

Greentree/McKenna Watershed Study Report

City of Madison, Dane County, WI

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Project 00373092

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1 Executive Summary

Background

Recognizing the changing rain patterns, and likelihood of more frequent future large rain events, the City of Madison (City) is conducting a multi-faceted approach to address stormwater flooding. As one component of that approach, the City is developing comprehensive stormwater management studies for each watershed within the City. The studies are conducted in two phases. Throughout both phases, the City incorporates multiple opportunities for public involvement and interaction.

Phase 1, Existing Conditions: Development of a hydrologic/hydraulic stormwater runoff model representing the physical and drainage properties of the watershed under existing conditions. The model is then calibrated to measured runoff events and used to identify the areas of the watershed most likely to flood under various rain conditions.

Phase 2, Proposed Conditions: Using the model, evaluate alternative methods and/or infrastructure improvements to eliminate, or reduce flooding impacts from large rain events.

It should be noted that the improvements documented in this report are not meant to be full design-level efforts; they are conceptual solutions that help the City's Engineering Division understand the magnitude of solution needed in a given area to meet the targets. As projects are looked at further, and if they move to the point they are contemplated for programming, then projects will then go into a more detailed design phase. This project phase collects detailed data needed for design and looks at refined design, permitting, and environmental issues associated with the particular project.

This document reports the methods, procedures, and results of the Greentree/McKenna Watershed Project. The project area covers approximately 1,290 acres (2.02 square miles) on the west side of Madison including Elver Park. **Figure ES-1** shows the extent of the project area.

City's Flood Mitigation Goals

The City developed a set of flood mitigation goals that exceed their current minimum design standards, so as to better understand where goals are being met and where the flooding conditions could be improved. The City's flood mitigation goals for the Greentree/McKenna Watershed Study are as follows. Note that these goals may change in the future.

1. No homes or businesses will be flooded during the 1% Annual Exceedance Probability (AEP) design storm.
2. Eliminate flooding from the storm sewer system for up to the 10% AEP design storm; all water shall be contained within the pipes and structures (exception: street vertical alignment sag points).
3. Allow no more than 0.5 feet of water above storm sewer inlet rim at inlet-restricted low points for up to the 10% AEP design storm.
4. Centerline of street to remain passable during 4% AEP design storm with no more than 0.5 feet of water at the centerline.
5. Enclosed depressions to be served to the 1% AEP design storm (which can include safe overland flow within street, easements, greenways or other public lands).
6. Greenway crossings at streets to be served to the 1% AEP design storm.

Existing and Proposed Conditions Results

The existing conditions analysis found numerous locations where the system does not meet the identified flood mitigation goals, as outlined in **Table ES-1**. **Figure ES-2** shows the surface flooding locations for the 4% AEP design storm event, and how the performance of the stormwater conveyance system compares to the City's flood mitigation goals.

Following the existing conditions analysis, an extensive process was conducted to brainstorm, evaluate and select a series of proposed solutions that would reduce flooding across the watershed. Then, all of the proposed solutions were integrated into the model and compared against the flood mitigation goals, to assess the anticipated flood reduction. **Table ES-1** shows how the proposed solutions reduce flooding, and **Figure ES-3** shows the surface flooding locations for the 4% AEP design storm event with all of the proposed solutions in place, and how the performance of the improved stormwater conveyance system would compare to the City's flood mitigation goals.

There are still some locations within the watershed where the flood mitigation goals are not yet met, even with the proposed solutions. This is due to a variety of reasons, including the lack of physical space for improvements, lack of topographical relief to adequately drain regions, and localized flooding on private property that cannot be remedied with public improvements.

Table ES.1: Existing and Proposed Conditions Results based on the City's Flood Mitigation Goals for the Greentree/McKenna Watershed

Goal	Watershed-wide metric	Existing Condition	Proposed Condition
No homes or businesses will be flooded (1% AEP design storm)	1,325 buildings/structures	48 buildings/structures impacted (4%)	20 buildings/structures impacted (2%)
Eliminate flooding from the storm sewer system (10% AEP design storm)	264 modeled publically owned access structures and stormwater inlets	189 access structures/inlets inundated (72%)	98 access structures/inlets inundated (37%)
Allow no more than 0.5 feet of water above storm sewer inlet rim at inlet-restricted low points (10% AEP design storm)	5 inlet-restricted low points	3 inlet-restricted low points inundated (60%)	0 inlet-restricted low points inundated (0%)
Less than 0.5-feet of water at road centerline (4% AEP design storm)	20.8 miles of road centerlines	2.7 miles of roads with more than 0.5-ft of water (13%)	0.5 miles of roads with more than 0.5-ft of water (2%)
Enclosed depressions served (1% AEP design storm)	15 enclosed depressions	9 enclosed depressions impact private property when overflowing (60%)	4 enclosed depressions impact private property when overflowing (27%)
Greenway crossings at streets served (1% AEP design storm)	7 greenway crossings	4 greenway crossings overtopping the road (57%)	0 greenway crossings overtopping the road (0%)

Proposed Solutions Cost

Improvements were evaluated throughout the watershed to improve the performance of the stormwater management system in terms of meeting the City flood mitigation goals, including upsizing existing piped infrastructure, retrofitting existing stormwater ponds/greenways, and a large regional pond in the downstream portion of the watershed. **Table A.2** lists the final selected solutions, along with an estimated design and construction cost for each. Design costs were estimated to be 8% of the construction cost. Figures of the proposed solutions are included later within this report.

Table ES.2: Proposed Solutions Project Cost Estimates for Greentree/McKenna Watershed

#	Project	Estimated Design Cost	Estimated Construction Cost	Estimated Total Cost
1	Struck St, Seybold Rd and Watts Rd Improvements	\$124K	\$1.55M	\$1.67M
2	Forward Dr Improvements	\$35K	\$443K	\$0.48M
3	High Point Estates Pond Reconstruction	\$83K	\$1.03M	\$1.11M
4	W and E Valhalla Way, E Valley Ridge Circle and N Holt Circle Improvements	\$139K	\$1.73M	\$1.87M
5	New Washburn Way and S Gammon Rd Improvements	\$56K	\$702K	\$0.76M
6	Schroeder Rd Trunkline Improvement	\$151K	\$1.88M	\$2.03M
7	Norman Clayton Park and Neighborhood Storm System Improvements	\$148K	\$1.85M	\$1.99M
8	Chapel Hill Greenway and Neighborhood Storm System Improvements	\$57K	\$719K	\$0.78M
9	McKenna Blvd Improvements	\$149K	\$1.86M	\$2.01M
10	Elver Park Greenway Reconstruction	\$154K	\$1.92M	\$2.08M
11	Marty Road/Mid Town Road Regional Pond	\$834K	\$10.43M	\$11.26M

ES-1 Figure Placeholder

ES-2 Figure Placeholder

ES-3 Figure Placeholder

2 Introduction

2.1 Project Background and Purpose

The City of Madison has experienced increased frequency and intensity of rainfall events over the past ten to fifteen years. In August 2018, an unprecedented rainfall event occurred on the City of Madison's west side. A nearby United States Geological Survey (USGS) rain gauge in Middleton's Pheasant Branch Conservancy (site # 05427948) recorded 10.5 inches of rain over a 12-hour period. For reference, NOAA Atlas 14 statistics show the 12-hour 0.1-percent chance recurrence interval storm at 8.92 inches for the Madison area. This event caused flash flooding, most significantly across the western half of Madison.

In response to the 2018 summer floods, the City of Madison initiated a city-wide focus on identifying and addressing issues within the urban drainage system. This includes creating comprehensive watershed plans for watersheds throughout the City, including the Greentree/McKenna watershed.

Figure 1 provides a detailed view of the watershed with subcatchments, with an inset map to show the location within the City.

2.2 Scope of Study

The scope of work includes:

- Development of an existing conditions XP-SWMM 1D/2D computer model of the 1,290 acre watershed;
- Calibration of the model against rainfall and flow/depth data collected at selected locations within the watershed during the summer of 2020
- Evaluation of calibrated model output for purposes of identifying locations within the watershed where the stormwater management system does not meet City of Madison flood mitigation goals
- Evaluation of flood mitigation alternatives;

During the course of this project significant resources were allocated to public involvement including multiple public information meetings, focus group meetings, and online data reporting efforts. Information collected and during the public information was used in the model development and problem identification efforts of this project.

This report documents the development and calibration of the existing conditions Greentree/McKenna watershed model. Following the existing conditions analysis, an extensive process was conducted to brainstorm, evaluate and select a series of proposed solutions that would reduce flooding across the watershed. Then, all of the proposed solutions were integrated into the model and compared against the flood mitigation goals, to assess the anticipated flood reduction.

2.3 Historic Flooding in the Watershed

Within the Greentree/McKenna watershed, there are several areas that have experienced flooding in the past. **Figure 2** depicts known flooding reports provided by the City in the Greentree/McKenna watershed. The known flooding locations include flood reports from a variety of data sources, including resident reports, emergency services reports, operations staff reports, and inlets with repetitive clogging history. *Note that the Greentree/McKenna Watershed includes area outside of the City of Madison corporate limits, and these flood reports are limited to areas within the city of Madison.*

Known flooding locations were discussed with City staff at a meeting on October 14, 2019. A summary of the major flooding locations discussed at the meeting are described below and displayed in **Figure 2**.

1. **The Lexington Condominiums at Park Ridge:** The existing stormwater system near these condominiums (Park Ridge Drive, just west of the Greentree pond) backs up, with water coming out of the inlets and filling the parking lot area. Additionally, there may be local drainage system capacity limitations which cannot handle internal drainage needs.
2. **Park Ridge Drive Development #1:** Stormwater runoff in excess of the capacity of the trunk storm sewer system serving Gammon Road flows down Park Ridge Drive and through the parking lot of this development. Vehicles parked within the lot might experience issues, but the residents have not reported impacts during major flooding events.
3. **Park Ridge Drive Development #2:** Similar cause as the previous item, stormwater runoff in excess of the capacity of the trunk storm sewer system serving Gammon Road collect on Park Ridge Drive, which runs along the north side of this development. The buildings in this development are just below the sidewalk elevation and it is suspected that when flows exceed the height of the street curb, water flows across the sidewalk and then against the buildings. Residents have recently built a short wall believed to be a flood barrier, but it has not been confirmed with residents if there have been reductions in flooding.
4. **Greenway Crossing at Chapel Hill Road:** The flow from the greenway to the east overtops Chapel Hill Road during large events. This was the site of the lone fatality caused by the August 20th, 2018 storm.
5. **90° Bend, S Gammon Rd:** The public storm system has a 90-degree bend that is hydraulically inefficient. Manholes in this area have popped off during large events. The City installed hydrovents on some structures to allow water to exit the system without damaging pavement or leaving an open manhole cover in the street.
6. **Prairie Park Senior Apartments:** The property is at the corner of Struck Street and Schroeder Road. The basement of this facility flooded in the August 20th, 2018 event and the facility was evacuated due to the flooding damage.
7. **John Powless Tennis Center Building:** This facility is located on the eastern side of Struck Street, just north of Schroeder Road. The tennis center building had approximately 2 feet of standing water inside it subsequent to the August 20th, 2018 event. This was the first time the facility reported structural issues due to flooding; other smaller, rain events created nuisance flooding.
8. **John Powless Tennis Courts:** The tennis courts regularly have standing water after rain events.
9. **John Powless Tennis Center Driveway:** There are known backwater on this region, with the driveway and parking lot areas at an elevation of 1016' and the outfall is at the same elevation of 1016'. The ditch adjacent to the driveway does not drain well across Struck Street into the main greenway channel.
10. **Low Point on Struck Street:** The sag point at this location has regularly flooded due to a combination of limited drainage capacity in the street and back-ups from the greenway immediately to the west.

11. **Seybold Road, Town of Middleton:** There have been anecdotal reports of flooding along Seybold Road, in the upstream portion of the Greentree/McKenna watershed. However, because this area is actually located within the Town of Middleton, City of Madison engineering staff are not familiar with the details of the flooding.

2.4 Flood Mitigation Goals

The following flood mitigation goals have been established by the City of Madison:

1. No homes or businesses will be flooded during the 1% Annual Exceedance Probability (AEP) design storm.
2. Eliminate flooding from the storm sewer system for up to the 10% AEP design storm; all water shall be contained within the pipes and structures (exception: street vertical alignment sag points).
3. Allow no more than 0.5 feet of water above storm sewer inlet rim at inlet-restricted low points for up to the 10% AEP design storm.
4. Centerline of street to remain passable during 4% AEP design storm with no more than 0.5 feet of water at the centerline. Note that the Watershed Study modeling approach will not explicitly account for cross flow conditions where more gutter flow on one side of the street can overtop the crown.
5. Enclosed depressions to be served to the 1% AEP design storm (which can include safe overland flow within street, easements, greenways or other public lands).
6. Greenway crossings at streets to be served to the 1% AEP design storm.

Additionally, the City has stipulated that implementation of any solutions intended to bring existing elements of the stormwater management system into compliance with these goals shall not negatively impact downstream properties.

It should be noted that the focus of the Watershed Study is on the capacity / deficiencies with City-owned infrastructure and right-of-way and that the Watershed Study should be considered a “planning-level” analysis. Therefore, there are several limitations to the study that are documented further in **Section 7.3**.

2.5 Summary of Past Studies

While there have been numerous site-specific stormwater management plans and design analyses associated with street reconstruction projects and land re-development projects, there have been only three large-scale drainage studies within the Greentree/McKenna Watershed. These include the following:

Upper Badger Mill Creek Stormwater Management Analysis, February 2001

This study covered an area approximately 10.6 square miles in size, of which, the Greentree/McKenna watershed as only a part. The purpose of the study was to guide planning for future development to avoid negative impacts on the quality and quantity of stormwater runoff. Specifically, this study evaluated locations for installation of regional stormwater management ponds to control peak discharge rates and provide water quality treatment for stormwater runoff within the larger Upper Badger Mill Creek watershed. The study did not identify any locations within the

Greentree/McKenna watershed for installation of new regional stormwater ponds; although the study did identify a pond for installation between Raymond Road and CTH 'PD', a location just downstream from the Greentree/McKenna watershed boundary. This pond was referred to in the report as the 'confluence' pond due to its location at the joining of two branches of the existing drainageway, with one of the branches being that serving Greentree/McKenna watershed. This pond was not evaluated in any way as part of this current project.

Southwest Neighborhood Plan, January 2008

The Southwest Neighborhood Planning area is bounded by Mineral Point Road on the north, South Whitney Way on the east, Raymond Road on the south, and McKenna Boulevard and South Gammon Road on the west. The Greentree/McKenna watershed overlaps the planning area in the study. The watershed occupies approximately half the planning area, and approximately half the watershed (the southern, less densely developed portion of the watershed) falls outside the planning area.

This study is an urban development plan focusing on quality of life issues including social and economic factors and only touched briefly on stormwater management within the watershed, recognizing the greenway style central drainage infrastructure.

McKenna Boulevard Flood Mitigation Project, 2019/2020

This study was conducted in support of the design of the McKenna Boulevard Flood Mitigation Project, a very significant drainage improvement project targeting the greenway between Elver Park (McKenna Boulevard) and Watts Road.

Implementation of the McKenna Blvd Flood Mitigation Project occurred in two phases, the first phase was constructed in 2019 and included the replacement of the culverts under McKenna Boulevard and substantial modification of the greenway channel for a length of approximately 1,500 feet upstream to the outlet of the existing pond along the greenway channel. Phase 2 of the project was constructed 2020 and began at a point approximately 600 feet south of Watts Road and included greenway modifications extending approximately 2,200 feet downstream (south), ending at the inlet to the existing pond along the greenway which marked the upstream end of Phase 1 of the project. Phase 2 of the project also included substantial upsizing of the cross-culverts under Schroeder Road.

The findings of this report, which focus on existing conditions within the watershed, reflected the improvements of phase 1 of this project, but did not include phase 2, as this project was not complete as of the completion of the existing conditions XP-SWMM model that this report was based on.

3 Water Resources Inventory

3.1 Study Setting

The Greentree/McKenna watershed is located on the west / near west side of the City of Madison as shown in **Figure 1**. Generally, the watershed extends from USH12/14 (the west beltline) southwest to Raymond Road.

The watershed can be divided into two distinct areas, a northern portion which includes those areas generally upstream from McKenna Boulevard and which is nearly fully developed and an area downstream from McKenna Boulevard which is largely undeveloped – although this portion of the watershed does include the large open space affiliated with Elver Park.

Prominent features within the watershed include:

- Greentree-Chapel Hills Park and Elver Park which includes the central greenway which serves as the main trunk drainageway for the watershed.
- A densely developed industrial and commercial corridor located off Seybold and Watts Road located in the uppermost portion of the watershed.
- The Exact Sciences Corporation business campus which includes very large onsite stormwater management practices.
- Large areas of undeveloped farmland bounding Mid Town Road at the lowermost portion of the watershed.

3.2 Watershed

The Greentree/McKenna watershed, as defined in this study, is approximately 1,290 acres (2.02 square miles). However, under runoff conditions above a certain threshold, a storm sewer that is sloped to convey stormwater runoff north into the West Towne Pond within the Spring Harbor watershed will reverse flow and discharge south into the Greentree/McKenna watershed. The exact conditions which cause this to occur are currently unknown; however, for this study, rainfall events simulated by the calibrated Spring Harbor watershed as small as 1.5 inches show discharges from the West Towne Pond into the Greentree/McKenna watershed. Because of this connection to the Greentree/McKenna watershed, the area tributary to the West Towne Pond could be considered part of the Greentree/McKenna watershed, but because the primary outlet for the pond is to the north towards Spring Harbor, it is included in that watershed and not in the Greentree/McKenna watershed. **Figure 3** shows the connection between these two watersheds.

Another location where runoff from the Spring Harbor watershed enters the Greentree/McKenna watershed is from the apartment complex at 801 – 877 Kottke Drive. The private storm sewer serving this area is exceeded during the 4% AEP event and above, producing overland flow into the Greentree/McKenna watershed. Compared to contributions from the West Towne Pond, this watershed connections is minor.

The Greentree/McKenna Watershed is bounded by the major watersheds listed below (**Figure 3**). Except for the Upper Badger Mill Creek watershed, all of these watersheds have ongoing Watershed Studies at various stages.

- Spring Harbor Watershed to the north
- Wingra West to the east
- East Badger Mill Creek to the south
- Upper Badger Mill Creek to the west

3.3 Topography

The following data sources were used for topography within the watershed. Topographic data was needed for both delineating subwatersheds and defining overland flow paths / channels).

- 2017 Aerial photography obtained from Dane County and 2018 Aerial photography from the City of Madison
- 2017 LiDAR DEM obtained from Dane County, and 1-foot contours generated from that DEM
- GIS data describing storm drainage infrastructure provided by the City of Madison
- Construction drawings for selected projects provided by the City of Madison
- Design plans and calculations for the Exact Sciences Corporation business campus provided by Vierbicher Associates, Inc.
- Site observations and limited topographic survey performed by MSA Staff.

3.4 Drainage System

The Greentree/McKenna watershed can be described as having different northern and southern drainage characteristics: the north has fully urban drainage, with a defined central greenway while the south has a mostly rural, undeveloped drainage system with a simple low area (in alignment with the greenway) accepting the flow from the north.

The overall drainage system is shown schematically in **Figure 1**.

3.5 Runoff Conditions

3.5.1 Land Use

Figure 4 shows the existing land use for the watershed. As mentioned previously, those areas generally upstream from McKenna Boulevard are nearly 100% developed and consist primarily of residential development in the lower reaches and commercial and industrial development in the upper reaches. Downstream from McKenna Boulevard, the watershed is occupied principally by recreation areas and undeveloped farmland and woodlands. There are some small areas of residential development in the far southwestern portion of the watershed.

3.5.2 Impervious Area

Figure 5 shows the total impervious area within the watershed. Total impervious area for this study was obtained from several different sources:

- Dane County's Building footprints
- City of Madison's Stormwater Utility impervious layer for nonresidential properties
- Digitized impervious area by MSA using the most recent high-resolution aerial imagery (2017 and 2018) to supplement data gaps, specifically driveways, sidewalks and streets.

The watershed as a whole is approximately 1,290 acres and is occupied by 396 acres of impervious, making it, on average, roughly 31% impervious. However, the northern portion of the watershed, the area generally upstream from McKenna Boulevard include a total area of 825 acres which includes 350 acres of impervious making it 42% impervious. The southern portion of the watershed, by comparison is 465 acres in size and contains only 46 acres of impervious, making it less than 10% impervious.

3.5.3 Soils

Figure 6 shows the Hydrologic Soil Group (HSG) classifications throughout the watershed. The HSG is a parameter that quantifies a soil's ability to infiltrate stormwater runoff. Well-drained soils with high infiltration rates are classified as 'HSG A,' while poorly drained soils with correspondingly low infiltration rates are classified as 'HSG D.' Soils with classifications as 'HSG B' or 'HSG C' fall between these two values. Soils that have a double classification such as B/D, indicate the respective HSG for drained and undrained conditions. Per modeling guidance provided by the City of Madison, dual classed soils were treated as though they were in an undrained condition.

Most soils in this study area are HSG B, with areas of HSG C located around the east and west perimeters as well as within a central corridor along within Greentree park. There are also two areas of dual classed B/D soils in the upper watershed which are shown as HSG 'D' soils on **Figure 6**.

4 Guidance and Data Sources

4.1 Model Guidance Documentation

The most current version of the Modeling Guidance Document that was available during model development was applied to the existing conditions calibrated model (**Appendix A**). Differences between the existing conditions modeling approach and the Modeling Guidance are noted in this report.

All elevations listed in this report are relative to National Adjusted Vertical Datum of 1988 (NAVD88) unless otherwise noted.

4.2 Data Sources

The following is a list of data used in this analysis:

- Dane County 2017 LiDAR DEM;
- City of Madison 2018 Aerial imagery;
- NRCS Soils Data for Web Soil Survey (downloaded 05-07-2020);
- Observed impervious surfaces as digitized by MSA using recent aerial photographs
- Existing storm sewer, Inlet, and structure data from City GIS database;
- Various construction drawings provided by the City;
- Limited survey data and site observations performed by MSA Staff;
- Input obtained through the Focus Groups (**Figures 7A-7G** and **Appendix F**);
- Rainfall, pipe flow, and greenway water level monitoring data collected by City and USGS

5 Model Development

5.1 Modeling Software

The version of XP-SWMM that was used for this study was XPSWMM 2019.1.3.

5.1.1 Modeling Approach

Three elements of XP-SWMM were used for this model, the hydrologic model, the 1D-hydraulic model, and the 2D-hydraulic model. The hydrologic model was used to simulate the runoff resulting from various rainfall events. The 1D/2D hydraulic models were used to simulate the accumulation and flow of runoff through the watershed.

The one-dimensional (1D) portion of the model only includes subsurface drainage systems (storm sewer and culverts) and their connection to the surface drainage system. The surface drainage was modeled almost entirely in two dimensions (2D). The exception to this is the approximately 5,200 ft length of open channel upstream of McKenna Boulevard (inclusive of the east branch), which was modeled in 1D. Additional detail on the 2D portion of the hydraulic model development is included in **Section 5.5**.

5.2 Rainfall Files

Two different rainfall data sources were needed for this study:

- Design rainfall distributions, and
- Measured rainfall data (gauged data) used for the model calibration.

5.2.1 Design Rainfall Events

The MSE4 24-hour rainfall intensity distribution with NOAA Atlas 14 rainfall depths were used for event-based modeling. Table 5.1 lists the design depths used in the analysis.

Table 5.1: NOAA Atlas 14 Design Storm Rainfall Depths

Rainfall Duration	50% AEP (inches)	20% AEP (inches)	10% AEP (inches)	4% AEP (inches)	2% AEP (inches)	1% AEP (inches)	0.2% AEP (inches)
24-hours	2.8	3.5	4.1	5.0	5.7	6.6	8.8

5.2.2 Measured Rainfall Events

Rainfall data was collected in a series of incrementally-recording tipping-bucket style rain gauges operated by the USGS across the west side of Madison between April and August 2020.

The City of Madison engineering staff developed a Thiessen polygon for each rain gauge indicating the area of influence that each gauge was to be assigned for purposes of calibrating the various watershed models. The Greentree/McKenna

watershed was divided into three separate regions corresponding to three separate rain gages (**Table 5.2, Figure 8**). **Appendix H** summarizes the respective rain gage assigned to each subcatchment.

Table 5.2: Rain Gauge Locations for the Greentree/McKenna Watershed

Gauge Location	Operated by
Greentree Park	USGS
Segoe Walthum Park	USGS
West Towne Ponds	USGS

Rainfall events to be used in the model calibration process were selected in coordination with City of Madison engineering staff. The event selection criteria focused on the largest events recorded, with the most complete rainfall station records during the monitoring period. The total depth, total duration, and 5-Day antecedent rainfall for the four selected calibration events used in this study are summarized in Table 5.3.

Table 5.3: Calibration Events Rainfall Summary

Name	Start	Stop	Duration	Total Rainfall Depth	5-Day Antecedent Rainfall
May 17	03:30, 05/17/20	03:00, 05/18/20	23.5 hours	1.79"	0.7"
June 9 – 10	15:30, 06/09/20	02:00, 06/11/20	34.5 hours	2.99"	1.1"
June 24	17:00, 06/24/20	12:30, 06/25/20	19.5 hours	1.40"	1.1"
July 9	17:30, 07/09/20	05:00, 07/10/20	11.5 hours	2.34"	0.7"

In addition to the four calibration events, the August 2018 flood event was evaluated based on rainfall hyetographs passed on to MSA by the City. Specific rainfall was applied to all watersheds located within each Thiessen polygon to produce this simulation.

5.3 Hydrologic Model Development

5.3.1 Methodology

Subcatchment runoff was computed using the XP-SWMM runoff (SWMM Runoff) routing methodology with Horton infiltration parameters. This approach was directed by the City.

The SWMM runoff method requires primary input values including subwatershed area, the percentage of directly connected impervious area, the subcatchment width, and the average subcatchment slope. Additionally, each subwatershed is assigned unique parameters describing the infiltration capacity of the soils within the subwatershed.

5.3.2 Subwatershed Input Data

5.3.2.1 Level of Detail

Subwatersheds (or subcatchments) were delineated to a level of detail such that subwatersheds:

- Contributed to each group of inlets along a street or at an intersection;
- Corresponded to level of detail for the modeled storm sewer system (discussed later in **Section 5.3**);
- Contributed to points along long stretches of streets with no existing storm sewer such that the model could demonstrate whether new storm sewer would need to be extended further up the street.

This approach is consistent with the Modeling Guidance referenced in **Section 4.1**.

5.3.2.2 Input Data

Appendix B contains input data for each subwatershed. The list below provides a summary overview of the input parameters and how they were calculated for use in the “pre-calibrated” model recognizing that parameters would potentially need to be adjusted as part of the calibration process.

- Subwatershed Area – calculated using GIS. A total of 243 subwatersheds were delineated for this watershed with areas ranging from 0.1 to 107.8 acres with a median size of 2.4 acres.
- Impervious / Pervious Area
 - Total Impervious Area – All identifiable impervious area within the Greentree/McKenna watershed was manually digitized by MSA using recent aerial imagery into the following 5 categories:
 - Street
 - Roof
 - Driveway
 - Parking
 - Sidewalk
 - Directly-connected impervious area. Impervious area within the watershed was assigned a level of ‘direct connectivity’ according to ratios published in the WinSLAMM computer model standard land use data tables as required by the City of Madison Modeling Guidance.
 - Indirectly-connected impervious area. Impervious area not classified as directly connected were classified as indirectly connected per Modeling Guidance. Runoff from indirectly connected impervious areas were directed via model routing, to flow over pervious areas within the hydrologic model before being transferred to the hydraulic model.
 - Pervious area, corresponding to lawns, terraces, parks, and greenways.

Internal subwatershed routing was used as follows:

- Directly-connected impervious area assigned as subcatchment 1 and routed to subwatershed outlet.
- Indirectly-connected impervious area assigned as subcatchment 2 and routed to pervious area.
- Pervious area assigned as Subcatchment 3 and runoff (including run-on from Subcatchment 2) routed to subwatershed outlet.

The sum of the area of directly connected impervious, indirectly connected impervious, and pervious areas equaled the total area of the subwatershed.

- Subwatershed width was calculated by manually delineating (in GIS) the principal flow path of each subwatershed from its outlet to its physically most distant upstream watershed boundary. The subcatchment area was then divided by the length of this flow path to calculate the subwatershed width.

$$\text{Width} = \text{Area} / \text{Hydraulic Length}$$

The same width value was assigned to each of the three subcatchments described above (directly connected impervious area, indirectly connected impervious area, and pervious area).

- Slope for the subwatershed was computed using the LiDAR DEM and computed as the average percent slope along the hydraulic length of each subwatershed. The same slope was assigned to all three subcatchments. Subwatershed slopes range from 1.6% to 16.7% with a median of 4.2%.
- Infiltration parameters were assigned as an area-weighted average of the different hydrologic soil groups (HSGs) within a subwatershed. Horton infiltration parameters for each soil HSG were initially taken from the Modeling Guidance Document referenced previously; however, infiltration parameters were ultimately modified during the calibration task.
- Antecedent runoff conditions were assumed to be standard for all statistical events simulated, with identical initial infiltration rates assigned for each event.
- Depression storages for impervious and pervious areas were set consistent with the Modeling Guidance referenced previously and applied to all events simulated.
- Runoff routing destination / receiving node – All subwatersheds were routed to either 1D or 2D surface nodes to begin inundation on the surface. Receiving nodes fall into two categories:
 - “Orphan” nodes are nodes where no storm sewer currently exists, but runoff to the 2D surface is needed to accurately reflect the potential inundation / flooding risk. Flows from these nodes may flow over the 2D surface and contribute to the 1D system. Similarly, excess runoff from nearby 1D system elements may flow overland to collect at the location of an orphan node.

- A surface node that is the upstream end of a culvert or storm sewer system. These nodes are also connected to both the 1D and 2D model systems.

5.4 1D Hydraulic Model Development

5.4.1 Level of Detail

City of Madison Modeling Guidance requires, with flexibility, the following level of detail for the 1D hydraulic model:

- Public system
 - Standard: 18" pipes (or equivalent) and larger
 - Process for exceptions: Provide justification for reason that the pipe does not need to be modeled in order to evaluate the system relative to the City's Flood Mitigation Goals that are outlined in Modeling Guidance.
 - Process for requiring inclusion of smaller pipes: Necessary when they are the only pipes draining a part of the public system.
- Private system
 - Standard: Not included.
 - Process for requiring inclusion of private pipes: Necessary for modeling stormwater detention facilities or when they are a major part of the system (e.g. Woodmans parking lot drainage).

Not all pipes 18-inches and larger were included in the Greentree/McKenna Tree Model. On the other hand, some pipes smaller than 18-inches were included in the model as deemed necessary to adequately reflect event-based flooding conditions in the watershed. Along a similar vein, not every storm sewer inlet was included in the model; rather, inlets were aggregated into groups as described further in **Section 5.4.3**. **Figure 9** illustrates the 1D storm sewer system that is included in the model.

5.4.2 Hydraulic Conveyance Systems Analysis

All storm sewer and culverts were modeled with inputs consistent with the Modeling Guidance referenced previously. Inverts, pipe sizes, pipe types, and pipe shape were input from a variety of sources as outlined in **Section 4.2**. Where conflicts in data sources existed, the most reliable data source was used. Hydraulic Input Parameters (Links and Nodes) are included in **Appendix C**.

During the course of the development of the existing conditions model of the Greentree/McKenna watershed, the City of Madison was constructing a very large drainage and flood reduction improvement in the watershed. This project is known as the McKenna Flood Mitigation Project which included the following improvements in Phase 1 which were substantially complete in 2019

- Replacement of existing culverts under McKenna Blvd with two (2) 5' x 12' and two (2) 5' x 10' box culverts
- Construction of approximately 1,350 ft of concrete lined channel from the above box culverts to the Greentree Pond. The concrete lined channel was constructed with invert 1.5 ft lower than existing channel along the entire profile from McKenna Blvd to Greentree Pond

Phase 2 of the City's McKenna Flood Mitigation project includes the following elements. This portion of the project was initiated in 2020 and is now complete.

- Replacement of the culverts at the inlet and outlet of the Greentree Pond.
 - Installation of dual (2) 4'x8' box culverts at the outlet of the pond approximately 18" lower than existing
 - Installation of four (4) 42" RCP culverts at the inlet to the pond.
- Regrading and lowering of the flowline of the Greentree channel from the Greentree Pond to Schroeder Rd.
- Replacement of existing culverts under Schroeder Rd. with two (2) 4' x 8' box culverts
- Regrading and lowering of the flowline of the Greentree channel for 800 ft north of Schroeder Rd.

Existing conditions model results reported in this document reflect complete implementation of both phases of this project.

As part of this study, the model was temporarily rebuilt to reflect conditions *prior* to the construction of the McKenna Flood Mitigation project. The pre-existing/pre-McKenna Flood Mitigation Project conditions evaluation (see **Appendix L**) demonstrated no overall increase in inundation outside of SWU property resulting from the improvement.

5.4.3 Inlet Capacity Analysis

5.4.3.1 Approach

Because surface flooding can be controlled either by storm sewer capacity, inlet capacity, or a combination of the two, it was necessary that the modeling approach include inlet capacity in some manner.

As previously mentioned, throughout the Greentree/McKenna watershed, inlets which are grouped in close proximity (for example all inlets in a single intersection) were aggregated into a single combined inlet on a one-per-subwatershed basis. These inlet nodes were located within the 1D model network but were connected to the 2D surface by selecting "Link Spill Crest to 2D" within the hydraulic node properties.

XP-SWMM has two methods for limiting inlet capacity for purposes of evaluating whether flooding may be caused by limited inlet capacity vs. limited pipe capacity. Unfortunately, the use of inlet capacity calculation routines greatly extends the model solution run times in XP-SWMM. For practicality purposes it was necessary to define where inlet capacity was truly limiting system capacity and assign XP-SWMM inlet capacity restrictions at only those locations.

Preliminary modeling indicated that there was more inlet capacity than pipe capacity in most elements of the 1D system and therefore pipe capacity was the limiting factor in causing flooding conditions. In areas where inlet capacity was limited, model elements for inlet capacity were included as described in **Section 5.4.3.4**.

5.4.3.2 Public System

Inlets that are part of the public system (i.e. street right-of-way) were grouped such that the combined inlet represented a particular location in the street. For example, inlets at a single intersection were modeled as a single, simplified inlet that reflects the combined capacity of the inlets at the intersection. Similarly, inlets on opposite sides of the street were modeled as a single, simplified inlet that reflects the combined capacity of both inlets.

5.4.3.3 Private System

While much of the private storm sewer system was not included in this study, ignoring the inlet capacity of the private system would underestimate the overall system's ability to direct runoff into the storm sewer system. Each private storm

sewer line was assessed on a case-by-case basis. Where a significant watershed area was drained via a private storm sewer system, such as the Woodman's parking lot, the private system was included in the 1D model.

5.4.3.4 Inlet Capacity Modeling

Inlet capacity was only modeled at nodes that were determined by preliminary modeling efforts to be inlet restricted. The workflow to determine which nodes required inlet capacity to be modeled is described below and is illustrated in **Figure 10**.

- An un-calibrated 10% AEP inundation map was created with unlimited inlet capacity assigned to each inlet node (the node can accept as much flow as the downstream hydraulic element can convey).
- A second un-calibrated 10% AEP inundation map was created with a uniform 5 cfs maximum capacity applied to every inlet node.
- Where the inundation maps were the same for each of the previously described scenarios, the system was determined to be pipe-limited, and therefore inlet capacity restrictions were not needed for those areas. Where a difference in the inundation maps was observed, a maximum inlet base-inflow of 3 cfs-per-inlet was assigned, reduced by the appropriate factor as identified in the Modeling Guidance for low slopes and sag conditions. An exception to this approach was for areas where there were a significant number of inlets in close proximity or where there was a 'high capacity terrace inlet' in place. In these instances, inlet capacity restrictions were not included.

Inlet capacity was modeled by flagging the "Inlet Capacity" check box within the hydraulic node properties and specifying the maximum capacity in cubic-feet-per-second (cfs). A memo describing the inlet capacity modeling approach for this watershed is included in **Appendix E**.

5.5 Detention Pond Analysis

All known public and private stormwater detention ponds were included in the analysis. To simplify the flood inundation mapping process, storage for all stormwater detention facilities were modeled using the 2D terrain. In the case of ponds whose construction occurred after the date of the generation of the 2D terrain input features, such as the Exact Science Corporate Campus pond, it was necessary to modify the 2D terrain to include the pond storage area.

Hydraulic structures controlling discharges from the ponds were entered into the 1D model system according to information provided by construction plans, GIS databases, topographic survey, and visual inspections.

5.5.1 Connections to the Spring Harbor Watershed

The Greentree/McKenna watershed, as defined in this study, is approximately 1,290 acres (2.02 square miles). However, under runoff conditions above a certain threshold, a storm sewer that is sloped to convey stormwater runoff north into the West Towne Pond within the Spring Harbor watershed will reverse flow and discharge south into the Greentree/McKenna watershed. The exact conditions which cause this to occur are currently unknown; however, for this study, rainfall events simulated by the calibrated Spring Harbor watershed as small as 1.5 inches show discharges from the West Towne Pond into the Greentree/McKenna watershed. Because of this connection to the Greentree/McKenna watershed, the area tributary to the West Towne Pond could be considered part of the Greentree/McKenna watershed,

but because the primary outlet for the pond is to the north towards Spring Harbor, it is included in that watershed and not in the Greentree/McKenna watershed. **Figure 3** shows the connection between these two watersheds. Inflow hydrographs for the 48" pipe connecting the two watershed study areas were provided to MSA by the City. These have been applied as a "User Inflow" at node AS2858-029_01, the upstream end of this connecting pipe, for each design and calibration event.

Another location where runoff from the Spring Harbor watershed enters the Greentree/McKenna watershed is from the apartment complex at 801 – 877 Kottke Drive. The private storm sewer serving the adjacent street is exceeded during the 4% AEP event and above, producing overland flow into the Greentree/McKenna watershed. Inflow hydrographs for the 4% AEP event and greater were provided to MSA by the City. These have been applied as a "User Inflow" at node PRIV06_01, which represents a small private storm sewer basin behind the strip mall, at the corner of Gammon Rd and Watts Rd.

5.5.2 1D Tailwater Conditions

The outfall of this watershed is to the Raymond Rd Confluence Pond, south of Raymond Road. The water surface in this pond could represent a tailwater condition which could restrict discharges from the Greentree/McKenna watershed. Unfortunately, this pond receives runoff from an area much larger area than the Greentree/McKenna watershed and it cannot be simulated at this time. City of Madison engineering staff have indicated that Raymond Rd has been known to overtop at the location of the outlet from the Greentree/McKenna watershed. In this location stormwater runoff from the watershed central drainageway is collected by a structure which emulates a pond outlet structure. The structure comprising a short 30" pipe section leading to an open top riser. These two elements connect to a 60" RCP which conveys flows under Raymond Road and into the Raymond Road Confluence pond.

With the limited data available on the Raymond Rd Confluence Pond, it was determined that a suitable tailwater condition would be a 'Fixed Backwater' equal to the invert of the abovementioned 30" pipe. This scenario produces overtopping of Raymond Road during the 10% AEP event and above, which appears to match with what we know anecdotally.

5.6 2D Hydraulic Model Development

5.6.1 2D Modeling Area

With the exception of the some of the greenway channels, specifically those along the main stem of the Greentree channel upstream from McKenna Boulevard, the entire surface drainage system was modeled in the 2D model layer.

5.6.2 2D Terrain Data

The LiDAR DEM was used for the 2D terrain with the following changes:

- The DEM was modified to according to available construction plans to reflect construction of the private ponds constructed at the Exact Sciences Corporate campus, north of Schroeder Rd, were added.
- The DEM was modified at Greentree Pond to lower the pond surface to reflect the newly constructed outfall, which lowered by permanent pool elevation.

It should be noted that the LiDAR DEM for wet detention ponds (such as the Elver Park Pond) reflect the pond water level and not the true ground surface. However, since the permanent pool of these ponds is not typically available for flood storage, the LiDAR DEM did not need to be edited to accurately model these systems.

5.6.3 2D Grid

For the Greentree/McKenna watershed, a 10-foot grid cell (with 3 second base time step) was assigned. A grid orientation default of 0 degrees was used as this visually appeared to match the orientation of most public streets within the watershed.

5.6.4 2D Land Use and Roughness Values

Figure 11 shows the Manning's n roughness value that was assigned to the 2D terrain. All values assigned were in accordance with City Modeling Guidance.

Figure 12 shows the Land Use designations which were assigned throughout the watershed. As described in **Section 5.3.2.2**, the land use was used in conjunction with the digitized impervious data to determine DCIA and UCIA within each subwatershed.

5.6.5 Inactive Areas

Per the Modeling Guidance, all buildings were modeled as inactive areas within the 2D surface. It is important to note that this approach requires engineering judgment when evaluating model output to determine whether a building is at risk for flooding, since it is unknown whether a building has low openings above or below modeled flood elevations. Additionally, this approach ignores any minor storage that flooded buildings provide. For example, several of the businesses and residential buildings along Struck St were filled with water during the 2018 flood.

Those channels which were modeled using the 1D hydraulic model layer, were indicated as inactive in the 2D model layer so as to not 'double count' the hydraulic conveyance capacity and flood storage volume of the channel. As indicated previously, this approach was specific to the main stem of the Greentree channel upstream from McKenna Boulevard and the Chapel Hill Channel branch to the east.

5.6.6 1D-2D Interface Lines

1D-2D interface lines were drawn completely around all channels thereby allowing flow to pass between the 1D and 2D layers as hydraulic conditions between the two model layers dictated.

5.6.7 2D Boundary Conditions

There are several locations where surface flow was predicted to leave the study area under the scenarios evaluated in this study. In these locations, a 2D boundary line was added to the model with an elevation set below the road ground elevation as defined by the 2D surface to allow surface flow to leave the model. These locations include:

- East Valley Ridge Drive
- Kottke Drive

- South High Point Road

There is also a boundary condition modeled at Raymond Road to simulate when this area spills to the Raymond Road Confluence Pond. This approach is consistent with XP-SWMM modeling guidance.

6 Model Calibration

6.1 Baseflow Conditions

In the Greentree/McKenna watershed, there is insignificant baseflow within the Greentree Park Channel. In fact, the permanent pool elevation of the channel directly upstream of the Greentree Pond periodically falls below the culvert inverts linking the two waterbodies suggesting loss of water through evapotranspiration or infiltration into the ground. For this reason, baseflow was not included in the model.

6.2 Recorded Rainfall and Flow Data

6.2.1 Calibration Events

As described previously in **Section 5.2.2**, four rainfall events were used to calibrate the model using rainfall, water level, and flow monitoring data collected by the USGS under a separate contract with the City.

Section 4.2 lists the rainfall, water level, and flow monitoring sites used in this study.

6.2.2 August 2018 Model Validation

In addition, high water marks and information gained from the Focus Groups (**Appendix F**) for the historic August 2018 event were used to validate the model for larger events than what were recorded during the 2020 monitoring data collection effort. Resident reports of the event were noted during the Focus Group meetings. Rainfall data for the August 2018 event was provided by the City.

6.3 Selected Runoff Events

The four events for use in the calibration were selected in collaboration with City staff. Events were selected with the following considerations (generally in order of importance):

- Total rainfall / recurrence interval estimate;
- Functioning monitoring equipment;
- Differences with the two other selected events (i.e. attempting to avoid two similar events);

Based on these factors, the events summarized in **Section 5.2.2** were selected for use in the calibration.

6.3.1 Metering Gauge Issues

As described in **Appendix H**, two of the three metering gauges installed within watershed produced results that were found to be not usable. This was discussed with the City Engineering staff at the regular monthly progress meetings on June 24th, 2020 and August 12th, 2020 and documented in MSA's model calibration Memorandum dated September 8th, 2020 (**Appendix H**). It was decided that only the Chapel Hill Road Channel Level Logger would be used to calibrate runoff for the XP SWMM model.

6.4 Calibration Performance

6.4.1 Calibration Criteria

The criteria for calibration are as follows:

- Overall average model bias for water surface elevations (or flow) is within +/- 5% with reasonable effort made to minimize the largest absolute error while at the same time balancing that effort with the relative importance of the model results at each monitoring site location.
- The largest absolute error at each monitored location is defined as +/- 25 percent.
- These calibration criteria are set recognizing that there may be some circumstances where calibration at a specific location cannot be accomplished. For example, in order to calibrate a larger portion of the model and/or produce results that are more accurate for the larger events, a particular gage may have an error that exceeds the 25 percent threshold.

6.4.2 Calibration Results

Table 6.1 summarizes the model bias for each event. Graphs comparing model results against metered data are shown in **Appendix H**.

Table 6.1: Chapel Hill Channel Level Logger Bias Summary

Event	Metered Data		Modeled Data	
	Maximum Channel Stage (ft)	Estimated Volume Over Storm Duration (ac-ft)	Maximum Channel Stage (ft)	Estimated Volume Over Storm Duration (ac-ft)
May 17	1.39	11.39	1.05 (-24.5%)	5.81 (-49.0%)
June 9 – 10	2.36	17.50	2.18 (-7.6%)	18.44 (+5.4%)
June 24	2.37	11.00	2.20 (-7.2%)	9.41 (-14.5%)
July 9	2.71	16.66	2.23 (-17.7%)	14.57 (-12.5%)

Nearly all of the results from the calibrated model fall within the +/- 25% error criteria. The one exception to this is the volume predicted during the May 17 event. As the following three rainfall events were all relatively larger in peak intensity and accumulated rainfall depth, this was accepted as a minor issue.

As well as statistically matching the peak channel elevations and runoff volumes, part of the calibration process was to match the shape of the metered elevation data with that of the XP SWMM model output.

A peer review of the model development was completed by a separate engineering firm, Stantec, before and after model calibration (see **Appendices G and I**).

7 Results Evaluation

The calibrated model was run for a series of design storm events. Inundation map from each event were qualitatively compared to the City's Observations (**Figure 13**) and then compared against the flood mitigation goals to identify regions where goals are not being met. **Figures 14-22** illustrate the calibrated model results for the design storm events. Inundation figures were prepared for the 50% AEP, 20% AEP, 10% AEP, 4% AEP, 2% AEP, 1% AEP, 1% AEP as a long duration storm, 0.2% AEP and simulating the August 18th, 2018 event.

Note that the model was originally constructed to match the existing conditions at the time of calibration (Summer 2020). After calibration, the model was revised to reflect the new existing conditions, to include the City completed improvements along Schroeder Road.

7.1 Model Results Compared to City Observations

Existing conditions model results can be compared against the City Staff observations outlined in **Section 2.3**. **Figure 13** displays the reported flooding records along with the August 20th, 2018 flood inundation map. It should be noted that the XPSWMM model of existing conditions that was used to simulate the 2018 flood event reflects the construction of the McKenna Boulevard Flood Reduction project which was not in place in 2018. As a result the modeling likely does not reflect conditions experienced along the length of that project corridor during the 2018 flood. It is also equally important to note that the 2018 flood was in excess of the 1% AEP.

A brief description below of each of the locations identified by City staff during the 10/14/2019 meeting is below and can be compared with **Figure 13**.

- **The Lexington Condominiums at Park Ridge:** The modeled August 18th, 2018 event shows inundation present within center of development area.
- **Park Ridge Drive Development #1:** The modeled August 18th, 2018 event shows inundation flowing through the parking lot area of this property.
- **Park Ridge Drive Development #2:** The modeled August 18th, 2018 event shows inundation flowing through the center part of this development.
- **Greenway Crossing at Chapel Hill Road:** Modeling of the August 18th, 2018 event shows the greenway overtops to overtop the road at this location.
- **90° Bend, S Gammon Rd:** The roadways was inundated at this location in the modeled August 18th, 2018 event.
- **Prairie Park Senior Apartments:** The modeled August 18th, 2018 event shows inundation through the parking lot area at this property.
- **John Powless Tennis Center:** The tennis courts and driveway to the entrance of the center are inundated in the modeled August 18th, 2018 event. The building footprint itself was within 5-feet of inundation and therefore would likely have been affected.

- **Low Point on Struck Street:** Struck Street was flooded at this location for the August 18th, 2018 event.
- **Seybold Road, Town of Middleton:** Two locations along Seybold Road clearly show regions with inundation along the road and within adjacent properties.

A set of existing conditions flooding depths and durations for different storm events are included in **Appendix D** for easy reference by City Staff.

7.2 Model Results Compared to Flood Mitigation Goals

The City identified six (6) major Flood Mitigation Goals. **Figures 23 - 28** show that there are numerous locations where the system does not meet the identified flood mitigation goals:

Goal 1 (Figure 23): No homes or businesses will be flooded during the 1% Annual Exceedance Probability (AEP) design storm.

- This criteria was evaluated by buffering the building footprints by 5-feet and intersecting them with the 1% AEP inundation raster. Any buffered building that had a maximum inundation of greater than 0.5 feet was classified as 'potentially experiencing flooding'. Note that this analysis does not account for modifications residents take to mitigate flooding on their own properties.
- Of the 1,325 structures identified within the watershed, 48 could be impacted by the 1% AEP design storm (3.6%).

Goal 2 (Figure 24): Eliminate flooding from the storm sewer system for up to the 10% AEP design storm; all water shall be contained within the pipes and structures (exception: street vertical alignment sag points).

- This criteria was evaluated by buffering all of the modeled publicly owned access structures and inlets by 15-feet. Any buffered structure that intersected the 10% AEP inundation raster was classified as a 'potential problem location'.
- Of the 264 modeled publically owned access structures and inlets, 189 of them were classified as a potential problem location. Note that the model did not include all of the publically owned structures.

Goal 3 (Figure 25): Allow no more than 0.5 feet of water above storm sewer inlet rim at inlet-restricted low points for up to the 10% AEP design storm.

- This criteria was evaluated by first identifying all of the low points within the existing stormwater system. A subset of these low points were classified as being "inlet restricted" (see **Section 5.4.3**). Next, the edge of pavement was clipped to 50-foot segments and intersected with the 10% AEP inundation raster to determine locations where the water was at least 0.5 feet or greater along the curb line. Any inlet-restricted low point with at least 0.5 feet of water along the curb line was classified as a 'potential problem area'.
- A total of 25 low points were identified within the watershed. Of these, 5 were classified as being inlet-restricted, and 3 of those 5 had more than 0.5-feet of water present along the curb line.

Goal 4 (Figure 26): Centerline of street to remain passable during 4% AEP design storm with no more than 0.5 feet of water at the centerline.

- This criteria was evaluated by using a road centerline dataset, split at 50-ft intervals and intersecting them with the 4% AEP inundation raster. Any segment with more than 0.5-feet of water was classified as a 'potential problem location'.
- Of the 20.8 miles of roads within the watershed, 2.7 miles were classified as problem locations (13.0%).

Goal 5 (Figure 27): Enclosed depressions to be served to the 1% AEP design storm (which can include safe overland flow within street, easements, greenways or other public lands).

- For purposes of the watershed studies, an enclosed depression is defined as a depression in the public right-of-way where stormwater impacts private property to overflow the depression.
- There are fifteen (15) enclosed depressions within the watershed within the street right-of-way, most with a constructed outlet. These were identified by visual inspection of the LiDAR contours, aerial imagery, and parcel boundaries. This criteria was evaluated by individually reviewing each depression to determine if water left the ROW onto private property in order to overflow the depression.
- Modeling predicts that the 1% AEP service levels are not achieved in nine (9) enclosed depressions.

Goal 6 (Figure 28): Greenway crossings at streets to be served to the 1% AEP design storm.

- This criteria was evaluated by identifying all of the locations where channelized overland flow crosses underneath a roadway. Each location was intersected with the 1% AEP inundation raster, to determine if water was present on top of the road. Most of these occurrences (4) are due to water flowing over the road from one side of a greenway to the other side. However, some locations (2) have water on the road due to flow accumulations in the street due to inadequate local storm sewer system capacity. An example of this is the McKenna Blvd crossing of the Greentree channel.
- There are seven (7) greenway crossings within the watershed, and four (4) of those indicated water overtopping the road from the greenway in the 1% AEP event.

7.3 Limitations of Study

The Greentree/McKenna Watershed Study is a planning-level study, and as such, it has several limitations for using the model and results beyond the scope of this study. While not an exhaustive list, the following limitations should be considered when reviewing results or using this study for future work:

- Flooding on private property due to localized drainage issues (such as backyards that do not drain well) are outside the scope of this study. Flooding on private property is generally only shown when it is the result of flooding conditions that originate from inadequate street or greenway flow capacity.
- Because this study covers over 2.0 square miles, it is not possible to review and confirm flood inundation (or a lack thereof) at every location throughout the watershed. Further, model calibration has its limitations as well, as described in **Section 6**. Finally, flooding along every part of every street is not shown. Therefore, if the flood inundation maps do not show flooding on a particular property, it is not a guarantee that the property does not flood. Correspondingly, while care was taken to confirm flooding conditions throughout the watershed, there may be flooded locations shown on the inundation maps that have less flood risk than shown.

- Inlets were modeled as simplified combined inlet into the system. Further, storm sewer laterals were in general not included in the analysis. Therefore, additional site-specific evaluations that more accurately looks at each individual inlet may be needed.
- Because every inlet was not modeled, there may be locations where there is more or less bypass flow or flooding depth on one side of the road than the other than what is shown in the model results.
- Each of the calibration events chosen were of decent magnitude. The largest of which was the July 9 event, with a total rainfall depth of 2.34 inches over 11.5 hours. This is in the realm of a 1- to 2-year rainfall event.
- This study is not intended to be used for FEMA floodplain mapping purposes.

8 Public Engagement

As part of the Greentree/McKenna Watershed study, the City carried out an extensive public information effort. In addition, various social media and web-based communication methods and public meetings were held. Key elements of the public information program are summarized below; with additional information available via the City's project website:

<https://www.cityofmadison.com/engineering/projects/greentree-mckenna-watershed-study>

8.1 Public Informational Meeting

An initial public information meeting (PIM #1) was held on October 23, 2019 at the Elver Park Neighborhood Center. Twenty-One (21) people attended the meeting. The purpose of the meeting was to inform the public that the study was underway, provide an overview of what will be accomplished by the study, and collect feedback from residents on experienced flooding. At that meeting, residents also had the opportunity to request neighborhood "focus group" meetings with City and consultant staff. Based on resident requests, focus groups were held with smaller groups in specific geographic areas that had experienced flooding (see **Section 8.2**)

A second public information meeting (PIM #2) was held on October 1, 2020 as a virtual Zoom meeting (due to the Covid-19 pandemic). Attendance by the public was light with only 4 people signing in to the meeting; however engagement by those attending was quite high. None of those in signing in had attended PIM#1. This meeting was held following existing conditions model draft calibration to present model results and gather feedback from the public regarding the model validity.

A third public information meeting (PIM #3) was held on May 12th, 2022 as a virtual Zoom meeting (due to the Covid-19 pandemic). The PIM was attended by approximately 3 residents (based on a count of participants within the Zoom meeting), and included a presentation on the proposed solutions and a question and answer session.

8.2 Focus Groups

8.2.1 Public Engagement (Round 1)

During the initial phase of the Greentree/McKenna Watershed study, nine (9) focus groups were held. The meetings discussed flooding issues residents had experienced and allowed for additional information to be collected. The location of each of these meetings is listed below along with times and dates, with locations shown in **Figures 7A-7G** with additional information listed in **Appendix F** that includes a brief written description of the focus group along with a map of key observations made during the Focus Group.

- Laurie Drive (morning July 23, 2020)
- Struck Street (morning July 23, 2020)
- Park Edge Drive (July 28, 2020 and evening July 30, 2020)
- Park Ridge Drive (July 28, 2020 and evening July 29, 2020)
- Saalsaa Road (afternoon July 29, 2020)

- Piping Rock Road (afternoon July 29, 2020)
- Gammon Road/Schroeder Road (afternoon July 30, 2020)

8.2.2 Public Engagement (Round 2)

The second round of focus groups was intended to be held as smaller Zoom meetings to be conducted immediately after PIM #2 on October 1, 2020. However, because attendance was so light (5 people in total), these 'breakout sessions' were not conducted in favor of a larger discussion involving the entire audience. In general, feedback from attendees showed the model reasonably represented past flood observations.

8.2.3 Public Engagement (Round 3)

The third round of focus groups was intended to be held as smaller Zoom meetings to be conducted immediately after PIM #3 on May 12, 2022. However, because attendance was so light (3 people in total), these 'breakout sessions' were not conducted in favor of a larger discussion involving the entire audience. No questions or concerns were raised by attendees.

11,627+ points of outreach or interactions for the Greentree/McKenna Watershed Study



Public Meetings
3 meetings, 28 participants



Postcards Sent
10,774



Project Website
767 views



Email List
19 residents



On-Site Focus Groups
9 groups, 23 participants



Social Media
16 related project posts

9 Proposed Solutions Development

Upon completion of the Existing Conditions analysis (outlined in Chapters 1-7 of this report), a draft Existing Conditions report was approved by the City, and the project team moved into the second phase of the study, evaluating proposed flood mitigation alternatives. The proposed solutions development process focused on “Peak Flow Control (PFC)” solutions. PFC solutions are defined by the City as any stormwater control measure that has the ability to store or convey water, but not infiltrate water.

The City of Madison has incorporated Green Infrastructure (GI) assessments as a part of alternative flood reduction analyses conducted under other watershed studies like this one. However, the findings of these analyses indicated that exceptionally intensive application of GI across an entire watershed is necessary to achieve significant benefits in terms of flood reduction. While the City believes in GI applications and is committed to implementing GI as opportunities arise, the need to provide clear solutions to address known problems with immediately recognizable results precludes the reasonable reliance on GI as a stand-alone solution for this watershed. As a result a specific analysis of GI was not included in this study.

This chapter outlines the methodology or process used to identify proposed solutions and elicit feedback from different agencies within the City. A list of all of the solutions considered, including those that were not ultimately recommended, is included with brief descriptions of each proposed solution. Chapter 10 will provide more specifics on each of the recommended alternatives.

9.1.1 Data Review

The existing conditions modeling was reviewed to identify 14 general locations where City goals were not met for one or more goals. These locations were identified by reviewing the existing flood conditions and identifying a qualitative cause(s) at each constriction point. Possible causes of flooding include: where a larger storm sewer discharged to a smaller sewer, a storm system is undersized, inadequate inlet capacity, storage deficiencies, and inadequate overland flow channels.

9.1.2 Solution Brainstorming

After the initial data review, MSA met with the City Engineering staff on in October 2020 to discuss the initial data review, consider various constriction points across the watershed, discuss conceptual scenarios and identify potential opportunities for flood mitigation measures. Improvements were grouped by areas/neighborhoods and nearly all locations involve a combination improvements, ranging from upsizing piped infrastructure, changing routing to reduce strain on intersections prone to flooding, revising greenway grading and adding storage capacity. Solutions were targeted within street-right-of-way areas and lands already owned by the City for stormwater use. Solutions on private property were not considered as part of this study, unless information was provided by the City indicating that land might be acquired by the City in the near future.

9.1.3 Evaluation of Potential Solutions

Following the brainstorming sessions, MSA developed preliminary solutions to meet the flood mitigation goals for each of the identified constriction points. The calibrated existing conditions XPSWMM model was used to evaluate each of

the flood control solutions (see **Section 9.2** for a brief description of all of the solutions considered throughout this phase of the study).

9.1.4 Discussions of Potential Solutions with City Engineering Staff

Throughout the proposed solutions modeling, MSA met with the City on a monthly basis to review the intermediate modeling results, and discuss the benefits and drawbacks of each. These discussions ultimately lead to some new solutions being added to the list, and while others were removed from further consideration. Some solutions were modeled individually at first, and then subsequently modeled in tandem with other improvements to determine their relative contribution to flood reductions.

9.1.5 Convergence on Solutions

As the evaluation progressed, a set of solutions (described in **Section 9.2.2**) were determined to provide the most viable path towards meeting the flood control goals for the project. This convergence was based on performance of the solutions, technical feasibility, and input from the City Engineering staff. All of the proposed solutions were subsequently mapped using the City's preferred template (to ensure that all of the proposed solutions from the various watershed studies appeared in the same format) and provided to the City for internal review.

9.1.6 City Agency Meetings

Once there was a convergence on solutions, the City Engineering Staff met with different City of Madison agencies to discuss the potential solutions and discuss the challenges/obstacles to implementation with each. Meetings were held with the Mayor's Office, Water Utility, Parks Division, Fire Department, Metro Transit, Planning Division, Community Development Division, Economic Development Division, Streets Division, Forestry, Transportation Engineering, Streets Design Section, and Engineering Operations Section.

9.1.7 Finalization of Solutions

The City agency meetings did not result in any major revisions to the solutions developed for the Greentree/McKenna watershed. Minor annotation additions were added to the solution figures. The proposed storm sewer alignment along the McKenna Blvd, southeast of the main channel, was requested to be moved to the south side of the road to avoid other utility conflicts. Following this, the solutions were finalized.

9.1.8 Drafts sent to all City Agencies for Comment

A copy of the proposed solution designs and cost estimates were provided to the City Agencies for additional comment. Comment and Feedback is included within **Appendix J**.

9.2 Description of All Solutions Considered

Stormwater control measures were considered in various locations across the Greentree/McKenna watershed. Ultimately, a variety of solutions were recommended for implementation, and there were a number of solutions that were reviewed, but not recommended. The following sections provide information about all solutions that were considered.

9.2.1 Solutions Not Recommended

The following flood mitigation methods were considered within the evaluation process; however, they were not recommended for implementation. Alternative solutions described in the following subsection were evaluated only so far as was necessary to find them infeasible or to be less feasible than other solutions addressing the same flooding concern. If, in the future, recommended alternatives are abandoned in favor of any of the solutions described herein, additional detailed investigations into the feasibility of each alternative will be required.

9.2.1.1 New Stormwater Detention in High Point Park

- **Conceptual Project Description:** Construct a new stormwater detention facility in the existing green space at High Point Park, to increase storage capacity and reduce flows to limit the required size of downstream infrastructure.
- **Reason for Exclusion:** Converting an existing park facility into a stormwater basin is general not preferred as local residents would like to continue using the green space for recreational activities. An alternative solution (retrofitting the nearby High Point Estate Pond) was recommended instead.

9.2.1.2 Redesigning the West Badger Mill Creek – Elver Park Greenway

- **Conceptual Project Description:** Redesign the greenway to improve the stormwater conveyance of the channel.
- **Reason for Exclusion:** Prior to the start of this study, the City had already completed the final design of this greenway, with Phase 1 complete and Phase 2 beginning construction. Phase 1 of the project extended from Greentree Pond to Elver Park, and Phase 2 extended north from Greentree Pond to approximately 800-ft north of Schroeder Road. In Phase 1, box culverts were upsized under McKenna Blvd, the paved channel heading north to Greentree Pond was realigned and set at a lower elevation, and the outlet of Greentree Pond was upsized. In Phase 2, existing pipes under Schroeder Road were upsized, the channel extending to Greentree Pond was lowered and converted from a paved to a natural channel, and the inlets to Greentree Pond were replaced. Since all of these improvements were already in the design/construction phase, changes to the greenway and Greentree Pond were not recommended for further investigation.

9.2.1.3 Woodman Pond Detention Improvements

- **Conceptual Project Description:** The Woodman Pond outlet needs a new channel (or pipe) constructed to convey discharge into the City-owned greenway paralleling Struck Street. Runoff from this private pond during large storm events impacts the adjacent apartment buildings.
- **Reason for Exclusion:** Since the Woodman Pond is a privately owned facility, it was not recommended for further consideration.

9.2.1.4 Different Channel Alignments for the Elver Park Greenway

- **Conceptual Project Description:** Elver Park is planned for expansion to the south, and the Elver Park Pond currently discharges to an open channel through an agricultural field. The channel could be redesigned to improve stormwater conveyance of the channel. Several layouts were considered, shifting the channel further to the west and further to the east.

- **Reason for Exclusion:** One channel alignment was ultimately recommended as part of this study. Several other channel layouts were considered, but eliminated from consideration after discussion with the Parks Department. Land areas for recreation was a high priority, and optimizing the available land for non-stormwater use eliminated other proposed design alternatives.

9.2.1.5 Different Sizes for a New Detention Pond South of Mid Town Rd (Marty Road/Mid Town Road Regional Pond)

- **Conceptual Project Description:** The City is planned to align Raymond Road, and acquire land south of Mid Town Road. This area was identified as a large regional detention basin at the base of the watershed which could accommodate larger flows. As more upstream pipes are upsized, more storage will be needed within this area to accommodate the increased volume. Several pond designs were considered, including a smaller pond design that would not require a sanitary pipe to be realigned.
- **Reason for Exclusion:** The larger pond better met the flood mitigation goals, and therefore the smaller pond was removed from consideration.

9.2.1.6 Piped improvements from Saalsaa Rd to the Greentree Pond

- **Conceptual Project Description:** The existing stormwater system serves a sag in Saalsaa Rd, at the intersection with Dumont Rd. The pipes pass through two residential homes through a parallel pipes (21" and 30"), and discharges to the Greentree pond. During larger stormwater events, water ponds within the road right-of-way, as is visible in the existing conditions inundation depths. However, residents reported that water has not flow overland between the houses when the system is overwhelmed, even during the August 2018 storm event. Modeling determined that flooding was occurring due to tail water conditions (not due to inlet capacity). This solution would entail redesigning the stormwater system to reduce the street flooding in this location.
- **Reason for Exclusion:** There is not enough grade between this intersection and the Greentree pond. The best solution, to reduce tail water conditions, would be to lower the pond elevation, to allow for better drainage from this location. Since the Greentree Pond area has recently been redesigned, this option was removed from consideration.

9.2.2 Solutions Recommended

The following flood mitigation methods were recommended for implementation within the Greentree/McKenna watershed. The locations of all the solutions are displayed in **Figure 29** and further details about each design is provided in **Chapter 10**. The solutions include local improvements (storm sewer and inlet capacity), greenway reconstructions and new/retrofitted detention basins.

9.2.2.1 Struck St, Seybold Rd and Watts Rd Improvements

- **Conceptual Project Description:** Localized flooding occurs at Grand Canyon Dr, along Seybold Road in the Town of Middleton, the western side of Watts Road and along Struck St. The City stated that although some of this piped infrastructure is within the Town (rather than the City), the Town will be annexed into the City in the near future, and therefore planning for stormwater improvements was prudent. Existing pipes were upsized, some new pipes added, and an existing culvert along the open channel west of Struck Street under a driveway will be improved.

- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts.

9.2.2.2 Forward Dr Improvements

- **Conceptual Project Description:** Localized flooding occurs along Forward Drive. Existing pipes were upsized, with the understanding that pipes further upstream (which were not included within the model) would also be upsized to improve stormwater conveyance.
- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts.

9.2.2.3 High Point Estates Pond Reconstruction

- **Conceptual Project Description:** Streets and neighborhoods adjacent to the High Point Estates pond experience flooding. The existing pond would be excavated to provide more storage and a new piped outlet added to provide a more direct connection to the downstream stormwater system.
- **Iterations Considered:** Various pond depth configurations were considered, as well as potential outlet configurations.

9.2.2.4 W and E Valhalla Way, E Valley Ridge Circle and N Holt Circle Improvements

- **Conceptual Project Description:** Much of the piped stormwater infrastructure within this neighborhood is undersized. Pipes were upsized to improve stormwater conveyance and reduce surface runoff.
- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts. Modeling iterations were completed in tandem with the High Point Estates Pond Reconstruction and the Schroeder Rd Trunkline Improvements.

9.2.2.5 New Washburn Way and S Gammon Rd Improvements

- **Conceptual Project Description:** Much of the piped stormwater infrastructure within this neighborhood is undersized. Pipes were upsized to improve stormwater conveyance and reduce surface runoff. Note that neighborhoods to the west do not have existing storm sewer and the proposed improvements assume the system will be extended to these areas when streets are reconstructed.
- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts.

9.2.2.6 Schroeder Rd Trunkline Improvements

- **Conceptual Project Description:** The existing stormwater connection from N Holt Circle to S Gammon Rd has historically flooded. The existing pipe layout includes a 90-degree bend from the west to the south, which has resulted in manhole lids 'popping off' during large storm events. The proposed solution includes a new storm sewer trunkline from S Gammon Rd heading northeast and then to the east down Schroeder Rd discharging to the West Badger Mill Creek – Elver Park Greenway. The existing connection to the pipes along Gammon Rd would be removed, reducing the strain on the existing infrastructure.

- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts. This solution was also modeled in tandem with the W and E Valhalla Way, E Valley Ridge Circle and N Holt Circle Improvements.

9.2.2.7 Norman Clayton Park and Storm System Improvements

- **Conceptual Project Description:** The existing stormwater system along Laurie Dr, Piping Rock Rd, and Hathaway Dr is undersized. Pipes were upsized to improve stormwater conveyance and reduce surface runoff within the neighborhood. A new connection along Piping Rock Rd (west of Frisch Rd) would alleviate some of the pressure from the existing storm system that cuts through Norman Clayton Park. The greenway within Norman Clayton Park (west of Chapel Hill Rd) is also redesigned. Note that some streets to the northeast do not have existing storm sewer and the proposed improvements assume the system will be extended to these areas when streets are reconstructed.
- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts. Different pipe alignments were also considered, particularly along Piping Rock Rd. Note that this solution pairs with the 'Chapel Hill Greenway and Storm System Improvements' solution.

9.2.2.8 Chapel Hill Greenway and Storm System Improvements

- **Conceptual Project Description:** The Chapel Hill Greenway overtops Chapel Hill Rd during large storm events, and the pipe network along Chapel Hill Rd and the connection to the greenway from Pipe Rock Rd are undersized. The proposed solution redesigns the greenway channel, upsizes the culverts under Chapel Hill Rd, upsizes the box culvert at the end of the greenway, and increases the pipe sizes within the surrounding neighborhood.
- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts. The greenway was designed to stay within the existing footprint of the Stormwater Utility lands and keep the adjacent footpath in place. Note that this solution pairs with the 'Norman Clayton Park and Storm System Improvements' solution.

9.2.2.9 McKenna Blvd Improvements

- **Conceptual Project Description:** The greenway crossing at McKenna Blvd was finishing construction during the time of this study, and therefore the model was revised to include all of improvements from this project. However, additional flooding occurs along McKenna Blvd and undersized pipes contribute to surficial flooding. Existing pipes were upsized along McKenna Blvd and a new inlet to Elver Park Pond was added to improve conveyance.
- **Iterations Considered:** Various pipe sizes were considered, accounting for existing elevations and utility conflicts. Along the east side of McKenna Blvd, different pipe alignments were considered, including adding a new stormwater pipe on the southern vs. northern side of McKenna Blvd.

9.2.2.10 Elver Park Greenway Reconstruction

- **Conceptual Project Description:** Elver Park is planned for expansion to the south, and the Elver Park Pond currently discharges to an open channel through an agricultural field. This proposed solution redesigns the

channel to improve stormwater conveyance of the channel. In addition, the pipes along Mid Town Rd were upsized and create a secondary inlet to the proposed Marty Road/Mid Town Road Regional Pond.

- **Iterations Considered:** Various grading alignments were considered, confirming with Park staff on the best use of space to optimize land available for recreation. Alternatives were also considered relative to the existing Madison Metropolitan Sewerage District (MMSD) main that runs adjacent to the proposed channel.

9.2.2.11 New Detention Basin (Marty Road/Mid Town Road Regional Pond)

- **Conceptual Project Description:** The City is planned to redesign Raymond Road, and acquire land south of Mid Town Road. This area was identified as a large regional detention basin at the base of the watershed which could accommodate larger flows. As more upstream pipes are upsized, more storage will be needed within this area to accommodate the increased volume.
- **Iterations Considered:** Several pond designs were considered, included a smaller pond design that would not require a sanitary pipe to be realigned. The larger pond better met the flood mitigation goals, and therefore the smaller pond was removed from consideration. Considerations of existing utilities, the proposed Raymond Rd layout, and future trails/paths crossing the new Raymond Rd alignment.

10 Recommended Solutions

The recommended solutions were introduced in **Section 9.2.2** and **Figure 29** is an index map, displaying all of the proposed solutions within the Greentree/McKenna watershed. Within this chapter, all of the solutions are described in more detail, with specific reference to the flood reduction benefits, the land ownership for the project, known utility conflicts, other known concerns (e.g. wetlands, archeological, etc.), any anticipated permit requirements, and potential water quality benefits. A detailed figure is provided along with each proposed solution using the City's preferred template, to allow for easy comparison with recommended improvements from other watershed studies. **Figures 30 A-K** display each of the proposed improvements at a zoomed in scale, with all of the City's mapped utility information. **Figures 31-38** display predicted maximum inundation depths with all of the solutions implemented.

It should be noted that while there are considerable improvements to the stormwater system functionality, even with all of the solutions implemented, there are some locations where goals were not met. These are described in further detail in **Chapter 11**.

It should also be noted that the improvements documented in this report are not meant to be full design-level efforts; they are conceptual solutions that help the City's Engineering Division understand the magnitude of solution needed in a given area to meet the targets. As projects are looked at further, and if they move to the point they are contemplated for programming, then projects will then go into a more detailed design phase. This project phase collects detailed data needed for design and looks at refined design, permitting, and environmental issues associated with the particular project.

10.1 Struck St, Seybold Rd and Watts Rd Improvements

Detailed Project Description

This project area is the northern part of the Greentree/McKenna watershed, in a fully built out area of the City. Land use consists primarily of commercial and office buildings, with the storm sewer system passing under the Highway 12 Beltline from Grand Canyon Dr to Struck St. Some of the pavement and infrastructure within this region appeared to be in disrepair, and potentially not functioning as well as intended when installed. The system along Seybold Rd transitions from piped to short ditch segments, before continuing south along Struck Street and entering the West Badger Mill Creek – Elver Park Greenway. Note that portions of this proposed solution is within the Town of Middleton, and any improvements would need to be made in conjunction with the Town.

The existing conditions model showed that much of the flooding along Grand Canyon Dr, Seybold Rd, Watts Rd, and Struck St was due to the mainline storm sewer being undersized for its drainage area. This region has extensive impervious area, densely filled with privately owned commercial properties, with little potential land area available for new stormwater detention. During large stormwater events, the undersized pipes operate in a surcharged condition, resulting in overland flow and flooding impacts. Therefore, increasing pipe sizes was the best viable option to improve flooding conditions within this region.

Pipes were upsized to accommodate the 10% AEP design storm, confirming that the increased pipe sizes would not overtop the greenway at Schroeder Rd and Struck St. Pipes were also lowered and slopes were modified as needed to meet the flood control goals. Some additional comments on the proposed design are below:

- The existing pipe along Watts Rd was re-routed to discharge directly into the greenway, improving the overall conveyance at the intersection of Watts Rd and Struck Rd.
- Much of the existing stormwater infrastructure along Seybold Rd appeared to be in poor condition, and not mapped within the City's current GIS database (due to it being owned and operated by the Town of Middleton).
- Two 4'x6' boxes are to be installed underneath a private driveway that crosses the City owned greenway. The existing culverts were undersized and the proposed solution will improve conveyance along the open channel.

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-A**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Four (4) buildings/structures are no longer impacted by the 1% AEP design storm. Two buildings/structures within this region still might be impacted, but this is due to flooding on private property.
- Goal 2: The proposed solution reduces the flooding, but does not eliminate all flooding within the street. The solution prevents some stormwater structures from flooding in the 10% AEP design storm.
- Goal 3: Inundation along the curblin decreases with this proposed improvement, with the majority of locations having less than 0.5-ft of water along the curblin during the 10% AEP design storm.
- Goal 4: The majority of the area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm. This goal was not met along Watts Rd, east of the main channel. In this case the tailwater condition within the channel was the limiting factor, not the capacity of the storm sewer.
- Goal 5: There are two enclosed depressions within this area that do not meet this goal under proposed conditions. The proposed pipes along Seybold Rd were sized to match the existing capacity of the greenway. Increasing the pipe capacity to meet this goal would cause downstream flooding elsewhere in the watershed.
- Goal 6: The greenway at Schroeder Rd and Struck St does not overtop in the 1% AEP design storm.

This solution improves historical flood conditions at the low point on Struck St and Seybold Rd in the Town of Middleton (See **Section 2.3, Figure 2**).

Project Constraints/Considerations

Most of this proposed solution will be contained within the City right-of-way or on Stormwater Utility land (the greenway). The improvement from Grand Canyon Drive to the Beltline falls within a stormwater easement. The two new box culverts within the greenway are underneath a privately owned driveway to the Greentree Glen Senior apartments. Construction of this improvement will require temporary access for these residents.

Note this area encompasses part of the Town of Middleton, including part of the proposed improvement along Seybold Rd. The City will not be able to implement this improvement, unless the Town is annexed at some point in the future.

Most of the pipes within this solution are pipe-replacements, without known major utility conflicts. The two new pipe segments along Seybold Rd follow an existing ditch alignment off the road, with sanitary and water mains on either side. Costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- WisDOT Work-in-ROW Permit
- WDNR Stormwater NOI (>1 acre disturbance) – if entire project is constructed concurrently

Water Quality Benefits

Local storm sewer improvements will not provide water quality benefits.

Additional Notes/Information

Fractions of this area are connect to both the Greentree/McKenna Watershed and to the Spring Harbor watershed. Refer to **Section 5.5.1** for more details on how these two watersheds are connected.

It should be also be noted that portions of this area are currently within the Town of Middleton. However, this land is anticipated to be annexed into the City of Madison at some point in the future, and therefore the City directed to have stormwater improvements modeled within this region.

The Country Meadow Apartments along Schroeder Rd have historically experienced flooding; however, this is due to the outlet design from the adjacent Woodman pond (privately owned, see **Section 9.2.1.3.**). Although this study was only focused on public improvements, there is a potential to redesign the outlet channel (or replace it with a pipe) to address some of the flooding concerns.

10.2 Forward Dr Improvements

Detailed Project Description

This project area is located at the northeast portion of the Greentree/McKenna watershed, adjacent to the new Exact Sciences development. The properties served by this roadway corridor include commercial properties, offices, and private recreation facilities. The existing conditions model showed that the flooding along Forward Dr was due to undersized storm sewers. This area has commercial development throughout, with large paved parking areas, and the Exact Sciences detention pond (formerly the Rayovac detention pond) at the northwest corner of Forward Dr and Schroeder Rd. Increasing the pipe capacity along Forward Dr will reduce flooding within this region.

Pipes were upsized to accommodate the 10% AEP design storm, also increasing the inlet capacity to the Exact Sciences pond. Note that pipes upstream of this proposed solution were not included within the stormwater model for this study, but those pipes should likely also be upsized when this project is implemented.

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-B**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: One buildings/structures within this region still might be impacted, but this is due to flooding on private property (a parking lot area). Impact to this property could not be avoided with increased pipe capacity, due to it's proximity to the low lying parking area.
- Goal 2: The proposed solution reduces the flooding, with just one stormwater structures touching surface flooding in the 10% AEP design storm. This one structure is on private property (this structure is located on a private driveway, but is maintained by the City)
- Goal 3: Inundation along the curbline decreases with this proposed improvement during the 10% AEP design storm. *Note that this area already fulfilled this goal under existing conditions.*
- Goal 4: This area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm. *Note that this area already fulfilled this goal under existing conditions*
- Goal 5: There is one enclosed depression within this area that does not meet this goal criteria under proposed conditions. To prevent flooding to the east, a private land owner would need to fill in a drainage ditch to stop water from overflowing onto their property.
- Goal 6: This solution does not impact any greenway areas.

