Town of Minto
Community of Palmerston

Infiltration and Inflow (I/I) Study

Report

August 2023
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ORANGEVILLE | FERGUS | HARRISTON

Contents

1.0 Introduction

Triton Engineering Services Limited (Triton) has prepared this Infiltration and Inflow (I/I) Study Report (Report) to document the data, results, and conclusions of the I/I monitoring program completed for the sanitary sewage collection system serving the distinct urban area of Palmerston.

Key components of this Report include the following:

- Introduction and background information
- I/I Study, Terms, and Methodology
- Extraneous Flow Analysis
- Data Gathering
- Analysis
- Conclusions
- Recommendations

1.1 Palmerston Sanitary Sewage System

The Palmerston sanitary sewage system (System) consists of works for the collection, transmission, and treatment of sewage. Collected sewage is conveyed to the Palmerston Wastewater Treatment Plant (WWTP) via trunk sewers, separate sewers and low-pressure forcemains. Treated effluent from the WWTP is discharged to the headwaters of the Wallace drain, a tributary to the Little Maitland River.

The sewage collection network is comprised of more than 19 km of sewer mains and provides more than 1,300 service connections. The sanitary sewer main diameters range from 100 mm to 600 mm with various materials including asbestos cement, concrete, PVC, and vitrified clay. It is expected that asbestos cement and vitrified clay sewers are approaching the end of their estimated service life.

The Palmerston WWTP is located at 605 Mill Lane, at the southwest corner of Mill Lane and Walker Street. The plant is a conventional mechanical plant with an extended aeration oxidation ditch facility that includes a bar screen for grit removal and preliminary treatment, an oxidation ditch for secondary treatment, followed by ultra-violet disinfection as tertiary treatment. The WWTP also includes the necessary biosolids management associated with a mechanical plant, including aerobic digestion and storage.

A new secondary clarifier was commissioned in 2023 to provide redundancy for the WWTP process as part of an upgrade project, which will ultimately become a component of a future full plant expansion. The existing clarifier and associated return/waste pumping/piping systems were left in place to handle flows more than the new clarifier's peak capacity, noting that the upgrade did not result in an increase to the WWTP's rated average flow capacity of the 2,010 m3/day.

The existing sanitary sewer collection network is presented in Figure 1 in Appendix A.

1.2 Previous Studies and Rehabilitation Programs

Several investigative studies and rehabilitation programs for the System have been completed in the decades prior to the preparation of this report. Notable past studies include the following:

- 1980 Sanitary Sewer System Investigation
  - Investigated the existing sanitary sewer system and determined that rehabilitation to reduce inflow was required.
- 1980-1982 Sanitary Sewer Rehabilitation Program
  - Infrastructure rehabilitation program to address conclusions from 1980 Sanitary Sewer System Investigation.
- 1986 Sanitary Sewer Rehabilitation Program
  - Supplemental camera inspection to 1980 Investigation to identify sources of infiltration. Also highlighted that sanitary service laterals contributed as the largest source of I/I into the system.

- 1990 Sanitary Sewer System Needs Study
    - Limited flow monitoring revealed increased flow in the System coinciding with rainfall and snowmelt and, indicating inflow and infiltration respectively. Inflow sources were determined to be primarily to illegal connections to the sanitary system. Camera inspection of sanitary service laterals revealed poor conditions, causing infiltration in study areas.
    - The 1986 Rehabilitation Program was updated to recommend priority of rehabilitation and replacement works.
- 2004 I/I Study
    - I/I study initiated in spring of 2004 after two by-pass events occurred due to exceedance of the WWTP peak capacity.
    - Flowmeters installed at key locations in the System to observe I/I by catchment area instead of for the entire system.
    - Recommendations included an implementation plan for System rehabilitation and stricter reinforcement of by-laws regulating the collection and treatment of sewage and stormwater.

This I/I report has been prepared keeping in mind the procedures and outcomes as respectively used and generated by past remedial studies on the System.

1.3 Reserve Capacity/Water and Sanitary Systems Servicing Strategy

Municipal wastewater treatment plants/facilities have rated flow capacities dictated by their Environmental Compliance Approval (ECA) or Certificate of Approval, issued by the Ministry of Environment, Conservation, and Parks (MECP). This rated flow is based on several factors, including the design of the plant and the capacity of the effluent watercourse to receive the treated flows without causing significant damage or harm to the environment. Without completing significant studies, and/or plant improvements, a municipality has a set capacity (Reserve Capacity) to treat municipal sewage, and as such there is a maximum amount of development that can be serviced based on the available Reserve Capacity.

The Town completed a Water and Sanitary Systems Servicing Strategy (Servicing Strategy) (Triton, January 26, 2022) to assist with infrastructure planning for its three urban centers of Palmerston, Harriston and Clifford. As part of the Servicing Strategy, Triton completed a review of the reserve capacity for the Palmerston WWTP, based on information to the end of calendar year 2020. Based on the population growth projections for Palmerston and the associated projected sewage flow, the design capacity of the existing WWTP is expected to be exceeded between 2031 and 2036, indicating the need for additional treatment capacity to permit future growth.

It was therefore recommended that the Town initiate technical studies, including this I/I study, to support a Municipal Class Environmental Assessment (Class EA) to review viable options to increase reserve sewage treatment capacity at the Palmerston WWTP.

1.4 Town of Minto Asset Management

In accordance with Ontario Regulation 588/17, the Town adopted Policy Number 3.3 “Strategic Asset Management Policy” on June 18, 2019, to guide the Town’s approach to asset management activities. Per the Policy, an Asset Management Plan was developed in 2019 to identify the state of the Town’s infrastructure and to document progress towards a defined level of service. The following is an excerpt from the updated 2022 Asset Management Plan that details its mission statement:

> *The goal of asset management is to minimize the lifecycle costs of delivering infrastructure services, manage the associated risks, while maximizing the value ratepayers receive from the asset portfolio.*

As part of the Plan, assets were assessed through CCTV inspections, Supervisory Control and Dada Acquisition (SCADA) system and other metrics for linear assets including age, material, location, and diameter. The weighted average condition of sanitary infrastructure was rated as fair (57%) in the updated 2022 report. This value is governed by a poor (28%) average rating for the Palmerston WWTP and balanced by a fair (53%) rating for maintenance holes (MH) and good (75%, 77%) ratings for gravity mains and forcemains respectively.

The Plan recommends that infiltration and inflow issues continue to be monitored as part of its Risk Management Strategy, and that risk-based decision-making is implemented as part of the asset management planning and budgeting processes.

2.0 Inflow & Infiltration Study

Extraneous flow from I/I sources reduces the capacity and capability of sewage collection systems and treatment facilities to transport and treat wastewater. Studying the respective impacts of inflow and infiltration on the sanitary collection system allows for the identification and prioritization of measures to rehabilitate the system.

Inflow is stormwater that enters the sanitary sewer system by direct connections. It is divided into direct inflow that results from immediate surface runoff due to precipitation and delayed inflow that leeks into the collection system from pipes and structures temporarily submerged in groundwater or from erroneous sanitary connections with larger response times (i.e., sump pumps, large parking lots, etc.).

Infiltration is water that enters the sanitary system from surrounding groundwater through cracks and/or leaks in the infrastructure.

An I/I study measures the performance of the sanitary sewage collection system and identifies sanitary infrastructure experiencing the highest I/I. This allows for the prioritization of remedial measures (i.e., rehabilitation or replacement of sewers, removal of illegal connections, etc.) implemented to reduce wastewater flows to the WWTP. The Town initiated an I/I study in 2021 as recommended by the Servicing Strategy (Triton, January 26, 2022) and supported by the Town’s Asset Management Plan (2022).

2.1 Sources of Inflow & Infiltration

Sources of inflow are commonly divided by their connection to the sanitary collection system. Connections from private property such as footing/foundation drains, roof drains or leaders, drains from window wells, outdoor basement stairwells and basement sump pumps can all cause inflow. These connections can be improperly or illegally connected to the sanitary system with discharges often into sinks and tubs connected to the sanitary sewers. This water should be directed to the stormwater system or allowed to soak into the ground. I/I from public sources includes municipal storm sewer connections improperly connected to the sanitary system. Public connections like maintenance hole covers, erroneously connected storm infrastructure, and sanitary pipes in poor condition can all cause inflow.

Infiltration to sewers and maintenance holes may be caused by age-related deterioration, loose joints, construction errors or tree root intrusion. Groundwater can enter these system deficiencies where sewers and services are beneath the water table or where the soil is saturated from rainfall events. Average sewer pipes are designed to last between 40 and 70 years depending on the type of pipe material. Sanitary service laterals are also a frequent source of I/I as these can often be poorly constructed and are rarely inspected by private property owners following installation unless there is a failure with the service. Service laterals can also be damaged by penetration of roots from trees and shrubs planted in proximity of the service lateral. Identifying the source of I/I as well as the severity of its impact on the sanitary system is crucial to prioritizing the direction of remedial efforts.

2.3 Calculating Infiltration

Quantifying infiltration requires the ability to isolate infiltration flows from all sources of demand in a sanitary system. This is accomplished by **identifying periods of time where infiltration is at a maximum while all other sources of demand are at a minimum.** The following paragraph is an excerpt from the 2014 *EPA Guide for Estimating Infiltration and Inflow* (the Guide) which summarizes the process for identifying these periods of time.

> *During seasonal high groundwater, which usually occurs after snow melt and soil thaw, infiltration will be at its highest. During this period, the infiltration rate can be quantified by averaging the 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).*

The Guide provides several generalizations that can be refined to estimate infiltration more precisely. An analysis of extraneous sanitary flows against temperature in the System can provide insights into when infiltration reaches an annual maximum. Collecting precipitation data in parallel allows for the identification of dry weather periods when inflow is likely to be negligible. The intersection of these time periods results in the **selection of a dry weather analysis period where infiltration is at its most isolated from other sources of sanitary demand.** Analyzing sanitary flows from a flow monitor recorded during the dry weather analysis period provides the highest probability that infiltration flows can be accurately isolated. Per the guide, separating sanitary flows into on- and off-peak periods allows for the calculation of three key parameters: **average day flow, infiltration,** and **base sanitary flow**.

Figure 1 provides a visual reference for each of these parameters for a sample flow monitor.

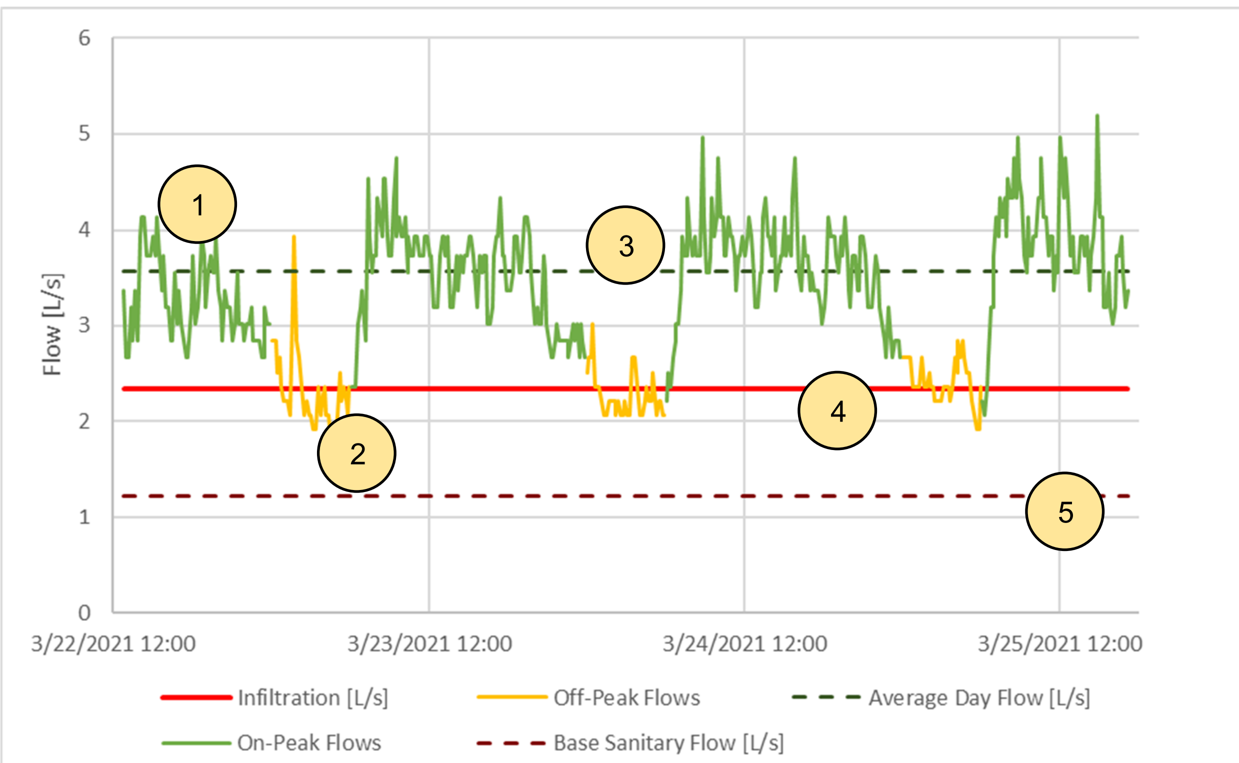

Figure 1 – Sample Figure for Dry Weather Period, Infiltration Analysis

1. **On-Peak Sanitary Flows:** Flow resulting from infiltration and from daily water use.
2. **Off-Peak Sanitary Flows:** Flow from infiltration and any 24-hr commercial water use
3. **Average Daytime Flow:** Average of sanitary flows during on-peak usage
4. **Infiltration Rate:** Average of sanitary flows during off-peak period
5. **Base Sanitary Flow:** Subtraction of the average infiltration rate from the average on-peak flow

Sanitary flows during the dry weather period are expected to follow the trends as shown in Figure ##, stable and predictable on-peak water demand during the day and with off-peak troughs well above zero, indicating that the system is experiencing some constant rate of infiltration.

With all other potential sources isolated, the assumption is that all off-peak flow during the dry weather period is infiltration. Taking an average of off-peak flows during the dry weather period produces an **average peak infiltration rate (Infiltration)**. Taking an average of on-peak flows during the dry weather period produces an average day flow rate (Average Day Flow). Subtracting the Infiltration rate from the Average Day Flow rate produces an average base sanitary flow rate (BSF) which represents the average rate of sanitary demand generation. Comparing infiltration to BSF for each flow monitor provides a measurement of the impact of infiltration on each sub-catchment of the sanitary system.

2.4 Calculating Inflow

Quantifying inflow requires the identification and isolation of extraneous flows during and immediately following an intense storm event. The following is a paragraph excerpted from the Guide (2014) which summarizes the inflow calculation process.

