# Greentree/McKenna Watershed Study Report Draft

City of Madison, Dane County, WI

**November 2, 2022**

MSA Professional Services

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*The City makes no representation about the accuracy of these records and shall not be liable for any damages.*

# Acknowledgments

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# Table of Contents

# List of Tables

*All tables are located within the report.*



# List of Figures

*All figures are included at the end of the report, with the exception for those in the Executive Summary.*

# List of Appendices

# 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 be 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 Theisen 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 Theisen 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.

  Width = Area / 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 where 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 though 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.

# 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 size 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 curbline decreases with this proposed improvement, with the majority of locations having less than 0.5-ft of water along the curbline 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 with 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 is 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 curbline decreases with this proposed improvement, with all locations having less than 0.5-ft of water along the curbline 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 met 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 curbline decreases with this proposed improvement, with the majority of locations having less than 0.5-ft of water along the curbline 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 with 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 curbline decreases with this proposed improvement, with the majority of locations having less than 0.5-ft of water along the curbline 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 with 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 secure 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 Morraine 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 do 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 curbline decreases with this proposed improvement, and there is less than 0.5-ft of water along the curbline 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 with 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 do 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 curbline decreases with this proposed improvement, and there is less than 0.5-ft of water along the curbline 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 curbline 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 curbline decreases with this proposed improvement, and there is less than 0.5-ft of water along the curbline 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 curbline 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 with 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 do 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 minimized 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 met 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 curbline 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 curbline decreases with this proposed improvement, and there is less than 0.5-ft of water along the curbline 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 safety store and graduall y 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 curbline decreases with this proposed improvement, and there is less than 0.5-ft of water along the curbline 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/and 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. Potions 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 where 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.

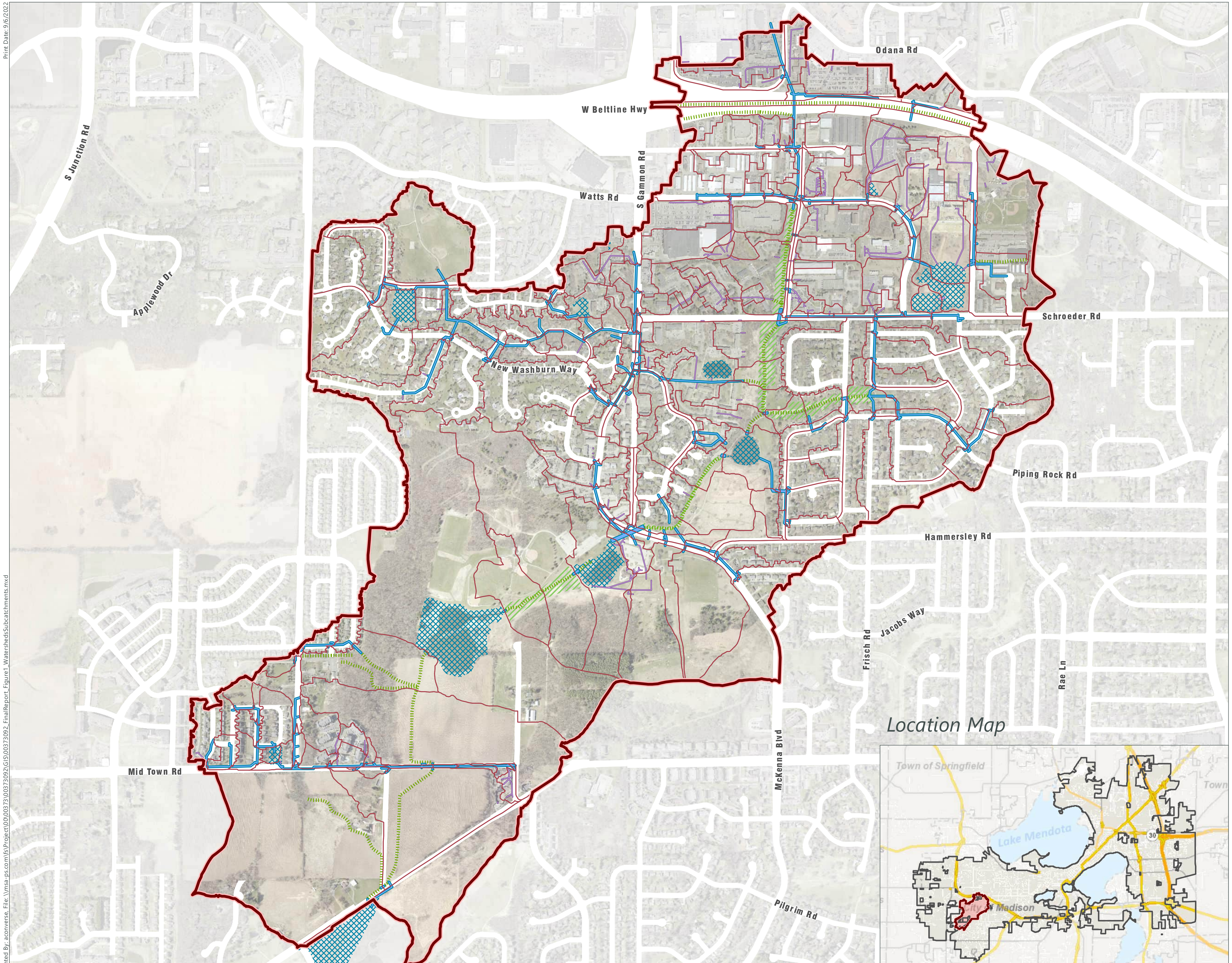
## 14.2 Citywide Implementation Prioritization

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 applicate Cities Agencies. Results can also be presented to stakeholders, including local Friends Groups, Neighborhood Organizations, interested Developers and neighborhood residents.

# 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*

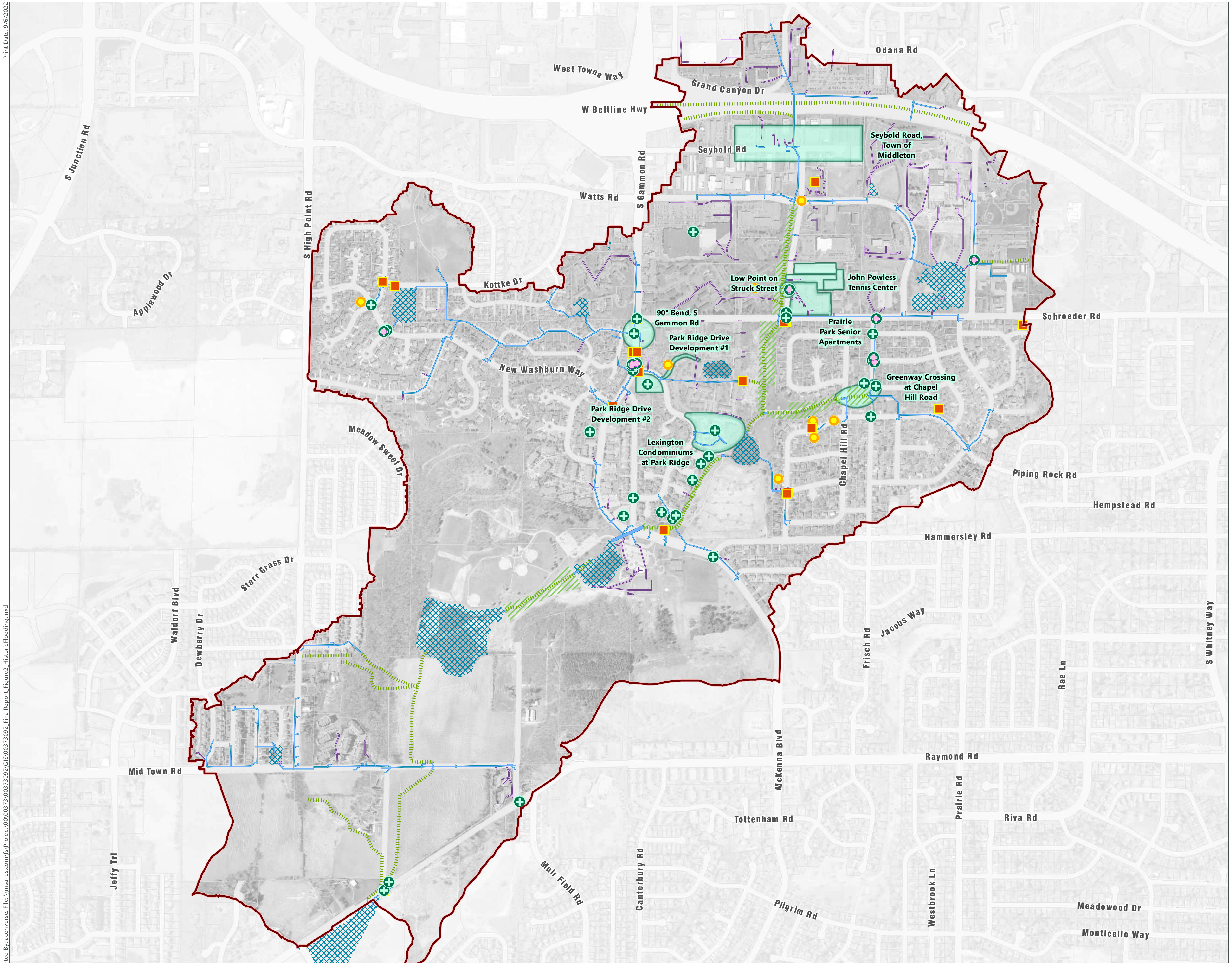
MSA

0 550 1,100 Feet

# 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*

MSA

0 550 1,100 Feet

N

Print Date: 9/6/2022

# Adjacent Watersheds

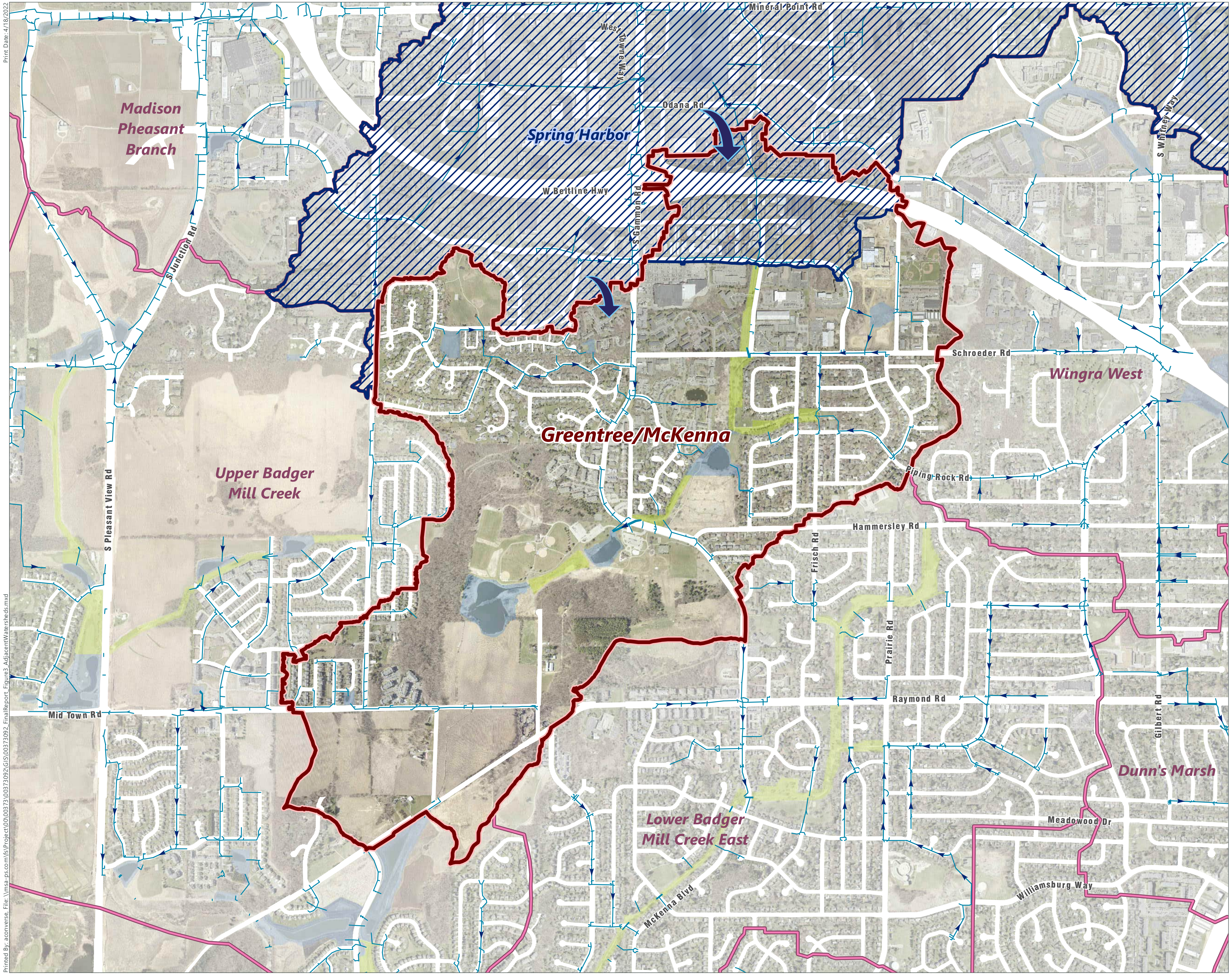



FIGURE 3
Greentree/McKenna Watershed
Study Report

**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*

MSA

0 550 1,100 Feet

Print Date: 4/18/2022
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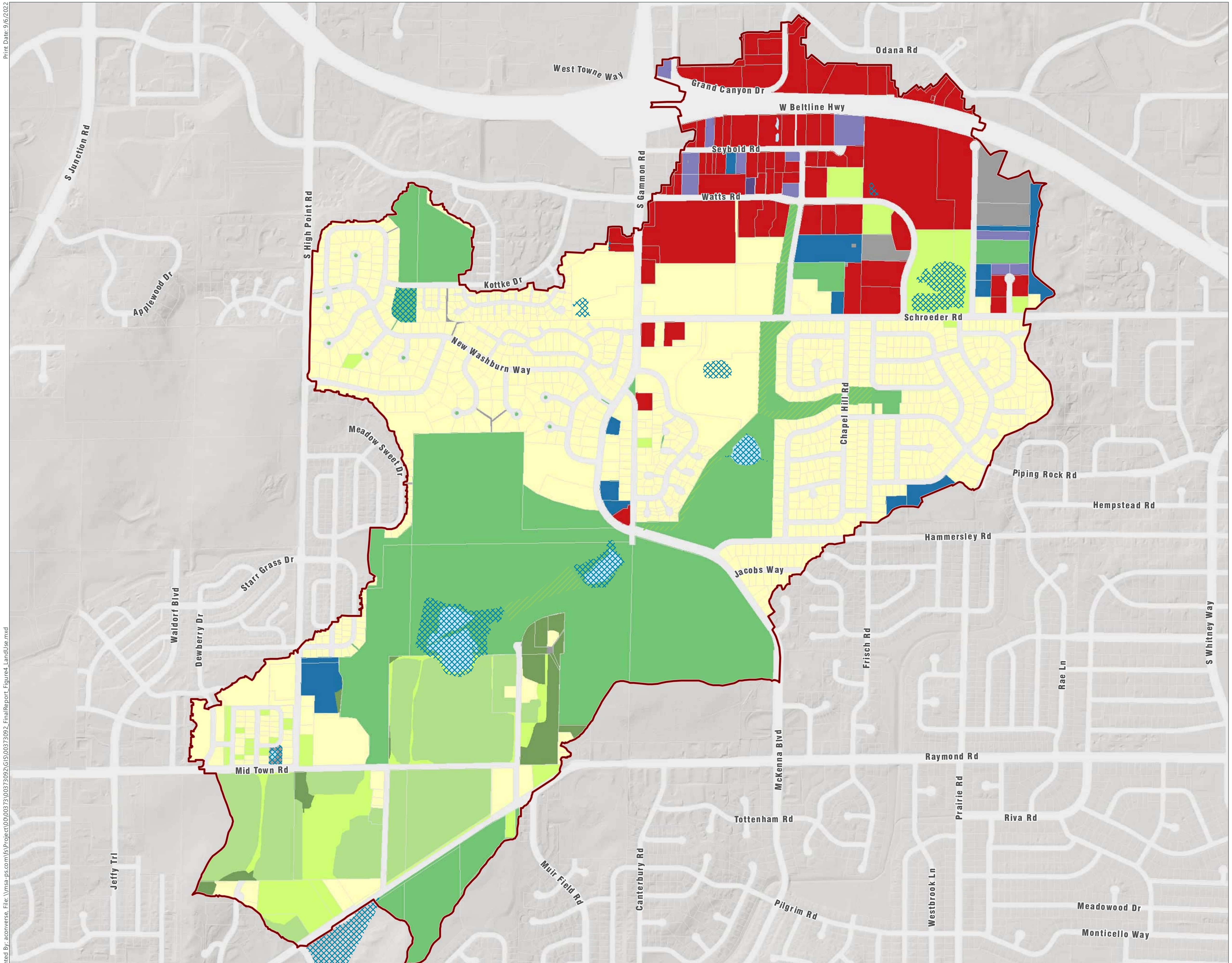
# Land Use

FIGURE 4
Greentree/McKenna Watershed
Study Report

**City of Madison**
**Dane County, WI**




Watershed Study Area

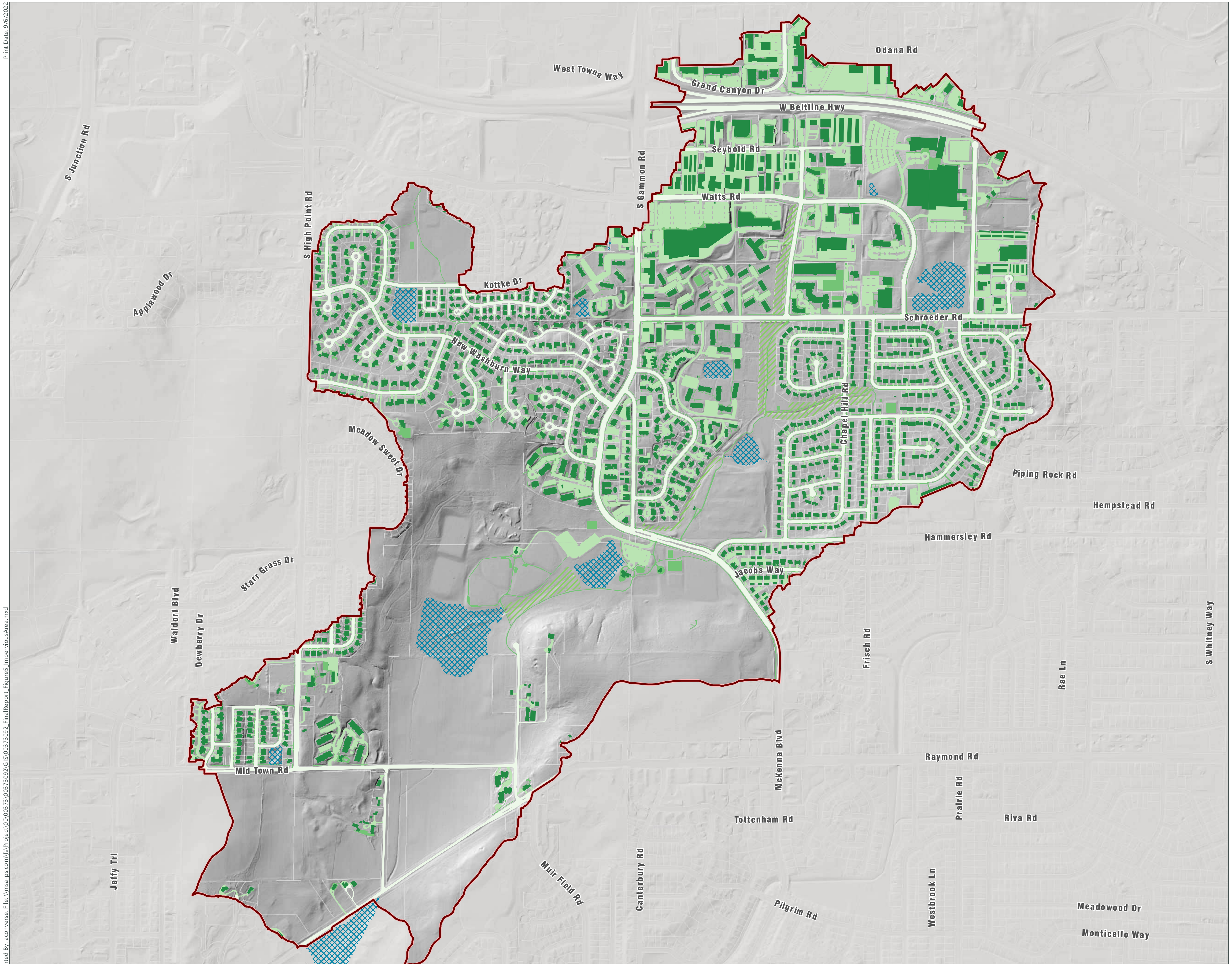
Land Use (2015)

- 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)*

MSA

0 550 1,100 Feet




# Impervious Areas

FIGURE 5
Greentree/McKenna Watershed
Study Report

**City of Madison**
**Dane County, WI**

Watershed Study Area

Impervious Area

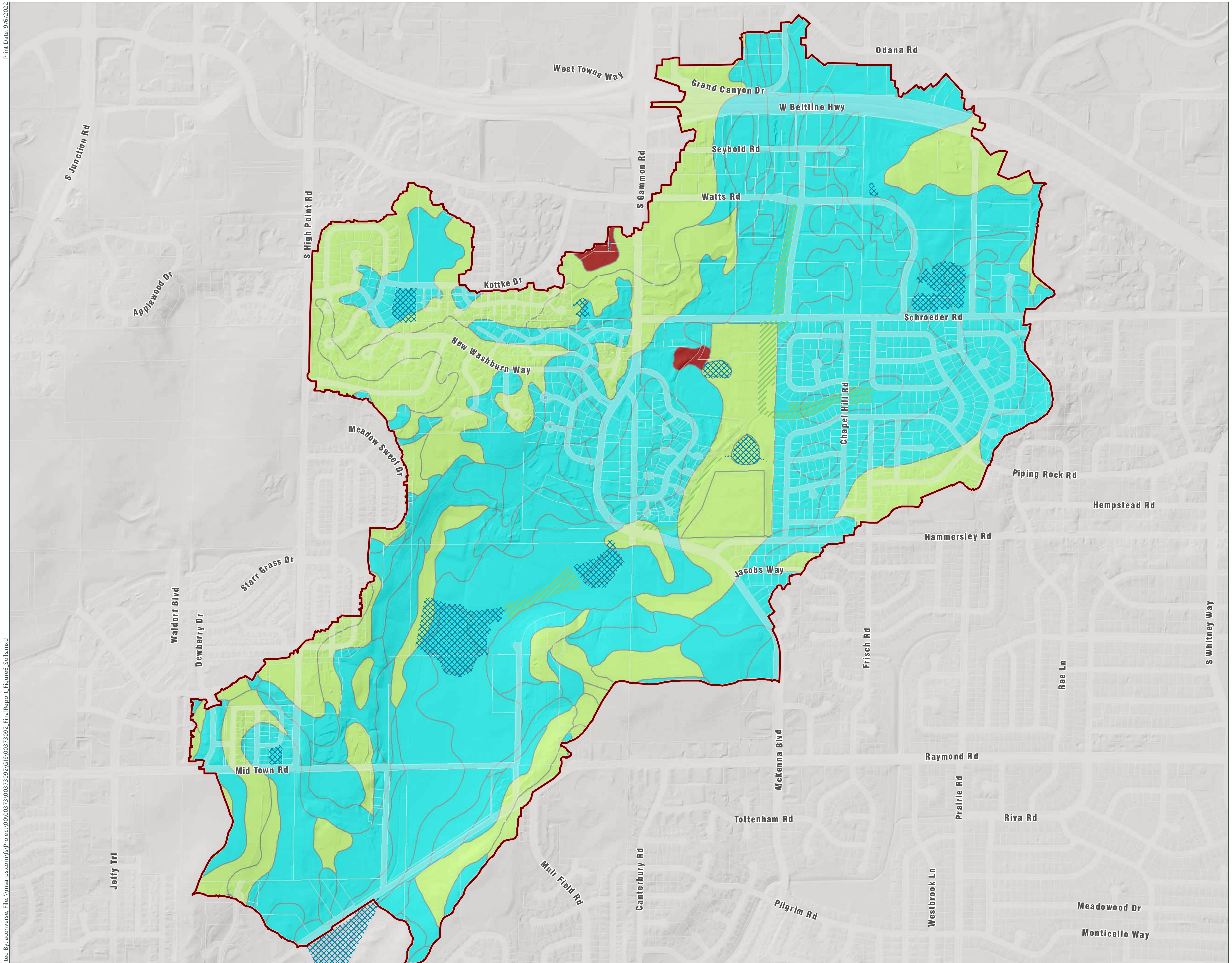
- Roof
- Sidewalk
- Driveway/Parking
- Street
- Greenway
- Pond

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

MSA

0 550 1,100 Feet

N




Print Date: 9/6/2022

# 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*

MSA

0 550 1,100 Feet

N


# Focus Group Gammon Rd-Schroeder Rd

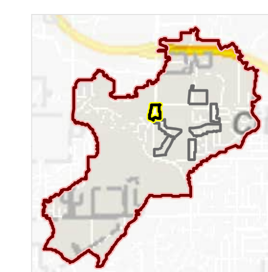
FIGURE 7A
Greentree/McKenna Watershed Study Report

**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.*

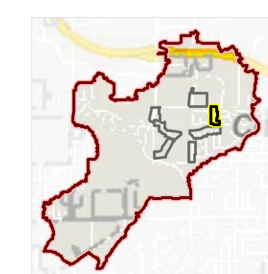
MSA

# 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.*

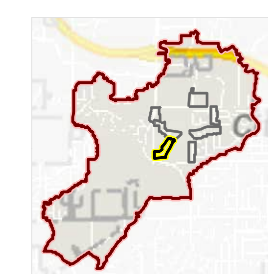
MSA

# 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.*

MSA

# Focus Group
# Park Ridge Dr

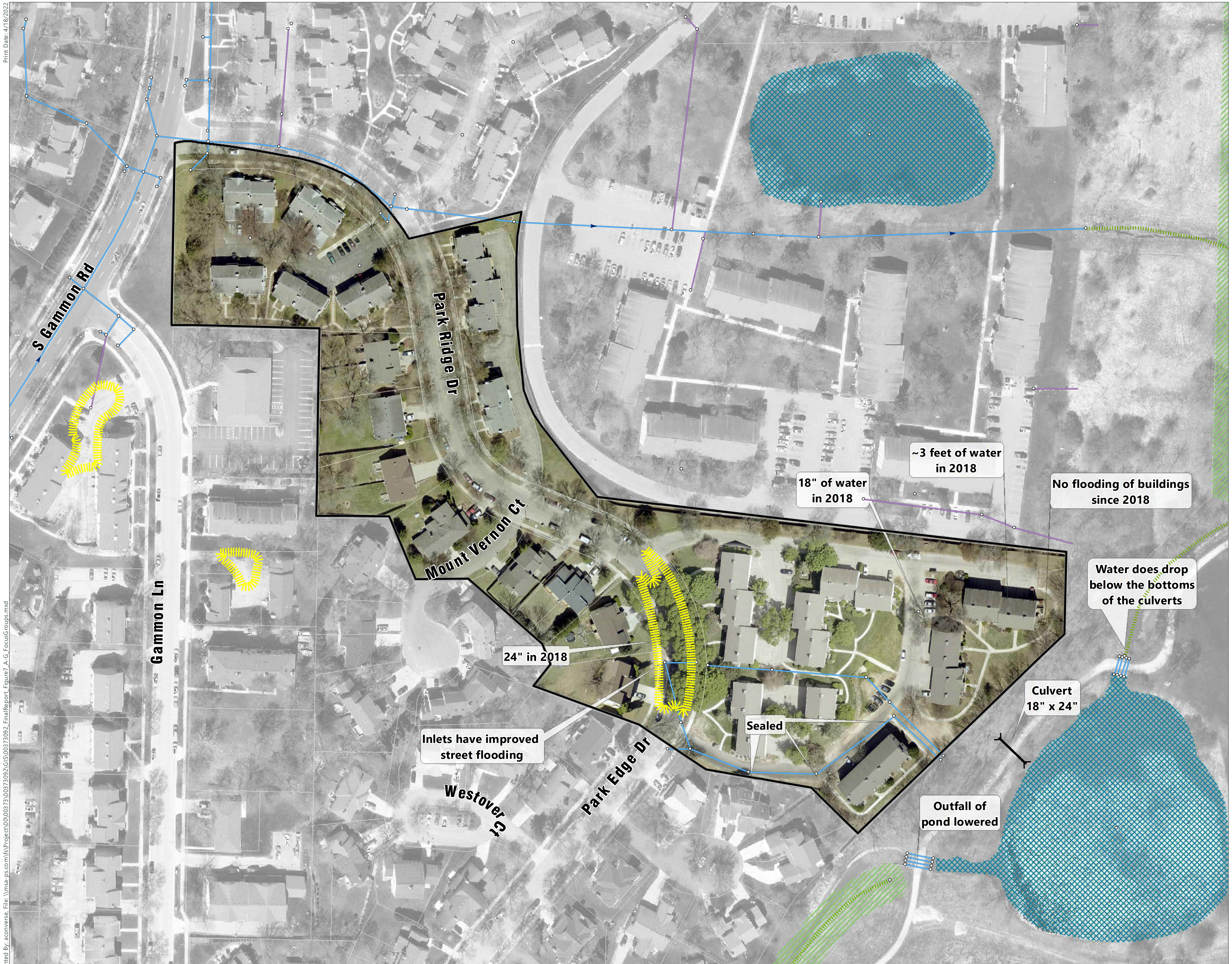
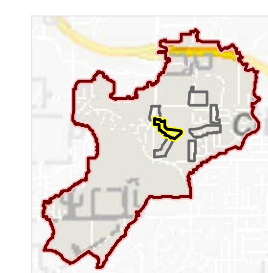



FIGURE 7D
Greentree/McKenna Watershed
Study Report

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.*

MSA


# 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.*

MSA

# 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.*

MSA

# Focus Group Struck St

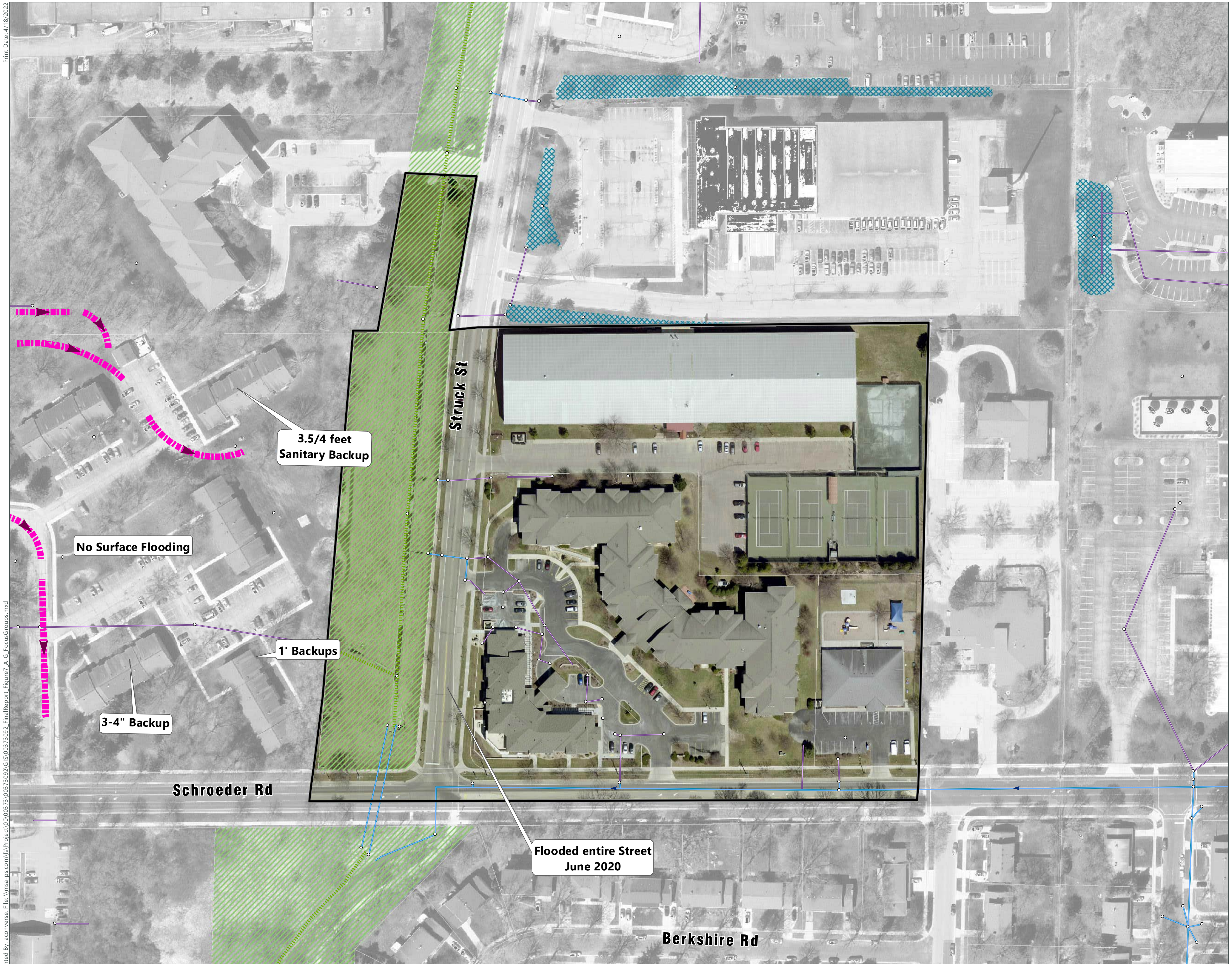


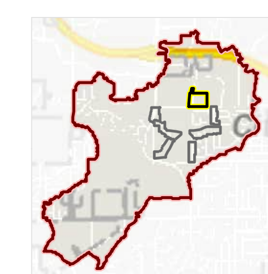

FIGURE 7G
Greentree/McKenna Watershed
Study Report

**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.*

MSA

Print Date: 4/18/2022

Printed By: aconverse, File: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092 FinalReport Figure7 A-G FocusGroups.mxd

