TETRA TECH

MEMO

To:	Marlene Chockley, Dan Willis - Northfield Township
From:	Tetra Tech
Date:	July 12, 2017
Subject:	2017 Flow Monitoring Results and Revised Capacity Analysis

1.0 INTRODUCTION

In March 2016, the available capacity of some of Northfield Township's major trunk sewers and pump stations was assessed. The available capacity was then compared to projected levels of development within the service area to evaluate conceptual-level improvements that would be necessary to convey post-development flows. At that time, the only flow data that was available was recorded at the Township's wastewater treatment plant (WWTP) and assumptions regarding the upstream flow rates had to be made. In April 2017, flow meters were installed at three locations along sewers found in the previous study to have limited available capacity for future flows to provide data to refine the flow estimates and available capacity of the Township's collection system infrastructure. The purpose of this memorandum is to describe the flow monitoring data and update the capacity analysis presented in March 2016.

Northfield Township has separate sanitary sewers, which were intended to only convey wastewater flows. It is common in Michigan for older separate sanitary collection systems to have high flow peaks and volumes during wet weather due to inflow and infiltration sources that allow rain or groundwater to get into the sewers. The State of Michigan's Sanitary Sewer Overflow (SSO) Policy requires collection system's to be able to convey and treat flows up to the 25-year, 24-hour design storm (3.90 inches) without overflowing. Therefore, the flow monitoring is particularly important to correlate rainfall to flow rate, which can then be extrapolated to this design storm.

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2.0 FLOW AND RAINFALL MONITORING LOCATIONS

Sewers in the March 2016 study predicted to have an available capacity less than the projected flows were selected for the flow monitoring sites. Temporary ISCO 2150 flow meters and a rain gauge were installed in the following locations:

- EightMile-27: Located in manhole SS-0035, in the gravity sewer immediately upstream of the Eight Mile Road Pump Station. The entire collection system is tributary to this meter except for the portion of the service area tributary to the North Territorial Pump Station.
- Barker-18: Located in manhole N-19, at Barker Road and US-23. This meter is upstream of the EightMile-27 meter and measures flow in the sewer where it crosses US-23. The portion of the system east of US-23 and south and east of Whitmore Lake are tributary to this meter location. The meter is located in the upstream pipe and does not measure flow from the sewer branch that serves customers located on the north and west shores of Whitmore Lake.
- EastShore-12: Located in manhole N-114, at the intersection of East Shore Drive and Elizabeth Street. This meter is upstream of the Barker-18 meter. Areas east of Whitmore Lake are tributary to this meter.
- A temporary, tipping bucket rain gauge was installed at the wastewater treatment plant.

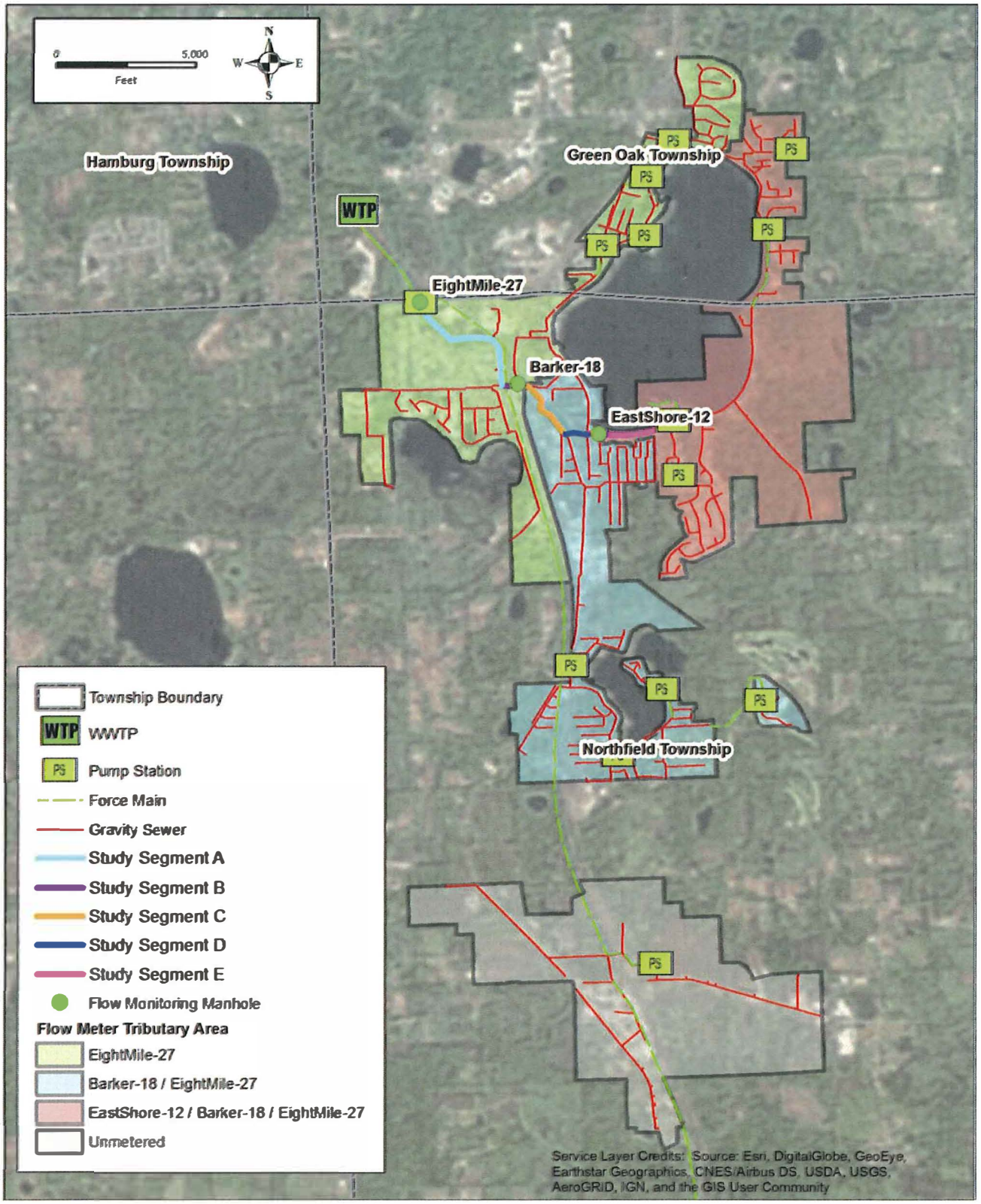
The meters and rain gauge were downloaded approximately once every two weeks and serviced at least once a month.