> *Inflow represents the influence of wet weather on the sewer system and is calculated by subtracting out the sanitary wastewater and infiltration flow during a time that the system has been influence by rain. Flow data during a significant storm event should be compared to the dry weather data immediately preceding the storm when groundwater conditions are similar. The rate and volume of inflow can be estimated by subtracting the base sanitary flow and infiltration flow data from the wet weather flow data.*

The Guide provides a starting point that can be refined more precisely to estimate direct and delayed inflow. An analysis of extraneous sanitary flows against temperature in a water treatment system can provide insights into when summer heat is likely to minimize infiltration. Collecting precipitation data in parallel allows for the identification of an intense, isolated storm event to avoid misinterpreting the impacts of successive storm or infiltration events. The intersection of these two analyses provides a wet weather analysis period that begins with dry weather, is interrupted by an intense rain event, and ends with dry weather. This wet weather period provides ideal conditions for calculating inflow characteristics.

Analyzing sewage flow at monitor locations before, during, and after the storm event allows for the elimination of as many variable sources of I/I as possible. Analyzing dry weather flows during pre-storm conditions enables the calculation of a pre-storm infiltration rate for the wet weather period. While the measured peak infiltration rate is less, it is almost impossible to eliminate infiltration from a System altogether. With the pre-storm infiltration calculated and the base sanitary flow rate from the prior infiltration analysis, their addition produces a nominal average flow rate that represents an expected average flow rate during the wet weather period absent the impact of any inflow.

Taking the nominal average flow rate as a threshold value for extraneous flow, all flow measured above the threshold can be defined as originating from sources of inflow. Therefore, all flow above the nominal threshold during the storm attributed to direct inflow and all flow above the threshold after the storm is delayed inflow. Figure 2 provides a visual reference for calculating inflow parameters for a sample flow monitor.

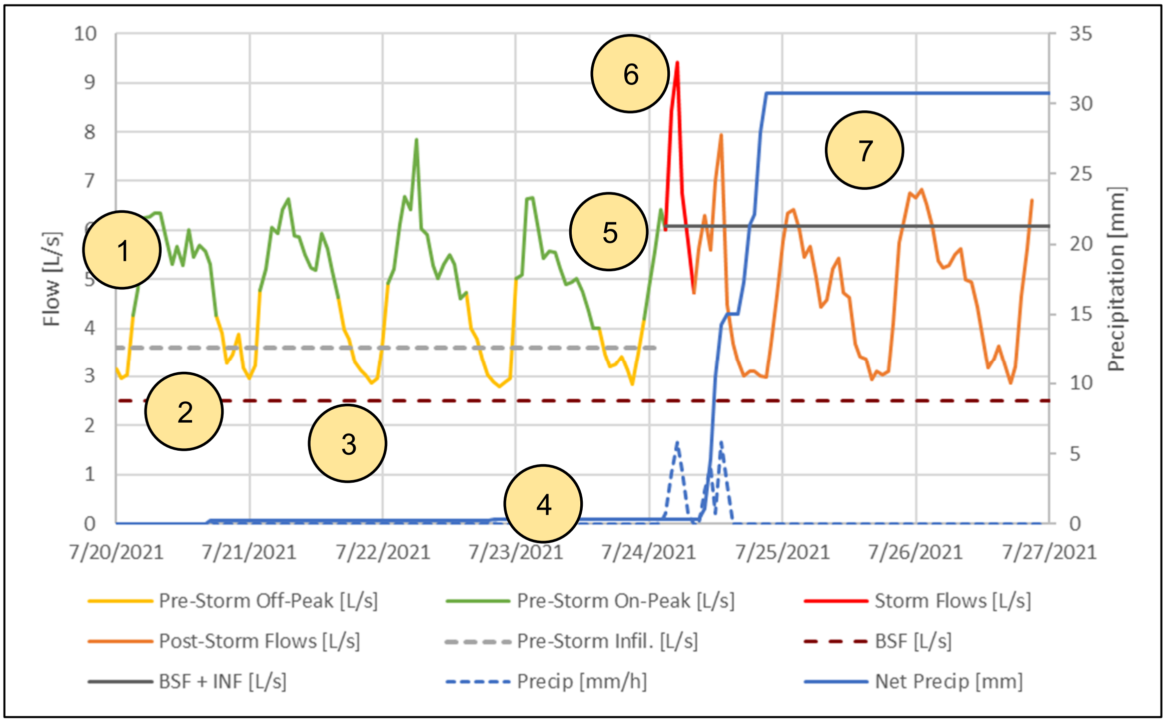

Figure 2 – Sample Figure for Wet Weather Period, Inflow Analysis

1. **On-Peak Pre-Storm Sanitary Flows:** Flows from infiltration and from daily water use
2. **Off-Peak Pre-Storm Sanitary Flows:** Flow from infiltration and any overnight water use.
3. **Pre-Storm Infiltration Rate:** Average of sanitary flows during off-peak use.
4. **Base Sanitary Flow:** Derived from prior dry weather analysis.
5. **Inflow Threshold:** Addition of BSF and pre-storm infiltration rates.
6. **Direct Inflow:** All flow above the nominal flow rate during the storm event.
7. **Indirect Inflow:** All flow above the nominal flow rate following the storm event.

Sanitary flows during the wet weather period are expected to follow the trends as shown in Figure 2: a dry period before the storm event to calculate pre-storm infiltration, a sharp spike in flow at the onset of precipitation indicating direct inflow, and decaying rises in on- and off-peak flows for several days following the event to indicate indirect inflow.

Inflow calculations require a BSF as calculated from a prior dry weather analysis to ensure that the impact of inflow from other storm events is minimized. However, a revised pre-storm infiltration rate is required as the wet weather period should have an infiltration rate much lower than the peak value as calculated during dry weather analysis.

With all other sanitary sources constrained and controlled, all flow above the nominal threshold for average use during and after the storm event is categorized as inflow.

2.5 Expected I/I

Making conclusions and recommendations based on measured I/I results requires both an internal comparison of sanitary collection areas in Palmerston and a general comparison to a comparable statistical area. The Ministry of Environment, Conservation, and Parks (MECP) provides a maximum recommended I/I rate of 1,400 L/cm/km/day for municipal sanitary collection systems. That is, a maximum of 1,400 L/day of I/I per pipe kilometer in the collection system, weighted by pipe diameter. This value is based on historical I/I data in Canada and follows the logic larger pipes provide more surface area for infiltration and that a larger collection system has great opportunity for erroneous, inflow-causing connections. Comparing flow characteristics from collection area to expected values helps to direct further data collection efforts and/or planned remedial works for the sanitary system.

2.6 Data Collection

LINK Utility Technologies Inc. (LUTI) was retained by the Town to supply sanitary sewer monitoring equipment (SmartCover Real-time Sewer Monitor) and services to support the I/I Study. The monitors record the depth (mm) of flow in the sewer, sewage flow (L/s), ambient air temperature (ºC) and several monitor performance parameters. A rain gauge was installed at the WWTP to record precipitation and ambient air temperature. Ambient air temperature data is used to understand periods of snow melting in fall, winter, and spring months, which can contribute to I/I flows in the sanitary sewage collection network.

Flow monitors were initially installed in four maintenance holes in Palmerston on March 17, 2021. The maintenance holes, identified as P112A, P118, P301, and P305A, each capture the total sewage flows for a discrete Sanitary Contribution Area (SCA) contribution area. The flow monitors were moved to new locations within the sewage collection system following a year of recording on May 31, 2022. The revised locations provided further insight into specific areas of concern for I/I based on preliminary results from the 2021 analysis year. The 2022 monitor locations are identified as P112C, P114, P115 and P500A. The 2021 and 2022 flow monitoring locations are presented respectively in Figures 3 and 4 on following pages as well as in tabulated formats in Tables 1 and 2.

Table 1 – Summary of 2021 Flow Monitoring Locations

Sanitary Structure ID	Location Description	SCA	Land Use[1]
P118	Jane Street 30m North of Mary Street	SCA 1	Residential, Industrial, Institutional and Main Street Mixed Use (Residential/Commercial)
P112A	Main Street and unopened ROW between Lorne Street and Henry Street	SCA 2	Industrial, Commercial, Residential and Mixed Use (Residential/Commercial)
P305A	Victoria Street and Albert Street	SCA 3	Residential, Institutional and Commercial (Residential/Commercial)
P302	Lowe Street and Victoria Street	SCA 4	Residential, Institutional, Commercial and Mixed Use (Residential/Commercial)

1 Listed in descending order of ground area.

Table 2 – Summary of 2022 Flow Monitoring Locations

Sanitary Structure ID	Location Description	SCA[1]	SCA Land Use[2]
P112C	Lorne Street, 90m North of Main Street	5	Industrial, Commercial, Residential
P114	Henry Lane, 45m North of Inkerman Street	6	Residential, Mixed Use (Residential/Commercial)
P115	Mary Street, 35m East of Henry Line	7	Residential, Industrial, Institutional, Commercial, Mixed Use (Residential/Commercial)
P500A	Cavan Street and Mill Line	8	Residential, Industrial, Institutional

1 Relative to 2021 flow monitoring locations. See Figure 3 for breakdown of 2022 SCAs.
2 Listed in descending order of ground area.

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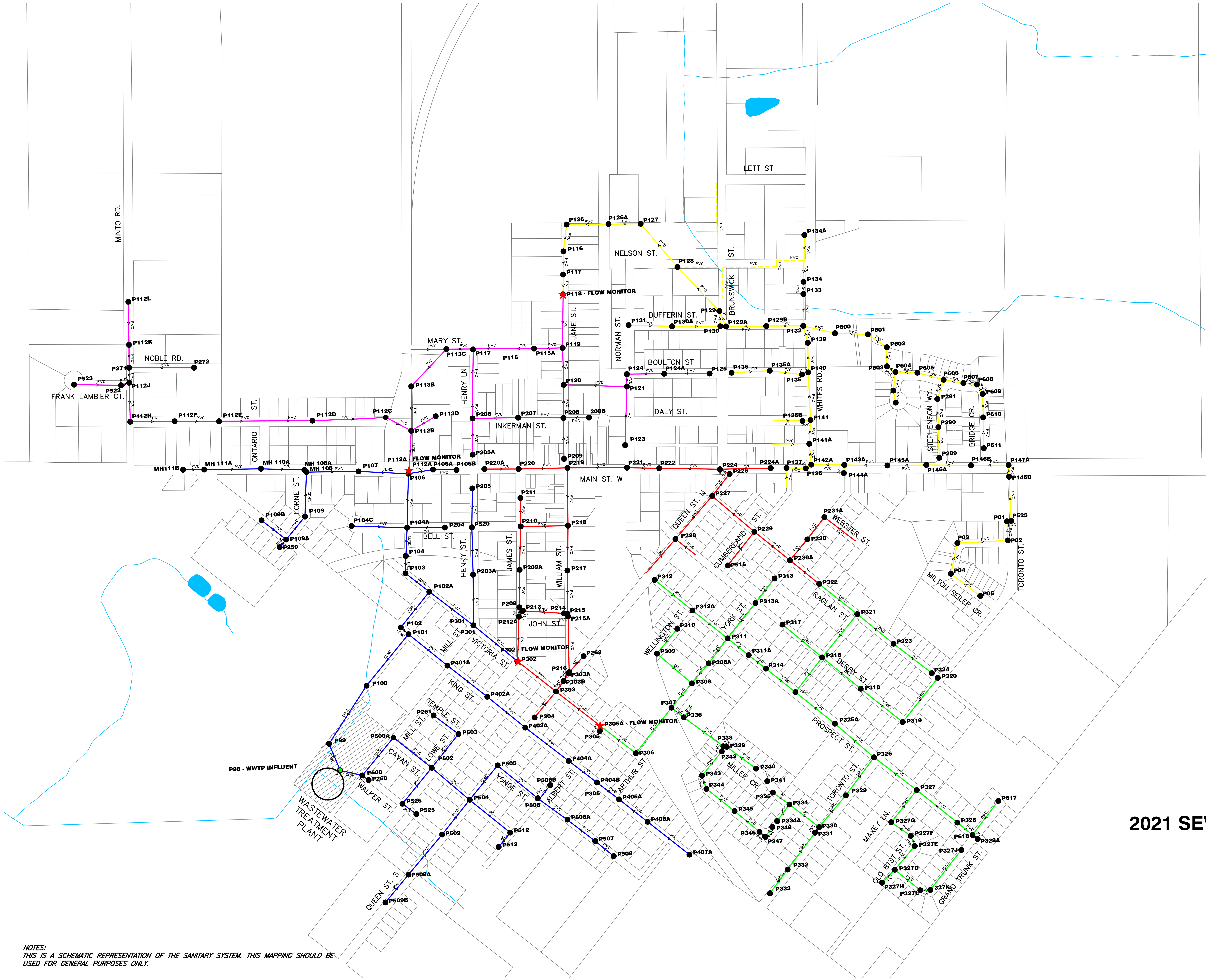

LEGEND

- DIRECTION OF FLOW
- P120 MAINTENANCE HOLE ID
- MAINTENANCE HOLE WITH FLOW MONITOR
- EXISTING FLOW MONITOR LOCATION
- WWTP

2021 FLOW MONITORING LOCATIONS AND SANITARY CONTRIBUTION AREA (SCA) SEWERS

P118	=	SCA 1
P112A	=	SCA 2
P305A	=	SCA 3
P302	=	SCA 4
WWTP	=	

FIGURE 3
PALMERSTON
2021 SEWAGE FLOW MONITOR LOCATIONS

NOT TO SCALE
W4996 - R00

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Consulting Engineers

NOTES:
THIS IS A SCHEMATIC REPRESENTATION OF THE SANITARY SYSTEM. THIS MAPPING SHOULD BE USED FOR GENERAL PURPOSES ONLY.

