

Sewer Flow Study

Stormwater Collection System and Capacity Analysis

Prepared for
City of Ionia
Ionia County, Michigan

September 2019

2130311

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1 INTRODUCTION

The State of Michigan awarded a SAW grant to the City of Ionia in 2016 for development of a stormwater system asset management plan. As part of the City’s asset management program, flow metering and flow modeling were performed to better understand current and future improvement needs. The goal of asset management is to determine and provide the desired level of service for the lowest life cycle cost. This includes developing long-term operations and maintenance practices as well as life-cycle funding strategies. This report provides the flow metering and modeling findings regarding the following aspects of the stormwater collection system:

- Compliance with Federal and State Regulations
- Desired level of service for existing development
- Capacity to serve existing and future development

Prein&Newhof evaluated the level of service of Ionia’s stormwater system by simulating flows using a computerized model and comparing those flows to the capacity of the storm sewers. This report describes building the model, calibrating the model, and evaluating system performance using the model results. This report provides conclusions and needs for fixing those portions of the system not providing the desired level of service.

2 STUDY AREA

Map 1 shows the owner of the pipes and Map 2 shows the pipes within the entire existing storm sewer system. Part of the Ionia stormwater system was divided into ten storm sewer districts that were metered by temporary flow meters, as seen in Map 3. The system was calibrated using the meter data and the calibrated parameters were applied to the remainder of the system. The metered districts are as follows:

Meter District:	Location:
1	Temporary Flow Meter #1 south of Yeomans Street and Main Street
2	Temporary Flow Meter #2 southwest of Adams Street and Dexter Street
3	Temporary Flow Meter #3 at Adams Street and Dexter Street
4	Temporary Flow Meter #4 at Hudson Street and Railroad Street
5	Temporary Flow Meter #5 on Jackson Street south of Bliss Street

- 6 Temporary Flow Meter #6 on Division Street south of Fargo Street
- 7 Temporary Flow Meter #7 on Jefferson Street north of Lincoln Avenue
- 8 Temporary Flow Meter #8 at Jefferson Street and Ionia Rivertrail
- 9 Temporary Flow Meter #9 at Harrison Street and Mill Street
- 10 Temporary Flow Meter #10 at Washington Street and Oak Street

It is important to recognize that the design standards for storm sewer have changed in recent years as analysis of new rainfall data indicates higher intensity and volume design storm events in some cases than previously experienced. Increased rainfall intensities have stressed the existing storm sewer systems and caused more frequent flooding, thereby reducing the level of service (LOS) provided by those systems.

3 FLOW METERING

3.1 Meter Locations

Ten flow meters were used in the storm sewer system at the locations shown on Map 3. Four of the ten meters were installed on April 4, 2018 and the remaining six were installed April 5, 2018. Two meters were removed July 9, 2018, one was removed on May 30, 2018, and seven were removed on July 10, 2018. ISCO Model 2150 Area Velocity flow meters were used for this study. Depth and flow measurements were logged every five minutes, 24 hours per day, throughout the period the meter was in the sewer. The flow rate (number of gallons per minute) was calculated from these measurements, resulting in a profile of the flow patterns over time.

3.2 Rainfall Events

Precipitation data from storm events was collected from a temporary rain gage located in the City of Ionia at the waste water treatment plant. Table 1 displays the storms that occurred during the study period.

The largest rainfall produced approximately 1.55 inches of rain in 69 hours during May. The second largest resulted in 1.48 inches of rainfall in 35 hours. These are relatively smaller rain events resulting in lower magnitude flow data giving a lower degree of confidence in the design storm simulations. The larger rain events that occur while the meters are installed creates a higher confidence when simulating a larger design storm as it is closer in volume and peak to the simulated design storm. Although the rain

event from April 12 to April 19 had a total volume of 2.29 inches, the event occurred over a seven day period. May 11 to May 15 resulted in 1.6 inches, but this event was not used because there was no meter response to the rainfall event.

3.3 Metering Results

Figures A-1 through A-10 display the level, velocity, flow rate, and rainfall data for Meters 1 through 10 over the study period. These figures display the response at each meter during each 2017 storm event. Table 3 provides a summary of the field data for the significant storm events.

4 HYDROLOGIC/HYDRAULIC MODELING

Storm sewer flows were simulated using InfoSWMM®, a hydrologic and hydraulic modeling software. The program's core analysis tool is the Storm Water Management Model (SWMM), originally developed for the United States Environmental Protection Agency and later refined with commercial software improvements and extensions. The storm sewer system model was developed based on the City's Geographic Information System (GIS) database with elements for all pipes, open drains, catch basins, manholes, and detention ponds. The model was populated with the physical properties of those system components such as:

- pipe diameter, material, and slope
- manhole rim and invert elevations
- open drain and pond characteristics

This study utilized the Modified Horton method to model infiltration and the EPA SWMM method to model runoff. The National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation frequency estimates were applied to simulate design storm events.

A capacity analysis was performed by simulating a variety of design storm events. The analysis determined where surface flooding and pipe surcharging is likely to occur during rain events of various intensities. The 2, 5, 10 and 25-year design storm events (for a 24-hour period) were simulated. These design storms represent a storm event of specified rainfall depth and return frequency (e.g. a 2-year design storm has a 50% chance of occurring in any given year). Table 2 gives the amount of rainfall and the peak rate of each design storm used. The model calculated the runoff volume and peak discharge rate

throughout the system for each of these design storms. Figure 1 shows an example of model output at a meter during a 10-year storm event.

5 MODEL CALIBRATION

Model calibration typically utilizes flow monitoring data to facilitate parameter adjustments that allow model duplication of field measured conditions. Additionally or if monitoring data is not available, anecdotal information on observed flow conditions can be utilized.

For this study, there were ten meters used to assist in calibrating the storm sewer model. Five rain events were chosen for calibration. Calibration results are provided in Table 3. Figure 2 provides an example of model calibration at Meter 7.

6 MODELING RESULTS

The model output was used to generate Level of Service (LOS) maps based on storm events with various return intervals (2, 5, 10, and 25-year) with a water surface level at the crown of the outlet pipe, as seen from Maps 4 through 7. Maps 4 through 7 assume the Grand River Water Surface Elevation is low to analyze the actual pipe capacity without water from the river influencing the pipe capacity or the duration of surface flooding. These maps show the maximum level versus the full capacity of each pipe. The performance of individual pipes is affected by the surrounding pipes, either upstream or downstream. Backwater effects from bottle necks or undersized pipes are often the cause of flooding. While pipes may be identified as over full flow capacity, this does not necessarily infer there is surface flooding. The maps identify storm structures that have flooding concerns, by showing the approximate duration of surface flooding at each structure for the 2-year storm and if the structure meets the level of service for the 5, 10, and 25-year storm. Areas with extended periods of surface flooding shown were reviewed to identify LOS concerns and potential improvement requirements.

7 CONCLUSIONS AND NEEDS

Based on the modeled analysis, conclusions are presented for areas of concern. Results vary through the community and are driven by soils, land use, available system capacity and the hydrology of the area.

The City has established its Level of Service (LOS) goals as follows:

1. 5-year storm - 100% in-pipe conveyance with no pipe surcharging
2. 10-year storm – Pipe surcharging allowed but no surface flooding
3. 25-year storm – Pipe surcharging allowed but no surface flooding greater than 30 minutes

Map 8 highlights projects required to meet 10-year storm LOS goals and also possible projects for future development. Pipe diameters in the yellow highlighted project areas on this map are proposed based on model analysis.

7.1 Adams Street and Steele Street

Adams Street and Steele Street are located in the southwest portion of the city and discharge into the pond located southwest of Adams Street and Dexter Street. This area is one of concern and flooding has been reported by the city. The sewers on Adam Street and Steele Street flood for the 2, 5, 10, and 25-year storm events. This section of storm sewer does not meet the LOS goals. The flooding in some sewers along Adams Street lasts longer than an hour for the 2, 5, 10, and 25-year storm events. The flooding is due to undersized main on Adams Street just east of Dexter Street. The pipes need to be upsized to adequately convey flow for the various storm events.

7.2 Dexter Street (MDOT Pipe)

Dexter Street is located in the southwest portion of the city and discharges into the pond located southwest of Adams Street and Dexter Street. Dexter Street and Adams Street combine into one sewer along Adams Street at the intersection of Dexter Street. Portions of the sewer on Dexter Street, north of Adam Street to Lincoln Street, flood for 2, 5, 10, and 25-year storm events. This section of storm main does not meet the LOS goals. The flooding in some sewers along Dexter Street lasts longer than 30 minutes during the 10-year storm event. The flooding is due to undersized main on Dexter Street between High Street and Adams Street. The pipes need to be upsized to adequately convey flow for the various storm events.

7.3 Lincoln Avenue and Jackson Street (Lincoln Avenue – MDOT Pipe)

Lincoln Avenue and Jackson Street are located in the northeast portion of the city and discharge into an open channel which eventually flows to the Grand River. The open channel has been noted as one of concern and flooding by the city. The sewer along Lincoln Avenue from Union Street to Jackson Street does not meet the LOS goals, as surcharged pipes and surface flooding is present during the 2, 5, 10, and 25-year storm events. This portion of the sewer is 12 to 15-inches in diameter with a steep slope. During the 5-year storm event the surface area flooding duration exceeds 15 minutes and a majority of the pipes experience surcharging. The flooding is caused by a 15-inch pipe on Lincoln Avenue just west of Jackson Street and a 12-inch pipe on Lincoln Avenue just east of Union Street. The undersized pipe should be replaced to adequately convey the storm water. These results can be seen on Maps 4 through 7.

7.4 State Road and Fargo Street (State Road – MDOT pipe)

State Road and Fargo Street are located in the northwest portion of the city and discharge into the retention pond on Forest Street, which eventually flows to the pond located southwest of Adams Street and Dexter Street. The sewer along State Street does not meet the LOS goals, as surface flooding occurs during the 2, 5, 10, and 25-year storm events. The surface flooding and surcharged pipes are due to pipes with relatively flat slope at Fargo Street and State Road. If an increase in slope is unavailable, the pipes will have to be upsized to alleviate the flooding.

7.5 Bayard Street and Mill Street

Bayard Street and Mill Street are located in the southeast corner of the city. The sewers discharge into the Grand River. This area is one of concern and flooding has been reported by the city. The flooding is caused by the 12-inch discharge pipe. The downstream invert was not able to be field-verified so contours and nearby outfalls were used to assign an outfall elevation. Surface flooding exceeded 60 minutes for the 2, 5, 10, and 25-year storm events. The outfall invert and diameter should be verified to confirm results. If verified, the outlet pipe needs to be upsized to adequately convey flow for the storm events.

7.6 Main Street

Flow blockage of over half the area of the pipe was found in the storm sewer on Main Street from Library Street to Rich Street, significantly reducing the capacity of the pipe. The flow blockage appears to be concrete that was poured into the storm sewer and has cured in the pipe. Removal of the flow

blockage from the pipe may not be feasible due to the large amount of concrete. A proposed parallel overflow pipe to allow for stormwater conveyance and avoid costly excavation of the brick road is shown in Map 8.

7.7 Future Flow

Map 8 shows projects that incorporate future development. The land northeast of Fargo Street and Union Street is planned for future residential development. Pipes along Fargo Street and Division Street are undersized with existing conditions. For the future development, a retention pond is proposed west of the dead end of Ridgewood Drive. The retention pond is modeled to discharge into the existing channel which enters the storm sewer at Fargo Street and Division Street. According to the Ionia County Guidelines for Storm Water Management, the discharge rate from a retention pond is 0.15 cubic feet per second (cfs) per acre. The area tributary to the proposed retention pond is 65 acres. The discharge rate out of the pond is 9.75 cfs.