Project Constraints/Considerations

Most of this proposed solution will be contained with the City right-of-way and within a stormwater easement. One replacement pipe (36") extends to an inlet that is located on private property without a mapped stormwater easement (Parcel # 070825400834, currently the Madison Ice Arena parking lot).

Most of the pipes within this solution are pipe-replacements, without known major utility conflicts. Costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control

Water Quality Benefits

Local storm sewer improvements will not provide water quality benefits.

Additional Notes/Information

Note that the Rayovac Detention Pond was recently reconstructed and is now called the Exact Sciences Detention Pond (constructed in 2018) but the mapped GIS data used in **Figure 30-B** has not been updated with the new pond and pipe layout. The pond was modeled with the updated layout for both the existing and proposed conditions model.

10.3 High Point Estates Pond Reconstruction

Detailed Project Description

The existing High Point Estates detention pond is currently a dry pond, with mowed vegetation along Kottke Dr in the northwest portion of the Greentree/McKenna watershed. Immediately across the street is High Point Park, which has open grassed areas for recreation, a basketball court and a paved path. The surrounding lots are all residential, primarily single family homes. During large storm events, flooding occurs along New Washburn Way (south of the pond) and along Kottke Dr (north of the pond), with runoff continuing to flow on the street down West Valley Ridge Rd. The storm system within this neighborhood sometimes cuts through the residential properties, rather than following along the street right-of-ways.

The existing conditions model showed that much of the neighborhood flooding near the High Point Estate Pond was due to a poor configuration of the outlet, and the limited storage capacity of the pond. This region is entirely residential, with little potential land area available for new stormwater detention. Therefore, retrofitting the existing detention basin was the best feasible option to increase storage capacity. Changing the outlet configuration also improved the conveyance of the stored water back into the piped system, and avoids the 90-degree pipe bend along Kottke Drive. Note that the existing piped outlet would remain intact; however, the new outlet would become the primary outlet for the pond.

It was recognized that the pond could be discharge directly east, connecting to a much lower elevation of the downstream storm sewer. A 12" outlet pipe was proposed to attenuate peak flows as much as possible. The volume of the pond was then sized to accommodate the 1% AEP event without spilling back onto Kottke Dr. Some additional comments on the proposed design are below:

- The existing High Point Estates detention pond is currently a dry pond, with mowed vegetation.
- The proposed solution increases the volume of the dry pond significantly, lowering the invert from 1129.4' to 1123.4'. This equates to a 1% AEP volume change of 6.8 ac-ft.
- The new 12" piped outlet passes through backyard areas to connect to the existing storm system that parallels a paved pedestrian path.
- The increased upstream storage of this pond reduces downstream pipe capacity limitations.
- The City requested additional pipe upsizing for two of the piped inflows to the pond: a new 36" pipe from the SW (from New Washburn Way) and a series of pipes ending in a 34" x 54" HERCP from the NW (from Dandaneau Trail). *Note that these piped improvements were added in after modeling was complete, and therefore the inundation maps (Figures 31-38) do not reflect their addition to the stormwater system.*

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-C**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: No buildings/structures are impacted by the 1% AEP design storm. *Note that this area already fulfilled this goal under existing conditions.*
- Goal 2: The proposed solution reduces the flooding, but does not eliminate all flooding within the street. The solution prevents some stormwater structures from flooding in the 10% AEP design storm.
- Goal 3: Inundation along the curblines decreases with this proposed improvement, with all locations having less than 0.5-ft of water along the curblines during the 10% AEP design storm.

- Goal 4: The majority of the area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm. The remaining locations with water at the centerline would be improved by upsizing the proposed upstream pipe diameters by approximately one size each.
- Goal 5: There is one enclosed depression within this solution area (on New Washburn Way) that would meet this goal criteria under proposed conditions.
- Goal 6: This solution does not impact any greenway areas.

This solution improves historical flood conditions at Lexington Condos at Park Ridge, Park Ridge Drive development #1 and #2 (See **Section 2.3, Figure 2**).

Project Constraints/Considerations

The redesign of the High Point Estates pond would take place on Stormwater Utility lands. However, changing the piped outlet would require a new easement behind residential properties. The new piped outlet would connect to the existing storm system which is located on a property owned by the “City of Madison Engineer Walkways & Bikepaths”.

There are not any known major utility conflicts. Costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- WDNR Stormwater NOI (>1 acre disturbance)

Water Quality Benefits

The site will remain a dry pond, and will not provide water quality benefits.

Additional Notes/Information

The properties to the east of the High Point detention basin have a homeowners association (Highland Village Homeowners Association) that might be impacted by the proposed new piped outlet.

10.4 W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements

Detailed Project Description

This project area is the western part of the Greentree/McKenna watershed, in a fully residential neighborhood. This project is downstream of the High Point Estate Pond Retrofit, and will also benefit from that solution. Water flows east towards S Gammon Rd along W and E Valhalla Way. Water flows down the street itself (rather than through the piped system) even during the 50% AEP design event. The Valley Ridge Apartment Pond serves the adjacent apartment complex, and connects the drainage from E Valley Rd Dr to the main pipe alignment along E Valhalla Way.

The existing conditions model showed that much of the flooding is due to the mainline storm sewer being undersized for its drainage area. This region is fully developed, with little potential land area available for new stormwater detention. During large stormwater events, the undersized pipes operate in a surcharged condition, resulting in overland flow and flooding impacts. Therefore, increasing pipe sizes was the best viable option to improve flooding conditions within this region.

Note that flooding occurs where this trunk line intersects S Gammon Rd, causing impacts to buildings/structures downstream. This proposed solution should be considered in tandem with the 'Schroeder Rd Trunkline Improvement' (see **Section 10.6**).

Pipes were upsized to accommodate the 10% AEP design storm. Pipes were also lowered and slopes were modified as needed to meet the flood control goals. Some additional comments on the proposed design are below:

- The pipes leading into the Valley Ridge Apartment Pond were increased, but the pond itself was not modified as part of this solution. The pond is on private property and therefore was not included within the proposed solutions. However, assuming the pond and outlet structure can be restructured, the outlet pipe from the pond could be increased to 30". *Note that the upsized outlet pipe was added as a proposed solution after modeling was complete, and therefore the inundation maps (Figures 31-38) do not reflect its addition to the stormwater system.*
- The paved street area throughout this neighborhood is narrow compared to other portions of the watershed. This might make construction more challenging.
- W and E Valhalla Way and N and S Holt Circle are private streets which may also complicate storm sewer/public works projects

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-D**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Two (2) buildings/structures are no longer impacted by the 1% AEP design storm. One (1) more building could be impacted due to the pond overtopping. Upsizing of the pond outlet would remove the 100-year flood risk from the structure in question, therefore should be considered in conjunction with the upsizing of the E Valley Ridge storm sewer.
- Goal 2: The proposed solution reduces the flooding, but does not eliminate all flooding within the street. The solution prevents some stormwater structures from flooding in the 10% AEP design storm.
- Goal 3: Inundation along the curblines decreases with this proposed improvement, with the majority of locations having less than 0.5-ft of water along the curblines during the 10% AEP design storm.

- Goal 4: The majority of the area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm. Due to the narrow street cross-sections, this goal will be very hard to achieve for all sections of Webano Ln and E Valhalla Way.
- Goal 5: There are no enclosed depressions within this proposed solutions area.
- Goal 6: This solution does not impact any greenway areas.

This solution improves historical flood conditions at Lexington Condos at Park Ridge, Park Ridge Drive development #1 and #2 (See **Section 2.3, Figure 2**).

Project Constraints/Considerations

Most of this proposed solution will be contained within the City right-of-way. However, W and E Valhalla Way and N and S Holt Circle are private streets, which will require more coordination from local residents to move forward with the project. The upsized pipe inlet to the Valley Ridge Apartment Pond passes through a stormwater easement. The existing right-of-way can be narrow in areas, and will need to be accounted for during construction.

Most of the pipes within this solution are pipe-replacements, without known major utility conflicts. Costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- WDNR Stormwater NOI (>1 acre disturbance)

Water Quality Benefits

Local storm sewer improvements will not provide water quality benefits.

Additional Notes/Information

There is a possibility of retrofitting the Valley Ridge Apartment Pond as part of this project, but it would require an agreement with private land owner.

10.5 New Washburn Way and S Gammon Rd Improvements

Detailed Project Description

This project area is the western part of the Greentree/McKenna watershed, in a fully residential neighborhood. Water flows east down New Washburn Way on the road, as it does not have existing piped stormwater infrastructure. It then flows to the northeast along S Gammon Rd, then east at Park Ridge Dr. Both New Washburn Way and S Gammon Rd flood the street right-of-way, and have historically flooded residential homes at the S Gammon Rd and Park Ridge Dr intersection.

Flooding on the street at New Washburn Way and part of the flooding on S Gammon Rd is due to the mainline storm sewer being undersized for its drainage area. In addition, the piped connection at the S Gammon Rd and Park Ridge Dr intersection receives flow from both the south and the north, overwhelming the system capacity, impacting the nearby residential properties. This solution addresses the former concern, while the later concern is addressed by the 'Schroeder Rd Trunkline Improvement' (see **Section 10.6**).

During large stormwater events, the undersized pipes operate in a surcharged condition, resulting in overland flow and flooding impacts. Therefore, increasing pipe sizes was the best viable option to improve flooding conditions within this region.

Pipes were upsized to accommodate the 10% AEP design storm. Pipes were also lowered and slopes were modified as needed to meet the flood control goals. Some additional comments on the proposed design are below:

- Much of New Washburn Way currently does not have storm sewer. This proposed improvements assumes that extensions to the west will happen along with this improvement to ensure stormwater is captured into the piped system.
- A single pipe drains the stormwater flow from Holt Circle, passing between residential properties. The proposed design follows the existing layout to minimize impacts to private property.
- The sag locations on Gammon Rd and Park Ridge Dr are benefited greatly by the proposed storm sewer along Schroeder Rd. This diverts a significant amount of volume and peak flow away from the abovementioned low points, reducing inundation impacts.
- Inlet capacity at the Park Ridge Dr should be increased significantly. Terrace inlets both sides of the street are recommended.

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-E**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Buildings/structures are no longer impacted by the 1% AEP design storm.
- Goal 2: The proposed solution reduces the flooding, but does not eliminate all flooding within the street. The solution prevents some stormwater structures from flooding in the 10% AEP design storm.
- Goal 3: Inundation along the curblines decreases with this proposed improvement, with the majority of locations having less than 0.5-ft of water along the curblines during the 10% AEP design storm.
- Goal 4: The majority of the area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm.

- Goal 5: There are no enclosed depressions within this proposed solutions area.
- Goal 6: This solution does not impact any greenway areas.

This solution improves historical flood conditions at Lexington Condos at Park Ridge, Park Ridge Drive development #1 and #2 (See **Section 2.3, Figure 2**).

Project Constraints/Considerations

Most of this proposed solution will be contained within the City right-of-way. The pipe leaving from Holt Circle connecting to S Gammon Rd passes through residential properties, but a stormwater easement was not visible on GtWeb. Permission will need to be secured from the properties owners prior to implementing this project.

Most of the pipes within this solution are pipe-replacements, without known major utility conflicts. Costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

New Washburn Way, upstream of the existing storm sewer network, has sections of street up to 1,800 ft long without any storm sewer inlets. Similarly, areas which directly drain to the Valhalla Way storm sewer have equally long runs without storm sewer and will spill to New Washburn Way once inlet or pipe capacity is reached. It would appear appropriate to extend storm sewer all the way to Elver Ct and along Moraine View Dr to Siskiwit Cir.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control

Water Quality Benefits

Local storm sewer improvements will not provide water quality benefits.

Additional Notes/Information

Note that **Figures 31-38** show the inundation after all of the improvements have been built. Flood reductions in this area are likely due to a combination of improvements, including the High Point Estates Pond Reconstruction; W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements; and Schroeder Rd Trunkline Improvement.

A significant element of the benefits at this location are the result of the re-routing of flows to the newly proposed Schroeder Rd Trunkline (See **Section 10.6**). The Schroeder Rd Trunkline would divert a significant quantity of flow down Schroeder Rd, away from the Park Ridge Dr storm sewer.

The value of this project will be greatly reduced without the Schroeder Rd Trunkline improvement (**Section 10.6**); however, this solution can still be effective without the improvements identified in **Sections 10.3 and 10.4**.

10.6 Schroeder Rd Trunkline Improvement

Detailed Project Description

This project area is in the central portion of the Greentree/McKenna watershed, at the intersection of Schroeder Rd and S Gammon Rd. The region is primarily residential, with single family homes to the west and multi-family homes to the north, east and south. S Gammon Rd, just south of the intersection with Schroeder Rd has historically flooded during large storm events. As described in **Section 2.3**, there is a 90-degree bend in the storm sewer, leading from N Holt Circle to S Gammon Rd. This is hydraulically inefficient, and manholes along S Gammon Rd have popped off during large events, leading the City to install hydrovents as a safety measure. In addition, stormwater runoff in excess of the capacity of the trunk storm sewer system serving Gammon Road flows down Park Ridge Drive and through the parking lot of the Park Ridge Drive Development.

To address flooding throughout this region, this project would disconnect the storm pipe from N Holt Circle to the south, and instead direct it to the north along a new 72" trunkline heading east along Schroeder Rd. The new trunkline would ultimately discharge into Greentree – Chapel Hills Park greenway. Adding this new trunkline would relieve some of the system capacity along S Gammon Rd, and both reduce flooding in the roadway and in the Park Ridge Dr development.

Pipes were upsized to accommodate the 10% AEP design storm. Some additional comments on the proposed design are below:

- The proposed design along Schroeder Rd does not include connections to the privately owned storm sewer to the north (Country Meadows Apartments). This could be added in with negotiations with the property owner and revising the sizing of the trunk line accordingly.
- A water mainline is currently within Schroeder Rd which will require more careful design at locations where the stormwater and water mains cross.
- The solution can be implemented in tandem with other projects, since it provides relief to the existing piped system. The newly available capacity in the pipes at Park Ridge Dr will be able to accommodate additional flow from upsized improvements along S Gammon Rd and New Washburn Way.
- Inlet capacity on Gammon Rd, north of Schroeder Rd will need to be increased. This is a steep section of road, and bypass will contribute to inundation at the Gammon Rd and Park Ridge Dr sag points. There are currently 7 standard inlets which serve this section of Gammon Rd. These likely have an existing capacity of approximately 15 cfs. The 10% AEP runoff contributing to this location is approximately 34 cfs, therefore inlet capacity will need to more than double.

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-F**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Buildings/structures are no longer impacted by the 1% AEP design storm. This is particularly true for the Park Ridge Drive development.
- Goal 2: The proposed solution reduces the flooding, and prevents stormwater structures from flooding along S Gammon Dr during 10% AEP design storm.
- Goal 3: Inundation along the curblines decreases with this proposed improvement, and there is less than 0.5-ft of water along the curblines during the 10% AEP design storm.

- Goal 4: This area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm.
- Goal 5: There is one enclosed depression to the south of this solution area along Park Ridge Dr. This depression would meet the goal criteria under the proposed conditions.
- Goal 6: This solution does not overtop the Greentree – Chapel Hills Park greenway.

This solution improves historical flood conditions at Lexington Condos at Park Ridge, Park Ridge Drive development #1 and #2, and the 90 degree bend at Gammon Rd (See **Section 2.3, Figure 2**).

Project Constraints/Considerations

Most of this proposed solution will be contained within the City right-of-way or on the City's Stormwater Utility land. The new trunkline sewer along Schroeder Rd will need to account for the existing water main already within that corridor. Along S Gammon Rd, each new connection line will also cross existing water mains. This cost has been included within the cost estimate. Additional costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control

Water Quality Benefits

The new trunkline storm sewer improvements will not provide water quality benefits.

Additional Notes/Information

Note that **Figures 31-38** show the inundation after all of the improvements have been built. Flood reductions in this area are likely due to a combination of improvements, including the High Point Estates Pond Reconstruction; W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements; and the New Washburn Way and S Gammon Rd Improvements. However, significant inundation reductions will be achieved by implementing improvement 10.6, even without improvements 10.3, 10.4, and 10.5.

As presented in this study, the Schroeder Rd trunkline improvements are predicated upon construction of additional inlets associated with Valhalla Way, Valley Ridge Circle, N Holt Circle and High Point Estates Pond Reconstruction. (See **Sections 10.4 and 10.3**). In advance or in absence of these improvements, additional inlet capacity will be required along Gammon Rd to realize the full capacity of the proposed Schroeder Rd trunkline improvement.

10.7 Norman Clayton Park and Storm System Improvements

Detailed Project Description

This project area is in the west central part of the Greentree/McKenna watershed consisting entirely of single family residential homes. Part of the neighborhood has existing stormsewer, but many streets are currently not served. Surface water is instead conveyed through surface flows within the street right-of-ways. This solution focuses on the updating the existing storm system, with the understanding that the adjacent streets would eventually be also served and any modifications to the downstream areas should account for this additional flow. The existing storm sewer system flows west toward Norman Clayton Park, eventually continuing into the Chapel Hill Greenway.

The neighborhoods east of Norman Clayton Park (including Laure Dr, Piping Rock Rd, and Hathaway Dr) experience flooding during all of the modeled rain events. Much of the flooding is contained to the street right-of-ways during the smaller events (e.g. 10% AEP), but currently much of the area is not meeting the goal of less than 0.5-ft of water at the street centerline for the 4% AEP design storm. In addition, when water leaves the piped system at Norman Clayton Park the greenway does not have enough capacity to handle the incoming flows, and therefore overflows the greenway into the adjacent street right-of-way (specifically at the intersection of Laurie Dr and Shoreham Dr and at the greenway crossing at Chapel Hill Rd).

To address flooding throughout this region, this project would increase the pipe sizes along Hathaway Dr, Piping Rock Rd, and Laurie Dr to reduce the flooding within the street right-of ways. In addition, a new pipe connection would be installed at Piping Rock Rd, to connect to the storm system that heads north from Frisch Rd to Norman Clayton Park. This would provide relief to the system storm system that heads north from Winston Dr. The newly added pipe would be in addition to the current storm system design, therefore providing bidirectional flow from Piping Rock Rd to the greenway.

The Norman Clayton Park greenway would also be reshaped to increase capacity for the increased pipe flows contributing to it. Proposed inverts were lowered by 2-3 ft, to match that of the proposed storm sewer improvements. This section of channel has been modeled under proposed conditions with a cross-section the same as the downstream Chapel Hill Channel and appears to be suitable sized. This should give the City the option of having this as a natural (set bottom) section or keeping the current paved channel base.

Pipes were upsized to accommodate the 10% AEP design storm. Some additional comments on the proposed design are below:

- The proposed design assumes that the nearby streets that currently do not have piped storm water infrastructure (e.g. Shoreham Dr, Romford Rd, Valley Stream Dr, portions of Hathaway Dr) will eventually have a storm system added. These pipes could be designed and sized during normal street reconstruction scheduling by the City, but should not be completed until after the Norman Clayton Park and Greentree-Chapel Hills Park greenways have been redesigned for additional capacity.
- Inlet capacity required for a proposed storm sewer draining Romford Rd, Valley Stream Dr, and Hathaway Dr is approximately 56 cfs to accommodate the 10% AEP event. Inlet capacity required at the intersection of Shoreham Dr and Laurie Dr is approximately 25 cfs to accommodate the 10% AEP event.
- The solution can be implemented in tandem with the 'Chapel Hill Greenway and Storm System Improvements' project.

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-G**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Buildings/structures are no longer impacted by the 1% AEP design storm.
- Goal 2: The proposed solution reduces the surface flooding, and prevents stormwater structures from flooding during 10% AEP design storm.
- Goal 3: Inundation along the curblin decreases with this proposed improvement, and there is less than 0.5-ft of water along the curblin during the 10% AEP design storm. The inlet restricted sag location at the corner of Laurie Dr and Shoreham Dr no longer has 0.5' of water at the curblin during the 10% AEP design storm.
- Goal 4: This area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm.
- Goal 5: There is one enclosed depression within this solution area (on Laurie Dr) that would met this goal criteria under proposed conditions.
- Goal 6: This solution prevents the greenway from overtopping. Note that there is still water on the street, but this is from street-flow rather than from the greenway.

This solution improves historical flood conditions at the Greenway Crossing at Chapel Hill Road (See **Section 2.3, Figure 2**).

Project Constraints/Considerations

This proposed solution will be contained with the City right-of-way or on the City's Stormwater Utility land. The new trunkline sewer along Piping Rock Rd (~300-ft) will need to account for the existing water and sanitary mains already within that corridor. Additional costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- WDNR Stormwater NOI (>1 acre disturbance) – if entire project is constructed concurrently

Water Quality Benefits

The new trunkline storm sewer improvements and greenway design will not provide water quality benefits.

Additional Notes/Information

Note that **Figures 31-38** show the inundation after all of the improvements have been built. Flood reductions in this area are likely do to a combination of improvements, including the Chapel Hill Greenway and Storm System Improvements.

10.8 Chapel Hill Greenway and Storm System Improvements

Detailed Project Description

The Chapel Hill Greenway is in the central portion of the Greentree/McKenna Watershed, and experienced significant flooding specifically during the August 2018 flood event (see **Section 2.3**). Both the Greenway and adjacent neighborhoods experience street flooding and flooding onto private property. These areas experience flooding partially due to the limited capacity within the greenway, and due to pipe sizing limitations. The culverts passing underneath Chapel Hill Rd are undersized, causing the flows to overtop the road during larger events. Much of the flooding is contained to the street right-of-ways during the smaller events (e.g. 10% AEP), but currently much of the area is not meeting the goal of less than 0.5-ft of water at the street centerline for the 4% AEP design storm.

To address flooding throughout this region, this project would increase the pipe sizes along Chapel Hill Rd as well as the pipe passing through the easement between resident homes on Piping Rock Rd. The two existing culverts along Chapel Hill Rd would be upsized to 48", and a new 48" culvert added in parallel. At the downstream end of the greenway, box culvert (4'x6') will replace existing corrugated pipes to improve conveyance.

The Chapel Hill greenway would also be reshaped to increase capacity for the increased pipe flows contributing to it. The proposed channel will remain grassed side slopes with a natural bottom.

Pipes were upsized to accommodate the 10% AEP design storm. Some additional comments on the proposed design are below:

- The proposed design assumes that several streets east of the project area, that currently do not have piped storm water infrastructure (e.g. Shoreham Dr, Romford Rd, Valley Stream, Dr, portions of Hathaway Dr) will eventually have a storm system added. These pipes could be designed and sized during normal street reconstruction scheduling by the City, but should not be completed until after the Norman Clayton Park and Greentree-Chapel Hills Park greenways have been redesigned for additional capacity.
- The solution can be implemented in tandem with the 'Norman Clayton Park and Storm System Improvements' project.

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-H**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Buildings/structures are no longer impacted by the 1% AEP design storm. *Note that this area already fulfilled this goal under existing conditions.*
- Goal 2: The proposed solution reduces the surface flooding, and prevents stormwater structures from flooding during 10% AEP design storm.
- Goal 3: Inundation along the curblin decreases with this proposed improvement, and there is less than 0.5-ft of water along the curblin during the 10% AEP design storm. The inlet restricted sag location at the corner of Laurie Dr and Shoreham Dr no longer has 0.5' of water at the curblin during the 10% AEP design storm.
- Goal 4: This area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm.
- Goal 5: There is one enclosed depression within this solution area (on Piping Rock Rd) that would met this goal criteria under proposed conditions.

- Goal 6: This solution prevents the greenway from overtopping. Note that there is still water on the street, but this is from street-flow rather than from the greenway.

This solution improves historical flood conditions at the Greenway Crossing at Chapel Hill Road (See **Section 2.3, Figure 2**).

Project Constraints/Considerations

This proposed solution will be contained within the City right-of-way or on the City's Stormwater Utility land. The project will require access to using the existing easement between two residential homes on Piping Rock Rd. The costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance. There are no other known or potential issues that could impact costs or the ability to construct the improvement.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- WDNR Stormwater NOI (>1 acre disturbance)

Water Quality Benefits

The new trunkline storm sewer improvements and greenway design will not provide water quality benefits.

Additional Notes/Information

Note that **Figures 31-38** show the inundation after all of the improvements have been built. Flood reductions in this area are likely due to a combination of improvements, including the 'Norman Clayton Park Greenway and Storm System Improvements' project.

10.9 McKenna Blvd Improvements

Detailed Project Description

The intersection of the Chapel Hills Park Greenway and McKenna Blvd was recently reconstructed (2019). The August 2018 storm event caused damage to the existing infrastructure, and the City upsized the culverts crossing McKenna Blvd into Elver Park to improve conveyance at this bottle neck location. Portions of the greenway were also reconstructed as part of this project. All of the modeling done within this study used the updated design conditions.

Note that the proposed solution maps do not include the 2019 design as the GIS data had not been updated yet at the time of writing this report.

While the 2019 project improved the connectivity between the Chapel Hill Greenway and Elver Park, there are additional flooding concerns associated with McKenna Blvd flooding. This water is coming from the street itself, rather than the greenway over topping the road. Flooding extends beyond the street right-of-way during the 10% AEP design event onto private property. Portions of McKenna Blvd, specifically between the Elver Park entrance and Hammersley Rd, has more than 0.5' of water at the centerline during the 25% AEP design storm.

To address flooding throughout this region, this project would upsize the existing piped stormwater system along McKenna Blvd, both to the west and east of the Elver Park Entrance. To the west, the existing pipes would be upsized and a new outlet configured to discharge flows directly to the Elver Park Pond, and remove the connection to the box culverts passing under McKenna Blvd. To the east, the existing stormwater system would be removed from the north side of the road, and instead conveyed along the south side, with a new discharge directly to the Elver Park Pond.

Both of these improvements would reduce the capacity needs for the newly designed culverts passing underneath McKenna Blvd. This capacity relief would allow for more systematic upgrades in the northern portions of the study area since any improvements to conveyance upstream must be managed within the lower reaches as well.

Pipes were upsized to accommodate the 10% AEP design storm, and to reduce 1% AEP inundation at the McKenna Blvd sag to locally drained runoff, not main channel overtopping. Some additional comments on the proposed design are below:

- The original proposed solution modeled the eastern pipes along McKenna Blvd on the northern side of the road (following the existing pipe configuration, but then crossing McKenna Blvd to discharge into the pond). This was initially done to minimize impact on the park property to the south. As part of the City's review, it was requested to shift the piped system to the south side of the road, due to feasibility of construction.
- The XPSWMM model was not updated to show the pipe alignments on the southern side of the road, as City staff indicated that this modification would likely not impact the modeling results dramatically, and it could be modeled in more detail if/when the project is formally designed.
- It is recommended that new storm sewer be installed on some of the eastern roads where there currently is no sewer system. The City requested that these not be modeled as part of this effort, but those locations should be considered for improvements when the streets are reconstructed. These roads include Hammersley (near the intersection with McKenna Blvd) and Jacobs Way. Adding in this storm sewer could help meet Goal 2 (reduce surface flooding during the 10% AEP design storm).
- Inlet capacity at the sag on Park Edge Dr, adjacent to Georgetown Ct, should be increased. The 10% AEP runoff to this location is approximately 19 cfs. The existing inlet capacity is approximately 6 cfs. A terrace inlet installed on the NW side of the street is recommended.

A map of the proposed storm sewer improvements for this area are shown on **Figure 30-I**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Buildings/structures are no longer impacted by the 1% AEP design storm. *Note that the Elver Park Shelter is still impacted by the 1% AEP Design storm with this proposed solution.*
- Goal 2: The proposed solution reduces the surface flooding, and prevents some (but not all) stormwater structures from flooding during 10% AEP design storm. *Note that some of the issues could be resolved by adding in storm sewer to the adjacent unsewered streets (Hammersley Rd, Jacobs Way, and extending further up McKenna Blvd).*
- Goal 3: Inundation along the curblin decreases with this proposed improvement. *Note that some of the issues could be resolved by adding in storm sewer to the adjacent unsewered streets (Hammersley Rd, Jacobs Way, and extending further up McKenna Blvd).*
- Goal 4: The majority of the area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm.
- Goal 5: There are no enclosed depressions within this proposed solutions area.
- Goal 6: This solution reduces the amount of water on the road at the greenway intersection with McKenna Blvd. *Note that the water present on the road in this area was from the road surface itself flooding, rather than the greenway overtopping.*

Project Constraints/Considerations

This proposed solution will be within the City right-of-way and also within Park lands. Both the western and eastern improvements on McKenna Blvd will require a new outfall into the Elver Park Pond, and will need careful coordination with the Parks Department. The eastern pipes will parallel the sidewalk on the southern side of the road on Park lands. The outfall with the pipes on the eastern side will require more careful review since the pipe alignment will cross underneath the existing parking lot. The Elver Park pond also has mapped wetlands, and they might be impacted by new outlet structures; therefore project planning should include a detailed wetland inventory and early discussions with WDNR.

The costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- Wisconsin DNR/USACE Permit for Wetland Disturbance (potential)
- WDNR Stormwater NOI (>1 acre disturbance) – if entire project is constructed concurrently

Water Quality Benefits

The new trunkline storm sewer improvements will not provide water quality benefits.

Additional Notes/Information

Note that **Figures 31-38** show the inundation after all of the improvements have been built.

10.10 Elver Park Greenway Reconstruction

Detailed Project Description

The Elver Park Greenway is near the downstream end of the watershed, and therefore provides an opportunity to increase the storage capacity of the stormwater system. Any upgrades to the piped system in the northern portions of the watershed will need to be conveyed through the watershed, and this greenspace can be designed handle additional flows. The space currently is owned by a private party, but will eventually be purchased by the City and incorporated into Elver Park. Therefore, the proposed design was purposefully kept near the western portion of the parcel (allowing for more land to the east to be utilized for park space), while also keeping the greenway east of the existing MMSD mainline.

The current land consists of a natural channel, with mowed/agricultural lands on either side. During large storm events, the fields are inundated and can cause overtopping of Mid Town Rd to the south. This solution should be paired with the 'New Detention Basin (Marty Road/Mid Town Road Regional Pond)' project, which includes replacing the culverts under Mid Town Rd.

The proposed greenway would expand the centralized channel width to 16 ft and an approximate high-flow channel of 200 ft. The channel would maintain the natural bottom. The existing 5' x 8' box culvert under Mid Town Rd would be replaced by four 3' x 6' boxes.

A map of the proposed greenway reconstruction is shown on **Figure 30-J**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Buildings/structures are no longer impacted by the 1% AEP design storm. *Note that this area already fulfilled this goal under existing conditions.*
- Goal 2: The proposed solution reduces the surface flooding, and prevents stormwater structures from flooding during 10% AEP design storm at Mid Town Rd (*assuming this project is coupled with the New Detention Basin to the south*).
- Goal 3: Inundation along the curblin decreases with this proposed improvement, and there is less than 0.5-ft of water along the curblin during the 10% AEP design storm (*assuming this project is coupled with the New Detention Basin to the south*).
- Goal 4: The area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm (*assuming this project is coupled with the New Detention Basin to the south*).
- Goal 5: There are no enclosed depressions within this proposed solutions area.
- Goal 6: This solution prevents the greenway crossing at Mid Town Rd from overtopping (*assuming this project is coupled with the New Detention Basin to the south*).

Project Constraints/Considerations

This proposed solution will be within the City right-of-way and also within future Park lands. Currently the land is owned by a private party; therefore the property must be acquired prior to advancing with the project. Note that the cost estimates for this project do not include the capital required for land acquisition. This project should be planned in coordination with the 'New Detention Basin (Marty Road/Mid Town Road Regional Pond)' since the greenway outlet design was optimized to work with the new basin to the south. The City also has plans to re-align Raymond Rd to the

south. Planning for this large stormwater effort should be coupled with detailed understanding of the new road layout(s).

Careful consideration should also be given to the MMSD sanitary main located just to the west of the proposed greenway grading. Careful consideration will be also be required to install the four new 3' x 6' box culverts directly under existing 8" City sanitary sewer main along the south side of Mid Town Road (minimal separation between box and sanitary main). The new box culverts under Mid Town Rd will need to have a WisDOT bridge number assigned since total span is >20'.

Also, the existing Elver Park pond has mapped wetlands. The realigned greenway might impact those areas and therefore project planning should include a detailed wetland inventory and early discussions with WDNR.

Note this area encompasses part of the Town of Middleton. The City will not be able to implement this improvement, unless the Town is annexed at some point in the future.

The costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- Wisconsin DNR/USACE Permit for Wetland Disturbance (if wetlands are present)
- WDNR Stormwater NOI (>1 acre disturbance)
- WDNR Chapter 30 individual permit
 - Culvert Construction
 - Grading
 - Stream Realignment
 - Dredging Streams
- WDNR Water Quality Certification (if wetlands are present)

Water Quality Benefits

The proposed greenway reconstruction will not provide water quality benefits.

Additional Notes/Information

Note that **Figures 31-38** shows the inundation after all of the improvements have been built. Flood reductions in this area are likely do to a combination of improvements, including the 'New Detention Basin (Marty Road/Mid Town Road Regional Pond)'.

10.11 New Detention Basin (Marty Road/Mid Town Road Regional Pond)

Detailed Project Description

A large agricultural field lies at the downstream end of the Greentree/McKenna watershed, and the land is slated to be purchased by the City of Madison at some point in the future. Since it is the furthest downstream point in the watershed, it provides a unique opportunity to construct a large regional detention basin to safely store and gradually release waters back into the existing channel flow to the south during larger rain events.

This area is also undergoing land use changes, specifically major roadway realignments. Raymond Rd will be re-aligned to curve to the north, intersecting Mid Town Rd to the west. The southern portion of Raymond Rd will be turned into a cul-de-sac, and Marty Rd will also be converted to a cul-de-sac. The new road alignments leaves an open area with enough space for a large regional stormwater pond to be constructed to capture the flows from the entire watershed. Since this is a proposed wet detention basin, there is a potential for water quality benefits, as well as flood reduction benefits.

The proposed pond will be a wet basin with a permanent water surface area of approximately 12 acres. It has been sized to accommodate the increased flows under proposed conditions, while not increasing discharge to downstream areas.

The proposed Raymond Rd alignment will pass over the existing Marty Rd. It is intended that a bike path will link both sides of the proposed Raymond Rd alignment and act as a high level overflow for the pond outlet. This study did not evaluate the bike path layout, but any future detailed design should accommodate a path with a similar alignment.

A map of the wet detention basin is shown on **Figure 30-K**.

Associated Flood Reduction Benefits

As a result of the local storm sewer improvements, the City's flood control goals will be met as follows:

- Goal 1: Buildings/structures are not impacted by the 1% AEP design storm.
- Goal 2: The proposed solution reduces the surface flooding, and prevents stormwater structures from flooding during 10% AEP design storm at Mid Town Rd.
- Goal 3: Inundation along the curblin decreases with this proposed improvement, and there is less than 0.5-ft of water along the curblin during the 10% AEP design storm.
- Goal 4: The area meets the goal of no more than 0.5-ft of water at the road centerline for the 4% AEP design storm.
- Goal 5: There are no enclosed depressions within this proposed solutions area.
- Goal 6: This solution prevents the greenway crossing at Mid Town Rd from overtopping.

Project Constraints/Considerations

Portions of this proposed solution will be within the City right-of-way. Currently the land for the wet detention basin is owned by a private party; therefore the property must be acquired prior to advancing with the project. Note that the cost estimates for this project do not include the capital required for land acquisition. This project should be planned in coordination with the 'Elver Park Greenway Reconstruction' since the greenway outlet design was optimized to work with the new basin. The City also has plans to re-align Raymond Rd to the south. Planning for this large stormwater effort should be coupled with detailed understanding of the new road layout(s).

Careful consideration should also be given to the MMSD sanitary main that parallels the project site. The costs associated with minor utility conflicts that are likely as part of any construction project within developed areas are included in the contingency allowance.

Note this area encompasses part of the Town of Verona. The City will not be able to implement this improvement, unless the Town is annexed at some point in the future.

Anticipated permits

Based on the planning level design, the following environmental permits would be needed:

- City of Madison Erosion Control
- WDNR Stormwater NOI (>1 acre disturbance)
- WDNR Chapter 30 individual permit
 - Culvert Construction
 - Grading
 - Stream Realignment
 - Dredging Streams
 - Pond
- WDNR Water Quality Certification (if wetlands are present)

Water Quality Benefits

The new Marty Road/Mid Town Road Regional Pond improvements could provide water quality benefits. The new pond would have a drainage area of ~1,189 acres, with a pond bottom elevation of 985', a normal water level elevation of 989.5', and the 1% AEP design storm peak elevation of 999.4'. The pond outlet will be a 4.5'x8' box culvert with an upstream elevation of 989.5' and a downstream elevation of 988.6', which will pass underneath the new Raymond Rd alignment; the bridge will also span a bike path and the overflow spillway. Modeling the bridge was not part of this study and will be evaluated during the formal design process. **Table 10.1** shows the proposed basin stage-storage:

Table 10.1: Marty Road/Mid Town Road Regional Proposed Pond Stage-Storage

Contour Elev.	Surface Area (ac)
1000 (Top of Bank)	14.6
999	14.3
998	14
997	13.7
996	13.5
995	13.2
994	12.9
993	12.7
992	12.4
991	12.1
990	11.9
989.5 (Pond NWL)	11.7
989	11.4
988.5 (Bottom Safety Shelf)	11.1
988	11
987	10.9
986	10.8
985	10.7
984.5 (Pond Bottom)	10.6

Additional Notes/Information

Note that **Figures 31-38** show the inundation after all of the improvements have been built. Flood reductions in this area are likely do to a combination of improvements, including the 'Elver Park Greenway Reconstruction'.

The 0.2% AEP event has been modeled without an overflow spillway from the proposed Marty Road Pond and reaches a peak elevation of 1001.6'. An overland flow route will be likely be constructed; therefore, a realistic 0.2% AEP event peak elevation may be lower than this value. The adjacent section of Marty Road will observe inundation at approximately 1002'.

With this proposed improvement in place (in conjunction with all of the other upstream improvements) the watershed outlet has a peak flow of 461 cfs for the 1% AEP design event. For comparison, under existing conditions the peak flow is 536 cfs for the 1% AEP design event.

11 Areas where Flood Control Goals are Not Met

In most of the Greentree/McKenna Watershed the City's flood control goals are met. However, in limited locations there are cases where the goals are not met. Further consideration of areas not meeting the flooding goals are provided in this section, to provide insight as to why some solutions are not feasible and/or beyond the scope of this study.

11.1 Goal 1: Homes and Businesses (1% AEP)

No homes or businesses will be flooded during the 1% Annual Exceedance Probability (AEP) design storm.

This criteria was evaluated by buffering the building footprints by 5-feet and intersecting them with the 1% AEP inundation raster. Any buffered building that had a maximum inundation of greater than 0.5 feet was classified as 'potentially experiencing flooding'. Note that this analysis does not account for modifications residents take to mitigate flooding on their own properties. Under existing conditions, 48 structures could be impacted by the 1% AEP design storm (3.6% of the 1,325 structures identified within the watershed). Under the proposed conditions, 20 structures could still be impacted by flooding during the 1% AEP design storm (1.5%).

One (1) residential structure is downstream of a private stormwater pond near Holt Ct. The proposed solutions modified the inlet pipe to this pond, but do not make modifications to the pond itself or the outlet structure as it was outside the scope of this study. It is recommended that the private pond be reviewed prior to installing the new stormwater system along E Valley Ridge Dr. Redesigning the pond to have more capacity and/or changing the outlet structure will reduce overland flow along Holt Ct and the potential concerns to adjacent structures.

Four (4) of these are non-residential structures, north east of Schroeder Rd and Struck St. For each of these locations, stormwater originating on private property is flowing across private property and potentially impacting the structures. Stormwater improvements would be required on private lands to alleviate these flooding concerns. Improvements have been installed within the public right-of-way for most of these locations, which improves the flooding conditions, but does not solve the problem entirely.

Seven (7) of the structures are associated with a multi-family development just west of Struck St and Schroeder Rd. Similarly, stormwater originating on private land flows over private property, potentially impacting the buildings. A portion of the overland flow is from a privately owned detention basin (see **Section 9.2.1.3**). Improvements have been installed within the public right-of-way along Schroeder Rd, which improves the flooding conditions, but does not solve the local problem.

One (1) structure associated with a single family home could be impacted in the southwest of the watershed, just north of Mid Town Rd. This flooding is believed to be associated with overflows from a private stormwater pond. Stormwater improvements would be required on private lands to alleviate this flooding concern.

Four (4) multi-family structures and one (1) single family structure along the west side of the greenway between McKenna and Schroeder are still subject to 1% AEP design storm flood risk. The situation adjacent to these structures is improved, but not entirely solved. This is due to capacity limitations within the publicly owned greenway to the east. The Greenway was redesigned to maximum capacity given its physical space limitations in 2019/2020 (see **Section 9.2.1.2**); Modifying the greenway was therefore not included as a potential solution within this study.

One (1) structure is a maintenance building, located within the Greentree Chapel Hills Park proper, immediately adjacent to the greenway. Redesigning the greenway to address flooding concerns was not included within this study (see **Section 9.2.1.2**).

One (1) structure is the Elver Park picnic shelter. Redesigning the park amenities, ice rink and Elver Park pond was not requested by the City as part of this study.

11.2 Goal 2: Flooding Storm Sewer (10% AEP)

Eliminate flooding from the storm sewer system for up to the 10% AEP design storm; all water shall be contained within the pipes and structures (exception: street vertical alignment sag points).

This criteria was evaluated by buffering all of the modeled publicly owned access structures and inlets by 15-feet. Any buffered structure that intersected the 10% AEP inundation raster was classified as a 'potential problem location'. The XPSWMM model contained 264 modeled publically owned access structures and inlets; note that the model did not include *all* of the publically owned structures. Under the existing conditions, 189 of the modeled structures were classified as a potential problem location. Under the proposed conditions, 98 of the modeled structures were classified as a potential problem location.

The criteria for evaluating this goal was quite strict, with any surface water triggering a potential problem location. The proposed scenario was not anticipated to alleviate all surface flooding and contain all runoff within the piped system, as this would require an unlikely level of upsizing throughout the watershed. It also would hinder efforts to identify the areas most in need of improvement.

11.3 Goal 3: Inlet Restricted Low Points (10% AEP)

Allow no more than 0.5 feet of water above storm sewer inlet rim at inlet-restricted low points for up to the 10% AEP design storm.

This criteria was evaluated by first identifying all of the low points within the existing stormwater system. A subset of these low points were classified as being "inlet restricted" (see **Section 5.4.3**). Next, the edge of pavement was clipped to 50-foot segments and intersected with the 10% AEP inundation raster to determine locations where the water was at least 0.5 feet or greater along the curb line. Any inlet-restricted low point with at least 0.5 feet of water along the curb line was classified as a 'potential problem area'. A total of 25 low points were identified within the watershed and 5 were classified as being inlet-restricted. Under existing conditions, 3 had more than 0.5-feet of water present along the curb line.

Under proposed conditions, none of the inlet-restricted low points were classified as a problem area. Therefore, this goal is met across the entire watershed.

11.4 Goal 4: Street Centerlines (4% AEP)

Centerline of street to remain passable during 4% AEP design storm with no more than 0.5 feet of water at the centerline.

This criteria was evaluated by using a road centerline dataset, split at 50-ft intervals and intersecting them with the 4% AEP inundation raster. Any segment with more than 0.5-feet of water was classified as a 'potential problem location'.

The watershed has the 20.8 miles of roads. Under existing conditions, 2.7 miles were classified as problem locations (13.0%). Under proposed conditions, 0.5 miles were classified as problem locations (2.4%).

This goal was not met along Watts Rd, east of the main channel. In this case the tailwater condition within the channel was the limiting factor, not the capacity of the storm sewer. Portions of Valhalla Way, New Washburn Way, and High Points Estate Dr also don't meeting this criteria. Proposed solution analysis showed local storm sewer capacity would need to be increased above the 10% AEP event in order for these areas not to be flagged, and was considered excessive. Valhalla Way in particular is narrow and increasing pipe capacity further may not fit in the available space.

The remaining locations where this goal was not met were small stretches with an average length of 100-ft. Many of these locations were not recommended by the City as major problem locations (due to their short lengths) and therefore solutions were not prioritized as part of this study. However, when these street segments are reconstructed as part of the traditional street maintenance/repair efforts, local storm sewer improvements may mean that these areas are no longer considered a concern.

11.5 Goal 5: Enclosed Depressions (1% AEP)

Enclosed depressions to be served to the 1% AEP design storm (which can include safe overland flow within street, easements, greenways or other public lands).

For purposes of the watershed studies, an enclosed depression is defined as a depression in the public right-of-way where stormwater impacts private property to overflow the depression. There are fifteen (15) enclosed depressions within the watershed within the street right-of-way, most with a constructed outlet. These were identified by visual inspection of the LiDAR contours, aerial imagery, and parcel boundaries. This criteria was evaluated by individually reviewing each depression to determine if water left the ROW onto private property in order to overflow the depression.

Under the existing conditions, modeling predicts that the 1% AEP service levels are not achieved in nine (9) enclosed depressions. Under the proposed conditions, four (4) enclosed depressions might impact private property.

Two (2) of the abovementioned enclosed depressions are along Seybold Rd, currently within the Town of Middleton. The pipes along this road were upsized under the proposed conditions to match the capacity of the downstream greenway. Increasing the pipe capacity any further along Seybold Rd would cause the greenway to overtop and cause downstream flooding in other areas of the watershed.

One (1) enclosed depression is along Forward Dr. Pipes were upsized here to flow into an existing pond to the west. Some of the overland flow will also spill over into the pond to the west, and some water will flow east onto private property which is currently designed as a drainage ditch. To prevent flooding to the east, the private land owner would need to fill in the drainage ditch to prevent water from ponding in this location. Pipe capacity alone is unlikely to mitigate the flood risk to structures at this location.

The final one (1) enclosed depression is along Saalsa Rd. This location already has a high capacity inlet and two pipes from the low point to the adjacent greenway. Inundation encroachment onto private property was minimal and a proposed improvement would require lowering the Greentree Pond depth to improve the drainage of this intersection (see **Section 9.2.1.6**) and therefore a solution was not recommended for this location.

11.6 Goal 6: Greenways (1% AEP)

Greenway crossings at streets to be served to the 1% AEP design storm.

This criteria was evaluated by identifying all of the locations where channelized overland flow crosses underneath a roadway. Each location was intersected with the 1% AEP inundation raster, to determine if water was present on top of the road. Most of these occurrences are due to water flowing over the road from one side of a greenway to the other side. However, some locations have water on the road due to flow accumulations in the street due to inadequate local storm sewer system capacity. An example of this is the McKenna Blvd crossing of the Greentree channel.

There are seven (7) greenway crossings within the watershed. Under existing conditions, four (4) of those indicated water overtopping the road from the greenway in the 1% AEP event. Under proposed conditions, these locations were no longer identified as potential problems.

Two locations still have water on the road, but this is due to flow accumulations within the street (rather than coming from the greenway). One location is McKenna Blvd crossing of the Greentree channel. Water at this location is due to flow accumulations in the street rather than the greenway over topping. The second is at Chapel Hill Rd. The neighborhood directly north of this intersection currently does not have piped storm sewer; therefore any overland drainage will be channeled in the street areas before entering the greenway. Adding in additional storm sewer to currently un-sewered streets and piping it to the greenway should alleviate this concern. There is also some overland flow contributing from the south.

12 Climate Resilience Analysis

12.1 0.2% Chance Analysis

The following section describes anticipated changes in 0.2% AEP (500-yr) flooding between existing and proposed conditions. It is important to note that alternatives analyses completed as part of this project were focused on improving conditions under 1% AEP event conditions with specific regard to not shifting existing problems from one area to another. Under 0.2% AEP event conditions the capacity of even the conceptually improved stormwater management infrastructure is anticipated to be exceeded and while some areas still see improvements in flooding relative to existing conditions, there are areas in the watershed where flooding under 0.2% AEP conditions are shown to be worse.

North of Schroeder Rd model result show a slight increase in the 0.2% AEP flood depths along Struck St. Most of the area where increases are shown are within Stormwater Utility lands, parks or street right-of-ways. However, there are small slivers to the east and west that appear to occur on private properties. Those to the west appear to be a result of model sensitivity, rather than any effects for any proposed improvements. Those to the east appear to be as a result of the DEM being out of date (it does not account for private improvements to reduce flood risk on the property).

South of Schroeder Rd the 0.2% AEP depths also show an increase in maximum depth for the 0.2% AEP event, with maximum increases shown to be ~0.5' immediately south of Schroeder Rd, dropping to zero at Greentree Pond. Maximum inundation depths within Elver Park also increase; however these increases are contained within the City owned Park Land.

Because of the highly developed condition of the upper portions of the Greentree/McKenna watershed (those areas north and east of Elver Park) nearly all of the improvements evaluated in this portion of the watershed focused on increasing drainage capacity in the form of larger storm sewers and improved open channel greenways. In general, these are the areas of the watershed where flood conditions, even in 0.2% AEP event conditions saw a substantial improvement in flooding conditions. The proposed pond between Mid Town Road and realigned Raymond Road is capable of controlling peak runoff rates from the watershed to well under existing conditions, so increases in 0.2% flood risk are limited to only the area described previously and will not pass downstream out of the Greentree/McKenna watershed.

Across the watersheds, with regard to structures at risk of 0.2% AEP event flooding, there is a substantial improvement under proposed conditions. Under existing conditions, 78 structures are anticipated to be affected by 0.2% AEP event flood conditions. Under full-watershed improved conditions, this number is anticipated to be reduced to 41. This is a net reduction of 37 structures. Proposed conditions do not cause any buildings not currently anticipated to be affected by 0.2% AEP flooding to be affected by 0.2% AEP flooding.

Figure 21 and **Figure 38** present a comparison of flooding conditions under 0.2% AEP (500-yr) conditions.

13 Cost Estimates

In order to help the City plan for future implementation, planning level cost estimates were developed for each of the stand-alone solutions outlined in **Section 10**. For each solution, cost estimates were prepared by creating a tabulated list of estimated quantities. The City provided average unit costs for typical bid items that are often included within stormwater improvement projects. Standard unit costs were adjusted by MSA based on specific project conditions that may result in higher or lower than average unit costs. In these cases, a note was added to justify the rationale for the cost revision. Initial cost estimates were provided to the City for review prior to finalizing them in the report.

The total estimates cost for each of the stand-alone projects is provided in **Table 13.1**. A detailed breakdown for each cost estimate, with quantities, average unit costs, and adjustments is provided in **Appendix K**. *Note that in the Appendix K, some improvements are broken down into smaller segments if the proposed improvement was not contiguous.*

Table 13.1: Stand-Alone Project Cost Estimates for Greentree/McKenna Watershed

#	Project	Estimated Cost
1	Struck St, Seybold Rd and Watts Rd Improvements	\$1.67 M
2	Forward Dr Improvements	\$478 K
3	High Point Estates Pond Reconstruction	\$1.11 M
4	W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements	\$1.87 M
5	New Washburn Way and S Gammon Rd Improvements	\$758 K
6	Schroeder Rd Trunkline Improvement	\$2.03 M
7	Norman Clayton Park and Storm System Improvements	\$1.99 M
8	Chapel Hill Greenway and Storm System Improvements	\$776 K
9	McKenna Blvd Improvements	\$2.01 M
10	Elver Park Greenway Reconstruction	\$2.08 M
11	New Detention Basin (Marty Road/Mid Town Road Regional Pond)	\$11.26 M

14 Recommended Implementation Order

14.1 Technical Implementation Needs

Implementing individual improvements in the one part of the watershed can impact other parts of the watershed. For example, increasing the pipe capacity upstream can negatively impact downstream areas without adequate capacity to handle the increase in peak flows. Within the Greentree/McKenna Watershed, there are some known limitations for implementation order that should be considered prior to advancing any of the proposed solutions. The following guidelines are recommended for implementation:

1. In general, improvement should be implemented from downstream end, progressing towards the upstream projects.
2. The New Detention Basin (Marty Road/Mid Town Road Regional Pond) would preferably be implemented prior to any major upstream storm sewer improvements. This large regional detention basin would provide a large amount of storage for the watershed, and was designed to handle the increased flows that would result from all of the other proposed solutions.
3. The Elver Park Greenway Reconstruction should be designed in tandem with the New Detention Basin (Marty Road/Mid Town Road Regional Pond). These two improvements are connected by a new culvert system, and both should be designed together.
4. Both the New Detention Basin (Marty Road/Mid Town Road Regional Pond) and the Elver Park Greenway need to be considered with the Raymond Rd re-alignment project. If the road alignment design changes, the proposed pond layout would also need to be adjusted.
5. The Chapel Hill Greenway and Storm System Improvements should be designed/completed prior to the Norman Clayton Park and Storm System Improvements. Redesigning the downstream greenway would provide additional capacity for the increased peak flows from the adjacent neighborhoods.
6. The Schroeder Rd Trunkline Improvement should be implemented prior to any of the storm system improvements to the west (Valhalla Way, E Valley Ridge Cir, N Hold Cir, New Washburn Way and S Gammon Rd). The intersection at S Gammon Rd and Schroeder Rd is already at capacity and cannot handle additional flows without first constructing a new trunkline.
7. The High Point Estates Pond Reconstruction should be implemented when possible. This improvement will result in a lower peak rate entering the downstream storm sewer system, which will lower flood risks independent of whether or not the downstream network has yet been upsized. This solution works in conjunction with the improvements identified in point 6, above.
8. The Struck, Seybold, and Watts Rd Improvements should be implemented when possible. The driveway culvert at the Greentree Glen Senior Apartments should be constructed prior to the associated storm sewer improvements.

14.2 Citywide Implementation Prioritization

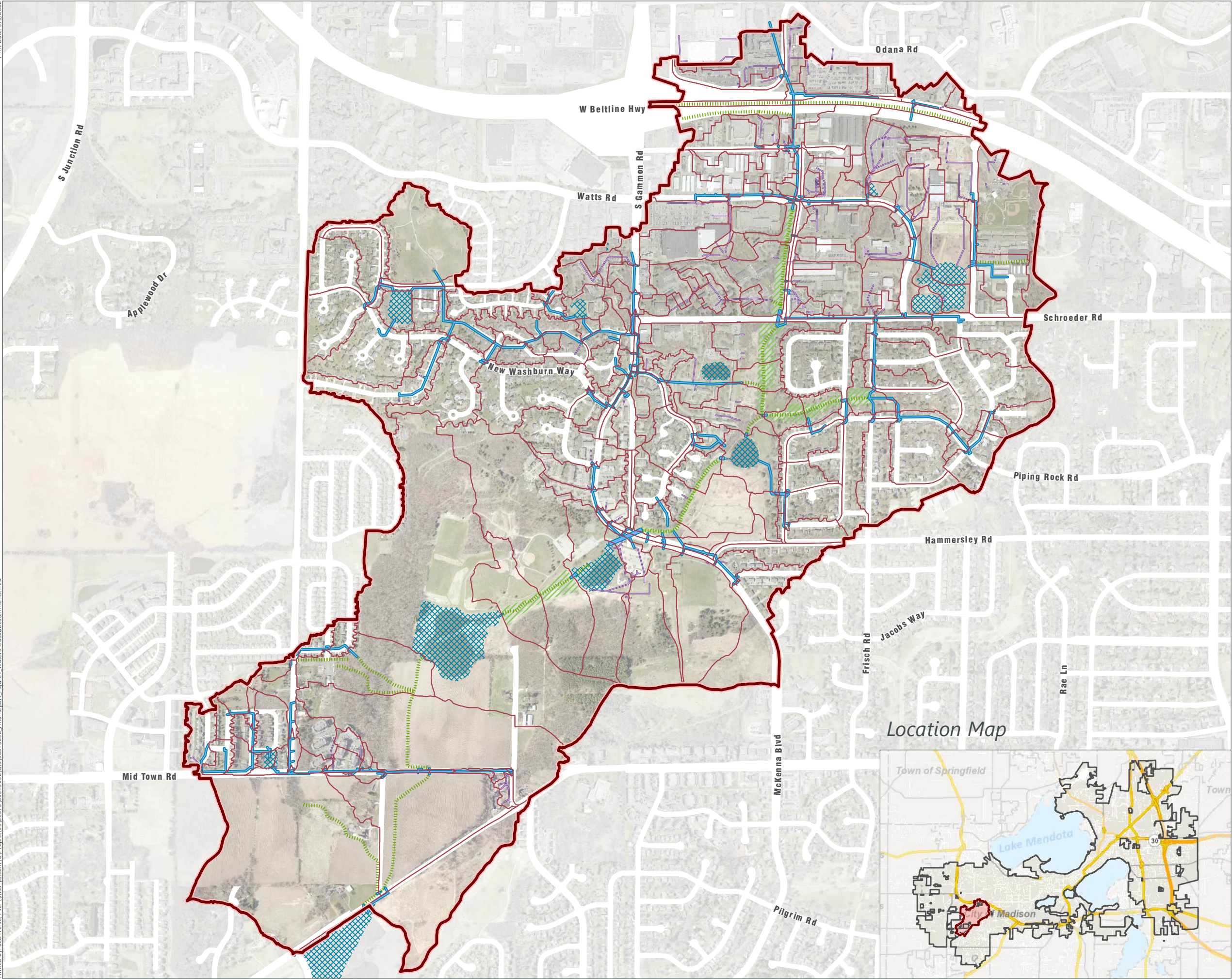
The City is conducting similar studies for all the watersheds in the City, all of which will have numerous recommendations. The City is developing a process to rank and prioritize the order in which the solutions might be implemented if and when funding and public support are obtained. Information on this process will be shared by the City when it is available.

15 Next Steps

At this point, the next steps in the watershed study are to disseminate the findings, for both the existing conditions modeling and the proposed solutions with interested parties. This includes coordinating with City design staff, presenting the information to City Council and other applicable Cities Agencies. Results can also be presented to stakeholders, including local Friends Groups, Neighborhood Organizations, interested Developers and neighborhood residents.

A thirty-day public comment period provided an opportunity to review and comment on the final draft Greentree/McKenna Watershed Study Report, which began on January 5th, 2023 and ended on February 6th, 2023. No comments were received during this period.

Figures

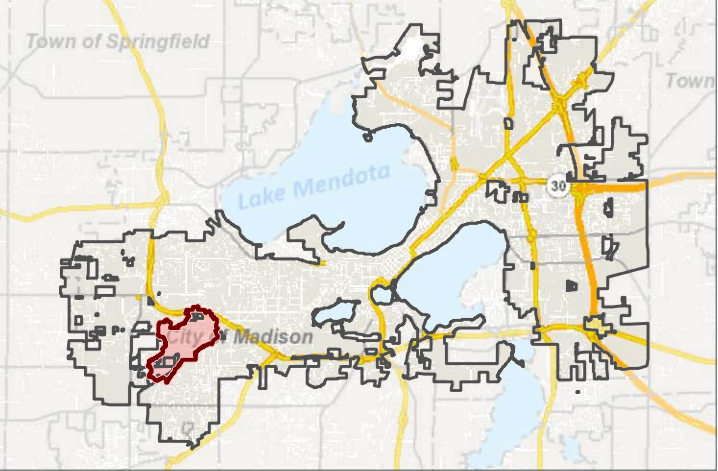


Watershed and Subcatchments

FIGURE 1
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Subcatchments
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow



Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



Historic Flooding

FIGURE 2
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

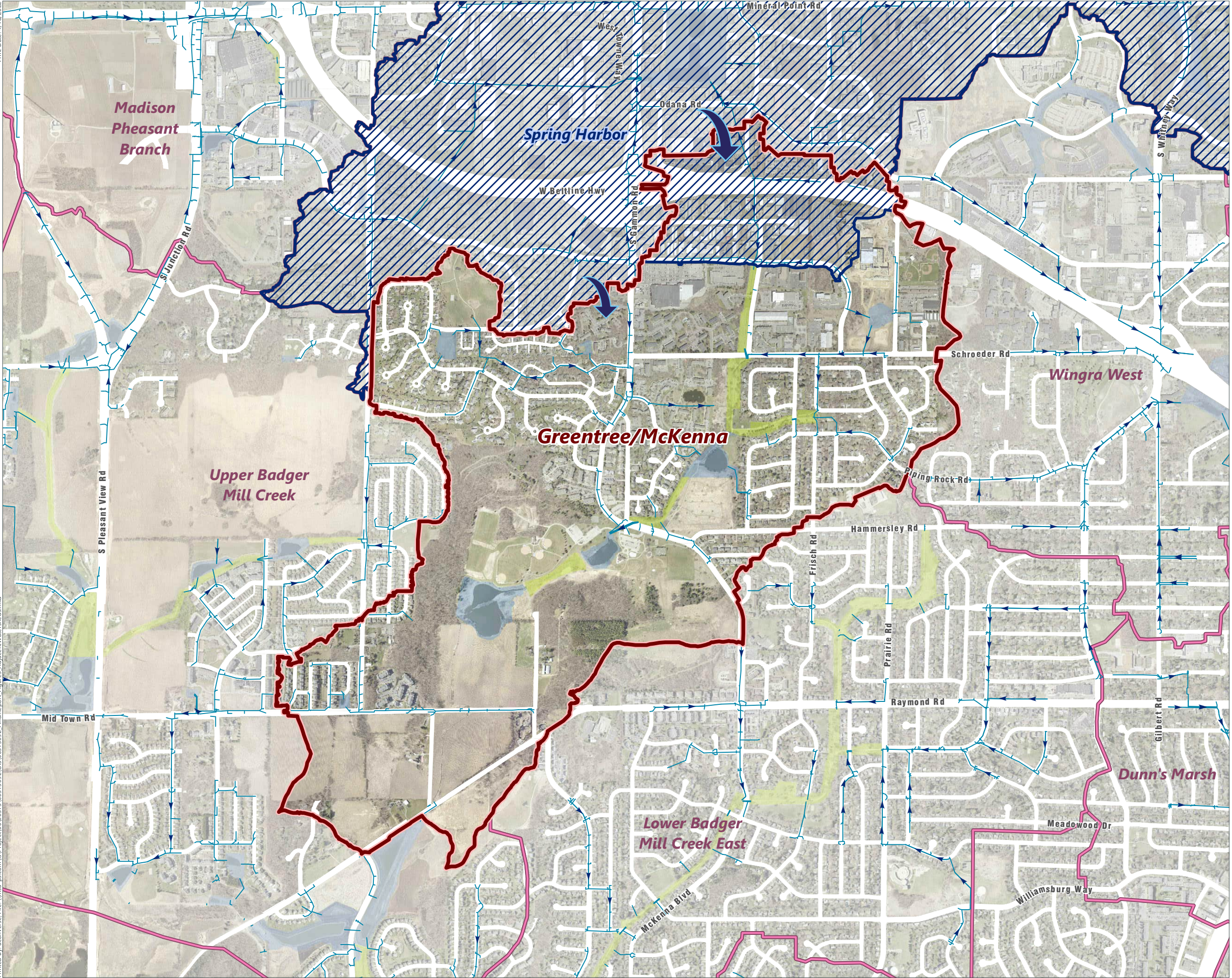
- Watershed Study Area
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow
- Reported Flooding
- Historic/Observed Flood Points
- Operations Flooding Points
- Priority Inlets
- Observations by City Engineering Staff

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Reported Flooding: City's Online Public Reporting (through July 2020)
Historic Flooding, Observations and Priority Inlets: City of Madison
Observations by City Staff: Based on discussions of known flooding concerns with City Engineering Staff on 10/14/2019



0 550 1,100 Feet





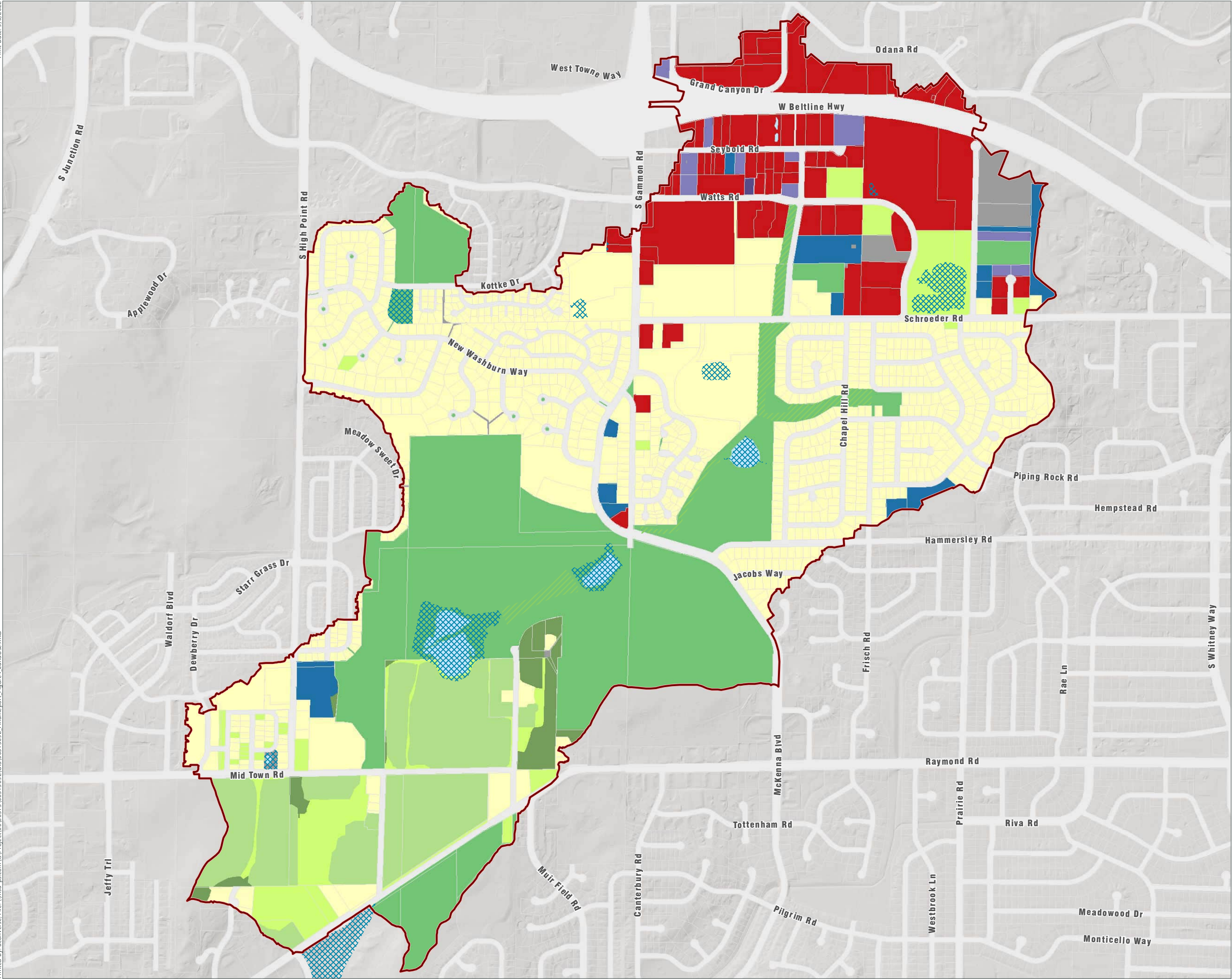
Adjacent Watersheds

FIGURE 3
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Greentree/McKenna Watershed
- Spring Harbor Watershed
- Other Watershed Study Areas
- Greenway
- Pond
- Public Storm System
- Connection/Overflow from Spring Harbor

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



Land Use

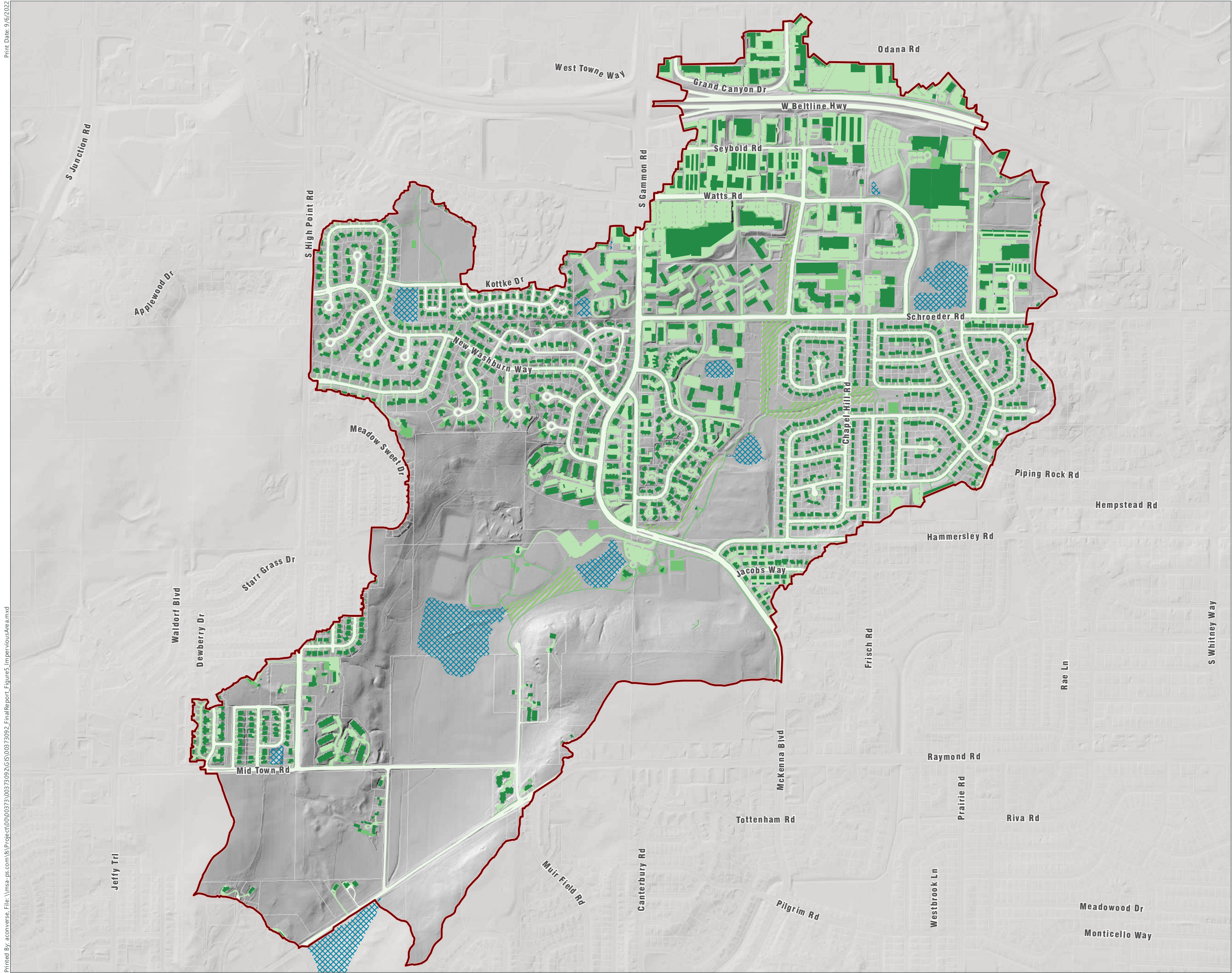
FIGURE 4
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Land Use (2015)
 - Agriculture
 - Commercial
 - Industrial
 - Institutional
 - Manufacturing
 - Recreation
 - Residential
 - Transportation/Utilities
 - Open Land
 - Water
 - Woodlands
 - Greenway
 - Pond

Data Sources:
Hillshade: Dane County LiDAR (2017)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Land Use: Dane County (2015)





Impervious Areas

FIGURE 5
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

-  Watershed Study Area
- Impervious Area
 -  Roof
 -  Sidewalk
 -  Driveway/Parking
 -  Street
 -  Greenway
 -  Pond

Data Sources:
Hillshade: Dane County LiDAR (2017)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Impervious Area: Dane County, City of Madison and MSA



Soils

FIGURE 6
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

 Watershed Study Area

 Greenway

 Pond

Modeled Hydrologic Soil Group

 A

 B

 C

 D

Data Sources:
Hillshade: Dane County LiDAR (2017)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Soils: USDA-NRCS

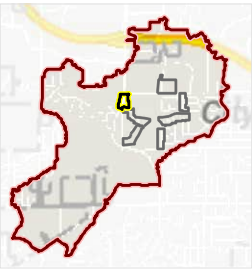


Focus Group Gammon Rd- Schroeder Rd

FIGURE 7A
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Focus Group
- Pond
- Public Storm System
- Private Storm System
- Focus Group Observations
- Flooding Extents
- Observed Flowpath



Focus Group Meeting Date:
7/30/2020

Data Sources:
Aerial: Dane County (2017), Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Focus Group Comments: Residential feedback to MSA staff.

Flooding extents, ponding, etc are in reference to the August 20th, 2018 rainfall event unless otherwise noted.

Print Date: 4/18/2022

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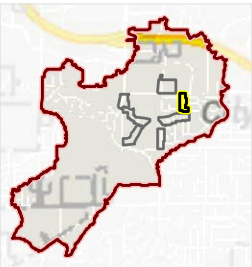


Focus Group Laurie Dr

FIGURE 7B
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Focus Group
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow
- Focus Group Observations
- Flooding Extents
- Observed Flowpath



Focus Group Meeting Date:
7/23/2020

Data Sources:
Aerial: Dane County (2017), Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Focus Group Comments: Residential feedback to MSA staff.

Flooding extents, ponding, etc are in reference to the August 20th, 2018 rainfall event unless otherwise noted.

Print Date: 4/18/2022

Printed By: acowse, File: \\msa-ps.com\is\Project\0000373\00373092\GIS\00373092_FinalReport_Figure7_A-G_FocusGroups.mxd

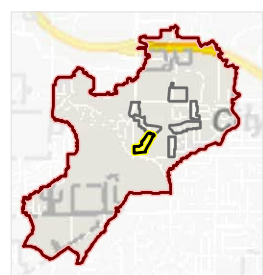


Focus Group Park Edge Dr

FIGURE 7C
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

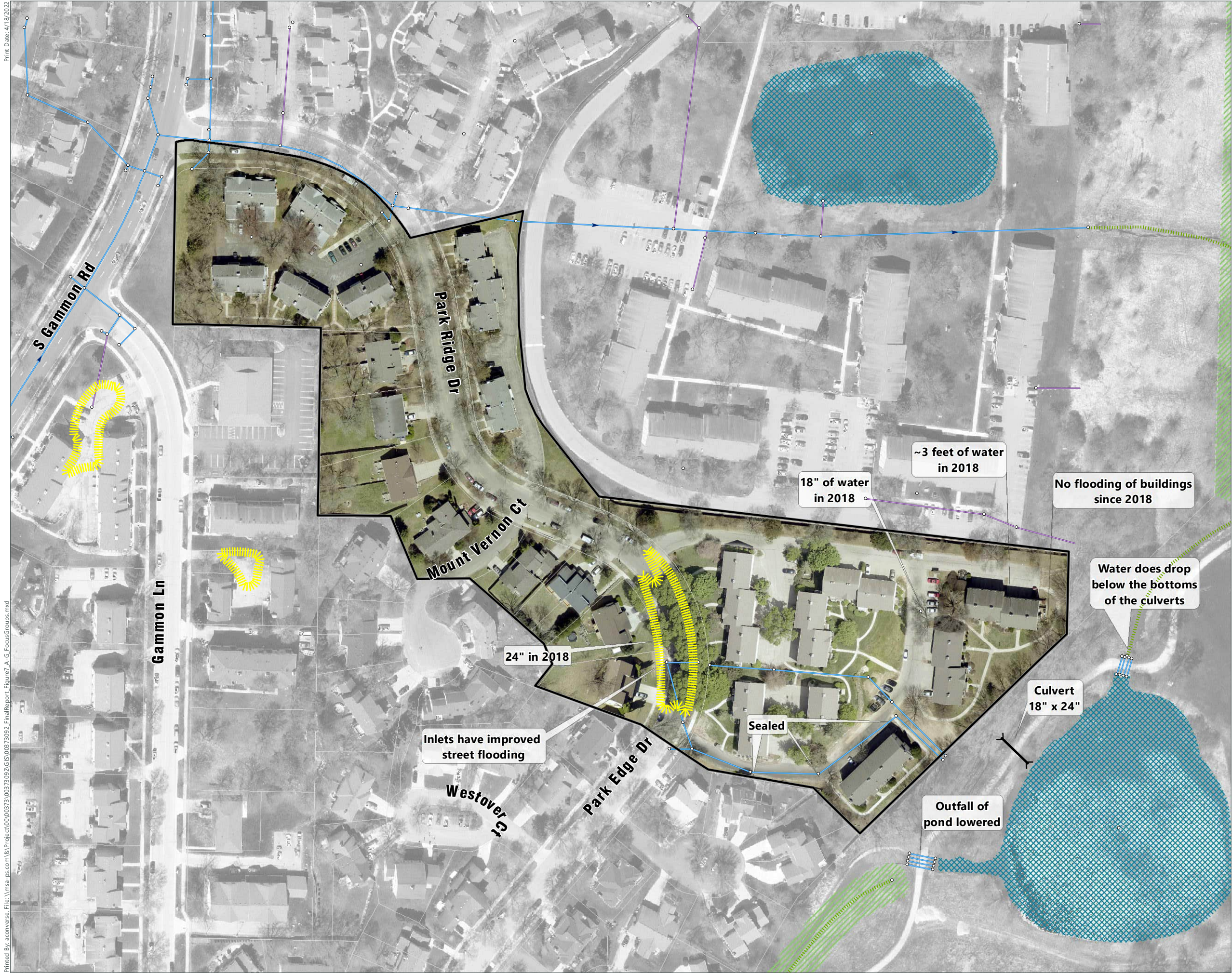
- Focus Group
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow



Focus Group Meeting Date:
7/28/2020

Data Sources:
Aerial: Dane County (2017), Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Focus Group Comments: Residential feedback to MSA staff.

Flooding extents, ponding, etc are in reference to the August 20th, 2018 rainfall event unless otherwise noted.

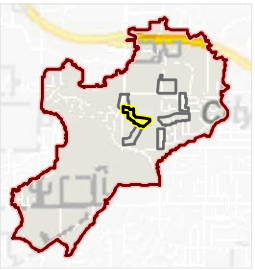


Focus Group Park Ridge Dr

FIGURE 7D
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Focus Group
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow
- Focus Group Observations
- Culvert
- Flooding Extents



Focus Group Meeting Date:
7/28/2020

Data Sources:
Aerial: Dane County (2017), Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Focus Group Comments: Residential feedback to MSA staff.

Flooding extents, ponding, etc are in reference to the August 20th, 2018 rainfall event unless otherwise noted.

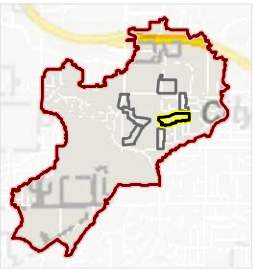


Focus Group Piping Rock Rd

FIGURE 7E
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Focus Group
- Greenway
- Pond
- Public Storm System
- Open Channel Flow
- Focus Group Observations
- Flooding Extents
- Observed Flowpath



Focus Group Meeting Date:
7/29/2020

Data Sources:
Aerial: Dane County (2017), Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Focus Group Comments: Residential feedback to MSA staff.

