Town of Forest
Inflow/Infiltration Study

Final Report

EO 97165
January, 1998

G.R.S./J.J.G./T.R.B.

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1. INTRODUCTION

The Town of Forest commissioned this project to investigate the sources of inflow and infiltration as they relate to the high volume of waste water entering the Town's sanitary sewer system. The scope of work includes an analysis of historical data relating to wastewater generation rates (from January 1982 to November 1997), water consumption rates (from January 1995 to June 1997) and precipitation data (January 1995 to September 1997). A hydraulic monitoring program was conducted in conjunction with various inspections to estimate the sources and quantity of inflow and infiltration (I/I) into the sanitary system. A review of various I/I control alternatives as they apply to the Town of Forest was also completed.

1.1. Background Information

The Town of Forest instituted the building of a new Waste Water Treatment plant to treat the sanitary waste water produced by the community. The plant was designed with a total average daily design capacity of 1800 m^3/d, with the knowledge that flow rates were approximately 900 m^3/d to 1200 m^3/d at the time of design. However, subsequent to construction being completed and the plant commissioned in 1996, the volume of waste water has increased. Currently, the average volumes are 1200 m^3/d, with peak flows often surpassing the design flow of 1800 m^3/d. The extra quantity of waste water is believed to be the result of inflow and infiltration into the town's thirty year old sanitary sewer system.

Inflow and infiltration are hydraulic processes or events that add non-polluted water to sanitary sewer systems. Inflow is the result of water directly entering the sewer system via connected foundation and roof drains, outdoor paved areas, and through perforated manhole covers. It is typically associated with precipitation and runoff events, and causes an immediate increase in the flow rates beyond background levels. Infiltration occurs when groundwater seeps into the sewer system through poor joints and cracks in pipes and manholes. Infiltration is water drawn from the soil into the sewer system. It can occur over an extended period of time, often occurring in dry weather too. A schematic diagram detailing the processes of inflow and infiltration is provided in Figure 1.1. Inflow and infiltration are both major problems affecting many sewer systems throughout North America (Brock, 1996; McGhee, 1991; Viessman & Hammer, 1993).

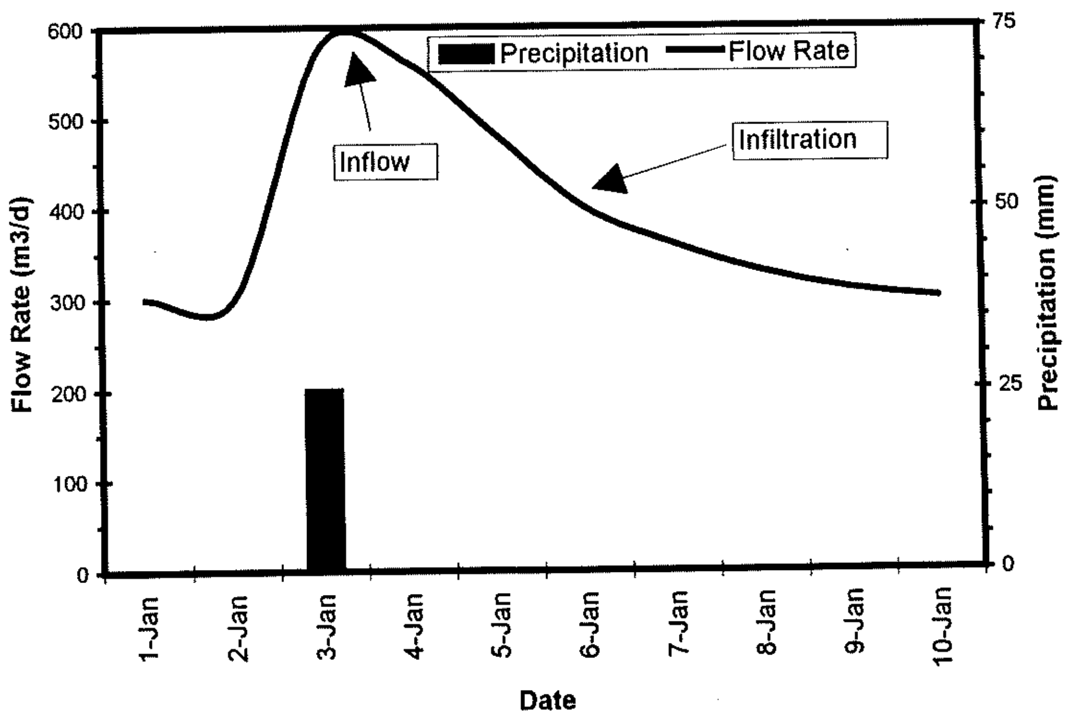


Figure 1.1.: Schematic of Inflow and Infiltration

1.2. Study Objectives

The overall objectives of this study were to locate and quantify significant problem areas in the sewer system that result in the introduction of storm and/or ground water. Control alternatives were reviewed such that their implementation will result in a reduced volume of extraneous water entering the sanitary sewer system.

2. STUDY AREA DESCRIPTION

The town of Forest was incorporated as a Village in 1872, and as a Town in 1889. It is located at the intersection of the Townships of Bosanquet, Plympton and Warwick, County of Lambton, Province of Ontario, Canada. Forest is located approximately 50 km north-east of Sarnia and 56 km north-west of London. The exact location of the south-western Ontario community is shown in Figure 2.1.

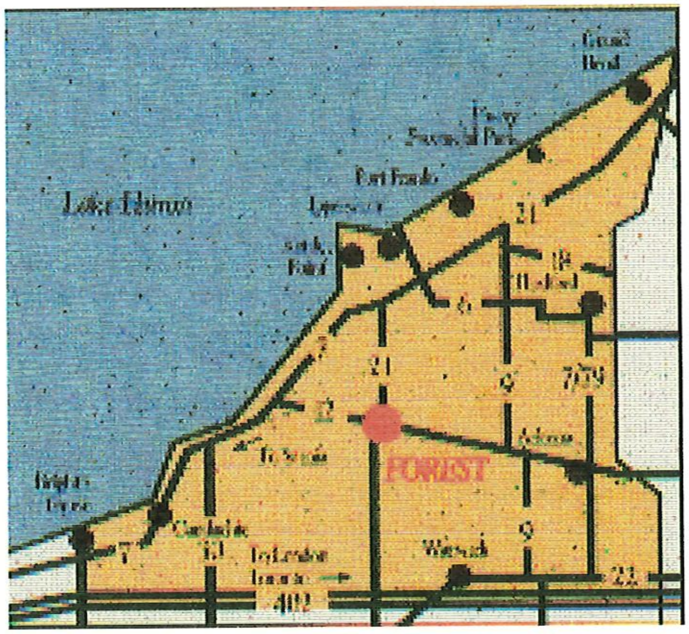


Figure 2.1.: Location of the Town of Forest

2.1. Population

The population of the Town of Forest was 2600 in 1988 (Proctor & Redfern Limited, 1992), 2868 in 1994 (http://xcelco.on.ca/forest, 1997). It is anticipated that the future population will be 4000 by 2015. The future population is estimated using a 2% growth rate between 1988 and 2015 (Proctor & Redfern Limited, 1992).

2.2. Land Use

The primary land use in the Town of Forest is residential. There is also a 90 acre section of land zoned as M1 for an industrial park. To date there are two industries present, the Ready-Mix Concrete Factory and Forest Agri-Services.

2.3. Drainage

The town is located adjacent to Hickory Creek and Lake Toria. These are the only water courses in the town, with the exception of a tributary of Hickory Creek. Discharge of treated effluents from the WWTP is directed to Hickory Creek. This water course drains a relatively small watershed over the course of its approximately 20 kilometre length. It has its headwaters upstream of the Town of Forest and discharges to Lake Huron approximately 8 kilometres due west of the Town. The separate storm water system discharges directly into the water shed.

2.4. Sanitary Sewer System Description

The sanitary sewer network servicing the Town of Forest is approximately 25 years old and reported to be fully separated from any municipal systems managing storm water. The Town's sanitary sewer system is divided into two distinct service areas covering the north-west (NW) and south-east (SE) areas of town. The two systems are principally divided by the CNR Rail line land that physically divides the town. The NW and SE halves of the sewer system converge at the Clyde Street pumping station after passing through the manhole located at the intersection of Eureka Street and Clyde Street (#85) for the NW section, and the manhole located directly east of the pumping station (#95) for the SE section. The combined sewage is pumped to the waste water treatment plant via a force main.

3. STUDY APPROACH

The study began in May of 1997 following the identification of the Terms of Reference for this project. Major components of the study include:

- background data collection and review
- field monitoring program
- assessment of control alternatives

The approach and methodology for each of these task components are summarized in the following sections.

3.1. Background Data Collection and Review

Historical flow data (from January 1982 to November 1997) was collected for the Town of Forest's Sanitary Sewer System. The flow data for the sewer system was reviewed to determine the historical monthly average flow rates, minimum and maximum daily flow rates for each month, and the total volume of waste water being generated by the town.

Precipitation records for the City of Sarnia, Ontario (January 1995 to September 1997) were obtained from Environment Canada, Ontario Climate Center. The City of Sarnia's precipitation data was selected as being the most comparable Municipality to Forest for precipitation data. The Town of Forest is approximately 50 km to the north-east of Sarnia, and lies in approximately the same storm track. The precipitation data was reviewed and compared with the WWTP flow data, since inflow and infiltration problems are typically associated with storm events.

Monthly potable water consumption rates for the Town of Forest were obtained for the period from January 1995 to June 1997. This data was compared to the quantity of waste water treated at the Waste Water Treatment Plant to estimate the quantity of waste water resulting from inflow and infiltration events.

3.2. Field Program

The field program conducted for this project consisted of the following work:

- Visual inspections of portions of the sewer system
  - ⇒ manual inspection of some manholes in the system
  - ⇒ camera work inspection of some sewers in the system
  - ⇒ roof leaders inspection
  - ⇒ industrial park inspection
- Hydraulic monitoring to quantify flow rates in some portions of the sewer system

3.2.1. Visual Inspections

Manual inspection of some of the Town's manholes was conducted by Proctor & Redfern Limited staff. The physical condition of the manholes in the sewer system were evaluated. The manhole inspections identified active I/I problems (i.e. observed) and potential I/I problems (i.e. cracks, wet spots, pooling around manhole covers, etc.). A list of manholes that were inspected during this study is provided in Table 3.1.

Table 3.1.: Location of Inspected Manholes

Manhole #	Location
36	South side of Church Ave. (east of MacNab St.)
38	North of dead-end on MacHenry St.
45	Intersection of Bayley St. and Broadway St.
50	Intersection of MacKenzie St. and MacDonald St.
85	Eureka St. & Clyde St.
86	Eureka St. (north of #85)
87	Eureka St. (north of #86)
88	Eureka St. (north of #87)
89	Intersection of Argyle St. and Ann St.
92	Intersection of Argyle St. and Clyde St.
93	Ontario St. (north of Clyde St.)
95	Eureka St. at Pump Station
97	Intersection of Ontario St. and Ann St.
102	Intersection of Ontario St. and Queen St.
114	Union St. (north of Queen St.)
185	Highway #21 near Industrial Park
209	Intersection of Bayley St. and Church Ave.

A review of existing video tapes, that were compiled from previous camera work, was undertaken by Proctor & Redfern Limited staff. The physical condition of some of the pipes in the sewer system was evaluated from this work. The tapes provided information regarding current and historic leaks, and potential inflow and infiltration problems that exist in the sanitary system.

A visual inspection was conducted to quantify the number of buildings (i.e. residential, commercial, institutional, etc.) that met the criteria of having roof leaders that terminate below grade level. This was completed by driving through the Town of Forest and recording all of the addresses of buildings that met the roof leader criteria.

A visual inspection of the industrial park was also conducted. The purpose of the inspection was to assess the contribution of I/I water from the industrial park to the Town's sewer system. The sanitary system was inspected including the two existing industries, the pumping station and wet well. A die test of the wet well was also conducted to verify a report that the force main in the industrial park may be leaking.

3.2.2. Hydraulic Monitoring

Hydraulic monitoring was conducted to quantify the waste water flows for various sections of the sanitary sewer system. Computerized ultrasonic type flow meters were used to complete this portion of the study. The meters measured and recorded the depth of flow and velocity, while calculating the volumetric flow rate through a given pipe as a function of time. The meters also tabulated the total volume of water passing through the sewer for a given day.

The meters were strategically stationed at different manholes throughout the Town to assess the contributions of the various service areas of the Town to the overall WWTP flows. A list of the manholes that were used as monitoring sites is provided in Table 3.2.

Table 3.2.: Site Locations for Hydraulic Monitoring

Manhole	Location	Reason
WWTP Outfall	Located on gravel access road for WWTP	• verify data from plant reports
86	Eureka St. (north of #85)	• selected to isolate the north-west section of town
93	Ontario St. (north of Clyde St.)	• further isolation of the north-west section of sewer system
114	Union St. (north of Queen St.)	• further isolation of the north-west section of sewer system
87	Eureka St. (north of #86)	• further isolation of the north-west section of sewer system
102	Intersection of Ontario St. and Queen St.	• further isolation of the north-west section of sewer system
95	Eureka St. at Pump Station	• selected to isolate the south-east section of town
45	Intersection of Bayley St. and Broadway St.	• further isolation of the south-east section of sewer system
50	Intersection of MacKenzie St. and Mac Donald St.	• further isolation of the south-east section of sewer system
36	South side of Church Ave. between MacNab St. and MacHenry St.	• further isolation of the south-east section of sewer system
185	Highway #21 near Industrial Park	• selected to isolate the industrial park flows
209	Intersection of Bayley St. and Church Ave.	• flooding was reported in this section of town

3.3. Assessment of Control Alternatives

An objective of this study was to develop a strategy for the reduction of infiltration and inflow into the sanitary sewer system. To this purpose, various I/I control techniques were reviewed for their applicability to the specific problem areas identified during this study. The control techniques that were evaluated included the following:

- Repair of Manholes
- Private Side Reduction
- Inlet Controls
- Reline Existing Sewers
- Replace Existing Sewers

4. RESULTS AND DISCUSSION

This chapter presents the data that was collected and analysed for this study. Sections of the sanitary system that are suspected of contributing significant inflow and infiltration volumes have been identified. An overall evaluation of the Town's I/I situation is presented in the integrated discussion.

4.1. Background Data Review

The historic waste water generation rates for the Town of Forest was collected and analysed as outlined in Section 3.1. The entire set of historic flow data for the sanitary sewer system is provided in Appendix A. The average, maximum, and minimum day flow rates for each month from January 1982 to October 1997 are provided in Figure 4.1.

The historical flow data from the WWTP indicates that the average rate of waste water generation is 1031 m^3/d with a standard deviation of 206 m^3/d over that time period. There is a moderate variation in flow throughout the month. The monthly maximum day peaking factors averaged 1.2, and has achieved a maximum of 2.5. The minimum day peaking factors averaged 0.8. It is clearly evident that the sewer system has collected high daily waste water flow rates (>1,800 m^3/d) on a periodic basis from 1982 to present.

The daily flow rates for the waste water treatment plant and the daily precipitation records from May 1, 1997 to September 21, 1997 are provided in Figure 4.2. The average flow rate was 1300 m^3/d over this time period, with five days in excess of 1800 m^3/d. The flow rates at the waste water treatment plant increase above background levels for the majority of precipitation events. This indicates the existence of inflow and infiltration problems since the sanitary system should not experience any significant increases in flow rates during a storm event.