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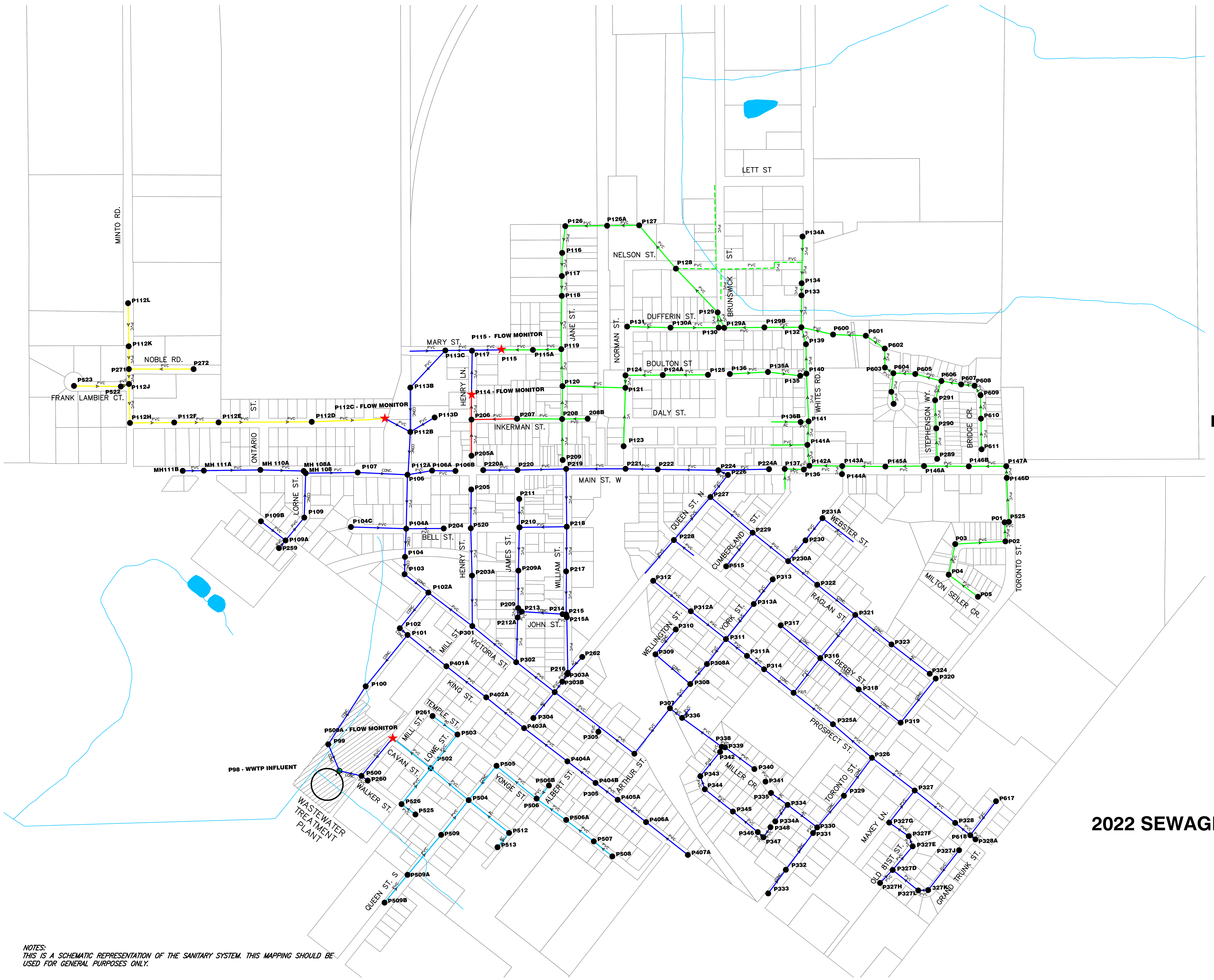

LEGEND

- DIRECTION OF FLOW
- P120 MAINTENANCE HOLE ID
- MAINTENANCE HOLE WITH FLOW MONITOR
- EXISTING FLOW MONITOR LOCATION
- WWTP

2022 FLOW MONITORING LOCATIONS AND SANITARY CONTRIBUTION AREA (SCA) SEWERS

P115 =	SCA 7
P114 =	SCA 6
P112C =	SCA 5
P500A =	SCA 8
WWTP =	

NOTES:
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FIGURE 4
PALMERSTON
2022 SEWAGE FLOW MONITORING LOCATIONS

NOT TO SCALE
W4996 - R00

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3.0 Extraneous Sewage Flow Analysis

Understanding where and when a system treats wastewater that is unaccounted for in water billing is essential to capturing the full scope of impact of I/I on the System. Any emergent patterns in unaccounted demand can assist in the development and guidance of analysis efforts to calculate I/I.

Moreover, 14 years have elapsed between the commission of this I/I study and the previous 2004 monitoring program. The System has continued to degrade during this time, except where rehabilitation or replacement activities have been completed. Change in unaccounted water demand can assist in forecasting changes in I/I characteristics as the System continues to age.

To both ends, a comparison of daily sewage flows and water demand/consumption from 2016 through 2020 was completed to understand unaccounted flows in higher resolution. This calculation, when compared across several years, can indicate time periods of interest for inflow and infiltration respectively. A ratio of sewage flow to water consumption above 1.0 indicates extraneous flows entering the system.

Table 3 – Monthly Influent Sewage at WWTP vs. Total Water Demand (SCADA) in Palmerston, 2016-2020

	Year					
Month	2016	2017	2018	2019	2020	Monthly Average
January	1.93	**2.39**	0.61	1.66	2.50	1.82
February	2.86	2.14	1.98	1.89	1.34	2.04
March	**3.50**	1.79	1.38	2.50	**3.19**	**2.47**
April	2.57	1.80	**2.83**	**2.96**	1.91	2.41
May	1.25	2.16	1.49	2.09	1.48	1.69
June	0.92	1.60	1.01	1.23	1.07	1.17
July	*0.77*	1.20	*0.86*	0.90	0.90	0.93
August	0.97	0.97	1.14	0.87	1.11	1.01
September	0.85	*0.87*	0.91	*0.83*	*0.86*	*0.86*
October	0.80	1.02	0.98	0.97	1.04	0.96
November	0.88	1.64	1.44	1.35	1.19	1.30
December	1.20	1.18	1.75	1.45	1.51	1.42
Annual Average	1.54	1.56	1.37	1.56	1.51	1.51

The annual average ratio was always greater than 1.0 and only the month of September experienced less monthly treated flow than was billed in all analysis years. This indicates that extraneous flows have been a consistent hindrance to the performance of the WWTP. Extraneous flows tended to peak in March and April and trough in September, consistent with seasonal changes in groundwater. This suggests that infiltration is a large source of I/I in Palmerston.

Comparing precipitation, water demand, and monthly sewage flows can provide insights into the specific impact of inflow on the system. This information is summarized in Figure 5.

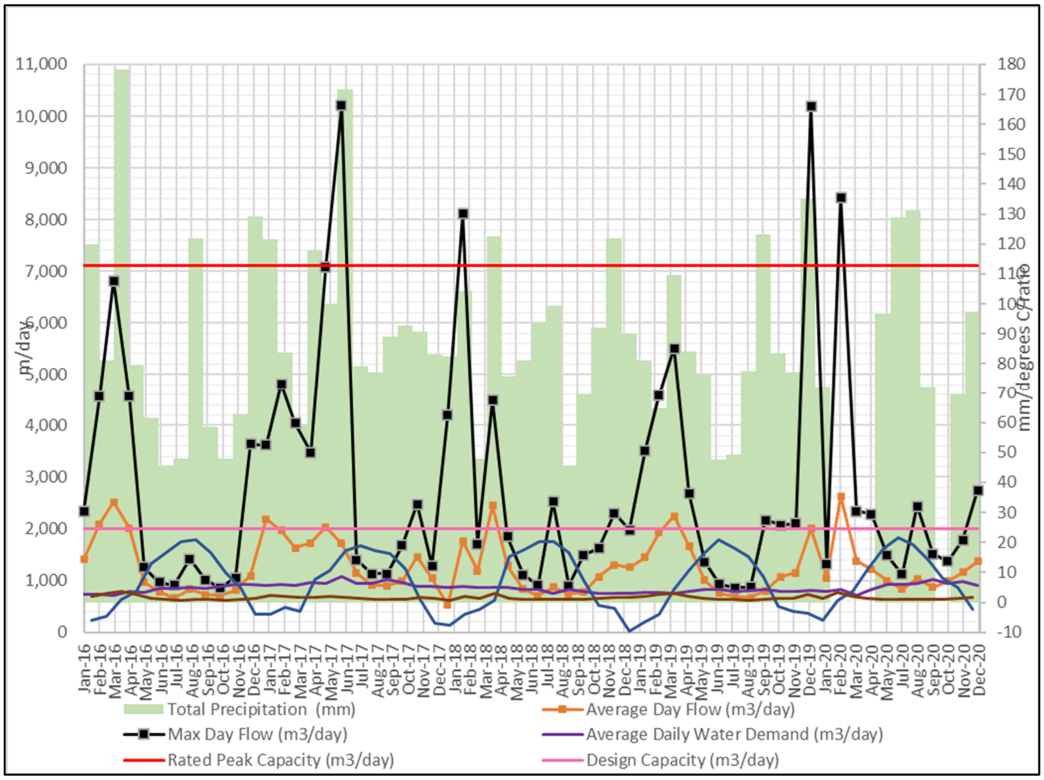

Figure 5 – 2015-2020 WWTP Sewage Flows and Precipitation

Per Graph 1, the maximum daily flow exceeded the rated peak capacity of the WWTP five times during the study period. The average daily flow exceeded the design capacity of the WWTP eight times. In both cases, peaks can be associated with large precipitation events. From this, it is expected that inflow is a major contributor to extraneous flows within the sewage collection network. Further, the average day flow remains consistent during the summer and early fall months when groundwater is lower, indicating that extraneous flows from infiltration fluctuate according to soil conditions.

The extraneous sewage demand analysis concludes that there are likely both inflow and infiltration in the system, but that the impact of infiltration is likely much more pronounced than inflow. It is expected that the infiltration rate will peak in either March or April and that inflow will be most apparent during storm events between August and October, when infiltration is at its lowest.

4.0 Data Collection and Processing

4.1 2021 Analysis Year

The system was discretized into several areas for the 2021 analysis year as shown in Table 1 and Figure 3 in section 2.6. The following Table 4 summarizes the collection characteristics for each sanitary contribution area (SCA) as required to estimate expected I/I.

Table 4 – Expected I/I, 2021 Analysis Year

MH	SCA	$L_{upstream}$ [km]	Ø [cm] X L [km]	Expected I/I [m^3/day]	Expected I/I [L/s]
P112A	2	2.8	76.33	106.86	1.24
P118	1	3.2	87.04	121.85	1.41
P305A	3	3.9	85.95	120.33	1.39
P302	4	2.5	59.90	83.86	0.97

Data gathered from P118 represents sanitary flows from the largest residential contribution area in Palmerston. It generates the highest value of expected I/I due the higher average sanitary pipe diameter, implying that expected I/I will be weighted more towards infiltration. In contrast, flows measured at P305A represent a large, low-density residential and industrial area. With the largest length of upstream pipe presenting more opportunities for erroneous connections, we expect to measure I/I weighted more towards inflow than infiltration.

Figure 6 summarizes sanitary flow and precipitation data collected for the 2021 analysis year.

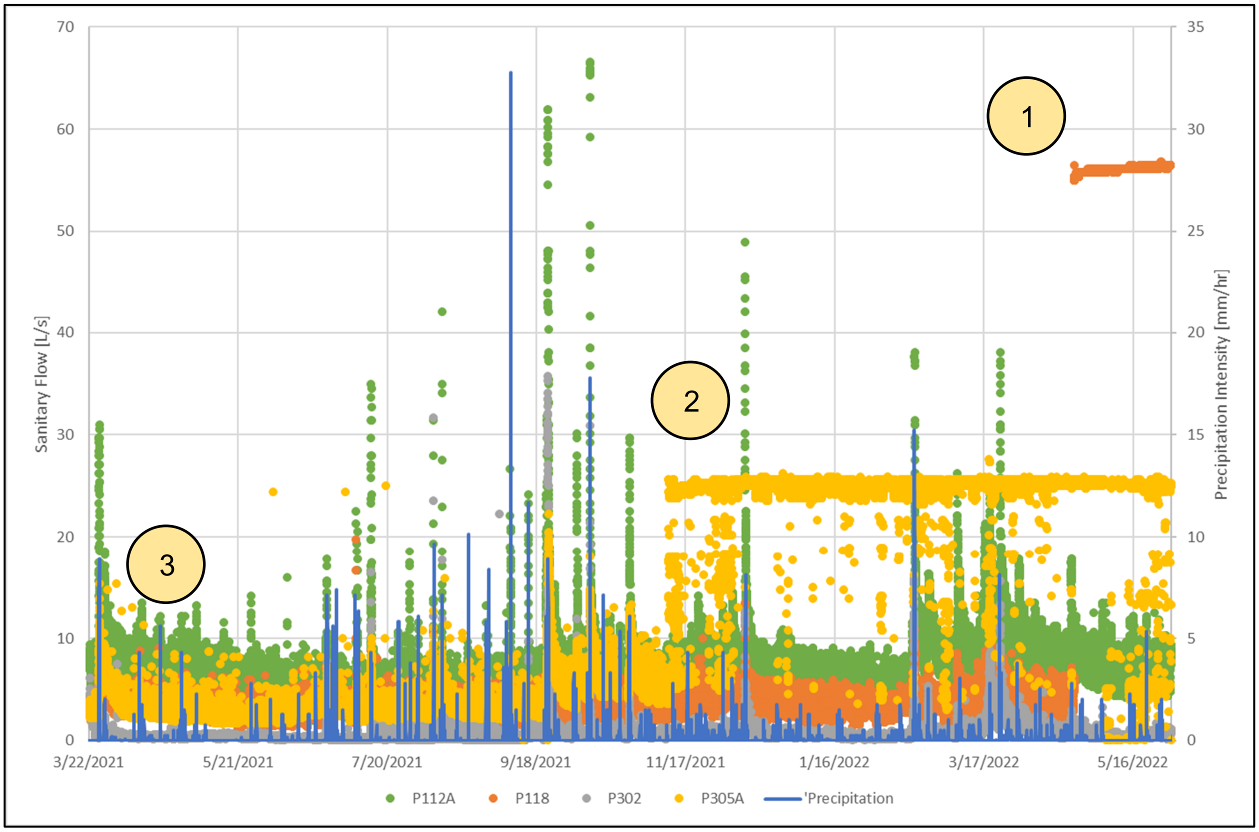

Figure 6 – Aggregated Flow Data, 2021 Analysis Year

Flows recorded at each location generally followed the expected form for sanitary flows, peaking daily between 6AM and 9AM and troughing between midnight and 6AM. Large spikes can be seen coincidentally with storm events, indicating approximately that direct inflow is likely a concern in Palmerston. Higher peak, trough and mean daily flows can be seen at the start of data collection and then again in February 2022, consistent with the beginning of snow melt in each year. This suggests approximately that groundwater infiltration is a factor in I/I in Palmerston.

Per results from the extraneous flow assessment (Section 3) and collected precipitation data, a primary dry weather period was selected between March 22-25, 2021. While not the longest period of dry weather recorded, in 2021, it was the longest period of consistent dry weather occurring during in proximity to annual peak times extraneous flows at the WWTP as recorded in Table 2. A secondary dry weather period between April 22-29, 2021, to ensure data fidelity as needed for effective analysis.

The wet weather period chosen for analysis in 2021 occurred from July 18-17, 2021, centered on a storm event on July 24. No secondary wet weather period was required for the 2021 analysis year.

Subsets of flow data that displayed erratic or unexplainable non-periodic activity during analysis periods were treated or omitted from analysis as required to minimize potential sources of calculation error. These errors and treatments are summarized in Table 4.