# Gage Locations

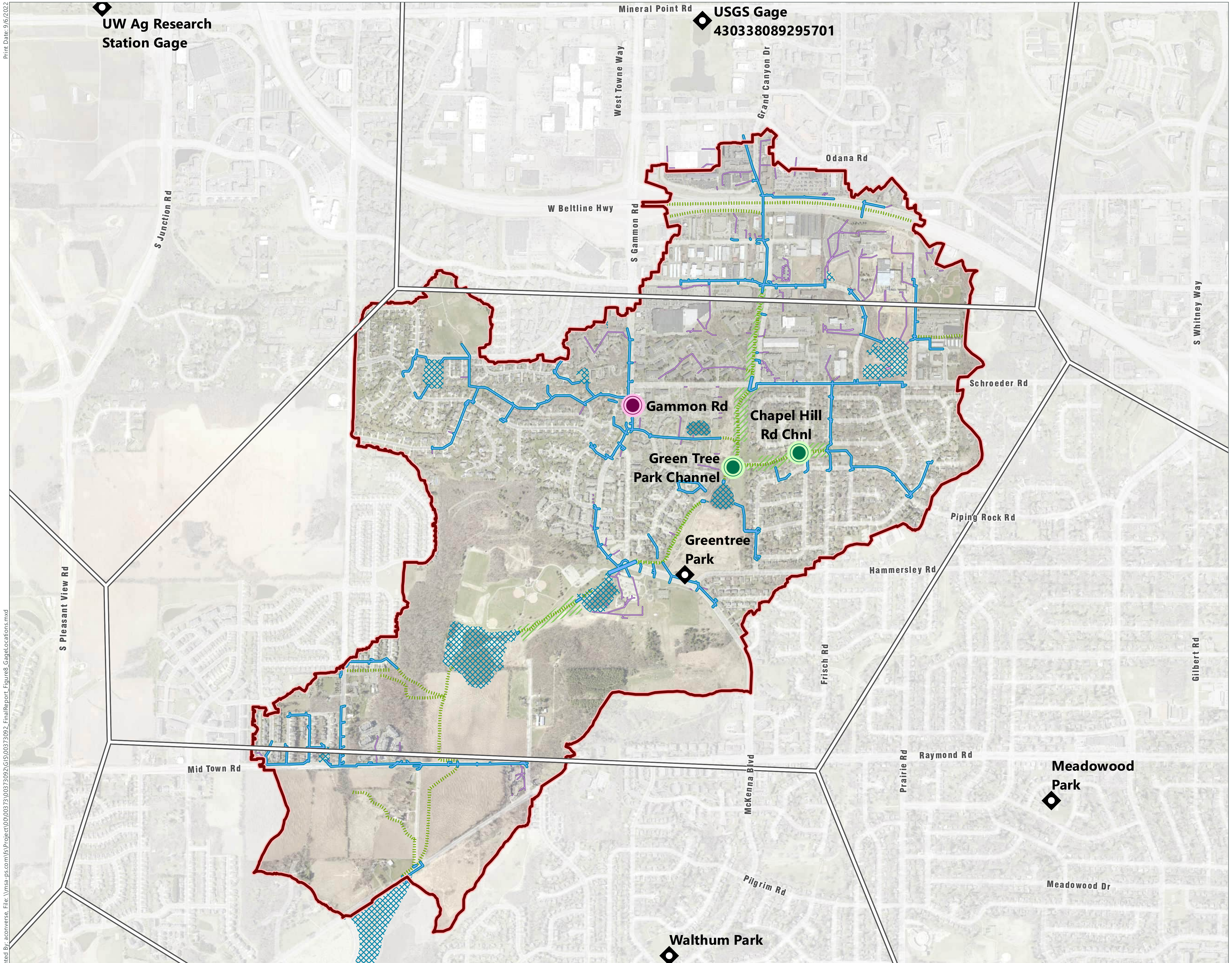



FIGURE 8
Greentree/McKenna Watershed
Study Report

**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*

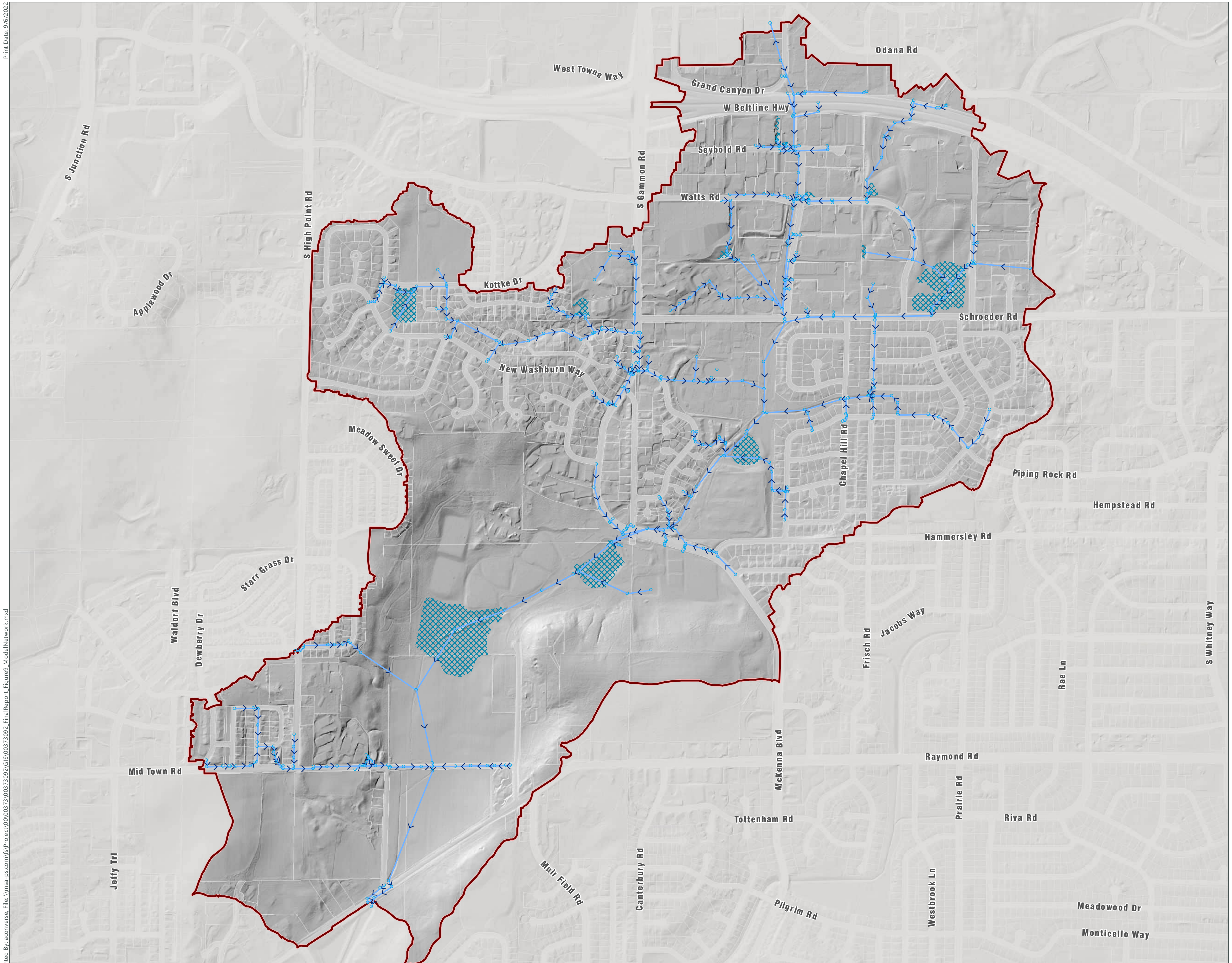
MSA

0 550 1,100 Feet

# Model Network

FIGURE 9
Greentree/McKenna Watershed
Study Report

**City of Madison**
**Dane County, WI**

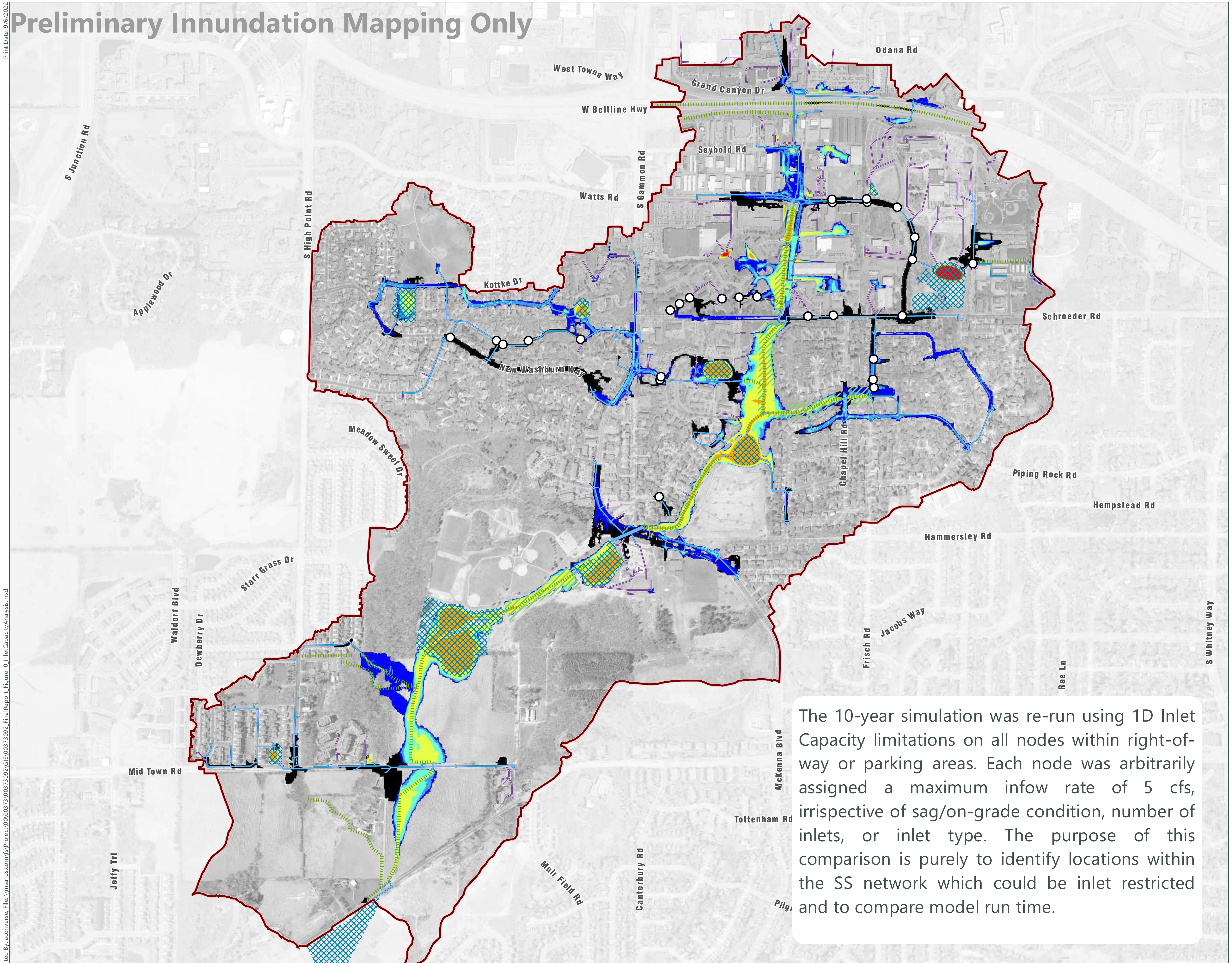



Watershed Study Area
Modeled Pond
Modeled Link
Modeled Node

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

MSA

Print Date: 9/6/2022




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*

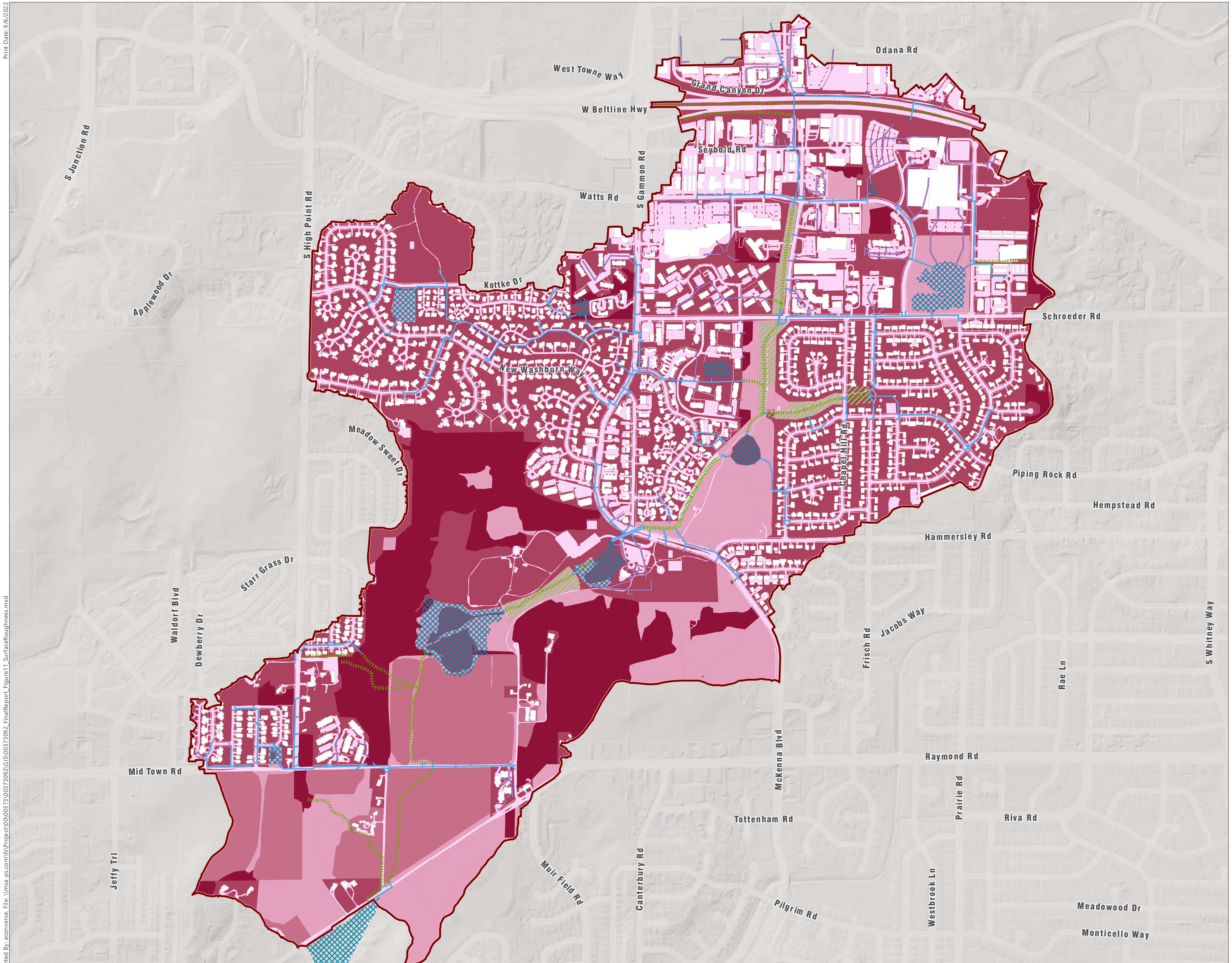
MSA

0 550 1,100 Feet

# 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*

MSA

0 550 1,100 Feet

N

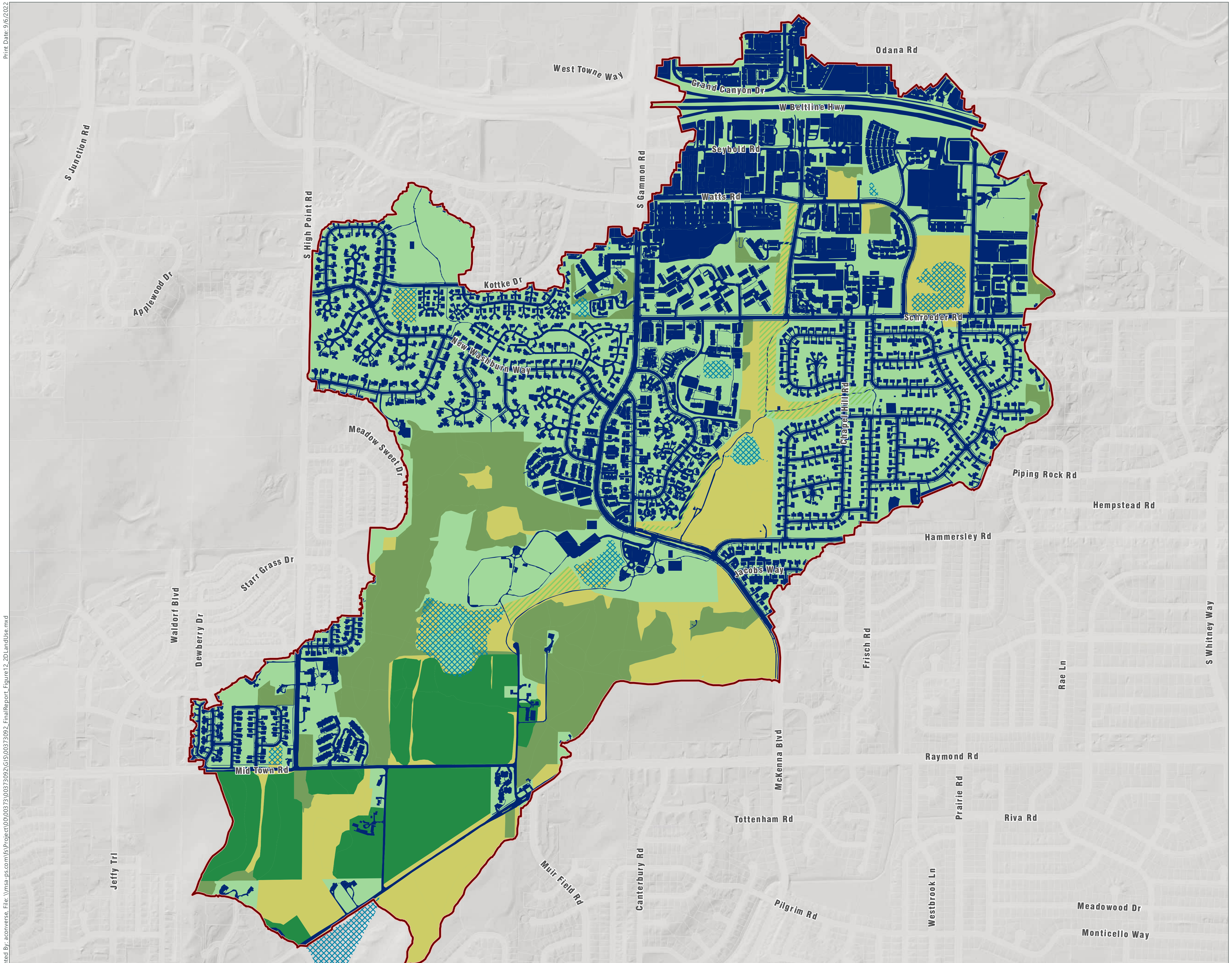
Print Date: 9/6/2022

Printed By: aconverse, File: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure11_SurfaceRoughness.mxd

# 2D Land Use

FIGURE 12
Greentree/McKenna Watershed
Study Report

**City of Madison**
**Dane County, WI**



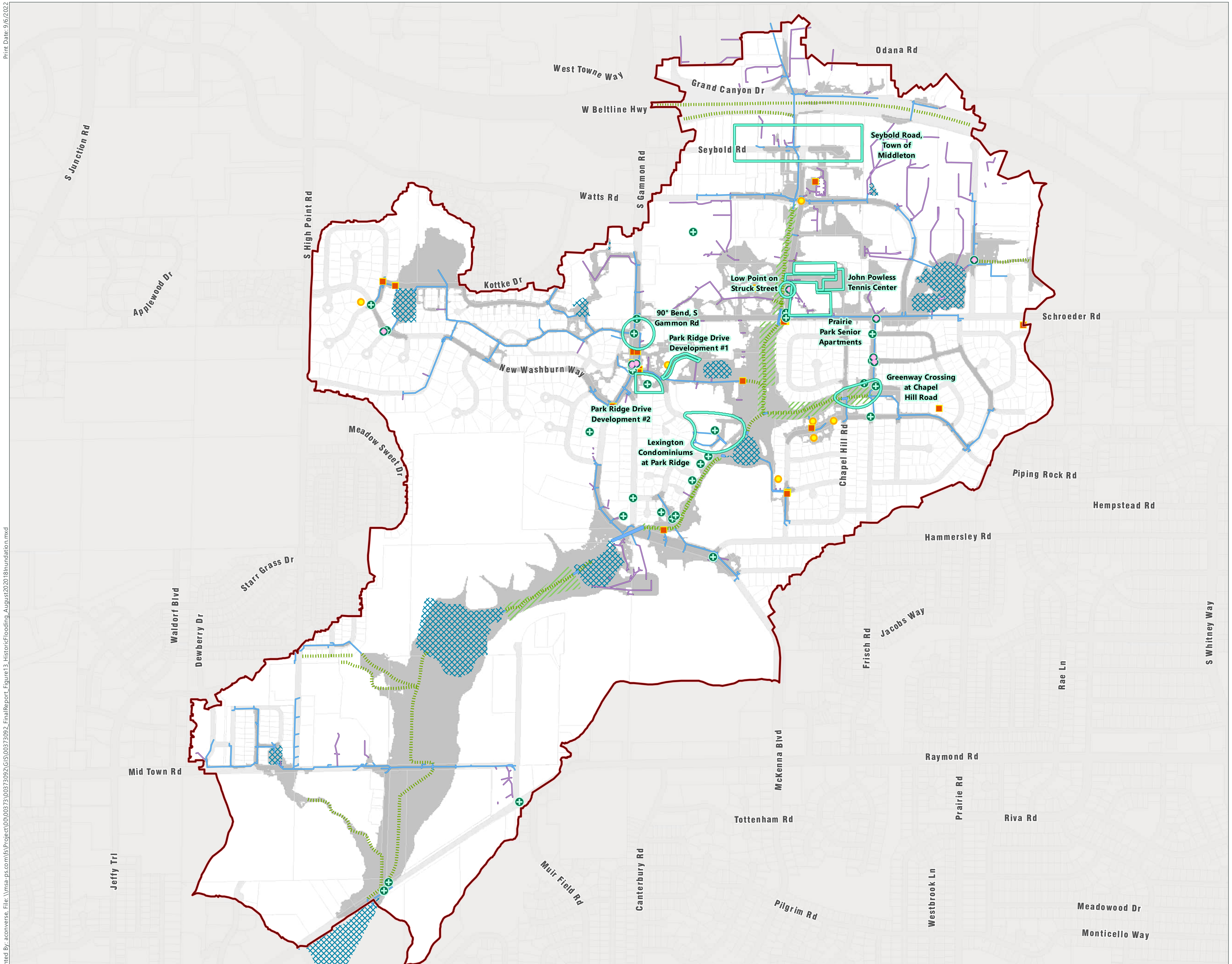

Watershed Study Area
Pervious, Wooded
Pervious, Prairie
Pervious, Agricultural
Pervious, Turf Grass
Impervious
Greenway
Pond