The precipitation data indicates that the majority of storms recorded at Sarnia, impacted Forest's WWTP, since the plant's flow rates increased. However, the 72.4 mm event that occurred on June 1, 1997, did not increase the WWTP flow rates significantly. Consequently, the use of precipitation data collected at Sarnia as it relates to storms at Forest is not 100% accurate. Therefore, it is recommended that a rain gauge be installed at the Town of Forest Waste Water Treatment Plant to quantify the storm events at Forest, and correlate them with the plant flow rates. This would allow the plant operators to better quantify the effects of inflow and infiltration on the plant.

The WWTP flow rates typically peaked either on the same day or the day following the storm. Inflow of water into sanitary sewer system occurs instantaneously, while infiltration occurs over a longer duration with decreasing intensity. This indicates that the problem is likely not just an inflow problem which would result in an immediate increase in flow rates. Consequently, it is suspected that the Town's sanitary system is experiencing both inflow and infiltration.

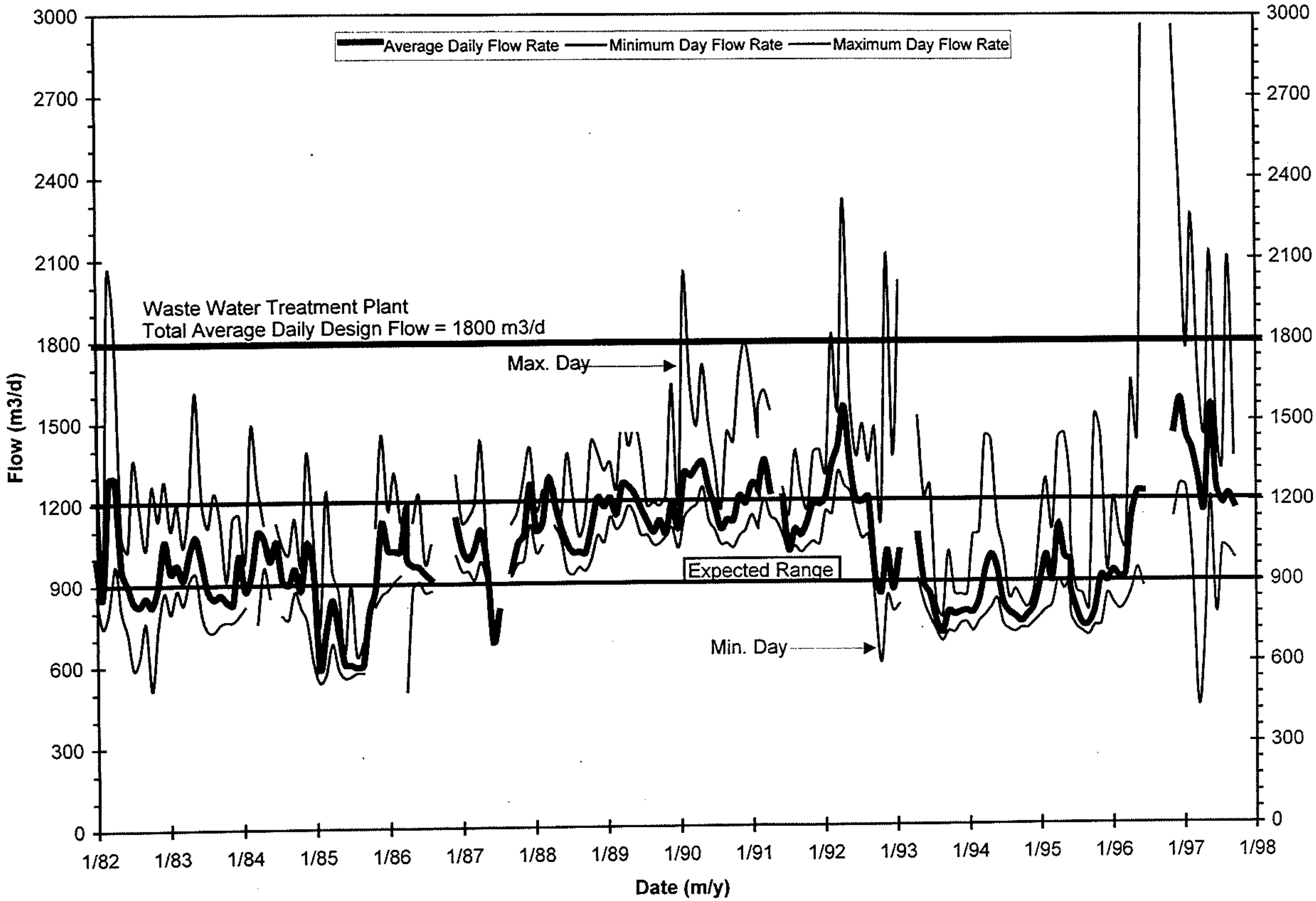


Figure 4.1.: Average, Maximum and Minuimum Daily Flow Rates for Each Month at WWTP

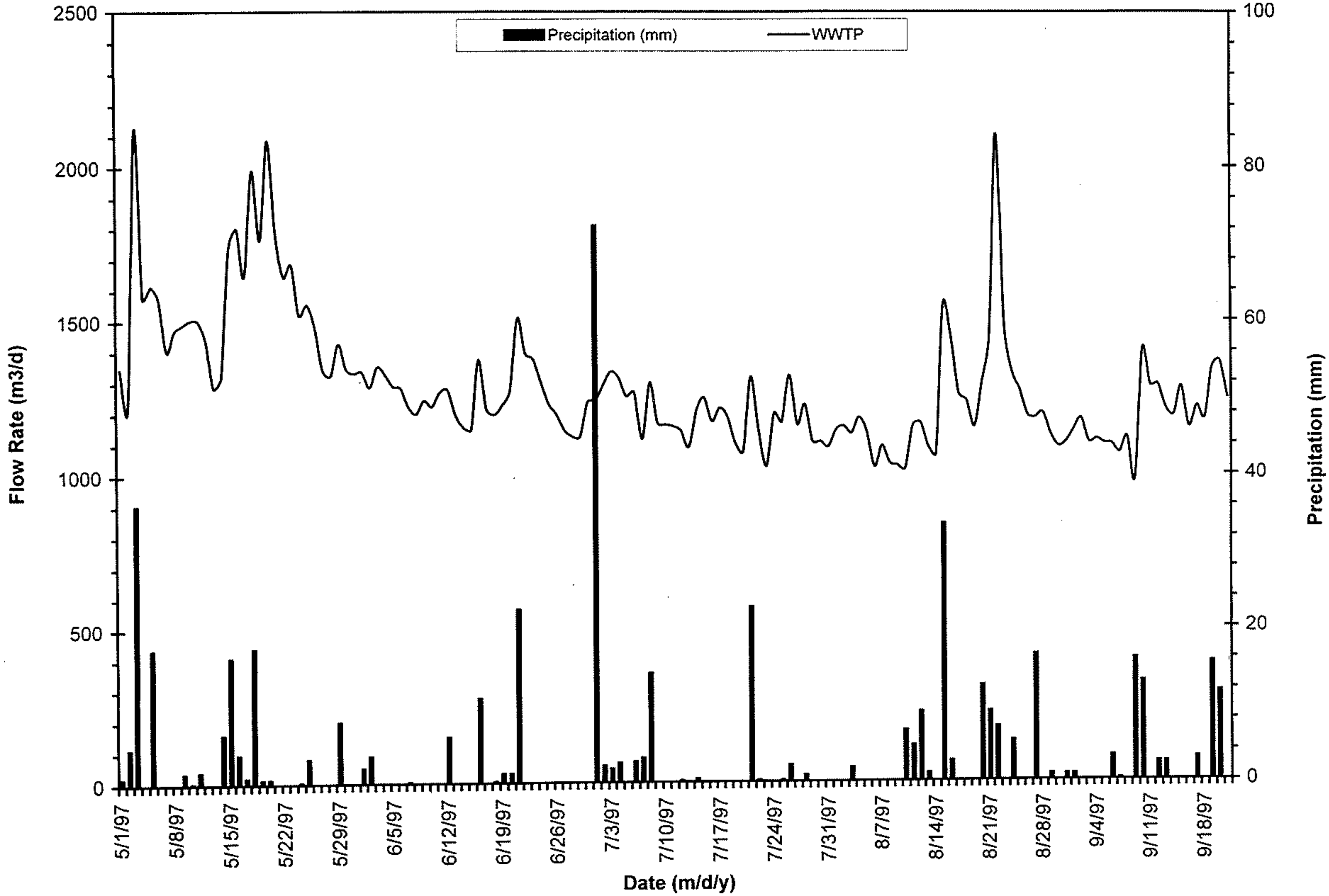


Figure 4.2.: Daily Waste Water Treatment Plant Flow Rates and Precipitation Events

The Town of Forest potable water usage rates were obtained from the Town of Forest as stated in Section 3.1. The monthly potable water volumes were compared to the waste water volumes, and are provided in Table 4.1. with a graphical representation provided in Figure 4.3.

It is clear that the volume of waste water being generated is significantly greater than the consumption of potable water. The difference in the volumes of water is likely caused by extraneous water entering the sanitary sewer system via inflow and infiltration. The volumes and rates of water as inflow and infiltration were estimated and are provided in Figure 4.4. The series of columns represent possible inflow/infiltration volumes assuming 15% consumptive water use. Viessman & Hammer (1993), indicate that a 15% loss from the distribution system and consumptive usage of potable water is accurate for most non-arid regions.

Inflow and infiltration volumes range from an average of 9,000 m^3 to 19,000 m^3 in a month. These volumes correspond to a range of flow rates from 300 m^3/d to 630 m^3/d on a continuous basis. However, it is estimated that volumes as high as 34,000 m^3 in one month have been observed. Inflow and infiltration contribute on average 34%, with a range of 0% to 56% of the total waste water volume being treated by the WWTP.

Inflow and infiltration likely occurred as far back as 1985 as shown in Figure 3.3 in the Class Environmental Assessment Document for the Town of Forest, Wastewater Facilities Environmental Study Report (Proctor & Redfern Limited, 1992). The figure indicates that on average 250 m^3/d to 300 m^3/d entered the sewer system as inflow and infiltration between 1985 and 1990. Clearly, inflow and infiltration is an issue that needs to be addressed in the Town of Forest Sanitary Sewer system.

Table 4.1.: Comparison of Waste Water Generation and Potable Water Consumption

	WWTP[1]		Potable Water[2]		85% of Potable Water[3]		I/I[4]	I/I[5]
Date	m^3	(m^3/d)	m^3	(m^3/d)	m^3	(m^3/d)	(m^3/d)	(%)
Jan-95	30849.2	995.1	25369.0	818.4	21563.7	695.6	299.5	30
Feb-95	25262.1	902.2	23716.0	847.0	20158.6	720.0	182.3	20
Mar-95	34276.8	1105.7	21669.0	699.0	18418.7	594.2	511.6	46
Apr-95	29717.2	990.6	24420.0	814.0	20757.0	691.9	298.7	30
May-95	30144.5	972.4	25346.0	817.6	21544.1	695.0	277.4	29
Jun-95	26175.9	872.5	ND	ND	NC	NC	NC	NC
Jul-95	24493.8	790.1	ND	ND	NC	NC	NC	NC
Aug-95	22866.4	737.6	25018.0	807.0	21265.3	686.0	51.6	7
Sep-95	22170.8	739.0	26160.0	872.0	22236.0	741.2	-2.2	0
Oct-95	24552.9	792.0	29609.0	955.1	25167.7	811.9	-19.8	-3
Nov-95	27512.4	917.1	21502.0	716.7	18276.7	609.2	307.9	34
Dec-95	27885.2	899.5	24417.0	787.6	20754.5	669.5	230.0	26
Jan-96	29067.1	937.6	23011.0	742.3	19559.4	630.9	306.7	33
Feb-96	26512.3	914.2	ND	ND	NC	NC	NC	NC
Mar-96	28589.8	922.3	ND	ND	NC	NC	NC	NC
Apr-96	34145.0	1138.2	19557.0	651.9	16623.5	554.1	584.1	51
May-96	38154.6	1230.8	30307.0	977.6	25761.0	831.0	399.8	32
Jun-96	37013.5	1233.8	26499.0	883.3	22524.2	750.8	483.0	39
Jul-96	ND	ND	22033.0	710.7	18728.1	604.1	NC	NC
Aug-96	ND	ND	42746.0	1378.9	36334.1	1172.1	NC	NC
Sep-96	50726.0	1690.9	28550.0	951.7	24267.5	808.9	882.0	52
Oct-96	ND	ND	30502.0	983.9	25926.7	836.3	NC	NC
Nov-96	43801.0	1460.0	22658.0	755.3	19259.3	642.0	818.1	56
Dec-96	48966.0	1579.5	29976.0	967.0	25479.6	821.9	757.6	48
Jan-97	44807.0	1445.4	24803.0	800.1	21082.6	680.1	765.3	53
Feb-97	38886.0	1388.8	23098.0	824.9	19633.3	701.2	687.6	50
Mar-97	39721.0	1281.3	25920.0	836.1	22032.0	710.7	570.6	45
Apr-97	35200.0	1173.3	29633.0	987.8	25188.1	839.6	333.7	28
May-97	48230.0	1555.8	27406.0	884.1	23295.1	751.5	804.4	52
Jun-97	37743.0	1258.1	33896.0	1129.9	28811.6	960.4	297.7	24
minimum	22170.8	737.6	19557.0	651.9	16623.5	554.1	-19.8	-3
maximum	50726.0	1690.9	42746.0	1378.9	36334.1	1172.1	882.0	56
average	**33610.0**	**1108.3**	**26454.7**	**869.2**	**22486.5**	**738.8**	**427.3**	**34**

Notes:
[1]WTTP - total volume of waste water treated during month & average daily flow rates for month
[2]potable water - total monthly consumption & average daily consumption rate for month
[3]calculations assumed 15% water supply loss or consumptive usage (i.e. lawn sprinkling)
[4]I/I was calculated by subtracting 85% of potable water from the WWTP flow rates
[5]Percent I/I was calculated by dividing I/I flow rates by WWTP flow rates
ND - no data available
NC - calculations not possible with current data

