Technical Memorandum TM-03

CITY OF PATEROS
WASTEWATER GENERAL SEWER PLAN AND FACILITIES PLAN

Inflow and Infiltration Evaluation

July 7, 2022

1.1 Introduction

This memorandum summarizes the methods and results used to identify the individual components of wastewater flow entering the wastewater treatment facility (WWTF). Areas of known infiltration are identified using past investigations and sanitary surveys which are compared to the results of this evaluation to develop recommendations for reducing infiltration/inflow (I/I) entering the system.

Individual flow components include:

- Sanitary Base Flow: flow from the private and public facilities such as residences, commercial facilities, and schools.
- Infiltration: groundwater entering the sewer through poor service connections, cracked or broken pipes and manhole walls.
- Inflow: water introduced into the system through area drains, roof drains, foundation drains, sump pumps, storm drains or direct flow through manhole lids. Inflow is directly related to storm (precipitation) events. Snowmelt can also contribute to inflow as well as infiltration. Inflow can be separated into direct and rainfall induced inflow (RDI/I). RDI/I is related to short term increased groundwater elevations due to precipitation.

The results determine if the collection system has excess I/I that can impact influent flows and operation of the WWTF.

1.2 Previous I/I Investigations

Pateros previously completed the following I/I investigations:

- 1999 Pateros Wastewater Facilities Plan & I/I Investigation
- 2003 Pateros Sanitary Sewer Collection System Investigation

Exhibit 1 summarizes the results provided in the 1999 and 2003 I/I and sanitary sewer condition investigations.

1.3 Data and Methods

Effluent flows from the WWTF were obtained from daily monitoring reports (DMR's) acquired from ECY's PARIS site. DMR's used for this I/I evaluation were from January 2016 through December 2021.

Weather records for the same period (1/2016 – 12/2021) are from the WSU AGNET Azwell site (https://weather.wsu.edu). The Azwell site is located at Wells Dam, approximately 7.5 miles south of Pateros.

Water use records for 2018 through 2021 were provided by the City. Winter (non-irrigation season) water use was estimated as the difference between the last monthly meter reading (typically read in October) and the following years first meter reading (typically read in March).

The residential population for the sewer service area was estimated in TM-01 "Planning Areas and Population".

The following methods were used to estimate I/I:

1.3.1 *Method 1: Annual I/I Report – ECY Information Manual for Treatment Plant Operators*

The Annual I/I Report is prepared by treatment plant operators as part of their annual wastewater report. The purpose of the Annual I/I Report is to track potential I/I issues. If large increases in I/I are noted, ECY requires an explanation and a plan for corrective action.

This I/I method assumes that the difference between the highest and lowest month average influent flow provides a reasonable estimate of I/I.

1.3.2 *Method 2: EPA Guide for Estimating Infiltration and Inflow, Region 1*

The 2014 EPA Guide provides guidance for estimating I/I. The guidance is based on EPA's 1991 Sewer System Infrastructure Analysis and Rehabilitation and the 1985 Infiltration/Inflow – I/I Analysis and Project Certification documents. Following is a description of steps used for estimating I/I:

<u>Step 1: Estimate Base Sanitary Flow (BSF)</u>

The sanitary portion of the wastewater flow can be estimated through two methods, which can be used to 'check' each other – influent flow data and winter domestic water consumption.

The first method analyzes influent wastewater flow at the WWTF during a dry weather period of 7 to 14 days. Influent flow data is used to calculate the average daily flow for the dry weather periods. Base sanitary flow (BSF) is estimated by subtracting groundwater infiltration (GWI) flow from the average daily dry weather wastewater (ADW) flow.

The second method uses winter (non-irrigation) water usage records to estimate base sanitary flow. During winter, wastewater from residential areas is assumed to be the same as the billed water use. Groundwater infiltration is estimated as the difference between the monitored wastewater flow and the billed water use.

<u>Step 2: Estimate Infiltration (GWI)</u>

Groundwater infiltration (GWI) can be estimated from influent flow data collected during dry weather when groundwater is high. Dry weather is defined as when there has been at least three days without a rain event. During dry weather, inflow is expected to be zero. In most cases, the GWI rate will approximate the maximum weekly infiltration.

The infiltration rate can also be estimated by averaging nighttime flows (midnight to 6 am) over several days, during dry weather conditions. The nighttime flows can be assumed to be mostly groundwater (after subtracting significant industrial or commercial nighttime flows). Note that nightime flows were not evaluated during the preparation of this TM.