Table 4 – Flow Monitor Error Assessment, 2021 Analysis Year

Issue	ID	Period of Issue	Apparent Issue	Treatment
1	P118	April 22nd, 2022, at 2:30 PM onward	Significant increase in flow rate, reduction in variance	Use spring 2021 data for dry weather analysis
2	P305A	November 10th, 2021, at 11:00AM onward	Significant increase in steady-state flow, reduction in variance	Use spring, summer 2021 data for analysis
3	P112A	Start of data through April 1, 2021	Excessive variance, non-periodicity in data	Use alternative dry weather period for P112A analysis

While errors in data occurred during key analysis periods, all errors could be mitigated or occurred outside the scope of analysis for the study. While bounded by precipitation events that make isolating infiltration challenging, the revised period is the next closest period of moderately dry weather during the spring.

4.2 2022 Analysis Year

The system was discretized again for the 2022 analysis year based on preliminary results from the 2021 analysis year. Monitor locations are tabulated in Table 2 or mapped in Figure 4 in Section 2.6. The following Table 5 summarizes the expected I/I of the revised SCAs based on their collection characteristics.

Table 5 – Expected I/I, 2021 Analysis Year

MH	SCA	$L_{upstream}$ [km]	Ø [cm] X L [km]	Expected I/I [m^3/day]	Expected I/I [L/s]
P112C	5	1.0	28.65	40.11	0.46
P114	6	0.2	4.46	6.24	0.07
P115	7	4.4	114.16	159.82	1.85
P500A	8	1.4	30.72	43.00	0.50

SCA 7 has almost entirely the same collection area as SCA 1 from the 2021 analysis year, leading to nearly identical expected I/I. SCAs 5 and 6 are both subdivisions of SCA 2 intended to capture its problem areas in greater detail. SCA 8 was included to capture an area of Palmerston that did not collect flow data in 2021. Figure 7 summarizes sanitary flow and precipitation data collected for the 2021 analysis year.

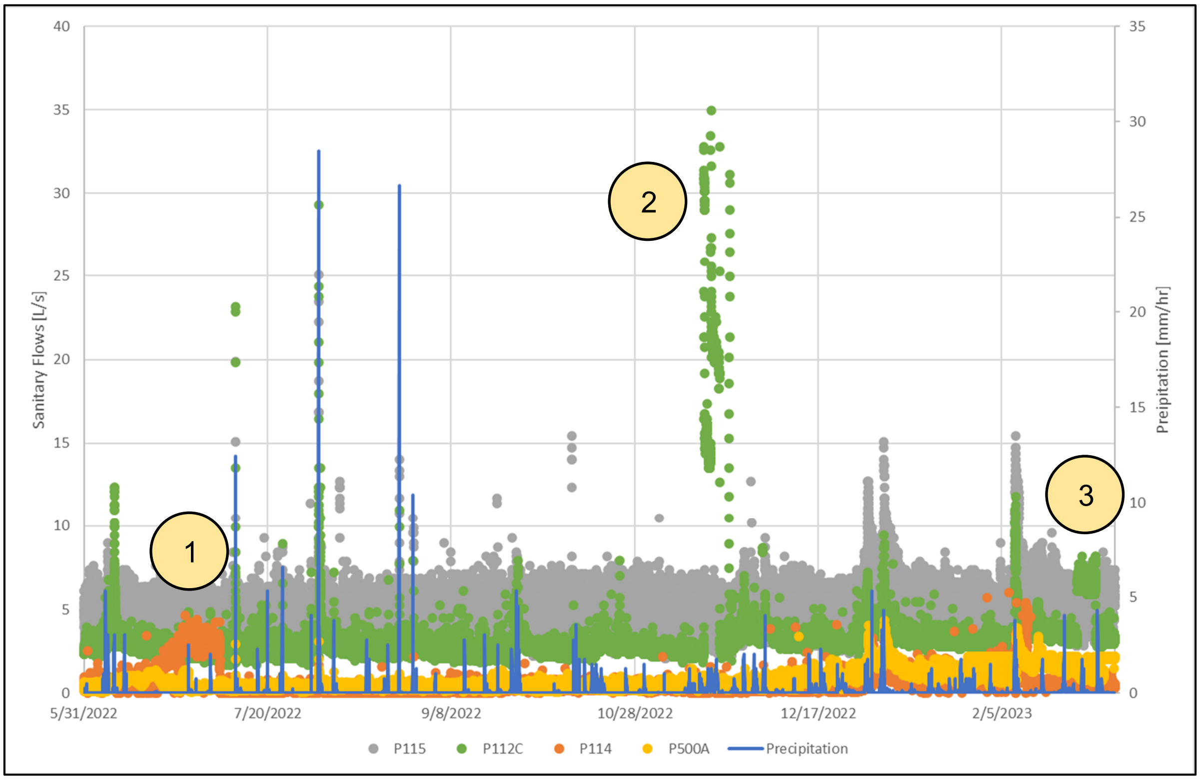

Figure 7 – Aggregated Flow Data, 2021 Analysis Year

Flows recorded at each location generally followed the expected form for sanitary flows, peaking daily between 6AM and 9AM and troughing between midnight and 6AM. Large spikes can be seen coincidentally with most storm events, indicating approximately that direct inflow is a concern in Palmerston. Peaks in flows followed daily trends or responded to storm events, and intense storm events captured were consistent with broader measured climate patterns.

The dry weather period chosen for analysis in 2022 occurred from April 10-16, 2022. It is the longest period of dry weather that occurred in proximity to the peak extraneous flows as recorded in Table 2. The wet weather period chosen for analysis in 2022 occurred from July 6-18, 2022, centered on a precipitation that began on July 12 at approximate midnight. Secondary analysis periods were not required for either of the respective dry and wet analyses.

Subsets of flow data that displayed erratic or unexplainable non-periodic activity during analysis periods were treated or omitted from analysis as required to minimize potential sources of calculation error. These errors and treatments are summarized in Table 6.

Table 6 – Flow Monitor Error Assessment, 2022 Analysis Year

Issue	ID	Period of Issue	Apparent Issue	Treatment
1	P114	June 22nd, 2022, at 12:15 AM through July 7th, 2022, at 9:20 PM	Period of excessive, non-periodic flows	Outside scope of analysis
2	P112C	Nov 16th, 2022, at 3:00 PM through Nov 30th at 5:30 PM	Period of excessive, non-periodic flows	Adjust dry weather period
3	P114	Dec 31st, 2022, at 6:30 AM through January 8th, 2023, at 7:30 AM	Period of excessive, non-periodic flows	Use 2022 dry weather period

While errors in data occurred during key analysis periods, all errors could be mitigated or were limited in extent for the study periods.

5.0 Analysis

Analyses are provided by analysis year, first by contribution area and then aggregated.

5.1 2021 Analysis Year

5.1.1 SCA 1 – P118

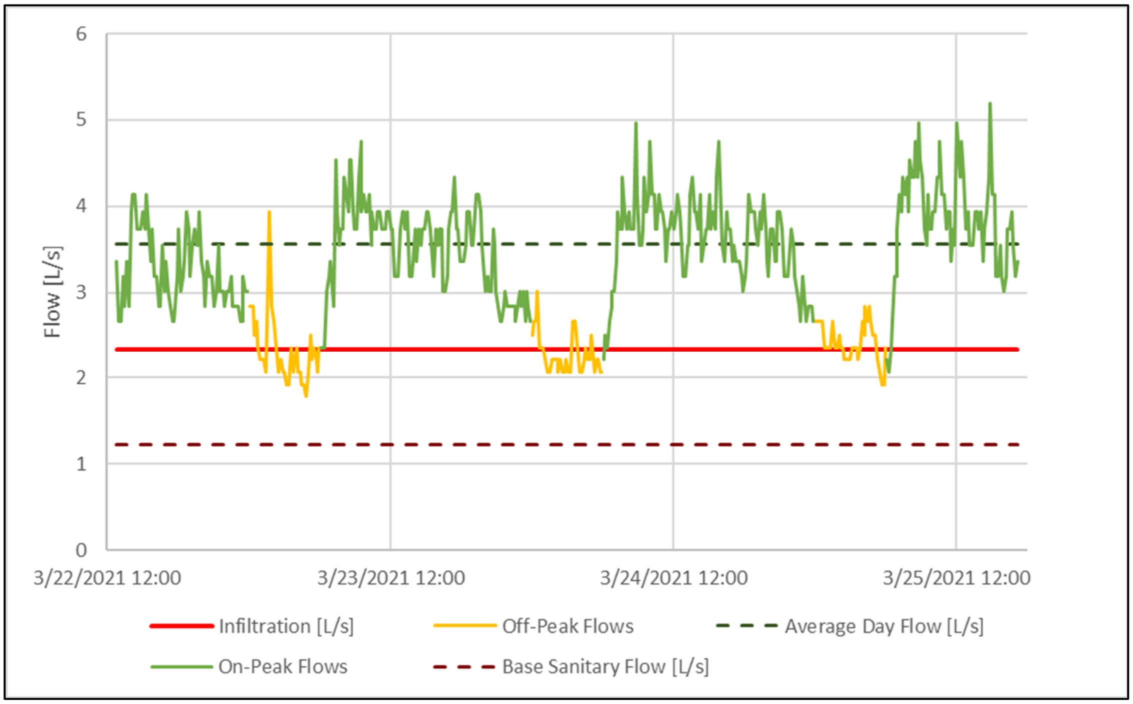

Figure 8 – Dry Weather Analysis, P118

P118 has clear evidence of infiltration during off-peak hours measured at 2.3 L/s. Subtracting infiltration from average day flow gives a base sanitary flow rate of 1.2 L/s. This indicates that, at its peak, as much as 65% of sanitary flows treated from SCA 1 are from infiltration sources.

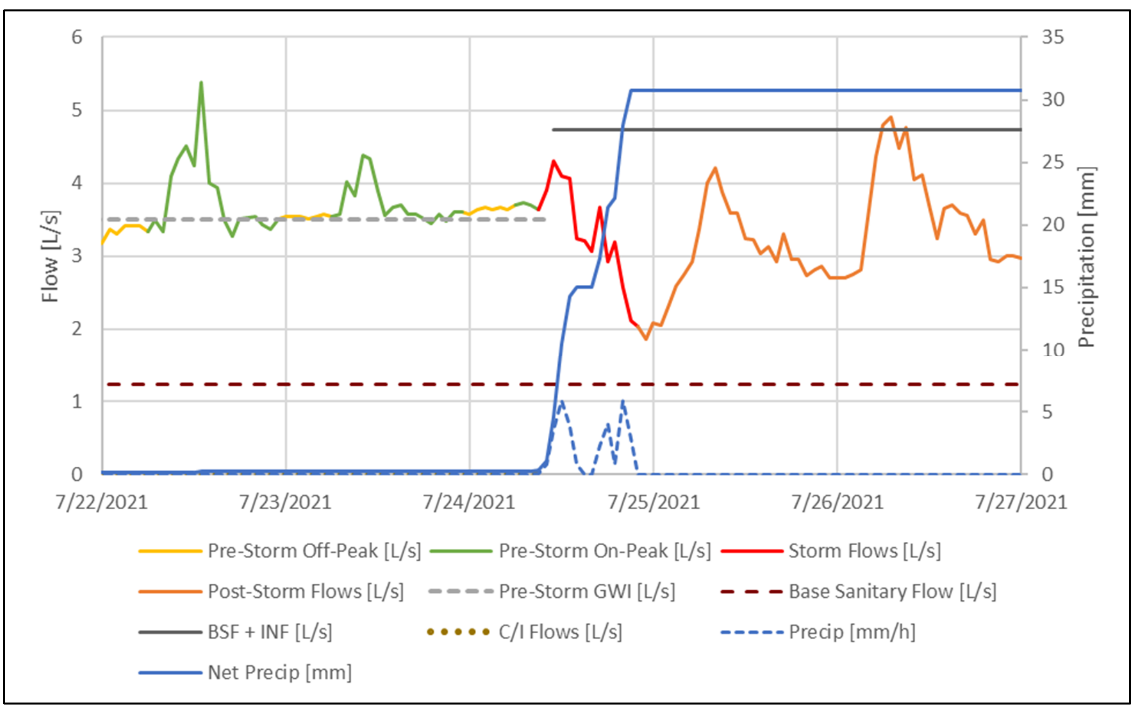

Figure 9 – Wet Weather Analysis, P118 Uncorrected

P118 pre-storm conditions provided an average day flow of 3.67 and an infiltration value of 3.5 L/s, well above the peak of 2.3 L/s recorded during seasonally high groundwater. The BSF as calculated during dry weather is also too large to accurately describe the dynamics of on-and peak-flows. These anomalies are likely caused by unattributed 24-hour commercial or industrial flows that were interrupted by the most intense rain event in 2021. To correct this, we take the difference in the measured pre-storm infiltration rate, $I_{pre\text{-}storm}$, and the measured peak infiltration rate, I_{peak}, to be flows caused by commercial and industrial use, $F_{C/I}$.

$$F_{C/I} = I_{pre-storm} - I_{peak}$$
$$F_{C/I} = 3.5 - 2.3$$
$$F_{C/I} = 1.2$$

With commercial and industrial corrections quantified, the measured pre-storm average day flow is used to back-calculate a more realistic base sanitary flow rate.

$$ADF = I_{peak} + BSF + F_{C/I}$$
$$BSF = ADF - I_{peak} - F_{C/I}$$
$$BSF = 3.7 - 2.3 - 1.2$$
$$BSF = 0.2$$

A revised BSF of 0.2 is significantly more indicative of the smaller difference between on-and off-peak flows in the pre-storm regime. And, with BSF recalculated, calculation of the nominal flow rate yields a value of 3.6 L/s. From here, any recorded sanitary flow above 3.6 L/s during or following the storm is attributed to direct and indirect inflow, respectively.

Figure 10 summarizes the corrected inflow characteristics of P118.

