City of Portland, Maine

PHASE 1 INVESTIGATION OF FLOWS – 2019 MONITORING PROGRAM

DECEMBER 2019

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EXECUTIVE SUMMARY

On September 29, 2012, the United States Environmental Protection Agency (US EPA) issued an Order for Compliance and Complaint to the City of Portland for sanitary sewer overflows (SSOs) from non-permitted portions of the City's sanitary sewer collection system. In accordance with that Order, the City completed a "Capacity, Management, Operation and Maintenance (CMOM) and Corrective Action Plan" Report in November of 2013. The recommendations of the CMOM Report included an Infiltration/Inflow (I/I) Removal and Monitoring Program.

This report summarizes the results of the Phase 1 - 2019 Flow Monitoring Program and provides recommendations for Phase 2 - Identification of Major I/I Sources. The 2019 Flow Monitoring Program was the second of a two-phase program. In conjunction with the implementation of the flow monitoring program, this report includes engineering analysis of flow data, including calculation of average daily flow, peak daily flow and peak hourly flow, and estimation of infiltration and inflow for each sub-area. Meter areas were evaluated and ranked by quantities of infiltration and inflow, and follow-on investigation recommendations were developed based on these evaluations and rankings.

This two-phase flow monitoring program includes installation, maintenance and monitoring of 40 flow meters over 2 successive spring periods. This report summarizes the results of the second 20 meters. The first set of meters were installed in Spring of 2018. The program was planned as a 2-year program to allow for potentially unfavorable weather conditions (low precipitation or groundwater), the ability to meter small subsections of each sub-area in Year 2 (as established by the first year of data), and time to allow for corrections to the City's collection system mapping and pipeline connectivity. The results and recommendations for the 2018 flow monitoring period were summarized in the "Phase 1 – 2018 Flow Monitoring Report", dated December 2018.

Results and Recommendations

Based on the 2019 flow metering results, summarized in Section 3.1 of this report, and ongoing sewer system evaluation survey (SSES) investigations, Phase 2 follow on recommendations were developed. Recommendations, as detailed in Section 3 of this Report, include:

- Flow isolation of 120,377 linear feet (LF) of pipe (based on 2019 flow metering results)
- Four hundred and sixty-seven (467) manhole inspections (based on 2019 flow metering results)
- Smoke testing of 119,244 linear feet (LF) of pipe (based on 2018 and 2019 flow metering results)
- Follow up building inspections and dyed water testing

Individual sub-area maps showing follow-on SSES recommendations are included in Appendix C of this report.

In accordance with the Spring 2019 flow metering results, flow isolation was completed in June 2019, manhole inspections were completed in September 2019, and smoke testing was completed in October 2019.

CCTV investigations to identify infiltration is currently ongoing. Large building inspections will be conducted during the winter of 2020, and dye testing will be used to confirm suspected direct inflow sources identified during smoke testing and large building inspections. Follow-on cost-effective sewer system rehabilitation and renewal recommendations will be developed for the removal of I/I and will be

presented in the “Wastewater Collection System Analysis and Action Plan”, scheduled to be finalized in June 2020.

1 INTRODUCTION

1.1 Scope of Work

On September 29, 2012, the EPA issued an Order for Compliance and Complaint, including a proposed civil penalty, for sanitary sewer overflows (SSOs) from non-permitted portions of the City of Portland's collection system. In accordance with that Order, the City completed a "Capacity, Management, Operation and Maintenance (CMOM) and Corrective Action Plan" Report in November of 2013. The recommendations of the CMOM Report included an Infiltration/Inflow (I/I) Removal and Monitoring Program, as well as improvements to the City's collection system GIS mapping. This I/I Program addresses those recommendations and sets the course for I/I mitigation and the City of Portland's continuing efforts to abate SSOs from the sanitary sewer collection system.

This report summarizes the results of the 2019 Flow Monitoring Program, the second phase of a comprehensive flow monitoring program, and provides recommendations for the continuation of Phase 2 – Identification of Major I/I Sources. Phase 1 includes development of a flow monitoring strategy that includes:

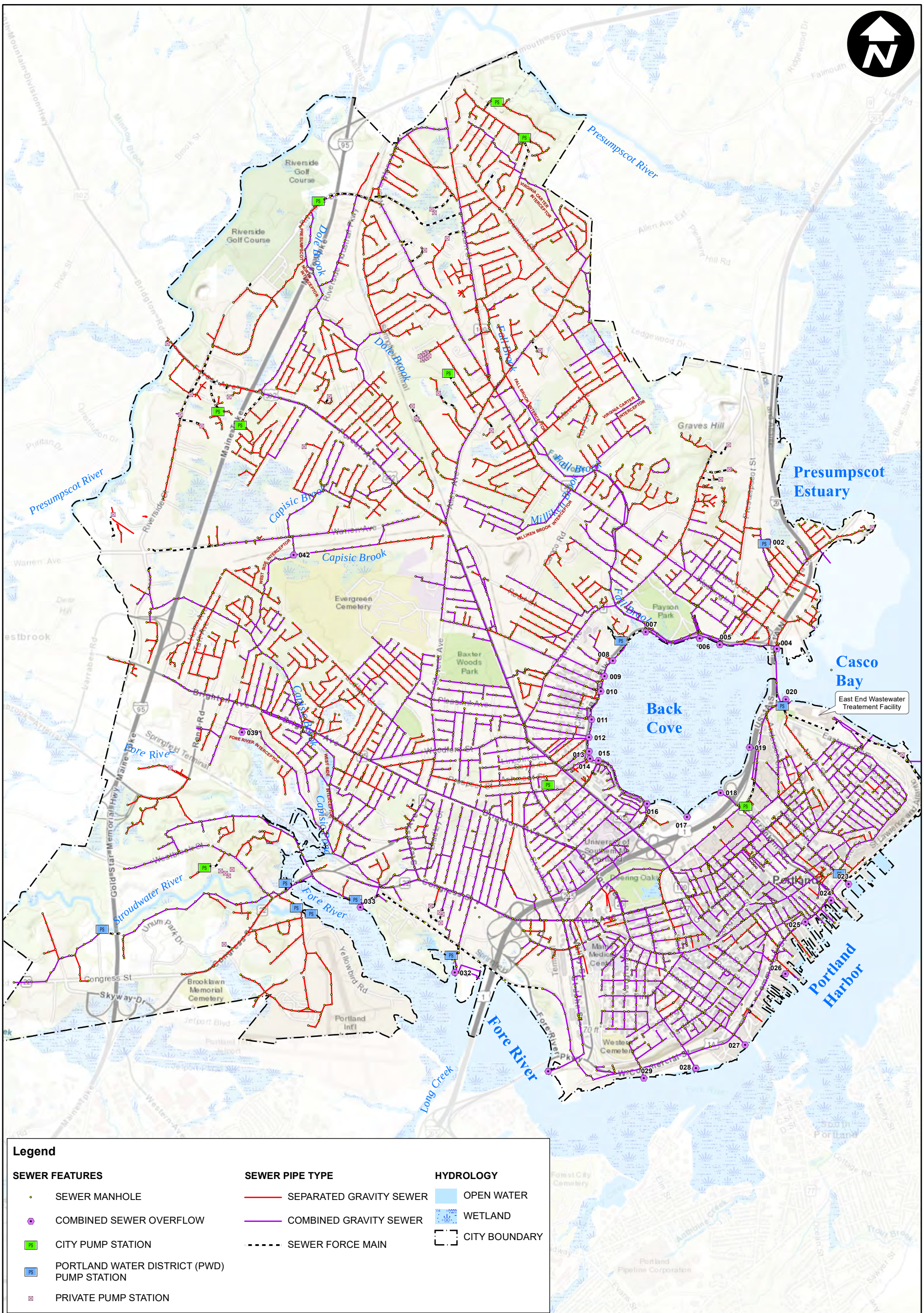
- review of recommended meter sites from the CMOM report
- identification, field verification and recommendation of other suitable sites
- installation of flow monitoring equipment and data collection;
- maintenance procedures for the flow monitoring equipment.

