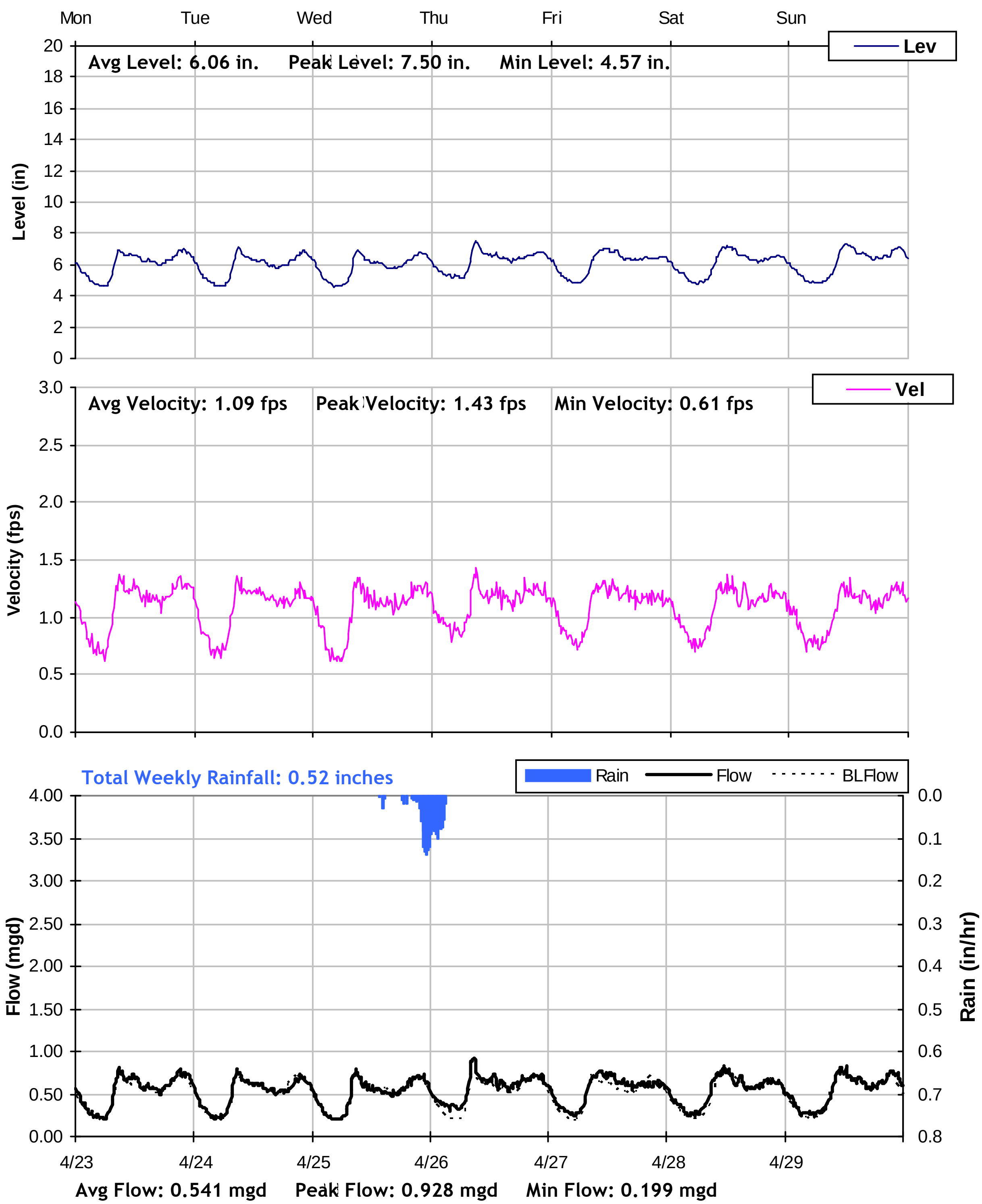
SITE 16
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



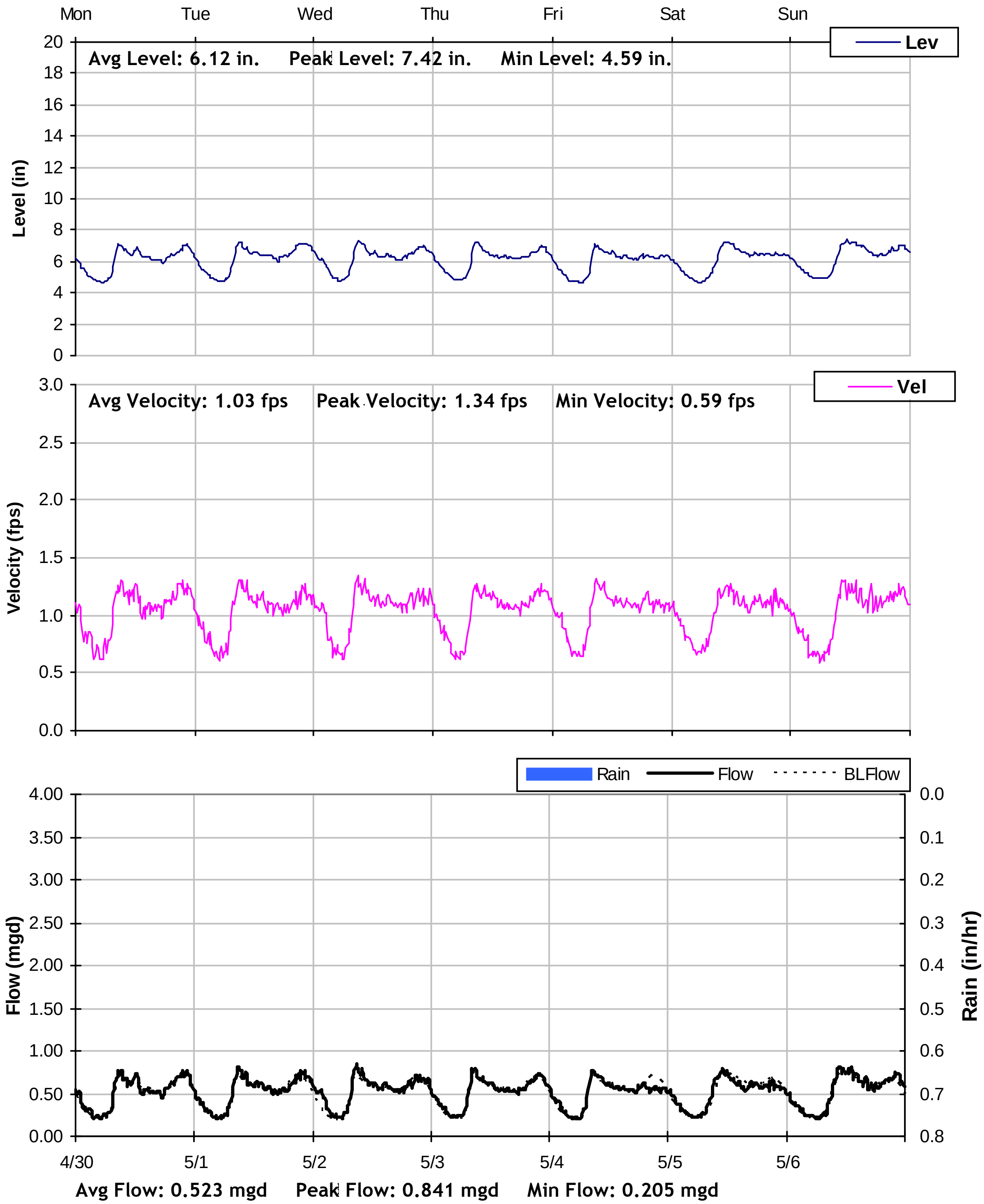
SITE 16
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012



SITE 16
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 16
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



City of Chico

Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

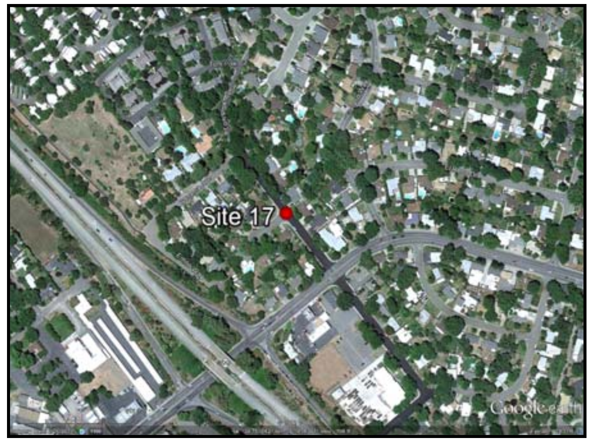
Monitoring Site: Site 17

Location: Tom Polk Avenue, northwest of East Avenue

Vicinity Map:

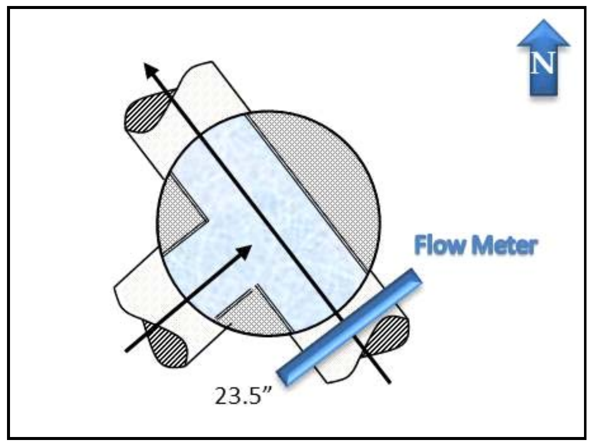
SITE 17
Site Information Report

Location:	Tom Polk Avenue, northwest of East Avenue
Coordinates:	121.8545° W, 39.7619° N
Elevation:	194 feet
Diameter:	23.5 inches
Baseline Flow:	0.309 mgd
Peak Measured Flow:	0.943 mgd

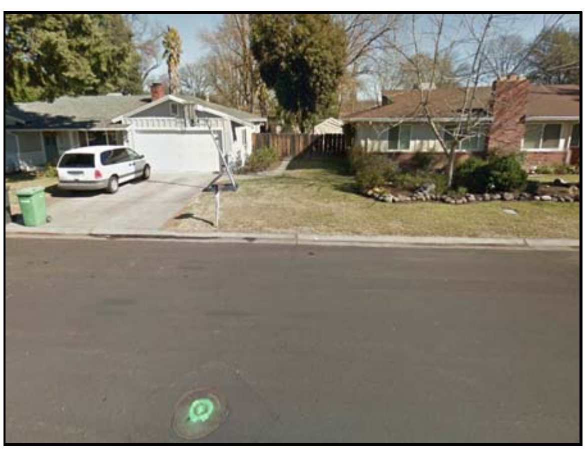


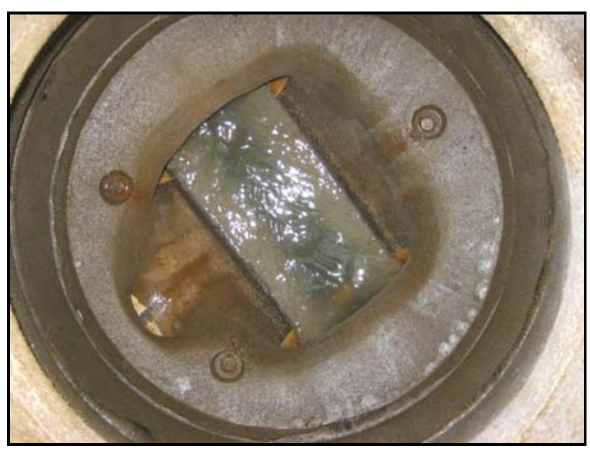
Satellite Map

Sanitary Sewer Map



Flow Sketch


View from Street

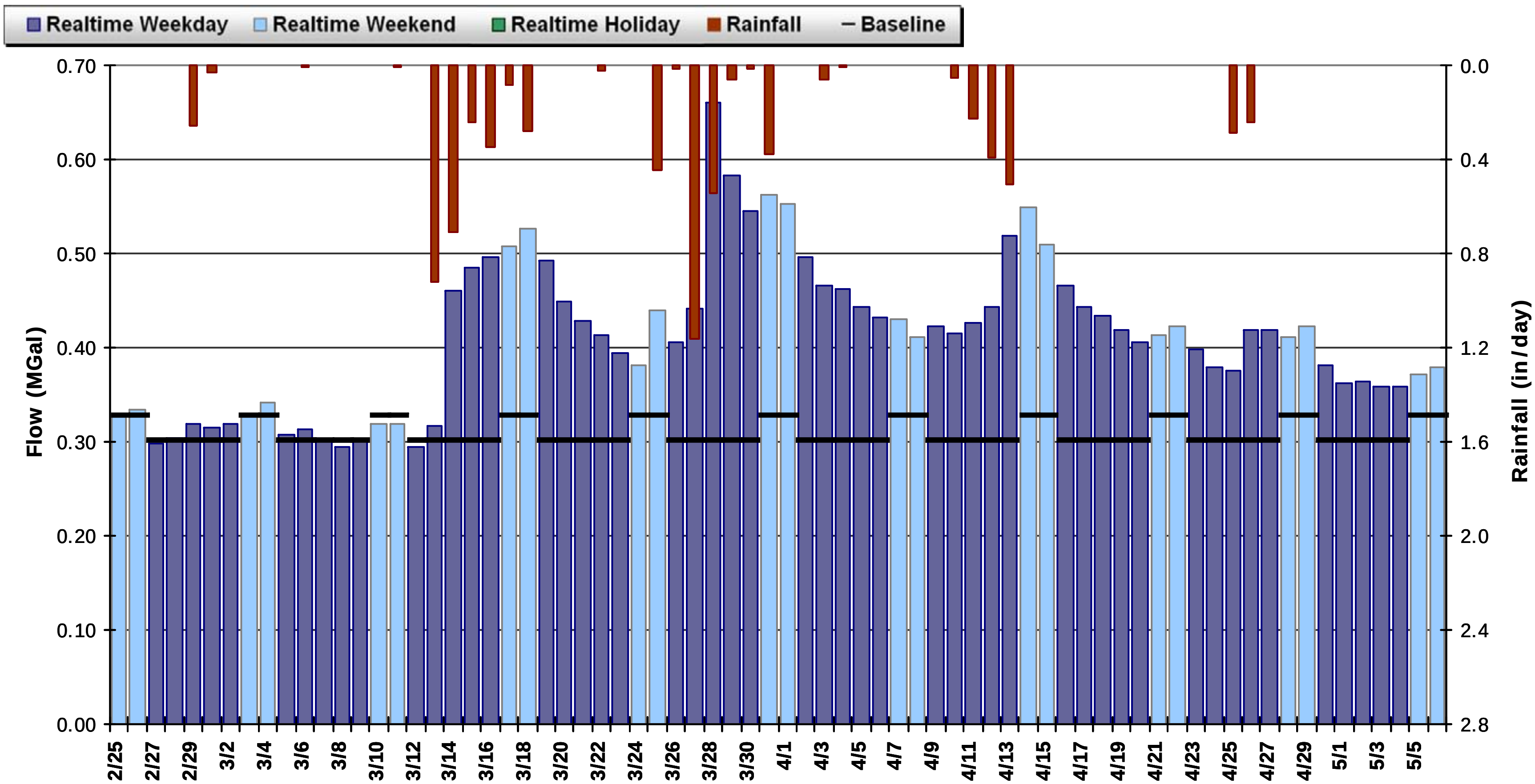

Plan View

SITE 17

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.413 MGal **Peak Daily Flow: 0.661 MGal** **Min Daily Flow: 0.295 MGal**

Total Period Rainfall: 7.29 inches

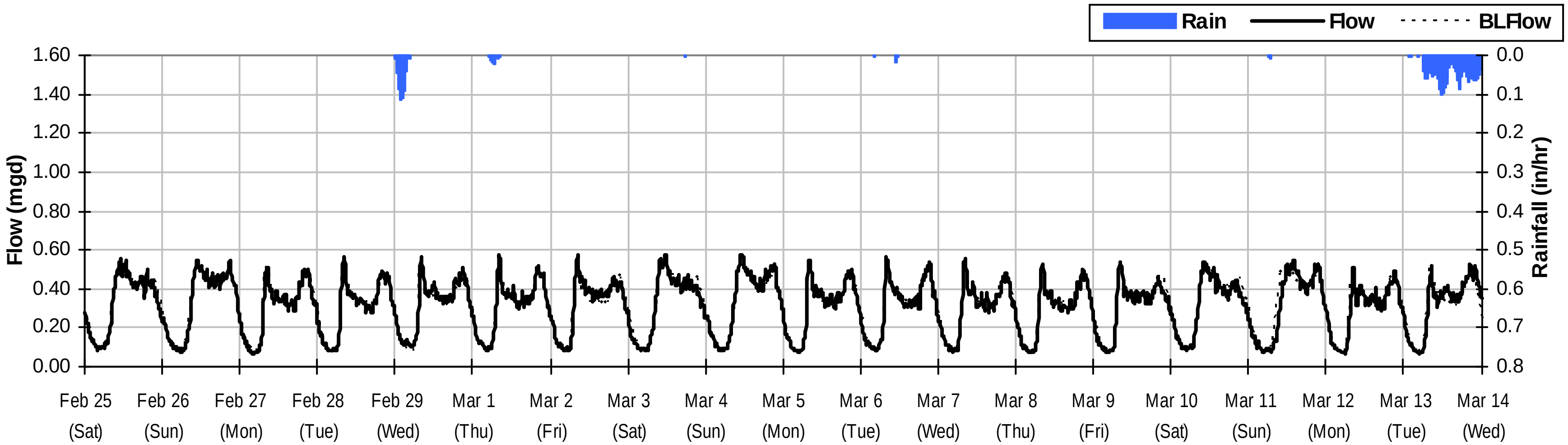


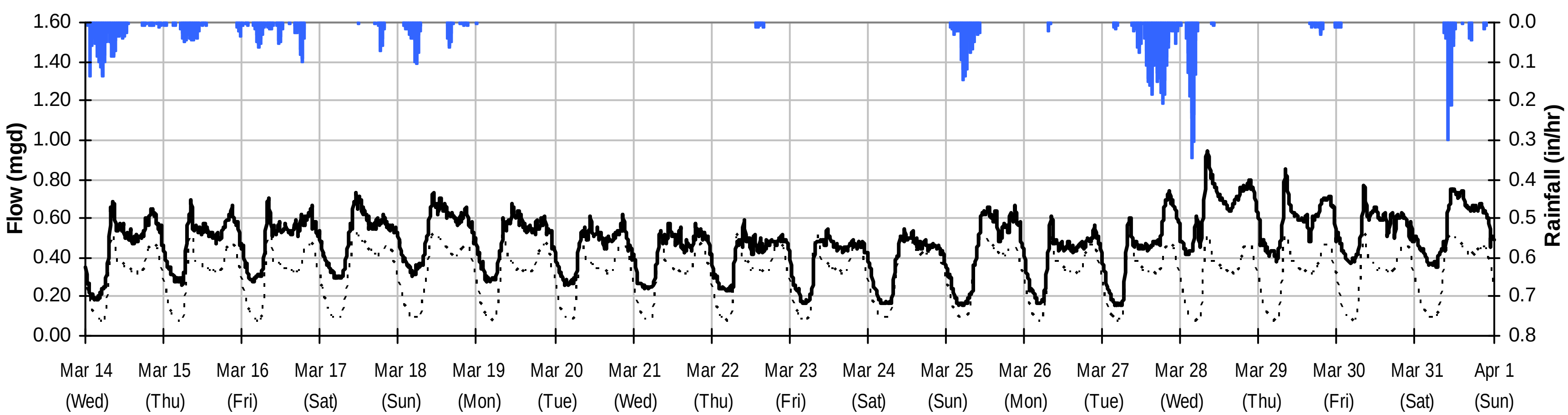
SITE 17

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.398 mgd **Peak Flow: 0.943 mgd** **Min Flow: 0.064 mgd**

Total Period Rainfall: 5.53 inches



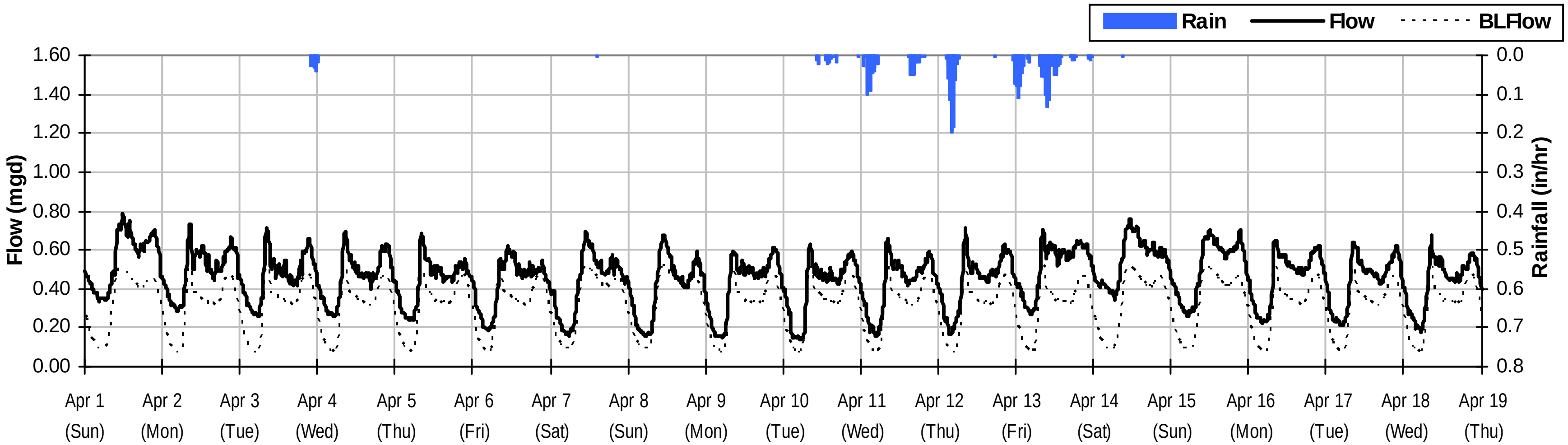


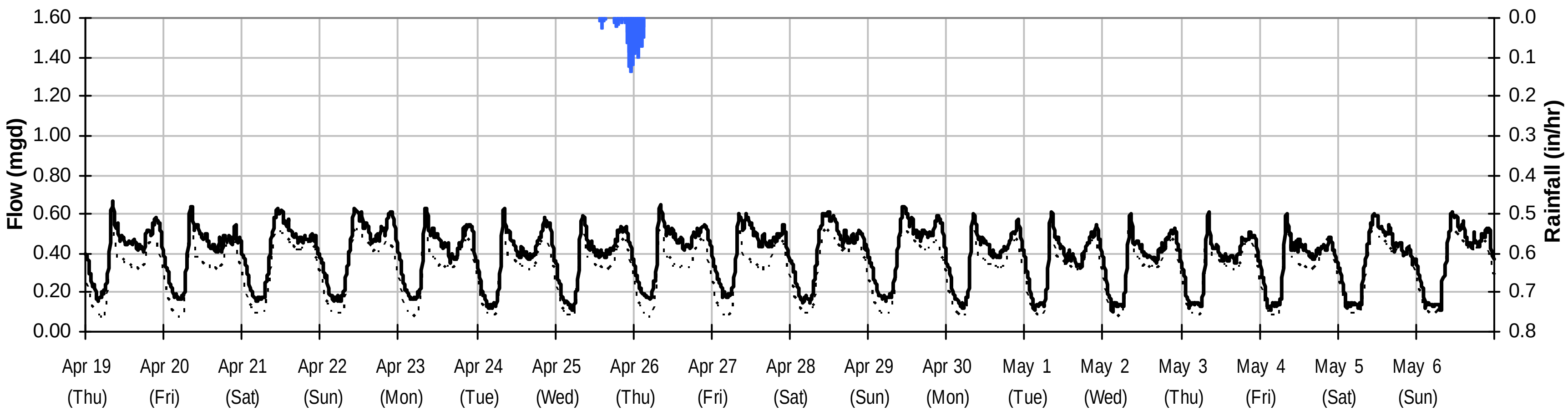
SITE 17

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.427 mgd   Peak Flow: 0.787 mgd   Min Flow: 0.104 mgd

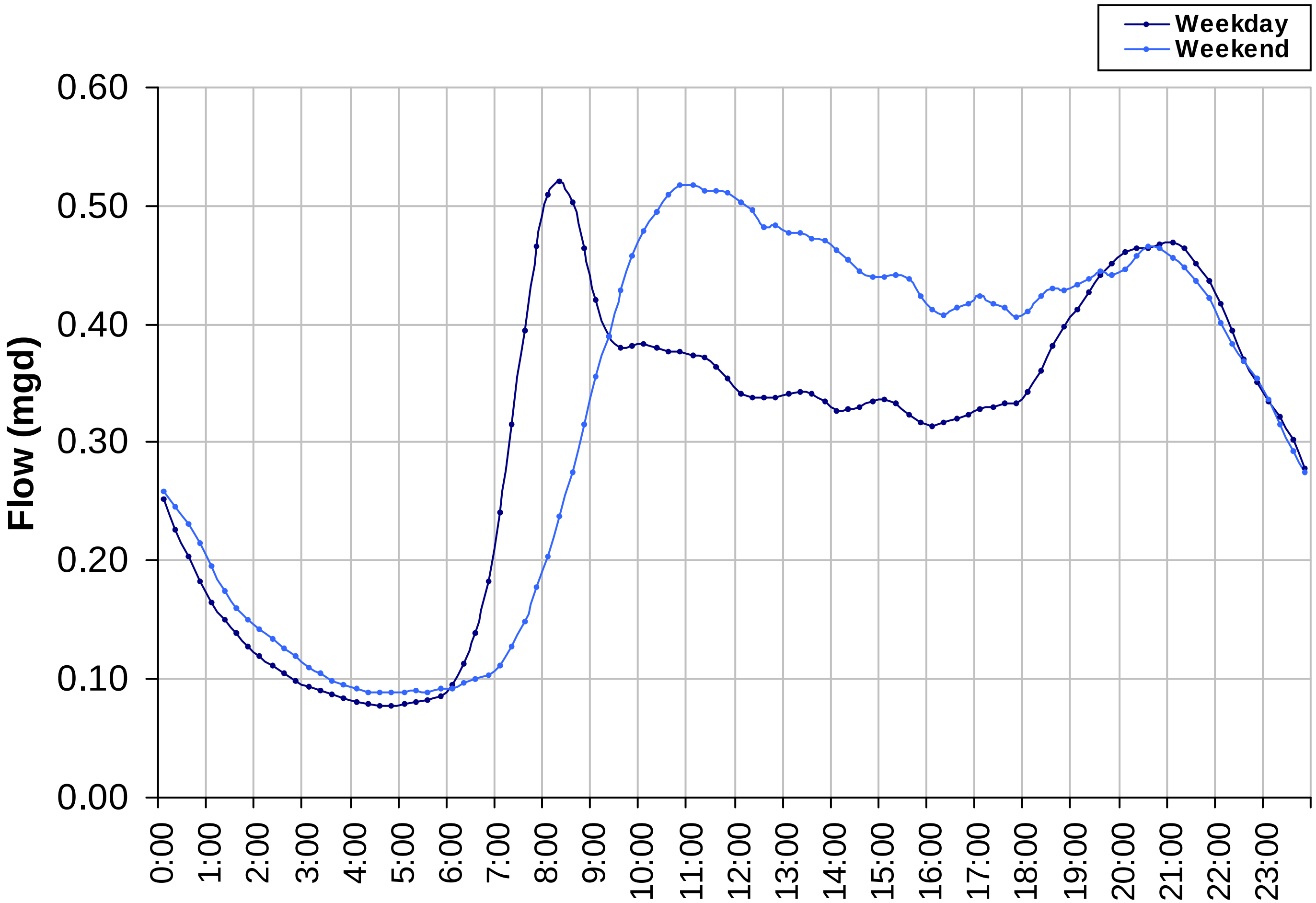
Total Period Rainfall: 1.77 inches





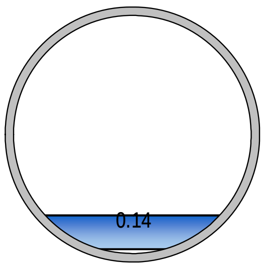
SITE 17

Baseline Flow Hydrographs



Baseline Flow:

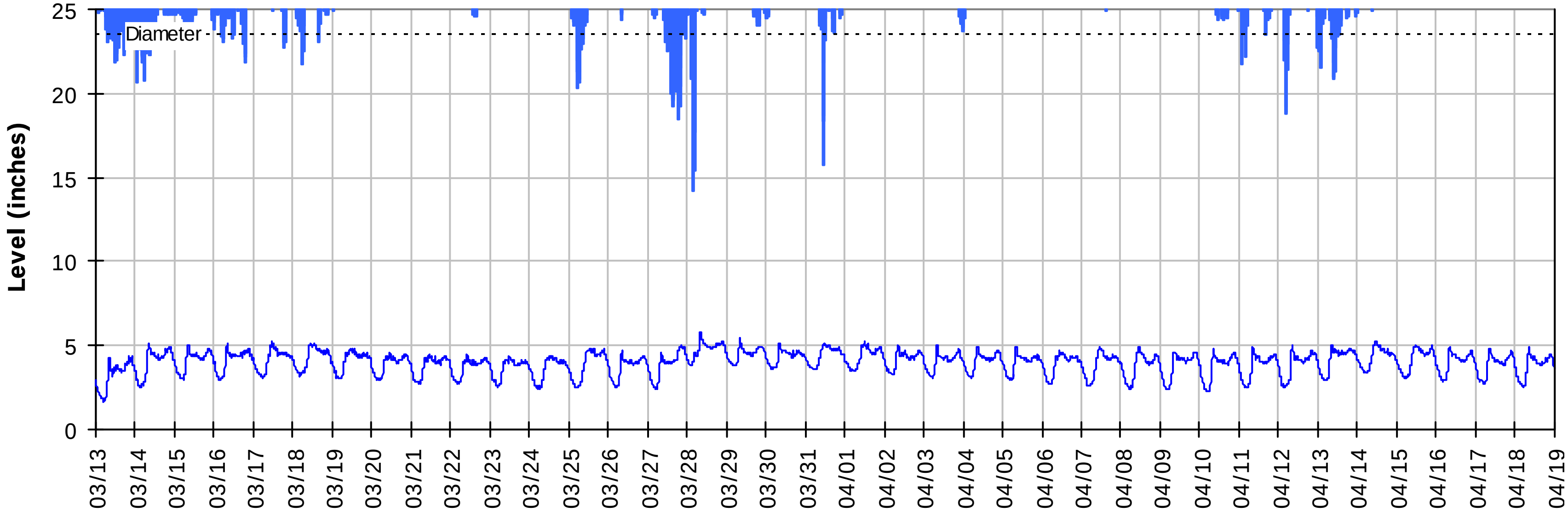
0.309 *mgd*

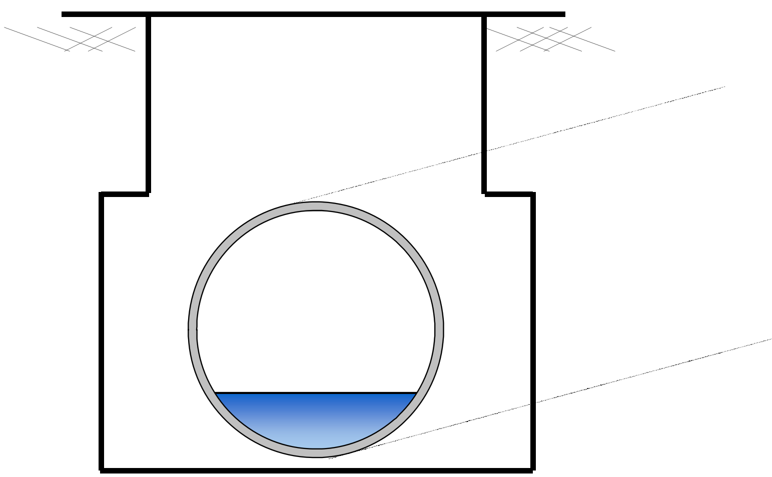


SITE 17

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





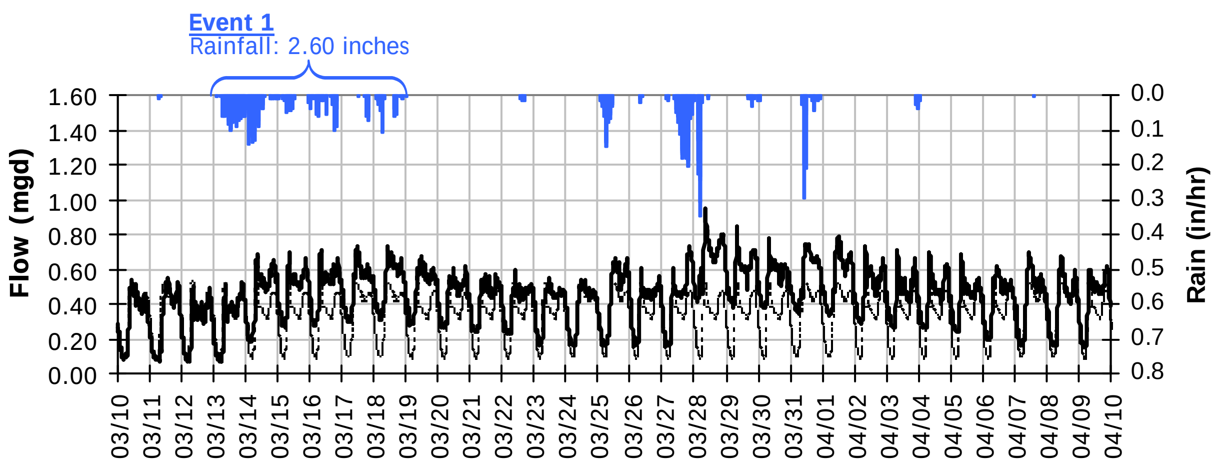
Pipe Diameter: 23.5 *inches*

Peak Measured Level: 5.76 *inches*

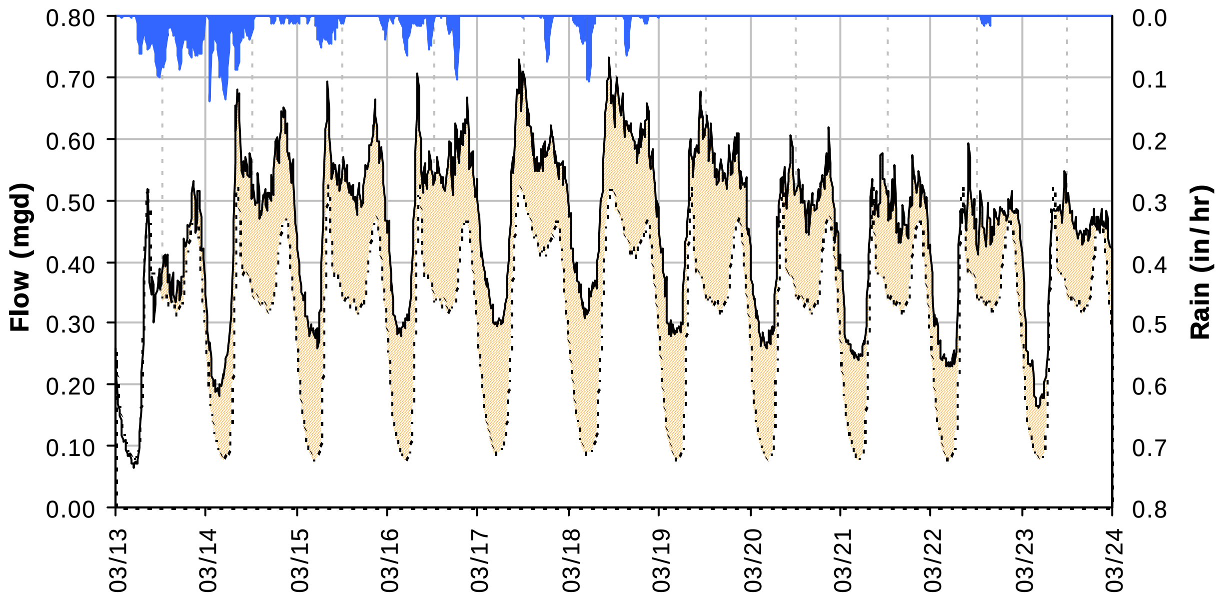
Peak d/D Ratio: 0.25

SITE 17
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 = 2.60 inches)

Capacity

Peak Flow:	0.73 *mgd*
PF:	2.37
Peak Level:	5.20 *in*
d/D Ratio:	0.22

Inflow

Peak I/I Rate:	0.30 *mgd*
PkI/I:IDM:	2,062 *gpd/IDM*
PkI/I:Acre:	412 *gpd/acre*
Pk I/I:ADWF:	0.97

RDI (infiltration)

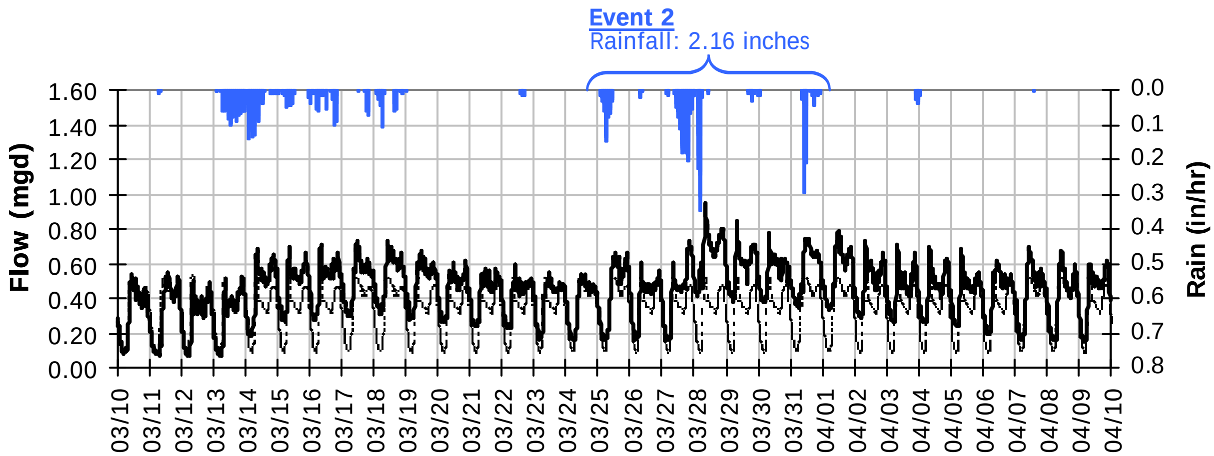
Infiltration Rate: (3/20/2012)	0.147 *mgd*
RDI:IDM:	1,007 *gpd/IDM*
RDI:Acre:	201 *gpd/acre*
RDI (% of BL):	49%

Combined I/I

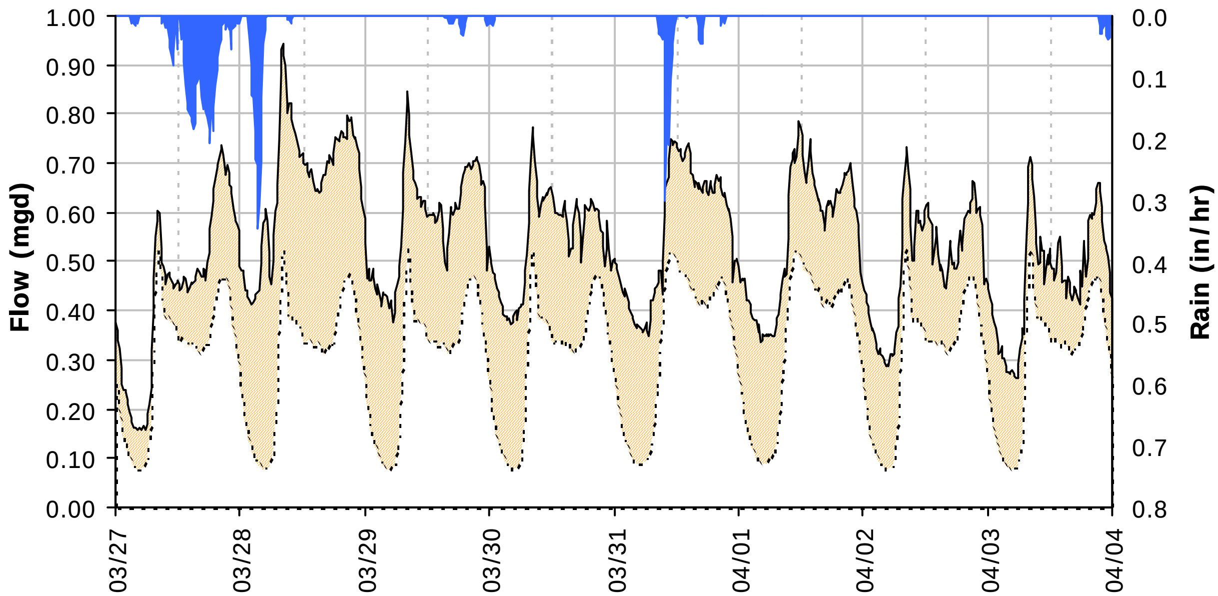
Total I/I:	1,600,000 *gallons*
Total I/I:IDM:	4,207 *gal/IDM/in*
R-Value:	3.1%
Total I/I:ADWF:	1.99 *per in-rain*

SITE 17
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 = 2.16 inches)

Capacity

Peak Flow:	0.94 *mgd*
PF:	3.05
Peak Level:	5.76 *in*
d/D Ratio:	0.25

Inflow

Peak I/I Rate:	0.53 *mgd*
PkI/I:IDM:	3,606 *gpd/IDM*
PkI/I:Acre:	720 *gpd/acre*
Pk I/I:ADWF:	1.70

RDI (infiltration)

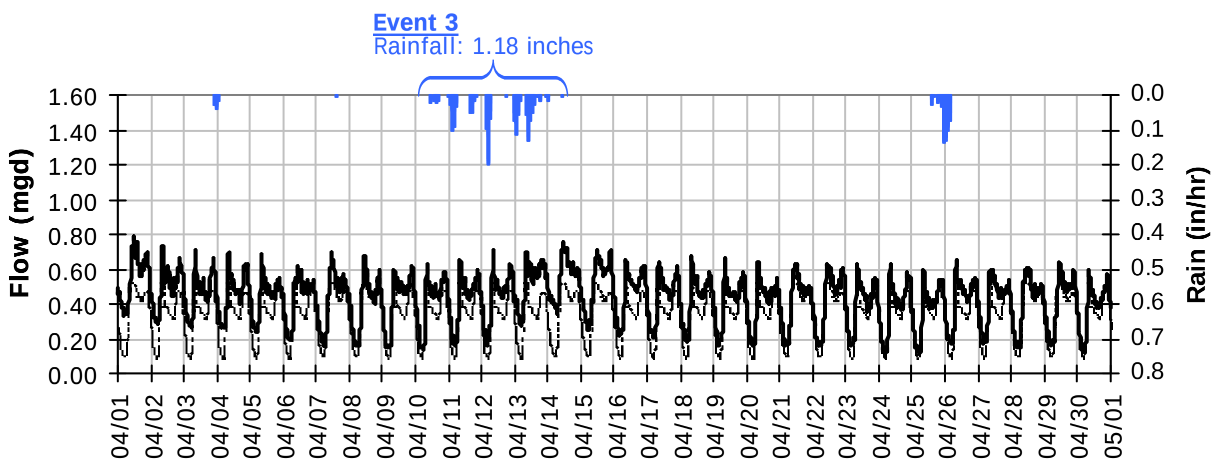
Infiltration Rate: (4/2/2012)	0.194 *mgd*
RDI:IDM:	1,324 *gpd/IDM*
RDI:Acre:	264 *gpd/acre*
RDI (% of BL):	64%

Combined I/I

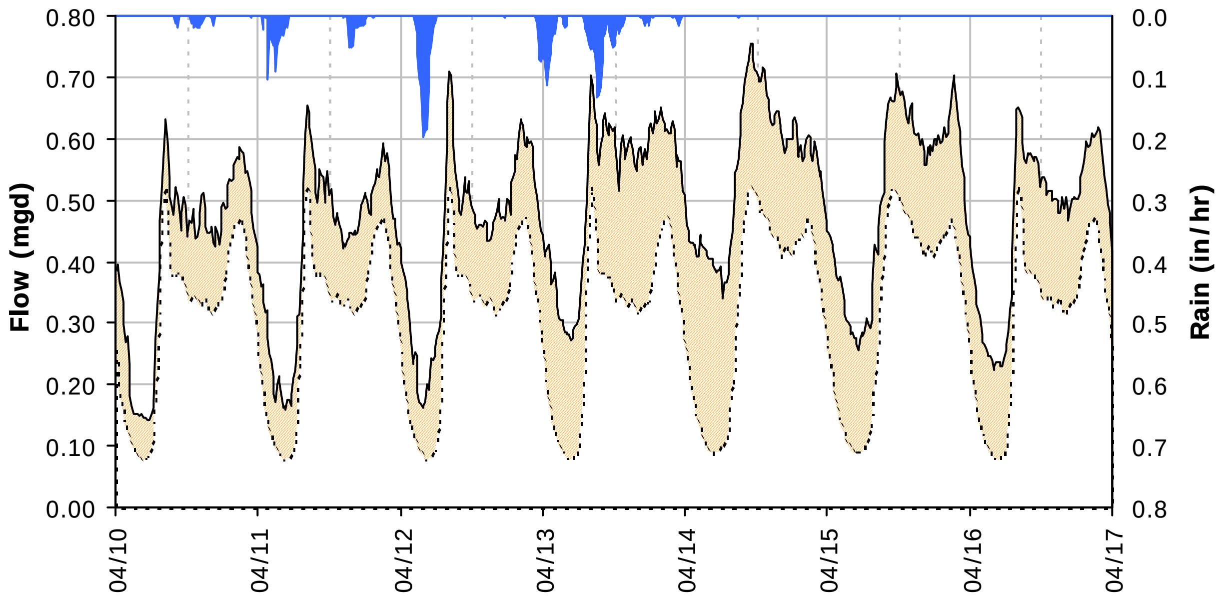
Total I/I:	1,840,000 *gallons*
Total I/I:IDM:	5,812 *gal/IDM/in*
R-Value:	4.3%
Total I/I:ADWF:	2.75 *per in-rain*

SITE 17
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.18 inches)

Capacity

Peak Flow:	0.76 *mgd*
PF:	2.44
Peak Level:	5.21 *in*
d/D Ratio:	0.22

Inflow

Peak I/I Rate:	0.32 *mgd*
PkI/I:IDM:	2,182 *gpd/IDM*
PkI/I:Acre:	436 *gpd/acre*
Pk I/I:ADWF:	1.03

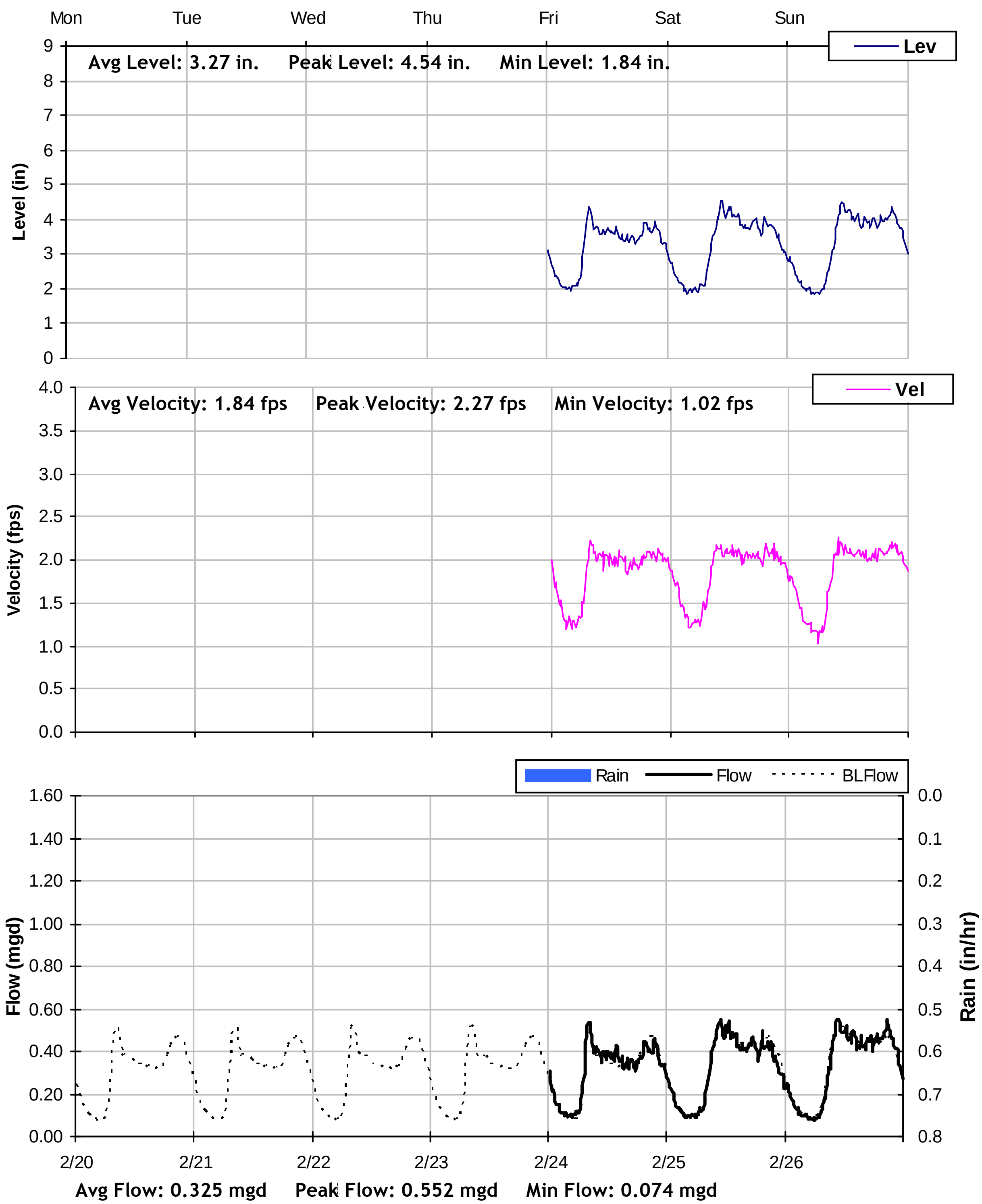
RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.182 *mgd*
RDI:IDM:	1,247 *gpd/IDM*
RDI:Acre:	249 *gpd/acre*
RDI (% of BL):	56%

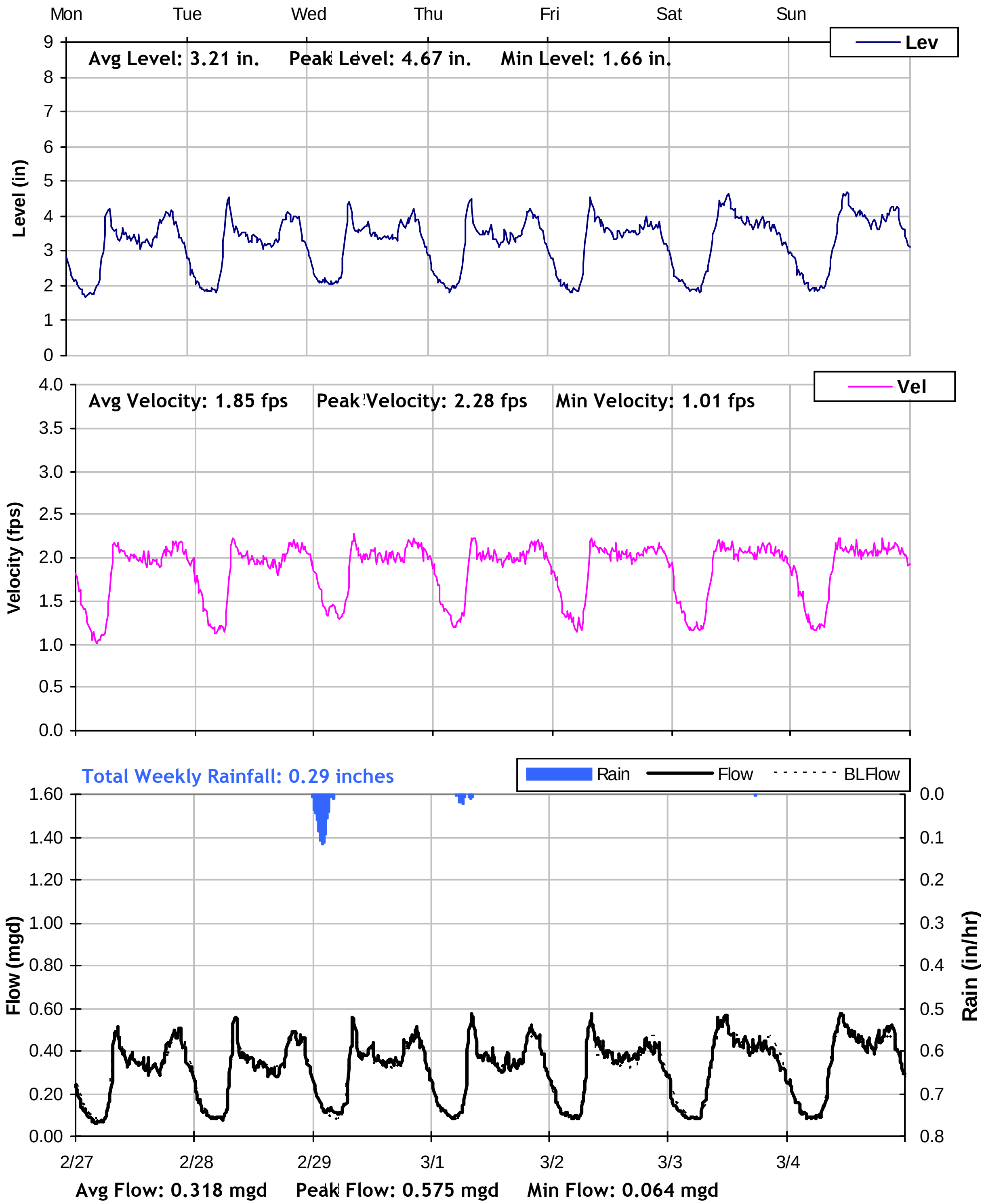
Combined I/I

Total I/I:	1,165,000 *gallons*
Total I/I:IDM:	6,770 *gal/IDM/in*
R-Value:	5.0%
Total I/I:ADWF:	3.20 *per in-rain*

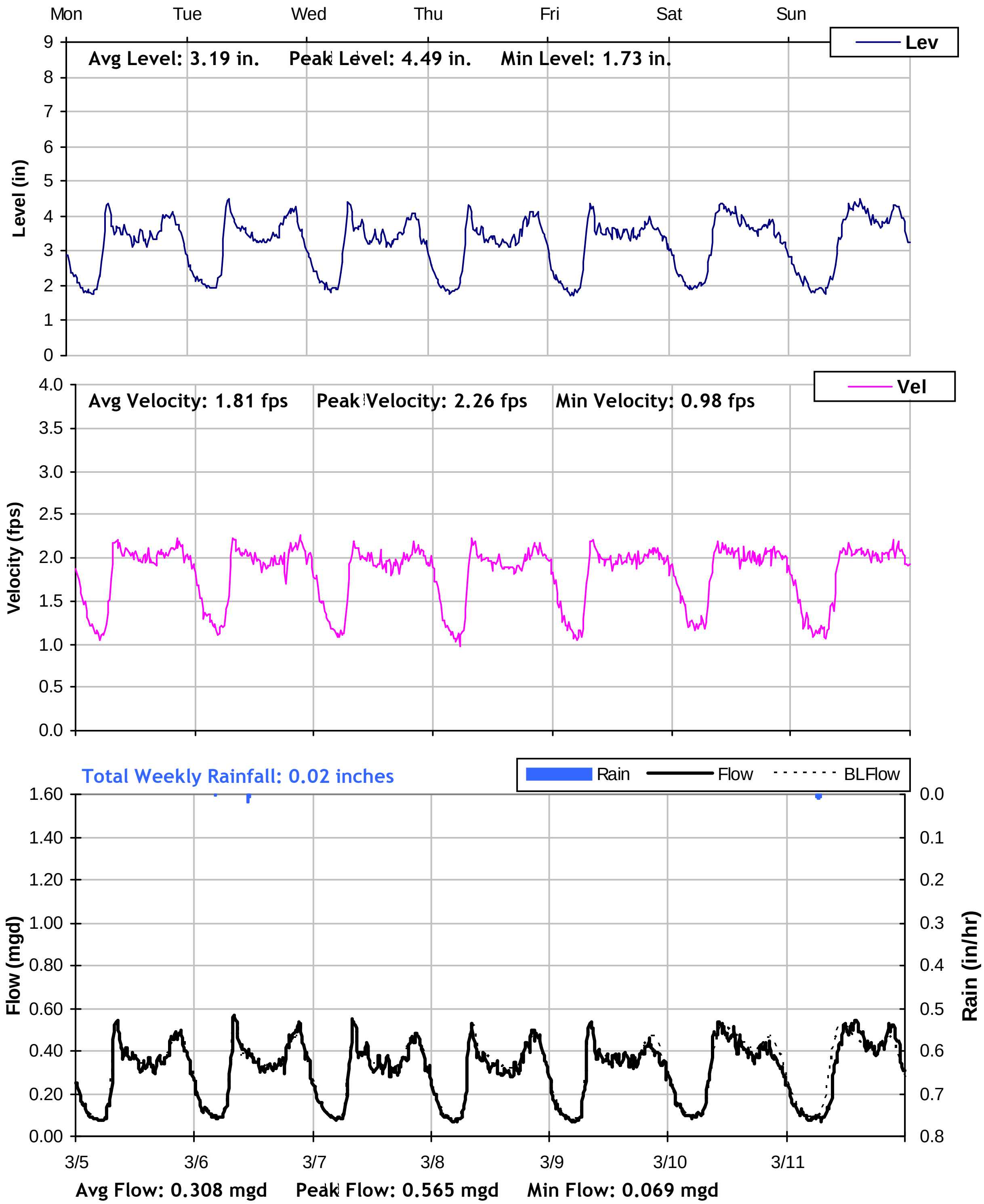
SITE 17
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



SITE 17
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



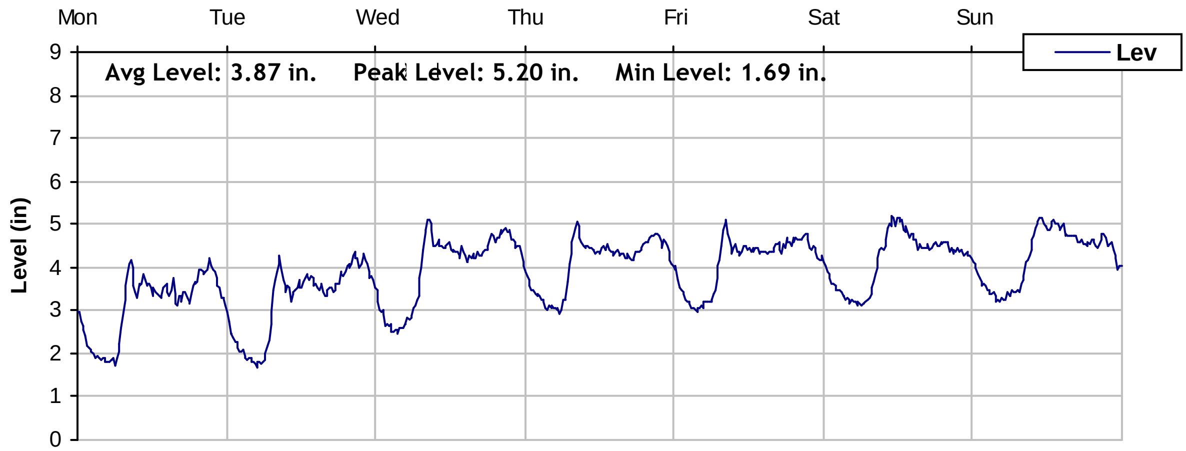
SITE 17
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012

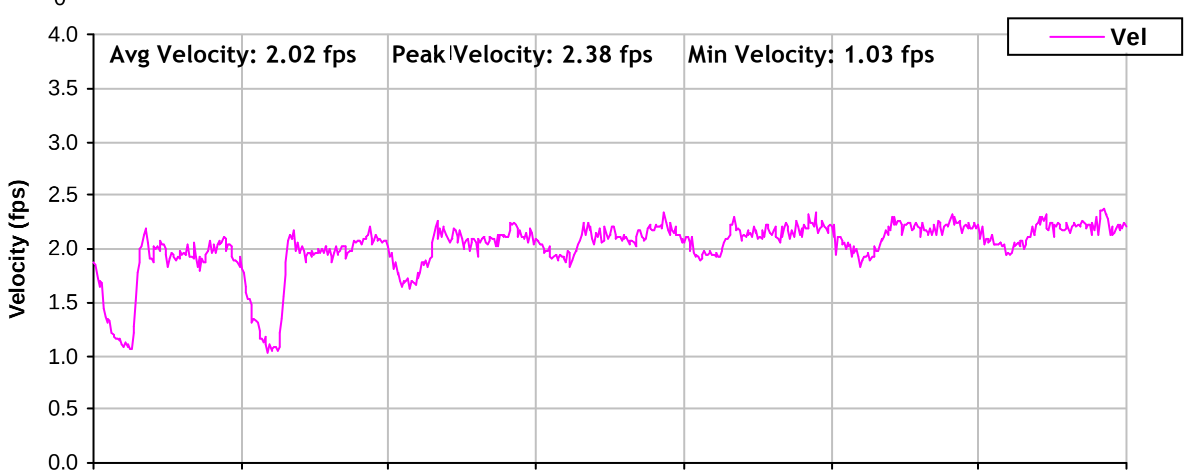


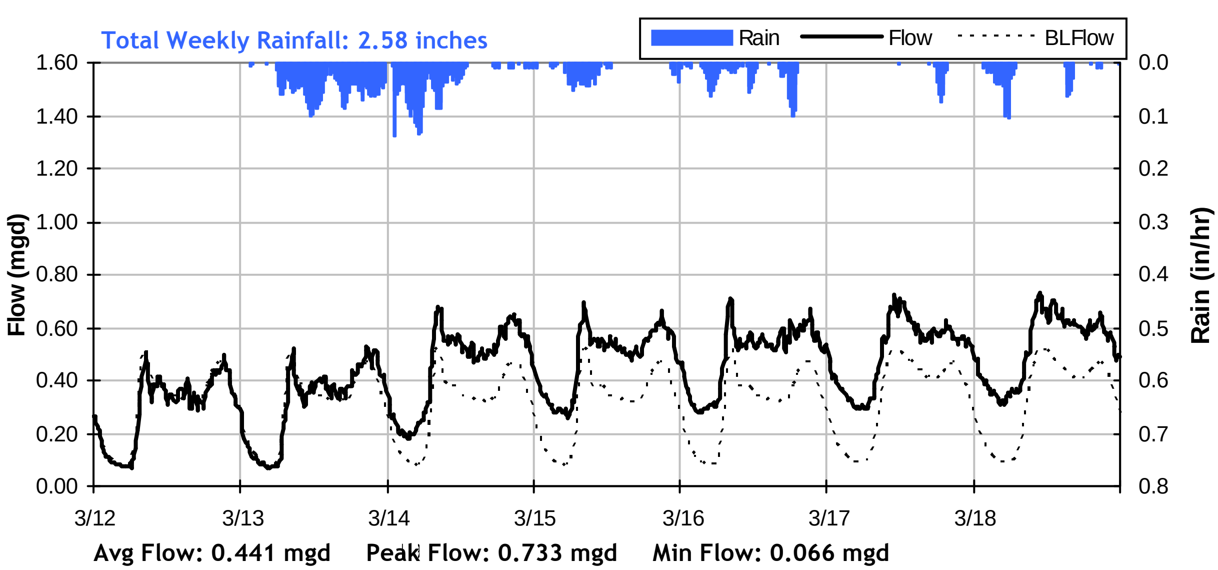
SITE 17

Weekly Level, Velocity and Flow Hydrographs

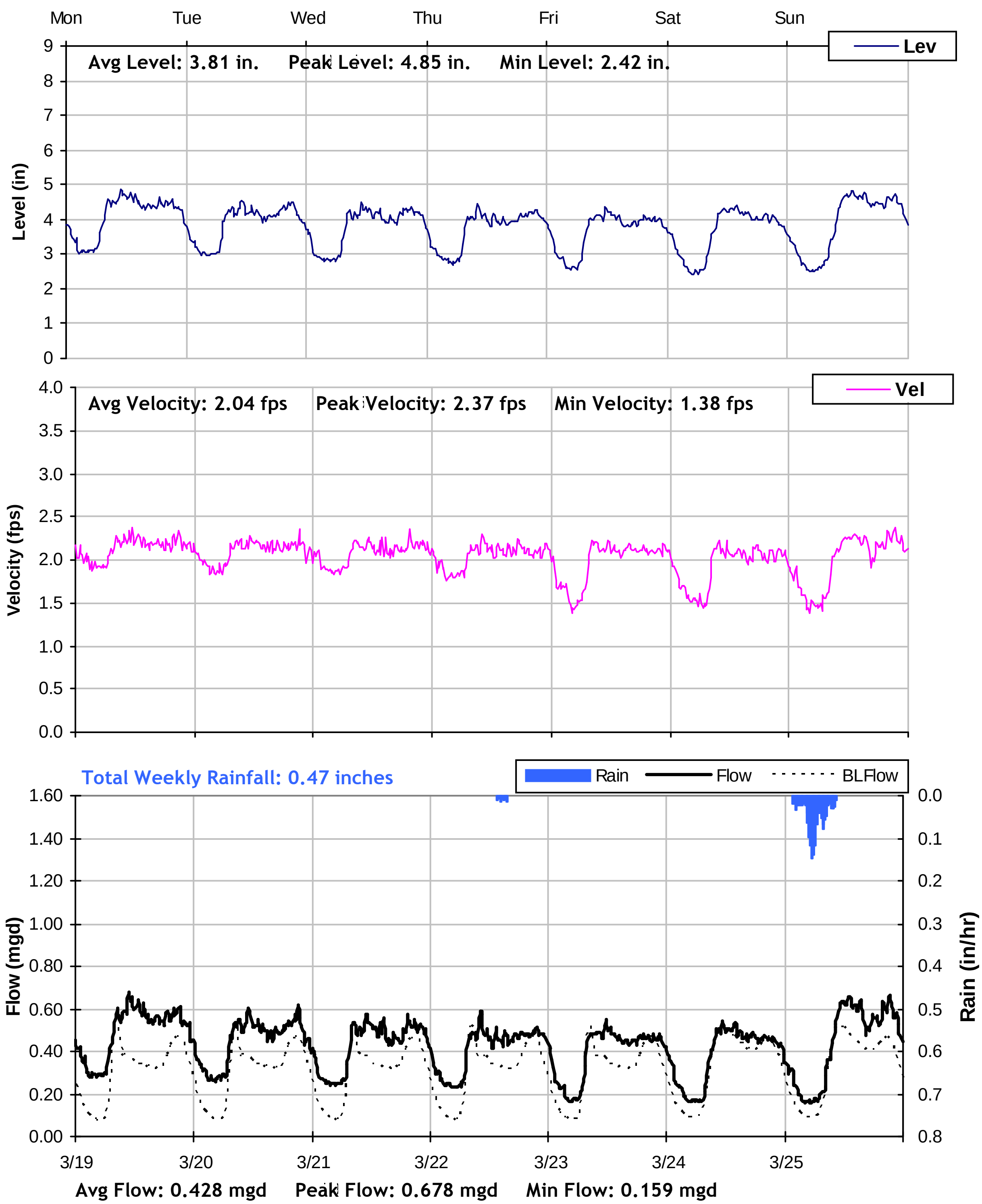
3/12/2012 to 3/19/2012



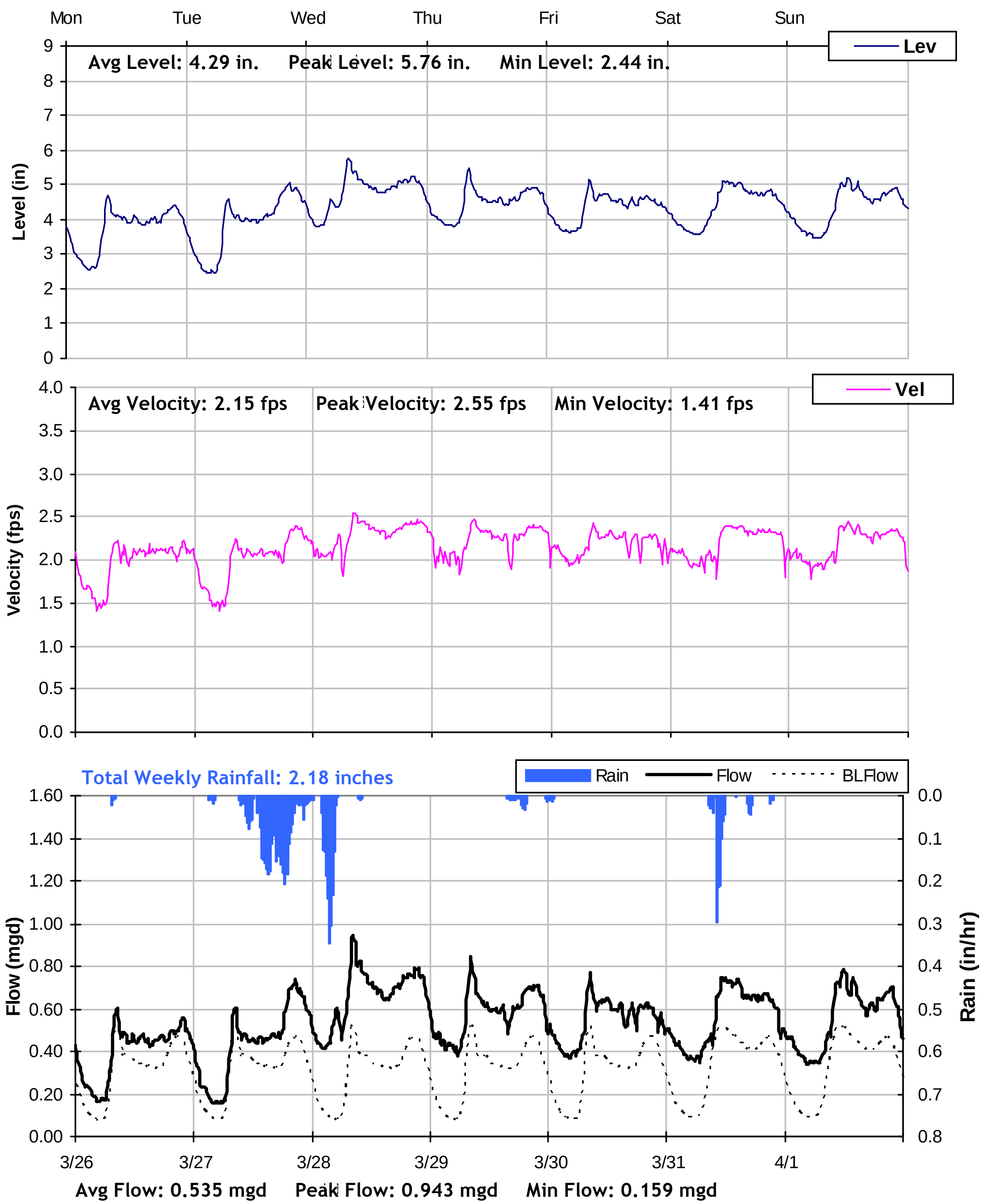




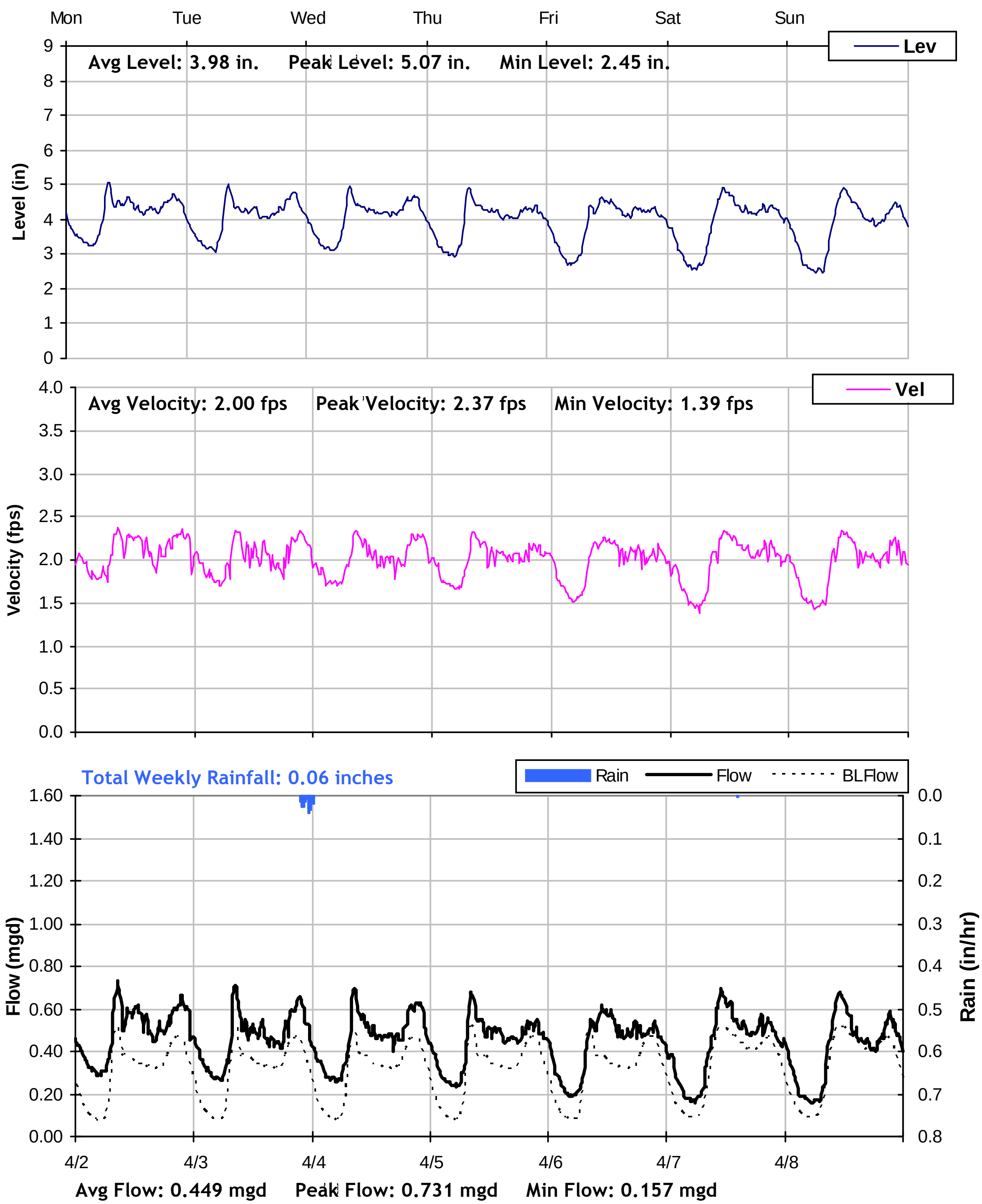
SITE 17
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



SITE 17
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



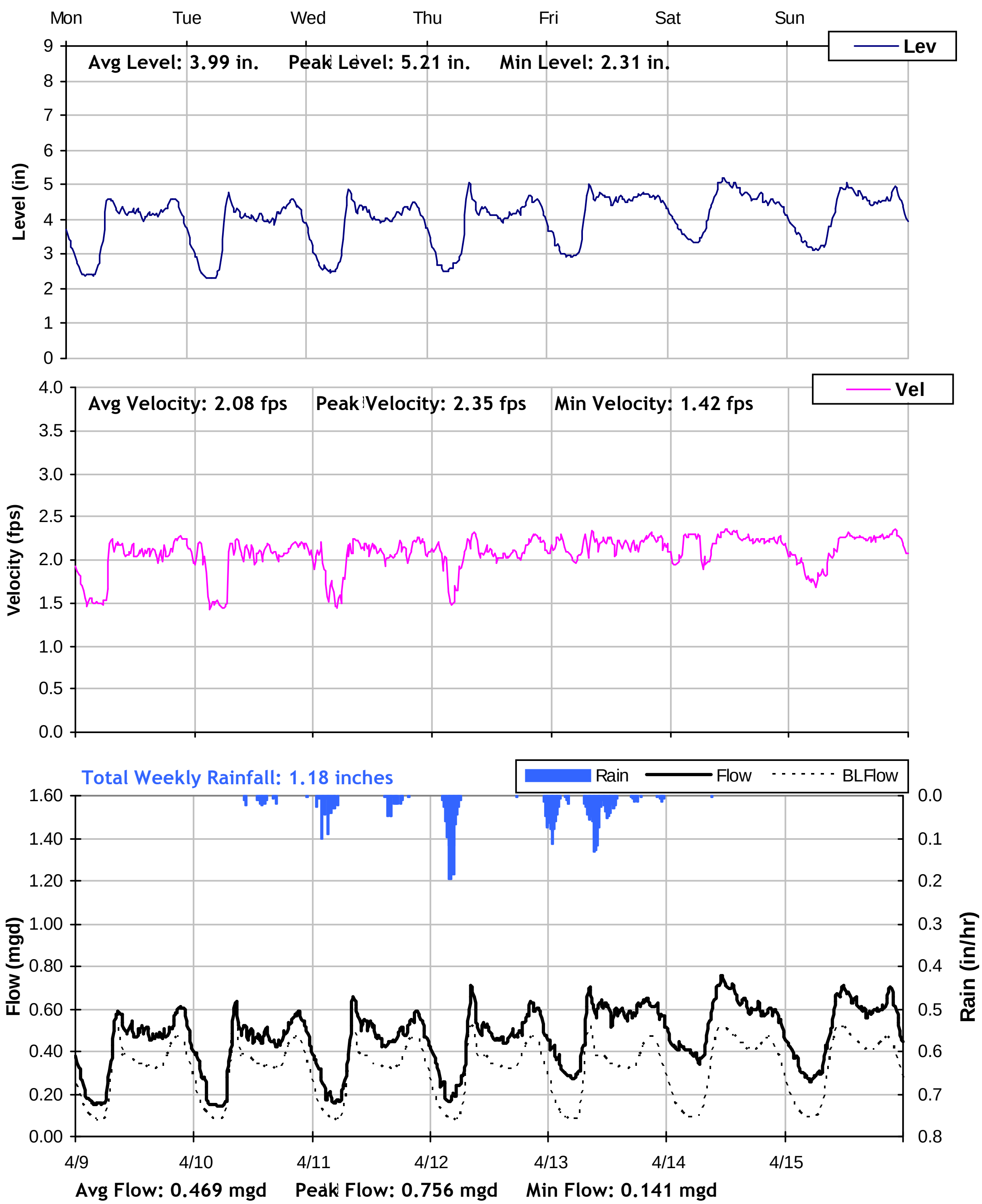
SITE 17
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



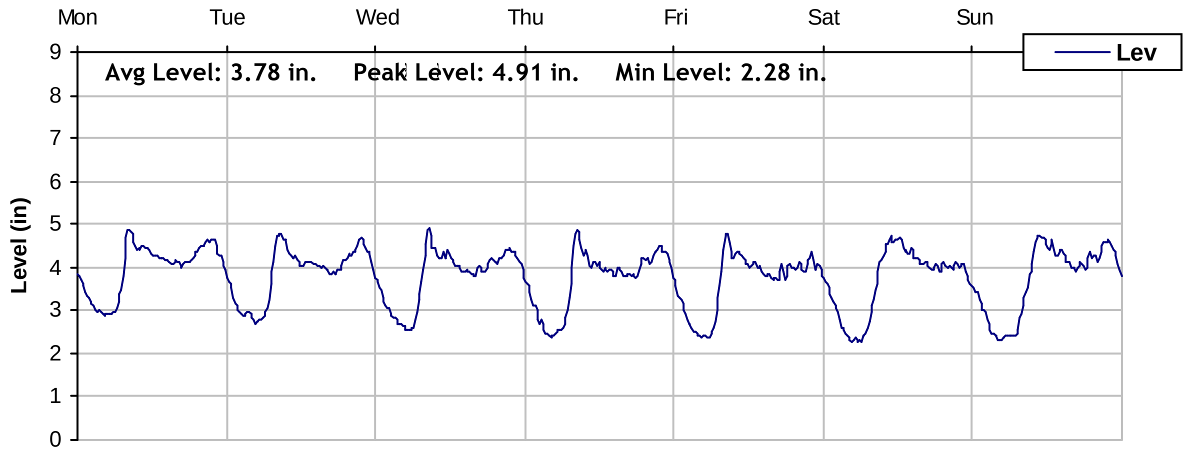
SITE 17

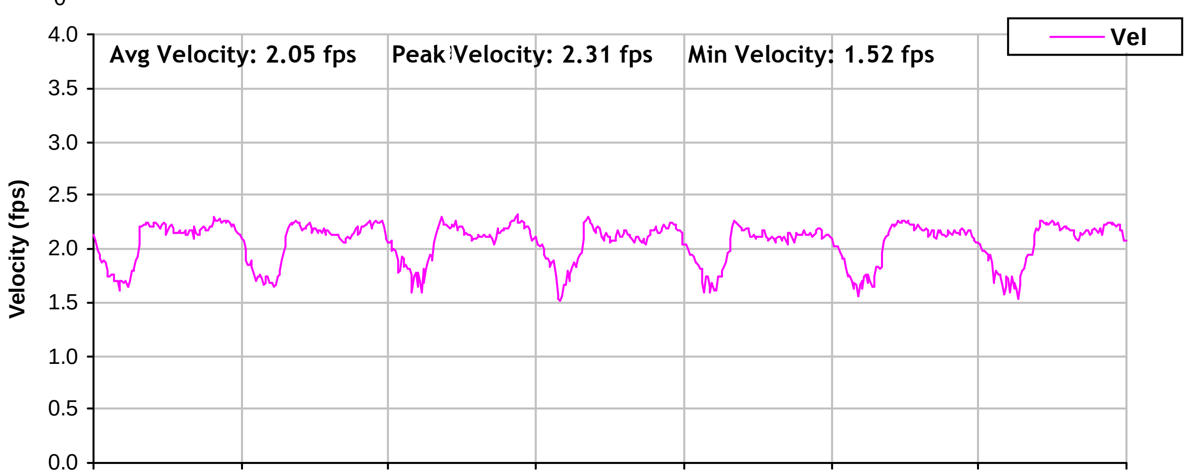
Weekly Level, Velocity and Flow Hydrographs

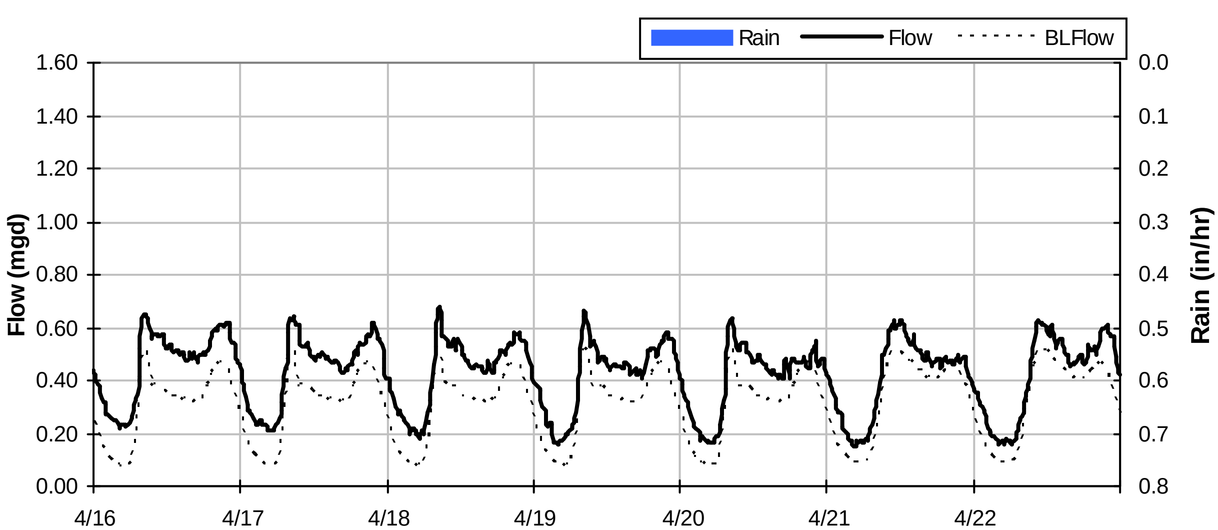
4/9/2012 to 4/16/2012



SITE 17
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012

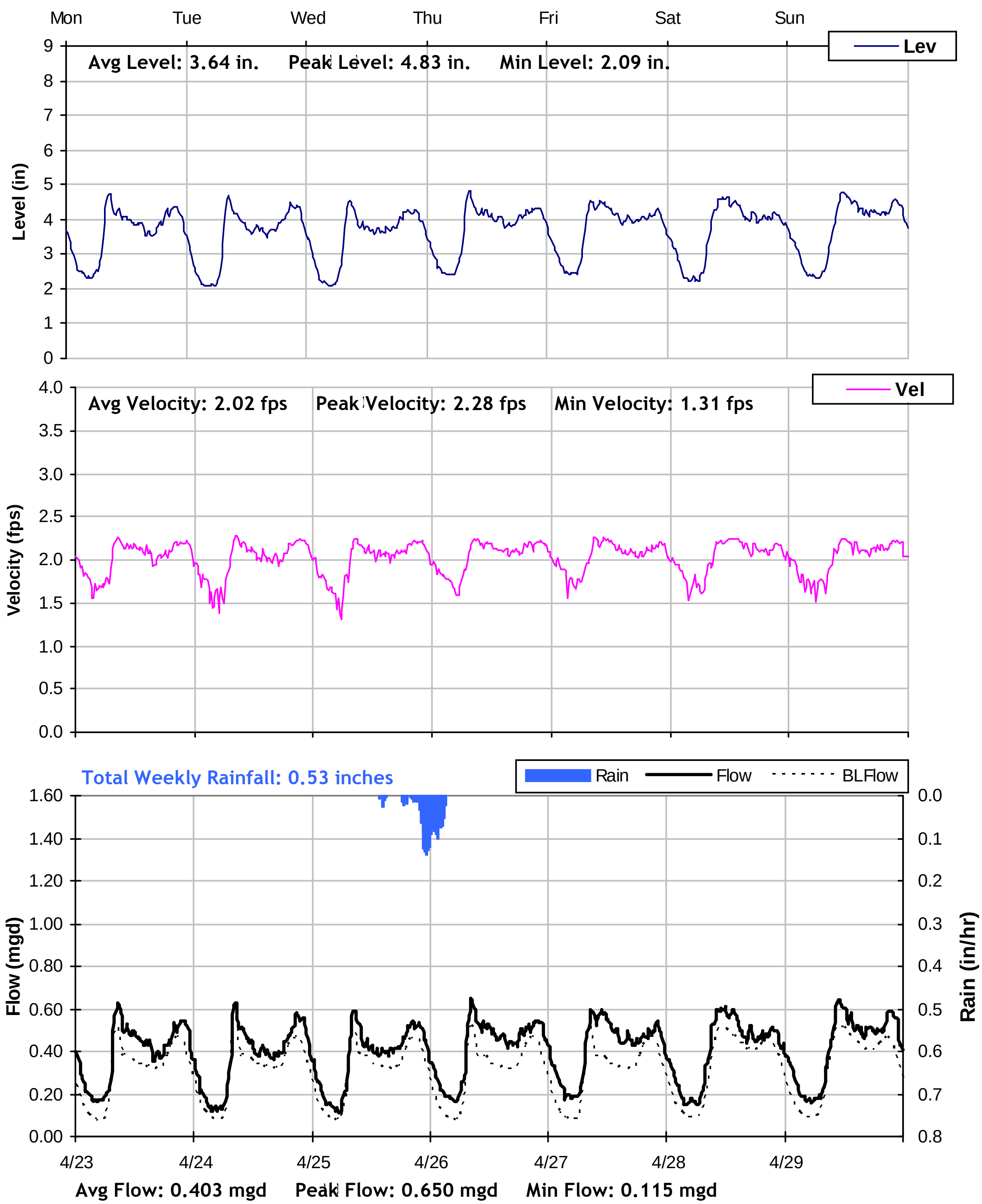




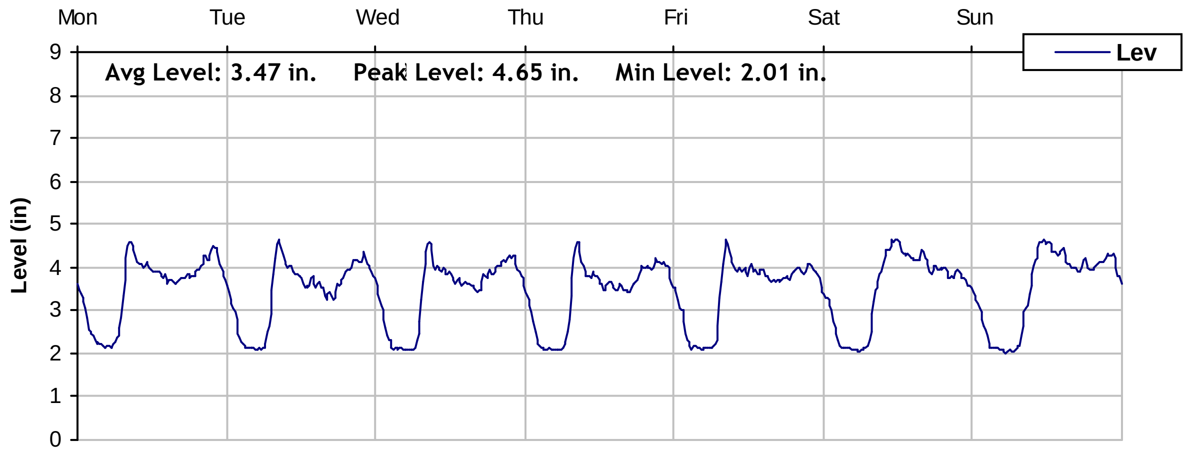


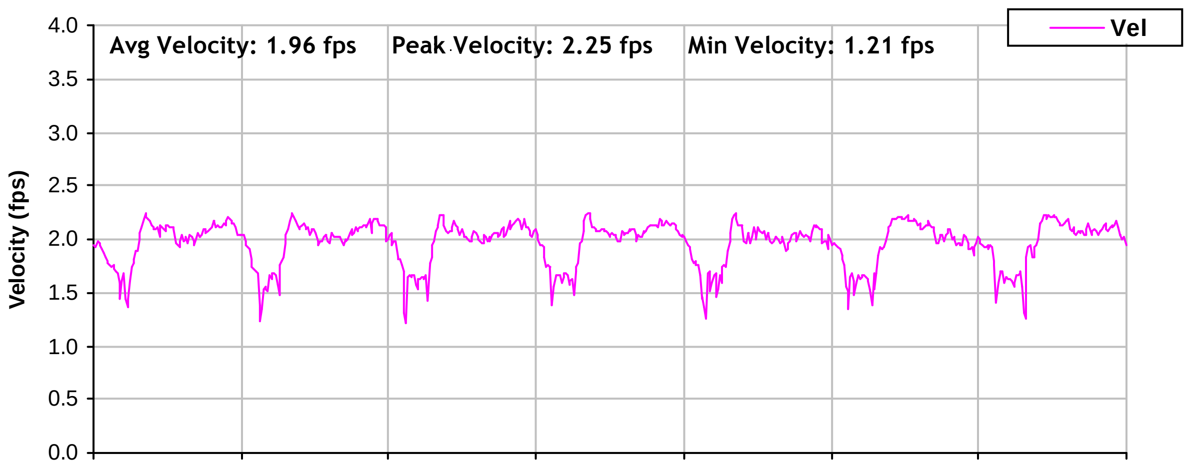
Avg Flow: 0.429 mgd **Peak Flow: 0.676 mgd** **Min Flow: 0.155 mgd**

