Memorandum

To: *Tom Simmons, MMSD*

From: *Dan Lau, CDM Smith; Pat Chiang, OTIE*

QA/QC: *Eric Loucks, CDM Smith*

Date: *November 14, 2014*

Subject: *Ad Hoc 110 (Edgewood Avenue Drainage Study)*
Technical Memorandum 2

Introduction

The Village of Shorewood (Village) has experienced basement backups and surface flooding for many years and over a wide range of rain events, including severe flooding during the July 15, 2010 and July 22, 2010 storm events. The flooding resulting from these storms prompted the Village to conduct investigations to find the causes of this flooding and develop solutions to improve their combined, storm, and sanitary sewer systems performance. However, a cost effective and acceptable alternative for the Village's combined sewer service area (CSSA) has yet to be identified. The Milwaukee Metropolitan Sewerage District (District) has initiated Ad Hoc Modeling Question 110 with the objective of identifying a cost effective solution that incorporates Green Infrastructure (GI) practices and does not increase peak flows to the District's facilities, thus avoiding the solution that could cause problems to the Village's downstream neighbors. While the Village experienced both basement backups and street flooding in the 2010 storms, the primary focus of this analysis is a solution to basement backups.

The initial step toward developing a feasible solution to the basement backup problems was preparation of a baseline hydraulic model to evaluate the combined sewer system capacity and restrictions and determine the root causes of the flooding. The results of the baseline model analysis were presented in a first technical memorandum (TM) titled Ad Hoc 110 TM1. TM1 documented the preparation of the Baseline model, including the review of the data and the model information provided, as well as the assumptions of the model boundary conditions setup to replicate the operation of the District's system. The modeling results showed that flooding and basement backup in the Village were primarily the result of severe storms exceeding the capacity of the Village combined sewer system. It was determined that the Village combined sewers and the District facilities accepting flow from the Village have adequate capacity to handle the 20 percent annual probability storm flow without creating a backwater condition or creating surcharge in the Village sewers.

This Technical Memorandum 2 (Ad Hoc 110 TM2) documents a screening analysis of potential solutions and outlines the assumptions and approaches utilized in the evaluation process. The assessment results identify solution effectiveness, along with the technical feasibility, practicality, and acceptability of the solutions. Based on the findings of the screening analysis, a comprehensive alternative, comprised of a combination of the selected potential solutions, was formulated and recommended. This proposed solution is a combination of GI initiatives, street conveyance, and relief storm sewers with a new relief outlet to the Milwaukee River.

Solution Screening

Solution Screening is a process where a set of potential solutions or solution components are evaluated conceptually for technical and institutional feasibility. This is generally accomplished without the use of detailed analyses. The solutions are evaluated according to a defined set of performance criteria and constraints. The criteria and constraints for this project are a blend of Village and District criteria. The key criteria are the following:

1. The solution must solve the basement backup problems during the 3-inch, 1-hour storm.
2. Flooding is considered solved if the maximum hydraulic grade line (HGL) is maintained lower than six feet below street grade.
3. There can be no increase in flow to District facilities.
4. Surface flows must be contained in defined easements or public right-of-way (ROW).

A thorough list of candidate solution strategies was developed by Ad Hoc Modeling and District staff based on previous similar studies. At a June 14, 2013 meeting of the "external committee," a list of potential solution components to mitigate the flooding problems in the Village was presented to the external committee members for their discussion and consideration. The external committee is made up of representatives from the District, Village, City of Milwaukee (City), Milwaukee County (County) and University of Wisconsin-Milwaukee (UWM). During the meeting, several solutions were identified to be considered further. Twenty-two potential solution components were proposed for the Edgewood Avenue Drainage Study. These are listed in the solution screening matrix included in Table 1. The candidate solutions are a mix of GI solutions (potential solution components a through h) and structural solutions (potential solution components i through v). It should be noted that none of these solutions is expected to work as a standalone solution; rather, each is a candidate to be a component of an overall comprehensive solution. Each candidate solution was evaluated on its own to determine if a reasonable implementation of the solution approach achieved an appreciable degree of success in meeting the performance criteria. The Wisconsin DNR requires water quality controls on stormwater discharges; thus projects that potentially increase discharges to the Milwaukee River or Lake Michigan may require additional water quality improvements. The screening analysis in Table 1 notes projects that could be subject to additional water quality requirements as well as those that could enhance water quality.

In an initial evaluation of the potential solutions, eight of the 22 potential solutions were determined to be infeasible in the Village due to lack of appropriate space or terrain or facility limitations. For example, green roofs require extensive areas of flat roof for effective implementation and significant numbers of suitable buildings are not present in the Edgewood Avenue Drainage Study area to result in a significant reduction in flow.

Table 1
Ad Hoc Modeling Question 110 - Edgewood Avenue Drainage Study
Solution Screening Table

November 14, 2014

	Potential Solution Component	Description/ Purpose	Modeling Assumptions/Approaches	Percent Reduction in a 3-inch, one-hour storm: Peak Flow at IS-073	Total Volume at IS-073	Peak Flow at IS-074A	Total Volume at IS-074A	Peak Flow at Maryland and Straford	Peak Flow at Edgewood and Murray	Peak Flow at Shorewood and Murray	Depth Reduction in a 3-in, 1-hr: HGL at Maryland and Stratford	HGL at Edgewood and Murray	HGL at Shorewood and Murray	MH not Meeting 6-ft Criterion (Baseline 242 MHs)	Comments on feasibility/performance	Incorporate into Alternative
a	Rain Gardens (Yards)	Reduce runoff through source control by retaining some flow on private property	Residential Rain Garden with a 25 ft by 16 ft footprint with 700 ft3 of storage per facility. Assumed 50% of participation rate for a total of 1500 rain gardens.	2	14	15	15	4	2	<1	<0.1	0.5	0.2	205	Could be a solution component. Modeling assumptions assume very aggressive rain garden design and participation rates that could be difficult to achieve. If implemented however, there is a significant benefit in terms of reduced flows. Existing system capacity restrictions mask the benefit at IS-073. This option has an added water quality benefit.	Yes
b	Underground Storage Trenches - 10% Converted	Reduce runoff through source control by storing flow in constructed facilities in the public right of way. These would be constructed in conjunction with the City's street maintenance program which defines a limited number of streets for reconstruction.	Storage units behind the curbline along the street. 2 units on each long side of every block that gets reconstructed. Each unit is 3 ft wide, 4 ft deep and 50 ft long and filled with 3-inch stones. There are three street inlets per unit. Each unit can store 400 cubic ft. Assumed 10% of streets listed in the Village's street replacement program with Storage Trenches (7 total trenches). See footnotes for program details.	<1	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1	242	Each unit has limited size. Would need to expand beyond current street program for more effectiveness. Provides water quality benefit.	No
b	Underground Storage Trenches - 50% Converted		Same as above. Assumed 50% of streets listed in the Shorewood's street replacement program and converted for 32 total trenches.	<1	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1	242	Same as above.	No
c	Street Bioretention Cells - 10% Converted	Reduce runoff through source control by storing flow in constructed facilities in the public right of way.	Street Bioretention 9 ft by 100 ft and 3 ft deep, 1500 ft3 of storage. It is back filled with 2 ft of granular material and 6-in of top soils leaving a 6 in depression that is filled with water-tolerant vegetation. 4 units on each long side of a block 2 on each short side of a block. Assumed that 10% of all the city streets are converted (96 total rain gardens). Number of streets converted is NOT limited by current street reconstruction program as it is in Alternative b.	<1	2	2	2	<1	<1	1	<0.1	<0.1	<0.1	240	Bioretention cells at this implementation percentage do not significantly reduce flows.	No
c	Street Bioretention Cells - 50% Converted		Same as above. Assumed 50% of all of the streets in the Study Area are converted (480 total Facilities).	2	11	15	12	4	1	12	<0.1	0	1	203	Bioretention at 50% of available sites show measurable reduction in flow and volume. 2% flow reduction for IS-073 is not representative of benefit. Volume reductions are better indicator of value to this component. However, feasibility is likely limited because of desire to preserve trees in the parkway. This option has an added water quality benefit.	Yes
d	Rain Barrels (Houses)	Reduce runoff through source control by storing roof runoff on private property	55 gallons per barrel, on average there would be 1 barrel per residential property or 3000 barrels.	1	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1	242	No significant benefit relative to improved system performance for 3 inch, 1 hour event.	No
e	Porous Pavement - 10% Converted	Use paver blocks with voids to reconstruct selected streets to reduce pavement runoff	Paving blocks with openings that allow infiltration into a sand and gravel layer underneath. Up to one inch of street runoff can be retained. Streets comprise 14% of the total area, assumed to be uniform across the study area. Assumed that 10% of all the city streets are converted. Number of streets converted NOT limited by current street reconstruction program.	<1	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1	242	No significant benefit relative to improved system performance for 3 inch, 1 hour event. Expect to show benefits with more frequent events	No
e	Porous Pavement - 50% Converted		Same as above. Assumed 50% of all the streets in the Study area are converted.	<1	3	3	3	<1	<1	2	<0.1	0.1	<0.1	239	No significant benefit relative to improved system performance for 3 inch, 1 hour event.	No
f	Bioswales	Use drainage swale to provide pollutant removal and storm water quality improvement	Not analyzed (not practical given limited opportunities for bioswales to provide meaningful runoff reduction)													No
g	Green Roofs	Use plantings or sod on roofs to absorb or delay roof runoff	Not analyzed (not practical given the limited flat roof opportunities in the Village and their ability to make a significant difference in the final solution)													No

CDM Smith

Table 1
Ad Hoc Modeling Question 110 - Edgewood Avenue Drainage Study
Solution Screening Table

November 14, 2014

	Potential Solution Component	Description/ Purpose	Modeling Assumptions/Approaches	Percent Reduction in a 3-inch, one-hour storm							Depth Reduction in a 3-in, 1-hr			MH not Meeting 6-ft Criterion (Baseline 242 MHs)	Comments on feasibility/performance	Incorporate into Alternative
				Peak Flow at IS-073	Total Volume at IS-073	Peak Flow at IS-074A	Total Volume at IS-074A	Peak Flow at Maryland and Straford	Peak Flow at Edgewood and Murray	Peak Flow at Shorewood and Murray	HGL at Maryland and Stratford	HGL at Edgewood and Murray	HGL at Shorewood and Murray			
h	Stormwater Trees	Plant additional deciduous trees to increase rainfall interception	Not analyzed (not practical given their effectiveness in runoff reduction compared to the magnitude of flows that must be addressed to solve the basement backup and surface flooding problems in the Village. Typical interception increases are 0.10 inches). Shorewood had numerous trees in the ROWs already so the ability to effectively increase capacity is limited.													No
i	Inlet Control (Street Storage)	Restrict inflow into the combined sewer system and store excess on the street	Not Analyzed (not feasible; limited flat areas; limited available storage on streets; street ponding and associated street berms not acceptable)													No
j	Street Conveyance	Restrict inflow into the combined sewer system and use the streets to convey the flow downstream. Requires construction of some storm sewer improvements to convey street flows to the river.	Limit inflow into the combined sewer system to 1 cfs/acre (5-year level of service) reducing stormwater load to combined sewer in the Village. Use streets to convey stormwater to relief sewer collection points and then to River. Decouple City flows from Village combined sewers at E. Edgewood Avenue to reduce flows in the E. Edgewood Avenue Trunk line.	12	39	Peak Flow Increases	Volume Increases	22	29	Peak Flow Increases	12	11.0	HGL Increases	96	Significant flow and volume reductions to Village combined system. A potential solution component. Peak flow reduction percentage at IS-073 is not representative of benefits provided due to existing capacity restrictions. Reduction in non-complying manholes is better indicator. Project could require additional water quality controls prior to discharging to the River.	Yes
k	Downspout Disconnection	Disconnect roof drains from the combined sewer system and redirect the flow to a grassed pervious surface	Assumed that half of the roof area is diverted to a pervious area thus net downspout disconnection is assumed at 50%. Some downspouts in the Village have already been disconnected but this is not reflected in the existing conditions model. On average, 50% downspout disconnection reduces flows by about 7% according to previous HSPF modeling of the City combined sewer area (30th St. Corridor).	2	7	7	7	2	<1	4	<0.1	0	0.1	221	Shows reductions in flow and volume to the combined system. A potential solution component. Peak flow reduction for IS-073 is not representative of benefits due to existing system capacity restrictions. Not a solution by itself. There may be some implementation challenges to achieve true 50% disconnection. This option provides water quality benefits.	Yes
l	Underground Storage at Menlo	Construct underground storage vault under E. Menlo Boulevard between N. Maryland Avenue and E. Prospect Avenue to reduce peak flow leaving this area	Construct a 1300 ft x 35ft offline underground storage vault under Menlo between Maryland and Prospect to provide 4 acre-ft of storage to temporary detain excess flow during a large storm. Gravity drains out of storage vault when downstream system capacity is available	3	8	0	0	28	6	<1	1	0.4	<0.1	242	Menlo storage has some positive effect on the overall system, but is more effective in reducing peak flows locally. Reduced local peak flows by nearly 30% at Stratford and Maryland and lowering HGL by 0.8 ft.	Yes
m	Underground Storage in the Park	Construct underground storage vault in the park at E. Edgewood Avenue and N. Oakland Avenue to lower the hydraulic grade line on E. Edgewood Avenue	19 acre-ft (2.5 acre x 7.5 ft deep) underground storage vault in the park at E. Edgewood Avenue and N. Oakland Avenue, pumps discharge to drain storage vault.	26	41	0	0	16	Peak flow increases	<1	1	9.1	0.6	231	The storage reduces flow at the river outlet, but the upstream capacity limitations are still the problem. Still have manholes not meeting required criteria. Not a good solution component. Solution was envisioned to limit increase in combined sewer flow and volume to the river (assuming the problem was the capacity of the existing CSO).	No
n	Underground Storage at the other locations	Locally store flow that exceeds pipe capacity in underground pipes/vaults.	Not Analyzed (no specific locations identified)												Could be a solution component based on Menlo results depending on whether potential locations are identified.	Yes
o	CSO Upsizing	Increase District CSO outfall capacity by increasing its size	Originally envisioned to address perceived bottleneck at CSO outlet pipe. However, bottlenecks extend throughout the system.	Peak flow increases	Volume is unchanged	Peak flow increases	Volume is unchanged	5	Peak flow increases	Peak flow increases	0.1	3.0	<0.1	239	CSO capacity is greater than the 20% probability flow. Further upsizing will not provide any significant benefit	No
p	Parallel Shorewood CSO	Increase District CSO capacity by adding a Village parallel pipe	Originally envisioned to address perceived bottleneck at CSO outlet pipe. However, bottlenecks extend throughout the system.	Peak flow increases	Volume is unchanged	Peak flow increases	Volume is unchanged	5	Peak flow increases	Peak flow increases	0.1	3.0	<0.1	239	Same as above.	No
q	Pump excess flow to the river	Pump flow that exceeds existing pipe capacity to the river	Originally envisioned to address perceived bottleneck at District CSO outlet pipe. However, bottlenecks extend throughout the system. Not analyzed.	Peak flow increases	Volume is unchanged	Peak flow increases	Volume is unchanged							239	Performance similar to Solutions o and p. Does not provide significant benefits unless other system capacity limitations are addressed.	No