In conjunction with implementation of the flow monitoring program, the 2019 Flow Monitoring Program presents an engineering analysis of flow data, including the calculation of average daily flows, peak daily flows, and peak hourly flows, and estimates of infiltration and inflow for each sub-area. Sub-areas were ranked by quantity of infiltration and inflow and follow-on investigation recommendations were developed based on these analyses and rankings.

This two-phase flow monitoring program includes installation, maintenance and monitoring of 40 flow meters over a period of 2 successive Springs. This report summarizes the results of the second 20 meters. The first 20 meters were installed in Spring of 2018. The program was planned as a 2-year program to allow for potentially unfavorable weather conditions (low precipitation or groundwater), the ability to meter small subsections of each sub-area in Year 2 (as established by the first year of data), and time to allow for corrections to the City's collection system mapping and pipeline connectivity. The results and recommendations for the 2018 flow monitoring period were summarized in the "Phase 1 – 2018 Flow Monitoring Report", dated December 2018.

1.2 Collection System Background and Description

The City of Portland's wastewater collection system, shown on Figure 1, contains approximately 240 miles of separated and combined sewers and 24 pump stations, 9 of which are owned and operated by the City with the remaining 15 either privately owned or owned and operated by the Portland Water District. The collection system and pump stations convey wastewater to the East End Wastewater Treatment Facility (WWTF) in Portland, which is owned and operated by the Portland Water District.



THE CITY OF PORTLAND, MAINE

Phase 1: Investigation of Flows - 2019 Monitoring

0 0.25 0.5 1 Miles

December 2019

FIGURE 1 - CITY OF PORTLAND COLLECTION SYSTEM MAP

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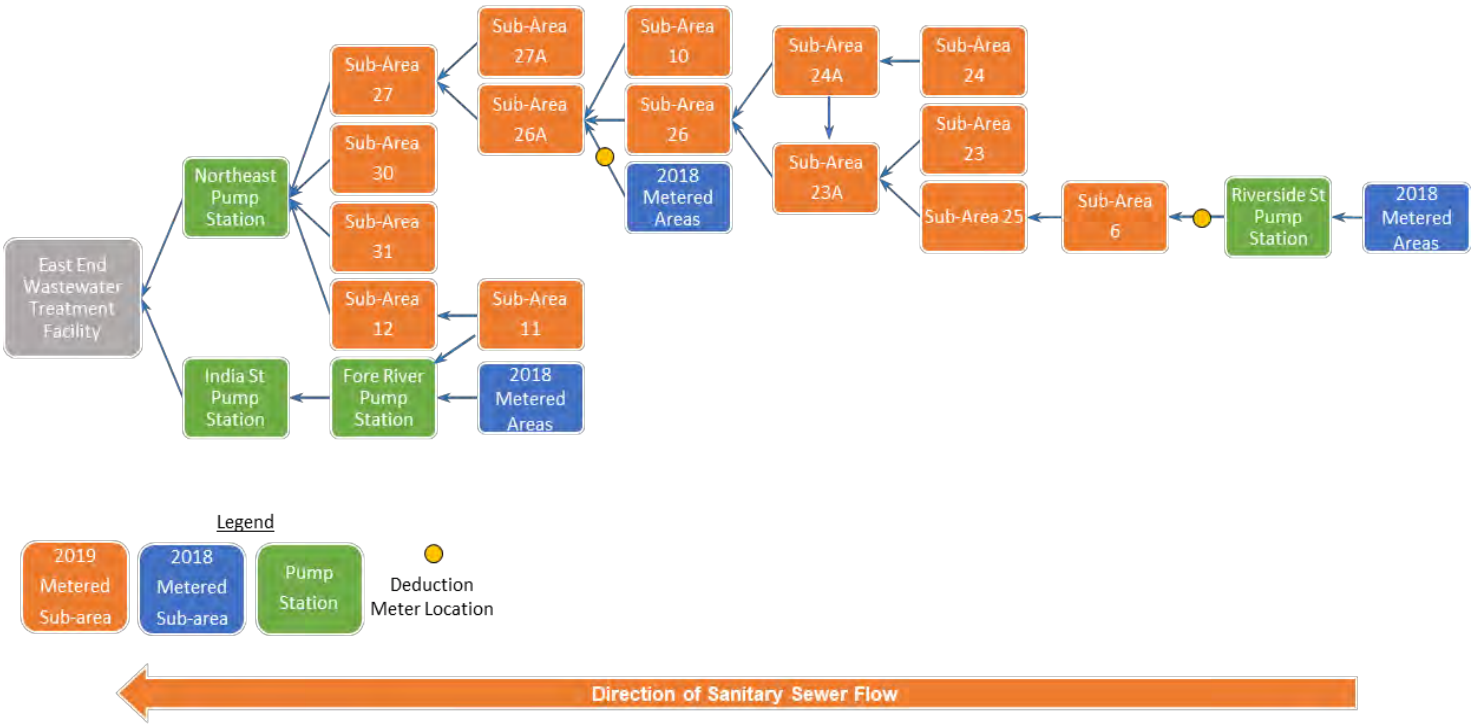
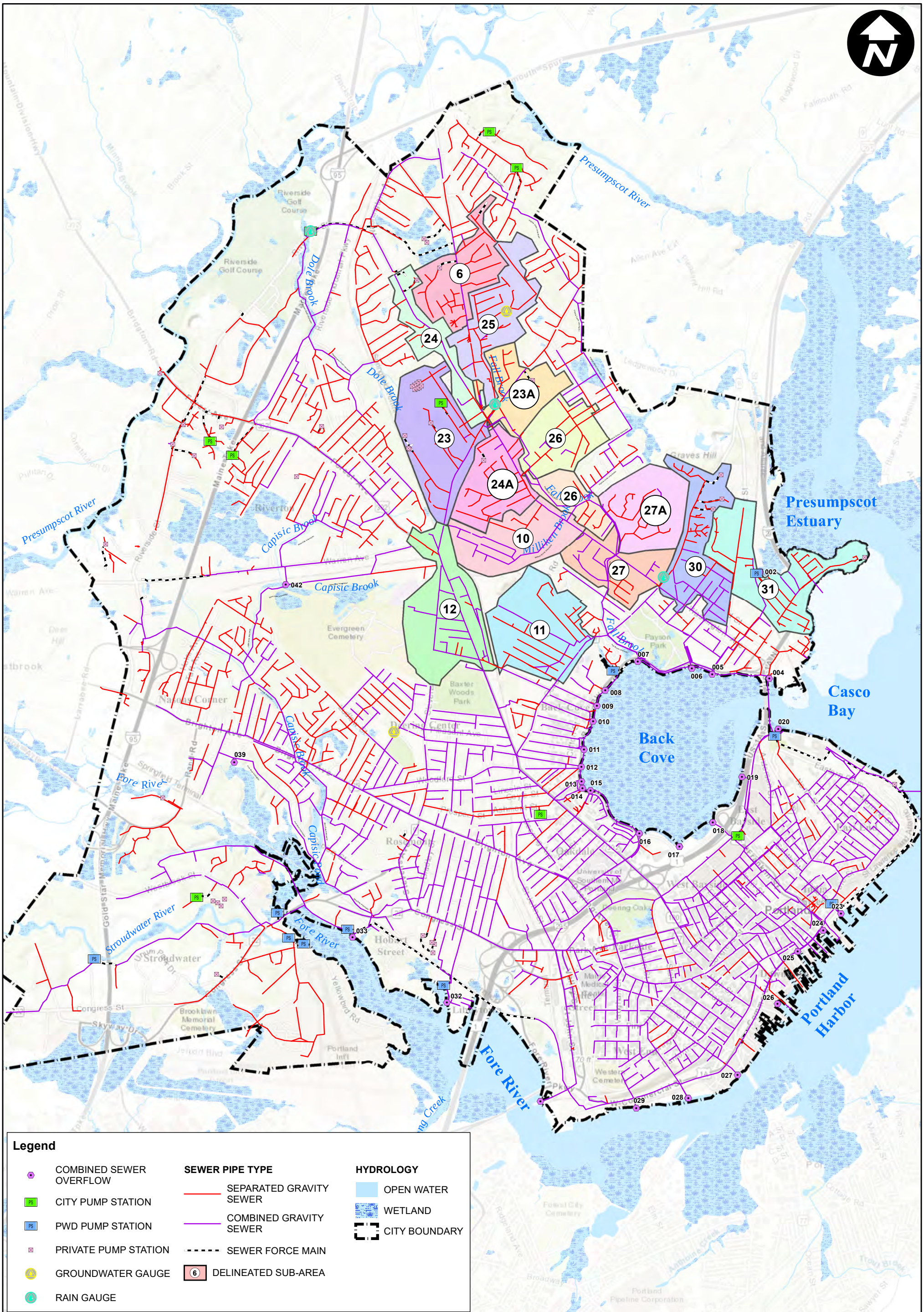
G:\GIS\Portland\2019 I-I Report\FIGURE 1 - CITYWIDE SANITARY SEWER SYSTEM.mxd