Flooding extents, ponding, etc are in reference to the August 20th, 2018
rainfall event unless otherwise noted.

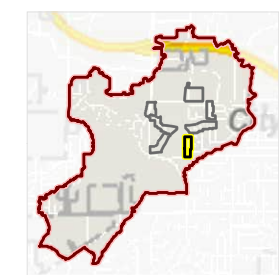


Focus Group Saalsaa Rd

FIGURE 7F
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Focus Group
- Pond
- Public Storm System
- Private Storm System
- Focus Group Observations
- Flooding Extents
- Observed Flowpath



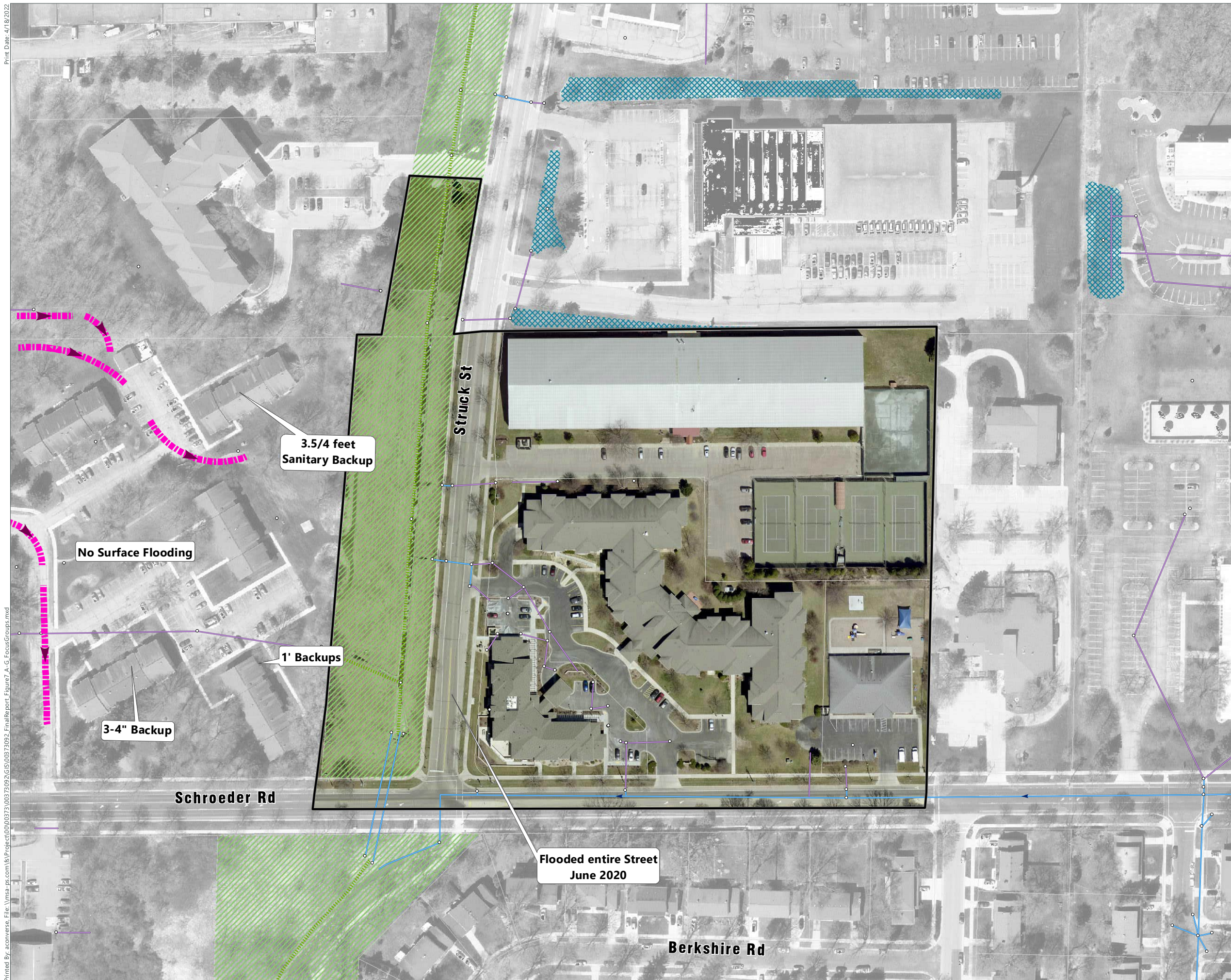
Focus Group Meeting Date:
7/29/2020

Data Sources:
Aerial: Dane County (2017), Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Focus Group Comments: Residential feedback to MSA staff.

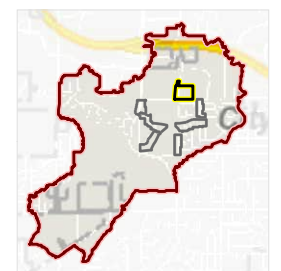
Flooding extents, ponding, etc are in reference to the August 20th, 2018 rainfall event unless otherwise noted.

Focus Group Struck St

FIGURE 7G
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

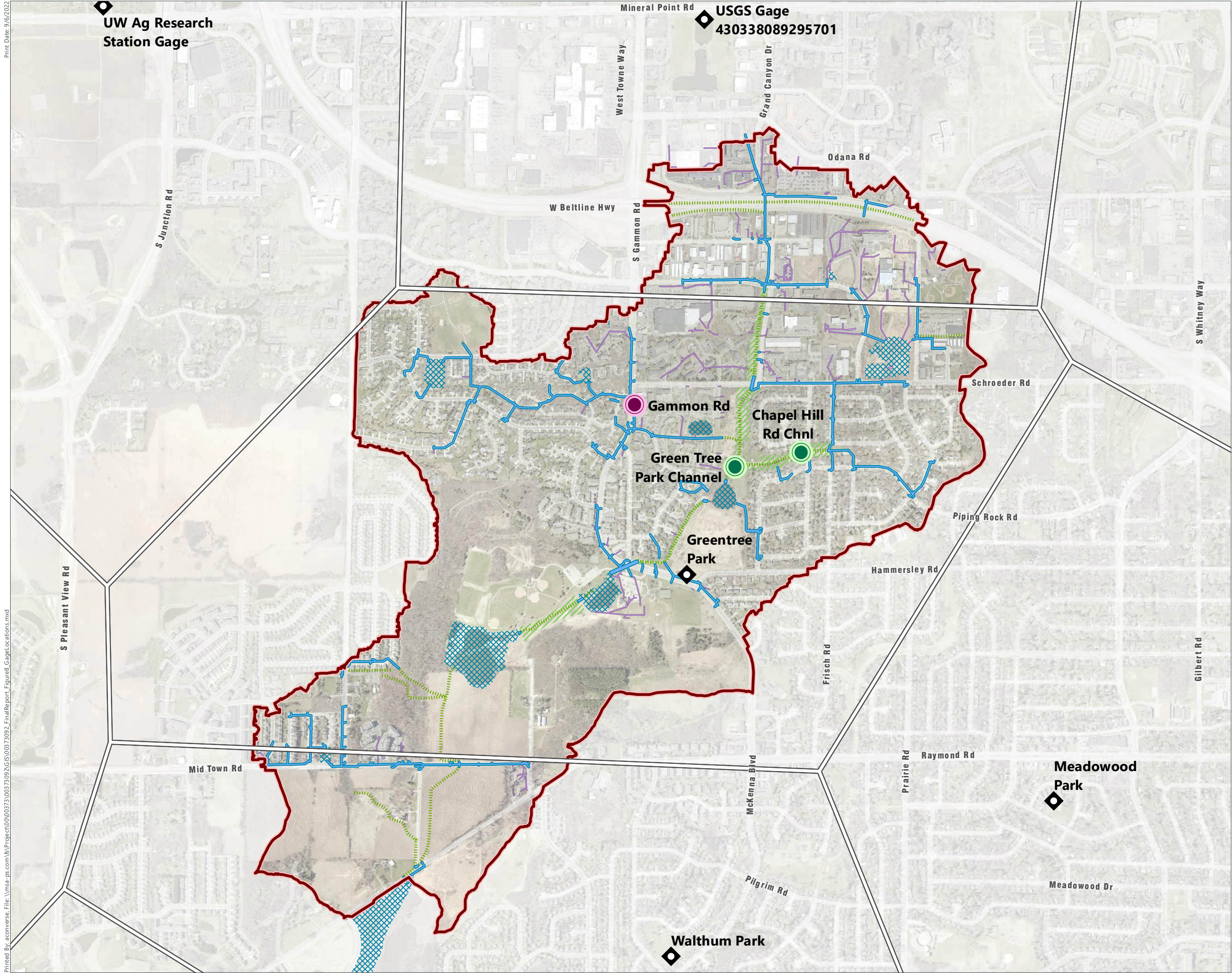
-  Focus Group
-  Greenway
-  Pond
-  Public Storm System
-  Private Storm System
-  Open Channel Flow
-  Focus Group Observations
-  Observed Flowpath



Focus Group Meeting Date:
7/23/2020

Data Sources:
Aerial: Dane County (2017), Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Focus Group Comments: Residential feedback to MSA staff.

Flooding extents, ponding, etc are in reference to the August 20th, 2018 rainfall event unless otherwise noted.



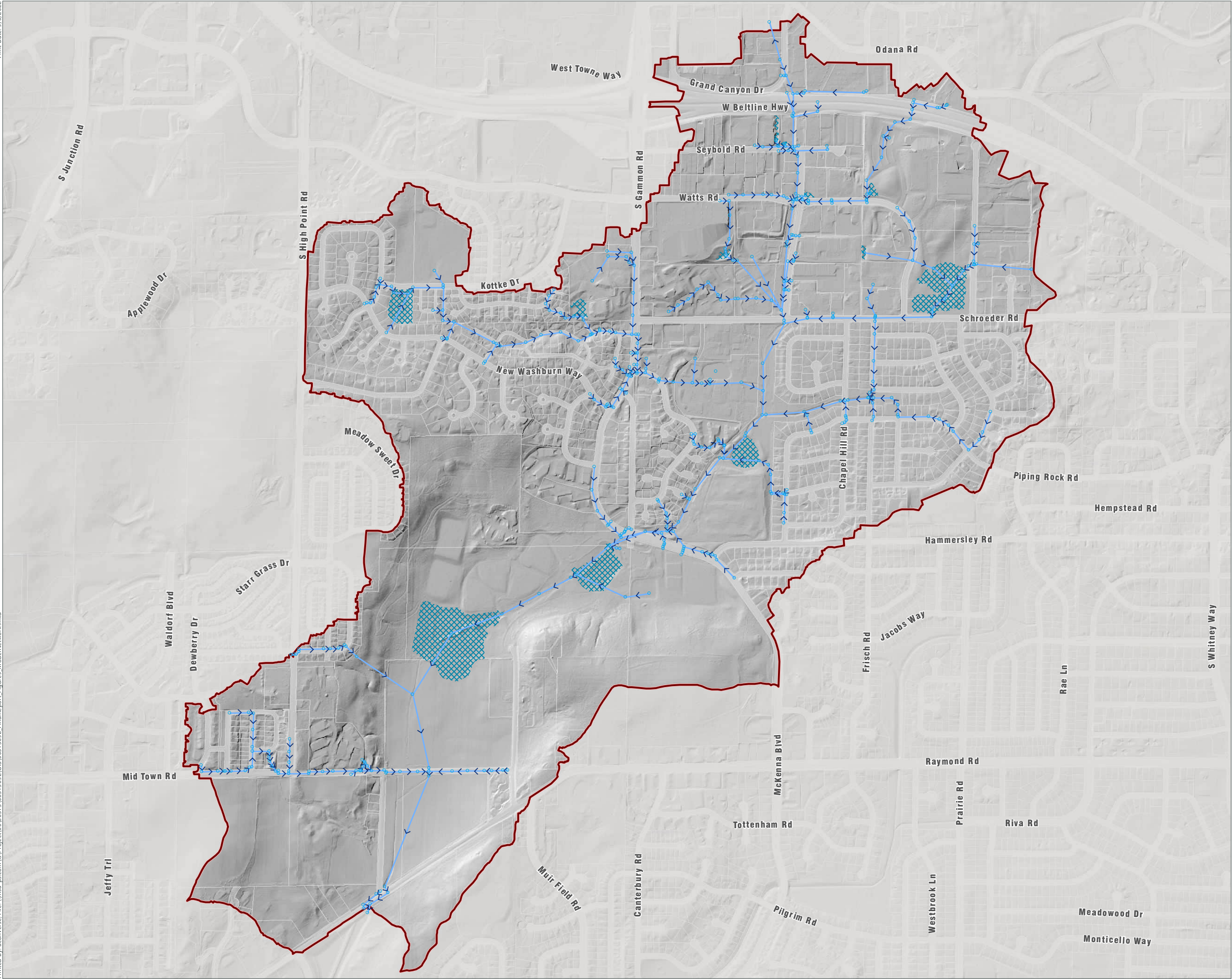
Gage Locations

FIGURE 8
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow
- Remote Monitoring
 - Rain Gage
 - Level Logger (Greenway)
 - Flow Meter (in pipe)
- ThiessenPolygons for Rain Gages

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Gage Locations: City of Madison and the USGS



Model Network

FIGURE 9
Greentree/McKenna Watershed
Study Report

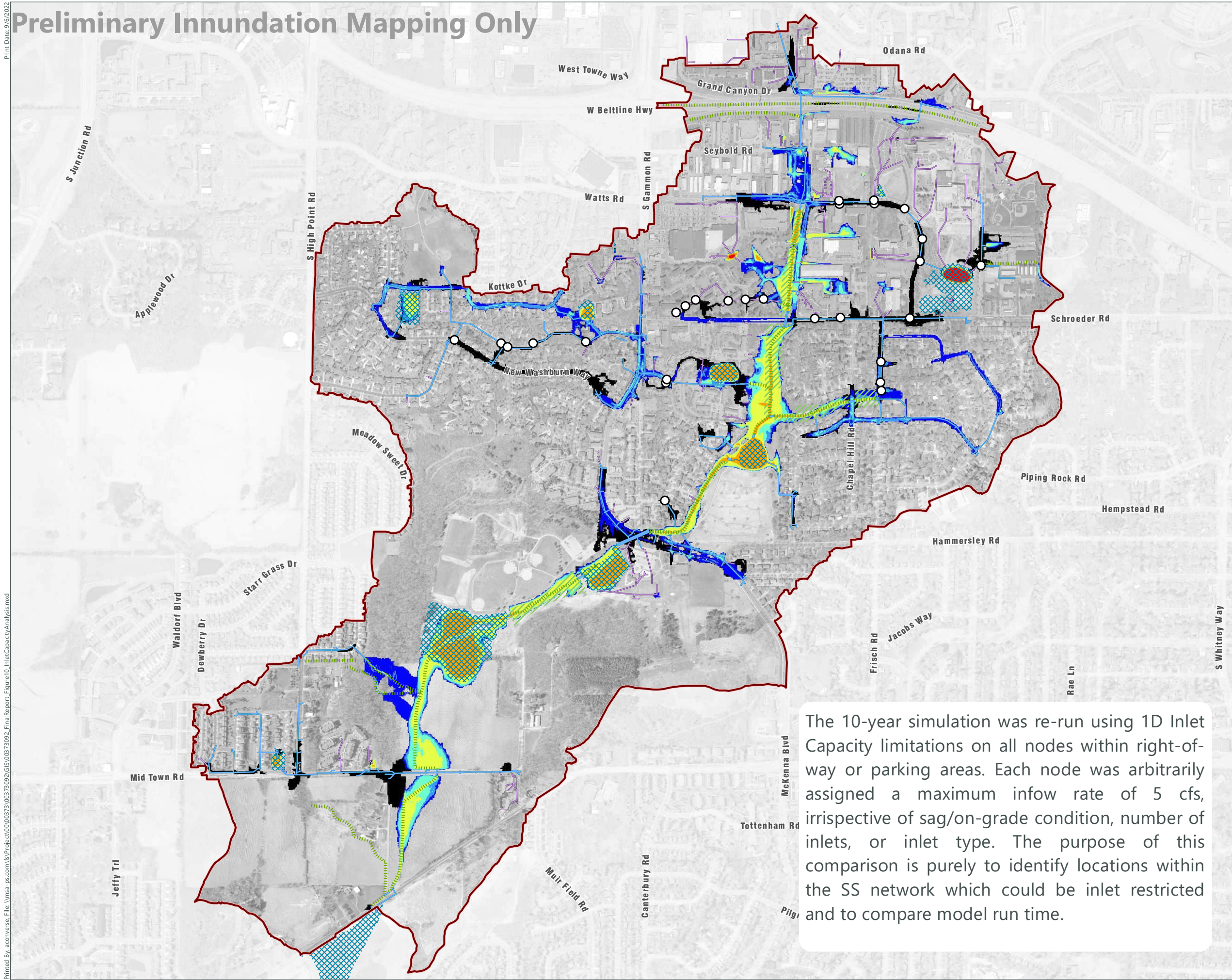
City of Madison
Dane County, WI

-  Watershed Study Area
-  Modeled Pond
-  Modeled Link
-  Modeled Node

Data Sources:
Hillshade: Dane County (2017)
Watershed Boundaries: MSA
Stormwater System: City of Madison



Preliminary Innundation Mapping Only



The 10-year simulation was re-run using 1D Inlet Capacity limitations on all nodes within right-of-way or parking areas. Each node was arbitrarily assigned a maximum infow rate of 5 cfs, irrespective of sag/on-grade condition, number of inlets, or inlet type. The purpose of this comparison is purely to identify locations within the SS network which could be inlet restricted and to compare model run time.

Inlet Capacity Comparison

FIGURE 10
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow
- Inlet Capacity Analysis Location

Preliminary 10% AEP Storm

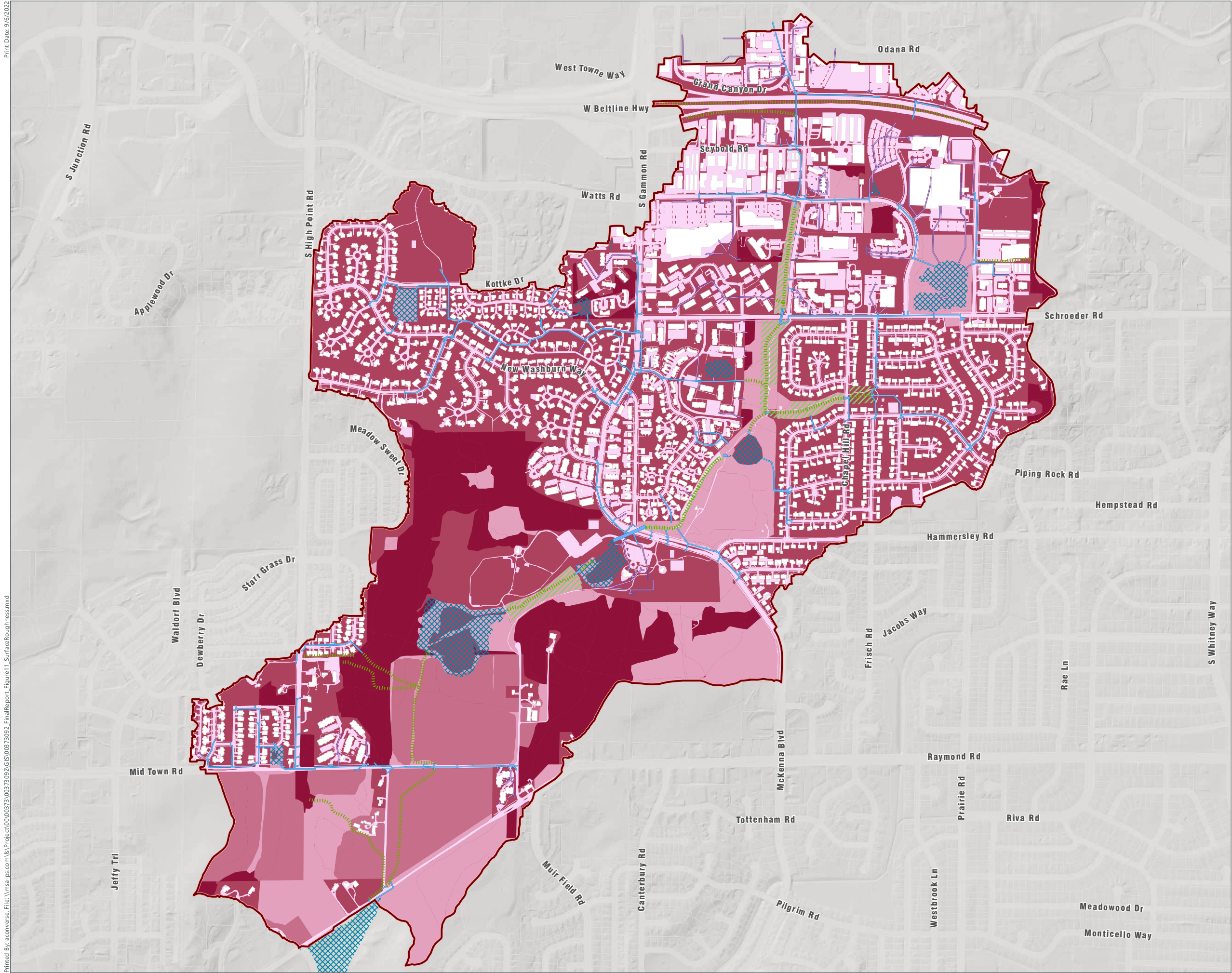
Flood Depths PRELIMINARY (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Flood Extent - INCLUDING INLET RESTRICTIONS



Data Sources:
Flood Hazard is approximate and to be revised upon completion of the project. Estimated using XPSWMM Rain on Grid methodology.
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



Surface Roughness Values

FIGURE 11
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Surface Roughness (Manning's n)
 - 0.1
 - 0.15
 - 0.17
 - 0.24
 - 0.4
- Inactive Area (building)
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow

Data Sources:
Hillshade: Dane County (2017)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Roughness values: MSA

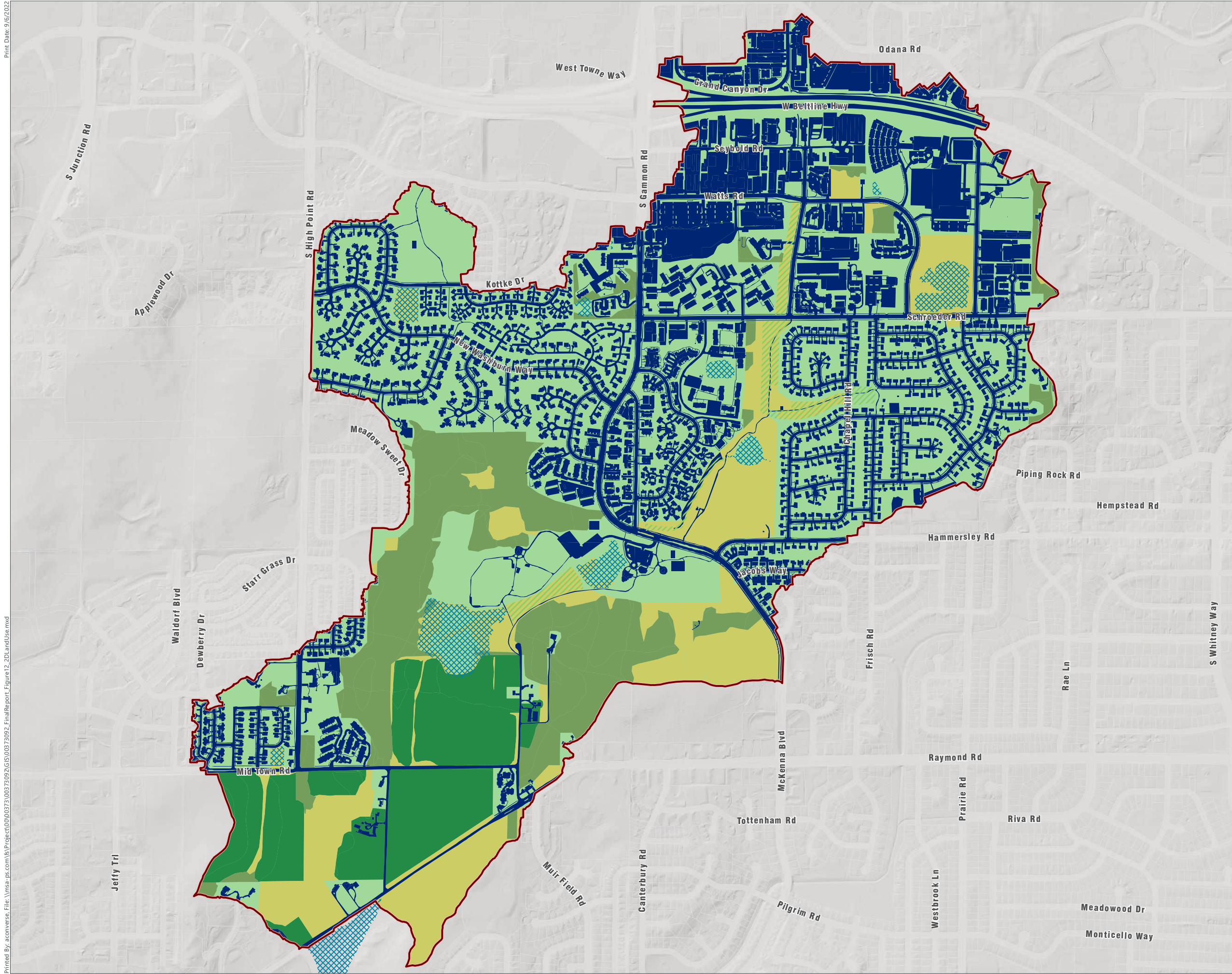
2D Land Use

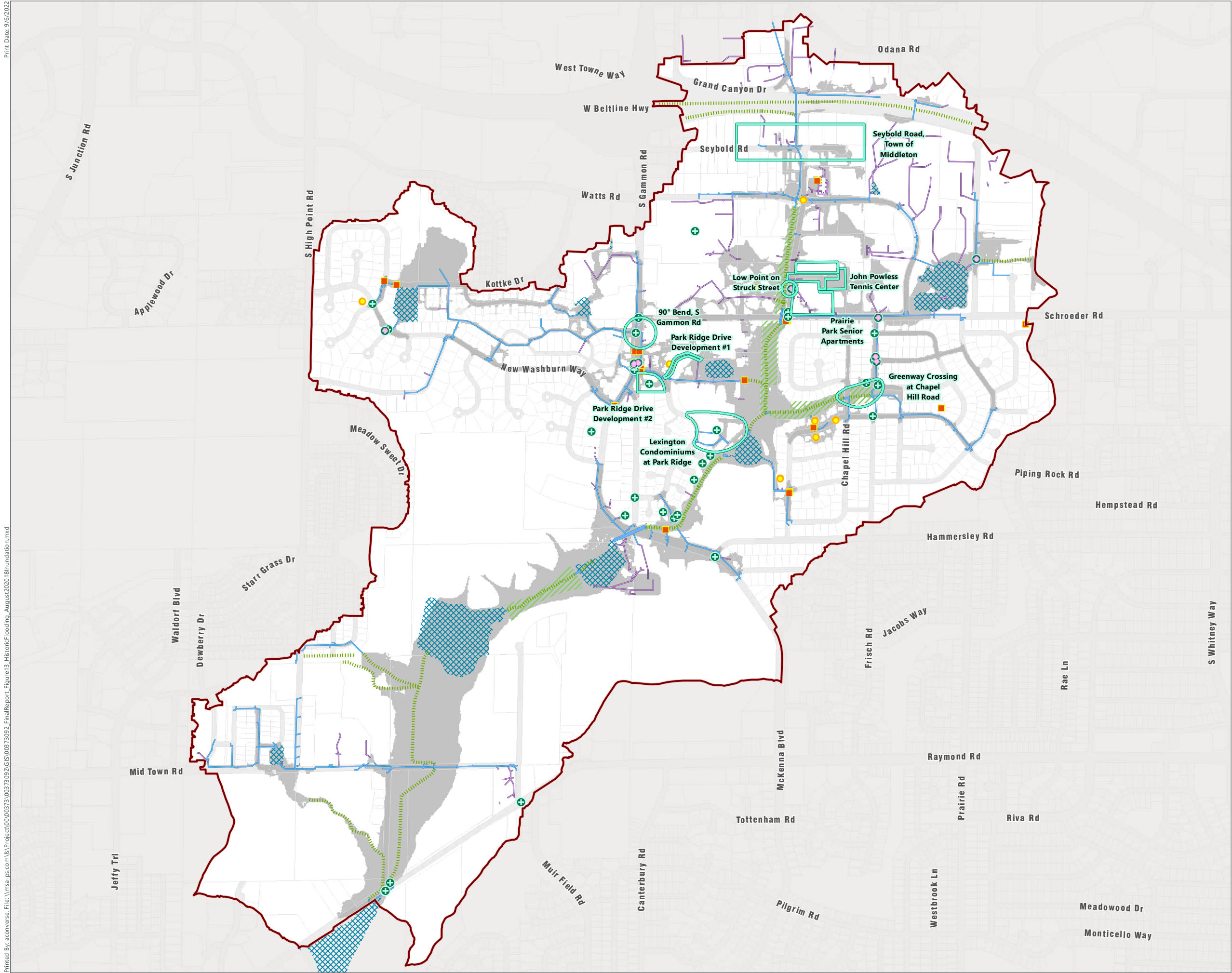
FIGURE 12
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Pervious, Wooded
- Pervious, Prairie
- Pervious, Agricultural
- Pervious, Turf Grass
- Impervious
- Greenway
- Pond

Data Sources:
Aerial: Dane County (2017)
Watershed Boundaries: MSA
Stormwater System: City of Madison
2D Land Use: MSA





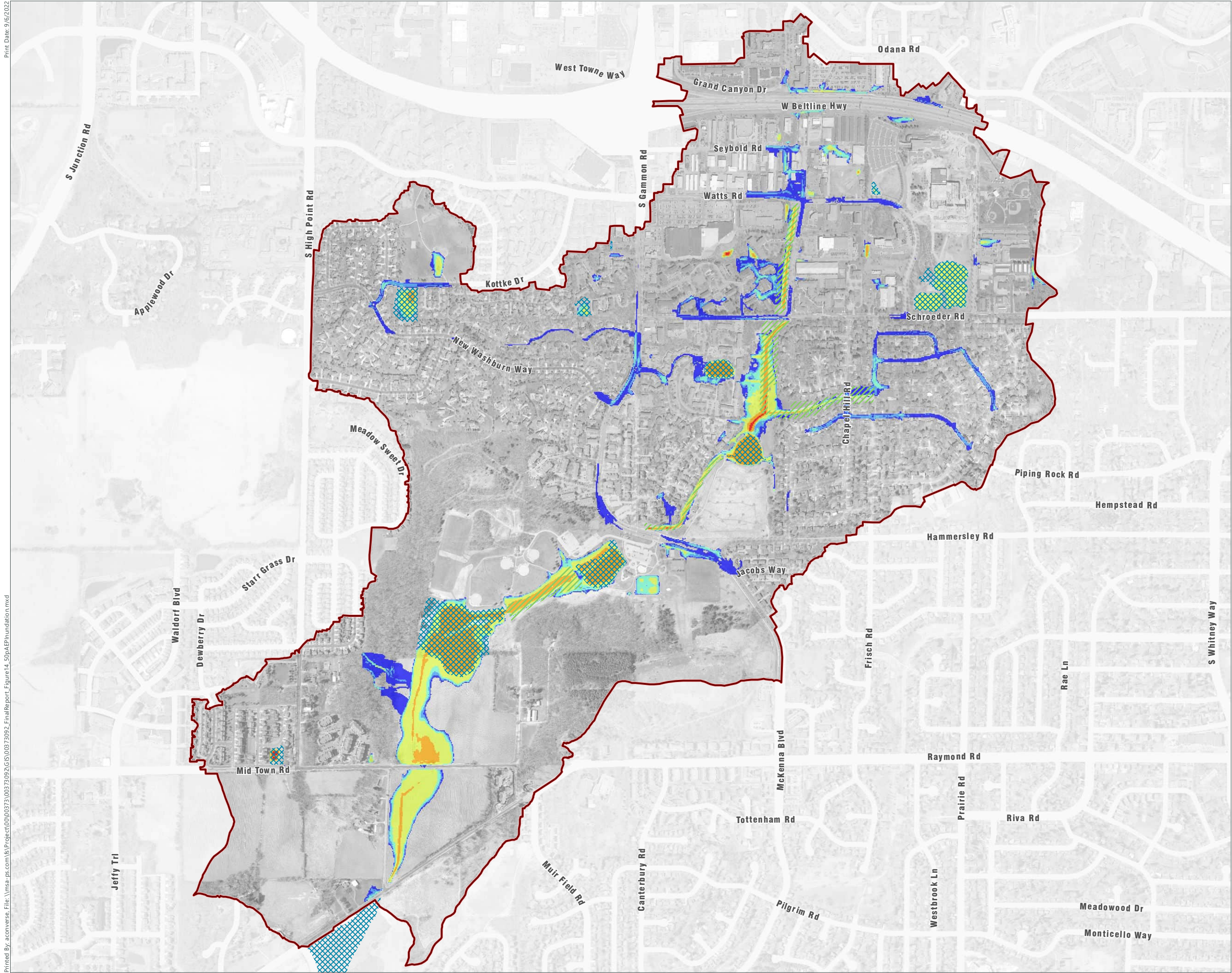
Historic Flooding Observations and 8/20/18 Modeled Inundation

FIGURE 13
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow
- Reported Flooding
- Historic/Observed Flood Points
- Operations Flooding Points
- Priority Inlets
- Observations by City Engineering Staff
- August 20th, 2018 Rain Event**
- Inundation Extents

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison
Reported Flooding: City's Online Public Reporting (through July 2020)
Historic Flooding, Observations and Priority Inlets: City of Madison
Observations by City Staff: Based on discussions of known flooding concerns with City Engineering Staff on 10/14/2019



50% AEP Inundation Existing Conditions

FIGURE 14
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

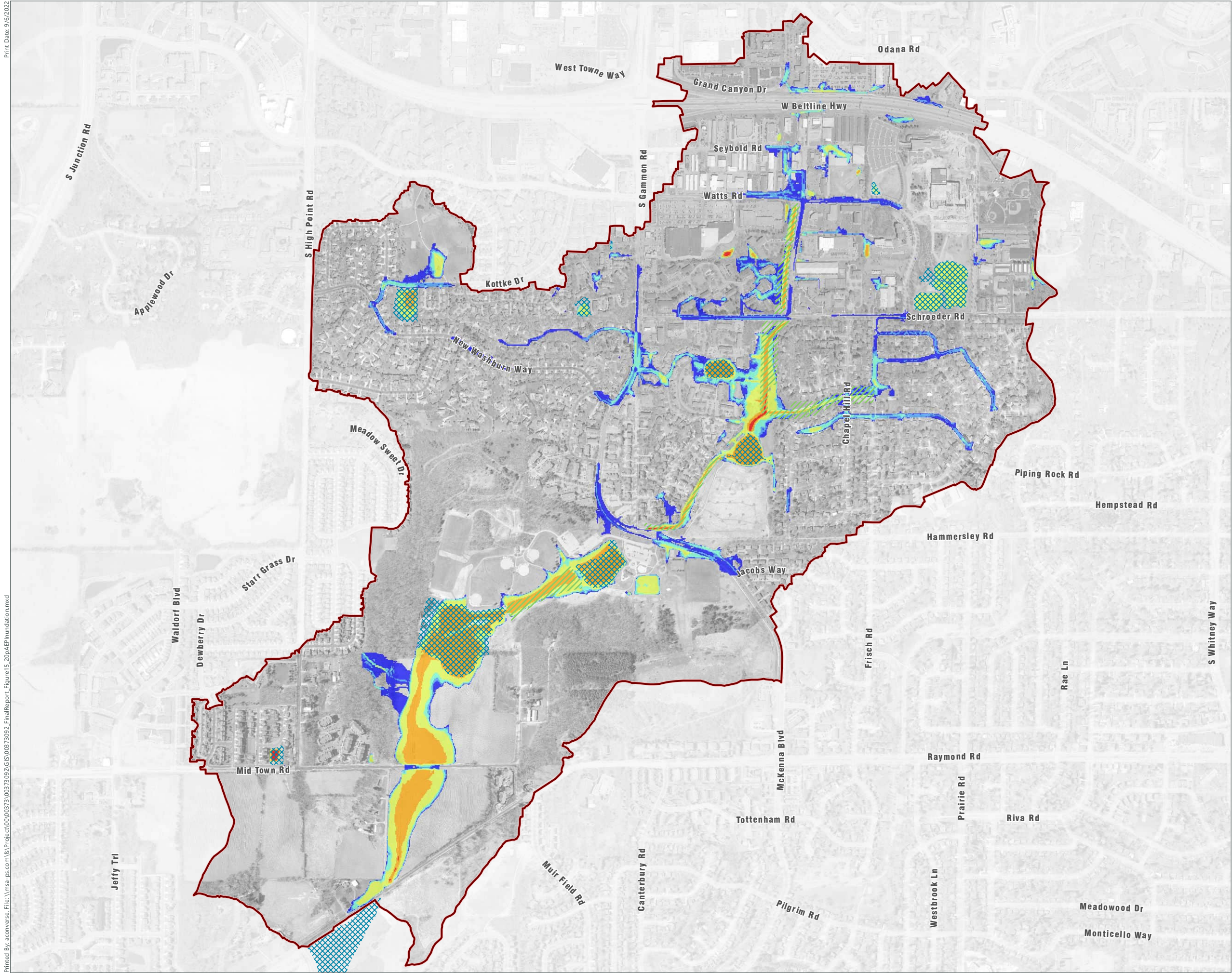
- Watershed Study Area
- Greenway
- Pond

50% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



20% AEP Inundation Existing Conditions

FIGURE 15
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

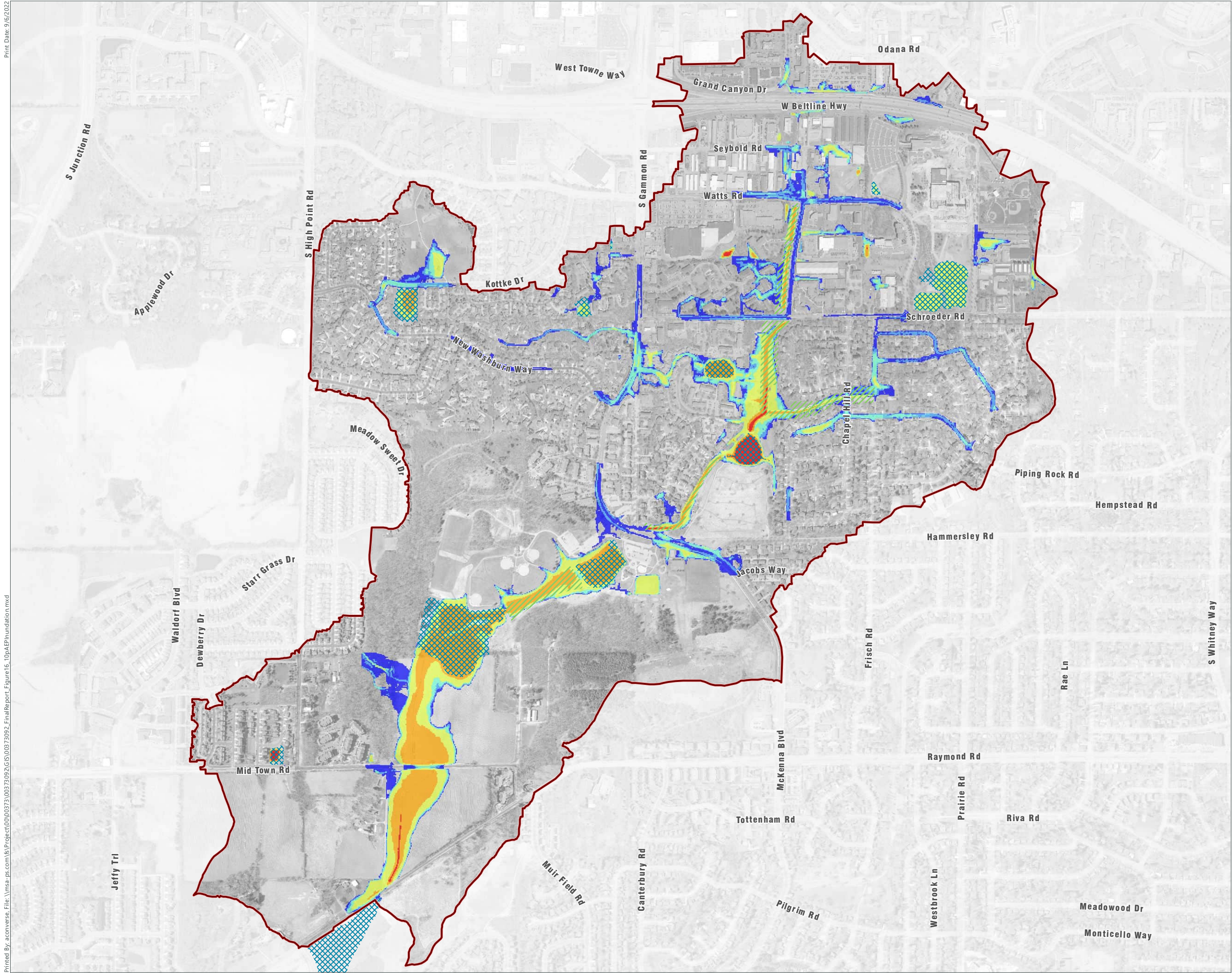
- Watershed Study Area
- Greenway
- Pond

20% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



10% AEP Inundation Existing Conditions

FIGURE 16
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

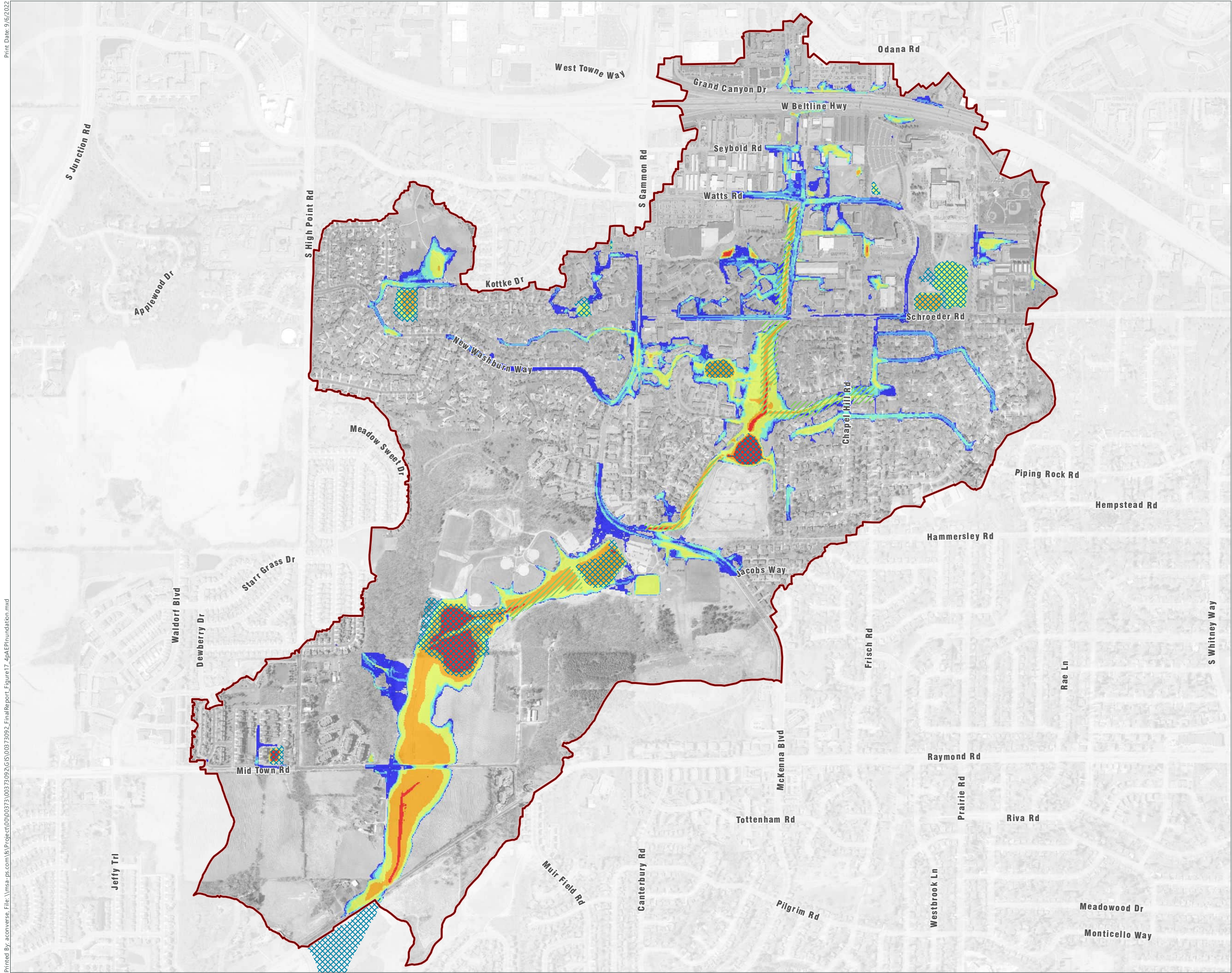
- Watershed Study Area
- Greenway
- Pond

10% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



4% AEP Inundation Existing Conditions

FIGURE 17
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

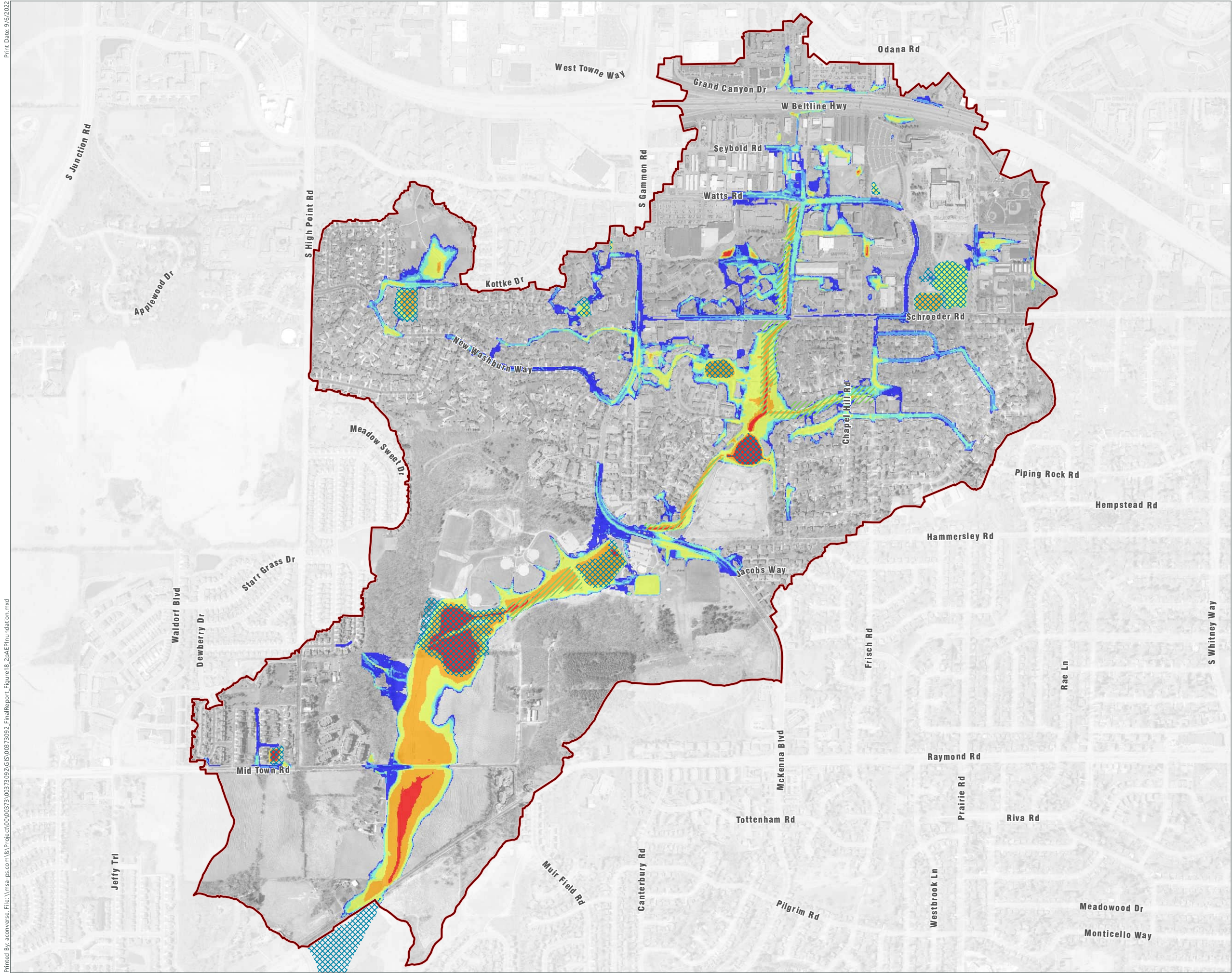
- Watershed Study Area
- Greenway
- Pond

4% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



2% AEP Inundation Existing Conditions

FIGURE 18
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

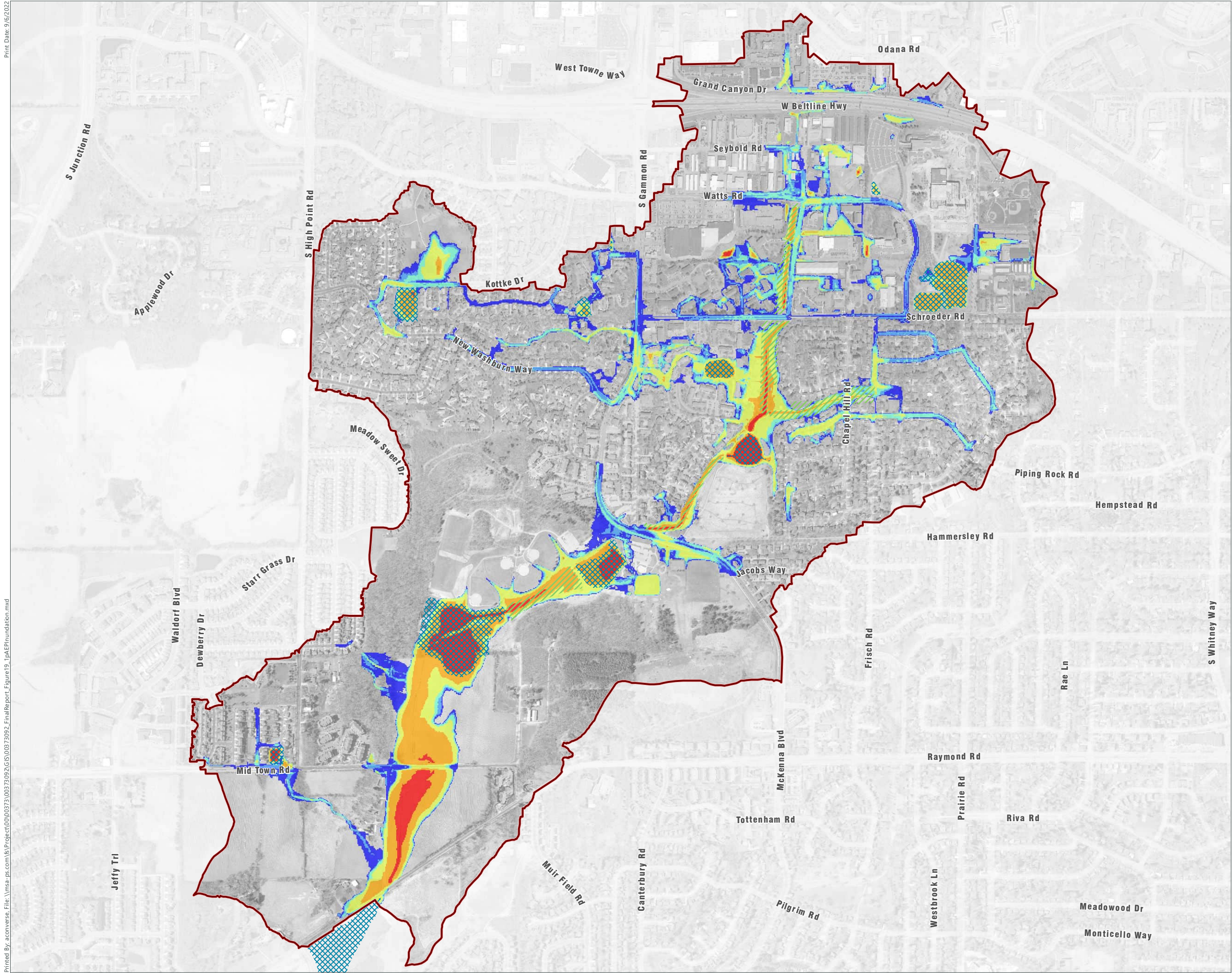
- Watershed Study Area
- Greenway
- Pond

2% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



1% AEP Inundation Existing Conditions

FIGURE 19
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond

1% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison

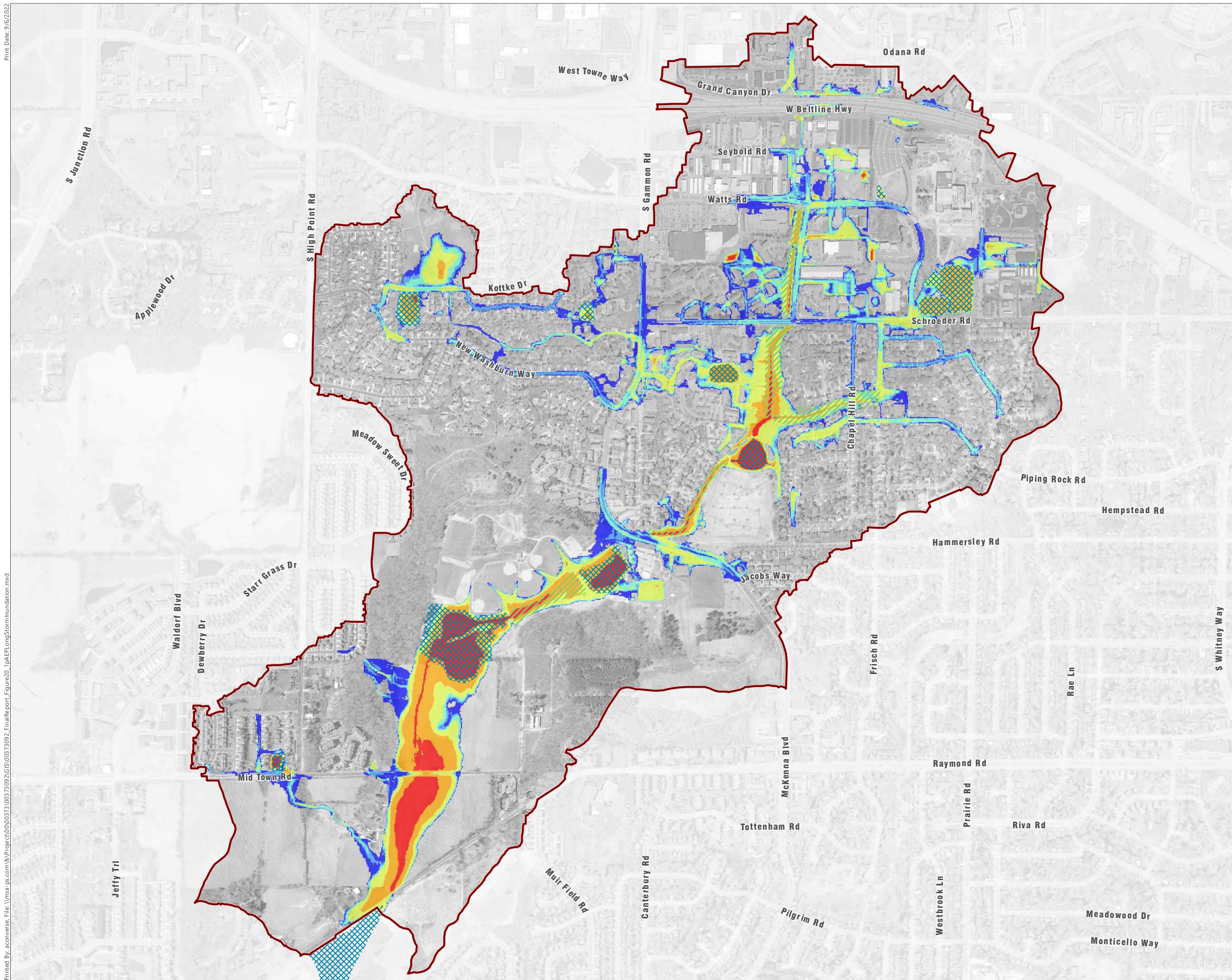


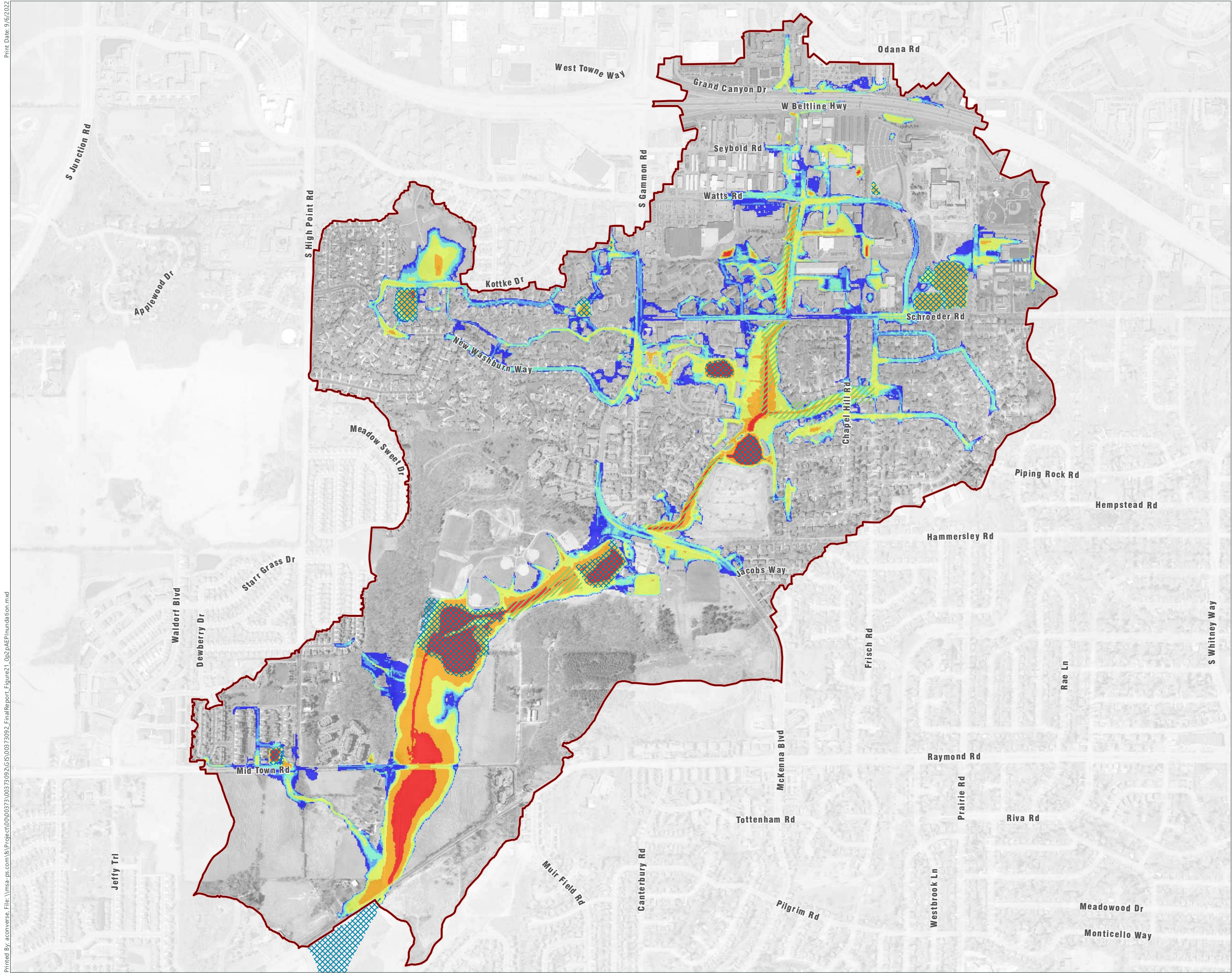
FIGURE 20
Greentree/McKenna Watershed
Study Report

 Watershed Study Area
 Greenway
 Pond

Maximum Water Depth (ft)

 0 - 0.25
 0.25 - 0.5
 0.5 - 1
 1 - 3
 3 - 6
 > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



0.2% AEP Inundation Existing Conditions

FIGURE 21
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

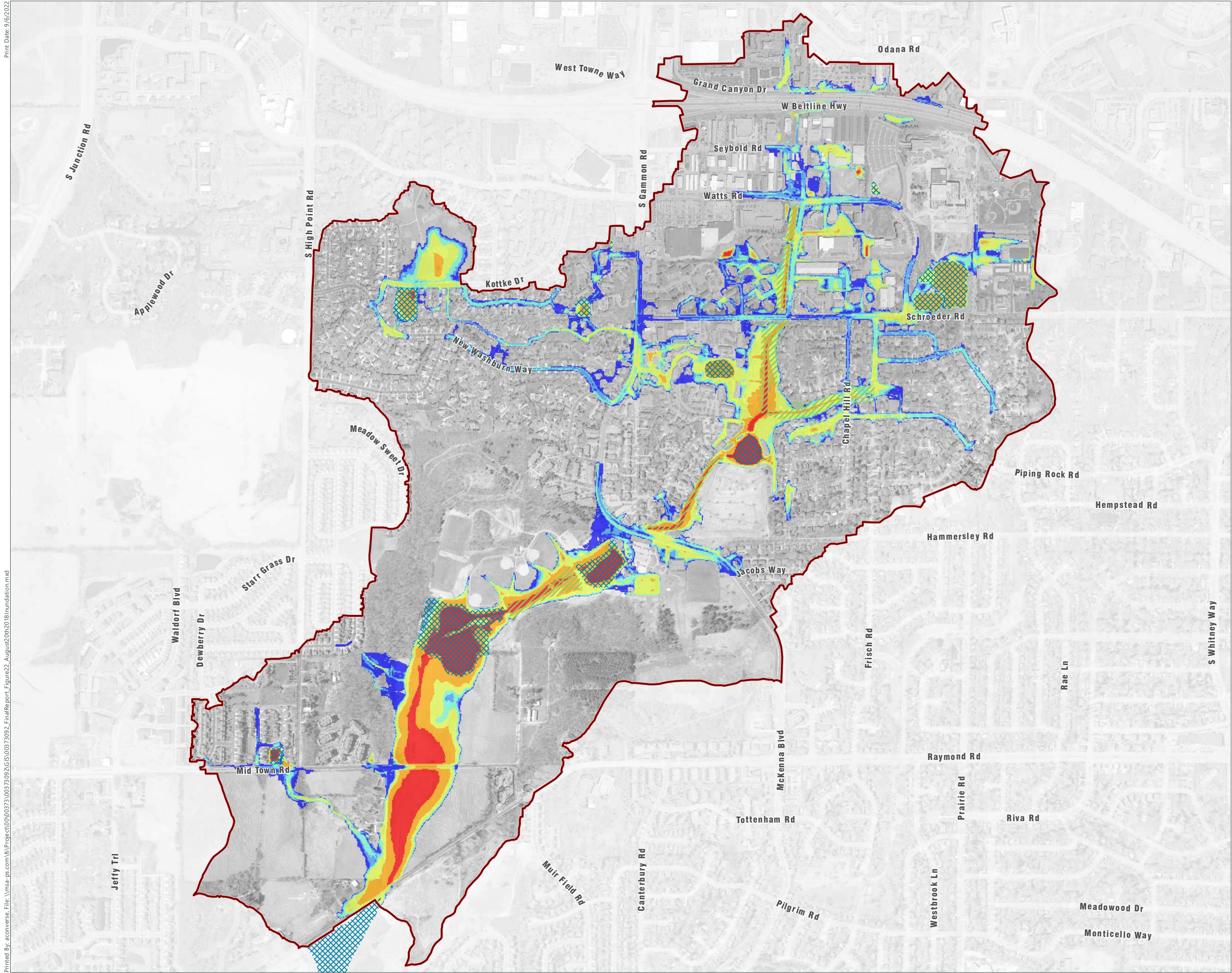
- Watershed Study Area
- Greenway
- Pond

0.2% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



August 20th, 2018 Inundation

FIGURE 22
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond

August 20th, 2018 Storm Event

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison

Goal 1 Existing Conditions

No home or business will be flooded during the 1% AEP design storm.

FIGURE 23
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Modeled Pond
- Modeled Link
- Modeled Node

1% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Building Footprint

Data Sources:
Parcels: Dane County
Watershed Boundaries: MSA
Stormwater System: City of Madison
BuildingFootprints: Dane County, Supplemented by MSA.

Goal 2 Existing Conditions

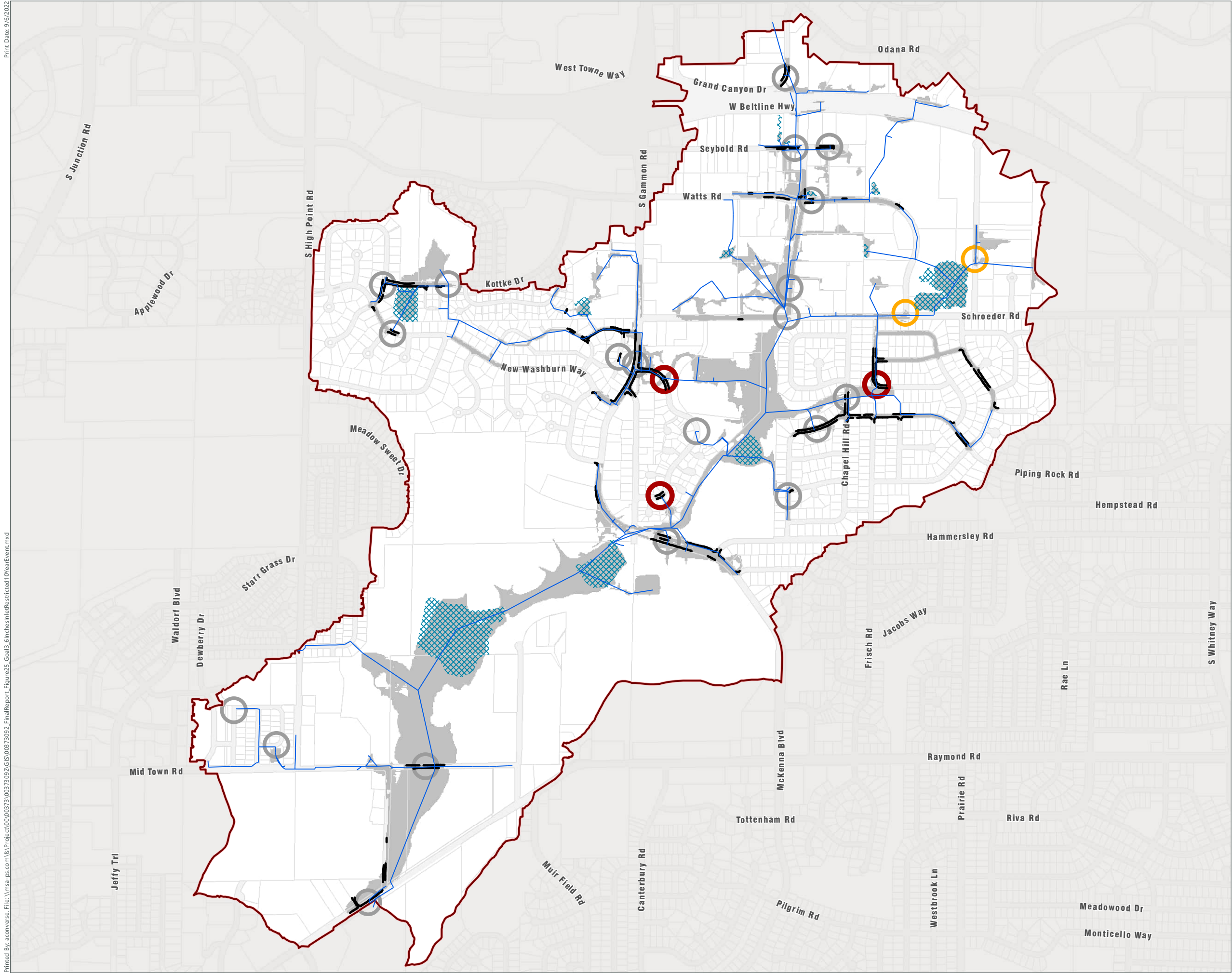
Eliminate flooding from the storm sewer system for the 10% AEP design storm; all water shall be contained within the system, except at low points.

FIGURE 24
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

-  Watershed Study Area
-  Modeled Pond
-  Modeled Link
-  Modeled Node
- 10% Annual Exceedance Probability Storm**
-  Innundation Extent
- Modeled Public Access Structure/Inlet
 -  Innundation within 15-ft of structure

Data Sources:
Watershed Boundaries: MSA
Stormwater System: City of Madison



Goal 3 Existing Conditions

Allow no more than 0.5 ft of water above storm sewer inlet rim at inlet-restricted low points for up to the 10% AEP design storm.

FIGURE 25
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Modeled Pond
- Modeled Link
- 10% Annual Exceedance Probability Storm**
 - Inundation Extent
 - 6" or Greater Inundation on Curbside
 - Sag Location, Not inlet restricted
 - Sag Location, Inlet restricted
 - Sag Location, Inlet restricted, 0.5' water at curb

Data Sources:
Parcels: Dane County
Watershed Boundaries: MSA
Stormwater System: City of Madison

Goal 4 Existing Conditions

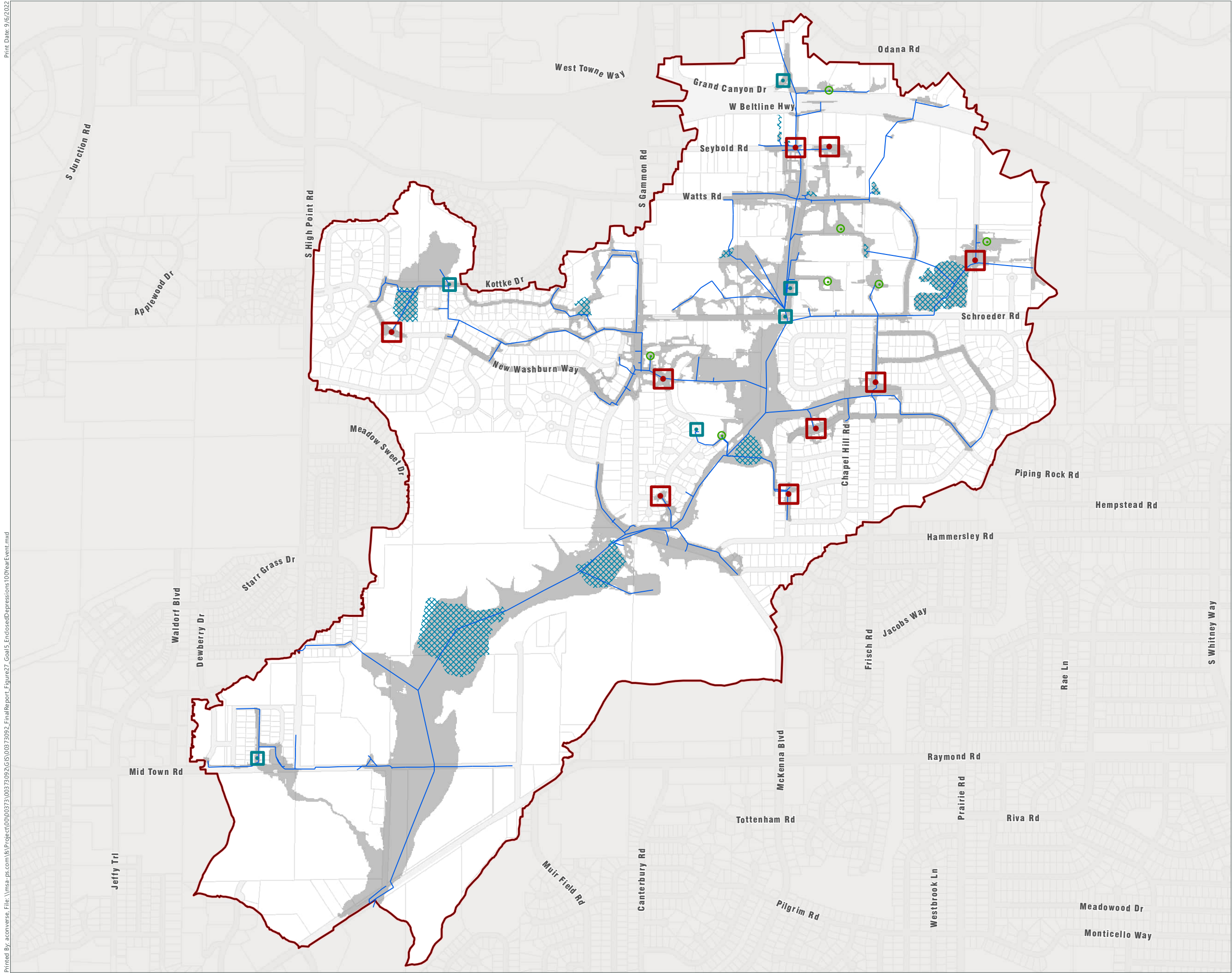
Streets to remain passable during 4% AEP design storm with no more than 0.5-ft of water at the centerline.

FIGURE 26
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

-  Watershed Study Area
-  Modeled Pond
-  Modeled Link
- 4% Annual Exceedance Probability Storm**
 -  Inundation Extent
 -  More than 0.5-ft Water at Centerline

Data Sources:
Parcels: Dane County
Watershed Boundaries: MSA
Stormwater System: City of Madison



Goal 5 Existing Conditions

Enclosed depressions to be served to the 1% AEP design storm.

FIGURE 27
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Modeled Pond
- Modeled Link
- Enclosed Depression on Private Property
- Enclosed Depressions within ROW***
- Predicted Flooding to Private Property
- No Predicted Flooding to Private Property
- 1% Annual Exceedance Probability Storm
- Inundation Extent

*For the purposes of the watershed study, enclosed depressions are defined as depressions in public right-of-way where stormwater needs to reach private property to overflow from the depression.

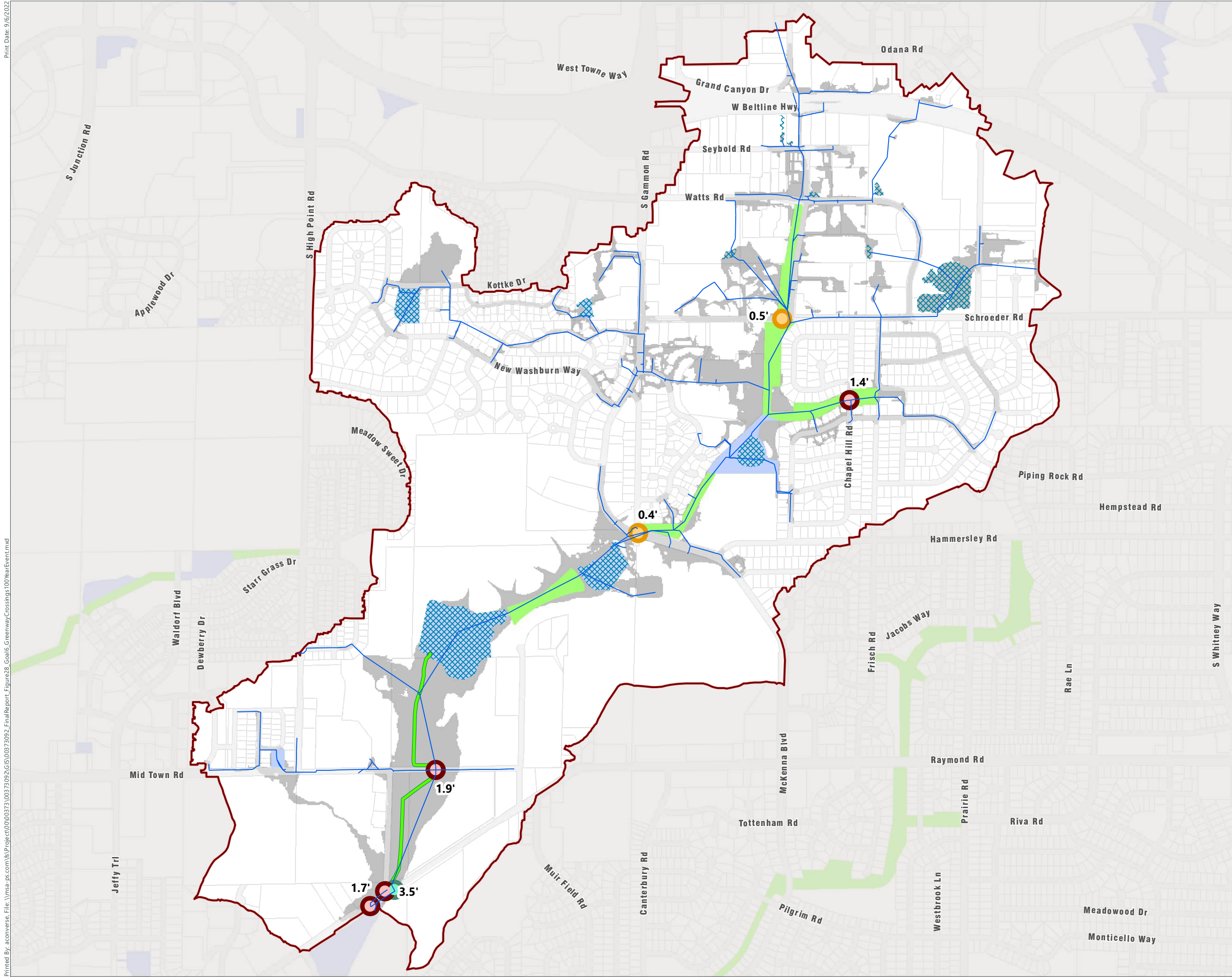
Data Sources:
Parcels: Dane County
Watershed Boundaries: MSA
Stormwater System: City of Madison

Goal 6 Existing Conditions

Greenway crossings at streets to be served to the 1% AEP design storm.

