CITY OF St. Joseph

St. Joseph Infiltration and Inflow Mitigation

MONITORING AND MODELING ANALYSIS

November 16, 2021

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1.0 INTRODUCTION

The St. Joseph collection system has three major branches that collect sanitary sewage and wet weather flow during storm events. This flow is delivered to the joint wastewater treatment (JWWTP) plant located on Marina Island for treatment before eventual discharge to the St. Joseph River. Under current conditions, the maximum deliverable flow from the St. Joseph system to the JWWTP is limited to approximately 2,400 gpm. During wet weather events, flows in excess of this capacity limit are discharged untreated as a sanitary sewer overflow (SSO) to the St. Joseph River from a location known as Combined Sewer Overflow (CSO) 005 under authorization of the City's CSO National Pollutant Discharge Elimination System (NPDES) permit. The costs for construction of a basin to store these overflows before discharge to the river possibly range from $10M to $20M. Due to these high basin construction costs, the City has been coordinating with the State of Michigan Department of Environment, Great Lakes & Energy (EGLE) to revise its CSO NPDES permit as part of the re-issuance process, allowing the City to assess the potential for additional wet weather infiltration and inflow (I/I) flow removal, and providing additional time to do so. Reductions in I/I from the system will have a corresponding reduction in the required size and cost of the storage basin.

The City of St. Joseph is currently working toward SSO compliance with the Environmental Protection Agency (EPA) and EGLE requirements as part of a two-phase approach. Phase 1 includes identifying and removing cost effective sources of I/I. Phase 2 will include sizing storage facilities to capture the remaining excessive wet weather flow. The City is currently working though Phase 1 of this SSO control effort.

This report summarizes the Phase 1 findings that have been completed to date. This effort incudes initial mapping of the system, video inspection of the sewers, rain and flow monitoring, data analysis, and computer model simulations. The goal of this initial effort was to identify specific areas of the collection system that are found to have higher quantities of I/I. These high I/I areas were evaluated for potential I/I removal that could be implemented as part of a separate project to reduce the required size and cost of the basin. The cost savings of the basin will be compared to the cost of I/I mitigation to determine if I/I mitigation is cost effective.

2.0 SEWER CONDITION ASSESSMENT MAPPING

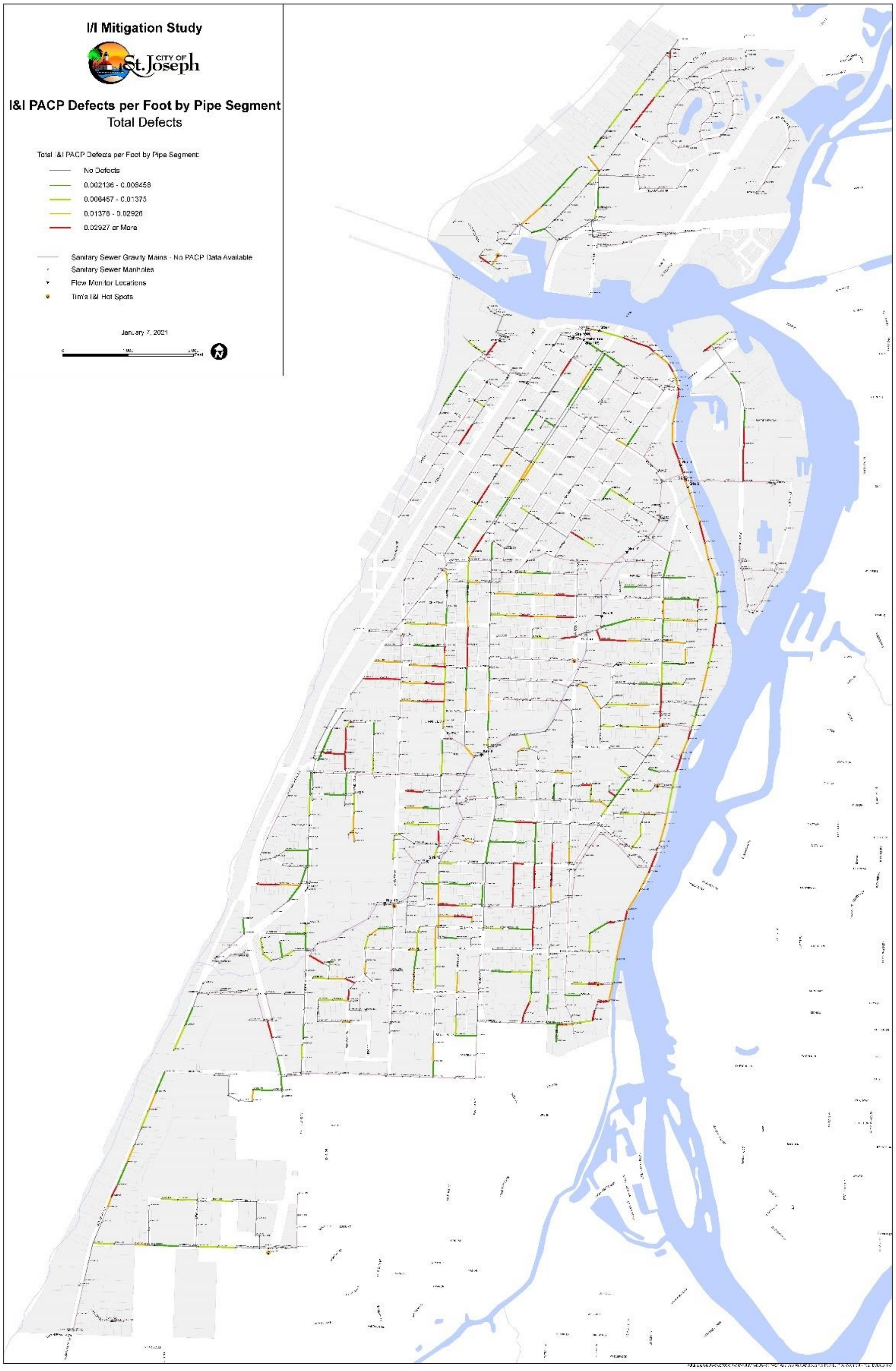
In 2016 and 2017 the collection system was inspected as part of a NASSCO Pipeline Assessment and Certification Program (PACP). Although this data was intended to be used for condition assessment to prioritize sewer improvements/replacements, some of the observations could be used to identify possible sections of sewer with high I/I. The full list of PACP codes were reviewed to focus the I/I investigation on the codes that were deemed relevant to I/I. A summary of the PACP codes that were identified to be related to high I/I are summarized in Table 2-1.

Table 2-1 I/I Related PACP Codes

Defect Description	PACP Code
Broken Soil Visible	BSV
Fracture (large)	FL
Hole	HSV
Infiltration Dripper	ID
Infiltration Gusher	IG
Infiltration Runner	IR
Joint Angular (large)	JAL
Joint Angular (medium)	JAM
Joint Angular (small)	JAS
Joint Offset (large)	JOL
Joint Offset (medium)	JOM
Joint Offset (small)	JOS
Joint Separation (large)	JSL
Joint Separation (medium)	JSM
Joint Separation (small)	JSS
Obstacles Obstructions	OBI
Root Ball	RBJ
Root Tap	RTB

In addition to the PACP codes developed in 2017, an additional field investigation was performed by City staff using the City owned Zoom Camera. The locations that were identified for Zoom camera investigation were based on institutional knowledge of the system to identify sewers that were suspected of having high I/I. The Zoom Camera videos collected as part of this investigation were reviewed by the project team and PACP codes were assigned to the inspected sewer segments. Using the combination of PACP codes collected in 2016, 2017, and 2021, a GIS map of the system was developed to identify areas of the system that could have high I/I. The mapping was performed by compiling the number of PACP defects per foot of sewer and developing a color coding. The final map from this PACP mapping effort is shown in **Figure 2-1**. A full-size version of this map is provided in **Appendix A.**