1.3 Sub-Area Delineation

The second phase of the metering program included the delineation of 15 sub-areas within the City and deployment of 20 meters. Due to the extent of combined sewers in the downtown area of Portland and on-going sewer separation efforts already in progress for those combined areas, efforts for this study were focused on the north and west areas of the City. Prioritization of meter areas was based on recent and on-going flow monitoring and CCTV data; historic and recently discovered problem areas where backups, surcharging and overflows occurred; areas tributary to known problem areas; areas where the hydraulic model identified potential I/I capacity issues; and areas near water bodies that could be contributing I/I to the system. Figure 2 shows a flow vector diagram for the 15 sub-areas included in the metering program. The flow vector diagram is a visual representation of tributary flow within the system. Sub-areas delineated and included in the 2019 metering program are shown on Figure 3.

Figure 2. Flow Vector Diagram





THE CITY OF PORTLAND, MAINE

Phase 1: Investigation of Flows - 2019 Monitoring

0 0.25 0.5 1 Miles

December 2019

FIGURE 3 - 2019 SUB-AREA DELINEATION

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G:\GIS\Portland\2019 I-I Report\FIGURE 3 - 2019 SUB-AREA DELINEATION.mxd

2 2019 METERING ANALYSIS

In March 2019, Arcadis and its subcontractor, Flow Assessment Services (FAS) started a 12-week flow monitoring program of 15 sub-areas throughout the City of Portland. Meters were installed by FAS in the most downstream manhole of each sub-area where hydraulic conditions were conductive for metering. While only 15 sub-areas were metered, 3 sub-areas required two meters each to ensure accurate data collection and 2 additional meters were installed as subtraction meters. Metering was performed using continuous monitoring devices incorporating depth and velocity sensors to measure velocity, depth and flow rate. Two record tipping bucket rain gauges measuring rainfall every fifteen minutes were installed on the roof of the Allen Ave Fire Station and the Ocean Ave Fire Station. Rain gauge data was supplemented with data from the City-owned rainfall gauge at the Riverside Street Pump Station.

Two permanent groundwater monitoring wells were installed on May 6, 2018 at the intersection of Martin Street and Bartley Street and on Leland Street across from the Deering High School parking lot. Maintenance and data collection for the groundwater gauges, rainfall gauges and flow meters were conducted bi-weekly by Flow Assessment Services.

2.1 Wastewater Characteristics

There are three major components of flow in a sanitary sewer system, base sanitary flow (BSF), groundwater infiltration (GWI) and rainfall derived inflow and infiltration (RDII - commonly referred to as inflow). The Environmental Protection Agency's "Guide for Estimating Infiltration and Inflow", June 2014, provides the following definitions:

Base Sanitary Flow (BSF) – The portion of wastewater which includes domestic, commercial, institutional, and industrial sewage and specifically excludes infiltration and inflow.

Groundwater Infiltration (GWI) – Measured during average dry weather flow period. The average of the low nighttime flows (midnight to 6am) per day for the same time period, minus significant industrial or commercial nighttime users

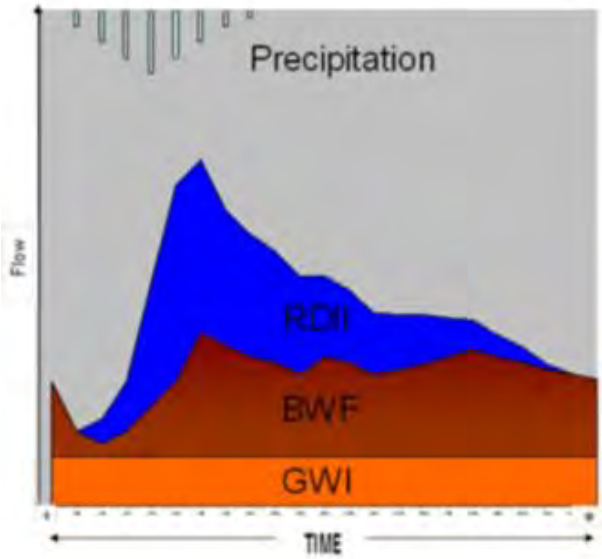
Rainfall Induced Infiltration (RII) – The short-term increase in infiltration which is the result of a rain event. Rainfall-induced infiltration is a portion of delayed inflow.