The meter locations and direct tributary areas are shown in Figure 2-1. The population and parcels tributary to each meter were also estimated for use with the flow monitoring results. They are shown in Table 2-1.

Table 2-1: Population and Parcels Tributary to Flow Monitoring Locations

Meter	Installation Date (2017)	Removal Date (2017)	Tributary Meter(s)	Tributary Population	Tributary Parcels
EightMile-27	April 4	July 5	Barker-18, EastShore-12	5,200	3,500
Barker-18	April 3	July 5	EastShore-12	3,700	2,000
EastShore-12	April 3	July 5	none	1,800	800

Figure 2-1: Meter Locations and Tributary Areas



3.0 FLOW MONITORING RESULTS AND DESIGN STORM PROJECTION

The primary focus of the flow monitoring was to evaluate the flow response to rainfall. However, dry weather flow is also important in the case of Northfield Township because prolonged periods of elevated flows that were measured following rainfall. These flows are not as high as the peak flow rate measured during the rainfall, but it would often take several days for them to subside back to the dry weather flow.

The flow monitoring terms used to describe the analysis that was performed include:

- Average dry weather flow rate, which includes wastewater flows and dry weather infiltration. Typical average wastewater flows are in the range of 70 to 100 gallons per capita per day (gpcd), so average dry weather flow rates above this range indicates a probability of dry weather infiltration. Dry weather flow was assumed to occur when no more than 0.10 inch of rain fell in the 72 hours prior to the flow measurement.
- Peak flow rate is the maximum measured flow rate during a rainfall.
- Peaking factor, which is the ratio of the peak flow rate to the average dry weather flow rate. As a general rule, a peaking factor greater than 5 in a separate sanitary sewer indicates a significant response to rainfall. Even so, lesser peaking factors may be important depending on the collection system.
- Nominal capacity is the flow rate that can be conveyed without surcharging the sewer. Sewers may be able to convey an additional flow rate without creating SSOs if they surcharge although this is not recommended.
- Surcharge is the water depth in the sewer that is above the pipe crown.

3.1 DRY WEATHER FLOW MONITORING RESULTS

The average dry weather flow rate at each meter location is shown in Table 3-1. The average dry weather flow over the entire flow monitoring period is higher than 100 gpcd. In general, the average dry weather flow decreased from April to June as the soil moisture became drier with warmer weather and less rainfall. Both these statements suggest infiltration in the system. Dry weather infiltration would be more likely in Northfield Township because of the high groundwater elevation caused by the lakes.

Table 3-1: Average Dry Weather Flow by Meter

	Average Dry Weather Flow Rate, MGD				Average Dry Weather Flow Rate, gpcd			
Meter	Overall	April	May	June	Overall	April	May	June
EightMile-27	0.62	0.69	0.71	0.54	120	130	140	100
Barker-18	0.48	0.56	0.56	0.40	130	150	150	110
EastShore-12	0.25	0.31	0.28	0.19	140	170	160	110

