ATTACHMENT A.7
LEVEL-VELOCITY SENSOR AND LOGGER DATA EVALUATION
REMEDIAL DESIGN SERVICES, SWAN ISLAND BASIN PROJECT AREA
CERCLA DOCKET NO. 10-2021-001
PORTLAND HARBOR SUPERFUND SITE
PORTLAND, MULTNOMAH COUNTY, OREGON

This technical memorandum presents an overview of level-velocity sensor data collection and processing as part of a stormwater evaluation in the City of Portland's (City) conveyance system between February 2022 and June 2023. Stormwater outfall and conveyance system sampling and monitoring activities were conducted as part of the Pre-Design Investigation (PDI) for the Swan Island Basin (SIB) Project Area within the Portland Harbor Superfund Site in Portland, Multnomah County, Oregon. HGL performed the work on behalf of the SIB Remedial Design Group based on the requirements of the Portland Harbor Superfund Site Record of Decision (U.S. Environmental Protection Agency [EPA], 2017) and the Administrative Settlement Agreement and Order on Consent (EPA, 2021). The work was performed in accordance with the final PDI Work Plan, which the EPA approved in May 2022 (HGL, 2022) and the Stormwater and Riverbank Assessment and Sampling Plan, which EPA approved in November 2021 (HGL, 2021).

The monitoring purposes were to assess seasonal stormwater discharge trends, including during stormwater high volume sampling (HVS) events and to collect data to support the calibration of a recontamination model for the SIB Project Area.

As outlined in the Field Sampling Plan, Appendix A to the PDI Work Plan (HGL, 2022) and described in the Programmatic Access Permit (City of Portland, 2021), Pulsar Measurement Stingray 2.0 level-velocity sensors and loggers were installed at permitted locations within the City's SIB stormwater conveyance system lateral pipes to measure water depth and velocity. The equipment was installed within outfall basins OFM-1 (outfall AAM104), OFM-2 (AAM169), OFM-3 (manhole AAQ005), OFS-1 (AAM131), and OFS-2 (AAP957) which all terminate in SIB. Figure 2-1 of the Stormwater Sampling Data Report shows outfall locations.

INSTALLATION

Sensors and loggers were installed in city outfalls in late January – early February 2022 as described below.

OFM-1

Three lateral stormwater pipes accessed via manhole **AAM104**, 2900 N. Ensign Street, Portland, Oregon.

- Lateral install AAM104-NW, 36-inch pipe:
  - One sensor (SN64452) 10 feet (ft) from the bottom of the manhole.
- Lateral install AAM104-SE, 27-inch pipe:
  - One sensor (SN59199) 10 ft from the bottom of the manhole.

- Lateral install AAM104-NE, 54-inch pipe:
    - One sensor (SN68424) 10 ft from the bottom of the manhole.

Installation Date: 01/27/2022
Demobilization Date: 06/18/2023

OFM-2
Three lateral stormwater pipes accessed via manhole **AAM169**, 6010 N. Basin Avenue, Portland, Oregon.

- Lateral install AAM169-NW, 21-inch pipe
    - One sensor (SN73705) 7.5 ft from the bottom of the manhole.
- Lateral install AAM169-SE, 27-inch pipe
    - One sensor (SN59019) 8 ft from the bottom of the manhole.
- Lateral install AAM169-E, 60-inch pipe
    - One sensor (SN76103 and SN71114 after January 2023) 10 ft from the bottom of the manhole.

Installation Date: 01/25/2022 and 01/26/2022
Demobilization Date: 06/17/2023

OFM-3
Single stormwater pipe accessed via manhole **AAQ005**, 5400 WI/ N. Basin Avenue, Portland, Oregon.

- Install AAQ005, 48-inch pipe
    - One flow sensor (SN76102) 10 ft from the bottom of the manhole.

Installation date 02/03/2022
Demobilization date 06/17/2023

OFS-1
Two lateral stormwater pipes accessed via manhole **AAM131**, 5700 N. Lagoon Avenue, Portland, Oregon.

- Lateral install AAM131-NW, 27-inch pipe
    - One flow sensor (SN64455) 10 ft from the bottom of the manhole.
- Lateral install AAM131-SE, 18-inch pipe
    - One flow sensor (SN74155) 28 inches from the bottom of the manhole.

Installation Date: 01/24/2022
Demobilization Date: 06/18/2023

OFS-2
Two lateral stormwater pipes accessed via manhole **AAP957**, 5050 N. Lagoon Avenue, Portland, Oregon.

- Lateral install AAP957-NW, 30-inch pipe
    - One flow sensor (SN76100) 77 inches from the bottom of the manhole.
- Lateral install AAP957-SE, 21-inch pipe

- One flow sensor (SN70063) 51 inches from the bottom of the manhole.

Installation Date: 01/25/2022
Demobilization Date: 06/17/2023

During installation, the pipe diameter and shape were programmed into each logger. Level-velocity data were collected near-continuously at 300-second intervals or longer during the wet and dry seasons, including the stormwater HVS events.

DATA PROCESSING METHODOLOGY

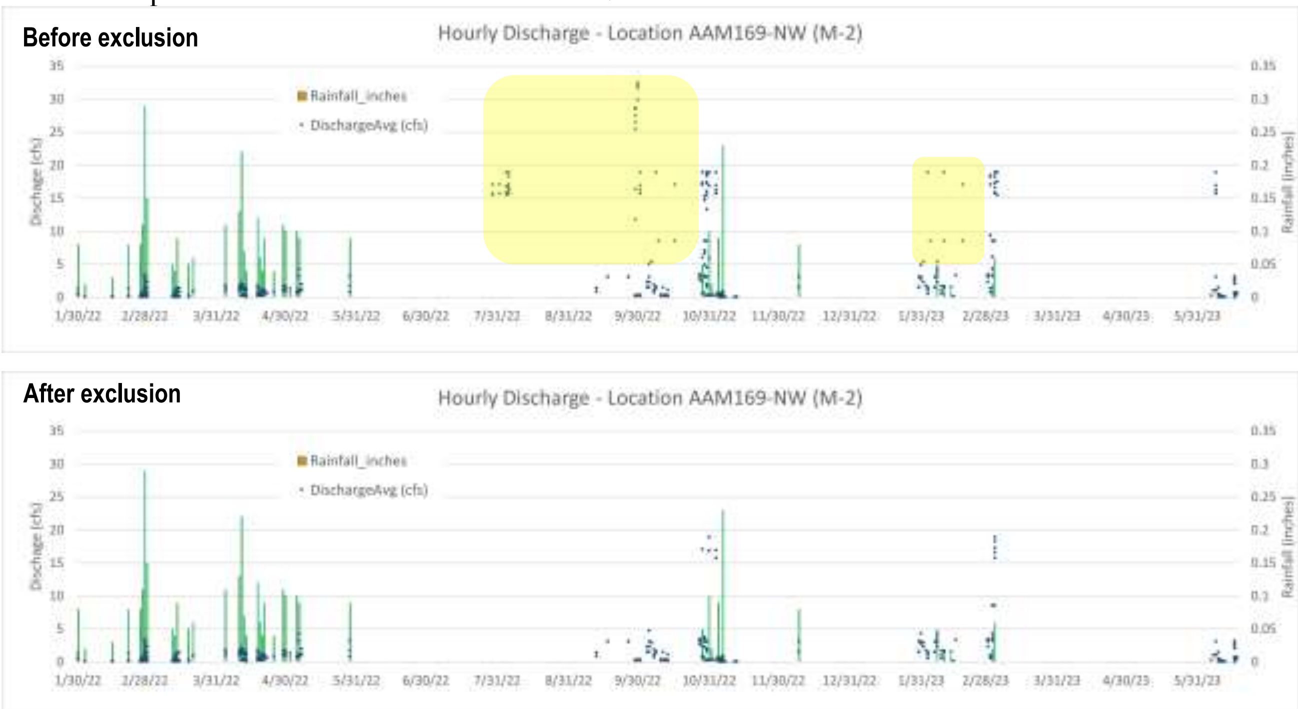
Data retrieval and maintenance for level-velocity sensors occurred on approximately 1-month intervals. The monthly raw data files were downloaded from each lateral's logger and screen shots of the water levels, velocities and temperatures and flows measured in each lateral during each approximate monthly monitoring period (raw data files from the logger downloads included electronically only).