Delayed Inflow Volume – The portion of total inflow which is generated from indirect connections to the collection system or connections which produce inflow after a significant time delay from the beginning of a storm. Delayed inflow sources include sump pumps, foundation drains, indirect sewer/drain cross connections, etc. Rainfall-induced infiltration cannot be distinguished from delayed inflow and is therefore included as part of delayed inflow. Delayed inflow sources have a gradual impact on the collection system and flow decreases gradually upon conclusion of the rainfall event, and after peak inflow caused by direct connections.

Inflow – Water other than sanitary wastewater that enters a sewer system from sources such as roof leaders, cellar/foundation drains, yard drains, area drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, and catch basins. Inflow does not include infiltration.

Rainfall derived infiltration and inflow includes both rainfall-induced infiltration and inflow. Figure 4 highlights the three key components of wastewater flow during a precipitation event. The GWI (orange line) remains constant and is not impacted by precipitation, the BWF (brown line) is a diurnal pattern based on actual usage and not impacted by precipitation, and the RDII (blue line) shows a very clear increase in flows as a direct response to precipitation.

Figure 4. Components of Wastewater Flow During Wet Weather (US EPA, 2007)



2.1.1 Flow Analysis Approach for Portland's Collection System

The City of Portland's collection system consists of approximately 240 miles of separated and combined sewers. A traditional infiltration and inflow analysis was conducted in the separated portion of the collection system, while a modified approach was used in the combined portion of the collection system. In the sub-areas where 75% or more of the collection system was separated, the I/I analysis focused on identifying groundwater infiltration, rainfall-induced infiltration and direct inflow. In the combined subareas, the I/I analysis focused on identifying groundwater infiltration and rainfall-induced infiltration (delayed inflow). Large volumes of direct inflow are expected in a combined system due to known cross connections between the sanitary system and the drainage system. While direct inflow values were calculated in these sub-areas, they were not used to develop follow-on investigation recommendations. Table 1 includes a summary of the total pipeline footage, percentage of combined pipes and the approach method for each sub-area.

Table 1. Sub-area Characteristics

Sub-area	Total Footage (LF)	Percent Combined (%)	Approach
Sub-Area 6	15,241	13%	Traditional
Sub-Area 10	13,417	77%	Modified
Sub-Area 11	21,085	87%	Modified
Sub-Area 12	20,125	33%	Modified
Sub-Area 23	15,048	19%	Traditional
Sub-Area 23A	10,072	27%	Modified
Sub-Area 24	11,037	37%	Modified
Sub-Area 24A	15,091	13%	Traditional
Sub-Area 25	16,547	7%	Traditional
Sub-Area 26	11,664	25%	Traditional
Sub-Area 26A	8,109	62%	Modified
Sub-Area 27	12,520	81%	Modified
Sub-Area 27A	9,922	26%	Modified
Sub-Area 30	20,905	50%	Modified
Sub-Area 31	22,861	15%	Traditional

2.2 Results and Findings

Table 2 identifies the average daily flow (ADF), peak daily flow (PDF) and peak hourly flow (PHF) measured from February 15, 2019 through May 31, 2019 for each of the fifteen sub-areas. Average daily flow is calculated by summing all metered flows and dividing by the duration of the metering period. Peak daily flow is the maximum daily flow over 24-hours measured throughout the metering period. Peak hourly flow is the maximum 1-hour flow rate measured. Peaking factor is calculated by dividing the peak hourly flow by the average daily flow for each sub-area. Table 2 shows net average daily flow within each sub-area itself (with upstream tributary flows subtracted out), net peak daily flow, net peak hourly flow and the hourly peaking factor.

Table 2. Flow Metering Results – ADF, PDF, PHF

Sub-Area	Average Daily Flow (GPD)	Peak Daily Flow (GPD)	Peak Hourly Flow (GPD)	Peaking Factor
Sub-Area 6*	381,064	563,000	929,000	2
Sub-Area 10	416,000	1,026,000	1,970,000	5
Sub-Area 11	583,594	1,437,000	5,362,000	9
Sub-Area 12*	478,901	1,253,000	2,608,000	5
Sub-Area 23	266,608	1,070,000	3,018,000	11
Sub-Area 23A*	506,788	865,000	1,622,000	3
Sub-Area 24	207,455	576,000	1,855,000	9
Sub-Area 24A*	85,268	585,000	1,115,000	13
Sub-Area 25*	81,644	1,219,000	4,082,000	50
Sub-Area 26*	-37,859	207,000	834,000	-22
Sub-Area 26A*	146,113	968,000	3,107,000	21
Sub-Area 27*	782,969	2,658,000	7,810,000	10
Sub-Area 27A	92,735	221,000	482,000	5
Sub-Area 30	339,538	1,385,000	5,070,000	15
Sub-Area 31	230,980	640,000	1,671,000	7

*Denotes net values with tributary sub-areas subtracted.

Hyetographs showing average daily flow and rainfall for each of the 15 sub-areas are included in Appendix B.

2.3 Groundwater Infiltration

Groundwater infiltration is defined as groundwater that enters or leaks into a sanitary sewer system through defective pipes, pipe joints, service connections, or manholes. The average groundwater infiltration rate is defined as 85% of the nighttime sanitary flow measured on dry days from 12:00am to 6:00am throughout the entire metering period. Only data for days that follow a minimum of 72-hours without a rainfall event are considered “dry days” to avoid inclusion of indirect inflow and rainfall induced infiltration (RII) in the infiltration estimate.

Groundwater levels were monitored throughout the metering period using the two groundwater monitoring wells installed. The groundwater depth during the metering period was analyzed in relation to the average sewer pipe elevations in the area, as shown in Figure 5, as groundwater depth can have a significant influent on the amount of groundwater infiltration entering a collection system.

