Appendix H MODEL CALIBRATION

(Included on CD)

Appendix H MODEL CALIBRATION

Characteristic dry weather flow (DWF) parameters and wet weather flow (WWF) characteristics were determined for each applicable flow monitoring station, including a comparison with data observed during the 2016 and 2017 flow monitoring periods to ensure overall consistency.

The model is calibrated to the monitored DWF, considering weekday and weekend flow patterns. The calibrated sanitary system model is then used to perform the wet weather calibration to monitored WWF events. Parameters were input to the hydraulic model on a trial basis and the routed flow hydrographs produced by the model at each flow monitoring site were compared to the observed monitored flow. The parameters were then varied in a systematic manner within a reasonable range until an acceptable fit to the observed flow was obtained. Comparisons were made between modeled versus monitored flow, depth, velocity, and volume. The calibration prioritized representing PWWF and total flow volume for each monitoring location, as these parameters are more indicative of potential capacity restrictions. Parameters for velocity and depth typically indicate significant differences between modeled and observed data, as field conditions such as sediment depth, minor defects and obstructions, and actual pipe slope in the vicinity of the flow monitor may vary from modeled conditions.

Calibration included modification of parameters such as wastewater generation rate, manning's n, and RTK values. The available flow monitoring data was evaluated in terms of overall data quality.

H.1 CALIBRATION CHALLENGES

Challenges encountered during model calibration include flow splits, flow monitors in series, spatial variation of regional wastewater flows, and flow monitor data quality.

Sewer networks often have various manholes with pipe bifurcation where flow may travel into two or more pipes. The exact contribution of flow to a downstream flow monitor is dependent on the characteristics of these flow splits and their response to varying levels of flow. The upstream catchment for flow monitoring sites 3 and 5 (old town) has several instances of bifurcation, which added a degree of uncertainty to the development of calibrated parameters. Without several concurrent monitors in place capturing a large array of flow regimes, the assumed flow splits and physical layout of the model must be relied upon.

Many of the flow monitors in the 2017 flow monitoring study were aligned in series, such that a downstream monitor receives flow from one or more upstream monitors. As part of the calibration process, the most upstream area is calibrated first and subsequent calibration for downstream areas are based on the difference in areas between the sewer-sheds. To accomplish this, flows are subtracted for monitors in series to get the associated flow for the difference in areas. There are inherent errors introduced when subtracting flow monitors in series due to variations in data quality, and travel time between monitors. Despite the induction of

error, the use of unique parameters for each area between successive monitors provides increased resolution on both dry weather diurnal patterns and wet weather flow responses.

For each monitor in series, the initial DWF parameter estimation assumed a straight subtraction of the DWF value. Flow data form the 2016 flow monitoring study was used to individually calibrate Flow Monitoring Shed 7A. Flow monitor connectivity for the calibration period is shown in **Figure H-1**.

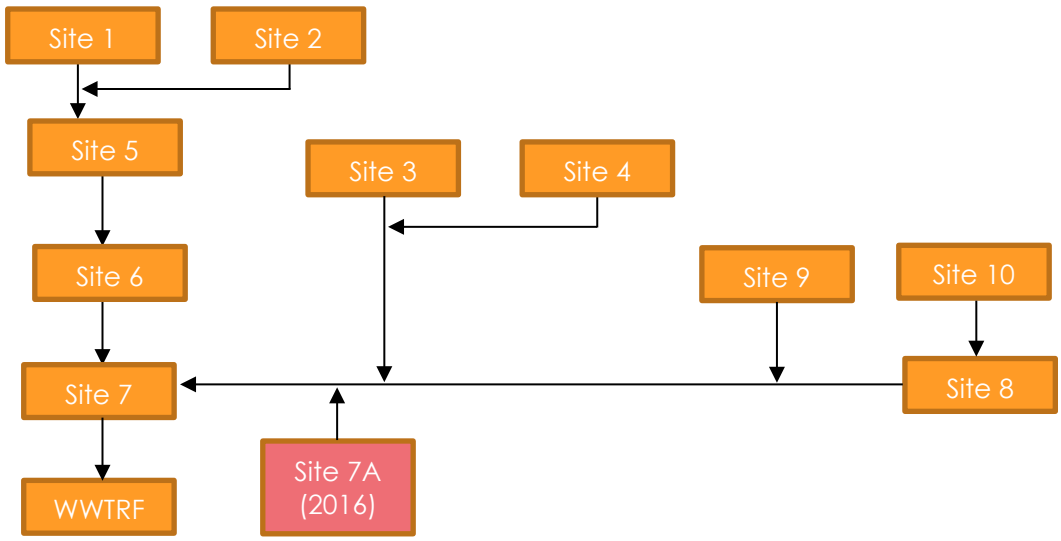


Figure H-1 Flow Monitoring Schematic

Regional wastewater flow from SMD1 is pumped through a 13.5 mile forcemain before connecting to the Regional Sewer trunk near the intersection of Hwy 193 and Stardust Lane. Calibration of flow from the SMD1 sewer-shed (Shed 4) was required to more accurately calibrate flow in downstream flow monitoring sheds. The spatial variation of rainfall between the SMD1 collection shed and the City of Lincoln impacts the wet weather flow response observed in the collection system. High resolution rainfall data from the SMD1 collection system was not available for use in calibration of the wet weather model. Therefore, rainfall data recorded in the City of Lincoln during a widespread storm event was used for calibration of Shed 4. Significant amounts of rain fell throughout Northern California between January 7th, 2017 and January 12th, 2017. Rainfall data from this wet weather flow event was used for calibration of flow from the SMD1 sewer-shed.

The PWWF simulated in the modeled scenarios was reduced to accurately represent the peak flow outlined in the existing servicing agreement, despite the calibration of wet weather flow parameters.

While raw data from flow monitors was made available, a review indicated that the quality of the data was not consistent between locations. The quality varied for each flow monitoring

location. In several instances, the flow monitor itself had erratic and unstable depth and velocity readings or complete velocity or level drop outs. The culmination of these issues is translated into the area-velocity computed flow which can affect the PWWF and volume that are compared to the calibration simulations. Interpretation of the flow monitoring data was required during calibration to assess the presence of outlier instantaneous spikes or drop outs, or inconsistencies between calibration and validation periods that could account for discrepancies. Despite variations in the quality of data between flow monitoring locations, the overall data quality was considered adequate for the purposes of calibration.

H.2 DRY WEATHER CALIBRATION

Dry weather flow calibration of the model was assessed both qualitatively by visual inspection, and quantitatively through an analysis of the maximum, minimum, and average flows for the period. The DWF model results for the flow monitoring sites were plotted and compared to the observed values.

H.2.1 Selection of Suitable Dry Weather Days

The 2017 flow monitoring study conducted by V&A Consulting Engineers (V&A) was performed over a period of two months from January 4th, 2017 to March 7th, 2017. Open channel flow monitoring was performed at nine sites using submerged area-velocity sensors, and volumetric time flow monitoring was performed at two pump stations with state loggers. Rainfall data was collected during the monitoring period by two rain gauges, intended to capture rainfall in the northern and southern regions of the collection system. The average of this data was used for the selection of suitable dry weather days. Average rainfall during the flow monitoring period is presented in **Figure H-2**.

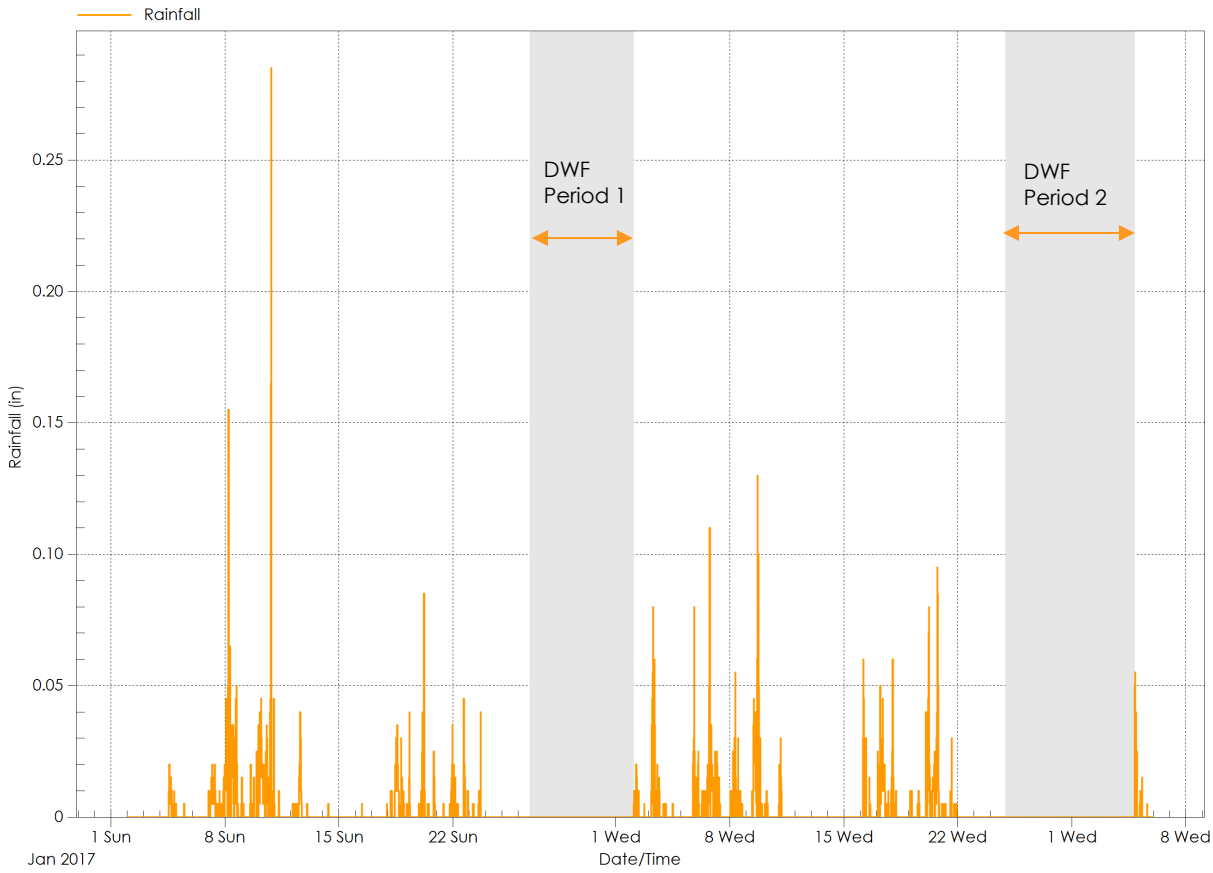


Figure H-2 2017 Rainfall Data

There were four main rainfall events that occurred over the course of the flow monitoring period and a total of approximately 15 inches of rain fell. With higher than average rainfall, there were limited suitable dry weather days for use in the dry weather flow calibration. Two dry weather periods were selected that had three days of dry weather prior to allow rainfall dependent infiltration (RDII) to recede. Each period provided approximately a week worth of dry weather flow data.

DWF Period 1: January 26th, 2017 (5:00 PM) through February 2nd, 2017 (2:15 AM)

DWF Period 2: February 24th, 2017 (10:15 PM) through March 4th, 2017 (8:30 PM)

H.2.2 Flow Monitoring Site 1

Description: Flow monitoring Site 1 recorded flow from the Nicolaus Road Pump Station collection shed. Flow was monitored with both a pump station state logger and a flow monitor downstream of the forcemain discharge in the 2017 flow monitoring study. Flow in this collection shed was monitored by V&A previously for use in *City of Lincoln – Nicolaus Road Pump Station Collection Shed Flow Monitoring* (Stantec, 2016). Flow was monitored at five different locations for 10 weeks from January 23rd, 2016 to April 3, 2016. Data from this study was used to distribute DWF throughout the shed as opposed to percent contributing area distribution used elsewhere in the system. The Flight Line Drive pump station is located within this shed.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. These graphs were used to assess the best fit manning's n value, and assess the quality of the data. The theoretical level vs. velocity curve presented in **Figure H-3**, doesn't provide a "good" fit to the observed data. Level and velocity vary from theoretical values because the flow monitor is located immediately downstream of the pump station's discharge location. Therefore, flow values cannot be represented by open channel flow. Visual inspection was the primary focus for calibration of Site 1.

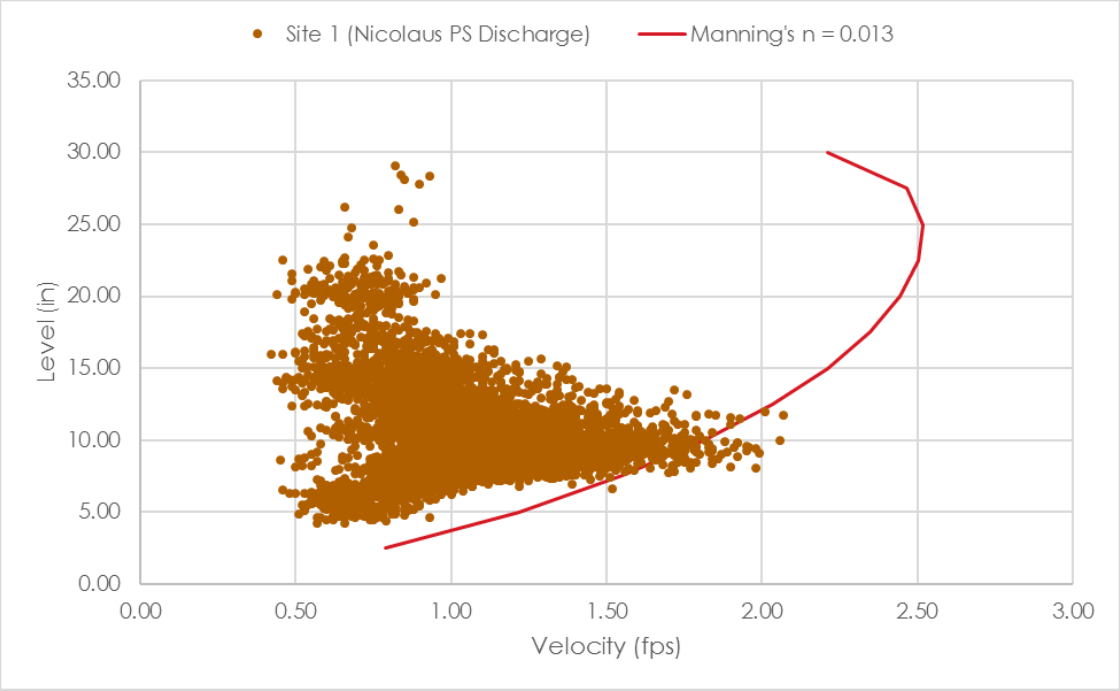


Figure H-3 Site 1: Level vs. Velocity Data

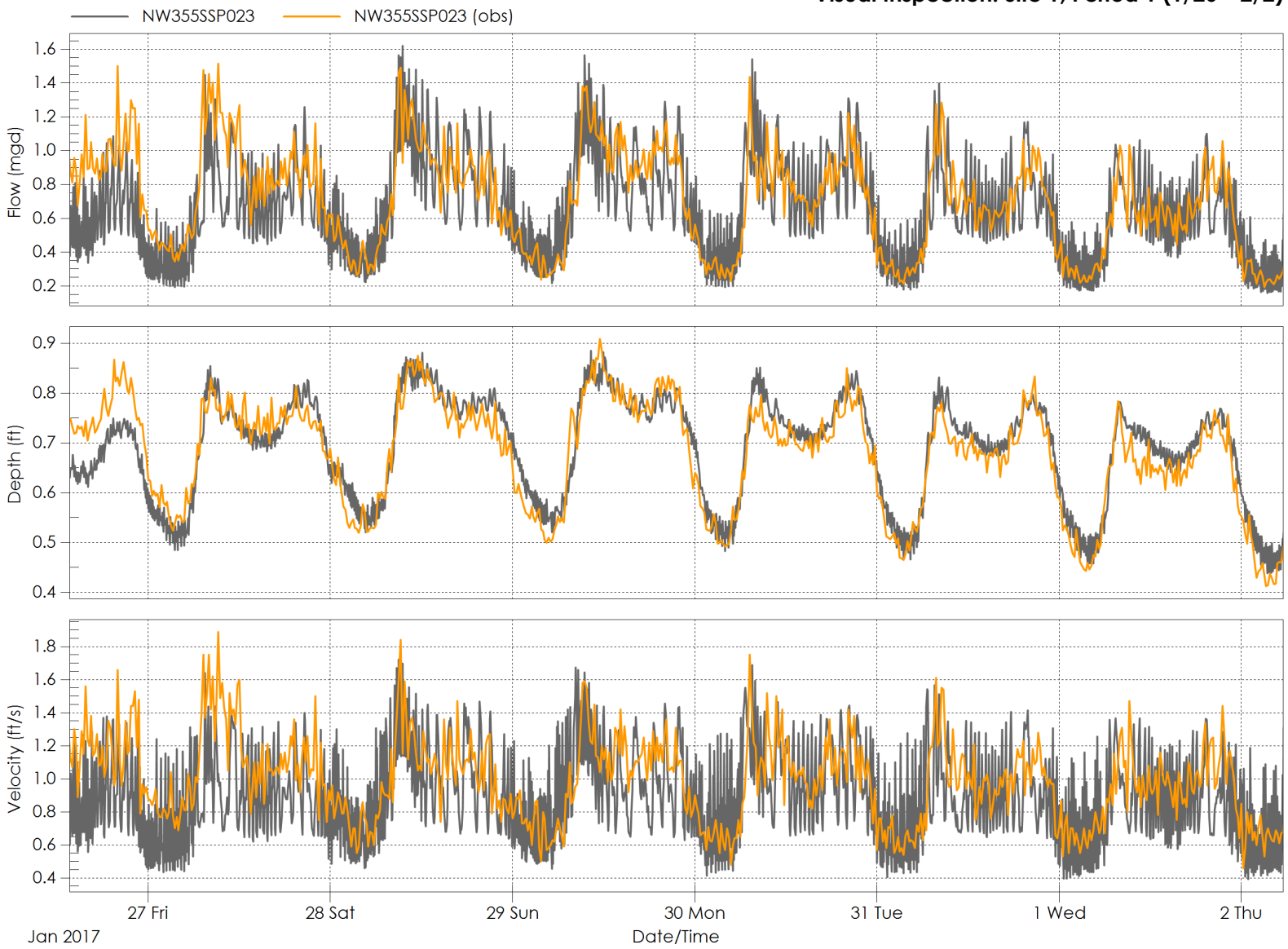
Site 1 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	0.72	1.63	0.17	4.61
	Measured	0.72	1.52	0.21	4.59
	Error	0.5%	7.7%	**-20.9%**	0.5%
Period 2 (2/24 - 3/4)	Modeled	0.72	1.64	0.16	5.71
	Measured	0.65	1.59	0.15	5.15
	Error	10.9%	3.4%	5.0%	10.9%

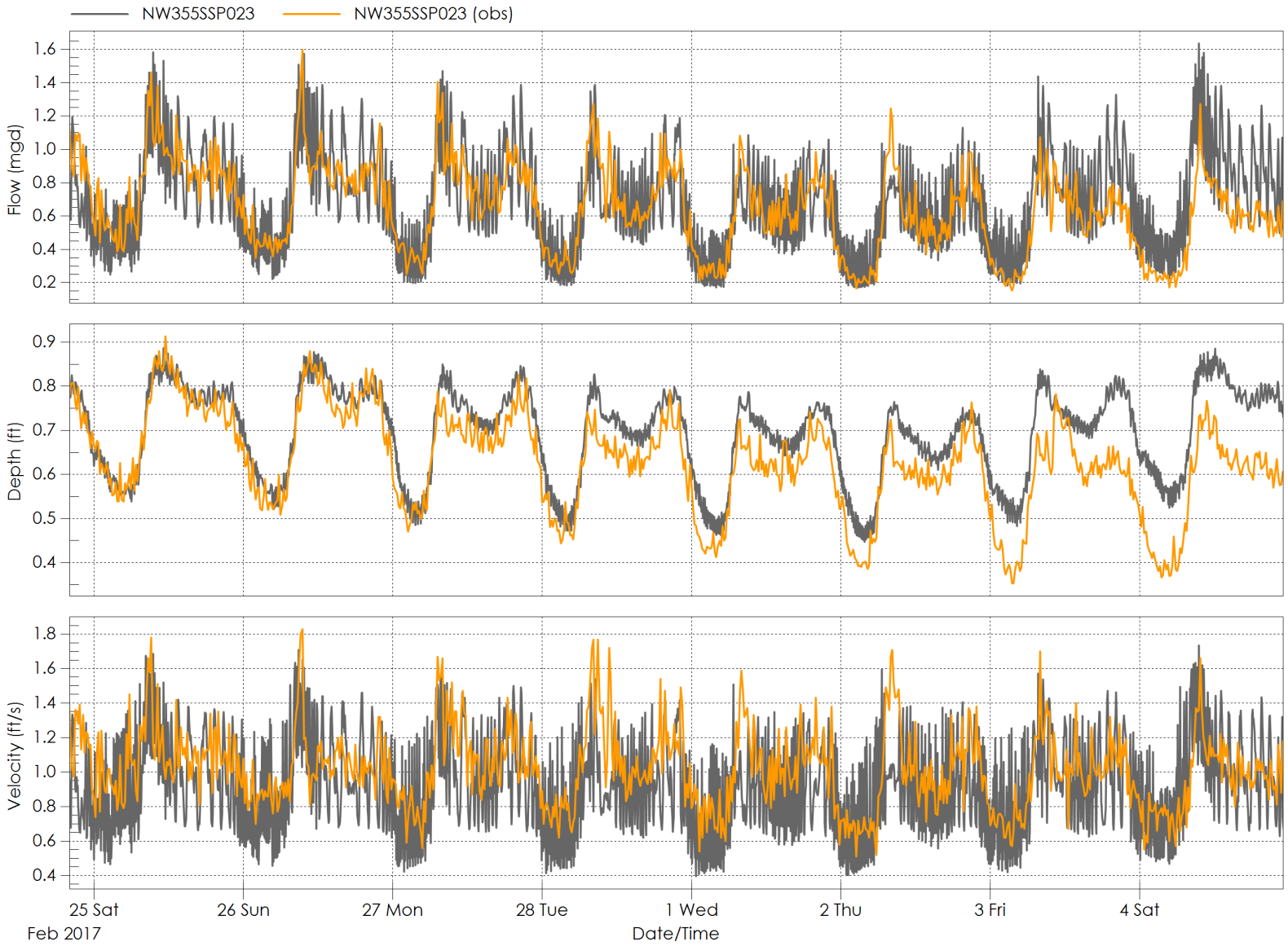
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	0.95	1.81	0.40
	Measured	1.00	1.89	0.46
	Error	-5.0%	-4.2%	-13.3%
Period 2 (2/24 - 3/4)	Modeled	0.95	1.81	0.41
	Measured	1.02	1.83	0.51
	Error	-6.4%	-1.4%	**-19.5%**

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.70	0.88	0.46
	Measured	0.68	0.91	0.43
	Error	3.1%	-3.6%	6.4%
Period 2 (2/24 - 3/4)	Modeled	0.70	0.88	0.44
	Measured	0.63	0.91	0.35
	Error	11.7%	-4.0%	**24.4%**

Visual Inspection: Site 1, Period 1 (1/26 – 2/2)



Visual Inspection: Site 1, Period 2 (2/24 – 3/4)



H.2.3 Flow Monitoring Site 2

Description: Flow monitoring Site 2 recorded flow data from the collection shed along North Joiner Parkway. This site experienced surcharging during the flow monitoring period. A "dumping event" from a pump station or release of a clog in the upstream sewer, was experienced on March 3rd.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. These graphs were used to assess the best fit manning's n value, and quality of the flow monitoring data. The low velocity and high depth indicate a surcharged condition was present during the flow monitoring period. The theoretical level vs. velocity curve presented in **Figure H-4**, doesn't provide a "good" fit to the observed data due to the surcharged condition. Therefore, visual inspection was the primary focus for calibration of Site 2.

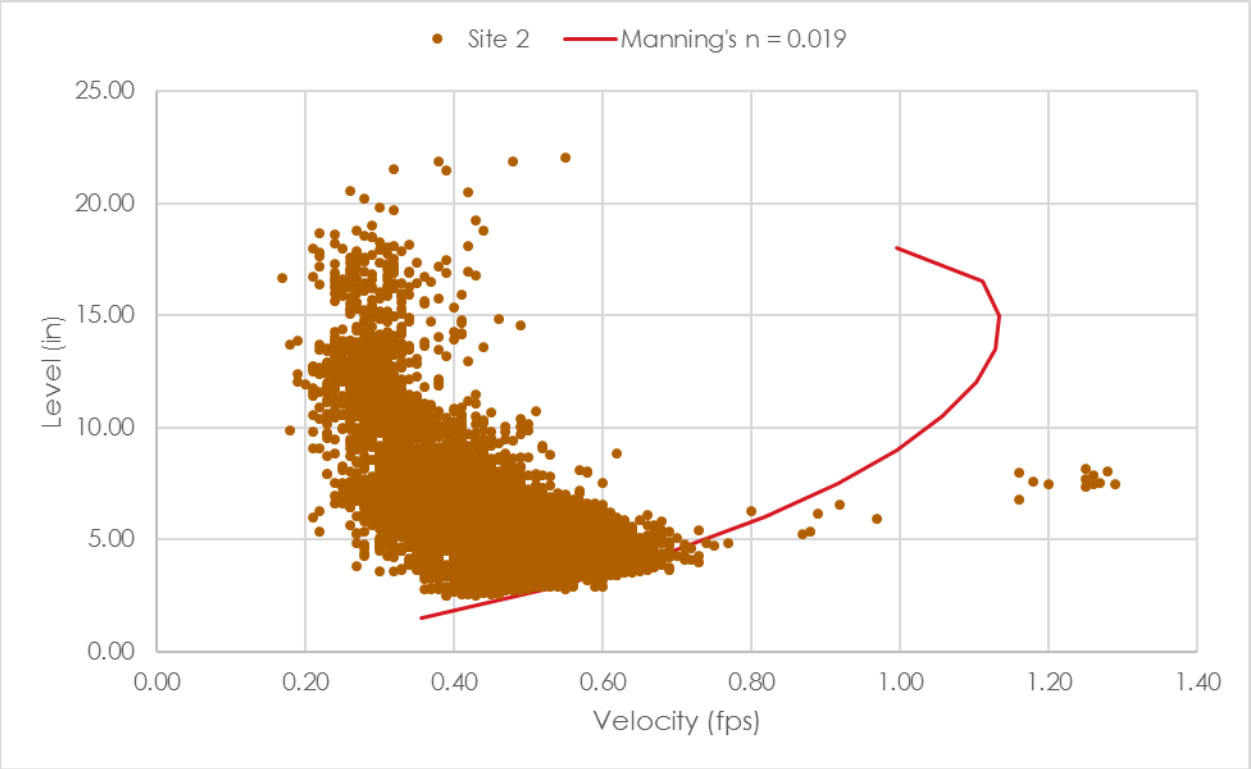


Figure H-4 Site 2: Level vs. Velocity Data

Site 2 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	0.12	0.22	0.05	0.80
	Measured	0.13	0.23	0.05	0.81
	Error	-2.0%	-6.4%	-0.9%	-2.0%
Period 2 (2/24 - 3/4)	Modeled	0.12	0.22	0.04	0.97
	Measured	0.12	0.63 (1)	0.04	0.94
	Error	3.6%	**-65.5%**	**15.8%**	3.6%

1. Flow spike associated with dumping event during DWF period 2.

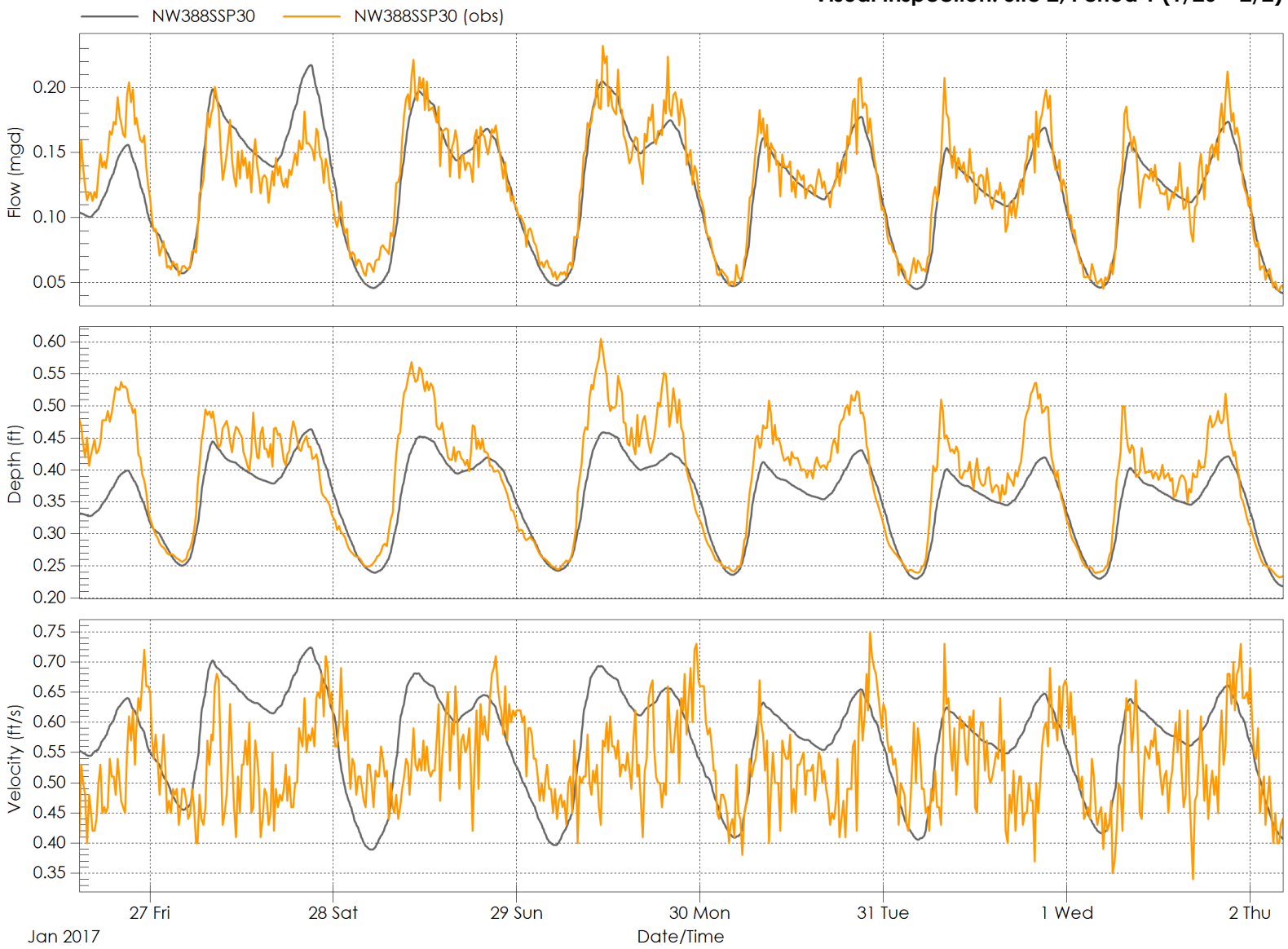
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	0.57	0.72	0.39
	Measured	0.54	0.75	0.34
	Error	6.9%	-3.5%	14.4%
Period 2 (2/24 - 3/4)	Modeled	0.57	0.72	0.39
	Measured	0.51	1.29 (1)	0.27
	Error	11.9%	**-43.9%**	**44.1%**

1. Velocity spike associated with dumping event during DWF period 2.

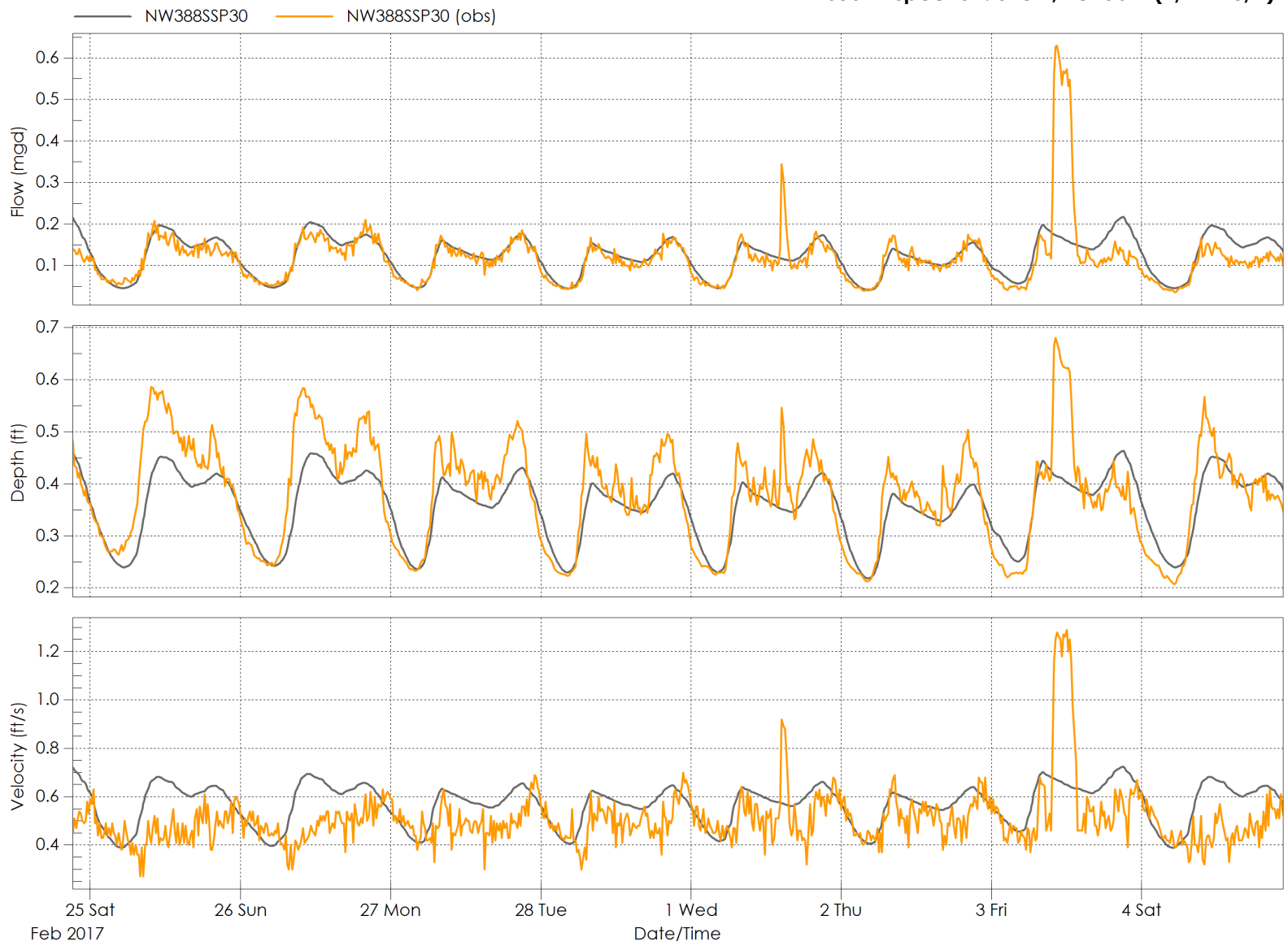
Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.36	0.46	0.23
	Measured	0.39	0.61 (1)	0.24
	Error	-8.6%	**-23.4%**	-3.6%
Period 2 (2/24 - 3/4)	Modeled	0.35	0.46	0.22
	Measured	0.38	0.68 (1)	0.21
	Error	-6.5%	**-31.9%**	5.6%

1. Maximum depths associated with surcharged conditions.

Visual Inspection: Site 2, Period 1 (1/26 – 2/2)



Visual Inspection: Site 2, Period 2 (2/24 – 3/4)



H.2.4 Flow Monitoring Site 3

Description: Flow monitoring Site 3 recorded flow data in the E Street trunk sewer. The E Street sewer was constructed as a relief sewer for the "old part of town". The E Street sewer redirected flow from this portion of the collection system to the Regional Sewer in Ferrari Ranch Road. It was assumed for modeling purposes that no flow splits occur. All flow from east of E Street was assumed to flow south down the E Street trunk and flow from west of E Street would continue flowing west through Shed 5. It should also be noted that there is an existing pump station upstream of this flow monitoring location.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. The theoretical data presented in **Figure H-5**, does not provide a good fit to the lower end of the observed data. No matter the observed velocity, depth did not drop below five inches. This could be due to affects from the upstream pump station and/or drop connections, inaccurate slope and/or invert elevation at the connection to the regional sewer (which doesn't match crown to crown), sediment noted in the pipe (0.75-inches), etc.