Step 3: Estimate Inflow

Inflow is calculated by subtracting sanitary and infiltration flows when the system has been influenced by rain. Flows during a significant storm event can be compared to the dry weather flows immediately preceding the storm when groundwater conditions are similar.

The calculations in this memo use "R: A language and environment for statistical computing" and various analytical packages. The workflow includes:

1. Gather Data
   - Download DMR data from the ECY PARIS website
   - Download weather data from the WSUAGNET site
   - Estimate sewer service area populations for the study period

2. Plot, review and clean data to remove outliers

3. Calculate ECY annual I/I (Method 1)
   - Calculate influent monthly average flows. Determine/select the annual maximum and minimum month influent flows.
   - GWI is estimated as the difference between maximum and minimum month flows. Add annual precipitation and population to the table.
   - Divide the annual flows and the GWI estimate by population to estimate flow per capita.
   - Compare flows to EPA and ECY guidelines for excess I/I (120 gpcd).

4. Estimate EPA dry weather BSF and GWI flow.
   - Calculate weekly, monthly, and annual flows. Evaluate for outliers and for seasonal trends.
   - Calculate weekly, monthly, and annual precipitation. Evaluate for outliers and for seasonal trends.
   - Merge weekly influent flows and precipitation into a table and do the same for the daily data.
   - Estimate BSF and GWI by filtering weekly average flows to include only non-precipitation weeks. High influent weeks during the dry periods are assumed to equal base flow plus infiltration from high groundwater. Low influent weeks are assumed to equal base wastewater flow. Note that even during low influent months a portion of the flow can be GWI and commercial flows.
   - Data can be further filtered for low precipitation months (see graphs made for seasonal trends) to refine the evaluation.
   - In practice, identifying the annual low and high weekly flows during non precipitation periods provides a reasonable estimate of BSF and GWI. BSF is then checked with water use records.

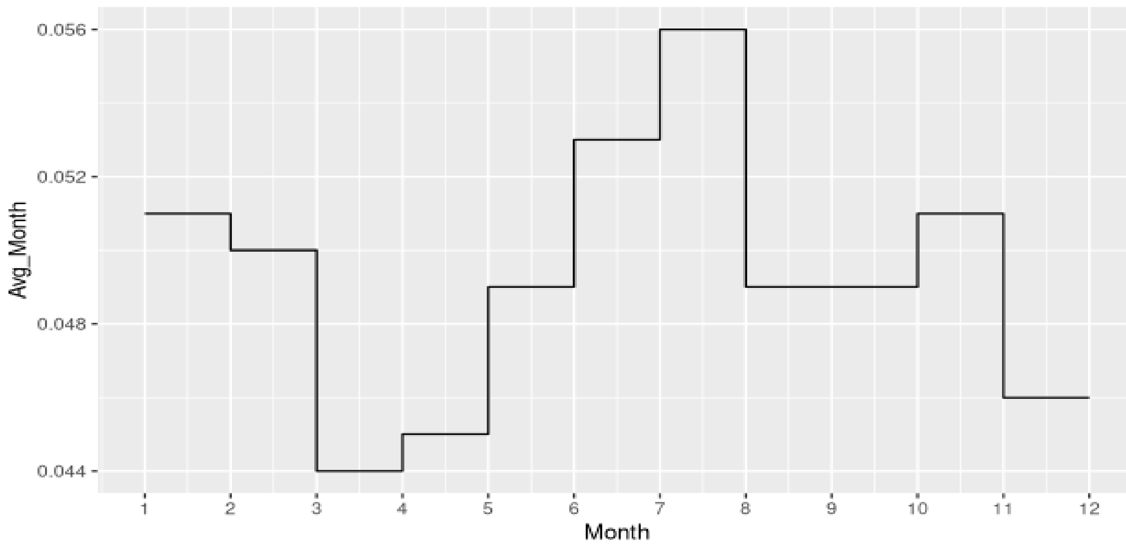
5. Estimate EPA Inflow.
   - Inflow is estimated using weekly and daily precipitation and flow records filtered for precipitation days. The data was further filtered by using a minimum rainfall to approximate more sustained rainfall events. The annual maximum week and maximum day influent are assumed to provide a reasonable approximation of potential inflow.
   - The correlation between precipitation and influent flow is checked to determine if there is a noticeable relationship.