Groundwater infiltration for each sub-area is normalized by calculating the gallons per day per inch diameter mile of pipe (gpd/in-mi). The inch-diameter-mile of pipe, or inch-miles (in-mi), in a sub-area is calculated by multiplying the sum of the miles of for each diameter of pipe by its respective inch diameter. As an example, if a system contained 1 mile of 10-inch diameter, 1.5 miles of 12-inch diameter, and 0.5 miles of 25-inch diameter of gravity sewers, the calculated inch-miles would be as follows:

(10-inch x 1 mile) + (12-inch x 1.5 miles) + (24-inch x 0.5 mile) = 40 in-mi

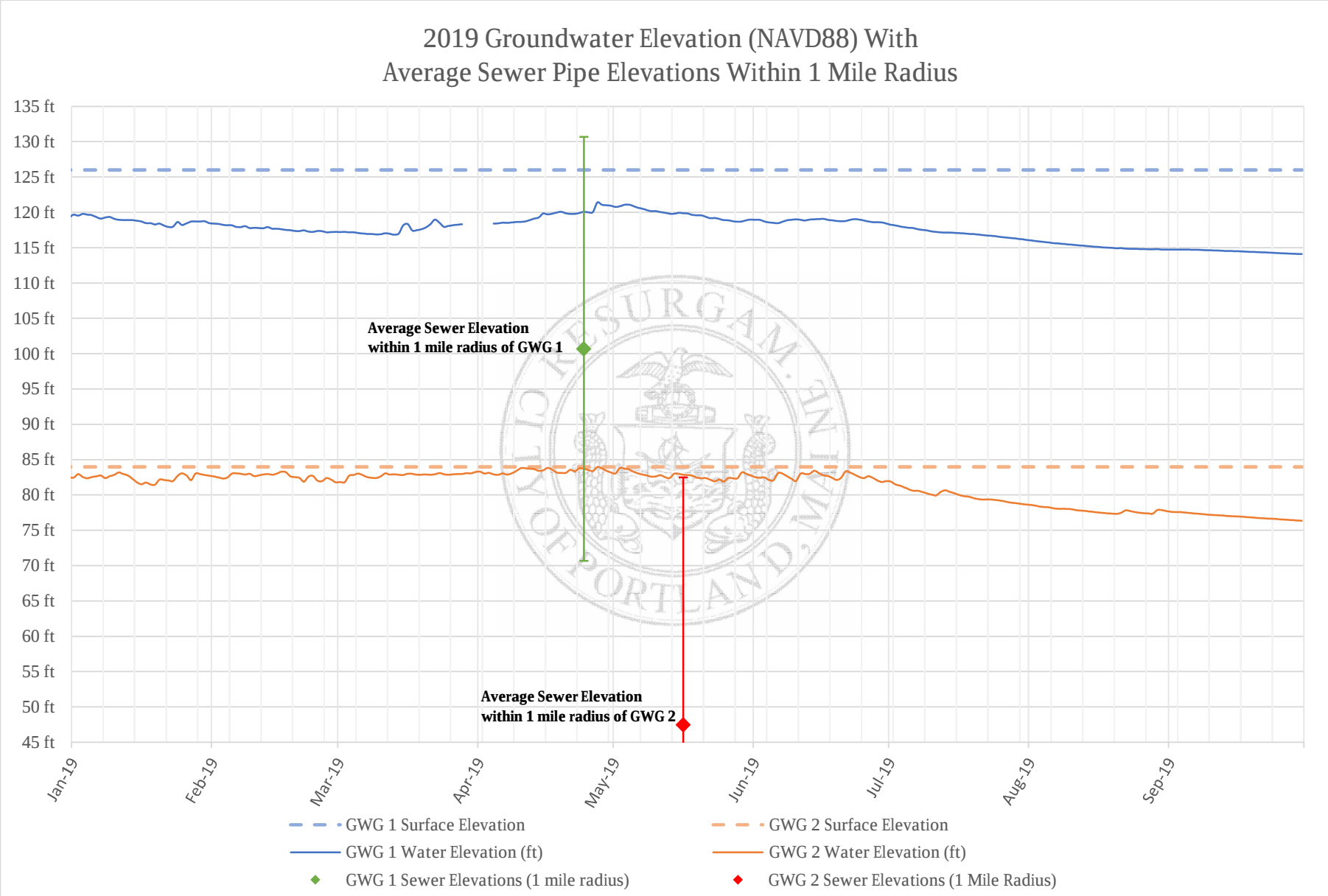
Groundwater infiltration rates for each sub-area were calculated by dividing the sub-area’s total groundwater infiltration by the number of inch-miles of sanitary sewer within the sub-area. The total groundwater infiltration rates for each sub-area during the metering period are shown in Table 3.

Table 3. Flow Metering Results – Infiltration

Sub-Area	Average Daily Flow (gpd)	Net Average Infiltration (gpd)	Infiltration GPD/Total LF (GPD/LF)	Infiltration Gallons per Day per Inch-Mile (GPDIM)
Sub-Area 6*	381,064	234,104	15	7,231
Sub-Area 10	416,000	271,664	20	5,784
Sub-Area 11	583,594	381,685	18	8,897
Sub-Area 12*	478,901	284,260	14	4,457
Sub-Area 23	266,608	160,190	11	4,790
Sub-Area 23A*	506,788	331,600	33	8,728
Sub-Area 24	207,455	140,498	13	6,038
Sub-Area 24A*	85,268	45,463	3	1,443
Sub-Area 25*	81,644	146,106	9	3,513
Sub-Area 26*	-37,859	196,795	17	4,230
Sub-Area 26A*	146,113	178,823	22	3,039
Sub-Area 27*	782,969	551,744	44	10,175
Sub-Area 27A	92,735	69,635	7	3,460
Sub-Area 30	339,538	176,534	8	3,749
Sub-Area 31	230,980	148,921	7	3,103

*Denotes net values with tributary sub-areas subtracted

Figure 5 - Groundwater Elevation
Infiltration and Inflow Program
January 2019 through September 2019



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2.4 Rainfall Derived Infiltration and Inflow (RDII)

Four rainfall events from the metering period were analyzed to calculate rainfall derived infiltration and inflow. Precipitation data was used from rain gauges at the Riverside Road Pump Station, Allen Avenue Fire Station and the Ocean Avenue Fire Station. The precipitation data acquired by these rain gauges was relatively similar; and the rain gauges were in sufficiently relative proximity to each other; as such, the average of these rain gauges was used in determining values for the four storm events selected for an inflow analysis of all sub-areas. Table 4 outlines the duration, total rainfall and peak intensity of the four selected storms.