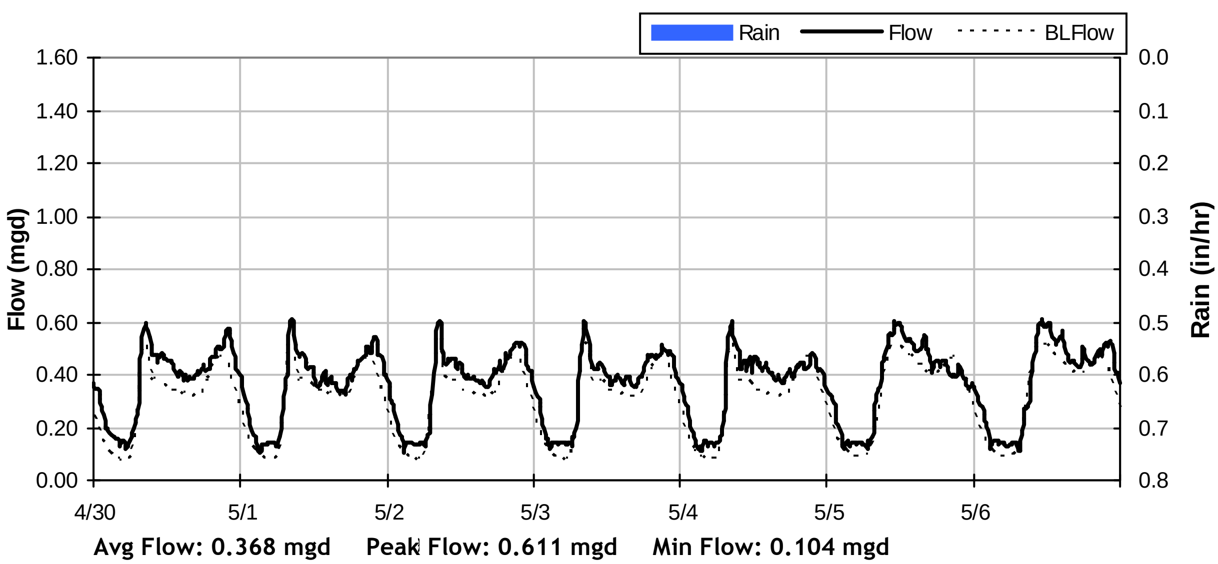
SITE 17
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 17
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012







City of Chico

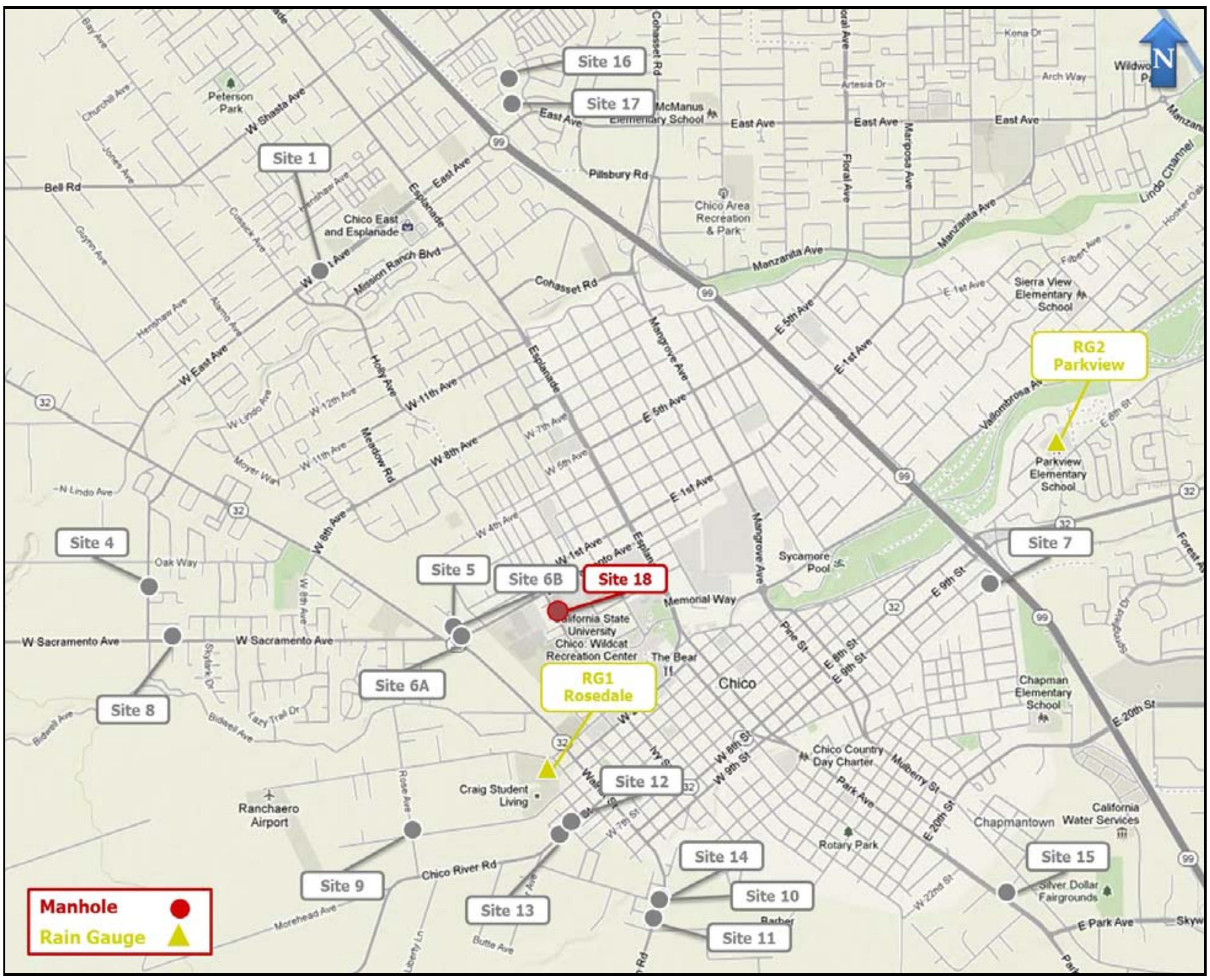
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 18

Location: Warner Street at La Vista Way

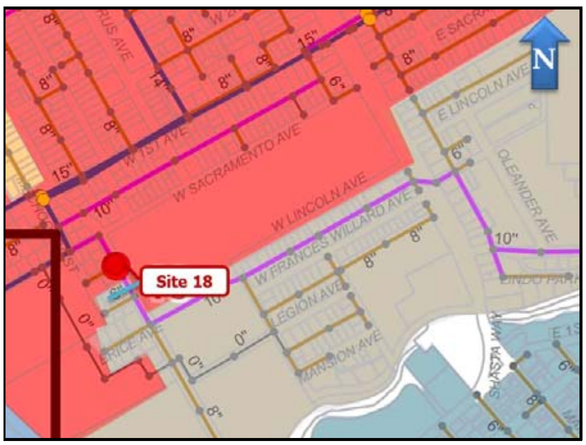
Vicinity Map:



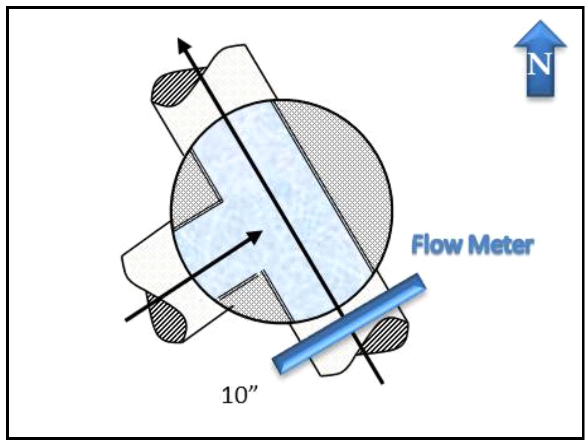
SITE 18
Site Information Report

Location:	Warner Street at La Vista Way
Coordinates:	121.8511° W, 39.7325° N
Elevation:	192 feet
Diameter:	10 inches
Baseline Flow:	0.113 mgd
Peak Measured Flow:	0.517 mgd

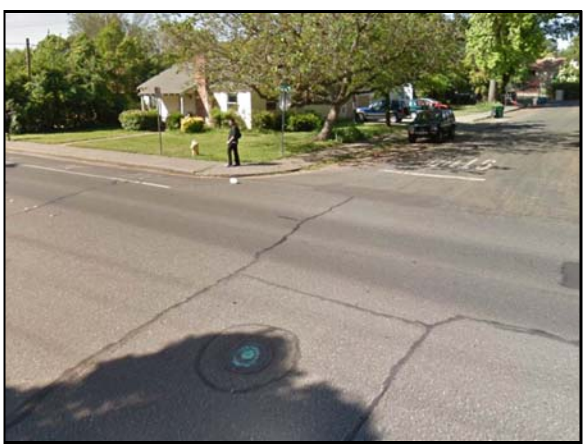
Satellite Map



Sanitary Sewer Map



Flow Sketch



View from Street

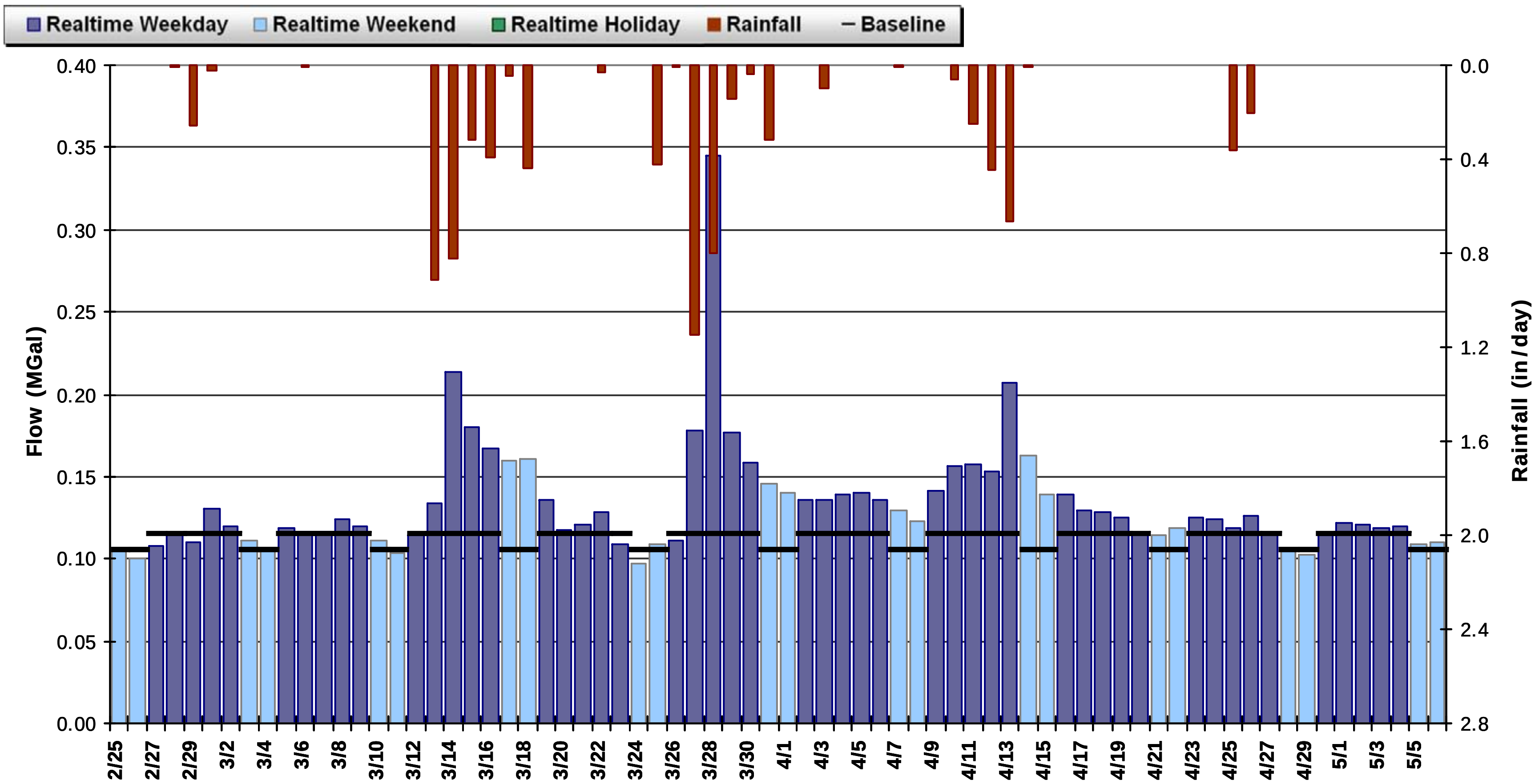
Plan View

SITE 18

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.133 MGal **Peak Daily Flow: 0.345 MGal** **Min Daily Flow: 0.097 MGal**

Total Period Rainfall: 8.24 inches

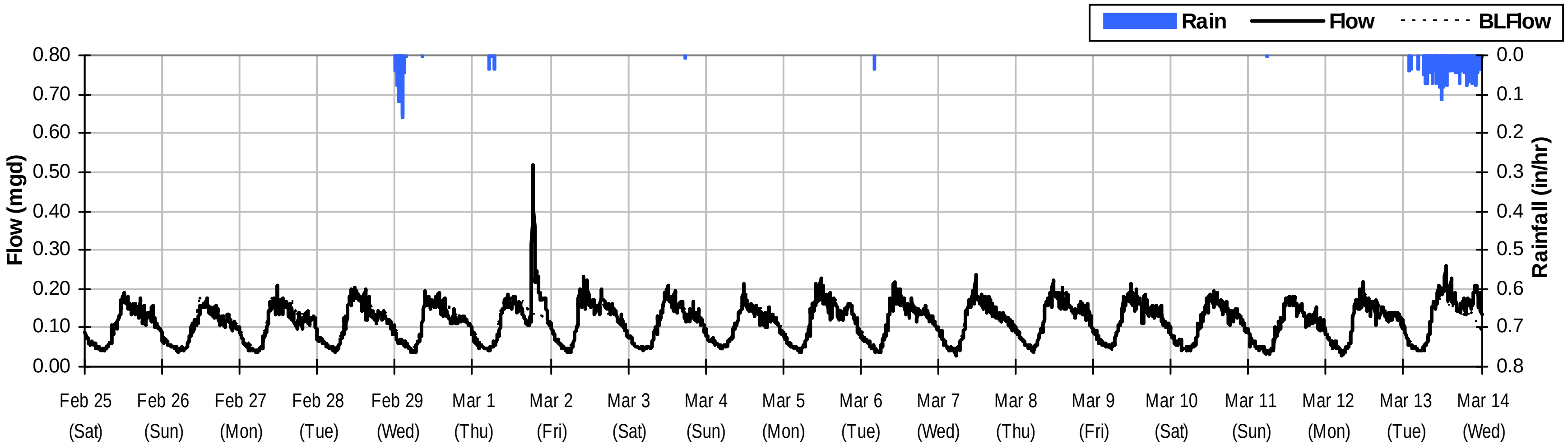


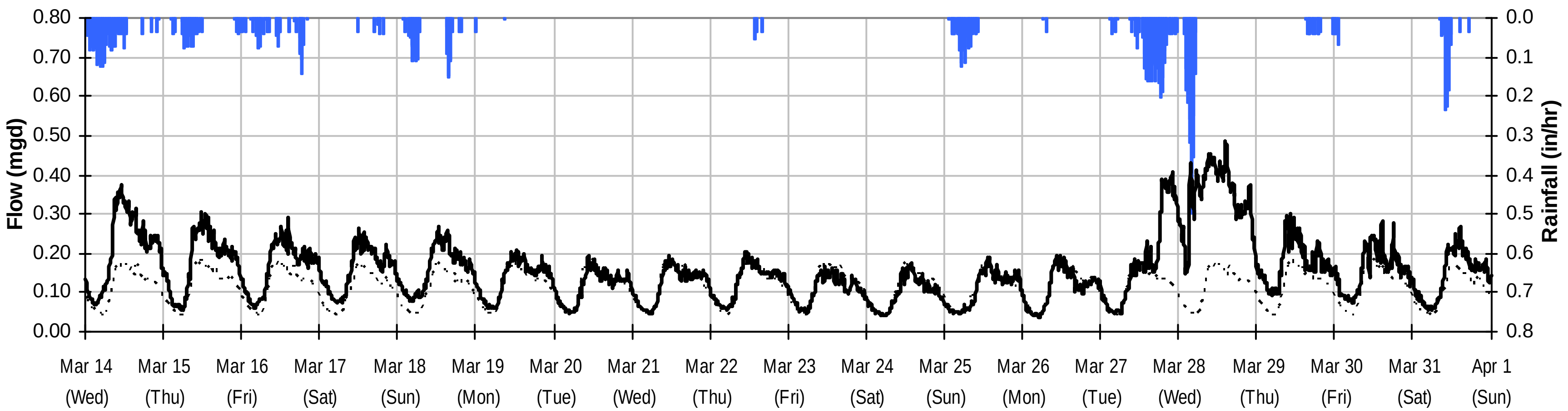
SITE 18

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.135 mgd **Peak Flow: 0.517 mgd** **Min Flow: 0.030 mgd**

Total Period Rainfall: 6.14 inches



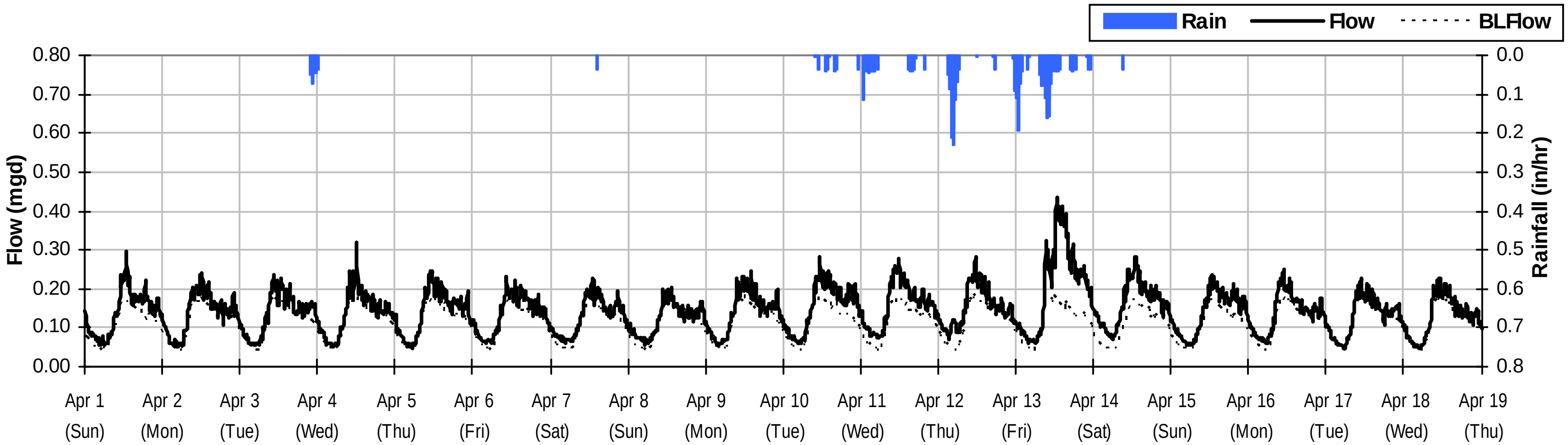


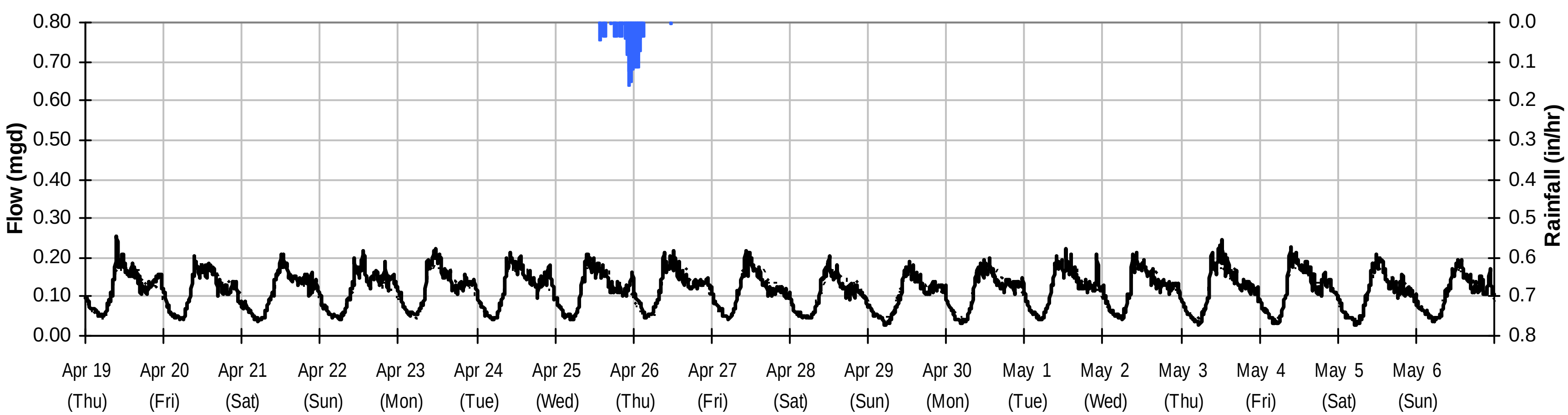
SITE 18

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.130 mgd **Peak Flow: 0.434 mgd** **Min Flow: 0.027 mgd**

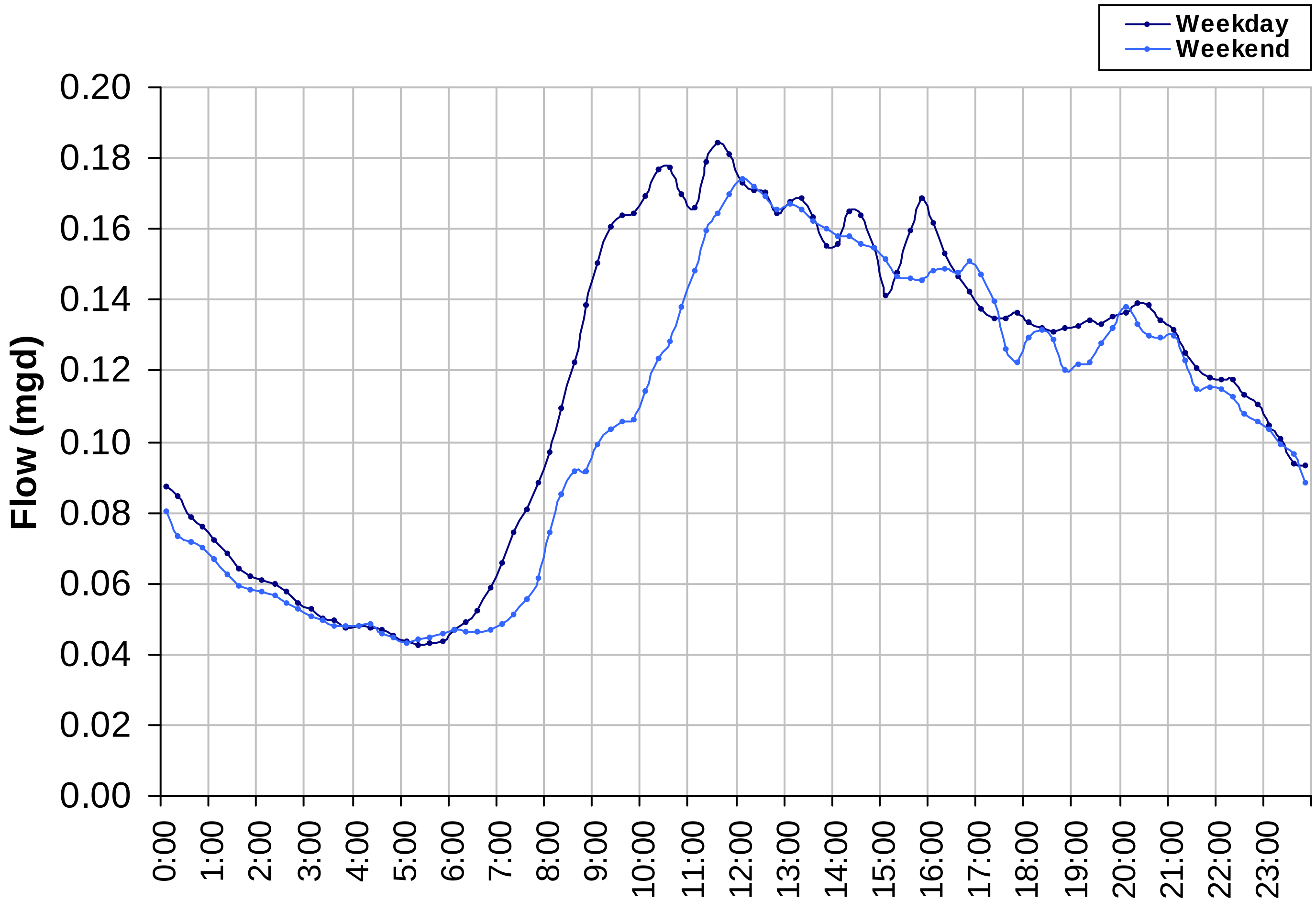
Total Period Rainfall: 2.10 inches





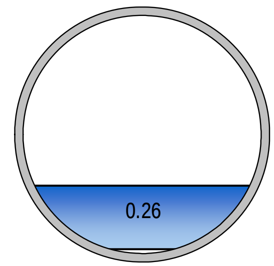
SITE 18

Baseline Flow Hydrographs



Baseline Flow:

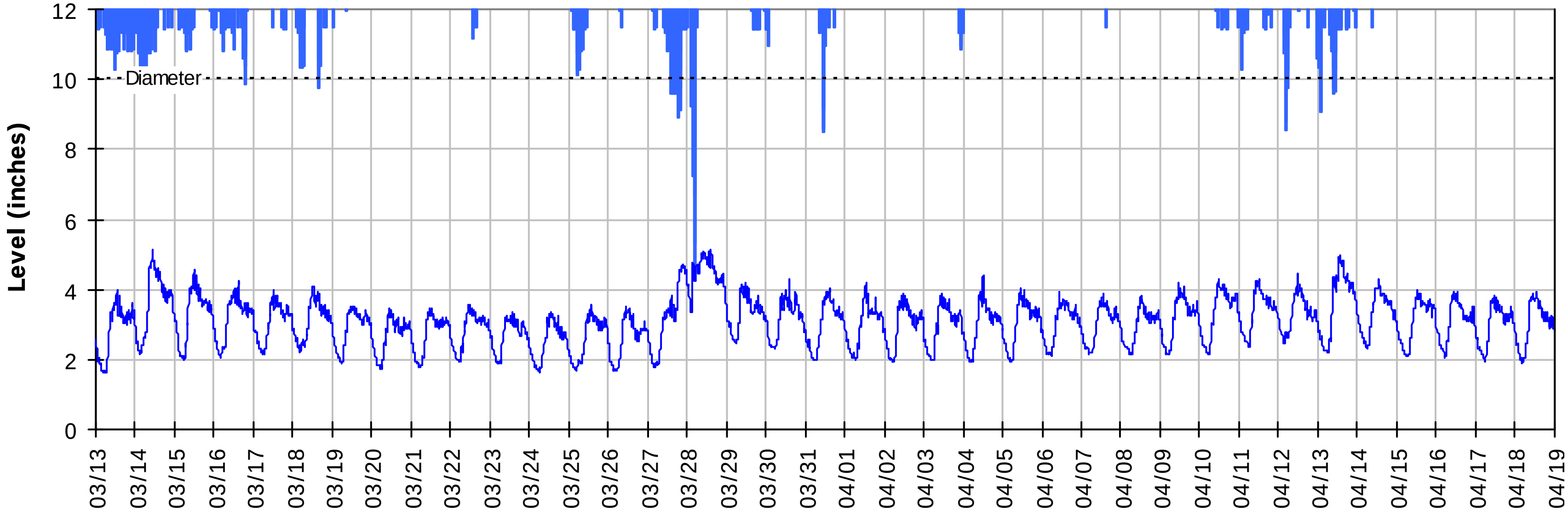
0.113 *mgd*

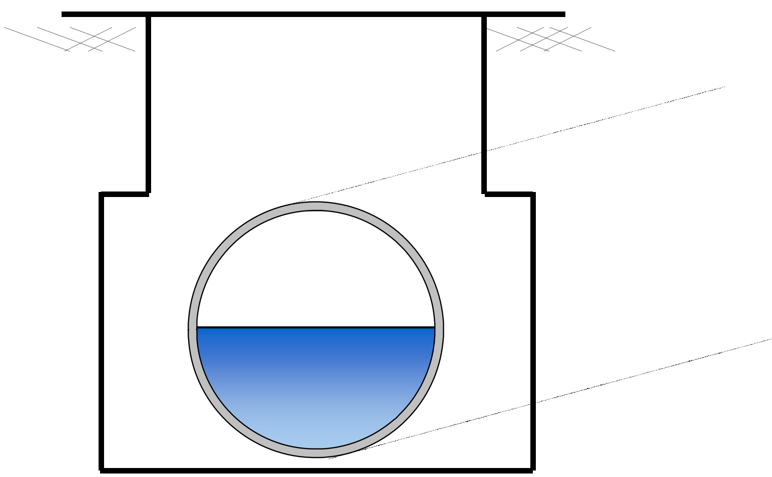


SITE 18

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





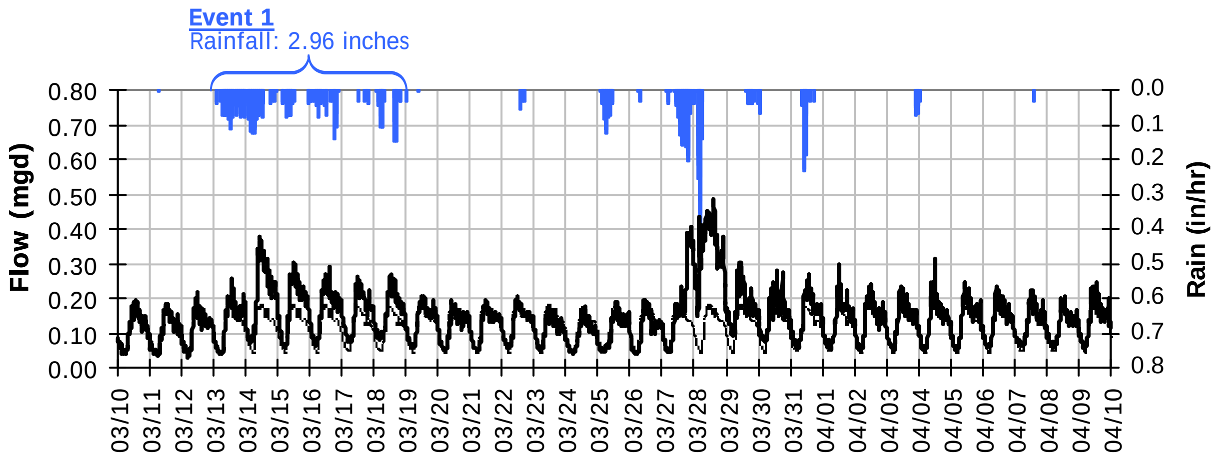
Pipe Diameter: 10 *inches*

Peak Measured Level: 5.16 *inches*

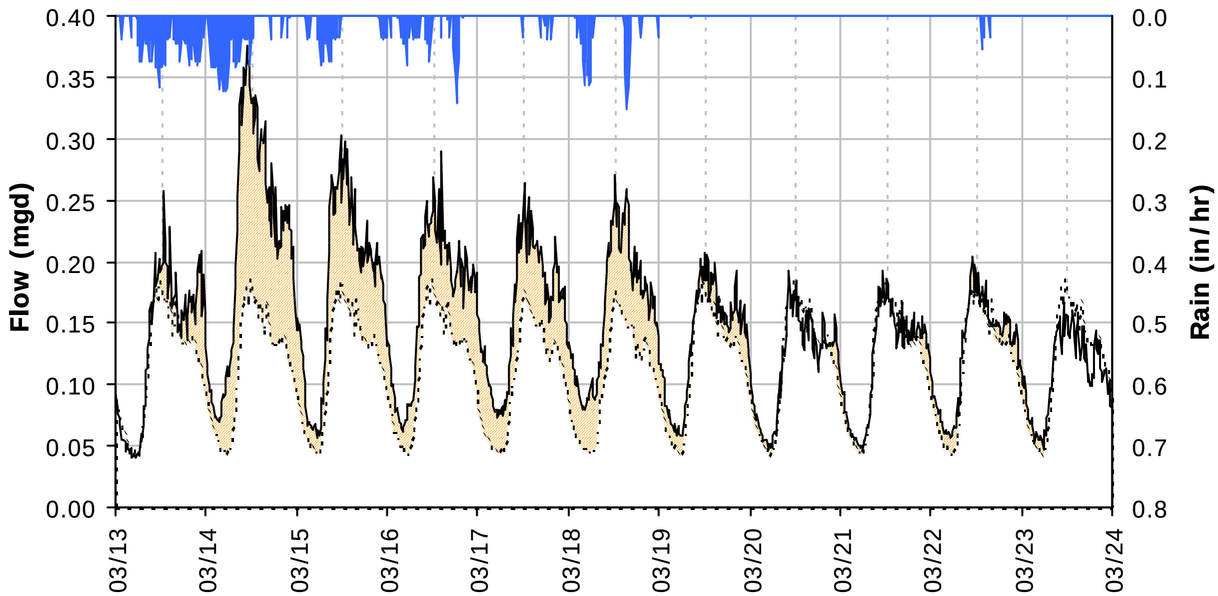
Peak d/D Ratio: 0.52

SITE 18
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 = 2.96 inches)

Capacity

Peak Flow:	0.38	*mgd*
PF:	3.33	
Peak Level:	5.16	*in*
d/D Ratio:	0.52	

Inflow

Peak I/I Rate:	0.21	*mgd*
PkI/I:IDM:	1,897	*gpd/IDM*
PkI/I:Acre:	299	*gpd/acre*
Pk I/I:ADWF:	1.82	

RDI (infiltration)

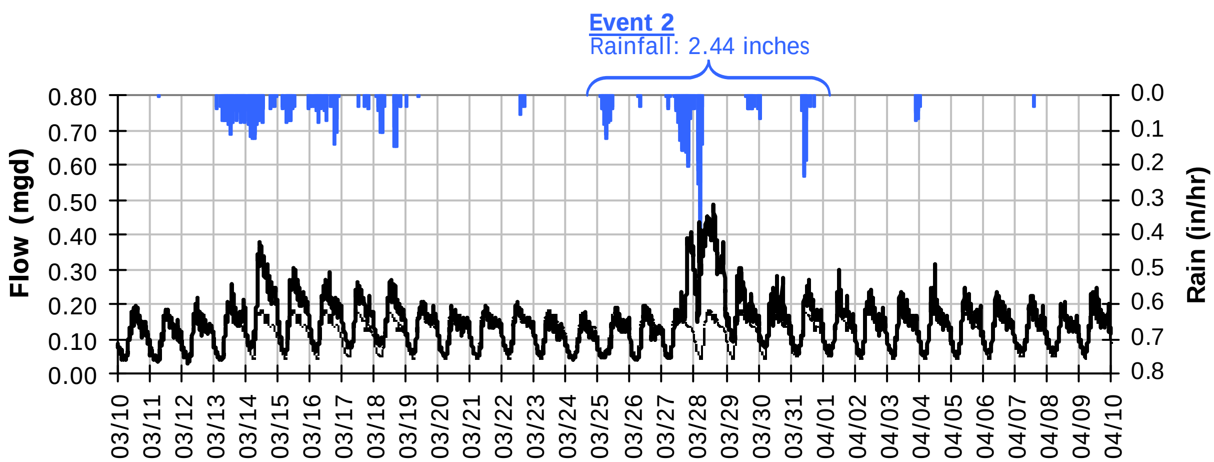
Infiltration Rate: (3/20/2012)	0.002	*mgd*
RDI:IDM:	20	*gpd/IDM*
RDI:Acre:	3	*gpd/acre*
RDI (% of BL):	2%	

Combined I/I

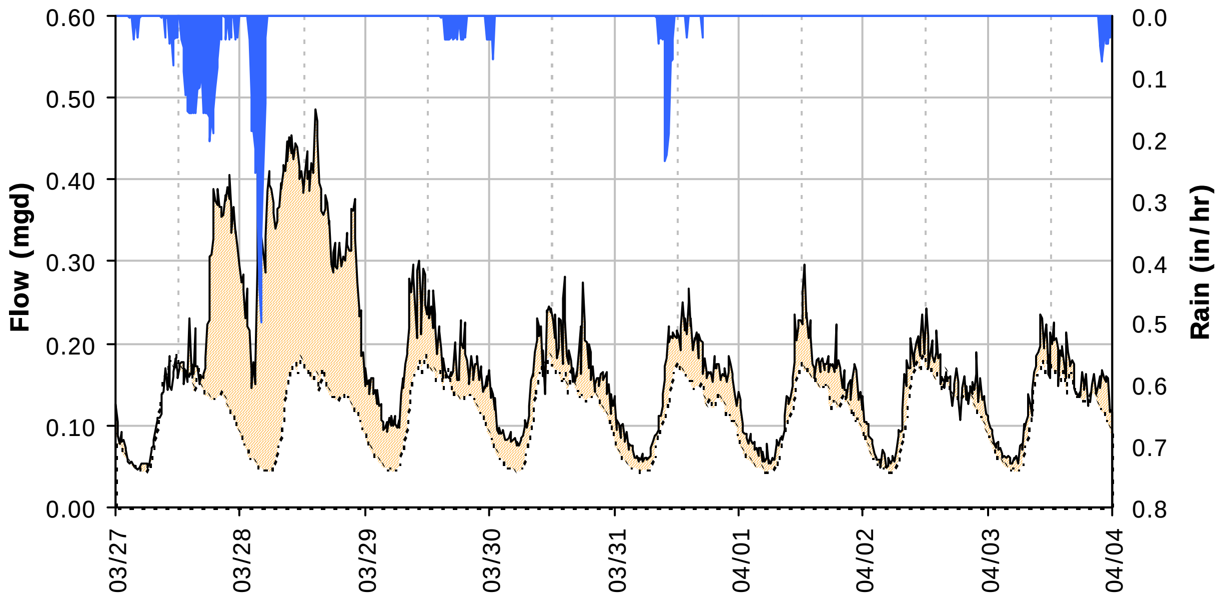
Total I/I:	374,000	*gallons*
Total I/I:IDM:	1,165	*gal/IDM/in*
R-Value:	0.7%	
Total I/I:ADWF:	1.12	*per in-rain*

SITE 18
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 = 2.44 inches)

Capacity

Peak Flow:	0.49	*mgd*
PF:	4.30	
Peak Level:	5.16	*in*
d/D Ratio:	0.52	

Inflow

Peak I/I Rate:	0.38	*mgd*
PkI/I:IDM:	3,484	*gpd/IDM*
PkI/I:Acre:	548	*gpd/acre*
Pk I/I:ADWF:	3.35	

RDI (infiltration)

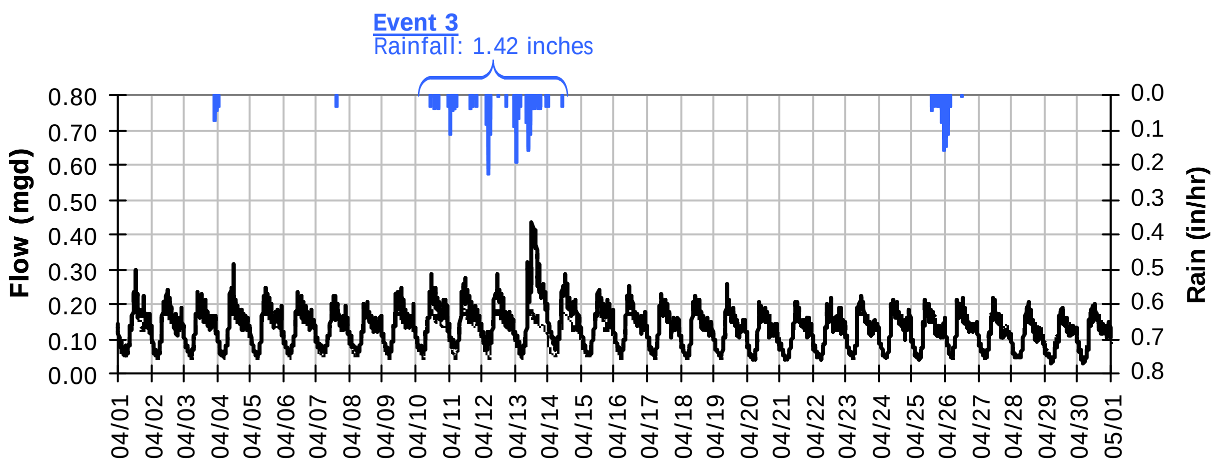
Infiltration Rate: (4/2/2012)	0.020	*mgd*
RDI:IDM:	187	*gpd/IDM*
RDI:Acre:	29	*gpd/acre*
RDI (% of BL):	18%	

Combined I/I

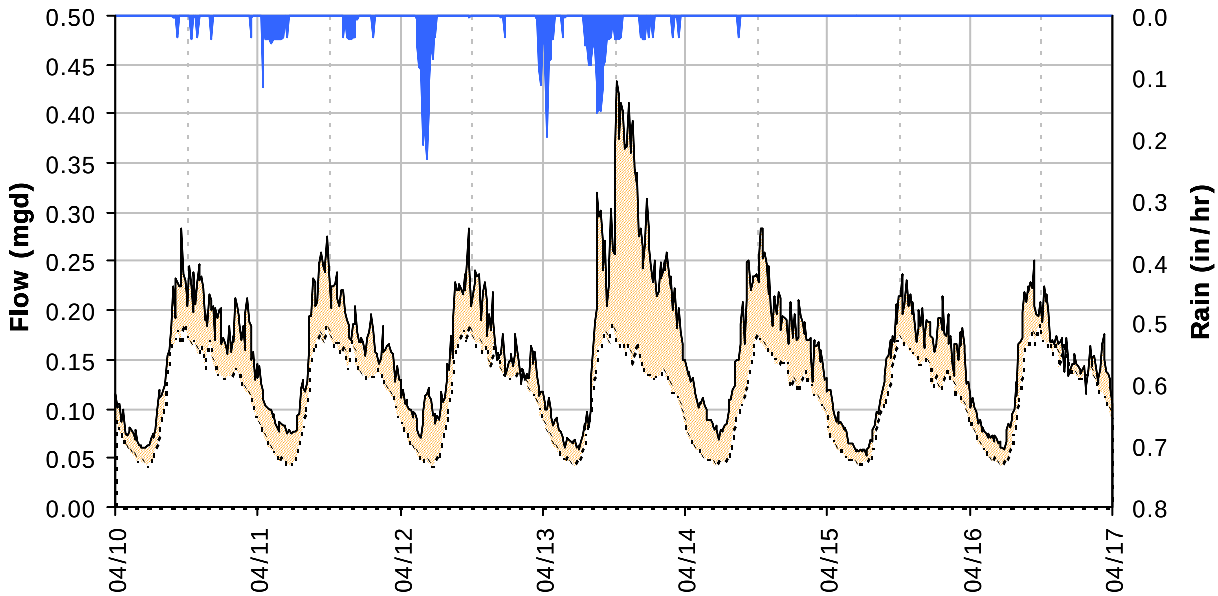
Total I/I:	509,000	*gallons*
Total I/I:IDM:	1,917	*gal/IDM/in*
R-Value:	1.1%	
Total I/I:ADWF:	1.84	*per in-rain*

SITE 18
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.42 inches)

Capacity

Peak Flow:	0.43 *mgd*
PF:	3.84
Peak Level:	4.98 *in*
d/D Ratio:	0.50

Inflow

Peak I/I Rate:	0.26 *mgd*
PkI/I:IDM:	2,424 *gpd/IDM*
PkI/I:Acre:	382 *gpd/acre*
Pk I/I:ADWF:	2.33

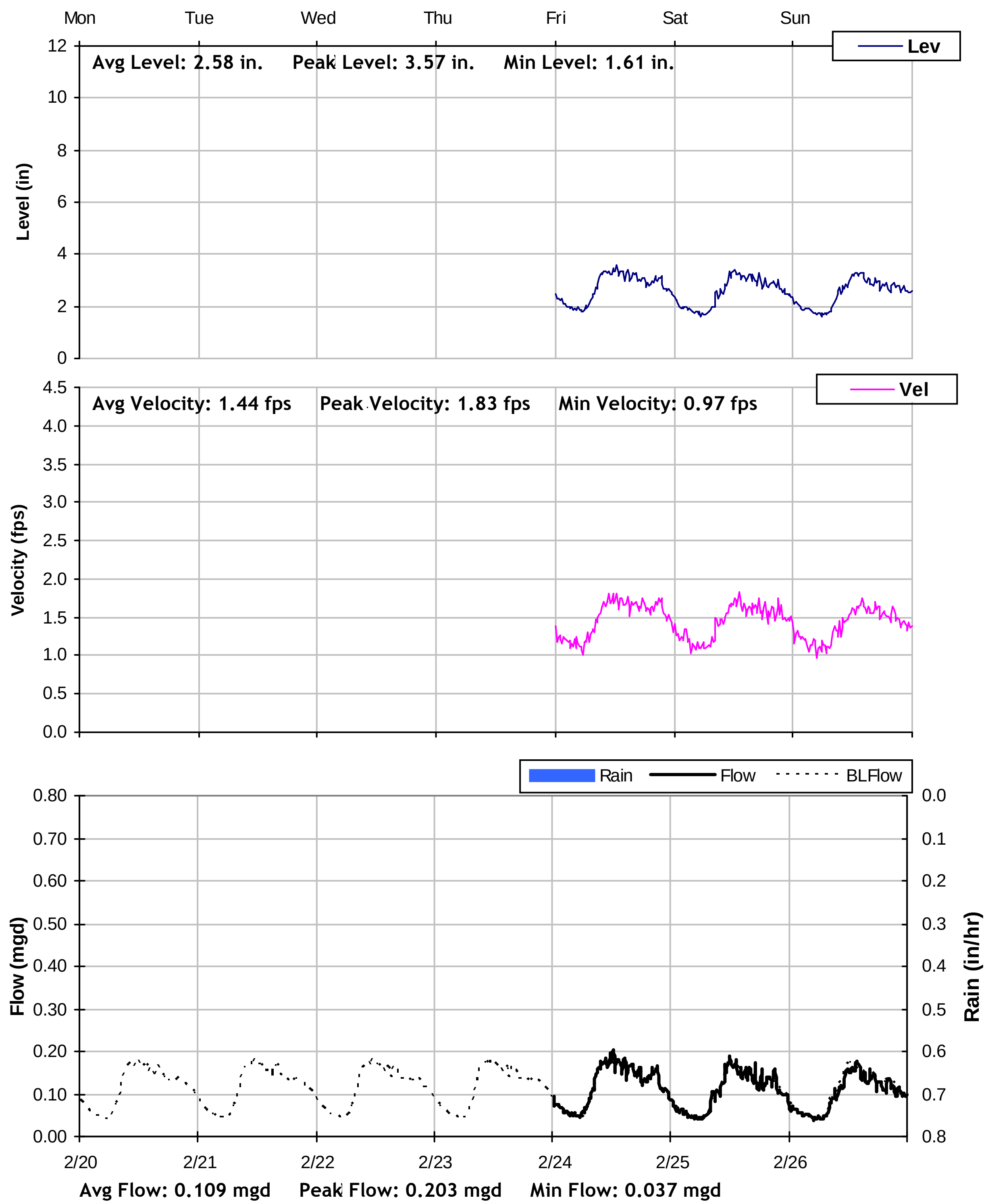
RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.033 *mgd*
RDI:IDM:	308 *gpd/IDM*
RDI:Acre:	49 *gpd/acre*
RDI (% of BL):	32%

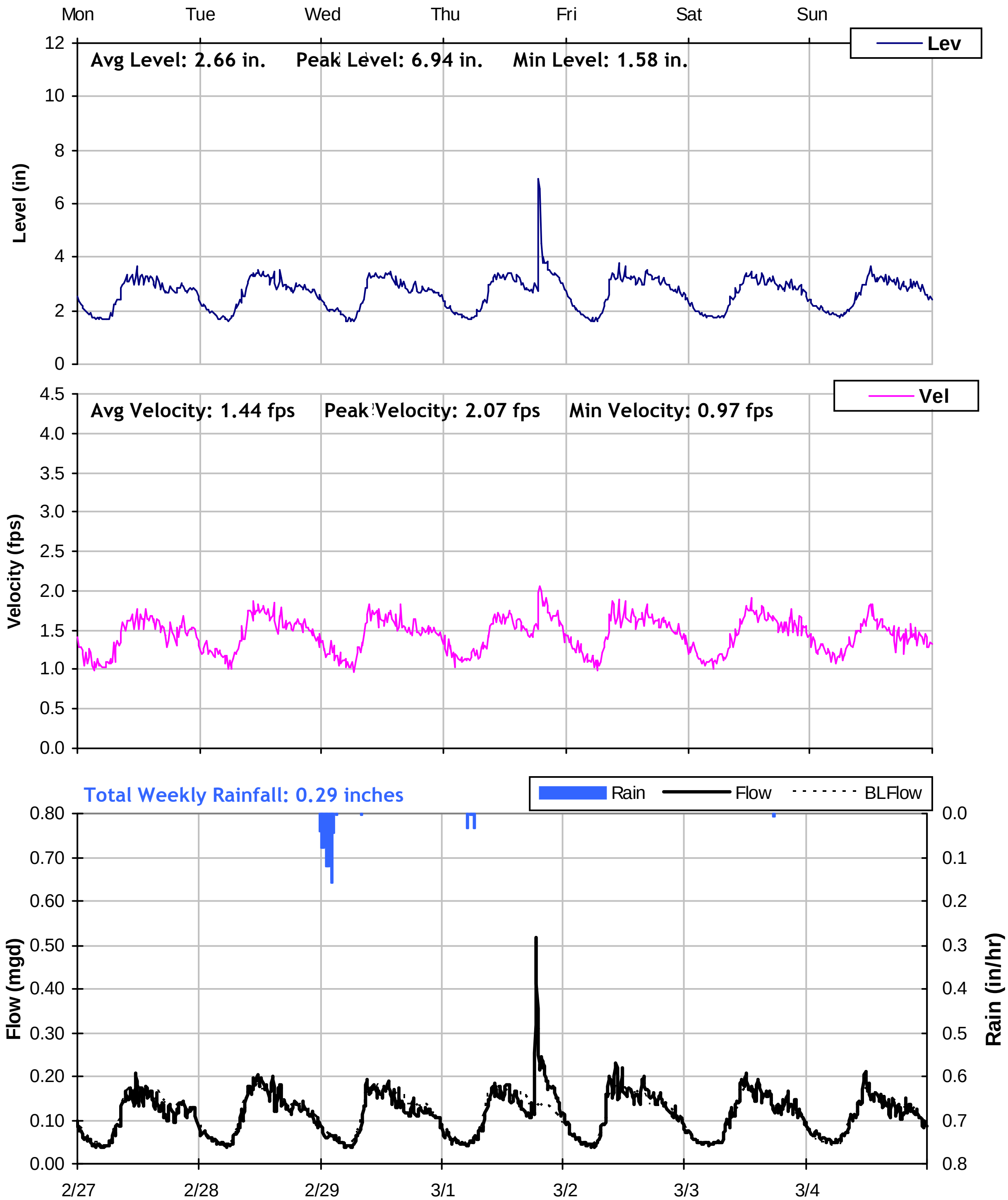
Combined I/I

Total I/I:	323,000 *gallons*
Total I/I:IDM:	2,097 *gal/IDM/in*
R-Value:	1.2%
Total I/I:ADWF:	2.02 *per in-rain*

SITE 18
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

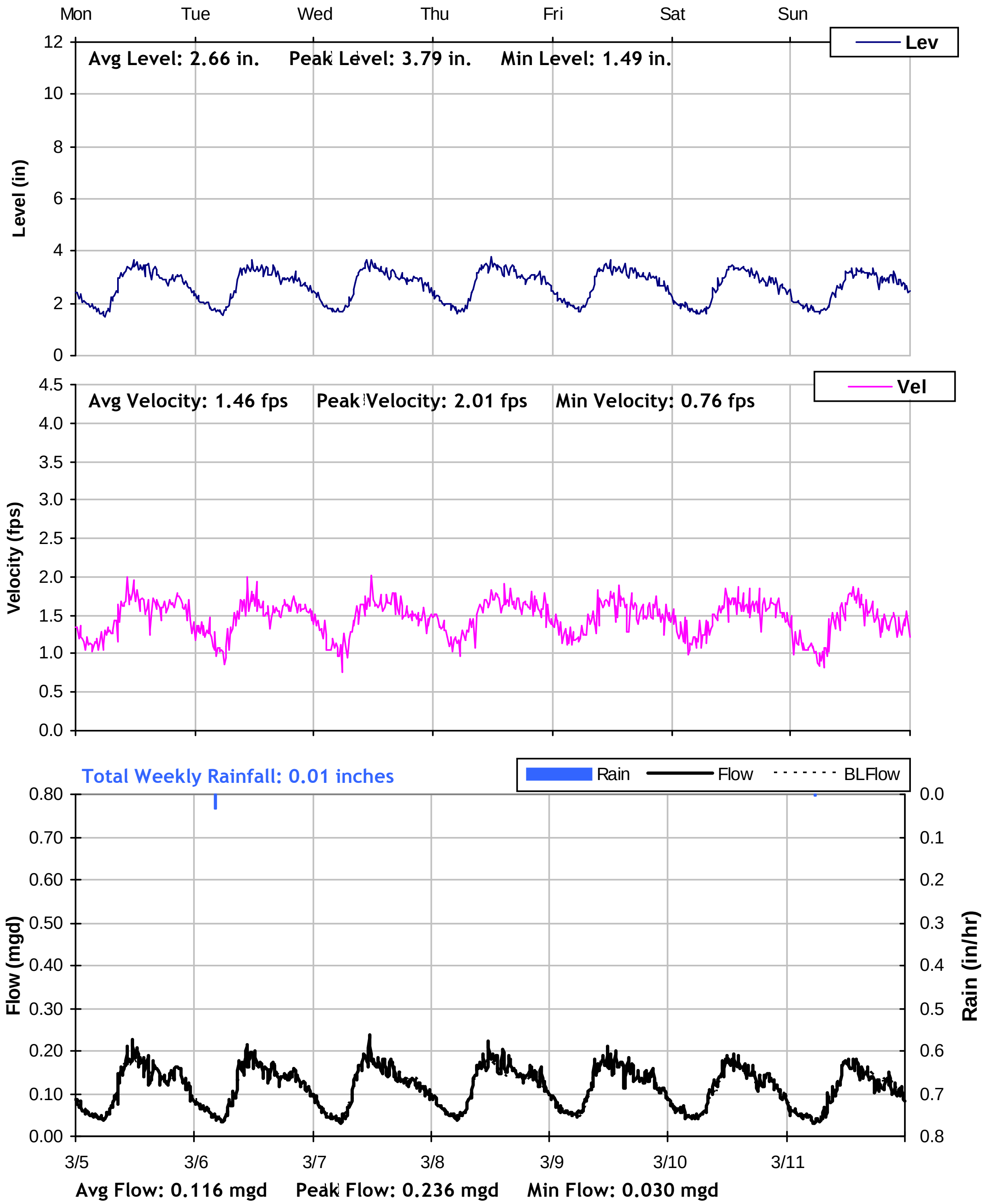


SITE 18
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



Avg Flow: 0.115 mgd   Peak Flow: 0.517 mgd   Min Flow: 0.036 mgd

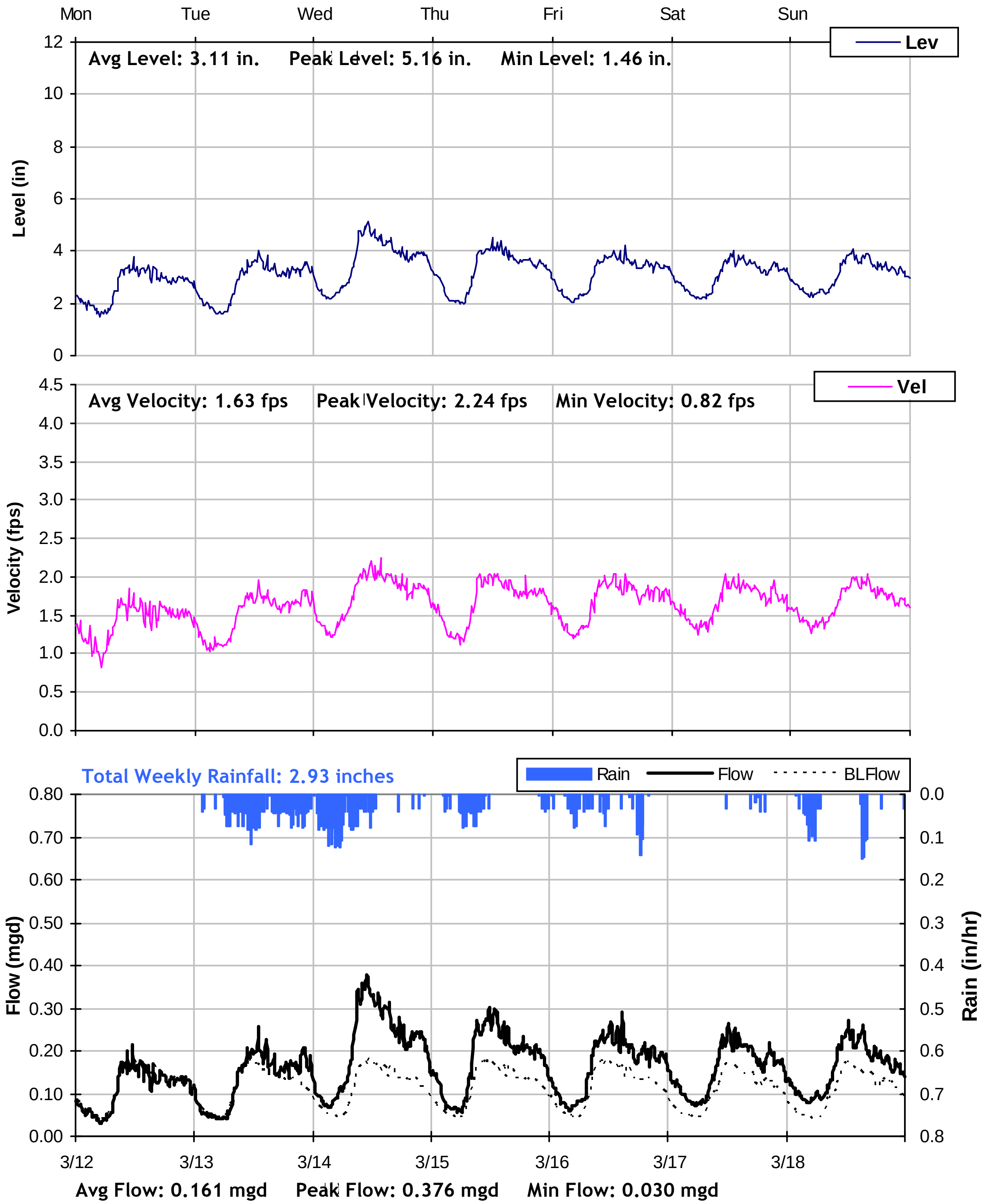
SITE 18
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



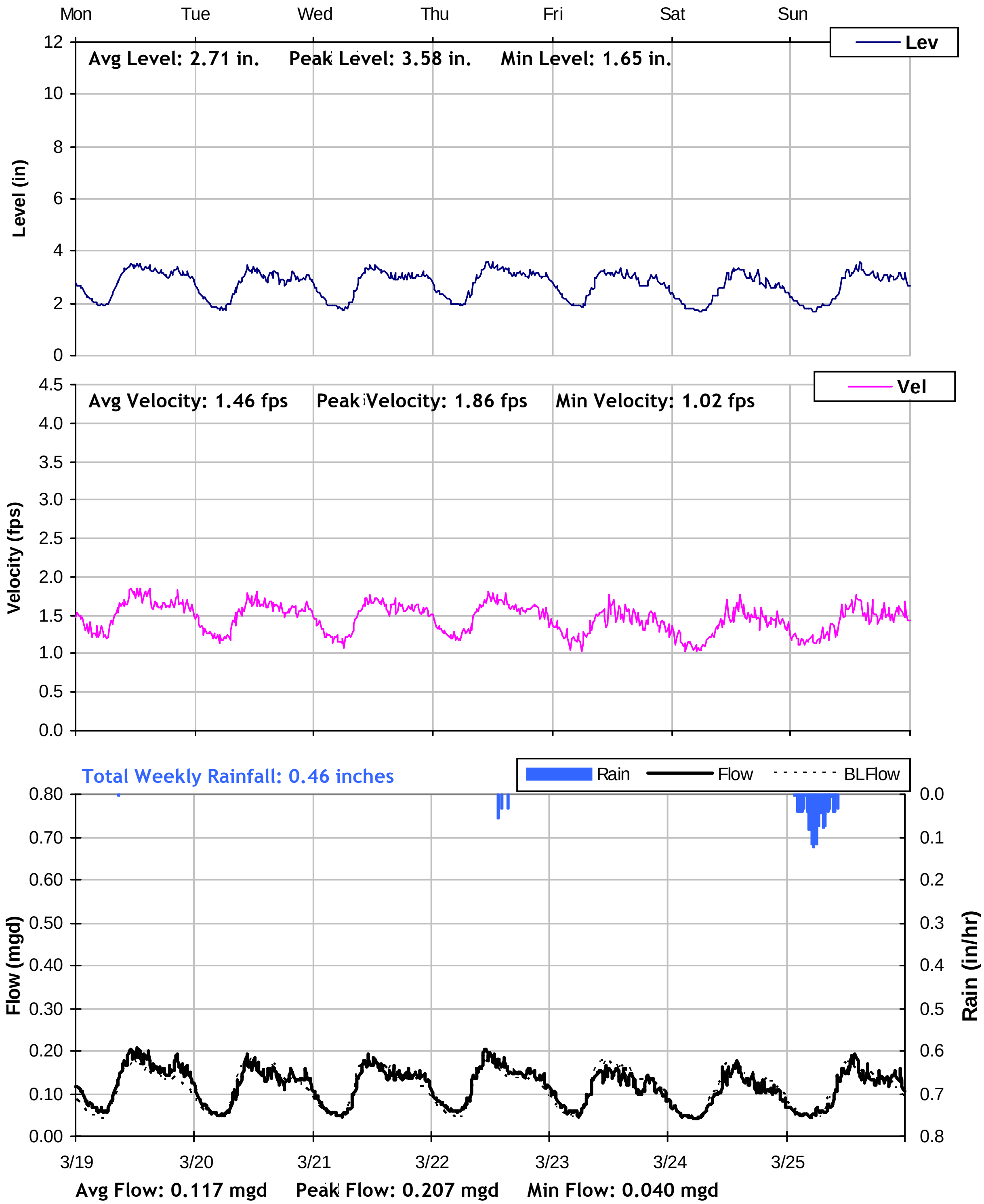
SITE 18

Weekly Level, Velocity and Flow Hydrographs

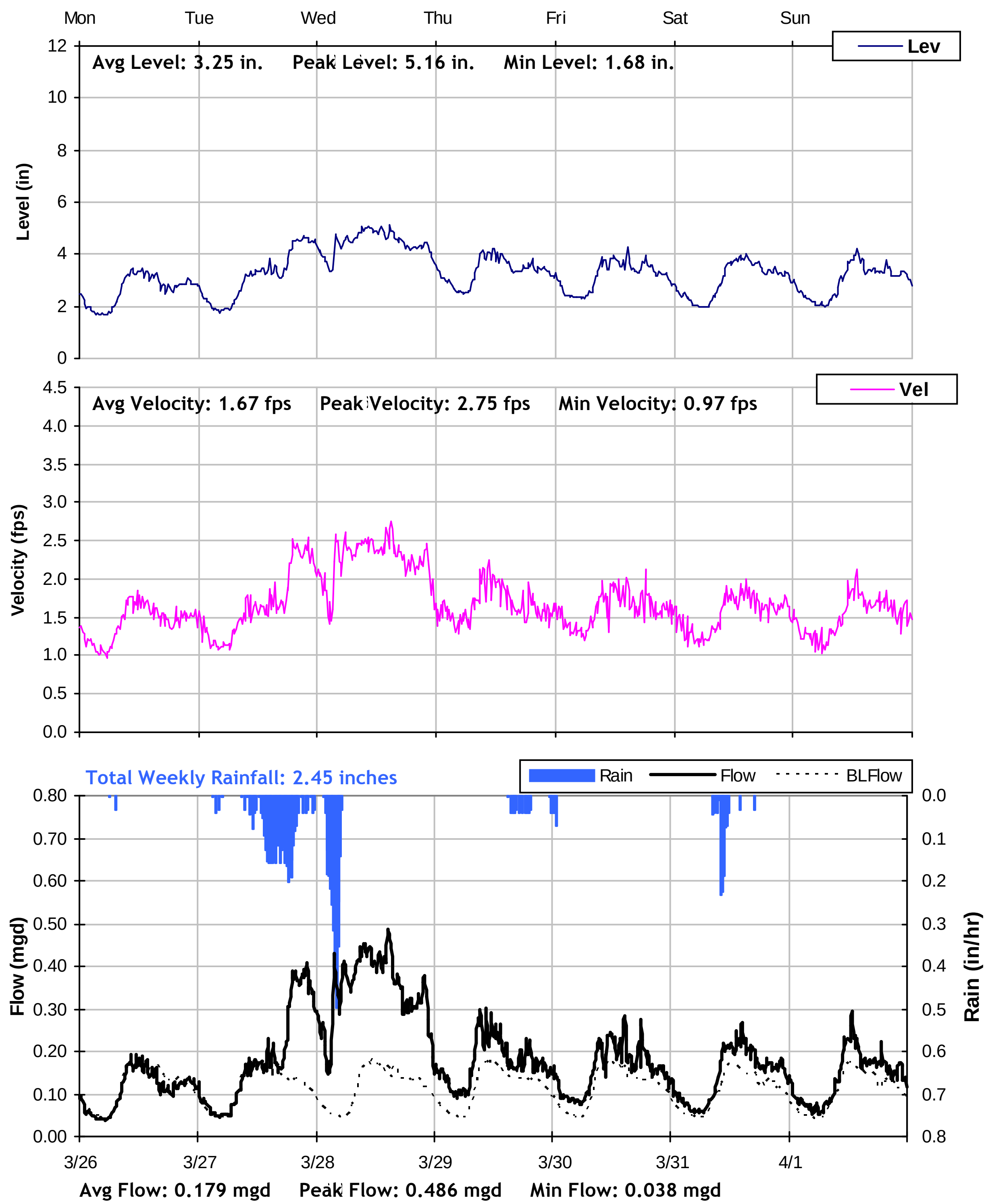
3/12/2012 to 3/19/2012



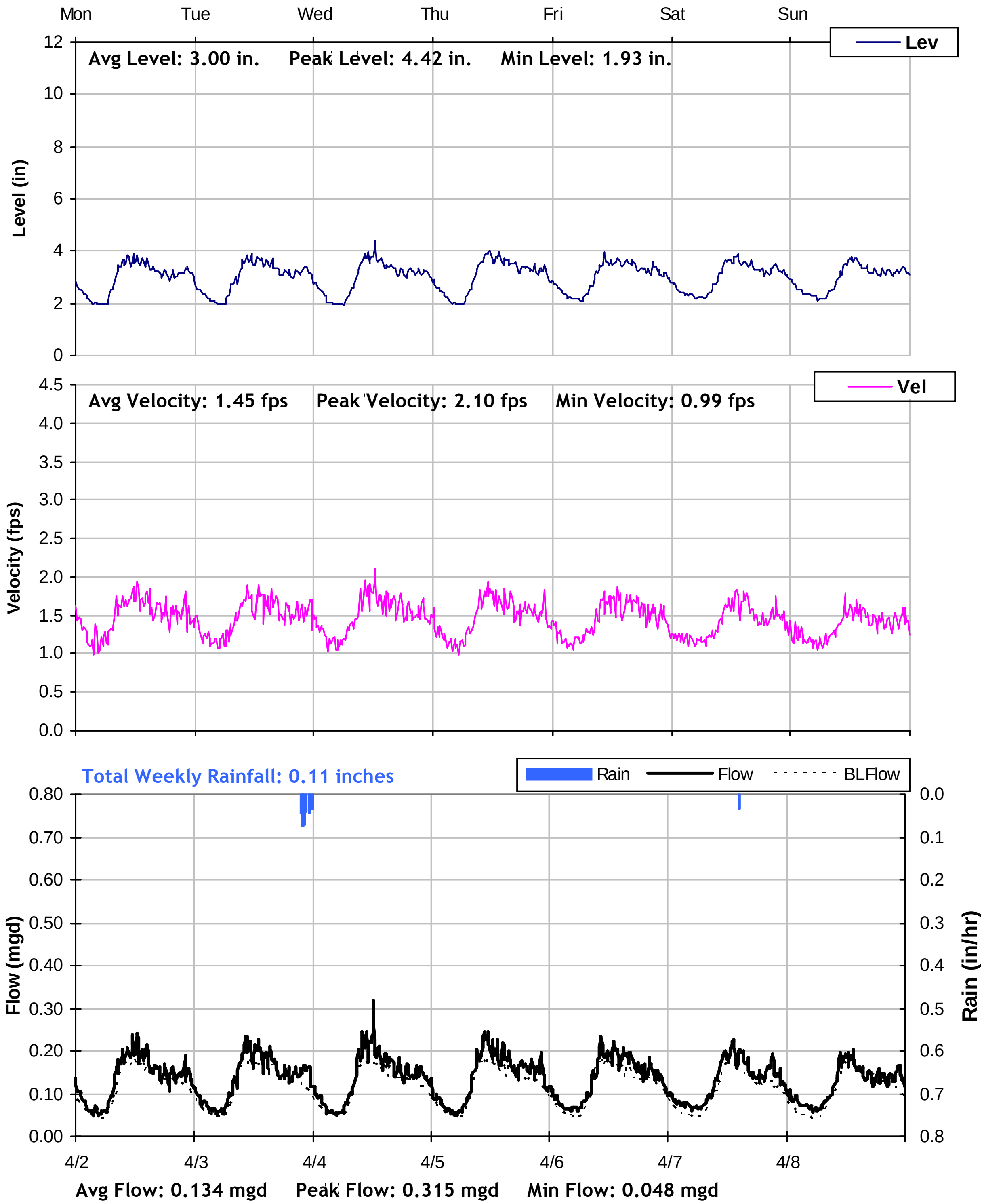
SITE 18
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



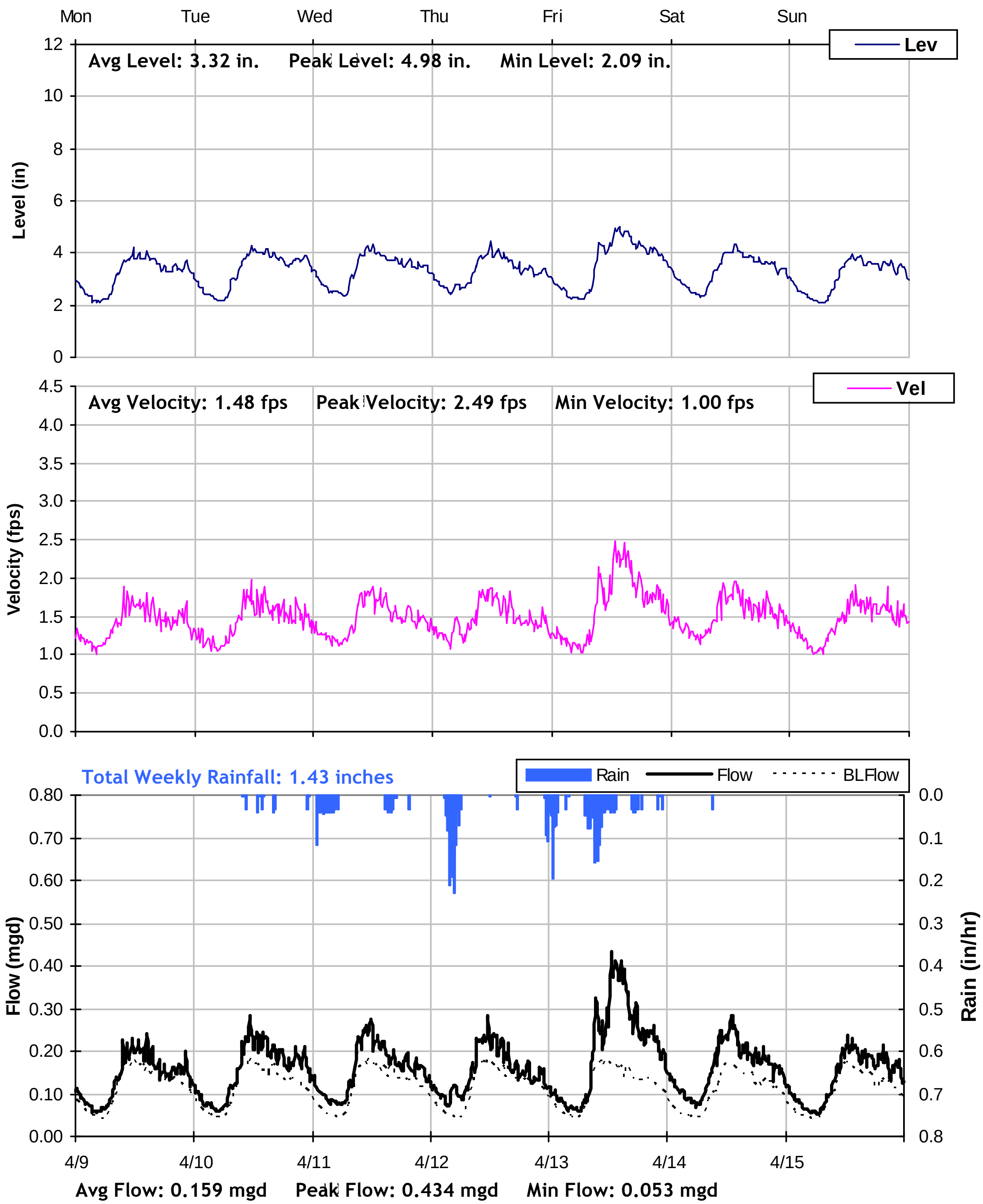
SITE 18
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



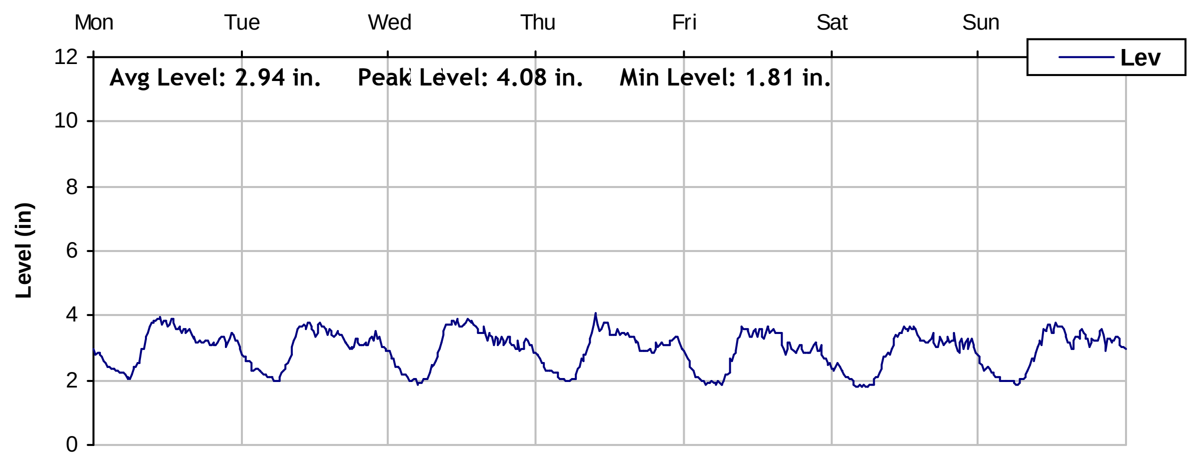
SITE 18
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012

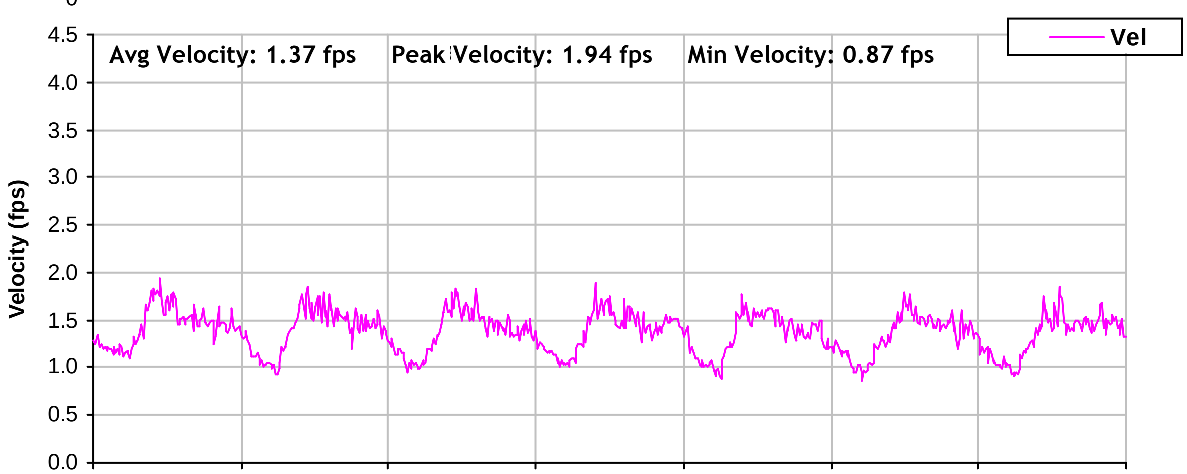


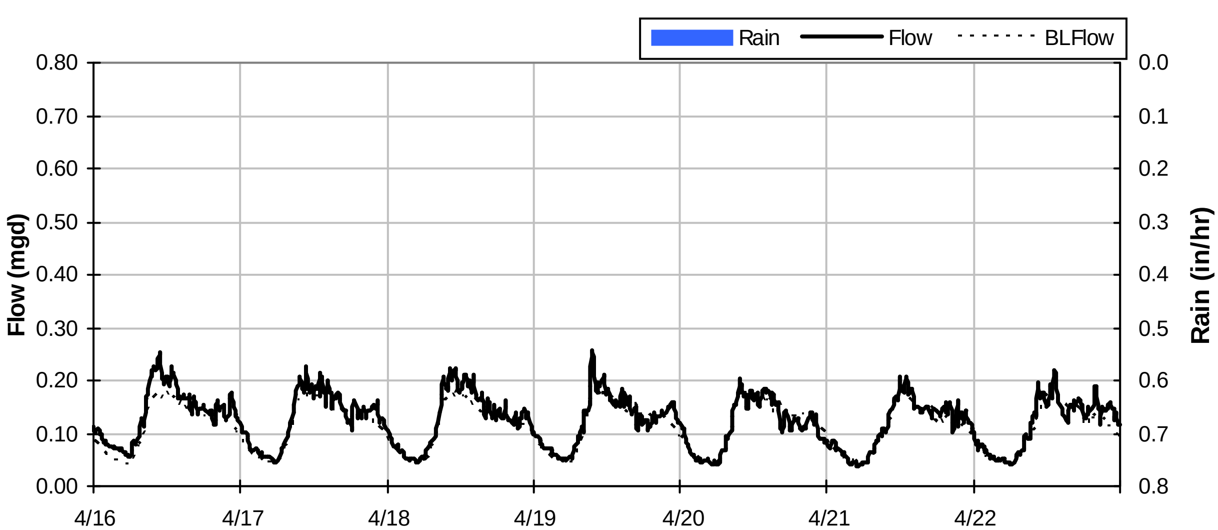
SITE 18
Weekly Level, Velocity and Flow Hydrographs
4/9/2012 to 4/16/2012



SITE 18
Weekly Level, Velocity and Flow Hydrographs
4/16/2012 to 4/23/2012

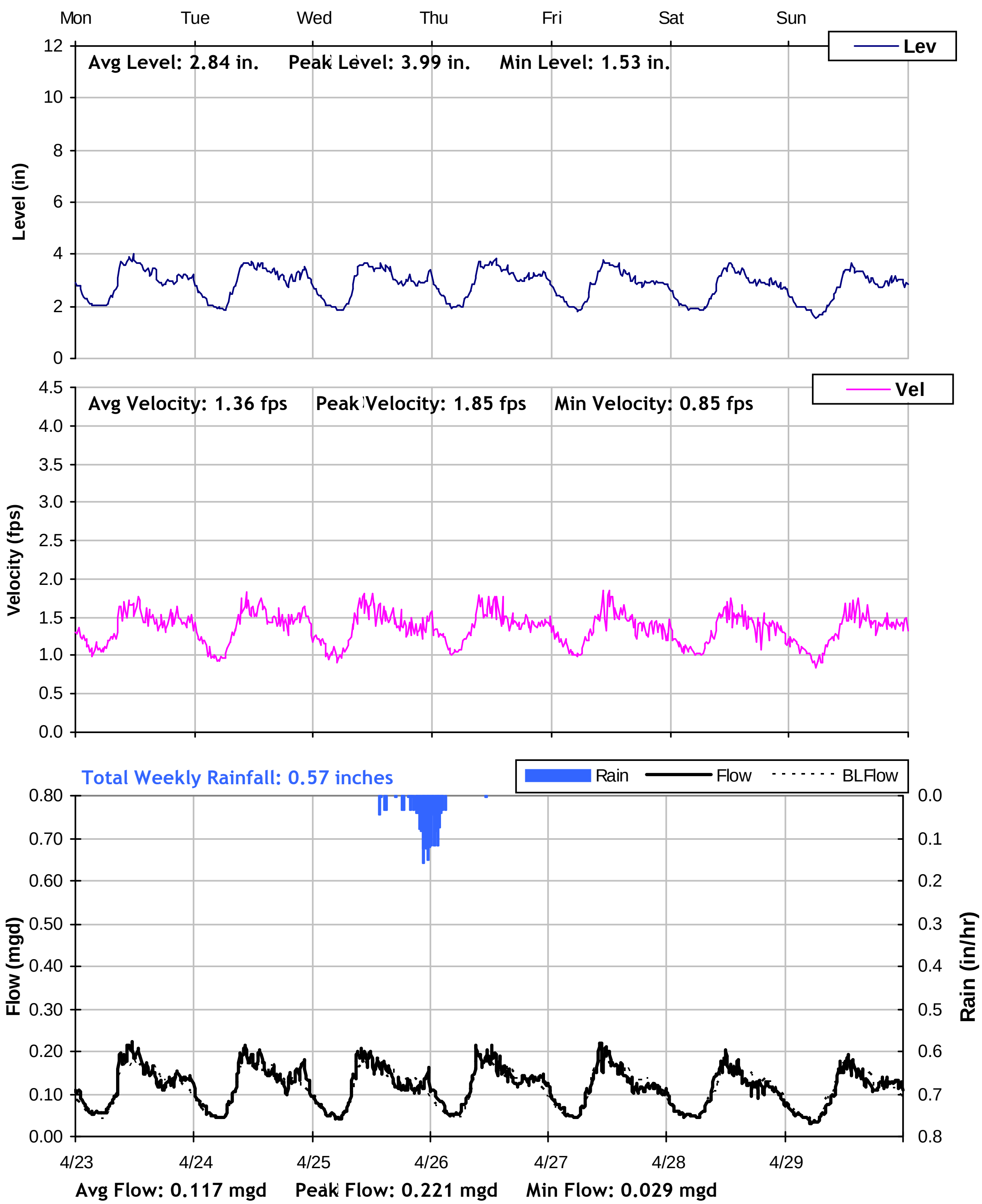




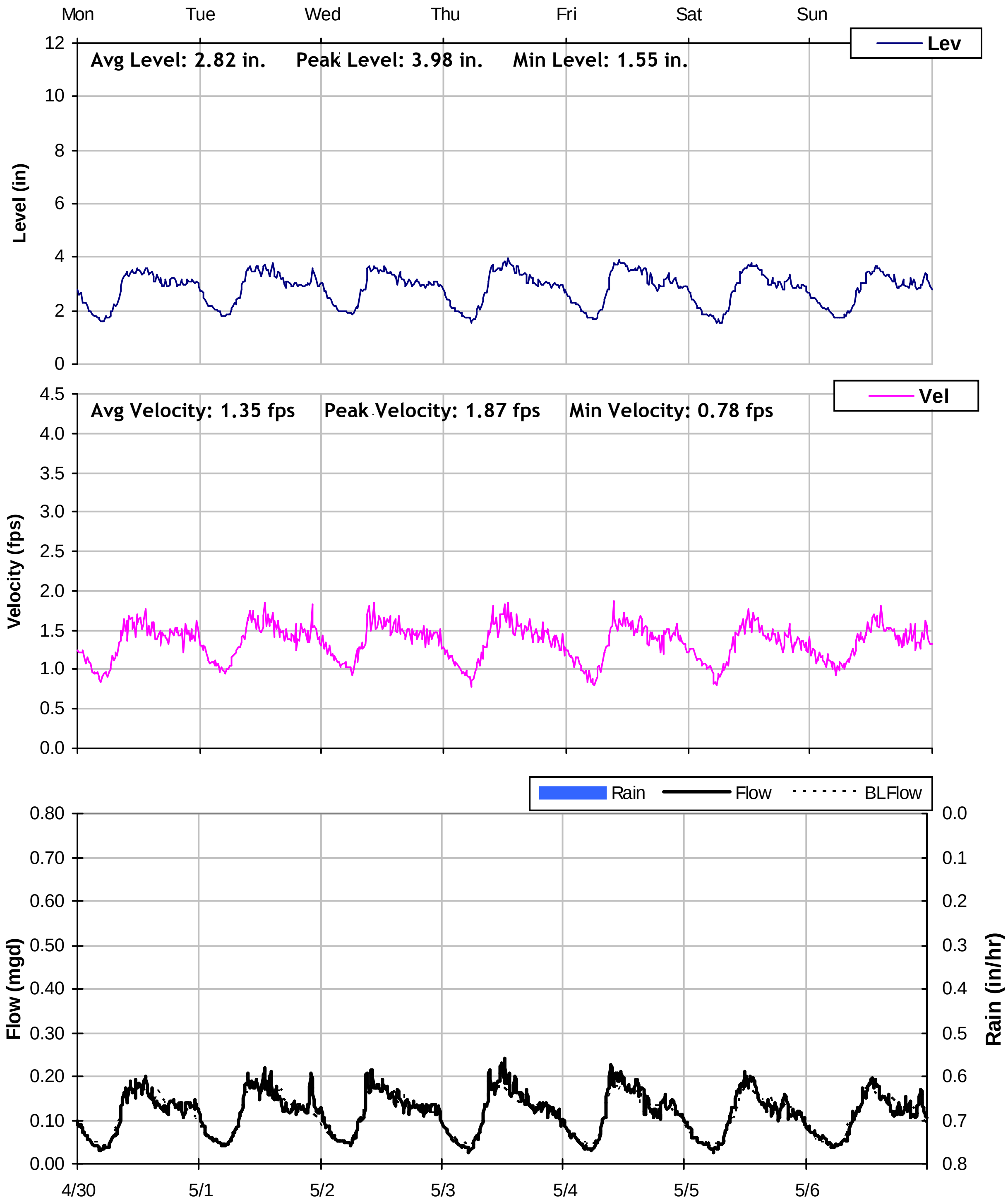


Avg Flow: 0.124 mgd **Peak Flow: 0.255 mgd** **Min Flow: 0.038 mgd**

SITE 18
Weekly Level, Velocity and Flow Hydrographs
4/23/2012 to 4/30/2012



SITE 18
Weekly Level, Velocity and Flow Hydrographs
4/30/2012 to 5/7/2012



Avg Flow: 0.116 mgd Peak Flow: 0.243 mgd Min Flow: 0.027 mgd

City of Chico

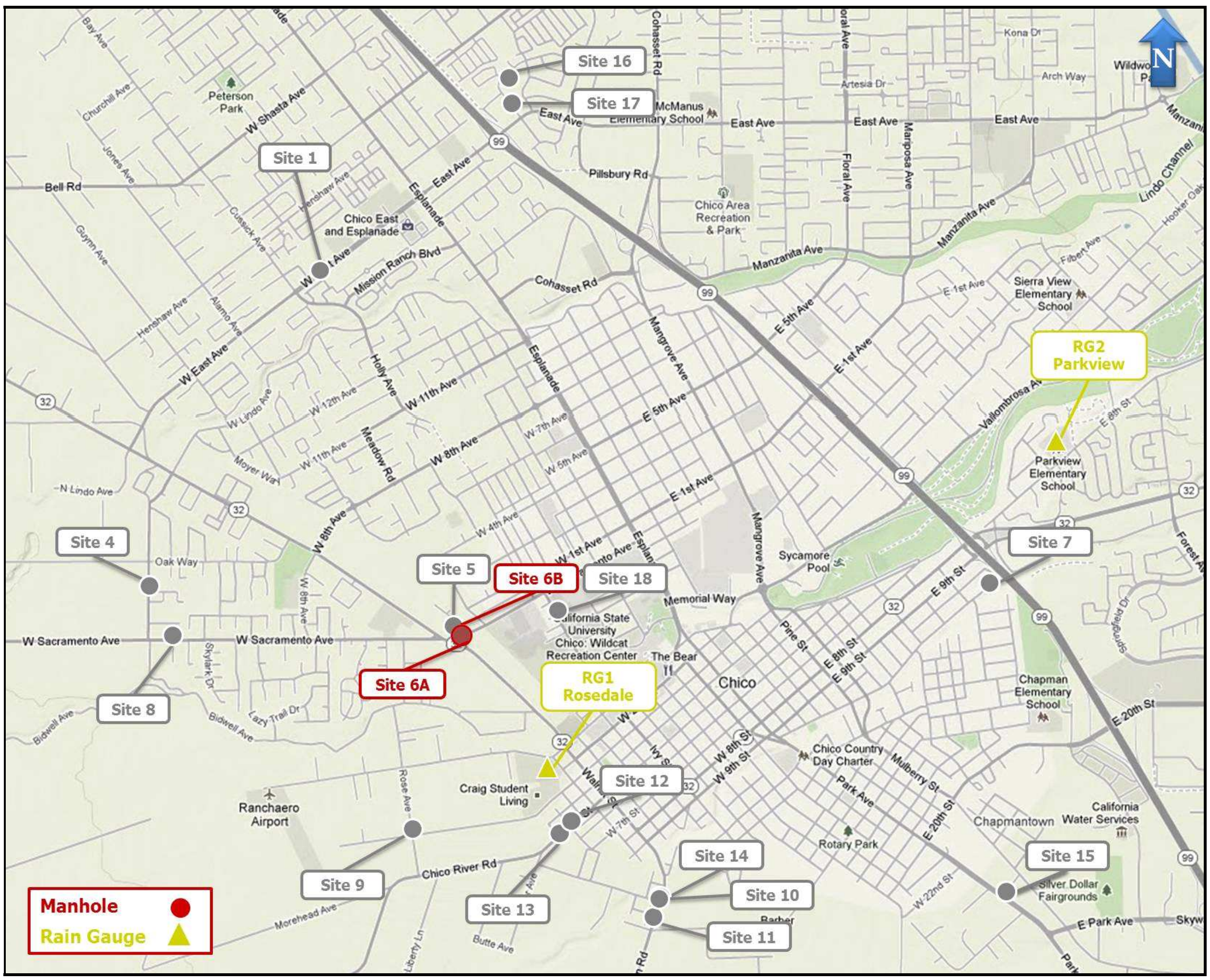
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 6A+6B

Location: Sum of Site 6A and Site 6B

Vicinity Map:

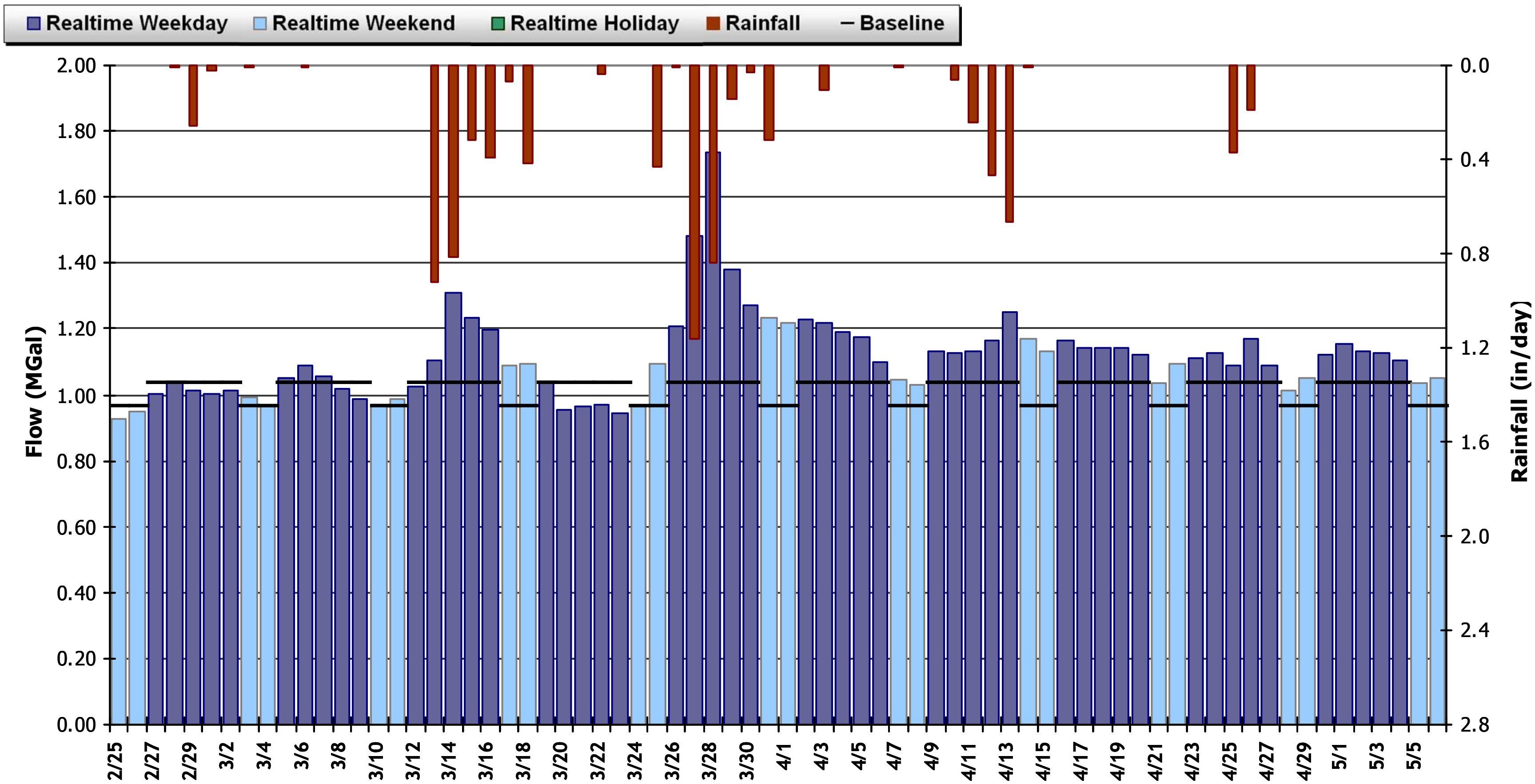


SITE 6A+6B

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.110 MGal **Peak Daily Flow: 1.735 MGal** **Min Daily Flow: 0.925 MGal**

Total Period Rainfall: 8.30 inches

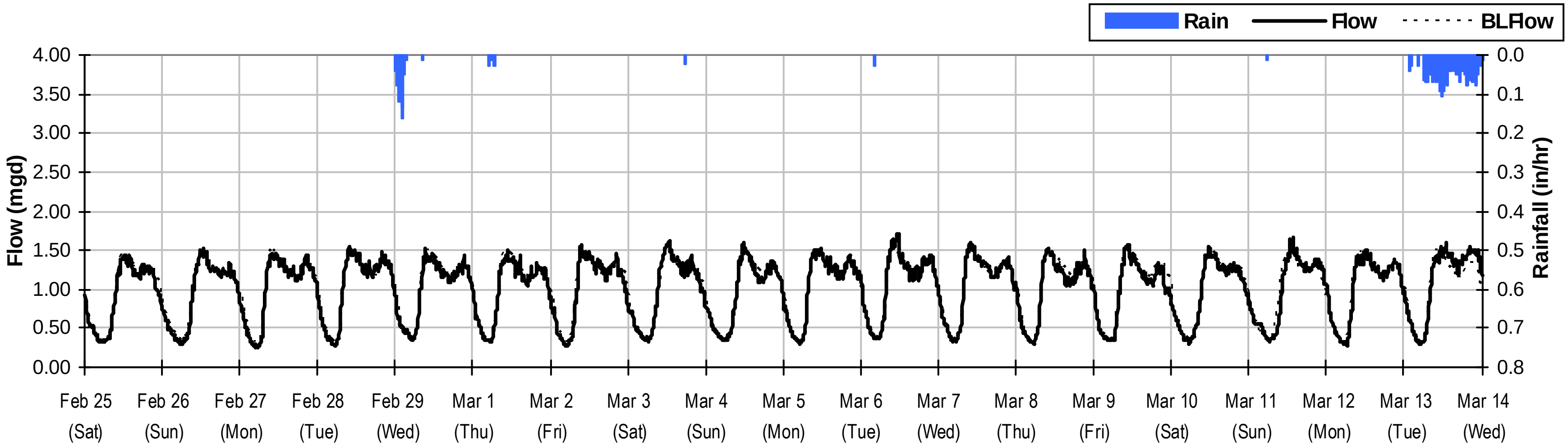


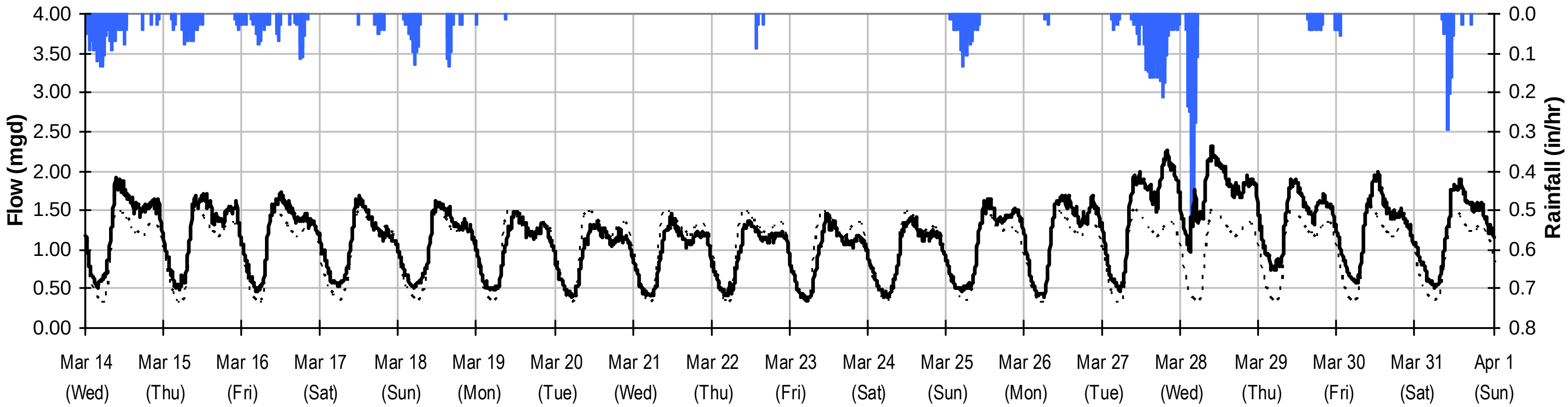
SITE 6A+6B

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 1.093 mgd **Peak Flow: 2.322 mgd** **Min Flow: 0.264 mgd**

Total Period Rainfall: 6.19 inches



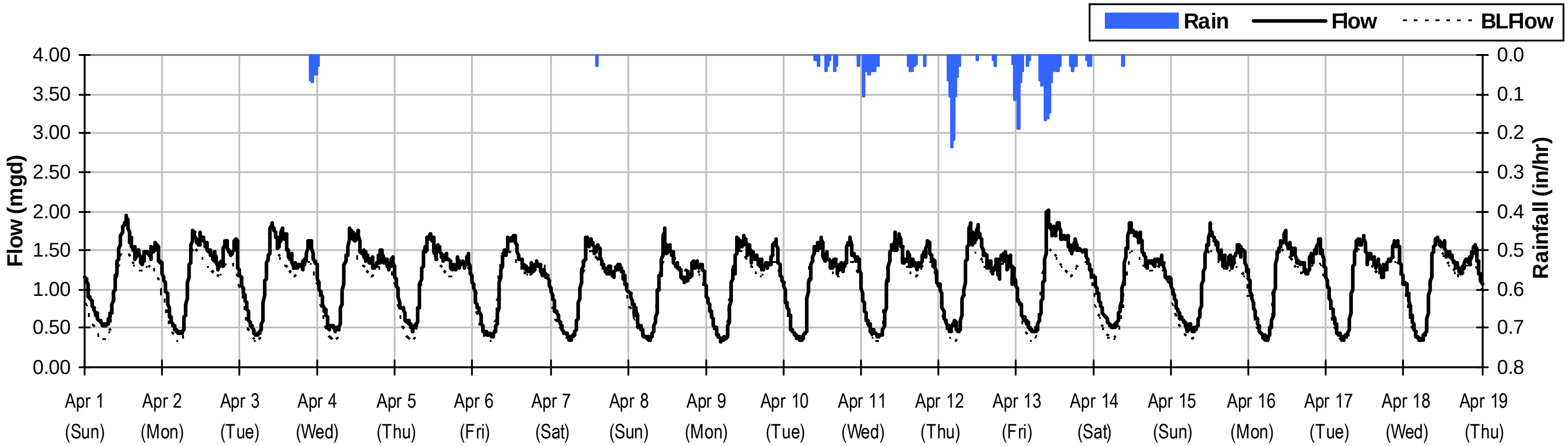


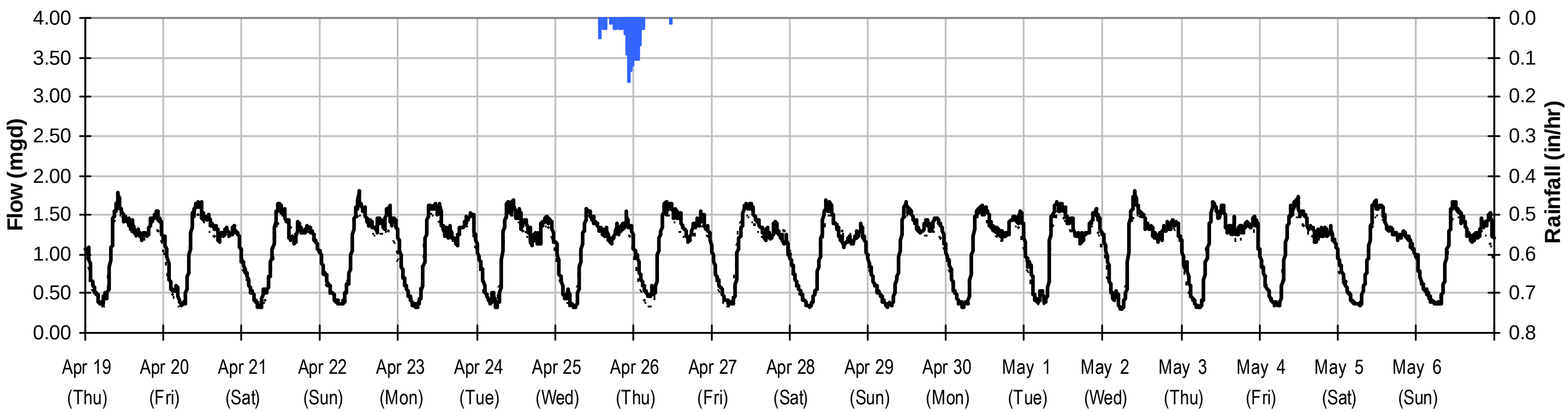
SITE 6A+6B

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 1.126 mgd **Peak Flow: 2.007 mgd** **Min Flow: 0.307 mgd**

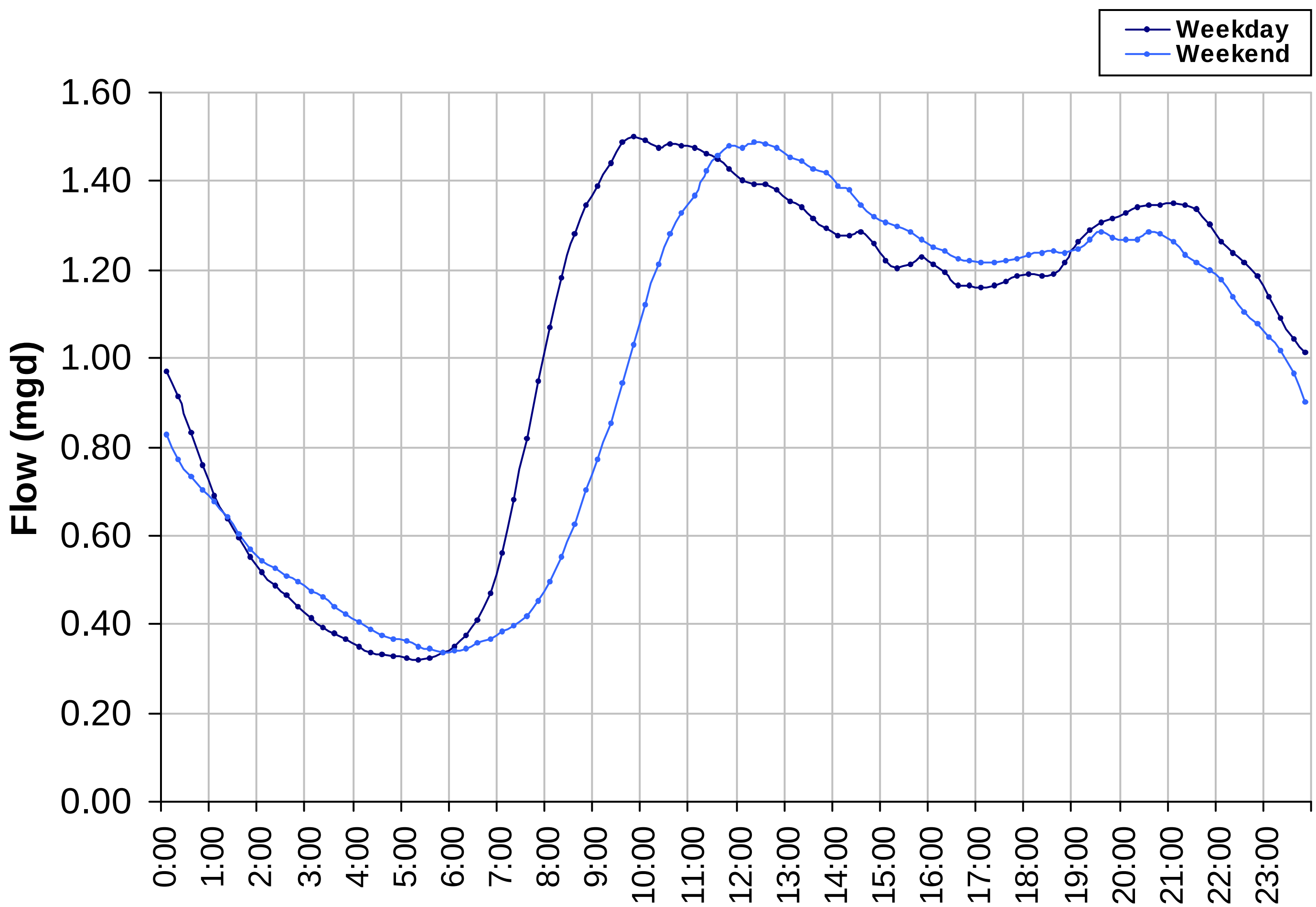
Total Period Rainfall: 2.11 inches





SITE 6A+6B

Baseline Flow Hydrographs



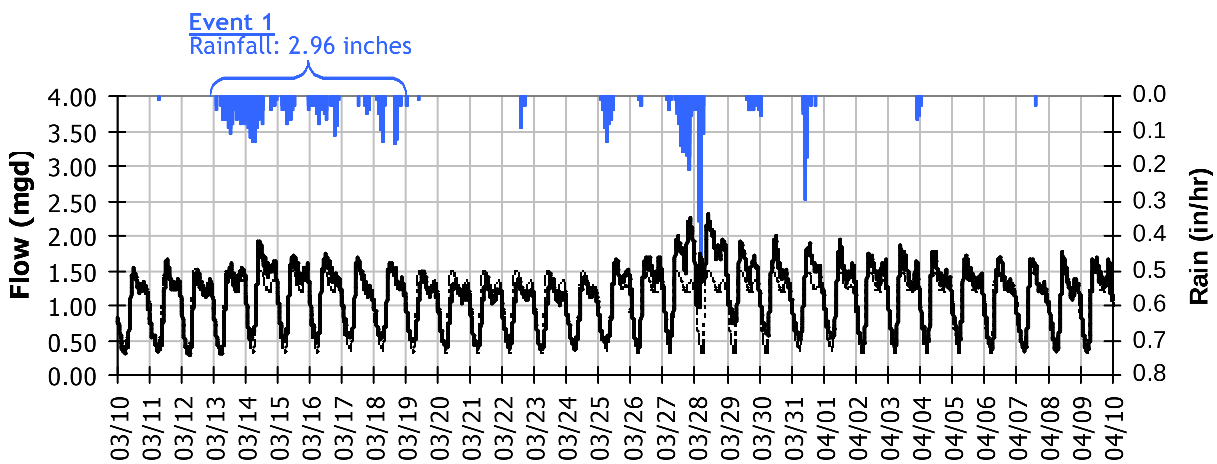
Baseline Flow:

1.014 *mgd*

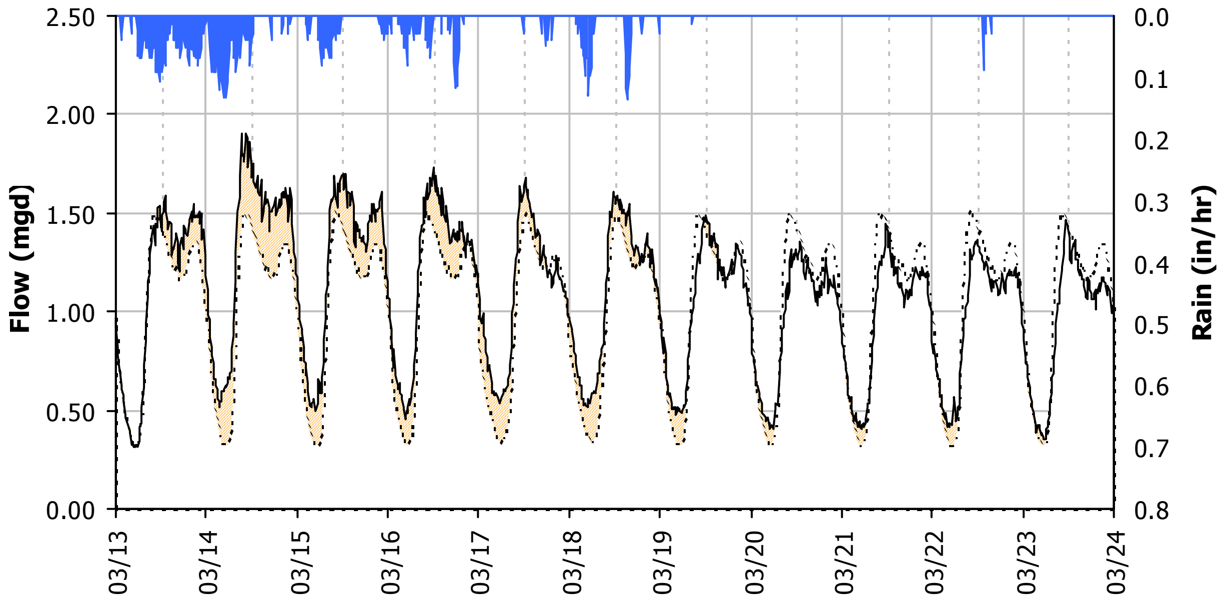
SITE 6A+6B

I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

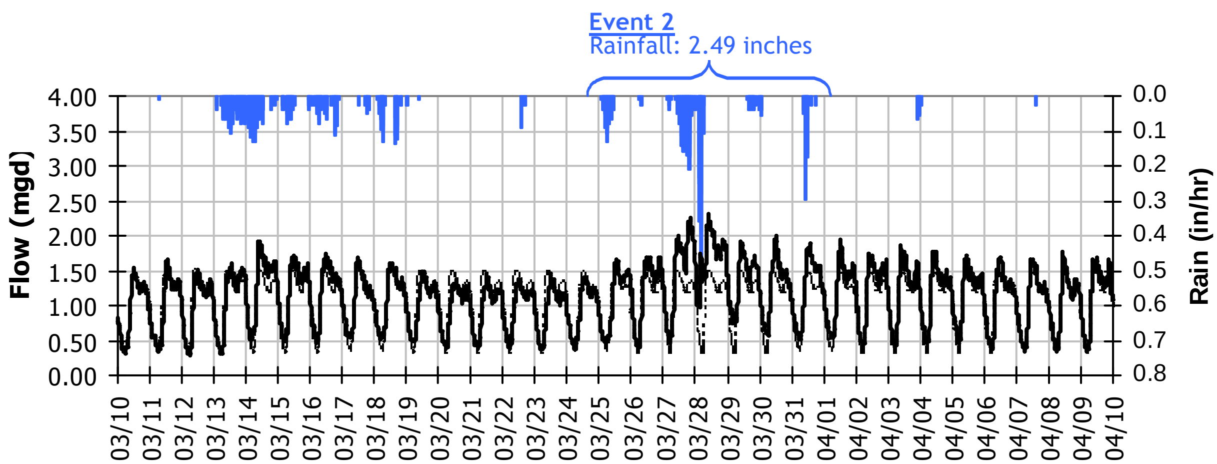


Storm Event I/I Analysis (Rain = 2.96 inches)

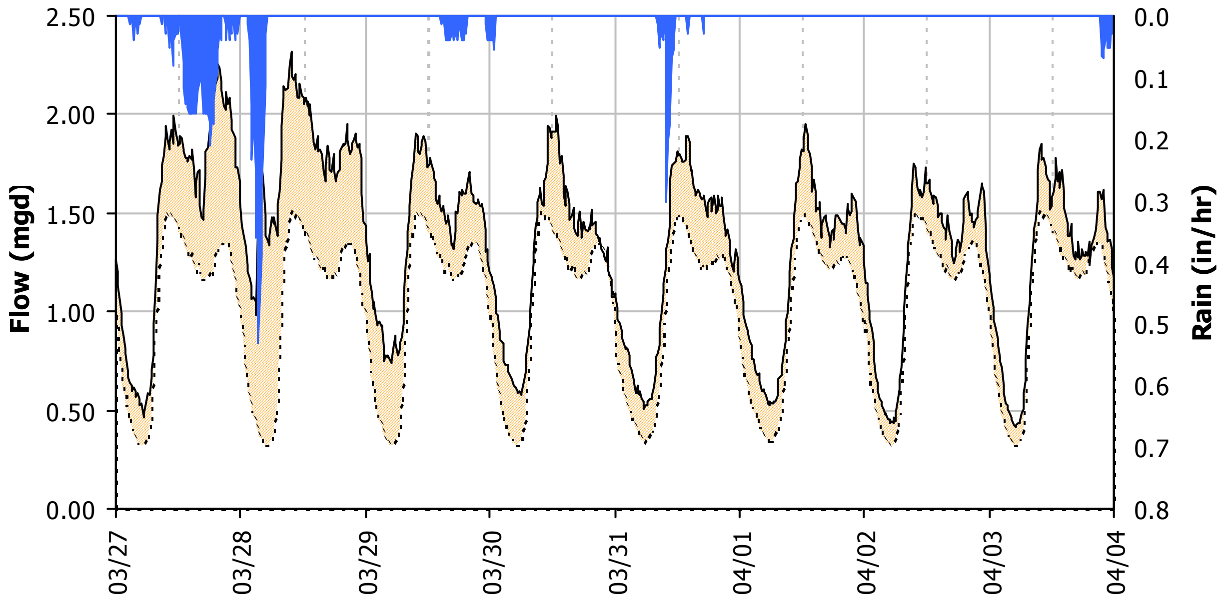
Capacity		**Inflow**		**RDI (infiltration)**		**Combined I/I**	
Peak Flow:	1.91 *mgd*	**Peak I/I Rate:**	0.47 *mgd*	**Infiltration Rate:** (3/20/2012)	0.000 *mgd*	**Total I/I:**	675,000 *gallons*
PF:	1.88	**PkI/I:IDM:**	1,489 *gpd/IDM*	**RDI:IDM:**	0 *gpd/IDM*	**Total I/I:IDM:**	727 *gal/IDM/in*
		PkI/I:Acre:	255 *gpd/acre*	**RDI:Acre:**	0 *gpd/acre*	**R-Value:**	0.5%
		Pk I/I:ADWF:	0.46	**RDI (% of BL):**	0%	**Total I/I:ADWF:**	0.23 *per in-rain*

SITE 6A+6B
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph

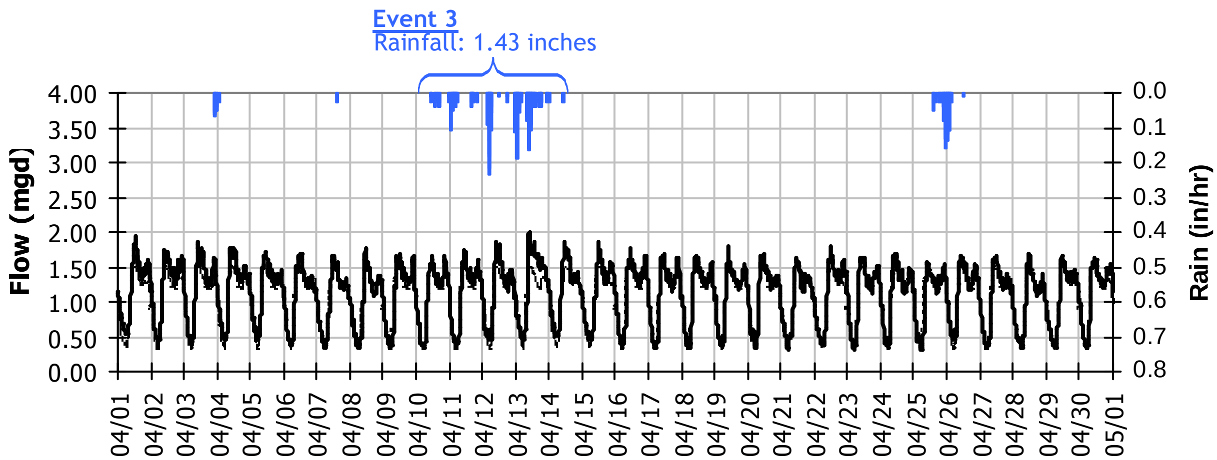


Storm Event I/I Analysis (Rain = 2.49 inches)

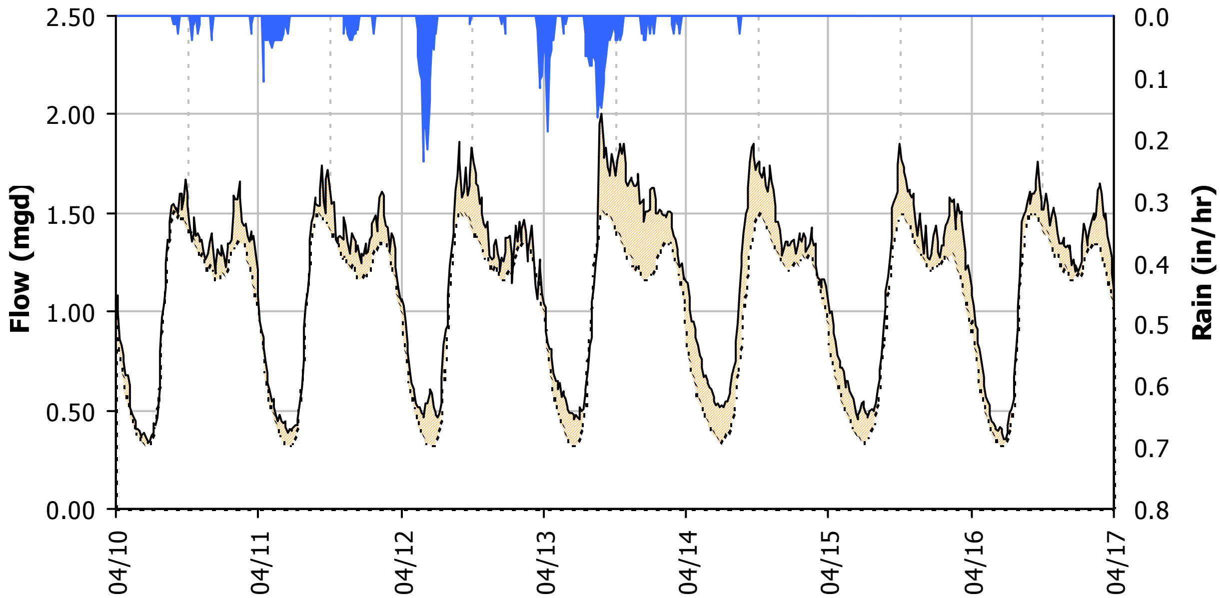
Capacity			Inflow			RDI (infiltration)			Combined I/I		
Peak Flow:	2.32	*mgd*	**Peak I/I Rate:**	1.41	*mgd*	**Infiltration Rate:** (4/2/2012)	0.195	*mgd*	**Total I/I:**	2,640,000	*gallons*
PF:	2.29		**PkI/I:IDM:**	4,485	*gpd/IDM*	**RDI:IDM:**	621	*gpd/IDM*	**Total I/I:IDM:**	3,378	*gal/IDM/in*
			PkI/I:Acre:	769	*gpd/acre*	**RDI:Acre:**	107	*gpd/acre*	**R-Value:**	2.1%	
			Pk I/I:ADWF:	1.39		**RDI (% of BL):**	19%		**Total I/I:ADWF:**	1.05	*per in-rain*

SITE 6A+6B
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.43 inches)

Capacity

Peak Flow:	2.01	*mgd*
PF:	1.98	

Inflow

Peak I/I Rate:	0.53	*mgd*
PkI/I:IDM:	1,695	*gpd/IDM*
PkI/I:Acre:	291	*gpd/acre*
Pk I/I:ADWF:	0.53	

RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.167	*mgd*
RDI:IDM:	532	*gpd/IDM*
RDI:Acre:	91	*gpd/acre*
RDI (% of BL):	17%	

Combined I/I

Total I/I:	1,044,000	*gallons*
Total I/I:IDM:	2,316	*gal/IDM/in*
R-Value:	1.5%	
Total I/I:ADWF:	0.72	*per in-rain*

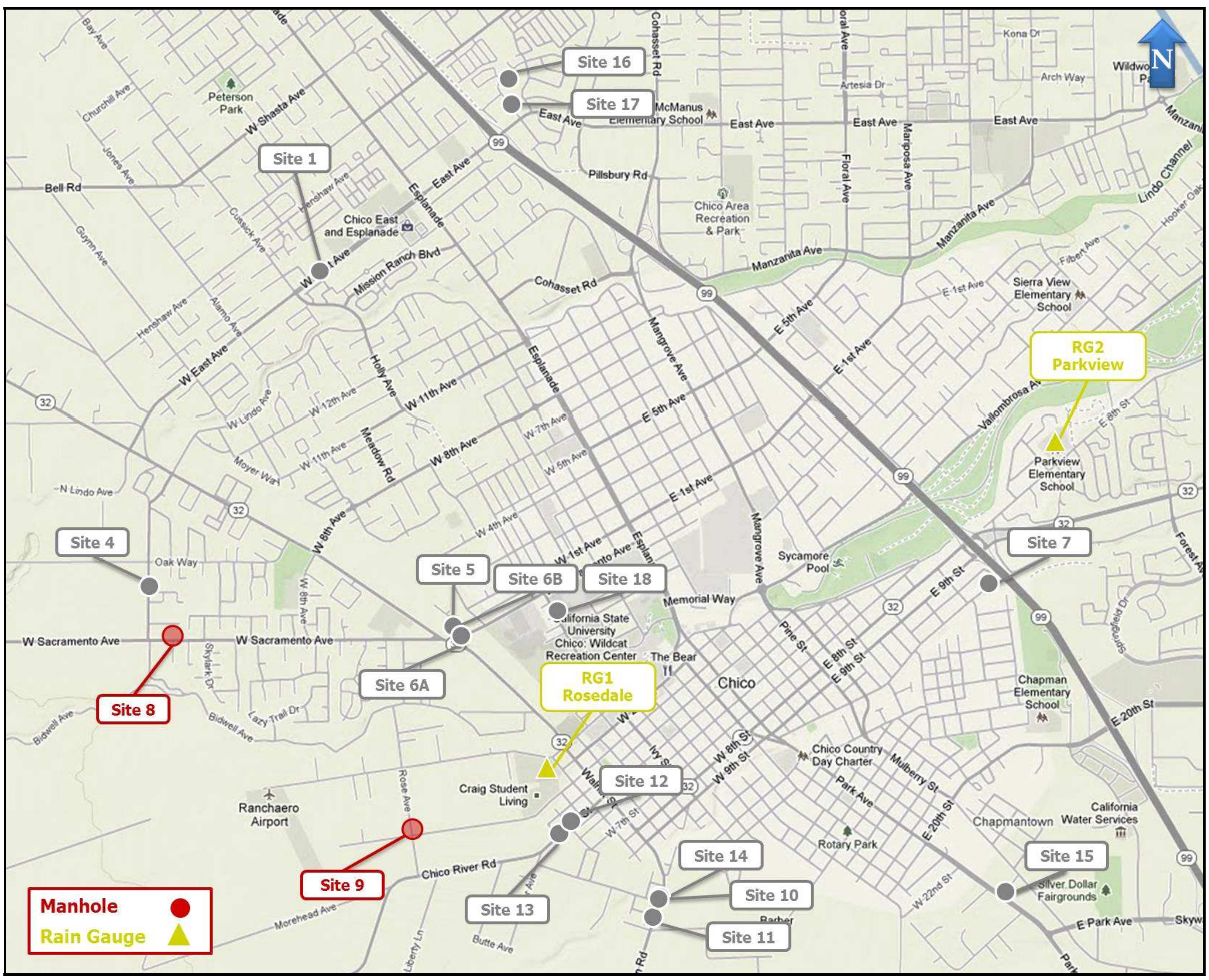
City of Chico

Sanitary Sewer Flow Monitoring and I/I Study
Year 2012

Monitoring Site: Site 8+9

Location: Sum of Site 8 and Site 9

Vicinity Map:

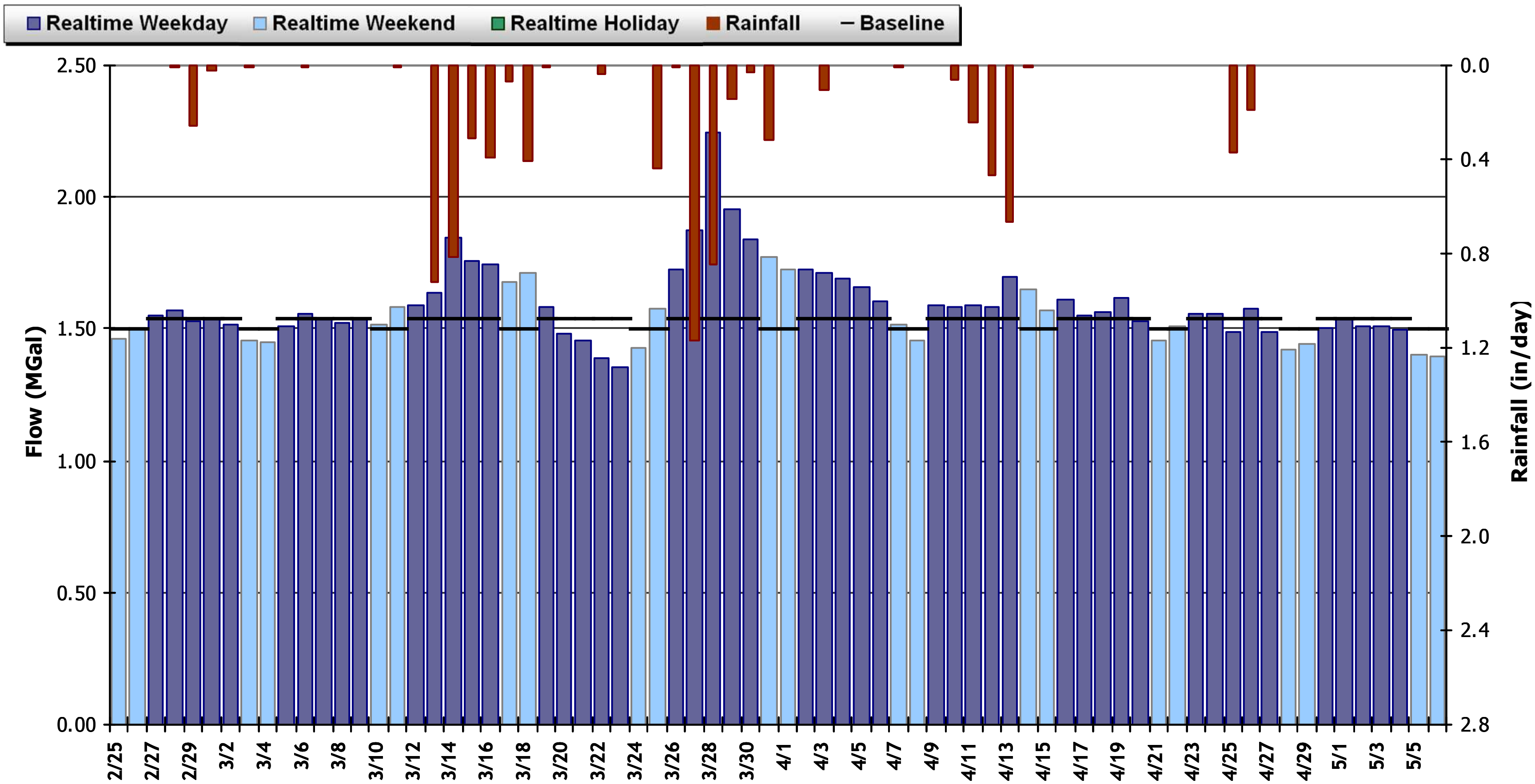


SITE 8+9

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.584 MGal **Peak Daily Flow: 2.241 MGal** **Min Daily Flow: 1.356 MGal**

Total Period Rainfall: 8.32 inches

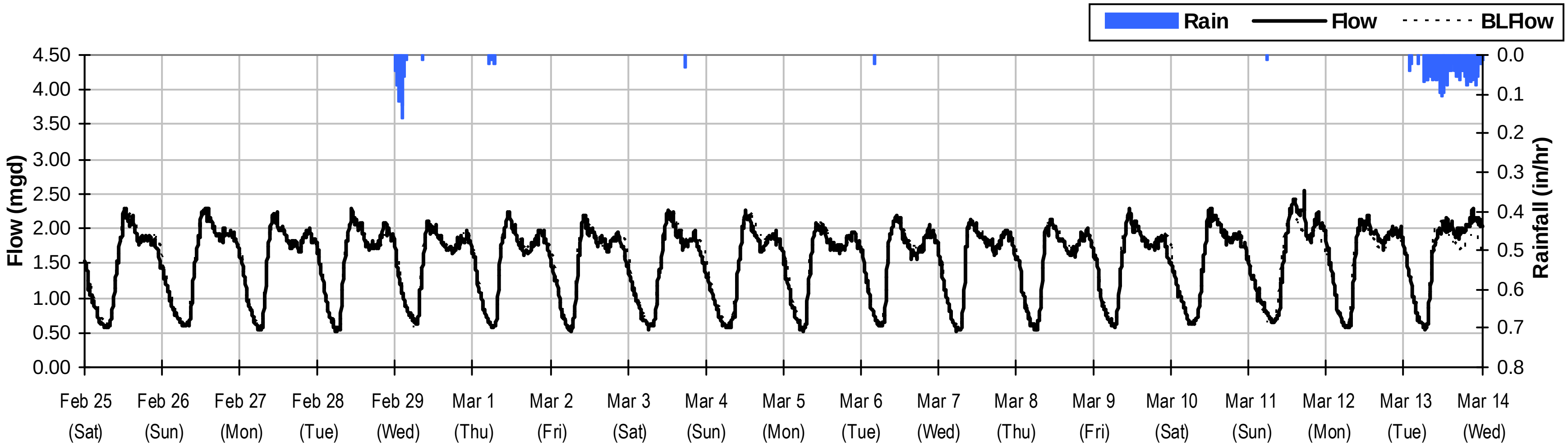


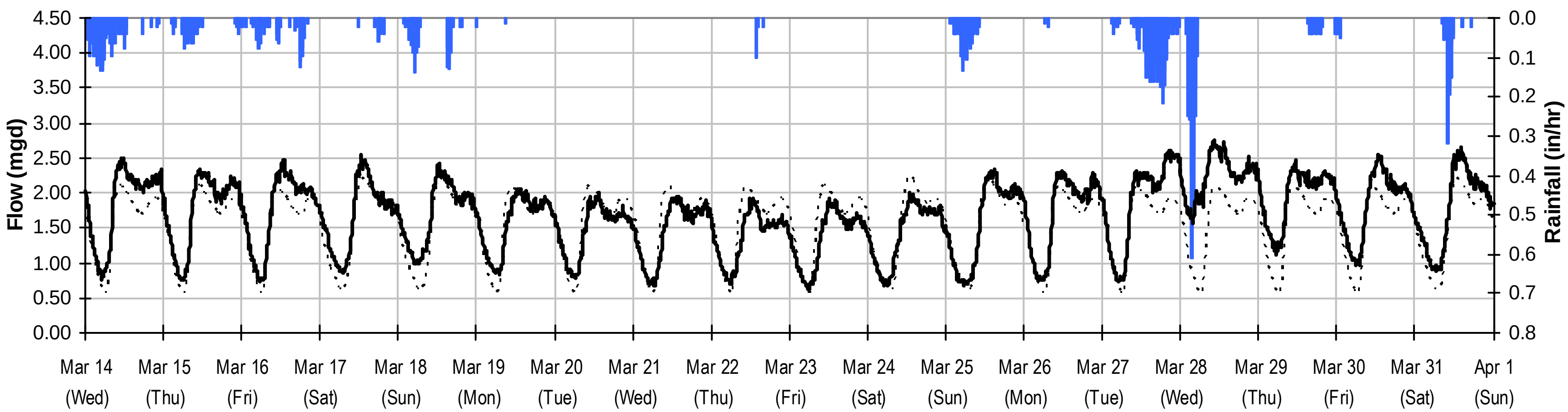
SITE 8+9

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 1.610 mgd **Peak Flow: 2.764 mgd** **Min Flow: 0.516 mgd**

Total Period Rainfall: 6.21 inches



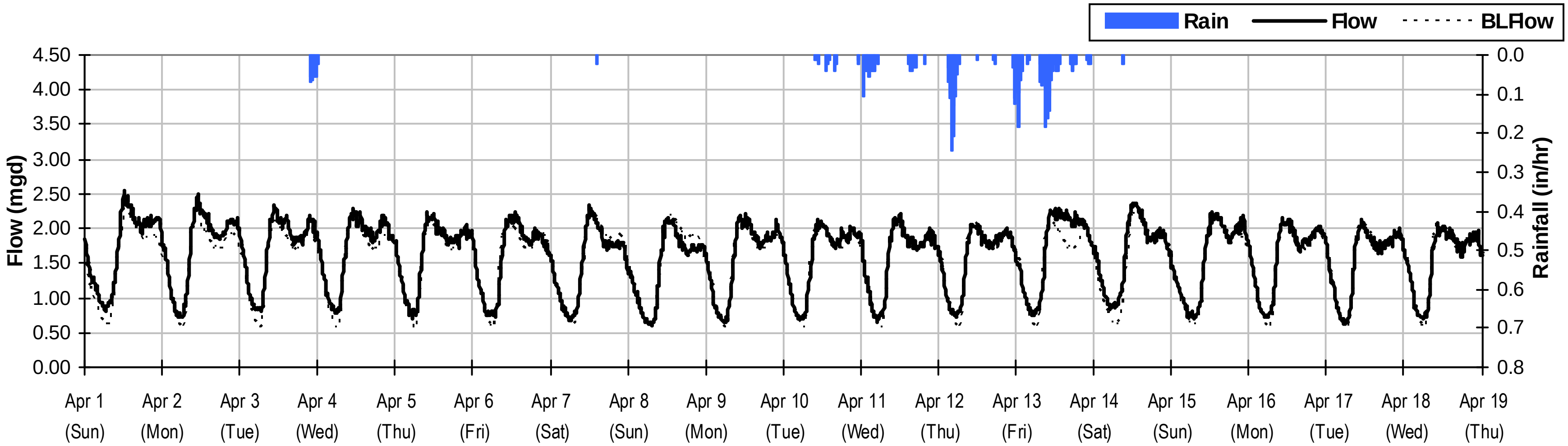


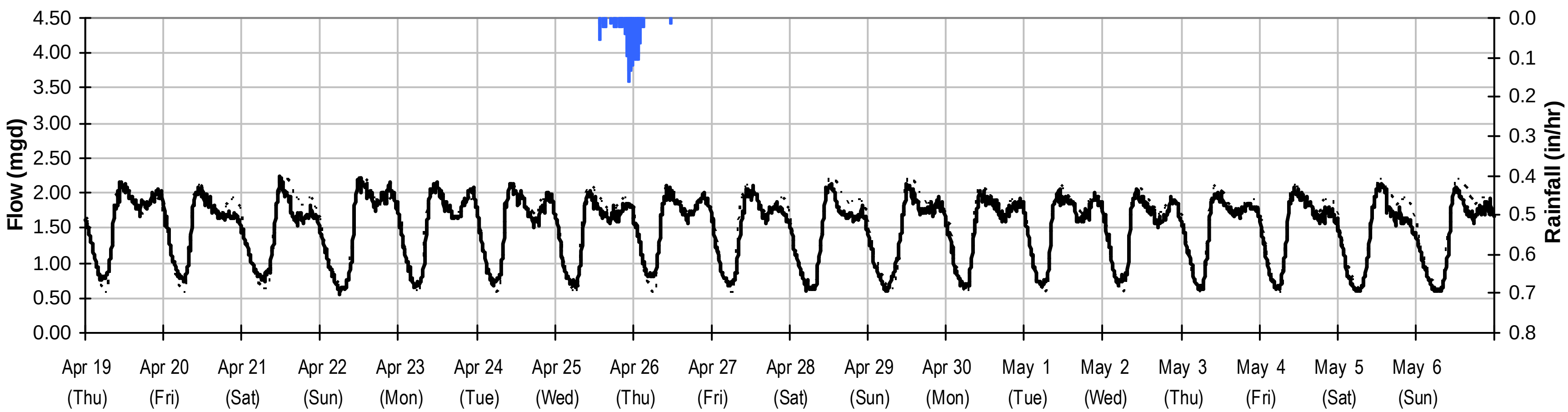
SITE 8+9

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 1.558 mgd **Peak Flow: 2.540 mgd** **Min Flow: 0.557 mgd**

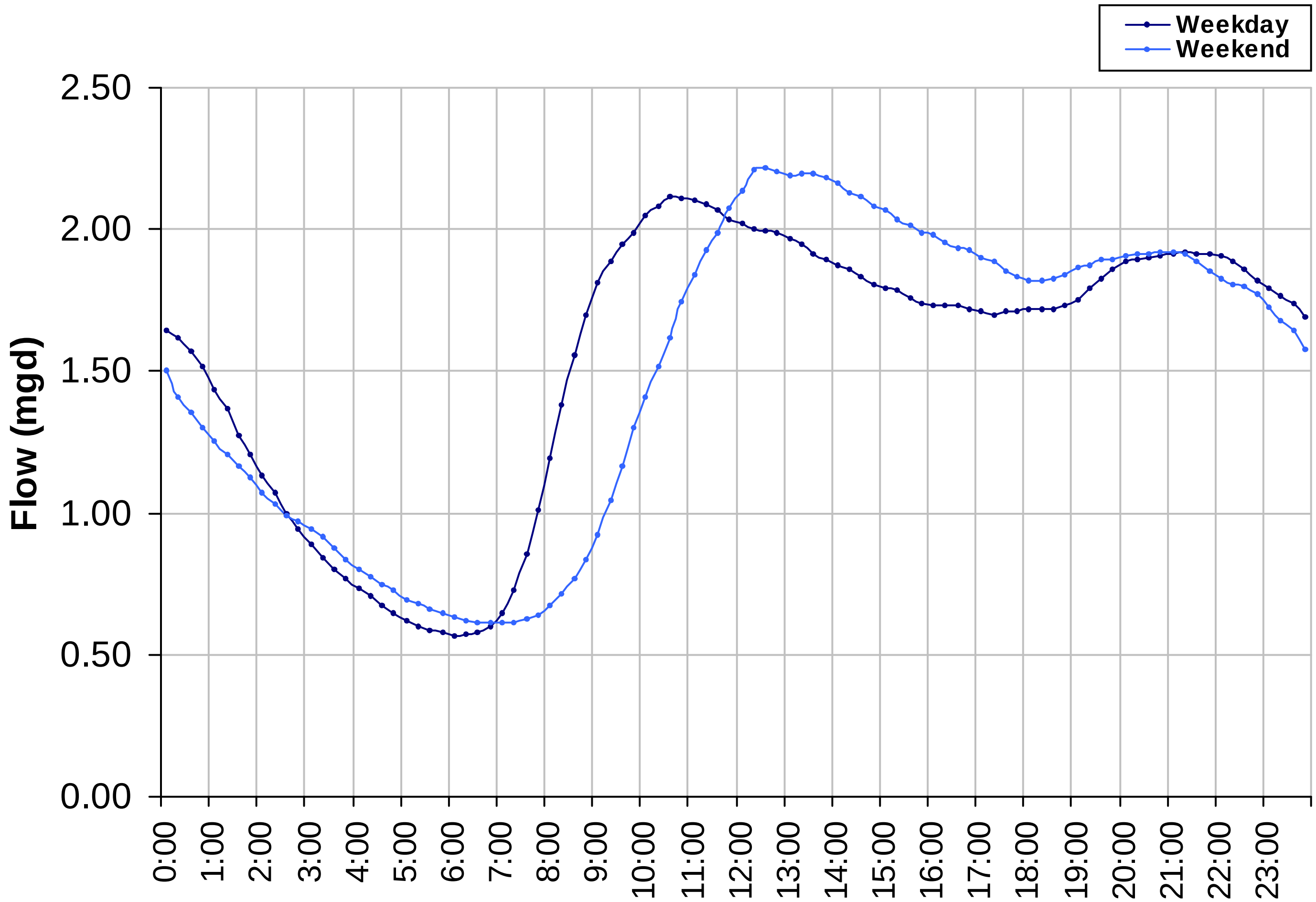
Total Period Rainfall: 2.11 inches





SITE 8+9

Baseline Flow Hydrographs



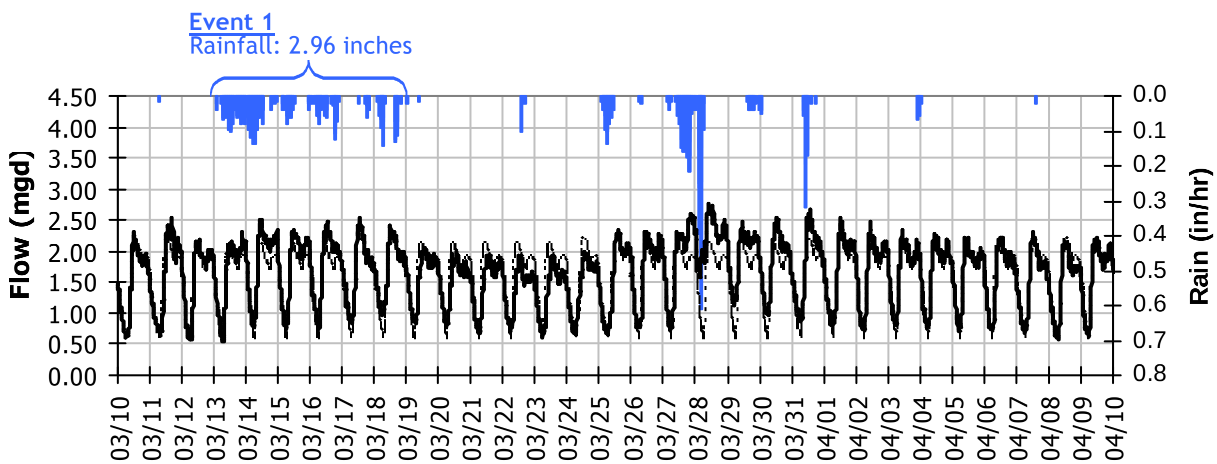
Baseline Flow:

1.526 *mgd*

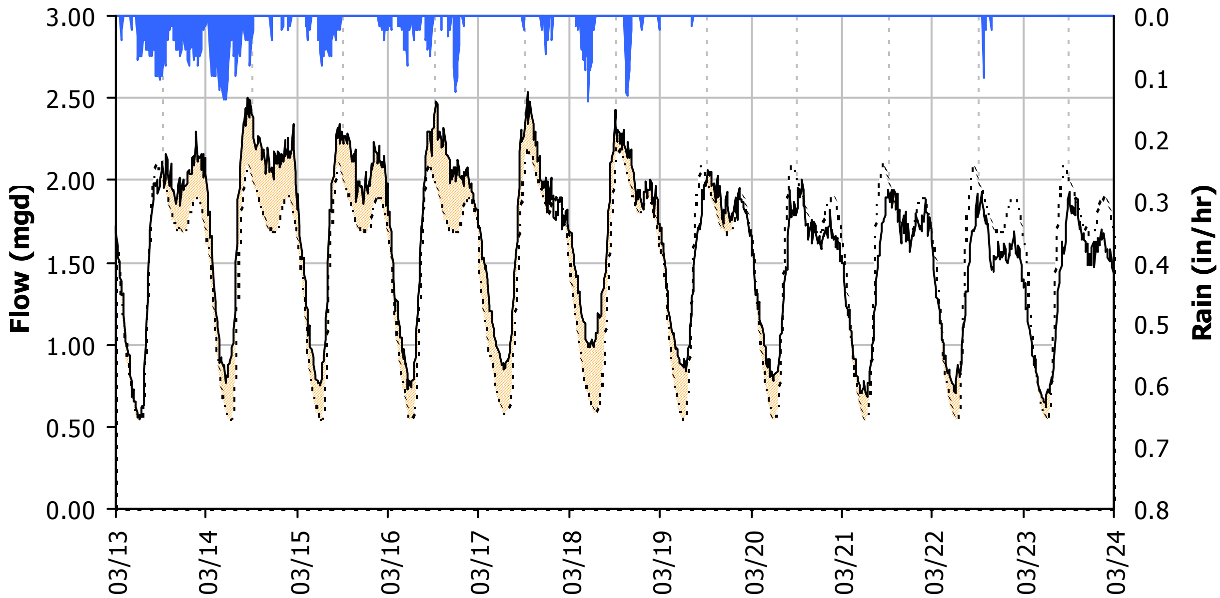
SITE 8+9

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 = 2.96 inches)

Capacity

Peak Flow: 2.54 *mgd*
PF: 1.67

Inflow

Peak I/I Rate: 0.55 *mgd*
PkI/I:IDM: 1,198 *gpd/IDM*
PkI/I:Acre: 218 *gpd/acre*
Pk I/I:ADWF: 0.36

RDI (infiltration)

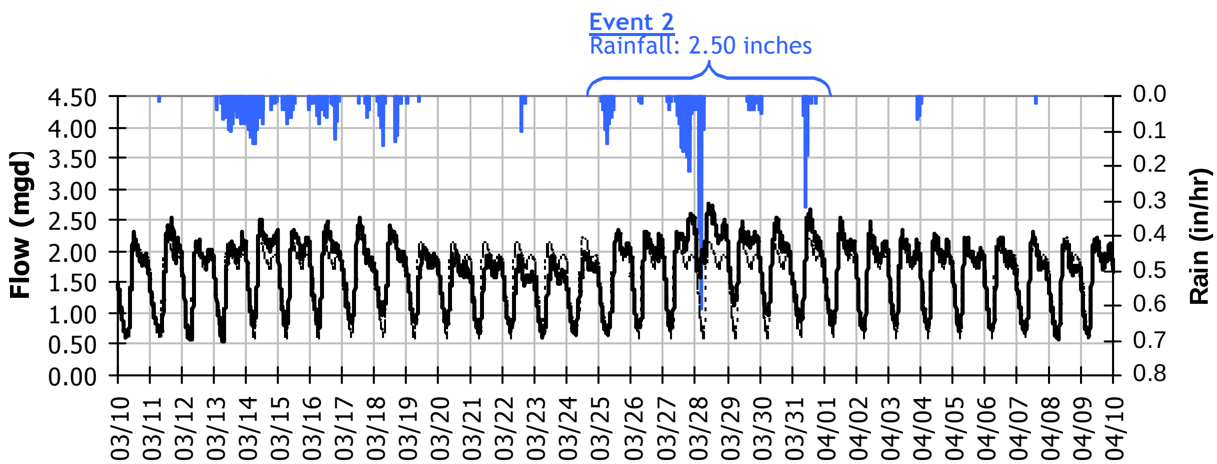
Infiltration Rate: 0.000 *mgd*
(3/20/2012)
RDI:IDM: 0 *gpd/IDM*
RDI:Acre: 0 *gpd/acre*
RDI (% of BL): 0%

Combined I/I

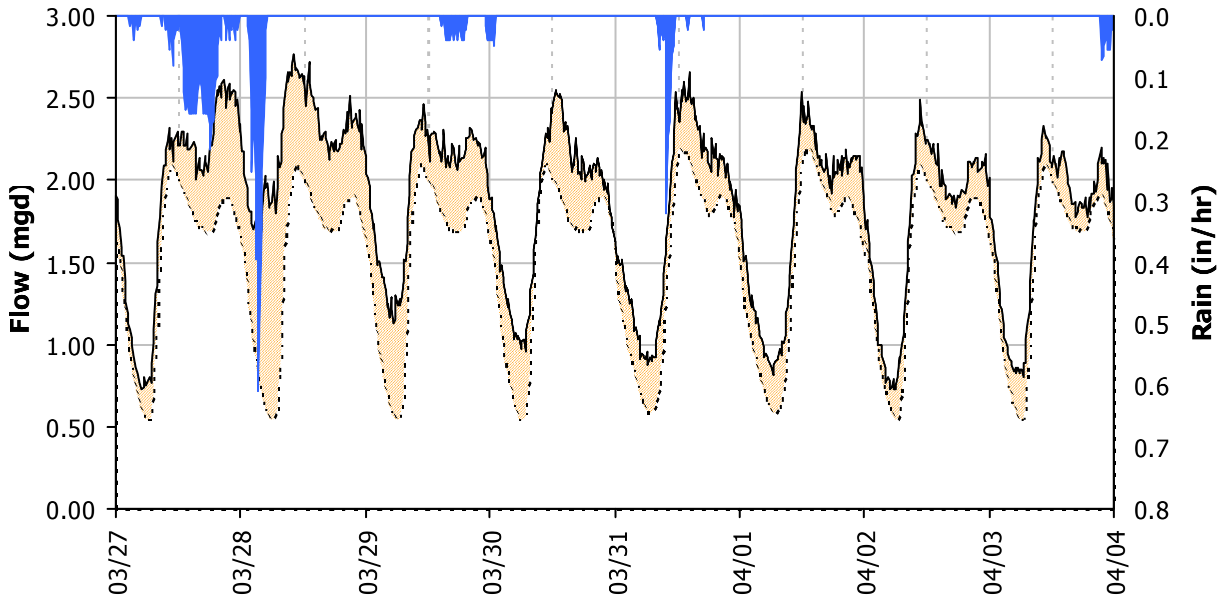
Total I/I: 1,093,000 *gallons*
Total I/I:IDM: 812 *gal/IDM/in*
R-Value: 0.5%
Total I/I:ADWF: 0.24 *per in-rain*

SITE 8+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 = 2.50 inches)

Capacity

Peak Flow: 2.76 *mgd*
PF: 1.81

Inflow

Peak I/I Rate: 1.42 *mgd*
PkI/I:IDM: 3,119 *gpd/IDM*
PkI/I:Acre: 567 *gpd/acre*
Pk I/I:ADWF: 0.93

RDI (infiltration)

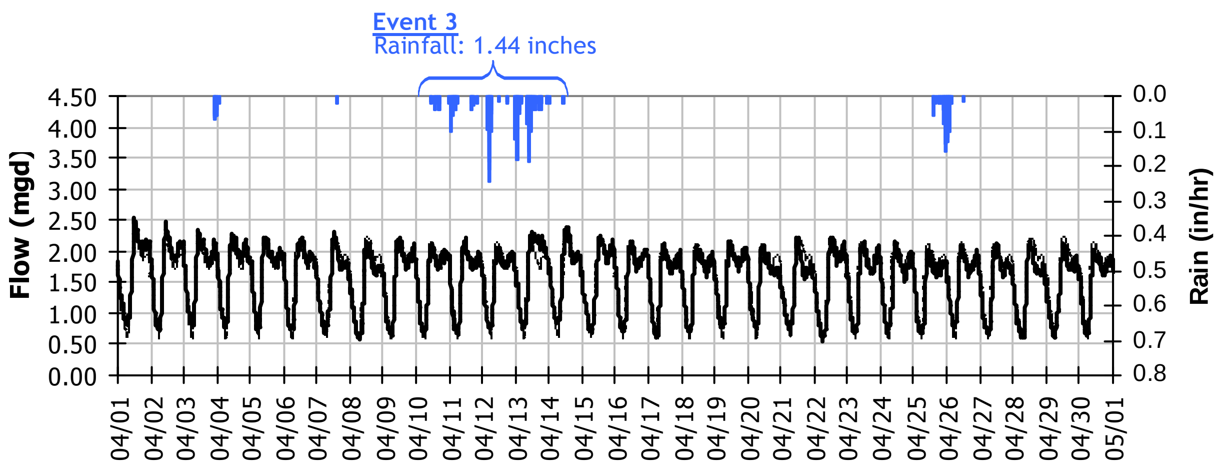
Infiltration Rate: 0.189 *mgd* (4/2/2012)
RDI:IDM: 416 *gpd/IDM*
RDI:Acre: 76 *gpd/acre*
RDI (% of BL): 12%

Combined I/I

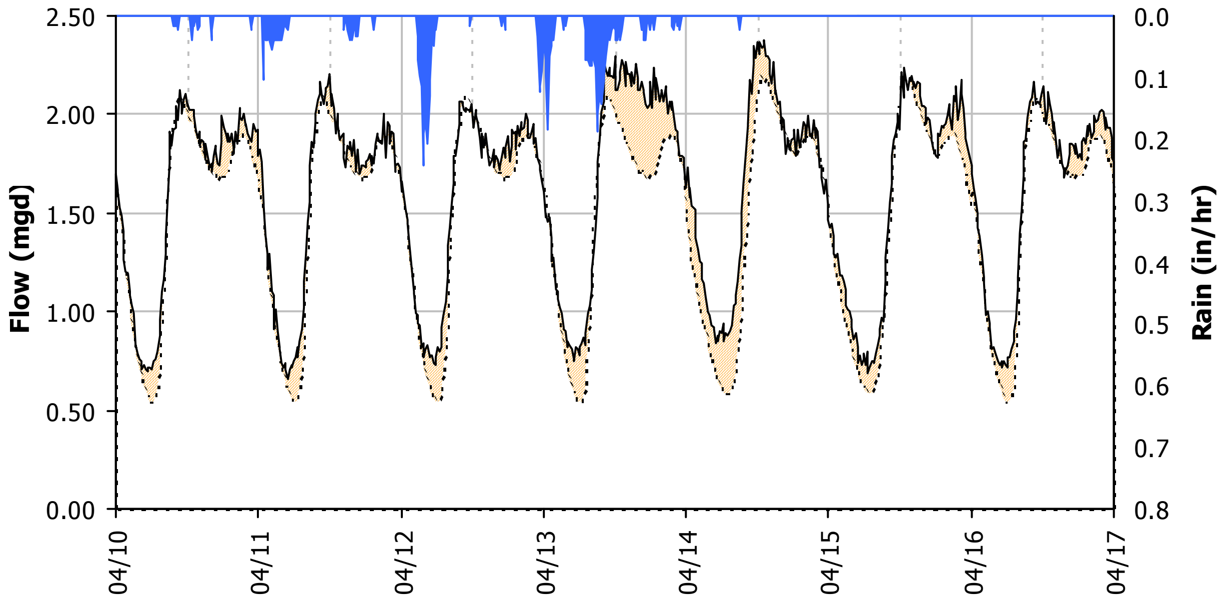
Total I/I: 2,835,000 *gallons*
Total I/I:IDM: 2,487 *gal/IDM/in*
R-Value: 1.7%
Total I/I:ADWF: 0.74 *per in-rain*

SITE 8+9
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.44 inches)

Capacity

Peak Flow:	2.38	*mgd*
PF:	1.56	

Inflow

Peak I/I Rate:	0.52	*mgd*
PkI/I:IDM:	1,153	*gpd/IDM*
PkI/I:Acre:	210	*gpd/acre*
Pk I/I:ADWF:	0.34	

RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.075	*mgd*
RDI:IDM:	165	*gpd/IDM*
RDI:Acre:	30	*gpd/acre*
RDI (% of BL):	5%	

Combined I/I

Total I/I:	788,000	*gallons*
Total I/I:IDM:	1,202	*gal/IDM/in*
R-Value:	0.8%	
Total I/I:ADWF:	0.36	*per in-rain*

City of Chico

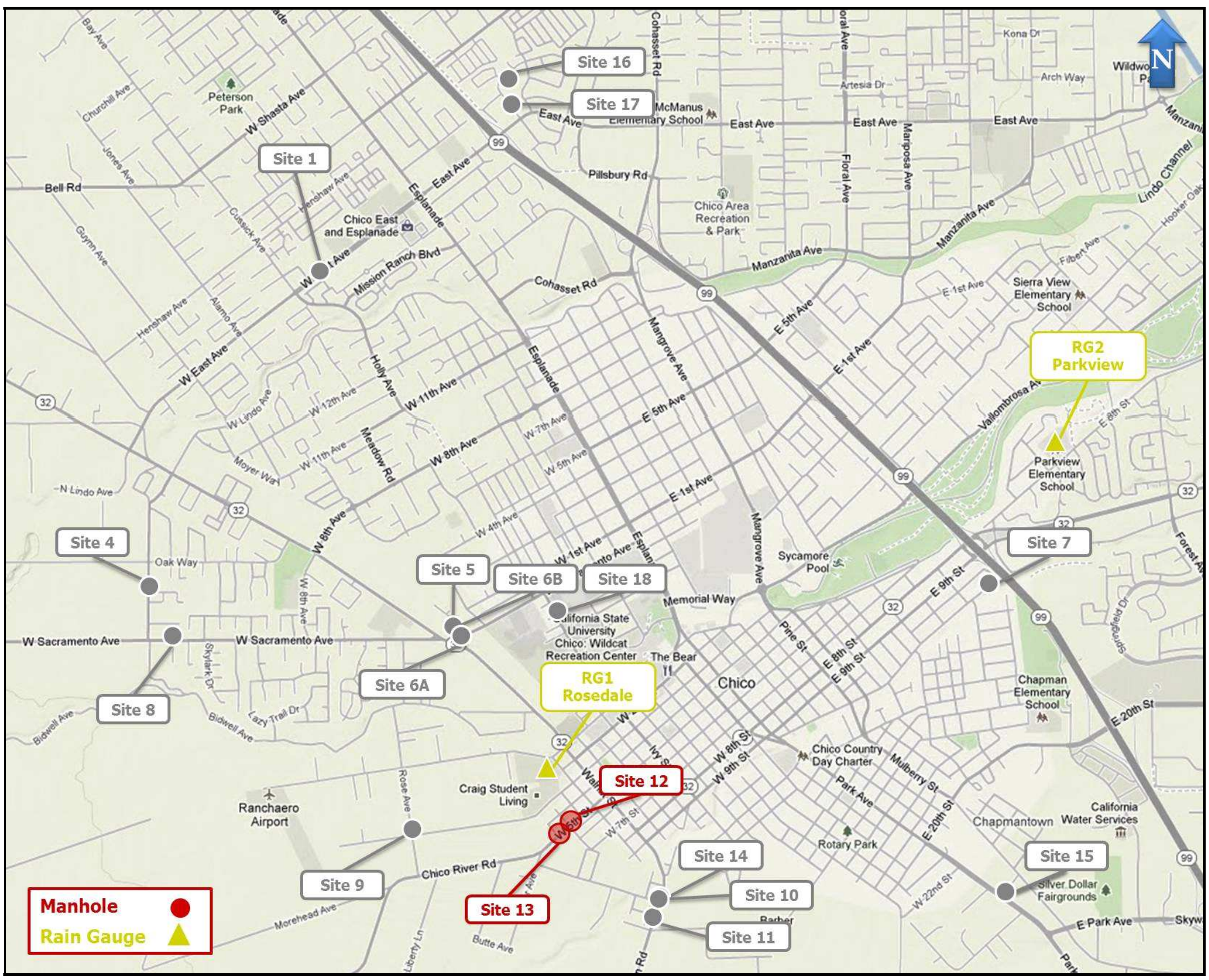
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Site 12+13

Location: Sum of Site 12 and Site 13

Vicinity Map:

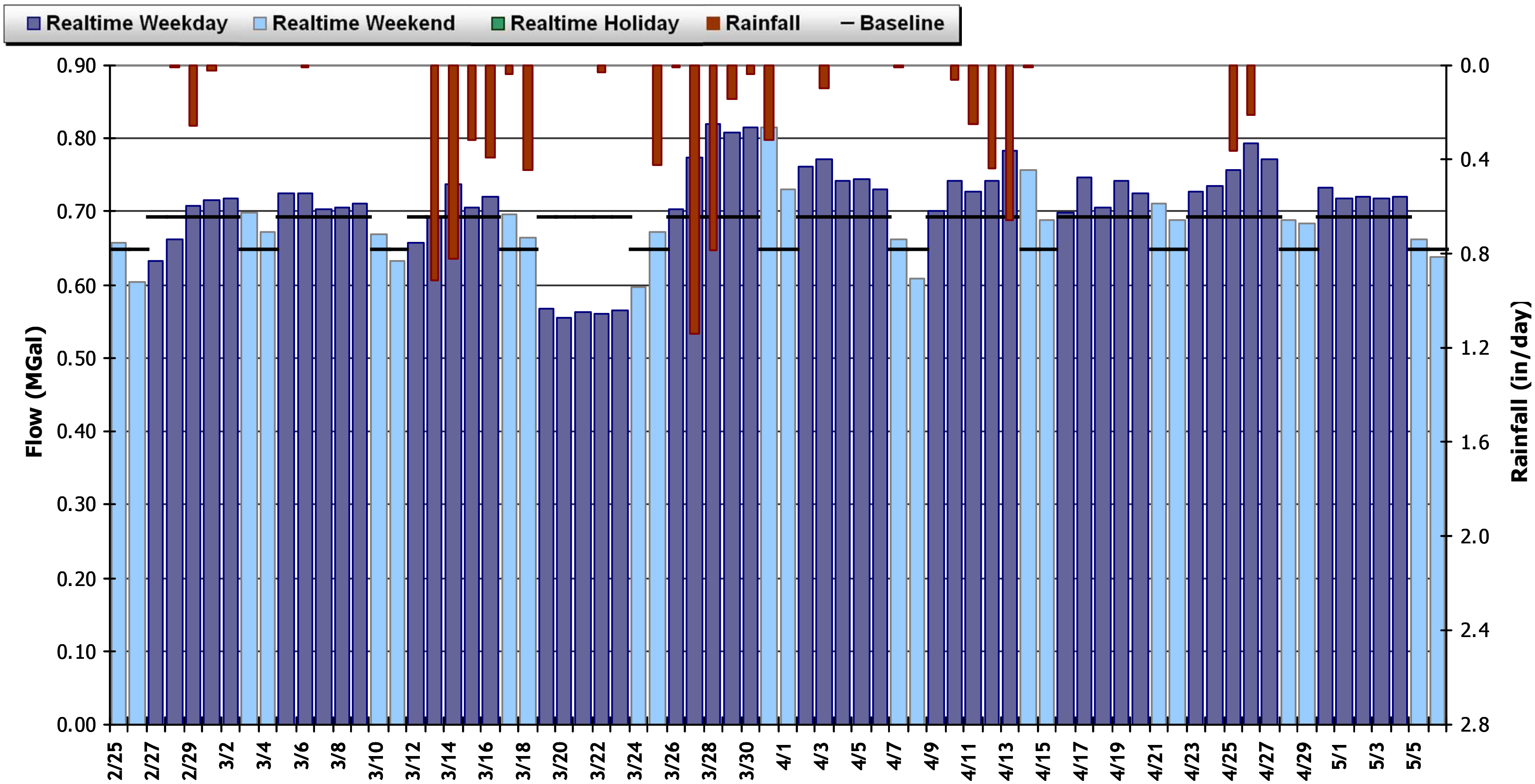


SITE 12+13

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.703 MGal **Peak Daily Flow: 0.819 MGal** **Min Daily Flow: 0.556 MGal**

Total Period Rainfall: 8.21 inches

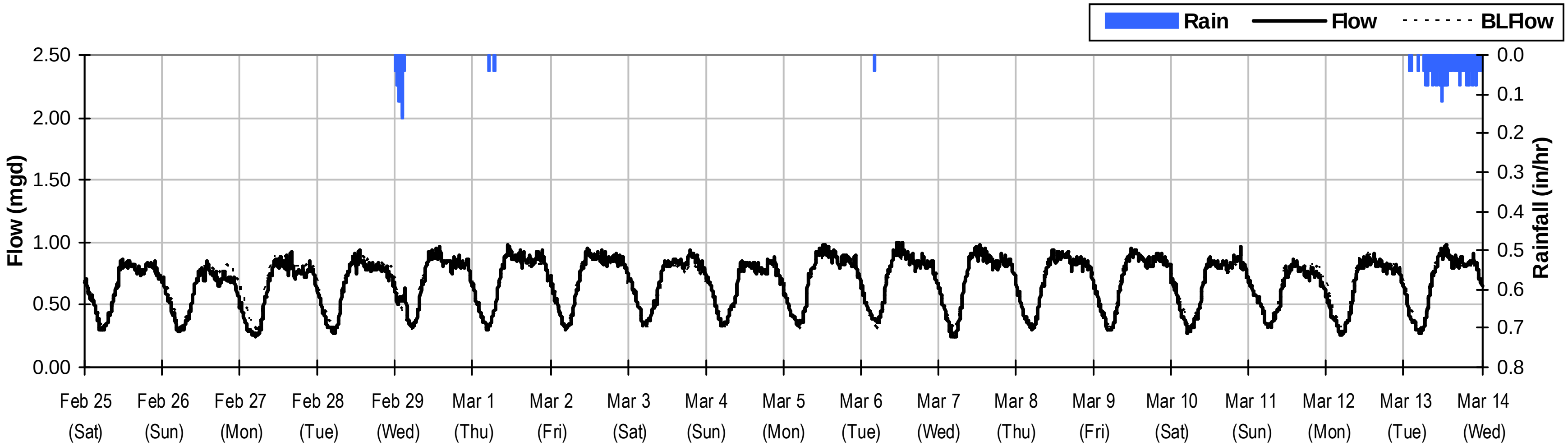


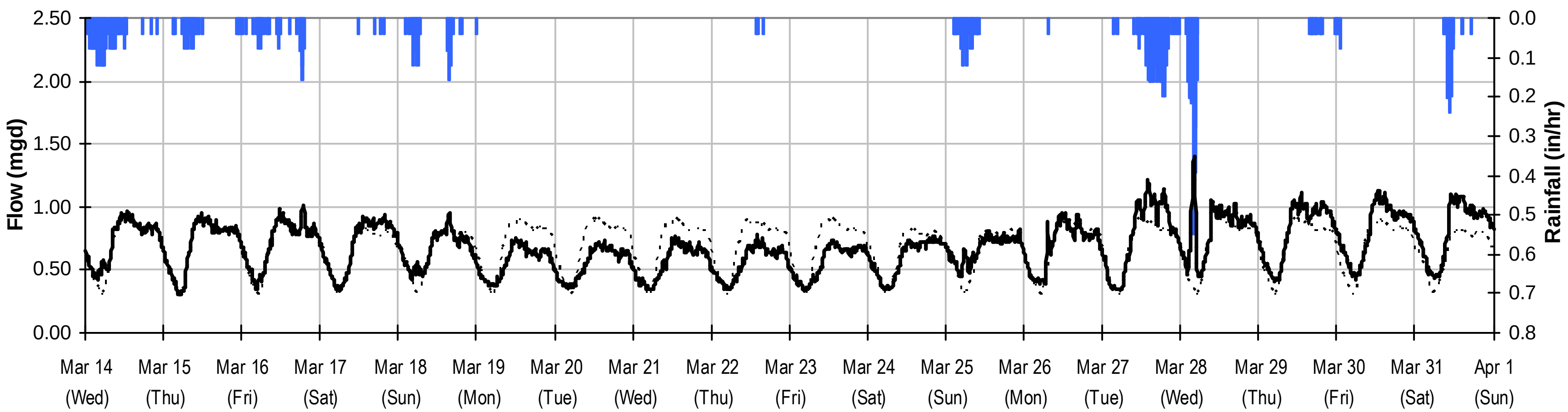
SITE 12+13

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 0.684 mgd **Peak Flow: 1.408 mgd** **Min Flow: 0.240 mgd**

Total Period Rainfall: 6.11 inches



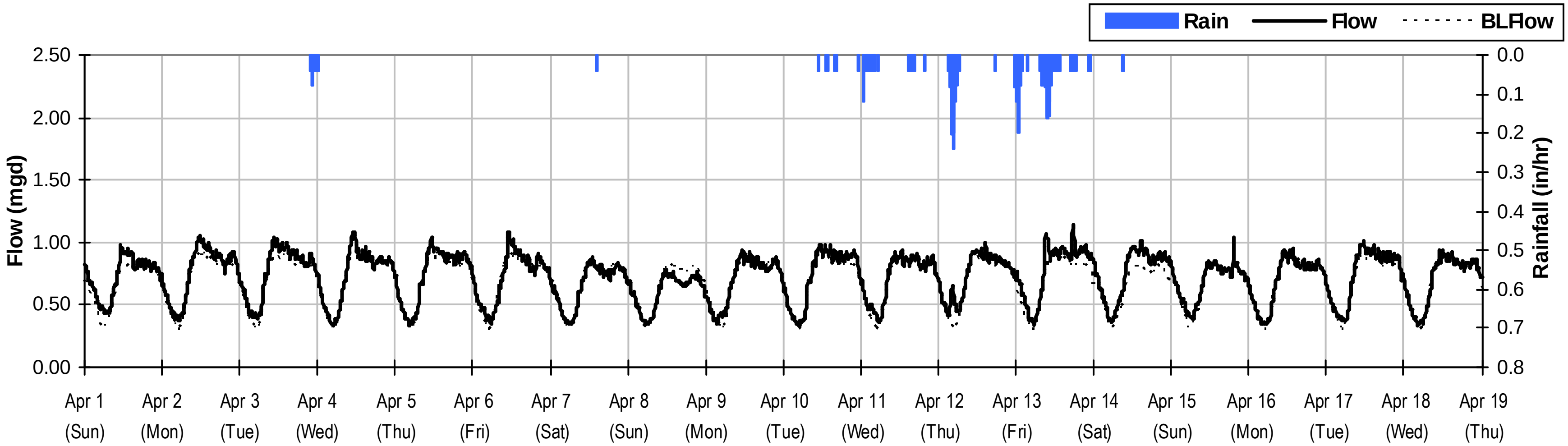


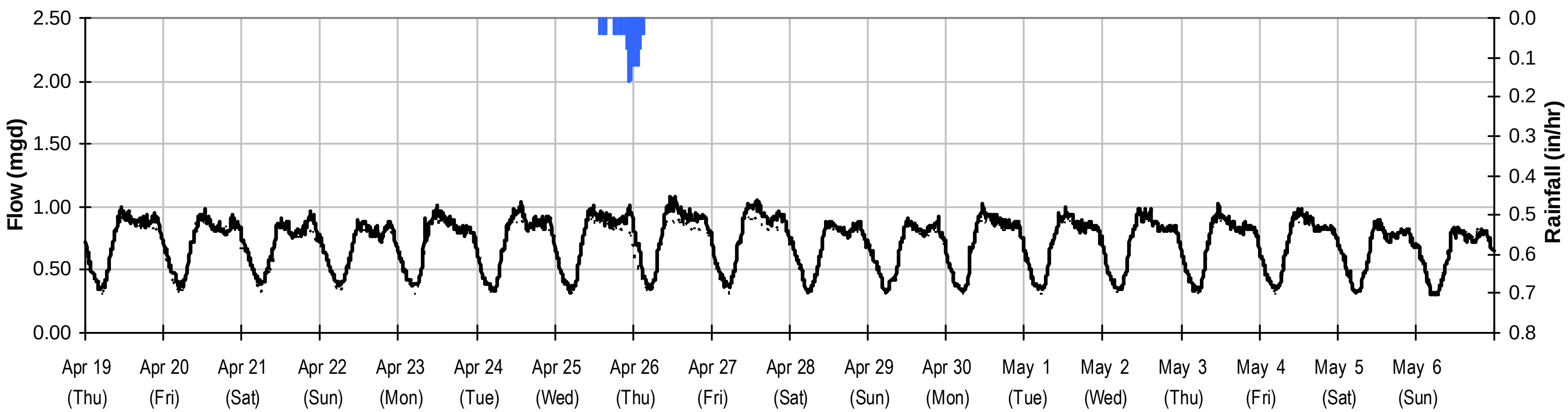
SITE 12+13

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 0.722 mgd **Peak Flow: 1.140 mgd** **Min Flow: 0.300 mgd**

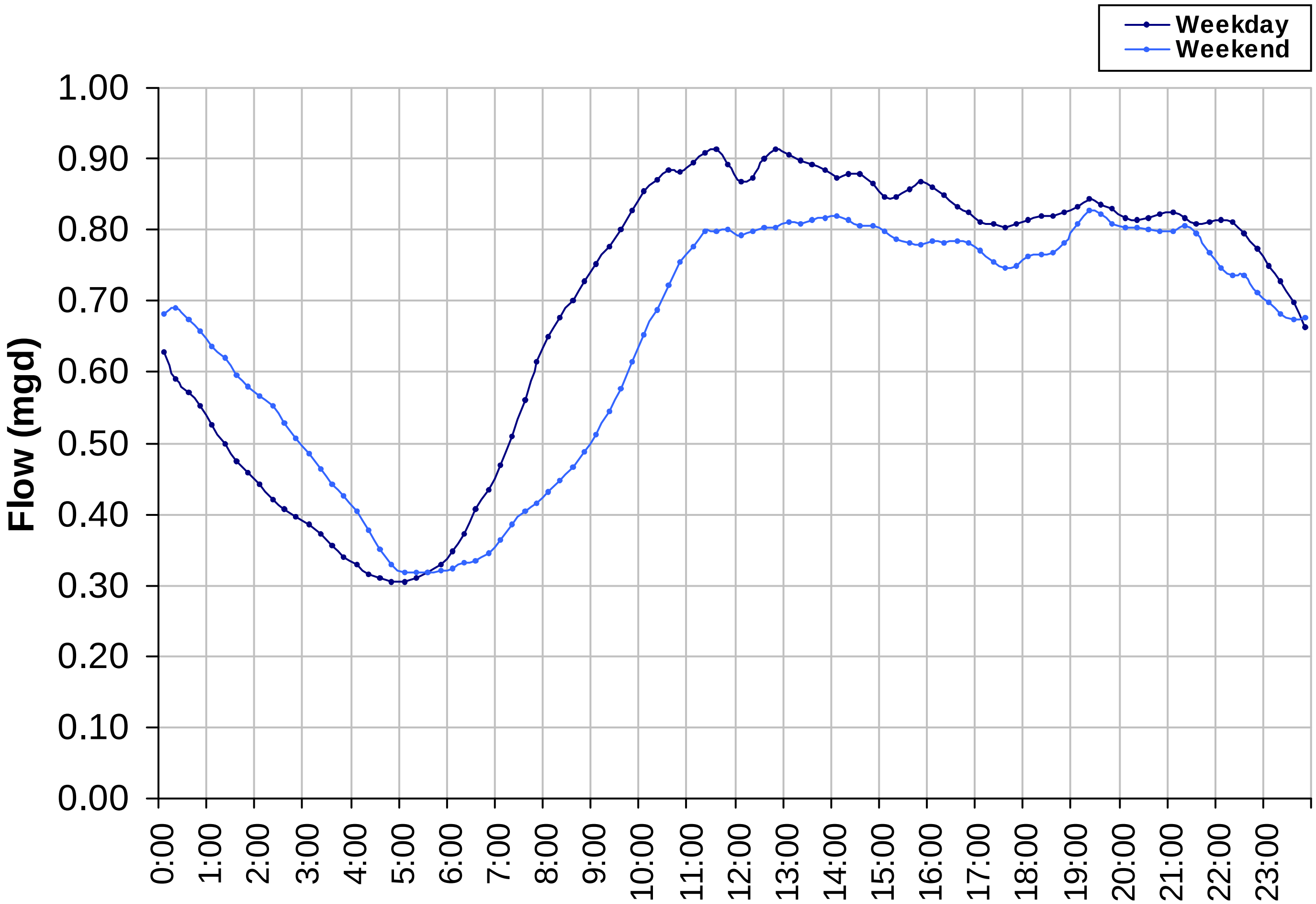
Total Period Rainfall: 2.10 inches





SITE 12+13

Baseline Flow Hydrographs

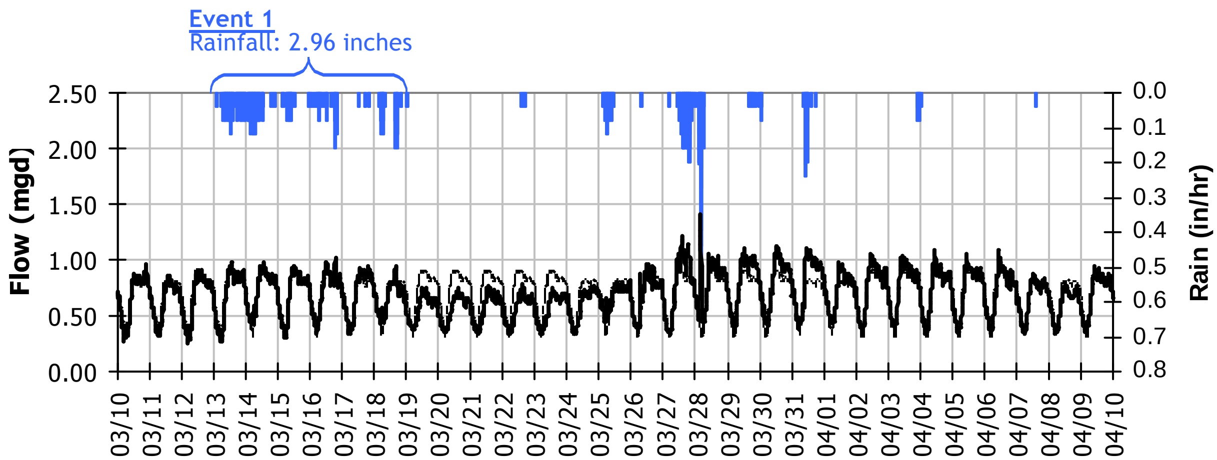


Baseline Flow:

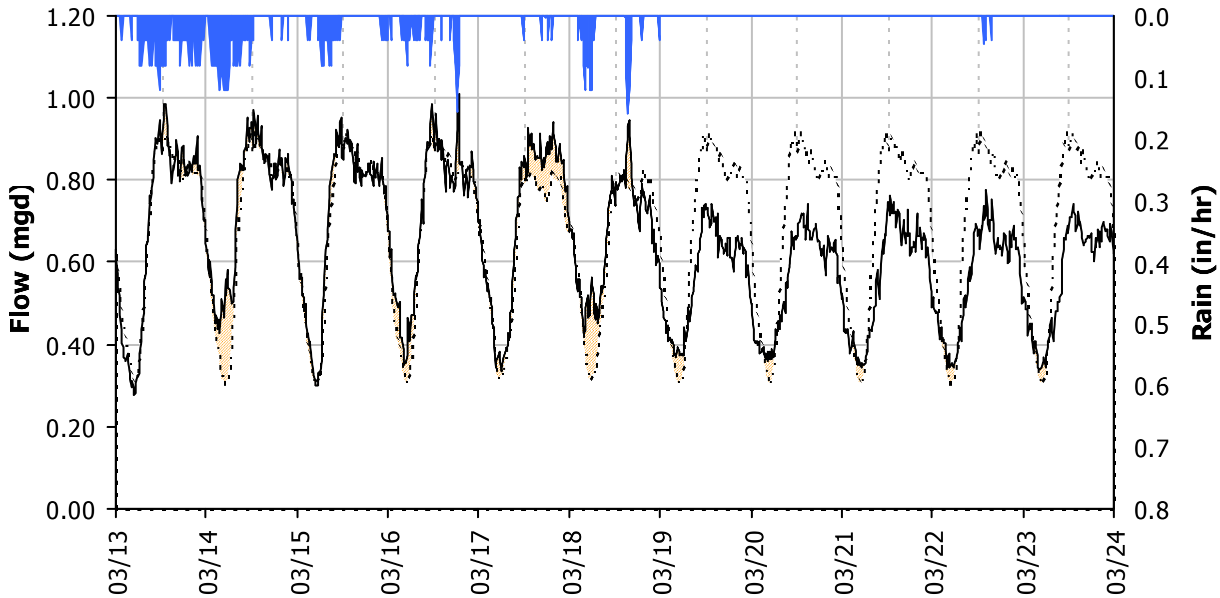
0.680 *mgd*

SITE 12+13
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

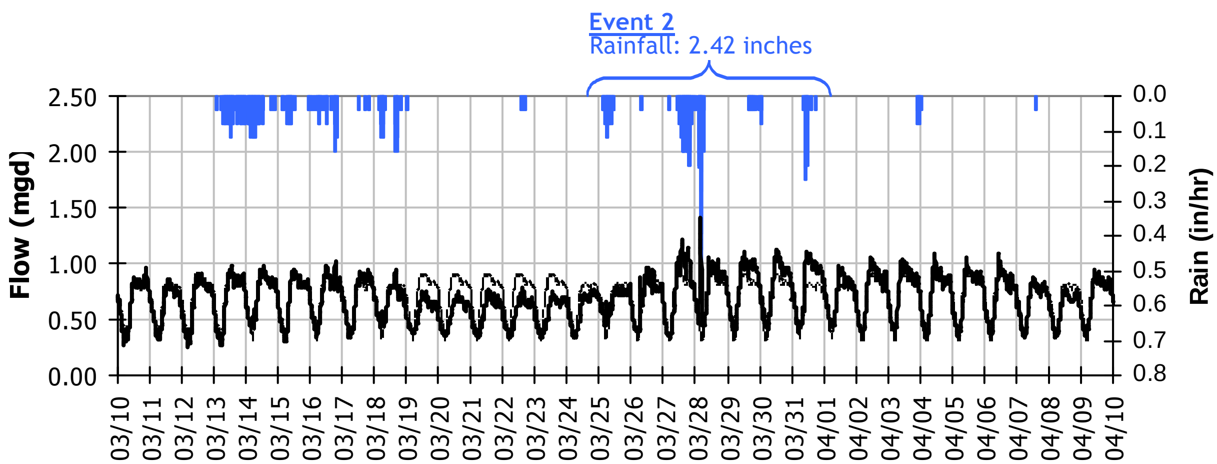


Storm Event I/I Analysis (Rain = 2.96 inches)