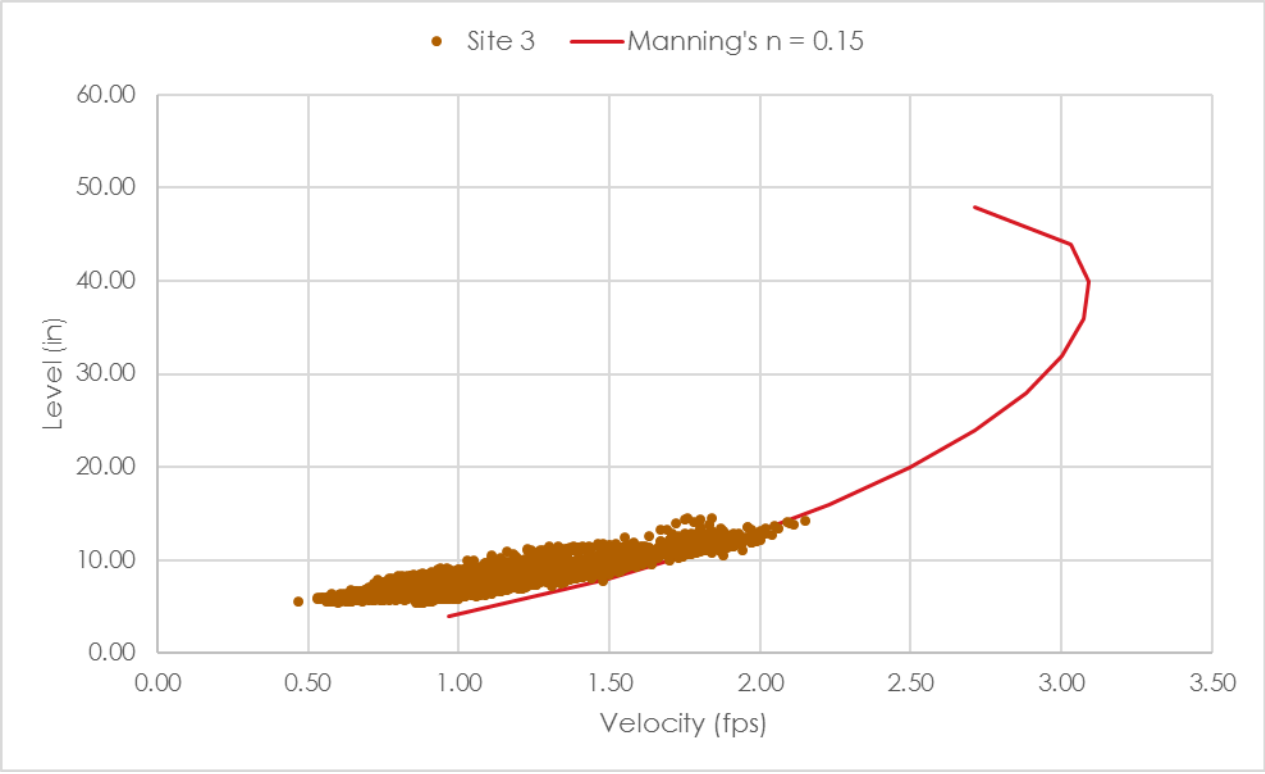


Figure H-5 Site 3: Level vs. Velocity Data

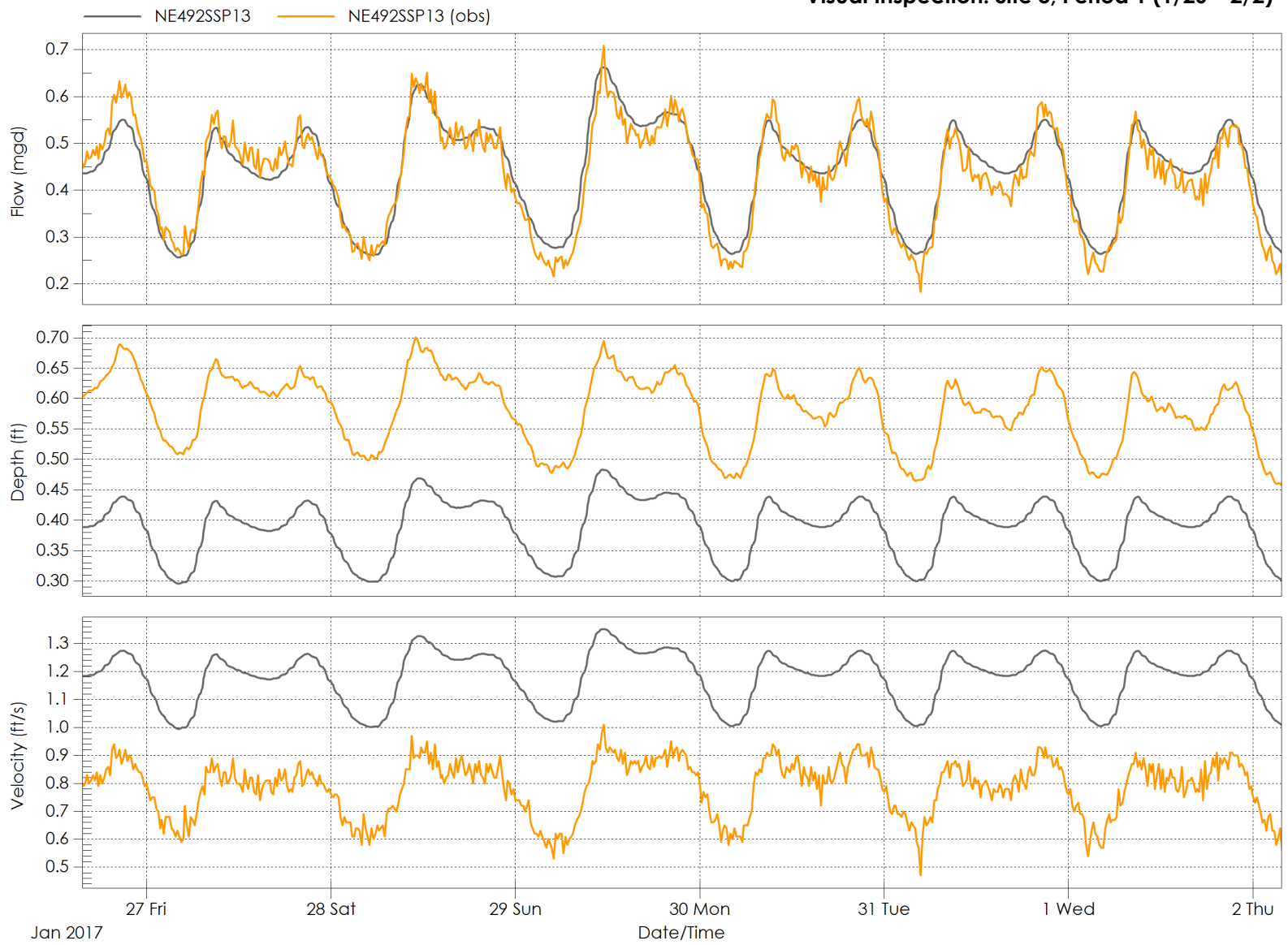
Site 3 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	0.44	0.66	0.26	2.82
	Measured	0.43	0.71	0.18	2.77
	Error	1.9%	-6.5%	**40.2%**	1.9%
Period 2 (2/24 - 3/4)	Modeled	0.44	0.66	0.26	3.49
	Measured	0.45	0.75	0.23	3.56
	Error	-1.9%	-11.7%	14.0%	-1.9%

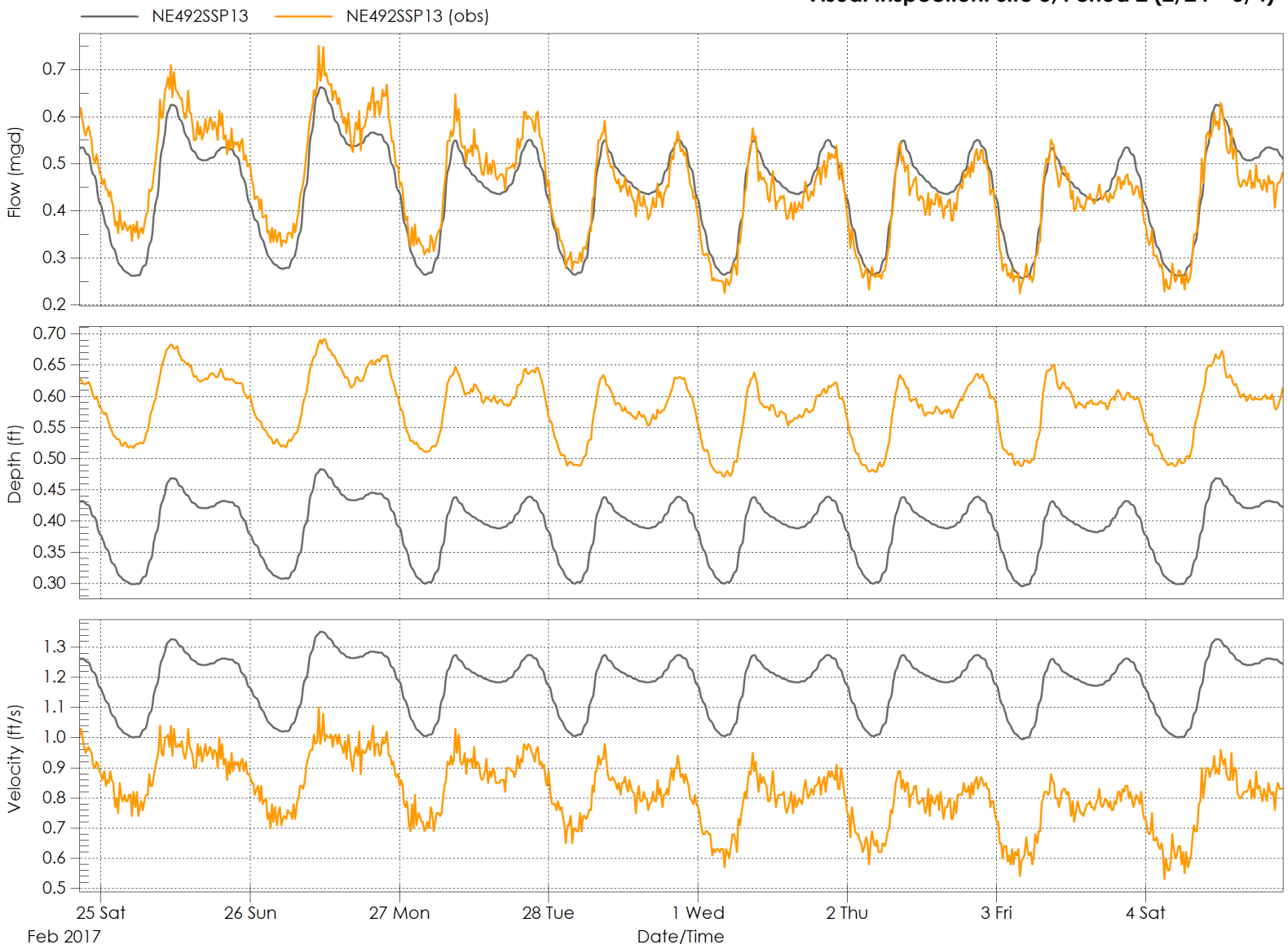
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	1.18	1.35	1.00
	Measured	0.79	1.01	0.47
	Error	**49.7%**	**33.9%**	**111.7%**
Period 2 (2/24 - 3/4)	Modeled	1.18	1.35	1.00
	Measured	0.82	1.10	0.53
	Error	**44.0%**	**22.9%**	**87.7%**

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.39	0.48	0.30
	Measured	0.58	0.70	0.47
	Error	**-33.2%**	**-31.1%**	**-36.4%**
Period 2 (2/24 - 3/4)	Modeled	0.39	0.48	0.30
	Measured	0.58	0.69	0.47
	Error	**-33.3%**	**-30.2%**	**-37.3%**

Visual Inspection: Site 3, Period 1 (1/26 – 2/2)



Visual Inspection: Site 3, Period 2 (2/24 – 3/4)



H.2.5 Flow Monitoring Site 4

Description: Flow monitoring Site 4 recorded flow discharged from the Mid-Western Placer Regional Pump Station. This flow was collected from the SMD1 collection shed. Rainfall data observed in the City of Lincoln is not representative of rainfall in the SMD1 collection shed. Therefore, this shed was primarily calibrated with data from dry weather period 1, in which wide spread rainfall was experienced throughout Northern California.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. The theoretical level vs. velocity curve for Site 4 provided a "good" match for a manning's n value of 0.012, shown in **Figure H-6**.

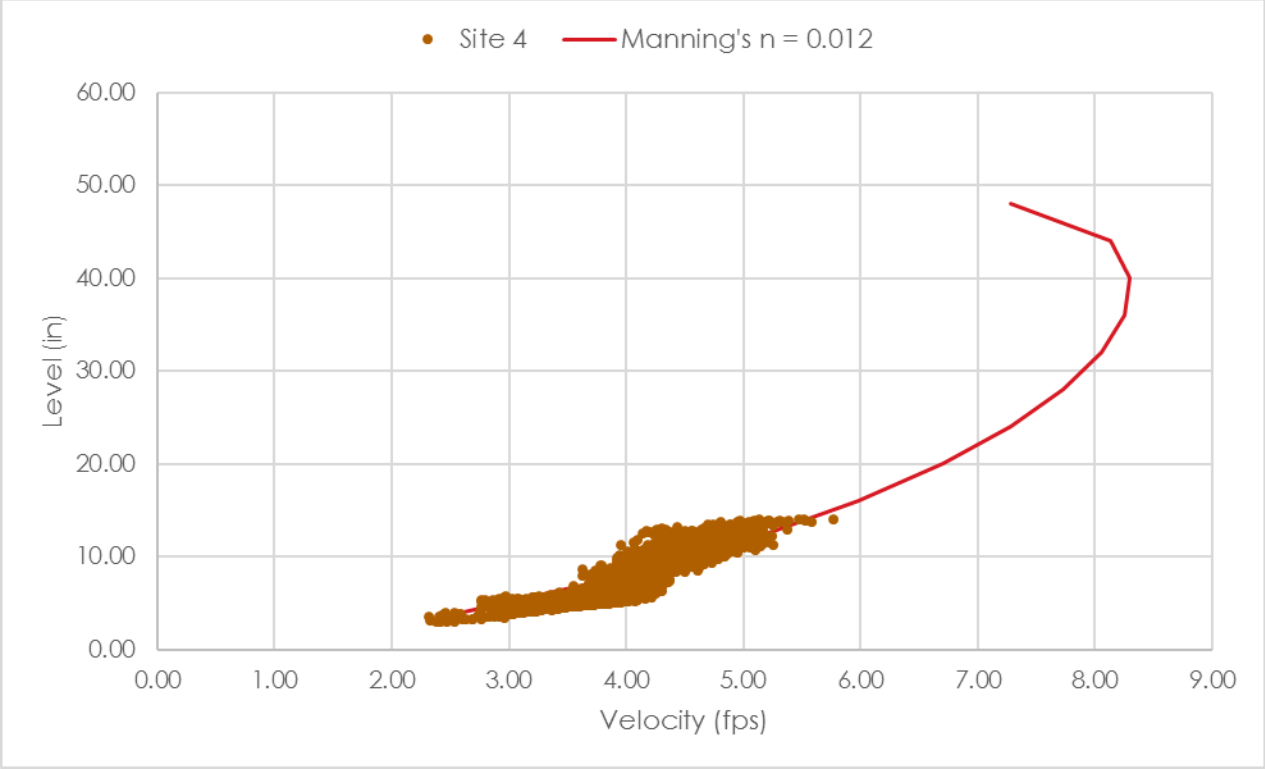


Figure H-6 Site 4: Level vs. Velocity Data

Site 4 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	1.80	3.77	0.46	11.50
	Measured	1.70	3.90	0.50	10.83
	Error	6.3%	-3.4%	-8.8%	6.2%
Period 2 [1] (2/24 - 3/4)	Modeled	1.81	3.77	0.46	14.33
	Measured	2.31	4.80	0.64	18.30
	Error	**-21.7%**	**-21.6%**	**-28.4%**	**-21.7%**

1. Dry weather flow in Flow Monitoring Shed 4 is not adequately represented by dry weather period 2.

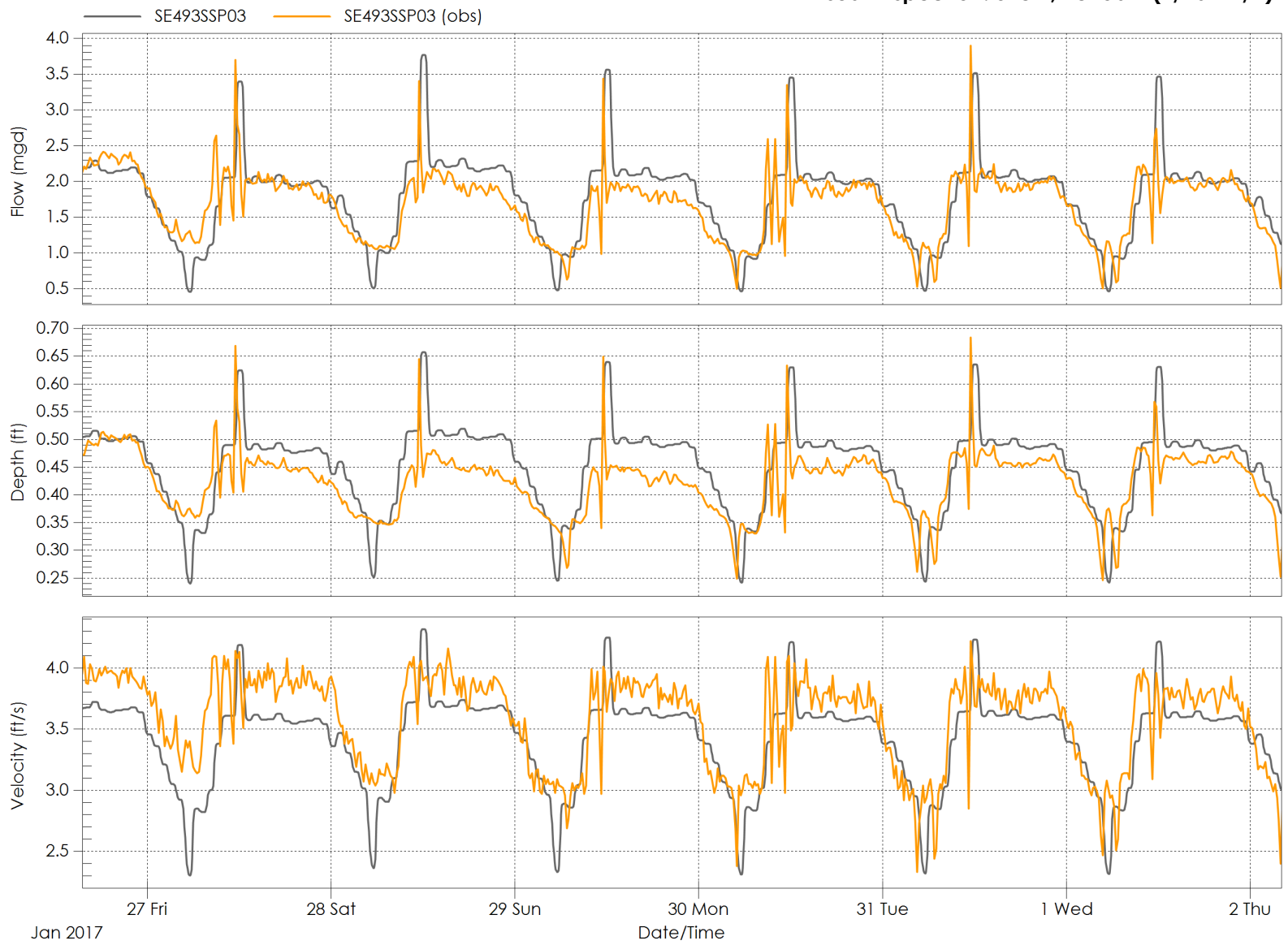
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	3.43	4.32	2.30
	Measured	3.59	4.22	2.33
	Error	-4.5%	2.3%	-1.2%
Period 2 [1] (2/24 - 3/4)	Modeled	3.43	4.32	2.30
	Measured	3.67	4.29	2.32
	Error	-6.5%	0.7%	-0.8%

1. Dry weather flow in Flow Monitoring Shed 4 is not adequately represented by dry weather period 2.

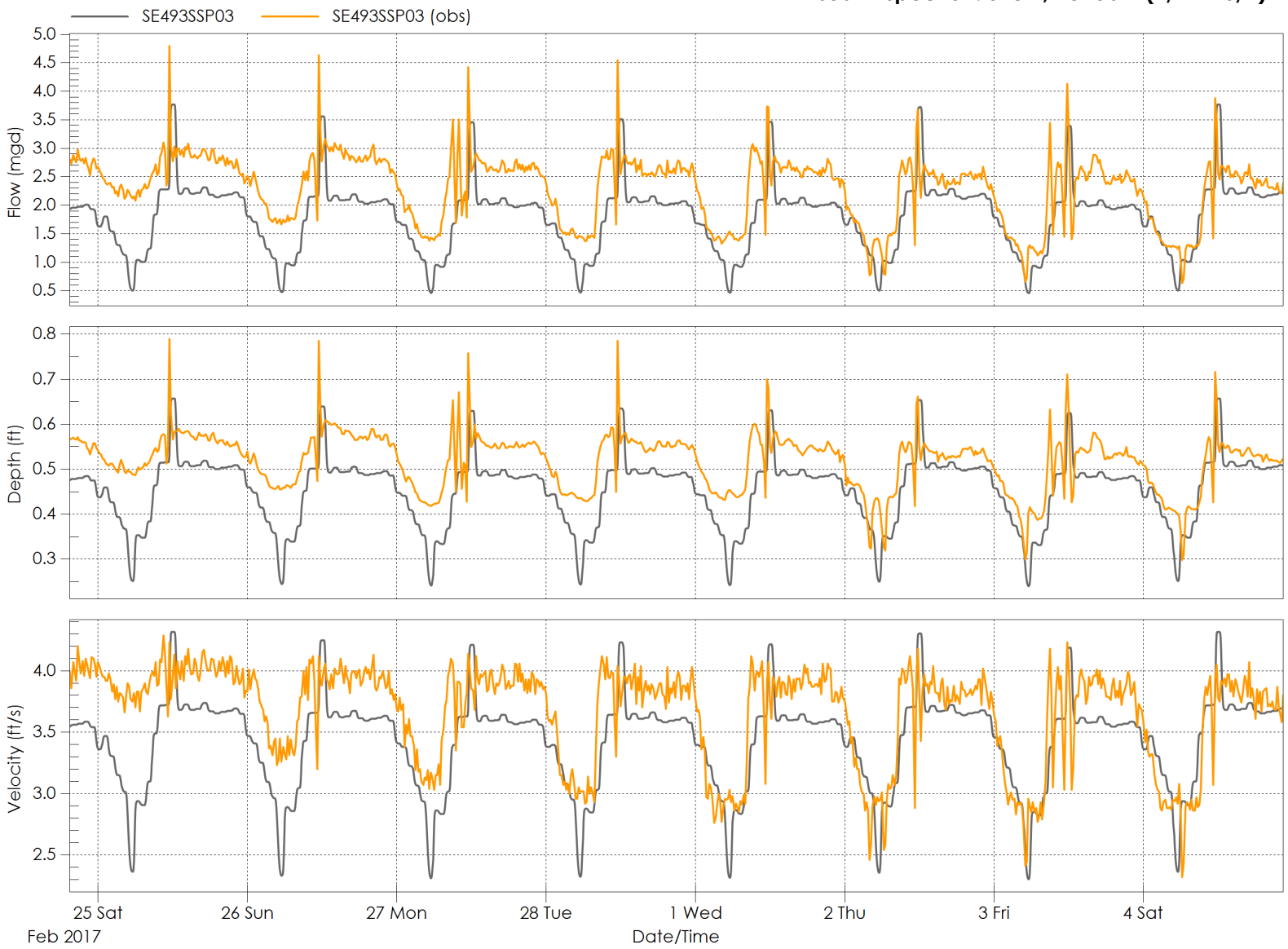
Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.45	0.66	0.24
	Measured	0.43	0.68	0.25
	Error	6.7%	-3.9%	-2.8%
Period 2 [1] (2/24 - 3/4)	Modeled	0.45	0.66	0.24
	Measured	0.52	0.79	0.30
	Error	**-12.3%**	**-16.8%**	**-19.6%**

1. Dry weather flow in Flow Monitoring Shed 4 is not adequately represented by dry weather period 2.

Visual Inspection: Site 4, Period 1 (1/26 – 2/2)



Visual Inspection: Site 4, Period 2 (2/24 – 3/4)



H.2.6 Flow Monitoring Site 5

Description: Flow monitoring Site 5 recorded flow from the oldest portion of the collection system. This flow meter was positioned downstream of flow monitors 1 and 2, and is influenced by discharge from the Nicolaus Road Pump Station. Odd velocity patterns were observed at Site 5 during dry weather period 1. It should also be noted that 2 inches of sediment was observed in the pipe during installation of the flow monitor. There are two pump stations in this flow monitoring shed.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. Data is influenced by the upstream pump stations and does not follow the typical level vs. velocity curve pattern, as seen in **Figure H-7**.

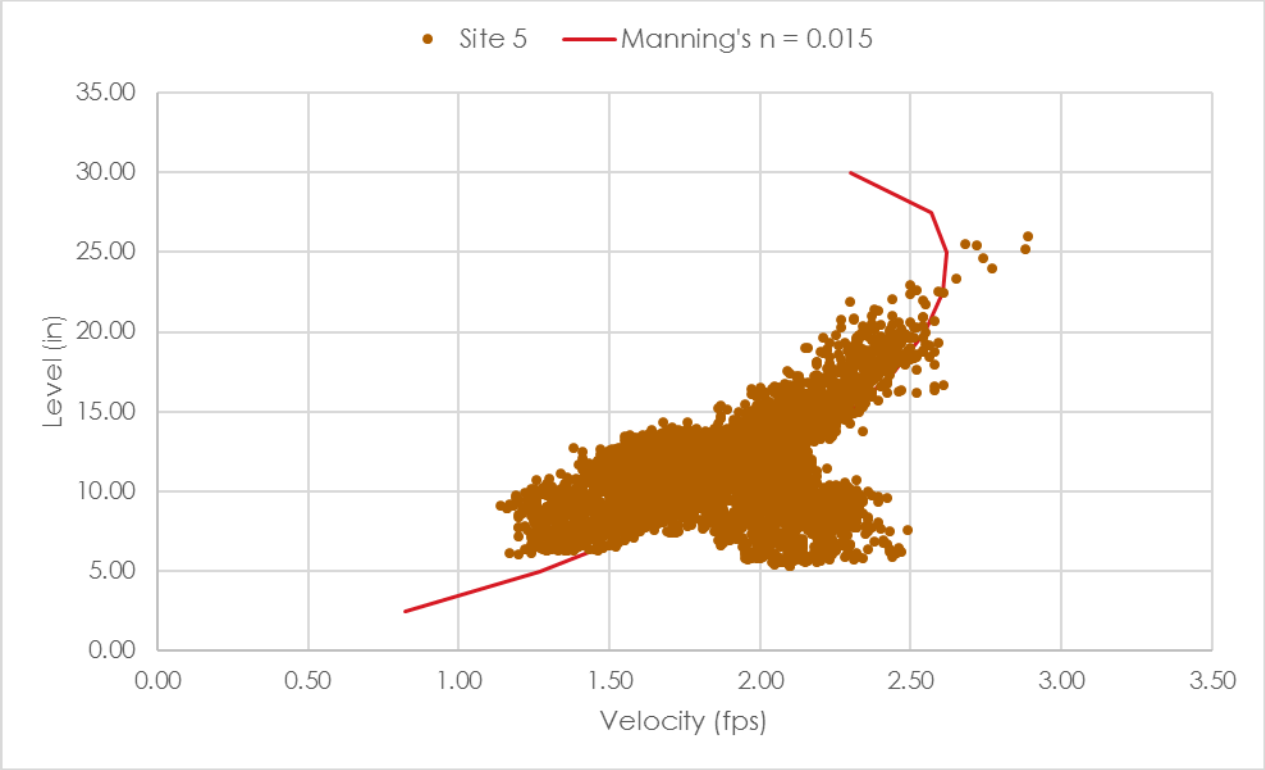


Figure H-7 Site 5: Level vs. Velocity Data

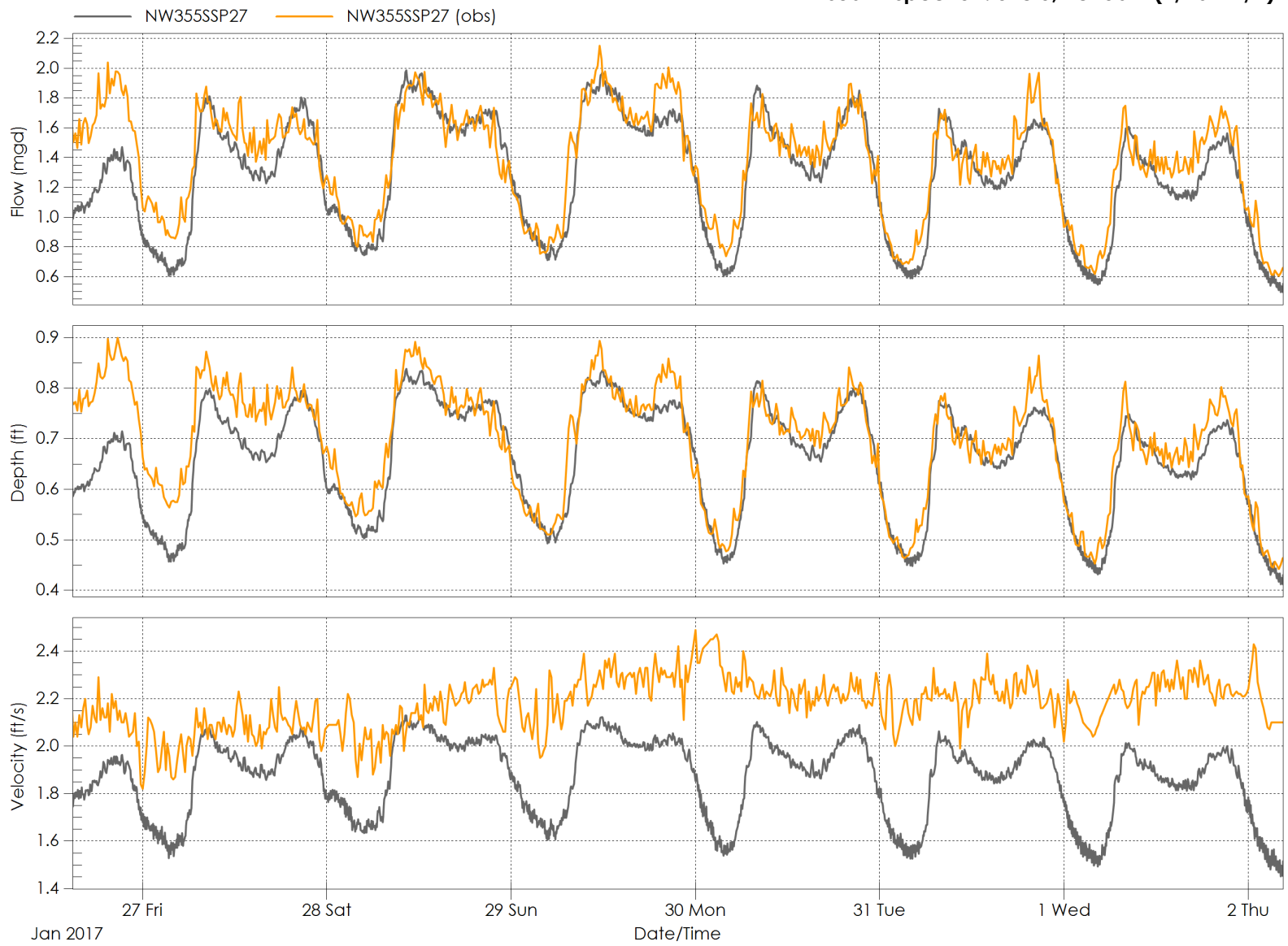
Site 5 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	1.33	2.04	0.55	8.51
	Measured	1.40	2.15	0.62	8.91
	Error	-4.4%	-5.0%	-10.6%	-4.5%
Period 2 (2/24 - 3/4)	Modeled	1.32	2.02	0.52	10.49
	Measured	1.19	2.04	0.43	9.42
	Error	11.3%	-1.2%	**18.9%**	11.3%