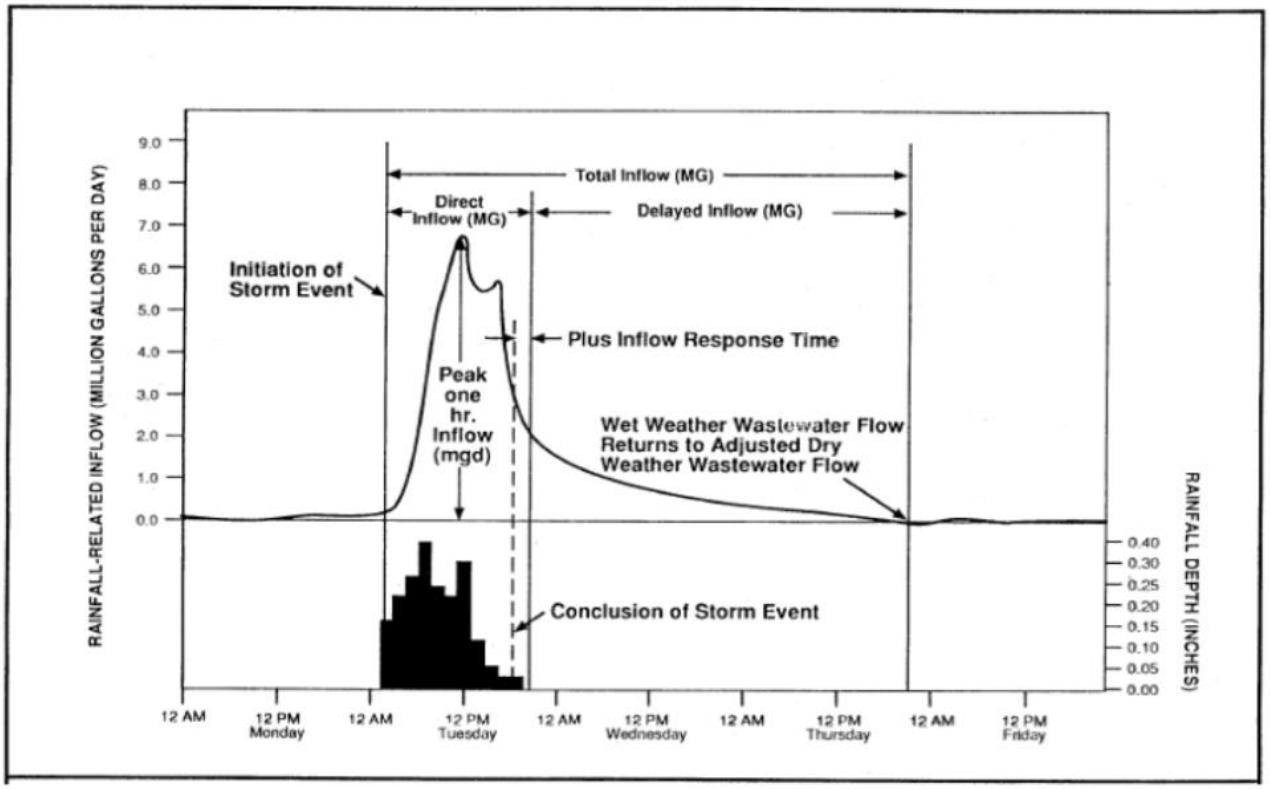
Table 4. Inflow Analysis – Selected Rainfall Events

Rainfall Event	Duration (min)	Duration (hrs)	Total Rainfall (in)	Peak Intensity (in/hr)
3/22/19 7:00 AM	1275	21.25	1.03	0.30
4/14/19 8:00 PM	1395	23.25	1.05	0.25
4/26/19 7:15 AM	1350	22.50	2.25	0.58
5/13/19 9:15 PM	1920	32	0.93	0.22

A wet weather hydrograph from each storm event was compared to a dry weather period on the same day of the week as each storm event. The dry weather flow is subtracted from the wet weather flow resulting in the inflow volumes presented in Table 5. The dry weather flow is calculated as an average of all dry days during the metering period for each day during the week. For example, all dry “Mondays” in the metering period are averaged together to determine the dry weather flow for each individual day.

The hydrograph shown as Figure 6 shows a typical inflow response to wet weather flow. The portion of inflow occurring during the storm event is identified as direct inflow and the portion of inflow that occurs once the storm has concluded is delayed inflow. Total inflow encompasses both direct and delayed inflow.

Figure 6. Wet Weather Hydrograph (MassDEP, 1993)



For the purposes of this study, direct inflow was calculated for all sub-areas; however, where the modified approach was used, only the delayed inflow results were used in the development of follow-on investigation recommendations.

Table 5 - Flow Metering Results - Inflow

Sub-Area	Friday, March 22, 2019			Sunday, April 14, 2019			Friday, April 26, 2019			Monday, May 13, 2019		
	Direct (gal)	Delayed (gal)	Total (gal)	Direct (gal)	Delayed (gal)	Total (gal)	Direct (gal)	Delayed (gal)	Total (gal)	Direct (gal)	Delayed (gal)	Total (gal)
Sub-Area 6	27,695	20,084	47,779	122,502	0	122,502	590,580	0	590,580	481,286	214,602	695,888
Sub-Area 10	417,218	378,794	796,013	253,943	176,448	430,391	330,280	867,732	1,198,012	53,060	1,251	54,311
Sub-Area 11	679,275	199,672	878,947	406,817	18,974	425,792	1,002,760	364,002	1,366,762	259,715	5,452	265,167
Sub-Area 12	657,513	266,396	923,909	448,874	401,028	849,902	642,173	789,315	1,431,488	327,192	56,374	383,567
Sub-Area 23	327,219	148,543	475,762	239,598	103,751	343,349	412,772	298,809	711,581	125,181	6,342	131,522
Sub-Area 23A	343,272	24,195	367,468	166,301	229,206	395,507	528,870	621,988	1,150,858	81,984	0	81,984
Sub-Area 24	246,992	152,598	399,590	287,383	200,802	488,185	238,793	717,174	955,968	160,641	39,090	199,730
Sub-Area 24A	120,590	7,208	127,797	53,495	20,601	74,096	254,546	209,444	463,990	111,486	391,847	503,333
Sub-Area 25	439,151	183,230	622,381	310,850	275,032	585,882	123,194	205,935	329,130	149,081	86,980	236,061
Sub-Area 26	107,516	64,533	172,049	145,852	85,249	231,101	27,059	12,256	39,316	41,077	16,049	57,126
Sub-Area 26A	698,734	840,485	1,539,219	776,918	164,967	941,885	599,368	343,528	942,896	0	0	0
Sub-Area 27	0	0	0	0	307,527	307,527	593,494	581,971	1,175,465	0	0	0
Sub-Area 27A	74,499	73,746	148,245	14,609	4,656	19,265	86,854	67,448	154,302	0	12,518	12,518
Sub-Area 30	989,499	476,189	1,465,688	648,877	440,456	1,089,332	1,022,197	1,075,307	2,097,504	217,114	10,073	227,187
Sub-Area 31	307,075	142,472	449,547	225,645	279,559	505,205	254,596	411,495	666,091	55,760	0	55,760

Direct/Delayed inflow values of "0" denote inconclusive inflow data results

3 SUB-AREA PRIORITIZATION AND RECOMMENDATIONS

3.1 High Infiltration and High RDII Sub-Areas

According to industry standards, infiltration within a sanitary sewer system is considered excessive if a defined area exceeds a dry weather infiltration rate of 4,000 gallons per day per inch diameter mile (gpd/idm). Sub-areas with infiltration rates exceeding 4,000 gpd/in-mi (Sub-areas 6, 10, 11, 12, 23, 23A, 24, 26, 27) are highlighted in Table 6.