The initial post-processing of the sensor data included the exclusion of measurements with water level or velocity readings showing a value of 0. However, following additional review, the data indicated a discontinuity with relationship to rainfall in the basin. Therefore, a revised validation process was initiated to re-evaluate the original measurement data, to assemble a data exclusion protocol, mark records for exclusion and identify the rationale for each record excluded.

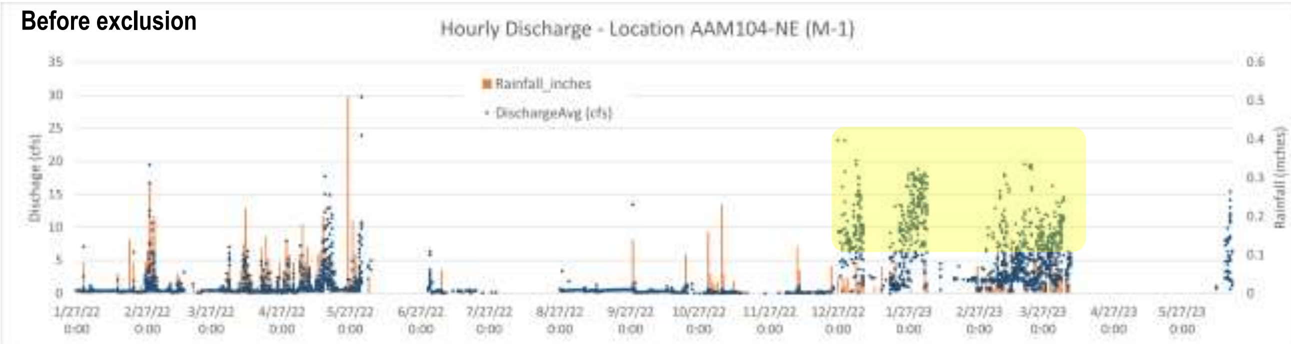
The exclusion methodology included the following:

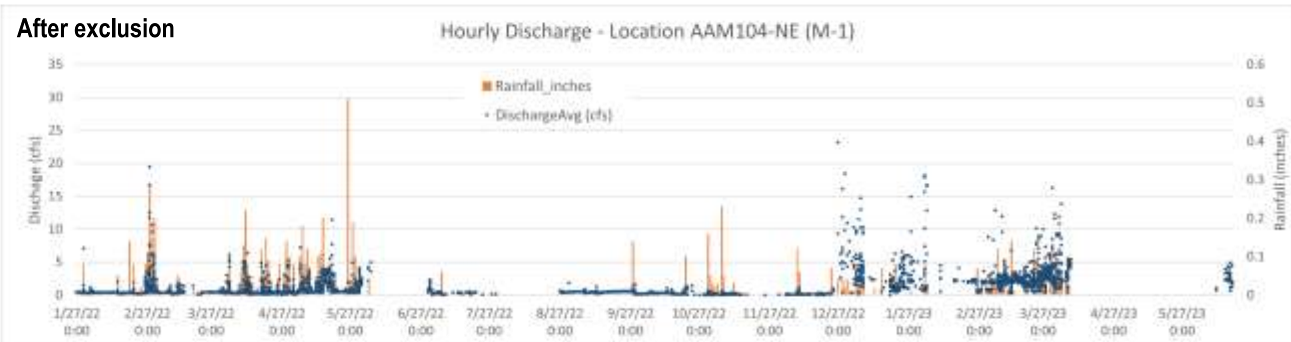
1) Exclude measurements with values outside valid sensor operation conditions as specified by the sensor vendor (Greyline Stingray 2.0 Brochure [pulsarmeasurement.com]):
   a) Water level or velocity readings indicating "0" or "NA",
   b) Water level readings below 0.083 ft (lower limit of operating range of sensor),
   c) Velocity readings less than 0.1 feet per second, and
   d) Temperature values outside the lower limit of -20 °C and an upper limit of 60 °C.
2) Exclude measurements with a water level value exceeding the diameter of the pipe where the sensor is installed.
3) Exclude measurements during periods when the river elevation was higher than the sensor's. Table A.7-1 and Figure A.7-1, attached at the end of this memorandum, show the periods when river elevations exceeded the invert elevations where sensors were installed.
4) Excessive and Inconsistent Flow Measurements Related to Rainfall
   a) Exclude measurements with elevated values for water level and/or velocity occurring during periods with no recorded rainfall. This step flagged records for exclusion where the hourly average water level multiplied by the velocity exceeded 2 (velocity*level > 2) and the hourly rainfall at the same period equaled zero.

Exclusion Step #4 was included to address excessive discharge when no rainfall was recorded. The uncertainty in this data is also supported by rapid change in elevation or velocity in adjacent records. A technician at the sensor equipment vendor, Pulsar, explained that localized atypical conditions can contribute to errant readings (such as a temporary washing of larger material just upstream of the sensor, small insects or animals residing nearby, or even wind moving over puddled water near the sensor). Therefore, it was surmised that temporary hydraulic conditions compromised the sensor producing errant readings for water elevation or velocity and Step #4 minimizes these readings. Figures A.7-2a and -2b and A.7-3a and -3b illustrate the effect of this removal step in the data at two lateral locations:



Figures A.7-2a and A.7-2b. Comparison of hourly discharge averages with concurrent hourly rainfall at location AAM169-SE. Points of discharge highlighted in the summer of 2022 were marked for exclusion.