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

MSA

0 550 1,100 Feet

Print Date: 9/6/2022




# 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**

- Innundation 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*

MSA

0 550 1,100 Feet

# 50% AEP Inundation Existing Conditions

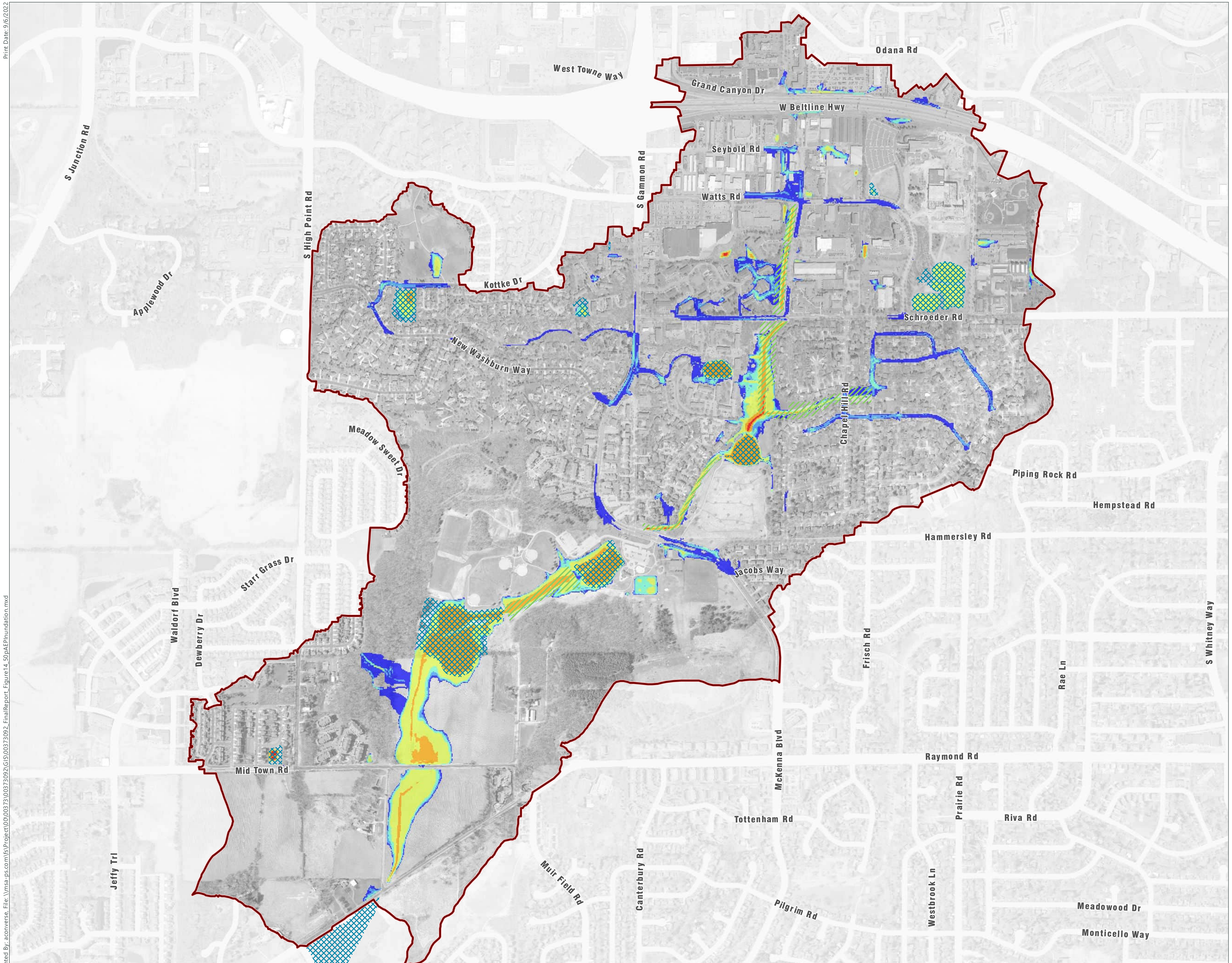



FIGURE 14
Greentree/McKenna Watershed
Study Report

**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*

MSA

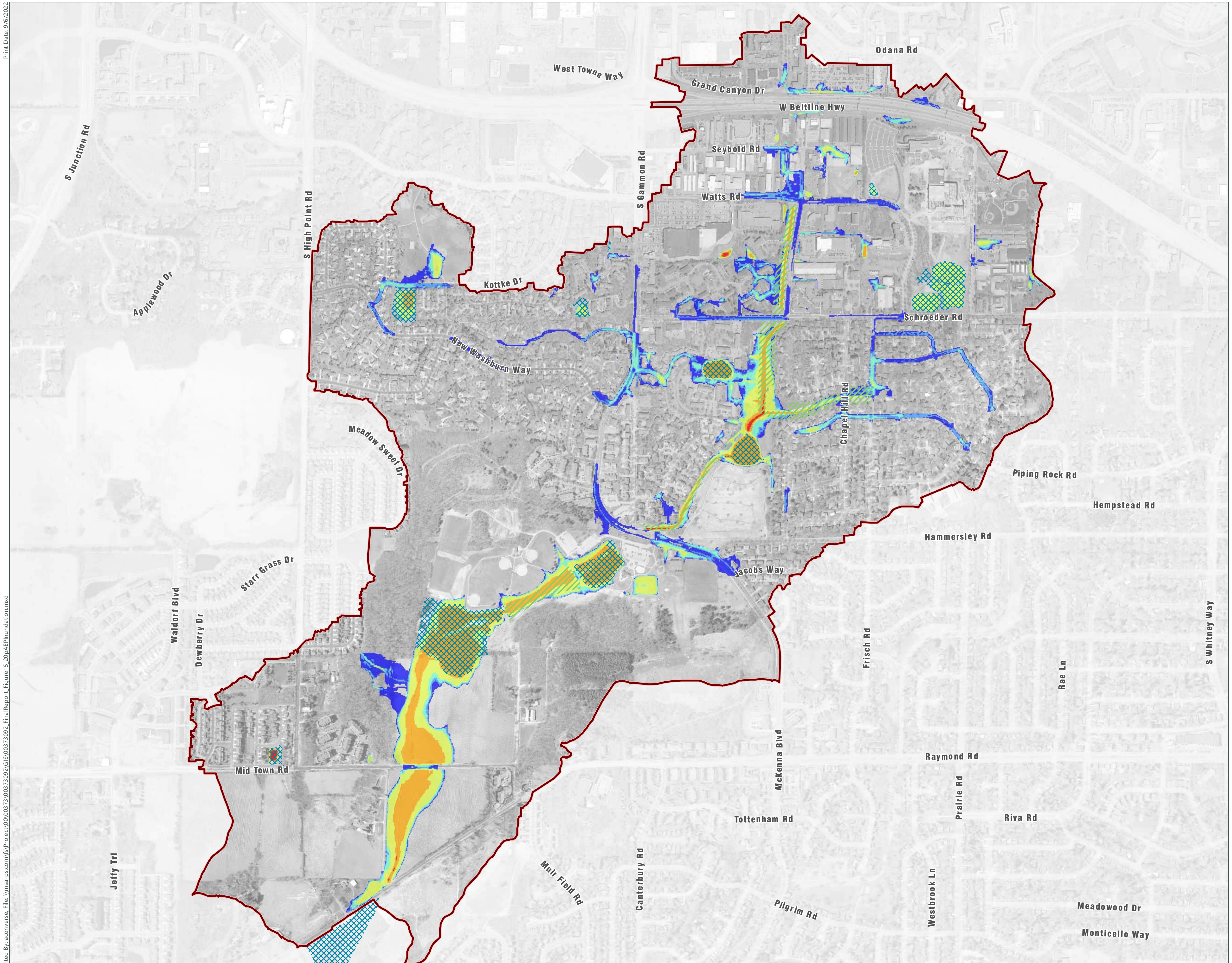
0 550 1,100 Feet

Print Date: 9/6/2022

# 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*

MSA

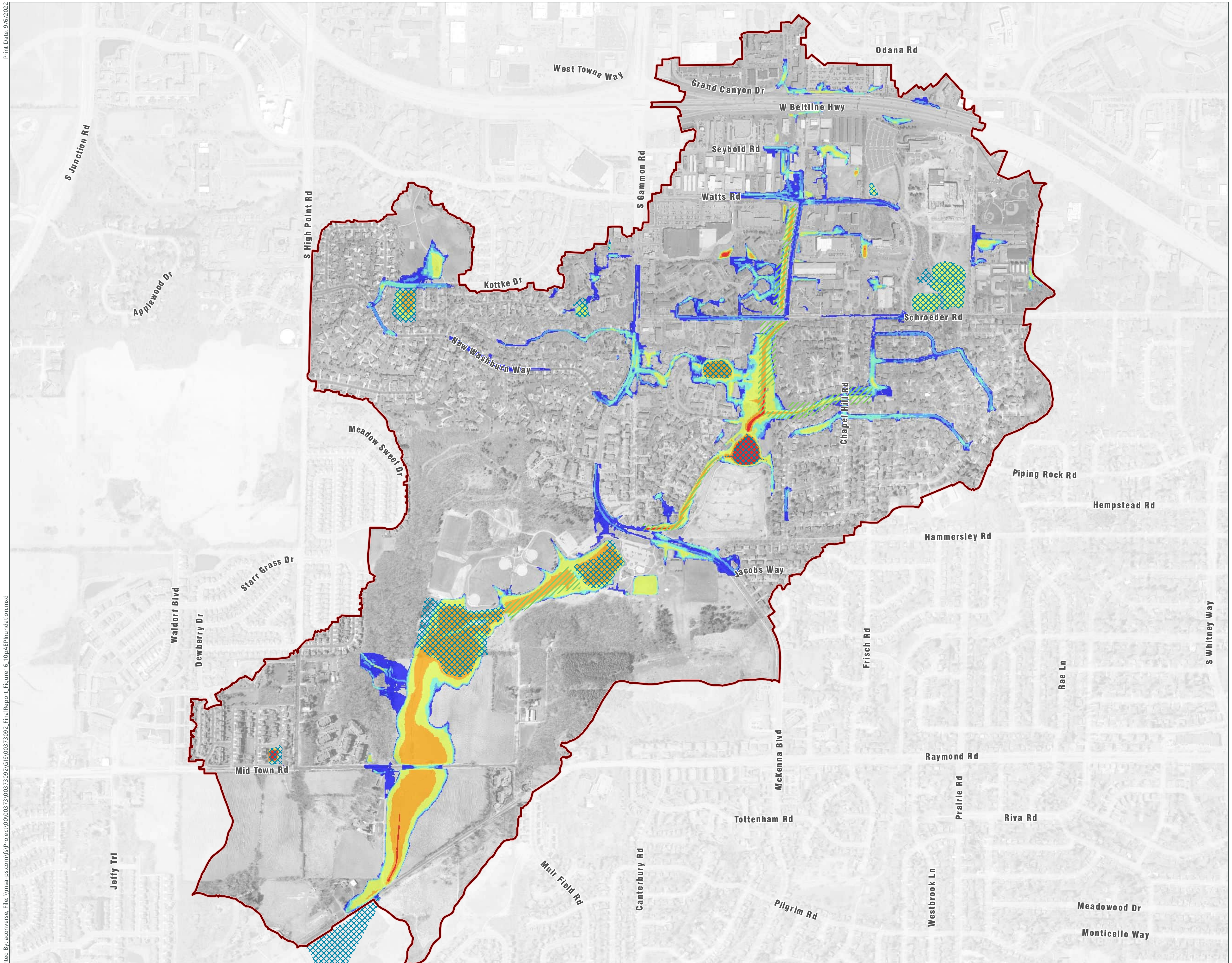
0 550 1,100 Feet

Print Date: 9/6/2022

# 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**

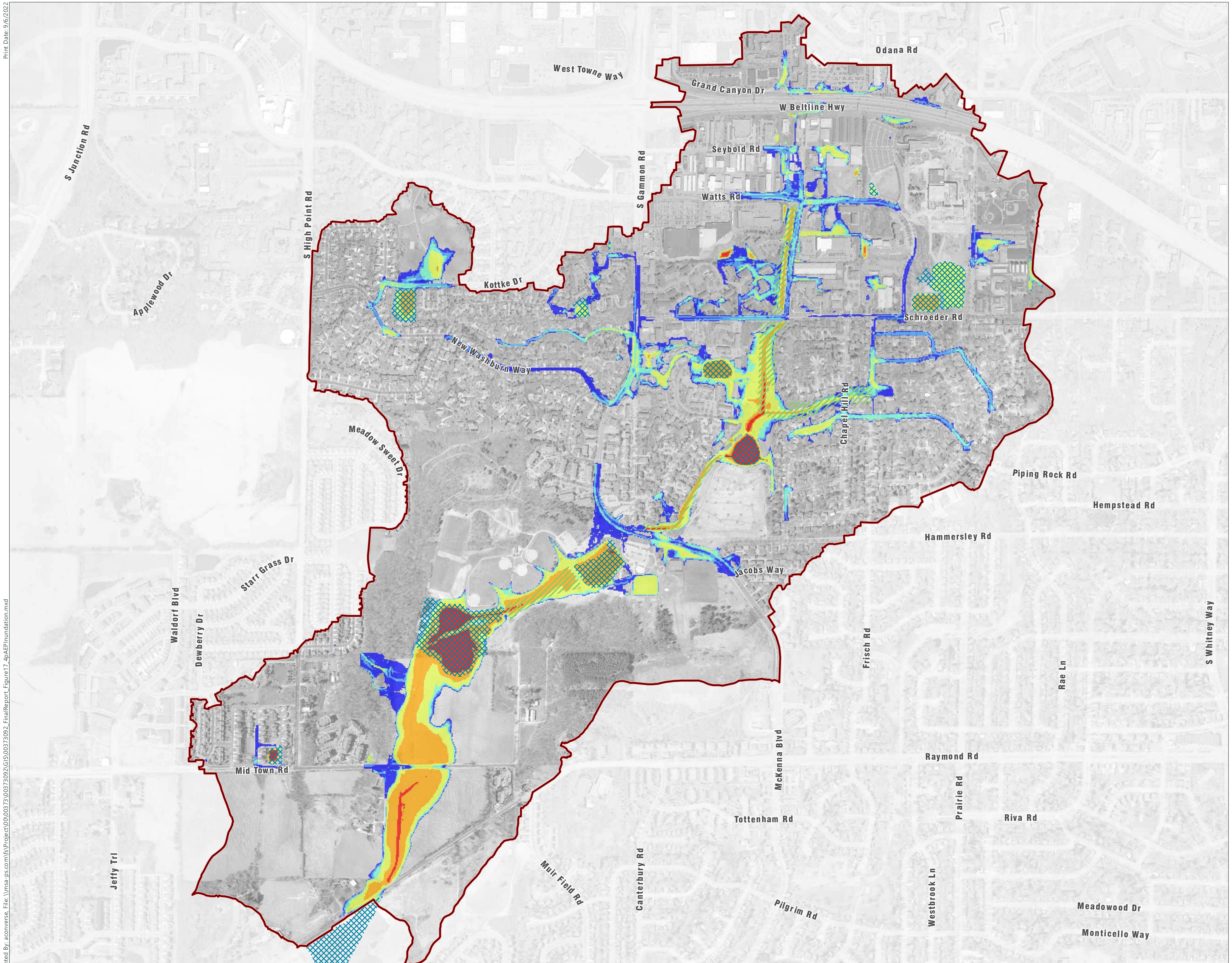
Maximum Water Depth (ft)

- 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*

MSA

0 550 1,100 Feet




# 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*

MSA

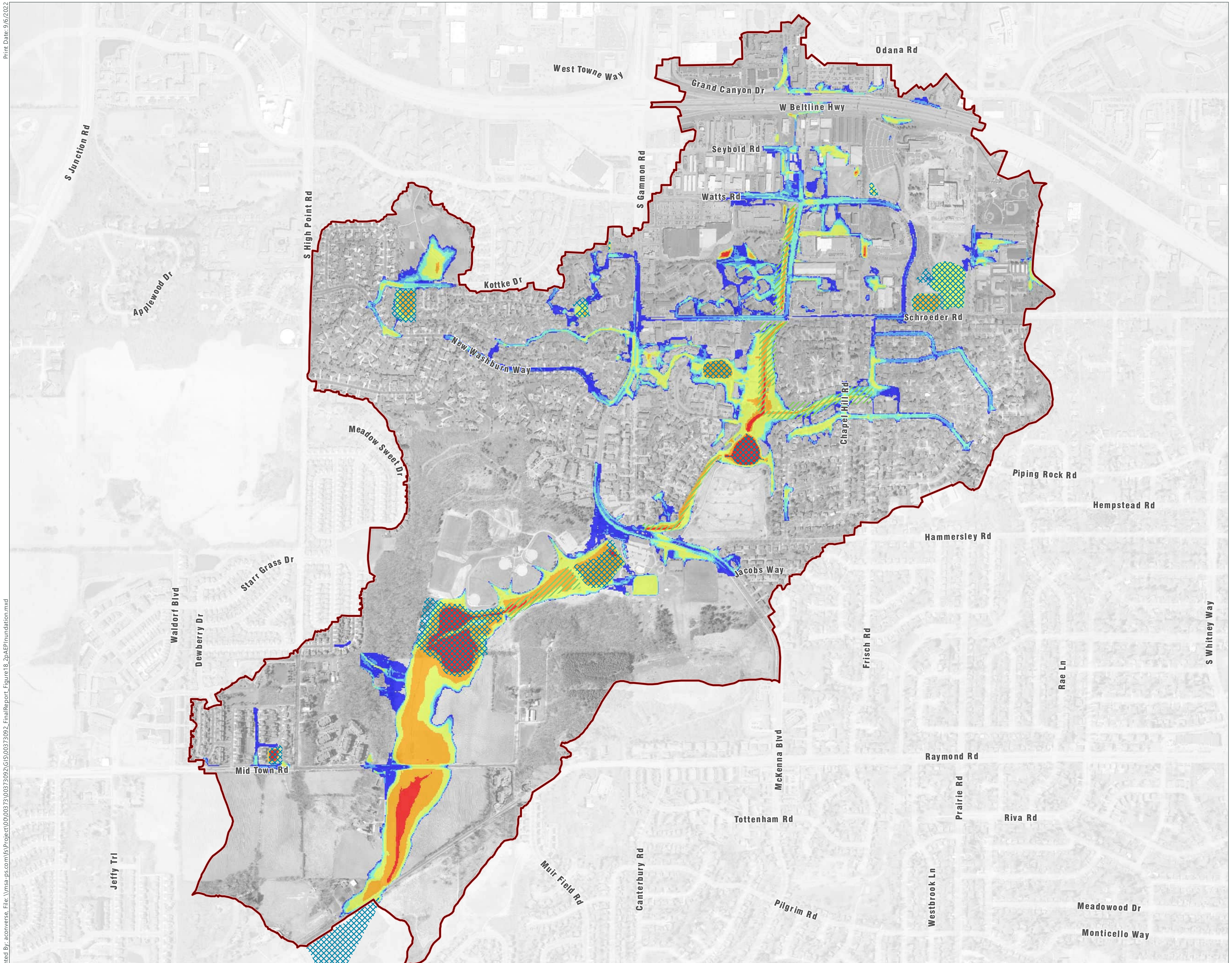
0 550 1,100 Feet

Print Date: 9/6/2022

# 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*

MSA

0 550 1,100 Feet

N

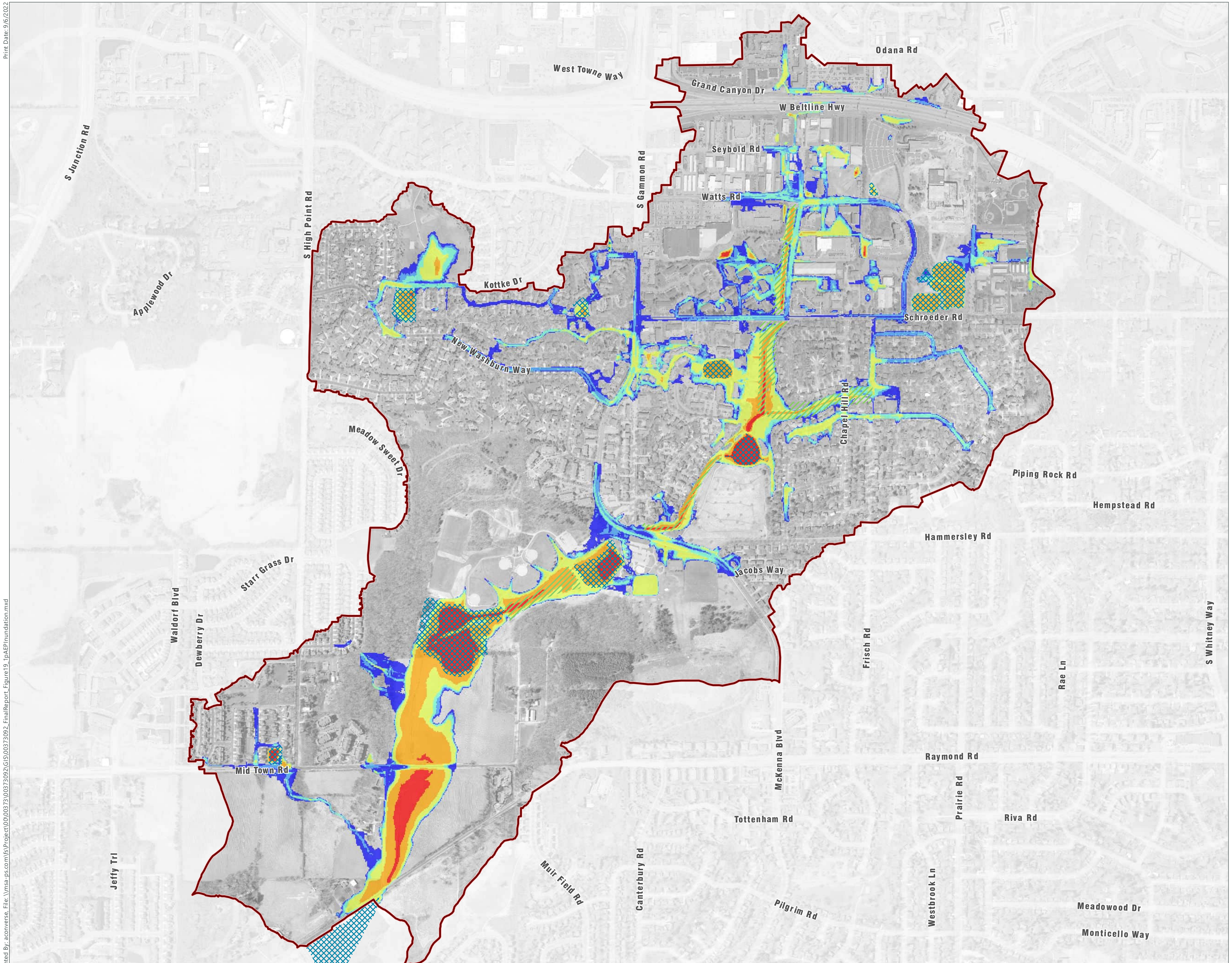
Print Date: 9/6/2022

Printed By: aconverse, File: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure18_2pAEPInundation.mxd

# 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

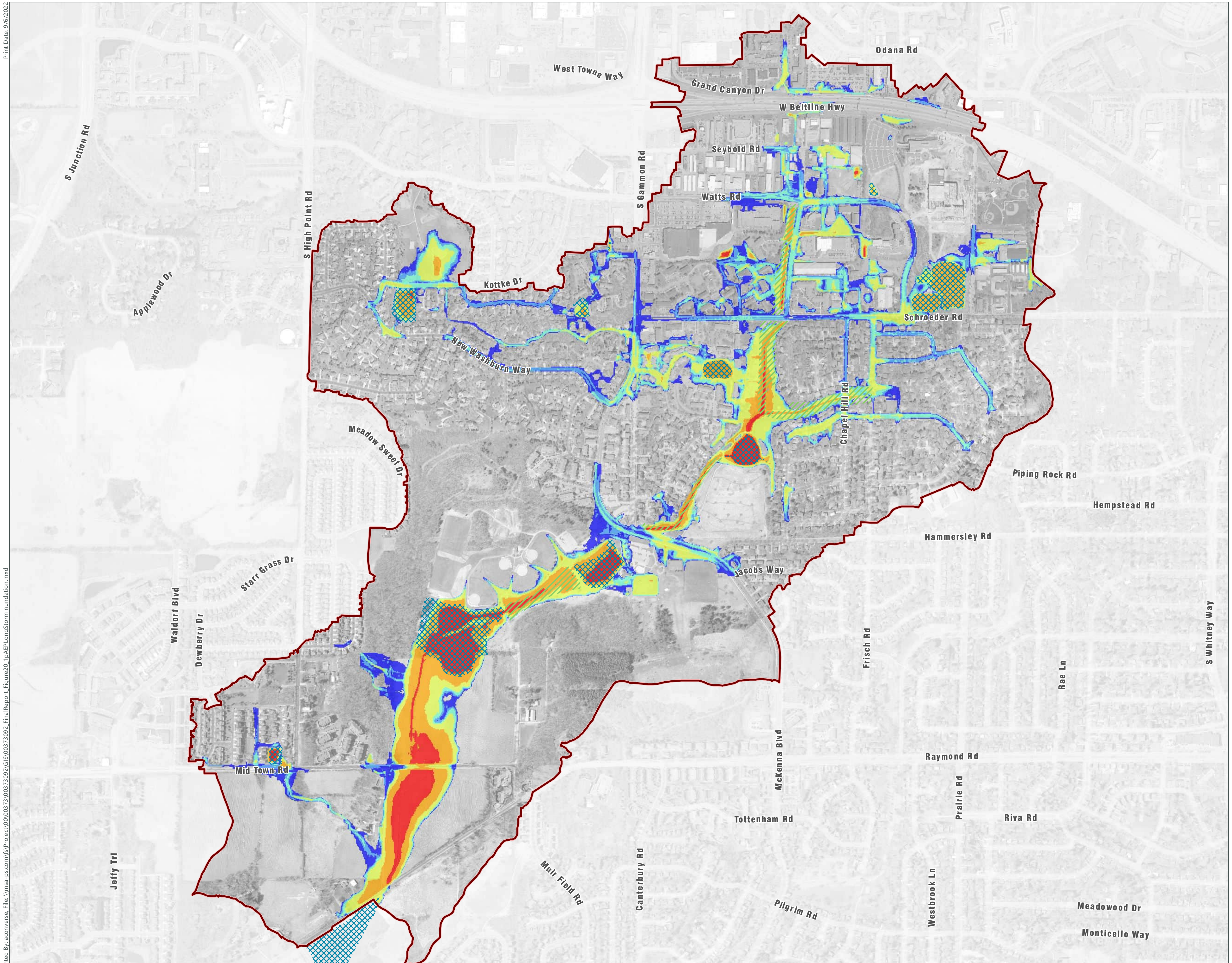
*Data Sources:*
*Aerial: City of Madison (2018)*
*Watershed Boundaries: MSA*
*Stormwater System: City of Madison*

MSA

0 550 1,100 Feet

N

Print Date: 9/6/2022




# Long 1% AEP Inundation Existing Conditions

FIGURE 20
Greentree/McKenna Watershed Study Report

**City of Madison**
**Dane County, WI**

Watershed Study Area
Greenway
Pond

**1% Long AEP Storm**

Maximum Water Depth (ft)

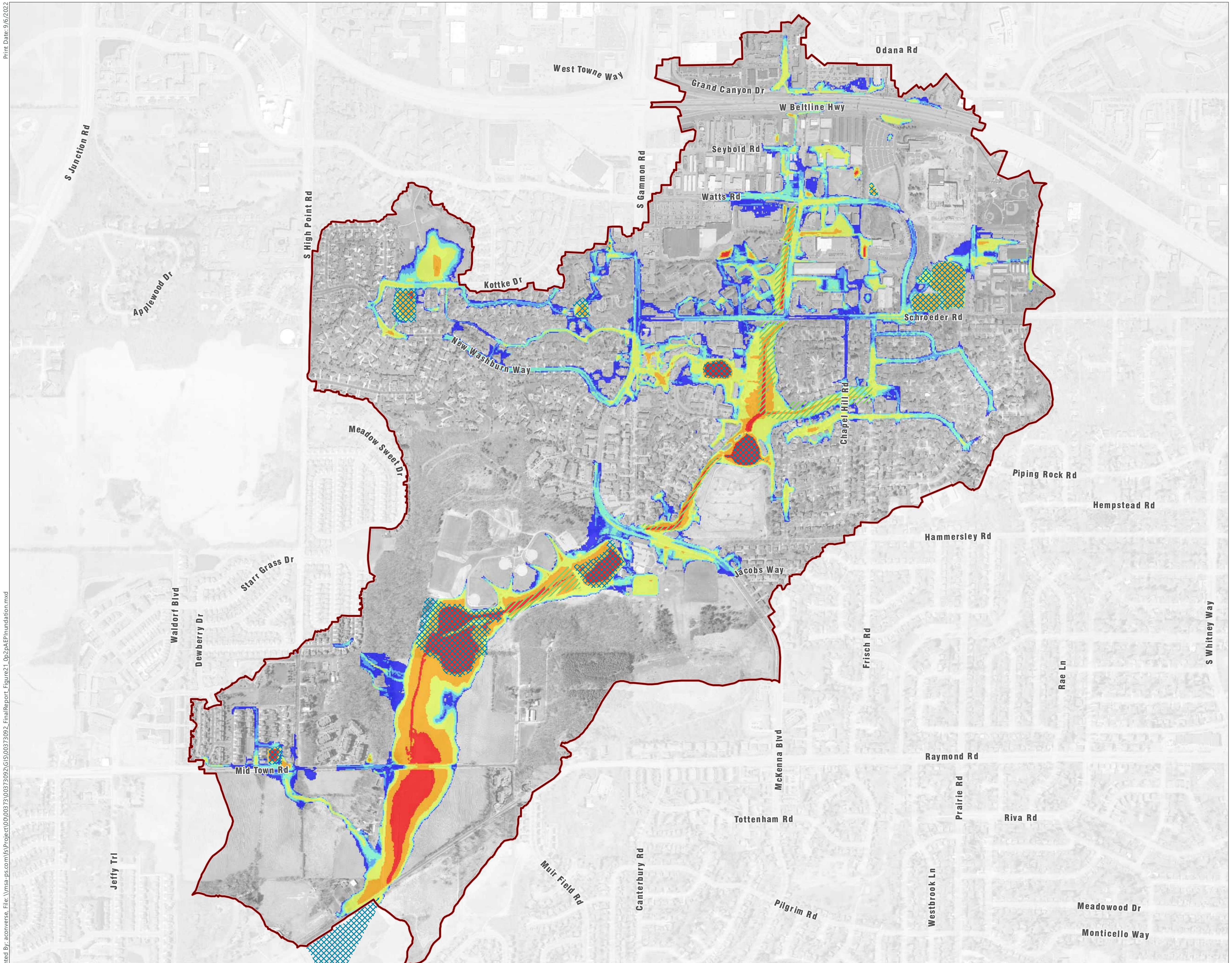
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

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

MSA

0 550 1,100 Feet

Print Date: 9/6/2022




# 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*

MSA

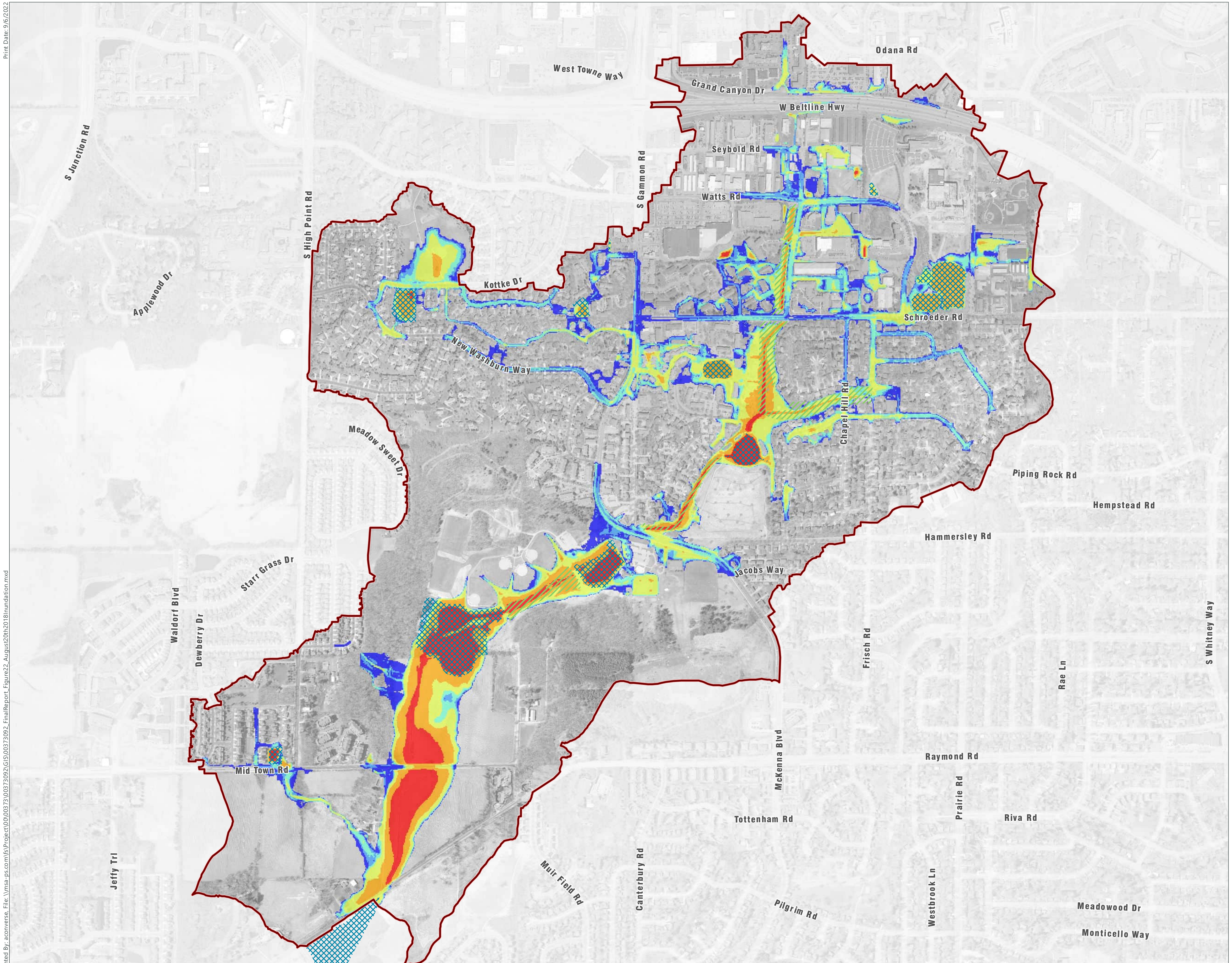
0 550 1,100 Feet

Print Date: 9/6/2022

# 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

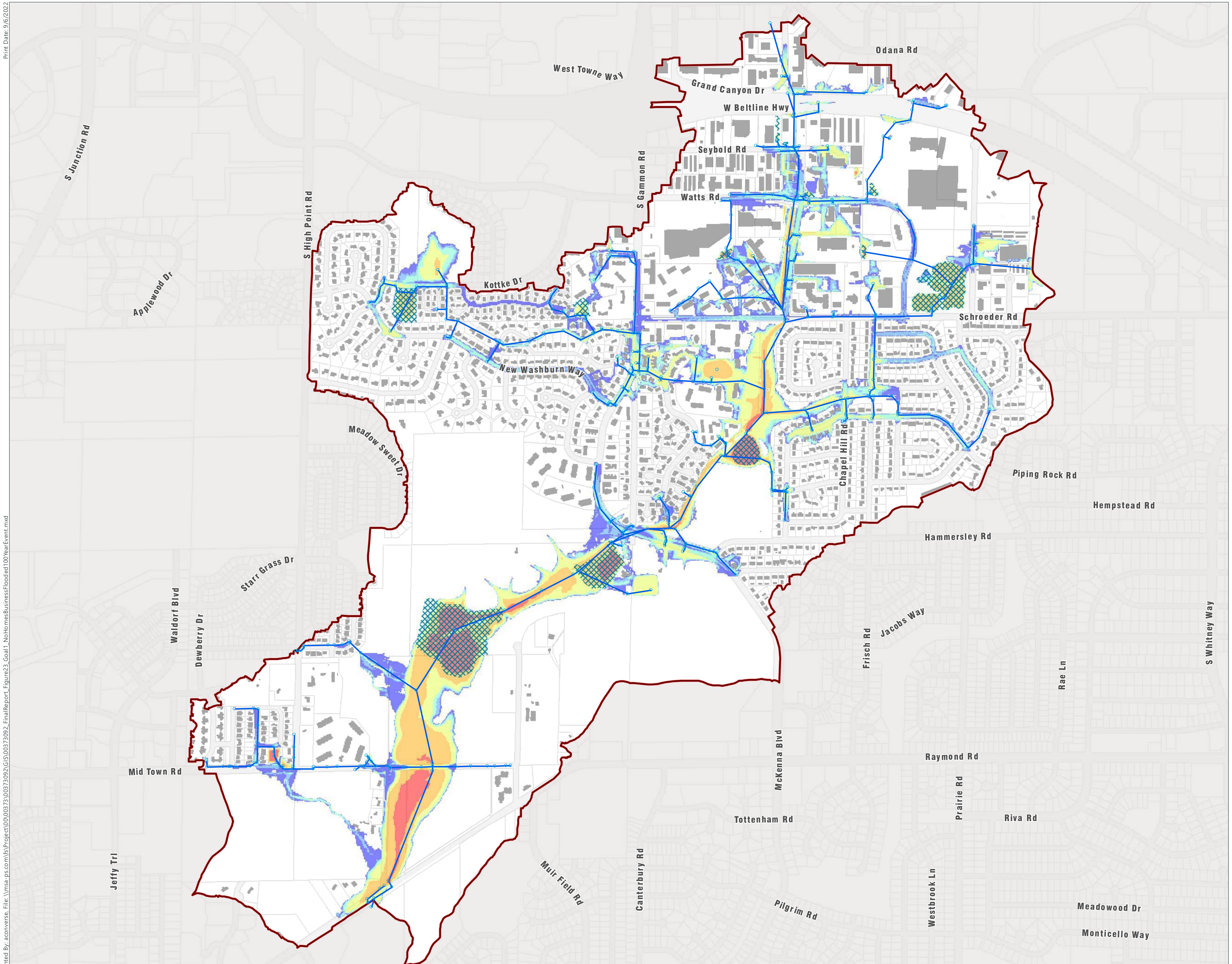
> 6

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

MSA

0 550 1,100 Feet

Print Date: 9/6/2022




# 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**

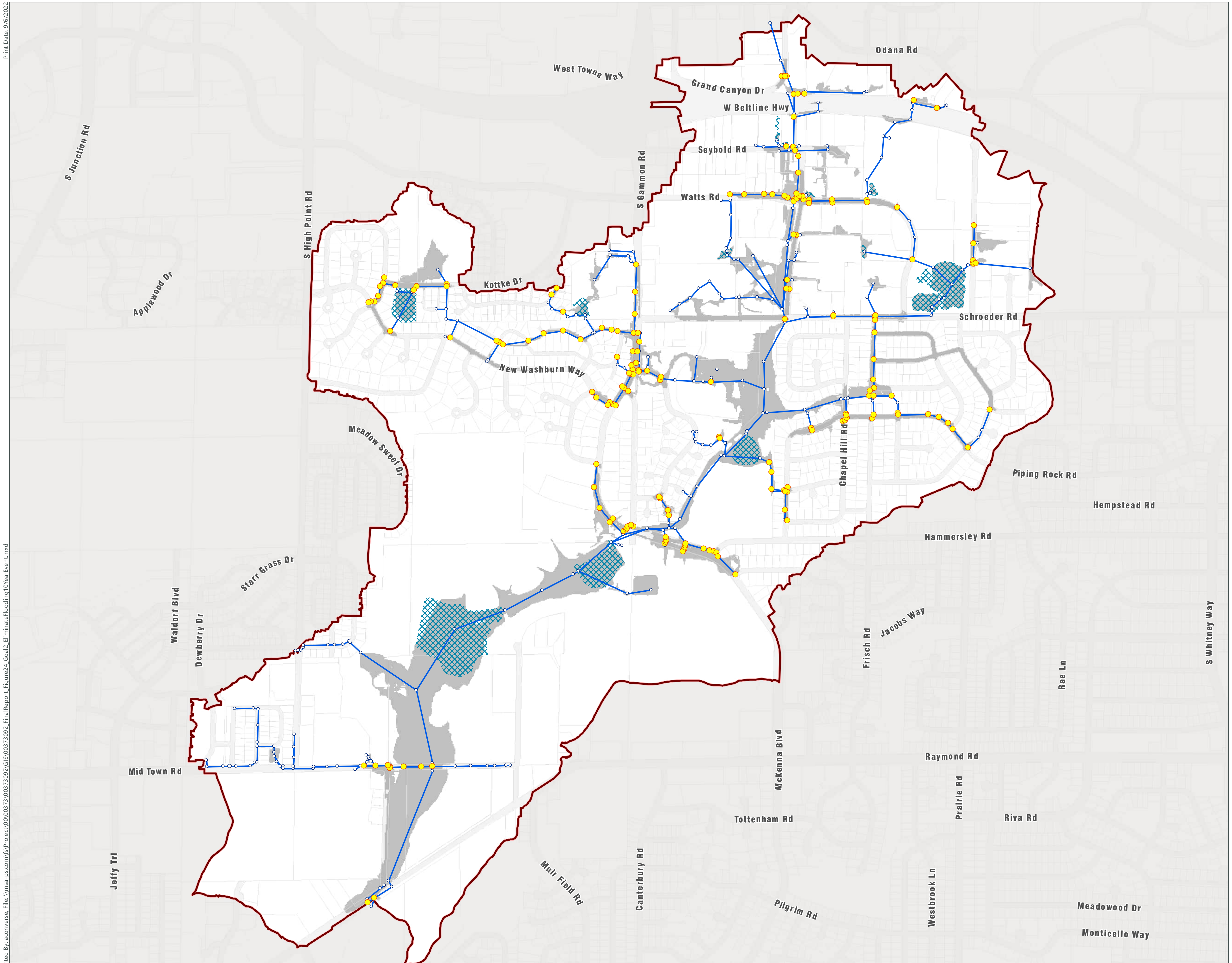
Maximum Water Depth (ft)