3.2 WET WEATHER FLOW MONITORING RESULTS

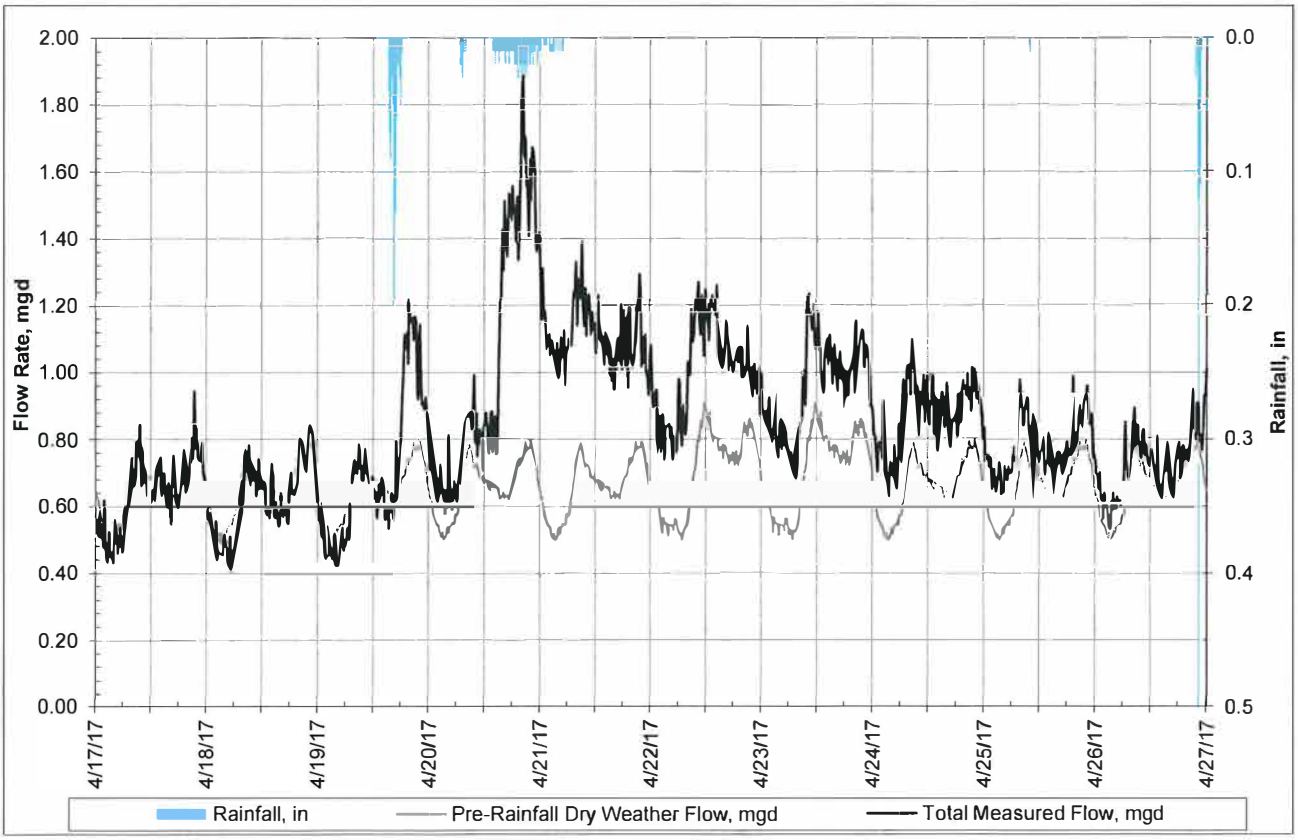
During the flow monitoring period, there were eight rainfall events that exceeded 0.25 inches, including two that exceeded 1.00 inch. These rainfall events and the peak flow rates during each event are presented in Table 3-2. During flow monitoring projects, it is desirable to obtain at least three or more storms with over 1 inch of rainfall to develop a definitive trend. The weather during this project did not provide this number of events, so there is more uncertainty in the trend than if higher volume rainfall events were recorded.

Table 3-2: Rainfall Events during the Monitoring Period

Event	Rainfall Date (2017)	Rainfall, inches	Duration, hours	Peak Hour Rainfall, inches	EightMile-27 Peak Flow Rate, MGD	Barker-18 Peak Flow Rate, MGD	EastShore-12 Peak Flow Rate, MGD
1	April 20	1.53	32.50	0.10	1.89	1.07	0.63
2	April 26	0.82	1.50	0.78	1.09	0.75	0.48
3	April 30	0.75	40.50	0.27	1.17	0.85	0.48
4	May 4	0.70	13.25	0.10	1.39	0.90	0.54
5	May 16	0.48	3.50	0.42	0.89	0.66	0.42
6	May 21	1.52	13.75	1.23	1.35	0.95	0.53
7	June 22	0.29	12.00	0.12	0.69	0.50	0.31
8	June 30	0.27	19.75	0.13	0.72	0.50	0.32

The measured peak flow rates were 50 to 70 percent of the pipe capacity at the monitoring sites. Additional information about the capacity analysis will be provided in Section 4.0. No surcharging (water level above the pipe crown) was recorded by the meters. A sample hydrograph from the EightMile-27 meter during the April 20 event is provided in Figure 3-1. The peak flow rate and return to dry weather flow following the event is shown.

Figure 3-1: Hydrograph for April 20, 2017 Rainfall at Gravity Sewer Discharge into Eight Mile Road Pump Station



The peaking factor is one indicator of the wet weather response and peaking factors typically increase with rainfall. At the flow monitoring sites, the peaking factor for every event at every meter, except one was 2 or less. Storage in upstream pump stations and the relatively small storms that were observed likely contributed to a smaller peaking factor.