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				Peak Flow at IS-073	Total Volume at IS-073	Peak Flow at IS-074A	Total Volume at IS-074A	Peak Flow at Maryland and Straford	Peak Flow at Edgewood and Murray	Peak Flow at Shorewood and Murray	HGL at Maryland and Stratford	HGL at Edgewood and Murray	HGL at Shorewood and Murray			
r	Diversion of stormwater flow to the river	Add additional capacity to for stormwater to discharge to the river	Originally envisioned to divert stormwater flow off of system. Was not analyzed as it is similar to "s" diversion to Lake Michigan or overall separation solution.	Peak flow increases	Volume is unchanged	Peak flow increases	Volume is unchanged							N/A	Expect performance similar to "s". Will provide local benefits, but additional improvements necessary to solve basement backup. Could be component of a solution that includes some separation. Project could require additional water quality controls prior to discharging to the River.	Yes
s	Stormwater diversion to Lake Michigan	Divert stormwater flow out of Village CSSA to Lake Michigan to reduce system flows.	New 60-inch storm sewer along E. Wood Avenue to divert stormwater to Lake Michigan. Part of Village's Alternative 2 in the Facilities Plans.	<1	5	0	0	3	<1	<1	<0.1	<0.1	<0.1	233	Provides a benefit to the immediate area around the Village storm sewer location but may not be cost-effective compared to the other potential solutions. Project could require additional water quality controls prior to discharging to the Lake.	No
t	Overland flow to the Milwaukee River	Construct an overland flow path from E. Edgewood Avenue and N. Oakland Avenue to the river	Originally envisioned to address significant overland flow at E. Edgewood Avenue and N. Oakland Avenue - which does not exist for the design event. Not analyzed.	Peak flow increases	Volume is unchanged	Peak flow increases	Volume is unchanged							239	Performance similar to Solutions o and p. Does not provide significant benefits without addressing other system capacity limitations.	No
u	Upsize Local Sewers	Provide parallel relief storm sewers by all existing sewers to reduce flows in CSSA	Double sewer capacities on all Village and District sewers.	Peak flow increases	Volume Increases slightly	Peak flow increases	Volume Increases slightly	Peak flow increases	Peak flow increases	Peak flow increases	0.3	Increase	11.1	80	This represents a 100% increase in Village sewer capacity but the 1% flow is 150% greater than the 20% flow so the system would need even more capacity to fully solve the problem with conveyance alone. The District system would need expansion to accommodate the 1% flow from this tributary area. Modified solution involving separation may be a viable component with discharge to river.	No/Yes
v	Alternative 2 from the Shorewood Comprehensive Facility Plan (2011)	Provide parallel relief storm sewers as per Alternative 2 and decouple City flows from Village combined sewers at E. Edgewood Avenue to reduce flows in the Edgewood Avenue Trunk line		18	47	1	<1	19	33	Peak flow increases	4.8	7.8	9.1	139	Provides substantial benefits throughout the drainage area but does not solve all of the problems. Benefits include 3 feet HGL reduction at E. Edgewood Avenue and N. Murray Avenue and 9 feet at E. Shorewood Boulevard and N. Murray Avenue. Components of this concept could be part of an overall solution.	Yes

IS-073 primarily receives flows from the Village and some drainage area from the City
IS-074A receives flows from the City
The Village's Street Replacement Program in the CSSA for year 2014 to 2020 includes reconstruct streets every two years along Kensington, Murray, Beverly, Newton, and Hackett

Solution Component Evaluations

The remaining fourteen solutions were evaluated either using XP-SWMM modeling or through desktop analysis.

GI solutions control stormwater runoff at its source by capturing, holding and infiltrating runoff from small areas. This capture of runoff helps avoid or reduce the construction of infrastructure needed to convey runoff to local watercourses. The GI facilities considered for the Village included residential rain gardens on private property, infiltration trenches and bioretention in the public street parkways, porous pavement on the public streets, and rain barrels on private property. While these measures differ in construction, they all capture and store runoff and ultimately let it infiltrate into the soil. All except porous pavement have a surface storage component and all but the rain barrels have a subsurface component where water is held underground in a specially designed granular medium.

For the purpose of evaluating the effectiveness of certain solutions, specific facility sizes and layouts were assumed as indicated in Table 2. However, these details would be expected to be modified to meet Village and site specific project needs if considered further for implementation.

Table 2. Green Infrastructure Solution Assumptions

	Surface Dimensions	Depression Depth (ft)	Total Depth (ft)	Depression Storage (ft^3)	Subsurface Storage (ft^3)	Total Storage (ft^3)
a. Residential Rain Gardens	16 ft x 25 ft	1.0	3.5	250	450	700
b. Underground Storage Trenches	50 ft x 3 ft	0.5	4.5	75	325	400
c. Street Bioretention	9 ft x 100 ft	0.5	3.5	450	1050	1500
d. Rain Barrels	55 gal barrel					7
e. Porous Pavement	Entire paved width of streets	N/A	N/A	N/A	1 inch over street area	1 inch over street area

Downspout disconnection works by diverting flow so that it is delayed from entering the combined sewer system immediately and, in some cases, given the opportunity to infiltrate into the soil. A detailed analysis of downspout disconnection effects was conducted for the District's 30th Street South Corridor Study using HSPF (Hydrologic System Program – Fortran). That analysis showed that disconnecting half of the roof area and diverting the flow to pervious areas reduced peak runoff flows by an average of seven percent. The result of a seven percent of peak flow reduction was applied in this study by reducing each runoff hydrograph in XP- SWMM. In Shorewood, downspout disconnection north of East Capitol Drive has a more substantial effect on flow in the combined sewer system because flow from the disconnected downspouts will enter the storm sewers in that area and drain to Lake Michigan rather than draining to the combined sewer system.

Structural solutions considered in the screening analysis included inlet control with street conveyance, underground storage and various conveyance improvements. The street conveyance solution restricts inflow into the combined sewer system then conveys the excess flows downstream using street flow. The underground storage solutions seek to construct off-line storage facilities in open spaces identified by the Village. Governed by the size of the open land and the available grades of the connecting sewer system, the detained water is either gravity drained or pumped out of the facility to the sewer system. In contrast to the storage solutions, the conveyance solutions increase the sewer capacity in the existing sewer system near bottleneck locations, previously identified by the Village in its own 2011 Facilities Plan.

Alternative Solution Screening Results

The performance measures defined in TM1 were adopted, as described above. Three locations in the Village's system were selected as additional indicators of performance and are shown in Table 1. They are as follows:

1. Village manhole #965 at the corner of East Shorewood Boulevard and North Murray Avenue where a 42-inch combined sewer in East Shorewood Boulevard and a 12-inch by 18-inch combined sewer in North Murray Avenue flow into a 42-inch combined sewer in North Murray Avenue;

2. Village manhole #1012 at the corner of East Edgewood Avenue and North Murray Avenue where a 54-inch combined sewer in North Murray Avenue and a 72-inch combined sewer in East Edgewood Avenue flow into a 78-inch combined sewer in East Edgewood Avenue; and

3. Village manhole #753 at the corner of East Stratford Court and North Maryland Avenue where a 78-inch combined sewer in East Stratford Court and a 66-inch sewer in North Maryland Avenue combine and flow into a 78-inch combined sewer in North Maryland Avenue.

4. For these three Village manholes, peak flows and maximum HGLs were selected as indicators for evaluating the performance of the solutions. The effectiveness of the solution components were measured as reduction rates, either as reduction of peak flows and total volume of runoff (in percent), or as reduction in number of problem manholes (manholes where the HGL is less than 6 feet below the ground elevation, which is assumed to create basement backups) and HGL elevations in feet.

Table 1 presented a comprehensive solution screening matrix of the potential solution components. For each solution, the table presents its description and purpose; modeling assumption and approach; and performance. The table also lists comments regarding the feasibility of the solution and its viability as a component of the comprehensive solution. Some solutions were analyzed using the XP SWMM model, while others utilized a desktop approach or engineering judgment. Nearly all are only partial solutions to the problem that, if feasible, will be combined together to formulate a comprehensive solution.

Among the GI solutions that were considered, residential rain gardens, underground storage trenches (in conjunction with Village's street replacement program), street rain gardens, rain barrels and porous pavement were evaluated and their results are provided in Table 1. However, bioswales, green roofs and stormwater trees were not analyzed because of limited implementation opportunities in the watershed. Among the analyzed GI solutions, only residential and street bioretention applications with an aggressive conversion rate (50 percent) can achieve a significant runoff reduction. These two solutions (with the assumed details shown) are theoretically able to relieve 15 percent of the basement backups in the area during a 3-inch, 1-hour design storm. The practical feasibility of these and other theoretical solutions will be considered when formulating the overall comprehensive solution.

Four infrastructure solutions were determined to be infeasible without the use of detailed analysis.

1. Inlet control with street storage is not feasible because street storage requires very flat street slopes and most streets in the Edgewood Avenue Drainage Study area have substantial slope.

2. Underground storage at locations other than East Menlo Boulevard or Hubbard Park was not considered because there are no other suitable sites in the study area.

3. Diversion of stormwater to the Milwaukee River using an overland flow path would require flow to be conveyed to a collection location such as the North Oakland Avenue/East Edgewood Avenue intersection. This approach was considered in conjunction with other solutions but was not evaluated on its own because its benefits and outcome would be similar to the solution of increasing the District CSO capacity. Modeling analysis presented in Ad Hoc 110 Technical Memorandum 1 showed that additional outlet capacity by itself has little beneficial effect.

4. Finally, pumping excess flow to the Milwaukee River was not evaluated because the baseline analysis showed that backwater from high river stages is not a significant issue. Therefore, gravity drainage will be just as effective for substantially lower cost and not affected by potential power outages.

Among the infrastructure improvements solutions analyzed, downspout disconnections, street conveyance, Menlo storage and stormwater diversion to either Lake Michigan or the Milwaukee River were selected to be incorporated into the comprehensive alternative. These solutions are able to provide an overall or a localized benefit to the CSSA.

Downspout Disconnections

Currently, the Village has 1,988 downspouts disconnected; representing about one third of the structures in the Village's CSSA. Due to the complexity and variability of the downspout disconnection implementation to date across the combined sewer watershed (for example, partial disconnection at some of the properties, complete disconnection or no disconnection at others), the existing downspout disconnection implementation cannot be practically simulated in the Baseline model. The proposed solution assumed that half of the roof area is diverted to pervious ground area (50 percent converted rate). With this aggressive rate, it is envisioned that actual implementation would be a challenge. However, downspout disconnections in the CSSA are mandatory (with several exceptions) under a new regulation proposed by the District. Disconnection to at least a 50 percent level was identified as a common component of any basement backup solution.