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.*

MSA

0 550 1,100 Feet




# 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

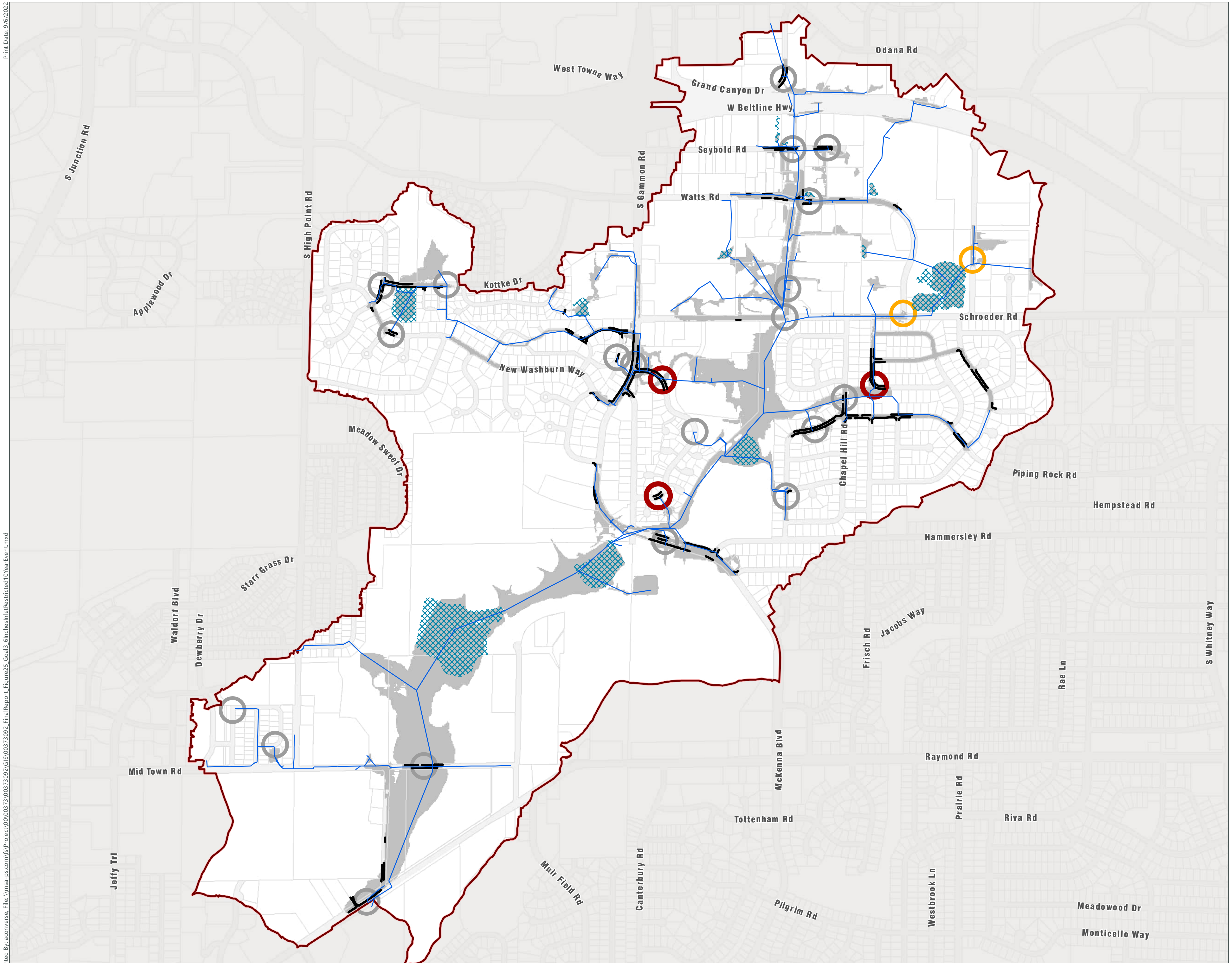
*Data Sources:*
*Watershed Boundaries: MSA*
*Stormwater System: City of Madison*

MSA

0 550 1,100 Feet

N

Print Date: 9/6/2022




# 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**

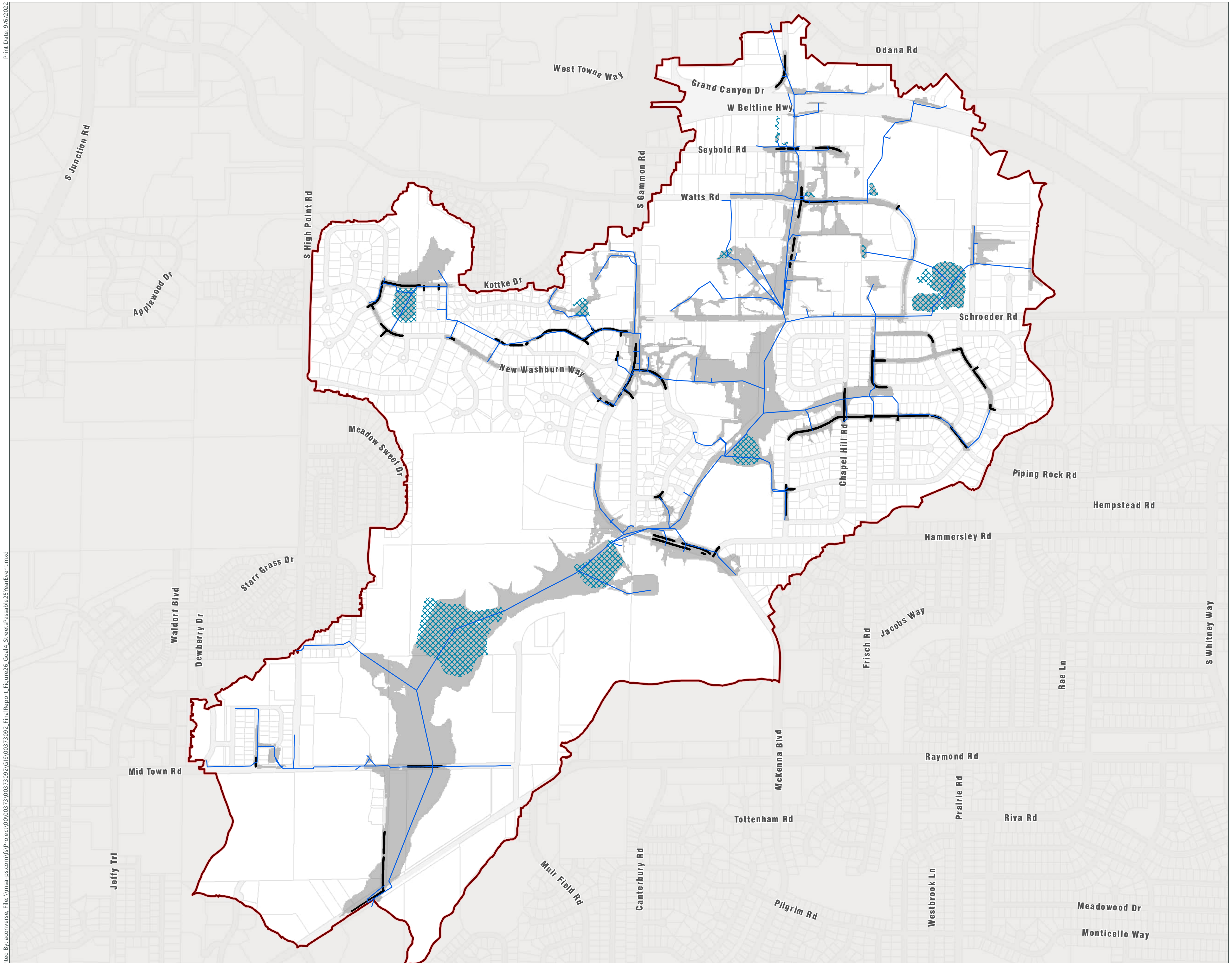
Innundation Extent
6" or Greater Innundation on Curbline
Sag Location, Not inlet restricted
Sag Location, Inlet restricted
Sag Location, Inlet restricted, 0.5' water at curb

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

MSA

0 550 1,100 Feet

Print Date: 9/6/2022




# 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**

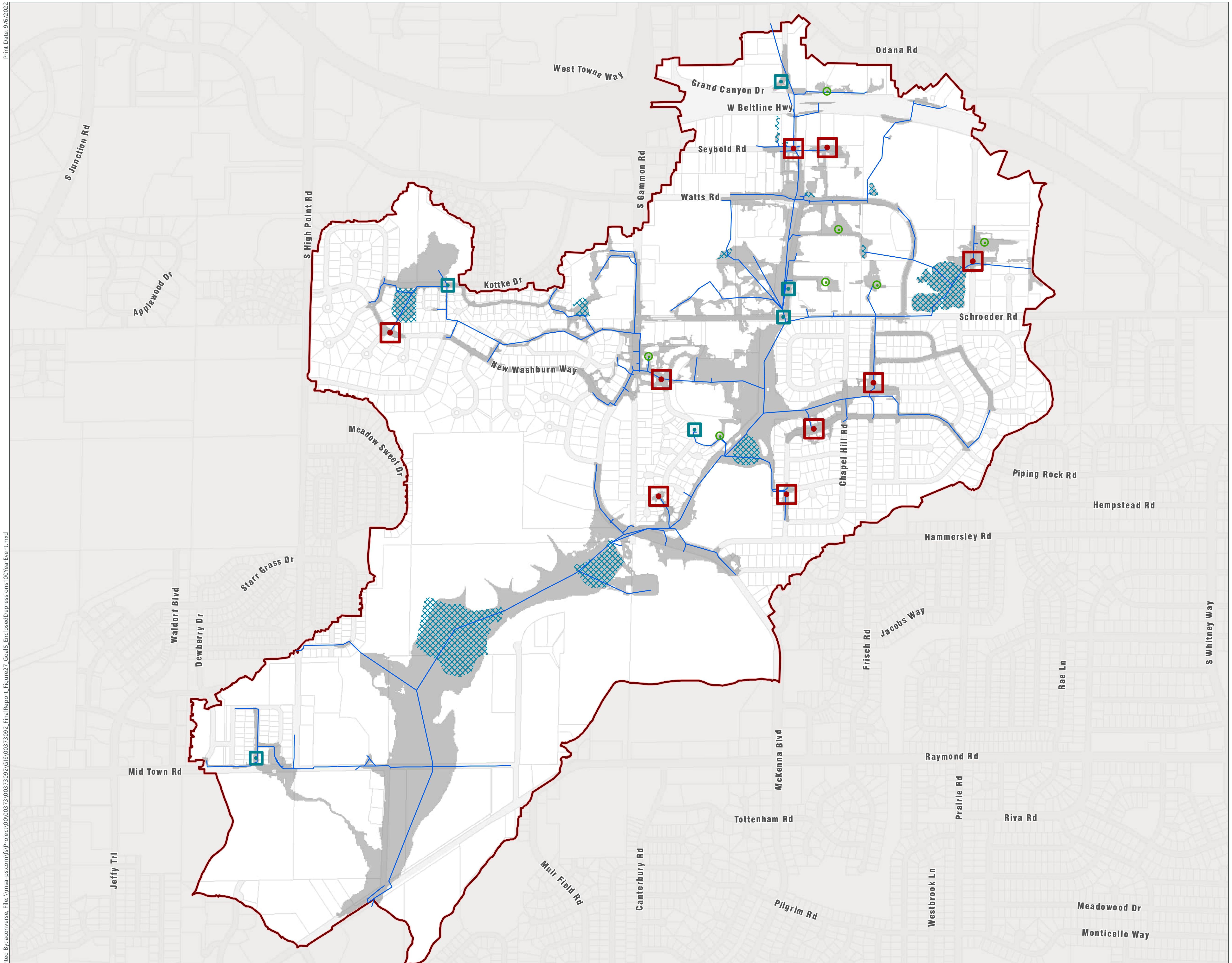
Innundation Extent
More than 0.5-ft Water at Centerline

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

MSA

0 550 1,100 Feet

N




# 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

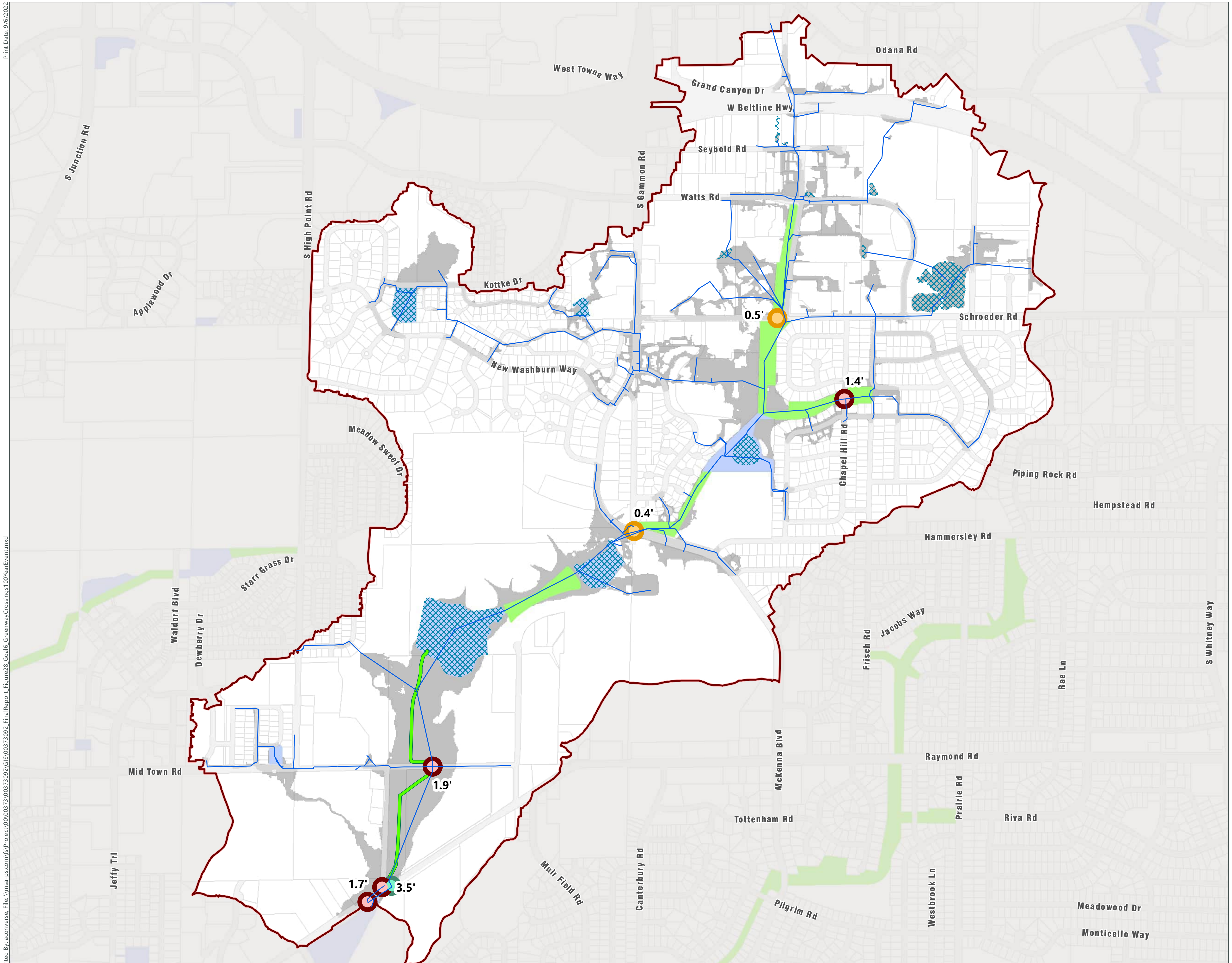
Innundation Extent

*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*

MSA

0 550 1,100 Feet




# 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**

Innundation Extent

Pond

Greenway

Overland Flow

Greenway Crossing*

Water on Road from Greenway

Flooding caused by street flow, not greenway overtopping

No Water on Road

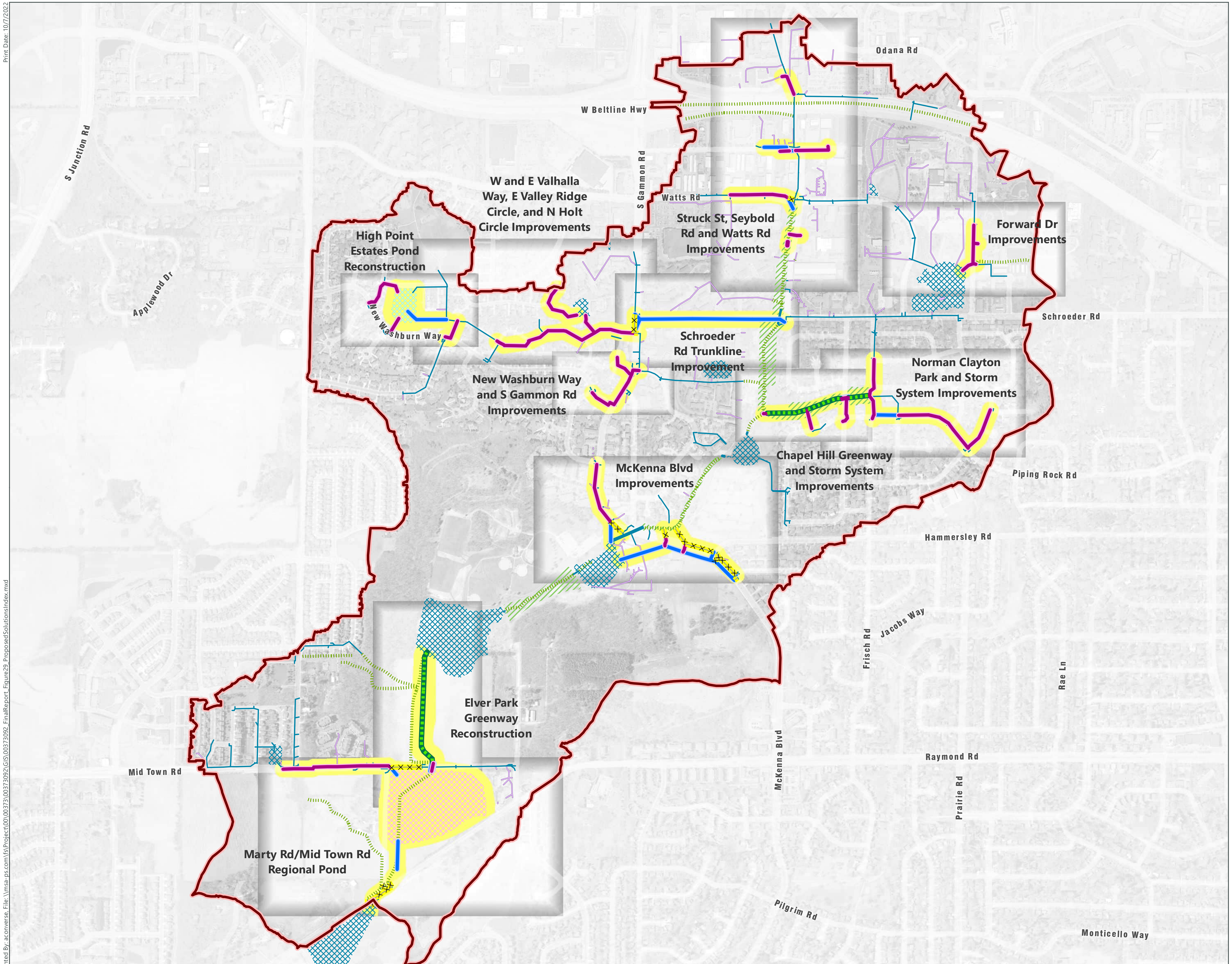
*Note: This map depicts greenway crossings where there is water over the road under 1% AEP storm. Most of these occurrences are due to water flowing over the road from one side of a greenway to the other side. However, some locations have water on the road due to flow accumulations in the street due 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*

MSA

0 550 1,100 Feet

Print Date: 9/6/2022




# 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**

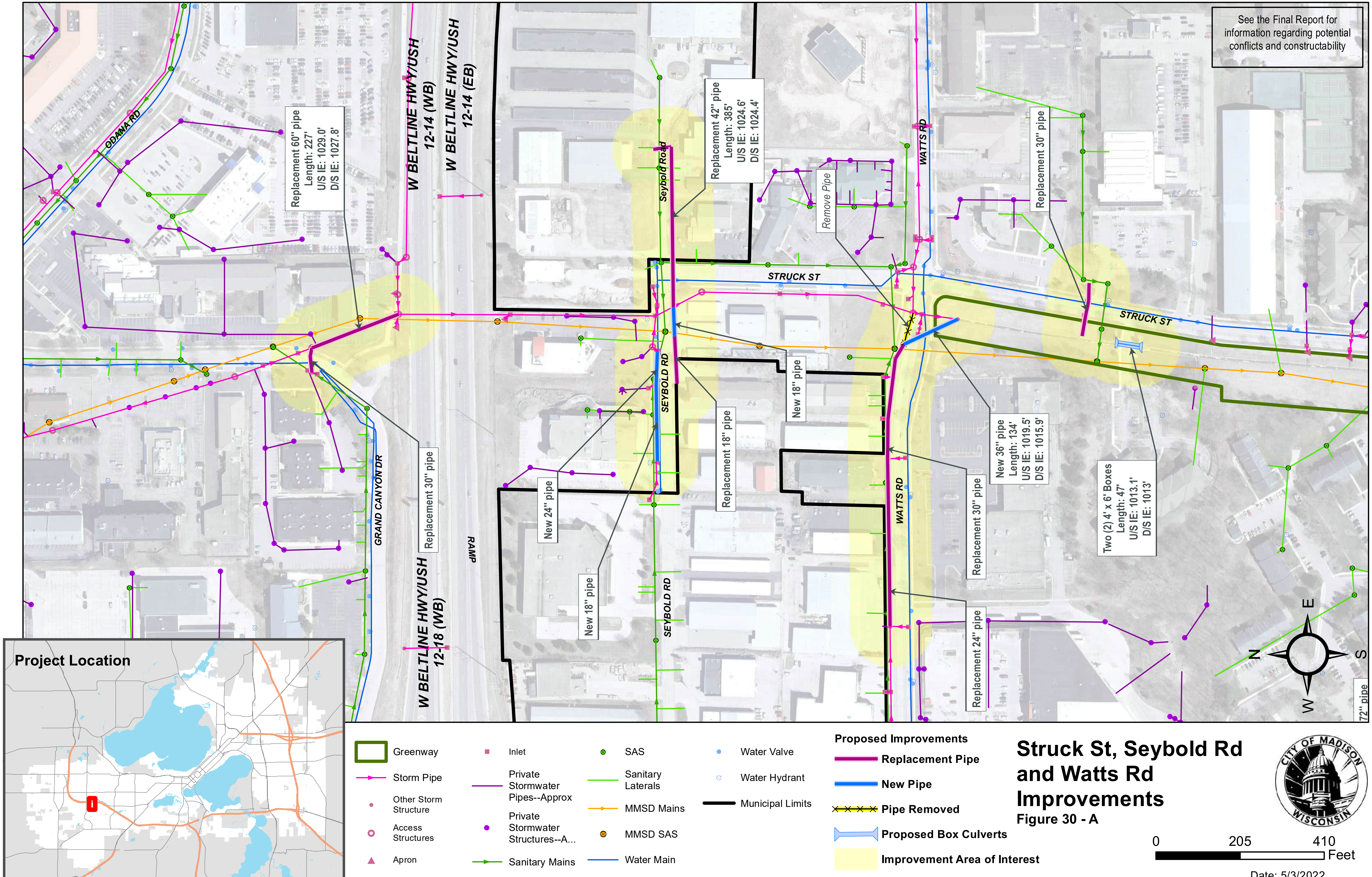
- Replacement Pipe
- New Pipe
- Channel Grading/Alignment
- Pipe Removed
- Proposed Marty Rd/Mid Town Rd Regional Pond
- Retrofitted High Point Estates Pond
- Improvement Area of Interest
- Map Extents (Figures 30 A-K)

