CITY OF HUDSON

SANITARY SEWER EVALUATION AND MODELING REPORT

Project No. E14002

September 23, 2014

Prepared By:

CTI ENGINEERS, INC.
Practical Innovation, By Design®

One Cascade Plaza, Suite 710 (330) 294-5996
Akron, Ohio 44308 (330) 315-0945 Fax
www.ctiengr.com

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES

TABLE OF CONTENTS (CONT'D)

LIST OF APPENDICES

LIST OF EXHIBITS

LIST OF ABBREVIATIONS

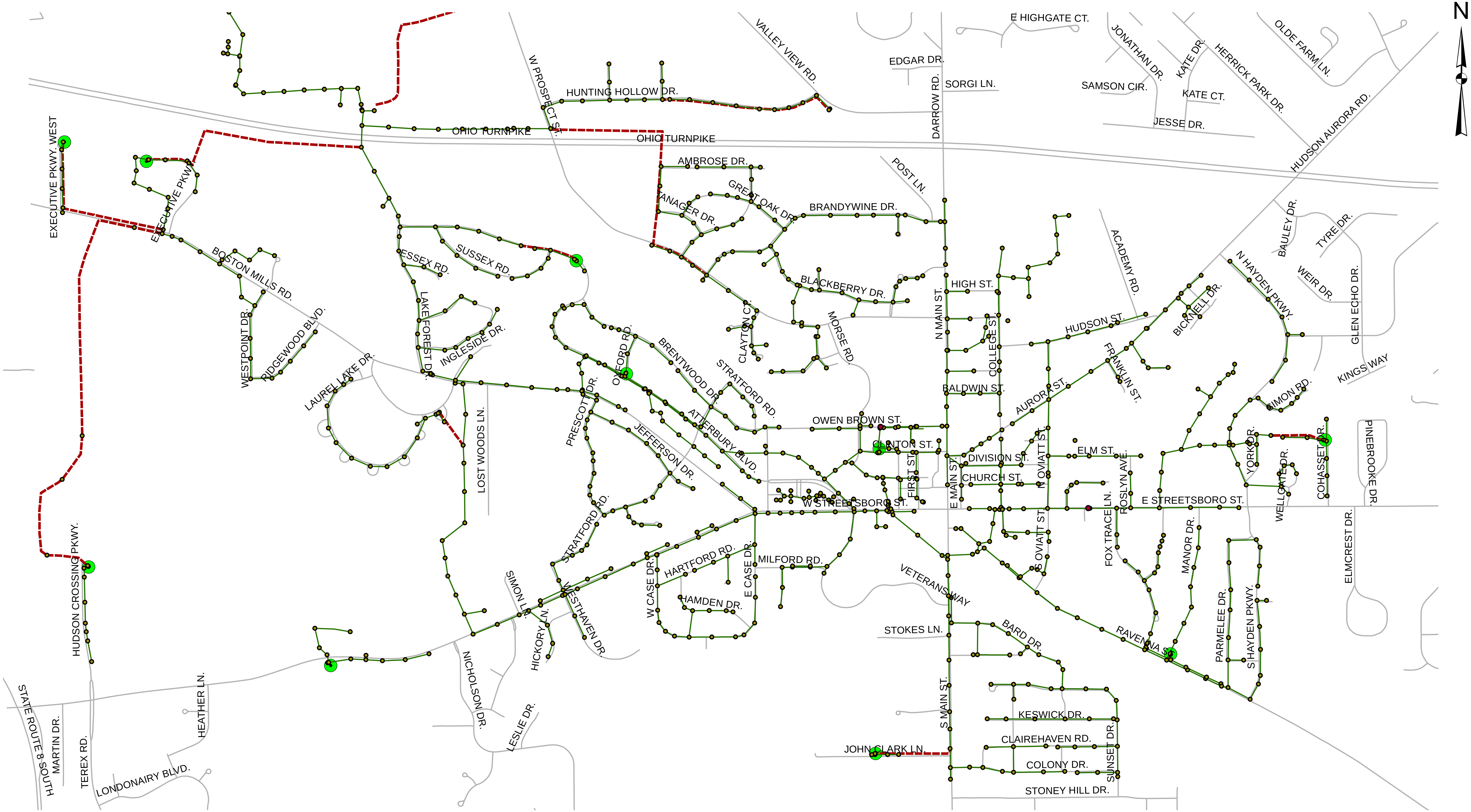
CSO	Combined Sewer Overflow
CVI	Cuyahoga Valley Interceptor
Diam.	Diameter
DOES	Department of Environmental Services
DWF	Dry Weather Flow
EPA	Environmental Protection Agency
EPS	Extended Period Simulation
FM	Force Main
GIS	Geographical Information System
GPM	Gallons Per Minute
GPS	Global Positioning System
I&I	Inflow and Infiltration
In.	Inches
MCF	Thousands of Cubic Feet
MGD	Millions of Gallons per Day
MH	Manhole
NEORSD	Northeast Ohio Regional Sewer District
NOAA	National Oceanic and Atmospheric Administration
RDII	Rain-Derived Inflow and Infiltration
SSO	Sanitary Sewer Overflow
SSOAP	Sanitary Sewer Overflow Analysis and Planning
SWMM	Storm Water Management Model
WWF	Wet Weather Flow

1.0 INTRODUCTION

The sanitary sewers within the City of Hudson are owned by two governmental entities. Sanitary sewers within the western and central portions of the City are owned and maintained by the City of Hudson, while the remainder of the sewer system is owned and maintained by the Summit County Department of Environmental Services (DOES). The City system consists of over 900 manholes and related gravity sewer, and eight (8) pump stations, including the City's abandoned wastewater plant that has been converted to an equalization tank and pump station. This pump station ultimately discharges flow from the City system to the North East Ohio Regional Sewer District's (NEORSD) Cuyahoga Valley Interceptor (CVI) sewer.

The City's sanitary sewer system, which is presented in Figure 1.1, experiences inflow and infiltration (I&I) during rain events. During rainfall events, downspouts, sump pumps, and yard drains that are connected illegally to the sanitary sewer system can direct large amounts of storm water or "inflow" into Hudson's sanitary sewer system. Similarly, as rainfall percolates through the soil, or as groundwater tables rise as a result of rainfall, this water can enter, or "infiltrate" privately owned sanitary sewer laterals, sewer mains, or manholes through cracked and damaged sections. The increase in flows due to I&I can cause basement flooding, an increase in the City's operational costs, as well as overflows of raw sewage at the City's sanitary sewer overflows (SSO's). In 1996, the Ohio Environmental Protection Agency (EPA) issued a consent order to the City to close its five (5) existing SSO's. Since then, the City has completed many capital improvement and maintenance projects, including manhole lining, sanitary sewer lining and replacement projects. These projects have enabled the City to close three of its SSO's. Due to these improvements to the sanitary sewer system, the City has determined that a comprehensive study was required in order to prioritize future studies or improvements, ultimately eliminating the two remaining SSO's, and thus meeting the Ohio EPA's consent order.

The services of CTI Engineers, Inc. (CTI) were retained to develop a calibrated computer model of the City's trunk sewer system (10 inches in diameter and larger), as well as smaller diameter sewers that were deemed critical to the system. This model reflects the hydraulic conditions within the City's existing trunk sewer system during dry weather conditions and during various rainfall events. The model and the work done as part of its development has been used to determine areas of the City's sanitary sewer system requiring additional study and to evaluate potential capital improvement projects to the system, which would minimize the effects caused by I&I and work to eliminate the two remaining SSO locations.



LEGEND

GRAVITY SANITARY SEWER
SANITARY SEWER FORCE MAIN
ROADWAY
SANITARY SEWER MANHOLE
LIFT STATION

0 500 1,000 2,000 Feet

CTI ENGINEERS, INC.

ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

FIGURE 1.1
CITY OF HUDSON, OH
SANITARY SEWER SYSTEM

2.0 PROJECT APPROACH

The objective of this study was to evaluate the City's sanitary trunk sewer system and offer recommendations for improvements. A computer model was developed and utilized to analyze the existing trunk system and evaluate alternative system improvements. The proposed trunk sewer improvements focused on improving the capacity and performance of sewers during rain events. The study also prioritized areas of the system requiring additional monitoring and further detailed study to better evaluate I&I and its effects on the trunk system and SSO's. The services performed by CTI to accomplish this task included the following:

1. Attend a pre-study meeting with City Officials to review project requirements and understand the City's concerns for the project.

2. Develop an initial flow monitoring plan to determine locations for sixteen (16) flow meters within the City's sanitary sewer system. The maps developed as part of the initial flow monitoring plan were developed from the City's Geographical Information System (GIS) and were later used as a digital base map for the computer model. Once the sixteen locations were determined, flow meters were installed for a period of sixty (60) consecutive days from the end of March through May 2014.

3. Identify and install two (2) rain gauges in conjunction with the City's existing rain gauge, which is located at the Fire Station on South Oviatt Street. The three (3) rain gauges were used to collect the required rainfall data necessary to calibrate the model.

4. Enter the required trunk sewer data collected from the City's GIS. This data included pipe lengths, diameters, as well as pipe material (and material roughness) into the model. All City sewers 10 inches in diameters or larger were added to the model, as well as any smaller sewers that were deemed to be critical to model performance (i.e. any sewer downstream of a flow meter to the trunk sewer if the flow meter was installed on a sanitary sewer less than 10 inches in diameter).

5. Enter the required manhole data (manhole diameter/size, invert elevations and rim elevations) into the model. Manhole rim elevations were established by field survey using GPS equipment. The invert elevations within each manhole were then determined

by subtracting the pipe depths, which were previously collected by City staff, from the rim elevations.

6. Validate entered pipe/manhole data, check for anomalies, and have the City field verify any data errors.

7. Collect flow meter data and review the data for measurement accuracy. Use the given flow data, as well as related rain gauge information, to establish dry-weather diurnal flow patterns for each flow meter. These dry weather flow (DWF) hydrographs were then entered into the computer model. The developed dry weather flow rates were then validated by estimating average daily sanitary flows for each drainage area (house count) as well as comparing with historical flow data to the CVI.

8. Determine the effect of I&I on the drainage area related to each flow meter using the EPA's Sanitary Sewer Overflow, Analysis and Planning (SSOAP) toolkit. In this analysis, coefficients were established for several storm events for each flow meter to create a "best fit" curve between theoretical and actual rain-derived I&I (RDII) flow rates. The developed coefficients were then used to determine the drainage areas which seem most affected by I&I, which can be later used to prioritize future improvement projects.

9. Develop wet weather hydrographs for each given drainage area and enter them into the model. The developed computer model was then run to verify that model results matched actual flow meter data within tolerances. From these calibrated wet weather hydrographs, design hydrographs were developed using 1,5,10,and 25 year, one-hour rainfall data. The developed computer model was then used to evaluate proposed alternatives based on the given design storms.

10. Conduct progress meetings with City personnel at the 50%, 90%, and completion (100%) stages of the study.

11. Prior to completion of the project, develop a report discussing the results of the study.

12. Attend two (2) meetings to discuss study findings with City Administration and City Council.

3.0 EXISTING CONDITIONS

CTI personnel met with City of Hudson personnel to discuss the existing sanitary sewer system, as well as discuss potential resources in developing the computer model. The following section is a summary of those discussions.

3.1 Background

(See Figure 1.1 for a map of the City of Hudson sanitary sewer system.) Sewers within this system range from 6-inch laterals to a 24-inch trunk sewer that eventually outfalls to the CVI pump station. This pump station used to be the City's wastewater treatment plant before it was rehabilitated to a pump station, which ultimately discharges into the NEORSD's Cuyahoga Valley Interceptor.

The eastern part of town is served primarily by two main branches - the southeast branch is an 8-inch diameter sewer along E. Streetsboro Road, while the northeast branch is a 12-inch diameter sewer that runs near Division Street before turning north along N. Main Street, and then west onto Owen Brown Street. These two branches combine near the intersection of Owen Brown Street and Atterbury Boulevard. The trunk sewer then continues along Atterbury before turning northwest along Boston Mills Road. At the intersection of Boston Mills Road and Lake Forest Drive, the trunk sewer changes in diameter from 24-inch to 18-inch diameter. This section of sewer is approximately 130 feet long and may have been originally constructed in order to limit peak flows to the City's then operational wastewater treatment plant (which has since been converted to a pump station). The trunk sewer then returns to 24 inches in diameter, and turns north along Lake Forest Drive until its outfall at the CVI pump station.

Theoretically, a sanitary sewer system should only convey sanitary wastewater. However, in practice this is not the case as all sanitary sewer systems experience some amount of I&I. Potential sources of I&I for any system may be leaking sewer joints, leaking joints at brick manholes, illegal connections of downspouts, footer drains, and other clean water connections from residential customers to the sanitary sewer system, or surface runoff that passes over a vented manhole lid. The extent of I&I increases with the age of the sanitary sewer system, as pipes, manholes, and their joints deteriorate versus time. For example, the eastern portion of the City's sanitary sewer system is older and experiences I&I during rainfall events. When this unintended flow enters pipes or manholes, it overloads the sanitary sewer system and can cause sewer backups, flooded basements, and also increase the total volume of flow sent to the NEORSD, increasing operational costs for the City.

As part of the sewer system's original construction, numerous sanitary sewer overflows (SSO's) were built to alleviate flooded basements and other stresses on the system during rain events. These SSO's allow raw sewage, which has mixed with I&I, to overflow from the sanitary sewer system to an alternate outfall. Because of significant capital improvements to the system aimed at eliminating I&I, only two SSO's remain. These SSO's are located at MH-430 (on Owen Brown Street at Brandywine Creek) and MH-264 (near #142 East Streetsboro Road).

3.2 GIS Data

The City compiles physical data related to its sanitary sewer system within the City's GIS. GIS information related to the pipes that comprise the gravity sewers includes pipe diameters, lengths, as well as the pipe material. GIS manhole data includes its rim elevation as well as the invert elevation of any pipe entering each manhole. In some cases, as-built drawings and a video of the sewer are also available within the GIS.

This sanitary sewer information within the GIS has been used to construct the computer model. Rim elevations of modeled manholes were measured by a professional surveyor to ensure accuracy. Manhole depth information, which had been collected by City personnel prior to the study, were then subtracted from the rim elevations to determine invert elevations.

Once this information was collected, a review of the data was performed in order to check it for accuracy. Physical anomalies, such as pipes with negative slopes, were identified and then later verified in the field by City personnel. The information was then adjusted based on findings of the field investigations.

4.0 FLOW MONITORING

Sixteen (16) flow meters were installed and maintained by C&K Industrial Services, Inc. Data was also collected from three (3) rain gauges to determine dry weather periods as well as the intensity of the storms experienced by the City during the flow monitoring time period. Meter and rain gauge locations were chosen in order to provide an equal distribution of flow data throughout the system to be modeled, and to target specific areas that may contribute relatively higher amounts of I&I when compared to the rest of the system. These target areas were based on factors known to contribute I&I, such as age of the system, surface features, or based on City staff experience with the sanitary sewer system during rainfall events. The preliminary locations determined by CTI were presented within their Initial Flow Monitoring Plan and agreed upon by the City prior to their installation. The agreed-upon locations are presented in Figure 4.1. A copy of CTI's Initial Flow Monitoring Plan is presented in Appendix A.

Installation and operation of flow meters began on March 27, 2014 and continued through May 30, 2014. Flow meter data was collected on a weekly basis and prior to forecasted rainfall events. Data was checked to verify that meters were continuing to collect accurate flow information.

Once the flow monitoring period was complete and all data was collected, it was checked for relative accuracy. Anomalies were identified, as well as time periods when the meter(s) may have performed atypically (i.e. frequent readings of "0" flow). Scatter graphs of the data for each flow meter were developed in order to review the relative performance of each meter. By plotting the velocity versus depth recorded by each flow meter, a scatter graph can provide the user with valuable information related to data repeatability. These scatter graphs are presented in Appendix B.

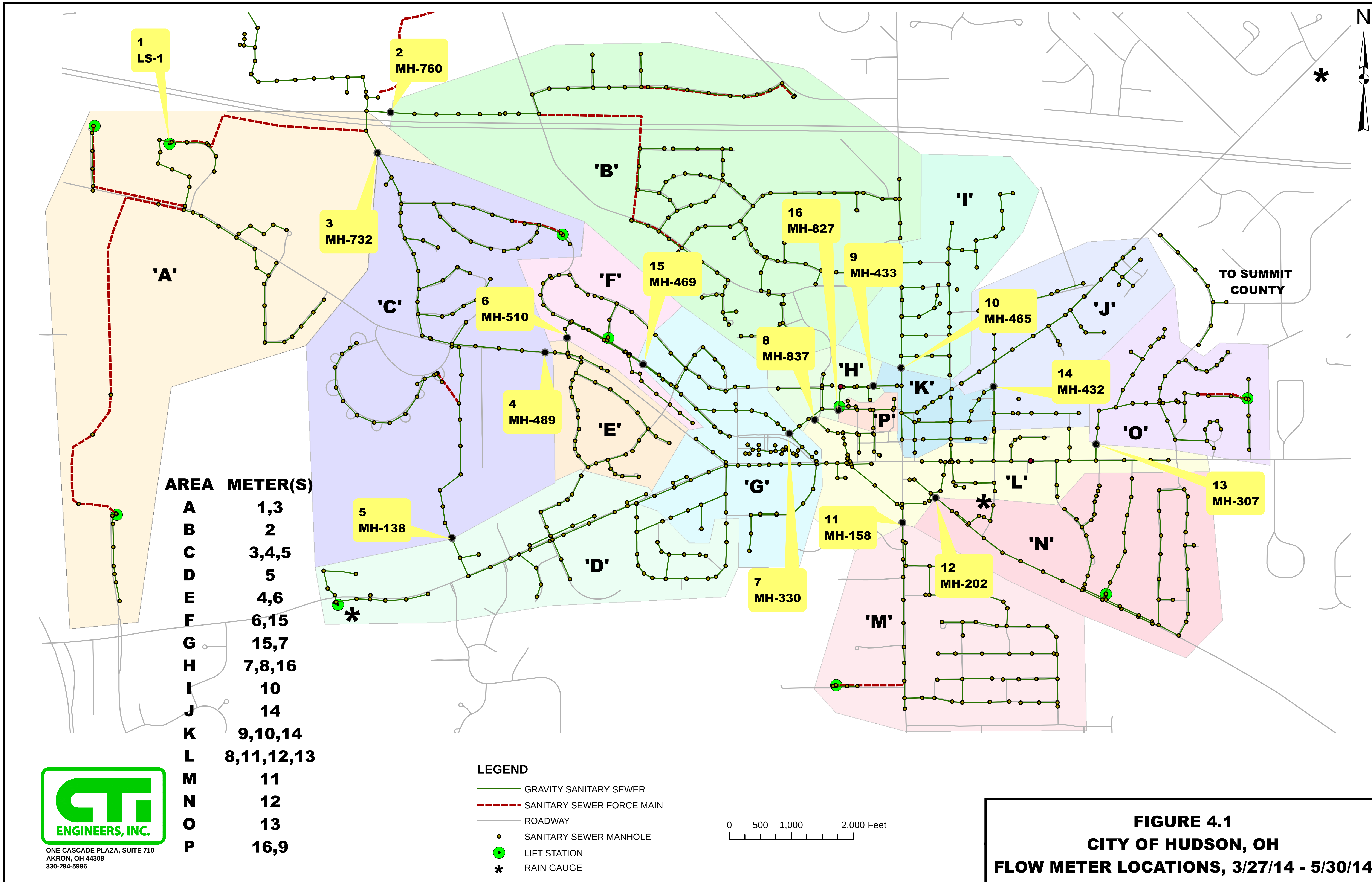


FIGURE 4.1
CITY OF HUDSON, OH
FLOW METER LOCATIONS, 3/27/14 - 5/30/14

5.0 SANITARY SEWER OVERFLOW ANALYSIS AND PLANNING (SSOAP) TOOLKIT

Once the flow meter data had been reviewed, it was then imported into the USEPA-developed Sanitary Sewer Overflow Analysis and Planning (SSOAP) toolkit for analysis. The SSOAP toolkit is a collection of software tools available from the U.S. EPA, which help quantify rain-derived inflow and infiltration (RDII). The information gathered from this analysis can then be entered into the U.S. EPA's Storm Water Management Model (SWMM) software, or other hydrologic and hydraulic software programs. The SSOAP toolkit is available for download at the following website:

http://www.epa.gov/nrmrl/wswrd/wq/models/ssoap/

The following sections describe the use of the SSOAP toolkit for the purpose of this study.