Street Conveyance

The street conveyance solution was evaluated through a desktop analysis by restricting 1 cfs/acre of runoff to the combined sewer system south of East Capitol Drive. The 1 cfs/acre flow rate is equivalent to an area-averaged 20 percent annual exceedance probability peak flow rate. The excess flows are conveyed from north to south along streets. Two major street flow routes were selected to evaluate potential street flow depths. One is along North Prospect Avenue from East Jarvis Street to East Menlo Boulevard. The other route is along North Murray Avenue from East Wood Place to East Menlo Boulevard. For a typical street cross section represented in the model with a 6-inch curb, a 6-inch crown and a 40-foot street width, the maximum street flow depth at the curb observed from the modeling results was about 7.5 inches near North Murray Avenue south of East Beverly Road and East Shorewood Boulevard in the 3-inch, 1 hour design storm. It should be recognized that each time the roadway is overlaid with pavement the storage or flow capacity of that segment of street is reduced.

Menlo Storage

The potential solution based on an underground storage facility along East Menlo Boulevard, employs a facility located under the road median along East Menlo Boulevard between North Downer Avenue and North Maryland Avenue. It provides a 4-acre-foot storage facility to detain the excess flow temporarily during a large storm. The facility would be designed to drain the water out of the facility by gravity when downstream sewer capacity is available. The solution has minor effect on the overall system, but achieves a 30 percent peak flow reduction at the intersection of East Stratford Court and North Maryland Avenue and lowers the HGL there by 0.8 feet for the 3-inch, 1 hour design storm.

Additional Stormwater Diversion to Lake Michigan

A potential solution based on diversion of combined sewer flow to Lake Michigan was first proposed in the Village's 2011 Facility Plan. It comprises a 48-inch storm sewer outlet that would extend from a flood control relief point at East Wood Place and North Downer Avenue to Lake Michigan. This potential solution was evaluated using the XP SWMM model of the Village's CSSA, but did not offer significant benefits for the area. As a combined sewer flow diversion, this solution would also have required construction of a new CSO to Lake Michigan, which would not be permitted. Therefore the 48-inch combined sewer diversion was determined to not be a viable solution component to basement backup reduction in the Village.

A second potential diversion solution to Lake Michigan was considered as a 60-inch storm sewer that would divert additional stormwater flow out of the Village combined sewer system to the east and discharge to Lake Michigan at East Wood Place extended. The proposed Village 60-inch storm sewer reduces the peak flow rate at North Maryland Avenue and East Stratford Court by only 3 percent and reduces the number of problem manholes by 9. Because this approach has limited effectiveness and the acquisition of right-of-way and an approval to discharge to Lake Michigan are expected to be difficult, it was dropped from further consideration and not included in the final solution.

Conveyance Solutions

Two conveyance solutions were analyzed in this study; an enhanced Village sewer capacity solution and Alternative 2 from the Village's 2011 Facility Plan. The enhanced Village sewer capacity solution was evaluated by placing a same size parallel combined sewer along every single combined sewer in the Village system, representing a 100 percent increase in Village sewer capacity. The model results reveal this solution is able to eliminate two-thirds of the problem manholes and lower the HGL at East Shorewood Boulevard and North Murray Avenue by 11 feet for the 3-inch, 1 hour design storm. Therefore, with a 100 percent increase in Village sewer capacity, the proposed solution is still not able to mitigate all the problem manholes in the area. The Baseline model analysis reveals the 1 percent probability peak flow is 150 percent greater than the 20 percent probability peak flow, so the system would need to add 50 percent more capacity (total of 150 percent of existing capacity) to fully solve the problem. In addition, this solution would increase flow to the District's system which is not allowed under the project constraints.

Alternative 2 from the Village's 2011 Facility Plan was evaluated through XP-SWMM modeling. The alternative consists of two parts: virtual separation of street runoff and decoupling of City of Milwaukee combined sewers from the Village of Shorewood combined sewers at East Edgewood Avenue and North Maryland Avenue. Virtual separation was proposed by installation of storm trunk sewers south of East Capitol Drive and a new storm outfall at East Menlo Boulevard to the Milwaukee River. Uncoupling of the City system was accomplished by installation of a combined sewer segment to route the City flow to the 60-inch City trunk sewer at East Providence Avenue. Alternative 2 was proposed by the Village's consultants with an assumption that the storm sewers in the sewer separation area north of East Capitol Drive are able to convey flow from the 3-inch storm event and discharge the storm water to the Lake Michigan. Their analysis was accomplished by desktop methods and no XP-SWMM model was developed. Based on the findings in the Village Facility Plan, the proposed parallel pipes were input into the Baseline model. That previous analysis indicates that some storm sewer segments north of East Capitol Drive do not have the capacity to convey the 3-inch flow to the lake and there would be surface ponding in these areas during such an event. The model results show that this solution is not able to fully solve the basement backups in the area. It eliminates almost 45 percent of the problem manholes and lowers the HGL at East Shorewood Boulevard and East Edgewood Avenue by 9 feet. Because of the uncoupling of the City of Milwaukee system from the East Edgewood Avenue combined sewer, the peak flow at intercepting structure IS-073 decreases 18 percent and the total volume of the runoff at the intercepting structure is reduced 47 percent.

Alternative Solution Screening Conclusions

The screening results were summarized in detail in Table 1. The following solution concepts were determined to have sufficient beneficial impact to be considered as a component of the eventual recommended solution strategy:

- Residential Rain Gardens
- Bioretention in the Street ROW
- Street Conveyance
- Downspout Disconnection
- Underground Storage
- Diversion of Stormwater to the Milwaukee River
- Alternative 2 from the Village 2011 Facility Plan

The screening results were presented to the Village and District staff on December 5, 2013. During the discussion of the results, it was recognized that the working solution from the Village Facility Plan was costly and would take a long time to implement. It was also noted that the Village had experienced problems with the long-term maintenance of residential rain gardens. With these issues in mind, the team agreed to move forward with the development of a comprehensive solution based on the components listed above.

Alternative Solution

A proposed solution to basement backups in the Village CSSA was developed and evaluated in XP-SWMM. The main components of this solution are the following:

- Restriction of street inlet flows in the Village CSSA, mainly south of East Capitol Drive, to approximately the 20 percent probability flow rate (1 cfs/acre).
- Further disconnection of downspouts throughout the CSSA until at least 50 percent of all roof area in the CSSA is diverted to the ground surface, rather than having a direct connection to the Village combined sewer system.
- Street conveyance of surface flows during extreme storms to Village storm sewers located in the topographic low areas.
- A 48- to 54-inch Village storm sewer under North Prospect Avenue from East Shorewood Boulevard to East Menlo Boulevard.
- A 66- to 72-inch Village storm sewer under East Menlo Boulevard leading to a new 72-inch outfall to the Milwaukee River.

- A 48-inch Village storm sewer under North Maryland Avenue from East Stratford Court to East Menlo Boulevard.

- Disconnection and abandonment of the existing 66-inch connection from the 66-inch Milwaukee combined sewer on the south side of East Edgewood Avenue, east of North Maryland Avenue, to the 78-inch Village combined sewer on the north side of East Edgewood Avenue west of North Maryland Avenue.

- Construction of a 66-inch combined sewer on the south side of East Edgewood Avenue to carry the flow of the existing 66-inch Milwaukee combined sewer from Edgewood and Maryland Avenues to IS-073 at Edgewood and Oakland Avenues.

- Installation of Village overhead sewers in target areas where the Village sewers were found to be too shallow to meet project criteria or where "residual" basement backups were thought to remain after the proposed improvements are in place.

- Installation of residential rain gardens and bioretention in street right-of-way as is practical for the Village.

The layouts of the structural components of the plan are shown in Figure 1. The primary feature of the plan will be installation of inlet restrictors on all Village street inlets between East Edgewood Avenue and East Capitol Drive. These restrictors will limit inflows to the Village combined sewers to the 20 percent probability flows which can be safely conveyed to the District facilities. Storms larger than the 20 percent probability storm would result in excess flows being conveyed generally to the south on the Village streets. Most streets will carry less than 10 cfs in most storms and flow depths will be less than a few inches. Some key streets will convey up to 60 cfs in the 1 percent probability storm. Maximum street depths will be limited to seven inches with the maximum depth occurring in the gutter. Depending on the height of the crown, streets should be passable for most automobiles at maximum depth. Ambulance specifications require the ability to ford 8 inches of water depth. Most street flow depths would be much less than six inches and any street depths exceeding 5 or 6 inches would occur only for short periods of time and only for infrequent, extreme storms such as the 3-inch, 1- hour design storm. The major street flows will be directed along North Maryland Avenue to East Shorewood Boulevard and then to North Prospect Avenue; North Downer Avenue to East Shorewood Boulevard to North Prospect Avenue; and, North Oakland Avenue to East Newton Avenue to North Murray Avenue. At the downstream ends of these street flow routes, the street flow will be captured in new Village stormwater relief sewers and conveyed to and along East Menlo Boulevard to a new stormwater outfall into the Milwaukee River.

Residential rain gardens and bioretention in the street right-of-way are included in the Alternative Solution, although their effectiveness during the 3-inch, 1-hour design event are limited. The screening analysis showed that rain gardens could not be installed in sufficient numbers to reduce the size or extent of the required infrastructure facilities, but they do contribute to an overall reduction in flows and HGL. However, their effectiveness if limited because of the difficulty in assuring long-term maintenance which is necessary for a permanent solution to the flooding in the Village. The Village has reported that only a few of the original 51 rain gardens previously installed in the Village are still fully functional and some have been eliminated completely. Although bioretention contributes to an overall solution, it was also determined that it could not be installed in most areas of the Village without damaging or removing existing trees along the edge of the right-of-way. The presence of trees throughout the area precludes the construction of sufficient bioswales to have an impact. Nonetheless, residential rain gardens and bioswales should be a component of the Alternative Solution and should be implemented by the Village where practical.

An additional component of the proposed solution is construction of a new 66-inch combined sewer in East Edgewood Avenue. The location of this proposed sewer is shown in Figure 1A. This sewer eliminates an existing bottleneck at Edgewood and Maryland where a 66-inch combined sewer from the east on Edgewood and a 78-inch combined sewer from the north on Maryland discharge into a single 78-inch sewer. By disconnecting the southern 66-inch combined sewer from the east, capacity is provided in the 78-inch combined sewer to receive street drainage from the north of East Edgewood Avenue between Maryland Avenue and Oakland Avenue.

Construction of a new 66-inch combined sewer in Edgewood Avenue will need to be confirmed through additional preliminary engineering prior to moving forward into design. There is an existing 78-inch combined sewer along the north side of Edgewood Avenue and a 30-inch to 42-inch combined sewer along the south side of Edgewood Avenue between South Maryland Avenue and North Cramer Street. Additional engineering will be needed to determine the feasibility of installing an additional 66-inch combined sewer between these two existing sewers. Initial examination of the locations of these sewers indicates that it should be possible to construct the proposed pipe, but a more detailed evaluation of utility conflicts is still needed. In the event of a major conflict that cannot be resolved, an alternative would be to replace the existing 78-inch combined sewer with a larger pipe that has the same capacity of the existing 78-inch sewer plus the proposed 66-inch combined sewer. A 12-foot wide by 5-foot high box culvert (or two 6 feet by 5 feet boxes) is slightly larger and could be constructed in the available space and achieve the required system performance.

System Performance

The proposed improvements were evaluated and verified by representing the improvements in the XP- SWMM model (Baseline model) provided by the Village. This model was utilized to evaluate baseline conditions and was deemed to be the most efficient tool for developing a solution. With some limitations identified in the footnote below[1], the model was determined to be sufficient for

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[1]*The Village's XP-SWMM model presented several challenges to representing the proposed solution. It is a large and complex model that appears to have been developed by several different modelers. As such, the model does not employ a logical or consistent naming convention for link and nodes and the basic documentation such as the sewer atlas and subbasin map is incomplete. Although it is adequate for some routine analysis for Village purposes, its detailed make-up is not conducive to efficient alternative representation and evaluation. However, the model appears to be comprehensive and, where it could be verified, it proved to be accurate. The model depicts 483 individual sewers that comprise 19.4 miles of circular sewer and 4.4 miles of arch and ovoid sewers. It contains both existing sewers and planned projects but the XP-SWMM model documentation does not clearly differentiate which are existing and which are planned. Similarly, it is not immediately apparent from the numbering system which pipes make up the storm drain network that drains to Lake Michigan. The model includes 433 trapezoidal segments used to represent street flow. These are all set up as parallel conduits to modeled*

conducting the conceptual analysis presented here based on the fact that the peak flows generated by the model are generally consistent with previous estimates for the 20 percent probability storm.