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

MSA

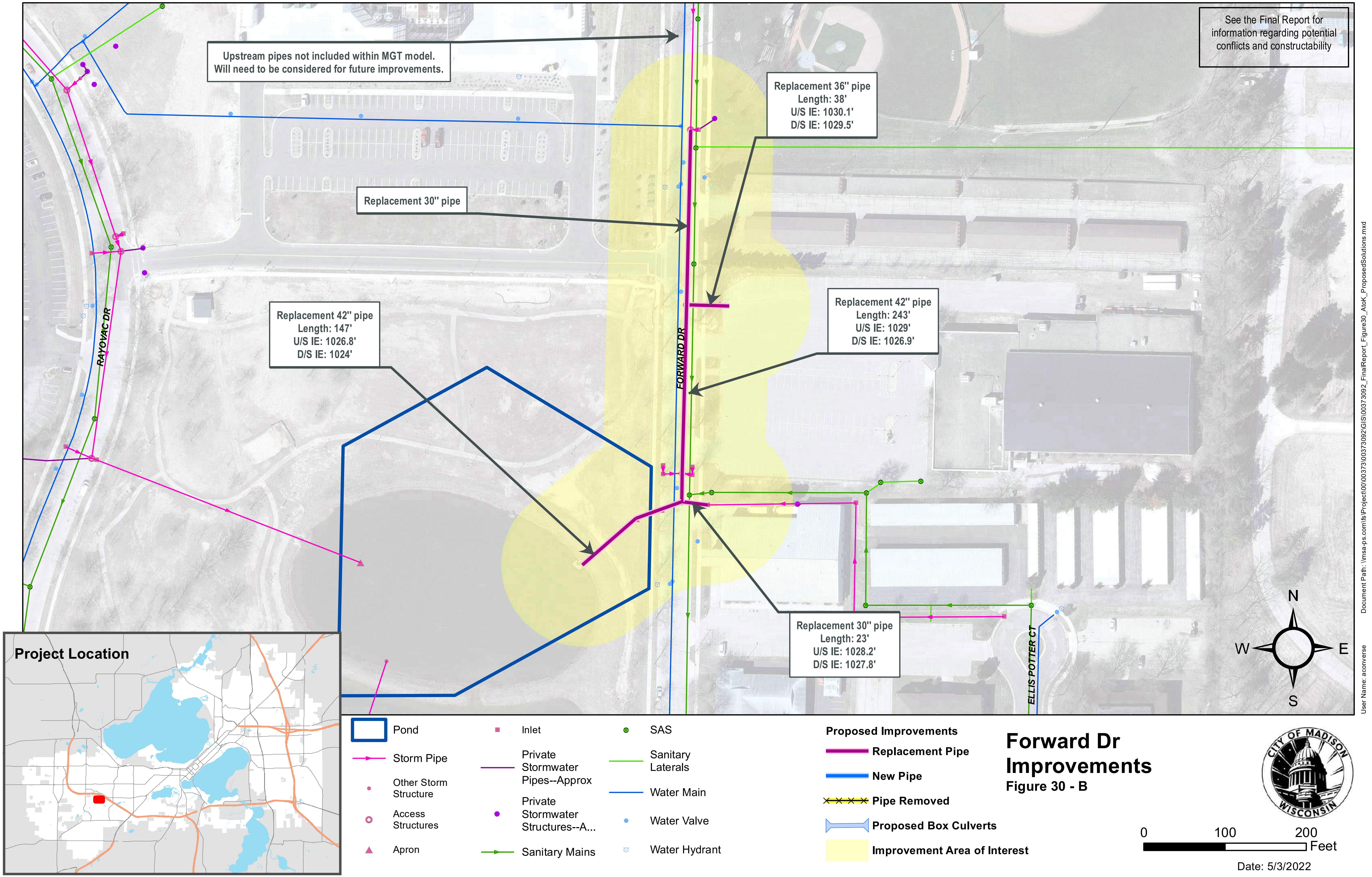
0 550 1,100 Feet

Print Date: 10/7/2022

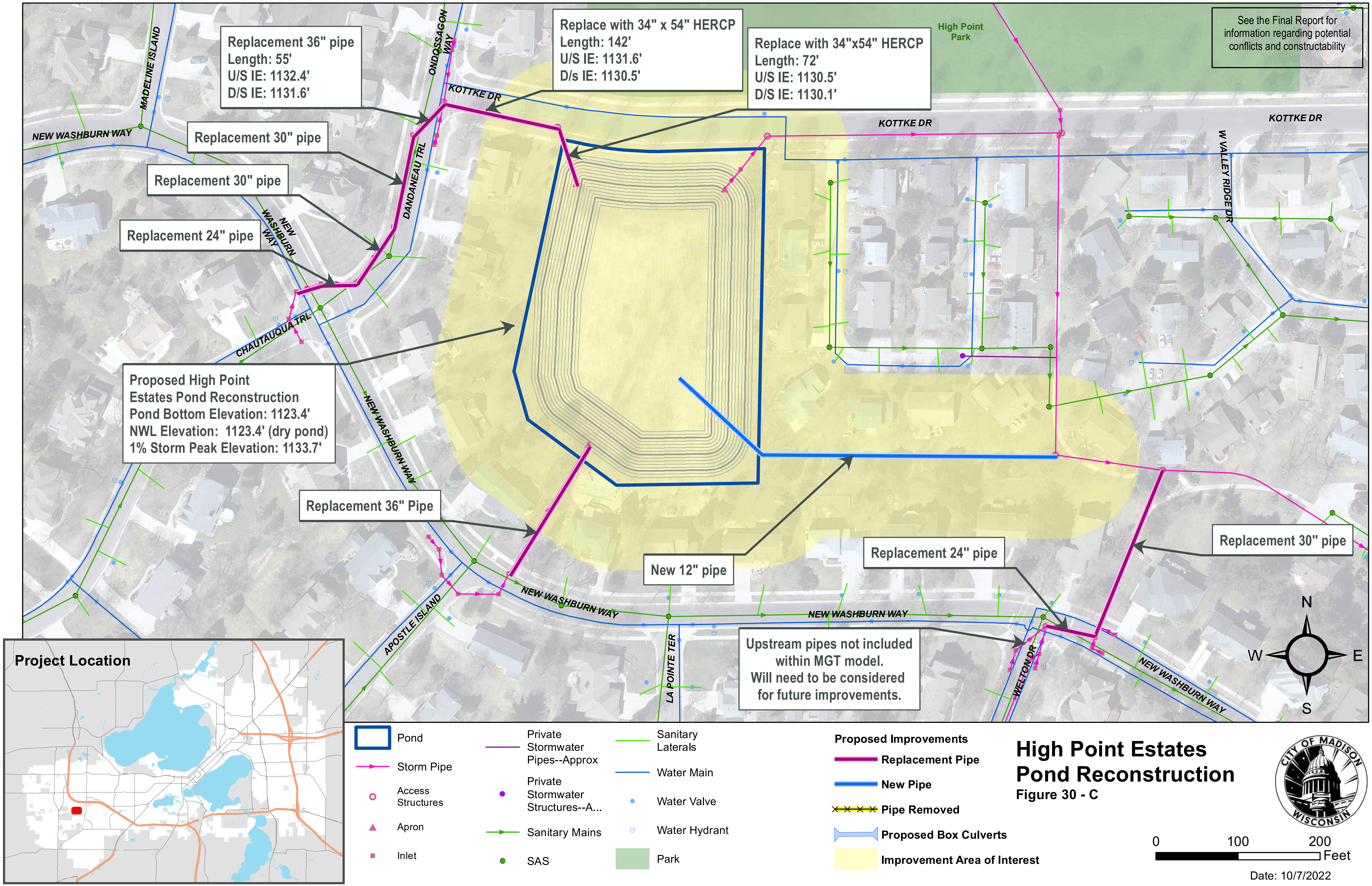



**Struck St, Seybold Rd and Watts Rd Improvements**

**Figure 30 - A**

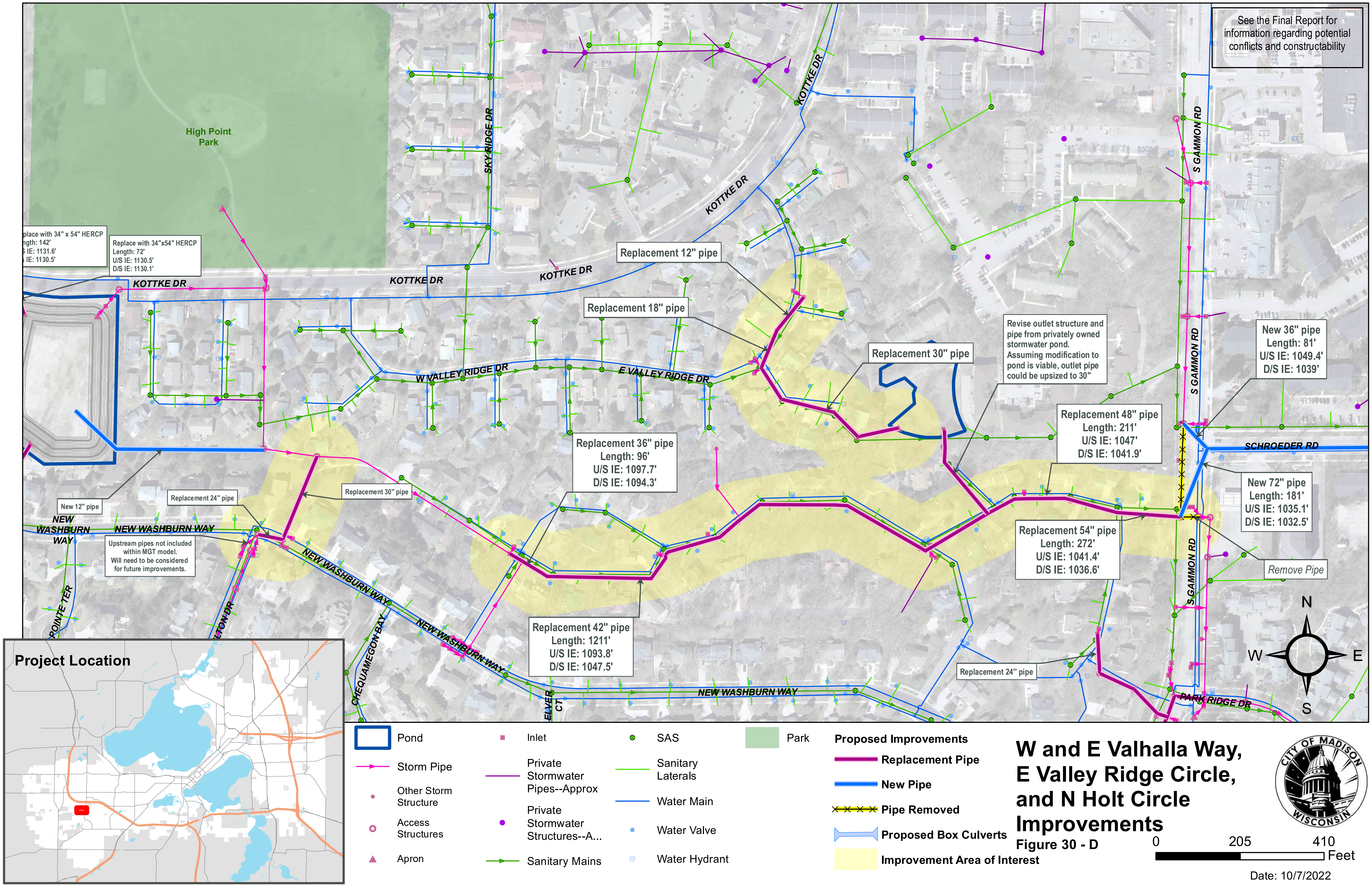


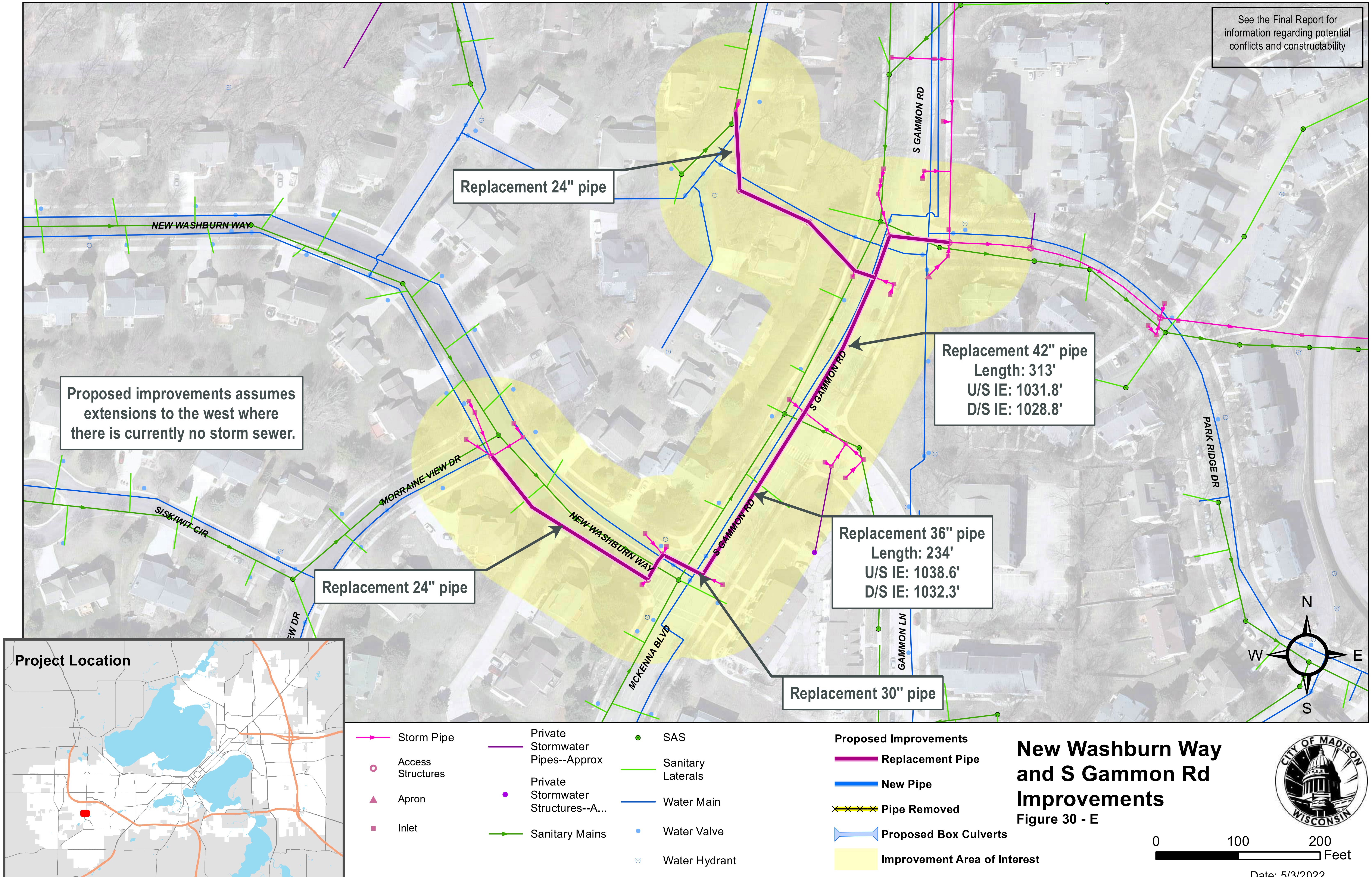
Upstream pipes not included within MGT model. Will need to be considered for future improvements.
See the Final Report for information regarding potential conflicts and constructability
Replacement 36" pipe
Length: 38'
U/S IE: 1030.1'
D/S IE: 1029.5'
Replacement 30" pipe
Replacement 42" pipe
Length: 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'
RAYOVAC DR
FORWARD DR
ELLIS POTTER CT
N
W
E
S
Project Location
Pond
Storm Pipe
Other Storm Structure
Access Structures
Apron
Inlet
Private Stormwater Pipes--Approx
Private Stormwater Structures--A...
Sanitary Mains
SAS
Sanitary Laterals
Water Main
Water Valve
Water Hydrant
Proposed Improvements
Replacement Pipe
New Pipe
Pipe Removed
Proposed Box Culverts
Improvement Area of Interest
Forward Dr Improvements
Figure 30 - B
0
100
200
Feet
Date: 5/3/2022
CITY OF MADISON WISCONSIN
Document Path: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure30_AtoK_ProposedSolutions.mxd
User Name: aconverse




## High Point Estates Pond Reconstruction

Figure 30 - C

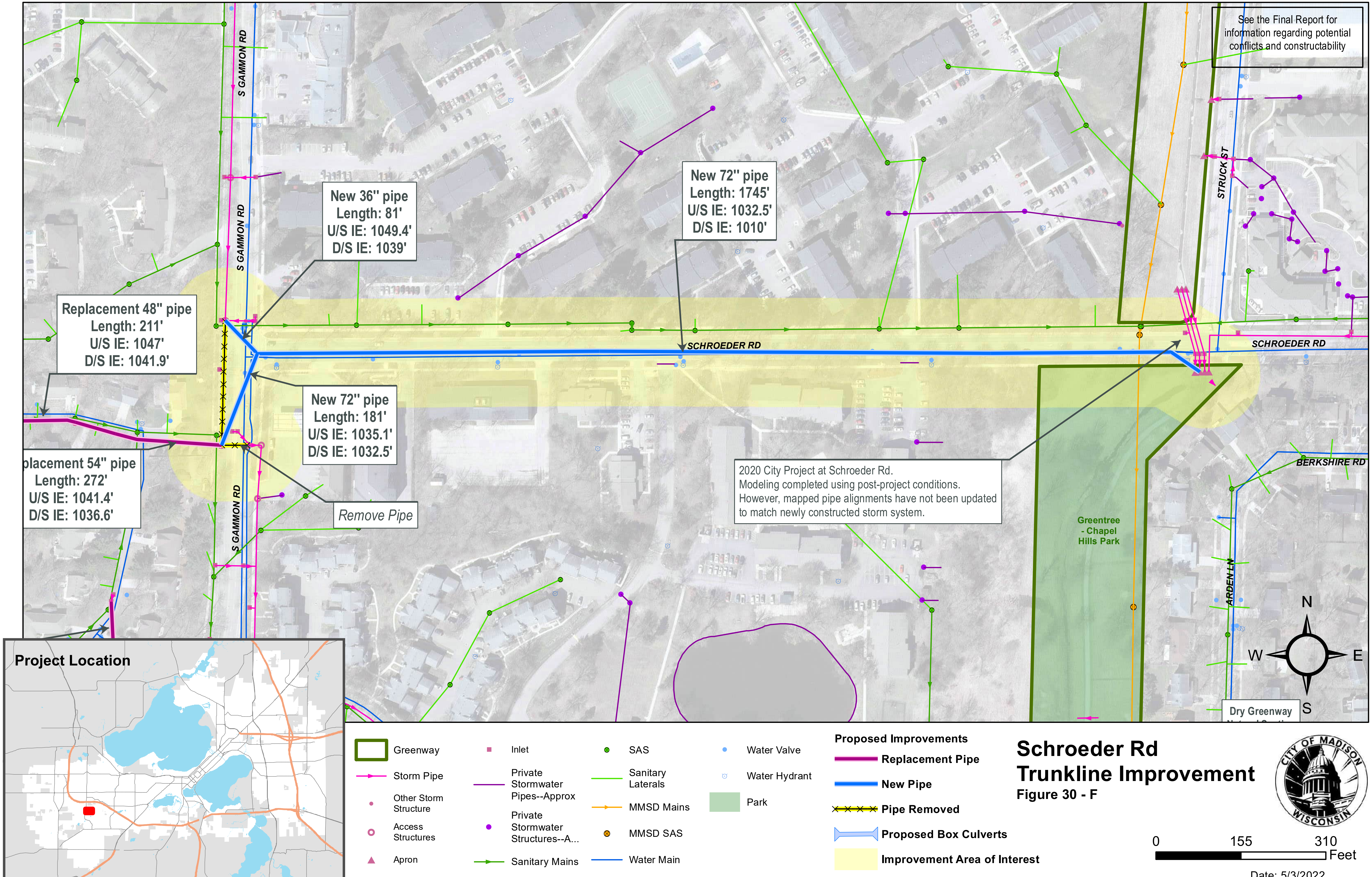

See the Final Report for information regarding potential conflicts and constructability
High Point Park
place with 34" x 54" HERCP
ngth: 142'
S IE: 1131.6'
s IE: 1130.5'
Replace with 34"x54" HERCP
Length: 72'
U/S IE: 1130.5'
D/S IE: 1130.1'
KOTTKE DR
SKY RIDGE DR
KOTTKE DR
W VALLEY RIDGE DR
E VALLEY RIDGE DR
Replacement 12" pipe
Replacement 18" pipe
Replacement 30" pipe
Revise outlet structure and pipe from privately owned stormwater pond. Assuming modification to pond is viable, outlet pipe could be upsized to 30"
New 36" pipe
Length: 81'
U/S IE: 1049.4'
D/S IE: 1039'
S GAMMON RD
Replacement 48" pipe
Length: 211'
U/S IE: 1047'
D/S IE: 1041.9'
SCHROEDER RD
New 72" pipe
Length: 181'
U/S IE: 1035.1'
D/S IE: 1032.5'
Replacement 36" pipe
Length: 96'
U/S IE: 1097.7'
D/S IE: 1094.3'
Replacement 24" pipe
Replacement 30" pipe
New 12" pipe
NEW WASHBURN WAY
Upstream pipes not included within MGT model. Will need to be considered for future improvements.
Replacement 54" pipe
Length: 272'
U/S IE: 1041.4'
D/S IE: 1036.6'
Remove Pipe
Replacement 42" pipe
Length: 1211'
U/S IE: 1093.8'
D/S IE: 1047.5'
Replacement 24" pipe
POINTE TER
CHEQUAMEGON BAY
PARK RIDGE DR
N
W
E
S
Project Location
Pond
Storm Pipe
Other Storm Structure
Access Structures
Apron
Inlet
Private Stormwater Pipes--Approx
Private Stormwater Structures--A...
Sanitary Mains
SAS
Sanitary Laterals
Water Main
Water Valve
Water Hydrant
Park
Proposed Improvements
Replacement Pipe
New Pipe
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
0
205
410
Feet
Date: 10/7/2022
CITY OF MADISON WISCONSIN
Document Path: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure30_AtoK_ProposedSolutions.mxd
User Name: aconverse




**New Washburn Way and S Gammon Rd Improvements**

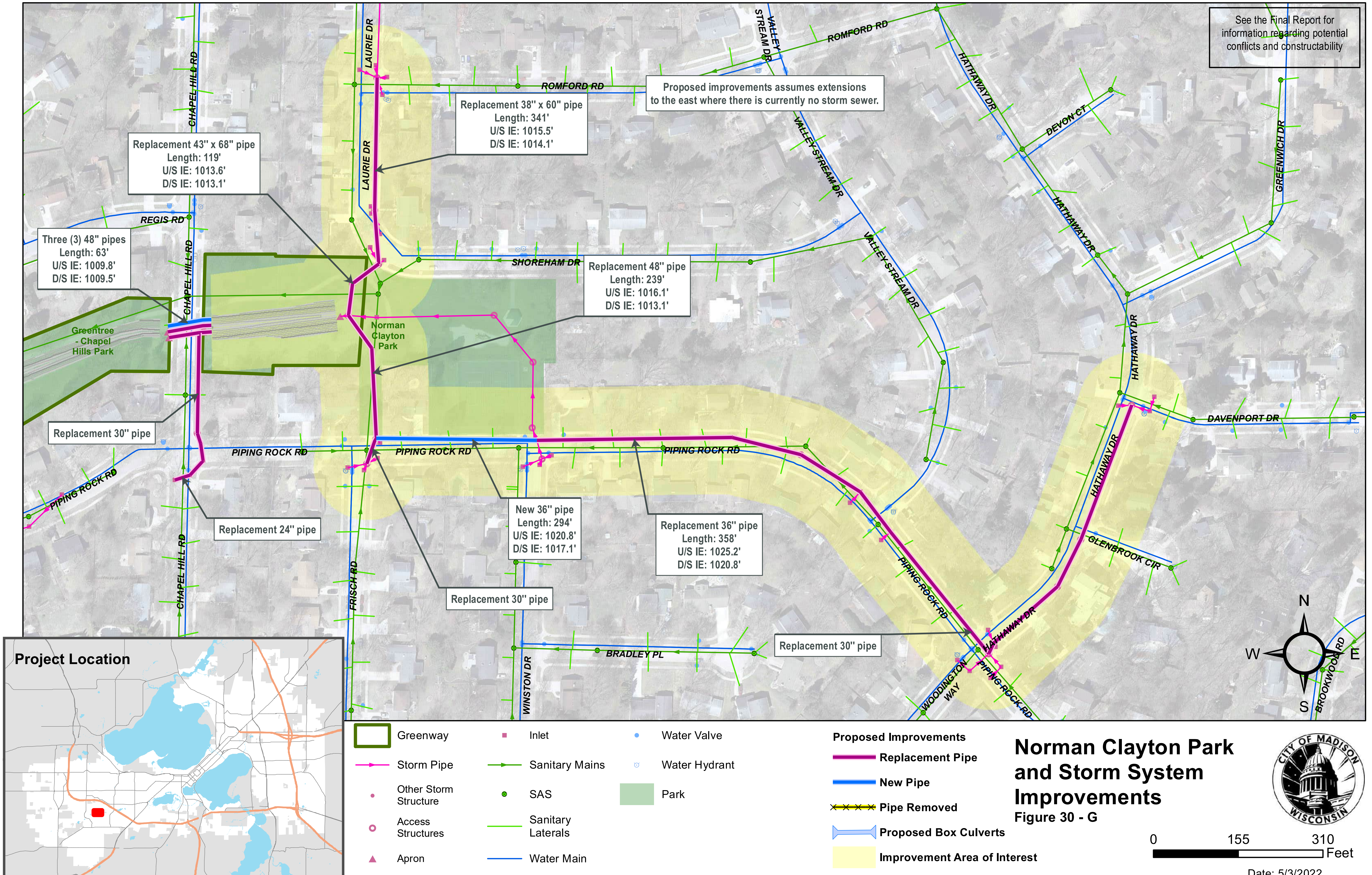
**Figure 30 - E**

Date: 5/3/2022

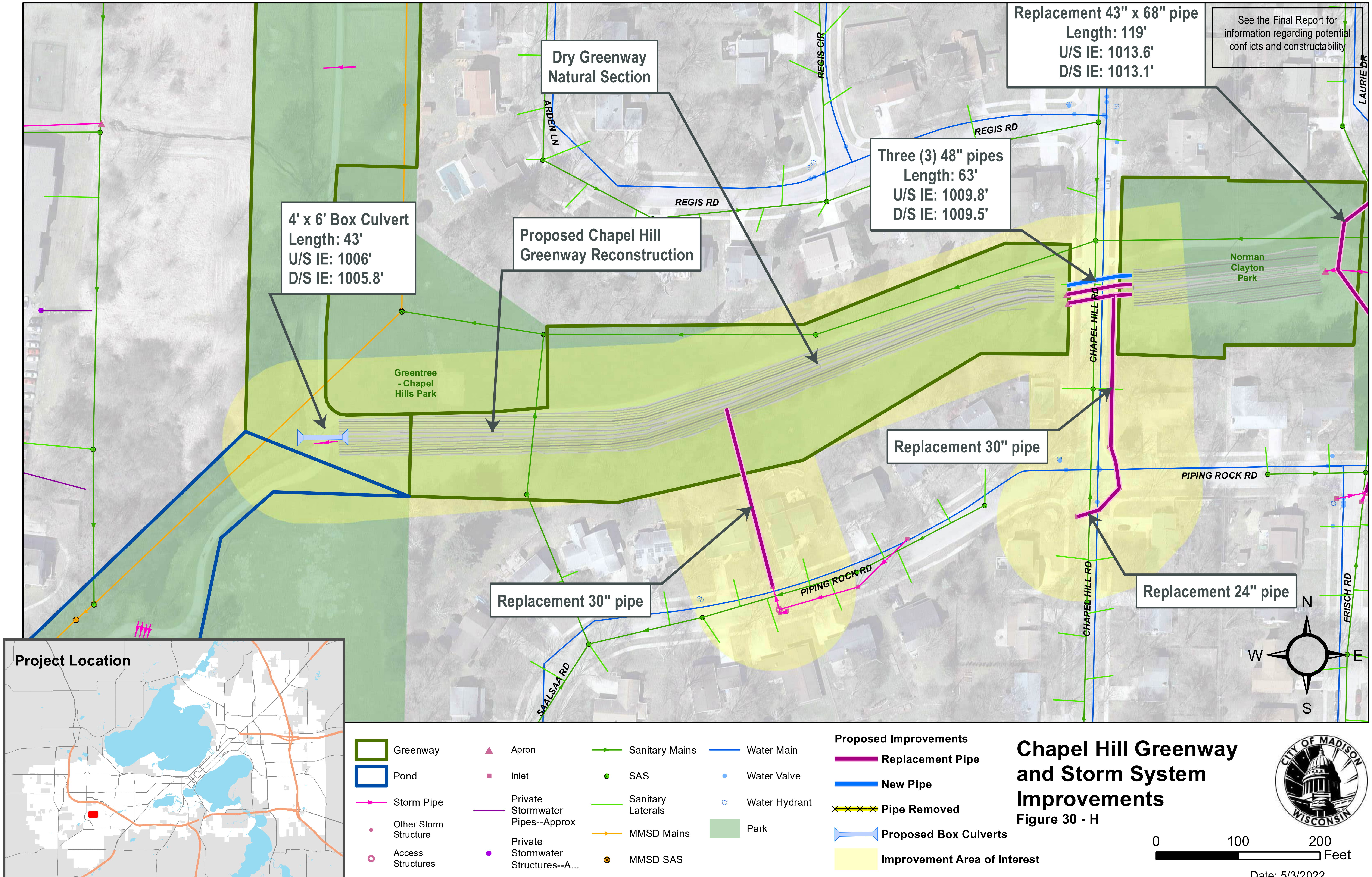



# Schroeder Rd Trunkline Improvement

Figure 30 - F

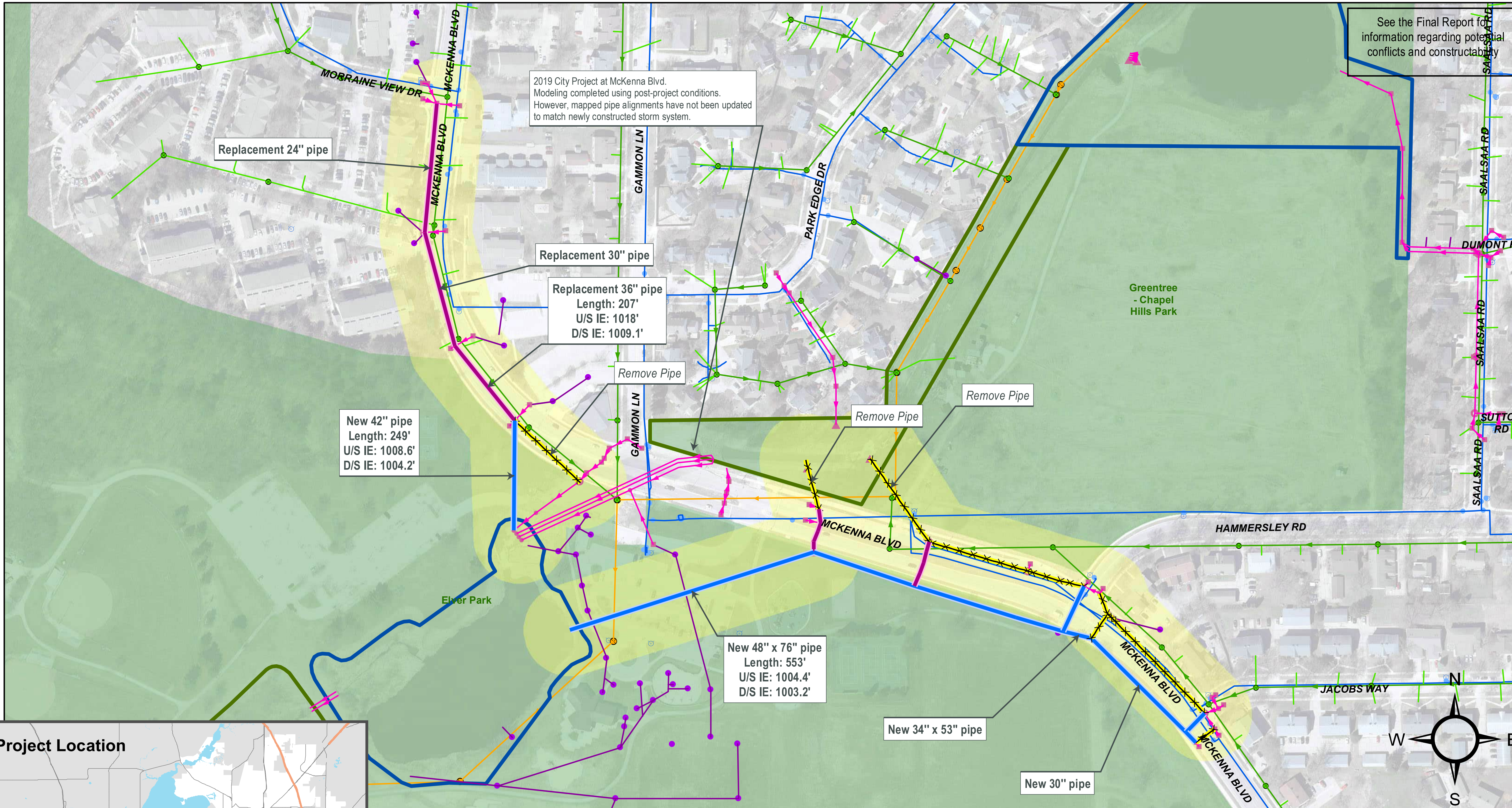


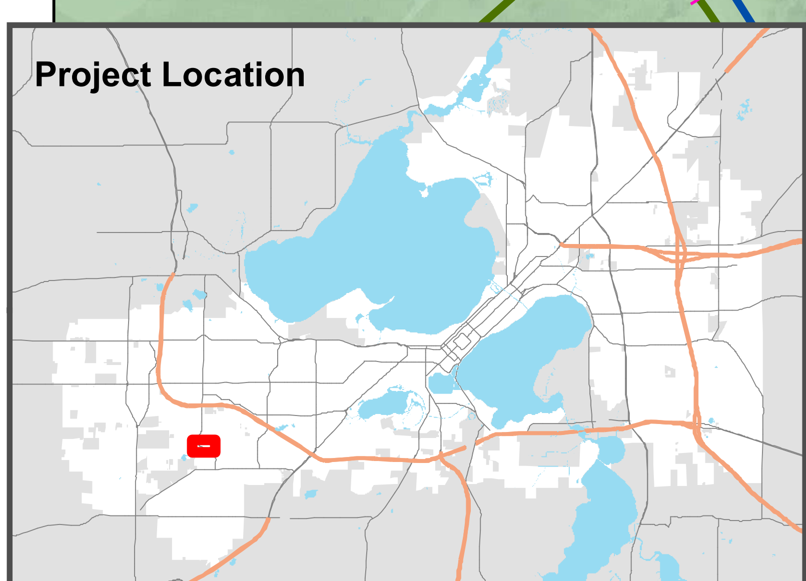
See the Final Report for information regarding potential conflicts and constructability
Proposed improvements assumes extensions to the east where there is currently no storm sewer.
Replacement 38" x 60" pipe
Length: 341'
U/S IE: 1015.5'
D/S IE: 1014.1'
Replacement 43" x 68" pipe
Length: 119'
U/S IE: 1013.6'
D/S IE: 1013.1'
Three (3) 48" pipes
Length: 63'
U/S IE: 1009.8'
D/S IE: 1009.5'
Replacement 48" pipe
Length: 239'
U/S IE: 1016.1'
D/S IE: 1013.1'
Replacement 30" pipe
Replacement 24" pipe
New 36" pipe
Length: 294'
U/S IE: 1020.8'
D/S IE: 1017.1'
Replacement 36" pipe
Length: 358'
U/S IE: 1025.2'
D/S IE: 1020.8'
Replacement 30" pipe
Replacement 30" pipe
ROMFORD RD
ROMFORD RD
VALLEY STREAM DR
VALLEY STREAM DR
VALLEY STREAM DR
HATHAWAY DR
HATHAWAY DR
HATHAWAY DR
HATHAWAY DR
HATHAWAY DR
DEVON CT
GREENWICH DR
LAURIE DR
LAURIE DR
CHAPEL HILL RD
CHAPEL HILL RD
CHAPEL HILL RD
REGIS RD
SHOREHAM DR
DAVENPORT DR
PIPING ROCK RD
PIPING ROCK RD
PIPING ROCK RD
PIPING ROCK RD
PIPING ROCK RD
PIPING ROCK RD
GLENBROOK CIR
FRISCH RD
WINSTON DR
BRADLEY PL
WOODINGTON WAY
BROOKWOOD RD
Greentree - Chapel Hills Park
Norman Clayton Park
N
W
E
S
Project Location
Greenway
Storm Pipe
Other Storm Structure
Access Structures
Apron
Inlet
Sanitary Mains
SAS
Sanitary Laterals
Water Main
Water Valve
Water Hydrant
Park
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
0
155
310
Feet
Date: 5/3/2022
CITY OF MADISON WISCONSIN
Document Path: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure30_AtoK_ProposedSolutions.mxd
User Name: aconverse




**Chapel Hill Greenway and Storm System Improvements**
**Figure 30 - H**

Date: 5/3/2022




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

# McKenna Blvd Improvements

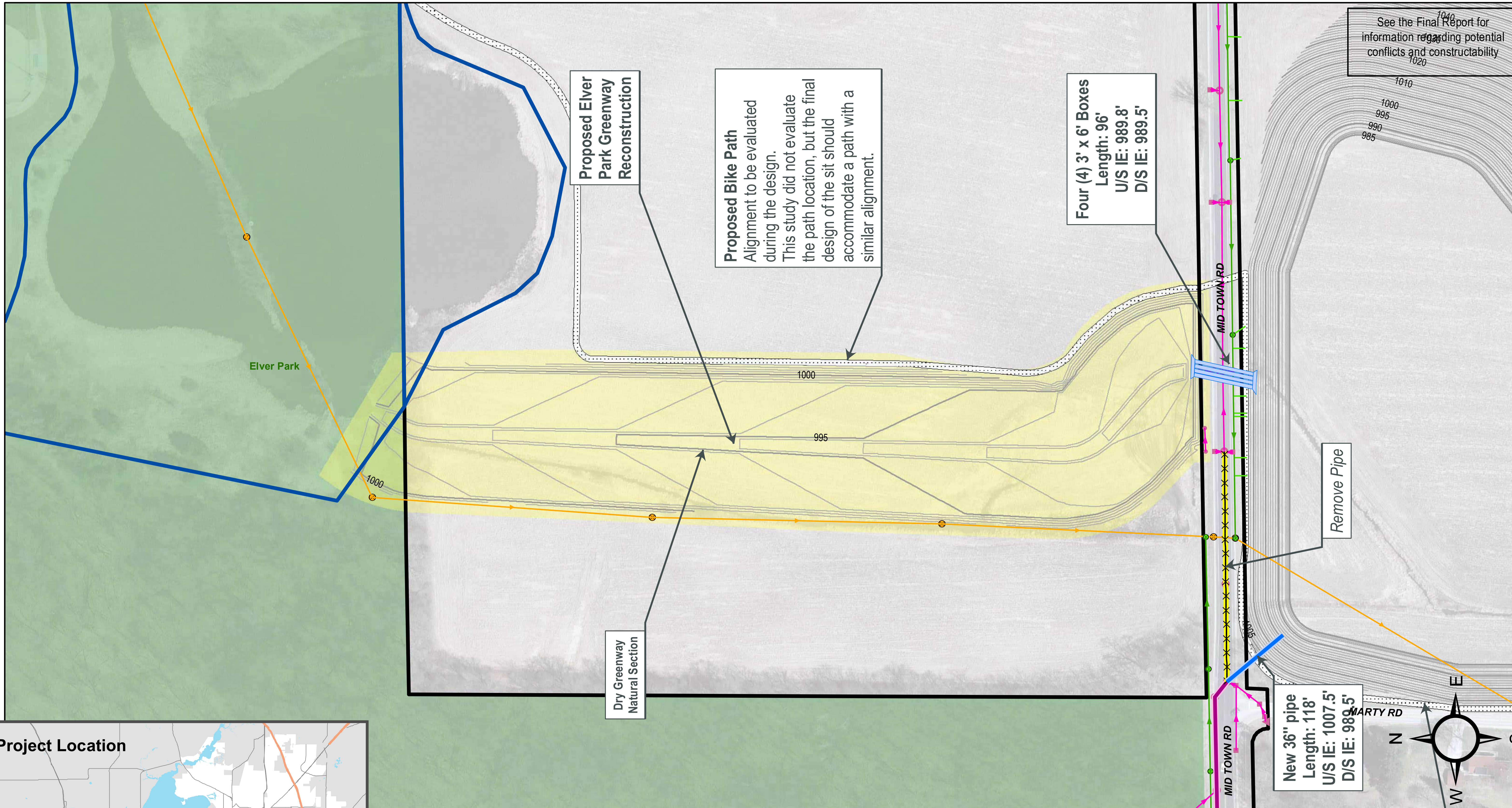
**Figure 30 - I**

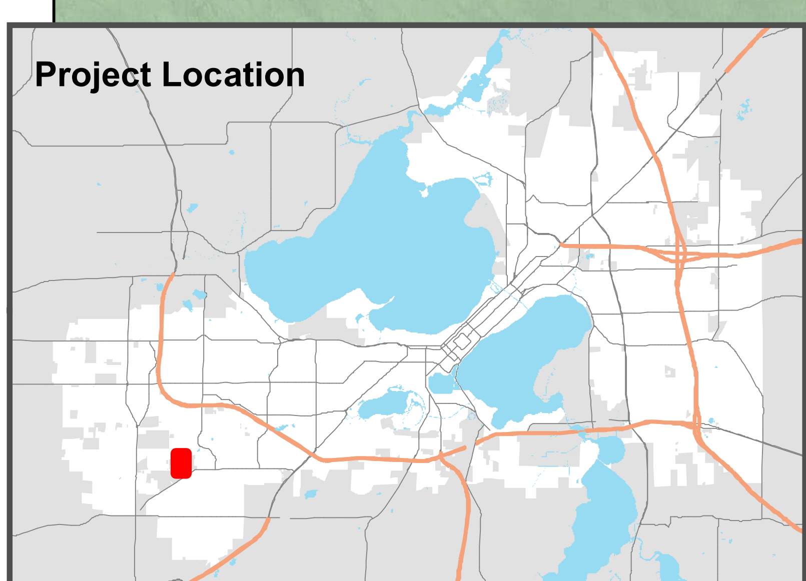
0 205 410 Feet

Date: 5/3/2022

User Name: aconverse

Document Path: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure30_AtoK_ProposedSolutions.mxd