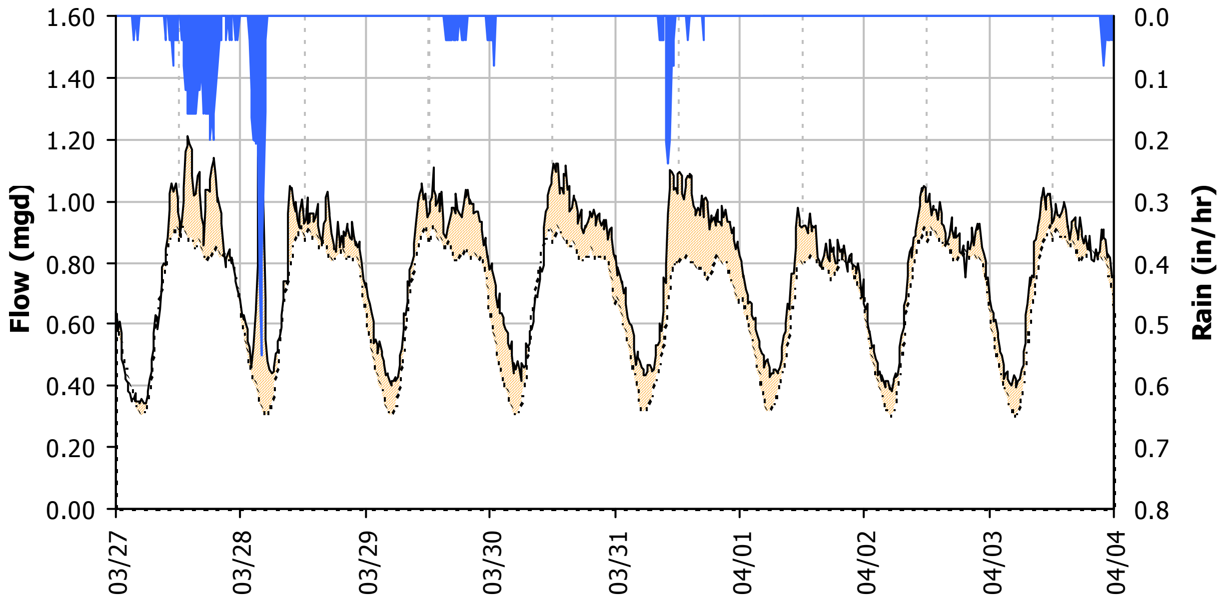
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	1.01 *mgd*	**Peak I/I Rate:**	0.26 *mgd*	**Infiltration Rate:** (3/20/2012)	0.000 *mgd*	**Total I/I:**	-497,000 *gallons*
PF:	1.49	**PkI/I:IDM:**	2,019 *gpd/IDM*	**RDI:IDM:**	0 *gpd/IDM*	**Total I/I:IDM:**	-1,287 *gal/IDM/in*
		PkI/I:Acre:	477 *gpd/acre*	**RDI:Acre:**	0 *gpd/acre*	**R-Value:**	-1.1%
		Pk I/I:ADWF:	0.39	**RDI (% of BL):**	0%	**Total I/I:ADWF:**	-0.25 *per in-rain*

SITE 12+13
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 = 2.42 inches)

Capacity

Peak Flow:	1.41	*mgd*
PF:	2.07	

Inflow

Peak I/I Rate:	1.08	*mgd*
PkI/I:IDM:	8,268	*gpd/IDM*
PkI/I:Acre:	1,954	*gpd/acre*
Pk I/I:ADWF:	1.59	

RDI (infiltration)

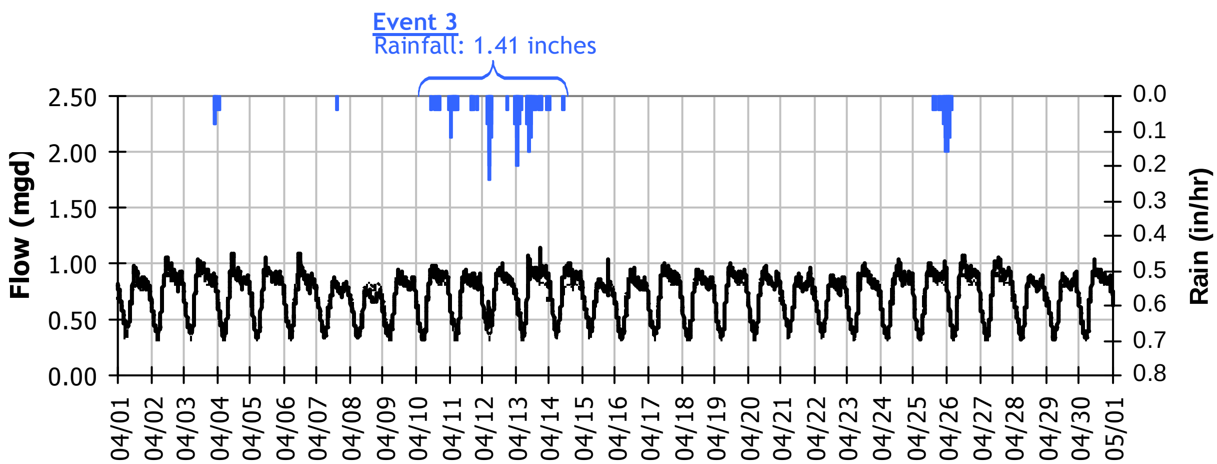
Infiltration Rate: (4/2/2012)	0.069	*mgd*
RDI:IDM:	532	*gpd/IDM*
RDI:Acre:	126	*gpd/acre*
RDI (% of BL):	10%	

Combined I/I

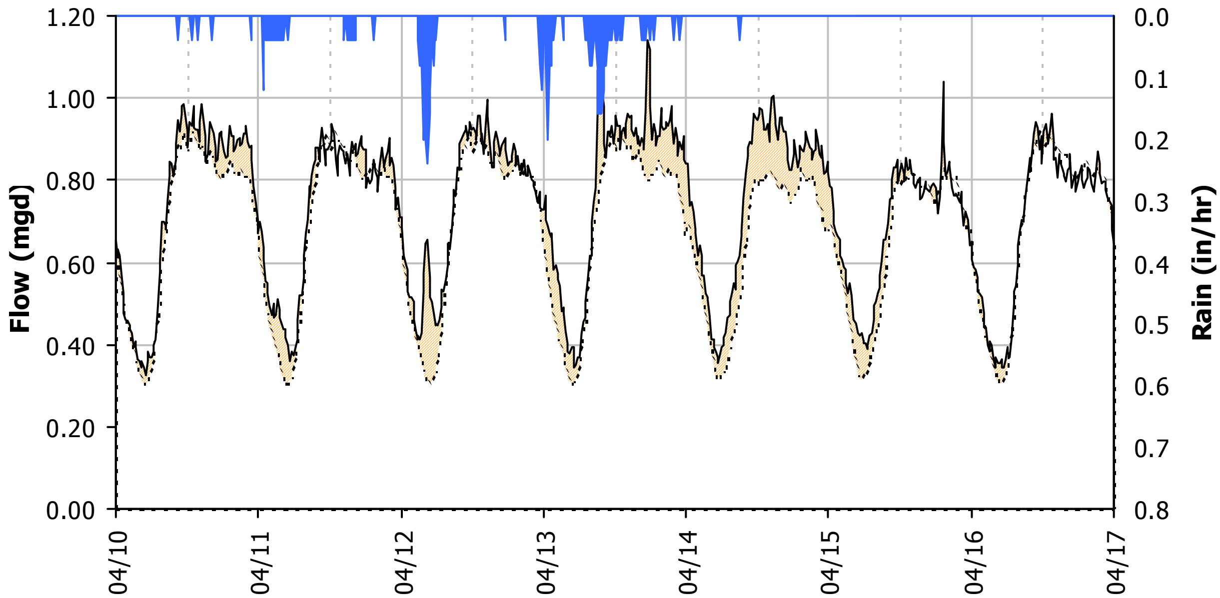
Total I/I:	846,000	*gallons*
Total I/I:IDM:	2,674	*gal/IDM/in*
R-Value:	2.3%	
Total I/I:ADWF:	0.51	*per in-rain*

SITE 12+13
I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.41 inches)

Capacity

Peak Flow:	1.14	*mgd*
PF:	1.68	

Inflow

Peak I/I Rate:	0.34	*mgd*
PkI/I:IDM:	2,634	*gpd/IDM*
PkI/I:Acre:	623	*gpd/acre*
Pk I/I:ADWF:	0.51	

RDI (infiltration)

Infiltration Rate: (4/15/2012)	0.041	*mgd*
RDI:IDM:	318	*gpd/IDM*
RDI:Acre:	75	*gpd/acre*
RDI (% of BL):	6%	

Combined I/I

Total I/I:	381,000	*gallons*
Total I/I:IDM:	2,067	*gal/IDM/in*
R-Value:	1.8%	
Total I/I:ADWF:	0.40	*per in-rain*

City of Chico

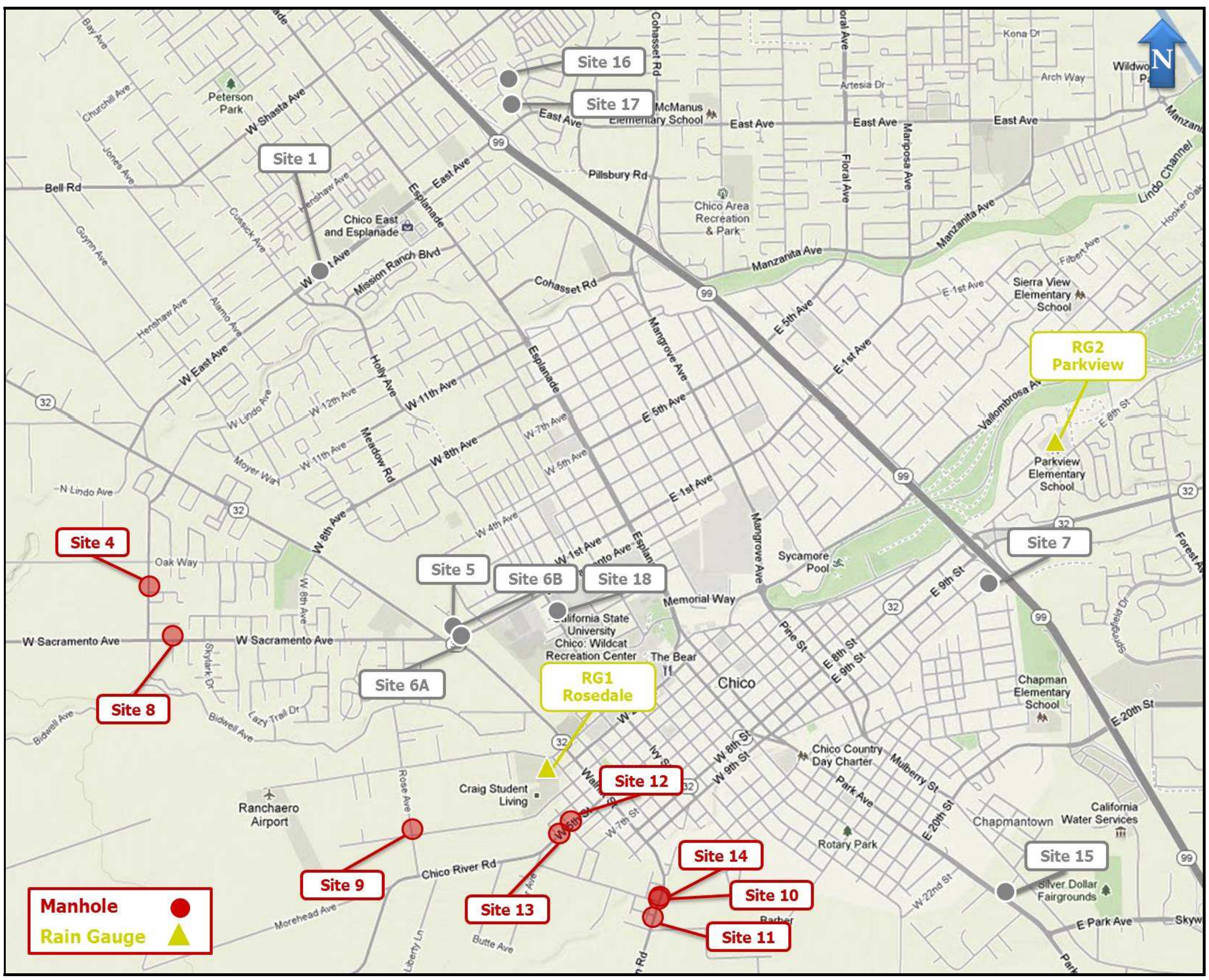
Sanitary Sewer Flow Monitoring and I/I Study

Year 2012

Monitoring Site: Total

Location: Sum of Sites 4, 8, 9, 10, 11, 12, 13 and 14

Vicinity Map:

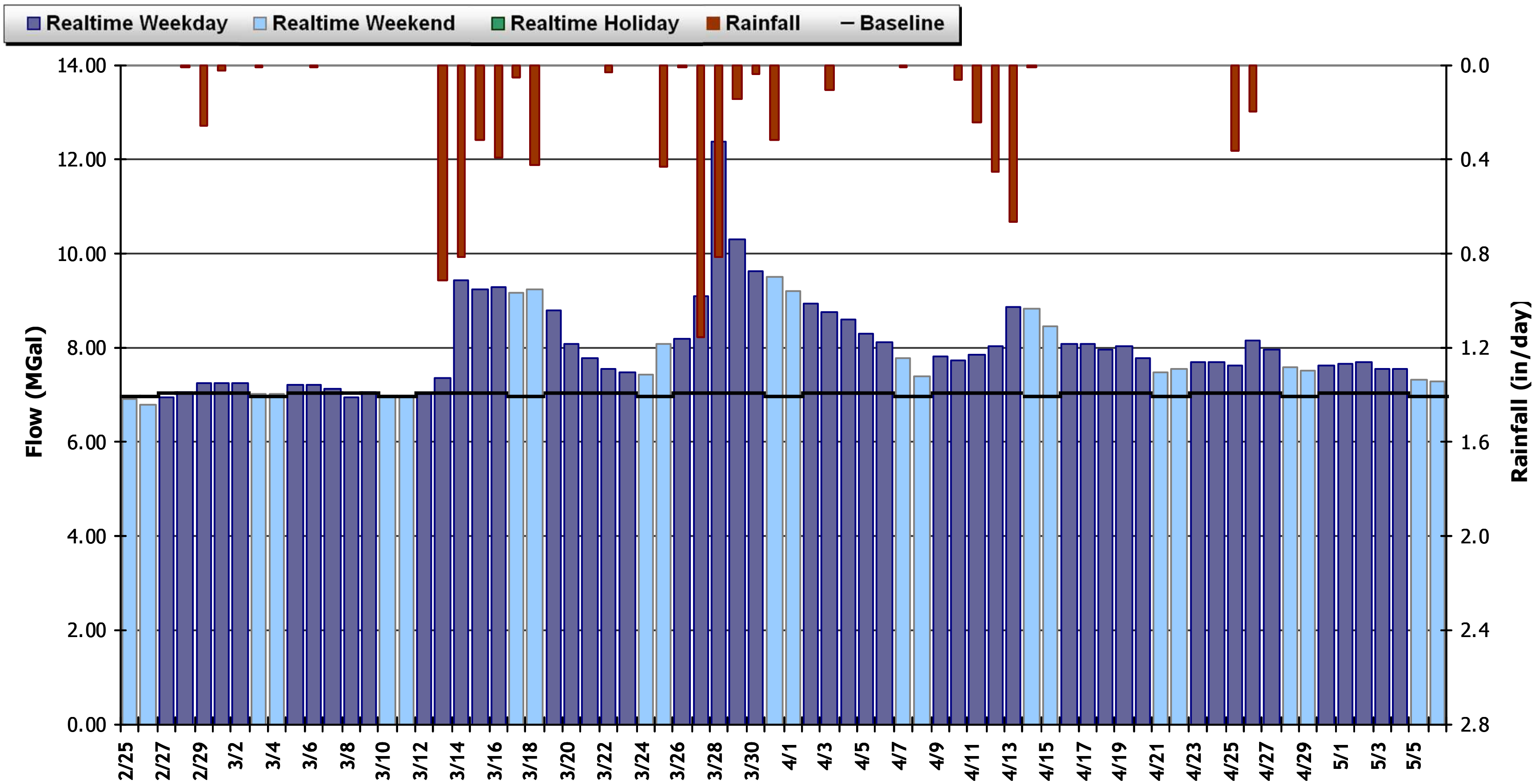


TOTAL

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 7.981 MGal **Peak Daily Flow: 12.392 MGal** **Min Daily Flow: 6.806 MGal**

Total Period Rainfall: 8.27 inches

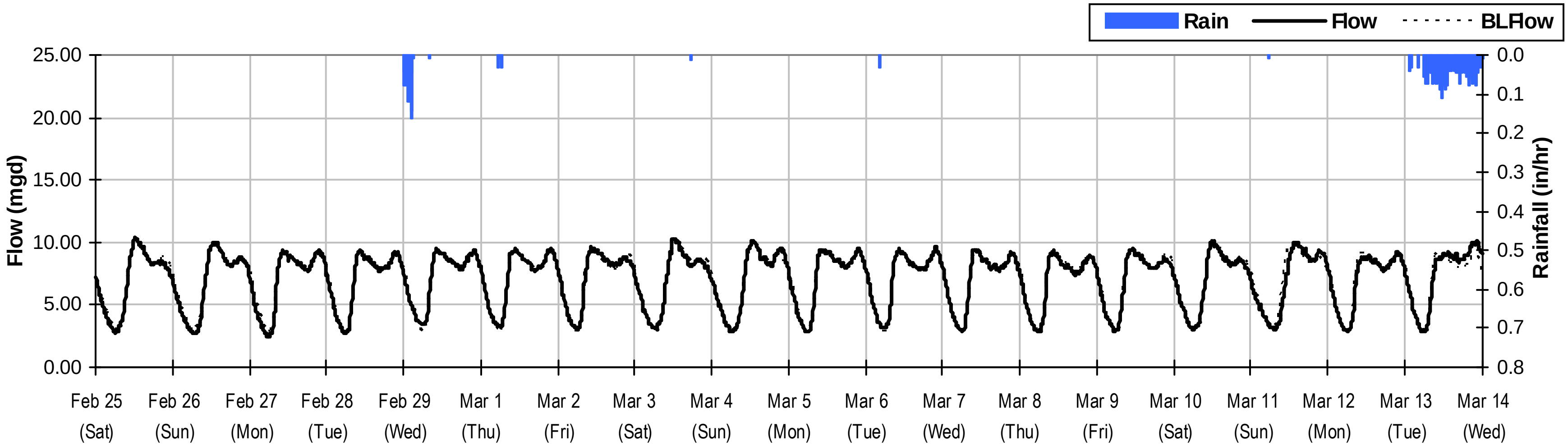


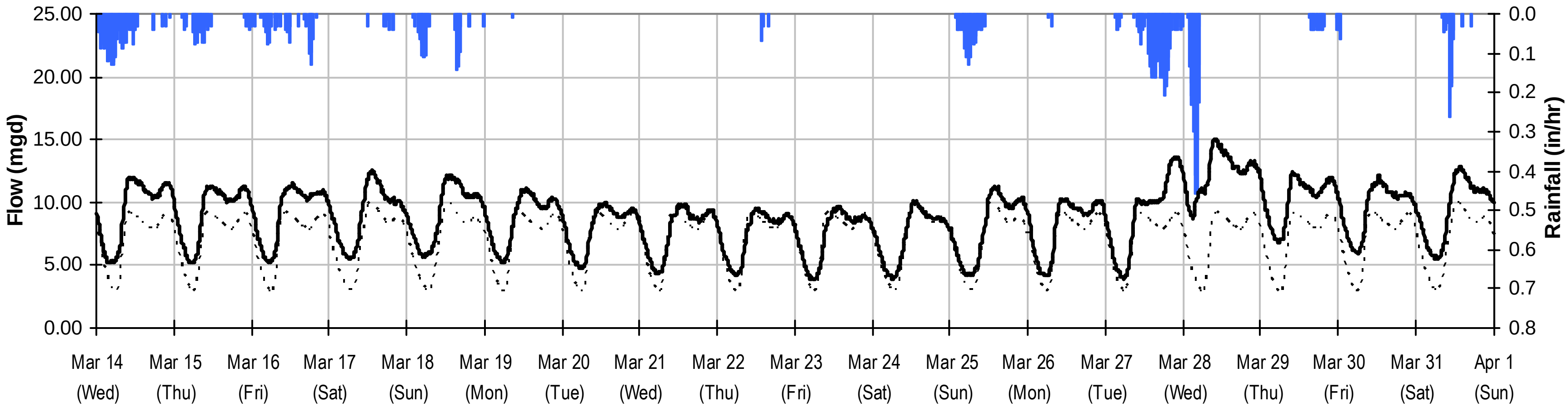
TOTAL

Period Flow Summary: February 25 to April 1, 2012

Avg Flow: 8.001 mgd **Peak Flow: 15.060 mgd** **Min Flow: 2.485 mgd**

Total Period Rainfall: 6.16 inches



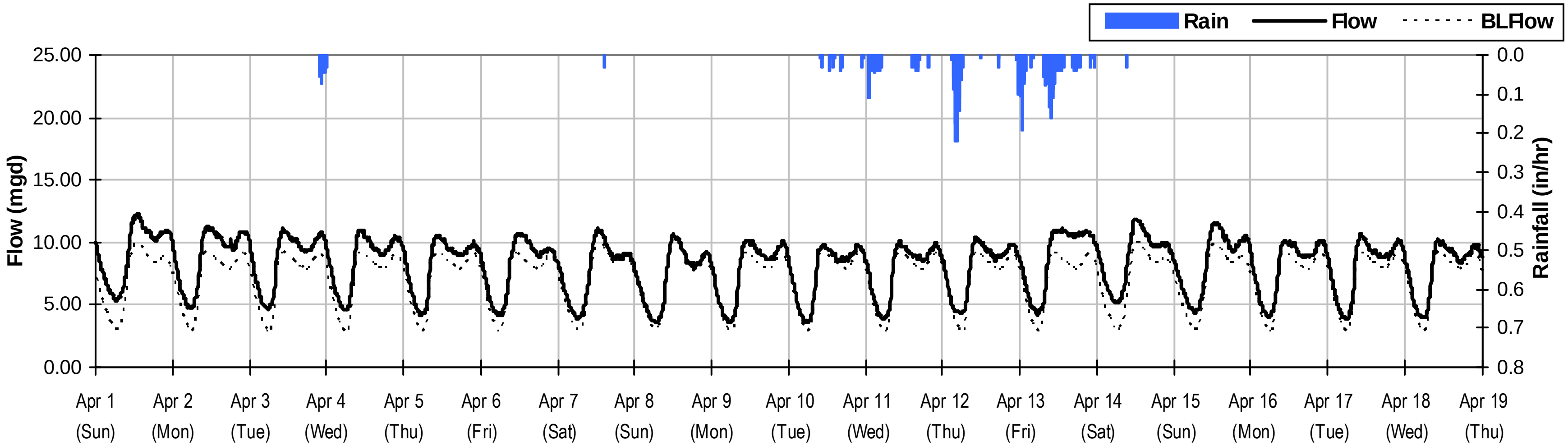


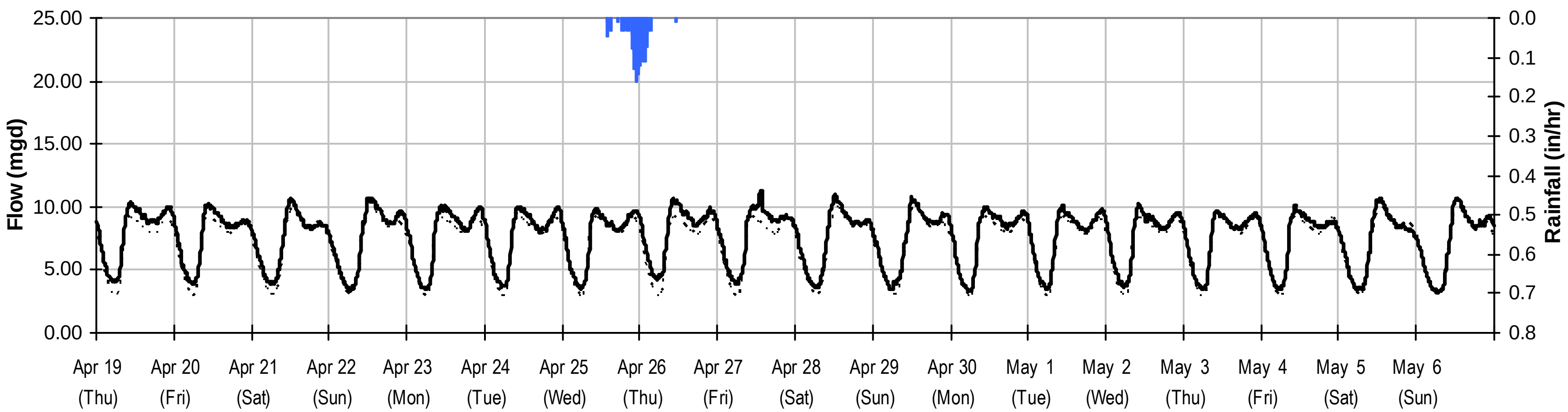
TOTAL

Period Flow Summary: April 1 to May 7, 2012

Avg Flow: 7.962 mgd **Peak Flow: 12.246 mgd** **Min Flow: 3.219 mgd**

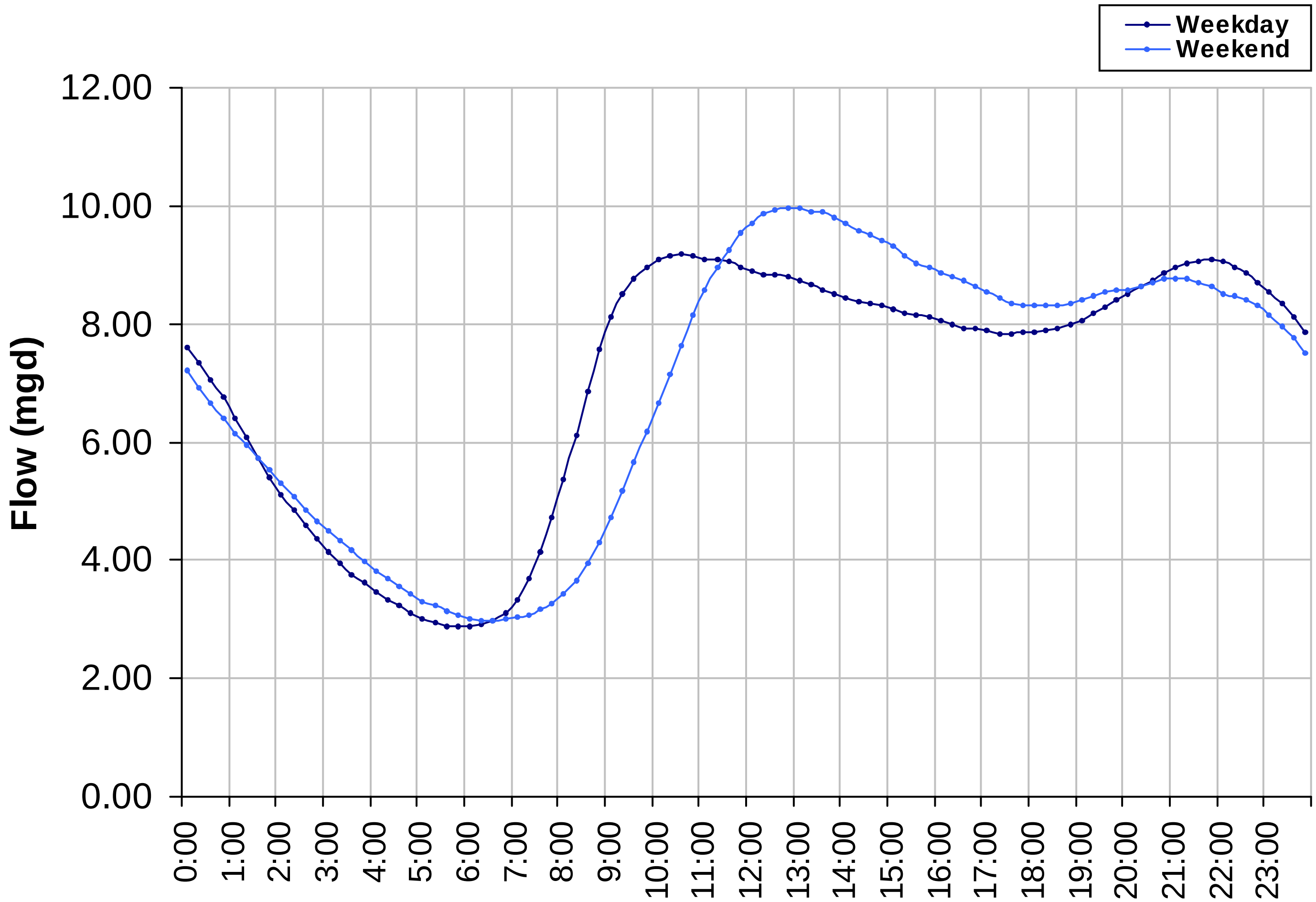
Total Period Rainfall: 2.11 inches





TOTAL

Baseline Flow Hydrographs

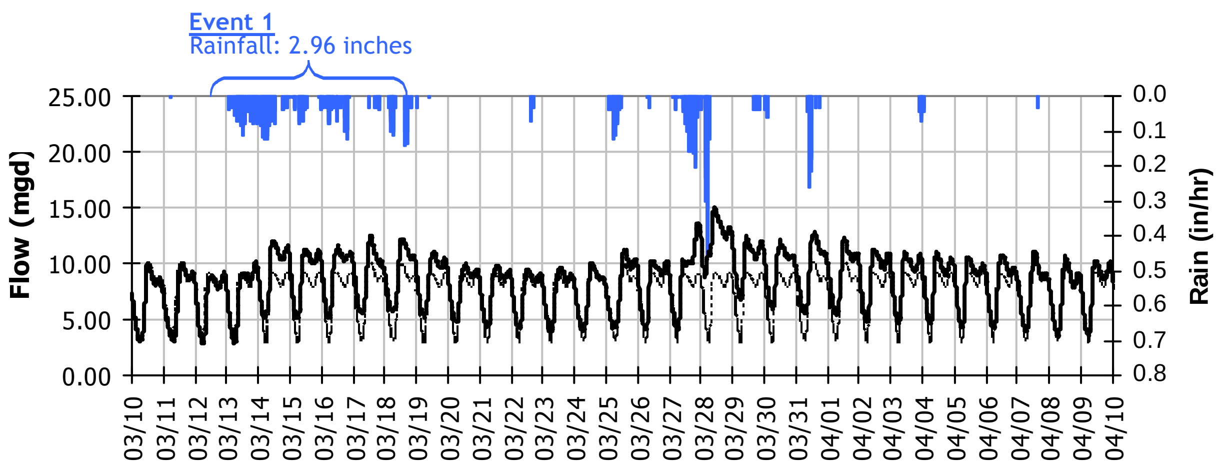


Baseline Flow:

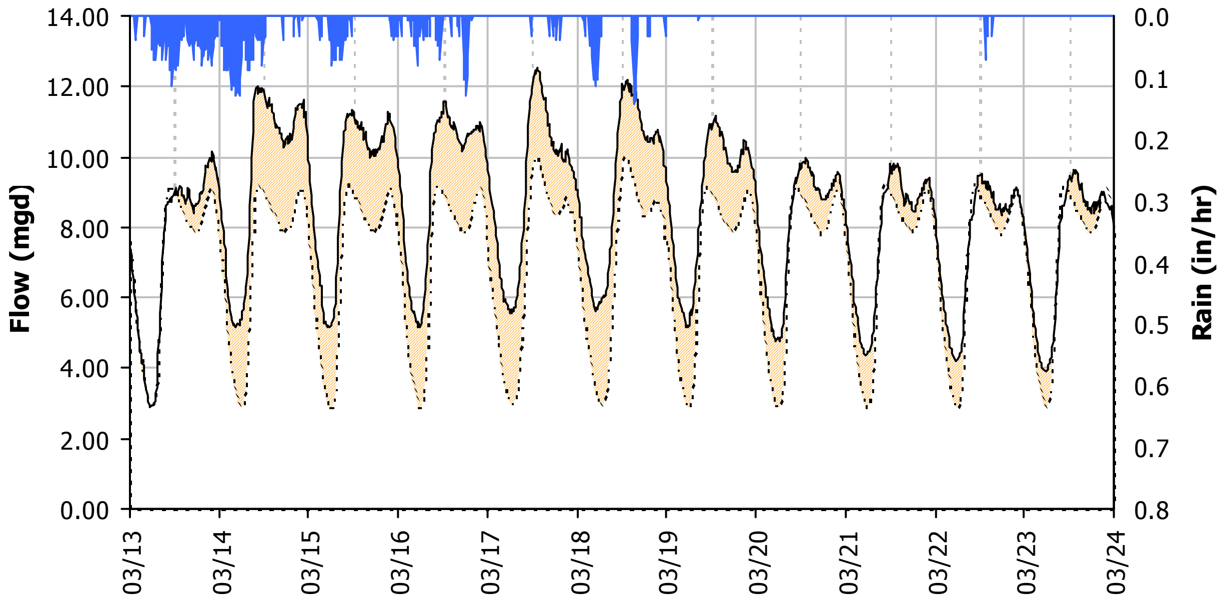
7.010 *mgd*

SYSTEM
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 = 2.96 inches)

Capacity

Peak Flow:	12.51	*mgd*
PF:	1.78	

Inflow

Peak I/I Rate:	3.12	*mgd*
PkI/I:IDM:	1,322	*gpd/IDM*
PkI/I:Acre:	226	*gpd/acre*
Pk I/I:ADWF:	0.44	

RDI (infiltration)

Infiltration Rate: (3/20/2012)	1.024	*mgd*
RDI:IDM:	434	*gpd/IDM*
RDI:Acre:	74	*gpd/acre*
RDI (% of BL):	15%	

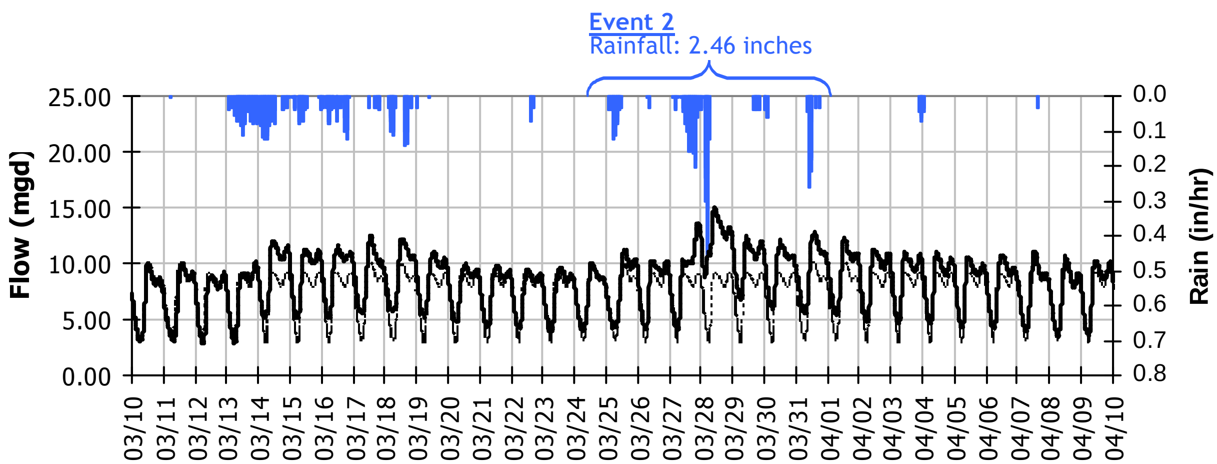
Combined I/I

Total I/I:	16,168,000	*gallons*
Total I/I:IDM:	2,318	*gal/IDM/in*
R-Value:	1.5%	
Total I/I:ADWF:	0.78	*per in-rain*

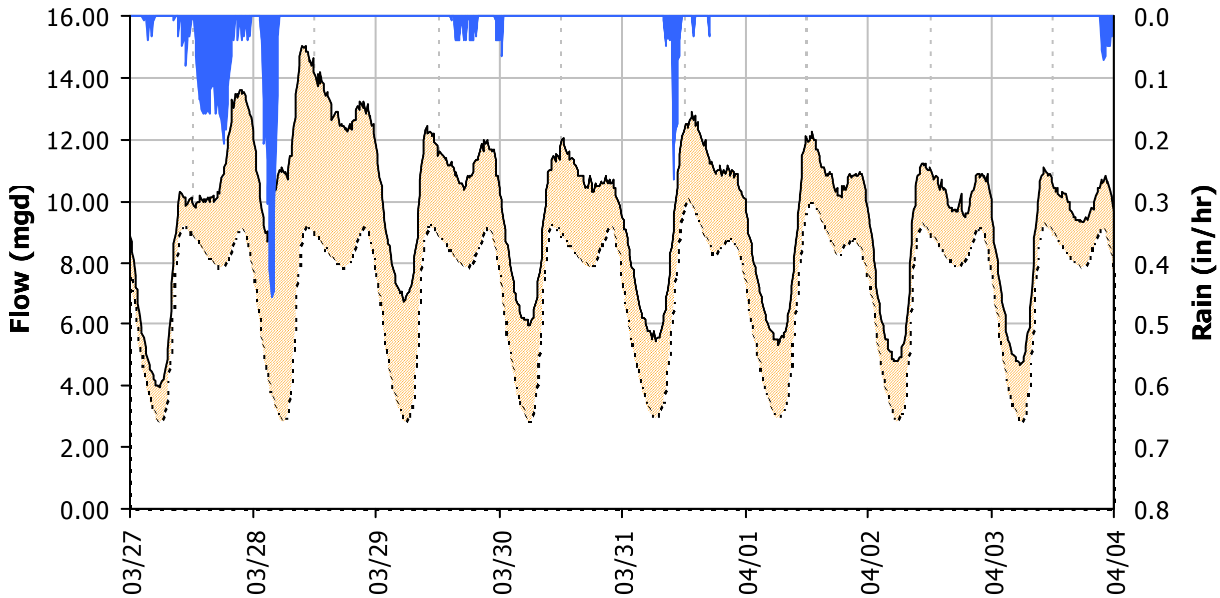
SYSTEM

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 = 2.46 inches)

Capacity

Peak Flow:	15.06	*mgd*
PF:	2.15	

Inflow

Peak I/I Rate:	8.23	*mgd*
PkI/I:IDM:	3,490	*gpd/IDM*
PkI/I:Acre:	595	*gpd/acre*
Pk I/I:ADWF:	1.17	

RDI (infiltration)

Infiltration Rate: (4/2/2012)	1.903	*mgd*
RDI:IDM:	807	*gpd/IDM*
RDI:Acre:	138	*gpd/acre*
RDI (% of BL):	27%	

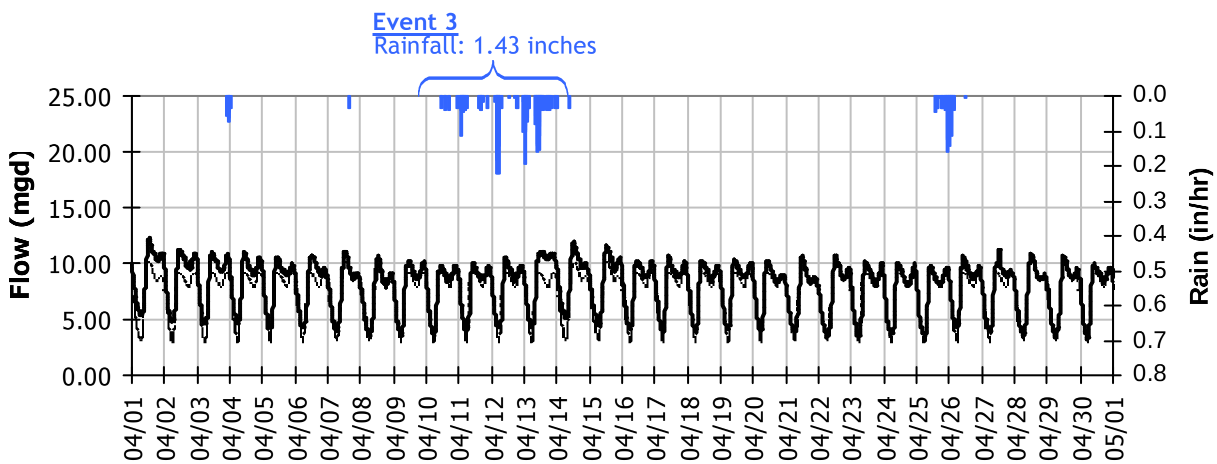
Combined I/I

Total I/I:	21,726,000	*gallons*
Total I/I:IDM:	3,741	*gal/IDM/in*
R-Value:	2.4%	
Total I/I:ADWF:	1.26	*per in-rain*

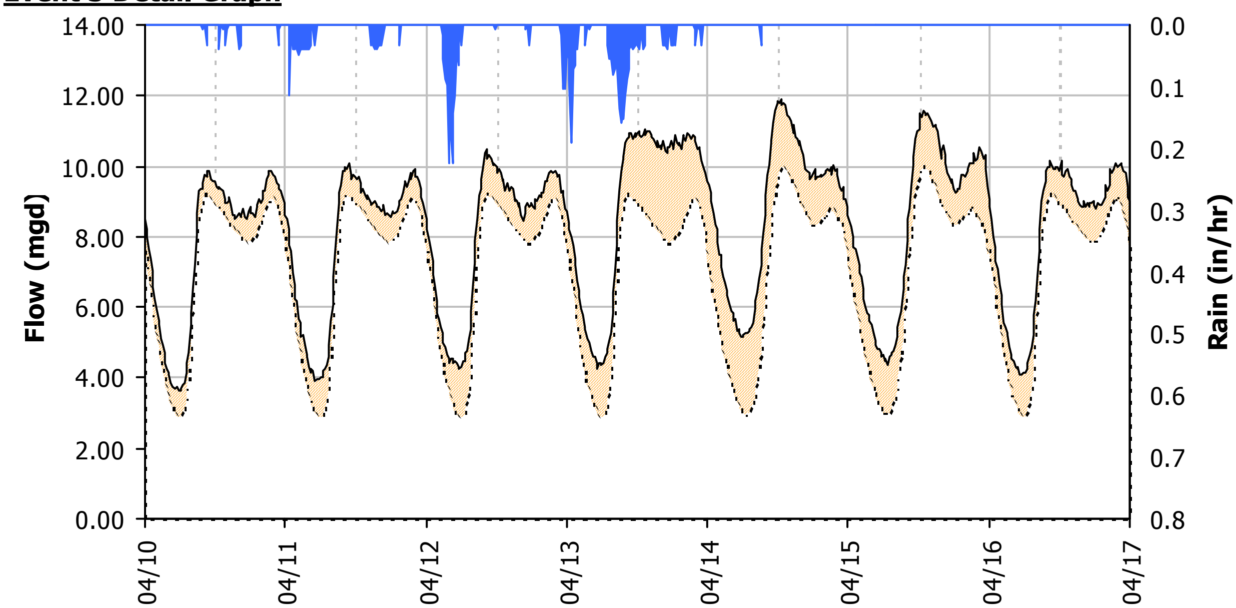
SYSTEM

I/I Summary: Event 3

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 3 Detail Graph



Storm Event I/I Analysis (Rain = 1.43 inches)

Capacity

Peak Flow:	11.92	*mgd*
PF:	1.70	

Inflow

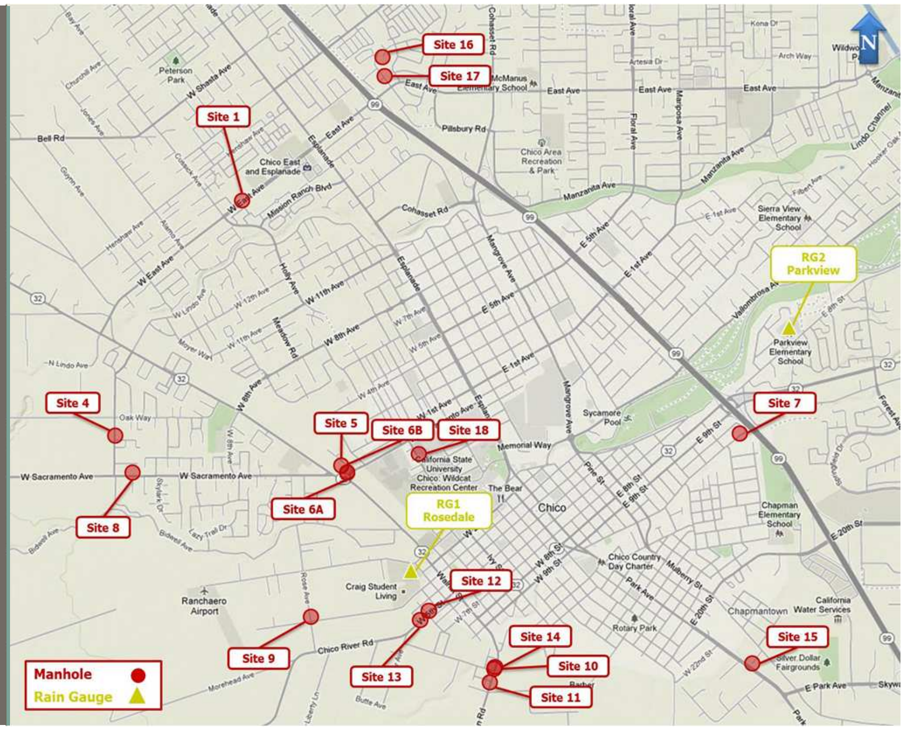
Peak I/I Rate:	2.97	*mgd*
PkI/I:IDM:	1,258	*gpd/IDM*
PkI/I:Acre:	215	*gpd/acre*
Pk I/I:ADWF:	0.42	

RDI (infiltration)

Infiltration Rate: (4/15/2012)	1.507	*mgd*
RDI:IDM:	639	*gpd/IDM*
RDI:Acre:	109	*gpd/acre*
RDI (% of BL):	22%	

Combined I/I

Total I/I:	8,789,000	*gallons*
Total I/I:IDM:	2,615	*gal/IDM/in*
R-Value:	1.6%	
Total I/I:ADWF:	0.88	*per in-rain*



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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**
858.576.0004 **Fax**

Seattle
14900 Interurban Avenue, Suite 268
Seattle, WA 96818
206.674.4560 **Tel**
206.674.4561 **Fax**

Houston
8220 Jones Road, Suite 500
Houston, TX 77065
713.840.6490 **Tel**
713.840.6491 **Fax**

vaengineering.com

APPENDIX C – HYDRAULIC MODELING SOFTWARE EVALUATION TECHNICAL MEMORANDUM

CITY OF CHICO

SANITARY SEWER MASTER PLAN UPDATE

TECHNICAL MEMORANDUM NO. 1

HYDRAULIC MODELING SOFTWARE EVALUATION

DRAFT
February 2011

CITY OF CHICO

SANITARY SEWER MASTER PLAN UPDATE

TECHNICAL MEMORANDUM
NO. 1
HYDRAULIC MODELING SOFTWARE EVALUATION

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HYDRAULIC MODELING SOFTWARE EVALUATION

1.0 INTRODUCTION

The City of Chico (City) has contracted with Carollo Engineers, Inc. (Carollo) to update its Sanitary Sewer Master Plan (2012 Master Plan). As part of the City's previous 2003 Sanitary Sewer Master Plan Update (2003 Master Plan), a hydraulic computer model of the City's trunk sewer system was developed using Version 6.1 of the HYDRA hydraulic modeling software application, by Pizer, Inc. (Pizer).

In the past decade, improvements have been made to the hydraulic modeling software available on the market. Some examples of the improvements that have been made include modifications to the hydraulic routing engine as well as an enhanced graphical user interface (GUI), model output reports, and geographic information systems (GIS) compatibility. This technical memorandum presents a summary of the major software vendors, briefly explains software features, compares the advantages and disadvantages of each software program, and provides a recommendation for the software program to be used for preparation of the 2012 Master Plan.

Appendix A includes a paper that provides a basic overview of what a sewer system hydraulic model is, as well as an explanation of the different computational methods that are used in the hydraulic models available in the marketplace today.

2.0 SOFTWARE VENDORS

There are many software packages that can potentially address the needs of the City, and all vary in their methods of analysis and user friendliness. Sanitary sewer hydraulic modeling software packages from six (6) major software vendors were evaluated and are listed below in alphabetical order:

- **Bentley Systems, Inc.**: Bentley Systems, Inc. (Bentley) is an engineering and architecture software company with corporate headquarters in Exton, Pennsylvania. Bentley added a suite of water, wastewater, and storm water analysis software through its acquisition of Connecticut based Haestad Methods, Inc. in 2004. The company offers two wastewater collection system software packages: SewerCAD and SewerGEMS.

- **Computational Hydraulics Institute**: Computational Hydraulics International (CHI) is a consulting engineering firm specializing in stormwater management. CHI is headquartered in Ontario, Canada with a US office in New York. The company has been providing the PC-SWMM software package since 1984.

- **Danish Hydraulic Institute**: The Danish Hydraulic Institute (DHI) is an international hydraulic consulting and research institution headquartered in Denmark. There are three offices in the United States: Portland, Oregon, St. Petersburg, Florida, and Solana Beach, California. The company's MIKE URBAN software application supports two computational engines for urban hydrology and open channel/closed pipe hydraulics: the Environmental Protection Agencies (EPA) open source SWMM5 engine, and DHI's proprietary MOUSE computational engine.

- **Innovyze:** Innovyze is headquartered in Broomfield, Colorado, and is a leading provider of software products geared towards hydraulics and hydrology. In 2009, Colorado based MWH Soft and British based Wallingford Software merged into a single company (MWH Soft), which in 2011 was renamed Innovyze. Innovyze offers three main sewer system modeling software packages. These are InfoSewer/H_2OMAP Sewer, InfoSWMM/H_2OMAP SWMM, and InfoWorks.

- **Pizer, Inc.**: Pizer is a software company with headquarters in Seattle, Washington. The company has been providing the Hydra software package since 1973.

- **XP Software, Inc.:** XP-Software, Inc is headquarted in Portland, Oregon. The company has been providing the XP-SWMM software package since 1993.

A comparison of the technical features of the six software vendors and the modeling software that each vendor offers is presented in Table 1. This table allows a side-by-side comparison of similar features in each software package. The features that have the greatest impact on the selection of an appropriate software package are discussed in detail as part of this memo.

3.0 EVALUATION CRITERIA

As a way to evaluate the pros and cons of each software package, several criteria are used for a software evaluation, including:

- Dry and Wet Weather Flow Calculations Methods
- Hydraulic Flow Routing Calculation Algorithms
- GIS Interface
- Scenario Management
- Customer Service and Support
- Cost
- Ease of Use
- Internet Based Model Network/Output Viewer

Table 1 Model Comparison
Sanitary Sewer Master Plan Update
City of Chico

	Innovyze			Bentley		Pizer	CHI	XP Software	DHI
Technical Characteristics	H$_2$OMAP Sewer/ InfoSewer[1]	H$_2$OMAP SWMM/ InfoSWMM[1]	InfoWorks	SewerCAD[2]	SewerGEMS	Hydra[3]	PCSWMM[4]	XP-SWMM	MIKE URBAN[5]
Computation Method	Quasi-Dynamic and Steady State	Dynamic Wave and Kinematic Wave	Dynamic Wave	Standard Step	Dynamic Wave and Kinematic Wave	Kinematic Wave	Dynamic Wave and Kinematic Wave	Dynamic Wave and Kinematic Wave	Dynamic Wave
GIS Compatible	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reads shapefiles directly	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Writes to shapefiles directly	Yes	Yes	No	Yes	Yes	Yes	No	No	No
Tools to fix GIS data topology problems	Yes	Yes	Yes	Partial	Yes	Partial	Partial	No	Partial
Utilizes Standard Database Format	Yes	Yes	Yes	Proprietary	Proprietary	No	Yes	ASCII-based	ASCII-based
Automatically sizes new mains	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes
Calculates pipe replacement costs	Yes	Yes	No	Yes	Yes	Yes	No	No	No
Calculates loads based on GIS land use	Yes	Yes	Yes	via GIS	via GIS	No	Yes	Yes	Yes
Time step	User Defined	User Defined	User Defined	User Defined	User Defined	Restricted	User Defined	User Defined	User Defined
Scenario manager	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Customizable tabular reports	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Graphically compares the results of multiple simulations	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Displays GIS data layers on screen	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Export tabular data to excel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internet Based Model Network/Output Viewer Available	Yes	Yes	Yes	No	No	No	Yes	Yes	No
Single Licenses Cost (2,000 pipe version)	$5,000	$7,000	$18,000	$7,995	$12,995	$4,500 ($3,150)	$2,999 ($3,999)	$12,195	$20,250
Maintenance and Service (Annual Fee)	$800	$1,500	$2,500	$1,925	$3,120	$1,250	$999 ($1,299)	$1,830	$2,370
Water Modeling Software	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes

Notes:
(1) Costs presented are for the standard fixed seat license. Pricing differs for the floating seat licenses and the suite packages.
(2) SewerCAD evaluation is based on the stand-alone version. SewerCAD with AutoCAD is priced at $9,995 for 2000 pipe version with $2,405 annual support and maintenance fee.
(3) Hydra comes as a single unlimited pipe version. Cost is $4,500 for a new license, $3,150 to updrade to Hydra Version 7 from Version 6.
(4) Pricing represents a single user license of PCSWMM Standard. Cost in parentheses is for PCSWMM Professional.
(5) Pricing is for MIKE URBAN supporting the MOUSE (and SWMM5) engine. MIKE URBAN supporting MOUSE also supports the EPANET engine, which means that is doubles as a sewer/storm as well as a water distribution system modeling software package.

Carollo recommends the City select a model that is easy to operate, compatible with GIS software and data sources, has the ability to analyze several scenarios with multiple facility options, and is cost effective. City staff may also find it necessary to use the software vendor's customer service and support to troubleshoot operating issues associated with model use. Each of the criteria listed above is briefly discussed in this TM.

3.1 Dry and Wet Weather Flow Calculations

Many of the models listed here were first developed not only for sanitary sewers but also for stormwater sewers. Therefore, these models contain modules for hydrologic (or wet weather flow - WWF) calculations as well as hydraulic calculations. When used as sanitary sewer models, the wet weather flow calculations are used to calibrate the infiltration and inflows (I/I) that enter the system as the result of rainfall events, and then apply these I/I characteristics to other rainfall events. Several of the models also have the ability to project dry weather flows (DWF) based on population, land use data, or parcel level water usage. Estimating accurate DWF and WWF is critical because all hydraulic calculations are based on these flows.

3.1.1 Dry Weather Flows

DWFs can be entered directly into a model, as a series of diurnal flows, or can be generated in the model based on population or land use estimates. Most of the models reviewed can accept a time series of diurnal flows. Certain models also have the ability to generate DWFs based on average dry weather flows (ADWFs) that are generated based on a population in a basin (in gallons per capita per day) or based on land use (in gallons per acre per day). Once the ADWF is estimated, a diurnal pattern can be applied to the ADWF.

3.1.2 Wet Weather Flows

WWFs can be generated using a variety of hydrologic techniques typically applied to stormwater runoff in order to approximate I/I in the collection system. Most models generate an I/I hydrograph by converting rainfall into flow based on the area that contributes flows to the collection system. Unlike stormwater, the area contributing to I/I in a sanitary sewer basin cannot be directly measured. Therefore, the area term is really a percent of the total sewer basin area, or "effective area," that contributes I/I (e.g., 5 percent).

Simple models usually employ a unit hydrograph type algorithm to generate the WWF hydrograph. This usually includes the use of an "effective area" variable that is sometimes referred to as an R-value. An R-value represents the amount of rainfall that enters a sewer basin as a percent of the total rainfall that fell on the basin (and is usually reported as a percentage). This variable, along with a variable that approximates the time of concentration of the basin is applied to the intensity of rainfall during a storm to calculate the I/I hydrograph. Some models include two or more of these types of hydrographs – one for inflow, and one or more for infiltration. If the system being modeled experiences little I/I, these simplistic routines may be all that is warranted.

Complex models employ a more rigorous estimation of WWFs. These models include more variables to better approximate the peak, volume, and shape of the I/I hydrograph by taking into account soil saturation and near surface groundwater interaction. These routines include linear reservoir, non-linear reservoir, and other combinations of algorithms. The more complex models like MOUSE, Infoworks CS, PCSWMM, and XP-SWMM employ these more complex routines to better approximate I/I hydrographs for systems that experience excessive WWFs.

3.2 Hydraulic Calculations

There are several differences among sewer models in how hydraulic computations are performed. The most important difference is in how the calculations involve time. There are two primary kinds of hydraulic sewer models:

- **Steady State** models do not account for changes in flow over time, and
- **Dynamic Models** involve time in their calculations, most notably in being able to vary flow over time and calculate the associated changes in depth and velocity.

Several other refinements may be used to further differentiate sewer hydraulic models, namely in how they handle changes in flow characteristics over the length of the channel, or spatial changes. Differences in the assumptions in the underlying equations may make an important difference in certain situations, while for others the “simpler is better” dictum may prevail. In other words, it is not always true that complex models are always “better,” it depends on the problem to be solved. Common differences in model calculations are demonstrated in Table 2 and Table 3.

3.2.1 Terminology

To simulate the flow of water in sewers, the equations describing the depth and velocity of flow through the sewerage network must be solved. Each sewer simulation model discussed above solves some form of these equations, known formally as the “1-dimensional Saint Venant equations of open channel flow.” The St. Venant equations are comprised of two simultaneous equations: a continuity equation that describes the conservation of mass and a momentum equation that describes the conservation of energy. While some models solve the complete equations with all terms included, other models solve simplifications of the equations to facilitate faster run times or to evaluate specific conditions that do not require the full sophistication of the complete equations.

Technical definitions from the field of open channel hydraulics are helpful to better understand the differences between different model solution techniques and to assist in the model selection process. The terms describe how depth and velocity of open channel flow is computed over the length of the channel over the simulation time period.

Temporal Terms:

Steady State: The flow rate is assumed constant in time at any point along the channel. Flow may change along the length of the channel (i.e., a constant tributary flow rate may be added at a point along the channel, or a diversion may reduce the flow by a constant rate at a certain point along the channel). Steady State model assumptions, the formulas used and the software that employ the specified methods are summarized in Table 2.

Table 2 Steady State Assumptions and Models
Sanitary Sewer Master Plan Update
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	Spatial Assumptions	Model or Equation
Uniform Flow	Water surface is parallel to slope of pipe invert.	Manning Equation
Varied Flow	Water surface may vary in depth along the length of the pipe or channel.	SewerCAD

Dynamic: In dynamic models, also known as "unsteady state" models, the flow rate may change over time. There are four primary solution schemes to the St. Venant equations listed below and the dynamic routing methods, assumptions, and modeling software for each are summarized in Table 3. :

a. "Kinematic Wave" assumption, the most simple of the dynamic models,

b. "Diffusion Wave" or "Non inertia" assumption. Both acceleration (inertial) terms are ignored.

c. "Quasi-Dynamic" - Four of five momentum terms are used. Only the local acceleration term is dropped.

d. "Dynamic Wave" - all five terms of the momentum equation are used.

In general, the complexity of the routing equation increases from Kinematic Wave to Dynamic Wave, with Dynamic Wave representing the full solution to the 1-Dimensional St. Venant equation. Kinematic Wave simplification allows for faster computational run times, but is not ideal for flat pipeline slopes (<0.002 ft/ft) and cannot calculate backwater effects as accurately as the Dynamic Wave routing equation. In addition to lacking adequate abilities to calculate backwater, the Kimematic Wave equations approximates flow attenuation by mathematical approximations, instead of wave propagation.

The kinematic wave equation was very popular, but with increases in computing power and improvements in the user interface, the use of the dynamic wave routing equations has become a much more user friendly and accessible software option.

Table 3 Dynamic Assumptions and Models Sanitary Sewer Master Plan Update City of Chico		
	Assumptions	**Model or Equation**
Kinematic Wave	Inertia and pressure are ignored, only gravitational and frictional forces are considered. The most simplified dynamic model.	Hydra Option in InfoSWMM Option in SewerGEMS Option in PCSWMM Option in XP-SWMM
Diffusion Wave	Pressure force term is included along with gravitational and frictional terms. Inertial acceleration terms are not included.	Option in MOUSE
Quasi-Dynamic	One inertial term is included, along with gravity, friction, and pressure. One inertial acceleration term is ignored.	H_2OMAP Sewer
Dynamic Wave	All five momentum terms are included: gravity, friction, pressure and two inertial acceleration terms. Computationally time-consuming to solve over large sewer networks.	InfoSWMM, MapSWMM, InfoWorks, SewerGEMS, MIKE URBAN, XP-SWMM, PCSWMM

3.3 GIS Interface

Municipal and utility operators use GIS software and databases to control, organize, and catalog system data into easy to access and useable formats. GIS compatibility is an essential element of any infrastructure modeling software. The ability to synchronize system databases with modeling software can result in significant time saving for City Staff. Software should be able to display GIS data, such as land use, aerial photos, zoning data, parcels, and growth boundaries on the screen in order to allocate flows, and evaluate new facilities based on planning assumptions.

Often, GIS data has topology flaws that need to be corrected before the modeling software can run. Software packages with data diagnostic tools to identify and correct these topology flaws can save time in the model building and updating process.

3.4 Scenario Management

Typically, a planning level hydraulic model serves several purposes. First, the model is used to analyze the existing system and determine where capacity deficiencies and operational problems exist. The second purpose is to evaluate the system under future flows or land use designations. To be used effectively by City Staff, the model will need to be able to create and modify multiple scenarios in order to evaluate the effects of infrastructure changes (e.g. new pipelines, pump stations) and increased demands on the collection system. The ability of a model to create and manage what-if scenarios is a necessary component of hydraulic model construction and analysis.

3.5 Customer Service and Support

Operation of a computer model requires a direct relationship with the software vendor in order to troubleshoot any problems that may arise during model operation. Technical service representatives, on-line help, help files and operating manuals all factor into the customer service and support evaluation. Customer support should be fast, responsive and technically qualified to handle the most advanced modeling questions. New and infrequent users usually have many questions regarding the operation of modeling software, and a helpful and responsive customer support department can be an invaluable tool.

An evaluation of customer service and support provided by the software vendors is subjective at best, since the evaluation is influenced by the specific personalities and experiences of both parties. Anecdotal information obtained from other software users is subject to biases as well. However, establishing and maintaining a good working relationship with the vendor can be very helpful to maximize the benefits obtained from the software. Maintaining a good personal relationship with the software vendor is probably the most effective way to obtain extra support and software enhancements when needed.

3.6 Cost

The cost of a software package involves several items. With any software package, the associated costs include a single license or network license fees, support and maintenance fees, and additional add-on modules. The cost for the packages evaluated in this report range from $2,999 to $20,250. Software package costs are given in the information matrices (Table 1). The cost of the software should be appropriate for the intended use by the City.

3.7 Ease of Use

In order for a model to be an effective tool for City Staff in planning and development, it must be user friendly and easy to operate. The operating system must be graphically based and intuitive in its operation. Adding facilities to the existing system and creating scenarios for new improvements should be straightforward and intuitive.

3.8 Internet Based Model Network/Output Viewer

In recent years, some of the software vendors have begun to offer internet based applications where the model network and model simulation results can be accessed without having to actually purchase the software license or be trained on how to use the model. This type of functionality is particularly desirable for clients that do not have the available manpower and/or need to maintain a hydraulic model, but would still like to be able to view hydraulic model output as the need arises.

4.0 SCREENING LEVEL EVALUATION

Carollo conducted a preliminary evaluation based on the hydraulic calculations, cost, and ease of use criteria. Table 1 displays a comparison between the sanitary sewer modeling software's cost and technical characteristics. Considering the criteria described above InfoWorks, MIKE URBAN, PCSWMM, and XP-SWMM are not recommended for the reasons described below.

MIKE URBAN has several nice features; however, priced at $20,250 with a $2,370 maintenance fee, it is the most expensive software package that was evaluated and is therefore not recommended.

Similarly, InfoWorks, priced at $18,000 with an annual support and maintenance fee of $2,500 was also not chosen due to excessive costs that are not likely to be justified by the City's needs.

XP-SWMM and PCSWMM are not recommended since the software is much less intuitive when compared to other software packages and requires a good knowledge and frequent use of hydraulic models to operate and maintain. These packages would not be the most logical choice for the City because the new or infrequent user will struggle with the operation, maintenance, and model updates.

The City's current hydraulic modeling software, HYDRA Version 6, is very difficult to use, as discussed below, and in recent years the company has been slow to address this issue. Pizer released HYDRA Version 6 in 1998. The next major version of the software (Version 7) was not released until 2010. Some of the usability issues have been addressed with Version 7, however the program remains less user friendly when compared to the other software packages. This program, however, was included in the comprehensive evaluation because there could be certain practical advantages to maintaining the same software platform from the 2003 Master Plan, such as upgrade cost.

5.0 COMPREHENSIVE EVALUATION

After the preliminary evaluation was completed, the remaining software packages, HYDRA (Pizer); SewerCAD, and SewerGEMS (Bentley); H_2OMAP Sewer/InfoSewer, H_2OMAP SWMM/InfoSWMM (Innovyze) were further evaluated.

5.1 Dry and Wet Weather Flow Calculations

The remaining software packages have varying capabilities of modeling dry and wet weather flows. Both the Innovyze and Bentley programs provide flexibility for developing dry weather flows from a variety of sources, such as geocoded billing records, population, land use, and other GIS based methods. All of the software packages also have the capability to load user-defined hydrographs into the model.

5.2 Hydraulic Calculations

The Chico collection system contains a number of flow diversions (locations where flow from one pipe is split between two outlet pipes). For the software applications with less robust computational engines (HYRDA, SewerCAD, H_2OMAP Sewer, InfoSewer), these structures are represented by developing custom diversion curves which distribute flow between the outlet pipelines. Hydra also only has the option of running the hydraulic calculations with the Kinematic Wave routing algorithm, which limits its ability to model looped systems and systems with multiple pump stations connected to a single forcemain. This significantly limits the software's ability to model complex systems with multiple diversion locations.

The software applications that feature fully dynamic flow routing capabilities (H_2OMAP SWMM, InfoSWMM, SewerGEMS) are better suited to simulate the flow diversions, and backwater conditions. In addition to the increased accuracy associated with the fully dynamic computational engine, these applications do not require the development of diversion curves, which can be difficult to generate accurately. The drawback of models that feature fully dynamic flow routing capabilities is increased computational time (longer "run" time). However, the City's hydraulic computer model is small enough that run times should not be a determining factor.

5.3 GIS Interface

Most of the data in a collection system model comes from GIS systems. These information systems are increasingly becoming the primary repository for spatial infrastructure data. Cities that have had these systems in place have usually been successful in significantly increasing the quality of this data.

Software programs such as H_2OMAP Sewer and H_2OMAP SWMM operate in a stand-alone mode that allows these programs to run very efficiently. These programs can easily read, write, and manipulate GIS data. HYDRA also runs in stand-alone mode.

InfoSewer and InfoSWMM run from within ESRI's ArcGIS software program, so every user of these modeling programs must also have a copy of the GIS software. These modeling programs are able to use additional GIS functionality. The hydraulic calculations are identical to the corresponding H_2OMAP Sewer and H_2OMAP SWMM software. This software tends to be selected by users who have experience and like working from within the GIS software. The City does have a copy of ESRI's ArcGIS software program.

SewerCAD and SewerGEMS users can work in an AutoCAD, MicroStation, or GIS environment when doing model creation and setup tasks. Modeling simulations are often performed in a stand-alone mode. These programs tend to open, load data, and run much slower than the Innovyze or Pizer programs.

5.4 Scenario Management

H_2OMAP Sewer, H_2OMAP SWMM, InfoSewer, InfoSWMM, SewerGEMS, and SewerCAD offer sophisticated parent child tree scenario creation and management schemes. This feature allows the user to set up multiple what if scenarios based on a variety of model parameters. HYDRA also has the ability to create different scenarios, but is less user friendly.

The Innovyze software packages also have a facility manager, which enables the model to display only the facilities that are modeled in that simulation. The Innovyze data set manager is very useful in organizing and controlling what facilities and controls are associated with each scenario. In SewerCAD and SewerGEMS, all facilities are displayed for all scenarios. Therefore, facilities that are not present in a particular scenario must be turned off manually.

5.5 Customer Service and Support

Innovyze customer support has been good with timely and supportive response to issues, such as software bugs and technical problems. Innovyze has shown that they are responsive to clients needs and are able to quickly provide enhancements when needed. Instructional manuals are adequate. Help files can be limited, so e-mail and telephone support is the best means of quickly obtaining solutions.

SewerCAD and SewerGEMS offers several support and maintenance options. Users have the option to pay an annual fee or pay a price for each service contract. Anecdotal information obtained from other users was less complimentary on timely responses and personal service.

The HYDRA support is responsive and can successfully handle support problems. Turn around time can be between one to three days, and support staff members have access to hydraulic engine and interface experts.

5.6 Cost

Software costs are a major factor in the selection of a modeling package. Costs discussed here are for a 2,000-pipe version unless otherwise noted. Based on a review of the City's existing model and GIS shapefiles, the City's hydraulic model will consist of roughly 1,430 links, so the 2,000-pipe versions should be sufficient for the City's current needs. The cost to model collection systems with more pipes will often be higher. The cost for all software packages are summarized in Table 1.

The cost for the HYDRA Version 7 is $4,500 for a new unlimited pipe license. The cost for existing Version 6 customers is reduced to a $3,150 upgrade fee. HYDRA offers a limited 200 pipe license or an unlimited license only. Because of the size of the City's model, the unlimited license is the only option available. The annual maintenance fee for HYDRA is $1,250.

Both InfoSewer and H_2OMAP Sewer have a single license fee of $5,000. Support and maintenance fees cost $800 annually. Network licenses are available, as well as Pro, Suite, and Pro Suite versions of the software for an additional cost (Pro cost has a $6,000 single license fee plus $800 annual maintenance, Suite has a $6,000 single license fee plus $1,000 annually, and Pro Suite has a single license fee of $7,000 plus $1,000 annually).

InfoSWMM and H_2OMAP SWMM are priced at $7,000 for a single license. Support and maintenance fees are $1,200 annually. Network licenses are available, as well as a Suite and Executive Suite version of the software for an additional cost (Suite has an $8,000 single license plus $1,500 annual maintenance fee, Executive Suite has a $9,000 single license fee plus $2,000 annual maintenance fee).

The stand-alone version of SewerCAD is priced at $7,995 with a support and maintenance fee of $1,925. SewerGEMS is priced at $12,995 with an annual support and maintenance fee $3,120.

5.7 Ease of Use

The ease of use of each package is an important factor in the software selection. Hydra is the least user friendly software program. It is difficult for a new user to learn and apply, and managing the many files that are required to perform a simulation can be difficult until the operator has spent considerable time working with the model.

The user interface for the Innovyze programs has many features that help the user to quickly see and identify associated facility data and controls. The attribute browser allows the user to click on a facility and view or edit information in the database. Another advantage is that output results are viewed in the same window as the model input. This feature is useful for analysis when focusing on specific sections of the system, such as new facilities or system upgrades. The user interface has a control center that displays GIS layer information as well as operational data, annotation, and map display operations that create an easy means to manipulate operational data and view output results for the entire system.

SewerCAD/SewerGEMS has many features that also have the disadvantage of unneeded complexity for the new or infrequent user. One drawback of the SewerCAD/SewerGEMS software is that it uses a proprietary database. In doing so, external databases, such as Microsoft Excel, cannot be used to view or edit model data or output results.

5.8 Internet Based Model Network/Output Viewer

Of the software vendors selected for comprehensive evaluation, only the Innovyze software packages offer the ability to export the model network and model analysis results to an internet based viewing application. Innovyze uses its "NetView" add on module to export the model network and output results to a ".kml file," which can be easily viewed by downloading a free copy of the Google Earth program. NetView is available as part of Innovyze's Executive Suite license at an additional cost of $2,000 for a single license fee and an $800 increase in the annual maintenance fee for the H_2OMAP SWMM/InfoSWMM software package. Even with the Executive Suite license, the H_2OMAP SWMM/InfoSWMM still costs less than Bentley's comparable program (SewerGEMS)

Depending on the City's intended model usage, however, purchase of the Executive Suite license may or may not be required in order to see the benefits of this feature. For example, if the City does not plan to have one or more of its staff member routinely update and/or use the model, it may be more practical for the City to use the exported NetView .kml file (which would be exported by Carollo) to view model results. If this is the case, the City could opt to purchase the Base package only (if City staff may occasionally want to run a model scenario) or simply not purchase the software at all, while still having the ability to see peak flows and other model output for any given model element.

6.0 RECOMMENDATION

Because the City's collection system includes a number of flow diversions, it is recommended that the City consider software applications that feature fully dynamic flow routing capabilities. Based on this criteria, the City could successfully implement a sanitary sewer-modeling program using either Innovyze (H_2OMAP SWMM, InfoSWMM) or Bentley (SewerGEMS) software programs. In our experience, Innovyzes's InfoSWMM software may be the best choice for the following reasons:

- Superior GIS capabilities
- Superior or comparable ease of use
- Excellent scenario manager
- Best value in terms of features/capabilities to cost
- Available NetView module allows for model network and output results to be viewed for free through Google Earth.

APPENDIX A – SEWER SYSTEM MODELING PAPER

SELECTING THE RIGHT MODEL
TO ANALYZE COLLECTION SYSTEM FLOWS AND HYDRAULICS

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ABSTRACT

There are a wide variety of public domain and commercial sewer system models available today. It can be challenging to select a model that meets the goals of a specific project due to the myriad of features now available in most software packages. The purpose of this paper is to provide a guide for selecting a model to analyze flows and hydraulics within a collection system network. A variety of core model features are detailed including dry and wet weather flow estimation, and hydraulics. The computational algorithms that are used in many models, such as the Saint-Venant equations, are also summarized. Other features are discussed that allow for the efficient management of data and the effective display of results. Various model application levels including gross planning, detailed planning, and design are also addressed.

KEY WORDS

Model, Collection System, Flow Estimation, Hydrology, Hydraulics, Infiltration and Inflow, Commercial Software

INTRODUCTION

The purpose of this paper is to provide a guide for selecting a model to analyze flows and hydraulics within a collection system network. There are a wide variety of public domain and commercial models available; some commercial models were developed by private software companies, while others are simply repackaged versions of public domain models and are sold by software companies with value-added support services. Still others are hybrids, they had their genesis as public domain models but subsequently private software companies have made significant additions and improvements. With the many choices on the market today, it can be challenging to select a model that meets the goals of a specific project and budget.

There are a wide variety of features available in most models today, including sophisticated interfaces, database and Geographic Information Systems (GIS) links and several different computational options. This paper cannot hope to cover details of every model, however the fundamental features in most models can be divided into understandable components. This paper will describe these core components of collection system models, delve into the specifics of generating both dry weather flow (DWF) and wet weather flow (WWF), compare the different hydraulic algorithms used to route flows through a pipe network, and include methods to select the right model for an individual system. This paper identifies specific commercial models, but attempts to compare these models based on only the core hydraulic features without taking into account the myriad of other features that may play into the selection of a specific model.

WHAT IS A MODEL?

A model is a schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics (dictionary.com). Frequently the most convenient and useful system models are mathematical in nature, and are solved with computer algorithms in software packages. This is what constitutes a "model" for most water resource engineers, and is the working definition for this paper. Every model is a simplification of the real system. The applicability of a given model depends on the degree of simplification that can be applied while still representing the system in a meaningful way to solve a problem. The accuracy and precision required dictates the amount of simplification the model should compromise from reality for a given project (e.g. planning level vs. design level). A model can be as simple as a spreadsheet with calculations for peaking factors of sanitary sewer flows and Manning's equation for calculations of depth and velocity in a single pipe. Or a model can be a complex, fully dynamic model that accurately simulates a sewer network with thousands of basins and pipes in a sophisticated software suite of programs.

Models can be classified in many different ways. Some of the basic classifications are included as applicable to collection system models. This paper deals strictly with sanitary and combined sewer system models, although many of the model traits are also applicable to storm water models. Some common ways of classifying models include:

- *Hydrologic vs. Hydraulic* – a hydrologic model estimates flow quantity over time, while a hydraulic model estimates properties of flow (typically depth and velocity) as it travels through a channel or a network of pipes. For the purposes of this paper, a hydrologic model will also be referred to as a flow estimation model since sewer modeling usually requires estimates of both DWF and WWF.
- *Deterministic vs. Stochastic* – deterministic models produce identical outputs for a given set of inputs while stochastic models produce different outputs for a given set of inputs (Nix, 1994). Stochastic models contain random variables usually defined by a probability density function, are used for probabilistic hydrologic projections, and are sometimes referred to as statistical models. Stochastic models will not be covered in this paper.
- *Lumped vs. Distributed* – these terms are applied to both hydrologic as well as hydraulic models. A lumped hydrologic model assumes that all characteristics are constant over a watershed or sewer basin, while a distributed hydrologic model accounts for spatial variability as a function of position in a watershed (Nix, 1994). In a lumped hydraulic model, the flow is calculated as a function of time alone at a particular location, while in a distributed hydraulic model, routing of flow is calculated as a function of space and time throughout the system (Chow et al, 1988).
- *Static vs. Dynamic* – a static simulation usually refers to a steady-state analysis of a single flow rate (e.g. a peak flow), while a dynamic simulation refers to time-variable flows typically over at least a day's period for sewer related analyses.
- *Single-Event vs. Continuous* – both single-event and continuous refer to a dynamic simulation (i.e. variation in flow characteristics are estimated over time). However for single-

event simulations, one event is analyzed based on some “event definition”. This could include an “event” defined as one day of DWF, or a single WWF event based on a minimum dry antecedent period. Continuous simulation refers to an analysis of both wet and dry periods in chronological sequence; the flow response of dry as well as wet periods is simulated. Continuous simulation is commonly used to estimate the probability of peak flows or volumes.

Most modern collection system models are deterministic and contain both hydrologic (or flow estimation) and hydraulic modules. Most models utilize lumped hydrologic processes, while hydraulic calculations can be either lumped or distributed. The majority of models simulate single-event projections, while some are also able to accommodate continuous simulations. For large collection systems, continuous simulation usually requires a more simplified model than single event analyses warrant, in order to reduce model run times.

WHY USE A MODEL?

It is always important to step back and ask if a model is necessary for a specific project. Many times the answer to this question is “yes”, even if that model is a spreadsheet with simple calculations. In fact, deciding on the degree of model sophistication required to solve a problem can be most challenging. All to often it is tempting to use the most sophisticated hydraulic model complete with GIS interfaces and a myriad of other features to model every pipe in a collection system. However the cost of this comprehensive modeling is frequently high, and many problems are more aptly, and cost-effectively accommodated using a more simplified model coupled with decision analysis tools (e.g. cost effectiveness models, uncertainty analysis and multiple objective optimization). This is especially true for planning level analyses. Assuming the project warrants analyses beyond what can be done in a spreadsheet, then some reasons to consider more sophisticated modeling software include:

- *Limitations in flow measurement* – Flow measurements should be included in any collection system modeling effort, but there are two major drawbacks to only using flow measurements for analysis of a collection system. First, you can only measure so much. Accurate flow monitoring is expensive, and unless the smallest project is considered, monitoring cannot fully describe the flows and hydraulics in a system. Second, the sewers and flows change over time. For example, service areas grow, pipes get rerouted, and new pipes age and deteriorate thus causing more infiltration and inflow (I/I) to enter the system. All of these factors could cause measured flows to be out of date within a few years.
- *Ability to predict* – one of the main reasons to model a system is to examine “what-if” scenarios once a model is calibrated and accurately predicting results. A model can provide spatial predictions of future DWF (based on changes in land use or population). A model can predict whether an improvement in a section of pipeline will be adequate. Many of today’s commercial models allow for scenario management to allow the modeler to test an almost unlimited amount of alternatives.
- *Stakeholder education* – many models today include impressive graphical displays of information in a variety of formats (e.g. graphs, dynamic “movies”, maps, etc.). Model output can be directly used to educate stakeholders at all levels within an organization, including board members, managers, engineers, and even operators. It is very useful to verify

model results with field observations from operators. This may also help in the future by demonstrating to operators system performance during unobserved, infrequent events, e.g. where to look for future Sanitary Sewer Overflows (SSOs), effects of major wet weather events on pump station failures, etc.

Assuming a model needs to be used, the real question then is… How detailed should the analysis be to efficiently and accurately solve the problem? To address this issue, the core components of a model will be examined, followed by more detailed descriptions of the flow estimation and hydraulic algorithms of a collection system model.

COMPONENTS OF A MODEL

The basic components of a model include input data, computational algorithms, output data, and a graphical user interface (GUI). Input data are included to describe the physical geometry of the system, define boundary conditions (i.e. at outfalls), and delineate time series that drive the system (e.g. rainfall, flow rates, etc).

The computational algorithms make up the "engine" that drives a model. Unfortunately, like engines in an automobile, model engines can be easily misunderstood and forgotten about when all that is seen is the "shiny exterior." The computational algorithms will be discussed in detail below in the flow estimation and hydraulics sections. Output are the results of the computational algorithms and may include time series (e.g. flow, velocity, depth for given pipes), scatter graphs (i.e. velocity vs. depth), volumes, hydraulic grade lines (HGL's), pipes that surcharge, nodes that overflow, depth to diameter (d/D) ratios of flow in pipes, and other statistics. Model output can be voluminous, so it is important that a model utilize some type of GUI that helps the user manage large quantities of information efficiently.

The purpose of a GUI is to facilitate efficient data input, execute the model runs, and present the results. It is easy to become enamored with all the features in today's models GUI's, and loose sight of what is happening "inside" the model; the computational algorithms that produce the results. Ultimately the decisions that will be made based on model results are inextricably tied to the features that today's model GUI's provide, which makes it is easier than ever to misapply a model to a given project. Typical features that are common to many model GUI's for management of both input and output are:

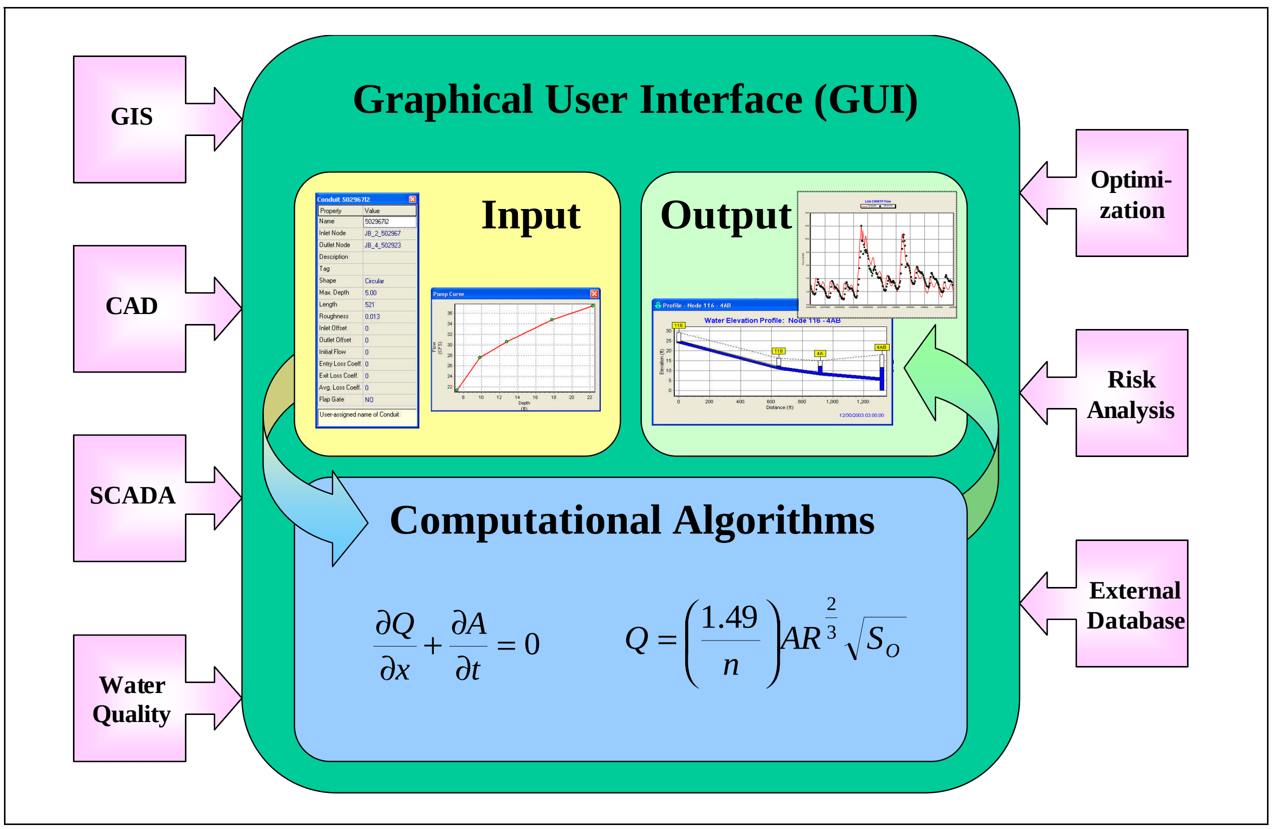
- *Time series database with tabular and graphic capabilities* – used to manage variables (e.g. hydrographs)
- *Spatial database with tabular and mapping capabilities* – used to manage structures and connectivity within the system (e.g. what pipes connect to what junctions)
- *Scenario manager* –manages multiple model runs in a structured format (otherwise model runs need to be managed at a file level by the modeler).
- *Model execution* – allows for starting a run and observing errors.
- *Dynamic displayer* – allows for dynamic display of results in either plan view or profile view. Plan view is typically a map were pipes and nodes change in size or color depending

on certain output variables. A profiler displays a pipeline segment with a varying HGL as it changes throughout the model simulation.

The spatial database feature can either be built into the model, or can be separate Geographic Information System (GIS) software. Many collection system models are moving toward integrating the model with a GIS (e.g. ArcView, ESRI). This provides the advantage of utilizing the graphical and database features of the GIS (without reprogramming them into the model). This structure leverages the many features within GIS and does not require the model to import or export data to a GIS since the data structure is already within the GIS. This feature significantly increases efficiency in inputting data as well as displaying results. The downside of this structure is that the GIS software has to be purchased along with the commercial model.

There are a variety of other model features too numerous to list. However, it's worth noting some linkages that now can be made relatively easily between modeling software and other software to expand the model's capabilities. Certain models now provide linkages to GIS, Computer Aided Design (CAD) software, Supervisory Control And Data Acquisition (SCADA) software, water quality models, optimization and risk analysis software, and external databases. **Figure 1** illustrates a conceptual layout of model components.

Figure 1 – Conceptual Layout of Model Components



FLOW ESTIMATION

Flow estimation is sometimes an overlooked aspect of collection system modeling. However, it is just as important as hydraulics in sizing improvements. If flows are not correctly estimated, the results from the hydraulic calculations will be inappropriate for estimating new or improved pipeline sizes. Flow estimation in a collection system model can be divided into DWF and WWF estimation. DWF is generated by domestic, commercial and industrial wastewater flows throughout a collection system. WWF represents the hydrology of the system and is a factor of the rainfall that enters a collection system either through designed sources, as is the case with combined sewers, or thorough deteriorated facilities or illicit connections, as is the case with sanitary sewers.

Dry Weather Flow

Depending on the complexity of the model, DWF's can either be directly entered into the model or calculated using GIS techniques. A simple approach could consist of calculating an Average Dry Weather Flow (ADWF) for a sewer basin, then applying a peaking factor (typically based on ADWF, sewer basin area, or population) to estimate a peak instantaneous DWF. This single flow value could then be used to calculate the hydraulic capacity required for a pipeline (i.e. steady-state analysis where variability in flow rate is taken into account in the conservativeness of the assumptions underlying ADWF and the peaking factor).

Land use, demographic data (population and employment), and water-use records are typically used to estimate DWF. Population and employment projections may be available as Transportation Analysis Zone (TAZ) data or Census data. Land use information may be available from local planning departments. Water use records may be available from local water agencies (however, water services boundaries may not directly overlap with sewer service boundaries and adjustments must be made). To efficiently utilize this spatial data, especially if it is available at a parcel level, a GIS is a necessity.

Some models, especially those that are integrated with GIS, have the capability of converting this information into Average Dry Weather Flow (ADWF) buy applying unit flow factors (e.g. gallons per capita per day, or gallons per acre per day) directly in the model software. This feature can save significant time and effort especially if multiple years need to be analyzed (e.g. current, buildout, etc.). If a model does not have this capability, the calculations can be done externally in a GIS or a spreadsheet, and then imported into the model. If a dynamic model is used, the ADWF then needs to be converted to a diurnal pattern by applying percentages for each time unit (e.g. every hour). Certain models can also use more than one diurnal pattern to account for day-today changes in the diurnal pattern (e.g. weekday vs. weekend, month by month variations, etc.). This will facilitate a more accurate simulation of DWF patterns over an extended period of time.

DWF's are usually calibrated by adjusting unit flow factors to match modeled volumes to measured volumes and adjusting the diurnal pattern to match the corresponding DWF model hydrograph (e.g. timing, shape, peak flow and minimum flow). Options exist to compare DWF hydrographs graphically, along with goodness-of-fit statistics (e.g. comparison of minimums, maximums, averages, R^2, etc.). Some modeling software packages calculate and graph these statistics directly. If this feature doesn't exist, then it's the responsibility of the modeler to complete these calculations externally. Automated methods for performing the DWF calibration process are not typically available as a built-in feature in most modeling software. However external optimization software can be used to perform the calibration. In cases where collection systems experience very little I/I, calibration of DWF along with the inclusion of some base I/I may be all that is needed for estimation. However, many systems suffer from significant I/I and require explicit modeling of WWF's.

Wet Weather Flow

Combined sewer systems (CSS's) are designed to accommodate WWF's up to the point of discharging out designed overflow points within the system – or Combined Sewer Overflows (CSO's). In this case WWF may include I/I as well as direct, purposeful stormwater connections. I/I is usually defined as extraneous flows that are not desirable in a sanitary collection system, while CSSs were originally designed to accommodate direct storm water drainage. However, the distinction is blurred, as many sanitary sewers also suffer from excessive I/I that result in SSOs that behave similarly to CSSs. In fact, some coastal systems have experienced wet weather peaking factors (peak wet weather flow divided by average dry weather flow) that approach the peaking factor of some CSS's. Therefore, it is extremely important that WWF be estimated as accurately as possible for analyzing and designing improvements for these types of systems.

I/I is a hydrologic component of both combined and separate sanitary systems. Combined systems are generally dominated by storm water that is in effect the same as sanitary inflow. Separate systems can be dominated by either inflow or infiltration. When portions of a combined sewer system are separated, the storm water contribution is greatly diminished, but infiltration may still be a significant component of flow, and may in turn exhibit characteristics of a sanitary system with significant I/I. In either case (a partially separated combined system or a sanitary system with significant I/I), infiltration can be the most difficult portion of the wet weather hydrograph to model, as well as one of the more challenging components of WWF to remove.

Modeling inflow is usually straightforward because the inflow response is a direct result of the rainfall pattern and the amount of impervious area that is tributary to the sewer system (it behaves very similarly to an urban storm water response to rainfall). Most collection system models adequately model inflow. However, infiltration is much more difficult to model than inflow since it can be an indirect response to rainfall and can be heavily influenced by groundwater conditions, which nearly always introduce a tremendous amount of uncertainty into any hydrologic analysis. Infiltration generally can be categorized in two ways:

- Near surface infiltration
- Groundwater infiltration

Near surface infiltration usually starts a few hours after the beginning a rain event and subsides within generally a day or two as the saturated soils return to normal. Groundwater infiltration is caused by groundwater that raises due to saturated soil conditions to a point where the groundwater table elevation exceeds that of the local collection system. This type of infiltration can be an issue for coastal communities or those located near lakes and rivers were the groundwater table is normally very close to sewer inverts. Groundwater infiltration will not necessarily influence a sewer system until multiple rainfall events saturate the soils and start to increase the groundwater table, but when it does, it can contribute infiltration that last for weeks or months. Also, certain systems directly adjacent to the ocean or estuaries can experience diurnal groundwater infiltration due to tidal fluctuations that directly affect the water table.