Table 6. High Infiltration Sub-areas

Sub-Area	Groundwater Infiltration (GWI)	Infiltration GPD/Total LF (GPDLF)	Gallons per Day per Inch-Mile (GPDIM)
Sub-Area 27*	551,744	44	10,175
Sub-Area 11	381,685	18	8,897
Sub-Area 23A*	331,600	33	8,728
Sub-Area 6*	234,104	15	7,231
Sub-Area 24	140,498	13	6,038
Sub-Area 10	271,664	20	5,784
Sub-Area 23	160,190	11	4,790
Sub-Area 12*	284,260	14	4,457
Sub-Area 26*	196,795	17	4,230
Sub-Area 30	176,534	8	3,749
Sub-Area 25*	146,106	9	3,513
Sub-Area 27A	69,635	7	3,460
Sub-Area 31	148,921	7	3,103
Sub-Area 26A*	178,823	22	3,039
Sub-Area 24A*	45,463	3	1,443

*Denotes net values with tributary sub-areas subtracted

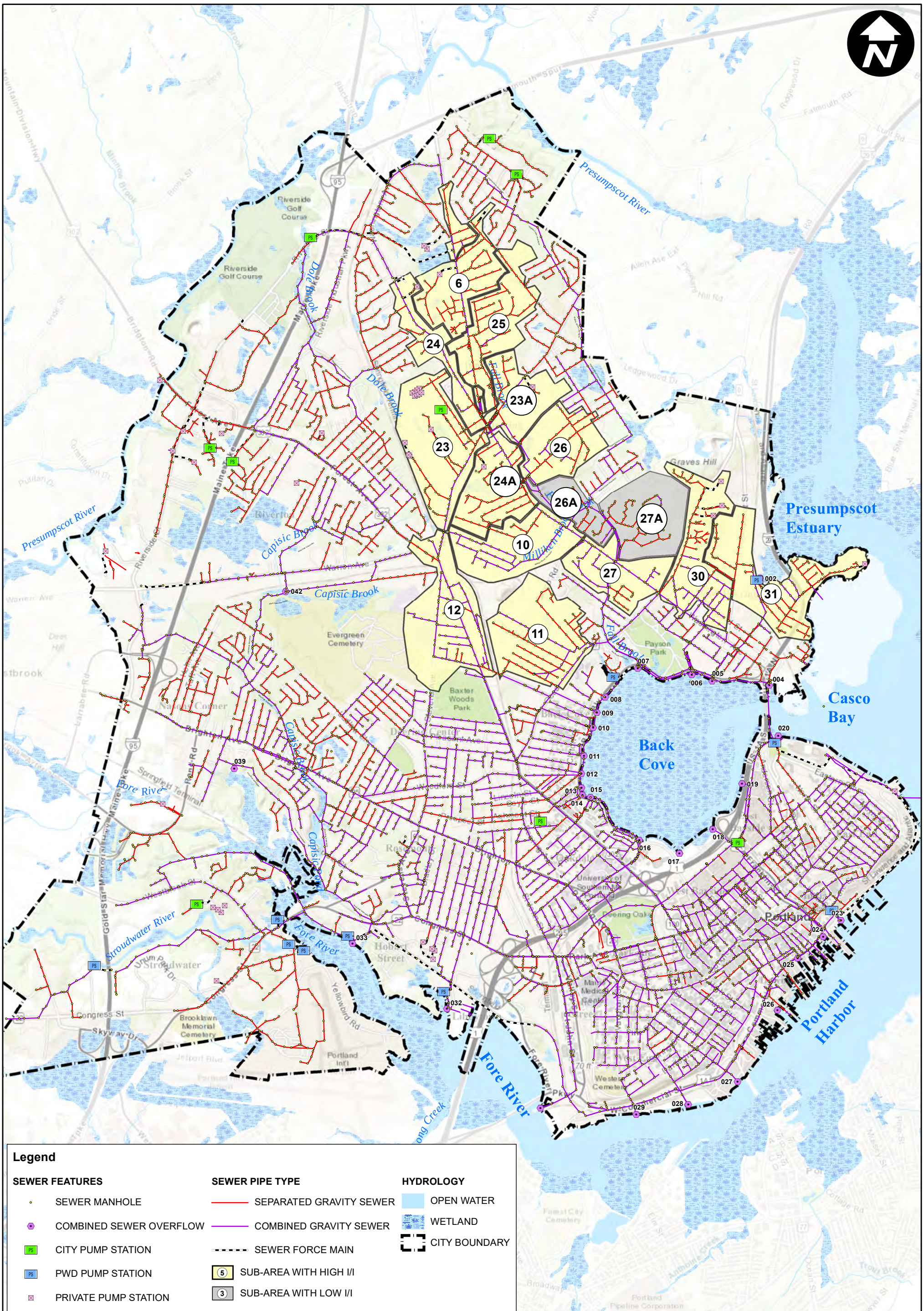
Inflow results were analyzed for the April 26, 2019 storm event to determine which sub-areas contribute excessive volumes of delayed inflow to the collection system. High delayed inflow sub-areas are shaded in Table 7.

Table 7. High Delayed Inflow Sub-areas – April 26, 2019 Storm Event

Subarea	Direct Inflow (Gal)	Delayed Inflow (Gal)	Total Inflow (Gal)
Sub-Area 30	1,022,197	1,075,307	2,097,504
Sub-Area 10	330,280	867,732	1,198,012
Sub-Area 12*	642,173	789,315	1,431,488
Sub-Area 24	238,793	717,174	955,968
Sub-Area 23A*	528,870	621,988	1,150,858
Sub-Area 27*	593,494	581,971	1,175,465
Sub-Area 31	254,596	411,495	666,091
Sub-Area 11	1,002,760	364,002	1,366,762
Sub-Area 26A*	599,368	343,528	942,896
Sub-Area 23	412,772	298,809	711,581
Sub-Area 24A*	254,546	209,444	463,990
Sub-Area 25*	123,194	205,935	329,130
Sub-Area 27A	86,854	67,448	154,302
Sub-Area 26*	27,059	12,256	39,316
Sub-Area 6*,**	590,580	-	590,580

*Denotes net values with tributary sub-areas subtracted
**Denotes sub-area with inconclusive delayed inflow data

High infiltration and inflow sub-areas are highlighted in Figure 7.



THE CITY OF PORTLAND, MAINE

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0 0.25 0.5 1 Miles

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FIGURE 7 - HIGH INFILTRATION AND INFLOW SUB-AREAS

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G:\GIS\Portland\2019 I-I Report\FIGURE 7 - HIGH I AND I SUB-AREAS.mxd

3.2 Investigation Recommendations

Based on the metering results summarized in Section 3.1 and ongoing investigation within the City of Portland, Phase 2 follow-on recommendations were developed. Recommendations, summarized in Table 8 and shown on Figure 8, include flow isolation, manhole inspections, and smoke testing. Smoke testing recommendations were developed based on 2018 and 2019 flow metering results. Flow isolation and manhole inspection recommendations are based on the 2019 flow metering results. Individual sub-area maps showing follow-on recommendations are included in Appendix C.