FIGURE 28
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

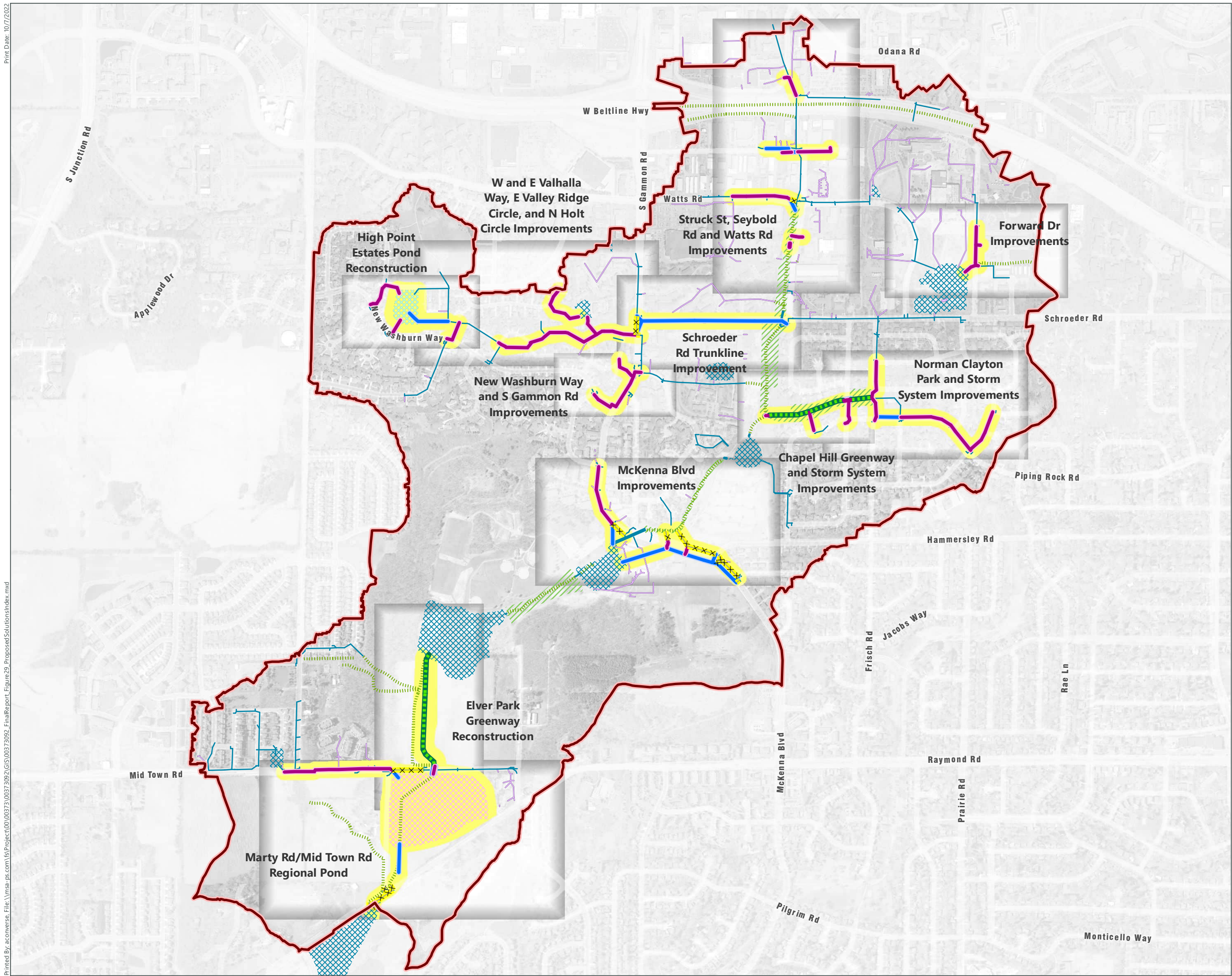


- Watershed Study Area
- Modeled Pond
- Modeled Link
- 1% Annual Exceedance Probability Storm**
 - Inundation Extent
 - Pond
 - Greenway
 - Overland Flow
- Greenway Crossing***
 - Water on Road from Greenway
 - Flooding caused by street flow, not greenway overtopping
 - No Water on Road

*Note: This map depicts greenway crossings where there is water over the road under 1% AEP storm. Most of these occurrences are due to water flowing over the road from one side of a greenway to the other side. However, some locations have water on the road due to flow accumulations in the street due to inadequate local storm sewer system capacity. An example of this is the McKenna Blvd crossing of the Greentree channel.

Data Sources:
Parcels: Dane County
Watershed Boundaries: MSA
Stormwater System: City of Madison
Ponds and Greenways: City of Madison





Proposed Solutions

FIGURE 29
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow

Proposed Improvements

- Replacement Pipe
- New Pipe
- Channel Grading/Alignment
- Pipe Removed
- Proposed Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond
- Improvement Area of Interest
- Map Extents (Figures 30 A-K)

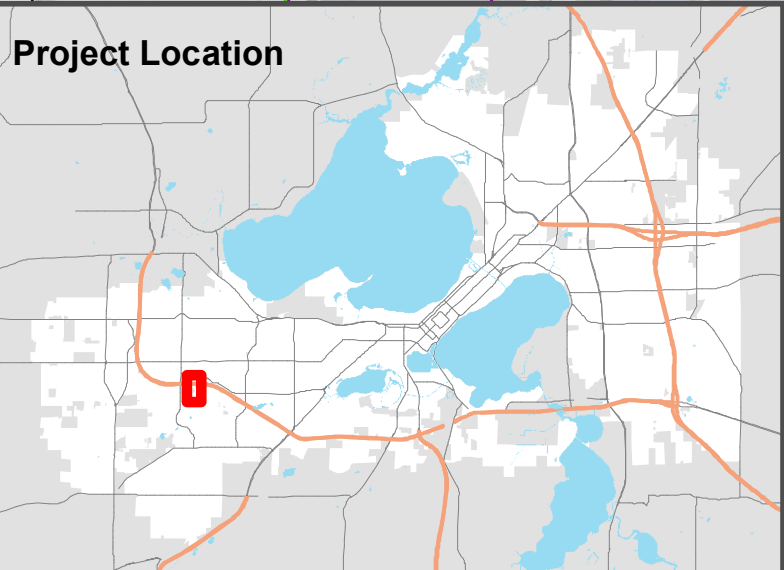
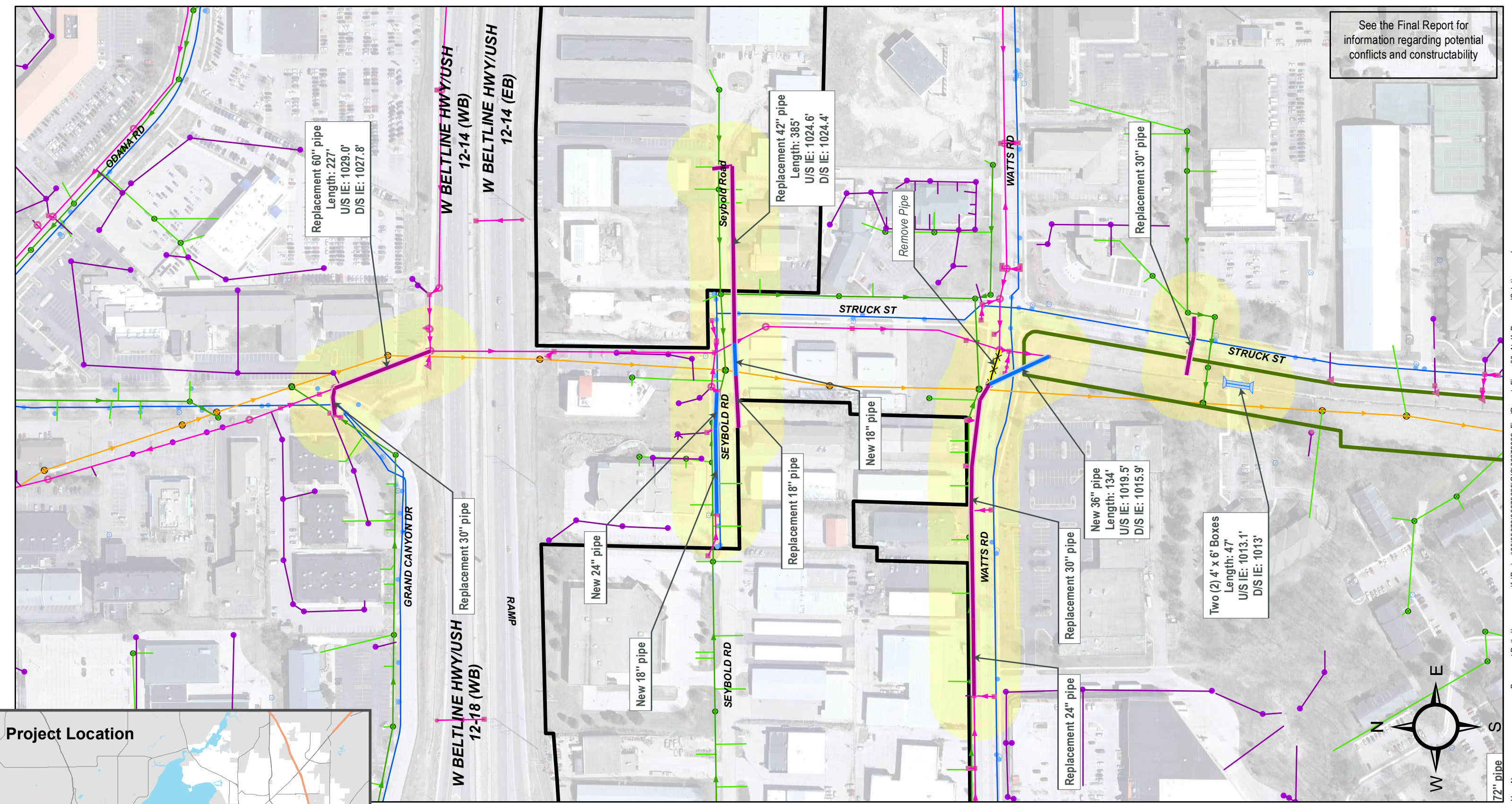
Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison



0 550 1,100 Feet



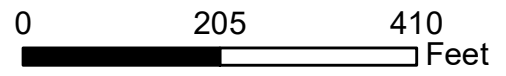
See the Final Report for information regarding potential conflicts and constructability



- | | | | | |
|-----------------------|-------------------------------------|-------------------|------------------|---|
| Greenway | Inlet | SAS | Water Valve | Proposed Improvements
Replacement Pipe
New Pipe
Pipe Removed
Proposed Box Culverts
Improvement Area of Interest |
| Storm Pipe | Private Stormwater Pipes--Approx | Sanitary Laterals | Water Hydrant | |
| Other Storm Structure | Private Stormwater Structures--A... | MMSD Mains | Municipal Limits | |
| Access Structures | Sanitary Mains | MMSD SAS | Water Main | |
| Apron | | | | |

Struck St, Seybold Rd and Watts Rd Improvements

Figure 30 - A



Date: 5/3/2022



See the Final Report for information regarding potential conflicts and constructability

Upstream pipes not included within MGT model.
Will need to be considered for future improvements.

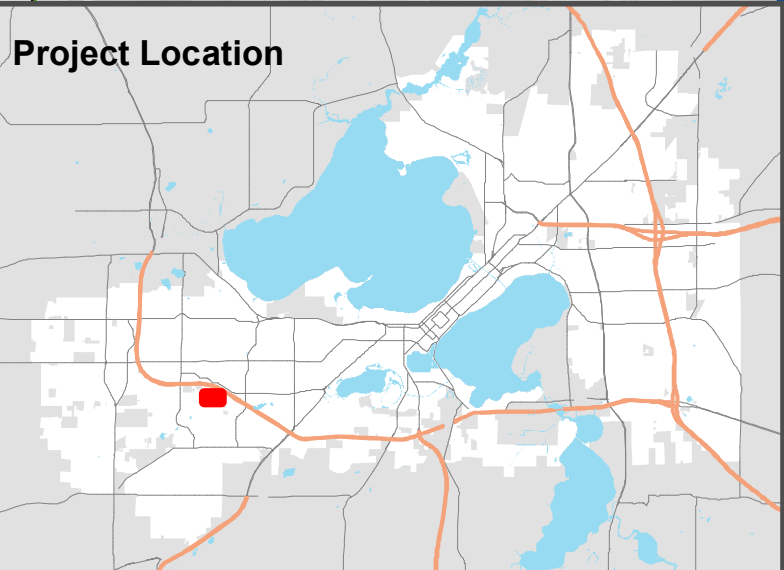
Replacement 36" pipe
Length: 38'
U/S IE: 1030.1'
D/S IE: 1029.5'

Replacement 30" pipe

Replacement 42" pipe
Length: 147'
U/S IE: 1026.8'
D/S IE: 1024'

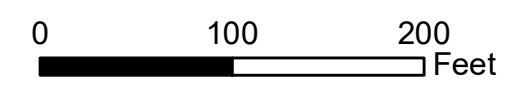
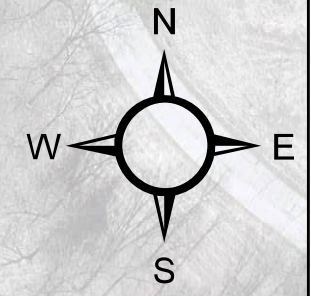
Replacement 42" pipe
Length: 243'
U/S IE: 1029'
D/S IE: 1026.9'

Replacement 30" pipe
Length: 23'
U/S IE: 1028.2'
D/S IE: 1027.8'



- | | | |
|-----------------------|-------------------------------------|-------------------|
| Pond | Inlet | SAS |
| Storm Pipe | Private Stormwater Pipes--Approx | Sanitary Laterals |
| Other Storm Structure | Private Stormwater Structures--A... | Water Main |
| Access Structures | Sanitary Mains | Water Valve |
| Apron | | Water Hydrant |

- Proposed Improvements**
- Replacement Pipe
 - New Pipe
 - Pipe Removed
 - Proposed Box Culverts
 - Improvement Area of Interest

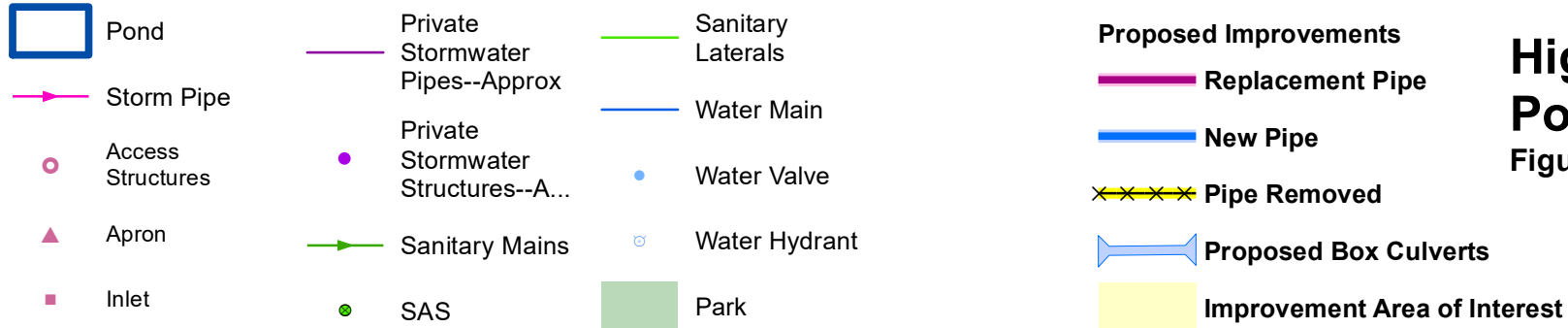
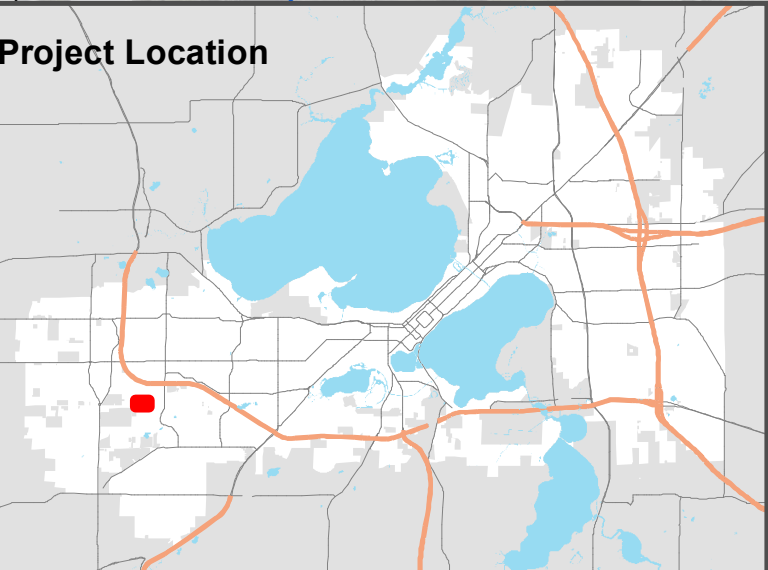
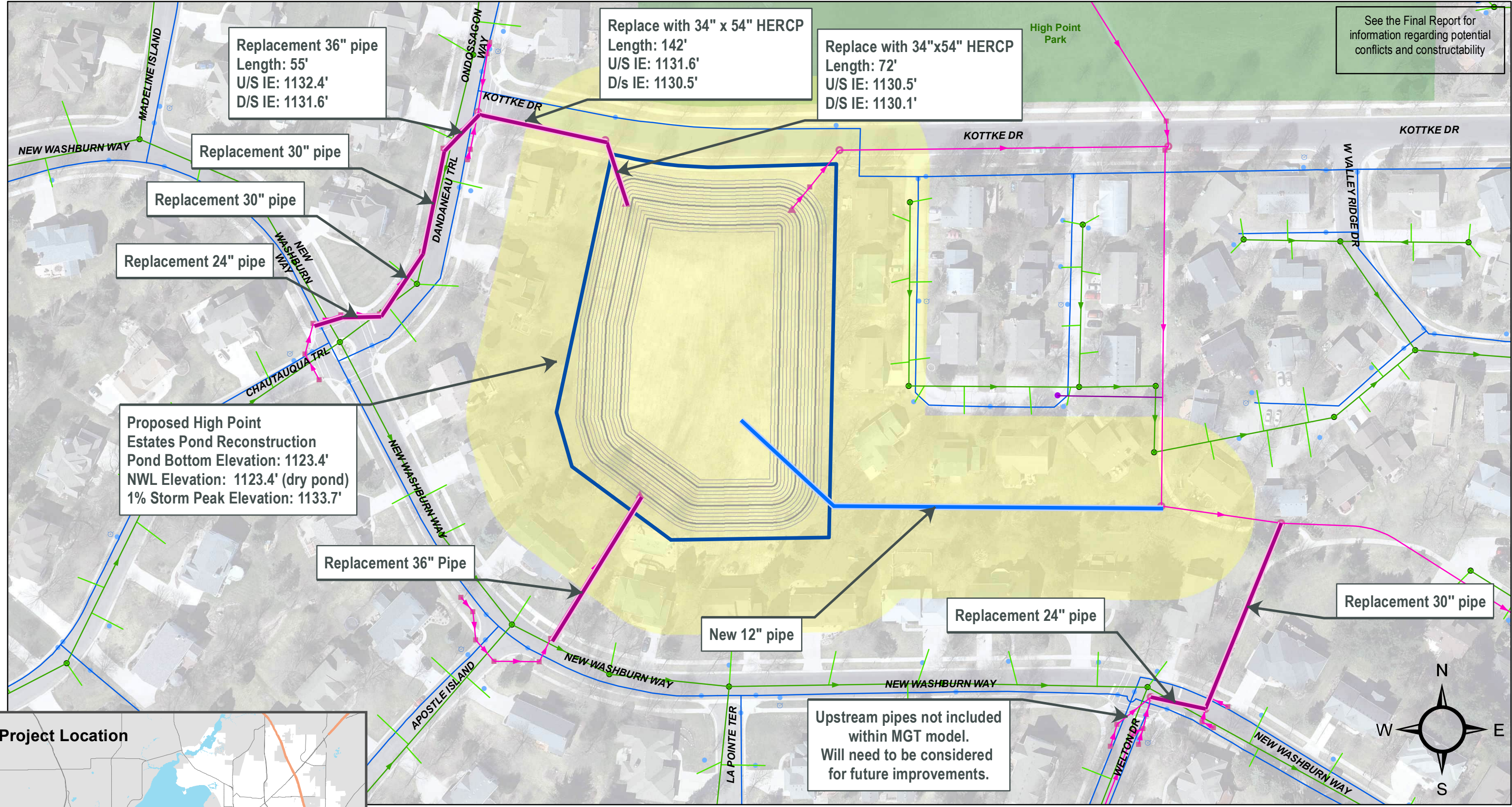


Date: 5/3/2022



**Forward Dr
Improvements**
Figure 30 - B

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User Name: aconverse



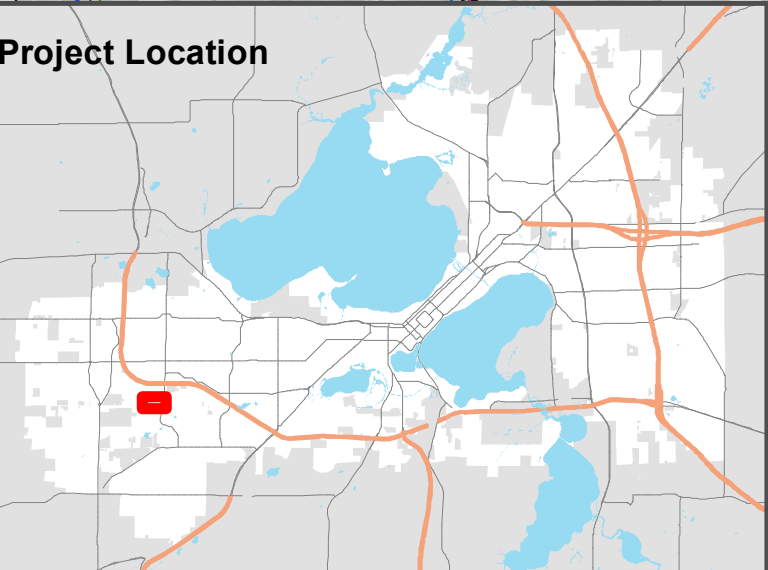
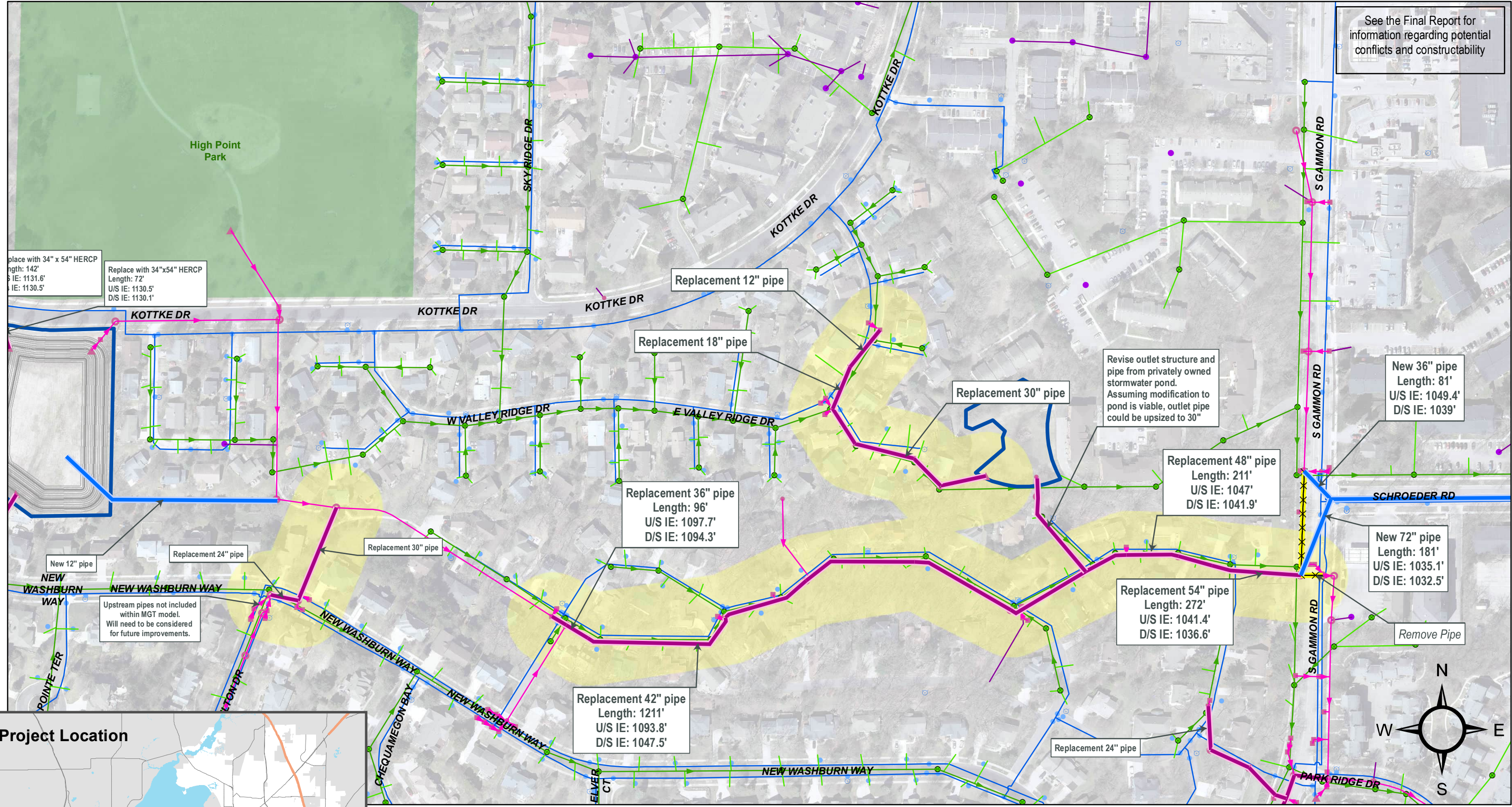
High Point Estates Pond Reconstruction

Figure 30 - C

0 100 200 Feet

Date: 10/7/2022

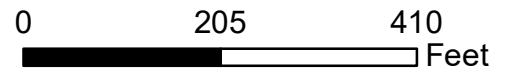
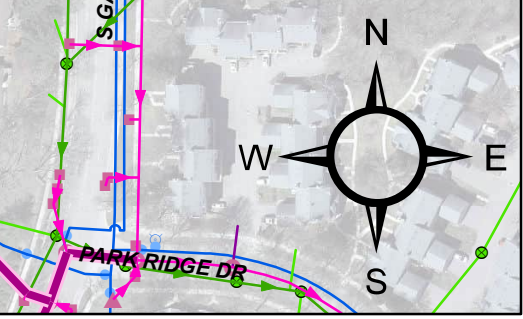
See the Final Report for information regarding potential conflicts and constructability



- | | | | |
|-----------------------|-------------------------------------|-------------------|------------------------------|
| Pond | Inlet | SAS | Park |
| Storm Pipe | Private Stormwater Pipes--Approx | Sanitary Laterals | Proposed Improvements |
| Other Storm Structure | Private Stormwater Structures--A... | Water Main | Replacement Pipe |
| Access Structures | Sanitary Mains | Water Valve | New Pipe |
| Apron | | Water Hydrant | Pipe Removed |
| | | | Proposed Box Culverts |
| | | | Improvement Area of Interest |

W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements

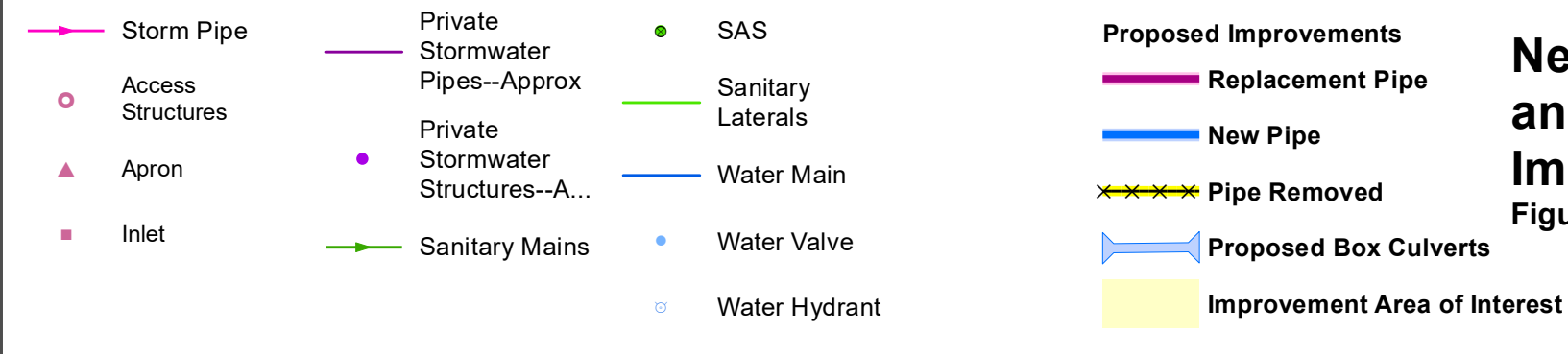
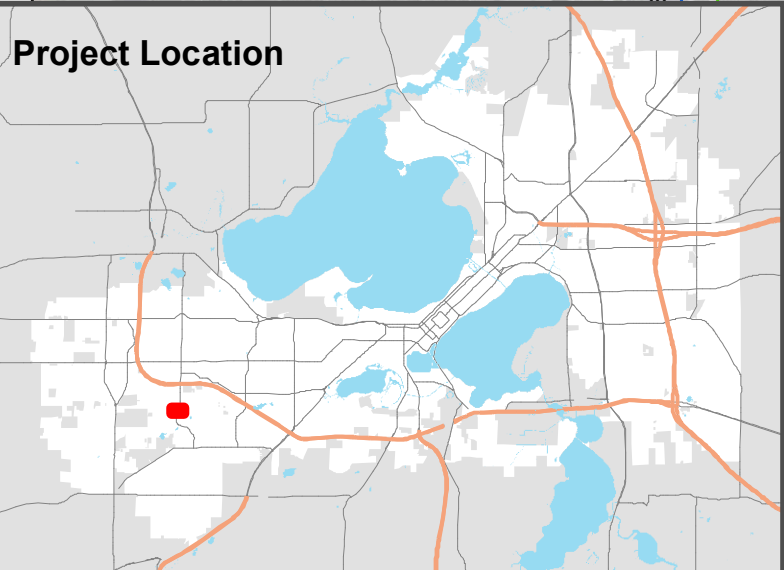
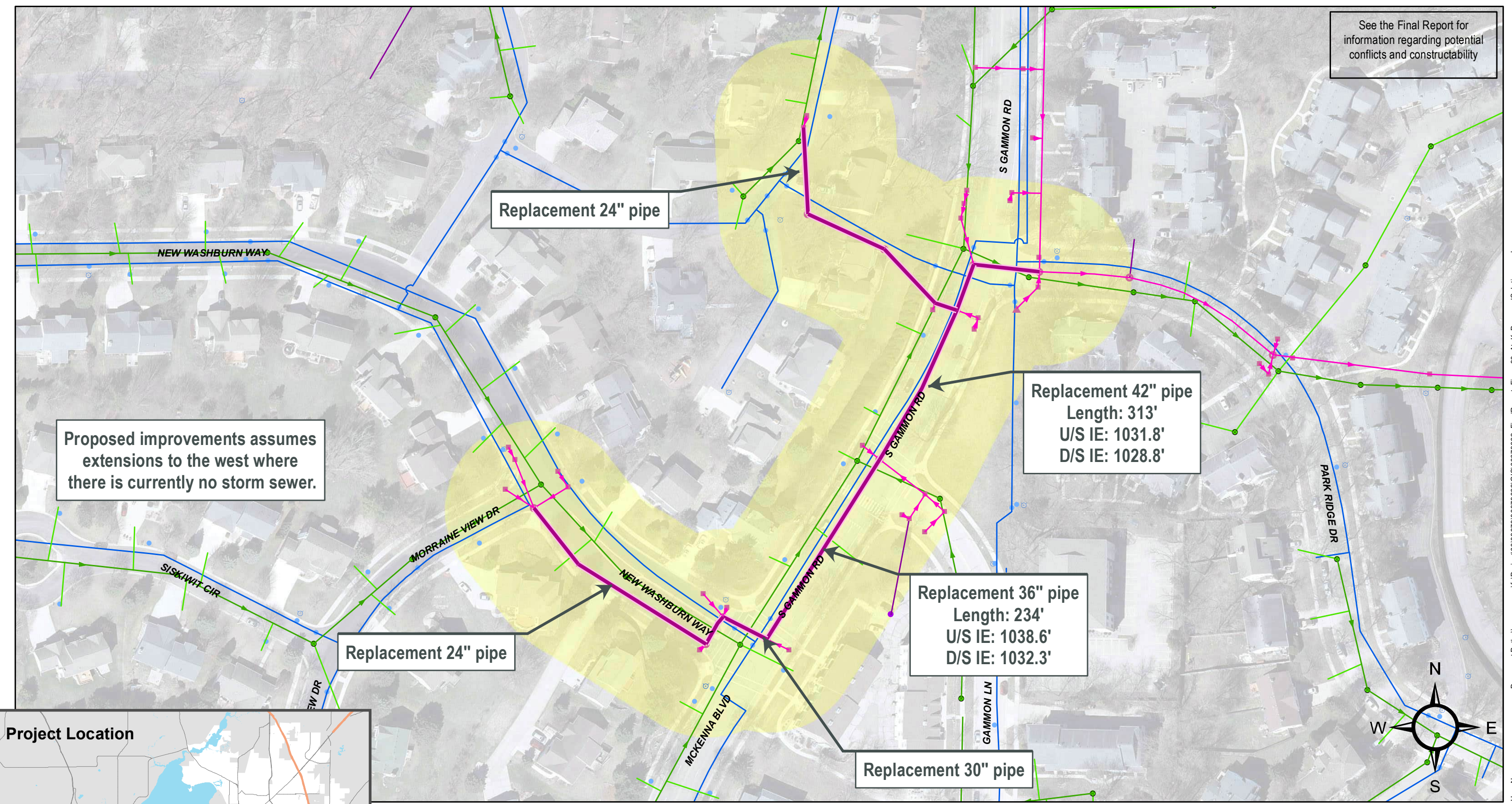
Figure 30 - D



Date: 10/7/2022

User Name: aconverse Document Path: \\msa-ps.com\fs\Project\00\00373\092\GIS\00373092_Fin\Report_Figure30_AtoK_ProposedSolutions.mxd

See the Final Report for information regarding potential conflicts and constructability

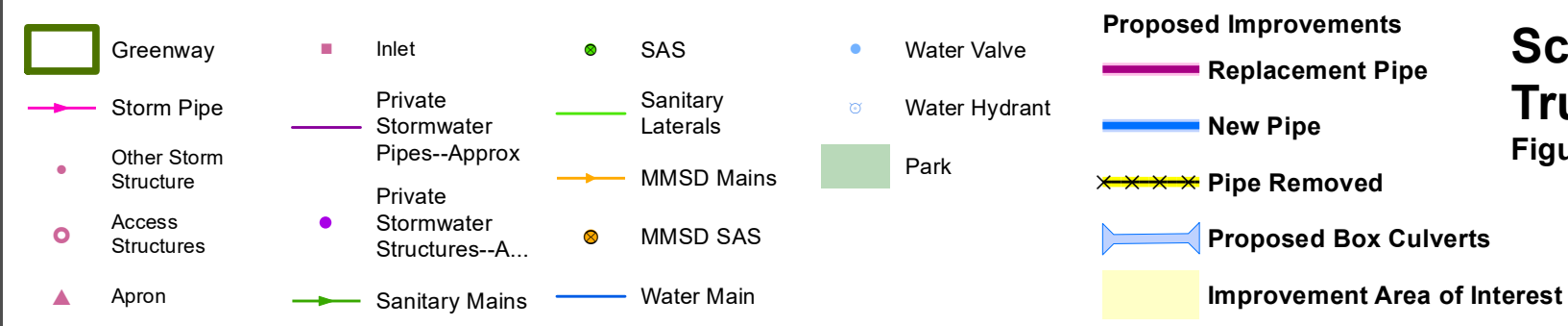
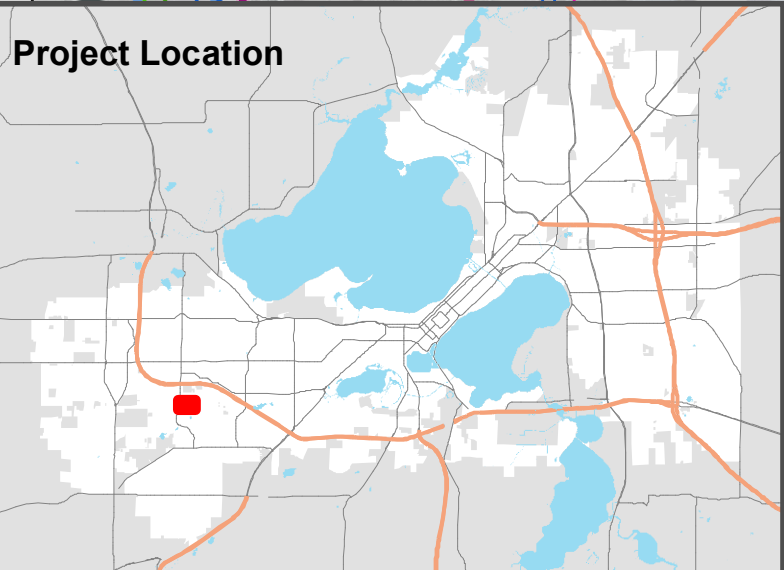
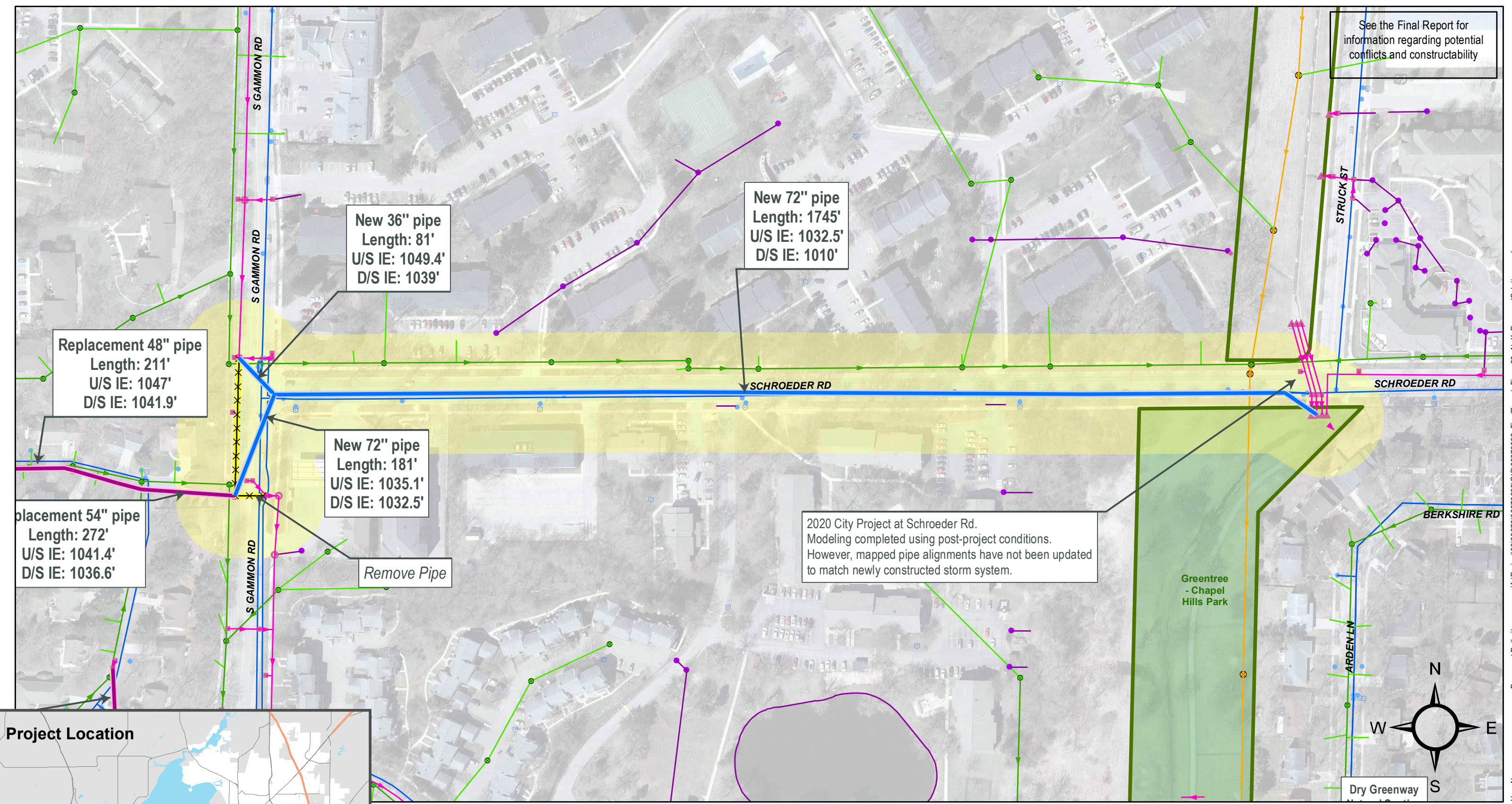


New Washburn Way and S Gammon Rd Improvements

Figure 30 - E

Date: 5/3/2022

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User Name: aconverse



Schroeder Rd Trunkline Improvement

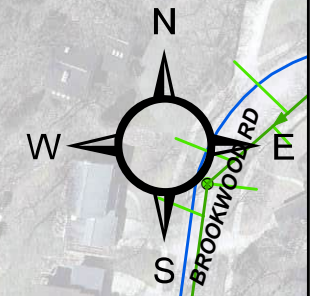
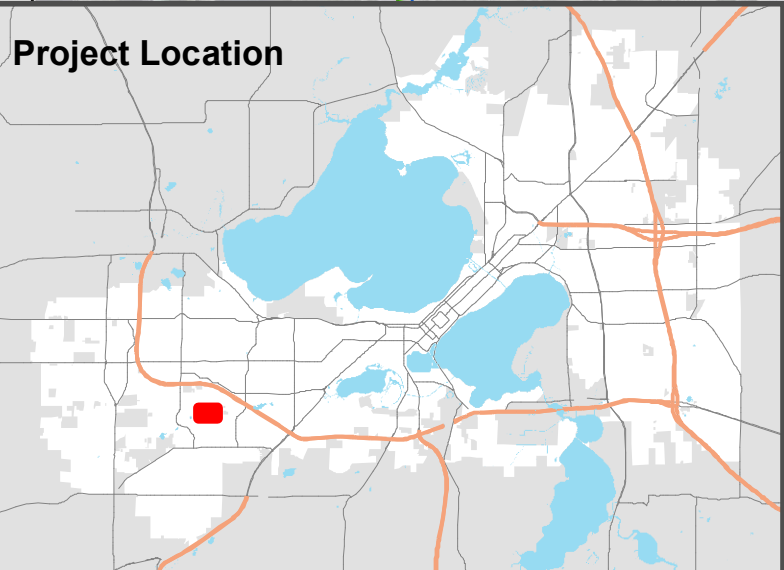
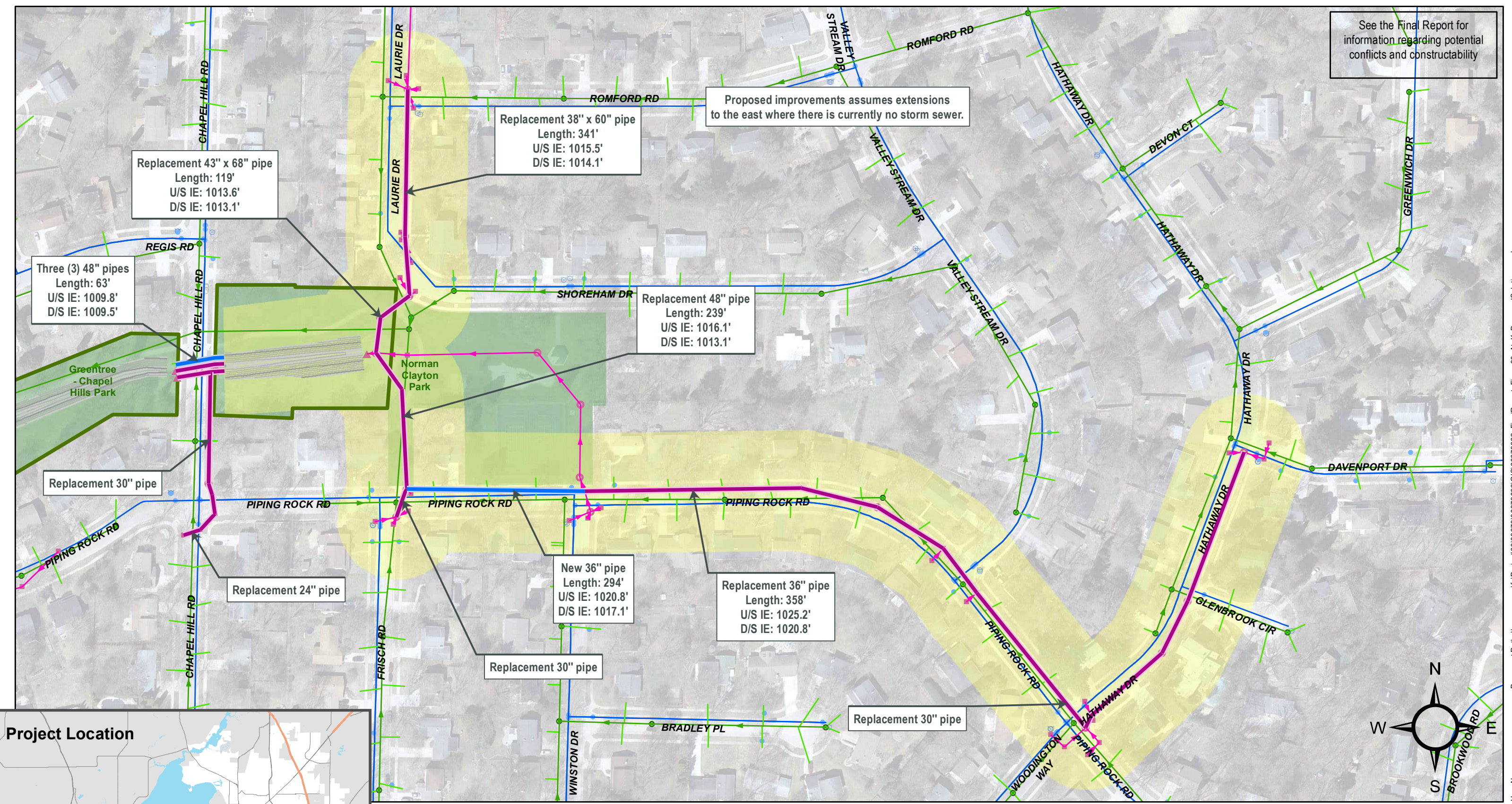
Figure 30 - F

0 155 310 Feet

Date: 5/3/2022

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User Name: aconverse

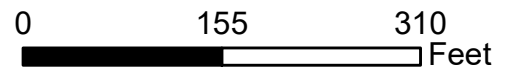
See the Final Report for information regarding potential conflicts and constructability



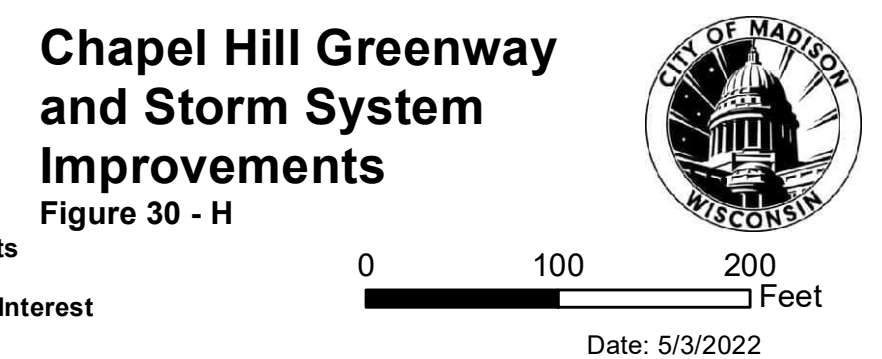
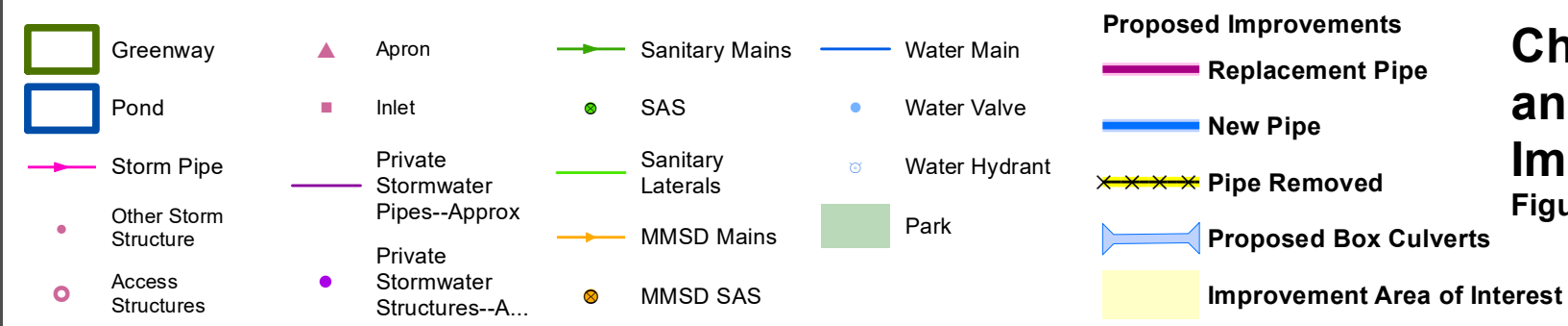
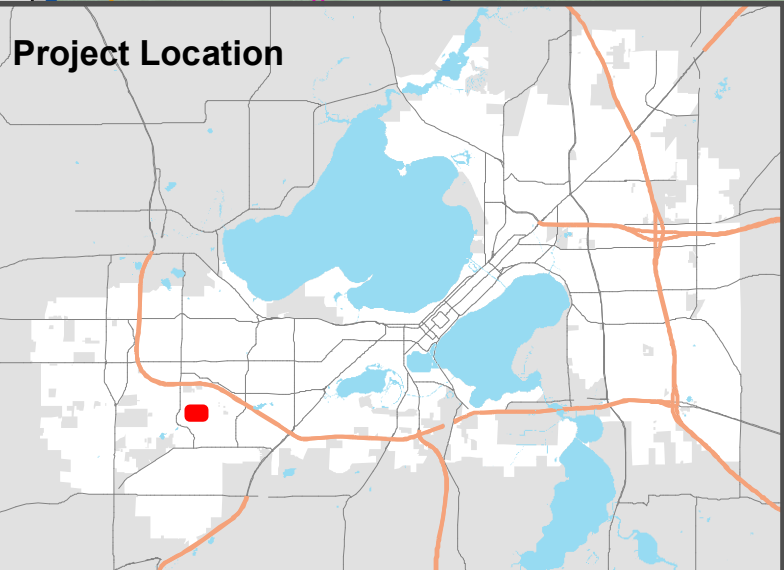
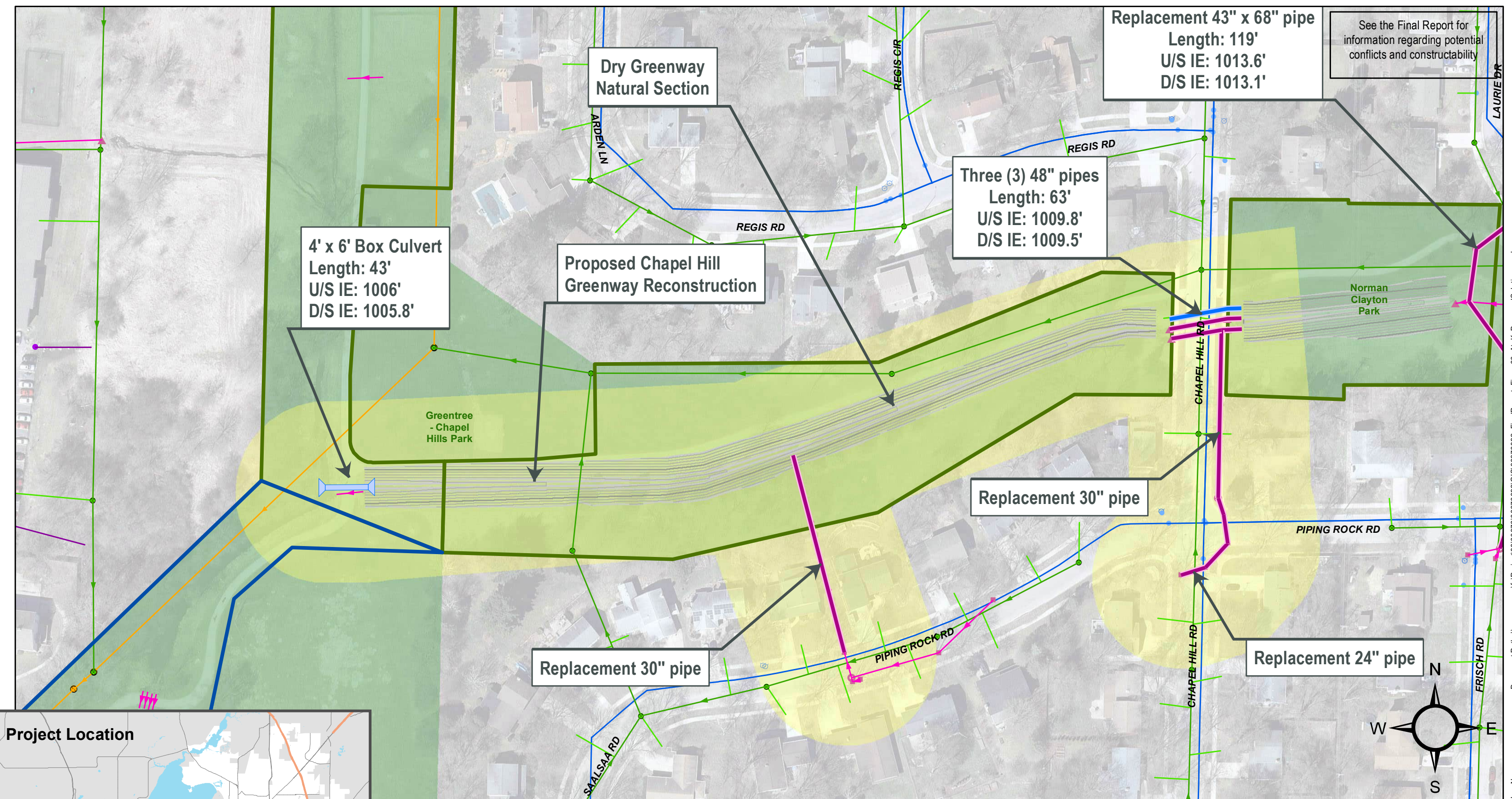
- | | | |
|-----------------------|-------------------|---------------|
| Greenway | Inlet | Water Valve |
| Storm Pipe | Sanitary Mains | Water Hydrant |
| Other Storm Structure | SAS | Park |
| Access Structures | Sanitary Laterals | |
| Apron | Water Main | |
-
- | |
|------------------------------|
| Proposed Improvements |
| Replacement Pipe |
| New Pipe |
| Pipe Removed |
| Proposed Box Culverts |
| Improvement Area of Interest |

Norman Clayton Park and Storm System Improvements

Figure 30 - G



Date: 5/3/2022



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User Name: aconverse

See the Final Report for information regarding potential conflicts and constructability

2019 City Project at McKenna Blvd.
Modeling completed using post-project conditions.
However, mapped pipe alignments have not been updated to match newly constructed storm system.

Replacement 24" pipe

Replacement 30" pipe

Replacement 36" pipe
Length: 207'
U/S IE: 1018'
D/S IE: 1009.1'

Remove Pipe

Remove Pipe

Remove Pipe

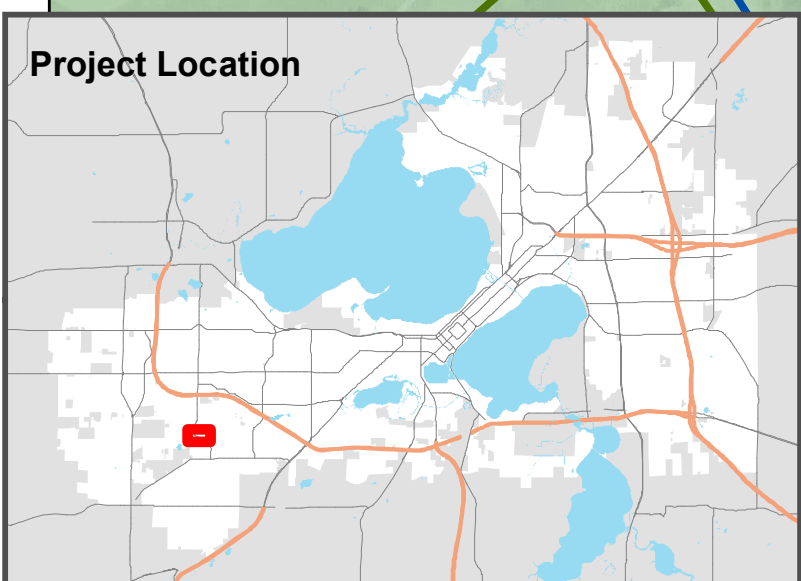
New 42" pipe
Length: 249'
U/S IE: 1008.6'
D/S IE: 1004.2'

New 48" x 76" pipe
Length: 553'
U/S IE: 1004.4'
D/S IE: 1003.2'

New 34" x 53" pipe

New 30" pipe

Project Location

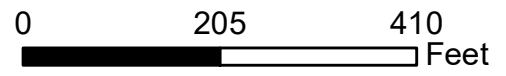


- | | | | |
|-----------------------|-------------------------------------|-------------------|---------------|
| Greenway | Apron | Sanitary Mains | Water Main |
| Pond | Inlet | SAS | Water Valve |
| Storm Pipe | Private Stormwater Pipes--Approx | Sanitary Laterals | Water Hydrant |
| Other Storm Structure | Private Stormwater Structures--A... | MMSD Mains | Park |
| Access Structures | | MMSD SAS | |

- Proposed Improvements**
- Replacement Pipe
 - New Pipe
 - Pipe Removed
 - Proposed Box Culverts
 - Improvement Area of Interest

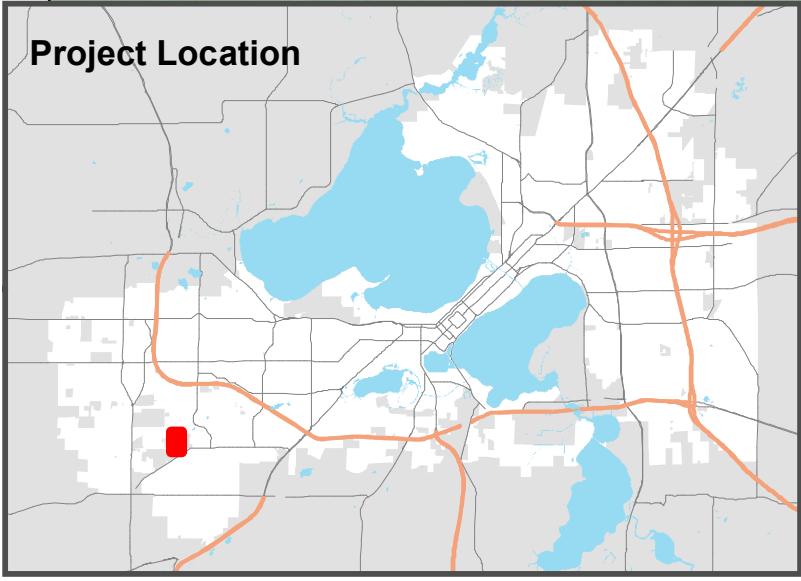
McKenna Blvd Improvements

Figure 30 - I



Date: 5/3/2022

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User Name: aconverse

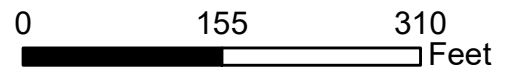


- | | | |
|-----------------------|-------------------|------------------|
| Pond | Inlet | MMSD SAS |
| Storm Pipe | Sanitary Mains | Municipal Limits |
| Other Storm Structure | SAS | Park |
| Access Structures | Sanitary Laterals | |
| Apron | MMSD Mains | |

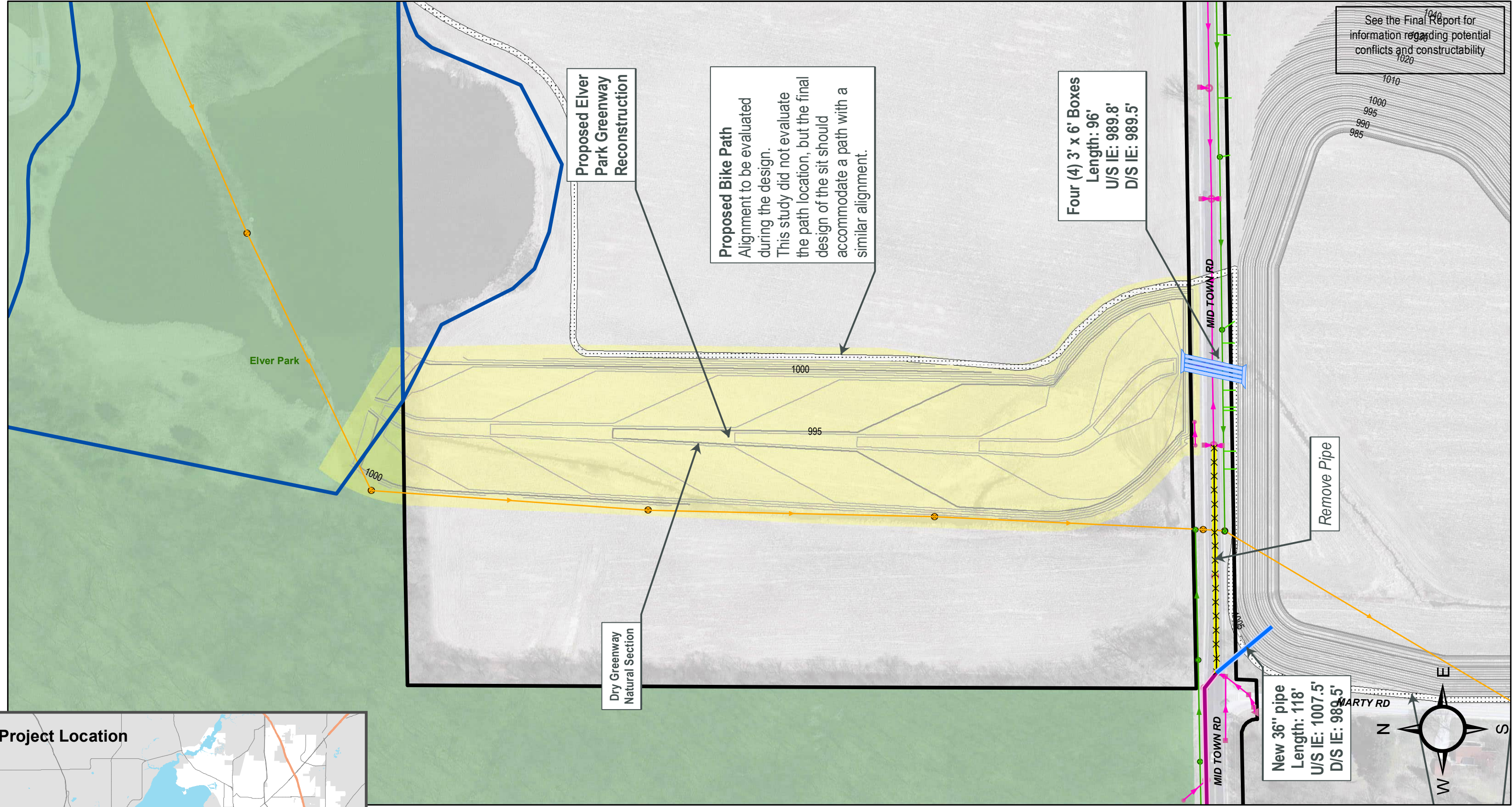
- Proposed Improvements**
- Replacement Pipe
 - New Pipe
 - Pipe Removed
 - Proposed Box Culverts
 - Improvement Area of Interest

Elver Park Greenway Reconstruction

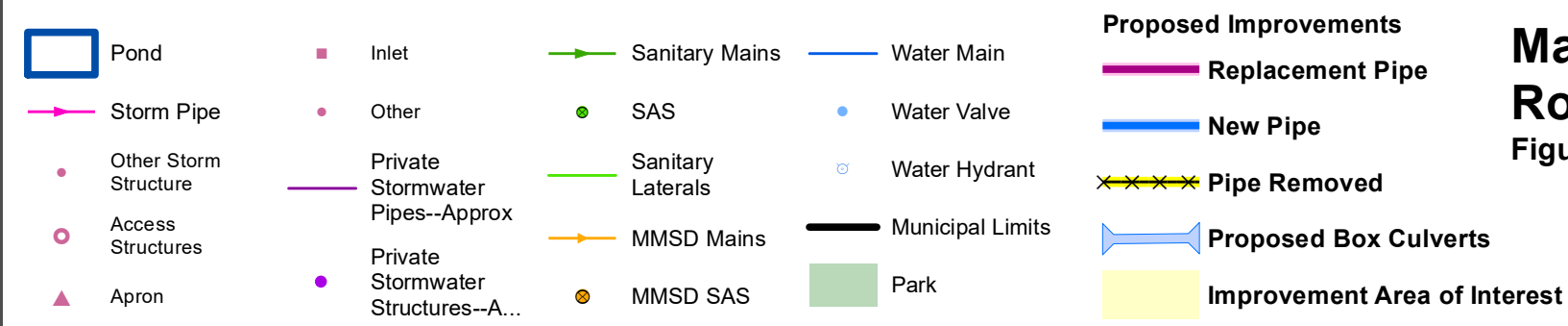
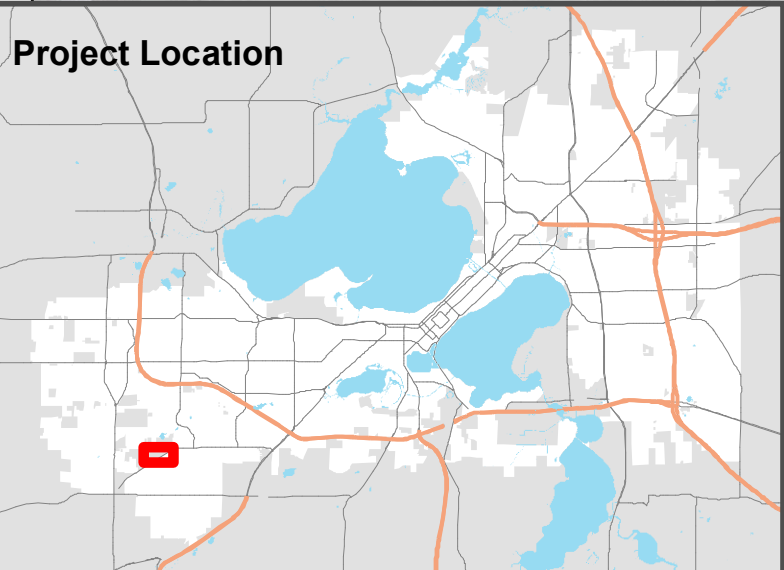
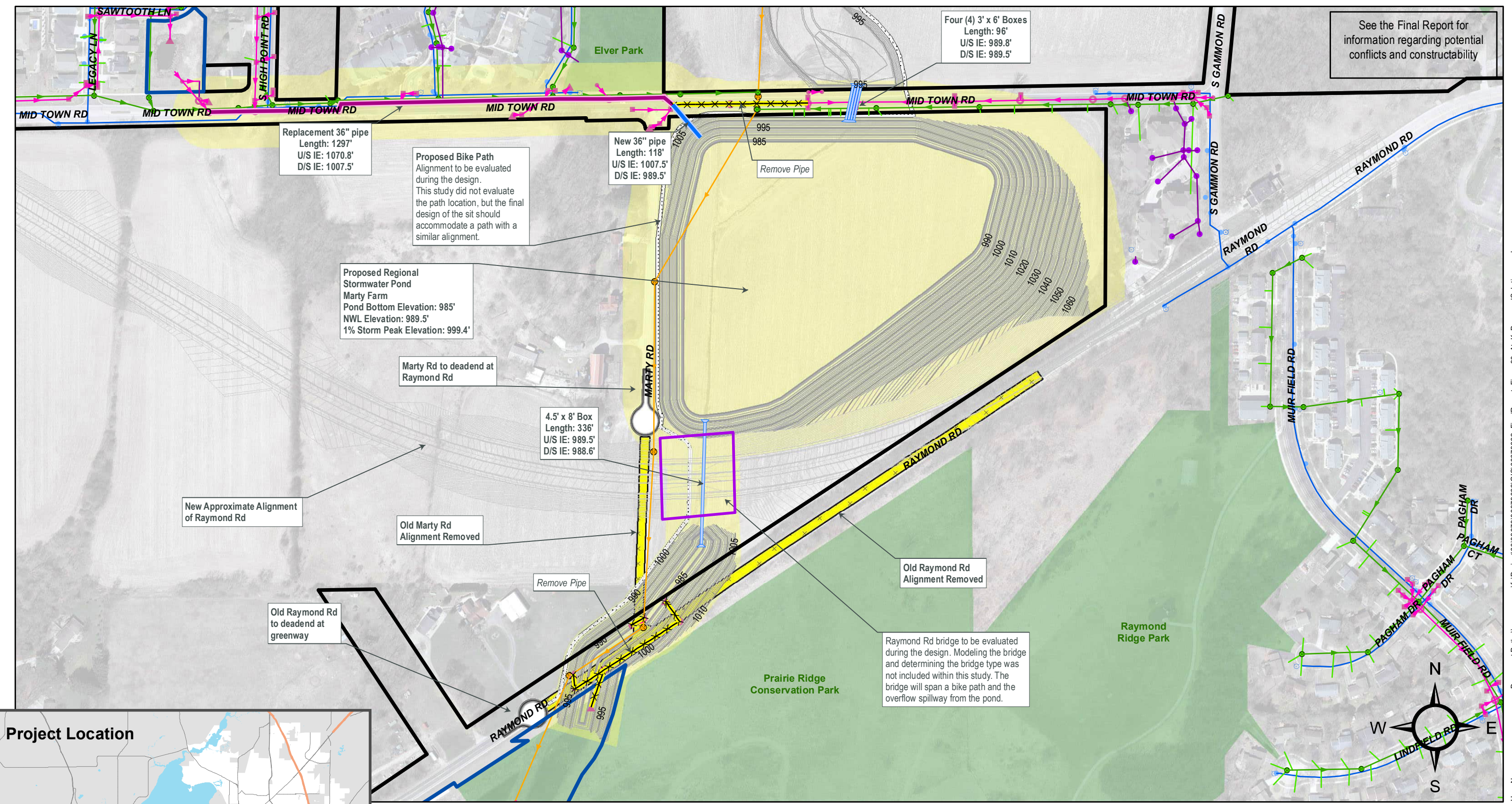
Figure 30 - J



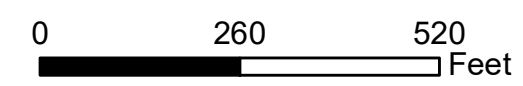
Date: 5/3/2022



See the Final Report for information regarding potential conflicts and constructability

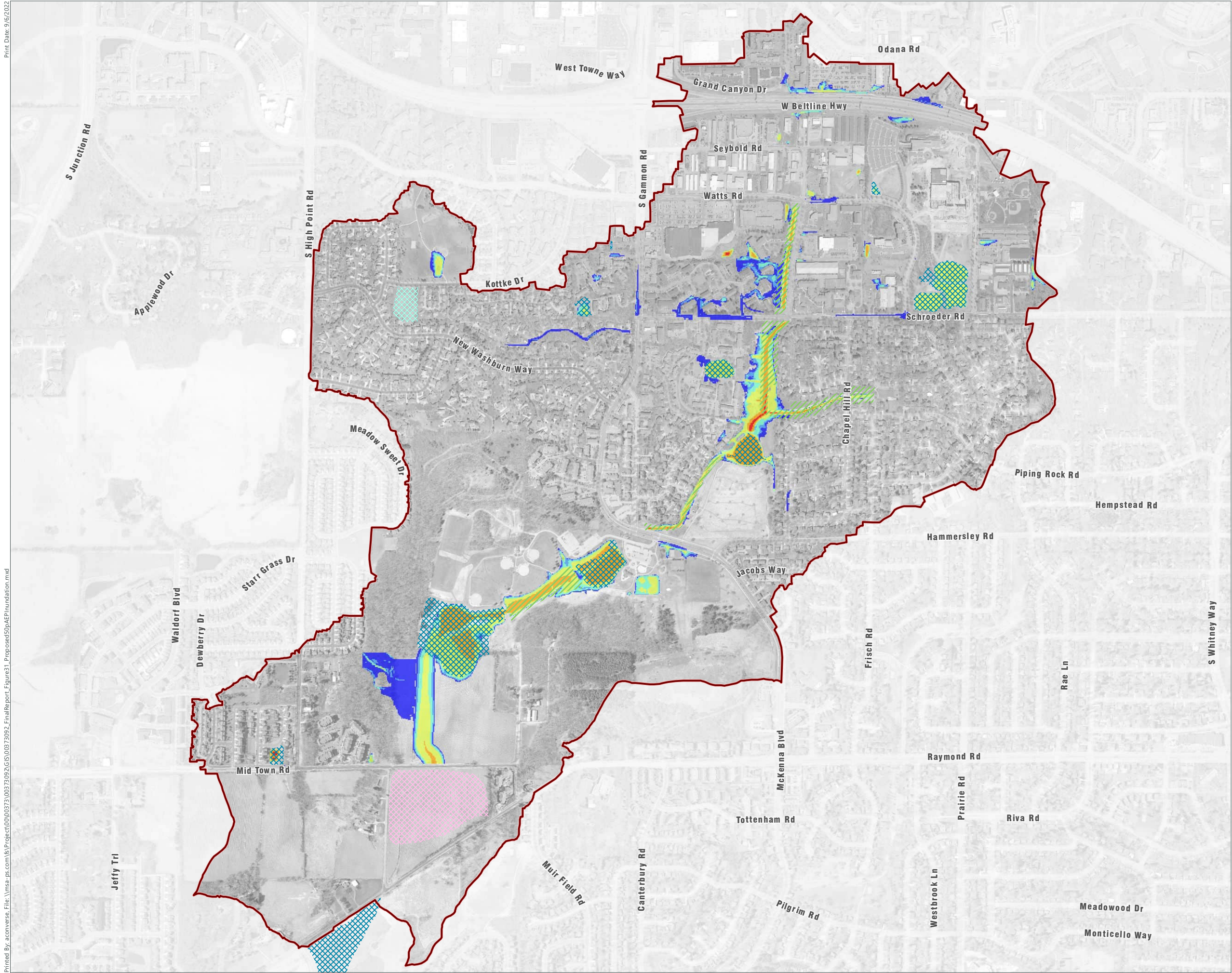


Marty Road/Mid Town Road Regional Pond
Figure 30 - K



Date: 5/9/2022

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User Name: aconverse



50% AEP Inundation Proposed Conditions

FIGURE 31
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond

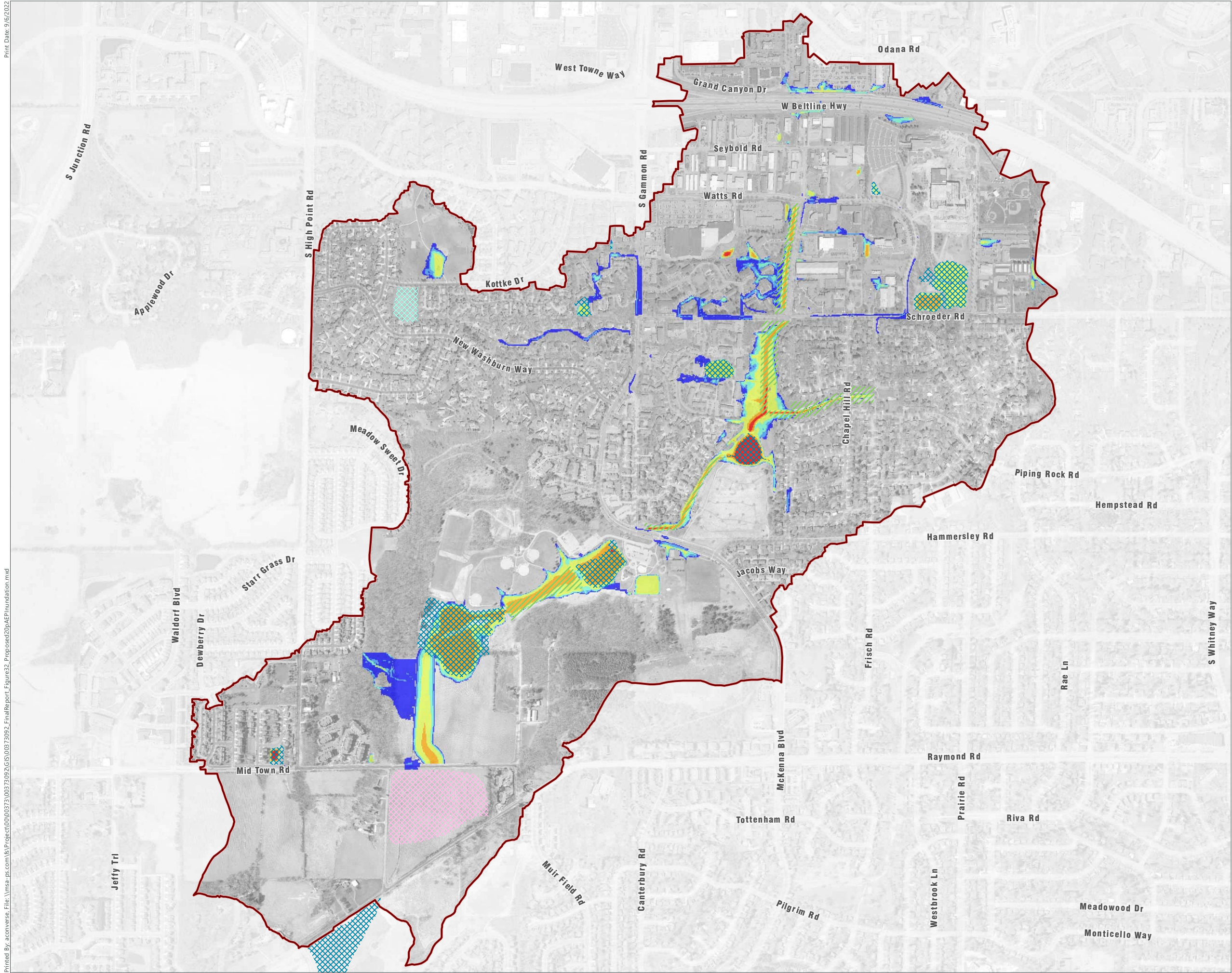
50% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison





20% AEP Inundation Proposed Conditions

FIGURE 32
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond

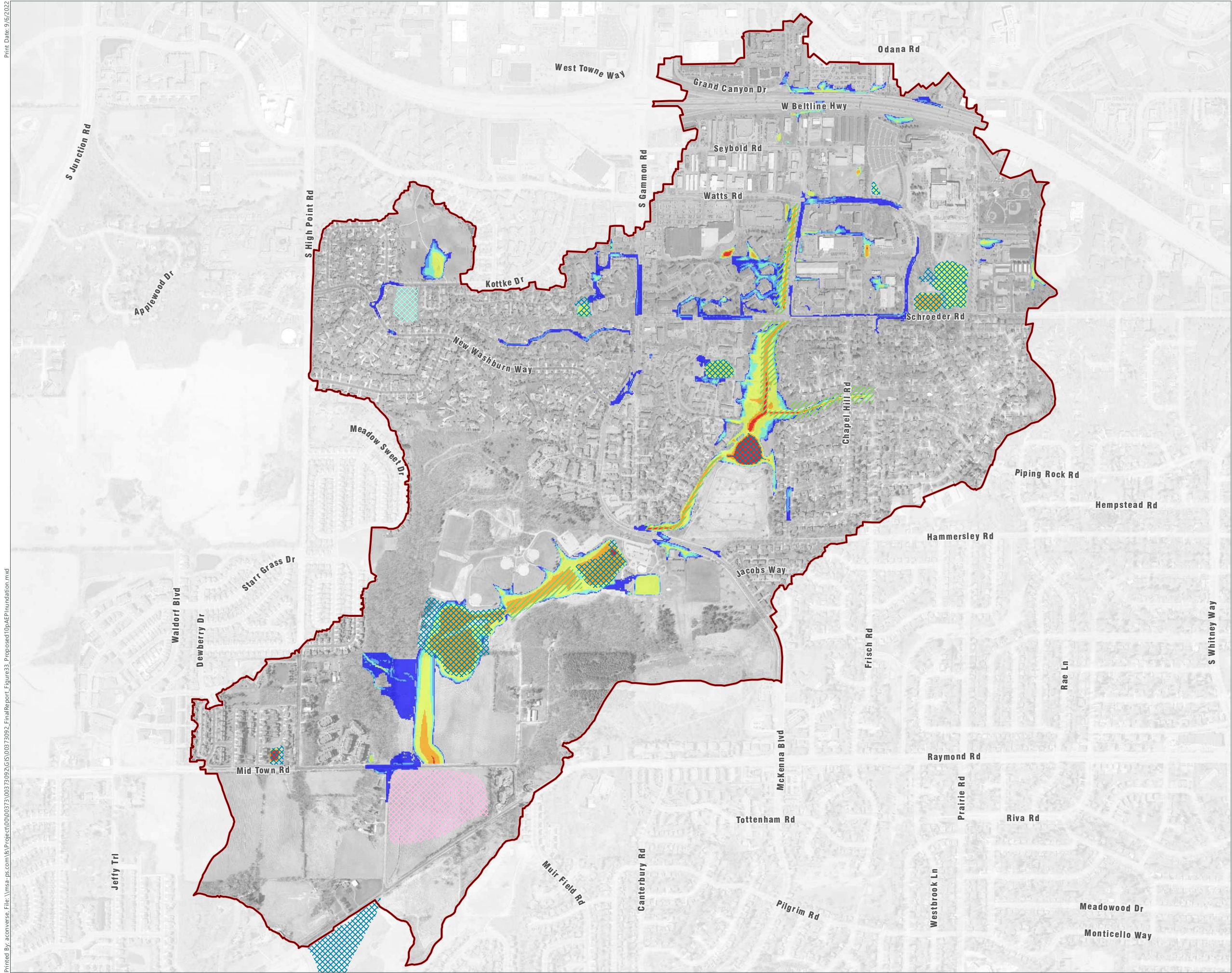
20% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison





10% AEP Inundation Proposed Conditions

FIGURE 33
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond

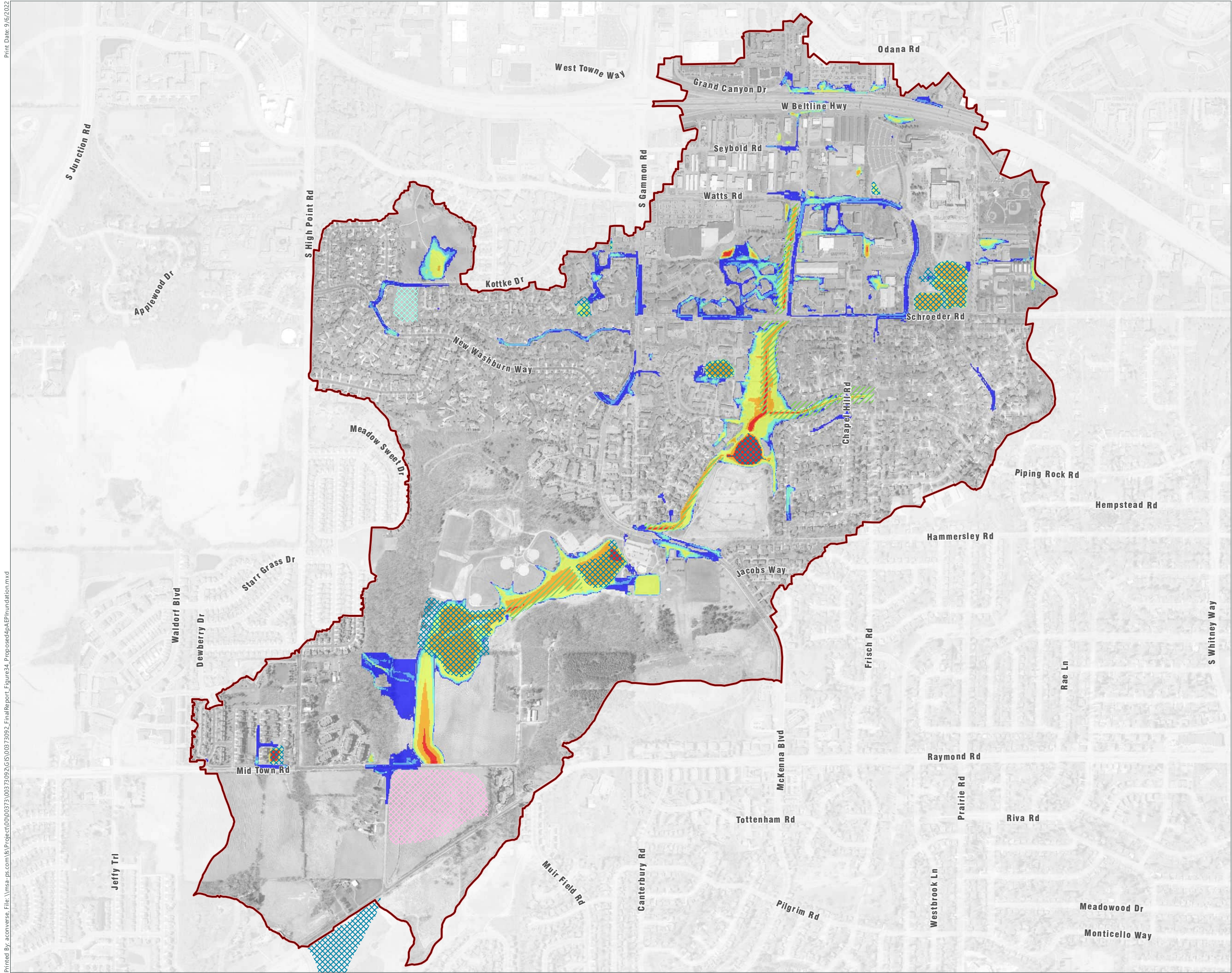
10% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison





4% AEP Inundation Proposed Conditions

FIGURE 34
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond

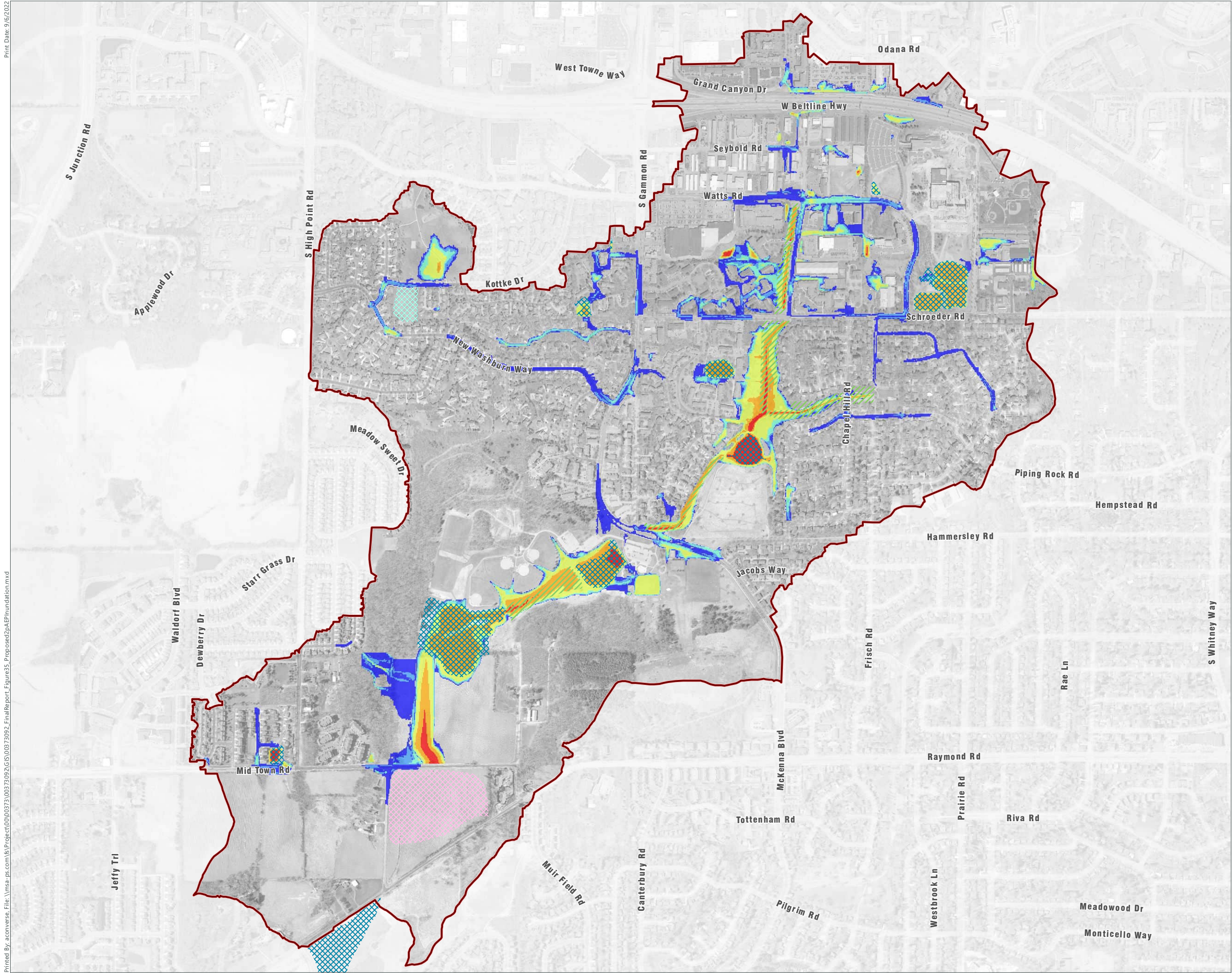
4% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison





2% AEP Inundation Proposed Conditions

FIGURE 35
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond

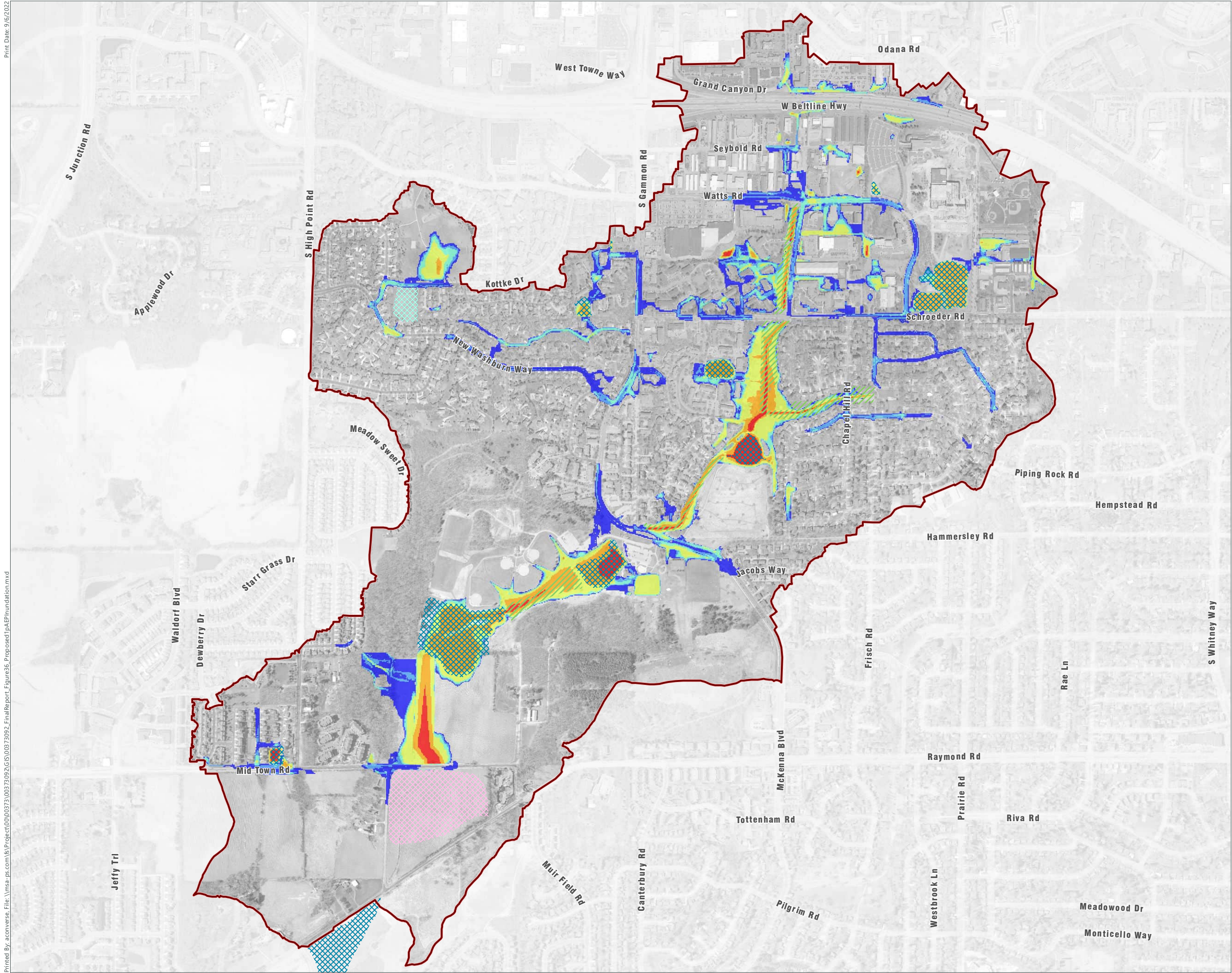
2% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison





1% AEP Inundation Proposed Conditions

FIGURE 36
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond

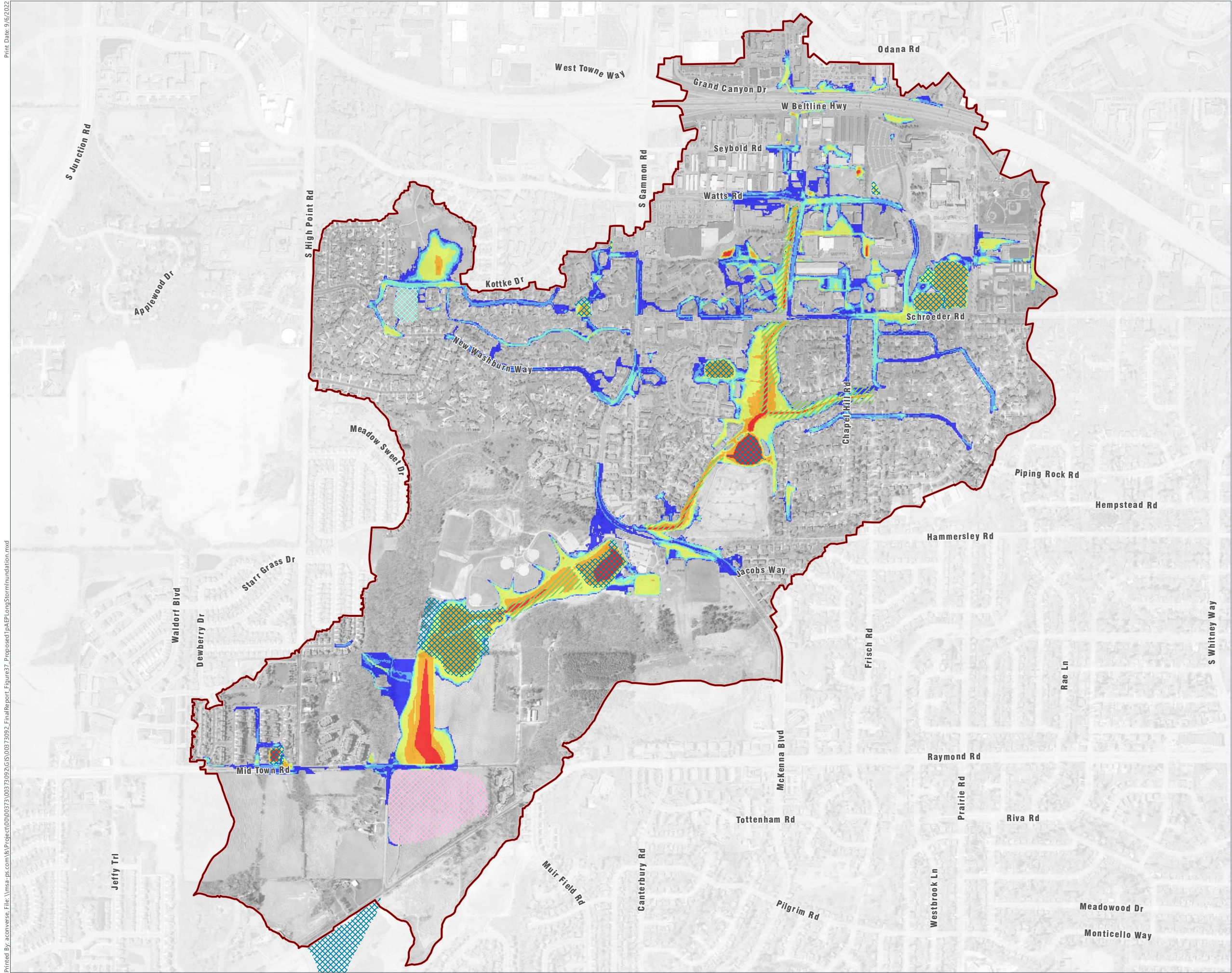
1% Annual Exceedance Probability Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison





Long 1% AEP Inundation Proposed Conditions

FIGURE 37
Greentree/McKenna Watershed
Study Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond

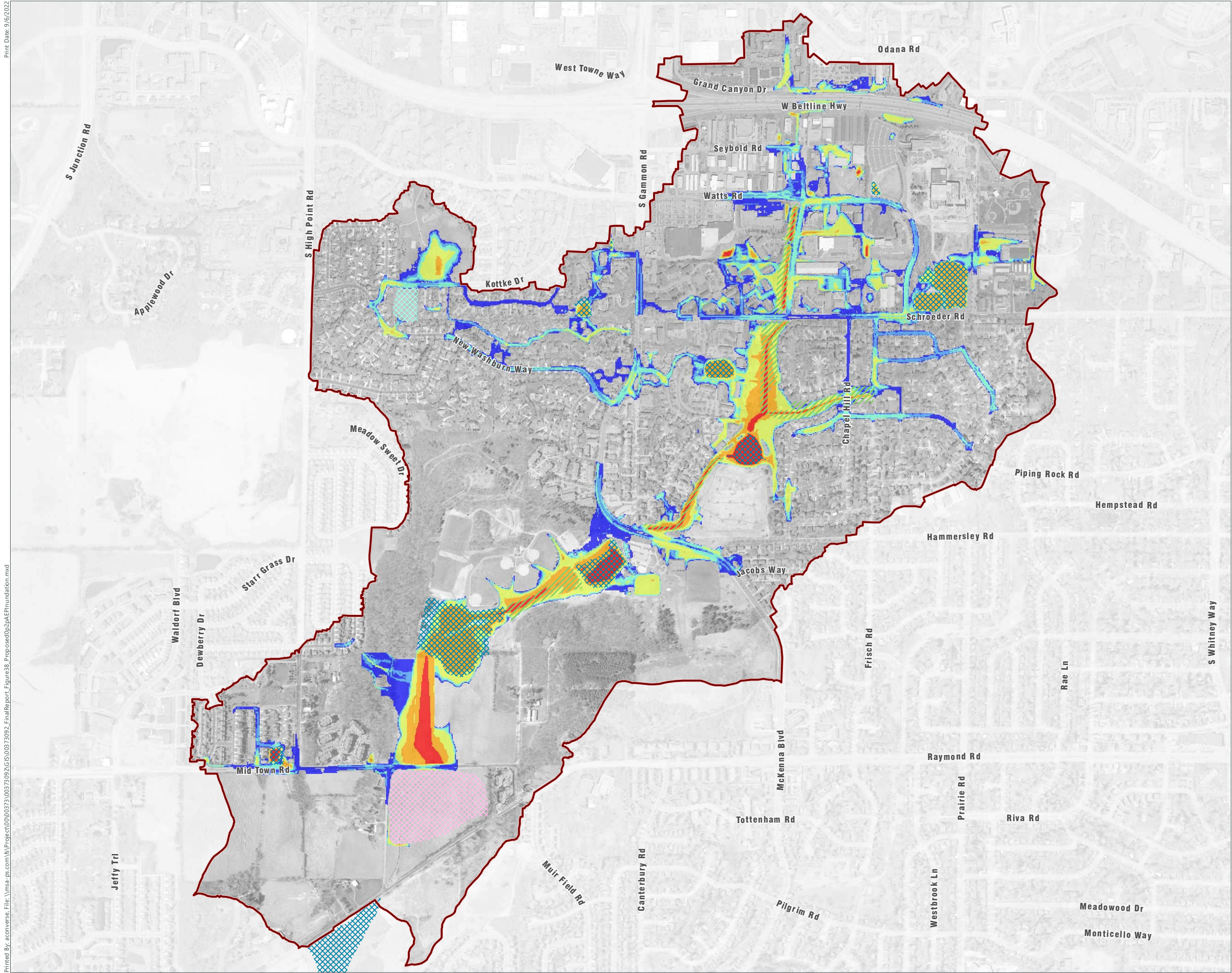
1% Long AEP Storm

Maximum Water Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Data Sources:
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison





Appendix A: Modeling Guidance

MODELING GUIDANCE

Version 2019-12-06 (DRAFT)

Latest Draft to Round 1 and Round 2 Study Consultants

The City recognizes that an important aspect of modeling is professional judgement; and it will be up to the Consultant to appropriately define parameters, variables, and methodology. However, it is in the City's best interest to aim for relative uniformity amongst all City models. Therefore, the Consultant may be expected to justify, document, and in some instances, modify various model inputs and assumptions.

City of Madison Flood Mitigation Goals

1. No home or business will be flooded during the 100-year design storm.
2. Eliminate flooding from the storm sewer system for up to the 10-year design storm; all water shall be contained within the pipes and structures (exception: low points).
3. Allow no more than 0.5 feet of water above storm sewer inlet rim at inlet-restricted low points for up to the 10-year design storm.
4. Centerline of street to remain passable during 25-year design storm with no more than 0.2 feet of water at the centerline.
 - a. Note that the Watershed Study modeling approach will not explicitly account for cross flow conditions where more gutter flow on one side of the street can overtop the crown.
5. Enclosed depressions to be served to the 100-year design storm (which can include safe overland flow within street, easements, greenways or other public lands).
6. Greenway crossings at streets to be served to the 100-year design storm.
7. Provide flooding solutions that do not negatively impact downstream properties.
8. For the purpose of the watershed studies "deficiencies" in the system shall be defined as existing infrastructure, drainage capacity or system limitations that fail to meet the goals stated in 1-7 above.

Guidance for Solutions

1. Watershed deficiencies will be reviewed, and solutions will be provided up to the 100-yr design storm.
2. In areas where flooding occurs in events exceeding the 100-year storm, those areas will not be prioritized for engineering solutions, but will be identified in existing conditions model for 500-year event storms.
3. Proposed solutions will be identified for only the publicly owned drainage system. Drainage issues that are private (water from the public infrastructure such as streets, greenways, ponds and/or easements is not the cause of the drainage issue) will not require modeling solutions but should be identified where possible in the existing conditions analysis so staff may work with property owners if necessary. (See Also Hydraulics section of Modeling Guidance for discussion on private system existing conditions modeling.)

DATA SOURCES:

In the report, document the file name and date for the following data sources:

- Land Use
- LiDAR
- Storm Sewer
- Culverts
- Greenways
- Planimetric Data
- Aerial Imagery

MODELING PARAMETERS:

Initial model parameters are the following items:

1. Model all storm sewer and culvert segments 18 inches in diameter (or equivalent) and larger, noting that the model will be required to identify all watershed deficiencies, including inlet capacity. Inclusion of smaller diameter pipes may be required to meet the goals of the model.
2. Street inlets are to be aggregated within the model to the 18-inch diameter (or equivalent) storm sewer level.
3. Incorporate existing storm water management facilities (public and private) into the model.
4. Subdivide provided outfall basins into smaller watersheds as needed in order to properly execute the model.
5. Coordinate System and Vertical Datum
 - a. Horizontal Coordinate System: Wisconsin County Coordinate System – Dane Zone NAD83 (HARN).
 - b. Vertical Datum: NAVD88 (pre 2007 adjustment) ft (City of Madison Datum + 845.6)
6. Naming convention
 - a. Names are limited to 20 characters
 - b. Subcatchments:
 - i. Begin with Subcatchments naming convention provided by the City in the Outfall Basin feature class.
 1. Add a three-digit designator to the end of the name, beginning with 000
 2. As subcatchments are subdivided, increase the added designator by 1.
 3. Example: ME04-A-0014-H (*Provided by City*) → ME04-A-0014-H-MAD-C-000 (*For the original basin*) → ME04-A-0014-H-001 (*For first subdivision*)
 - ii. Final outfall basin feature class file, including supporting files used to compute runoff timing and volume parameters shall be part of the deliverables provided to the City of Madison.
 - c. Structures and Junctions:
 - i. Node (Junction/Storage/Outfall) names for existing structures shall retain the asset identification provided by the City.
 - ii. Proposed Structure names are to be determined by the Consultant but shall be given a "logical" name that reflects general location, function, or other.
 - iii. For junctions that need to be added that are storm sewer tees as constructed, use the downstream manhole / structure with "_01" added in increasing order moving from downstream to upstream. For example, the first junction added for a tee upstream of MI3350-001 would be MI3350-001_01
 - d. Pipes:
 - i. Conduit names for existing pipes shall retain the asset identification provided by the City, except that:
 1. The first two letters (i.e AE, IN, etc) will be removed
 2. Leads with an asset ID that takes up all 20 characters can be shortened to the corresponding assigned ID. For example, 3350-032_3350-007_3350-001 can be changed to 3350-032_3350-001_01
 - ii. Proposed Pipe names are to be determined by the Consultant but shall be named in a manner similar to the City pipe naming convention, which includes the upstream and downstream structure names.
 - e. Channel/Street Flow Segments:
 - i. Conduit names for drainage-ways shall be named in a manner that identifies the greenway segment it represents by Greenway Node Number and the distance from the upstream end. Example: GR7541-062_125 would represent a channel segment that begins 125 feet into the North Door Creek Greenway – Sprecher Road Section.
 - ii. Conduit names for streets shall be named with "Rd_"[US_Node_Name]_[DS_Node_Name] and remove the first two letters in the node name similar to how pipes are named.
 - f. Natural Channels:
 - i. Natural channel transects shall be named with the same ID as the conduit name.

- ii. Street models as natural channels shall be named in a manner that is easily identifiable for the street or street type it represents.
- iii. A shapefile shall be created documenting where natural channel transects are cut.
- g. Other SWMM Features (Weirs, orifices, etc)
 - i. Other SWMM features shall have readily identifiable names corresponding to the type of feature they are trying to model. For example, an orifice for a detention pond should have an ID that is "<Detention Pond ID>_ORIF_01", keeping within a 20 character limit.
- h. Ponds
 - i.

7. Rainfall

- a. MSE4 24-hour Distribution and NOAA Atlas 14 Depths

Recurrence Interval (years)	Rainfall Depth (inches)
2	2.8
5	3.5
10	4.1
25	5.0
50	5.7
100	6.6
500	8.8

- b. Long-Duration Storm – Two 24-hour, 100-year MSE4 storm events with the time between peak rainfalls shorted from 24 hours to 12 hours.

8. Hydrology (SWMM Method with Horton Infiltration) (References: A, B, C)

- Parameters listed are default parameters and may need to be adjusted based on calibration data.
- a. Subcatchment Detail for Street Drainage
 - i. Contributing area to the existing storm sewer system that is to be modeled (Determined on a watershed by watershed basis)
 - ii. Provides information that there is or is not an issue with upstream street flooding / storm sewer capacity that would be detailed out as part of a future street improvement design project.
- b. SWMM Routing Parameters (if calibration is not available to adjust parameters)
 - i. Percent Impervious - Follow Step 1 (pages 1-3) of the "HowTo_CalculateCN" document.
 - ii. DCIA – Reference WinSLAMM Standard Land Use DCIA Spreadsheet
 - iii. Width – Estimated based on subcatchment shape. Estimation methodology shall be documented.
A single width shall be calculated for the entire subcatchment. The single width will then be prorated based on sub area acreage for each sub area. DCIA will be prorated based on the area of the DCIA sub area compared to the total subcatchment area. The prorated width for the non-DCIA sub area and pervious sub area will be the same; it will be based on the sum of the non-DCIA plus the pervious area compared to the total subcatchment area.
It is expected Width is one of the first calibration parameters for peak flow.
 - iv. Slope – Computed manually or estimated based on LiDAR. Computation or estimation methodology shall be documented.
 - v. Each subcatchment is to be split into area of (1) DCIA, (2) non-DCIA, and (3) pervious area. Within the model, the non-DCIA shall be routed to the pervious area.
- c. Horton Infiltration

- i. For typical urban pervious area (Based on range of values for different soil types, moisture conditions, and vegetation conditions found in Reference A):

HSG Group ^a	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)	Decay Rate (1/hr)	Dry Days ^b
A	4.0	1.0	4.0	3.1
B	2.0	0.5	4.0	4.4
C	1.0	0.2	4.0	7.0
D	0.5	0.1	4.0	9.9
Water	0	0	0	0

^aFor HSG listed as A/D, B/D, C/D, the default approach will be to assume the HSG associated with the lower infiltration rate (HSG D).

^bUse equation 4-12, pg 99, SWMM Reference Manual Volume 1 – Hydrology (Revised), January 2016

- ii. Impervious Manning's n – 0.016
- iii. Pervious Manning's n – 0.20
- iv. Depression Storage for Impervious – 0.05 inches
- v. Depression Storage for Pervious – 0.15 inches
- vi. Factors for adjusting
 - 1. Forest – Multiply max and min infiltration rates by 2.
 - 2. Farmland – Divide max and min infiltration rates by 2.
 - 3. Other land uses – see reference
- vii. Area-weight the Horton Infiltration parameters for each subcatchment based on the area of each soil type within a subcatchment.
- viii. It is understood the NRCS/SCS updates the soil mapping at various times. The project teams will identify a date the soils data will be downloaded and that will be the data used for the duration of the project.

9. 1D Hydraulics (References: A, B, D, E, F)

- Dynamic mode with constant / variable timestep sufficient to model system accurately.
- Conduit lengthening shall not be used unless prior approval from City on reason.
- Parameters are default parameters and may need to be adjusted based on calibration data.
- This list is not intended to be exhaustive.
- a. System to be Modeled
 - i. Public
 - 1. Standard: 18" Pipes and Larger
 - 2. Process for Exceptions: Provide justification for reason that a pipe 18" and larger does not need to be modeled.
 - 3. Process for requiring inclusion of pipes less than 18": Necessary when they are the only pipes draining parts of the street or drainage system. For example, a 15" pipe stubbing out to a greenway from the street or a long trunk-line that is less than 18".
 - ii. Private
 - 1. Standard: Not included
 - 2. Process for requiring inclusion of private pipes:
 - a. Stormwater management detention facilities
 - b. When necessary to understand the functioning of the public system. For example, the West Towne Mall parking lot drainage system.
 - iii. All greenways and major surface drainages
 - iv. All stormwater detention facilities (public and private). Private systems may be simplified if serving a single site.
 - v. Street surface drainage, but not necessary to the block level unless needed to understand major overflow routes
- b. Loss Coefficients
 - i. Entry

Commented [BC1]: Add maximum infiltration volume in inches

1. Culverts – Select Inlet Type based on the Help File or HEC-RAS Hydraulic Reference Manual
 2. Storm Sewer (internal at MHs) = 0.1
 3. Storm Drainage Structures (MH) at 45 degree bend = 0.25
 4. Storm Drainage Structures (MH) at 90 degree bend = 0.5
 5. For culverts and entrances to storm sewer from an open channel or pond, both the energy loss coefficient and the inlet control (culvert code) shall be used.
- ii. Exit
 1. Culverts –
 - a. Exit closed conduit to open channel = 0.5
 - b. Exit closed conduit to lake or pond = 1.0
 2. Storm Sewer (internal at MHs) = 0.05
 3. Storm Drainage Structures (MH) at 45 degree bend = 0.25
 4. Storm Drainage Structures (MH) at 90 degree bend = 0.5
- c. Coefficient of Discharge
 - i. Weirs
 1. Sharp Crested – 3.0
 2. Roadway embankment – 2.6
 3. Flatter overflow – Use engineering judgment
 - ii. Orifices
 1. 0.6
 - d. Manning's n
 - i. Pipes
 1. Concrete Pipe: 0.013
 2. All other n values shall be chosen within generally acceptable ranges.
 - ii. Channels
 1. Use Chow's Open Channel Hydraulics, Reference E
 - iii. Bank Flow, including developed urban areas
 1. Use Chow's Open Channel Hydraulics, Reference E
 - e. Transect Placement and Modifiers
 - i. Splitting long open channels
 1. Changes in cross section
 2. Significant changes in slope and roughness
 3. Overflow points
 - ii. Segment Lengths
 - iii. Channel Geometry
 - iv. Provide shapefile where natural channel transects are selected along with XS Identifier
 - f. Tailwater Conditions:
 - i. Lake Mendota: one foot over Summer Maximum – 851.10
 - ii. Lake Wingra:
 - g. Inlet Clogging Factors
 - i. Continuous Slopes
 1. Street slope < 1% - 25% Clogging
 2. Street slope >= 1% - No Clogging
 - ii. Sags – 50% Clogging
10. 2D Data
- a. Surface Roughness – The average Manning's n may vary by land cover / land use. Referencing TR-55, the following roughness shall be used:
 - i. Impervious areas - 0.1
 - ii. Turf grass areas - 0.24
 - iii. Wooded – 0.4
 - iv. Prairie – 0.15
 - v. Other – reference TR-55

There is not currently a city-wide impervious area layer. The consultant may choose to delineate the impervious area for the watershed.

Or, the existing data may be utilized. The following assumptions can be made using the existing land use data:

- i. For non-residential parcels, impervious and pervious area is available, therefore, that shall be used.
- ii. A percent impervious is available for residential parcels. Calculate a composite roughness using the percent impervious area. Remove roofs from the composite roughness calculation – reference the Dane County land use for residential roofs. (roofs will be entered as blocked obstructions)
- iii. Average the roughness within the ROW based impervious and pervious area.
- b. Blocked Obstructions – enter roofs as blocked obstructions
 - i. Non-residential – use City impervious area data for roofs
 - ii. Residential – use Dane County roof layer

11. Non-Modeling Data

- a. In the Notes field, include the sources of data

12. Scenarios

- a. Scenarios shall be set up as follows:
 - a. 'Children' of the BASE scenario:
 - i. EXISTING
(grandchildren of BASE scenario, children of EXISTING)
 1. EXISTING_002_YR
 2. EXISTING_005_YR
 3. EXISTING_010_YR
 4. EXISTING_025_YR
 5. EXISTING_050_YR
 6. EXISTING_100_YR
 7. EXISTING_500_YR
 8. EXISTING_100YR_LONG_STORM
 - ii. PROP_ALT1
(grandchildren of BASE scenario, children of PROP_ALT1)
 1. PROP_ALT1_002_YR
 2. PROP_ALT1_005_YR
 3. PROP_ALT1_010_YR
 4. PROP_ALT1_025_YR
 5. PROP_ALT1_050_YR
 6. PROP_ALT1_100_YR
 7. PROP_ALT1_500_YR
 8. PROP_ALT1_100YR_LONG_STORM
 - iii. PROP_ALT2
(grandchildren of BASE scenario, children of PROP_ALT2)
 1. PROP_ALT2_002_YR
 2. PROP_ALT2_005_YR
 3. PROP_ALT2_010_YR
 4. PROP_ALT2_025_YR
 5. PROP_ALT2_050_YR
 6. PROP_ALT2_100_YR
 7. PROP_ALT2_500_YR
 8. PROP_ALT2_100YR_LONG_STORM
 - iv. PROP_ALT3
(grandchildren of BASE scenario, children of PROP_ALT3)
 1. PROP_ALT3_002_YR

Commented [BC2]: Do we know if the scenario manager works for XP-SWMM? Otherwise we can come up with a model naming convention and use global storms.

2. PROP_ALT3_005_YR
 3. PROP_ALT3_010_YR
 4. PROP_ALT3_025_YR
 5. PROP_ALT3_050_YR
 6. PROP_ALT3_100_YR
 7. PROP_ALT3_500_YR
 8. PROP_ALT3_100YR_LONG_STORM
- b. Facility for children of the BASE scenario is defined via database queries. Facility for grandchildren of the BASE scenario are defined by inheritance.
 - c. Data sets for children of the BASE scenario should be BASE except where needed to define different datasets. Data sets for the grandchildren of the BASE scenario shall be defined by inheritance except for the raingage, which should be set as defined below.
 - i. Data set naming convention should match the children of the BASE scenario. For example, if a different junction data set is needed for PROP_ALT2, the junction data set should be called "PROP_ALT2".
 - ii. Data set naming convention for raingage sets should be based on the event used in the scenario naming convention, e.g. 002_YR, 005_YR...100YR_LONGSTORM.

REFERENCES

- A. Help File
- B. Storm Water Management Model version 5.1 User's Manual. (Available at: <https://www.epa.gov/water-research/storm-water-management-model-swmm-version-51-users-manual>)
- C. SWMM reference manual volume I – hydrology (Available at: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100NYRA.txt>)
- D. SWMM reference manual volume volume II – hydraulics (Available at: <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100S9AS.PDF?Dockey=P100S9AS.PDF>)
- E. Chow, Open Channel Hydraulics, 1959
- F. HEC-RAS Hydraulic Reference Manual. (Available at: <https://www.hec.usace.army.mil/software/hec-ras/documentation/HEC-RAS%205.0%20Reference%20Manual.pdf>)

Appendix B: Hydrology Input Parameters per Subbasin

McKenna Greentree Watershed Study - Existing Conditions Report
Appendix B: Hydrology Input Parameters per Subbasin

Subcatchment	DCIA	UCIA	Pervious	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)	Decay Rate (1/s)	Dry Days
2665-004_426	3.412	0.638	44.778	0.21	0.21	0.001	4.8
2665-004_942	0.675	0.045	12.974	0.18	0.18	0.001	4.5
2665-005_00	3.962	0.181	17.892	0.20	0.20	0.001	4.7
2665-005_01a_01	1.967	0.088	1.312	0.10	0.10	0.001	5.7
2763-010_01	2.408	0.163	7.312	0.06	0.06	0.001	6.7
2764-015_1374_01	0.831	0.426	3.238	0.11	0.11	0.001	5.4
2764-015_446	0.897	0.497	3.086	0.08	0.08	0.001	6.3
2764-015_883	0.874	0.468	11.791	0.06	0.06	0.001	6.8
2861-019_397	0.165	0.031	2.098	0.15	0.15	0.001	4.4
2862-008_1183	0.947	0.145	4.564	0.07	0.07	0.001	6.4
2862-008_1489_01	1.623	0.07	3.659	0.09	0.09	0.001	6.2
2862-008_461	0.199	0.25	2.717	0.15	0.15	0.001	4.4
2862-008_570	1.781	0.365	7.308	0.08	0.08	0.001	6.4
2862-008_893	0.133	0.115	3.348	0.07	0.07	0.001	6.6
2862-008_916	0.155	0.124	2.57	0.14	0.14	0.001	4.7
2961-017_02	0.001	0	4.077	0.15	0.15	0.001	4.4
AE2367-047	0.407	0.169	1.112	0.15	0.15	0.001	4.4
AE2461-017	0.169	0.299	3.294	0.13	0.13	0.001	4.9
AE2469-017	1.902	0.227	34.831	0.08	0.08	0.001	4.5
AE2469-020	2.272	1.134	71.538	0.09	0.09	0.001	5.1
AE2561-003	0.6	0.439	19.502	0.10	0.10	0.001	5.7
AE2765-015	0.482	0.018	4.376	0.10	0.10	0.001	5.8
AE2859-002	3.849	0.086	3.859	0.12	0.12	0.001	5.2
AE2859-017	3.489	0.091	1.679	0.13	0.13	0.001	4.9
AE2861-013	2.15	0.294	7.336	0.16	0.16	0.001	4.5
AE2862-002	0.192	0.031	0.118	0.15	0.15	0.001	4.4
AE2863-027	0.445	0.257	3.618	0.15	0.15	0.001	4.4
AE3061-006	4.946	0.299	12.251	0.14	0.14	0.001	5.2
AS2367-020	0.465	0.364	0.833	0.12	0.12	0.001	5.1
AS2367-028	0.496	0.115	1.287	0.12	0.12	0.001	5.1
AS2461-003	0.194	0.08	0.243	0.07	0.07	0.001	6.4
AS2467-012	0.113	0.005	0.225	0.07	0.07	0.001	6.5
AS2562-005	3.229	1.91	5.87	0.15	0.15	0.001	4.4
AS2562-008	0.724	0.481	1.978	0.26	0.26	0.001	4.9
AS2568-006	0.235	0	0.038	0.06	0.06	0.001	6.8
AS2568-007	0.464	0	0.006	0.05	0.05	0.001	7.0
AS2568-009	0.251	0	0.246	0.08	0.08	0.001	4.4
AS2568-011	0.459	0.02	0.196	0.10	0.10	0.001	4.4
AS2568-014	0.832	0.073	0.668	0.11	0.11	0.001	4.4
AS2661-012	0.69	0.073	0.967	0.13	0.13	0.001	4.4
AS2661-013	1.753	0.189	1.701	0.09	0.09	0.001	6.0
AS2661-015	1.299	0.046	0.528	0.20	0.20	0.001	5.3
AS2662-020	4.413	2.754	11.806	0.08	0.08	0.001	6.9
AS2662-025	0.498	0.423	1.77	0.05	0.05	0.001	7.0
AS2662-028	0.683	0.52	2.358	0.11	0.11	0.001	5.4
AS2662-031	1.154	0.839	4.335	0.06	0.06	0.001	6.6
AS2662-043	0.211	0.02	0.069	0.10	0.10	0.001	5.6

McKenna Greentree Watershed Study - Existing Conditions Report
Appendix B: Hydrology Input Parameters per Subbasin

Subcatchment	DCIA	UCIA	Pervious	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)	Decay Rate (1/s)	Dry Days
AS2663-006	0.263	0.101	0.208	0.10	0.10	0.001	5.7
AS2663-007	0.717	0.346	1.458	0.08	0.08	0.001	7.0
AS2664-004	2.791	0.128	1.47	0.14	0.14	0.001	4.8
AS2762-003	0.072	0.006	0.025	0.15	0.15	0.001	4.4
AS2762-008	6.214	0.508	8.033	0.15	0.15	0.001	4.4
AS2762-012	0.688	0.019	0.076	0.15	0.15	0.001	4.4
AS2762-013	0.236	0	0.043	0.11	0.11	0.001	5.8
AS2765-011	0.29	0	0.226	0.06	0.06	0.001	6.8
AS2765-030	4.341	0.497	13.044	0.05	0.05	0.001	7.0
AS2858-005	1.133	0.009	0.744	0.05	0.05	0.001	7.0
AS2858-021	6.304	0.143	3.816	0.16	0.16	0.001	4.5
AS2858-029	5.993	0.034	1.784	0.15	0.15	0.001	4.4
AS2863-045	0.92	0.654	2.595	0.10	0.10	0.001	5.8
AS2864-011	0.243	0.12	0.288	0.15	0.15	0.001	4.4
AS2864-013	1.199	0.494	2.54	0.15	0.15	0.001	4.4
AS2960-007	2.635	0.016	1.64	0.15	0.15	0.001	4.4
AS2960-010	0.404	0	0.653	0.10	0.10	0.001	5.7
AS2960-011	3.322	0.01	0.855	0.15	0.15	0.001	4.4
AS2961-003	0.38	0.001	0.463	0.09	0.09	0.001	5.9
AS2961-007	1.101	0	1.916	0.15	0.15	0.001	4.4
AS2961-008	3.525	1.201	6.004	0.15	0.15	0.001	4.4
AS2962-022	0.822	0.53	2.224	0.15	0.15	0.001	4.4
AS2962-029	1.28	0.796	4.182	0.15	0.15	0.001	4.4
AS2962-034	5.658	3.633	15.964	0.15	0.15	0.001	4.4
AS2962-039	1.746	0.697	2.089	0.16	0.16	0.001	4.4
AS2962-040	0.545	0.166	1.167	0.15	0.15	0.001	4.4
AS2963-038	0.274	0.022	0.184	0.15	0.15	0.001	4.4
AS2963-045	4.158	1.594	7.827	0.15	0.15	0.001	4.4
AS2963-068	1.664	0.998	3.585	0.08	0.08	0.001	6.2
AS3060-001	5.558	0.018	2.16	0.08	0.08	0.001	6.2
AS3061-001	3.61	0.078	1.38	0.06	0.06	0.001	6.8
AS3063-006	0.878	0.453	3.292	0.15	0.15	0.001	4.4
AS-ES-4	1.139	0	0.154	0.20	0.20	0.001	4.4
AS-ES-6	1.135	0	4.381	0.12	0.12	0.001	4.9
DT2567-003	1.533	0.121	47.286	0.16	0.16	0.001	5.3
DT2567-003_01	1.709	0.348	16.677	0.11	0.11	0.001	5.5
DT2859-009	2.003	0	0.495	0.15	0.15	0.001	4.4
GR2861-019-801	4.609	0.84	2.579	0.15	0.15	0.001	4.4
GR2861-019-802	0.892	0.118	0.67	0.05	0.05	0.001	7.0
IN2366-026	0.147	0.054	1.513	0.12	0.12	0.001	5.2
IN2367-002	3.023	0.333	2.019	0.10	0.10	0.001	5.8
IN2367-014	0.915	0.149	1.33	0.11	0.11	0.001	5.4
IN2367-018	0.653	0.388	1.417	0.10	0.10	0.001	6.3
IN2367-023	0.337	0.107	0.627	0.05	0.05	0.001	7.0
IN2367-026	0.233	0.107	2.04	0.19	0.19	0.001	4.8
IN2367-033	1.215	0.822	3.566	0.05	0.05	0.001	6.9
IN2461-004	0.971	0.425	1.048	0.08	0.08	0.001	6.3

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Appendix B: Hydrology Input Parameters per Subbasin

Subcatchment	DCIA	UCIA	Pervious	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)	Decay Rate (1/s)	Dry Days
IN2461-008	1.379	1.071	3.426	0.06	0.06	0.001	6.9
IN2461-010	2.376	1.36	4.737	0.06	0.06	0.001	6.7
IN2461-012	2.469	1.403	6.25	0.05	0.05	0.001	6.9
IN2462-007	2.74	2.255	10.195	0.05	0.05	0.001	7.0
IN2466-004	0.834	0.404	0.826	0.05	0.05	0.001	7.0
IN2466-008	0.119	0.008	0.023	0.05	0.05	0.001	6.9
IN2466-011	0.835	0.537	1.012	0.23	0.23	0.001	4.4
IN2467-002	0.549	0.07	1.29	0.15	0.15	0.001	4.9
IN2467-005	1.76	0.3	2.94	0.09	0.09	0.001	5.9
IN2467-007	0.965	0.204	0.875	0.28	0.28	0.001	4.4
IN2467-016	0.54	0.023	0.602	0.10	0.10	0.001	6.2
IN2467-023	1.401	0.183	2.545	0.08	0.08	0.001	6.0
IN2468-002	0.261	0	0.61	0.08	0.08	0.001	4.4
IN2468-007	0.116	0	0.121	0.11	0.11	0.001	5.6
IN2469-019	1.463	0.003	24.152	0.09	0.09	0.001	6.1
IN2561-007	0.522	0.019	0.542	0.14	0.14	0.001	4.7
IN2561-010	0.749	0.233	0.909	0.07	0.07	0.001	6.5
IN2562-020	0.794	0.841	3.514	0.08	0.08	0.001	6.1
IN2562-025	0.344	0.121	0.581	0.05	0.05	0.001	7.0
IN2661-002	0.414	0.247	0.508	0.07	0.07	0.001	6.5
IN2661-005	2.737	1.269	3.001	0.05	0.05	0.001	7.0
IN2661-009	0.124	0.091	0.248	0.05	0.05	0.001	7.0
IN2661-010	0.208	0.058	0.174	0.08	0.08	0.001	6.3
IN2662-004	0.263	0.18	0.751	0.15	0.15	0.001	4.4
IN2662-008	0.18	0	0.137	0.09	0.09	0.001	5.9
IN2662-011	0.2	0.171	0.696	0.15	0.15	0.001	4.5
IN2662-013	0.672	0.161	0.789	0.15	0.15	0.001	4.4
IN2662-014	2.03	0.18	1.664	0.17	0.17	0.001	4.4
IN2662-038	0.257	0.133	0.755	0.17	0.17	0.001	4.6
IN2662-041	0.791	0.313	2.202	0.15	0.15	0.001	5.5
IN2662-045	0.545	0.114	1.484	0.08	0.08	0.001	6.3
IN2662-047	0.881	0.508	2.09	0.14	0.14	0.001	4.6
IN2662-050	0.113	0.112	0.694	0.15	0.15	0.001	4.4
IN2663-002	0.869	0.048	0.439	0.14	0.14	0.001	4.7
IN2663-012	3.921	1.148	6.16	0.15	0.15	0.001	4.4
IN2664-001	3.456	0.401	2.365	0.20	0.20	0.001	4.4
IN2664-008	0.174	0.012	0.063	0.12	0.12	0.001	5.2
IN2664-011	0.205	0	0.058	0.15	0.15	0.001	4.4
IN2664-016	0.806	0.053	0.404	0.12	0.12	0.001	5.1
IN2664-019	0.215	0.002	0.058	0.15	0.15	0.001	4.5
IN2664-020	0.849	0.092	0.509	0.09	0.09	0.001	5.9
IN2760-001	4.388	0.1	0.455	0.06	0.06	0.001	6.6
IN2760-002	5.278	0.327	0.773	0.15	0.15	0.001	4.4
IN2762-002	0.695	0.054	0.653	0.15	0.15	0.001	4.4
IN2762-010	1.405	0.385	1.923	0.15	0.15	0.001	4.4
IN2762-011	0.56	0.111	0.422	0.05	0.05	0.001	7.0
IN2762-014	0.196	0.004	0.077	0.15	0.15	0.001	4.4

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Subcatchment	DCIA	UCIA	Pervious	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)	Decay Rate (1/s)	Dry Days
IN2762-016	0.153	0.024	0.125	0.11	0.11	0.001	5.4
IN2763-006	1.169	0.151	1.049	0.15	0.15	0.001	4.4
IN2763-013	0.768	0.095	0.486	0.15	0.15	0.001	4.4
IN2763-014	1.9	0.995	3.377	0.15	0.15	0.001	4.5
IN2764-002	0.58	0.07	0.408	0.15	0.15	0.001	4.4
IN2764-018	1.715	0.631	2.342	0.06	0.06	0.001	6.7
IN2764-029	0.757	0	1.812	0.05	0.05	0.001	7.0
IN2765-002	0.374	0	0.143	0.07	0.07	0.001	6.4
IN2765-012	0.783	0.007	0.502	0.14	0.14	0.001	5.2
IN2765-014	0.537	0.034	20.336	0.05	0.05	0.001	7.0
IN2765-022	0.631	0.017	1.881	0.11	0.11	0.001	5.3
IN2765-025	1.67	0.57	3.519	0.07	0.07	0.001	6.4
IN2765-027	1.853	0.138	1.056	0.11	0.11	0.001	5.3
IN2858-039	3.531	0.054	1.34	0.10	0.10	0.001	5.7
IN2859-003	0.681	0.028	0.579	0.15	0.15	0.001	4.4
IN2859-006	0.157	0.017	0.071	0.15	0.15	0.001	4.4
IN2860-006	0.396	0.042	0.107	0.15	0.15	0.001	4.4
IN2860-007	1.371	0.043	0.509	0.15	0.15	0.001	4.4
IN2860-009	0.498	0.003	0.244	0.15	0.15	0.001	4.4
IN2860-010	0.285	0	0.078	0.15	0.15	0.001	4.4
IN2860-013	0.238	0	0.295	0.15	0.15	0.001	4.4
IN2860-018	0.439	0	0.282	0.15	0.15	0.001	4.4
IN2860-019	0.335	0.009	1.816	0.15	0.15	0.001	4.4
IN2860-021	2.735	0.155	0.66	0.15	0.15	0.001	4.4
IN2860-022	0.102	0.015	0.619	0.15	0.15	0.001	4.4
IN2860-030	1.659	0.058	1.833	0.18	0.18	0.001	4.4
IN2860-032	0.247	0	0.1	0.15	0.15	0.001	4.4
IN2860-034	0.315	0.036	0.074	0.15	0.15	0.001	4.4
IN2860-038	0.104	0	0.023	0.15	0.15	0.001	4.4
IN2860-039	0.653	0.046	0.183	0.15	0.15	0.001	4.4
IN2860-040	0.909	0.025	0.238	0.15	0.15	0.001	4.4
IN2861-001	1.677	0.152	0.693	0.15	0.15	0.001	4.4
IN2861-003	0.277	0	0.086	0.15	0.15	0.001	4.4
IN2861-004	0.414	0.001	0.092	0.15	0.15	0.001	4.4
IN2861-016	0.428	0.001	0.306	0.15	0.15	0.001	4.4
IN2861-017	0.197	0.019	0.101	0.15	0.15	0.001	4.4
IN2862-006	3.192	0.372	4.285	0.13	0.13	0.001	4.9
IN2863-018	1.015	0.506	1.63	0.15	0.15	0.001	4.4
IN2863-021	1.758	1.089	5.096	0.12	0.12	0.001	5.1
IN2863-042	0.744	0.381	0.908	0.15	0.15	0.001	4.4
IN2864-004	0.801	0.452	1.945	0.15	0.15	0.001	4.4
IN2864-020	0.037	0.067	2.912	0.08	0.08	0.001	6.2
IN2864-022	0.44	0.225	0.424	0.15	0.15	0.001	4.4
IN2864-024	1.374	0.888	3.733	0.15	0.15	0.001	4.4
IN2959-010	2.121	0.06	1.682	0.14	0.14	0.001	4.6
IN2960-001	0.217	0.013	0.202	0.19	0.19	0.001	4.4
IN2960-002	0.242	0	2.136	0.12	0.12	0.001	5.2

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Subcatchment	DCIA	UCIA	Pervious	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)	Decay Rate (1/s)	Dry Days
IN2961-014	0.758	0	0.672	0.15	0.15	0.001	4.4
IN2963-061	3.023	1.77	7.825	0.12	0.12	0.001	5.2
IN2963-064	0.173	0.044	0.118	0.15	0.15	0.001	4.4
IN2963-065	0.367	0.205	0.95	0.13	0.13	0.001	4.9
IN3061-008	4.967	0.171	2.505	0.14	0.14	0.001	4.6
PD2367-048	0.176	0.08	0.628	0.14	0.14	0.001	4.7
PD2566-001	8.588	1.174	98.044	0.15	0.15	0.001	4.4
PD2661-020	1.033	0.164	2.606	0.17	0.17	0.001	5.1
PD2961-017	3.71	0.033	8.23	0.15	0.15	0.001	4.4
PD-ES-S12	4.23	0.054	2.365	0.14	0.14	0.001	6.3
PDPRIV01	0.028	0	0.564	0.21	0.21	0.001	4.4
PDPRIV12	2.467	0.025	4.289	0.15	0.15	0.001	4.4
PDPRIV20	0.619	0.012	0.498	0.15	0.15	0.001	4.4
PDPRIV21	1.491	0.032	1.014	0.09	0.09	0.001	6.5
PRIV01_02	0.977	0.088	0.626	0.08	0.08	0.001	6.2
PRIV02_03	0	0	0.297	0.21	0.21	0.001	4.4
PRIV02_04	0.066	0.007	16.396	0.15	0.15	0.001	5.6
PRIV06_01	1.311	0.11	1.659	0.03	0.03	0.001	9.2
PRIV07_01	0.147	0.07	1.438	0.17	0.17	0.001	5.4
PRIV07-01	0.289	0.026	1.248	0.15	0.15	0.001	4.4
PRIV08_01	0.304	0.045	2.332	0.15	0.15	0.001	4.4
PRIV09_01	0.667	0.087	0.309	0.06	0.06	0.001	6.8
PRIV10-01	0	0	2.102	0.07	0.07	0.001	6.4
PRIV11-01	3.477	0.015	1.244	0.06	0.06	0.001	6.7
PRIV15_01	2.556	0.026	0.513	0.15	0.15	0.001	4.4
PRIV17_02	7.29	0.006	1.508	0.20	0.20	0.001	4.4
PRIV17_05	0.72	0	0.222	0.20	0.20	0.001	4.9
PRIV17_08	6.533	0.012	0.827	0.15	0.15	0.001	4.4
PRIV25_02	0.976	0.026	0.133	0.14	0.14	0.001	4.6
PRIVATE100151	0.363	0.016	0.135	0.15	0.15	0.001	4.4
PRIVATE100383	0.931	0.022	0.319	0.13	0.13	0.001	5.5
PRIVATE-100385_01	5.553	0	1.13	0.15	0.15	0.001	4.4
PRIVATE100387	2.307	0.056	0.347	0.15	0.15	0.001	4.4
PRIVATE-101149_01	1.059	0.101	0.442	0.15	0.15	0.001	4.4
PRIVATE133	0.561	0.06	0.46	0.15	0.15	0.001	4.4
PRIVATE133_01	1.123	0.117	2.18	0.12	0.12	0.001	5.3
PRIVATE133_03	1.116	0.093	0.984	0.14	0.14	0.001	4.6
PRIVATE133_06	0.231	0.105	0.554	0.09	0.09	0.001	5.9
PRIVATE133_07	0.099	0.059	0.248	0.05	0.05	0.001	7.0
PRIVATE133_08	1.797	0.147	1.343	0.05	0.05	0.001	7.0
PRIVATE133_09	0.2	0.019	0.133	0.05	0.05	0.001	7.0
PRIVATE133_10	0.537	0.101	0.984	0.05	0.05	0.001	7.0
PRIVATE136_02	0.646	0	0.346	0.15	0.15	0.001	4.4
PRIVATE144_01	0.523	0.045	0.32	0.13	0.13	0.001	4.9
PRIVATE173	4.824	0.118	3.385	0.15	0.15	0.001	4.4
PRIVATE206	0.468	0.367	1.379	0.07	0.07	0.001	6.5
PRIVATE207_02	0.951	0.053	0.547	0.04	0.04	0.001	8.4

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Subcatchment	DCIA	UCIA	Pervious	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)	Decay Rate (1/s)	Dry Days
PRIVATE207_03	1.065	0.226	1.99	0.06	0.06	0.001	7.0
PRIVATE88	4.616	0.039	2.904	0.15	0.15	0.001	4.4
PRIVATE98	0.679	0.006	0.152	0.15	0.15	0.001	4.4
PRIVATE98_01	1.499	0.011	2.812	0.15	0.15	0.001	4.4
TE2562-023	2.693	2.003	7.97	0.06	0.06	0.001	6.8
TO2859-011	2.315	0	3.172	0.12	0.12	0.001	5.1
TO2959-002	1.443	0	0.559	0.13	0.13	0.001	5.0
TP2863-033	5.144	2.41	9.208	0.15	0.15	0.001	4.4

Appendix C: Hydraulic Input Parameters

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Appendix C: Hydraulic Input Parameters (Links)

Link Name	Upstream Node Name	Downstream Node Name	Length (ft)	Shape	Diameter / Height (ft)	Bottom Width (ft)	Roughness	Downstream Invert Elevation (ft)	Upstream Invert Elevation (ft)
GR2862-008_461	AE2863-028	AE2863-028.1	87.18	Natural	2.5	0	0.025	1011.38	1011.74
AS2469-013_AE2469-012	AS2469-013	2470-016_01	108.00	Circular	5	0	0.013	988.10	988.99
AS2469-014_AS2469-013	AS2469-014	AS2469-013	248.00	Circular	5	0	0.013	988.99	990.24
1301.1	AE2469-017	Node571	5.00	Circular	2.5	0	0.013	992.78	992.78
RaymondGrate	AE2469-017	Node571							
IN2469-019 AS2469-013	IN2469-019	AS2469-013	95.90	Circular	2.5	0	0.013	988.99	995.66
AE2469-020 IN2469-019	AE2469-020	IN2469-019	42.00	Circular	2.5	0	0.024	995.66	996.10
DT2567-003 DT2568-019.1	AS2568-006	DT2568-019	27.99	Rectangular	5	8	0.013	995.00	995.00
AS2568-007 AS2568-006	AS2568-007	AS2568-006	131.00	Circular	3	0	0.013	996.75	996.99
AS2467-032 AS2568-007	AS2467-032	AS2568-007	214.00	Circular	2.5	0	0.013	996.99	999.32
AS2467-033 AS2467-032	AS2467-033	AS2467-032	158.20	Circular	2.5	0	0.013	999.32	1007.50
IN2468-002 AS2467-033	IN2468-002	AS2467-033	16.00	Circular	2	0	0.013	1007.50	1010.56
AS2568-009 AS2568-006	AS2568-009	AS2568-006	273.00	Circular	1.75	0	0.013	998.05	1002.32
AS2568-011 AS2568-009	AS2568-011	AS2568-009	180.90	Circular	1.75	0	0.013	1002.32	1010.77
AS2568-012 AS2568-011	AS2568-012	AS2568-011	200.00	Circular	1.75	0	0.013	1010.77	1022.05
AS2568-013 AS2568-012	AS2568-013	AS2568-012	89.00	Circular	1.75	0	0.013	1022.05	1028.29
AS2568-014 AS2568-013	AS2568-014	AS2568-013	130.70	Circular	1.75	0	0.013	1028.29	1036.75
IN2468-007 IN2467-006	IN2468-007	IN2467-006	75.40	Circular	1	0	0.013	1041.00	1049.15
AS2859-005 AS2860-001	AS2859-005	IN2860-021	196.08	Circular	5.5	0	0.013	1019.61	1021.81
AS2858-005 IN2859-001	AS2858-005	IN2859-001	272.30	Circular	5	0	0.013	1024.99	1027.80
AS2960-003 AS2860-020	AS2960-003	AS2860-020	411.50	Circular	2.5	0	0.013	1018.79	1026.81
AS2960-007 AS2960-011	AS2960-007	AS2960-011	212.70	Circular	2	0	0.013	1038.64	1039.74
AS2960-010 AS2961-003	AS2960-010	AS2961-003	257.60	Circular	2	0	0.013	1025.10	1033.69
AS2960-011 AS2960-010	AS2960-011	AS2960-010	209.40	Circular	2	0	0.013	1033.69	1038.64
AS2860-001 IN2860-013	AS2860-001	IN2860-013	22.30	Circular	6	0	0.013	1015.95	1015.95
AS2860-003 AS2860-001	AS2860-003	AS2860-001	79.20	Circular	4.5	0	0.013	1017.45	1017.95
AS2860-011 AS2860-001_01	AS2860-011	AS2860-001_01	69.60	Circular	3.5	0	0.013	1016.64	1017.77
AS2860-020 AS2860-029	AS2860-020	AS2860-029	276.30	Circular	3.5	0	0.013	1017.96	1018.79
AS2461-002 AE2461-001	AS2461-002	AE2461-001	72.30	Special	3.16	0	0.013	1131.10	1131.50
AS2461-003 AS2461-002	AS2461-003	AS2461-002	142.30	Circular	2.25	0	0.013	1131.50	1132.60
AS2561-005 IN2562-020	AS2561-005	IN2562-020	537.30	Circular	2.5	0	0.013	1098.20	1119.10
AS2561-006 AS2561-002	AS2561-006	IN2561-010	358.60	Circular	3	0	0.013	1126.73	1128.65
AS2661-003 AE2661-004	AS2661-003	AE2661-004	101.10	Circular	1.5	0	0.013	1075.35	1081.05
AS2661-012 AS2662-043	AS2661-012	AS2662-043	227.60	Circular	2	0	0.013	1037.60	1049.36
AS2661-013 AS2661-012	AS2661-013	AS2661-012	261.90	Circular	1.5	0	0.013	1049.36	1061.65
AS2661-015 AS2661-013	AS2661-015	AS2661-013	325.80	Circular	1.5	0	0.013	1061.65	1073.75
AS2661-017 IN2661-016	AS2661-017	AS2661-015	159.90	Circular	1.25	0	0.013	1075.71	1079.76
AS2661-019 TP2662-056	AS2661-019	TP2662-056	202.60	Circular	1.5	0	0.013	1048.03	1062.60
AS2861-015 AE2862-001	AS2861-015	AS3061-015	328.37	Circular	4	0	0.013	1013.98	1015.66
IN2961-002 AE2961-007	AS2961-003	AE2961-007	278.00	Circular	2.5	0	0.013	1023.34	1025.10
AS2961-008 AS2961-015	AS2961-008	AS2961-007	348.57	Circular	4	0	0.013	1019.62	1021.27
AS2961-015 AS2861-015	AS2961-015	AS2861-015	498.20	Circular	4	0	0.013	1015.66	1018.10
AS3061-001 AE2961-010	AS3061-001	AE2961-010	60.10	Circular	3	0	0.013	1026.08	1027.40
AS3061-003 AS3061-001	AS3061-003	AS3061-001	35.10	Special	3.16	0	0.013	1027.40	1028.00
AS3061-005 AS3061-003	AS3061-005	AS3061-003	207.80	Special	3.16	0	0.013	1028.00	1029.84
AS2662-007 AS2663-001	AS2663-001	AS2662-007	234.00	Circular	1.5	0	0.013	1034.38	1041.22
AS2663-006 AS2663-001	AS2663-006	AS2663-001	54.10	Circular	1.5	0	0.013	1041.22	1042.65
AS2663-007 IN2663-004	AS2663-007	AS2663-006	36.00	Circular	1.5	0	0.013	1042.65	1042.60
AS2664-004 AS2664-007	AS2664-004	AS2664-007	206.90	Circular	2	0	0.013	1010.06	1019.38
AS2664-007 AS2664-010	AS2664-007	AS2664-010	191.70	Circular	2.5	0	0.013	1007.10	1010.06
AS2664-010 2665-005_01d_01	AS2664-010	2665-005_01d_01	21.00	Circular	3	0	0.013	1004.16	1007.10
AS2858-021 AS2858-005	AS2858-021	AS2858-005	226.70	Special	4.41	0	0.013	1027.80	1028.96
IN2662-052 AS2858-021	AS2858-029	AS2858-021	200.50	Circular	4	0	0.013	1028.96	1029.93
AS2662-005 AS2762-003	AS2662-005	AS2762-003	73.00	Circular	3	0	0.024	1027.86	1030.80
AS2662-005 AS2662-006	AS2662-006	AS2662-005	53.80	Circular	2	0	0.013	1030.80	1031.82
AS2662-006 AS2662-007	AS2662-007	AS2662-006	185.50	Circular	2	0	0.013	1031.82	1034.38
AS2662-020 IN2663-009	AS2662-020	IN2663-009	78.90	Circular	1.5	0	0.013	1052.60	1055.10
AS2662-025 AS2662-028	AS2662-025	AS2662-028	198.00	Circular	3	0	0.013	1073.14	1082.85
TP2662-057 AS2662-031	AS2662-028	IN2662-050	246.44	Circular	3	0	0.013	1063.56	1073.14
AS2662-031 MI2662-055	AS2662-031	TP2662-056	192.50	Circular	3	0	0.013	1048.03	1054.16
AS2662-040 AS2662-043	AS2662-040	IN2662-041	76.23	Circular	3.5	0	0.013	1041.04	1042.38
AS2662-043 AS2762-013	AS2662-043	AS2762-013	48.00	Circular	3.5	0	0.013	1036.77	1037.60
AS2662-048 AS2662-049	AS2662-048	AS2662-049	92.50	Circular	1.25	0	0.013	1036.36	1040.99
AS2662-049 IN2662-011	AS2662-049	IN2662-011	82.20	Circular	1.25	0	0.013	1033.30	1036.36
AS2562-005 AS2562-008	AS2562-005	AS2562-008	60.90	Circular	1.75	0	0.013	1129.85	1130.75
IN2562-006 AS2561-005	AS2562-008	AS2561-005	218.90	Circular	1.75	0	0.013	1119.10	1129.85
AS2562-018 IN2662-024	AS2562-018	IN2562-025	60.35	Circular	3	0	0.013	1095.21	1097.00
AS2762-003 AS2762-004	AS2762-003	AS2762-004	99.60	Circular	4	0	0.013	1024.27	1027.86
AS2762-004 AS2762-005	AS2762-004	AS2762-005	182.40	Circular	4	0	0.013	1020.40	1024.27
AS2762-005 IN2762-006	AS2762-005	IN2762-006	174.00	Circular	4	0	0.013	1012.29	1020.40
AS2762-008 AE2762-009	AS2762-008	AE2762-009	375.80	Special	6.33	0	0.013	1009.60	1010.41
AS2762-012 AS2762-003_02	AS2762-012	AS2762-003_02	115.90	Circular	3.5	0	0.013	1032.10	1034.30
AS2762-013 AS2762-020	AS2762-013	AS2762-020	25.00	Circular	3.5	0	0.013	1036.30	1036.77
AS2962-022 IN2962-026	AS2962-022	AS2962-029	98.80	Special	3.16	0	0.013	1016.00	1016.15
AS2962-029 AS2962-044	AS2962-029	AS2962-044	60.00	Special	3.16	0	0.013	1016.23	1016.00
AS2962-040 AS2962-039	AS2962-040	AS2962-039	152.80	Circular	2.5	0	0.013	1018.20	1019.00
AS2962-040 AS2961-015	AS2962-040	AS2961-015	44.40	Circular	2.5	0	0.013	1018.10	1019.00
AS2963-045 AS2963-038	AS2963-045	AS2963-038	49.60	Circular	1.5	0	0.013	1018.10	1018.60
AS2963-047 AS2963-048	AS2963-047	AS2963-048	112.20	Circular	1.75	0	0.013	1018.60	1018.90
AS2963-048 IN2963-060	AS2963-048	IN2963-060	215.50	Circular	2	0	0.024	1016.20	1018.60

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Appendix C: Hydraulic Input Parameters (Links)

Link Name	Upstream Node Name	Downstream Node Name	Length (ft)	Shape	Diameter / Height (ft)	Bottom Width (ft)	Roughness	Downstream Invert Elevation (ft)	Upstream Invert Elevation (ft)
AS2863-022_TP2863-033	AS2863-022	TP2863-033	185.00	Circular	1.5	0	0.013	1012.06	1013.85
IN2861-001_IN2861-003	IN2861-001	IN2861-003	35.30	Circular	1.5	0	0.013	1014.08	1014.20
IN2861-003_AE2861-009	IN2861-003	AE2861-009	19.80	Circular	1.5	0	0.013	1014.00	1014.08
IN2861-004_AE2861-008	IN2861-004	AE2861-008	27.00	Circular	2	0	0.013	1014.26	1014.34
Link473	AE2861-007	AE2861-008	235.29	Natural	5.5	0	0.016	1011.36	1012.28
Link518	AE2861-008	AE2861-009	103.25	Natural	5.5	0	0.016	1010.95	1011.36
Link470	AE2861-009	AE2861-013	242.31	Natural	5.5	0	0.014	1010.00	1010.95
AE2861-013_IN2862-006	AE2861-013	IN2862-006	110.00	Rectangular	4	8	0.013	1011.28	1012.00
IN2861-016_AS2861-015	IN2861-016	AS2861-015	11.50	Circular	1	0	0.013	1015.66	1018.82
AE2961-010_2961-017_03	AE2961-010	2961-017_03	87.10	Circular	3	0	0.013	1024.00	1026.00
IN2961-014_AS2961-015	IN2961-014	AS2961-015	10.10	Circular	1	0	0.013	1018.10	1018.90
IN3061-002_AS3061-001	IN3061-002	AS3061-001	11.90	Circular	2	0	0.013	1027.40	1028.53
AE3061-006_AS3061-005	AE3061-006	AS3061-005	38.00	Circular	2	0	0.013	1029.84	1030.12
IN3061-008_IN3061-002	IN3061-008	IN3061-002	20.10	Circular	2	0	0.013	1028.53	1028.72
IN2663-002_AS2663-001	IN2663-002	AS2663-001	27.10	Circular	1	0	0.013	1041.22	1042.48
IN2663-009_AS2663-007	IN2663-009	AS2663-007	165.80	Circular	1.5	0	0.013	1042.60	1052.60
IN2663-012_IN2664-001	IN2663-012	IN2664-001	279.00	Circular	1.5	0	0.013	1031.33	1044.60
IN2664-001_AS2664-004	IN2664-001	AS2664-004	253.50	Circular	1.75	0	0.013	1019.38	1031.33
IN2664-008_AS2664-007	IN2664-008	AS2664-007	15.70	Circular	1	0	0.013	1010.06	1012.75
IN2664-011_AS2664-010	IN2664-011	AS2664-010	23.50	Circular	1.5	0	0.013	1007.10	1008.65
IN2765-002_IN2765-017	IN2765-002	IN2765-017	24.00	Circular	1	0	0.013	1008.76	1008.95
IN2764-007_AE2764-008	IN2764-007	2764-015_1074	82.80	Circular	1.5	0	0.013	1007.60	1009.52
Link498	AE2764-011	2764-015_1374_01	229.48	Natural	6.6	0	0.014	1000.40	1000.56
Link497	AE2764-012	2764-015_1074	77.84	Natural	3.2	0	0.016	1004.62	1004.74
IN2662-004_AS2662-005	IN2662-004	AS2662-005	53.10	Circular	1.25	0	0.013	1030.80	1032.67
IN2662-008_AS2662-006	IN2662-008	AS2662-006	24.90	Circular	1.25	0	0.013	1031.82	1033.40
IN2662-011_AS2662-006	IN2662-011	AS2662-006	25.30	Circular	1.5	0	0.013	1031.82	1033.30
IN2662-013_AS2662-007	IN2662-013	AS2662-007	24.60	Circular	1	0	0.013	1035.38	1036.38
IN2662-014_AS2662-007	IN2662-014	AS2662-007	63.10	Circular	1.25	0	0.013	1034.38	1035.32
IN2662-038_TP2662-036_AS2662-040	IN2662-038	AS2662-040_01	16.90	Circular	1	0	0.013	1045.43	1047.80
IN2662-045_IN2762-014	IN2662-045	IN2762-014	52.30	Circular	1	0	0.013	1032.56	1034.90
IN2562-020_AS2562-018	IN2562-020	AS2562-018	36.20	Circular	2.5	0	0.013	1097.00	1098.20
IN2762-002_AS2762-003	IN2762-002	AS2762-003	16.80	Circular	1	0	0.013	1027.86	1031.60
IN2762-006_MI2762-007_01	IN2762-006	MI2762-007_01	222.20	Circular	5	0	0.013	1011.32	1012.29
IN2762-010_AS2762-005	IN2762-010	AS2762-005	22.10	Circular	1.5	0	0.013	1020.40	1024.05
IN2762-011_AS2762-005	IN2762-011	AS2762-005	17.80	Circular	1.25	0	0.013	1020.40	1024.47
IN2762-014_AS2762-012_AS2762-003	IN2762-014	AS2762-003_02	23.00	Circular	1	0	0.013	1032.10	1032.56
IN2762-016_AS2762-012_AS2762-003	IN2762-016	AS2762-003_01	32.40	Circular	1	0	0.024	1029.51	1032.60
AS2962-034_AS2962-022	AS2962-034	AS2962-022	242.60	Special	3.16	0	0.013	1016.15	1016.70
AS2962-039_AS2962-034	AS2962-039	AS2962-034	314.10	Circular	2.5	0	0.013	1016.70	1018.20
AS2963-038_MI2963-059	AS2963-038	MI2963-059	165.70	Circular	1.75	0	0.013	1016.35	1018.10
AS2963-046_AS2963-047	AS2963-046	AS2963-047	120.00	Circular	1.75	0	0.013	1018.90	1022.10
GR2862-008_570	AE2862-002	2862-008_570	575.43	Natural	3	0	0.025	1007.97	1010.00
IN2862-006_AE2862-002	IN2862-006	AE2862-002	74.00	Rectangular	4	8	0.013	1010.80	1011.28
IN2863-018_IN2863-019	IN2863-018	IN2863-019	28.40	Circular	1	0	0.013	1014.42	1014.60
IN2863-019_IN2863-020	IN2863-019	IN2863-020	35.90	Circular	1.25	0	0.013	1014.18	1014.42
IN2863-020_IN2863-021	IN2863-020	IN2863-021	32.20	Circular	1.25	0	0.013	1013.97	1014.18
IN2863-021_AS2863-022	IN2863-021	AS2863-022	19.20	Circular	1.5	0	0.013	1013.85	1013.97
AE2863-027_TP2863-033	AE2863-027	TP2863-033	7.20	Circular	3.5	0	0.024	1012.06	1012.10
IN2859-001_IN2859-003	IN2859-001	IN2859-003	353.90	Circular	5	0	0.013	1022.75	1024.99
AE2859-002_IN2859-001	AE2859-002	IN2859-001	18.10	Circular	2	0	0.013	1024.99	1028.10
IN2960-001_AS2960-003	IN2960-001	AS2960-003	31.50	Circular	1	0	0.013	1027.66	1029.46
IN2960-002_AS2960-003	IN2960-002	AS2960-003	8.00	Circular	3	0	0.013	1026.81	1026.98
IN2860-006_IN2860-034	IN2860-006	IN2860-034	147.80	Circular	1.5	0	0.013	1025.86	1030.68
IN2860-007_IN2860-006	IN2860-007	IN2860-006	96.90	Circular	1.5	0	0.013	1030.68	1034.38
IN2860-009_IN2860-010	IN2860-009	IN2860-010	34.90	Circular	2	0	0.013	1016.21	1016.36
IN2860-010_AE2860-024	IN2860-010	AE2860-024	16.10	Circular	2	0	0.013	1016.10	1016.21
IN2860-013_GR2860-015	IN2860-013	GR2860-015	87.00	Circular	6	0	0.013	1015.93	1015.95
IN2860-018_AS2860-020	IN2860-018	AS2860-020	30.40	Circular	1	0	0.013	1018.79	1021.50
Link474	AE2860-024	2861-019_397	84.90	Natural	3.5	0	0.016	1015.24	1015.33
IN2760-001_IN2860-007	IN2760-001	IN2860-007	239.00	Circular	1.5	0	0.013	1034.38	1045.18
IN2760-002_IN2760-001	IN2760-002	IN2760-001	169.90	Circular	1.5	0	0.013	1045.18	1056.06
IN2461-004_AS2461-003	IN2461-004	AS2461-003	64.20	Circular	1.25	0	0.013	1132.60	1134.56
IN2461-008_AS2461-003	IN2461-008	AS2461-003	55.30	Circular	2	0	0.013	1132.60	1133.35
IN2461-009_IN2461-008	IN2461-009	IN2461-008	114.80	Circular	1.75	0	0.013	1133.35	1135.60
IN2461-010_IN2461-009	IN2461-010	IN2461-009	82.10	Circular	1.5	0	0.013	1135.60	1138.14
IN2461-011_IN2461-010	IN2461-011	IN2461-010	42.50	Circular	1.5	0	0.013	1138.14	1139.19
IN2461-012_IN2461-011	IN2461-012	IN2461-011	31.80	Circular	1.5	0	0.013	1139.19	1139.79
AS2561-006_IN2461-016	IN2461-016	AS2561-006	52.00	Circular	3	0	0.013	1128.65	1128.97
AE2561-003_IN2561-007	AE2561-003	IN2561-007	197.30	Circular	1	0	0.013	1127.60	1129.10
IN2561-007_AS2561-002	IN2561-007	IN2561-010	32.70	Circular	1	0	0.013	1126.73	1127.60
IN2661-001_IN2661-002	IN2661-001	IN2661-002	131.70	Circular	1.5	0	0.013	1088.60	1094.10
IN2661-002_AS2661-003	IN2661-002	AS2661-003	84.00	Circular	1.5	0	0.013	1081.05	1088.60
IN2661-005_IN2661-001	IN2661-005	IN2661-001	90.80	Circular	1.5	0	0.013	1094.10	1095.51
IN2661-009_IN2661-005	IN2661-009	IN2661-005	99.50	Circular	1.25	0	0.013	1095.51	1096.36
IN2661-010_IN2661-009	IN2661-010	IN2661-009	103.10	Circular	1	0	0.013	1096.36	1097.08
IN2859-003_AS2859-005	IN2859-003	IN2859-006	49.19	Circular	5.5	0	0.013	1022.39	1022.75
IN2662-047_AS2662-048	IN2662-047	AS2662-048	95.40	Circular	1.25	0	0.013	1040.99	1042.12
IN2763-006_AE2763-007	IN2763-006	AE2763-007	106.40	Circular	1	0	0.013	1008.44	1008.88
IN2764-005_IN2764-006	IN2764-005	IN2764-006	168.00	Circular	1.5	0	0.013	1010.99	1021.45