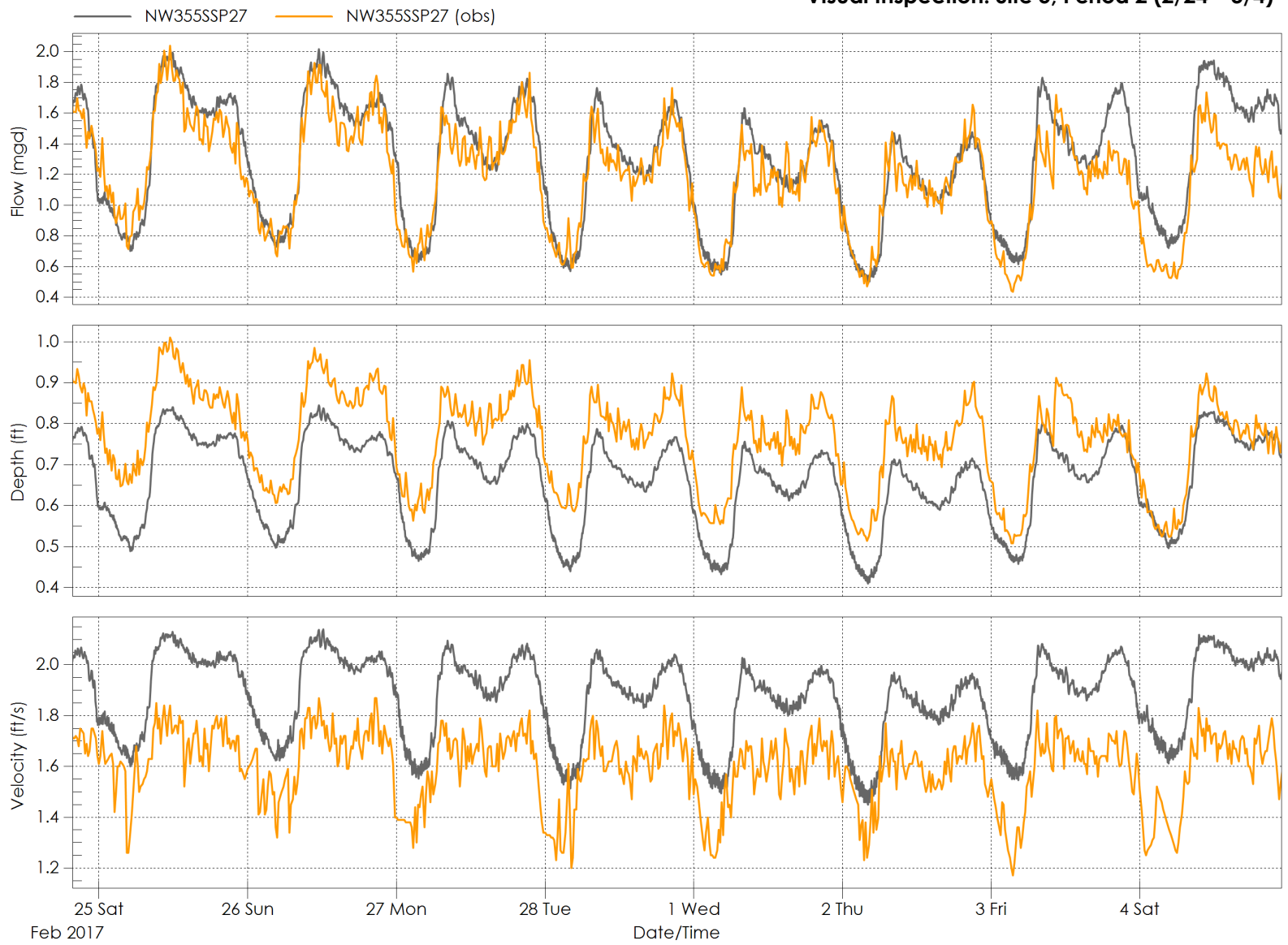
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	1.89	2.15	1.50
	Measured	2.19	2.49	1.82
	Error	-13.5%	-13.8%	**-17.7%**
Period 2 (2/24 - 3/4)	Modeled	1.89	2.14	1.47
	Measured	1.60	1.87	1.17
	Error	**17.9%**	14.3%	**25.6%**

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.67	0.85	0.42
	Measured	0.70	0.90	0.45
	Error	-4.1%	-6.1%	-7.4%
Period 2 (2/24 - 3/4)	Modeled	0.67	0.85	0.44
	Measured	0.76	1.01	0.51
	Error	-11.7%	**-15.9%**	-14.1%

Visual Inspection: Site 5, Period 1 (1/26 – 2/2)



Visual Inspection: Site 5, Period 2 (2/24 – 3/4)



H.2.7 Flow Monitoring Site 6

Description: Flow monitoring Site 6 recorded flow collected along the Moore Road trunk sewer south of the Auburn Ravine sewer crossing. This flow meter was located downstream of flow monitors 1, 2, and 5. Site 6 had the highest rate of rainfall dependent infiltration based on the 2017 V&A Flow Monitoring Report. This may be due to the ravine crossing immediately upstream of this monitoring location.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. The theoretical level vs. velocity curve for Site 6 provided an "excellent" match for a manning's n value of 0.011, shown in **Figure H-8**

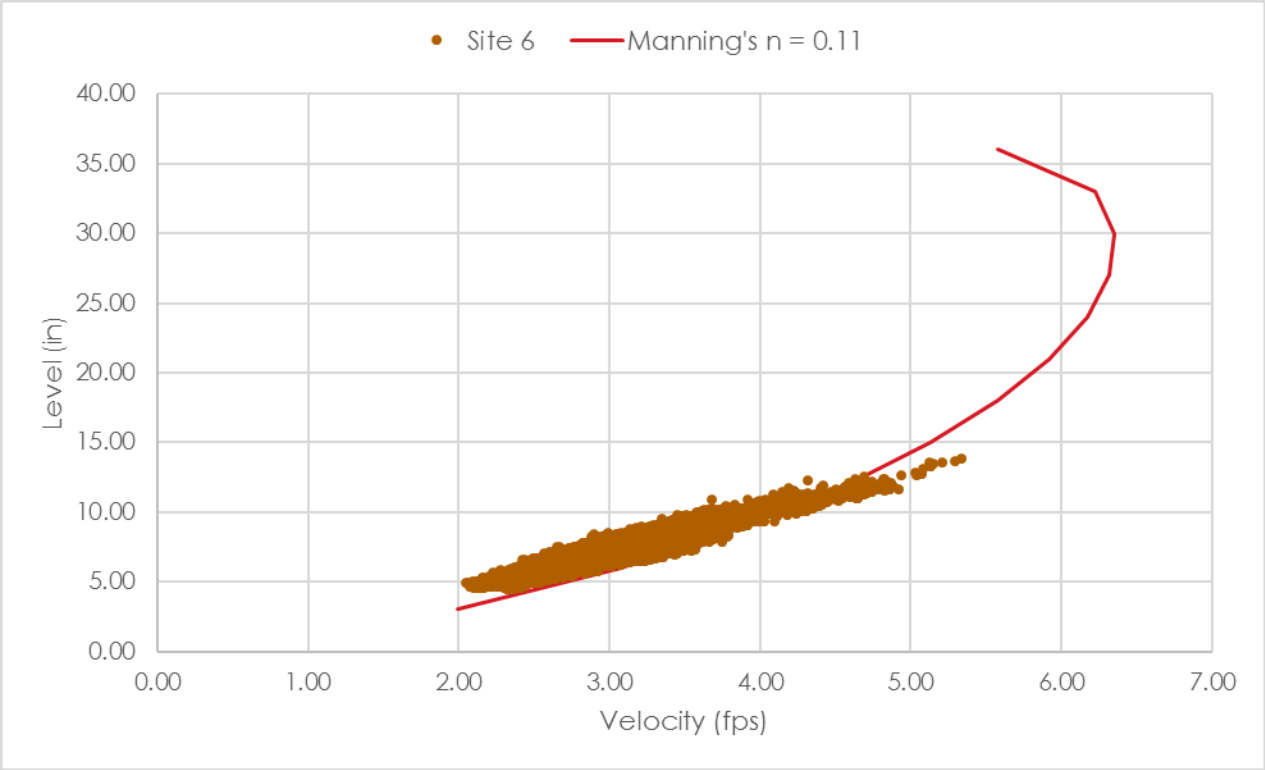


Figure H-8 Site 6: Level vs. Velocity Data

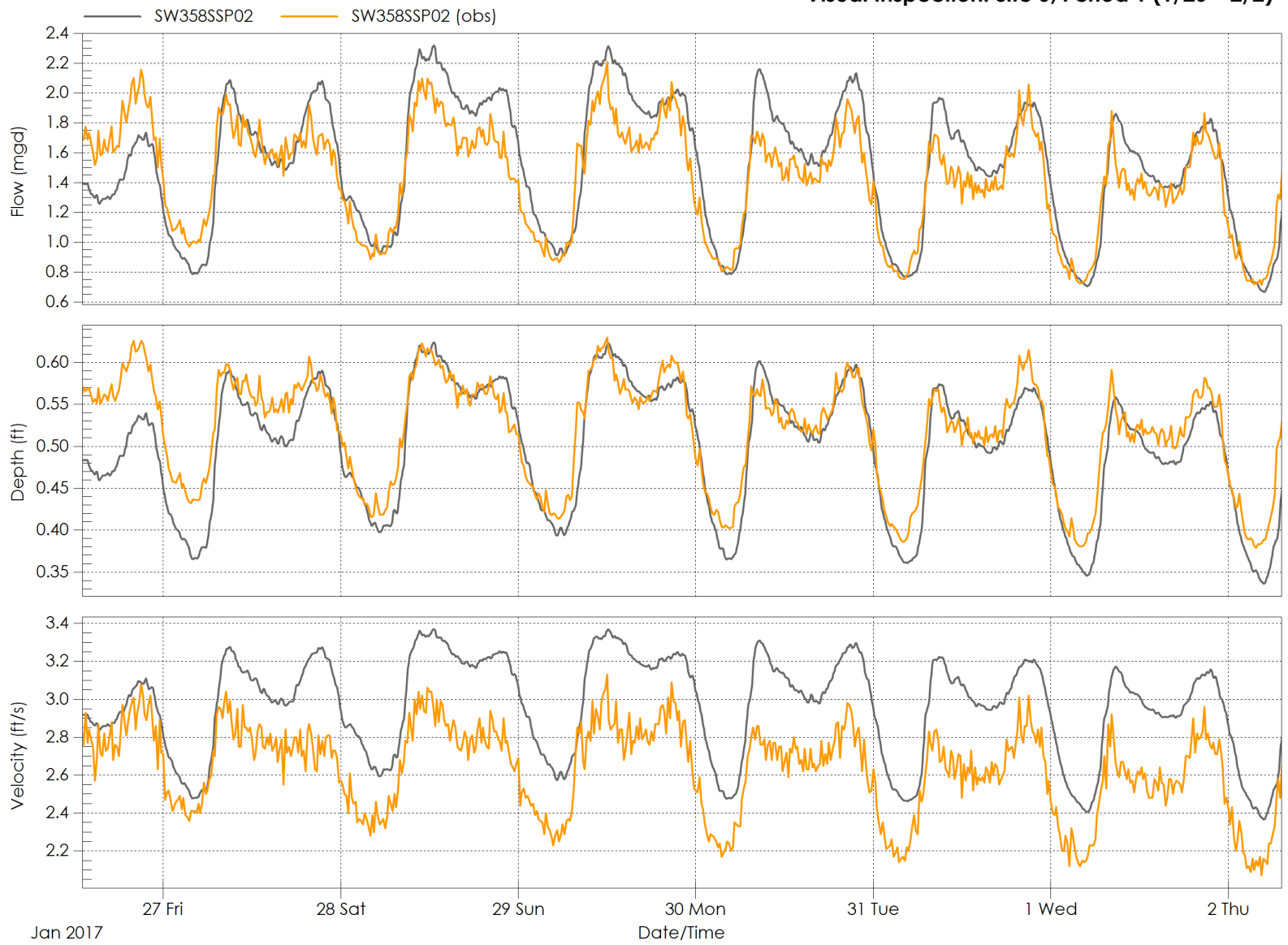
Site 6 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	1.58	2.37	0.73	10.10
	Measured	1.45	2.21	0.72	9.24
	Error	9.4%	7.1%	1.1%	9.4%
Period 2 (2/24 - 3/4)	Modeled	1.57	2.37	0.70	12.45
	Measured	1.59	2.50	0.77	12.62
	Error	-1.4%	-5.2%	-9.1%	-1.3%

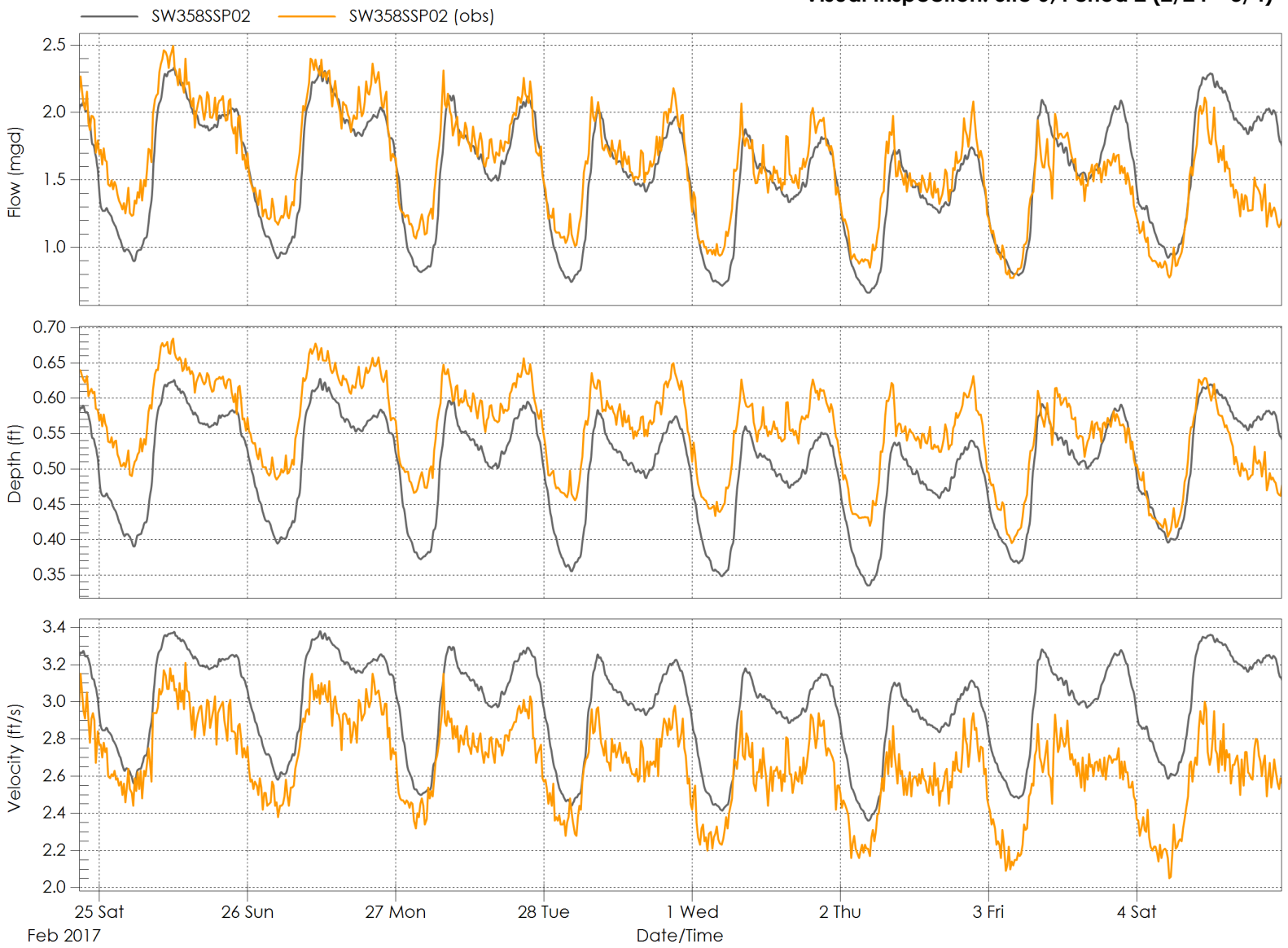
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	3.00	3.39	2.43
	Measured	2.65	3.13	2.12
	Error	13.3%	8.2%	14.6%
Period 2 (2/24 - 3/4)	Modeled	2.99	3.39	2.40
	Measured	2.66	3.21	2.05
	Error	12.5%	5.5%	**17.1%**

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.51	0.63	0.35
	Measured	0.52	0.63	0.38
	Error	-2.0%	0.1%	-7.6%
Period 2 (2/24 - 3/4)	Modeled	0.51	0.63	0.34
	Measured	0.56	0.69	0.40
	Error	-8.5%	-8.0%	-12.7%

Visual Inspection: Site 6, Period 1 (1/26 – 2/2)



Visual Inspection: Site 6, Period 2 (2/24 – 3/4)



H.2.8 Flow Monitoring Site 7

Description: Flow monitoring Site 7 recorded flow in the 66-inch Regional Sewer Trunk, upstream of the WWTRF headworks. This monitor was the most downstream flow monitor and was used to balance flow from each of the other flow monitoring sheds. Therefore, flow distributed within this shed also incurred the highest error. Surcharged conditions were observed due to WWTRF operations.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. The theoretical curve provides a reasonably "good" fit for a manning's n value of 0.009. Isolation of flow from this sewer-shed incurred the largest error due to the subtraction of the upstream flow data.

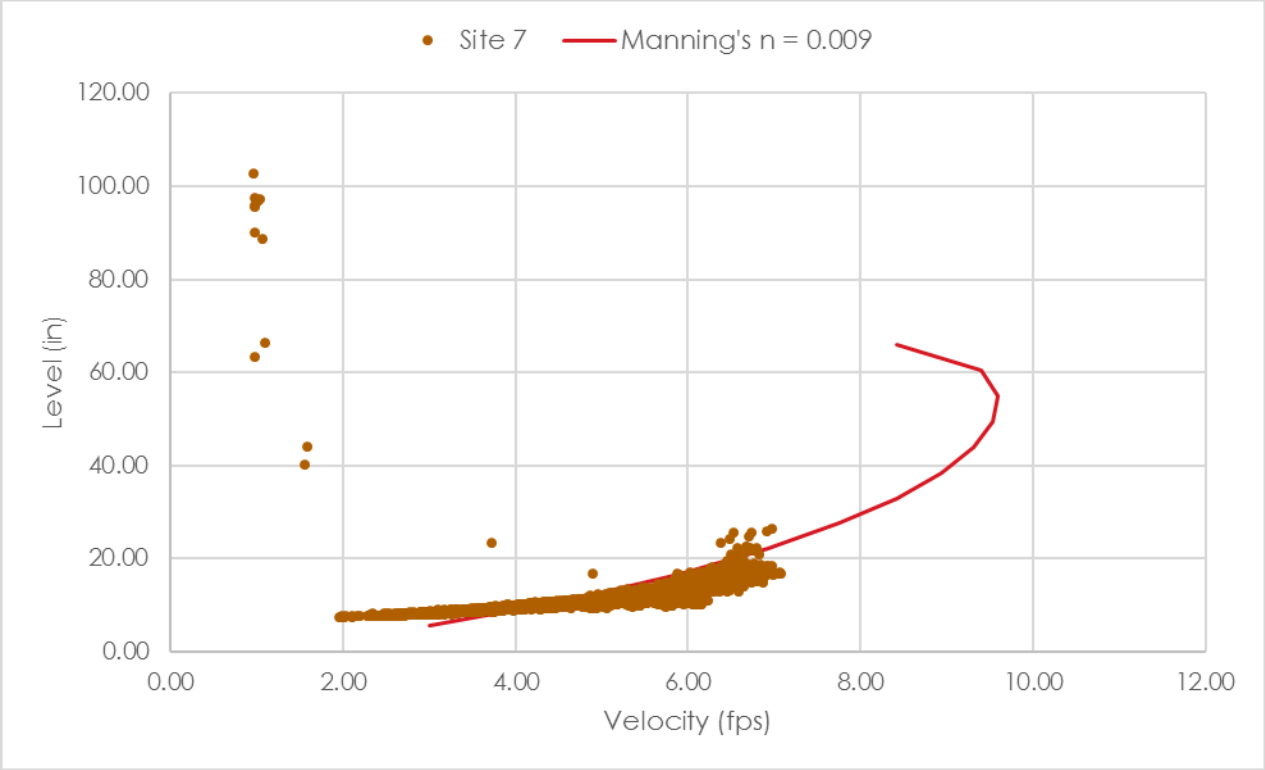


Figure H-9 Site 7: Level vs. Velocity

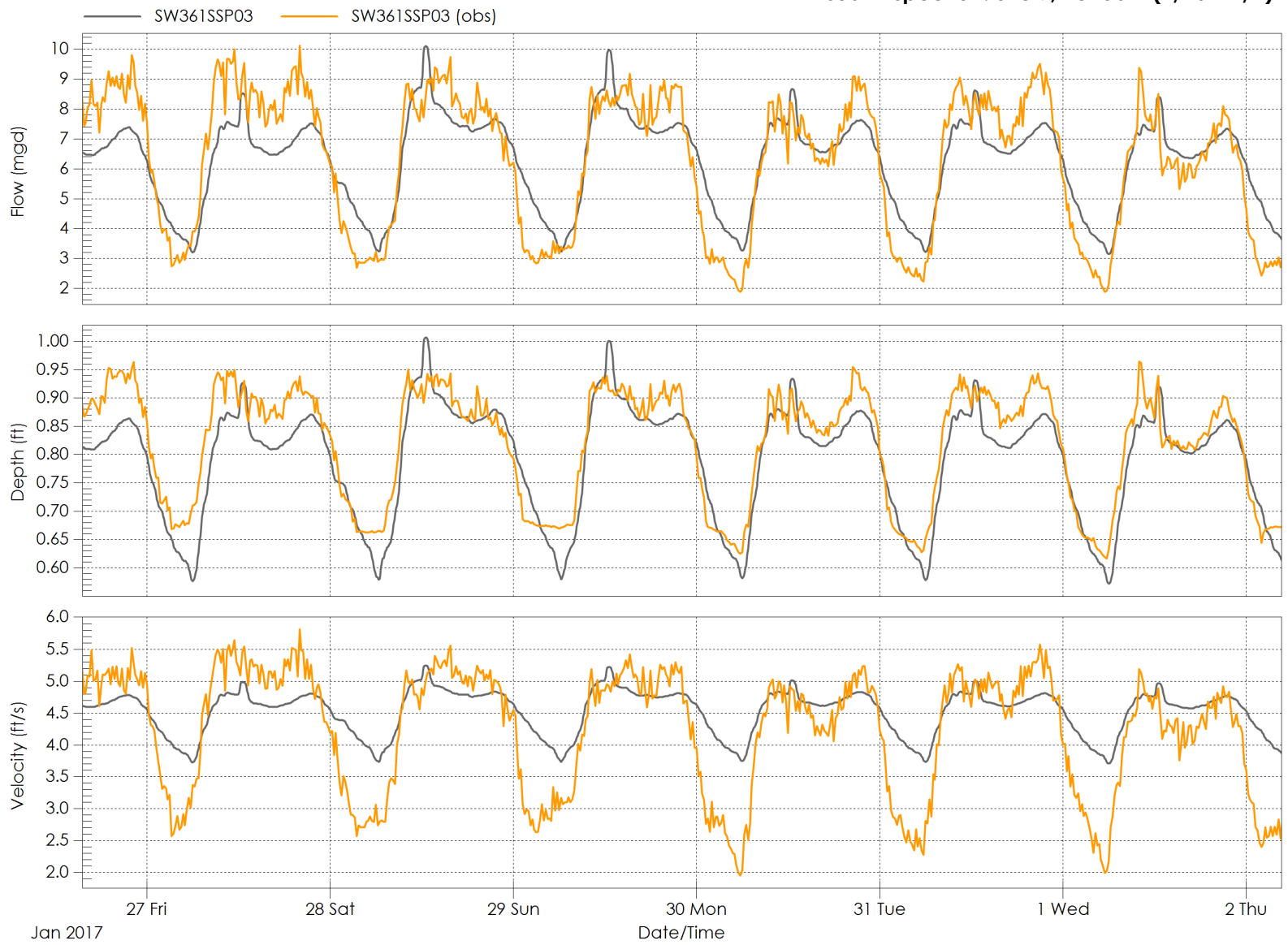
Site 7 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	6.34	10.18	3.20	40.45
	Measured	6.38	10.13	1.88	40.77
	Error	-0.8%	0.5%	**70.2%**	-0.8%
Period 2 (2/24 - 3/4)	Modeled	6.31	10.16	3.19	50.06
	Measured	6.93	11.03	2.52	54.94
	Error	-8.9%	-7.9%	**26.4%**	-8.9%

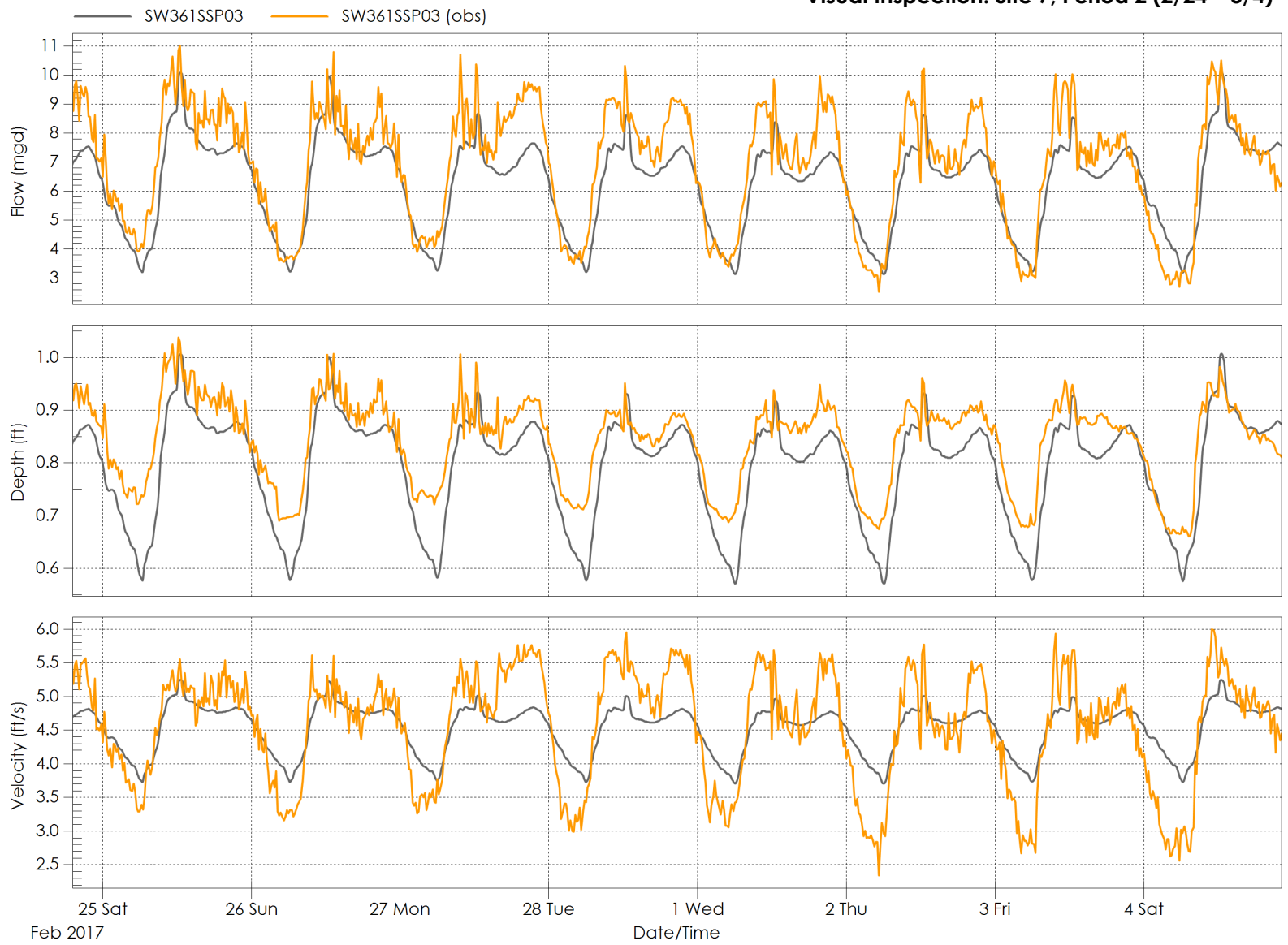
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	4.54	5.26	3.73
	Measured	4.27	5.82	1.95
	Error	6.4%	-9.7%	**91.1%**
Period 2 (2/24 - 3/4)	Modeled	4.53	5.25	3.72
	Measured	4.55	6.00	2.34
	Error	-0.3%	-12.4%	**59.1%**

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.80	1.01	0.58
	Measured	0.82	0.96	0.62
	Error	-3.3%	4.9%	-6.5%
Period 2 (2/24 - 3/4)	Modeled	0.79	1.01	0.58
	Measured	0.84	1.04	0.66
	Error	-5.7%	-2.7%	-12.9%

Visual Inspection: Site 7, Period 1 (1/26 – 2/2)



Visual Inspection: Site 7, Period 2 (2/24 – 3/4)



H.2.9 Flow Monitoring Site 7A

Description: Flow Monitoring Shed 7A was developed using flow monitoring data from the 2016 flow monitoring study. The 2016 flow monitoring study monitored wastewater flow at three locations in the Lincoln Crossings development in south Lincoln. This data was more representative of flow patterns and distributions within this sewer-shed than that collected at Site 7, along the Regional Sewer.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. The theoretical curve provides a reasonably "good" fit for a manning's n value of 0.016, as shown in **Figure H-10**.

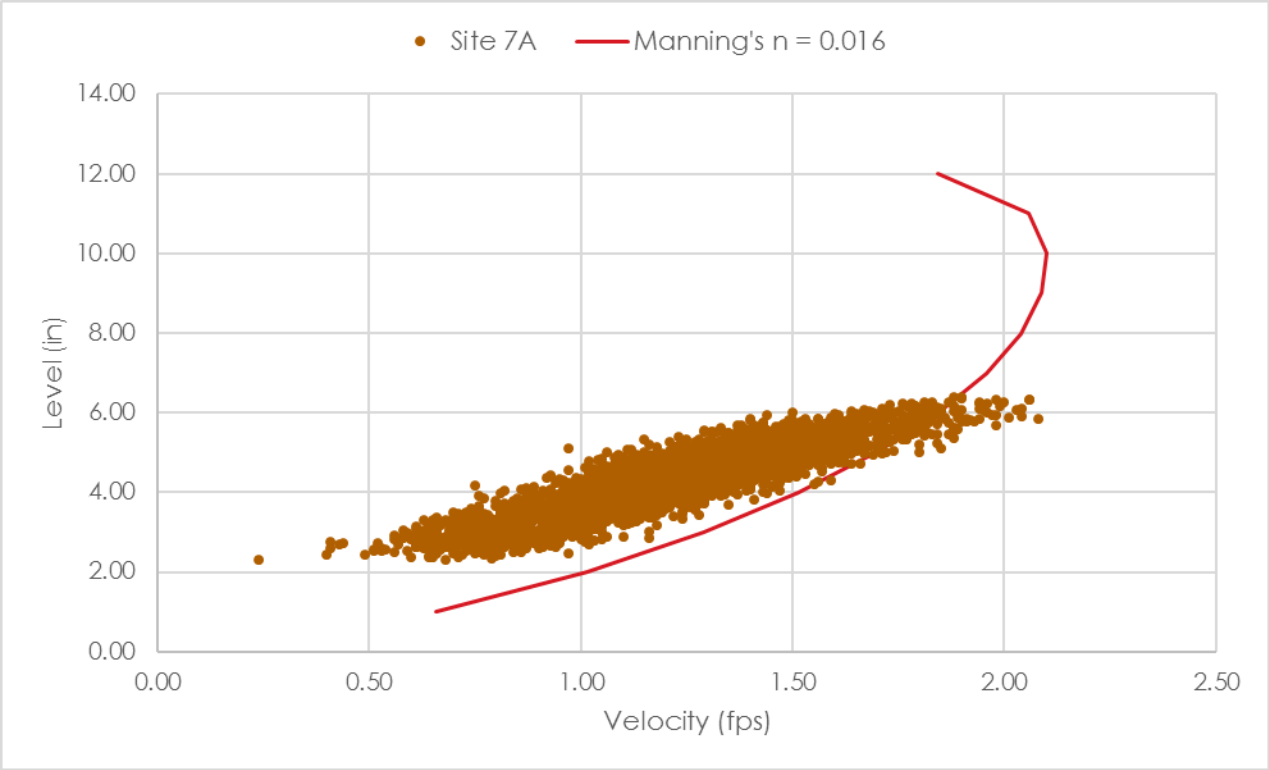


Figure H-10 Site 7A: Level vs. Velocity Data

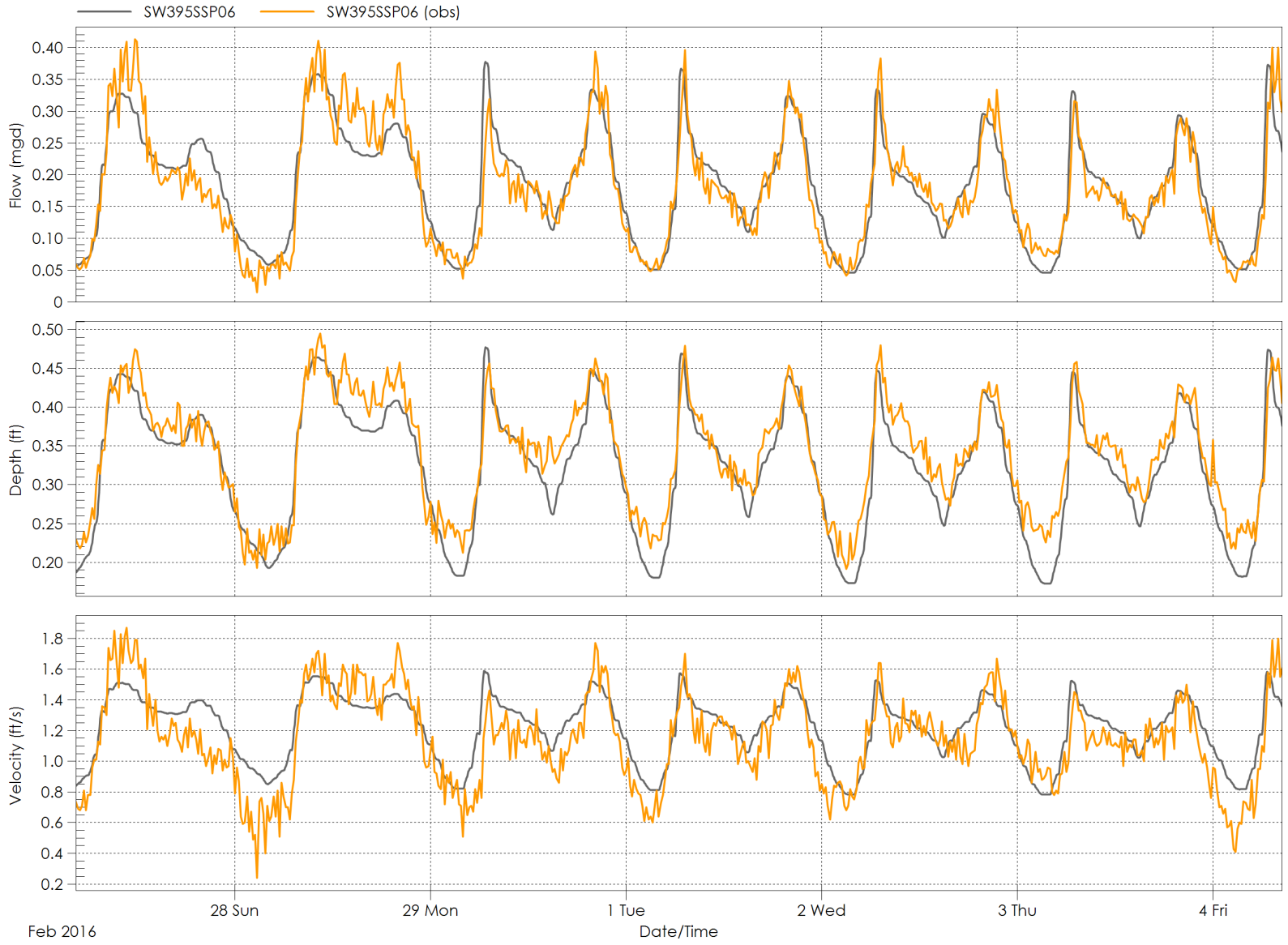
Site 7A Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1A (2/27/2016 – 3/4/2016)	Modeled	0.18	0.38	0.05	1.10
	Measured	0.18	0.41	0.02	1.08
	Error	1.7%	-8.5%	**205.2%**	1.7%
Period 2A (3/25/2016 – 4/3/2016)	Modeled	0.19	0.38	0.05	1.79
	Measured	0.18	0.43	0.03	1.77
	Error	1.1%	-11.1%	**38.7%**	1.2%