The Baseline model indicated that 242 manholes in the Edgewood area experienced HGL elevations that exceeded the flooding criterion established for the area of six feet below the manhole rim elevation during the 3-inch, 1-hour storm as shown in Table 3. The proposed solution eliminates flooding at most of these locations with only 19 manholes still experiencing unacceptable HGL elevations. The proposed solution strategy works by lowering the HGL throughout the collection system. As indicated in Table 3, the Average Maximum HGL is reduced by an average of 4.0 feet, which is sufficient to solve the basement backup problem at nearly every location in the study area. The proposed plan results in peak flow changes to IS-073 and IS-074A; these changes are discussed in the next section on Impacts to District Facilities. The Appendix provides additional information on flow hydrographs and more detailed graphics showing the proposed improvements and the system performance for the design events.

Table 3. Summary of System Performance Results

Design Storm	Scenario	Peak Flow at IS-073 (cfs)	Total Volume at IS-073 (MG)	Peak Flow at IS-074A (cfs)	Total Volume at IS-074A (MG)	No. of Manholes with HGL less than 6 ft below Grade	Average Maximum HGL (ft)
20% probability storm	Baseline	404	12.3	64	2.4	9	83.8
	Alternative Solution	350	11.3	64	2.4	8	83.7
2-inch 1-hour	Baseline	493	16.3	90	3.3	77	85.3
	Alternative Solution	416	14.3	90	3.3	10	84.1
3-inch 1-hour	Baseline	515	26.4	163	5.4	242	89.1
	Alternative Solution	521	19.9	164	5.4	19	85.1

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sewers but are not consistently assigned to "conduit #2" which would have made them easier to deal with. The street sections are all input as 3 foot wide, 0.5 foot deep sections. Their capacity is so small that it creates significant flooding in the model and prevents flow from reaching the locations where flooding has been experienced in recent years. This modeling approach was adequate for typical event pipe analysis, but not for extreme event performance evaluation and alternative development such as the street conveyance solution concept being evaluated in this Ad Hoc Modeling Question. To evaluate this adequately, the small street flow sections were replaced in the alternative evaluation model by generic surveyed street sections, typically 64 feet wide. Eight street sections were surveyed in January 2014 for use in the model.

It was also noted that the Village's model does not include dry weather flow input nor does it account for extraneous inflows from foundation drains, sumps pumps or area drains. If the project moves forward into preliminary engineering, it may be prudent to revise this model for use in additional preliminary engineering analysis or design. It is suggested that some improvements be made to the model so that it is easier to interpret and better documented.

With the proposed solution in place, nineteen residual surcharging locations still do not meet the six foot criterion for the 3-inch, 1-hour design storm as shown in Table 3 and Figure 2. Eight of these locations are in the City on North Cramer Street and East Hartford Avenue. These problems, caused by undersized City combined sewers, are not addressed in this proposed plan. The 11 remaining problem areas are scattered throughout the Edgewood area and all are the result of low lying ground and shallow sewers. In fact, at two of the sites, East Kensington Boulevard at North Murray Avenue and North Prospect Boulevard north of East Jarvis Street, the sewer is less than six feet below the rim. In this case, meeting the design criterion is impossible.

Residual HGL elevations at two of these locations are less than 0.6 feet above the six foot depth criterion. Additional fine-tuning of the inlet control strategy or other engineering solutions could be performed locally to eliminate these problem areas. The residual HGL elevations at the seven remaining locations range from 2.5 to 5.2 feet below grade. While it may be possible to reduce the HGL during final design of the proposed facilities, the likely solution is to install overhead, pumped sewer services in structures near these locations. It is also possible that 2.5 to 5.2 feet is sufficient freeboard for some of the structures near these locations. This can also be determined during final engineering.

The proposed improvements include a new Village storm outfall to the river at East Menlo Boulevard extended. This proposed outfall discharges stormwater flows to the river for each of the three design rainfall events. Peak stormwater flows discharged to the river range from 32 cfs for the 20 percent probability storm, up to 371 cfs for the 3-inch, 1-hour storm as presented in Table 4. For smaller rainfall events, such as the 20 percent probability storm, the new storm outfall peak flow of 32 cfs is completely offset by a 54 cfs decrease in the existing peak CSO flow. For the 2-inch event, the 105 cfs increase in stormwater flow to the river, is mostly offset by a corresponding decrease in the peak CSO discharge of 76 cfs. However, for the more significant events, there is a net increase in stormwater flow discharged to the Milwaukee River which must be considered to determine if there are any negative impacts from a quality or quantity perspective.

Table 4. Summary of Flows Affecting MMSD Facilities and Watercourses

Event	Scenario	Peak Flow at IS-074A (cfs)	Peak Flow at IS-073 (cfs)	Total Peak Flow to District IS (cfs)	Peak Flow of CSO (cfs)	New Storm Sewer Outfall (cfs)
20% Probability Storm	Baseline	64	404	468	412	0
	Proposed	64	350	413	358	32
2-inch, 1-hour Storm	Baseline	90	493	582	523	0
	Proposed	90	416	505	447	105
3-inch, 1-hour Storm	Baseline	163	515	679	614	0
	Proposed	164	521	680	613	371

From a quantity perspective, these flow increases are relatively minor compared to the 10 percent and 1 percent probability flows in the river, estimated at 8,800 cfs and 14,800 cfs respectively (SEWRPC M.R. No. 172, 2010). In addition, the large area of the Milwaukee River watershed, compared to the Edgewood Avenue Drainage area, make it extremely unlikely that both the local drainage area and the Milwaukee River would be experiencing similar coincident peak flooding events at the same time. Although, we do not anticipate a problem from a quantity perspective, additional analysis could be done if necessary to quantify any potential impacts on Milwaukee River flows or stages.

From a water quality perspective, the proposed storm sewer will discharge additional stormwater volumes to the river during major rainfall events. Although there are some reductions in CSO volumes and a corresponding reduction pollutant discharge, there may be an increase in the pollutant load discharged to the river during significant rainfall events. However, the stormwater flows discharged through the new Village outfall would be "diluted" stormwater, not combined sewerage. The proposed solution would capture the low flow through the entire event, and would expect to capture the entire early portion of large storm events (up to the 20% probability event) in the existing conveyance and treatment facilities. Under current conditions, flows that are not able to be discharged to the District's system or through the District CSO outfall are stored in the system as basement backups. Combined sewer volume stored in basements ultimately is discharged to the Village combined sewer system and District conveyance facilities and may receive treatment at one of the District's water reclamation facilities if capacity is available in the District's conveyance and storage systems when flows in the local system begin to recede.

The proposed storm sewer improvements and new outfall to the river result in a net increase in the stormwater pollutant load for this solution. However, the recommended solution in the Village's 2011 Facility Plan has a similar new stormwater outfall to the river that would result in similar, if not greater, stormwater loading. Nonetheless, this new Village outfall may require further analysis to determine whether any additional water quality improvements may be necessary. Discussions with the Wisconsin Department of Natural Resources (WDNR) are recommended on this matter to determine the best approach to resolve this potential issue. However, for both the proposed improvements in this TM or the 2011 Village Facility Plan, the tradeoff for this increased stormwater discharge to the river is the elimination of the basement backups and the associated minimization of the safety and public health hazards associated with combined sewage in basements.

Figure 2 also illustrates how the proposed system is expected to perform in the 3-inch, 1-hour storm event. Flows through street inlets will be restricted to the 20 percent probability flow rate. Excess flows will be diverted in streets to the proposed storm sewers on North Prospect Boulevard and East Menlo Boulevard. Maximum street flows will be generally 15 cfs or less. Some larger peak flows may occur during the 3-inch, 1-hour storm on East Murray Street, North Maryland Avenue, and East Shorewood Boulevard. Figure 2 shows the peak flows on the streets and in the proposed Village storm sewer pipes. Figure 3 shows where street flows are anticipated and the estimated maximum depths in the 3-inch, 1-hour storm. The flow depths were determined using a typical street cross-section based on street surveys conducted in January 2014. As shown, about half of the streets will have maximum street flow depths of 3 inches or less. The remaining street depths will be in the 3 to 6-inch range, but such depths will occur only in extreme storm conditions. In this initial analysis, flow on three streets is shown to exceed the six inch standard. It is possible that some adjustment of street grades, curb heights or flow restrictors will be needed to assure that street flooding is limited to approximately a six-inch depth and that all flows are maintained in the public right-of-way. These adjustments can be made during the engineering design phase of the project. It may also be possible to incorporate any necessary street modifications as a part of the Village's ongoing street rehabilitation program to ensure that any street flow depths are acceptable to the Village and local residents.

The proposed plan does not presently include any improvements south of East Edgewood Avenue. However, the proposed system does provide benefits to Milwaukee and UWM by reducing the hydraulic grade line in the combined sewer in East Edgewood Avenue, east of Maryland Avenue by up to 6 feet. This reduction increases the outlet capacity of local sewers draining north from Milwaukee into the Edgewood Avenue sewer.

Impact on District Facilities

The proposed project captures up to 371 cfs in the proposed Village storm sewer and discharges to the Milwaukee River. This diverted flow would otherwise flood low areas and basements under current conditions and ultimately discharge to District facilities. Flows discharging to and through District facilities are summarized in Table 4. The proposed solution results in small increases in peak flow to District intercepting structures during the 3-inch storm. The flow increase to IS-073 is 6 cfs and the increase to IS-074A is 1 cfs. The overall peak flows to District facilities are within 1 percent of existing flows and are actually more than 10 percent lower in the 20 percent probability design storm.

Total flow volumes discharging to and through District facilities during the first three hours of each modeled storm are listed in Table 5. As shown, the proposed plan reduces the volume of flow to District facilities in all events. The reduction in stormwater volume will reduce the total flow treated at District reclamation facilities, the volume in the ISS, and the volume of CSO discharges.

Table 5. Summary of Flow Volumes Affecting MMSD Facilities and Watercourses

Event	Scenario	Flow Volume at IS-074A (MG)	Flow Volume at IS-073 (MG)	Flow Volume to District IS (MG)[1]	Volume of CSO (MG)[2]	New Storm Sewer Outfall (MG)
20% Probability Storm	Baseline	2.4	12.3	14.8	11.3	0
	Proposed	2.4	11.3	13.8	10.6	0.4
2-inch, 1-hour Storm	Baseline	3.3	16.3	19.5	15.8	0
	Proposed	3.3	14.2	17.5	14.0	1.5
3-inch, 1-hour Storm	Baseline	5.4	26.4	31.8	27.5	0
	Proposed	5.4	19.9	25.3	21.4	5.5

1 – Volumes may not sum to total due to rounding
2 – Includes volume captured in ISS

Figures A1 through A6 present hydrographs that compare flows under baseline and proposed conditions for the 20 percent probability storm, 2-inch, and 3-inch storms. For the purpose of this presentation, the "CSO" hydrograph includes all flow diverted to either the ISS or the CSO outfall. Figures A7 to A9 present the peak flows in schematic form.