7.8 Redirect Open Channel Flow

A proposed pipe on Jackson Street from Perry Park to Railroad Street and Railroad Street to Jefferson Street is also shown on Map 8. The intent of this pipe is to alleviate flooding concerns of residents adjacent to the open channel west of Jackson Street by redirecting stormwater from the open channel into an enclosed pipe in Jackson Street. With the addition of the proposed retention pond mentioned above, the future pipe along Jackson Street can be reduced from a 48-inch to a 36-inch pipe along Jackson Street and a 42-inch pipe along Railroad Street.

Tables

Table 1 **Metering Period Storm Events**

Table 2 **Design Storm Events**

Table 3 **Calibration Data**

Table 1: Metering Period Storm Events

Date	Total Vol [in]	Duration [hr]	Average Intensity [in/hr]	Peak Hr. Intensity [in/hr]
4/12/2018 - 4/19/2018	2.29	156	0.01	0.01
5/3/2018 - 5/4/2018	1.48	35	0.04	0.04
5/11/2018 - 5/15/2018	1.6	12	0.13	0.13
5/19/2018 - 5/21/2018	1.55	69	0.02	0.02
5/30/2018 - 5/31/2018	1.2	4	0.30	0.30
6/3/2018	0.37	3	0.12	0.12
6/9/2018	1.44	7	0.21	0.21
6/27/2018	0.74	4	0.00	0.19

Notes: Rainfall data from the Temporary Raingage in Ionia, Michigan.

Bolded storm events were used in model calibration.

Table 2: Design Storm Events

24-Hour Duration Design Storm	Percent chance of occurrence in any given year	Total Rainfall (in)	Peak Rate (in/hr)
2-Year	50%	2.51	1.10
5-Year	20%	3.11	1.37
10-Year	10%	3.66	1.61
25-Year	4%	4.51	1.98
100-Year	1%	5.99	2.63

Note: 24-Hour Design Storm rainfall parameters acquired using NOAA Atlas 14 precipitation estimates.

Table 3: Calibration Data

Storm Event Flow Conditions																					
Date		5/3/2018 - 5/4/2018				5/19/2018 - 5/21/2018				5/30/2018 - 5/31/2018				6/9/2018				6/27/2018			
Rainfall ¹ , inches		1.48				1.55				1.20				1.44				0.74			
Peak Hour Intensity ¹ , inches		0.04				0.02				0.30				0.21				0.19			
Duration ¹ , hours		35				69				4				7				4			
Date:		Field Data		Model Data		Field Data		Model Data		Field Data		Model Data		Field Data		Model Data		Field Data		Model Data	
Meters ²		Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³	Maximum Rate, gpm	Total Storm Event Volume, mgal ³		
Meter 1		NA	NA	NA	NA	4222	0.310	2762	0.274	3970	0.969	4517	1.058	NA	NA	NA	NA	NA	NA		
Meter 2		NA	NA	NA	NA	19353	2.052	8134	0.810	25603	6.535	29323	6.632	NA	NA	NA	NA	NA	NA		
Meter 3		5923	0.247	2034	0.230	5760	0.696	7637	0.753	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		
Meter 4		NA	NA	NA	NA	4822	0.683	6801	0.624	9949	2.187	10648	2.289	NA	NA	NA	NA	NA	NA		
Meter 5		NA	NA	NA	NA	5479	1.196	9293	1.010	NA	NA	NA	NA	3460	0.620	2645	0.527	NA	NA		
Meter 6		NA	NA	NA	NA	923	0.119	1295	0.117	1252	0.347	2118	0.374	NA	NA	NA	NA	NA	NA		
Meter 7		NA	NA	NA	NA	NA	NA	NA	NA	2397	0.475	2659	0.525	NA	NA	NA	NA	2511	0.319		
Meter 8		NA	NA	NA	NA	NA	NA	NA	NA	3849	1.005	4917	0.927	2682	0.664	3320	0.722	NA	NA		
Meter 9		NA	NA	NA	NA	NA	NA	NA	NA	1905	0.459	2569	0.500	NA	NA	NA	NA	1497	0.274		
Meter 10		NA	NA	NA	NA	NA	NA	NA	NA	2798	0.633	3700	0.749	2900	0.665	2554	0.585	NA	NA		

¹ Rainfall Data - 2018 data from the temporary rain gage located in the City of Ionia.

² Data in this table is separated by meter.

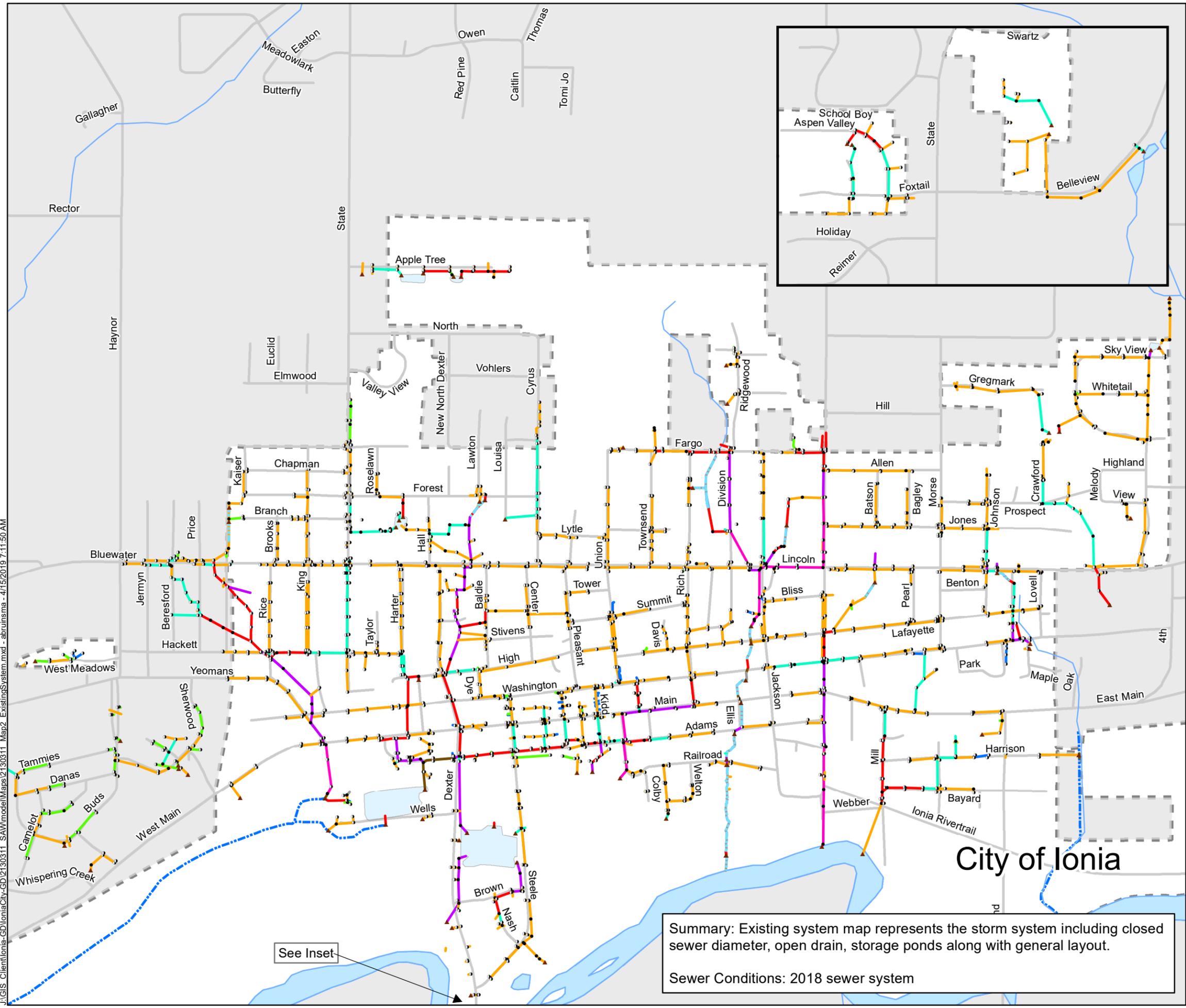
³ Total storm event volume refers to the total flow volume recorded by the meters during the storm event.

- Map 1 Ownership**
- Map 2 Existing System**
- Map 3 Collection Districts**
- Map 4 Existing Duration of Flooding (2-Yr Storm Low River Level)**
- Map 5 Existing Duration of Flooding (5-Yr Storm Low River Level)**
- Map 6 Existing Duration of Flooding (10-Yr Storm Low River Level)**
- Map 7 Existing Duration of Flooding (25-Yr Storm Low River Level)**
- Map 8 Future Project Areas**

CITY OF IONIA
 IONIA COUNTY, MI
 STORMWATER COLLECTION SYSTEM
MAP 2: EXISTING SYSTEM
 SEPTEMBER 2019
 Prein&Newhof
 2130311

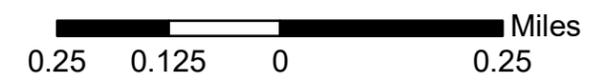
LEGEND

- ▲ Outfall
- Catch Basin
- Manhole
- Open Drain
- Diameter**
- 4" - 6"
- 8" - 10"
- 12" - 15"
- 18" - 21"
- 24" - 30"
- 35" - 42"
- 48" - 54"
- 57" or Larger
- Unknown
- County Drain
- Pond



City of Ionia

Summary: Existing system map represents the storm system including closed sewer diameter, open drain, storage ponds along with general layout.
 Sewer Conditions: 2018 sewer system