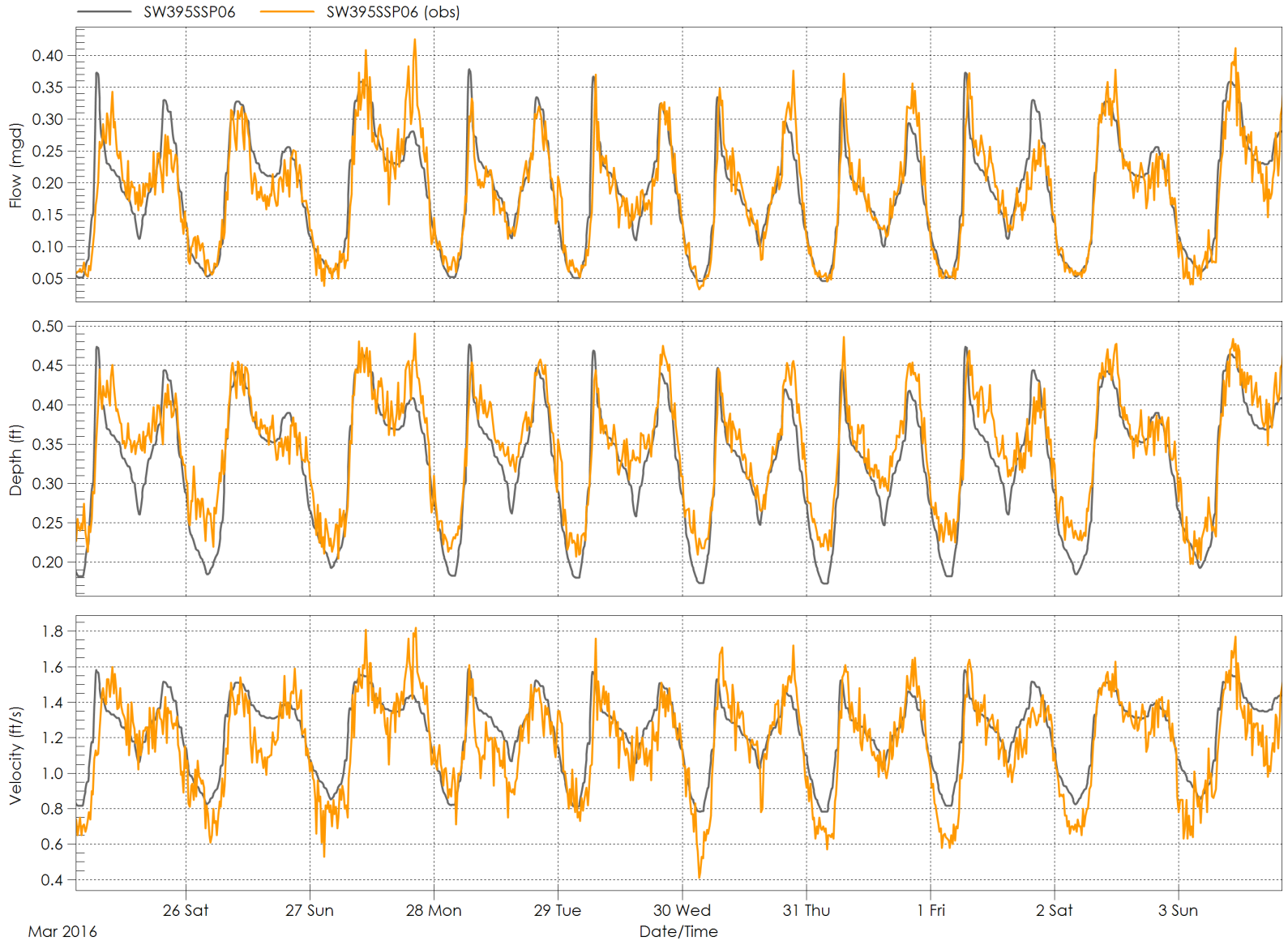
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1A (2/27/2016 – 3/4/2016)	Modeled	1.21	1.59	0.78
	Measured	1.14	1.82	0.24
	Error	6.2%	-12.8%	**225.8%**
Period 2A (3/25/2016 – 4/3/2016)	Modeled	1.22	1.59	0.78
	Measured	1.16	1.87	0.41
	Error	4.9%	**-15.1%**	**90.7%**

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1A (2/27/2016 – 3/4/2016)	Modeled	0.32	0.48	0.17
	Measured	0.34	0.49	0.19
	Error	-6.0%	-2.8%	-10.0%
Period 2A (3/25/2016 – 4/3/2016)	Modeled	0.32	0.48	0.17
	Measured	0.34	0.50	0.20
	Error	-6.0%	-3.6%	-12.6%

Visual Inspection: Site 7A, Period 1A (2/27 – 3/4)



Visual Inspection: Site 7A, Period 2A (3/25 – 4/3)



H.2.10 Flow Monitoring Site 8

Description: Flow monitoring Site 8 recorded flow from the south-east area of Lincoln, or the northern portion of the Twelve Bridges development. The ELPPS is located upstream of this flow monitoring location. Velocities greater than 7 fps were observed in sewers with high slopes during the flow monitoring period.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. The theoretical level vs. velocity curve for Site 8 provided a "good" match for a manning's n value of 0.01, shown in **Figure H-11**.

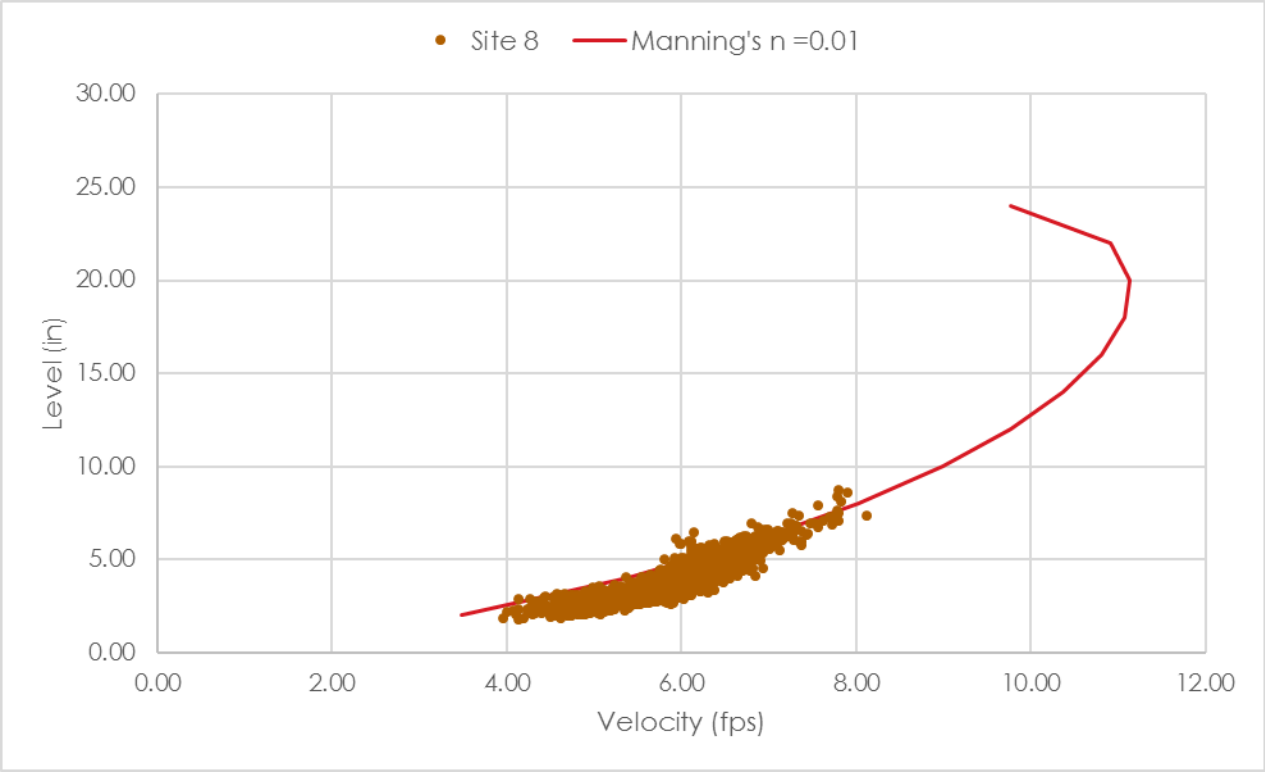


Figure H-11 Site 8: Level vs. Velocity Data

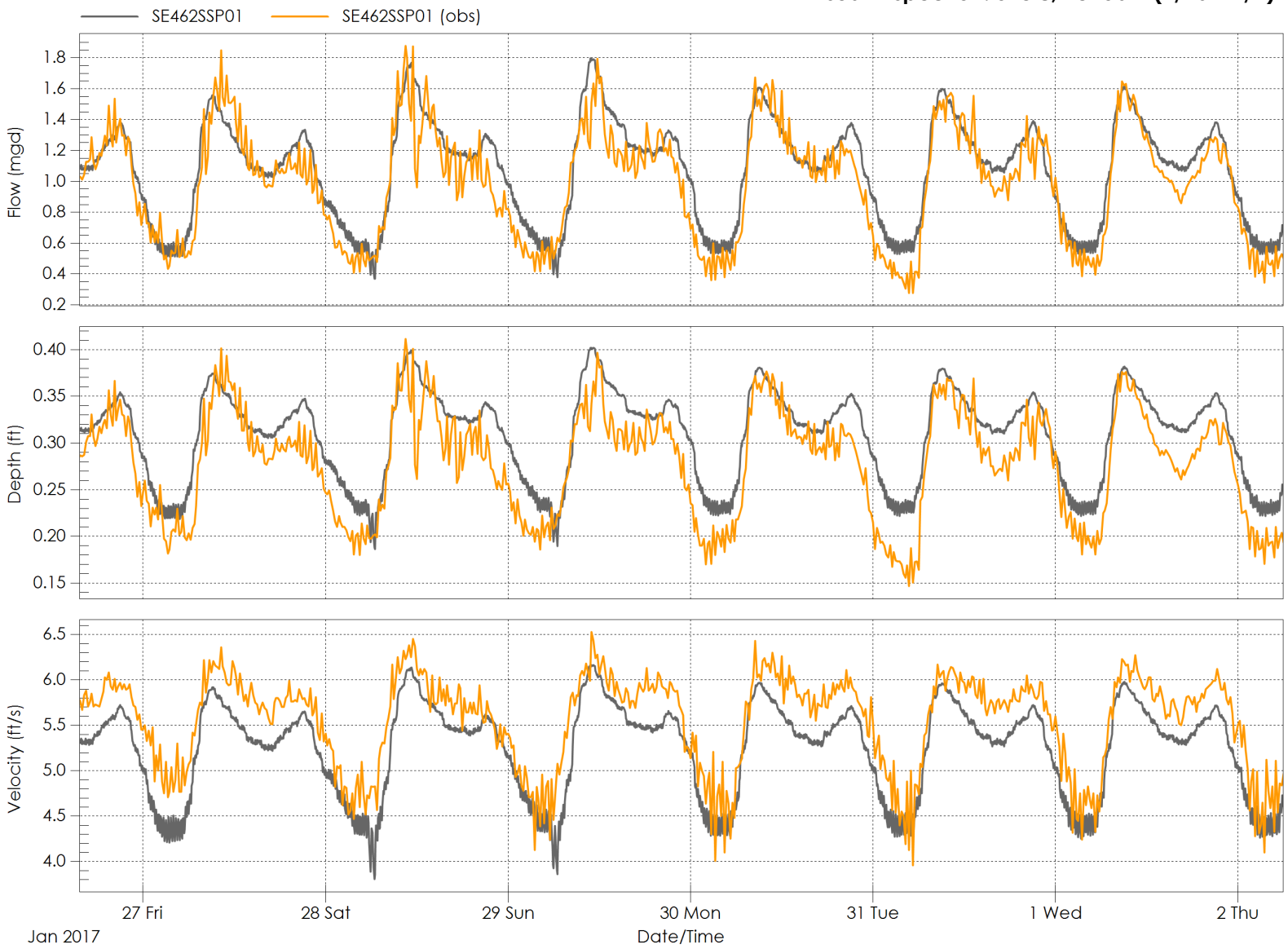
Site 8 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	1.08	1.80	0.37	6.92
	Measured	1.00	1.88	0.28	6.41
	Error	7.9%	-4.4%	**32.5%**	7.9%
Period 2 (2/24 - 3/4)	Modeled	1.08	1.82	0.35	8.57
	Measured	1.15	2.28	0.49	9.09
	Error	-5.7%	-20.2%	**-27.3%**	-5.7%

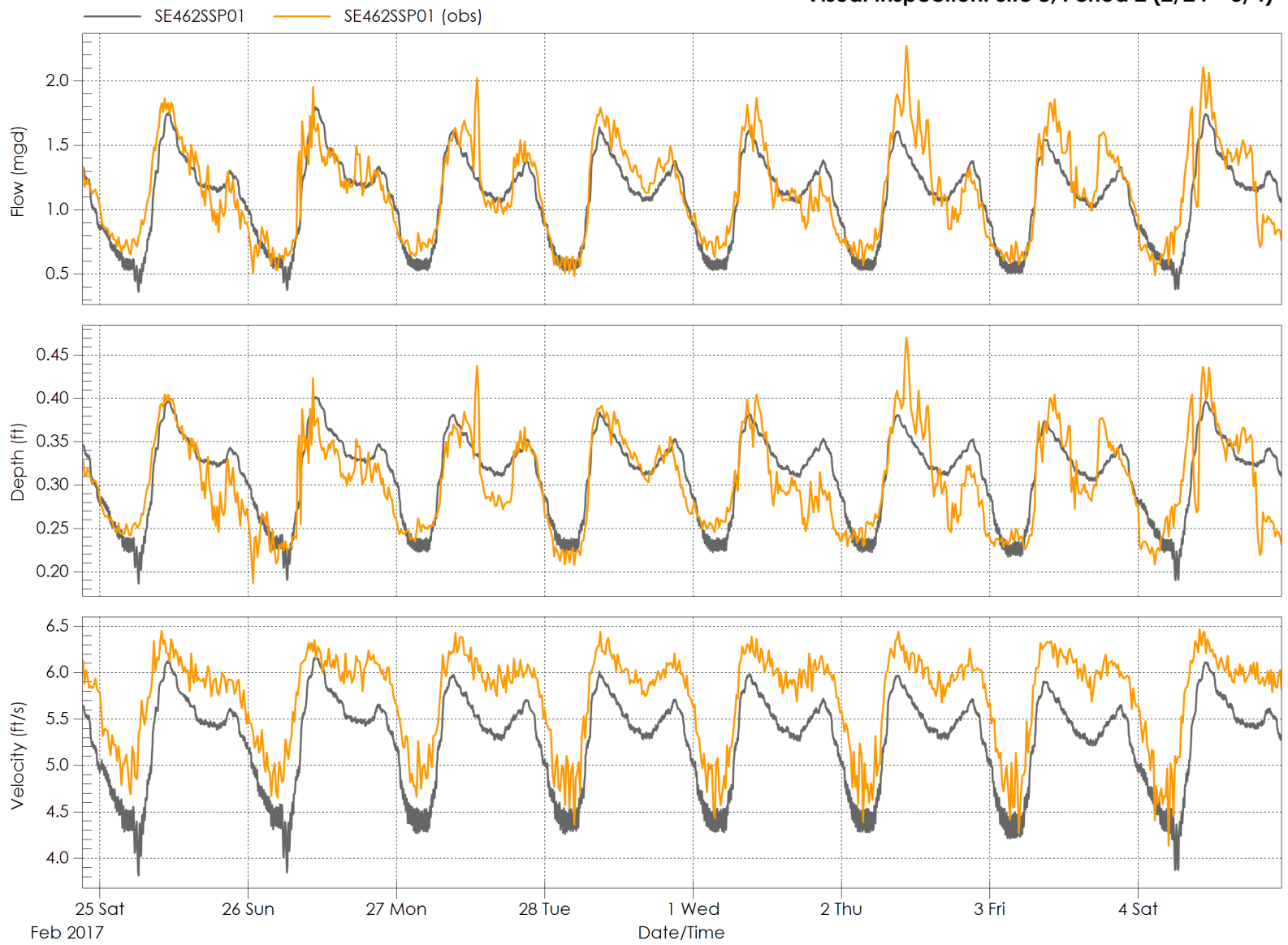
Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	5.26	6.17	3.82
	Measured	5.58	6.53	3.96
	Error	-5.7%	-5.5%	-3.6%
Period 2 (2/24 - 3/4)	Modeled	5.26	6.19	3.78
	Measured	5.75	6.47	4.14
	Error	-8.6%	-4.4%	-8.7%

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.31	0.40	0.19
	Measured	0.28	0.41	0.15
	Error	10.3%	-2.3%	**27.1%**
Period 2 (2/24 - 3/4)	Modeled	0.31	0.40	0.18
	Measured	0.30	0.47	0.19
	Error	1.9%	-14.1%	-1.6%

Visual Inspection: Site 8, Period 1 (1/26 – 2/2)



Visual Inspection: Site 8, Period 2 (2/24 – 3/4)



H.2.11 Flow Monitoring Site 9

Description: Flow monitoring Site 9 recorded flow from upstream of the intersection of Lincoln Boulevard and Joiner Parkway, around the golf course. This sewer-shed has high flow velocity and very steep pipe slopes. High wastewater flow per acre was noted for this flow monitoring shed.

Data Quality: Theoretical level vs. velocity curves were developed and graphed against the collected level vs. velocity data. The theoretical level vs. velocity curve for Site 9 provided an "excellent" match for a manning's n value of 0.008, shown in **Figure H-12**.

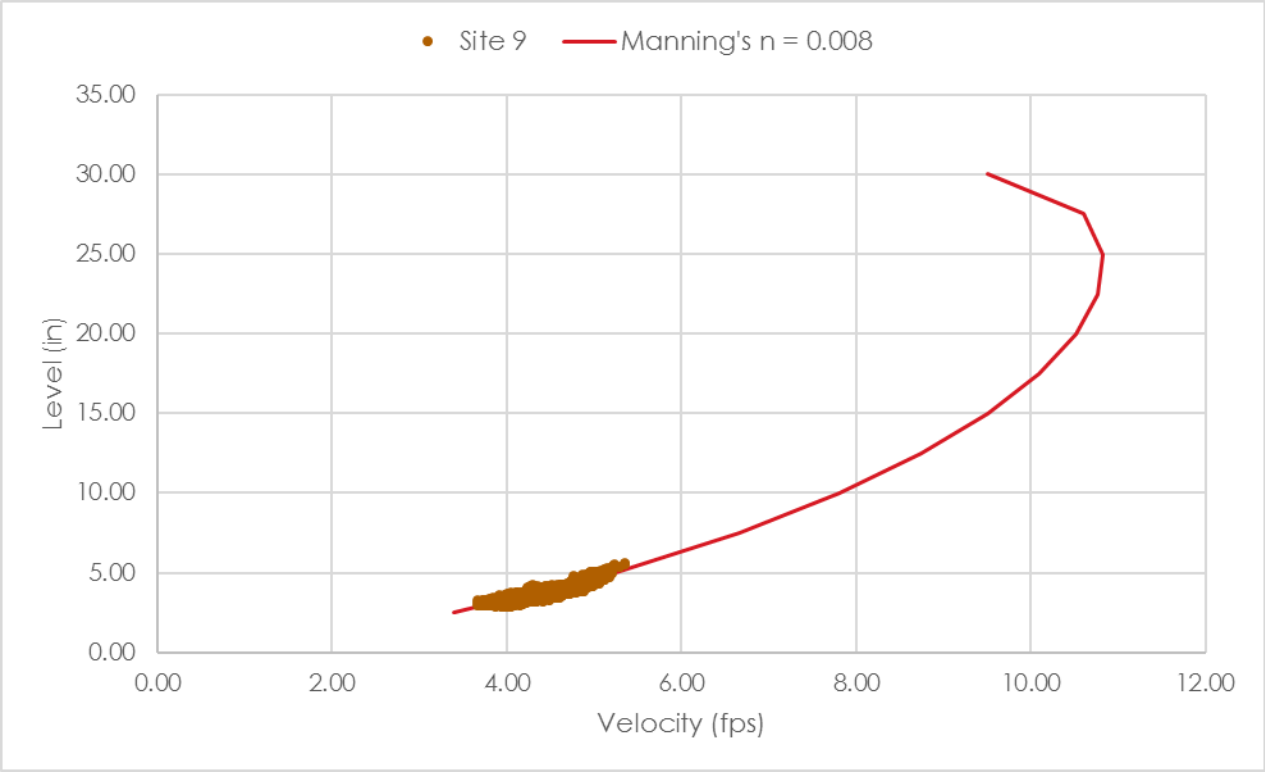


Figure H-12 Site 9: Level vs. Velocity Data

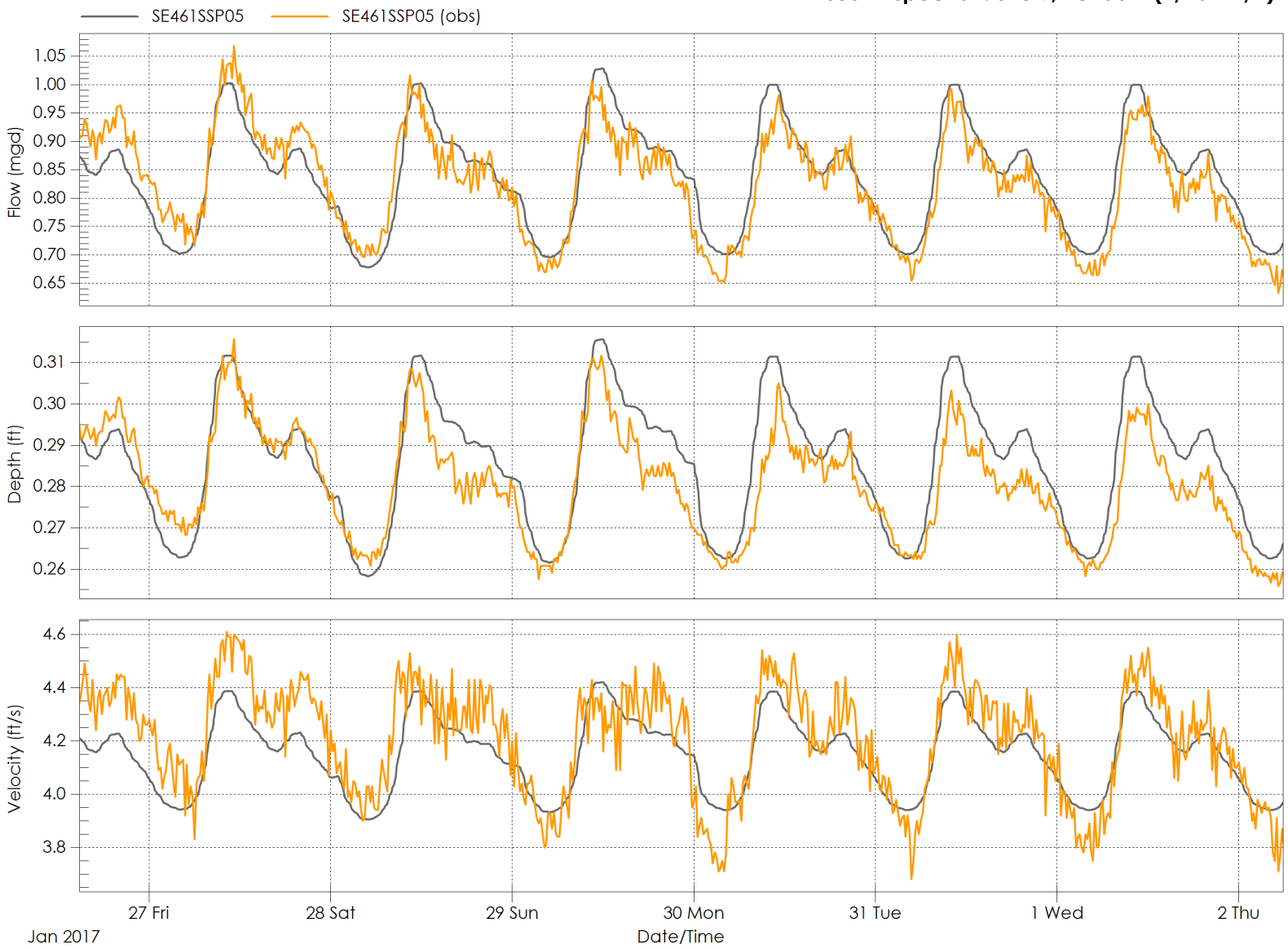
Site 9 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	0.84	1.03	0.68	5.36
	Measured	0.83	1.07	0.65	5.30
	Error	1.2%	-3.7%	3.9%	1.2%
Period 2 (2/24 - 3/4)	Modeled	0.84	1.03	0.68	6.65
	Measured	0.85	1.22	0.61	6.74
	Error	-1.2%	**-15.7%**	11.5%	-1.2%

Velocity Calibration		Average Velocity (ft/s)	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)
Period 1 (1/26 - 2/2)	Modeled	4.15	4.42	3.90
	Measured	4.22	4.61	3.68
	Error	-1.6%	-4.1%	6.1%
Period 2 (2/24 - 3/4)	Modeled	4.15	4.42	3.90
	Measured	4.15	4.59	3.66
	Error	0.0%	-3.7%	6.7%

Depth Calibration		Average Depth (ft)	Maximum Depth (ft)	Minimum Depth (ft)
Period 1 (1/26 - 2/2)	Modeled	0.29	0.32	0.26
	Measured	0.28	0.32	0.26
	Error	1.7%	0.0%	0.3%
Period 2 (2/24 - 3/4)	Modeled	0.29	0.32	0.26
	Measured	0.29	0.35	0.25
	Error	-1.0%	-10.0%	4.4%

Visual Inspection: Site 9, Period 1 (1/26 – 2/2)



Visual Inspection: Site 9, Period 2 (2/24 – 3/4)

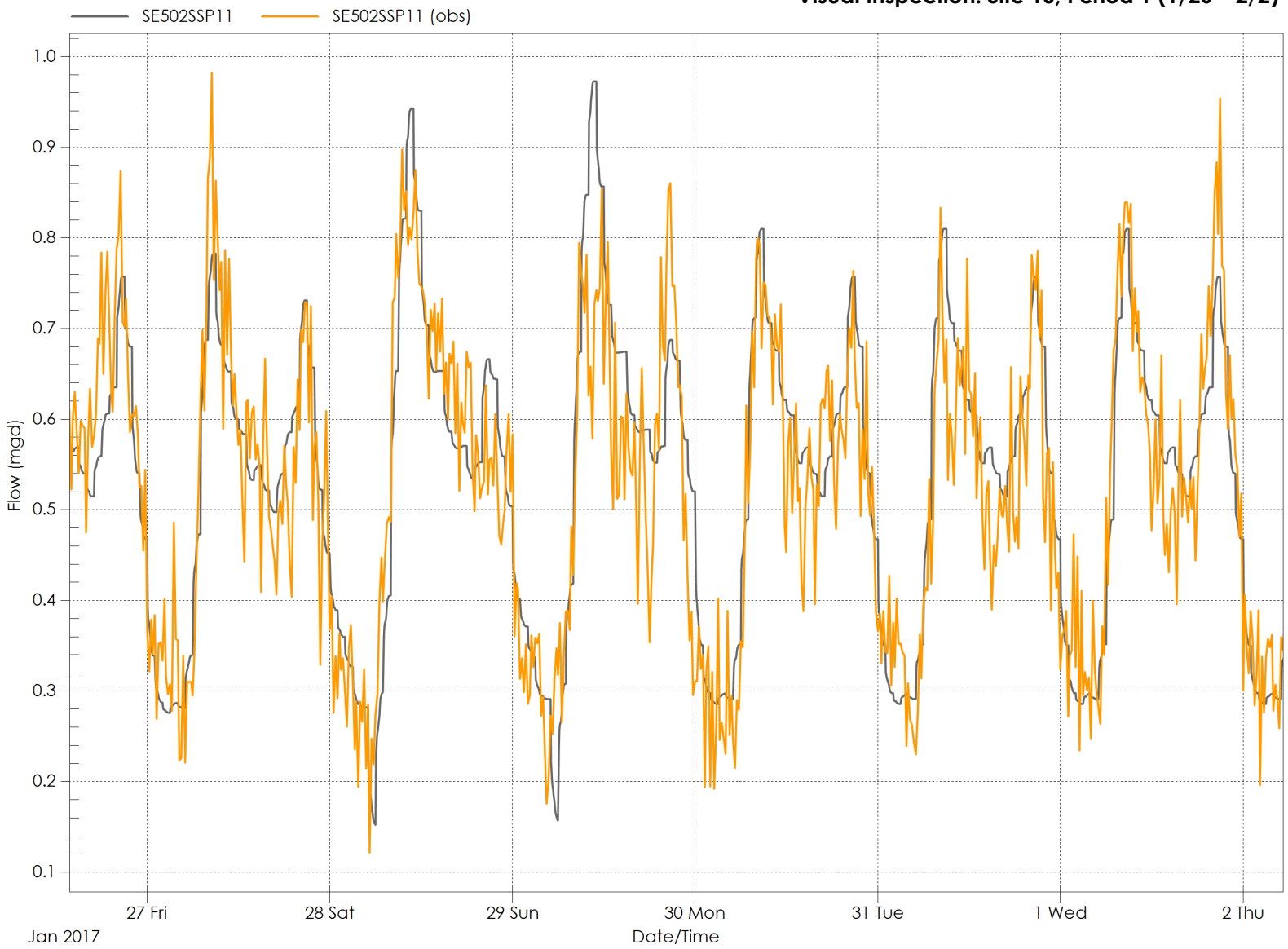
H.2.12 Flow Monitoring Site 10

Description: Flow monitoring Site 10 recorded flow from the East Lincoln Parkway Pump Station (ELPPS) collection shed. This flow monitor was positioned upstream of Site 8. Flow monitoring at Site 10 was conducted using a pump station state logger. Therefore, level and velocity readings were not recorded for this flow monitoring location. Calibration was performed using flow data from both dry weather flow events.

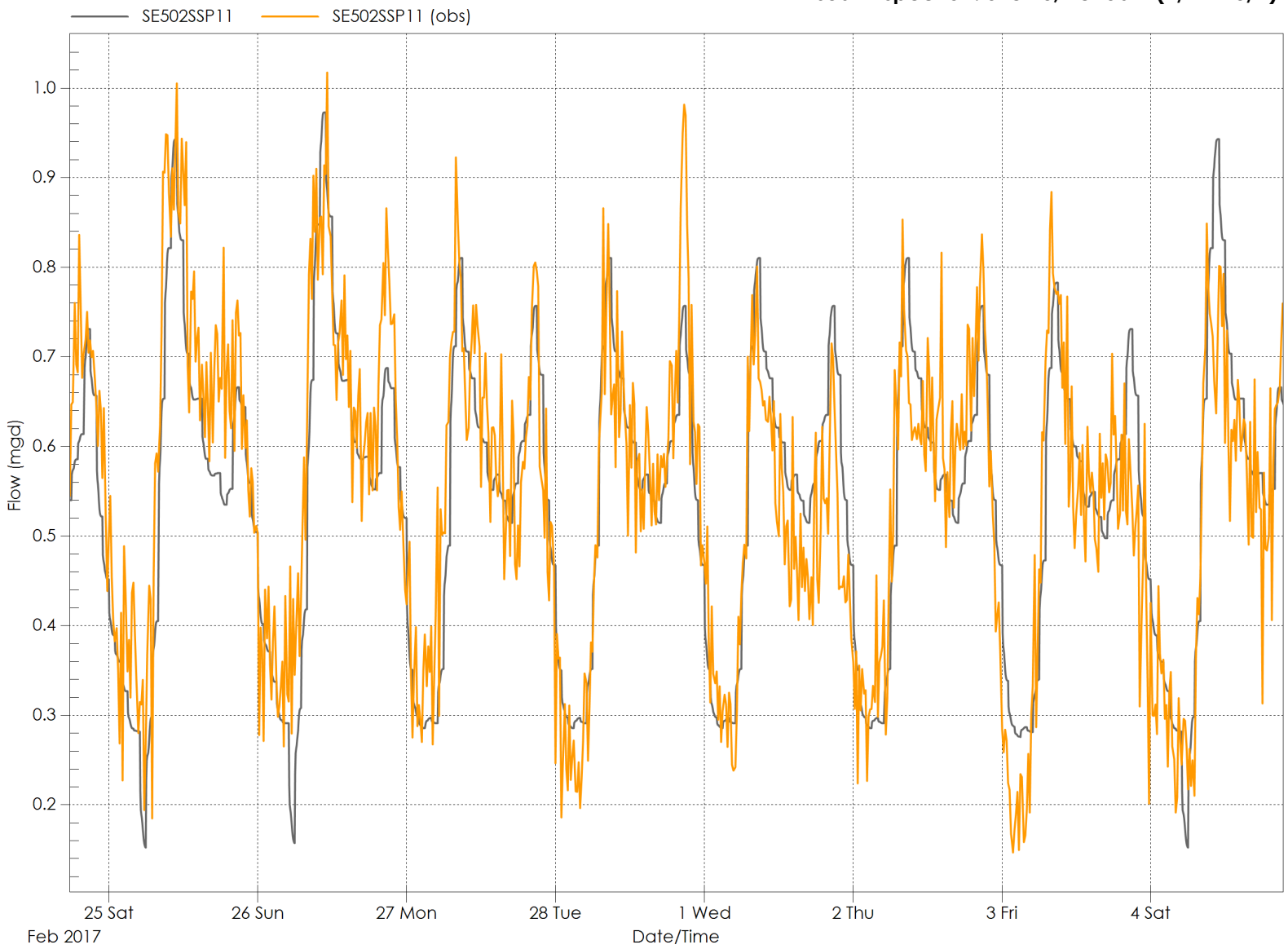
Site 10 Calibration Results:

Flow Calibration		Average Flow (MGD)	Maximum Flow (MGD)	Minimum Flow (MGD)	Total Flow (MG)
Period 1 (1/26 - 2/2)	Modeled	0.54	0.97	0.15	3.44
	Measured	0.53	0.98	0.12	3.38
	Error	1.7%	-1.0%	**25.2%**	1.7%
Period 2 (2/24 - 3/4)	Modeled	0.54	0.97	0.15	4.26
	Measured	0.55	1.02	0.15	4.33
	Error	-1.8%	-4.4%	3.9%	-1.8%

Visual Inspection: Site 10, Period 1 (1/26 – 2/2)



Visual Inspection: Site 10, Period 2 (2/24 – 3/4)



H.3 WET WEATHER CALIBRATION AND VALIDATION

H.3.1 Selection of Suitable Rainfall Events

Wet weather events from the 2017 flow monitoring period that produced the highest wet weather flow response were selected from the data provided by V&A. V&A installed rain gauges and collected rainfall data at the Nicolaus Road Pump Station (NRPS) and the East Lincoln Parkway Pump Station (ELPPS). Accuracy of the V&A rainfall data was verified based on data available on the California Data Exchange Center (CDEC) for their Lincoln (LCN) weather station. The validation gauge showed a similar rainfall pattern to the data collected by V&A, as shown in **Figure H-13**.

