MEMORANDUM REPORT NO. 241

A WATERCOURSE SYSTEM PLAN FOR SCHOONMAKER CREEK

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special Acknowledgement is due to Laura K. Herrick, PE, CFM, Chief Environmental Engineer; Julia C. Orlowski, PE, Engineer; Zijia Li, PE, Engineer; Megan I. Deau, Senior Graphic Designer; and Timothy R. Gorsegner, GIS Specialist for their contributions to the conduct of this study and the preparation of this report.

MEMORANDUM REPORT
NUMBER 241

A WATERCOURSE SYSTEM PLAN FOR SCHOONMAKER CREEK

Prepared by the
Southeastern Wisconsin Regional Planning Commission
W239 N1812 Rockwood Drive
P.O. Box 1607
Waukesha, Wisconsin 53187-1607
www.sewrpc.org

December 2020

A WATERCOURSE SYSTEM PLAN FOR SCHOONMAKER CREEK

EXECUTIVE SUMMARY

INTRODUCTION AND BACKGROUND

This report summarizes the Southeastern Wisconsin Regional Planning Commission's (SEWRPC) effort to evaluate existing flood risk in the Schoonmaker Creek watershed and to develop 16 alternative stormwater management plans to mitigate those flood risks. This analysis expands upon work done in 2011 by RA Smith, Inc., who analyzed flooding in the Schoonmaker Creek watershed and developed six alternatives to mitigate flooding at the request of the City of Wauwatosa.

The Schoonmaker Creek watershed encompasses roughly 1,100 acres (1.7 square miles) in the City of Wauwatosa and the City of Milwaukee. Much of the original Schoonmaker Creek now flows underground through stormwater sewer systems, except for a short reach in the City of Wauwatosa where it flows in an open channel. It then flows through an enclosure that daylights just south of W. State Street where Schoonmaker Creek discharges to the Menomonee River.

The watershed has experienced numerous heavy storm events since 1986, causing flooding to streets, homes, and businesses due to undersized storm sewer capacity, a confined open channel, and inadequate enclosure capacity at the downstream end of the watershed.

ANALYSIS

To estimate flooding extents under existing conditions and proposed alternatives, two models were utilized. SEWRPC staff expanded upon the XPStorm modeling done by R.A. Smith, Inc. to develop flows and estimate surface water ponding throughout the Schoonmaker Creek watershed. Based on the XPStorm analysis, under existing conditions over 250 structures in the storm sewer system upstream (north) of W. Lloyd Street may be impacted by peak storm ponding on streets for the one-percent-annual-probability (100-year recurrence interval) event. The City of Wauwatosa has jurisdiction to develop projects to reduce surface ponding in the Schoonmaker Creek watershed storm sewer system. SEWRPC staff also developed a HEC-RAS model to delineate the 0.2-, one-, two-, and 10-percent-annual-probability floodplains from the upstream end of the open channel at W. Lloyd Street to the confluence with the Menomonee River. The floodplain delineations showed that under existing conditions an estimated 46 structures would experience flood damage during a one-percent-annual-probability (100-year recurrence interval) event. The Milwaukee Metropolitan Sewerage District (MMSD) has jurisdiction to implement projects to reduce flooding in the Schoonmaker Creek mainstem from W. Lloyd Street to its confluence with the Menomonee River.

SUMMARY OF ALTERNATIVES

Sixteen alternatives were developed and summarized in this report. Alternatives 1 through 3 were developed solely to reduce the flooding risk for the 46 structures in the enclosure area that are included in the one-percent-annual-probability floodplain. Alternatives 4 through 16 provide the same protection for the 46 structures, and include options to relieve street ponding in the storm sewer system in the upper reaches of the watershed, and to various degrees impacted peak flows to the existing open channel section. Alternatives 4 through 16 included sewer improvements, an open channel design, storage alternatives, and sewer and channel bypass alternatives. Additionally, green infrastructure components were evaluated for their ability to supplement the flood alternatives.

EVALUATION OF THE ALTERNATIVES

The 16 alternatives were analyzed and compared for flood reduction impacts, cost, and implementability. Planning level costs were estimated for each alternative. Planning level costs for the three alternatives to solely protect the impacted 46 structures in the enclosure area ranged from $5.6 million to $6.7 million. The remaining 13 alternatives that also relieved the upper watershed street ponding had planning level costs that ranged from $20.4 million to $69.2 million.

FUTURE WORK

The City of Wauwatosa will need to consult with local officials, staff, and residents to determine which of these 16 alternatives are preferable. From there, the City of Wauwatosa should further refine the preferred alternative(s) and conduct a more detailed study of their expected costs and impacts.

LIST OF FIGURES

LIST OF MAPS

LIST OF TABLES

INTRODUCTION AND BACKGROUND 1

On January 29, 2014, the Milwaukee Metropolitan Sewerage District (MMSD) requested that the Southeastern Wisconsin Regional Planning Commission (SEWRPC) perform a planning study of alternative approaches to resolving stormwater management and flooding problems in the Schoonmaker Creek watershed, which is a subwatershed of the Menomonee River watershed. Numerous flooding events have occurred between 1986 and 2018 in the Schoonmaker Creek watershed, both in the upper and lower portions served by storm sewers, as well as in the small middle section that remains an open channel.

The City of Wauwatosa has jurisdiction to develop projects to reduce surface ponding in the Schoonmaker Creek watershed storm sewer system. MMSD has jurisdiction to implement projects to reduce flooding in the Schoonmaker Creek mainstem from W. Lloyd Street to its confluence with the Menomonee River.

Prior to the 2014 MMSD request, R.A. Smith National, Inc. (now R.A. Smith, Inc.) conducted a study of the Creek for the City of Wauwatosa, involving hydrologic and hydraulic analyses using an XPStorm model of existing and alternative conditions in the Schoonmaker Creek watershed. R.A. Smith, Inc. documented their findings in a report titled "Schoonmaker Creek Watershed Study", dated December 29, 2011 (Appendix A). The report identified several problem flooding areas and presented six alternatives to resolve the Schoonmaker Creek stormwater flooding in the City of Wauwatosa portion of the watershed. Four of the alternatives were determined to be feasible: two alternatives with storm sewer improvements, one relief tunnel alternative, and an underground storage alternative.

1.1 PLAN GOALS AND MAJOR TASKS

The original goals for this planning study as identified in the scope of work[1] are listed below:

- Address the stormwater flooding problems in the City of Wauwatosa north of W. Lloyd Street as identified in the December 2011 R.A. Smith, Inc. report
- Address the flooding problem along W. State Street between N. 60th Street and N. 63rd Street in the context of the ongoing MMSD Western Milwaukee flood mitigation project
- Identify and address potential stormwater flooding problems in the City of Milwaukee portion of the Schoonmaker Creek watershed
- Address additional flooding problems that may be identified as part of this study

Based on the above goals, the major plan tasks completed by SEWRPC staff as part of this plan include the following:

1. Perform hydrologic and hydraulic analyses using the XPStorm model and the U.S. Army Corps of Engineers (USACE) HEC-RAS river analysis system program
2. Analyze conveyance and storage alternatives to address Schoonmaker Creek watershed flooding in the Cities of Wauwatosa and Milwaukee
3. Compute the 50-, 10-, four-, two-, one-, and 0.2-percent-annual-probability (two-, 10-, 25-, 50-, 100-, and 500-year recurrence interval, respectively) water surface profiles along the open channel reach of Schoonmaker Creek for existing year land use and existing channel conditions; delineate the one-

[1] *Scope of Work for the Milwaukee Metropolitan Sewerage District Schoonmaker Creek Watercourse System Plan (January 29, 2014, revised April 14, 2014).*

and 0.2-percent-annual-probability floodplain boundaries and the one-percent-annual-probability floodway boundary along the open channel and enclosure area reaches of the Creek

4. Prepare meeting materials and attend meetings with staffs of the Cities of Wauwatosa and Milwaukee, as well as meetings with residents of the study area

5. Prepare a planning report summarizing the study

SEWRPC staff updated the R.A Smith, Inc. XPStorm model to evaluate the entire Schoonmaker Creek watershed. Currently, no FEMA regulatory floodplain exists for Schoonmaker Creek, and for this reason a USACE HEC-RAS hydraulic model of the open channel and enclosure area portions of Schoonmaker Creek was developed to identify structures in the one-percent-annual-probability floodplain. Sixteen alternatives were evaluated for their ability to reduce flooding in the downstream (southern) portion of the watershed and the upstream (northern) sewered areas in the Cities of Wauwatosa and Milwaukee. SEWRPC also completed planning level cost estimates for each of the 16 draft alternatives. The alternatives were primarily intended to mitigate potential flood damages for 46 buildings located within the non-regulatory one-percent-annual-probability (100-year recurrence interval) floodplain in the southern part of the watershed near the enclosed section of Schoonmaker Creek. The alternative plans were also evaluated for their ability to reduce street ponding in the City of Wauwatosa sewered areas during a one-percent-annual-probability storm event and reduce peak flows in the open channel section of Schoonmaker Creek.

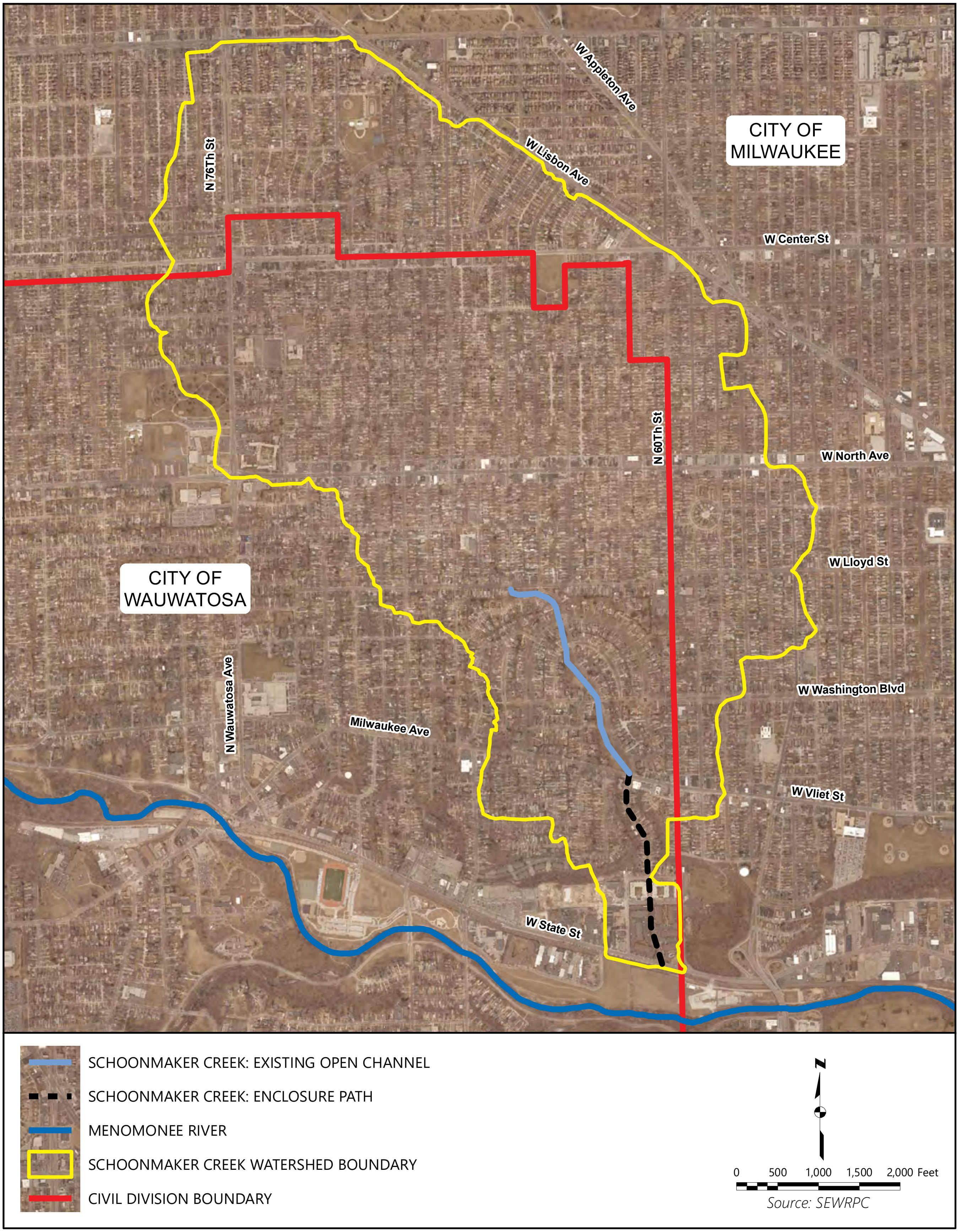
All of the alternatives discussed in this report were developed to reduce flooding caused by Schoonmaker Creek. MMSD is currently working on a project in the vicinity of the Schoonmaker Creek outlet, which is called the Western Milwaukee Phase 2B project.[2] The Phase 2B project is a levee project, with the intent of providing flood risk reduction for high Menomonee River water levels. The Phase 2B project includes a levee to manage Menomonee River flooding, and interior drainage storm sewers to manage ponding behind the levee to meet FEMA requirements on W. State Street in the area of the Schoonmaker Creek enclosure. The FEMA levee and interior drainage requirements will be used to map the updated Menomonee River FEMA floodplain once the Phase 2B project is complete. These requirements include a wider range of Menomonee River high water levels than what was analyzed in this report, and results in several structures remaining in the Menomonee River floodplain on W. State Street. As documented in this report, all of the evaluated alternatives discussed alleviate flooding caused by flood flows on Schoonmaker Creek.

1.2 DESCRIPTION OF STUDY AREA

The Schoonmaker Creek watershed is approximately 1,100 acres (1.7 square-miles) in area and includes portions of the City of Milwaukee and the City of Wauwatosa, as seen in Map 1.1. The watershed is predominantly residential and commercial land use, has curb and gutter streets, and has a relatively steep average land slope of three percent. The watershed boundaries were determined by R.A. Smith, Inc. using topographic mapping and storm sewer system maps. The watershed is bounded approximately by W. Burleigh Street and W. Lisbon Avenue to the north, by N. 80th Street to the west, by N. 56th Street to the east, and by W. State Street to the south. A majority of the upstream portion of the former Schoonmaker Creek channel has been enclosed in storm sewers within the City of Wauwatosa, except through the Washington Highlands neighborhood from W. Lloyd Street to Milwaukee Avenue. At Milwaukee Avenue, the stream enters a large enclosure that extends to W. State Street. Schoonmaker Creek resurfaces as an open channel south of W. State Street, just upstream of the confluence with the Menomonee River.

[2] *Stantec, Technical Memorandum TM-FD3: Interior Drainage, 2020.*

Map 1.1
Schoonmaker Creek Watershed Civil Divisions



Source: SEWRPC

HYDROLOGIC AND HYDRAULIC ANALYSIS 2

This section discusses the baseline Schoonmaker Creek existing conditions modeling effort completed for this study. Existing conditions represent year 2019 as the watershed is urbanized and fully developed. It documents the progression of the XPStorm existing conditions model used to develop flows and model the hydraulic components of the Schoonmaker Creek watershed. Flows developed in the updated existing conditions XPStorm model were then used to delineate the 0.2-, one-, two-, and 10-percent-annual-probability floodplains for the open channel and enclosure areas of Schoonmaker Creek. Flood damage estimates were completed for structures impacted by the delineated floodplains.

Throughout this plan the storm and flooding events will be described by a percent-annual-probability, which represents the percent chance the event will occur in any single year. Storm events can also be described by year recurrence interval and the relationship between the two descriptions are included below for reference.

- 0.2-percent-annual-probablity event is equivalent to the 500-year recurrence interval event
- One-percent-annual-probability event is equivalent to the 100-year recurrence interval event
- Two-percent-annual-probability event is equivalent to the 50-year recurrence interval event
- Four-percent-annual-probability event is equivalent to the 25-year recurrence interval event
- 10-percent-annual-probability event is equivalent to the 10-year recurrence interval event
- 50-percent-annual-probability event is equivalent to the two-year recurrence interval event

2.1 PREVIOUS WORK SUMMARY

Modeling analyses for the Schoonmaker Creek watershed were first completed by R.A. Smith, Inc. and were documented in the draft "Schoonmaker Creek Watershed Study", dated December 29, 2011 (Appendix A). The modeling was completed using the 2011 version of the XPStorm proprietary software, which is supported by XP Solutions, Inc. The R.A. Smith, Inc. XPStorm model included a hydrologic representation of the watershed and a hydraulic representation of storm sewers and open channel portions of the Schoonmaker Creek drainage system. The hydrologic model used historical rainfall data from a storm in July 2010, as well as design storm events utilizing the Natural Resource Conservation Service (NRCS) 24-hour duration storm, Type II rainfall distribution, and rainfall volumes from SEWRPC Technical Report 40.[3] Modeled design storms included the 10-, two-, one-, and 0.2-percent-annual-probability storms. The hydraulic model also included select street reaches explicitly in the XPStorm model as well as a topographic representation of the watershed via a gridded surface. The grid allowed runoff that was not captured by a modeled sewer or street feature to flow overland until encountering a modeled feature that had capacity. Additional details regarding the R.A. Smith, Inc. modeling can be found in the 2011 draft report included in Appendix A.

2.2 EXISTING CONDITION MODEL UPDATES

SEWRPC staff reviewed the year 2011 R.A. Smith, Inc. model in XPStorm version 2014 SP1, and made the following updates to the model for this planning study to refine the model, reflect projects that have occurred since the R.A. Smith model was developed, and to account for updated rainfall standards. Updates to the XPStorm hydrologic model included refining drainage basins for the City of Milwaukee sewer serving the eastern side of the Schoonmaker Creek watershed and updating the design rainfall events. XPStorm hydraulic model updates included a revision of the enclosure south of W. State Street to represent the MMSD daylighting

[3] *SEWRPC Technical Report No. 40,* Rainfall Frequency in the Southeastern Wisconsin Region*, April 2000.*

project, providing additional detail to the City of Milwaukee sewers serving the east side of the watershed, and a re-evaluation of the Menomonee River water level used for the Schoonmaker Creek outlet condition (also called the tailwater) in the XPStorm model.

The first XPStorm hydrologic update included subdividing and refining basins 744, 745, and 746 into 14 basins along the eastern edge of the Schoonmaker Creek watershed to better represent the contributing drainage areas to the City of Milwaukee storm sewers serving this area. As was done for the R.A. Smith, Inc. work, the NRCS Technical Release 55 (TR-55) method was used to develop composite curve numbers and time of concentration values for the refined basins.

The other major update to the R.A. Smith, Inc. XPStorm hydrologic model was to update design rainfall events to the NOAA Atlas 14[4] rainfall standards. NOAA Atlas 14 rainfall totals were utilized with the 2006 SEWRPC rainfall distribution.[5] Rainfall totals were taken from NOAA Atlas 14 Point Precipitation Frequency Estimates[6] for the National Weather Service (NWS) Mount Mary College COOP gaging station (47-5474) which is located near the Schoonmaker Creek watershed. The rainfall information in NOAA Atlas 14 supersedes that found in SEWRPC Technical Report No. 40. The SEWRPC storm distribution issued on March 30, 2006, was used in the XPStorm hydrologic model and a critical duration evaluation was completed as discussed below.

The first modification to the XPStorm hydraulic model included an update to the enclosure at the downstream end of Schoonmaker Creek where it discharges to the Menomonee River. Schoonmaker Creek was daylighted from a box culvert to an open channel in this section as part of the MMSD Western Milwaukee Flood Management Project Phase 2A, completed in December 2015. Model updates were based on the November 2014 as-bid plans for the Phase 2A project.[7] Enclosure changes extended from W. State Street approximately 230 feet downstream.

The City of Milwaukee storm sewers that collect runoff along and east of N. 60th Street were refined in the XPStorm model using data from the City of Milwaukee. This sewer line was refined to more accurately represent surcharged conditions that cause overflows that move west along streets into the City of Wauwatosa portion of the Schoonmaker Creek watershed. The City of Milwaukee sewer data included GIS manhole information (dated 2014) and a spreadsheet of pipe sizes between City manholes (dated 2015). The City of Milwaukee N. 60th Street sewer drains south to W. Vliet Street where it drops approximately 40 feet into a large storm sewer that drains east under W. Vliet Street out of the Schoonmaker Creek watershed. The updated existing conditions XPStorm model schematic is included as Map 2.1.

SEWRPC staff also evaluated the Schoonmaker Creek tailwater condition included in the XPStorm hydraulic model that represents water levels on the Menomonee River. It was determined that Schoonmaker Creek flows would peak prior to the Menomonee River during a three-hour storm, therefore a free outfall condition[8] was used for modeling both existing conditions as well as the alternatives. This evaluation is discussed in detail in the "Evaluation of the Alternatives" section of this report. The free outfall condition produces an existing conditions one-percent-annual-probability water level approximately two feet deep at the outlet of the enclosure south of W. State Street. This translates to a little under half full for the existing double 5-foot x 9-foot (ft) reinforced concrete box (RCB) culverts at the enclosure outlet. As a check, a Menomonee River water elevation of 50.5 feet in City of Wauwatosa datum (630.8 in NGVD29) was evaluated in the XPStorm model as well, which represents the 10-percent-annual-probability level for the river.[9] The 10-percent-annual-probability

[4] *NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0: Midwestern States (Colorado, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, Wisconsin), 2013.*

[5] *www.sewrpc.org/SEWRPCFiles/Environment/Rainfall/sewrpc-wdnr-rainfall-data-analysis-procedure.pdf.*

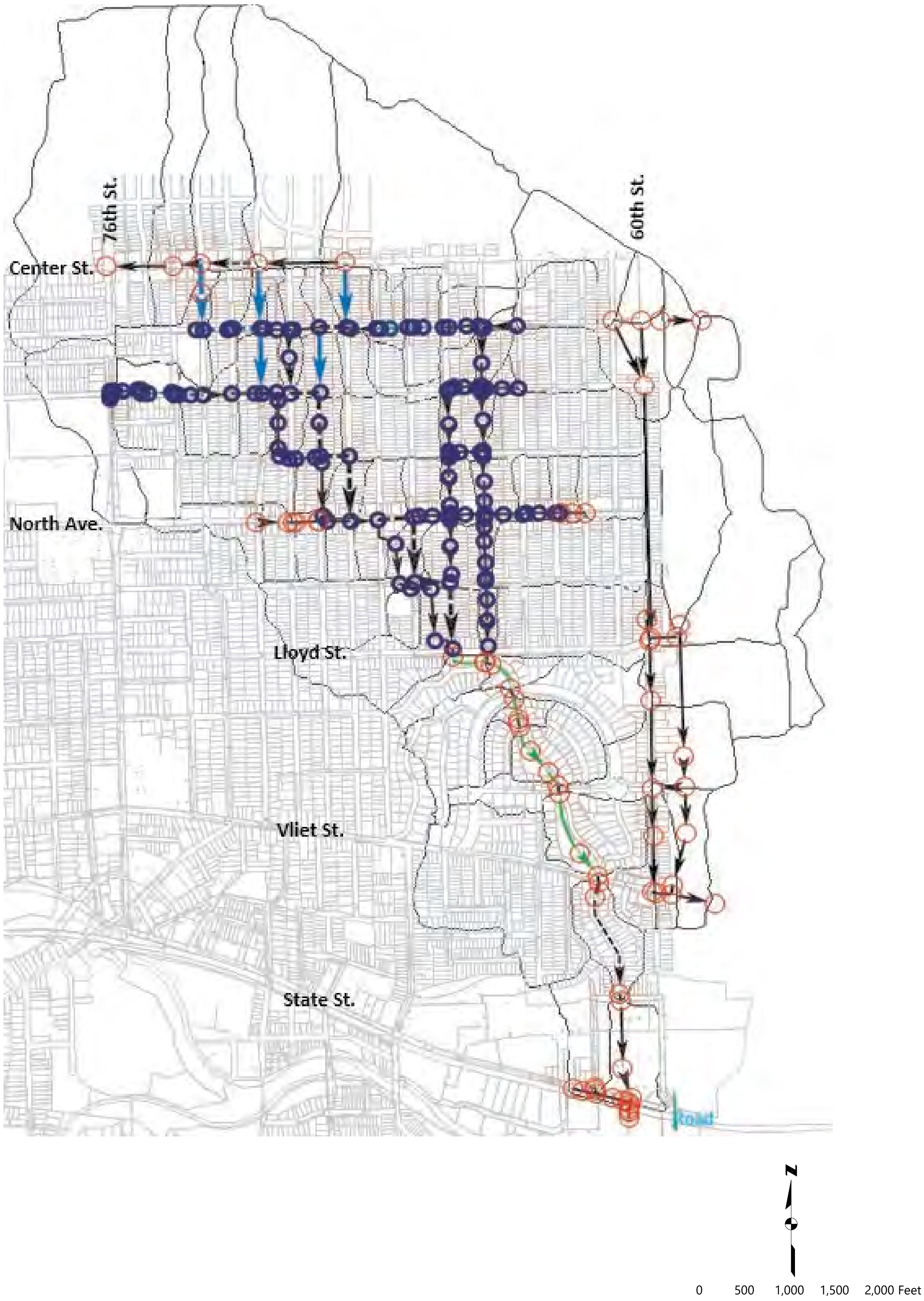
[6] *The NOAA Atlas 14 data can be found at* hdsc.nws.noaa.gov/hdsc/pfds/.

[7] *Western Milwaukee Flood Management Project Phase 2A, MMSD, Attachment No. 2 to Addendum No. 5, Bid-November 2014.*

[8] *A free outfall condition for this effort means that the Menomonee River is low enough that the final pipe cross section(s) under W. State Street control the water surface elevation at the modeled system outlet. This is equivalent to nonflood times, when the Menomonee River water level is within its channel banks.*

[9] *Menomonee River Conditional Letter of Map Revision (CLOMR) submitted by the Cities of Milwaukee and Wauwatosa in December 2014. The CLOMR was issued by the Federal Emergency Management Agency (FEMA) on April 21, 2016.*

Map 2.1
Schoonmaker Creek Watershed XPSTORM Model for Existing Conditions



Source: SEWRPC

water level on the Menomonee River only impacted water levels in the enclosed portion of Schoonmaker Creek south of W. Martin Drive, based on the updated XPStorm model for the one-percent-annual-probability storm. There was no change to flood water levels in the storm sewer system upstream of W. Martin Drive. The Schoonmaker Creek updated existing conditions XPStorm input file is included in Appendix B.

2.3 CRITICAL DURATION ANALYSIS

A critical duration analysis was performed using the updated existing conditions XPStorm model to determine the rainfall duration that produces the highest peak flows on the Schoonmaker Creek open channel. Rainfall totals for the critical duration analysis were taken from NOAA Atlas 14 for the NWS Mount Mary College gaging station (47-5474). The 50-percent and one-percent-annual-probability storm events were evaluated for the 1-, 3-, 6-, 12-, and 24-hour durations using the SEWRPC rainfall distribution.[10] XPStorm peak flows for each storm event and duration were compiled for the open channel portion of Schoonmaker Creek between W. Lloyd Street and Milwaukee Avenue. The 3-hour duration storm produced the largest peak flows for both the 50-percent and the one-percent-annual-probability storms in the open channel portion of Schoonmaker Creek. Therefore the 3-hour storm was selected to develop the Schoonmaker Creek floodplains and for evaluating the alternatives. NOAA Atlas 14 design storm rainfall totals for the 3-hour event for the NWS Mount Mary College gage are listed in Table 2.1. NOAA Atlas 14 precipitation frequency estimates for the Mount Mary gage for various storm recurrence intervals and durations are included in Appendix C.

Table 2.1
Design Storm Characteristics NOAA Atlas 14, 3-Hour Storm Event*

Storm Event (Recurrence Interval)	Depth (inches)
50% annual-probability (2-year)	1.72
10% annual-probability (10-year)	2.62
4% annual-probability (25-year)	3.23
2% annual-probability (50-year)	3.75
1% annual-probability (100-year)	4.28
0.2% annual-probability (500-year)	5.67

*National Weather Service Mount Mary gage

Source: SEWRPC

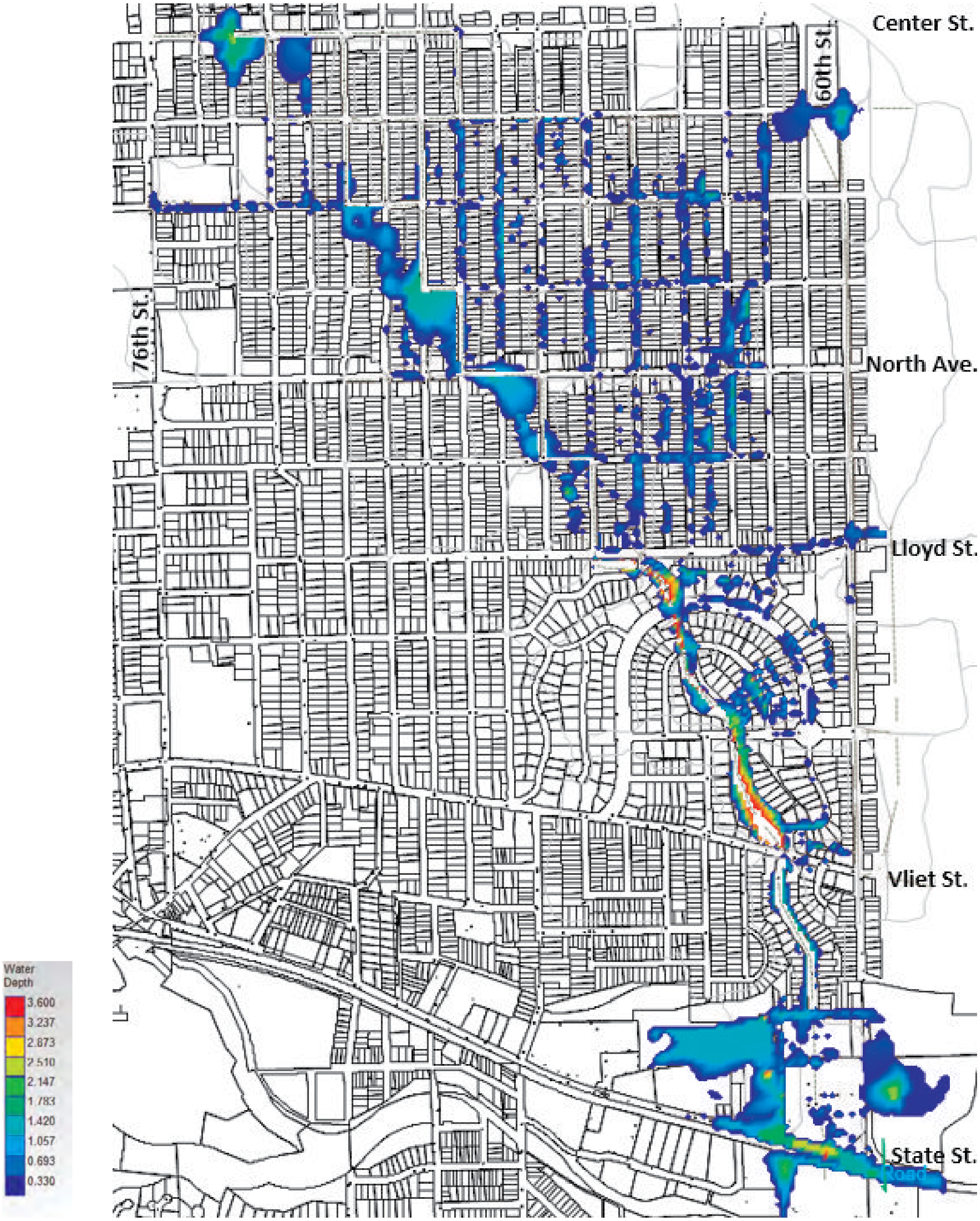
2.4 HISTORICAL STORM REVIEW

Several historical storms were modeled in XPStorm as part of the flooding analysis of the Schoonmaker Creek watershed. This was done to confirm the representation of the watershed in the model was reasonable. The Milwaukee area has experienced several severe rainfall events, including storms in August 1986, June 1997, August 1998, June 2008, July 2010, and June 2018. Limited data details were available for the 1986, 1997, and 1998 events, but most of these events were the most intense for a 6-hour to 24-hour duration. The historical July 2010 flooding event was used for this analysis because it was an intense, relatively short storm event, which tends to cause higher flood flows in a small, steep watershed like Schoonmaker Creek. This watershed response was also shown by the critical duration analysis discussed above. The hyetographs (rainfall depth over time) for the 2010 and 2018 historical events discussed below and the NOAA Atlas 14 design events are also documented in Appendix C.

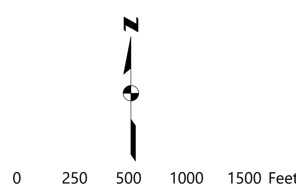
In order to model the July 22, 2010, flooding event, rainfall data recorded at the U.S. Geological Survey gaging station on the Menomonee River at N. 70th Street was used. The City of Wauwatosa operates a rain gage at City Hall, but this gage data was not used for this event as it did not accurately archive the extremely intense rainfall. The July 2010 storm resulted in approximately 5.5 inches of rain falling over a 24-hour period and had a peak 3-hour total rainfall of 4.2 inches. The 24-hour total rainfall volume of this storm is between a two-percent- and a one-percent-annual-probability event. The 3-hour total rainfall volume of this storm is approximately a one-percent-annual-probability event. The peak street ponding for the July 2010 storm based on the XPStorm model is shown in Map 2.2. Street ponding depths from the July 2010 model at selected locations can be found in Table 2.2, and a map of these ponding locations is shown in Map 2.3. Depths of ponding for the modeled July 2010 event from N. 74th Street and W. Center Street to N. 66th Street and W. Lloyd Street range from 1.3 feet to 2.4 feet. These modeled flood depths were comparable to observed flood depths in the watershed.

[10] *Documentation for the SEWRPC rainfall distribution can be found at www.sewrpc.org/SEWRPC/Environment/RainfallFrequency.htm.*

Map 2.2
Schoonmaker Creek Watershed July 2010 Peak Ponding Depths from XPSTORM Model[a]



[a] Depth is reported in feet.



Source: SEWRPC

Table 2.2
Peak Roadway Ponding Depths in the Study Area During July 2010 Storm Event (XPStorm Model Results)

Location	Jurisdiction	Peak Ponding Depth (feet)
N. 74th Street and W. Center Street	City of Milwaukee	2.4
N. 60th Street and W. Clarke Street	City of Milwaukee	1.7
N. 70th Street and W. Meinecke Avenue	City of Wauwatosa	1.7
N. 68th Street and W. North Avenue	City of Wauwatosa	1.7
N. 67th Street and W. Garfield Avenue	City of Wauwatosa	1.3

Source: SEWRPC

Street ponding again occurred in the City of Wauwatosa sewered portion of the Schoonmaker Creek watershed on June 18, 2018. A review of the Mount Mary College rainfall gage indicated the June 18, 2018, rainfall event totaled 3.8 inches in 24-hours, which is approximately a 10-percent-annual-probability rainfall event. Since the NWS Mount Mary station only reports 24-hour rainfall totals, the Milwaukee Mitchell International Airport (MMIA) hourly rainfall data for June 18, 2018, was used to approximate the hourly rainfall over the Schoonmaker Creek watershed. Using the MMIA data as a guide, the June 2018 3-hour rainfall for the Mount Mary College gage was approximated at 2.7 inches, which also translates to approximately a 10-percent-annual-probability event. A time series of photos facing southwest at N. 70th Street and W. Meinecke Avenue for the June 18, 2018 event are included as Figure 2.1. As can be seen from the photos, the street ponding was intense but only for approximately an hour for this event. It appears the maximum depth of street ponding at this location for the June 18, 2018, event was between one and two feet.

2.5 SUMMARY OF EXISTING CONDITIONS

XPStorm Modeling

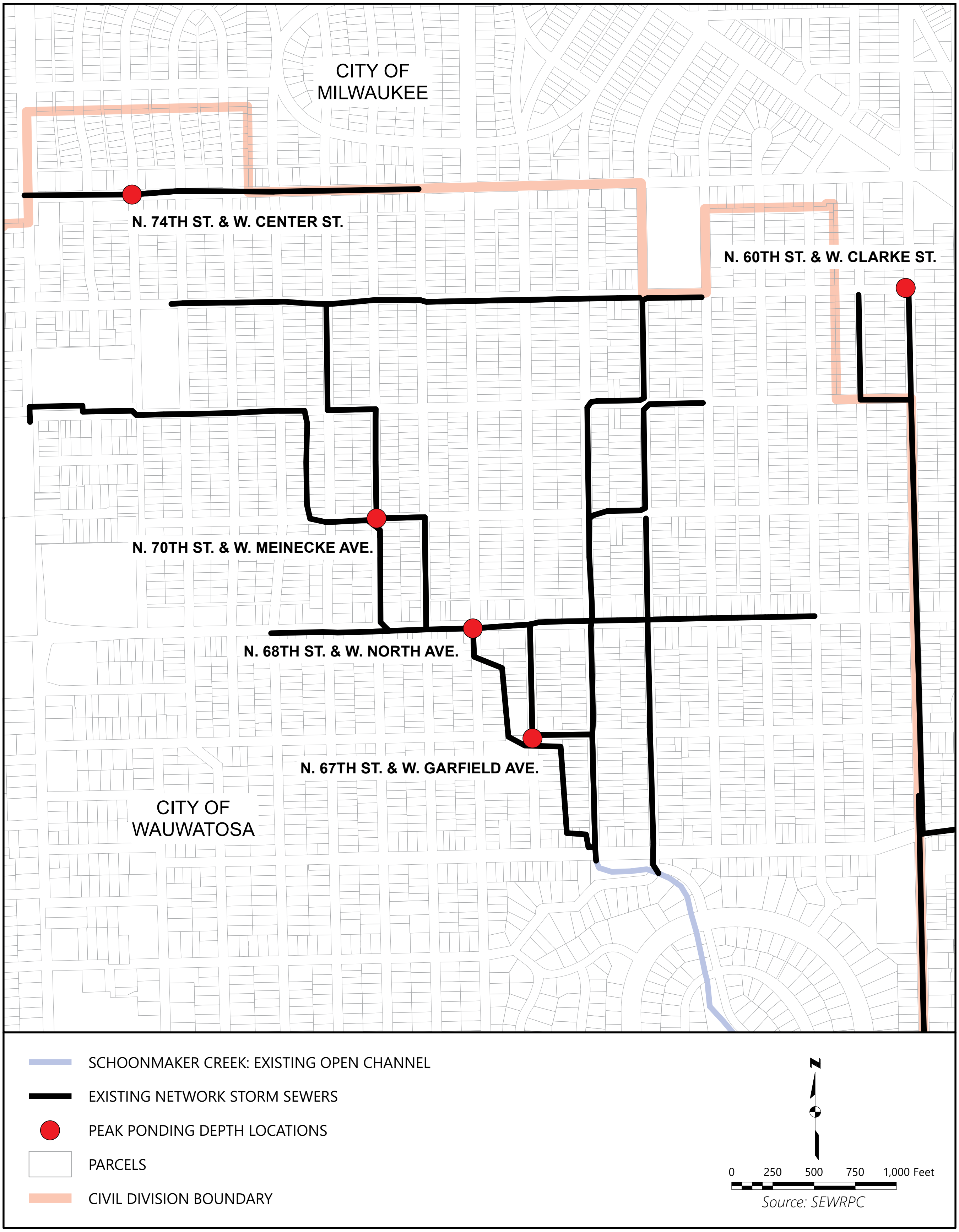
The updated existing conditions XPStorm model was run for the 50-, 10-, four-, two-, one-, and 0.2-percent-annual-probability rainfall events listed in Table 2.1. Based on the sewer network included in this model (Map 2.1), the existing City of Wauwatosa and City of Milwaukee storm sewer networks have capacity to convey the 10-percent-annual-probability event without street ponding. As discussed in a subsequent section, the Schoonmaker Creek enclosure from Milwaukee Avenue to south of W. State Street has a little less than a 10-percent-annual-probability event capacity.

Three of the four road bridges along the open channel portion of Schoonmaker Creek would be expected to be overtopped during events with a one-percent-annual-probability or less frequent. These Schoonmaker Creek bridges are located at Revere Avenue, Washington Circle, and Upper Parkway North.

XPStorm model results for the one-percent-annual-probability event for the Wauwatosa sewer area are represented two different ways on the maps included in this report. This is due to how the Schoonmaker Creek watershed was represented in the XPStorm model. On one set of maps ponding depths are shown graphically from the XPStorm grid for runoff that was not captured by a modeled sewer or street feature. The second set of maps depict the XPStorm results using different color highlights for the sewer and street reaches that were modeled explicitly. Reaches with street conveyance (ponding) are highlighted red. Reaches where the modeled storm sewers are surcharged are highlighted yellow. Surcharged pipes are under pressure flow conditions, with the hydraulic grade line being above the crown, or top, of the sewer but below the top of the adjacent manholes. A green color on the highlighted maps indicates the peak water level is below the crown of the sewer pipe. Thus those storm sewers are flowing partially full, and not under pressure flow conditions. Together these two map depictions provide a complete picture of XPStorm results for the Schoonmaker Creek Wauwatosa sewer area.

The updated existing conditions XPStorm model results for the one-percent-annual-probability 3-hour design storm predict significant street ponding at multiple intersections in the City of Wauwatosa (Table 2.3). Depths of ponding for that event range from 0.9 feet to 2.0 feet for the area from N. 74th Street and Center Street to N. 66th Street and W. Lloyd Street. The XPStorm model also indicates that there would be a significant amount of street conveyance for the one-percent-annual-probability event (Maps 2.4, 2.5).

Map 2.3
Schoonmaker Creek Watershed Reference Locations for Peak Ponding Depths



The peak ponding depths depicted on Map 2.4 were used to estimate the number of structures that would be impacted by the one-percent-annual-probability storm event. Structures were considered impacted where the one-percent-annual-probability storm ponding was six inches deep or greater. Due to the coarseness of the grid used to map the ponded areas within the XPStorm model, it was also assumed that structures less than 10 feet away from a flooded area would be affected by the one-percent-annual-probability flooding event. Based on these criteria, approximately 280 structures in the City of Wauwatosa sewer area and 8 structures in the City of Milwaukee sewer area may be impacted by peak storm ponding for the one-percent-annual-probability event.

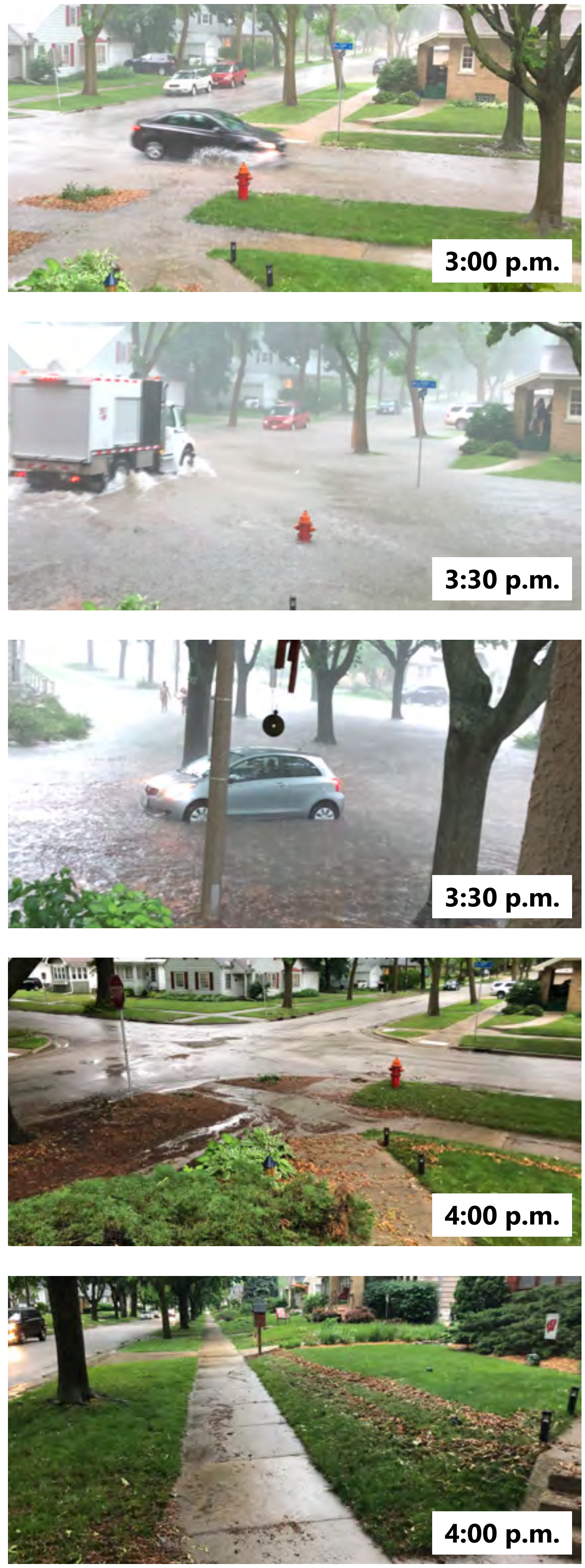
Schoonmaker Creek Floodplain

A US Army Corps of Engineers (USACE) HEC-RAS hydraulic model of the open channel and downstream enclosed portions of Schoonmaker Creek was developed from W. Lloyd Street to the confluence with the Menomonee River. Graphical Information System (GIS) topographic data in combination with the USACE tool HEC-GeoRAS were used to develop the HEC-RAS model stream valley cross-sections, channel and overbank lengths, bank stations, and roadway profiles for Schoonmaker Creek. Cross-section profiles were primarily defined using data extracted from the 2010 Milwaukee County Digital Terrain Model (DTM) obtained by LiDAR. As part of the MMSD Western Milwaukee Flood Management Project Phase 2A (Phase 2A), the enclosed section of Schoonmaker Creek downstream of W. State Street to the confluence with Menomonee River was daylighted and an initial section of levee was constructed in 2015. The November 2014 as-bid grading plans for the Phase 2A project were used to define cross-sections impacted by construction. Structural data including road, bridge, culvert, and enclosure dimensions were acquired from three primary sources: structural plans, the R.A. Smith, Inc. XPStorm model, and the 2010 Milwaukee County DTM. Data from all three sources were used in combination in the HEC-RAS model to best represent the hydraulic structures along Schoonmaker Creek.

Flood flows utilized in the Schoonmaker Creek hydraulic model were determined using the updated existing conditions XPStorm model. Peak flow rates for the critical duration 3-hour storm event with the existing land use and existing channel conditions were used in the HEC-RAS hydraulic model. Peak flows utilized in the HEC-RAS model are summarized in Table 2.4. These flows were used to develop the floodplain and floodway delineations.

In addition to the stream representation, an overland flow route was simulated in the HEC-RAS model from Milwaukee Avenue to the Menomonee River. The overland flow route was required for flood flows that exceeded the capacity of the enclosure at the

Figure 2.1
Flooding at N. 70th Street and W. Meinecke Avenue in Wauwatosa on June 18, 2018[a]



[a] *Photos were taken during a storm event that produced 2.7 inches of rain in 3 hours, which is approximately a 10-percent-annual-probability storm event.*

Source: SEWRPC

Table 2.3
Peak Roadway Ponding Depths in the Study Area During 100-Year 3-Hour Storm Event (XPStorm Model Results)

Location	Jurisdiction	Peak Ponding Depth (feet)
N. 74th Street and W. Center Street	City of Milwaukee	2.0
N. 60th Street and W. Clarke Street	City of Milwaukee	1.4
N. 70th Street and W. Meinecke Avenue	City of Wauwatosa	1.5
N. 68th Street and W. North Avenue	City of Wauwatosa	1.4
N. 67th Street and W. Garfield Avenue	City of Wauwatosa	0.9

Source: SEWRPC

downstream end of Schoonmaker Creek. The enclosure flow capacity was computed in the updated existing conditions XPStorm model as 630 cubic feet per second (cfs).[11] Downstream of Martha Washington Drive, the overland flow route splits at W. Martin Drive between N. 62nd Street and N. 60th Street, then subsequently converges back onto W. State Street and flows east. The overland flow path then drains to the east past the Phase 2A levee before discharging into the Menomonee River. The HEC-RAS flow optimization function was utilized to balance flows at the flow split at W. Martin Drive. Final flows pertaining to the overland flow route and the downstream enclosure are summarized in Table 2.5. Map 2.6 depicts the non-regulatory one-percent-annual-probability floodplain for Schoonmaker Creek from W. Lloyd Street to the Menomonee River.

The 50-, 10-, four-, two-, one-, and 0.2-percent-annual-probability floodplain mapping was initially completed using the HEC-GeoRAS automated delineation process, then subsequently edited manually, in detail, to ensure accuracy and completeness according to the 2010 Milwaukee County digital topographic map. Floodplain boundaries of the overland flow route along W. State Street and the daylighted section of Schoonmaker Creek were delineated manually in GIS using the 2014 Phase 2A as-bid grading plans. Additionally, the one-percent-annual-probability floodway for Schoonmaker Creek was drawn manually (Map 2.6). All floodplain and floodway boundaries were delineated using elevations in the North American Vertical Datum, 1988 (NAVD88).

Estimation of Potential Flood Damages

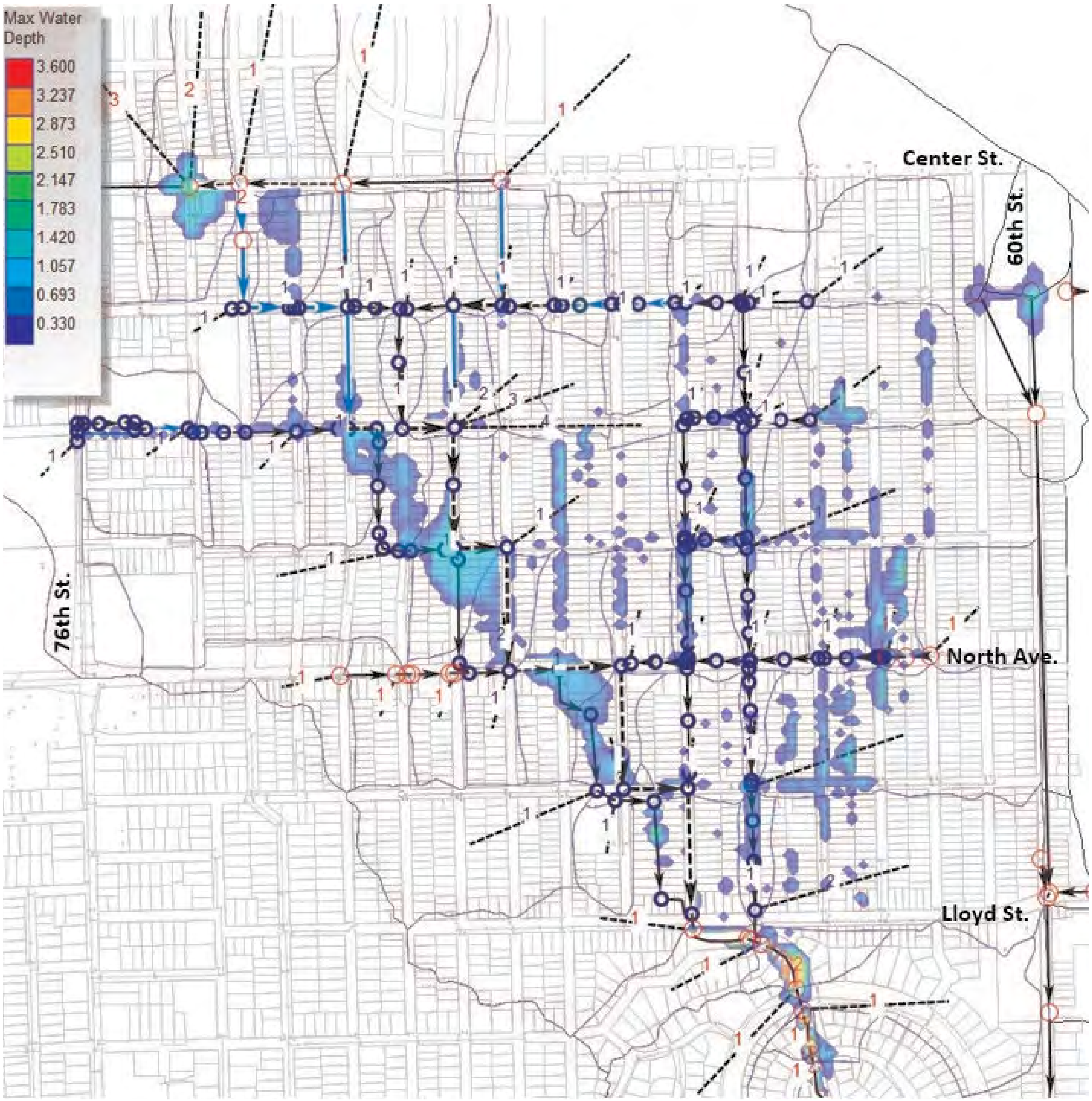
Flooding of Buildings

The methodology to develop the open channel and enclosure area floodplains was described above. Map 2.6 shows the extent of the non-regulatory one-percent-annual-probability floodplain for Schoonmaker Creek from W. Lloyd Street to W. State Street. Forty-six (46) structures are contained in the one-percent-annual-probability floodplain. This flood hazard exists primarily along Martha Washington Drive, W. Martin Drive, N. 62nd Street, N. 60th Street, and W. State Street. No structures are impacted by the one-percent-annual-probability floodplain in the open channel portion of Schoonmaker Creek from W. Lloyd Street to Milwaukee Avenue. The estimated number and types of buildings in each municipality that would be flooded during the 10-, two-, one-, and 0.2-percent-annual-probability floods on Schoonmaker Creek are included in Table 2.6. Thirteen structures are impacted by the 10-percent-annual-probability floodplain and 45 structures are flooded by the two-percent-annual-probability event. Forty-six structures are flooded by the one-percent-annual-probability event and 66 structures are impacted by the 0.2-percent-annual-probability floodplain.

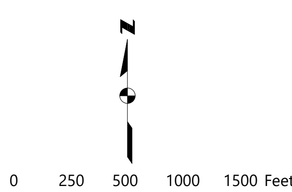
SEWRPC staff conducted a parcel-based analysis to estimate the damages that would be sustained by buildings as the result of the 10-, two-, one-, and 0.2-percent-annual-probability flood events. GIS was used to identify those parcels that are wholly or partially located within each of the floodplains, and then the structures were examined using 2010 aerial photographs to determine whether a principal building, such as a house, a commercial building, or an industrial building was located within each floodplain. For those parcels in which a principal building was located wholly or partially in the floodplain, the 2019 assessed value of improvements was obtained from the City of Wauwatosa. Assessment data was used to classify each principal building as residential, commercial, industrial, governmental, or other. For each principal building, the elevation of the ground at the building was determined from the 2010 Milwaukee County one-foot contours generated from the digital terrain model.

[11] *The maximum enclosure capacity of 630 cfs assumes a free outfall condition at the Menomonee River.*

Map 2.4
Schoonmaker Creek XPSTORM Grid Results Existing Conditions
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

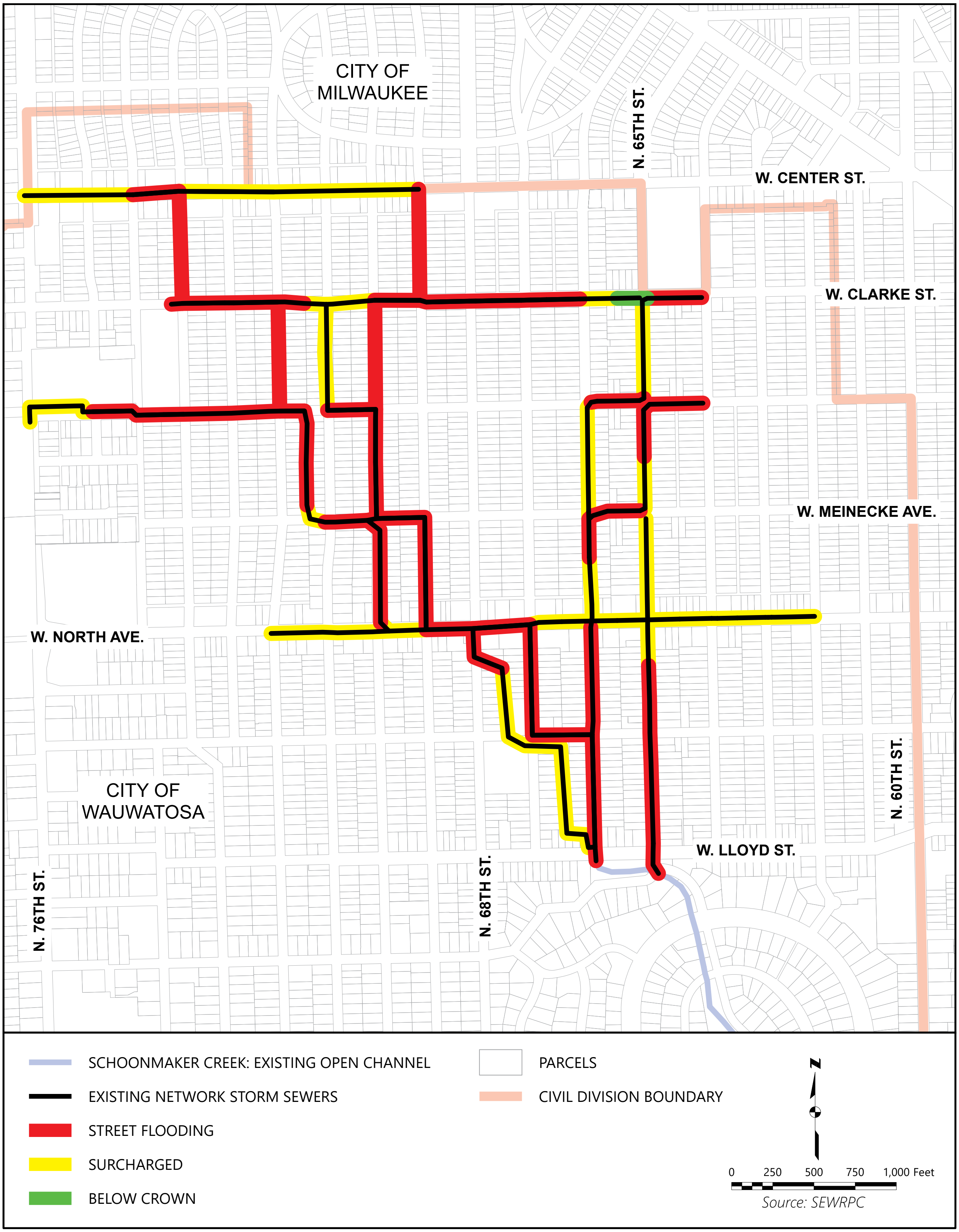


[a] Depth is reported in feet.



Source: SEWRPC

Map 2.5
Schoonmaker Creek XPSTORM Reach Results Existing Conditions
Peak Conveyance Results for 100-Year Recurrence Interval Storm



Source: SEWRPC

Table 2.4
Schoonmaker Creek Open Channel Peak Flow Rates Existing Land Use and Channel Conditions

Model River Station (Feet)	Location[b]	Peak Flow (cfs)[a]					
		50 Percent	10 Percent	4 Percent	2 Percent	1 Percent	0.2 Percent
5964	D/S of W. Lloyd Street	210	450	550	590	740	1,270
4868	U/S of Upper Parkway North	290	600	730	830	950	1,550
4089	U/S of W. Washington Boulevard	280	350	400	420	440	520
3068	U/S of Milwaukee Avenue	380	690	990	1,040	1,080	1,820

[a] *Percent-annual-probability flows in cubic feet per second (cfs).*

[b] *U/S = upstream and D/S = downstream.*

Source: SEWRPC

Table 2.5
Schoonmaker Creek Overland Flow Route and Enclosure Peak Flow Rates Existing Land Use and Enclosure Conditions

Model River Station (Feet)	Location[b]	Peak Flow (cfs)[a]					
		50 Percent	10 Percent	4 Percent	2 Percent	1 Percent	0.2 Percent
3068	Milwaukee Avenue to Menomonee River via enclosure	380	630	630	630	630	630
7268	U/S end of overland flow route at Milwaukee Avenue	0	60	360	410	450	1,190
4193	U/S end of N. 62nd Street flow split at intersection of Martha Washington Drive and W. Martin Drive	0	39	214	244	268	719
1614	U/S end of N. 60th Street flow split at intersection of Martha Washington Drive and W. Martin Drive	0	21	146	166	182	471

[a] *Percent-annual-probability flows in cubic feet per second (cfs).*

[b] *U/S = upstream.*

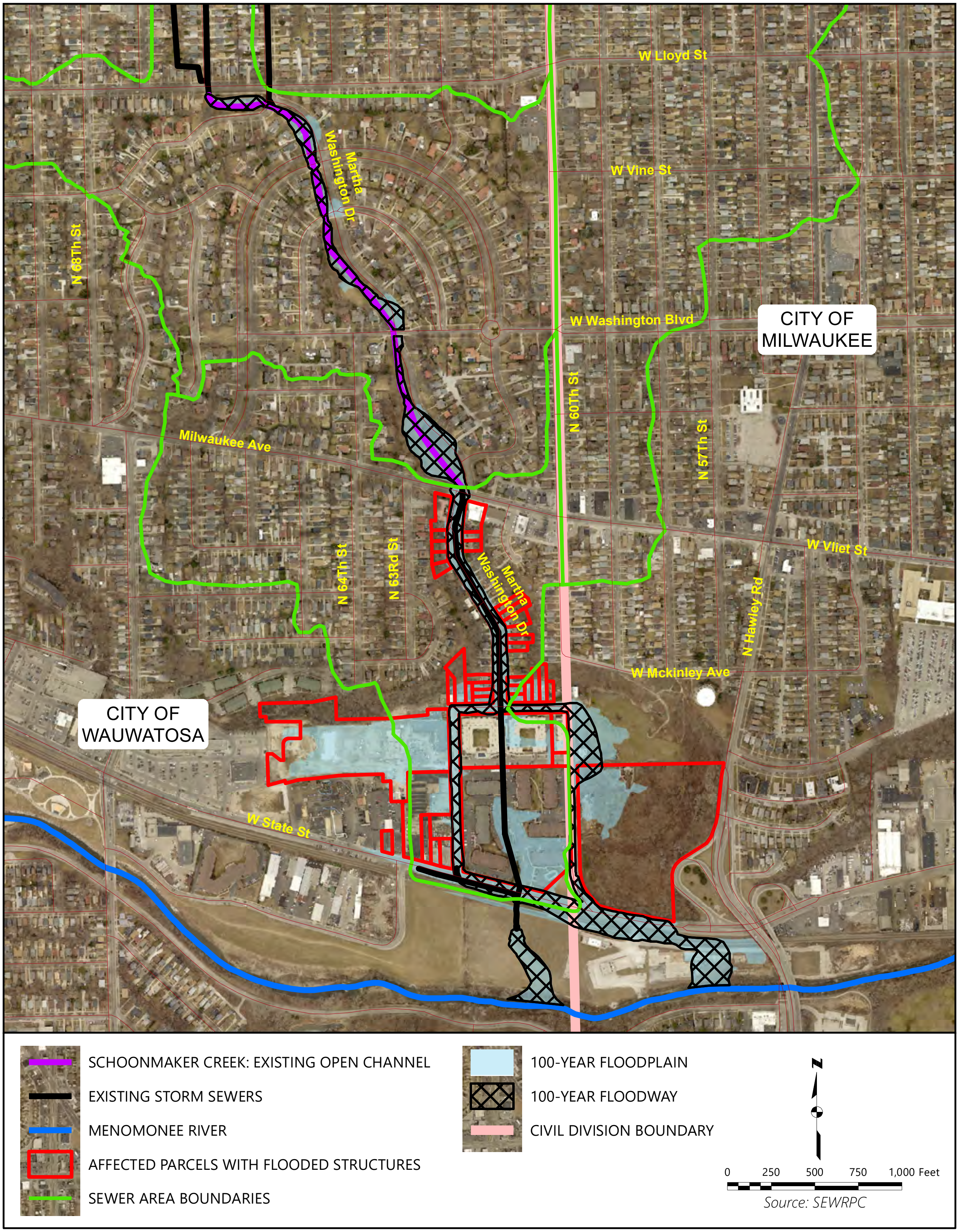
Source: SEWRPC

An assumption was made for the elevation of the first floors of the principal buildings for the Schoonmaker Creek damage calculation. For all building types, it was assumed that the first floor was one foot above the adjacent ground elevation. Flood elevations for the 10-, two-, one-, and 0.2-percent-annual-probability flood events were derived from the floodplain hydraulic modeling described above. Total market value with contents was assumed to be the 2019 assessed value of improvements times 1.5 if the depth of flooding was above the first floor elevation, or times 1.15 if the depth of flooding was below the first floor elevation (basement flooding only).

For each building, the first floor elevation was compared to the appropriate flood elevation. The extent of direct damage, such as the costs associated with cleaning, repairing, or replacing the structure and its contents, for each principal building was estimated as a percent of the total market value plus contents, based on standardized flood loss depth-damage curves prepared by the Federal Emergency Management Agency, USACE, and SEWRPC. Residential structures were assumed to have a basement, while commercial structures were assumed to not have basements for the purposes of estimating flood damages. Indirect damages, such as the costs associated with temporary evacuations, relocations, lost wages, lost production and sales, and the incremental costs of traffic detours, were estimated to be a percentage of direct damages, with indirect damages representing 15 percent of direct damages for residential buildings and 40 percent of direct damages for commercial and industrial buildings. The total damage for each flood event was the sum of direct and indirect damages.

The resulting total flood damages by municipality for the enclosure area structures are presented in Table 2.7. Total damages expected to be caused by the 10-, two-, one-, and 0.2-percent-annual-probability flood events for Schoonmaker Creek were determined to be $5.4 million, $8.2 million, $8.4 million, and $11.7 million, respectively.