| | | |
|---|---|---|
| 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**

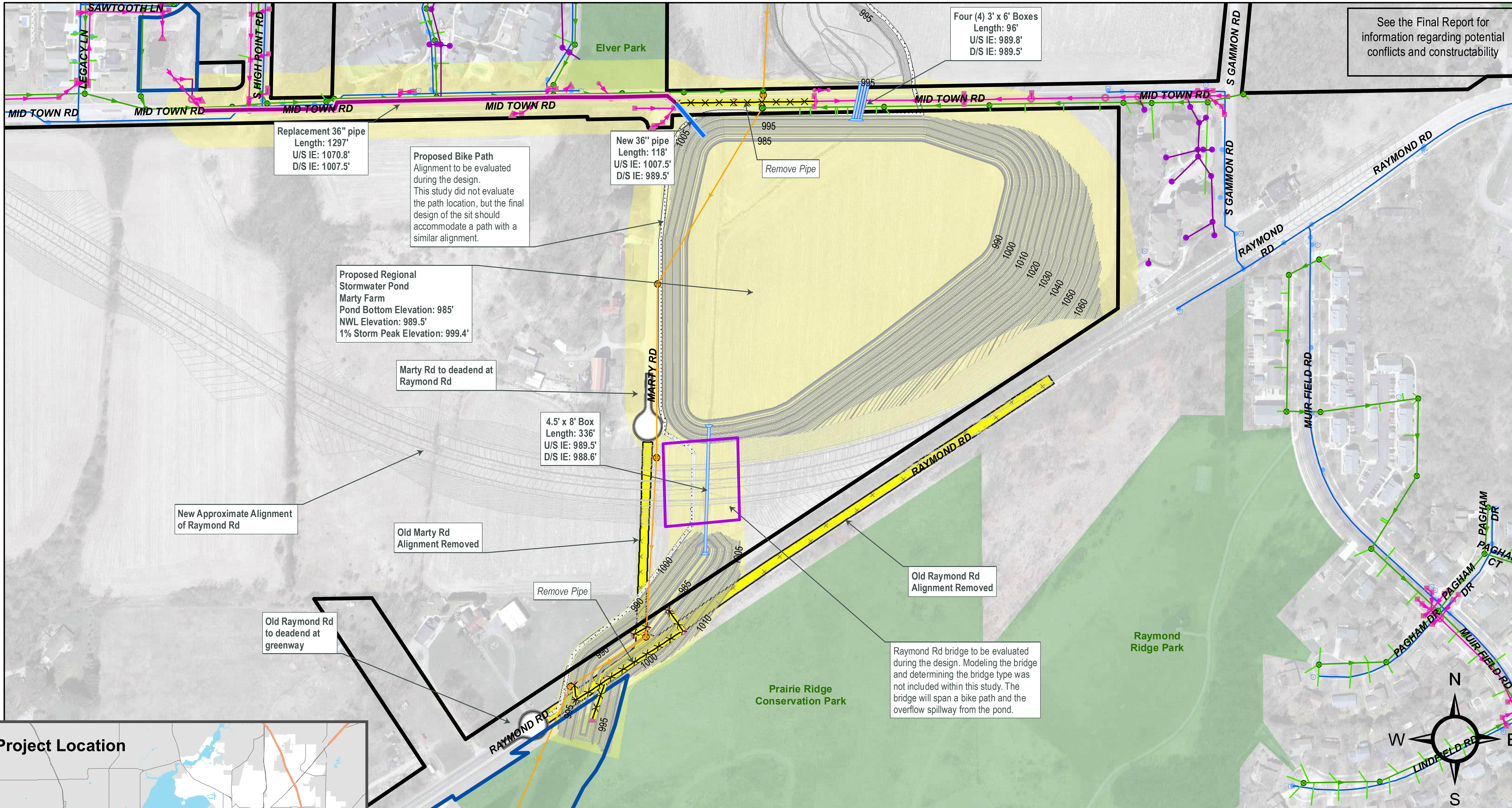
CITY OF MADISON WISCONSIN

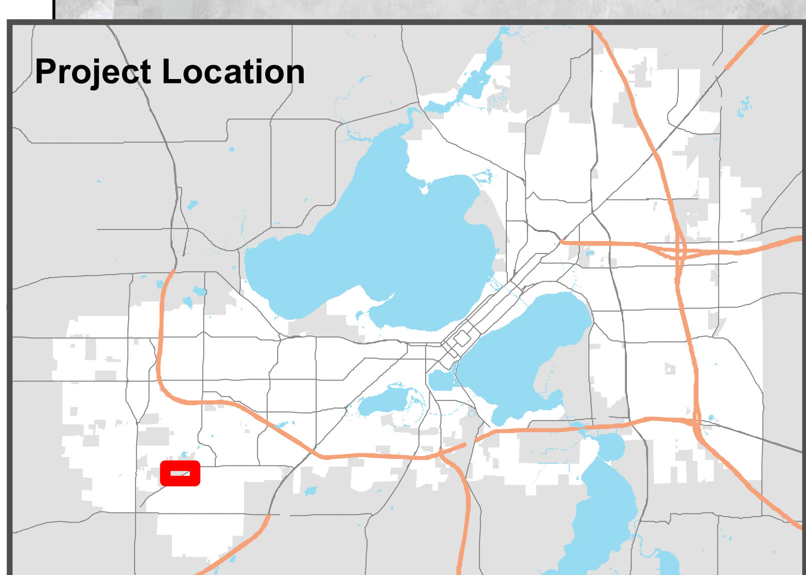
0 155 310 Feet

Date: 5/3/2022

Document Path: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure30_AtoK_ProposedSolutions.mxd

User Name: aconverse




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

# Marty Road/Mid Town Road Regional Pond

**Figure 30 - K**

CITY OF MADISON WISCONSIN

0 260 520 Feet

Date: 5/9/2022

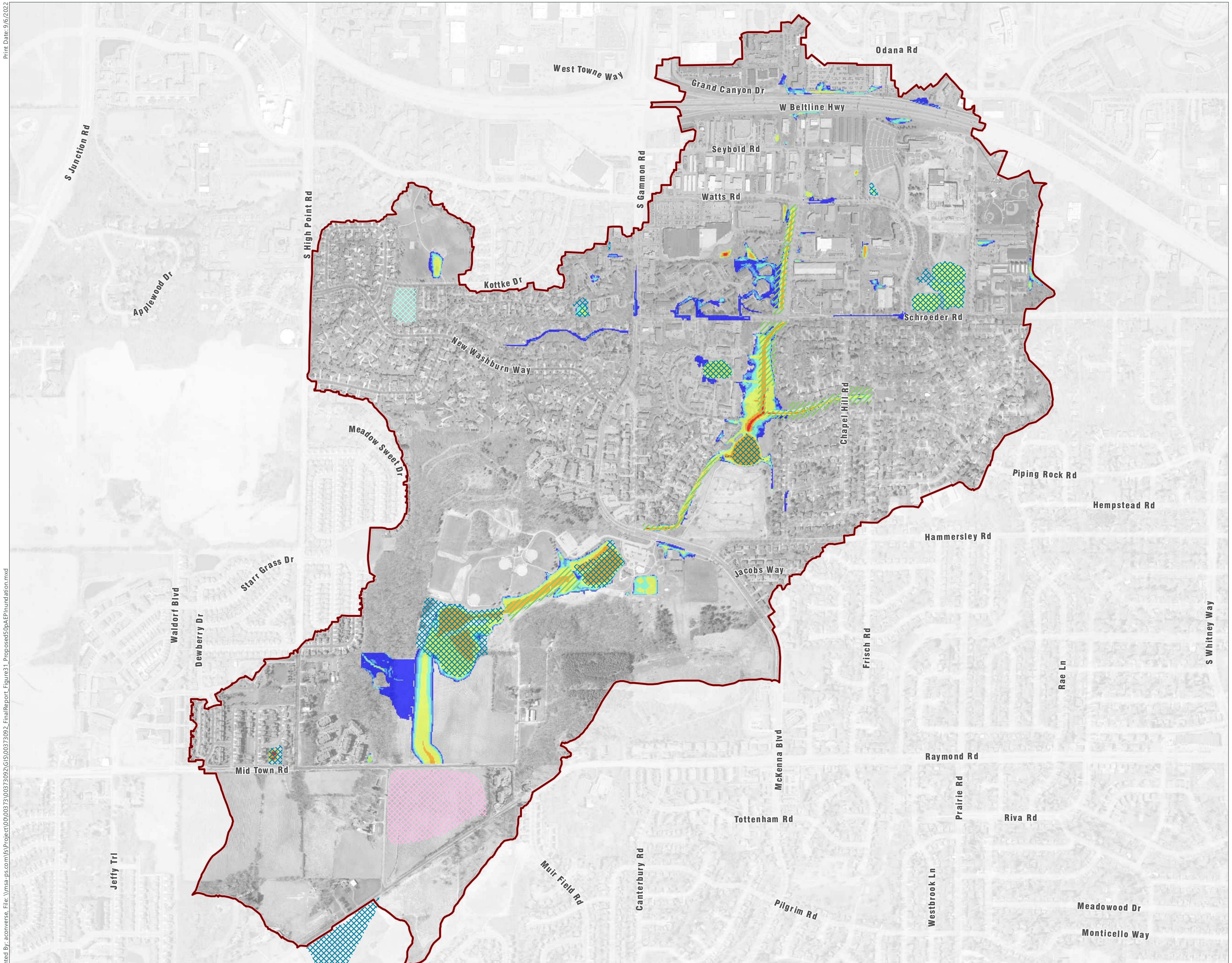
Document Path: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_FinalReport_Figure30_AtoK_ProposedSolutions.mxd

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*

MSA

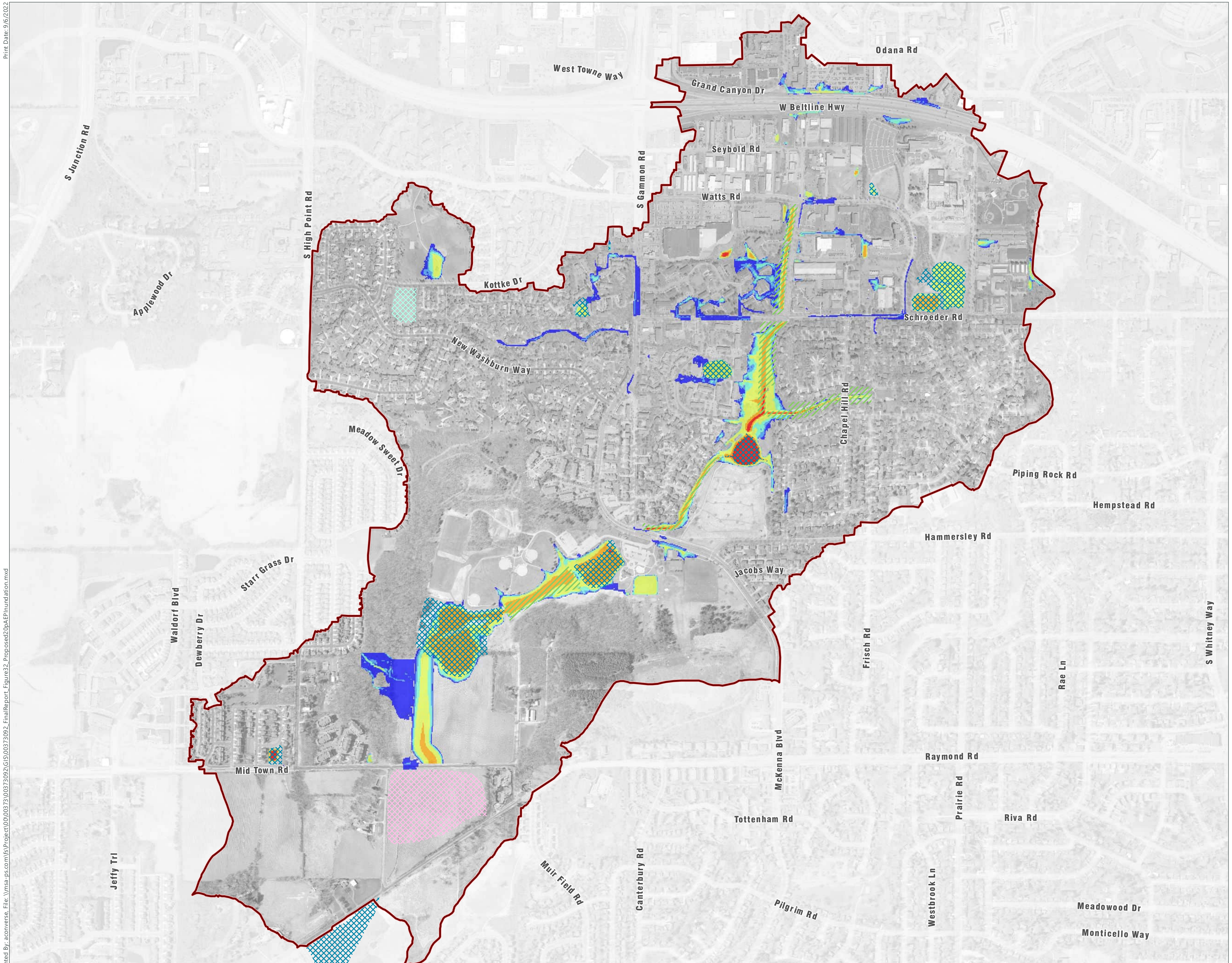
0 550 1,100 Feet

Print Date: 9/6/2022

# 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*

MSA

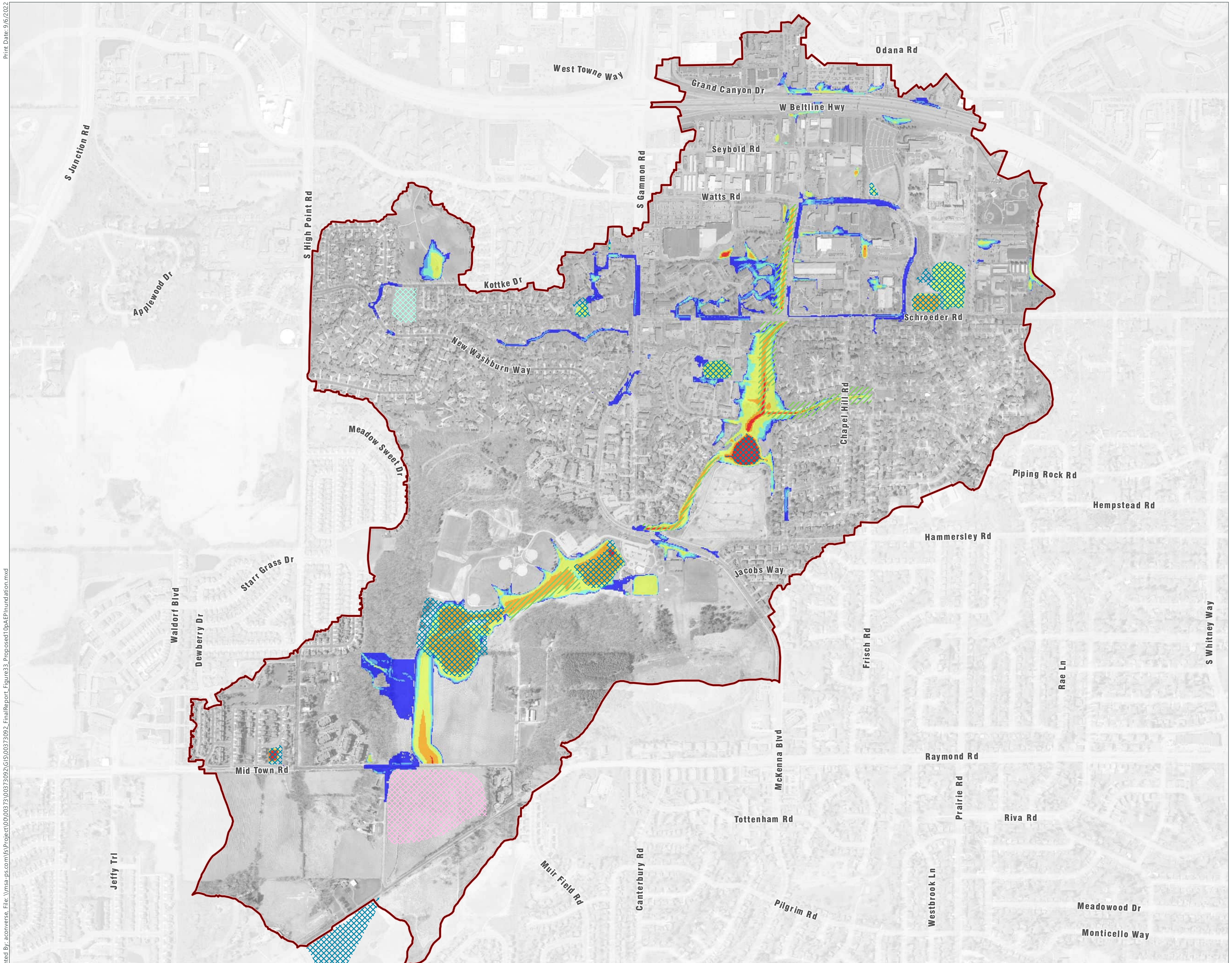
0 550 1,100 Feet

Print Date: 9/6/2022

# 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

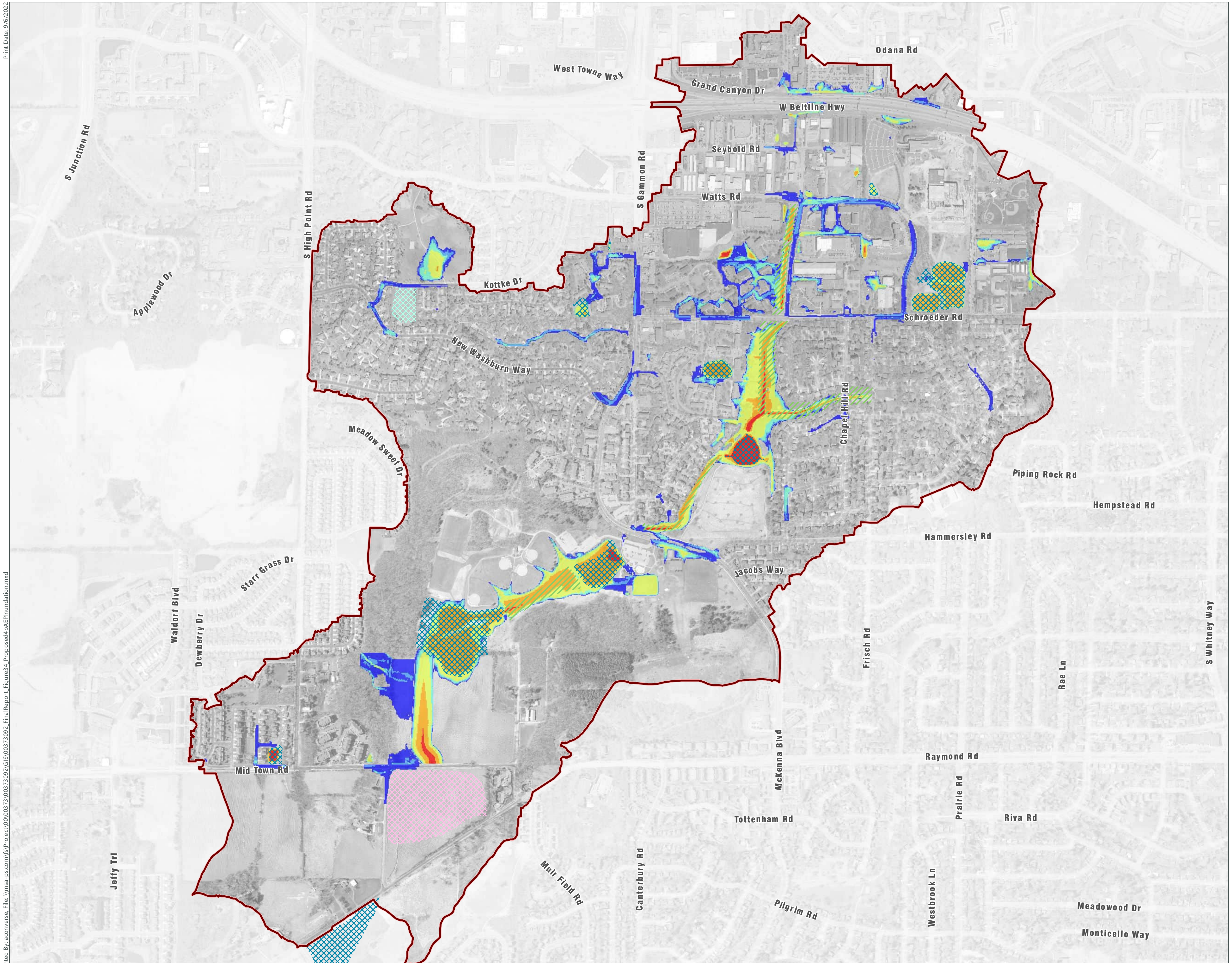
*Data Sources:*
*Aerial: City of Madison (2018)*
*Watershed Boundaries: MSA*
*Stormwater System: City of Madison*

MSA

0 550 1,100 Feet

N

Print Date: 9/6/2022




# 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)

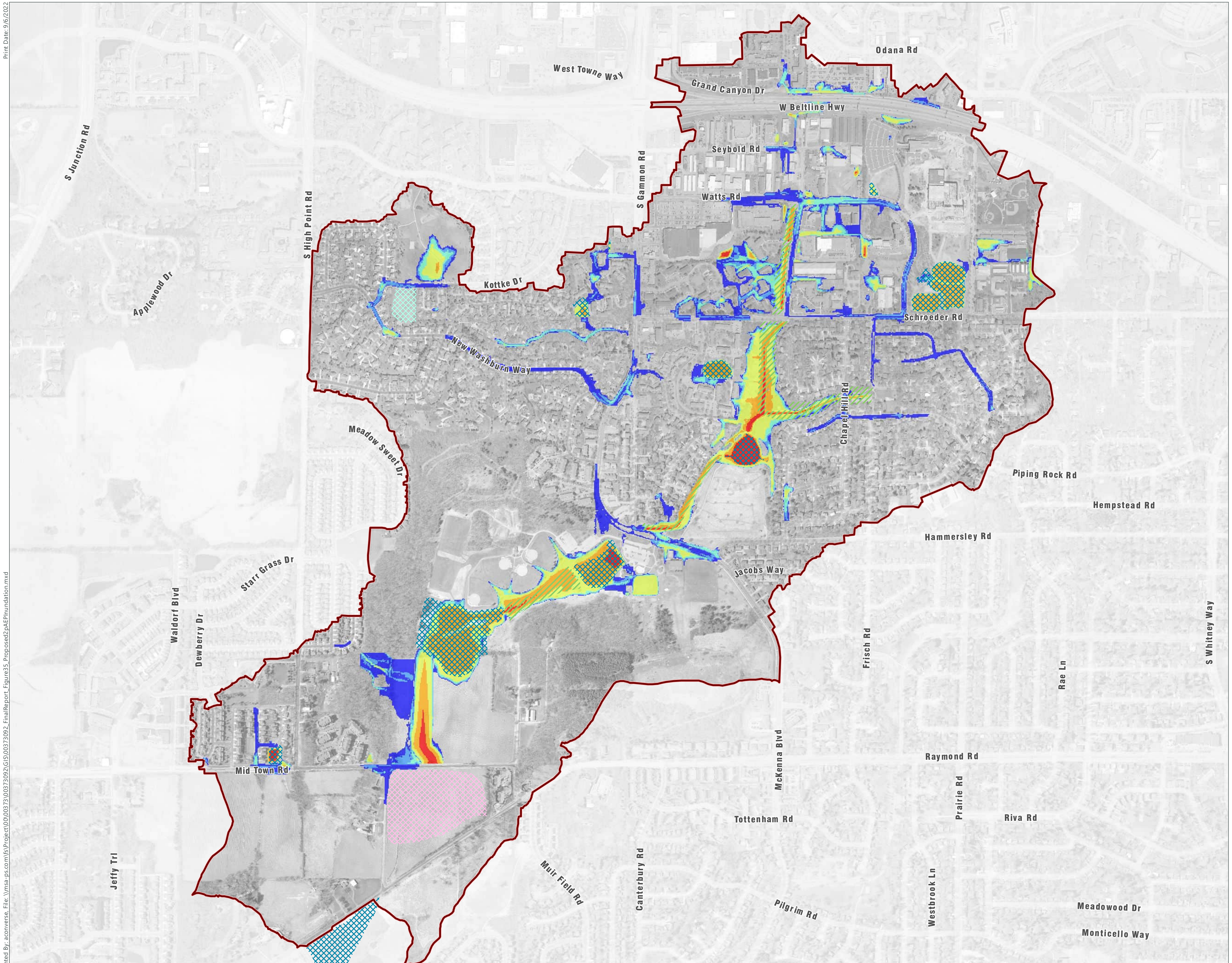
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 3
3 - 6
> 6

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

MSA

0 550 1,100 Feet

Print Date: 9/6/2022




# 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)

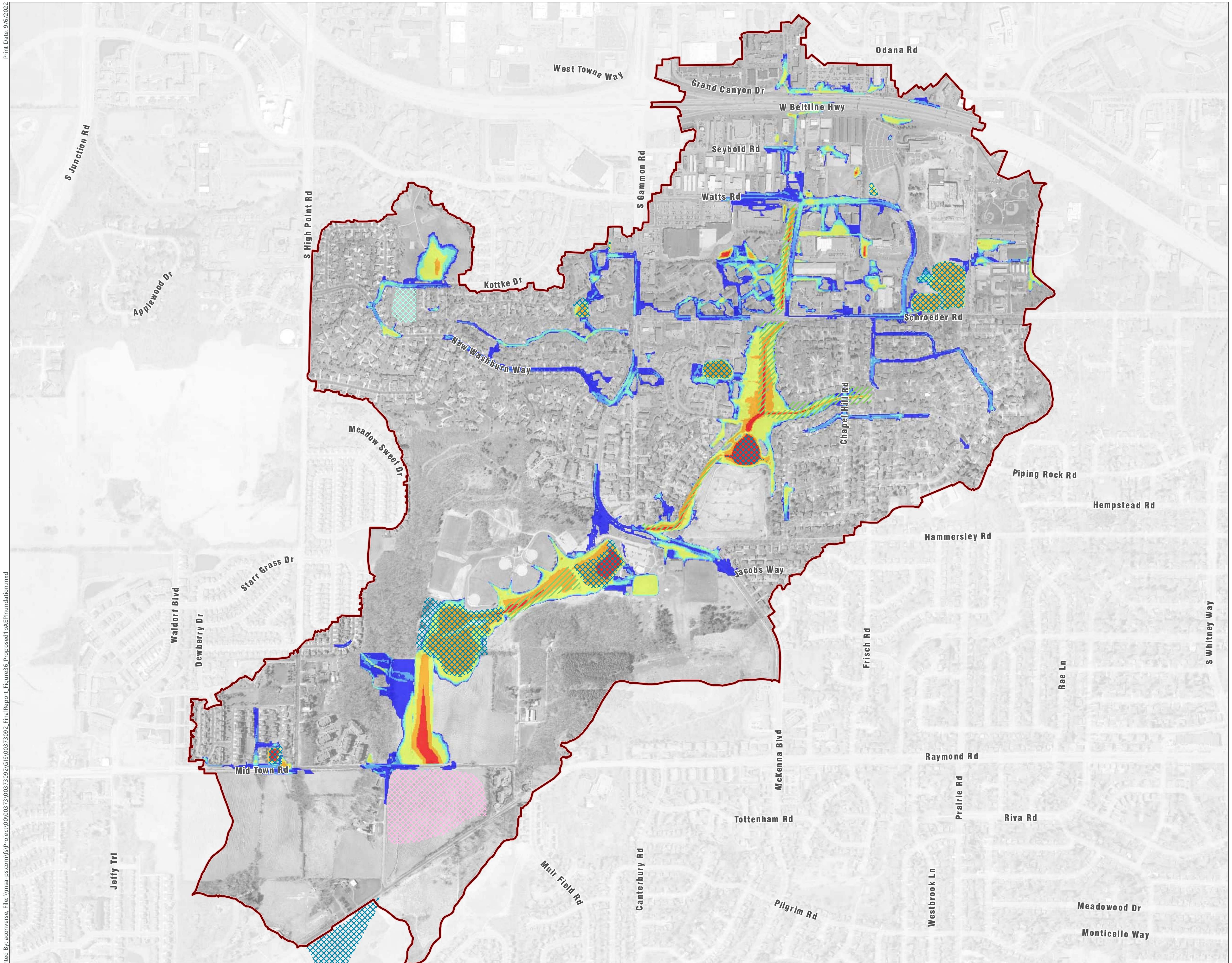
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- 3 - 6
- > 6

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

MSA

0 550 1,100 Feet

Print Date: 9/6/2022




# 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**

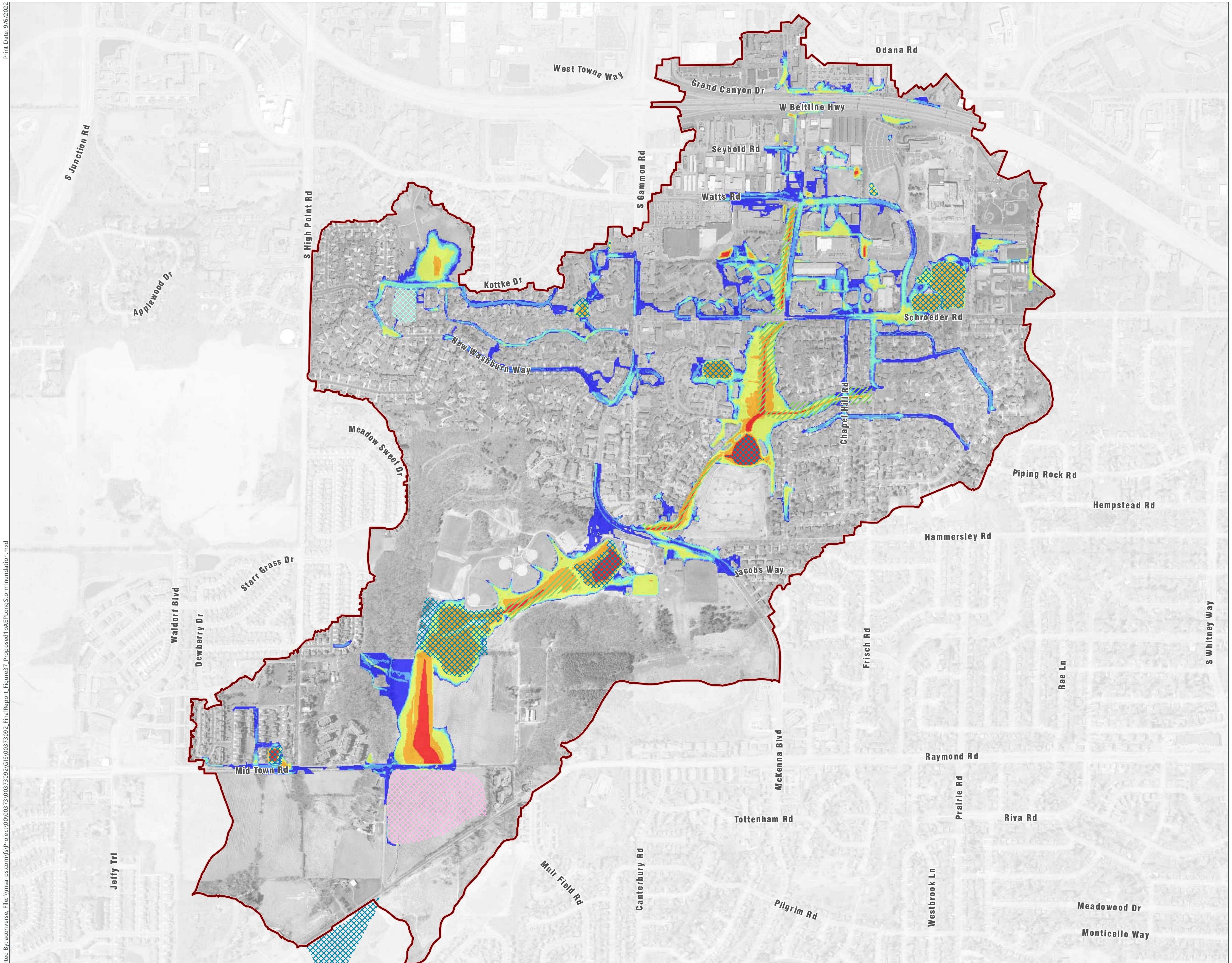
Maximum Water Depth (ft)

- 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*

MSA

0 550 1,100 Feet




# 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*

MSA

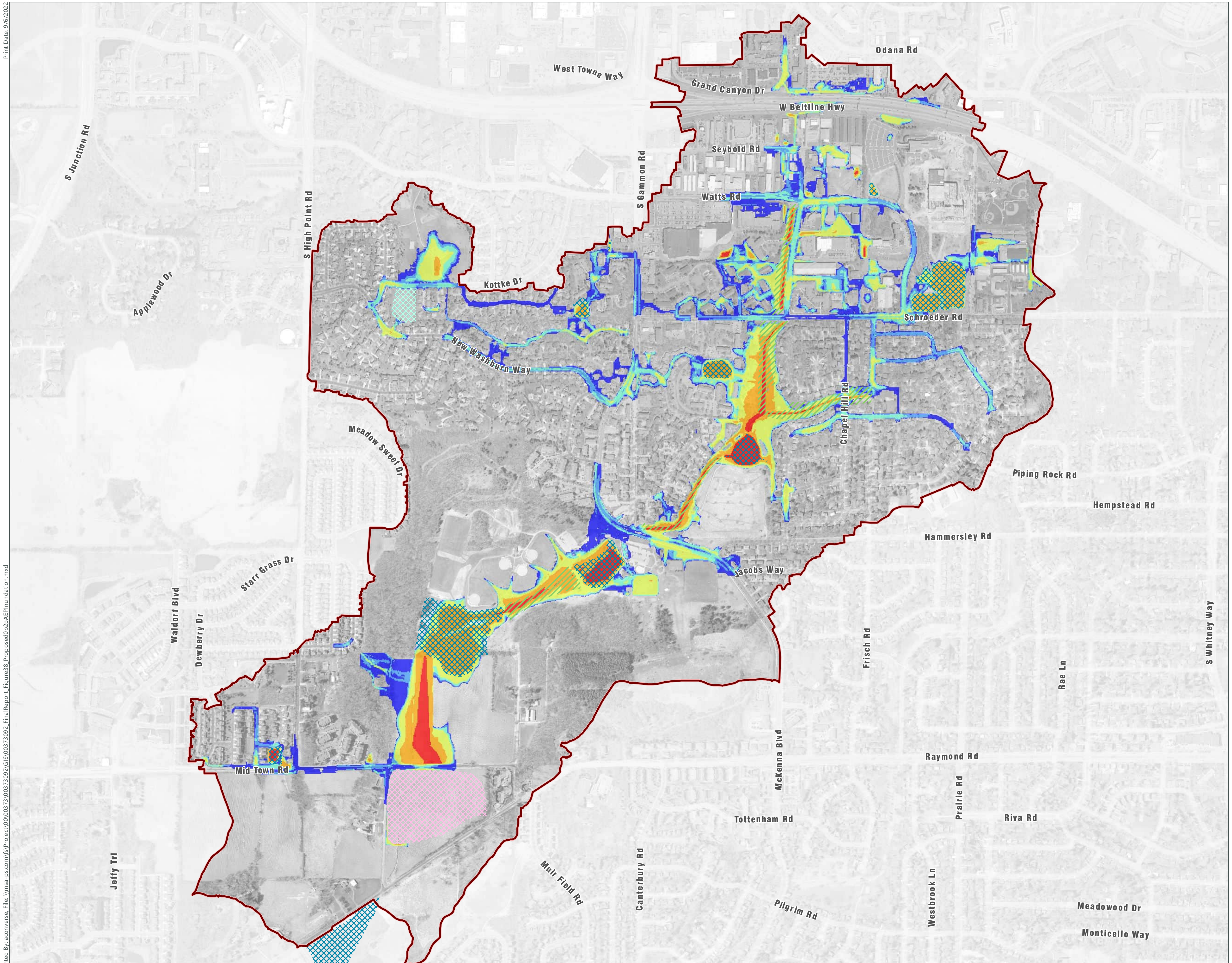
0 550 1,100 Feet

N

# 0.2% AEP Inundation Proposed Conditions

FIGURE 38
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

**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*

MSA

0 550 1,100 Feet

N

Print Date: 9/6/2022

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# 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 with 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 |

[a]For 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).