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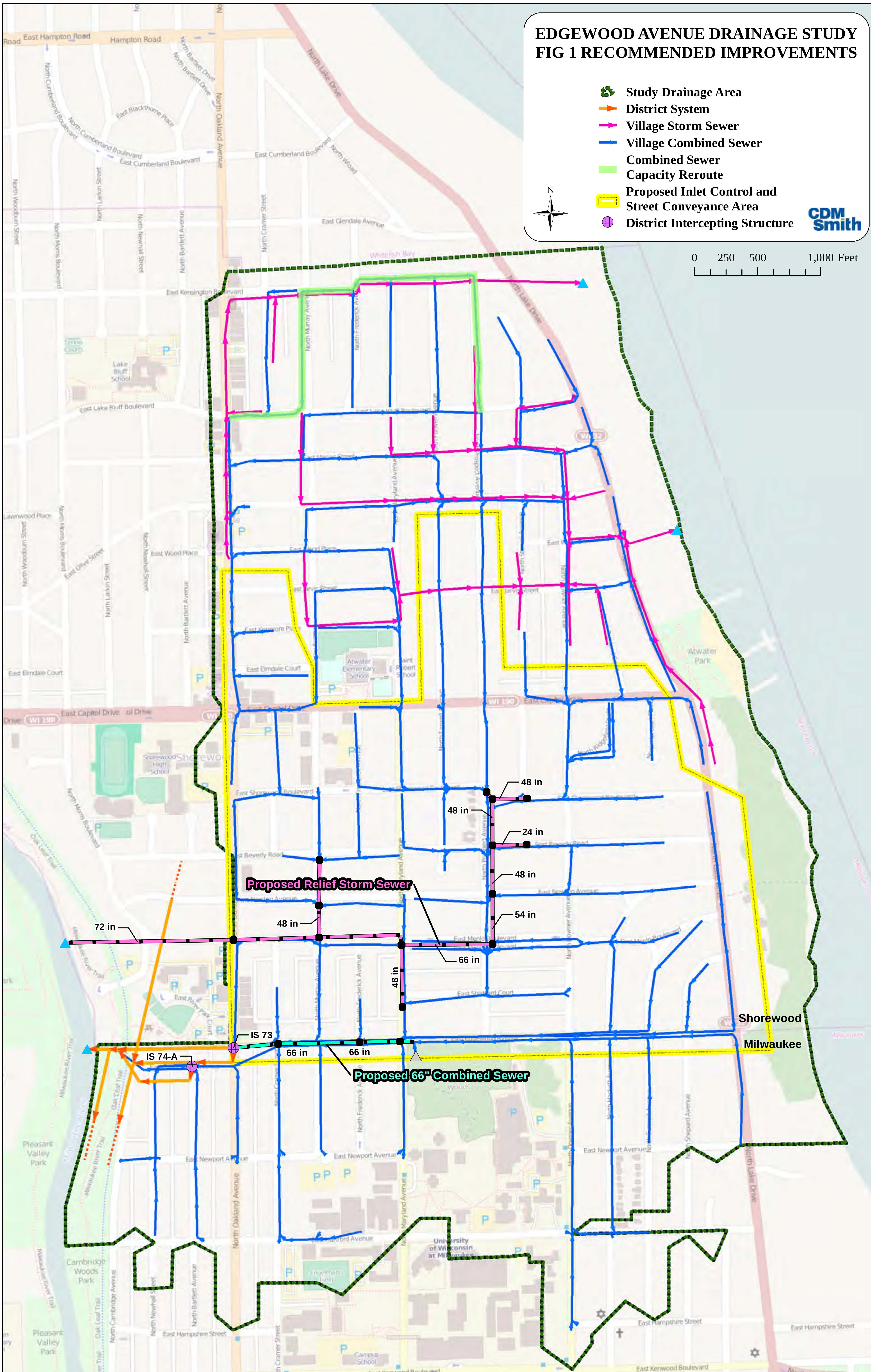
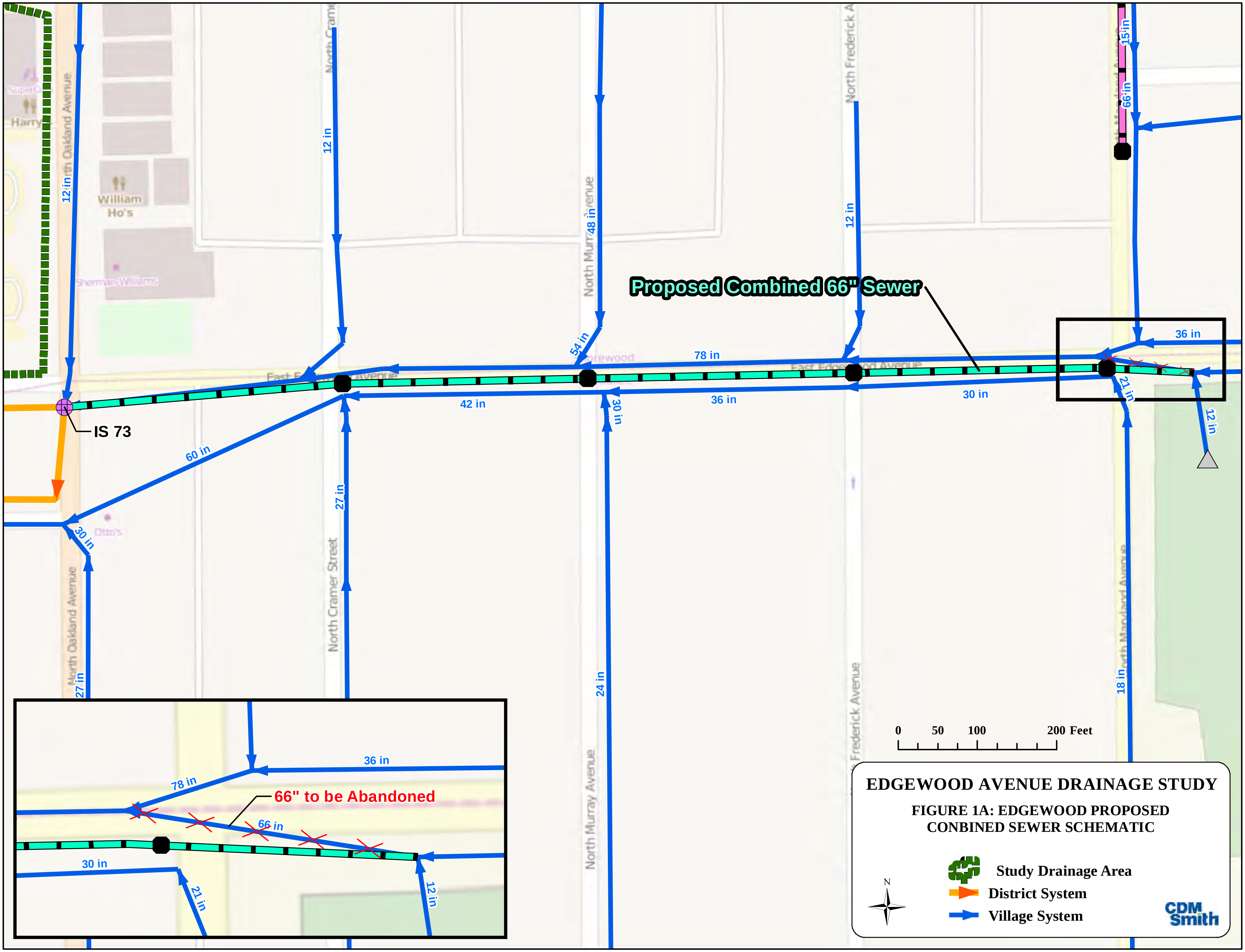
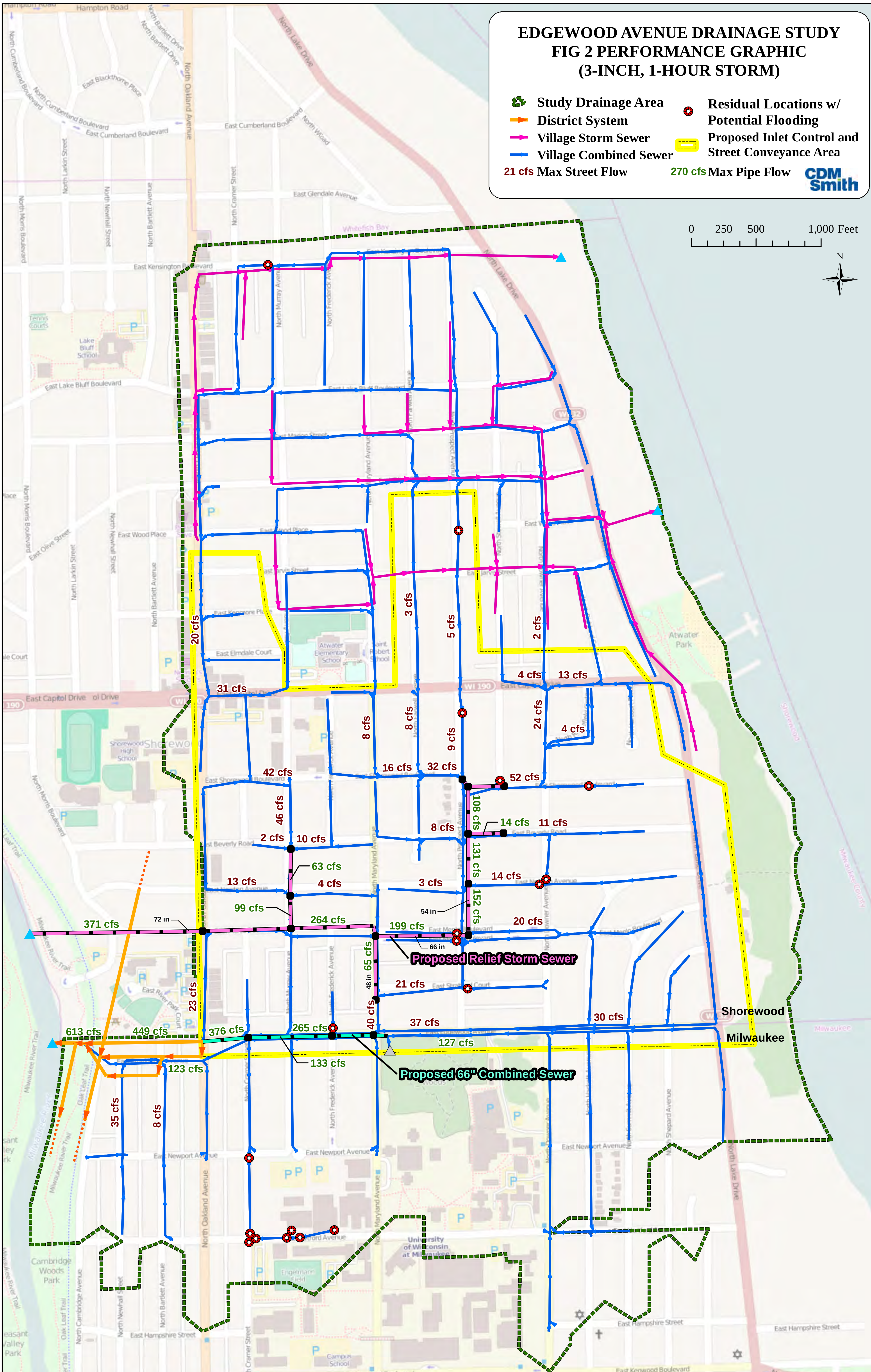


EDGEWOOD AVENUE DRAINAGE STUDY
FIG 1 RECOMMENDED IMPROVEMENTS
Study Drainage Area
District System
Village Storm Sewer
Village Combined Sewer
Combined Sewer Capacity Reroute
Proposed Inlet Control and Street Conveyance Area
District Intercepting Structure
N
CDM Smith
0 250 500 1,000 Feet
Proposed Relief Storm Sewer
Proposed 66" Combined Sewer
72 in
48 in
24 in
54 in
66 in
IS 73
IS 74-A
Shorewood
Milwaukee
East Hampton Road
Hampton Road
North Oakland Avenue
North Lake Drive
East Capitol Drive
East Kensington Boulevard
East Lake Bluff Boulevard
East Newport Avenue
East Hampshire Street
East Kenwood Boulevard
North Maryland Avenue
North Frederick Avenue
Atwater Park
Atwater Elementary School
Lake Bluff School
Shorewood High School
Pleasant Valley Park
Cambridge Woods Park
University of Wisconsin at Milwaukee



EDGEWOOD AVENUE DRAINAGE STUDY

FIGURE 1A: EDGEWOOD PROPOSED CONBINED SEWER SCHEMATIC


EDGEWOOD AVENUE DRAINAGE STUDY
FIG 2 PERFORMANCE GRAPHIC
(3-INCH, 1-HOUR STORM)
Study Drainage Area
District System
Village Storm Sewer
Village Combined Sewer
21 cfs Max Street Flow
Residual Locations w/ Potential Flooding
Proposed Inlet Control and Street Conveyance Area
270 cfs Max Pipe Flow
CDM Smith
0 250 500 1,000 Feet
N
Proposed Relief Storm Sewer
Proposed 66" Combined Sewer
Shorewood
Milwaukee
72 in
54 in
66 in
48 in
371 cfs
264 cfs
199 cfs
99 cfs
63 cfs
613 cfs
449 cfs
376 cfs
265 cfs
133 cfs
127 cfs
123 cfs
108 cfs
131 cfs
152 cfs
65 cfs
14 cfs
20 cfs
31 cfs
23 cfs
42 cfs
46 cfs
2 cfs
10 cfs
13 cfs
4 cfs
3 cfs
3 cfs
5 cfs
2 cfs
4 cfs
13 cfs
24 cfs
4 cfs
8 cfs
8 cfs
9 cfs
16 cfs
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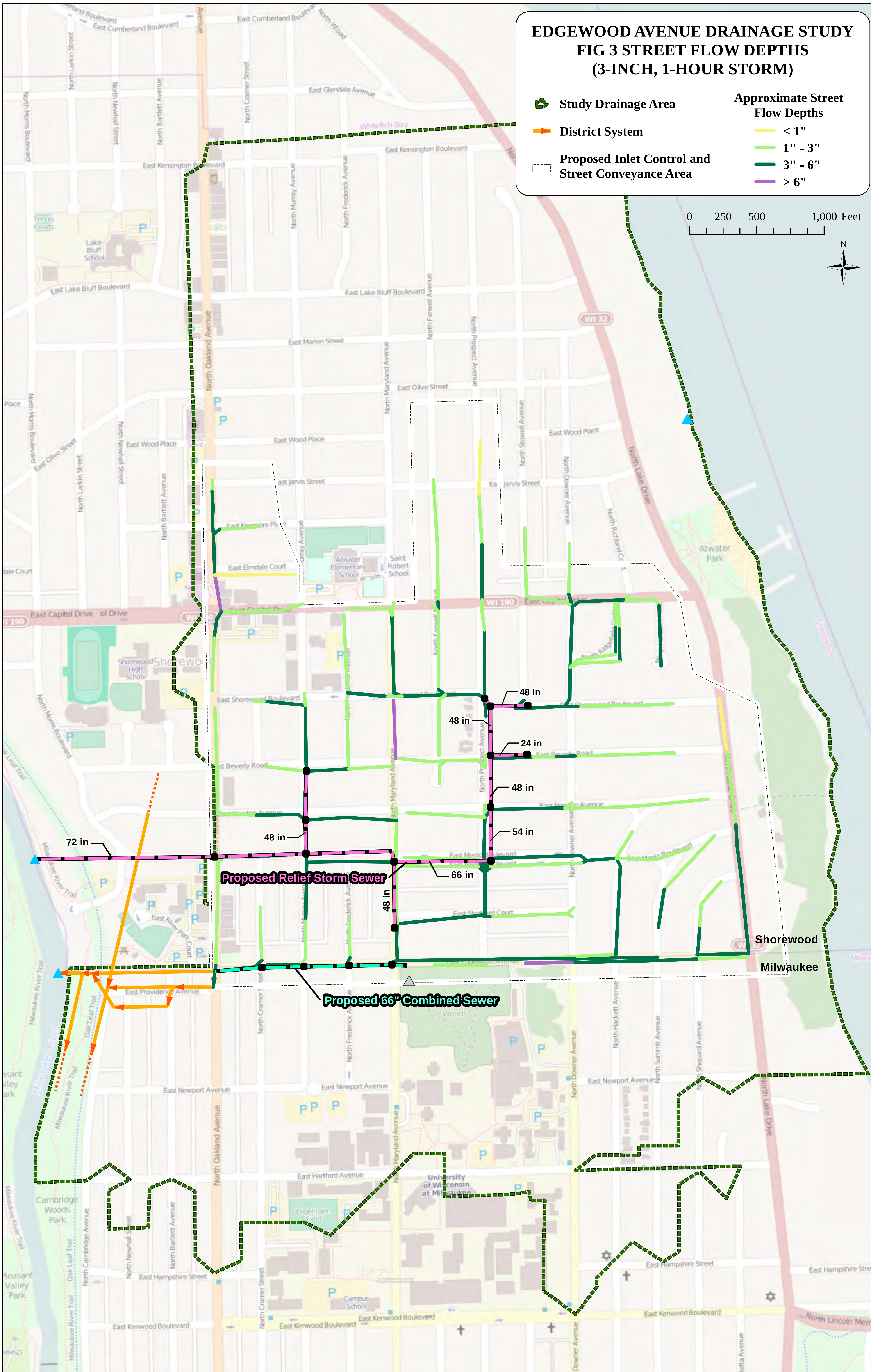
30 cfs
40 cfs
35 cfs
8 cfs