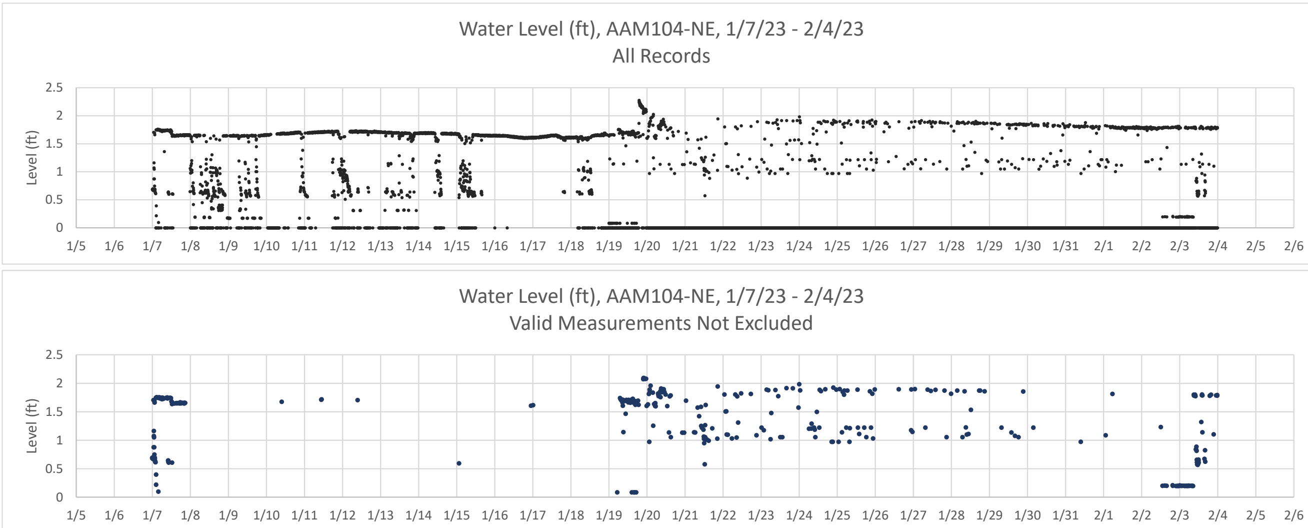




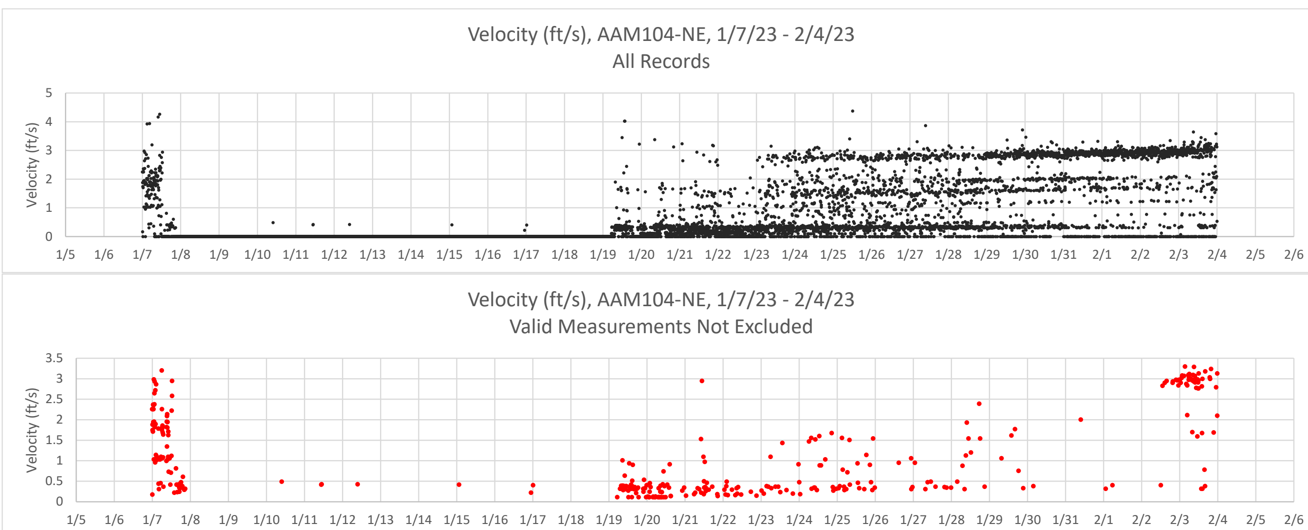
Figures A.7-3a and A.7-3b. Comparison of hourly discharge averages with concurrent hourly rainfall at location AAM104-NE.

It is important to emphasize that this exclusion method depends on rainfall to identify compromised readings. This method compares measurement data with only rainfall records as the primary indicator of an abnormality with the sensor. No other data or qualitative information is currently available to suggest that other water sources enter the stormwater system in addition to rainfall, data that could potentially validate the elevated measurements. Observed dry-weather flow in laterals to the M1 and M2 outfalls are reflected in the remaining data, but new information about alternative water sources would require that this data exclusion step be re-evaluated or eliminated.

To illustrate the reduction to the original sensor data using the exclusion methodology, selected data were extracted from the AAM104-NE sensor. This sensor was highlighted in the City of Portland's comments to the PDI ER Rev.0 and Stormwater Sampling Data Report Rev. 0. Figures A.7-4a and -4b and A.7-5a and -5b match this location and the same time periods to illustrate the change in range and density of water level and velocity readings before and after exclusions were applied.



Figures A.7-4a and A.7-4b. Selected measurement data from location AAM104-NE comparing the original records for water level and then the level records remaining following the exclusion process.



Figures A.7-5a and A.7-5b. Selected velocity data at location AAM104-NE during the same period with original data on top and the remaining data considered valid on the bottom.

A tabulation of the total count of exclusions completed at each location and the categories that triggered exclusion are shown in Table A.7-2.

Table A.7-2 Counts of Data Records Excluded from Original Measurements *

Location	Equipment Threshold Exceeded	Inundated by River	Level Greater than Pipe Diameter	Atypical Discharge for Zero Precipitation	Total Records Excluded	Total Original Measurements	% of Original Measurements Valid for Summary
AAM104-NE	70,825	2,721	-	2,416	75,962	119,445	36.4%
AAM104-NW	117,985	72	1	174	118,232	140,030	15.6%
AAM104-SE	117,238	1,888	1	996	120,123	126,863	5.3%
AAM169-E	29,248	3,939	-	406	33,593	118,360	71.6%
AAM169-NW	68,651	1,998	14,677	502	85,828	88,513	3.0%
AAM169-SE	119,974	8,077	320	730	129,101	147,521	12.5%
AAQ005	93,977	2,320	-	1,077	97,374	129,423	24.8%
AAM131-NW	134,427	431	-	37	134,895	145,869	7.5%
AAM131-SE	113,633	27	1	18	113,679	118,387	4.0%
AAP957-NW	133,676	547	22	264	134,509	142,937	5.9%
AAP957-SE	87,547	109	412	191	88,259	92,591	4.7%

** Records were often excluded for more than one parameter; however, the counts shown in the table are non-overlapping. Starting from the left column, once a data record was counted as excluded, it was not counted in subsequent parameters. This was done to avoid the duplication in this table and ensures all exclusion records add up to the total.*

RESULTS

Discharge Volumes per Outfall

An estimation of discharge volume at each outfall is included in this analysis. However, the total volumes from the monitoring data are likely to under-represent the actual drainage volume at each outfall. There are two primary reasons for the lowered volume estimate from the data:

1. Some of the sensors experienced power failures that prevented data collection during periods as long as several weeks. This resulted in the absence of monitoring data during some rainfall events.
2. Exclusion of erroneous measurements or hydraulic data during periods of minimal rainfall were excluded from estimates (exclusion parameters #3 and #4 above).
    a. Note that most of the exclusions applied to the data were records with “0” values for water level or velocity and had no effect on discharge calculations. However, the additional exclusions of atypical hydraulic data (primarily Steps #2 and #4 of the exclusion conditions listed above) removed extraneous discharge.

Figures A.7-6a and -6b illustrate the weekly contributions to discharge volume at the outfalls before and after the additional data exclusions, compared with weekly rainfall.

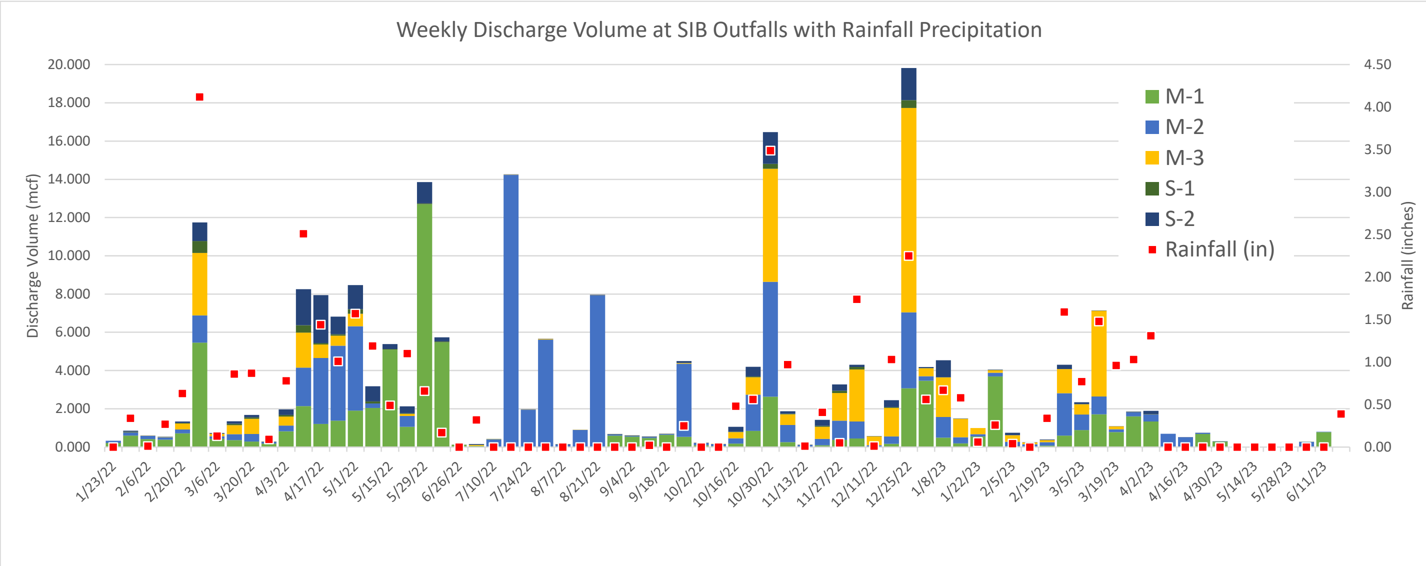


Figure A.7-6a. Weekly flow volumes prior to the additional exclusions (the "new" exclusions). Notable is the discharge from the M-2 outfall during the summer of 2022 during periods of no rainfall.