Table 3-3: Summary of Peaking Factors by Meter

Event	Rainfall Date (2017)	EightMile-27 Peaking Factor	Barker-18 Peaking Factor	EastShore-12 Peaking Factor
1	April 20	2.7	1.9	2.0
2	April 26	1.6	1.3	1.5
3	April 30	1.7	1.5	1.5
4	May 4	2.0	1.6	1.9
5	May 16	1.3	1.2	1.5
6	May 21	1.9	1.7	1.9
7	June 22	1.3	1.3	1.6
8	June 30	1.3	1.3	1.7

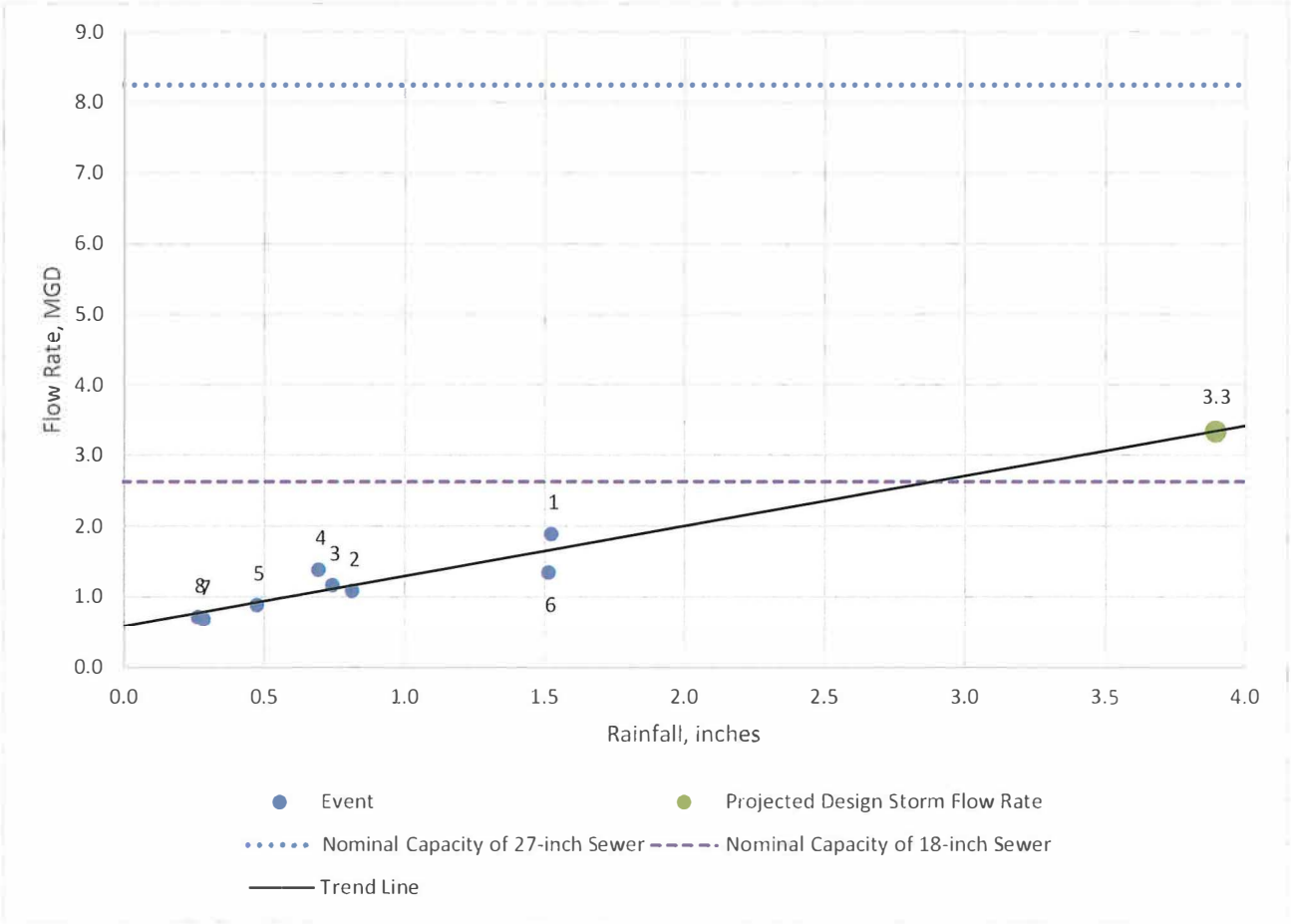
3.3 DESIGN STORM PROJECTIONS AT METER LOCATIONS

For each of the meter locations, a relationship between the measured peak flow rates and rainfall was developed and projected to the 25-year, 24-hour design storm, which the Michigan Department of Environmental Quality defines as 3.9 inches of rainfall with normal soil moisture during the vegetative growing season (April through October). The peak hour rainfall is 1.7 inches if the SCS Type II distribution is used.