Map 2.6
Schoonmaker Creek Non-Regulatory One-Percent-Annual-Probability Floodplain



Source: SEWRPC

Table 2.6
Inventory of Buildings Located Within 10- Through 0.2-Percent-Annual-Probability Floodplains[a]

	Number of Buildings Located Within:											
	10-Percent-Annual-Probability Floodplain			Two-Percent-Annual-Probability Floodplain			One-Percent-Annual-Probability Floodplain			0.2-Percent-Annual-Probability Floodplain		
Municipality	Commercial	Recreational	Residential	Commercial	Recreational	Residential	Commercial	Recreational	Residential	Commercial	Recreational	Residential
City of Wauwatosa	5	0	8	14	0	28	14	0	29	20	0	43
City of Milwaukee	0	0	0	1	2	0	1	2	0	1	2	0
Total by Structure Type	5	0	8	15	2	28	15	2	29	21	2	43
Total by Storm Event	13			45			46			66		

[a] *This table represents buildings affected by flooding from Schoonmaker Creek between W. Lloyd Ave. and the Menomonee River. This count does not include buildings affected by local street ponding.*

Source: SEWRPC

Table 2.7
Schoonmaker Creek Total Flood Damages

Municipality	**10-Percent-Annual-Probability (10-year recurrence interval) Total Flood Damages ($)**	**Two-Percent-Annual-Probability (50-year recurrence interval) Total Flood Damages ($)**	**One-Percent-Annual-Probability (100-year recurrence interval) Total Flood Damages ($)**	**0.2-Percent-Annual-Probability (500-year recurrence interval) Total Flood Damages($)**
City of Wauwatosa	5,422,990	7,950,910	8,165,170	10,977,020
City of Milwaukee	0	222,310	234,470	684,600
Total	5,422,990	8,173,220	8,399,640	11,661,620

Source: SEWRPC

Expected Annual Flood Risks

The expected annual flood damage risk for a stream reach was defined as the sum of the direct and indirect monetary flood losses resulting from floods of all probabilities, each weighted by its probability of occurrence or exceedance in any year. This methodology was used to compute expected annual flood risks for Schoonmaker Creek under existing land use conditions. The inventory of buildings in the 10-, two-, one, and 0.2-percent-annual-probability floodplains is set forth in Table 2.6. The expected annual flood risks by municipality are presented in Table 2.8. The average annual flood damage for Schoonmaker Creek was estimated to be $3.2 million for the City of Wauwatosa and approximately $16,300 for the City of Milwaukee.

Table 2.8
Schoonmaker Creek Average Annual Flood Damages

Municipality	Average Annual Flood Damages ($)
City of Wauwatosa	3,155,108
City of Milwaukee	16,334

Source: SEWRPC

ALTERNATIVES TO ADDRESS FLOODING 3

Sixteen alternatives were developed to reduce flooding risks in three areas of the Schoonmaker Creek watershed as shown in Map 3.1. These three areas were used to locate the portion of the watershed impacted for each alternative. The 16 alternatives consist of feasible potential options to reduce flooding for the one-percent-annual-probability event. The first three alternatives were developed to alleviate flooding in the enclosure area of the watershed from Milwaukee Avenue to the Menomonee River. Alternatives 1, 2, and 3 only mitigate the 46 structures in the one-percent-annual-probability floodplain as discussed above. Alternatives 4 through 16 protect the 46 impacted structures in the enclosure area as well as reduce street ponding in the City of Wauwatosa sewer area (288 potentially impacted structures). All the alternatives were evaluated for their impact to the open channel area of Schoonmaker Creek.

A variety of feasible alternatives were evaluated as part of this study, in four broad categories. The four categories include conveyance improvements (larger storm sewers), detention storage, extension of the open channel, and conveyance improvements with a channel bypass (tunnel or storm sewer). Each alternative was evaluated using an XPStorm model, with the alternative model configuration being built from the updated existing conditions model.

Several assumptions were made when developing the alternatives; all are designed to drain by gravity (no pumping required), underground features have at least four feet of cover to existing ground, storm sewer inverts were generally maintained for new or additional pipes, and the Menomonee River water levels were at nonflood stage (within its banks) for all alternatives as described previously.

Each of the 16 alternatives discussed below has a bulleted list of included features in the broad categories of sewer, tunnel, channel, bridge, detention, enclosure, existing open channel improvement, and dam as applicable.

3.1 ALTERNATIVES TO ADDRESS FLOODING AT ENCLOSURE AREA

The first three alternatives include storm sewer improvements and/or storage options to reduce the risk of street flooding in the enclosure area and mitigate flooding of the 46 structures in the one-percent-annual-probability floodplain.

Alternative 1 – Relief Pipe at Enclosure

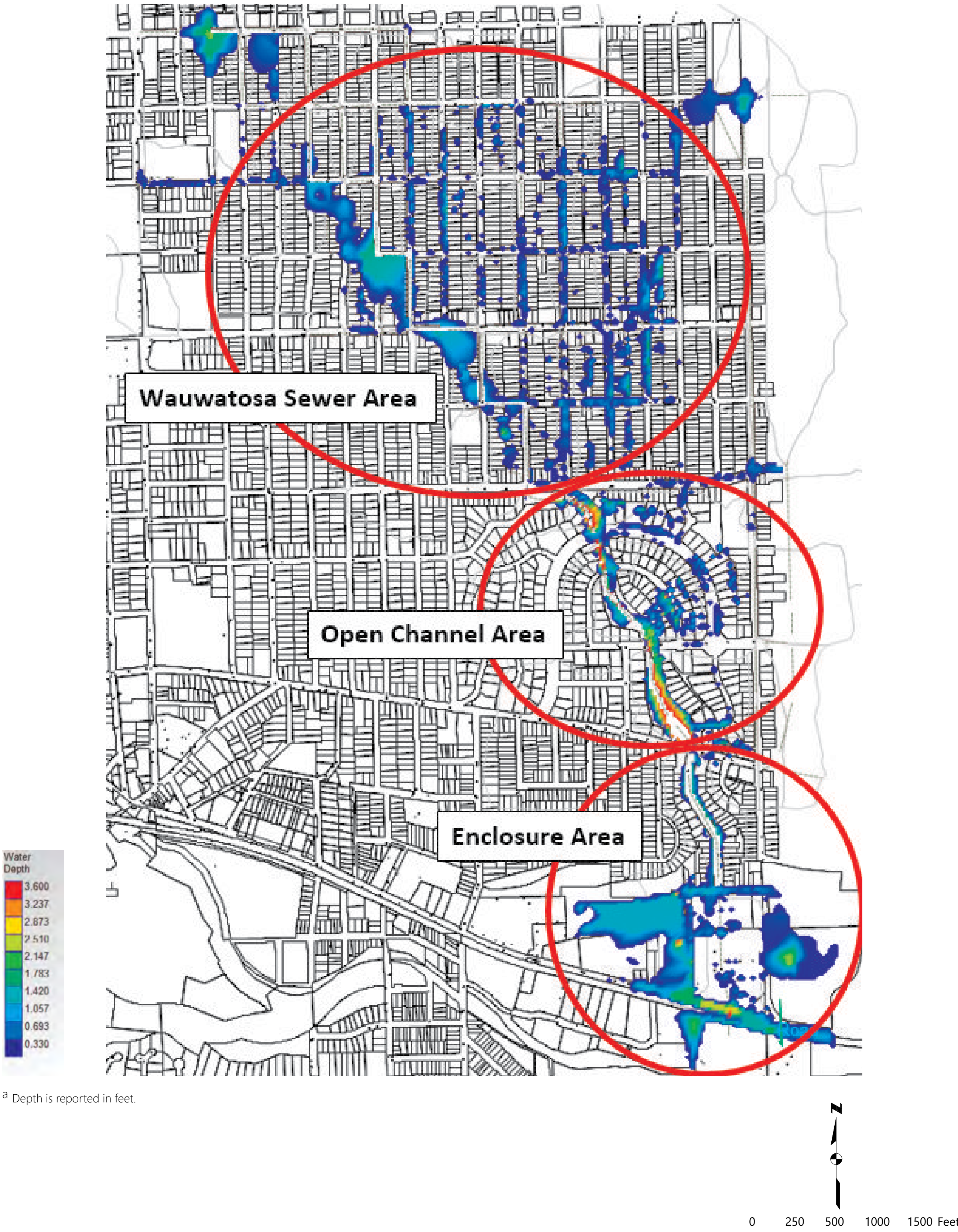
Alternative 1 consists of an additional storm sewer line in the lower enclosure area to minimize the surface flooding for the one-percent-annual-probability event between Milwaukee Avenue and the Menomonee River (Map 3.2). The alignment of the additional storm sewer is included in Map 3.2, and pipe details are listed below. In total approximately 3,080 feet of storm sewer would be required. Under Alternative 1, it is estimated that a one-percent-annual-probability storm event would not cause any flood damages to the 46 structures within the existing conditions one-percent-annual-probability floodplain between Milwaukee Avenue and W. State Street.

- ENCLOSURE
    - 5-ft x 6-ft reinforced concrete box culvert (RCB) Milwaukee Avenue to W. Martin Drive
    - 5-ft x 10-ft RCB W. Martin Drive to the Menomonee River

Alternative 2 – Relief Pipe at Enclosure with Storage

Alternative 2 is similar to Alternative 1 but includes an additional storm sewer line plus excavation of detention storage in the Hawthorne Glen area. This alternative was sized to minimize surface flooding for the one-percent-annual-probability event between Milwaukee Avenue and the Menomonee River (Map 3.3). Map 3.3 depicts the alignment of the additional storm sewer and detention pond location, and the Alternative 2 feature details are listed below. Approximately 3,270 feet of new storm sewer would be needed for this alternative. The Alternative 2 proposed detention storage did reduce the enclosure pipe

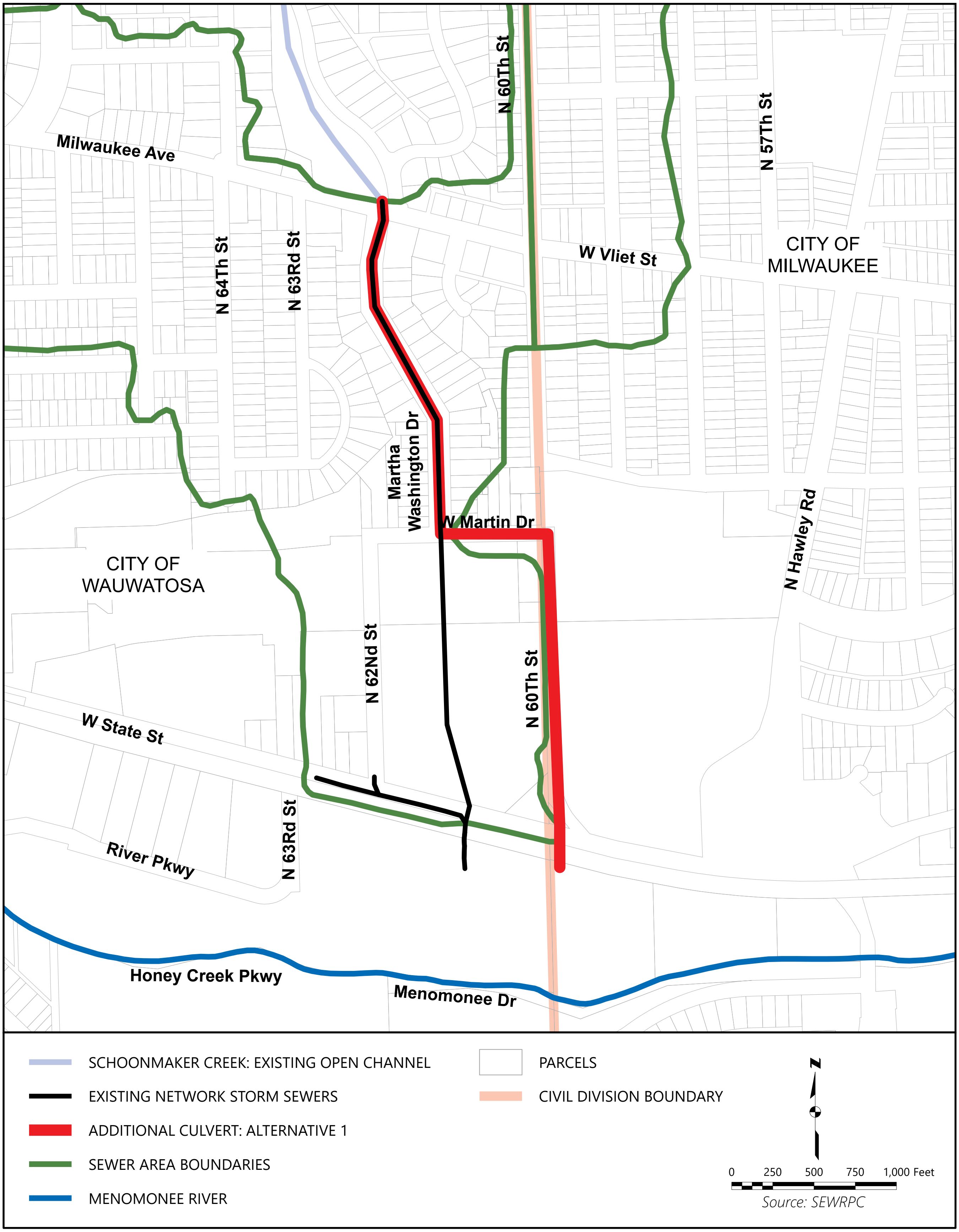
Map 3.1
Schoonmaker Creek Study Focus Areas With July 2010 Storm Results[a]



[a] Depth is reported in feet.

Source: SEWRPC

Map 3.2
Schoonmaker Creek Alternative 1: Relief Pipe at Enclosure



Map 3.3
Schoonmaker Creek Alternative 2: Relief Pipe at Enclosure with Storage

Source: SEWRPC

size as compared to Alternative 1 for a portion of its length. Alternative 2 eliminates the damages to the 46 structures within the one-percent-annual-probability floodplain between Milwaukee Avenue and W. State Street. The Alternative 2 XPStorm model results indicate that 23.8 acre-feet (ac-ft) of storage would be utilized at the Hawthorne Glen detention facility for the one-percent-annual-probability event.

- DETENTION FACILITY AT HAWTHORNE GLEN
    - 3.3 acres for top surface area
    - 11 feet deep, 3:1 side slopes
    - 29.2 acre feet (ac-ft) of storage available

- ENCLOSURE
    - 5-ft x 6-ft RCB Milwaukee Avenue to W. Martin Drive
    - 5-ft x 10-ft RCB W. Martin Drive to inlet at detention facility
    - 3-ft reinforced concrete pipe (RCP) along N. 60th Street between inlet and outlet of detention facility
    - 5-ft x 6-ft RCB outlet of detention facility to the Menomonee River

Alternative 3 – Inline Storage

Alternative 3 consists of an earthen dam placed at the downstream end of the open channel section of Schoonmaker Creek, just upstream of Milwaukee Avenue. Excavation would be required upstream of the dam to provide the necessary storage to protect 46 structures in the enclosure area between Milwaukee Avenue and W. State Street from flood damages during the one-percent-annual-probability event (Map 3.4). The storage volume required to accomplish this would be 33.2 ac-ft for the one-percent-annual-probability event. The location of the dam is included in Map 3.4, and the Alternative 3 feature details are listed below.

- EARTHEN DAM
    - 3.3 acres would be inundated
    - Excavate 22,000 cubic yards (CY) to gain storage
    - Includes a 7-foot vertical cut to gain required storage volume
    - Dam maximum height of 18 feet with 3:1 side slopes
    - 5-ft x 10-ft RCB outlet pipe through dam

Alternative 3 would also require the buyout of one home and replacement of one driveway. Martha Washington Drive would also be lost in the detention area as shown on Map 3.4. The required excavation would extend into 12 adjacent private properties and also necessitate the removal of approximately 80 trees. The Alternative 3 earthen dam would most likely be rated a High Hazard Dam and would require a dam failure analysis and hydraulic shadow mapping. Due to the anticipated High Hazard rating, the design plans and specifications for the dam would require approval from the Wisconsin Department of Natural Resources. The dam would also require an operation and maintenance plan, emergency operating procedures, and be inspected every four years.

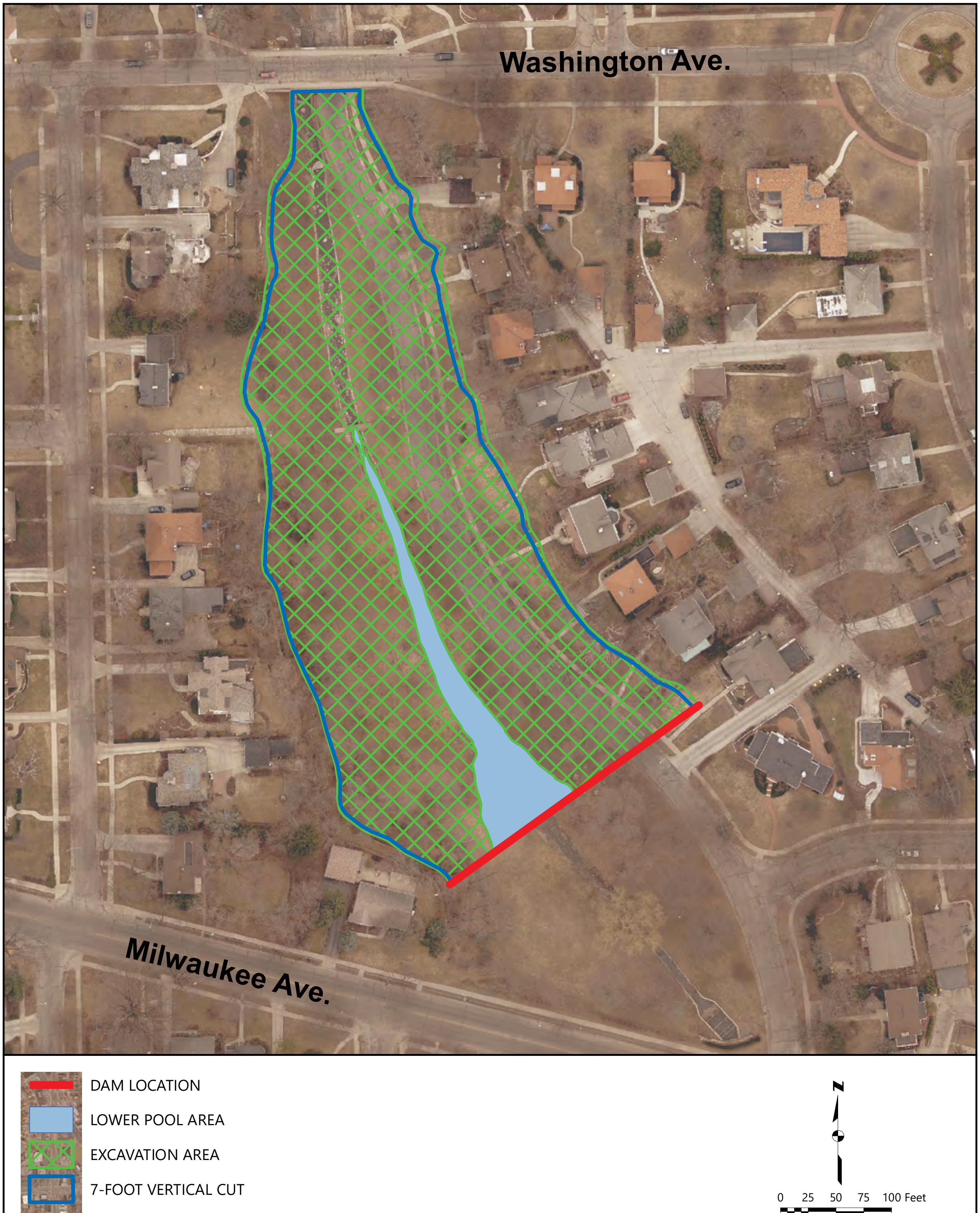
3.2 ALTERNATIVES DESIGNED TO ADDRESS WAUWATOSA SEWER AREA STREET PONDING

Alternatives 4 through 16 were developed to minimize flooding in the enclosure area for the one-percent-annual-probability event and also significantly reduce surface ponding for storms up to either the four- or the one-percent-annual-probability event in the Wauwatosa sewer area. The alternatives are organized in this report by type of improvement, in the categories of storm sewer, open channel, storage, and storm sewer and channel bypass.

Storm Sewer Conveyance Alternatives

These alternatives all have storm sewer improvements in the Wauwatosa sewer area to reduce street ponding. Alternatives 4, 5, and 6 in the City of Wauwatosa also include sewer improvements in the enclosure area to protect 46 structures in the enclosure area from surface flooding during the one-percent-annual-probability storm. Alternatives 7 and 8 consist of improvements to a City of Milwaukee storm sewer network only.

Map 3.4
Schoonmaker Creek Alternative 3: Inline Storage



Source: SEWRPC

Alternative 4 – 25-Year Sewer

Alternative 4 consists of increasing capacity in the current City of Wauwatosa sewer system through a combination of sewer replacements and new relief sewers in order to reduce street ponding during a four-percent-annual-probability (25-year recurrence interval) storm event (Map 3.5). Alternative 4 pipe improvements were originally developed by RA Smith, Inc. and the alternative was called the 10-year Design Storm Sewer (Appendix A).[12] This alternative was analyzed to evaluate the performance of a less extensive storm sewer improvement. Alternative 4 also includes a relief sewer in the enclosure area to eliminate the surface flooding for the one-percent-annual-probability event between Milwaukee Avenue and the Menomonee River (Map 3.6). Map 3.5 depicts the alignment of the storm sewers to be replaced or added, and pipe details are listed below. This alternative protects the 46 structures from flood damage during the one-percent-annual-probability storm event. Alternative 4 also incorporates bridge improvements at three locations along the open channel portion of Schoonmaker Creek (Map 3.6).

The open channel section of Schoonmaker Creek currently experiences erosion problems during intense storm events. The upsized sewer system included in this alternative would increase peak flows through the open channel. In order to reduce the impact of these increased flows from causing erosion problems, Alternative 4 includes removal of the existing channel retaining wall, regrading of the channel banks, and a riprap lining. The improved channel was designed such that the channel bottom is at least 10 feet wide and that the channel banks have a slope of 2:1 or shallower, which gives the open channel a larger flow volume capacity (Figure 3.1). For planning purposes armoring the channel to the 10-percent-annual-probability event was selected, and this assumption will be re-evaluated and refined if this option is chosen for future work. This channel modification does not increase the maximum water surface elevation for events 10-percent-annual-probability or less frequent.

- SEWER
  - Full sewer schedule can be found in Appendix D
  - New pipes range from 2.5-ft to 7-ft RCP
  - Total length of sewer improvements of 9,900 feet

- BRIDGE
  - Additional 5-ft x 7-ft RCB at Revere Avenue, Washington Circle, and Upper Parkway

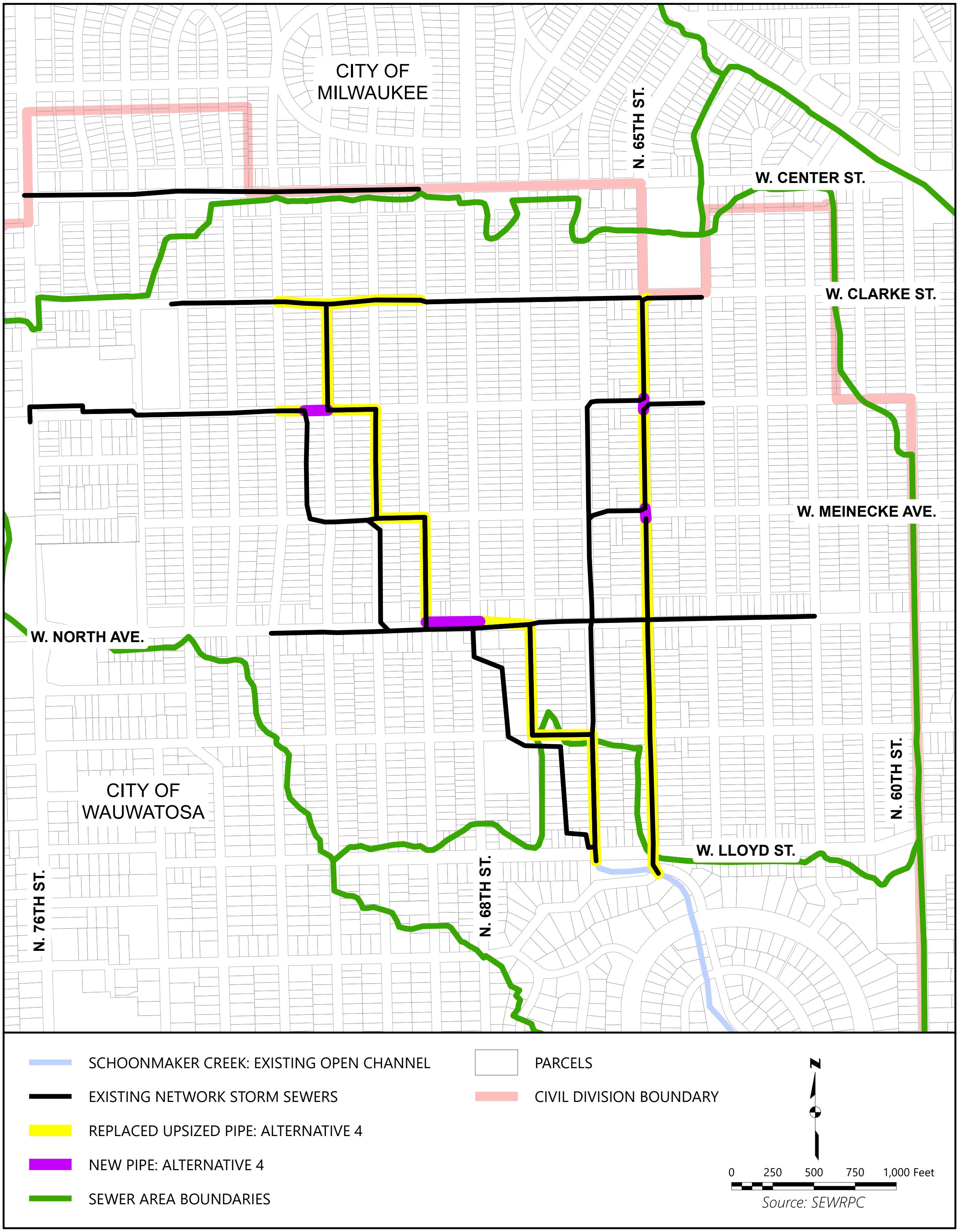
- EXISTING OPEN CHANNEL IMPROVEMENT
  - Removal of existing retaining walls along the open channel section
  - Regrade channel banks to minimum 2:1 horizontal-to-vertical side slope
  - Installation of riprap along the open channel
  - Removal of approximately 44 trees

- ENCLOSURE
  - 5-ft x 7-ft RCB Milwaukee Avenue to W. Martin Drive
  - 2-5-ft x 6-ft RCB W. Martin Drive to the Menomonee River

The remaining one-percent-annual-probability street ponding in the Wauwatosa sewer area with the Alternative 4 improvements is shown on Maps 3.7 and 3.8. Comparing the street ponding of Alternative 4 to existing conditions (Maps 2.4 and 2.5), street ponding is eliminated for the southern and eastern portions of the Wauwatosa sewer area, but not for the northwest portion of the sewer system.

[12] *The RA Smith, Inc evaluation used the 24-hour storm events to develop alternatives, hence the sewer pipes for this alternative were sized for the 10-year 24-hour storm event. Those same sewer pipe sizes can convey the 25-year 3-hour storm event for this analysis.*

Map 3.5
Schoonmaker Creek Alternative 4: 25-Year Sewer



Map 3.6
Bridge and Enclosure Area Improvement Locations for Alternatives: 4, 5, 6, 9, 10, 11, 12, and 16

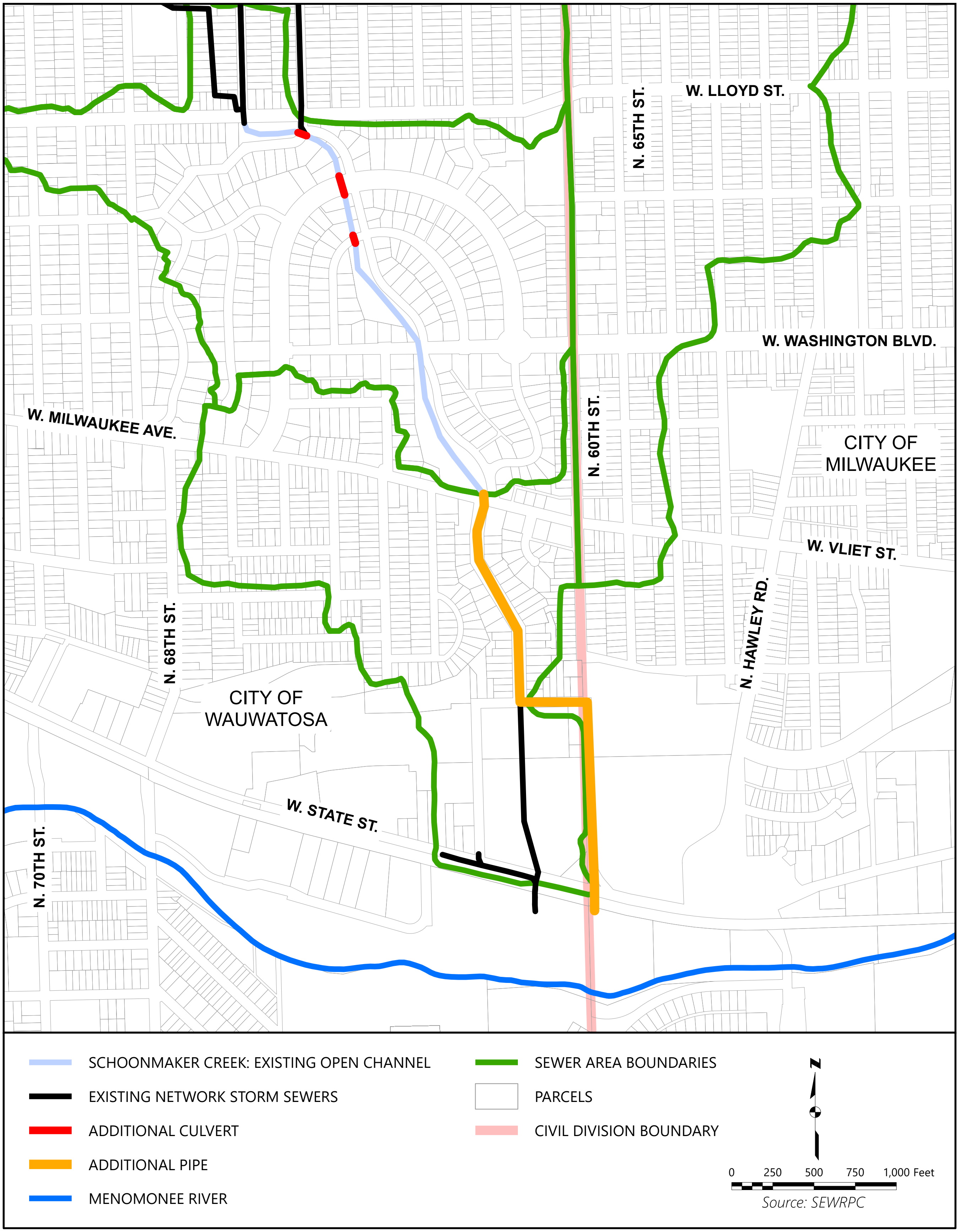
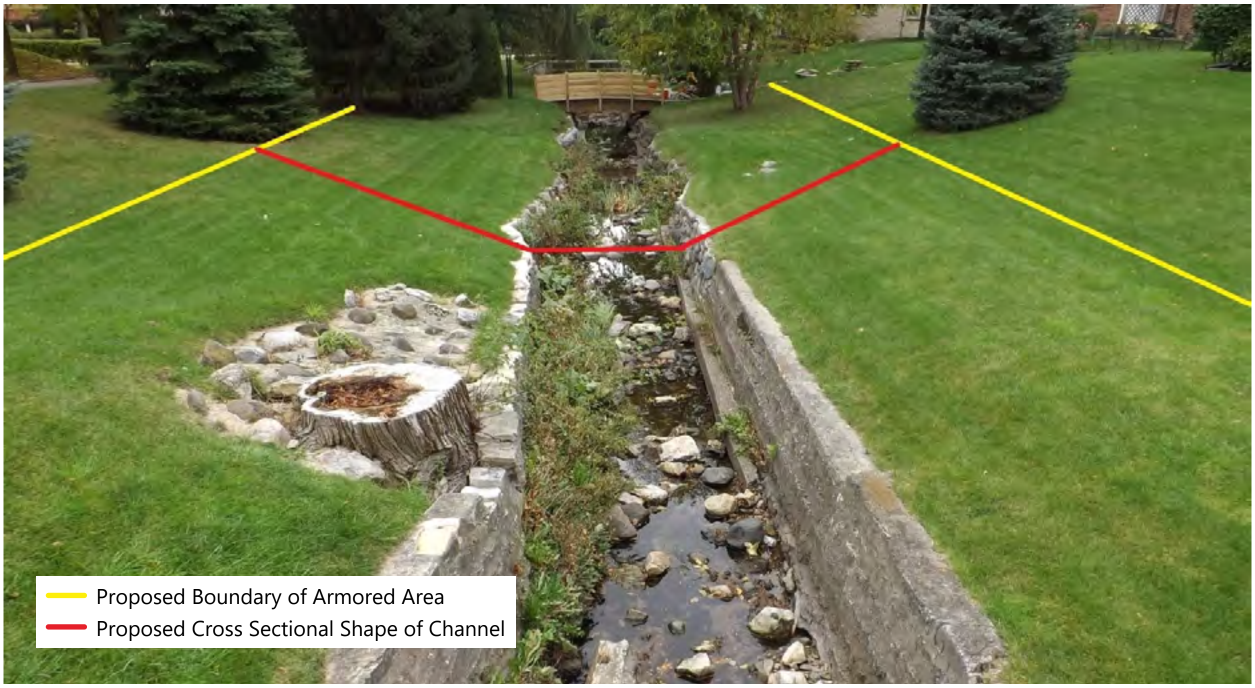
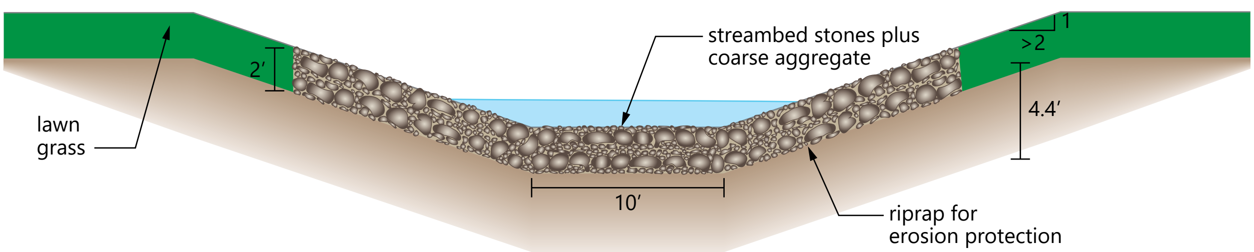


Figure 3.1
Schoonmaker Creek Restored Channel Cross Sections

Proposed Cross Section Shown Looking Downstream
from the Channel Crossing at Washington Circle



Typical Schoonmaker Creek Restored Channel Cross Section



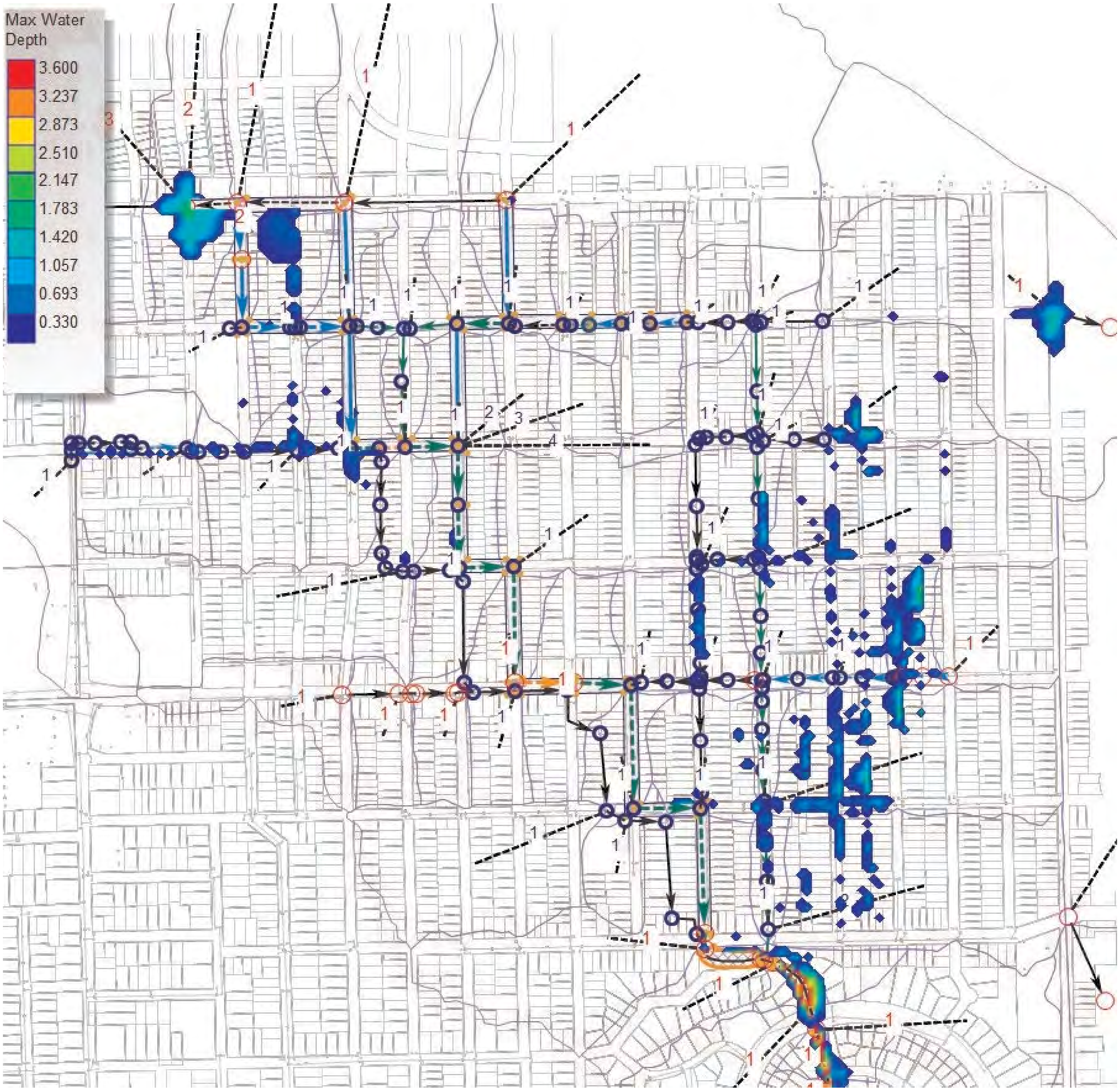
Source: SEWRPC

Alternative 5 – 100-Year Sewer

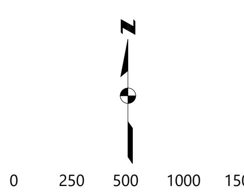
Under Alternative 5, the current sewer system in the City of Wauwatosa would be enlarged through a combination of sewer replacement and new relief sewers in order to reduce street ponding during a one-percent-annual-probability (100-year recurrence interval) storm event (Map 3.9). Alternative 5 also incorporates a relief sewer in the enclosure area to minimize surface flooding for the one-percent-annual-probability event between Milwaukee Avenue and the Menomonee River (Map 3.6). The alignment of the storm sewers to be replaced or added is included in Map 3.9, and pipe details are listed below. This alternative protects the 46 structures from flooding damage during the one-percent-annual-probability storm event. Alternative 5 also includes bridge improvements at three locations along the open channel portion of Schoonmaker Creek (Map 3.6), as well as the open channel improvements as described for Alternative 4.

- SEWER
  - Full sewer schedule can be found in Appendix D
  - New pipes range from 2-ft to 8-ft RCP
  - Total length of sewer improvements of 12,900 feet

Map 3.7
Schoonmaker Creek XPSTORM Grid Results Alternatives 4 and 13
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

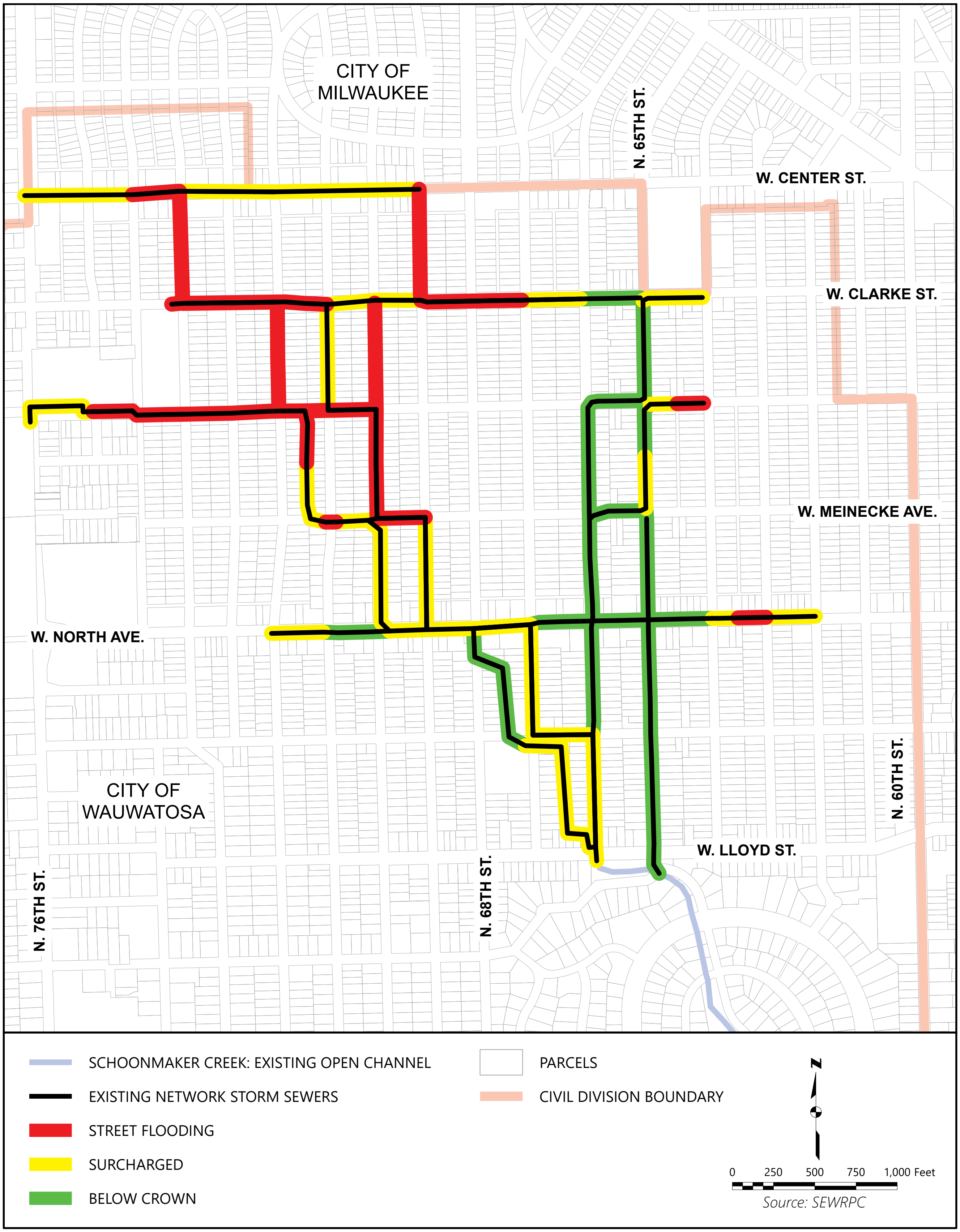


[a] Depth is reported in feet.



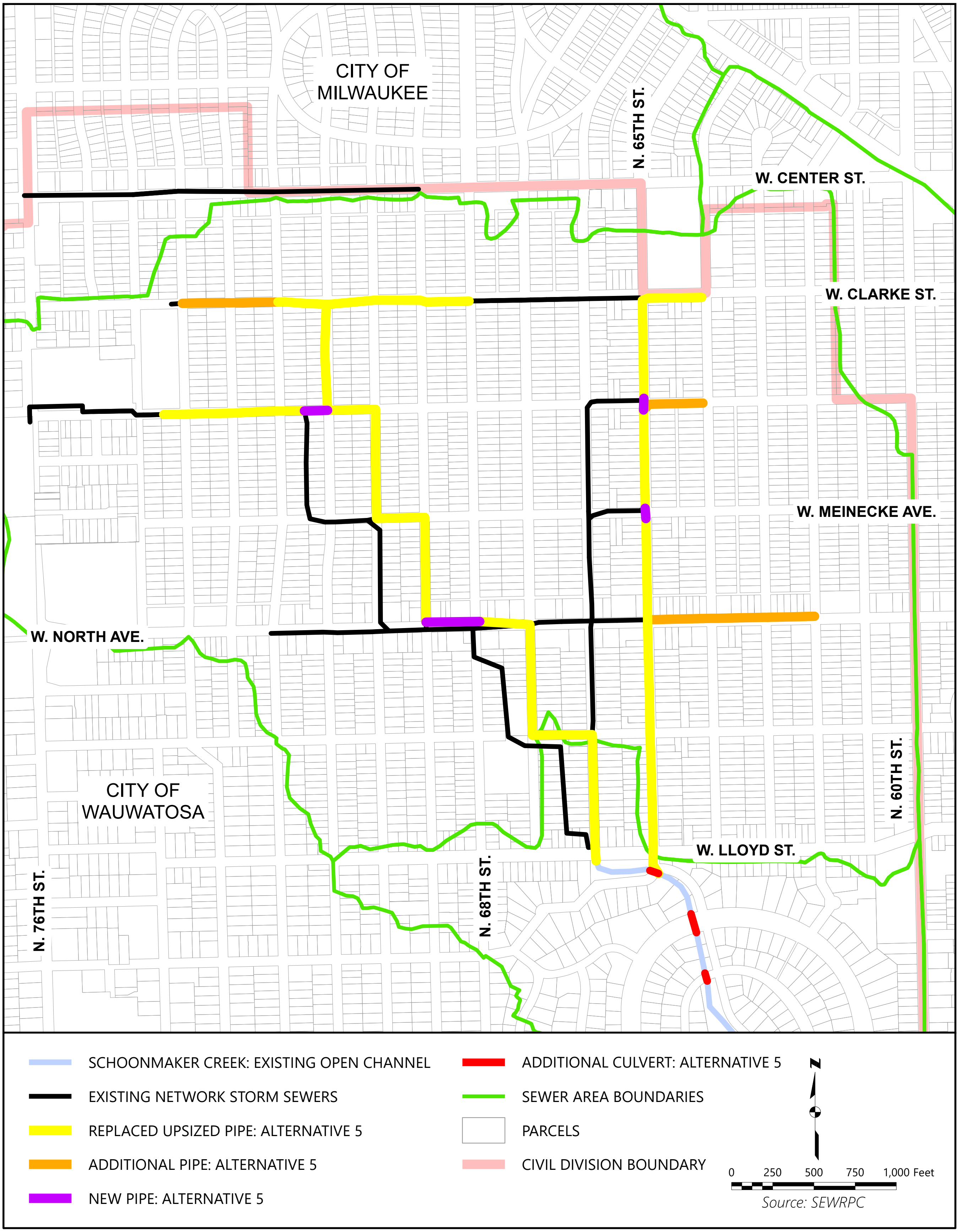
Source: SEWRPC

Map 3.8
Schoonmaker Creek XPSTORM Reach Results Alternatives 4 and 13
Peak Conveyance Results for 100-Year Recurrence Interval Storm



Source: SEWRPC

Map 3.9
Schoonmaker Creek Alternative 5: 100-Year Recurrence Interval Sewer



- BRIDGE
  - Additional 5-ft x 5-ft RCB at Revere Avenue
  - Additional 5-ft x 6-ft RCB at Washington Circle and Upper Parkway

- EXISTING OPEN CHANNEL IMPROVEMENT
  - Removal of existing retaining walls along the open channel section
  - Regrade channel banks to minimum 2:1 horizontal-to-vertical side slope
  - Installation of riprap along the open channel
  - Removal of approximately 44 trees

- ENCLOSURE
  - 6-ft x 6-ft RCB at inlet at Milwaukee Avenue
  - 6-ft x 9-ft RCB downstream of inlet to W. Martin Drive
  - 2-6-ft x 7-ft RCB W. Martin Drive to the Menomonee River

The remaining one-percent-annual-probability street ponding in the Wauwatosa sewer area with the Alternative 5 improvements is shown on Maps 3.10 and 3.11. Comparing the street ponding of Alternative 5 to existing conditions (Maps 2.4 and 2.5), street ponding is essentially eliminated for the one-percent-annual-probability storm, except for the W. Center Street area.

Alternative 6 – 100-Year Sewer Extended

Alternative 6 builds on Alternative 5, with the goal of reducing the ponding on W. Center Street from N. 72nd Street to N. 74th Street as shown on Map 2.4. Alternative 6 consists of all the features of Alternative 5 plus additional 4-foot diameter sewer pipes as listed below (Map 3.12). These improvements to the current sewer system in the City of Wauwatosa would reduce street ponding during a one-percent-annual-probability (100-year recurrence interval) storm event. Alternative 6 also includes a relief sewer in the enclosure area to minimize the surface flooding for the one-percent-annual-probability event between Milwaukee Avenue and the Menomonee River (Map 3.6). The alignment of the new or replacement storm sewers is included in Map 3.12, and pipe details are listed below. This alternative protects the 46 structures in the enclosure from flood damage during the one-percent-annual-probability storm event. Alternative 6 also requires bridge improvements at three locations along the open channel portion of Schoonmaker Creek (Map 3.6), as well as the open channel improvements as described for Alternative 4.

- SEWER
  - Sewer pipe schedule for Alternative 5 can be found in Appendix D
  - New 4-ft RCP from W. Center Street to W. Clarke Street along N. 73rd Street and N. 69th Street
  - New 4-ft RCP from N. 73rd Street to N. 72nd Street on W. Clarke Street
  - Total length of sewer improvements of 14,700 feet

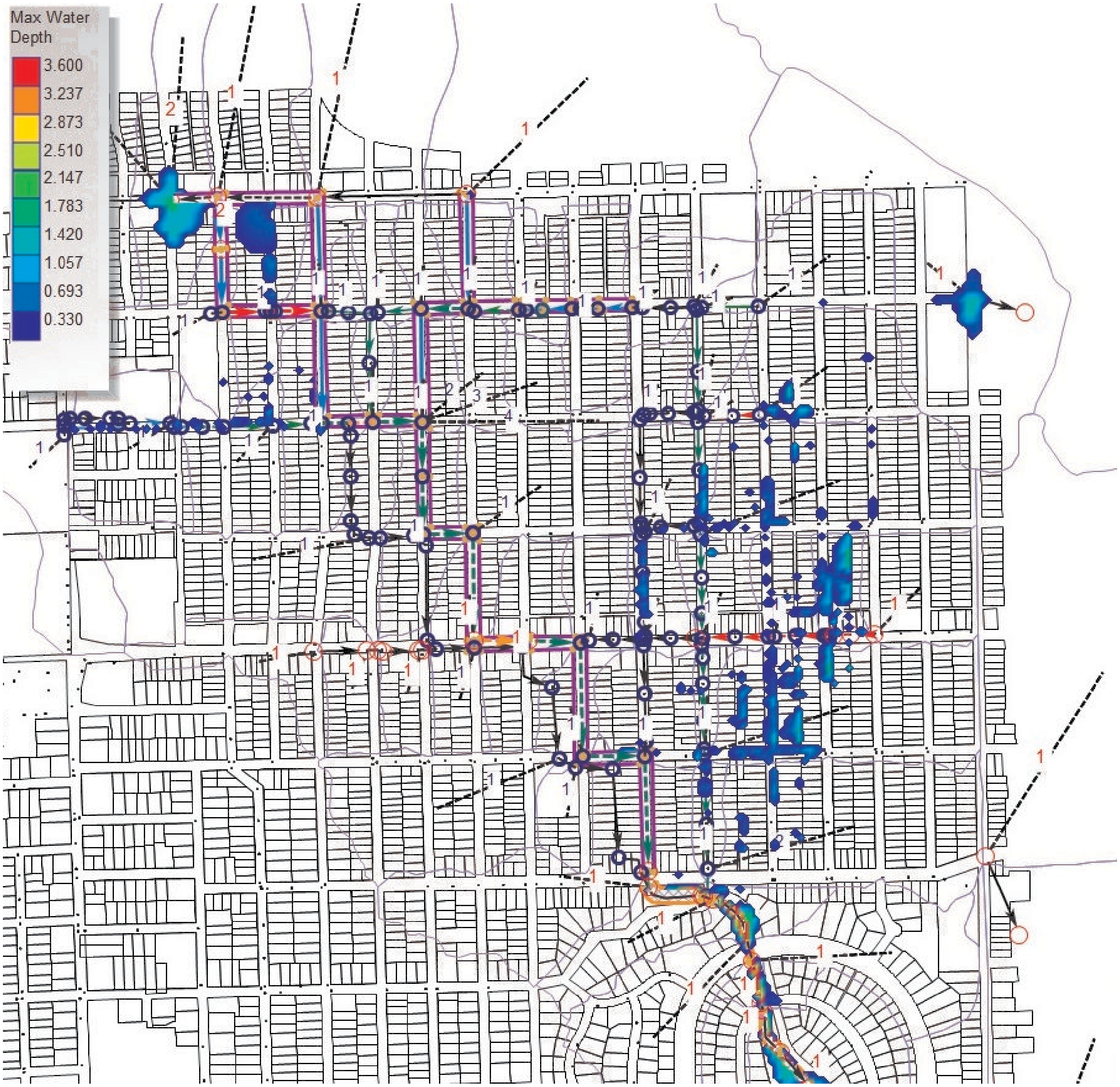
- BRIDGE
  - Additional 5-ft x 5-ft RCB at Revere Avenue
  - Additional 5-ft x 6-ft RCB at Washington Circle and Upper Parkway

- EXISTING OPEN CHANNEL IMPROVEMENT
  - Removal of existing retaining walls along the open channel section
  - Regrade channel banks to minimum 2:1 horizontal-to-vertical side slope
  - Installation of riprap along the open channel
  - Removal of approximately 44 trees

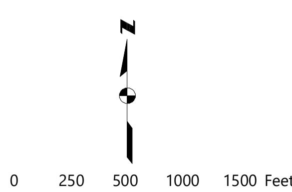
- ENCLOSURE
  - 6-ft x 6-ft RCB at inlet at Milwaukee Avenue
  - 6-ft x 9-ft RCB downstream of inlet to W. Martin Drive
  - 2-6-ft x 7-ft RCB W. Martin Drive to the Menomonee River

The remaining one-percent-annual-probability street ponding in the City of Wauwatosa with the Alternative 6 improvements is shown on Maps 3.13 and 3.14. Comparing the Wauwatosa sewer area street ponding of Alternative 6 to existing conditions (Maps 2.4 and 2.5), street ponding is essentially eliminated for this

Map 3.10
Schoonmaker Creek XPSTORM Grid Results Alternatives 5, 14, and 16
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

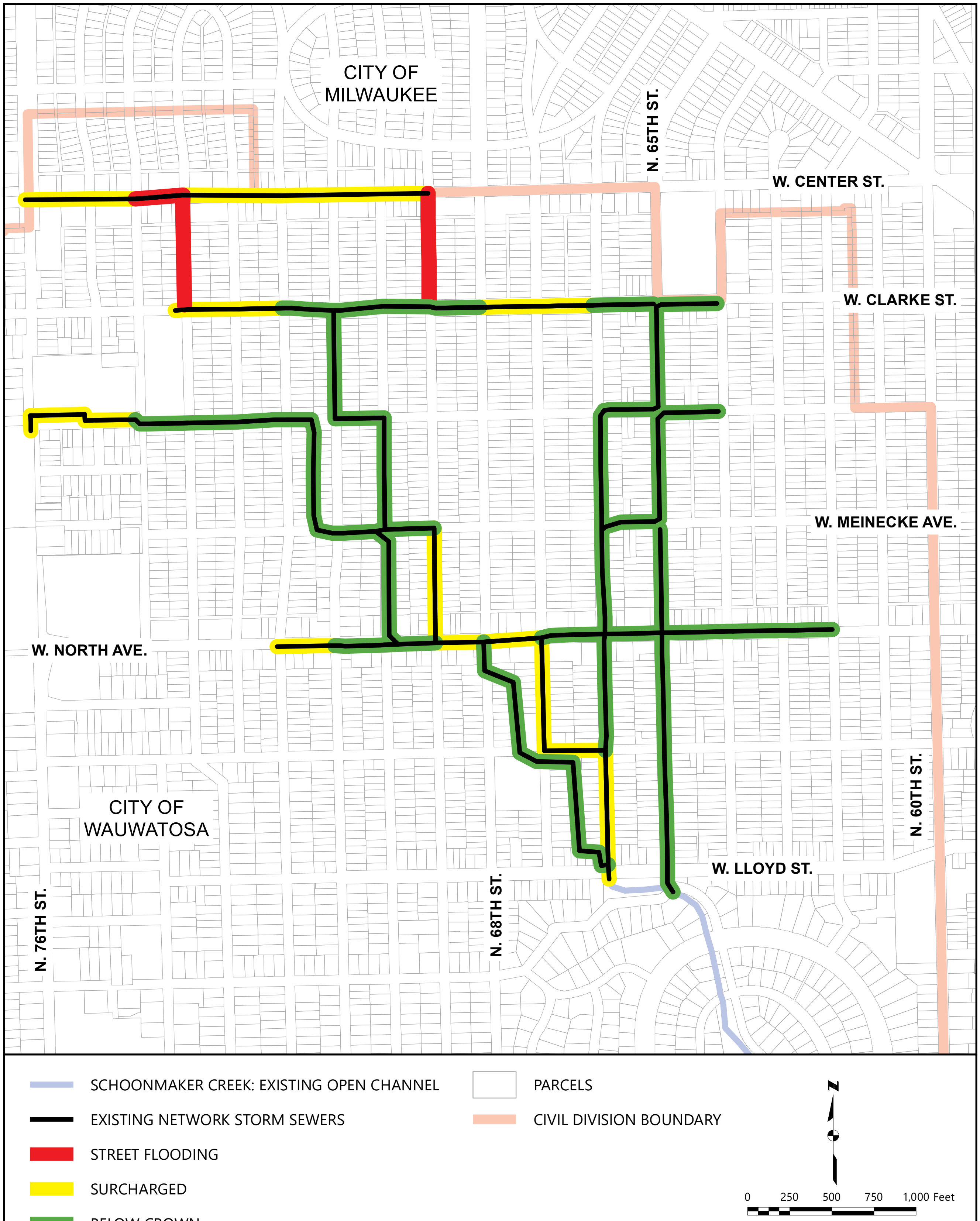


[a] Depth is reported in feet.



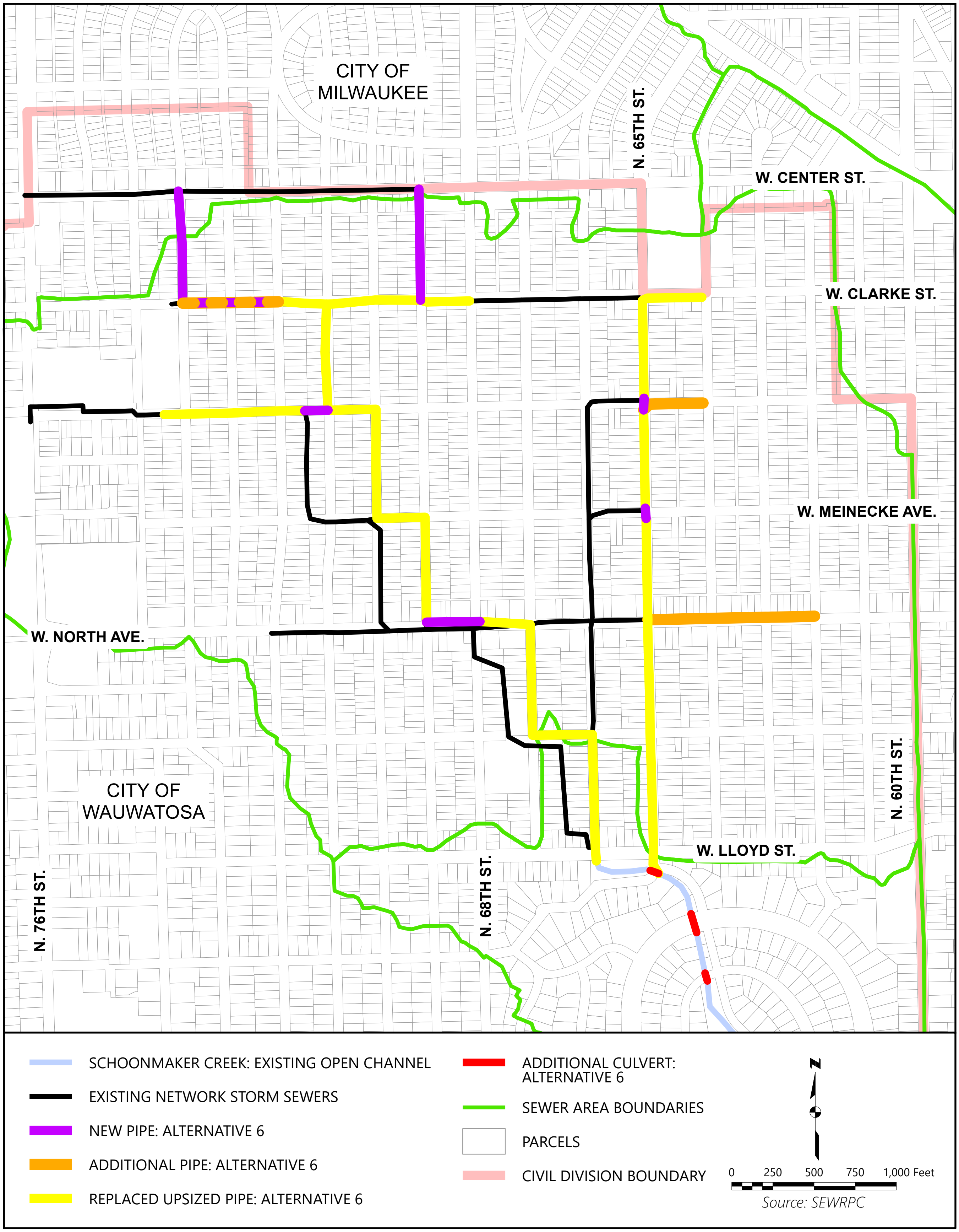
Source: SEWRPC

Map 3.11
Schoonmaker Creek XPSTORM Reach Results Alternatives 5, 14, and 16
Peak Conveyance Results for 100-Year Recurrence Interval Storm



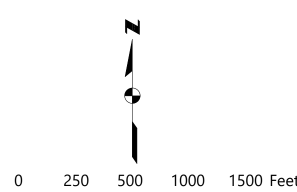
Source: SEWRPC

Map 3.12
Schoonmaker Creek Alternative 6: 100-Year Recurrence Interval Sewer Extended



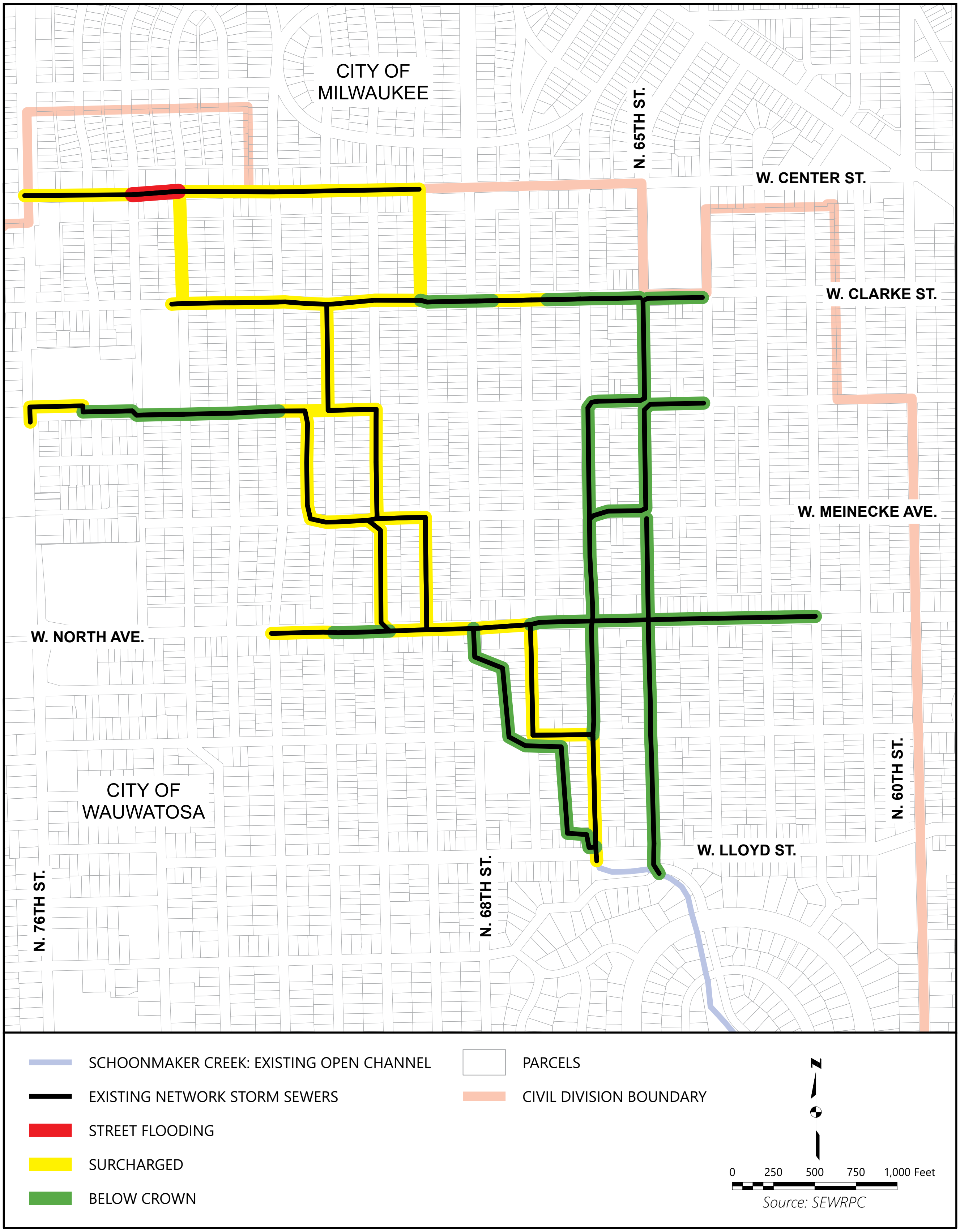
Map 3.13
Schoonmaker Creek XPSTORM Grid Results Alternatives 6 and 15
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

[a] Depth is reported in feet.