Modeling of WWF generally falls into these categories (Wright and Dent, 2001):

- Rational Method - calculation of an individual peak flow or volume using the simplistic equation Q=CiA, or R-values (which are calculated the same way, but "C" is replaced by an "R")
- Unit Hydrograph – includes SCS curve number methods, the RTK method (triple unit triangular hydrographs), and regression analysis (linear or non-linear)
- Physically based - Non-linear reservoir, multiple non-linear reservoirs (when groundwater is included in the model)

The Rational Method should only be used in the case of calculating inflow for small, highly impervious areas. R-values are easy to calculate but can be applied beyond their accurate limits, and should only be used as a first check to see if sanitary sewer basins suffer from significant I/I. To adequately model wet weather flow hydrographs, a unit hydrograph or physically based method should be applied. These methods are more complex and take more time and experience to apply properly. If groundwater is a significant issue, and if there is the possibility that storage facilities are going to be sized to manage excess I/I, a physically based multiple non-linear reservoir method should be applied. For a more in-depth discussion on modeling wet weather flows, refer to Dent et al (2000) and Wright et al (2000).

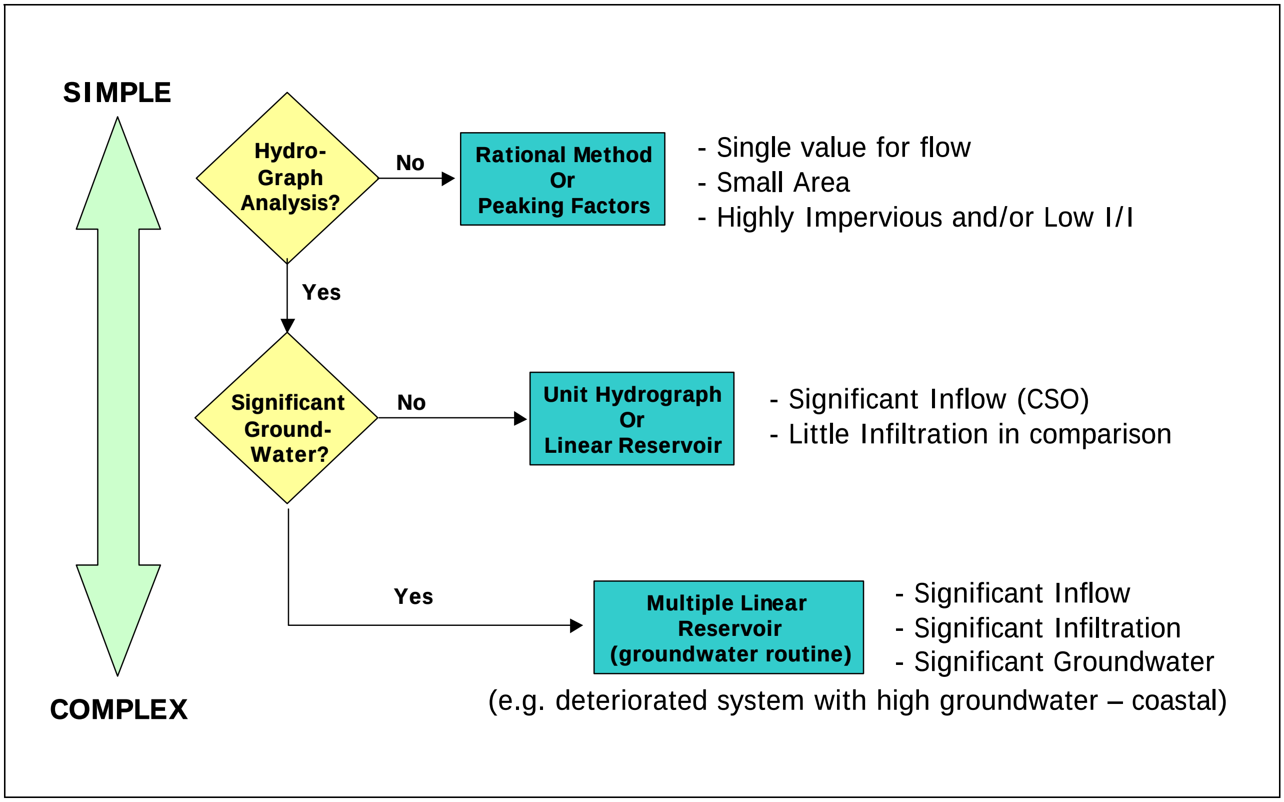
There are usually a variety of wet weather flow estimation options available in most public domain and commercial models, so no specific model or models will be discussed since the topic is too extensive for this paper. However, it is worth noting that automated calibration of WWF's is beginning to be explored in certain commercial collection system models. There also exists the opportunity to link external optimization software to efficiently run iterative calculations for WWF calibration in public domain models (Dent et al, 2004). **Figure 2** illustrates a flowchart to help chose a wet weather flow estimation method.

HYDRAULICS

Hydraulics, and the application of hydraulics, are often misunderstood. Many books are available that explain hydraulic theory and application, but few if any exist that provide a consolidated summary of hydraulic modeling for practical purposes. This explanation of hydraulics hopefully provides this consolidated review.

Due to the wide variety of flow conditions that may exist in an open channel, a complete but sometimes confusing nomenclature has developed to describe the fundamental properties of fluid flow. Yen (2001) provides a simple breakdown of these terms for overland and open-channel flow in terms of variation with time and space.

Figure 2 – Flowchart for Choosing a Wet Weather Flow Estimation Method



Flow variation with time is commonly referred to as either:

- Steady (time invariant), or
- Unsteady (dynamic flow)

A steady state model only uses a single flow within the analysis. A peak flow is a common way to analyze the capacity of a pipe. An unsteady, or dynamic flow model, uses a time series of flows. A hydrograph is commonly used in a dynamic model and can range from several values (e.g. diurnal DWF's over 24 hours) to millions of flow values (e.g. long term continuous simulation). Both steady and unsteady flow will be discussed below as they relate to flow variation in space.

Flow variation in space, or flow along the length of a channel, is referred to as either:

- Uniform, or
- Nonuniform (gradually or rapidly varied)

Uniform flow is the simplest type of open channel flow and the governing equations give unique flow rates as a function of depth. One simple way to envision this type of flow is a pipeline where the slope of the hydraulic grade line (HGL) is parallel to the slope of the pipe. Under this regime the two forces acting on the flow, gravity and friction, are balanced, and there is no acceleration of the flow in any dimension. Under uniform flow the friction slope is equal to the pipe bed slope (i.e. $S_f = S_0$). By definition, uniform flow must exhibit uniform depth along the length of a pipeline. This depth is commonly referred to as normal depth (Chaudry, 1993).

Steady Flow (Uniform and Nonuniform)

Steady flow models, those where only a single flow is used, are solved for depth and velocity using uniform or nonuniform techniques. When considering flow in time and space, the simplest type of flow is steady uniform flow. The flow rate does not change with time, the depth of flow does not change in space, and the streamlines are all parallel. All acceleration terms are zero, e.g. friction and gravity are in perfect balance. Manning's equation (developed by Robert Manning in 1891) is frequently used to determine the flow rate or velocity for uniform flow because under uniform flow conditions the depth of flow and flow rate are related by a unique rating curve (i.e. the flow rate is a unique function of depth). **Figure 3** illustrates Manning's equation expressed in customary US units.

Figure 3 – Manning's Equation

$$Q = \left(\frac{1.49}{n}\right) A R^{\frac{2}{3}} \sqrt{S_O}$$

where: Q = Flow (cfs)
n = Manning's roughness coefficient (unitless)
A = Area (ft^2)
R = Hydraulic Radius
S_o = Pipe Slope

Manning's equation is an empirical equation (i.e. derived from field and laboratory experimental observations) and is appropriate if the conditions mentioned above for uniform flow exist in the pipeline that is being analyzed. If flow in a sewer pipe approaches a steady uniform condition, then Manning's equation may give reasonable results. However, actual sewer pipelines frequently experience a variety of flow conditions where the uniform flow principle is violated and the more complete nonuniform solution techniques are required.

Nonuniform conditions take into account that a single flow will usually exhibit different depths along a length of pipeline. Nonuniform flow is typically categorized as gradually varied and rapidly varied flow. Rapidly varied flow will not be covered in this paper since sewer flows rarely exhibit this flow condition, and no models covered in this paper solve for this condition. Therefore, from now on, this paper will refer to nonuniform flow only in terms of gradually varied flow.

Gradually varied flow can be either steady or unsteady in time. Steady, gradually varied flow, requires calculations beyond Manning's equation to solve for depth and velocity in a open channel (unsteady gradually varied flow will be addressed in detail later in this paper). The Step Method has been developed to solve the gradually varied flow equation. Numerical integration is necessary because the equations are not generally explicitly soluble (Henderson, 1966). Two common solutions of this method include the Standard and Direct Step Method. These methods can be used to solve for changing depths and velocities for a given flow along the length of an open channel (or pipeline if the flow does not surcharge beyond the crown of the pipe). Two commercial models that utilize the Direct Step Method include SewerCAD and StormCAD both by Haestad Solutions (Bentley Systems).

Unsteady Gradually Varied Flow

The most computationally complex type of one-dimensional open channel flow is unsteady flow, which is, for practical purposes, also nonuniform (Chaudry 1993). Unsteady gradually varied flow can be solved using distributed flow routing models where flow rate and water level are computed as functions of space and time, rather than space alone (such as the Standard Step Method discussed above) or time alone (such as spatially lumped models which are not covered in this paper) – (Chow et al, 1988). Most of the unsteady sewer models on the market today utilize distributed flow routing and solve a form of the Saint-Venant equations. These equations are covered in detail in many publications including, but not limited to, Chow et al (1988), Bedient and Huber (1992), Chaudry (1993), Yen (2001), and Henderson (1966).

The Saint-Venant equations, first developed by Barre de Saint-Venant in 1871, describe one-dimensional unsteady open channel flow where depth and velocity only vary in the longitudinal direction of the channel, the bottom slope of the channel is small, and Manning's equation can be used to describe resistance effects (Chow et al, 1988). So why are these equations so important in distributed flow routing models? One primary reason why these equations are needed are because a wave (a variation in energy in time and space) can are propagated upstream and downstream in unsteady gradually varied flow. Waves cannot be accounted for in the simplified forms of the St. Venant equations that do not consider changes in acceleration over time and space. The Saint-Venant equations generally consist of equations of continuity and momentum and are able to estimate wave celerity (the velocity of a wave along the channel). These partial differential equations are summarized in **Figure 4** (adapted from Chow et al, 1988).

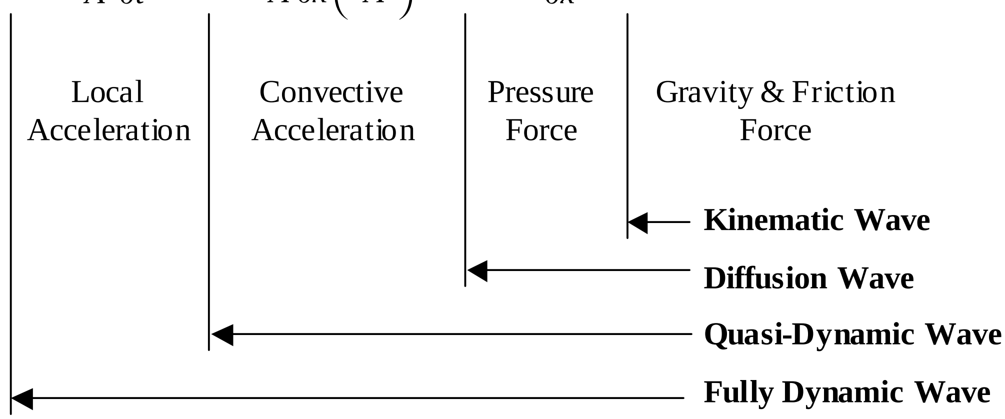
The kinematic wave solution, as shown in Figure 4, balances the gravity and frictional forces and assumes the flow does not accelerate appreciably. The diffusion wave solution is the kinematic solution with the pressure term included which takes into account the change in water pressure with depth along the channel. The Quasi-Dynamic wave solution is the diffusion wave solution with the inclusion of the convective acceleration term which describes the change in momentum due to the change in velocity along the channel. The Fully Dynamic solution includes all terms in the momentum equation including the local acceleration term, which describes the change in momentum due to the change in velocity over time.

Figure 4 – Saint-Venant Equations

Continuity Equation: $$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

Momentum Equation:

$$\frac{1}{A}\frac{\partial Q}{\partial t} \quad + \quad \frac{1}{A}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) \quad + \quad g\frac{\partial y}{\partial x} \quad - \quad g\left(S_o - S_f\right) \quad = \quad 0$$



where:
- Q = Flow
- A = Area
- t = Time
- x = Distance
- y = Depth
- S_o = Pipe Slope
- S_f = Friction Slope (slope of hydraulic grade line)

The Saint Venant equations are partial differential equations that describe one dimensional, unstready, gradually varied flow. Unfortunately they are not amenable to analytical solution methods and therefore must be solved using numerical approximations. A common method for approximating the solution of these equations, although not covered in detail here, is the finite-difference method. This method can employ either an explicit scheme (where unknown values are solved for sequentially) or implicit scheme (where unknowns are solved for simultaneously). The explicit method is iterative and somewhat simpler to implement in a computer program, but can produce unstable results. The implicit method is more complicated from a programming perspective, but generally provides a more stable solution and can provide faster simulation times than the explicit method. Explicit solutions were applied in the past, but implicit methods are more commonly used in today's distributed flow models.

Another mathematical solution issue, which may seem somewhat esoteric, but is necessary to understand because of how certain sewer models are marketed, include the way the equations are applied to solve for surcharge flow (when flows exceed the crown of a pipe and transition into pressure flow). There are two ways to simulate unsteady surcharged flow in sewer models and include the standard transient flow approach and the hypothetical piezometric open slot approach. The hypothetical piezometric open slot approach, is also known as the Priessmann slot approach. According to Yen (2001), both solution techniques have their own pros and cons and it is not clear whether one method is superior in all cases, regardless of how some commercial software is marketed.

Generally, the more terms of the Saint-Venant equations that are included in the solution, the more computational intensive the model can become and the slower the simulation times become. Excessive run times can still be a problem (even with the computational power of today's computers) if the sewer network becomes large enough. Therefore, some models standard solution routine applies the kinematic wave solution, such as the Hydra software by Pizer, or provides this solution technique as an option, as is the case with the US EPA Storm Water Management Model - SWMM5. This simplification of the Saint-Venant equations will provide very efficient simulation run times. However, the kinematic wave routine does have some significant limitations in that flow is routed only in a downstream direction, only open channel flow (or gravity flow as it is sometimes called) can be simulated (no surcharge), and flow in looped pipes (e.g. cross connections) cannot be directly calculated.

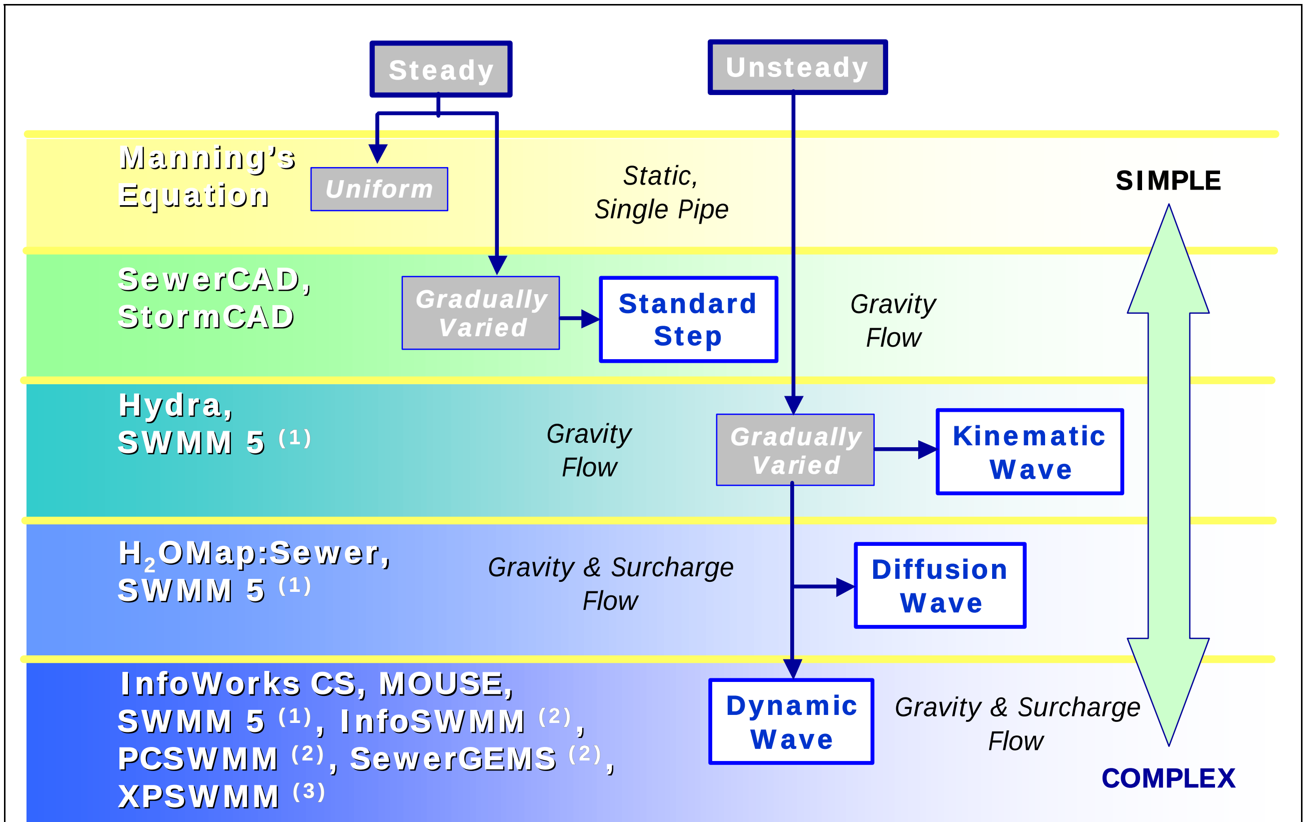
Many distributed flow routing models on the market today include fully dynamic wave solutions as well as options to model only quasi-dynamic or diffusion wave solutions for sewer networks. H2Omap:Sewer (MWH Soft) includes a diffusion wave solution routine. Other models such as SWMM5, MOUSE (Danish Hydraulic Institute – DHI), InfoWorks CS (Wallingford Software), and XPSWMM (XP Software) include fully dynamic wave solutions and may offer options for diffusion and quasi-dynamic wave solutions. PCSWMM (Computational Hydraulic Institute – CHI), InfoSWMM (MWH Soft), and SewerGEMS (Haestad Methods/Bentley Solutions) utilize the SWMM5 engine but provide a more comprehensive GUI than the standard SWMM5 package. **Figure 5** provides a graphical characterization of hydraulic solution methods along with a summary of which models apply which routines.

OTHER MODEL FEATURES

What about the other features that are available in today's public domain or commercial models? The core features of today's models are described above, but it is also necessary to investigate other model features that may influence the choice of selecting one model over another. The following list is by no means comprehensive, but hopefully provides some features that should be investigated before an individual model is chosen or upgraded:

- Who will be the model users (consultant vs. client, full-time vs. part time, experienced with hydrology and hydraulics)
- Cost (both initial purchase as well as yearly service contracts for technical support and upgrades)

Figure 5 – Characterization of Hydraulic Solution Methods



Notes:

(1) SWMM 5 has four solution routine options, which include kinematic wave, diffusion wave, quasi-dynamic wave, and fully dynamic wave. The dynamic wave section of this graphic encompasses both the quasi and fully dynamic wave solutions.

(2) PCSWMM, InfoSWMM and SewerGEMS utilize the SWMM 5 engine.

(3) XPSWMM utilizes a modified SWMM engine.

- Database and Engine structure (ability to work with 3rd party software, ability to easily extract model input/output from model)
- Estimate DWF from population or landuse
- Utilize monitored data for calibration
- Perform automated calibration
- Efficiently complete continuous simulation modeling
- Perform automated pipe sizing (upgrades or parallel pipelines under open channel and surcharge conditions)
- Water quality (i.e. hydrogen sulfide) and sediment transport modeling
- Simulate Real Time Controls (RTC) at pumps, weirs, orifices, etc.
- Link with SCADA software to provide real time modeling capabilities

Many of the options mentioned in the above list can be found in some of the models listed previously in this paper. However, two features that would be extremely helpful in sewer system model, but aren't available (to the authors knowledge) include:

(1) Ability to directly distribute WWF's into unmonitored areas of the system

(2) Ability to analyze capacity of sewer pipes based on a comparison of the HGL to the slope of the sewer pipe

Feature (1) addresses the need to provide a modeler with a mechanism to distribute WWF's throughout sewer basins even when basins are not monitored for flow (which is typically the case). Statistical methods do exist (see Wright et al, 2005) but could be included as an option in software packages.

Feature (2) is related to automated pipe sizing, but seems to be feature that has been overlooked. If a model could illustrate, during a dynamic simulation, which pipes in a network have an HGL equal to, greater than, or less than the slope of the pipe, the modeler would be able to easily identify which pipes need to be upgraded. This is especially true when pipes become surcharged. For example, if a pipe has an HGL slope greater than the slope of the pipe, and portion of the pipe is surcharged, then that pipe has a capacity restriction for the modeled flow and needs be upgraded (e.g. larger diameter or parallel pipeline). Likewise, if a pipe has an HGL slope less than the slope of the pipe, and the pipe is surcharged, the pipe does not represent a restriction (and the restriction is somewhere downstream). This relatively simple feature would provide the modeler with invaluable information to identify deficiencies within a sewer network and help focus capacity improvements.

MODEL APPLICATION

Selection of any model always comes back to what type of project the model is being used for, and what accuracy is needed in the results. Three examples, or levels of sewer system modeling include:

- Gross Planning Level
- Detailed Planning Level
- Design Level

Gross planning level modeling can be accomplished in several ways. One example of gross planning level modeling is the use of hydrologic routines to simulate the overall WWF response of a sewer system. For example, if a municipality wants to identify the I/I response of a sewer system upstream of some critical point (e.g. a pump station or wastewater treatment plant), a model could be constructed by simplifying the entire sewer network upstream of that point into one or more sewer basins. Measured WWF can then be used to calibrate the models I/I response and design flow events can be projected (either using design storms or continuous simulation techniques). This simplified technique, although it does not provide information on the detailed hydraulics of the upstream sewer system, can provide invaluable information regarding the management of WWF at a pump station or wastewater treatment plant. If a sophisticated model is used to perform this simplified effort (such as SWMM), the model can always be expanded at a later time to include the detailed upstream sewer hydraulics.

Detailed planning level modeling would be considered for existing systems when the flows (both DWF and WWF) are estimated throughout a sewer network, and the flows are routed through the sewer network to a downstream point. This type of modeling is typically performed during master planning projects. In selecting a model for detailed planning level investigations, it is necessary to not only identify the core hydrologic and hydraulic features of a model, but also all the options that might be necessary to provide an efficient analysis of a complex system (see the Other Model Features above). When selecting a model based on core features, the model should simulate what the system is experiencing (i.e. surcharge, looped connections, complex pump stations and forcemains, etc). Also, many times the optional features tend to be the discriminating factors in selecting a model when the core features are very similar (e.g. PCSWMM, InfoSWMM, and SewerGEMS – which all have the same SWMM5 engine, but different GUI's).

Design level models are used to design new facilities, but may not need to be as sophisticated as models used for detailed planning. If new pipes are being designed that do not surcharge, then less sophisticated hydraulic routines may be adequate (e.g. models that utilize the Step Method or the Kinematic wave method). These models are very useful for designing sewers for new developments or even completing detailed planning level modeling if an existing system is not hydraulically complex and any surcharging will be relieved with upsized or paralleled pipelines. However, the results from these types of models are not typically satisfactory for combined sewer systems or sanitary sewer systems that experience extensive I/I (i.e. if surcharging could occur).

CONCLUSIONS

Too simple of a model does not adequately represent reality and can lead to inappropriate decisions. Too complex of a model may be difficult to use (including interpretation of results) and my lead to abandonment. Modeling software packages have a variety of strengths and weaknesses. Each software company has developed its own software package based on its vision, experience, and client base. Therefore, a software package may be stronger for some applications than for others. A model should only be used to assist in informed decision-making. Since all models include some simplification of the actual system, the engineer or operator should make the final decision, not the model.

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APPENDIX D – DRY WEATHER FLOW CALIBRATION PLOTS

Table 1 Dry Weather Flow Calibration Results
Sanitary Sewer Master Plan Update
City of Chico

		Weekday Dry Weather Flow												Weekend Dry Weather Flow												Average Dry Weather Flow[4]		
		Measured Data[1]				Modeled Data[2]				Percent Error[3]				Measured Data[1]				Modeled Data[2]				Percent Error[3]						
Meter Number	Pipe Diameter (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (%)	Peak Flow (%)	Avg. Velocity (%)	Avg. Level (%)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (%)	Peak Flow (%)	Avg. Velocity (%)	Avg. Level (%)	Measured ADWF (mgd)	Modeled ADWF (mgd)	Percent Difference (%)
1	30	1.330	1.843	1.90	8.0	1.366	1.883	1.90	8.1	2.7%	2.2%	0.2%	1.2%	1.357	2.084	1.90	8.1	1.403	2.141	1.91	8.2	3.4%	2.7%	0.7%	0.8%	1.338	1.377	2.9%
4	36	2.149	2.902	1.64	11.1	2.148	2.853	1.72	11.2	-0.1%	-1.7%	4.8%	1.0%	2.202	3.338	1.65	11.1	2.221	3.210	1.74	11.3	0.9%	-3.8%	5.0%	1.7%	2.164	2.169	0.2%
5	15	0.207	0.275	0.65	6.2	0.207	0.267	0.72	5.7	0.0%	-3.0%	11.2%	-6.9%	0.221	0.323	0.68	6.2	0.221	0.314	0.74	5.9	0.1%	-2.8%	9.2%	-5.7%	0.211	0.211	0.0%
6A	18	0.568	0.770	1.82	5.6	0.555	0.744	1.81	5.5	-2.2%	-3.4%	-0.5%	-0.3%	0.496	0.696	1.68	5.3	0.493	0.673	1.75	5.2	-0.5%	-3.2%	3.9%	-2.3%	0.547	0.538	-1.8%
6B	18	0.466	0.713	1.78	4.7	0.490	0.677	1.87	4.9	5.2%	-5.1%	5.1%	3.2%	0.469	0.784	1.75	4.8	0.429	0.607	1.80	4.6	-8.6%	-22.6%	2.6%	-3.8%	0.467	0.472	1.3%
7	15	0.503	0.834	1.44	6.5	0.505	0.861	1.50	6.3	0.4%	3.2%	3.9%	-2.6%	0.514	0.818	1.45	6.6	0.509	0.870	1.49	6.3	-1.0%	6.3%	3.2%	-3.5%	0.506	0.506	0.0%
8	24	0.507	0.781	1.04	6.5	0.465	0.755	0.99	6.3	-8.4%	-3.4%	-5.3%	-4.3%	0.497	0.870	1.02	6.4	0.453	0.832	0.97	6.1	-8.9%	-4.4%	-5.1%	-5.5%	0.504	0.461	-8.6%
9	21	1.030	1.307	1.43	9.8	1.070	1.319	1.44	10.0	3.9%	0.9%	1.0%	2.5%	0.998	1.336	1.42	9.6	1.031	1.330	1.42	9.8	3.3%	-0.4%	0.3%	2.6%	1.021	1.059	3.7%
10	18	0.902	1.250	2.37	6.5	0.913	1.366	2.30	6.7	1.2%	9.2%	-3.2%	3.0%	0.903	1.280	2.35	6.5	0.921	1.432	2.30	6.7	2.0%	11.9%	-2.2%	2.8%	0.902	0.915	1.4%
11	33	1.456	1.865	1.81	8.6	1.430	1.801	1.85	8.3	-1.8%	-3.4%	2.0%	-3.1%	1.376	1.858	1.79	8.2	1.377	1.830	1.83	8.1	0.1%	-1.5%	2.2%	-0.8%	1.433	1.415	-1.3%
12	14	0.231	0.306	1.34	4.1	0.225	0.329	1.25	4.1	-2.6%	7.4%	-6.5%	0.8%	0.217	0.283	1.33	3.9	0.198	0.282	1.18	3.9	-8.5%	-0.5%	-10.9%	0.0%	0.227	0.217	-4.2%
13	12	0.462	0.596	1.77	6.0	0.465	0.570	1.83	5.9	0.8%	-4.3%	3.5%	-0.8%	0.431	0.540	1.80	5.8	0.441	0.530	1.83	5.7	2.2%	-1.8%	1.7%	-0.6%	0.453	0.458	1.2%
14	18	0.299	0.435	1.73	3.7	0.293	0.407	1.75	3.5	-2.1%	-6.3%	1.5%	-5.3%	0.318	0.491	1.75	3.8	0.308	0.461	1.77	3.6	-2.9%	-6.1%	1.4%	-5.2%	0.304	0.297	-2.4%
15	24	1.062	1.371	2.41	6.5	1.060	1.351	2.28	6.6	-0.2%	-1.5%	-5.1%	1.7%	1.030	1.371	2.36	6.3	1.024	1.353	2.25	6.5	-0.6%	-1.3%	-4.7%	3.8%	1.053	1.050	-0.3%
16	33	0.497	0.690	0.98	6.1	0.497	0.669	1.02	6.0	0.0%	-3.1%	3.6%	-1.9%	0.510	0.748	0.99	6.1	0.510	0.732	1.04	6.0	0.1%	-2.1%	5.0%	-2.9%	0.501	0.501	0.0%
17	23.5	0.302	0.500	1.81	3.1	0.304	0.542	1.73	3.2	0.6%	8.5%	-4.5%	3.1%	0.328	0.514	1.83	3.3	0.323	0.541	1.74	3.3	-1.5%	5.4%	-4.7%	0.7%	0.309	0.309	0.0%
18	10	0.116	0.178	1.46	2.7	0.115	0.171	1.40	2.7	-0.5%	-3.7%	-4.3%	3.2%	0.106	0.170	1.43	2.5	0.106	0.166	1.36	2.6	0.4%	-2.5%	-4.7%	3.4%	0.113	0.113	-0.3%

Notes:
1. Source: City of Chico 2012 Temporary Flow Monitoring Program, V&A Consulting Engineers
2. Average flow, level, and velocity are calculated from weekday/weekend dry weather flow monitoring data. Maximum flow values are hourly peaks corresponding to either weekend or weekday confitions, as appropriate.
3. Percent Difference = (Modeled - Measured)/Measured*100.
4. Average Dry Weather Flow = (5*Weekday Dry Weather Flow + 2*Weekend Dry Weather Flow)/7

City of Chico

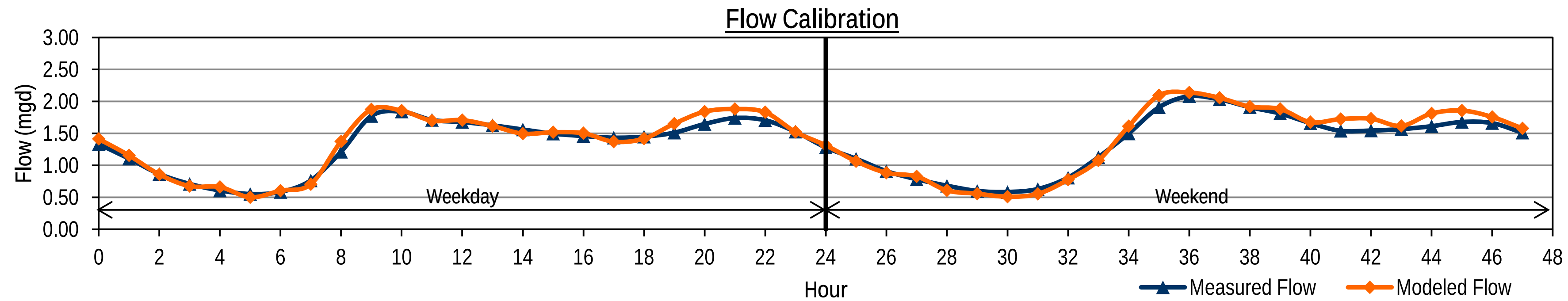
Sanitary Sewer Master Plan Update

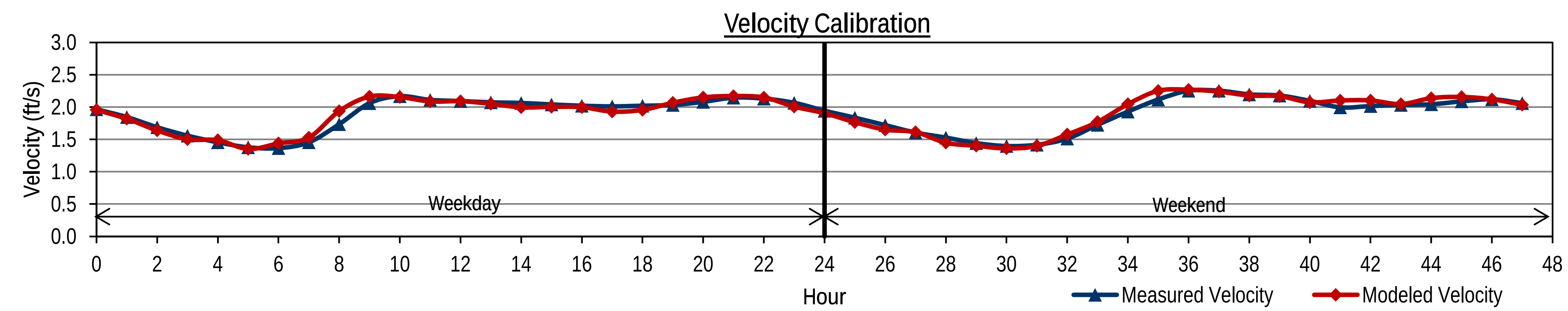
FLOW MONITORING SITE 1 DRY WEATHER FLOW CALIBRATION

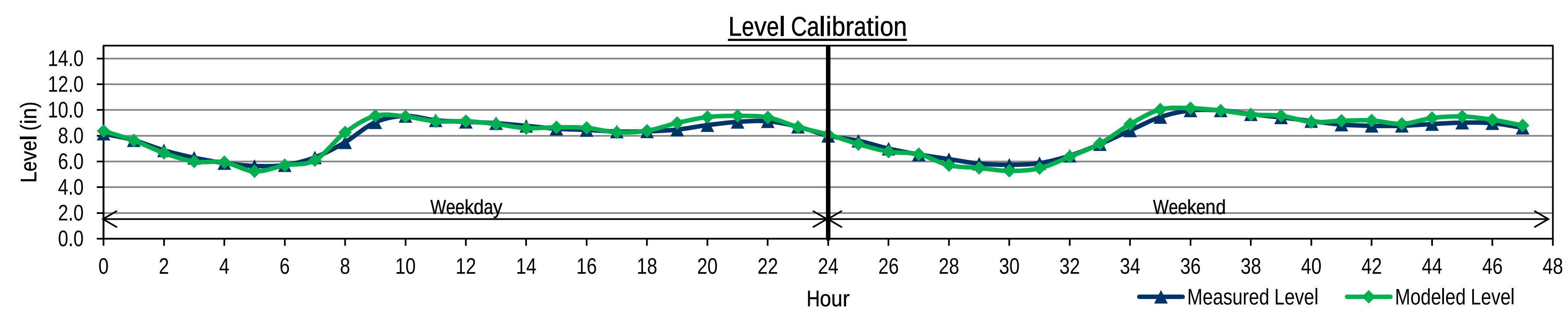
		Measured Data			Modeled Data			Diurnal		
	Hour	Flow (mgd)	Level (in)	Velocity (ft/s)	Flow (mgd)	Level (in)	Velocity (ft/s)	Initial Curve	Modified Curve	Calibrated Diurnal
Weekday	0	1.334	8.2	1.97	1.416	8.4	1.96	0.83	0.65	0.65
	1	1.107	7.7	1.85	1.158	7.6	1.82	0.65	0.53	0.53
	2	0.866	6.9	1.69	0.861	6.7	1.64	0.53	0.45	0.45
	3	0.711	6.3	1.56	0.678	6.0	1.50	0.45	0.41	0.41
	4	0.608	5.9	1.46	0.664	5.9	1.49	0.41	0.44	0.44
	5	0.553	5.6	1.38	0.503	5.2	1.35	0.44	0.57	0.57
	6	0.585	5.7	1.37	0.606	5.7	1.44	0.57	0.91	0.91
	7	0.765	6.3	1.46	0.707	6.1	1.53	0.91	1.33	1.33
	8	1.214	7.5	1.74	1.376	8.3	1.94	1.33	1.38	1.38
	9	1.774	9.0	2.06	1.877	9.5	2.16	1.38	1.28	1.28
	10	1.843	9.5	2.17	1.858	9.5	2.15	1.28	1.26	1.26
	11	1.712	9.2	2.11	1.701	9.1	2.09	1.26	1.22	1.22
	12	1.680	9.1	2.09	1.709	9.1	2.09	1.22	1.17	1.17
	13	1.628	9.0	2.07	1.618	8.9	2.05	1.17	1.12	1.12
	14	1.562	8.8	2.06	1.498	8.6	2.00	1.12	1.09	1.09
	15	1.498	8.5	2.04	1.520	8.7	2.00	1.09	1.07	1.07
	16	1.461	8.4	2.02	1.505	8.6	2.00	1.07	1.08	1.08
	17	1.434	8.3	2.01	1.373	8.3	1.93	1.08	1.13	1.13
	18	1.450	8.3	2.02	1.420	8.4	1.96	1.13	1.23	1.23
	19	1.513	8.5	2.03	1.654	9.0	2.07	1.23	1.30	1.30
	20	1.649	8.8	2.08	1.842	9.5	2.15	1.30	1.28	1.28
	21	1.743	9.1	2.15	1.883	9.5	2.17	1.28	1.14	1.14
	22	1.708	9.1	2.13	1.833	9.4	2.15	1.14	1.00	1.00
	23	1.528	8.7	2.07	1.525	8.7	2.01	1.00	0.83	0.83
Weekend	24	1.282	8.0	1.94	1.316	8.1	1.91	0.83	0.68	0.68
	25	1.105	7.6	1.84	1.066	7.4	1.77	0.68	0.59	0.59
	26	0.911	7.0	1.72	0.886	6.8	1.65	0.59	0.51	0.51
	27	0.783	6.5	1.61	0.829	6.6	1.61	0.51	0.45	0.45
	28	0.683	6.2	1.53	0.611	5.7	1.45	0.45	0.44	0.44
	29	0.600	5.8	1.44	0.559	5.5	1.40	0.44	0.47	0.47
	30	0.584	5.7	1.40	0.512	5.3	1.36	0.47	0.60	0.60
	31	0.630	5.9	1.42	0.556	5.5	1.40	0.60	0.84	0.84
	32	0.809	6.4	1.51	0.778	6.4	1.58	0.84	1.12	1.12
	33	1.129	7.3	1.73	1.078	7.4	1.77	1.12	1.43	1.43
	34	1.500	8.4	1.93	1.614	8.9	2.05	1.43	1.56	1.56
	35	1.910	9.5	2.12	2.096	10.0	2.25	1.56	1.52	1.52
	36	2.084	10.0	2.25	2.141	10.1	2.27	1.52	1.43	1.43
	37	2.035	10.0	2.25	2.059	10.0	2.24	1.43	1.36	1.36
	38	1.912	9.7	2.20	1.920	9.6	2.18	1.36	1.24	1.24
	39	1.814	9.4	2.18	1.884	9.6	2.17	1.24	1.15	1.15
	40	1.663	9.1	2.10	1.678	9.1	2.07	1.15	1.16	1.16
	41	1.542	8.9	2.00	1.726	9.2	2.10	1.16	1.17	1.17
	42	1.546	8.8	2.02	1.732	9.2	2.10	1.17	1.21	1.21
	43	1.569	8.8	2.03	1.619	8.9	2.05	1.21	1.26	1.26
	44	1.614	8.9	2.04	1.813	9.4	2.14	1.26	1.24	1.24
	45	1.681	9.0	2.09	1.859	9.5	2.16	1.24	1.13	1.13
	46	1.663	9.0	2.12	1.759	9.2	2.12	1.13	0.96	0.96
	47	1.513	8.6	2.06	1.580	8.8	2.04	0.96	0.83	0.83
Average										
Weekday		1.330	8.0	1.90	1.366	8.1	1.90	0.99	0.99	0.99
Weekend		1.357	8.1	1.90	1.403	8.2	1.91	1.01	1.01	1.01
ADWF[(1)]		1.338	8.0	1.90	1.377	8.1	1.90	1.00	1.00	1.00
% Error										
Weekday					2.7%	1.2%	0.2%			
Weekend					3.4%	0.8%	0.7%			

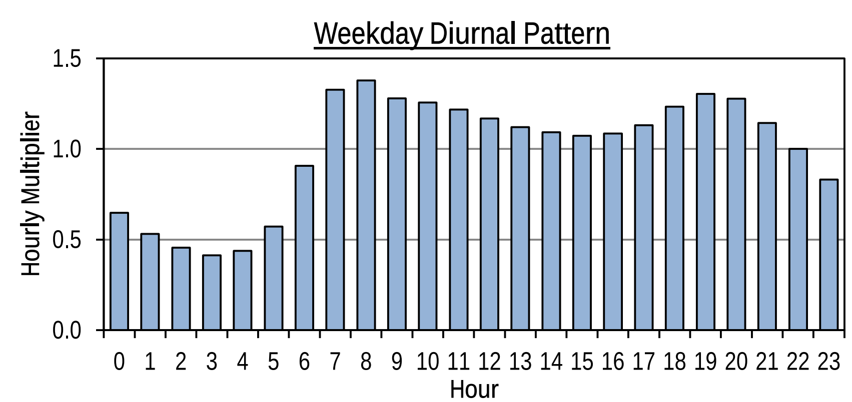
Note:

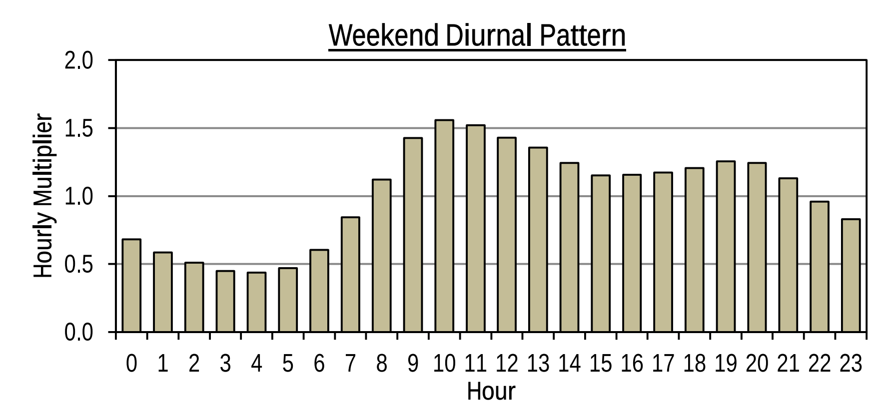
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

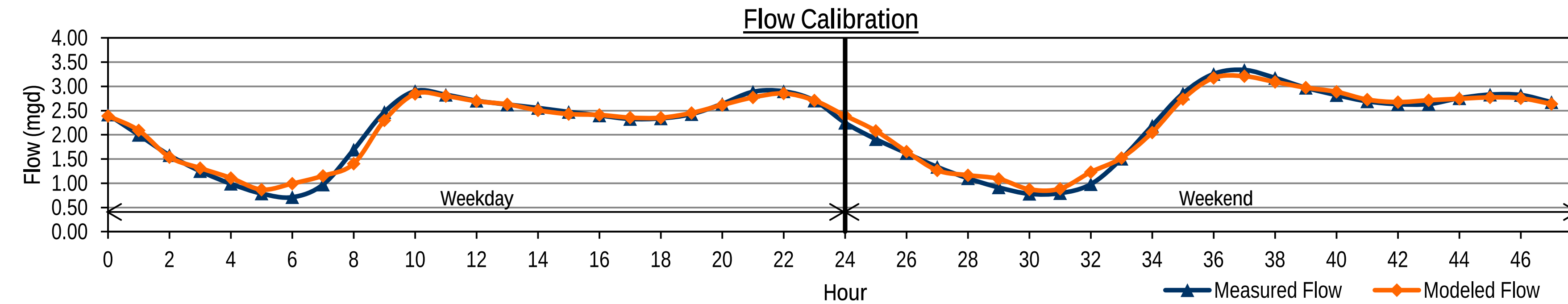
Sanitary Sewer Master Plan Update

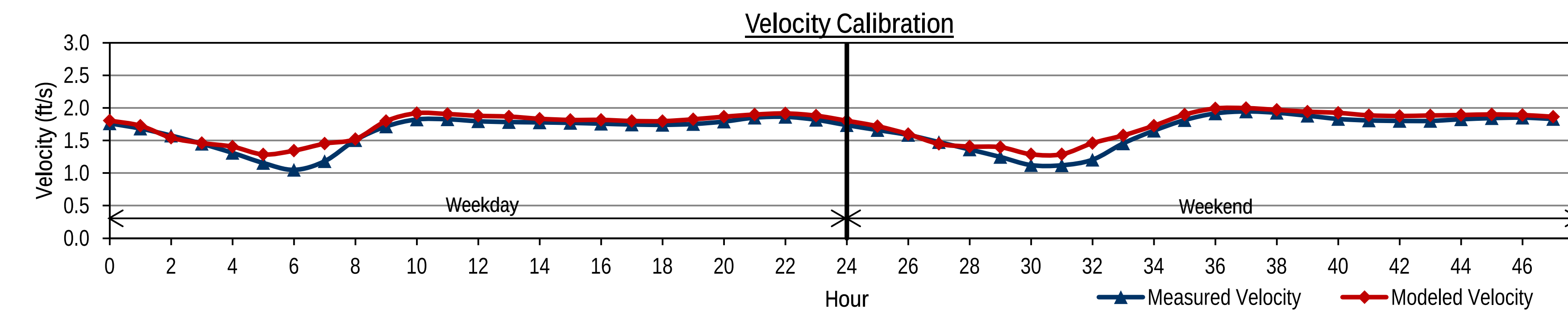
FLOW MONITORING SITE 4 DRY WEATHER FLOW CALIBRATION

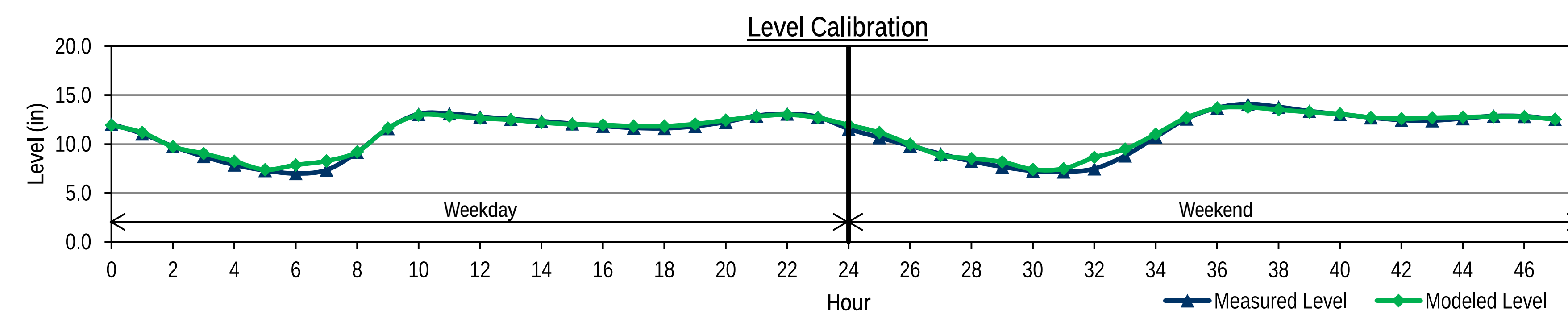
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	2.418	12.0	1.76	2.388	11.9	1.81	0.92	0.58	0.58
	1	1.999	11.0	1.68	2.090	11.2	1.73	0.73	0.44	0.44
	2	1.579	9.8	1.58	1.538	9.7	1.54	0.58	0.34	0.34
	3	1.251	8.7	1.45	1.311	9.0	1.46	0.46	0.30	0.30
	4	0.990	7.9	1.31	1.107	8.2	1.41	0.36	0.43	0.43
	5	0.789	7.3	1.16	0.867	7.4	1.29	0.33	0.76	0.76
	6	0.713	7.0	1.05	0.991	7.9	1.35	0.45	1.07	1.07
	7	0.974	7.3	1.18	1.151	8.3	1.45	0.78	1.40	1.40
	8	1.693	9.2	1.51	1.403	9.2	1.52	1.14	1.35	1.35
	9	2.471	11.6	1.72	2.297	11.6	1.80	1.34	1.27	1.27
	10	2.902	13.1	1.82	2.844	13.0	1.92	1.31	1.22	1.22
	11	2.827	13.1	1.83	2.800	12.9	1.91	1.25	1.18	1.18
	12	2.704	12.8	1.80	2.693	12.6	1.88	1.21	1.14	1.14
	13	2.626	12.5	1.78	2.629	12.5	1.87	1.18	1.11	1.11
	14	2.555	12.3	1.78	2.505	12.2	1.83	1.14	1.08	1.08
	15	2.472	12.1	1.77	2.428	12.0	1.82	1.11	1.08	1.08
	16	2.400	11.8	1.76	2.410	12.0	1.82	1.08	1.12	1.12
	17	2.327	11.6	1.75	2.354	11.8	1.80	1.08	1.22	1.22
	18	2.339	11.6	1.74	2.352	11.8	1.80	1.12	1.33	1.33
	19	2.427	11.8	1.75	2.450	12.1	1.83	1.22	1.34	1.34
	20	2.638	12.2	1.79	2.615	12.4	1.87	1.33	1.25	1.25
	21	2.887	12.9	1.85	2.771	12.8	1.90	1.34	1.12	1.12
	22	2.898	13.1	1.86	2.853	13.0	1.92	1.25	0.92	0.92
	23	2.706	12.8	1.82	2.709	12.7	1.88	1.12	0.73	0.73
Weekend	24	2.249	11.5	1.74	2.396	12.0	1.80	0.88	0.62	0.62
	25	1.911	10.7	1.66	2.081	11.2	1.72	0.75	0.51	0.51
	26	1.622	9.8	1.59	1.653	10.0	1.60	0.62	0.42	0.42
	27	1.338	9.0	1.48	1.265	8.9	1.45	0.51	0.36	0.36
	28	1.103	8.2	1.36	1.164	8.5	1.41	0.42	0.37	0.37
	29	0.915	7.7	1.25	1.090	8.2	1.40	0.36	0.45	0.45
	30	0.783	7.3	1.12	0.872	7.4	1.29	0.37	0.70	0.70
	31	0.796	7.2	1.12	0.885	7.5	1.29	0.45	1.01	1.01
	32	0.981	7.5	1.21	1.229	8.6	1.46	0.70	1.32	1.32
	33	1.506	8.8	1.46	1.520	9.5	1.58	1.01	1.50	1.50
	34	2.187	10.7	1.65	2.047	11.0	1.73	1.32	1.54	1.54
	35	2.852	12.6	1.81	2.738	12.7	1.90	1.50	1.47	1.47
	36	3.255	13.7	1.92	3.174	13.7	1.99	1.54	1.37	1.37
	37	3.338	14.1	1.95	3.210	13.8	2.00	1.47	1.30	1.30
	38	3.174	13.8	1.93	3.091	13.5	1.97	1.37	1.24	1.24
	39	2.971	13.4	1.88	2.974	13.3	1.94	1.30	1.22	1.22
	40	2.820	13.0	1.83	2.888	13.1	1.93	1.24	1.22	1.22
	41	2.691	12.7	1.81	2.727	12.7	1.89	1.22	1.27	1.27
	42	2.632	12.4	1.80	2.675	12.6	1.88	1.22	1.31	1.31
	43	2.634	12.4	1.80	2.713	12.7	1.89	1.27	1.30	1.30
	44	2.755	12.6	1.83	2.744	12.8	1.89	1.31	1.24	1.24
	45	2.830	12.9	1.84	2.772	12.8	1.90	1.30	1.04	1.04
	46	2.822	12.8	1.85	2.755	12.8	1.89	1.24	0.88	0.88
	47	2.674	12.5	1.83	2.637	12.5	1.87	1.04	0.75	0.75
Average										
Weekday		2.149	11.1	1.64	2.148	11.2	1.72	0.99	0.99	0.99
Weekend		2.202	11.1	1.65	2.221	11.3	1.74	1.02	1.02	1.02
ADWF[(1)]		2.164	11.1	1.65	2.169	11.2	1.73	1.00	1.00	1.00
% Error										
Weekday					-0.1%	1.0%	4.8%			
Weekend					0.9%	1.7%	5.0%			

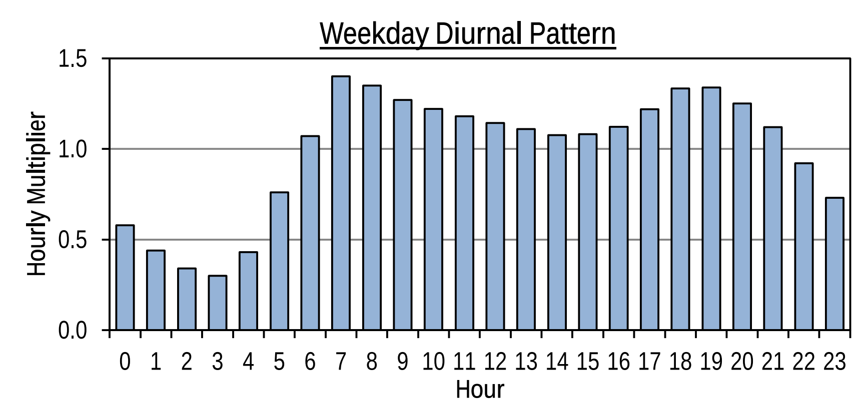
Note:

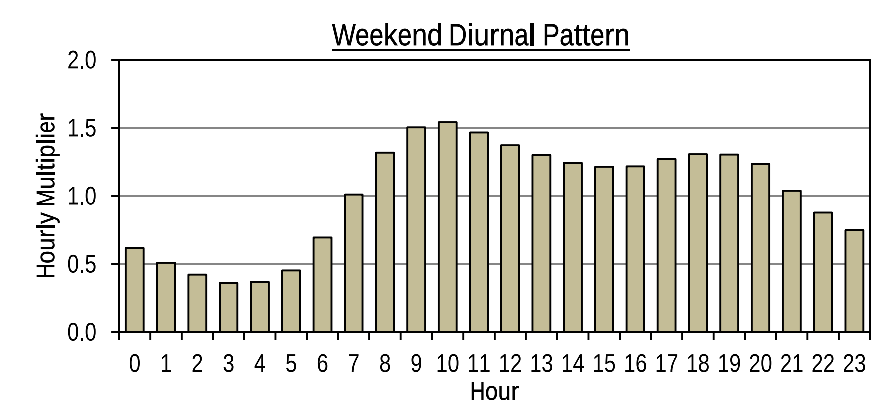
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

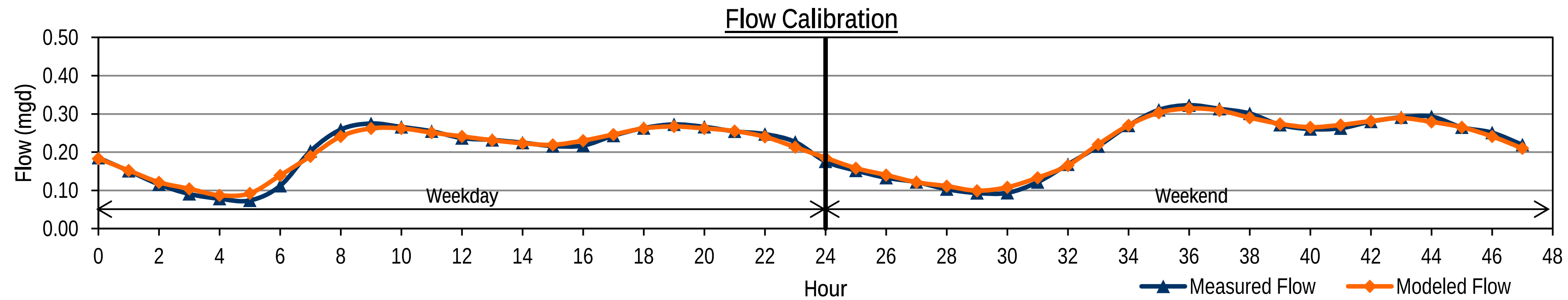
Sanitary Sewer Master Plan Update

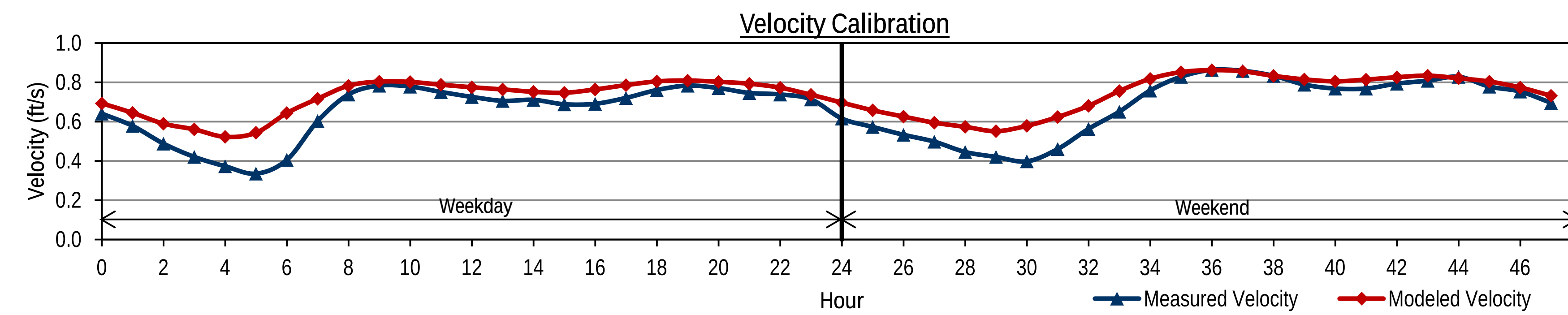
FLOW MONITORING SITE 5 DRY WEATHER FLOW CALIBRATION

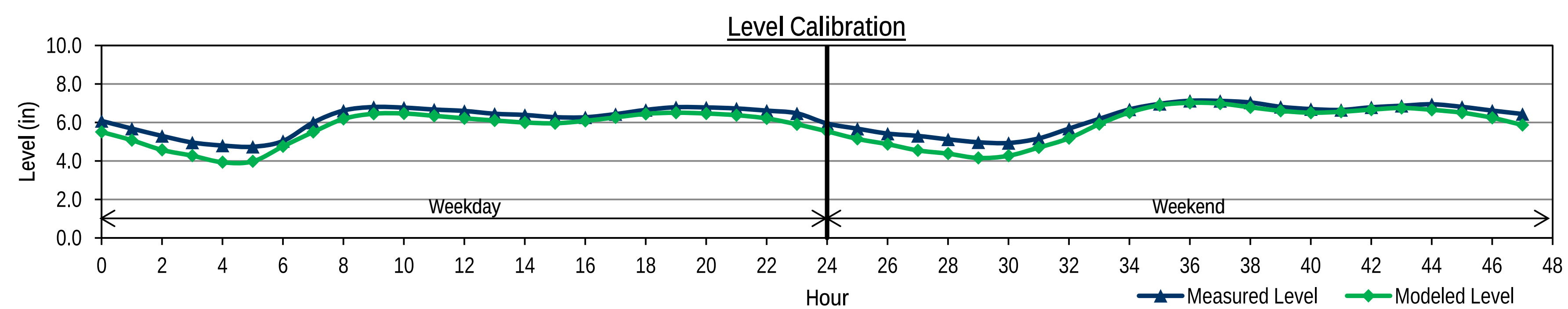
		Measured Data			Modeled Data			Diurnal		
		Flow	Level	Velocity	Flow	Level	Velocity	Initial	Modified	Calibrated
	Hour	(mgd)	(in)	(ft/s)	(mgd)	(in)	(ft/s)	Curve	Curve	Diurnal
Weekday	0	0.186	6.1	0.64	0.183	5.5	0.69	0.72	0.55	0.55
	1	0.151	5.7	0.58	0.152	5.1	0.64	0.55	0.43	0.43
	2	0.116	5.3	0.49	0.121	4.6	0.59	0.43	0.37	0.37
	3	0.091	5.0	0.42	0.104	4.3	0.56	0.37	0.35	0.35
	4	0.079	4.8	0.37	0.087	3.9	0.52	0.35	0.53	0.53
	5	0.074	4.7	0.34	0.092	4.0	0.54	0.53	0.96	0.96
	6	0.112	5.0	0.41	0.139	4.8	0.64	0.96	1.23	1.23
	7	0.203	6.0	0.60	0.189	5.5	0.72	1.23	1.30	1.30
	8	0.259	6.6	0.74	0.241	6.2	0.78	1.30	1.26	1.26
	9	0.275	6.8	0.78	0.262	6.5	0.80	1.26	1.21	1.21
	10	0.266	6.8	0.78	0.262	6.5	0.80	1.21	1.12	1.12
	11	0.255	6.7	0.75	0.251	6.3	0.79	1.12	1.10	1.10
	12	0.237	6.6	0.73	0.241	6.2	0.77	1.10	1.07	1.07
	13	0.232	6.5	0.71	0.231	6.1	0.76	1.07	1.03	1.03
	14	0.225	6.4	0.71	0.223	6.0	0.75	1.03	1.03	1.03
	15	0.216	6.3	0.69	0.219	6.0	0.75	1.03	1.15	1.15
	16	0.218	6.3	0.69	0.230	6.1	0.76	1.15	1.25	1.25
	17	0.243	6.4	0.72	0.246	6.3	0.79	1.25	1.29	1.29
	18	0.263	6.7	0.76	0.262	6.4	0.80	1.29	1.26	1.26
	19	0.273	6.8	0.78	0.267	6.5	0.81	1.26	1.21	1.21
	20	0.266	6.8	0.77	0.262	6.5	0.80	1.21	1.17	1.17
	21	0.255	6.7	0.75	0.255	6.4	0.79	1.17	1.08	1.08
	22	0.247	6.6	0.74	0.240	6.2	0.77	1.08	0.88	0.88
	23	0.227	6.5	0.71	0.213	5.9	0.74	0.88	0.72	0.72
Weekend	24	0.176	5.9	0.62	0.185	5.5	0.70	0.72	0.63	0.63
	25	0.152	5.7	0.57	0.158	5.1	0.66	0.63	0.58	0.58
	26	0.133	5.4	0.53	0.140	4.9	0.63	0.58	0.49	0.49
	27	0.122	5.3	0.50	0.121	4.6	0.59	0.49	0.44	0.44
	28	0.104	5.1	0.45	0.111	4.4	0.57	0.44	0.44	0.44
	29	0.094	5.0	0.42	0.099	4.2	0.55	0.44	0.58	0.58
	30	0.094	4.9	0.40	0.108	4.3	0.58	0.58	0.80	0.80
	31	0.122	5.2	0.46	0.133	4.7	0.62	0.80	1.02	1.02
	32	0.168	5.7	0.56	0.165	5.2	0.68	1.02	1.28	1.28
	33	0.216	6.2	0.65	0.220	5.9	0.76	1.28	1.47	1.47
	34	0.270	6.7	0.76	0.270	6.5	0.82	1.47	1.53	1.53
	35	0.311	7.0	0.83	0.303	6.9	0.85	1.53	1.49	1.49
	36	0.323	7.1	0.86	0.314	7.0	0.86	1.49	1.43	1.43
	37	0.314	7.1	0.86	0.309	7.0	0.86	1.43	1.29	1.29
	38	0.302	7.0	0.83	0.290	6.8	0.83	1.29	1.24	1.24
	39	0.272	6.8	0.79	0.274	6.6	0.81	1.24	1.25	1.25
	40	0.261	6.7	0.77	0.265	6.5	0.80	1.25	1.33	1.33
	41	0.263	6.7	0.77	0.271	6.6	0.81	1.33	1.38	1.38
	42	0.280	6.8	0.79	0.281	6.7	0.83	1.38	1.39	1.39
	43	0.291	6.9	0.81	0.289	6.8	0.83	1.39	1.26	1.26
	44	0.293	6.9	0.83	0.279	6.7	0.82	1.26	1.19	1.19
	45	0.265	6.8	0.78	0.265	6.5	0.80	1.19	1.04	1.04
	46	0.251	6.6	0.75	0.241	6.2	0.77	1.04	0.83	0.83
	47	0.220	6.4	0.70	0.210	5.9	0.73	0.83	0.72	0.72
Average										
Weekday		0.207	6.2	0.65	0.207	5.7	0.72	0.98	0.98	0.98
Weekend		0.221	6.2	0.68	0.221	5.9	0.74	1.05	1.05	1.05
ADWF[1]		0.211	6.2	0.66	0.211	5.8	0.73	1.00	1.00	1.00
% Error										
Weekday					0.0%	-6.9%	11.2%			
Weekend					0.1%	-5.7%	9.2%			

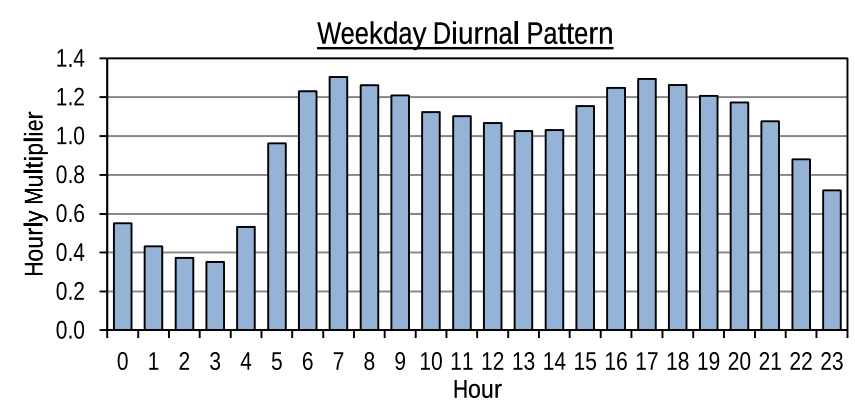
Note:

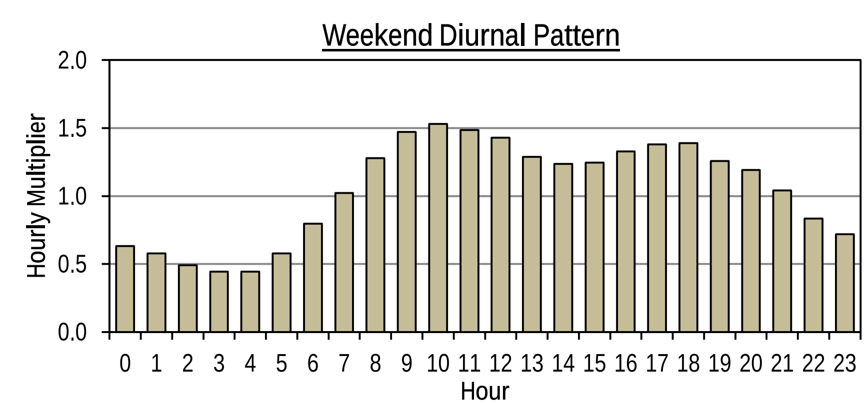
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

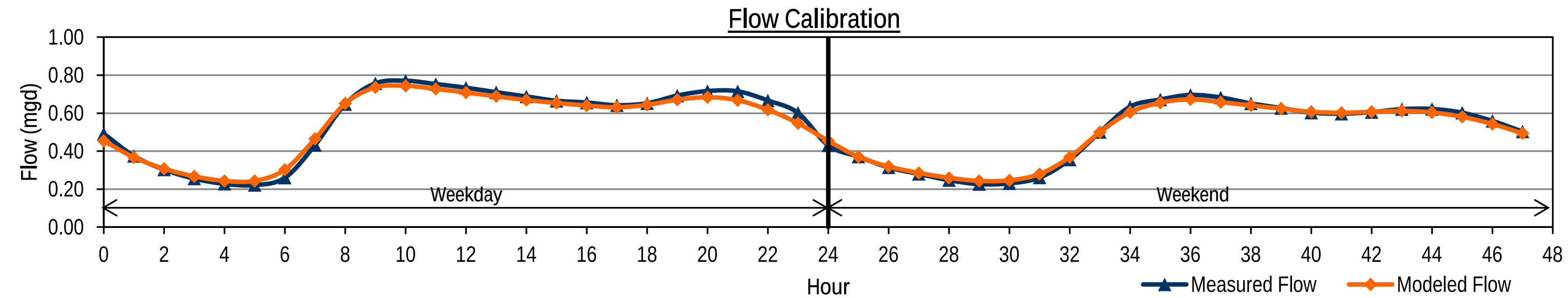
Sanitary Sewer Master Plan Update

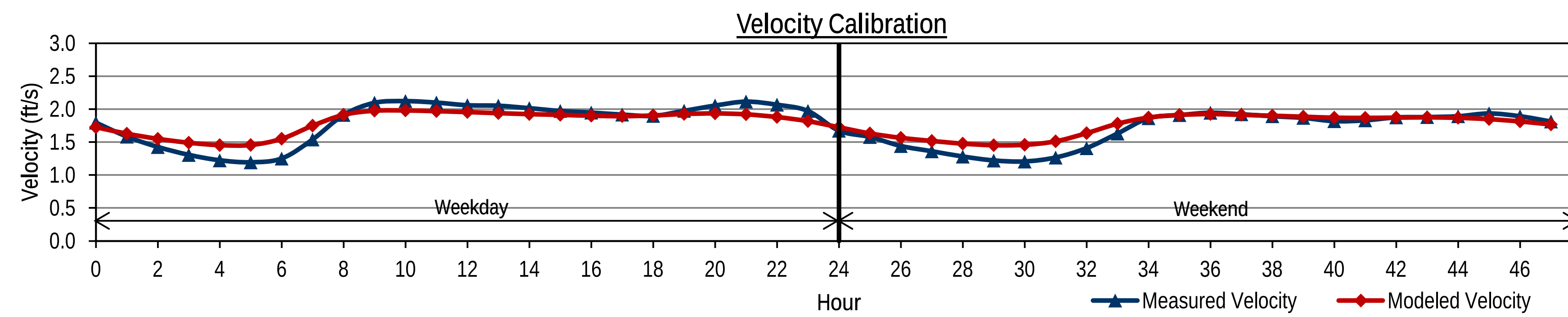
FLOW MONITORING SITE 6A DRY WEATHER FLOW CALIBRATION

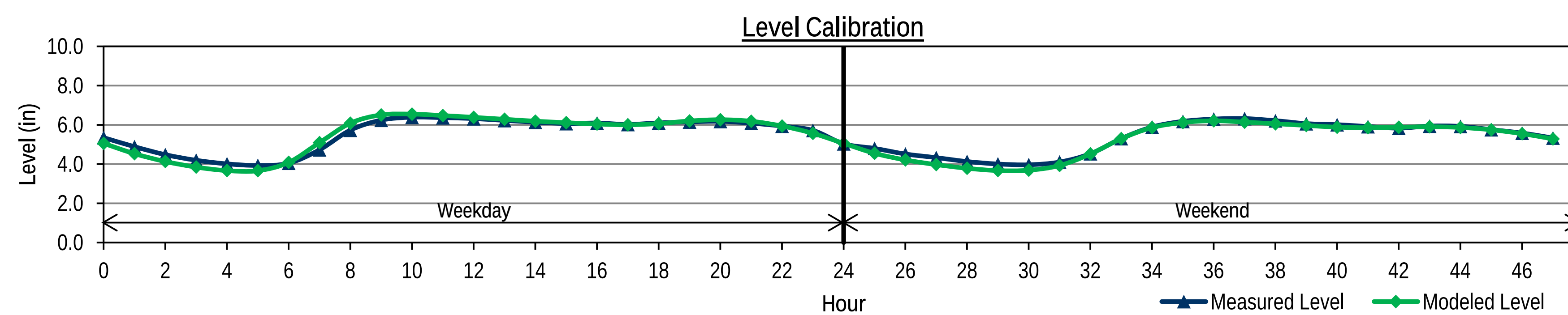
		Measured Data			Modeled Data			Diurnal		
		Flow	Level	Velocity	Flow	Level	Velocity	Initial	Modified	Calibrated
	Hour	(mgd)	(in)	(ft/s)	(mgd)	(in)	(ft/s)	Curve	Curve	Diurnal
Weekday	0	0.492	5.3	1.80	0.454	5.1	1.73	0.68	0.55	0.55
	1	0.375	4.9	1.58	0.367	4.5	1.63	0.55	0.47	0.47
	2	0.303	4.5	1.43	0.307	4.1	1.55	0.47	0.42	0.42
	3	0.256	4.2	1.31	0.267	3.9	1.49	0.42	0.41	0.41
	4	0.228	4.0	1.22	0.243	3.7	1.45	0.41	0.48	0.48
	5	0.222	3.9	1.19	0.243	3.7	1.46	0.48	0.79	0.79
	6	0.260	4.0	1.25	0.302	4.1	1.55	0.79	1.18	1.18
	7	0.432	4.7	1.54	0.465	5.1	1.75	1.18	1.38	1.38
	8	0.647	5.7	1.91	0.651	6.1	1.92	1.38	1.41	1.41
	9	0.757	6.2	2.10	0.736	6.5	1.98	1.41	1.38	1.38
	10	0.770	6.4	2.12	0.744	6.5	1.98	1.38	1.34	1.34
	11	0.753	6.4	2.10	0.728	6.5	1.97	1.34	1.30	1.30
	12	0.734	6.3	2.06	0.709	6.4	1.96	1.30	1.26	1.26
	13	0.710	6.2	2.05	0.689	6.3	1.94	1.26	1.22	1.22
	14	0.688	6.1	2.02	0.669	6.2	1.93	1.22	1.20	1.20
	15	0.665	6.1	1.97	0.654	6.1	1.91	1.20	1.17	1.17
	16	0.656	6.1	1.95	0.640	6.0	1.90	1.17	1.19	1.19
	17	0.642	6.0	1.92	0.631	6.0	1.89	1.19	1.26	1.26
	18	0.652	6.1	1.90	0.644	6.1	1.91	1.26	1.31	1.31
	19	0.692	6.1	1.98	0.671	6.2	1.93	1.31	1.31	1.31
	20	0.716	6.2	2.06	0.684	6.3	1.94	1.31	1.22	1.22
	21	0.715	6.1	2.12	0.668	6.2	1.92	1.22	1.10	1.10
	22	0.667	5.9	2.07	0.618	5.9	1.88	1.10	0.90	0.90
	23	0.601	5.7	1.97	0.547	5.6	1.82	0.90	0.68	0.68
Weekend	24	0.430	5.0	1.67	0.454	5.1	1.73	0.68	0.58	0.58
	25	0.371	4.8	1.58	0.370	4.6	1.63	0.58	0.51	0.51
	26	0.315	4.5	1.44	0.319	4.2	1.57	0.51	0.45	0.45
	27	0.280	4.3	1.36	0.285	4.0	1.52	0.45	0.41	0.41
	28	0.248	4.1	1.28	0.259	3.8	1.48	0.41	0.42	0.42
	29	0.227	4.0	1.22	0.243	3.7	1.45	0.42	0.48	0.48
	30	0.231	4.0	1.21	0.246	3.7	1.46	0.48	0.65	0.65
	31	0.261	4.1	1.27	0.279	3.9	1.51	0.65	0.91	0.91
	32	0.356	4.5	1.41	0.368	4.5	1.64	0.91	1.16	1.16
	33	0.500	5.3	1.63	0.500	5.3	1.78	1.16	1.23	1.23
	34	0.634	5.9	1.86	0.605	5.9	1.87	1.23	1.27	1.27
	35	0.672	6.2	1.91	0.655	6.1	1.91	1.27	1.25	1.25
	36	0.696	6.3	1.95	0.673	6.2	1.93	1.25	1.19	1.19
	37	0.682	6.3	1.92	0.658	6.1	1.91	1.19	1.15	1.15
	38	0.651	6.2	1.89	0.641	6.1	1.90	1.15	1.10	1.10
	39	0.627	6.1	1.87	0.624	6.0	1.89	1.10	1.09	1.09
	40	0.603	6.0	1.82	0.607	5.9	1.87	1.09	1.11	1.11
	41	0.597	5.9	1.83	0.602	5.9	1.87	1.11	1.13	1.13
	42	0.605	5.8	1.88	0.607	5.9	1.87	1.13	1.14	1.14
	43	0.621	5.9	1.88	0.612	5.9	1.88	1.14	1.10	1.10
	44	0.622	5.9	1.89	0.604	5.9	1.87	1.10	1.02	1.02
	45	0.602	5.8	1.94	0.581	5.7	1.85	1.02	0.92	0.92
	46	0.559	5.6	1.89	0.543	5.5	1.81	0.92	0.79	0.79
	47	0.503	5.3	1.81	0.494	5.3	1.77	0.79	0.68	0.68
Average										
Weekday		0.568	5.6	1.82	0.555	5.5	1.81	1.04	1.04	1.04
Weekend		0.496	5.3	1.68	0.493	5.2	1.75	0.91	0.91	0.91
ADWF[(1)]		0.547	5.5	1.78	0.538	5.4	1.79	1.00	1.00	1.00
% Error										
Weekday					-2.2%	-0.3%	-0.5%			
Weekend					-0.5%	-2.3%	3.9%			

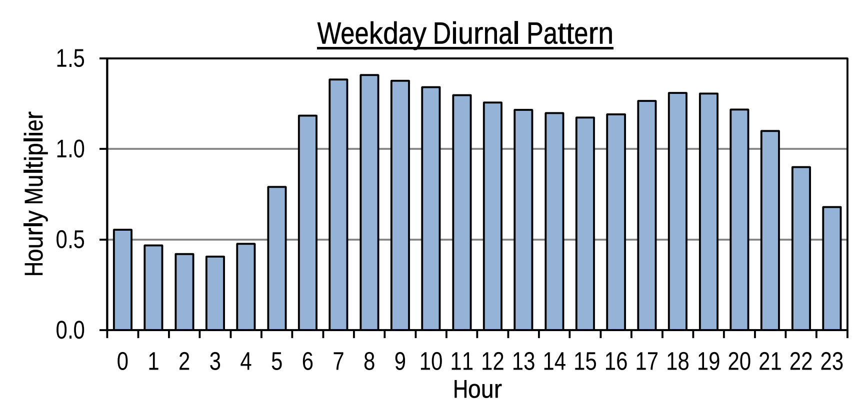
Note:

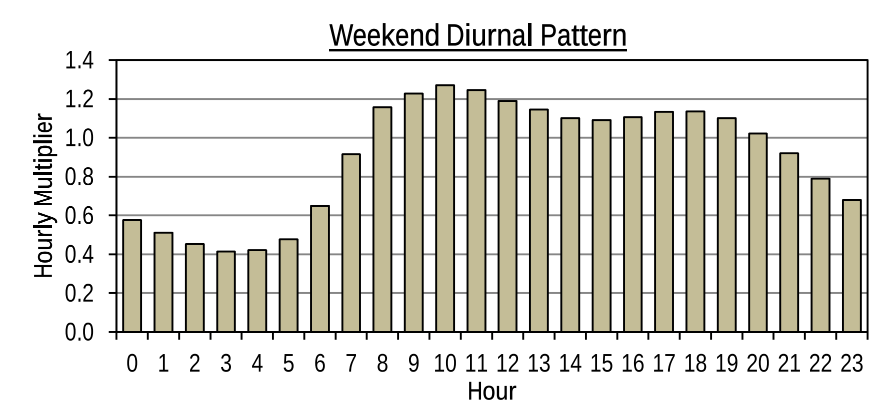
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7







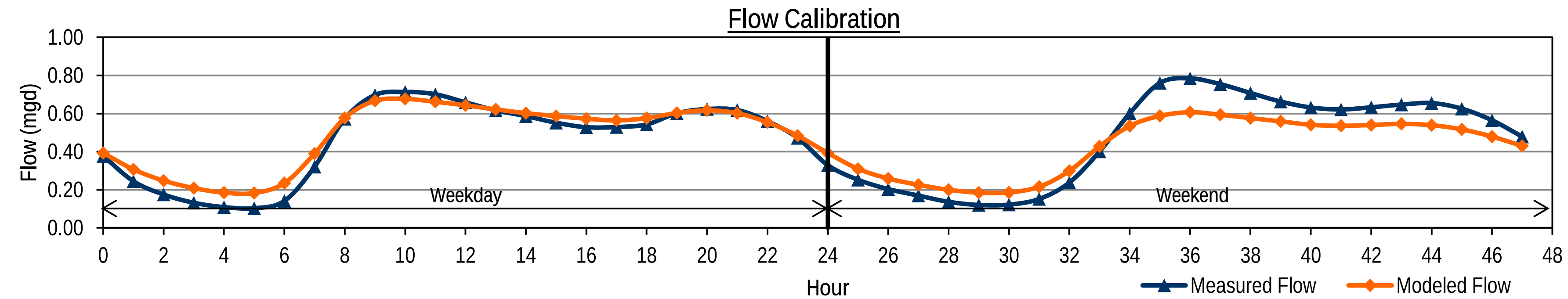


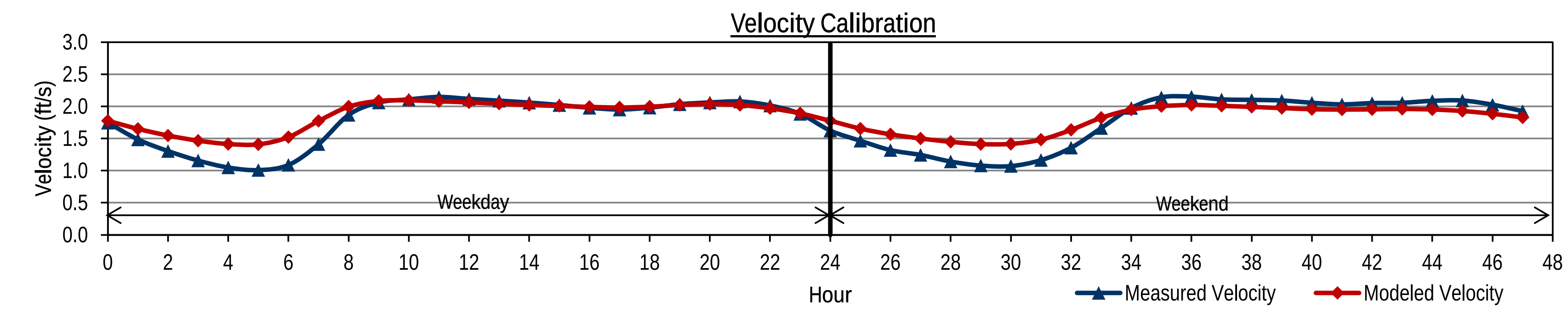


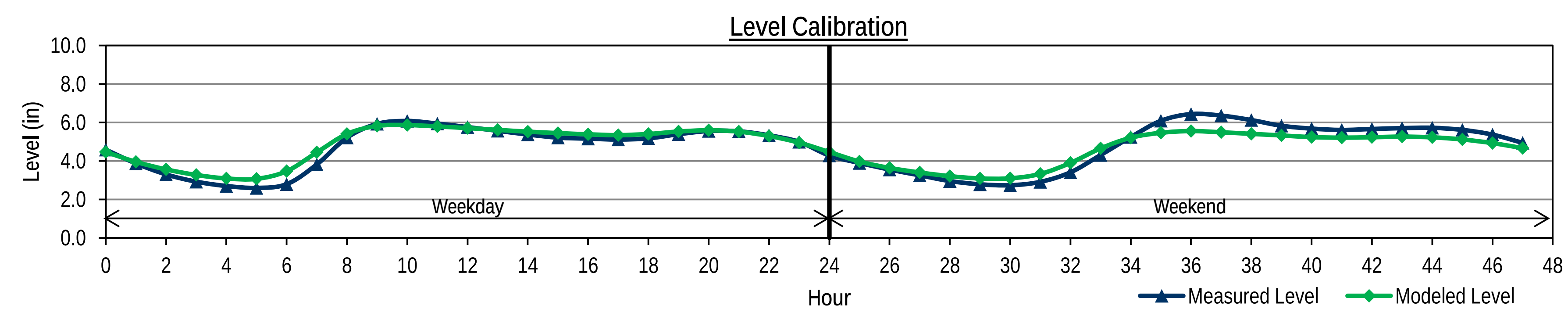
City of Chico
Sanitary Sewer Master Plan Update
FLOW MONITORING SITE 6B DRY WEATHER FLOW CALIBRATION

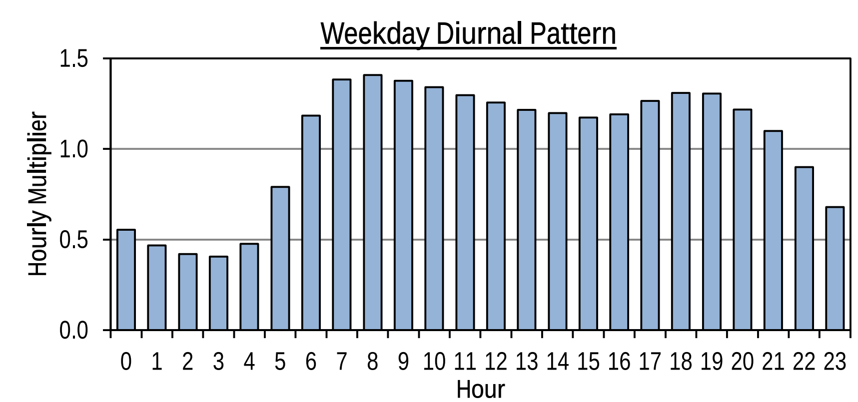
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	0.377	4.6	1.75	0.393	4.5	1.78	0.52	0.38	0.55
	1	0.245	3.9	1.49	0.307	4.0	1.65	0.38	0.28	0.47
	2	0.175	3.3	1.31	0.248	3.6	1.55	0.28	0.23	0.42
	3	0.132	2.9	1.16	0.209	3.3	1.47	0.23	0.22	0.41
	4	0.109	2.7	1.05	0.185	3.1	1.41	0.22	0.30	0.48
	5	0.104	2.6	1.01	0.183	3.1	1.41	0.30	0.69	0.79
	6	0.142	2.8	1.09	0.235	3.5	1.52	0.69	1.23	1.18
	7	0.321	3.8	1.41	0.390	4.5	1.77	1.23	1.49	1.38
	8	0.572	5.2	1.87	0.577	5.4	2.00	1.49	1.53	1.41
	9	0.697	5.9	2.06	0.667	5.8	2.09	1.53	1.50	1.38
	10	0.713	6.1	2.11	0.677	5.9	2.10	1.50	1.41	1.34
	11	0.701	5.9	2.15	0.662	5.8	2.08	1.41	1.32	1.30
	12	0.659	5.8	2.12	0.643	5.7	2.06	1.32	1.26	1.26
	13	0.617	5.6	2.09	0.622	5.6	2.04	1.26	1.18	1.22
	14	0.586	5.4	2.06	0.602	5.5	2.02	1.18	1.13	1.20
	15	0.552	5.2	2.02	0.587	5.5	2.01	1.13	1.13	1.17
	16	0.528	5.2	1.98	0.573	5.4	1.99	1.13	1.16	1.19
	17	0.529	5.1	1.95	0.564	5.3	1.98	1.16	1.29	1.26
	18	0.543	5.2	1.98	0.576	5.4	2.00	1.29	1.34	1.31
	19	0.601	5.4	2.03	0.603	5.5	2.02	1.34	1.33	1.31
	20	0.624	5.6	2.06	0.617	5.6	2.04	1.33	1.20	1.22
	21	0.618	5.5	2.08	0.602	5.5	2.02	1.20	1.01	1.10
	22	0.560	5.3	2.01	0.554	5.3	1.97	1.01	0.81	0.90
	23	0.472	5.0	1.88	0.484	5.0	1.89	0.81	0.52	0.68
Weekend	24	0.329	4.3	1.62	0.393	4.5	1.78	0.54	0.44	0.58
	25	0.253	3.9	1.47	0.310	4.0	1.65	0.44	0.36	0.51
	26	0.204	3.6	1.32	0.259	3.6	1.57	0.36	0.29	0.45
	27	0.170	3.3	1.25	0.226	3.4	1.50	0.29	0.26	0.41
	28	0.137	3.0	1.14	0.200	3.2	1.45	0.26	0.26	0.42
	29	0.120	2.8	1.08	0.185	3.1	1.41	0.26	0.33	0.48
	30	0.122	2.7	1.07	0.186	3.1	1.42	0.33	0.51	0.65
	31	0.152	2.9	1.17	0.216	3.3	1.48	0.51	0.86	0.91
	32	0.238	3.4	1.36	0.299	3.9	1.64	0.86	1.29	1.16
	33	0.401	4.3	1.66	0.428	4.7	1.82	1.29	1.63	1.23
	34	0.601	5.2	1.98	0.535	5.2	1.95	1.63	1.68	1.27
	35	0.760	6.1	2.14	0.588	5.5	2.00	1.68	1.62	1.25
	36	0.784	6.4	2.15	0.607	5.6	2.02	1.62	1.52	1.19
	37	0.754	6.4	2.11	0.594	5.5	2.01	1.52	1.42	1.15
	38	0.708	6.1	2.10	0.576	5.4	1.99	1.42	1.35	1.10
	39	0.663	5.8	2.09	0.559	5.3	1.98	1.35	1.33	1.09
	40	0.632	5.7	2.06	0.541	5.2	1.96	1.33	1.36	1.11
	41	0.621	5.6	2.03	0.536	5.2	1.95	1.36	1.39	1.13
	42	0.633	5.7	2.05	0.540	5.2	1.96	1.39	1.40	1.14
	43	0.647	5.7	2.06	0.546	5.3	1.96	1.40	1.34	1.10
	44	0.655	5.7	2.09	0.539	5.2	1.95	1.34	1.21	1.02
	45	0.625	5.6	2.09	0.517	5.1	1.93	1.21	1.03	0.92
	46	0.564	5.4	2.03	0.479	4.9	1.89	1.03	0.71	0.79
	47	0.479	4.9	1.93	0.430	4.7	1.83	0.71	0.54	0.68
Average										
	Weekday	0.466	4.7	1.78	0.490	4.9	1.87	1.00	1.00	1.04
	Weekend	0.469	4.8	1.75	0.429	4.6	1.80	1.00	1.00	0.91
	ADWF[1]	0.467	4.8	1.77	0.472	4.8	1.85	1.00	1.00	1.00
% Error										
	Weekday				5.2%	3.2%	5.1%			
	Weekend				-8.6%	-3.8%	2.6%			

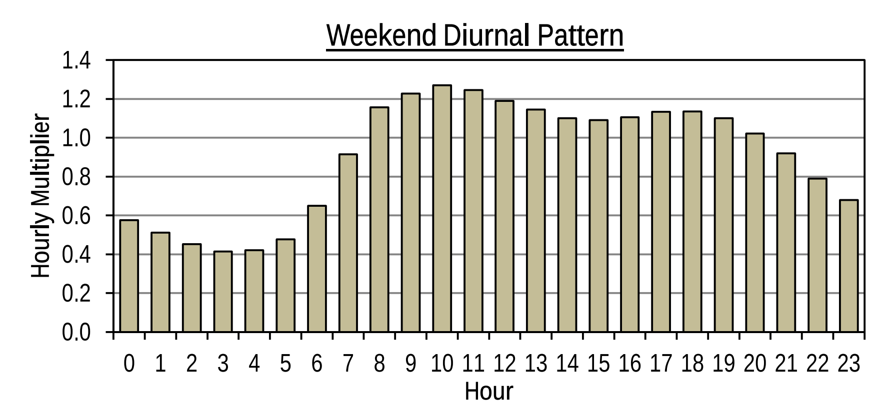
Note:
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