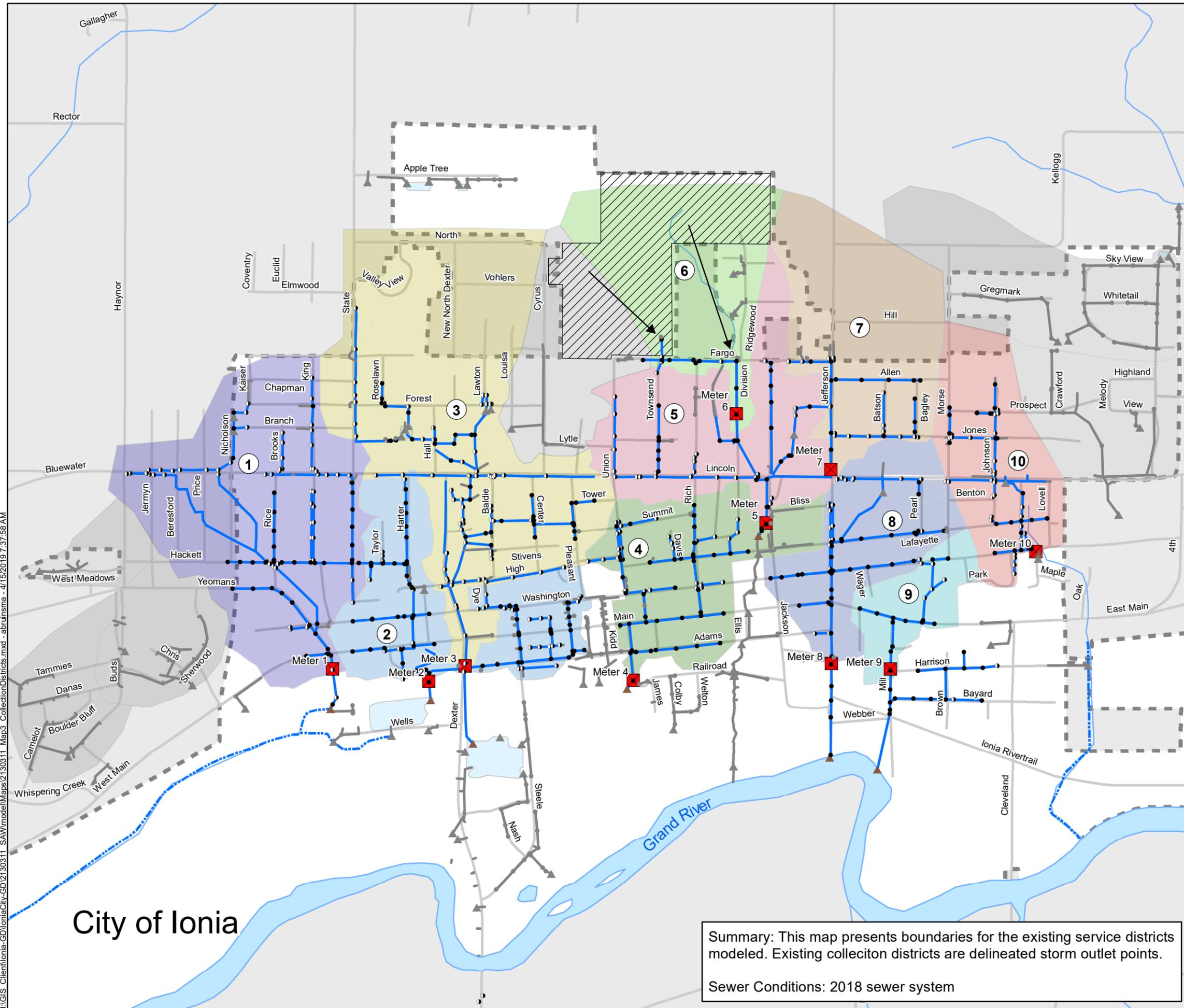
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CITY OF IONIA
 IONIA COUNTY, MI
 STORMWATER COLLECTION SYSTEM
MAP 3: COLLECTION DISTRICTS
 SEPTEMBER 2019
 Prein&Newhof
 2130311

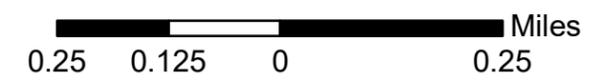
LEGEND

-  Meter Locations
-  Manhole (Modeled)
-  Manhole (Not Modeled)
-  Catch Basin (Modeled)
-  Discharge Point (Modeled)
-  Discharge Point (Not Modeled)
-  Gravity Main (Modeled)
-  Gravity Main (Not Modeled)
-  Collection District (Modeled)
-  Collection District (Not Modeled)
-  Future Development
-  County Drain
-  Pond



City of Ionia

Summary: This map presents boundaries for the existing service districts modeled. Existing collection districts are delineated storm outlet points.
 Sewer Conditions: 2018 sewer system



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CITY OF IONIA
 IONIA COUNTY, MI
 STORMWATER COLLECTION SYSTEM
MAP 4: EXISTING DURATION OF FLOODING
(2-YR STORM LOW RIVER ELEVATION)
 SEPTEMBER 2019
 Prein&Newhof
 2130311

LEGEND

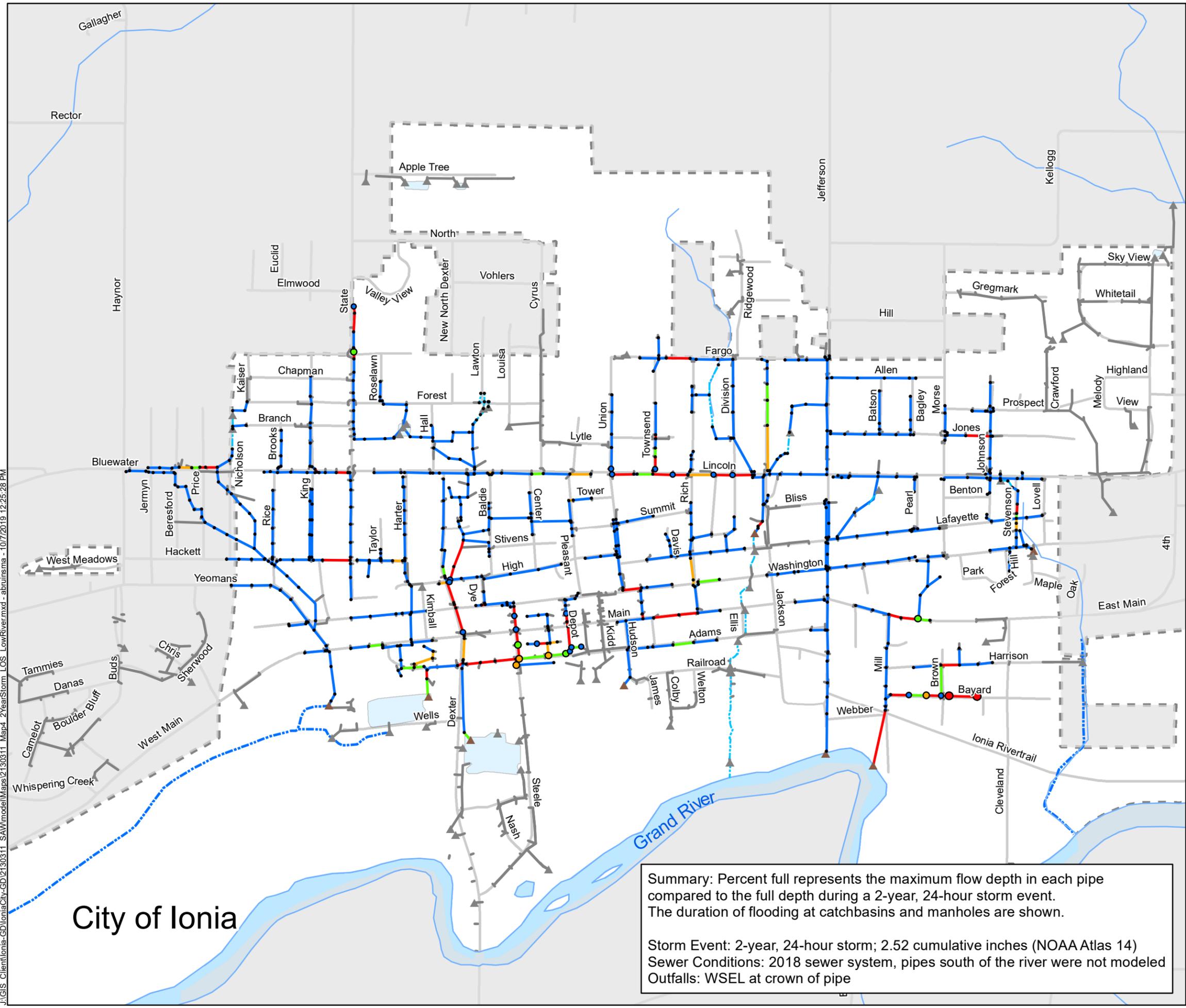
Duration of Flooding

- No Flooding
- < 15 Mins
- 15 - 30 Mins
- 30 - 60 Mins
- > 60 Mins

Percent Full

- < 70% Full
- 70% - 80% Full
- 80% - 99% Full
- > 100% Full

- ▲ Discharge Point (Modeled)
- ▲ Discharge Point (Not Modeled)
- Gravity Main (Not Modeled)
- Open Drain
- County Drain
- Pond



City of Ionia

Summary: Percent full represents the maximum flow depth in each pipe compared to the full depth during a 2-year, 24-hour storm event. The duration of flooding at catchbasins and manholes are shown.

Storm Event: 2-year, 24-hour storm; 2.52 cumulative inches (NOAA Atlas 14)
 Sewer Conditions: 2018 sewer system, pipes south of the river were not modeled
 Outfalls: WSEL at crown of pipe



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CITY OF IONIA
 IONIA COUNTY, MI
 STORMWATER COLLECTION SYSTEM
MAP 5: EXISTING DURATION OF FLOODING
(5-YR STORM LOW RIVER ELEVATION)
 SEPTEMBER 2019
 Prein&Newhof
 2130311

LEGEND

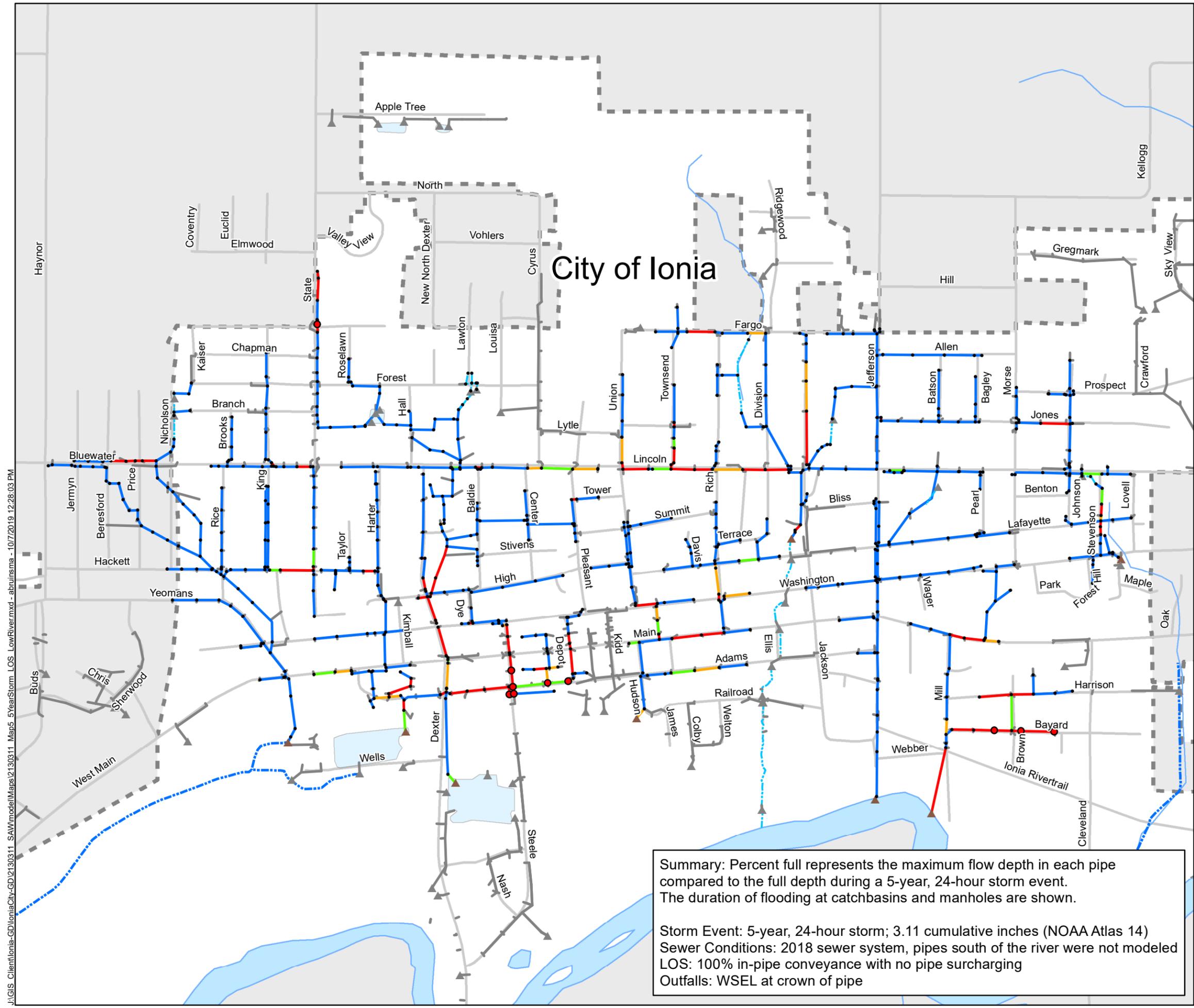
Level of Service

- Meets LOS
- Does Not Meet LOS

Percent Full

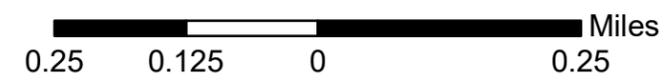
- < 70% Full
- 70% - 80% Full
- 80% - 99% Full
- > 100% Full (Does Not Meet LOS)

- ▲ Discharge Point (Modeled)
- ▲ Discharge Point (Not Modeled)
- Gravity Main (Not Modeled)
- - - Open Drain
- - - County Drain
- ☪ Pond



Summary: Percent full represents the maximum flow depth in each pipe compared to the full depth during a 5-year, 24-hour storm event. The duration of flooding at catchbasins and manholes are shown.