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Appendix C: Hydraulic Input Parameters (Links)

Link Name	Upstream Node Name	Downstream Node Name	Length (ft)	Shape	Diameter / Height (ft)	Bottom Width (ft)	Roughness	Downstream Invert Elevation (ft)	Upstream Invert Elevation (ft)
IN2764-006 IN2764-007	IN2764-006	IN2764-007	61.90	Circular	1.5	0	0.013	1009.52	1010.99
AS2561-004 AS2561-005	AS2561-004	AS2561-005	131.80	Circular	2.5	0	0.013	1119.10	1121.05
IN2466-004 IN2466-009	IN2466-004	IN2466-009	97.70	Circular	1.5	0	0.013	1115.60	1120.23
IN2466-005 IN2466-004	IN2466-005	IN2466-004	74.60	Circular	1.25	0	0.013	1120.23	1123.76
IN2466-006 IN2466-007	IN2466-006	IN2466-007	41.20	Circular	1	0	0.013	1138.32	1139.97
IN2466-007 IN2466-008	IN2466-007	IN2466-008	29.50	Circular	1	0	0.013	1137.72	1138.32
IN2466-008 IN2466-005	IN2466-008	IN2466-005	294.60	Circular	1	0	0.013	1123.76	1137.72
IN2466-009 IN2466-010	IN2466-009	IN2466-010	84.10	Circular	1.5	0	0.013	1114.08	1115.60
IN2466-010 IN2466-011	IN2466-010	IN2466-011	24.80	Circular	1.75	0	0.013	1113.60	1114.08
IN2466-011 AE2466-012	IN2466-011	AE2466-012	174.90	Circular	1.75	0	0.013	1096.85	1113.60
AS2367-001 MI2367-010	AS2367-001	MI2367-010	194.20	Circular	2	0	0.013	1115.09	1117.91
IN2367-002 AS2367-001	IN2367-002	AS2367-001	76.40	Circular	2	0	0.013	1117.91	1119.43
IN2467-002 IN2467-005	IN2467-002	IN2467-005	117.80	Circular	2.5	0	0.013	1058.23	1062.70
IN2467-005 IN2467-006	IN2467-005	IN2467-006	279.20	Circular	2.5	0	0.013	1041.00	1058.23
IN2467-006 IN2467-007	IN2467-006	IN2467-007	43.30	Circular	2.5	0	0.013	1037.60	1041.00
IN2467-007 AE2467-010	IN2467-007	AE2467-010	43.80	Circular	1	0	0.013	1036.52	1037.60
SAS3	IN2467-007	Node556							
AS2467-011 AS2467-012	AS2467-011	AS2467-012	151.20	Circular	2.5	0	0.013	1010.70	1025.55
AS2467-012 AS2467-033	AS2467-012	AS2467-033	31.60	Circular	2.5	0	0.013	1007.50	1010.70
AS2963-057 AE2963-058	AS2963-057	AE2963-058	15.00	Circular	3	0	0.013	1015.60	1015.80
AS2962-044 AS2963-057	AS2962-044	AS2963-057	59.10	Special	3.16	0	0.013	1015.80	1016.23
GR2963-056	AE2963-058	AE2863-027	238.77	Natural	3	0	0	1012.10	1015.60
IN2963-060 AS2963-057	IN2963-060	AS2963-057	51.80	Circular	2	0	0.013	1015.80	1016.20
AS2762-020 AS2762-012	AS2762-020	AS2762-012	105.50	Circular	3.5	0	0.013	1034.30	1036.30
IN2466-016 IN2466-006	IN2466-016	IN2466-006	31.90	Circular	1	0	0.013	1139.97	1140.13
IN2366-026 IN2466-016	IN2366-026	IN2466-016	33.20	Circular	1	0	0.013	1140.13	1140.30
AS2860-029 AS2860-011	AS2860-029	AS2860-011	68.10	Circular	3.5	0	0.013	1017.77	1017.96
IN2860-030 AS2860-029	IN2860-030	AS2860-029	9.90	Circular	1.5	0	0.013	1017.96	1019.60
IN2860-032 AS2860-029	IN2860-032	AS2860-029	30.30	Circular	1.5	0	0.013	1017.96	1019.60
IN2860-019 AS2860-020	IN2860-019	AS2860-020	7.90	Circular	2	0	0.013	1018.79	1020.06
IN2561-010 AS2561-004_01	IN2561-010	AS2561-004_01	266.90	Circular	2.5	0	0.013	1122.83	1126.73
IN2462-007 AE2461-015	IN2462-007	AE2461-015	184.90	Circular	2.25	0	0.013	1133.60	1135.00
IN2367-011 IN2367-012	IN2367-011	IN2367-012	15.00	Circular	2	0	0.013	1112.64	1115.00
IN2367-012 IN2367-014	IN2367-012	IN2367-014	68.20	Circular	2	0	0.013	1110.52	1112.64
IN2367-014 IN2367-015	IN2367-014	IN2367-015	171.00	Circular	2	0	0.013	1093.85	1110.52
IN2367-015 IN2367-016	IN2367-015	IN2367-016	60.20	Circular	2	0	0.013	1089.07	1093.85
IN2367-016 IN2367-018	IN2367-016	IN2367-018	31.70	Circular	2.25	0	0.013	1088.27	1089.07
IN2367-018 AS2367-020	IN2367-018	AS2367-020	188.40	Circular	2.75	0	0.013	1086.85	1088.27
AS2367-020 IN2367-033	AS2367-020	IN2367-033	196.10	Circular	2.75	0	0.013	1072.15	1086.85
IN2367-022 AS2367-020	IN2367-022	AS2367-020	47.60	Circular	1.75	0	0.013	1086.85	1090.65
IN2367-023 IN2367-022	IN2367-023	IN2367-022	205.60	Circular	1.5	0	0.013	1090.65	1099.23
AS2367-025 IN2367-023	AS2367-025	IN2367-023	191.90	Circular	1.5	0	0.013	1099.23	1111.77
IN2367-026 AS2367-025	IN2367-026	AS2367-025	53.80	Circular	1.5	0	0.013	1111.77	1113.07
AS2367-028 IN2367-026	AS2367-028	IN2367-026	227.90	Circular	1.25	0	0.013	1113.07	1124.32
IN2367-033 AE2367-036	IN2367-033	AE2367-036	65.90	Circular	3.5	0	0.013	1071.60	1072.15
AS2467-014 IN2467-031	AS2467-014	IN2467-031	19.10	Circular	2.5	0	0.013	1067.10	1067.33
AS2367-043 AS2467-015	AS2367-043	AS2467-015	125.90	Circular	2.5	0	0.013	1070.32	1070.79
AS2367-044 AS2367-043	AS2367-044	AS2367-043	42.00	Circular	2.25	0	0.013	1070.79	1071.55
AE2367-047 AS2367-044	AE2367-047	AS2367-044	25.80	Circular	1.5	0	0.013	1071.55	1072.53
AS2959-007 TO2959-002	AS2959-007	TO2959-002	84.50	Circular	2.5	0	0.013	1046.10	1046.10
IN2959-010 IN2959-006	IN2959-010	AS2959-007	28.40	Circular	2.5	0	0.013	1046.10	1046.55
IN2959-012 AS2959-007	IN2959-012	AS2959-007	287.70	Circular	2	0	0.013	1046.10	1057.60
IN2858-033 AS2858-034	IN2858-033	AS2858-034	75.70	Circular	2.5	0	0.013	1031.24	1032.10
AE2858-010 AS2858-005	AS2858-034	AS2858-005	48.50	Circular	3	0	0.013	1027.80	1031.24
IN2860-034 AS2860-003	IN2860-034	AS2860-003	40.90	Circular	1.5	0	0.013	1020.95	1025.86
IN2860-038 AS2860-011 AS2860-001	IN2860-038	AS2860-001_01	14.50	Circular	1.5	0	0.013	1016.64	1020.62
IN2860-039 AS2860-011	IN2860-039	AS2860-011	40.90	Circular	1.5	0	0.013	1017.77	1020.19
IN2860-040 IN2860-039	IN2860-040	IN2860-039	35.00	Circular	1	0	0.013	1020.19	1020.92
IN2859-018 AE2859-019	IN2859-018	AE2859-019	13.00	Special	2.5	0	0.013	1033.91	1034.01
AS2467-015 AS2467-014	AS2467-015	AS2467-014	231.10	Circular	2.5	0	0.013	1067.33	1070.32
IN2467-016 AS2467-015	IN2467-016	AS2467-015	29.80	Circular	1.75	0	0.013	1070.32	1075.40
IN2467-019 IN2467-016	IN2467-019	IN2467-016	104.60	Circular	1.75	0	0.013	1075.40	1080.98
IN2467-021 IN2467-019	IN2467-021	IN2467-019	123.40	Circular	1.5	0	0.013	1080.98	1092.20
IN2467-023 IN2467-021	IN2467-023	IN2467-021	151.30	Circular	1.5	0	0.013	1092.20	1107.38
IN2467-031 IN2467-002	IN2467-031	IN2467-002	161.90	Circular	2.5	0	0.013	1062.70	1067.10
IN2863-042 GR2863-034	IN2863-042	GR2863-034	147.80	Circular	1.25	0	0.013	1011.17	1011.06
IN2858-039 IN2858-041	IN2858-039	IN2858-041	38.80	Circular	1.5	0	0.013	1029.66	1031.00
IN2764-018 IN2764-005	IN2764-018	IN2764-005	19.70	Circular	1.5	0	0.013	1021.45	1021.70
IN2858-041 AS2858-021	IN2858-041	AS2858-021	20.20	Circular	1	0	0.013	1028.96	1029.66
AS2859-021 IN2859-003	AS2859-021	IN2859-003	75.00	Circular	2	0	0.013	1022.75	1025.51
IN2963-061 AS2963-046	IN2963-061	AS2963-046	24.40	Circular	1.5	0	0.013	1022.10	1022.06
IN2963-062 IN2963-061	IN2963-062	IN2963-061	358.10	Circular	1.5	0	0.013	1022.06	1025.72
AS2963-063 IN2963-062	AS2963-063	IN2963-062	129.90	Circular	1.25	0	0.013	1025.72	1029.45
IN2963-064 AS2963-063	IN2963-064	AS2963-063	128.40	Circular	1.25	0	0.013	1029.45	1035.29
IN2963-065 IN2963-064	IN2963-065	IN2963-064	91.80	Circular	1.25	0	0.013	1035.29	1037.78
AS2963-068 IN2963-065	AS2963-068	IN2963-065	286.80	Circular	1.25	0	0.013	1037.78	1040.85
AE2765-015 IN2765-012	AE2765-015	IN2765-012	22.70	Circular	2	0	0.013	1006.71	1008.35
IN2765-014 IN2765-002	IN2765-014	IN2765-002	30.80	Circular	1	0	0.013	1008.95	1009.01
IN2664-016 AS2664-007	IN2664-016	AS2664-007	46.80	Circular	1	0	0.013	1010.06	1012.81
IN2664-017 IN2664-011	IN2664-017	IN2664-011	40.00	Circular	1.5	0	0.013	1008.65	1008.69

McKenna Greetree Watershed Study - Existing Conditions Report

Appendix C: Hydraulic Input Parameters (Links)

Link Name	Upstream Node Name	Downstream Node Name	Length (ft)	Shape	Diameter / Height (ft)	Bottom Width (ft)	Roughness	Downstream Invert Elevation (ft)	Upstream Invert Elevation (ft)
IN2664-021 IN2664-020	IN2764-002	IN2664-020	36.60	Circular	1	0	0.013	1009.05	1009.32
IN2664-018 IN2664-017	IN2664-018	IN2664-017	9.50	Circular	1.5	0	0.013	1008.69	1008.73
IN2664-019 IN2664-018	IN2664-019	IN2664-018	24.20	Circular	1.5	0	0.013	1008.73	1008.87
IN2664-020 IN2664-019	IN2664-020	IN2664-019	44.80	Circular	1.25	0	0.013	1008.87	1009.05
IN2765-012 IN2765-016	IN2765-012	IN2765-016	24.20	Circular	2	0	0.013	1006.51	1006.71
IN2765-016 IN2764-028	IN2765-016	IN2764-028	18.50	Circular	2	0	0.013	1006.45	1006.51
IN2764-028 IN2764-029	IN2764-028	IN2764-029	33.60	Circular	2	0	0.013	1006.38	1006.45
IN2764-029 AE2764-011	IN2764-029	AE2764-011	88.70	Circular	2	0	0.013	1006.47	1006.38
IN2765-017 IN2765-018	IN2765-017	IN2765-018	24.00	Circular	1	0	0.013	1008.49	1008.76
IN2765-018 AS2765-011	IN2765-018	AS2765-011	21.80	Circular	1.25	0	0.013	1007.73	1008.49
IN2765-022 AS2765-020	IN2765-022	AS2765-020	73.70	Circular	2	0	0.013	1009.18	1009.62
IN2765-023 IN2765-022	IN2765-023	IN2765-022	51.30	Circular	2	0	0.013	1009.62	1009.93
IN2765-025 IN2765-023	IN2765-025	IN2765-023	37.60	Circular	1.5	0	0.013	1010.15	1010.35
IN2765-027 IN2765-025	IN2765-027	IN2765-025	47.90	Circular	1.5	0	0.013	1010.35	1010.56
IN2864-004 MI2864-021	IN2864-004	IN2864-022	58.90	Circular	1.25	0	0.013	1011.91	1012.50
IN2864-020 IN2864-023	IN2864-020	IN2864-023	202.90	Circular	2.5	0	0.013	1007.58	1008.74
IN2864-022 IN2864-020	IN2864-022	IN2864-020	155.70	Circular	2.5	0	0.013	1008.74	1011.91
IN2864-023 IN2863-048	IN2864-023	IN2863-048	120.90	Circular	2.5	0	0.013	1007.15	1007.58
IN2863-048 AE2863-049	IN2863-048	AE2863-049	121.00	Circular	2.5	0	0.013	1006.52	1007.15
IN2864-024 AS2864-009	IN2864-024	AS2864-009	27.40	Circular	1.5	0	0.013	1011.25	1011.80
IN2763-013 IN2763-014	IN2763-013	IN2763-014	45.10	Circular	2	0	0.013	1015.69	1017.50
IN2763-014 IN2763-015	IN2763-014	IN2763-015	87.80	Circular	3	0	0.013	1011.62	1015.69
IN2763-015 AS2763-016	IN2763-015	AS2763-016	39.30	Circular	3	0	0.013	1011.07	1011.62
DT2469-002 DT2469-004	DT2469-002	DT2469-004	45.00	Special	3.16	0	0.013	998.50	999.60
DT2859-009 DT2859-010	DT2859-009	DT2859-010	124.00	Circular	1.5	0	0.024	1031.38	1034.10
GR2861-019 305	GR2860-015	AE2860-024	319.40	Natural	3.5	0	0.016	1015.33	1015.93
PD2661-020 AS2661-019	PD2661-020	AS2661-019	36.00	Circular	1.5	0	0.025	1062.60	1071.95
PD2467-013 AS2467-011	PD2467-013	AS2467-011	50.00	Special	2.5	0	0.013	1025.55	1030.27
PD2367-045 AS2367-044	PD2367-045	AS2367-044	70.80	Circular	2	0	0.013	1071.55	1076.10
DT2567-003 DT2568-019	DT2567-003	AS2568-006	37.11	Rectangular	5	8	0.013	995.00	995.00
AS3063-004 AS2963-068	AS3063-004	AS2963-068	177.70	Circular	1	0	0.013	1040.85	1041.17
AS3063-005 AS3063-004	AS3063-005	AS3063-004	96.50	Circular	1	0	0.013	1041.17	1041.34
AS3063-006 AS3063-005	AS3063-006	AS3063-005	262.30	Circular	1	0	0.013	1041.34	1041.80
AS2765-011 AE2764-012	AS2765-011	AE2764-012	221.10	Circular	2	0	0.013	1007.03	1007.73
AS2765-020 AS2765-011	AS2765-020	AS2765-011	222.90	Circular	2	0	0.013	1007.73	1009.18
AS2765-030 IN2765-029	AS2765-030	IN2765-027	299.60	Circular	1.5	0	0.013	1010.56	1021.41
AS2863-045 IN2863-042	AS2863-045	IN2863-042	29.00	Circular	1.5	0	0.013	1011.06	1011.40
IN2864-010 MI2864-019	AS2864-009	MI2864-019	152.20	Circular	1.75	0	0.013	1010.30	1011.25
AS2864-009 IN2864-022	AS2864-009	IN2864-022	16.00	Circular	1.5	0	0.013	1011.91	1011.25
AS3864-011 AS2864-009	AS2864-011	AS2864-009	222.80	Circular	1.5	0	0.013	1011.25	1012.36
AS2864-013 AS2864-011	AS2864-013	AS2864-011	121.60	Circular	1.5	0	0.013	1012.36	1014.91
AE2960-004 IN2960-002	AS2960-017	IN2960-002	62.00	Circular	3	0	0.013	1026.98	1029.19
AS2763-016 AS2763-018	AS2763-016	AS2763-018	88.10	Circular	3	0	0.013	1009.69	1011.07
AS2763-018 AS2763-019	AS2763-018	AS2763-019	95.60	Circular	3	0	0.013	1008.14	1009.69
AS2763-019 AS2763-020	AS2763-019	AS2763-020	136.00	Special	4.41	0	0.013	1007.51	1008.14
AS2763-020 AE2763-021	AS2763-020	AE2763-021	90.00	Special	4.41	0	0.013	1007.15	1007.51
TP2662-056 AS2662-040 01	TP2662-056	AS2662-040 01	96.90	Circular	3.5	0	0.013	1045.43	1048.03
TE2562-023 AS2562-018	TE2562-023	AS2562-018	244.10	Circular	1.75	0	0.013	1097.00	1117.44
MI2762-007 AS2762-008	MI2762-007	AS2762-008	92.10	Special	6.33	0	0.013	1010.41	1010.81
TP2863-033 AE2863-028	TP2863-033	AE2863-028	55.80	Circular	3.5	0	0.024	1011.74	1012.06
MI2963-059 AS2963-057	MI2963-059	AS2963-057	73.50	Circular	1.5	0	0.013	1015.80	1016.35
MI2367-010 IN2367-011	MI2367-010	IN2367-011	69.00	Circular	2	0	0.013	1115.00	1115.09
PRIVATE207 03 PRIVATE207 02	PRIVATE207 03	PRIVATE207 02	342.40	Circular	1	0	0.013	1081.60	1083.80
PRIVATE207 02 PRIVATE207 01	PRIVATE207 02	PRIVATE207 01	216.40	Circular	1.25	0	0.013	1080.99	1081.60
PRIVATE206 IN2561-001/AS2561-004	PRIVATE206	AS2561-004 01	116.00	Circular	1.25	0	0.013	1122.83	1128.10
2665-005 01a 01 2665-005 01a	2665-005 01a 01	2665-005 01b	66.50	Circular	1.75	0	0.013	1004.41	1005.20
PRIVATE133 10 PRIVATE133 09	PRIVATE133 10	PRIVATE133 09	134.80	Circular	1	0	0.013	1041.73	1042.25
PRIVATE133 09 PRIVATE133 08	PRIVATE133 09	PRIVATE133 08	141.80	Circular	1.25	0	0.013	1041.39	1041.73
PRIVATE133 08 PRIVATE133 07	PRIVATE133 08	PRIVATE133 07	154.10	Circular	1.25	0	0.013	1039.24	1041.39
PRIVATE-101149 01 MI2762-007 01	PRIVATE-101149 01	MI2762-007 01	284.70	Circular	1.5	0	0.013	1012.79	0.00
PRIVATE133 07 PRIVATE133 06	PRIVATE133 07	PRIVATE133 06	155.60	Circular	1.75	0	0.013	1025.48	1039.24
PRIVATE133 06 PRIVATE133 05	PRIVATE133 06	PRIVATE133 05	190.30	Circular	2	0	0.013	1022.85	1025.48
PRIVATE133 02 PRIVATE133 01	PRIVATE133 02	PRIVATE133 01	30.30	Circular	2.5	0	0.013	1017.75	1018.06
PRIVATE133 01 PRIVATE133	PRIVATE133 01	PRIVATE133	217.80	Special	3.75	0	0.013	1015.25	1017.75
PRIVATE133 GR2861-005	PRIVATE133	GR2861-005	181.90	Special	3.75	0	0.013	1014.83	1015.25
PRIVATE101214 IN2859-018	PRIVATE101214	IN2859-018	67.30	Circular	2	0	0.013	1034.01	1037.62
PRIVATE100905 AS2859-021	PRIVATE100905	AS2859-021	38.90	Circular	1	0	0.013	1025.43	1025.65
PRIVATE-100385	PRIVATE-100385 0	IN2858-033	33.40	Circular	1	0	0.013	1032.10	1035.52
PRIVATE100387 DT2858-036	PRIVATE100387	DT2858-036	39.00	Circular	1	0	0.013	1041.88	1042.76
PRIVATE98 AS2961-013	PRIVATE98	IN2961-014	234.00	Circular	1.25	0	0.013	1018.90	1021.85
PRIVATE98 01 PRIVATE98	PRIVATE98 01	PRIVATE98	183.30	Circular	1.25	0	0.013	1021.85	1022.50
AS-ES-1 AS2960-017	AS-ES-1	AS2960-017	166.00	Circular	3	0	0.013	1029.31	1031.88
AS-ES-2 AS-ES-1	AS-ES-2	AS-ES-1	319.80	Circular	3	0	0.013	1031.88	1036.89
AS-ES-4 AS-ES-3	AS-ES-4	AS-ES-3	76.20	Circular	1	0	0.013	1040.44	1041.00
AS-ES-3 AS-ES-2	AS-ES-3	AS-ES-2	252.30	Circular	3	0	0.013	1036.94	1038.99
AS-ES-6 AS-ES-3	AS-ES-6	AS-ES-3	200.50	Circular	3	0	0.013	1039.04	1042.13
PD-ES-1 AS-ES-1	PD-ES-12	AS-ES-13	13.00	Circular	1.5	0	0.013	1036.87	1037.00
PD-ES-1 AS2960-017	AS-ES-13	AS2960-017	37.00	Circular	1.5	0	0.013	1032.15	1034.00
TO2959-002 DT2959-003	TO2959-002	DT2959-003	114.00	Circular	2.5	0	0.013	1046.10	1046.10
GR2764-015 583	2764-015 446	2764-015 883	437.62	Natural	2.9	0	0.016	1004.92	1005.61

McKenna Greetree Watershed Study - Existing Conditions Report

Appendix C: Hydraulic Input Parameters (Links)

Link Name	Upstream Node Name	Downstream Node Name	Length (ft)	Shape	Diameter / Height (ft)	Bottom Width (ft)	Roughness	Downstream Invert Elevation (ft)	Upstream Invert Elevation (ft)
GR2764-015 1074	2764-015 883	AE2764-012	114.82	Natural	3.2	0	0.016	1004.74	1004.92
GR2764-015 1374	2764-015 1074	AE2764-011	66.25	Natural	6.6	0	0.025	1000.56	1000.60
Link533	2862-008 1183	Node575	55.65	Natural	4.8	0	0.025	1005.61	1005.81
GR2862-008 916	2862-008 461	2862-008 916	454.96	Natural	2.5	0	0.025	1008.00	1009.88
GR2862-008 1183	2862-008 893	2862-008 1183	289.80	Natural	3.6	0	0.025	1005.81	1006.83
GR2862-008 893	2862-008 570	2862-008 893	323.12	Natural	3	0	0.025	1006.83	1007.97
GR2861-019 430	2861-019 397	2861-019 430	46.90	Circular	4	0	0.013	1015.15	1015.24
GR2861-019 634	2861-019 430	AE2861-007	182.20	Natural	5.5	0	0.016	1012.28	1013.00
2665-005 01d 01 2665-005 01d	2665-005 01d 01	2665-005 01b	155.00	Rectangular	5	5	0.013	1004.16	1004.16
2862-008 916 2862-008 1183	2862-008 916	2862-008 1183	43.30	Circular	2.5	0	0.013	1007.90	1008.00
PRIVATE144 AS2762-004	PRIVATE144	AS2762-004	45.50	Circular	1	0	0.013	1024.27	1024.50
PRIVATE207 IN2661-016	PRIVATE207	AS2661-015	73.30	Circular	1.25	0	0.013	1073.75	1080.79
PRIVATE207 01 PRIVATE207	PRIVATE207 01	PRIVATE207	73.20	Circular	1.25	0	0.013	1080.79	1080.99
PRIVATE133 03 PRIVATE133 02	PRIVATE133 03	PRIVATE133 02	171.60	Circular	2.5	0	0.013	1018.06	1021.31
PRIVATE133 05 PRIVATE133 03	PRIVATE133 05	PRIVATE133 03	67.10	Circular	2	0	0.013	1021.31	1022.85
IN2961-018 AS2961-008	IN2961-018 01	AS2961-008	56.70	Circular	4	0	0.013	1021.27	1021.37
2961-017 02 2961-017 01	2961-017 02	2961-017 01	56.20	Circular	2	0	0.013	1024.00	1024.00
Tunnel 02 Tunnel 01	Tunnel 02	Tunnel 01	251.10	Rectangular	8	8	0.013	1031.90	1035.64
AS2860-001 01 AS2860-001	AS2860-001 01	AS2860-001	42.50	Circular	3.5	0	0.013	1015.95	1016.64
AS2561-004 01 AS2561-004	AS2561-004 01	AS2561-004	121.60	Circular	2.5	0	0.013	1121.05	1122.83
PRIVATE88 IN2860-009	PRIVATE88	IN2860-009	18.70	Circular	2	0	0.013	1016.36	1016.40
PRIVATE100151 IN2861-016	PRIVATE100151	IN2861-016	31.90	Circular	0.833	0	0.011	1018.82	1018.82
PRIVATE173 IN2861-004	PRIVATE173	IN2861-004	60.10	Special	2.5	0	0.013	1014.34	1014.05
PRIVATE101150 AS2762-008	PRIVATE101150	AS2762-008	49.60	Circular	1.25	0	0.013	1010.41	1011.61
PRIVATE144.1	PRIVATE144 01	PRIVATE144	120.49	Circular	1	0	0.013	1024.50	1025.10
2665-005 00 2665-004 00	2665-005 00	2665-004 00	75.20	Rectangular	3	5	0.013	1002.14	1002.49
2763-010 01 2764-015	2763-010 01	2764-015	48.00	Rectangular	4	8	0.013	1006.30	1006.30
2764-015 1374 02 2665-005 01d 01	2764-015 1374 01	2665-005 01d 01	251.00	Rectangular	5	12	0.013	1004.16	1004.16
2764-015 1374 2665-005 01b	2764-015 1374 01	2665-005 01b	408.00	Rectangular	5	10	0.013	1004.16	1004.16
2862-008-1489 01 2763-010 02	2862-008 1489 01	2763-010 02	32.00	Circular	3.5	0	0.013	1006.60	1006.60
AS2858-029 AS2858-029 01	AS2858-029 01	AS2858-029	462.60	Circular	4	0	0.013	1029.93	1029.17
AS2762-003 01 AS2762-003	AS2762-003 01	AS2762-003	86.80	Circular	3.5	0	0.013	1027.86	1029.51
AS2762-003 02 AS2762-003 01	AS2762-003 02	AS2762-003 01	136.50	Circular	3.5	0	0.013	1029.51	1032.10
AS2662-040 01 AS2662-040	AS2662-040 01	AS2662-040	114.10	Circular	3.5	0	0.013	1042.38	1045.43
MI2762-007 01 MI2762-007	MI2762-007 01	MI2762-007	114.90	Circular	5	0	0.013	1010.81	1011.32
GR2764-015 446	2764-015	2764-015.1	137.95	Natural	4.7	0	0.016	1006.09	1006.30
PRIVATE136 AE2861-007	PRIVATE136 02	AE2861-007	80.00	Circular	2	0	0.013	1014.90	1015.22
PRIV01 02 PRIV01 01	PRIV01 02	PRIV01 01	31.80	Circular	2	0	0.013	1035.20	1046.58
PRIV17 08 PRIV17 07	PRIV17 08	PRIV17 07	113.00	Circular	2	0	0.013	1054.60	1059.84
PRIV17 04 PRIV17 03	PRIV17 04	PRIV17 03	40.20	Circular	3	0	0.013	1035.60	1035.94
PRIV17 02 PRIV17 01	PRIV17 02	PRIV17 01	96.60	Circular	1.25	0	0.013	1034.80	1035.60
PRIV17 07 PRIV17 06	PRIV17 07	PRIV17 06	168.30	Circular	2.25	0	0.013	1050.52	1054.60
PRIV17 05 PRIV17 06 04	PRIV17 05	PRIV17 04	122.90	Circular	2.75	0	0.013	1036.77	1043.65
PRIV17 06 PRIV17 05	PRIV17 06	PRIV17 05	285.50	Circular	2.25	0	0.013	1043.65	1050.52
PRIV17 01 PRIV17 00	PRIV17 01	PRIV17 00	47.80	Circular	1.25	0	0.013	1032.01	1034.80
PRIV25 02 PRIV25 01	PRIV25 02	PRIV25 01	75.00	Circular	1.5	0	0.011	1062.14	1062.80
Link522	PD2367-048	AS2367-044	45.00	Circular	0.833	0	0.011	1075.60	1076.60
MTR Wr 1	PD2367-048	PD2367-045							
MTR Or 1	PD2367-048	PD2367-045							
MTR Or 2	PD2367-048	PD2367-045							
Link455	TO2859-011	DT2859-008	102.00	Circular	1.5	0	0.013	1037.70	1040.00
PDPRIV12 Pump	PDPRIV12	AS2961-003							
PRIV06 01 AS2661-017	PRIV06 01	AS2661-017	285.00	Circular	2	0	0.013	1079.76	1081.99
PRIV15 01 PRIVATE136 01	PRIV15 01	PRIVATE136 01	83.30	Circular	2	0	0.013	1015.57	1017.77
IN2859-003 AS2859-005.1	IN2859-006	AS2859-005	77.81	Circular	5.5	0	0.013	1021.81	1022.39
AS2562-018 IN2662-024.1	IN2562-025	AS2662-025	332.55	Circular	3	0	0.013	1082.85	1095.21
AS2662-040 AS2662-043.1	IN2662-041	AS2662-043	195.57	Circular	3.5	0	0.013	1037.60	1041.04
TP2662-057 AS2662-031.1	IN2662-050	AS2662-031	241.76	Circular	3	0	0.013	1054.16	1063.56
AS2859-005 AS2860-001.1	IN2860-021	IN2860-022	248.97	Circular	5.5	0	0.013	1016.81	1019.61
AS2859-005 AS2860-001.1.1	IN2860-022	AS2860-001	76.95	Circular	5.5	0	0.013	1015.95	1016.81
AS3060-001 AS3061-005	AS3060-001	AS3061-005	289.50	Circular	1.75	0	0.013	1029.84	1038.42
IN2467-007 AS2467-011	Node556	AS2467-011	135.80	Circular	2.5	0	0.013	1025.55	1037.60
Link516	GR2861-019-801	GR2861-019-802	44.00	Circular	1	0	0.013	1026.90	1028.62
Link517	GR2861-019-802	IN2859-006	385.00	Circular	1	0	0.013	1022.39	1026.90
A Overflow	PDPRIV20	PRIVATE100905							
C Orifice	PDPRIV20	PRIVATE100905							
B Orifice	PDPRIV20	PRIVATE100905							
AE2461-017 IN2461-016	AE2461-017	IN2461-016	30.00	Circular	1	0	0.013	1129.40	1129.40
NW Seybold	PDPRIV21	PRIVATE101214	10.00	Circular	1	0	0.011	1039.69	1039.73
SW Seybold	PDPRIV21	PRIVATE101214	10.00	Circular	1	0	0.011	1040.12	1040.13
Link523	PRIV09 01	IN2861-017	66.30	Circular	1	0	0.013	1017.32	1018.65
Link524	IN2861-017	AS3061-015	8.00	Circular	1	0	0.013	1016.92	1017.32
AS2861-015 AE2862-001.1	AS3061-015	AE2862-002	305.83	Circular	4	0	0.013	1012.42	1013.98
PRIV10 01	PRIV10-01	IN2961-018 01							
AS2961-008 AS2961-015.1	AS2961-007	AS2961-015	319.13	Circular	4	0	0.013	1018.10	1019.62
IN2469-016 AS2469-014	Node571	AS2469-014	67.10	Circular	5	0	0.013	990.24	990.24
GR2764-015 446.1	2764-015.1	2764-015 446	307.44	Natural	2.9	0	0.016	1005.61	1006.09
GR2862-008 461.1	AE2863-028.1	2862-008 461	363.87	Natural	2.5	0	0.025	1009.88	1011.38
GR2862-008 1489	Node575	2862-008 1489 01	243.33	Natural	4.8	0	0.025	1004.75	1005.61
Link534	Node577	Node578	30.13	Special	1.91	0	0.025	1008.50	1009.00

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Appendix C: Hydraulic Input Parameters (Nodes)

Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
AS2469-013	1000.25	988.99	Link Spill Crest to 2D	-	465562.9	786231.6
AS2469-014	1005.9	990.24	Link Spill Crest to 2D	-	465697.8	786439.8
AE2469-017	996.69	992.78	Link Invert to 2D	-	465765.4	786398.8
IN2469-019	1000.54	995.66	Link Spill Crest to 2D	-	465510.5	786151.4
AE2469-020	998.7	996.1	Link Invert to 2D	-	465552.3	786147.7
AS2568-006	1002.85	995	Link Spill Crest to 2D	-	467128.2	786925
AS2568-007	1001.92	996.99	Link Spill Crest to 2D	-	467125.9	786794
AS2467-032	1005.72	999.32	Link Spill Crest to 2D	-	467123.7	786580
AS2467-033	1014.95	1007.5	Link Spill Crest to 2D	-	467121.7	786421.8
IN2468-002	1015.46	1010.56	Link Spill Crest to 2D	-	467107	786415.5
AS2568-009	1006.82	1002.32	Link Spill Crest to 2D	-	467130.2	787198
AS2568-011	1015.38	1010.77	Link Spill Crest to 2D	-	467133.9	787378.8
AS2568-012	1026.45	1022.05	Link Spill Crest to 2D	-	467136.6	787578.8
AS2568-013	1030.88	1028.29	Link Spill Crest to 2D	-	467138.2	787667.8
AS2568-014	1041.75	1036.75	Link Spill Crest to 2D	-	467140.2	787798.5
IN2468-007	1051.4	1049.15	Link Spill Crest to 2D	-	467093.9	786004.6
AS2859-005	1031.91	1021.81	Link Spill Crest to 2D	-	474395.7	791278.8
AS2858-005	1038.3	1027.8	Link Spill Crest to 2D	-	475134.8	791224.6
AS2960-003	1032.2	1026.81	Link Spill Crest to 2D	-	473875.9	792094.4
AS2960-007	1044	1039.74	Link Spill Crest to 2D	9.00	473784.4	792458.1
AS2960-010	1037.8	1033.69	Link Spill Crest to 2D	6.00	473425.8	792664.9
AS2960-011	1043.2	1038.64	Link Spill Crest to 2D	-	473624.2	792597.9
AS2860-001	1024.6	1015.95	Link Spill Crest to 2D	-	473880.5	791228
AS2860-003	1026.1	1017.95	Link Spill Crest to 2D	-	473903.2	791152.1
AS2860-011	1022.1	1017.77	Link Spill Crest to 2D	-	473879.9	791340.1
AS2860-020	1023.6	1018.79	Link Spill Crest to 2D	-	473869.6	791683
AS2461-002	1135.35	1131.5	Link Spill Crest to 2D	-	472854.3	786481
AS2461-003	1136.1	1132.6	Link Spill Crest to 2D	-	472884.7	786342
AS2561-005	1127.93	1119.1	Link Spill Crest to 2D	-	472435.9	787218.3
AS2561-006	1133.1	1128.65	Link Spill Crest to 2D	-	472843.3	786736.6
AS2661-003	1083.8	1081.05	Link Spill Crest to 2D	-	472484.2	788537.4
AS2661-012	1054.66	1049.36	Link Spill Crest to 2D	-	472516.2	789330.5
AS2661-013	1067.34	1061.65	Link Spill Crest to 2D	-	472777.9	789340.1
AS2661-015	1079.02	1073.75	Link Spill Crest to 2D	-	473103.5	789348.5
AS2661-017	1083.11	1079.76	Link Spill Crest to 2D	-	473259.6	789313.8
AS2661-019	1072.9	1062.6	Link Spill Crest to 2D	-	472459.9	788748.2
AS2861-015	1020.84	1015.66	Link Spill Crest to 2D	-	472485.6	791697
AS2961-003	1029.2	1025.1	Link Spill Crest to 2D	6.00	473166.8	792636.5
AS2961-008	1026.5	1021.27	Link Spill Crest to 2D	-	472498.6	792862.8
AS2961-015	1024.76	1018.1	Link Spill Crest to 2D	-	472490	792195.2
AS3061-001	1031.5	1027.4	Link Spill Crest to 2D	9.00	473116.1	793356.3
AS3061-003	1031.4	1028	Link Spill Crest to 2D	-	473151.2	793356.6
AS3061-005	1033.5	1029.84	Link Spill Crest to 2D	-	473358.9	793362
AS2663-001	1046.4	1041.22	Link Spill Crest to 2D	-	471438.8	789081.3
AS2663-006	1045.92	1042.65	Link Spill Crest to 2D	-	471463.6	789033.2
AS2663-007	1044.6	1042.6	Link Spill Crest to 2D	-	471433.1	789014.2
AS2664-004	1023	1019.38	Link Spill Crest to 2D	-	470205.8	788914.8
AS2664-007	1014.4	1010.06	Link Spill Crest to 2D	-	470044.2	789044.1
AS2664-010	1012.3	1007.1	Link Spill Crest to 2D	-	469913.2	789184.1
AS2858-021	1035.95	1028.96	Link Spill Crest to 2D	-	475346.1	791142.4
AS2858-029	1036.65	1029.93	Link Spill Crest to 2D	-	475534.3	791073
AS2662-005	1037.23	1030.8	Link Spill Crest to 2D	-	471851.8	789309.2

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Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
AS2662-006	1037.45	1031.82	Link Spill Crest to 2D	-	471801.2	789291
AS2662-007	1039.54	1034.38	Link Spill Crest to 2D	-	471636.8	789205.9
AS2662-020	1059.6	1055.1	Link Spill Crest to 2D	-	471583.3	788824.7
AS2662-025	1088.76	1082.85	Link Spill Crest to 2D	6.00	472196.4	788067.9
AS2662-028	1079.38	1073.14	Link Spill Crest to 2D	-	472281.8	788251.5
AS2662-031	1059.99	1054.16	Link Spill Crest to 2D	7.50	472213.3	788690.2
AS2662-040	1048.83	1042.38	Link Spill Crest to 2D	-	472330.7	789056.3
AS2662-043	1044.18	1037.6	Link Spill Crest to 2D	-	472288.7	789323.4
AS2662-048	1049.21	1040.99	Link Spill Crest to 2D	-	471907.7	789126.5
AS2662-049	1043.21	1036.36	Link Spill Crest to 2D	-	471869.1	789210.6
AS2562-005	1135.6	1130.75	Link Spill Crest to 2D	-	472246.1	787076
AS2562-008	1134.6	1129.85	Link Spill Crest to 2D	6.00	472233.3	787135.5
AS2562-018	1102.46	1097	Link Spill Crest to 2D	-	472179.9	787179.9
AS2762-003	1034	1027.86	Link Spill Crest to 2D	-	471843.8	789381.7
AS2762-004	1031.01	1024.269	Link Spill Crest to 2D	-	471837.2	789481.1
AS2762-005	1026.4	1020.4	Sealed	-	471752.3	789639.3
AS2762-008	1016.39	1010.41	Link Spill Crest to 2D	-	471709.3	790240.6
AS2762-012	1040.79	1034.297	Link Spill Crest to 2D	-	472182.9	789389.1
AS2762-013	1044.54	1036.77	Link Spill Crest to 2D	-	472288.3	789371.4
AS2962-022	1018.8	1016.15	Link Spill Crest to 2D	6.00	471736.5	792171.1
AS2962-029	1018.75	1016	Link Spill Crest to 2D	4.50	471638	792179
AS2962-040	1024.12	1019	Link Spill Crest to 2D	-	472445.6	792192.6
AS2963-045	1022.49	1018.6	Link Spill Crest to 2D	-	471271.8	792157.3
AS2963-047	1025.3	1018.9	Link Spill Crest to 2D	-	471457.6	792461.9
AS2963-048	1023.21	1018.6	Link Spill Crest to 2D	-	471544.1	792390.5
AS2863-022	1016.8	1013.85	Link Spill Crest to 2D	-	471327.2	791846.8
IN2861-001	1017	1014.2	Link Spill Crest to 2D	-	472811.2	791173.6
IN2861-003	1017	1014.08	Link Spill Crest to 2D	-	472815.6	791138.6
IN2861-004	1017.53	1014.34	Link Spill Crest to 2D	-	472921	791147.3
AE2861-007	1019.02	1012.283	Link Invert to 2D	-	473151.9	791121.7
AE2861-008	1018.32	1011.358	Link Invert to 2D	-	472917.4	791102.7
AE2861-009	1017.34	1010.952	Link Invert to 2D	-	472814.5	791094.6
AE2861-013	1017.25	1010	Link Invert to 2D	-	472572.7	791078.7
IN2861-016	1021.9	1018.82	Link Spill Crest to 2D	2.25	472497	791696.8
AE2961-007	1025.84	1023.34	Link Invert to 2D	-	473069.7	792887.4
AE2961-010	1029.6	1026	Link Spill Crest to 2D	-	473095.9	793299.7
IN2961-014	1024.55	1018.9	Link Spill Crest to 2D	-	472500.1	792195.7
IN3061-002	1032.72	1028.53	Link Spill Crest to 2D	-	473114.7	793368.1
AE3061-006	1032.73	1030.12	Link Invert to 2D	-	473360.1	793413
IN3061-008	1031.3	1028.72	Link Spill Crest to 2D	-	473118.3	793391.6
AE2763-007	1010.28	1008.44	Link Invert to 2D	-	470979.8	790415.7
IN2663-002	1045.74	1042.48	Link Spill Crest to 2D	-	471427	789105.7
IN2663-009	1056.6	1052.6	Link Spill Crest to 2D	-	471521.5	788873.9
IN2663-012	1048.7	1044.6	Link Spill Crest to 2D	-	470728.4	788876.4
IN2664-001	1035.5	1031.33	Link Spill Crest to 2D	-	470450.7	788849.6
IN2664-008	1015.95	1012.75	Link Spill Crest to 2D	-	470032.8	789033.4
IN2664-011	1013.23	1008.65	Link Spill Crest to 2D	-	469931	789199.4
IN2765-002	1011.93	1008.95	Link Spill Crest to 2D	-	469714.9	789918.6
IN2764-007	1013.91	1009.52	Link Spill Crest to 2D	-	470118.7	789737.3
AE2764-011	1009.34	1000.555	Link Invert to 2D	-	469961.9	789670.3
AE2764-012	1009.8	1004.742	Link Invert to 2D	-	469979.4	789812.8
IN2662-004	1036.09	1032.67	Link Spill Crest to 2D	-	471903.1	789295.2

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Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
IN2662-008	1036.69	1033.4	Link Spill Crest to 2D	-	471792.9	789314.5
IN2662-011	1036.82	1033.3	Link Spill Crest to 2D	-	471809.3	789267
IN2662-013	1038.64	1036.38	Link Spill Crest to 2D	-	471652.2	789186.6
IN2662-014	1038.73	1035.32	Link Spill Crest to 2D	-	471598.2	789255.8
IN2662-038	1051.38	1047.8	Link Spill Crest to 2D	-	472349.8	788942.6
IN2662-045	1037.36	1034.9	Link Spill Crest to 2D	-	472068.8	789311.3
IN2562-020	1104.05	1098.2	Link Spill Crest to 2D	9.00	472198.7	787689
IN2762-002	1034.88	1031.6	Link Spill Crest to 2D	-	471827	789380.4
IN2762-006	1022.3	1012.29	Link Spill Crest to 2D	-	471730.8	789811.9
AE2762-009	1014.89	1009.6	Link Invert to 2D	-	471721.6	790616.2
IN2762-010	1027.6	1024.05	Link Spill Crest to 2D	3.00	471730.8	789634.1
IN2762-011	1027.65	1024.47	Link Spill Crest to 2D	3.00	471769.3	789644.5
IN2762-014	1037.14	1032.56	Link Spill Crest to 2D	-	472067.7	789363.6
IN2762-016	1036.18	1032.6	Link Spill Crest to 2D	-	471930.8	789351.3
AS2962-034	1019.7	1016.7	Link Spill Crest to 2D	9.00	471979.1	792175.6
AS2962-039	1022	1018.2	Link Spill Crest to 2D	-	472293	792187.5
AS2963-038	1023.52	1018.1	Link Spill Crest to 2D	-	471318.1	792174.6
AS2963-046	1026.75	1022.1	Link Spill Crest to 2D	-	471337.5	792460.4
AE2862-002	1016.5	1010	Link Invert to 2D	-	472422.6	791120.6
IN2862-006	1018.7	1011.282	Link Spill Crest to 2D	-	472455	791120
IN2863-018	1017.1	1014.6	Link Spill Crest to 2D	-	471242.1	791805.7
IN2863-019	1017.17	1014.415	Link Spill Crest to 2D	-	471250.6	791832.8
IN2863-020	1016.86	1014.183	Link Spill Crest to 2D	-	471277	791857.1
IN2863-021	1016.33	1013.974	Link Spill Crest to 2D	-	471308.9	791852.7
AE2863-027	1016.18	1012.1	Link Invert to 2D	-	471516.1	791871
AE2863-028	1016.13	1011.74	Link Invert to 2D	-	471504.4	791785.4
IN2859-001	1032.62	1024.99	Link Spill Crest to 2D	-	474862.5	791224
AE2859-002	1031.52	1028.1	Link Spill Crest to 2D	-	474876.9	791213.2
IN2960-001	1033.25	1029.46	Link Spill Crest to 2D	3.00	473844.5	792097.5
IN2960-002	1033.25	1026.98	Link Spill Crest to 2D	3.00	473883.9	792095.1
IN2860-006	1034.36	1030.68	Link Spill Crest to 2D	-	473942.3	790970
IN2860-007	1038.01	1034.38	Link Spill Crest to 2D	-	473942.8	790873.1
IN2860-009	1020.25	1016.36	Link Spill Crest to 2D	-	473455.9	791256.6
IN2860-010	1019.98	1016.21	Link Spill Crest to 2D	-	473463.2	791222.4
IN2860-013	1025.06	1015.945	Link Spill Crest to 2D	-	473858.5	791224.7
IN2860-018	1024.7	1021.5	Link Spill Crest to 2D	2.25	473839.2	791684.2
AE2860-024	1020.84	1015.33	Link Invert to 2D	-	473471.4	791169.7
IN2760-001	1048.98	1045.18	Link Spill Crest to 2D	-	473939.3	790634.1
IN2760-002	1059.74	1056.06	Link Spill Crest to 2D	-	473937.3	790464.2
AE2461-001	1133.22	1131.1	Link Invert to 2D	-	472785.7	786503.5
IN2461-004	1138.24	1134.56	Link Spill Crest to 2D	-	472948.1	786352.1
IN2461-008	1137.1	1133.35	Link Spill Crest to 2D	-	472844.8	786303.8
IN2461-009	1139.6	1135.6	Link Spill Crest to 2D	-	472732.4	786280.5
IN2461-010	1142.14	1138.14	Link Spill Crest to 2D	-	472664.3	786234.8
IN2461-011	1143.78	1139.19	Link Spill Crest to 2D	-	472663.4	786192.3
IN2461-012	1143.92	1139.79	Link Spill Crest to 2D	-	472653.7	786162
AE2461-015	1136.35	1133.6	Link Invert to 2D	-	472467.4	786518.6
IN2461-016	1134	1128.97	Link Spill Crest to 2D	-	472802.8	786703.9
AE2561-003	1130.42	1129.1	Link Invert to 2D	-	473041.6	786988.1
IN2561-007	1132.44	1127.6	Link Spill Crest to 2D	-	472874.5	787093
IN2661-001	1098.9	1094.1	Link Spill Crest to 2D	-	472575.7	788350.6
IN2661-002	1091.9	1088.6	Link Spill Crest to 2D	-	472544.3	788478.5

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Appendix C: Hydraulic Input Parameters (Nodes)

Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
AE2661-004	1076.85	1075.35	Link Invert to 2D	-	472505.4	788636.2
IN2661-005	1102.7	1095.51	Link Spill Crest to 2D	-	472652.1	788301.5
IN2661-009	1101.47	1096.36	Link Spill Crest to 2D	-	472743.6	788340.5
IN2661-010	1100.46	1097.08	Link Spill Crest to 2D	-	472824.3	788404.7
IN2859-003	1031.66	1022.75	Link Spill Crest to 2D	-	474508.5	791220.4
IN2662-047	1045.26	1042.12	Link Spill Crest to 2D	-	472003	789121.8
IN2763-006	1011.95	1008.88	Link Spill Crest to 2D	-	471055	790340.3
IN2764-005	1025.45	1021.45	Sealed	-	470319.4	789636.1
IN2764-006	1016.02	1010.99	Link Spill Crest to 2D	-	470180.1	789729.9
AS2561-004	1128.8	1121.05	Link Spill Crest to 2D	-	472454.7	787087.8
IN2466-004	1123.86	1120.228	Link Spill Crest to 2D	-	468577.9	785757.5
IN2466-005	1126.94	1123.762	Link Spill Crest to 2D	-	468576.3	785682.9
IN2466-006	1142.78	1139.97	Link Spill Crest to 2D	-	468511.6	785358.7
IN2466-007	1141.62	1138.32	Link Spill Crest to 2D	-	468542	785386.5
IN2466-008	1141.06	1137.72	Link Spill Crest to 2D	-	468571.4	785388.3
IN2466-009	1120.42	1115.6	Link Spill Crest to 2D	-	468581.2	785855.1
IN2466-010	1119.05	1114.08	Link Spill Crest to 2D	-	468621.2	785929.1
IN2466-011	1118.89	1113.6	Link Spill Crest to 2D	-	468603.1	785946.1
AE2466-012	1099.56	1096.85	Link Invert to 2D	-	468483.3	786073.5
AS2367-001	1126.76	1117.91	Link Spill Crest to 2D	-	467124.4	784240
IN2367-002	1123.62	1119.43	Link Spill Crest to 2D	-	467200.6	784234.8
IN2467-002	1068.45	1062.7	Link Spill Crest to 2D	-	467127.1	785669.9
IN2467-005	1063.97	1058.23	Link Spill Crest to 2D	-	467130	785787.7
IN2467-006	1046.69	1041	Link Spill Crest to 2D	-	467136.6	786066.8
IN2467-007	1043.37	1037.6	Link Spill Crest to 2D	-	467137.4	786109.7
AE2467-010	1040.48	1036.52	Link Invert to 2D	-	467180.4	786142.8
AS2467-011	1031.73	1025.55	Link Spill Crest to 2D	-	467137.9	786245.9
AS2467-012	1016.92	1010.7	Link Spill Crest to 2D	-	467141.4	786397.1
AS2963-057	1020.5	1015.8	Link Spill Crest to 2D	-	471543.3	792123.3
AS2962-044	1019.71	1016.23	Link Spill Crest to 2D	-	471601.9	792131.1
AE2963-058	1019.47	1015.6	Link Invert to 2D	-	471542	792108.4
IN2963-060	1019.79	1016.2	Link Spill Crest to 2D	-	471539.4	792175
AS2762-020	1045.81	1036.3	Link Spill Crest to 2D	-	472288.2	789396.4
IN2466-016	1143.6	1140.13	Link Spill Crest to 2D	-	468509.9	785326.8
IN2366-026	1142.7	1140.3	Link Spill Crest to 2D	-	468508.2	785293.7
AS2860-029	1022.4	1017.96	Link Spill Crest to 2D	-	473865.3	791406.6
IN2860-030	1023.35	1019.6	Link Spill Crest to 2D	-	473875.2	791405.9
IN2860-032	1023.35	1019.6	Link Spill Crest to 2D	-	473835.1	791405
IN2860-019	1024.7	1020.06	Link Spill Crest to 2D	2.25	473877.6	791682.7
IN2561-010	1132.5	1126.73	Link Spill Crest to 2D	-	472843.1	787091.8
IN2462-007	1139.77	1135	Link Spill Crest to 2D	-	472310	786421.5
IN2367-011	1117.55	1115	Link Spill Crest to 2D	-	467129.8	784503.2
IN2367-012	1117.25	1112.64	Link Spill Crest to 2D	-	467131.8	784518.1
IN2367-014	1113.6	1110.52	Link Spill Crest to 2D	-	467131.3	784586.2
IN2367-015	1098.6	1093.85	Link Spill Crest to 2D	-	467136.1	784757.2
IN2367-016	1094.08	1089.07	Link Spill Crest to 2D	-	467172.9	784804.9
IN2367-018	1094.02	1088.27	Link Spill Crest to 2D	-	467179.9	784835.8
AS2367-020	1094.72	1086.85	Link Spill Crest to 2D	-	467368.2	784840.9
IN2367-022	1095.65	1090.65	Link Spill Crest to 2D	-	467415.8	784839.4
IN2367-023	1103.83	1099.23	Link Spill Crest to 2D	-	467621.4	784844.7
AS2367-025	1116.87	1111.77	Link Spill Crest to 2D	-	467813.2	784848.7
IN2367-026	1117.67	1113.07	Link Spill Crest to 2D	-	467824.7	784796.1

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Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
AS2367-028	1128.32	1124.32	Link Spill Crest to 2D	-	467819	784568.3
IN2367-033	1087.95	1072.15	Link Spill Crest to 2D	-	467366.4	785036.9
AE2367-036	1076.12	1071.6	Link Invert to 2D	-	467300.5	785036
AS2467-014	1073.76	1067.33	Link Spill Crest to 2D	-	467106	785501.7
AS2367-043	1080.26	1070.79	Link Spill Crest to 2D	-	467101.6	785144.7
AS2367-044	1078.3	1071.55	Link Spill Crest to 2D	-	467132.8	785116.6
AE2367-047	1075.2	1072.53	Link Invert to 2D	-	467138.1	785146.2
AS2959-007	1054	1046.1	Link Spill Crest to 2D	-	475028.5	792646.2
IN2959-010	1051.3	1046.55	Link Spill Crest to 2D	-	475060.8	792651.7
IN2959-012	1061.6	1057.6	Link Spill Crest to 2D	-	474971	792928.1
IN2858-033	1038	1032.1	Link Spill Crest to 2D	-	475136.9	791348.7
AS2858-034	1038.2	1031.24	Link Spill Crest to 2D	-	475136.9	791273
IN2860-034	1028.91	1025.86	Link Spill Crest to 2D	-	473923.6	791116.6
IN2860-038	1024.5	1020.62	Link Spill Crest to 2D	-	473891.7	791261.6
IN2860-039	1024	1020.19	Link Spill Crest to 2D	-	473918.9	791327.8
IN2860-040	1024.79	1020.92	Link Spill Crest to 2D	-	473920.8	791292.8
AE2859-017	1049.61	1047.3	Link Invert to 2D	-	474506.7	790865.3
IN2859-018	1037.2	1034.01	Link Spill Crest to 2D	-	474525.1	791044.6
AE2859-019	1035.7	1033.91	Link Invert to 2D	-	474509.6	791052.4
AS2467-015	1078.88	1070.32	Link Spill Crest to 2D	-	467103.1	785270.6
IN2467-016	1079.99	1075.4	Link Spill Crest to 2D	-	467132.9	785269.4
IN2467-019	1085.56	1080.98	Link Spill Crest to 2D	-	467237.5	785273.2
IN2467-021	1096.88	1092.2	Link Spill Crest to 2D	-	467360.9	785275.9
IN2467-023	1111.76	1107.38	Link Spill Crest to 2D	-	467512.1	785279.2
IN2467-031	1073.73	1067.1	Link Spill Crest to 2D	-	467124	785508
IN2863-042	1014.41	1011.06	Link Spill Crest to 2D	-	471157.3	791434.6
IN2858-039	1033.93	1031	Link Spill Crest to 2D	-	475346.1	791084
IN2764-018	1024.87	1021.7	Link Spill Crest to 2D	6.00	470335.7	789625
IN2858-041	1034.16	1029.658	Link Spill Crest to 2D	-	475349.9	791122.6
AS2859-021	1032.08	1025.43	Link Spill Crest to 2D	-	474510.2	791138.8
IN2963-061	1026.69	1022.06	Link Spill Crest to 2D	-	471314.5	792468.3
IN2963-062	1030.16	1025.72	Link Spill Crest to 2D	-	471319.7	792826.3
AS2963-063	1034.2	1029.45	Link Spill Crest to 2D	-	471288.2	792952.4
IN2963-064	1040.04	1035.29	Link Spill Crest to 2D	-	471219.9	793061
IN2963-065	1042.53	1037.78	Link Spill Crest to 2D	-	471146.6	793116.3
AS2963-068	1045.31	1040.85	Link Spill Crest to 2D	-	470923.8	793296.9
AE2765-015	1010.35	1008.35	Link Invert to 2D	-	469760.3	789688.9
IN2765-014	1010.01	1009.01	Link Invert to 2D	-	469687	789905.6
IN2664-016	1016.33	1012.81	Link Spill Crest to 2D	-	470078.4	789076.1
IN2664-017	1013.87	1008.69	Link Spill Crest to 2D	-	469954.4	789231.8
IN2764-002	1012.8	1009.32	Link Spill Crest to 2D	-	469984.4	789318.1
IN2664-018	1014.01	1008.73	Link Spill Crest to 2D	-	469962.3	789237
IN2664-019	1013.4	1008.87	Link Spill Crest to 2D	-	469984.1	789247.6
IN2664-020	1012.96	1009.05	Link Spill Crest to 2D	-	470004.5	789287.5
IN2765-012	1010.65	1006.71	Link Spill Crest to 2D	-	469783	789689
IN2765-016	1011.42	1006.51	Link Spill Crest to 2D	-	469805.2	789698.4
IN2764-028	1011.16	1006.45	Link Spill Crest to 2D	-	469822.9	789703.7
IN2764-029	1010.23	1006.38	Link Spill Crest to 2D	-	469856.1	789698.4
IN2765-017	1012.55	1008.76	Link Spill Crest to 2D	-	469737.8	789925.8
IN2765-018	1013.47	1008.49	Link Spill Crest to 2D	-	469760.9	789932.1
IN2765-022	1013.98	1009.62	Link Spill Crest to 2D	-	469697.5	790222.2
IN2765-023	1014.27	1009.927	Link Spill Crest to 2D	-	469686.5	790272.3

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Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
IN2765-025	1014.42	1010.35	Link Spill Crest to 2D	-	469671.1	790306.6
IN2765-027	1015.04	1010.56	Link Spill Crest to 2D	-	469626.1	790322.8
IN2864-004	1015.46	1012.5	Link Spill Crest to 2D	-	470454.1	791151.2
IN2864-020	1011.34	1008.74	Link Spill Crest to 2D	-	470428.7	790958.1
IN2864-022	1015.46	1011.91	Link Spill Crest to 2D	-	470415.5	791111.2
IN2864-023	1011.1	1007.58	Link Spill Crest to 2D	-	470631.6	790959.3
IN2863-048	1010	1007.15	Link Spill Crest to 2D	-	470750	790934.7
IN2864-024	1015.32	1011.798	Link Spill Crest to 2D	-	470397.2	791149.4
IN2763-013	1020.94	1017.5	Link Spill Crest to 2D	-	471111.1	790068.8
IN2763-014	1021.06	1015.69	Link Spill Crest to 2D	-	471111.1	790023.7
IN2763-015	1021.93	1011.62	Link Spill Crest to 2D	-	471026.4	790046.4
DT2469-002	1002.8	999.6	Link Invert to 2D	-	465711.7	786353
DT2469-004	1001.7	998.5	Link Invert to 2D	-	465677.2	786304.4
DT2568-019	1001	995	Link Invert to 2D	-	467074.4	786922.4
DT2959-003	1048.7	1046.1	Link Invert to 2D	-	474833.3	792610
DT2859-009	1035.7	1034.1	Link Invert to 2D	-	474458.8	791054.5
DT2859-010	1032.98	1031.38	Link Invert to 2D	-	474461.9	791171.1
GR2860-015	1021.93	1015.93	Link Invert to 2D	-	473785	791214.8
PD2661-020	1074.2	1071.95	Link Spill Crest to 2D	-	472502.9	788746
GR2861-005	1018.74	1014.26	Link Invert to 2D	-	472689.8	790970.2
GR2863-034	1014.23	1011.17	Link Invert to 2D	-	471330.2	791390.1
PD2467-013	1034.93	1030.27	Link Spill Crest to 2D	-	467190.2	786197.8
DT2858-036	1042.88	1041.88	Link Invert to 2D	-	475147.2	792059.9
PD2367-045	1087.03	1076.1	Link Spill Crest to 2D	-	467185.6	785069.5
DT2567-003	1001.59	995	Link Invert to 2D	-	467169.9	786921.2
AS3063-004	1046.28	1041.17	Link Spill Crest to 2D	-	471046.7	793422.8
AS3063-005	1046.91	1041.34	Link Spill Crest to 2D	-	471133.4	793465.3
AS3063-006	1045.4	1041.8	Link Spill Crest to 2D	-	471378.8	793558
AS2765-011	1012.55	1007.73	Link Spill Crest to 2D	-	469782	789937.8
AS2765-020	1013.6	1009.18	Link Spill Crest to 2D	-	469719.2	790151.7
AS2765-030	1026.56	1021.41	Link Spill Crest to 2D	-	469412.4	790532.7
AS2863-045	1014.4	1011.4	Link Spill Crest to 2D	-	471129.4	791442.7
AS2864-009	1015.26	1011.25	Link Spill Crest to 2D	-	470404.7	791123
AS2864-011	1016.21	1012.36	Link Spill Crest to 2D	-	470182	791118.3
AS2864-013	1018.55	1014.73	Link Spill Crest to 2D	-	470056.3	791148.1
AS2960-017	1036.56	1029.19	Link Spill Crest to 2D	-	473945.9	792096.5
AS2763-016	1023.01	1011.07	Link Spill Crest to 2D	-	470989.4	790059.9
AS2763-018	1019.4	1009.69	Link Spill Crest to 2D	-	470956.7	790141.7
AS2763-019	1013.78	1008.14	Link Spill Crest to 2D	-	470954.5	790237.2
AS2763-020	1012.53	1007.51	Link Spill Crest to 2D	-	471035.7	790346.3
TP2662-056	1054.48	1048.026	Link Spill Crest to 2D	-	472297.5	788854.7
TE2562-023	1124.93	1117.438	Link Spill Crest to 2D	-	471972.5	787591.3
MI2762-007	1017.26	1010.813	Link Spill Crest to 2D	-	471714.2	790148.6
TP2863-033	1016.26	1012.058	Link Spill Crest to 2D	-	471509.9	791842.5
MI2963-059	1020.83	1016.35	Link Spill Crest to 2D	-	471483.6	792166.1
MI2367-010	1119.82	1115.09	Link Spill Crest to 2D	-	467128.5	784434.2
MI2864-019	1012.54	1010.3	Link Invert to 2D	-	470410	790971
AE2863-049	1009.02	1006.3	Link Invert to 2D	-	470799.3	790824.2
AE2763-021	1011.11	1007.15	Link Invert to 2D	-	470974	790411.8
PRIVATE207_03	1087.92	1083.8	Link Spill Crest to 2D	-	472924.5	788853
PRIVATE207_02	1084.4	1081.6	Link Spill Crest to 2D	-	473212.3	789038.5
PRIVATE206	1132.19	1128.1	Link Spill Crest to 2D	-	472577.9	786973.1

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Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
2665-005_01a_01	1011.07	1005.2	Link Spill Crest to 2D	-	469756.6	789178.6
PRIVATE133_10	1045.55	1042.25	Link Spill Crest to 2D	3.00	472560.4	789755.3
PRIVATE133_09	1046.67	1041.73	Link Spill Crest to 2D	1.50	472637.7	789865.6
PRIVATE133_08	1046.68	1041.39	Link Spill Crest to 2D	1.50	472709.3	789988
PRIVATE-101149_01	1019.79	0	Link Spill Crest to 2D	-	472002.3	790069.1
PRIVATE133_07	1043.02	1039.24	Link Spill Crest to 2D	-	472825.4	790089.2
PRIVATE133_06	1032.78	1025.48	Link Spill Crest to 2D	-	472907.1	790221.7
PRIVATE133_02	1024.46	1018.06	Link Spill Crest to 2D	-	472714.7	790542.4
PRIVATE133_01	1022.95	1017.75	Link Spill Crest to 2D	1.50	472714.7	790572.7
PRIVATE133	1018.74	1015.25	Link Spill Crest to 2D	1.50	472718.3	790790.5
PRIVATE101214	1043	1037.62	Link Invert to 2D	-	474580.3	791026.9
PRIVATE100905	1029.95	1025.65	Link Spill Crest to 2D	-	474539.4	791124.6
PRIVATE-100385_01	1037.17	1035.52	Link Spill Crest to 2D	-	475165.1	791366.8
PRIVATE100387	1044.05	1042.76	Link Invert to 2D	-	475168.3	792092.7
PRIVATE98	1024.48	1021.85	Link Spill Crest to 2D	-	472711.6	792098
PRIVATE98_01	1024.04	1022.5	Link Spill Crest to 2D	-	472880.4	792169.3
AS-ES-1	1038.78	1031.88	Link Spill Crest to 2D	-	474111.9	792094.7
AS-ES-2	1047.21	1036.89	Link Spill Crest to 2D	-	474378.8	792271
AS-ES-4	1046.28	1041	Link Spill Crest to 2D	-	474612.7	792363.4
AS-ES-3	1045.85	1038.99	Link Spill Crest to 2D	-	474630.4	792289.3
AS-ES-6	1045.63	1042.13	Link Invert to 2D	-	474800.3	792427
PD-ES-S12	1038.6	1037	Link Invert to 2D	-	473962.6	792138.7
AS-ES-S13	1039.37	1034	Link Spill Crest to 2D	-	473959.1	792129.8
TO2959-002	1055.27	1046.1	Link Spill Crest to 2D	-	474945.6	792629.7
2764-015_446	1008.51	1005.605	Link Invert to 2D	-	470463.3	790068.4
2764-015_883	1008.13	1004.922	Link Invert to 2D	-	470070.2	789877
2764-015_1074	1009.1	1000.6	Link Invert to 2D	-	469964	789736.5
2862-008_1183	1011.58	1005.805	Link Invert to 2D	-	471336.8	790861.7
2862-008_461	1012.38	1009.878	Link Invert to 2D	-	471378.8	791354.8
2862-008_893	1011.9	1006.828	Link Invert to 2D	-	471625.4	790874.7
2862-008_570	1012.31	1007.968	Link Invert to 2D	-	471948.4	790867.6
2861-019_397	1020.95	1015.24	Link Invert to 2D	-	473384.4	791154.7
2861-019_430	1021.17	1013	Link Invert to 2D	-	473332.4	791146.7
2665-004_00	1012.31	1002.14	Link Invert to 2D	-	469419.1	788599.7
2665-004_426	1002.08	1001.08	Link Invert to 2D	-	469224.8	788225.9
2665-004_942	1000.49	999.49	Link Invert to 2D	-	468988.5	787785.5
DT2567-003_01	1000.05	999.05	Link Invert to 2D	-	468039.1	786728.7
2665-005_01d_01	1013.08	1004.16	Link Spill Crest to 2D	-	469894.3	789193.3
2862-008_916	1010.5	1008	Link Invert to 2D	-	471341.2	790904.8
PRIVATE144	1030.84	1024.497	Link Spill Crest to 2D	-	471882.5	789484.8
PRIVATE207	1084.57	1080.79	Link Spill Crest to 2D	-	473143.6	789287.1
PRIVATE207_01	1084.58	1080.994	Link Spill Crest to 2D	-	473209.3	789254.9
PRIVATE133_03	1027.11	1021.31	Link Spill Crest to 2D	6.00	472698.3	790371.7
PRIVATE133_05	1028.15	1022.85	Link Spill Crest to 2D	-	472755.9	790337.3
PRIVATE136_01	1017.57	1015.57	Link Invert to 2D	-	473167.7	791234.9
IN2961-018_01	1026.7	1021.37	Link Spill Crest to 2D	-	472554.7	792869.8
2961-017_02	1028.7	1024	Link Invert to 2D	-	472705.1	793012.1
2961-017_01	1028.3	1024	Link Invert to 2D	-	472691.5	792957.6
2961-017_03	1027	1024	Link Invert to 2D	-	473041.2	793232
Tunnel_02	1043.64	1035.64	Link Invert to 2D	-	475144.8	791155.3
Tunnel_01	1039.9	1031.9	Link Invert to 2D	-	474904.1	791227.2
AS2860-001_01	1024.58	1016.64	Link Spill Crest to 2D	-	473880.3	791270.6

McKenna Greentree Watershed Study - Existing Conditions Report
Appendix C: Hydraulic Input Parameters (Nodes)

Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
AS2561-004_01	1131.18	1122.827	Link Spill Crest to 2D	-	472576.3	787089.1
PRIVATE88	1020.55	1016.4	Link Spill Crest to 2D	-	473454.6	791298.9
PRIVATE100151	1019.89	1018.82	Link Spill Crest to 2D	-	472539.2	791700.2
PRIVATE100383	1022.18	1020.417	Link Spill Crest to 2D	-	473935.1	791370.3
PRIVATE173	1016.55	1014.05	Link Invert to 2D	-	472924.7	791207.2
PRIVATE101150	1012.9	1011.61	Link Invert to 2D	-	471758.8	790243.4
PRIVATE144_01	1027.95	1025.1	Link Spill Crest to 2D	-	472002.7	789494.2
2665-005_00	1013.08	1002.49	Link Invert to 2D	-	469460	788662.9
2763-010_01	1011.3	1006.3	Link Invert to 2D	-	470824.8	790401.1
2764-015_1374_01	1011.61	1000.4	Link Invert to 2D	-	469967.2	789453.9
2862-008_1489_01	1011.74	1004.75	Link Invert to 2D	-	471121.5	790669.7
2470-016_01	994.64	988.1	None	-	465461	786196
AS2858-029_01	1036.65	1029.17	None	-	475977.8	790941.7
AS2762-003_01	1037.19	1029.507	Link Spill Crest to 2D	-	471930.6	789383.6
AS2762-003_02	1037.91	1032.098	Link Spill Crest to 2D	-	472067.1	789386.6
AS2662-040_01	1051.38	1045.433	Link Spill Crest to 2D	-	472332.9	788942.6
MI2762-007_01	1018.42	1011.316	Link Spill Crest to 2D	-	471719.8	790033.8
2665-005_01b	1013.08	1004.16	Link Invert to 2D	-	469795.6	789053.2
2763-010_02	1011.74	1006.3	Link Invert to 2D	-	471089.4	790658.9
2764-015	1011.3	1006.3	Link Invert to 2D	-	470805.8	790337.7
PRIVATE136_02	1017.22	1015.22	Link Invert to 2D	-	473154.4	791227.5
PRIV01_02	1050.38	1046.58	Link Spill Crest to 2D	-	467261.1	786134.3
PRIV02_03	1011.82	1010.82	Link Invert to 2D	-	469188.3	789243.7
PRIV02_04	1010.6	1009.6	Link Invert to 2D	-	469231.3	789526.5
PRIV17_08	1067.07	1059.84	Link Spill Crest to 2D	-	473868.7	790359.2
PRIV17_04	1051.36	1035.94	Link Spill Crest to 2D	-	473303.2	790422.5
PRIV17_02	1040.66	1035.6	Link Invert to 2D	-	473220.7	790435
PRIV17_07	1059.92	1054.6	Link Spill Crest to 2D	-	473868.7	790472.2
PRIV17_05	1052.82	1043.65	Link Spill Crest to 2D	-	473414.9	790473.6
PRIV17_06	1057.68	1050.52	Link Spill Crest to 2D	-	473700.4	790476.8
PRIV17_01	1036.08	1034.8	Link Spill Crest to 2D	-	473166.8	790515.1
PRIV25_01	1063.96	1062.14	Link Invert to 2D	-	474969.8	792958.9
PRIV25_02	1067.3	1062.8	Link Spill Crest to 2D	-	474998.1	793033.4
PD2566-001	999.89	998.89	Link Invert to 2D	-	468663.9	787205
PD2961-017	1027.93	0	Link Spill Crest to 2D	-	472992.2	793070.1
PD2367-048	1087.6	1076.6	Link Invert to 2D	-	467250.5	785044.8
TO2859-011	1042	1040	Link Spill Crest to 2D	-	475035.4	791513.6
PDPRIV01	1035.36	0	Link Spill Crest to 2D	-	467222.5	786172.1
PDPRIV12	1023.6	1011.6	Link Invert to 2D	-	473260.5	792065.8
PRIV08_01	1040.1	1039.1	Link Invert to 2D	-	473058.1	794038.4
PRIV17_00	1033.3	1032.01	Link Invert to 2D	-	473166.8	790562.9
PRIV06_01	1085.08	1081.99	Link Invert to 2D	-	473275.8	789029.3
PRIV15_01	1019.77	1017.77	Link Invert to 2D	-	473248.1	791256.8
PRIV01_01	1037.2	1035.2	Link Invert to 2D	-	467238.9	786163.5
PRIV17_03	1038.7	1035.6	Link Invert to 2D	-	473263.1	790425.4
IN2859-006	1030.74	1022.386	Sealed	-	474464.9	791243
IN2562-025	1100.12	1095.211	Link Spill Crest to 2D	3.00	472151.5	787766.9
PRIV07_01	1023.25	1022.25	Link Invert to 2D	-	473209	790740.6
IN2662-041	1047.66	1041.039	Link Spill Crest to 2D	-	472309.7	789129.4
IN2662-050	1069.05	1063.559	Link Spill Crest to 2D	-	472318.3	788480.2
IN2860-021	1029.164	1019.609	Link Spill Crest to 2D	-	474198.4	791278.8
IN2860-022	1025.678	1016.814	Link Spill Crest to 2D	-	473950.6	791257.7

McKenna Greentree Watershed Study - Existing Conditions Report
Appendix C: Hydraulic Input Parameters (Nodes)

Name	Ground Elevation / Spill Crest (ft)	Invert Elevation (ft)	Ponding Type	Maximum Inlet Capacity (cfs)	Node Y	Node X
DT2859-008	1039.7	1037.7	Link Invert to 2D	-	474926.2	791514.6
AS3060-001	1042.2	1038.42	Link Spill Crest to 2D	-	473572.1	793367.2
Node556	1043.37	1037.6	Link Spill Crest to 2D	-	467137.9	786118.6
GR2861-019-801	1030.62	1028.62	Link Invert to 2D	-	474517.2	791625.6
GR2861-019-802	1028.4	1026.9	Link Spill Crest to 2D	-	474472.7	791631.3
PDPRIV20	1031	1030.06	Link Invert to 2D	-	474545.5	791121.4
AE2461-017	1130.5	1129.4	Link Invert to 2D	-	472802.8	786703.9
PDPRIV21	1043	1036.4	Link Invert to 2D	-	474588.5	791023.2
PRIV09_01	1020.12	1018.646	Link Spill Crest to 2D	-	472580.9	791370.8
IN2861-017	1020.1	1017.32	Link Spill Crest to 2D	2.25	472490.4	791395.8
AS3061-015	1020.74	1013.982	Link Spill Crest to 2D	-	472480.3	791396.3
PRIV10-01	1028	1023	Link Invert to 2D	-	472599.1	792871.3
PRIV07-01	1026.71	1024.71	Link Invert to 2D	-	474229.4	791955.7
AS2961-007	1025.592	1019.615	Link Spill Crest to 2D	4.50	472494.1	792515.6
PRIV11-01	1027.61	1025.61	Link Invert to 2D	-	473771.6	791114.8
Node571	1005.9	990.24	None	-	465753.9	786406.1
2764-015.1	1010.79	1006.085	Link Invert to 2D	-	470726.4	790234.3
AE2863-028.1	1015.405	1011.38	Link Invert to 2D	-	471496.9	791700.5
Node575	1011.58	1005.608	Link Invert to 2D	-	471307.3	790814.5
Node577	1011	1009	Link Invert to 2D	-	470994.2	790503.4
Node578	1010.5	1008.5	Link Invert to 2D	-	470975.2	790526.8

Appendix D: Existing Conditions Flooding Depth and Duration at Specific Locations

Appendix D – Existing conditions flooding depth and duration for up to 25 locations for each design storm

Flood report locations were selected with help from the City. Locations where preliminary modeling showed structure damage was possible were prioritized. 27 locations in total were selected.