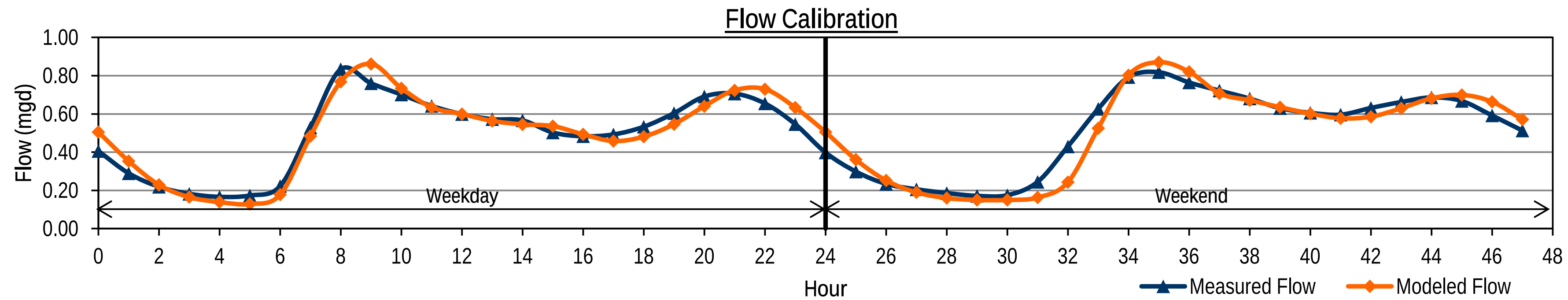
City of Chico

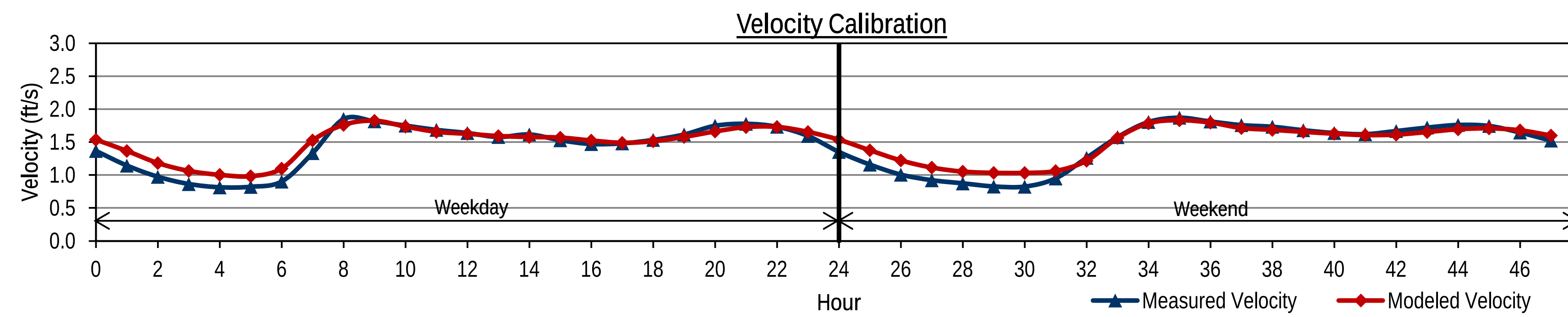
Sanitary Sewer Master Plan Update

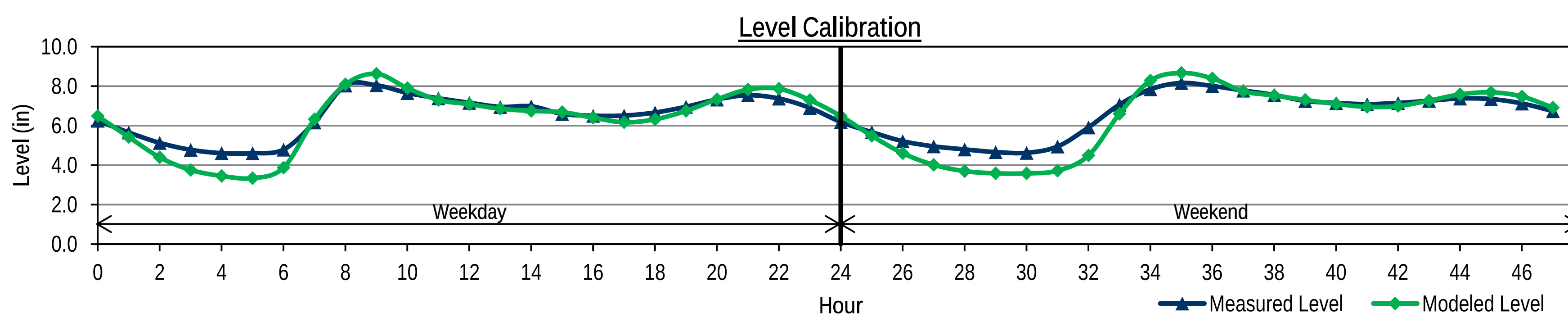
FLOW MONITORING SITE 7 DRY WEATHER FLOW CALIBRATION

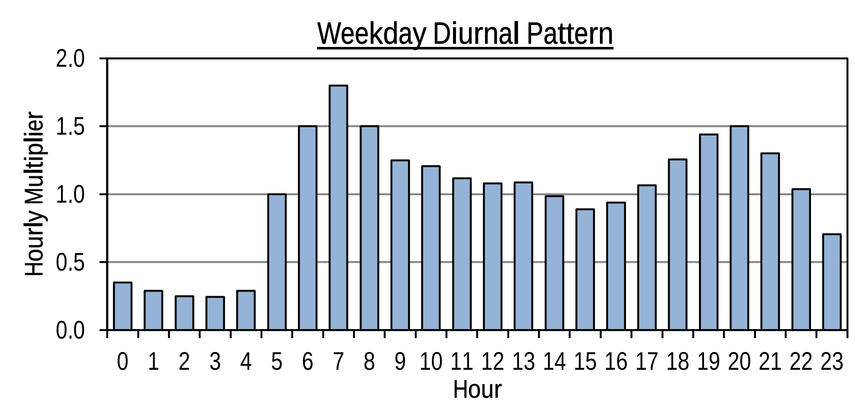
		Measured Data			Modeled Data			Diurnal		
		Flow	Level	Velocity	Flow	Level	Velocity	Initial	Modified	Calibrated
	Hour	(mgd)	(in)	(ft/s)	(mgd)	(in)	(ft/s)	Curve	Curve	Diurnal
Weekday	0	0.406	6.3	1.37	0.505	6.5	1.54	0.57	0.35	0.35
	1	0.289	5.7	1.14	0.353	5.4	1.37	0.43	0.29	0.29
	2	0.219	5.1	0.97	0.229	4.4	1.18	0.36	0.25	0.25
	3	0.182	4.8	0.86	0.165	3.8	1.06	0.33	0.24	0.24
	4	0.166	4.6	0.81	0.139	3.5	1.00	0.34	0.29	0.29
	5	0.173	4.6	0.82	0.129	3.3	0.98	0.44	1.00	1.00
	6	0.223	4.8	0.90	0.178	3.9	1.10	1.04	1.50	1.50
	7	0.528	6.2	1.33	0.484	6.3	1.53	1.65	1.80	1.80
	8	0.834	8.0	1.85	0.768	8.1	1.76	1.50	1.50	1.50
	9	0.760	8.0	1.82	0.861	8.6	1.82	1.39	1.25	1.25
	10	0.701	7.7	1.75	0.734	7.9	1.73	1.27	1.21	1.21
	11	0.642	7.4	1.69	0.634	7.3	1.65	1.18	1.12	1.12
	12	0.599	7.2	1.64	0.599	7.1	1.62	1.13	1.08	1.08
	13	0.573	6.9	1.58	0.563	6.9	1.59	1.12	1.09	1.09
	14	0.566	7.0	1.62	0.545	6.7	1.58	0.99	0.99	0.99
	15	0.503	6.6	1.53	0.536	6.7	1.57	0.95	0.89	0.89
	16	0.483	6.5	1.47	0.493	6.4	1.52	0.97	0.94	0.94
	17	0.493	6.5	1.48	0.458	6.2	1.49	1.05	1.06	1.06
	18	0.533	6.7	1.53	0.481	6.3	1.51	1.19	1.26	1.26
	19	0.604	7.0	1.62	0.546	6.7	1.58	1.37	1.44	1.44
	20	0.691	7.3	1.75	0.640	7.3	1.66	1.40	1.50	1.50
	21	0.706	7.5	1.78	0.723	7.8	1.73	1.29	1.30	1.30
	22	0.655	7.4	1.73	0.729	7.9	1.73	1.08	1.04	1.04
	23	0.546	6.9	1.59	0.633	7.3	1.65	0.80	0.71	0.71
Weekend	24	0.398	6.2	1.35	0.505	6.5	1.54	0.59	0.44	0.44
	25	0.298	5.7	1.16	0.361	5.5	1.38	0.46	0.33	0.33
	26	0.234	5.2	1.01	0.252	4.6	1.22	0.41	0.29	0.29
	27	0.206	5.0	0.92	0.190	4.0	1.11	0.37	0.30	0.30
	28	0.186	4.8	0.87	0.160	3.7	1.05	0.34	0.30	0.30
	29	0.171	4.7	0.83	0.150	3.6	1.03	0.34	0.31	0.31
	30	0.175	4.6	0.82	0.150	3.6	1.03	0.48	0.47	0.47
	31	0.244	4.9	0.95	0.163	3.7	1.06	0.85	1.02	1.02
	32	0.430	5.9	1.26	0.243	4.5	1.22	1.24	1.60	1.60
	33	0.626	7.1	1.58	0.525	6.6	1.56	1.57	1.75	1.75
	34	0.792	7.8	1.81	0.802	8.3	1.78	1.62	1.70	1.70
	35	0.818	8.2	1.87	0.870	8.7	1.83	1.51	1.40	1.40
	36	0.765	8.0	1.81	0.820	8.4	1.79	1.43	1.35	1.35
	37	0.722	7.8	1.76	0.707	7.7	1.71	1.34	1.27	1.27
	38	0.680	7.6	1.73	0.671	7.5	1.68	1.25	1.20	1.20
	39	0.630	7.2	1.68	0.635	7.3	1.65	1.20	1.14	1.14
	40	0.606	7.1	1.64	0.601	7.1	1.63	1.18	1.15	1.15
	41	0.596	7.1	1.62	0.577	7.0	1.61	1.25	1.24	1.24
	42	0.631	7.1	1.67	0.585	7.0	1.61	1.31	1.35	1.35
	43	0.662	7.3	1.72	0.629	7.3	1.65	1.36	1.41	1.41
	44	0.687	7.4	1.76	0.681	7.6	1.69	1.32	1.36	1.36
	45	0.668	7.3	1.75	0.699	7.7	1.71	1.17	1.16	1.16
	46	0.592	7.1	1.65	0.663	7.5	1.68	1.01	0.94	0.94
	47	0.513	6.7	1.52	0.571	6.9	1.60	0.79	0.71	0.71
Average										
Weekday		0.503	6.5	1.44	0.505	6.3	1.50	0.99	1.00	1.00
Weekend		0.514	6.6	1.45	0.509	6.3	1.49	1.02	1.01	1.01
ADWF[(1)]		0.506	6.5	1.44	0.506	6.3	1.50	1.00	1.00	1.00
% Error										
Weekday					0.4%	-2.6%	3.9%			
Weekend					-1.0%	-3.5%	3.2%			

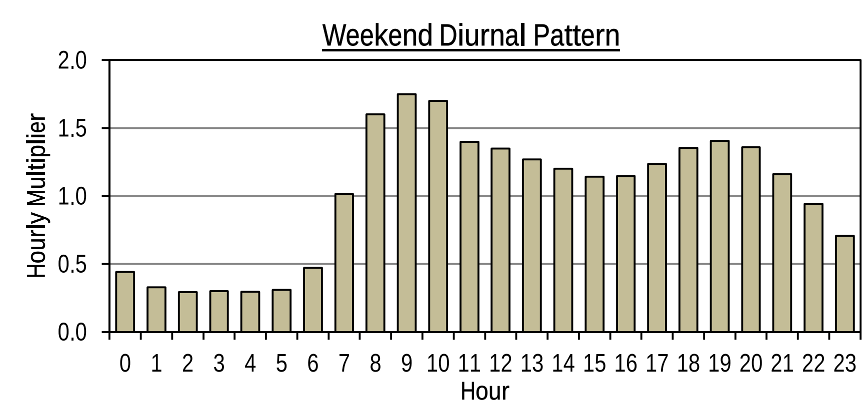
Note:
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 8 DRY WEATHER FLOW CALIBRATION

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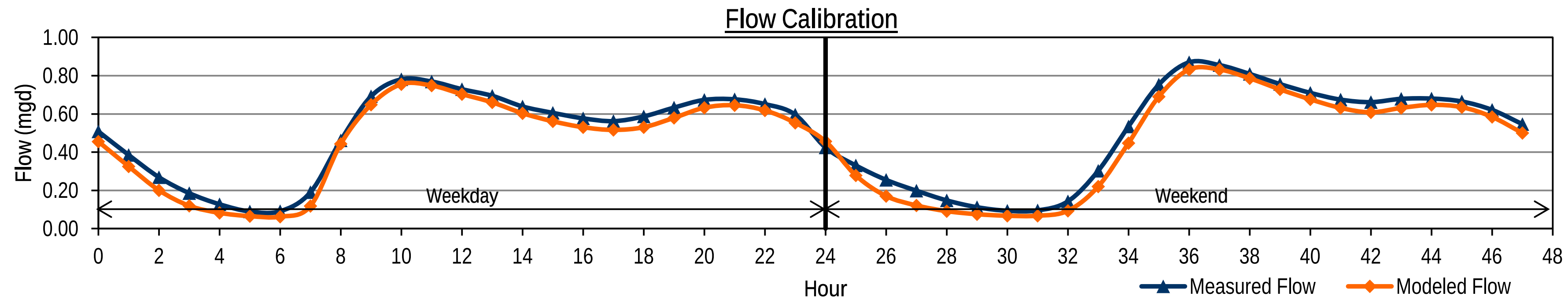
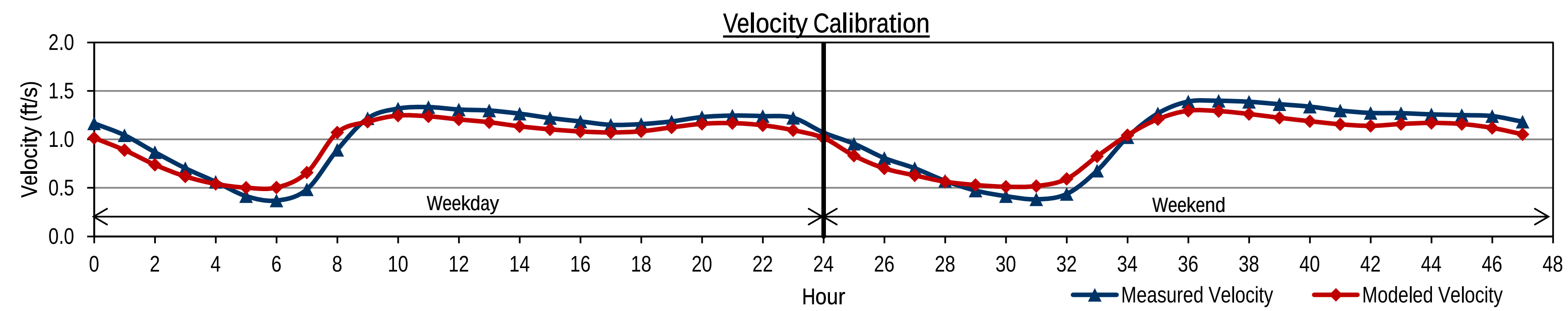
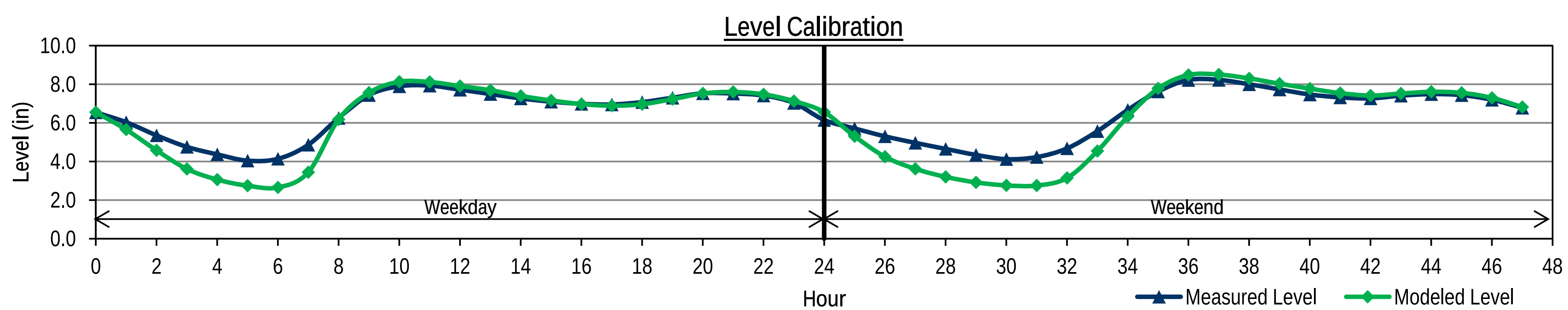
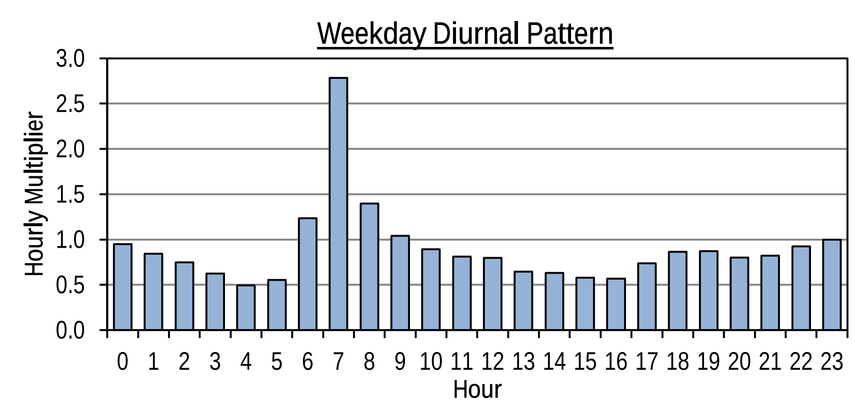
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	0.508	6.5	1.17	0.455	6.6	1.01	0.764	0.95	0.95
	1	0.385	6.0	1.04	0.325	5.7	0.89	0.533	0.84	0.84
	2	0.269	5.4	0.87	0.200	4.6	0.74	0.368	0.75	0.75
	3	0.186	4.8	0.70	0.119	3.6	0.62	0.253	0.62	0.62
	4	0.128	4.4	0.56	0.082	3.1	0.54	0.178	0.49	0.49
	5	0.090	4.0	0.42	0.065	2.7	0.50	0.181	0.56	0.56
	6	0.091	4.1	0.37	0.062	2.7	0.50	0.378	1.24	1.24
	7	0.191	4.9	0.49	0.118	3.4	0.66	0.915	2.78	2.78
	8	0.462	6.3	0.89	0.443	6.2	1.07	1.373	1.40	1.40
	9	0.692	7.4	1.22	0.648	7.6	1.18	1.549	1.04	1.04
	10	0.781	7.9	1.32	0.755	8.1	1.25	1.526	0.89	0.89
	11	0.770	7.9	1.33	0.748	8.1	1.24	1.446	0.81	0.81
	12	0.729	7.7	1.31	0.703	7.9	1.21	1.377	0.80	0.80
	13	0.695	7.5	1.30	0.660	7.7	1.18	1.267	0.65	0.65
	14	0.639	7.3	1.27	0.603	7.4	1.13	1.201	0.63	0.63
	15	0.606	7.1	1.22	0.561	7.2	1.10	1.144	0.58	0.58
	16	0.577	7.0	1.19	0.530	7.0	1.08	1.115	0.57	0.57
	17	0.562	7.0	1.15	0.516	6.9	1.07	1.164	0.74	0.74
	18	0.587	7.1	1.16	0.530	7.0	1.08	1.255	0.86	0.86
	19	0.633	7.3	1.19	0.579	7.2	1.12	1.335	0.87	0.87
	20	0.674	7.5	1.23	0.632	7.5	1.16	1.341	0.80	0.80
	21	0.677	7.5	1.25	0.645	7.6	1.17	1.292	0.82	0.82
	22	0.652	7.4	1.24	0.618	7.5	1.15	1.182	0.92	0.92
	23	0.596	7.0	1.22	0.553	7.1	1.09	1.008	1.00	1.00
Weekend	24	0.425	6.1	1.07	0.456	6.6	1.01	0.656	0.58	0.58
	25	0.331	5.7	0.96	0.278	5.3	0.83	0.506	0.74	0.74
	26	0.255	5.3	0.81	0.170	4.2	0.70	0.394	0.78	0.78
	27	0.199	5.0	0.70	0.121	3.6	0.63	0.293	0.68	0.68
	28	0.148	4.7	0.57	0.091	3.2	0.56	0.223	0.59	0.59
	29	0.112	4.3	0.47	0.075	2.9	0.53	0.186	0.54	0.54
	30	0.094	4.1	0.42	0.067	2.8	0.51	0.189	0.60	0.60
	31	0.096	4.2	0.38	0.067	2.8	0.52	0.283	0.92	0.92
	32	0.143	4.7	0.44	0.093	3.1	0.59	0.600	1.98	1.98
	33	0.303	5.6	0.68	0.220	4.5	0.83	1.059	1.94	1.94
	34	0.534	6.7	1.02	0.447	6.3	1.04	1.494	2.04	2.04
	35	0.753	7.6	1.27	0.690	7.8	1.21	1.725	2.16	2.16
	36	0.870	8.2	1.39	0.832	8.5	1.30	1.696	1.85	1.85
	37	0.856	8.2	1.40	0.832	8.5	1.29	1.605	1.69	1.69
	38	0.809	8.0	1.39	0.786	8.3	1.26	1.500	1.56	1.56
	39	0.756	7.7	1.36	0.728	8.0	1.22	1.408	1.47	1.47
	40	0.710	7.5	1.34	0.676	7.8	1.19	1.338	1.42	1.42
	41	0.675	7.3	1.30	0.631	7.5	1.16	1.312	1.37	1.37
	42	0.662	7.3	1.27	0.608	7.4	1.14	1.346	1.40	1.40
	43	0.679	7.4	1.27	0.631	7.5	1.16	1.349	1.34	1.34
	44	0.680	7.5	1.26	0.647	7.6	1.17	1.319	1.34	1.34
	45	0.665	7.4	1.25	0.635	7.6	1.16	1.232	1.29	1.29
	46	0.621	7.2	1.24	0.584	7.3	1.12	1.084	1.20	1.20
	47	0.547	6.8	1.18	0.500	6.8	1.05	0.842	0.44	0.44
Average										
Weekday		0.507	6.5	1.04	0.465	6.3	0.99	1.01	0.90	0.90
Weekend		0.497	6.4	1.02	0.453	6.1	0.97	0.98	1.25	1.25
ADWF[(1)]		0.504	6.5	1.04	0.461	6.2	0.98	1.00	1.00	1.00
% Error										
Weekday					-8.4%	-4.3%	-5.3%			
Weekend					-8.9%	-5.5%	-5.1%			

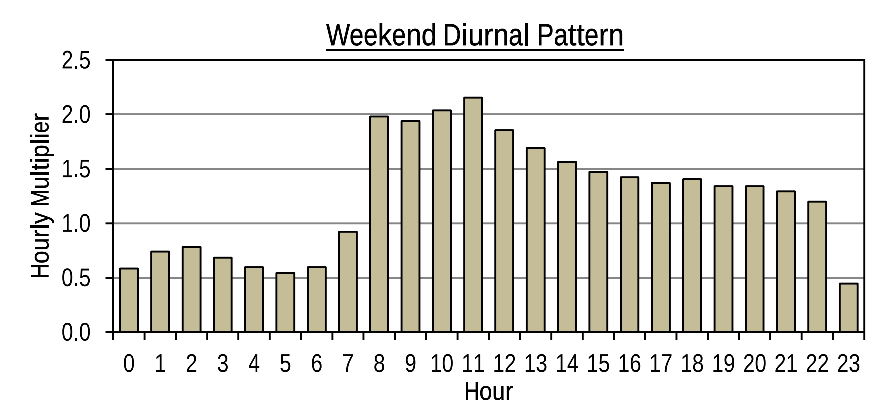
Note:
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

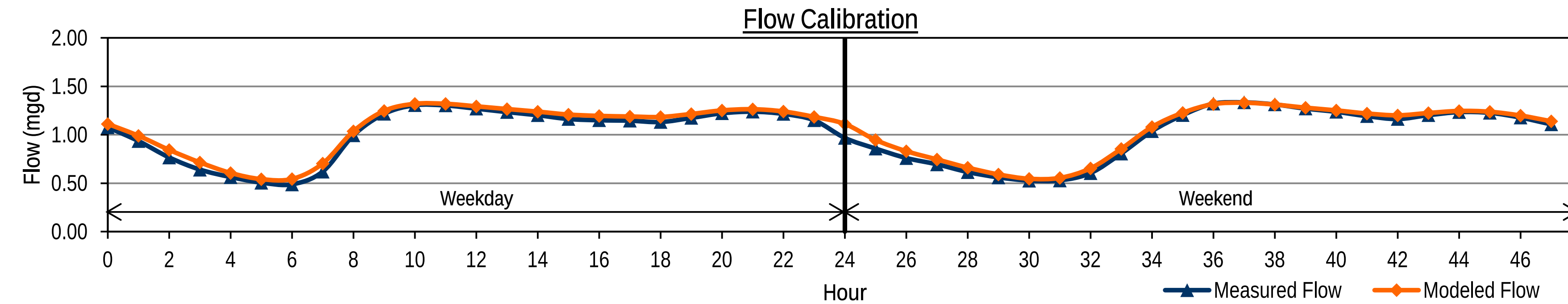
Sanitary Sewer Master Plan Update

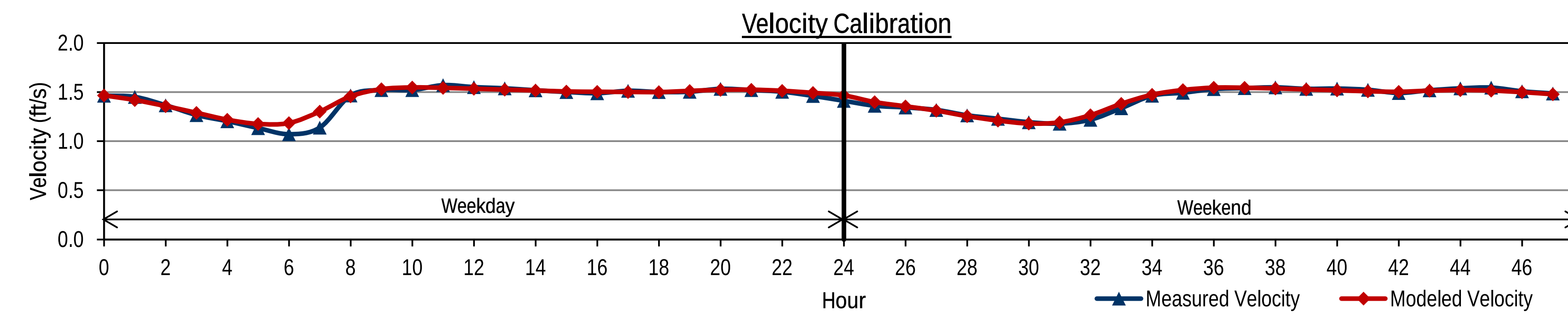
FLOW MONITORING SITE 9 DRY WEATHER FLOW CALIBRATION

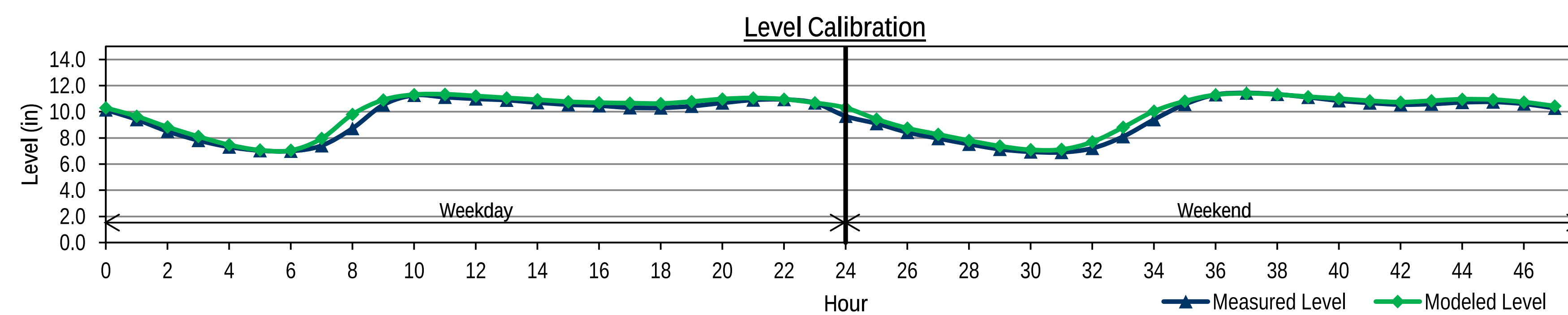
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	1.078	10.2	1.46	1.111	10.3	1.47	0.92	0.84	0.84
	1	0.936	9.4	1.45	0.989	9.7	1.42	0.75	0.29	0.29
	2	0.766	8.5	1.37	0.843	8.8	1.36	0.63	0.13	0.13
	3	0.640	7.8	1.27	0.714	8.1	1.29	0.55	0.09	0.09
	4	0.563	7.3	1.20	0.605	7.5	1.22	0.49	0.06	0.06
	5	0.505	7.0	1.13	0.541	7.1	1.18	0.48	0.09	0.09
	6	0.488	7.0	1.07	0.543	7.1	1.18	0.61	0.13	0.13
	7	0.620	7.4	1.14	0.703	8.0	1.30	0.97	0.90	0.90
	8	0.995	8.7	1.47	1.036	9.8	1.46	1.19	1.39	1.39
	9	1.218	10.5	1.52	1.246	10.9	1.53	1.28	1.64	1.64
	10	1.307	11.3	1.52	1.319	11.3	1.55	1.28	1.63	1.63
	11	1.304	11.1	1.57	1.319	11.3	1.54	1.24	1.51	1.51
	12	1.271	11.0	1.55	1.293	11.2	1.53	1.21	1.39	1.39
	13	1.236	10.9	1.54	1.265	11.1	1.52	1.18	1.29	1.29
	14	1.203	10.7	1.52	1.238	10.9	1.52	1.14	1.14	1.14
	15	1.164	10.6	1.50	1.208	10.8	1.51	1.13	1.12	1.12
	16	1.151	10.5	1.49	1.194	10.7	1.50	1.12	1.13	1.13
	17	1.146	10.3	1.51	1.188	10.7	1.50	1.11	1.03	1.03
	18	1.133	10.3	1.50	1.183	10.6	1.50	1.15	1.19	1.19
	19	1.175	10.4	1.50	1.214	10.8	1.51	1.20	1.38	1.38
	20	1.223	10.7	1.53	1.251	11.0	1.52	1.21	1.47	1.47
	21	1.240	10.9	1.52	1.263	11.0	1.52	1.19	1.44	1.44
	22	1.216	10.9	1.50	1.240	11.0	1.51	1.13	1.30	1.30
	23	1.151	10.7	1.46	1.184	10.7	1.49	1.06	1.23	1.23
Weekend	24	0.968	9.7	1.41	1.111	10.3	1.47	0.84	0.34	0.34
	25	0.858	9.1	1.36	0.946	9.4	1.40	0.74	0.22	0.22
	26	0.760	8.4	1.34	0.830	8.7	1.35	0.68	0.17	0.17
	27	0.695	8.0	1.32	0.745	8.3	1.31	0.60	0.09	0.09
	28	0.615	7.5	1.26	0.660	7.8	1.25	0.55	0.06	0.06
	29	0.560	7.1	1.23	0.590	7.4	1.21	0.52	0.03	0.03
	30	0.527	6.9	1.19	0.545	7.1	1.18	0.52	0.06	0.06
	31	0.529	6.9	1.18	0.554	7.1	1.19	0.59	0.09	0.09
	32	0.604	7.2	1.22	0.653	7.7	1.26	0.79	0.37	0.37
	33	0.807	8.1	1.34	0.854	8.8	1.38	1.02	0.98	0.98
	34	1.038	9.4	1.46	1.080	10.0	1.47	1.18	1.48	1.48
	35	1.204	10.6	1.49	1.226	10.8	1.52	1.30	1.98	1.98
	36	1.323	11.3	1.53	1.316	11.3	1.54	1.31	2.01	2.01
	37	1.336	11.4	1.54	1.330	11.4	1.54	1.29	1.96	1.96
	38	1.315	11.3	1.55	1.311	11.3	1.54	1.25	1.79	1.79
	39	1.272	11.1	1.53	1.279	11.1	1.53	1.21	1.69	1.69
	40	1.238	10.9	1.54	1.251	11.0	1.52	1.17	1.49	1.49
	41	1.194	10.7	1.52	1.219	10.8	1.51	1.14	1.30	1.30
	42	1.164	10.6	1.49	1.200	10.7	1.50	1.18	1.50	1.50
	43	1.203	10.6	1.52	1.224	10.8	1.51	1.21	1.68	1.68
	44	1.235	10.7	1.54	1.245	11.0	1.52	1.20	1.71	1.71
	45	1.228	10.8	1.55	1.237	10.9	1.51	1.15	1.54	1.54
	46	1.179	10.6	1.51	1.198	10.7	1.50	1.09	1.34	1.34
	47	1.109	10.3	1.49	1.139	10.4	1.48	0.95	0.55	0.55
Average										
	Weekday	1.030	9.8	1.43	1.070	10.0	1.44	1.01	0.99	0.99
	Weekend	0.998	9.6	1.42	1.031	9.8	1.42	0.98	1.02	1.02
	ADWF(1)	1.021	9.7	1.43	1.059	9.9	1.44	1.00	1.00	1.00
% Error										
	Weekday				3.9%	2.5%	1.0%			
	Weekend				3.3%	2.6%	0.3%			

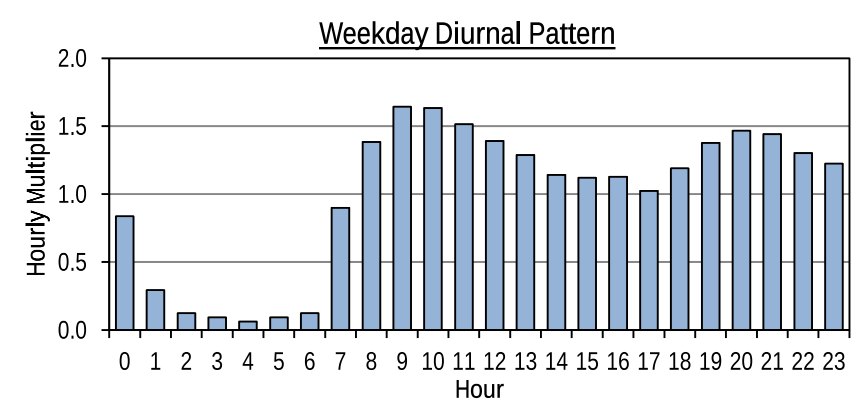
Note:

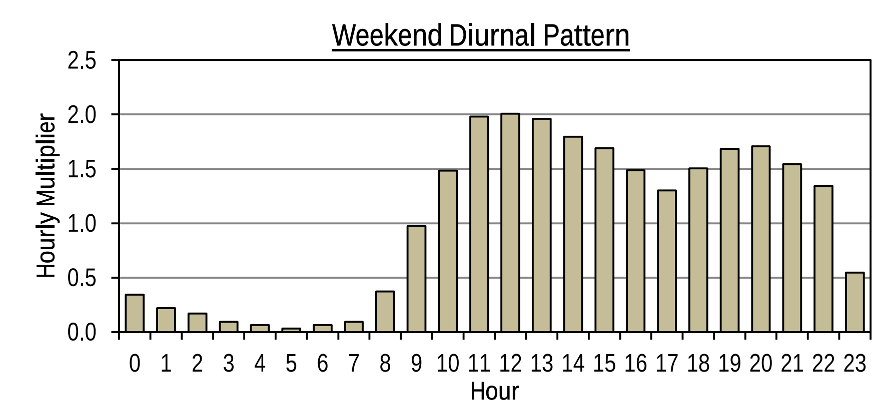
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7







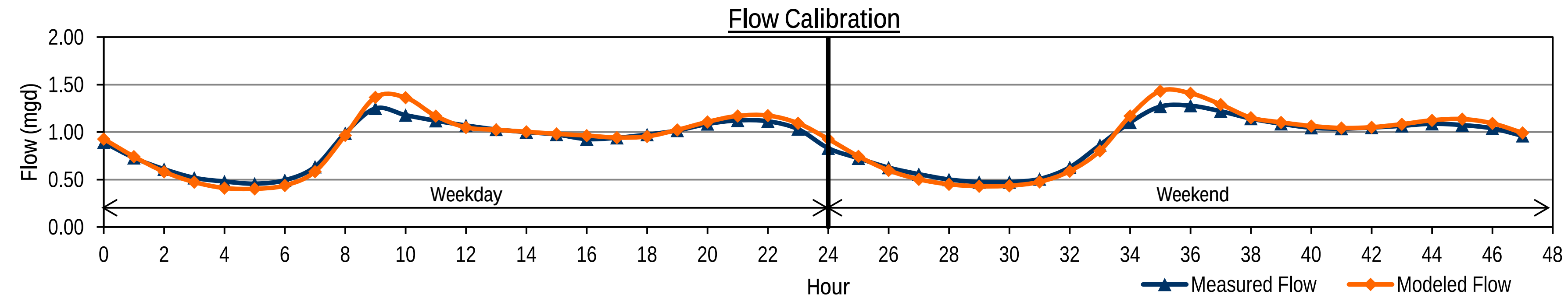


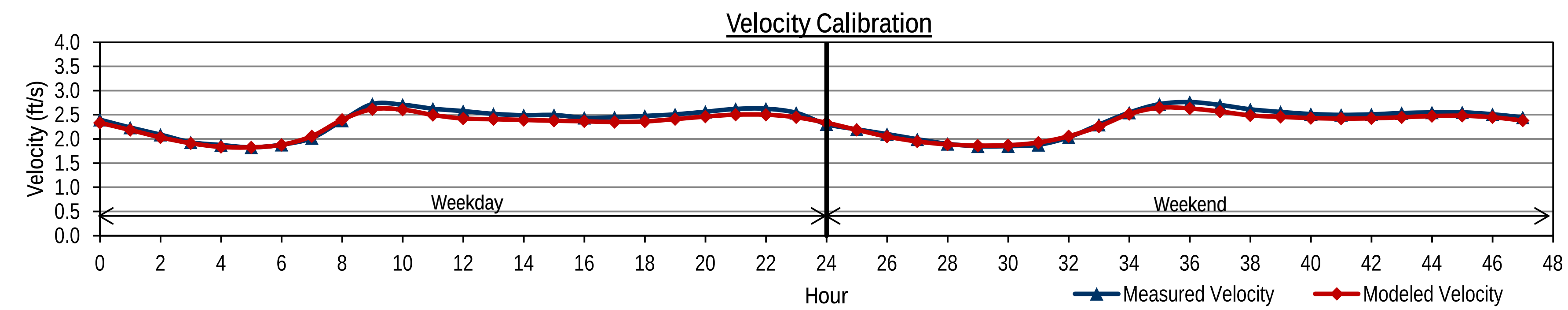


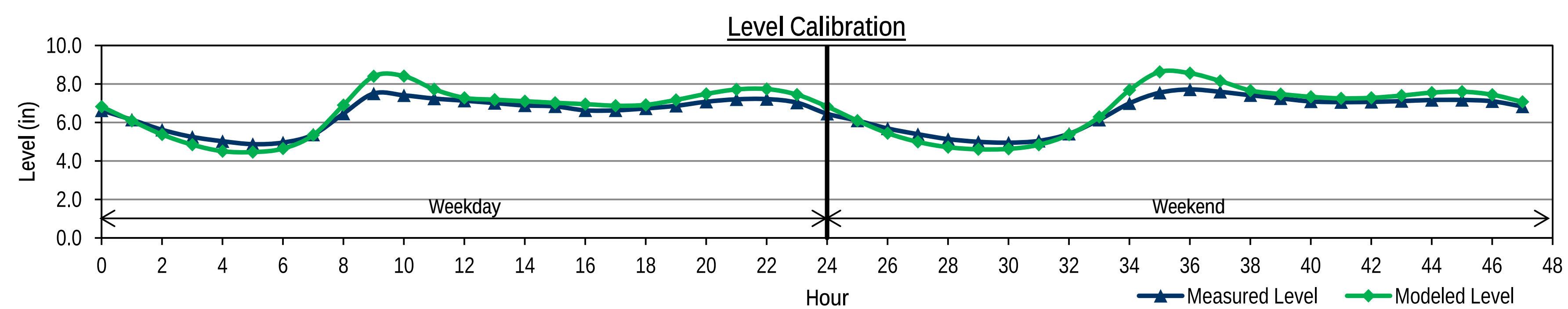
City of Chico
Sanitary Sewer Master Plan Update
FLOW MONITORING SITE 10 DRY WEATHER FLOW CALIBRATION

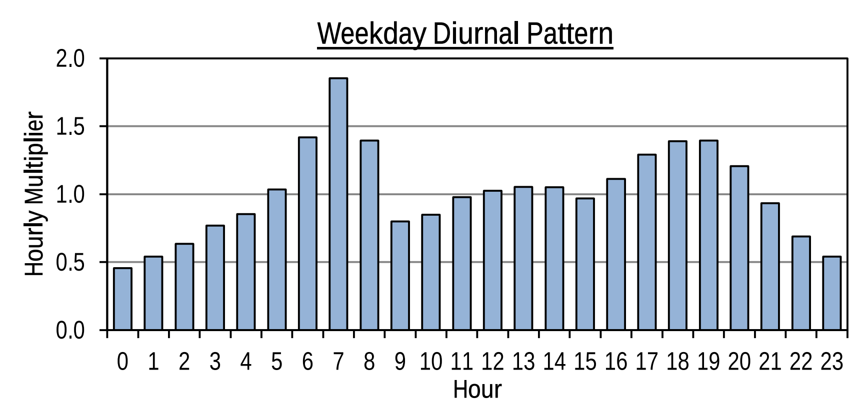
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	0.893	6.6	2.40	0.927	6.8	2.33	0.81	0.46	0.46
	1	0.730	6.1	2.24	0.742	6.1	2.18	0.68	0.54	0.54
	2	0.610	5.6	2.09	0.582	5.4	2.03	0.58	0.64	0.64
	3	0.519	5.3	1.93	0.473	4.8	1.91	0.53	0.77	0.77
	4	0.480	5.0	1.87	0.411	4.5	1.83	0.51	0.85	0.85
	5	0.457	4.9	1.83	0.403	4.5	1.83	0.55	1.04	1.04
	6	0.494	5.0	1.88	0.438	4.6	1.88	0.70	1.42	1.42
	7	0.636	5.4	2.02	0.584	5.3	2.06	1.10	1.85	1.85
	8	0.989	6.5	2.38	0.966	6.9	2.40	1.39	1.40	1.40
	9	1.250	7.5	2.72	1.366	8.4	2.61	1.31	0.80	0.80
	10	1.180	7.4	2.71	1.363	8.4	2.61	1.24	0.85	0.85
	11	1.121	7.2	2.63	1.169	7.7	2.50	1.19	0.98	0.98
	12	1.071	7.1	2.58	1.049	7.3	2.42	1.14	1.03	1.03
	13	1.029	7.0	2.52	1.024	7.2	2.41	1.11	1.05	1.05
	14	1.001	6.9	2.49	1.003	7.1	2.39	1.08	1.05	1.05
	15	0.976	6.8	2.50	0.981	7.0	2.38	1.03	0.97	0.97
	16	0.927	6.6	2.44	0.963	7.0	2.36	1.04	1.11	1.11
	17	0.941	6.6	2.45	0.942	6.9	2.35	1.08	1.29	1.29
	18	0.975	6.7	2.48	0.954	6.9	2.36	1.13	1.39	1.39
	19	1.018	6.9	2.51	1.023	7.2	2.41	1.20	1.40	1.40
	20	1.087	7.1	2.56	1.107	7.5	2.46	1.25	1.21	1.21
	21	1.124	7.2	2.62	1.170	7.7	2.50	1.24	0.93	0.93
	22	1.115	7.2	2.63	1.174	7.7	2.50	1.14	0.69	0.69
	23	1.033	7.0	2.54	1.093	7.4	2.45	0.99	0.54	0.54
Weekend	24	0.831	6.5	2.31	0.927	6.8	2.33	0.80	0.45	0.45
	25	0.725	6.1	2.20	0.745	6.1	2.19	0.69	0.56	0.56
	26	0.627	5.7	2.10	0.597	5.4	2.05	0.62	0.70	0.70
	27	0.558	5.4	1.99	0.503	5.0	1.95	0.56	0.76	0.76
	28	0.502	5.1	1.90	0.450	4.7	1.89	0.53	0.83	0.83
	29	0.474	5.0	1.85	0.430	4.6	1.86	0.53	0.91	0.91
	30	0.474	5.0	1.85	0.435	4.6	1.87	0.56	1.03	1.03
	31	0.506	5.0	1.88	0.476	4.8	1.92	0.70	1.38	1.38
	32	0.630	5.4	2.03	0.588	5.4	2.06	0.96	1.88	1.88
	33	0.864	6.1	2.30	0.802	6.3	2.26	1.22	1.82	1.82
	34	1.103	7.0	2.55	1.170	7.7	2.51	1.41	1.29	1.29
	35	1.270	7.6	2.72	1.432	8.6	2.65	1.42	0.94	0.94
	36	1.280	7.7	2.76	1.409	8.6	2.63	1.35	0.90	0.90
	37	1.221	7.6	2.70	1.291	8.2	2.57	1.27	0.91	0.91
	38	1.144	7.4	2.61	1.152	7.7	2.49	1.21	0.94	0.94
	39	1.088	7.3	2.56	1.102	7.5	2.46	1.16	0.94	0.94
	40	1.047	7.1	2.52	1.064	7.3	2.43	1.15	1.03	1.03
	41	1.038	7.1	2.50	1.043	7.3	2.42	1.16	1.14	1.14
	42	1.049	7.1	2.51	1.051	7.3	2.43	1.18	1.18	1.18
	43	1.067	7.1	2.54	1.083	7.4	2.45	1.21	1.12	1.12
	44	1.089	7.2	2.55	1.124	7.6	2.47	1.19	0.92	0.92
	45	1.075	7.2	2.55	1.137	7.6	2.48	1.15	0.76	0.76
	46	1.041	7.1	2.51	1.092	7.4	2.45	1.07	0.64	0.64
	47	0.962	6.8	2.45	0.992	7.1	2.38	0.92	0.36	0.36
Average										
Weekday		0.902	6.5	2.37	0.913	6.7	2.30	1.00	1.01	1.01
Weekend		0.903	6.5	2.35	0.921	6.7	2.30	1.00	0.97	0.97
ADWF[1]		0.902	6.5	2.37	0.915	6.7	2.30	1.00	1.00	1.00
% Error										
Weekday					1.2%	3.0%	-3.2%			
Weekend					2.0%	2.8%	-2.2%			

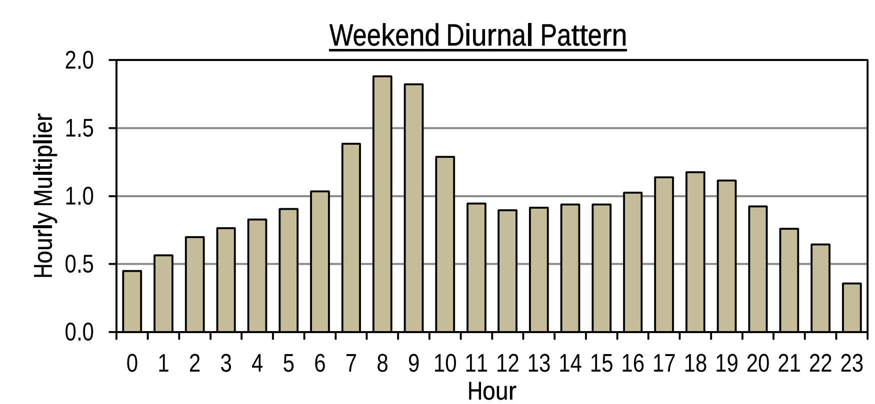
Note:
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

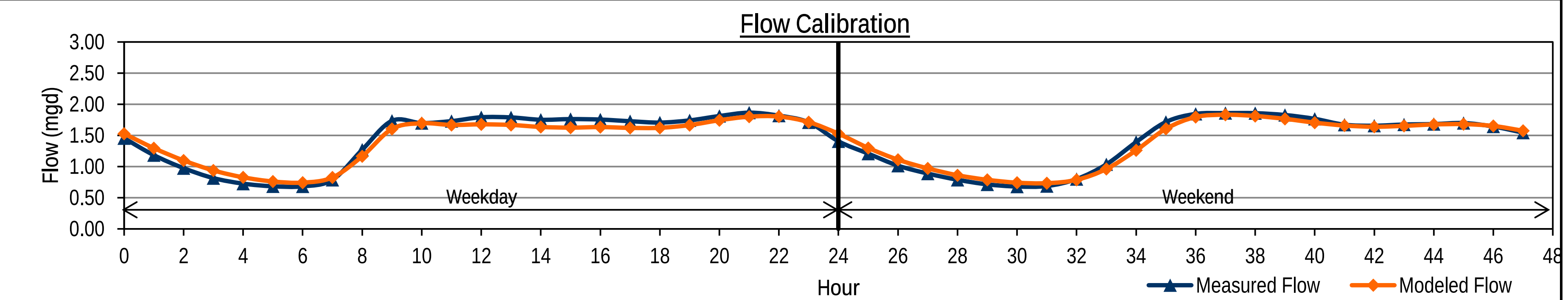
Sanitary Sewer Master Plan Update

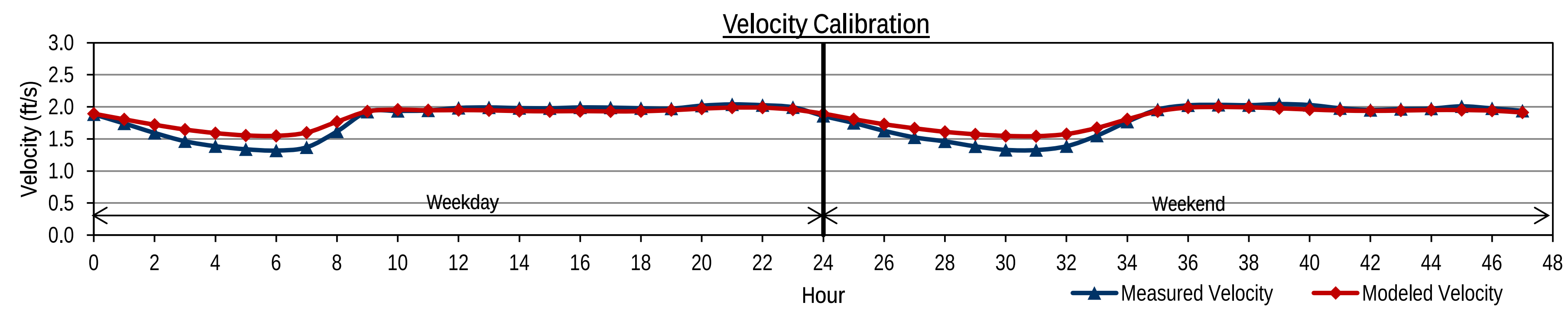
FLOW MONITORING SITE 11 DRY WEATHER FLOW CALIBRATION

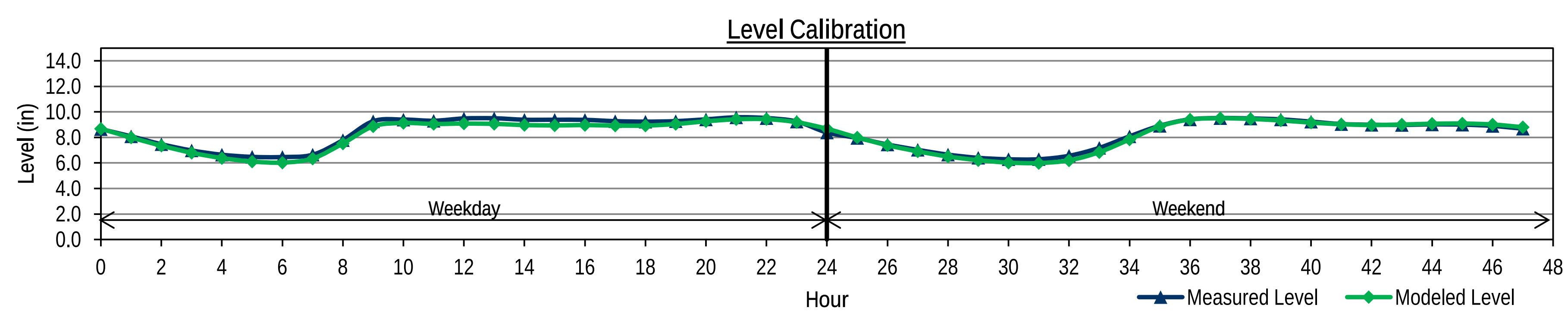
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	1.454	8.6	1.89	1.526	8.7	1.89	0.82	0.57	0.57
	1	1.182	8.1	1.74	1.294	8.0	1.81	0.68	0.51	0.51
	2	0.973	7.5	1.60	1.096	7.3	1.72	0.57	0.48	0.48
	3	0.813	7.0	1.47	0.936	6.8	1.65	0.51	0.47	0.47
	4	0.724	6.7	1.39	0.826	6.4	1.59	0.48	0.55	0.55
	5	0.682	6.5	1.34	0.759	6.1	1.55	0.47	0.89	0.89
	6	0.680	6.5	1.32	0.741	6.0	1.55	0.55	1.21	1.21
	7	0.786	6.7	1.37	0.824	6.3	1.60	0.89	1.18	1.18
	8	1.270	7.8	1.62	1.164	7.5	1.77	1.21	1.21	1.21
	9	1.734	9.3	1.93	1.603	8.9	1.93	1.18	1.25	1.25
	10	1.697	9.4	1.94	1.693	9.1	1.96	1.21	1.25	1.25
	11	1.729	9.3	1.95	1.666	9.1	1.95	1.25	1.22	1.22
	12	1.791	9.5	1.99	1.676	9.1	1.95	1.25	1.23	1.23
	13	1.788	9.5	1.99	1.666	9.1	1.95	1.22	1.22	1.22
	14	1.751	9.4	1.98	1.634	9.0	1.94	1.23	1.21	1.21
	15	1.761	9.4	1.98	1.623	8.9	1.93	1.22	1.19	1.19
	16	1.754	9.4	1.99	1.632	9.0	1.93	1.21	1.21	1.21
	17	1.727	9.3	1.99	1.619	8.9	1.93	1.19	1.26	1.26
	18	1.706	9.2	1.98	1.620	8.9	1.93	1.21	1.30	1.30
	19	1.741	9.3	1.98	1.664	9.0	1.95	1.26	1.27	1.27
	20	1.811	9.4	2.02	1.742	9.3	1.97	1.30	1.19	1.19
	21	1.865	9.6	2.04	1.799	9.4	1.99	1.27	1.01	1.01
	22	1.816	9.5	2.03	1.801	9.4	1.99	1.19	0.82	0.82
	23	1.708	9.2	2.00	1.711	9.2	1.96	1.01	0.68	0.68
Weekend	24	1.404	8.4	1.86	1.525	8.7	1.89	0.84	0.62	0.62
	25	1.206	8.0	1.75	1.297	8.0	1.81	0.71	0.55	0.55
	26	1.012	7.4	1.63	1.108	7.4	1.73	0.62	0.50	0.50
	27	0.886	7.0	1.53	0.969	6.9	1.66	0.55	0.47	0.47
	28	0.786	6.7	1.46	0.859	6.5	1.61	0.50	0.48	0.48
	29	0.712	6.4	1.39	0.786	6.2	1.57	0.47	0.56	0.56
	30	0.677	6.3	1.33	0.740	6.0	1.55	0.48	0.72	0.72
	31	0.686	6.3	1.33	0.732	6.0	1.54	0.56	0.97	0.97
	32	0.798	6.6	1.39	0.786	6.2	1.57	0.72	1.20	1.20
	33	1.035	7.2	1.55	0.960	6.8	1.67	0.97	1.29	1.29
	34	1.393	8.1	1.77	1.260	7.8	1.81	1.20	1.30	1.30
	35	1.715	8.9	1.96	1.605	8.9	1.93	1.29	1.30	1.30
	36	1.845	9.4	2.03	1.794	9.4	1.99	1.30	1.27	1.27
	37	1.858	9.5	2.03	1.830	9.5	2.00	1.30	1.23	1.23
	38	1.857	9.5	2.03	1.810	9.4	1.99	1.27	1.17	1.17
	39	1.827	9.4	2.05	1.764	9.3	1.98	1.23	1.15	1.15
	40	1.765	9.2	2.03	1.703	9.2	1.96	1.17	1.17	1.17
	41	1.671	9.0	1.98	1.657	9.0	1.94	1.15	1.17	1.17
	42	1.655	9.0	1.95	1.637	9.0	1.94	1.17	1.18	1.18
	43	1.674	9.0	1.97	1.652	9.0	1.94	1.17	1.15	1.15
	44	1.682	9.0	1.98	1.674	9.1	1.95	1.18	1.08	1.08
	45	1.698	9.0	2.01	1.679	9.1	1.95	1.15	0.98	0.98
	46	1.642	8.9	1.98	1.650	9.0	1.94	1.08	0.84	0.84
	47	1.543	8.7	1.94	1.573	8.8	1.91	0.98	0.71	0.71
Average										
	Weekday	1.456	8.6	1.81	1.430	8.3	1.85	1.02	1.02	1.02
	Weekend	1.376	8.2	1.79	1.377	8.1	1.83	0.96	0.96	0.96
	ADWF[1]	1.433	8.5	1.81	1.415	8.3	1.84	1.00	1.00	1.00
% Error										
	Weekday				-1.8%	-3.1%	2.0%			
	Weekend				0.1%	-0.8%	2.2%			

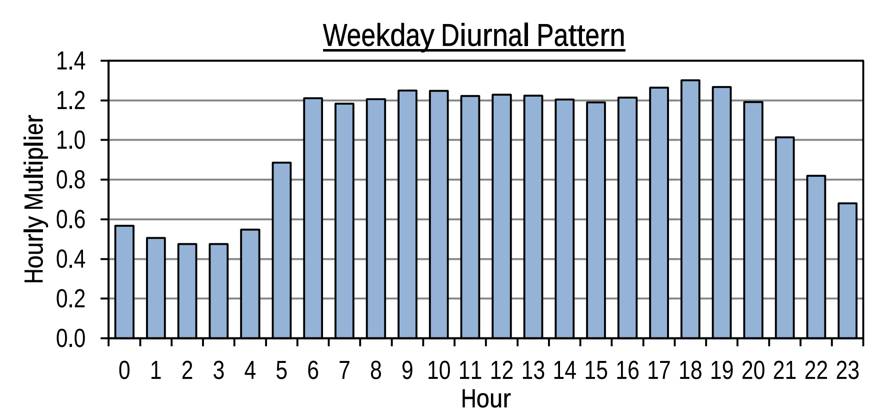
Note:

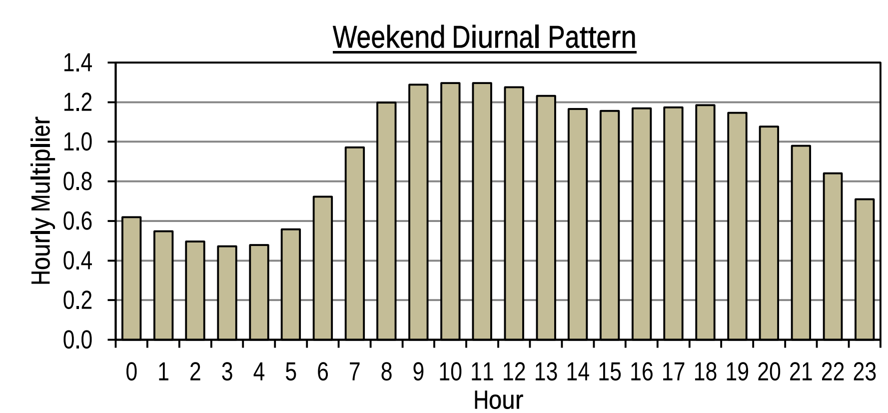
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

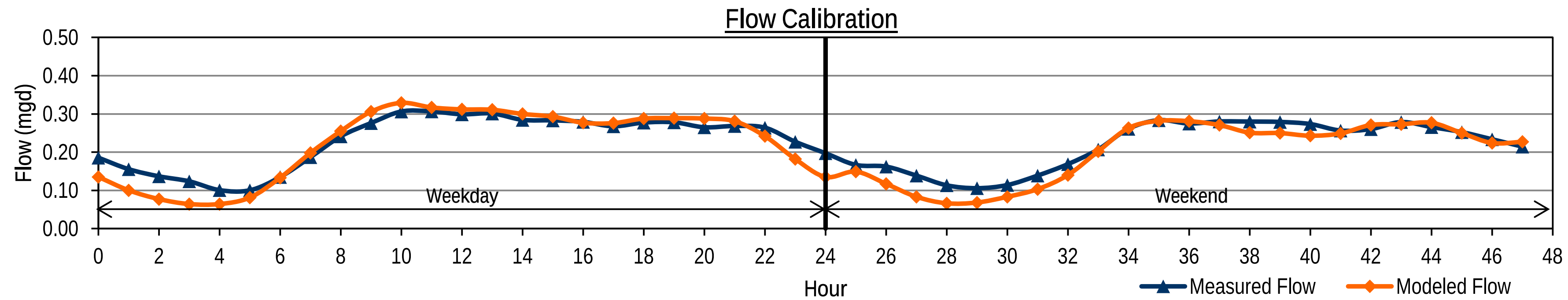
Sanitary Sewer Master Plan Update

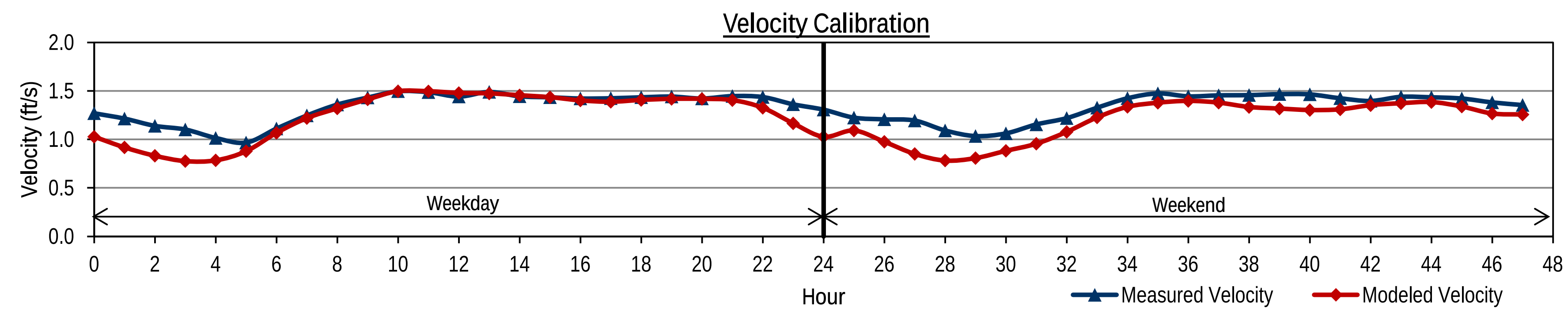
FLOW MONITORING SITE 12 DRY WEATHER FLOW CALIBRATION

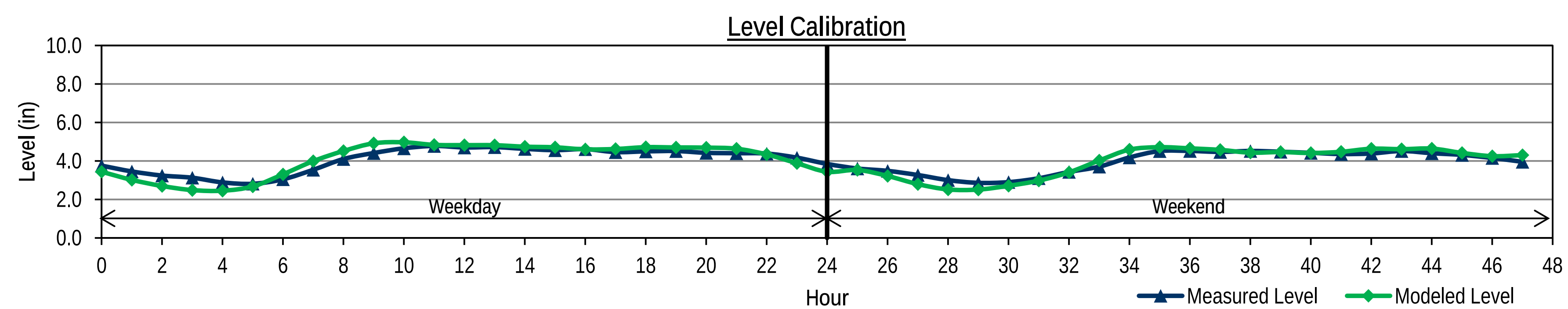
		Measured Data			Modeled Data			Diurnal		
	Hour	Flow (mgd)	Level (in)	Velocity (ft/s)	Flow (mgd)	Level (in)	Velocity (ft/s)	Initial Curve	Modified Curve	Calibrated Diurnal
Weekday	0	0.185	3.8	1.27	0.135	3.4	1.03	0.68	0.82	0.62
	1	0.155	3.5	1.22	0.100	3.0	0.92	0.60	0.68	0.53
	2	0.137	3.2	1.14	0.077	2.7	0.83	0.54	0.60	0.47
	3	0.124	3.1	1.10	0.064	2.5	0.78	0.44	0.54	0.48
	4	0.101	2.9	1.02	0.064	2.5	0.78	0.44	0.44	0.56
	5	0.100	2.8	0.97	0.081	2.7	0.88	0.59	0.44	0.78
	6	0.135	3.0	1.11	0.133	3.3	1.07	0.82	0.59	0.99
	7	0.187	3.5	1.25	0.198	4.0	1.22	1.06	0.82	1.13
	8	0.241	4.1	1.36	0.255	4.5	1.32	1.22	1.06	1.25
	9	0.276	4.4	1.43	0.306	4.9	1.41	1.35	1.22	1.32
	10	0.306	4.7	1.50	0.329	5.0	1.50	1.35	1.35	1.30
	11	0.306	4.8	1.49	0.317	4.8	1.50	1.32	1.35	1.31
	12	0.299	4.7	1.44	0.312	4.8	1.48	1.33	1.32	1.30
	13	0.301	4.7	1.49	0.311	4.8	1.47	1.25	1.33	1.26
	14	0.284	4.6	1.45	0.300	4.7	1.45	1.25	1.25	1.24
	15	0.283	4.6	1.44	0.293	4.7	1.43	1.23	1.25	1.19
	16	0.279	4.6	1.42	0.277	4.6	1.40	1.18	1.23	1.20
	17	0.267	4.5	1.43	0.276	4.6	1.39	1.22	1.18	1.23
	18	0.277	4.5	1.44	0.288	4.7	1.41	1.22	1.22	1.22
	19	0.278	4.5	1.44	0.289	4.7	1.42	1.17	1.22	1.21
	20	0.265	4.4	1.42	0.288	4.7	1.42	1.18	1.17	1.18
	21	0.268	4.4	1.45	0.281	4.6	1.40	1.16	1.18	1.07
	22	0.264	4.4	1.44	0.242	4.3	1.33	1.00	1.16	0.88
	23	0.227	4.2	1.36	0.182	3.9	1.17	0.82	1.00	0.74
Weekend	24	0.197	3.8	1.31	0.135	3.4	1.03	0.73	0.87	0.83
	25	0.167	3.6	1.23	0.149	3.5	1.09	0.71	0.73	0.70
	26	0.162	3.5	1.21	0.117	3.2	0.98	0.61	0.71	0.56
	27	0.139	3.3	1.20	0.083	2.8	0.85	0.50	0.61	0.47
	28	0.113	3.0	1.09	0.066	2.5	0.78	0.47	0.50	0.49
	29	0.106	2.9	1.04	0.068	2.5	0.81	0.50	0.47	0.56
	30	0.114	2.9	1.06	0.083	2.7	0.88	0.61	0.50	0.64
	31	0.139	3.1	1.16	0.103	3.0	0.96	0.74	0.61	0.78
	32	0.169	3.4	1.22	0.140	3.4	1.08	0.91	0.74	0.98
	33	0.207	3.7	1.33	0.202	4.0	1.23	1.15	0.91	1.13
	34	0.261	4.2	1.43	0.263	4.6	1.34	1.25	1.15	1.16
	35	0.283	4.5	1.48	0.282	4.7	1.38	1.21	1.25	1.18
	36	0.275	4.5	1.45	0.281	4.7	1.40	1.23	1.21	1.17
	37	0.280	4.5	1.46	0.271	4.6	1.38	1.23	1.23	1.12
	38	0.280	4.5	1.46	0.251	4.4	1.33	1.23	1.23	1.13
	39	0.279	4.5	1.47	0.250	4.5	1.32	1.20	1.23	1.10
	40	0.273	4.4	1.47	0.243	4.4	1.30	1.13	1.20	1.12
	41	0.256	4.4	1.43	0.249	4.5	1.31	1.15	1.13	1.19
	42	0.260	4.4	1.40	0.271	4.6	1.35	1.23	1.15	1.18
	43	0.278	4.5	1.44	0.273	4.6	1.37	1.17	1.23	1.19
	44	0.265	4.4	1.44	0.277	4.6	1.38	1.11	1.17	1.10
	45	0.252	4.3	1.42	0.250	4.4	1.34	1.03	1.11	1.03
	46	0.233	4.2	1.38	0.224	4.3	1.27	0.94	1.03	1.06
	47	0.214	4.0	1.36	0.227	4.3	1.26	0.87	0.94	0.97
Average										
Weekday		0.231	4.1	1.34	0.225	4.1	1.25	1.02	1.02	1.02
Weekend		0.217	3.9	1.33	0.198	3.9	1.18	0.96	0.96	0.95
ADWF(1)		0.227	4.0	1.33	0.217	4.1	1.23	1.00	1.00	1.00
% Error										
Weekday					-2.6%	0.8%	-6.5%			
Weekend					-8.5%	0.0%	-10.9%			

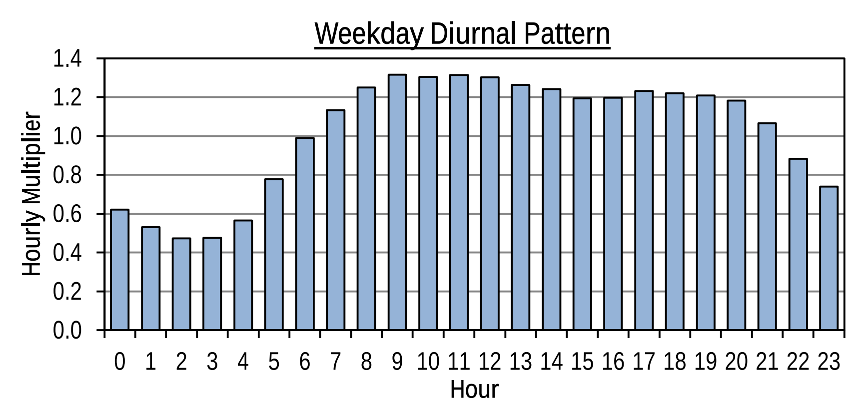
Note:

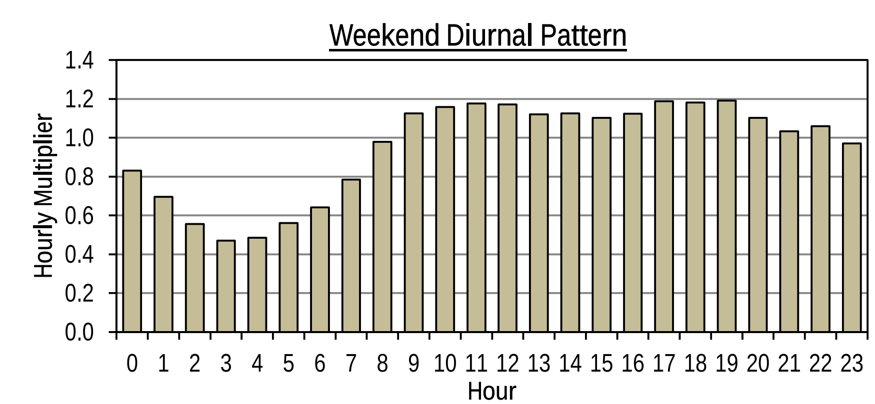
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

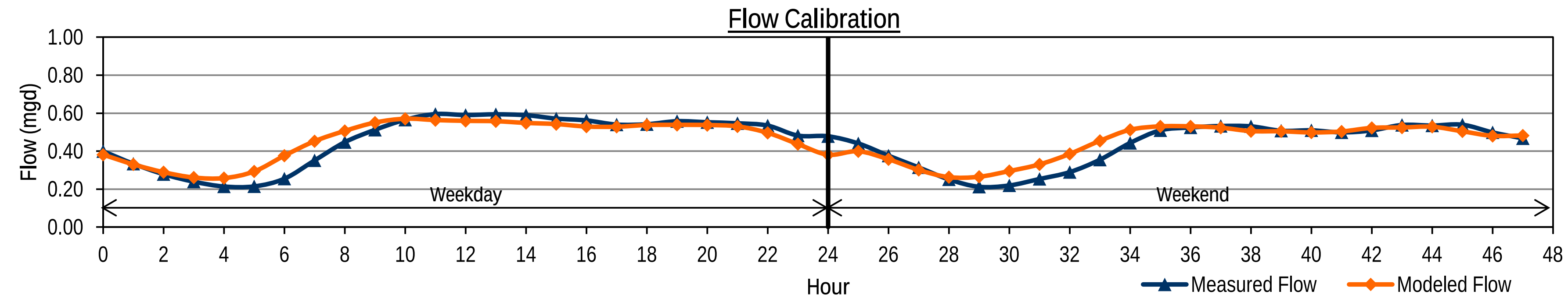
Sanitary Sewer Master Plan Update

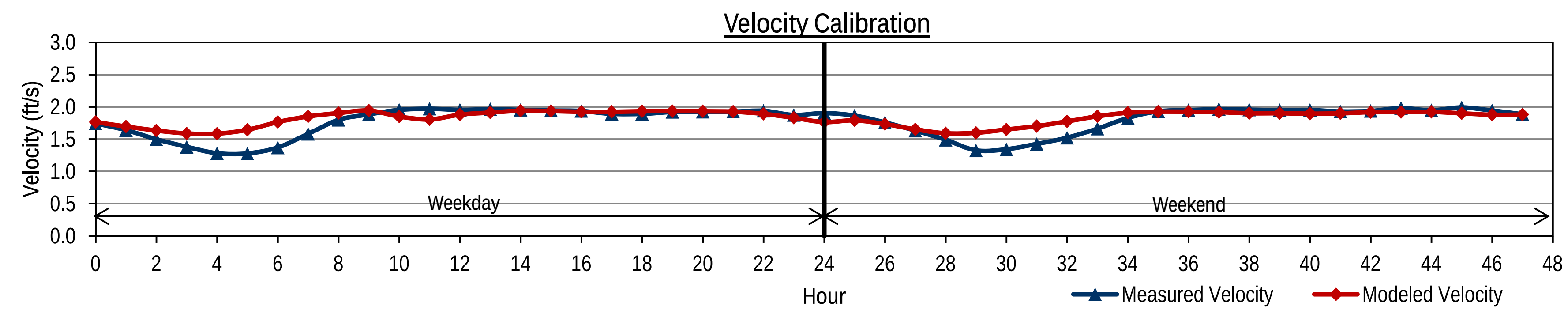
FLOW MONITORING SITE 13 DRY WEATHER FLOW CALIBRATION

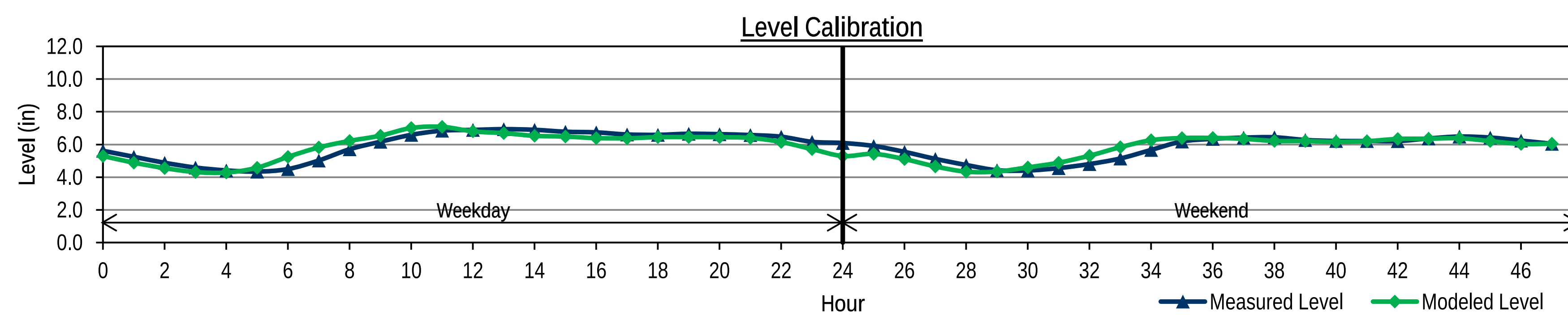
		Measured Data			Modeled Data			Diurnal		
	Hour	Flow (mgd)	Level (in)	Velocity (ft/s)	Flow (mgd)	Level (in)	Velocity (ft/s)	Initial Curve	Modified Curve	Calibrated Diurnal
Weekday	0	0.400	5.6	1.75	0.381	5.3	1.77	0.74	0.62	0.62
	1	0.334	5.2	1.64	0.330	4.9	1.70	0.62	0.53	0.53
	2	0.279	4.9	1.50	0.289	4.6	1.63	0.53	0.47	0.47
	3	0.240	4.6	1.38	0.261	4.3	1.59	0.47	0.47	0.48
	4	0.214	4.4	1.28	0.258	4.3	1.59	0.47	0.56	0.56
	5	0.215	4.3	1.28	0.293	4.6	1.65	0.56	0.78	0.78
	6	0.255	4.5	1.37	0.376	5.2	1.77	0.78	0.99	0.99
	7	0.352	5.0	1.58	0.452	5.8	1.85	0.99	1.13	1.13
	8	0.448	5.7	1.80	0.506	6.2	1.91	1.13	1.25	1.25
	9	0.513	6.2	1.89	0.550	6.5	1.94	1.25	1.32	1.32
	10	0.566	6.6	1.96	0.570	7.0	1.85	1.32	1.30	1.30
	11	0.596	6.8	1.97	0.563	7.1	1.81	1.30	1.31	1.31
	12	0.591	6.9	1.96	0.559	6.8	1.88	1.31	1.30	1.30
	13	0.594	6.9	1.97	0.557	6.7	1.91	1.30	1.26	1.26
	14	0.590	6.9	1.96	0.548	6.5	1.94	1.26	1.24	1.24
	15	0.572	6.8	1.95	0.542	6.5	1.94	1.24	1.19	1.19
	16	0.562	6.7	1.94	0.529	6.4	1.92	1.19	1.20	1.20
	17	0.540	6.6	1.89	0.528	6.4	1.92	1.20	1.23	1.23
	18	0.542	6.6	1.89	0.537	6.4	1.93	1.23	1.22	1.22
	19	0.558	6.7	1.92	0.538	6.5	1.93	1.22	1.21	1.21
	20	0.553	6.6	1.93	0.537	6.4	1.93	1.21	1.18	1.18
	21	0.547	6.6	1.93	0.530	6.4	1.93	1.18	1.07	1.07
	22	0.535	6.5	1.94	0.496	6.2	1.89	1.07	0.88	0.88
	23	0.482	6.2	1.88	0.437	5.7	1.83	0.88	0.74	0.74
Weekend	24	0.479	6.1	1.91	0.381	5.3	1.77	0.97	0.83	0.83
	25	0.441	5.9	1.87	0.399	5.4	1.79	0.83	0.70	0.70
	26	0.377	5.5	1.76	0.357	5.1	1.73	0.70	0.56	0.56
	27	0.315	5.1	1.63	0.301	4.7	1.65	0.56	0.47	0.47
	28	0.252	4.7	1.49	0.263	4.3	1.59	0.47	0.49	0.49
	29	0.213	4.4	1.33	0.265	4.3	1.60	0.49	0.56	0.56
	30	0.220	4.4	1.34	0.295	4.6	1.65	0.56	0.64	0.64
	31	0.254	4.6	1.43	0.330	4.9	1.70	0.64	0.78	0.78
	32	0.290	4.8	1.52	0.385	5.3	1.78	0.78	0.98	0.98
	33	0.355	5.1	1.66	0.454	5.8	1.86	0.98	1.13	1.13
	34	0.443	5.7	1.83	0.512	6.3	1.91	1.13	1.16	1.16
	35	0.510	6.2	1.93	0.530	6.4	1.93	1.16	1.18	1.18
	36	0.525	6.3	1.95	0.530	6.4	1.93	1.18	1.17	1.17
	37	0.533	6.4	1.97	0.523	6.3	1.92	1.17	1.12	1.12
	38	0.531	6.4	1.96	0.505	6.2	1.90	1.12	1.13	1.13
	39	0.508	6.3	1.95	0.504	6.2	1.90	1.13	1.10	1.10
	40	0.510	6.2	1.95	0.498	6.2	1.90	1.10	1.12	1.12
	41	0.499	6.2	1.93	0.503	6.2	1.90	1.12	1.19	1.19
	42	0.509	6.2	1.94	0.522	6.3	1.92	1.19	1.18	1.18
	43	0.538	6.4	1.98	0.524	6.4	1.92	1.18	1.19	1.19
	44	0.535	6.5	1.95	0.528	6.4	1.92	1.19	1.10	1.10
	45	0.540	6.4	1.99	0.504	6.2	1.90	1.10	1.03	1.03
	46	0.499	6.2	1.95	0.480	6.0	1.88	1.03	1.06	1.06
	47	0.468	6.0	1.89	0.482	6.0	1.88	1.06	0.97	0.97
Average										
Weekday		0.462	6.0	1.77	0.465	5.9	1.83	1.02	1.02	1.02
Weekend		0.431	5.8	1.80	0.441	5.7	1.83	0.95	0.95	0.95
ADWF[(1)]		0.453	5.9	1.78	0.458	5.9	1.83	1.00	1.00	1.00
% Error										
Weekday					0.8%	-0.8%	3.5%			
Weekend					2.2%	-0.6%	1.7%			

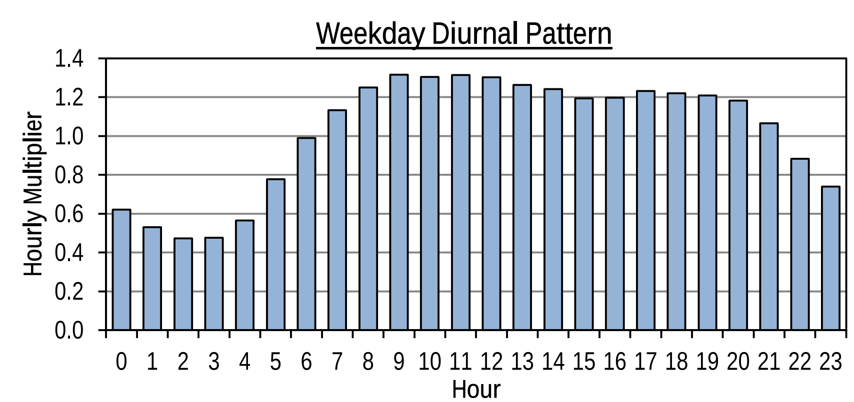
Note:

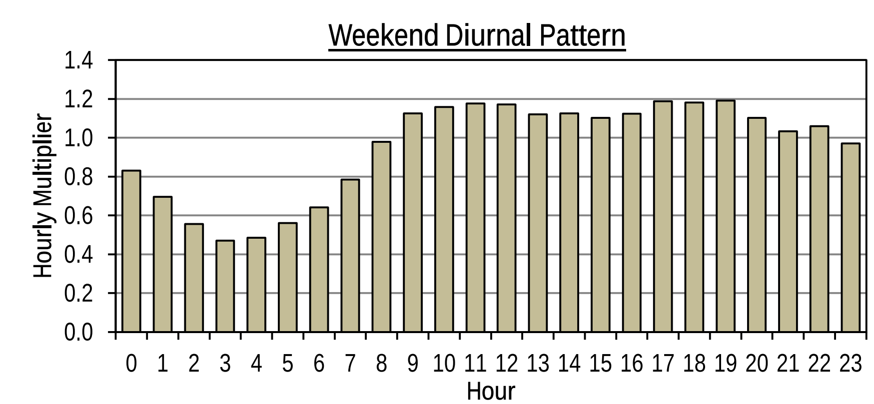
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

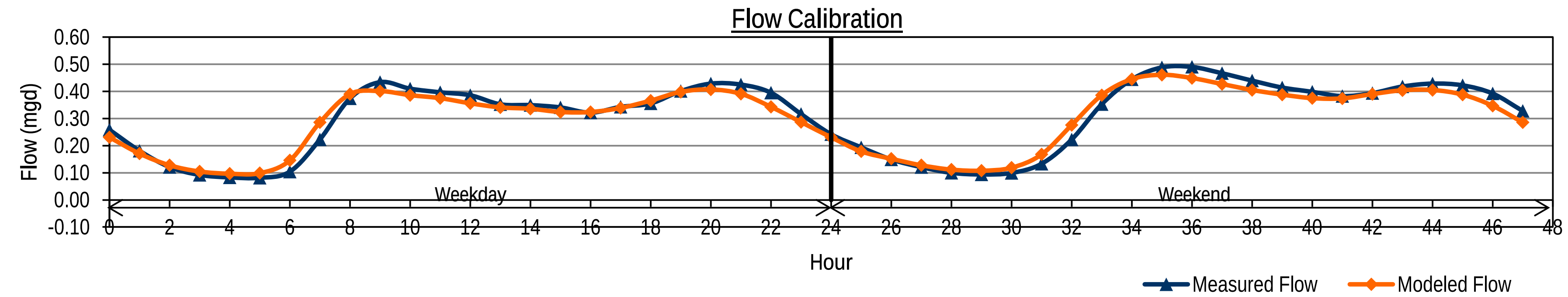
Sanitary Sewer Master Plan Update

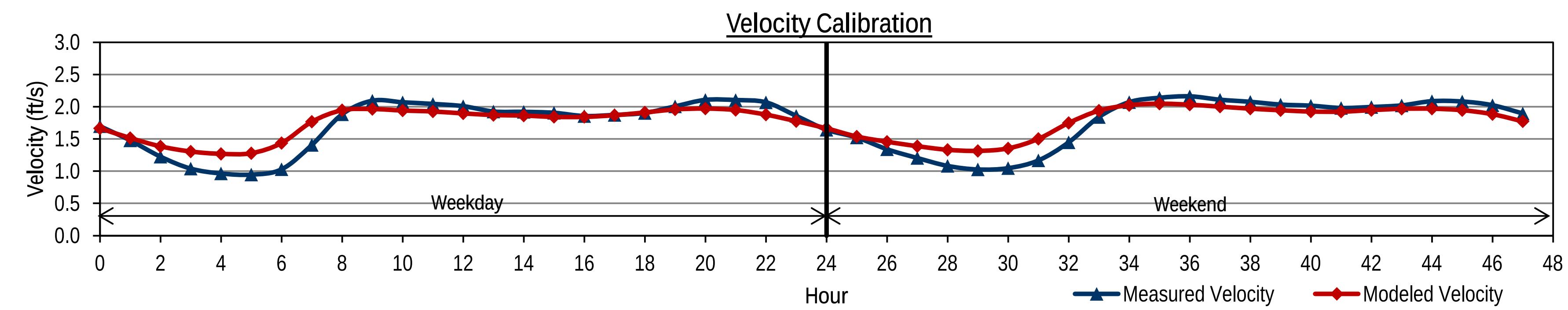
FLOW MONITORING SITE 14 DRY WEATHER FLOW CALIBRATION

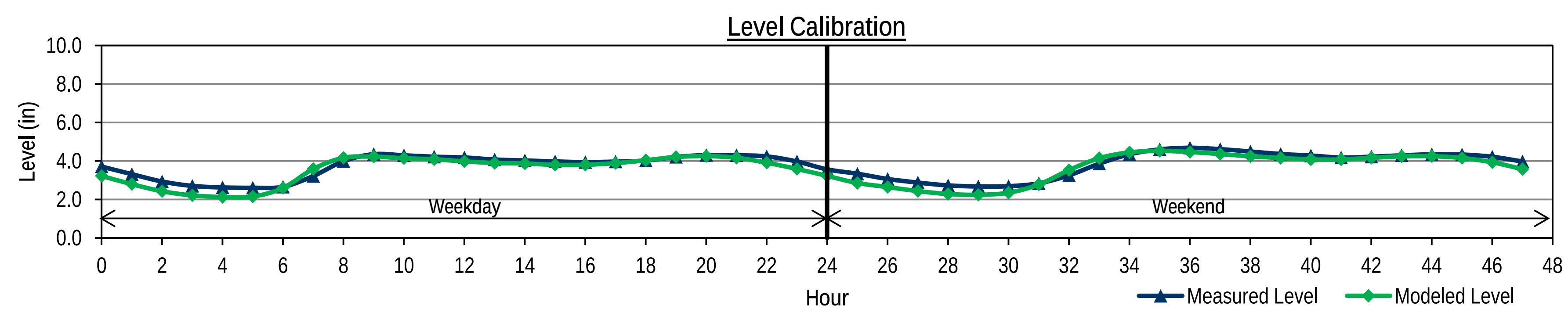
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	0.259	3.7	1.70	0.231	3.2	1.66	0.59	0.40	0.40
	1	0.181	3.3	1.48	0.171	2.8	1.51	0.40	0.30	0.30
	2	0.121	2.9	1.23	0.128	2.4	1.38	0.30	0.27	0.27
	3	0.092	2.7	1.04	0.105	2.2	1.30	0.27	0.27	0.27
	4	0.083	2.6	0.97	0.097	2.1	1.27	0.27	0.34	0.34
	5	0.082	2.6	0.95	0.099	2.2	1.28	0.34	0.73	0.73
	6	0.104	2.7	1.03	0.146	2.6	1.44	0.73	1.23	1.23
	7	0.223	3.2	1.41	0.286	3.6	1.77	1.23	1.43	1.43
	8	0.374	4.0	1.88	0.390	4.2	1.95	1.43	1.35	1.35
	9	0.435	4.4	2.09	0.401	4.2	1.96	1.35	1.30	1.30
	10	0.410	4.3	2.07	0.386	4.1	1.94	1.30	1.27	1.27
	11	0.397	4.2	2.04	0.375	4.1	1.93	1.27	1.16	1.16
	12	0.386	4.2	2.01	0.356	4.0	1.90	1.16	1.15	1.15
	13	0.353	4.1	1.93	0.341	3.9	1.87	1.15	1.12	1.12
	14	0.350	4.0	1.92	0.336	3.9	1.86	1.12	1.06	1.06
	15	0.341	4.0	1.91	0.324	3.8	1.84	1.06	1.13	1.13
	16	0.322	3.9	1.86	0.324	3.8	1.84	1.13	1.17	1.17
	17	0.343	4.0	1.87	0.339	3.9	1.87	1.17	1.32	1.32
	18	0.356	4.0	1.90	0.366	4.0	1.91	1.32	1.41	1.41
	19	0.402	4.2	2.01	0.398	4.2	1.96	1.41	1.40	1.40
	20	0.429	4.3	2.11	0.407	4.3	1.97	1.40	1.30	1.30
	21	0.426	4.3	2.10	0.391	4.2	1.95	1.30	1.04	1.04
	22	0.395	4.2	2.07	0.343	3.9	1.88	1.04	0.85	0.85
	23	0.317	4.0	1.86	0.287	3.6	1.78	0.85	0.59	0.59
Weekend	24	0.242	3.6	1.64	0.231	3.2	1.66	0.64	0.49	0.49
	25	0.194	3.3	1.52	0.179	2.9	1.54	0.49	0.40	0.40
	26	0.149	3.1	1.34	0.152	2.6	1.46	0.40	0.33	0.33
	27	0.121	2.9	1.21	0.128	2.4	1.39	0.33	0.31	0.31
	28	0.100	2.7	1.08	0.112	2.3	1.33	0.31	0.33	0.33
	29	0.094	2.7	1.03	0.108	2.2	1.31	0.33	0.44	0.44
	30	0.099	2.7	1.05	0.119	2.4	1.35	0.44	0.73	0.73
	31	0.133	2.8	1.17	0.168	2.8	1.50	0.73	1.16	1.16
	32	0.223	3.3	1.45	0.276	3.5	1.75	1.16	1.46	1.46
	33	0.353	3.9	1.84	0.386	4.1	1.94	1.46	1.61	1.61
	34	0.445	4.4	2.07	0.445	4.4	2.02	1.61	1.61	1.61
	35	0.489	4.6	2.14	0.461	4.5	2.05	1.61	1.54	1.54
	36	0.491	4.7	2.16	0.449	4.5	2.03	1.54	1.45	1.45
	37	0.467	4.6	2.11	0.427	4.4	2.00	1.45	1.36	1.36
	38	0.440	4.5	2.08	0.405	4.2	1.97	1.36	1.31	1.31
	39	0.415	4.4	2.03	0.388	4.2	1.95	1.31	1.26	1.26
	40	0.399	4.3	2.02	0.375	4.1	1.93	1.26	1.29	1.29
	41	0.383	4.2	1.98	0.374	4.1	1.92	1.29	1.37	1.37
	42	0.394	4.2	2.00	0.390	4.2	1.95	1.37	1.41	1.41
	43	0.418	4.3	2.02	0.404	4.2	1.97	1.41	1.39	1.39
	44	0.429	4.4	2.09	0.405	4.2	1.97	1.39	1.29	1.29
	45	0.423	4.3	2.08	0.388	4.2	1.95	1.29	1.08	1.08
	46	0.393	4.2	2.02	0.347	3.9	1.88	1.08	0.80	0.80
	47	0.328	4.0	1.90	0.286	3.6	1.77	0.80	0.64	0.64
Average										
Weekday		0.299	3.7	1.73	0.293	3.5	1.75	0.98	0.98	0.98
Weekend		0.318	3.8	1.75	0.308	3.6	1.77	1.04	1.04	1.04
ADWF[(1)]		0.304	3.8	1.73	0.297	3.6	1.76	1.00	1.00	1.00
% Error										
Weekday					-2.1%	-5.3%	1.5%			
Weekend					-2.9%	-5.2%	1.4%			