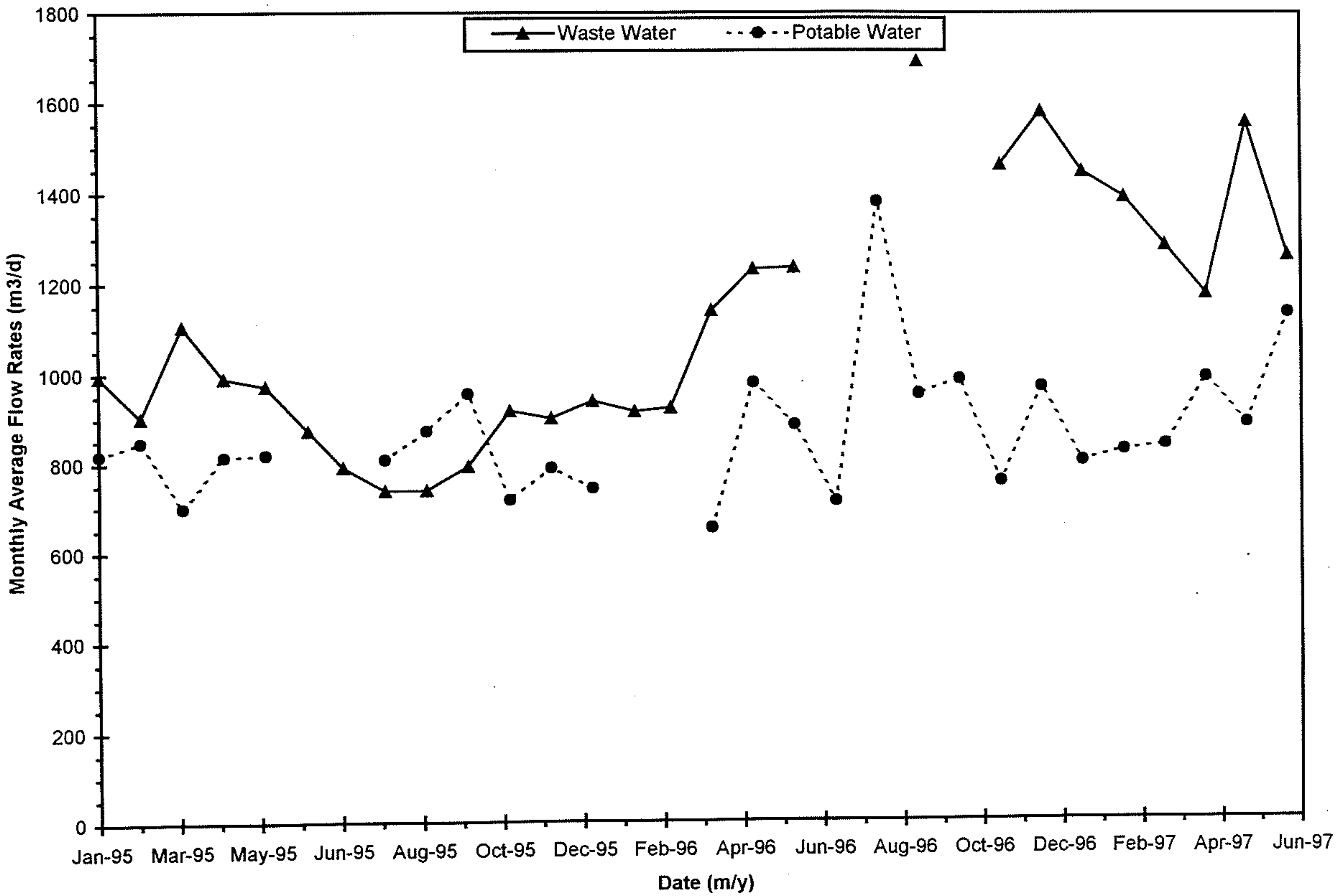


Figure 4.3.: Comparison of Waste Water Generation Rates and Potable Water Consumption Rates

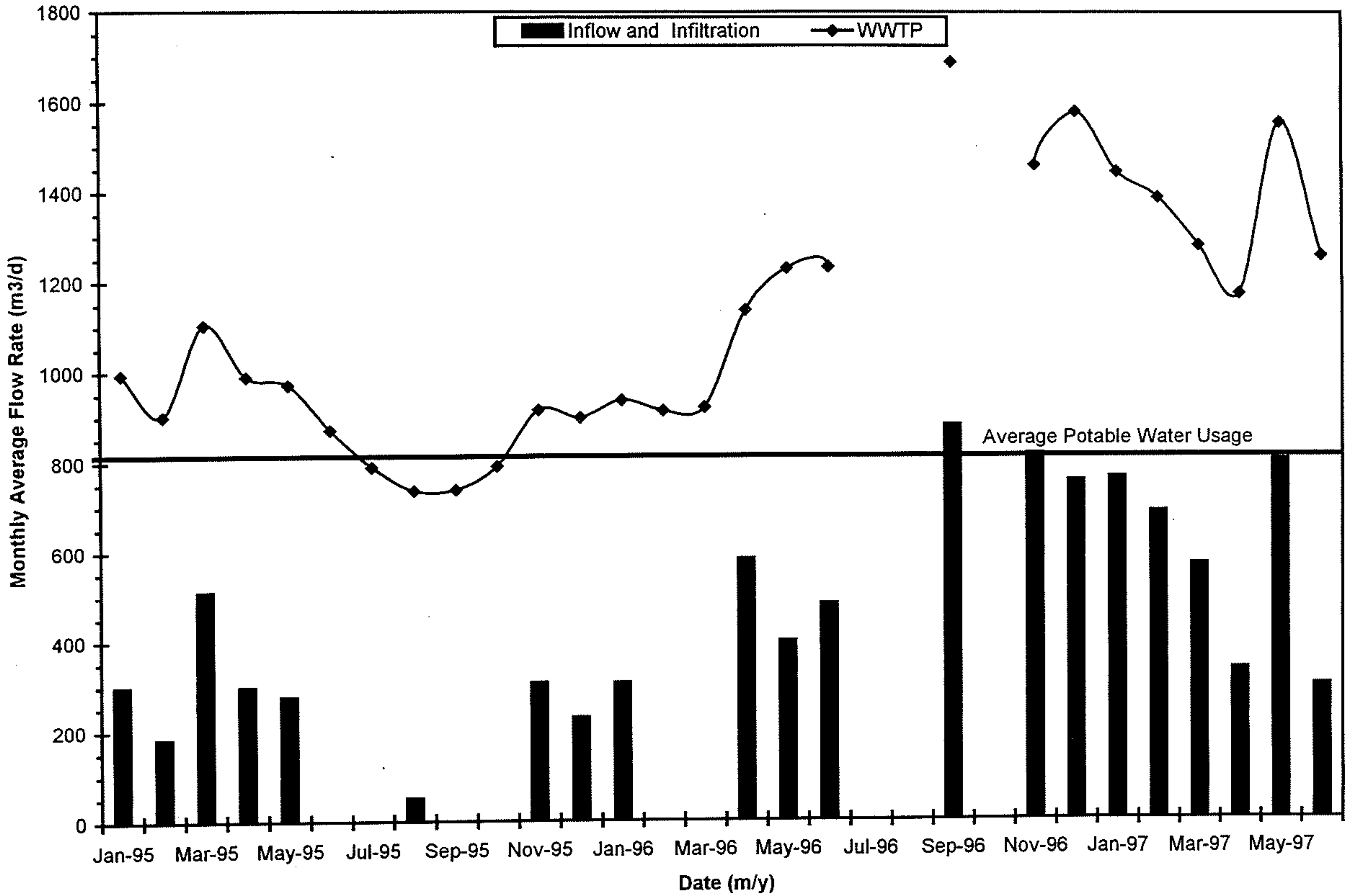


Figure 4.4.: Flow Rates of Water Entering the Sewer System Via Inflow and Infiltration

4.2. Field Program

4.2.1. Visual inspections

Visual Inspections were conducted to evaluate the contributions of various manholes, sewer pipes, roof leaders, and regions of the town such as the industrial park to the I/I problem identified in Section 4.1. The following sections present the findings of the visual inspections conducted or reviewed during this study.

4.2.1.1. Manhole Inspections

A number of manholes were inspected throughout the town as outlined in Table 3.1 in Section 3.2.1. The relevant findings of these inspections are provided in the following sections.

Manhole #36

Manhole #36 is located on the south side of Church Avenue just east of Hickory Creek. The manhole is in a depression on a steep slope where surface runoff enters the creek. The manhole cover is positioned below the surrounding grade level. It is believed that substantial pooling and inflow of storm water through the manhole cover occurs during rain events.

Manhole #38

Manhole #38 is located approximately 25 meters north of the dead end on MacHenry Street. The manhole is positioned approximately 5 meters from the edge of the creek at the bottom of a 4 to 1 slope. There are two residential storm drain pipes discharging directly uphill from the manhole. It was found that during heavy rainfalls, the water level around the manhole rises above its cover. Consequently, significant inflow of water occurs through the holes in the manhole lid.

There had been no precipitation for the five days preceding the inspection, yet the ground was extremely wet. The water table is high in this area, and infiltration of groundwater will conceivably continue even after direct inflow has ceased.

Picture 4.1.: Location of Manhole #38

Picture 4.2.: Storm drains discharging towards manhole #38

Manhole #50

Manhole #50 is located on MacDonald Street, at the intersection of MacKenzie Street. Active infiltration of ground water was observed at numerous ladder rung connection slots.

Manhole #85

Manhole #85 is located on Eureka Street, near the intersection of Eureka and Clyde Streets. A sanitary sewer, servicing six new homes built on Clyde street has been connected to the sanitary system via this manhole. The 6" PVC sewer was inserted through a rough hole broken through the side of the manhole. The hole is approximately seven inches in diameter and located 1.5 meters below the finished road grade. The hole was parged to seal it, however the parging has subsequently cracked. These cracks allow water to enter the manhole at numerous points. The leaks are continuous and during periods of heavy rain resemble the flow from garden hoses. The inflow of water continued at reduced rates even during dry periods.

Manhole #86

Manhole #86 is located in the center of Argyle Street, directly north of manhole #85. Water was found to penetrate the side of the manhole at numerous ladder rung connection slots. The infiltration rate was a slow, steady drip.

Manhole #87

Manhole #87 is located at the intersection of Eureka Street and Ann Street. Active infiltration through the ladder rung connection slots was observed even during periods of no precipitation.

Manhole #88

Manhole #88 is located in the center of Eureka Street, just north of Ann Street. The bottom of this manhole was full of sludge, and water was seeping up from the bottom of the manhole.

Manhole #89

Manhole #89 is located at the intersection of Argyle Street and Ann Street. Infiltration of water into this deep manhole occurs continuously.

Manhole #92

This manhole is located at the corner of Argyle Street and Clyde Street. There is a pipe entering the manhole from the field to the south-east. During inspection, it was found that water was flowing through the pipe, even though there are no buildings or services located in the field.

Manhole #97

This manhole is located at the intersection of Ontario Street And Ann Street. Infiltration of water into this deep manhole occurred continuously.

Pumping Station Overflow

The pumping station overflow pipe is located about 2 m from the edge of Hickory Creek. The overflow pipe discharges excess waste water that can not be handled by the pumps at the pumping station to the creek. The purpose for originally installing the overflow was as protection against surcharging in the sewer system because of a lack of a back up power supply at the pumping station. Although, the overflow still provides a level of protection against sewer surcharging, it is not required due to the installation of a back up power supply.

The overflow pipe was found to be $^{3}/_{4}$ full of river sediment, indicating that the creek's hydraulic grade increases higher than the overflow pipe during some storm events. Consequently, water from the creek has entered the pump station, and is then pumped to the WWTP for treatment. This may be a significant source of short term inflow for a few storm events each year.

Picture 4.3.: Overflow Structure with Sediment

Picture 4.4.: Clyde Street Pumping Station Overflow in Relation to Hickory Creek

4.2.1.2. Camera Work

Review of existing camera work was completed as outlined in Section 3.2.1. The findings are provided in Table B.1. of Appendix B. The table includes street names, tape numbers, where the information is located, upstream and downstream manhole numbers, distance from the upstream manhole, and inflow/infiltration problems encountered.

This review of camera work has identified some problems in various pipes that may require attention. Inflow and infiltration problems such as cracked pipes, poor joints, etc., have been identified in sections of the sewer system on Argyle St., Broadway St., James St., MacNab St., Main St., Morris St., Ontario St., Queen St. and Union St.

4.2.1.3. Roof Leaders

An inspection to quantify the number of roof leaders that terminate below grade level was completed as outlined in Section 3.2.1. The tabulated data gathered during the roof leader inspection is provided in Table 4.2.

It was found that numerous homes in Forest have roof leaders that terminate below ground. In total, 317 individual residences, the downtown core, and 5 major community facilities have roof leaders that terminate below grade level. It is unknown how many of these leaders are illicitly connected to the sanitary line. A physical die test was performed at one home, and it was determined that this specific roof leader was attached directly to the storm sewer.

Table 4.2.: Buildings with Roof Leaders Terminating Below Grade

Frances		King St.	Park Lane	Union St.	MacNab	
1	23	Downtown	2	14	9	66
3	25	24	7	16	12	71
4	26	45	14	23	39	78
5	27	54	15	24	55	80
6	28	56	18	26	61	87
7	29	58	19	28	62	89
8	31	59	21	32	63	104
9	32	60	23	38	64	106
11	33	62	25	44	Church	
13	34	90	29	45	5	28
18	35	99	30	56	22	29
20	37	101	31	64	24	31
21	38	103	33	66	25	32
James St.		Ontario St.	Beechwood St.	Morris St.	Queen St.	
24	73	9	10	Forestview Villa	26	43
66	75	15	12	18	27	46
68	76	32	20	24	28	54
69	80	41	30	40		
		51	38	54		
Bayley	MacHenry	MacDonald St.	Townsend	Broadway	Washington	Clyde St.
3	40	32	6015	36	37	6
6	45	34	6046	50	42	15
8	59	39	Community	55	44	25
9	62	40	Center	57	47	32
11	63	43	6204	67	Albert St.	Woodside
12	64	44	6218	69	17	6
14	75	68	6226	104	25	8
15	82	92	6318			
25	83	93	6319			
Maple St.		Argyle St.	Wellington St.	Gore St.	Jefferson St.	Water
6	20	18	4	6	19	8
8	27	21	Forest Central	18	20	
10	29	28	High School	26	25	Stanley
Palace	32	39	17	46	30	1
	23					4
Main St.		(4) MacKenzie		Eureka St.	Ann St.	William
1	51	16	28	23	13	6
16	56	22	30	27	17	Forest
24	60	25	34	29	20	Legion
27	60	27	36	31	48	33
40	64	Prince St.	Arthur St.		51	George
Library	74	2	19			9
Firehall	77	22	28			
50	91	51	54			

Notes: Numbers represent addresses of individual residences
Non Residual Units are denoted by their appropriate name

4.2.1.4. Industrial Park Inspection

The industrial park located in the north-east corner of town was visually inspected. The industrial park's sewage system consists of a wet well for collection of waste water, followed by pumping via force main to the gravity sewer system. It was determined that at the time of inspection, only two facilities were present. These included the Ready-Mix Concrete Plant, and the Forest Agri-Services Building. The relevant findings from the inspection of each facility are provided below.

Ready-Mix Concrete Plant:

Two catch basins were found, both discharged to the north east towards the storm sewer. The storm drains were inspected and found to lead directly into the industrial parks storm sewer. Consequently, this property does not appear to contribute significant quantities of water via inflow to the sanitary system.

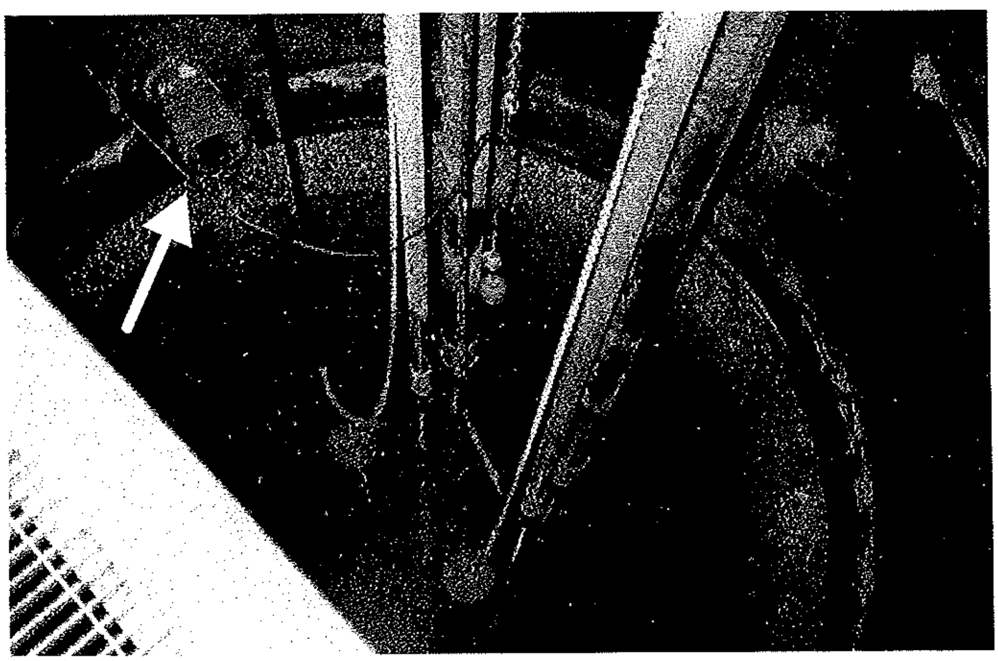
Forest Agri-Services:

A municipal drain was found 10 meters east of the building, two meters below the grade of highway #21. The drain had three inlets and one outlet pipe. One inlet is believed to be the buildings roof leader connection. Another inlet was found to a ditch drain, while the third was a tile drain from the field to the south of the building. The outlet pipe runs north out of the basin and heads directly perpendicular to the sanitary main. It is unknown if this outlet is connected to the sanitary sewer line. However, it is unlikely that this pipe would be connected, since the sanitary line is a force main.