Storm Event: 5-year, 24-hour storm; 3.11 cumulative inches (NOAA Atlas 14)
 Sewer Conditions: 2018 sewer system, pipes south of the river were not modeled
 LOS: 100% in-pipe conveyance with no pipe surcharging
 Outfalls: WSEL at crown of pipe



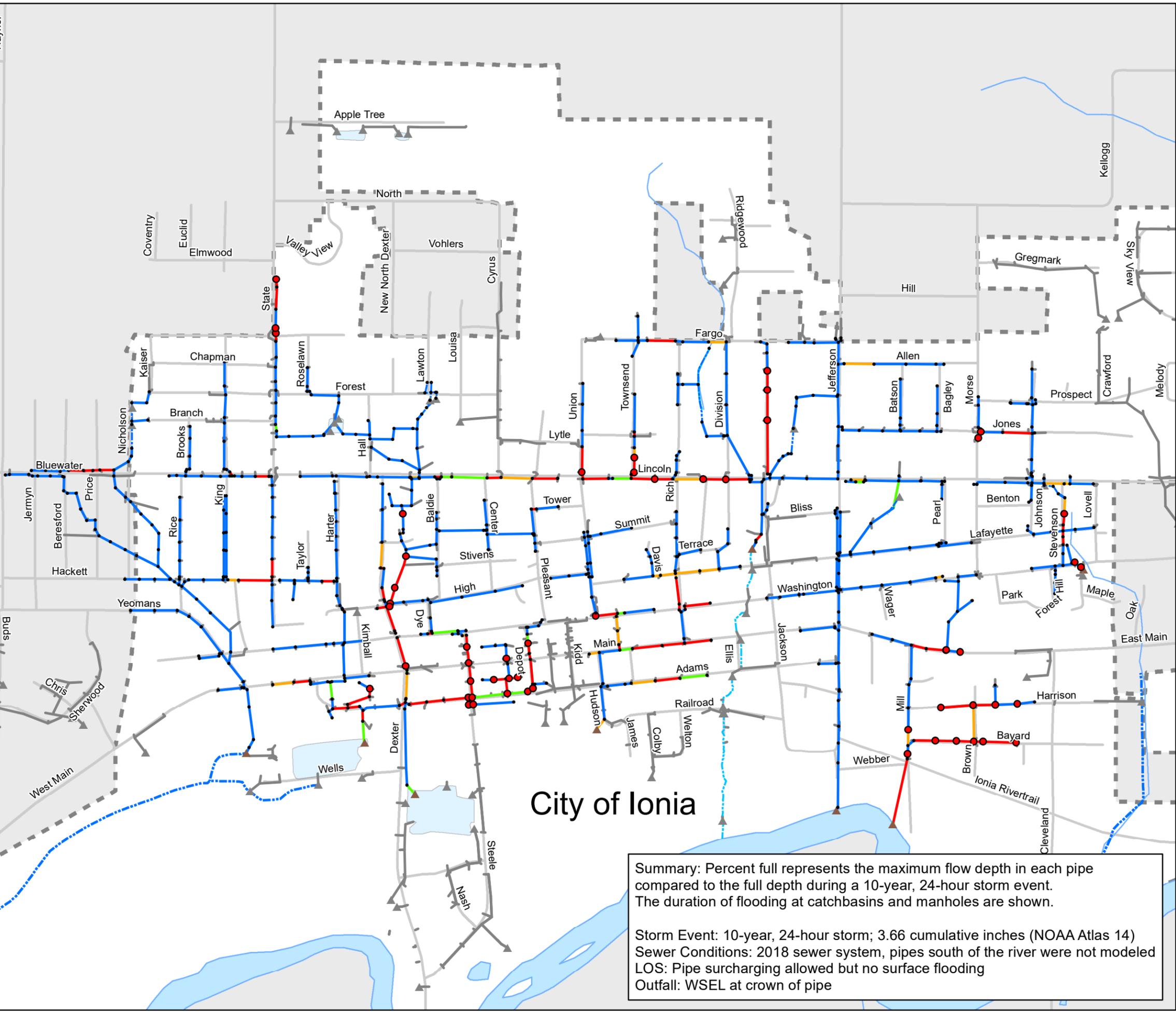
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CITY OF IONIA
 IONIA COUNTY, MI
 STORMWATER COLLECTION SYSTEM
MAP 6: EXISTING DURATION OF FLOODING
(10-YR STORM LOW RIVER LEVEL)
 SEPTEMBER 2019
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 2130311

LEGEND

- Level of Service**
- Meets LOS
 - Does Not Meet LOS
- Percent Full**
- < 70% Full
 - 70% - 80% Full
 - 80% - 99% Full
 - > 100% Full
- ▲ Discharge Point (Modeled)
- ▲ Discharge Point (Not Modeled)
- Gravity Main (Not Modeled)
- Open Drain
- County Drain
- ☪ Pond



City of Ionia

Summary: Percent full represents the maximum flow depth in each pipe compared to the full depth during a 10-year, 24-hour storm event. The duration of flooding at catchbasins and manholes are shown.

Storm Event: 10-year, 24-hour storm; 3.66 cumulative inches (NOAA Atlas 14)
 Sewer Conditions: 2018 sewer system, pipes south of the river were not modeled
 LOS: Pipe surcharging allowed but no surface flooding
 Outfall: WSEL at crown of pipe



CITY OF IONIA
 IONIA COUNTY, MI
 STORMWATER COLLECTION SYSTEM
MAP 7: EXISTING DURATION OF FLOODING
(25-YR STORM LOW RIVER ELEVATION)
 SEPTEMBER 2019
 Prein&Newhof
 2130311

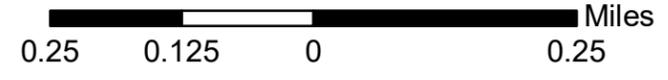
City of Ionia

LEGEND

- Level of Service**
- Meets LOS
 - Does Not Meet LOS
- Percent Full**
- < 70% Full
 - 70% - 80% Full
 - 80% - 99% Full
 - > 100% Full
- ▲ Discharge Point (Modeled)
- ▲ Discharge Point (Not Modeled)
- Gravity Main (Not Modeled)
- Open Drain
- County Drain
- ☪ Pond

Summary: Percent full represents the maximum flow depth in each pipe compared to the full depth during a 25-year, 24-hour storm event. The duration of flooding at catchbasins and manholes are shown.

Storm Event: 25-year, 24-hour storm; 4.51 cumulative inches (NOAA Atlas 14)
 Sewer Conditions: 2018 sewer system, pipes south of the river were not modeled
 LOS: Pipe surcharging allowed but no surface flooding greater than 30 minutes
 Outfalls: WSEL at crown of pipe



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CITY OF IONIA
IONIA COUNTY, MI
STORMWATER COLLECTION SYSTEM
MAP 8: FUTURE PROJECT AREAS
SEPTEMBER 2019

Prein&Newhof
2130311

LEGEND

- ▲ Discharge Point (Modeled)
- ▲ Discharge Point (Not Modeled)
- Manhole (Modeled)
- Catch Basin (Modeled)

- Future Project Areas
- Proposed Pond

Future Diameter

- 6"
- 8"
- 10"
- 12"
- 15"
- 18"
- 21"
- 24"
- 30"
- 36"
- 42"
- 48"
- 54"
- 60"



Summary: Future project map shows future build out and future projects to meet the 10-Year Storm LOS goals with low river elevation and future flows.
Sewer Conditions: 2018 sewer system

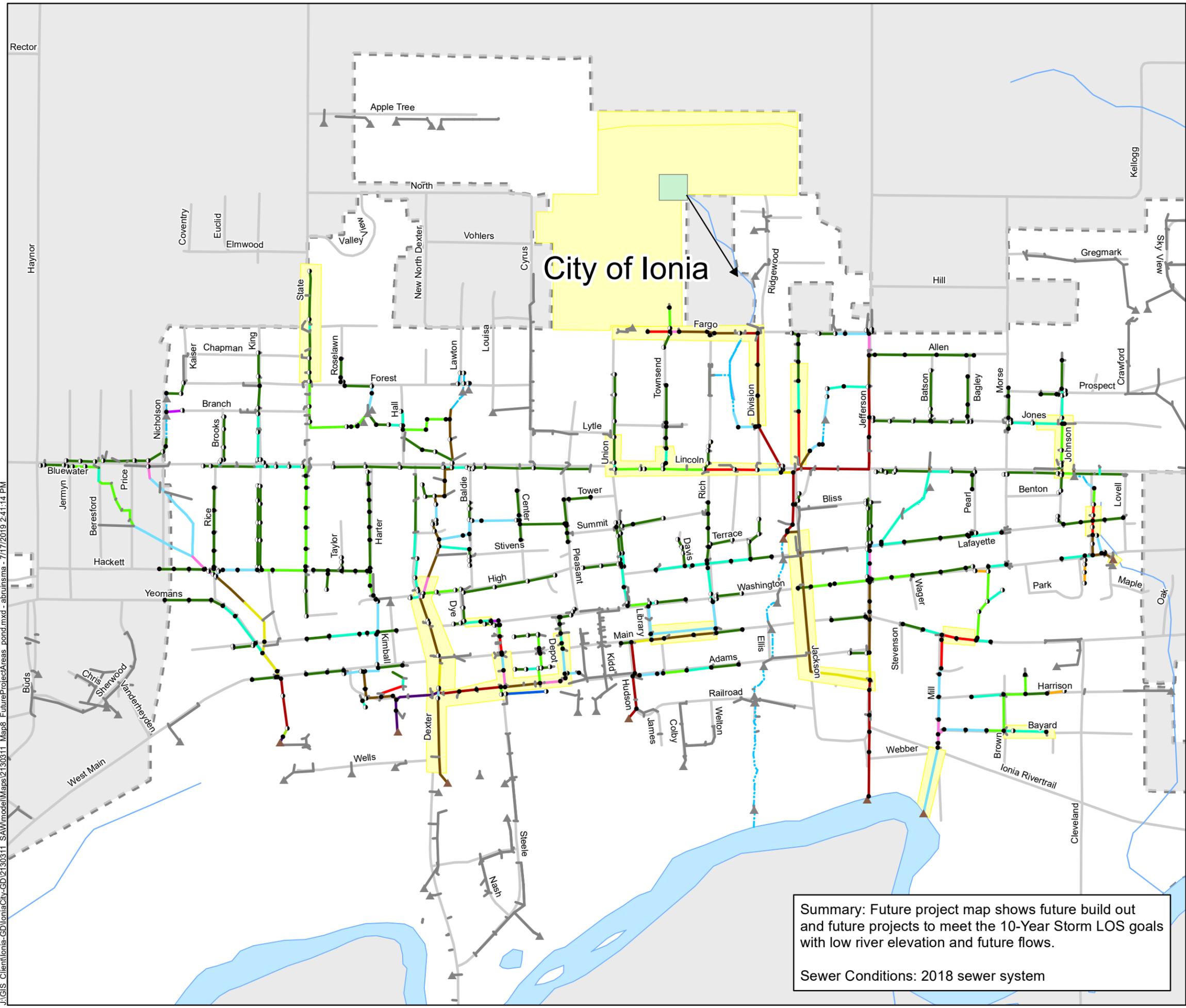


Figure 1 **Model Output Hydrograph (24-Hour, 10-Year Storm Event)**

Figure 2 **Example Calibration Graph (Meter 7)**

Figure 1: Model Output Hydrograph (24-Hour, 10-Year Storm Event)