5.1 Dry Weather Flow Identification

Dry-weather flows were first determined within the SSOAP toolkit as a baseline condition without the effect of RDII. However, this analysis would also include any ground water infiltration or other sources of flow that normally occur without precipitation, as well as normal sanitary flows. The SSOAP toolkit allows the user to superimpose rain gauge data with flow meter data, and then determines the time periods where precipitation did not occur. The user then has the ability to review these periods graphically and remove any anomalies that should not be considered as part of the dry weather flow analysis. Once this has been performed, the SSOAP toolkit then averages the remaining dry weather days into a dry weather, diurnal (average daily) hydrograph. Since sanitary flow patterns differ between a weekday compared to a weekend, the toolkit also has the option to derive a hydrograph for each one of these separately. Figure 5.1 is an example of the hydrographs derived for a flow meter within the SSOAP toolkit.

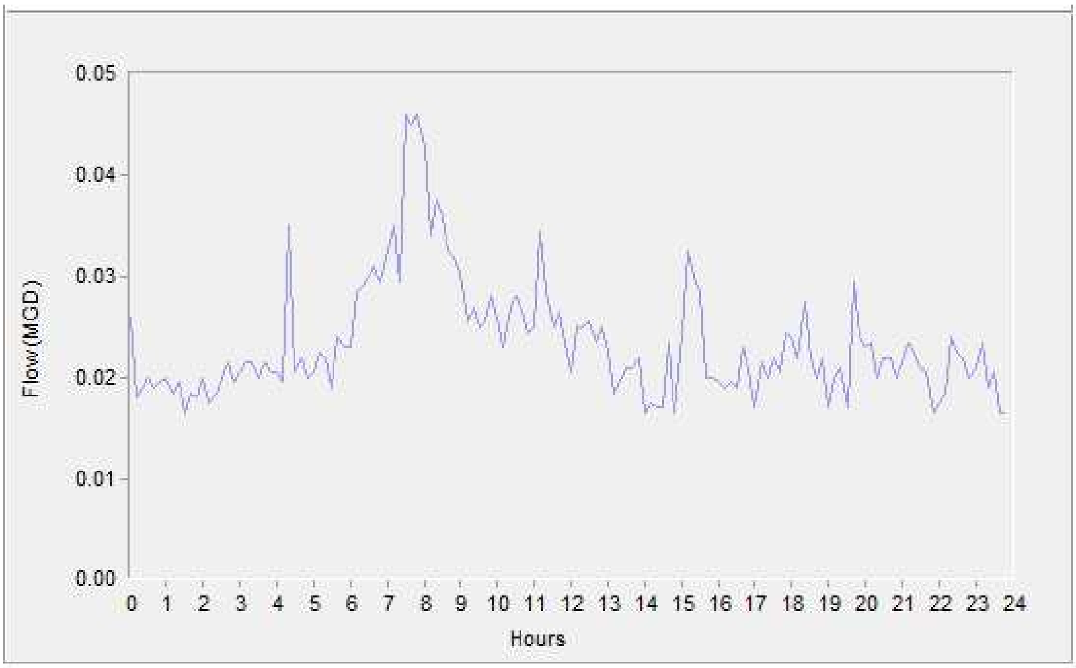


Figure 5.1 - Example DWF Hydrograph Derived Within the SSOAP Toolkit

Once the dry weather flow hydrographs for each flow meter were estimated, their daily average flow rates were compared to estimates conducted separately from the SSOAP toolkit. The data used to establish this estimate was derived from aerial photos from the City GIS, a 400 GPD estimate for each residential dwelling, and a 1,700 GPD/acre estimate for commercial areas (per EPA flow guidelines). The estimated average dry weather flow rate for each area is presented in Table 5.1. As shown in the table, the average dry weather flow rate for the City's sanitary sewer system is approximately 0.765 MGD.

Table 5.1

Hudson, Ohio

DWF Rate Estimate By Sub-Area Summary

Flow Meter	Sub - Area	Drainage Area (Acres)	DWF (MGD)
1	A	610.4	0.035
2	B	605.6	0.05
3	C	464.9	0.049
4	E	98.1	0.023
5	D	224.1	0.08
6	F	66.5	0.029
7	H	37.2	0.037
8	L	142.7	0.097
9	K	40.4	0.014
10	I	138.9	0.048
11	M	249.2	0.095
12	N	205.2	0.061
13	O	125.5	0.061
14	J	152.3	0.040
15	G	169.6	0.081
16	P	10.6	0.012

TOTAL = 0.765 MGD

Note: Please consult Figure 4.1 for flow meter locations and their related sub-areas

This value was compared with historical, metered flows from the City to the NEORSD. Figure 5.2 illustrates the monthly, metered flow from the City of Hudson to the CVI versus its monthly precipitation. The data in this figure can be extrapolated to estimate a theoretical month that had zero precipitation, or a monthly DWF. As illustrated in the figure, extrapolating the best fit line from this figure gives a monthly DWF of 3,130 MCF. This can be converted to a DWF (MGD) by the following equation:

$$\frac{3{,}130\ \text{MCF}}{\text{month}} \times \frac{1{,}000\ \text{ft}^3}{1\ \text{MCF}} \times \frac{12\ \text{months}}{1\ \text{year}} \times \frac{1\ \text{year}}{365\ \text{days}} \times \frac{7.48\ \text{gal}}{1\ \text{ft}^3} \times \frac{1\ \text{MG}}{1{,}000{,}000\ \text{gallons}} = 0.77\ \text{MGD}$$

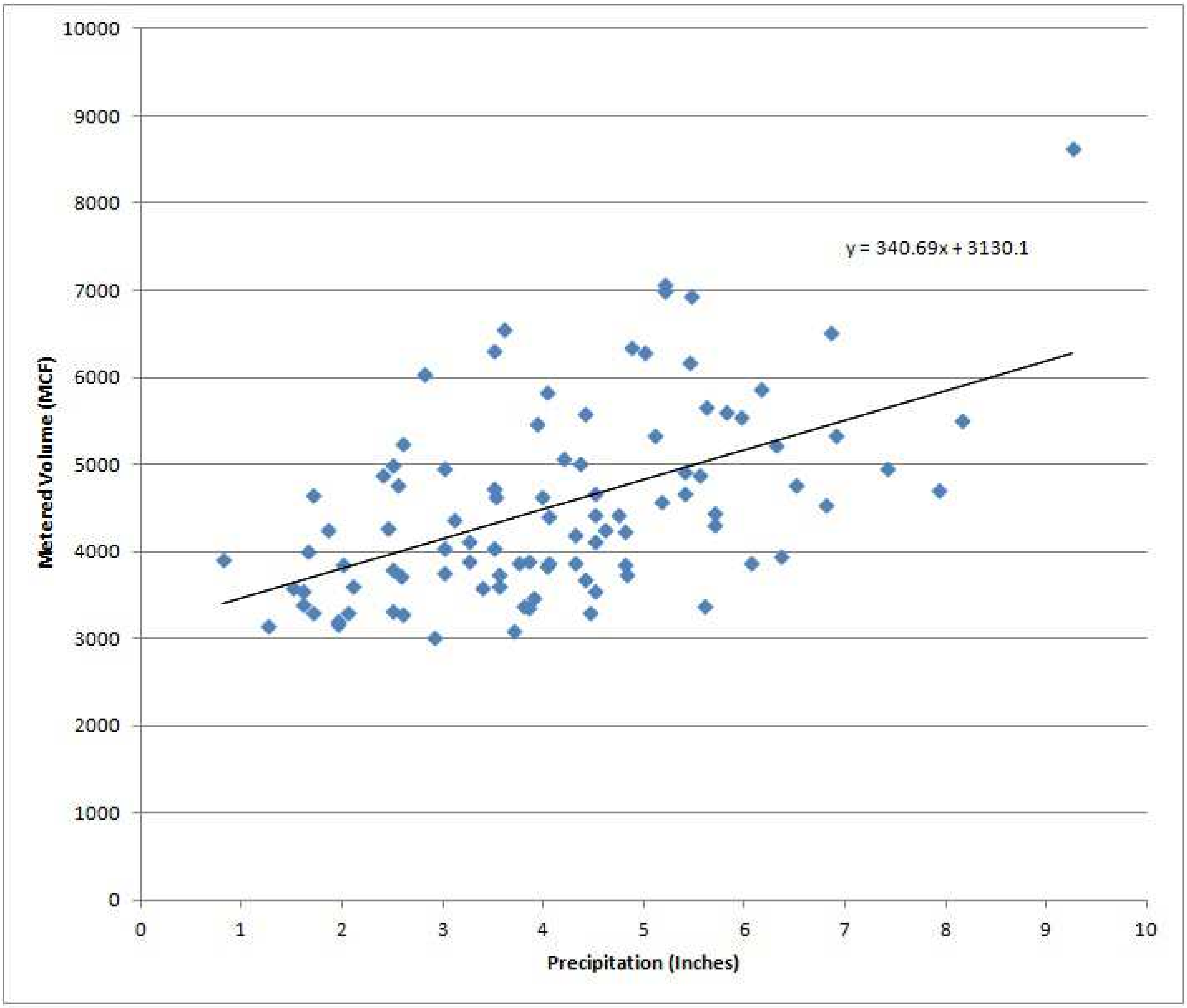


Figure 5.2 - City of Hudson, OH Metered Monthly Volume to CVI Versus Monthly Precipitation: January 2006 - May 2014

Therefore, the DWF hydrographs developed within the SSOAP (0.765 MGD) correlate well with the estimated DWF for the City (0.77 MGD). Note that the developed hydrographs do not include the flows from the residential neighborhood north of I-80 due to metering limitations. Therefore, the developed DWF hydrographs may slightly over-estimate the actual DWF's in the system, but these missing flows should not significantly affect results or the model.

5.2 RTK Development

The SSOAP toolkit was then used to estimate RTK coefficients for each flow meter. The RTK method is used to estimate the RDII response of any sub-area by creating a set of three triangular unit hydrographs. Each triangular hydrograph is composed of three variables: R, T, and K, which are defined as the following (see Figure 5.3 for a graphical representation):

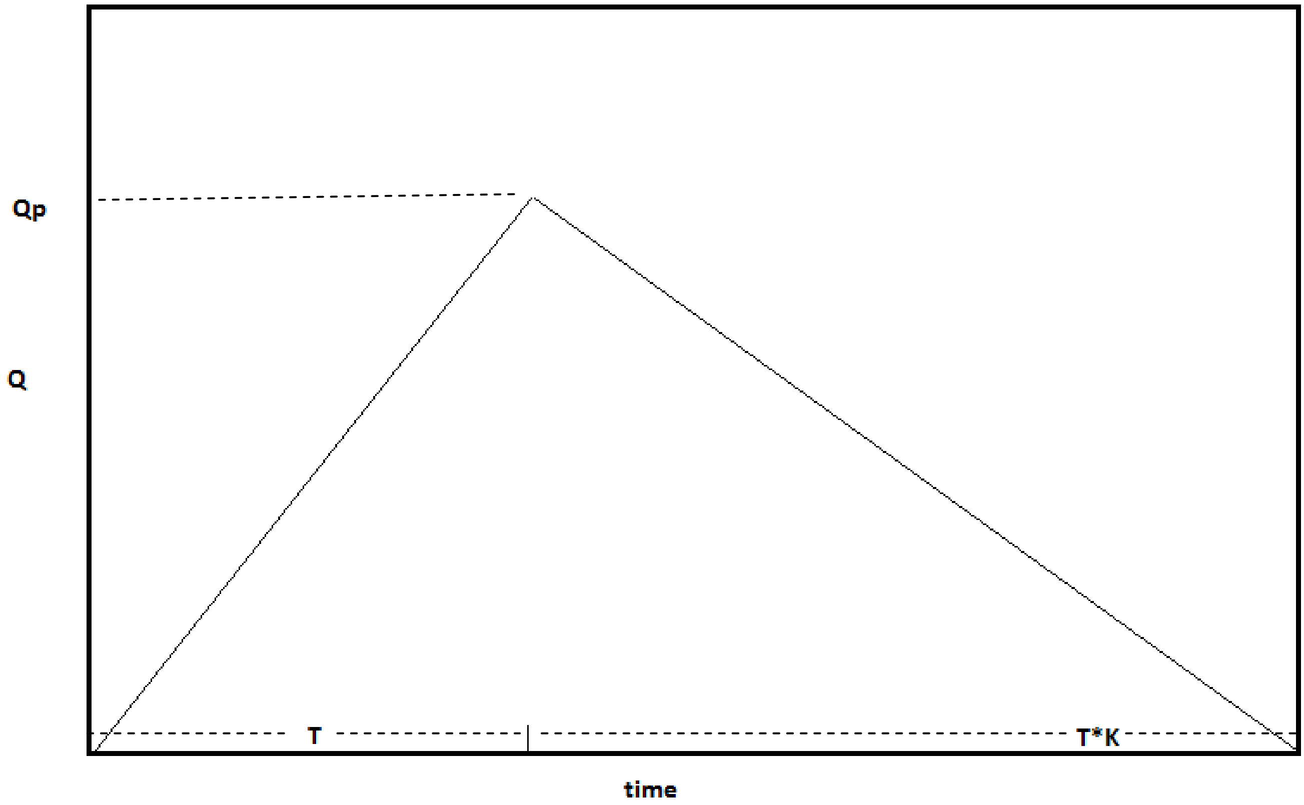


Figure 5.3 - Example RTK Triangular Unit Hydrograph

R = The fraction of rainfall falling on a particular drainage area that enters its sanitary sewer system;

T = The time it takes from the start of the rainfall event until the peak RDII flow rate occurs;

K = The time it takes from the peak RDII flow rate until the RDII recedes, expressed as a ratio of (time to recede)/(time to peak).

This process is repeated until three triangle unit hydrographs are formed, whose composite best estimates the actual metered RDII response.

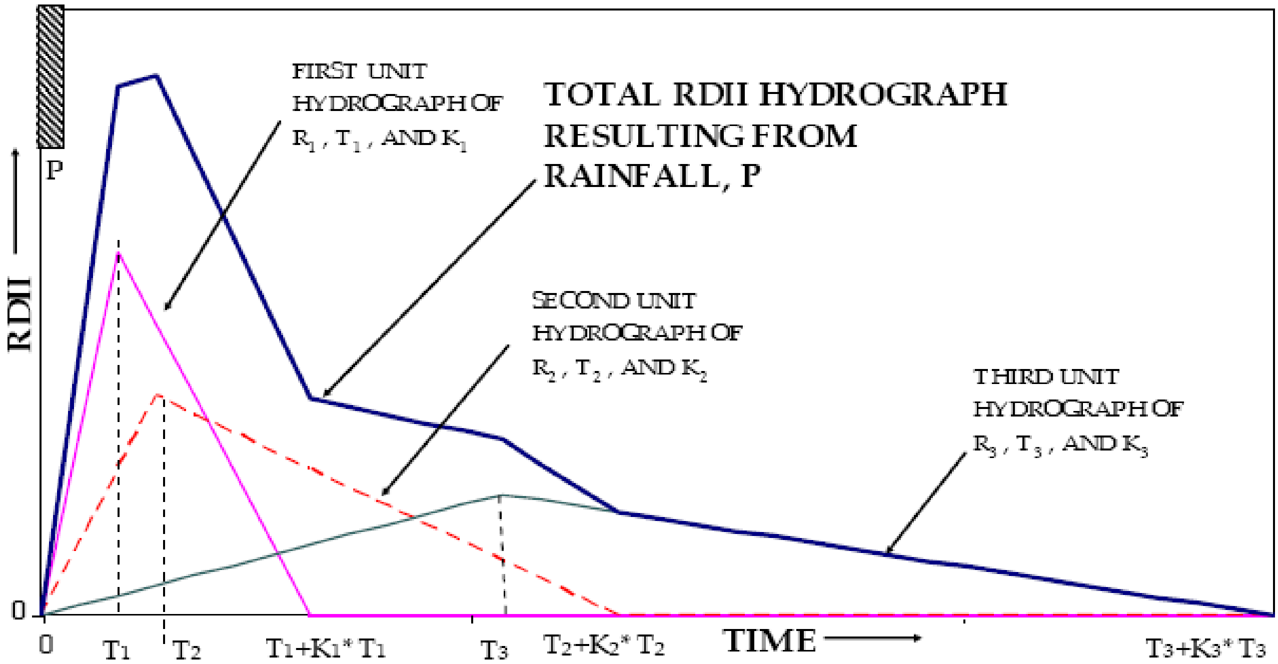


Figure 5.4 - Example RDII Composite Hydrograph (From: *SSOAP Toolkit Help File*)

Each triangle can relatively be described by the following RDII components:

First Unit Hydrograph (R_1, T_1, K_1) - A rapid response, resulting in a high peak and short receding leg, indicating significant inflow sources;

Second Unit Hydrograph (R_2, T_2, K_2) - A mixture of inflow sources and infiltration sources;

Third Unit Hydrograph (R_3, T_3, K_3) - A slow response followed by a long receding leg, indicating significant infiltration sources.

This process of developing these three different unit hydrographs is then performed for every increment of time within the rainfall event. For the purpose of this study, the rain gauges were programmed to record rainfall in ten-minute increments. The composite hydrograph that results from adding these three unit hydrographs for every time increment within the rainfall event is the RDII hydrograph for this area.

This iterative process can be time-consuming without the use of a software package such as the SSOAP toolkit that will develop these RDII hydrographs in a fraction of the time it would take to do them by hand. Within the SSOAP toolkit, collected flow meter data and related rain gauge data is entered into a database. The toolkit then graphically displays the flow meter data, as well as the dry weather flow that was previously derived. The software will then subtract the dry weather flow from the flow meter data in order to represent the wet weather flow (RDII response). The toolkit then allows the user to iteratively adjust these nine variables for each rain event, and presents the theoretical RDII response graphically, until a "best fit" is developed. Figure 5.5 is an example of the graphical presentation within the SSOAP toolkit while adjusting RTK coefficients.