Figure 2-1



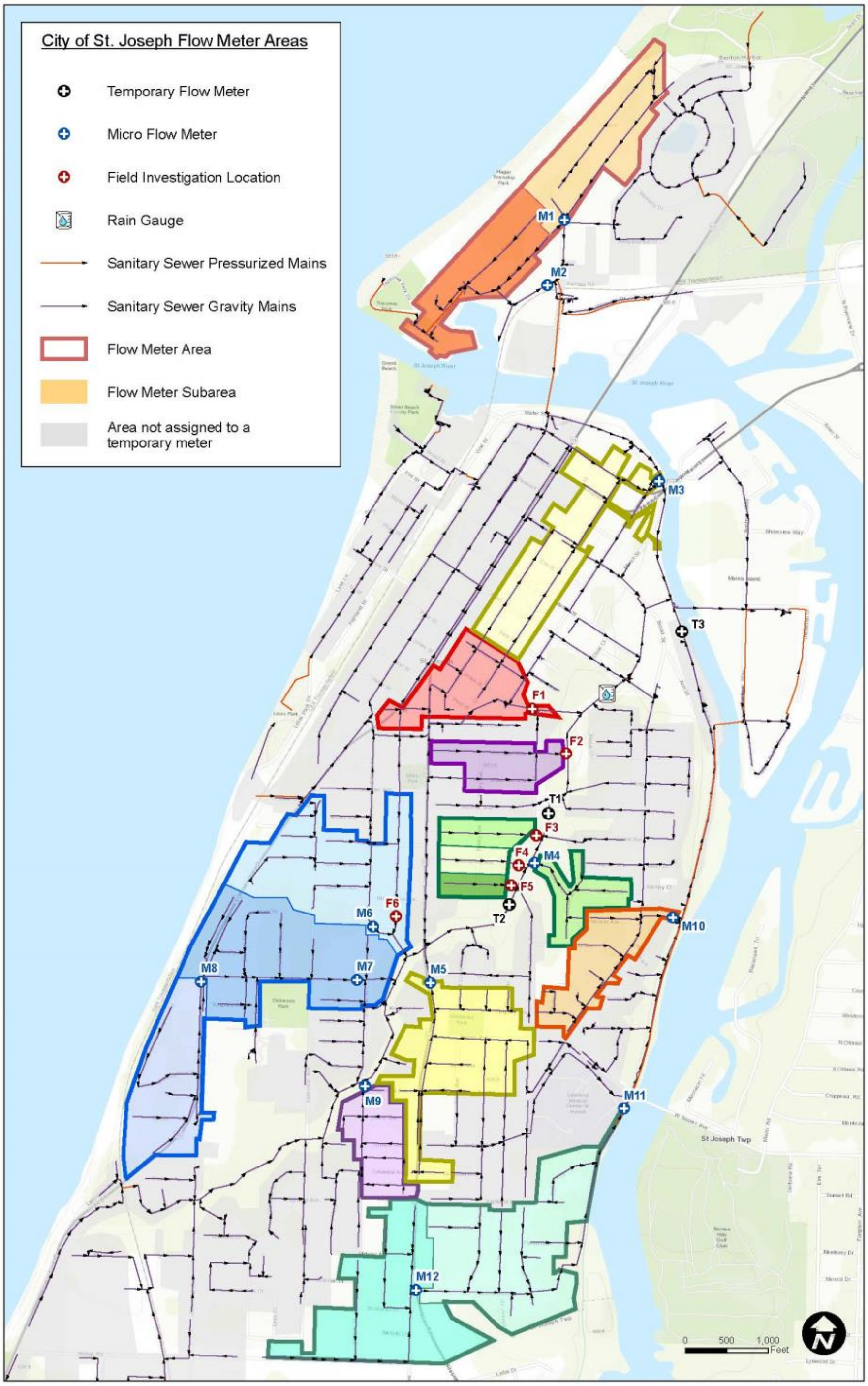
I/I Defects Per Foot of Sewer Segment

After the mapping was completed, the project team met to discuss the results and determine if there were any obvious stand out areas of the system that could be conclusively identified as having high I/I based on the PACP mapping. The team concluded that the PACP mapping did not conclusively identify any areas of high I/I but could be used as a guide for further field and flow monitoring investigations.

3.0 FLOW MONITORING, I/I INVESTIGATION

After the initial PACP mapping was completed, the project team met to discuss areas of the system that were suspected of having high I/I. The team drew on the PACP mapping, institutional knowledge of the system, and previous flow monitoring that had been performed. The City staff provided significant insight of the system performance during historic wet weather events. The results from this meeting resulted in an area delineation map of areas that were suspected of having high I/I. These suspected areas would be the focus of a follow up investigation using a combination of temporary flow meters, micro- meters, and field investigation. The areas identified for further investigation are show in **Figure 3-1**.

Figure 3-1



I/I Field Investigation Area

Assessment of the I/I magnitude in these areas was conducted as part of a micro-metering program. Prior to installing flow meters, a hydraulic assessment was performed at each site to understand the hydraulic conditions within each area and determine if reasonably accurate flow meter data could be collected. Based on this hydraulic assessment, six areas that had been planned for flow monitoring were modified to conduct field investigation only. The result of this screening process resulted in six areas selected for field investigation, three temporary flow monitoring sites, and twelve micro-metering sites.

3.1 Flow Monitoring and Field Monitoring Plan

After the suspected high I/I areas were identified, a flow monitoring and field investigation plan was developed. The flow monitoring plan identified three locations for temporary flow meters. These temporary flow meter locations were intended to provide a system wide average response to wet weather that could be used for a baseline comparison to flow data collected at the micro-metering locations. The monitoring plan also included twelve micro-metering locations. Data from the micro-meters was used to identify areas with a larger wet weather response relative to the system wide average. Flow meters in the three temporary and twelve micro-meter locations were installed by ADS Environmental Services in the Spring of 2021. Unfortunately, the spring 2021 monitoring period was very dry and the initial micro-meters locations only recorded wet weather response for a single event. After this event the data was analyzed, and the micro-meters were relocated based on information collected from the one event. After the micro-meters were relocated, several large events were recorded. Due to the unusually dry spring conditions, the flow monitoring period was extended by 4-weeks through June 27, 2021 to capture additional events.

In six locations, micro-meters could not be installed due to poor hydraulic conditions. In these locations, field crews performed dry and wet weather field observations to determine the magnitude of wet weather response. Field crews visited each site prior to wet weather to develop a baseline assessment of the site. During wet weather, the field crews returned to the site to make comparative wet weather observations. All wet weather observations were performed by Abonmarche Consultants using the City provided Zoom Camera.

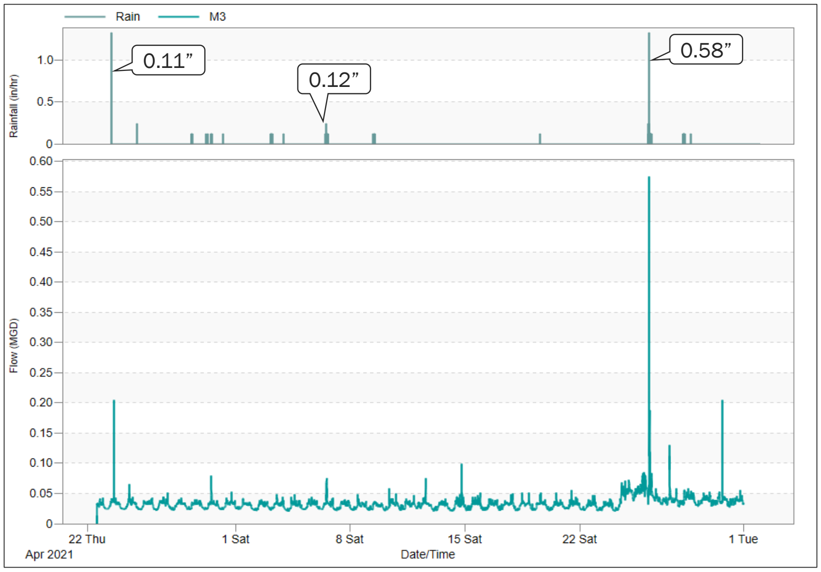
4.0 FLOW MONITORING AND FIELD INVESTIGATION FINDINGS

Data collected at the flow meter and field investigation locations was analyzed to identify areas with high I/I. The following sections describe the findings from the initial monitoring locations and the subsequent locations.