1.4 Background and Information

1.4.1 *Influent Wastewater Flow*

Effluent wastewater flow in million gallons per day (MGD) is measured at the WWTF. **Figure 1** shows monthly seasonal average flows. Effluent flows out of the WWTF are assumed to be the same as influent flows into the WWTF. As can be seen on the figure, minimum influent flows occur in March and April with peak monthly flows occurring in June and July.

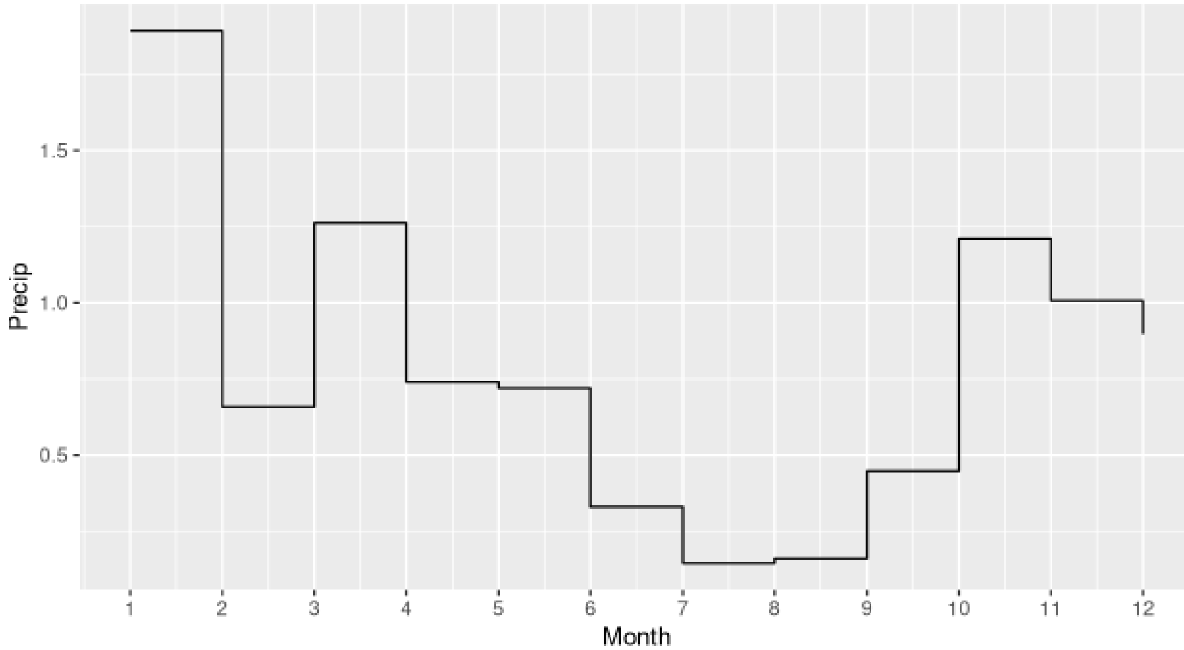
Figure 1 City of Pateros Seasonal Influent Flows



1.4.2 *Precipitation*

The months of July, August and September have periods of low to no precipitation as can be seen on **Figure 2**.

Figure 2 City of Pateros Precipitation Pattern (WSU Agnet – Azwell Site)



1.4.3 *Lake Pateros/Wells Dam Water Surface Elevations*

Wells Dam controls the elevation of Lake Pateros. Lake Pateros water surface elevation is about 10 to 12 feet below the ground surface at Lake Shore Drive. This area of the City includes the AC trunk sanitary sewers installed in 1966 after the construction of Wells Dam. The City has indicated that infiltration may be occurring in this area associated with the lake elevation.

Average Lake Pateros elevations vary about 1.5 feet throughout the year as shown on **Figure 3**. Elevations are highest in June, July, and August. Maximum month flows into the WWTF occur in June and July as shown on **Figure 1**. The correlation between both daily and monthly average Lake Pateros elevations and WWTF influent flows are poor (r = 0.2).