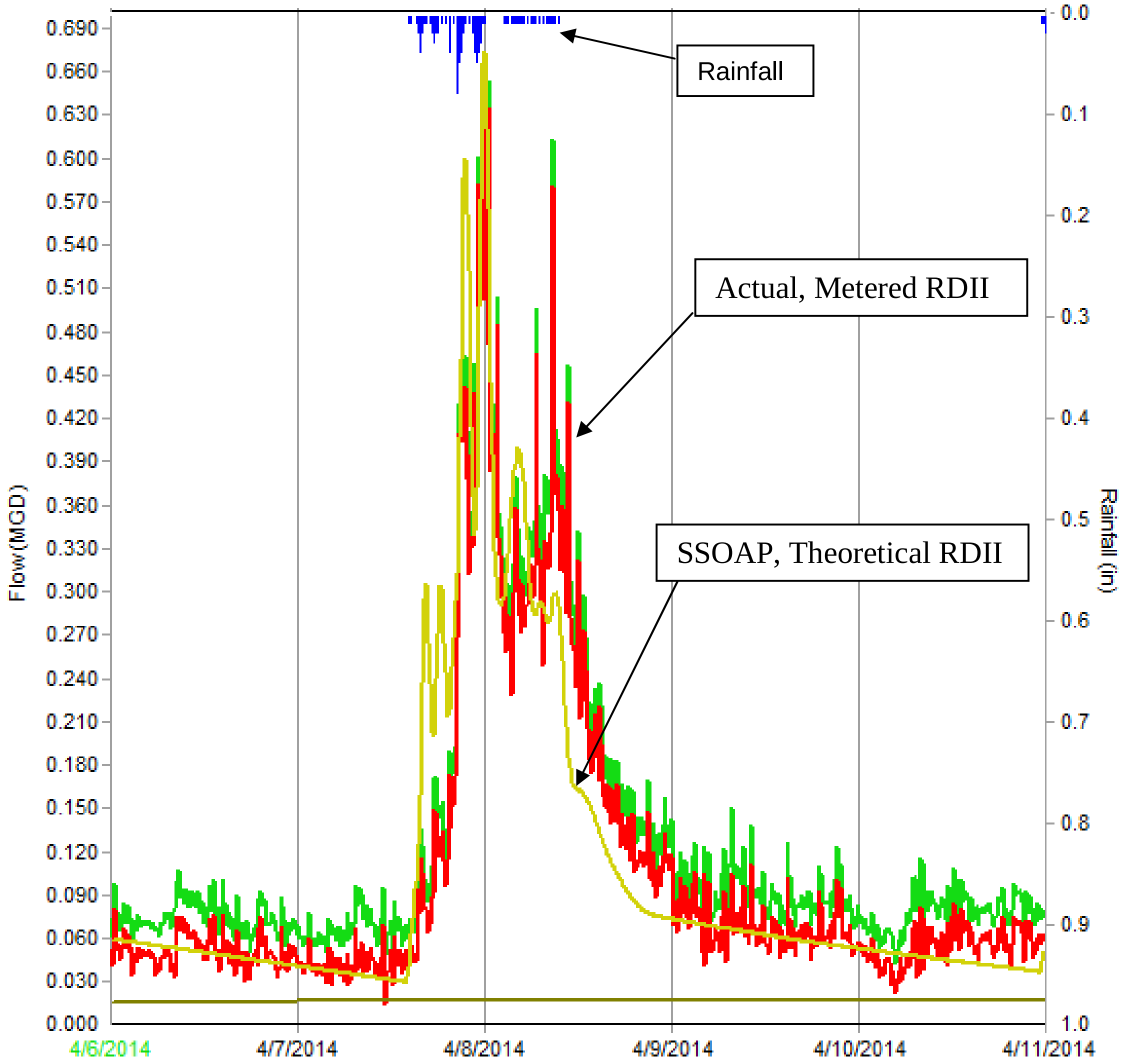


Figure 5.5 - SSOAP Toolkit, Actual Versus Theoretical RDII Response (FM 14)

This graphical representation allows the user to attain a rough estimate for the nine (9) total RTK coefficients for each rain event. In order to estimate these more accurately, the SSOAP toolkit then allows the user to "calibrate" these values, by comparing theoretical versus actual results among four parameters for each rain event:

- Total Rain Event Volume
- Total Peak Flow Rate
- RDII Volume (Total R)
- Peak I&I Flow Rate

The RTK values were then adjusted to match theoretical and actual values of these parameters within ten percent. This process of selecting the nine RTK coefficients was then performed for multiple rain events during the flow monitoring period for fifteen of the sixteen (16) flow meters. (RTK values could not be estimated for FM 1, which was installed within a lift station where only pump on/off data was recorded.)The following table summarizes the RTK coefficients for each flow meter.

Table 5.2
Hudson, Ohio
RTK Coefficients - March 27, 2014 through May 30, 2014

FM 14 (Area J)	R	T	K
1	0.035	1	1.3
2	0.035	3	1.5
3	0.06	6	4
	0.13		

FM 13 (Area O)	R	T	K
1	0.018	0.9	1
2	0.01	4	2
3	0.01	6	2.5
	0.038		

FM 10 (Area I)	R	T	K
1	0.014	1	1
2	0.018	4	1.5
3	0.015	10	2.5
	0.047		

FM 12 (Area N)	R	T	K
1	0.003	1	1
2	0.007	3	1.3
3	0.006	8	2.5
	0.016		

FM 9 (Areas I, J, K)	R	T	K
1	0.015	0.7	1
2	0.0035	2	2
3	0.011	4.6	2.5
	0.0295		

FM 11 (Area M)	R	T	K
1	0.008	0.8	1.3
2	0.01	6	2
3	0.013	16	2.5
	0.031		

Table 5.2

Hudson, Ohio

RTK Coefficients - March 27, 2014 through May 30, 2014 (Continued)

FM 16 (Areas I, J, K, P)	R	T	K
1	0.016	1.8	1
2	0.015	3	2
3	0.025	10	4.5
	0.056		

FM 8 (Areas L - O)	R	T	K
1	0.055	1.6	1
2	0.055	5	2.5
3	0.14	10	6
	0.25		

FM 7 (Areas H, I - P)	R	T	K
1	0.02	1.5	1.4
2	0.025	4	1
3	0.04	12	6
	0.085		

FM 15 (Areas G, H - P)	R	T	K
1	0.01	1.5	1.2
2	0.01	3	1.5
3	0.02	8	3
	0.04		

FM 6 (Areas F, G - P)	R	T	K
1	0.02	1.8	1
2	0.02	3.5	1.5
3	0.035	6	4
	0.075		

FM 4 (Areas E, F - P)	R	T	K
1	0.012	1.5	1.2
2	0.011	3	1.75
3	0.035	6	4
	0.058		

FM 5 (Area D)	R	T	K
1	0.006	1	1.8
2	0.005	2.2	2
3	0.007	5	2.5
	0.018		

FM 3 (Areas C, D - P)	R	T	K
1	0.013	2.1	1.2
2	0.013	6	2.5
3	0.03	16	4
	0.056		

FM 2 (Area B)	R	T	K
1	0.00085	1	1.5
2	0.001	4	2
3	0.0018	10	2.5
	0.00365		

FM 1* (Areas A, C - P)	R	T	K
1	NA	NA	NA
2	NA	NA	NA
3	NA	NA	NA

* RTK Values for FM1 could not be derived due to the installation of the flow meter within a lift station where only pump on/off data was recorded.

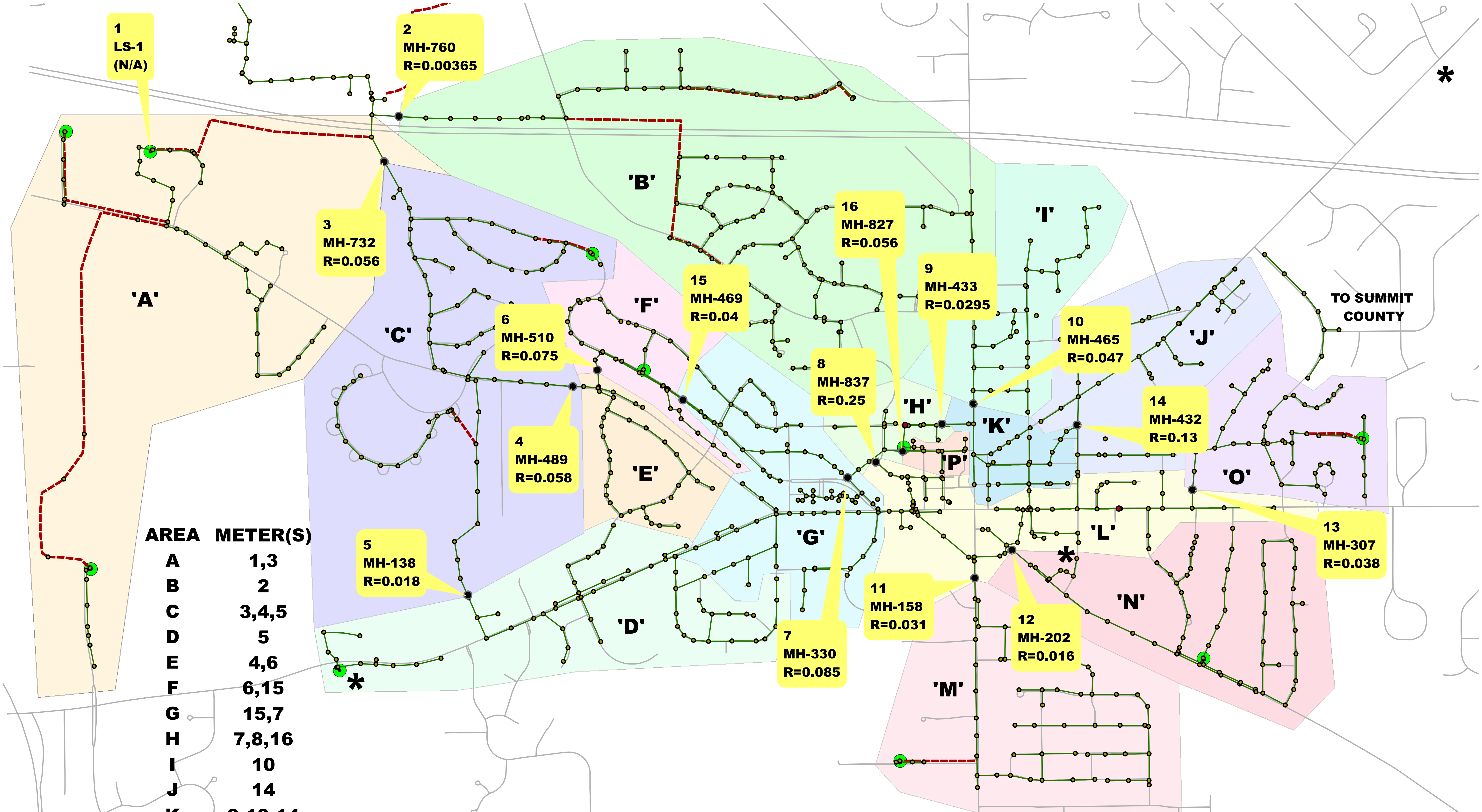
These RTK coefficients can be used to make relative comparisons among each flow meter's drainage area regarding its RDII response. (See Figure 5.6 for a review of the flow meter locations as well as their corresponding R values.) The variables T and K are time-dependent, and are general indicators of the size of the sub-area being evaluated, as well as how quickly RDII flows are conveyed through it. The cumulative R values define the percentage of rainfall that falls over each sub-area and is able to enter the sanitary sewer. For example, the majority of the cumulative R values lie within the range of 0.02-0.05. This means that roughly 2-5% of the rainfall that falls within that drainage area eventually ends up in the sanitary sewer. This can be compared to FM 14 (Area 'J' on Figure 4.1), which has an R value of 0.13 (13%). This means that Area 'J' has a significantly higher RDII response (more I&I) than most of the other drainage areas.

Another item to note is that some of these flow meters were installed at locations with multiple contributing areas. In these cases, a relative comparison can still be made. An example of this is illustrated in Table 5.3

Table 5.3
Hudson, Ohio - East Streetsboro Road
RTK Coefficients - March 27, 2014 through May 30, 2014

FM No.	Area Label	Contributing Areas	Total Drainage Area (acres)	R Value
13	'O'	'O'	125.5	0.038
12	'N'	'N'	205.2	0.016
11	'M'	'M'	249.2	0.031
8	'L'	'L', 'M', 'N', 'O'	722.7	0.250

Areas 'M', 'N', and 'O' (Flow Meters 11, 12, and 13, respectively) are all areas that contribute flow to the sewer along E. Streetsboro Road. Their individual R values lie within the range of 0.016 - 0.038, which was the relative average for the system during this evaluation. However, FM 8, which collects flow from Area 'L' *as well as* Areas 'M', 'N', and 'O', has a significantly higher R value of 0.25. This indicates that 25% of the precipitation that falls in the contributing drainage area of FM 8 enters the sanitary sewer. Furthermore, if FM 8 could have been installed in a location where only Area 'L'



AREA	METER(S)
A	1,3
B	2
C	3,4,5
D	5
E	4,6
F	6,15
G	15,7
H	7,8,16
I	10
J	14
K	9,10,14
L	8,11,12,13
M	11
N	12
O	13
P	16,9

CTI ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

FIGURE 5.6
CITY OF HUDSON, OH
RTK ANALYSIS
R-VALUE SUMMARY

contributed flow and contributing Areas 'M', 'N', and 'O' were not included, we would expect to see an R value specific to Area 'L' only that would be even higher than 0.25.

It should be noted that these RTK values should be used as a *general* indicator of the RDII response of the sanitary sewer during the flow monitoring period that they were derived. For example, R values will increase over time as the system ages, joints deteriorate, and other sources of I&I enter the system. However, they may also decrease, with the replacement of older, aging sewers, and manhole and sewer line rehabilitation projects, which will minimize the amount of I&I within that particular area. Consequently, these coefficients can be used to identify sewer areas that currently exhibit relatively higher I&I rates and then prioritize these areas for further investigation and future capital improvement projects.

There are a number of potential solutions in reducing I&I within the City's sanitary sewer system, which range in terms of the financial investment involved. These potential solutions include, but are not limited to:

- **Ordinance to Reducing I&I** - A new I&I Ordinance could include imposing fines on private downspouts and sump pumps that are connected to the sanitary sewer, repairs to broken laterals, etc. The ordinance could also a point-of-sale (POS) inspection program that would prompt sanitary sewer inspections and necessary repairs during the purchase of a new home or business. The new Ordinance could also include a Public Education program to inform the public why the ordinance and reducing I&I are necessary. Examples of ordinances, point-of sale programs, and public education materials are provided in Appendix C.

- **Additional Investigation** - Flow meter data and model results have shown that all modeled areas have varying amount of I&I. Specifically, two areas have been identified in this study as being highly affected by I&I, relative to the rest of the system. Further studies, such as additional flow monitoring, smoke testing, and dye testing, would help identify the sources of I&I within these specific areas as well as system-wide. The City could also investigate I&I sources on their own by investing in additional equipment (flow meters, rain gauges, etc).

- **Capital Improvement Projects** - The City should continue its rehabilitation program throughout its system to eliminate sources of I&I. Reducing the amount of I&I system-wide reduces the City's operating cost by reducing the volume of wastewater pumped to the NEORSD. Improvements can be made to the system to reduce I&I when funds are available within the budget. Sewer lining, manhole rehabilitation, and sewer replacement projects help reduce the amount of I&I that can enter the system and can be identified and prioritized as part of ongoing investigations. Potential improvement projects can be identified during routine maintenance and inspection of the sanitary sewer system and using system modeling.

6.0 MODEL DEVELOPMENT

The hydraulic model of the trunk sections of the City of Hudson's sanitary sewer was developed within Bentley® SewerGEMS® Version 8.11. The extents of the developed model is shown graphically in Figure 6.1. SewerGEMS® is a comprehensive software package that can simulate a sanitary or combined (storm and sanitary) sewer system under an extended period simulation (EPS). This hydrologic and hydraulic model allows the user to simulate dynamic conditions, which provides valuable insight into tangible solutions in meeting SSO and combined sewer overflow (CSO) regulations. The following section is a description of how the model was developed.

6.1 Data Entry - Physical Information

Physical information related to specific sewers, such as pipe diameters, lengths, and material, were gathered within the City's GIS and entered into the program. Rim elevations of each manhole to be entered into the model were measured in the field. Inverts were then calculated by subtracting rim-to-invert depths, which had previously been measured by City personnel. Head loss coefficients were also entered for each manhole based on its physical configuration. The physical information of the City's sanitary sewer system that was entered into the model is presented in Appendix C.

6.2 Hydrograph Development

Dry weather flow hydrographs for each flow meter, whose development within the SSOAP toolkit was previously described in Section 5.1, were entered into the model at the appropriate manhole locations. As mentioned previously, the overall dry weather flow within the model is 0.77 MGD, which correlates well with historical information of the City's metered data to the NEORSD (see discussion in Section 5.1). A separate scenario was created within the model in order to simulate diurnal dry weather conditions to evaluate the capacity of the sanitary sewer based solely on sanitary flows.