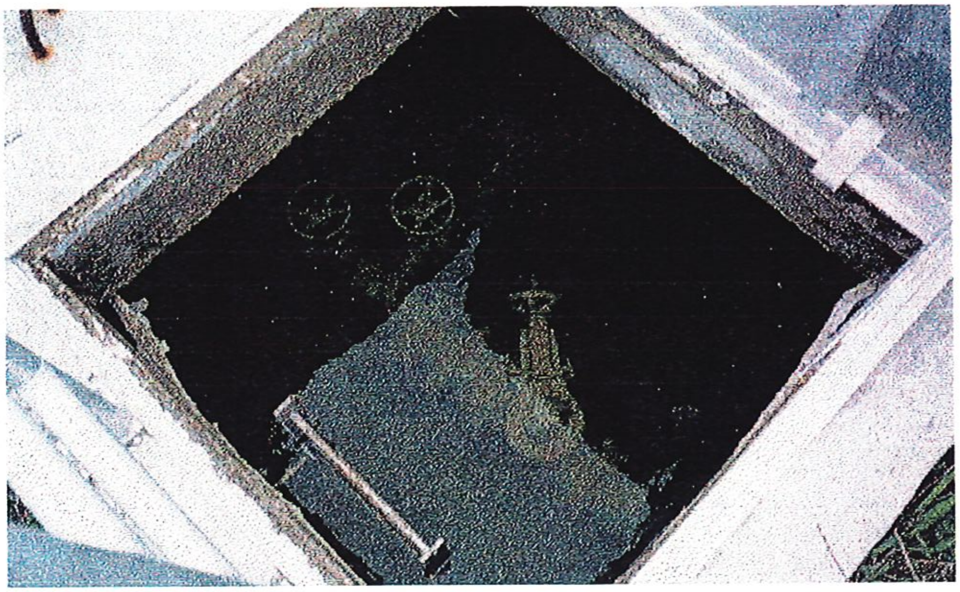
Wet Well:

The wet well at the industrial park was visually inspected at various times throughout the study. It was found that a steady flow of water entered the wet well from a pipe in the north side of the well. The pipe leads from a vacant field to the north of the wet well. The exact reason for this constant flow of water into the well is not known. However, it is suspected to be the result of infiltration, since there are no buildings or services in the specific field.

Inspection of the valve chamber at the wet well and pumping station revealed that the valve chamber was filled with ground water, indicating that the water table is high. Consequently, infiltration of ground water into all of the collection sewers in the industrial park likely occurs. It is recommended that the industrial park be inspected with a camera to access the condition of the pipes and joints in the park's sewers. This would allow for corrective measures to be taken if some deficient areas are located.



Picture 4.5.: Industrial Park Wet Well showing Constant Inflow from Pipe



Picture 4.6.: Industrial Park Valve Chamber Filled with Water

Wet Well Pumpage:

The wet well collects the waste water from the industrial park and pumps it into the gravity sewer system. This occurs only when the water level in the wet well reaches a predetermined level. The total weekly pump run times at the pumping station are recorded by the staff of OMI Inc. These figures have been provided by OMI Inc. for the study period and are provided in Table 4.3. It is seen that the wet well pumps at the industrial park run on average 12 minutes per week. This translates into approximately 10 m^3/d of waste water pumped from the industrial wet well into the Town's gravity sewer system (based upon a pump rate of 100L/s). This is an insignificant volume when compared to the flow rates experienced at the WWTP. Consequently, the industrial park does not appear to contribute significant volumes of waste water to the system, based on the pumping times. However, based on visual observations, infiltration is a problem in the industrial park. .

Table 4.3.: Industrial Park Pump Station Weekly Run Times

	Pump Run Times (hours)		
Weekending	**Pump #1**	**Pump #2**	**Total Run Time**
23-May-97	0.3	0.4	0.7
30-May-97	0.2	0.1	0.3
6-Jun-97	0.1	0.1	0.2
13-Jun-97	0	0	0
20-Jun-97	0.1	0.1	0.2
27-Jun-97	0.1	0.1	0.2
4-Jul-97	0	0.1	0.1
11-Jul-97	0.1	0	0.1
18-Jul-97	0.1	0.1	0.2
25-Jul-97	0.1	0.1	0.2
1-Aug-97	0	0.1	0.1
8-Aug-97	0.1	0	0.1
15-Aug-97	0	0.1	0.1
22-Aug-97	0.2	0.1	0.3
29-Aug-97	0.1	0.1	0.2
5-Sep-97	0.1	0.1	0.2
12-Sep-97	0	0.1	0.1
19-Sep-97	0.1	0.1	0.2
26-Sep-97	0.2	0.1	0.3
3-Oct-97	0.1	0.1	0.2
10-Oct-97	0.1	0.1	0.2
17-Oct-97	0	0	0
24-Oct-97	0.1	0.1	0.2
31-Oct-97	0.2	0.2	0.4
		Average =	0.2

The wet well was dye tested on December 9, 1997 by adding fluorosene to the wet well. The pumps were turned on and were allowed to run for approximately 2 minutes until the allowable draw down was reached. The pumps were shut off and the area around the wet well was inspected for signs of green (fluorosene) water. A green puddle was found later that afternoon by OMI Inc. staff about 12 feet from the wet well. This indicates that the force main is leaking, and should be repaired. It is recommended that the entire industrial park, including the force main be inspected. This would allow for identification of problem areas and the appropriate corrective actions could be taken.

4.2.2. Hydraulic Monitoring

Computerized flow meters were used to measure flow rates, as outlined in Section 3.2.2. The various sections of the sewer were monitored at the locations stated in Table 3.1. A complete set of site descriptions including location, rational for monitoring and any problems encountered during study are provided in Appendix C. The following sections provide the data and discussion for the flow measurements made at each site.

4.2.2.1. Meter Validation

A flow meter was placed at the outfall of the WWTP (Site #6) to compare the flow data generated by the meter to the WWTP screen dump reports (i.e. flow data compiled from the plant's SCADA system) provided by OMI Inc. The meter was in place for 19 days from June 27 to July 15. Two flow meters were periodically placed at manholes #86 and #95 from May 31 to October 6, 1997. The entire volume of waste water generated by the town passes through both manholes prior to entering the pumping station. Consequently, the flow rates from these two manholes were combined and compared to the WWTP data. The data from the WWTP, flow rates recorded by the meter at the WWTP, and combined flow rates recorded by the meters at the manholes on Eureka Street (#86) and just east of the Clyde Street pumping station (#95) are provided in Figure 4.5.

Figure 4.5. shows that initially (from May 31 to July 6) the data measured by the meters both at the WWTP, and the two manholes did not agree with the plant data (i.e. screen dump report). However, flow measurements were in reasonable agreement with the WWTP data, following this initial period.

The meter located at the WWTP was on average 17% different than the WWTP screen dump data over the period from July 7 to July 15, 1997. Flow rates obtained from the combination of flows at the two manholes, accounted for on average 90% of the WWTP flow. This indicates that the combination of flows at these two manholes is a good indication of sewer system flow rates. Further, all of these readings are within the suggested ±20% accuracy range for the flow meters.

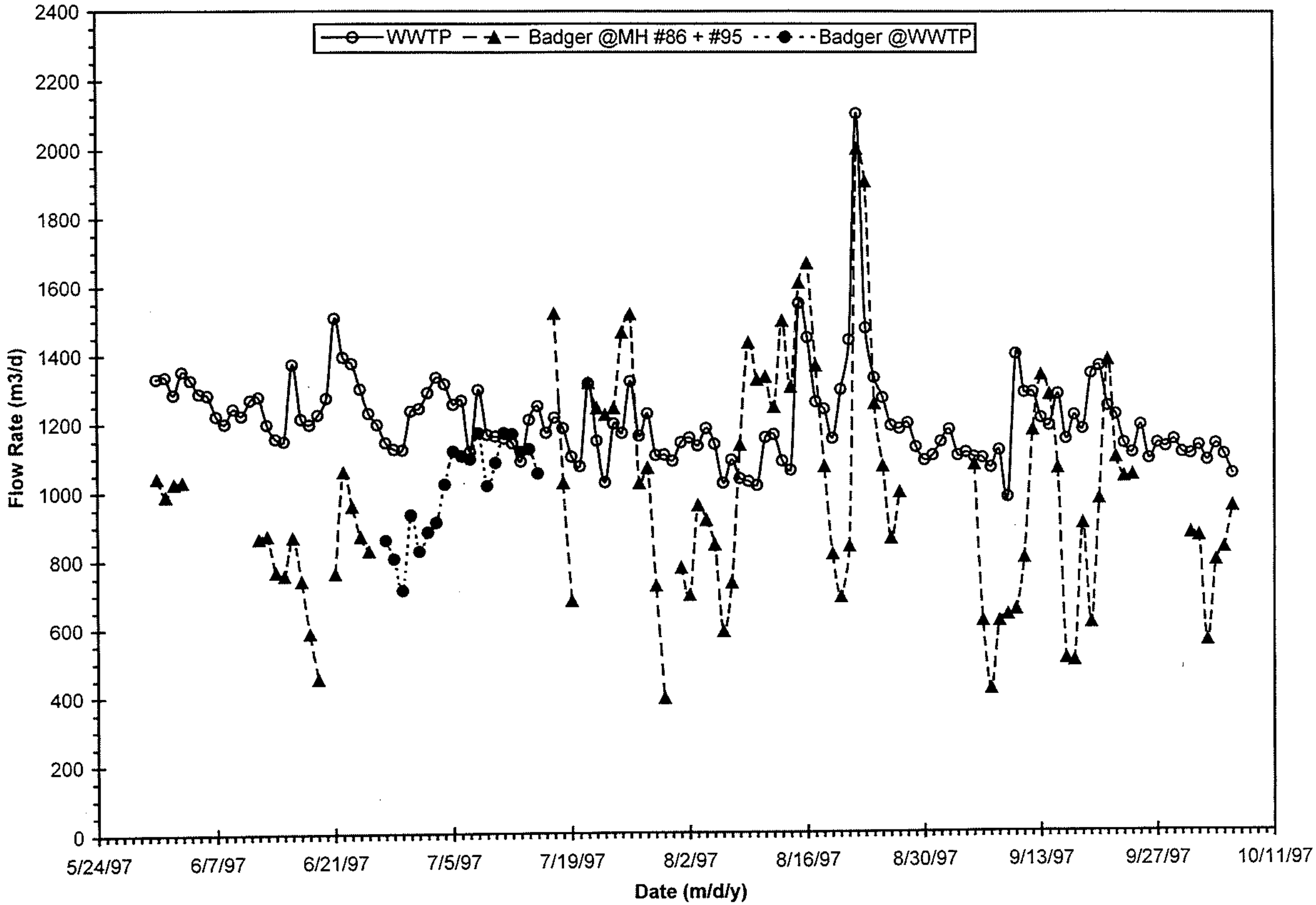


Figure 4.5.: Comparison of Flows Measured by Badger Meters to WWTP Flow Data

4.2.2.2. Flow Measurement

A flow meter was located in the manhole at the intersection of Queen Street and Ontario Street (#102) for the period of August 23 to September 3, 1997. The flow data recorded for manhole #102, manhole #86, and the WWTP, as well as precipitation data for the period are provided in Figure 4.6. There were 5 storm events, 3 insignificant events, and 2 small (6 & 14 mm) events during this time. The WWTP flows declined from 1450 m3/d to 1100 m3/d over the period. The flow rates at manhole #102 were measured over the entire study period. The meter located at manhole #86 collected data for the first 5 days of this study period prior to the batteries going dead. The projected data for manhole #86 was calculated by subtracting the flow rates measured at manhole #95 from the WWTP data. This provides some understanding of the flows rates at #86, since the combined flow of the two meters have been shown to be comparable to the WWTP data. The flow rates measured at manhole #86 were larger than the flow rates measured at manhole #102, with the exception of August 26, 1997. It is expected that flows at #86 would be larger than at #102 since it is downstream of #102. However, manhole #102 on average accounts for 40% of the flow at manhole #86. Consequently, 60% of the water flowing through manhole #86 is being introduced into the sewer downstream of #102. Based upon the size of the service areas for these manholes, it is estimated that between 50 and 300 m^3/d of extraneous flow is entering the sewer system between these two manholes.

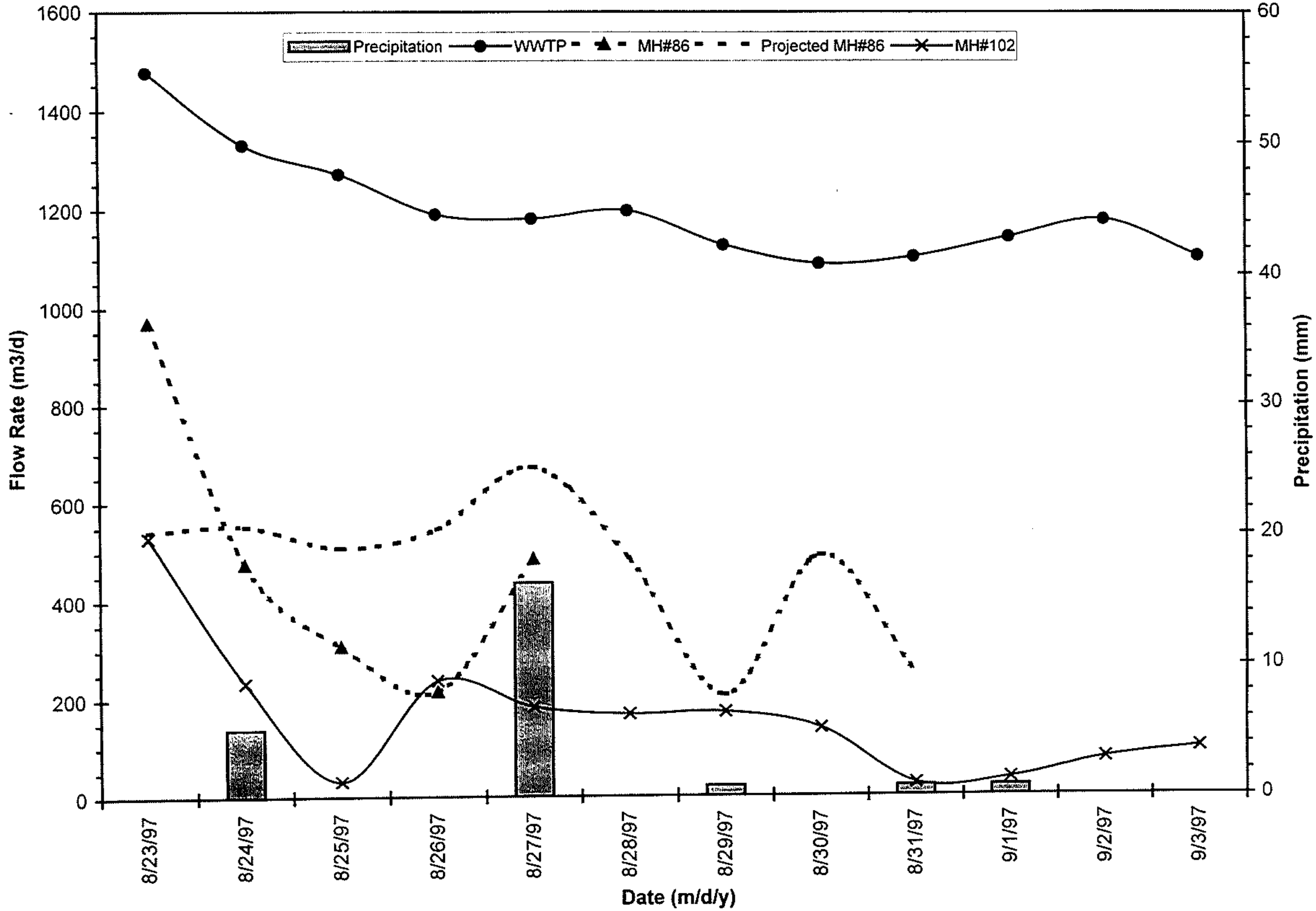


Figure 4.6.: Contribution of Flow at MH #102 to Flows at MH #86

A flow meter was placed in the manhole located on Ontario Street near the intersection of Clyde Street (#93) for the period of October 1, 1997 to October 7, 1997. The flow was very small and consequently the meter did not record any flow measurements over the period. Consequently, the contribution of the upstream service area to this manhole is considered insignificant. Therefore, the extraneous flow as discussed above does not initiate from this service area.