4.1 Initial Monitoring Locations

The initial monitoring locations are shown in **Figure 3-1**. After several weeks of dry weather, the flow meters captured a wet weather event on May 26, 2021. This May event had a total rainfall of 0.58-inches. The data collected at the flow meters was analyzed for wet weather response. The data from the individual flow meters showed a range of response to wet weather. An example of a rapid response to wet weather is demonstrated by the response at the M3 monitoring location. At the M3 monitoring location, the flow meter showed a 10X increase in flow relative to the dry weather base flow. The wet weather response at M3 is shown in **Figure 4-1**.

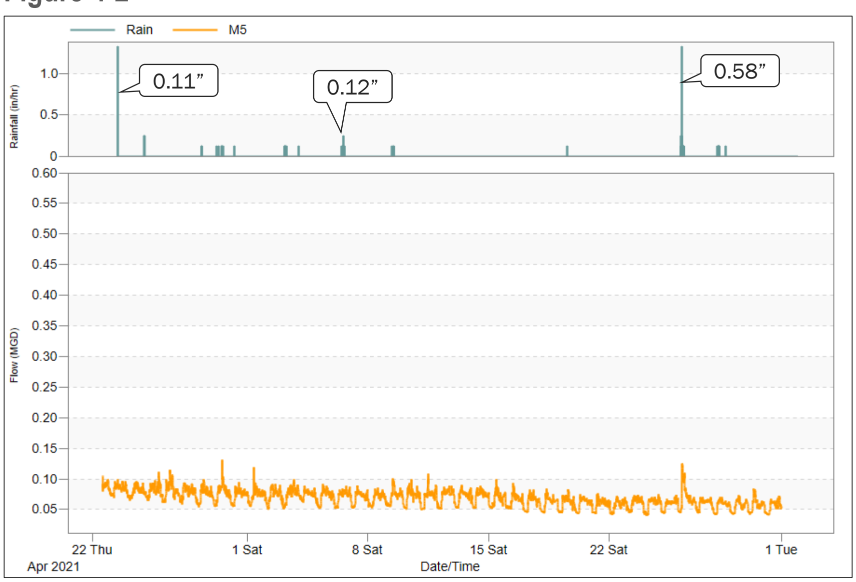
Figure 4-1



Meter M3 – May 26, 2021, Wet Weather Response

An example of a more limited response to wet weather is demonstrated at monitoring location M5. Meter location M5 which shows a more limited response to the same event. The response to the May 26, 2021, event at M5 is shown in **Figure 4-2.** The peak wet weather flow during the May 26, 2021 event doubles the pre-event dry weather flow.

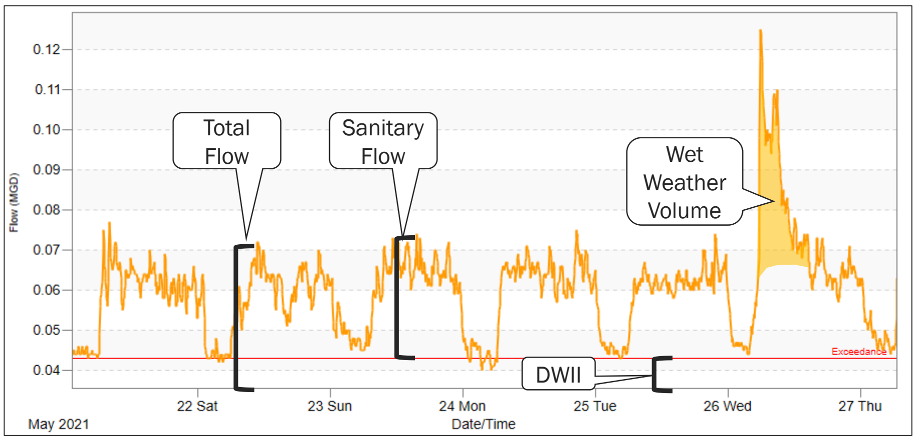
Figure 4-2



Meter M5 – May 26, 2021, Wet Weather Response

The flow meter data hydrographs from each of the meters was deconstructed to separate the flow into its individual flow components. Dry weather infiltration and inflow (DWII) was assumed to include all flow below the minimum flow occurring in the middle of the night. Sanitary flow was assumed to include all diurnal flow above the DWII during wet weather periods. Wet weather flow was assumed to include the flow above the diurnal flow pattern. The individual components of flow are shown graphically in **Figure 4-3**.

Figure 4-3



Measured Flow Deconstruction

The initial flow data analysis focused on the quantity of DWII measured at each of the flow meters. A summary of the DWII analysis is shown in **Table 4-1** Central Ravine Area and **Table 4-2** South Interceptor Area. The results are presented as MGD of flow per 1000-feet of upstream tributary sewer. The DWII flow rates calculated at each flow meter were compared to the measured flow at the temporary flow meters. Meters with high DWII relative to the system meters have been highlighted. Based on this analysis, DWII appears to be elevated at meters M5, M6, M10, M11, and M12.

Table 4-1 Dry Weather I/I, Central Ravine Area

Meter ID	Average Total Flow (MGD)	Dry Weather Inflow (MGD)	Average Sanitary Flow (MGD)	Tributary Sewer Length (ft)	Total Flow/1000' of Sewer (MGD/ft)	Dry Weather Inflow/1000' of Sewer (MGD/ft)	Sanitary Flow/1000' of Sewer MGD/ft
T1	0.385	0.240	0.145	106,968	0.0036	0.0022	0.0014
T2	0.322	0.190	0.132	95,110	0.0034	0.0020	0.0014
M1				5,227			
M2	0.020	0.008	0.012	6,947	0.0029	0.0012	0.0017
M3	0.030	0.022	0.008	6,802	0.0044	0.0032	0.0012
M4				2,325			
M5	0.059	0.043	0.016	7,218	0.0082	0.0060	0.0022
M6	0.046	0.030	0.016	4,858	0.0095	0.0062	0.0033
M7	0.057	0.033	0.024	13,699	0.0042	0.0024	0.0018
M8				5,642			
M7-M8				8,058			
M9	0.066	0.040	0.026	4,014	0.0164	0.0100	0.0065

Table 4-2 Dry Weather I/I, South Interceptor Area

Meter ID	Total Flow (MGD)	Dry Weather Inflow (MGD)	Sanitary Flow (MGD)	Tributary Sewer Length (ft)	Total Flow/1000' of Sewer (MGD/ft)	Dry Weather Inflow/1000' of Sewer (MGD/ft)	Sanitary Flow/1000' of Sewer MGD/ft
T3	0.316	0.170		42,668	0.0074	0.0040	0.0034
M10	0.071	0.055		3,665	0.0194	0.0150	0.0044
M11	0.280	0.160		17,231	0.0162	0.0093	0.0070
M12	0.160	0.056		6,533	0.0245	0.0086	0.0159
M11-M12	0.140	0.060		10,698	0.0131	0.0056	0.0075

A separate wet weather analysis was performed for the system response to the May 26, 2021, event. At each flow meter, the increase in peak flow above dry weather flow and event wet weather volume was calculated. The wet weather volume was normalized to the upstream length of tributary sewer. The result of this analysis is shown in **Tables 4-3** and **4-4**. Based on the wet weather analysis, the wet weather response at meters M3, M5, M6, M9, and M10 appear to be elevated.