Once the dry weather hydrographs had been entered into the model, wet weather hydrographs were developed to simulate an actual storm event during the flow monitoring period, as well as a one-hour design storms with a 1-year, 5-year, 10-year,

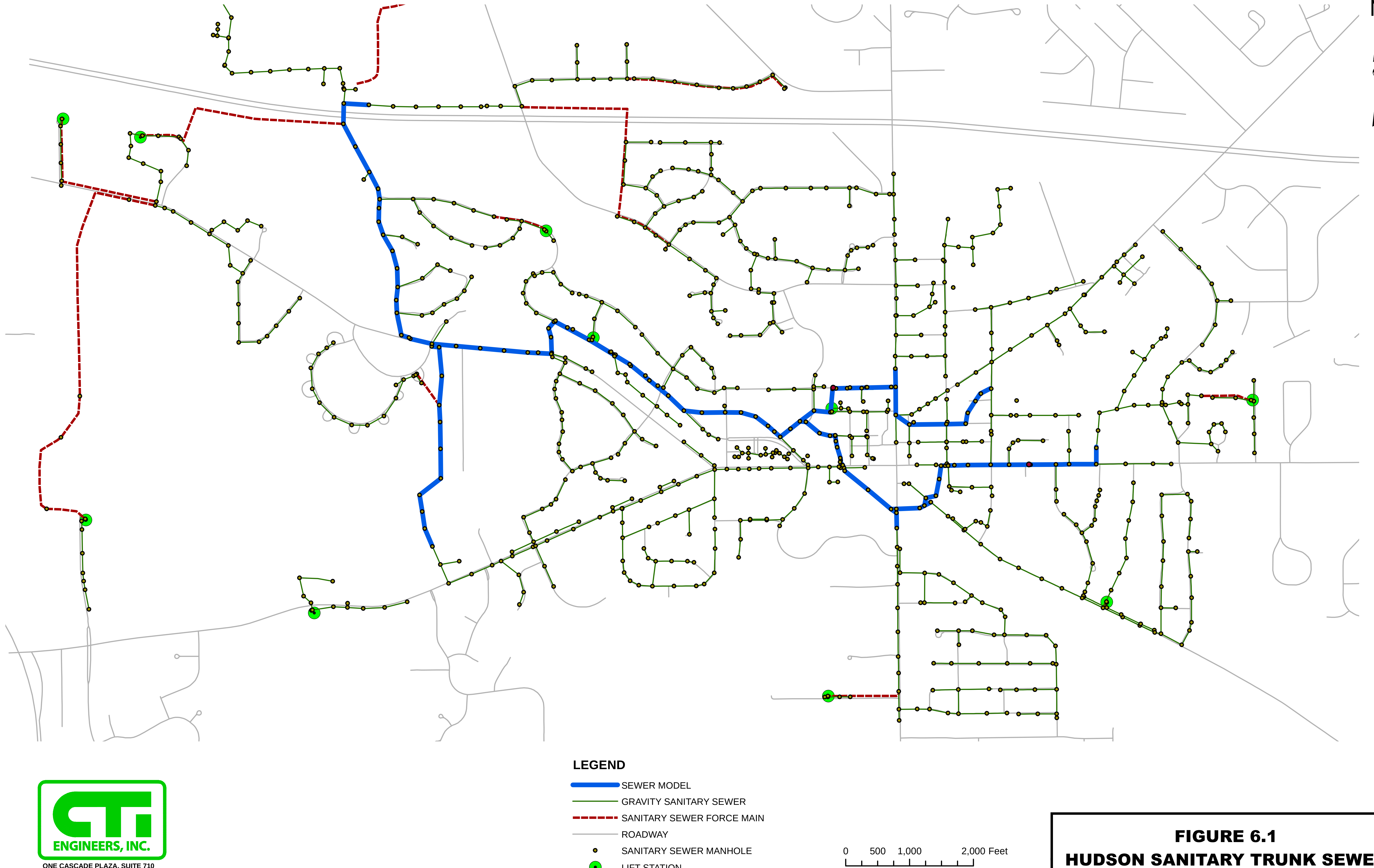


FIGURE 6.1
HUDSON SANITARY TRUNK SEWER MODEL OVERVIEW

ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

and 25-year return interval. A return interval can be defined as the time period for a storm of that size to occur just once. For instance, a 25-year design storm should only occur once in twenty-five years. Another perspective would be to estimate the probability of any size storm occurring in any given year. For example, if a 25-year storm should only occur once in twenty-five years, then the chance of that storm occurring in any given year is 4% (1/25). The National Oceanic and Atmospheric Administration (NOAA) continuously measures and records rainfall data and modifies these rainfall events as necessary. Table 6.1 lists the precipitation-frequency estimates, published by the NOAA as of June 1, 2014. Updated rainfall information can be found at the website http://hdsc.nws.noaa.gov

Table 6.1

Hudson, Ohio

Point Precipitation - Frequency Estimates (Inches)*

	Average Recurrence Interval (Years)									
Duration	**1**	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5 - min	0.323	0.386	0.466	0.528	0.607	0.667	0.726	0.785	0.865	0.923
10 - min	0.502	0.603	0.725	0.815	0.928	1.01	1.09	1.17	1.27	1.34
15 - min	0.615	0.737	0.890	1.00	1.15	1.25	1.36	1.46	1.59	1.68
30 - min	0.814	0.986	1.22	1.39	1.62	1.79	1.96	2.13	2.35	2.52
60 - min	0.994	1.21	1.53	1.77	2.10	2.36	2.62	2.89	3.25	3.54
2 - hr	1.16	1.41	1.78	2.08	2.51	2.85	3.21	3.59	4.13	4.57
3 - hr	1.23	1.50	1.90	2.22	2.68	3.06	3.45	3.88	4.48	4.98
6 - hr	1.48	1.79	2.25	2.64	3.19	3.66	4.16	4.70	5.49	6.15
12 - hr	1.74	2.09	2.60	3.04	3.68	4.21	4.79	5.43	6.36	7.15
24 - hr	2.04	2.44	3.03	3.52	4.24	4.84	5.48	6.19	7.21	8.06
2 - day	2.35	2.82	3.46	3.99	4.76	5.40	6.09	6.82	7.88	8.75
3 - day	2.52	3.01	3.68	4.24	5.02	5.67	6.36	7.09	8.13	9.01
4 - day	2.69	3.20	3.91	4.48	5.28	5.94	6.63	7.36	8.39	9.27
7 - day	3.23	3.84	4.64	5.29	6.20	6.93	7.70	8.50	9.61	10.5
10 - day	3.72	4.41	5.28	5.97	6.91	7.65	8.41	9.19	10.3	11.1
20 - day	5.15	6.08	7.16	8.00	9.10	9.95	10.8	11.6	12.7	13.5
30 - day	6.49	7.64	8.89	9.83	11.1	12.0	12.9	13.8	14.9	15.7
45 - day	8.32	9.76	11.2	12.3	13.7	14.7	15.6	16.5	17.7	18.5
60 - day	10.1	11.8	13.4	14.6	16.1	17.2	18.2	19.1	20.3	21.1

***Data is from the NOAA, based on 90% confidence intervals

Actual rainfall data from the flow monitoring period was compared with the NOAA data within Table 6.1. As a reference, several of the larger rainfall events during the flow monitoring period, along with the data in Table 6.1, are presented graphically in Figure 6.2 for comparison.

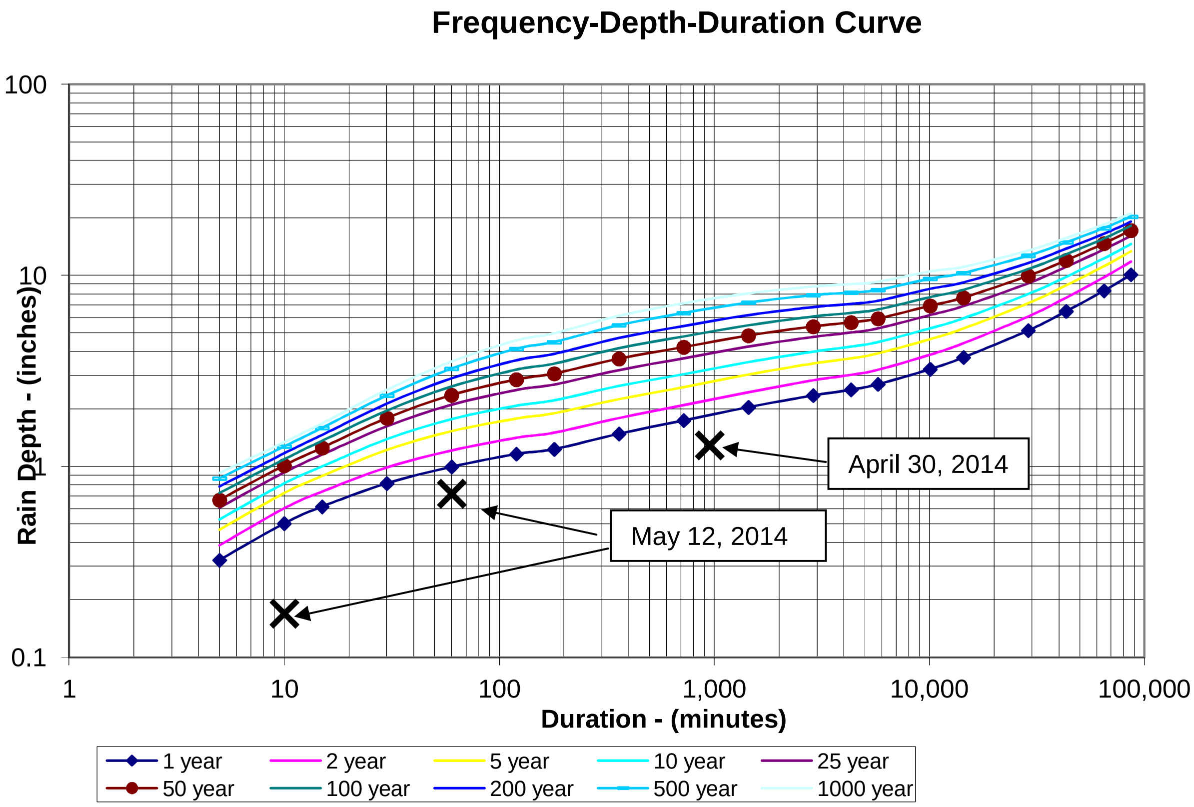


Figure 6.2: Hudson, OH Rainfall Frequency-Duration Curves Versus Rainfall Data 4/1/14-5/12/14 (Note: For clarity, not all rainfall events within this time period are shown.)

During the flow monitoring period, the largest rainfall event occurred on May 12th, which was a total precipitation of 0.72 inches in sixty minutes. This falls just below the one-year, 1-hour event (0.994 inches). Therefore, the hydrographs measured at each flow meter (minus their corresponding dry weather flows) were entered into the model to represent the wet weather flow (WWF). These hydrographs represent the RDII response of each sub-area during the May 12th rain event.

Hydrographs of downstream flow meters (i.e. those meters along the trunk sewer) were adjusted by subtracting the upstream hydrographs from the measured data. The hydrograph remaining represents the additional I&I specific to that area. These hydrographs were then entered into the model at their appropriate locations and the model was run in order to simulate the May 12th storm. Model results conclude that flows within the model correlate well with those during the May 12th storm event. An example of actual flow metered data versus the model simulated flow is presented in Figure 6.3.

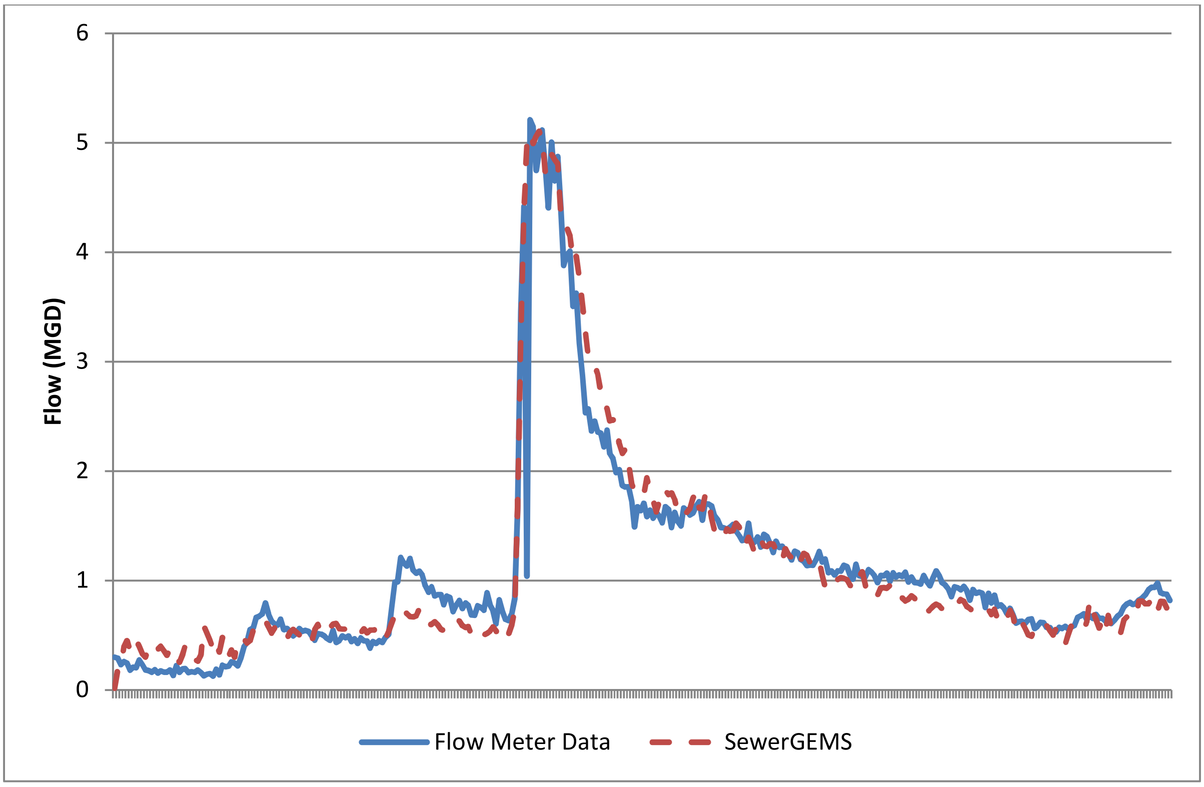


Figure 6.3: Flow Meter Number 7 - Flow Meter Data Versus SewerGEMS Results, 5-12-14

As an additional check, the model was run to simulate the May 12, 2014 rainfall event and the model-reported volumes at the SSO locations were compared with the actual volumes reported to the EPA at these locations. Table 6.2 presents the model-reported versus actual-reported SSO volumes of the May 12,2014 rainfall event.

Table 6.2

City of Hudson, OH May 12, 2014 - Rainfall Event

Actual Versus Model-Reported SSO Volumes

	Volumes (gallons)	
Location	**Actual**	**Model**
MH-264	3,000	2,700
MH-430	116,000	105,000

The good correlation between the actual versus model SSO volumes is another good indication that the developed model with the WWF hydrographs is simulating the hydrology and hydraulics within the actual sanitary sewer system. Once these WWF hydrographs were developed and validated, they were modified by the following ratio in order to create a family of design one-hour storm hydrographs for the 1-year, 5-year, 10-year, and 25-year design storms:

$$\text{Design Storm Flow}_{(t)} = \frac{\text{May 12th Flow x (Design Storm Precipitation (in.))}}{\text{May 12th Precipitation (0.72 in.)}}$$

Hydrographs from each flow meter were adjusted by this ratio for every increment of time (every ten minutes) along the hydrograph. Once these families of hydrographs were created, additional scenarios were created within the model to represent a one-hour, 1-year, 5-year, 10-year, and 25-year storm event.

7.0 MODEL RESULTS

Once the City of Hudson's sanitary sewer model was developed, reviewed for erroneous data, and results validated by comparing them with flow meter data, it was used to evaluate its existing capacity during dry weather and wet weather conditions. The model was then used to evaluate potential improvements to the system to reduce I&I and increase capacity, which will minimize and possibly eliminate the need for the City's two remaining overflow locations. The following sections describe the analysis involved with this evaluation.

7.1 Existing System Evaluation 1 - Dry Weather Modeling

The model was initially used to evaluate the system's existing performance. First, a model simulation was performed to evaluate the capacity of the sewers during dry weather conditions. The criteria used to determine whether a pipe segment was above or below design capacity was based on design criteria presented in the American Society of Civil Engineers (ASCE) Manual and Reports on Engineering Practice Number 60 titled *Gravity Sanitary Sewer Design and Construction*. This manual states that it is customary to design sanitary sewers with some reserve capacity. According to this ASCE document, sanitary sewers through 15-inch in diameter should be designed to flow half full. Larger sanitary sewers are recommended to be designed to flow three-fourths full. This is recommended by ASCE in designing sewers to prevent flow within the sanitary sewer to flow into connected sanitary laterals and the basements of buildings that use them.

Model results show that overall the modeled trunk system meet the described ASCE design standard with only one exception. An 8-inch diameter sewer near 204 E. Streetsboro Road (CO-1066 in the model) is shown to have a maximum depth of 4.45 inches during dry weather, which is slightly higher than the ASCE standard for pipes with diameters less than 15 inches.

7.2 Existing System Evaluation 2 - Wet Weather Modeling

The wet weather model was originally developed using a rainfall event from May 12, 2014, which was shown in figure 6.2 to be less than a 1-year, 1-hour event. As shown in

Table 6.2, the rainfall event on this date resulted in SSO's at both locations within the system, and therefore was not able to contain all of the subsequent flows.

The Ohio EPA requires that sanitary sewer collection systems be able to contain all flows entering the system for rainfall events up to a 10-year, 1-hour event. Therefore, a number of potential long-term capital improvement projects were evaluated using this rainfall event. The ultimate goal of these modeled improvements was to contain all flows within the sanitary sewer that resulted from a 10-year, 1-hour rainfall event within the model. The evaluations include examining improvements such as, but were not limited to, the following:

- Replacing sections of the sanitary sewers found to be under capacity in order to increase available capacity during storm events;
- Provide temporary storage within the system to temporarily detain peak flows when capacity is not available downstream;
- Re-direct flows from areas with capacity issues to those with available capacity (i.e. pump stations, relief sewers);
- Rehabilitate (i.e. lining or other methods) existing sewers and/or manholes in order to reduce I&I and minimize flows during the 10-year, 1-hour rainfall event;

These long-term capital improvements, along with short-term and medium-term improvements, are further evaluated and discussed in the following sections. It should be re-stated that the goal of all of these modeled improvements were based on the 10-year, 1-hour rainfall event, which the Ohio EPA has required for sanitary sewer projects throughout the State. However, the EPA's consent order with the City states that it must eliminate all occurrences of SSO's within its system for all sizes of storm events. Therefore, these modeled improvements, while reducing the number of SSO occurrences in the system, would not affect the status of the EPA consent order with the City of Hudson. A capital improvement project to accommodate every possible rainfall event would theoretically be infinite in capacity and size, which cannot be modeled.

7.3 Potential Long-Term Capital Improvements

The model was used to evaluate different proposed alternatives, which would contain flows resulting from a 10-year, 1-hour rainfall event as noted previously. Separate scenarios were created within the model to simulate proposed improvement conditions (i.e. increasing the diameter or slope of a pipe, providing storage, or reducing I&I) whose goal was to meet the Ohio EPA requirements and eliminate SSO's at MH-264 (E. Streetsboro Road) and MH-430 (Owen Brown Street) during the design storm. The following section describes the results of those model simulations.

7.3.1 MH-264 (East Streetsboro Road Overflow)

Several alternatives were simulated within the model in an attempt to reduce, and possibly eliminate, occurrences of SSO's at MH-264 on East Streetsboro Road. The alternatives evaluated included: adding a storage facility for storage of peak flows, providing a pump station to re-route flows to sewers with available capacity, increasing trunk sewer capacity, and reduce overall I&I from entering the system. The following is a description of each of these alternatives.

<u>Storage Facility Alternative</u>

The model was used to estimate the potential storage volume required upstream of MH-264 in order to eliminate any SSO occurring from this location. The following table summarizes model results for this evaluation.

Table 7.1
Hudson Sanitary Trunk Sewer
Model - Simulated Storage Volumes,
East Streetsboro Road

Rainfall Event Frequency	Required Storage Volume (gallons)*	Approximate Dimensions*
1 - Hour, 1 - Year	17,000	15 ft. x 15 ft. x 10 ft.
1 - Hour, 5 - Year	40,000	24 ft. x 24 ft. x 10 ft.
1 - Hour, 10 - Year	50,000	26 ft. x 26 ft. x 10 ft.
1 - Hour, 25 - Year	66,000	30 ft. x 30 ft. x 10 ft.