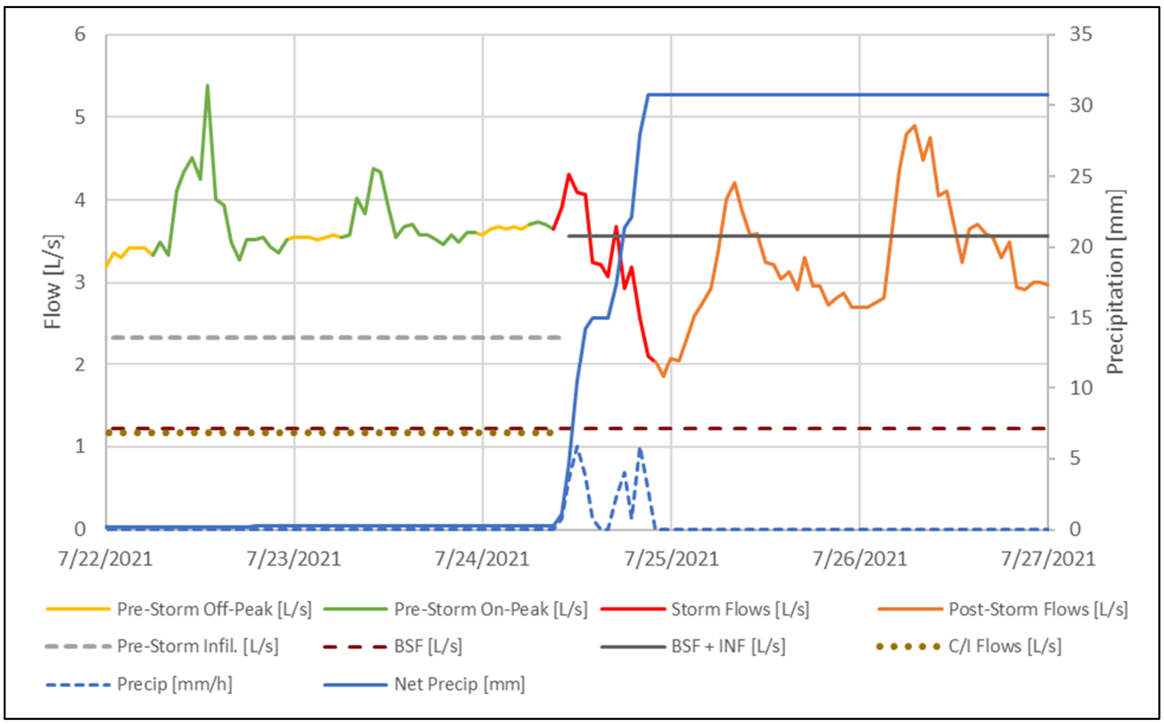

Figure 10 – Wet Weather Analysis, P118 Corrected

The July 24 rain event produced average direct and indirect inflow rates of 0.18 L/s and 0.16 L/s respectively. Flows peaked two days following the onset of rain and all flows remained high for several days. This indicates that sump pump discharge, rather than groundwater itself, contributes to delayed inflow. Small inflow values and the maintenance of periodic sanitary flows indicate that inflow in SCA is governed by fluctuations in groundwater, but that inflow does not have a robust impact on sanitary demand in SCA 2.

5.1.2 SCA 2 – P112A

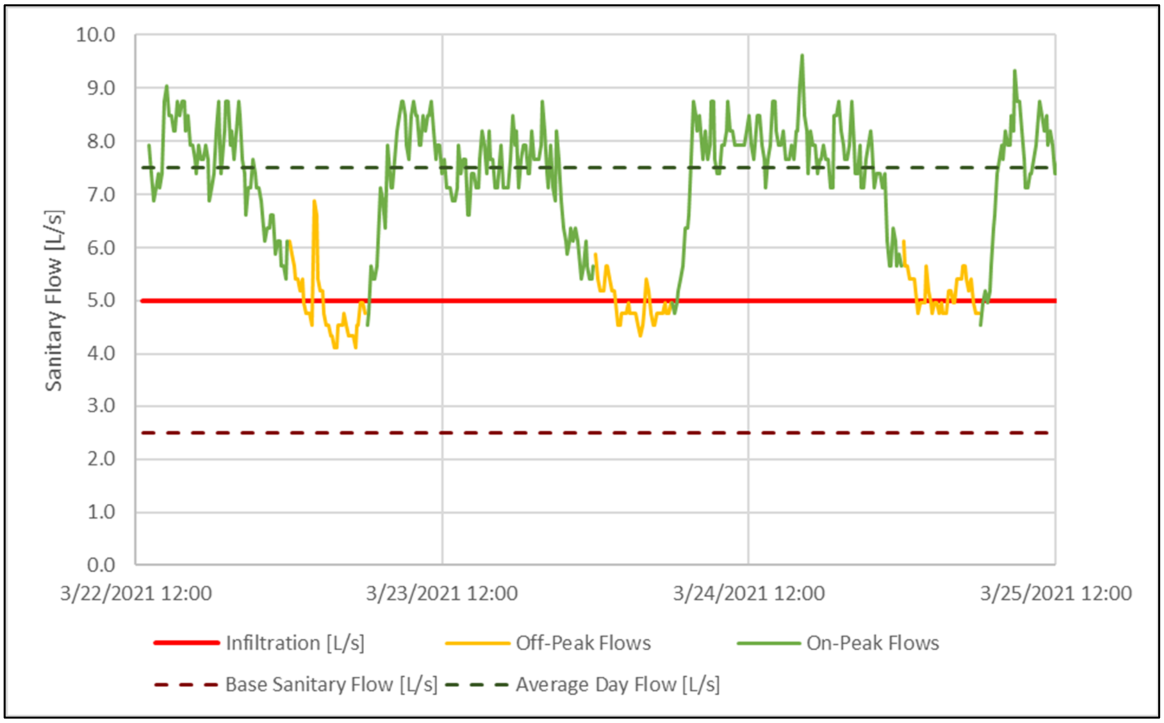

Figure 11 – Dry Weather Analysis, P112A

Dry weather analysis for P112A yielded rates of infiltration and base sanitary flow of 5.0 and 2.5 L/s respectively. This indicates that, at its peak, as much as 50% of sanitary flows treated from SCA 1 and 2 are from infiltration sources.

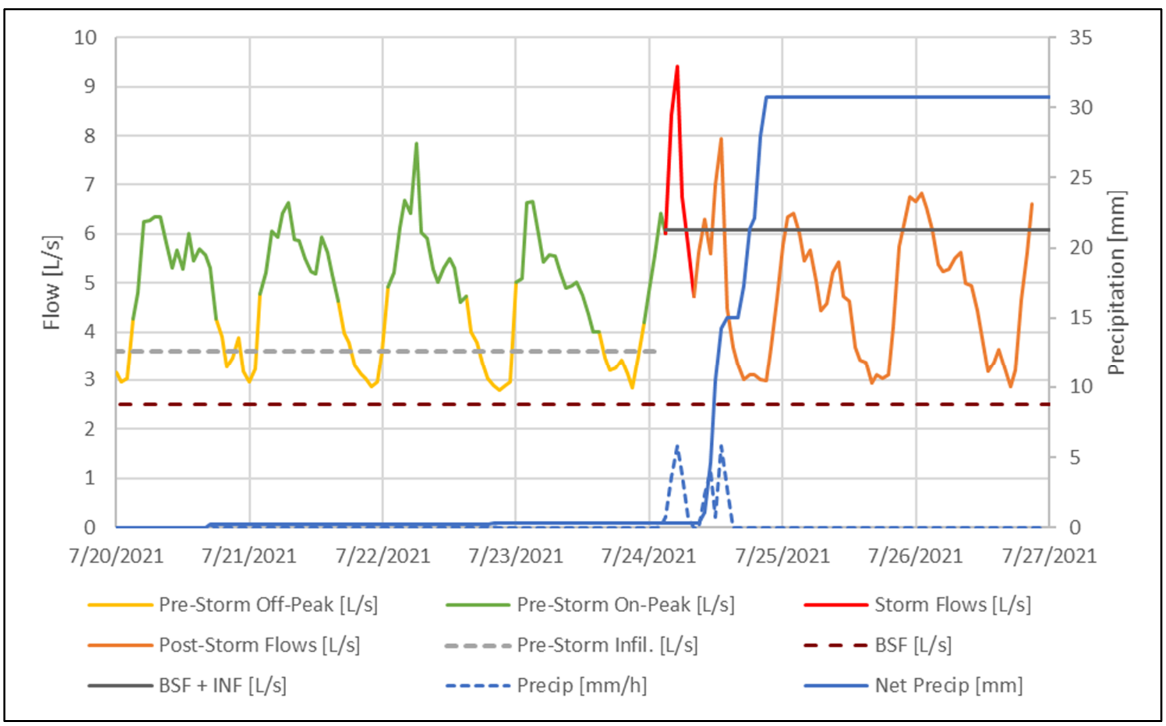

Figure 12 – Wet Weather Analysis, P112A

Wet weather analysis for P112A produced a nominal flow threshold of 6.1 L/s from BSF and a pre-storm infiltration rate of 3.6 L/s. The BSF calculated during dry weather analysis accurately describes the dynamics between on-and off-peak flows.

This produced average direct and indirect inflow rates of 1.05 L/s and 0.11 L/s respectively. Sharp spikes in direct inflow and rapid decay in indirect inflow indicate that inflow in SCA 2 is governed by downspouts rather than by fluctuations in groundwater.

5.1.3 SCA 3 – P305A

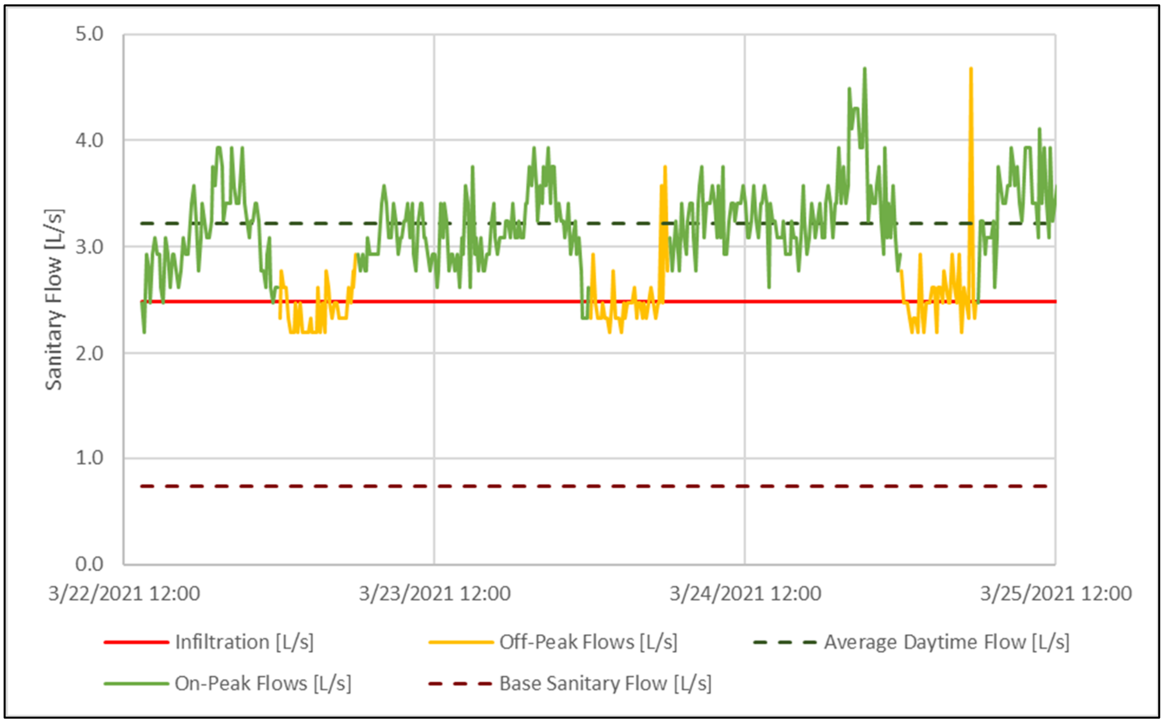

Figure 13 - Dry Weather Analysis, P305A

Dry weather analysis for P305A yielded rates of infiltration and base sanitary flow of 2.5 and 0.7 L/s respectively. This indicates that, at peak infiltration, as much as 78% of sanitary flows treated from SCA 3 are from infiltration sources.

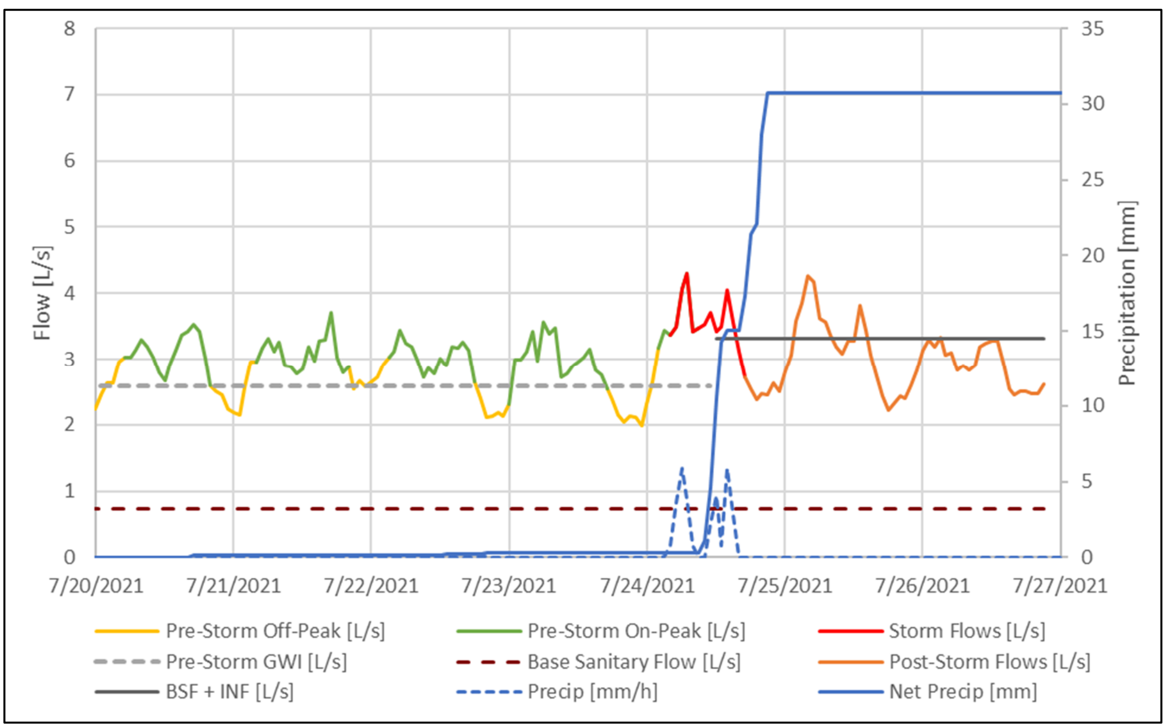

Figure 14 - Dry Weather Analysis, P305A

Wet weather analysis for P305A yielded a pre-storm infiltration rate of 2.3 L/s and a nominal flow threshold of 3.0 L/s. This resulted in average direct and indirect inflow rates of 0.55 L/s and 0.17 L/s respectively. This is shown by two peaks occurring during the two periods of highest rainfall intensity during the storm, and higher average on- and off-peak flows in the days following the storm event. This means that SCA 3 is impacted both by downspouts and by fluctuations in groundwater.