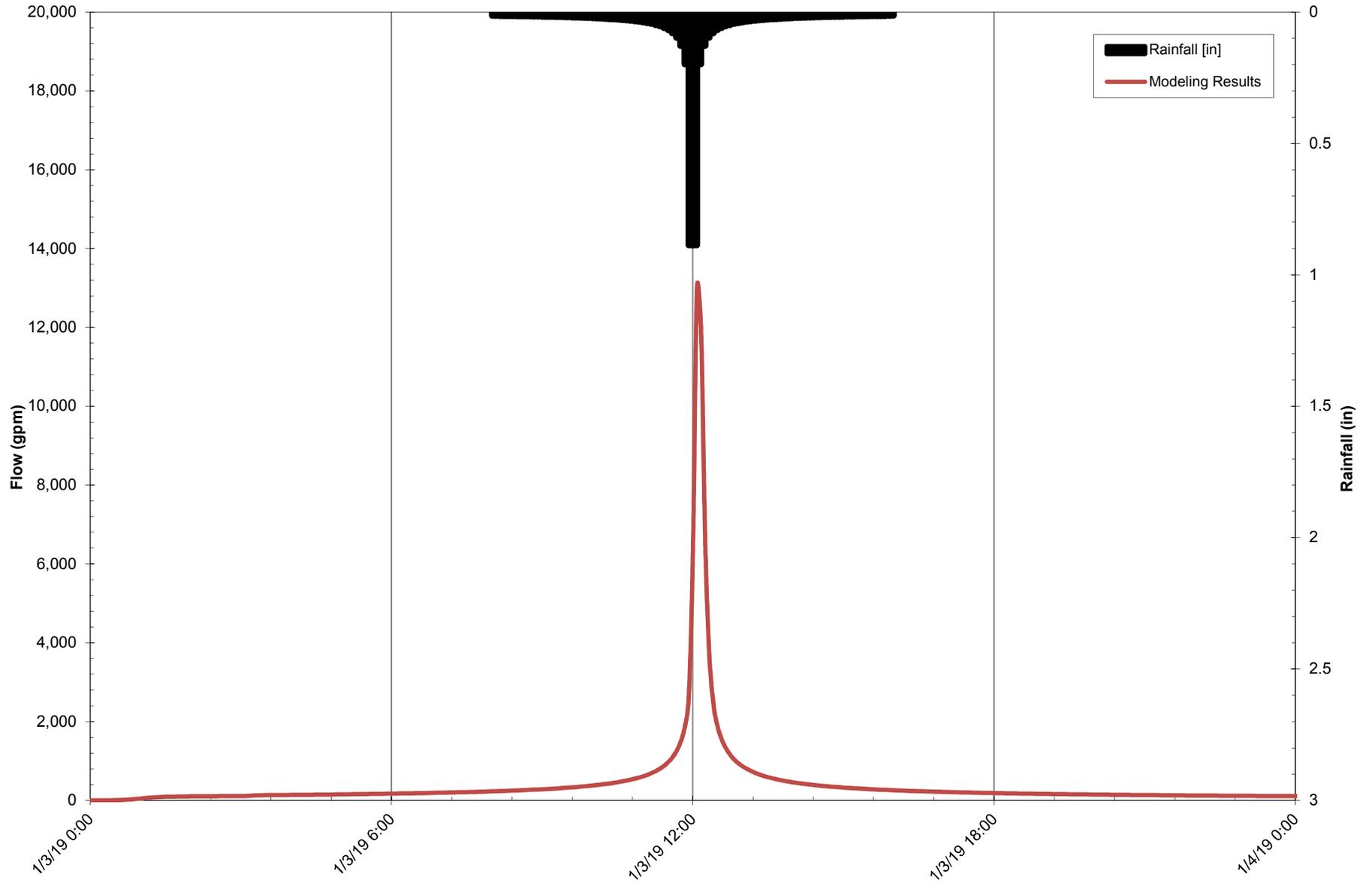
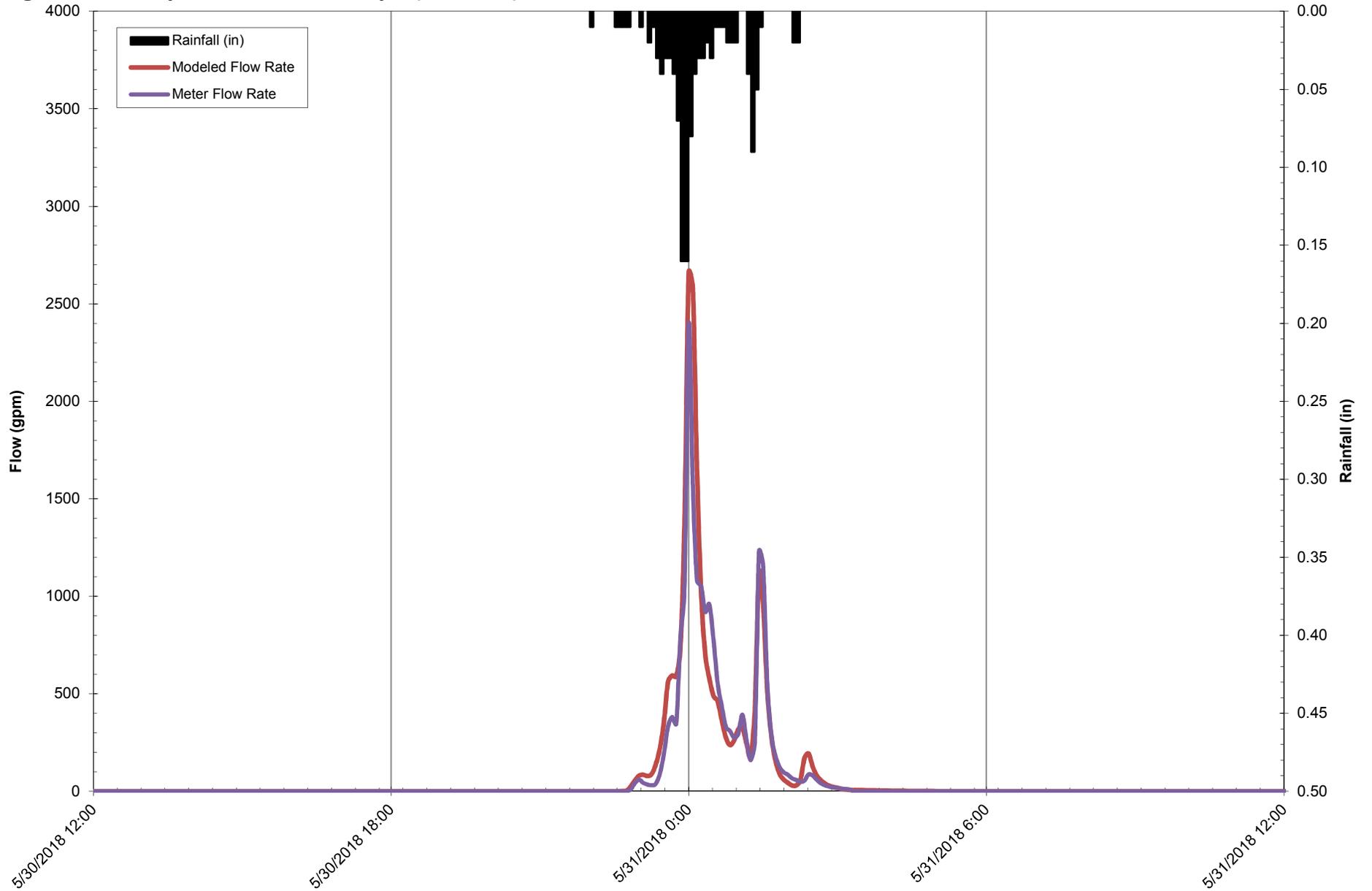


Figure 2: Example Calibration Graph (Meter 7)