*Volumes stated are preliminary, and have been increased by roughly 25% from model results. Final storage volumes will be estimated during design. Dimensions were approximated assuming a 10-foot depth and square footprint, but are only preliminary and would be evaluated during design.

In this scenario, a storage chamber upstream of the SSO would be constructed. During rainfall events, peak flows would pass over an overflow weir within the trunk sewer and be directed into the storage facility. Once the storm event and flows had subsided, this stored volume could then be pumped back into the system, as capacity is available downstream. Provisions within the storage chamber can also be provided to keep the interior clean to reduce odors and reduce overall day-to-day maintenance.

Pump Station Alternative

If the cause of the SSO at MH-264 is localized, then a pump station could be constructed to intercept the peak flows before the SSO, and then pump this flow downstream where there is available capacity. This would be a cheaper option than the storage facility, because storage volumes and required maintenance would be minimized. Therefore, the capacity of the downstream sewers along East Streetsboro Road was reviewed to evaluate if this was a feasible option. Table 7.3 presents a list of the sewers along East Streetsboro Road, their available capacity, and peak flows simulated within the model during the 1-hour, 10-year rainfall event.

Table 7.2

Hudson, Ohio

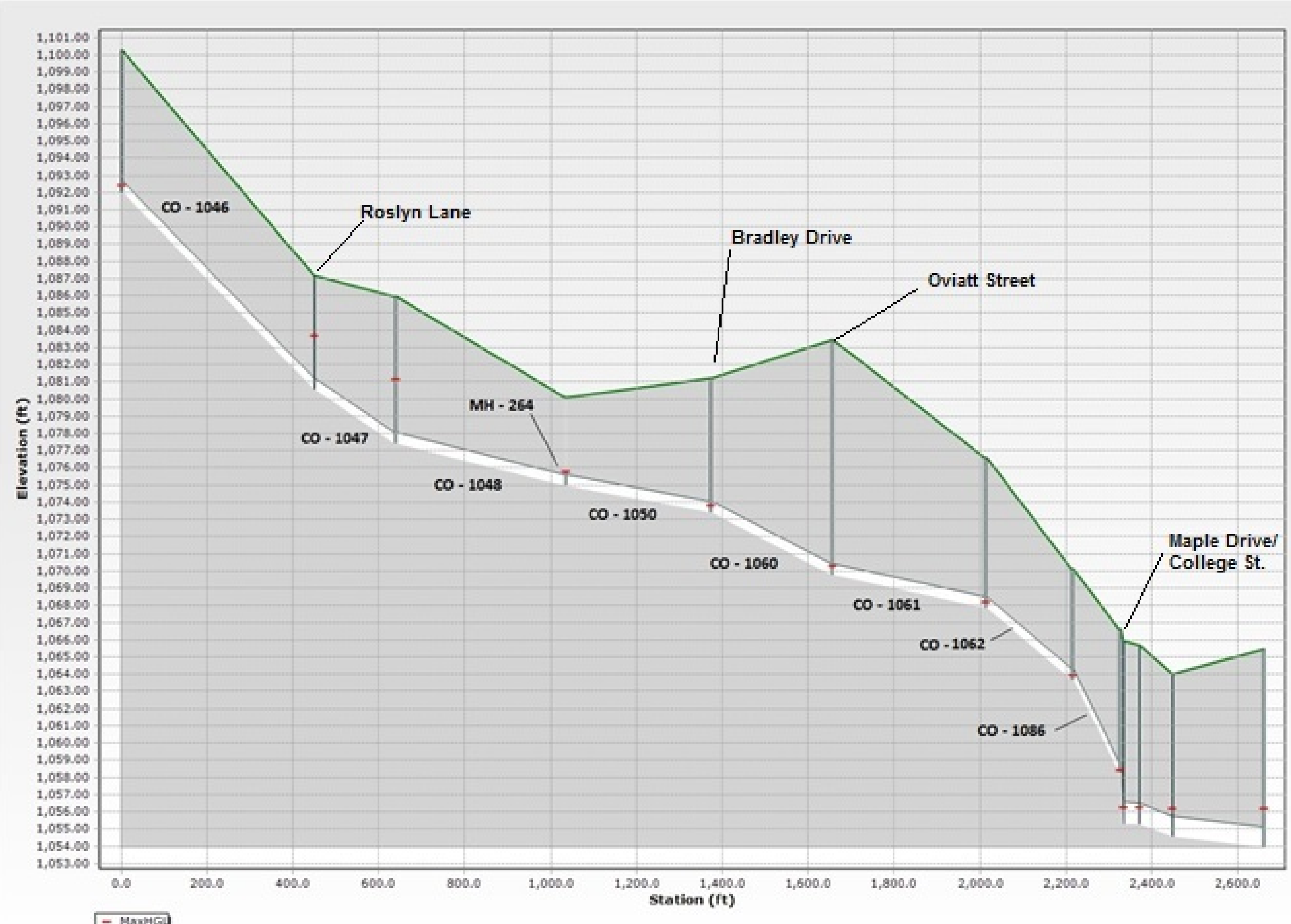
East Streetsboro Road Existing Sanitary Sewer Capacities Versus

1-Hour, 10-Year, Model-Simulated Flows

Label	Diameter (in.)	Length (ft.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow Rate (GPM)
CO-1046	8	450	0.025	864	615
CO-1047	8	189	0.017	698	614
CO-1048	8	397	0.006	429	613
CO-1050	8	337	0.005	365	396*
CO-1060	8	283	0.013	616	396
CO-1061	8	358	0.005	396	396
CO-1062	8	202	0.021	778	396
CO-1086	8	111	0.049	1,198	396

Note: Peak flows are reduced due to the SSO immediately upstream of CO-1050.

The manhole that links CO-1048 and CO-1050 is MH-264 (the location of the SS). The table shows that CO-1048 and 1050 (along with CO-1061) are under capacity for the 1-hour, 10-year rainfall event. A profile that highlights the sewers along East Streetsboro Road is presented in Figure 7.1. Based on this information, constructing a pump station to capture flows upstream of the SSO and then route the flows downstream where there is sufficient capacity would require a relatively short force main, and be a less expensive alternative than a storage facility.



LEGEND

GROUND SURFACE

MAXIMUM HYDRAULIC GRADE LINE

CO-XXX CONDUIT

MH-XXX MANHOLE

CTI ENGINEERS, INC.

ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

FIGURE 7.1
HUDSON SANITARY TRUNK SEWER MODEL RESULTS
EAST STREETSBORO ROAD
EXISTING SANTIARY SEWER
1 - HOUR, 10 - YEAR RAINFALL EVENT

The peak model-simulated flow rate along East Streetsboro Road during the 1-hour, 10-year rainfall event is approximately 615 GPM. Table 7.2 shows the limiting section of sewer in this area (CO-1050) has a capacity of 365 GPM. Therefore, the pump station would be roughly sized for 250 GPM (615 GPM - 365 GPM). The length of force main required would depend on where the pump station would be located. However, the estimated minimum length of force main would be equivalent to the length of sewer sections to be bypassed, which would be the sections CO-1048, CO-1050, CO-1060, and CO-1061, a total of 1,375 feet.

Increasing Capacity Alternative

Since the bottleneck along East Streetsboro Road appears to be localized, the capacity of the sewers in this area could also be increased. This option would eliminate the operation and maintenance costs associated with a new pump station. Figure 7.1 shows that the majority of sewers along this area have fairly steep slopes, with the exceptions of the bottleneck areas. Therefore, the model was modified to re-align the sewers in this area to increase the slope. The following Table 7.3 presents the capacities of the proposed sewers versus the model-simulated peak flows. A figure presenting the proposed profile for the sewer along East Streetsboro Road is presented in Figure 7.2.

Table 7.3

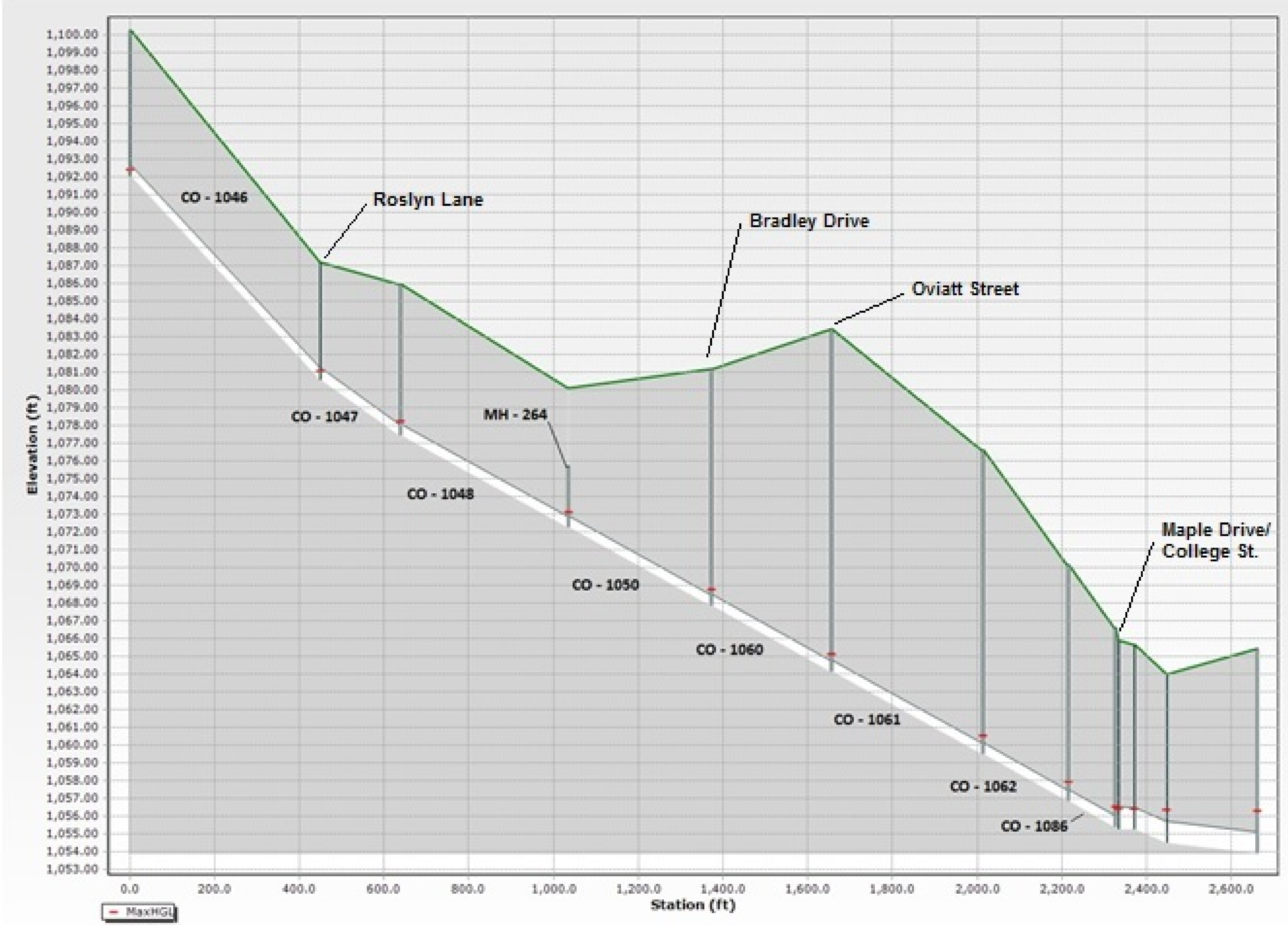
Hudson, Ohio

East Streetsboro Road Proposed Sanitary Sewer Capacities Versus

1-Hour, 10-Year Model-Simulated Flows

Label	Diameter (in.)	Length (ft.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow Rate (GPM)
CO-1046	8	450	0.025	864	615
CO-1047	8	189	0.017	698	615
CO-1048*	8	397	0.013	620	639
CO-1050*	8	337	0.013	620	656
CO-1060*	8	283	0.013	620	656
CO-1061*	8	358	0.013	620	646
CO-1062*	8	202	0.013	620	646
CO-1086*	8	111	0.013	620	648

* Sections of sewer that were modified as part of this model evaluation. See the Appendix for physical data related to these existing sewers.



LEGEND

(green line)	GROUND SURFACE
(red mark)	MAXIMUM HYDRAULIC GRADE LINE
CO-XXX	CONDUIT
MH-XXX	MANHOLE

CTI ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

FIGURE 7.2
HUDSON SANITARY TRUNK SEWER MODEL RESULTS
EAST STREETSBORO ROAD
PROPOSED SANTIARY SEWER
1 - HOUR, 10 - YEAR RAINFALL EVENT

These proposed modifications to the sanitary sewer resulted in no SSO occurring at MH-264. However, Table 7.3 shows that some of the proposed sewers would still be undersized, based on model-simulated peak flow rates. Therefore, the diameter was increased in order to increase capacity (same alignment). The results of that model simulation is presented in Table 7.4. This table shows that a 12-inch diameter would have sufficient capacity based on the simulated flows. It should be noted that flows were only entered at each flow meter, and not at every manhole or tributary sewer. Therefore, this peak flow of approximately 615 GPM may underestimate the actual flow experienced by the sewer. While the additional capacity provided by upsizing this sewer to a 12-inch diameter pipe should be adequate, an additional, more detailed study should be conducted to verify these flows during the design phase if this option is selected.

Table 7.4
Hudson, Ohio
East Streetsboro Road Proposed (12-Inch) Sanitary Sewer Capacities Versus 1-Hour, 10-Year, Model-Simulated Flows

Label	Diameter (in.)	Length (ft.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow Rate (GPM)
CO-1046	8	450	0.025	864	615
CO-1047	8	189	0.017	698	615
CO-1048*	12	397	0.013	1,825	615
CO-1050*	12	337	0.013	1,825	615
CO-1060*	12	283	0.013	1,825	615
CO-1061*	12	358	0.013	1,825	615
CO-1062*	12	202	0.013	1,825	615
CO-1086*	12	111	0.013	1,825	615

* Sections of sewer that were modified as part of this model evaluation. See the Appendix for physical data related to these existing sewers.

Increasing capacity via removal and replacement of existing sanitary sewers with larger diameter sewers can be more expensive than construction of new storage facilities typically due to the large, linear footprint of the project. Costs involved with maintenance of traffic, restoration of pavement and inconvenience to the public will need further examined before selecting this alternative.

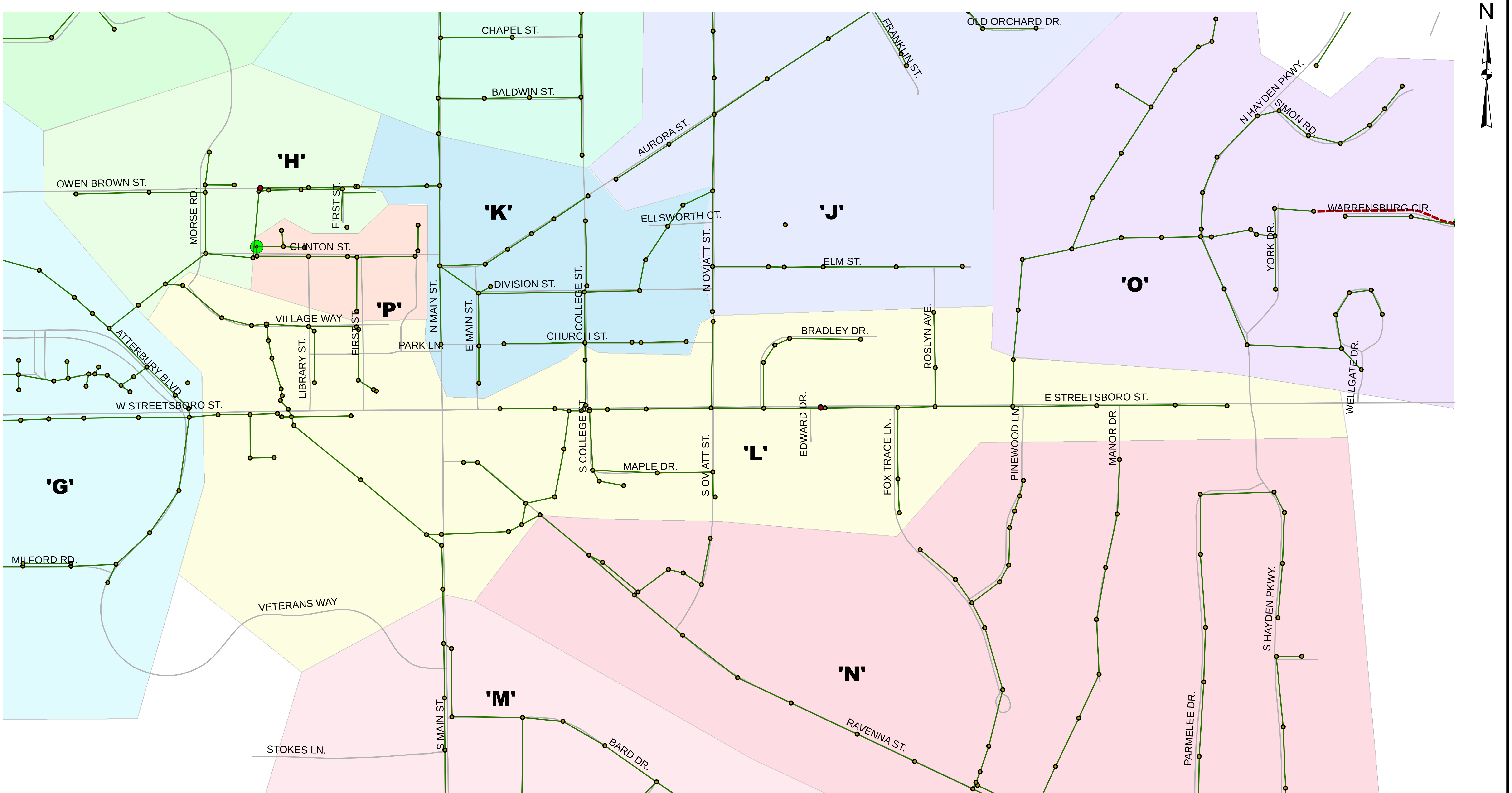
I&I Reduction Alternative

Another option that may alleviate the occurrences of SSO's at MH-264 is the reduction of I&I through capital improvement projects such as sewer lining and manhole rehabilitation. The "R" values for the East Streetsboro Road branch of the City's sanitary sewer are presented in Table 7.6.

Table 7.5
City of Hudson, Ohio - E. Streetsboro Road
RTK Coefficients - March 27, 2014 through May 30, 2014

FM No.	Area Label	Contributing Areas	Total Drainage Area (acres)	R Value
13	'O'	'O'	125.5	0.038
12	'N'	'N'	205.2	0.016
11	'M'	'M'	249.2	0.031
8	'L'	'L', 'M', 'N', 'O'	722.7	0.250

As shown in this table, the RTK analysis would indicate that the majority of I&I in this area comes from Area 'L'. A detailed depiction of this area is presented in Figure 7.3. As the City has already completed significant rehabilitation and reconstruction projects in Area 'L', future trunk sewer projects cannot be recommended until location-specific investigation is performed. The investigations should include televising, smoke testing, and dye testing of both private and public systems. After specific features are identified, work such as sewer lining, manhole rehabilitation, and lateral repairs could eliminate I&I from occurring. Given the scope of this study and the necessary detail for this type of improvement, a cost estimate was not repaired for this alternative.



ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

LEGEND

- GRAVITY SANITARY SEWER
- SANITARY SEWER FORCE MAIN
- ROADWAY
- SANITARY SEWER MANHOLE
- LIFT STATION

0 205 410 820 Feet

FIGURE 7.3
HUDSON SANITARY TRUNK SEWER MODEL
AREA 'L'

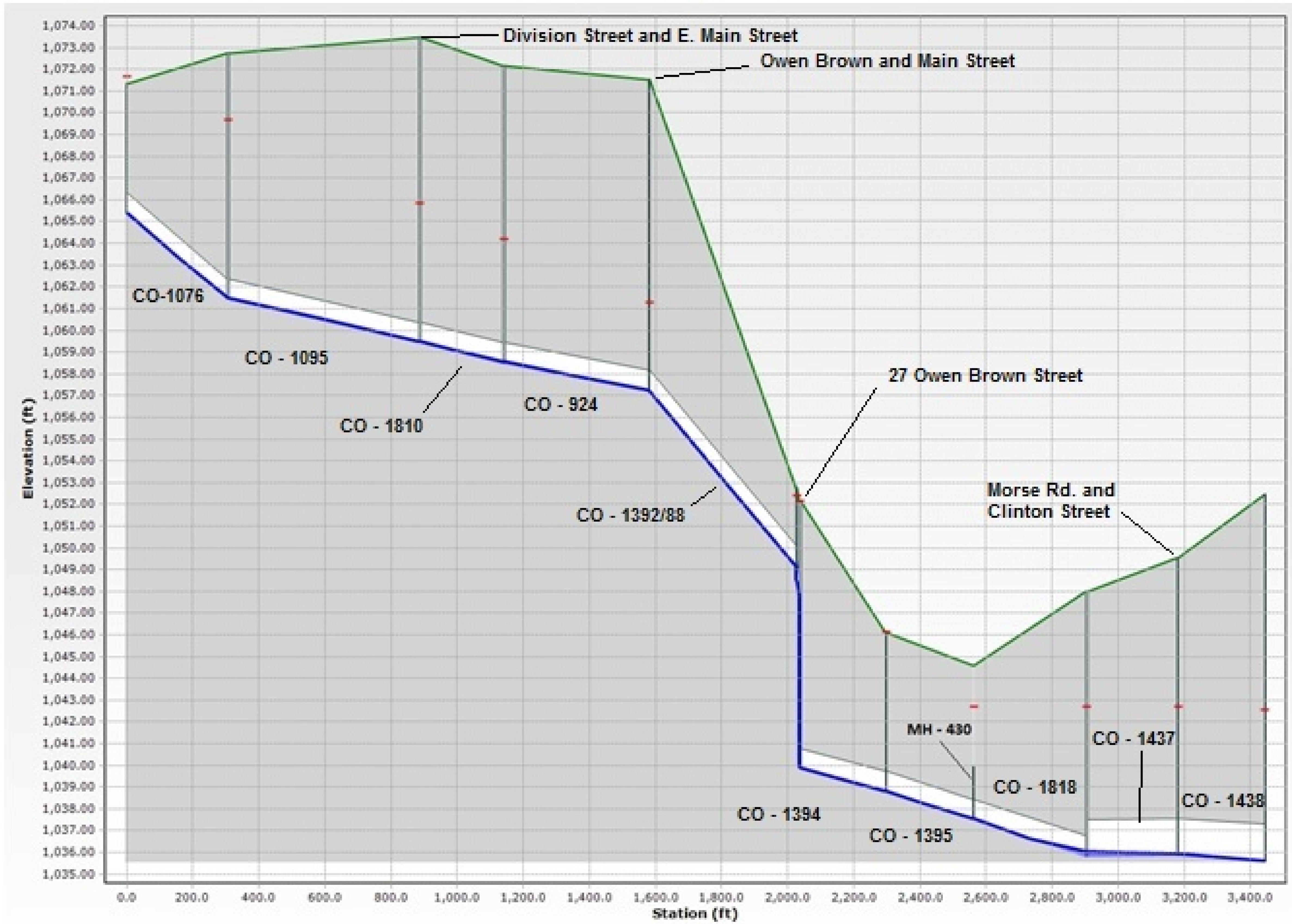
7.3.2 MH-430 (Owen Brown Overflow)

Modeling results conclude that the issues involving SSO's occurring at MH-430 on Owen Brown Street are more complex in nature than those at MH-264 on East Streetsboro Road. A figure presenting the sanitary profile in this area is presented in Figure 7.4.

The overflow at MH-430 is different from the overflow at MH-264 based on its elevation in relation to the trunk sewer. MH-264 on East Streetsboro Road (see Figure 7.2) has an elevation difference of approximately 20 feet from the downstream trunk sewer (1075 versus 1055 feet). Therefore, it is not affected significantly by any limited capacity downstream within the trunk sewer. However, MH-430 on Owen Brown Street is relatively at the same elevation as the trunk sewer downstream. Therefore, it not only is affected by local bottlenecks, but also limitations within the trunk sewer. This is better illustrated in Figure 7.5, which shows the entire profile, from Owen Brown to the outfall at the CVI pump station.

Figure 7.5 shows the relative elevation of MH-430 in relation to the trunk sewer, as well as the capacity of the trunk sewer when compared to the 10-year rainfall event. The red tick marks above each manhole indicate the level each manhole is surcharged during the rain event. Some manholes show these tick marks above the ground surface. This is an indication that the model predicts surcharging of sanitary sewer flows onto the ground surface during a 1 -hour, 10 - year rainfall event. Therefore, the model was used to evaluate alternatives to minimize the SSO's occurrences at MH-430 and to eliminate surcharging in other trunk sewer sections during the 10-year rainfall event.

As studied in the overflow at MH-430 on East Streetsboro Road, improvement alternatives including a pump station, storage facility, overall I&I reduction and increasing trunk sewer capacity were evaluated for the overflow at MH-264 on Owen Brown Street. The following is a description of each of these alternatives.

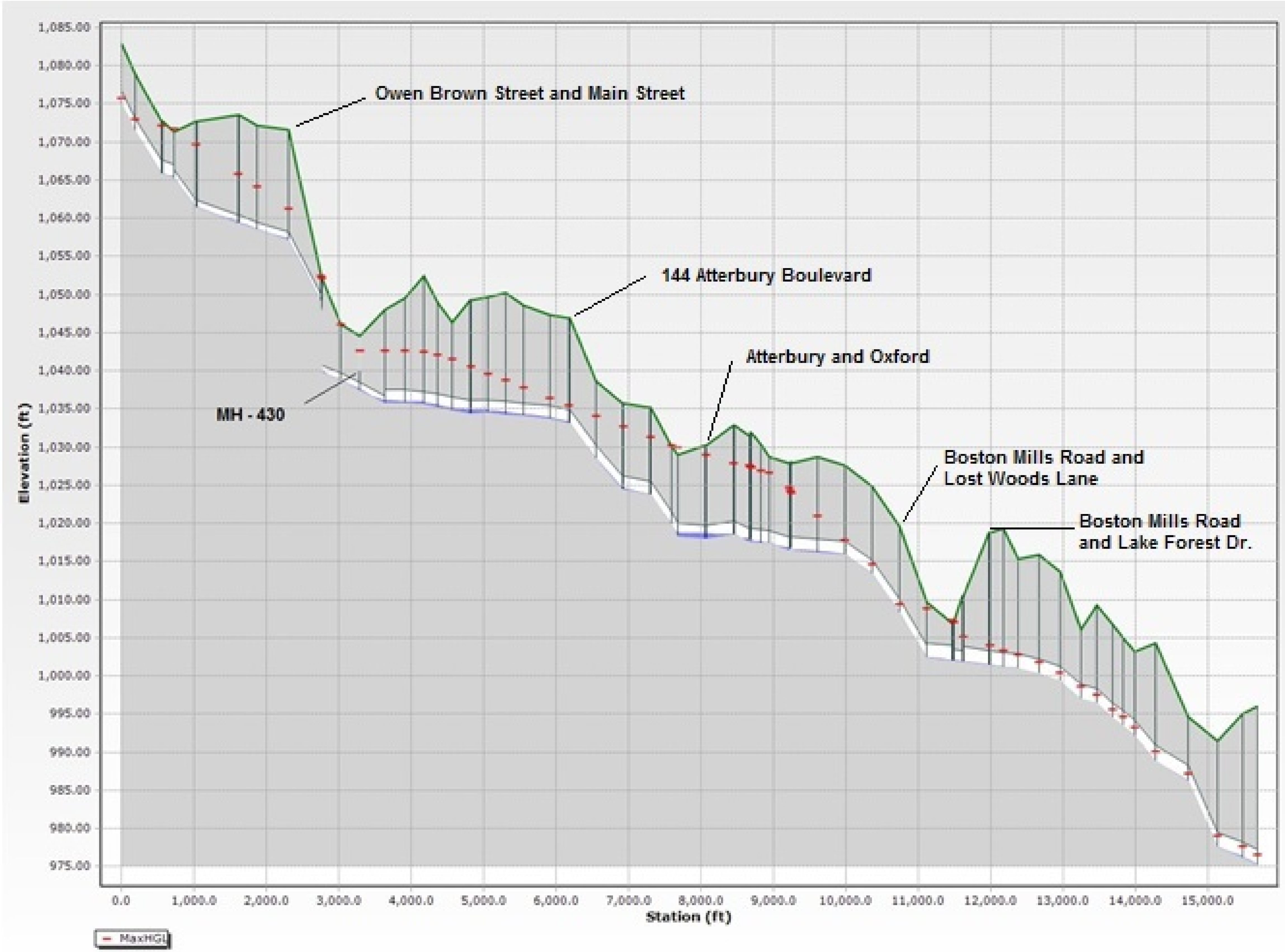


LEGEND

(green line)	GROUND SURFACE
(red dash)	MAXIMUM HYDRAULIC GRADE LINE
CO-XXX	CONDUIT
MH-XXX	MANHOLE

FIGURE 7.4
HUDSON SANITARY TRUNK SEWER MODEL
OWEN BROWN STREET TO
ATTERBURY BOULEVARD

CTI ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996



LEGEND

(green line)	GROUND SURFACE
(red dash)	MAXIMUM HYDRAULIC GRADE LINE
CO-XXX	CONDUIT
MH-XXX	MANHOLE

CTI ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

FIGURE 7.5
HUDSON SANITARY TRUNK SEWER MODEL
OWEN BROWN STREET TO OUTFALL

Pump Station Alternative

Due to the limited capacity within the trunk sewer downstream of MH-430, a pump station would not appear to be a feasible solution to minimize SSO's at this location. Re-routing this flow to some other location along the existing trunk sewer would only compound capacity issues in the localized area of the force main connection. To route flows to the nearest section of trunk sewer where there is sufficient capacity would involve a large diameter force main of at least two miles in length and a pump station designed to pump 2,200 GPM, well above normal pump station capacities. Due to these reasons, a pump station was not further evaluated as a feasible option at this time.

Storage Facility Alternative

The model was used to estimate the potential storage volume required upstream of MH-430 in order to eliminate any SSO occurring from this location. Table 7.6 summarizes model results for this evaluation.

Table 7.6
Hudson Sanitary Trunk Sewer
Model - Simulated Storage Volumes,
Owen Brown

Rainfall Event Frequency	Required Storage Volume (gallons)*	Approximate Dimensions*
1 - Hour, 1 - Year	180,000	40 ft. x 40 ft. x 15 ft.
1 - Hour, 5 - Year	520,000	70 ft. x 70 ft. x 15 ft.
1 - Hour, 10 - Year	675,000	80 ft. x 80 ft. x 15 ft.
1 - Hour, 25 - Year	850,000	90 ft. x 90 ft. x 15 ft.

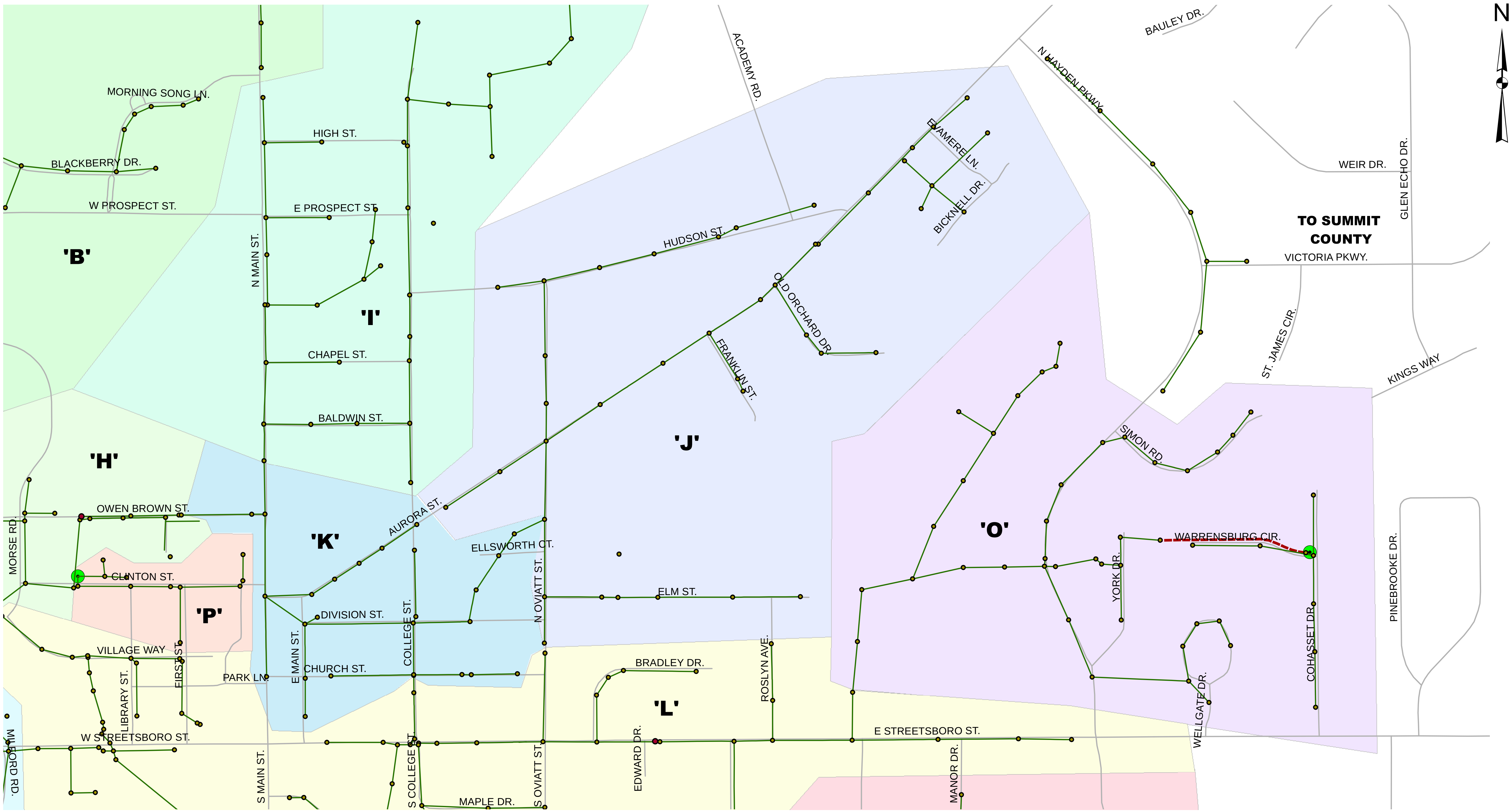
*Volumes stated are preliminary, and have been increased by roughly 25% from model results. Final storage volumes will be estimated during design. Dimensions were approximated assuming a 15-foot depth and square footprint, but are only preliminary and would be evaluated during design.

Required storage volumes reported by the model are significantly larger for MH-430 than those required for MH-264. In addition, the volumes reported within the model may be underestimated, as model-simulated rainfall events of greater intensity (i.e. the 25-year rainfall event) also cause surface surcharging in other areas of the system as well. Due to these reasons, a storage facility was not further evaluated as a feasible option at this time.

I&I Reduction Alternative

Occurrences of SSO's at MH-430 are due in part to hydraulic bottlenecks in the system downstream. Therefore, a system-wide reduction of I&I should be performed in order to reduce the overall peak flow within the trunk sewer. Based on the RTK analysis summarized in section 5.2, the areas with significantly higher I&I compared to the rest of the system is Area 'L' (R Value of 0.25 - area presented previously in Figure 7.3) and Area 'J' (R value of 0.13). A more detailed depiction of Area 'J' is presented in Figure 7.6. The additional flows resulting from I&I from both these areas significantly affect the probability of an SSO occurring at MH-430. Therefore, the model was modified to represent reductions in I&I in those two areas. Therefore, the developed RDII hydrographs for both Area 'J' and Area 'L' were reduced in order to make them relatively similar to the rest of the system (Average R Value of 0.05). It should be noted, however, that the amount of rehabilitation work required to decrease I&I to this extent cannot be determined within the scope of this study.

Model results of this evaluation conclude that while this degree of proposed rehabilitation greatly decreases the SSO volume greatly (roughly by 50%), it does not eliminate the SSO entirely. This is primarily due to the limited capacity of the sanitary sewers affecting surcharging within MH-430. Therefore, an evaluation was performed to investigate the amount of capacity required to eliminate SSO's at MH-430 within the model.