5.1.4 SCA 4 – P302

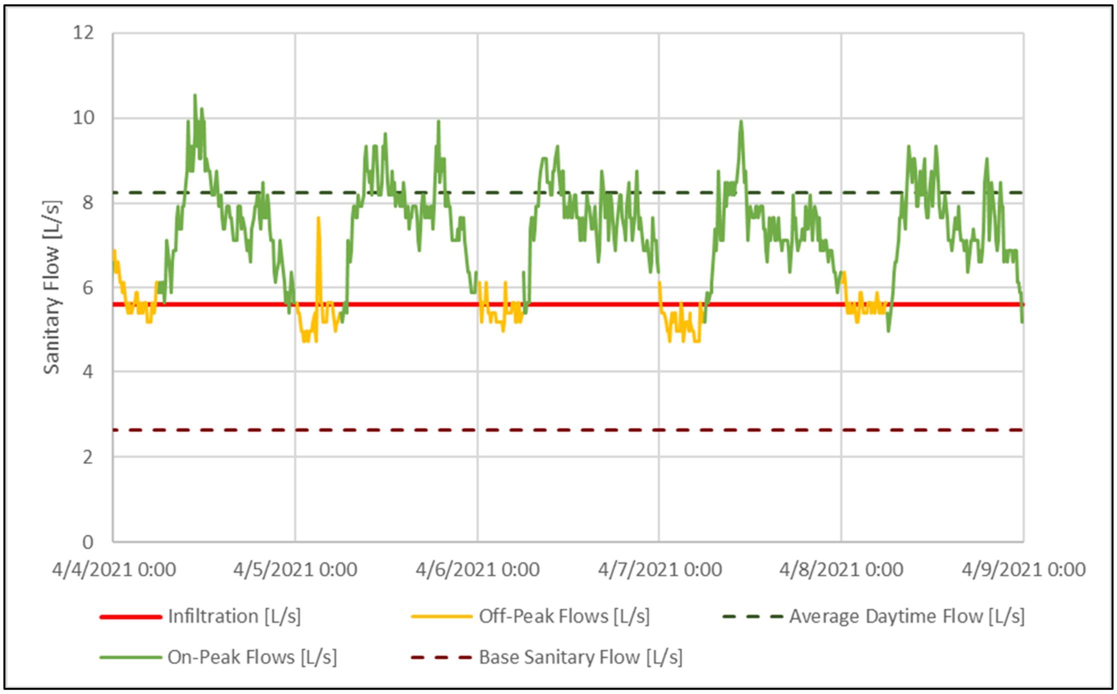

Figure 15 – Dry Weather Analysis, P302

Dry weather analysis for P302 required the consideration of the secondary dry weather period due to profound data errors during the primary dry weather period. The analysis yielded a peak average infiltration rate of 5.5 L/s on a base sanitary flow rate of 2.6 L/s.

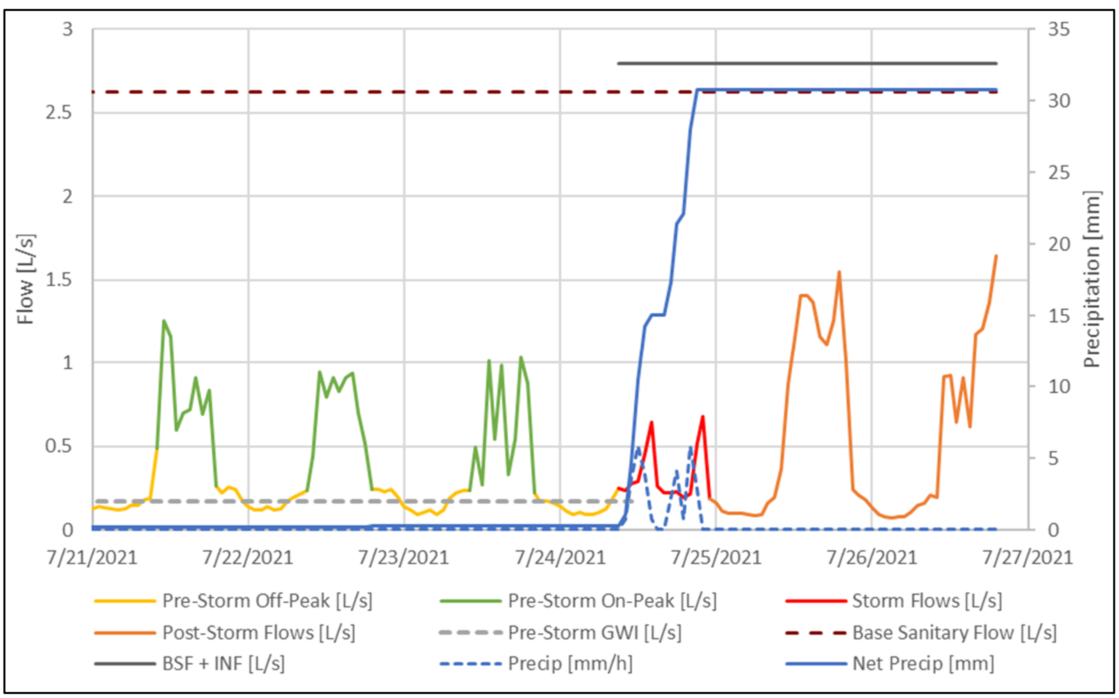

Figure 16 – Wet Weather Analysis, P302 Uncorrected

Wet weather analysis for P302 revealed drastic changes to BSF and pre-storm ADF characteristics indicative of seasonal changes in system use. The dry weather BSF of 2.62 L/s is more than double the pre-storm ADF of 0.7 L/s, necessitating a correction to BSF for wet weather using the equation for calculation of ADF. Analyzing pre-storm on- and off-peak flows alone provided a BSF and nominal flow 0.5 L/s and 0.7 L/s respectively. Figure 17 summarizes the corrected wet weather analysis for P305A.

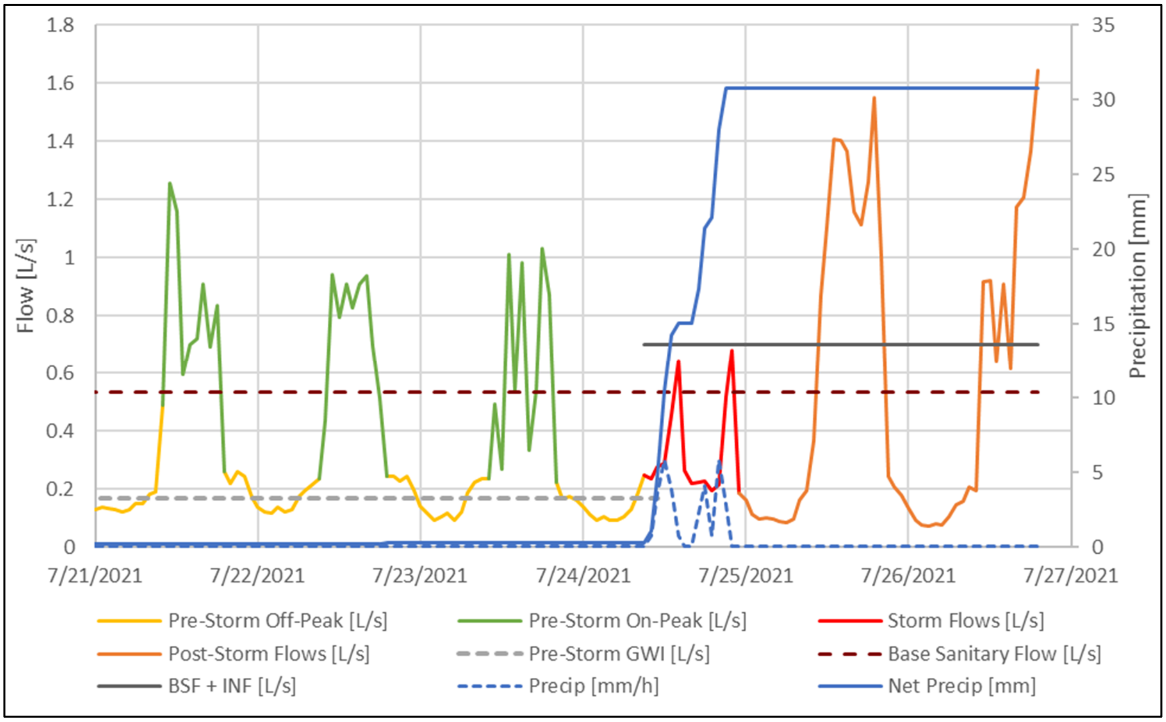

Figure 17 – Wet Weather Analysis, P302 Corrected

Corrected rate values generated no direct inflow and an average indirect inflow rate of 0.2 L/s.

Flow monitor P302 captures SCA 4, which is comprised partially of recreational, industrial, and commercial land uses. This, combined with the lowest average day flow occurring on the day of the rain event, suggests that user behavior in SCA 4 is very reactive to changes in weather. A small indirect inflow value suggests that sup pumps or secondary drainage devices in SCA 4 __. The presence of indirect inflow without direct inflow suggests that indirect inflow in SCA 4 is caused by improper connections on sump pumps and other secondary drainage devices rather than from storm-induced fluctuations in groundwater.

5.1.5 Aggregated 2021 Analysis

Tables 6, 7, and 8 provide an aggregated summary of I/I performance for the system relative to both BSF and expected values during the 2021 analysis year.

Table 6 - Infiltration Assessment, 2021 Analysis Year

MH	SCA	BSF [L/s]	Peak Infiltration [L/s]	Infil. / BSF Ratio	Ranking
P118	1	1.2	2.3	1.9	4
P112A	2	2.5	5.0	2.0	3
P305A	3	0.7	2.5	3.6	1
P302	4	2.6	5.6	2.1	2

Aggregated infiltration analysis shows that infiltration is a concern in all contribution areas studied in 2021. SCA 3 provided the highest ratio of peak infiltration to base sanitary flow primarily due to its low base sanitary flow.

Table 7 - Inflow Assessment, 2021 Analysis Year

MH	SCA	Direct Inflow [L/s]	Indirect Inflow [L/s]	Σ Inflow [L/s]	Infl. / BSF Ratio	Ranking
P118	1	0.18	0.16	0.34	1.7	1
P112A	2	1.1	0.11	1.2	0.47	3
P305A	3	0.55	0.17	0.72	0.98	2
P302	4	0	0.19	0.19	0.35	4

2021 inflow analysis shows that inflow is of much lower concern in Palmerston than infiltration. SCA 1 recorded the highest ratio of inflow to base sanitary flow due to its high indirect inflow relative to its base sanitary rate. Direct inflow sources in SCA 2 present the highest priority for further analysis in 2022.

Table 8 - Expected I/I Assessment, 2021 Analysis Year

MH	SCA	Expected I/I [L/s]	Measured I/I[1] [L/s]	Meas. / Exp. Ratio	Ranking
P118	1	1.4	2.6	1.9	4
P112A	2	1.2	6.2	5.1	2
P305A	3	1.4	3.2	2.3	3
P302	4	0.97	5.8	6.0	1

1: Addition of infiltration and inflow

All areas studied in 2021 produced I/I results higher than expected values for a system operating in good condition (throw to MECP source for expected I/I). SCA 4 was the area of highest concern as recorded in 2021.

5.2 2022 Analysis Year

5.2.1 SCA 5 – P112C

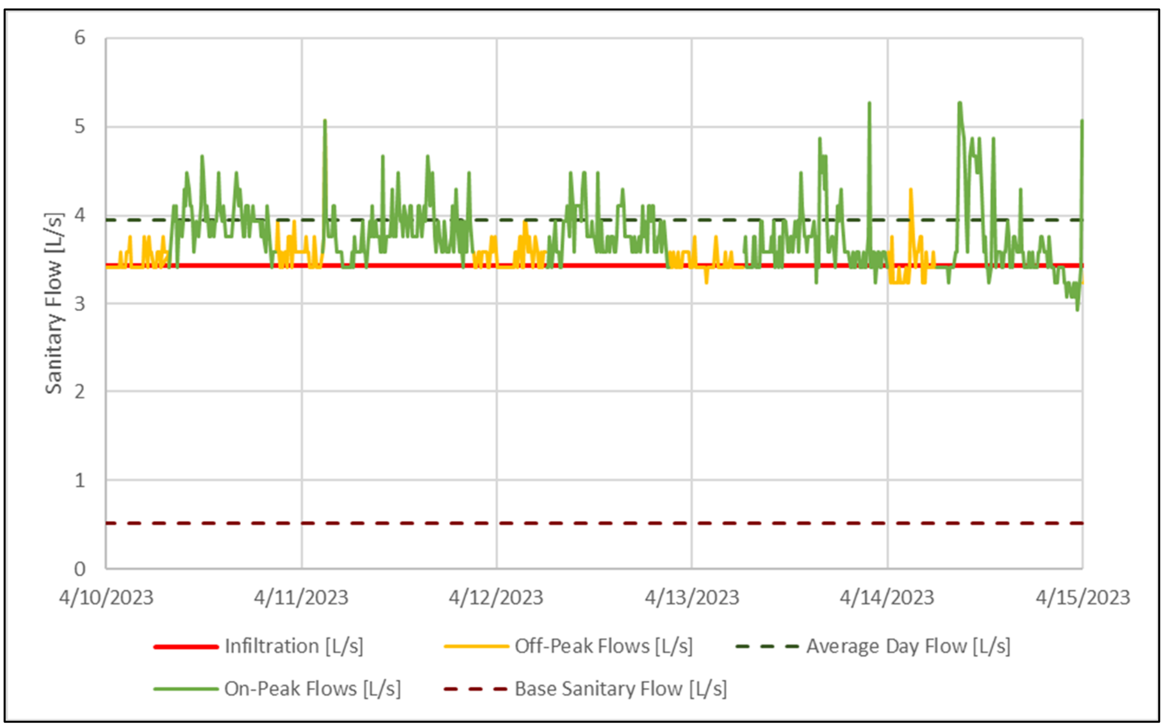

Figure 18 – Dry Weather Analysis, P112C

Dry weather analysis for P112C resulted in an infiltration rate of 3.4 L/s and a BSF of 0.5 L/s. These values are convoluted by the presence of industrial land uses in SCA 5. It is possible that some amount of continuous industrial flow was misattributed to infiltration.