Source: SEWRPC

Map 3.14
Schoonmaker Creek XPSTORM Reach Results Alternatives 6 and 15
Peak Conveyence Results for 100-Year Recurrence Interval Storm



Source: SEWRPC

event. To note, the surface ponding at the low spot on W. Center Street at N. 74th Street was not completely removed as the storm sewer invert elevation at this location was too low to allow gravity relief to the City of Wauwatosa storm sewer network.

Alternative 7 – East Milwaukee Sewer Additional Pipe

Alternative 7 was developed to avoid the diversion of one-percent-annual-probability flood flows from the City of Milwaukee storm sewer along N. 60th Street to the Wauwatosa sewer area. The XPStorm model indicated overflows from the manholes at N. 60th Street and W. Clarke Avenue and N. 60th Street and W. Lloyd Street for flood events in excess of the ten-percent-annual-probability. Following the surface topography in this area this overflow could proceed westward into the City of Wauwatosa sewer system.

Under Alternative 7 additional relief sewers would be installed in the City of Milwaukee to reduce street ponding during a one-percent-annual-probability storm event as shown in Map 3.15. Alternative 7 by itself would not eliminate the surface flooding for the one-percent-annual-probability event between Milwaukee Avenue and the Menomonee River. Alternative 7 improvements would need to be combined with Alternatives 5 or 6 to minimize Wauwatosa sewer area street ponding and to protect the 46 structures from flooding damage during the one-percent-annual-probability storm event. Alternative 7 improvements along N. 60th Street stop at W. Vliet Street as the City of Milwaukee storm sewer drops approximately 40 feet at that location into a 6.5-ft RCP collector sewer under W. Vliet Street.

- SEWER
    - Additional 1.25-ft RCP W. Clarke Street from N. 59th Street to N. 58th Street
    - Additional 1.5-ft RCP N. 60th Street from W. Clarke Street to W. Wright Street
    - Additional 2-ft RCP N. 61st Street from W. Clarke Street to W. Wright Street and W. Wright Street from N. 61st Street to N. 60th Street
    - Additional 2.5-ft RCP N. 60th Street from W. Wright Street to W. Vliet Street
    - Total length of sewer improvements of 7,100 feet

The City of Milwaukee has chosen not to pursue Alternative 7 as the current sewer is capable of handling a 10-percent-annual-probability storm event, which meets the City's criteria for the design of municipal storm sewers.

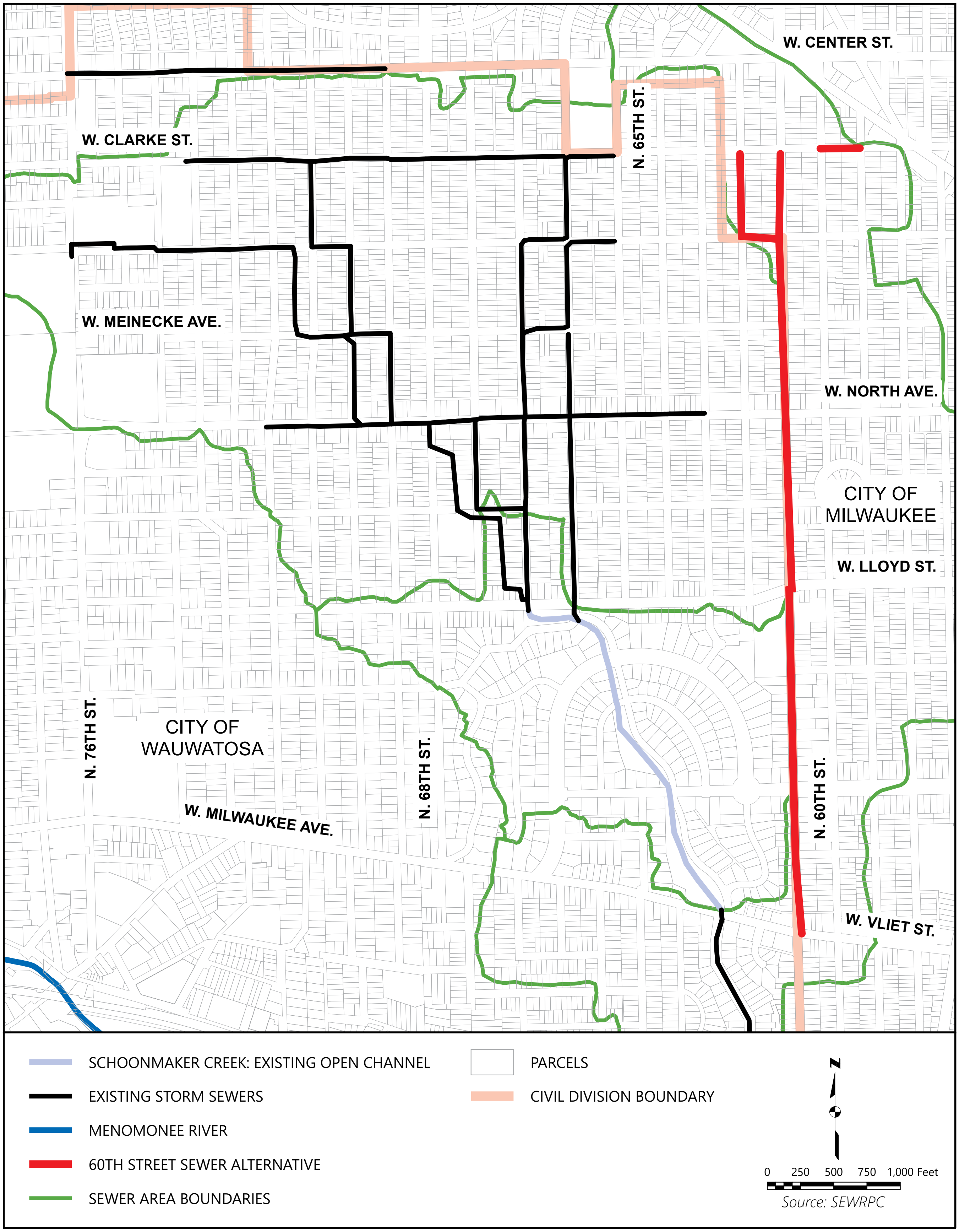
Alternative 8 – East Milwaukee Sewer New Pipe

Alternative 8 was also developed to avoid the one-percent-annual-probability flood overflows from the City of Milwaukee storm sewer along N. 60th Street to the Wauwatosa sewer area. Alternative 8 consists of new replacement sewer pipes instead of additional pipes as was proposed for Alternative 7. The XPStorm model indicated overflows from the manholes at N. 60th Street and W. Clarke Avenue and N. 60th Street and W. Lloyd Street for flood events in excess of the ten-percent-annual-probability.

Alternative 8 includes the installation of new replacement sewers in City of Milwaukee to minimize street ponding during a one-percent-annual-probability storm event as shown in Map 3.15. Alternative 8 improvements would need to be combined with Alternatives 5 or 6 to reduce Wauwatosa sewer area street flooding and to protect the 46 structures in the enclosure area during a one-percent-annual-probability storm event. Alternative 8 improvements along N. 60th Street stop at W. Vliet Street as the City of Milwaukee storm sewer drops approximately 40 feet at that location into a 6.5-ft RCP collector sewer under W. Vliet Street.

- SEWER
    - 1.75-ft RCP W. Clarke Street from N. 59th Street to N. 58th Street
    - 2-ft RCP N. 60th Street from W. Clarke Street to W. Wright Street
    - 3-ft RCP N. 61st Street from W. Clarke Street to W. Wright Street and W. Wright Street from N. 61st Street to N. 60th Street
    - 3.5-ft RCP N. 60th Street from W. Wright Street to W. Lloyd Street
    - 4-ft RCP N. 60th Street at W. Lloyd Street
    - 4.5-ft RCP N. 60th Street from W. Lloyd Street to W. Galena Street
    - 5-ft RCP N. 60th Street from W. Galena Street to W. Vliet Street
    - Total length of sewer improvements of 7,100 feet

Map 3.15
Schoonmaker Creek Alternatives 7 and 8: East Milwaukee Sewer Alternatives



The City of Milwaukee has chosen not to pursue Alternative 8 as the current sewer is capable of handling a 10-percent-annual-probability storm event, which meets the City's criteria for the design of municipal storm sewers.

Open Channel Alternative

This alternative incorporates the addition of a new channel for Schoonmaker Creek upstream of W. Lloyd Avenue to reduce street ponding. Alternative 9 also includes improvements to the existing open channel and sewer improvements in the downstream enclosure area to minimize surface flooding for the one-percent-annual-probability storm.

Alternative 9 – Open Channel

Alternative 9 would essentially daylight a portion of Schoonmaker Creek from N. 73rd Street and W. Center Street to the existing open channel at N. 66th Street and W. Lloyd Street (Map 3.16). The alignment chosen for the open channel follows the low surface topography which approximates the original Schoonmaker Creek channel before storm sewers were placed. The approximate total length of the additional open channel is about 4,900 feet and major features are listed below. A relief sewer in the enclosure area is included to minimize the surface flooding for the one-percent-annual-probability event between Milwaukee Avenue and the Menomonee River (Map 3.6). This alternative protects the 46 structures from flooding damage during the one-percent-annual-probability storm event. Alternative 9 also includes bridge improvements at three locations along the existing open channel portion of Schoonmaker Creek (Map 3.6), as well as the open channel improvements as described for Alternative 4.

- CHANNEL
  - Trapezoidal channel, 10-foot wide bottom
  - 6 feet to 11 feet deep, 3:1 side slopes
  - 3-ft RCP to connect existing sewers to channel

- NEW CHANNEL BRIDGES
  - 8-ft x 10-ft RCB at crossings at N. Lefeber Avenue, N. 72nd Street and W. Clarke Avenue, W. Wright Street, N. 71st Street, N. 70th Street and W. Meinecke Avenue, N. 69th St and W. North Avenue, N. 68th Street, W. Garfield Avenue, and N. 67th Street (nine bridges total)

- EXISTING CHANNEL BRIDGES
  - Additional 5-ft x 5-ft RCB at Revere Ave
  - Additional 5-ft x 6-ft RCB at Washington Circle and Upper Parkway

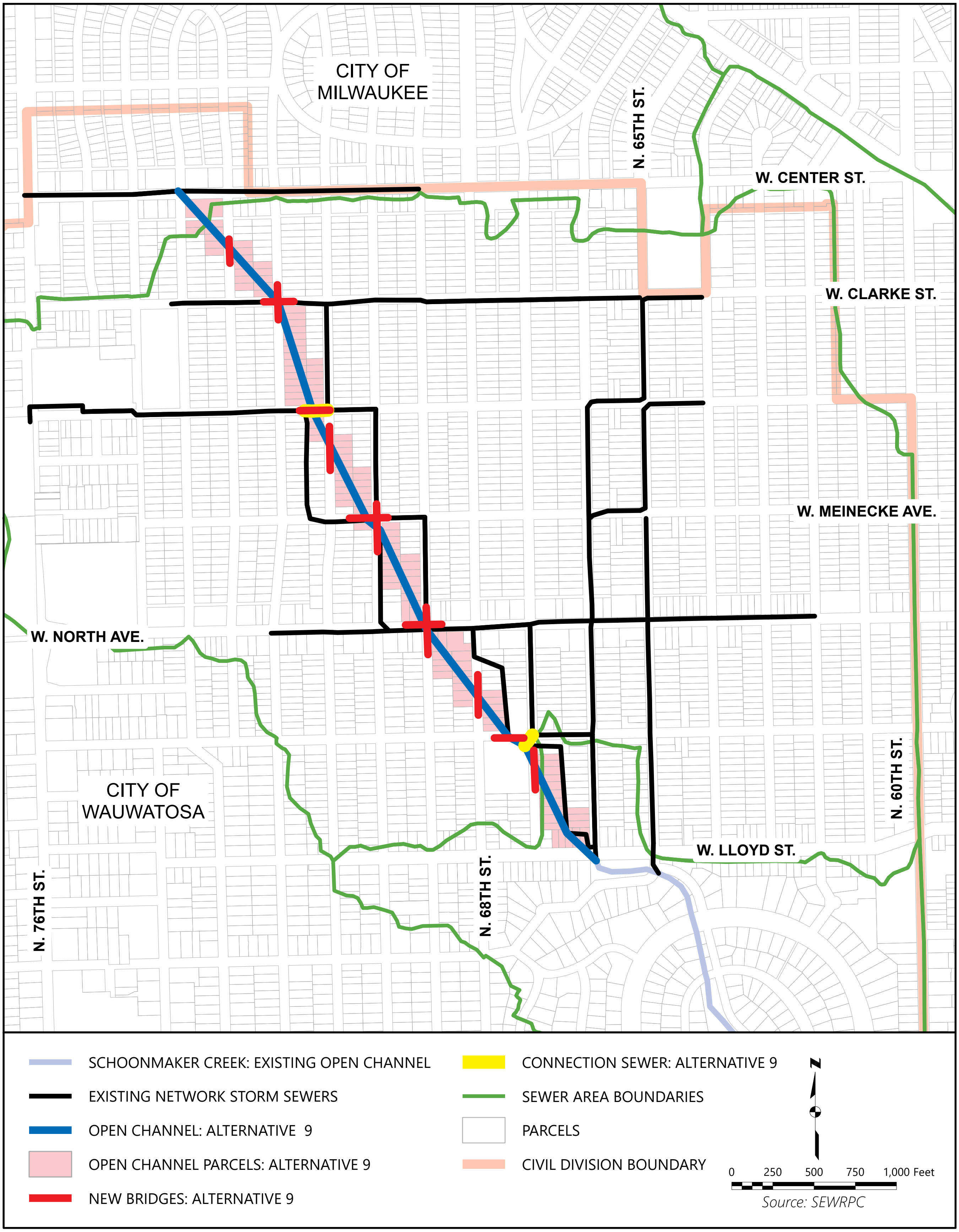
- EXISTING OPEN CHANNEL IMPROVEMENT
  - Removal of existing retaining walls along the open channel section
  - Regrade channel banks to minimum 2:1 horizontal-to-vertical side slope
  - Installation of riprap along the open channel
  - Removal of approximately 44 trees

- ENCLOSURE
  - 6-ft x 6-ft RCB at inlet at Milwaukee Avenue
  - 6-ft x 9-ft RCB downstream of inlet to W. Martin Drive
  - 2-6-ft x 7-ft RCB W. Martin Drive to the Menomonee River

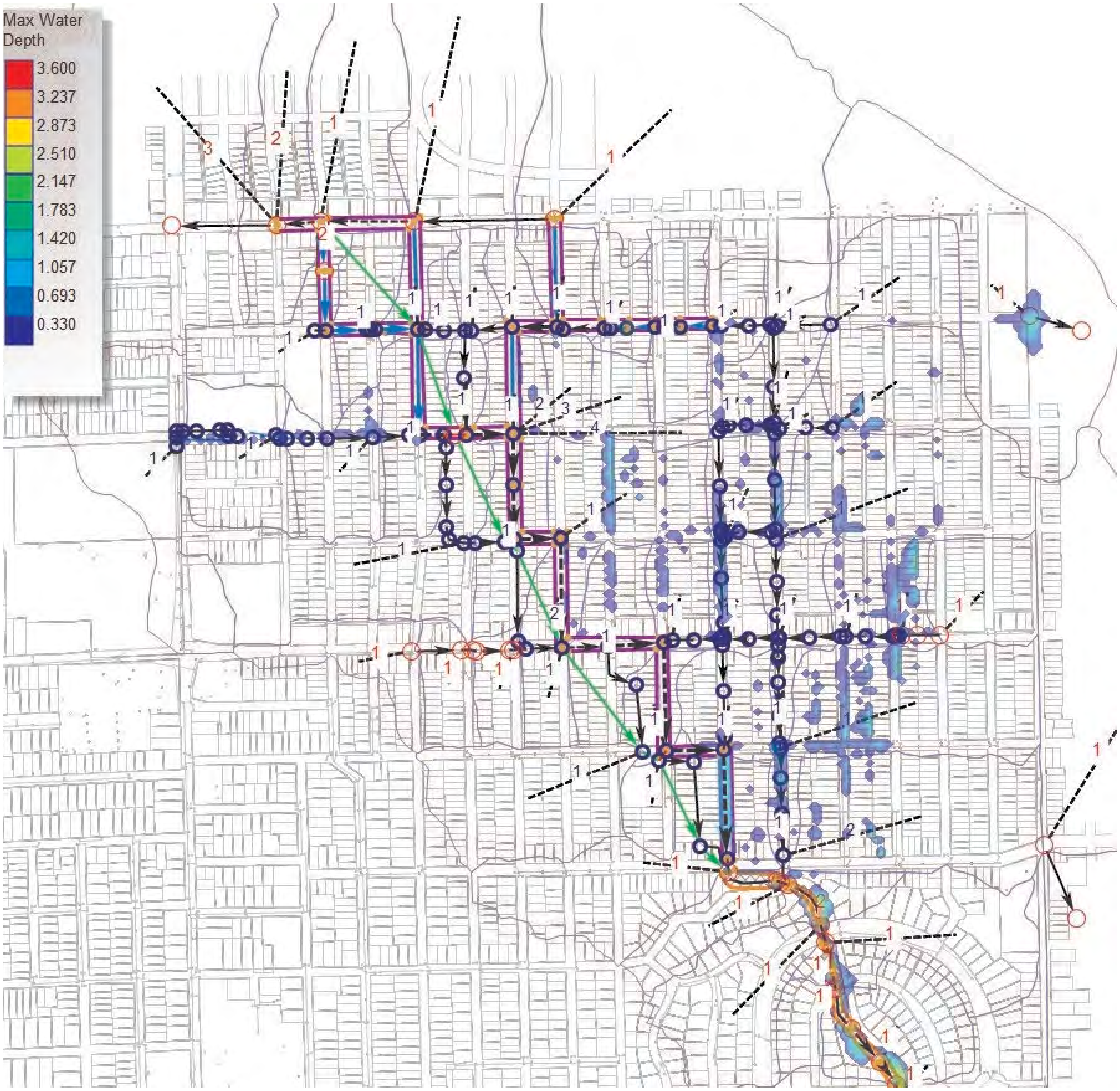
In order to construct the new open channel, approximately 122 properties would need to be acquired and the existing buildings demolished (Map 3.16).

The remaining one-percent-annual-probability street ponding in the City of Wauwatosa with the Alternative 9 improvements is shown on Maps 3.17 and 3.18. The proposed open channel reaches are depicted on Maps 3.17 and 3.18 as green lines or green arrows. Comparing the street ponding of Alternative 9 to existing conditions (Maps 2.4 and 2.5), street ponding in the Wauwatosa sewer area is essentially eliminated along the western low area of the sewer system.

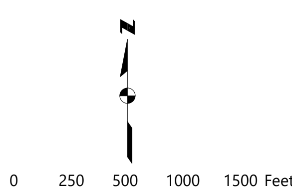
Map 3.16
Schoonmaker Creek Alternative 9: Open Channel



Map 3.17
Schoonmaker Creek XPSTORM Grid Results Alternative 9
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

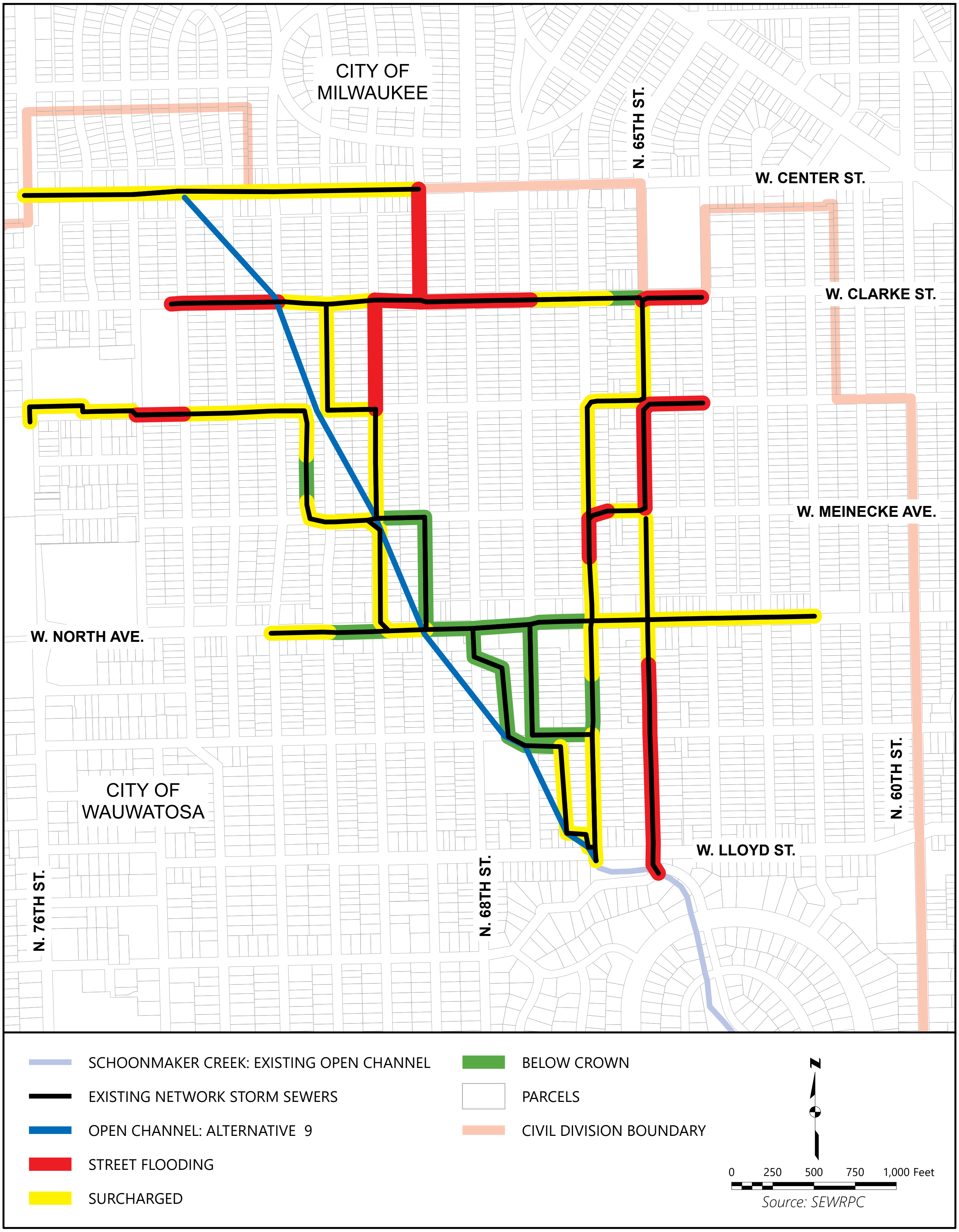


[a] Depth is reported in feet.



Source: SEWRPC

Map 3.18
Schoonmaker Creek XPSTORM Reach Results Alternative 9
Peak Conveyance Results for 100-Year Recurrence Interval Storm



Source: SEWRPC

Storage Alternatives

These alternatives consist of the addition of large dry detention storage facilities in the Wauwatosa sewer area to reduce street ponding. The alternatives also include sewer improvements in the downstream enclosure area to reduce surface flooding for the one-percent-annual-probability storm.

Alternative 10 – North Storage

Alternative 10 includes excavation of a stormwater detention pond at N. 71st Street and W. Wright Street to relieve the existing storm sewers in the area (Map 3.19). The proposed dry pond would drain by gravity to relieve two City of Wauwatosa sewer lines. This alternative still requires bridge and enclosure improvements to protect the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event. The XPStorm model results indicate that 23.8 ac-ft of storage were utilized at the North Storage facility for the one-percent-annual-probability event.

- DETENTION FACILITY AT N. 71st STREET AND W. WRIGHT STREET
  - 3.7 acres (1.5 blocks) for top surface area
  - 8 feet deep, 3:1 side slopes
  - 26.4 ac-ft of storage available

- BRIDGE
  - Additional 5-ft x 5-ft RCB at Revere Ave
  - Additional 5-ft x 6-ft RCB at Washington Circle and Upper Parkway

- ENCLOSURE
  - 5-ft x 6-ft RCB Milwaukee Avenue to W. Martin Drive
  - 5-ft x 10-ft RCB W. Martin Drive to the Menomonee River

In order to build the North Storage pond, approximately 45 properties would need to be acquired and the existing buildings demolished (Map 3.19).

The remaining one-percent-annual-probability street ponding in the City of Wauwatosa with the Alternative 10 improvements is shown on Maps 3.20 and 3.21. The proposed Alternative 10 pond features are depicted on Maps 3.20 and 3.21 as a red triangle and red arrows. Comparing the street ponding of Alternative 10 to existing conditions (Maps 2.4 and 2.5), street ponding is significantly decreased for most of the Wauwatosa sewer area in the western low area of the sewer system.

Alternative 11 – South Storage

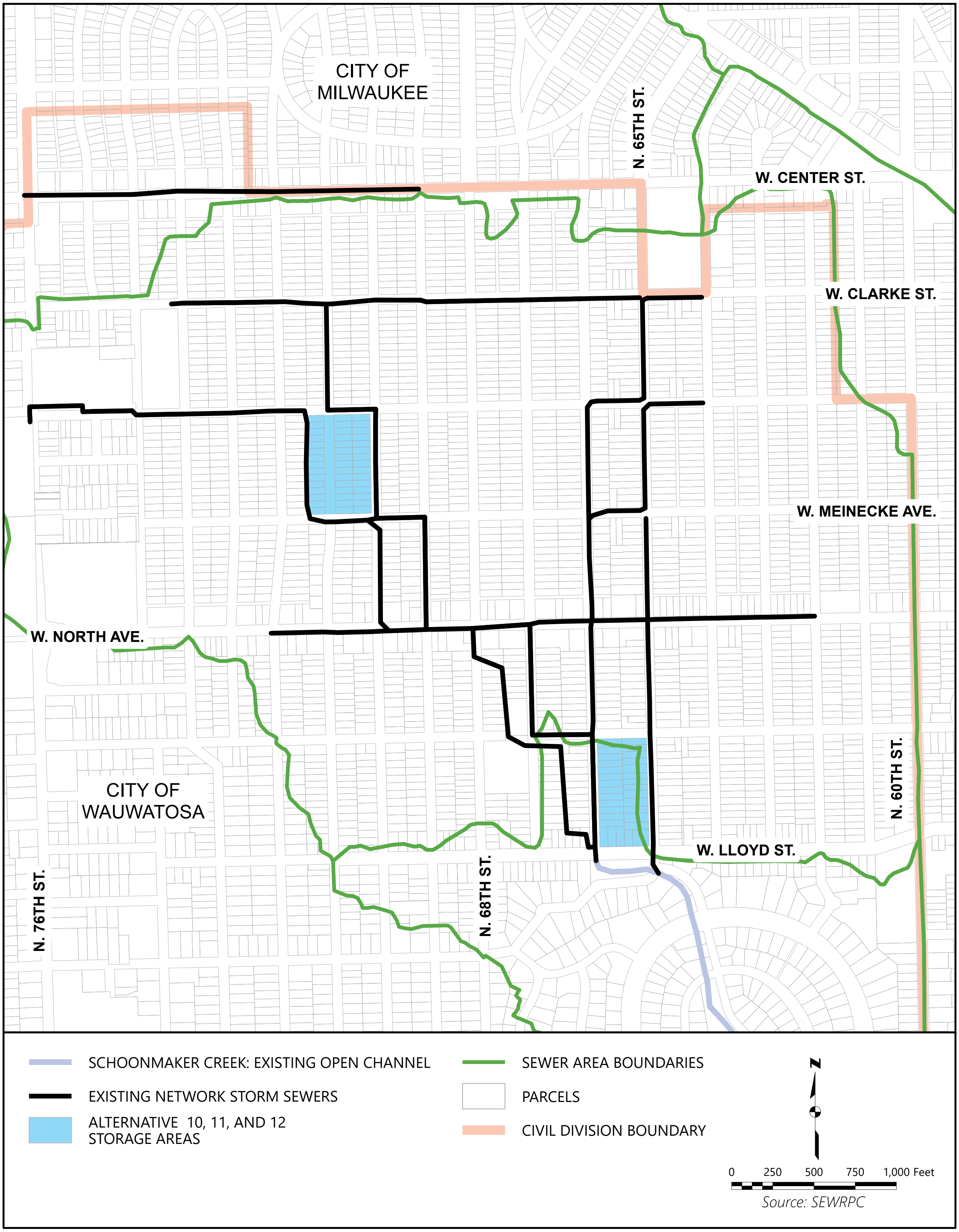
Alternative 11 includes excavation of a stormwater detention pond at N. 65th Street and W. Lloyd Street to relieve the existing storm sewers in the area (Map 3.19). The proposed dry pond would drain by gravity and would relieve both of the adjacent City of Wauwatosa sewer lines. Alternative 11 still requires enclosure improvements to protect the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event. The XPStorm model results indicate that 27.0 ac-ft of storage were utilized at the South Storage facility for the one-percent-annual-probability event.

- DETENTION FACILITY AT N. 65th STREET AND W. LLOYD STREET
  - 3.5 acres (1 block) for top surface area
  - 9 feet deep, 3:1 side slopes
  - 27.0 ac-ft of storage available

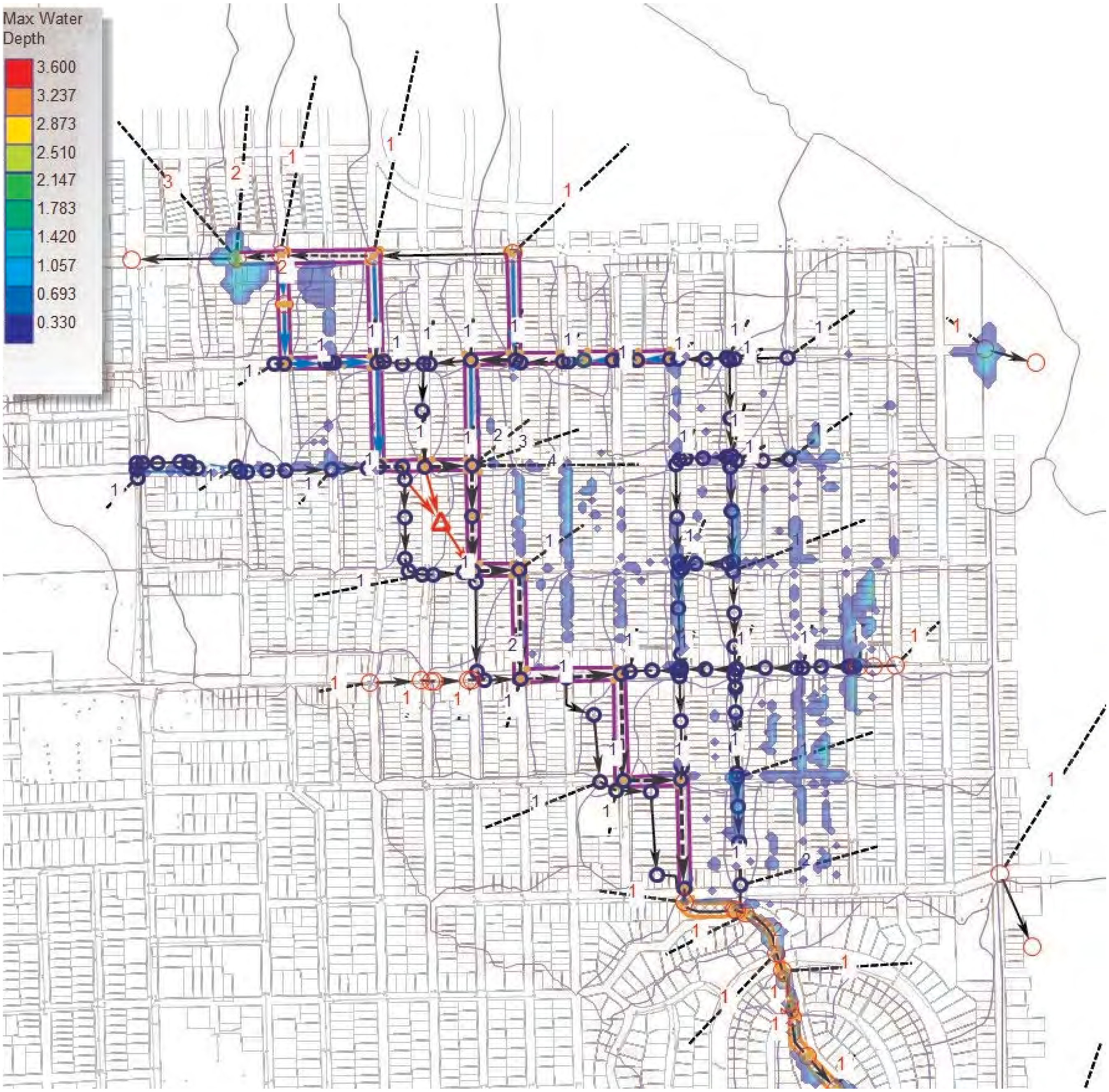
- ENCLOSURE
  - 5-ft x 5-ft RCB Milwaukee Avenue to W. Martin Drive
  - 5-ft x 7-ft RCB W. Martin Drive to the Menomonee River

In order to build the South Storage pond, approximately 31 properties would need to be acquired and the existing buildings demolished (Map 3.19).

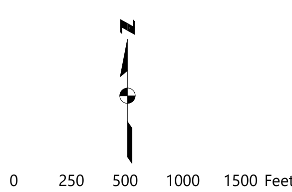
Map 3.19
Schoonmaker Creek Alternatives: 10, 11, and 12 Storage Areas



Map 3.20
Schoonmaker Creek XPSTORM Grid Results Alternative 10
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

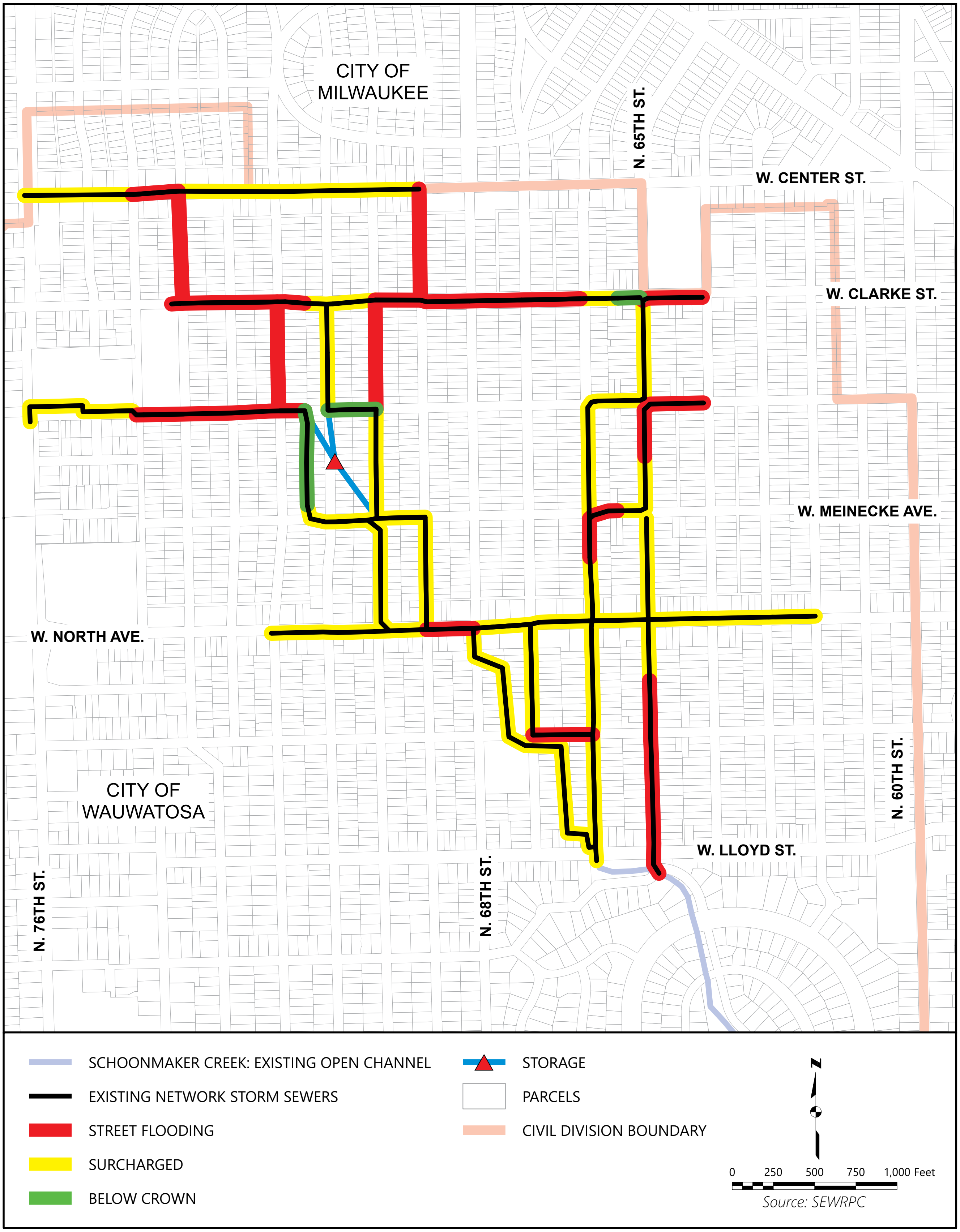


[a] Depth is reported in feet.



Source: SEWRPC

Map 3.21
Schoonmaker Creek XPSTORM Reach Results Alternative 10
Peak Conveyance Results for 100-Year Recurrence Interval Storm



The remaining one-percent-annual-probability street ponding in the City of Wauwatosa with the Alternative 11 improvements is shown on Maps 3.22 and 3.23. The proposed Alternative 11 pond features are included on Maps 3.22 and 3.23 as a red triangle and red arrows. Comparing the street ponding of Alternative 11 to existing conditions (Maps 2.4 and 2.5), street ponding is only removed in the area around the detention facility.

Alternative 12 – North and South Storage

Alternative 12 includes excavation of stormwater detention ponds at both N. 71st Street and W. Wright Street and N. 65th Street and W. Lloyd Street to relieve the existing storm sewers in the area (Map 3.19). The proposed dry ponds would drain by gravity and would relieve both of the major City of Wauwatosa sewer lines in the upper Schoonmaker Creek watershed. Alternative 12 still requires enclosure improvements to protect the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event. The XPStorm model results indicate that 23.1 ac-ft of storage was utilized at the North Storage facility and 27.0 ac-ft of storage was utilized at the South Storage facility for the one-percent-annual-probability event.

- DETENTION FACILITY AT N. 71st STREET AND W. WRIGHT STREET
  - 3.7 acres (1.5 blocks) for top surface area
  - 8 feet deep, 3:1 side slopes
  - 26.4 ac-ft of storage available

- DETENTION FACILITY AT N. 65th STREET AND W. LLOYD STREET
  - 3.5 acres (1 block) for top surface area
  - 9 feet deep, 3:1 side slopes
  - 27 ac-ft of storage available

- ENCLOSURE
  - 5-ft x 5-ft RCB Milwaukee Avenue to W. Martin Drive
  - 5-ft x 7-ft RCB W. Martin Drive to the Menomonee River

In order to build the both the North and South Storage ponds, approximately 76 properties would need to be acquired and the existing buildings demolished (Map 3.19).

The remaining one-percent-annual-probability street ponding in the City of Wauwatosa with the Alternative 12 improvements is shown on Maps 3.24 and 3.25. The proposed Alternative 12 pond features are depicted on Maps 3.24 and 3.25 as red triangles and red arrows. Comparing the street ponding of Alternative 12 to existing conditions (Maps 2.4 and 2.5), street ponding is greatly reduced for most of the western low area of the City of Wauwatosa storm sewer system.

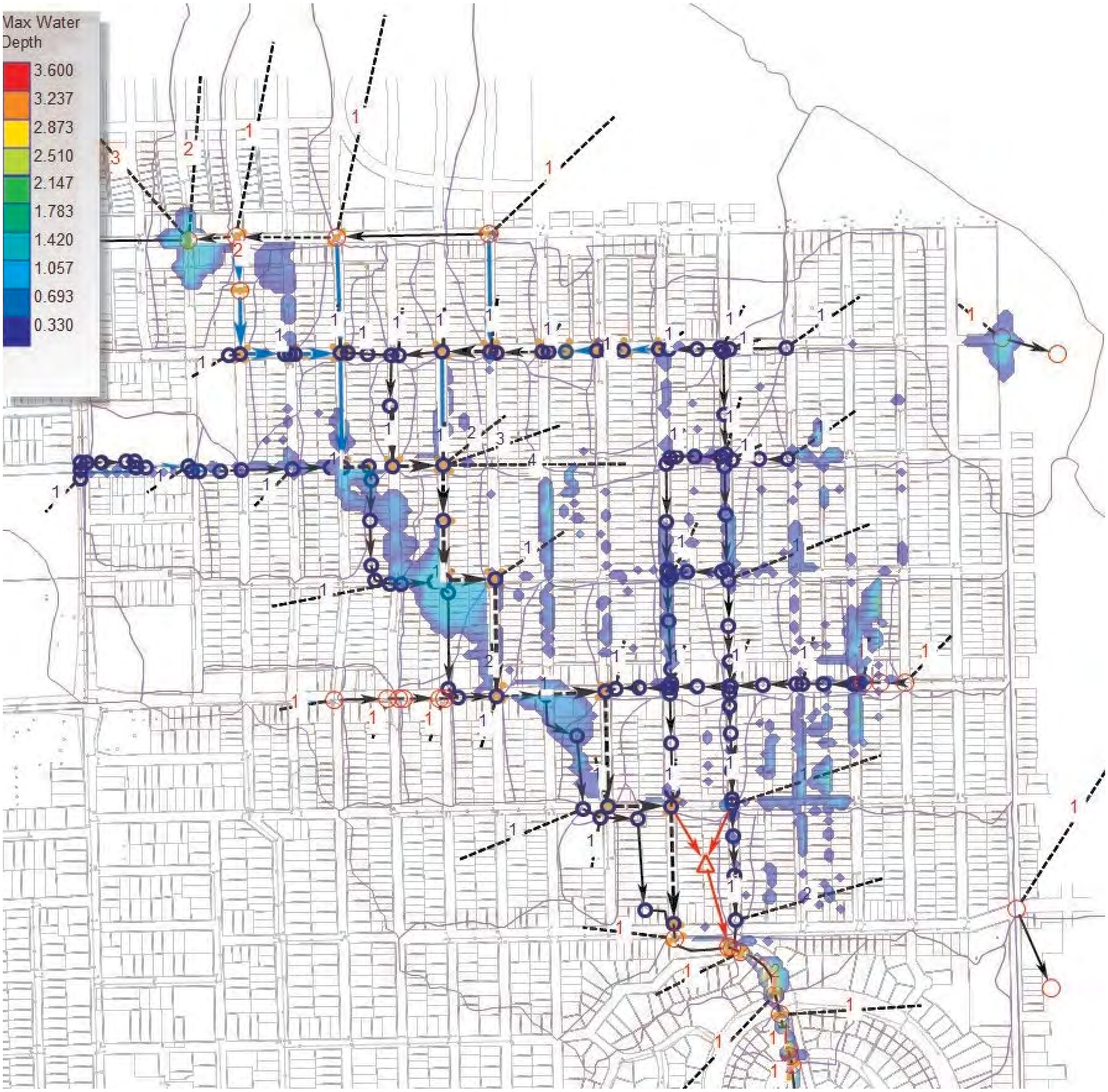
Sewer and Channel Bypass Alternatives

These alternatives all incorporate storm sewer improvements in the Wauwatosa sewer area to reduce street ponding. The alternatives also incorporate a large diameter tunnel or sewer bypass to convey sewer area flows around the existing open channel to the Menomonee River, which minimizes surface flooding in the downstream enclosure area for the one-percent-annual-probability storm. These alternatives do not require modifications to the existing open channel.

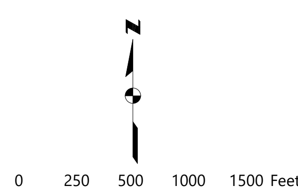
Alternative 13 – 25-Year Sewer and Tunnel

Alternative 13 consists of the same sewer improvements as Alternative 4 north of the existing open channel of Schoonmaker Creek. These sewer improvements in the City of Wauwatosa would reduce street ponding during a four-percent-annual-probability (25-year recurrence interval) storm event (Map 3.5). Alternative 13 also incorporates a large diameter tunnel to convey flood flows directly to the Menomonee River. The alignment of the proposed tunnel is shown on Map 3.26, and feature details are listed below. This alternative protects the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event. Portions of the proposed 5,300 foot tunnel would be very deep, with approximately 4,000 feet of the tunnel 20 to 30 feet below the surface.

Map 3.22
Schoonmaker Creek XPSTORM Grid Results Alternative 11
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

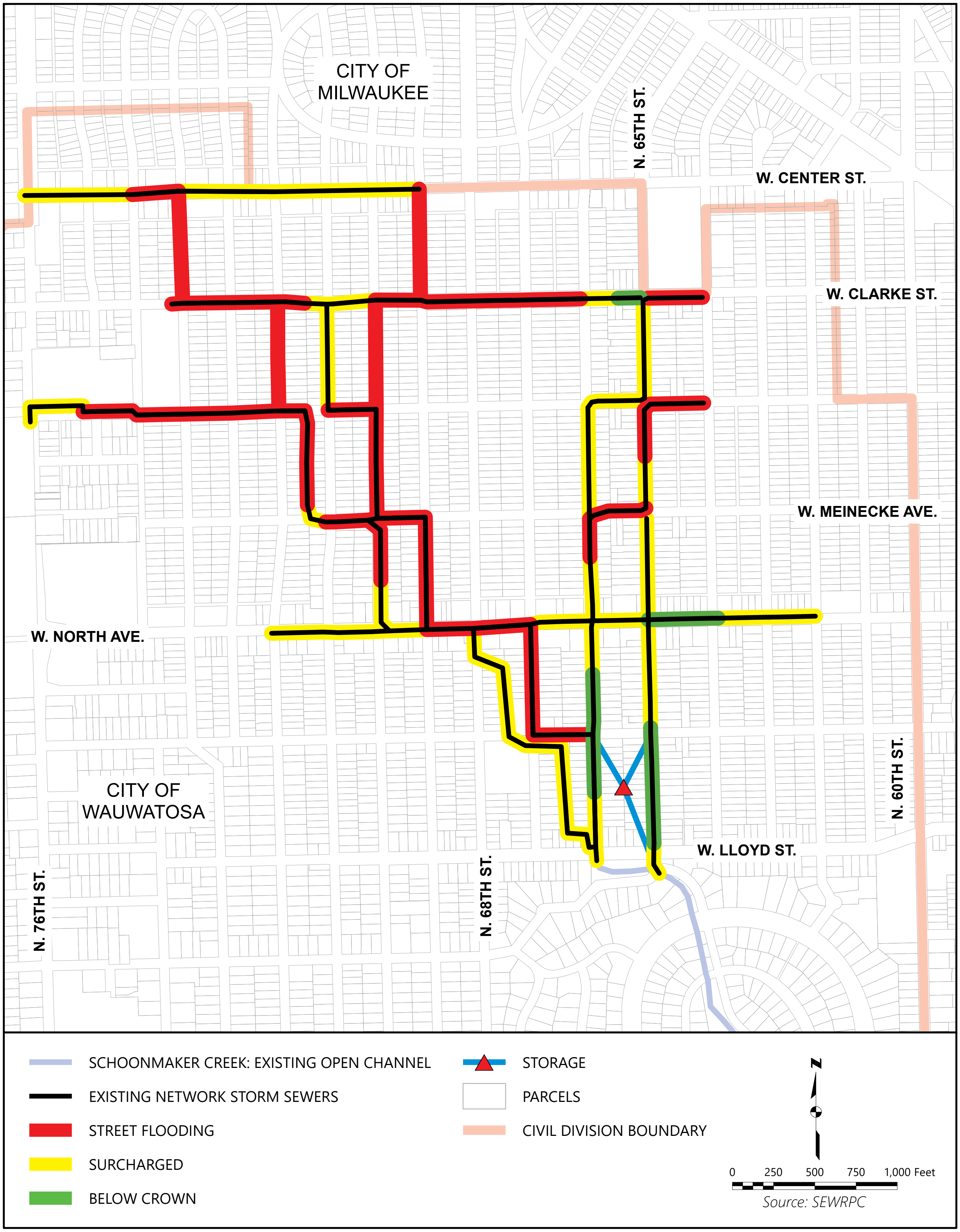


[a] Depth is reported in feet.

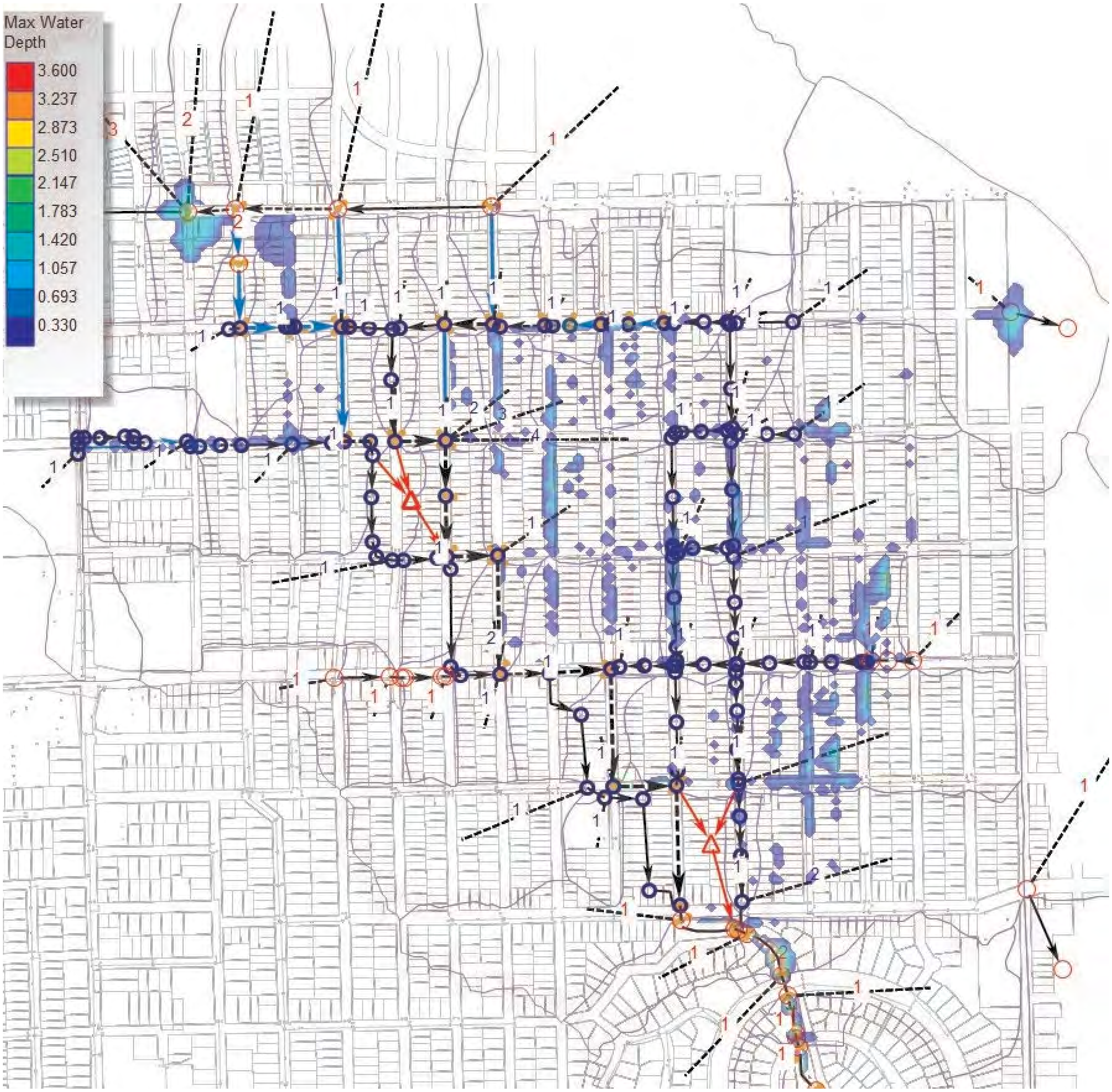


Source: SEWRPC

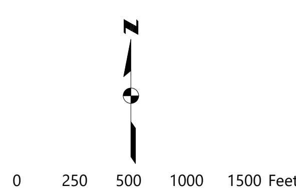
Map 3.23
Schoonmaker Creek XPSTORM Reach Results Alternative 11
Peak Conveyance Results for 100-Year Recurrence Interval Storm



Map 3.24
Schoonmaker Creek XPSTORM Grid Results Alternative 12
Peak Street Ponding Depths During 100-Year Recurrence Interval Storm[a]

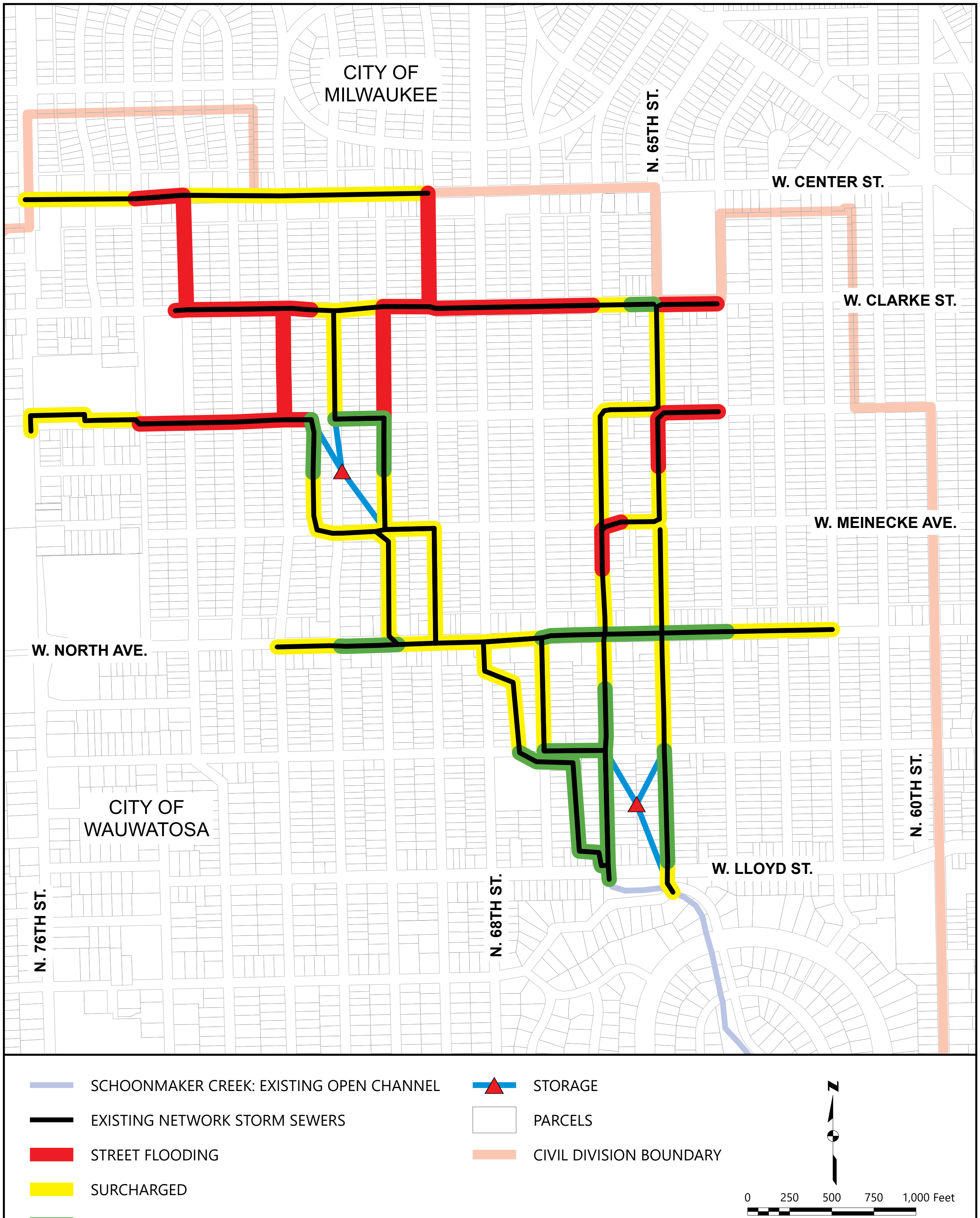


[a] Depth is reported in feet.



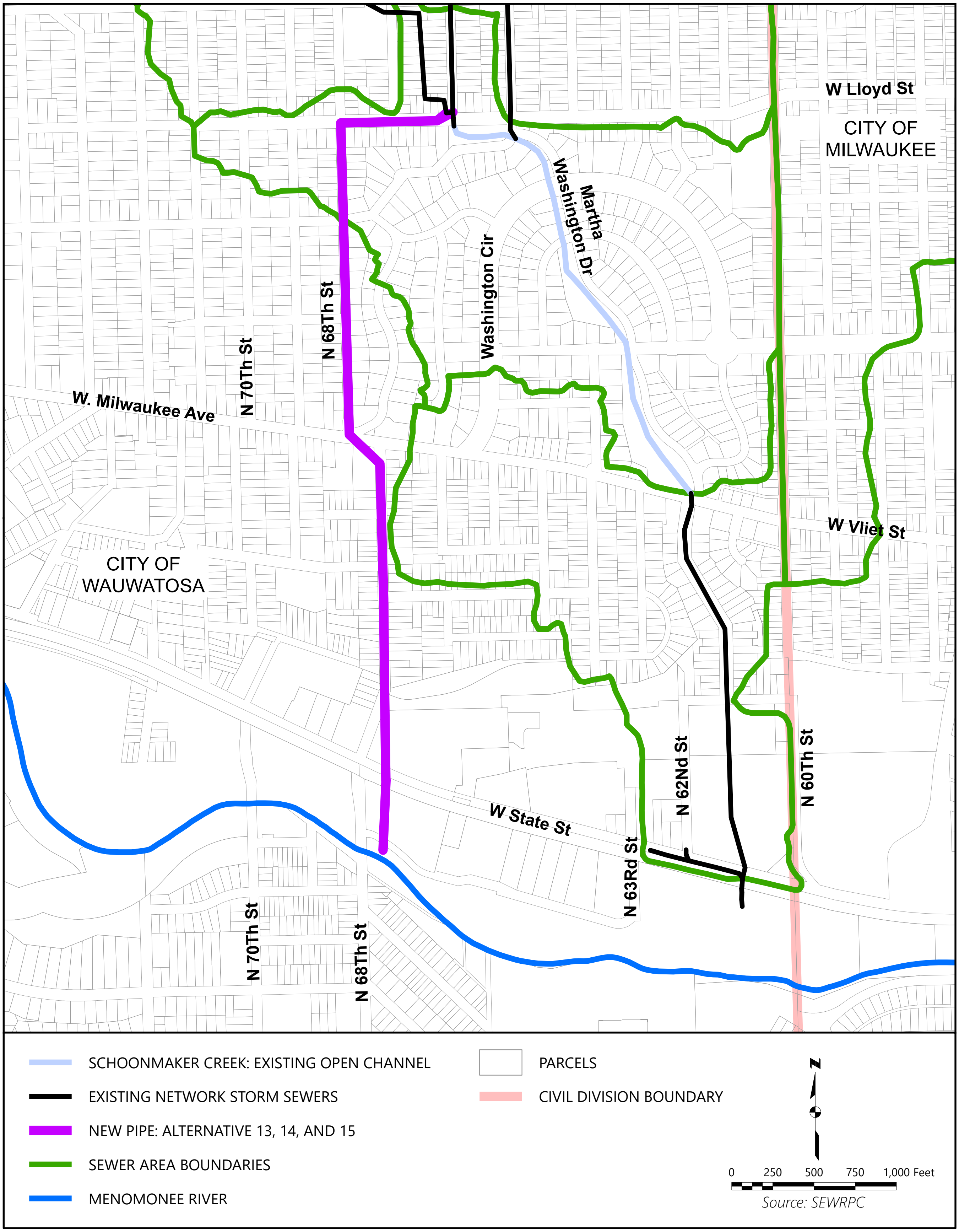
Source: SEWRPC

Map 3.25
Schoonmaker Creek XPSTORM Reach Results Alternative 12
Peak Conveyance Results for 100-Year Recurrence Interval Storm



Source: SEWRPC

Map 3.26
Schoonmaker Creek Alternatives 13, 14, and 15: Tunnel Bypass



- SEWER
  - Sewer pipe schedule for Alternative 4 can be found in Appendix D
  - New pipes range from 2.5-ft to 7-ft RCP
  - Total length of sewer improvements of 9,900 feet

- TUNNEL
  - 8.5-ft RCP from N. 66th Street and W. Lloyd Street along W. Lloyd St to N. 68th Street, then on N. 68th Street to the Menomonee River
  - Total length of tunnel of 5,300 feet

The Alternative 13 improvements would reduce the one-percent-annual-probability street ponding by the same amount as the Alternative 4 improvements (Maps 3.7 and 3.8). Comparing the street ponding of Alternative 13 to existing conditions (Maps 2.4 and 2.5), street ponding is greatly reduced for the southern and eastern portions of the system, but not for the northwest portion of the Wauwatosa sewer area.

Alternative 14 – 100-Year Sewer and Tunnel

Alternative 14 incorporates the same sewer improvements as Alternative 5 north of the existing open channel of Schoonmaker Creek. These sewer improvements in the City of Wauwatosa would reduce street ponding during a one-percent-annual-probability (100-year recurrence interval) storm event (Map 3.9). Alternative 14 also includes a large diameter tunnel to convey flood flows directly to the Menomonee River. The alignment of the proposed tunnel is shown on Map 3.26, and feature details are listed below. This alternative protects the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event. Portions of the proposed 5,300 foot tunnel would be very deep, with approximately 4,000 feet of the tunnel 20 to 30 feet below the surface.

- SEWER
  - Sewer pipe schedule for Alternative 5 can be found in Appendix D
  - New pipes range from 2-ft to 8-ft RCP
  - Total length of sewer improvements of 12,900 feet

- TUNNEL
  - 8.5-ft RCP from N. 66th Street and W. Lloyd Street along W. Lloyd St to N. 68th Street, then on N. 68th Street to the Menomonee River
  - Total length of tunnel of 5,300 feet

The Alternative 14 improvements would reduce the one-percent-annual-probability street ponding by the same amount as the Alternative 5 improvements (Maps 3.10 and 3.11). Comparing the street ponding of Alternative 14 to existing conditions (Maps 2.4 and 2.5), Wauwatosa sewer area street ponding is greatly reduced, except for the W. Center Street area.

Alternative 15 – 100-Year Sewer Extended and Tunnel

Alternative 15 incorporates the same sewer improvements as Alternative 6 north of the existing open channel of Schoonmaker Creek. These sewer improvements in the City of Wauwatosa would reduce street ponding during a one-percent-annual-probability (100-year recurrence interval) storm event and reduce street ponding on W. Center Street (Map 3.12). Alternative 15 also includes a large diameter tunnel to convey flood flows directly to the Menomonee River. The alignment of the proposed tunnel is shown on Map 3.26, and feature details are listed below. This alternative protects the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event. To note, portions of the proposed 5,300 foot tunnel would be very deep, with approximately 4,000 feet of the tunnel 20 to 30 feet below the surface.

- SEWER
  - Sewer pipe schedule for Alternative 5 can be found in Appendix D
  - New 4-ft RCP from W. Center Street to W. Clarke Street along N. 73rd Street and N. 69th Street
  - New 4-ft RCP from N. 73rd Street to N. 72nd Street on W. Clarke Street
  - Total length of sewer improvements of 14,700 feet

- TUNNEL
  - 9-ft RCP from N. 66th Street and W. Lloyd Street along W. Lloyd St to N. 68th Street, then on N. 68th Street to the Menomonee River
  - Total length of tunnel of 5,300 feet

The Alternative 15 improvements would reduce the one-percent-annual-probability street ponding by the same amount as the Alternative 6 improvements (Maps 3.13 and 3.14). Comparing the street ponding of Alternative 15 to existing conditions (Maps 2.4 and 2.5), Wauwatosa sewer area street ponding is greatly reduced for this event.

Alternative 16 – 100-Year Sewer with Open Channel Bypass

Alternative 16 includes the same plan for replacing sewer lines and adding sewer relief pipes that is described in Alternative 5 (Map 3.9). Alternative 16 also incorporates most of the Alternative 5 relief sewer in the enclosure area, with a slight modification for the relief pipe under Milwaukee Avenue. To mitigate high peak flows through the open channel portion of Schoonmaker Creek, Alternative 16 includes a bypass storm sewer underneath Martha Washington Drive from W. Lloyd Street to Milwaukee Avenue (Map 3.27). The 5 foot by 7 foot box culvert bypass takes all flow from a sewer line at the corner of W. Lloyd Street and N. 65th Street. The bypass also takes a portion of the flow from a sewer line at the corner of W. Lloyd Street and N. 66th Street via a 4 foot diameter sewer. The upstream invert of this diversion pipe is set one foot higher than the invert connecting to the open channel to better preserve existing low flows to the open channel. Because the bypass sewer reduces peak flows in the one-percent-annual-probability storm event, the bridge and existing open channel improvements described in Alternative 5 are not needed. This alternative protects the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event.