Appendix A - Meter Data Figures

Figure A-1 Meter Location #1 Rainfall and Meter Data Comparison

Figure A-2 Meter Location #2 Rainfall and Meter Data Comparison

Figure A-3 Meter Location #3 Rainfall and Meter Data Comparison

Figure A-4 Meter Location #4 Rainfall and Meter Data Comparison

Figure A-5 Meter Location #5 Rainfall and Meter Data Comparison

Figure A-6 Meter Location #6 Rainfall and Meter Data Comparison

Figure A-7 Meter Location #7 Rainfall and Meter Data Comparison

Figure A-8 Meter Location #8 Rainfall and Meter Data Comparison

Figure A-9 Meter Location #9 Rainfall and Meter Data Comparison

Figure A-10 Meter Location #10 Rainfall and Meter Data Comparison

Figure A-1: Meter Location #1 Rainfall and Meter Data Comparison

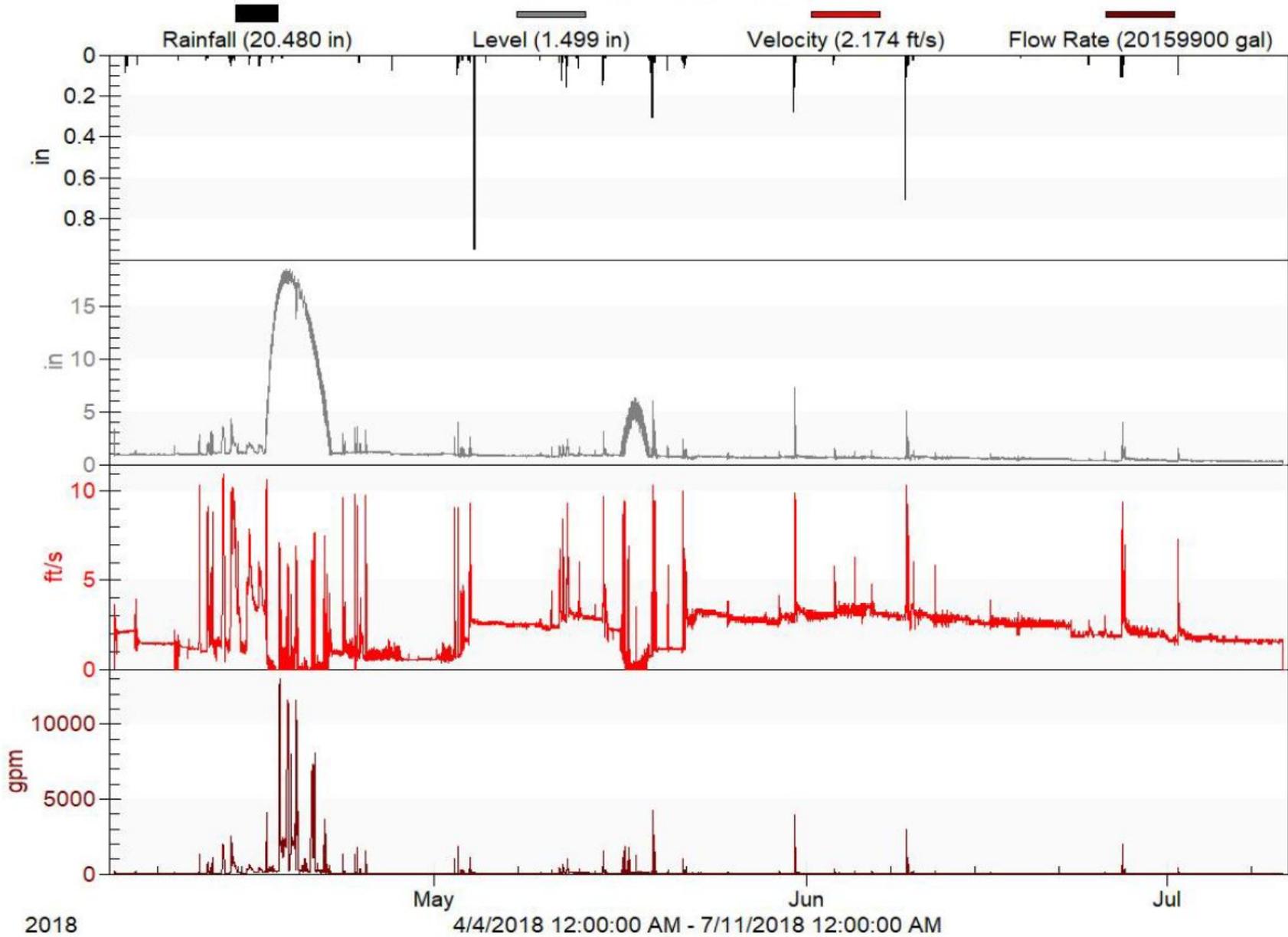


Figure A-2: Meter Location #2 Rainfall and Meter Data Comparison

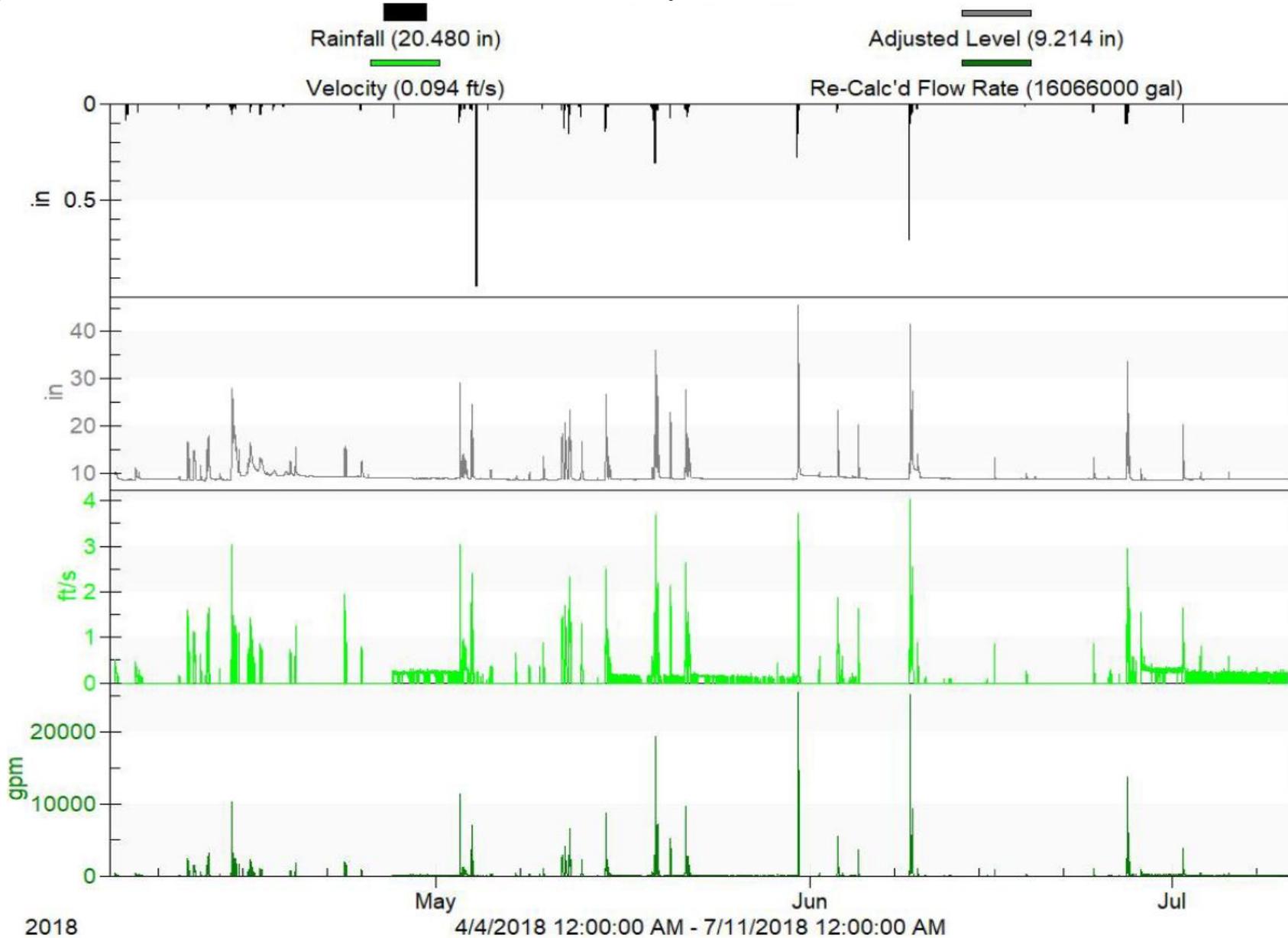


Figure A-3: Meter Location #3 Rainfall and Meter Data Comparison

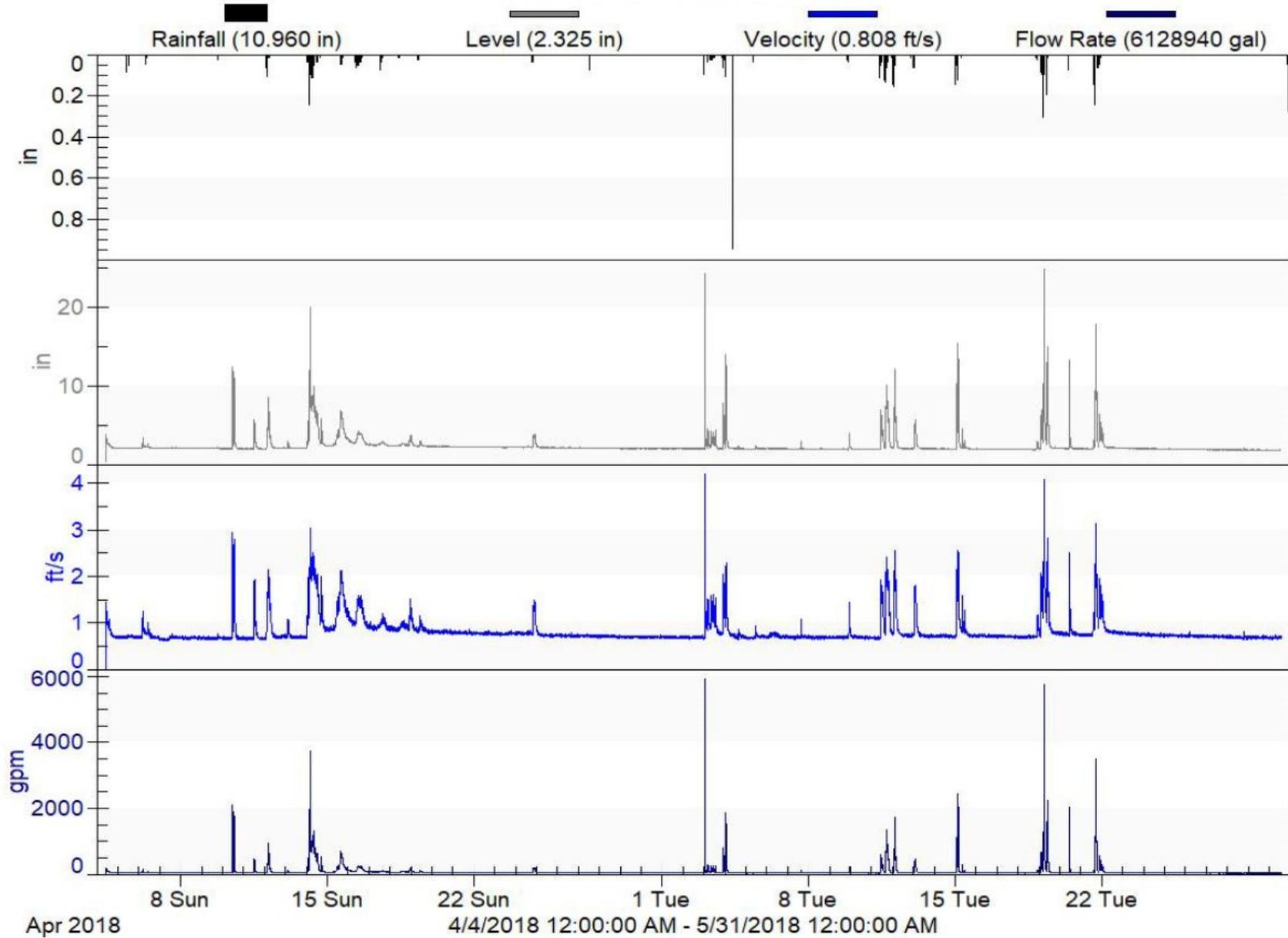


Figure A-4: Meter Location #4 Rainfall and Meter Data Comparison

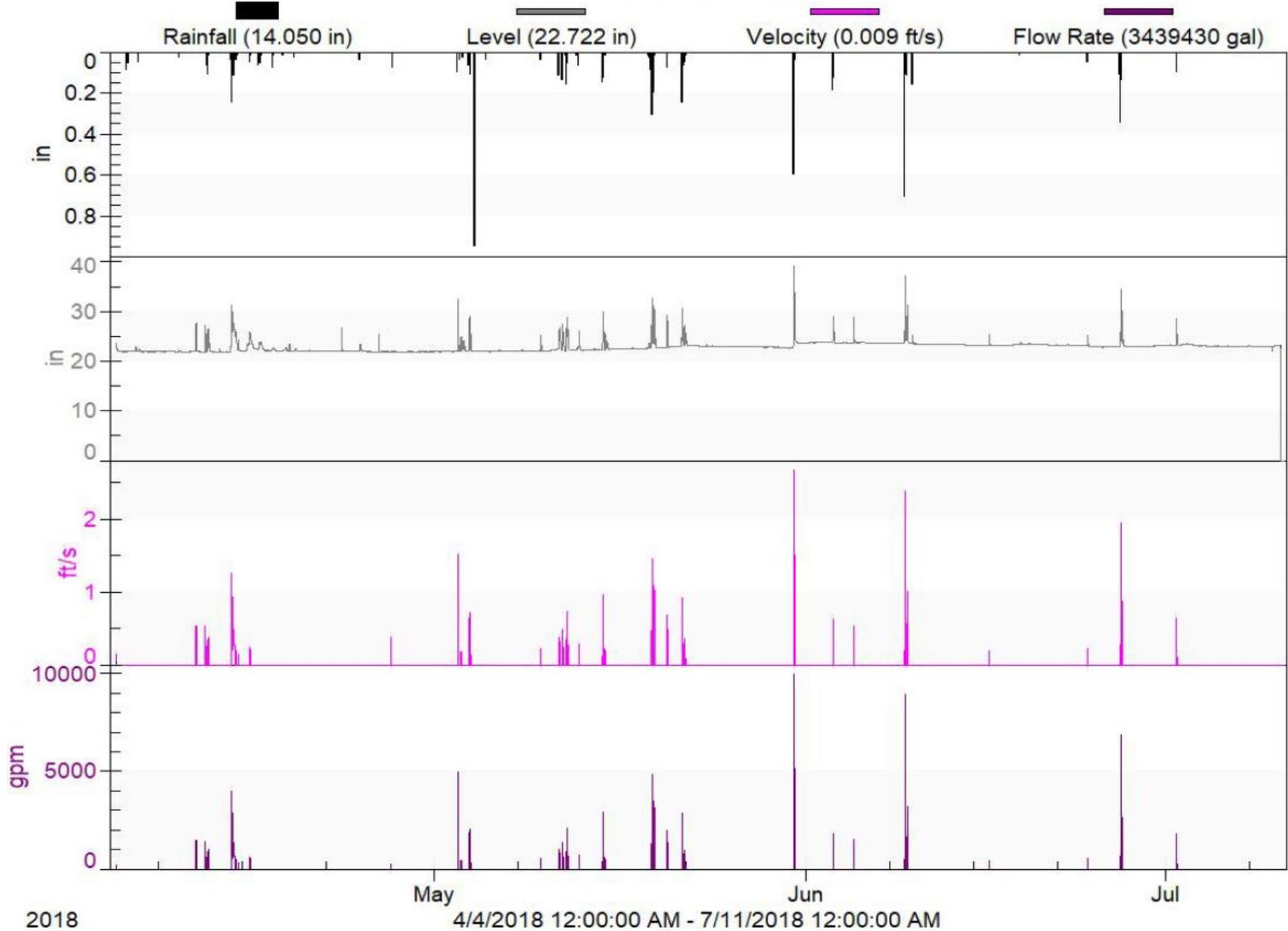


Figure A-5: Meter Location #5 Rainfall and Meter Data Comparison