Figure 3 Lake Pateros Water Surface Elevations

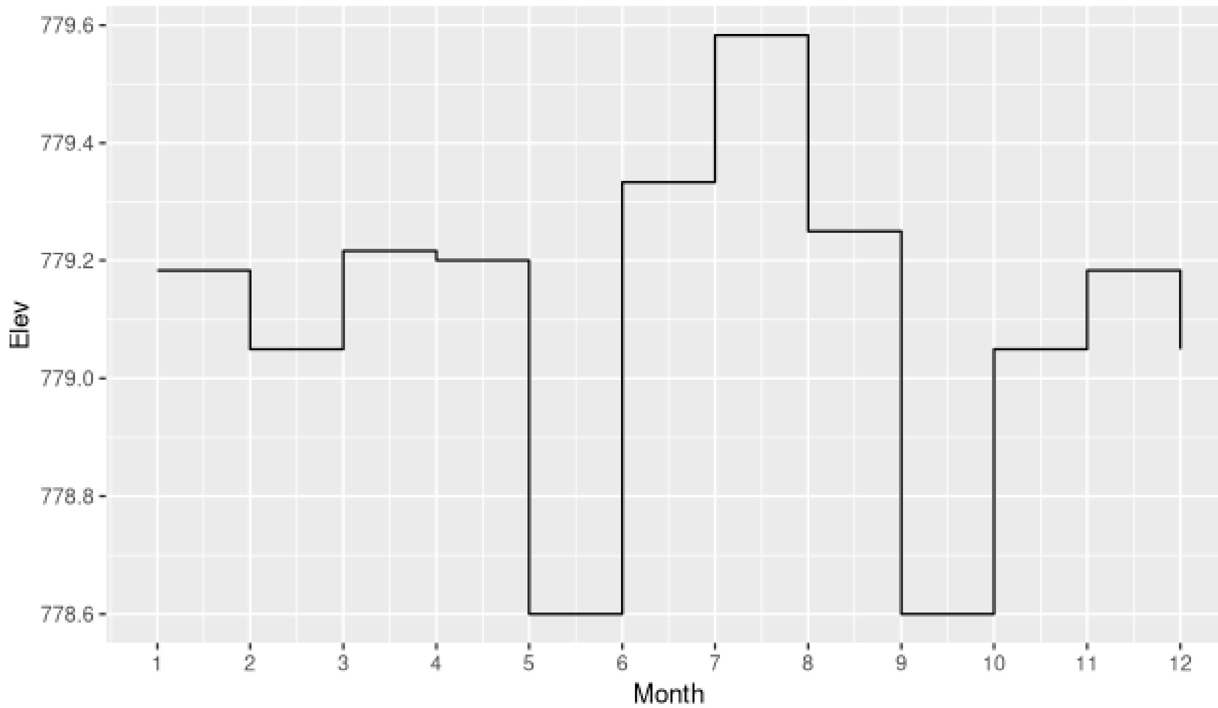


Exhibit 1 shows areas where mains are believed to below the Lake Pateros water surface elevation and where infiltration is known to be occurring per the 2003 Sanitary Sewer Collection System Investigation.

1.4.4 *Background Discussion*

Influent flows entering the WWTF exhibit seasonal changes with high monthly flows occurring during the summer and low flows occurring during the spring. This is an uncommon pattern for the northwest and may indicate GWI impacts from the elevation of Lake Pateros.

1.5 I/I Calculations

1.5.1 *Annual I/I WWTF Report Method*

This section provides the calculations used to determine total I/I as described in Method 1, above. This method is typically used for screening and to easily estimate if I/I is significant. WWTF influent flows from January 2016 through December 2021 are used. **Table 1** shows the results of the calculations.

Table 1 Estimated I/I Flows

Variable	Year					
	2016	2017	2018	2019	2020	2021
Min Month (MGD)	0.043	0.041	0.039	0.041	0.04	0.039
Avg Month (MGD)	0.054	0.049	0.049	0.047	0.046	0.050
Max Month (MGD)	0.065	0.061	0.058	0.054	0.054	0.059
Peak Day (MGD)	0.108	0.095	0.081	0.082	0.082	0.085
Population	560	580	583	585	593	590
Precip (in)	13.05	11.24	10.26	7.78	6.77	7.72
Total (MG)	19.7	17.9	17.9	17.2	16.8	18.3
I/I (MGD)	0.022	0.02	0.019	0.013	0.014	0.02
ADF/Cap (gal)	**96**	**84**	**84**	**80**	**78**	**85**
MMF/Cap (gal)	116	105	99	92	91	100
I/I/cap (gal)	**39.3**	**34.5**	**32.6**	**22.2**	**23.6**	**33.9**
% I/I/ADF	41%	41%	39%	28%	30%	40%