- SEWER
  - Full sewer schedule can be found in Appendix D
  - New pipes range from 2-ft to 8-ft RCP
  - Total length of sewer improvements of 12,900 feet

- OPEN CHANNEL BYPASS SEWER
  - Additional 4-ft diameter round pipe from N. 66th Street to 65th Street along W. Lloyd Street
  - Additional 5-ft x 7-ft RCB along Martha Washington Drive from W. Lloyd Street to Milwaukee Avenue

- ENCLOSURE
  - 6-ft x 9-ft RCB downstream of inlet to W. Martin Drive
  - 2-6-ft x 7-ft RCB W. Martin Drive to the Menomonee River

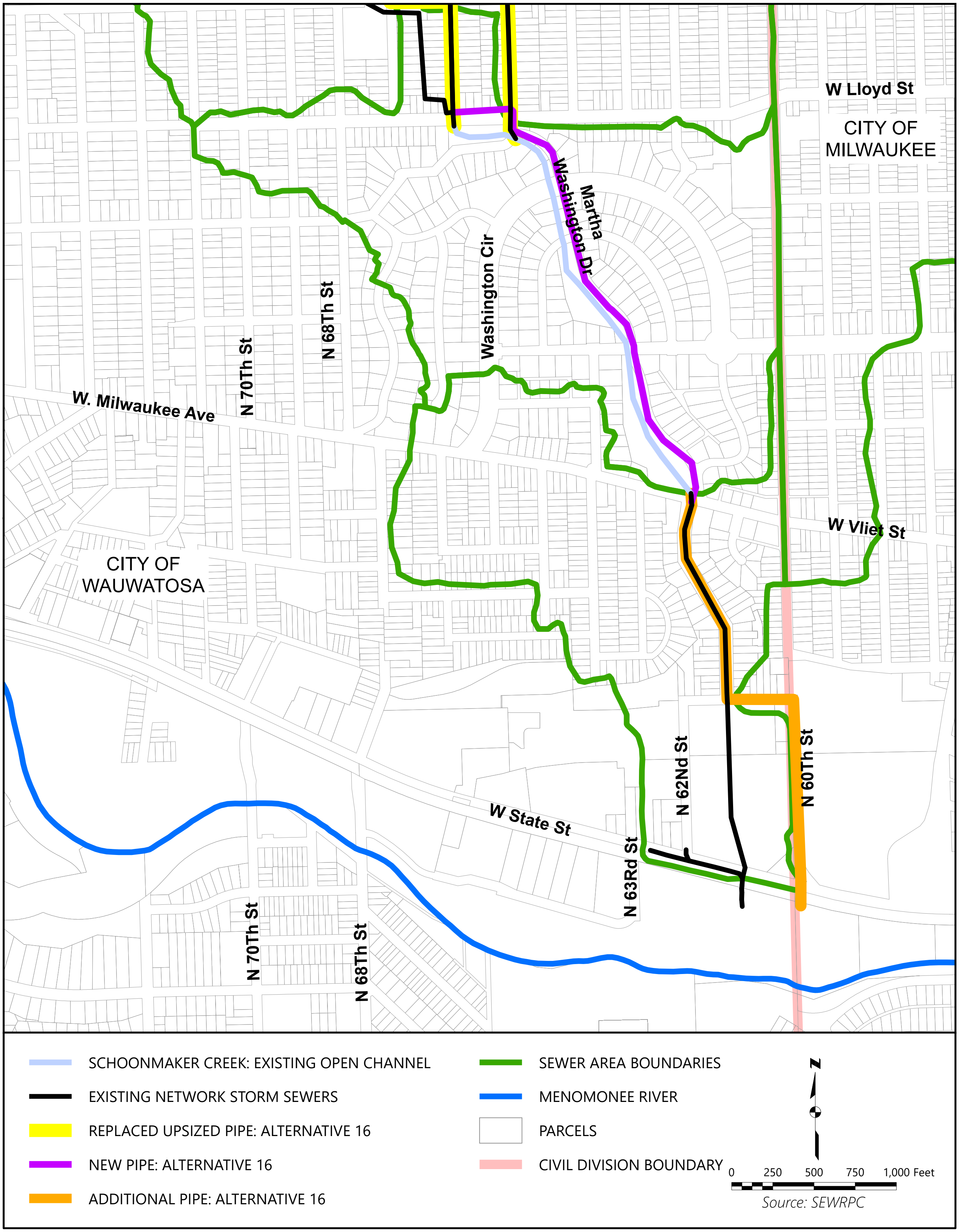
The remaining one-percent-annual-probability street ponding in the Wauwatosa sewer area with the Alternative 16 improvements is shown on Maps 3.10 and 3.11. Comparing the street ponding of Alternative 16 to existing conditions (Maps 2.4 and 2.5), street ponding is greatly reduced for the one-percent-annual-probability storm, except for the W. Center Street area.

3.3 GREEN INFRASTRUCTURE

In addition to the 16 alternatives discussed above, green infrastructure options were evaluated for their impact on flooding in the Schoonmaker Creek watershed. As the watershed is predominantly residential, the green infrastructure options focused on reasonable residential choices. The three residential green infrastructure options evaluated were rain barrels, cisterns, and rain gardens. These three options were evaluated for their reduction to the one-percent-annual-probability rainfall amount for the Schoonmaker Creek watershed.

For this plan a typical rain barrel was assumed to have a 50 gallon capacity (6.7 cubic feet (ft^3)), and a 200 gallon capacity (26.7 ft^3) was assumed for a residential cistern. A typical rain garden was assumed to be 150 square feet (ft^2) in area, with an average depth of one foot. This evaluation optimistically assumed that each residence in the Schoonmaker Creek watershed had either two rain barrels or one cistern capturing runoff from the entire roof. For the rain garden option, one out of every four houses in the watershed was conservatively assumed to capture runoff from the entire roof.

Map 3.27
Open Channel Bypass Sewer and Enclosure Area Improvements for Alternative 16



Source: SEWRPC

Table 3.1
Schoonmaker Creek Green Infrastructure Roof Area Summary

Area	Average Home Roof Area (ft^2)[a]	Number of Homes	Area of Home Roofs (ac)	Total Area per Basin (ac)	Home Roofs Percentage
North Milwaukee	1,200	1,222	33.7	273	12.3
East Milwaukee	1,500	1,059	36.5	192	19.0
Wauwatosa Sewer	1,400	2,175	69.9	448	15.6
Wauwatosa Channel/Enclosure Area	1,700	638	24.9	184	13.5

[a] *Based on an average of 6-9 samples per area*

Source: SEWRPC

To evaluate the impacts of green infrastructure the average roof area, number of homes, and percentage of roof area was determined (Table 3.1) for four distinct municipal areas of the Schoonmaker Creek watershed (Map 3.28). Roof and area data were used to determine the rain barrel, cistern, and rain garden impact on rainfall totals for each of the four areas within the Schoonmaker Creek watershed. Example calculations are below for the rain barrel and rain garden options.

<u>Two rain barrels for all homes in the Wauwatosa Sewer Area</u>

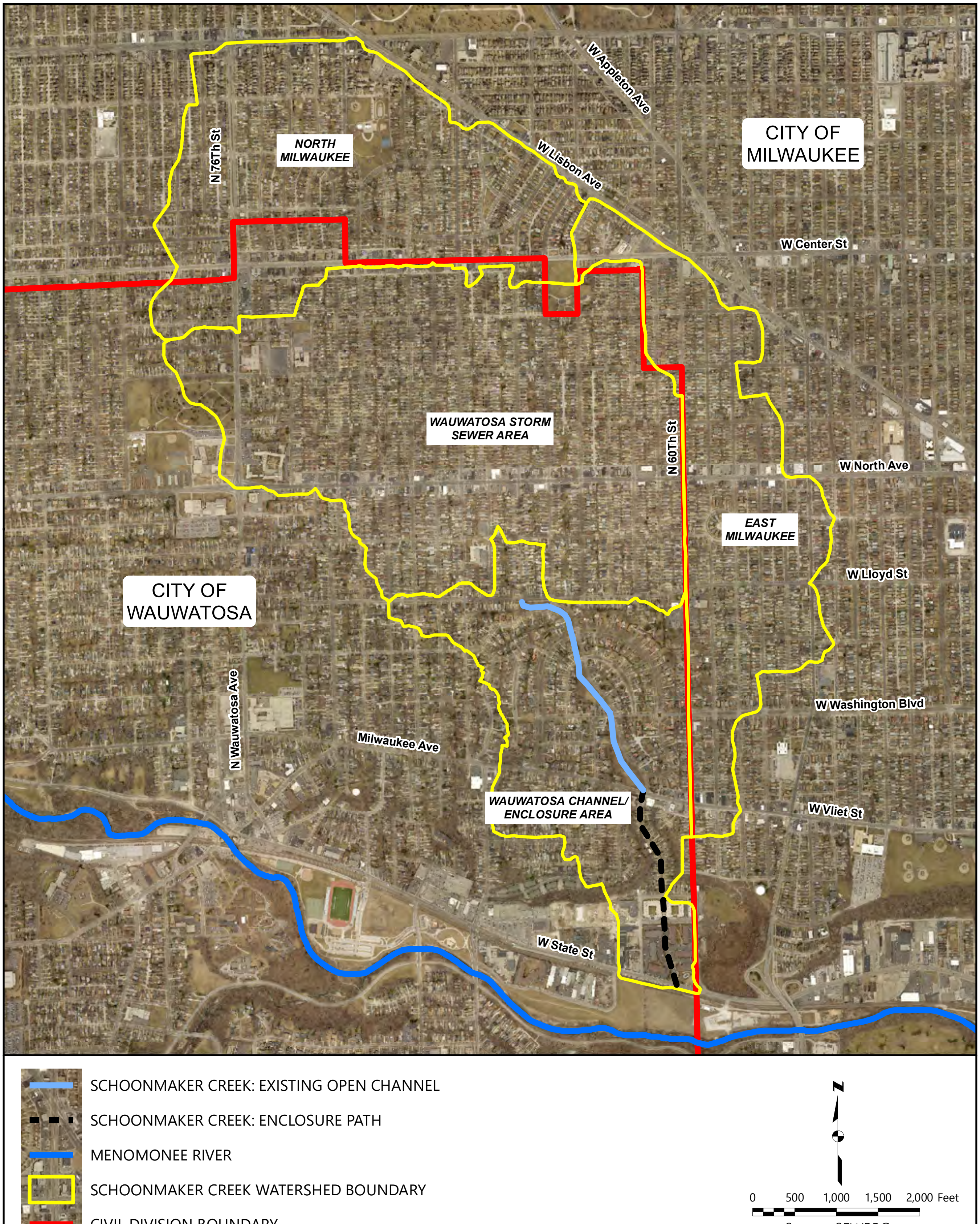
Total rain barrel volume = (2* 6.7 ft^3) = 13.4 ft^3
Depth of rain captured for two rain barrels = 13.4 ft^3 / 1,400 ft^2 average roof area = 0.11 inches
Roof percentage of basin = 15.6% (Table 3.1)
One-percent-annual-probability storm (4.28 inches in 3 hours)
Effective rain on Wauwatosa Sewer Area = (4.28 * % non-roof area) + ((4.28-captured) * % roof area)
Effective rain on Wauwatosa Sewer Area = (4.28 * (1-0.156)) + ((4.28-0.11) * 0.156) = 4.26 inches

<u>A rain garden on one out of every four homes in the Wauwatosa Sewer Area</u>

Total rain garden volume = (150 ft^2 * 1.0 ft) = 150.0 ft^3
Depth of rain captured by rain garden = 150 ft^3 / 1,400 ft^2 Avenue roof area = 1.28 inches
Roof percentage of basin = 2,175 homes / 4 = 544 homes * 1,400 ft^2 = 17.5 ac / 448 ac = 3.9%
One-percent-annual-probability storm (4.28 inches in 3 hours)
Effective rain on Wauwatosa Sewer Area = (4.28 * (1-0.039)) + ((4.28-1.28) * 0.039) = 4.23 inches

Expanding the calculations to include all four areas of the Schoonmaker Creek watershed (Map 3.28), the installation of two rain barrels at every home will reduce the effective rainfall of a storm event on the Schoonmaker Creek watershed by about 0.02 inches (0.5 percent reduction to one-percent-annual-probability storm). A similar set of calculations for the single 200 gallon cistern at every home yielded a reduction of 0.04 inches to the effective rainfall of a storm event. The rain garden reduction to the effective rainfall on the Schoonmaker Creek watershed was 0.05 inches (1.2 percent reduction to one-percent-annual-probability storm). When compared to the design rainfall totals included in Table 1, these green infrastructure rainfall reductions would have a minimal impact on Schoonmaker Creek flood flows. Green infrastructure can be a viable complement to the 16 alternatives included in this study, but would not solely be able to relieve flooding in the Schoonmaker Creek watershed.

Map 3.28
Schoonmaker Creek Subwatersheds for Green Infrastructure Analysis



Source: SEWRPC

EVALUATION OF THE ALTERNATIVES 4

The alternatives to reduce flooding in the Schoonmaker Creek watershed were evaluated in this section for changes in peak flow to receiving waters, construction costs, implementability, and effectiveness. A summary of public input regarding the draft alternatives was also prepared.

4.1 PEAK FLOWS TO THE OPEN CHANNEL AND MENOMONEE RIVER

Table 4.1 summarizes the one-percent-annual-probability peak flows from the XPStorm model for each of the City of Wauwatosa alternatives at both the upstream end of the open channel of Schoonmaker Creek and at the Menomonee River. Two locations were evaluated at the upstream end of the open channel of Schoonmaker Creek to account for each of the two main storm sewer networks discharging to the channel. Comparing alternative peak flows to existing conditions, only storage Alternatives 10, 11, and 12 and tunnel Alternatives 13, 14, and 15 reduce peak one-percent-annual-probability flows at the upstream end of the open channel portion of Schoonmaker Creek. Sewer Alternatives 4, 5, and 6 as well as the channel Alternative 9 all increase the one-percent-annual-probability peak flow to the upstream section of the Schoonmaker Creek open channel section. The open channel bypass sewer included in Alternative 16 somewhat decreases the peak flows of the 100-year sewer system as compared to Alternative 5. To note, the enclosure Alternatives 1, 2, and 3 have no impact on existing flows to the open channel portion of Schoonmaker Creek.

Comparing peak flows to the Menomonee River, only storage Alternatives 2, 3, 11, 12, and 16 reduce the one-percent-annual-probability peak flow as compared to existing conditions (Table 4.1). A comparison of the timing of Schoonmaker Creek peak flow to the peak flow on the Menomonee River is included in Appendix E. The conclusion of this comparison was that Schoonmaker Creek peak flows will precede the peak flow on the Menomonee River at their confluence, and creek flows will be a very small percentage of the peak flow on the Menomonee River at their confluence.

It is worth noting that Alternatives 4, 5, 6, and 9 include armoring a portion of the existing Schoonmaker Creek open channel that would mitigate the effects of higher flows. The open channel improvement included in these alternatives would protect the channel by decreasing flow velocities, increasing the channel capacity, and armoring the open channel for flows up to the 10-percent-annual-probability event. Armoring the channel to the 10-percent-annual-probability event was selected for planning purposes, and this assumption will be re-evaluated and refined if this option is chosen for future work.

4.2 PLANNING LEVEL COSTS

A summary of planning level construction costs for the 16 alternatives to reduce Schoonmaker Creek flooding is shown in Table 4.2. The planning level costs include a 35% contingency for final design, permitting, and miscellaneous minor costs. It should be noted that these planning level costs do not reflect utility relocation costs, which could significantly increase total construction costs. Although estimates of utility relocation costs are not included, the following Implementability section of the report notes the alternatives that are more likely to have high utility relocation impacts. The costs of potential property acquisitions were estimated based on average year 2014 fair market values adjusted to 2019 values. Acquisition costs were comprised of purchase of the property, demolition of the buildings, removal of debris, and relocation costs. Average annual costs included in Table 4.2 were based on a project life of 50 years and an interest rate of 6 percent. The average annual cost for each alternative does not include annual operations and maintenance costs.

Among the alternatives that only provide flood relief to the 46 structures in the overflow and enclosure area (Alternatives 1, 2, and 3), Alternative 1 has the lowest capital planning level construction cost of $5.6 million (2019 dollars).

Table 4.1
XPStorm Peak Flow Comparison at Receiving Stream One-Percent-Annual-Probability Storm

Scenario[a]	Peak Flow in Open Channel just Downstream of W. Lloyd Street (cfs)[b]	Peak Flow in Open Channel just Downstream of Revere Avenue (cfs)[b]	Total Peak Flow in the Enclosure at the Confluence with the Menomonee River (cfs)[b]
Existing Conditions	740	430	1,080
Enclosure Alternatives			
Alternative 1 – Relief Pipe at Enclosure	740	430	1,180
Alternative 2 – Relief Pipe at Enclosure with Storage	740	430	[890]
Alternative 3 – Inline Storage	740	430	[630]
Enclosure and Sewer Area Alternatives			
Alternative 4 – 25-Year Sewer	810	630	1,380
Alternative 5 – 100-Year Sewer	900	710	1,570
Alternative 6 – 100-Year Sewer Extended	1,010	720	1,570
Alternative 9 – Open Channel	1,160	750	1,650
Alternative 10 – North Storage	[610]	640	1,220
Alternative 11 – South storage	[480]	[410]	[900]
Alternative 12 – North and South Storage	[420]	[400]	[880]
Alternative 13 – 25-Year Sewer and Tunnel	0[c]	[320]	1,450
Alternative 14 – 100-Year Sewer and Tunnel	0[c]	[320]	1,480
Alternative 15 – 100-Year Sewer Extended and Tunnel	0[c]	[320]	1,590
Alternative 16 – 100-Year Sewer and Open Channel Bypass	740	600	1,010

[a] *Alternatives 7 and 8 are not included as they would only reduce flooding for the City of Milwaukee sewer along N. 60th Street.*

[b] *Brackets indicate decreased peak flows as compared to existing conditions. Units are cubic feet per second (cfs).*

[c] *In the XPStorm model all sewer flows were diverted to the proposed tunnel at this location. In reality, some local flow would utilize this portion of the open channel.*

Source: SEWRPC

Table 4.2
Planning Level Costs

Alternative	Total Capital Cost[a] (millions)	Average Annual Cost[b] (millions)
Enclosure Area Alternatives		
Alternative 1 – Relief Pipe at Enclosure	5.6	0.4
Alternative 2 – Relief Pipe at Enclosure with Storage	6.7	0.4
Alternative 3 – Inline Storage	5.9	0.4
Enclosure and Sewer Area Alternatives		
Alternative 4 – 25-Year Sewer[c]	22.8	1.4
Alternative 5 – 100-Year Sewer[c]	30.1	1.9
Alternative 6 – 100-Year Sewer Extended[c]	31.3	2.0
Alternative 7 – East Milwaukee Sewer Additional Pipe	3.2	0.2
Alternative 8 – East Milwaukee Sewer New Pipe	5.8	0.4
Alternative 9 – Open Channel[c]	69.2	4.4
Alternative 10 – North Storage	28.2	1.8
Alternative 11 – South Storage	20.4	1.3
Alternative 12 – North and South Storage	42.8	2.7
Alternative 13 – 25-Year Sewer and Tunnel	35.2	2.2
Alternative 14 – 100-Year Sewer and Tunnel	39.0	2.5
Alternative 15 – 100-Year Sewer Extended and Tunnel	40.4	2.6
Alternative 16 – 100-Year Sewer and Open Channel Bypass	29.3	1.9

[a] *Based on 2019 dollars and includes construction, materials, property buyouts, and a 35 percent contingency. Does not include utility relocation, annual operation and maintenance costs, and assumes no contaminated soils.*

[b] *Amortized capital cost is based on an annual interest rate of 6 percent and a project life of 50 years.*

[c] *Costs for these alternatives include the cost of the channel improvement in the open channel area.*

Source: SEWRPC

For the remaining Schoonmaker Creek alternatives that provide flood relief to the 46 impacted structures and reduce street ponding in the Wauwatosa sewer area, sewer Alternatives 4, 5, and 6 planning level construction costs range from $22.8 million to $31.3 million. Open channel Alternative 9 had a planning level construction cost of $69.2 million. The storage Alternatives 10, 11, and 12 construction costs range from $20.4 million to $42.8 million. Sewer and channel bypass Alternatives 13, 14, 15, and 16 had planning level construction costs ranging from $29.3 million to $40.4 million. Planning level construction cost estimate details can be found in Appendix F.

4.3 IMPLEMENTABILITY

While this alternative evaluation category is more subjective, it is possible to evaluate and compare the relative implementability of the potential Schoonmaker Creek alternatives included in this report. Considerations for building the various alternatives encompass disruption during construction, potential for utility conflicts, need for acquisitions, and dam regulation considerations. Alternatives 7 and 8 will not be discussed in this section as the City of Milwaukee does not plan to implement these alternatives.

Alternatives 1, 2, and 3 provide flood relief for the channel enclosure area from Milwaukee Avenue to the Menomonee River and each one protects the 46 structures in the enclosure area from flooding damage during the one-percent-annual-probability storm event. The disruption during construction for Alternatives 1 and 2 would predominantly be street closures for sewer construction. Alternative 3, the inline storage alternative, would be disruptive during construction for the area impacted by the impoundment and dam. The potential for utility conflicts would be greater for Alternatives 1 and 2 for existing storm sewers, water mains, sanitary sewers and other utilities under the streets. There may be utility conflicts for Alternative 3, but they would be anticipated to be only under the impacted portion of Martha Washington Drive. For these three alternatives, only Alternative 3 requires an acquisition of a home. Alternative 3 also has numerous concerns with implementability related to the anticipated designation as a High Hazard dam, as discussed in the previous Alternatives section.

Alternatives 4 through 16 also provide relief from street ponding in the Wauwatosa sewer area, as well as flood relief for the enclosure area from Milwaukee Avenue to the Menomonee River to reduce the risk of damages to the 46 structures within the Schoonmaker Creek one-percent-annual-probability floodplain. Disruption during construction would be significant for storm sewer Alternatives 4, 5, and 6 due to street closures for sewer and enclosure construction. The open channel Alternative 9 would also be very disruptive during construction, more so due to the large area impacted and large number of bridge crossings. Alternatives 4, 5, 6, and 9 would also cause some disruption along Martha Washington Drive due to regrading and installing riprap along the open channel. Storage Alternatives 10, 11, and 12 would only be disruptive in the immediate vicinity of each basin. Sewer and channel bypass Alternatives 13, 14, 15, and 16 include the sewer portions of Alternatives 4, 5, 6, and 5, respectively, hence the same street closure issues would be present. Depending on construction technique, the tunnel alternatives may also have street closures for the anticipated open cut construction for the downstream tunnel portion along N. 68th Street. Alternative 16 would also require the closure of Martha Washington Drive for installation of the channel bypass sewer.

The potential for utility conflicts would be lowest for the more concentrated storage Alternatives 10, 11, and 12. The remaining sewer Alternatives 4, 5, and 6, channel Alternative 9, and sewer and channel bypass Alternatives 13, 14, 15, and 16 would have significant potential for conflicts with existing underground utilities due to the large areas impacted. The acquisition and removal of homes would be significant for channel Alternative 9, with 122 homes requiring removal. Storage Alterative 10 requires the acquisition and removal of 45 homes, and storage Alternative 11 requires the removal of 31 homes. Storage Alternative 12 combines the north and south basins, requiring the removal of 76 homes. The loss of homes would also impact the City of Wauwatosa tax base and would create gaps in the residential character of the affected neighborhoods.

4.4 EFFECTIVENESS OF PROTECTION

As previously discussed, all the existing Schoonmaker Creek watershed storm sewers evaluated in this study meet the local ordinance required ten-percent-annual-probability level of protection. This means the City of Wauwatosa and City of Milwaukee storm sewers are sufficient to convey the ten-percent-annual-probability 3-hour storm without surcharging from manholes and flooding streets.

All of the alternatives listed in this report (excluding City of Milwaukee sewer Alternatives 7 and 8) would protect the 46 structures in the enclosure area during one-percent-annual-probability storm event. Additionally, Alternatives 4 through 16 would provide varying levels of relief from large storm event street ponding that currently affects approximately 288 structures (280 in Wauwatosa, 8 in Milwaukee). Based on the report maps for ponding or street conveyance discussed previously for each alternative, sewer Alternatives 5 and 6 as well as sewer and channel bypass Alternatives 14, 15, and 16 eliminate the most street ponding for the Wauwatosa sewer area. Sewer Alternative 4 would be the next most effective, providing partial relief from street ponding. Channel Alternative 9 and storage Alternatives 10, 11, and 12 also provide partial relief from street ponding, with Alternative 11 being the least effective at reducing large storm event street ponding for the Wauwatosa sewer area.

4.5 PUBLIC INPUT

There were two opportunities for stakeholder input on the Schoonmaker Creek alternatives during the development of this plan. The two meetings are summarized below, as well as subsequent comments submitted to the City of Wauwatosa after the public open house.

January 24, 2017 Neighborhood Group Meeting

To gain input on the potential Schoonmaker Creek alternatives from the impacted neighborhood groups, a meeting was held on January 24, 2017. Those in attendance included City of Wauwatosa elected officials and engineering staff, MMSD staff, SEWRPC staff, and eleven members of the Washington Highlands Association, the Olde Hillcrest Neighborhood Association, the Pabst Park Neighborhood Association, the Quarry Heights Neighborhood Association, and Tosa East Towne Neighborhood Association. No major concerns regarding the alternatives were offered at the meeting by the participating neighborhood groups.

November 13, 2017 Public Open House

A public open house was held at the Wauwatosa City Hall on November 13, 2017, to present the design alternatives to the Schoonmaker Creek watershed stakeholders and receive feedback. Those in attendance included City of Wauwatosa elected officials and engineering staff, MMSD staff, SEWRPC staff, and 44 members of the public. To simplify the presentation of the alternatives at the open house, the four categories of alternatives (sewer, open channel, storage, and bypass tunnel) were presented, with details shown for Alternatives 5, 9, 12, and 14 respectively. After the open house nine handwritten and 70 electronic stakeholder comments were received by the City of Wauwatosa. A summary of those comments is included below and the open house presentations can be found in Appendix G.

Summary of Major Themes in Stakeholder Comments from the November 13, 2017, Open House

There was a general consensus among the stakeholder comments that the sewer conveyance and bypass tunnel conveyance alternatives were more desirable than the open channel or storage alternatives. Public comments were fairly evenly split between preferring the sewer or the bypass tunnel alternatives. Some stakeholders thought that the bypass tunnel alternative would be more desirable as it would divert flow away from the Washington Highlands Schoonmaker Creek open channel area, while other stakeholders commented that the additional benefit from the bypass tunnel alternative did not justify the additional cost.

Many stakeholder comments indicated strong opposition to removing homes, which is required for the open channel and storage alternatives. Concerns for these two alternatives included that the City tax revenue would decrease with the loss of residences; removal would intensify the housing shortage in Wauwatosa; these alternatives are very expensive; and they might reduce aesthetics and neighborhood feel, thus lowering property values. Many stakeholder comments also indicated safety concerns for the open channel and storage alternatives.

Suggestions to improve the alternatives provided in stakeholder comments included additional green infrastructure features. Green infrastructure ideas were comprised of green roofs, bioswales, and pervious pavement. Stakeholders also offered adding many smaller storage areas instead of the two large facilities included in the study, and adding an underground storm sewer parallel to the open channel.[13]

Stakeholder comments also included the need for more public meetings in the future and more communication about the Schoonmaker Creek project in general. Details of stakeholder interest consisted of the cost/benefit for each alternative, as well as a future timeline for major decisions by the City.

4.6 FUTURE WORK

This plan summarizes the alternatives developed to mitigate large storm event flooding in the Schoonmaker Creek watershed. Sixteen alternatives were evaluated, which include all feasible potential options to reduce large rainfall event flooding. All the presented alternatives protect the 46 structures in the Schoonmaker Creek from flooding damage during the one-percent-annual-probability storm event in the enclosure area of the watershed from Milwaukee Avenue to the Menomonee River. Alternatives 1, 2, and 3 only mitigate the 46 flooded structures. Alternatives 4 through 16 also reduce the street ponding in the Schoonmaker Creek watershed in the Wauwatosa sewer area. Major issues for the alternatives as discussed in this report are summarized in Table 4.3.

City of Wauwatosa elected officials, staff, and residents will need to work together to determine which of the 16 alternatives documented in this report to evaluate in greater detail. Factors influencing the selection of alternative(s) for further study may consist of the issues summarized in Table 4.3 as well as additional public stakeholder input. The selected alternative(s) may be refined based on the level of flood protection desired, utility conflicts, and refined construction costs. Refined alternatives may be a combination of the alternatives evaluated in this plan and may include adjustments to proposed pipe sizes to best accommodate the desired level of flood protection. Review of the expected flow velocities in the open channel portion of Schoonmaker Creek for the refined alternative(s) may also be a consideration.

Table 4.3
Schoonmaker Creek Alternative Summary

Alternative	100-year Recurrence Interval Peak Flow to Open Channel	Implementability			100-year Recurrence Interval Storm Ponding Reduction in the Wauwatosa Sewer Area	Total Capital Cost[a] (millions)
		Disruption During Construction	Utility Conflict Potential	Property Acquisitions Required		
Enclosure Alternatives						
Alternative 1 – Relief Pipe at Enclosure	No change	Medium	Medium	No	None	5.6
Alternative 2 – Relief Pipe at Enclosure with Storage	No change	Medium	Medium	No	None	6.7
Alternative 3 – Inline Storage[b]	No change	Medium	Medium	Yes	None	5.9
Enclosure and Sewer Area Alternatives						
Alternative 4 – 25-Year Sewer	Increase	High	High	No	Medium	22.8
Alternative 5 – 100-Year Sewer	Increase	High	High	No	High	30.1
Alternative 6 – 100-Year Sewer Extended	Increase	High	High	No	High	31.3
Alternative 7 – East Milwaukee Sewer Additional Pipe	NA[c]	Medium	Medium	No	Low[d]	3.2
Alternative 8 – East Milwaukee Sewer New Pipe	NA	Medium	Medium	No	Low[d]	5.8
Alternative 9 – Open Channel	Increase	High	High	Yes	Medium	69.2
Alternative 10 – North Storage	Decrease	Low	Low	Yes	Medium	28.2
Alternative 11 – South Storage	Decrease	Low	Low	Yes	Low	20.4
Alternative 12 – North and South Storage	Decrease	Low	Low	Yes	High	42.8
Alternative 13 – 25-Year Sewer and Tunnel	Decrease	High	High	No	Medium	35.2
Alternative 14 – 100-Year Sewer and Tunnel	Decrease	High	High	No	High	39.0
Alternative 15 – 100-Year Sewer Extended and Tunnel	Decrease	High	High	No	High	40.4
Alternative 16 – 100-Year Sewer and Open Channel Bypass	Decrease	High	High	No	High	29.3

[a] *Based on 2019 dollars and includes construction, materials, property buyouts, and a 35% contingency. Does not include utility relocation, annual operation and maintenance costs, and assumes no contaminated soils.*

[b] *Alternative 3 would most likely be designated a High Hazard dam which would be a significant issue if this alternative were implemented.*

[c] *NA means not applicable for this alternative.*

[d] *Alternatives 7 and 8 only eliminate flooding from the City of Milwaukee N. 60th St. sewer to the Wauwatosa sewer area.*

Source: SEWRPC

APPENDICES

APPENDIX A

SCHOONMAKER CREEK WATERSHED STUDY BY R.A. SMITH NATIONAL

DRAFT

Schoonmaker Creek Watershed Study

Prepared for

City of Wauwatosa, Wisconsin

December 29, 2011

R.A. Smith National

Beyond Surveying and Engineering

Table of Contents

List of Figures

List of Tables

Section 1
Introduction

This watershed study provides a detailed evaluation of the stormwater system within the Schoonmaker Creek watershed in the City of Wauwatosa. The purpose of this study is to identify improvements that could be implemented to reduce the frequency and severity of surface water flooding in the watershed. Several locations in the watershed have experienced excessive stormwater ponding that has resulted in flooding of streets and buildings in the past several years, most particularly in July 2010.

1.1 Project Area

Schoonmaker Creek watershed lies in the City of Wauwatosa and the City of Milwaukee, as shown in Figure 1. The watershed boundaries were determined based on topographic mapping and storm sewer system maps. As defined in this study, the 1100-acre watershed is approximately bounded by W. Burleigh Street and W. Lisbon Avenue on the north, 76th Street on the west, 56th Street on the east, and W. State Street on the south. Approximately 62 % of the watershed is in the City of Wauwatosa and 38% is in the City of Milwaukee.

1.1.1 Wauwatosa Drainage Area

The Schoonmaker Creek watershed drains generally from the north to the south and discharges to the Menomonee River near 61st Street and W. State Street. The primary drainage system consists of storm sewers ranging in size from 12-inch diameter to 5.5-foot by 9-foot box culvert, and an open channel between W. Lloyd Street and Milwaukee Avenue. The secondary drainage system consists of the streets, which have several low points susceptible to flooding.

1.1.2 Milwaukee Drainage Area

Areas north of Center Street, mostly in the City of Milwaukee, would naturally drain into Schoonmaker Creek based on the topography. However, storm sewers in Center Street intercept runoff from this area and carry the stormwater west to the Menomonee River. During severe rainfall events, runoff exceeding the capacity of the City of Milwaukee Center Street storm sewer system flows south into the City of Wauwatosa.

Also, areas east of 60th Street would drain into Schoonmaker Creek based on topography. However, City of Milwaukee combined sewers intercept stormwater runoff from that area. During severe rainfall events, runoff exceeding the capacity of the combined sewers flows west into City of Wauwatosa toward Schoonmaker Creek.

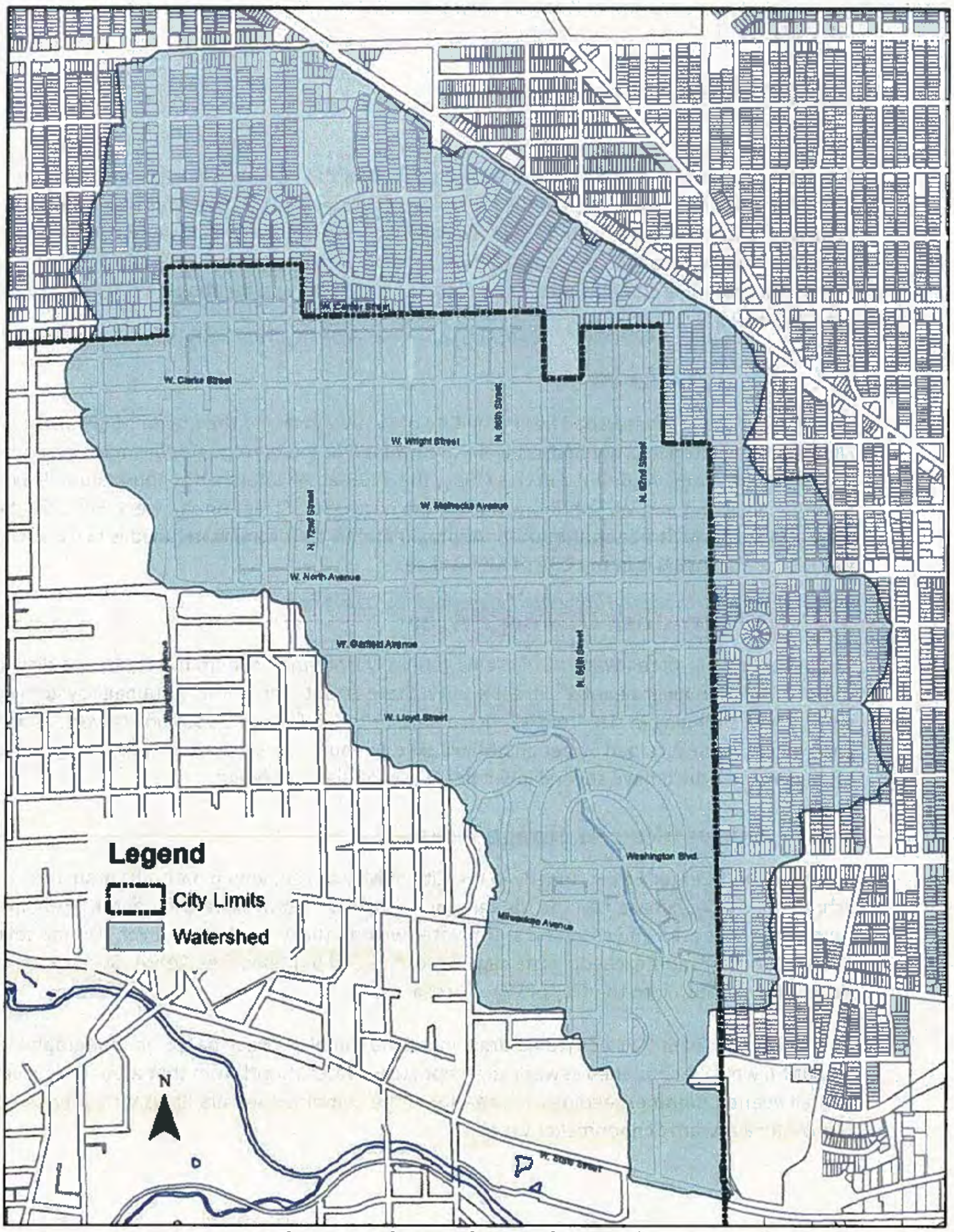


Figure 1. Schoonmaker Creek Watershed

1.2 Problem Areas

The City requested a detailed evaluation of the drainage systems and alternative improvements to mitigate the flooding in these areas:

- 66th Street and Lloyd Street – nuisance street flooding
- 68th Street and North Avenue – nuisance flooding and structure flooding
- State Street between 62nd and 63rd Streets - nuisance flooding and structure flooding

1.3 Overview of Analysis

The stormwater study for the Schoonmaker Creek watershed is intended to provide alternative improvement plans for mitigating both nuisance flooding and structural flooding problems recently experienced in the watershed. The alternative and recommended plans are based on hydraulic modeling of the stormwater runoff and conveyance through storm sewers as well as overland routes. The primary tasks in the investigation are:

- Storm sewer condition assessment based on internal inspection
- Hydraulic modeling of stormwater runoff through existing storm sewers, overland flow routes, and ponding areas
- Examination of flooding problem areas to formulate alternative mitigation measures
- Evaluation of alternative improvements utilizing the hydraulic model
- Consolidating alternative improvements into watershed-based plans
- Preparing preliminary capital costs estimates for alternative plans

Section 2

Data Obtained for Analysis

2.1 Storm Sewer Data

The City provided storm sewer data in several forms. The locations of manholes, inlets, and storm sewers were provided in an AutoCAD file. Additional data consisting of pipe size, length, rim elevation, and invert elevation were provided on Storm Sewer System Plan drawings. In addition, the City provided copies of design plans, and supplemental survey data upon request. Sewer data provided by the City were in City of Wauwatosa datum.

2.2 Milwaukee Storm Sewer Data

Storm Sewer System Plan drawings were obtained from the City of Milwaukee to aid in quantifying runoff from the watershed area outside the City of Wauwatosa.

2.3 Recent Construction Data

A consultant to the City of Wauwatosa recently completed design of storm sewer improvements in the vicinity of Mountain Avenue, Hill Crest Drive, Washington Circle, and Alta Vista. The changes in tributary drainage area boundaries and storm sewer discharge locations were obtained from the City and incorporated in the modeling.

R.A. Smith National recently completed the site design for The Enclave, at W. Martin Drive and 62nd Street. The site grading design data were converted to City datum and incorporated into the City datum topographic contours, as described in the following section.

2.4 Topographic Data

The City provided one-foot contour mapping in an AutoCAD file. This mapping was prepared using aerial photogrammetric methods. The date of the mapping was approximately 2005. The contour data were in National Geodetic Vertical Datum (NGVD).

The City also provided street centerline elevations at intersections and mid-block for selected streets. These elevations were in City of Wauwatosa datum, which is 580.28 feet below NGVD.

The contour mapping data were converted from NGVD to City datum and combined with the street centerline elevations and The Enclave design topography. One-foot contours in City datum were created for use in the overland flow analysis.

Section 3

Storm Sewer Inspection

As part of the watershed study, R.A. Smith National contracted with Visu-Sewer, Inc. to televise and report on the condition of approximately 14,170 feet of storm sewer in the Schoonmaker Creek watershed. The storm sewers to be inspected were identified by the City and ranged in size from 15-inch diameter to 5.5-foot by 9-foot box culvert.

3.1 CCTV Inspection

The storm sewers were inspected using closed circuit television (CCTV) cameras pulled through the storm sewers. Video imagery of the sewer interior was captured and later evaluated to determine the sewer condition. Inspection work was completed in accordance with the National Association of Sewer Service Contractors (NASSCO) standards.

3.2 Condition Assessment

The results of the storm sewer television were documented in a separate report provided to the City. Each sewer segment was assigned a condition rating or grade from 0 to 5, based on NASSCO standards. This rating system is oriented to sanitary sewers, where the severity of defects has a greater impact on the overall performance of the sewer system. For example, defects that allow infiltration are less of a concern in storm sewers than in sanitary sewers. Therefore, the actual conditions of the storm sewers are better than indicated by the numeric NASSCO ratings.

Approximately 90% of the televised sewers were found to be in good or better condition with ratings of 1 to 3. The remaining 10% (1,411 feet) were found to have defects such as surface spalling, break-in connections, small cracks, and minor infiltration. Overall the CCTV did not reveal any major structural or maintenance related issues with the existing system.

The assessment results of the storm sewer condition based on the CCTV inspection are summarized in Figure 2.

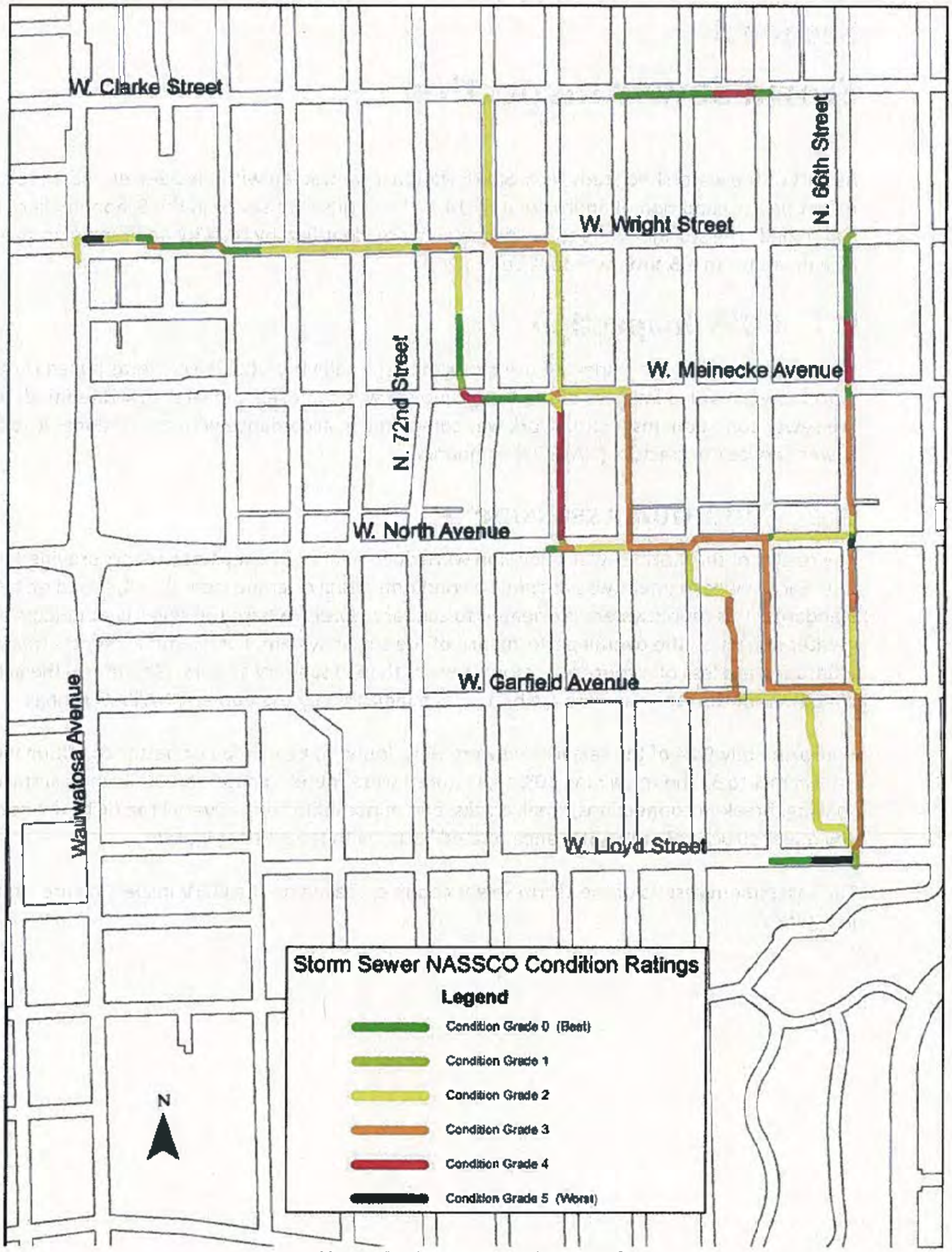


Figure 2. CCTV Inspection Results

3.3 Identified Problem Areas

One area of concern is the storm sewer in W. Wright Street east of Wauwatosa Avenue. The City sewer data indicates that the storm sewer is back-pitched between manholes 37 and 38. Photo 3-1 is a snapshot taken during the CCTV work between manholes 37 and 38. About 45 feet east of manhole 37 in Wright Street, water begins to back up. At 70 feet east of manhole 37, it's fully surcharged as shown in the photo. This surcharging is consistent with the sewer elevation data.

Photo 3-1. Wright Street Storm Sewer, east of Wauwatosa Avenue

Another issue of concern is adjacent to the one above. Between manholes 38 and 39 there is an obstruction that is causing both water and debris to back up in the storm sewer. Photo 3-2 shows the obstruction and Photo 3-3 shows the debris that has accumulated upstream of the obstruction. Dye flooding in the vicinity did not identify any major leaks into the sanitary sewer system at this location, but this obstruction limits the storm sewer capacity.

Photo 3-2. Wright Street Storm Sewer (above water)

Photo 3-3. Wright Street Storm Sewer (underwater)

Section 4

Hydraulic Model Development

The analysis of the Schoonmaker Creek drainage system and the evaluation of alternative configurations were based on modeling the storm sewers and overland flow routes. This section addresses the development of the hydraulic model for existing conditions and application of the model to evaluate alternative scenarios for mitigating flooding problems in the watershed.

4.1 Rainfall Events

Several storm events were used in analyzing the Schoonmaker Creek watershed. These events included the July 2010 historic storm, as well as 10-year, 50-year, 100-year and 500-year recurrence interval (10-percent, 2-percent, 1-percent, and 0.2-percent annual chance, respectively) synthetic design storm events.

Although the City operates a rain gage just outside the watershed at City Hall, during the July 2010 event the gage did not properly record the extremely intense rainfall. Therefore, we obtained the rainfall data recorded at the U.S. Geological Survey gaging station on the Menomonee River at 70th Street. This station is very close to the Schoonmaker Creek watershed and provided 5-minute interval rainfall data. The July 2010 storm exceeded a 100-year recurrence interval event based on the characteristics shown in Table 1.

As also shown in Table 1, two other locations in the Milwaukee area recorded rainfall amounts during this storm greater than at the 70th Street gage.

Table 1. July 2010 Storm Characteristics

Storm Event	Max 1-hour Rainfall	Max 2-hour Rainfall	Max 3-hour Rainfall
100-Year Recurrence Interval	2.82 inches	3.64 inches	3.89 inches
July 2010 - 70th Street	3.03 inches	3.58 inches	4.16 inches
July 2010 - Menomonee Falls	4.02 inches	4.42 inches	4.64 inches
July 2010 - 5335 N Teutonia Ave.	3.74 inches	5.72 inches	6.15 inches

Source: SEWRPC

Additional extreme historic storm events were also considered for the analysis. Severe rainfall events occurred in the Milwaukee area in 1986, June 1997, and August 1998. Limited data is available for these events, but most appear to have been most intense in the 6- to 24-hour duration time period. Because the Schoonmaker Creek watershed is relatively small and steep, the most severe flows will occur with intense shorter duration storm events like the July 2010 event.

For the synthetic design storm events, the SCS 24-hour duration with Type II storm distribution was used with rainfall volumes obtained from SEWRPC Technical Report 40, as shown in Table 2.

Table 2. Design Storm Characteristics

Storm Event	24-hour Rainfall
10-year Recurrence Interval (10-percent Annual Chance)	3.62 inches
50-year Recurrence Interval (2-percent Annual Chance)	5.11 inches
100-year Recurrence Interval (1-percent Annual Chance)	5.88 inches
500-year Recurrence Interval (0.2-percent Annual Chance)	8.02 inches

Source: SEWRPC

4.2 Existing Condition Model Setup

The 2011 version of XP-Storm was chosen for the hydrologic and hydraulic modeling in this study. XP-Storm is proprietary software developed and supported by XP Software, Inc. The program was used to quantify the flows, volume, and timing of storm runoff for various rainfall events. The model performed hydrograph routing through storm sewers, overland flow routes, culverts, and open channels in the Schoonmaker Creek watershed.

4.2.1 Hydrologic Parameters

The watershed was divided into 75 subbasins based on the topography as shown in Figure 3. The parameters affecting the volume and rate of runoff were determined for each subbasin. These parameters consisted of the subbasin area, runoff curve number, and time of concentration. The runoff curve number was derived from the hydrologic soil type and land cover in each subbasin. Times of concentration were determined based on length of flow path and slope of each subbasin. The subbasins ranged in size from 0.9 acre to 95.9 acres. The subbasin parameters were utilized in the model to determine runoff hydrographs from each subbasin. The subbasin flow hydrographs were connected to storm sewers at designated manhole locations.

4.2.2 Sewers & Channels

Data provided by the City was used to develop a model of the primary conveyance system including storm sewers, open channels, roadway culverts, and extended length box culvert sections in the watershed. The modeled sewers and channel segments are shown in Figure 3. The model included the mainline storm sewers and storm sewers that drain locations where sag conditions or very flat gradients exist. This approach assumes that runoff exceeding the capacity of the non-modeled storm sewers will follow overland flow routes to either sag locations or open channel reaches.

4.2.3 Overland Flow and Ponding

In the model, overland flow routes were identified and modeled in two ways. In well-defined flow paths following the streets, the overland flow route was represented as an open channel based on the street cross section and the slope from manhole to manhole or intersection to intersection. These routes are show in Figure 4. In areas without easily defined overland flow routes, the overland flow was represented in the model based on the topography. The modeling utilized the 1-foot contour data and street centerline elevation data provided by the City to simulate ponding and non-discrete overland flows.

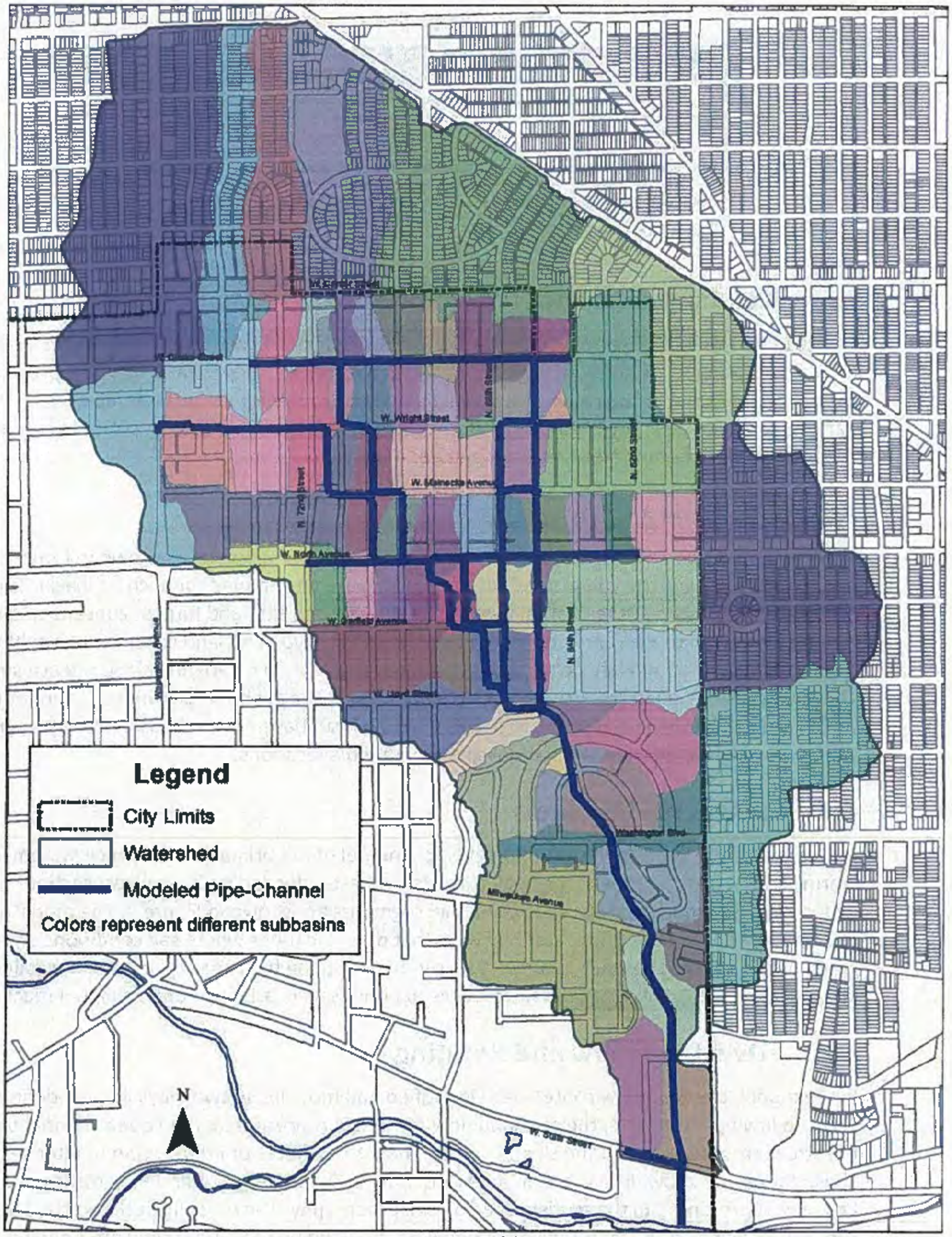


Figure 3. Subbasins

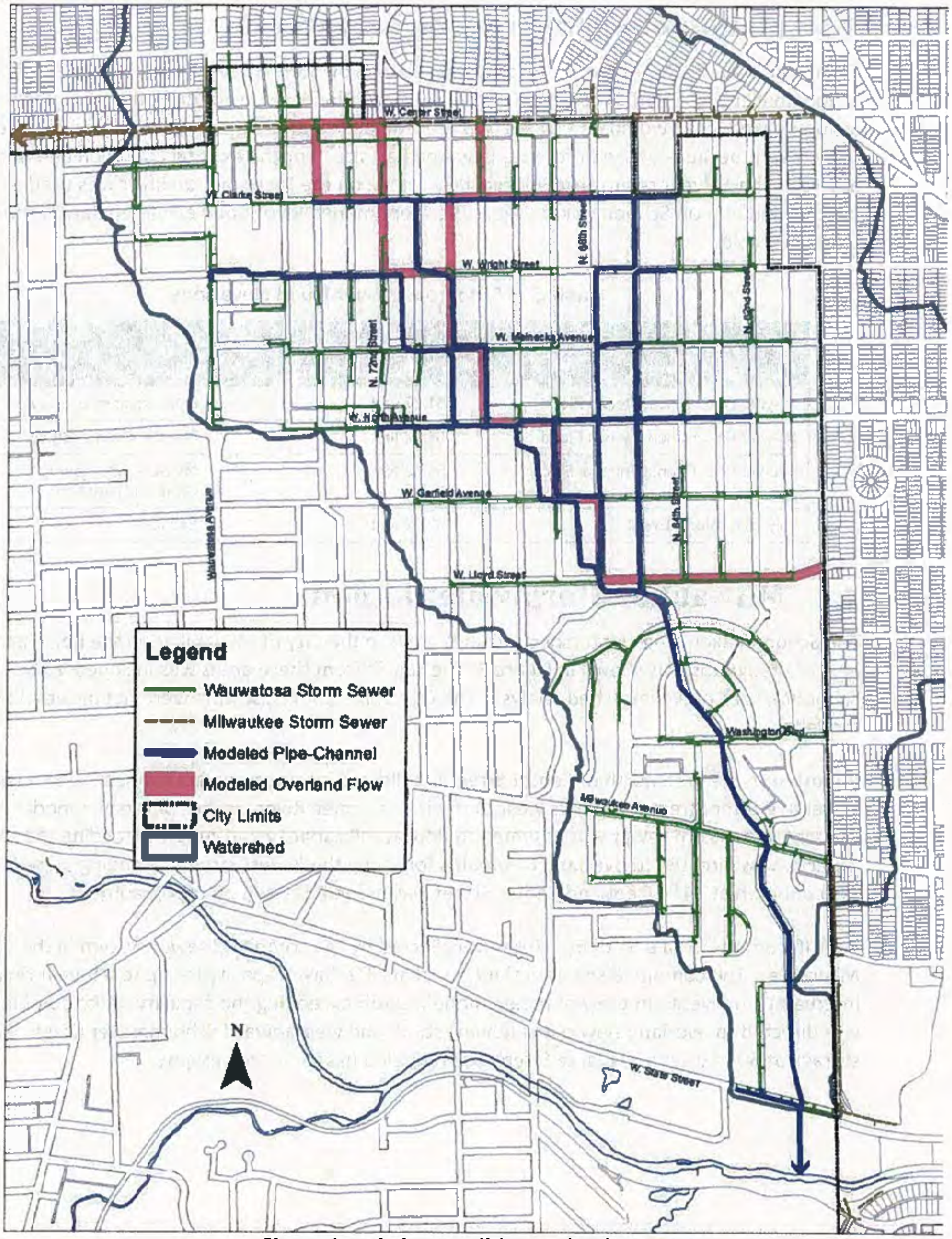


Figure 4. Existing Condition Hydraulic Model

4.3 Menomonee River Flood Elevations

Flood stages on the Menomonee River affect flooding on State Street, but have limited effect on the Schoonmaker Creek hydraulic profile upstream of Martin Drive. In addition, the peak flows on Schoonmaker Creek would be expected to precede peak stages on the Menomonee River for a given storm event because of the difference in watershed size. For the existing condition and alternative analyses, the 10-year recurrence interval flood stage on the Menomonee River was used as the outfall condition on Schoonmaker Creek. The Menomonee River flood elevation data is shown in the following table.

Table 3. Menomonee River Flood Elevations

Flood Event	Menomonee River Stage (Wauwatosa Datum)	Source
10-year Recurrence Interval Flood	51.32 feet	Flood Insurance Study
50-year Recurrence Interval Flood	54.22 feet	Flood Insurance Study
100-year Recurrence Interval Flood	54.52 feet	MMSD – with County Grounds Detention
July 2010 Storm Event	53.72 feet	Estimated

4.4 Milwaukee Stormwater Runoff

The Schoonmaker Creek watershed includes areas in the City of Milwaukee to the north and to the east of Wauwatosa, as shown in Figure 3. The runoff from these areas was included in the Schoonmaker Creek watershed analysis. The City of Milwaukee sewers were not included in the modeling.

Runoff from the area north of Center Street is collected by storm sewers connecting to a large storm sewer in Center Street that flows west to the Menomonee River. In the watershed model, the Center Street storm sewer was assumed to flow at full capacity and runoff exceeding the sewer capacity was directed to overland flow paths following the lowest streets. Ponding storage in the sag condition at 74th Street and Center Street was modeled based on topography.

Runoff from the area east of 60th Street is collected by the combined sewer system in the City of Milwaukee. The combined sewer outlet is estimated to have capacity for up to a 5-year recurrence interval storm event. In the watershed model, runoff exceeding the capacity of the combined sewer was directed to overland flow paths flowing south and west toward Schoonmaker Creek. Ponding storage at 60th Street and Clarke Street was modeled based on topography.

Section 5

Existing Condition Modeling Results

The XP-STORM model was used to simulate the performance of the existing Schoonmaker Creek drainage system for the July 2010 historic storm event and the 10-year design event. The results of these simulations were evaluated relative to historic flooding observations obtained from the City and media reports. The results appeared to be consistent with the reports and available data on ponding depths in select locations.

5.1 Stormwater Ponding & Overland Flow

In locations where the runoff rate exceeds the storm sewer capacity, the model simulates stormwater ponding and overland flow routes based on the topography. The ponding depths and overland flow rates fluctuate during the course of the storm event. Figure 5 illustrates the extent of overland flow and ponding simulated in the Schoonmaker Creek watershed for the July 2010 storm event. In this figure, stormwater flooding areas are shown in various colors representing depth, with blue indicating greater than 0.25 feet and red indicating greater than 2.5 feet.

Table 4. Simulated Ponding Depths

Location	July 2010 Storm Event Peak Ponding Depth
74th and Center	2.8 feet
72nd and Clarke	0.9 feet
70th and Wright	1.3 feet
70th and Meinecke	2.3 feet
68th and North	1.8 feet
67th and Garfield	0.7 feet
62nd and State	2.6 feet

5.2 Sewer Capacity

The modeling analysis identified many storm sewer segments inadequate to carry the peak flows that would result from a 10-year recurrence interval storm event. Those segments, as shown in Figure 6, were identified as sewers with capacities less than the peak flow tributary to the segment. This evaluation did include the ponding that occurs within the existing watershed conditions. The unintentional ponding provides storage which reduces downstream flows. Additional segments with deficient capacity may be identified once ponding in the upstream areas is reduced.