Table 4-3 May 26, 2021, Wet Weather Response, Central Ravine Area

Meter ID	Peak Flow MGD	Peak Flow/1000' of Sewer MGD/ft	Peak Flow Above DWF (%)	Wet Weather Volume (MG)	Wet Weather Vol/1000' of Sewer MG/ft
T1	0.69	0.0065	179%	0.019	0.0002
T2	0.71	0.0075	220%	0.046	0.0005
M1	MWWR				
M2	MWWR				
M3	0.575	0.0845	1917%	0.025	0.0037
M4	MWWR				
M5	0.125	0.0173	212%	0.010	0.0014
M6	0.147	0.0303	320%	0.006	0.0012
M7	0.127	0.0093	223%	0.008	0.0006
M8	MWWR				
M7-M8	0.074	0.0092			
M9	0.165	0.0411	250%	0.014	0.0035

MWWR: Minimal wet weather response

Table 4-4 May 26, 2021, Wet Weather Response, South Interceptor Area

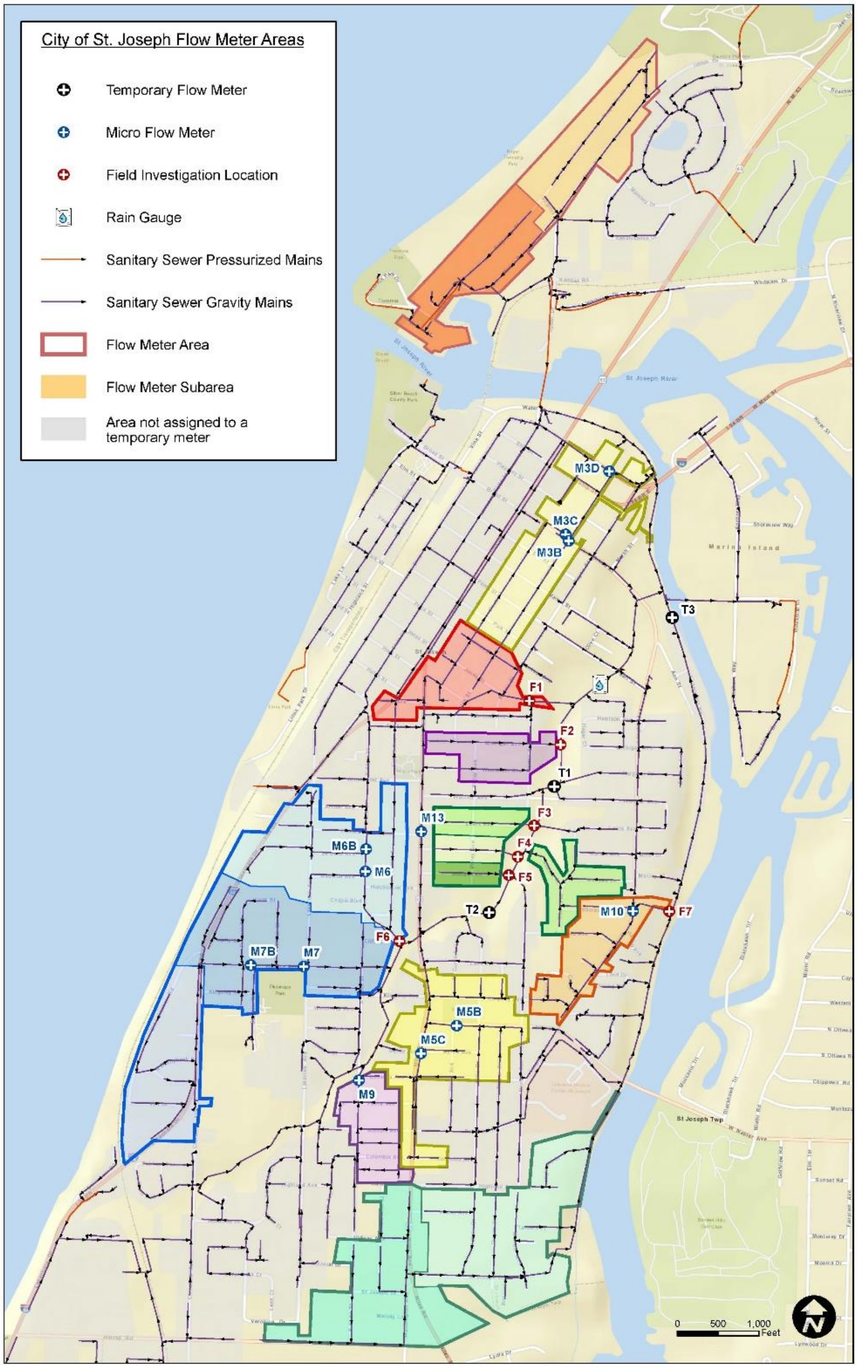
Meter ID	Peak Flow MGD	Peak Flow/1000' of Sewer MGD/ft	Peak Flow Above DWF (%)	Wet Weather Volume (MG)	Wet Weather Vol/1000' of Sewer MG/ft
T3	MWWR				
M10	0.204	0.0557	287%	0.050	0.0136
M11	MWWR				
M12	0.335	0.0513	209%	0.004	0.0006
M11-M12	MWWR				

MWWR: Minimal wet weather response

4.2 Secondary Monitoring Locations

The dry and wet weather analysis that was performed for the initial meter locations was shared with the project team. Based on the analysis of the flow data collected at the initial meter locations and follow-up discussions with the team, a set of secondary monitoring locations were selected. The secondary locations are shown in **Figure 4-4**.

Figure 4-4



Secondary Flow Monitoring Locations

After the installation of the flow meters in the secondary locations, three large storm events occurred over the St. Joseph system. The events included 6/21/2021 (1.65”), 6/25/2021 (1.92”), and

6/26/2021 (2.50”). The wet weather data from these events was processed in a similar manner as previously described. The results from the wet weather analysis of these events are presented in **Tables 4-5**, **4-6**, and **4-7**.

Table 4-5 June 21, 2021, Wet Weather Response

Meter ID	Peak Flow MGD	Peak Flow/1000' of Sewer MGD/ft	Peak Flow Above DWF (%)	Wet Weather Volume (MG)	Wet Weather Vol/1000' of Sewer MG/ft
T1	0.614	0.0057	152%	0.020	0.0002
T2	0.535	0.0056	174%	0.023	0.0002
M3B	0.083	0.0484	1660%	0.003	0.0016
M3C	0.078	0.0377	1560%	0.002	0.0007
M3D	0.455	0.3167	2275%	0.010	0.0067
M5B					
M5C	0.160	0.0489	364%	0.008	0.0023
M6	0.093	0.0191	216%	0.002	0.0004
M6B	0.059	0.0516	257%	0.003	0.0023
M6-M6B	0.053	0.0142	293%	0.002	0.0004
M7	MWWR				
M7B	0.120	0.0109	154%	0.010	0.0009
M7-M7B					
M9	MWWR				
M13	MWWR				
T3	0.709	0.0166	231%	0.039	0.0009
M10	MWWR				

MWWR – minimal wet weather response

Table 4-6 June 25, 2021, Wet Weather Response

Meter ID	Peak Flow MGD	Peak Flow/1000' of Sewer MGD/ft	Peak Flow Above DWF (%)	Wet Weather Volume (MG)	Wet Weather Vol/1000' of Sewer MG/ft
T1	4.094	0.0383	1016%	0.875	0.0082
T2	3.708	0.0390	1204%	0.718	0.0075
M3B	0.498	0.2903	9960%	0.027	0.0157
M3C	0.311	0.1505	6220%	0.013	0.0063
M3D	2.043	1.4219	10215%	0.049	0.0341
M5B					
M5C	0.448	0.1369	1018%	0.041	0.0125
M6	0.219	0.0451	509%	0.039	0.0080
M6B	0.110	0.0962	478%	0.015	0.0127
M6-M6B	0.179	0.0482	994%	0.007	0.0018
M7	0.328	0.0239	575%	0.059	0.0043
M7B	0.479	0.0437	614%	0.073	0.0066
M7-M7B					
M9	0.767	0.1911	1112%	0.124	0.0309
M13	MWWR				
T3	2.471	0.0579	805%	0.554	0.0130
M10	0.528	0.1442	744%	0.072	0.0196

MWWR – minimal wet weather response

Table 4-7 June 26, 2021, Wet Weather Response

Meter ID	Peak Flow MGD	Peak Flow/1000' of Sewer MGD/ft	Peak Flow Above DWF (%)	Wet Weather Volume (MG)	Wet Weather Vol/1000' of Sewer MG/ft
T1	5.755	0.0538	1428%	3.451	0.0323
T2	3.796	0.0399	1232%		
M3B	0.725	0.4226	14500%		
M3C	0.232	0.1123	4640%	0.056	0.0271
M3D	2.059	1.4330	10295%	0.112	0.0780
M5B					
M5C	0.456	0.1394	1036%	0.199	0.0610
M6	0.218	0.0449	507%	0.089	0.0183
M6B	0.131	0.1146	570%	0.059	0.0519
M6-M6B	0.204	0.0550	1134%	0.034	0.0090
M7	0.329	0.0240	577%	0.342	0.0249
M7B	0.491	0.0448	629%	0.344	0.0314
M7-M7B					
M9	1.332	0.3318	1930%	0.373	0.0928
M13	MWWR				
T3	3.164	0.0742	1031%	1.745	0.0409
M10	0.695	0.1897	979%	0.310	0.0846

MWWR – minimal wet weather response

4.3 Field Investigation

Field investigations were performed for the March 26, 2021 and June 26, 2021 wet weather events. These investigations included a pre-event dry weather survey that was followed by a wet weather survey during the event. All observations of the system were documented on video using the City provided Zoom Camera. The qualitative observations compared the relative increase in flow from dry weather to wet weather conditions. The results of these field observations are summarized below.