A flow meter was located at the manhole located on the south side of Church Avenue adjacent to the creek (#36) for the period from September 5 to September 14, 1997. The flow data for manhole #36, manhole #95, and the WWTP, as well as precipitation data for the period are provided in Figure 4.6. There were 6 storm events, 4 insignificant events, and 2 events of 13 & 16 mm over the period. The WWTP flows were steady with the exception of increase in flow due to the storms on September 9th and 10th. The meter at manhole #95 collected data for the entire period. However only flow rates from the first and last three days of the study were used because the other days recorded flows that were unrealistically low. It was assumed that the meter was temporarily fouled with solids at those times. The projected data for manhole #95 was calculated by subtracting the flows of manhole #86 from the WWTP data. This provides some understanding of the flow rates at #95, since the combined flow of the two meters has been shown to be comparable to the plant data. The flows at manhole #36 are provided over the entire study period.

The flow rates at both manholes #36 & #95 were approximately 650 m3/d over the entire period. The flow rates at manhole #36 were on average 95% of the flows at manhole #95. The service areas for manhole #36 is approximately half of the service area for manhole #95. Consequently, it was expected that the flow rates at manhole #36 would be approximately half of the flow at manhole #95. Therefore, inflow and infiltration of water is suspected to be occurring upstream of manhole #36.

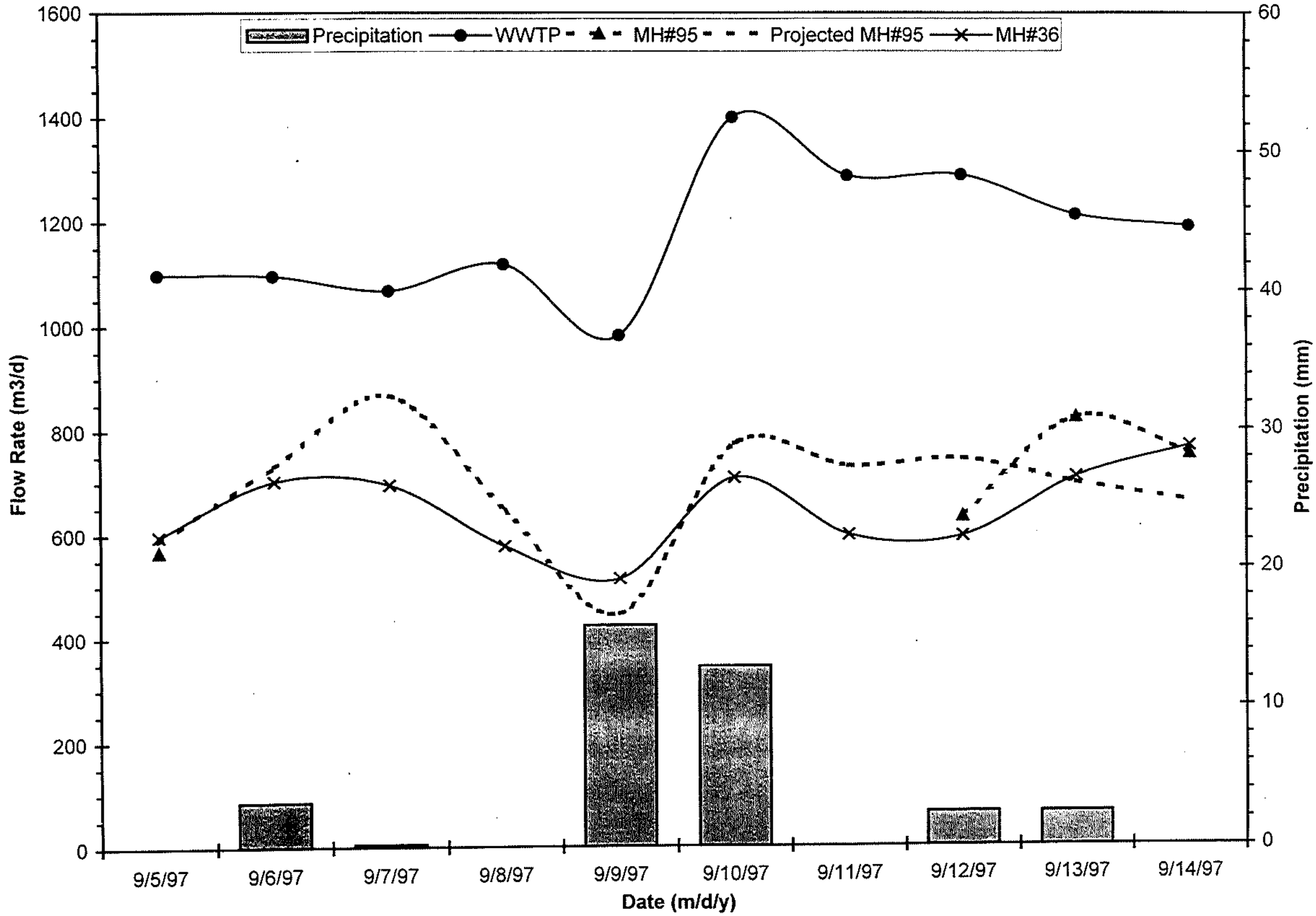


Figure 4.7.: Contributions of Flow at MH #36 to Flows at MH #95

There are three major service areas that contribute waste water to manhole #36. The industrial park flows from the force main can be isolated at a manhole located on Highway #21 (#185). A small section of town (north of the CP Rail line property) plus the industrial park can be isolate at a manhole located at the intersection of Broadway Street and Bayley Street (#45). A small section of town (west of MacDonald St. & south of MacKenzie St.) also contributes to manhole #36, which can be isolated at a manhole located at the intersection of MacKenzie Street and MacDonald Street (#50). The contributions of these service areas to the flow rate at manhole #36 will be addressed in the following sections.

A flow meter was installed at manhole #185 for the period of June 29 to July 25, 1997 to isolate the flows from the industrial park force main. The precipitation data, and the flow rates from the WWTP, manhole #95, and manhole #85 are provided in Figure 4.8.

There were 10 storm events over the entire study period, including 6 insignificant events, and 4 larger (8, 10, 12, & 22 mm) events. The WWTP flows remained fairly steady around 1400 m3/d, and the flows at manhole #95 were fairly steady around 600 m3/d. The industrial park flow rates were always less than 50 m3/d, and contributed at maximum 5% and 15% of the flow received at the WWTP and manhole #95 respectively.

The flow rates at the WWTP and manhole #95 increased due to the precipitation events on June 16 and 21 respectively. However, flow rates from the industrial park measured at manhole #185 maintained steady rates regardless of precipitation events. The waste water generated at the industrial park is collected in a wet well and periodically pumped via a force main into the sewer system upstream of manhole #185. Pump data provided by OMI Inc. indicates that the total run time for the pumps at the pumping station was 0.6 hours over the entire 28 day study period. This translates into approximately 8 m^3/d of flow from the wet well (based on a pump rate of 100L/s). The data indicates that the industrial park contributes insignificant flows to the sanitary system. However, the visual inspection has found that the structural integrity of the industrial park force main is in question. Therefore, some uncertainty exists as to the effectiveness of the force main at delivering all of the water collected in the wet well into the gravity sewer system.

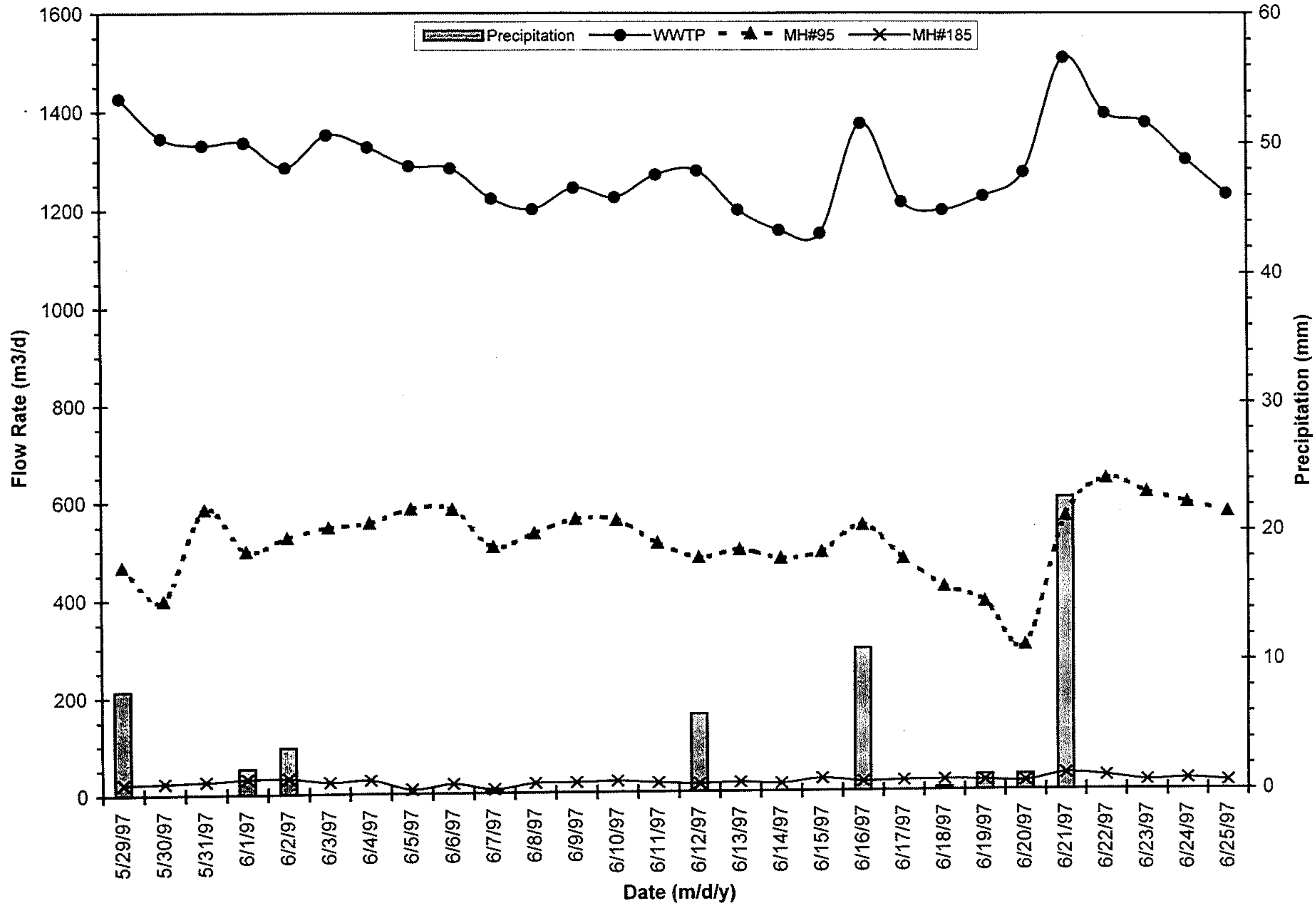


Figure 4.8.: Contribution of Flows at MH #185 to Flows at MH #95

A flow meter was installed at manhole #50 for the period of October 8 to October 28, 1997. The WWTP flows remained steady at 1100 m3/d for the first half of the study, and then increased to greater than 1400 m^3/d. The flows at manhole #50 were steady at less than 200 m3/d. The data indicates that this section of town did not contribute significant volumes of inflow and infiltration.

Visual observations were made at manhole #45 on Tuesday, October 7, 1997 and Wednesday, October 29, 1997. The flow rates through this manhole were extremely high on both occasions. The inlet pipe was flowing approximately ¾ full and the water appeared silty, similar to ground water. Another inspection on Friday, November 7, 1997, revealed reduced flow rates. It was believed that the instantaneous high flows were either coming from the industrial park or the overflow from the elevated potable water tank. The elevated water tank was inspected and it was found that the overflow discharges to the storm sewer system. Further verification should be undertaken to ensure that the water tank overflow is not connected to the sanitary sewer system. The industrial park pump weekly run times were obtained from OMI Inc. The data revealed that the pumps operated for only a total of 0.2 and 0.4 hours during the respective weeks that the first two inspections were conducted. However, it is conceivable that the observed high flow rates were the result of one of the pumps at the industrial park being in operation at the same instant that the first two inspections were conducted.

4.2.2.3. Surcharging

Hydraulic monitoring has uncovered that on two occasions during this study, portions of the sewer system have surcharged. The downstream portion of the system was surcharged on August 22, and August 27, 1997. The depth of water in manholes #86, #95 and #102 recorded by the flow meters are provided in Figure 4.9.

On August 22, 1997 at 4:00 AM the pipe upstream of manhole #95 became surcharged. The data suggests the level of water in the manhole reached 1.3 m above the invert of the sewer. The pipe upstream of manhole #86 then became surcharged at 6:00 AM, but data was not available to determine the peak height in this manhole.

On August 27, 1997 the sewer system surcharged again. The pipe upstream of manhole #95 became surcharged at 6:00 AM and reached a peak height of 2.5 m above the sewer invert. The pipe upstream of manhole #86 surcharged at 8:00 AM and reached a maximum peak of 2.5 m above the invert. Manhole #102 was also surcharged starting at 11:00 AM and reached a maximum height of 1 m above the invert.

The fact that the pipes (i.e. manholes) became surcharged in the order shown in the figure indicates that the water likely entered the sewer system from Hickory Creek. Subsequent to a phone conversation with OMI Inc., it was determined that precipitation events at Forest for both of these days were very intense in the morning. During the field visit by Proctor & Redfern Limited staff on September 4, 1997, the flow meter located in manhole #95 was no longer supported by the ladder rung, but was hanging down in the manhole by the safety strap. This indicates that the surcharge event actually occurred and that the levels in the manhole reached near to the top of the manhole and floated the monitor off of the ladder rung.