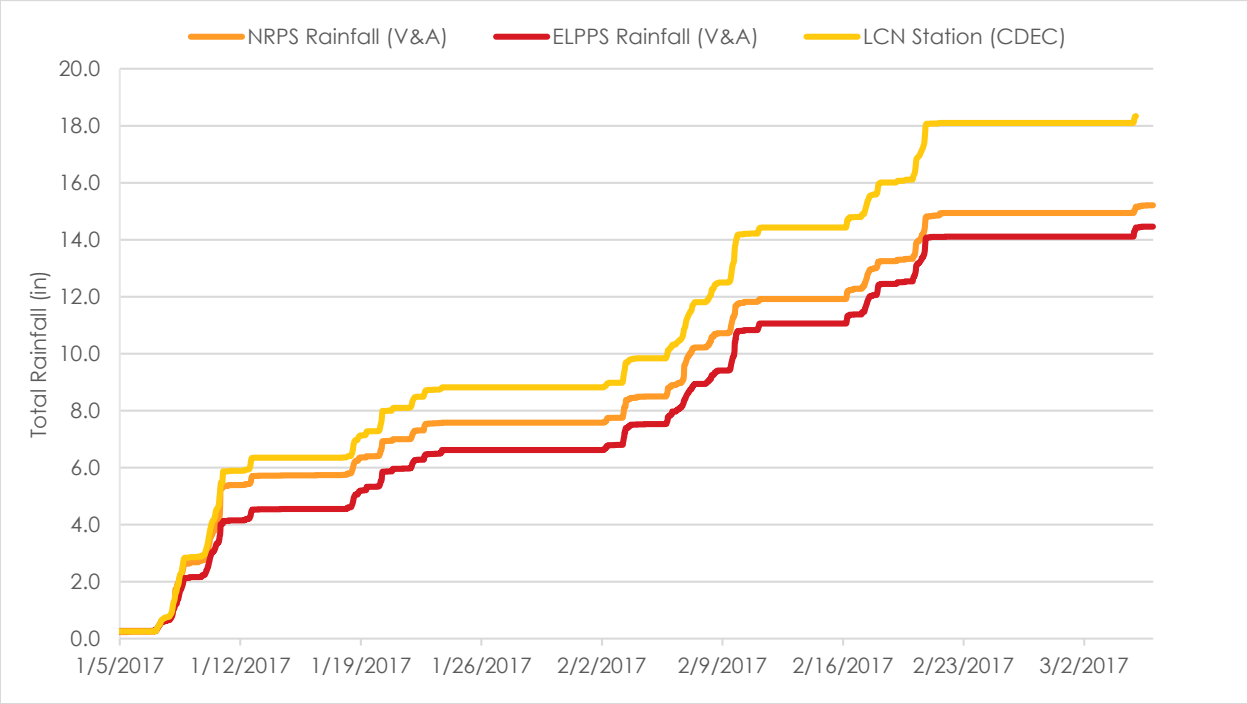


Figure H-13 Comparison of Cumulative Rainfall at Rain Gauge Stations

In general, the LCN CDEC weather station tended to show higher rainfall volumes than the V&A gauges. Differences in rainfall volumes at each of the rain gauges can be attributed to spatial variations in the storm events combined with differences in accuracy for various rain gauge technologies. Each of the rain gauges showed similar timing and magnitude of storm events, therefore confirming the validity of the V&A gauges. Overall, this period experienced higher than average wet weather conditions.

Rainfall for each sewer-shed was interpolated between the two V&A rain gauges using the inverse distance weighting (IDW) method. The IDW method is an interpolation method that

assumes the influence of each rain gauge location diminishes with distance. The rain gauge distribution for each sewer-shed is presented in **Table H-1**.

Table H-1 Rain Gauge Distribution by Sewer-shed

Sewer-shed	NRPS Rain Gauge	ELPPS Rain Gauge
Site 1	98%	2%
Site 2	95%	5%
Site 3	59%	41%
Site 4	38%	62%
Site 5	81%	19%
Site 6	75%	25%
Site 7	43%	57%
Site 8	14%	86%
Site 9	39%	61%
Site 10	3%	97%

The model was calibrated and validated to three wet weather events based on storms with significant depth. The first event produced that the most significant rainfall response in the collection system and was used for calibration. The remaining two events were used for validation of the calibrated wet weather parameters. **Table H-2** summarizes the event characteristics for the identified wet weather events.

Table H-2 Wet Weather Event Characteristics

Event	Start	End of Rain	Duration (hr)	Total Rain (in)	Peak Intensity (in/hr)	End of WWF Response
1	1/6/2017 9:40 PM	~ 1/12/17 5:00 PM	139.33	• Average: 4.84 • NRPS: 5.45 • ELPPS: 4.25	• Average: 1.14 • NRPS: 1.88 • ELPPS: 0.76	~ 1/14/2017 9:45 PM
2	2/2/2017 12:30 AM	~ 2/11/2017 4:45 PM	232.25	• Average: 4.39 • NRPS: 4.34 • ELPPS: 4.44	• Average: 0.52 • NRPS: 0.8 • ELPPS: 0.92	~ 2/14/2017 11:35 PM
3	2/16/2017 2:00 AM	~ 2/21/2017 10:45 PM	140.75	• Average: 4.39 • NRPS: 4.34 • ELPPS: 4.44	• Average: 0.52 • NRPS: 0.8 • ELPPS: 0.92	~ 2/24/2017 2:45 AM

The model was further refined using data from the 2016 flow monitoring study. V&A monitored flow from the Lincoln Crossing development collection shed from February 26th to April 3rd, 2016. The flow monitor used for calibration was located on a 12-inch sewer up stream of the intersection of Calden Circle and Ferrari Ranch Road. Wet weather characteristics of this event are presented in **Table H-3**.

Table H-3 Wet Weather Event Characteristics (7A)

Event	Start	End of Rain	Duration (hr)	Total Rain (in)	Peak Intensity (in/hr)	End of WWF Response
1A	3/4/2016 1:00 PM	~ 3/14/2016 9:00 AM	337.08	4.66	1.20	~ 3/17/2016 12:00 AM

H.3.2 Calibration Overview

The wet weather response is generated in the model based on RTK input parameters. The initial RTK parameters were derived from flow monitoring response over the identified calibration event. The Sensitivity-based Radio Tuning Calibration (SRTC) tool in PCSWMM was then used to evaluate the variability of each set of RTK parameters per flow monitor, to fine-tune the response. **Table H-4** presents the resulting wet weather input parameters.

Table H-4 Wet Weather R-T-K Parameters

Site	Short-Term R	Short-Term T	Short-Term K	Medium-Term R	Medium-Term T	Medium-Term K	Long-Term R	Long-Term T	Long-Term K
FM1	0.031	0.59	32	0.022	17.76	7	0.039	98.19	4
FM2	0.010	0.20	39	0.005	12.64	6	0.007	50.40	4
FM3	0.078	0.25	52	0.037	9.09	5	0.054	48.00	5
FM4	0.027	0.25	52	0.019	9.52	3	0.023	18.75	4
FM5	0.034	0.18	41	0.016	9.82	5	0.021	48.00	5
FM6	0.048	0.20	42	0.023	9.09	5	0.033	48.00	5
FM7	0.068	0.20	52	0.048	8.73	10	0.034	29.69	1
FM7A	0.012	0.20	39	0.018	12.64	18	0.010	30.00	4
FM8	0.009	0.25	52	0.004	9.09	5	0.006	48.00	5
FM9	0.029	0.27	65	0.015	10.00	3	0.011	12.00	2
FM10	0.017	0.25	52	0.008	9.09	5	0.012	48.00	5

Overall the wet weather response is replicated well in the model, with some variability between wet weather events. This can be attributed to the application of average uniform parameters to differing types of events (duration, intensity), and is to be expected. For purposes of this Master Plan, the capture of extreme events is considered acceptable, and the calibration/validation process confirms the general pipe connectivity and contributing sewage and wet weather generation rates.

The following sections describe the specific findings of the wet weather calibration for each monitor location. Each flow monitoring location was calibrated to a PWWF and total volume level of accuracy of ±15%.

H.3.3 Flow Monitoring Site 1

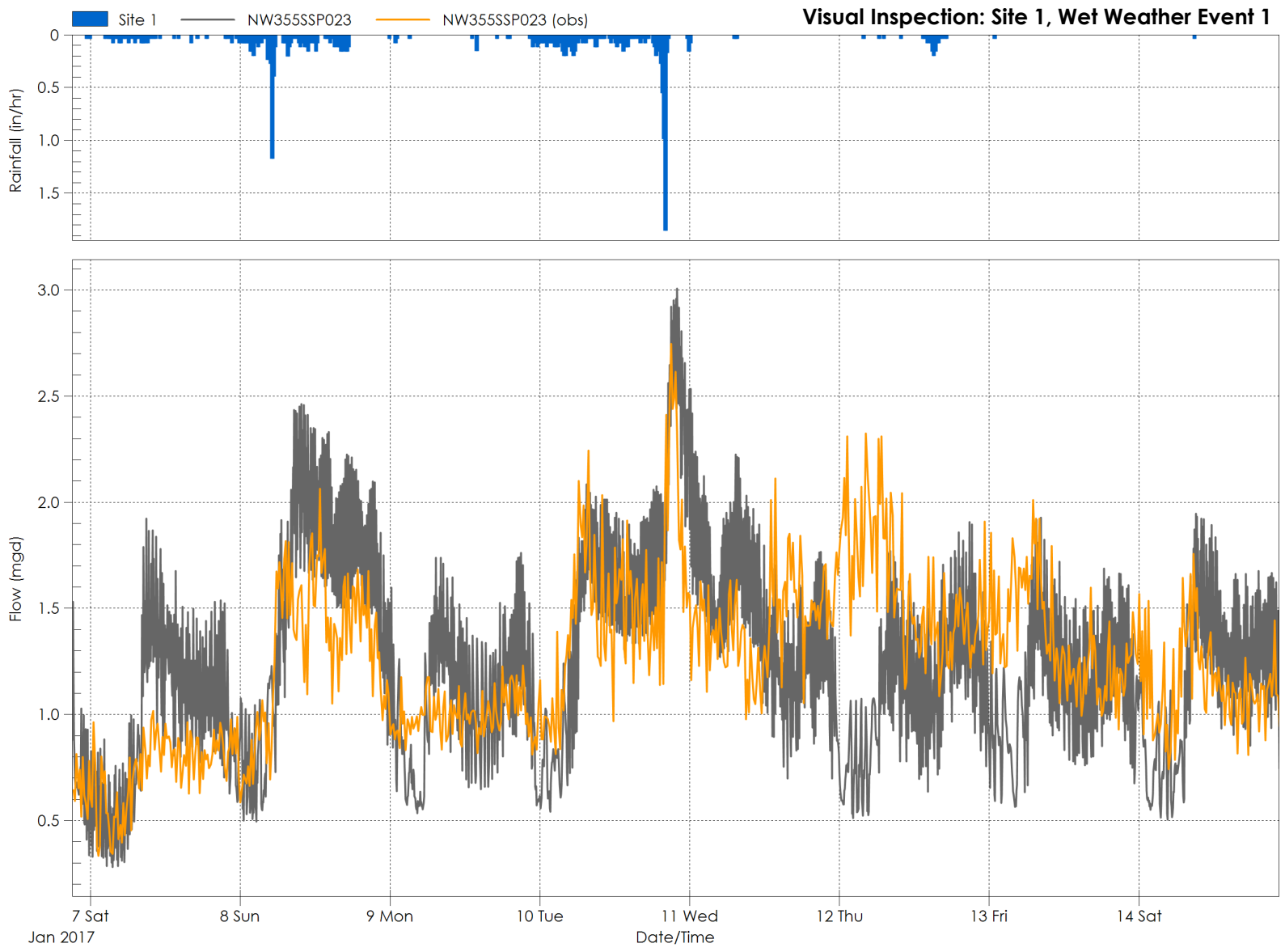
Model results for flow monitoring Site 1 overestimate the PWWF for wet weather events, as shown in **Table H-5**. The discrepancy in PWWF is consistent with the DWF calibration, where PWWF was also over estimated due to the influence of the discharge of the Nicolaus Road Pump Station. This margin of error for DWF would be compounded for the WWF simulations. The difference in PWWF for WWF simulations was considered acceptable for calibration.

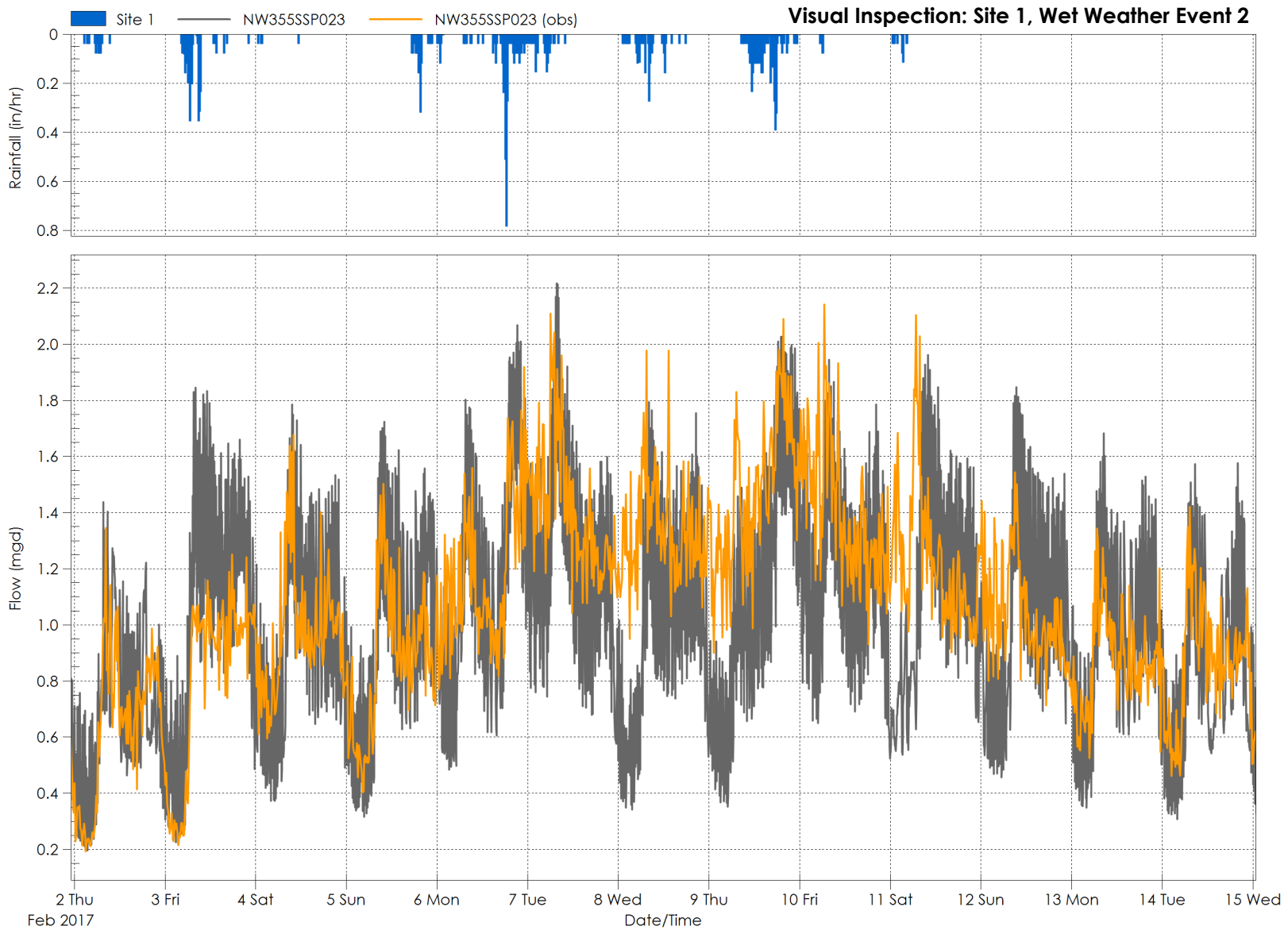
Table H-5 Site 1 PWWF Calibration Results

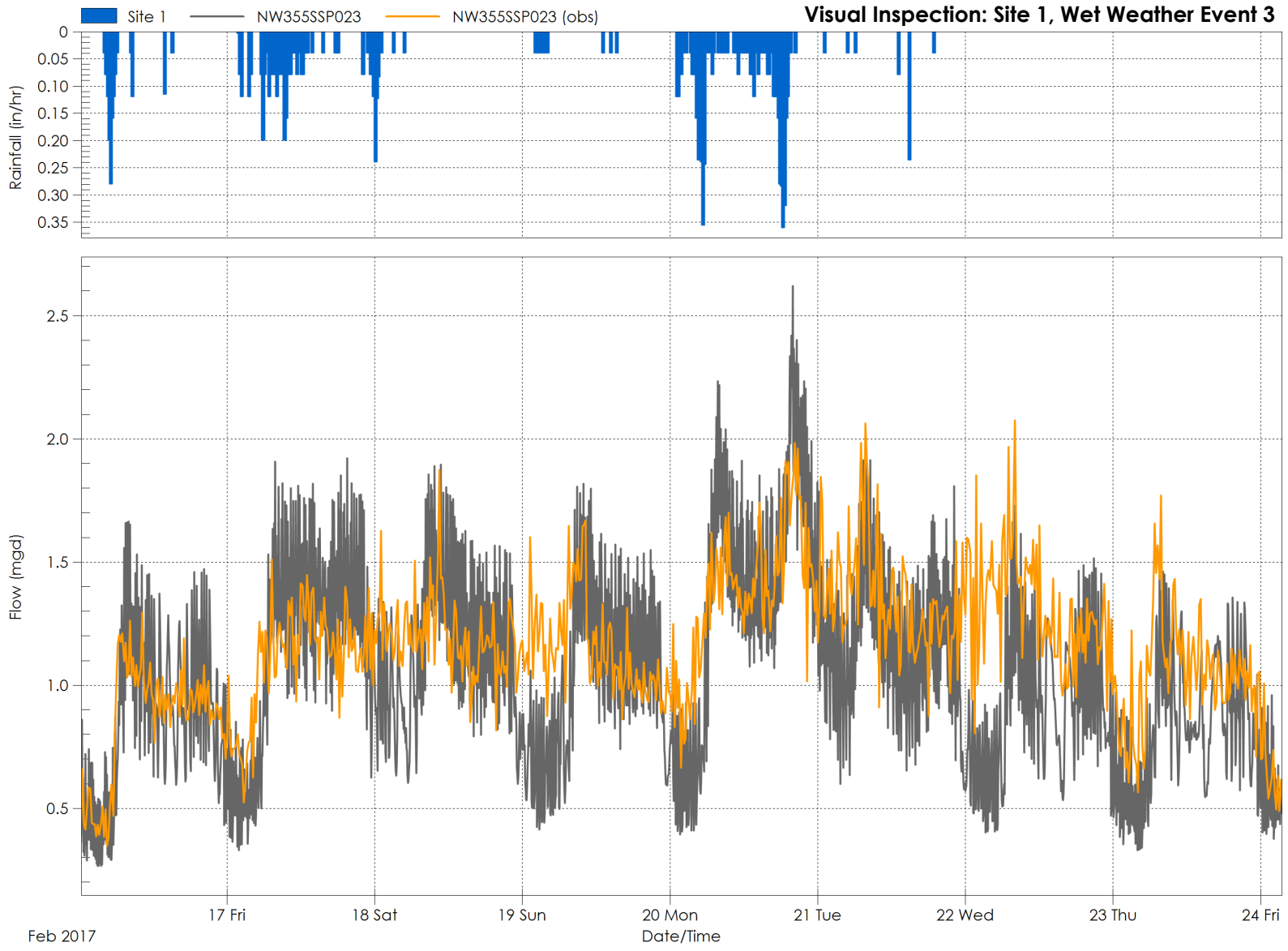
Site 1 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	2.91	2.75	5.9%	10.29	10.08	2.1%
Event 2	2.17	2.14	1.5%	13.48	14.08	-4.3%
Event 3	2.50	2.08	20.3%	8.70	9.42	-7.6%

Event 1 was used for calibration and Events 2 and 3 were used to validate the results. Event 3 results did not fall within the target level of accuracy of 10%. Total volume is underestimated in the model for Site 1 for each wet weather event. The total volume error for events 1 and 3 are within 15% and considered to be acceptable for calibration.

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Visual Inspection: Site 1, Wet Weather Event 1
Site 1
NW355SSP023
NW355SSP023 (obs)
Rainfall (in/hr)
0
0.5
1.0
1.5
Flow (mgd)
3.0
2.5
2.0
1.5
1.0
0.5
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Visual Inspection: Site 1, Wet Weather Event 2
Site 1
NW355SSP023
NW355SSP023 (obs)
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
Flow (mgd)
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Visual Inspection: Site 1, Wet Weather Event 3
Site 1
NW355SSP023
NW355SSP023 (obs)
Rainfall (in/hr)
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Flow (mgd)
2.5
2.0
1.5
1.0
0.5
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

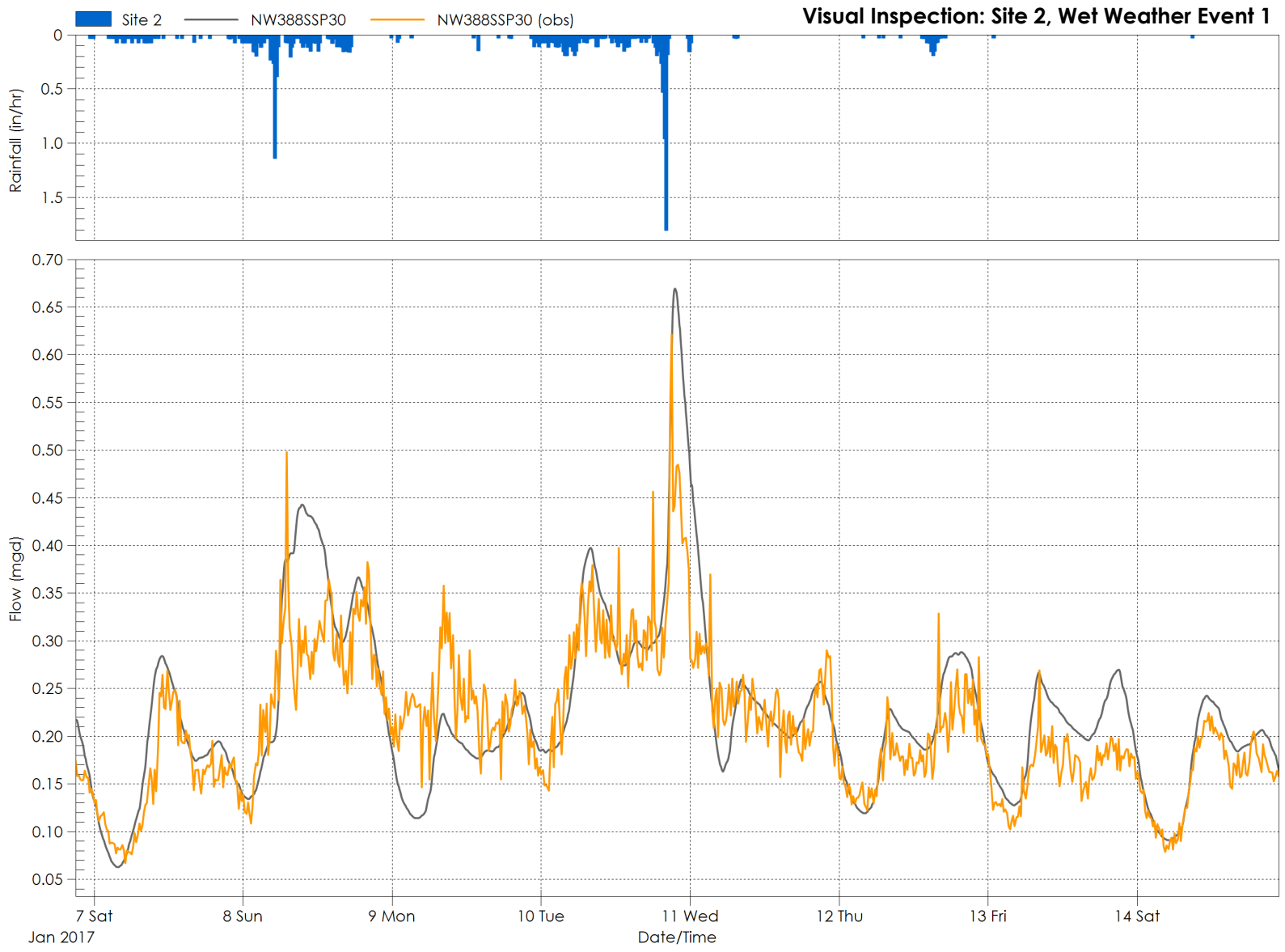
H.3.4 Flow Monitoring Site 2

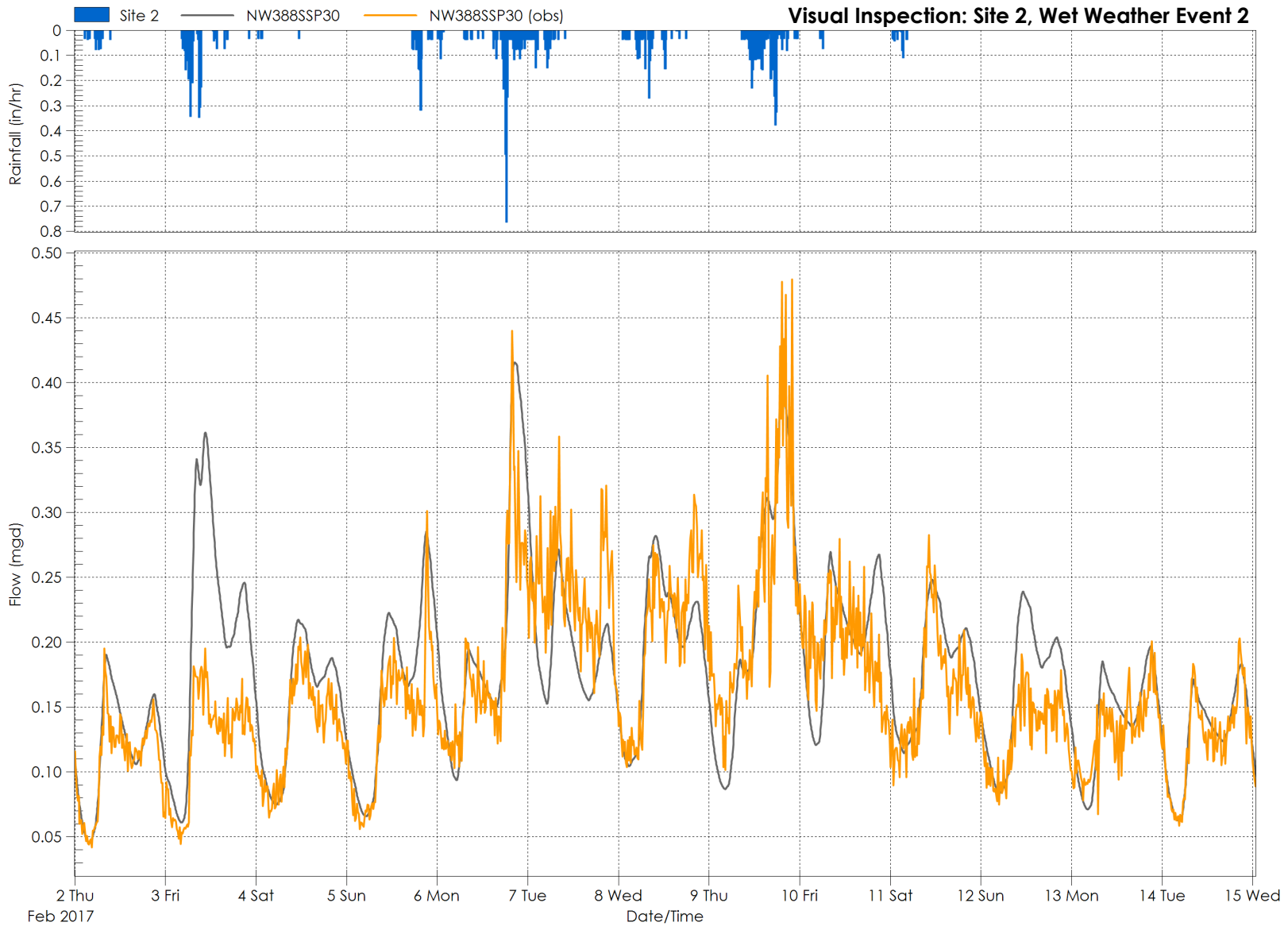
Model results for flow monitoring Site 2 overestimate and underestimate the PWWF for wet weather events, as shown in **Table H-6**. Flow at this location is impacted by surcharging and shallow slopes. The modeled total volume and PWWF are within 15% of measured values. The error in PWWF for WWF simulations was considered acceptable for calibration.

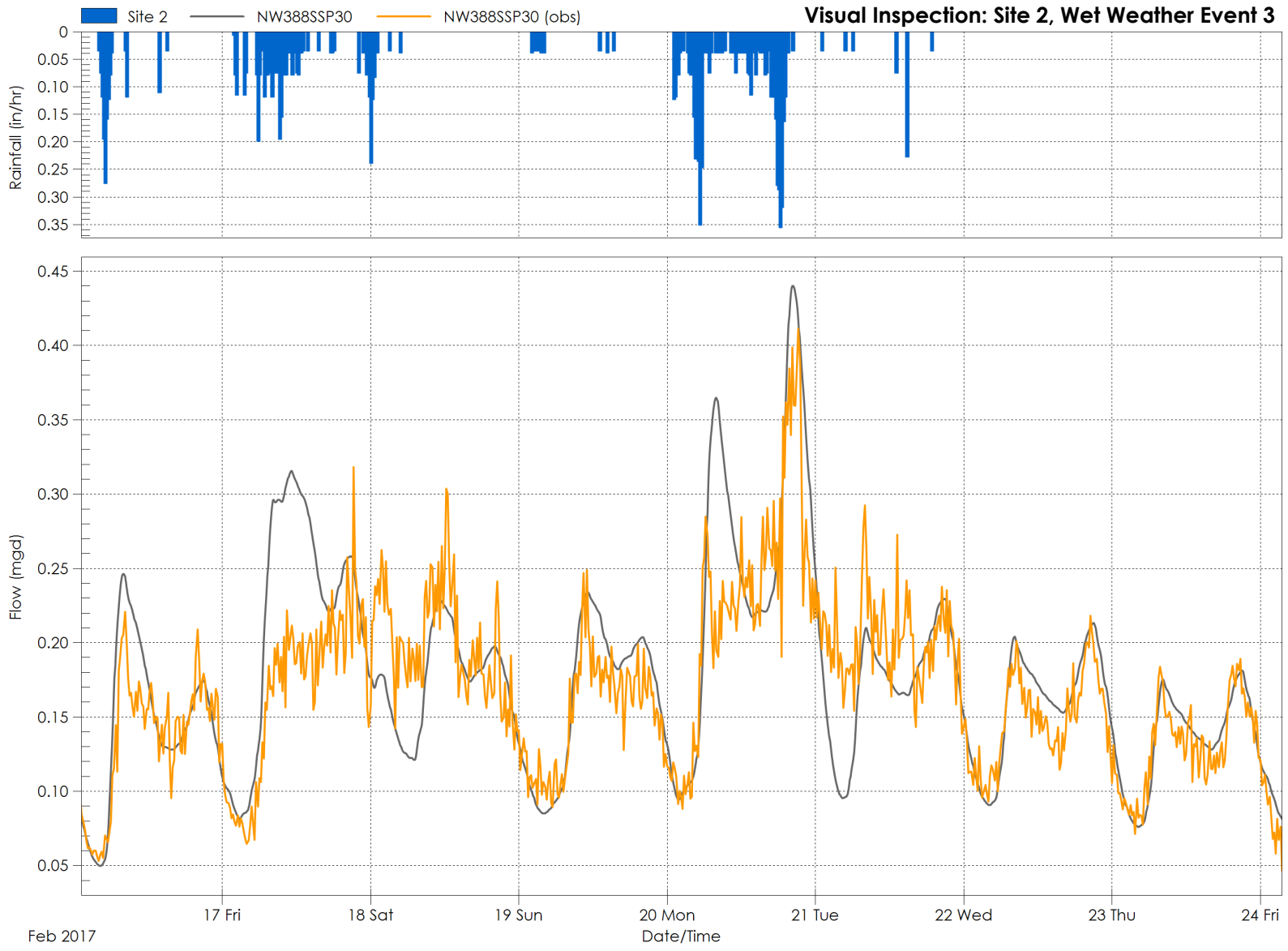
Table H-6 Site 2 PWWF Calibration Results

Site 2 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	0.67	0.62	7.8%	1.81	1.70	6.3%
Event 2	0.42	0.48	-13.4%	2.28	2.11	8.2%
Event 3	0.44	0.41	7.0%	1.42	1.36	4.2%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Visual Inspection: Site 2, Wet Weather Event 1
Site 2
NW388SSP30
NW388SSP30 (obs)
Rainfall (in/hr)
0
0.5
1.0
1.5
Flow (mgd)
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Site 2
NW388SSP30
NW388SSP30 (obs)
Visual Inspection: Site 2, Wet Weather Event 2
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Flow (mgd)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Site 2
NW388SSP30
NW388SSP30 (obs)
Visual Inspection: Site 2, Wet Weather Event 3
Rainfall (in/hr)
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Flow (mgd)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