LEGEND

- GRAVITY SANITARY SEWER
- SANITARY SEWER FORCE MAIN
- ROADWAY
- SANITARY SEWER MANHOLE
- LIFT STATION

CTI ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

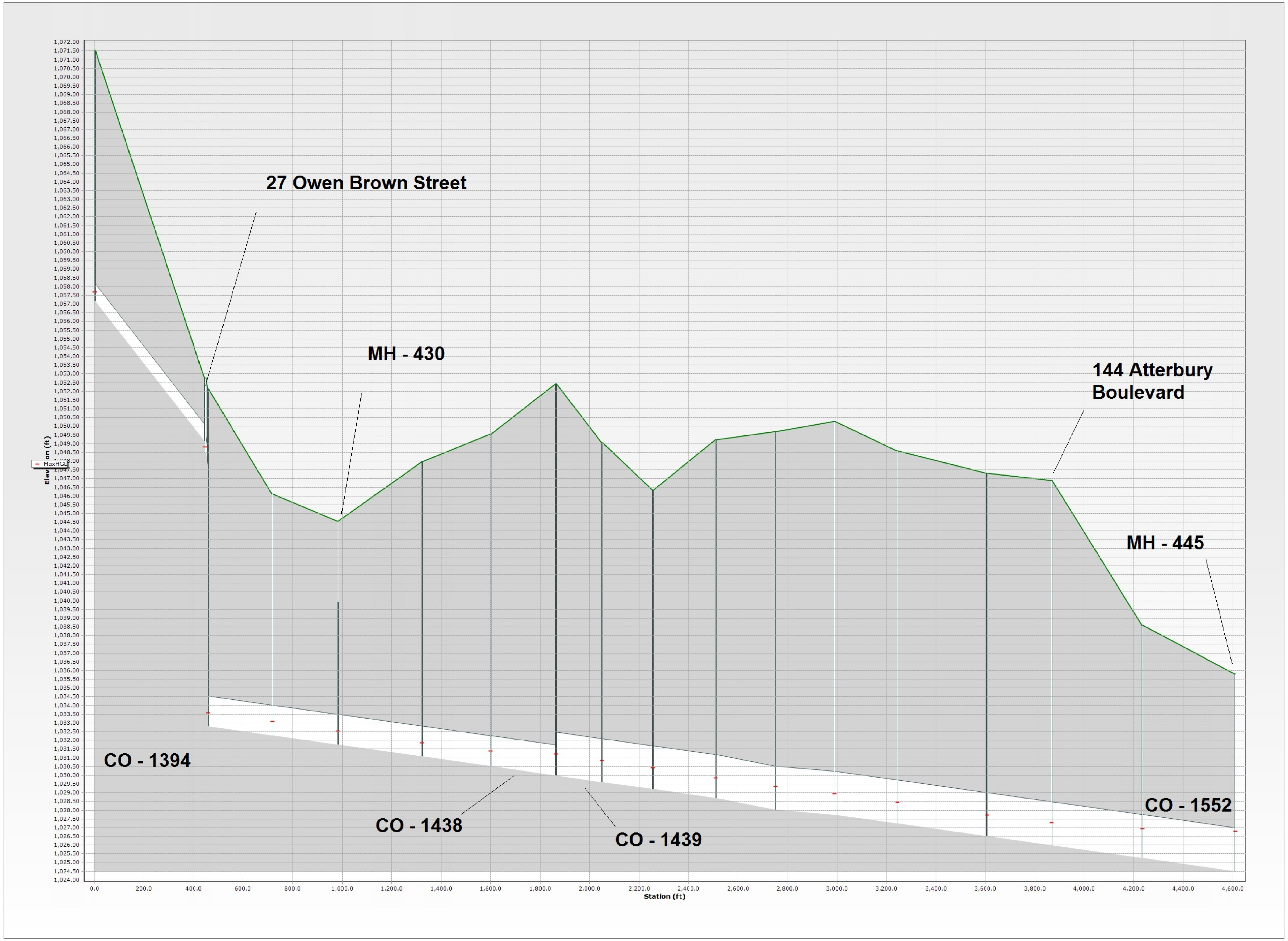
FIGURE 7.6
HUDSON SANITARY TRUNK SEWER MODEL
AREA 'J'

Increasing Capacity Alternative

The model was used to increase the capacities of sewers within the system in order to eliminate model-simulated SSO's at MH-430. Due to the length of sewers identified to meet this goal, this was done in two parts:

- Identify the section(s) of sanitary sewer to be replaced in order to eliminate model-simulated overflows for a 1-year return event;
- Identify additional sewers required to be replaced in order to eliminate model-simulated overflows for a 10-year return event.

The following figure shows the proposed alignment necessary to eliminate SSO's within the model at MH-430 for rainfall events with an intensity equivalent to a 1-hour, 1-year event. (Note: Labels for only selected sewers have been shown for clarity.)



LEGEND

GROUND SURFACE

MAXIMUM HYDRAULIC GRADE LINE

CO-XXX CONDUIT

MH-XXX MANHOLE

CTI ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

FIGURE 7.7
HUDSON SANITARY TRUNK SEWER MODEL RESULTS
PROPOSED SANITARY SEWER
OWEN BROWN TO 194 ATTERBURY BOULEVARD
1 - HOUR, 1 - YEAR RAINFALL EVENT

A complete list of the sewers proposed to be modified during this scenario is presented in Table 7.7.

Table 7.7
Hudson, Ohio MH-430 Area
Existing Versus Proposed Long-Term Improvements

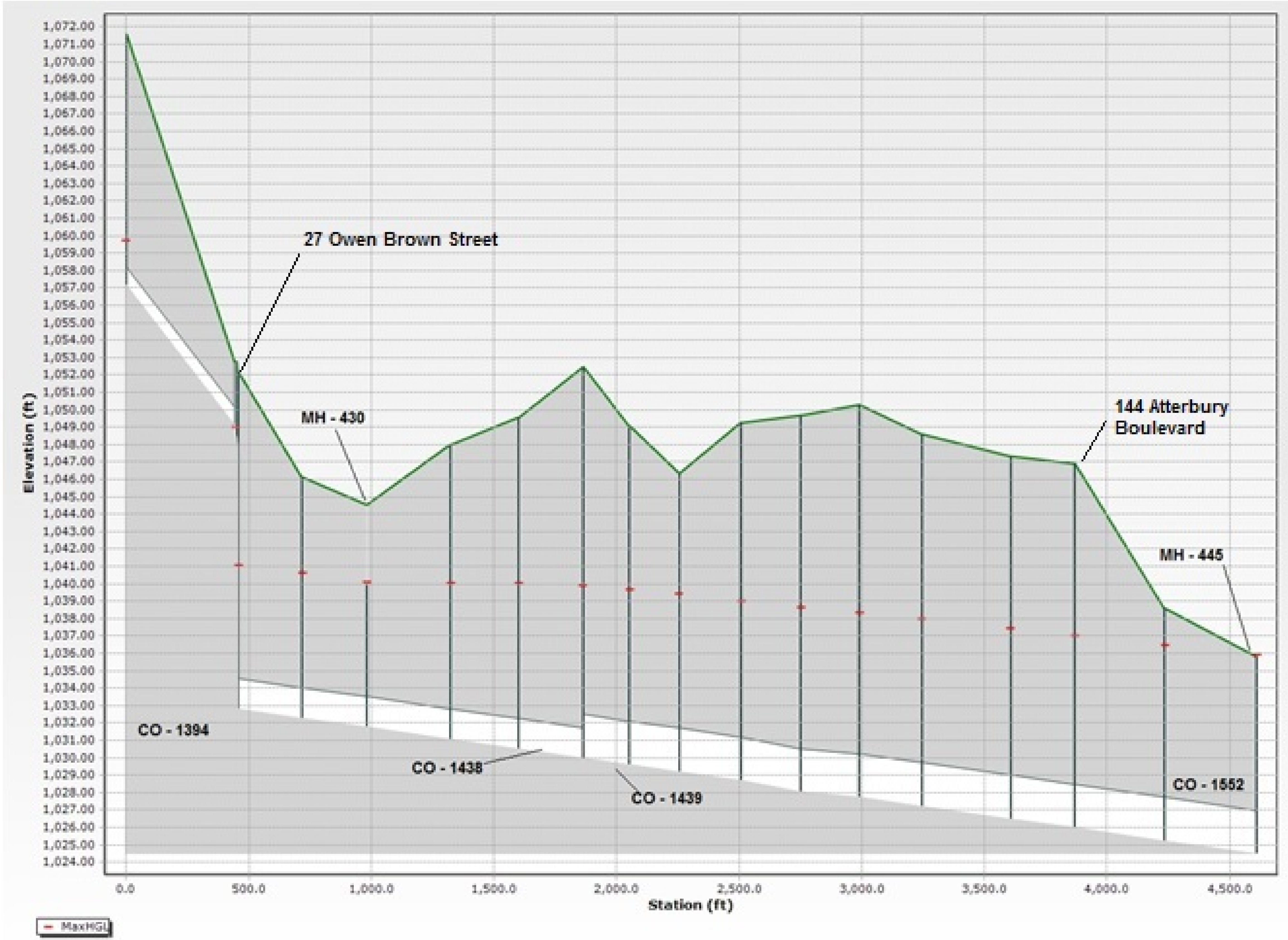
Label	Length (ft.)	EXISTING				PROPOSED			
		Diam. (in.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow (GPM)	Diam. (in.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow (GPM)
CO-1394	260	12	0.004	1,012	1,316	21	0.002	3,180	1,320
CO-1395	265	12	0.005	1,115	1,316	21	0.002	3,180	1,320
CO-1818	342	12	0.005	1,117	1,210	21	0.002	3,190	1,320
CO-1437	276	21	0.000	428	1,125	21	0.002	3,175	1,340
CO-1438	264	21	0.001	2,054	1,100	21	0.002	3,190	1,340
CO-1439	188	21	0.002	3,151	3,562	30	0.002	8,270	4,075
CO-1440	204	21	0.002	3,030	3,550	30	0.002	8,150	4,060
CO-1407/8*	254	21	0.002	2,860	3,560	30	0.002	8,250	4,060
CO-1304	243	21	0.000	1,116	3,554	30	0.003	9,660	4,022
CO-1305	238	21	0.001	2,260	3,550	30	0.001	6,540	3,985
CO-1306	253	21	0.001	1,900	3,550	30	0.002	8,190	3,988
CO-1545	363	21	0.001	2,360	3,535	30	0.002	8,200	4,010
CO-1546	262	21	0.002	3,109	3,520	30	0.002	8,300	4,025
CO-1551	367	21	0.013	8,068	3,520	30	0.002	8,200	4,000
CO-1552	375	21	0.011	7,290	3,520	30	0.002	8,200	4,000

Note: Peak flows are based on model-simulated flows for a 1-Hour, 1-Year rainfall event

During this scenario, the sewers proposed to be replaced were preliminarily sized to contain all flows during the 1-hour, 1-year rainfall event. With these proposed modifications to the sanitary sewer system, no SSO occurred at MH-430 during the 1-hour, 1-year rainfall event.

These same improvements, as listed in Table 7.7, were then examined within the model to simulate their performance under a 1-hour, 10-year rainfall event.

Model results are graphically presented in the following figure. (Note: Labels for only selected sewers have been shown for clarity.) As shown in Figure 7.8, during a 1-hour, 10-year rainfall event, the benefit of these initially proposed improvements are minimized due to the limited capacity of the downstream trunk sewer. This is primarily due to the flat slope of the existing sanitary trunk sewer near Atterbury Boulevard. Note that the red tick (showing the maximum extent of surcharging) at MH-445 is above the ground level, indicating a potential surcharge at the ground surface at this location. This is also shown in Figure 7.9 by showing the entire profile, from Owen Brown to the outfall.



LEGEND

GROUND SURFACE

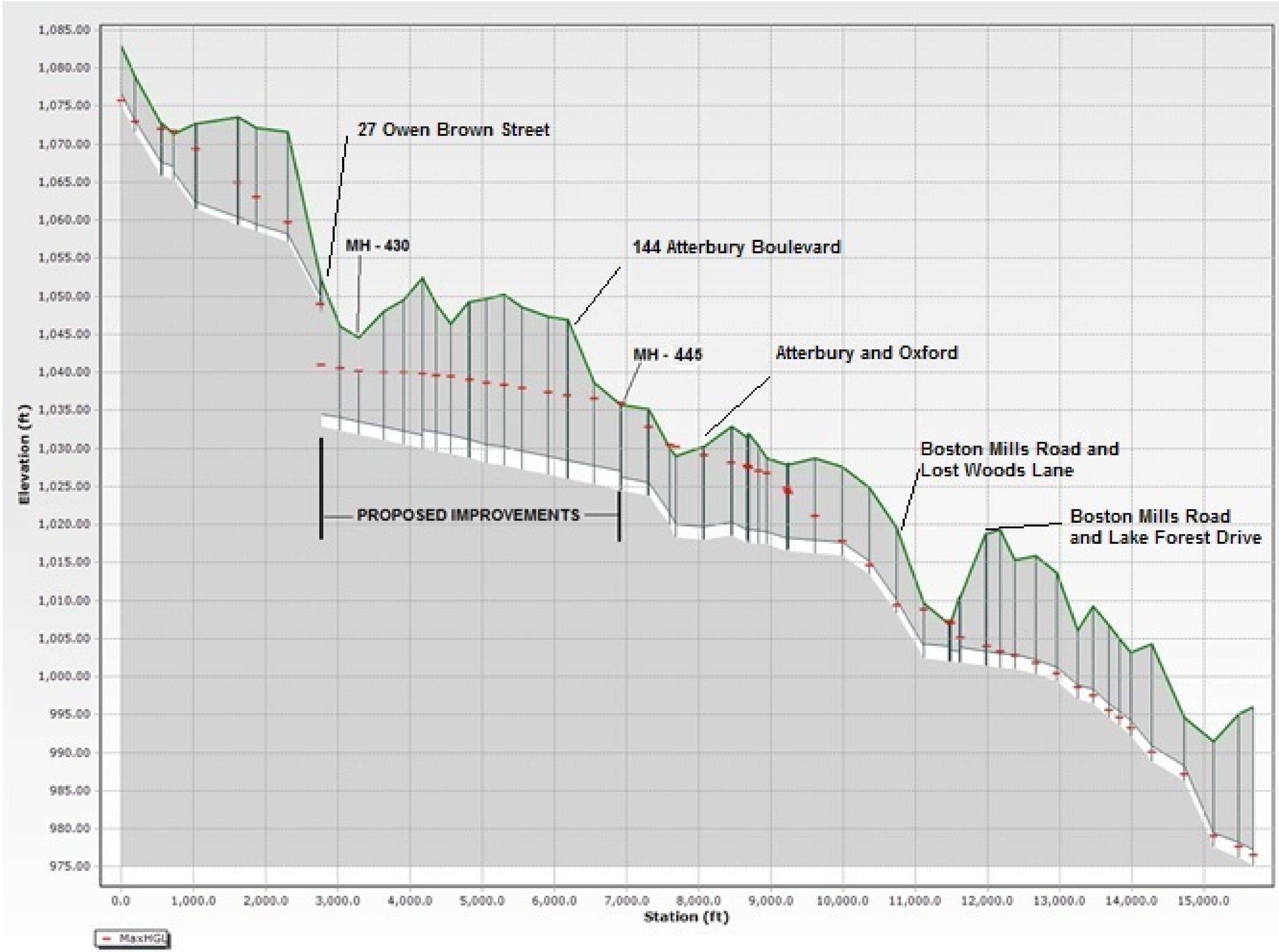
MAXIMUM HYDRAULIC GRADE LINE

CO-XXX CONDUIT

MH-XXX MANHOLE

ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

FIGURE 7.8
HUDSON SANITARY TRUNK SEWER MODEL RESULTS
PROPOSED SANITARY SEWER IMPROVEMENTS
OWEN BROWN TO 194 ATTERBURY BOULEVARD
1 - HOUR, 10 - YEAR RAINFALL EVENT



LEGEND

(green line)	GROUND SURFACE
(red dash)	MAXIMUM HYDRAULIC GRADE LINE
CO-XXX	CONDUIT
MH-XXX	MANHOLE

CTI ENGINEERS, INC.

ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

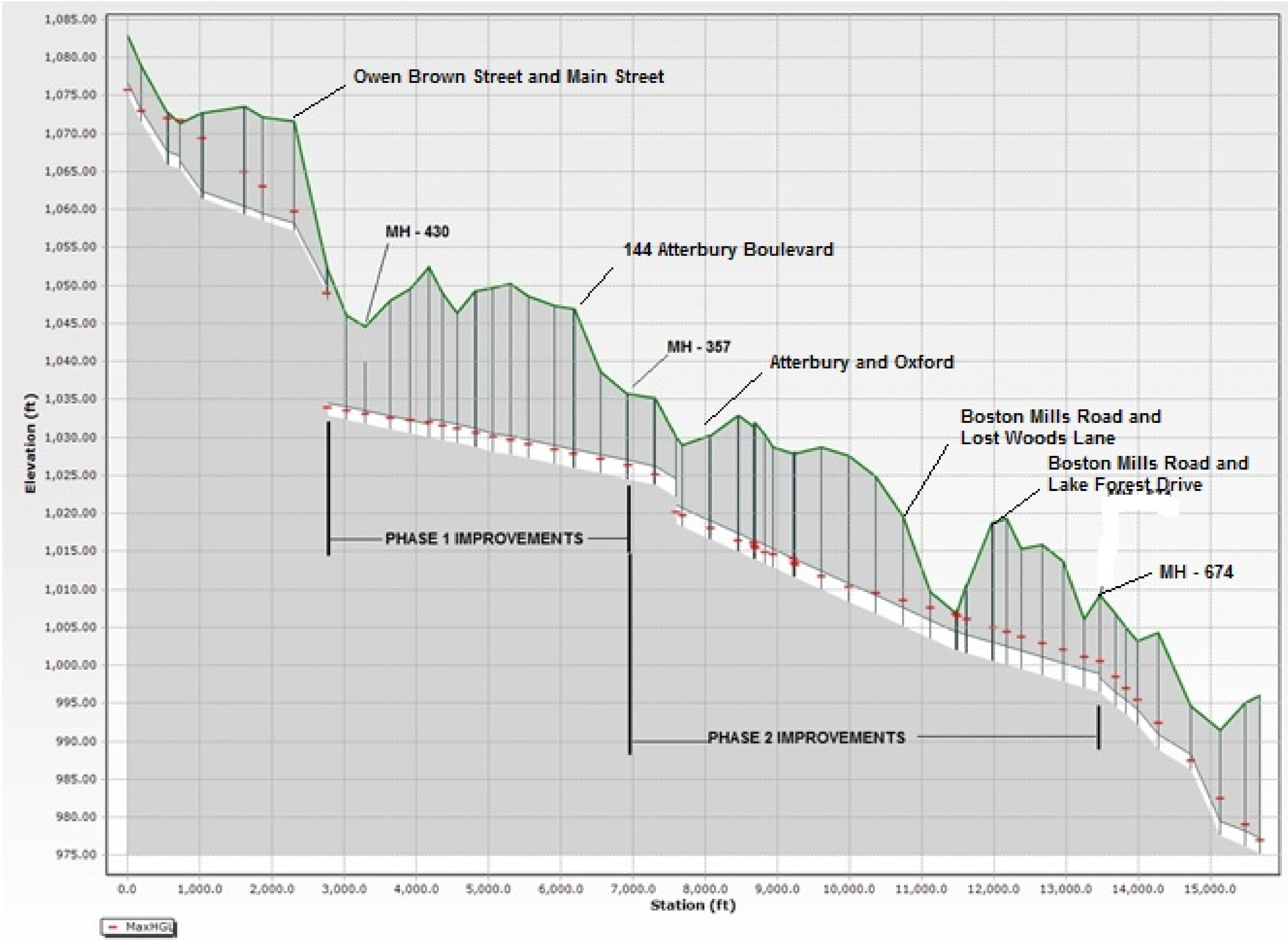
FIGURE 7.9
HUDSON SANITARY TRUNK SEWER MODEL RESULTS
PROPOSED PHASE I
SANITARY SEWER IMPROVEMENTS
1 - HOUR, 10 - YEAR RAINFALL EVENT

In this scenario, a 1-hour, 10-year rainfall event causes surface overflows in several locations due to the limited capacity of the downstream trunk sewer, and still causes a SSO at MH-430. These events still occur due to the capacity of the existing trunk sewer downstream. Therefore, the model was modified again to preliminarily size the trunk sewer in order to handle the 1-hour, 10-year rainfall event. A figure showing the proposed profile is presented in Figure 7.10.