F1 Location – There is a slight increase in flow above DWF but very marginal
F2 Location – Limited increase in flow above DWF
F3 Location – Limited increase in flow above DWF

F4 Location – Limited increase in flow above DWF
F5 Location – Not a large increase in flow but a larger response than seen at F3 and F4.
F6 Location – This location had the largest response of any of the field investigation areas. The inflow at this location was compared to the flow originating from meter area M6. The Meter area M6 was found to have a larger wet weather response than F6. This comparison provided a method for the field crews to calibrate their observed field findings to measured data. Although this area was found to have the largest inflow of any of field investigation areas, the magnitude of this inflow was not identified as high enough to be carried forward for further investigation.
F7 Location – Limited increase in flow above DWF. Observed velocity was very high due to steep pipe slope.

4.4 Monitoring and Field Investigation Conclusions

Based on the findings of the monitoring program and the field Investigation, seven micrometer areas were recommended for further analysis as part of a modeling study. These areas were selected based on the consistently higher than average peak flow and volume response to wet weather. The selected micrometer areas include M3B, M3C, M3D, M5, M5B, M5C, M6B, M9, and M10.

Observations and Zoom Camera data at the seven field investigation areas did not indicate excess I/I. Based on this information, none of the field investigation areas were moved forward for model analysis.

5.0 MODELING ANALYSIS

The goal of the modeling analysis is to determine the reduction in SSO basin size and cost if the selected areas of the system found to have high I/I were improved to reduce the peak and volume of inflow to the system. This model analysis was built on the SWMM model of the system that was updated and calibrated in 2020.

5.1 Model Update

The SWMM model of the St Joseph sanitary sewer system is based on a hydrologic model of the system that utilizes RTK triangular unit hydrographs as the basis for generating wet weather inflow to the system. For this task, the triangular unit hydrographs were modified to simulate the reduction in inflow to the system as a result of system improvements to reduce I/I into the system in the selected areas. These I/I modifications to the model hydrology focused on a reduction of the capture coefficient within the overall meter district while maintaining the shape of the triangular unit hydrograph.

The individual selected areas for I/I mitigation fall within larger hydrologic areas within the model. For example, mitigation areas M6B and M9 have a combined tributary area of 34 acres but fall within a larger hydrologic area (Site 8) that has a total tributary area of 276 acres. To account for the reduction in inflow for area M6B and M9, a more limited reduction in the capture coefficient for the entire Site 8 (277 acre) area was applied. The reduction in capture coefficient for the M6B and M9 area was assumed to reduce the capture coefficient to a value halfway between the original value of 0.078 and the average Site 8 value of 0.0135. This assumption reduced the capture coefficient in the M6B and M9 areas by 41% to a value of 0.0457. To achieve this inflow volume reduction, the overall capture coefficient in the Site 8 area was reduced by 29%. A similar analysis was performed for the remaining selected areas of the system. The final reductions in capture coefficients for each hydrologic district are as follows.

Site 1 = 32% (M3)
Site 2 = 3% (M10)
Site 6 = 6% (M5, M5B, and M5C)
Site 8 = 29% (M6B and M9)

5.2 Model Simulations

After updating the model inputs to reflect the reductions in inflow from the selected M3B, M3C, M3D, M9, M5, M5B, M5C, M6B, and M10 areas, the model was run as a continuous 50-year model simulation for the years including 1960 – 1996 and 2006 – 2020. The model was run for existing conditions and as with the proposed reductions in capture coefficients in the selected areas. The CSO-005 overflow results were compiled for both of these simulations. The top ten largest CSO-005 overflow events from these simulations are summarized in **Table 5-1**. Following the SSO design standards established by the Michigan Department of Environment Great Lakes and Energy (EGLE), SSO is assumed to be controlled if the frequency of overflow is less than 1 overflow in 10 years. Following this standard, the fifth largest event shown in **Table 5-1** must be fully captured. Under existing conditions, the required basin size is 1.2 MG of storage. Assuming I/I reduction improvements to the system within the selected areas, the reduction of inflow to the system reduces the required storage volume by 12.7% to 1.05 MG.

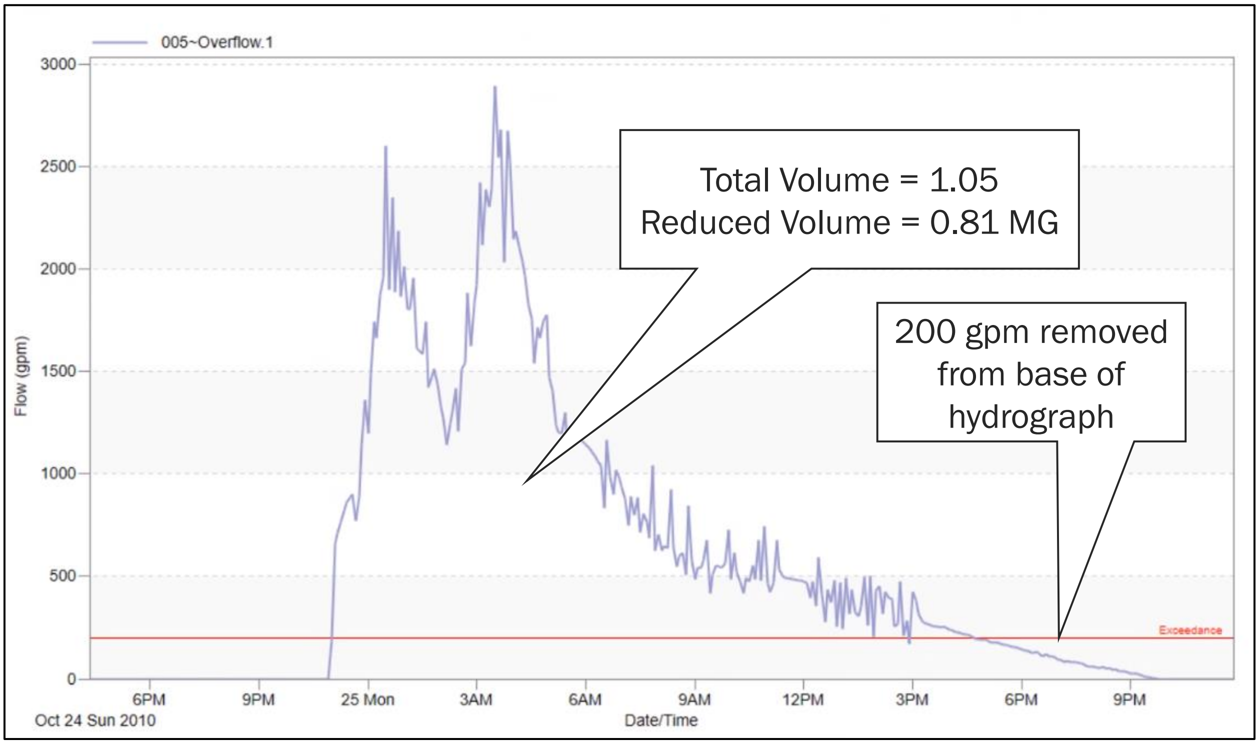
Table 5-1 Continuous Model Simulation, CSO-005 Overflow Volume