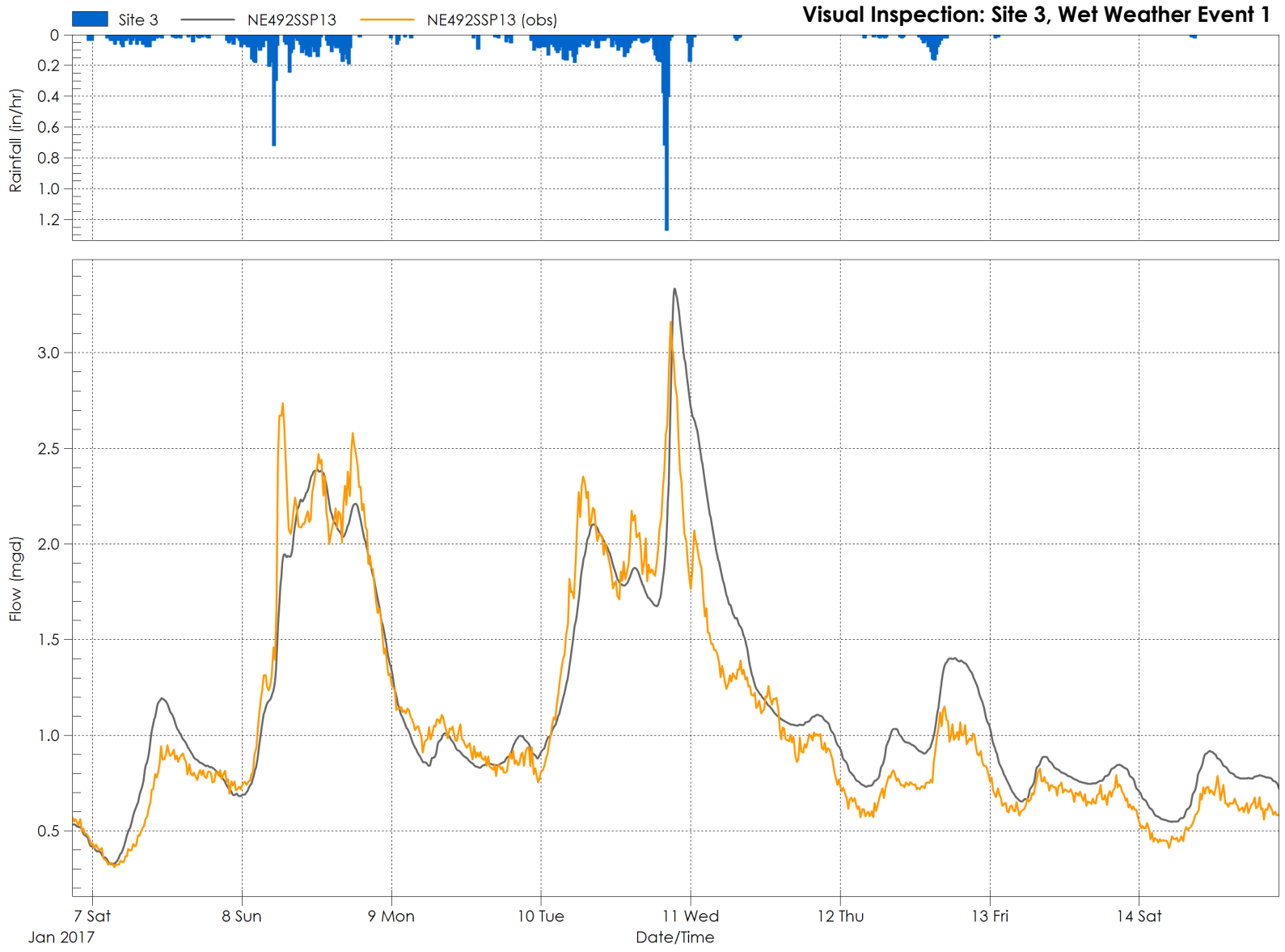
H.3.5 Flow Monitoring Site 3

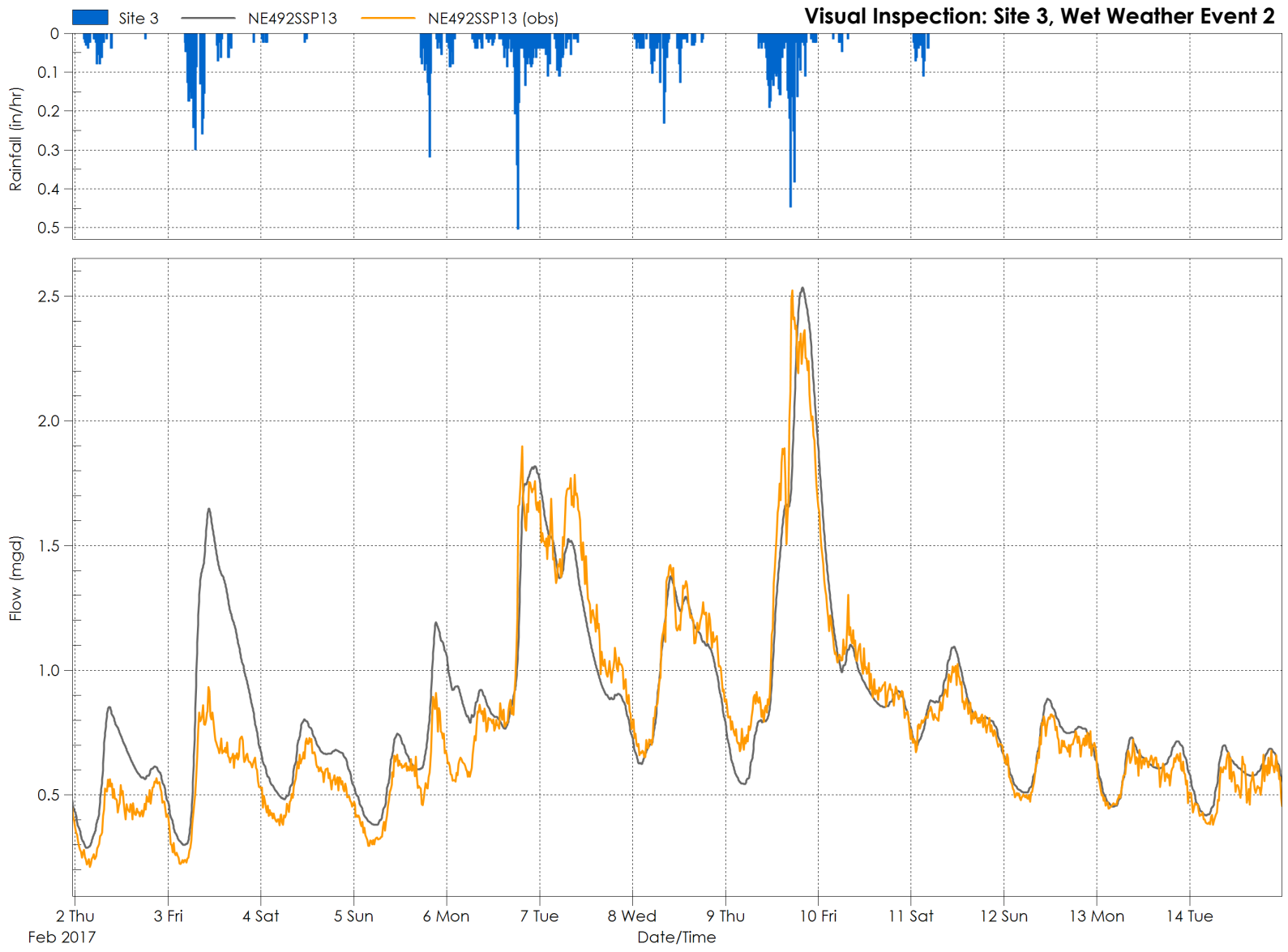
Model results for flow monitoring Site 3 overestimate and underestimate the PWWF for wet weather events, as shown in **Table H-7**. The total modeled volume was within 10% of measured values for each event. The modeled PWWFs are within 15% of measured values. The error in PWWF for WWF simulations was considered acceptable for calibration.

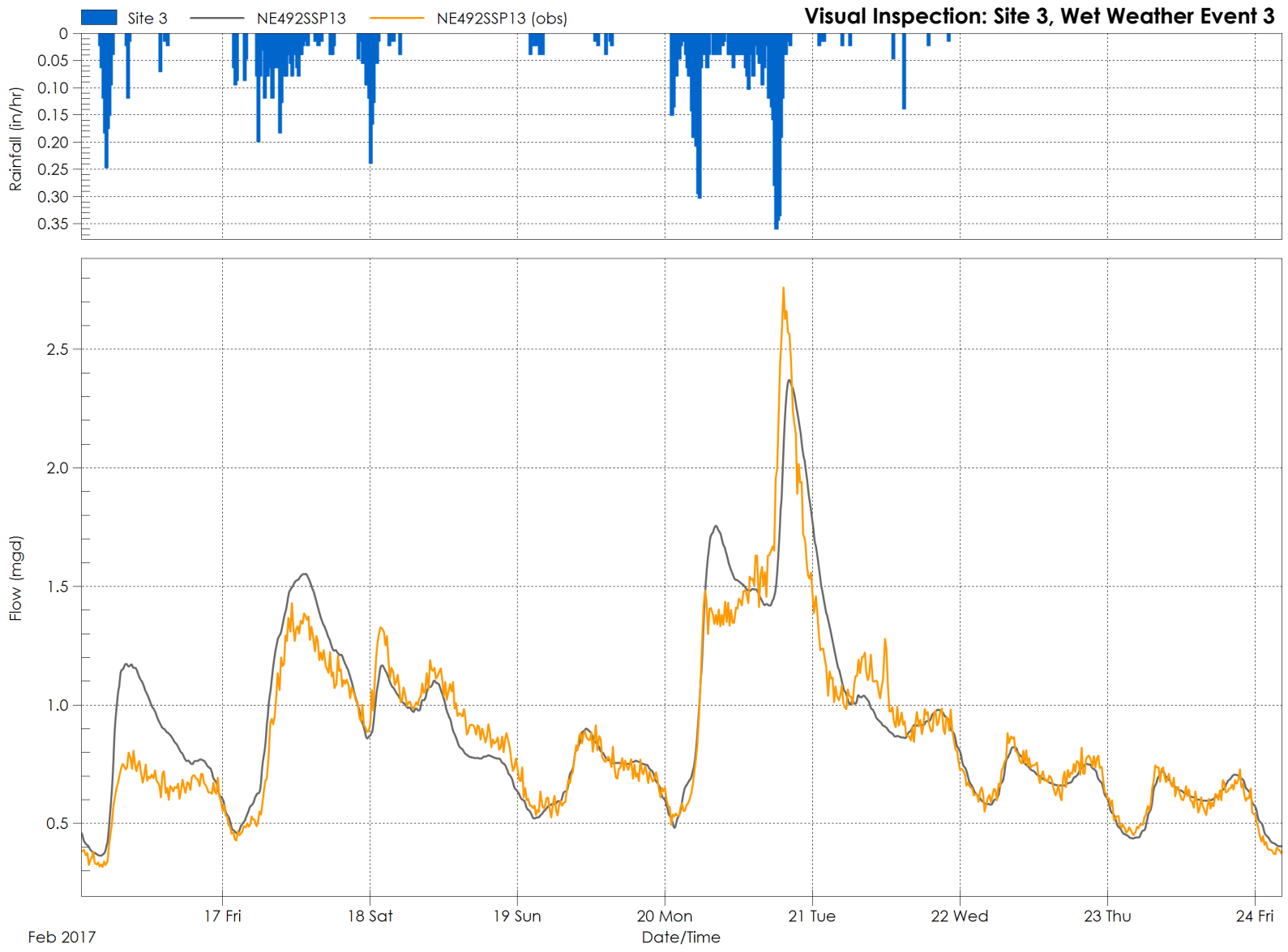
Table H-7 Site 3 PWWF Calibration Results

Site 3 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	3.34	3.16	5.5%	9.32	8.69	7.2%
Event 2	2.54	2.52	0.5%	11.17	10.40	7.4%
Event 3	2.37	2.76	-14.2%	7.25	7.04	3.0%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Visual Inspection: Site 3, Wet Weather Event 1
Site 3
NE492SSP13
NE492SSP13 (obs)
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
1.0
1.2
Flow (mgd)
3.0
2.5
2.0
1.5
1.0
0.5
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Site 3
NE492SSP13
NE492SSP13 (obs)
Visual Inspection: Site 3, Wet Weather Event 2
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
Flow (mgd)
2.5
2.0
1.5
1.0
0.5
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
Date/Time


Visual Inspection: Site 3, Wet Weather Event 3
Site 3
NE492SSP13
NE492SSP13 (obs)
Rainfall (in/hr)
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Flow (mgd)
2.5
2.0
1.5
1.0
0.5
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

H.3.6 Flow Monitoring Site 4

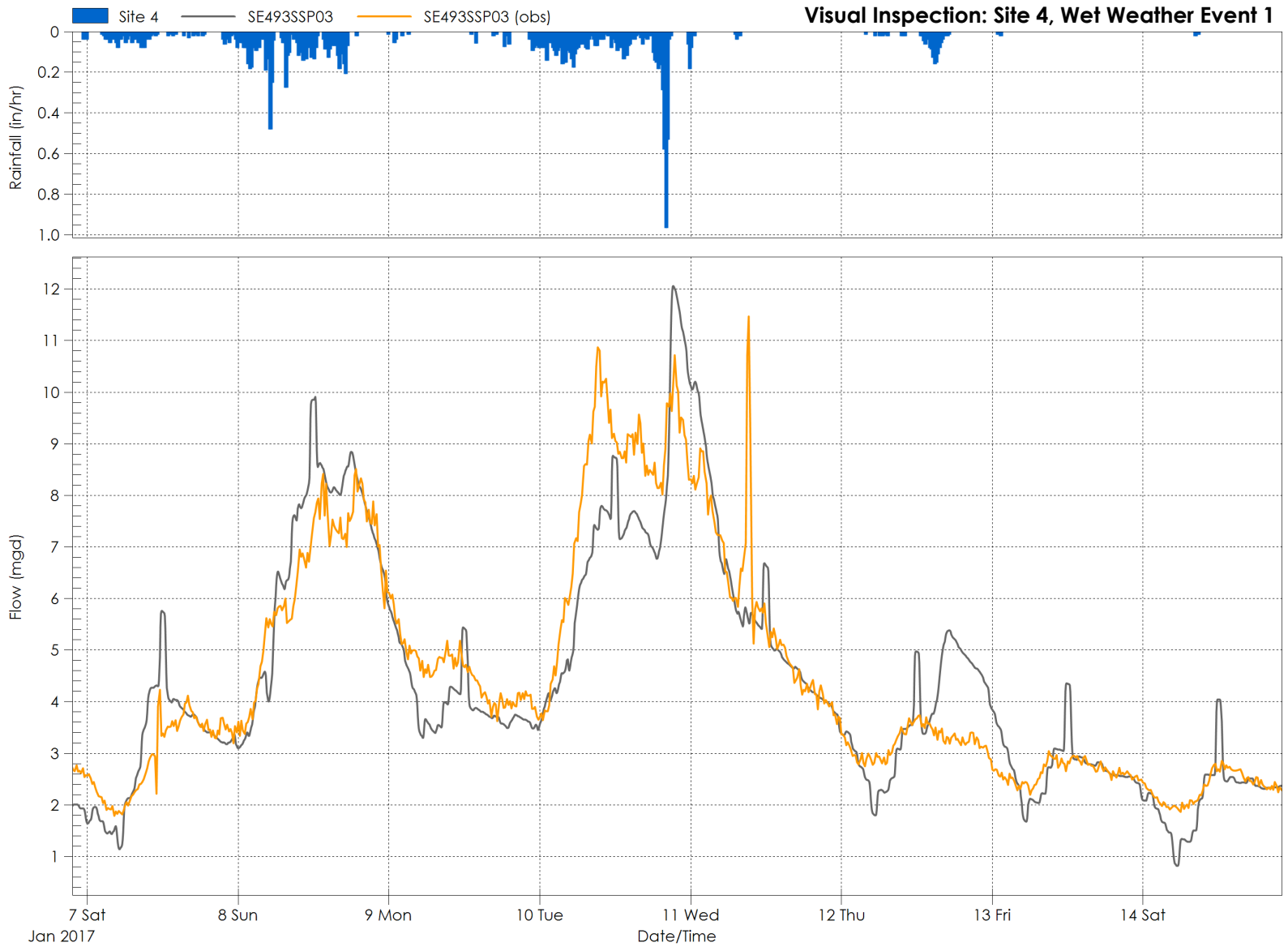
Model results for flow monitoring Site 4 overestimate and underestimate the PWWF for wet weather events, as shown in **Table H-8**. Rainfall distributions in the SMD1 service area are not representative of those simulated, observed and used for calibration within the City of Lincoln. Rainfall data from the SMD1 area was not available for use in calibration, RTK parameters for Shed 4 (SMD1) were developed to match equalized flow conditions from the Regional Pump Station during Event 1. Widespread rainfall throughout California was experienced during Event 1, therefore the model was calibrated using Event 1 and validated using Event 2 and 3.

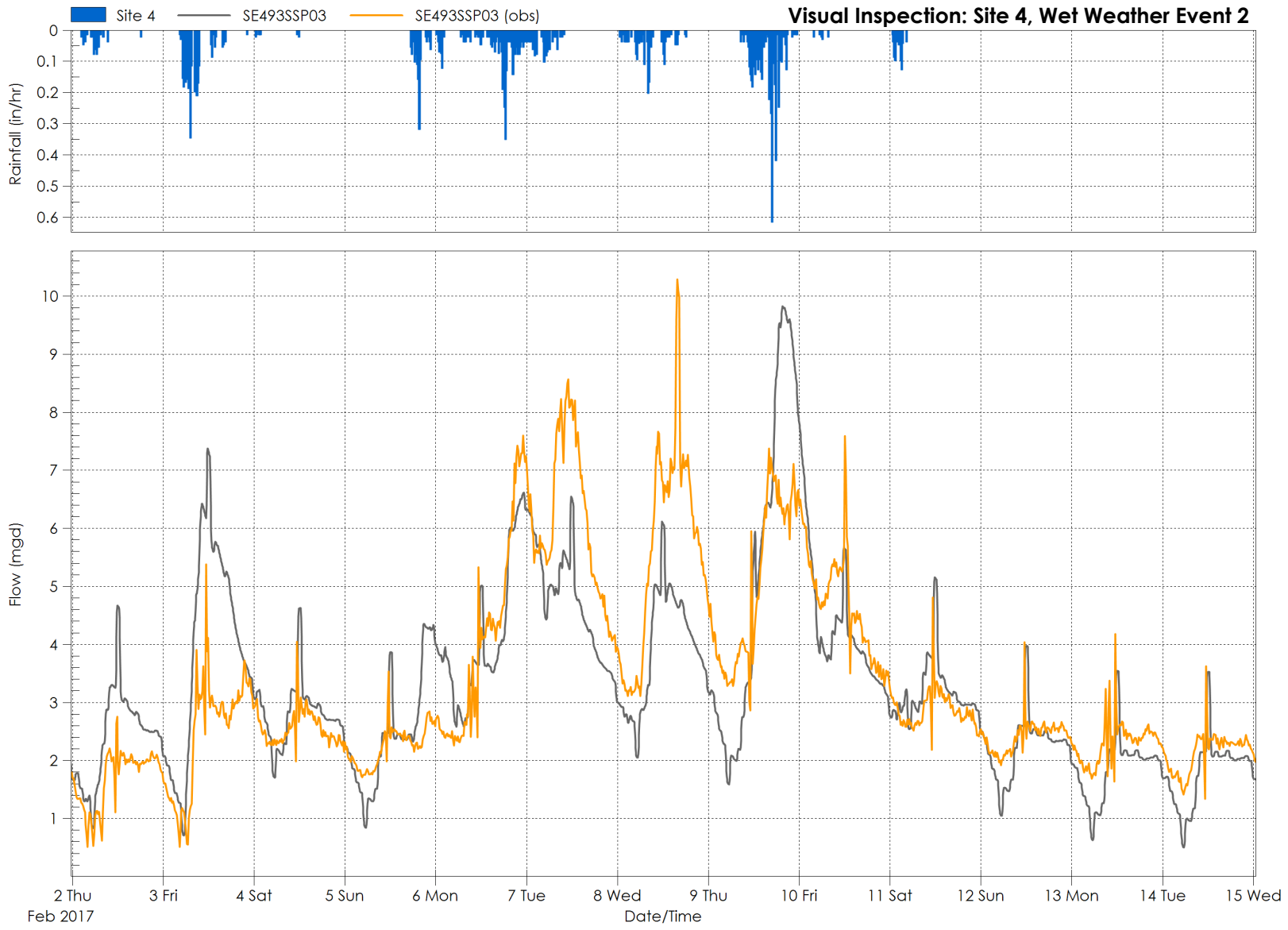
The total modeled volume was within 5% of measured values for each event. The error in PWWF for WWF simulations was considered acceptable for calibration.

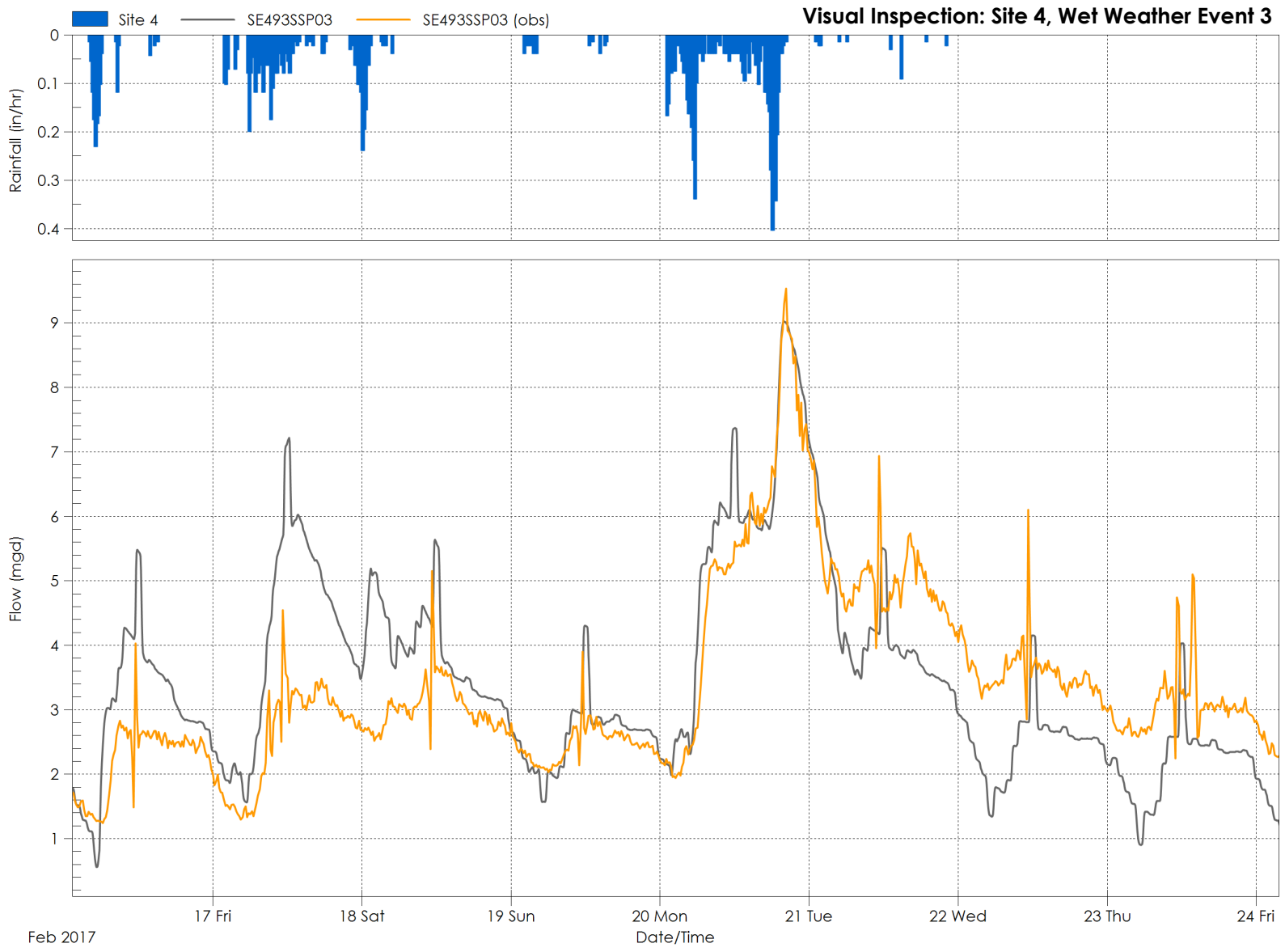
Table H-8 Site 4 PWWF Calibration Results

Site 4 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	12.06	11.47	5.1%	35.51	36.12	-1.7%
Event 2	9.83	10.29	-4.5%	42.98	44.17	-2.7%
Event 3	9.03	9.54	-5.4%	28.02	27.34	2.5%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Site 4
SE493SSP03
SE493SSP03 (obs)
Visual Inspection: Site 4, Wet Weather Event 1
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
1.0
Flow (mgd)
1
2
3
4
5
6
7
8
9
10
11
12
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Site 4
SE493SSP03
SE493SSP03 (obs)
Visual Inspection: Site 4, Wet Weather Event 2
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
Flow (mgd)
1
2
3
4
5
6
7
8
9
10
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Site 4
SE493SSP03
SE493SSP03 (obs)
Visual Inspection: Site 4, Wet Weather Event 3
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
Flow (mgd)
1
2
3
4
5
6
7
8
9
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

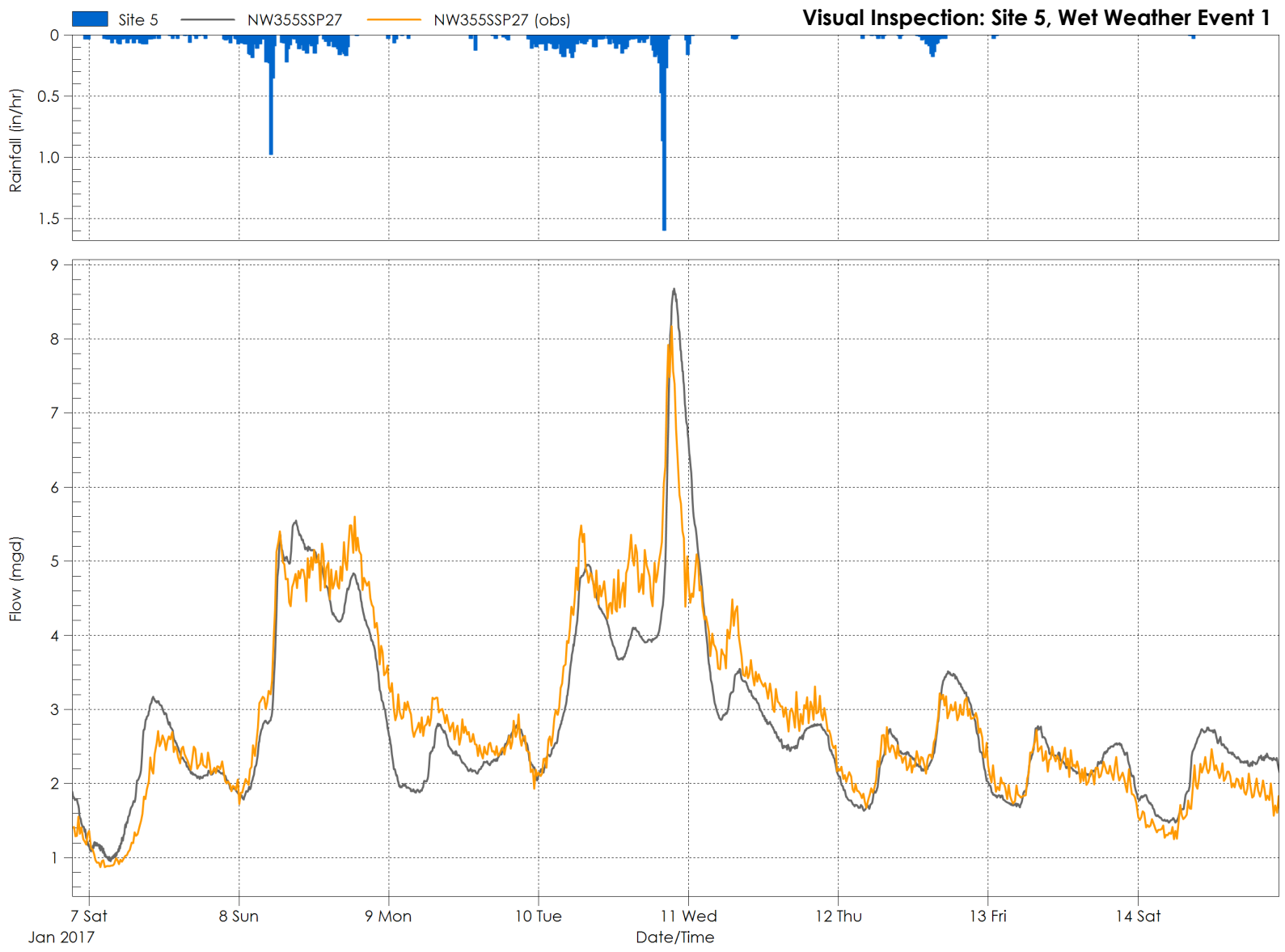
H.3.7 Flow Monitoring Site 5

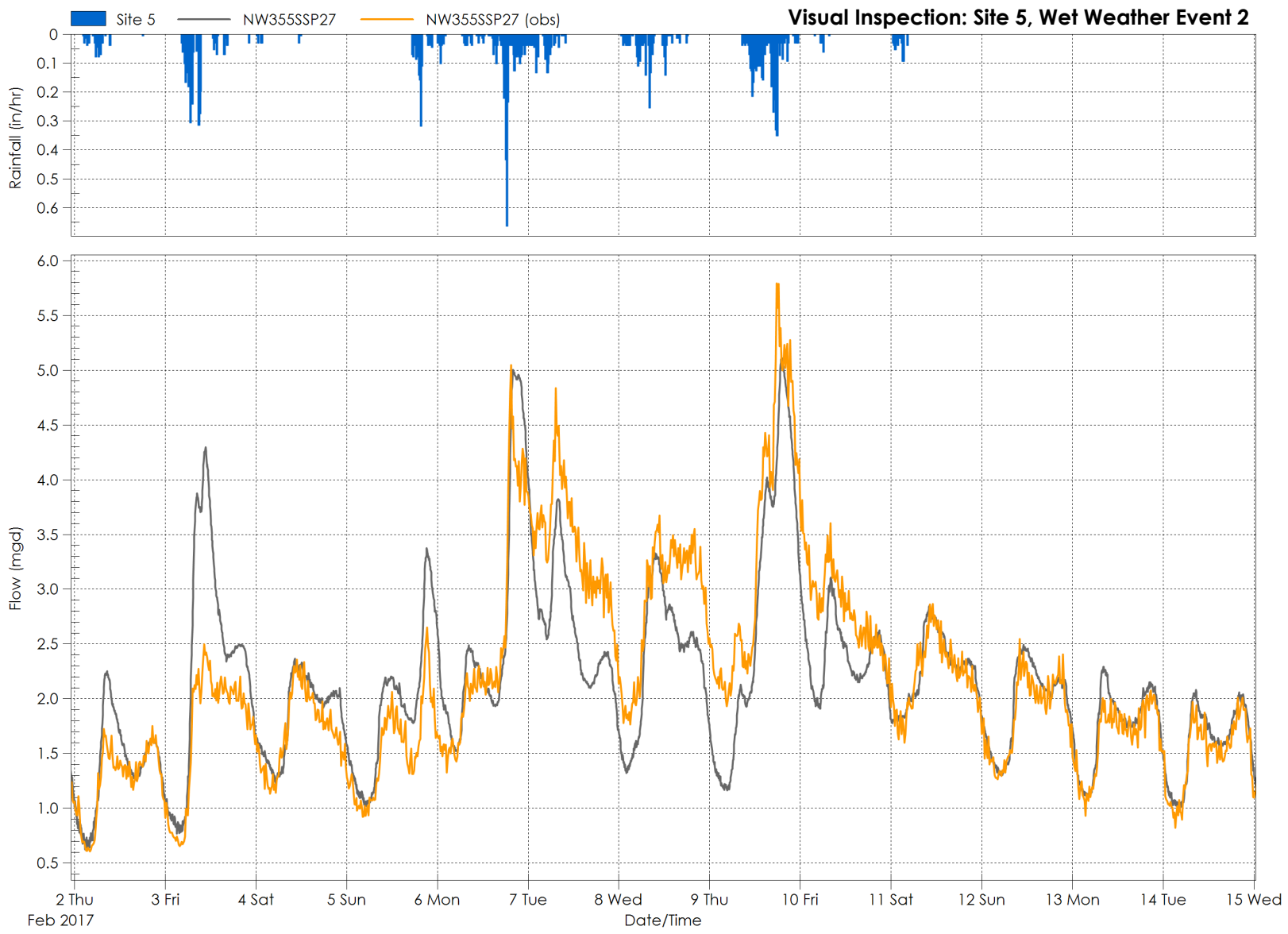
Model results for flow monitoring Site 5 overestimate and underestimate the PWWF for wet weather events, as shown in **Table H-5**. The total modeled volume was within 5% of measured values for each event. The modeled PWWFs are within 10% of measured values. The error in PWWF for WWF simulations was considered acceptable for calibration.