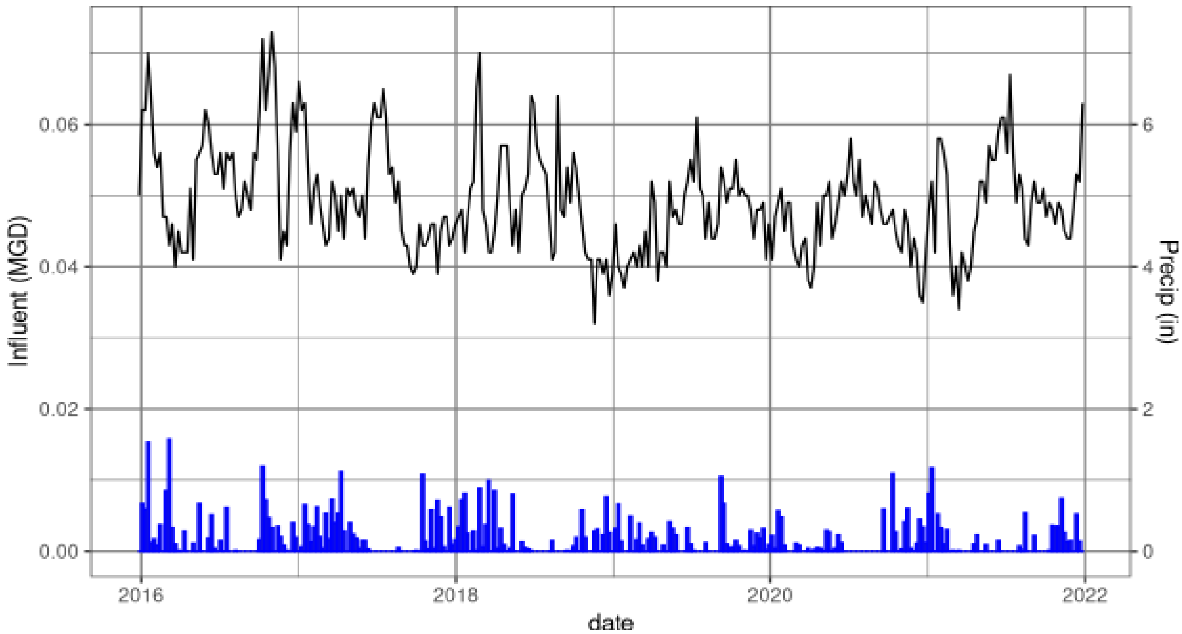
Based on the information provided in **Table 1** excess flows from I/I contribute between 30 and 40 percent of annual influent flow. The ADF per capita is approximately 85 gal which is lower than the EPA guideline of 120 gpcd for excessive infiltration. These calculations show that the total annual influent flow into the WWTF has been consistent over the past five years. There is a good correlation (r = 0.8) between annual rainfall and total annual I/I.

1.6 EPA Guide for Estimating I/I

1.6.1 *Estimated Sanitary Baseflow and Infiltration*

Wastewater influent flows provide an estimate of base sanitary flow (BSF) and groundwater infiltration (GWI). Average weekly influent flows and precipitation are calculated for the study period. Flow data was divided into weeks when there was no precipitation and weeks when precipitation occurred. For the weeks of no precipitation, weekly influent flows for the average and minimum year, month, and week were calculated to estimate BSF and GWI flows. The data used the entire years data, the data was not divided into wet and dry seasons. **Figure 4** shows the weekly average influent flow and precipitation.

Figure 4 Weekly Average Influent Flow and Precipitation



Dry weather flow information was evaluated. The minimum week flow for each year was used to approximate BSF while the difference between the maximum and minimum week flows were used to approximate GWI as shown in **Table 2**.

Table 2 Estimated Sanitary Base Flow and Groundwater Infiltration

Date	Max. Week (MGD)	Min. Week (MGD)	Population	BSF/Cap (gal/d)	GWI/Cap (gal/d)	ADF/Cap (gal/d)
2016	0.068	0.042	560	75	46	121
2017	0.066	0.039	580	67	47	114
2018	0.064	0.039	583	67	43	110
2019	0.061	0.037	585	63	41	104
2020	0.058	0.037	593	62	35	98
2021	0.067	0.038	590	64	49	113
Average	**0.06**	**0.039**	**582**	**67**	**44**	**110**

These calculations indicate that sanitary base flow is at the low end of the range of typical textbook values of 60 to 90 gpcd for small communities (including the commercial component but not including I/I). A typical average is 75 gpcd.