Rank	Overflow Event Date	Total Rainfall (in)	Overflow Volume - Original Model (gal)	Overflow Volume - Adjusted Model (gal)	Reduction (gal)	Reduction (%)
1	10/14/2017	5.40	5,820,000	5,262,000	558,000	9.6
2	10/30/2009	3.17	1,645,000	1,426,000	219,000	13.3
3	5/26/1968	3.65	1,422,000	1,185,000	237,000	16.7
4	10/31/2013	3.49	1,394,000	1,150,000	244,000	17.5
5	10/24/2010	3.00	1,203,000	1,050,000	153,000	12.7
6	10/18/2011	3.19	1,071,000	900,600	170,400	15.9
7	6/7/1986	2.23	974,200	817,900	156,300	16.0
8	10/19/1985	2.57	864,600	734,400	130,200	15.1
9	6/14/1960	2.76	647,700	529,200	118,500	18.3
10	5/1/2019	2.00	728,700	617,100	111,600	15.3
Total					2,098,000	
Average						14.1

Continuous Model Simulation, CSO-005 Overflow Volume

Although the system improvements include nine selected areas, only areas M5, M5B, M5C, M6B, and M9 are tributary to CSO-005. Improvements to the remaining areas M3B, M3C, M3D, and M10 will not directly reduce the required storage at CSO-005. However, improvements to areas M3B, M3C, M3D, and M10 will reduce the peak flow to the WWTP by approximately 200 gpm. Assuming the CSO-005 can take a 200-gpm credit and increased the capacity of the CSO-005 regulator, the required CSO-005 storage volume can be further reduced. The overflow hydrograph from the 5th largest storm (10/24/2021) is shown in **Figure 5-1**. The total volume of the overflow hydrograph is 1.05 MG. Removing 200 gpm from the base of the hydrograph for this event reduces the required storage to 0.81 MG.

Figure 5-1



10/24/2010 Event

6.0 COST BENEFIT ANALYSIS

The goal of I/I mitigation analysis is to determine if reducing I/I from the system is cost effective (i.e., reduction in basin cost greater than I/I mitigation cost). To perform this cost benefit analysis, it is necessary to establish the cost for basin construction and the cost for I/I mitigation.

6.1 CSO-005 Basin Cost

An estimated cost for construction of a CSO-005 basin was developed and documented in a technical memorandum (TM) titled "City of St. Joseph CSO Storage Basin SRF Budget Development" dated August 18, 2020. This TM developed basin costs for two separate basin location options. A description of the two basin options is described below and shown graphically in **Figure 6-1**.

Option A:

- At skating park
- Below grade concrete tank
- Gravity in, pumped dewatering
- $17.3M
- $14.42/gallon of storage

Option B:

- At basketball courts
- Above grade
- Pumped in, gravity dewatering
- $9.8M
- $8.17/gallon of storage

Figure 6-1

Basin Location Options

6.2 I/I Mitigation Cost

A separate cost estimate was developed for mitigating the I/I from the selected areas M3B, M3C, M3D, M5, M5B, M5C, M6B, M9, and M10. The I/I mitigation costs estimate focused on sewer rehabilitation (sewer lining) and manhole rehabilitation. The assumed unit cost for this estimate is as follows:

Sewer Rehabilitation = $150/foot of sewer
Manhole Rehabilitation = $2000/manhole

Separate I/I mitigation costs were developed depending on the fraction of sewers rehabilitated in each area. For this analysis, separate costs were developed assuming 90% and 60% of the sewers were rehabilitated. Both cost estimates assume 50% of the manholes will be rehabilitated. The cost was further broken down by areas tributary to CSO-005 (Ravine Interceptor) and "other areas" of the system not tributary to CSO-005. The I/I mitigation cost breakdown is shown in **Tables 6-1** and **6-2.**

Table 6-1 I/I Mitigation- 90% Sewer Lining

Meter ID	Tributary Sewer Length (ft)	Number of Upstream Manholes	Sewer Rehab		Manhole Rehab	
			Fraction Rehab	Cost	Fraction Rehab	Cost
Ravine Interceptor						
M5	7218	27	0.9	$974,430	0.5	$27,000
M5B	2404	8	0.9	$324,540	0.5	$8,000
M5C	3271	13	0.9	$441,585	0.5	$13,000
M6B	1144	6	0.9	$154,440	0.5	$6,000
M9	4014	20	0.9	$541,890	0.5	$20,000
Subtotal	18051	74		$2,436,885		$74,000
Other Areas						
M3	6802	26	0.9	$918,270	0.5	$26,000
M3B	1715	7	0.9	$231,525	0.5	$7,000
M3C	2067	6	0.9	$279,045	0.5	$6,000
M3D	1437	7	0.9	$193,995	0.5	$7,000
M10	3665	20	0.9	$494,775	0.5	$20,000
Subtotal	15686	66		$2,117,610		$66,000
Total	33737	140		$4,554,495		$140,000

Table 6-2 I/I Mitigation – 60% Sewer Lining

Meter ID	Tributary Sewer Length (ft)	Number of Upstream Manholes	Sewer Rehab		Manhole Rehab	
			Fraction Rehab	Cost	Fraction Rehab	Cost
Ravine Interceptor						
M5	7218	27	0.6	$649,620	0.5	$27,000
M5B	2404	8	0.6	$216,360	0.5	$8,000
M5C	3271	13	0.6	$294,390	0.5	$13,000
M6B	1144	6	0.6	$102,960	0.5	$6,000
M9	4014	20	0.6	$361,260	0.5	$20,000
Subtotal	18051	74		$1,624,590		$74,000
Other Areas						
M3	6802	26	0.6	$612,180	0.5	$26,000
M3B	1715	7	0.6	$154,350	0.5	$7,000
M3C	2067	6	0.6	$186,030	0.5	$6,000
M3D	1437	7	0.6	$129,330	0.5	$7,000
M10	3665	20	0.6	$329,850	0.5	$20,000
Subtotal	15686	66		$1,411,740		$66,000
Total	33737	140		$3,036,330		$140,000

Although areas outside of the CSO-005 will reduce the total wet weather inflow to the system, the reduction in inflow volume will not be realized as a reduction in overflow volume at CSO-005 without additional infrastructure improvements. These infrastructure improvements include increasing the capacity of the underflow from the CSO-005 regulator toward the WWTP. The exiting connection is a 12-inch diameter pipe 409-feet long with an average depth of 10-feet. Replacing or installing a parallel pipe to increase the capacity was assumed to cost $250,000. This cost has been included in the benefit cost benefit and recognizes there are contaminated soils in the area.

6.3 Treatment Cost Reduction

In addition to reducing overflow to the river, reductions in wet weather inflow to the system will reduce the total wet weather volume that is sent to the WWTP. This volume reduction toward the WWTP will occur for all wet weather events large and small. Reducing wet weather volume will reduce the treatment cost at the WWTP. To account for this cost savings, an annual wet weather volume reduction and cost savings was calculated. This calculation was based on the reductions in capture coefficients in the targeted areas and the following assumptions.

Average Annual Rainfall = 32.17-inches (Bulletin 71)
Sewer Charge Rate = $3.59/100cft
Life Cycle Return Period = 20 years
Interest Rate = 3%

Based on this information, annual treatment volume reductions were developed for the targeted areas. Using these annual volume reductions, treatment cost savings were developed. These cost savings were separated into savings for the targeted Ravine Area only and for all targeted areas in the system. A summary of the volume reduction calculations and treatment cost savings is presented in **Table 6-3**.