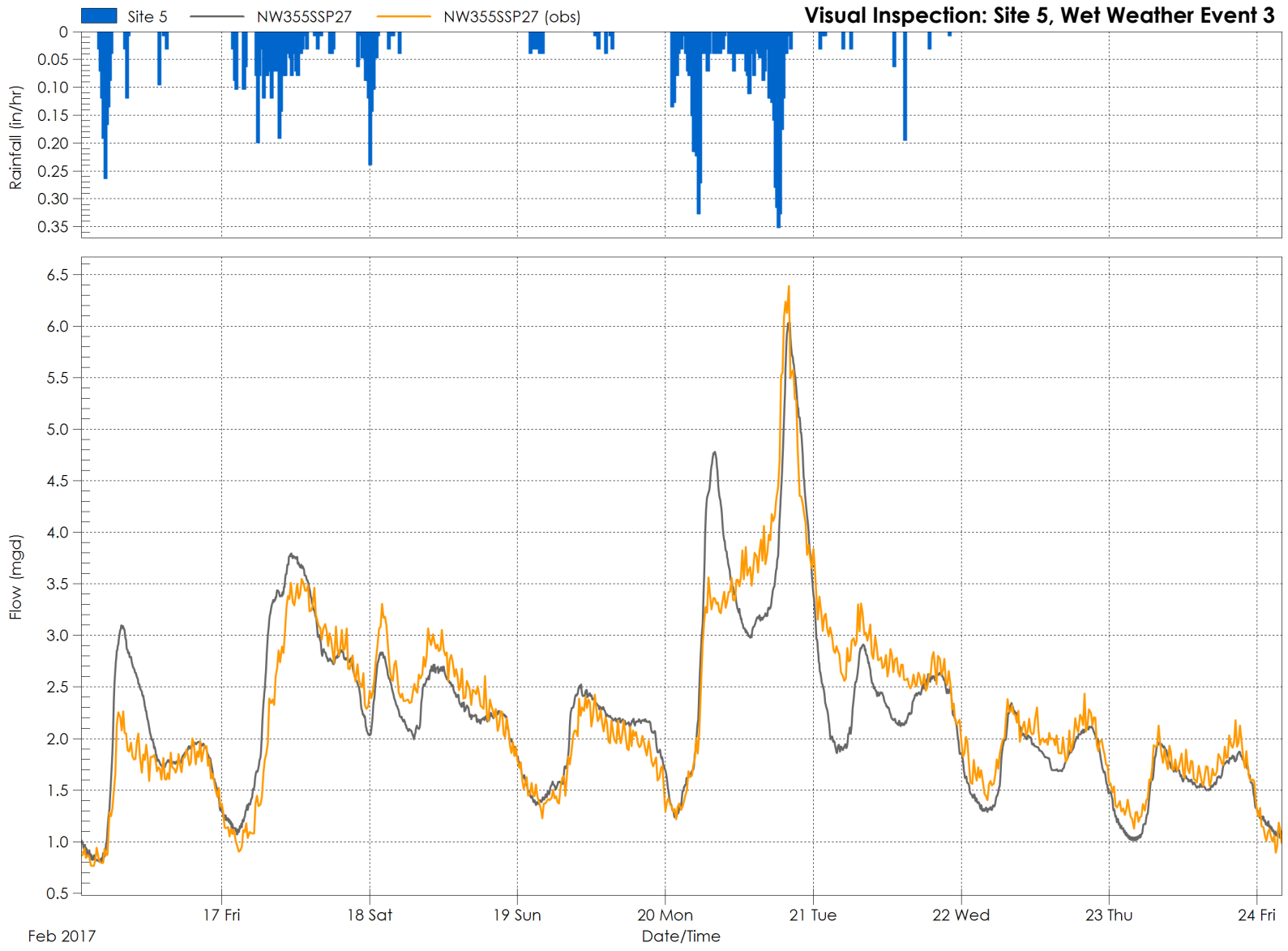
Table H-9 Site 5 PWWF Calibration Results

Site 5 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	8.70	8.17	5.1%	22.94	23.26	-1.4%
Event 2	5.26	5.79	-9.2%	28.21	28.42	-0.7%
Event 3	5.97	6.39	-6.5%	18.09	18.19	-0.5%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Site 5
NW355SSP27
NW355SSP27 (obs)
Visual Inspection: Site 5, Wet Weather Event 1
Rainfall (in/hr)
0
0.5
1.0
1.5
Flow (mgd)
9
8
7
6
5
4
3
2
1
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Site 5
NW355SSP27
NW355SSP27 (obs)
Visual Inspection: Site 5, Wet Weather Event 2
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
Flow (mgd)
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Site 5
NW355SSP27
NW355SSP27 (obs)
Visual Inspection: Site 5, Wet Weather Event 3
Rainfall (in/hr)
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Flow (mgd)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

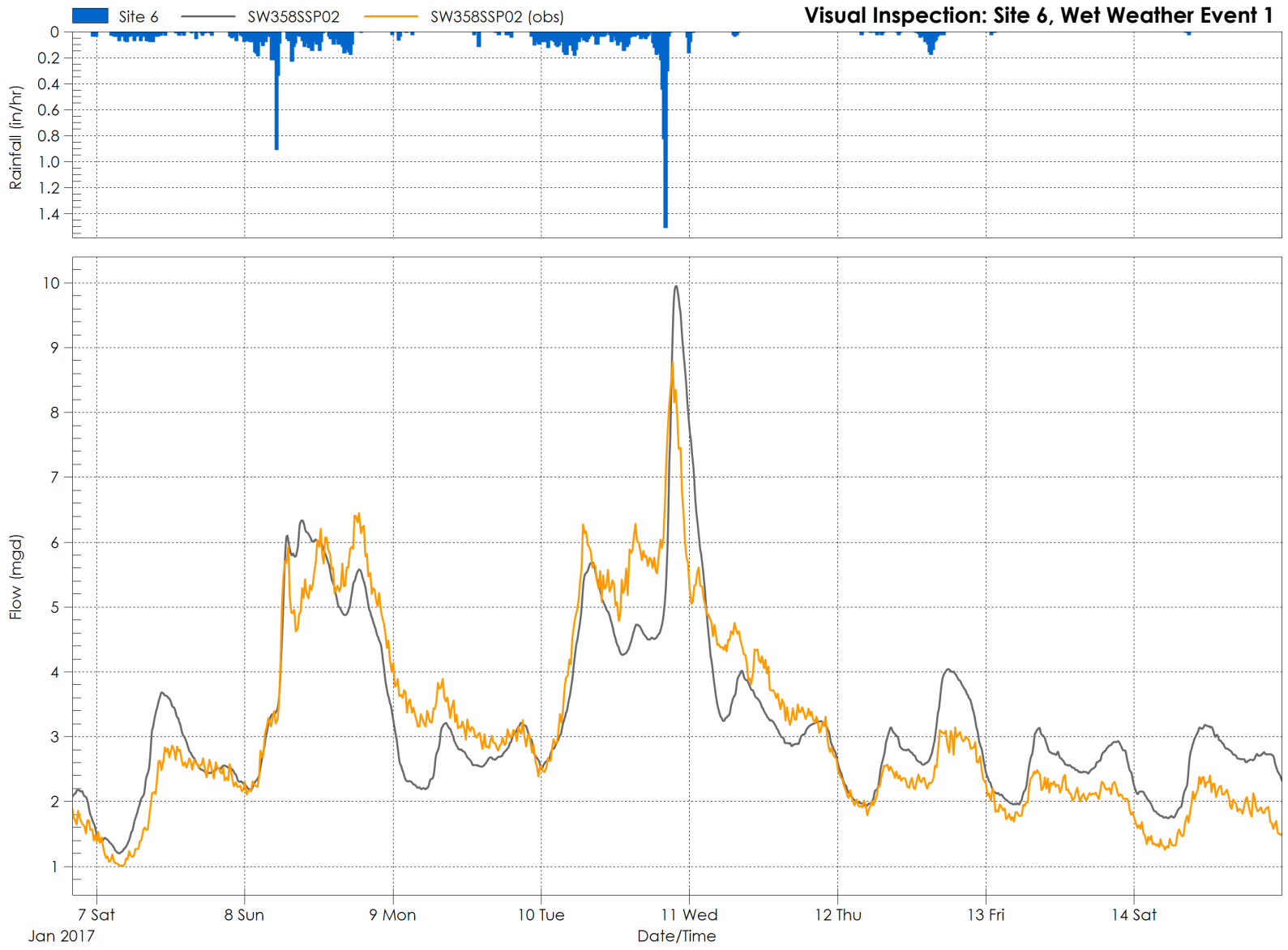
H.3.8 Flow Monitoring Site 6

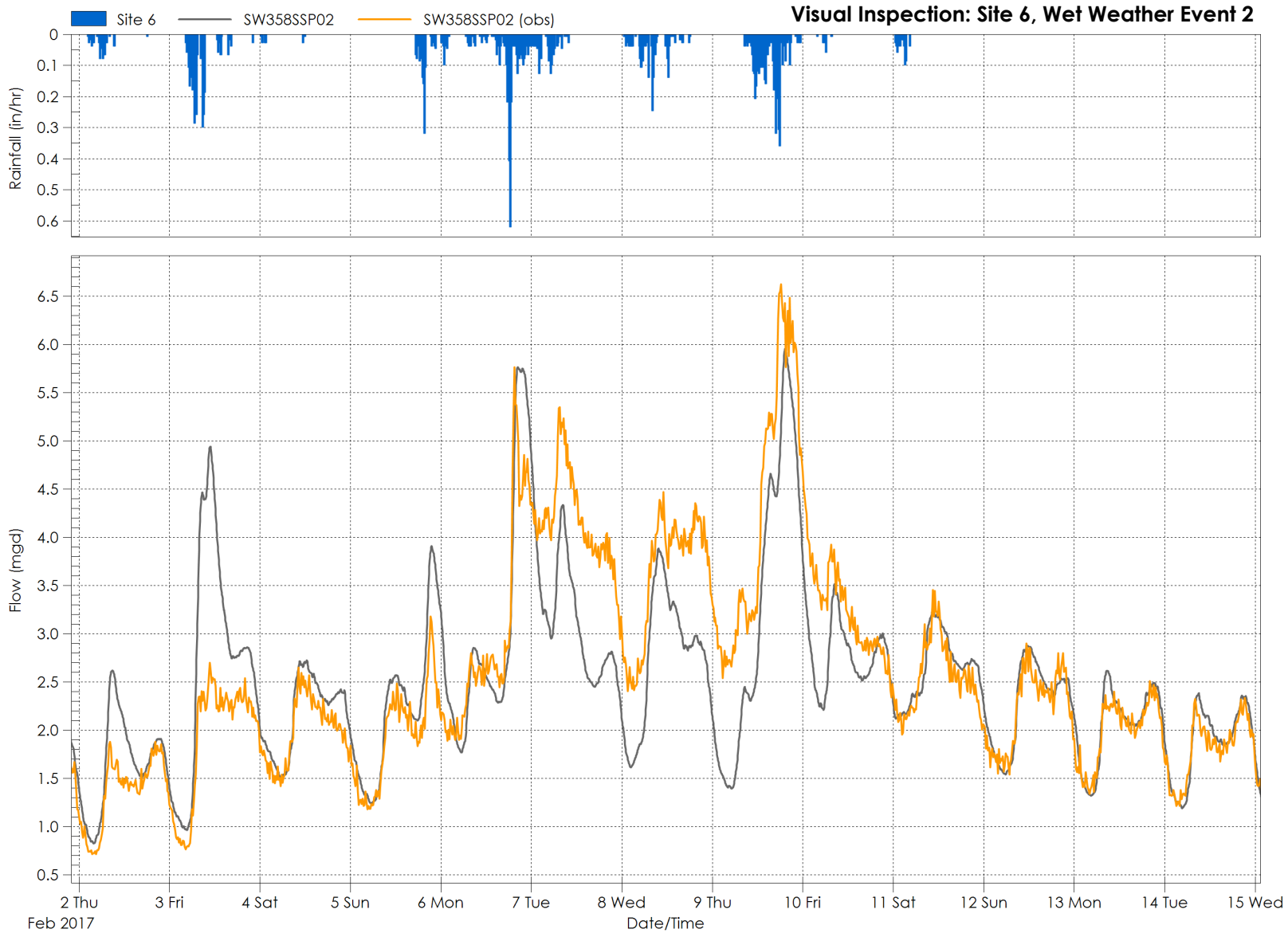
Model results of Event 1 for flow monitoring Site 6 overestimate the PWWF, as shown in **Table H-10**. Validation results from Events 2 and 3 underestimate flow from Shed 6. This is may be due to high groundwater infiltration observed at this site and successive rainfall events. The total modeled volume was within 10% of measured values for each event. The modeled PWWFs for each Event are within 15% of measured values. The error in PWWF for WWF simulations was considered acceptable for calibration.

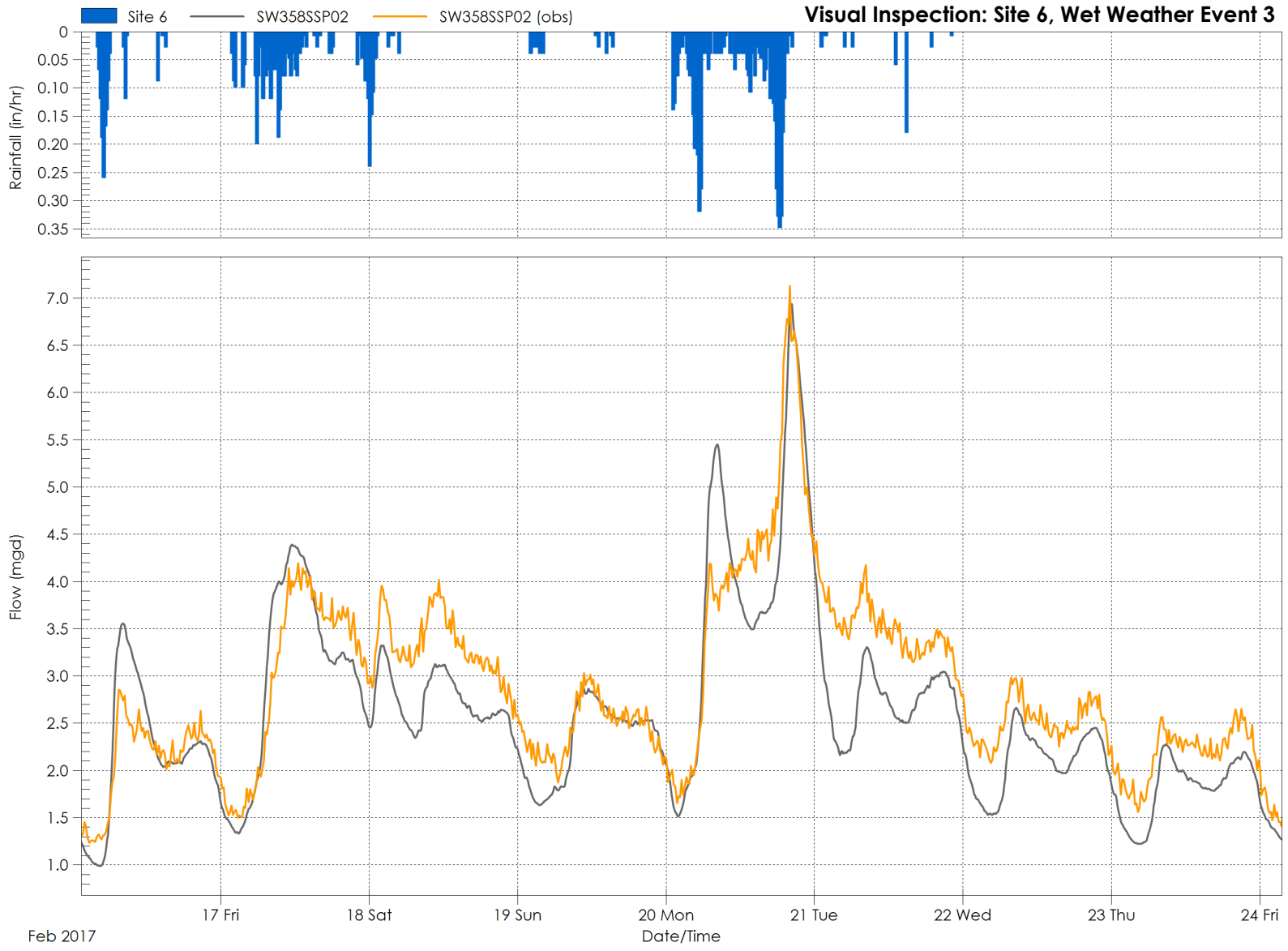
Table H-10 Site 6 PWWF Calibration Results

Site 6 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	9.94	8.78	13.2%	26.63	25.71	3.6%
Event 2	6.11	6.63	-7.8%	32.92	33.96	-3.1%
Event 3	6.84	7.13	-4.0%	21.08	23.13	-8.9%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Site 6
SW358SSP02
SW358SSP02 (obs)
Visual Inspection: Site 6, Wet Weather Event 1
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Flow (mgd)
10
9
8
7
6
5
4
3
2
1
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Visual Inspection: Site 6, Wet Weather Event 2
Site 6
SW358SSP02
SW358SSP02 (obs)
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
Flow (mgd)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Site 6
SW358SSP02
SW358SSP02 (obs)
Visual Inspection: Site 6, Wet Weather Event 3
Rainfall (in/hr)
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Flow (mgd)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Feb 2017
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Date/Time

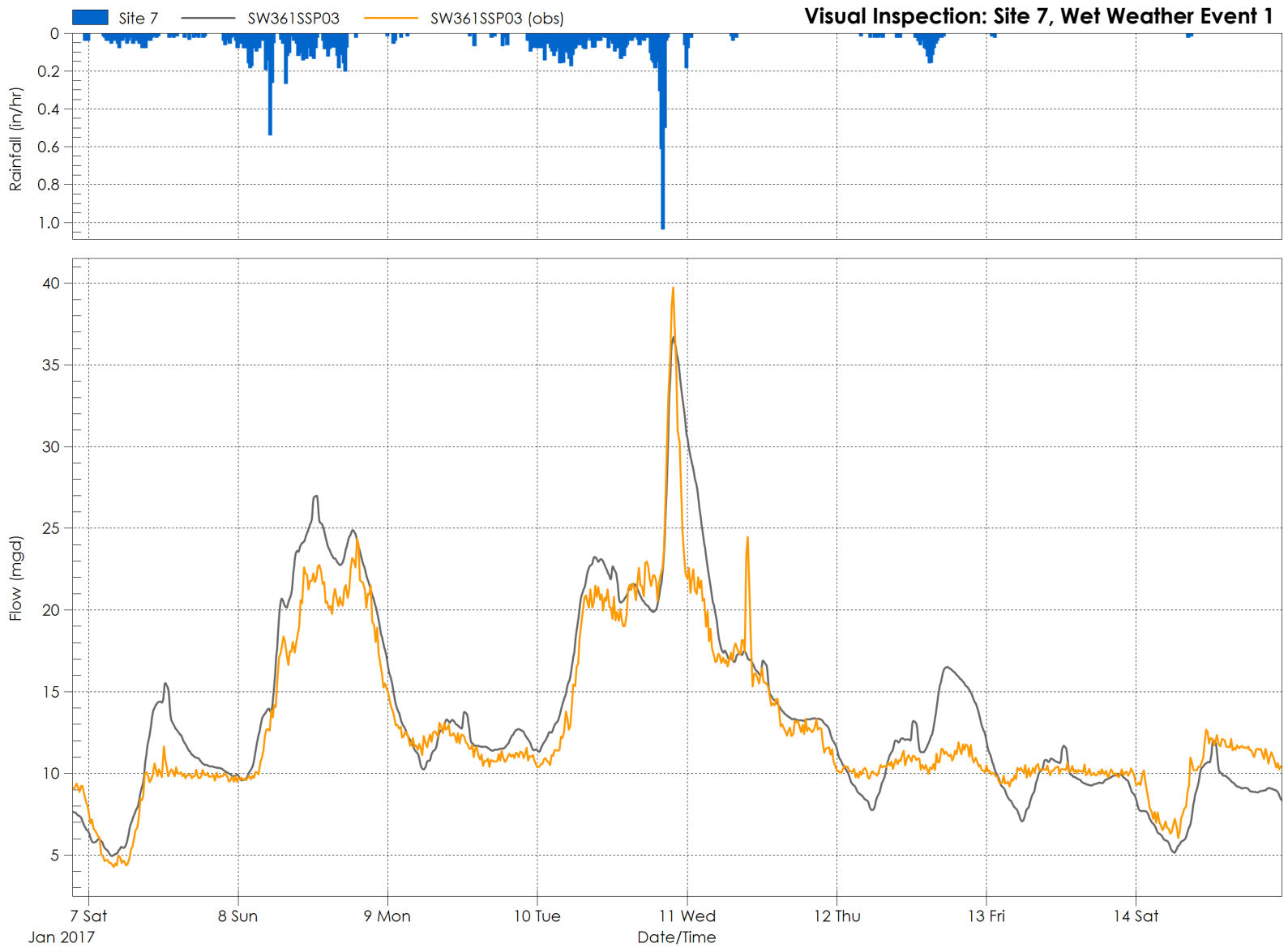
H.3.9 Flow Monitoring Site 7

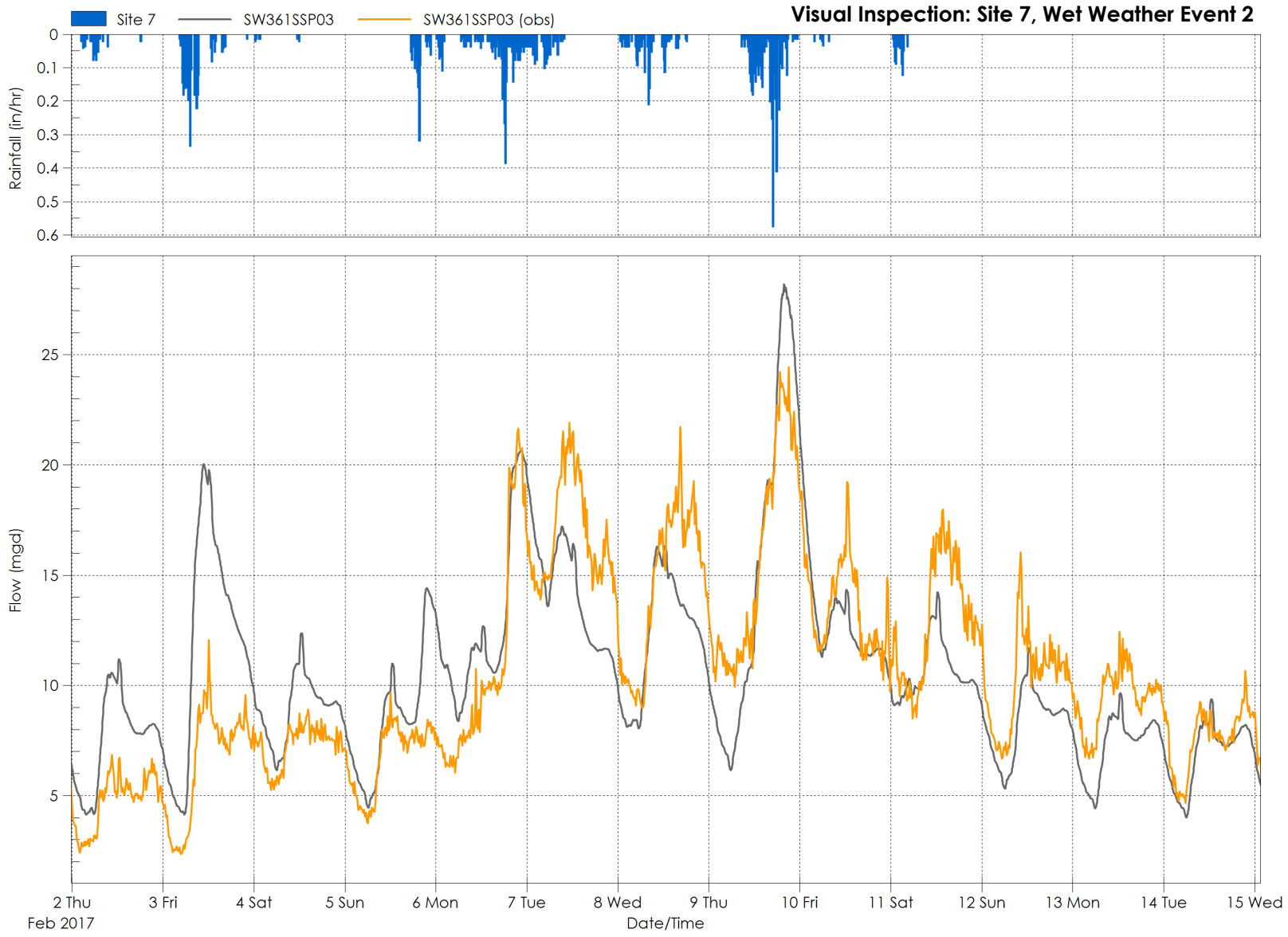
Model results for flow monitoring Site 7 overestimate and underestimate the PWWF for wet weather events, as shown in **Table H-11**. Site 7 being the most downstream flow meter was considered during calibration. PWWF error can be associated with system attenuation, differences in geographical rainfall intensity, and a variety of other impacts. The total modeled volume was within 5% of measured values for each event. The modeled PWWFs for each Event are typically within 15% of measured values. The error in PWWF for WWF simulations was considered acceptable for calibration.

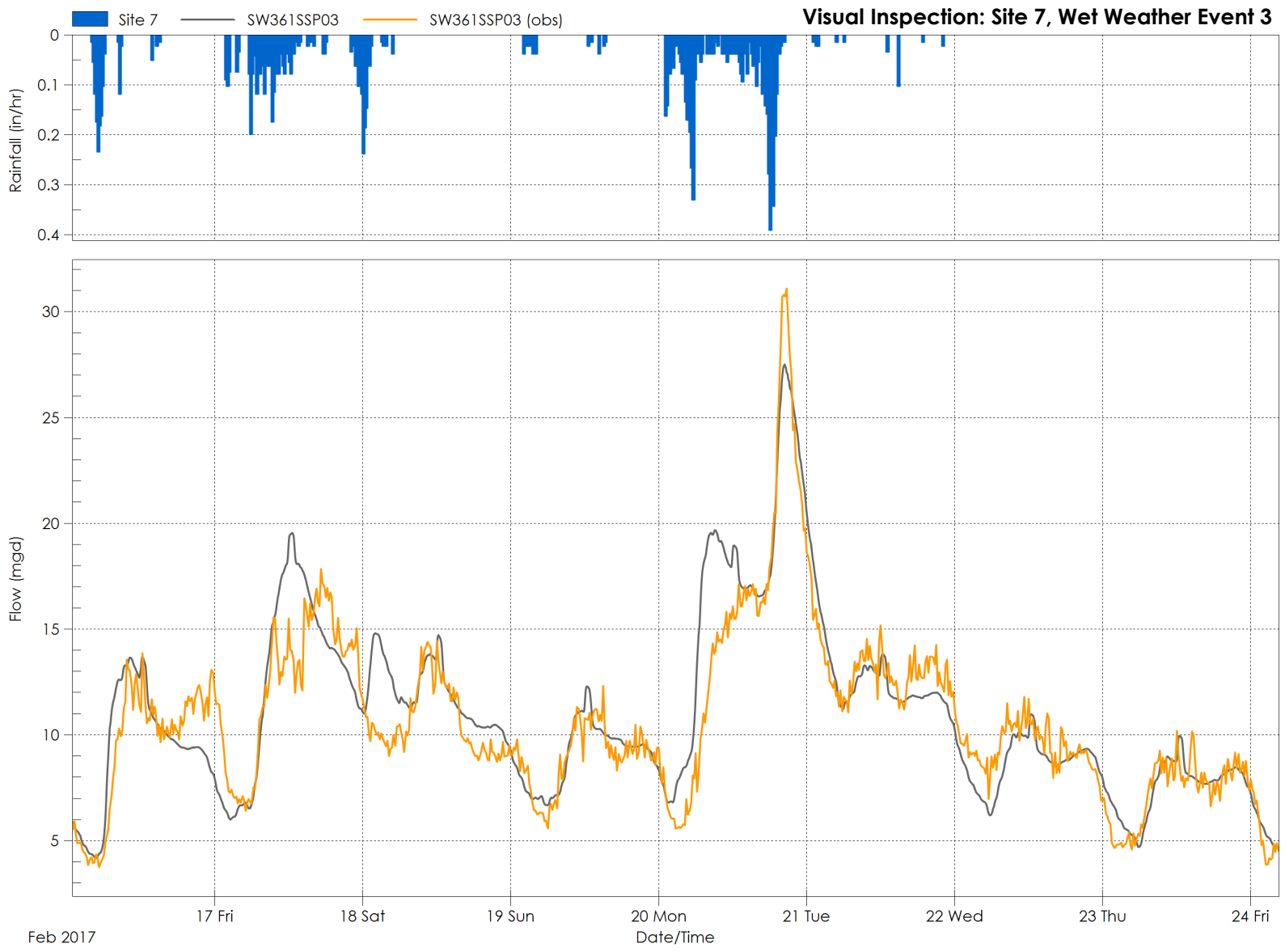
Table H-11 Site 7 PWWF Calibration Results

Site 7 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	34.99	39.76	-12.0%	106.80	104.30	2.4%
Event 2	27.13	24.45	11.0%	134.50	136.80	-1.7%
Event 3	26.32	31.11	-15.4%	86.68	86.56	0.1%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Site 7
SW361SSP03
SW361SSP03 (obs)
Visual Inspection: Site 7, Wet Weather Event 1
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
1.0
Flow (mgd)
40
35
30
25
20
15
10
5
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Visual Inspection: Site 7, Wet Weather Event 2
Site 7
SW361SSP03
SW361SSP03 (obs)
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
Flow (mgd)
25
20
15
10
5
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Visual Inspection: Site 7, Wet Weather Event 3
Site 7
SW361SSP03
SW361SSP03 (obs)
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
Flow (mgd)
30
25
20
15
10
5
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

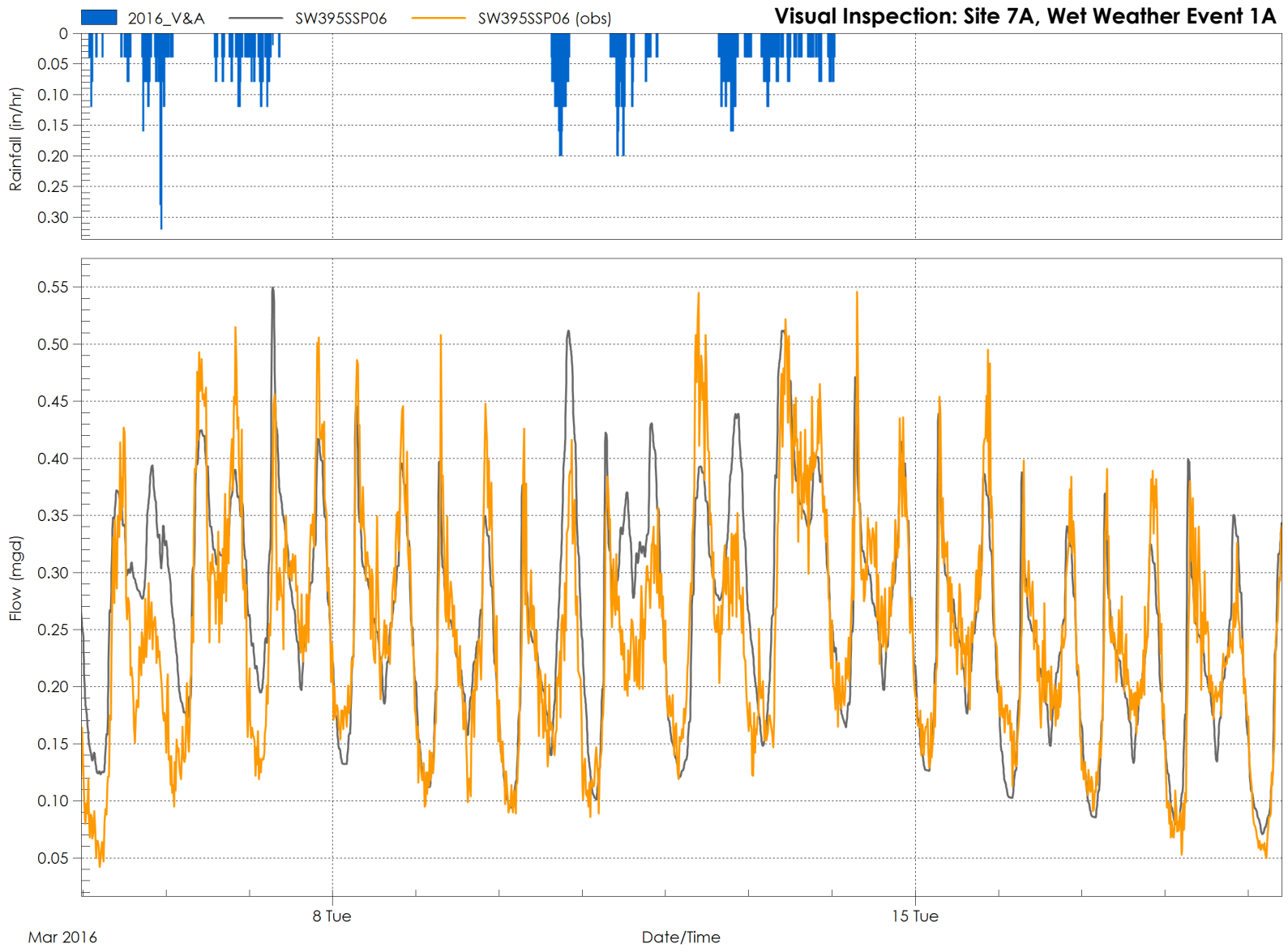
H.3.10 Flow Monitoring Site 7A

One rainfall event, Event 1A was used to calibrate flow monitoring Site 7A. Data from the 2016 flow monitoring study was used for calibration. The intensity of this storm was much less than those used to calibrate the remaining collection system. The RTK parameters for Shed 7A represent a relatively dry season condition, when compared to those determined for remaining Sheds. Modeled PWWF and total volume were within 5% of those measured for Event 1A, as shown in **Table H-12**.