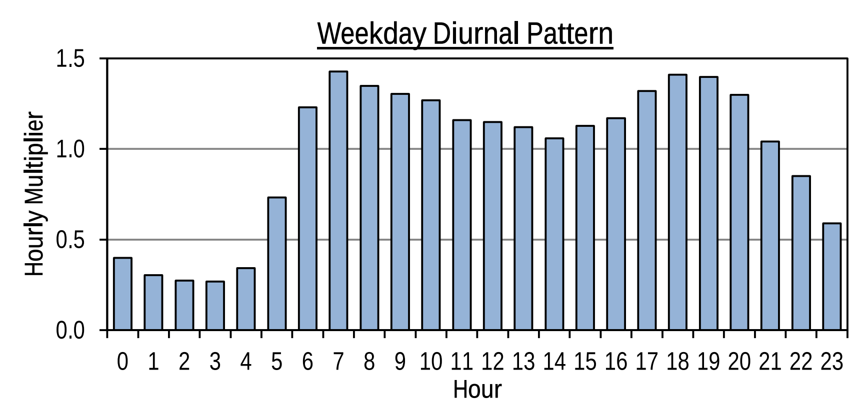
Note:

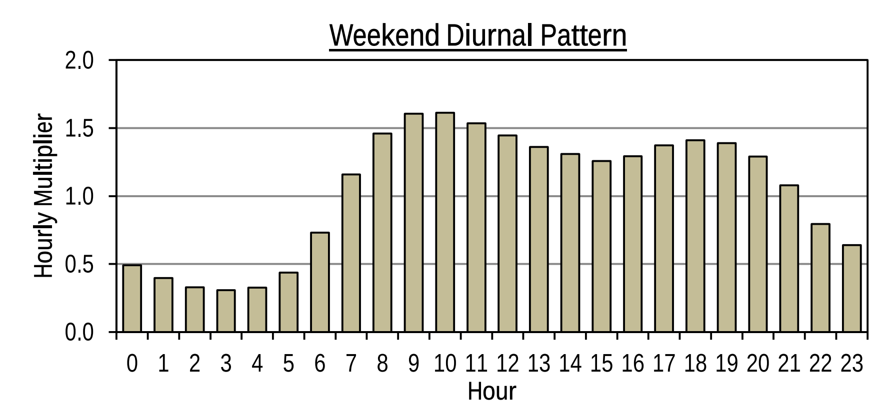
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7







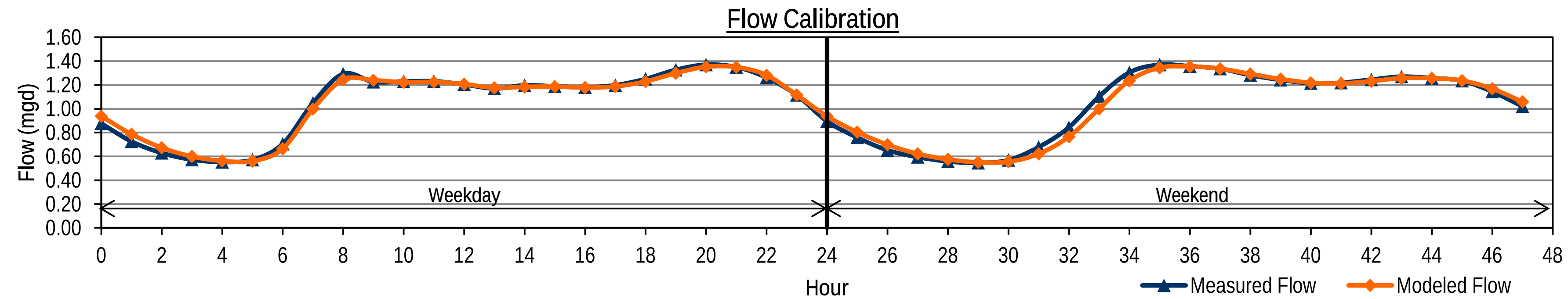


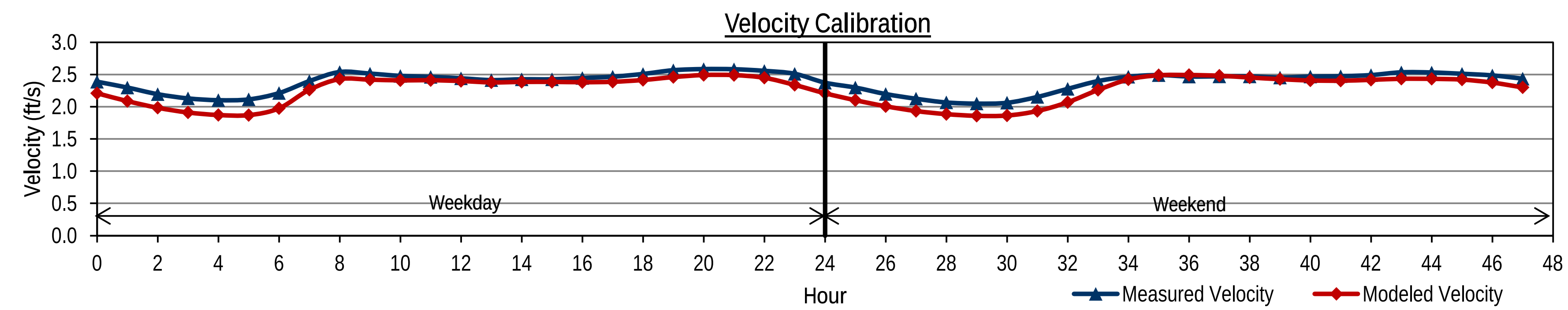


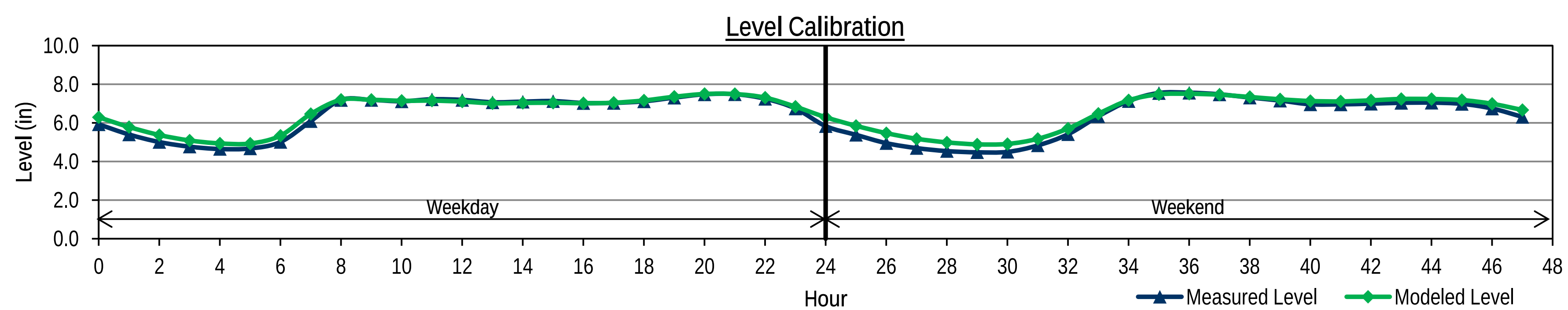
City of Chico
Sanitary Sewer Master Plan Update
FLOW MONITORING SITE 15 DRY WEATHER FLOW CALIBRATION

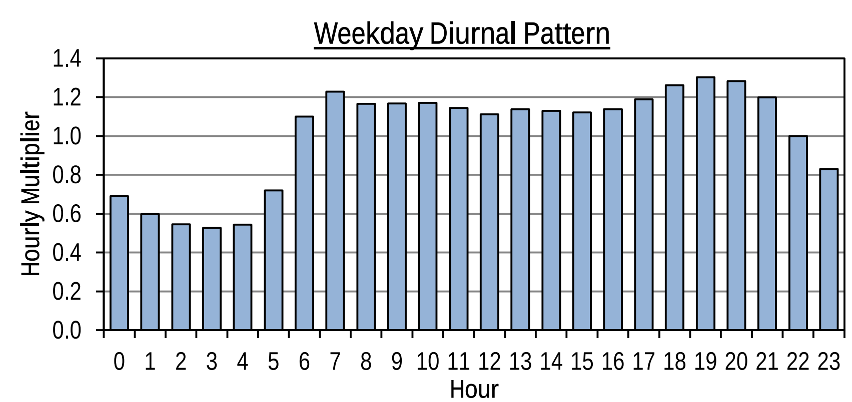
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	0.878	5.9	2.39	0.937	6.3	2.21	0.69	0.69	0.69
	1	0.726	5.4	2.30	0.787	5.8	2.09	0.60	0.60	0.60
	2	0.630	5.0	2.20	0.673	5.4	1.98	0.54	0.54	0.54
	3	0.574	4.8	2.13	0.600	5.1	1.91	0.53	0.53	0.53
	4	0.554	4.7	2.10	0.562	4.9	1.87	0.54	0.54	0.54
	5	0.573	4.7	2.12	0.561	4.9	1.87	0.67	0.72	0.72
	6	0.706	5.0	2.21	0.664	5.3	1.98	1.00	1.10	1.10
	7	1.049	6.1	2.40	0.997	6.5	2.26	1.23	1.23	1.23
	8	1.294	7.2	2.54	1.244	7.2	2.43	1.16	1.16	1.16
	9	1.227	7.2	2.51	1.239	7.2	2.42	1.17	1.17	1.17
	10	1.230	7.1	2.48	1.222	7.1	2.41	1.17	1.17	1.17
	11	1.232	7.2	2.46	1.225	7.2	2.41	1.14	1.14	1.14
	12	1.205	7.2	2.44	1.207	7.1	2.40	1.11	1.11	1.11
	13	1.171	7.1	2.41	1.175	7.0	2.38	1.14	1.14	1.14
	14	1.198	7.1	2.43	1.183	7.0	2.39	1.13	1.13	1.13
	15	1.189	7.1	2.43	1.186	7.0	2.39	1.12	1.12	1.12
	16	1.181	7.0	2.45	1.178	7.0	2.38	1.14	1.14	1.14
	17	1.199	7.0	2.47	1.187	7.0	2.39	1.19	1.19	1.19
	18	1.251	7.1	2.51	1.228	7.2	2.42	1.26	1.26	1.26
	19	1.328	7.3	2.57	1.298	7.4	2.46	1.30	1.30	1.30
	20	1.371	7.5	2.58	1.351	7.5	2.49	1.28	1.28	1.28
	21	1.351	7.5	2.58	1.349	7.5	2.49	1.20	1.20	1.20
	22	1.263	7.2	2.56	1.282	7.3	2.45	1.06	1.00	1.00
	23	1.116	6.7	2.51	1.115	6.8	2.34	0.83	0.83	0.83
Weekend	24	0.897	5.8	2.37	0.937	6.3	2.21	0.72	0.72	0.72
	25	0.760	5.4	2.30	0.804	5.8	2.10	0.62	0.62	0.62
	26	0.653	5.0	2.20	0.699	5.5	2.01	0.57	0.57	0.57
	27	0.596	4.7	2.13	0.622	5.2	1.93	0.53	0.53	0.53
	28	0.559	4.5	2.07	0.575	5.0	1.89	0.52	0.52	0.52
	29	0.547	4.5	2.05	0.551	4.9	1.86	0.54	0.54	0.54
	30	0.570	4.5	2.06	0.556	4.9	1.86	0.64	0.64	0.64
	31	0.679	4.8	2.15	0.622	5.2	1.93	0.80	0.80	0.80
	32	0.844	5.4	2.28	0.765	5.7	2.07	1.05	1.05	1.05
	33	1.104	6.3	2.40	0.999	6.5	2.26	1.24	1.24	1.24
	34	1.305	7.1	2.47	1.235	7.2	2.42	1.30	1.30	1.30
	35	1.371	7.5	2.49	1.344	7.5	2.49	1.29	1.29	1.29
	36	1.358	7.6	2.47	1.353	7.5	2.49	1.27	1.27	1.27
	37	1.337	7.5	2.47	1.335	7.5	2.48	1.22	1.22	1.22
	38	1.283	7.3	2.47	1.292	7.3	2.45	1.18	1.18	1.18
	39	1.244	7.2	2.45	1.249	7.2	2.43	1.15	1.15	1.15
	40	1.216	7.0	2.47	1.218	7.1	2.41	1.16	1.16	1.16
	41	1.219	7.0	2.47	1.211	7.1	2.40	1.18	1.18	1.18
	42	1.246	7.0	2.49	1.231	7.2	2.42	1.21	1.21	1.21
	43	1.271	7.0	2.53	1.257	7.2	2.43	1.20	1.20	1.20
	44	1.259	7.0	2.53	1.255	7.2	2.43	1.17	1.17	1.17
	45	1.236	7.0	2.51	1.236	7.2	2.42	1.09	1.09	1.09
	46	1.145	6.7	2.49	1.168	7.0	2.38	0.97	0.97	0.97
	47	1.022	6.3	2.44	1.059	6.7	2.30	0.85	0.85	0.85
Average										
Weekday		1.062	6.5	2.41	1.060	6.6	2.28	1.01	1.01	1.01
Weekend		1.030	6.3	2.36	1.024	6.5	2.25	0.98	0.98	0.98
ADWF[1]		1.053	6.4	2.39	1.050	6.6	2.28	1.00	1.00	1.00
% Error										
Weekday					-0.2%	1.7%	-5.1%			
Weekend					-0.6%	3.8%	-4.7%			

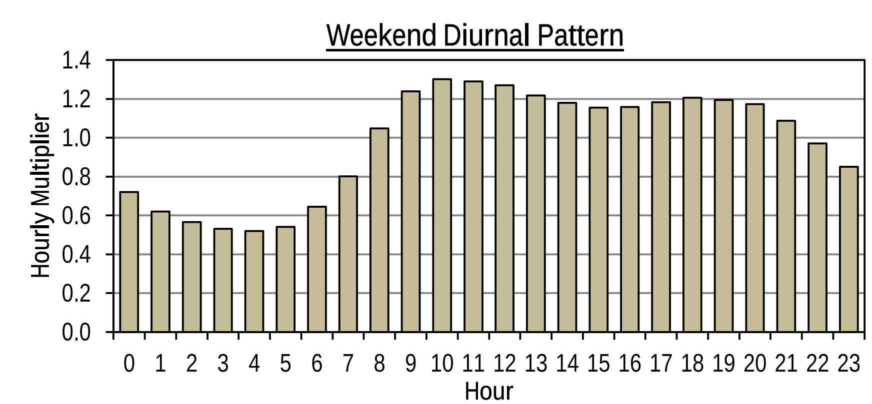
Note:
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7









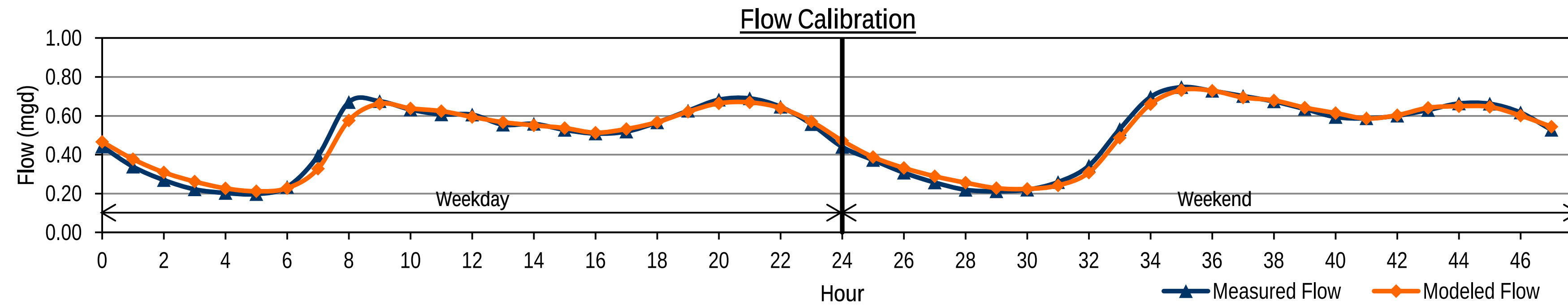


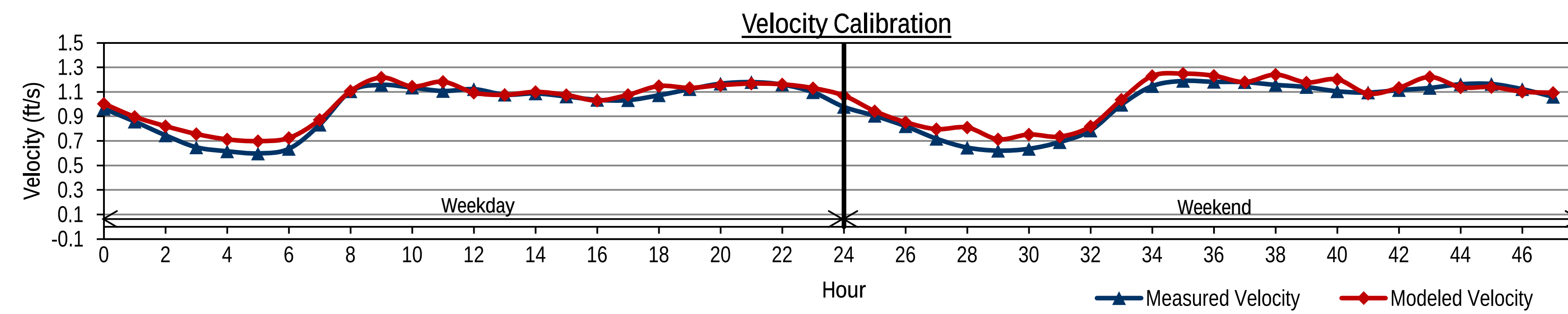
City of Chico
Sanitary Sewer Master Plan Update
FLOW MONITORING SITE 16 DRY WEATHER FLOW CALIBRATION

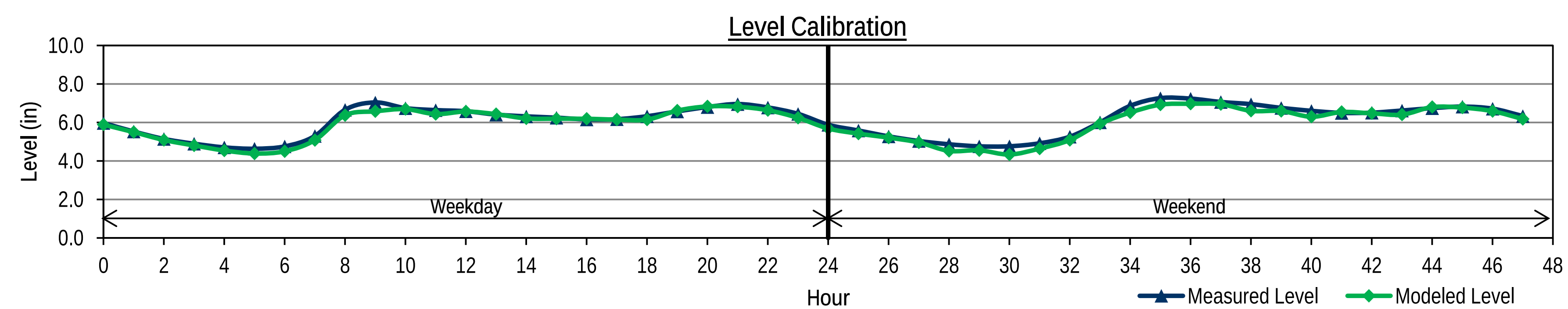
carollo

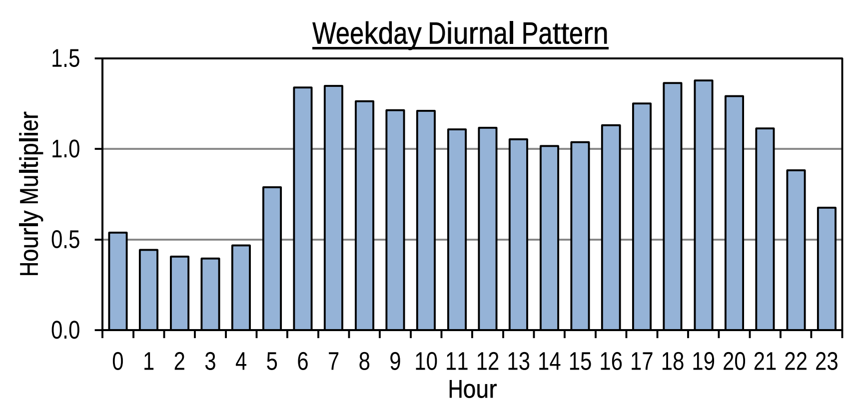
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	0.442	6.0	0.96	0.466	5.891	1.003	0.68	0.54	0.54
	1	0.339	5.5	0.86	0.377	5.5	0.90	0.54	0.44	0.44
	2	0.270	5.1	0.75	0.309	5.1	0.82	0.44	0.41	0.41
	3	0.222	4.9	0.65	0.262	4.8	0.76	0.41	0.39	0.39
	4	0.203	4.7	0.62	0.227	4.5	0.71	0.39	0.47	0.47
	5	0.198	4.6	0.60	0.212	4.4	0.70	0.47	0.79	0.79
	6	0.234	4.8	0.64	0.228	4.5	0.72	0.79	1.34	1.34
	7	0.395	5.3	0.83	0.328	5.1	0.87	1.34	1.35	1.35
	8	0.671	6.7	1.11	0.576	6.4	1.11	1.35	1.26	1.26
	9	0.676	7.0	1.16	0.662	6.6	1.22	1.26	1.21	1.21
	10	0.633	6.7	1.14	0.638	6.7	1.14	1.21	1.21	1.21
	11	0.608	6.6	1.11	0.624	6.4	1.18	1.21	1.11	1.11
	12	0.607	6.6	1.12	0.594	6.6	1.09	1.11	1.12	1.12
	13	0.555	6.4	1.08	0.567	6.4	1.08	1.12	1.05	1.05
	14	0.559	6.3	1.09	0.551	6.2	1.10	1.05	1.02	1.02
	15	0.528	6.2	1.06	0.537	6.2	1.07	1.02	1.04	1.04
	16	0.509	6.2	1.04	0.513	6.2	1.03	1.04	1.13	1.13
	17	0.519	6.2	1.03	0.532	6.2	1.08	1.13	1.25	1.25
	18	0.566	6.3	1.07	0.567	6.2	1.15	1.25	1.36	1.36
	19	0.626	6.6	1.12	0.621	6.6	1.13	1.36	1.38	1.38
	20	0.683	6.8	1.17	0.664	6.8	1.15	1.38	1.29	1.29
	21	0.690	7.0	1.18	0.669	6.8	1.17	1.29	1.11	1.11
	22	0.647	6.8	1.16	0.640	6.6	1.16	1.11	0.88	0.88
	23	0.557	6.4	1.10	0.571	6.2	1.13	0.88	0.68	0.68
Weekend	24	0.440	5.9	0.98	0.472	5.7	1.07	0.74	0.61	0.61
	25	0.373	5.6	0.91	0.388	5.4	0.94	0.61	0.51	0.51
	26	0.308	5.3	0.82	0.332	5.2	0.85	0.51	0.44	0.44
	27	0.257	5.0	0.72	0.289	5.0	0.80	0.44	0.42	0.42
	28	0.220	4.9	0.65	0.256	4.5	0.81	0.42	0.44	0.44
	29	0.212	4.8	0.62	0.228	4.6	0.71	0.44	0.52	0.52
	30	0.220	4.8	0.64	0.224	4.3	0.75	0.52	0.69	0.69
	31	0.259	4.9	0.69	0.242	4.6	0.74	0.69	1.06	1.06
	32	0.343	5.3	0.79	0.308	5.1	0.82	1.06	1.39	1.39
	33	0.532	6.0	1.00	0.487	5.9	1.04	1.39	1.49	1.49
	34	0.697	6.9	1.15	0.660	6.5	1.23	1.49	1.46	1.46
	35	0.748	7.3	1.19	0.732	6.9	1.25	1.46	1.40	1.40
	36	0.729	7.2	1.18	0.729	7.0	1.23	1.40	1.35	1.35
	37	0.702	7.1	1.18	0.694	7.0	1.18	1.35	1.27	1.27
	38	0.675	6.9	1.16	0.679	6.6	1.24	1.27	1.19	1.19
	39	0.636	6.8	1.14	0.642	6.6	1.18	1.19	1.17	1.17
	40	0.594	6.6	1.11	0.614	6.3	1.20	1.17	1.20	1.20
	41	0.587	6.5	1.10	0.586	6.5	1.09	1.20	1.26	1.26
	42	0.601	6.5	1.12	0.603	6.5	1.13	1.26	1.33	1.33
	43	0.630	6.6	1.13	0.641	6.4	1.22	1.33	1.32	1.32
	44	0.664	6.7	1.16	0.649	6.8	1.14	1.32	1.23	1.23
	45	0.663	6.8	1.17	0.646	6.8	1.14	1.23	1.05	1.05
	46	0.617	6.7	1.12	0.601	6.6	1.10	1.05	0.88	0.88
	47	0.528	6.3	1.06	0.544	6.2	1.09	0.88	0.74	0.74
Average										
Weekday		0.497	6.1	0.98	0.497	6.0	1.02	0.99	0.99	0.99
Weekend		0.510	6.1	0.99	0.510	6.0	1.04	1.02	1.02	1.02
ADWF[1]		0.501	6.1	0.99	0.501	6.0	1.02	1.00	1.00	1.00
% Error										
Weekday					0.0%	-1.9%	3.6%			
Weekend					0.1%	-2.9%	5.0%			

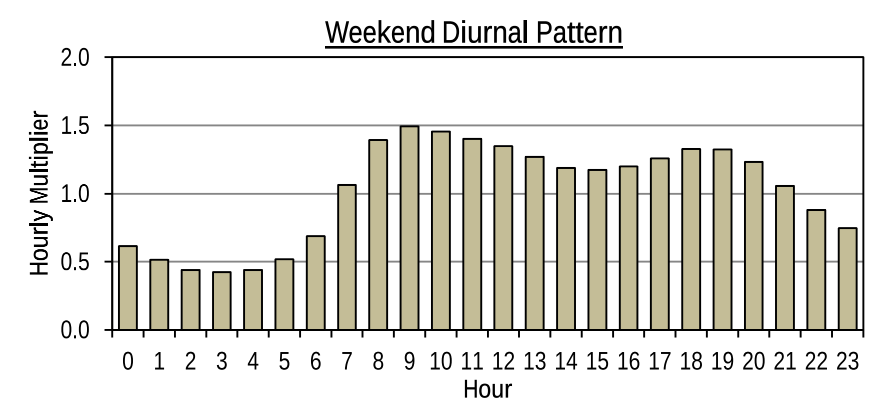
Note:
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

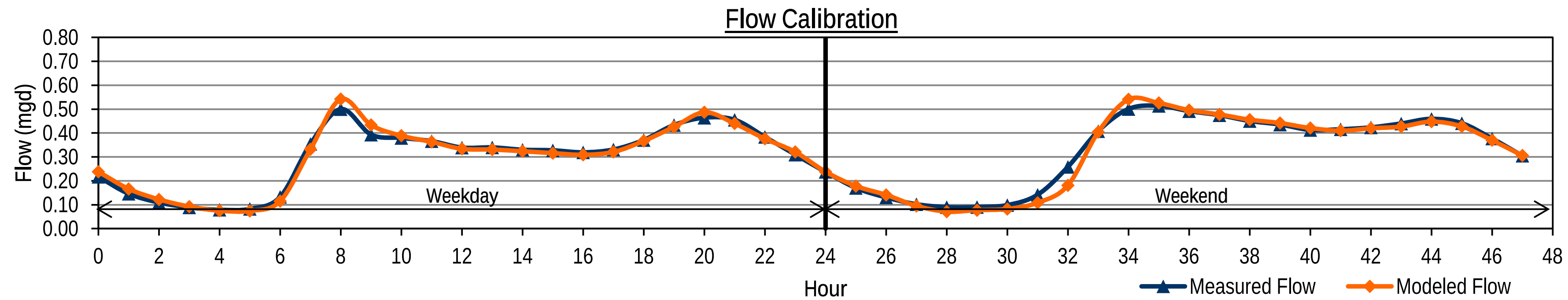
Sanitary Sewer Master Plan Update

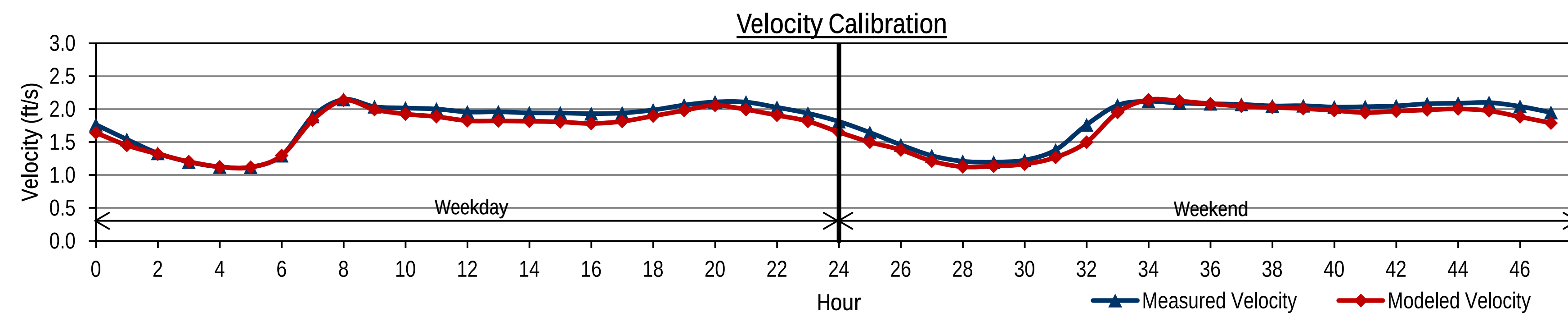
FLOW MONITORING SITE 17 DRY WEATHER FLOW CALIBRATION

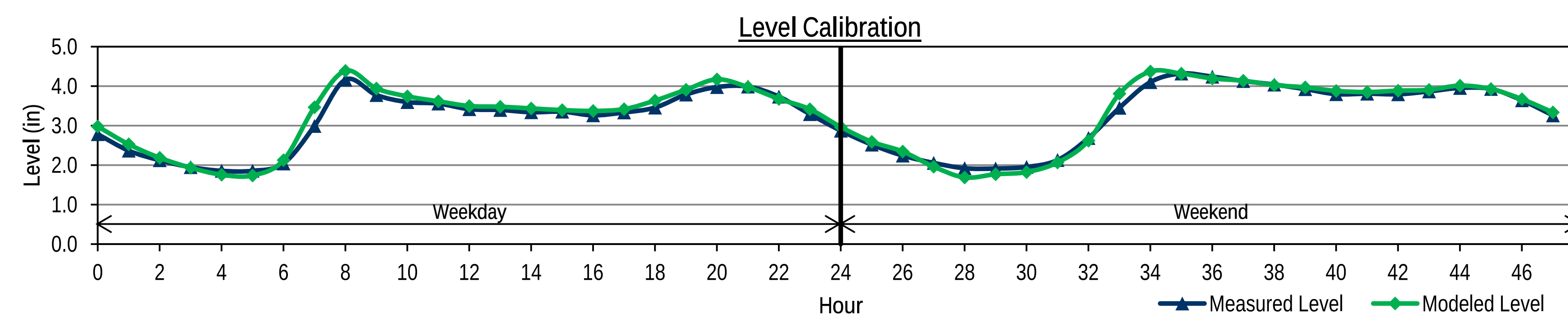
	Hour	Measured Data Flow (mgd)	Measured Data Level (in)	Measured Data Velocity (ft/s)	Modeled Data Flow (mgd)	Modeled Data Level (in)	Modeled Data Velocity (ft/s)	Diurnal Initial Curve	Diurnal Modified Curve	Diurnal Calibrated Diurnal
Weekday	0	0.217	2.8	1.77	0.238	3.0	1.64	0.47	0.45	0.45
	1	0.146	2.4	1.54	0.166	2.5	1.45	0.35	0.33	0.33
	2	0.109	2.1	1.33	0.122	2.2	1.32	0.29	0.25	0.25
	3	0.089	2.0	1.20	0.092	1.9	1.20	0.26	0.22	0.22
	4	0.079	1.9	1.12	0.075	1.8	1.12	0.27	0.25	0.25
	5	0.082	1.9	1.12	0.074	1.7	1.12	0.43	0.50	0.50
	6	0.133	2.0	1.30	0.115	2.1	1.30	1.15	1.32	1.32
	7	0.354	3.0	1.89	0.332	3.5	1.83	1.62	1.83	1.83
	8	0.500	4.2	2.15	0.542	4.4	2.13	1.27	1.33	1.33
	9	0.393	3.8	2.04	0.434	3.9	1.99	1.23	1.25	1.25
	10	0.379	3.6	2.02	0.389	3.7	1.93	1.18	1.16	1.16
	11	0.366	3.6	2.00	0.363	3.6	1.89	1.10	1.06	1.06
	12	0.339	3.4	1.96	0.334	3.5	1.82	1.10	1.08	1.08
	13	0.340	3.4	1.96	0.331	3.5	1.82	1.07	1.04	1.04
	14	0.330	3.3	1.95	0.324	3.4	1.82	1.06	1.02	1.02
	15	0.327	3.4	1.94	0.316	3.4	1.81	1.03	1.00	1.00
	16	0.319	3.3	1.93	0.309	3.4	1.78	1.07	1.06	1.06
	17	0.331	3.3	1.94	0.321	3.4	1.81	1.20	1.23	1.23
	18	0.371	3.5	1.99	0.367	3.6	1.90	1.40	1.42	1.42
	19	0.433	3.8	2.06	0.426	3.9	1.98	1.50	1.61	1.61
	20	0.464	4.0	2.11	0.487	4.2	2.06	1.47	1.40	1.40
	21	0.455	4.0	2.11	0.440	4.0	1.99	1.24	1.18	1.18
	22	0.384	3.7	2.03	0.376	3.7	1.91	1.00	1.00	1.00
	23	0.309	3.3	1.94	0.321	3.4	1.82	0.70	0.66	0.66
Weekend	24	0.237	2.9	1.81	0.238	3.0	1.65	0.55	0.52	0.52
	25	0.170	2.5	1.65	0.178	2.6	1.50	0.42	0.40	0.40
	26	0.131	2.2	1.46	0.141	2.3	1.38	0.33	0.20	0.20
	27	0.102	2.1	1.29	0.095	2.0	1.21	0.29	0.24	0.24
	28	0.090	1.9	1.21	0.071	1.7	1.13	0.29	0.26	0.26
	29	0.090	1.9	1.20	0.077	1.8	1.13	0.32	0.27	0.27
	30	0.098	2.0	1.23	0.082	1.8	1.17	0.46	0.43	0.43
	31	0.142	2.1	1.38	0.108	2.1	1.27	0.83	0.70	0.70
	32	0.258	2.7	1.76	0.181	2.6	1.50	1.32	1.50	1.50
	33	0.408	3.5	2.06	0.404	3.8	1.95	1.62	1.80	1.80
	34	0.500	4.1	2.12	0.541	4.4	2.14	1.66	1.70	1.70
	35	0.514	4.3	2.09	0.526	4.3	2.12	1.59	1.60	1.60
	36	0.491	4.2	2.08	0.496	4.2	2.08	1.53	1.55	1.55
	37	0.474	4.1	2.07	0.478	4.1	2.04	1.45	1.47	1.47
	38	0.450	4.0	2.05	0.456	4.0	2.03	1.41	1.43	1.43
	39	0.435	3.9	2.05	0.442	4.0	2.01	1.33	1.36	1.36
	40	0.413	3.8	2.03	0.421	3.9	1.98	1.34	1.33	1.33
	41	0.416	3.8	2.04	0.410	3.9	1.95	1.37	1.37	1.37
	42	0.423	3.8	2.05	0.420	3.9	1.97	1.42	1.39	1.39
	43	0.439	3.9	2.08	0.427	3.9	1.99	1.48	1.47	1.47
	44	0.459	4.0	2.09	0.448	4.0	2.00	1.43	1.37	1.37
	45	0.441	3.9	2.10	0.428	3.9	1.97	1.22	1.16	1.16
	46	0.377	3.6	2.04	0.370	3.7	1.88	0.99	0.93	0.93
	47	0.305	3.3	1.95	0.306	3.3	1.79	0.77	0.77	0.77
Average										
Weekday		0.302	3.1	1.81	0.304	3.2	1.73	0.98	0.99	0.99
Weekend		0.328	3.3	1.83	0.323	3.3	1.74	1.06	1.05	1.05
ADWF[(1)]		0.309	3.2	1.81	0.309	3.3	1.73	1.00	1.00	1.00
% Error										
Weekday					0.6%	3.1%	-4.5%			
Weekend					-1.5%	0.7%	-4.7%			

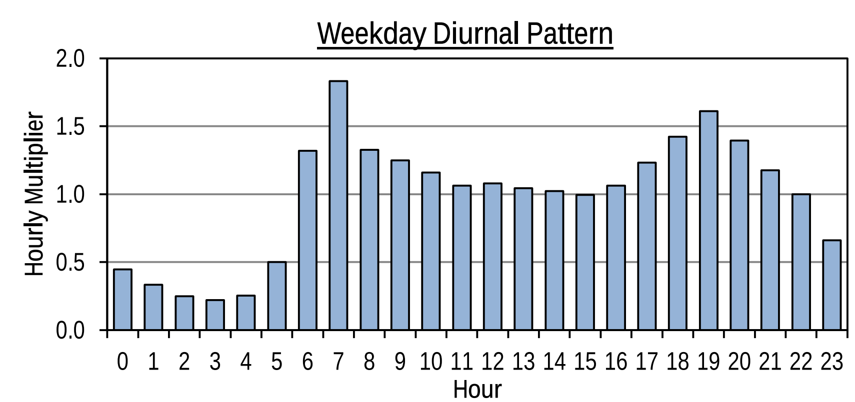
Note:

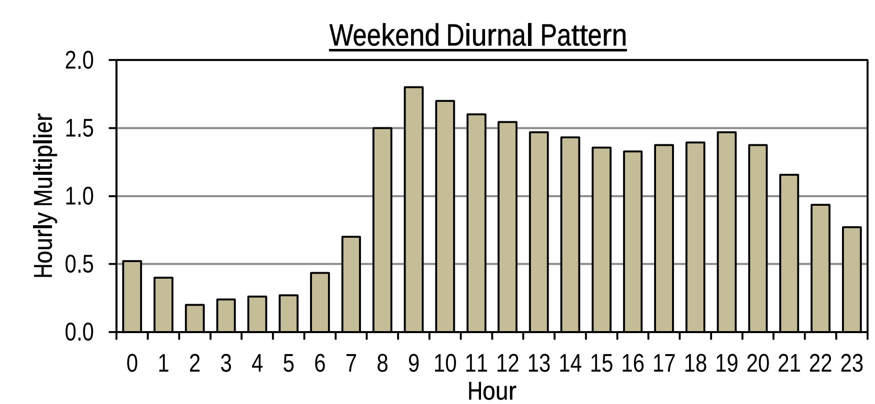
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











City of Chico

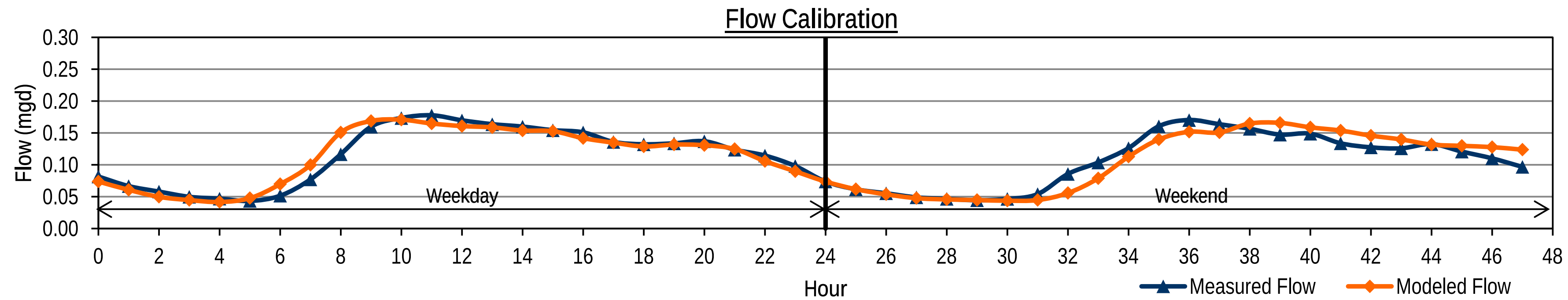
Sanitary Sewer Master Plan Update

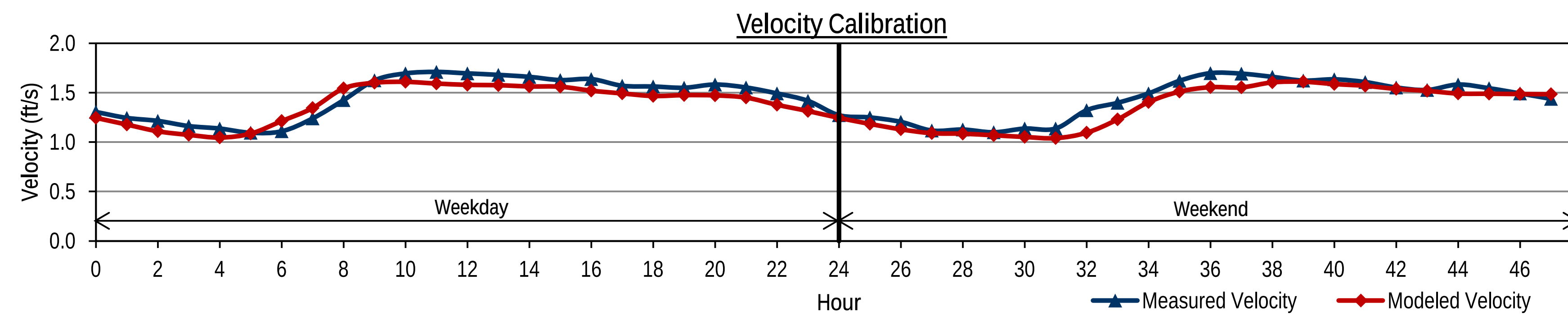
FLOW MONITORING SITE 18 DRY WEATHER FLOW CALIBRATION

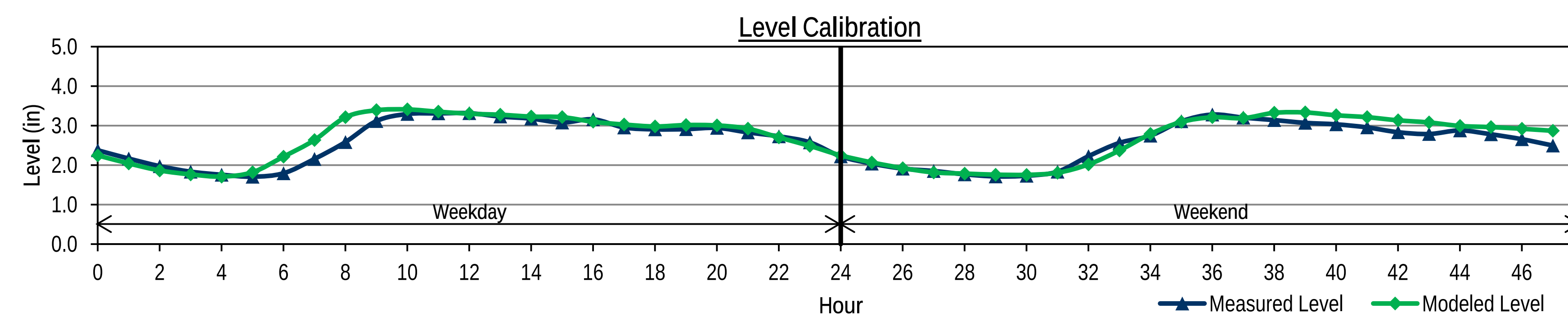
		Measured Data			Modeled Data			Diurnal		
		Flow	Level	Velocity	Flow	Level	Velocity	Initial	Modified	Calibrated
	Hour	(mgd)	(in)	(ft/s)	(mgd)	(in)	(ft/s)	Curve	Curve	Diurnal
Weekday	0	0.082	2.4	1.31	0.074	2.2	1.25	0.59	0.37	0.45
	1	0.067	2.2	1.25	0.061	2.0	1.18	0.51	0.32	0.34
	2	0.058	2.0	1.22	0.050	1.9	1.11	0.44	0.40	0.25
	3	0.050	1.8	1.16	0.045	1.8	1.07	0.42	0.35	0.22
	4	0.047	1.8	1.14	0.042	1.7	1.05	0.38	0.65	0.25
	5	0.043	1.7	1.10	0.048	1.8	1.09	0.46	1.20	0.50
	6	0.052	1.8	1.11	0.070	2.2	1.21	0.68	1.45	1.32
	7	0.077	2.2	1.24	0.100	2.6	1.35	1.03	1.55	1.83
	8	0.117	2.6	1.43	0.151	3.2	1.54	1.41	1.48	1.33
	9	0.160	3.1	1.63	0.169	3.4	1.60	1.54	1.45	1.25
	10	0.173	3.3	1.70	0.171	3.4	1.61	1.57	1.40	1.16
	11	0.178	3.3	1.71	0.165	3.4	1.59	1.50	1.35	1.06
	12	0.170	3.3	1.70	0.161	3.3	1.58	1.45	1.40	1.08
	13	0.164	3.2	1.68	0.159	3.3	1.58	1.42	1.31	1.04
	14	0.160	3.2	1.66	0.154	3.2	1.56	1.37	1.28	1.02
	15	0.154	3.1	1.63	0.153	3.2	1.56	1.34	1.09	1.00
	16	0.151	3.2	1.64	0.142	3.1	1.52	1.20	1.09	1.06
	17	0.136	3.0	1.57	0.135	3.0	1.49	1.17	1.20	1.23
	18	0.132	2.9	1.56	0.129	3.0	1.47	1.18	1.25	1.42
	19	0.134	2.9	1.55	0.132	3.0	1.48	1.21	1.01	1.61
	20	0.137	2.9	1.58	0.131	3.0	1.47	1.10	0.91	1.40
	21	0.124	2.8	1.55	0.125	2.9	1.45	1.01	0.72	1.18
	22	0.115	2.7	1.49	0.106	2.7	1.38	0.87	0.56	1.00
	23	0.098	2.6	1.42	0.090	2.5	1.32	0.72	0.41	0.66
Weekend	24	0.074	2.2	1.27	0.074	2.2	1.25	0.55	0.43	0.52
	25	0.062	2.0	1.25	0.062	2.1	1.19	0.49	0.40	0.40
	26	0.055	1.9	1.21	0.054	1.9	1.13	0.43	0.39	0.20
	27	0.049	1.9	1.12	0.048	1.8	1.09	0.41	0.38	0.24
	28	0.047	1.8	1.13	0.046	1.8	1.09	0.39	0.37	0.26
	29	0.045	1.7	1.10	0.045	1.8	1.07	0.41	0.38	0.27
	30	0.047	1.7	1.14	0.044	1.8	1.05	0.48	0.50	0.43
	31	0.054	1.8	1.14	0.045	1.8	1.04	0.76	0.92	0.70
	32	0.086	2.2	1.32	0.056	2.0	1.10	0.92	1.20	1.50
	33	0.104	2.6	1.40	0.079	2.4	1.23	1.12	1.40	1.80
	34	0.126	2.7	1.49	0.113	2.8	1.41	1.42	1.12	1.70
	35	0.160	3.1	1.62	0.140	3.1	1.51	1.51	1.42	1.60
	36	0.170	3.3	1.70	0.152	3.2	1.56	1.45	1.51	1.55
	37	0.164	3.2	1.69	0.151	3.2	1.55	1.39	1.45	1.47
	38	0.157	3.1	1.66	0.165	3.3	1.61	1.31	1.39	1.43
	39	0.147	3.1	1.62	0.166	3.3	1.61	1.32	1.31	1.36
	40	0.149	3.0	1.64	0.159	3.3	1.59	1.19	1.32	1.33
	41	0.134	3.0	1.61	0.154	3.2	1.57	1.13	1.19	1.37
	42	0.127	2.8	1.55	0.146	3.1	1.54	1.12	1.13	1.39
	43	0.126	2.8	1.53	0.140	3.1	1.52	1.17	1.12	1.47
	44	0.133	2.9	1.58	0.132	3.0	1.49	1.07	1.17	1.37
	45	0.121	2.8	1.55	0.130	3.0	1.49	0.98	1.07	1.16
	46	0.110	2.7	1.49	0.128	2.9	1.49	0.86	0.98	0.94
	47	0.097	2.5	1.44	0.124	2.9	1.49	0.65	0.55	0.77
Average										
Weekday		0.116	2.7	1.46	0.115	2.7	1.40	1.02	1.01	0.99
Weekend		0.106	2.5	1.43	0.106	2.6	1.36	0.94	0.96	1.05
ADWF[(1)]		0.113	2.6	1.45	0.113	2.7	1.39	1.00	0.99	1.00
% Error										
Weekday					-0.5%	3.2%	-4.3%			
Weekend					0.4%	3.4%	-4.7%			

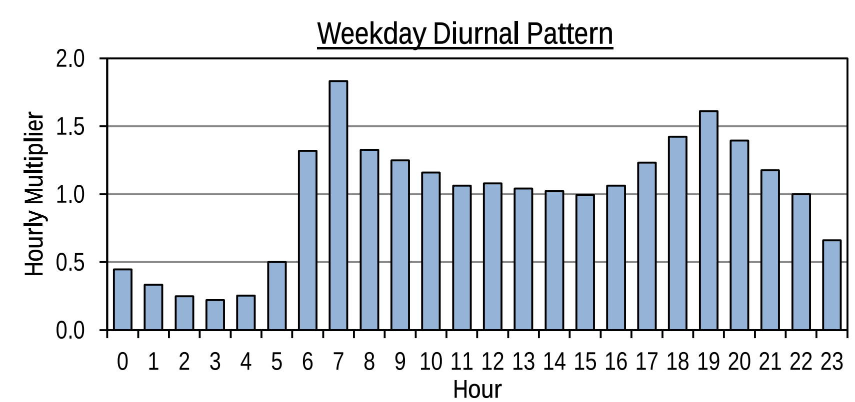
Note:

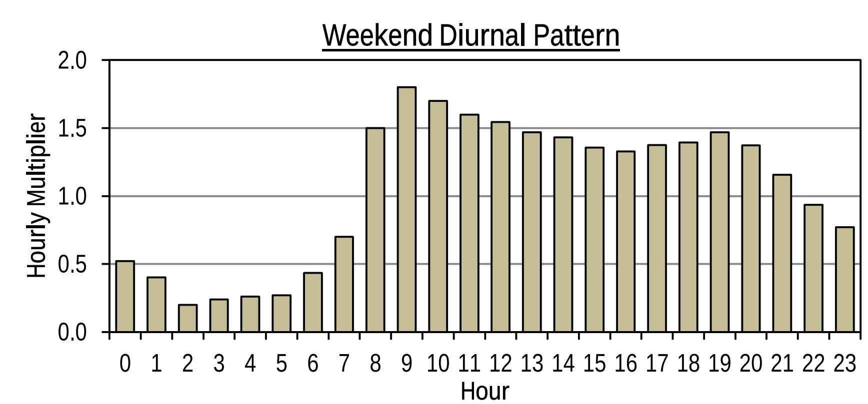
1. ADWF = (5xWeekday Average + 2xWeekend Average)/7











APPENDIX E – WET WEATHER FLOW CALIBRATION PLOTS

Table 2 Wet Weather Flow Calibration Results
Sanitary Sewer Master Plan Update
City of Chico

		Storm 1 (3/13/2012-3/24/2012)											
		Measured Data[1]				Modeled Data[2]				Percent Error[3]			
Meter Number	Pipe Diameter (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (%)	Peak Flow (%)	Avg. Velocity (%)	Avg. Level (%)
1	30	1.830	2.989	2.15	9.2	1.908	3.199	2.07	9.8	4.3%	7.0%	-3.9%	6.1%
4	36	2.637	4.334	1.78	12.7	2.782	4.239	1.85	12.9	5.5%	-2.2%	3.9%	1.3%
5	15	0.212	0.353	0.67	6.2	0.225	0.335	0.73	6.1	6.4%	-5.0%	9.5%	-1.6%
6A	18	0.600	0.945	1.85	5.8	0.628	0.883	1.89	5.9	4.5%	-6.5%	1.8%	2.2%
6B	18	0.472	0.964	1.80	4.8	0.601	0.873	1.98	5.5	*27.3%*	-9.4%	10.2%	14.5%
7	15	0.773	1.215	1.74	8.1	0.737	1.346	1.68	8.0	-4.6%	10.8%	-3.5%	-1.3%
8	24	0.538	1.023	1.01	7.1	0.594	1.089	1.05	7.2	10.5%	6.5%	3.9%	1.7%
9	21	1.050	1.477	1.29	10.8	1.174	1.454	1.47	10.6	11.7%	-1.6%	13.7%	-1.3%
10	18	1.134	1.738	2.61	7.2	1.286	1.975	2.52	8.1	13.5%	13.6%	-3.5%	12.9%
11	33	1.883	2.594	1.99	9.6	1.872	2.756	1.98	9.6	-0.6%	6.2%	-0.3%	-0.1%
12	14	0.212	0.362	1.30	3.9	0.224	0.420	1.23	4.1	5.6%	16.1%	-5.4%	5.5%
13	12	0.424	0.641	1.79	5.6	0.512	0.659	1.90	6.3	*20.8%*	2.8%	5.9%	11.6%
14	18	0.524	0.766	2.12	4.7	0.554	0.784	2.12	5.0	5.7%	2.3%	0.0%	4.5%
15	24	1.288	1.925	2.37	7.5	1.293	1.822	2.39	7.4	0.4%	-5.3%	0.7%	-0.8%
16	33	0.845	1.591	1.27	7.4	0.854	1.569	1.21	7.7	1.0%	-1.4%	-4.4%	3.6%
17	23.5	0.447	0.704	2.05	3.9	0.448	0.799	1.96	4.0	0.4%	13.4%	-4.3%	1.8%
18	10	0.144	0.359	1.56	3.0	0.164	0.345	1.56	3.3	14.0%	-3.8%	0.1%	10.7%

		Storm 2 (3/27/2012-4/4/2012)											
		Measured Data[1]				Modeled Data[2]				Percent Error[3]			
Meter Number	Pipe Diameter (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (%)	Peak Flow (%)	Avg. Velocity (%)	Avg. Level (%)
1	30	2.041	3.721	2.24	9.7	2.093	4.324	2.14	10.2	2.5%	16.2%	-4.6%	5.3%
4	36	2.906	5.313	1.84	13.3	2.977	5.317	1.90	13.3	2.5%	0.1%	3.1%	-0.3%
5	15	0.234	0.365	0.71	6.4	0.228	0.329	0.73	6.1	-2.2%	-9.9%	3.7%	-4.1%
6A	18	0.644	0.948	1.92	5.9	0.675	1.104	1.92	6.1	4.8%	16.4%	0.3%	3.6%
6B	18	0.684	1.291	2.00	5.9	0.649	1.104	2.03	5.7	-5.1%	-14.5%	1.5%	-3.3%
7	15	0.816	1.583	1.80	8.2	0.798	1.728	1.72	8.3	-2.3%	9.2%	-4.5%	1.9%
8	24	0.691	1.243	1.15	7.8	0.658	1.424	1.09	7.5	-4.7%	14.5%	-4.7%	-2.8%
9	21	1.146	1.525	1.36	11.1	1.211	1.604	1.48	10.9	5.7%	5.2%	8.8%	-2.3%
10	18	1.411	2.209	2.79	8.1	1.379	2.403	2.57	8.5	-2.3%	8.8%	-8.0%	4.7%
11	33	2.071	3.525	2.06	10.1	2.012	3.728	2.03	10.0	-2.8%	5.8%	-1.5%	-1.1%
12	14	0.258	0.405	1.38	4.3	0.238	0.466	1.27	4.2	-7.7%	14.9%	-8.5%	-1.8%
13	12	0.525	0.769	1.88	6.4	0.523	0.679	1.91	6.3	-0.3%	-11.7%	1.3%	-0.7%
14	18	0.595	0.835	2.13	5.2	0.608	0.953	2.19	5.2	2.1%	14.1%	2.8%	0.0%
15	24	1.429	2.443	2.53	7.7	1.389	2.251	2.44	7.7	-2.8%	-7.9%	-3.4%	0.0%
16	33	0.994	2.471	1.29	8.1	0.961	2.419	1.26	8.1	-3.4%	-2.1%	-2.2%	-0.4%
17	23.5	0.530	0.896	2.13	4.3	0.509	0.989	2.04	4.2	-4.0%	10.4%	-4.1%	-1.2%
18	10	0.173	0.455	1.63	3.2	0.173	0.484	1.58	3.4	0.1%	6.5%	-3.3%	3.8%

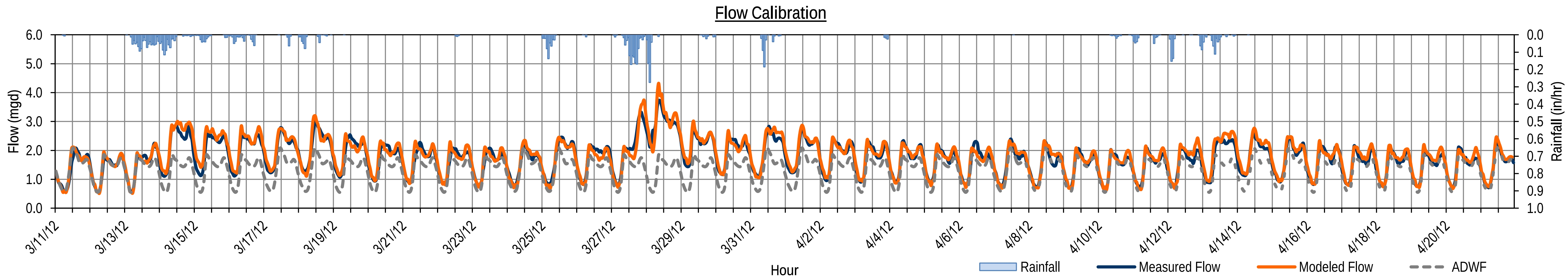
		Storm 3 (4/10/2012-4/17/2012)											
		Measured Data[1]				Modeled Data[2]				Percent Error[3]			
Meter Number	Pipe Diameter (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (mgd)	Peak Flow (mgd)	Avg. Velocity (ft/s)	Avg. Level (in)	Avg. Flow (%)	Peak Flow (%)	Avg. Velocity (%)	Avg. Level (%)
1	30	1.635	2.573	2.02	8.9	1.732	2.770	2.00	9.3	5.9%	7.7%	-1.2%	5.0%
4	36	2.499	4.006	1.74	12.4	2.573	3.808	1.80	12.4	3.0%	-5.0%	3.5%	-0.3%
5	15	0.229	0.357	0.70	6.3	0.220	0.329	0.72	6.0	-3.8%	-7.7%	3.0%	-4.7%
6A	18	0.669	1.346	1.95	5.9	0.605	0.868	1.87	5.8	-9.6%	*-35.5%*	-4.0%	-2.6%
6B	18	0.492	1.072	1.72	4.9	0.577	0.854	1.96	5.4	17.4%	*-20.3%*	13.7%	8.8%
7	15	0.697	1.121	1.62	7.8	0.662	1.261	1.62	7.5	-4.9%	12.5%	-0.4%	-4.0%
8	24	0.472	0.814	0.91	6.9	0.559	1.094	1.02	7.0	18.5%	*34.4%*	12.1%	0.6%
9	21	1.133	1.532	1.47	10.3	1.151	1.443	1.47	10.5	1.7%	-5.8%	-0.3%	2.1%
10	18	1.196	1.652	2.64	7.4	1.144	1.954	2.44	7.6	-4.3%	18.3%	-7.8%	2.3%
11	33	1.809	2.481	1.99	9.3	1.753	2.788	1.95	9.3	-3.1%	12.4%	-2.1%	-0.4%
12	14	0.233	0.352	1.35	4.1	0.210	0.330	1.19	4.0	-9.8%	-6.3%	*-11.7%*	-0.5%
13	12	0.503	0.709	1.88	6.2	0.499	0.608	1.88	6.2	-0.7%	*-14.3%*	0.1%	-0.4%
14	18	0.400	0.687	1.86	4.2	0.428	0.623	1.96	4.3	6.9%	-9.4%	5.7%	3.3%
15	24	1.285	1.719	2.49	7.2	1.250	1.857	2.36	7.3	-2.7%	8.0%	-5.1%	1.4%
16	33	0.666	1.138	1.19	6.5	0.689	1.294	1.11	7.0	3.4%	13.7%	-6.5%	7.3%
17	23.5	0.471	0.728	2.09	4.0	0.447	0.723	1.96	4.0	-5.1%	-0.7%	-6.1%	-0.7%
18	10	0.155	0.395	1.48	3.3	0.147	0.253	1.52	3.1	-5.2%	*-36.0%*	2.7%	-4.9%

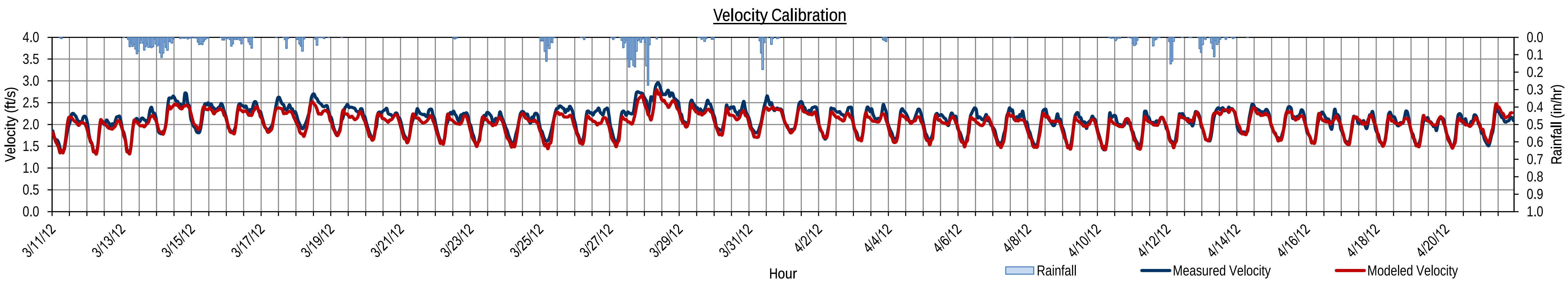
Notes:
1. Source: City of Chico 2012 Temporary Flow Monitoring Program, V&A Consulting Engineers
2. Average flows are calculated from flow monitoring data. Maximum flow values are hourly peaks.
3. Percent Difference = (Modeled - Measured)/Measured*100.

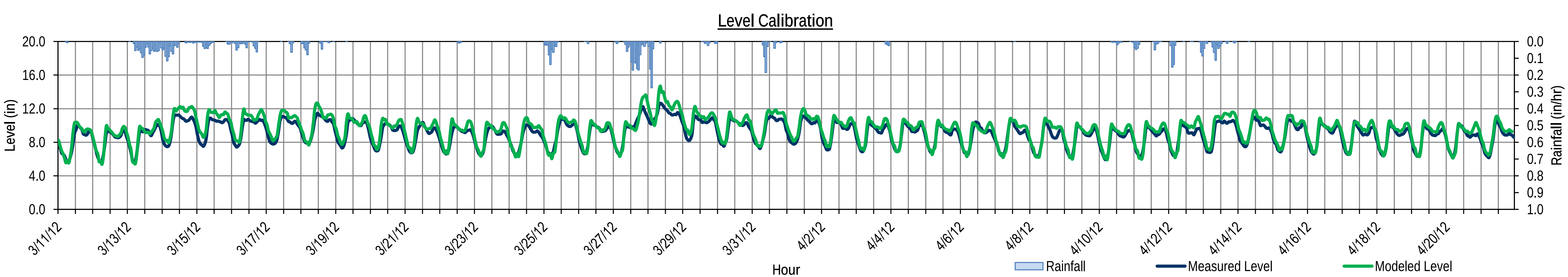
City of Chico

Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 1 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)



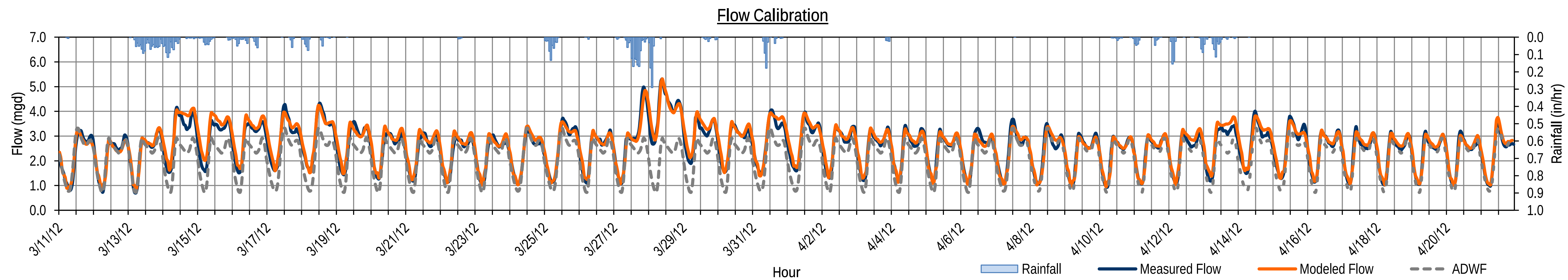


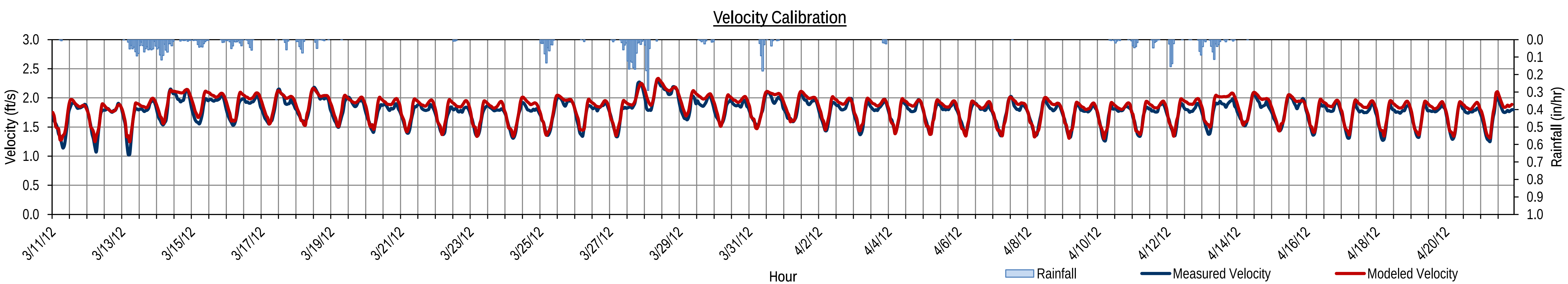


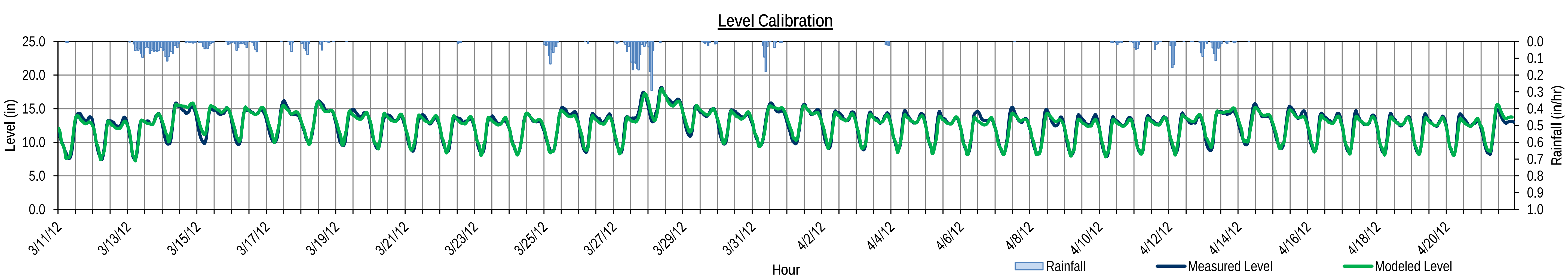
City of Chico

Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 4 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)





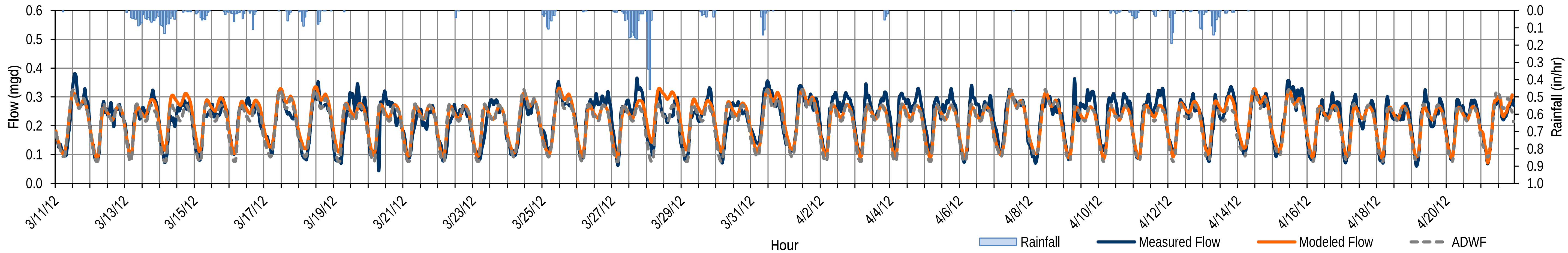


City of Chico

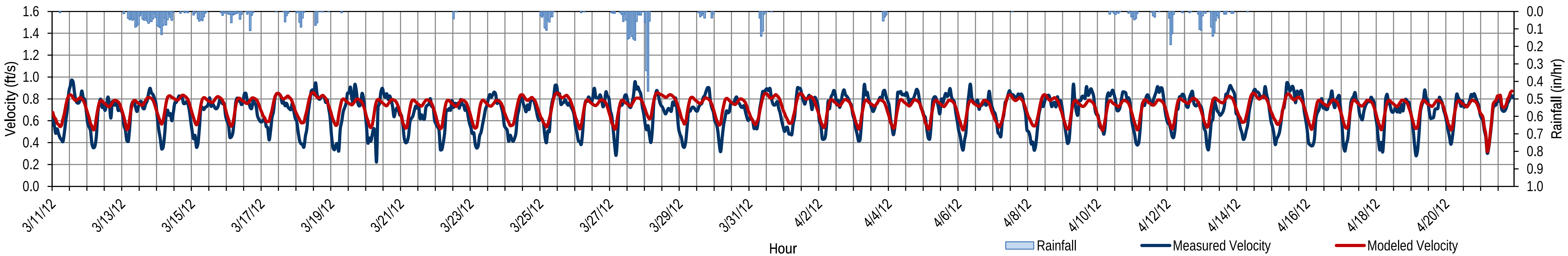
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 5 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

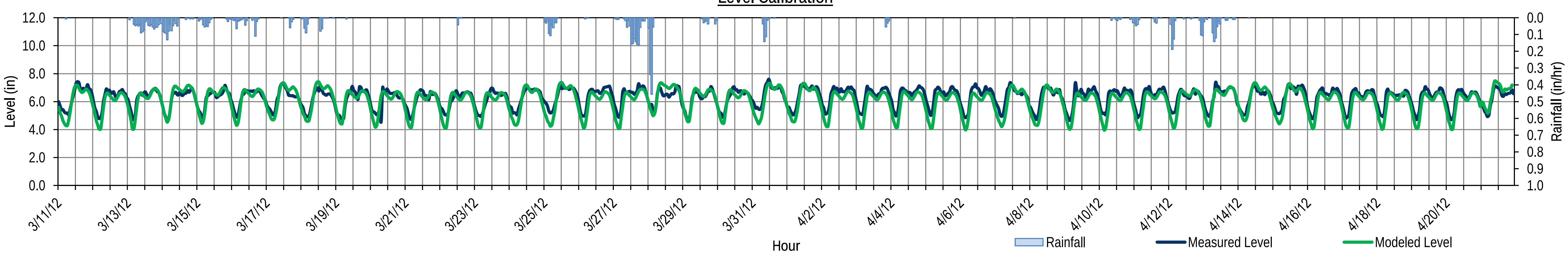
Flow Calibration



Velocity Calibration



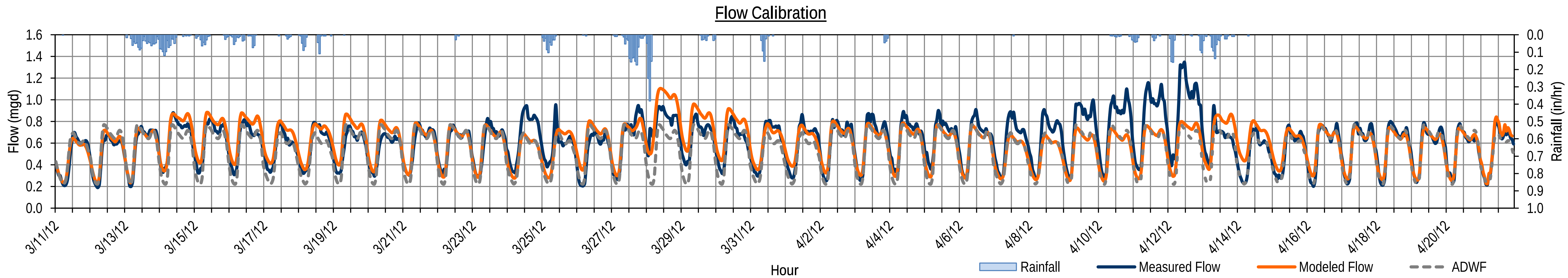
Level Calibration

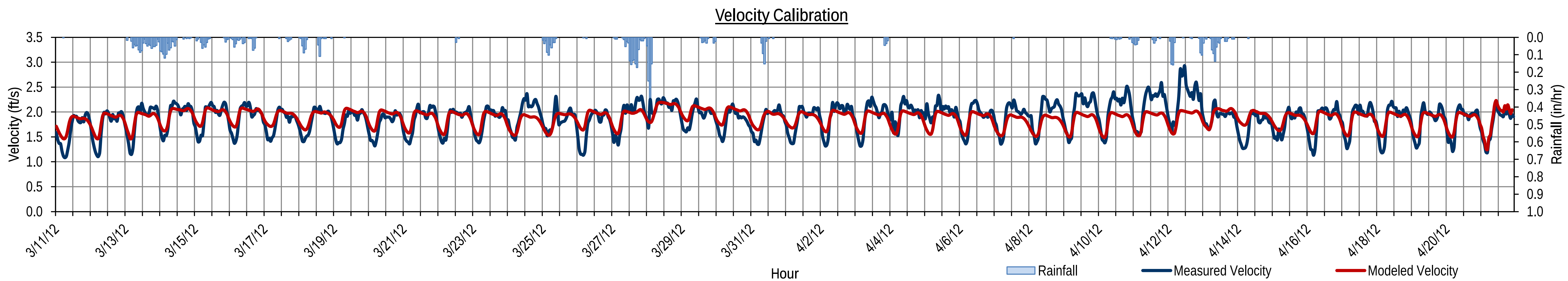


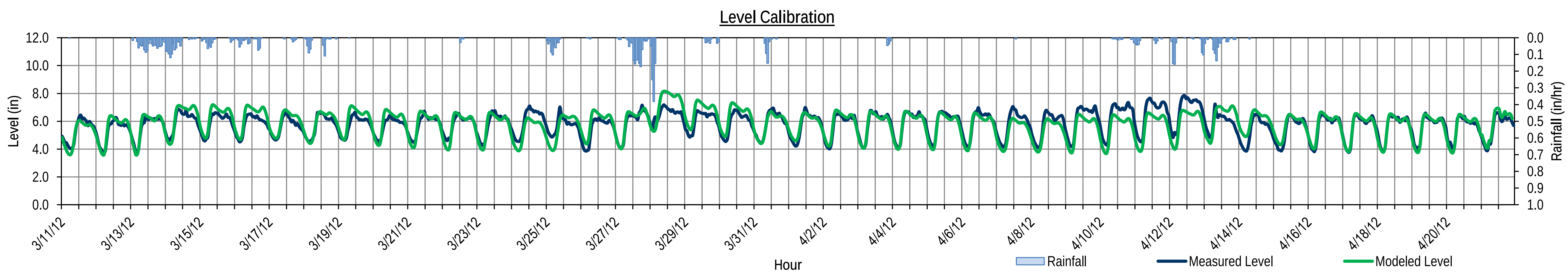
City of Chico

Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 6A WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)





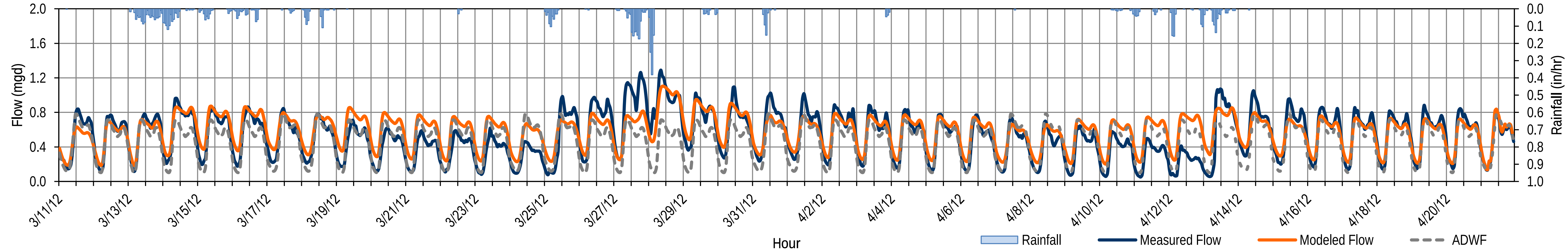


City of Chico

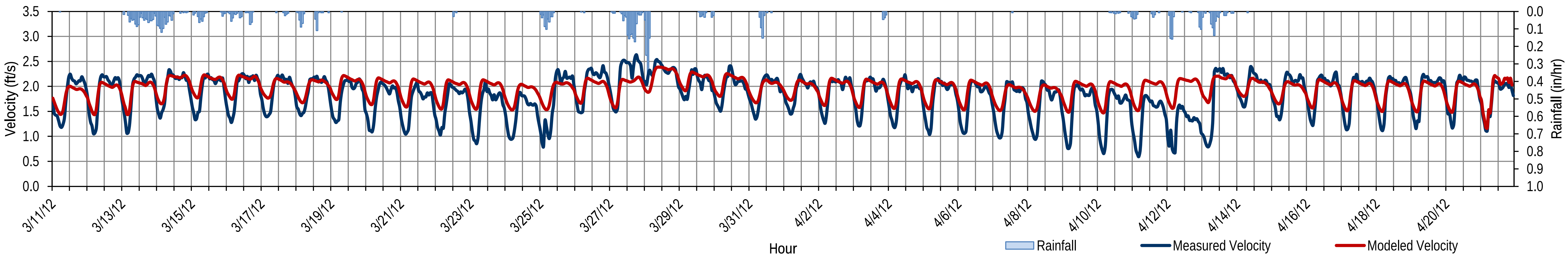
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 6B WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

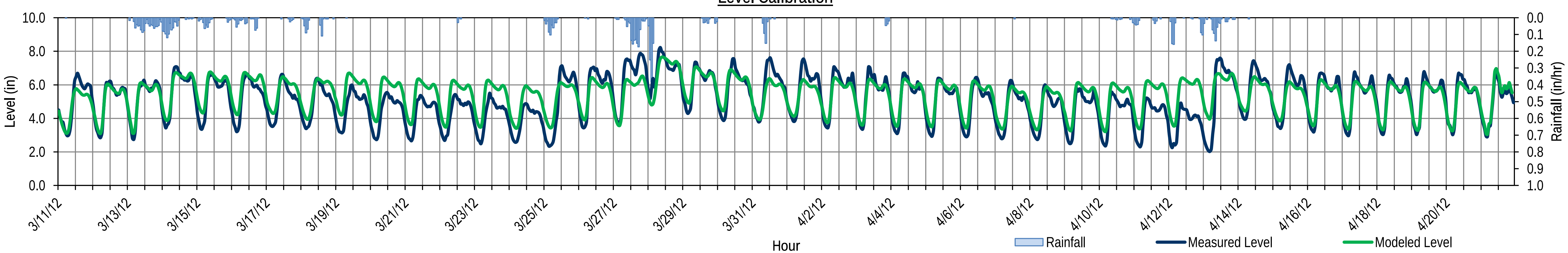
Flow Calibration



Velocity Calibration



Level Calibration

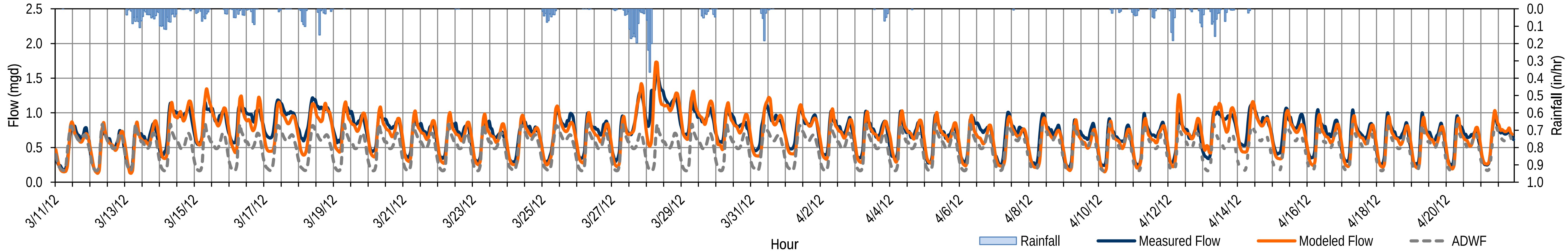


City of Chico

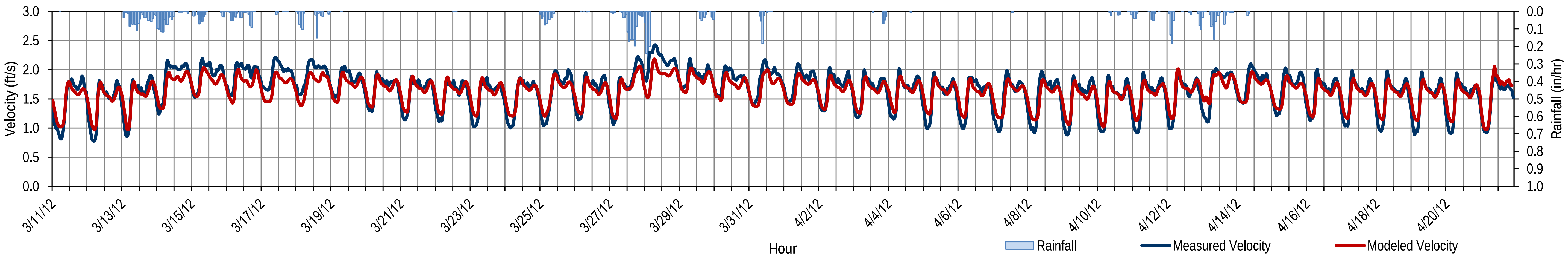
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 7 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

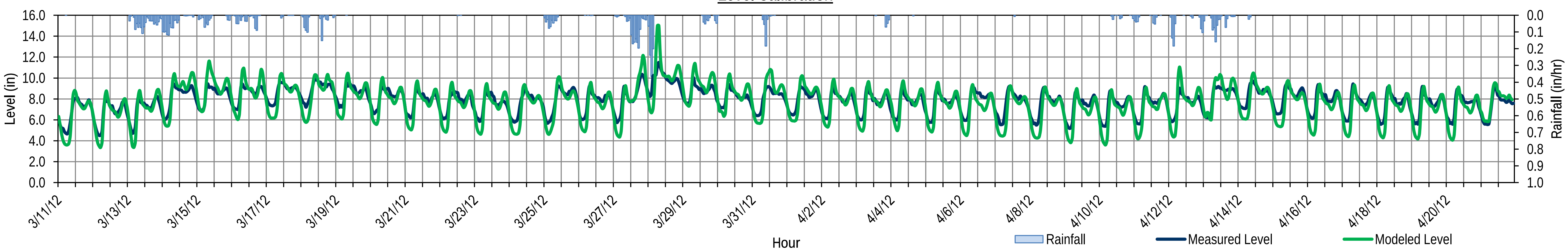
Flow Calibration



Velocity Calibration



Level Calibration

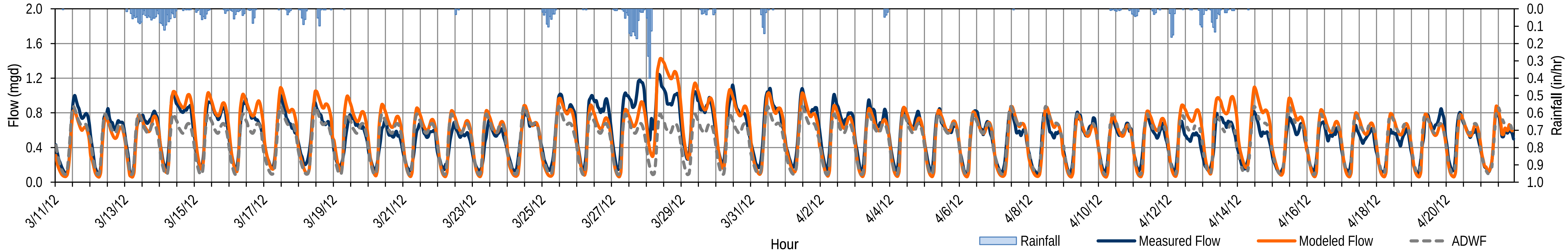


City of Chico

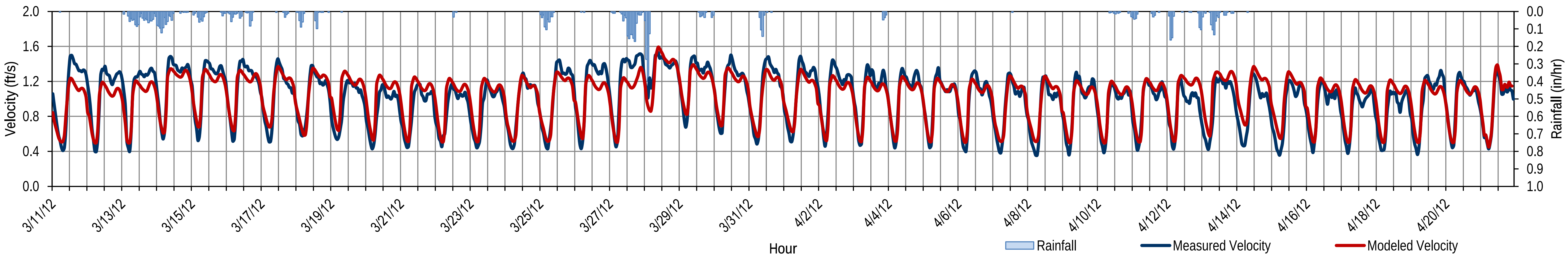
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 8 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

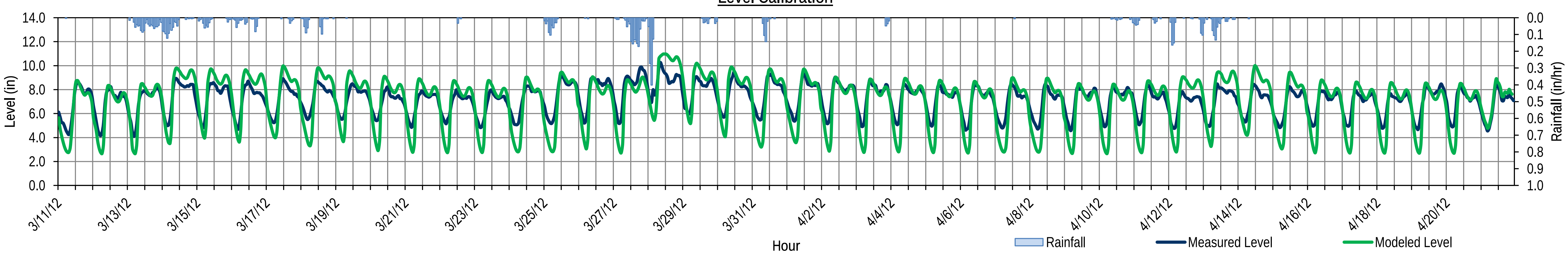
Flow Calibration



Velocity Calibration



Level Calibration

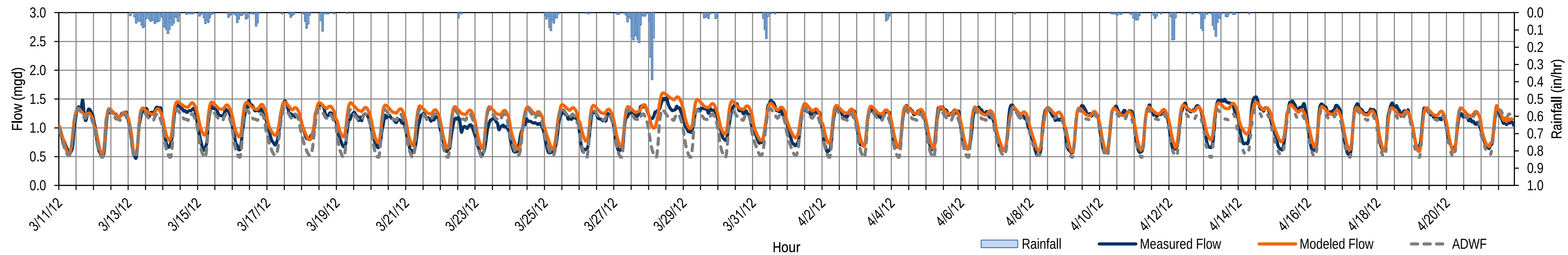


City of Chico

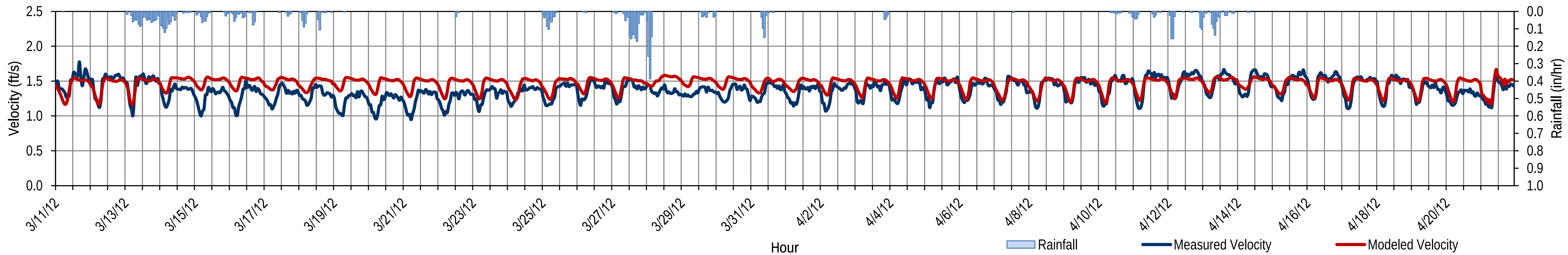
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 9 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