The gravity sewer between Barker Road and the Eight Mile Road Pump is primarily an 18-inch diameter sewer, except the last segment of pipe where the meter was located, which is a 27-inch diameter sewer. The measured peak flow rate at this site reached 70 percent of the nominal capacity (the full flow capacity of the sewer without surcharging) of the 18-inch portion of the sewer in April. A linear relationship between the flow rate and rainfall produced a projected 25-year, 24-hour design storm peak flow rate that is less than the nominal capacity of the 27-inch portion of the sewer, but greater than the 18-inch portion of the sewer. This is shown in Figure 3-2. The events are labeled chronologically in the figure and are the same events listed in Table 3-2.

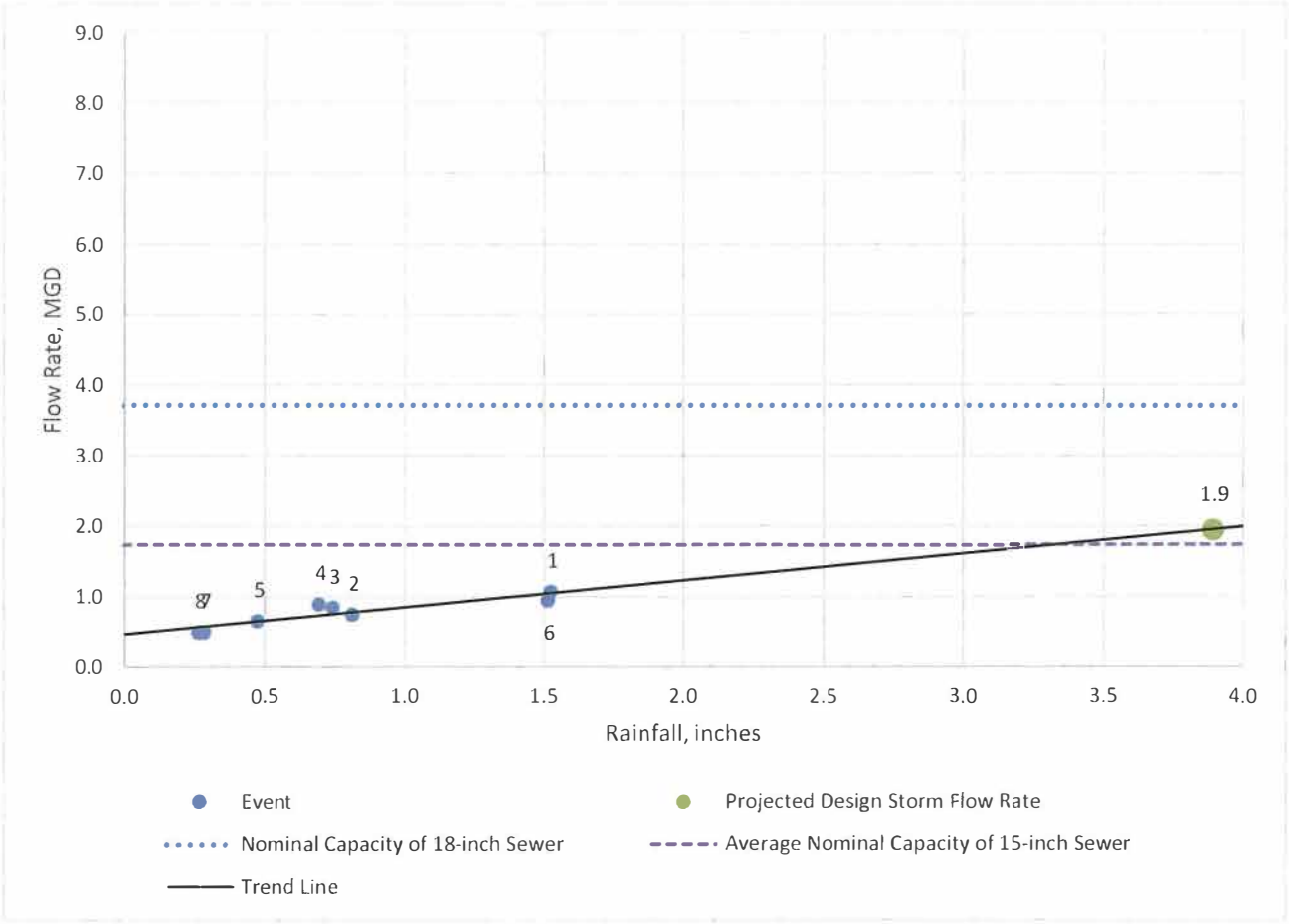
The limited number of large rainfall events adds some uncertainty to the projection, but a decrease in the design storm projection below the pipe capacity would not be expected even with additional data given the magnitude of the measured flow rates.