Combining estimated sanitary base flow and GWI results in an average daily influent flow per capita of 110 gallons. This is below the EPA guideline of 120 gpcd for excessive infiltration. This dry weather evaluation indicates that GWI is high but not excessive in Pateros as defined by ECY.

1.6.2 *Estimated Base Sanitary Flow with Winter Water Use*

A second method to estimate base sanitary flow is from winter water use records. The City has provided water use records between 2018 and 2021. Typically, the last water reading before winter occurs in October of each year and meters are read again in March of the following year. Winter water use is estimated by subtracting the March reading from the previous Octobers meter reading. The City provided the total amount invoiced for each invoice period. The total water meter readings are divided by the number of days (in practice number of months times 30 days) between the meter readings. This data is converted to gallons per day and gallons per day per capita.

Pateros has a number of water use classifications. To estimate BSF only the residential, rental, and multi-family classifications were used. **Table 3** shows the winter water use for these classifications from the City.

Table 3 Estimated BSF Based on Winter Water Use

Date	Multi-family (gal)	Rental (gal)	Residential (gal)	Total		Population	BSF (gpcd)
				(gal)	(gpd)		
2018	1,009,249	453,070	3,566,028	5,028,347	33,522	583	57
2019	1,924,654	967,490	4,643,530	7,535,674	41,865	585	72
2020	1,752,394	694,620	4,637,631	7,084,645	47,231	593	80
2021 (1)	0	2,595,851	10,614,578	13,210,429	88,070	590	149

1. *City staff indicate that 2021 water use data contains accounting errors.*

The winter water use records show an increase in residential water use from 2018 to 2021. The 2021 winter water use numbers are almost double any of the other years. City staff indicate that 2021 water use numbers contain numerous accounting errors.

Using the 2019 and 2020 water use data, BSF is in the 70 to 80 gpcd range. This is a bit higher than calculated by the DMR data that had an average of 67 gpcd but the two methods of estimating BSF are considered close.

1.6.3 *Estimated Inflow*

Inflow is estimated using both daily and weekly precipitation and flow data. For both the weekly and daily data, days and weeks with no precipitation were removed. The table was sorted to include only precipitation events with a daily rainfall greater than 0.25 inches to approximate larger, more sustained rainfall events during the entire year.

A first pass compared average weekly influent flows to average weekly precipitation. The relationship between precipitation and influent flows is poor (r value of 0.2).

A second pass using daily data was made to determine that relationship. Daily precipitation does not have a close relationship to influent flows (r = 0.1). Tables are shown for both cases with a total flow per capita during wet weather.

This evaluation to determine inflow shows that inflow is not a significant issue in Pateros and can be considered non-existent.

Table 4 Estimated Inflow Based on Weekly Influent Averages

Date	Population	Max. Week (mgd)	ADF Inflow/Cap (gal)	Inflow/Cap (gal)	Inflow/Cap (gal)
2016	560	0.073	121	130	-9
2017	580	0.063	114	109	5.2
2018	583	0.07	110	120	-10.3
2019	585	0.054	104	92	11.9
2020	593	0.052	98	88	10.1
2021	590	0.058	113	98	14.7

Table 5 Estimated Inflow Based on Daily Influent Flows

Date	Population	Wet Weather Daily Max (mgd)	ADF Inflow/Cap (gal)	Inflow/Cap (gal)	Inflow/Cap (gal)
2016	560	0.082	121	146	-25.0
2017	580	0.064	114	110	3.5
2018	583	0.081	110	139	-29.1
2019	585	0.06	104	103	1.6
2020	593	0.065	98	110	-11.8
2021	590	0.069	113	117	-3.9

1.7 Previous Investigations Discussion

1.7.1 *1999 Wastewater Facilities Plan*

The City prepared a Facility Plan in 1999 which included an I/I investigation. Two late night flow investigations were performed to quantify infiltration in the collection system. The collection system service area was divided into six (6) subareas to measure flow from each subarea. Total average infiltration in 1999 was estimated at 32,300 gpd and 56 gpcd. **Exhibit 1** provides a summary of the infiltration results including subarea contributions from the 1999 Facility Plan.

Based on the results of the 1999 I/I analysis, the highest concentration of the City's infiltration occurs along the rubber gasketed asbestos concrete pipe installed in 1966 after the construction of Wells Dam. It is estimated that approximately 50% of this pipe is below the average elevation of Wells Dam Pool.