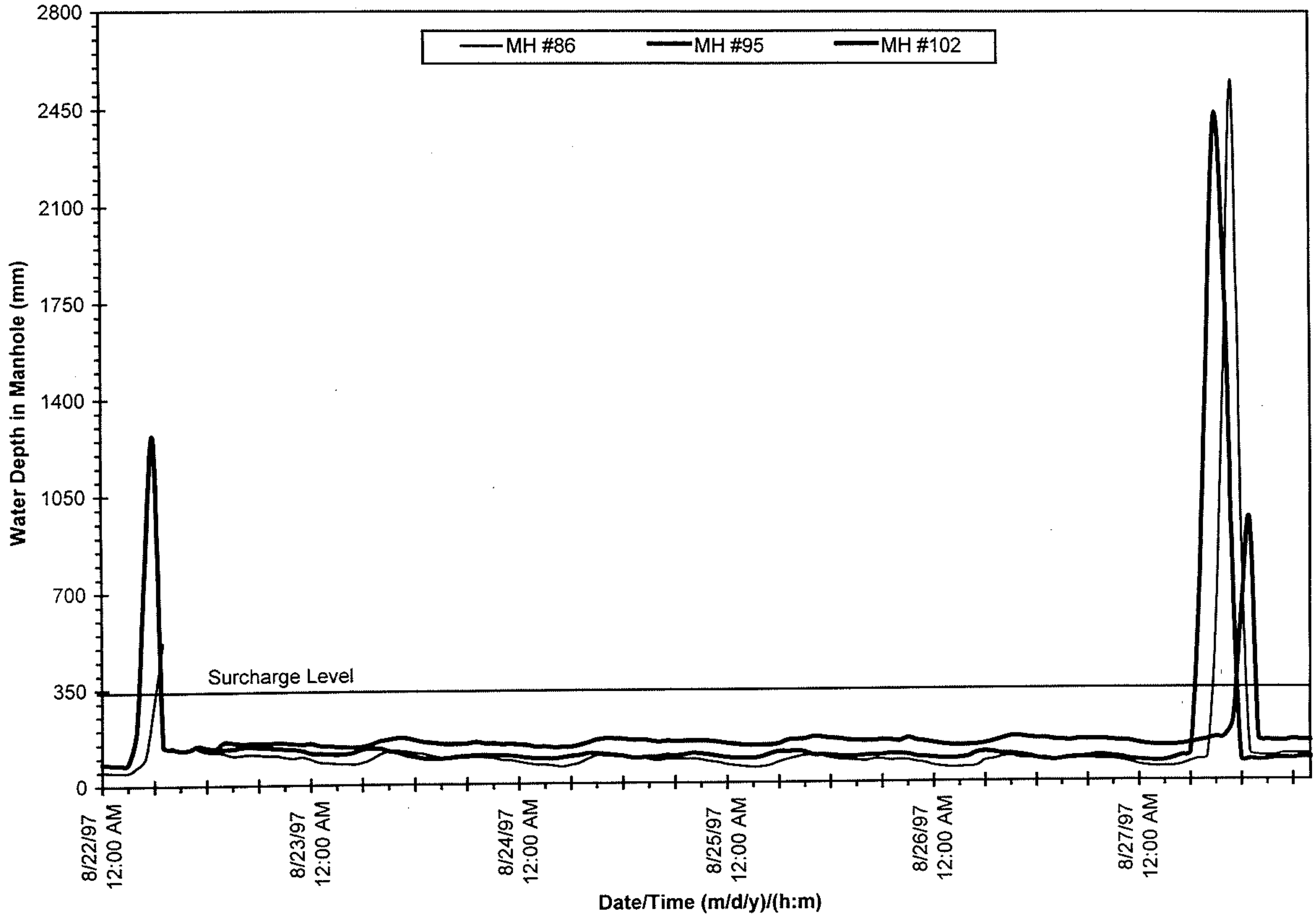


Figure 4.9.: Surcharging in the Town of Forest Sewer System

The recorded surcharging events and the visual inspection of the pumping station overflow indicate that the water from the Creek rises at times sufficiently high to enter the overflow pipe. This would result in the short term surcharging events that were observed. It is recommended that a one way flap valve be installed on the pumping station overflow to arrest the back flow of water from the creek into the sewer system.

4.3. Integrated Discussion

This section of the report integrates all of the findings of the study into an overall evaluation of the inflow and infiltration problems that exist in the Town of Forest's sanitary sewer system. The data collected from the various visual inspections and hydraulic monitoring indicates that certain sections of the sewer system contribute to the inflow and infiltration of water. A schematic overview of the sewer system is provided in Figure 4.10.

The various colored areas represent sections of the Town that are serviced by the identified manholes. These manholes were used to install the flow meters for the hydraulic monitoring of this project. The manholes depicted as black dots indicate the location of manholes in the system that were inspected and found to be contributing to inflow and infiltration of water. The sections of sewer pipe depicted with long grey ellipses indicate sections of the system that were identified as contributing to infiltration from the review of the camera work.

The hydraulic monitoring indicates that certain sections of the sewer system contribute to the inflow and infiltration of water into the sewer system. The section of Town identified as Magenta in Figure 4.10., downstream of manhole #102 has been shown to contribute to inflow and infiltration. The flow data is in agreement with the visual observations made in this area, since there are some manholes and pipes that have been identified as contributors.

The section of Town identified as Light Blue in Figure 4.10., immediately downstream of manhole #45 has been shown to contribute to inflow and infiltration. A large section of the sewer on Broadway St. has been shown to be in poor condition.

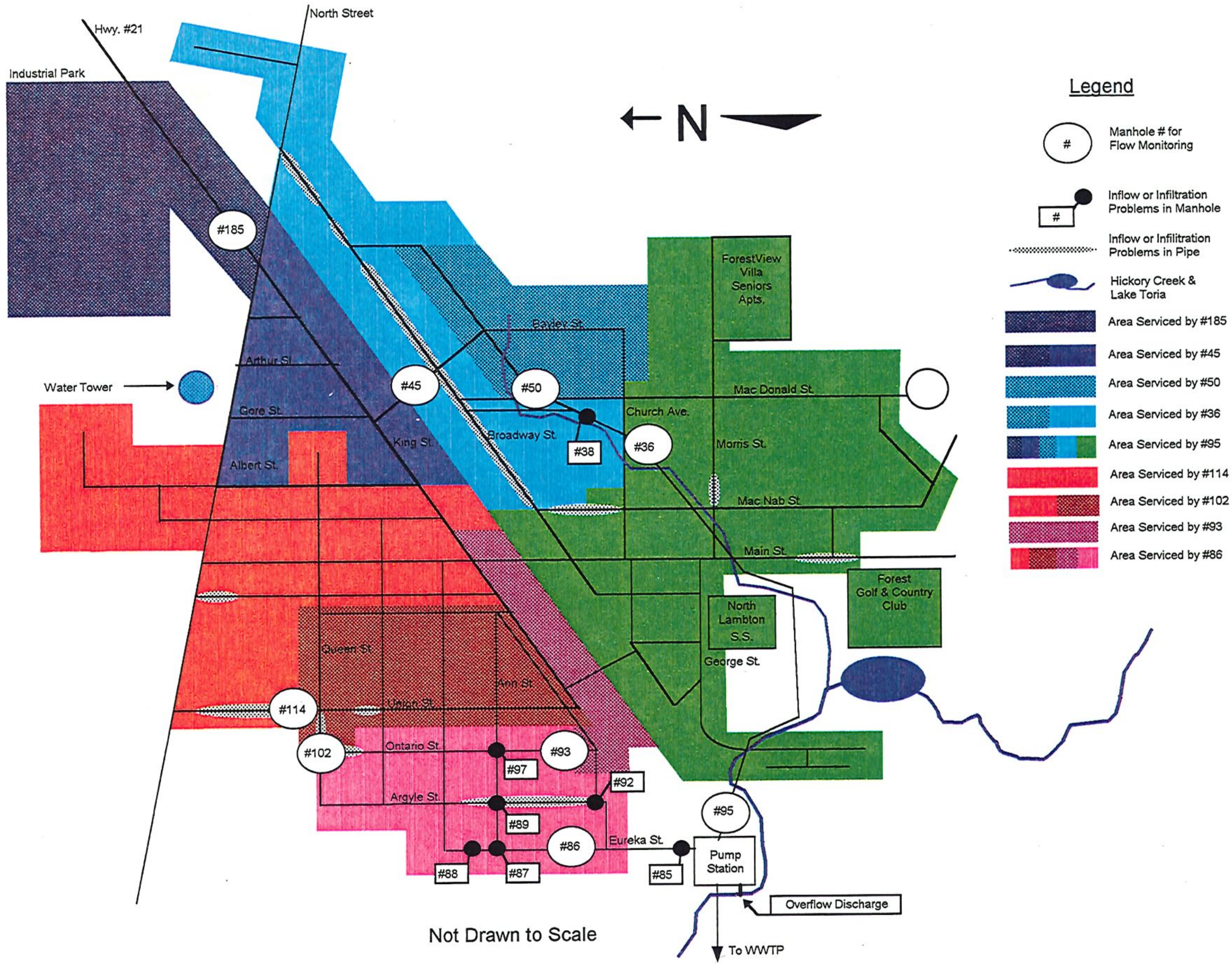


Figure 4.10.: Overview of Inflow and Infiltration in Town of Forest Sanitary Sewer System

5. ASSESSMENT OF CONTROL ALTERNATIVES

5.1. Repair of Manholes

Numerous manholes in the Town of Forest have been identified in Section 4.2.1.1. as contributing to inflow and infiltration. The integrity of these manholes needs to be improved such that active inflow and infiltration will be reduced or eliminated. Manholes that allow water to infiltrate through ladder rung connection slots and poor lateral connections such as manholes #50, #85, #86 #87, #88, #89, #92 and #97should be repaired. This will decrease the total quantity of water entering the sewer system during storm events. Manholes that are located in land depressions, such as manholes #36 and #38 should be modified by adding a riser to increase the level of the manhole cover to alleviate direct inflow through the lid. Another technique involves installing a pan to stop the direct inflow of water to the sewer system. These techniques will decrease the quantity of water entering the sanitary system. This work is relatively inexpensive and can be completed by the local Public Works Department at marginal cost.

5.2. Private Side Reduction

Disconnection of roof leaders from the sanitary system and directing the discharge onto the ground surface reduces the volume of runoff entering the sanitary sewers. It can significantly reduce the total inflow volume and may result in significant reductions in peak flow following rainfall events. Elimination of these connections may significantly reduce the volume of water entering the system via direct inflow. However, the effectiveness of roof leader disconnection is variable. Disconnection programs in other municipalities have not achieved much more than a 50% success rate. This process may be difficult to accomplish if storm sewers are not available and lot grading does not facilitate surface discharge.

It is apparent that a large number of buildings in the Town of Forest have roof leaders that terminate below grade level as identified in Section 4.2.1.3. However, it is uncertain as to the number of these roof leaders that are connected to the sanitary sewer system. Consequently, private side reduction is not anticipated to provide a significant reduction in inflow and infiltration.

5.3. Inlet Controls

Inlet controls can be effective at reducing short duration peak flows from entering specific areas of the sewer system. It is believed that Hickory Creek can rise to levels that are higher than the overflow pipe for the pumping station. The visual inspection revealed evidence that this phenomenon has occurred in the past. This was substantiated during the hydraulic monitoring exercise when portions of the sewer system became surcharged on two different occasions. The data presented in Section 4.2.2.2. suggests that the source of the water was from the creek.

Consequently, it is recommended that a one way flap valve be installed at the pumping station overflow to ensure that the creek can not backup into the pumping station. This will reduce the volume of water entering the WWTP during large storm events when the creek level rises higher than the pumping station overflow.

5.4. Reline Existing Sewer

This alternative involves the relining of existing sewer pipes in place (e.g. polyethylene slip lining or in situ form lining). It restores the structural integrity of the existing sewer and reduces infiltration through cracks and pipe joints, which will reduce the total infiltration volume of water reaching the treatment plant. There is also limited disruption to the community during the construction phase of the work.

Relining sewers is an effective method to reduce infiltration through cracks and pipe joints. However, the overall effectiveness of the technique at reducing infiltration through lateral connections depends on method of connection and quality of workmanship. Further, large lengths of sewers must be relined in order to have significant impact on infiltration rates.

5.5. Replace Existing Sewer

This alternative involves the construction of new sewers to replace existing sewer pipes. It restores the structural integrity of the sewer system and reduces infiltration, which will reduce the total volume of water received by the treatment plant. Replacing existing sewers is an effective method to reduce infiltration through cracks, joints, and lateral connections (assuming proper workmanship). However, large lengths of sewers must be replaced in order to have a significant impact on flows. There is also considerable cost and disruption to the community during construction.

It is recommended that the structural integrity of the underlain sewer pipe be ascertained particularly in the problem areas identified in Figure 4.10. when road reconstruction projects are undertaken by the Town of Forest. If required, concurrent sewer replacement and road reconstruction will result in reduced overall construction costs.

6. CONCLUSIONS AND RECOMMENDATIONS

Inflow and infiltration are problems that exist in the Town of Forest's sanitary sewer system. Historical data indicates that high daily flow rates were experienced back as far as 1990. The comparison of potable water consumption to waste water generation indicates that there is significant inflow and infiltration occurring that has worsened from November 1995 to present. The flow rate of inflow and infiltration has been estimated to range up to 800 m^3/d, which contributes up to 54% of the total flow at the waste water treatment plant.

Visual inspections and hydraulic monitoring have identified certain areas of the Town's sanitary sewer system that require attention. The two major problem areas are found on Broadway St. and the section of Town west of Union St. These areas have manholes and pipes that require corrective action to remedy the problem. These actions include installing manhole pans or risers to stop the direct inflow of water to the system. Further, the structural integrity of many manholes should be improved (i.e. parging active leaks and ladder rung slots) to decrease infiltration into the sewer system. Sewer pipes should also be replaced concurrently with road reconstruction projects to minimize installation costs.

The pumping station overflow pipe that discharges to Hickory Creek has been identified as a problem location. It is recommended that a one way flap valve be installed on the overflow pipe to stop the back flow of water from the creek to the pumping station and treatment plant during large storm events.

The above mentioned corrective measures should be undertaken even though there is currently reserve capacity at the treatment plant. On average the WWTP receives 300 m^3/d of water from inflow and infiltration sources. In future, the cost of a plant expansion to recapture that capacity would be in the neighbourhood of $1,000,000 (based upon the construction cost of $6,000,000 for 1800 m^3/d capacity). It is therefore economically justifiable to spend a small fraction of the cost of a plant upgrade now to regain the lost capacity from inflow and infiltration. Further, the MOEE uses the total flow to a WWTP to calculate the per capita waste water production for a community for the purposes of new development. It is therefore worth spending money proactively to aggressively address this issue rather than in a reactive mode in the future.

On a positive note, the WWTP is currently operating with only one treatment train in service (i.e. half capacity), despite the high flow rates. It is recommended that a request to the MOEE be made on behalf of the Town of Forest to have the WWTP rated at a higher capacity. This would increase the rated capacity of the treatment plant and would allow for future growth in the Town of Forest.

An active inflow and infiltration abatement program would likely be seen as a positive step towards responsible waste water management by the MOEE. Therefore, it is recommended that the remedial action as discussed above be implemented. A detailed list of the remedial actions and the respective costs are provided in Table 6.1. A short term (i.e. immediate) action plan is presented first, followed by a medium term action plan follows.