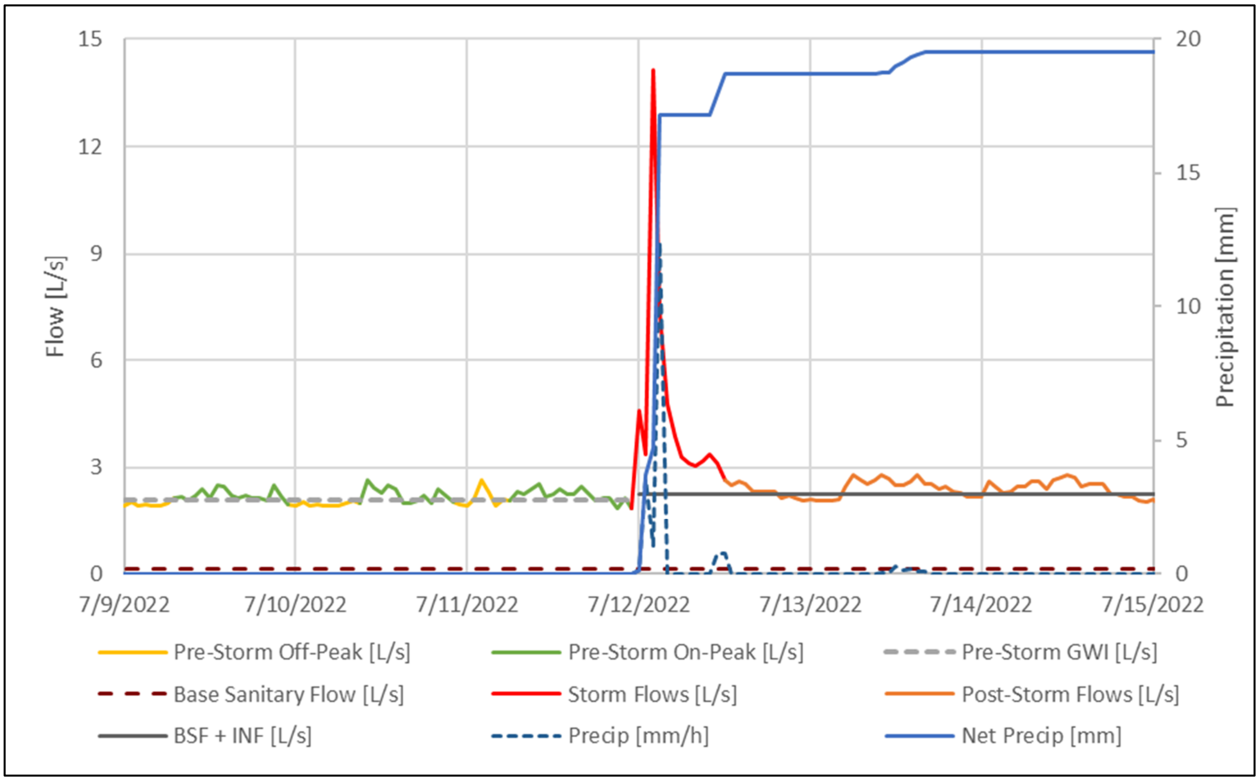

Figure 19 – Wet Weather Analysis, P302 Uncorrected

Wet weather analysis for P112C yielded a pre-storm infiltration rate of 2.1 L/s on an average ore-storm day flow of 2.2 L/s. This results in a pre-storm BSF of 0.15 L/s, down from 0.5 L/s during the dry weather period. This change in dynamic system demand can be caused by several convoluting factors but is not attributable to constant industrial flows or prior inflow events.

Lower BSF and pre-storm infiltration rate yielded a nominal flow threshold of 2.2 L/s. This led to direct and indirect average inflow rates of 2.18 L/s and 0.16 L/s respectively. These values are corroborated visually by the spike to more than five times the average day flow rate during the rain event and the decaying amounts of indirect inflow in the days following the event. High direct inflow and quickly decaying indirect inflow indicates that inflow in SCA 5 is governed by improper connections in primary stormwater infrastructure to the sanitary system.

5.2.2 SCA 6 – P114

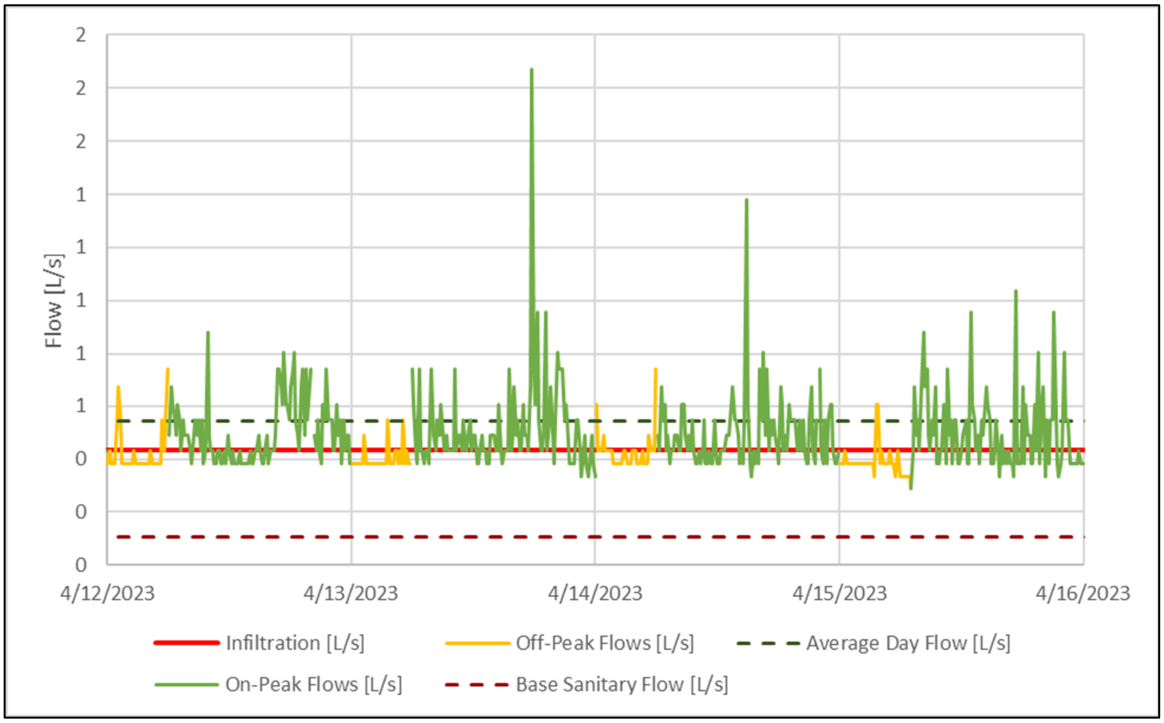

Figure 20 – Dry Weather Analysis, P114

Dry weather analysis for P114 yielded an infiltration rate of 0.4 L/s and a BSF of 0.1 L/s. This was the lowest infiltration rate produced by any SCA in either analysis year, driven primarily by its much lower contribution size.

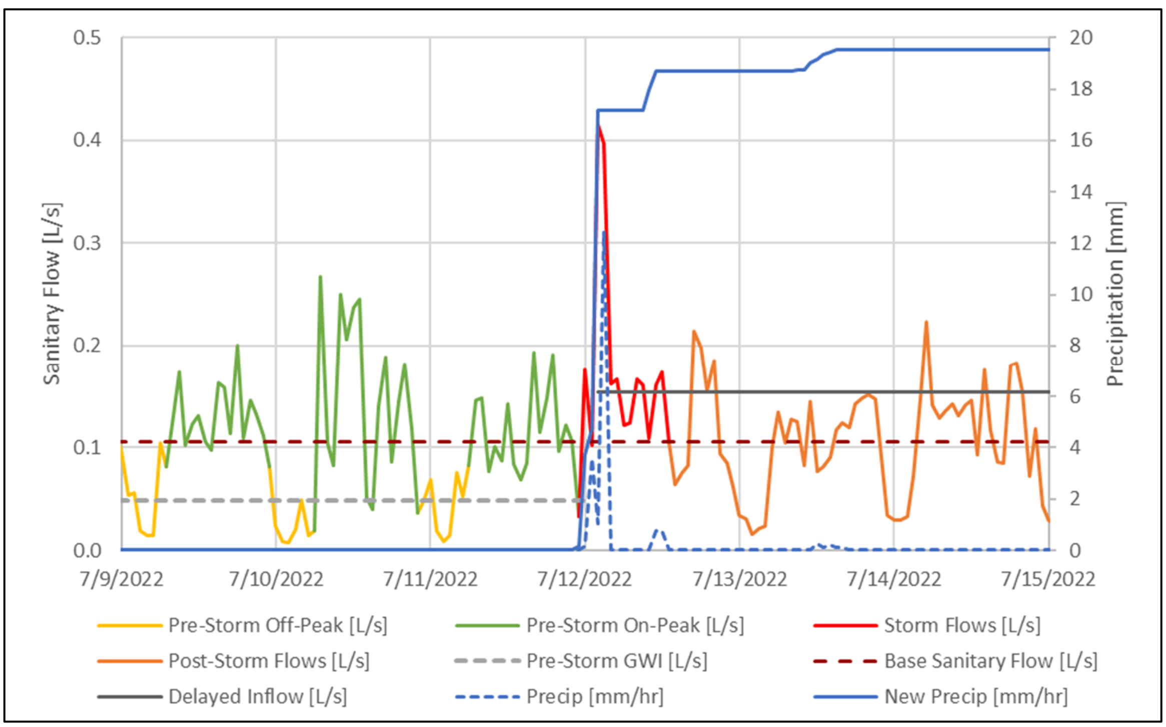

Figure 20 – Wet Weather Analysis, P114

Wet weather analysis for P114 yielded a pre-storm infiltration rate of 0.048 L/s on an average pre-storm daytime flow rate of 0.13 L/s.

P114 produced direct and indirect average inflow rates of 0.04 L/s and 0.01 L/s, respectively. The spike in flow at the onset of the storm event indicates the presence of at least one improper drainage connection to the sanitary system. However, the low average inflow values indicate that the connection(s) have little impact on the entire system.

5.2.3 SCA 7 – P115

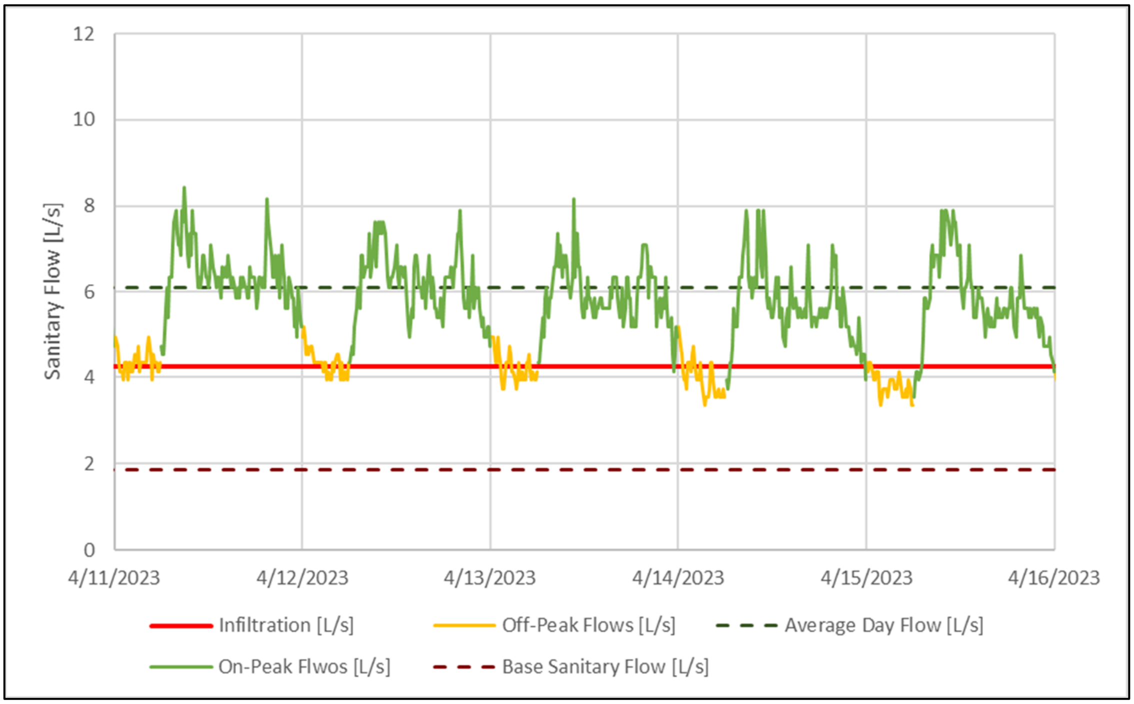

Figure 21 – Dry Weather Analysis, P115

Dry weather analysis for P115 yielded an infiltration rate of 4.3 L/s on a BSF of 1.8 L/s. The decaying behaviors of off-peak flows during the dry weather period was attributed to indirect inflow from prior storm event, but whose impact on average infiltration rate is statistically insignificant.

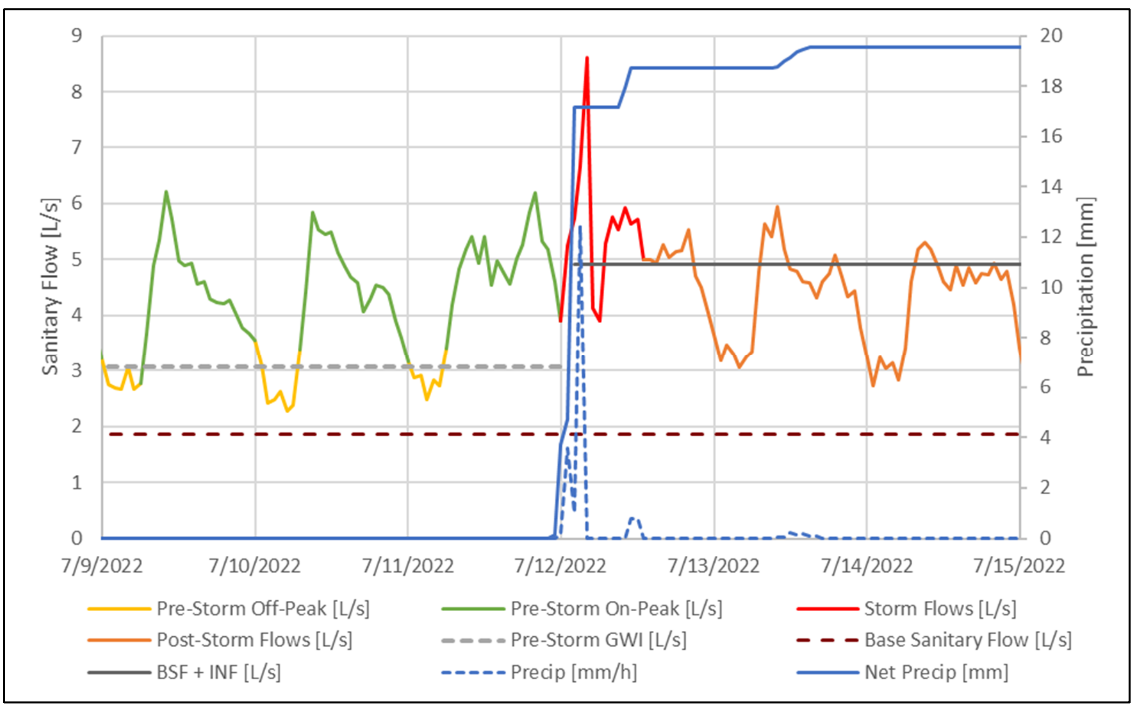

Figure 21 – Wet Weather Analysis, P115

Wet weather analysis yielded a pre-storm infiltration rate of 3.1 L/s on an average daytime flow rate of 4.8 L/s. This resulted in a nominal flow threshold of 4.9 L/s. P115 recorded average direct and indirect inflow rates of 0.79 L/s and 0.09 L/s respectively. The spike in flow recorded at the onset of the storm is indicative of one or more improper direct connections to the system.