EDGEWOOD AVENUE DRAINAGE STUDY
FIG 3 STREET FLOW DEPTHS
(3-INCH, 1-HOUR STORM)
Study Drainage Area
District System
Proposed Inlet Control and Street Conveyance Area
Approximate Street Flow Depths
< 1"
1" - 3"
3" - 6"
> 6"
0 250 500 1,000 Feet
N
48 in
48 in
24 in
48 in
54 in
72 in
48 in
66 in
48 in
Proposed Relief Storm Sewer
Proposed 66" Combined Sewer
Shorewood
Milwaukee
East Capitol Drive
WI 190
WI 32
East Kensington Boulevard
East Lake Bluff Boulevard
East Marion Street
East Olive Street
East Wood Place
East Shorewood Boulevard
East Providence Avenue
East Newport Avenue
East Hartford Avenue
East Hampshire Street
East Kenwood Boulevard
North Oakland Avenue
North Maryland Avenue
North Downer Avenue
North Lake Drive
Atwater Elementary School
Shorewood High School
Lake Bluff School
Atwater Park
University of Wisconsin at Milwaukee

Appendix

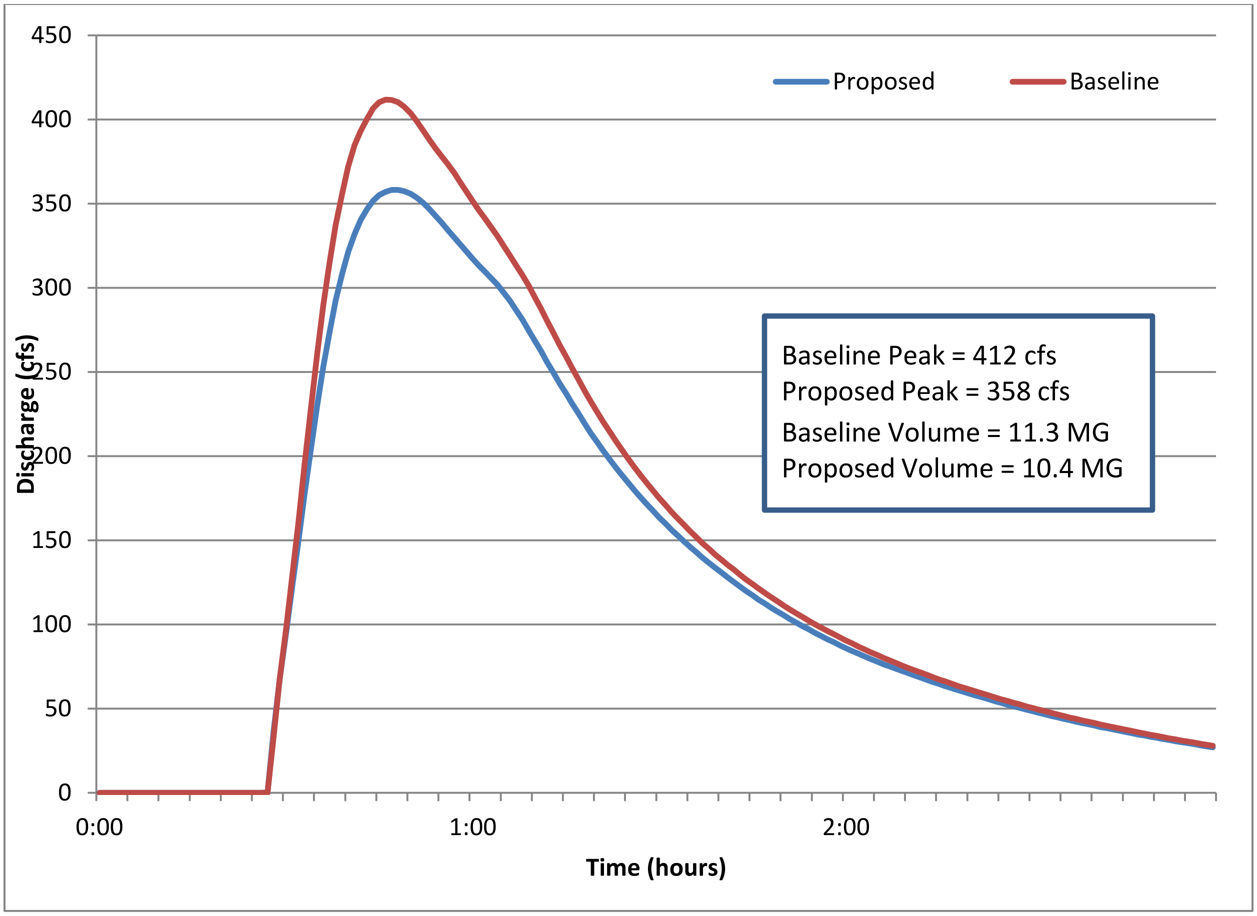


Figure A1: CSO Discharge - 20% Probability Storm

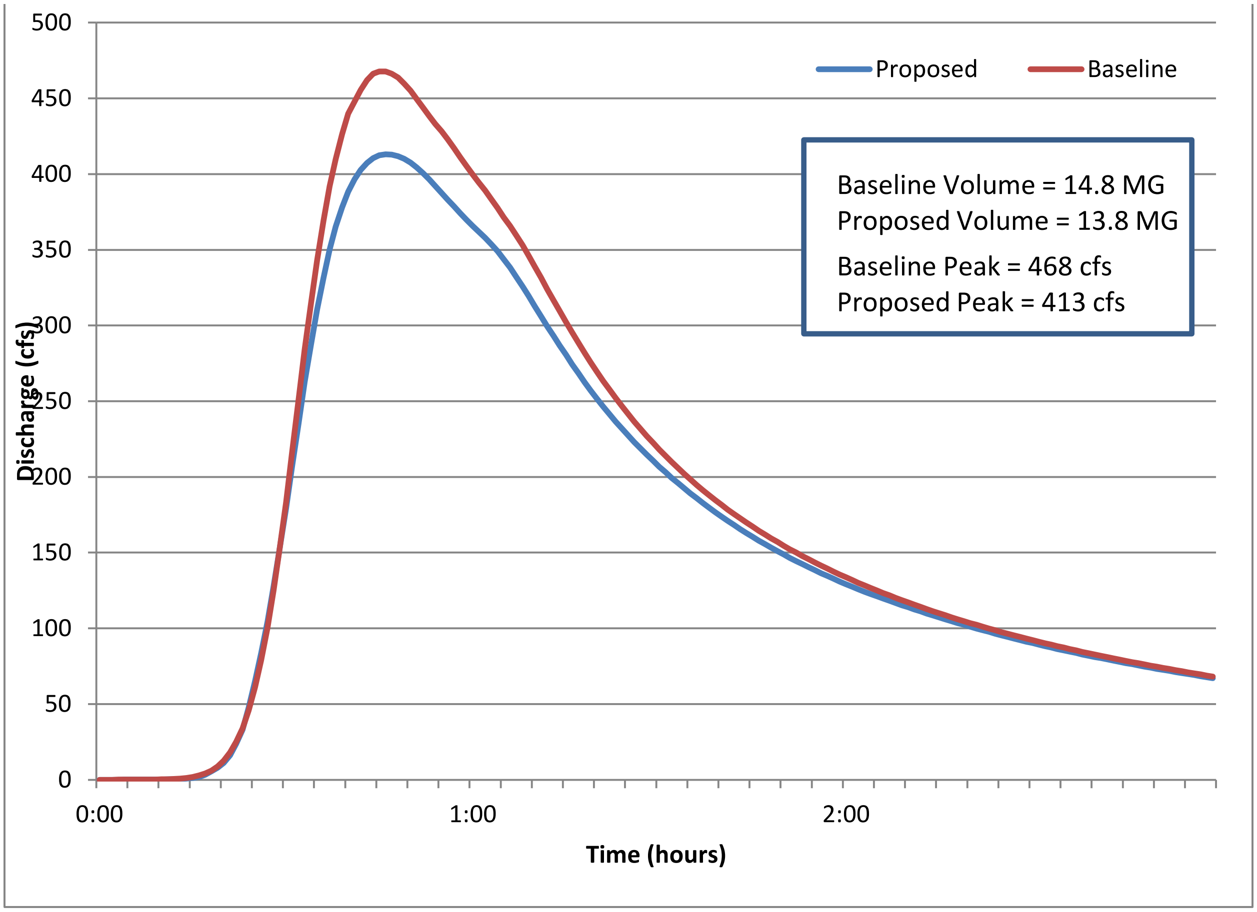


Figure A2: Total Flow to District Intercepting Structures - 20% Probability Storm (City of Milwaukee plus Edgewood Area)