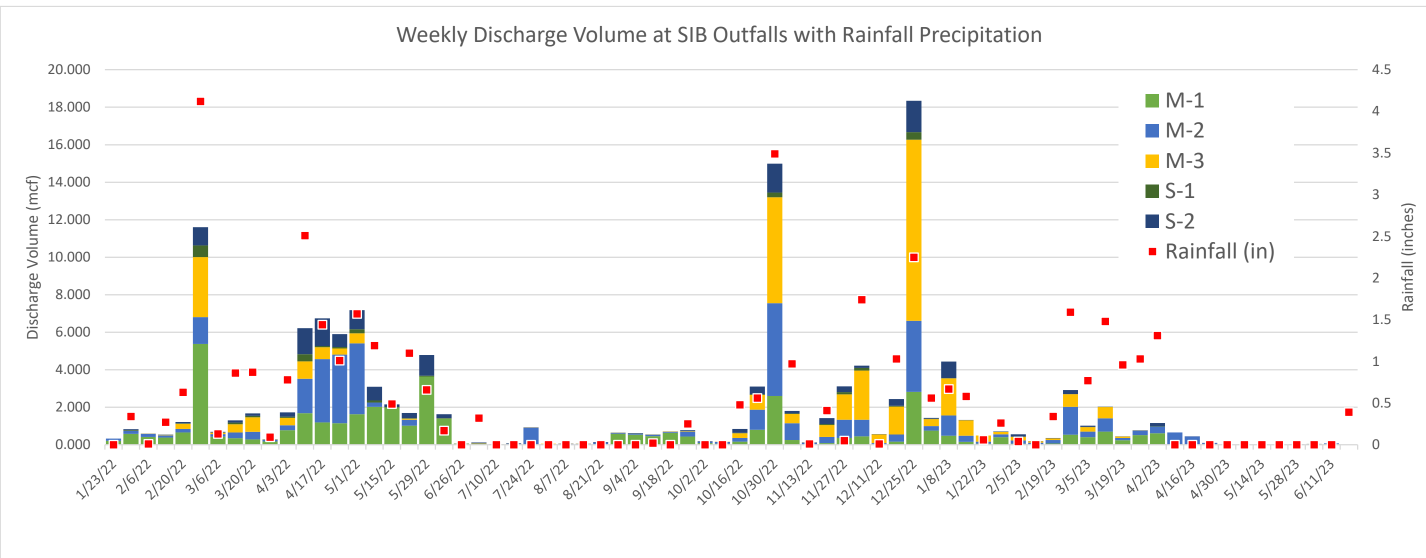


Figure A.7-6b. Weekly volume contributions by outfall after the additional data exclusions. The unlikely flow patterns in 2022 are no longer present.

Table A.7.3 Monthly discharge volumes by outfall (mcf)

Month	M-1	M-2	M-3	S-1	S-2	Rainfall Total (in)
2022-Jan	0.198	0.304		0.017	0.012	5.35
2022-Feb	1.872	1.903	0.809	0.306	0.214	5.03
2022-Mar	1.100	1.584	0.808	0.344	0.236	2.01
2022-Apr	2.049	3.801	1.495	0.414	0.882	5.74
2022-May	3.018	1.406	0.347	0.353	0.642	5.03
2022-Jun	0.859			0.096	0.098	2.31
2022-Jul	0.103	0.183	0.122	0.009	0.016	0.32
2022-Aug	0.148	0.122	0.047	0.000	0.007	0.01
2022-Sep	1.025	0.531	0.052	0.017	0.018	0.27
2022-Oct	0.834	1.709	0.901	0.101	0.179	5.27
2022-Nov	1.373	3.411	1.950	0.345	0.386	3.42
2022-Dec	2.021	3.766	3.435	0.559	0.438	7.93
2023-Jan	1.336	2.181	1.666	0.037	0.250	4.05
2023-Feb	0.572	1.273	0.419	0.000	0.109	2.85
2023-Mar	2.453	1.648	0.777	0.011	0.055	4.24
2023-Apr	0.657	1.159	0.000	0.013	0.075	5.80
2023-May	0.005	0.006		0.002	0.011	0.12
2023-Jun	0.104	0.070		0.014		0.67

Table A.7-4: Estimated Annual Discharge Volume by Outfall (mcf, based on 2022 data)

	M-1	M-2	M-3	S-1	S-2	Grand Total
Discharge Vol (mcf)	14.60	18.72	9.97	2.56	3.13	48.97
Portion of Total Volume	29.8%	38.2%	20.3%	5.2%	6.4%	

Discharge Rates per Outfall

The following charts illustrate weekly average discharge rates per outfall and weekly average discharge rates per outfall laterals to illustrate which laterals and sub basins contribute the largest volumes and flows to the outfalls. Further, the charts of discharge at each lateral also include minimum and maximum of discharge for each month to illustrate variability in the data.