Table 6-3 Treatment Volume and Cost Reduction

Site Area	Meter Districts	Site Area (acres)	Original Capture Coefficient	Original Annual Inflow Volume ft^3	Reduced Capture Coefficient	Reduced Annual Inflow Volume ft^3	Annual Volume Reduction ft^3	Annual Cost Savings $	Present Worth $
1 (Other)	M3	75	0.077	674,612	0.052	451,990	222,622	7,992	$118,903
2 (Other)	M10	335	0.112	4,388,498	0.109	4,256,843	131,655	4,726	$70,317
6 (Ravine)	M5, M5B, M5C	192	0.246	5,515,616	0.231	5,184,679	330,937	11,881	$176,754
8 (Ravine)	M6b, M9	276	0.013	434,698	0.010	308,636	126,062	4,526	$67,330
Ravine Area Subtotal									$244,084
All Area Total									$433,304

6.4 Benefit Cost Analysis

Using the basin cost data and the I/I mitigation cost data, a benefit cost comparison can be developed. The cost benefit can be compared for a number of combinations of cost assumptions including the basin location cost, extent of rehabilitation in the system, and the percent of sewers lined. A summary of this cost data has been separated into two tables that assume 90% sewer lining and 60% sewer lining. The cost reductions for basin construction are compared to I/I mitigation costs as a ratio. The cost comparisons for 90% sewer lining is presented in **Table 6-4.** The cost comparisons for 60% sewer lining is presented in **Table 6-5**. The reduction in basin cost was developed assuming a linear relationship of basin cost/gallon of storage. Based on this data the following conclusions can be made.

Below Ground Storage Option A

1. The higher cost for construction of a below ground storage option results in a larger cost savings per gallon as the basin size is reduced making the comparison to I/I mitigation more attractive.
2. Assuming only the Ravine interceptor areas are mitigated, the I/I cost savings range from $-0.54M for 90% sewer lining to $0.28M for 60% sewer lining.
3. If the rehabilitation is extended to the other areas of the system, the I/I cost savings range from $1.11M for 90% sewer lining to $2.63 for 60% sewer lining.

Above Ground Storage Option B

1. The lower cost for construction of an above ground storage option results in a lower cost savings per gallon as the basin size is reduced making the comparison to I/I mitigation less attractive.
2. Assuming only the Ravine interceptor areas are mitigated, the I/I mitigation costs savings range from $-1.29M for 90% sewer lining $-0.47M for 60% sewer lining.
3. If the rehabilitation is extended to the other areas of the system, the I/I mitigation costs savings range from $-1.33M for 90% sewer lining to $0.19M for 60% sewer lining.

Table 6-4 Benefit Cost Analysis 90% Sewer Lining

	No Rehab	Rehab Ravine Only		Rehab Ravine and Other Areas	
	1.2 MG Basin	1.05 MG Basin		0.81 MG Basin	
Basin Cost Version	Cost $M	Cost $M	Reduction $M	Cost $M	Reduction $M
Below Grade	$17.30	$15.57	$1.73	$11.68	$5.62
Above Grade	$9.80	$8.82	$0.98	$6.62	$3.19
I/I Removal Cost (90% Sewers)			$2.51		$4.69
CSO-005 capacity increase cost					$0.25
WWTP treatment reduction savings			$0.24		$0.43
Benefit Cost Ratio					
Below Grade			0.76		1.25
Above Grade			0.43		0.71

Table 6-5 Benefit Cost Analysis 60% Sewer Lining

Basin Cost Version	No Rehab	Rehab Ravine Only		Rehab Ravine and Other Areas	
	1.2 MG Basin	1.05 MG Basin		0.81 MG Basin	
	Cost $M	Cost $M	Reduction $M	Cost $M	Reduction $M
Below Grade	$17.30	$15.57	$1.73	$11.68	$5.62
Above Grade	$9.80	$8.82	$0.98	$6.62	$3.19
I/I Removal Cost (60% Sewers)			$1.70		$3.18
CSO-005 capacity increase Cost					$0.25
WWTP treatment reduction savings			$0.24		$0.43
Benefit Cost Ratio					
Below Grade			1.19		1.88
Above Grade			0.67		1.06

7.0 CONCLUSIONS RECOMMENDATIONS

The City of St. Joseph has conducted an I/I investigation of its system to identify areas with high I/I that can be mitigated to reduce the size and associated cost of constructing an SSO control basin. This I/I investigation was performed using a combination of PACP video inspection data, supplemental field investigations, institutional knowledge of the system, previous flow metering data, and micro-metering of the system. This investigation identified five areas of the system that were suspected of having relatively high I/I. These areas were included in a model analysis of the system that compared the SSO volumes under existing conditions and conditions with I/I mitigation in the selected areas.

The results from this modeling analysis identified potential reductions in the storage tank size and the cost. These storage tank cost reductions were compared to the cost for I/I mitigation to determine the cost benefit of I/I removal. The cost effectiveness was found to be dependent on the following assumptions:

1. Effectiveness of I/I mitigation (fraction of wet weather flow removed)
2. Number of targeted areas included in the I/I mitigation
3. Fraction of sewers and manholes requiring I/I mitigation

4. Storage basin cost (above or below grade structure)

Depending on how the above assumptions were adjusted, this study showed the benefit cost ratio for I/I mitigation ranged from a high of 1.88 (below grade basin, 60% sewer lining in all targeted areas of the system) to a low of 0.43 (above grade basin, 90% sewer lining in ravine area only).

Due to the range in cost effectiveness of I/I mitigation, the team decided to pursue I/I mitigation within two pilot areas of the system. The goal of these pilot areas is to determine the actual reduction of I/I from a portion of the system that is known to have high I/I. As part of a planned project, the City has recently completed rehabilitation of the sewers in Area 10. In addition to Area 10, Area 9 was selected as the pilot area for I/I mitigation (See Figure 4-4). Area 9 includes 20.6 acres, 20 manholes, and 4,014 linear feet of sewer. The sewers in Area 9 are known to have significant defects that require rehabilitation and were previously planned for rehabilitation.

The proposed next steps for I/I mitigation process in Area 9 are described as follows:

1. Development of plans and specifications for I/I mitigation in Area 9. This mitigation will focus on sewer lining and manhole rehabilitation
2. Construction of the planned I/I mitigation in Area 9
3. Post construction rainfall and flow monitoring in Area 9
4. Flow data analysis and/or model calibration of the Area 9 to determine the effectiveness of the I/I mitigation

The above-described next steps for Area 9 are expected to take approximately 2-years to complete. Based on the results of this follow-up construction and analysis, the city will decide if additional I/I mitigation areas should be performed to further reduce I/I and the associated basin size.

Concurrent with the I/I mitigation in Area 9, a basin siting investigation will be performed within the Kiwanis Park area. This goal of this site investigation is to determine the final location of the storage basin and determine if the basin will be constructed above or below grade. The results of this site investigation will better define the cost for construction of the basin allowing for a better understanding of the cost effectiveness of additional I/I mitigation in other areas of the City.

The I/I mitigation program in Area 9 will require additional time that will ultimately push back the construction of the storage basin by approximately 2-years. After the Area 9 pilot project is complete, follow-up monitoring and analysis will be performed to quantify the effectiveness of the I/I mitigation. If the Area 9 I/I mitigation is found to be cost effective, the I/I mitigation effort will be extended to additional target areas of the system. If found necessary, I/I mitigation in these additional areas will require additional time that will push the construction of the storage basin back an additional 2-years.

Appendix A.
System Maps

I/I Mitigation Study

CITY OF St. Joseph

I&I PACP Defects per Foot by Pipe Segment

Total Defects

Total I&I PACP Defects per Foot by Pipe Segment:

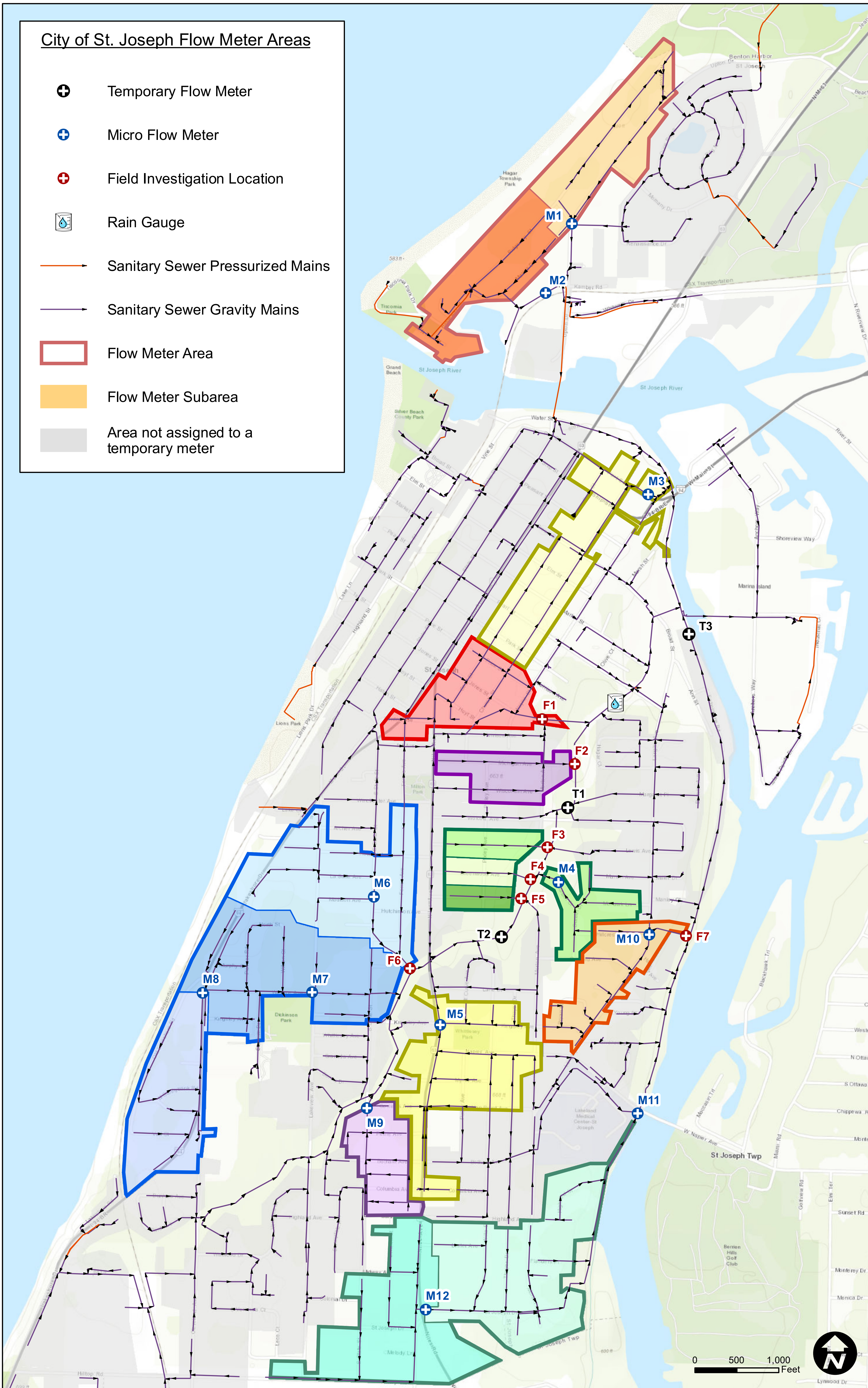
- No Defects
- 0.002136 - 0.006456
- 0.006457 - 0.01375
- 0.01376 - 0.02926
- 0.02927 or More

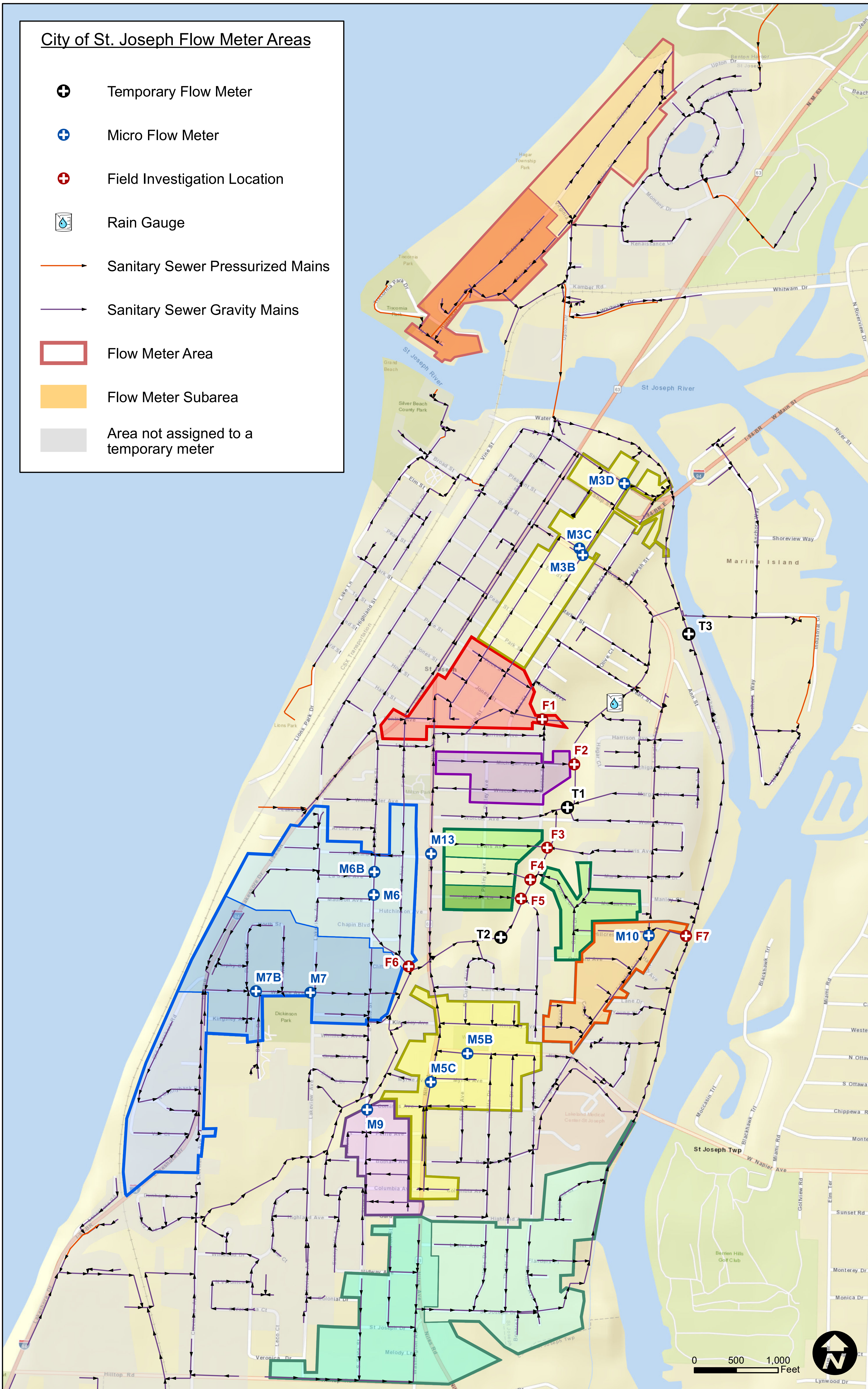
- Sanitary Sewer Gravity Mains - No PACP Data Available
- Sanitary Sewer Manholes
- Flow Monitor Locations
- Tim's I&I Hot Spots

January 7, 2021

0 1,000 2,000 Feet

\\dtdata\projects\Sjo2003\01\GIS-data\Projects\I&I PACP Analysis Maps\Defects per Foot by Pipe Segment - Total Defects.mxd


City of St. Joseph Flow Meter Areas
Temporary Flow Meter
Micro Flow Meter
Field Investigation Location
Rain Gauge
Sanitary Sewer Pressurized Mains
Sanitary Sewer Gravity Mains
Flow Meter Area
Flow Meter Subarea
Area not assigned to a temporary meter
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M12
T1
T2
T3
F1
F2
F3
F4
F5
F6
F7
St Joseph River
St Joseph Twp
0
500
1,000
Feet


City of St. Joseph Flow Meter Areas
Temporary Flow Meter
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Rain Gauge
Sanitary Sewer Pressurized Mains
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Flow Meter Area
Flow Meter Subarea
Area not assigned to a temporary meter
M3D
M3C
M3B
T3
F1
F2
T1
F3
F4
F5
M13
M6B
M6
T2
M10
F7
F6
M7B
M7
M5B
M5C
M9
St Joseph River
Marina Island
St Joseph Twp
0
500
1,000
Feet