Figure 3-2: Projected Design Storm Peak Flow Rate at EightMile-27 Meter



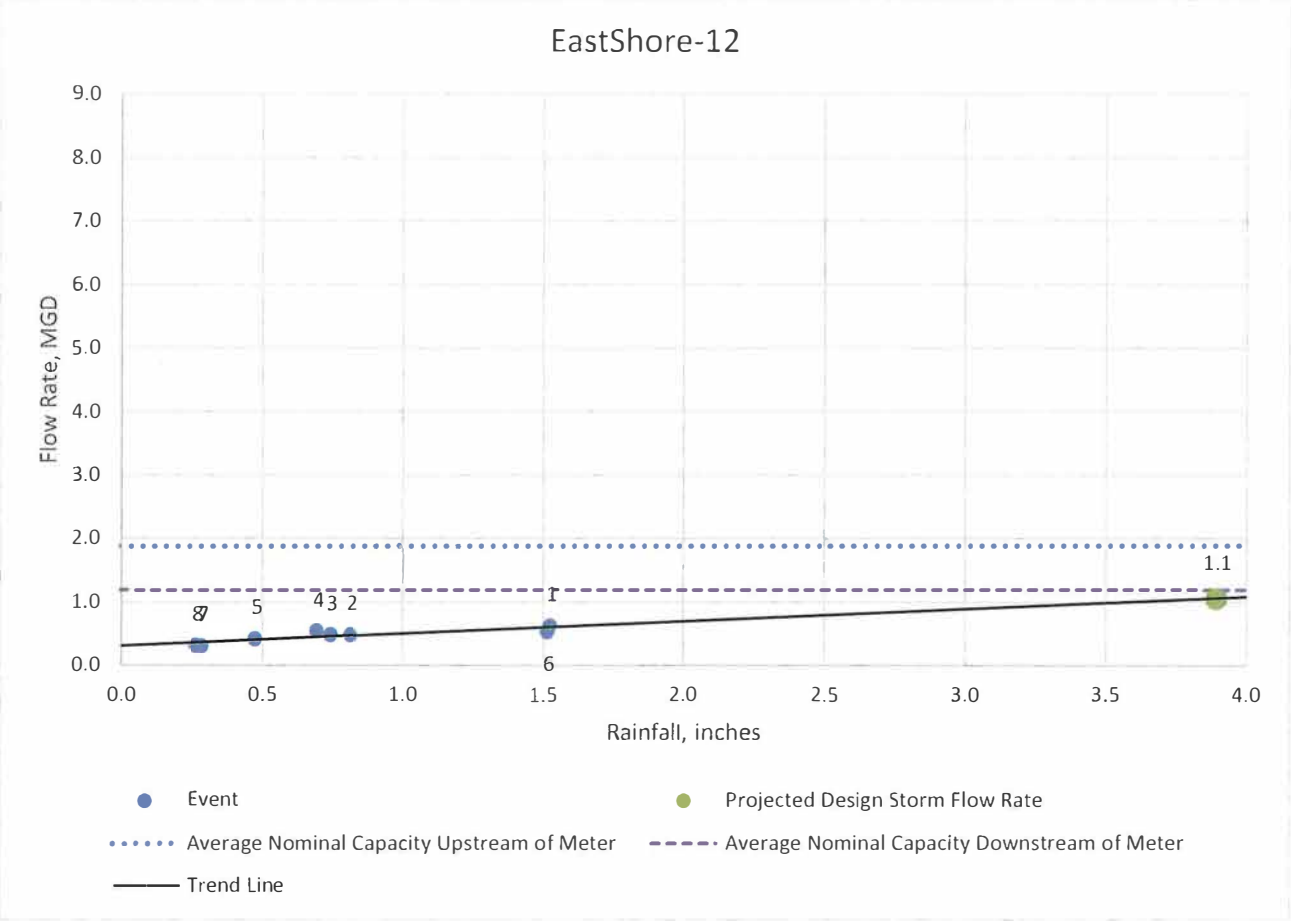
The sewer along Barker Road and the railroad is comprised of two diameters of pipe, 15 and 18 inches. The peak measured flow rate reached 60 percent of the 15-inch sewer's nominal capacity. The 25-year, 24-hour design storm peak flow rate was projected to be just above the nominal capacity of the 15-inch portion of the sewer. The projected design storm peak flow rate and the nominal capacity of the sewers are shown in Figure 3-3.

Figure 3-3: Projected Design Storm Peak Flow Rate at Barker-18 Meter



The East Shore Drive sewer has a constant 12-inch diameter, although differences in the pipe slope occur. The pipe in which the meter was located and upstream of that point has a steeper slope, and therefore, a larger capacity. The downstream reach of sewer has a flatter slope and smaller capacity. Both these capacities are shown in Figure 3-4. During the flow monitoring period, the measured peak flow rate reached 50 percent of the average nominal capacity of the sewer downstream of the meter location. The projected 25-year, 24-hour design storm peak flow rate, shown in Figure 3-4, is less than the average nominal capacity of the sewer both upstream and downstream of the meter location.

Figure 3-4: Projected Design Storm Peak Flow Rate at EastShore-12 Meter



The projected design storm peak flow rates at 3.9 inches of rainfall are summarized in Table 3-4. The peaking factors for the design storm are larger than those that were measured because the peak flow rate for the design storm is larger than the measured events.