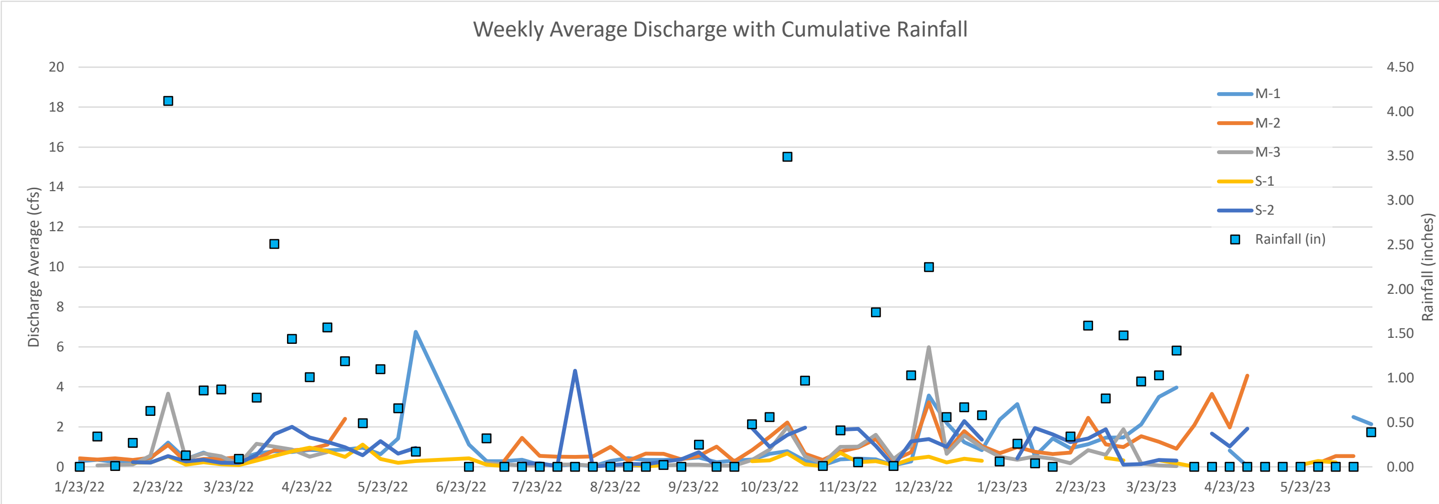


Figure A.7-7. Weekly Outfall Discharge with Cumulative Rainfall

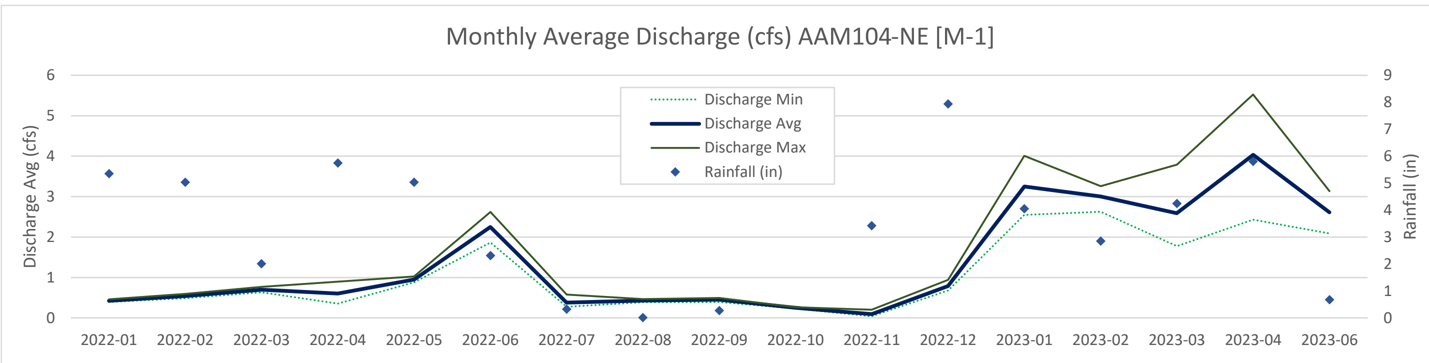


Figure A.7-8a. Lateral AAM104-NE Contribution to Outfall M-1 Weekly Discharge with Cumulative Rainfall

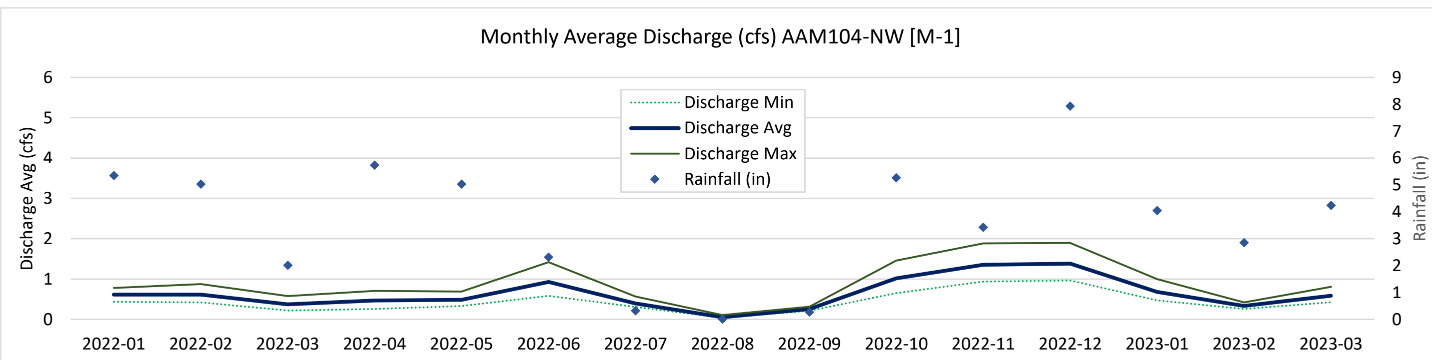


Figure A.7-8b. Lateral AAM104-NW Contribution to Outfall M-1 Weekly Discharge with Cumulative Rainfall

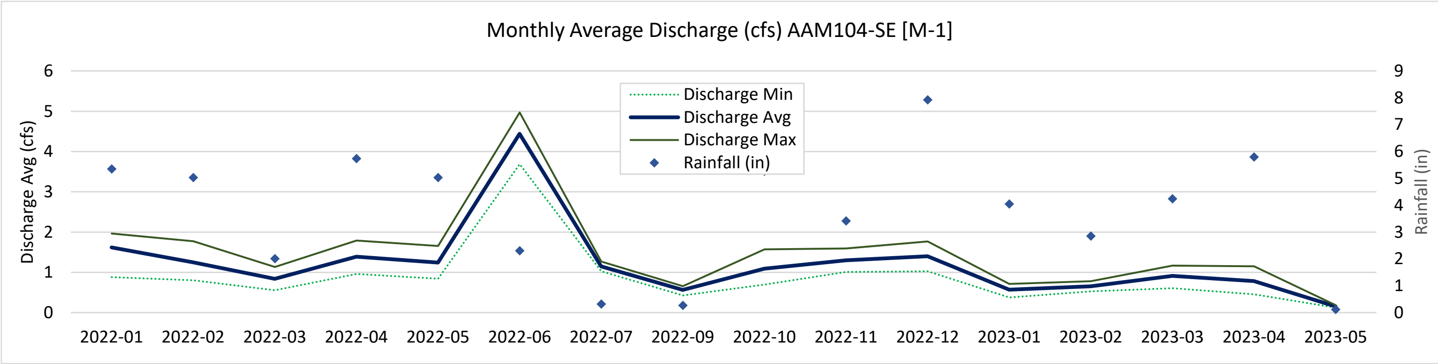


Figure A.7-8c. Lateral AAM104-SE Contribution to Outfall M-1 Weekly Discharge with Cumulative Rainfall

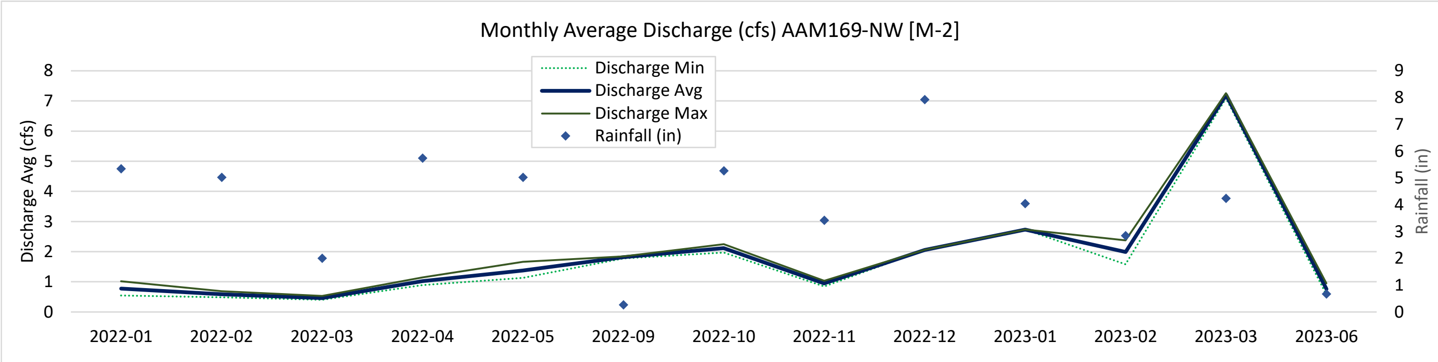


Figure A.7-9a. Lateral AAM169-NW Contribution to Outfall M-2 Weekly Discharge with Cumulative Rainfall

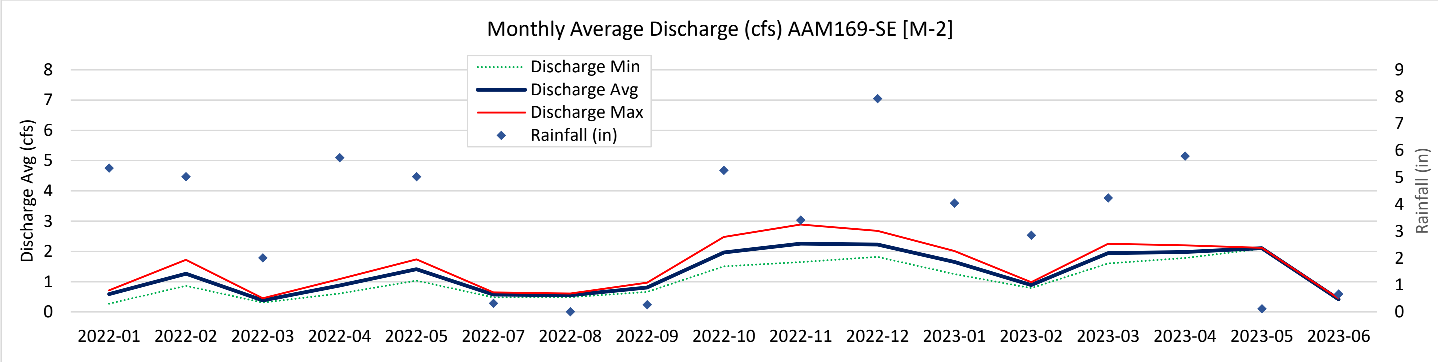


Figure A.7-9b. Lateral AAM169-SE Contribution to Outfall M-2 Weekly Discharge with Cumulative Rainfall