Table 6.1.: Remedial Action Plan and Associated Costs

Short Term (1 to 2 years)

Action	**Associated Costs**
• Install Flap Valve at Clyde Street Pumping Station Overflow	$ 3,000.00
• Install Pans @ Manholes #36 and #38	$ 1,400.00
OR	
• Install Risers @ Manholes #36 and #38	$ 1,200.00
• Repair Manholes #50, #85, #86, #87, #88, #89, #92 and #97 (i.e. seal active infiltration points - ladder connection slots)	$ 4,000.00
• Apply to MOEE to Increase the Rating of the WWTP	$ 5,000.00
• Camera the Industrial Park Sewers	$ 1,750.00
TOTAL $ 14,950.00 to $	**15,150.00**

Medium Term (2 to 10 years)

Action	**Associated Costs**
• Replace Existing Sewer (Cost per 100 m of Sewer)	$ 12,000.00

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APPENDIX A: HISTORIC FLOW DATA FOR TOWN OF FOREST'S SANITARY SEWER SYSTEM

Historic Flow Data

			Monthly		
Date	Days	Total Volume (m^3)	Average Day Flow (m^3/d)	Max. Day Flow (m^3/d)	Min. Day Flow (m^3/d)
1/82	31	30472	983	1491	859
2/82	28	24144	862	959	746
3/82	31	39996	1290	2046	809
4/82	30	38814	1294	1850	973
5/82	31	29904	965	1082	805
6/82	30	26994	900	1027	723
7/82	31	25976	838	1364	591
8/82	31	25567	825	1182	636
9/82	30	25658	855	1032	759
10/82	31	25499	823	1264	514
11/82	30	27085	903	1141	741
12/82	31	32931	1062	1287	873
1/83	31	29404	949	1105	796
2/83	28	27321	976	1200	882
3/83	31	28581	922	1041	827
4/83	30	30472	1016	1227	918
5/83	31	33399	1077	1614	941
6/83	30	29531	984	1214	791
7/83	31	27235	879	1114	732
8/83	31	26290	848	1241	727
9/83	30	25912	864	1141	755
10/83	31	26058	841	914	764
11/83	30	24912	830	1146	764
12/83	31	31236	1008	1159	786
1/84	31	27244	879	991	818
2/84	29	27326	942	1487	
3/84	31	33927	1094	1273	759
4/84	30	32195	1073	1127	964
5/84	31	30686	990		855
6/84	30	31763	1059	1127	
7/84	31	28472	918	1046	786
8/84	31	27894	900	1014	773
9/84	30	28767	959	1146	873
10/84	31	27294	880	968	814
11/84	30	31617	1054	1391	764
12/84	31	29754	960	1077	609
1/85	31	18379	593	741	536
2/85	28	20284	724	1241	568
3/85	31	26080	841	950	682
4/85	30	21853	728	873	586
5/85	31	18807	607	646	555
6/85	30	18093	603	900	559
7/85	31	18411	594	636	573
8/85	31	18675	602	686	573
9/85	30	23857	795		

10/85	31	27467	886	1114	818
11/85	30	33795	1126	1455	859
12/85	31	31831	1027	1177	877
1/86	31	31690	1022	1314	909
2/86	28	28617	1022	1132	932
3/86	31	36736	1185		
4/86	30	29826	994		505
5/86	31	30008	968	1132	882
6/86	30	28863	962	1232	909
7/86	31	29067	938	977	868
8/86	31	28408	916	1046	873
9/86	30				
10/86	31				
11/86	30				
12/86	31	35313	1139	1305	1005
1/87	31	31904	1029	1127	946
2/87	28	27717	990	1146	946
3/87	31	31981	1032	1200	914
4/87	30	32918	1097	1427	982
5/87	31	29899	964	1009	909
6/87	30	20639	688		
7/87	31	24717	797		
8/87	31				
9/87	30	28408	947	1123	927
10/87	31	32458	1047	1173	973
11/87	30	32554	1085	1296	986
12/87	31	39309	1268	1405	1118
1/88	31	34059	1099	1173	1014
2/88	29	32640	1126	1246	1041
3/88	31	40014	1291		
4/88	30	36018	1201	1255	1114
5/88	31	34472	1112	1150	1064
6/88	30	31399	1047	1382	946
7/88	31	31426	1014	1223	932
8/88	31	31508	1016	1073	959
9/88	30	30358	1012	1155	946
10/88	31	34440	1111	1427	991
11/88	30	36541	1218	1387	1077
12/88	31	36700	1184	1318	1050
1/89	31	37755	1218	1350	1146
2/89	28	32349	1155	1250	1100
3/89	31	39314	1268	1527	1127
4/89	30	37750	1258	1409	1187
5/89	31	38077	1228	1491	1150
6/89	30	35322	1177	1396	1077
7/89	31	35022	1130	1187	1077
8/89	31	33727	1088	1200	1041
9/89	30	33931	1131	1187	1046
10/89	31	33577	1083	1227	1073

11/89	30	36023	1201	1637	1105
12/89	31	34236	1104	1191	1027
1/90	31	40578	1309	2041	1141
2/90	28	36318	1297	1646	1173
3/90	31	41232	1330	1482	1191
4/90	30	40414	1347	1709	1255
5/90	31	38786	1251	1496	1132
6/90	30	35477	1183	1341	1096
7/90	31	34090	1100	1173	1041
8/90	31	35136	1133	1459	1046
9/90	30	33927	1131	1423	1027
10/90	31	37845	1221	1677	1073
11/90	30	35836	1195	1791	1096
12/90	31	39282	1267	1659	1150
1/91	31	38823	1252	1441	1100
2/91	28	34800	1243	1550	1114
3/91	31	42010	1355	1614	1209
4/91	30	37086	1236	1541	1146
5/91	31	53143			1127
6/91	30	36482	1216	1250	1073
7/91	31	31613	1020	1150	1009
8/91	31	33954	1095	1387	1032
9/91	30	32290	1076	1246	1009
10/91	31	34904	1126	1173	1032
11/91	30	35813	1194	1382	1050
12/91	31	36868	1189	1391	1041
1/92	31	37723	1217	1309	1164
2/92	29	38841	1339	1818	1155
3/92	31	43687	1409	1546	1309
4/92	30	46546	1552	2318	1259
5/92	31	41228	1330	1582	1232
6/92	30	36100	1203	1368	1132
7/92	31	37182	1199	1487	1059
8/92	31	37609	1213	1346	1073
9/92	30	28158	939	1468	841
10/92	31	26603	858	1137	600
11/92	30	30431	1014	2114	846
12/92	31	27076	873	1373	791
1/93	31	31317	1010	2014	814
2/93	28				
3/93	31				
4/93	30	32140	1071	1514	909
5/93	31	27658	892	1214	818
6/93	30	25544	851	1259	764
7/93	31	23516	759	823	718
8/93	31	21975	709	768	677
9/93	30	23544	785	1009	714
10/93	31	24017	775	855	709
11/93	30	23512	784	850	741

12/93	31	24476	790	850	746
1/94	31	24312	784	1073	714
2/94	28	23289	832	1082	750
3/94	31	29140	940	1441	773
4/94	30	29899	997	1427	800
5/94	31	29281	945	1127	832
6/94	30	24603	820	1018	741
7/94	31	24248	782	836	718
8/94	31	23757	766	868	709
9/94	30	22430	748	827	723
10/94	31	23939	772	800	723
11/94	30	24071	802	868	746
12/94	31	27735	895	1105	768
1/95	31	30849	995	1282	791
2/95	28	25262	902	1096	809
3/95	31	34277	1106	1432	905
4/95	30	29717	991	1450	868
5/95	31	30145	972	1264	909
6/95	30	26176	873	1055	782
7/95	31	24494	790	864	727
8/95	31	22866	738	850	709
9/95	30	22171	739	796	696
10/95	31	24553	792	1514	732
11/95	30	27512	917	1441	736
12/95	31	27885	900	941	850
1/96	31	29067	938	1209	818
2/96	29	26512	914	1082	791
3/96	31	28590	922	1027	814
4/96	30	34145	1138	1646	868
5/96	31	38155	1231	1446	946
6/96	30	37014	1234	2959	882
7/96	31				
8/96	31				
9/96	30	50726	1691	3106	1312
10/96	31				
11/96	30		1460	2957	1142
12/96	31	48966	1580	2424	1260
1/97	31	44807	1445	1768	1249
2/97	28	38886	1389	2260	995
3/97	31	39721	1281	1658	443
4/97	30	35200	1173	1458	690
5/97	31	48230	1556	2124	1216
6/97	30	37743	1258	1509	784
7/97	31	36887	1190	1335	1027
8/97	31	37896	1222	2105	1017
9/97	30	35372	1179	1366	982
10/97	31	39670	1280	2011	1050
11/97	30	36487	1216	1390	1113

APPENDIX B: DATA FROM REVIEW OF EXISTING CAMERA WORK

Table B.1.: Summary of Camera Work: Locations of Inflow/Infiltration Problems

Street Name	Tape #	M.H. # U/S-D/S	Distance (m)	Inflow and Infiltration Problems Encountered
Argyle St.	95001-GT	91-89	23.2	broken pipe (fixed) and infiltration runner
	95-01	92-91	34.6	cracked pipe
	95-01	91-89	22.2	active infiltration
	95-01	89-90	20.4	possible active infiltration
Broadway	96001	44-43	23.9	infiltration runner
	91-04	45-44	29.9	possible active infiltration at lateral
	91-04	45-44	38.6	spiral crack
	91-04	45-44	38.6	possible active infiltration
	91-04	45-44	49.2	active infiltration at lateral
	91-04	45-44	69.9	possible active infiltration at lateral
	91-04	45-44	76.5	possible active infiltration at lateral
	91-04	44-43	23.6	cracked pipe
	91-04	44-43	24.3	active infiltration at lateral
	91-04	44-43	39.3	active infiltration at lateral
	91-04	44-43	50.3	possible active infiltration at lateral
	96002	44-43	23.9	defective connection
	96002	44-43	31.1	circumferential fracture
	96002	44-43	44.1	infiltration runner
	96002	43-42	40.6	infiltration runner
	96002	43-42	61.4	circumferential fracture
	91-01 GT	45-44	49.1	active infiltration at lateral
	91-01 GT	44-43	24.3	infiltration at connection visible leak
	91-01 GT	44-43	32	infiltration at joint visible leak
	91-01 GT	43-42	64.1	joint or spiral crack visible leak
	91-02	44-43	24	possible break
	91-02	43-44	4.2-7.6	spider crack
	91-03	35-41	28.3	spiral crack
	91-03	35-41	57.2	spiral crack
	91-03	49-48	10.6	active infiltration at joint
	91-03	49-48	45.2	chipped joint
	91-03	47-46	87.9	cracked pipe
	91-03	45-44	29.9	possible active infiltration
	91-03	45-44	49	active infiltration
	91-03	44-45	20.2	spiral crack
	91-03	44-43	0.5	possible active infiltration
	91-03	43-44	41.3	possible active infiltration at lateral
	91-03	43-44	72.9	possible active infiltration at lateral
	91-03	43-44	86.6	calcite at joint possible leak
	91-03	41-42	7.8	cracked pipe
James St.	95001 GT	144-143	83.9	defective connection (fixed)
	95-01	144-145	93.3	cracked pipe
MacNab St.	94-01	34-203	22.8	possible active infiltration
	94-01	34-203	27.3	possible active infiltration
	94-01	34-33	23.8	possible active infiltration

Table B.1.: Summary of Camera Work: Locations of Inflow/Infiltration Problems (con't.)

Street Name	Tape #	M.H. # U/S-D/S	Distance (m)	Inflow and Infiltration Problems Encountered
Main St.	89-1	4-5	57.8	pipe wall damage
	89-1	4-3	64.9	active infiltration
	89-1	2-1	0.5	infiltration through lift holes in manhole
	89-1	2-1	106.3	infiltration through joints and lift holes
Morris St.	95001 GT	30-22	48.5	defective connection (fixed)
	95001 GT	30-22	82.8	defective connection (fixed)
	95001 GT	30-22	83.2	defective connection (fixed)
	95-01	22-30	22.9	active infiltration
Ontario St.	95001 GT	99-101	29.5	defective connection (fixed)
	95001 GT	99-101	33.5	defective connection (fixed)
	95001 GT	99-101	57.5	defective connection (fixed)
	95-01	102-101	34.2	active infiltration at lateral
	95-01	102-101	52.8	active infiltration at lateral
Queen St.	95-01	113-102	66.4	possible active infiltration
Union St.	94-01	189-111	34.9	possible active infiltration
	94-01	113-114	35.9	possible active infiltration
	94-01	113-114	56.9	active infiltration
	94-01	115-115A	44.3	active infiltration

APPENDIX C: HYDRAULIC MONITORING SITE DESCRIPTION

Table C.1.: Site Descriptions for Badger Flow Meter Placement

Site/Manhole #	• 1/188
Location	• Industrial Park Force Main
Reason	• selected to isolate the industrial park flows
Problems	• minimal flow; meter could not be calibrated correctly
Site/Manhole #	• 2/85
Location	• Corner of Clyde and Eureka Streets
Reason	• selected to isolate the north half of the town
Problems	• internal drop structure; water falling from structure directly hit the probe & depth readings were inaccurate
Site/Manhole #	• 3/95
Location	• Adjacent to Clyde St. Pumping Station
Reason	• selected to isolate the south half of town
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 4/185
Location	• Corner of King St. and Townsend Rd.; Knechtel's Groceries
Reason	• correct problem encountered at site #1; first manhole south of #188 which contained enough flow to calibrate meter
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 5/86
Location	• Center of Eureka St.
Reason	• correct problem encountered at site #2
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 6/Outflow Manhole for WWTP
Location	• Located on gravel access road for WWTP
Reason	• verify screen dump reports
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 7/102
Location	• Intersection of Ontario St. and Queen St.
Reason	• flow contribution; bordered by Eureka St., Clyde St. & Ontario St.
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 8/36
Location	• Located on the south side of Church Ave.; east of creek
Reason	• isolate the eastern section of the towns south sewer system
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 10/209
Location	• Corner of Church Ave. Bayley St.
Reason	• flooding was reported in this section of town
Problems	• minimal flow; meter could not be calibrated correctly
Site/Manhole #	• 11/93
Location	• Center of Ontario St.; north of Clyde St.
Reason	• further isolation of the north western section of the sewer system
Problems	• minimal flow, meter did not record data

Table C.1.: Site Descriptions for Badger Flow Meter Placement (cont.)

Site/Manhole #	• 13/45
Location	• Intersection of Broadway St. And Bayley St.
Reason	• further isolation of the south eastern section of the sewer system
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 14/50
Location	• MacDonald St. at intersection of MacKenzie St.
Reason	• further isolation of the south eastern section of the sewer system
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 21/114
Location	• Union St. - north of Queen St.
Reason	• further isolation of the north western section of the sewer system
Problems	• no problems encountered; probe did not accumulate solids
Site/Manhole #	• 20/87
Location	• Intersection of Eureka St. And Ann St.
Reason	• further isolation of the north western section of the sewer system
Problems	• no problems encountered; probe did not accumulate solids

APPENDIX D: SAMPLE DATA SET FOR HYDRAULIC MONITORING

Study Name/Site I.D.

Town of Forest Manhole #36

Date 09/04/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
13:00	65.50	0.16	2.13	
14:00	82.91	0.19	2.75	
15:00	86.45	0.40	6.03	
16:00	87.36	0.31	4.74	
17:00	92.51	0.26	4.31	
18:00	98.21	0.34	6.10	
19:00	105.85	0.53	11.01	
20:00	96.49	0.39	6.85	
21:00	97.53	0.31	5.51	
22:00	97.06	0.33	5.85	
23:00	89.08	0.29	4.62	

Min Level	**7.44**	@13:40	Max Level	**120.45**	@19:25	Avg Level	**90.81**
Min Velocity	**0.06**	@13:40	Max Velocity	**0.92**	@19:25	Avg Velocity	
Min Flow	**0.03**	@13:40	Max Flow	**21.77**	@19:25	Avg Flow	**5.45**
Total Volume	**210,532.03**	Liters					

Study Name/Site I.D.