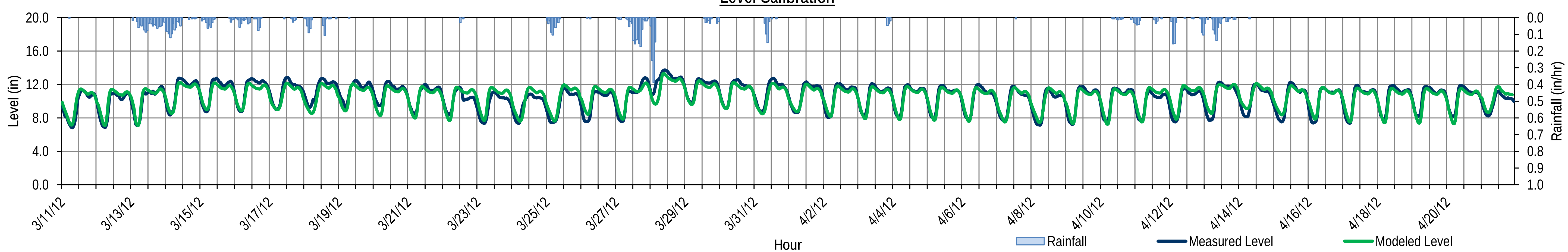
Flow Calibration



Velocity Calibration



Level Calibration



City of Chico

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FLOW MONITORING SITE 10 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

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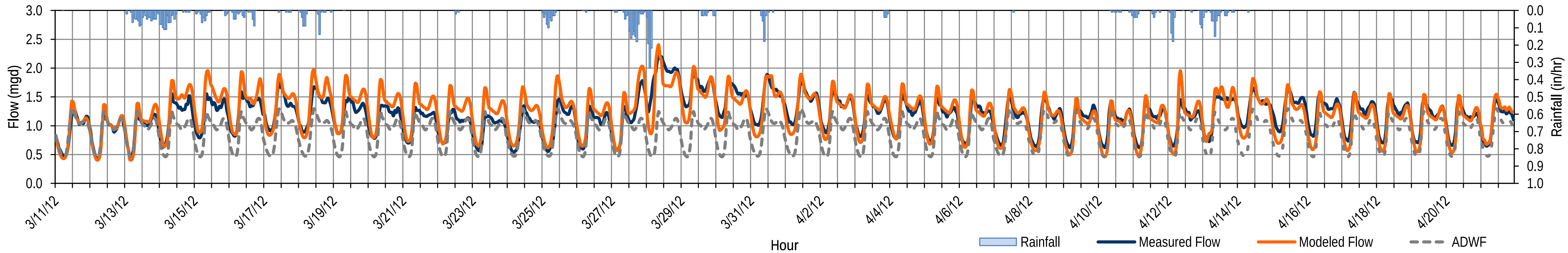
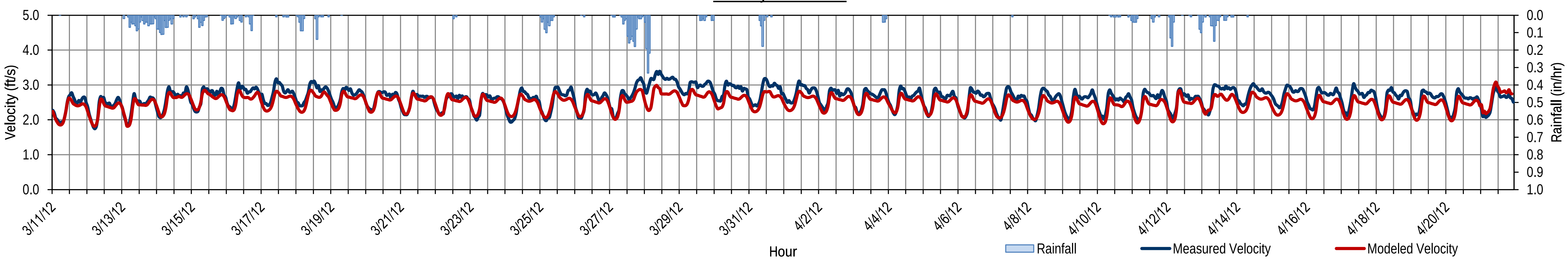
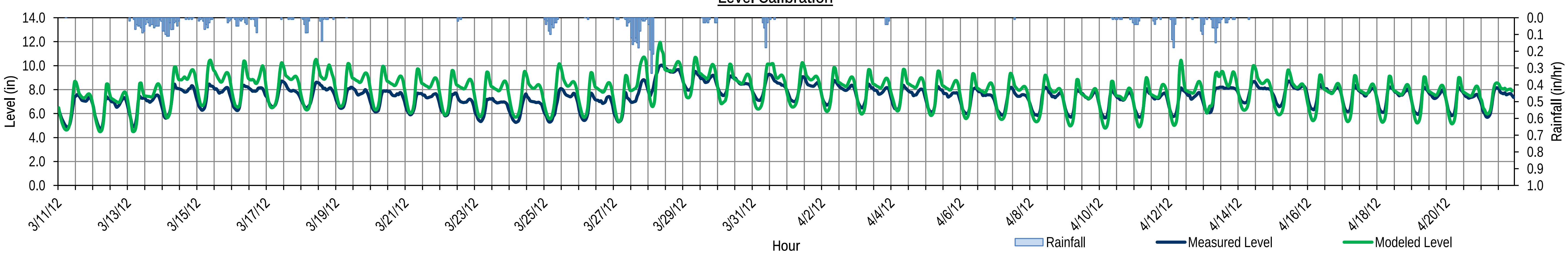
Flow Calibration



Velocity Calibration



Level Calibration



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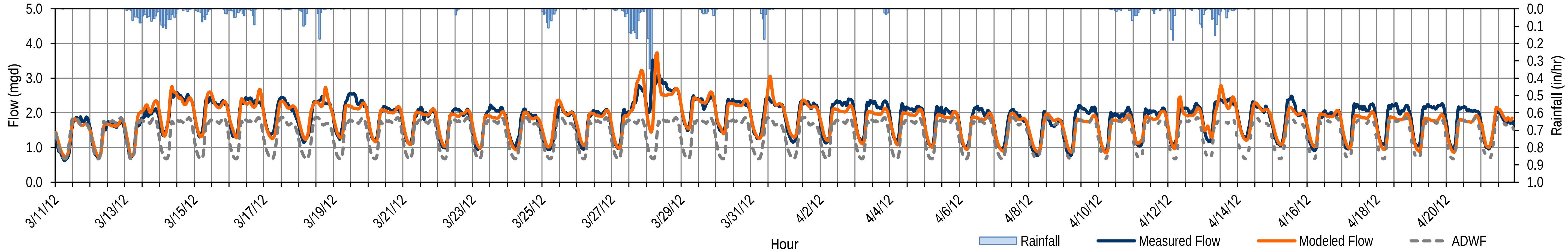
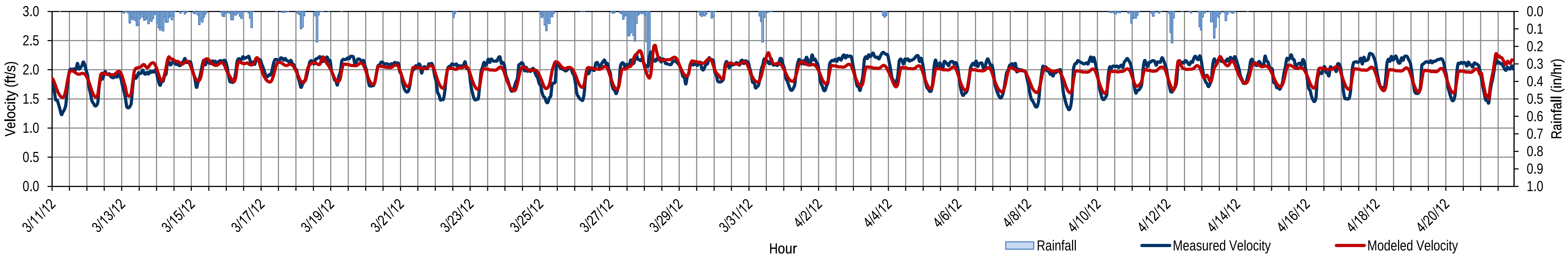
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 11 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

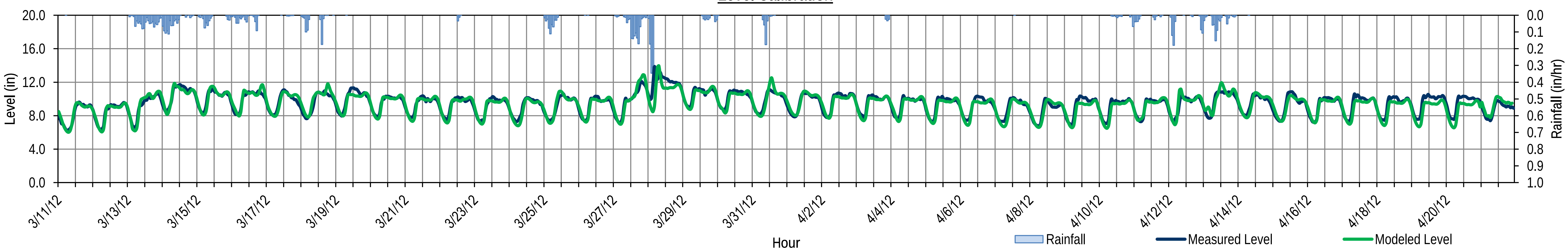
Flow Calibration



Velocity Calibration

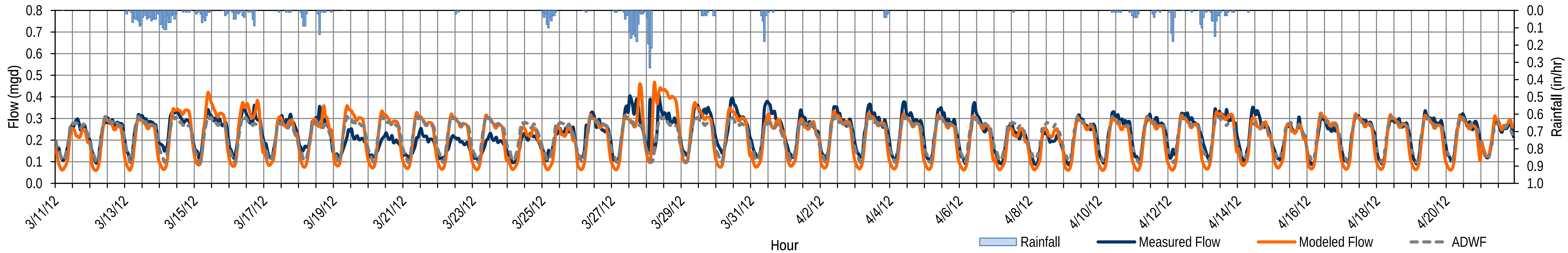


Level Calibration

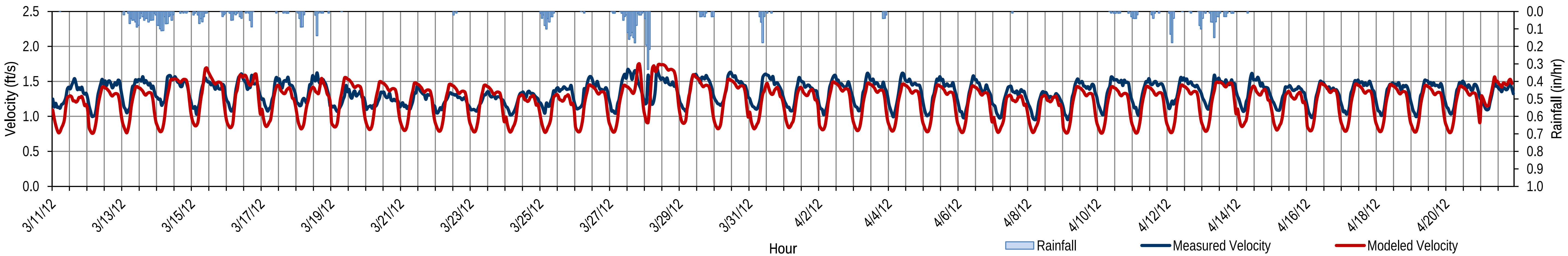


City of Chico
Sanitary Sewer Master Plan Update
FLOW MONITORING SITE 12 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

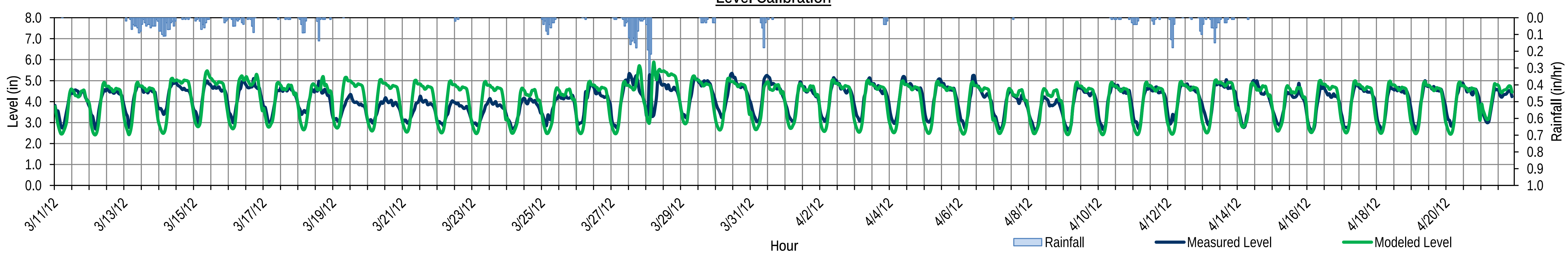
Flow Calibration



Velocity Calibration



Level Calibration

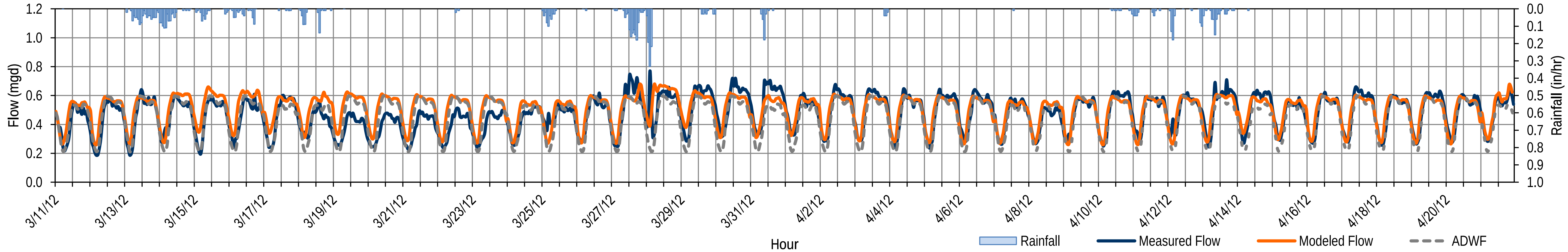


City of Chico

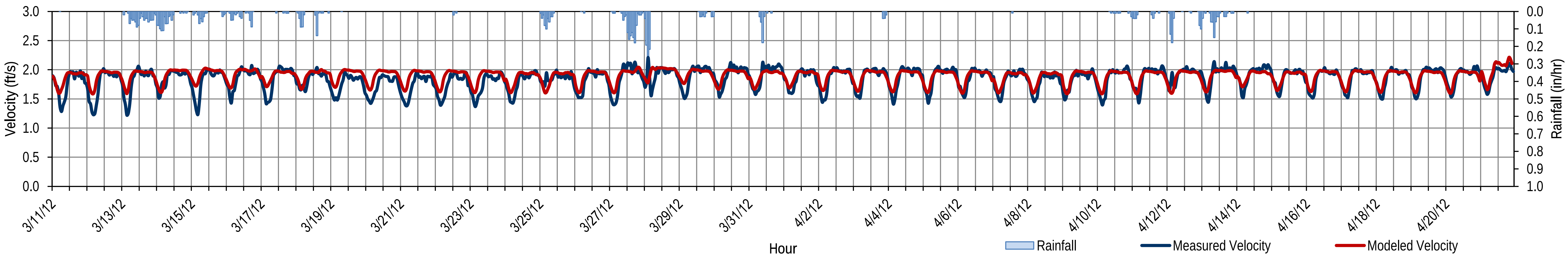
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 13 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

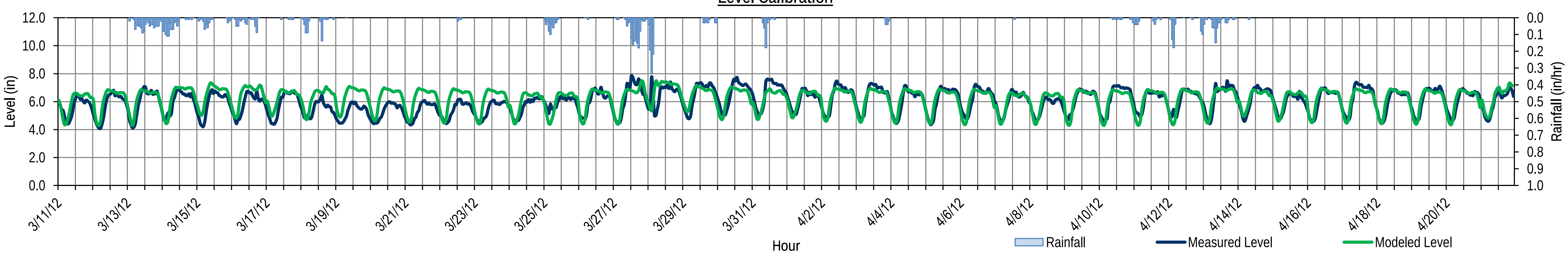
Flow Calibration



Velocity Calibration



Level Calibration

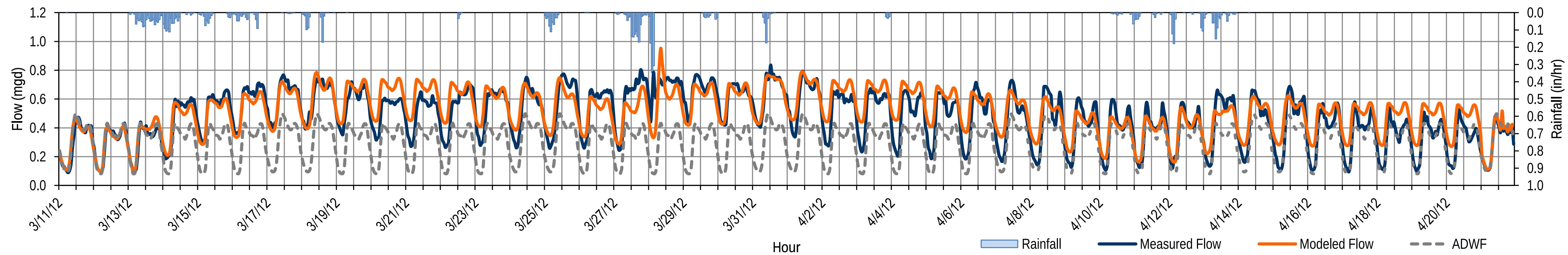


City of Chico

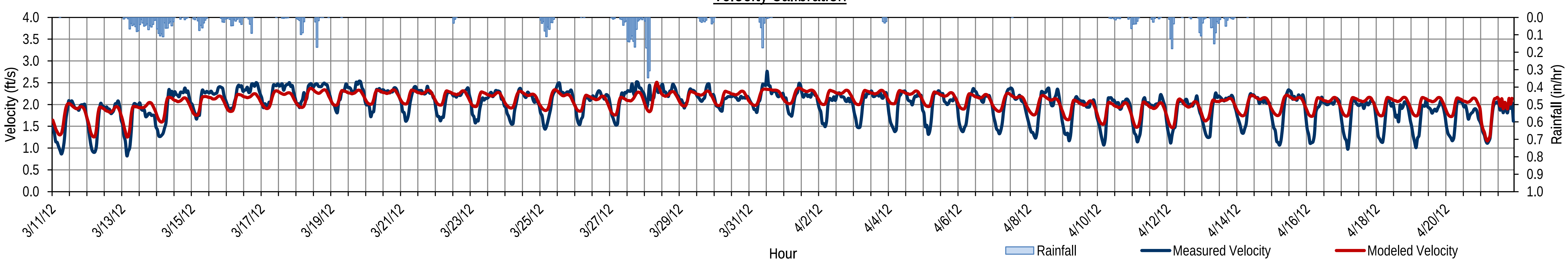
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 14 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

Flow Calibration



Velocity Calibration



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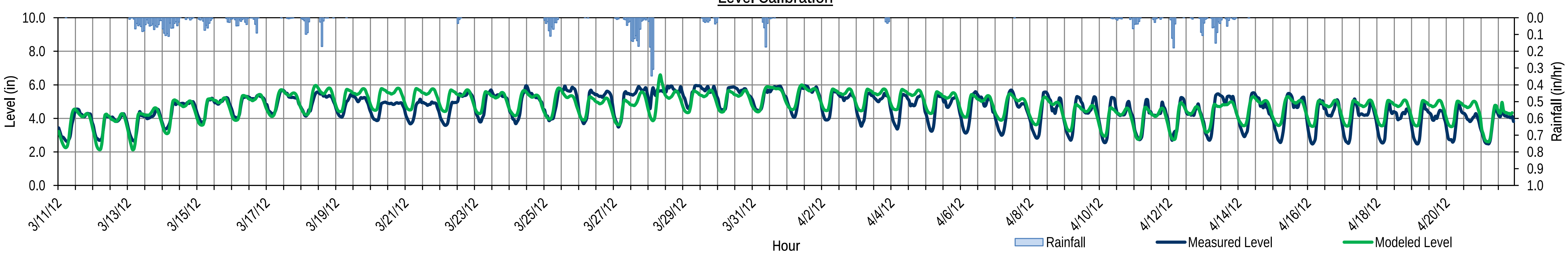
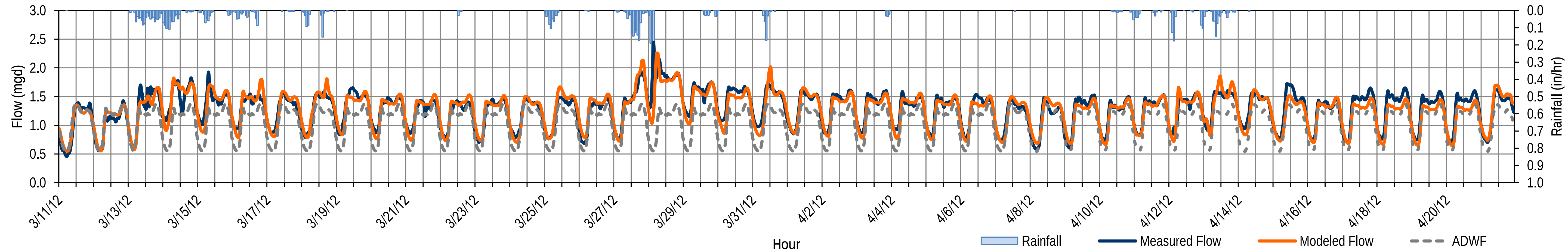


City of Chico

Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 15 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

Flow Calibration



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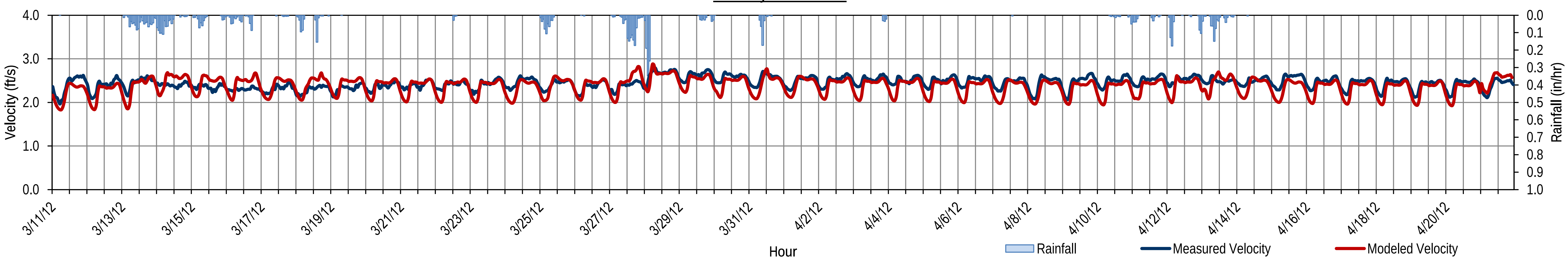
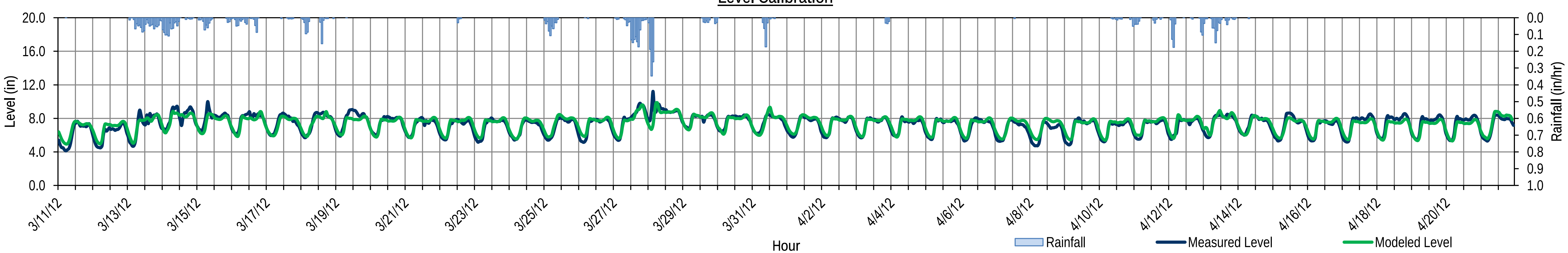
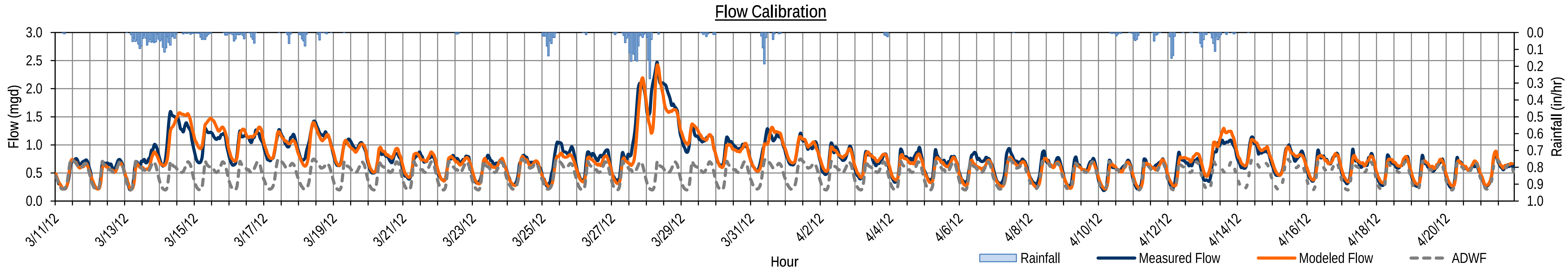
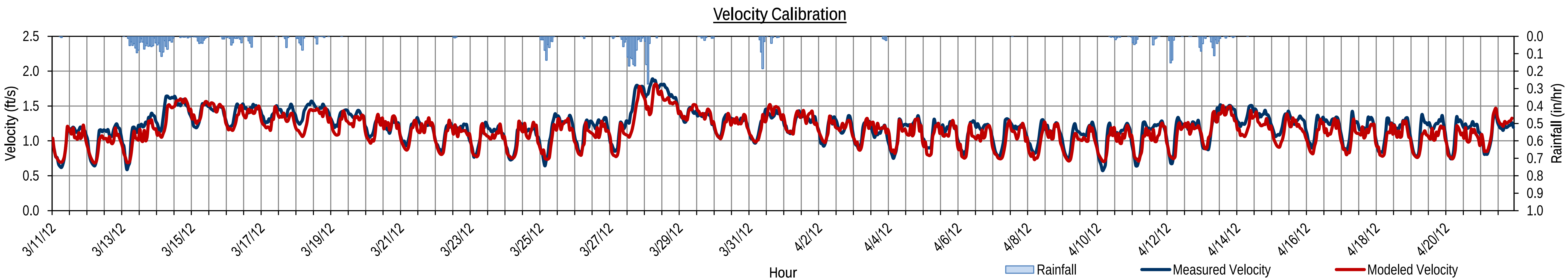


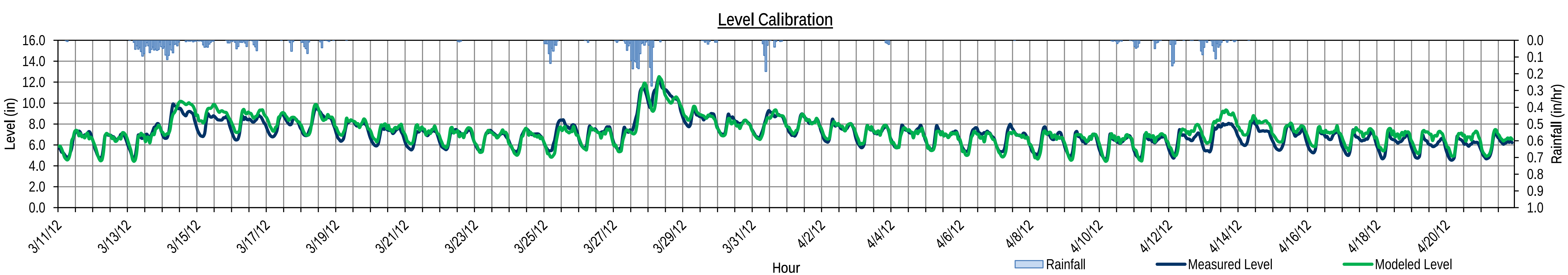
Level Calibration



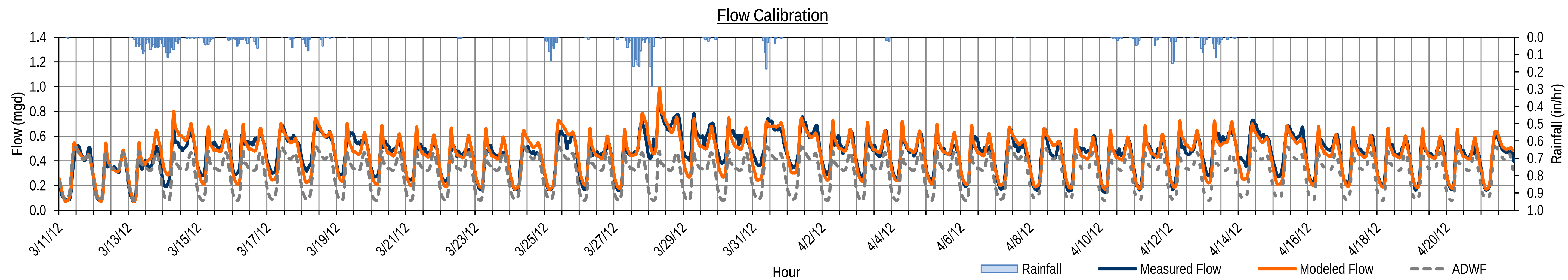
City of Chico
Sanitary Sewer Master Plan Update
FLOW MONITORING SITE 16 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

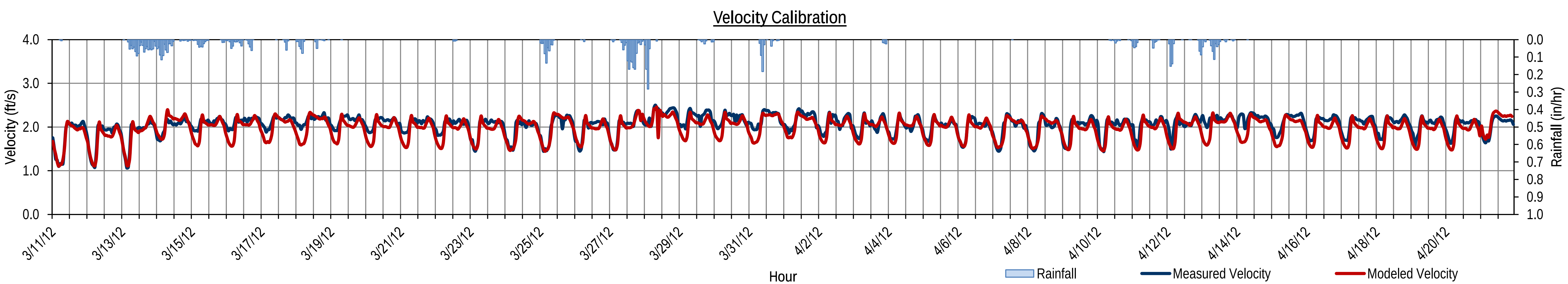


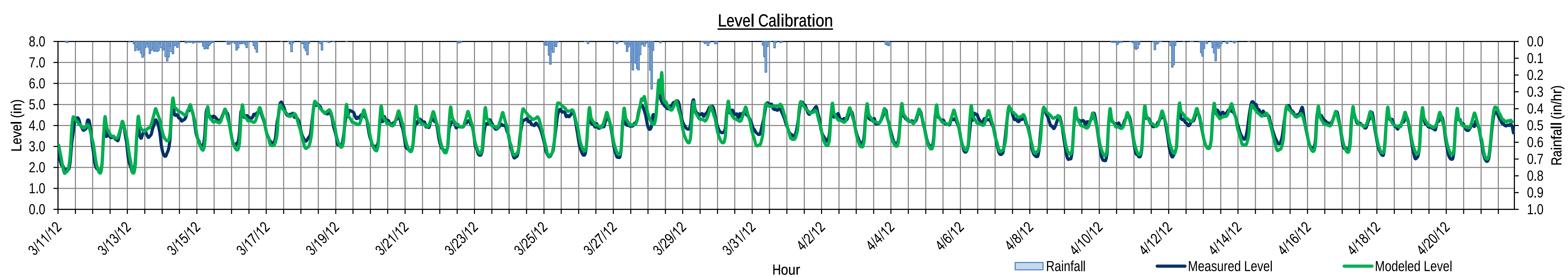




City of Chico
Sanitary Sewer Master Plan Update
FLOW MONITORING SITE 17 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)





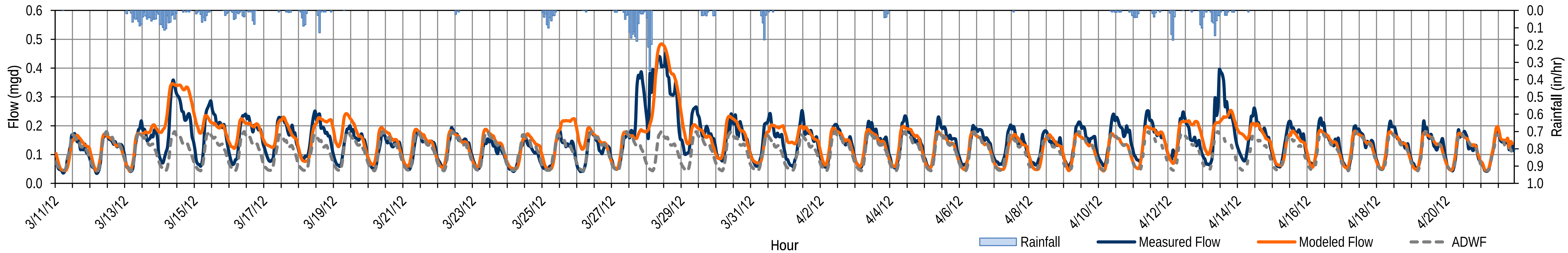


City of Chico

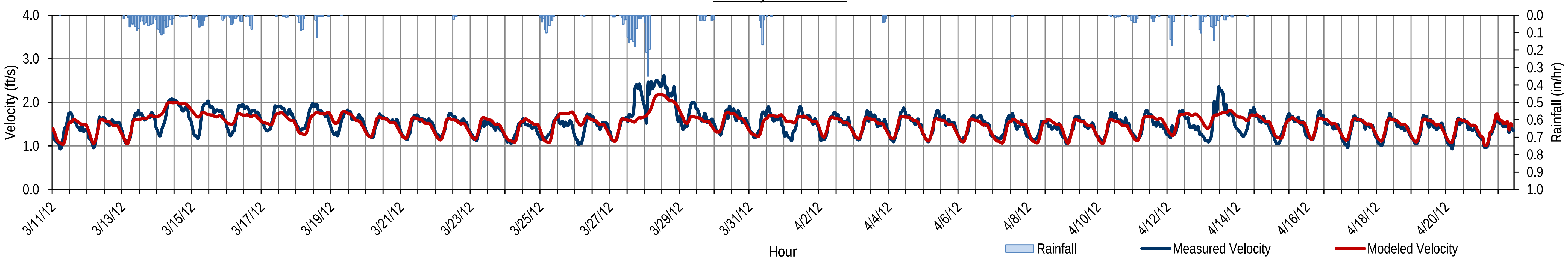
Sanitary Sewer Master Plan Update

FLOW MONITORING SITE 18 WET WEATHER FLOW CALIBRATION (3/11/2012-4/21/2012)

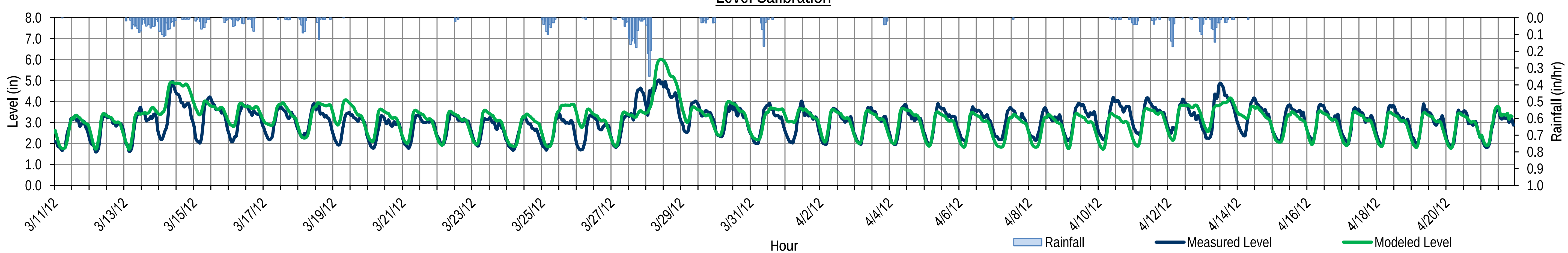
Flow Calibration



Velocity Calibration



Level Calibration



APPENDIX F – CHICO RIVER ROAD TRUNK SEWER REPLACEMENT PROJECT MEMORANDUM

PROJECT MEMORANDUM

Project:	River Road Trunk Sewer Hydraulic Analysis	**Date:**	March 2, 2010
Purpose:	Analysis Documentation		
By:	Jason Nikaido		
Distribution:	Scott Parker, Tamara Miller, City	**File:**	8387A.00

Summary and Recommendations

The River Road Trunk Sewer has been reported to be in poor condition and the City of Chico has determined that it should be replaced with a new trunk sewer located in the center of Chico River Road. Carollo Engineers was retained to hydraulically evaluate the appropriate replacement diameter and to assess the feasibility of alternative connection options at the upstream and downstream extents of the replacement segment. Our findings indicate that the 24-inch diameter is a suitable replacement when factoring in the future growth scenarios being considered by the General Plan Update. No currently foreseeable benefit would result from upsizing the trunk sewer beyond 24 inches.

The hydraulic analysis of the connection alternatives indicate that the most cost effective approach for downstream connection should occur by splitting the proposed 24-inch trunk sewer into two parallel 18-inch pipelines for reconnection into the existing junction box located within the City's Water Pollution Control Plant (WPCP) fenceline. At the upstream terminus in the vicinity of Miller Avenue, the existing 12, 14, and 18-inch sewers should be recombined into a single 24-inch trunk sewer. The single 24-inch trunk should then extend to a connection point on the existing 18-inch line immediately downstream of Manhole 46002, the connection with the existing 33-inch SECSAD Trunk Sewer. These connection alternatives appear to provide the most constructible and hydraulically efficient approach.

Background

The River Road Trunk Sewer consists primarily of a 24-inch gravity pipeline, which was originally constructed in 1929 per the City's GIS data. At its upper end, the River Road Trunk Sewer is fed from a 12-inch trunk pipeline in the westbound lane, a 14-inch trunk pipeline in the eastbound lane, and an 18-inch trunk pipeline in the eastbound shoulder of Chico River Road between Morehead Avenue and Rose Avenue. At its lower end, the River Road Trunk Sewer splits from its 24-inch diameter pipeline into two 18-inch diameter parallel pipes, ostensibly to mitigate the minimal cover available as the trunk sewer approaches the City's WPCP.

In addition, the 33-inch Southeast Chico Sewer Assessment District (SECSAD) trunk line is located in the westbound shoulder, paralleling the River Road Trunk throughout the study area. Along Chico River Road between Reavis Avenue and Taffee Avenue, the Northeast Chico Sewer Assessment District (NECSAD) 33-inch trunk sewer joins the road right-of-way from the north and parallels the River Road Trunk and SECSAD Trunk sewers at the northerly extent of the public right-of-way. The River Road Trunk Sewer is hydraulically interconnected with the SECSAD line at the intersection of Chico River Road and Miller Avenue. Per the City's GIS, the lines remain separate from this intersection to the junction manhole located just within the Chico WPCP fence line.

The River Road Trunk Sewer has been reported to be in poor condition, most recently evaluated in 1992 by Black and Veatch Consultants. Several options for improvement were presented, from rehabilitation through direct replacement.

In May 2003, Carollo completed a Sanitary Sewer Master Plan Update (2003 SSMP) for the City, which focused exclusively on capacity related issues. At that time, no capacity improvements were recommended for the River Road Trunk Sewer.

The City has expressed interest in consolidating the 12, 14, and 18-inch pipelines into a single pipeline up to the intersection of Miller Avenue and Chico River Road, coupled with a realignment of the River Road Trunk Sewer along the Chico River Road centerline to improve maintenance access.

The purpose of this study is to determine whether changes in land use associated with the forthcoming General Plan Update, or the more recent flow monitoring subsequent to the completion of the 2003 SSMP, indicates that a different design storm calibration should be utilized for determining an appropriate replacement diameter. In addition, the study was intended to also hydraulically evaluate the River Road Trunk Sewer connection alternatives for integration into the existing and future sewer collection system.

Hydraulic Model Update

As part of the 2003 SSMP effort, a hydraulic model was created utilizing Pizer's Hydra software. The model was calibrated and the existing and proposed future sanitary sewer collection system was analyzed with a 10-Year, 24-Hour Design Storm for build-out conditions. For this study, it was anticipated to update the Hydra model by:

1) Using flow metering data from City-installed meters to update the calibration on the model, and

2) Using build-out equivalent dwelling unit (EDU) projections from the City's 2030 General Plan Update by Pacific Municipal Consultants.

The City's current collection system flow monitoring program consists of nine meters that measure flow in sewer basins 1, 6A, 6B, 7, 10, 11, 12, 13, and 14, as identified in the 2003 SSMP. Basins 2A, 2B, 3, 4, and 5 are not metered and instead rely on either downstream basins, in the case of sewer basins 4 and 5, or the WPCP meter, in the case of sewer basins 2A, 2B, and 3. The metered areas measured an average dry weather flow (ADWF) of 3.51 mgd for the period of March 20 – April 3, 2009. Comparatively, the hydraulic model estimated an ADWF of 5.75 mgd for the metered areas. WPCP influent flow data for March 20 – 31, 2009 measured an ADWF of 7.2 mgd, well within the model's level of accuracy, which calculated an ADWF of 7.45 mgd based on current land use. A summary of ADWF results is presented in Table 1. The large flow discrepancy in the City's current flow metering program could not be explained by the City's flow metering program provider, Utility Systems Science and Software in email correspondence with City staff. Therefore, the 2003 SSMP calibration was not updated to reflect the significantly lower measured flows.

Table 1	**Metered and Modeled Average Dry Weather Flow Summary River Road Trunk Sewer Hydraulic Analysis City of Chico**			
	Metered[1] (mgd)	**Model[2]** (mgd)	**Difference** (mgd)	**% Difference** (%)
Sum of Metered Areas	3.51	5.75	2.24	64.1%
WPCP	7.20	7.45	0.25	3.5%
Notes: 1. March 20 – April 3, 2009 2. March 20 – 31, 2009				

A wet weather analysis of the flow metering data was performed. The inflow and infiltration (I/I) components of the flow data were isolated from the dry weather flow. By doing this, the I/I response of the metered system could be quantified and compared to the 2003 SSMP values. The model was calibrated to the isolated I/I with the following assumptions:

1) An ADWF of 7.45 mgd was used (equivalent to the 2003 SSMP existing scenario).

2) The calibration event was February 16-18, 2009 with a total volume of 2.72 inches.

Once the meters were sufficiently calibrated, the 10-Year, 24-Hour Design Storm was simulated. The 2009 calibration estimated a peak wet weather flow (PWWF) of 14.5 mgd at the WPCP while the 2003 SSMP estimated 18.4 mgd, a difference of 3.9 mgd. A comparison of the two calibrations is summarized in Table 2. The primary reason for the lower PWWF is the calibration storm used. In the 2003 SSMP, the calibration storm was a 2-5 year event whereas the 2009 calibration storm was a less than a 2-year event. The closer the calibration storm is to the design storm, the greater the confidence in the design PWWF. While the 2009 calibration is more recent, the 2003 SSMP calibration is still preferable due to the larger calibration storm and reliability in the flow monitoring data. If combined together, the 2009 I/I response and the lower ADWF discussed previously would result in design flows that are significantly less than the 2003 SSMP. This could result in undersized facilities and put the City at risk for sanitary sewer overflows.

Table 2	**Wet Weather Calibration Summary River Road Trunk Sewer Hydraulic Analysis City of Chico**			
	Calibration Storm Volume (Inches)	**Maximum 24-Hour Volume** (Inches)	**Max 24-Hour Return Period[1]** (Years)	**WPCP Design Storm PWWF[2]** (mgd)
2003 SSMP[3]	3.23	3.04	2 - 5	18.4
River Road Analysis[4]	2.72	1.58	< 2	14.5

Notes:
1. Estimated using NOAA Atlas 2 precipitation-frequency plots. 2-Year, 24-Hour Storm volume = ~2.5 inches, 5-Year, 24-Hour Storm volume = ~3.3 inches.
2. PWWF simulated in Existing Scenario Hydra model with 10-Year, 24-Hour Design Storm with volume of 3.75 inches (ADWF = 7.45 mgd).
3. January 1 – 3, 2002 at City Hall rain gauge.
4. February 16 – 18, 2009 at rain gauge near Meter 7.

The City is currently in the process of updating its General Plan for Year 2030. As part of this effort, Pacific Municipal Consultants estimated the number of EDUs for existing and build-out conditions. Table 3 summarizes the EDUs in the General Plan Update and the 2003 SSMP. There is a substantial difference in the number of existing EDUs in the General Plan and 2003 SSMP. Based on the 7.2 mgd measured at the WPCP for March 21 – 30, 2009, a unit flow factor of 230.53 gpd/EDU is calculated for the existing General Plan EDUs. The 2003 SSMP established a flow factor of 317.52 gpd/EDU, far greater than the calculated General Plan value. While existing EDU totals are far apart, build-out EDUs were extremely close (the 2030 General Plan anticipates more densification in the downtown area). However, because of the lower flow factor calculated using the existing General Plan EDU value, build-out flows would be approximately 5.5 mgd less than the 2003 SSMP flow. The model was not updated with the 2030 General Plan numbers since the 2003 SSMP build-out flows are more conservative.

Table 3	**EDU Summary River Road Trunk Sewer Hydraulic Analysis City of Chico**			
	2030 General Plan[1] (EDU)	**2003 SSMP** (EDU)	**Difference** (EDU)	**% Difference** (%)
Existing	31,233	21,802.5	-9,430.5	-30.2%
Build-Out	62,575	62,681.3	106.3	0.2%

Notes:
1. Sewered areas only. Does not include properties on septic system.

Facility updates to the model were also performed based on recent projects and information from City staff. A diversion manhole was incorporated into the model at 7th Street and Orange Street to reflect our understanding of current conditions. The manhole diverts flow from Basins 12 and 13 to Basin 14. This diversion was not included in the 2003 SSMP because it did not appear in the GIS data provided by the City for the completion of the 2003 SSMP.

Alternatives Analysis

The River Road Trunk Sewer Study Area begins at Miller Avenue and 5th Street and continues all the way to the WPCP. As part of the analysis, the City staff requested evaluation of connection alternatives at the upstream end of the proposed River Road Trunk Sewer, and additionally requested guidance regarding downstream interconnection.

The City has indicated a desire to utilize a single trunk sewer to replace the 12, 14, and 18-inch pipes in the upper reach. Two options were analyzed to split flow between the existing 33-inch and new 24-inch pipes. Figures 1 – 4 illustrate Option 1 and its possible construction phasing. Figures 5 – 8 illustrate Option 4B and its possible construction phasing. Option 1 and 4B were analyzed using the model and both are hydraulically feasible. Operations and constructability were also considered and are summarized in Table 4.

The downstream connection approach was evaluated for cost efficiency and hydraulic capabilities. A schematic sketch of the existing collection system layout is illustrated in Figure 9. As part of the WPCP 12 MGD Expansion Project, three 18-inch sewers, which served as the original extension of the River Road Trunk Sewer into the WPCP, were abandoned. A new junction box was constructed within the WPCP fence line, with two 36-inch reinforced concrete pipe bell ring inserts to facilitate the connection of the new Northwest Trunk Sewer, and to provide a means of distributing flow from the existing River Road Trunk Sewer into the new 66-inch interceptor leading to the new headworks facilities. As there were no identified plans at the time to relocate the existing River Road Trunk Sewer, no further provisions were made for a separate means of interconnection.

One option considered for downstream connection would make use of the proposed Northwest Trunk Sewer connection point at the new junction box. Given that all of the existing influent sewers entering the WPCP are at approximately the same elevation, the NECSAD, SECSAD, and proposed River Road Trunk Sewers would need to be hydraulically integrated within Chico River Road to allow the wastewater to distribute to the identified connection point. This approach would also require extending another connection for the Northwest Trunk Sewer, and given the substantial construction effort and impacts to Chico River Road, this option is not recommended.

The option to connect the proposed River Road Trunk Sewer directly into the 33-inch SECSAD line was considered, but is not recommended due to the capacity limitations this bottleneck would create.

The most appropriate option for connection of the River Road Trunk Sewer would be to utilize a similar approach as the existing system – split the 24-inch trunk into two 18-inch diameter pipes to provide an equivalent cross sectional area, to facilitate connection to the existing junction box, and to maximize the available cover over the pipes as they cross under the southerly shoulder of Chico River Road. This option is highly constructible and does not limit the hydraulic capacity of the overall conveyance system. A schematic sketch of this option is illustrated in Figure 10.

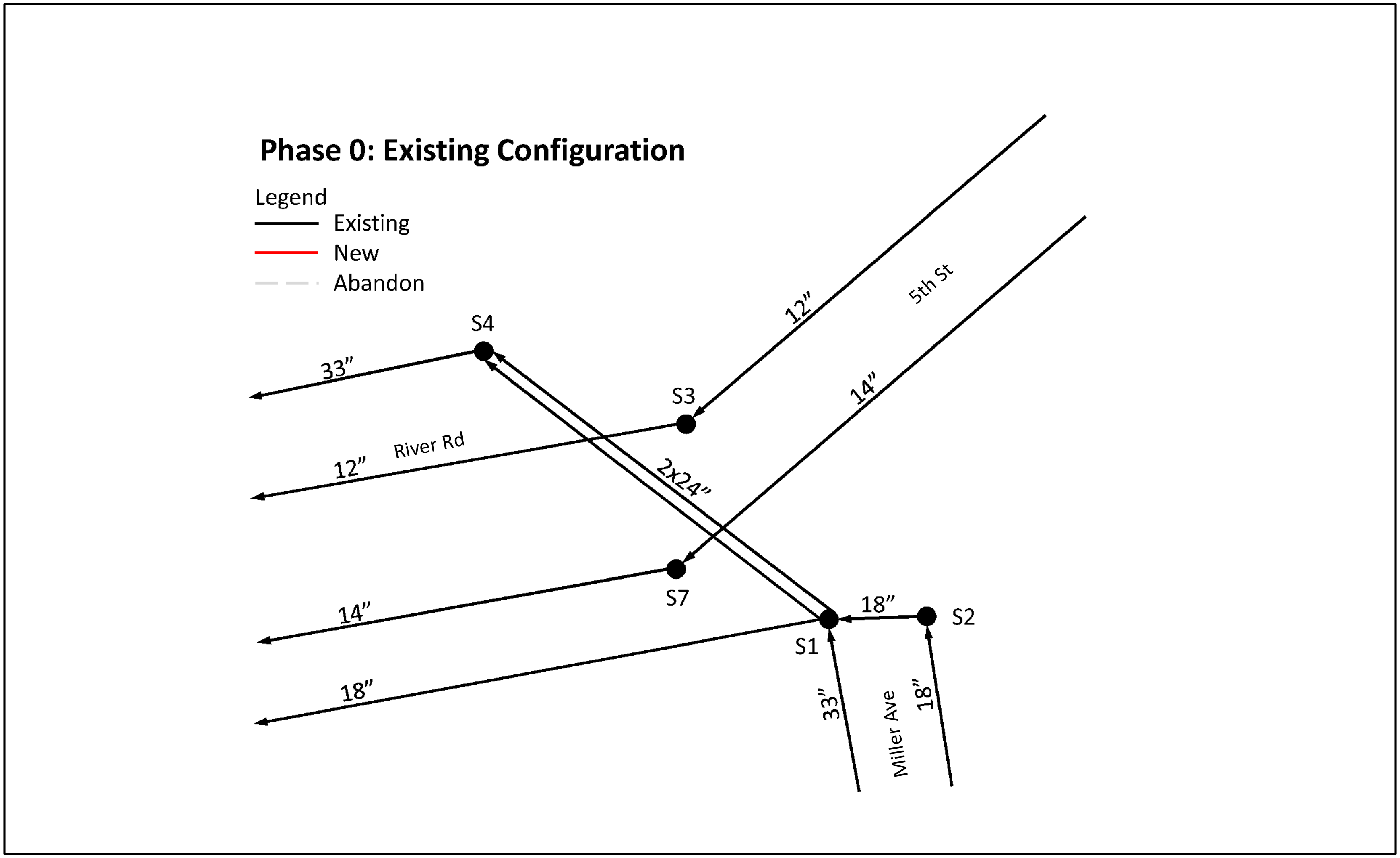


Figure 1
5TH AND MILLER OPTION 1: EXISTING LAYOUT
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
CITY OF CHICO

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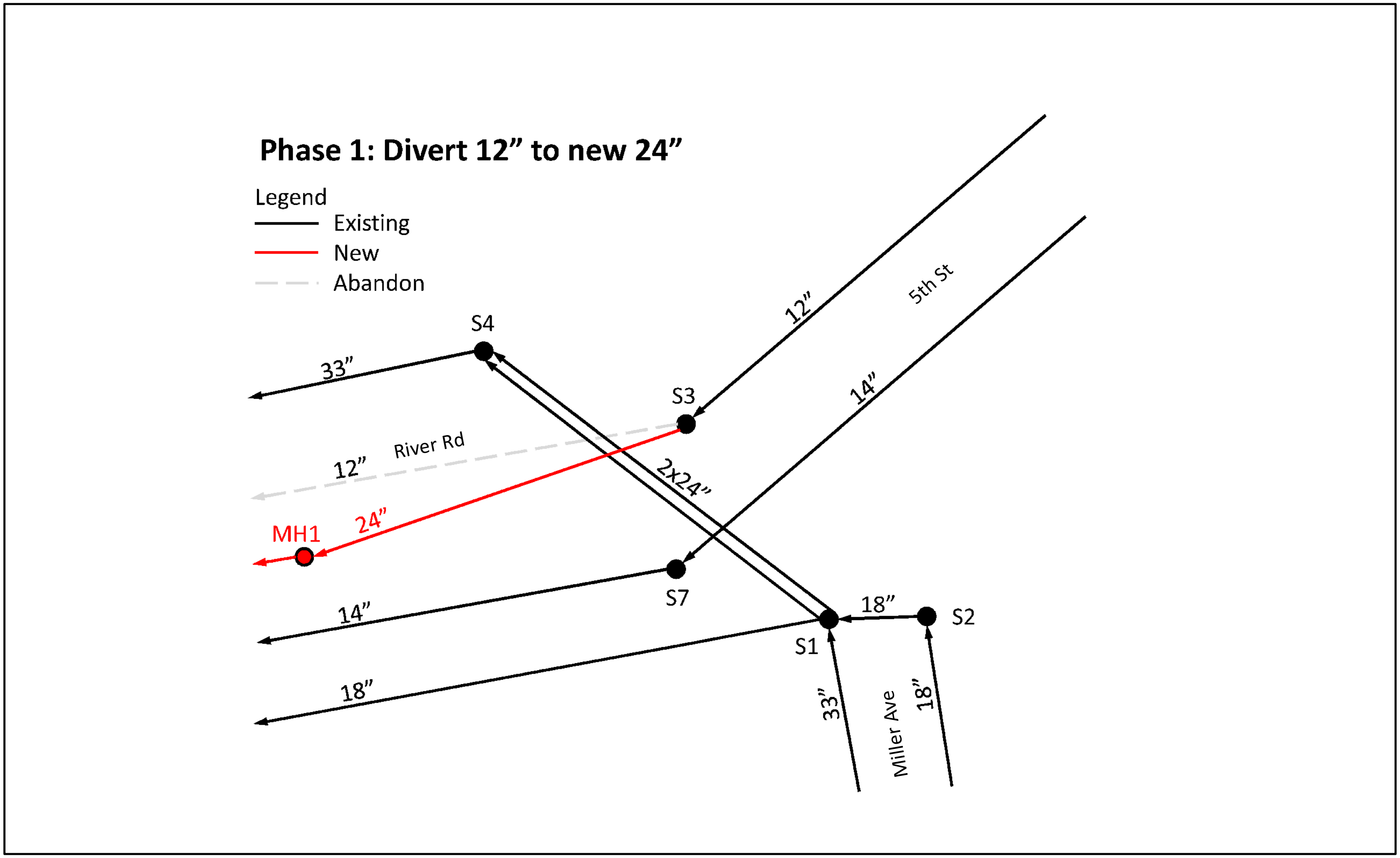

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Figure 2
5TH AND MILLER OPTION 1: PHASE 1
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
CITY OF CHICO

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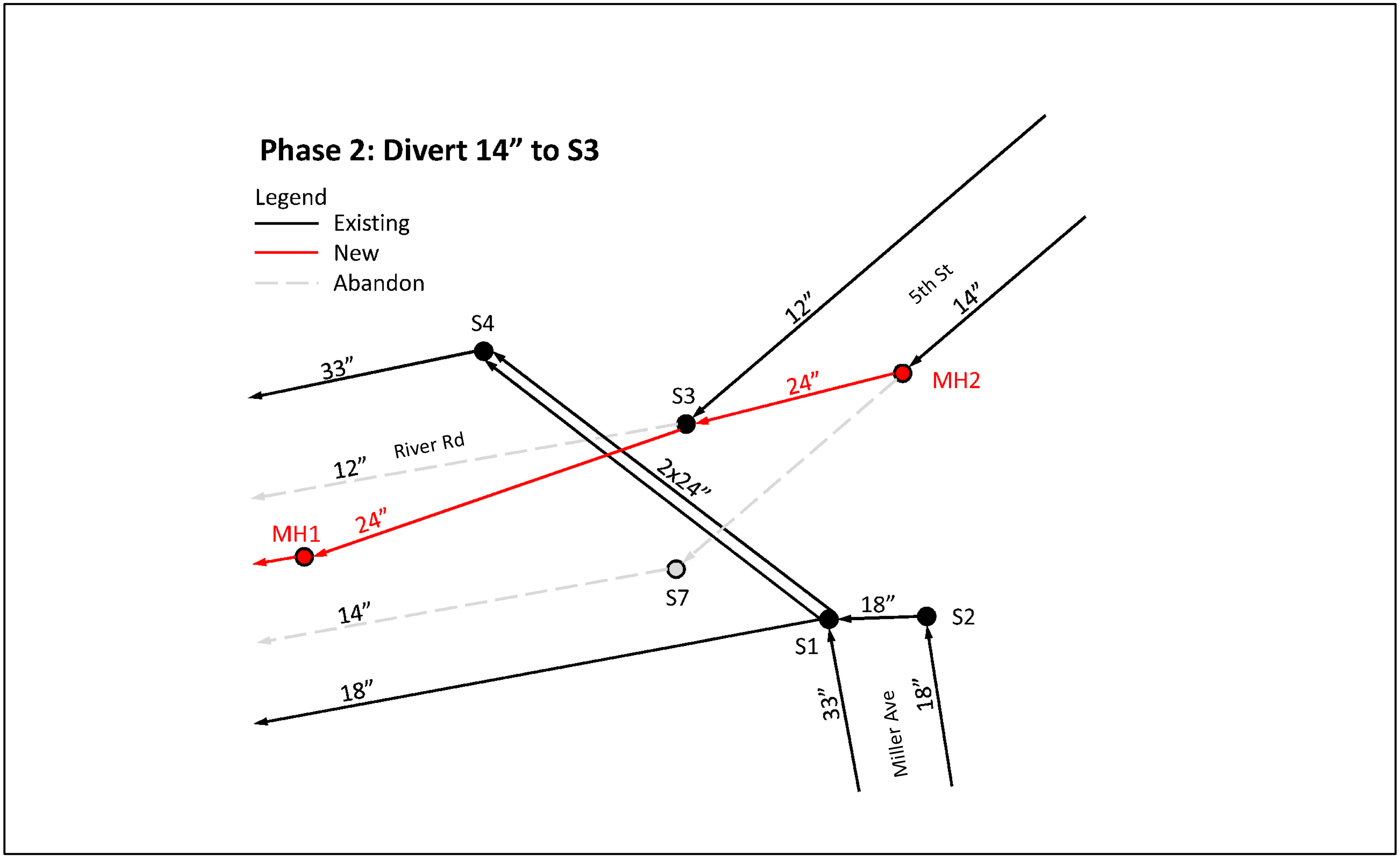

Figure 3
5TH AND MILLER OPTION 1: PHASE 2
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
CITY OF CHICO

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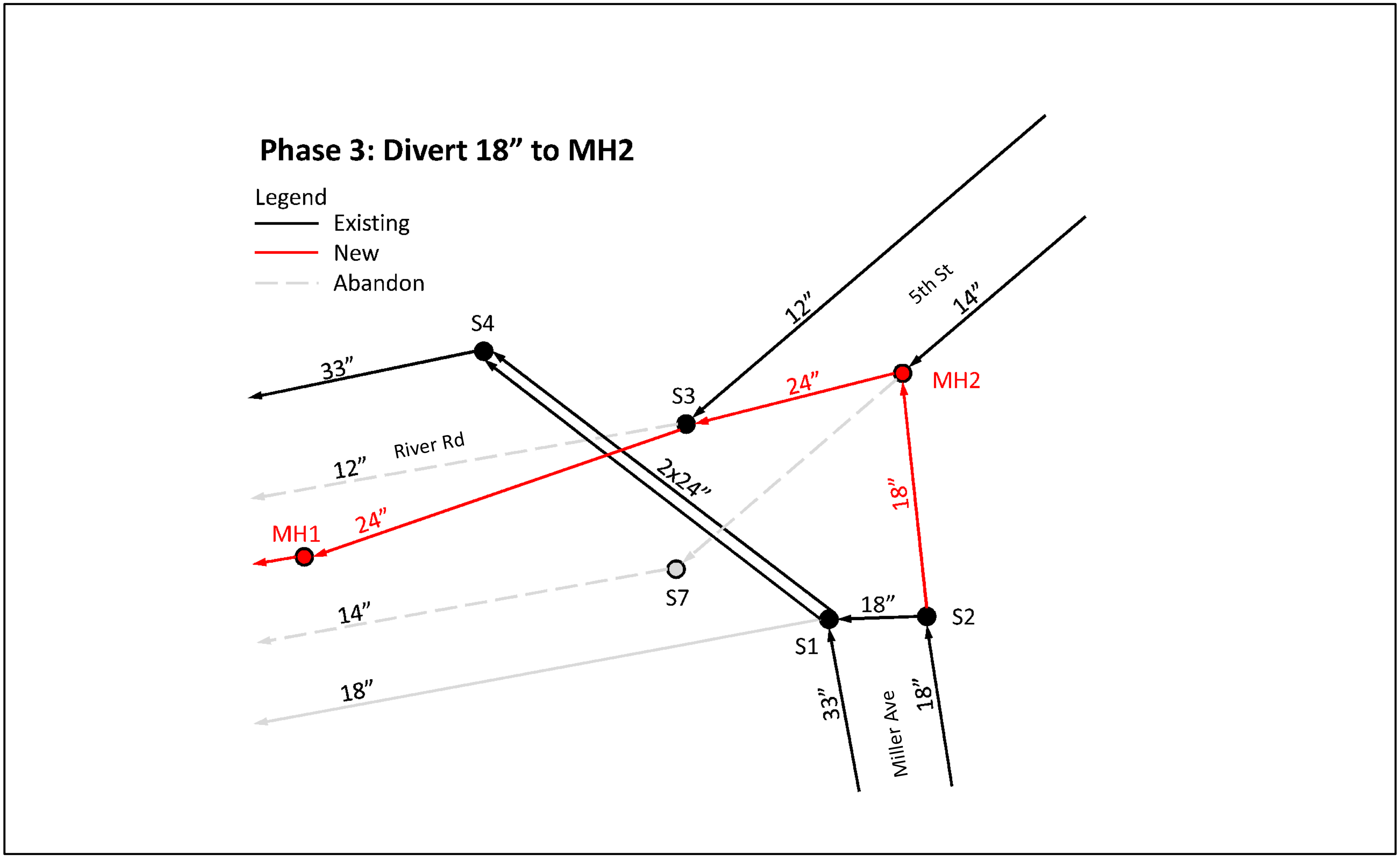

Figure 4
5TH AND MILLER OPTION 1: PHASE 3
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
CITY OF CHICO

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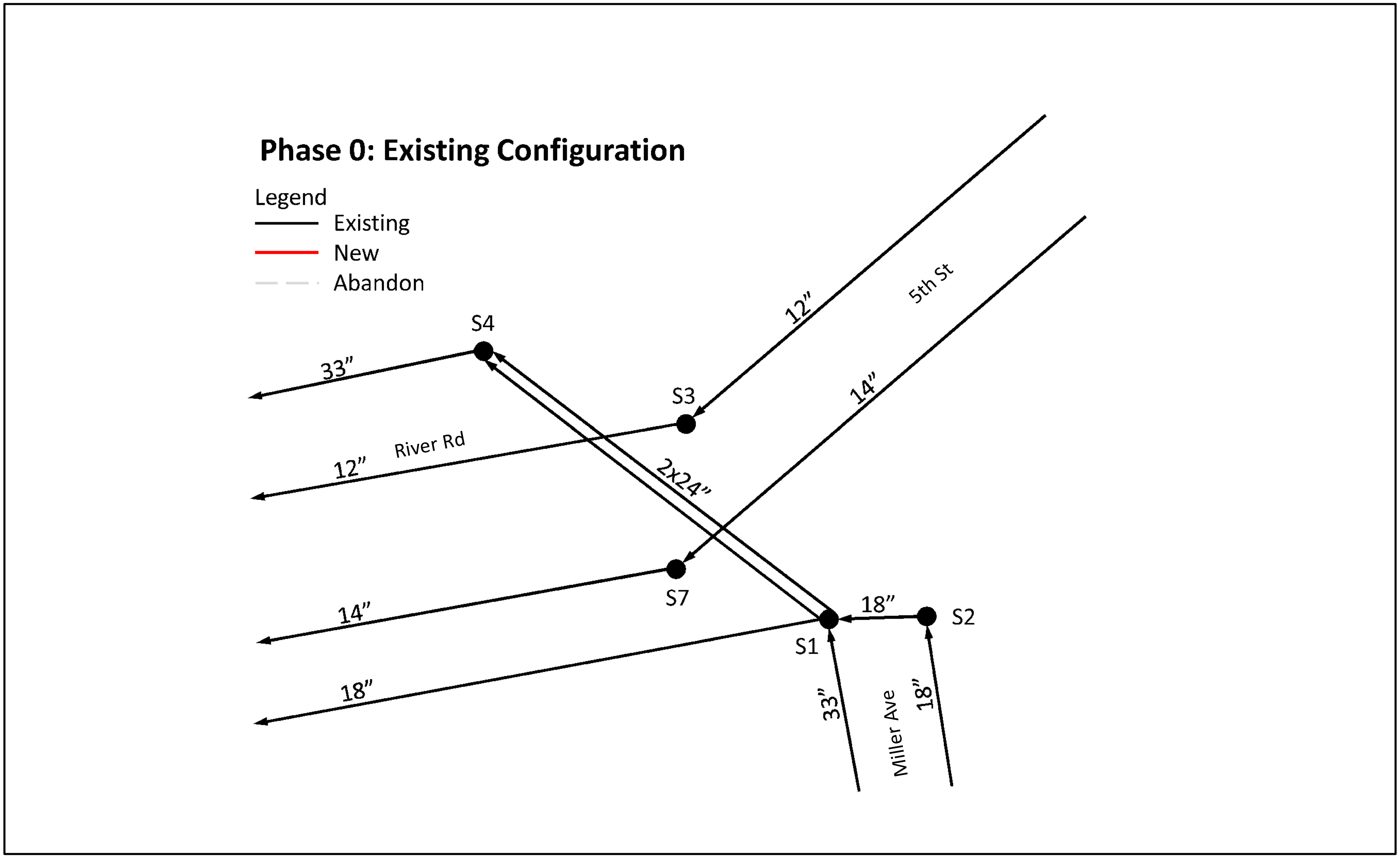

Figure 5
5TH AND MILLER OPTION 4B: EXISTING LAYOUT
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
CITY OF CHICO

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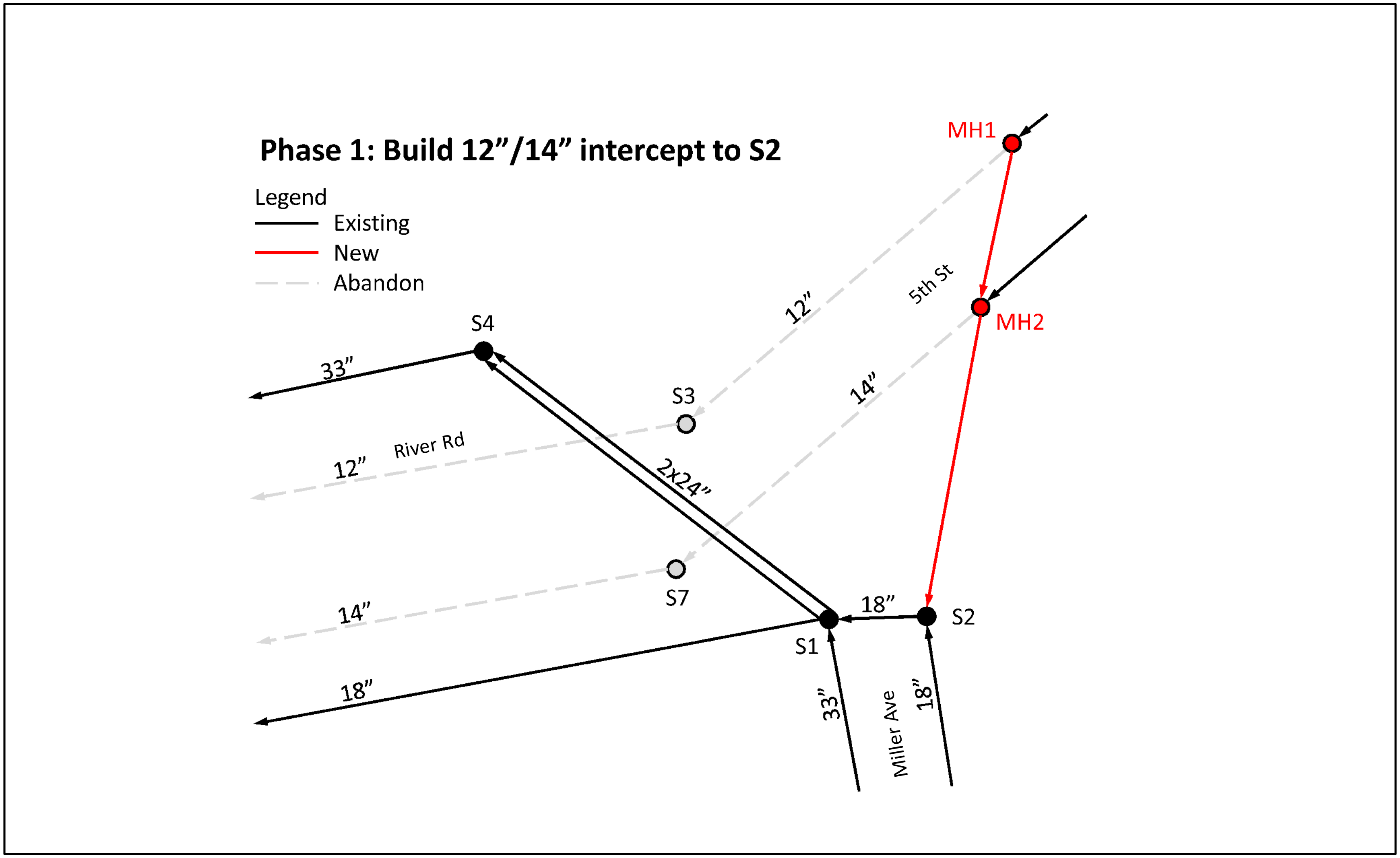

Figure 6
5TH AND MILLER OPTION 4B: PHASE 1
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
CITY OF CHICO

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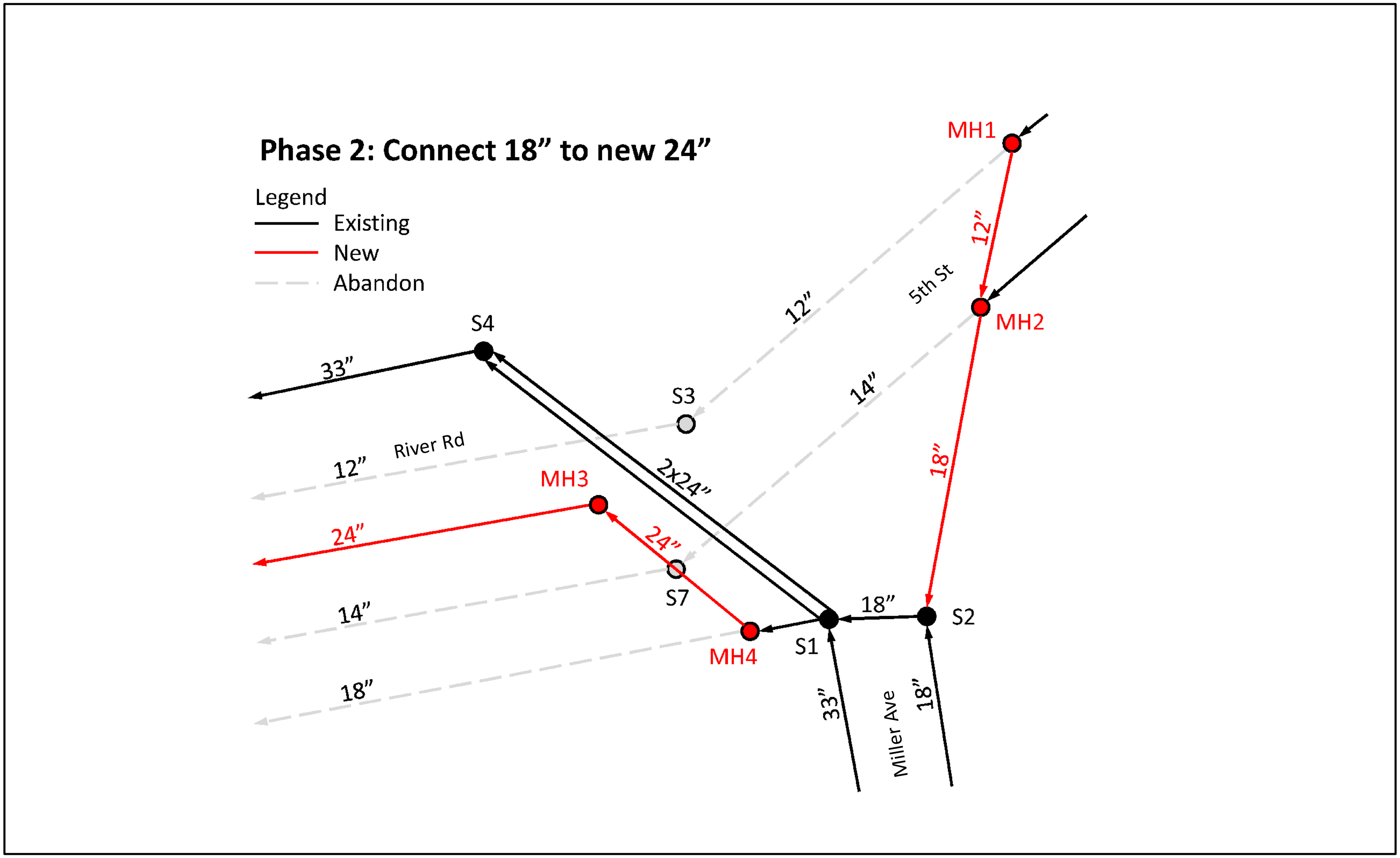

Figure 7
5TH AND MILLER OPTION 4B: PHASE 2
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
CITY OF CHICO

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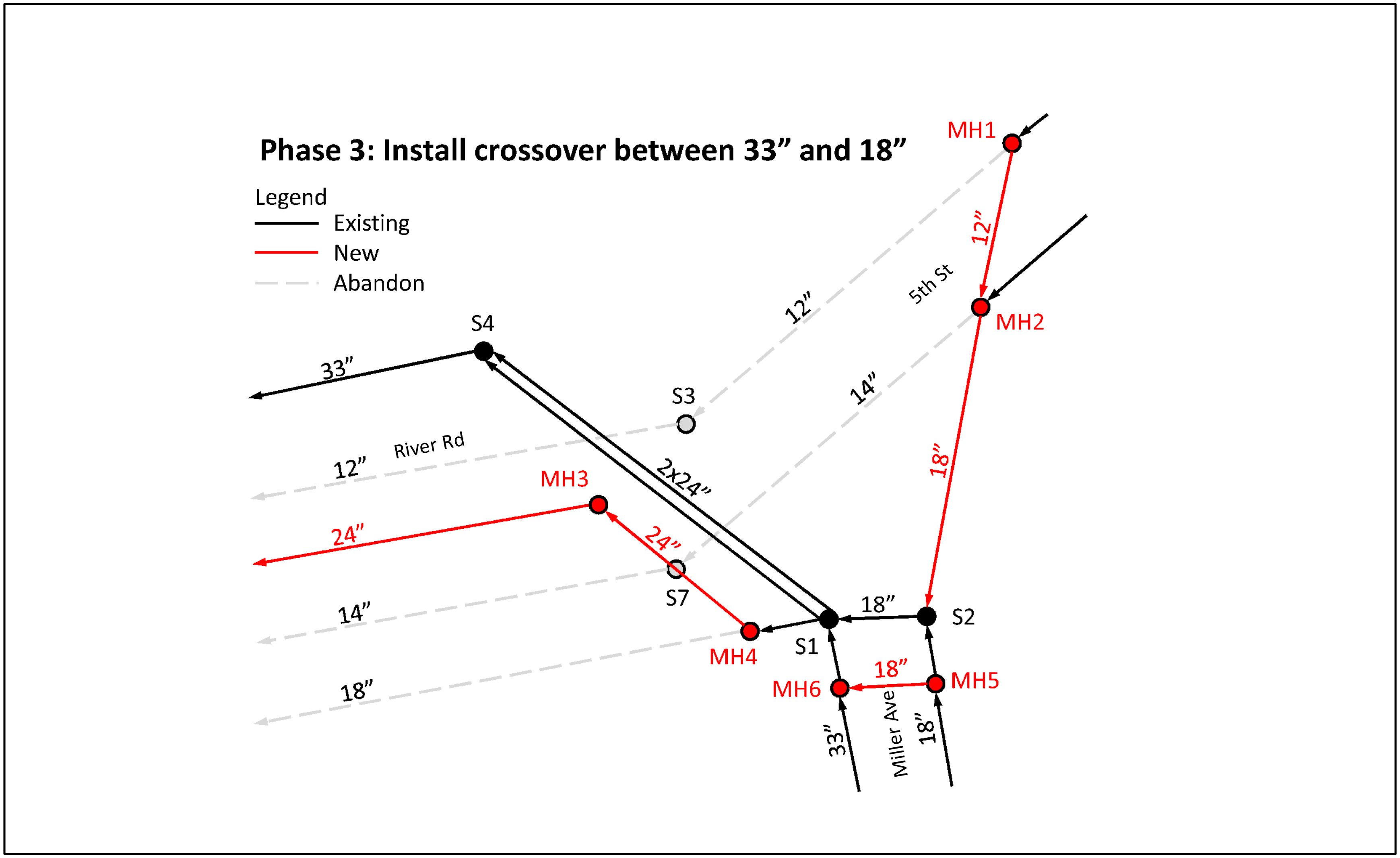

Figure 8
5TH AND MILLER OPTION 4B: PHASE 3
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
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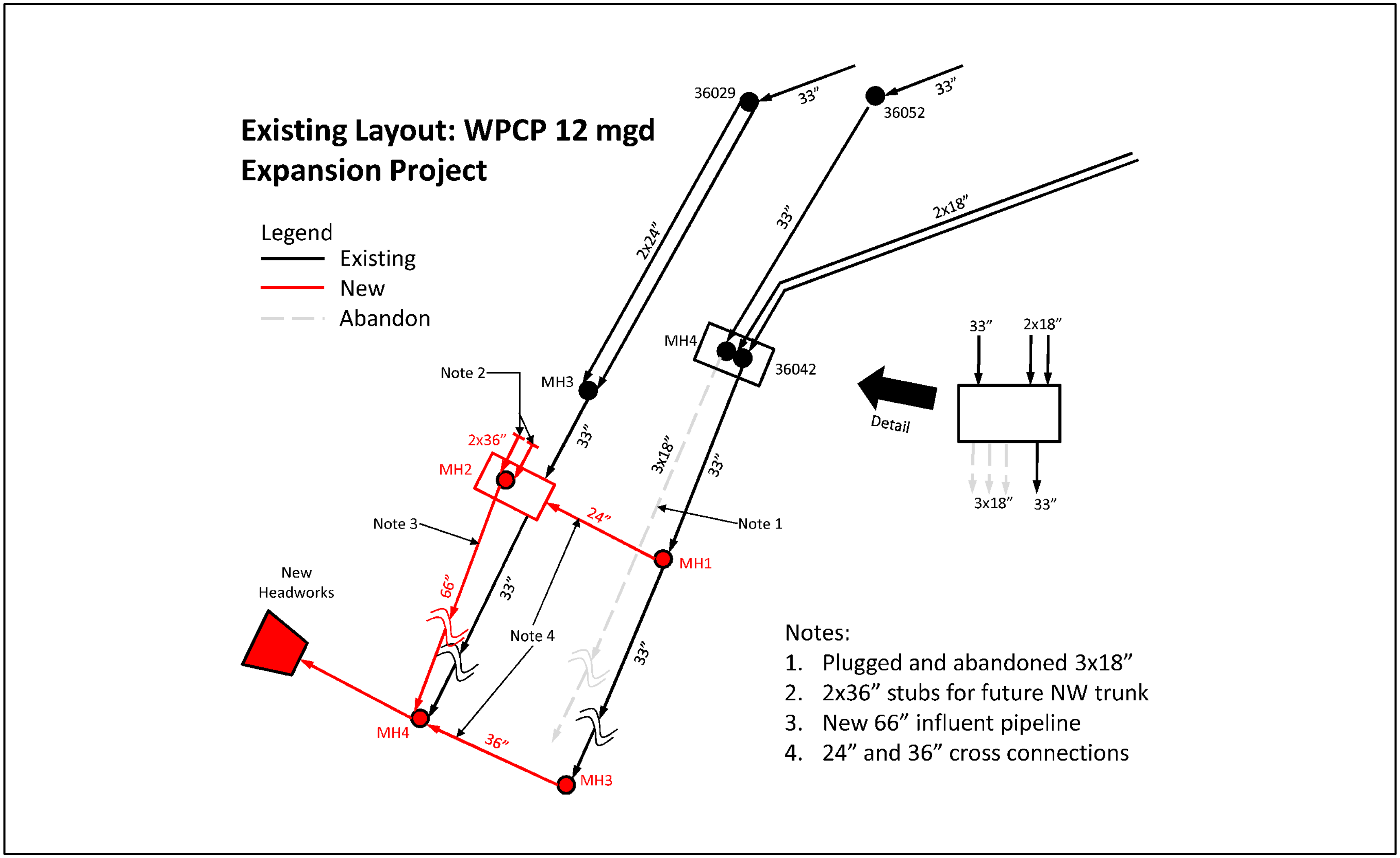

Figure 9
EXISTING WPCP SYSTEM LAYOUT
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
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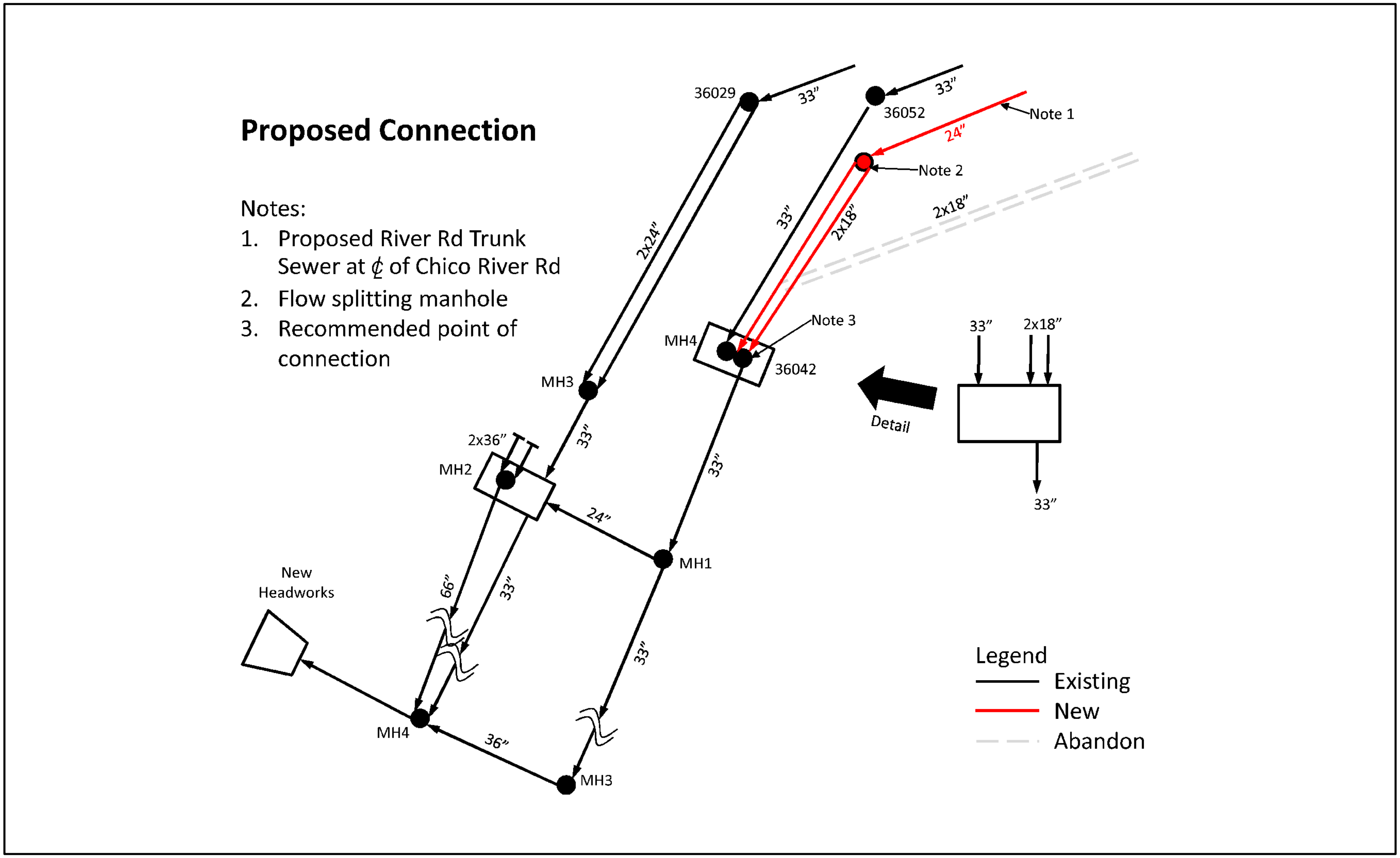

Figure 10
PROPOSED RIVER ROAD TRUNK SEWER CONNECTION
RIVER ROAD TRUNK SEWER HYDRAULIC ANALYSIS
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Table 4 Option Comparison
River Road Trunk Sewer Hydraulic Analysis
City of Chico

	Option 1	**Option 4B**
Pro	• Hydraulically feasible • Flow and HGL balanced between 24-inch and 33-inch pipes	• Hydraulically feasible • Flow and HGL balanced between 24-inch and 33-inch pipes • Flow diverted from higher invert pipes to lower invert pipes • Twin 24-inch pipes avoided
Con	• Flow diverted from lower invert pipes to higher invert pipes • S3 to MH1 pipe goes under twin 24-inch pipes • S3 and MH2 become drop manholes (~4 feet)	• None

It is recommended that the City proceed with Option 4B as it combines hydraulic feasibility with good operational performance and constructability. As previously stated, the division of the River Road Trunk Sewer into twin 18-inch pipes from a turning manhole located within Chico River Road, and connecting to the existing River Road Trunk Sewer Junction Box at the same invert elevation provides the most straightforward, cost efficient approach.

Study Conclusions

As currently modeled, the existing 33-inch SECSAD Trunk Sewer coupled with a proposed 24-inch River Road Trunk Sewer have an excess capacity of 4.5 mgd upstream of Rose Avenue during the 10-Year, 24-Hour Design Storm at build-out. This excess capacity can be used to delay construction of the proposed Northwest Trunk Sewer and/or absorb additional EDUs relocated into downtown due to planned densification in the 2030 General Plan. Interconnections between the existing NECSAD, SECSAD, and River Road Trunk Sewers will be necessary to fully utilize this available capacity; however, this analysis is outside the scope of this study and should be considered as part of both the design of the River Road Trunk Sewer Replacement Project and the forthcoming SSMP Update Project.

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