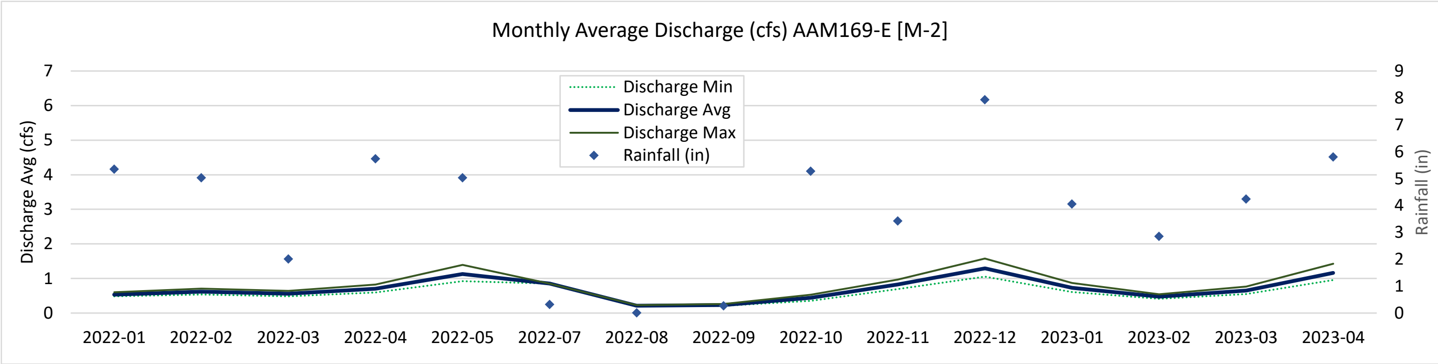


Figure A.7-9c. Lateral AAM169-E Contribution to Outfall M-2 Weekly Discharge with Cumulative Rainfall

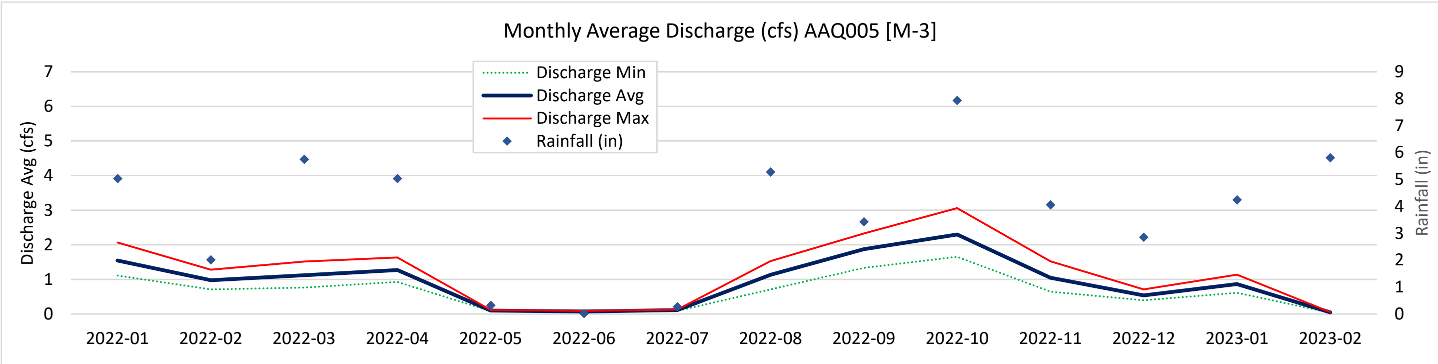


Figure A.7-10. Outfall M-3 at Manhole AAQ005 Weekly Discharge with Cumulative Rainfall

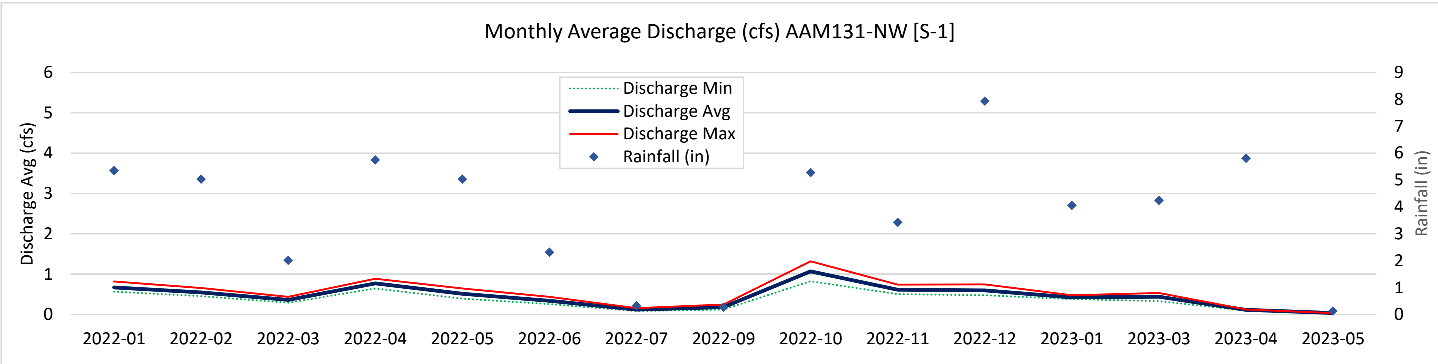


Figure A.7-11a. Lateral AAM131-NW Contribution to Outfall S-1 Weekly Discharge with Cumulative Rainfall

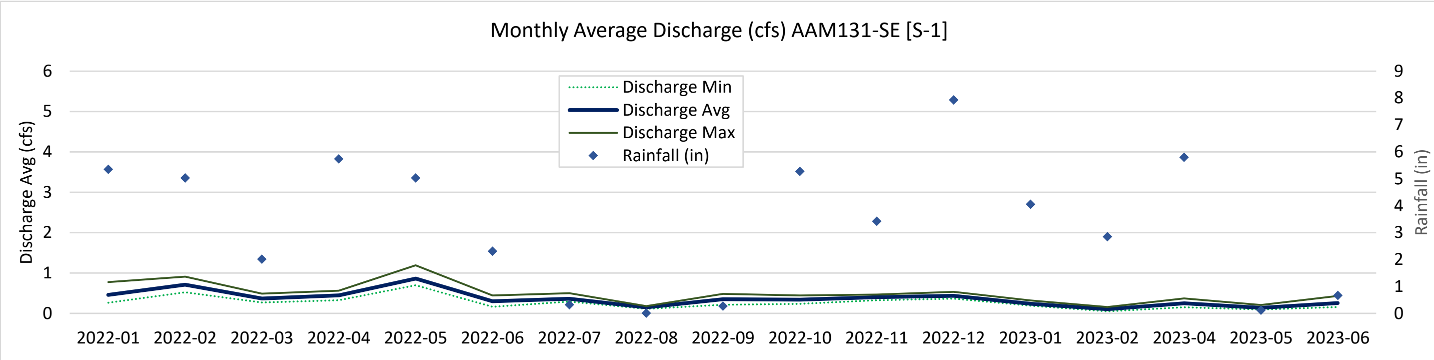


Figure A-7.11b. Lateral AAM131-SE Contribution to Outfall S-1 Weekly Discharge with Cumulative Rainfall