[b]Use 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.

**Commented [BC1]:** Add maximum infiltration volume in inches

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

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

| 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 |

| 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 |

| 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 |

| 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 |

| 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 |

| 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

| 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 |

| 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_TP2662-056_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 |

| 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_IN2756-012 | 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 |

| 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_0 | 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 |
| PDES-1_AS-ES1 | PD-ES-S12 | AS-ES-S13 | 13.00 | Circular | 1.5 | 0 | 0.013 | 1036.87 | 1037.00 |
| PDES-1_AS2960-017 | AS-ES-S13 | 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 |

| 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_O1 | 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 |

| 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 |

| 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 | 787719.9 |
| 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 |

| 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 |

| 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 |

| 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 |

| 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 |

| 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 |

| 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 |

| 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) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2859-006 | 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 |

**Watts Rd - Struck St Intersection**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2860-001 | 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 |

**6512 Watts Rd**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2860-020 | 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 |

**John Powless Tennis Center**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: PRIVATE173 | 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 |

**Prairie Park Senior Apartments**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2861-001 | 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 |

**Greenway Culvert U/S of Schoeder Rd**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AE2861-013 | 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 |

**New Washburn Way Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2462-007 | 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 |

**Kottke Dr D/S of Highpoint Estates Detention Pond**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2561-006 | 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 |

**Gammon Rd (South Gammon Mobile Station)**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2662-043 | 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 |

**S Holt Cir Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2662-047 | 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 |

**919-949 S Gammon Rd Apartments Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: PRIVATE144_01 | 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 |

**Gammon Rd - Park Ridge Dr Intersection**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2762-003 | 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 |

**Park Ridge Dr Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2762-005 | 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 |

**Laurie Dr - Shoreham Dr Corner Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2962-029 | 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 - Winston Dr Intersection**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2963-061 | 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 |

**Piping Rock Rd - Chapel Hill Rd Intersection**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2863-021 | 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 |

**Piping Rock Rd Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2863-042 | 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 |

**Chapel Hill Rd Channel Crossing**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: TP2863-033 | 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 |

**Forward Dr Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS3061-001 | 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 |

**Park Edge Dr Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2764-018 | 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 |

**1202 McKenna Blvd**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2664-004 | 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 |

**McKenna Blvd (west of Hammersley Ave)**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2765-011 | 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 |

**Elver Park Ditch (south of McKenna Blvd) Sag**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AE2765-015 | 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 |

**Greenway Culvert U/S of McKeena Blvd**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: 2764-015_1374_01 | 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 |

**Mid Town Rd - Legacy Ln Intersection**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: IN2367-018 | 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 |

**Mid Town Rd Channel Crossing**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: AS2568-006 | 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 |

**Greenway Culvert U/S of Raymond Rd**

| Event | Max Depth (ft) | Duration of Flooding (mins) |
|---|---|---|
| | Node: DT2469-004 | 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.

**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 'assymptotic' 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 no 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 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.

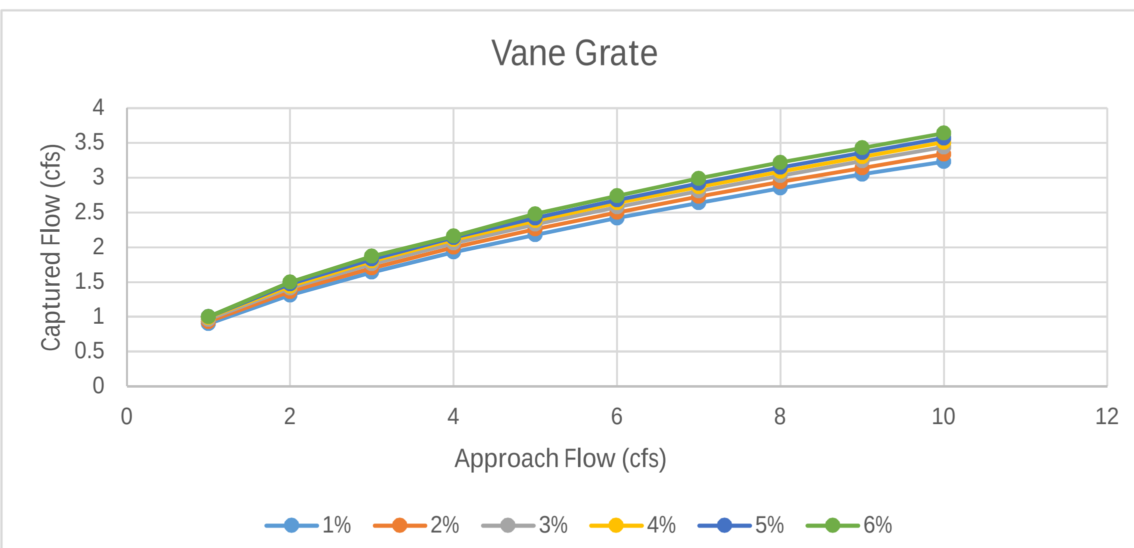
## Inlet Capture Rating Curve for Sag Condition

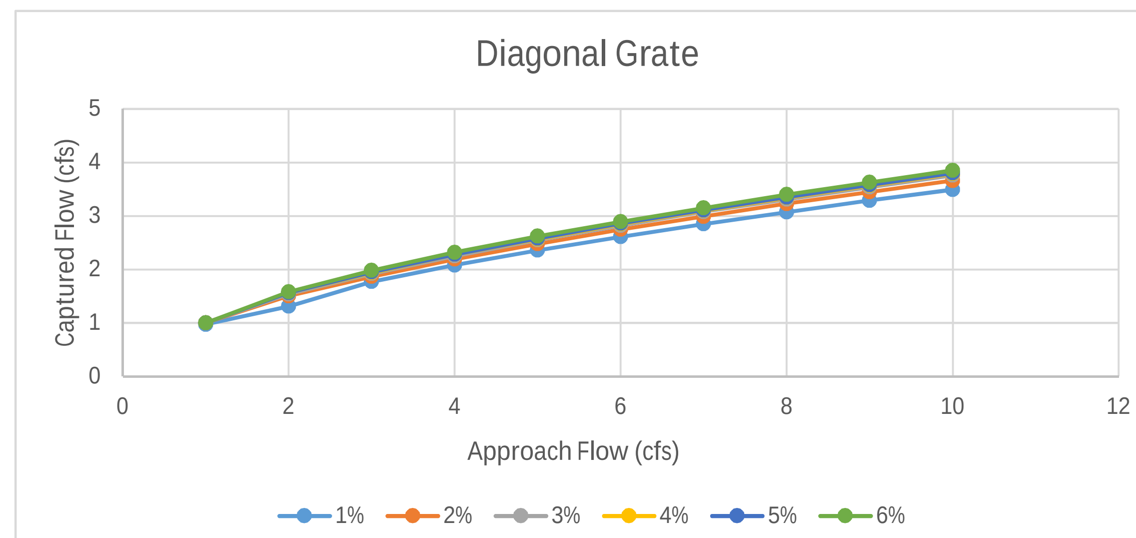
Vane Grate - MSA Spreadsheet

| | Longitudinal slope | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1% | 2% | 3% | 4% | 5% | 6% | AVERAGE |
| Approach Flow | Inlet Capture | | | | | | |
| (cfs) | (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

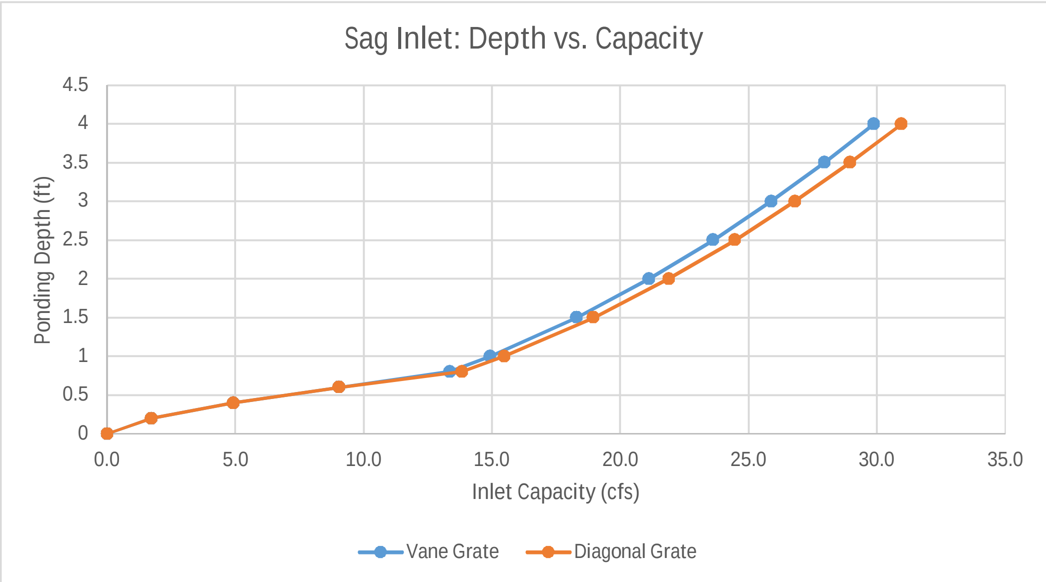
| | Longitudinal slope | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1% | 2% | 3% | 4% | 5% | 6% | AVERAGE | Approach Flow | Inlet Capture |
| Approach Flow | Inlet Capture | | | | | | | | |
| (cfs) | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) |
| 1 | 0.97 | 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

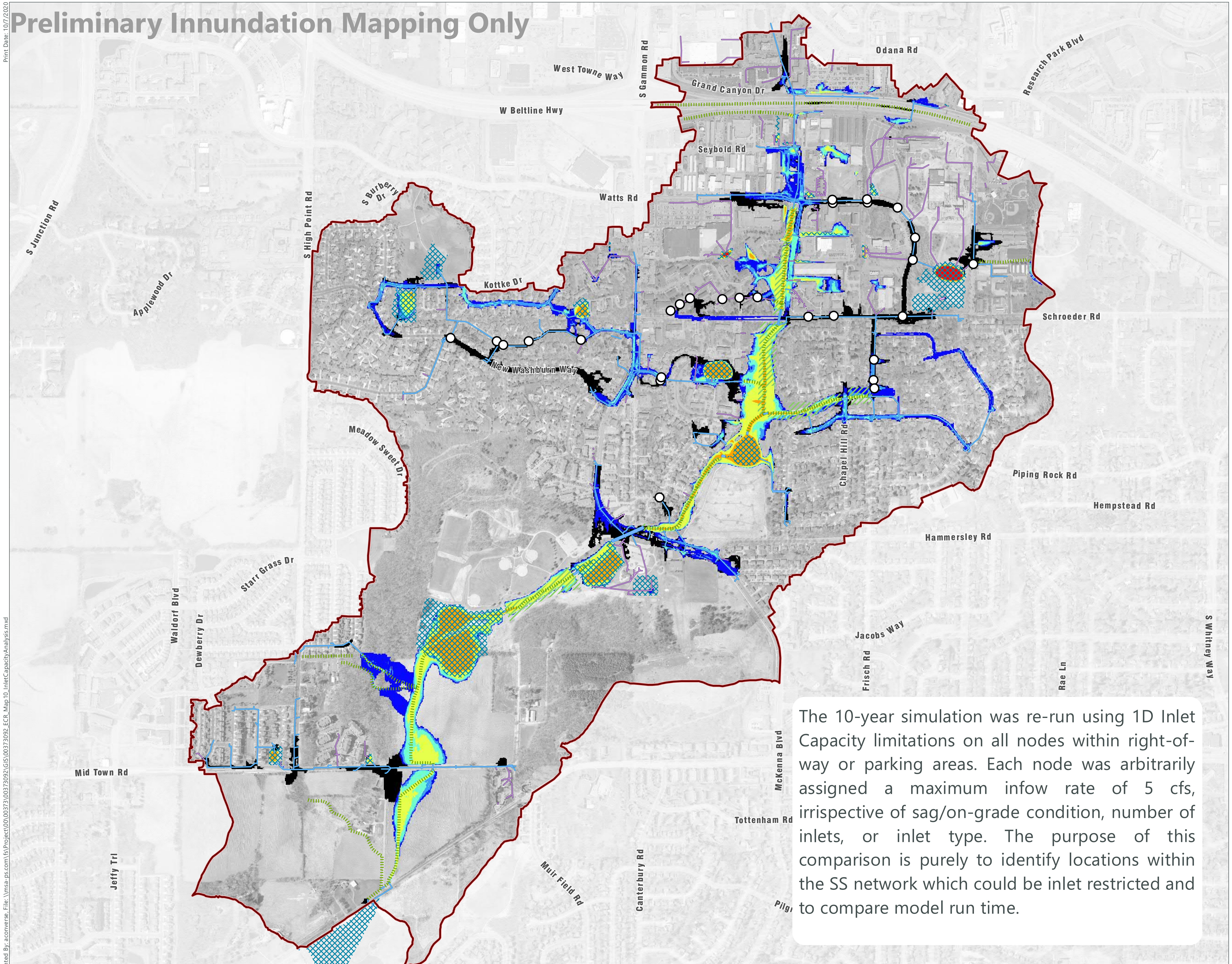
| Vane Grate | | | | Diagonal Grate | | | | Average | |
|---|---|---|---|---|---|---|---|---|---|
| | Area | Perimeter | | | Area | Perimeter | | | |
| | 2.779 | 5.9 | | | 2.879 | 5.9 | | | |
| Depth (ft) | Orifice Capacity (cfs) | Weir Capacity (cfs) | Capacity (cfs) | Depth (ft) | Orifice Capacity (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 |



# Inlet Capacity Comparison

FIGURE 10
McKenna/Greentree Watershed Study
Existing Conditions Report

**City of Madison**
**Dane County, WI**




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.

- 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*

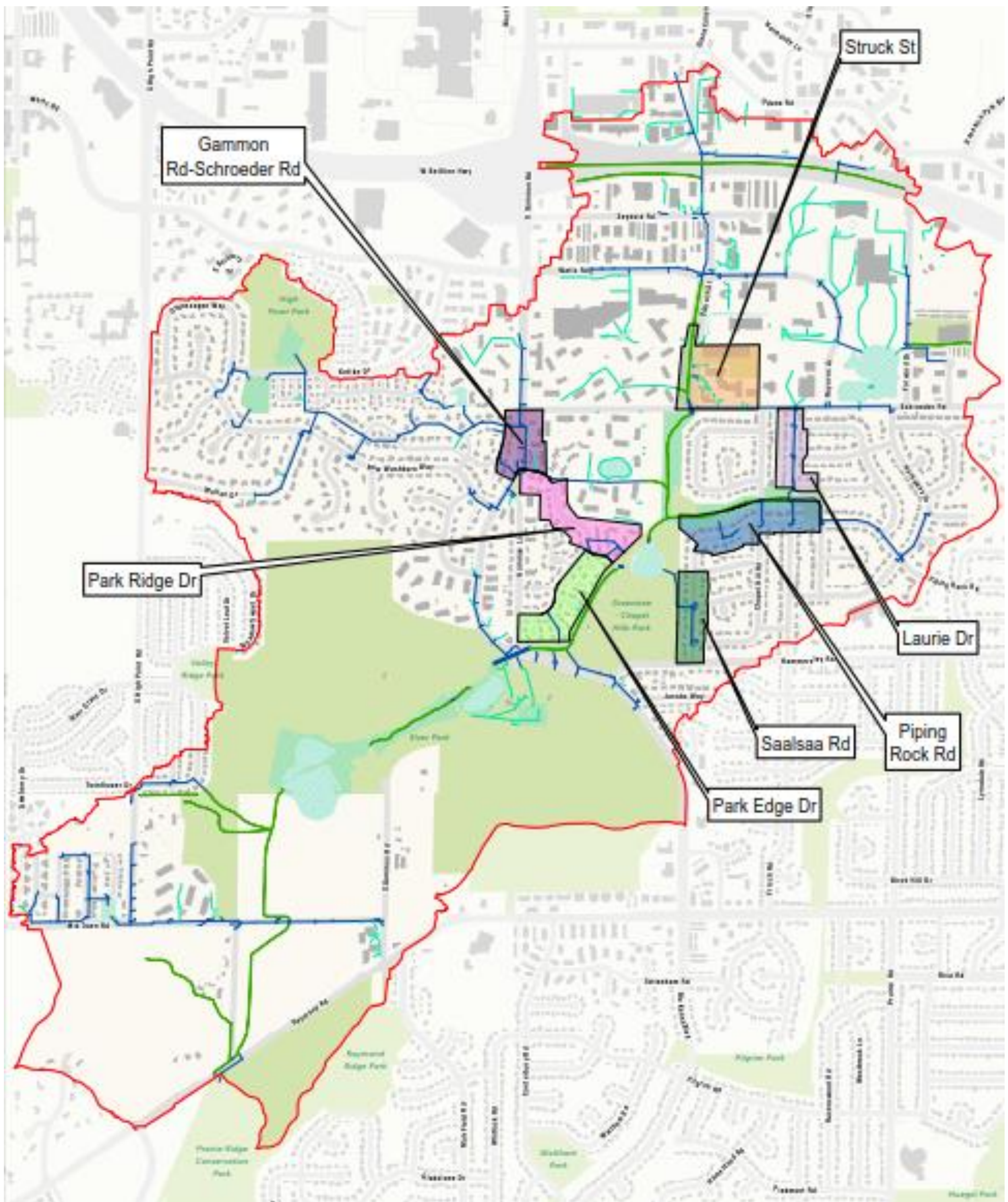
MSA

0 550 1,100 Feet

# Appendix F: Focus Group Summary

# Appendix F – Focus Group Summary

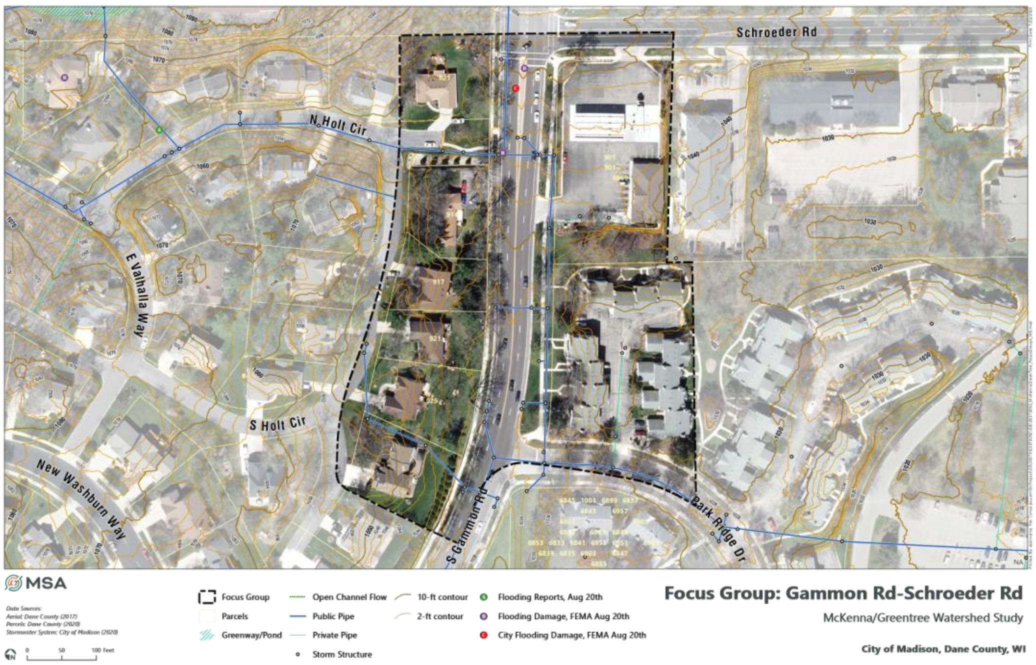
Please refer to Figures 7A – 7G of the Existing Conditions Report for detailed findings recorded during the Focus Group meetings.



## 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*

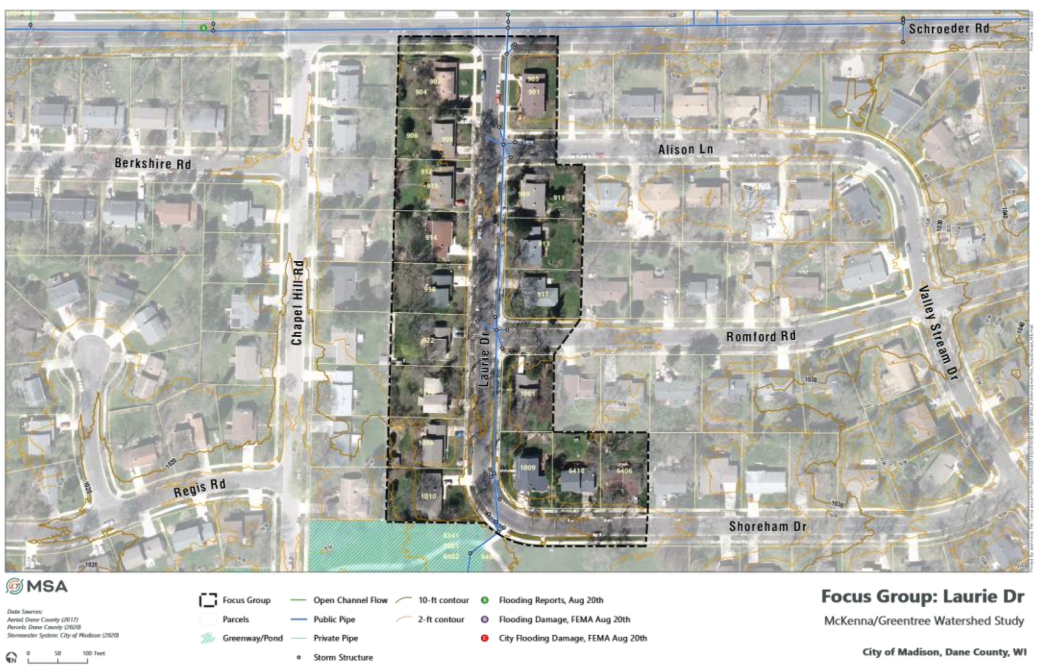
- Indicated flooding on the west side of Gammon Road during the August 20th, 2018 Event
- Indicated water flowing form the south towards Park Ridge Road




## 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

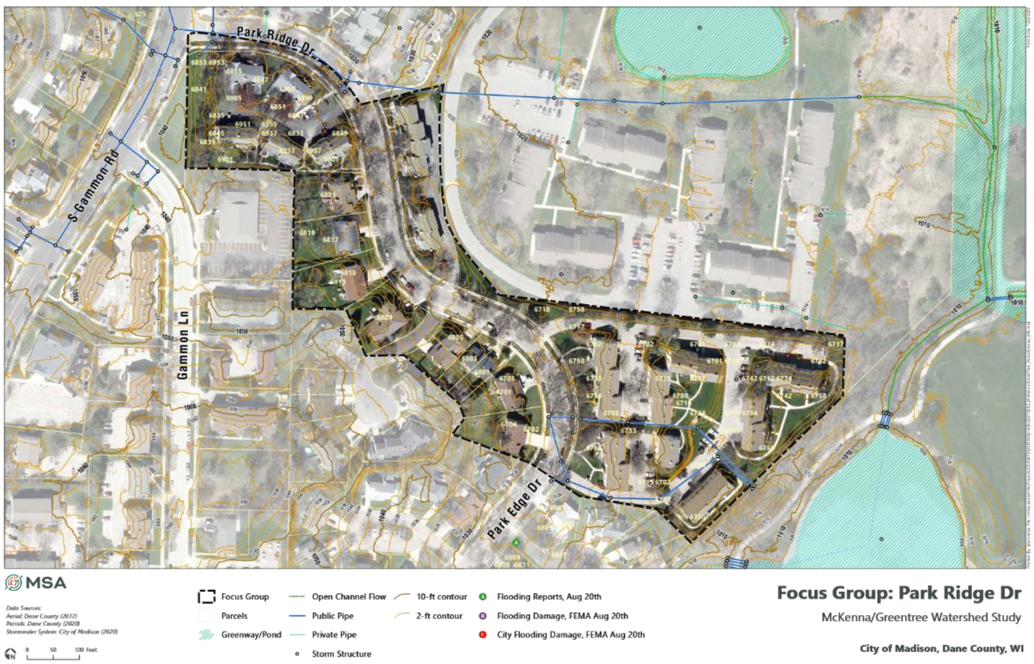
MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.
Public Attendees: 1
*Photos taken during Focus Group meeting.*

- 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.*

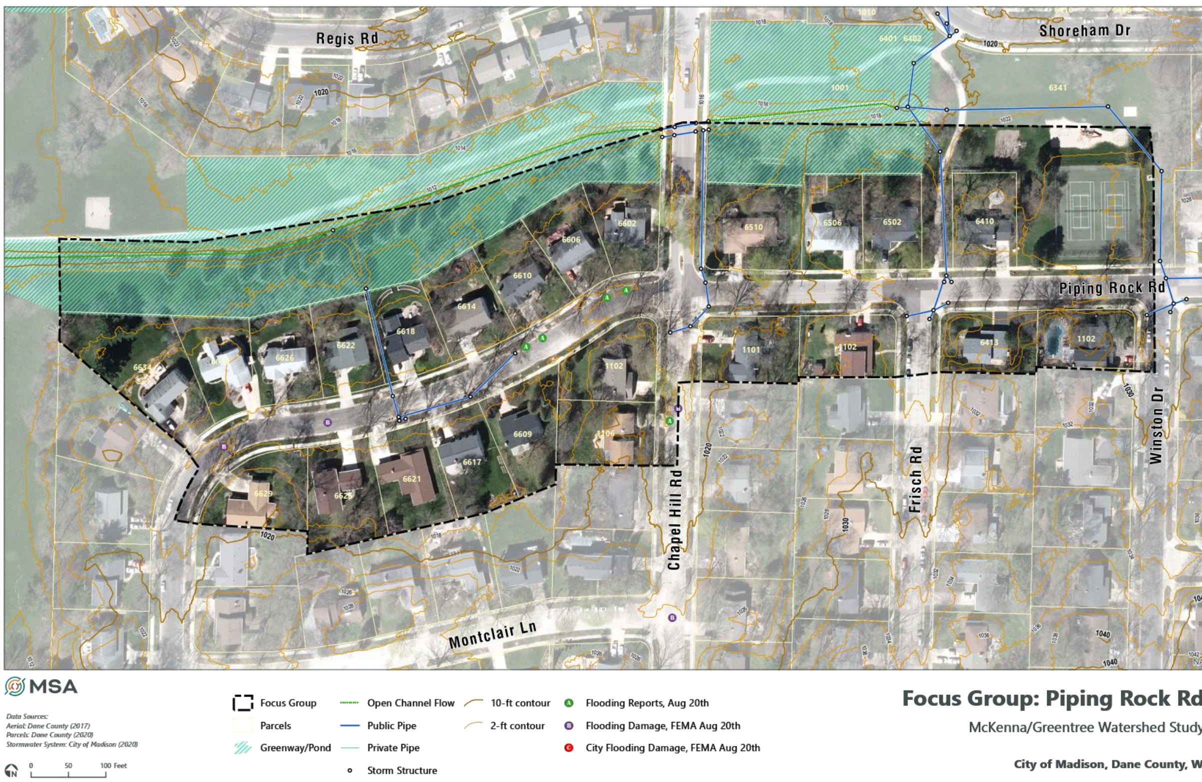
- Properties on the eastern side of the focus group had inches to feet of water in the August 20th, 2018 event (however, no flooding since). Water in the parking lot was ~18".
- New inlets along Park Ridge Dr have improve drainage within the ROW sag
- An unknown culvert was identified to add into the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

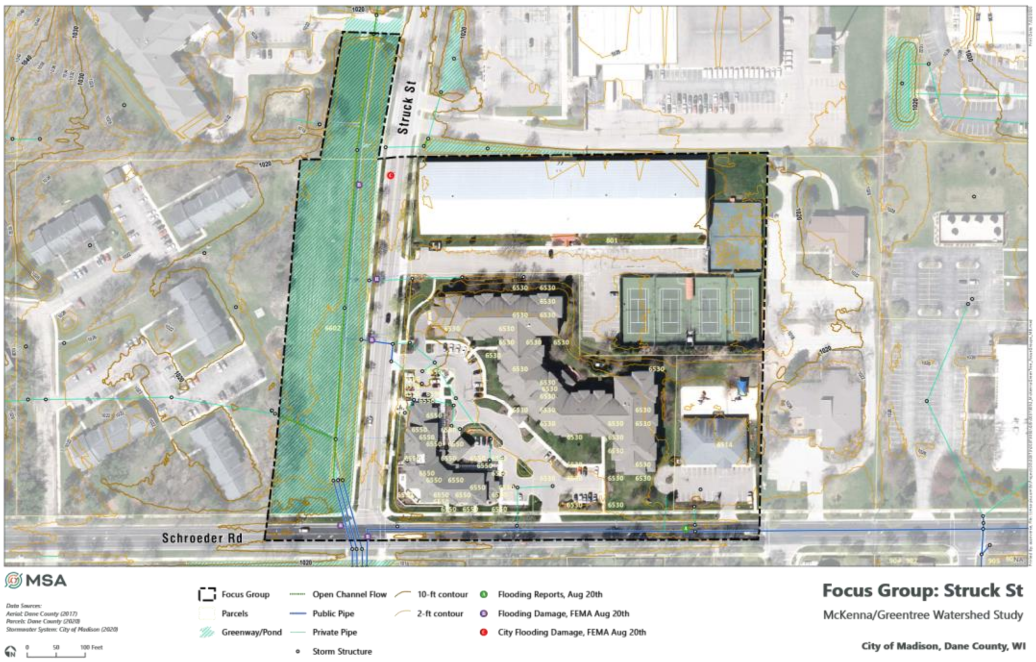
MSA and City Staff: Eric Thompson, Alistair Hancox, Matt Allie.
Public Attendees: 9
*Photo taken during Focus Group meeting.*

- 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

Stantec

# Memo

| | | | |
|---|---|---|---|
| To: | Caroline Burger, City of Madison<br>Matt Allie, City of Madison<br>Eric Thompson, MSA | From: | Aaron Volkening<br><br>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

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.