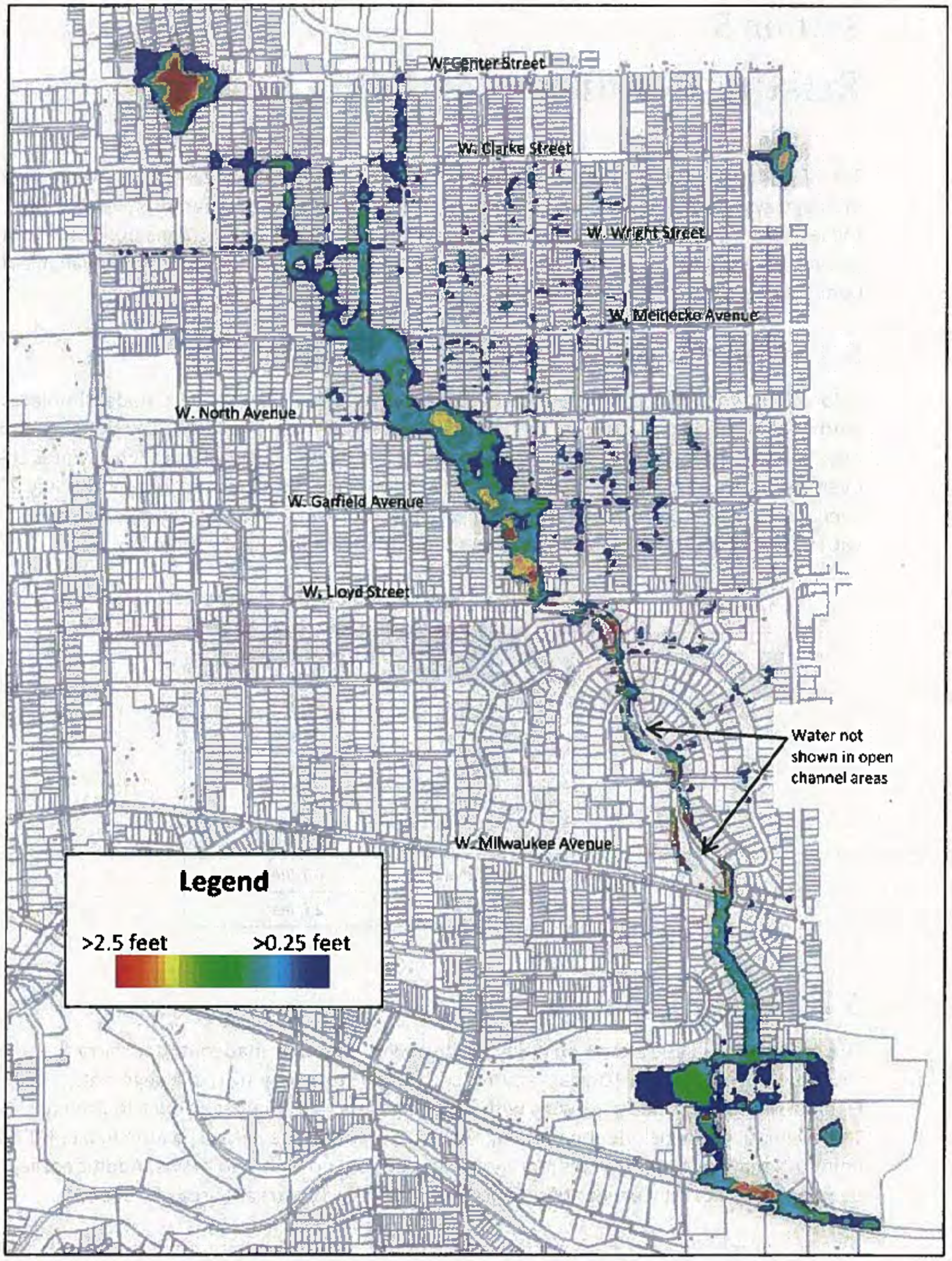


Figure 5. July 2010 Simulated Ponding and Overland Flow Areas

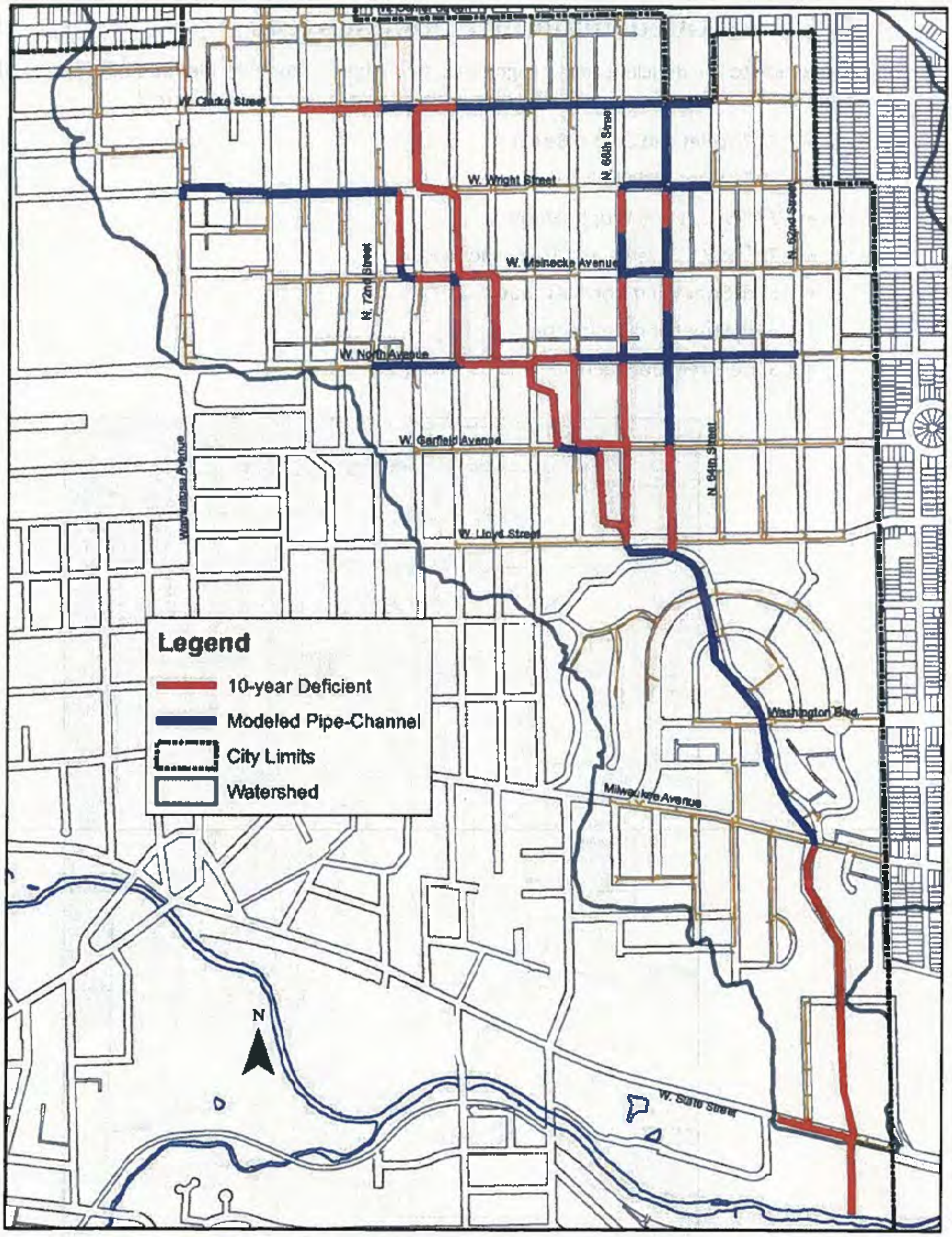


Figure 6. Sewers Deficient for 10-year Event

5.3 Identified Flooding Problem Areas

In addition to the deficient sewer segments, the hydraulic modeling identified the potential for significant ponding and possible flooding in these areas, as shown in Figure 7:

- 74th Street and Center Street
- 72nd Street and Clark Street
- 72nd Street and Wright Street
- 70th to 71st Streets and Meinecke Avenue
- 68th Street and North Avenue
- 66th Street and Lloyd Street
- State Street between 60th and 63rd Streets

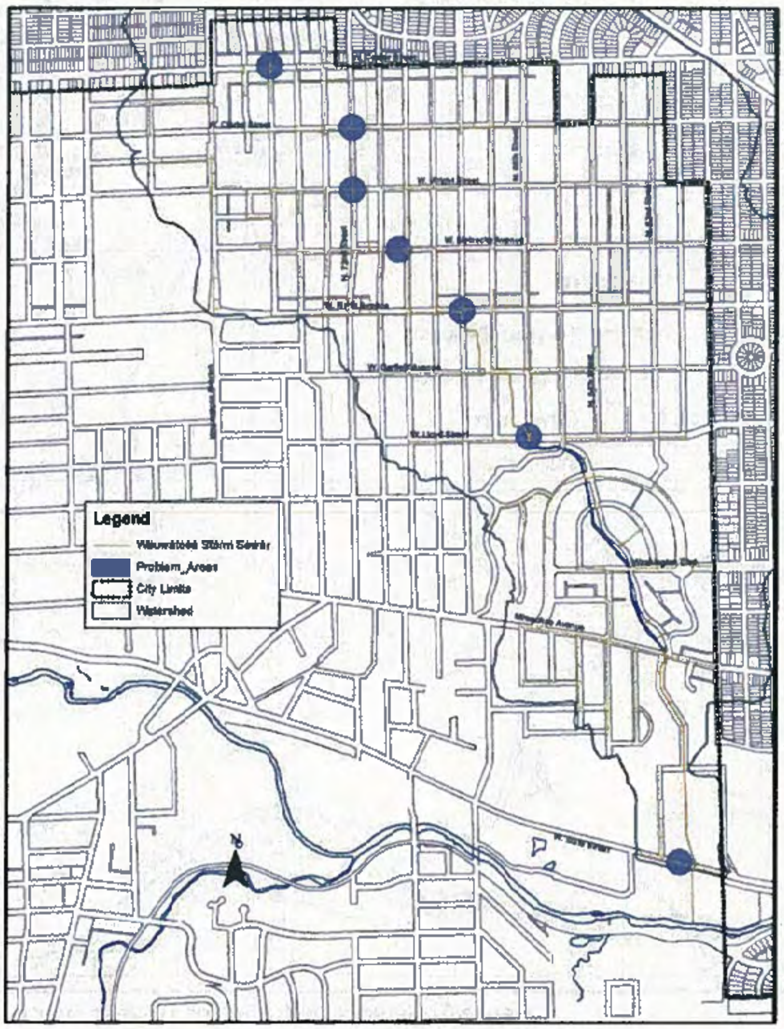


Figure 7. Identified Flooding Problem Areas

Section 6

Alternatives Evaluation

Possible improvements considered in the alternatives evaluation included additional storm sewer capacity, modification of street grades, additional inlets, detention storage near ponding areas and detention storage along the open channel segment. Based on the results of the existing system analysis, it is apparent that upgrades are necessary for the system to handle a 10-year recurrence interval storm event.

The topography of the Schoonmaker Creek watershed concentrates the runoff into a corridor less than 800 feet wide. North of Lloyd Street, this corridor is oriented diagonal to the street rights-of-way where it is preferable to construct public works. With the topography and right-of-way constraints, the practicable alternative sewer routes in the watershed are limited.

6.1 Alternative Screening

Various alternatives were considered and those with potential to mitigate flooding in the problem areas were identified for further analysis. Some alternatives were dropped from further consideration.

6.1.1 Eliminated Alternatives

Installing additional inlets was not considered to be a viable solution because storm sewers draining the flooded areas do not have capacity to accept additional runoff. For additional inlets to be effective, the storm sewer capacity must be available. Adequate inlet capacity, with consideration to potential clogging, is an essential part of all alternatives considered for adding storm sewer capacity.

Detention storage on lots that are presently vacant or city-owned was considered, but eliminated because the magnitude of excess flood waters is far beyond the detention volume that could be created by excavation in a limited space. For example, on an 80-foot by 120-foot lot, an open detention basin could provide approximately 20,000 cubic feet of storage and an underground concrete tank would provide approximately 34,000 cubic feet of storage, assuming gravity drainage. In comparison, the typical ponding volume for a 10-year storm at one of the flooding problem areas is in excess of 100,000 cubic feet, approximately three to five times greater than the volume of a detention basin. Detention storage is further addressed in Alternatives E and F.

Detention storage along the open channel portions of Schoonmaker Creek between Lloyd Street and Milwaukee Avenue was also considered but eliminated. With existing conditions, there is flood storage upstream of each crossing due to the limited capacity of the culverts at Revere Avenue, Washington Circle, Upper Parkway North, and Milwaukee Avenue. The modeling indicates that floodwaters also overtop Martha Washington Drive beneath W. Washington Boulevard. Further restriction or raising these crossings to increase storage would cause flooding on adjacent properties. Although some additional storage could be created by excavation along the creek between W. Washington Boulevard and Milwaukee Avenue, the storage volume gained would be insufficient to affect any benefits downstream.

6.1.2 Retained Alternatives

Alternatives remaining in consideration for mitigating the flooding problems may be characterized as conveyance measures. These consist of replacing existing storm sewers with larger sewers (upsizing), adding additional storm sewers, upsizing or adding culverts, enlarging channels, and modifying street grades to increase capacity for overland flow. Proposed improvements are located within public right-of-way, unless noted otherwise.

To the extent practicable, alternatives were developed to address flooding problems throughout the watershed. This was necessary because changes in one area would affect the stormwater ponding or conveyance in other areas. Problem areas not adequately addressed by the primary alternatives are discussed in subsequent sections. Estimated construction costs for the viable alternatives are presented at the end of this chapter.

6.2 Alternative A – 10-year Design Storm Sewer

Alternative A consists of storm system modifications to convey the 10-year design storm flows with the hydraulic grade line within the pipes – no surcharging. The key features of Alternative A include:

- Upsize approximately 9,600 lineal feet of storm sewer with inlets for design runoff
- Construct second box culverts (or construct new crossings) at Revere Drive, Washington Circle, and Upper Parkway North
- Construct a second box culvert in Martha Washington Drive from Milwaukee Avenue to Martin Drive
- Construct a box culvert in Martin Drive and 60th Street and outfall to the Menomonee River
- Enclose the existing culvert between State Street and the railroad

Alternative A, as shown in Figure 8 and described in Table 5, includes measures to provide increased capacity downstream of Lloyd Street because the larger sewers, while reducing the ponding, convey the runoff downstream at higher flow rates.

Alternative A focuses on constructing a large sewer through the center of the upper watershed, relieving flow from the west trunk sewer, which flows through backyards south of North Avenue, and upsizing the 65th Street storm sewer to capture runoff from the east. Directing flows from the west into a larger central trunk sewer avoids the need to upsize the west trunk sewer.

Alternative A would lower the elevation of the 65th Street storm sewer downstream of North Avenue. This would eliminate the existing "inverted siphon" at North Avenue. Upsizing the storm sewer in 65th Street would create an east trunk sewer to capture all runoff from the watershed area east of 65th Street. Existing sewers flowing west in Meinecke Avenue and Wright Street would be redirected into the 65th Street sewer. The 65th Street sewer upsizing could be constructed in conjunction with sanitary sewer replacement contemplated in several of the alternatives proposed in the study of sewershed WA4002.

To relieve flows from the west trunk sewer, an existing diversion sewer flowing east in Meinecke at 70th Street would be upsized and a new sewer segment in Wright Street at 71st Street would divert flow into the upsized central sewer. At North Avenue, connections to the west trunk would be eliminated.

The replacement central trunk sewer invert would be lower than the existing sewer by as much as 4 feet in 67th Street, North Avenue, and 69th Street, and only slightly less in Garfield Avenue, Meinecke Avenue, and 70th Street. Changes to sanitary sewers would likely be required due to grade conflicts and may be part of the sanitary system upgrades being considered. With limited data available at this time regarding other utilities, the design is hydraulically valid but is a conceptual design.

Table 5. Alternative A - 10-year Design Components

Street	Block	Existing Size	Proposed Size	Comments
60th Street	Menomonee River to Martin	None	5 ft. x12 ft. Box	
Martin Street	60th to M. Washington	None	5 ft. x12 ft. Box	
M. Washington Dr.	Martin to Milwaukee	4.4 ft.x7.5 ft.	5 ft. x7 ft. Box	In addition to existing culvert
Upper Parkway North	Creek crossing	5.5 ft. x 9 ft.	5 ft. x 7 ft. Box	In addition to existing culvert
Washington Circle	Creek crossing	5.5 ft. x 9 ft.	5 ft. x 7 ft. Box	In addition to existing culvert
Revere Avenue	Creek crossing	5.5 ft. x 9 ft.	5 ft. x 7 ft. Box	In addition to existing culvert
65th Street	Lloyd to Garfield	36-inch	66-inch	Add parallel sanitary sewer
65th Street	Garfield to North	36-inch	60-inch	Add parallel sanitary sewer
65th Street	North to Meinecke	30 to 24-inch	36-inch	
65th Street	Meinecke to Wright	24-inch	36-inch	
65th Street	Wright to Clark	24-inch	36 to 30-inch	
66th Street	Lloyd to Garfield	60-inch	84-inch	Add parallel sanitary sewer
Garfield Street	66th to 67th	54-inch	84-inch	
67th Street	Garfield to North	54-inch	84-inch	Add parallel sanitary sewer
North Avenue	67th to 69th	48 to 60-inch	84-inch	Add parallel sanitary sewer
69th Street	North to Meinecke	60-inch	72-inch	Add parallel sanitary sewer
Meinecke Avenue	69th to 70th	60-inch	72-inch	
70th Street	Meinecke to Wright	54-inch	72 to 66-inch	Add parallel sanitary sewer
Wright Street	70th to 72nd	48-inch	66 to 54-inch	
71st Street	Wright to Clarke	36 to 42-inch	60-inch	Add parallel sanitary sewer
Clarke Street	69th to 72nd	30-inch	54-inch	

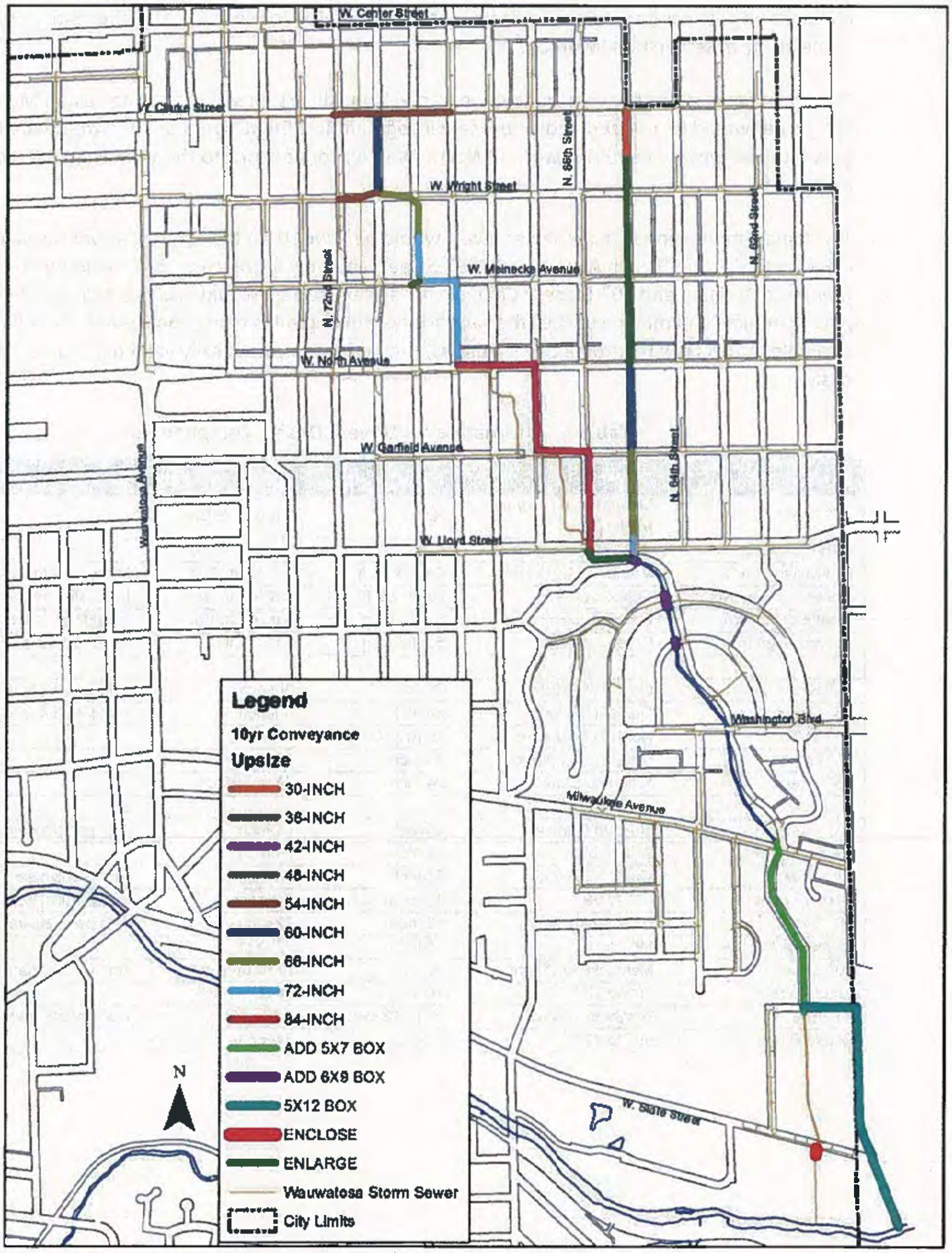


Figure 8. Alternative A - 10-year Design

The performance of Alternative A was modeled for a range of storm events. To demonstrate the effectiveness of the alternative, the ponding depths at key locations are compared in Table 6. Since Alternative A is designed to convey the 10-year storm without surcharging, significant ponding would still occur for more severe events. Significant ponding occurs at State Street for all events because of high stages on the Menomonee River.

Table 6. Alternative A – Ponding Depth Comparison

Location	July 2010 Storm Event Peak Ponding Depth	Alternative A 10-year Event	Alternative A 50-year Event	Alternative A 100-year Event	Alternative A 500-year Event
72nd and Clarke	0.9 feet	-4.2 feet	0.3 feet	0.3 feet	0.8 feet
72nd and Wright	1.3 feet	-4.5 feet	0.3 feet	0.5 feet	0.9 feet
70th and Meinecke	2.3 feet	-3.9 feet	1.5 feet	2.3 feet	2.9 feet
68th and North	1.8 feet	-6.4 feet	-1.4 feet	0.1 feet	1.6 feet
67th and Garfield	0.7 feet	-5.6 feet	-1.1 feet	-0.6 feet	1.0 feet
66th and Lloyd	0.6 feet	-2.2 feet	-1.0 feet	-0.7 feet	0.6 feet
62nd and State	2.6 feet	2.1 feet	2.2 feet	2.2 feet	2.5 feet

Note: Negative values indicate the hydraulic gradeline is below ground elevation.

6.3 Alternative B – 100-year Design Storm Sewer

Alternative B consists of storm system modifications to convey the 100-year design storm flows with the hydraulic grade line below the ground surface. Alternative B follows the design format of Alternative A. The key features of Alternative B include:

- Upsize approximately 10,700 lineal feet of storm sewer with inlets for design runoff
- Construct second box culverts (or construct new crossings) at Revere Drive, Washington Circle, and Upper Parkway North
- Construct a second box culvert in Martha Washington Drive from Milwaukee Avenue to Martin Drive
- Construct a box culvert in Martin Drive and 60th Street and outfall to the Menomonee River
- Enclose the existing culvert between State Street and the railroad

Alternative B, as shown in Figure 9 and described in Table 7, includes measures to provide increased capacity downstream of Lloyd Street because the larger storm sewers, while reducing the ponding, convey the runoff downstream at higher flow rates.

Alternative B focuses on constructing a large sewer through the center of the upper watershed, relieving flow from the west trunk sewer, which flows through backyards south of North Avenue, and upsizing the 65th Street storm sewer to capture runoff from the east. Directing flows from the west into a larger central trunk sewer avoids the need to upsize the west trunk sewer.

Alternative B would lower the elevation of the 65th Street storm sewer downstream of North Avenue. Upsizing the storm sewer in 65th Street would create an east trunk sewer to capture all runoff from the watershed area east of 65th Street. Existing sewers flowing west in Meinecke Avenue and Wright Street would be redirected into the 65th Street sewer. The 65th Street sewer upsizing could be constructed in conjunction with sanitary sewer replacement contemplated in several of the alternatives proposed in the study of sewershed WA4002.

To relieve flows from the west trunk sewer, an existing diversion sewer flowing east in Meinecke at 70th Street would be upsized and a new sewer segment in Wright Street at 71st Street would divert flow into the upsized central sewer. At North Avenue, connections to the west trunk would be eliminated.

The replacement central trunk sewer invert would be lower than the existing sewer by as much as 7.5 feet in Garfield Avenue, 67th Street, North Avenue, and 69th Street, and only slightly less in 66th Street, Meinecke Avenue, and 70th Street. Changes to sanitary sewers would likely be required due to grade conflicts and may be part of the sanitary system upgrades being considered. With limited data available at this time regarding other utilities, the design is hydraulically valid but is a conceptual design.

Table 7. Alternative B - 100-year Storm Sewer Components

Street	Block	Existing Size	Proposed Size	Comments
60th Street	River to Martin	None	Double 6 ft.x8 ft. Box	
Martin Street	60th to M. Washington	None	Double 6 ft.x8 ft. Box	
M. Washington Dr.	Martin to Milwaukee	4.4 ft.x7.5 ft.	6 ft. x 9 ft. Box	In addition to existing culvert
Upper Parkway North	Creek crossing	5.5 ft. x 9 ft.	6 ft. x 9 ft. Box	In addition to existing culvert
Washington Circle	Creek crossing	5.5 ft. x 9 ft.	6 ft. x 9 ft. Box	In addition to existing culvert
Revere Avenue	Creek crossing	5.5 ft. x 9 ft.	6 ft. x 9 ft. Box	In addition to existing culvert
65th Street	Lloyd to Garfield	36-inch	72-inch	Add parallel sanitary sewer
65th Street	Garfield to North	36-inch	66-inch	Add parallel sanitary sewer
65th Street	North to Meinecke	30 to 24-inch	48-inch	
65th Street	Meinecke to Wright	24-inch	48 to 42-inch	
65th Street	Wright to Clark	24-inch	42-inch	
Clarke Street	65th to 64th	24-inch	36-inch	
66th Street	Lloyd to Garfield	60-inch	120-inch	Add parallel sanitary sewer
Garfield Street	66th to 67th	54-inch	120-inch	
67th Street	Garfield to North	54-inch	120-inch	Add parallel sanitary sewer
North Avenue	67th to 69th	48 to 60-inch	120-inch	Add parallel sanitary sewer
69th Street	North to Meinecke	60-inch	120-inch	Add parallel sanitary sewer
Meinecke Avenue	69th to 70th	60-inch	108-inch	
70th Street	Meinecke to Wright	54-inch	108 to 96-inch	Add parallel sanitary sewer
Wright Street	70th to 72nd	48-inch	96 to 66-inch	
71st Street	Wright to Clarke	36 to 42-inch	84-inch	Add parallel sanitary sewer
Clarke Street	68th to 72nd	36 to 27-inch	72 to 54-inch	

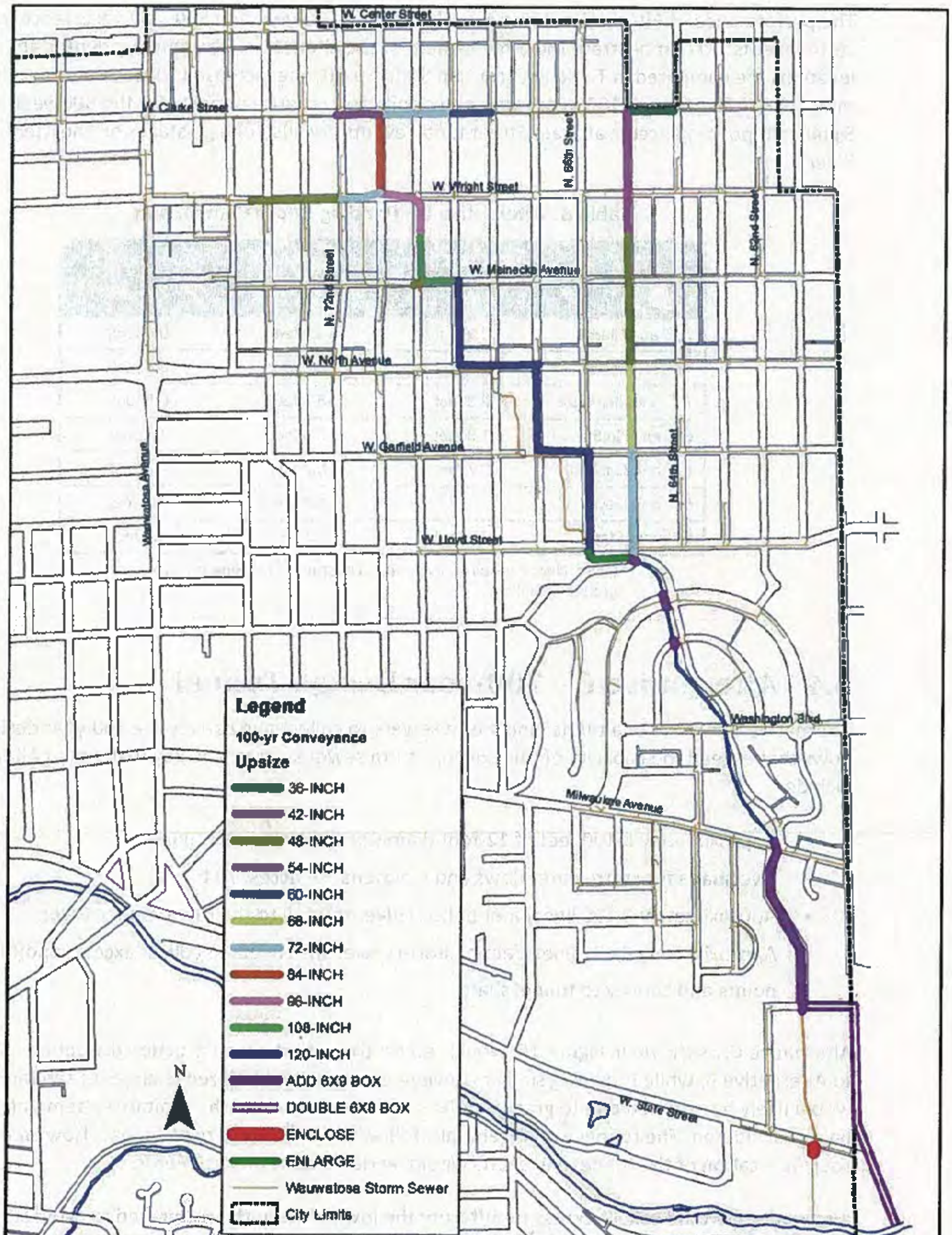


Figure 9. Alternative B - 100-year Design Storm Sewer System

The performance of Alternative B was modeled for the 100-year and 500-year recurrence interval storm events. To demonstrate the effectiveness of the alternative, the ponding depths at key locations are compared in Table 8. Except on State Street, the increased conveyance capacity would mitigate flooding for the 100-year event and significantly reduce ponding for the 500-year event. Significant ponding occurs at State Street for all events because of high stages on the Menomonee River.

Table 8. Alternative B – Ponding Depth Comparison

Location	July 2010 Storm Event Peak Ponding Depth	Alternative B 100-year Event	Alternative B 500-year Event
72nd and Clarke	0.9 feet	-3.1 feet	0.4 feet
72nd and Wright	1.3 feet	-6.5 feet	0.4 feet
70th and Meinecke	2.3 feet	-6.3 feet	0.8 feet
68th and North	1.8 feet	-6.6 feet	-0.7 feet
67th and Garfield	0.7 feet	-5.2 feet	-1.5 feet
66th and Lloyd		-1.9 feet	-1.0 feet
62nd and State	2.6 feet	2.3 feet	2.8 feet

Note: Negative values indicate the hydraulic gradeline is below ground elevation.

6.4 Alternative C – 100-year Design Tunnel

Alternative C consists of a tunnel and storm sewers to collect and convey the 100-year design storm flows that exceed the capacity of the existing storm sewer system. The key features of Alternative D include:

- Approximately 6,100 feet of 12-foot diameter concrete lined tunnel
- Five shafts for stormwater flows and maintenance access to tunnel
- Approximately 1,000 lineal feet of box culvert outfall to the Menomonee River
- Approximately 6,400 lineal feet of storm sewer with inlets to collect excess runoff from low points and convey to tunnel shafts

Alternative C, as shown in Figure 10, would reduce the extent of construction disruption compared to Alternative B, while providing similar conveyance capacity. Localized changes to sanitary sewers would likely be required due to grade conflicts and may be part of the sanitary system upgrades being considered. The tunnel would generally follow the 68th Street right-of-way. However the specific location of the tunnel and shafts would be dependent on easements.

Alternative C would collect excess runoff from the low points in the watershed to avoid surcharging the existing storm sewer system and lower the hydraulic grade line below the ground surface.

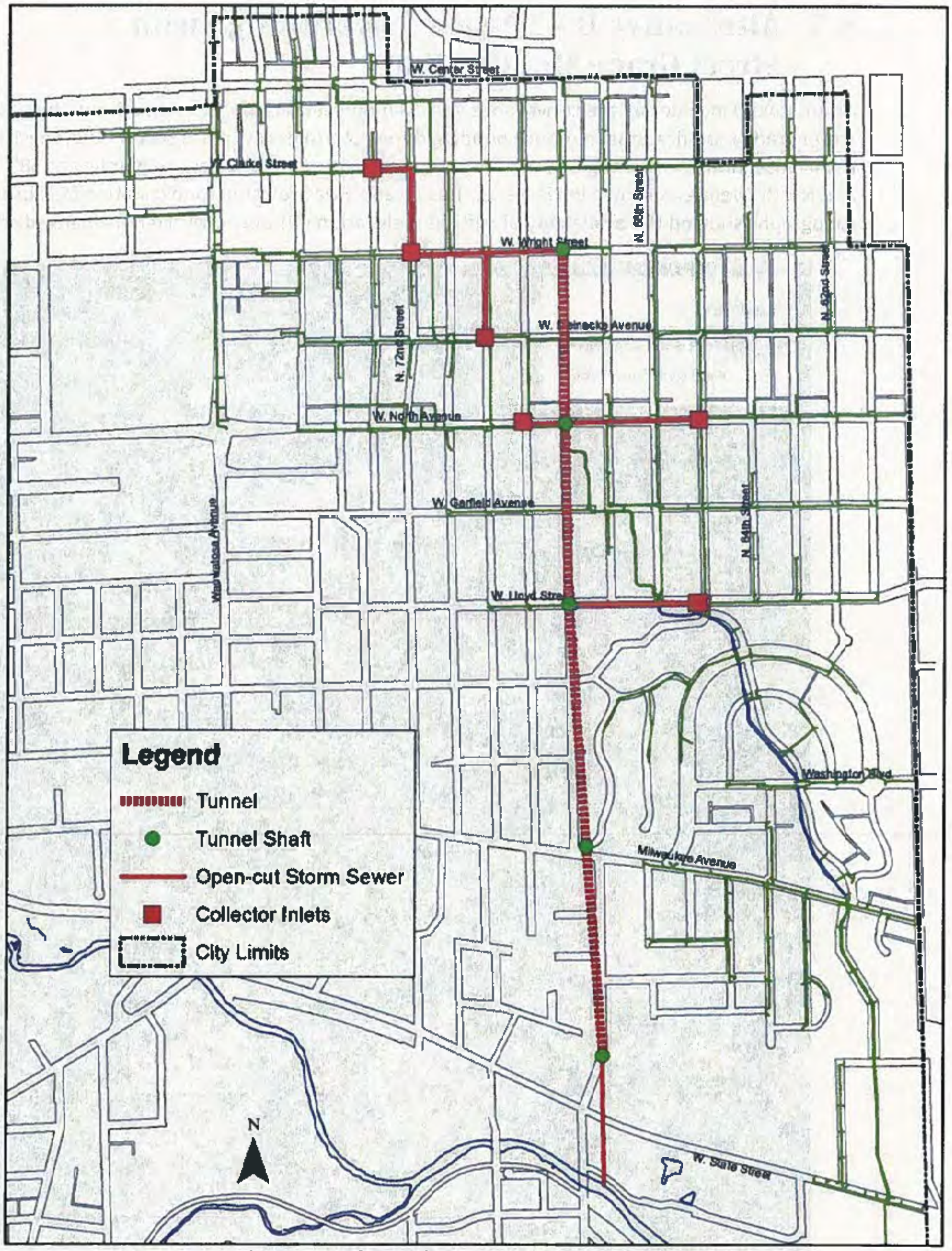


Figure 10. Alternative C - 100-year Design Tunnel

6.5 Alternative D – 10-year Sewer Design with Street Grade Modification

Alternative D includes all the conveyance system modifications of Alternative A and the addition of street grade modifications to reduce ponding during storm events more severe than the 10-year recurrence interval. Street grade modifications were considered to reduce ponding at 68th Street and North Avenue as shown in Figure 11. This location was selected for evaluation because the topography showed the availability of sufficient elevation difference within reasonable distance.

Figure 11. Alternative D - Street Grade Modifications

Although the 70th and Meinecke intersection had residual ponding depths larger than at 68th Street and North Avenue, improving the overland flow capacity from 70th and Meinecke would require lowering the street grades over five blocks from 70th and Meinecke to 66th and Lloyd. This would require extensive reconstruction of streets along the primary route as well as adjacent streets, for transition, and was deemed not feasible.

The performance of Alternative D was modeled for the 100-year and 500-year recurrence interval storm events. To demonstrate the effectiveness of the alternative, the ponding depths at key locations are compared in Table 9. The street lowering had minimal effect on the 100-year ponding depths. For the 500-year event, the ponding at 68th and North would be reduced by 0.8 feet, but ponding downstream at Garfield and at Lloyd increased by 0.2 feet.

Table 9. Alternative D – Ponding Depth Comparison

Location	July 2010 Storm Event Peak Ponding Depth	100-year Event		500-year Event	
		Alternative A	Alternative D	Alternative A	Alternative D
68th and North	1.8 feet	0.1 feet	0.0 feet	1.6 feet	0.8 feet
67th and Garfield	0.7 feet	-0.6 feet	-0.6 feet	1.0 feet	1.2 feet
66th and Lloyd	0.6 feet	-0.7 feet	-0.7 feet	0.6 feet	0.8 feet

Note: Negative values indicate the hydraulic gradeline is below ground elevation.

The street grade modifications in Alternative D provide marginal improvement in flooding associated with the 100-year event. For the 500-year event, Alternative D provides significant reduction in ponding depth at North Avenue, but produces a increases in ponding depths at locations downstream. Overall, Alternative D does not provide significant benefits over Alternative A.

6.6 Alternative E – 10-year Sewer Design with Underground Storage

Alternative E includes all the conveyance system modifications of Alternative A (10-year conveyance design) and the addition of underground storage at 70th Street and Meinecke Avenue, as shown in Figure 11. The underground storage would serve to reduce ponding during storm events more severe than the 10-year recurrence interval.

The underground storage would be provided by constructing a reasonable size facility beneath 70th Street, north of Meinecke Avenue. Approximately 550 feet of double 6-foot by 10-foot reinforced concrete box culverts would be constructed within the existing right-of-way. The 65,000 cubic feet of storage would be constructed immediately west of the proposed 72-inch storm sewer and would require relocating a sanitary sewer and a water main.

The performance of Alternative E was modeled for the 50-year, 100-year, and 500-year recurrence interval storm events. Alternative E was found to provide no significant reduction in ponding depths.

This underground storage volume, although reasonable to construct, is insufficient to provide a measureable improvement in the flooding in this area. To eliminate flooding at this location during a 100-year event would require approximately six storage facilities similar in size to this one.

Figure 12. Alternative E – Underground Storage at 70th and Meinecke

6.7 Alternative F - 100-year Storage

Alternate F would provide facilities for temporary detention of storm water runoff that exceeds the capacity of the existing storm sewer system. The watershed model was utilized to determine the detention storage needed to avoid surface flooding at the flood-prone locations. The required storage volumes are shown in Table 10. Additional storm sewer capacity would still be needed downstream of Milwaukee Avenue to convey the peak 100-year flows with the hydraulic grade line below the ground surface. The required storm sewer capacity upgrades would be similar to that shown for the area south of Milwaukee Avenue as part of Alternative A (Figure 8) and listed in Table 10.

Table 10. Alternative F – Storm Sewer Upgrade Component

Street	Block	Existing Size	Proposed Size	Comments
60th Street	Menomonee River to Martin	None	5 ft. x12 ft. Box	
Martin Street	60th to M. Washington	None	5 ft. x12 ft. Box	
M. Washington Dr.	Martin to Milwaukee	4.4 ft.x7.5 ft.	5 ft. x7 ft. Box	In addition to existing culvert

Because there are no vacant or undeveloped sites within the vicinity of these storage locations, stormwater detention storage facilities would need to be constructed underground. As discussed for Alternative E, underground storage that is shallow enough to drain by gravity into the storm sewer system would not be feasible due to the large size required to provide the necessary volume. Deeper storage facilities with pumped discharges would be required.

One alternative storage facility design approach would be concrete tanks constructed beneath streets. Assuming construction within the street right-of-way and allowing room for sanitary and water lines, the maximum storage tank dimensions would be 25 feet wide and 20 feet deep. The tanks would occupy a total of approximately five blocks, with the approximate lengths shown in Table 10. Pumping facilities would be required to empty the storage tanks.

Another alternative storage design would consist of vertical shafts excavated within street right-of-way. The approximate total depths needed for 20-foot diameter shafts are shown in Table 11. Multiple shafts may be required at each location. Pumping facilities would be required to empty the storage shafts.

Table 11. Alternative F – 100-year Detention Storage Volumes

Location	Volume (Million Gallons)	Equivalent Water Depth (feet) on a Football Field	Length of Tank (feet) 25' wide & 20' deep	Depth of 20-foot Diameter Shaft (feet)
72nd and Clarke	1.5	4.2	400	650
72nd and Wright	2.1	6.4	560	900
70th and Meinecke	4.0	11.3	1080	1800
68th and North	1.3	4.1	360	600

6.8 State Street Flooding

The flooding problem on State Street between 60th Street and 63rd Street would not be resolved by the alternatives discussed above. The flooding on State Street is caused by flood stages on the Menomonee River and by Schoonmaker Creek runoff in excess of the existing culvert capacity.

Prevention of State Street flooding caused by runoff from Schoonmaker Creek would require adding additional conveyance capacity from Milwaukee Avenue to the river, hydraulically isolating the existing box culvert from inlets south of Martin Drive, and enclosing the existing box culvert between State Street and the railroad. The inlets south of Martin Drive would require a new outfall to the river.

High stages on the Menomonee River will continue to cause flooding on State Street. The 10-year recurrence interval flood stage on the river is 0.1 feet above the low point along State Street. This is similar to the situation at 63rd Street and River Parkway. The levee constructed by the MMSD along River Parkway prevents overland flooding from the river, but the 63rd Street storm sewer outfall provides a hydraulic connection between the river and the low point at 63rd Street.

The MMSD plans to remove the box culvert and construct an open channel for Schoonmaker Creek south of the railroad to the river will not change the flooding on State Street.

It appears the only solution for flooding on State Street would be to extend the levee east from 63rd Street and construct an interior drainage system for the area behind the levee. The interior drainage system would require a pumped outlet or a new outfall with adequate capacity to a downstream discharge point where flood stages are lower.

6.9 Flooding at 74th Street and Center Street

The alternatives discussed above do not resolve the flooding at 74th Street and Center Street. Center Street is drained by a storm sewer system flowing west to the Menomonee River. The Schoonmaker Creek modeling accounts for excess runoff that overflows from Center Street into the Schoonmaker Creek storm sewer system.

Providing additional sewer capacity to adequately drain Center Street into Schoonmaker Creek would require lowering the slope and further increasing the size of proposed sewers from Center Street to Lloyd Street. Additional capacity increases may also be needed downstream of Lloyd Street to convey additional stormwater from Center Street.

To evaluate the Center Street flooding and mitigation alternatives, a separate model of the Center Street storm sewer system would be needed.

6.10 Estimated Capital Costs

The capital costs were estimated for the alternatives. These costs are planning level capital costs based on estimates of the construction costs, including a 30-percent contingency, and a 25-percent allowance for engineering and administration. The construction costs were based on unit costs derived from a variety of sources, including MMSD's Hart Park project construction bids and recent local stormwater and sewer system projects. The alternative costs include costs of changes in sanitary sewers, water mains, and other utilities anticipated to be necessary for the construction of the storm system improvements, and the costs for restoration of areas disturbed for construction of the stormwater system upgrades.

Cost for land acquisition or easements outside of public rights-of-way and annual operation & maintenance are **not** included in the costs.

These alternatives do not resolve flooding at 74th Street and Center Street, which is drained by a storm sewer system flowing west to the Menomonee River. Flooding on State Street would not be resolved by these alternatives, because the flood stages on the Menomonee River are above the low point along State Street.

Estimated planning level capital costs for the alternatives are presented in Table 12. These costs are subject to refinement in the final recommendations and during design.

Table 12. Estimated Capital Costs

Alternative	Description	Cost
A. 10-year Storm Sewer	Storm sewer system modifications for no surcharging during a 10-year recurrence interval storm event	$35,800,000
B. 100-year Storm Sewer	Storm sewer system modifications for no street closures during a 100-year recurrence interval storm event	$45,900,000
C. 100-year Tunnel	Tunnel and storm sewers for no street closures during a 100-year recurrence interval storm event	$56,000,000
D. 10-year Storm Sewer with Localized Street Grade Modifications	Not feasible	--
E. 10-year Storm Sewer with Localized Underground Storage	Not feasible	--
F. 100-year Storage	Underground storage tanks or shafts with pumped discharges and storm sewer upgrades south of Milwaukee Avenue	$77,000,000

Section 7

Recommended Plan

(To be added later)

APPENDIX B

EXISTING CONDITION XPSTORM INPUT FILE

```
Current Directory:   C:\PROGRA~1\XPSOLU~1\XPSTOR~1
 Engine Name: C:\PROGRA~1\XPSOLU~1\XPSTOR~1\SWMMEN~2.EXE
 Input File : 012\Existing Conditions\EX_2D_WMFinal_MilwSewers_Dec2015_100-3.XP (#247986)

          *================================================*
          |                    xpswmm                      |
          |     Storm and Wastewater Management Model      |
          |         Developed by XP Solutions Inc.         |
          |================================================|
          |                                                |
          | Last Update      : June, 2014                  |
          | Interface Version: 2012                        |
          | Engine Version   : 12.0                        |
          | Data File Version: 12.6                        |
          |                                                |
          |                                                |
          *================================================*

Engine Name: C:\PROGRA~1\XPSOLU~1\XPSTOR~1\SWMMEN~2.EXE

  ###################################################
  #  Table R1.  S U B C A T C H M E N T  D A T A    #
  #           Physical Hydrology Data               #
  ###################################################
```

Number	Subcatchment Name	Channel or inlet	Width (ft)	Area (ac)	Per-cent Imperv	Slope ft/ft	"n" Imprv	"n" Perv	Deprs -sion Storge Imprv	Deprs -sion Strge Perv	Prcnt Zero Deten -tion
1	PROP491#1	PROP491	1.0000	11.710	0.00	1.000	0.020	0.020	0.000	0.000	0.00
2	PR207#1	PR207	1.0000	1.2800	0.00	1.000	0.020	0.020	0.000	0.000	0.00
3	203#1	203	1.0000	3.8500	0.00	1.000	0.020	0.020	0.000	0.000	0.00
4	187#1	187	1.0000	4.0500	0.00	1.000	0.020	0.020	0.000	0.000	0.00
5	317#1	317	1.0000	13.530	0.00	1.000	0.020	0.020	0.000	0.000	0.00
6	201#1	201	1.0000	1.6700	0.00	1.000	0.020	0.020	0.000	0.000	0.00
7	170#1	170	1.0000	7.7800	0.00	1.000	0.020	0.020	0.000	0.000	0.00
8	165A#1	165A	1.0000	5.2500	0.00	1.000	0.020	0.020	0.000	0.000	0.00
9	139#1	139	1.0000	22.910	0.00	1.000	0.020	0.020	0.000	0.000	0.00
10	125#1	125	1.0000	10.210	0.00	1.000	0.020	0.020	0.000	0.000	0.00
11	457#1	457	1.0000	4.4100	0.00	1.000	0.020	0.020	0.000	0.000	0.00
12	115#1	115	1.0000	5.4200	0.00	1.000	0.020	0.020	0.000	0.000	0.00
13	111#1	111	1.0000	6.0600	0.00	1.000	0.020	0.020	0.000	0.000	0.00
14	106#1	106	1.0000	2.0800	0.00	1.000	0.020	0.020	0.000	0.000	0.00
15	105#1	105	1.0000	23.990	0.00	1.000	0.020	0.020	0.000	0.000	0.00
16	102#1	102	1.0000	2.7300	0.00	1.000	0.020	0.020	0.000	0.000	0.00
17	102#2	102	1.0000	25.960	0.00	1.000	0.020	0.020	0.000	0.000	0.00

18	049#1	049	1.0000	24.250	0.00	1.000	0.020	0.020	0.000	0.000	0.00
19	505#1	505	1.0000	13.450	0.00	1.000	0.020	0.020	0.000	0.000	0.00
20	498#1	498	1.0000	10.450	0.00	1.000	0.020	0.020	0.000	0.000	0.00
21	Node748#1	Node748	1.0000	71.520	0.00	1.000	0.020	0.020	0.000	0.000	0.00
22	206#1	206	1.0000	2.6400	0.00	1.000	0.020	0.020	0.000	0.000	0.00
23	227#1	227	1.0000	4.9700	0.00	1.000	0.020	0.020	0.000	0.000	0.00
24	230#1	230	1.0000	9.8100	0.00	1.000	0.020	0.020	0.000	0.000	0.00
25	491#1	491	1.0000	5.2000	0.00	1.000	0.020	0.020	0.000	0.000	0.00
26	291#1	291	1.0000	5.9900	0.00	1.000	0.020	0.020	0.000	0.000	0.00
27	238#1	238	1.0000	3.7600	0.00	1.000	0.020	0.020	0.000	0.000	0.00
28	240#1	240	1.0000	3.8000	0.00	1.000	0.020	0.020	0.000	0.000	0.00
29	271#1	271	1.0000	1.8700	0.00	1.000	0.020	0.020	0.000	0.000	0.00
30	268#1	268	1.0000	2.7600	0.00	1.000	0.020	0.020	0.000	0.000	0.00
31	267#1	267	1.0000	6.2100	0.00	1.000	0.020	0.020	0.000	0.000	0.00
32	267#2	267	1.0000	4.4500	0.00	1.000	0.020	0.020	0.000	0.000	0.00
33	267#3	267	1.0000	4.1300	0.00	1.000	0.020	0.020	0.000	0.000	0.00
34	267#4	267	1.0000	1.3600	0.00	1.000	0.020	0.020	0.000	0.000	0.00
35	255#1	255	1.0000	10.050	0.00	1.000	0.020	0.020	0.000	0.000	0.00
36	254#1	254	1.0000	14.540	0.00	1.000	0.020	0.020	0.000	0.000	0.00
37	Node753#1	Node753	1.0000	50.760	0.00	1.000	0.020	0.020	0.000	0.000	0.00
38	Node754#1	Node754	1.0000	28.000	0.00	1.000	0.020	0.020	0.000	0.000	0.00
39	Node754#2	Node754	1.0000	.92000	0.00	1.000	0.020	0.020	0.000	0.000	0.00
40	248#1	248	1.0000	11.630	0.00	1.000	0.020	0.020	0.000	0.000	0.00
41	246#1	246	1.0000	7.5800	0.00	1.000	0.020	0.020	0.000	0.000	0.00
42	Node749#2	Node749	1.0000	26.980	0.00	1.000	0.020	0.020	0.000	0.000	0.00
43	Node749#3	Node749	1.0000	95.880	0.00	1.000	0.020	0.020	0.000	0.000	0.00
44	244#1	244	1.0000	3.9600	0.00	1.000	0.020	0.020	0.000	0.000	0.00
45	496#1	496	1.0000	11.250	0.00	1.000	0.020	0.020	0.000	0.000	0.00
46	022#1	022	1.0000	25.900	0.00	1.000	0.020	0.020	0.000	0.000	0.00
47	066#1	066	1.0000	8.9300	0.00	1.000	0.020	0.020	0.000	0.000	0.00
48	063#1	063	1.0000	5.7200	0.00	1.000	0.020	0.020	0.000	0.000	0.00
49	060#1	060	1.0000	4.8500	0.00	1.000	0.020	0.020	0.000	0.000	0.00
50	016#1	016	1.0000	4.3600	0.00	1.000	0.020	0.020	0.000	0.000	0.00
51	016#2	016	1.0000	4.7800	0.00	1.000	0.020	0.020	0.000	0.000	0.00
52	015#1	015	1.0000	10.990	0.00	1.000	0.020	0.020	0.000	0.000	0.00
53	415#1	415	1.0000	5.6700	0.00	1.000	0.020	0.020	0.000	0.000	0.00
54	152#1	152	1.0000	4.9000	0.00	1.000	0.020	0.020	0.000	0.000	0.00
55	151#1	151	1.0000	8.3900	0.00	1.000	0.020	0.020	0.000	0.000	0.00
56	013#1	013	1.0000	18.710	0.00	1.000	0.020	0.020	0.000	0.000	0.00
57	012#1	012	1.0000	4.1100	0.00	1.000	0.020	0.020	0.000	0.000	0.00
58	11326#1	11326	1.0000	25.490	0.00	1.000	0.020	0.020	0.000	0.000	0.00
59	10939#1	10939	1.0000	7.9700	0.00	1.000	0.020	0.020	0.000	0.000	0.00
60	10587#1	10587	1.0000	16.840	0.00	1.000	0.020	0.020	0.000	0.000	0.00
61	10587#2	10587	1.0000	4.4800	0.00	1.000	0.020	0.020	0.000	0.000	0.00
62	10487#1	10487	1.0000	15.750	0.00	1.000	0.020	0.020	0.000	0.000	0.00
63	10250#1	10250	1.0000	1.1800	0.00	1.000	0.020	0.020	0.000	0.000	0.00
64	10183#1	10183	1.0000	5.3700	0.00	1.000	0.020	0.020	0.000	0.000	0.00

```
  65         9600#1            9600 1.0000    13.690      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  66         9309#1            9309 1.0000    16.080      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  67         8700#1            8700 1.0000    17.090      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  68           N1#1              N1 1.0000    48.220      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  69           N1#2              N1 1.0000    7.1800      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  70   Junction 1#1      Junction 1 1.0000    11.640      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  71      Junct 3#1         Junct 3 1.0000    12.340      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  72          517#1             517 1.0000    13.790      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  73      330A049#1         330A049 1.0000    5.7600      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  74      330A024#1         330A024 1.0000    17.780      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  75      330D026#1         330D026 1.0000    12.660      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  76      346B007#1         346B007 1.0000    39.740      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  77      345A007#1         345A007 1.0000    6.0800      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  78      345D005#1         345D005 1.0000    24.890      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  79      346B073#1         346B073 1.0000    26.900      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  80      368B800#1         368B800 1.0000    15.960      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  81      368B007#1         368B007 1.0000    11.040      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  82      369A900#1         369A900 1.0000    6.9800      0.00 1.000 0.020 0.020 0.000 0.000  0.00
  83      330B039#1         330B039 1.0000    6.4600      0.00 1.000 0.020 0.020 0.000 0.000  0.00


#########################################################################################################
#          Table R2.  SUBCATCHMENT  DATA                                                                #
#                     Infiltration or Time of Concentration Data                                        #
#                                                                                                       #
# Infiltration Type      Infl #1(#5)       Infl #2(#6)          Infl #3(#7)             Infl #4(#8)  #
# SCS                  ->   Comp CN          Time Conc         Shape Factor        Depth or Fraction  #
# SBUH                 ->   Comp CN          Time Conc                  N/A                      N/A  #
# Green Ampt           ->   Suction          Hydr Cond           Initial MD                      N/A  #
# Horton               ->  Max Rate           Min Rate   Decay Rate (1/sec)      Max. Infilt. Volume  #
# Proportional         ->  Constant                N/A                  N/A                      N/A  #
# Initial/Cont Loss    ->   Initial         Continuing                  N/A                      N/A  #
# Initial/Proportional ->   Initial           Constant                  N/A                      N/A  #
# Laurenson Parameters ->   B Value       Pervious "n"      Impervious Cont                 Exponent  #
# Rational Formula     -> Tc Method   Flow Path Length      Flow Path Slope  Roughness or Retardance  #
#                                 (#1 - #4 is Impervious Data / #5 - #8 is Pervious Data)               #
#                      Rational Formula Tc Method: 1 = Constant                                         #
#                                                  2 = Friend's Equation                                #
#                                                  3 = Kinematic Wave                                   #
#                                                  4 = Alameda Method                                   #
#                                                  5 = Izzard's Formula                                 #
#                                                  6 = Kerby's Equation                                 #
#                                                  7 = Kirpich's Equation                               #
#                                                  8 = Bransby Williams Equation                        #
#                                                  9 = Federal Aviation Authority Equation              #
#########################################################################################################
```

Subcatchment Number	Name	Infl # 1	Infl # 2	Infl # 3	Infl # 4	Infl # 5	Infl # 6	Infl # 7	Infl # 8
1	PROP491#1	85.0000	0.3333	484.0000	0.2000				
2	PR207#1	83.0000	0.2833	484.0000	0.2000				
3	203#1	86.0000	0.3000	484.0000	0.2000				
4	187#1	86.0000	0.3000	484.0000	0.2000				
5	317#1	85.0000	0.4333	484.0000	0.2000				
6	201#1	86.0000	0.3000	484.0000	0.2000				
7	170#1	86.0000	0.3000	484.0000	0.2000				
8	165A#1	87.0000	0.2500	484.0000	0.2000				
9	139#1	86.0000	0.3667	484.0000	0.2000				
10	125#1	88.0000	0.2333	484.0000	0.2000				
11	457#1	86.0000	0.2500	484.0000	0.2000				
12	115#1	86.0000	0.2500	484.0000	0.2000				
13	111#1	86.0000	0.2500	484.0000	0.2000				
14	106#1	87.0000	0.1667	484.0000	0.2000				
15	105#1	85.0000	0.3833	484.0000	0.2000				
16	102#1	86.0000	0.1667	484.0000	0.2000				
17	102#2	85.0000	0.3833	484.0000	0.2000				
18	049#1	85.0000	0.4500	484.0000	0.2000				
19	505#1	88.0000	0.2667	484.0000	0.2000				
20	498#1	86.0000	0.4167	484.0000	0.2000				
21	Node748#1	86.0000	0.3667	484.0000	0.2000				
22	206#1	82.0000	0.8833	484.0000	0.2000				
23	227#1	86.0000	0.2167	484.0000	0.2000				
24	230#1	85.0000	0.5000	484.0000	0.2000				
25	491#1	86.0000	0.2500	484.0000	0.2000				
26	291#1	86.0000	0.2500	484.0000	0.2000				
27	238#1	85.0000	0.2500	484.0000	0.2000				
28	240#1	87.0000	0.2500	484.0000	0.2000				
29	271#1	85.0000	0.2500	484.0000	0.2000				
30	268#1	87.0000	0.1667	484.0000	0.2000				
31	267#1	86.0000	0.2500	484.0000	0.2000				
32	267#2	85.0000	0.2500	484.0000	0.2000				
33	267#3	85.0000	0.2500	484.0000	0.2000				
34	267#4	87.0000	0.1667	484.0000	0.2000				
35	255#1	86.0000	0.2000	484.0000	0.2000				
36	254#1	86.0000	0.4667	484.0000	0.2000				
37	Node753#1	85.0000	0.5167	484.0000	0.2000				
38	Node754#1	87.0000	0.4833	484.0000	0.2000				
39	Node754#2	87.0000	0.1667	484.0000	0.2000				
40	248#1	87.0000	0.2667	484.0000	0.2000				
41	246#1	86.0000	0.2833	484.0000	0.2000				
42	Node749#2	86.0000	0.4833	484.0000	0.2000				
43	Node749#3	87.0000	0.5333	484.0000	0.2000				
44	244#1	87.0000	0.2500	484.0000	0.2000				