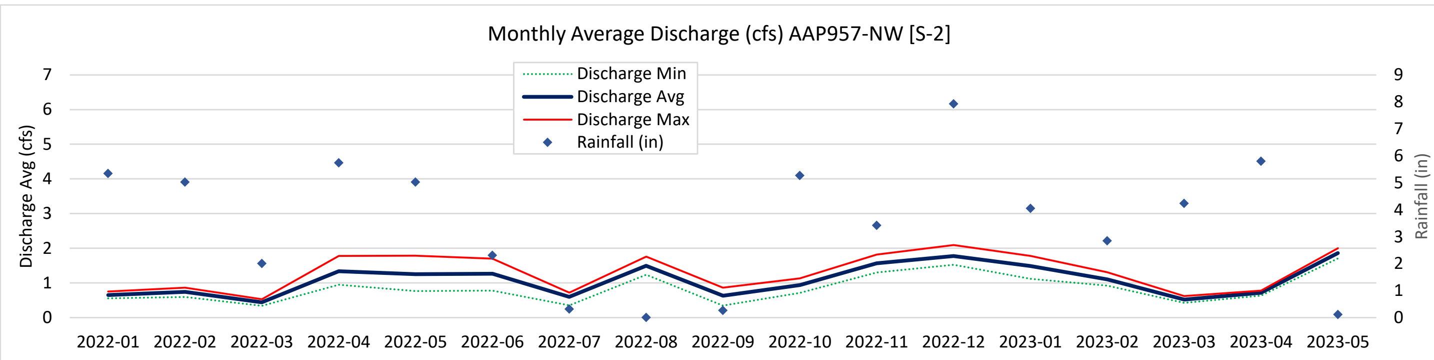


Figure A.7-12a. Lateral AAP957-NW Contribution to Outfall S-2 Weekly Discharge with Cumulative Rainfall

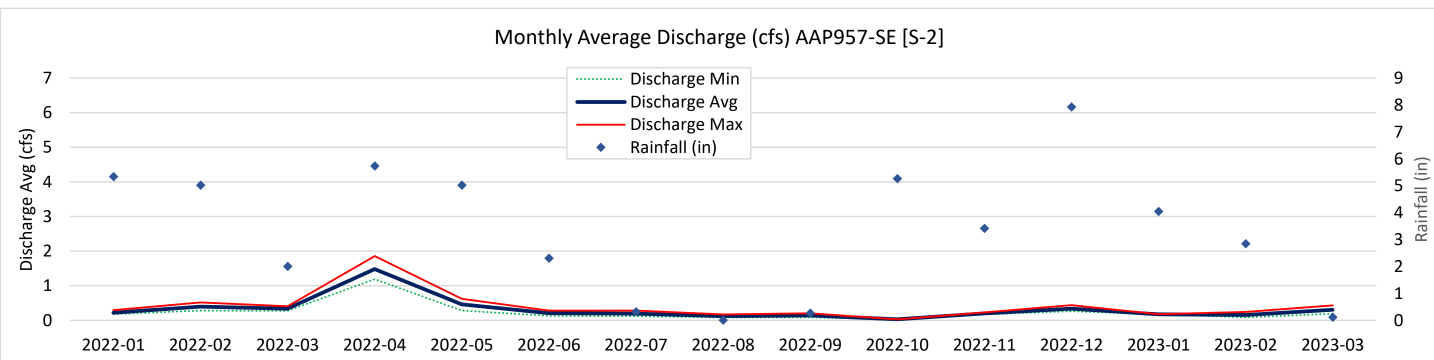


Figure A.7-12b. Lateral AAP957-SE Contribution to Outfall S-2 Weekly Discharge with Cumulative Rainfall

Attached Table

Table A7-1 River Inundation Periods

Attached Figure

Figure A.1-1 Determination of Inundation Periods, SIB City Stormwater Conveyance Systems

Attached Raw Data Files

Raw data files can be accessed here: Raw Data Files

Supporting Information

Microsoft Access database containing the original and processed measurement data can be access here: Access Database

Microsoft Excel workbooks extracting summary data from the database subsequently used to develop summary tables and charts contained within this memorandum: Excel Workbooks

TABLE

Table A.7-1
River Inundation Periods

Surface Water Elevation > Monitoring Point Invert Elevation		Outfall
from	**to**	
5/16/2022 4:30	5/16/2022 7:30	M-1
5/17/2022 4:45	5/17/2022 8:30	M-1
5/18/2022 5:45	5/18/2022 9:15	M-1
5/19/2022 7:15	5/19/2022 8:45	M-1
6/5/2022 19:00	6/30/2022 15:00	M-1
6/30/2022 17:45	7/1/2022 0:15	M-1
7/1/2022 0:45	7/1/2022 0:45	M-1
7/1/2022 4:00	7/1/2022 10:15	M-1
5/6/2023 6:00	5/6/2023 7:15	M-1
5/6/2023 19:00	5/6/2023 22:00	M-1
5/7/2023 3:30	5/8/2023 1:15	M-1
5/8/2023 4:00	5/8/2023 13:00	M-1
5/8/2023 19:15	5/9/2023 0:45	M-1
5/9/2023 5:15	5/9/2023 12:00	M-1
5/10/2023 6:30	5/10/2023 12:15	M-1
5/10/2023 22:30	5/11/2023 0:15	M-1
5/11/2023 9:00	5/11/2023 9:15	M-1
5/11/2023 10:00	5/11/2023 10:00	M-1
5/16/2023 1:45	5/25/2023 12:00	M-1
3/1/2022 14:00	3/1/2022 20:45	M-2
3/2/2022 2:45	3/5/2022 2:30	M-2
3/5/2022 3:15	3/5/2022 11:45	M-2
3/5/2022 17:30	3/5/2022 21:15	M-2
3/6/2022 6:30	3/6/2022 8:30	M-2
5/7/2022 8:45	5/7/2022 12:30	M-2
5/7/2022 20:15	5/11/2022 7:15	M-2
5/11/2022 7:45	5/13/2022 21:30	M-2
5/14/2022 1:00	5/23/2022 14:30	M-2
5/24/2022 0:45	5/24/2022 1:45	M-2
5/26/2022 1:45	5/26/2022 5:45	M-2
5/27/2022 1:45	5/27/2022 9:15	M-2
5/27/2022 14:45	5/27/2022 21:30	M-2
5/28/2022 1:15	5/28/2022 9:30	M-2
5/28/2022 16:30	7/2/2022 17:00	M-2
7/2/2022 17:45	7/3/2022 1:30	M-2
7/3/2022 5:45	7/3/2022 11:15	M-2
7/10/2022 1:00	7/10/2022 3:15	M-2
7/11/2022 1:45	7/11/2022 3:30	M-2
7/12/2022 2:30	7/12/2022 5:00	M-2
7/13/2022 3:00	7/13/2022 6:45	M-2
7/14/2022 3:45	7/14/2022 8:30	M-2
7/15/2022 4:45	7/15/2022 8:15	M-2