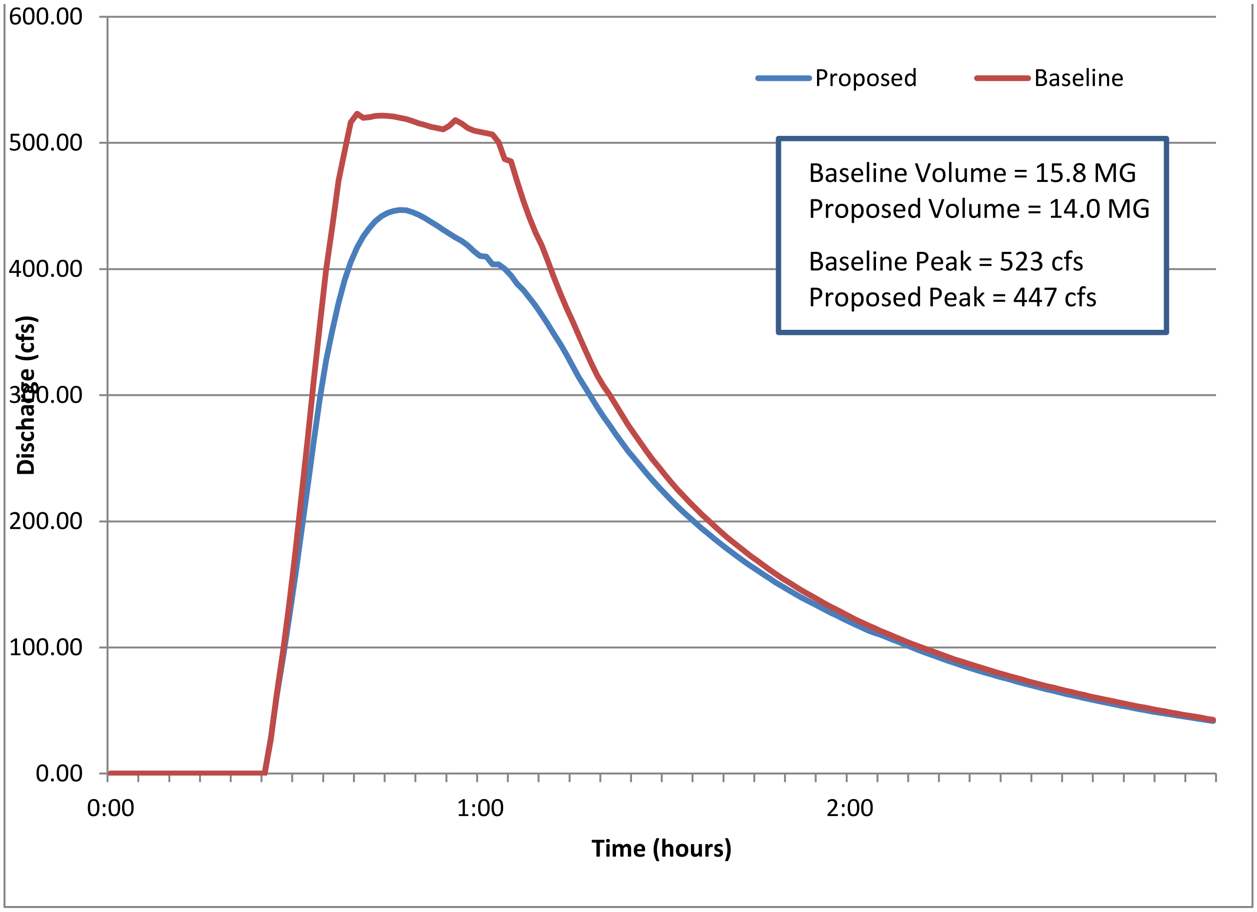


Figure A3: CSO Discharge - 2-inch, 1-hour Storm

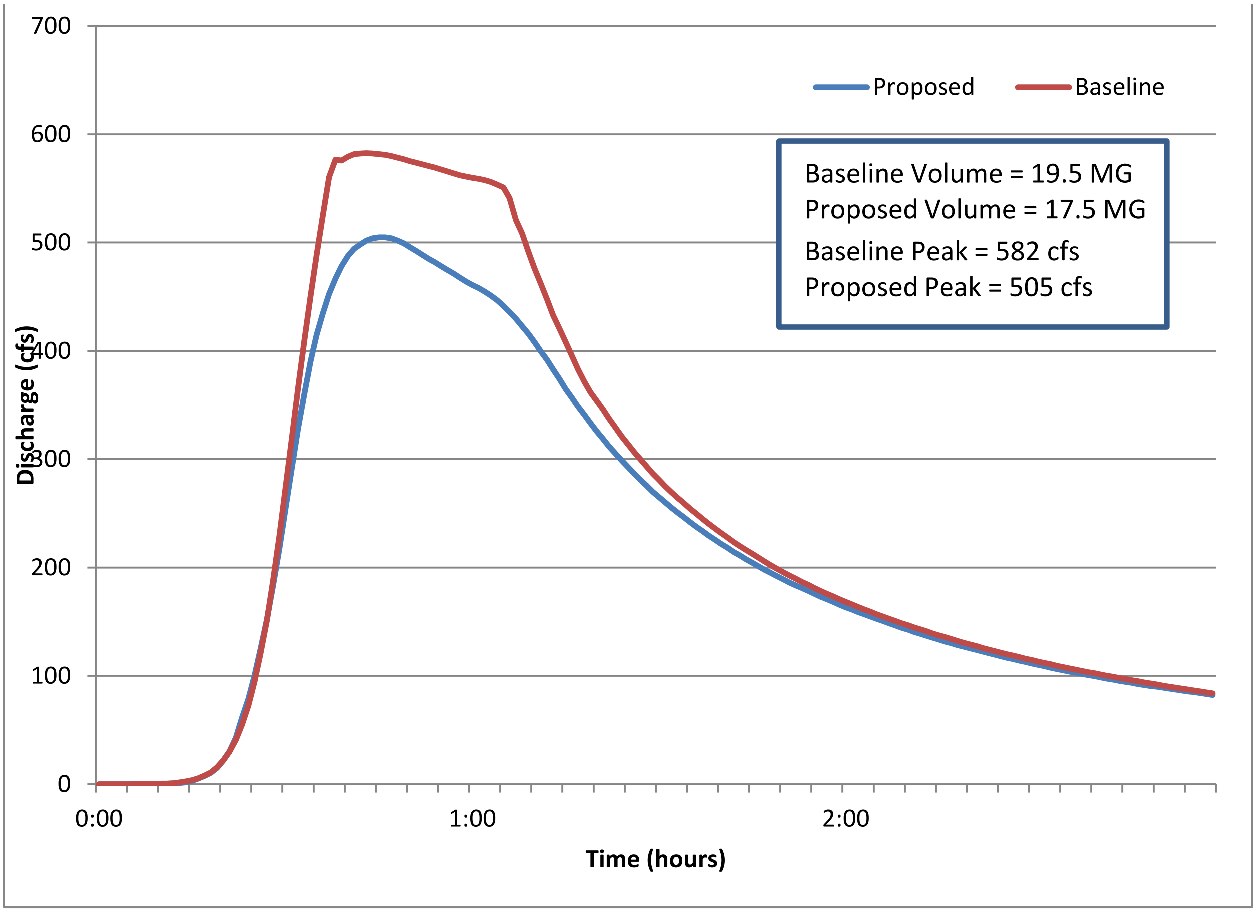


Figure A4: Total Flow to District Intercepting Structures - 2-inch, 1-hour Storm (City of Milwaukee plus Edgewood Area)

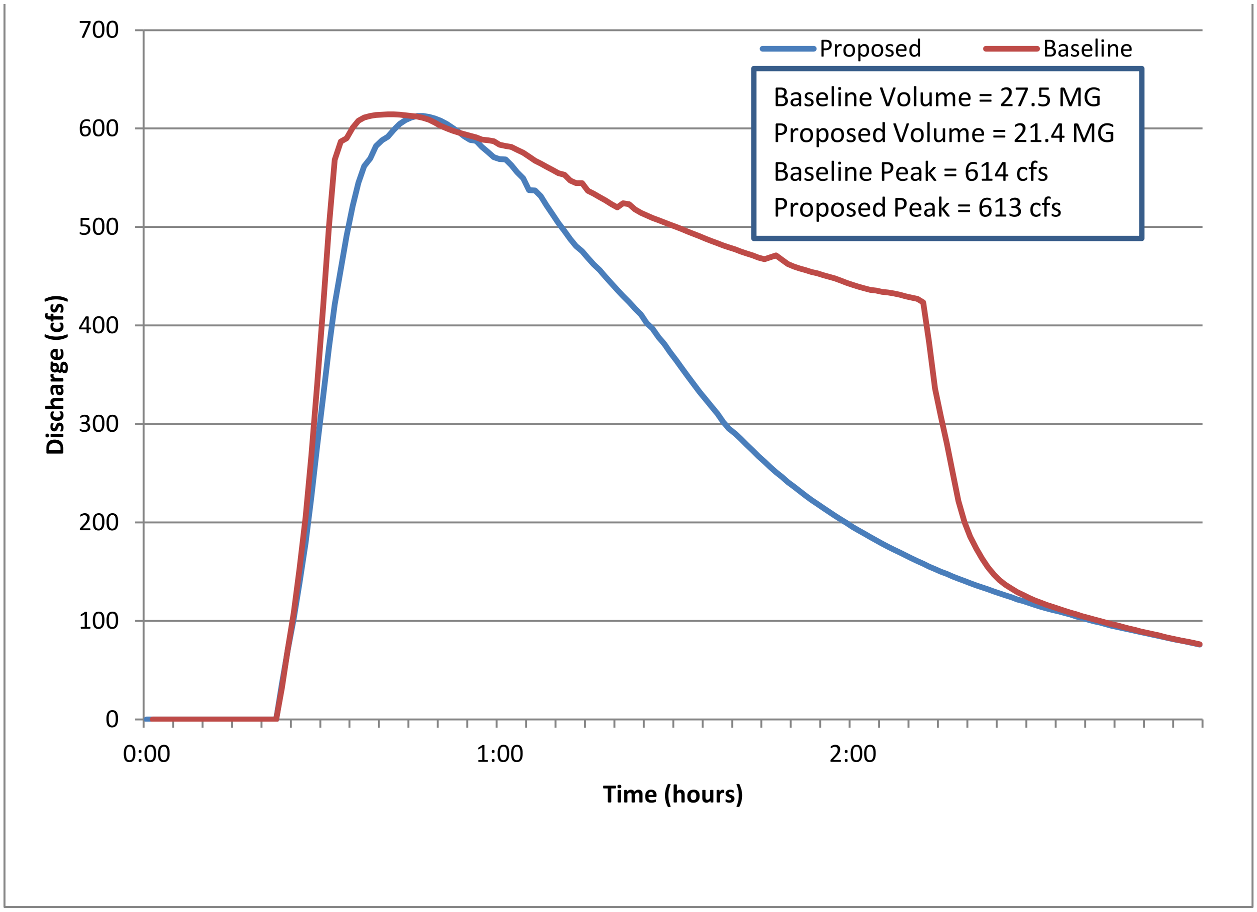


Figure A5: CSO Discharge- 3-inch, 1-hour Storm

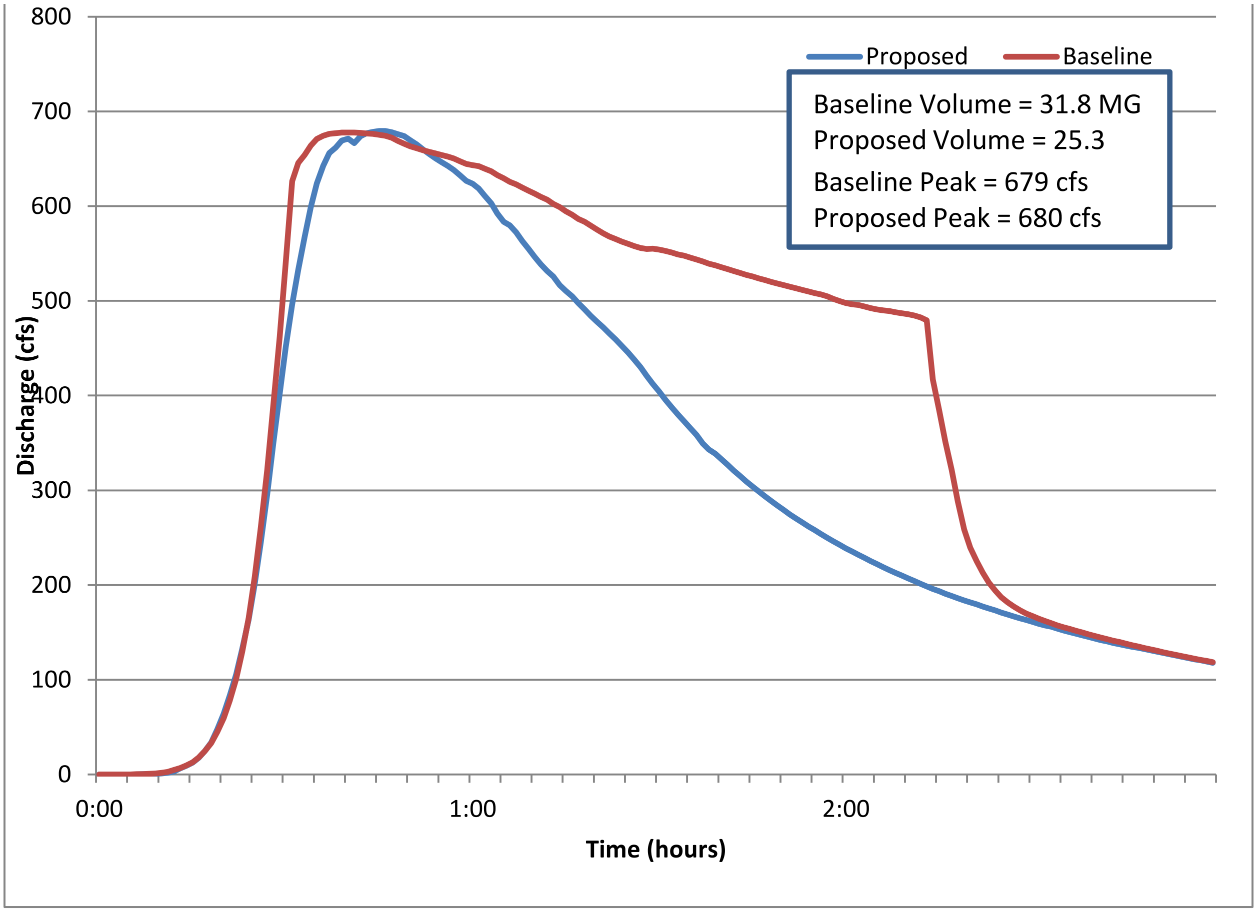
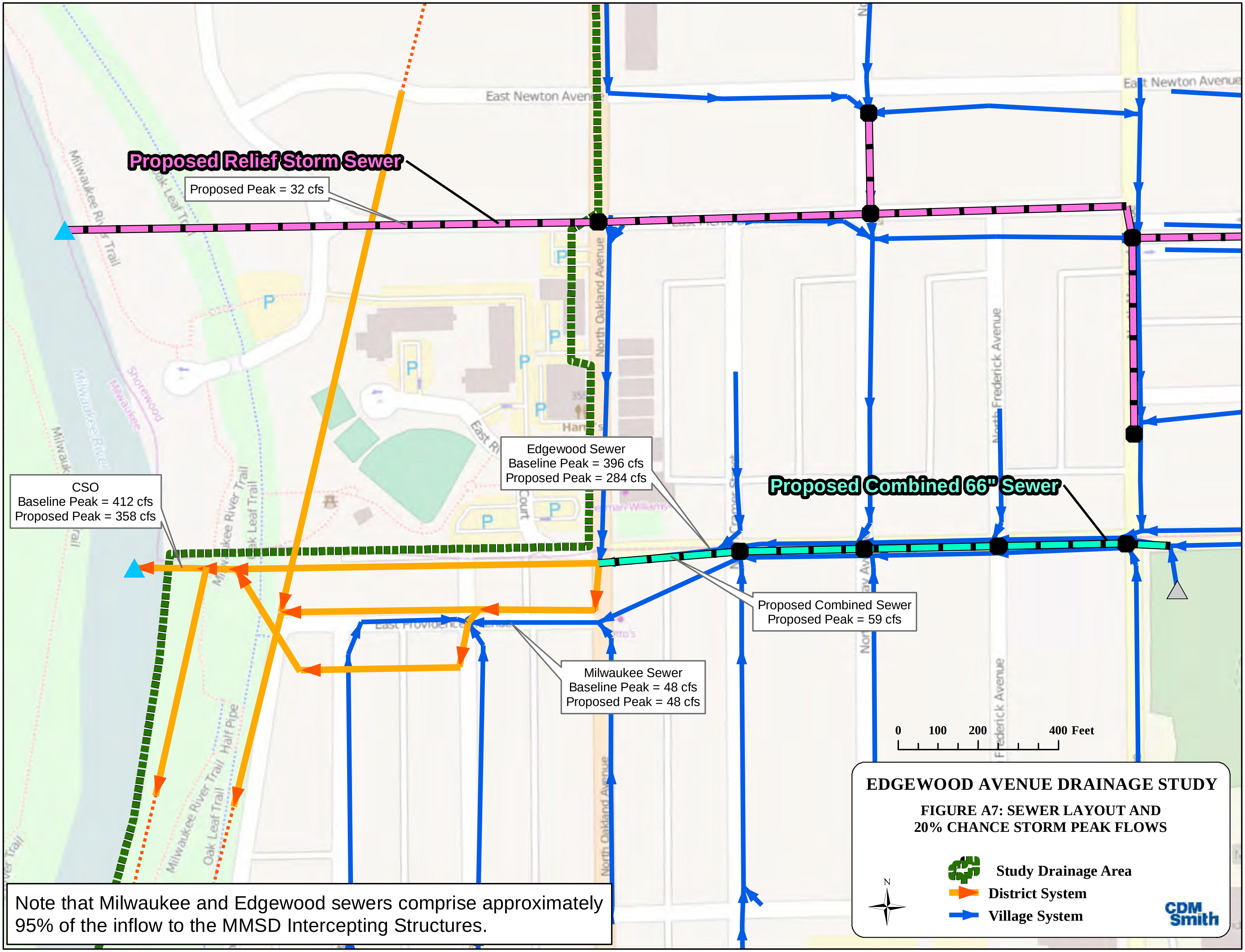