Town of Forest Manhole #36

Date 09/05/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	88.85	0.31	4.84	
01:00	68.88	0.33	3.66	
02:00	71.04	0.36	4.20	
03:00	65.46	0.36	3.71	
04:00	58.26	0.28	2.48	
05:00	62.82	0.28	2.81	
06:00	87.82	0.31	4.79	
07:00	110.87	0.68	14.55	
08:00	113.03	0.62	13.63	
09:00	105.74	0.48	9.54	
10:00	107.79	0.50	10.48	
11:00	117.94	0.81	18.71	
12:00	100.83	0.35	6.54	
13:00	98.89	0.30	5.54	
14:00	95.92	0.32	5.55	
15:00	95.23	0.34	5.82	
16:00	94.09	0.33	5.70	
17:00	95.24	0.37	6.38	
18:00	94.78	0.37	6.33	
19:00	93.88	0.35	5.94	
20:00	92.04	0.39	6.39	
21:00	93.98	0.33	5.56	
22:00	91.13	0.34	5.51	
23:00	93.75	0.44	7.51	

Min Level	55.18	@05:10	Max Level	119.99	@11:25	Avg Level	91.52
Min Velocity	0.19	@05:10	Max Velocity	0.86	@11:40	Avg Velocity	0.39
Min Flow	1.53	@05:10	Max Flow	19.90	@11:25	Avg Flow	6.88
Total Volume	596,412.25	Liters					

Study Name/Site I.D.

Town of Forest   Manhole #36

Date 09/06/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	86.56	0.54	8.25	
01:00	75.27	0.43	5.45	
02:00	71.06	0.41	4.75	
03:00	72.87	0.45	5.48	
04:00	69.67	0.39	4.37	
05:00	70.81	0.40	4.59	
06:00	71.73	0.44	5.14	
07:00	86.91	0.51	7.65	
08:00	106.08	0.45	8.91	
09:00	104.25	0.56	11.05	
10:00	103.90	0.62	12.06	
11:00	101.85	0.55	10.52	
12:00	99.70	0.57	10.44	
13:00	98.90	0.58	10.59	
14:00	95.35	0.40	7.01	
15:00	94.10	0.46	7.91	
16:00	89.64	0.49	7.73	
17:00	92.95	0.41	6.92	
18:00	94.09	0.38	6.46	
19:00	94.79	0.33	5.72	
20:00	94.11	0.65	11.01	
21:00	93.88	0.67	11.45	
22:00	91.01	0.69	11.28	
23:00	89.42	0.66	10.55	

Min Level	**68.40**	@04:10	Max Level	**111.35**	@08:25	Avg Level	**89.54**
Min Velocity	**0.28**	@19:55	Max Velocity	**0.74**	@21:40	Avg Velocity	**0.50**
Min Flow	**3.86**	@04:10	Max Flow	**12.94**	@10:55	Avg Flow	**8.14**
Total Volume	**703,024.72**	Liters					

Study Name/Site I.D.

Town of Forest   Manhole #36

Date 09/07/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	87.25	0.63	9.76	
01:00	83.94	0.50	7.26	
02:00	81.77	0.45	6.36	
03:00	80.40	0.34	4.67	
04:00	79.72	0.33	4.50	
05:00	79.71	0.36	4.86	
06:00	80.29	0.39	5.41	
07:00	82.80	0.48	7.02	
08:00	91.46	0.61	9.76	
09:00	107.11	0.47	9.60	
10:00	115.54	0.66	14.98	
11:00	114.75	0.59	13.12	
12:00	111.44	0.55	11.80	
13:00	104.82	0.45	8.87	
14:00	98.44	0.36	6.49	
15:00	103.34	0.46	8.98	
16:00	100.14	0.41	7.59	
17:00	98.43	0.36	6.51	
18:00	98.78	0.32	5.85	
19:00	101.17	0.31	5.83	
20:00	101.51	0.32	6.05	
21:00	107.46	0.47	9.69	
22:00	104.14	0.45	8.82	
23:00	107.45	0.45	9.34	

Min Level	78.48	@04:25	Max Level	121.81	@10:16	Avg Level	96.74
Min Velocity	0.26	@09:01	Max Velocity	0.84	@10:16	Avg Velocity	0.45
Min Flow	3.94	@04:46	Max Flow	20.26	@10:16	Avg Flow	8.05
Total Volume	695,245.14	Liters					

Study Name/Site I.D.

Town of Forest   Manhole #36

Date 09/08/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	103.80	0.37	7.19	
01:00	94.89	0.18	3.07	
02:00	92.95	0.18	3.01	
03:00	93.53	0.15	2.55	
04:00	91.48	0.13	2.20	
05:00	92.95	0.16	2.66	
06:00	106.98	0.56	11.47	
07:00	111.57	0.58	12.64	
08:00	112.24	0.62	13.54	
09:00	106.07	0.49	9.83	
10:00	106.19	0.50	10.05	
11:00	104.14	0.44	8.73	
12:00	102.99	0.38	7.27	
13:00	103.45	0.40	7.76	
14:00	103.11	0.30	5.75	
15:00	98.77	0.31	5.62	
16:00	97.63	0.30	5.30	
17:00	97.75	0.28	5.12	
18:00	99.81	0.36	6.74	
19:00	102.42	0.43	8.30	
20:00	100.26	0.33	6.07	
21:00	99.92	0.28	5.24	
22:00	96.72	0.29	5.13	
23:00	94.09	0.30	5.08	

Min Level	87.12	@05:01	Max Level	119.99	@08:01	Avg Level	100.57
Min Velocity	0.11	@05:01	Max Velocity	0.79	@08:01	Avg Velocity	0.35
Min Flow	1.64	@05:01	Max Flow	18.58	@08:01	Avg Flow	6.68

Total Volume 577,094.33 Liters

Study Name/Site I.D.

Town of Forest Manhole #36

Date 09/09/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	86.23	0.29	4.35	
01:00	59.06	0.27	2.53	
02:00	59.06	0.29	2.62	
03:00	57.22	0.27	2.36	
04:00	55.76	0.25	2.11	
05:00	68.99	0.32	3.63	
06:00	91.12	0.29	4.76	
07:00	102.64	0.40	7.88	
08:00	108.70	0.49	10.15	
09:00	106.19	0.41	8.20	
10:00	102.43	0.35	6.71	
11:00	102.77	0.34	6.60	
12:00	96.71	0.29	5.19	
13:00	96.72	0.30	5.34	
14:00	91.36	0.33	5.35	
15:00	92.84	0.33	5.56	
16:00	99.69	0.32	5.93	
17:00	99.46	0.30	5.48	
18:00	100.37	0.33	6.09	
19:00	104.94	0.38	7.57	
20:00	105.40	0.39	7.85	
21:00	107.67	0.46	9.46	
22:00	102.99	0.47	9.07	
23:00	99.47	0.43	7.87	

Min Level	50.61	@01:46	Max Level	111.35	@21:16	Avg Level	91.57
Min Velocity	0.19	@02:01	Max Velocity	0.57	@20:16	Avg Velocity	0.35
Min Flow	1.38	@02:01	Max Flow	11.72	@20:16	Avg Flow	5.94
Total Volume	513,643.11	Liters					

Study Name/Site I.D.

Town of Forest Manhole #36

Date 09/10/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	92.72	0.38	6.41	
01:00	91.01	0.45	7.36	
02:00	85.31	0.37	5.48	
03:00	86.34	0.35	5.29	
04:00	88.16	0.37	5.77	
05:00	92.62	0.42	7.07	
06:00	92.73	0.53	8.87	
07:00	107.11	0.61	12.58	
08:00	117.84	0.56	13.06	
09:00	112.47	0.45	9.78	
10:00	108.14	0.35	7.29	
11:00	105.28	0.38	7.56	
12:00	104.93	0.43	8.53	
13:00	105.62	0.46	9.05	
14:00	105.50	0.46	9.07	
15:00	103.23	0.42	8.14	
16:00	103.81	0.43	8.28	
17:00	105.85	0.39	7.85	
18:00	104.58	0.40	7.76	
19:00	106.88	0.38	7.62	
20:00	105.73	0.36	7.17	
21:00	102.43	0.42	7.98	
22:00	105.85	0.54	10.86	
23:00	100.71	0.43	7.98	

Min Level	82.12	@02:31	Max Level	123.21	@08:16	Avg Level	101.45
Min Velocity	0.30	@20:46	Max Velocity	0.75	@07:46	Avg Velocity	0.43
Min Flow	4.88	@02:31	Max Flow	18.18	@07:46	Avg Flow	8.20
Total Volume	708,547.21	Liters					

Study Name/Site I.D.

Town of Forest Manhole #36

Date 09/11/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	99.00	0.45	8.31	
01:00	89.87	0.26	4.16	
02:00	87.36	0.29	4.65	
03:00	86.68	0.28	4.27	
04:00	84.96	0.19	2.80	
05:00	85.66	0.24	3.65	
06:00	96.71	0.47	8.31	
07:00	108.93	0.52	10.73	
08:00	111.21	0.44	9.33	
09:00	110.30	0.34	7.14	
10:00	108.13	0.29	5.96	
11:00	103.00	0.31	5.98	
12:00	101.40	0.42	7.99	
13:00	98.66	0.43	7.81	
14:00	98.88	0.35	6.35	
15:00	97.30	0.40	7.12	
16:00	102.89	0.51	9.86	
17:00	99.11	0.42	7.71	
18:00	102.20	0.39	7.41	
19:00	105.16	0.41	8.08	
20:00	101.52	0.37	6.95	
21:00	102.54	0.34	6.52	
22:00	101.06	0.35	6.64	
23:00	96.96	0.46	8.20	

Min Level	82.59	@05:16	Max Level	116.34	@07:31	Avg Level	99.15
Min Velocity	0.18	@04:16	Max Velocity	0.65	@08:16	Avg Velocity	0.37
Min Flow	2.62	@05:01	Max Flow	13.73	@08:16	Avg Flow	6.91
Total Volume	597,364.86	Liters					

Study Name/Site I.D.

Town of Forest Manhole #36

Date 09/12/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	87.26	0.44	6.77	
01:00	83.15	0.37	5.39	
02:00	79.95	0.26	3.52	
03:00	84.97	0.30	4.47	
04:00	83.71	0.28	4.10	
05:00	85.19	0.35	5.30	
06:00	90.44	0.49	7.96	
07:00	104.93	0.49	9.79	
08:00	111.10	0.55	11.71	
09:00	105.27	0.41	8.14	
10:00	103.91	0.38	7.46	
11:00	101.97	0.33	6.23	
12:00	99.12	0.38	6.95	
13:00	102.30	0.34	6.58	
14:00	100.26	0.34	6.23	
15:00	101.05	0.41	7.73	
16:00	98.77	0.53	9.71	
17:00	100.72	0.46	8.72	
18:00	99.92	0.47	8.69	
19:00	97.86	0.41	7.41	
20:00	94.89	0.29	5.02	
21:00	96.61	0.35	6.16	
22:00	96.72	0.31	5.54	
23:00	93.41	0.33	5.65	

Min Level	74.37	@02:01	Max Level	113.59	@07:46	Avg Level	95.98
Min Velocity	0.19	@04:46	Max Velocity	0.65	@08:31	Avg Velocity	0.39
Min Flow	2.58	@04:46	Max Flow	14.15	@08:31	Avg Flow	6.88
Total Volume	594,783.86	Liters					

Study Name/Site I.D.

Town of Forest   Manhole #36

Date 09/13/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	88.86	0.39	6.17	
01:00	86.22	0.43	6.47	
02:00	78.58	0.45	5.96	
03:00	80.85	0.44	6.07	
04:00	77.43	0.45	5.91	
05:00	76.41	0.46	5.88	
06:00	81.08	0.50	6.99	
07:00	87.82	0.47	7.29	
08:00	106.07	0.55	10.96	
09:00	111.78	0.60	12.90	
10:00	111.56	0.64	13.73	
11:00	109.73	0.58	12.24	
12:00	113.39	0.66	14.69	
13:00	109.17	0.62	12.88	
14:00	104.71	0.47	9.22	
15:00	101.17	0.39	7.31	
16:00	98.66	0.34	6.22	
17:00	99.81	0.40	7.49	
18:00	99.34	0.39	7.19	
19:00	100.03	0.46	8.45	
20:00	96.38	0.38	6.84	
21:00	95.92	0.30	5.23	
22:00	96.96	0.29	5.20	
23:00	95.13	0.32	5.59	

Min Level	73.91	@05:16	Max Level	127.31	@12:46	Avg Level	96.13
Min Velocity	0.25	@22:01	Max Velocity	0.86	@12:46	Avg Velocity	0.46
Min Flow	4.24	@22:01	Max Flow	21.79	@12:46	Avg Flow	8.20
Total Volume	708,708.30	Liters					

Study Name/Site I.D.

Town of Forest   Manhole #36

Date 09/14/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	92.62	0.32	5.24	
01:00	86.33	0.46	7.04	
02:00	84.96	0.51	7.58	
03:00	83.26	0.55	7.96	
04:00	80.85	0.54	7.46	
05:00	81.42	0.54	7.52	
06:00	82.92	0.55	7.88	
07:00	87.24	0.53	8.03	
08:00	100.83	0.38	7.22	
09:00	109.39	0.62	13.02	
10:00	112.13	0.72	15.54	
11:00	106.41	0.58	11.66	
12:00	105.73	0.54	10.74	
13:00	103.90	0.56	10.89	
14:00	107.56	0.65	13.39	
15:00	105.51	0.58	11.71	
16:00	96.04	0.33	5.71	
17:00	97.07	0.37	6.68	
18:00	97.86	0.42	7.65	
19:00	102.89	0.51	10.15	
20:00	100.04	0.48	8.94	
21:00	98.88	0.42	7.76	
22:00	95.58	0.40	7.06	
23:00	92.85	0.33	5.61	

Min Level	79.37	@04:01	Max Level	114.99	@19:16	Avg Level	96.34
Min Velocity	0.26	@00:01	Max Velocity	0.83	@19:16	Avg Velocity	0.50
Min Flow	4.37	@23:31	Max Flow	18.46	@19:16	Avg Flow	8.85
Total Volume	764,754.17	Liters					

Study Name/Site I.D.

Town of Forest   Manhole #36

Date 09/15/97	Level mm	Velocity M/S	Flowrate L/S	Battery Voltage 12.00 Volts
00:00	86.68	0.42	6.43	
01:00	81.55	0.47	6.66	
02:00	81.20	0.49	6.90	
03:00	79.26	0.47	6.31	
04:00	78.23	0.44	5.83	
05:00	80.40	0.46	6.36	
06:00	89.77	0.46	7.37	
07:00	100.25	0.51	9.63	
08:00	106.87	0.64	12.93	
09:00	105.51	0.64	12.86	
10:00	103.91	0.62	12.02	

Min Level	**76.62**	@04:31	Max Level	**109.06**	@08:31	Avg Level	**90.33**
Min Velocity	**0.33**	@00:16	Max Velocity	**0.81**	@09:31	Avg Velocity	**0.51**
Min Flow	**5.06**	@00:16	Max Flow	**16.62**	@09:31	Avg Flow	**8.48**
Total Volume	**335,893.11**	Liters					