Table 3-4: Summary of 25-year, 24-hour Design Storm Projection

Meter	Average Dry Weather Flow Rate, MGD	Peak Flow Rate, MGD	Peaking Factor
EightMile-27	0.62	3.3	5.3
Barker-18	0.48	1.9	4.0
EastShore-12	0.25	1.1	4.4

4.0 CAPACITY ANALYSIS

The flow monitoring provided more precise data on which to base the design storm flow rates and, therefore, projected flows are different that those presented in Table 2 of the March 2016 memorandum. The changes in the design storm flow rates are shown in Table 4-1. Using the flow monitoring data, the design storm peak flow rates increased up to 0.5 MGD from the estimates shown in the March 2016 memorandum.

Table 4-1: Comparison of Flow Rates to Estimates made in March 2016 without Flow Monitoring Data

Meter / Sewer Segment†	Average Dry Weather Flow Rate, MGD		Design Storm Peak Flow Rate, MGD		Peaking Factor	
	March 2016	July 2017	March 2016	July 2017	March 2016	July 2017
EightMile-27 / A	0.70	0.62	2.8	3.3	4.0	5.3
Barker-18 / C	0.40	0.48	1.6	1.9	4.0	4.0
EastShore-12 / E	0.17	0.25	0.7	1.1	4.0	4.4

† From Table 2 of the March 22, 2016 memorandum.

In all cases, the design storm peak flow rate was greater using the flow monitoring data as a basis. Therefore, the capacity analysis for Sewer Segments A through E from the March 2016 study was updated using the revised numbers. The capacity analysis for other sewer segments and pump stations is not updated because there is no basis for changing those numbers.

The updated peak flow rate and available capacity are presented in Table 4-2. As a result of the larger design storm flow rates, the available capacity is reduced from the March 2016 memorandum (where it was greater than zero), except Segment E where the nominal sewer capacity was revised. As in the March 2016 memorandum, the methodology for calculating the number of additional REUs that can be served by a particular sewer assumes a peak hour flow of 1,040 gallons per day per REU.

Table 4-2: Capacity Analysis

Sewer Segment†	Location	Pipe Diameter, inches	Nominal Capacity, MGD	Design Storm Peak Flow Rate, MGD	Available Capacity, REUs
A	Barker Road to Eight Mile Road Pump Station	18	2.6	3.3	0
B	Barker Road across US-23	18	2.4	2.7	0
C	Barker Road to East Shore Drive (extended)	15	1.7	1.9	0
D	East Shore Drive (extended) west of Main Street	12	1.2	1.1	100
E	East Shore Drive east of Main Street	12	1.9	1.1	770

† From Table 2 of the March 22, 2016 memorandum.

Given that there is no available capacity in the gravity sewer at the downstream end of the system, additional significant development anywhere in the system upstream of the gravity sewer discharging into the Eight Mile Road Pump Station is not recommended until capacity can be increased.

The March 2016 memorandum also provided an estimate of the magnitude of the projected development tributary to each sewer segment. Projected development demand (as presented in Table 2 of the March 2016 memorandum) already exceeds the available capacity at all sewer segments A through E. Therefore, capacity improvements are projected to be necessary to convey the existing design storm peak flow rate plus the additional flows from the projected development. The additional conveyance capacity that is projected to be needed is presented in Table 4-3.

Table 4-3: Capacity Required to Convey Existing and Projected Development Design Flow Rate

Sewer Segment†	Maximum Projected Development, REUs†	Average Flow from Projected Development, MGD	Peak Flow from Projected Development, MGD	Projected Future Design Storm Peak Flow Rate, MGD	Additional Capacity Needed, MGD
A	764	0.20	0.80	4.1	1.5
B	614	0.16	0.64	3.3	0.9
C	510	0.13	0.52	2.4	0.7
D	386	0.10	0.40	1.5	0.3
E	386	0.10	0.40	1.5	0.0

† From Table 2 of the March 22, 2016 memorandum.

5.0 CONCEPTUAL IMPROVEMENTS

Conceptual improvements were identified that will allow the Township to begin planning for future improvements that may be necessary to realize any significant growth. It is likely that the Michigan Department of Environmental Quality will not allow permits to new developments that would become tributary to the sewers in this memorandum without other data (such as a numerical model) showing that pipe surcharging will not cause sanitary sewer overflows or basement flooding.

The conceptual improvements were evaluated for the additional capacity that they would provide and compared to the required additional capacity that is projected to be needed and shown in Table 4-3. Larger improvements may be necessary if development projections increase.

5.1 SEWER SEGMENTS A AND B

Improvements #2 and #3 documented in the March 2016 memorandum are still feasible with the revised flow projections. These improvements for Sewer Segments A and B replace the existing gravity sewer with a larger sewer, which consist of the following elements:

- Replace 3,700 feet of the existing 18-inch cross-country sewer between Barker Road and the Eight Mile Road Pump Station with a 21-inch diameter sewer. This is the same as Improvement #2 listed in Table 3 of the March 2016 memorandum.

  A replacement sewer was recommended over a relief sewer based on the age of the existing sewer and its construction material. If the existing pipe is later determined to be in good condition, a relief sewer may be able to increase the conveyance capacity at a lower cost than estimated in this document. A 15-inch relief sewer would be recommended.