It was realized during the compilation of this data that the XP SWMM 1D results for “*Hydraulic Grade Line*”, “*Maximum Flooding Depth*”, and “*Duration of Flooding*” don’t necessarily correspond with the 2D depth of flooding at the surface of the node. For instance, if an area is inundated due to upstream bypass, yet has adequate downstream pipe capacity, the 1D results for “*Hydraulic Grade Line*” may be below the ground elevation. We know that there is flooding on the surface because of the inundation mapping, yet the 1D results can not tell us how deep or for how long.

To measure maximum flooding depths at every chosen location, a GIS intersect of the flood inundation result files and the XP SWMM node point locations was done. This removed the need to use 1D model results to obtain this information.

To estimate the duration of flooding at the chosen locations, results from all adjacent nodes to the Maximum Flooding Depth node were reviewed for the 1% ACE event. The “*Duration of Flooding*” results were compared, and the most appropriate node was selected to report this statistic, based on the area surface hydraulics and engineering judgement.

Seybold Rd - Struck St Intersection		
Event	Max Depth (ft) Node: IN2859-006	Duration of Flooding (mins) Node: AE2859-017
50% ACE	1.2	12.6
20% ACE	1.3	18.9
10% ACE	1.4	24.1
4% ACE	1.4	29.7
2% ACE	1.5	34.8
1% ACE	1.6	40.2
1% ACE (B2B)	1.6	81.3
0.2% ACE	1.8	52.6

John Powless Tennis Center		
Event	Max Depth (ft) Node: PRIVATE173	Duration of Flooding (mins) Node: PRIVATE173
50% ACE	0.9	9.1
20% ACE	1.2	23.2
10% ACE	1.4	33.7
4% ACE	1.6	50.9
2% ACE	1.7	63.1
1% ACE	1.9	79.8
1% ACE (B2B)	1.9	179.6
0.2% ACE	2.2	104.0

New Washburn Way Sag		
Event	Max Depth (ft) Node: IN2462-007	Duration of Flooding (mins) Node: IN2462-007
50% ACE	0.1	0.0
20% ACE	0.3	4.3
10% ACE	0.8	26.1
4% ACE	1.6	43.8
2% ACE	2.1	57.3
1% ACE	2.6	69.1
1% ACE (B2B)	2.6	139.1
0.2% ACE	3.3	90.1

S Holt Cir Sag		
Event	Max Depth (ft) Node: IN2662-047	Duration of Flooding (mins) Node: IN2662-047
50% ACE	0.0	0.0
20% ACE	0.2	3.1
10% ACE	0.9	12.5
4% ACE	1.5	24.2
2% ACE	1.8	30.6
1% ACE	2.1	36.6
1% ACE (B2B)	2.1	73.0
0.2% ACE	2.4	45.4

Park Ridge Dr Sag		
Event	Max Depth (ft) Node: AS2762-005	Duration of Flooding (mins) Node: IN2762-010
50% ACE	0.6	93.3
20% ACE	1.3	123.7
10% ACE	1.7	147.4
4% ACE	2.2	175.1
2% ACE	2.5	193.5
1% ACE	2.9	213.1
1% ACE (B2B)	2.9	376.0
0.2% ACE	3.6	301.5

Piping Rock Rd - Chapel Hill Rd Intersection		
Event	Max Depth (ft) Node: IN2863-021	Duration of Flooding (mins) Node: IN2863-021
50% ACE	0.5	39.4
20% ACE	0.7	57.1
10% ACE	0.9	68.5
4% ACE	1.1	83.7
2% ACE	1.2	95.4
1% ACE	1.3	108.1
1% ACE (B2B)	1.3	231.4
0.2% ACE	1.6	135.3

Forward Dr Sag		
Event	Max Depth (ft) Node: AS3061-001	Duration of Flooding (mins) Node: AS3061-001
50% ACE	0.3	83.0
20% ACE	0.4	98.8
10% ACE	0.4	110.1
4% ACE	0.5	159.2
2% ACE	0.6	193.7
1% ACE	0.8	216.6
1% ACE (B2B)	0.9	286.6
0.2% ACE	1.3	311.9

McKenna Blvd (west of Hammersley Ave)		
Event	Max Depth (ft) Node: AS2765-011	Duration of Flooding (mins) Node: AS2765-011
50% ACE	0.3	0.0
20% ACE	0.4	60.9
10% ACE	0.5	95.8
4% ACE	0.6	172.8
2% ACE	0.6	225.8
1% ACE	0.7	292.7
1% ACE (B2B)	0.9	687.3
0.2% ACE	1.0	377.4

Mid Town Rd - Legacy Ln Intersection		
Event	Max Depth (ft) Node: IN2367-018	Duration of Flooding (mins) Node: IN2367-018
50% ACE	0.0	0.0
20% ACE	0.0	0.0
10% ACE	0.0	0.0
4% ACE	0.3	2.8
2% ACE	0.7	10.6
1% ACE	0.9	16.7
1% ACE (B2B)	0.9	33.9
0.2% ACE	1.2	26.6

Watts Rd - Struck St Intersection		
Event	Max Depth (ft) Node: AS2860-001	Duration of Flooding (mins) Node: IN2860-030
50% ACE	0.0	0.0
20% ACE	0.0	7.5
10% ACE	0.0	24.6
4% ACE	0.1	35.5
2% ACE	0.2	42.6
1% ACE	0.4	52.2
1% ACE (B2B)	0.4	105.9
0.2% ACE	0.4	64.0

Prairie Park Senior Apartments		
Event	Max Depth (ft) Node: IN2861-001	Duration of Flooding (mins) Node: IN2861-001
50% ACE	0.1	0.0
20% ACE	0.1	0.0
10% ACE	0.2	1.6
4% ACE	0.4	33.4
2% ACE	0.8	55.1
1% ACE	0.9	66.5
1% ACE (B2B)	1.0	136.1
0.2% ACE	1.5	81.9

Kottke Dr D/S of Highpoint Estates Detention Pond		
Event	Max Depth (ft) Node: AS2561-006	Duration of Flooding (mins) Node: AS2561-006
50% ACE	0.0	0.0
20% ACE	0.1	0.0
10% ACE	0.2	0.0
4% ACE	0.4	0.0
2% ACE	0.5	0.0
1% ACE	0.8	92.5
1% ACE (B2B)	1.0	212.1
0.2% ACE	1.1	143.0

919-949 S Gammon Rd Apartments Sag		
Event	Max Depth (ft) Node: PRIVATE144_01	Duration of Flooding (mins) Node: PRIVATE144_01
50% ACE	0.3	12.4
20% ACE	1.1	41.2
10% ACE	2.3	91.6
4% ACE	3.3	126.9
2% ACE	3.5	137.4
1% ACE	3.7	152.6
1% ACE (B2B)	3.7	312.9
0.2% ACE	4.1	182.2

Laurie Dr - Shoreham Dr Corner Sag		
Event	Max Depth (ft) Node: AS2962-029	Duration of Flooding (mins) Node: AS2962-029
50% ACE	0.3	97.6
20% ACE	0.5	122.7
10% ACE	0.6	145.0
4% ACE	0.8	168.9
2% ACE	0.9	184.6
1% ACE	1.0	211.6
1% ACE (B2B)	1.4	404.0
0.2% ACE	1.4	338.8

Piping Rock Rd Sag		
Event	Max Depth (ft) Node: IN2863-042	Duration of Flooding (mins) Node: IN2863-042
50% ACE	0.6	51.4
20% ACE	1.4	105.2
10% ACE	1.9	152.6
4% ACE	2.4	213.8
2% ACE	2.7	240.5
1% ACE	2.9	264.5
1% ACE (B2B)	3.0	554.6
0.2% ACE	3.3	304.9

Park Edge Dr Sag		
Event	Max Depth (ft) Node: IN2764-018	Duration of Flooding (mins) Node: IN2764-018
50% ACE	0.6	54.7
20% ACE	0.8	78.0
10% ACE	1.0	96.3
4% ACE	1.1	114.9
2% ACE	1.2	126.4
1% ACE	1.3	137.9
1% ACE (B2B)	1.3	203.2
0.2% ACE	1.4	229.3

Elver Park Ditch (south of McKenna Blvd) Sag		
Event	Max Depth (ft) Node: AE2765-015	Duration of Flooding (mins) Node: AE2765-015
50% ACE	1.6	173.3
20% ACE	2.1	249.3
10% ACE	2.5	299.3
4% ACE	2.9	364.4
2% ACE	3.2	422.1
1% ACE	3.5	504.2
1% ACE (B2B)	3.9	1299.3
0.2% ACE	4.0	553.3

Mid Town Rd Channel Crossing		
Event	Max Depth (ft) Node: AS2568-006	Duration of Flooding (mins) Node: AS2568-006
50% ACE	0.0	0.0
20% ACE	0.0	0.0
10% ACE	0.4	104.1
4% ACE	0.7	291.5
2% ACE	1.0	385.3
1% ACE	1.3	492.4
1% ACE (B2B)	2.0	1281.7
0.2% ACE	1.9	584.4

6512 Watts Rd		
Event	Max Depth (ft) Node: AS2860-020	Duration of Flooding (mins) Node: AS2860-020
50% ACE	0.0	0.0
20% ACE	0.0	10.2
10% ACE	0.3	24.6
4% ACE	0.6	35.2
2% ACE	0.8	42.3
1% ACE	1.0	51.7
1% ACE (B2B)	1.0	104.6
0.2% ACE	1.2	63.6

Greenway Culvert U/S of Schoeder Rd		
Event	Max Depth (ft) Node: AE2861-013	Duration of Flooding (mins) Node: AE2861-013
50% ACE	1.6	N/A
20% ACE	2.1	N/A
10% ACE	2.4	N/A
4% ACE	2.7	N/A
2% ACE	3.0	N/A
1% ACE	3.5	N/A
1% ACE (B2B)	3.7	N/A
0.2% ACE	4.6	N/A

Gammon Rd (South Gammon Mobile Station)		
Event	Max Depth (ft) Node: AS2662-043	Duration of Flooding (mins) Node: AS2662-043
50% ACE	0.5	9.9
20% ACE	0.6	24.2
10% ACE	0.7	35.7
4% ACE	0.8	56.4
2% ACE	0.9	72.7
1% ACE	1.0	90.5
1% ACE (B2B)	1.0	198.4
0.2% ACE	1.1	125.4

Gammon Rd - Park Ridge Dr Intersection		
Event	Max Depth (ft) Node: AS2762-003	Duration of Flooding (mins) Node: AS2762-003
50% ACE	0.0	0.0
20% ACE	0.4	0.0
10% ACE	0.7	0.0
4% ACE	0.7	23.8
2% ACE	0.9	33.5
1% ACE	1.0	44.5
1% ACE (B2B)	1.0	91.5
0.2% ACE	1.4	62.4

Piping Rock Rd - Winston Dr Intersection		
Event	Max Depth (ft) Node: IN2963-061	Duration of Flooding (mins) Node: IN2963-061
50% ACE	0.8	45.1
20% ACE	1.0	58.6
10% ACE	1.1	71.0
4% ACE	1.2	85.4
2% ACE	1.3	96.5
1% ACE	1.5	109.3
1% ACE (B2B)	1.5	226.5
0.2% ACE	1.7	142.6

Chapel Hill Rd Channel Crossing		
Event	Max Depth (ft) Node: TP2863-033	Duration of Flooding (mins) Node: TP2863-033
50% ACE	0.3	0.0
20% ACE	0.5	0.0
10% ACE	0.5	0.0
4% ACE	0.9	15.1
2% ACE	1.0	37.1
1% ACE	1.2	56.2
1% ACE (B2B)	1.4	146.3
0.2% ACE	1.7	84.8

1202 McKenna Blvd		
Event	Max Depth (ft) Node: AS2664-004	Duration of Flooding (mins) Node: AS2664-004
50% ACE	0.0	1.5
20% ACE	0.2	11.8
10% ACE	0.4	17.2
4% ACE	0.6	25.8
2% ACE	0.7	30.4
1% ACE	0.8	35.5
1% ACE (B2B)	0.8	74.0
0.2% ACE	1.0	49.4

Greenway Culvert U/S of McKeena Blvd		
Event	Max Depth (ft) Node: 2764-015_1374_01	Duration of Flooding (mins) Node: 2764-015_1374_01
50% ACE	9.3	N/A
20% ACE	9.7	N/A
10% ACE	10.2	N/A
4% ACE	10.6	N/A
2% ACE	10.9	N/A
1% ACE	11.2	N/A
1% ACE (B2B)	11.6	N/A
0.2% ACE	11.7	N/A

Greenway Culvert U/S of Raymond Rd		
Event	Max Depth (ft) Node: DT2469-004	Duration of Flooding (mins) Node: DT2469-004
50% ACE	0.6	N/A
20% ACE	1.4	N/A
10% ACE	2.9	N/A
4% ACE	3.6	N/A
2% ACE	4.0	N/A
1% ACE	4.3	N/A
1% ACE (B2B)	4.9	N/A
0.2% ACE	4.8	N/A

Appendix E: Inlet Capacity Analysis Documentation



Memo

To: City of Madison Engineering Department
From: Eric Thompson, P.E. and Alistair Hancox
Subject: Inlet Capacity Modeling Approach
Date: October 8, 2020

Introduction

This memorandum presents MSA's proposed approach for modeling inlet capacity for the Greentree/McKenna Watershed.

Traditional Inlet Capacity Calculations

MSA's typical approach to determining inlet capacity is to follow the procedure of the Wisconsin Department of Transportation (WisDOT) Facilities Development Manual (FDM) Chapter 13-25, "Storm Sewer Design".

The design of inlets is documented in FDM section 13-25-30 and follows procedures developed by Neenah Foundry. The process for calculating inlet capacity, regardless of whether the inlet is on a continuous grade or in a sump condition, involves formulae dependent on flow depth and various grate coefficients published by Neenah Foundry. Determination of flow depth is described in FDM section 13-25-25 and involves application of Manning's equation to determine the hydraulic capacity of a street cross-section. Important variables include geometric conditions such as cross-slope, longitudinal slope.

For castings installed on continuous grades (i.e. not in sump/sag conditions), it is not uncommon to find that up to a certain, relatively low, flow rate or depth, a typical casting can capture 100% of the approach flow. However, above this threshold, there is commonly bypass of some of the approach flow. The percentage of bypass changes with changing approach flow.

Limitations in Application to Watershed Modeling

The process described above requires a detailed assessment of flow conditions in the gutter at the location of each inlet. This is generally not too cumbersome when dealing with a typical design, since the engineer is usually dealing with a single design event and usually only concerned with flow capture under peak flow conditions (a single flow condition). However, in the context of the City of Madison's watershed studies, the scope includes evaluation of multiple events under unsteady conditions where flows may be changing at every model time step. Given the scale of each watershed and the number of inlets installed in unique conditions and the application of the FDM procedure becomes unrealistically cumbersome.

MEMO

October 8, 2020

Development of Inlet Rating Curves

XP-SWMM allows several methods for calculation of inlet capacity. These include a method as simple as establishing a maximum inlet capacity to methods as complex as those described in the previous section, which depend on the hydraulics of the street and gutter cross-section as well as various inlet characteristics. In between the simple and complex method are two rating-curve methods where inlet capture is determined according to approach flow and approach depth. For this application, inlet capture is determined either as a fraction of total flow in the street/gutter section or as a pre-calculated value dependent on depth. The 'approach flow' method is generally suited to applications where inlets are on continuous grade while 'approach depth' is suited for applications where inlets are in sump conditions.

Application of either of these inlet capture methods allows for accommodation of changing flow conditions as will occur in the modeling required for the City's watershed studies. However, it is still necessary to develop rating curves for inlets whose function will be affected by the different variables introduced previously. To evaluate the significance of these variables, MSA developed rating curves for the two grates typically used by the City of Madison – the 3067-R (diagonal grate) and the 3067-V (vane grate). Note that for this exercise, MSA assumed a 'typical' street and gutter cross-section based on Madison standard details and so the only effective variables were approach flow, longitudinal slope, and grate capacity coefficients.

Initial Approach Attempt

Initially, MSA had intended to reduce the data presented in the previous section to a pair of two rating curves, which would be applied to all inlets in the watershed. One rating curve would represent the hydraulics of inlets on continuous grades and inlet capture would be determined as a function of approach flow. The second rating curve would represent the hydraulics of inlets in a sag condition and inlet capture would be determined as a function of approach depth

For each application within the XP-SWMM model, the effect of multiple inlets at any location will be reflected by application of an 'inlet efficiency' multiplier, which would also reflect recommended plugging factors per modeling guidance.

The rating curves developed are presented below:

Continuous Grade

Approach Flow (cfs)	Inlet Capture (cfs)
1	0.98
2	1.46
3	1.84
4	2.15
5	2.43
6	2.70
7	2.94
8	3.17
9	3.38
10	3.59

Sag Condition

Approach Depth (ft)	Inlet Capture (cfs)
0.0	0.00
0.2	1.74
0.4	4.93
0.6	9.05
0.8	13.60
1.0	15.21
1.5	18.63
2.0	21.51
2.5	24.05
3.0	26.35
3.5	28.46
4.0	30.42

There are several inherent limitations to this approach which, unfortunately eroded confidence in its application.

1. The first limitation in this approach is that the XP-SWMM model does not include discrete elements for every individual inlet within the watershed. As a result, the hydraulic capacity of the inlets need to be aggregated. This introduces potentially significant error into the model, as upstream inlets where approach flows and depths are more shallow, may have greater capture rates than downstream inlets where there may be greater bypass. With all inlets within a single hydrologic subcatchment being aggregated to a location effectively at the downstream end of the watershed, there is great difficulty in determining that the rating curve reasonably accurately reflects actual inlet capacity in the subcatchment for all possible flow conditions simulated.
2. A second limitation is that the 2D surface used for nearly all simulation of street flows represents each street as a series of 'grid cells', each 10-feet on a side, and each having essentially a flat surface. This has two effects. The first is that flow depth in the street (the gutter section where the inlets are typically located) will not match reality and the capture rate of inlets at sags will be misrepresented. The second is that under high flows, where water depths may exceed the center crown of the street, flows may not be distributed within either lanes of the street in a way that necessarily reflects reality, and inlet capacities base on approach flow may be misrepresented.
3. A third limitation, which is related to the practicalities of operating an complex 1D/2D XP-SWMM model is that wholesale application of inlet capacity routines in the model greatly extends run times. Run times become so long that it is overly burdensome to

solve the model during the development process to evaluate the ramifications of application of various inlet capacity routines.

Approach used in the XP-SWMM model

Because there are concerns that there are elements of the storm sewer system that are inlet capacity limited, despite concerns raised in the previous section, it was still necessary to evaluate every system in the watershed to determine if it was sensitive to inlet capacity limitations.

Ultimately, the rating curve method was abandoned due to simple concerns that the complexity of the approach was not warranted given the relative level of uncertainty with the application of inlet capacity restrictions on an aggregated inlet basis. Instead, a constant base value of 3 cfs-per-inlet was applied in the modeling. This value was multiplied by the number of inlets in the aggregated set and subsequently reduced by a clogging factor per the City's modeling guidance. A value of 3 cfs was selected as a maximum since it appeared to be approximately the point where inlet capacity for a single inlet on grade approached an 'asymptotic' effective maximum value per calculations developed under the rating curve approach. Note that while this value would underestimate the potential capacity of inlets at sags, most of these locations were either identified as pipe-capacity limited or have already been retrofit by the City to have high capacity inlets and so inlet capacity restrictions were not applied in these locations (see discussion that follows).

To determine where inlet capacity was the limiting factor in the storm sewer system, the existing conditions (uncalibrated) model was solved several times in succession:

Iteration #1 – The first step in this investigation was to solve the model for a 10% AEP design storm (the 10% storm representing the City's typical design standard for storm sewer systems). This model allowed unlimited inlet capacity for each modeled inlet node (the node can accept as much flow as the downstream hydraulic element can convey). An inundation map was created from the results of this model and used as a basis for comparison

Iteration #2 – The model developed in the prior step was modified by applying a uniform 5 cfs maximum-capacity applied to every modeled inlet node. A 5 cfs per-inlet capacity was an initial estimate of a limited, but still high level, of inlet capacity. Where the resulting inundation maps was the same as for iteration #1, for each of the previously described scenarios, the system was determined to be pipe-limited, and therefore inlet capacity restrictions were not needed for those areas.

Iteration #3 - Where a difference in the inundation maps was observed, a maximum inlet base-inflow of 3 cfs-per-inlet was assigned, reduced by the appropriate factor as identified in the Modeling Guidance for low slopes and sag

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conditions. An exception to this approach was for areas where there were a significant number of inlets in close proximity or where there was a 'high capacity terrace inlet' in place. In these instances, inlet capacity restrictions were not included.

Inlet capacity was modeled by flagging the "Inlet Capacity" check box within the 1D hydraulic node properties and specifying the maximum capacity in cubic-feet-per-second (cfs).

Ultimately, this approach was determined by MSA to be acceptable due to the general agreement of the inundation maps from the calibrated model matching reported flooding problems, as well as the general agreement between calibrated model output and the metered events used for model calibration.

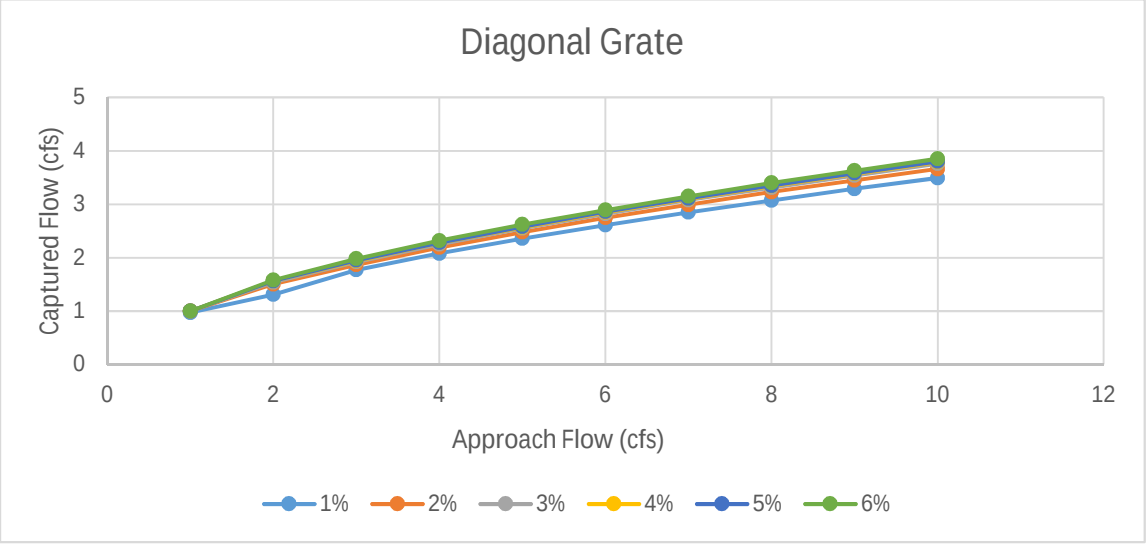
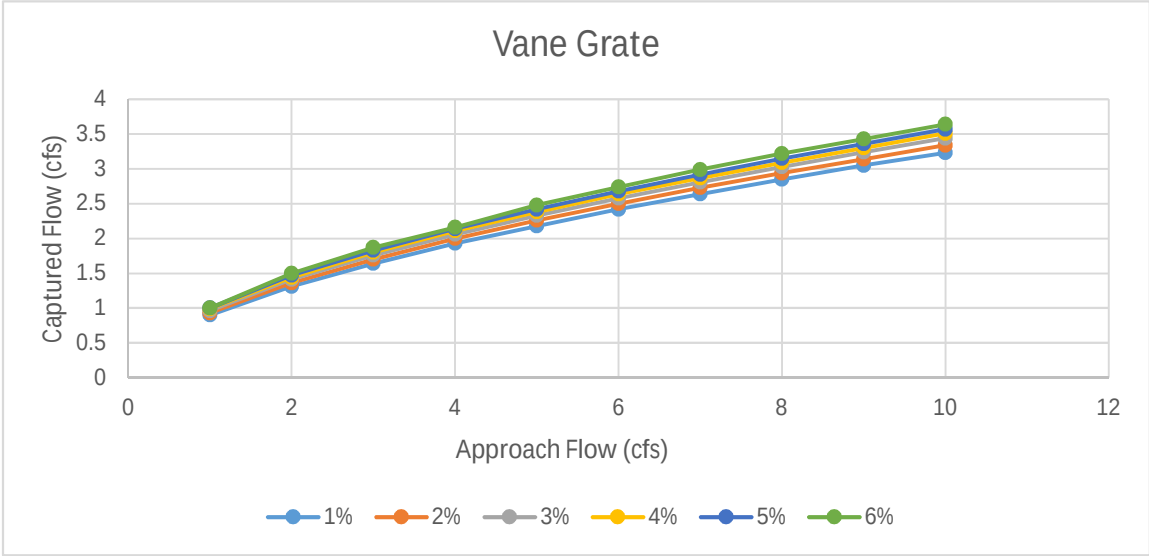
Inlet Capture Rating Curve for Sag Condition

Vane Grate - MSA Spreadsheet

Approach Flow (cfs)	Longitudinal slope						AVERAGE
	1%	2%	3%	4%	5%	6%	
Inlet Capture	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
1	0.9	0.93	0.96	0.99	1	1	0.963
2	1.31	1.36	1.41	1.44	1.47	1.5	1.415
3	1.64	1.7	1.76	1.8	1.83	1.87	1.767
4	1.93	2	2.06	2.11	2.14	2.16	2.067
5	2.18	2.26	2.33	2.38	2.42	2.48	2.342
6	2.42	2.5	2.58	2.64	2.68	2.74	2.593
7	2.64	2.73	2.81	2.87	2.92	2.99	2.827
8	2.85	2.94	3.03	3.09	3.15	3.22	3.047
9	3.05	3.14	3.24	3.3	3.36	3.43	3.253
10	3.23	3.34	3.44	3.51	3.57	3.64	3.455

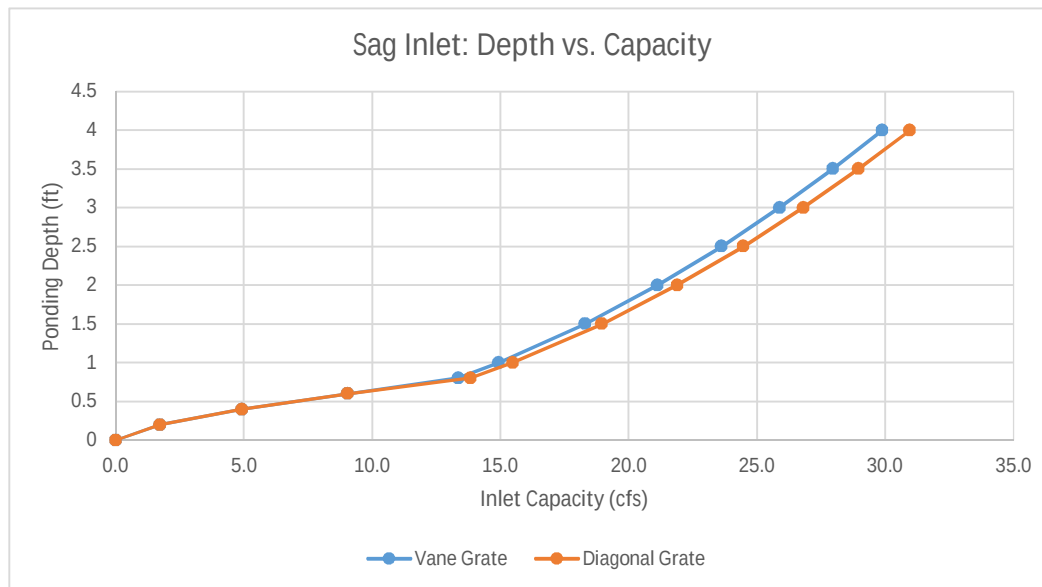
Diagonal Grate - MSA Spreadsheet

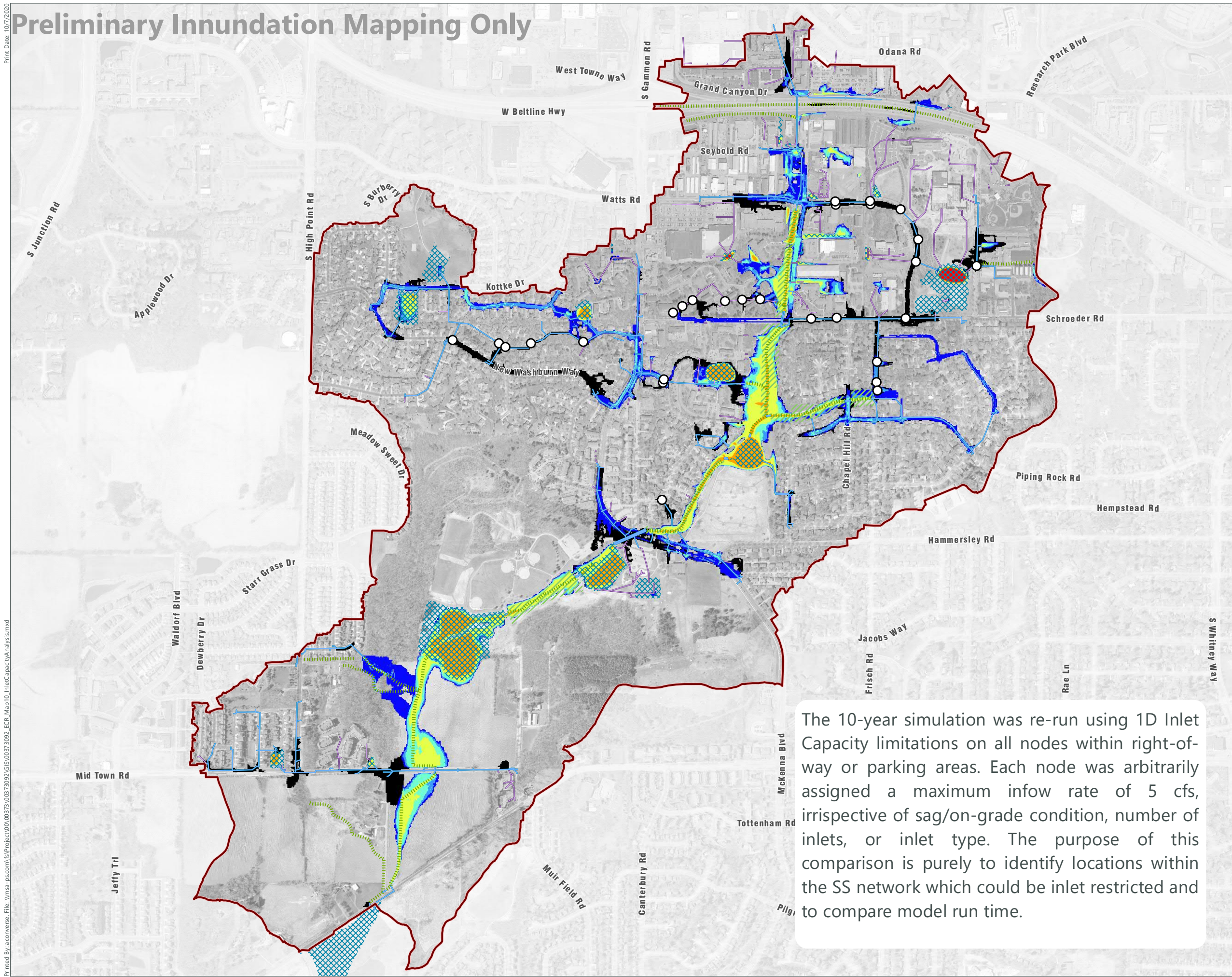
Approach Flow (cfs)	Longitudinal slope						AVERAGE	Approach Flow	Inlet Capture
	1%	2%	3%	4%	5%	6%			
Inlet Capture	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
1	0.97	1	1	1	1	1	0.995	1	0.98
2	1.31	1.5	1.54	1.56	1.56	1.58	1.508	2	1.46
3	1.77	1.87	1.92	1.94	1.95	1.98	1.905	3	1.84
4	2.08	2.19	2.25	2.28	2.28	2.32	2.233	4	2.15
5	2.36	2.48	2.55	2.57	2.58	2.62	2.527	5	2.43
6	2.61	2.75	2.82	2.85	2.86	2.89	2.797	6	2.70
7	2.85	2.99	3.08	3.1	3.11	3.15	3.047	7	2.94
8	3.07	3.23	3.31	3.34	3.35	3.4	3.283	8	3.17
9	3.29	3.45	3.54	3.57	3.58	3.63	3.510	9	3.38
10	3.49	3.66	3.76	3.79	3.8	3.85	3.725	10	3.59



Inlet Capture Rating Curve for Sag Condition

Vane Grate				Diagonal Grate				Average	
Area		Perimeter		Area		Perimeter			
2.779		5.9		2.879		5.9			
Depth (ft)	Orifice Capacity (cfs)	Weir Capacity (cfs)	Capacity (cfs)	Depth (ft)	Orifice Capacity (cfs)	Weir Capacity (cfs)	Capacity (cfs)	Depth (ft)	Inlet Capture (cfs)
0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.00
0.2	6.7	1.7	1.7	0.2	6.9	1.7	1.7	0.2	1.74
0.4	9.5	4.9	4.9	0.4	9.8	4.9	4.9	0.4	4.93
0.6	11.6	9.0	9.0	0.6	12.0	9.0	9.0	0.6	9.05
0.8	13.4	13.9	13.4	0.8	13.8	13.9	13.8	0.8	13.60
1	14.9	19.5	14.9	1	15.5	19.5	15.5	1	15.21
1.5	18.3	35.8	18.3	1.5	19.0	35.8	19.0	1.5	18.63
2	21.1	55.1	21.1	2	21.9	55.1	21.9	2	21.51
2.5	23.6	77.0	23.6	2.5	24.5	77.0	24.5	2.5	24.05
3	25.9	101.2	25.9	3	26.8	101.2	26.8	3	26.35
3.5	28.0	127.5	28.0	3.5	29.0	127.5	29.0	3.5	28.46
4	29.9	155.8	29.9	4	31.0	155.8	31.0	4	30.42





Preliminary Innundation Mapping Only

Inlet Capacity Comparison

FIGURE 10
McKenna/Greentree Watershed Study
Existing Conditions Report

City of Madison
Dane County, WI

- Watershed Study Area
- Greenway
- Pond
- Public Storm System
- Private Storm System
- Open Channel Flow
- Inlet Capacity Analysis Location

Preliminary 10% AEP Storm

Flood Depths PRELIMINARY (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

Flood Extent - INCLUDING INLET RESTRICTIONS



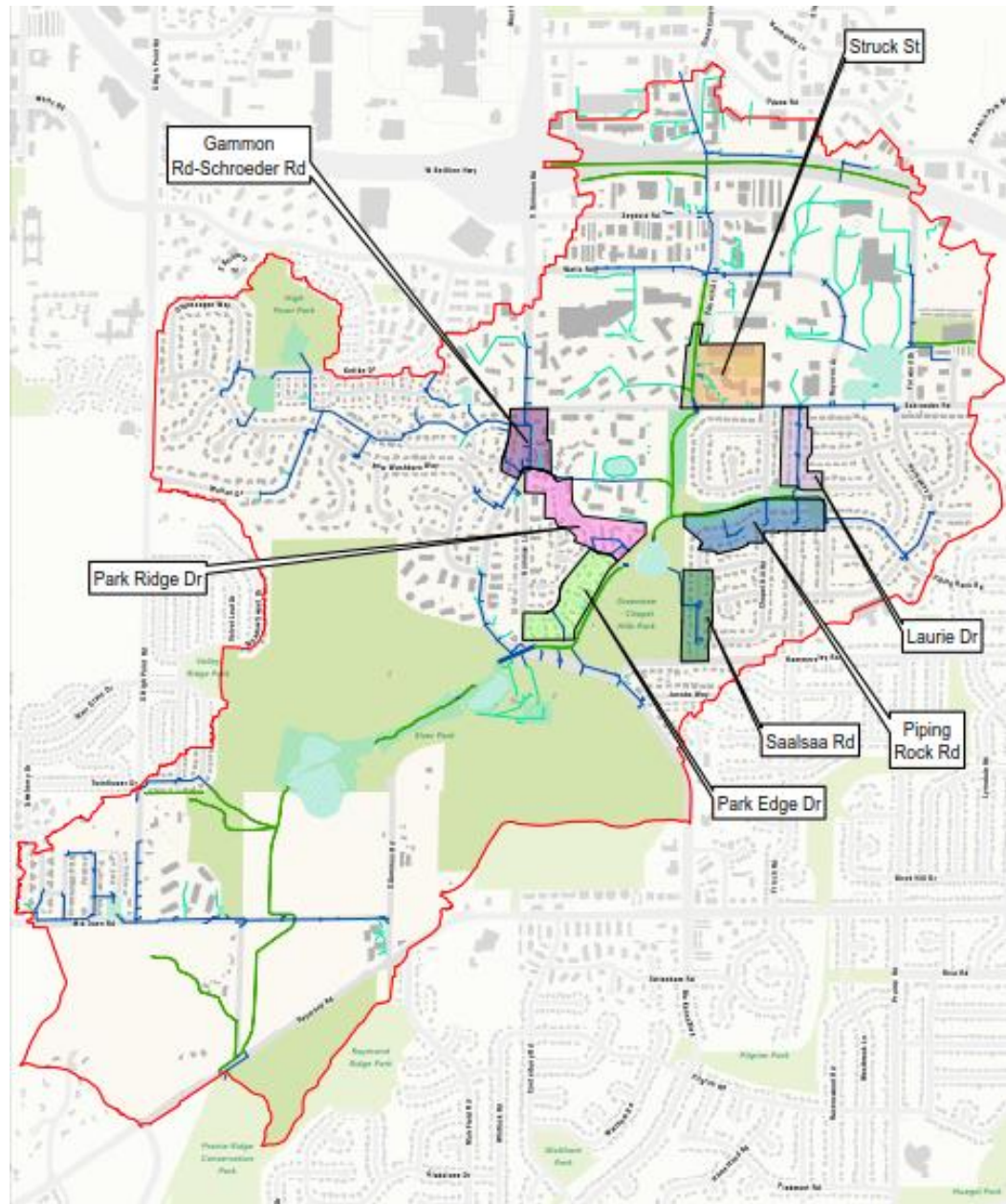
The 10-year simulation was re-run using 1D Inlet Capacity limitations on all nodes within right-of-way or parking areas. Each node was arbitrarily assigned a maximum infow rate of 5 cfs, irrespective of sag/on-grade condition, number of inlets, or inlet type. The purpose of this comparison is purely to identify locations within the SS network which could be inlet restricted and to compare model run time.

Data Sources:
Flood Hazard is approximate and to be revised upon completion of the project. Estimated using XPSWMM Rain on Grid methodology.
Aerial: City of Madison (2018)
Watershed Boundaries: MSA
Stormwater System: City of Madison

Appendix F: Focus Group Summary

Appendix F – Focus Group Summary

Please refer to Figures 7A – 7G of the Existing Conditions Report for detailed findings recorded during the Focus Group meetings.



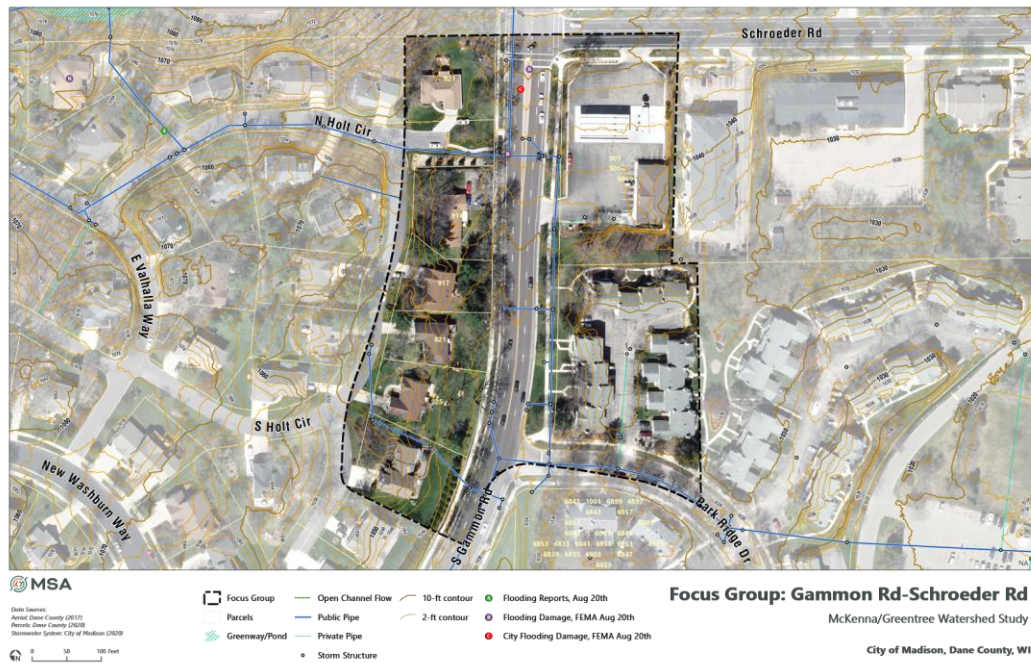
Gammon Rd – Schroeder Rd, 7/30/2020

MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.

Public Attendees: 1

Photo taken during Gammon Rd meter inspections

- Indicated flooding on the west side of Gammon Road during the August 20th, 2018 Event
- Indicated water flowing form the south towards Park Ridge Road



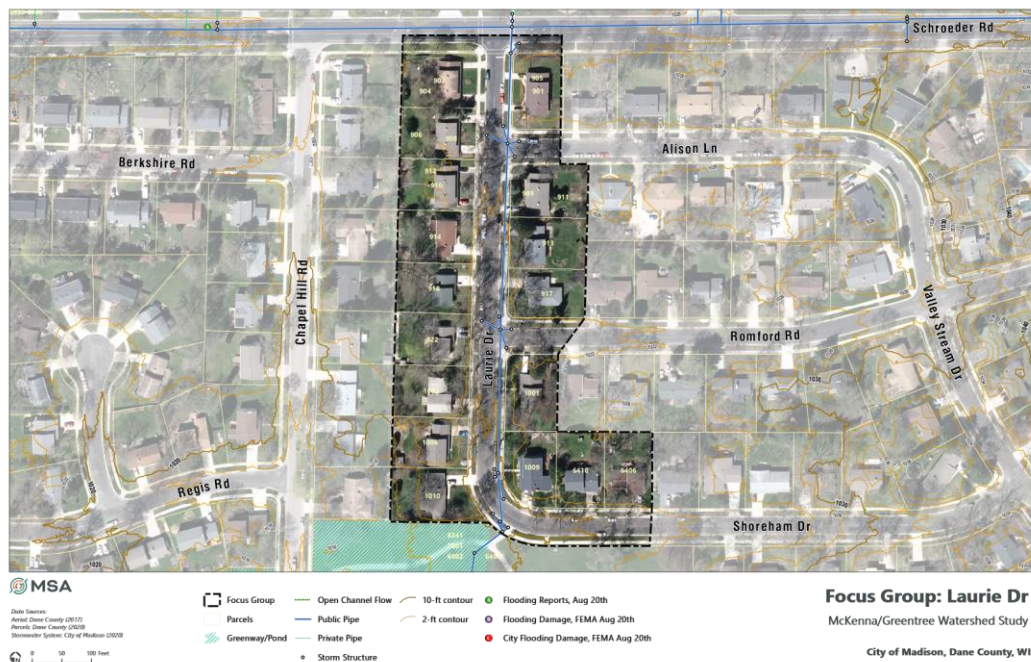
Laurie Drive, 7/23/2020

MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.

Public Attendees: 5

Resident's Photo of June 2020 Storm Event

- Flooding occurs in the street at the bend along Shoreham Drive before spilling into the greenway to the southwest. Inlets at this corner require frequent cleaning.
- Sag point at the intersection of Romford Road and Shoreham Drive
- Significant overland flow runs down Romford Road during large storm events, and causes inundation in the driveway at the SW corner of Laurie Dr and Shoreham Dr. The photo below shows an example of the road inundation at this location.
- The driveways at the Laurie Dr/Shoreham Dr intersection are frequently inundated, but typically not the homes.



Park Edge Drive, 7/28/2020

MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.

Public Attendees: 1

Photos taken during Focus Group meeting.

- No spilling observed from Park Edge Drive into their neighborhood
- Resident along the greenways experienced flooding in their basements through windows in the August 20th, 2018 event





Park Ridge Dr, 7/28/2020

MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.

Public Attendees: 2

Photo taken during Focus Group meeting.

- Properties on the eastern side of the focus group had inches to feet of water in the August 20th, 2018 event (however, no flooding since). Water in the parking lot was ~18".
- New inlets along Park Ridge Dr have improve drainage within the ROW sag
- An unknown culvert was identified to add into the XPSWMM model

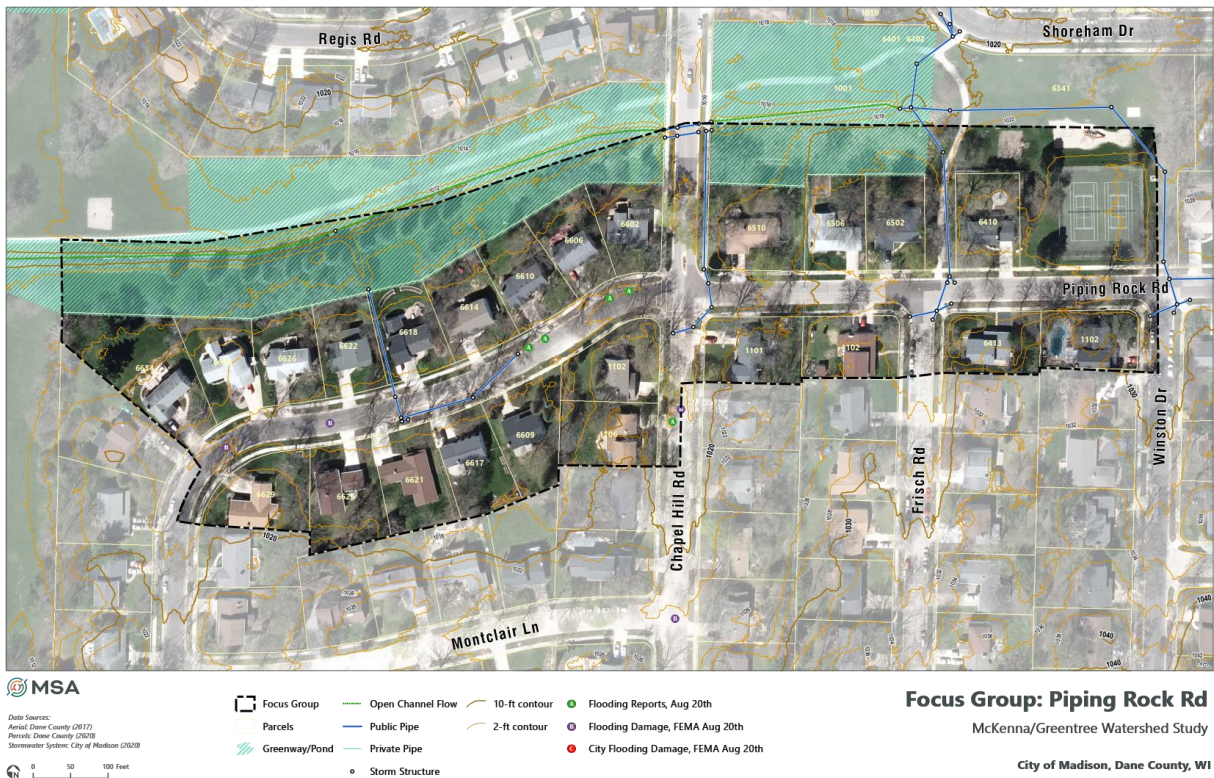


Piping Rock Rd, 7/29/2020

MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.

Public Attendees: 3

- Water filled the ROW of Piping Rock Road twice within 2020 (sag area)
- Properties on the north side of Piping Rock, adjacent to the greenway, experience basement backups. Some properties south of the road as well.
- Water routinely overtops Chapel Hill Road, between the two greenway segments
- Water along Frisch Rd flows north, bypassing the inlets.



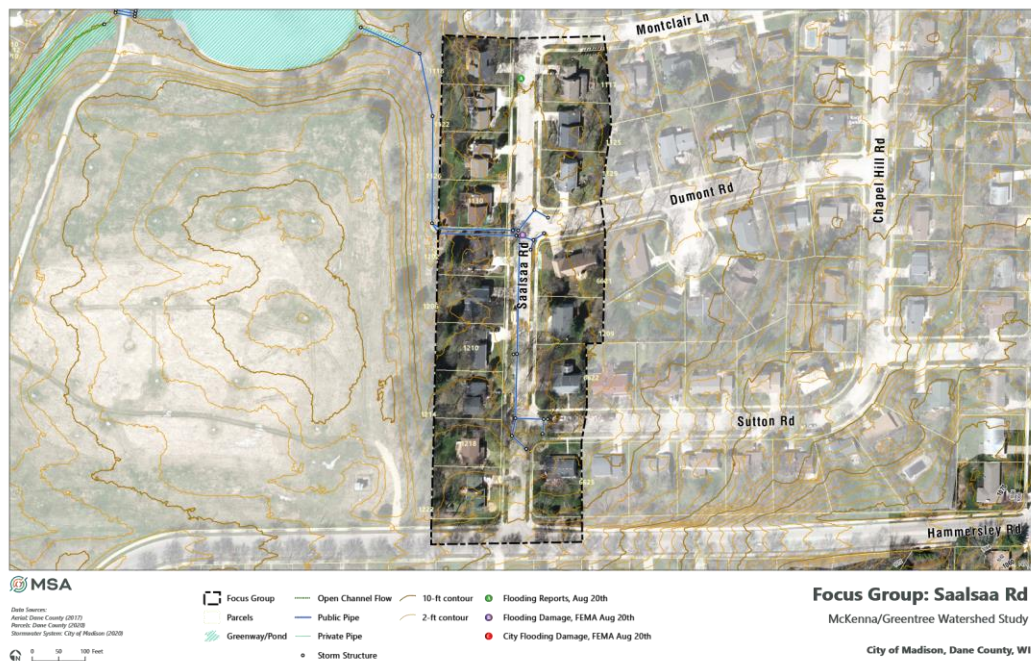
Saalsaa Rd, 7/29/2020

MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.

Public Attendees: 9

Photo taken during Focus Group meeting.

- Intersection of Saalsaa Rd and Dumont Rd floods during rain events
- Water flows Sutton road flows west, then north (bypass inlets?)
- Pipes leaving Saalsaa Rd, heading west to the greenway/pond were surcharged in the August 18th, 2020 storm.
- Flooding from the pond in the August 18th, 2020 event extended into residents back yards.



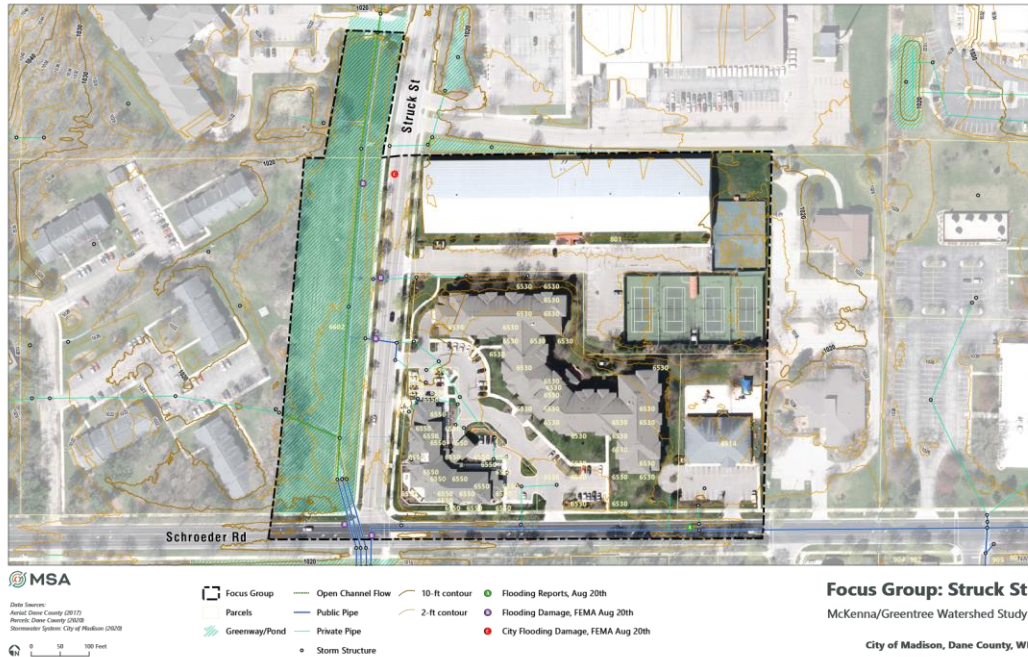
Struck St, 7/23/2020

MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.

Public Attendees: 2

Photo taken during Focus Group meeting.

- All of Struck Street flooded in June 2020
- Development just west of Struck Street had 1-3' backups in the August 18th, 2020 event. Water flowed from the west, through the development parking lot towards the greenway.



Appendix G: Peer Review of Greentree/McKenna Noncalibrated XPSWMM Model

To:	Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA	From:	Aaron Volkening Stantec
File:	Peer review of Greentree/ McKenna Noncalibrated XPSWMM model	Date:	July 7, 2020

Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

Stantec has performed a peer review of the Greentree / McKenna XPSWMM hydrologic / hydraulic computer model. This model was developed by the consultant team at MSA, to support the watershed study for the Greentree / McKenna study area.

The XPSWMM model and supporting information was downloaded from an ftp site provided by MSA on 6/17/2020.

The XPSWMM model name is "MGT_Existing_UNCALIBRATED_20200617.xp"

Supporting information that was transmitted included:

- The xptin file for the 2D modeling in xpswmm:
"dem2017_mgt_postexactsciences_resampled10ft.xptin"
- Georeferenced air photo that can be used as a background image in XPSWMM
- Subbasin GIS layer (Watershed_Boundary_MSA.shp)
- Various GIS layers of impervious areas and pervious surface types
- A geodatabase that includes the storm sewer pipe system used to develop the hydraulic model network, and a layer showing ponds and greenways reflected in the modeling

The model is in the noncalibrated phase, and in future modeling phases will be calibrated both to monitored runoff hydrographs and observed flooding conditions.

Our peer review was referenced to the Modeling Guidance developed by the City of Madison. The version of the Modeling Guidance used was the 6/3/2020 guidance for Round 1 and Round 2 consultants.

We have the following comments:

MSA Responses in RED.

Hydrology

1. The watershed was divided into over 240 subbasins. Stantec reviewed the overall watershed boundary in comparison to the area Digital Elevation Model (DEM). The watershed boundary appears to follow the appropriate surface water divides in the DEM. As MSA and the City have noted previously, there are several areas of known or potential inter-watershed flow connections to other watersheds. We also spot-checked numerous individual subbasin boundaries, and at every location we checked, the delineated subbasin boundary appeared correct based upon topographic mapping and the storm sewer / inlet configuration. The subbasin delineation appears to have been done with a

July 7, 2020

Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA

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Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

high level of accuracy and precision.

Noted.

2. Catchment imperviousness data appears reasonable; detailed GIS mapping of impervious areas was performed and included in the transmittal. As the Modeling Guidance states, each subbasin was divided into three subcatchments, representing the directly connected impervious area, the disconnected impervious area, and the pervious area. However, when we opened the xpswmm file, the flag for the disconnected impervious areas to be directed onto the pervious areas was not active. Thus, the model may be simulating both impervious subcatchments as being directly connected, and the flag for subcatchment redirection should be turned on.

Correction made.

3. The calculated values for catchment width and slope appear reasonable based upon spot checks of random catchments, though GIS data to support calculation of catchment width and slope was not included in the submittal. Based on independent checks of the subbasin boundaries and elevation data, catchment width appears to have been calculated by dividing the catchment area (in square feet) by the maximum overland flow path length. This overall catchment width was assigned to each of the three subcatchments representing impervious categories – not prorated. This follows the approach in the latest Modeling Guidance which states that for the Round 1 watersheds a better calibration fit for width was obtained by not prorating the widths.

Noted.

4. The Horton infiltration parameters used appear reasonable, with the exception of the decay rate. A value of 4 was entered – this is the value given in the Modeling Guidance in units of 1/hr, but in XPSWMM the decay rate is entered in units of 1/sec. The value of 4/hr converts to approximately 0.001 /sec.

Correction made.

5. The Runoff parameter for the percentage of the catchment with zero depression storage was set at 25% for all catchments, which is the XP-SWMM default value. The Modeling Guidance does not specify a value for this parameter. Stantec changed this value to zero for the Dunn's Marsh model, but 25% would also be a reasonable estimate, and we will consider also changing this parameter in the Dunn's Marsh model to 25%. This value affects runoff volume for small storms but is expected to have little influence on hydrologic results for larger events and design storms. We could discuss a consistent approach.

The City has since discussed this parameter internally and have determined that the XP SWMM default of 25% zero detention storage should be used. Therefore, we have left this as is.

1D Hydraulics

The 1D hydraulic model, consisting primarily of storm sewers and culverts, appears to be set up reasonably and in accordance with the City's modeling guidance. Naming conventions appear to be in accordance with City guidance.

1. The only significant deviation we observed from the Modeling Guidance is that at culverts, an Inlet Type (various types of headwalls, wingwalls, or projecting conditions) was not selected and activated in the Conduit Factors dialog box. Entrance and exit losses were used, but per the Modeling Guidance, an inlet type should also be selected for the culvert hydraulics simulation.

Correction made.

July 7, 2020

Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA

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Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

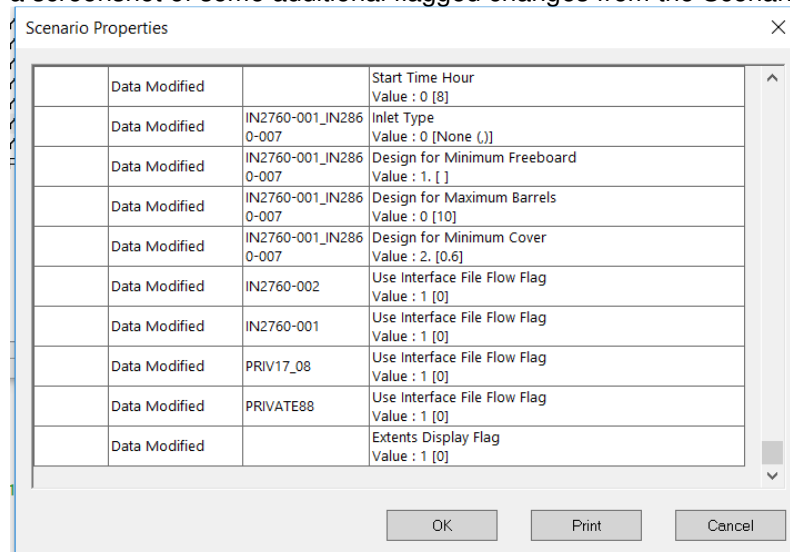
2. Like Stantec did for the Dunn's Marsh xpswmm model, the Greentree McKenna model typically assumes that invert elevations match when two circular pipes of different diameter meet at a manhole. This is based on the GIS data model, which appears to assign the invert of the downstream manhole to the incoming pipe. It is likely that in many instances, the crowns of the different-sized pipes match instead of the inverts. To individually check this on a pipe-by-pipe basis would require a review of each record drawing, which is why Stantec, like MSA, initially set up the models to have inverts match rather than crowns. However, we may wish to discuss whether a more realistic default assumption would be to assume pipe crown elevations match instead of invert elevations, or whether this is not significant.

Noted.

3. As discussed in project meetings, there is a cross-connection between this watershed and the "West Towne ponds" area to the north. MSA has modeled this cross connection by entering a User Inflow at node AS2858-029_01, that will bring additional flow into the Greentree McKenna watershed from the West Towne ponds area. It appears that the Scenario Manager is used to change the user-defined inflow according to storm event. It is our understanding that MSA is still awaiting detailed hydrograph data from the other consultant modeling the north area; therefore MSA has entered a dummy or approximate hydrograph for the time being. Therefore, we did not review this connection in detail, but understand that refinement is still ongoing in this area. One additional question on this area: is there any indication that inter-watershed flow may occur in the other direction – from Greentree McKenna to the north, or are there indications that inter-watershed flow can only occur in one direction.

The Spring Harbor XP SWMM model built by AE2S included the entire portion of the McKenna Greentree study area north of the Beltline. Their modeling results observed flows flowing south into the McKenna Greentree watershed during all simulated events.

4. We noted that Scenario Manager settings were sometimes used to change model settings, besides the rainfall design storm data and the user-defined inflow from West Towne. For example, following is a screenshot of some additional flagged changes from the Scenario Manager for the 100-year event.



	Data Modified		Start Time Hour Value : 0 [8]
	Data Modified	IN2760-001_IN286 0-007	Inlet Type Value : 0 [None (.)]
	Data Modified	IN2760-001_IN286 0-007	Design for Minimum Freeboard Value : 1. []
	Data Modified	IN2760-001_IN286 0-007	Design for Maximum Barrels Value : 0 [10]
	Data Modified	IN2760-001_IN286 0-007	Design for Minimum Cover Value : 2. [0.6]
	Data Modified	IN2760-002	Use Interface File Flow Flag Value : 1 [0]
	Data Modified	IN2760-001	Use Interface File Flow Flag Value : 1 [0]
	Data Modified	PRIV17_08	Use Interface File Flow Flag Value : 1 [0]
	Data Modified	PRIVATE88	Use Interface File Flow Flag Value : 1 [0]
	Data Modified		Extents Display Flag Value : 1 [0]

Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

We were unable to determine the specific reason for these Scenario Manager modifications, or whether they are in an area of the model that is active and have any impact on results, but consider reviewing any non-rainfall and non-flow modifications that Scenario Manager is triggering, to make sure they are intentional.

MSA has double checked all modifications within the Scenario Manager. We could not find any cases where modifications were made to specific scenarios that should not have been. It seems that records may be been created of modifications when variables were checked within a particular scenario, but not actually modified.

2D Hydraulics

1. The Grid Extents of the 2D domain appear reasonable, and appear to cover the necessary areas. A cell size of 10 feet was used.
Noted.
2. The 2D domain was mapped according to various land uses, so that different roughnesses can be assigned, per the Modeling Guidance. The mapping of various 2D surfaces was done at a high level of detail and follows the Modeling Guidance, with the possible exception about Buildings in the following comment.
Noted.
3. One possible deviation from the Modeling Guidance is that it appears that buildings were simulated in the 2D surface by assigning them a very high roughness value (3), rather than explicitly mapping them as excluded / inactive areas.
Correction made.
4. As discussed in our last monthly progress meeting, currently the main channel / greenway is being simulated in 2D. As MSA described, they are evaluating whether some of this channel should be simulated as 1D conduits, with a connection to the 2D domain. Either approach is a possible way to simulate the hydraulics of the channel / greenway system. If the channel / greenway continues to be simulated in 2D, consider adjusting the surface roughness to better represent resistance to channel flow as opposed to sheet flow.
Noted. MSA will continue with the current approach and determine if greater channel detail is needed once calibration has commenced.
5. Inlet capacity is represented by activating global Inflow Capture in 2D Hydraulics Job Control. The global equation used was $Q = 13.382 * \text{Depth}^{0.5}$. We did not observe any locations where the global equation was overridden at individual nodes. At our Peer Review meeting, we would like to discuss various approaches to inlet capacity simulation, and possible levels of detail. For example, if an R-3067 inlet grate is assumed, the open area is 2.0 feet. If the inlet is assumed to operate as an orifice with 50% clogging, the orifice equation $Q = C * A * (2g * \text{depth})^{0.5}$ simplifies to $Q = 4.8 * \text{Depth}^{0.5}$ for one inlet. Therefore, the global equation $13.4 * \text{Depth}^{0.5}$ approximates ponded flow around a cluster of three inlets at approximately the same elevation. This appears to be a reasonable approximation for many conditions and configurations, but we'd like to discuss possible approaches further.
To be discussed further.
6. The downstream end of the model is just southwest (downstream) of the intersection of Raymond Road and Marty Road, just upstream from a regional detention basin. The outfall consists of a 1D pipe/outfall node and a 2D head boundary. A fixed backwater elevation of 992.78 is assigned to the

Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

1D node. With the elevation of 1000 assigned to the 2D boundary which is below the ground elevation, the 2D boundary will function as a free outfall. This appears to be a reasonable representation of the downstream boundary condition; the modeling report should document the source of the downstream backwater elevation and whether consideration should be given to varying the pipe backwater elevation with storm event or whether model results in areas of importance are not sensitive to downstream tailwater.

For stormwater to enter the storm sewer that passes beneath Raymond Road, it must enter into one of two 30" pipes. The tailwater condition chosen for the system outlet reflects the invert of the lowest of these 30" pipes.

Without in-depth analysis of the downstream Raymond Road Pond system, we were unable to choose varying tailwater conditions for each rainfall event. As such, we have chosen one that allows smaller events to pass through, while observing overtopping of Raymond Road during large event simulations. Overtopping was observed during the August 2018 event, and therefore is a benchmark we are calibrating our model to.

7. Detention ponds are modeled in 2D. The storage volume is modeled in the 2D grid, with connecting storm sewers modeled as a 1D element, and any overflow modeled in the 2D grid. The detention pond modeling appears reasonable; one thing we noted is that most of the 1D outlets from ponds are pipe links – storm sewers or culverts. We did not see many ponds modeled with orifice, risers, weir plates or other multi-stage or low-flow outlets. Consider whether it is possible that some ponds have a low-flow or multi-stage outlet upstream of the pipe outlet that needs to be added as a 1D element. (one possible example is the small detention pond on the north side of Mid Town Road, west of Marty Road.

The Midtown Road Apartments stormwater plan has been rechecked to verify the lack of an outlet structure detail. Other detention ponds, which have design plans that do show the presence of a more complex outlet structure, have been modeled using multi-links to simulate them accurately. An example of this is the Southern Ridge Detention Basin, directly west of the one mentioned above.

8. We noted that in addition to the main surface outfall at the downstream end of the channel, there are several other 2D head boundaries at the edges of the 2D domain: one on East Valley Ridge Drive, one on Kottke Drive, and one on High Point Road at the intersection with Twinflower Drive. These appear to be locations where the street topography is low enough that cross-basin flow could occur, and appear to be a reasonable representation of these areas; we did not check whether flow actually occurs out of these head boundaries during some storm events, but this could introduce flow into other watersheds.

These are all locations where we observe flow out of our study area when the storm sewer system is exceeded.

9. As MSA noted on our June phone call, there may be some further edits needed to the DEM or XPTIN representation in the Exact Sciences area. We do not have the raw data for the Exact Sciences area and so cannot comment further on any further changes in the 2D surface needed here, but our understanding is that MSA has already identified any refinements needed in this area.

Correction made.

July 7, 2020

Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA
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Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

Spot Checks and Specific Areas / Issues

Stantec performed a spot check of several representative areas, such as the Hathaway Drive / Piping Rock Road storm sewer system. With these spot checks, we reviewed the GIS data for the area (such as storm sewer and structure mapping and data, DEM topography, and aerial photography) and compared it to model input. We reviewed Runoff data and parameters such as catchment boundaries and areas, node locations where catchment runoff enters the Hydraulics model, and catchment parameters such as imperviousness, widths and slopes. We also reviewed Hydraulics data – primarily pipe data such as storm sewer shapes, diameters and invert elevations. In the areas we spot checked, the model development process seemed clear and in accordance with the GIS data.

We did have a couple specific locations or issues to comment on, particularly in regards to hydraulics simulation.

1. For the upper Elver Park wet pond, an air photo appears to indicate some sort of control structure or outlet on the northwest shoreline, leading from the pond to the downstream channel. This structure does not appear to have been explicitly simulated in XPSWMM, though the 2D surface does represent some sort of surface opening here. Evaluate whether this structure may be a significant hydraulic control for the storm range of interest, and whether it is adequately defined by the 2D surface or if additional detail is needed.
Upon reviewing the plans for this pond, and the DEM, we are confident that the 2D surface is accurately modeling this outlet.
2. Near the southwest corner of Elver Park, just upstream from the southern Elver Park ponds, the air photo shows a trail that crosses the main channel on a bridge or boardwalk. The hydraulics of this area are represented by the 2D grid; we recommend considering whether backwater or other hydraulic effects of this trail crossing may warrant a 1D element or additional detail in the 2D simulation. (If specific water elevations in this portion of Elver Park are not an important model result, then additional detail may not be warranted).
The photo on the following page was taken of this bridge by an MSA surveyor. Also shown below is the DEM surface, which is representing the 2D surface within our model. Approximately 900 ft upstream of this bridge are two 3' x 5' box culverts that drain the Upper Elver Park pond. The cross sectional area of these culverts is 30 sq-ft.

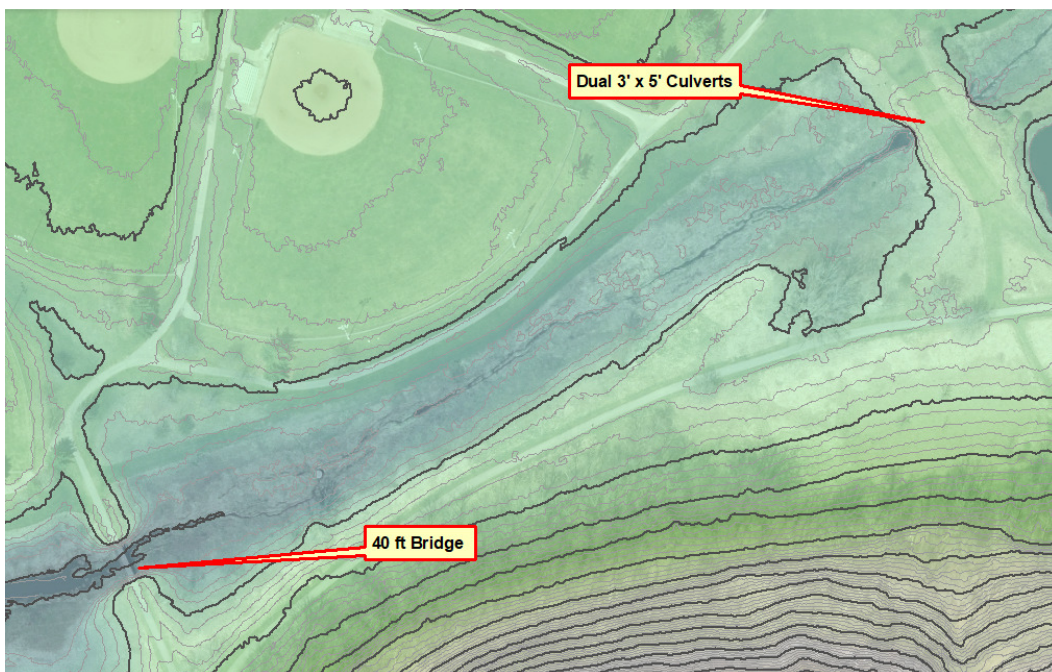
The bridge has a support in the center of the channel, which is the only impediment to flow. As the span of the bridge is approximately 40 ft, with only the one support, the capacity of this “flow element” will be significantly larger than that of the upstream culverts. For this reason, we feel that this structure will not have a significant effect on modeling results, and has therefore been excluded from the model.

July 7, 2020

Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA

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Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model



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Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

3. The model represents the outflow from the southern Elver Park pond as 2D overflow over the southern lip of the pond; there is not a control structure or one constructed location of concentrated outflow, though there is one specific low point in the ground surrounding the southern edge of the pond. This matches my understanding of the southern Elver Park pond, that there is not a defined control structure or outlet, but this should be confirmed if it has not yet been.
This too is our understanding of this pond, based on the provided plans.
4. The outlet path from the detention pond at the southeast corner of Woodman's is modeled in 2D, down to the intersection of Schroeder Rd and Struck Street. Below are model and GIS snapshots of this area. It is unclear from the DEM, but it appears that Woodman's pond outfall might flow through one or more additional detention areas downstream. Consider whether there are any additional 1D hydraulic controls along this flow path or whether the 2D grid adequately reflects the hydraulics of this route.

The two downstream detention areas have been checked and are offline from the Woodmans Pond outlet. Both of these detention areas are private BMPs within the Greentree Glen Senior Apartments property.

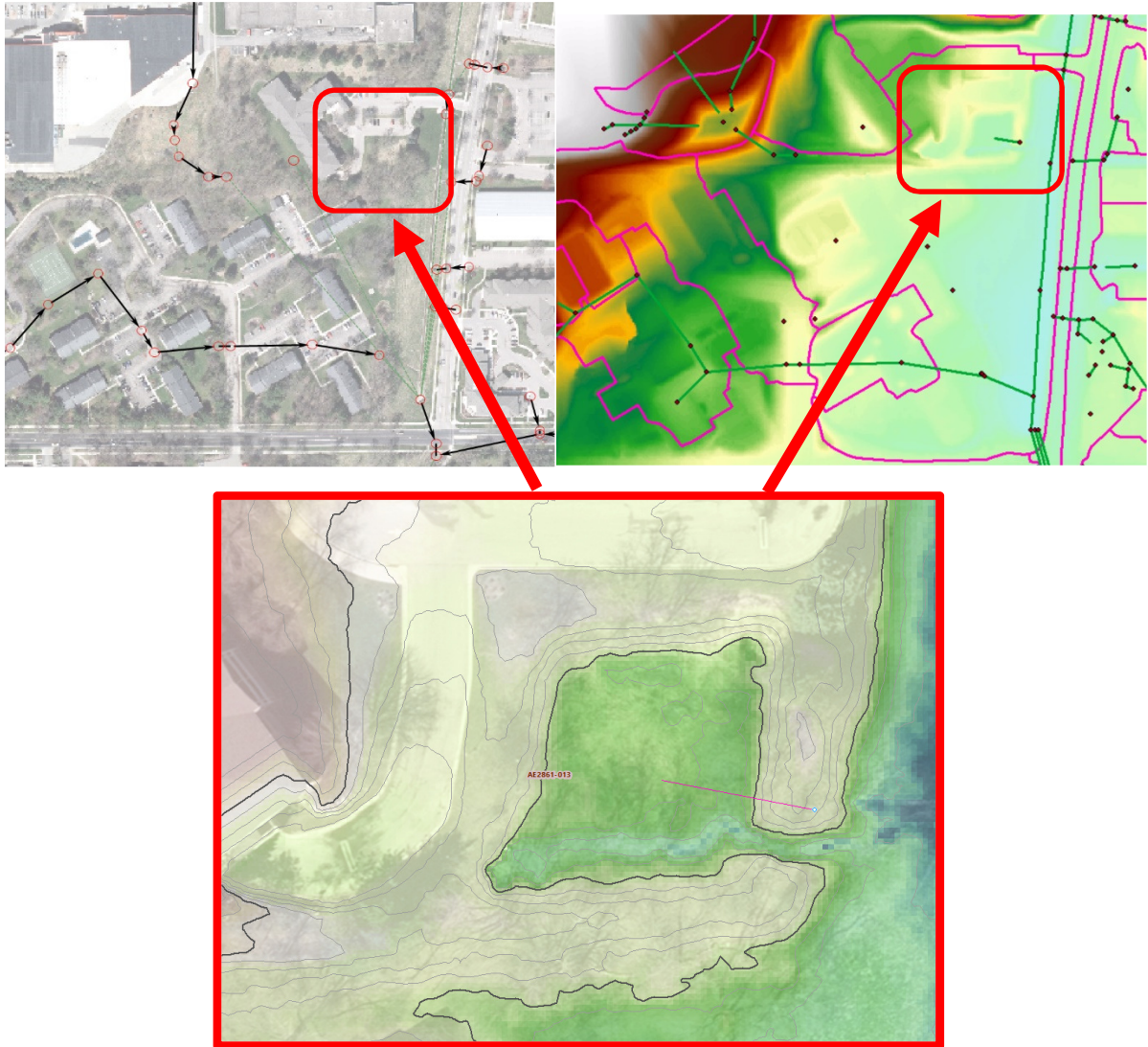
Highlighted below is a close-up of the downstream of these basins. The DEM shows that this basin is not contained by the surrounding embankment. There is approximately only 1ft of storage available here before runoff is discharged to the main channel. For this reason, this basin was ignored for detailed modeling.

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Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model



5. We understand that the City has an ongoing greenway / channel flood mitigation project in the Greentree area. It is our understanding that some of this project has been constructed, and some elements are under constructed but scheduled for near-future construction. We did not review what phase of construction this “existing conditions” model represents and are aware that MSA has discussed this at some length with the City; we recommend that the report clearly document how the ongoing construction project is represented in the model – whether the project is represented in its completed stage, or whether some interim stage of construction is represented.

Noted. The existing conditions model has been built to simulate the watershed with the McKenna Blvd culvert and improvements.

July 7, 2020

Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA

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Reference: Peer review of Greentree / McKenna Noncalibrated XPSWMM model

Summary

Overall, it appears that the Greentree McKenna XPSWMM model is a detailed model that very closely follows the City modeling guidance. Although we noted a few possible corrections to individual input parameters and specific locations to be checked, as described in this memo and on the attached spreadsheet, we found the overall model to be of high quality, and should be ready to be used both in the calibration process and the alternatives evaluation process.

Stantec Consulting Services Inc.



Aaron Volkening

Phone: 262-202-1361

Aaron.Volkening@stantec.com

Attachment: Spreadsheet

Appendix H: Existing Conditions Model Calibration Memo



To: Matt Allie - City of Madison
From: Alistair Hancox and Eric Thompson, P.E.
Subject: McKenna Greentree Watershed Study – Model Calibration
Date: September 8, 2020

This memorandum presents the results of MSA's efforts to calibrate the 1D/2D XP-SWMM model for the McKenna Green Tree watershed. Monitoring equipment was installed and operational from May until August of this year. Installed within this watershed was one rain gauge, two level loggers, and one flow meter. The location of these can be seen in the attached Remote Monitoring pdf.

Greentree Park – Rain Gauge

Four rainfall events were identified and used for calibrating the model. Just this one gauge was used to model the calibration events.

Table 1, Calibration Storms

Name	Start	Stop	Duration	Total Rainfall Depth	5-Day Antecedant Rainfall
May 17	03:30, 05/17/20	03:00, 05/18/20	23.5 hours	1.79"	0.7"
June 9 – 10	15:30, 06/09/20	02:00, 06/11/20	34.5 hours	2.99"	1.1"
June 24	17:00, 06/24/20	12:30, 06/25/20	19.5 hours	1.40"	1.1"
July 9	17:30, 07/09/20	05:00, 07/10/20	11.5 hours	2.34"	0.7"

For cross connections between the McKenna Greentree watershed and the Spring Harbor watershed, inflows from Spring Harbor were simulated using the above storm time and dates, while using rainfall data collected at the USGS gauge located at the West Towne Ponds.