45	496#1	86.0000	0.5667	484.0000	0.2000
46	022#1	87.0000	0.4833	484.0000	0.2000
47	066#1	88.0000	0.2000	484.0000	0.2000
48	063#1	87.0000	0.2500	484.0000	0.2000
49	060#1	87.0000	0.2500	484.0000	0.2000
50	016#1	87.0000	0.2500	484.0000	0.2000
51	016#2	87.0000	0.2500	484.0000	0.2000
52	015#1	87.0000	0.2333	484.0000	0.2000
53	415#1	87.0000	0.2500	484.0000	0.2000
54	152#1	86.0000	0.3000	484.0000	0.2000
55	151#1	86.0000	0.2667	484.0000	0.2000
56	013#1	86.0000	0.4167	484.0000	0.2000
57	012#1	87.0000	0.2500	484.0000	0.2000
58	11326#1	85.0000	0.3333	484.0000	0.2000
59	10939#1	82.0000	0.2667	484.0000	0.2000
60	10587#1	83.0000	0.2667	484.0000	0.2000
61	10587#2	82.0000	0.2833	484.0000	0.2000
62	10487#1	83.0000	0.5333	484.0000	0.2000
63	10250#1	80.0000	0.2000	484.0000	0.2000
64	10183#1	82.0000	0.2667	484.0000	0.2000
65	9600#1	81.0000	0.3333	484.0000	0.2000
66	9309#1	84.0000	0.4167	484.0000	0.2000
67	8700#1	85.0000	0.3000	484.0000	0.2000
68	N1#1	85.0000	0.5000	484.0000	0.2000
69	N1#2	86.0000	0.4333	484.0000	0.2000
70	Junction 1#1	86.0000	0.2000	484.0000	0.2000
71	Junct 3#1	84.0000	0.2000	484.0000	0.2000
72	517#1	86.0000	0.2000	484.0000	0.2000
73	330A049#1	86.0000	0.1530	484.0000	0.2000
74	330A024#1	86.0000	0.2570	484.0000	0.2000
75	330D026#1	86.0000	0.1270	484.0000	0.2000
76	346B007#1	86.0000	0.2180	484.0000	0.2000
77	345A007#1	86.0000	0.1940	484.0000	0.2000
78	345D005#1	86.0000	0.1730	484.0000	0.2000
79	346B073#1	86.0000	0.1530	484.0000	0.2000
80	368B800#1	86.0000	0.1380	484.0000	0.2000
81	368B007#1	86.0000	0.1330	484.0000	0.2000
82	369A900#1	86.0000	0.1270	484.0000	0.2000
83	330B039#1	86.0000	0.1550	484.0000	0.2000

```
*============================================================*
 |        HYDRAULICS TABLES IN THE OUTPUT FILE                |
*============================================================*

         Natural Cross-Section information for Channel WashBlv
         =====================================================
          Cross-Section ID (from X1 card) :     1.0 Channel sequence number :     1

   Left Overbank Length   :    128.0 ft                Maximum Elevation        :    99.70 ft.
   Main Channel Length    :    128.0 ft                Maximum Depth            :     7.70 ft.
   Right Overbank Length  :    128.0 ft                Maximum Section Area     : 311.7000 ft^2
                                                       Maximum hydraulic radius :     2.93 ft.
   Manning N :      0.060  to Station           0.0    Max topwidth             :    90.00 ft.
     "    "  :      0.020  in main Channel             Maximum Wetted Perimeter : 1.06E+02 ft
     "    "  :      0.020  Beyond station      13.0    Max left bank area       :     0.00 ft^2
                                                       Max right bank area      :   219.50 ft^2
   Allowable Encroachment Depth :    0.00 ft           Max center channel area  :  92.2000 ft^2

         Natural Cross-Section information for Channel OPEN1
         =====================================================
          Cross-Section ID (from X1 card) :     2.0 Channel sequence number :     2

   Left Overbank Length   :    340.0 ft                Maximum Elevation        :   125.15 ft.
   Main Channel Length    :    340.0 ft                Maximum Depth            :     9.90 ft.
   Right Overbank Length  :    340.0 ft                Maximum Section Area     : 355.4389 ft^2
                                                       Maximum hydraulic radius :     3.68 ft.
   Manning N :      0.060  to Station          55.8    Max topwidth             :    89.23 ft.
     "    "  :      0.033  in main Channel             Maximum Wetted Perimeter : 9.66E+01 ft
     "    "  :      0.060  Beyond station      64.5    Max left bank area       :   158.06 ft^2
                                                       Max right bank area      :   112.07 ft^2
   Allowable Encroachment Depth :    0.00 ft           Max center channel area  :  85.3125 ft^2

         Natural Cross-Section information for Channel OPEN2
         =====================================================
          Cross-Section ID (from X1 card) :     3.0 Channel sequence number :     3

   Left Overbank Length   :     20.0 ft                Maximum Elevation        :   122.20 ft.
   Main Channel Length    :     20.0 ft                Maximum Depth            :     8.70 ft.
   Right Overbank Length  :     20.0 ft                Maximum Section Area     : 215.5303 ft^2
                                                       Maximum hydraulic radius :     3.05 ft.
   Manning N :      0.060  to Station          43.8    Max topwidth             :    62.86 ft.
     "    "  :      0.033  in main Channel             Maximum Wetted Perimeter : 7.08E+01 ft
     "    "  :      0.060  Beyond station      54.5    Max left bank area       :    67.31 ft^2
                                                       Max right bank area      :    57.92 ft^2
   Allowable Encroachment Depth :    0.00 ft           Max center channel area  :  90.3000 ft^2
```

```
      Natural Cross-Section information for Channel OPEN5
      =====================================================
       Cross-Section ID (from X1 card) :     4.0 Channel sequence number :     4

Left Overbank Length   :    180.0 ft               Maximum Elevation        :   114.10 ft.
Main Channel Length    :    180.0 ft               Maximum Depth            :     7.00 ft.
Right Overbank Length  :    180.0 ft               Maximum Section Area     : 111.0555 ft^2
                                                   Maximum hydraulic radius :     2.57 ft.
Manning N :      0.070  to Station          50.0   Max topwidth             :    37.36 ft.
  "    "  :      0.033  in main Channel            Maximum Wetted Perimeter : 4.31E+01 ft
  "    "  :      0.070  Beyond station      61.2   Max left bank area       :    21.06 ft^2
                                                   Max right bank area      :    19.50 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  70.4924 ft^2

      Natural Cross-Section information for Channel OPEN6
      =====================================================
       Cross-Section ID (from X1 card) :     5.0 Channel sequence number :     5

Left Overbank Length   :     75.0 ft               Maximum Elevation        :   111.15 ft.
Main Channel Length    :     75.0 ft               Maximum Depth            :     6.80 ft.
Right Overbank Length  :     75.0 ft               Maximum Section Area     :  95.2645 ft^2
                                                   Maximum hydraulic radius :     2.35 ft.
Manning N :      0.060  to Station          55.5   Max topwidth             :    34.71 ft.
  "    "  :      0.033  in main Channel            Maximum Wetted Perimeter : 4.05E+01 ft
  "    "  :      0.100  Beyond station      66.8   Max left bank area       :    17.66 ft^2
                                                   Max right bank area      :    11.10 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  66.5000 ft^2

      Natural Cross-Section information for Channel OPEN7
      =====================================================
       Cross-Section ID (from X1 card) :     6.0 Channel sequence number :     6

Left Overbank Length   :    275.0 ft               Maximum Elevation        :   106.90 ft.
Main Channel Length    :    275.0 ft               Maximum Depth            :     6.80 ft.
Right Overbank Length  :    275.0 ft               Maximum Section Area     : 145.6050 ft^2
                                                   Maximum hydraulic radius :     2.15 ft.
Manning N :      0.060  to Station         105.0   Max topwidth             :    61.00 ft.
  "    "  :      0.033  in main Channel            Maximum Wetted Perimeter : 6.78E+01 ft
  "    "  :      0.060  Beyond station     122.0   Max left bank area       :    18.75 ft^2
                                                   Max right bank area      :    26.11 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  : 100.7450 ft^2
```

```
      Natural Cross-Section information for Channel OPEN8A
      =====================================================
       Cross-Section ID (from X1 card) :     7.0 Channel sequence number :     7

Left Overbank Length   :    270.0 ft               Maximum Elevation        :   102.42 ft.
Main Channel Length    :    270.0 ft               Maximum Depth            :     6.15 ft.
Right Overbank Length  :    270.0 ft               Maximum Section Area     :  76.7520 ft^2
                                                   Maximum hydraulic radius :     1.64 ft.
Manning N :      0.060  to Station          84.5    Max topwidth             :    38.34 ft.
  "    "  :      0.033  in main Channel             Maximum Wetted Perimeter : 4.67E+01 ft
  "    "  :      0.060  Beyond station      99.0    Max left bank area       :     0.00 ft^2
                                                   Max right bank area      :     2.86 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  73.8870 ft^2

      Natural Cross-Section information for Channel OPEN9
      =====================================================
       Cross-Section ID (from X1 card) :     8.0 Channel sequence number :     8

Left Overbank Length   :    530.0 ft               Maximum Elevation        :    93.64 ft.
Main Channel Length    :    530.0 ft               Maximum Depth            :     7.50 ft.
Right Overbank Length  :    530.0 ft               Maximum Section Area     : 402.0625 ft^2
                                                   Maximum hydraulic radius :     2.47 ft.
Manning N :      0.050  to Station          94.0    Max topwidth             :   157.00 ft.
  "    "  :      0.033  in main Channel             Maximum Wetted Perimeter : 1.63E+02 ft
  "    "  :      0.060  Beyond station     106.0    Max left bank area       :   195.55 ft^2
                                                   Max right bank area      :   122.61 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  83.9025 ft^2

      Natural Cross-Section information for Channel OPEN10
      =====================================================
       Cross-Section ID (from X1 card) :     9.0 Channel sequence number :     9

Left Overbank Length   :    360.0 ft               Maximum Elevation        :    90.74 ft.
Main Channel Length    :    360.0 ft               Maximum Depth            :     7.10 ft.
Right Overbank Length  :    360.0 ft               Maximum Section Area     : 605.1079 ft^2
                                                   Maximum hydraulic radius :     2.68 ft.
Manning N :      0.050  to Station         110.0    Max topwidth             :   221.47 ft.
  "    "  :      0.033  in main Channel             Maximum Wetted Perimeter : 2.25E+02 ft
  "    "  :      0.060  Beyond station     126.0    Max left bank area       :   239.11 ft^2
                                                   Max right bank area      :   259.16 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  : 106.8350 ft^2
```

```
      Natural Cross-Section information for Channel OPEN8B
      =====================================================
       Cross-Section ID (from X1 card) :    10.0 Channel sequence number :    10

Left Overbank Length   :    190.0 ft               Maximum Elevation        :   102.42 ft.
Main Channel Length    :    190.0 ft               Maximum Depth            :     6.15 ft.
Right Overbank Length  :    190.0 ft               Maximum Section Area     :  76.7520 ft^2
                                                   Maximum hydraulic radius :     1.64 ft.
Manning N :      0.060  to Station          84.5   Max topwidth             :    38.34 ft.
  "    "  :      0.033  in main Channel            Maximum Wetted Perimeter : 4.67E+01 ft
  "    "  :      0.100  Beyond station      99.0   Max left bank area       :     0.00 ft^2
                                                   Max right bank area      :     2.86 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  73.8870 ft^2

      Natural Cross-Section information for Channel OPEN3
      =====================================================
       Cross-Section ID (from X1 card) :    11.0 Channel sequence number :    11

Left Overbank Length   :    350.0 ft               Maximum Elevation        :   122.40 ft.
Main Channel Length    :    350.0 ft               Maximum Depth            :     8.50 ft.
Right Overbank Length  :    350.0 ft               Maximum Section Area     : 180.2092 ft^2
                                                   Maximum hydraulic radius :     3.23 ft.
Manning N :      0.060  to Station          25.8   Max topwidth             :    47.11 ft.
  "    "  :      0.033  in main Channel            Maximum Wetted Perimeter : 5.58E+01 ft
  "    "  :      0.060  Beyond station      37.8   Max left bank area       :    37.46 ft^2
                                                   Max right bank area      :    41.35 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  : 101.4000 ft^2

      Natural Cross-Section information for Channel 73rdST
      =====================================================
       Cross-Section ID (from X1 card) :    12.0 Channel sequence number :    12

Left Overbank Length   :    400.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    400.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    400.0 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station          17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      42.5   Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2
```

```
      Natural Cross-Section information for Channel 72ndST
      =====================================================
       Cross-Section ID (from X1 card) :    13.0 Channel sequence number :    13

Left Overbank Length   :    650.0 ft              Maximum Elevation        :   100.00 ft.
Main Channel Length    :    650.0 ft              Maximum Depth            :     0.80 ft.
Right Overbank Length  :    650.0 ft              Maximum Section Area     :  22.6000 ft^2
                                                  Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station         17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel           Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station     42.5   Max left bank area       :     4.38 ft^2
                                                  Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft         Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel 70thST
      =====================================================
       Cross-Section ID (from X1 card) :    14.0 Channel sequence number :    14

Left Overbank Length   :    620.0 ft              Maximum Elevation        :   100.00 ft.
Main Channel Length    :    620.0 ft              Maximum Depth            :     0.80 ft.
Right Overbank Length  :    620.0 ft              Maximum Section Area     :  22.6000 ft^2
                                                  Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station         17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel           Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station     42.5   Max left bank area       :     4.38 ft^2
                                                  Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft         Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel Link659
      =====================================================
       Cross-Section ID (from X1 card) :    15.0 Channel sequence number :    15

Left Overbank Length   :    250.0 ft              Maximum Elevation        :   100.00 ft.
Main Channel Length    :    250.0 ft              Maximum Depth            :     0.80 ft.
Right Overbank Length  :    250.0 ft              Maximum Section Area     :  22.6000 ft^2
                                                  Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station         17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel           Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station     42.5   Max left bank area       :     4.38 ft^2
                                                  Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft         Max center channel area  :  13.8500 ft^2
```

```
      Natural Cross-Section information for Channel Link660
      =====================================================
       Cross-Section ID (from X1 card) :    16.0 Channel sequence number :    16

Left Overbank Length   :    620.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    620.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    620.0 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station         17.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station     42.5    Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel Link661
      =====================================================
       Cross-Section ID (from X1 card) :    17.0 Channel sequence number :    17

Left Overbank Length   :    620.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    620.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    620.0 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station         17.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station     42.5    Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel WrtWRd1
      =====================================================
       Cross-Section ID (from X1 card) :    18.0 Channel sequence number :    18

Left Overbank Length   :    350.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    350.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    350.0 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station         14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station     45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel WrtWRd2
      =====================================================
       Cross-Section ID (from X1 card) :    19.0 Channel sequence number :    19

Left Overbank Length   :    245.1 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    245.1 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    245.1 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel WrtWRd5
      =====================================================
       Cross-Section ID (from X1 card) :    20.0 Channel sequence number :    20

Left Overbank Length   :    123.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    123.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    123.0 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel WrtWRd6
      =====================================================
       Cross-Section ID (from X1 card) :    21.0 Channel sequence number :    21

Left Overbank Length   :    119.5 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    119.5 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    119.5 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel Wright_1
      =====================================================
       Cross-Section ID (from X1 card) :    22.0 Channel sequence number :    22

Left Overbank Length   :    157.7 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    157.7 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    157.7 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel North_1
      =====================================================
       Cross-Section ID (from X1 card) :    23.0 Channel sequence number :    23

Left Overbank Length   :    263.2 ft               Maximum Elevation        :   100.10 ft.
Main Channel Length    :    263.2 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    263.2 ft               Maximum Section Area     :  21.3500 ft^2
                                                   Maximum hydraulic radius :     0.32 ft.
Manning N :      0.020  to Station           9.0    Max topwidth             :    66.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.69E+01 ft
  "    "  :      0.020  Beyond station      57.0    Max left bank area       :     1.80 ft^2
                                                   Max right bank area      :     1.80 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.7500 ft^2

      Natural Cross-Section information for Channel WrtWRd3
      =====================================================
       Cross-Section ID (from X1 card) :    24.0 Channel sequence number :    24

Left Overbank Length   :     37.1 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     37.1 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     37.1 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel WrtWRd4
      =====================================================
       Cross-Section ID (from X1 card) :    25.0 Channel sequence number :    25

Left Overbank Length   :     44.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     44.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     44.0 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel Wright_3
      =====================================================
       Cross-Section ID (from X1 card) :    26.0 Channel sequence number :    26

Left Overbank Length   :    264.8 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    264.8 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    264.8 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel 70th_1
      =====================================================
       Cross-Section ID (from X1 card) :    27.0 Channel sequence number :    27

Left Overbank Length   :    346.5 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    346.5 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    346.5 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station          17.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      42.5    Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2
```

```
      Natural Cross-Section information for Channel 70th_2
      =====================================================
       Cross-Section ID (from X1 card) :    28.0 Channel sequence number :    28

Left Overbank Length   :    339.2 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    339.2 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    339.2 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station          17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      42.5   Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel Meinecke_1
      =====================================================
       Cross-Section ID (from X1 card) :    29.0 Channel sequence number :    29

Left Overbank Length   :    286.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    286.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    286.0 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station          17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      42.5   Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel Garfield_1
      =====================================================
       Cross-Section ID (from X1 card) :    30.0 Channel sequence number :    30

Left Overbank Length   :    390.3 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    390.3 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    390.3 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station          17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      42.5   Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2
```

```
      Natural Cross-Section information for Channel 67th_1
      =====================================================
       Cross-Section ID (from X1 card) :    31.0 Channel sequence number :    31

Left Overbank Length   :    661.5 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    661.5 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    661.5 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station          17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      42.5   Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel Clarke_1
      =====================================================
       Cross-Section ID (from X1 card) :    32.0 Channel sequence number :    32

Left Overbank Length   :    236.4 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    236.4 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    236.4 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5   Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel Clarke_2
      =====================================================
       Cross-Section ID (from X1 card) :    33.0 Channel sequence number :    33

Left Overbank Length   :     26.5 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     26.5 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     26.5 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5   Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel Clarke_3
      =====================================================
       Cross-Section ID (from X1 card) :    34.0 Channel sequence number :    34

Left Overbank Length   :     24.6 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     24.6 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     24.6 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel Clarke_4
      =====================================================
       Cross-Section ID (from X1 card) :    35.0 Channel sequence number :    35

Left Overbank Length   :    237.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    237.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    237.0 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel Clarke_5
      =====================================================
       Cross-Section ID (from X1 card) :    36.0 Channel sequence number :    36

Left Overbank Length   :    250.7 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    250.7 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    250.7 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel ClkERdA
      =====================================================
       Cross-Section ID (from X1 card) :    37.0 Channel sequence number :    37

Left Overbank Length   :     38.6 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     38.6 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     38.6 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel ClkERdB
      =====================================================
       Cross-Section ID (from X1 card) :    38.0 Channel sequence number :    38

Left Overbank Length   :    259.5 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    259.5 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    259.5 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel ClkERd1
      =====================================================
       Cross-Section ID (from X1 card) :    39.0 Channel sequence number :    39

Left Overbank Length   :     49.2 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     49.2 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     49.2 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel ClkERd4
      =====================================================
       Cross-Section ID (from X1 card) :    40.0 Channel sequence number :    40

Left Overbank Length   :     58.9 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     58.9 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     58.9 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel ClkERd5
      =====================================================
       Cross-Section ID (from X1 card) :    41.0 Channel sequence number :    41

Left Overbank Length   :     95.2 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     95.2 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     95.2 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel ClkERd6
      =====================================================
       Cross-Section ID (from X1 card) :    42.0 Channel sequence number :    42

Left Overbank Length   :    204.1 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    204.1 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    204.1 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel EWrtRd3
      =====================================================
       Cross-Section ID (from X1 card) :    43.0 Channel sequence number :    43

Left Overbank Length   :    162.2 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    162.2 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    162.2 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5   Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel EWrtRd2
      =====================================================
       Cross-Section ID (from X1 card) :    44.0 Channel sequence number :    44

Left Overbank Length   :    163.5 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    163.5 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    163.5 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5   Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel EWrtRd1
      =====================================================
       Cross-Section ID (from X1 card) :    45.0 Channel sequence number :    45

Left Overbank Length   :     51.1 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     51.1 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :     51.1 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5   Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2
```

```
      Natural Cross-Section information for Channel ClkERd3
      =====================================================
       Cross-Section ID (from X1 card) :    46.0 Channel sequence number :    46

Left Overbank Length   :    175.3 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    175.3 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    175.3 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel ClkERd2
      =====================================================
       Cross-Section ID (from X1 card) :    47.0 Channel sequence number :    47

Left Overbank Length   :    101.4 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    101.4 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    101.4 ft               Maximum Section Area     :  24.4000 ft^2
                                                   Maximum hydraulic radius :     0.41 ft.
Manning N :      0.030  to Station          14.5    Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      45.5    Max left bank area       :     3.62 ft^2
                                                   Max right bank area      :     3.62 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.1500 ft^2

      Natural Cross-Section information for Channel Revere_2
      =====================================================
       Cross-Section ID (from X1 card) :    48.0 Channel sequence number :    48

Left Overbank Length   :     57.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     57.0 ft               Maximum Depth            :     2.00 ft.
Right Overbank Length  :     57.0 ft               Maximum Section Area     :  76.0000 ft^2
                                                   Maximum hydraulic radius :     1.83 ft.
Manning N :      0.020  to Station           0.0    Max topwidth             :    39.00 ft.
  "    "  :      0.020  in main Channel             Maximum Wetted Perimeter : 4.15E+01 ft
  "    "  :      0.020  Beyond station      39.0    Max left bank area       :     0.00 ft^2
                                                   Max right bank area      :     0.00 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  76.0000 ft^2
```

```
      Natural Cross-Section information for Channel Wash_Rd
      =====================================================
       Cross-Section ID (from X1 card) :    49.0 Channel sequence number :    49

Left Overbank Length   :    102.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    102.0 ft               Maximum Depth            :     2.00 ft.
Right Overbank Length  :    102.0 ft               Maximum Section Area     :  76.0000 ft^2
                                                   Maximum hydraulic radius :     1.83 ft.
Manning N :      0.020  to Station           0.0    Max topwidth             :    39.00 ft.
  "    "  :      0.020  in main Channel             Maximum Wetted Perimeter : 4.15E+01 ft
  "    "  :      0.020  Beyond station      39.0    Max left bank area       :     0.00 ft^2
                                                   Max right bank area      :     0.00 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  76.0000 ft^2

      Natural Cross-Section information for Channel UPPkyRd
      =====================================================
       Cross-Section ID (from X1 card) :    50.0 Channel sequence number :    50

Left Overbank Length   :     43.0 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :     43.0 ft               Maximum Depth            :     2.00 ft.
Right Overbank Length  :     43.0 ft               Maximum Section Area     :  76.0000 ft^2
                                                   Maximum hydraulic radius :     1.83 ft.
Manning N :      0.020  to Station           0.0    Max topwidth             :    39.00 ft.
  "    "  :      0.020  in main Channel             Maximum Wetted Perimeter : 4.15E+01 ft
  "    "  :      0.020  Beyond station      39.0    Max left bank area       :     0.00 ft^2
                                                   Max right bank area      :     0.00 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  76.0000 ft^2

      Natural Cross-Section information for Channel Milw_Rd
      =====================================================
       Cross-Section ID (from X1 card) :    51.0 Channel sequence number :    51

Left Overbank Length   :     74.4 ft               Maximum Elevation        :    93.00 ft.
Main Channel Length    :     74.4 ft               Maximum Depth            :     2.00 ft.
Right Overbank Length  :     74.4 ft               Maximum Section Area     : 265.0000 ft^2
                                                   Maximum hydraulic radius :     1.39 ft.
Manning N :      0.020  to Station           0.0    Max topwidth             :   190.00 ft.
  "    "  :      0.020  in main Channel             Maximum Wetted Perimeter : 1.90E+02 ft
  "    "  :      0.020  Beyond station     190.0    Max left bank area       :     0.00 ft^2
                                                   Max right bank area      :     0.00 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  : 265.0000 ft^2
```

```
      Natural Cross-Section information for Channel MWD_2
      =====================================================
       Cross-Section ID (from X1 card) :    52.0 Channel sequence number :    52

Left Overbank Length   :   1134.0 ft               Maximum Elevation        :     2.00 ft.
Main Channel Length    :   1134.0 ft               Maximum Depth            :     2.00 ft.
Right Overbank Length  :   1134.0 ft               Maximum Section Area     : 132.8900 ft^2
                                                   Maximum hydraulic radius :     1.24 ft.
Manning N :      0.030  to Station          22.0    Max topwidth             :   105.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 1.07E+02 ft
  "    "  :      0.030  Beyond station      83.0    Max left bank area       :    20.00 ft^2
                                                   Max right bank area      :    20.00 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  92.8900 ft^2

      Natural Cross-Section information for Channel MWD_1
      =====================================================
       Cross-Section ID (from X1 card) :    53.0 Channel sequence number :    53

Left Overbank Length   :    146.0 ft               Maximum Elevation        :     2.00 ft.
Main Channel Length    :    146.0 ft               Maximum Depth            :     2.00 ft.
Right Overbank Length  :    146.0 ft               Maximum Section Area     : 132.8900 ft^2
                                                   Maximum hydraulic radius :     1.24 ft.
Manning N :      0.030  to Station          22.0    Max topwidth             :   105.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 1.07E+02 ft
  "    "  :      0.030  Beyond station      83.0    Max left bank area       :    20.00 ft^2
                                                   Max right bank area      :    20.00 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  92.8900 ft^2

      Natural Cross-Section information for Channel CtrRd7273
      =====================================================
       Cross-Section ID (from X1 card) :    54.0 Channel sequence number :    54

Left Overbank Length   :    572.0 ft               Maximum Elevation        :   100.10 ft.
Main Channel Length    :    572.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    572.0 ft               Maximum Section Area     :  21.3500 ft^2
                                                   Maximum hydraulic radius :     0.32 ft.
Manning N :      0.020  to Station           9.0    Max topwidth             :    66.00 ft.
  "    "  :      0.014  in main Channel             Maximum Wetted Perimeter : 6.69E+01 ft
  "    "  :      0.020  Beyond station      57.0    Max left bank area       :     1.80 ft^2
                                                   Max right bank area      :     1.80 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.7500 ft^2
```

```
      Natural Cross-Section information for Channel CtrRd
      =====================================================
       Cross-Section ID (from X1 card) :    55.0 Channel sequence number :    55

Left Overbank Length   :    284.0 ft               Maximum Elevation        :   100.10 ft.
Main Channel Length    :    284.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    284.0 ft               Maximum Section Area     :  21.3500 ft^2
                                                   Maximum hydraulic radius :     0.32 ft.
Manning N :      0.020  to Station           9.0   Max topwidth             :    66.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.69E+01 ft
  "    "  :      0.020  Beyond station      57.0   Max left bank area       :     1.80 ft^2
                                                   Max right bank area      :     1.80 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.7500 ft^2

      Natural Cross-Section information for Channel 69th_1
      =====================================================
       Cross-Section ID (from X1 card) :    56.0 Channel sequence number :    56

Left Overbank Length   :    687.9 ft               Maximum Elevation        :   100.00 ft.
Main Channel Length    :    687.9 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    687.9 ft               Maximum Section Area     :  22.6000 ft^2
                                                   Maximum hydraulic radius :     0.38 ft.
Manning N :      0.030  to Station          17.5   Max topwidth             :    60.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
  "    "  :      0.030  Beyond station      42.5   Max left bank area       :     4.38 ft^2
                                                   Max right bank area      :     4.38 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2

      Natural Cross-Section information for Channel North_B
      =====================================================
       Cross-Section ID (from X1 card) :    57.0 Channel sequence number :    57

Left Overbank Length   :    340.0 ft               Maximum Elevation        :   100.10 ft.
Main Channel Length    :    340.0 ft               Maximum Depth            :     0.80 ft.
Right Overbank Length  :    340.0 ft               Maximum Section Area     :  21.3500 ft^2
                                                   Maximum hydraulic radius :     0.32 ft.
Manning N :      0.020  to Station           9.0   Max topwidth             :    66.00 ft.
  "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.69E+01 ft
  "    "  :      0.020  Beyond station      57.0   Max left bank area       :     1.80 ft^2
                                                   Max right bank area      :     1.80 ft^2
Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  17.7500 ft^2
```

```
       Natural Cross-Section information for Channel 66th1_Rd
       ====================================================
        Cross-Section ID (from X1 card) :    58.0 Channel sequence number :    58

 Left Overbank Length   :    693.4 ft               Maximum Elevation        :   100.00 ft.
 Main Channel Length    :    693.4 ft               Maximum Depth            :     0.80 ft.
 Right Overbank Length  :    693.4 ft               Maximum Section Area     :  22.6000 ft^2
                                                    Maximum hydraulic radius :     0.38 ft.
 Manning N :      0.030  to Station         17.5    Max topwidth             :    60.00 ft.
   "    "  :      0.014  in main Channel            Maximum Wetted Perimeter : 6.02E+01 ft
   "    "  :      0.030  Beyond station     42.5    Max left bank area       :     4.38 ft^2
                                                    Max right bank area      :     4.38 ft^2
 Allowable Encroachment Depth :    0.00 ft          Max center channel area  :  13.8500 ft^2

 =====================================================
 Input Information from Closed Conduit Link603
 =====================================================
Point                 Top    Area or     Wetted
 No.       Depth     Width    Offset  Perimeter
            feet      feet    feet^2     feet
-----     ------     -----   -------  ---------
    1      0.000     0.010     0.000      0.000
    2      0.500     5.348     1.725      5.473
    3      1.000     9.000     5.312      9.259
    4      1.500     9.222     9.868     10.284
    5      2.000     9.444    14.535     11.308
    6      2.500     9.667    19.312     12.333
    7      3.000     9.889    24.201     13.357
    8      3.500    11.502    29.375     15.452
    9      4.000    12.000    35.354     16.811
   10      4.500    12.000    41.354     17.811
   11      5.000    12.000    47.354     18.811
   12      5.500    12.000    53.354     19.811
   13      6.000    12.000    59.354     20.811
   14      6.500    12.000    65.354     21.811
   15      7.000    12.000    71.354     22.811
   16      7.312    12.000    75.104     36.936

 =====================================================
 Cross-Section Information for Closed Conduit Link603
 =====================================================
 Maximum Depth            :       7.31 Feet.    Maximum Section Area     :       75.10 Sq.Ft.
 Maximum Hydraulic Radius :       2.03 Feet.    Maximum Top Width        :       12.00 Feet.
 Channel Sequence Number  :         99
```

```
 =====================================================
 Input Information from Closed Conduit Milw_Cond
 =====================================================
Point                Top    Area or     Wetted
 No.       Depth      Width     Offset  Perimeter
            feet       feet     feet^2     feet
-----     ------      -----    -------  ---------
    1      0.000      0.010      0.000      0.000
    2      0.500      7.630      3.250      7.820
    3      1.000      8.860      7.400      9.410
    4      1.500      9.640     12.040     10.680
    5      2.000     10.170     17.000     11.810
    6      2.500     10.520     22.180     12.860
    7      3.000     12.000     27.990     14.950
    8      3.500     12.000     33.990     15.950
    9      4.000     12.000     39.990     16.950
   10      4.500     12.000     45.990     17.950
   11      5.000     12.000     51.990     18.950
   12      5.500     12.000     57.990     19.950
   13      6.000     12.000     63.990     32.950

 =====================================================
 Cross-Section Information for Closed Conduit Milw_Cond
 =====================================================
 Maximum Depth            :        6.00 Feet.    Maximum Section Area     :        63.99 Sq.Ft.
 Maximum Hydraulic Radius :        1.94 Feet.    Maximum Top Width        :        12.00 Feet.
 Channel Sequence Number  :         222

 =====================================================
 Input Information from Closed Conduit MWD1SS
 =====================================================
Point                Top    Area or     Wetted
 No.       Depth      Width     Offset  Perimeter
            feet       feet     feet^2     feet
-----     ------      -----    -------  ---------
    1      0.000      0.010      0.000      0.000
    2      0.500      4.620      1.750      4.810
    3      1.000      5.850      4.400      6.400
    4      1.500      6.640      7.530      7.670
    5      2.000      7.160     10.990      8.800
    6      2.500      7.500     14.660      9.860
    7      3.000      9.000     18.970     11.950
    8      3.500      9.000     23.470     12.950
    9      4.000      9.000     27.970     13.950
   10      4.500      9.000     32.470     14.950
   11      5.000      9.000     36.970     15.950
   12      5.500      9.000     41.470     16.950
```

```
  13      6.000      9.000     45.970     26.950

 ====================================================
 Cross-Section Information for Closed Conduit MWD1SS
 ====================================================
 Maximum Depth           :       6.00 Feet.    Maximum Section Area     :       45.97 Sq.Ft.
 Maximum Hydraulic Radius :       1.71 Feet.    Maximum Top Width        :        9.00 Feet.
 Channel Sequence Number  :        228
```

==
| Table E1 - Conduit Data |
==

Inp Num	Conduit Name	Length (ft)	Conduit Class	Area (ft^2)	Manning Coef.	Max Width (ft)	Depth (ft)	Trapezoid Side Slopes	Hazen Williams c-factor
1	Link420	53.6000	Circular	3.1416	0.0130	2.0000	2.0000		
2	Link421	36.5000	Circular	3.1416	0.0130	2.0000	2.0000		
3	Link422	35.6000	Rectangle	9.0000	0.0130	3.0000	3.0000		
4	Link423	88.9000	Circular	4.9087	0.0130	2.5000	2.5000		
5	Link424	140.0000	Circular	4.9087	0.0130	2.5000	2.5000		
6	Link425	54.3000	Circular	4.9087	0.0130	2.5000	2.5000		
7	Link426	36.5000	Circular	4.9087	0.0130	2.5000	2.5000		
8	Link427	10.0000	Circular	4.9087	0.0130	2.5000	2.5000		
9	Link436	288.2000	Circular	7.0686	0.0130	3.0000	3.0000		
10	Link437	265.7000	Circular	7.0686	0.0130	3.0000	3.0000		
11	Link438	21.0000	Circular	7.0686	0.0130	3.0000	3.0000		
12	Link440	10.0000	Circular	9.6211	0.0130	3.5000	3.5000		
13	Link441	281.5000	Circular	9.6211	0.0130	3.5000	3.5000		
14	Link442	257.3000	Circular	9.6211	0.0130	3.5000	3.5000		
15	Link443	95.1000	Circular	9.6211	0.0130	3.5000	3.5000		
16	Link444	93.2000	Circular	12.5664	0.0130	4.0000	4.0000		
17	Link445	64.2000	Circular	12.5664	0.0130	4.0000	4.0000		
18	Link446	216.0000	Circular	12.5664	0.0130	4.0000	4.0000		
19	Link447	65.6000	Circular	12.5664	0.0130	4.0000	4.0000		
20	Link448	556.3000	Circular	15.9043	0.0130	4.5000	4.5000		
21	Link449	80.5000	Circular	15.9043	0.0130	4.5000	4.5000		
22	Link450	247.0000	Circular	15.9043	0.0130	4.5000	4.5000		
23	Link452	357.0000	Circular	19.6350	0.0130	5.0000	5.0000		
24	Link453	423.5000	Circular	19.6350	0.0130	5.0000	5.0000		
25	Link454	118.5000	Circular	23.7583	0.0130	5.5000	5.5000		
26	Link455	205.1000	Circular	23.7583	0.0130	5.5000	5.5000		
27	Link456	583.9000	Circular	23.7583	0.0130	5.5000	5.5000		
28	Link459	318.1000	Circular	9.6211	0.0130	3.5000	3.5000		
29	Link467	21.1000	Circular	9.6211	0.0130	3.5000	3.5000		
30	Link468	101.8000	Circular	9.6211	0.0130	3.5000	3.5000		
31	Link469	182.3000	Circular	9.6211	0.0130	3.5000	3.5000		

32	Link470	15.0000	Circular	7.0686	0.0130	3.0000	3.0000
33	Link473	38.0000	Rectangle	7.0525	0.0130	3.2500	2.1700
34	Link474	284.8000	Circular	7.0686	0.0130	3.0000	3.0000
35	Link479	337.5000	Circular	3.1416	0.0130	2.0000	2.0000
36	Link481	274.1000	Circular	3.1416	0.0130	2.0000	2.0000
37	Link482	18.7000	Circular	3.1416	0.0130	2.0000	2.0000
38	Link484	286.8000	Circular	4.9087	0.0130	2.5000	2.5000
39	Link485	76.8000	Rectangle	7.5950	0.0130	3.5000	2.1700
40	Link486	74.5000	Circular	7.0686	0.0130	3.0000	3.0000
41	Link490	288.8000	Circular	9.6211	0.0130	3.5000	3.5000
42	Link491	51.0000	Circular	3.1416	0.0130	2.0000	2.0000
43	Link496	64.1000	Circular	4.9087	0.0130	2.5000	2.5000
44	Link498	38.0000	Circular	7.0686	0.0130	3.0000	3.0000
45	Link499	280.5000	Circular	7.0686	0.0130	3.0000	3.0000
46	Link508	57.3000	Circular	2.4053	0.0130	1.7500	1.7500
47	Link509	169.3000	Circular	2.4053	0.0130	1.7500	1.7500
48	Link510	134.7000	Circular	2.4053	0.0130	1.7500	1.7500
49	Link511	33.3000	Circular	3.1416	0.0130	2.0000	2.0000
50	Link513	330.8000	Circular	3.1416	0.0130	2.0000	2.0000
51	Link514	366.0000	Circular	3.1416	0.0130	2.0000	2.0000
52	Link515	227.0000	Circular	3.1416	0.0130	2.0000	2.0000
53	Link517	150.4000	Circular	3.9761	0.0130	2.2500	2.2500
54	Link518	107.9000	Circular	3.9761	0.0130	2.2500	2.2500
55	Link523	282.0000	Circular	3.1416	0.0130	2.0000	2.0000
56	Link524	314.0000	Circular	3.1416	0.0130	2.0000	2.0000
57	Link526	215.5000	Circular	3.1416	0.0130	2.0000	2.0000
58	Link527	88.0000	Circular	3.1416	0.0130	2.0000	2.0000
59	Link528	32.4000	Circular	3.1416	0.0130	2.0000	2.0000
60	Link530	264.0000	Circular	3.1416	0.0130	2.0000	2.0000
61	Link531	206.6000	Circular	3.1416	0.0130	2.0000	2.0000
62	Link532	143.2000	Circular	4.9087	0.0130	2.5000	2.5000
63	Link533	10.0000	Circular	7.0686	0.0130	3.0000	3.0000
64	Link534	186.5000	Circular	7.0686	0.0130	3.0000	3.0000
65	Link535	194.0000	Circular	7.0686	0.0130	3.0000	3.0000
66	Link536	35.7000	Circular	3.1416	0.0130	2.0000	2.0000
67	Link537	121.7000	Circular	3.1416	0.0130	2.0000	2.0000
68	Link538	167.5000	Circular	3.1416	0.0130	2.0000	2.0000
69	Link539	17.8000	Circular	2.4053	0.0130	1.7500	1.7500
70	Link540	20.8000	Circular	2.4053	0.0130	1.7500	1.7500
71	Link543	40.6000	Rectangle	24.0000	0.0130	8.0000	3.0000
72	Link544	76.7000	Circular	7.0686	0.0130	3.0000	3.0000
73	Link545	154.8000	Circular	7.0686	0.0130	3.0000	3.0000
74	Link546	216.0000	Circular	7.0686	0.0130	3.0000	3.0000
75	Link547	166.7000	Circular	7.0686	0.0130	3.0000	3.0000
76	Link548	28.0000	Circular	7.0686	0.0130	3.0000	3.0000
77	Link549	186.1000	Circular	7.0686	0.0130	3.0000	3.0000
78	Link550	225.1000	Circular	7.0686	0.0130	3.0000	3.0000

79	Link551	263.0000	Circular	7.0686	0.0130	3.0000	3.0000
80	Link553	145.6000	Circular	23.7583	0.0130	5.5000	5.5000
81	Link559	36.4000	Circular	3.9761	0.0130	2.2500	2.2500
82	Link560	42.5000	Circular	3.9761	0.0130	2.2500	2.2500
83	Link574	63.9000	Circular	7.0686	0.0130	3.0000	3.0000
84	Link575	131.4000	Circular	4.9087	0.0130	2.5000	2.5000
85	Link576	136.4000	Circular	4.9087	0.0130	2.5000	2.5000
86	Link577	282.2000	Circular	7.0686	0.0130	3.0000	3.0000
87	Link580	47.9000	Circular	3.1416	0.0130	2.0000	2.0000
88	Link581	231.5000	Circular	4.9087	0.0130	2.5000	2.5000
89	WashBlv	128.0000	Natural	311.7000	0.0200	90.0000	7.7000
90	8X4.5_BOX	700.0000	Rectangle	36.0000	0.0130	8.0000	4.5000
91	4x9Box	61.5000	Rectangle	36.0000	0.0130	9.0000	4.0000
92	OPEN1	340.0000	Natural	355.4389	0.0330	89.2300	9.9000
93	OPEN2	20.0000	Natural	215.5303	0.0330	62.8600	8.7000
94	OPEN5	180.0000	Natural	111.0555	0.0330	37.3576	7.0000
95	OPEN6	75.0000	Natural	95.2645	0.0330	34.7125	6.8000
96	OPEN7	275.0000	Natural	145.6050	0.0330	61.0000	6.8000
97	OPEN8A	270.0000	Natural	76.7520	0.0330	38.3438	6.1500
98	OPEN9	530.0000	Natural	402.0625	0.0330	157.0000	7.5000
99	Link603	116.1000	Closd Cnd	75.1044	0.0130	12.0000	7.3125
100	Link604	151.5000	Circular	7.0686	0.0130	3.0000	3.0000
101	Link605	23.5000	Rectangle	6.8340	0.0130	3.4170	2.0000
102	Link606	313.4000	Circular	3.1416	0.0130	2.0000	2.0000
103	Link607	62.9000	Circular	3.1416	0.0130	2.0000	2.0000
104	Link608	23.7000	Circular	3.1416	0.0130	2.0000	2.0000
105	Link609	212.1000	Circular	3.1416	0.0130	2.0000	2.0000
106	Link610	30.0000	Circular	4.9087	0.0130	2.5000	2.5000
107	Link611	78.5000	Circular	4.9087	0.0130	2.5000	2.5000
108	Link612	142.0000	Circular	2.4053	0.0130	1.7500	1.7500
109	Link613	99.8000	Circular	2.4053	0.0130	1.7500	1.7500
110	Link614	18.6000	Circular	2.4053	0.0130	1.7500	1.7500
111	Link615	99.7000	Circular	2.4053	0.0130	1.7500	1.7500
112	Link616	140.1000	Circular	3.9761	0.0130	2.2500	2.2500
113	Link617	27.0000	Circular	12.5664	0.0130	4.0000	4.0000
114	Link618	42.3000	Circular	12.5664	0.0130	4.0000	4.0000
115	Link619	166.9000	Circular	12.5664	0.0130	4.0000	4.0000
116	Link620	97.0000	Circular	23.7583	0.0130	5.5000	5.5000
117	Link621	54.8000	Circular	23.7583	0.0130	5.5000	5.5000
118	Link622	33.0000	Circular	23.7583	0.0130	5.5000	5.5000
119	Link624	12.0000	Rectangle	36.0000	0.0130	8.0000	4.5000
120	OpenToRR	26.0000	Rectangle	112.0000	0.0130	20.0000	5.6000
121	OPEN10	360.0000	Natural	605.1079	0.0330	221.4742	7.1000
122	OPEN8B	190.0000	Natural	76.7520	0.0330	38.3438	6.1500
123	OPEN3	350.0000	Natural	180.2092	0.0330	47.1100	8.5000
124	Link633	170.0000	Circular	7.0686	0.0130	3.0000	3.0000
125	Link637	644.0000	Circular	19.6350	0.0130	5.0000	5.0000

126	Link641	880.0000	Circular	12.5664	0.0130	4.0000	4.0000
127	73rdST	400.0000	Natural	22.6000	0.0140	60.0000	0.8000
128	72ndST	650.0000	Natural	22.6000	0.0140	60.0000	0.8000
129	70thST	620.0000	Natural	22.6000	0.0140	60.0000	0.8000
130	Link659	250.0000	Natural	22.6000	0.0140	60.0000	0.8000
131	Link660	620.0000	Natural	22.6000	0.0140	60.0000	0.8000
132	Link661	620.0000	Natural	22.6000	0.0140	60.0000	0.8000
133	WrtWRd1	350.0000	Natural	24.4000	0.0140	60.0000	0.8000
134	Link525	17.8000	Circular	3.1416	0.0130	2.0000	2.0000
135	Link516	29.8000	Circular	3.1416	0.0130	2.0000	2.0000
136	Link541	185.0000	Circular	7.0686	0.0130	3.0000	3.0000
137	8X4.5Box.1	300.0000	Rectangle	36.0000	0.0130	8.0000	4.5000
138	Link675	890.7000	Circular	4.9087	0.0130	2.5000	2.5000
139	Link676	298.0000	Circular	1.7671	0.0130	1.5000	1.5000
140	Link677	658.0000	Circular	1.7671	0.0130	1.5000	1.5000
141	Link679	230.8000	Circular	7.0686	0.0130	3.0000	3.0000
142	Link680	283.5000	Circular	9.6211	0.0130	3.5000	3.5000
143	Link682	22.8000	Circular	9.6211	0.0130	3.5000	3.5000
144	Link685	2633.6000	Circular	4.9087	0.0130	2.5000	2.5000
145	Link686	656.2000	Circular	12.5664	0.0130	4.0000	4.0000
146	Link687	798.9000	Circular	12.5664	0.0130	4.0000	4.0000
147	Link688	12.0000	Circular	28.2743	0.0130	6.0000	6.0000
148	Link689	270.0000	Circular	33.1831	0.0130	6.5000	6.5000
149	Link690	860.0000	Circular	33.1831	0.0130	6.5000	6.5000
150	Link691	597.2000	Circular	15.9043	0.0130	4.5000	4.5000
151	Link692	566.5000	Circular	12.5664	0.0130	4.0000	4.0000
152	Link693	1272.2000	Circular	12.5664	0.0130	4.0000	4.0000
153	Link694	260.9000	Circular	12.5664	0.0130	4.0000	4.0000
154	Link695	502.6000	Circular	12.5664	0.0130	4.0000	4.0000
155	Link696	641.0000	Circular	15.9043	0.0130	4.5000	4.5000
156	Link697	43.0000	Circular	7.0686	0.0130	3.0000	3.0000
157	Link698	298.0000	Circular	3.1416	0.0130	2.0000	2.0000
158	WrtWSS2	245.1000	Circular	4.9087	0.0130	2.5000	2.5000
159	WrtWRd2	245.1000	Natural	24.4000	0.0140	60.0000	0.8000
160	WrtWSS5	123.0000	Circular	7.0686	0.0130	3.0000	3.0000
161	WrtWRd5	123.0000	Natural	24.4000	0.0140	60.0000	0.8000
162	WrtWSS6	119.5000	Circular	7.0686	0.0130	3.0000	3.0000
163	WrtWRd6	119.5000	Natural	24.4000	0.0140	60.0000	0.8000
164	Wright1SS	157.7000	Circular	9.6211	0.0130	3.5000	3.5000
165	Wright_1	157.7000	Natural	24.4000	0.0140	60.0000	0.8000
166	North1SS	263.2000	Circular	19.6350	0.0130	5.0000	5.0000
167	North_1	263.2000	Natural	21.3500	0.0140	66.0000	0.8000
168	WrtWSS3	37.1000	Circular	7.0686	0.0130	3.0000	3.0000
169	WrtWRd3	37.1000	Natural	24.4000	0.0140	60.0000	0.8000
170	WrtWSS4	44.0000	Circular	7.0686	0.0130	3.0000	3.0000
171	WrtWRd4	44.0000	Natural	24.4000	0.0140	60.0000	0.8000
172	Wright3SS	264.8000	Circular	12.5664	0.0130	4.0000	4.0000

173	Wright_3	264.8000	Natural	24.4000	0.0140	60.0000	0.8000
174	70th1SS	346.5000	Circular	15.9043	0.0130	4.5000	4.5000
175	70th_1	346.5000	Natural	22.6000	0.0140	60.0000	0.8000
176	70th2SS	339.2000	Circular	15.9043	0.0130	4.5000	4.5000
177	70th_2	339.2000	Natural	22.6000	0.0140	60.0000	0.8000
178	MeineckeSS	286.0000	Circular	19.6350	0.0130	5.0000	5.0000
179	Meinecke_1	286.0000	Natural	22.6000	0.0140	60.0000	0.8000
180	GarfieldSS	390.3000	Circular	15.9043	0.0130	4.5000	4.5000
181	Garfield_1	390.3000	Natural	22.6000	0.0140	60.0000	0.8000
182	67th1SS	661.5000	Circular	15.9043	0.0130	4.5000	4.5000
183	67th_1	661.5000	Natural	22.6000	0.0140	60.0000	0.8000
184	Clarke1SS	236.4000	Circular	3.1416	0.0130	2.0000	2.0000
185	Clarke_1	236.4000	Natural	24.4000	0.0140	60.0000	0.8000
186	Clarke2SS	26.5000	Circular	3.9761	0.0130	2.2500	2.2500
187	Clarke_2	26.5000	Natural	24.4000	0.0140	60.0000	0.8000
188	Clarke3SS	24.6000	Circular	3.9761	0.0130	2.2500	2.2500
189	Clarke_3	24.6000	Natural	24.4000	0.0140	60.0000	0.8000
190	Clarke4SS	237.0000	Circular	3.9761	0.0130	2.2500	2.2500
191	Clarke_4	237.0000	Natural	24.4000	0.0140	60.0000	0.8000
192	Clarke5SS	250.7000	Circular	4.9087	0.0130	2.5000	2.5000
193	Clarke_5	250.7000	Natural	24.4000	0.0140	60.0000	0.8000
194	ClkESSA	38.6000	Circular	4.9087	0.0130	2.5000	2.5000
195	ClkERdA	38.6000	Natural	24.4000	0.0140	60.0000	0.8000
196	ClkESSB	259.5000	Circular	3.9761	0.0130	2.2500	2.2500
197	ClkERdB	259.5000	Natural	24.4000	0.0140	60.0000	0.8000
198	ClkESS1	49.2000	Circular	3.9761	0.0130	2.2500	2.2500
199	ClkERd1	49.2000	Natural	24.4000	0.0140	60.0000	0.8000
200	ClkESS4	58.9000	Circular	3.1416	0.0130	2.0000	2.0000
201	ClkERd4	58.9000	Natural	24.4000	0.0140	60.0000	0.8000
202	ClkESS5	95.2000	Circular	2.4053	0.0130	1.7500	1.7500
203	ClkERd5	95.2000	Natural	24.4000	0.0140	60.0000	0.8000
204	ClkESS6	204.1000	Circular	2.4053	0.0130	1.7500	1.7500
205	ClkERd6	204.1000	Natural	24.4000	0.0140	60.0000	0.8000
206	EWrtSS3	162.2000	Circular	3.1416	0.0130	2.0000	2.0000
207	EWrtRd3	162.2000	Natural	24.4000	0.0140	60.0000	0.8000
208	EWrtSS2	163.5000	Circular	3.1416	0.0130	2.0000	2.0000
209	EWrtRd2	163.5000	Natural	24.4000	0.0140	60.0000	0.8000
210	EWrtSS1	51.1000	Circular	3.1416	0.0130	2.0000	2.0000
211	EWrtRd1	51.1000	Natural	24.4000	0.0140	60.0000	0.8000
212	ClkESS3	175.3000	Circular	3.1416	0.0130	2.0000	2.0000
213	ClkERd3	175.3000	Natural	24.4000	0.0140	60.0000	0.8000
214	ClkESS2	101.4000	Circular	3.1416	0.0130	2.0000	2.0000
215	ClkERd2	101.4000	Natural	24.4000	0.0140	60.0000	0.8000
216	Revere_1	57.0000	Rectangle	49.5000	0.0130	9.0000	5.5000
217	Revere_2	57.0000	Natural	76.0000	0.0200	39.0000	2.0000
218	Wash_culv	102.0000	Rectangle	49.5000	0.0130	9.0000	5.5000
219	Wash_Rd	102.0000	Natural	76.0000	0.0200	39.0000	2.0000

```
 220         UPPkycul    43.0000  Rectangle   49.5000     0.0130     9.0000     5.5000
 221          UPPkyRd    43.0000    Natural   76.0000     0.0200    39.0000     2.0000
 222        Milw_Cond    74.4000  Closd Cnd   63.9900     0.0130    12.0000     6.0000
 223          Milw_Rd    74.4000    Natural  265.0000     0.0200   190.0000     2.0000
 224           MWD2SS  1134.0000  Rectangle   32.4750     0.0130     7.5000     4.3300
 225            MWD_2  1134.0000    Natural  132.8900     0.0140   105.0000     2.0000
 226             Box1    22.2500  Rectangle   45.0000     0.0130     9.0000     5.0000
 227             Box2    22.2500  Rectangle   45.0000     0.0130     9.0000     5.0000
 228           MWD1SS   146.0000  Closd Cnd   45.9700     0.0130     9.0000     6.0000
 229            MWD_1   146.0000    Natural  132.8900     0.0140   105.0000     2.0000
 230          WMilw_1    84.4000  Rectangle   45.0000     0.0130     9.0000     5.0000
 231          WMilw_2    84.4000  Rectangle   45.0000     0.0130     9.0000     5.0000
 232              RR1    32.0000  Rectangle   50.0000     0.0130    10.0000     5.0000
 233              RR2    32.0000  Rectangle   50.0000     0.0130    10.0000     5.0000
 234        CtrSS7273   572.0000   Circular   15.9043     0.0130     4.5000     4.5000
 235        CtrRd7273   572.0000    Natural   21.3500     0.0140    66.0000     0.8000
 236            CtrSS   284.0000   Circular   15.9043     0.0130     4.5000     4.5000
 237            CtrRd   284.0000    Natural   21.3500     0.0140    66.0000     0.8000
 238          69th1SS   687.9000   Circular   19.6350     0.0130     5.0000     5.0000
 239           69th_1   687.9000    Natural   22.6000     0.0140    60.0000     0.8000
 240        NorthB_SS   359.2000   Circular   12.5664     0.0130     4.0000     4.0000
 241          North_B   340.0000    Natural   21.3500     0.0140    66.0000     0.8000
 242          66th1_SS   693.4000   Circular   19.6350     0.0130     5.0000     5.0000
 243          66th1_Rd   693.4000    Natural   22.6000     0.0140    60.0000     0.8000
Total length of all conduits ....     56159.1000 feet

*===================================================*
|      Table E2 -  Conduit Factor Data              |
*===================================================*

                                                              Time    Low Flow  Depth at
        Conduit     Number  Entrance      Exit Exp/Contc Weighting Roughness     Which  Sediment    Flow
           Name of Barrels Loss Coef Loss Coef Coefficnt Parameter    Factor n Changes     Depth Routing
--------------- ---------- --------- --------- --------- --------- --------- --------- --------- -------
      8X4.5_BOX     1.0000    0.3000    0.5000    0.0000    0.6500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
        Link603     1.0000    0.0000    0.0000    0.0000    0.6500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
     8X4.5Box.1     1.0000    0.3000    0.5000    0.0000    0.8500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
       Revere_1     1.0000    0.5000    1.0000    0.3000    0.8500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
       Revere_2     1.0000    0.0000    0.0000    0.0000    0.8500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
      Wash_culv     1.0000    0.5000    1.0000    0.3000    0.8500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
       UPPkycul     1.0000    0.5000    1.0000    0.3000    0.8500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
           Box1     1.0000    0.3000    0.5000    0.0000    0.6500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
           Box2     1.0000    0.3000    0.5000    0.0000    0.8500    1.0000    0.0000    0.0000 Standard - Dynamic Wave
```

Table E3a - Junction Data

Inp Num	Junction Name	Ground Elevation	Crown Elevation	Invert Elevation	Qinst cfs	Initial Depth-ft	Interface Flow (%)
1	183	157.0400	153.3700	151.3700	0.0000	0.0000	100.0000
2	186	175.1100	171.4500	169.2000	0.0000	0.0000	100.0000
3	268	147.1300	147.1300	138.6800	0.0000	0.0000	100.0000
4	254	144.0900	144.0900	134.7600	0.0000	0.0000	100.0000
5	269	149.3200	144.1300	140.6300	0.0000	0.0000	100.0000
6	022	144.6300	140.3900	136.3900	0.0000	0.0000	100.0000
7	021	144.1200	140.2900	136.2900	0.0000	0.0000	100.0000
8	020	142.6400	140.7400	135.5100	0.0000	0.0000	100.0000
9	019	142.7100	138.5800	134.0800	0.0000	0.0000	100.0000
10	033	164.1800	164.1800	158.9700	0.0000	0.0000	100.0000
11	505	159.7300	159.7300	153.4500	0.0000	0.0000	100.0000
12	034	165.5600	162.6200	160.0400	0.0000	0.0000	100.0000
13	025	146.2000	142.4700	138.9700	0.0000	0.0000	100.0000
14	024	146.2000	141.5700	138.0700	0.0000	0.0000	100.0000
15	049	171.4300	167.4300	165.4300	0.0000	0.0000	100.0000
16	048	170.2900	167.0100	164.2600	0.0000	0.0000	100.0000
17	039	169.5800	166.3500	163.3500	0.0000	0.0000	100.0000
18	162	133.7300	131.3100	128.3100	0.0000	0.0000	100.0000
19	151	132.9400	132.9400	124.1000	0.0000	0.0000	100.0000
20	012	134.9200	130.2800	124.7800	0.0000	0.0000	100.0000
21	152	133.9700	133.9700	126.6700	0.0000	0.0000	100.0000
22	013	137.4000	131.1400	125.6400	0.0000	0.0000	100.0000
23	014	137.5000	133.2000	128.2000	0.0000	0.0000	100.0000
24	035	168.5000	164.3000	161.6200	0.0000	0.0000	100.0000
25	036	170.0300	164.8000	162.3000	0.0000	0.0000	100.0000
26	037	170.5500	165.8000	163.3000	0.0000	0.0000	100.0000
27	038	168.9000	168.8000	161.6700	0.0000	0.0000	100.0000
28	497	147.5900	145.0200	142.0200	0.0000	0.0000	100.0000
29	496	147.3600	147.3600	141.6600	0.0000	0.0000	100.0000
30	494	146.6200	146.6200	139.9300	0.0000	0.0000	100.0000
31	266	144.1800	144.1800	136.4100	0.0000	0.0000	100.0000
32	167	143.0400	140.3000	137.8000	0.0000	0.0000	100.0000
33	165	141.0000	138.5600	134.4800	0.0000	0.0000	100.0000
34	153	139.2300	139.2300	129.4400	0.0000	0.0000	100.0000
35	160	140.9600	137.9800	134.4800	0.0000	0.0000	100.0000
36	159	140.1000	137.4900	133.9900	0.0000	0.0000	100.0000
37	415	139.6600	136.9300	133.4300	0.0000	0.0000	100.0000
38	015	137.9600	137.9600	130.0100	0.0000	0.0000	100.0000
39	018	143.9000	136.4900	131.9900	0.0000	0.0000	100.0000
40	017	143.2600	139.6800	131.7700	0.0000	0.0000	100.0000

41	016	140.3000	140.3000	130.5000	0.0000	0.0000	100.0000
42	011	134.0000	128.7800	123.2800	0.0000	0.0000	100.0000
43	010	130.0000	125.3800	119.8800	0.0000	0.0000	100.0000
44	163	136.9300	134.5000	131.5000	0.0000	0.0000	100.0000
45	164	140.6100	136.4100	133.4100	0.0000	0.0000	100.0000
46	504	159.5600	159.5600	152.6000	0.0000	0.0000	100.0000
47	500	157.4000	157.4000	149.0200	0.0000	0.0000	100.0000
48	503	158.8100	158.8100	152.0600	0.0000	0.0000	100.0000
49	502	157.9800	157.9800	150.5200	0.0000	0.0000	100.0000
50	498	152.3500	147.9500	144.9500	0.0000	0.0000	100.0000
51	267	145.5800	145.5800	137.4800	0.0000	0.0000	100.0000
52	023	147.1100	140.8000	136.8000	0.0000	0.0000	100.0000
53	165A	141.6500	139.4700	135.5200	0.0000	0.0000	100.0000
54	184	157.1500	154.1500	152.1500	0.0000	0.0000	100.0000
55	185	168.1900	165.0900	163.0900	0.0000	0.0000	100.0000
56	168	148.3500	146.4300	143.9300	0.0000	0.0000	100.0000
57	026	146.0400	142.6900	139.1900	0.0000	0.0000	100.0000
58	255	141.9000	141.9000	135.2300	0.0000	0.0000	100.0000
59	188	176.1700	172.4200	170.1500	0.0000	0.0000	100.0000
60	198	163.4400	159.2000	156.8000	0.0000	0.0000	100.0000
61	172	162.8000	158.5000	156.1200	0.0000	0.0000	100.0000
62	171	158.8000	154.8000	152.8000	0.0000	0.0000	100.0000
63	199	167.3800	164.4000	160.9000	0.0000	0.0000	100.0000
64	201	177.5100	177.5100	171.8600	0.0000	0.0000	100.0000
65	203	177.7600	174.2100	172.0300	0.0000	0.0000	100.0000
66	204	184.6200	180.9800	178.9800	0.0000	0.0000	100.0000
67	270	151.4100	147.9500	142.2200	0.0000	0.0000	100.0000
68	PR207	188.6200	184.5800	181.6000	0.0000	0.0000	100.0000
69	205	187.9700	183.1900	180.9300	0.0000	0.0000	100.0000
70	202	177.2400	173.7200	171.4700	0.0000	0.0000	100.0000
71	200	176.2800	176.2800	170.0000	0.0000	0.0000	100.0000
72	105	134.2000	130.7600	122.9600	0.0000	0.0000	100.0000
73	106	134.2000	131.0900	123.2100	0.0000	0.0000	100.0000
74	137	148.2800	143.7000	141.2000	0.0000	0.0000	100.0000
75	166	142.1000	139.1400	136.1400	0.0000	0.0000	100.0000
76	123	158.5700	153.8200	152.0700	0.0000	0.0000	100.0000
77	120	157.5600	152.9000	151.1500	0.0000	0.0000	100.0000
78	118	151.6900	146.7000	144.7000	0.0000	0.0000	100.0000
79	119	157.0600	152.1400	147.1700	0.0000	0.0000	100.0000
80	113	145.2100	141.2700	138.2700	0.0000	0.0000	100.0000
81	115	148.0600	143.7800	141.7800	0.0000	0.0000	100.0000
82	114	147.3600	143.2500	140.2500	0.0000	0.0000	100.0000
83	112	144.1400	140.6800	137.6800	0.0000	0.0000	100.0000
84	111	144.0700	140.4000	129.9200	0.0000	0.0000	100.0000
85	138	154.4300	150.2700	148.2700	0.0000	0.0000	100.0000
86	110	143.8300	131.6400	128.1000	0.0000	0.0000	100.0000
87	307	142.4700	138.8500	127.9900	0.0000	0.0000	100.0000

88	108	139.9000	136.2000	126.6200	0.0000	0.0000	100.0000
89	107	136.6000	132.9500	124.6900	0.0000	0.0000	100.0000
90	104	132.2000	128.4900	125.4900	0.0000	0.0000	100.0000
91	103	130.6000	126.5600	123.5600	0.0000	0.0000	100.0000
92	102	128.2800	124.1300	116.9600	0.0000	0.0000	100.0000
93	PROP491	194.1400	187.2300	185.2300	0.0000	0.0000	100.0000
94	317	180.2200	180.2200	174.5400	0.0000	0.0000	100.0000
95	318	179.5300	179.5300	173.3700	0.0000	0.0000	100.0000
96	469	176.5500	172.9600	170.7100	0.0000	0.0000	100.0000
97	139	162.8000	158.6600	156.6600	0.0000	0.0000	100.0000
98	170	156.7100	153.2400	151.2400	0.0000	0.0000	100.0000
99	169	155.5900	152.4900	149.9900	0.0000	0.0000	100.0000
100	248	153.5500	149.8200	147.8200	0.0000	0.0000	100.0000
101	247	153.1400	153.1000	147.6700	0.0000	0.0000	100.0000
102	246	152.1700	152.1700	146.7300	0.0000	0.0000	100.0000
103	245	151.6800	151.6800	146.5100	0.0000	0.0000	100.0000
104	470	151.8000	151.8000	146.6200	0.0000	0.0000	100.0000
105	244	150.6500	150.6500	144.1500	0.0000	0.0000	100.0000
106	243	150.5400	147.5600	144.0000	0.0000	0.0000	100.0000
107	240	151.7500	148.1700	143.1400	0.0000	0.0000	100.0000
108	238	154.0400	154.0400	146.3500	0.0000	0.0000	100.0000
109	236	155.7000	155.7000	149.6800	0.0000	0.0000	100.0000
110	491	160.0200	160.0200	153.2000	0.0000	0.0000	100.0000
111	234	160.5300	160.5300	153.7800	0.0000	0.0000	100.0000
112	291	155.2200	155.2200	149.1700	0.0000	0.0000	100.0000
113	230	165.8000	165.8000	159.1100	0.0000	0.0000	100.0000
114	492	169.6400	169.6400	162.9300	0.0000	0.0000	100.0000
115	229	166.6000	166.6000	160.1000	0.0000	0.0000	100.0000
116	227	175.8300	175.8300	168.9700	0.0000	0.0000	100.0000
117	226	176.6100	172.4600	170.7100	0.0000	0.0000	100.0000
118	225	184.0000	180.4200	178.6700	0.0000	0.0000	100.0000
119	206	188.2800	182.8400	181.0900	0.0000	0.0000	100.0000
120	Culv1.1	127.1200	127.1200	118.6000	0.0000	0.0000	100.0000
121	187	175.4700	171.9700	169.7200	0.0000	0.0000	100.0000
122	271	150.4500	146.8500	143.3500	0.0000	0.0000	100.0000
123	493	162.4500	162.4500	155.8700	0.0000	0.0000	100.0000
124	11326	128.4500	128.4000	118.5000	0.0000	0.0000	100.0000
125	10996	124.7000	124.6700	113.7500	0.0000	0.0000	100.0000
126	10939	124.7000	124.1700	113.2000	0.0000	0.0000	100.0000
127	10587	120.2000	120.1800	109.6200	0.0000	0.0000	100.0000
128	10487	119.8000	119.7800	108.6100	0.0000	0.0000	100.0000
129	10226	115.2500	115.2500	104.7300	0.0000	0.0000	100.0000
130	10183	115.2500	114.7500	104.3000	0.0000	0.0000	100.0000
131	9450	110.1000	100.5000	92.8000	0.0000	0.0000	100.0000
132	9309	110.1000	98.2000	90.5000	0.0000	0.0000	100.0000
133	8418.5	93.0000	93.0000	78.0000	0.0000	0.0000	100.0000
134	N1	93.0000	92.0000	77.2600	0.0000	0.0000	100.0000

135	N2	66.5500	66.5500	57.4600	0.0000	0.0000	100.0000
136	N3	54.0000	50.4200	45.9200	0.0000	0.0000	100.0000
137	N4	54.0000	51.2700	44.7300	0.0000	0.0000	100.0000
138	N7	53.5000	50.2000	45.2000	0.0000	0.0000	100.0000
139	8700	92.0000	91.5000	84.0000	0.0000	0.0000	100.0000
140	9700	108.0000	106.3000	99.5000	0.0000	0.0000	100.0000
141	10250	120.4000	112.9000	105.7000	0.0000	0.0000	100.0000
142	11022	126.1000	123.9000	113.3000	0.0000	0.0000	100.0000
143	060	145.0200	141.6900	139.1900	0.0000	0.0000	100.0000
144	061	145.8500	141.9500	139.4500	0.0000	0.0000	100.0000
145	062	157.8300	153.9500	150.0700	0.0000	0.0000	100.0000
146	455	159.1000	154.1600	152.1600	0.0000	0.0000	100.0000
147	063	160.6900	155.0500	153.0500	0.0000	0.0000	100.0000
148	066	163.6400	158.7400	156.7400	0.0000	0.0000	100.0000
149	125	170.2900	164.2800	162.5300	0.0000	0.0000	100.0000
150	124	164.0700	158.8200	157.0700	0.0000	0.0000	100.0000
151	457	158.9700	154.1400	152.3900	0.0000	0.0000	100.0000
152	520E	52.8000	51.0000	47.0000	0.0000	0.0000	100.0000
153	520	52.7000	50.8900	46.8900	0.0000	0.0000	100.0000
154	517	52.4200	50.6500	46.5500	0.0000	0.0000	100.0000
155	516	51.7300	50.9700	45.4700	0.0000	0.0000	100.0000
156	515	51.5900	50.5800	45.0800	0.0000	0.0000	100.0000
157	518	52.7700	50.2500	48.0000	0.0000	0.0000	100.0000
158	519	53.2800	50.7000	48.9500	0.0000	0.0000	100.0000
159	514	51.5600	50.3600	44.8600	0.0000	0.0000	100.0000
160	Junction 1	86.1500	86.1500	73.7500	0.0000	0.0000	100.0000
161	Junction 2	65.8000	59.7300	55.2300	0.0000	0.0000	100.0000
162	N8	53.0000	48.3200	43.3200	0.0000	0.0000	100.0000
163	N5	55.0900	50.8000	45.2000	0.0000	0.0000	100.0000
164	N6	53.7000	50.2000	45.2000	0.0000	0.0000	100.0000
165	9600	110.0000	101.7500	95.6000	0.0000	0.0000	100.0000
166	330A049	194.4000	190.9400	189.4400	0.0000	0.0000	100.0000
167	Node748	161.6700	161.6000	144.9300	0.0000	0.0000	100.0000
168	Node749	151.4500	151.4500	133.1200	0.0000	0.0000	100.0000
169	Node753	159.6100	159.6100	139.7500	0.0000	0.0000	100.0000
170	Node754	153.3000	153.3000	135.0000	0.0000	0.0000	100.0000
171	Node755	163.0000	135.3000	130.3000	0.0000	0.0000	100.0000
172	Node759	154.0000	154.0000	146.0000	0.0000	0.0000	100.0000
173	Junct 3	58.8000	53.2000	48.7000	0.0000	0.0000	100.0000
174	330A024	195.4000	189.6600	187.1600	0.0000	0.0000	100.0000
175	330D026	199.4000	187.0000	184.1000	0.0000	0.0000	100.0000
176	330B039	198.4000	195.0000	193.5000	0.0000	0.0000	100.0000
177	330B038	201.4000	193.7500	192.2500	0.0000	0.0000	100.0000
178	345A007	199.4000	155.0800	152.0800	0.0000	0.0000	100.0000
179	345A013	164.4000	155.6000	151.5100	0.0000	0.0000	100.0000
180	345A010	164.4000	153.7700	149.7700	0.0000	0.0000	100.0000
181	346B007	165.9000	156.0900	152.5900	0.0000	0.0000	100.0000

182	346B073	166.4000	151.4800	147.4800	0.0000	0.0000	100.0000
183	345D005	155.4000	144.0400	140.0400	0.0000	0.0000	100.0000
184	369A002	128.4000	119.7700	115.7700	0.0000	0.0000	100.0000
185	369A900	115.4000	105.6200	101.1200	0.0000	0.0000	100.0000
186	369A720	108.9000	99.9300	54.0000	0.0000	0.0000	100.0000
187	368B072	108.9000	60.2500	53.7500	0.0000	0.0000	100.0000
188	368B902	108.9000	59.5000	53.0000	0.0000	0.0000	100.0000
189	368C250	111.4000	57.9800	51.4800	0.0000	0.0000	100.0000
190	346C059	153.4000	140.7400	136.7400	0.0000	0.0000	100.0000
191	368B800	128.4000	121.3200	113.1500	0.0000	0.0000	100.0000
192	368B007	117.4000	107.6300	103.1300	0.0000	0.0000	100.0000
193	368B710	113.4000	103.1000	56.5900	0.0000	0.0000	100.0000

Table E4 - Conduit Connectivity

Input Number	Conduit Name	Upstream Node	Downstream Node	Upstream Elevation	Downstream Elevation	
1	Link420	049	048	165.4300	165.0100	No Design
2	Link421	048	039	164.2600	163.6000	No Design
3	Link422	039	038	163.3500	161.6700	No Design
4	Link423	037	038	163.3000	161.6800	No Design
5	Link424	037	036	163.3000	162.3000	No Design
6	Link425	036	035	162.3000	161.8000	No Design
7	Link426	035	034	161.6200	160.1200	No Design
8	Link427	034	033	160.0400	158.9700	No Design
9	Link436	500	498	149.0200	144.9500	No Design
10	Link437	498	497	144.9500	142.0200	No Design
11	Link438	497	496	142.0200	141.6600	No Design
12	Link440	494	026	139.9300	139.1900	No Design
13	Link441	026	025	139.1900	138.9700	No Design
14	Link442	025	024	138.9700	138.0700	No Design
15	Link443	024	023	138.0700	136.8000	No Design
16	Link444	023	022	136.8000	136.3900	No Design
17	Link445	022	021	136.3900	136.2900	No Design
18	Link446	021	020	136.2900	135.5100	No Design
19	Link447	020	019	135.5100	134.0800	No Design
20	Link448	019	018	134.0800	131.9900	No Design
21	Link449	018	017	131.9900	131.7700	No Design
22	Link450	017	016	131.7700	130.5000	No Design
23	Link452	015	014	130.0100	128.2000	No Design
24	Link453	014	013	128.2000	125.6400	No Design
25	Link454	013	012	125.6400	124.7800	No Design
26	Link455	012	011	124.7800	123.2800	No Design
27	Link456	011	010	123.2800	119.8800	No Design

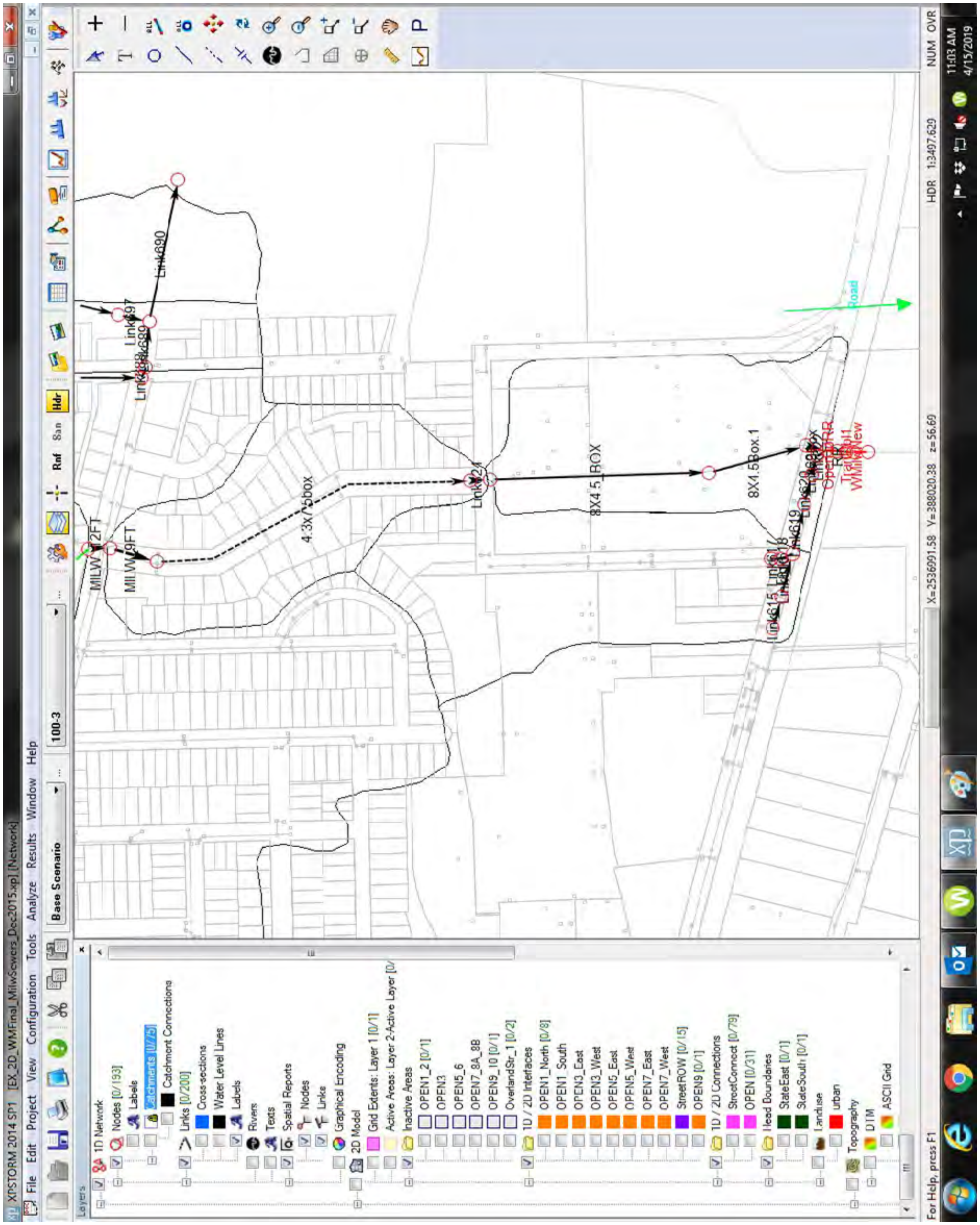
28	Link459	269	268	140.6300	138.9200	No Design
29	Link467	415	153	133.4300	132.3000	No Design
30	Link468	159	415	133.9900	133.4300	No Design
31	Link469	160	159	134.4800	133.9900	No Design
32	Link470	165	160	135.5600	134.6600	No Design
33	Link473	165	164	134.4800	133.4800	No Design
34	Link474	164	163	133.4100	131.5000	No Design
35	Link479	186	185	169.2000	163.0900	No Design
36	Link481	185	184	163.0900	152.1500	No Design
37	Link482	184	183	152.1500	151.3700	No Design
38	Link484	168	167	143.9300	137.8000	No Design
39	Link485	167	165A	137.8000	137.3000	No Design
40	Link486	162	151	128.3100	126.1000	No Design
41	Link490	270	269	142.2200	140.6300	No Design
42	Link491	248	247	147.8200	147.6700	No Design
43	Link496	244	243	145.5300	145.0600	No Design
44	Link498	240	270	145.1700	144.9500	No Design
45	Link499	238	240	146.3500	145.1700	No Design
46	Link508	226	227	170.7100	168.9700	No Design
47	Link509	225	226	178.6700	170.7100	No Design
48	Link510	206	225	181.0900	178.6700	No Design
49	Link511	PR207	205	181.6000	181.1900	No Design
50	Link513	PROP491	PR207	185.2300	182.5800	No Design
51	Link514	205	204	180.9300	178.9800	No Design
52	Link515	204	203	178.9800	172.2100	No Design
53	Link517	202	469	171.4700	170.7100	No Design
54	Link518	469	188	170.7100	170.1700	No Design
55	Link523	200	199	170.9400	162.4000	No Design
56	Link524	199	198	162.0000	157.2000	No Design
57	Link526	172	171	156.1200	152.8000	No Design
58	Link527	171	170	152.8000	151.2400	No Design
59	Link528	170	169	151.2400	150.3400	No Design
60	Link530	139	138	156.6600	148.2700	No Design
61	Link531	138	137	148.2700	141.7000	No Design
62	Link532	137	111	141.2000	135.1100	No Design
63	Link533	112	111	137.6800	137.4000	No Design
64	Link534	113	112	138.2700	137.6800	No Design
65	Link535	114	113	140.2500	138.2700	No Design
66	Link536	115	114	141.7800	140.7300	No Design
67	Link537	118	115	144.7000	141.7800	No Design
68	Link538	119	118	147.1700	144.7000	No Design
69	Link539	120	119	151.1500	150.3900	No Design
70	Link540	123	120	152.0700	151.1500	No Design
71	Link543	111	110	129.9200	128.6400	No Design
72	Link544	307	110	135.8500	128.1000	No Design
73	Link545	307	108	135.8500	133.2000	No Design
74	Link546	108	107	133.2000	129.9500	No Design