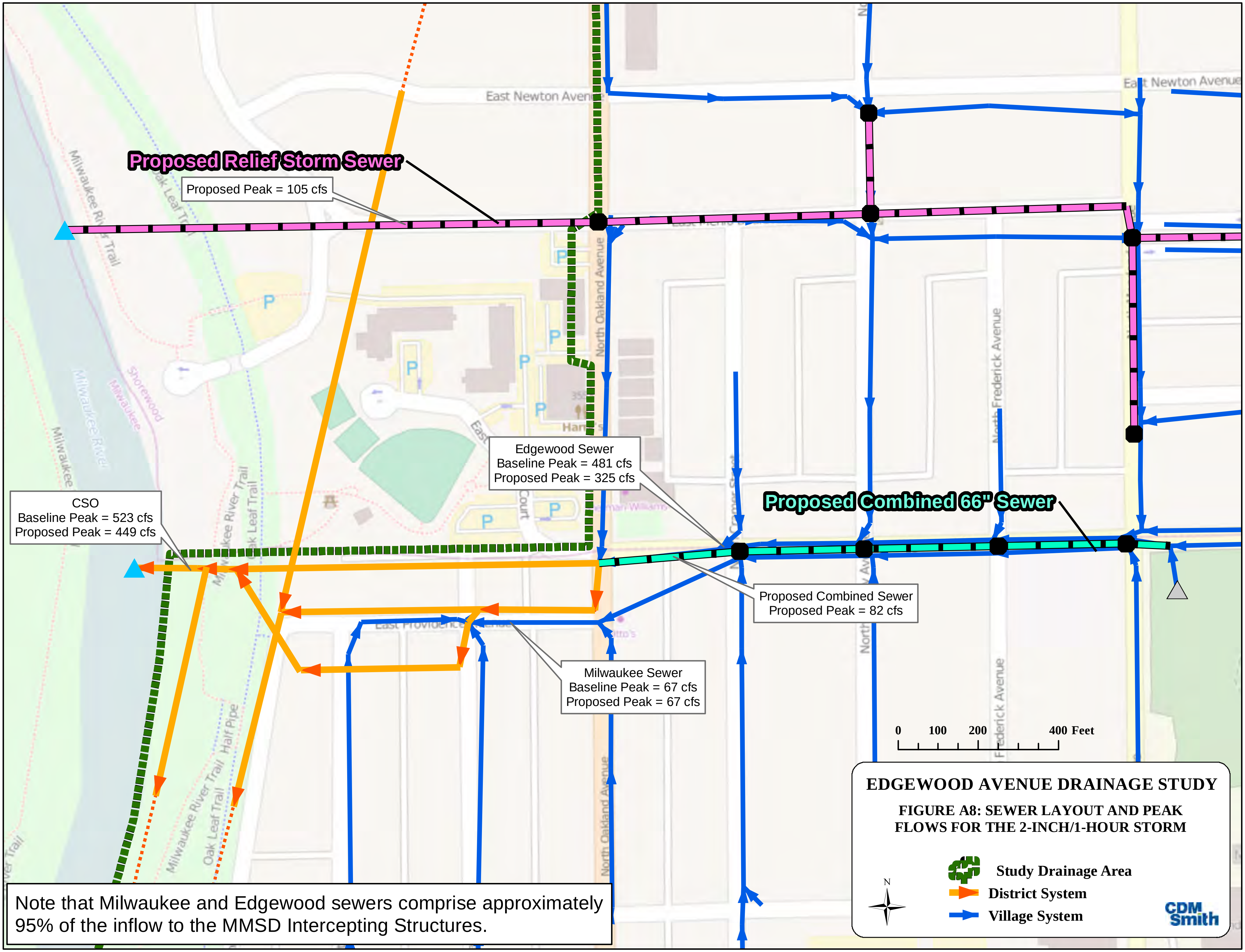
Figure A6: Total Flow to District Intercepting Structures - 3-inch, 1-hour Storm (City of Milwaukee plus Edgewood Area)

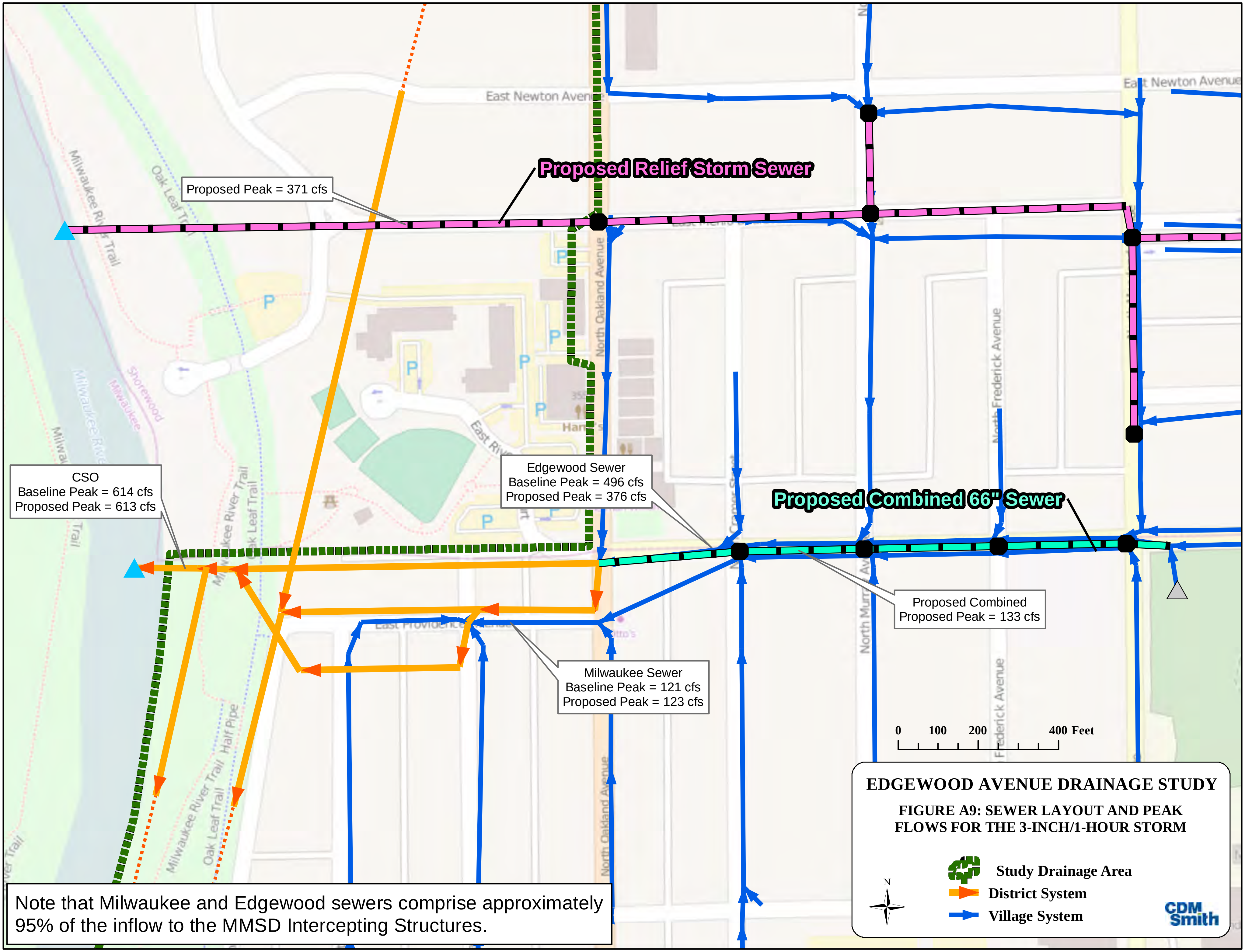


EDGEWOOD AVENUE DRAINAGE STUDY

FIGURE A7: SEWER LAYOUT AND 20% CHANCE STORM PEAK FLOWS

Note that Milwaukee and Edgewood sewers comprise approximately 95% of the inflow to the MMSD Intercepting Structures.


Proposed Relief Storm Sewer
Proposed Peak = 105 cfs
Edgewood Sewer
Baseline Peak = 481 cfs
Proposed Peak = 325 cfs
CSO
Baseline Peak = 523 cfs
Proposed Peak = 449 cfs
Proposed Combined 66" Sewer
Proposed Combined Sewer
Proposed Peak = 82 cfs
Milwaukee Sewer
Baseline Peak = 67 cfs
Proposed Peak = 67 cfs
East Newton Avenue
East Newton Avenue
North Oakland Avenue
North Frederick Avenue
East Providence Avenue
Milwaukee River Trail
Oak Leaf Trail
Milwaukee River
Shorewood
Milwaukee
0 100 200 400 Feet
N
Note that Milwaukee and Edgewood sewers comprise approximately 95% of the inflow to the MMSD Intercepting Structures.
EDGEWOOD AVENUE DRAINAGE STUDY
FIGURE A8: SEWER LAYOUT AND PEAK FLOWS FOR THE 2-INCH/1-HOUR STORM
Study Drainage Area
District System
Village System
CDM Smith



EDGEWOOD AVENUE DRAINAGE STUDY

FIGURE A9: SEWER LAYOUT AND PEAK FLOWS FOR THE 3-INCH/1-HOUR STORM

Note that Milwaukee and Edgewood sewers comprise approximately 95% of the inflow to the MMSD Intercepting Structures.