Table H-12 Site 7A PWWF Calibration Results

Site 7A WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1A	0.55	0.55	0.7%	3.73	3.56	4.7%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


2016_V&A
SW395SSP06
SW395SSP06 (obs)
Visual Inspection: Site 7A, Wet Weather Event 1A
Rainfall (in/hr)
0
0.05
0.10
0.15
0.20
0.25
0.30
Flow (mgd)
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
8 Tue
15 Tue
Mar 2016
Date/Time

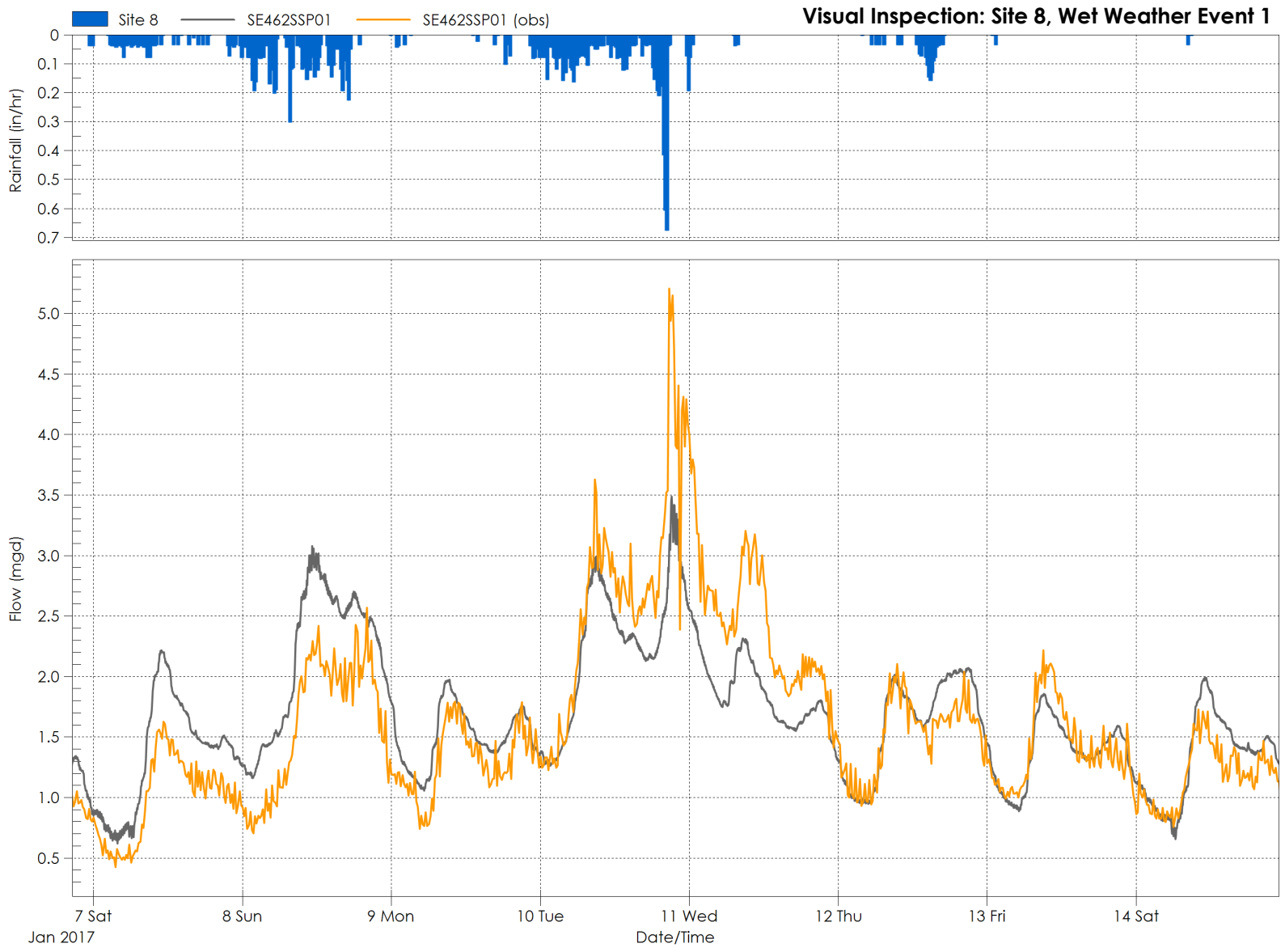
H.3.11 Flow Monitoring Site 8

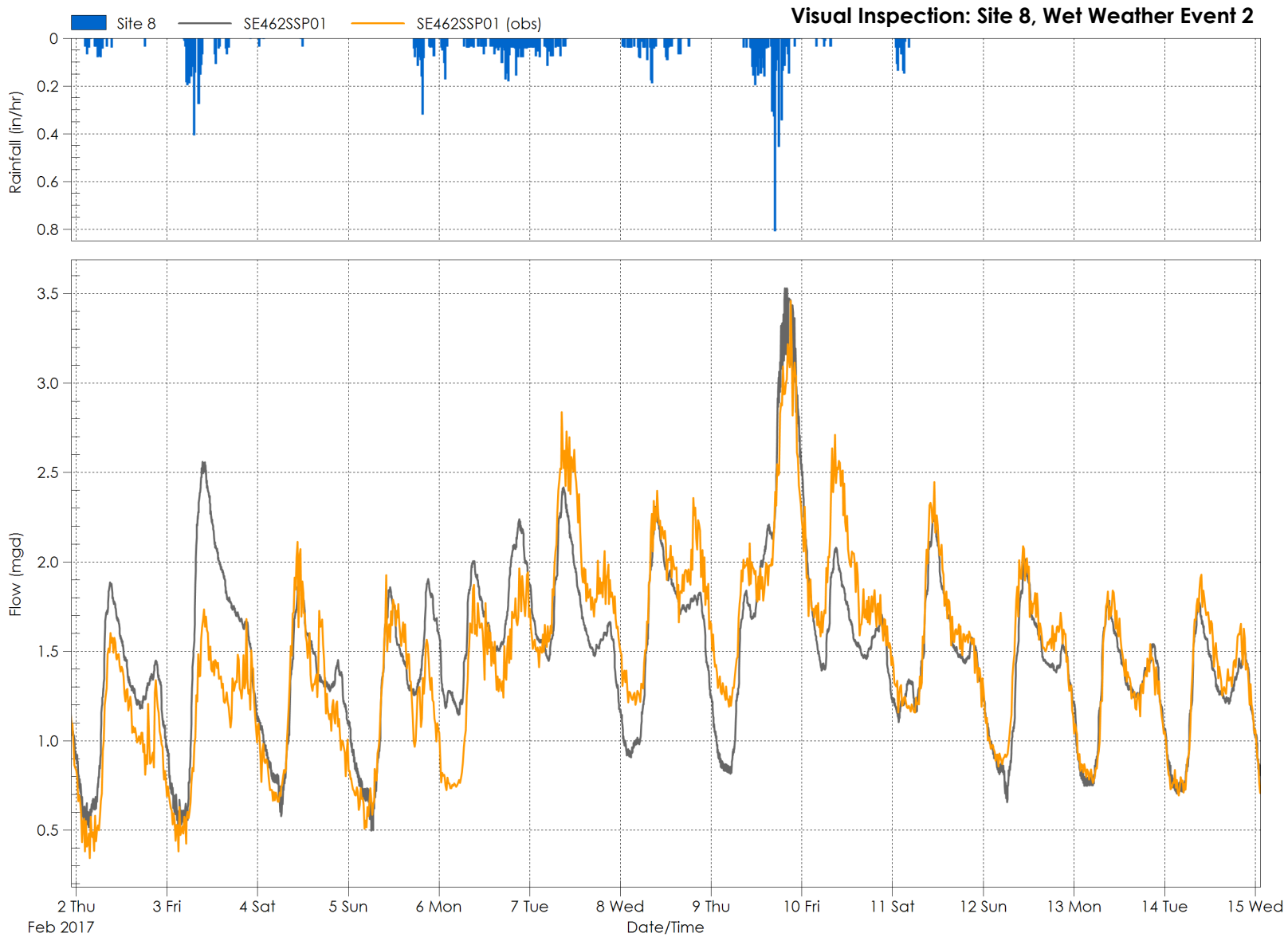
Model results of Event 1 for flow monitoring Site 8 overestimate the PWWF, as shown in **Table H-13**. Validation results from Events 2 and 3 provide better results. Rainfall in Shed 8 may have been more intensity due the higher elevation with respect to the remaining system and rainfall collection locations. The total modeled volume was within 5% of measured values for each event. The modeled PWWFs for validation events are within 15% of measured values. The error in PWWF for WWF simulations was considered acceptable for calibration.

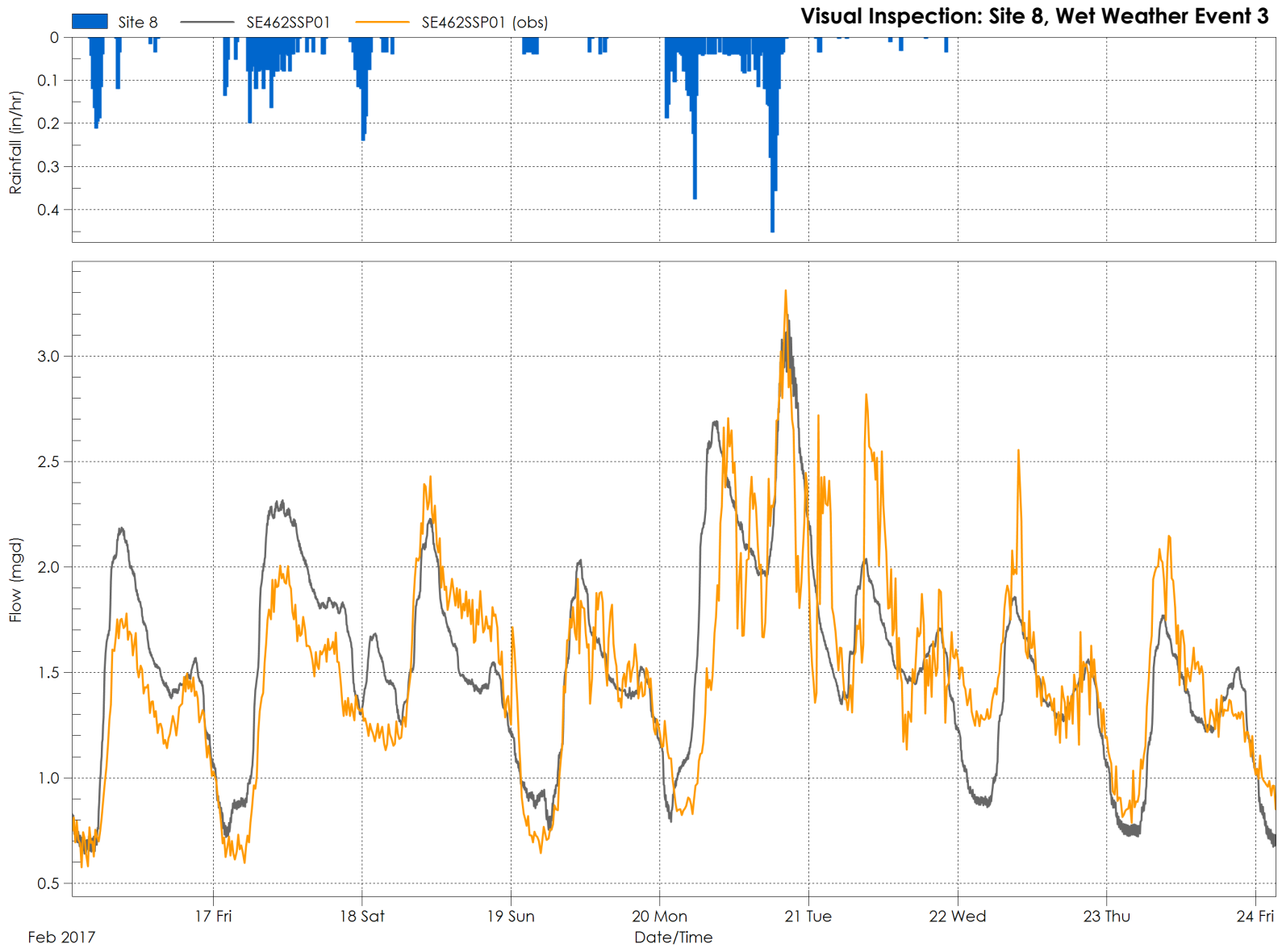
Table H-13 Site 8 PWWF Calibration Results

Site 8 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	3.49	5.21	-33.0%	13.43	13.12	2.4%
Event 2	3.53	3.46	2.1%	19.25	19.06	1.0%
Event 3	3.20	3.31	-3.5%	12.27	12.09	1.5%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Visual Inspection: Site 8, Wet Weather Event 1
Site 8
SE462SSP01
SE462SSP01 (obs)
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Flow (mgd)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Visual Inspection: Site 8, Wet Weather Event 2
Site 8
SE462SSP01
SE462SSP01 (obs)
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
Flow (mgd)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Visual Inspection: Site 8, Wet Weather Event 3
Site 8
SE462SSP01
SE462SSP01 (obs)
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
Flow (mgd)
3.0
2.5
2.0
1.5
1.0
0.5
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

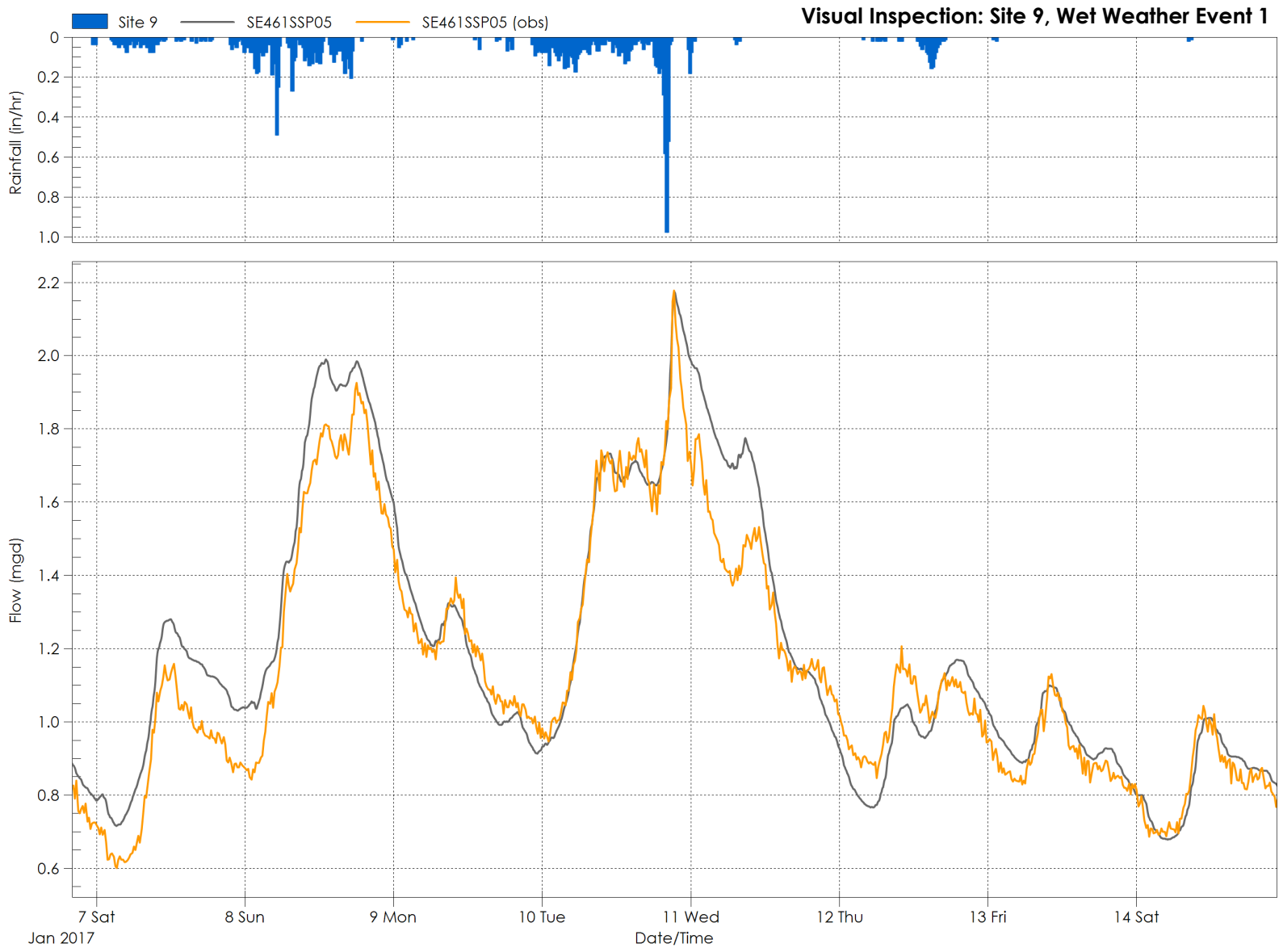
H.3.12 Flow Monitoring Site 9

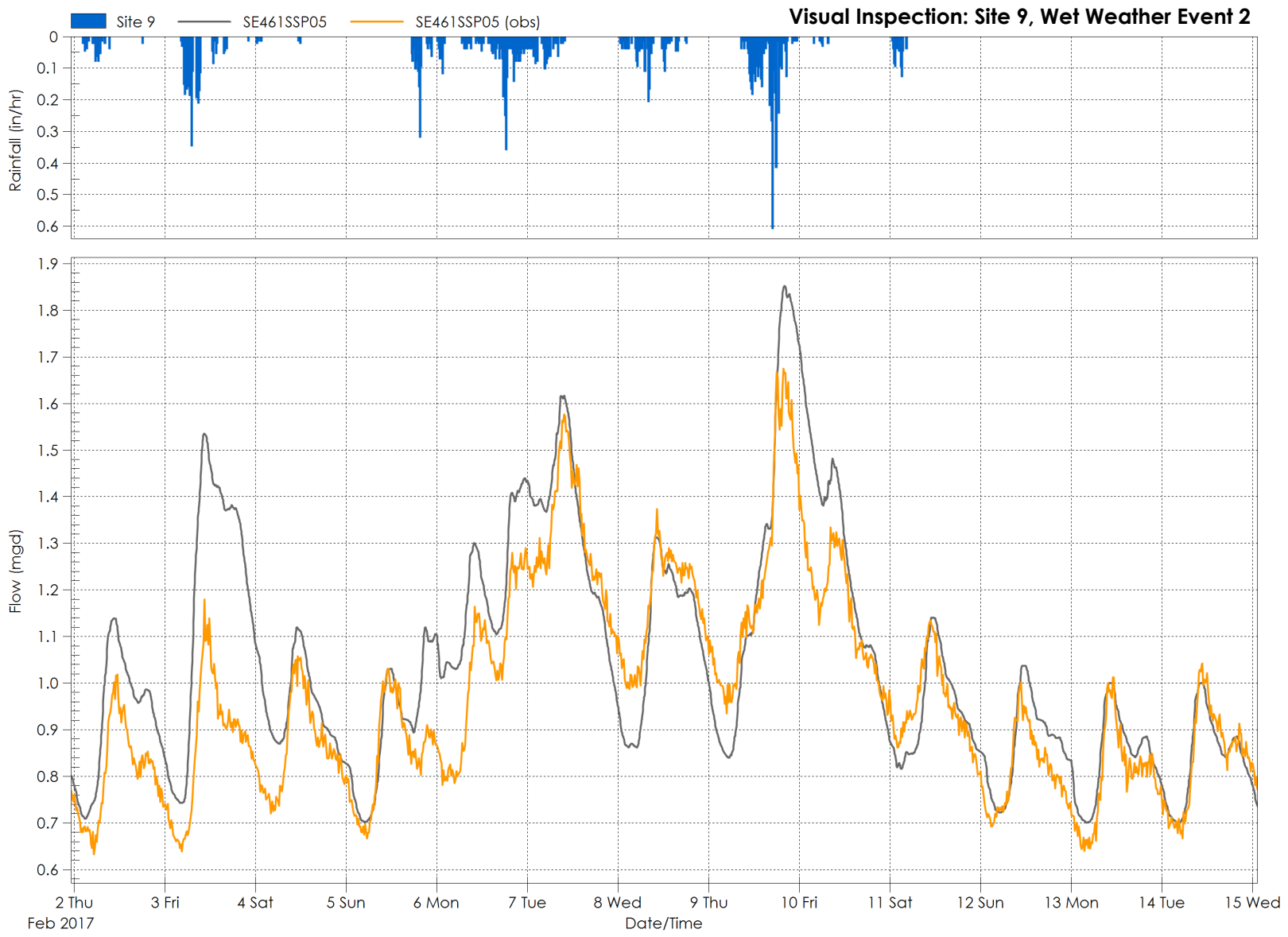
Model results of flow monitoring Site 9 over attenuate flow the PWWF for wet weather events, as shown in **Table H-14**. Rainfall in Shed 9 may have been more intensity due the higher elevation with respect to the remaining system and rainfall collection locations. The total modeled volume was within 10% of measured values for each event. The modeled PWWFs are within 15% of measured values. The error in PWWF for WWF simulations was considered acceptable for calibration.

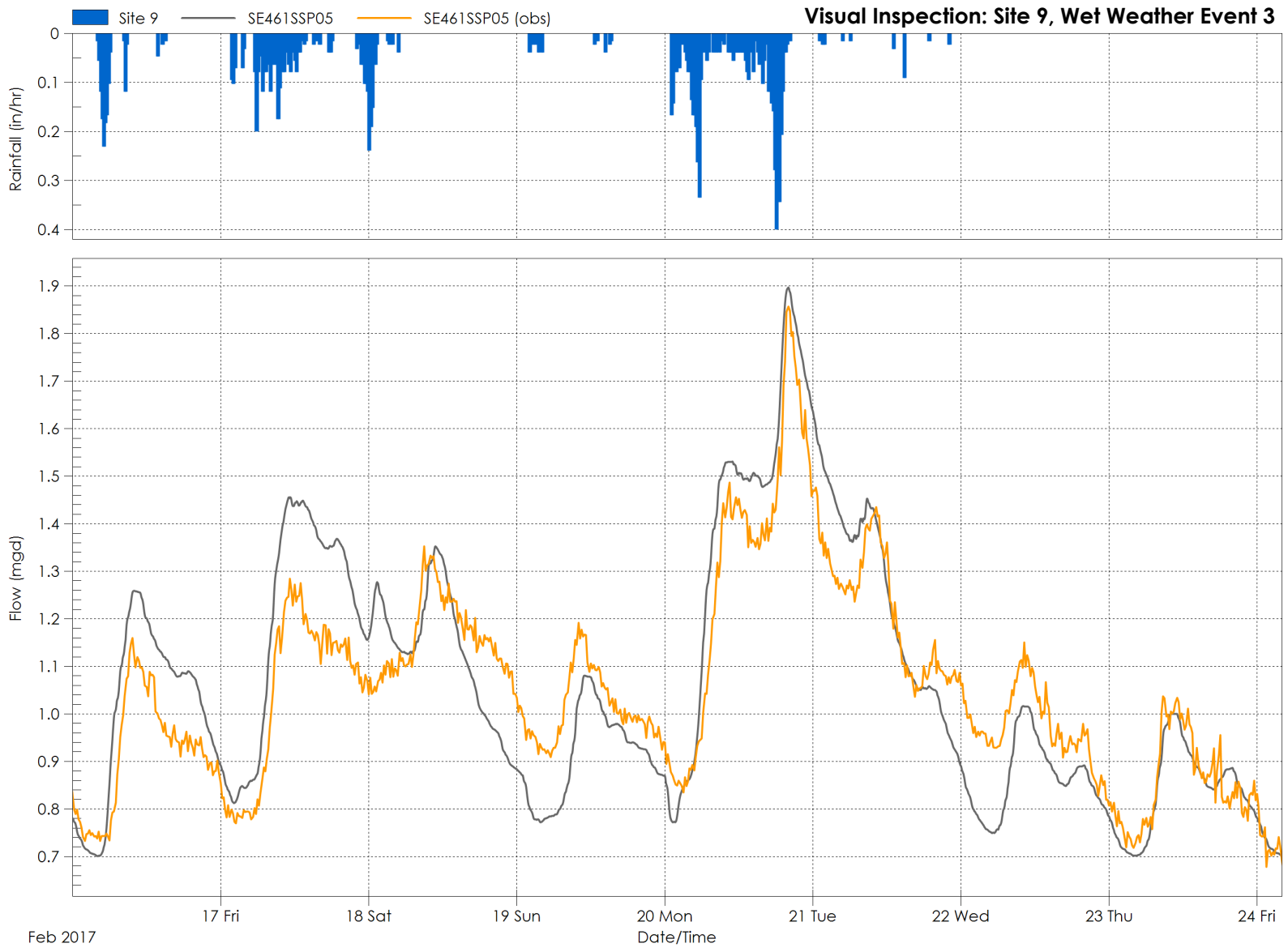
Table H-14 Site 9 PWWF Calibration Results

Site 9 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	2.17	2.18	-0.2%	9.61	9.20	4.4%
Event 2	1.85	1.68	10.6%	13.57	12.65	7.3%
Event 3	3.20	3.31	-3.5%	12.27	12.09	1.5%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Visual Inspection: Site 9, Wet Weather Event 1
Site 9
SE461SSP05
SE461SSP05 (obs)
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
1.0
Flow (mgd)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Visual Inspection: Site 9, Wet Weather Event 2
Site 9
SE461SSP05
SE461SSP05 (obs)
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
Flow (mgd)
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Site 9
SE461SSP05
SE461SSP05 (obs)
Visual Inspection: Site 9, Wet Weather Event 3
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
Flow (mgd)
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time

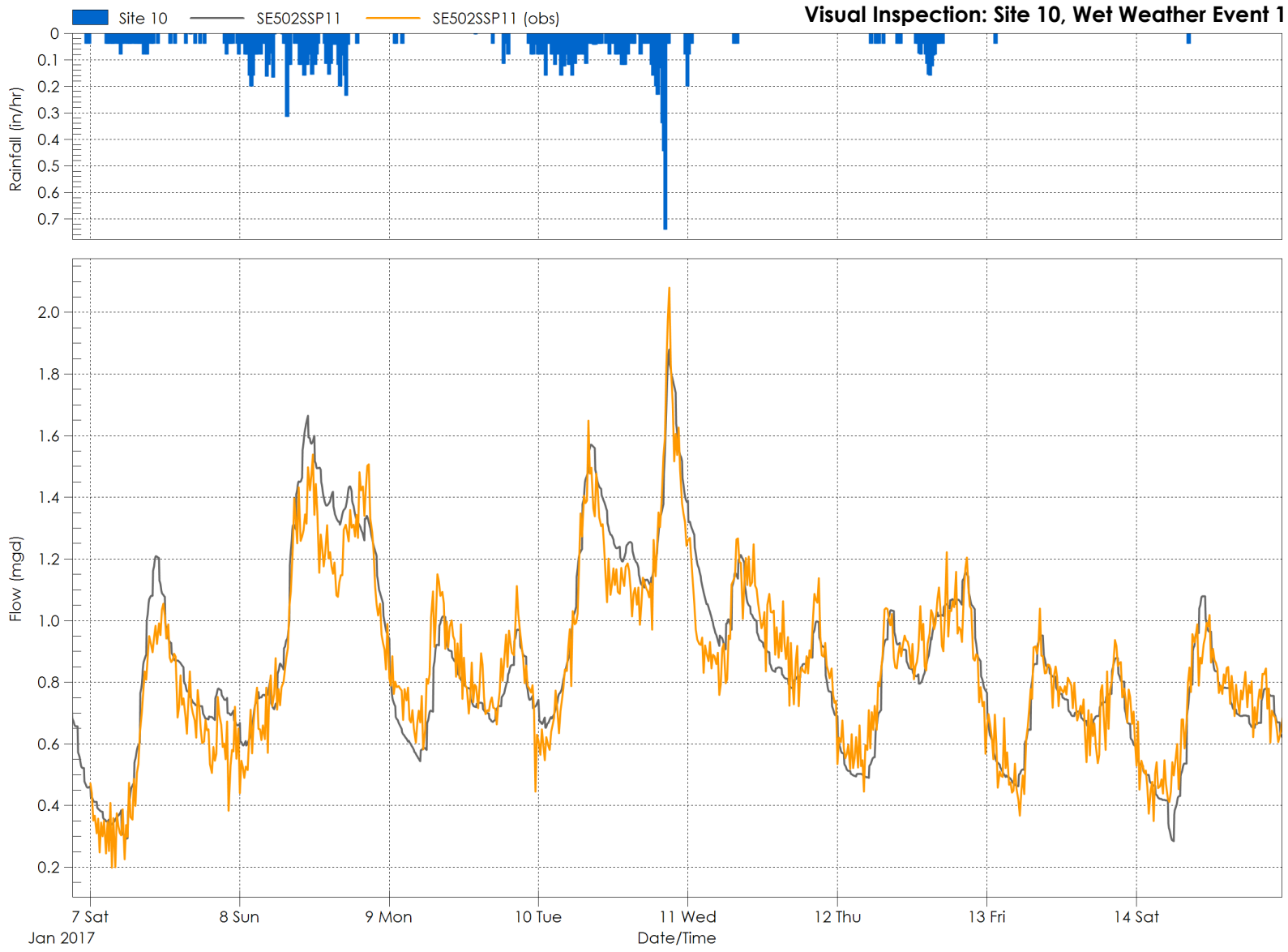
H.3.13 Flow Monitoring Site 10

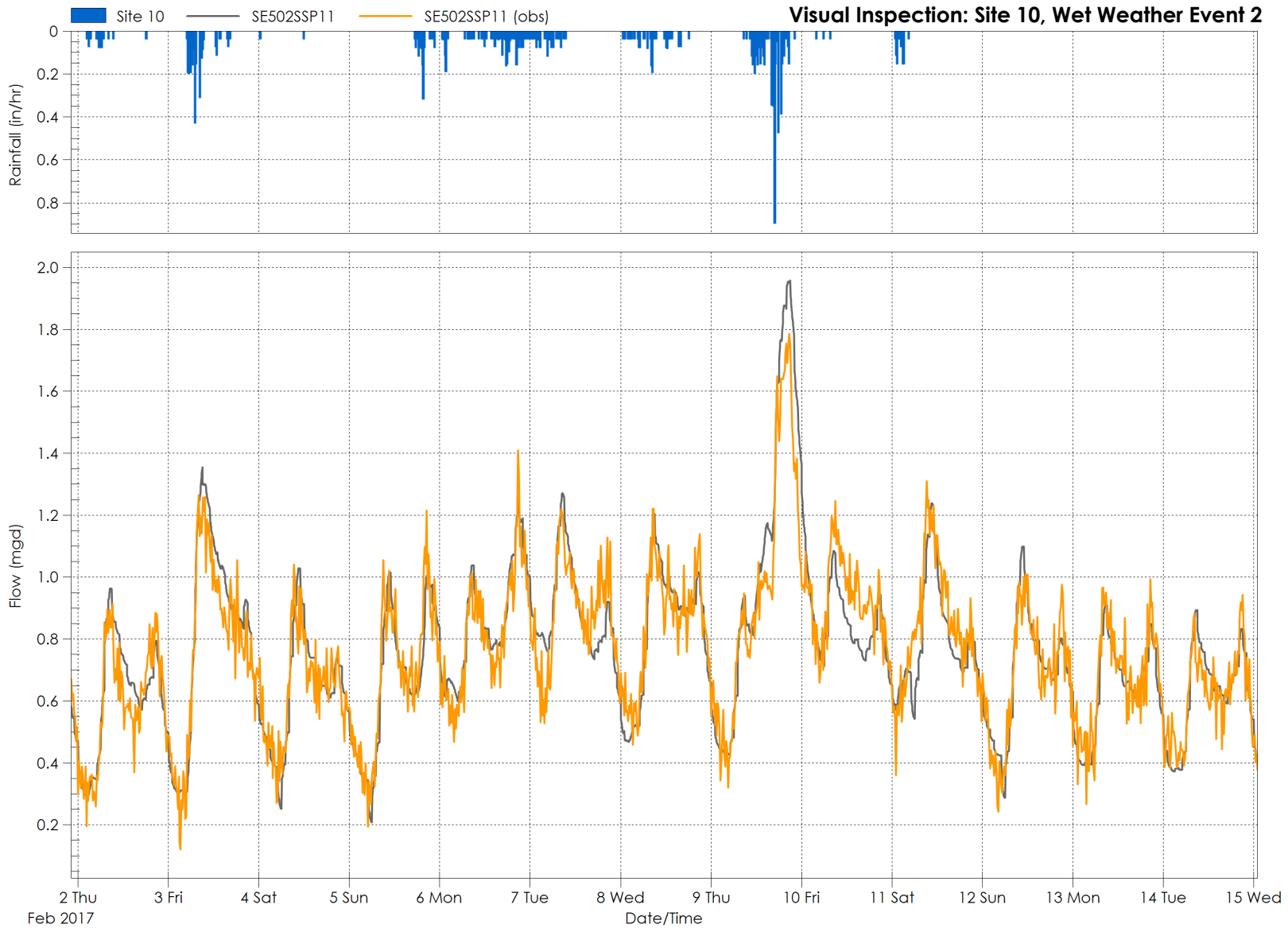
Model results for PWWF at monitoring Site 10 are within 10% of measured values, as shown in **Table H-15**. The total modeled volume was within 5% of measured values for each event. The error in PWWF for WWF simulations was considered acceptable for calibration.

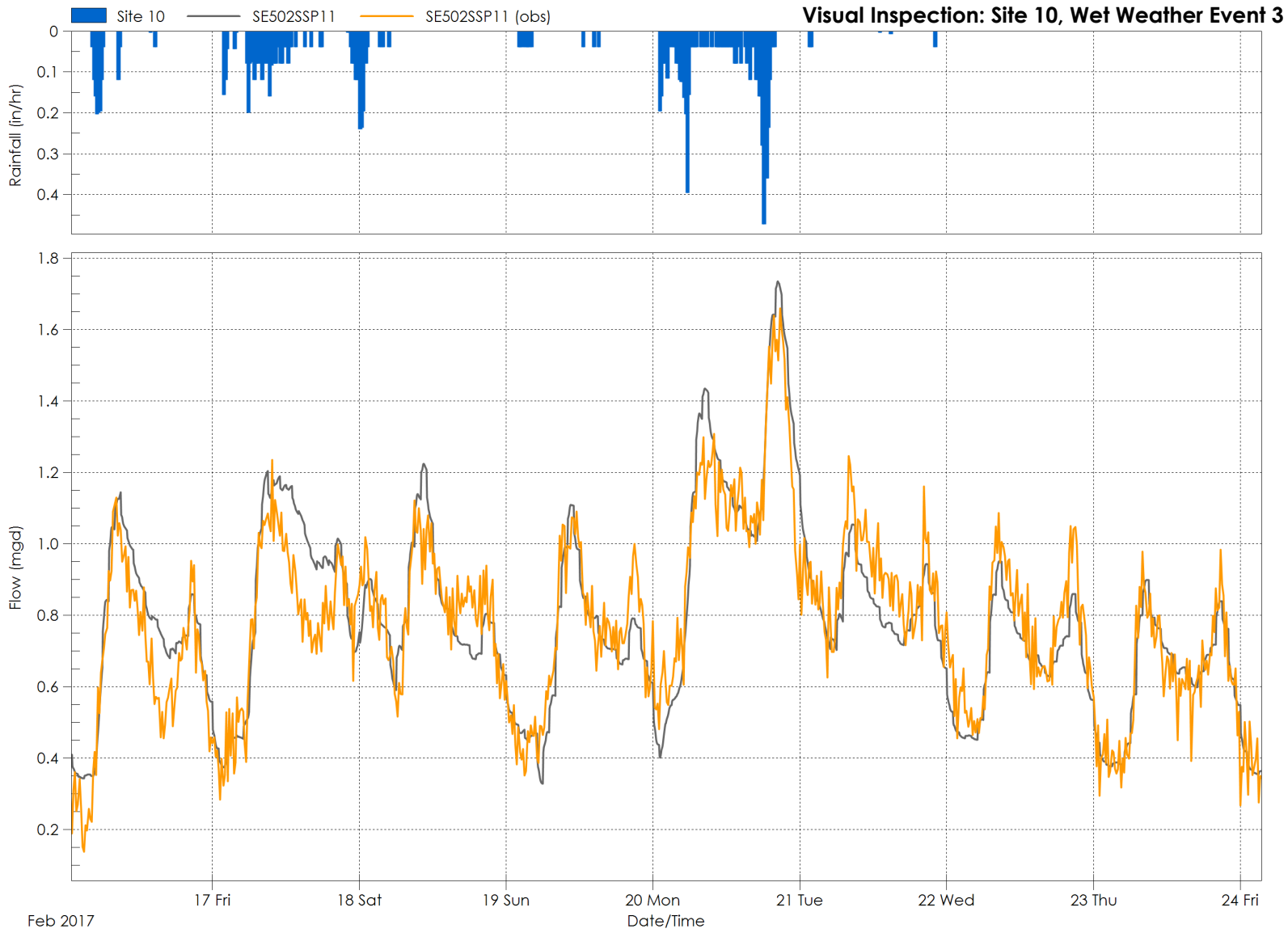
Table H-15 Site 10 PWWF Calibration Results

Site 10 WWF Results	Peak Modeled Flow (MGD)	Peak Measured Flow (MGD)	PWWF Error	Total Modeled Volume (MG)	Total Measured Volume (MG)	Total Volume Error
Event 1	1.88	2.08	-9.7%	6.96	6.81	2.2%
Event 2	1.96	1.79	9.7%	9.90	9.89	0.1%
Event 3	1.74	1.66	4.6%	6.32	6.31	0.2%

Visual inspection results, including observed vs modeled flow and rainfall data for the calibration and validation events are presented in the following figures.


Visual Inspection: Site 10, Wet Weather Event 1
Site 10
SE502SSP11
SE502SSP11 (obs)
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Flow (mgd)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
7 Sat
Jan 2017
8 Sun
9 Mon
10 Tue
11 Wed
12 Thu
13 Fri
14 Sat
Date/Time


Site 10
SE502SSP11
SE502SSP11 (obs)
Visual Inspection: Site 10, Wet Weather Event 2
Rainfall (in/hr)
0
0.2
0.4
0.6
0.8
Flow (mgd)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
2 Thu
Feb 2017
3 Fri
4 Sat
5 Sun
6 Mon
7 Tue
8 Wed
9 Thu
10 Fri
11 Sat
12 Sun
13 Mon
14 Tue
15 Wed
Date/Time


Site 10
SE502SSP11
SE502SSP11 (obs)
Visual Inspection: Site 10, Wet Weather Event 3
Rainfall (in/hr)
0
0.1
0.2
0.3
0.4
Flow (mgd)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
17 Fri
18 Sat
19 Sun
20 Mon
21 Tue
22 Wed
23 Thu
24 Fri
Feb 2017
Date/Time