The improvements illustrated in this figure not only stopped any SSO from occurring at MH-430 during the 1-hour, 10-year rainfall event, but also any other ground surface overflows due to surcharging manholes. However, the amount of replacement of the sanitary trunk sewer in order for this to occur is extensive. Being able to split these improvements into two phases helps to relieve some of the issues involved with construction of such a project (funding, scheduling, impact to residents, etc.) while still achieving the ultimate goal of alleviating SSO's. A list of Phase 1 and Phase 2 improvements, are included in Tables 7.8 and 7.9, respectively. A summary of the two phases of construction are as follows:

- **Phase 1 Improvements** were identified so that no SSO occurred at MH-430 within the model during a 1-hour, 1-year rainfall event with only Phase 1 improvements. These improvements would also eliminate all SSO's during rainfall events less than the 1-hour, 1-year rainfall event. This would greatly reduce the number of SSO occurrences per year. (By definition, the 1-hour, 1-year rainfall event should only occur once per year.)

- **Phase 2 Improvements** were identified to meet the EPA requirement that sanitary sewers must contain all flows resulting from a 1-hour, 10-year rainfall event. With both Phase 1 and Phase 2 improvements, no SSO occurred at MH-430 within the model during a 1-hour, 10-year rainfall event.



CTI ENGINEERS, INC.
ONE CASCADE PLAZA, SUITE 710
AKRON, OH 44308
330-294-5996

LEGEND

- GROUND SURFACE
- MAXIMUM HYDRAULIC GRADE LINE
- CO-XXX CONDUIT
- MH-XXX MANHOLE

FIGURE 7.10
HUDSON SANITARY TRUNK SEWER MODEL RESULTS
PROPOSED PHASE I AND II
SANITARY SEWER IMPROVEMENTS
1 - HOUR, 10 - YEAR RAINFALL EVENT

Table 7.8

Hudson, Ohio

Existing Conditions Versus Proposed Phase 1 Improvements (1-Hour, 10-Year Rain Event)

Label	Length (ft.)	EXISTING				PROPOSED			
		Diam. (in.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow (GPM)	Diam. (in.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow (GPM)
CO-1394	260	12	0.004	1,012	2,400	21	0.002	3,180	2,600
CO-1395	265	12	0.005	1,115	2,400	21	0.002	3,180	2,600
CO-1818	342	12	0.005	1,117	1,500	21	0.002	3,190	2,600
CO-1437	276	21	0.000	428	1,500	21	0.002	3,175	2,600
CO-1438	264	21	0.001	2,054	1,300	21	0.002	3,190	2,600
CO-1439	188	21	0.002	3,151	4,400	30	0.002	8,270	8,100
CO-1440	204	21	0.002	3,030	4,400	30	0.002	8,150	8,100
CO-1407/8*	254	21	0.002	2,860	4,500	30	0.002	8,250	8,100
CO-1304	243	30	0.001	1,116	4,500	30	0.003	9,660	8,000
CO-1305	238	30	0.001	2,260	4,500	30	0.001	8,540	8,000
CO-1306	253	30	0.001	1,900	4,500	30	0.002	8,190	8,000
CO-1545	363	30	0.001	2,360	4,450	30	0.002	8,200	7,900
CO-1546	262	30	0.002	3,109	4,400	30	0.002	8,300	7,900
CO-1551	367	30	0.013	8,068	4,400	30	0.002	8,200	7,900
CO-1552	375	30	0.011	7,290	4,400	30	0.002	8,200	7,900

Note: Peak flows are based on model-simulated flows for a 1-Hour, 10-Year rainfall event

***** CO-1407 and CO-1408 were modeled as one pipe within the model

Table 7.9

Hudson, Ohio

Existing Conditions Versus Proposed Phase 2 Improvements (1-Hour, 10-Year Rain Event)

Label	Length (ft.)	EXISTING				PROPOSED			
		Diam. (in.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow (GPM)	Diam. (in.)	Slope (ft./ft.)	Capacity (GPM)	Peak Flow (GPM)
CO-1553	376	21	0.002	3,200	4,500	30	0.002	8,300	8,000
CO-1554	296	21	0.013	8,200	4,500	30	0.006	14,000	8,000
CO-1555	84	21	0.019	9,700	4,500	30	0.004	12,000	8,000
CO-1409	388	21	0.001	1,900	4,500	30	0.004	12,000	8,000
CO-1835	389	21	0.001	1,900	4,500	30	0.004	12,000	8,000
CO-1836	215	21	0.005	4,800	4,500	30	0.004	12,000	8,000
CO-1639	11	21	0.03	12,000	4,500	30	0.004	12,000	8,000
CO-1640	9	21	0.04	14,000	4,500	30	0.004	12,000	8,000
CO-1805	135	21	0.001	1,900	4,500	30	0.004	12,000	8,000
CO-1412	118	21	0.001	1,900	4,500	30	0.004	12,000	8,000
CO-1642	278	21	0.003	4,100	6,500	30	0.004	12,000	10,000
CO-1643	16	21	0.019	10,000	6,500	30	0.004	12,000	10,000
CO-1644	9	21	0.027	12,000	6,500	30	0.004	12,000	10,000
CO-1645 /1502*	360	21	0.001	1,900	6,500	30	0.004	12,000	10,000
CO-1503	380	21	0.001	1,900	6,500	30	0.004	12,000	10,000
CO-1504	372	21	0.006	5,700	6,500	30	0.004	12,000	10,000
CO-1505	381	21	0.013	8,200	6,500	30	0.004	12,000	10,000
CO-1506	380	21	0.016	9,000	6,500	30	0.004	12,000	10,000
CO-1509	345	24	0.001	3,200	6,500	30	0.004	12,000	10,000
CO-1510	22	24	0.002	3,400	5,700	30	0.003	10,000	10,000
CO-1511	131	24	0.001	3,200	5,700	30	0.003	10,000	10,000
CO-1512	361	24	0.001	3,700	5,700	30	0.003	10,000	10,000
CO-1513	199	24	0.001	3,800	5,700	30	0.003	10,000	10,000
CO-1514	202	24	0.001	3,000	5,700	30	0.003	10,000	10,000
CO-1515	288	24	0.002	5,000	5,700	30	0.003	10,000	10,000
CO-1516	291	24	0.003	5,900	5,700	30	0.003	10,000	10,000
CO-1517	292	24	0.008	9,200	5,700	30	0.003	10,000	10,000
CO-1518	217	24	0.002	5,000	5,700	30	0.003	10,000	10,000

Note: Peak flows are based on model-simulated flows for a 1-Hour, 10-Year rainfall event

***** CO-1645 and CO-1502 were modeled as one pipe within the model

8.0 RECOMMENDATIONS

Final recommendations of this study are provided in the following section whose goal is to reduce I&I, reduce the number of occurrences of SSO's, and ultimately eliminate the two remaining SSO's within the City of Hudson's sanitary sewer system. It should be noted that none of these recommendations, on their own, are the single solution in achieving this goal. Instead, it is a combination of these recommendations that will provide a complete solution and they should be implemented when the City has available funds and resources to do so. For this reason, the recommendations have been categorized in terms of "short-term", "medium-term", and "long-term" improvements to emphasize the size of resources required to implement these recommendations, and they are described in the following sections.

Short-Term Improvements

The City should develop the following short-term recommendations, which should take little cost to develop, to reduce I&I within its sanitary trunk sewer:

- Create a City ordinance to eliminate private sources of I&I. Included in the ordinance should be methods of incentives for private sources to be eliminated.

- Adopt a City point-of-sale (POS) ordinance requiring property owners to inspect private laterals upon sale of property and to repair defective private laterals as a requirement of the transfer of the property.

- Create a public education program (flyers, brochures, outreach programs) on how I&I affects the City and why it is important to eliminate I&I sources.

These short-term improvements would reduce I&I by eliminating existing sources of I&I and minimize the creation of new sources of I&I by educating the public about the related issues. Note that while these short-term improvements are more economical to create, it will take additional City resources in order to implement and enforce these ordinances and maintain a public education program.

Medium-Term Improvements

The following recommendations, while more expensive than the short-term improvements, would help to identify sources of I&I and minimize their effect. These improvements could be focused in priority areas that have been identified within this study to contain higher amounts of I&I than the rest of the City's sanitary sewer system. However, this study has also determined that I&I is found system-wide (which is typical to varying extents in all sanitary sewer systems), and the City should continue its efforts to identify and eliminate sources of I&I throughout the entire system:

- Additional modeling and investigations of sub-areas shown to have higher I&I compared to the rest of the system. (Areas 'J' and 'L' on Figures 4.1 and 5.6). This includes additional flow metering, smoke testing, dye testing, modeling of these areas to identify specific sources of I&I.

- City to purchase and operate new testing and metering equipment (rain gauges, flow meters, smoke testing) to conduct additional investigations on their own.

- Continued, ongoing maintenance and inspection program to not only maintain the performance of the sanitary sewer system, but to also help in identifying new priority areas for rehabilitation or capital improvement projects.

- Continued lining/rehabilitation/replacement of older, existing infrastructure to reduce I&I in known contributing areas.

- Impact evaluation/s study of known future projects within the City (i.e. roadway improvement projects, First and Main, Phase 2 development, etc.) and how projects to improve the performance of the sanitary trunk sewer (I&I reduction, sanitary sewer replacement) can be incorporated into these projects. For example, a parking lot for a new commercial development could be constructed above a new storage facility, which would reduce peak flow rates within the sanitary sewer and reduce surcharging and SSO occurrences.

Long-Term Improvements

Long-term improvements are projects that would help to immediately reduce the number of SSO's occurring in the system. They are the most expensive solutions as well. The highest recommended long-term improvement is the replacement of sections of the existing sanitary trunk sewer system that have limited capacity. This project was found to have the most economical solution to reduce SSO occurrences at both the Owen Brown overflow (MH-430) and E. Streetsboro Road overflow (MH-264). These sections of sewer that have been identified as needing replacement are noted in Section 7. In addition to sanitary trunk sewer replacement, it is recommended that other short-term and/or medium-term solutions are incorporated as well.

Other long-term improvements were also evaluated. Of the alternatives that were evaluated, the most cost-effective measure in both cases was to replace the existing sanitary sewer with one of a larger capacity (Alternative 3 for the overflow on E.Streetsboro Road and Alternative 6A/B for the overflow on Owen Brown Street). The other alternatives evaluated were either more expensive, or had larger operation and maintenance costs associated with them. However, replacement of the sanitary sewer will involve a significant amount of land and traffic disturbance, as the majority of the trunk sewer is built along major roadways through the City (Atterbury Boulevard, East Streetsboro Road, Boston Mills Road). Other alternatives, may become more feasible, if they can be incorporated into known City projects (i.e. potential storage facility underneath new development).

The goal of the long-term improvements evaluated within this report was to eliminate SSO's from occurring during a 1-hour, 10-year rainfall event. This is based on the EPA guideline which is used for evaluating proposed sanitary sewer projects, as part of the approval process of the EPA's northeast Ohio district office. The same guideline is used when evaluating loans obtained from the State's Division of Environmental and Funding Assistance (DEFA).

Note that the long-term alternatives evaluated within this report are sized for a 1-hour, 10-year rainfall event to meet the EPA's criteria for sanitary sewer design. However, the City's consent Order states that the SSO's should be "eliminated", and that no SSO's should occur regardless of the intensity of rainfall. Regardless of the rainfall intensity used, there will always be the chance that a larger, more intense rainfall event will occur than the designed event. The only possibility that rainfall intensity will have no negative effect on the City's sanitary trunk sewer system would be if the City's system were completely devoid of I&I and that only sanitary flows were conveyed by the sanitary sewer. This is a scenario that is virtually impossible in most Cities throughout the United States. Even if the City were to construct any of these long-term alternatives, a chance still remains that a more intense rainfall event would occur and result in a sanitary sewer overflow.

This reinforces the idea that a <u>combination</u> of these recommendations must be implemented in order to meet the City's objective to remove the EPA consent order. These recommendations also are interdependent of each other, meaning that they affect each other and create an overall effect that is more beneficial to the City. For example, an inspection of a private, residential lateral due to a new point-of-sale ordinance may lead to an inspection of the connecting sewer, and possible identification of more I&I sources. The reduction of I&I with rehabilitation projects may reduce the necessary storage basin volume. In addition, removal of I&I will reduce the overall cost of construction of any of the large-scale capital improvements. While each of these recommendations provide some benefit to the City and its sanitary sewer system, there is no exact formula to meeting this objective.

Once the City does implement or construct a combination of these recommended improvements, it could decide that the occurrence of SSO's are so infrequent that they could be eliminated, thereby meeting the Ohio EPA's consent order. However, eliminating the SSO would ignore the SSO's original purpose, which was to minimize the number of flooded basements caused by surcharging of the sanitary sewer system. Before closing either of the two remaining SSO's, the City should fully investigate the original design and intent of the SSO, including reviewing basement elevations of nearby buildings and comparing them to the modeled hydraulic grade line of the sanitary sewer.

Specifically, it is recommended that a new ordinance and point-of-sale program should be implement to start addressing private I&I issues. Public education of the cause and issues associated with I&I is also recommended. The City should investigate the relatively high I&I rates in study areas 'J' and 'L' either by hiring a consultant or purchasing the necessary equipment needed to perform the work in-house. Also, ongoing maintenance and routine inspections should continue to reduce the potential for problems in the system and identify future rehabilitation type projects. Finally, if deemed necessary, the City could budget for design and construction of the replacement of the undersized trunk sewer sections, or other long-term improvements described within this report.

In conclusion, the developed computer model is a skeletonized version of the City's sanitary trunk sewer system, calibrated with data from the time period March 27, 2014 through May 30, 2014. The given model stands as a "snapshot" of the sanitary sewer's performance during this flow monitoring period. Field conditions will change over time as rehabilitation projects are completed, existing sewers and manholes age, etc. All sanitary sewer systems require ongoing maintenance and improvements due to these changing field conditions. Consequently, the model must be maintained and updated in order for it provide results as accurately as possible in the future.

9.0 PRELIMINARY OPINIONS OF PROBABLE CONSTRUCTION COST

The following preliminary opinions of probable construction cost are presented based on the "short-term", "medium-term" and "long-term" recommendations described in Section 8.0.

Short-Term Improvements

There are no opinions of probable construction associated with short-term improvements recommended as part of this study. This is due to these recommendations (ordinances, public education and outreach material) requiring little procurement of equipment, or construction of facilities in order to be implemented. However, indirect costs such as personnel time and publication of education materials will be encountered. These short-term improvements should be evaluated and implemented based on the available manpower and resources.

Medium-Term Improvements

Table 9.1 presents examples of preliminary opinions of probable cost to conduct additional, more detailed flow monitoring in the target areas identified within the study - Areas 'J' and 'L'. Also listed are the costs for the City to purchase new flow meters, rain gauges, and smoke testing kits for ongoing testing and investigation.

Table 9.1
Hudson, Ohio
Preliminary Opinions of Probable Cost , Medium-Term Recommendations

Alternative	Cost
Additional, Detailed Flow Monitoring - Area 'J' (4 Flow Meters - 2 Month Study)	$35,000
Additional, Detailed Flow Monitoring - Area 'L' (8 Flow Meters - 2 Month Study)	$65,000
City Purchase of Area-Velocity Flow Meter, (x 4)	$26,000
City Purchase of Additional Rain Gauge, Each	$1,000
Smoke Testing Kit (Blower, Residence Notices, Sand Bags, Smoke Liquid, Etc.)	$3,000

Long-Term Improvements

Table 9.2 presents preliminary opinions of probable construction cost for the long-term capital improvements evaluated within the model to eliminate SSO's at MH-264 (East Streetsboro Road) during the 10-year, 1-hour rainfall event.

Table 9.2

Hudson, Ohio

Preliminary Opinions of Probable Cost , MH-264 Area Long-Term Alternatives[1]

Alternative	Cost
Alternative 1 - Storage Facility, Estimated Volume of 50,000 Gallons	$1,500,000
Alternative 2 - Pump Station, 250 GPM and 1,375 ft. 4-Inch Force Main	$375,000
Alternative 3 - Increase Sewer Capacity, Replacement of Approximately 1,700 feet with 12-in. Diameter Sewer	$400,000

[1] Sizes and volumes based on model results of a 1 - hour, 10 - year rainfall event

Due to the relatively small volume required, it appears that the storage facility Alternative 1) would not be cost-effective. Essentially, the proposed pump station (Alternative 2) would be an "online" storage facility, which minimizes the total storage volume required and eliminates other equipment and instrumentation in order to operate and maintain the storage facility. As Alternatives 2 and 3 are fairly similar in cost, other factors such as site availability, disturbance of traffic during construction, and annual O&M costs, will factor in final selection.

Table 9.3 presents preliminary opinions of probable construction cost for the long-term capital improvements evaluated within the model to eliminate SSO's at MH-430 (Owen Brown) during the 10-year, 1-hour rainfall event.

Table 9.3

Hudson, Ohio

Preliminary Opinions of Probable Cost , MH-430 Area Long-Term Alternatives[1]

Alternative	Cost
Alternative 4 - Pump Station, 2,200 GPM and 10,700 ft. 16-in. Diameter Force Main	$2,500,000
Alternative 5 - Storage Facility, Estimated Volume of 675,000 Gallons	$3,200,000
Alternative 6A - Increase Capacity, Phase 1 1,400 feet 21-in. Diameter Sewer 2,750 feet 30-in. Diameter Sewer	$800,000
Alternative 6B - Increase Capacity, Phase 2 6,545 feet of 30-in. Diameter Sewer	$1,250,000

[1] Sizes and volumes based on model results of a 1 - hour, 10 - year rainfall event

In contrast to Table 9.2, Table 9.3 shows that the cost associated with the proposed storage facility (Alternative 5) is more comparable to the other alternatives, but still remains the most expensive alternative. However, it may become a more feasible option if there is a location readily available for its construction. Alternative 4 (Pump Station) is the next most expensive option, but may provide some flexibility as the force main could be directionally drilled, minimizing the land disturbed during the construction of the project. Alternatives 6A and 6B are the cheapest overall option, but would require a significant amount of construction along roadways (i.e. Atterbury Blvd., Boston Mills Road), while providing some economic flexibility by constructing the improvements in phases.

It should be noted that the preliminary sizing and costs shown in Tables 9.2 and 9.3 do not account for recently completed or currently budgeted sewer rehabilitation projects, which would reduce peak flows and the overall size of these projects. However, these rehabilitation projects and their associated costs should be handled on a case-by-case basis, and further investigations should be conducted to identify more specific areas to focus the rehabilitation efforts. It should also be re-stated that these improvements were only sized to eliminate SSO's for a 10-year rainfall event, and would not eliminate SSO's entirely. However, by definition, these improvements would reduce the probability of an SSO occurring to less than 10% on an annual basis (1 event occurring in 10 years).