Table 8. Follow-on Investigation Recommendations

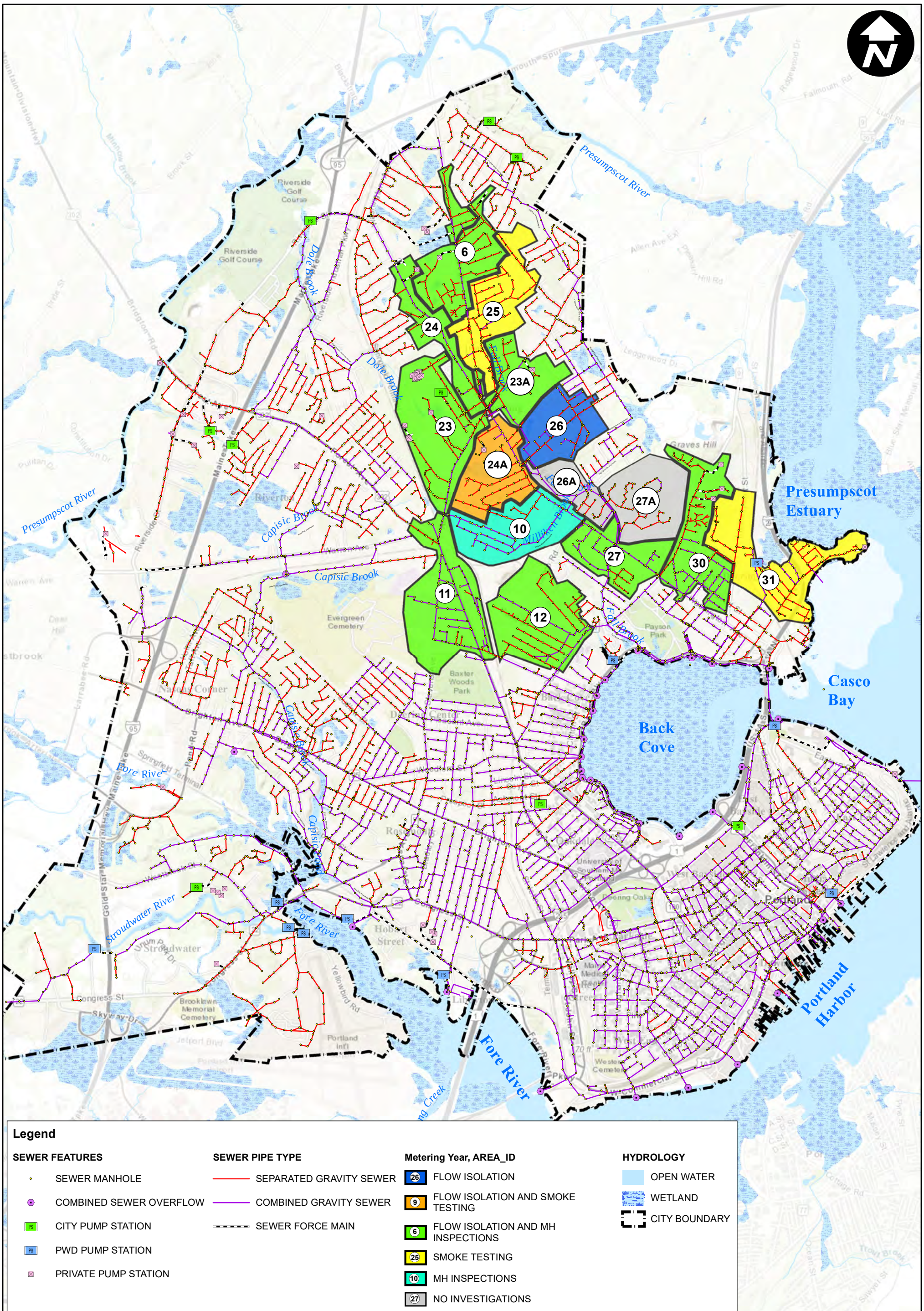
Sub-Area	Approach	High Infiltration Sub-areas	High Delayed Inflow Sub-area	Recommendations		
				Flow Isolation (LF)	Manhole Inspections	Smoke Testing (LF)
Sub-Area 1**	Traditional		X			19,994
Sub-Area 2**	Traditional		X			11,916
Sub-Area 4**	Traditional	X	X			8,894
Sub-Area 6*	Traditional	X		15,813	91	
Sub-Area 7**	Traditional	X	X			23,950
Sub-Area 10	Modified	X	X		66	
Sub-Area 11	Modified	X	X	20,485	103	
Sub-Area 12*	Modified	X	X	13,949	3	
Sub-Area 23	Traditional	X	X	12,442	89	
Sub-Area 23A*	Modified	X	X	6,635	46	
Sub-Area 24	Modified	X	X	10,450	2	
Sub-Area 24A*	Traditional		X	12,625		15,084
Sub-Area 25*	Traditional		X			16,546
Sub-Area 26*	Traditional	X		7,907		
Sub-Area 26A***	Modified		X			
Sub-Area 27*	Modified	X	X	9,293	64	
Sub-Area 27A	Modified					
Sub-Area 30	Modified		X	10,778	3	
Sub-Area 31	Traditional		X			22,860
Total				**120,377**	**467**	**119,244**

*Denotes net values with tributary sub-areas subtracted;
** Denotes sub-areas evaluated during 2018 flow monitoring program;
*** Due to the prevalence of combined sewers in sub-area 26A, inflow investigations are not recommended because they would not provide valid results.

Flow isolation was completed in sub-areas 6, 11, 12, 23, 23A, 24, 24A, 26, 27, and 30 in June 2019. Manhole Inspections were completed in September 2019 in sub-areas 6,10, 11, 12, 23, 23A, 24, 27, and 30. Smoke Testing was completed in October 2019 in sub-areas 1, 2, 4, 7, 24A, 25, and 31.

Follow-up building inspections and dye testing will be conducted for select large buildings in the Winter of 2020.

The results of all SSES investigations and recommendations for sewer system rehabilitation and renewal for I/I mitigation will be presented in the final I/I study report, “Wastewater Collection System Analysis and Action Plan”.



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0 0.25 0.5 1 Miles

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FIGURE 8 - INVESTIGATION RECOMMENDATIONS

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G:\GIS\Portland\2019 I-I Report\FIGURE 8 - I AND I INVESTIGATION SUB-AREAS.mxd

APPENDIX A

2019 Meter Area Figures

APPENDIX B

Flow Meter Hydrographs with Related Rainfall Hyetographs

APPENDIX C

Follow-on Investigation Sub-Area Figures

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