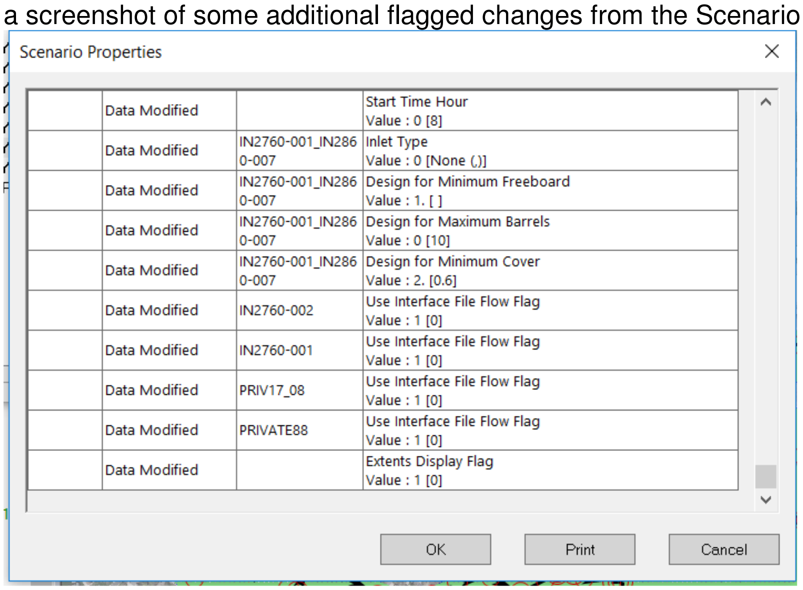
1. The only significant deviation we observed from the Modeling Guidance is that at culverts, an Inlet Type (various types of headwalls, wingwalls, or projecting conditions) was not selected and activated in the Conduit Factors dialog box. Entrance and exit losses were used, but per the Modeling Guidance,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

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

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*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*depth)^0.5 simplifies to Q = 4.8*Depth^0.5 for one inlet. Therefore, the global equation 13.4*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 additional 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.

**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.

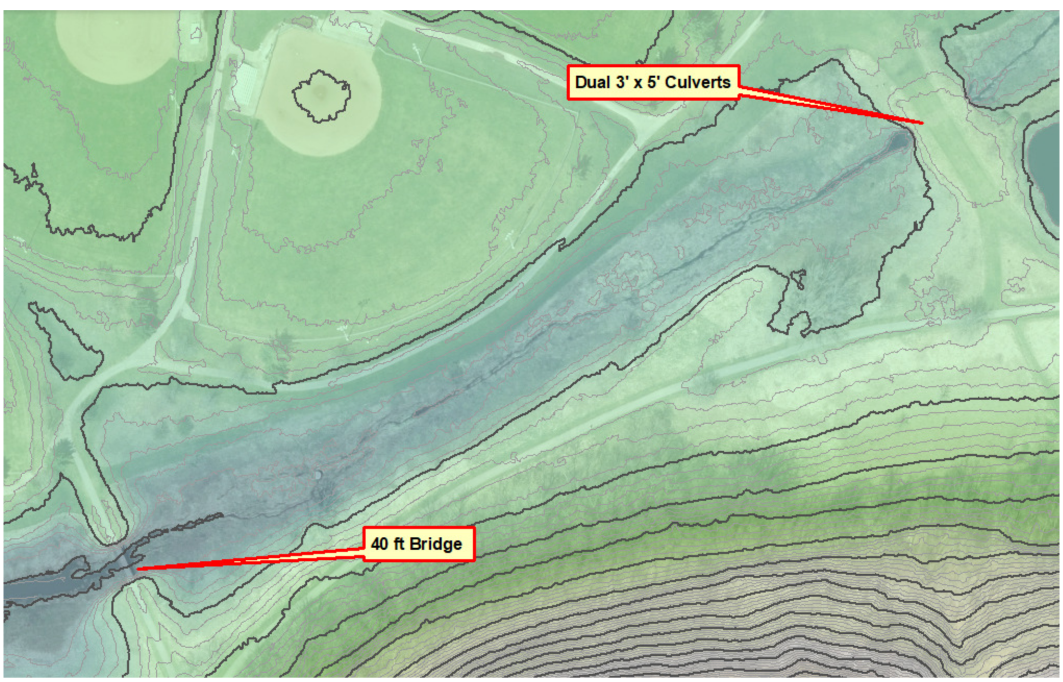
We did have a couple specific locations or issues to comment on, particularly in regards to hydraulics simulation.

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 be 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.

**Reference:** **Peer review of Greentree / McKenna Noncalibrated XPSWMM model**

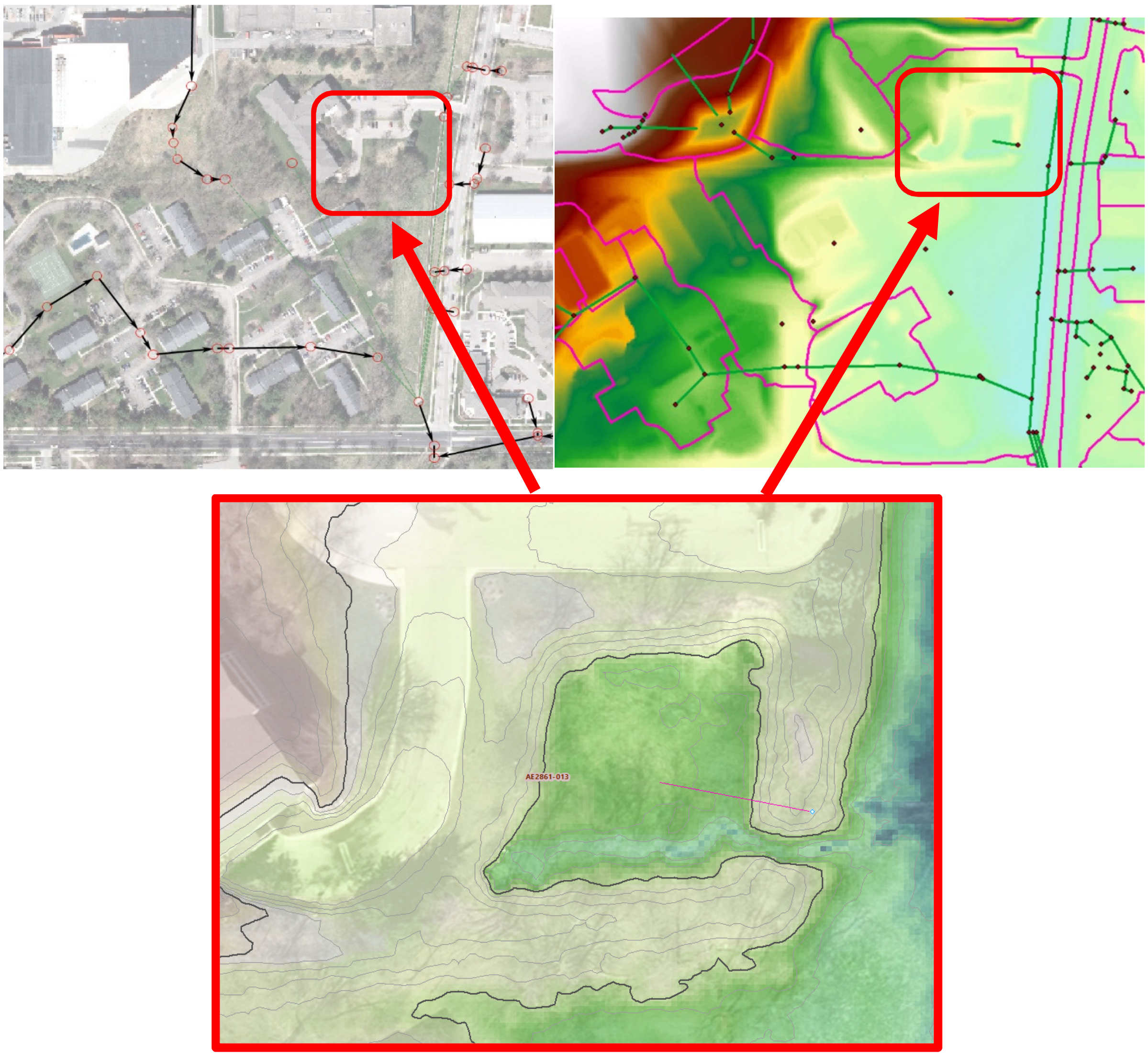


**Reference:** **Peer review of Greentree / McKenna Noncalibrated XPSWMM model**

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.



5. We understand that the City has an ongoing greenway / channel flood mitiation 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.

**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

# 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

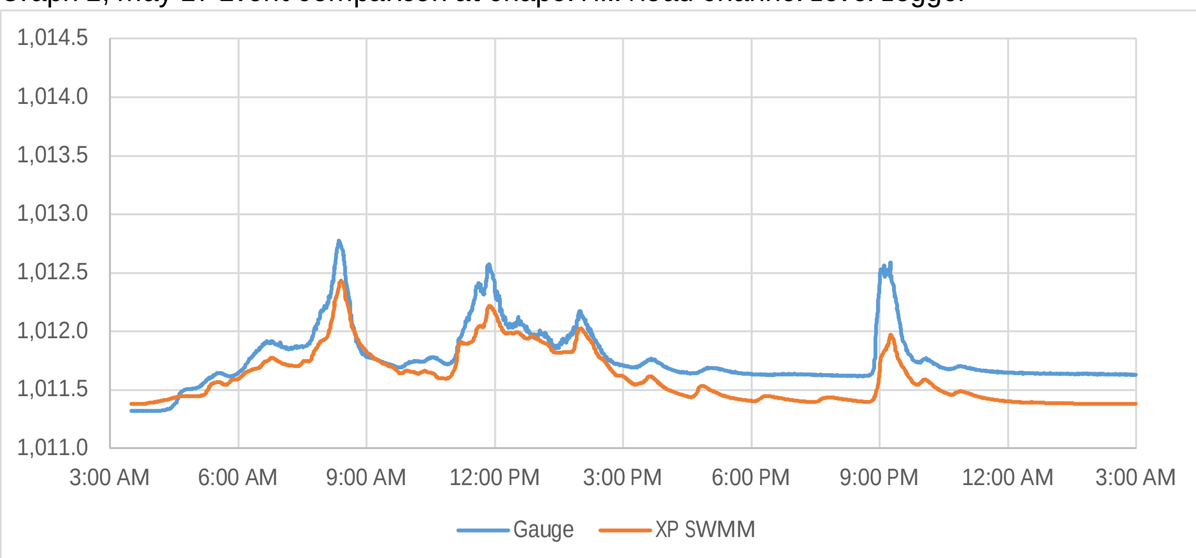
To calibrate the model to this level logger, the model was reduced down to include just that which drains to this location. The un-calibrated model results showed levels below that observed at the level logger for the above storms. Timing of each runoff peak lined up well with the metered and modeled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

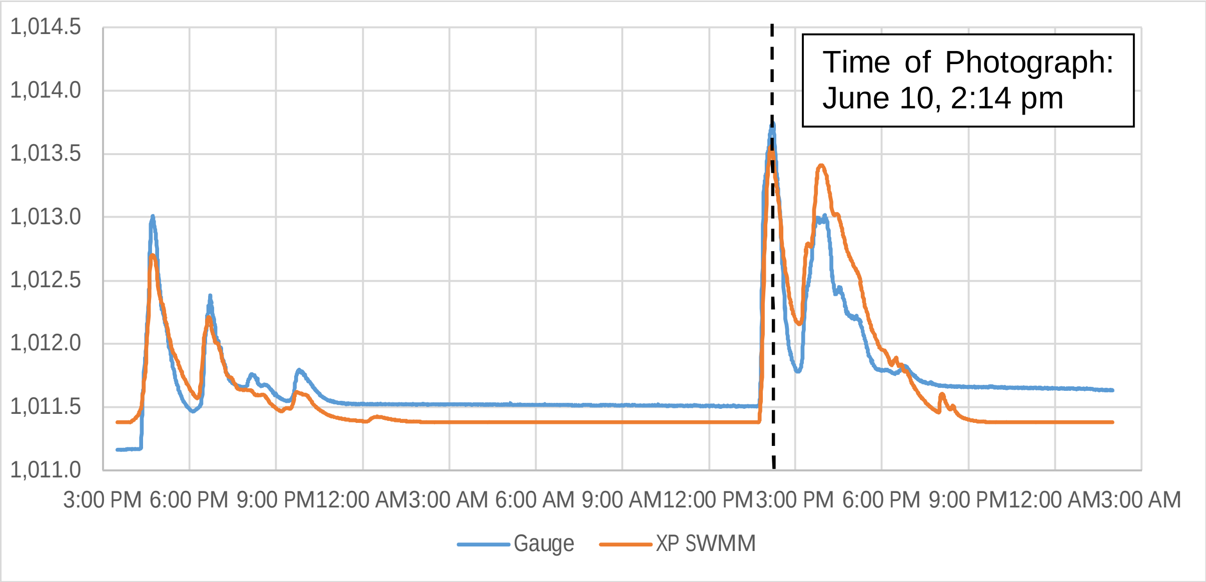
Table 2, Calibrated Infiltration Rates

| 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 |

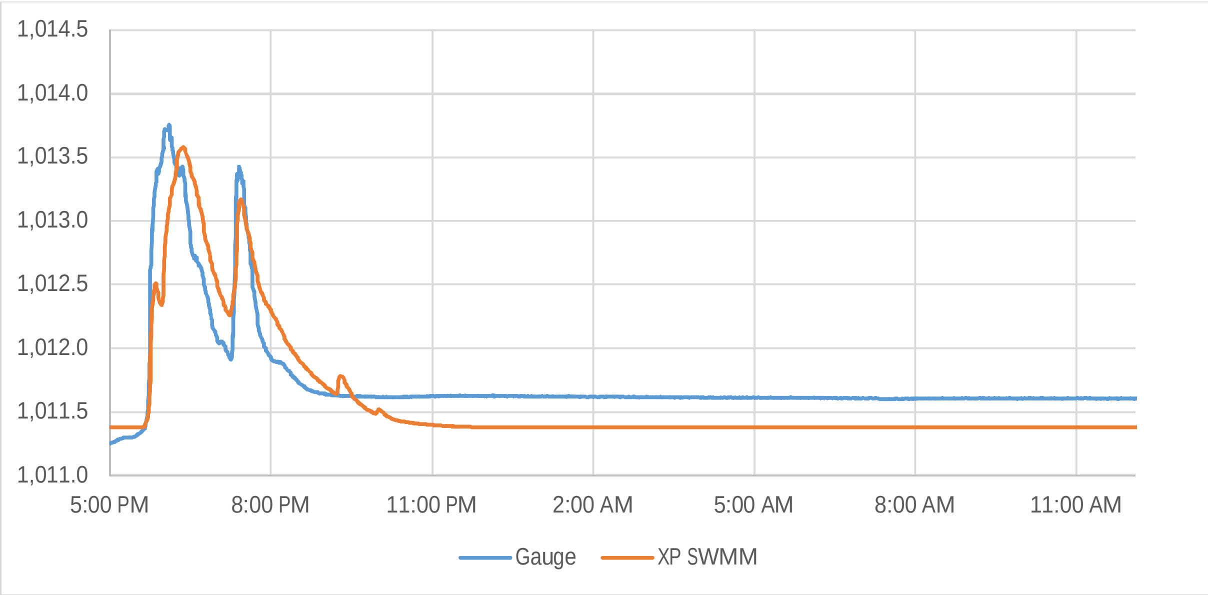
Graph 1, May 17 Event Comparison at Chapel Hill Road Channel Level Logger



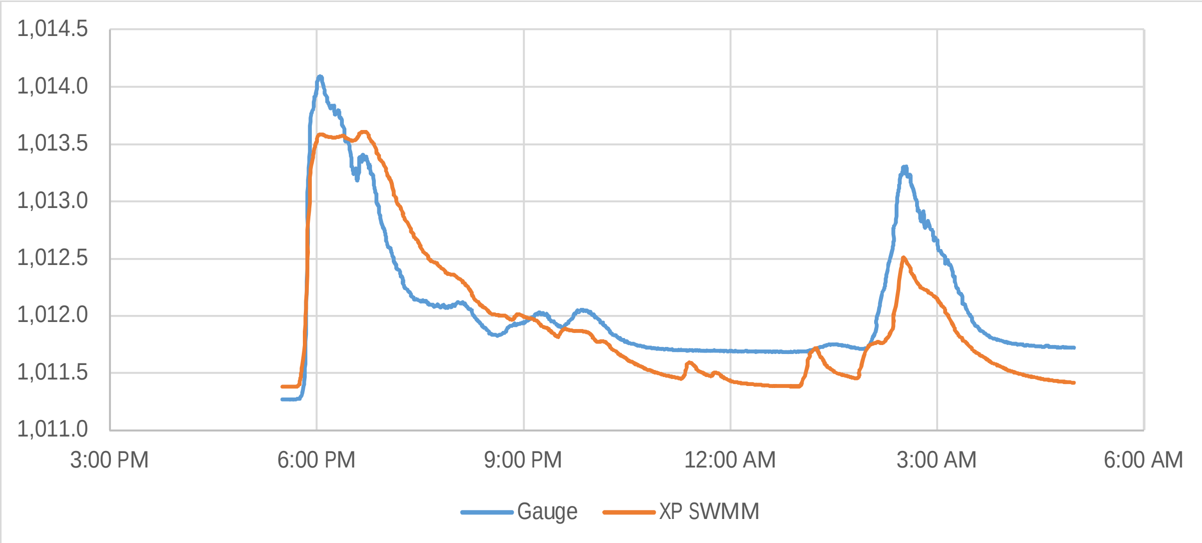
Graph 2, June 9 – 10 Event Comparison at Chapel Hill Road Channel Level Logger




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

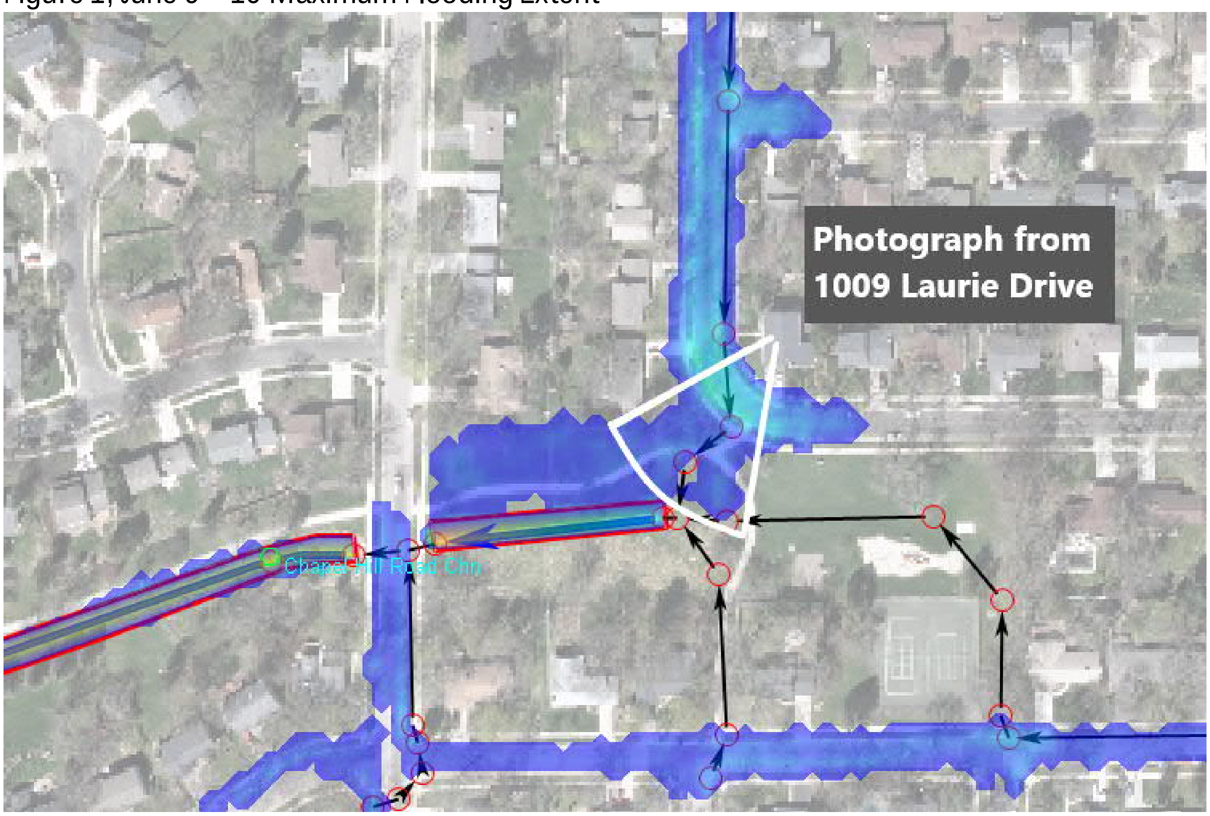


Graph 4, July 9 Event Comparison at Chapel Hill Road Channel Level Logger




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 to following photograph at exactly 2:14 pm, June 10$^{th}$, capturing the peak of the rainfall event.

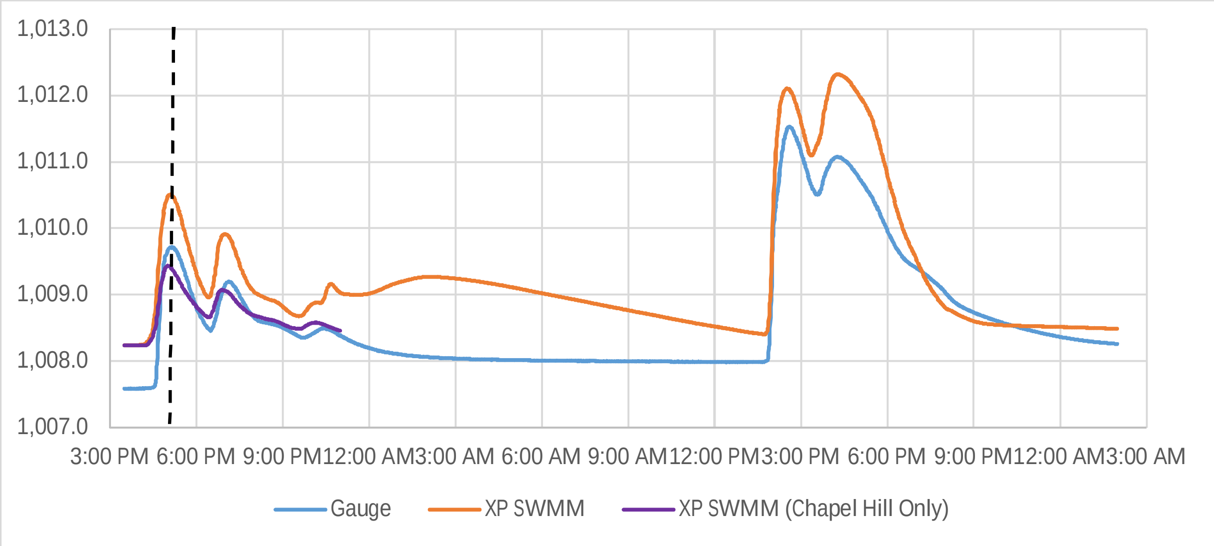
Figure 2, Residents Photograph at Peak of June 9 – 10 Rainfall Event


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.

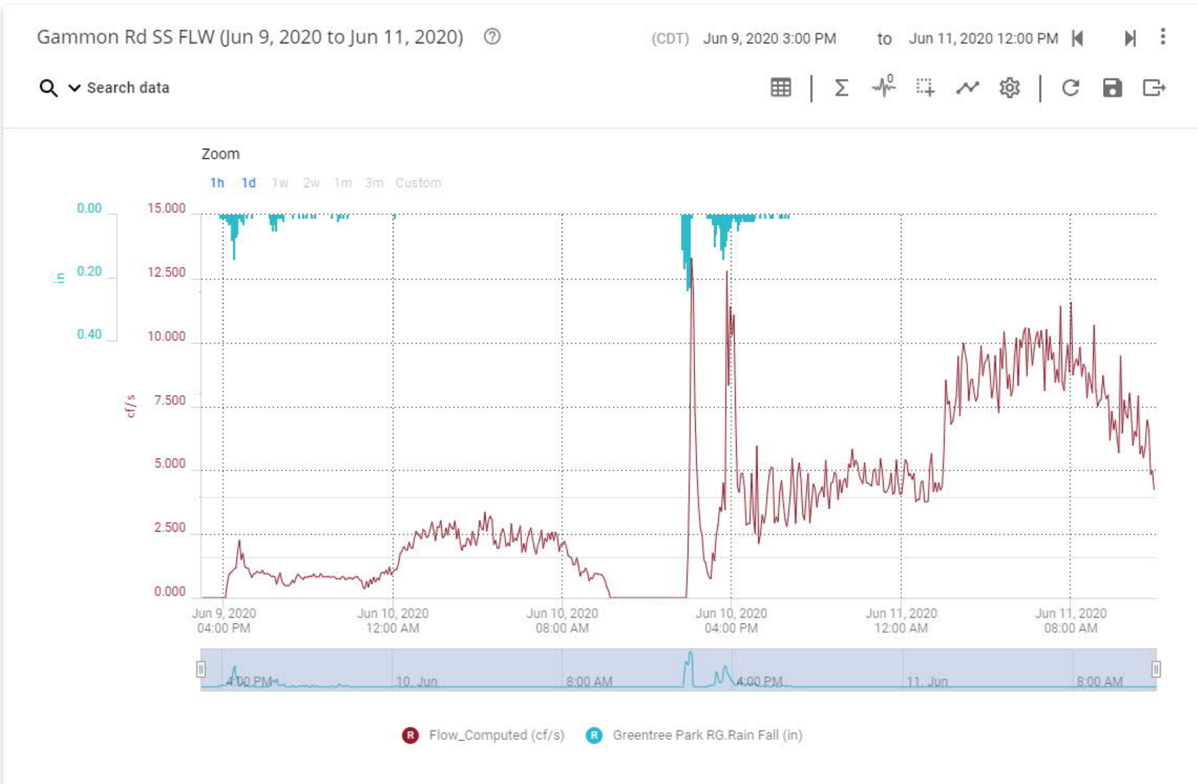
Metered (Gauge) = 30 cfs
Modeled (XP SWMM) = 100 cfs

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.

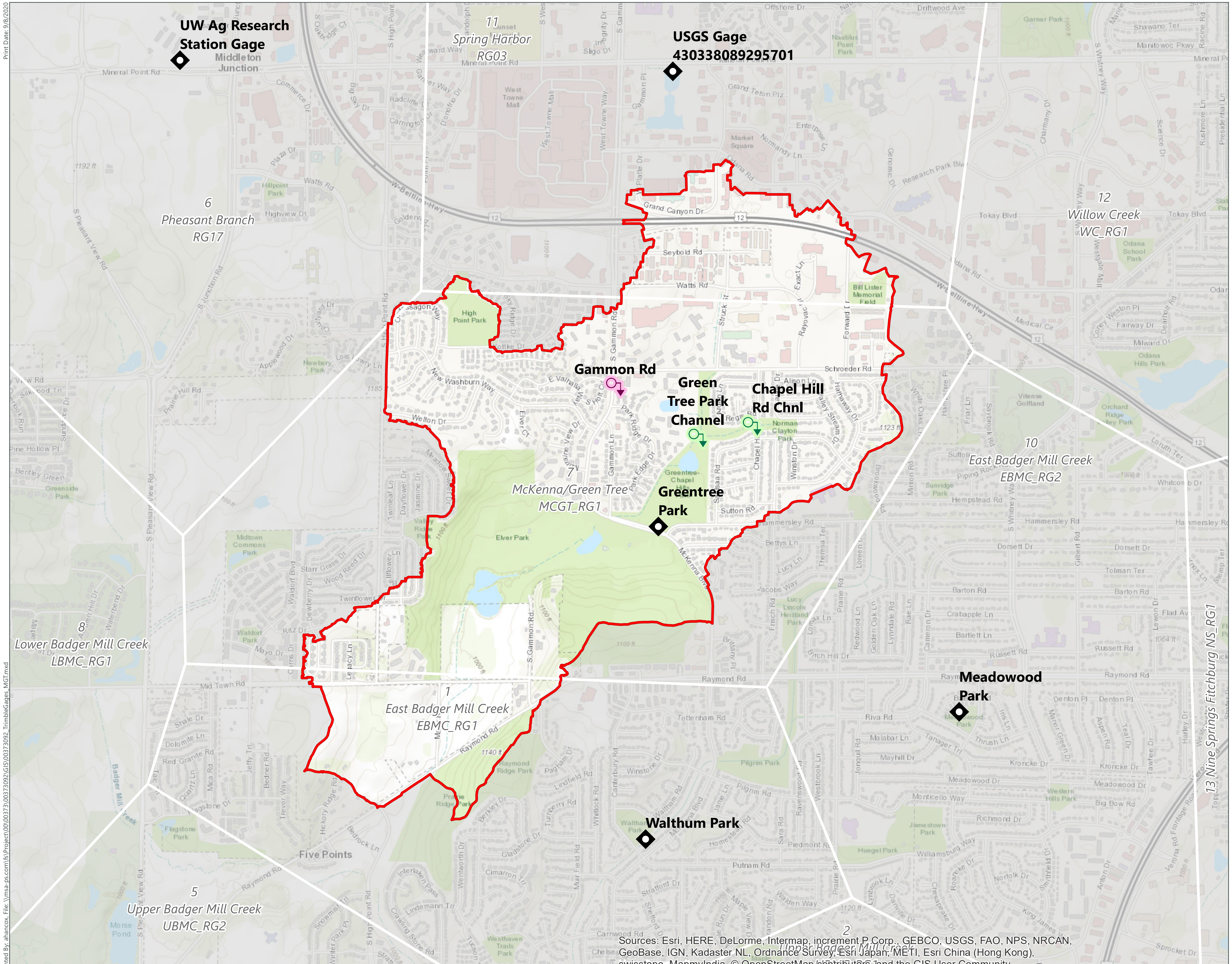
Figure 3, Trimble Output Gammon Rd Flowmeter – June 9 – 10




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

MSA

0 0.15 0.3 Miles

Print Date: 9/8/2020
Printed By: ahancox File: \\msa-ps.com\fs\Project\00\00373\00373092\GIS\00373092_TrimbleGages_MGT.mxd

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

Stantec

# Memo

| | | | |
|---|---|---|---|
| To: | Caroline Burger, City of Madison<br>Matt Allie, City of Madison<br>Eric Thompson, MSA | From: | Aaron Volkening<br><br>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.

**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.

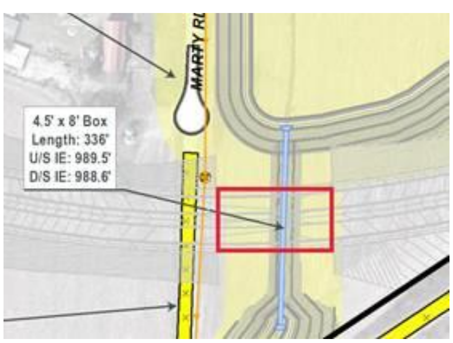
## Initial Comments (received 3/22/2022)

- **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.”

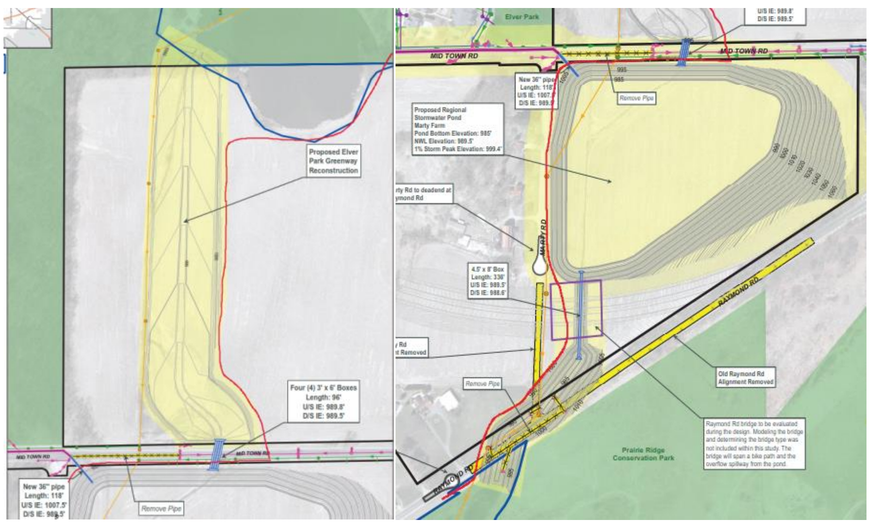
- **Comment on Proposed Solution Figures 30 K: “**Please add a label showing the NWL elevation and modeled 1% storm peak elevation. In addition, the pond bottom elevation or 5’ contour labels would be useful. At the break in the Raymond Rd. proposed alignment contours, could you add a shape and label 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 | |
| | | | | **Subtotal** | **$ 273,111** | |
| | | | | **Contingency 25%** | **$ 68,278** | |
| | | | | **Design 10%** | **$ 27,311** | |
| | | | | **Total** | **$ 368,700** | |
| | | | | **Land Acquisition** | **$ -** | |
| | | | | **Wetland Mitigation** | **$ -** | |
| | | | | **Total Total** | **$ 368,700** | |

**DID NOT INCLUDE ROADWAY PAVEMENT, STORM IN TERRACE-**
**CONCERN OF PAVEMENT DAMAGE FROM CONSTRUCTION ACTIVITIES**

**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' X6' 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 appartment 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.