Chapel Hill Road Channel – Level Logger

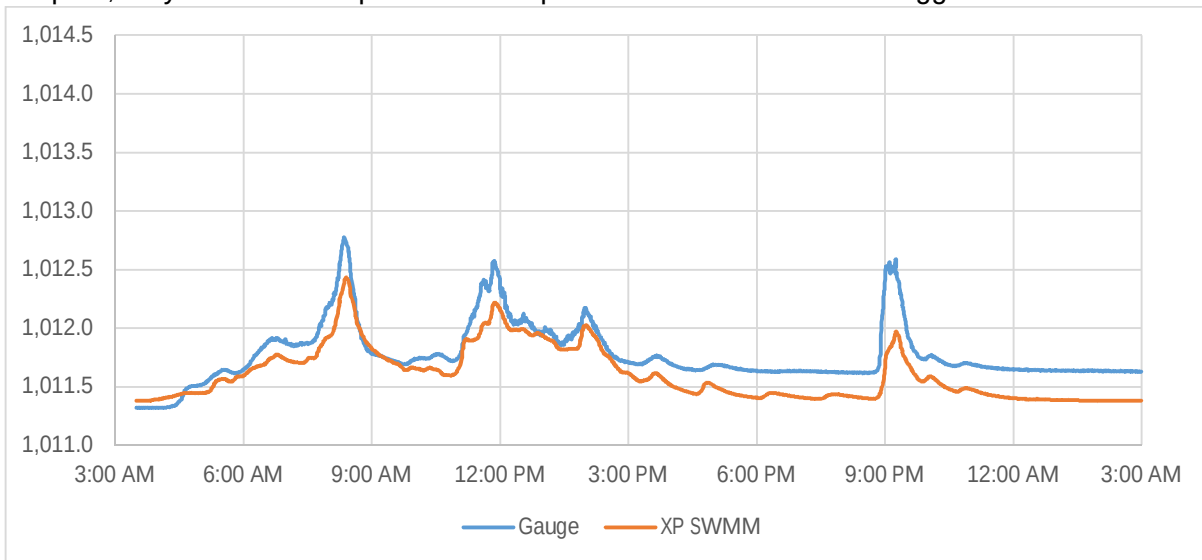
To calibrate the model to this level logger, the model was reduced down to include just that which drains to this location. The un-calibrated model results showed levels below that observed at the level logger for the above storms. Timing of each runoff peak lined up well with the metered and modeled levels. Initial observations of the data suggested that the modeled infiltration rates should be lowered.

This portion of the study area has only HSG 'B' and 'C' soils present. To achieve a good match between the metered and modeled levels, all infiltration rates were reduced to the following:

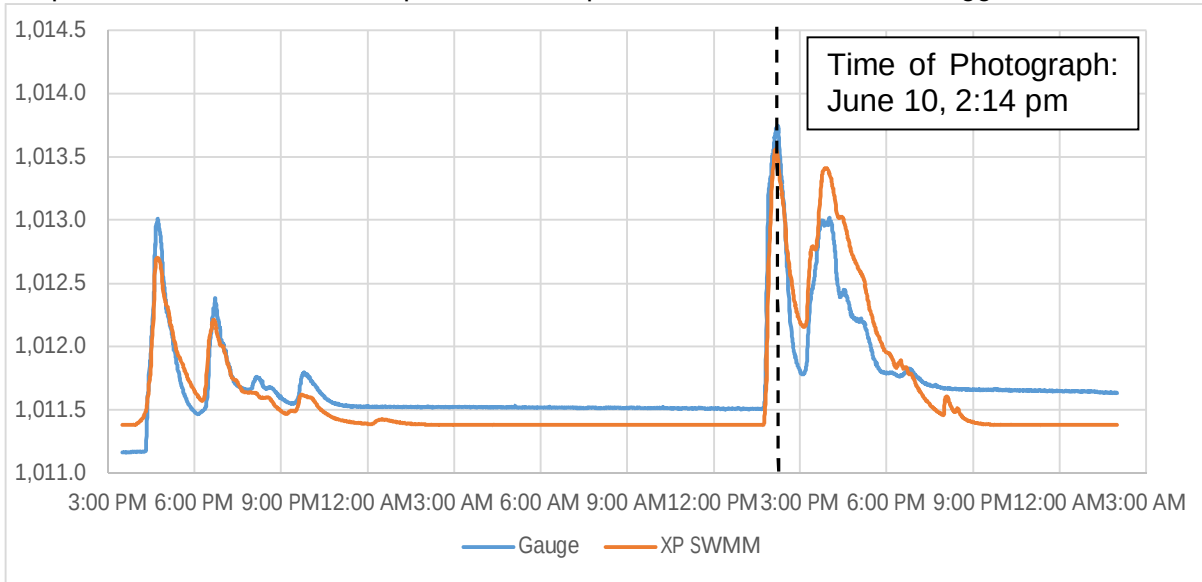
Table 2, Calibrated Infiltration Rates

HSG Group	Max Infil. Rate (in/hr)	Min Infil. Rate (in/hr)
A	N/A	N/A
B	0.15	0.15
C	0.05	0.05
D	0.025	0.025

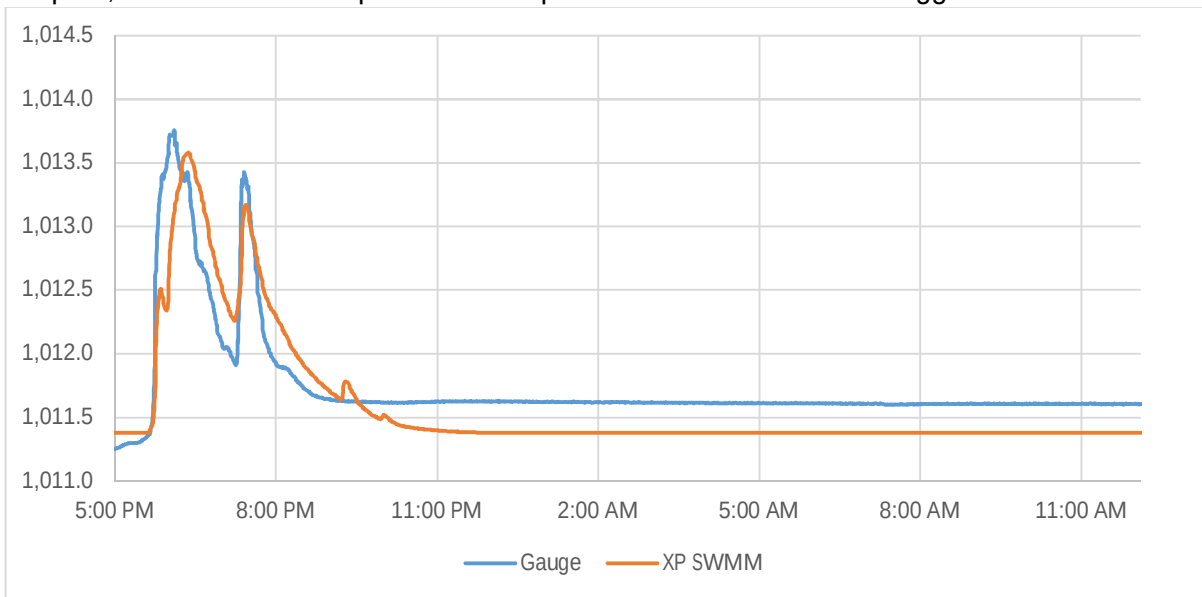
Graph 1, May 17 Event Comparison at Chapel Hill Road Channel Level Logger



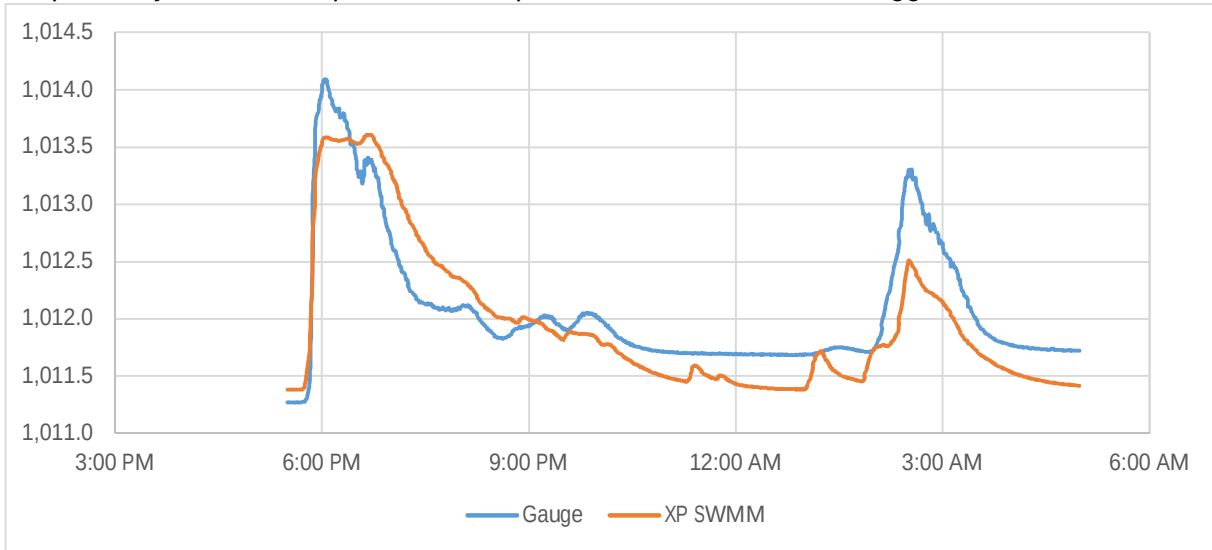
Graph 2, June 9 – 10 Event Comparison at Chapel Hill Road Channel Level Logger



Graph 3, June 24 Event Comparison at Chapel Hill Road Channel Level Logger

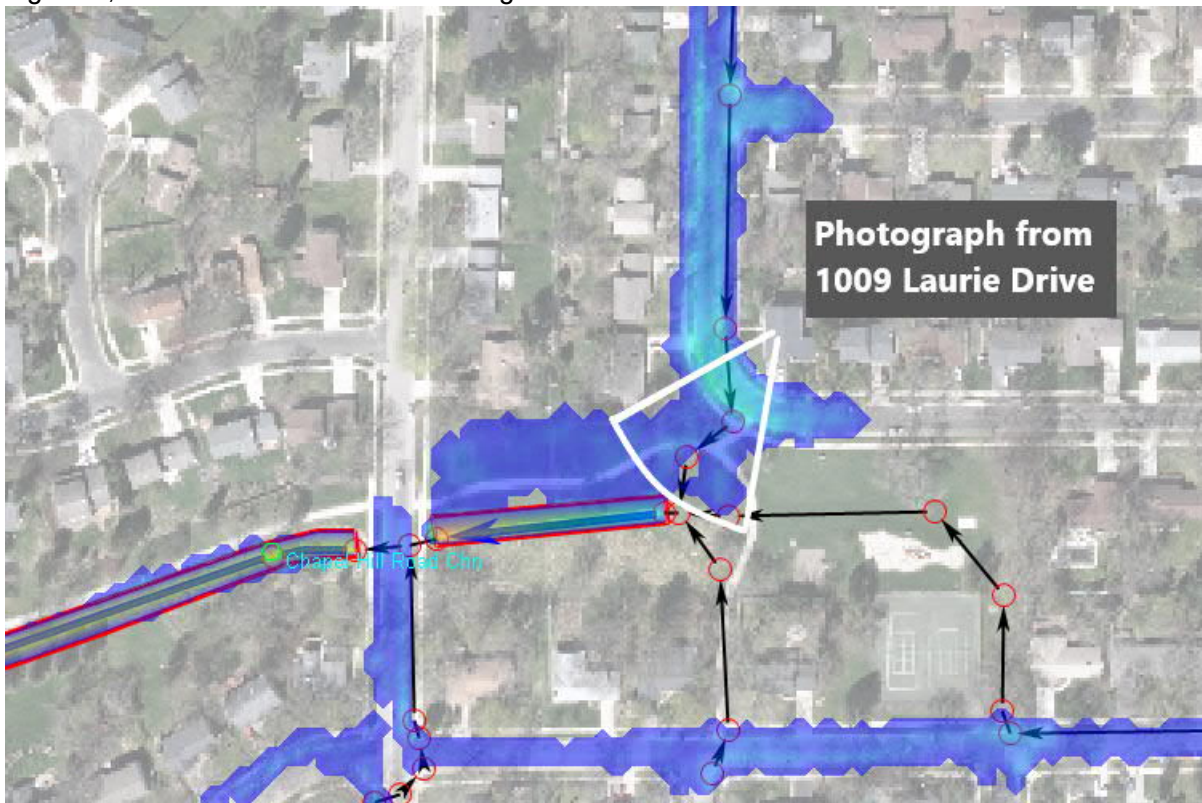


Graph 4, July 9 Event Comparison at Chapel Hill Road Channel Level Logger



In addition to the well-matched elevation charts, MSA was also able to obtain some resident photos graphs taken during one of the larger calibration events. For the event of June 9 – 10, the peak rainfall comes at approximately 2:15 pm on June 10. The model for this event gives us the following maximum flood extent achieved at this time interval:

Figure 1, June 9 – 10 Maximum Flooding Extent



The resident at 1009 Laurie Dr took the following photograph at exactly 2:14 pm, June 10th, capturing the peak of the rainfall event.

Figure 2, Residents Photograph at Peak of June 9 – 10 Rainfall Event

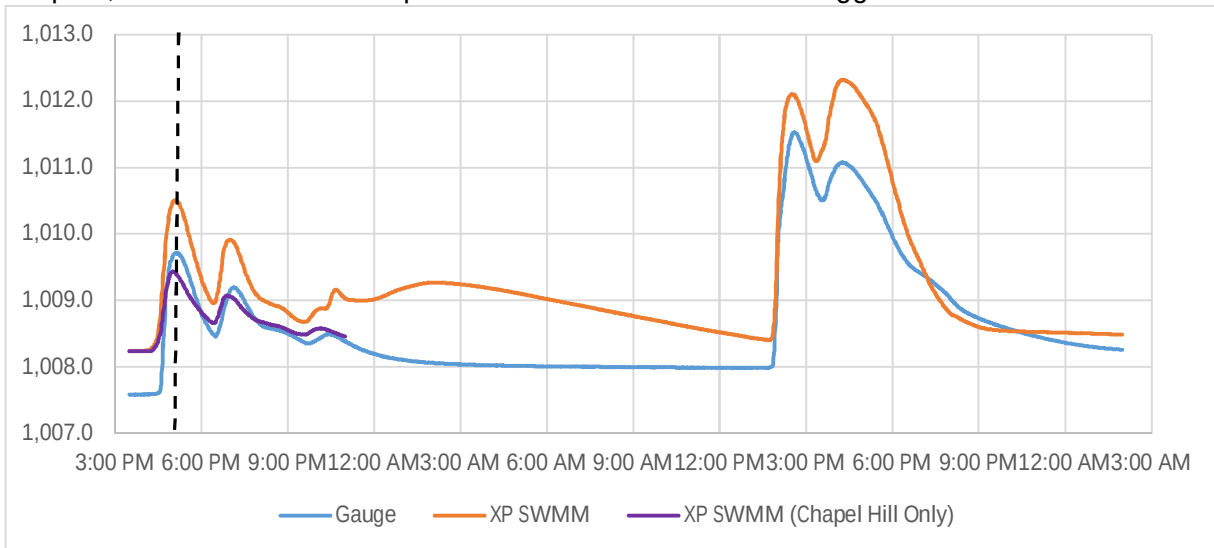


The image clearly shows runoff spilling from this street corner towards the Chapel Hill Road Channel. This evidence, combined with the close pairing of the level data for each calibration event gives us great confidence that the area draining to this level logger has been well calibrated by simply changing the aforementioned infiltration rates.

Green Tree Park Channel – Level Logger

Modeled vs. metered levels at the Green Tree Park level logger provided very different results from that of the Chapel Hill Road meter. All calibration events showed modeled elevations significantly above the metered levels. However, for the purposes of this discussion, the June 9 – 10 event will be focused on.

Graph 5, June 9 – 10 Event Comparison at Greentree Park Level Logger



The water elevations in this portion of the channel are governed by the capacity of the 4 x 42" CMP culverts 250 ft downstream of the level logger, until the culverts are overtopped at approximately 1011.6'. The peak elevation at approximately 5:20 pm on June 9 (hashed line) is a moment when both the modeled and metered data show the culverts flowing, but not overtopping. Therefore, MSA determined the flow in the channel from a steady state hydraulic calculation based on the upstream water elevation at the culverts.

Metered (Gauge) = 30 cfs

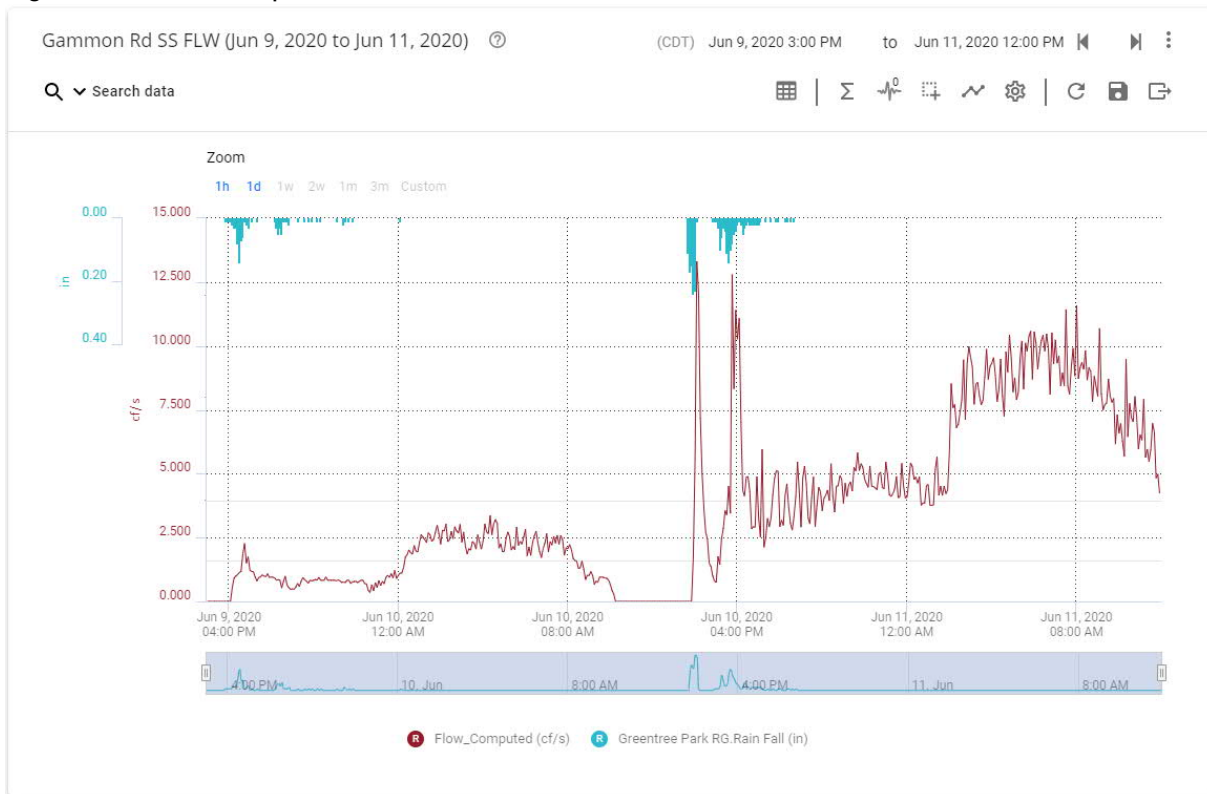
Modeled (XP SWMM) = 100 cfs

These flows are drastically different which has lead us to believe that there is an issue with the metered data. The additional data series added to the above graph is a model simulation where all hydrologic nodes upstream of the Greentree Park Channel level logger have been turned off, except for those within the already calibrated Chapel Hill Road portion of the study area. This simulation shows modeled elevations very close to the metered. To calibrate all other areas to this almost zero flow would be unrealistic. Given the confidence in the Chapel Hill Road Channel calibration, as described above, it was felt the data from this meter was not accurate and should be ignored.

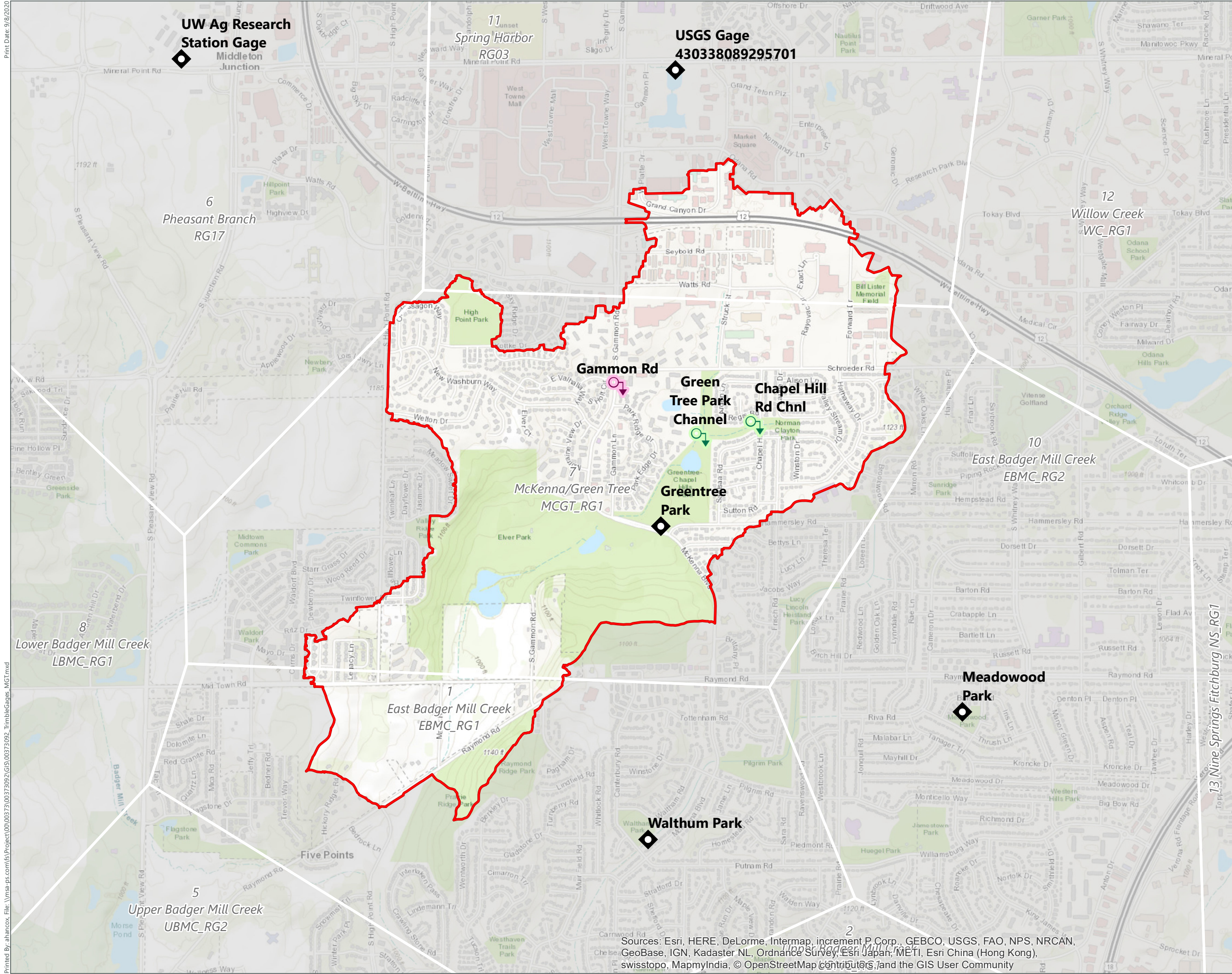
Gammon Road - Flow Meter

As discussed with the City on a number of occasions, the Gammon Rd flow meter was displaying results that did not align well with rainfall data. The following Trimble graph is taken from the June 9 – 10th rainfall events. Rainfall on June 9 and June 10 totaled 0.9 inches and 2.1 inches, respectively.

Figure 3, Trimble Output Gammon Rd Flowmeter – June 9 – 10



MSA saw two problems with the data this flow meter was producing. The first is that the peak flow observed did not appear to be proportional to the rainfall intensity of each event. The maximum rainfall intensity on June 9 does not correspond with a significant response at the flow meter. Compare that with the peaks on June 10, which are far greater in magnitude and uniformity. The second issue is that the tail of each event has a flow approximately equal in magnitude to that seen at the peak rainfall intensity. For these reasons, the data obtained from this flow meter was not used in this calibration process.



Remote Monitoring

McKenna Greentree

-  Rain Gage
-  Level Logger (Greenway)
-  Flow Meter (in pipe)
-  Level Logger (in pipe)
-  Thiessen Polygons

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Appendix I: Peer Review of Greentree/McKenna Calibrated XPSWMM Model

To:	Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA	From:	Aaron Volkening Stantec
File:	Peer review of Greentree/ McKenna Calibrated XPSWMM model	Date:	September 22, 2020

Reference: Peer review of Greentree / McKenna Calibrated XPSWMM model

Stantec has performed a peer review of the Greentree / McKenna calibrated XPSWMM hydrologic / hydraulic computer model. This model was developed by the consultant team at MSA, to support the watershed study for the Greentree / McKenna study area.

The XPSWMM model and supporting information was downloaded from an ftp site provided by MSA on 9/8/2020.

The XPSWMM model name is "MGT_Existing_CALIBRATION_20200904.xp". An updated xptin file and a calibration memo were also provided. **MSA comments in RED.**

We have the following comments:

1. As the calibration memo describes, two of the three level meters (Green Tree Park, Gammon Road) did not appear to provide reliable data for calibration. Therefore, calibration was based on data recorded by the Chapel Hill level logger. The documentation in the calibration memo regarding the issues with the data at Green Tree Park and Gammon Road appears reasonable. It appears that both MSA and City staff have spent time reviewing the Green Tree and Gammon Road data in detail; therefore we did not the review the data from these meters but could do so if requested.
Noted.
2. Portions of the main channel have been modeled as 1D conduits, connected to the 2D overbank simulation with a 1D/2D boundary. Most of the channel sections have a set maximum depth of 1.5 feet to 3.0 feet. We recommend checking whether this depth is exceeded in some storm events, and if this set depth artificially constrains the channels depths or capacities.
Checked.
3. To calibrate the XP-SWMM model to the Chapel Hill measurements, both maximum and minimum Horton infiltration rates were lowered. For hydrologic soil group B, maximum and minimum Horton infiltration rates were lowered to 0.15 inches per hour. For hydrologic soil group C, maximum and minimum infiltration rates were lowered to 0.05 inches per hour. Stantec made similar adjustments to the minimum infiltration rates for the Dunn's Marsh model: our final infiltration rate for B soils was 0.25 inches per hour and our final infiltration rate for C soils was 0.1 inches per hour.

The calibrated values for minimum infiltration rate seem reasonable, but seem low for a maximum infiltration rate, aside from specific storm events with wet antecedent moisture conditions. The calibrated model does closely match the metered hydrographs. Consider whether there are other parameters that could be adjusted in lieu of lowering the maximum infiltration rate to the same value. The calibration memo does not discuss whether other model parameters such as catchment width were considered for adjustment. How sensitive are model results to a reduction in minimum infiltration rates, but no or a lesser reduction in maximum infiltration rates?

Runoff volume and channel depth estimates within the model were both lower than that suggested by the level logger. Increasing runoff volume by decreasing infiltration appeared to be an appropriate way to combat this issue.

September 22, 2020

Caroline Burger, City of Madison Matt Allie, City of Madison Eric Thompson, MSA

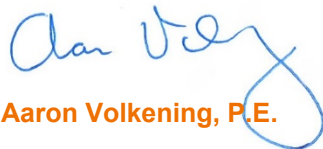
Page 2 of 2

Reference: Peer review of Greentree / McKenna Calibrated XPSWMM model

4. The graphs of measured vs. modeled water levels at the Chapel Hill meter site show close agreement and good visual model calibration. No quantification of calibration results was included in the memo, so it is recommended that discussion of model error be added to the existing conditions report (i.e. overall bias / error less than +/- 5% if possible, individual maximum errors less than 25% if possible).
Overall bias percentage table added to main body of Existing Conditions Report.
5. Inlet inflow capture is being simulated in 2D with a global equation. We assume this will be documented in the Existing Conditions report.
Modeling of inflow capacity has been explained in detail elsewhere in the Existing Conditions Report.
6. Only one rain gauge is being used for rainfall simulation. Some areas on the edges of the watershed could be assigned by Thiessen polygon mapping to two other nearby rain gauges. The difference between rain gauges may be insignificant, or perhaps the drainage areas covered by the other rain gauges are not large enough to significantly change downstream hydrographs, but consider discussing this in the Existing Conditions report.
The watershed draining to the Chapel Hill Rd level logger was all within the one raingauge Thiessen polygon.
7. Our review focused on overall modeling approach / global conditions, especially related to calibration. We did not review specifics of individual areas, as these were reviewed during the Noncalibrated modeling phase.
Noted.

Feel free to contact me with any questions / comments.

Stantec Consulting Services Inc.



Aaron Volkening, P.E.

Phone: 262-202-1361

Aaron.Volkening@stantec.com

Attachment: N/A

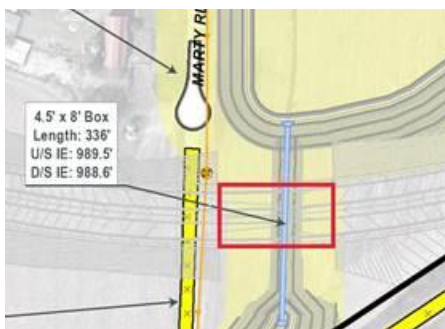
Appendix J: City Agency Comments on Proposed Solutions

Appendix J: City Agency Comments on Proposed Solutions

Comments were received in email format from the Greentree/McKenna Project Manager, Matt Allie. Quotes below are taken from the email conversations.

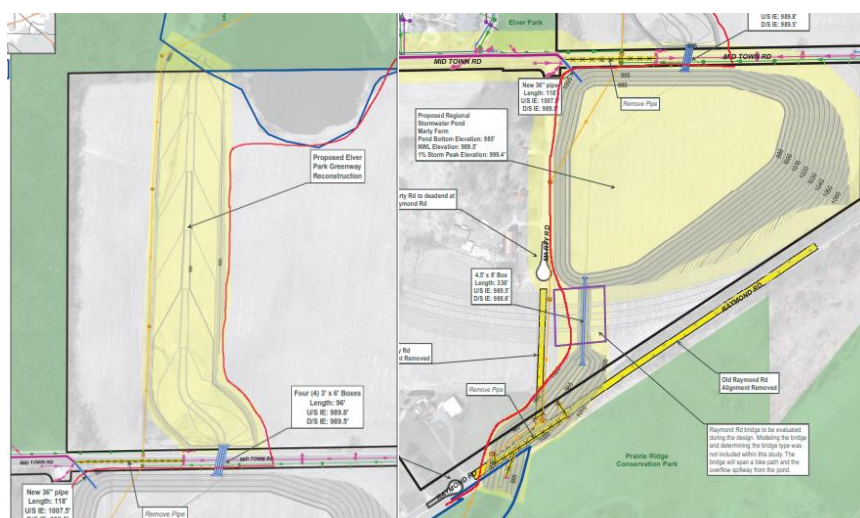
Initial Comments (received 3/22/2022)

- **Comment on Proposed Solution Figures 30 C:** “Please add a label showing the NWL elevation/pond bottom and modeled 1% storm peak elevation.”
- **Comment on Proposed Solution Figures 30 F, I:** “Can you add a note that both the Schroeder Rd. and McKenna Blvd. culverts were modeled using post-project (2020 and 2019, respectively) culvert sizes even though the existing pipe layer doesn’t reflect that? We’re caught in a weird spot timing-wise where it’s not a proposed solution, but also the culverts weren’t yet included in the existing pipe layer. I’m not opposed to these being shown with your proposed pipe symbology if a note is included that indicates they’ve already been installed.”
- **Comment on Proposed Solution Figures 30 I:** “On the east side of the figure can you show the 34”x53” and 30” replacement pipes as new pipes under the terrace/behind sidewalk on the south side of the road instead? Rob indicated that this alternative is very unlikely to be built in the foreseeable future with the pipe location as shown. Running along the south side of the road would certainly require coordination with Parks and utilities, but otherwise it’s more feasible. It isn’t my intention to cause updated model runs with this comment, just to show it different graphically. If there’s a reason you think this would change model results, please touch base with me about that first.”
- **Comment on Proposed Solution Figures 30 K:** “Please add a label showing the NWL elevation and modeled 1% storm peak elevation. In addition, the pond bottom elevation or 5’ contour labels would be useful. At the break in the Raymond Rd. proposed alignment contours, could you add a shape and label that indicates a bridge should be evaluated here during design? You can note in the report discussion that the bridge was not included in the modeling and bridge type was not evaluated as part of the study. Please include that a bridge would be intended to span a bike path and overflow spillway from the pond.”



Parks and Planning Comments (received 4/7/2022)

- Comment on Proposed Solution Figures 30 G, H, J:** “Please add a note indicating the channel treatments, as modeled (grass or lined/material & wet or dry). I realize further evaluation will be needed during design, but it’s good to have as a starting point.)”
- Comment on Proposed Solution Figures 30 J, K:** “Please show a rough alignment for a bike path, similar to what I sketched in red in the attachment. If you’d like, you can note (in the report or on map) that MSA did not evaluate path location as part of this study, but that design of these alternatives needs to accommodate a path on a similar alignment that will be finalized at a later date. This comment came up at multiple internal meetings.”



- Comment on Proposed Solution Figures 30 K:** “Please let me know the Marty Pond spillway/overflow channel elevation. Was this included in the model? Based on the contours in the drawing, it appears that a connection between the pond and new channel south of proposed Raymond Rd. has a bottom elevation of ~994. Given the peak pond elevation for the 1% storm, I’m realizing that those grading contours might be left from an earlier iteration. If it’s not easy to clean up those contours, I don’t have a problem with them being left in the display, but it would be worth noting the pond overflow elevation in the report at the very least.”

Appendix K: Detailed Cost Estimates Stand-Alone Proposed Solutions

Struck St, Seybold Rd and Watts Rd Improvements*Sub Area: Grand Canyon Drive Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
10911	MOBILIZATION	1	LUMP SUM	50,000.00	\$ 50,000	10% of other bid items.
20312	REMOVE CATCH BASIN	2	EACH	900.00	\$ 1,800	
20313	REMOVE INLET	4	EACH	630.00	\$ 2,520	
20314	REMOVE PIPE	287	L.F.	25.00	\$ 7,175	
20321	REMOVE CONCRETE CURB & GUTTER	120	L.F.	8.00	\$ 960	
20323	REMOVE CONCRETE SIDEWALK & DRIVE	100	S.F.	5.00	\$ 500	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	175	T.F.	5.00	\$ 875	
21092	TERRACE RESTORATION	40	S.Y.	5.00	\$ 200	
30201	TYPE "A" CONCRETE CURB & GUTTER	120	L.F.	35.00	\$ 4,200	
30301	5 INCH CONCRETE SIDEWALK	100	S.F.	7.32	\$ 732	
50211	SELECT BACKFILL FOR STORM SEWER	210	T.F.	15.00	\$ 3,150	
50226	UTILITY TRENCH TYPE III	450	S.Y.	95.00	\$ 42,750	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	60	L.F.	160.00	\$ 9,600	
50413	60 INCH TYPE I RCP STORM SEWER PIPE	227	L.F.	300.00	\$ 68,100	
50725	5' X 5' STORM SAS	2	EACH	7,000.00	\$ 14,000	
50761	SADDLE INLET TYPE 1	1	EACH	3,600.00	\$ 3,600	
50792	STORM SEWER TAP	6	EACH	1,500.00	\$ 9,000	
50793	PRIVATE STORM SEWER RECONNECT, TYPE 1	1	EACH	2,110.00	\$ 2,110	
50794	PRIVATE STORM SEWER RECONNECT, TYPE 11	1	EACH	3,755.00	\$ 3,755	
50801	UTILITY LINE OPENING (ULO)	3	EACH	900.00	\$ 2,700	
70101	FURNISH AND INSTALL STYROFOAM	32	S.F.	2.00	\$ 64	
	EROSION CONTROL	1	LUMP SUM	2,500.00	\$ 2,500	
	JUNCTION STRUCTURE	2	EACH	20,000.00	\$ 40,000	
	TREE REMOVAL	2	EACH	500.00	\$ 1,000	
				Subtotal	\$ 281,291	
				Contingency 25%	\$ 70,323	
				Design 10%	\$ 28,129	
				Total	\$ 379,743	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 379,743	

Struck St, Seybold Rd and Watts Rd Improvements*Sub Area: Seybold Road Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	7,500.00	\$ 7,500	
10911	MOBILIZATION	1	LUMP SUM	26,500.00	\$ 26,500	10% of other bid items.
20313	REMOVE INLET	3	EACH	630.00	\$ 1,890	
20314	REMOVE PIPE	518	L.F.	25.00	\$ 12,950	
20321	REMOVE CONCRETE CURB & GUTTER	60	L.F.	8.00	\$ 480	
20323	REMOVE CONCRETE SIDEWALK AND DRIVE	17	S.Y.	5.00	\$ 85	
21092	TERRACE RESTORATION	725	S.Y.	5.00	\$ 3,625	
30201	TYPE "A" CONCRETE CURB & GUTTER	40	L.F.	8.00	\$ 320	
30301	5 INCH CONCRETE SIDEWALK	48	S.F.	7.32	\$ 351	
50211	SELECT BACKFILL FOR STORM SEWER	255	T.F.	15.00	\$ 3,825	
50226	UTILITY TRENCH TYPE III	465	S.Y.	95.00	\$ 44,175	
50403	18 INCH TYPE I RCP STORM SEWER PIPE	374	L.F.	115.00	\$ 43,010	
50405	24 INCH TYPE I RCP STORM SEWER PIPE	98	L.F.	125.00	\$ 12,250	
50410	42 INCH TYPE I RCP STORM SEWER PIPE	430	L.F.	185.00	\$ 79,550	
50724	4' X 4' STORM SAS	1	EACH	5,500.00	\$ 5,500	
50726	6' X 6' STORM SAS	2	EACH	9,500.00	\$ 19,000	
50792	STORM SEWER TAP	4	EACH	1,500.00	\$ 6,000	
50801	UTILITY LINE OPENING (ULO)	4	EACH	900.00	\$ 3,600	
	EROSION CONTROL	1	LUMP SUM	2,500.00	\$ 2,500	
DID NOT INCLUDE ROADWAY PAVEMENT, STORM IN TERRACE- CONCERN OF PAVEMENT DAMAGE FROM CONSTRUCTION ACTIVITIES				Subtotal	\$ 273,111	
				Contingency 25%	\$ 68,278	
				Design 10%	\$ 27,311	
				Total	\$ 368,700	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 368,700	

Struck St, Seybold Rd and Watts Rd Improvements*Sub Area: Watts Road Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
10911	MOBILIZATION	1	LUMP SUM	38,000.00	\$ 38,000	10% of other bid items.
20312	REMOVE CATCH BASIN	1	EACH	900.00	\$ 900	
20313	REMOVE INLET	3	EACH	630.00	\$ 1,890	
20314	REMOVE PIPE	775	L.F.	25.00	\$ 19,375	
20321	REMOVE CONCRETE CURB & GUTTER	720	L.F.	8.00	\$ 5,760	
20323	REMOVE CONCRETE SIDEWALK AND DRIVE	150	S.Y.	5.00	\$ 750	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	90	T.F.	5.00	\$ 450	
21092	TERRACE RESTORATION	600	S.Y.	5.00	\$ 3,000	
30201	TYPE "A" CONCRETE CURB & GUTTER	720	L.F.	25.00	\$ 18,000	
30301	5 INCH CONCRETE SIDEWALK	100	S.F.	7.32	\$ 732	
30302	7 INCH CONCRETE SIDEWALK & DRIVE	1,250	S.F.	12.00	\$ 15,000	
50211	SELECT BACKFILL FOR STORM SEWER	740	T.F.	15.00	\$ 11,100	
50226	UTILITY TRENCH TYPE III	900	S.Y.	95.00	\$ 85,500	
50405	24 INCH TYPE I RCP STORM SEWER PIPE	410	L.F.	125.00	\$ 51,250	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	286	L.F.	160.00	\$ 45,760	
50409	36 INCH TYPE I RCP STORM SEWER PIPE	134	L.F.	175.00	\$ 23,450	
50468	36 INCH RCP AE	1	EACH	2,000.00	\$ 2,000	
50608	36 INCH RCP AE GATE	1	EACH	1,500.00	\$ 1,500	
50724	4' X 4' STORM SAS	2	EACH	5,500.00	\$ 11,000	
50725	5' X 5' STORM SAS	4	EACH	7,000.00	\$ 28,000	
50792	STORM SEWER TAP	4	EACH	1,500.00	\$ 6,000	
	EROSION CONTROL	1	LUMP SUM	5,000.00	\$ 5,000	
				Subtotal	\$ 389,417	
				Contingency 25%	\$ 97,354	
				Design 10%	\$ 38,942	
				Total	\$ 525,713	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 525,713	

Struck St, Seybold Rd and Watts Rd Improvements*Sub Area: Struck Street & Private Drive Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
10911	MOBILIZATION	1	LUMP SUM	25,500.00	\$ 25,500	10% of other bid items.
20313	REMOVE INLET	2	EACH	630.00	\$ 1,260	
20314	REMOVE PIPE	225	L.F.	25.00	\$ 5,625	
20321	REMOVE CONCRETE CURB & GUTTER	120	L.F.	8.00	\$ 960	
20323	REMOVE CONCRETE SIDEWALK AND DRIVE	36	S.Y.	5.00	\$ 180	
21092	TERRACE RESTORATION	250	S.Y.	5.00	\$ 1,250	
30201	TYPE "A" CONCRETE CURB & GUTTER	120	L.F.	35.00	\$ 4,200	
30301	5 INCH CONCRETE SIDEWALK	300	S.F.	7.32	\$ 2,196	
50211	SELECT BACKFILL FOR STORM SEWER	60	T.F.	15.00	\$ 900	
50226	UTILITY TRENCH TYPE III	110	S.Y.	95.00	\$ 10,450	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	128	L.F.	160.00	\$ 20,480	
50407	30 INCH RCP AE	1	EACH	1,700.00	\$ 1,700	
50607	30 INCH RCP AE GATE	1	EACH	1,000.00	\$ 1,000	
50724	4' X 4' STORM SAS	2	EACH	5,500.00	\$ 11,000	
50793	PRIVATE STORM SEWER RECONNECT, TYPE 1	1	EACH	2,110.00	\$ 2,110	
	EROSION CONTROL	1	LUMP SUM	2,500.00	\$ 2,500	
	4' X 6' BOX CULVERT	94	L.F.	800.00	\$ 75,200	
	4' X 6' BOX CULVERT WINGWALLS	2	EACH	28,000.00	\$ 56,000	
	CHANNEL DEMOLITION	80	L.F.	39.00	\$ 3,120	
	CONCRETE CHANNEL	320	S.F.	25.00	\$ 8,000	
	RE-ESTABLISH LANDSCAPE & FENCING	1	L.S.	20,000.00	\$ 20,000	
	TEMPORARY ACCESS ROAD	1	L.S.	30,000.00	\$ 30,000	
				Subtotal	\$ 293,631	
				Contingency 25%	\$ 73,408	
				Design 10%	\$ 29,363	
				Total	\$ 396,402	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 396,402	

Forward Dr Improvements*Sub Area: NA***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
10911	MOBILIZATION	1	LUMP SUM	34,000.00	\$ 34,000	10% of other bid items.
20312	REMOVE CATCH BASIN	5	EACH	900.00	\$ 4,500	
20314	REMOVE PIPE	666	L.F.	25.00	\$ 16,650	
20321	REMOVE CONCRETE CURB & GUTTER	70	L.F.	8.00	\$ 560	
20323	REMOVE CONCRETE SIDEWALK AND DRIVE	35	S.Y.	5.00	\$ 175	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	60	T.F.	5.00	\$ 300	
21092	TERRACE RESTORATION	60	S.Y.	5.00	\$ 300	
30201	TYPE "A" CONCRETE CURB & GUTTER	70	L.F.	35.00	\$ 2,450	
30301	5 INCH CONCRETE SIDEWALK	250	S.F.	7.32	\$ 1,830	
50211	SELECT BACKFILL FOR STORM SEWER	525	T.F.	15.00	\$ 7,875	
50226	UTILITY TRENCH TYPE III	850	S.Y.	95.00	\$ 80,750	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	238	L.F.	160.00	\$ 38,080	
50409	36 INCH TYPE I RCP STORM SEWER PIPE	38	L.F.	175.00	\$ 6,650	
50410	42 INCH TYPE I RCP STORM SEWER PIPE	390	L.F.	185.00	\$ 72,150	
50469	42 INCH RCP AE	1	EACH	2,300.00	\$ 2,300	
50609	42 INCH RCP AE GATE	1	EACH	1,750.00	\$ 1,750	
50725	5' X 5' STORM SAS	1	EACH	7,000.00	\$ 7,000	
50726	6' X 6' STORM SAS	5	EACH	8,000.00	\$ 40,000	
50763	TERRACE INLET	1	EACH	7,000.00	\$ 7,000	
50792	STORM SEWER TAP	5	EACH	1,500.00	\$ 7,500	
	EROSION CONTROL	1	LUMP SUM	7,500.00	\$ 7,500	
				Subtotal	\$ 354,320	
				Contingency 25%	\$ 88,580	
				Design 10%	\$ 35,432	
				Total	\$ 478,332	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 478,332	

High Point Estates Pond Reconstruction

Sub Area: NA

Conceptual Cost Estimate

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	2,500.00	\$ 2,500	
10911	MOBILIZATION	1	LUMP SUM	77,000.00	\$ 77,000	10% of other bid items.
20101	EXCAVATION CUT	21,300	C.Y.	25.00	\$ 532,500	
20221	TOPSOIL	10,000	S.Y.	5.00	\$ 50,000	Salvage & Respread
20705	DETENTION BASIN SEEDING	12,000	S.Y.	3.00	\$ 36,000	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	400	T.F.	5.00	\$ 2,000	
21073	EROSION MATTING CLASS 11, TYPE C - ORGANIC	10,000	S.Y.	6.25	\$ 62,500	
50401	12 INCH TYPE I RCP STORM SEWER PIPE	496	L.F.	100.00	\$ 49,600	
50723	3' X 3' STORM SAS	1	EACH	4,300.00	\$ 4,300	
50792	STORM SEWER TAP	1	EACH	1,500.00	\$ 1,500	
	EROSION CONTROL	1	LUMP SUM	7,500.00	\$ 7,500	
				Subtotal	\$ 825,400	
				Contingency 25%	\$ 206,350	
				Design 10%	\$ 82,540	
				Total	\$ 1,114,290	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 1,114,290	

W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements

Sub Area: New Washburn Way Storm Sewer Improvement

Conceptual Cost Estimate-

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	2,500.00	\$ 2,500	
10911	MOBILIZATION	1	LUMP SUM	13,000.00	\$ 13,000	10% of other bid items.
20312	REMOVE CATCH BASIN	4	EACH	900.00	\$ 3,600	
20314	REMOVE PIPE	279	L.F.	25.00	\$ 6,975	
20321	REMOVE CONCRETE CURB & GUTTER	20	L.F.	8.00	\$ 160	
20323	REMOVE CONCRETE SIDEWALK AND DRIVE	100	S.Y.	5.00	\$ 500	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	75	T.F.	5.00	\$ 375	
21092	TERRACE RESTORATION	200	S.Y.	5.00	\$ 1,000	
30201	TYPE "A" CONCRETE CURB & GUTTER	20	L.F.	35.00	\$ 700	
30301	5 INCH CONCRETE SIDEWALK	925	S.F.	7.32	\$ 6,771	
50211	SELECT BACKFILL FOR STORM SEWER	290	T.F.	15.00	\$ 4,350	
50226	UTILITY TRENCH TYPE III	160	S.Y.	95.00	\$ 15,200	
50401	12 INCH TYPE I RCP STORM SEWER PIPE	60	L.F.	100.00	\$ 6,000	
50405	24 INCH TYPE I RCP STORM SEWER PIPE	60	L.F.	125.00	\$ 7,500	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	219	L.F.	160.00	\$ 35,040	
50725	5' X 5' STORM SAS	3	EACH	7,000.00	\$ 21,000	
50741	TYPE "H" INLET	2	EACH	2,900.00	\$ 5,800	
50792	STORM SEWER TAP	6	EACH	1,500.00	\$ 9,000	
	EROSION CONTROL	1	LUMP SUM	5,000.00	\$ 5,000	
	TREE REMOVAL	3	EACH	1,000.00	\$ 3,000	
Subtotal					\$ 147,471	
Contingency 25%					\$ 36,868	
Design 10%					\$ 14,747	
Total					\$ 199,086	
Land Acquisition					\$ -	
Wetland Mitigation					\$ -	
Total Total					\$ 199,086	

W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements*Sub Area: Valhalla Way Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
10911	MOBILIZATION	1	LUMP SUM	96,000.00	\$ 96,000	10% of other bid items.
20312	REMOVE CATCH BASIN	4	EACH	900.00	\$ 3,600	
20313	REMOVE INLET	12	EACH	630.00	\$ 7,560	
20314	REMOVE PIPE	1,790	L.F.	25.00	\$ 44,750	
20321	REMOVE CONCRETE CURB & GUTTER	1,790	L.F.	8.00	\$ 14,320	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	65	T.F.	5.00	\$ 325	
21092	TERRACE RESTORATION	1,000	S.Y.	5.00	\$ 5,000	
30201	TYPE "A" CONCRETE CURB & GUTTER	1,790	L.F.	20.00	\$ 35,800	
50211	SELECT BACKFILL FOR STORM SEWER	1,790	T.F.	15.00	\$ 26,850	
50226	UTILITY TRENCH TYPE III	2,000	S.Y.	95.00	\$ 190,000	INCLUDED 1/2 OF ROADWAY - 10 FT WIDE*TRENCH
50409	36 INCH TYPE I RCP STORM SEWER PIPE	96	L.F.	175.00	\$ 16,800	
50410	42 INCH TYPE I RCP STORM SEWER PIPE	1,211	L.F.	185.00	\$ 224,035	
50411	48 INCH TYPE I RCP STORM SEWER PIPE	211	L.F.	200.00	\$ 42,200	
50412	54 INCH TYPE I RCP STORM SEWER PIPE	272	L.F.	250.00	\$ 68,000	
50725	5' X 5' STORM SAS	2	EACH	7,000.00	\$ 14,000	
50726	6' X 6' STORM SAS	9	EACH	8,000.00	\$ 72,000	
50761	SADDLED INLET TYPE 1	12	EACH	3,600.00	\$ 43,200	
50792	STORM SEWER TAP	11	EACH	1,500.00	\$ 16,500	
	EROSION CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
	7' X 7' STORM SAS	2	EACH	11,000.00	\$ 22,000	
	TREE TRIMMING	1	LUMP SUM	8,000.00	\$ 8,000	
				Subtotal	\$ 975,940	
				Contingency 25%	\$ 243,985	
				Design 10%	\$ 97,594	
				Total	\$ 1,317,519	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 1,317,519	

W and E Valhalla Way, E Valley Ridge Circle, and N Holt Circle Improvements*Sub Area: Valley Ridge Dr Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
10911	MOBILIZATION	1	LUMP SUM	24,000.00	\$ 24,000	10% of other bid items.
20312	REMOVE CATCH BASIN	1	EACH	900.00	\$ 900	
20313	REMOVE INLET	5	EACH	630.00	\$ 3,150	
20314	REMOVE PIPE	586	L.F.	25.00	\$ 14,650	
20321	REMOVE CONCRETE CURB & GUTTER	100	L.F.	8.00	\$ 800	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	200	T.F.	5.00	\$ 1,000	
21092	TERRACE RESTORATION	100	S.Y.	5.00	\$ 500	
30201	TYPE "A" CONCRETE CURB & GUTTER	100	L.F.	35.00	\$ 3,500	
50211	SELECT BACKFILL FOR STORM SEWER	400	T.F.	39.50	\$ 15,800	
50226	UTILITY TRENCH TYPE III	550	S.Y.	95.00	\$ 52,250	
50401	12 INCH TYPE I RCP STORM SEWER PIPE	95	L.F.	100.00	\$ 9,500	
50403	18 INCH TYPE I RCP STORM SEWER PIPE	98	L.F.	115.00	\$ 11,270	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	393	L.F.	160.00	\$ 62,880	
50467	30 INCH RCP AE	1	EACH	1,700.00	\$ 1,700	
50607	30 INCH RCP AE GATE	1	EACH	1,000.00	\$ 1,000	
50723	3' X 3' STORM SAS	1	EACH	5,500.00	\$ 5,500	
50725	5' X 5' STORM SAS	4	EACH	7,000.00	\$ 28,000	
50741	TYPE "H" INLET	1	EACH	3,500.00	\$ 3,500	
50792	STORM SEWER TAP	3	EACH	1,500.00	\$ 4,500	
	EROSION CONTROL	1	LUMP SUM	5,000.00	\$ 5,000	
				Subtotal	\$ 264,400	
				Contingency 25%	\$ 66,100	
				Design 10%	\$ 26,440	
				Total	\$ 356,940	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 356,940	

New Washburn Way and S Gammon Rd Improvements

Sub Area: NA

Conceptual Cost Estimate

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	25,000.00	\$ 25,000	
10911	MOBILIZATION	1	LUMP SUM	55,000.00	\$ 55,000	10% of other bid items.
20312	REMOVE CATCH BASIN	9	EACH	900.00	\$ 8,100	
20313	REMOVE INLET	5	EACH	630.00	\$ 3,150	
20314	REMOVE PIPE	1,176	L.F.	25.00	\$ 29,400	
20321	REMOVE CONCRETE CURB & GUTTER	200	L.F.	8.00	\$ 1,600	
20323	REMOVE CONCRETE SIDEWALK AND DRIVE	50	S.Y.	5.00	\$ 250	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	235	T.F.	5.00	\$ 1,175	
21092	TERRACE RESTORATION	150	S.Y.	5.00	\$ 750	
30201	TYPE "A" CONCRETE CURB & GUTTER	200	L.F.	35.00	\$ 7,000	
30302	7 INCH CONCRETE SIDEWALK & DRIVE	450	S.F.	12.00	\$ 5,400	
50211	SELECT BACKFILL FOR STORM SEWER	940	T.F.	15.00	\$ 14,100	
50226	UTILITY TRENCH TYPE III	1,250	S.Y.	95.00	\$ 118,750	
50405	24 INCH TYPE I RCP STORM SEWER PIPE	574	L.F.	125.00	\$ 71,750	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	55	L.F.	160.00	\$ 8,800	
50409	36 INCH TYPE I RCP STORM SEWER PIPE	234	L.F.	175.00	\$ 40,950	
50410	42 INCH TYPE I RCP STORM SEWER PIPE	313	L.F.	185.00	\$ 57,905	
50724	4' X 4' STORM SAS	6	EACH	5,500.00	\$ 33,000	
50725	5' X 5' STORM SAS	3	EACH	7,000.00	\$ 21,000	
50725	6' X 6' STORM SAS	3	EACH	8,000.00	\$ 24,000	
50792	STORM SEWER TAP	13	EACH	1,500.00	\$ 19,500	
	EROSION CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
				Subtotal	\$ 561,580	
				Contingency 25%	\$ 140,395	
				Design 10%	\$ 56,158	
				Total	\$ 758,133	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 758,133	

Schroeder Rd Trunkline Improvement*Sub Area: NA***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	25,000.00	\$ 25,000	
10911	MOBILIZATION	1	LUMP SUM	150,000.00	\$ 150,000	10% of other bid items.
20312	REMOVE CATCH BASIN	1	EACH	900.00	\$ 900	
20313	REMOVE INLET	1	EACH	630.00	\$ 630	
20314	REMOVE PIPE	273	L.F.	25.00	\$ 6,825	
20321	REMOVE CONCRETE CURB & GUTTER	50	L.F.	8.00	\$ 400	
20323	REMOVE CONCRETE SIDEWALK AND DRIVE	12	S.Y.	5.00	\$ 60	
21092	TERRACE RESTORATION	125	S.Y.	5.00	\$ 625	
30201	TYPE "A" CONCRETE CURB & GUTTER	50	L.F.	35.00	\$ 1,750	
30301	5 INCH CONCRETE SIDEWALK	100	S.F.	7.32	\$ 732	
50211	SELECT BACKFILL FOR STORM SEWER	2,120	T.F.	15.00	\$ 31,800	
50226	UTILITY TRENCH TYPE III	3,450	S.Y.	95.00	\$ 327,750	
50401	12 INCH TYPE I RCP STORM SEWER PIPE	150	L.F.	100.00	\$ 15,000	
50409	36 INCH TYPE I RCP STORM SEWER PIPE	81	L.F.	175.00	\$ 14,175	
50415	72 INCH TYPE I RCP STORM SEWER PIPE	1,926	L.F.	380.00	\$ 731,880	
50474	72 INCH RCP AE	1	EACH	4,500.00	\$ 4,500	
50614	72 INCH RCP AE GATE	1	EACH	4,500.00	\$ 4,500	
50725	5' X 5' STORM SAS	1	EACH	7,000.00	\$ 7,000	
50741	TYPE "H" INLET	6	EACH	3,500.00	\$ 21,000	
50763	TERRACE INLET	1	EACH	8,000.00	\$ 8,000	
50792	STORM SEWER TAP	2	EACH	1,500.00	\$ 3,000	
	EROSION CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
	WATERMAIN OFFSET	1	LUMP SUM	60,000.00	\$ 60,000	(3) 10", 12", & 16" Watermain Crossing
	8' X8' STORM SAS	5	EACH	15,000.00	\$ 75,000	
				Subtotal	\$ 1,505,527	
				Contingency 25%	\$ 376,382	
				Design 10%	\$ 150,553	
				Total	\$ 2,032,461	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 2,032,461	

Norman Clayton Park and Storm System Improvements

Sub Area: NA

Conceptual Cost Estimate

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
10911	MOBILIZATION	1	LUMP SUM	139,000.00	\$ 139,000	10% of other bid items.
20101	EXCAVATION CUT	1,060	C.Y.	25.00	\$ 26,500	
20221	TOPSOIL	1,500	S.Y.	5.00	\$ 7,500	Salvage & Respread
20312	REMOVE CATCH BASIN	15	EACH	900.00	\$ 13,500	
20313	REMOVE INLET	6	EACH	630.00	\$ 3,780	
20314	REMOVE PIPE	2,276	L.F.	25.00	\$ 56,900	
20321	REMOVE CONCRETE CURB & GUTTER	1,700	L.F.	8.00	\$ 13,600	
20323	REMOVE CONCRETE SIDEWALK & DRIVE	950	S.F.	5.00	\$ 4,750	
20705	DETENTION BASIN SEEDING	1,500	S.Y.	3.00	\$ 4,500	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	150	T.F.	5.00	\$ 750	
21073	EROSION MATTING CLASS 11, TYPE C - ORGANIC	1,500	S.Y.	6.25	\$ 9,375	
21092	TERRACE RESTORATION	1,500	S.Y.	5.00	\$ 7,500	
30201	TYPE "A" CONCRETE CURB & GUTTER	1,700	L.F.	20.00	\$ 34,000	
30302	7 INCH CONCRETE SIDEWALK & DRIVE	950	S.F.	12.00	\$ 11,400	
50211	SELECT BACKFILL FOR STORM SEWER	2,315	T.F.	15.00	\$ 34,725	
50226	UTILITY TRENCH TYPE III	3,550	S.Y.	95.00	\$ 337,250	Pvmt 1/2 Roadway - 14 ft wide + bike path
50401	12 INCH TYPE I RCP STORM SEWER PIPE	100	L.F.	100.00	\$ 10,000	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	1,219	L.F.	160.00	\$ 195,040	
50409	36 INCH TYPE I RCP STORM SEWER PIPE	652	L.F.	175.00	\$ 114,100	
50411	48 INCH TYPE I RCP STORM SEWER PIPE	239	L.F.	200.00	\$ 47,800	
50423	38 INCH X 60 INCH TYPE I HERCP STORM SEWER PIPE	341	L.F.	300.00	\$ 102,300	
50424	43 INCH X 68 INCH TYPE I HERCP STORM SEWER PIPE	119	L.F.	350.00	\$ 41,650	
50725	5' X 5' STORM SAS	5	EACH	7,000.00	\$ 35,000	
50726	6' X 6' STORM SAS	3	EACH	9,500.00	\$ 28,500	
50741	TYPE "H" INLET	2	EACH	3,500.00	\$ 7,000	
50761	SADDLED INLET TYPE 1	4	EACH	3,600.00	\$ 14,400	
50763	TERRACE INLET	2	EACH	8,000.00	\$ 16,000	
50792	STORM SEWER TAP	23	EACH	1,500.00	\$ 34,500	
	EROSION CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
	8' X8' STORM SAS	4	EACH	12,000.00	\$ 48,000	
	TREE TRIMMING	1	LUMP SUM	4,000.00	\$ 4,000	
	WATERMAIN OFFSET	1	LUMP SUM	20,000.00	\$ 20,000	
	JUNCTION STRUCTURE	1	EACH	20,000.00	\$ 20,000	
	CHANNEL DEMOLITION	235	L.F.	39.00	\$ 9,165	
				Subtotal	\$ 1,477,485	
				Contingency 25%	\$ 369,371	
				Design 10%	\$ 147,749	
				Total	\$ 1,994,605	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 1,994,605	

Chapel Hill Greenway and Storm System Improvements

Sub Area: NA

Conceptual Cost Estimate

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	2,500.00	\$ 2,500	
10911	MOBLIZATION	1	LUMP SUM	48,000.00	\$ 48,000	10% of other bid items.
20101	EXCAVATION CUT	2,828	C.Y.	25.00	\$ 70,700	
20221	TOPSOIL	6,500	S.Y.	5.00	\$ 32,500	Salvage & Respread
20312	REMOVE CATCH BASIN	2	EACH	900.00	\$ 1,800	
20313	REMOVE INLET	9	EACH	630.00	\$ 5,670	
20314	REMOVE PIPE	649	L.F.	25.00	\$ 16,225	
20321	REMOVE CONCRETE CURB & GUTTER	150	L.F.	8.00	\$ 1,200	
20323	REMOVE CONCRETE SIDEWALK & DRIVE	1,200	S.F.	5.00	\$ 6,000	
20705	DETENTION BASIN SEEDING	6,500	S.Y.	3.00	\$ 19,500	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	215	T.F.	5.00	\$ 1,075	
21073	EROSION MATTING CLASS 11, TYPE C - ORGANIC	6,500	S.Y.	6.25	\$ 40,625	
21092	TERRACE RESTORATION	300	S.Y.	5.00	\$ 1,500	
30201	TYPE "A" CONCRETE CURB & GUTTER	150	L.F.	35.00	\$ 5,250	
30301	5 INCH CONCRETE SIDEWALK & DRIVE	1,200	S.F.	12.00	\$ 14,400	
50211	SELECT BACKFILL FOR STORM SEWER	360	T.F.	15.00	\$ 5,400	
50226	UTILITY TRENCH TYPE III	330	S.Y.	95.00	\$ 31,350	
50405	24 INCH TYPE I RCP STORM SEWER PIPE	118	L.F.	125.00	\$ 14,750	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	405	L.F.	160.00	\$ 64,800	
50411	48 INCH TYPE I RCP STORM SEWER PIPE	189	L.F.	200.00	\$ 37,800	
50725	5' X 5' STORM SAS	3	EACH	7,000.00	\$ 21,000	
50741	TYPE "H" INLET	4	EACH	3,500.00	\$ 14,000	
50761	SADDLED INLET TYPE 1	4	EACH	3,600.00	\$ 14,400	
50792	STORM SEWER TAP	1	EACH	1,500.00	\$ 1,500	
	EROSION CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
	4' X6' BOX CULVERT	43	L.F.	800.00	\$ 34,400	
	4' X6' BOX CULVERT WING WALL	2	EACH	28,000.00	\$ 56,000	
	TREE REMOVAL	1	LUMP SUM	2,500.00	\$ 2,500	
				Subtotal	\$ 574,845	
				Contingency 25%	\$ 143,711	
				Design 10%	\$ 57,485	
				Total	\$ 776,041	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 776,041	

McKenna Blvd Improvements*Sub Area: McKenna Blvd. North Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	30,000.00	\$ 30,000	
10911	MOBILIZATION	1	LUMP SUM	45,000.00	\$ 45,000	10% of other bid items.
20312	REMOVE CATCH BASIN	2	EACH	900.00	\$ 1,800	
20313	REMOVE INLET	3	EACH	630.00	\$ 1,890	
20314	REMOVE PIPE	938	L.F.	25.00	\$ 23,450	
20321	REMOVE CONCRETE CURB & GUTTER	400	L.F.	8.00	\$ 3,200	
20323	REMOVE CONCRETE SIDEWALK & DRIVE	125	S.F.	5.00	\$ 625	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	225	T.F.	5.00	\$ 1,125	
21092	TERRACE RESTORATION	300	S.Y.	5.00	\$ 1,500	
30201	TYPE "A" CONCRETE CURB & GUTTER	400	L.F.	25.00	\$ 10,000	
30301	5 INCH CONCRETE SIDEWALK & DRIVE	125	S.F.	12.00	\$ 1,500	
50211	SELECT BACKFILL FOR STORM SEWER	940	T.F.	15.00	\$ 14,100	
50226	UTILITY TRENCH TYPE III	1,250	S.Y.	95.00	\$ 118,750	
50405	24 INCH TYPE I RCP STORM SEWER PIPE	282	L.F.	125.00	\$ 35,250	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	254	L.F.	160.00	\$ 40,640	
50409	36 INCH TYPE I RCP STORM SEWER PIPE	207	L.F.	175.00	\$ 36,225	
50410	42 INCH TYPE I RCP STORM SEWER PIPE	249	L.F.	185.00	\$ 46,065	
50469	42 INCH RCP AE	1	EACH	2,300.00	\$ 2,300	
50609	42 INCH RCP AE GATE	1	EACH	1,750.00	\$ 1,750	
50724	4' X 4' STORM SAS	1	EACH	5,500.00	\$ 5,500	
50725	5' X 5' STORM SAS	2	EACH	7,000.00	\$ 14,000	
50792	STORM SEWER TAP	10	EACH	1,500.00	\$ 15,000	
50801	UTILITY LINE OPENING (ULO)	3	EACH	900.00	\$ 2,700	
	EROSION CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
	TREE REMOVAL	1	LUMP SUM	2,500.00	\$ 2,500	
				Subtotal	\$ 464,870	
				Contingency 25%	\$ 116,218	
				Design 10%	\$ 46,487	
				Total	\$ 627,575	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 627,575	

McKenna Blvd Improvements*Sub Area: McKenna Blvd. South Storm Sewer Improvement***Conceptual Cost Estimate**

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	30,000.00	\$ 30,000	
10911	MOBILIZATION	1	LUMP SUM	94,000.00	\$ 94,000	10% of other bid items.
20312	REMOVE CATCH BASIN	4	EACH	900.00	\$ 3,600	
20313	REMOVE INLET	9	EACH	630.00	\$ 5,670	
20314	REMOVE PIPE	1,413	L.F.	25.00	\$ 35,325	
20321	REMOVE CONCRETE CURB & GUTTER	800	L.F.	8.00	\$ 6,400	
20323	REMOVE CONCRETE SIDEWALK & DRIVE	1,100	S.F.	5.00	\$ 5,500	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	150	T.F.	5.00	\$ 750	
21092	TERRACE RESTORATION	600	S.Y.	5.00	\$ 3,000	
30201	TYPE "A" CONCRETE CURB & GUTTER	800	L.F.	25.00	\$ 20,000	
30302	7 INCH CONCRETE SIDEWALK & DRIVE	1,100	S.F.	12.00	\$ 13,200	
50211	SELECT BACKFILL FOR STORM SEWER	1,230	T.F.	15.00	\$ 18,450	
50226	UTILITY TRENCH TYPE III	2,050	S.Y.	95.00	\$ 194,750	
50401	12 INCH TYPE I RCP STORM SEWER PIPE	150	L.F.	100.00	\$ 15,000	
50407	30 INCH TYPE I RCP STORM SEWER PIPE	300	L.F.	160.00	\$ 48,000	
50422	34 INCH X 53 INCH HERCP STORM SEWER PIPE	783	L.F.	260.00	\$ 203,580	
50425	48 INCH X 76 INCH HERCP STORM SEWER PIPE	553	L.F.	380.00	\$ 210,140	
50488	48 INCH X 76 INCH HERCP AE	1	EACH	4,500.00	\$ 4,500	
50628	48 INCH X 76 INCH HERCP AE GATE	1	EACH	3,500.00	\$ 3,500	
50724	4' X 4' STORM SAS	1	EACH	5,500.00	\$ 5,500	
50741	TYPE "H" INLET	5	EACH	3,500.00	\$ 17,500	
50792	STORM SEWER TAP	11	EACH	1,500.00	\$ 16,500	
50801	UTILITY LINE OPENING (ULO)	8	EACH	900.00	\$ 7,200	
	EROSION CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
	8' X8' STORM SAS	5	EACH	10,000.00	\$ 50,000	
				Subtotal	\$ 1,022,065	
				Contingency 25%	\$ 255,516	
				Design 10%	\$ 102,207	
				Total	\$ 1,379,788	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 1,379,788	

Elver Park Greenway Reconstruction

Sub Area: NA

Conceptual Cost Estimate

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	2,500.00	\$ 2,500	
10911	MOBILIZATION	1	LUMP SUM	75,000.00	\$ 75,000	5% of other bid items.
20101	EXCAVATION CUT	57,097	C.Y.	15.00	\$ 856,455	Changed from \$25 for magnitude
20221	TOPSOIL	42,000	S.Y.	5.00	\$ 210,000	Salvage & Respread
20705	DETENTION BASIN SEEDING	42,000	S.Y.	3.00	\$ 126,000	
21073	EROSION MATTING CLASS 11, TYPE C - ORGANIC	42,000	S.Y.	6.25	\$ 262,500	
	EROSION CONTROL	1	LUMP SUM	7,500.00	\$ 7,500	
				Subtotal	\$ 1,539,955	
				Contingency 25%	\$ 384,989	
				Design 10%	\$ 153,996	
				Total	\$ 2,078,939	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 2,078,939	

New Detention Basin (Marty Road/Mid Town Road Regional Pond)

Sub Area: NA

Conceptual Cost Estimate -Marty Farm Pond

9/5/2022

DRAFT

Item #	Item	Quantity	Unit	Unit Cost	Cost	Comments
10701	TRAFFIC CONTROL	1	LUMP SUM	15,000.00	\$ 15,000	
10911	MOBILIZATION	1	LUMP SUM	400,000.00	\$ 400,000	5% of other bid items.
20101	EXCAVATION CUT	473,117	C.Y.	12.00	\$ 5,677,404	Changed from \$25.00 for magnitude
20221	TOPSOIL	60,000	S.Y.	5.00	\$ 300,000	Salvage & Respread
20312	REMOVE CATCH BASIN	6	EACH	900.00	\$ 5,400	
20313	REMOVE INLET	5	EACH	630.00	\$ 3,150	
20314	REMOVE PIPE	2,207	L.F.	25.00	\$ 55,175	
20321	REMOVE CONCRETE CURB & GUTTER	1,050	L.F.	8.00	\$ 8,400	
20323	REMOVE CONCRETE SIDEWALK & DRIVE	800	S.F.	5.00	\$ 4,000	
20705	DETENTION BASIN SEEDING	60,000	S.Y.	3.00	\$ 180,000	
20711	TRENCH RESTORATION 4 INCH TOPSOIL, SEED, FERTILIZE AND MULCH	100	T.F.	5.00	\$ 500	
21073	EROSION MATTING CLASS 11, TYPE C - ORGANIC	60,000	S.Y.	6.25	\$ 375,000	
21092	TERRACE RESTORATION	1,450	S.Y.	5.00	\$ 7,250	
30201	TYPE "A" CONCRETE CURB & GUTTER	1,050	L.F.	20.00	\$ 21,000	
30301	5 INCH CONCRETE SIDEWALK & DRIVE	800	S.F.	12.00	\$ 9,600	
50211	SELECT BACKFILL FOR STORM SEWER	1,500	T.F.	15.00	\$ 22,500	
50226	UTILITY TRENCH TYPE III	1,200	S.Y.	95.00	\$ 114,000	
50409	36 INCH TYPE I RCP STORM SEWER PIPE	1,415	L.F.	175.00	\$ 247,625	
50725	5' X 5' STORM SAS	5	EACH	7,000.00	\$ 35,000	
50468	36 INCH RCP AE	1	EACH	2,000.00	\$ 2,000	
50608	36 INCH RCP AE Gate	1	EACH	1,500.00	\$ 1,500	
50761	SADDLED INLET TYPE 1	5	EACH	3,600.00	\$ 18,000	
50792	STORM SEWER TAP	6	EACH	1,500.00	\$ 9,000	
	EROSION CONTROL	1	LUMP SUM	10,000.00	\$ 10,000	
	3' X6' BOX CULVERT	384	L.F.	800.00	\$ 307,200	
	4.5' X8' BOX CULVERT	336	L.F.	1,200.00	\$ 403,200	
	3' X6' BOX CULVERT WING WALL	2	EACH	28,000.00	\$ 56,000	
	4.5' X8' BOX CULVERT WING WALL	2	EACH	28,000.00	\$ 56,000	
				Subtotal	\$ 8,343,904	
				Contingency 25%	\$ 2,085,976	
				Design 10%	\$ 834,390	
				Total	\$ 11,264,270	
				Land Acquisition	\$ -	
				Wetland Mitigation	\$ -	
				Total Total	\$ 11,264,270	

Appendix L: Documentation of Pre- McKenna Flood Mitigation Project

Appendix L – Documentation of Pre- McKenna Flood Mitigation Project

As mentioned in the main report, this watershed study began during the time when the City's McKenna Boulevard Flood Mitigation Project was being constructed. This was a very significant drainage improvement project targeting the greenway between Elver Park (McKenna Boulevard) and Watts Road. Implementation of the McKenna Blvd Flood Mitigation Project occurred in two phases, the first phase was constructed in 2019 and included the replacement of the culverts under McKenna Boulevard and substantial modification of the greenway channel for a length of approximately 1,500 feet upstream to the outlet of the existing pond along the greenway channel. Phase 2 of the project was constructed 2020 and began at a point approximately 600 feet south of Watts Road and included greenway modifications extending approximately 2,200 feet downstream (south), ending at the inlet to the existing pond along the greenway which marked the upstream end of Phase 1 of the project. Phase 2 of the project also included substantial upsizing of the cross-culverts under Schroeder Road. The existing conditions assessment conducted as part of this study reflect the improvements of phase 1 of this project, but do not include phase 2, as this project was not complete as of the completion of the existing conditions XP-SWMM model.

The proposed conditions model reflects both phases of the McKenna Boulevard Flood Mitigation Project as well as other upstream stormwater management improvements. As these upstream alternative solutions were being developed, it was felt that it should be verified that none of the planned improvements should reverse the flood-reduction effect of original McKenna Boulevard Flood Mitigation Project. As an add-on to the original watershed study project scope, the existing conditions watershed model was revised to replace the Phase 1 improvement constructed under the McKenna Boulevard Flood Mitigation Project with pre-project conditions. The table below presents a comparison of flood conditions along the extent of the Phase 1 improvements. Results show some small increases in 100-yr flood elevations immediately downstream (south) of Schroeder road under both Phase 1 and fully-improved proposed conditions in the watershed; however, these increases are confined to the greenway itself (i.e. publicly owned lands). While there is some reduction in flood benefit in various locations along the limits of Phase 1 of the McKenna Boulevard Flood Mitigation Project, except as noted at Schroeder Road, the local and systemic benefits of the fully improved proposed conditions are still substantially better than pre-Phase 1 channel improvements.

McKenna Greentree - Pre-Channel Improvement Comparison

		100-Year Event						
		PRE-CHANNEL IMPROVEMENTS		EXISTING CONDITION			PROPOSED CONDITION	
Name	Node Station from McKenna Blvd (ft)	Invert Elevation (ft)	Max Water Elevation (ft)	Invert Elevation (ft)	Max Water Elevation (ft)	Change from Pre- Improved Condition (ft)	Max Water Elevation (ft)	Change from Pre- Improved Condition (ft)
2861-019_430	4182	1015.15	1019.44	1013.00	1018.14	-1.31	1018.47	-0.98
AE2861-007	4000	1014.90	1019.43	1012.28	1017.80	-1.63	1018.13	-1.29
AE2861-008	3764	1014.26	1019.41	1011.36	1017.52	-1.89	1017.90	-1.51
AE2861-009	3661	1014.00	1019.41	1010.95	1017.46	-1.95	1017.86	-1.55
AE2861-013	3419	1013.90	1019.40	1010.00	1017.34	-2.06	1017.76	-1.64
Schroeder Rd - Culvert Peak Flows		337.6 cfs		557.0 cfs			602.0 cfs	
AE2862-002	3309	1012.30	1014.72	1010.00	1014.91	0.19	1015.51	0.79
2862-008_570	2733	1010.56	1014.37	1007.97	1014.39	0.02	1014.70	0.33
2862-008_893	2410	1008.65	1014.34	1006.83	1014.34	0.00	1014.61	0.27
2862-008_1183	2120	1005.81	1014.33	1005.81	1014.22	-0.12	1014.47	0.14
Node575	2065	1008.28	1014.33	1005.61	1014.19	-0.14	1014.45	0.12
2862-008_1489_01	1821	1008.10	1014.32	1004.75	1014.04	-0.27	1014.29	-0.03
2763-010_02	1789	1008.10	1014.26	1006.30	1013.72	-0.54	1013.99	-0.27
Greentree Pond								
2763-010_01	1419	1007.80	1014.11	1006.30	1012.75	-1.36	1012.98	-1.13
2764-015	1371	1007.80	1014.01	1006.30	1011.84	-2.17	1011.99	-2.03
2764-015.1	1233	1007.23	1014.01	1006.09	1011.79	-2.22	1011.94	-2.07
2764-015_446	926	1006.98	1013.98	1005.61	1011.70	-2.28	1011.84	-2.14
2764-015_883	488	1006.54	1013.97	1004.92	1011.62	-2.36	1011.75	-2.22
AE2764-012	374	1006.31	1013.97	1004.74	1011.60	-2.37	1011.73	-2.24
2764-015_1074	296	1006.15	1013.97	1000.60	1011.59	-2.38	1011.72	-2.25
AE2764-011	229	1006.07	1013.97	1000.56	1011.56	-2.41	1011.69	-2.28
2764-015_1374_01	0	1005.80	1013.96	1000.40	1011.45	-2.51	1011.59	-2.37
McKenna Blvd								

Notes

Major capacity increases, due to the recently installed Schroeder Rd Box Culverts, are driving up flows downstream of Schroeder Rd.

Increase in flood elevations are due to the above mentioned culvert capacity increases, as well as the addition of a proposed storm sewer along Shroeder Rd, from Gamon Rd, which outlets at the upstream end of this channel section. The inundations footprint does not appear to change from pre-improved condition and all increases are maintained within the greenway.

The apartment buildings adjacent to Greentree Pond, which saw a slight increase in flood elevations from Existing to Proposed conditions, are maintained below the Pre-channel improvements levels. All peak water elevations south of Greentree Pond are significantly reduced.