The 1999 Facilities Plan concluded that infiltration removal is not cost effective and that the most cost effective solution for addressing I/I is to continue to treat at the wastewater treatment facility.

1.7.2 *2003 Sanitary Sewer Collection System Investigation*

In 2003 the City completed extensive CCTV inspection and smoke testing of the sewer collection system, the results of which are summarized below:

- Some pipelines were observed with no apparent defects while others were observed with multiple kinds of defects. A prioritization schedule was developed which separated replacements into 3 priorities; with the 1st priority pipelines identified as having the potential to cause problems in the future which will likely increase in frequency over time.

- The smoke testing revealed a few abandoned service connections and sanitary sewer services that had missing cleanout caps

- Infiltration was largely observed along pipe stretches and in manholes known to be below the Lake Pateros dam pool elevation. Manholes and sewer mains reported as infiltration sources were determined to not be in bad enough shape to replace due solely to their physical condition and were therefore not added to the prioritization schedule.

1.8 Summary Discussion and Recommendations

Pateros' combined sanitary base flows, groundwater infiltration, and inflow are high but below the EPA's guidelines for excessive infiltration. They are similar to the 1999 findings. Inflow is not a significant issue and essentially non-existent. Infiltration from groundwater is the primary cause of excess flows in the Pateros collection system.

Previous I/I studies and collection system assessments show the highest concentration of infiltration occurs in Subareas 1 and 3. These areas include older AC sewer mains near the Columbia River which are buried below the surface elevation of Lake Pateros. **Exhibit 1** includes a table that shows that over 60% of the measured infiltration occurs in Subareas 1 & 3.

Previous studies noted that the capacity of the treatment plant was sufficient to treat the excess flows and that replacement of the AC sewer mains in Subareas 1 and 3 was not cost effective. The CCTV sewer inspection was performed about 20 years ago. It is likely that sewer condition has deteriorated since the 2003 condition assessment. The City has not completed repairs identified in the 2003 priority sewer plan.

1.8.1 *Recommendation*

Influent flows to the treatment plant are projected to increase over the 20 year planning period. The projected flows are slightly below the hydraulic capacity of the treatment plant (0.125 mgd). The older AC sewers located in Subarea 1 and 3 contribute about 60% of the City's infiltration (about 20,000 gpd) per the 2003 study. It is difficult to predict the effectiveness that replacing/lining these mains/manholes would have on reducing I/I, but it can be assumed that a reduction if infiltration of 50% (10,000 gpd) might be achievable. It is recommended that that City plan to line the sewer mains and repair leaky manholes in Subareas 1 & 3 which were previously identified in the 2003 evaluation and shown on **Exhibit 1**. **Table 6** is the cost estimate for lining and repair of the mains/manholes in Subarea 1 and 3.