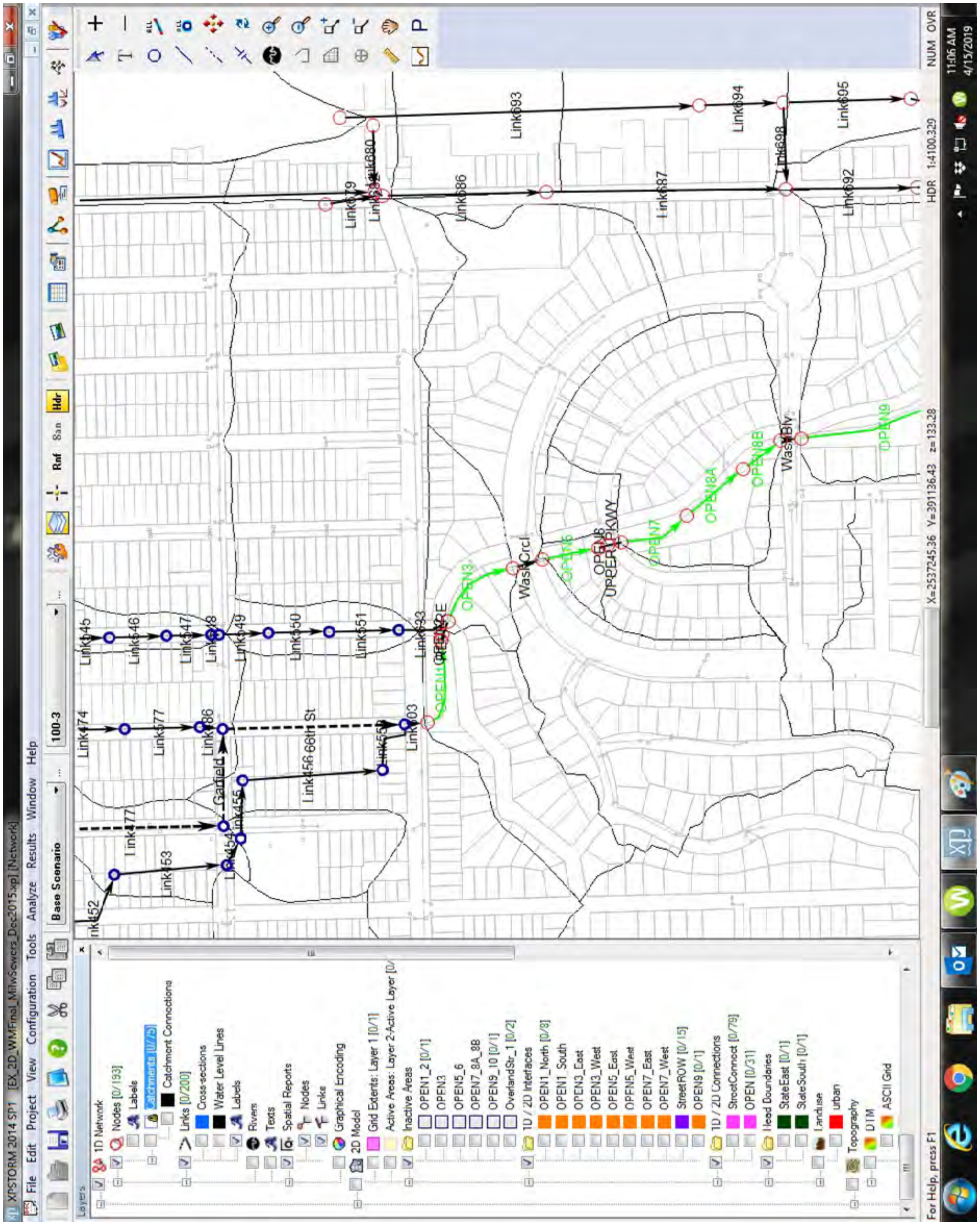
75	Link547	107	106	129.9500	128.0900	No Design
76	Link548	106	105	128.0900	127.7600	No Design
77	Link549	105	104	127.7600	125.4900	No Design
78	Link550	104	103	125.4900	123.5600	No Design
79	Link551	103	102	123.5600	121.1300	No Design
80	Link553	010	Culv1.1	119.8800	118.6000	No Design
81	Link559	188	187	170.1500	169.7200	No Design
82	Link560	187	186	169.7200	169.2000	No Design
83	Link574	020	255	137.7400	135.2300	No Design
84	Link575	243	271	145.0600	144.3500	No Design
85	Link576	271	270	144.3500	143.2200	No Design
86	Link577	163	162	131.5000	128.3100	No Design
87	Link580	183	169	151.3700	150.4400	No Design
88	Link581	169	168	149.9900	143.9300	No Design
89	WashBlv	9450	9309	92.8000	90.5000	No Design
90	8X4.5_BOX	Junction 2	Junct 3	55.2300	48.7000	No Design
91	4x9Box	N3	N4	45.9200	45.6700	No Design
92	OPEN1	11326	11022	118.5000	114.0000	No Design
93	OPEN2	11022	10996	114.0000	113.7500	No Design
94	OPEN5	10487	10250	108.6100	105.9000	No Design
95	OPEN6	10250	10226	105.9000	104.7300	No Design
96	OPEN7	10183	9700	104.3000	99.5000	No Design
97	OPEN8A	9700	9600	99.5000	95.6000	No Design
98	OPEN9	9309	8700	90.5000	84.0000	No Design
99	Link603	Culv1.1	11326	118.6000	118.5000	No Design
100	Link604	166	165	136.1400	135.0400	No Design
101	Link605	165A	165	135.5200	135.3600	No Design
102	Link606	066	063	156.7400	153.0500	No Design
103	Link607	063	455	153.0500	152.1600	No Design
104	Link608	455	062	152.1600	151.9500	No Design
105	Link609	062	061	150.0700	139.5200	No Design
106	Link610	061	060	139.4500	139.1900	No Design
107	Link611	060	017	139.1900	137.1800	No Design
108	Link612	125	124	162.5300	157.0700	No Design
109	Link613	124	457	157.0700	152.3900	No Design
110	Link614	457	123	152.3900	152.0700	No Design
111	Link615	519	518	48.9500	48.5000	No Design
112	Link616	518	517	48.0000	47.5900	No Design
113	Link617	520E	520	47.0000	46.8900	No Design
114	Link618	520	517	46.8900	46.6500	No Design
115	Link619	517	516	46.5500	45.8800	No Design
116	Link620	516	515	45.4700	45.0800	No Design
117	Link621	515	514	45.0800	44.8600	No Design
118	Link622	514	N4	44.8600	44.7300	No Design
119	Link624	N2	Junction 2	57.4600	55.2300	No Design
120	OpenToRR	N4	N5	45.6700	45.2000	No Design
121	OPEN10	8700	8418.5	84.0000	78.0000	No Design

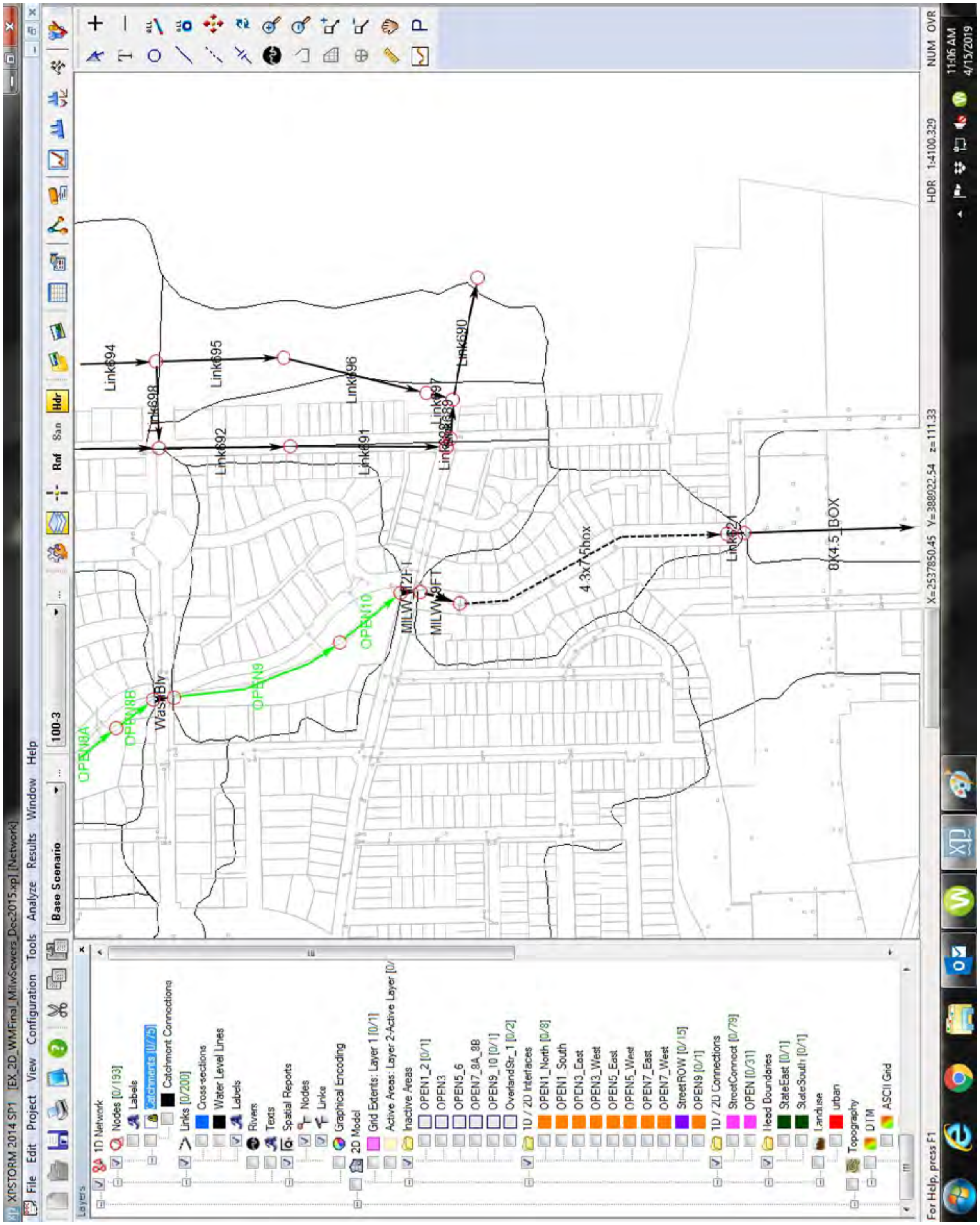
122	OPEN8B	9600	9450	95.6000	92.8000	No Design
123	OPEN3	10939	10587	113.2000	109.6200	No Design
124	Link633	102	10939	116.9600	114.5000	No Design
125	Link637	Node749	Node755	133.1200	130.3000	No Design
126	Link641	Node748	Node753	144.9300	140.2500	No Design
127	73rdST	Node759	247	153.2000	152.3000	No Design
128	72ndST	244	496	149.8500	146.5600	No Design
129	70thST	238	267	153.2400	144.7800	No Design
130	Link659	Node759	Node754	153.2000	152.5000	No Design
131	Link660	Node753	244	158.8000	149.8000	No Design
132	Link661	Node748	291	160.8000	154.4000	No Design
133	WrtWRd1	038	033	168.0000	163.3800	No Design
134	Link525	198	172	156.8000	156.5000	No Design
135	Link516	203	202	172.0300	171.5400	No Design
136	Link541	111	166	137.2600	136.1400	No Design
137	8X4.5Box.1	Junct 3	N3	48.7000	45.9200	No Design
138	Link675	330A024	330D026	187.1600	184.1000	No Design
139	Link676	330B039	330B038	193.5000	192.2500	No Design
140	Link677	330A049	330D026	189.4400	185.5000	No Design
141	Link679	345A007	345A010	152.0800	150.1700	No Design
142	Link680	346B007	345A013	152.5900	151.5100	No Design
143	Link682	345A013	345A010	151.5100	150.0500	No Design
144	Link685	330D026	345A013	184.1000	153.1000	No Design
145	Link686	345A010	345D005	149.7700	140.0400	No Design
146	Link687	345D005	369A002	140.0400	115.7700	No Design
147	Link688	369A720	368B072	54.0000	53.7500	No Design
148	Link689	368B072	368B902	53.7500	53.0000	No Design
149	Link690	368B902	368C250	53.0000	51.4800	No Design
150	Link691	369A900	369A720	101.1200	95.4300	No Design
151	Link692	369A002	369A900	115.7700	101.1200	No Design
152	Link693	346B073	346C059	147.4800	136.7400	No Design
153	Link694	346C059	368B800	136.7400	113.1500	No Design
154	Link695	368B800	368B007	113.1500	103.6300	No Design
155	Link696	368B007	368B710	103.1300	98.6000	No Design
156	Link697	368B710	368B902	56.5900	54.7500	No Design
157	Link698	368B800	369A002	119.3200	117.3100	No Design
158	WrtWSS2	033	505	158.9700	154.3600	No Design
159	WrtWRd2	033	505	163.3800	158.9300	No Design
160	WrtWSS5	503	502	152.0600	150.5200	No Design
161	WrtWRd5	503	502	158.0100	157.1800	No Design
162	WrtWSS6	502	500	150.5200	149.0200	No Design
163	WrtWRd6	502	500	157.1800	156.6000	No Design
164	Wright1SS	496	494	141.6600	140.1400	No Design
165	Wright_1	496	494	146.5600	145.8200	No Design
166	North1SS	016	015	130.5000	130.2900	No Design
167	North_1	016	015	139.5000	137.1600	No Design
168	WrtWSS3	505	504	153.4500	153.1000	No Design

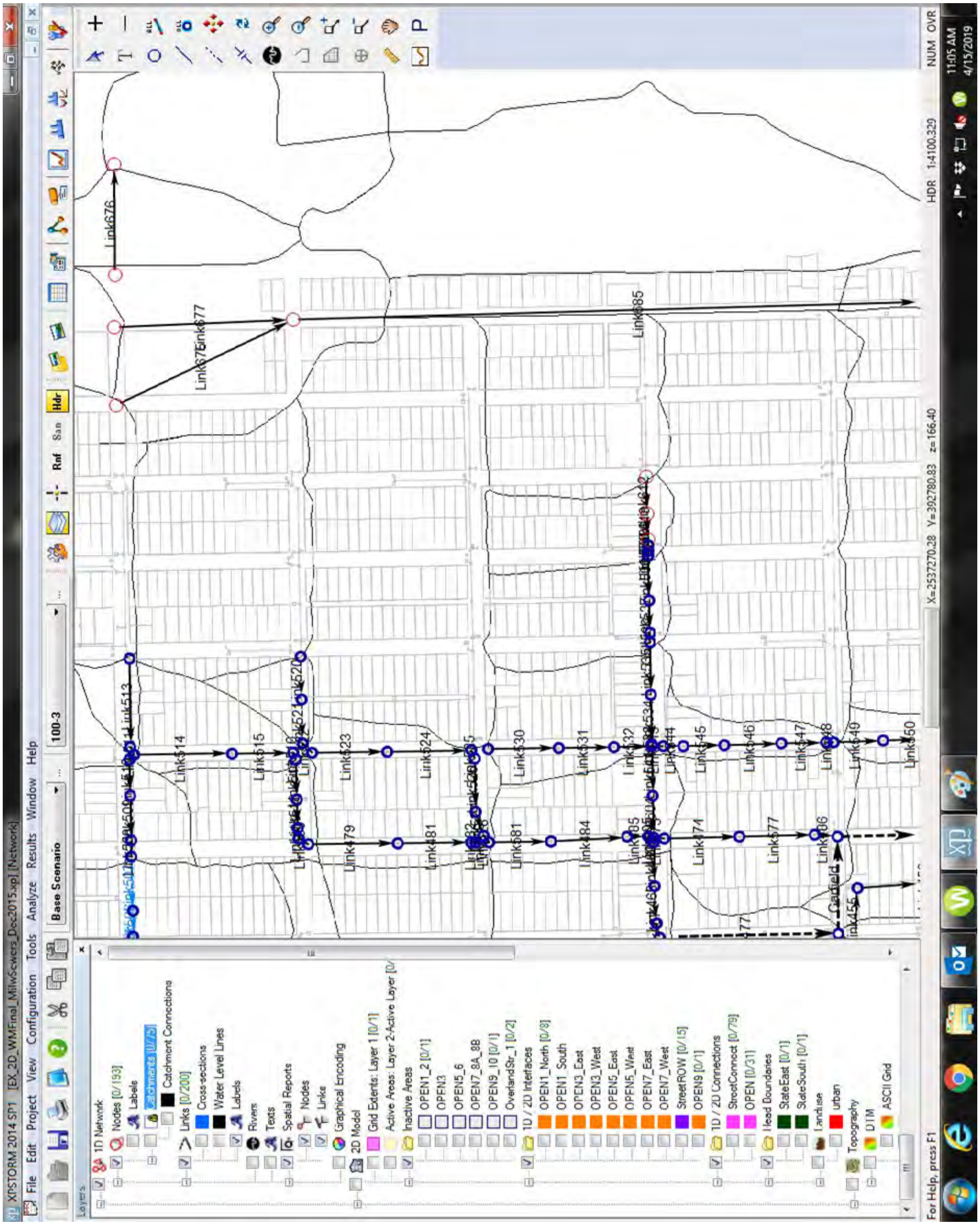
169	WrtWRd3	505	504	158.9300	158.7600	No Design
170	WrtWSS4	504	503	152.6000	152.0600	No Design
171	WrtWRd4	504	503	158.7600	158.0100	No Design
172	Wright3SS	268	267	138.6800	137.7300	No Design
173	Wright_3	268	267	146.3300	144.7800	No Design
174	70th1SS	267	266	137.4800	136.4100	No Design
175	70th_1	267	266	144.7800	143.3800	No Design
176	70th2SS	266	255	136.4100	135.2300	No Design
177	70th_2	266	255	143.3800	141.1000	No Design
178	MeineckeSS	255	254	135.2300	134.7600	No Design
179	Meinecke_1	254	255	143.2900	141.1000	No Design
180	GarfieldSS	152	151	126.6700	124.6000	No Design
181	Garfield_1	152	151	133.1700	132.1400	No Design
182	67th1SS	153	152	129.4400	126.6700	No Design
183	67th_1	153	152	138.4300	133.1700	No Design
184	Clarke1SS	247	246	147.6700	146.8700	No Design
185	Clarke_1	247	246	152.3000	151.3700	No Design
186	Clarke2SS	246	470	146.7300	146.6200	No Design
187	Clarke_2	246	470	151.3700	151.0000	No Design
188	Clarke3SS	470	245	146.6200	146.5100	No Design
189	Clarke_3	470	245	151.0000	150.8800	No Design
190	Clarke4SS	245	244	146.5100	145.5300	No Design
191	Clarke_4	245	244	150.8800	149.8500	No Design
192	Clarke5SS	291	238	149.1700	146.8800	No Design
193	Clarke_5	291	238	154.4200	153.2400	No Design
194	ClkESSA	236	291	149.6800	149.1700	No Design
195	ClkERdA	236	291	154.9000	154.4200	No Design
196	ClkESSB	491	236	153.2000	149.8700	No Design
197	ClkERdB	491	236	159.2200	154.9000	No Design
198	ClkESS1	234	491	153.7800	153.2000	No Design
199	ClkERd1	234	491	159.7300	159.2200	No Design
200	ClkESS4	229	230	160.1000	159.1100	No Design
201	ClkERd4	229	230	165.8000	165.0000	No Design
202	ClkESS5	492	229	162.9300	160.1000	No Design
203	ClkERd5	492	229	168.8400	165.8000	No Design
204	ClkESS6	227	492	168.9700	162.9300	No Design
205	ClkERd6	227	492	175.0300	168.8400	No Design
206	EWrtSS3	317	318	174.5400	173.3700	No Design
207	EWrtRd3	317	318	179.4200	178.7300	No Design
208	EWrtSS2	318	201	173.3700	172.1100	No Design
209	EWrtRd2	318	201	178.7300	176.7100	No Design
210	EWrtSS1	201	200	171.8600	170.9800	No Design
211	EWrtRd1	201	200	176.7100	175.4800	No Design
212	ClkESS3	230	493	159.1100	155.8700	No Design
213	ClkERd3	230	493	165.0000	161.6500	No Design
214	ClkESS2	493	234	155.8700	153.9900	No Design
215	ClkERd2	493	234	161.6500	159.7300	No Design

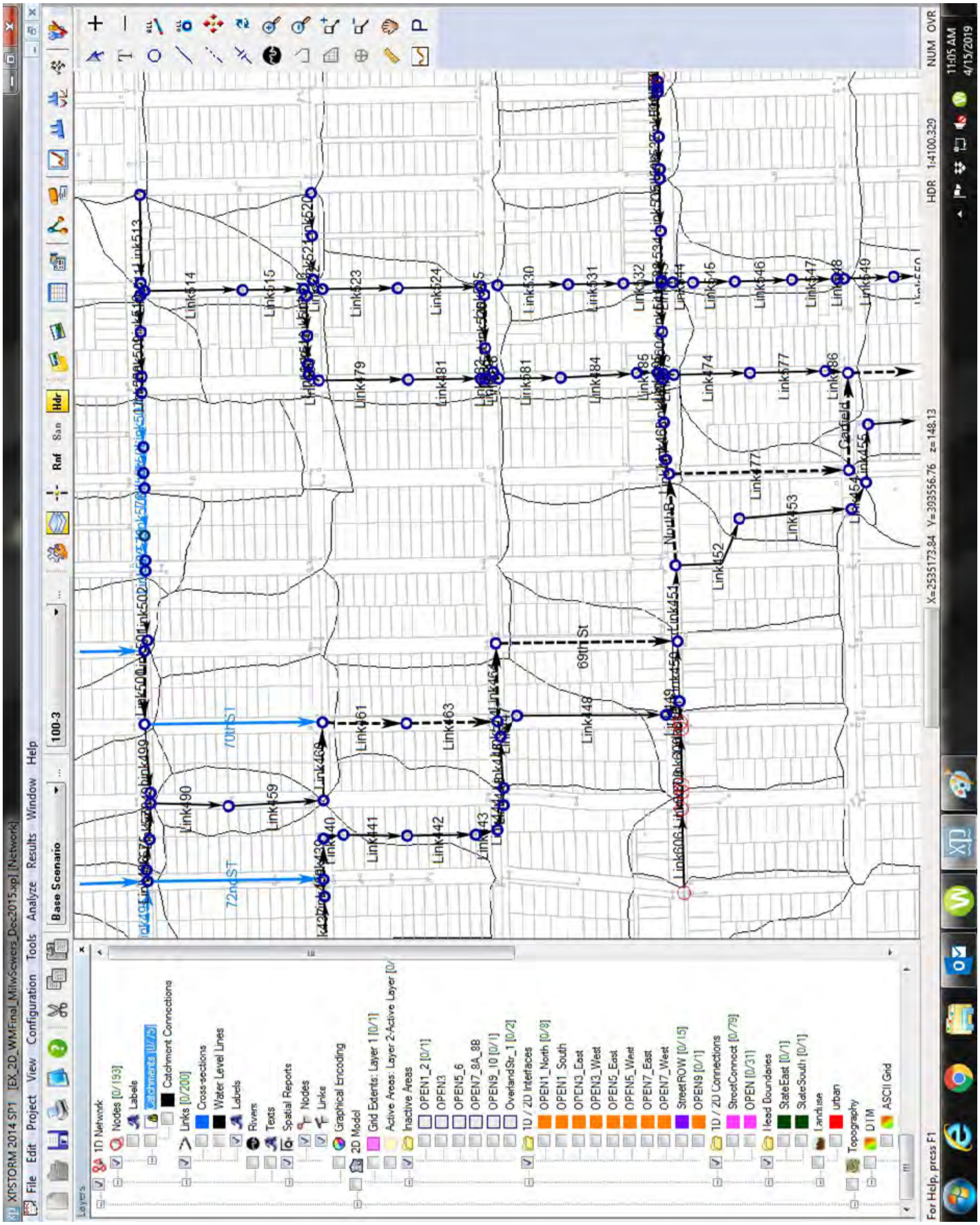
216	Revere_1	10996	10939	113.7500	113.2000	No Design
217	Revere_2	10996	10939	122.6700	122.1700	No Design
218	Wash_culv	10587	10487	109.6200	108.6100	No Design
219	Wash_Rd	10587	10487	118.1800	117.7800	No Design
220	UPPkycul	10226	10183	104.7300	104.3000	No Design
221	UPPkyRd	10226	10183	113.2500	112.7500	No Design
222	Milw_Cond	8418.5	N1	78.0000	77.2600	No Design
223	Milw_Rd	8418.5	N1	91.0000	90.0000	No Design
224	MWD2SS	Junction 1	N2	73.7500	58.4600	No Design
225	MWD_2	Junction 1	N2	84.1500	64.5500	No Design
226	Box1	N6	N7	45.2000	45.2000	No Design
227	Box2	N6	N7	45.2000	45.2000	No Design
228	MWD1SS	N1	Junction 1	77.2600	75.7500	No Design
229	MWD_1	N1	Junction 1	89.8500	84.1500	No Design
230	WMilw_1	N7	N8	45.2000	43.3200	No Design
231	WMilw_2	N7	N8	45.2000	43.3200	No Design
232	RR1	N5	N6	45.2000	45.2000	No Design
233	RR2	N5	N6	45.2000	45.2000	No Design
234	CtrSS7273	Node753	Node754	139.7500	135.0000	No Design
235	CtrRd7273	Node753	Node754	158.8100	152.5000	No Design
236	CtrSS	Node754	Node749	135.0000	133.5200	No Design
237	CtrRd	Node754	Node749	152.5000	150.6500	No Design
238	69th1SS	254	016	134.7600	132.3000	No Design
239	69th_1	254	016	143.2900	139.5000	No Design
240	NorthB_SS	015	153	131.0000	129.4400	No Design
241	North_B	153	015	138.4000	137.1600	No Design
242	66th1_SS	151	Culv1.1	124.1000	118.6000	No Design
243	66th1_Rd	151	Culv1.1	132.1400	126.3200	No Design

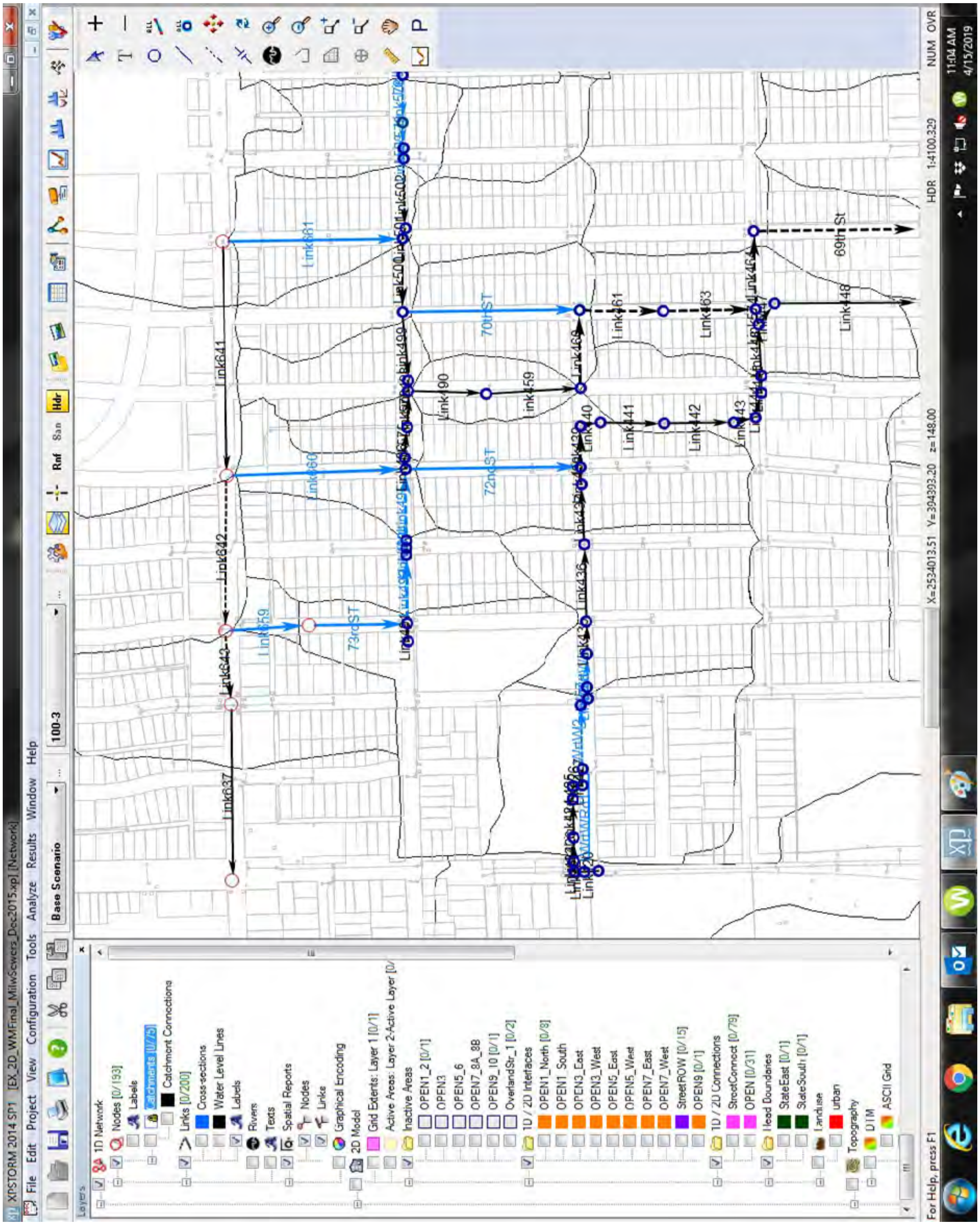

Link690
4.3x7.5box
8X4.5 BOX
8X4.5Box.1
Road
Base Scenario
100-3
For Help, press F1

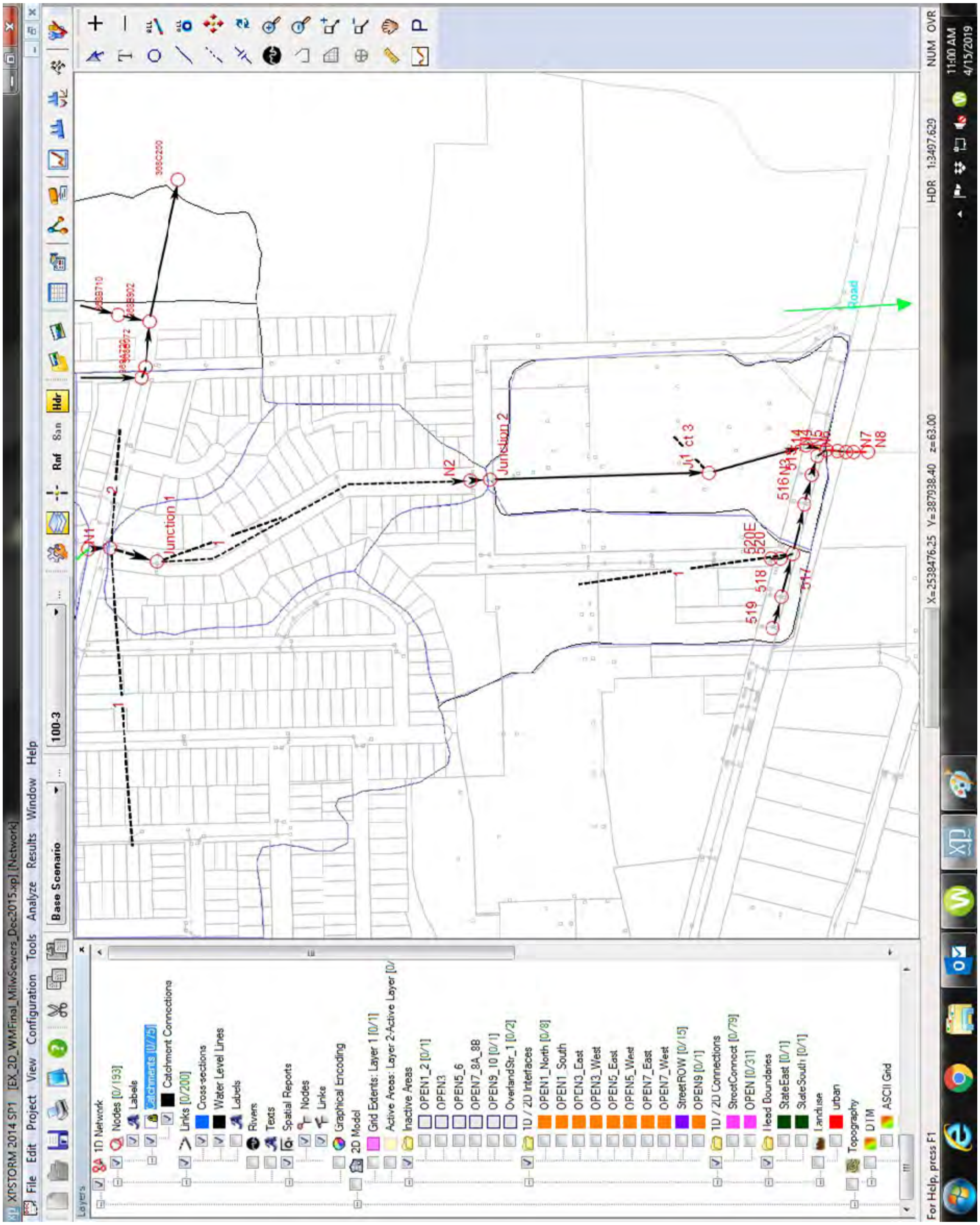



File Edit Project View Configuration Tools Analyze Results Window Help
Base Scenario
100-3
Link694
Link695
Link696
Link690
Link692
Link691
Link698
OPEN8A
OPEN8B
OPEN9
OPEN10
4.3x7.5box
8X4.5_BOX
Layers
1D Network
Nodes [0/193]
Links [0/200]
Cross-sections
Water Level Lines
Rivers
Texts
Spatial Reports
Graphical Encoding
2D Model
Inactive Areas
1D / 2D Interfaces
1D / 2D Connections
Head Boundaries
Landuse
Topography
ASCII Grid
For Help, press F1
HDR 1:4100.329
NUM OVR
11:06 AM
4/15/2019

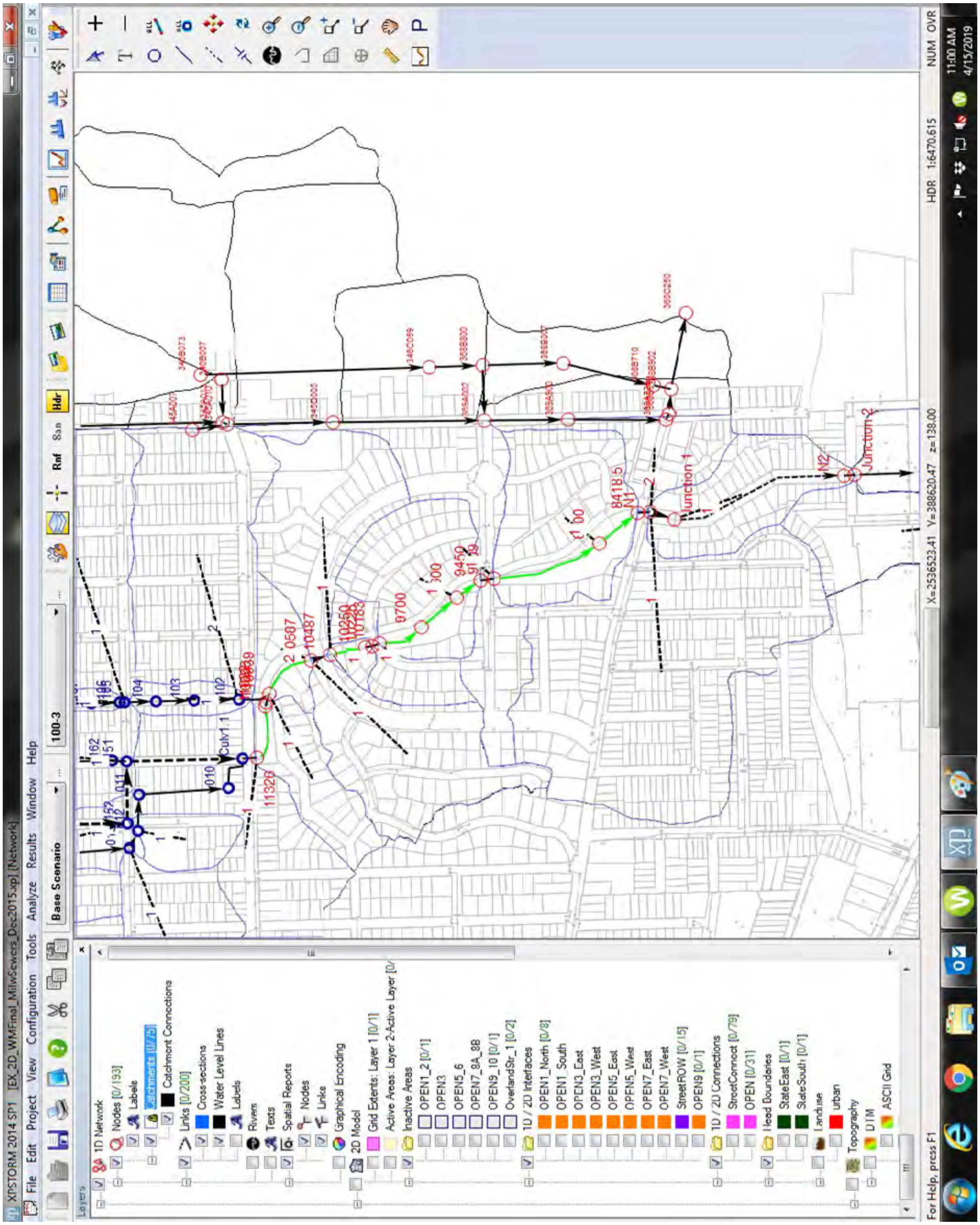

XPSTORM 2014 SP1 [EX_2D_WMFinal_MilwSewers_Dec2015.xp] [Network]
File Edit Project View Configuration Tools Analyze Results Window Help
Base Scenario
100-3
Layers
1D Network
Nodes [0/193]
Labels
Catchments
Catchment Connections
Links [0/200]
Cross-sections
Water Level Lines
Labels
Rivers
Texts
Spatial Reports
Nodes
Links
Graphical Encoding
2D Model
Inactive Areas
OPEN1_2 [0/1]
OPEN3
OPEN5_6
OPEN7_8A_8B
OPEN9_10 [0/1]
1D / 2D Interfaces
OPEN1_North [0/8]
OPEN1_South
OPEN3_East
OPEN3_West
OPEN5_East
OPEN5_West
OPEN7_East
OPEN7_West
StreetROW [0/15]
OPEN9 [0/1]
1D / 2D Connections
StreetConnect [0/79]
OPEN [0/31]
Head Boundaries
StateEast [0/1]
StateSouth [0/1]
Landuse
Urban
Topography
DTM
ASCII Grid
Link676
Link677
Link685
Link513
Link514
Link515
Link520
Link523
Link524
Link530
Link531
Link532
Link545
Link546
Link547
Link549
Link550
Link479
Link481
Link581
Link484
Link474
Link577
Garfield
X=2537270.28 Y=392780.83 z=166.40
HDR 1:4100.329
NUM OVR
For Help, press F1
11:05 AM
4/15/2019

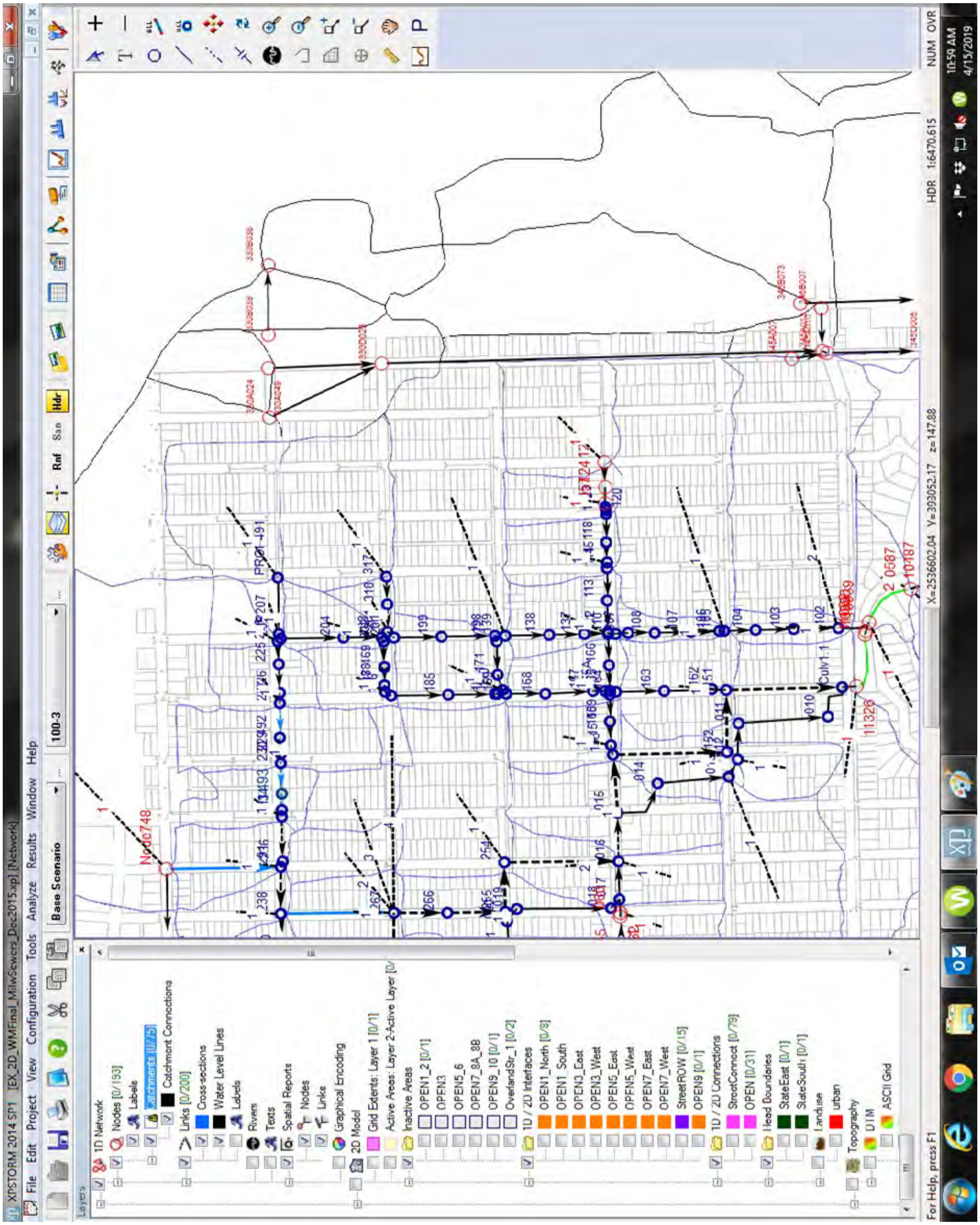


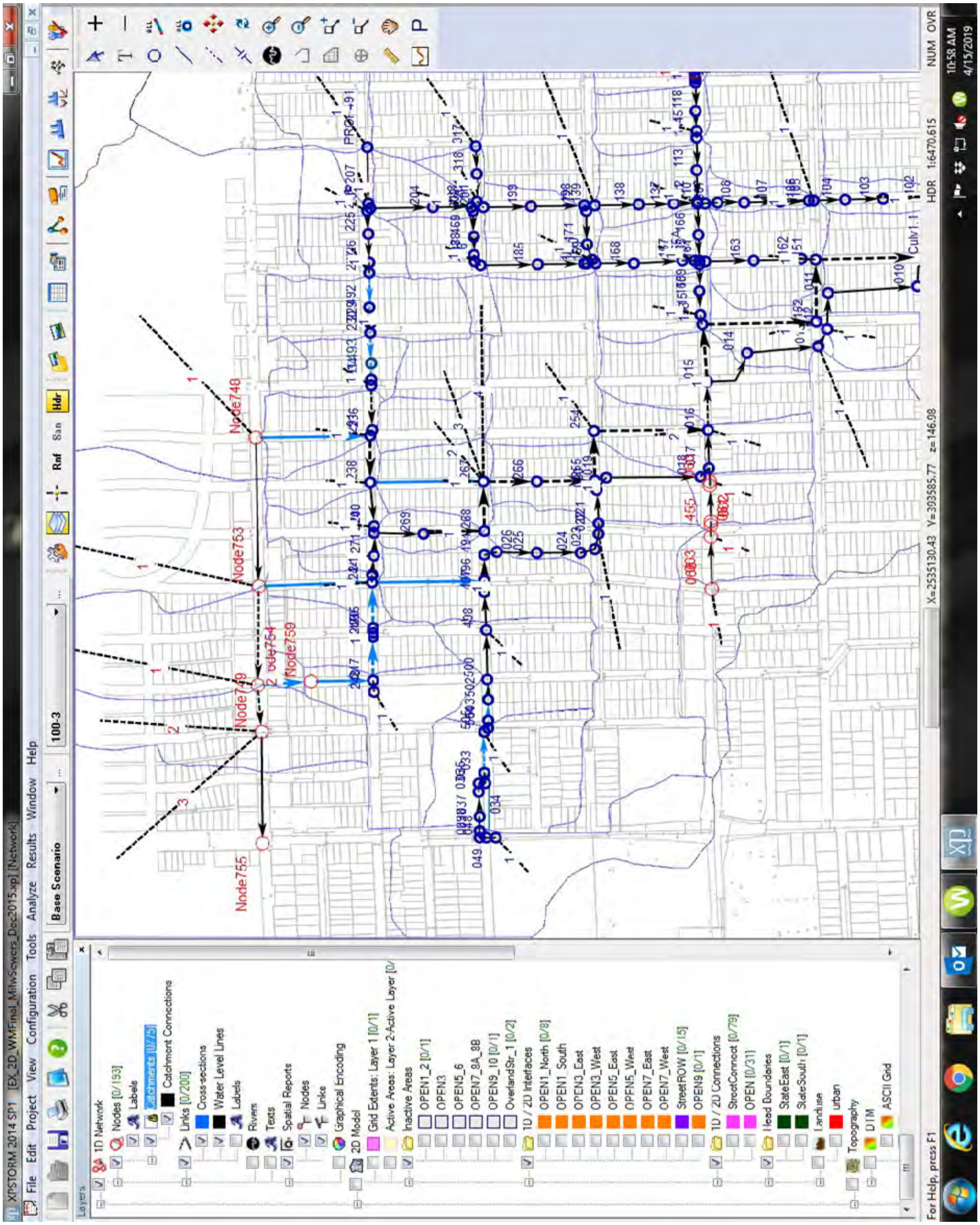

73rd ST
72nd ST
70th ST
69th St



Junction 1
Junction 2
N1
N2
Road


XPSTORM 2014 SP1 [EX_2D_WMFinal_MilwSewers_Dec2015.xp] [Network]
File Edit Project View Configuration Tools Analyze Results Window Help
Base Scenario
For Help, press F1

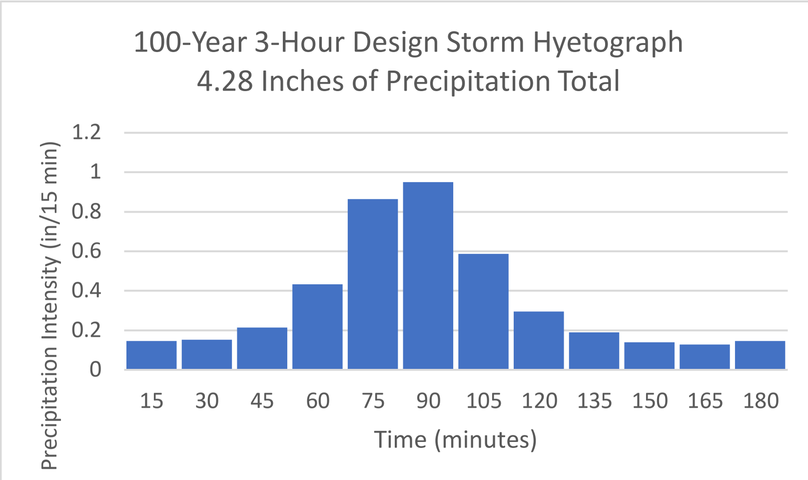


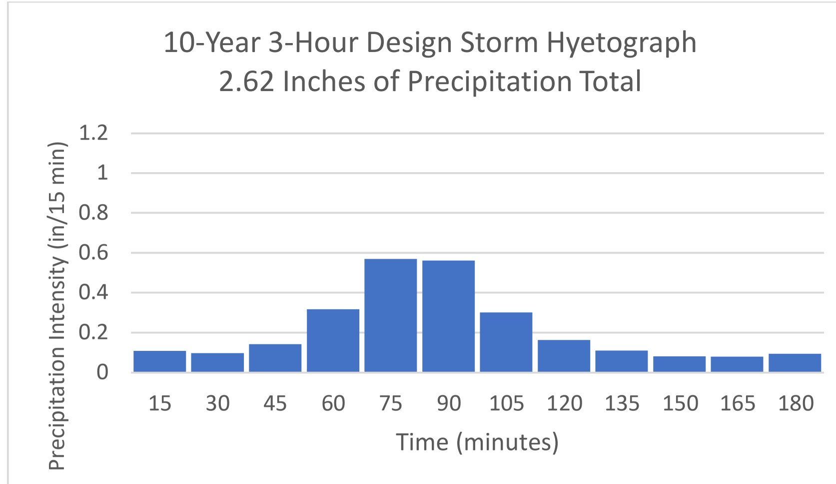

XPSTORM 2014 SP1
File Edit Project View Configuration Tools Analyze Results Window Help
Base Scenario
100-3
Layers
1D Network
Nodes [0/193]
Labels
Catchment Connections
Links [0/200]
Cross-sections
Water Level Lines
Rivers
Texts
Spatial Reports
Graphical Encoding
2D Model
Inactive Areas
1D / 2D Interfaces
1D / 2D Connections
Head Boundaries
Landuse
Urban
Topography
DTM
ASCII Grid
Node755
Node749
Node753
Node759
Node748
For Help, press F1
X=2535130.43 Y=393585.77 z=146.98
HDR 1:6470.615
NUM OVR

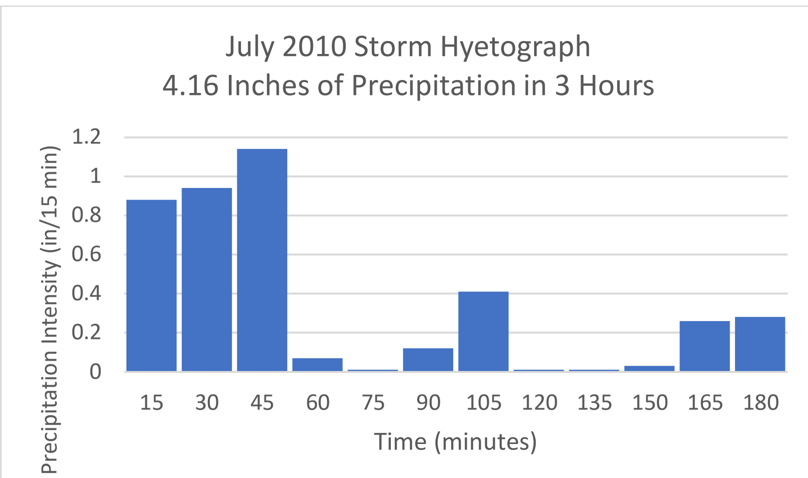
APPENDIX C

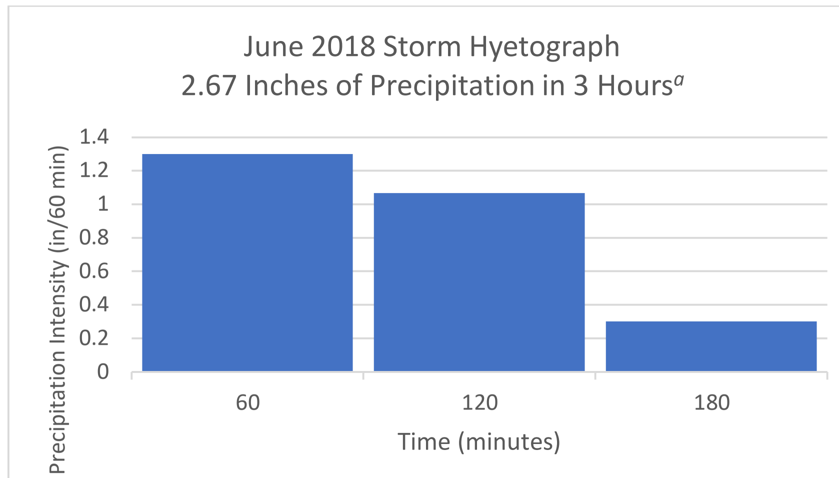
RAINFALL DEPTHS AND DURATIONS

Storm Hyetographs









[a]The axes of the June 2018 hyetograph differ from the other hyetographs shown here. The June 2018 hyetograph displays rainfall measurements in one hour increments.

NOAA Atlas 14, Volume 8,
Version 2 MILWAUKEE MT MARY COL
Station ID: 47-5474
Location name: Milwaukee, Wisconsin, USA*
Latitude: 43.0719°, Longitude: -88.0294°
Elevation:
Elevation (station metadata): 726 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

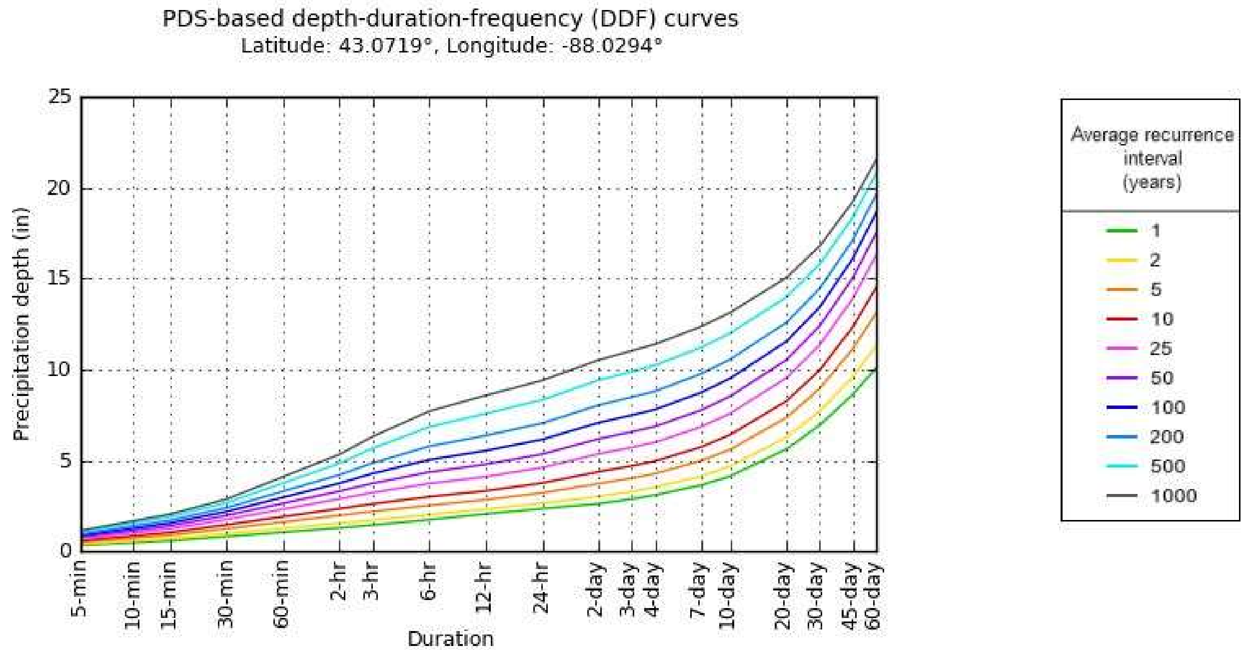
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.329 (0.256-0.412)	0.394 (0.306-0.494)	0.500 (0.387-0.627)	0.586 (0.452-0.737)	0.701 (0.526-0.893)	0.788 (0.582-1.01)	0.874 (0.630-1.14)	0.959 (0.670-1.26)	1.07 (0.726-1.43)	1.15 (0.768-1.55)
10-min	0.481 (0.374-0.603)	0.577 (0.449-0.724)	0.732 (0.567-0.919)	0.858 (0.662-1.08)	1.03 (0.770-1.31)	1.15 (0.852-1.48)	1.28 (0.922-1.66)	1.40 (0.981-1.85)	1.56 (1.06-2.09)	1.68 (1.12-2.27)
15-min	0.587 (0.456-0.735)	0.704 (0.547-0.883)	0.892 (0.692-1.12)	1.05 (0.807-1.32)	1.25 (0.939-1.60)	1.41 (1.04-1.81)	1.56 (1.12-2.03)	1.71 (1.20-2.25)	1.91 (1.30-2.55)	2.05 (1.37-2.77)
30-min	0.817 (0.635-1.02)	0.984 (0.764-1.23)	1.25 (0.969-1.57)	1.47 (1.13-1.85)	1.76 (1.32-2.24)	1.98 (1.46-2.53)	2.19 (1.58-2.84)	2.40 (1.68-3.16)	2.67 (1.82-3.57)	2.87 (1.92-3.88)
60-min	1.06 (0.822-1.32)	1.27 (0.985-1.59)	1.62 (1.25-2.03)	1.91 (1.48-2.40)	2.32 (1.75-2.98)	2.64 (1.96-3.41)	2.97 (2.15-3.88)	3.31 (2.32-4.37)	3.76 (2.56-5.04)	4.10 (2.74-5.54)
2-hr	1.30 (1.02-1.61)	1.55 (1.22-1.92)	1.98 (1.56-2.46)	2.36 (1.84-2.93)	2.89 (2.21-3.67)	3.31 (2.49-4.24)	3.75 (2.75-4.86)	4.21 (2.99-5.53)	4.84 (3.34-6.45)	5.33 (3.60-7.15)
3-hr	1.45 (1.15-1.79)	1.72 (1.37-2.12)	2.20 (1.74-2.71)	2.62 (2.06-3.23)	3.23 (2.50-4.12)	3.75 (2.84-4.78)	4.28 (3.17-5.54)	4.86 (3.48-6.37)	5.67 (3.94-7.54)	6.31 (4.28-8.42)
6-hr	1.75 (1.40-2.12)	2.02 (1.63-2.46)	2.53 (2.03-3.09)	3.01 (2.40-3.67)	3.74 (2.95-4.74)	4.36 (3.36-5.54)	5.04 (3.78-6.48)	5.78 (4.19-7.54)	6.84 (4.81-9.06)	7.71 (5.28-10.2)
12-hr	2.06 (1.68-2.48)	2.33 (1.90-2.80)	2.84 (2.31-3.42)	3.33 (2.69-4.03)	4.11 (3.29-5.17)	4.79 (3.74-6.04)	5.54 (4.21-7.08)	6.37 (4.68-8.26)	7.58 (5.39-9.96)	8.58 (5.93-11.3)
24-hr	2.35 (1.94-2.80)	2.66 (2.19-3.16)	3.22 (2.65-3.84)	3.76 (3.08-4.50)	4.61 (3.73-5.73)	5.35 (4.23-6.66)	6.15 (4.73-7.78)	7.05 (5.23-9.04)	8.34 (5.99-10.9)	9.40 (6.57-12.2)
2-day	2.63 (2.20-3.09)	3.02 (2.53-3.55)	3.73 (3.11-4.39)	4.38 (3.64-5.17)	5.37 (4.38-6.56)	6.19 (4.94-7.61)	7.08 (5.49-8.83)	8.05 (6.03-10.2)	9.41 (6.82-12.1)	10.5 (7.43-13.6)
3-day	2.88 (2.43-3.36)	3.29 (2.78-3.84)	4.03 (3.39-4.71)	4.71 (3.94-5.52)	5.72 (4.70-6.94)	6.58 (5.28-8.02)	7.49 (5.85-9.28)	8.48 (6.40-10.7)	9.89 (7.21-12.7)	11.0 (7.83-14.2)
4-day	3.10 (2.63-3.60)	3.53 (2.99-4.10)	4.28 (3.62-4.98)	4.97 (4.18-5.80)	6.00 (4.96-7.25)	6.87 (5.55-8.34)	7.80 (6.12-9.62)	8.81 (6.67-11.0)	10.2 (7.50-13.1)	11.4 (8.12-14.6)
7-day	3.64 (3.13-4.19)	4.13 (3.54-4.75)	4.98 (4.26-5.74)	5.74 (4.88-6.63)	6.85 (5.70-8.16)	7.76 (6.32-9.31)	8.73 (6.90-10.6)	9.76 (7.45-12.1)	11.2 (8.26-14.2)	12.4 (8.88-15.7)
10-day	4.13 (3.57-4.72)	4.68 (4.04-5.34)	5.60 (4.83-6.42)	6.41 (5.49-7.36)	7.58 (6.34-8.95)	8.53 (6.98-10.1)	9.51 (7.56-11.5)	10.6 (8.09-13.0)	12.0 (8.88-15.1)	13.1 (9.48-16.6)
20-day	5.63 (4.94-6.36)	6.28 (5.51-7.10)	7.36 (6.43-8.33)	8.27 (7.19-9.39)	9.55 (8.06-11.1)	10.5 (8.73-12.4)	11.6 (9.28-13.8)	12.6 (9.74-15.3)	14.0 (10.5-17.4)	15.1 (11.0-18.9)
30-day	6.94 (6.14-7.77)	7.71 (6.81-8.64)	8.95 (7.89-10.1)	9.97 (8.74-11.2)	11.3 (9.64-13.0)	12.4 (10.3-14.4)	13.4 (10.8-15.9)	14.5 (11.2-17.4)	15.8 (11.9-19.4)	16.8 (12.3-21.0)
45-day	8.63 (7.70-9.60)	9.60 (8.56-10.7)	11.1 (9.89-12.4)	12.3 (10.9-13.8)	13.9 (11.9-15.8)	15.0 (12.6-17.3)	16.1 (13.1-18.8)	17.1 (13.4-20.4)	18.4 (13.8-22.4)	19.2 (14.2-23.9)
60-day	10.1 (9.06-11.2)	11.3 (10.1-12.5)	13.1 (11.7-14.5)	14.5 (12.9-16.2)	16.3 (13.9-18.3)	17.5 (14.7-20.0)	18.6 (15.2-21.6)	19.6 (15.4-23.3)	20.8 (15.7-25.2)	21.5 (16.0-26.6)