  The Township sewer O&M staff have noted that a replacement interceptor would require significant tree clearing. Pipe bursting is a technique to replace sewer line with a reduced amount of excavation. Pipe bursting would require less excavation, but substantial tree removal would likely still be required along the route to allow truck access and for construction pits.
- Replace 420 feet of existing 18-inch sewer along Barker Road under US-23 with a 21-inch diameter sewer. This is the same as Improvement #3 listed in Table 3 of the March 2016 memorandum, except that the length of the improvement has decreased.

These improvements would increase the nominal capacity of Segments A and B to 4.1 MGD. The opinion of probable cost from the March 2016 memorandum for these improvements is $1,950,000.

Another alternative that was evaluated and has a comparable cost would divert all or a portion of the flows from the gravity sewer at US-23 and Barker Road to a new pump station that would pump those flows to the Eight Mile Road Pump Station. It is estimated that up to 1.5 MGD would have to be diverted from the gravity sewer during the design storm to prevent surcharging, which would be approximately 40 percent of the projected design storm flow rate at this location. This alternative would also include 4,100 feet of 8-inch diameter force main.

5.2 SEWER SEGMENTS C, D, AND E

Improvements #4 and #5 documented in the March 2016 memorandum are also still feasible with the revised flow projections. These improvements impact Sewer Segments C and D. No improvements are needed for Segment E because the nominal capacity of the sewer is greater than the projected peak flow rate. Improvements #4 and #5 replace the existing sewer with a larger diameter sewer and consist of the following elements:

- Replace 1,700 feet of the existing 15-inch cross-country sewer between Segment D and Barker Road with an 18-inch diameter sewer. This is the same as Improvement #4 listed in Table 3 of the March 2016 memorandum.
- Replace 600 feet of the existing 12-inch cross-country sewer between Main Street and Segment C with a 15-inch diameter sewer. This is the same as Improvement #5 listed in Table 3 of the March 2016 memorandum. Given the short reach of sewer in this recommendation, small offsets in the published sewer invert elevations from the actual elevations may lead to errors in the slope used to calculate the nominal capacity of the sewer that are more discernable than for longer reaches of sewer. Differences in the slope from one reach to the next may result in an extension or reduction in the length of this portion of the improvement.

These improvements would increase the nominal capacity of Segments C and D to 2.8 and 2.1 MGD, respectively. The opinion of probable cost from the March 2016 memorandum for these improvements is $920,000.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The spring 2017 flow monitoring period was relatively dry with only two storms over 1 inch in volume. The small rains produced mild responses in the sewer flows. As a result of the mild storms, there is still some uncertainty with the flow rates that can be expected for the 25-year, 24-hour storm.

The projected wet weather response for the 25-year, 24-hour design storm did increases from the theoretical projections made in the March 2016 memorandum to the Township. The wet weather response often lasted several days after the rainfall. Future flow monitoring that captures larger storms may further modify the peak flow projections and results of this memorandum.

Based on the current knowledge of flow rates, conveyance improvements should accompany significant new connections to the sanitary sewer. Measured flow rates in the downstream 18-inch gravity sewer at the Eight Mile Road Pump Station were already 70 percent of its nominal capacity for a 1.5-inch rainfall. The projected 25-year, 24-hour design storm for this segment of sewer was greater than its nominal capacity.

The recommended improvements did not change from the March 2016 memorandum. They consist of the following elements:

- 3,700 feet of 21-inch diameter cross-country sewer between Barker Road and the Eight Mile Road Pump Station to replace the existing sewer. Pipe bursting would also be a feasible alternative for this segment of sewer.
- 420 feet of 21-inch diameter sewer along Barker Road to replace the existing sewer.
- 1,700 feet of 18-inch cross-country sewer between Segment D and Barker Road.
- 600 feet of 15-inch cross-country sewer between Main Street and Segment C.

The total opinion of cost of the improvements is $2,870,000.

An alternative with a similar cost that could be used to avoid replacing or bursting the existing gravity sewer would be to divert all or a portion of the flows from the gravity sewer at US-23 and Barker Road to a new pump station that would pump those flows to the existing Eight Mile Road Pump Station. This alternative would consist of a 1.5 MGD firm capacity pump station and 4,100 feet of 8-inch force main.

The Township plans to do future flow monitoring. Locations that would be beneficial to flow monitor during planned future flow monitoring projects include:

- Flows from Green Oak Township to establish contributions from customers outside Northfield Township.
- Influent sewers to significant pump stations because if those flows are known, it may be possible to develop alternatives that can include re-routing force mains or replacing aging pumps that would likely be lower cost to the Township than new gravity sewers.
- Areas in close proximity to proposed developments to ensure sewer branches further upstream in the collection system also have adequate capacity.

Most future flow monitoring should also repeat the monitoring along the trunk sewer upstream of the Eight Mile Road Pump Station because this collects wastewater from a majority of the Township and has the most expensive improvements that were identified.

If the Township decides to purse these improvements, the Township should consider updating the system development charge (i.e. connection fee) to allow the cost of the improvements to be recovered from new connections, which are the primary stimulus in requiring these improvements.