5.2.4 SCA 8 – P500A

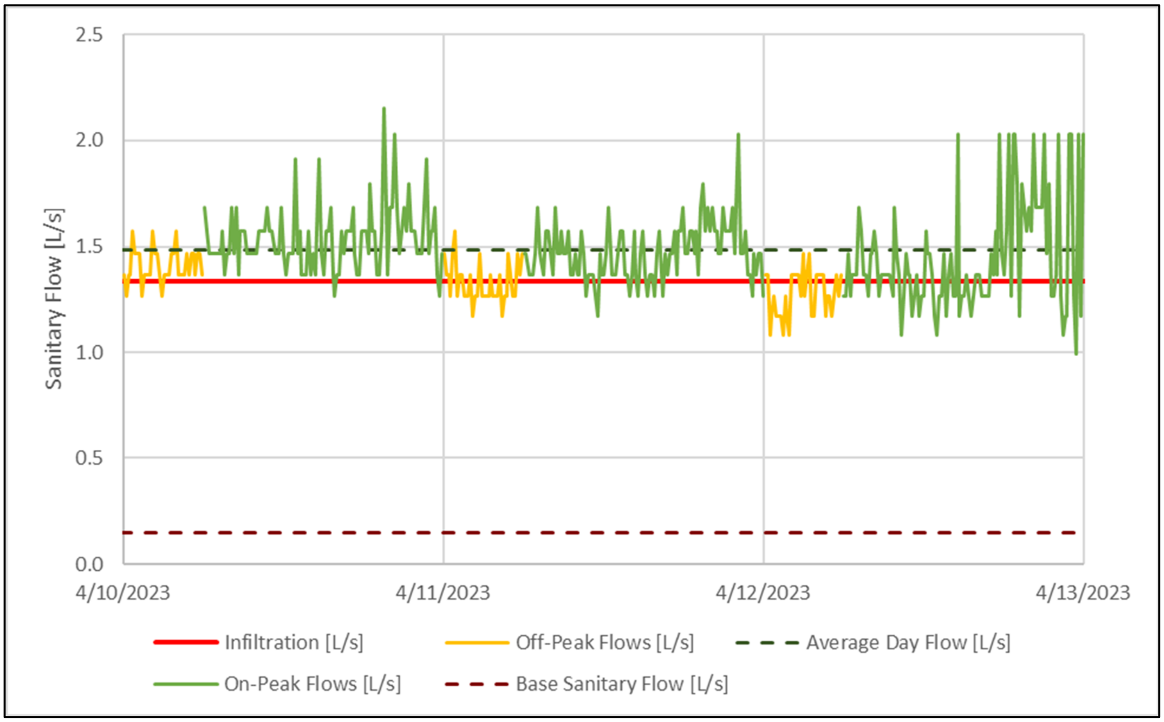

Figure 22 – Dry Weather Analysis, P500A

Dry weather analysis for P500A yielded an average infiltration rate of 1.3 L/s on a SBF of 0.15 L/s.

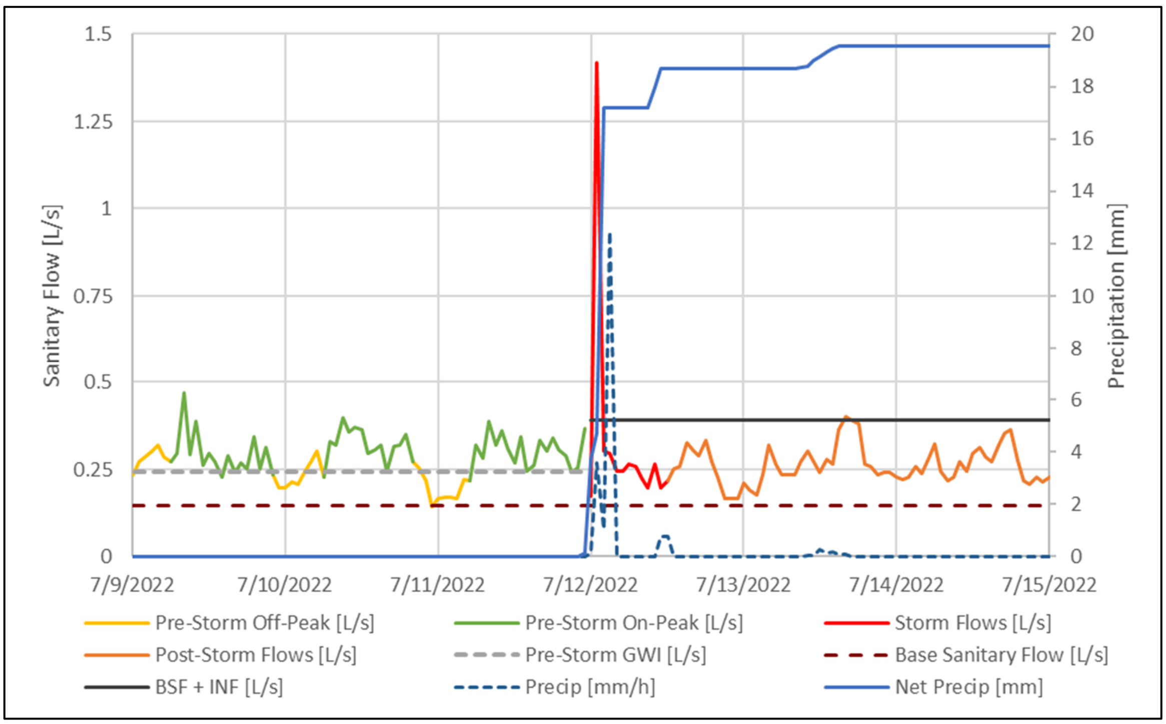

Figure 23 – Wet Weather Analysis, P500A

Wet weather analysis for P115 provided a pre-storm infiltration rate of 0.24 L/s on an average pre-storm daytime flow of 0.3 L/s. The resultant nominal flow threshold was 0.37 L/s. This resulted in direct and indirect average inflow rates of 0.075 and 0.002 L/s. There is at least one improper connection to the system. However, inflow sources in SCA 8 do not have a significant impact on the system.

5.2.3 Aggregated 2022 Analysis

Tables 9, 10, and 11 summarize the I/I characteristics as recorded during the 2022 analysis year.

Table 9 - Infiltration Assessment, 2022 Analysis Year

MH	SCA	BSF [L/s]	Peak Infiltration [L/s]	Infil. / BSF Ratio	Ranking
P112C	5	0.5	3.4	6.8	2
P114	6	0.1	0.4	4.0	3
P115	7	1.8	4.3	2.4	4
P500A	8	0.2	1.3	8.7	1

Aggregated infiltration analysis shows that infiltration is a concern in all contribution areas studied in 2022. SCA 8 provided the highest ratio of peak infiltration to base sanitary flow primarily due to its low base sanitary flow. SCA 7 was the largest area of concern for infiltration in 2022.

Table 10 - Inflow Assessment, 2022 Analysis Year

MH	SCA	Direct Inflow [L/s]	Indirect Inflow [L/s]	Σ Inflow [L/s]	Infl. / BSF Ratio	Ranking
P112C	5	2.18	0.16	2.3	15.6	1
P114	6	0.04	0.01	0.05	0.47	4
P115	7	0.79	0.09	0.88	0.48	3
P500A	8	0.075	0.02	0.08	0.51	2

2022 inflow analysis shows that inflow is of much lower concern in Palmerston than infiltration. SCA 5 recorded the highest ratio of inflow to base sanitary flow due to direct inflow in its tributary area.

Table 11 - Expected I/I Assessment, 2022 Analysis Year

MH	SCA	Expected I/I [L/s]	Measured I/I[1] [L/s]	Meas. / Exp. Ratio	Ranking
P112C	5	0.46	5.74	12.5	1
P114	6	0.07	0.45	6.4	2
P115	7	1.85	5.18	2.8	3
P500A	8	0.5	1.38	2.8	4

1: Addition of infiltration and inflow

All areas studied in 2022 produced I/I results higher than expected values for a system operating in good condition (throw to MECP source for expected I/I). Areas of highest concern in 2022 are subdivided from SCA 1, the area of highest concern in 2021.

6.0 Conclusions and Recommendations

Infiltration has a significant impact on extraneous sewage flows in Palmerston. Areas of high concern create more sewage flow from infiltration during spring thaw than from human sources. Areas of lower concern are still producing sewage flows above MECP guidelines for an ideal sanitary system of equivalent size. These issues will have an escalating impact on sanitary demand until infrastructure rehabilitation programs can be implemented.

Inflow has a much less significant impact on the Palmerston sanitary system than infiltration. Areas of highest inflow concern experienced sharp spikes in sanitary flow consistent with improperly connected drainage infrastructure. Areas of lower concern experience sustained higher on- and off-peak flows consistent with sump pumps draining groundwater into the sanitary system directly.

It is noteworthy that inflow is of much lower concern in Palmerston than was noted in past studies. This suggests that past remedial methods for inflow have effectively reduced impact of inflow on the system.

6.1 Areas of Concern

The following areas are of concern and should be investigated further to determine what remedial action is required. These are listed in order of priority, based on the overall impact these appear to be having on the system.

1. Clarke Street Unopened Right-of-Way and Minto Road – P112C

Sanitary infrastructure along Clarke Street and Minto Road is the highest priority concern due to the combined impacts of inflow and infiltration. The analysis found high seasonal infiltration and sensitivity to changes in groundwater, likely arising from waterproofing failures in open drainage fields in the tributary area. Flow peaks during storm events also showed evidence of possible improper direct connections to the system. It is recommended that the Town consider manhole inspection and flow tracing and property surveys as warranted to find precise sources of inflow in the area. Inspections of pipes and structures should identify opportunities for waterproofing or rehabilitation as appropriate.

2. Henry Lane, North of Main Street – P114

Sanitary infrastructure under and along Henry Lane is the area of second highest concern in Palmerston. In this area, high infiltration and direct inflow combine to produce considerable extraneous sewage flows. CCTV inspection or smoke testing of pipes and structures will identify areas in the system for infiltration to occur. It is recommended that the Town consider manhole inspection and flow tracing and property surveys as warranted to find precise sources of inflow in the area. Inspections of pipes and structures should identify opportunities for waterproofing or rehabilitation as appropriate. It should be noted that Inkerman is not expected to be a high contributor of infiltration or inflow given that it has been recently reconstructed.

3. Main Street, Downtown Core – P302

Downtown Palmerston, bounded by Cumberland Street and Henry Lane, is the third area of concern. Infiltration in the problem area during spring thaw peaks at more than half of recorded sanitary flows. It is recommended that the Town CCTV the entire Main Street in conjunction with the upcoming reconstruction project, with thorough consideration given to reconstruction or other rehabilitation measures to address infiltration concerns on Main Street. Substantially reduced flows on the day of the storm event suggest that sanitary demand in the area is highly dependent on weather. It is recommended that the Town assess possible drainage connections from Palmerston Lion's Park and from other commercial land uses on William Street. Installing flow meters at structures P226 and P218 for a third analysis year would also provide more specific areas of concern.

4. Mary Street and Jane Street – P115

The expansion of SCA 1 by two blocks along the intersection of Mary Street and Jane Street introduced significant increases to direct inflow. This may suggest improper downspout connections along the additional 90 meters between P118 and P115 however it is likely indicative of inflow through the structures between P126 and P129 through the Cargill property and/or between P120 and P121 (Jane to Norman). It is recommended that the Town consider manhole inspection and flow tracing and property surveys as warranted to find precise sources of inflow in the area. Inspections of pipes and structures should identify opportunities for waterproofing or rehabilitation as appropriate. Installing a flow meter at structure P120 for a third analysis year would also provide more specific areas of concern.

6.2 Next Steps

Remedial works can be recommended only when specific I/I sources are found and as such, the following methods should be implemented to help determine exact locations of I/I sources.

Inspection Methods

The use of these methods will need to be determined on a case-by-case basis as the effectiveness of each will be contingent on the details of the area of concern.

1. Maintenance Hole Inspection & Flow Tracing:
    - Visually examine each MH for overall condition and observe the sewer flows, starting at the downstream location. Photograph and log the findings of the inspection. A template can be provided upon request.
    - Follow sources of higher flow in each upstream MH until the source of higher flow can be isolated. This process will need to consider the upstream service area as this will affect the flow rate. Ideally, this process is completed following a significant rainfall event and/or during high groundwater conditions to estimate inflow or infiltration respectively.
2. Acoustic Inspection (Simple):
    - One operator at the nearest sanitary MH and another at the nearest storm structure, one of the structures is tapped on using a metal tool. The sound will then be clearly heard at the other structure if they are connected.
3. CCTV Inspection:
    - Conduct CCTV inspections during a wet period to provide the exact location of the inflow. A list of findings is to be prepared.
    - Cameras should be equipped with side-launching lateral inspection capabilities. All service laterals should be inspected for potentially collapsed or obvious surface connections.
    - Identify any cracks, joint separations, or other defects that may allow water to infiltrate.
4. Door-to-Door Inspections:
    - Complete per-house inspections of foundation drain and sump pump connections for connections to the sanitary network. If so, these connections should be disconnected and rerouted to a storm service or surface discharge location as appropriate.

Remedial Measures and Suggestions

The following additional measures should be taken moving forward to reduce the risk of inflow and infiltration in the future.

- Ensure that new homes include the installation of storm sewer services and that sump pumps are connected to this service as per the Town's Municipal Servicing Standards.
- Ensure storm sewers are installed for the entire length of roads during new builds or reconstructions. The Town will need to weigh the costs and benefits of accommodating private storm services, foundation drains, or sump pump connections on an as-needed basis.
- Provide and maintain adequate drainage features to ensure storm blockages do not cause additional inflow during rainfall events.
- Install inserts in maintenance holes which may be susceptible to surface flooding.
- Repair all sewer and maintenance holes with identified deficiencies. This may include parging structure cracks, replacing brick/moduloc works, and grouting or lining leaking sewers and tees.

Once the Town has had a chance to review this information, we suggest a meeting to consider a course of action for further work.

Respectfully submitted,

Zach von Massow, EIT Dustin Lyttle, P.Eng

Triton Engineering Services Limited

References

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United States Environmental Protection Agency. (2014). *Guide for Estiamting Inflow and Infiltration.*