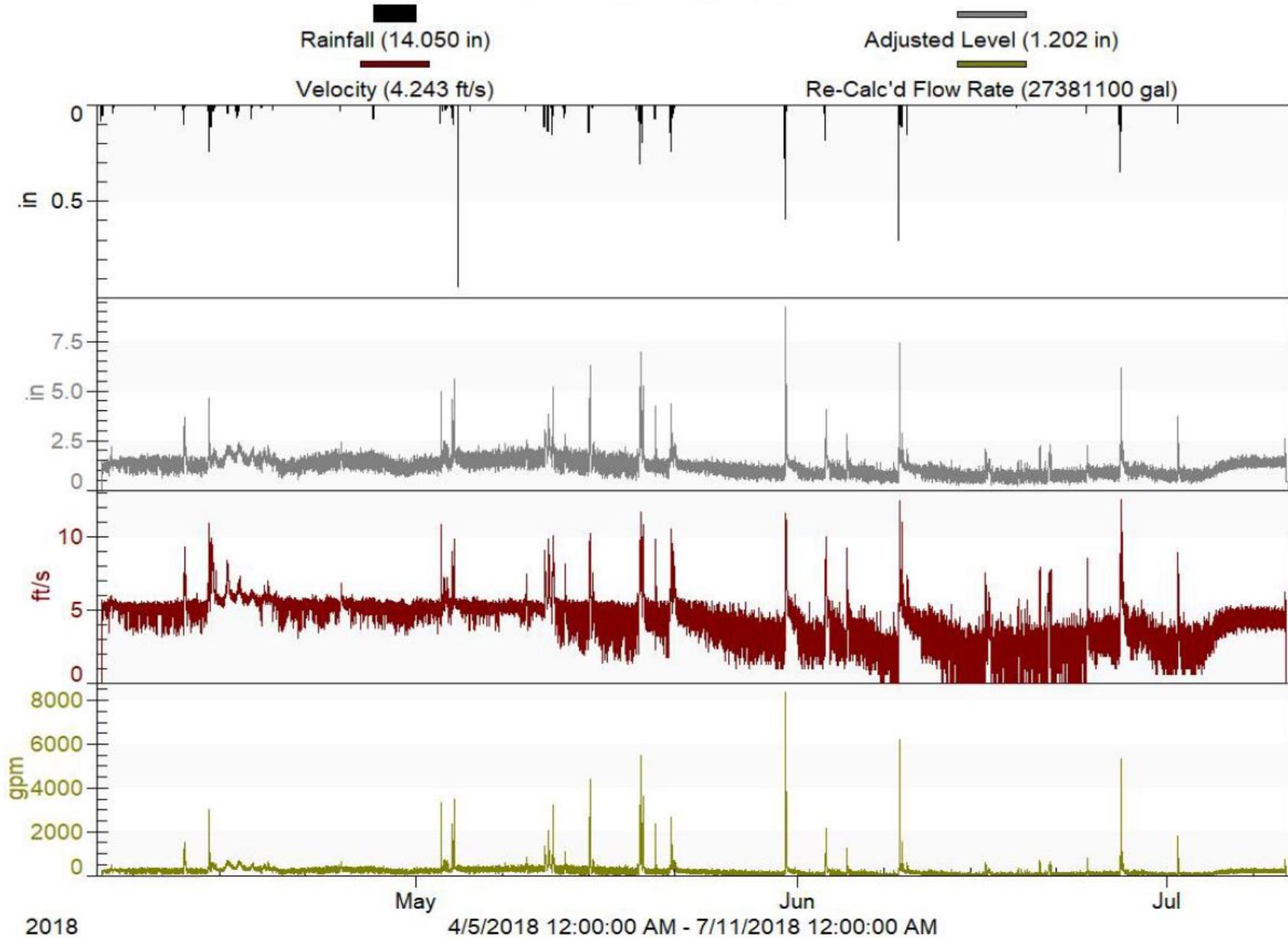


Figure A-6: Meter Location #6 Rainfall and Meter Data Comparison

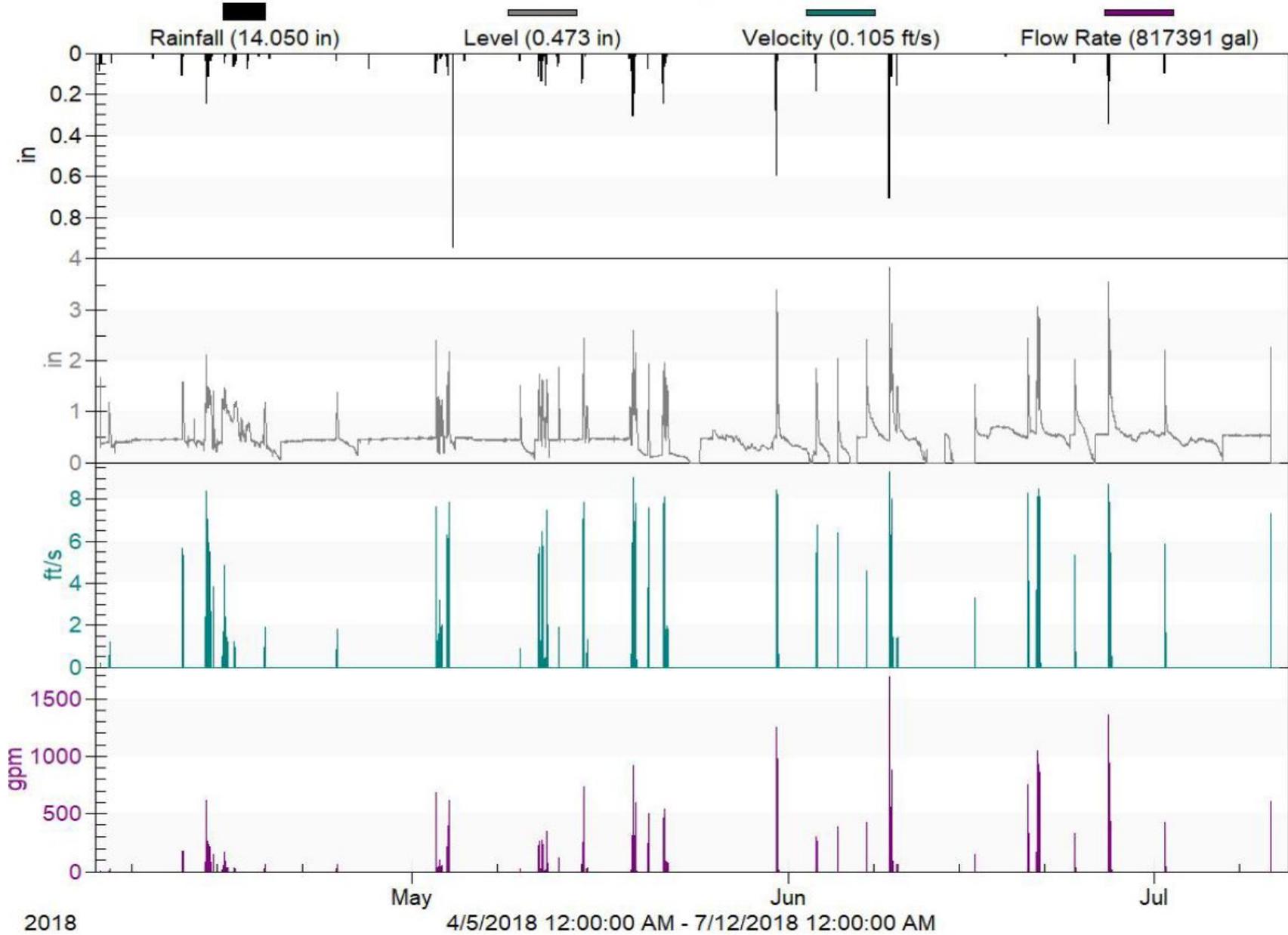


Figure A-7: Meter Location #7 Rainfall and Meter Data Comparison

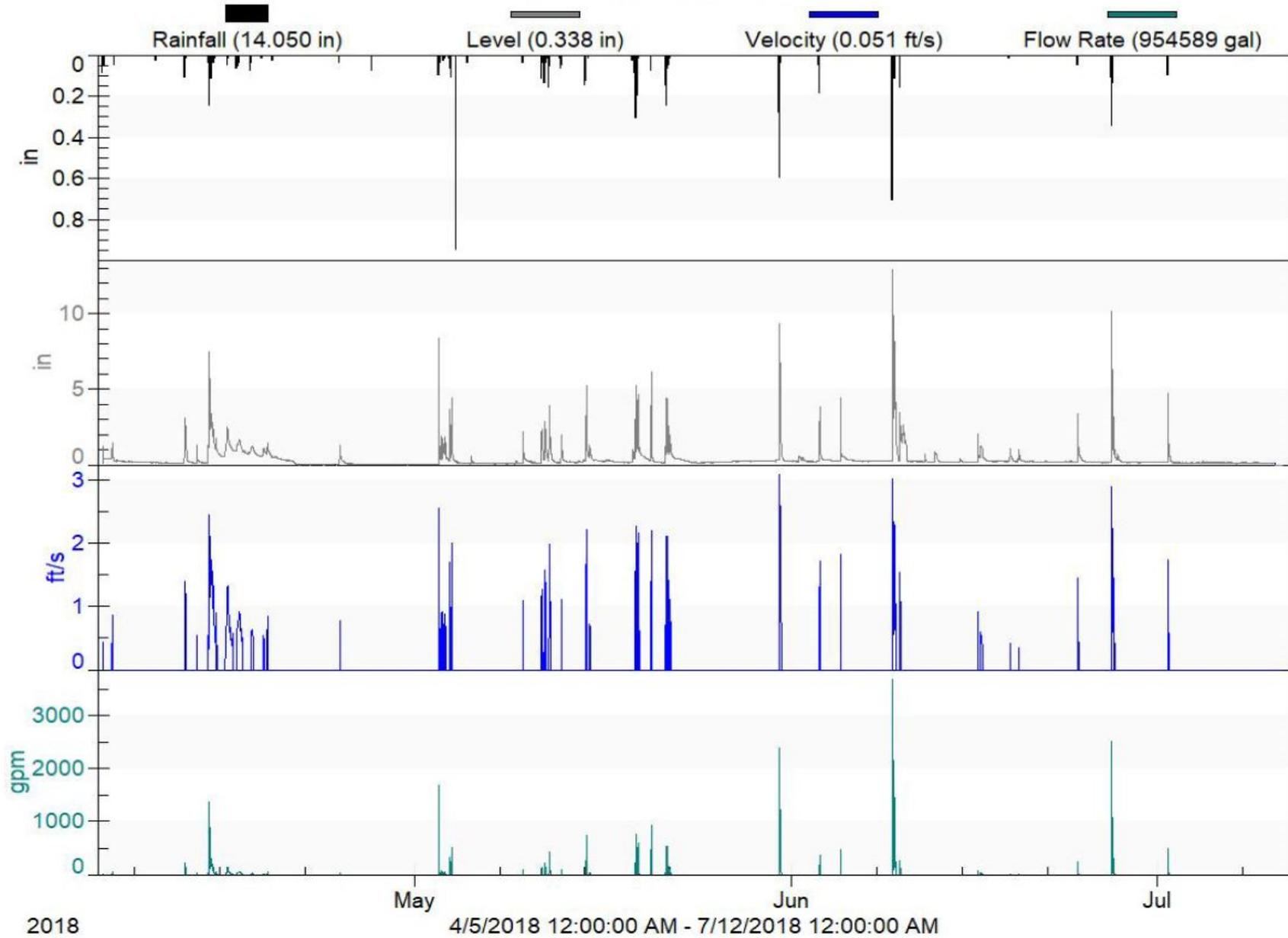


Figure A-8: Meter Location #8 Rainfall and Meter Data Comparison

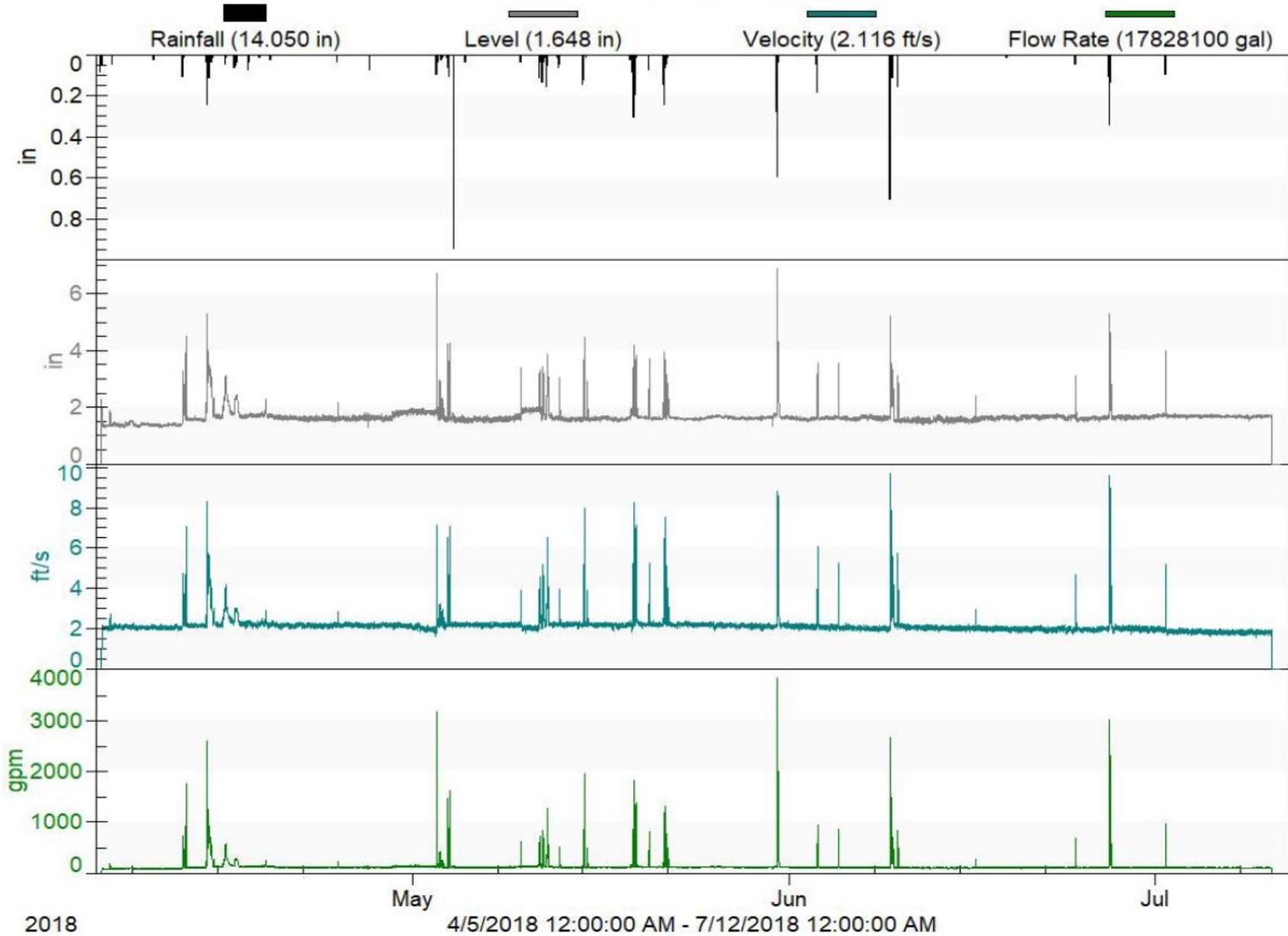


Figure A-9: Meter Location #9 Rainfall and Meter Data Comparison

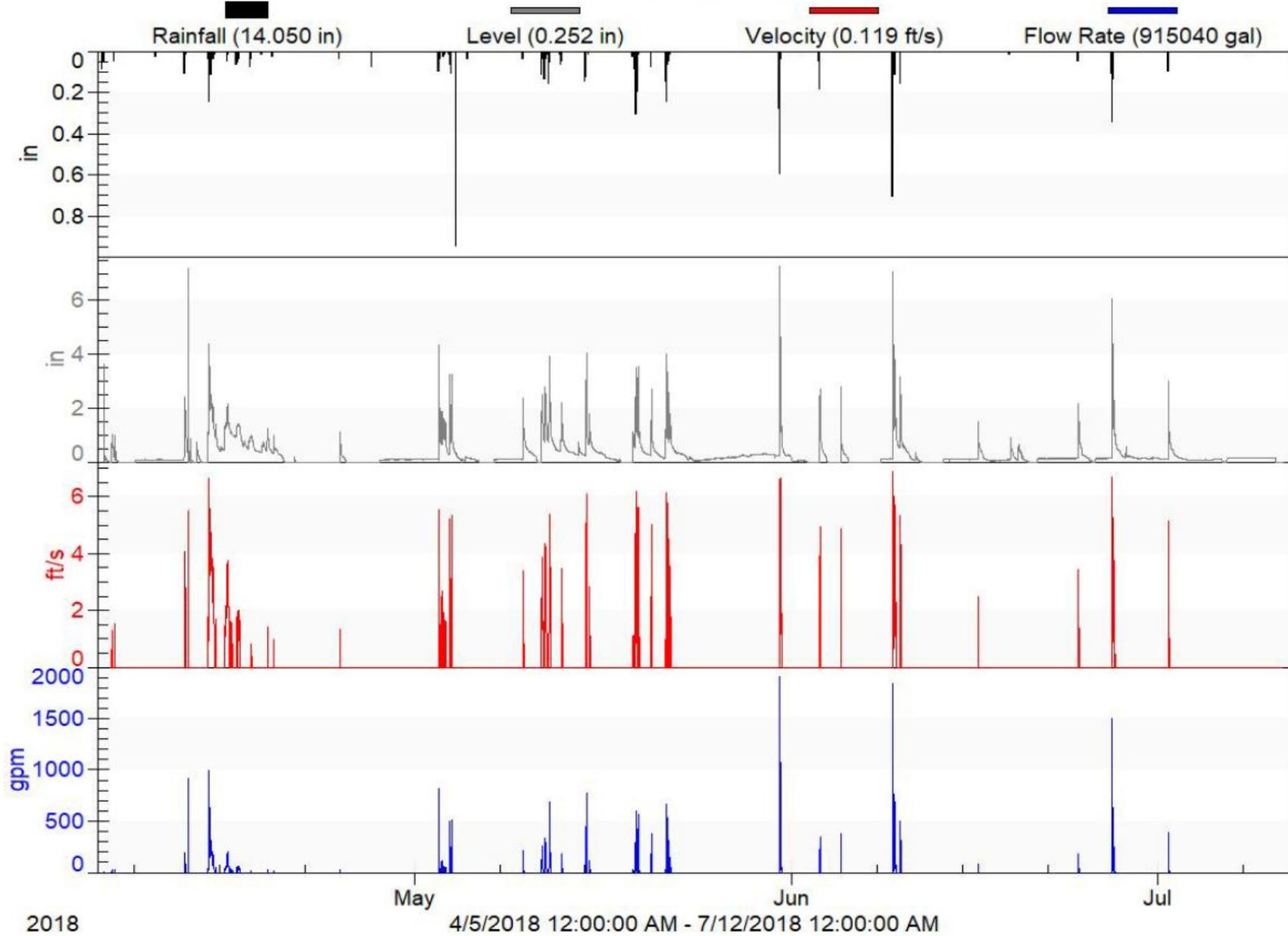


Figure A-10: Meter Location #10 Rainfall and Meter Data Comparison