Table A.7-1
River Inundation Periods

Surface Water Elevation > Monitoring Point Invert Elevation		Outfall
from	to	
7/16/2022 6:30	7/16/2022 7:15	M-2
12/27/2022 18:45	12/29/2022 3:45	M-2
12/29/2022 9:45	12/29/2022 11:00	M-2
5/3/2023 4:00	5/3/2023 5:15	M-2
5/3/2023 15:45	5/27/2023 13:45	M-2
2/28/2022 13:30	2/28/2022 16:00	M-3
3/1/2022 3:15	3/1/2022 6:30	M-3
3/1/2022 13:00	3/6/2022 0:15	M-3
3/6/2022 5:00	3/6/2022 11:45	M-3
3/6/2022 19:30	3/6/2022 20:15	M-3
3/7/2022 7:00	3/7/2022 8:30	M-3
3/22/2022 7:30	3/22/2022 8:15	M-3
5/7/2022 6:15	5/23/2022 20:45	M-3
5/23/2022 22:00	5/23/2022 22:00	M-3
5/23/2022 22:30	5/24/2022 6:00	M-3
5/25/2022 0:30	5/25/2022 7:00	M-3
5/25/2022 13:00	5/25/2022 16:45	M-3
5/26/2022 0:15	5/26/2022 10:30	M-3
5/26/2022 13:00	5/26/2022 21:15	M-3
5/27/2022 0:15	7/3/2022 15:45	M-3
7/3/2022 18:45	7/4/2022 2:15	M-3
7/4/2022 7:00	7/4/2022 10:00	M-3
7/6/2022 23:00	7/7/2022 0:15	M-3
7/7/2022 23:15	7/8/2022 1:30	M-3
7/8/2022 23:15	7/9/2022 4:45	M-3
7/9/2022 23:45	7/10/2022 7:00	M-3
7/11/2022 0:45	7/11/2022 6:15	M-3
7/12/2022 1:45	7/12/2022 8:00	M-3
7/13/2022 2:00	7/13/2022 9:30	M-3
7/14/2022 3:00	7/14/2022 11:00	M-3
7/14/2022 18:30	7/14/2022 21:45	M-3
7/15/2022 3:45	7/15/2022 10:30	M-3
7/15/2022 19:45	7/15/2022 20:45	M-3
7/16/2022 5:30	7/16/2022 9:30	M-3
7/17/2022 7:15	7/17/2022 8:30	M-3
12/27/2022 18:00	12/29/2022 14:30	M-3
12/30/2022 10:00	12/30/2022 13:45	M-3
12/30/2022 23:45	12/31/2022 2:15	M-3
12/31/2022 10:45	12/31/2022 15:15	M-3
1/20/2023 14:15	1/20/2023 15:30	M-3
1/21/2023 15:00	1/21/2023 17:15	M-3
1/22/2023 16:00	1/22/2023 16:45	M-3

Table A.7-1
River Inundation Periods

Surface Water Elevation > Monitoring Point Invert Elevation		Outfall
from	to	
4/21/2023 5:30	4/21/2023 6:00	M-3
5/3/2023 2:00	5/27/2023 19:15	M-3
5/27/2023 21:00	5/28/2023 6:15	M-3
5/30/2023 1:15	5/30/2023 1:30	M-3
5/30/2023 2:00	5/30/2023 3:00	M-3
5/31/2023 2:30	5/31/2023 2:45	M-3
5/31/2023 3:15	5/31/2023 3:30	M-3
6/1/2023 2:30	6/1/2023 4:00	M-3
6/2/2023 3:30	6/2/2023 3:30	M-3
6/4/2023 4:15	6/4/2023 5:30	M-3
6/6/2022 8:45	6/7/2022 4:15	S-1
6/7/2022 4:45	6/7/2022 5:15	S-1
6/8/2022 0:45	6/8/2022 3:45	S-1
6/8/2022 9:45	6/26/2022 12:30	S-1
6/26/2022 15:30	6/26/2022 22:15	S-1
6/27/2022 0:15	6/27/2022 11:15	S-1
6/27/2022 17:45	6/28/2022 0:00	S-1
6/28/2022 0:45	6/28/2022 12:45	S-1
6/28/2022 17:15	6/29/2022 0:30	S-1
6/29/2022 2:00	6/29/2022 11:00	S-1
5/17/2023 2:00	5/24/2023 14:45	S-1
6/5/2022 21:45	6/30/2022 11:30	S-2
5/7/2023 4:45	5/7/2023 12:00	S-2
5/8/2023 6:00	5/8/2023 9:30	S-2
5/9/2023 7:30	5/9/2023 8:15	S-2
5/16/2023 3:30	5/16/2023 5:30	S-2
5/16/2023 6:00	5/16/2023 6:30	S-2
5/16/2023 7:00	5/16/2023 7:30	S-2
5/16/2023 13:45	5/25/2023 2:45	S-2

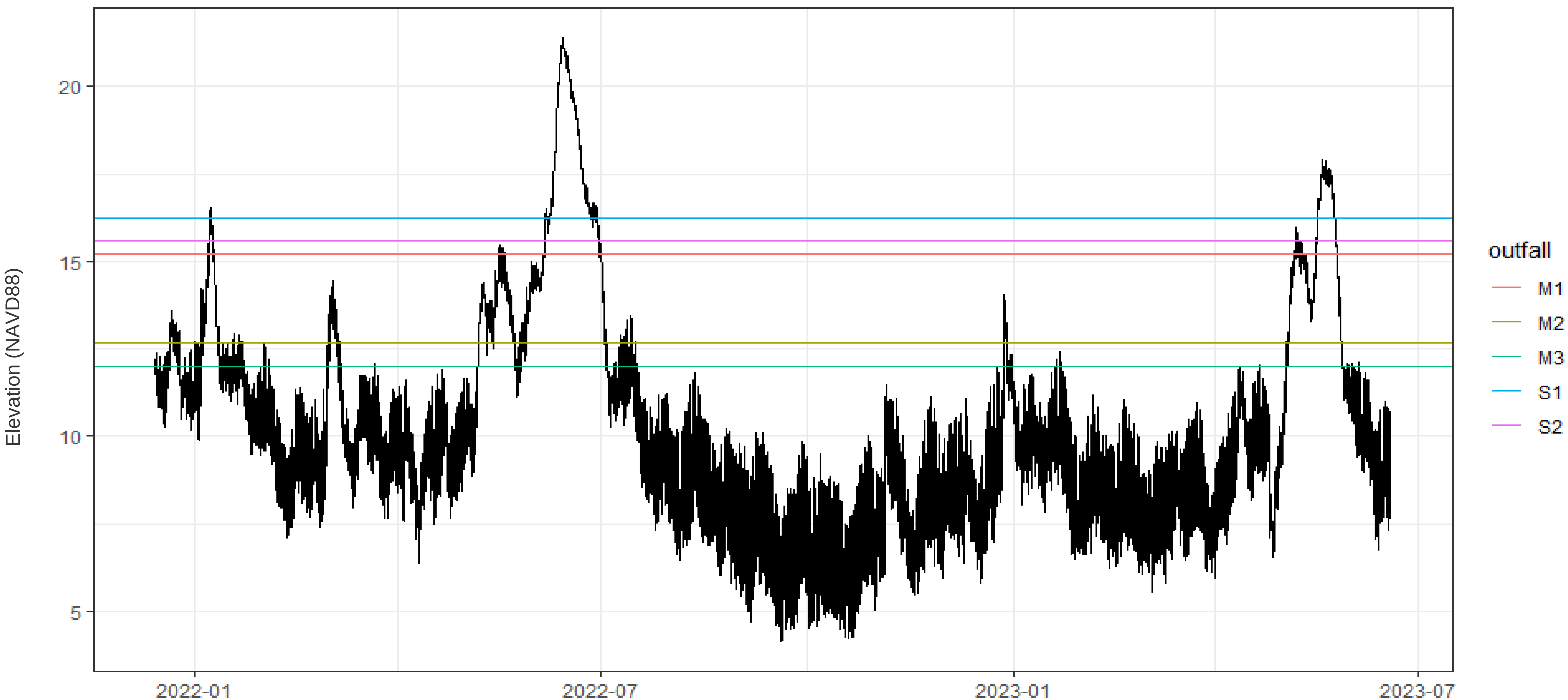
Notes:

Intervals based on review of data in Figure A .7-1

Invert elevations from Table 2-1

River elevations from gage installed in Swan Island Basin

FIGURE



Notes:
Black line = Surface water elevations from river gage installed in Swan Island Basin
Elevation survey = 14.97 ft City of Portland datum + 2.10 = 17.07 NAVD88
Hobo sensor = 12.0 ft below survey point
Hobo elevation in ft NAVD 88 = 17.07 – 12 = 5.07
Colored lines = Invert elevations of velocity - level sensor installations in City outfall basins
When surface water elevation line crosses outfall equipment invert elevation line, surface water inundates the system
For evaluation purposes, inundation periods were removed from flow monitoring data

NAVD88 - North American Vertical Datum of 1988

Attachment A.7 Figure A.7-1

Determination of Inundation Periods, SIB City Stormwater Conveyance Systems, January 2022 – June 2023

Prepared on: 3/8/2024
Stormwater Sampling Data Report
Swan Island Basin