Table 6 Estimated Improvements Cost for Lining Subarea 1 and 3

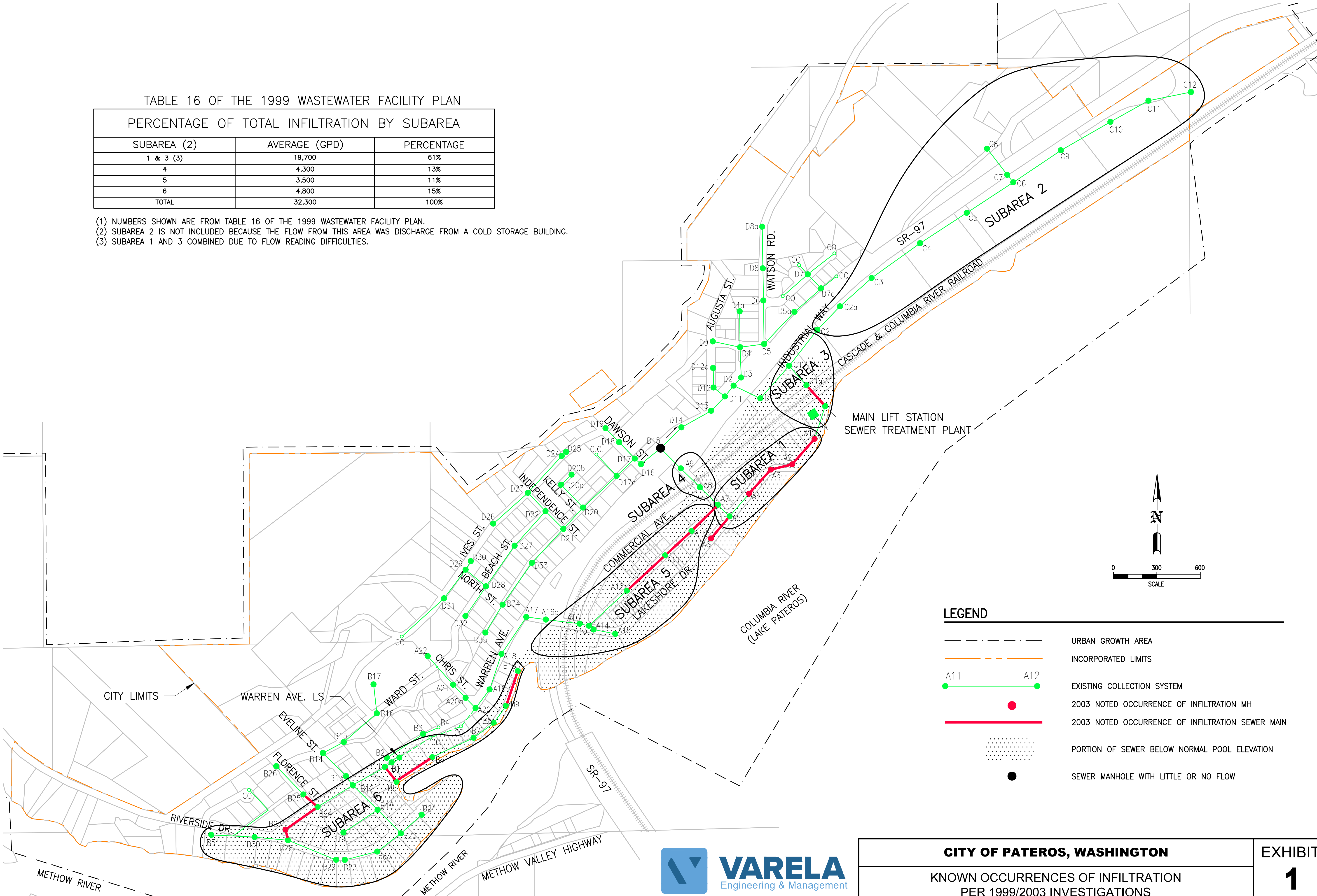
Description	Estimated Quantity	Units	Unit Price	Amount
Internal CCTV Inspection	2,400	LF	$5	$12,000
Root Removal	200	HR	$625	$125,000
Reopen Existing Sewer Service Connection	20	EA	$450	$9,000
CIPP Liner Installation, 8" Dia. (1)	500	LF	$160	$80,000
CIPP Liner Installation, 10" Dia. (1)	1,900	LF	$175	$332,500
CIPM Liner Installation (2)	12	EA	$3,000	$36,000
			Subtotal	$457,500
			Contractor Mobilization/ Admin. (10% of Subtotal)	$45,800
			Sales Tax (8%)	$40,300
			Contingency (25%)	$125,800
			Estimated Construction Cost	$669,400
			Eng, Const Mgmt, Inspection (25%)	$167,400
			Environmental Permitting	$5,000
			Estimated Improvements Cost Total	**$841,800**

2. *CIPP – Cast-in-place pipe*
3. *CIPM – Cast-in-place manhole*

TABLE 16 OF THE 1999 WASTEWATER FACILITY PLAN

PERCENTAGE OF TOTAL INFILTRATION BY SUBAREA		
SUBAREA (2)	AVERAGE (GPD)	PERCENTAGE
1 & 3 (3)	19,700	61%
4	4,300	13%
5	3,500	11%
6	4,800	15%
TOTAL	32,300	100%

(1) NUMBERS SHOWN ARE FROM TABLE 16 OF THE 1999 WASTEWATER FACILITY PLAN.
(2) SUBAREA 2 IS NOT INCLUDED BECAUSE THE FLOW FROM THIS AREA WAS DISCHARGE FROM A COLD STORAGE BUILDING.
(3) SUBAREA 1 AND 3 COMBINED DUE TO FLOW READING DIFFICULTIES.



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DATE:	7/07/22

VARELA
Engineering & Management

CITY OF PATEROS, WASHINGTON

KNOWN OCCURRENCES OF INFILTRATION
PER 1999/2003 INVESTIGATIONS

EXHIBIT
1