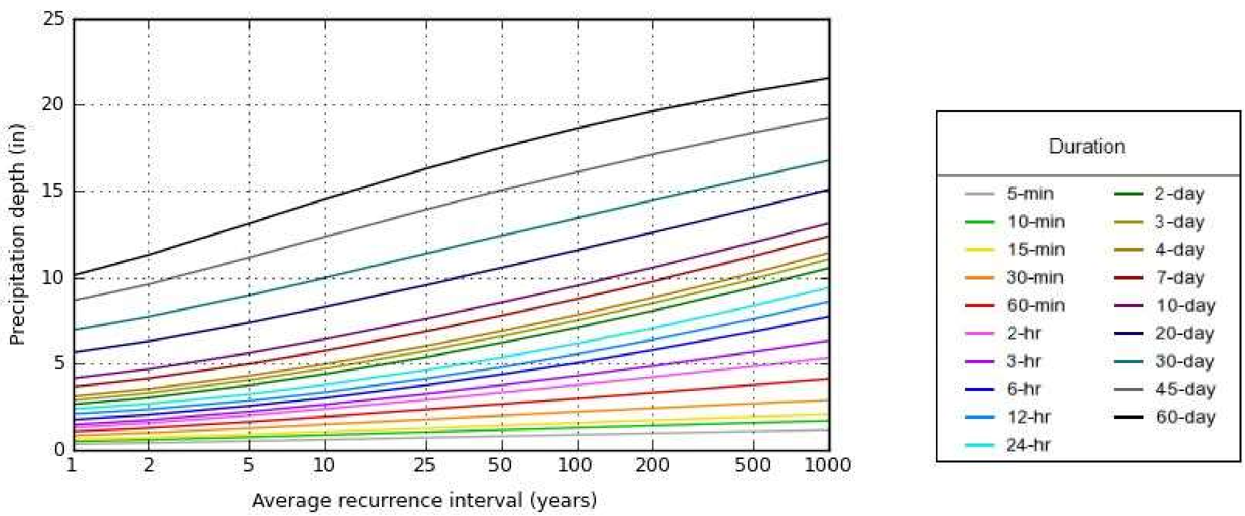
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

PF graphical





ALTERNATIVES 4 AND 5 SEWER SCHEDULES

APPENDIX D

ALTERNATIVE 4 - 25-YEAR SEWER			#223398		
SEWER IMPROVEMENTS - 65TH STREET SEWER					
STREET	BLOCK	EXISTING PIPE DIAMETER (FT)	PROPOSED REPLACEMENT SIZE (FT)	PROPOSED LENGTH (FT)	COMMENTS
N. 65th Street	Clarke to Wright	2	2.5	366	
N. 65th Street	Clarke to Wright	2	3	292	
N. 65th Street	Wright to Meinecke	2	3	651	
N. 65th Street	Meinecke to North	2	3	471	
N. 65th Street	Meinecke to North	2.5	3	143	
N. 65th Street	North to Garfield	3	5	642	
N. 65th Street	Garfield to Lloyd	3	5.5	674	
N. 65th Street	Lloyd to Channel	3	6	170	
SEWER IMPROVEMENTS - NORTHWEST SEWER					
W. Clarke Street	69th to 70th	2.5	5	251	
W. Clarke Street	70th to 71Street	3	5	280	
W. Clarke Street	70th to 71Street	3	5	38	
W. Clarke Street	72nd to 71Street	2.5	4	198	
W. Clarke Street	72nd to 71Street	2.5	4.5	136	
N. 71st Street	Clarke to Wright	3.5	5	607	
W. Wright Street	70th to 71st	4	5.5	265	
W. Wright Street	72nd to 71st	3.5	4.5	283	New connection of 125-ft
N. 70th Street	Wright to Meinecke	4.5	5.5	347	
N. 70th Street	Wright to Meinecke	4.5	6	339	
W. Meinecke Avenue	At 70th	3	4	64	New cross connection to existing line
W. Meinecke Avenue	70th to 69th	5	6	286	
N. 69th Street	Meinecke to North	5	6	688	
W. North Avenue	69th to 68th	5	5.5	263	Replace existing pipe
W. North Avenue	69th to 68th	--	7	263	New parallel pipe
W. North Avenue	68th to 67th	4	7	340	
N. 67th Street	North to Garfield	4.5	7	662	
W. Garfield Avenue	67th to 66th	4.5	7	390	
N. 66th Street	Garfield to channel	5	7	773	
BRIDGE IMPROVEMENTS					
STREET		EXISTING BRIDGE SIZE (FT)	PROPOSED ADDITIONAL BRIDGE SIZE (FT)	PROPOSED LENGTH (FT)	COMMENTS
Revere Avenue		5.5'x9' RCB	5'x7' RCB	57	
Washington Circle		5.5'x9' RCB	5'x7' RCB	102	
Upper Parkway		5.5'x9' RCB	5'x7' RCB	43	
ENCLOSURE IMPROVEMENT					
STREET	BLOCK	EXISTING PIPE DIAMETER (FT)	PROPOSED ADDITIONAL PIPE SIZE (FT)	PROPOSED LENGTH (FT)	COMMENTS
Martha Washington Drive	Milw Avenue to Martin Dr	4.33'x7.5' RCB	5'x7' RCB	1354	
W. Martin Drive	Martha Wash to 60th	--	2-5'X6' RCB	770	
N. 60th Street	Martin to Menom R.	--	2-5'X6' RCB	2500	

ALTERNATIVE 5 - 100-YEAR SEWER			#223398		
SEWER IMPROVEMENTS - 65TH STREET SEWER					
STREET	BLOCK	EXISTING PIPE DIAMETER (FT)	PROPOSED REPLACEMENT SIZE (FT)	PROPOSED LENGTH (FT)	COMMENTS
W. Clarke Street	64th to 65th	2	3	364	
N. 65th Street	Clarke to Wright	2	3	658	
N. 65th Street	Wright to Meinecke	2	3	282	
N. 65th Street	Wright to Meinecke	2	4	369	
N. 65th Street	Meinecke to North	2	4	471	
N. 65th Street	Meinecke to North	2.5	4	143	
N. 65th Street	North to Garfield	3	5	642	
N. 65th Street	Garfield to Lloyd	3	5	674	
N. 65th Street	Lloyd to Channel	3	5	170	
W. Wright Street	64th to 65th	2	2	376	Additional pipe
W. North Ave	62nd to 63rd	1.75	2	300	Additional pipe
W. North Ave	63rd to 64th	2	2	325	Additional pipe
W. North Ave	64th to 65th	3	2	390	Additional pipe
SEWER IMPROVEMENTS - NORTHWEST SEWER					
W. Clarke Street	73rd to Lefeber	2	3	236	Additional pipe
W. Clarke Street	Lefeber to 72nd	2.25	3	288	Additional pipe
W. Clarke Street	68th to 69th	2.25	4	260	
W. Clarke Street	68th to 69th	2.5	4	39	
W. Clarke Street	69th to 70th	2.5	5	251	
W. Clarke Street	70th to 71st	3	5	280	
W. Clarke Street	70th to 71st	3	6	38	
W. Clarke Street	72nd to 71st	2.5	4	334	
N. 71st Street	Clarke to Wright	3.5	6	607	
W. Wright Street	74th to 72nd	3	4	634	
W. Wright Street	72nd to 71st	3.5	5	158	
W. Wright Street	72nd to 71st	--	5	125	New connection
W. Wright Street	70th to 71st	4	7	265	
N. 70th Street	Wright to Meinecke	4.5	7	347	
N. 70th Street	Wright to Meinecke	4.5	8	339	
W. Meinecke Avenue	At 70th	3	4	64	New cross connection to existing line
W. Meinecke Avenue	70th to 69th	5	8	286	
N. 69th Street	Meinecke to North	5	8	688	
W. North Avenue	69th to 68th	--	8	263	New parallel pipe
W. North Avenue	68th to 67th	4	8	340	
N. 67th Street	North to Garfield	4.5	8	662	
W. Garfield Avenue	67th to 66th	4.5	8	390	
N. 66th Street	Garfield to channel	5	8	773	
BRIDGE IMPROVEMENTS					
STREET		EXISTING BRIDGE SIZE (FT)	PROPOSED ADDITIONAL BRIDGE SIZE (FT)	PROPOSED LENGTH (FT)	COMMENTS
Revere Ave		5.5'x9' RCB	5'x5' RCB	57	
Washington Circle		5.5'x9' RCB	5'x6' RCB	102	
Upper Parkway		5.5'x9' RCB	5'x6' RCB	43	
ENCLOSURE IMPROVEMENT					
STREET	BLOCK	EXISTING PIPE DIAMETER (FT)	PROPOSED ADDITIONAL PIPE SIZE (FT)	PROPOSED LENGTH (FT)	COMMENTS
Martha Washington Drive	Milw Ave to Martin Dr	4.33'x7.5' RCB	6'x6' RCB	220	
Martha Washington Drive	Milw Ave to Martin Dr	4.33'x7.5' RCB	6'x9' RCB	1134	
W. Martin Drive	Martha Wash to 60th	--	2-6'X7' RCB	770	
N. 60th St	Martin to Menom R.	--	2-6'X7' RCB	2780	

APPENDIX E

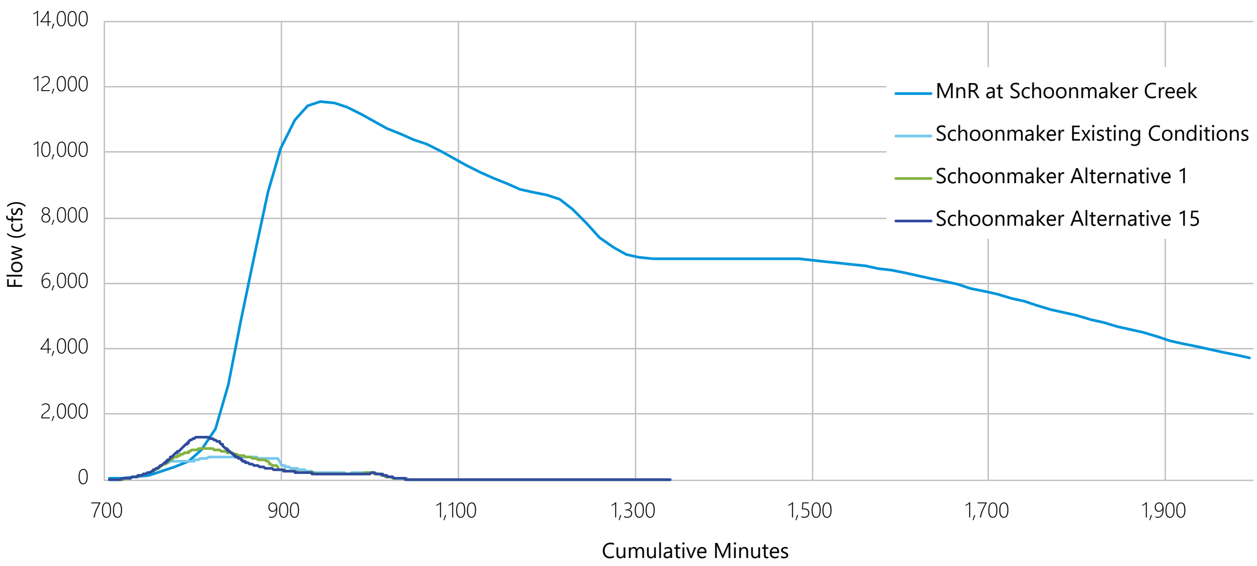
SCHOONMAKER CREEK IMPACT ON THE MENOMONEE RIVER

A comparison was made of the timing of peak flows from Schoonmaker Creek relative to peak flows on the Menomonee River at the confluence of the two streams. Two scenarios were done, one for a design storm and a second using a historical event. The design storm comparison was completed using the one-percent-annual-probability storm with a six hour duration, utilizing NOAA Atlas 14 rainfall and the SEWRPC rainfall distribution. The six hour duration storm was selected as it approximately represents the watershed response time for the Menomonee River. The design storm flow hydrograph for the Menomonee River was determined using the Hydrologic Simulation Program – Fortran (HSPF) from the SEWRPC Milwaukee County Automated Mapping and Land Information System (MCAMLIS) model completed in 2012. The design storm flow hydrographs for Schoonmaker Creek were determined using the updated existing conditions XPStorm model. A comparison of the modeled hydrographs is on the next page. For the design storm event, Schoonmaker Creek peaks between 1.8 hours (existing conditions) and 2.2 hours (Alternatives 1 and 15) earlier than the Menomonee River (peaks at 4.0 hours). The Schoonmaker Creek flow contribution at the time of the peak flow on the Menomonee River is less than 2 percent for existing conditions as well as the two alternatives.

The second scenario reviewed for timing of peak flows between Schoonmaker Creek and the Menomonee River was for the June 2008 event. The actual observed flow data from the USGS gage at N. 70th Street (04087120) was used for the Menomonee River. This was compared to the June 2008 updated existing conditions XPStorm model run for Schoonmaker Creek. The comparison of gaged to modeled hydrographs can be found on the final page of this appendix. For the June 2008 storm event, Schoonmaker Creek peaks approximately 2.5 hours earlier than the first and highest peak on the Menomonee River (peak at 3.6 hours). For the second river peak flow of the June 2008 storm event, Schoonmaker Creek peaks approximately 1.6 hours earlier than the second peak on the Menomonee River (peak at 8.3 hours). The Schoonmaker Creek flow contribution at the time of the June 2008 peak flow on the Menomonee River is less than 1 percent for each of the peaks described above.

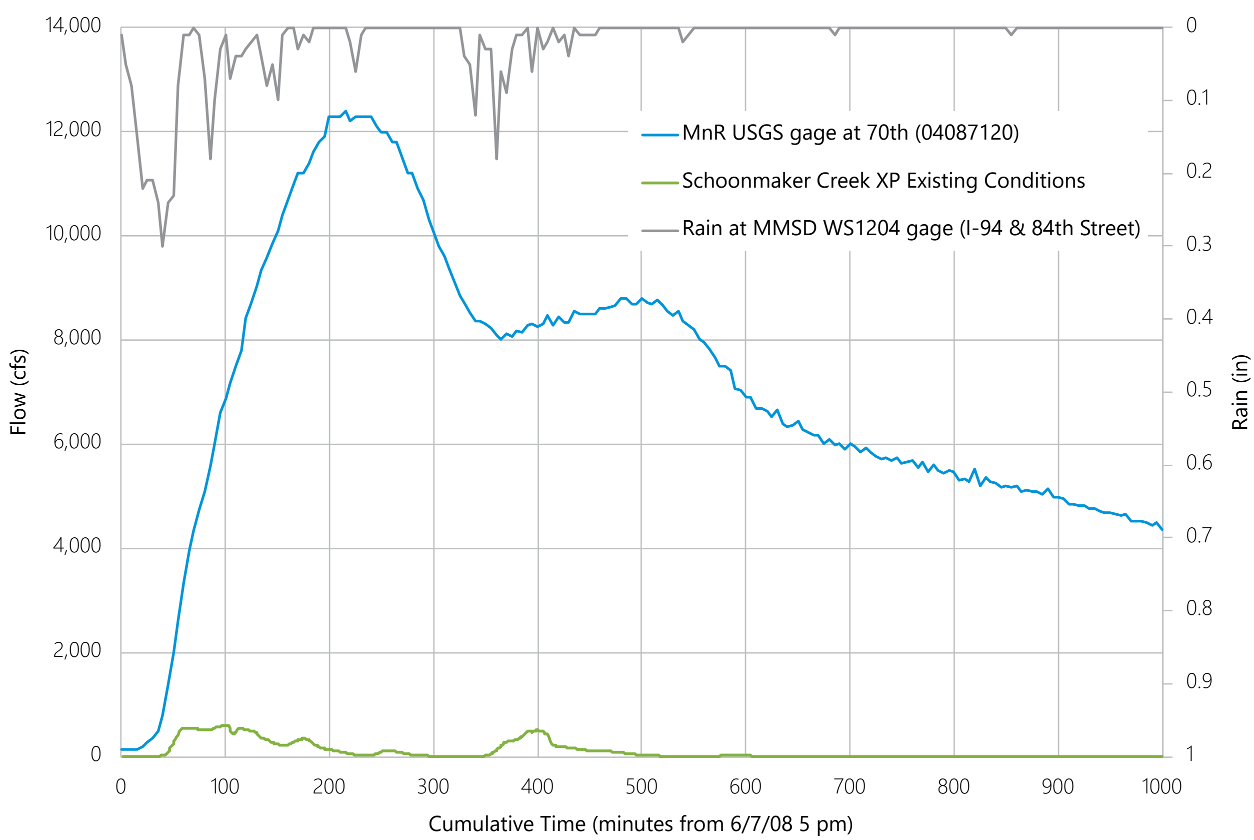
Based on the two scenarios discussed above, Schoonmaker Creek under both existing conditions and the proposed Alternatives 1 and 15 will produce peak flows to the Menomonee River ahead of the peak flow on the river. The Schoonmaker Creek flow contribution at the time of the Menomonee River peak flow will be very small as well (review indicates less than 2 percent).

Figure E.1
Hydrograph Comparison – 100-Year 6-Hour Storm



Source: SEWRPC

Figure E.2
Menomonee River and Schoonmaker Creek Flow Comparison - June 2008 Event



Source: SEWRPC

PLANNING LEVEL COST ESTIMATE DETAILS

APPENDIX F

Schoonmaker Creek Cost Alternatives - Summary

		2014 CCI	12767					
		2019 CCI	14743.85		1.1548	multiplier (compared to 2014)		
Alternative No.		Description	Total 2014 Construction cost without home acquisition costs	Total 2019 Construction cost (with 2019 home acquisition costs)	Total 2019 Construction Cost (with 35% contingency)	Average Annual Cost		
1		Relief Pipe at Enclosure	$3,607,561	$4,166,158	$5,624,313	$356,831		
2		Relief Pipe at Enclosure with Storage	$4,301,947	$4,968,063	$6,706,885	$425,514		
3		Inline Storage	$3,414,375	$4,365,459	$5,893,370	$373,901		
4		25-yr sewer	$12,717,077	$16,871,359	$22,776,335	$1,445,028		
5		100-yr Sewer	$17,392,312	$22,270,510	$30,065,189	$1,907,464		
6		100-yr Sewer Extended to 74th St	$18,167,485	$23,165,712	$31,273,711	$1,984,138		
7		Milwaukee East Sewer - Additional Pipe	$2,032,467	$2,347,176	$3,168,687	$201,035		
8		Milwaukee East Sewer - Upsize	$3,707,372	$4,281,423	$5,779,922	$366,703		
9		Open Channel	$11,086,668	$51,285,523	$69,235,456	$4,392,594		
10		North Storage	$5,147,491	$20,896,907	$28,210,824	$1,789,816		
11		South Storage	$4,143,105	$15,085,151	$20,364,954	$1,292,040		
12		North & South Storage	$5,555,647	$31,668,786	$42,752,862	$2,712,425		
13		25-yr Sewer & Bypass Tunnel	$22,589,259	$26,086,994	$35,217,442	$2,234,345		
14		100-yr Sewer & Bypass Tunnel	$25,010,391	$28,883,015	$38,992,070	$2,473,824		
15		100-yr Sewer Extended to 74th & Bypass Tunnel	$25,910,476	$29,922,469	$40,395,334	$2,562,853		
16		100-yr Sewer Plus Open Channel Bypass	$18,782,528	$21,690,826	$29,282,614	$1,857,815		
					Assumed project life:	50	years	
					Assumed interest rate:	0.06		
	Does not include costs for changes in sanitary sewers, water mains, and other utilities							
	Does not include costs for annual operation & maintenance							
	Land acquisition costs are only included for Alternatives 9 & 10, 11, 12							
	No land acquisition or easement costs outside of the public ROW were included for the other alternatives.							
	Assumed no contaminated soils							

Schoonmaker Creek Cost Alternatives

Averages for cost estimates (2014 dollars):

Item	Avg. Cost (2014)	Unit
5' x 6' RCB	$593.44	per LF
5' x 7' RCB	$698.85	per LF
5' x 10' RCB	$1,030.21	per LF
4' x 6' RCB	$571.51	per LF
3' x 5' RCB	$516.04	per LF
6' x 10' RCB	$1,280.74	per LF
5' x 5' RCB	$546.52	per LF
6' x 6' RCB	$769.91	per LF
6' x 7' RCB	$995.35	per LF
6' x 9' RCB	$1,111.15	per LF
8' x 10' RCB	$1,307.32	per LF
1' diameter pipe	$45.86	per LF
1.25' DIAMETER PIPE	$46.38	per LF
1.5' DIAMETER PIPE	$54.69	per LF
1.75' diameter pipe	$62.40	per LF
2' diameter pipe	$71.48	per LF
2.5' RCP	$101.01	per LF
3' diameter pipe	$117.57	per LF
3.5' diameter pipe	$155.25	per LF
4' diameter pipe	$180.95	per LF
4.5' RCP	$213.72	per LF
5' diameter pipe	$283.83	per LF
5.5' RCP	$298.04	per LF
6' diameter pipe	$406.70	per LF
7' diameter pipe	$501.06	per LF
8' diameter pipe	$699.04	per LF
8.5' RCP	$804.64	per LF
9' RCP	$910.24	per LF
Pipe Removal	$14.44	per LF
Pipe Installation	$50.43	per LF

Item	Avg. Cost (2014)	Unit
Clearing and Grubbing	$4,235.48	per acre
Topsoil Stripping	$4.26	per CY
Topsoil	$3.13	per SY
Seeding	$0.72	per SY
Excavation	$12.63	per CY
Hauling earth	$7.57	per CY
Grading	$5.43	per SY
Pavement Removal	$6.76	per SY
Pavement Installation	$57.05	per SY
Pavement Hauling	$7.57	per CY (assume same as earth)
Gravel Fill	$32.94	per CY
Tunnel boring machine mobilization	8.50%	not to exceed of total bid
Tunnel Access Shaft Construction	$18,294.12	per vertical LF
Tunnel Excavation and Lining	$2,971.05	per LF
Manholes	$6,159.33	EACH
DEWATERING - 12" PVC	$39.07	per LF
DEWATERING - PUMPING	$3,706.21	per DAY (24 hr)
Tree removal	$382.39	EACH
Common Fill (Embankment)	$5.29	LCY
Select Fill (Clay core)	$8.00	LCY
Embankment Compaction	$0.55	ECY
Riprap (Emergency Spillway)	$107.42	CY
Geotextile (Emergency Spillway)	$3.35	SY
Retaining Wall (8" large)	$18.88	SF
Retaining Wall (4" small)	$20.06	SF

RELIEF PIPE AT ENCLOSURE				
Alternative 1:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for pipes	17,364	CY	$12.63	$219,266
Pavement Removal	4,736	SY	$6.76	$32,015
Hauling removed pavement	1,692	CY	$7.57	$12,813
Hauling excess excavation	16,735	CY	$7.57	$126,720
Pipe Installation	3,083	LF	$50.43	$155,483
5' x 6' RCB	1,310	LF	$593.44	$777,412
5' x 10' RCB	1,773	LF	$1,030.21	$1,826,570
Manholes	6	EACH	$6,159.33	$36,956
Gravel Fill	4,559	CY	$32.94	$150,162
Pavement replacement	4,736	SY	$57.05	$270,163
			Total:	**$3,607,561**
RELIEF PIPE AT ENCLOSURE WITH DETENTION				
Alternative 2:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for pipes	16385	CY	$12.63	$206,902
Pavement Removal	4469	SY	$6.76	$30,210
Hauling removed pavement	1597	CY	$7.57	$12,091
Hauling excess excavation	75132	CY	$7.57	$568,899
Clear & Grub	3.3	AC	$4,235.48	$14,019
Pipe Installation	3450	LF	$50.43	$173,992
5' x 6' RCB	2530	LF	$593.44	$1,501,414
5' x 10' RCB	560	LF	$1,030.21	$576,920
3' diameter pipe	360	LF	$117.57	$42,326
Manholes	7	EACH	$6,159.33	$43,115
Gravel Fill	4649	CY	$32.94	$153,134
Pavement replacement	4469	SY	$57.05	$254,930
Topsoil stripping	2670	CY	$4.26	$11,372
Excavation of pond	47472	CY	$12.63	$599,464
Grading pond	16020	SY	$5.43	$87,049
Topsoil replacement (grading)	2670	CY	$5.43	$14,508
Seeding pond	16020	SY	$0.72	$11,602
				$4,301,947
INLINE STORAGE ALTERNATIVE				
Alternative 3:	Amount	Unit	Unit Cost	Total Cost
Topsoil stripping	2,339	CY	$4.26	$9,964
Excavation	17,827	CY	$12.63	$225,117
Hauling excavated material	22,284	CY	$7.57	$168,735
Clear & Grub	1.6	AC	$4,235.48	$6,777
Grading	14,036	SY	$5.43	$76,266
Seeding	16,712	SY	$0.72	$12,102
Pavement removal	3,631	SY	$6.76	$24,548
Hauling removed pavement	1,116	CY	$7.57	$8,452
Pavement replacement	160	SY	$57.05	$9,128
Retaining walls - large	10,005	SF	$18.88	$188,934
Retaining walls - small	495	SF	$20.06	$9,930
Tree removal	80	EACH	$382.39	$30,591
5' x 10' RCB	118	ft	$1,030.21	$121,565
Common Fill	7,000	LCY	$5.29	$37,024
Clay Core Fill	1,770	LCY	$8.00	$14,160
Compaction	7,893	ECY	$0.55	$4,365
Riprap (emergency spillway)	738	CY	$32.94	$24,308
Geotextile (emergency spillway)	1,108	SY	$12.63	$13,991
Land Purchase - impoundment and dam	3.28	AC	$740,645	$2,428,418
Home Acquisition (2014)	1	home	NA	$386,000
Home Acquisition (2019)	1	home	NA	$422,400
	Total (without home acquisition cost):			**$3,414,375**
	Total (with 2014 home acquisition cost):			**$3,800,376**

RAS 10-YEAR SEWER - 25 YR SEWER				
Alternative 4:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for sewers	42,155	CY	$12.63	$532,324
Excavation/trenching for enclosure	19,973	CY	$12.63	$252,210
Pavement Removal	16,932	SY	$6.76	$114,468
Hauling removed pavement	6,050	CY	$7.57	$45,813
Hauling excess excavation	59,892	CY	$7.57	$453,502
Pipe Removal	9,374	LF	$14.44	$135,393
Pipe Installation	15,593	LF	$50.43	$786,378
5' x 7' RCB (3 bridges)	202	LF	$698.85	$141,168
Dewatering - 12" PVC	600	LF	$39.07	$23,445
Dewatering - pumping (16 reaches)	240	DAYS	$3,706.21	$889,490
5' x 7' RCB (enclosure)	1,354	LF	$698.85	$946,522
5' x 6' RCB (enclosure)	3,270	LF	$593.44	$1,940,562
Manholes	44	EACH	$6,159.33	$271,011
2.5' RCP	366	LF	$101.01	$36,969
3' RCP	1557	LF	$117.57	$183,037
4' RCP	262	LF	$180.95	$47,426
4.5' RCP	419	LF	$213.72	$89,571
5' RCP	1818	LF	$283.83	$516,092
5.5' RCP	1549	LF	$298.04	$461,581
6' RCP	1483	LF	$406.70	$603,170
7' RCP	2428	LF	$501.06	$1,216,678
Gravel Fill	20,445	CY	$32.94	$673,395
Pavement replacement	16,932	SY	$57.05	$965,951
Existing Open Channel Improvement				$1,390,921.42
			Total:	**$12,717,077**
100-YEAR SEWER				
Alternative 5:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for sewers	55,534	CY	$12.63	$701,261
Excavation/trenching for enclosure	24,434	CY	$12.63	$308,542
Pavement Removal	20,836	SY	$6.76	$140,860
Hauling removed pavement	7,445	CY	$7.57	$56,375
Hauling excess excavation	78,095	CY	$7.57	$591,332
Pipe Removal	10,408	LF	$14.44	$150,319
Pipe Installation	17,937	LF	$50.43	$904,627
Manholes	53	EACH	$6,159.33	$326,445
5' x 5' RCB (1 bridge)	57	LF	$546.52	$31,152
5' x 6' RCB (2 bridges)	145	LF	$593.44	$86,049
6' x 6' RCB (enclosure)	220	LF	$769.91	$169,380
6' x 7' RCB (enclosure)	3,550	LF	$995.35	$3,533,506
6' x 9' RCB (enclosure)	1134	LF	$1,111.15	$1,260,040
2' RCP	1391	LF	$71.48	$99,439
3' RCP	1829	LF	$117.57	$214,993
4' RCP	2314	LF	$180.95	$418,671
5' RCP	2300	LF	$283.83	$652,900
6' RCP	645	LF	$406.70	$262,278
7' RCP	611	LF	$501.06	$306,299
8' RCP	3741	LF	$699.04	$2,615,329
Dewatering - 12" PVC	600	LF	$39.07	$23,445
Dewatering - pumping (19 reaches)	285	DAYS	$3,706.21	$1,056,269
Gravel Fill	27,422	CY	$32.94	$903,222
Pavement replacement	20,836	SY	$57.05	$1,188,659
Existing Open Channel Improvement				$1,390,921.42
			Total:	**$17,392,312**

100-YEAR SEWER EXTENDED - ADDITIONAL COST FOR 4-FT PIPE				
Alternative 6:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for sewers	5,688	CY	$12.63	$71,824
Pavement Removal	1,827	SY	$6.76	$12,351
Hauling removed pavement	653	CY	$7.57	$4,943
Hauling excess excavation	5,193	CY	$7.57	$39,319
Pipe Installation	1,860	LF	$50.43	$93,804
4' RCP	1860	LF	$180.95	$336,558
Gravel Fill	2,283	CY	$32.94	$75,192
Manholes	6	EACH	$6,159.33	$36,956
Pavement replacement	1,827	SY	$57.05	$104,225
			Total:	**$775,173**

MILWAUKEE EAST SEWER IMPROVEMENT ONLY - 100-YEAR DESIGN				
Alternative 7:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for sewers	20,502	CY	$12.63	$258,890
Pavement Removal	5,412	SY	$6.76	$36,591
Hauling removed pavement	1,934	CY	$7.57	$14,644
Hauling excess excavation	11,929	CY	$7.57	$90,328
Pipe Installation	7,099	LF	$50.43	$358,020
Pipe Removal		LF	$14.44	$0
15-inch RCP (1.25')	298	LF	$46.38	$13,822
18-inch RCP (1.5')	658	LF	$54.69	$35,988
24-inch RCP (2')	891	LF	$71.48	$63,686
30-inch RCP (2.5')	5252	LF	$101.01	$530,492
Dewatering - 12" PVC	0	LF		$0
Dewatering - pumping (12 reaches)	0	DAYS		$0
Gravel Fill	5,265	CY	$32.94	$173,409
Manholes	24	EACH	$6,159.33	$147,824
Pavement replacement	5,412	SY	$57.05	$308,774
			Total:	**$2,032,467**

MILWAUKEE EAST SEWER IMPROVEMENT ONLY - 100-YEAR DESIGN				
Alternative 8 NEW PIPES:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for sewers	29,002	CY	$12.63	$366,221
Pavement Removal	6,670	SY	$6.76	$45,094
Hauling removed pavement	2,383	CY	$7.57	$18,048
Hauling excess excavation	19,371	CY	$7.57	$146,674
Pipe Installation	7,122	LF	$50.43	$359,180
Pipe Removal	7,122	LF	$14.44	$102,863
21-inch RCP (1.75')	298	LF	$62.40	$18,595
24-inch RCP (2')	658	LF	$71.48	$47,032
36-inch RCP (3')	891	LF	$117.57	$104,757
42-inch RCP (3.5')	2634	LF	$155.25	$408,922
48-inch RCP (4')	23	LF	$180.95	$4,162
54-inch RCP (4.5')	2021	LF	$213.72	$431,933
60-inch RCP (5')	597	LF	$283.83	$169,448
Dewatering - 12" PVC	600	LF	$39.07	$23,445
Dewatering - pumping (12 reaches)	180	DAYS	$3,706.21	$667,117
Gravel Fill	8,062	CY	$32.94	$265,531
Manholes	24	EACH	$6,159.33	$147,824
Pavement replacement	6,670	SY	$57.05	$380,527
			Total:	**$3,707,372**

OPEN CHANNEL				
Alternative 9:	Amount	Unit	Unit Cost	Total Cost
Excavation for channel	50,524	CY	$12.63	$637,998
Hauling earth	63,155	CY	$7.57	$478,207
Clear & Grub	14.0	AC	$4,235.48	$59,312
Pavement Removal	4500	SY	$6.76	$30,422
Hauling removed pavement	1608	CY	$7.57	$12,176
8' x 10' RCB for bridges (9)	990	LF	$1,307.32	$1,294,243
Sewer connections (10 - 3' RCP at 50-ft)	500	LF	$117.57	$58,786
Bridge & Pipe Installation	1,490	LF	$50.43	$75,144
Pavement replacement	4500	SY	$57.05	$256,721
Grading	30,256	SY	$5.43	$164,397
Topsoil for channel	31,151	SY	$3.13	$97,392
Seeding	30,256	SY	$0.72	$21,910
Excavation/trenching for enclosure	24,434	CY	$12.63	$308,542
Pavement Removal	6,170	SY	$6.76	$41,716
Hauling removed pavement	2,205	CY	$7.57	$16,696
Hauling excess excavation	24,067	CY	$7.57	$182,236
Pipe Installation (exist channel and enclosure)	5,106	LF	$50.43	$257,508
Manholes	6	EACH	$6,159.33	$36,956
5' x 5' RCB (1 bridge)	57	LF	$546.52	$31,152
5' x 6' RCB (1 bridge)	43	LF	$593.44	$25,518
6' x 9' RCB (1 bridge)	102	LF	$1,111.15	$113,337
6' x 6' RCB (enclosure)	220	LF	$769.91	$169,380
6' x 7' RCB (enclosure)	3,550	LF	$995.35	$3,533,506
6' x 9' RCB (enclosure)	1,134	LF	$1,111.15	$1,260,040
Gravel Fill	5,478	CY	$32.94	$180,432
Pavement replacement	6,170	SY	$57.05	$352,020
Existing Open Channel Improvement				$1,390,921.42
Home Acquisition (2014)	122	homes	NA	$33,112,156
Home Acquisition (2019)	122	homes	NA	$38,482,189
	Total (without home acquisition cost):			**$11,086,668**
	Total (with 2014 home acquisition cost):			**$44,198,823**

STORAGE ALTERNATIVES						
Alternative 10: North Detention	Amount	Unit	Unit Cost	Total Cost		
Topsoil stripping	2,985	CY	4.26	$12,712		
Total pond excavation	42,592	CY	$12.63	$537,837		
Hauling earth from pond	53,240	CY	$7.57	$403,132		
Clear & Grub	3.7	AC	$4,235.48	$15,671		
Grading	17,908	SY	$5.43	$97,305		
Seeding	17,908	SY	$0.72	$12,968		
Pipe excavation	1,410	CY	$12.63	$17,806		
Hauling earth from trenches	1,335	CY	$7.57	$10,110		
Pavement removal	174	SY	$6.76	$1,176		
Hauling removed pavement	62	CY	$7.57	$471		
Pavement replacement	174	SY	$57.05	$9,927		
5' x 10' RCB	200	ft	$1,030.21	$206,043		
1' diameter pipe	100	ft	$45.86	$4,586		
Pipe Installation	300	ft	$50.43	$15,130		
Topsoil for detention	17,908	SY	$3.13	$55,988		
Gravel Fill	355	CY	$32.94	$11,681	$1,412,542	w/out home
Excavation/trenching for enclosure	17,364	CY	$12.63	$219,266		acquisition, channel
Pavement Removal	4,736	SY	$6.76	$32,015		bridges or enclosure
Hauling removed pavement	1,692	CY	$7.57	$12,813		
Hauling excess excavation	16,735	CY	$7.57	$126,720		
Pipe Installation (exist channel and enclosure)	3,285	LF	$50.43	$165,671		
Manholes	6	EACH	$6,159.33	$36,956		
5' x 5' RCB (1 bridge)	57	LF	$546.52	$31,152		
5' x 6' RCB (1 bridge)	145	LF	$593.44	$86,049		
5' x 6' RCB (enclosure)	1,310	LF	$593.44	$777,412		
5' x 10' RCB (enclosure)	1,773	LF	$1,030.21	$1,826,570		
Gravel Fill	4,559	CY	$32.94	$150,162		
Pavement replacement	4,736	SY	$57.05	$270,163		
Home Acquisition (2014)	45	homes	NA	$12,526,875		
Home Acquisition (2019)	45	homes	NA	$14,952,375		
	Total (without home acquisition costs):			**$5,147,491**		
	Total (with 2014 home acquisition costs):			**$17,674,366**		

Alternative 11: South Detention	Amount	Unit	Unit Cost	Total Cost		
Topsoil stripping	2,823	CY	4.26	$12,025		
Total pond excavation	43,560	CY	$12.63	$550,060		
Hauling earth from pond	54,450	CY	$7.57	$412,294		
Clear & Grub	3.5	AC	$4,235.48	$14,824		
Grading	16,940	SY	$5.43	$92,045		
Seeding	16,940	SY	$0.72	$12,267		
Pipe excavation	1,127	CY	$12.63	$14,227		
Hauling earth from trenches	1,066	CY	$7.57	$8,073		
Pavement removal	24	SY	$6.76	$160		
Hauling removed pavement	8	CY	$7.57	$64		
Pavement replacement	24	SY	$57.05	$1,354		
4' x 6' RCB	100	ft	$571.51	$57,151		
3' x 5' RCB	100	ft	$516.04	$51,604		
1' diameter pipe	150	ft	$45.86	$6,879		
Pipe Installation	350	ft	$50.43	$17,651		
Topsoil for detention	16,940	SY	$3.13	$52,962		
Gravel Fill	264	CY	$32.94	$8,694		
Excavation/trenching for enclosure	14,222	CY	$12.63	$179,592		
Pavement Removal	3,936	SY	$6.76	$26,610		
Hauling removed pavement	1,406	CY	$7.57	$10,650		
Hauling excess excavation	13,647	CY	$7.57	$103,337		
Pipe Installation (enclosure)	3,083	LF	$50.43	$155,483		
Manholes	6	EACH	$6,159.33	$36,956		
5' x 5' RCB (enclosure)	1,310	LF	$546.52	$715,942		
5' x 7' RCB (enclosure)	1,773	LF	$698.85	$1,239,061		
Gravel Fill	4,208	CY	$32.94	$138,592		
Pavement replacement	3,936	SY	$57.05	$224,547	$4,143,105	w/out home
Home Acquisition (2014)	31	homes	NA	$8,629,625		acquisition
Home Acquisition (2019)	31	homes	NA	$10,300,525		
	Total (without home acquisition costs):			**$4,143,105**		
	Total (with 2014 home acquisition costs):			**$12,772,730**		
Alternative 12: North & South Detention				Total Cost		
North Detention				$1,412,542		
North Detention - home acquisition (2014)				$12,526,875		
North Detention - home acquisition (2019)				$14,952,375		
South Detention and enclosure				$4,143,105		
South Detention - home acquisition (2014)				$8,629,625		
South Detention - home acquisition (2019)				$10,300,525		
	Total (without home acquisition costs):			**$5,555,647**		
	Total (with 2014 home acquisition costs):			**$26,712,147**		

RAS 10-YEAR SEWER ONLY (NO ENCLOSURE) - use Tunnel costs from Alt 14					
Alternative 13:	Amount	Unit	Unit Cost	Total Cost	
Excavation/trenching for sewers	42,155	CY	$12.63	$532,324	
Excavation/trenching for enclosure					
Pavement Removal	11,404	SY	$6.76	$77,099	
Hauling removed pavement	4,075	CY	$7.57	$30,857	
Hauling excess excavation	40,727	CY	$7.57	$308,382	
Pipe Removal	9,374	LF	$14.44	$135,393	
Pipe Installation	10,759	LF	$50.43	$542,618	
5' x 7' RCB (3 bridges)					
Dewatering - 12" PVC	600	LF	$39.07	$23,445	
Dewatering - pumping (16 reaches)	240	DAYS	$3,706.21	$889,490	
5' x 7' RCB (enclosure)					
5' x 6' RCB (enclosure)					
Manholes	37	EACH	$6,159.33	$227,895	
2.5' RCP	366	LF	$101.01	$36,969	
3' RCP	1557	LF	$117.57	$183,037	
4' RCP	262	LF	$180.95	$47,426	
4.5' RCP	419	LF	$213.72	$89,571	
5' RCP	1818	LF	$283.83	$516,092	
5.5' RCP	1549	LF	$298.04	$461,581	
6' RCP	1483	LF	$406.70	$603,170	
7' RCP	2428	LF	$501.06	$1,216,678	
Gravel Fill	16,741	CY	$32.94	$551,389	
Pavement replacement	11,404	SY	$57.05	$650,610	
			Total:	**$7,124,027**	
				$22,589,259	With Alt 14 Tunnel costs

100-YEAR SEWER with RELIEF TUNNEL (NO ENCLOSURE)					
Alternative 14:	Amount	Unit	Unit Cost	Total Cost	
Excavation/trenching for sewers	55,534	CY	$12.63	$701,261	
Excavation/trenching for enclosure					
Pavement Removal	14,665	SY	$6.76	$99,144	
Hauling removed pavement	5,240	CY	$7.57	$39,680	
Hauling excess excavation	54,028	CY	$7.57	$409,097	
Pipe Removal	10,408	LF	$14.44	$150,319	
Pipe Installation	12,831	LF	$50.43	$647,119	
Manholes	47	EACH	$6,159.33	$289,489	
2' RCP	1391	LF	$71.48	$99,439	
3' RCP	1829	LF	$117.57	$214,993	
4' RCP	2314	LF	$180.95	$418,671	
5' RCP	2300	LF	$283.83	$652,900	
6' RCP	645	LF	$406.70	$262,278	
7' RCP	611	LF	$501.06	$306,299	
8' RCP	3741	LF	$699.04	$2,615,329	
Dewatering - 12" PVC	600	LF	$39.07	$23,445	
Dewatering - pumping (19 reaches)	285	DAYS	$3,706.21	$1,056,269	
Gravel Fill	21,944	CY	$32.94	$722,790	
Pavement replacement	14,665	SY	$57.05	$836,638	
Tunnel - 7' RCP inlet	110	LF	$501.06	$55,117	
Tunnel - 5.5' RCP inlet	70	LF	$298.04	$20,863	
Tunnel - 8.5' RCP open trench	960	LF	$804.64	$772,456	
Tunnel open trench excavation	8249	CY	$12.63	$104,159	
Pavement Removal	1,735	SY	$6.76	$11,729	
Hauling removed pavement	620	CY	$7.57	$4,694	
Hauling excess excavation	8,490	CY	$7.57	$64,286	
Pipe Installation	1,140	LF	$50.43	$57,493	
Gravel Fill	3,076	CY	$32.94	$101,307	
Tunnel boring machine mobilization	$12,389,293	boring	8.50%	$1,053,090	
Tunnel - 8.5' bore	4170	LF	$2,971.05	$12,389,293	
Access Shaft (assume 1)	40	LF	$18,294.12	$731,765	
Pavement replacement	1,735	SY	$57.05	$98,979	
			Total:	**$25,010,391**	
			Tunnel Cost Only:	**$15,465,232**	
			Sewer Only:	**$9,545,159**	
100-YEAR SEWER EXTENDED with RELIEF TUNNEL (NO ENCLOSURE)					
Alternative 15:	Amount	Unit	Unit Cost	Total Cost	
Tunnel - 7' RCP inlet	110	LF	$501.06	$55,117	
Tunnel - 5.5' RCP inlet	70	LF	$298.04	$20,863	
Tunnel - 9' RCP open trench	960	LF	$910.24	$873,831	
Tunnel open trench excavation	8852	CY	$12.63	$111,774	
Pavement Removal	1,797	SY	$6.76	$12,148	
Hauling removed pavement	642	CY	$7.57	$4,862	
Hauling excess excavation	9,179	CY	$7.57	$69,502	
Pipe Installation	1,140	LF	$50.43	$57,493	
Gravel Fill	3,276	CY	$32.94	$107,898	
Tunnel boring machine mobilization	$12,389,293	boring	8.50%	$1,053,090	
Tunnel - 9' bore	4170	LF	$2,971.05	$12,389,293	
Access Shaft (assume 1)	40	LF	$18,294.12	$731,765	
Pavement replacement	1,797	SY	$57.05	$102,509	
			Tunnel Cost Only:	**$15,590,144**	
				$25,910,476	With Alt 14 Sewer
					and Alt 6 extension

100-YEAR SEWER PLUS OPEN CHANNEL BYPASS - ALT 16				
Alternative 16:	Amount	Unit	Unit Cost	Total Cost
Excavation/trenching for sewers	55,534	CY	$12.63	$701,261
Excavation/trenching for enclosure	24,077	CY	$12.63	$304,038
Excavation/trenching for open channel bypass	18,613	CY	$12.63	$235,085
Pavement Removal	24,905	SY	$6.76	$168,368
Hauling removed pavement	8,899	CY	$7.57	$67,385
Hauling excess excavation	92,316	CY	$7.57	$699,012
Pipe Removal	10,408	LF	$14.44	$150,319
Pipe Installation	20,800	LF	$50.43	$1,049,015
Manholes	61	EACH	$6,159.33	$375,719
5' x 5' RCB (1 bridge)	0	LF	$546.52	$0
5' x 6' RCB (2 bridges)	0	LF	$593.44	$0
5' x 7' RCB (open channel bypass)	2,793	LF	$698.85	$1,951,887
6' x 6' RCB (enclosure)	146	LF	$769.91	$112,407
6' x 7' RCB (enclosure)	3,550	LF	$995.35	$3,533,506
6' x 9' RCB (enclosure)	1134	LF	$1,111.15	$1,260,040
2' RCP	1391	LF	$71.48	$99,439
3' RCP	1829	LF	$117.57	$214,993
4' RCP (sewer + bypass pipe)	2660	LF	$180.95	$481,278
5' RCP	2300	LF	$283.83	$652,900
6' RCP	645	LF	$406.70	$262,278
7' RCP	611	LF	$501.06	$306,299
8' RCP	3741	LF	$699.04	$2,615,329
Dewatering - 12" PVC	600	LF	$39.07	$23,445
Dewatering - pumping (19 reaches)	285	DAYS	$3,706.21	$1,056,269
Gravel Fill	31,620	CY	$32.94	$1,041,472
Pavement replacement	24,905	SY	$57.05	$1,420,784
			Total:	**$18,782,528**

Existing Open Channel Improvement	Quantity	Unit	Unit Cost	Total Cost	Source	
Retaining Wall Demolition	16110	CF	$2.80	$45,111.95	RSMEANS	
Concrete Ped. Bridge Demolition	480	SF	$24.12	$11,577.48	RSMEANS	
Wooden Ped. Bridge Demolition	275	SF	$14.71	$4,044.47	RSMEANS	
Hauling Demolition Materials (retaining wall and ped. bridges)	999	CY	$7.57	$7,565.51	AVERAGE OF RSMEANS, MNDOT	
Silt Fence - Erosion Protection	5500	LF	$1.08	$5,953.46	RSMEANS	
Tree Removal up to 6" (includes chipping, stump removal and hauling)	21	Each	$654.17	$13,737.67	RSMEANS - SUMMED PARTS	
Tree Removal 8" to 12" (includes chipping, stump removal and hauling)	23	Each	$857.72	$19,727.61	RSMEANS - SUMMED PARTS	
Light Clearing	0	Acre	$244.73	$20.23	RSMEANS	
Excavation	11000	CY	$12.63	$138,930.00	Average of RSMEANS, MNDOT, WISDOT, LPC, Wauwatosa	
Hauling Excess Excavated Material	13750	CY	$7.57	$104,087.50	AVERAGE OF RSMEANS, MNDOT	
Grading	10454	SY	$5.43	$56,762.92	Average of RSMEANS, LPC	
Topsoil Stripping	497	CY	$5.01	$2,492.18	RSMEANS	
Topsoil Placement	2983	SY	$3.13	$9,337.83	Average of WISDOT, LPC	
Seeding	2983	SY	$0.72	$2,148.00	Average of MNDOT, LPC	
Jute Mesh - Erosion Protection	2983	SY	$2.08	$6,212.90	RSMEANS	
Geotextile	10454	SY	$3.35	$35,019.48	AVERAGE OF RSMEANS, MNDOT, Virgina Dam	
Channel and Bank Stone/Riprap	6474	CY	$73.92	$478,555.58	Average of RSMEANS, MNDOT, WISDOT, LPC	
Channel Gravel Underlayer	1618	CY	$32.94	$53,310.27	Average of MNDOT, WISDOT, LPC	
Dewatering - Cofferdam	2250	SF	$31.77	$71,476.85	RSMEANS	
Dewatering - 12" PVC	1200	LF	$39.07	$46,884.00	Average of RSMEANS, MNDOT	
Dewatering - Pumping	75	Day	$3,706.21	$277,965.51	RSMEANS	
			Total:	$1,390,921.42		

PUBLIC OPEN HOUSE PRESENTATIONS

APPENDIX G

Schoonmaker Creek Watercourse System Plan

Public Open House #1

November 13th, 2017

1

Outline

- Why We Are Here
- Area Studied
- Flooding Issues
- Alternative Solutions to Flooding
- Open Channel Erosion Issues
- Green Infrastructure Analysis
- Cost Estimates
- Next Steps

2

Why We Are Here

- The City of Wauwatosa, the Milwaukee Metropolitan Sewerage District (MMSD), and the Southeastern Wisconsin Regional Planning Commission (SEWRPC) have worked together to analyze flooding issues in the Schoonmaker Watershed.
- Several alternative options have been developed as strategies to mitigate Wauwatosa's flooding risks.
- The goal of this open house is to collect public comments and insights on these alternatives.
- The City staff is not recommending any of these alternatives at this time.

3

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Area Studied

- A watershed is an area of land that captures precipitation and funnels it to a common outlet point (Schoonmaker Creek).
- The areas labeled on this map will be referenced on the Alternatives posters around the room.
- A poster of this area is also available for reference.

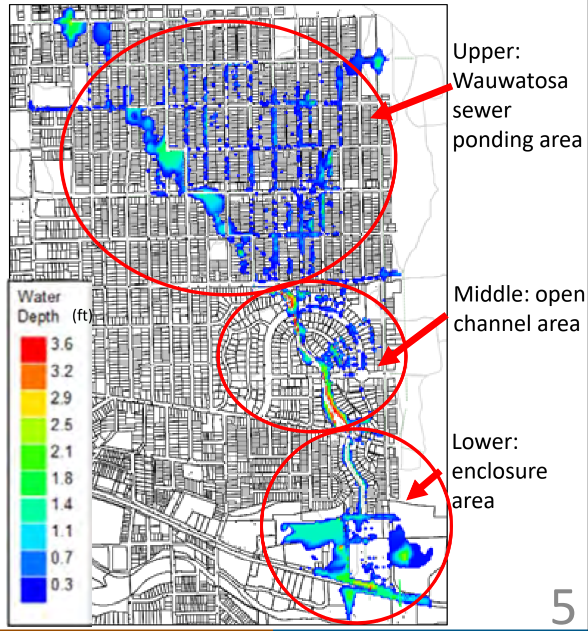
4

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Flooding Issues

- The map on the right is an estimation of the street flooding during a major storm in July 2010.
- Building additional stormwater infrastructure would help mitigate flooding during larger storm events.

Historic Storm – July 2010 Model Results



5

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Alternative Solutions to Flooding

- SEWRPC developed a total of 15 alternatives as potential solutions for mitigating storm flooding.
- The four categories of solutions are presented around the room – we would greatly appreciate your feedback on what type of alternative plan you think would be best for your community.
- An analysis of the flooding situation and all the alternatives will be presented in a final report that will be available on the City of Wauwatosa's website in 2018.

6

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Alternative Solutions to Flooding

- Alternative 1: Piped Conveyance
- Alterative 2: Tunneled Conveyance
- Alternative 3: Open Channel Extension
- Alternative 4: Storage

Above: construction workers install a reinforced concrete box culvert, like those used in several of the alternatives. Photo credit: Gossett Concrete Pipe Co., Inc.

7

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Open Channel Erosion Issues

- This study is focused on flood mitigation and did not address specific solutions to remediate the Open Channel erosion issues.
- The Storage and Tunneled Conveyance alternatives would reduce peak flow rates to the open channel.
- None of the alternatives presented here would eliminate the erosion issue along the existing channel banks.

Bank failure along W. Lloyd St.

Channel erosion just south of Washington Blvd

(Photos taken 6/10/2015)

8

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Green Infrastructure Analysis

- SEWRPC analyzed rain barrels as a way to reduce street flooding during storm events.
- In the study area, a 100-year storm rains 4.28” in 3 hours. This deposits approximately 3,870 gallons of water onto the average Wauwatosa roof.
- Having two 50 gallon rain barrels at the average house would decrease the flow from roof to sewer by about 2.6%.
- Rain barrels could complement the infrastructure alternatives presented here, but would not solely meet Wauwatosa’s flood mitigation needs.

Above: A rain barrel set up to catch rainwater from a gutter. This prevents some rainwater from flooding the streets during a storm.

Draft Planning Level Construction Cost Estimates

Alternative	Description	Draft Construction Flood Mitigation Cost Estimate (August 2017)*	Other City Utilities	Total Cost Estimate**
1	Piped Conveyance	$23.3M	TBD	TBD
2	Tunneled Conveyance	$36.5M	TBD	TBD
3	Open Channel Extension	$62.4M	TBD	TBD
4	Storage	$39.0M	TBD	TBD

TBD = To Be Determined at time of construction and final design

* Includes construction, materials, property buyouts, and a 35% contingency

** Current estimates do not include utility relocation in streets or annual operating and maintenance costs, and assumes no contaminated soils

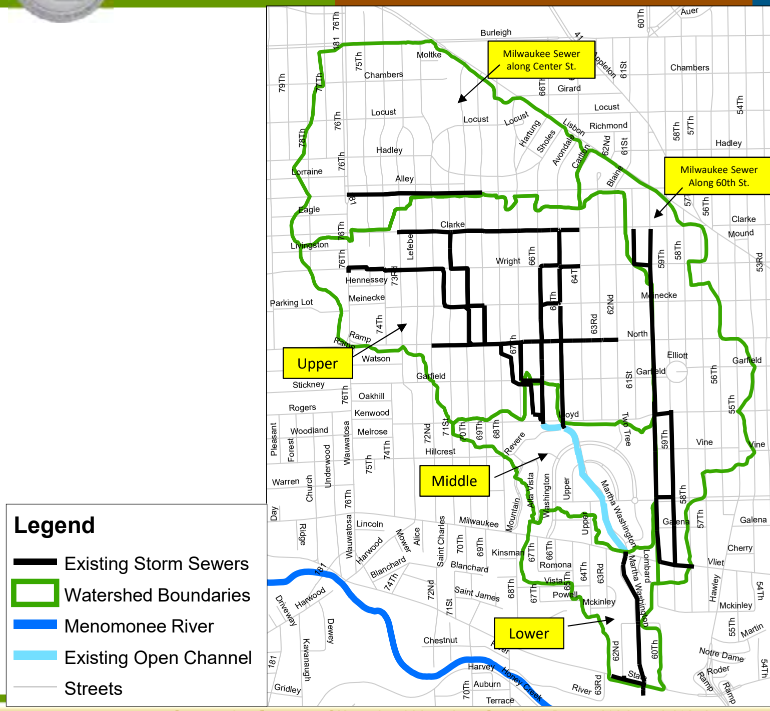
Next Steps

- The City of Wauwatosa and MMSD will review the SEWRPC report available in 2018.
- Additional public comment will follow staff recommendations.

11

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Watershed Overview



Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

This looping presentation contains 11 slides and runs for approximately 8 minutes.

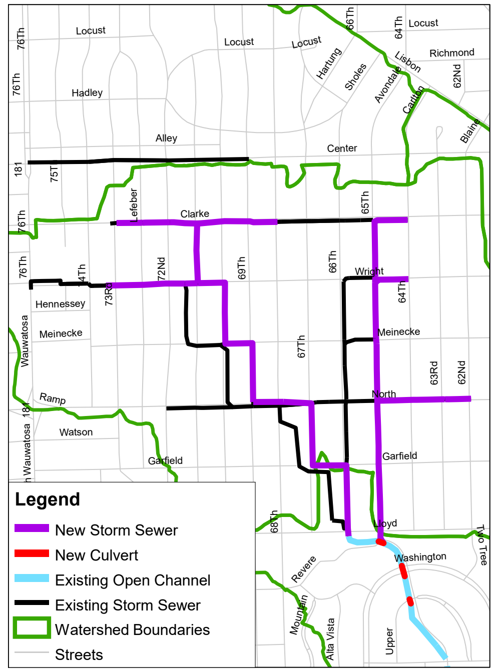
Information in this presentation can also be found in the handout packets.

Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Alternative I – Piped Conveyance

Features

- Add new pipes in the Upper Area
  - Upsize along 65th St. (~3,800 ft of 2-3' diameter to 3-5' diameter reinforced concrete pipe)
  - Add ~1,400 ft of 2' diameter pipes to eastern side of 65th St.
  - Upsize along low area sewer route 72th and Clarke to open channel (~7,700 ft of 2.25 – 5' diameter to 4-8' diameter reinforced concrete pipe)
- Middle Area – additional culverts
  - Revere Ave. – add a 5' x 5' reinforced concrete box culvert
  - Washington Circle and Upper Parkway – add a 5' x 6' reinforced concrete box culvert to each



Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Alternative I – Piped Conveyance

Features (continued)

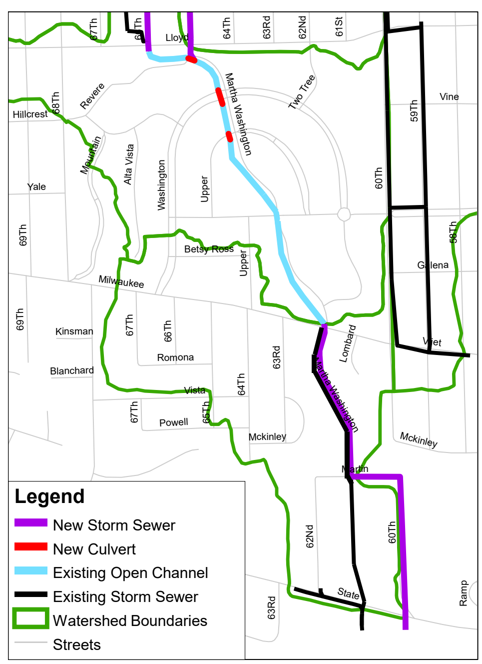
- Lower Area – additional pipe
  - ~3,550 ft of concrete box culvert from Milwaukee Ave. to State St.

Effects

- Would eliminate street flooding south of Milwaukee Ave., preventing structural damage to surrounding buildings during 100-year storm event
- Minimal street flooding in the Upper Area during a 100-year storm event

Cost (2017)

- Approximate cost: $23.3 million



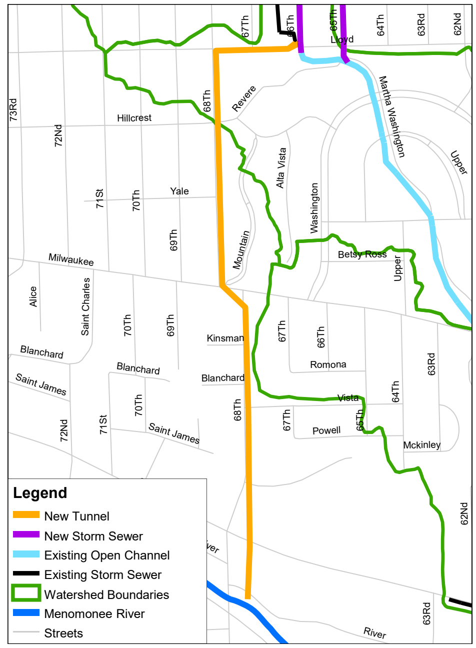
Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Alternative 2 – Tunneled Conveyance

Features
- Storm sewer upsizing north of Lloyd St. (see Alternative 1)
- Bypass Tunnel box culvert
  - ~5,300 ft of 8.5’ reinforced concrete pipe from 66th St. and Lloyd St. to the Menomonee River
  - Takes majority of flow from the Upper Area for 100-year event

Effects
- Would eliminate street flooding in the Lower Area, preventing structural damage to surrounding buildings during a 100-year storm event
- Significantly reduces street flooding in the Upper Area during a 100-year storm event, primarily near the new and replaced pipe

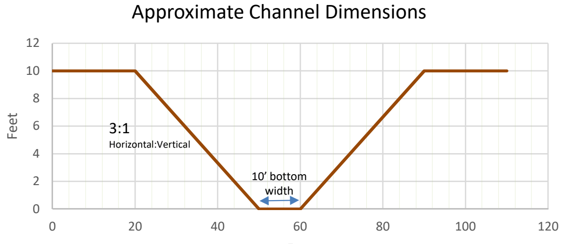
Cost (2017)
- Approximate cost: $36.5 million

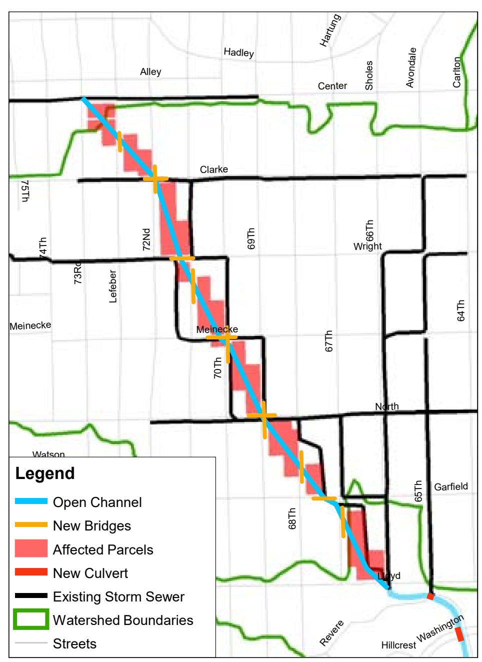


Alternative 3 – Open Channel Extension

Features
- New open channel in Upper Area
  - Trapezoidal shape channel with 10-ft wide bottom, 6-10’ depth and 3:1 side slopes
  - New channel length: ~4,910 ft
  - 9 new bridges across channel
  - 122 properties would be affected
- Middle Area – additional bridge openings at Revere Ave., Washington Cir., and Upper Pkwy.

Approximate Channel Dimensions





Alternative 3 – Open Channel Extension

<u>Features (continued)</u>

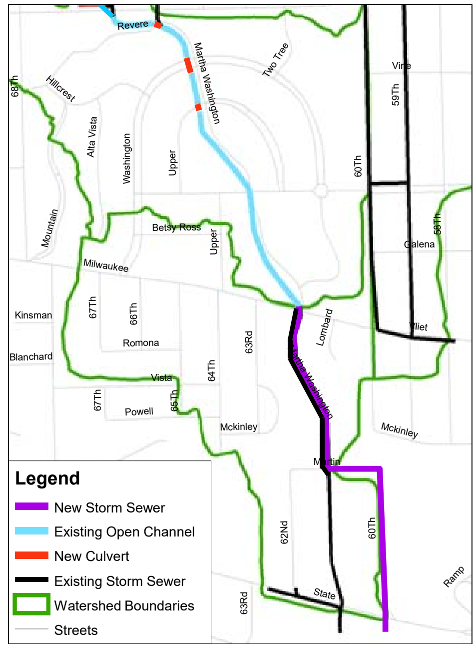
- Lower Area – additional pipe
  - ~3,550 ft of concrete box culvert from Milwaukee Ave. to State St.

<u>Effects</u>

- Would eliminate street flooding in the Lower Area, preventing structural damage to surrounding buildings during 100-year event
- Partially reduces street conveyance of stormwater compared to existing conditions in Upper Area.

<u>Cost (2017)</u>

- Approximate cost: $62.4 million

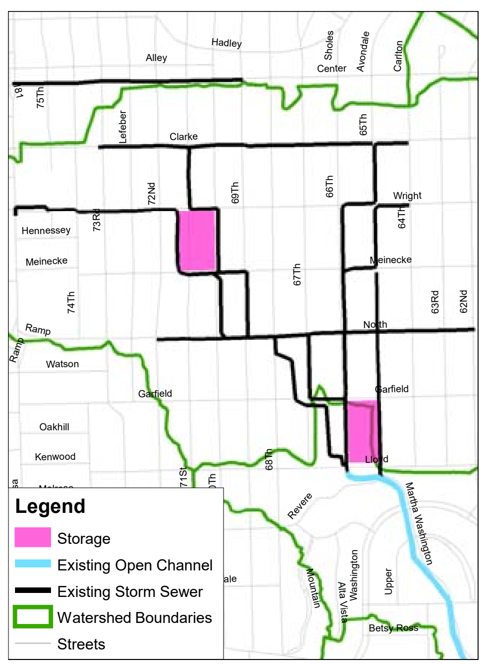


Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

Alternative 4 - Storage

<u>Features</u>

- North Storage
  - 71st St. and Wright St. (1.5 blocks)
  - 45 properties to acquire
  - 8 feet deep
- South Storage
  - 65th St. and Lloyd St. (1 block)
  - 31 properties to acquire
  - 9 feet deep
- Could be implemented separately or together
- Rectangular shape with 3:1 side slopes
- Together they can hold ~16.4 million gallons of water during a 100-year 3-hour storm, as much as 350,000 standard rain barrels (50 gal each)
- Additional 5'x10' reinforced concrete box culvert from Martin Dr. to Menomonee River



Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

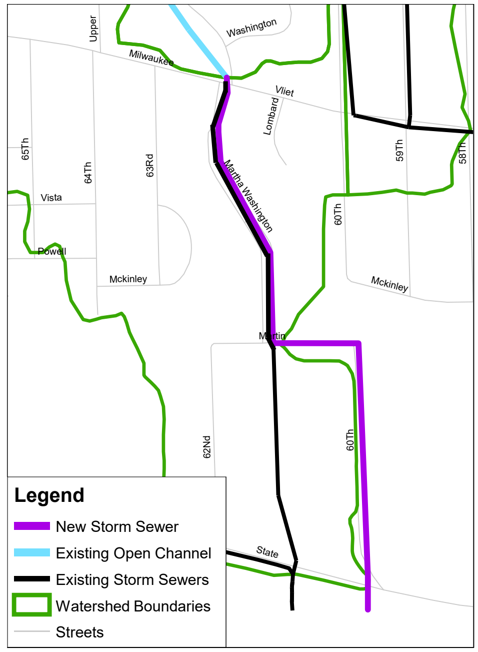
Alternative 4 - Storage

<u>Effects</u>

- Would eliminate street flooding in the Lower Area, preventing structural damage to surrounding buildings during a 100-year storm event
- When combined, street conveyance of stormwater is partially reduced during 100-year storm event

<u>Cost (2017)</u>

- Approximate cost: $39.0 million



Serving the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha