Technical Memorandum

Date:	Friday, August 19, 2016
Project:	O Avenue Basin Drainage Study
To:	City of Cedar Rapids
From:	Dave Haugen, PE/HDR, Mike Schubert, PE/HDR, Brice Stafne PE/HDR
Subject:	TM 3.3 O Avenue Basin Drainage Study – Modeling, Results, and Recommendations

This Technical Memorandum presents the basin-scale stormwater model development, results from the model, and the conclusions based on this modeling study for the O Avenue basin. The intent is to document model input data, modeling methodology, provide relevant information from the simulation results, and discuss improvement strategies for the O Avenue basin in light of modeling results. The Technical Memorandum is organized as follows.

- Objective
- Summary
- O Avenue Basin Background
- Model Development
- Model Analysis
- Recommendations

Objective

The City of Cedar Rapids (City) is in the process of updating the City's Stormwater Master Plan. As part of this effort, the City is developing a city-wide hydraulic model to evaluate the stormwater collection and conveyance system. The model was developed in two main steps: development of a "macro-scale" model and development of detailed basin models.

The first modeling effort focused on modeling the large pipes (48" and larger), open channels, and major detention facilities of the City's stormwater conveyance system. The development and results from this first effort are detailed in TM 3.1. The macro-scale model is the foundational model for the subsequent step, the basin-scale models. The macro-scale model is a one dimensional (1D) network model, simulating conveyance in the storm sewer network.

Detailed basin models, which simulate ponding, overland flow, and a more extensive pipe network, will be developed to enable evaluation of mitigation strategies in the context of the entire system. The O Avenue basin model consists of a more detailed one dimensional (1D) model for conveyed flow as well as a two dimensional (2D) flow domain to predict overland flow.

The objective of this Technical Memorandum is to summarize the development, validation, simulation results, and discuss potential improvement recommendations drawn from the O Avenue basin-scale model. This document will be incorporated in the Stormwater Master Plan as Technical Memorandum 3.3 (TM 3.3).

Summary

Model Approach
HDR has developed a basin-scale model of the City's stormwater conveyance system in the O Avenue basin. The model was developed based on GIS data provided by the City, including topography, soil type, land use, pipe network data and additional survey data. Catchments were developed using LiDAR data and pipe network data. Time of concentration and curve numbers were developed from the provided spatial and elevation data. Based on these characteristics and rainfall, the model can calculate a runoff hydrograph, which is applied to the one-dimensional (1D) network.

The 1D network was developed based on the GIS-data provided and additional pipe survey data provided. Generally, pipe diameter and invert data were provided for approximately 30% of the pipe junctions in the GIS database. Survey data was used to confirm and/or document select sewer characteristics at key locations. Any remaining gaps in data (pipes without data) have been resolved at this point by inferring geometric and attribute data based on upstream and downstream reaches. Open channels connecting pipe sections were included as 1D elements with cross sectional shapes which were determined using LiDAR data and surveyed cross sections in select key locations.

The 2D flow domain was used to predict overland flow and conveyance across the ground surface. The surface model was developed based on LiDAR topographic data. Triangular mesh polygons that make up the 2D flow domain were developed from LiDAR and roadway planimetry (footprint) GIS data. The resulting mesh polygons generally represent the elevations present in overbank areas and roadways, but do not represent curb flow lines or other influential flow features. Resolution in roadway areas was increased (compared to other overland areas) to better represent the geometry. Most roadway sections were represented by a minimum of two mesh elements across the width.

A grouped-inlet approach was used in this evaluation to connect the 1D and 2D domains. This approach groups several inlets close in proximity, and connects the 1D and 2D domains at a single node without considering individual inlet capacity. The grouped-inlet approach is useful for evaluating storm sewer conveyance independent of inlet capacity, because it prevents an inlet capacity limitation from masking a sewer conveyance limitation. This approach also reduces the amount of field verification necessary to inform model inputs.

The model was used to simulate the 5-year and 100-year 24-hour nested storm events over the O Avenue basin. Anecdotally, results from these simulations replicated staff's recollection of the magnitudes of surface water ponding in areas where stormwater complaints and damages have been observed in the past.

Results and Basin Evaluation
Model results indicated that several locations experience ponding due to inadequate pipe capacity during the 5-year event. Those locations include Greenlefe Drive NW and Richland Drive NW, O Avenue Between 30th Street NW and 24th Street NW, Koehler Drive between O

Avenue and N Avenue, and downstream of Harrison Basin. Areas experiencing surcharging and overland flow were similar for the 100-year event, with flooding depths and extents being larger in magnitude for the 100-year event.

The model results were used, along with soils data, topographic data, and land use data to evaluate the potential effectiveness of green infrastructure, local distributed storage, regional storage, and conveyance improvements to develop a recommended strategy to meet the City's stormwater management objectives. Metro Area Standards for stormwater quantity management include conveying the minor storm event (5-year) within the pipe network and minimizing the risk of damage outside of the right of way for the major storm event (100-year). Specifically for the O Avenue Basin, the City's objectives also include reducing overtopping risk at Harrison Basin to occur less frequently than the 100-year event and not increasing peak flows downstream of Harrison Basin due to the future construction of stormwater pump stations as part of the Cedar River Flood Control System.

Recommendation

HDR recommends that the City include the collection of concepts identified in Table 1 in the City's stormwater capital improvement program (CIP). This collection of projects can be implemented to reduce the risk of overtopping of Harrison basin to less frequently than the 100-year event. This collection of projects includes construction of stormwater basins near Koehler Drive and Edgewood Drive, expansion of Harrison Basin, and construction of a wet detention pond with a capacity of approximately 101 ac-ft along Meth-Wick Creek near 18th Street. This alternative is the most cost effective method to achieve Metro Area Standards with the least impact to the neighborhoods within the O Avenue watershed. This alternative, which has an estimated cost of $7.42 million, also meets City's goal to not increase peak outflows from Harrison Basin.

Table 1: Recommended O Avenue Basin Improvements and Associated Costs

Improvement	Cost
Conveyance Improvements	$1.3 mil
Harrison Basin Expansion	$1.1 mil
18th St Basin – 101 ac-ft	$4.3 mil
Edgewood Basin	$0.37 mil
Koehler Basin	$0.35 mil
Total Cost	**$7.42 mil**

An incremental approach can be taken when constructing the improvements. Expansion of Harrison Basin would reduce the risk of Harrison Basin overtopping to less frequently than a 5-year event. Construction of the Edgewood Basin and conveyance improvements identified in the vicinity of O Avenue would achieve a 5-year level of service elsewhere in the O Avenue Basin and 100-year level of service upstream of the 18th Street basin location. Finally, construction of the 18th Street Basin could reduce the risk of Harrison Basin overtopping to less frequently than a 100-year event. Construction of Koehler basin provides an independent benefit of reduction in risk of ponding on O Avenue and risk of overland flow between O Avenue and Meth-Wick Creek.

O Avenue Basin Background

The O Avenue watershed is located in the northwestern quadrant of the City of Cedar Rapids. The watershed begins west of Edgewood Road NW and follows Meth-Wick Creek, an open channel drainageway paralleling O Avenue NW. Meth-Wick Creek daylights South of O Avenue at 24th St NW and generally flows east, through City Detention basin No. 206 (Harrison Basin). Harrison Basin is located directly north of Harrison Elementary School. Downstream of Harrison Basin, Meth-Wick Creek flows into a large box culvert. The culvert starts as an 8-foot-by-4.3-foot box that transitions to an 11-foot-by-5-foot box at 5th Street until its outlet into the Cedar River. The location of the O Avenue basin is shown in Figure 1. A general overview of the O Avenue Basin is shown in Figure 2.

Table 2 describes the existing land use within the O Avenue basin. Current land use is largely residential and undeveloped lands, with those areas making up over 80% of the basin. The existing impervious area is estimated at 208 acres, or 25% of the total basin area and total areas available for future development were estimated at 160 acres.

Table 2: O Avenue Basin Land Use Characteristics

Land Use Type	Total Area (ac)
Total Basin Area (Commercial, Residential, Undeveloped, and Roads)	822
Total Commercial	9
Total Residential	455
Total Undeveloped	226
Potential Development	*157*
Roads/ Other Impervious	132
Total Impervious Area – Existing Conditions (Including Residential and Commercial)	208

The basin has a history of flooding. In several peak events, Meth-Wick Creek overtopped Highwood Drive NW. In 1993, 1998, and 2014, Harrison basin overtopped, flowing over 11th Street NW and flooding the residential area downstream. Areas to the east along the river have been flooded, generally as a result of backflow from the Cedar River through the storm piping or lack of a storm pump station to handle precipitation during high river events.

On June 29, 2014, heavy rainfall resulted in widespread flooding throughout the City. Gauge-adjusted radar rainfall records indicate that between 3.5-5.0 inches of rain fell, mostly within a one hour long period. Peak 5-minute rainfall intensities exceeded 8 inches per hour in isolated areas. This storm approximates a 100-yr to 500-yr 1-hour duration rainfall event. Following the event, reports were received that Harrison Basin overtopped, resulting in the flooding of basements and garages of several downstream property owners. Incident report locations and additional solid waste call densities are shown in Figure 3 and Figure 4, respectively. These figures can be used to identify areas impacted by flash flooding.

A 1983 study by Shive-Hattery & Associates and the City's1998 Stormwater Master Plan recommended either expansion of drainage capacity of the box culvert from Harrison basin to the Cedar River or enlargement/addition of detention facilities. These studies identified that the most cost efficient method would be the expansion of Harrison Basin and construction of an additional temporary stormwater basin (18th Street Basin) along Meth-Wick Creek between Highwood Drive NW and 18th St NW.

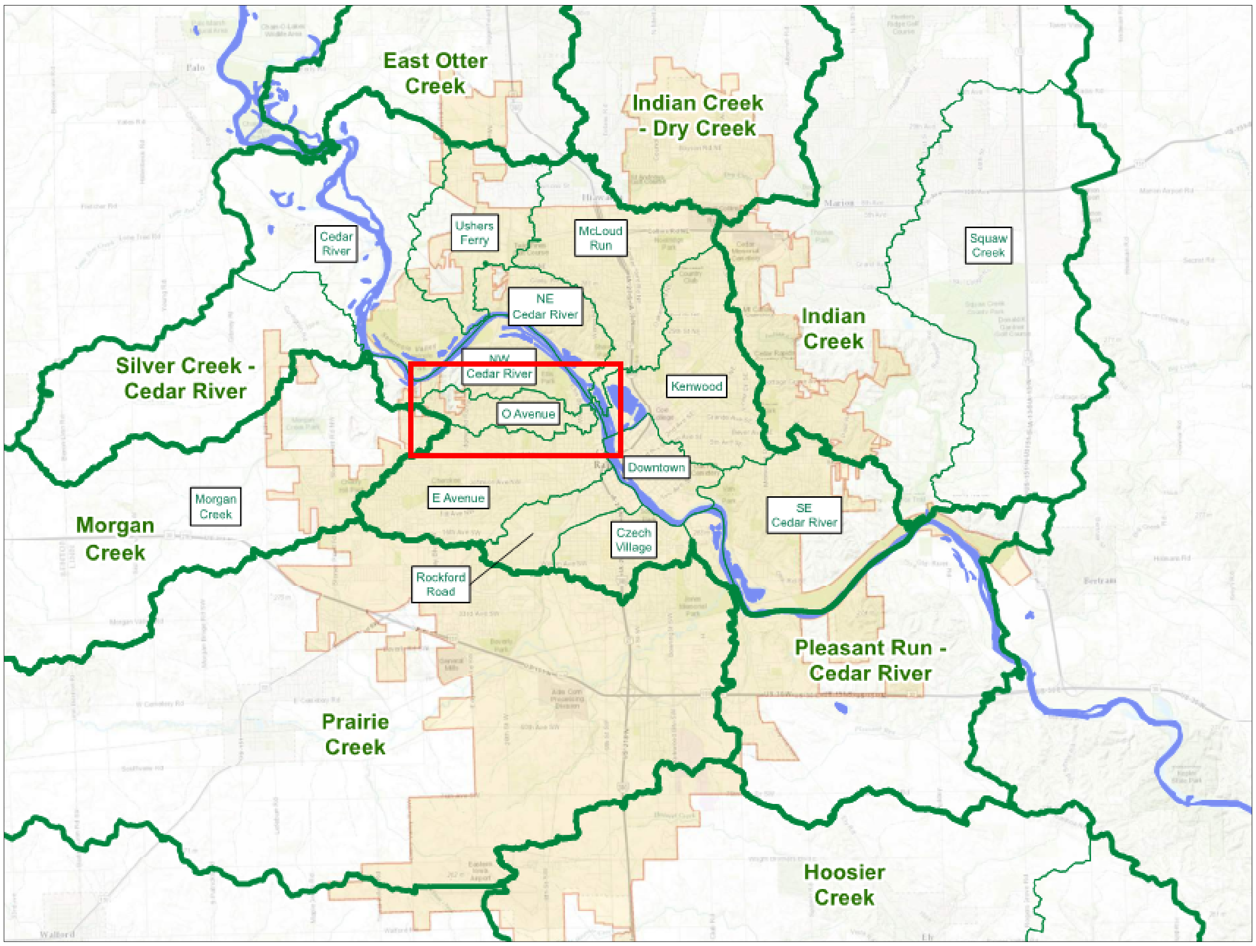


Figure 1: Location of O Avenue Basin within Cedar Rapids

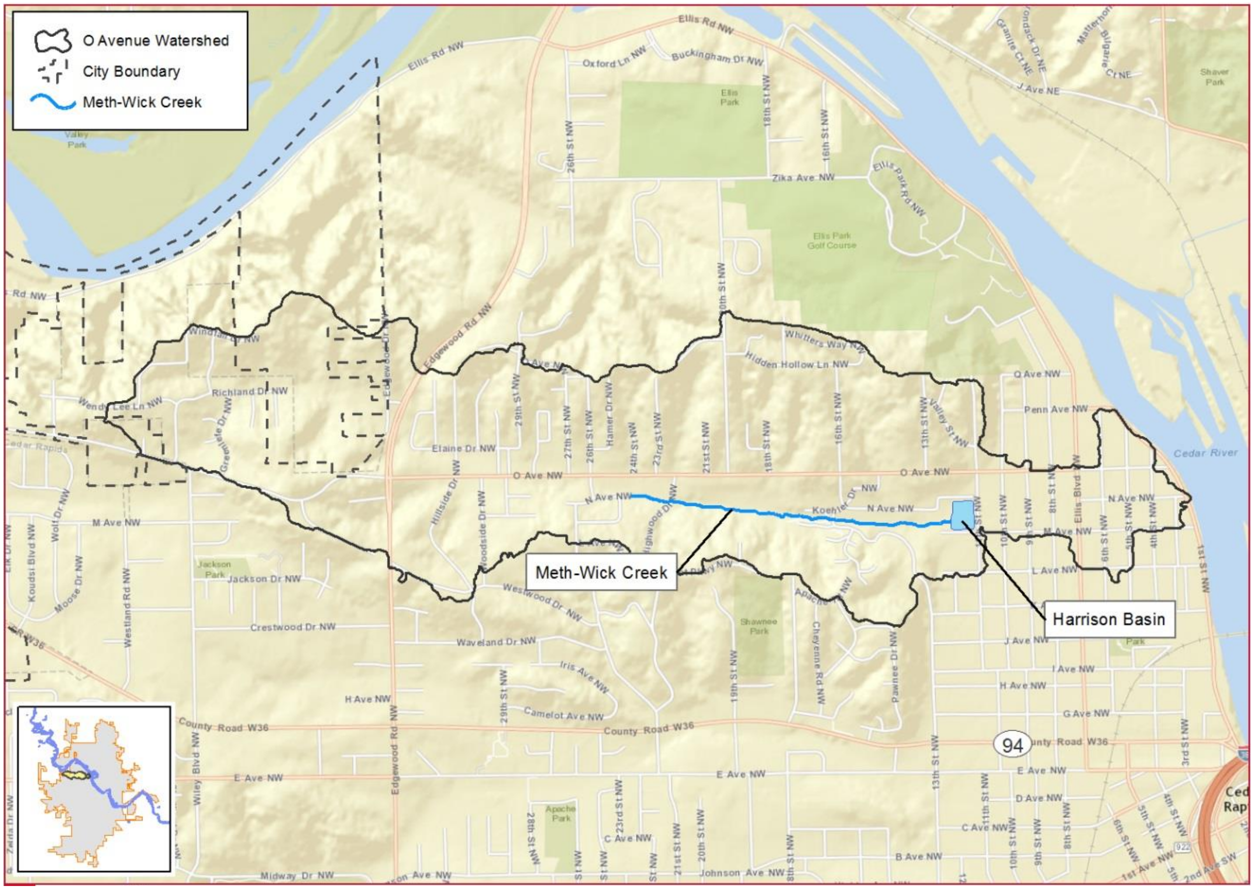


Figure 2: Overview of O Avenue Basin

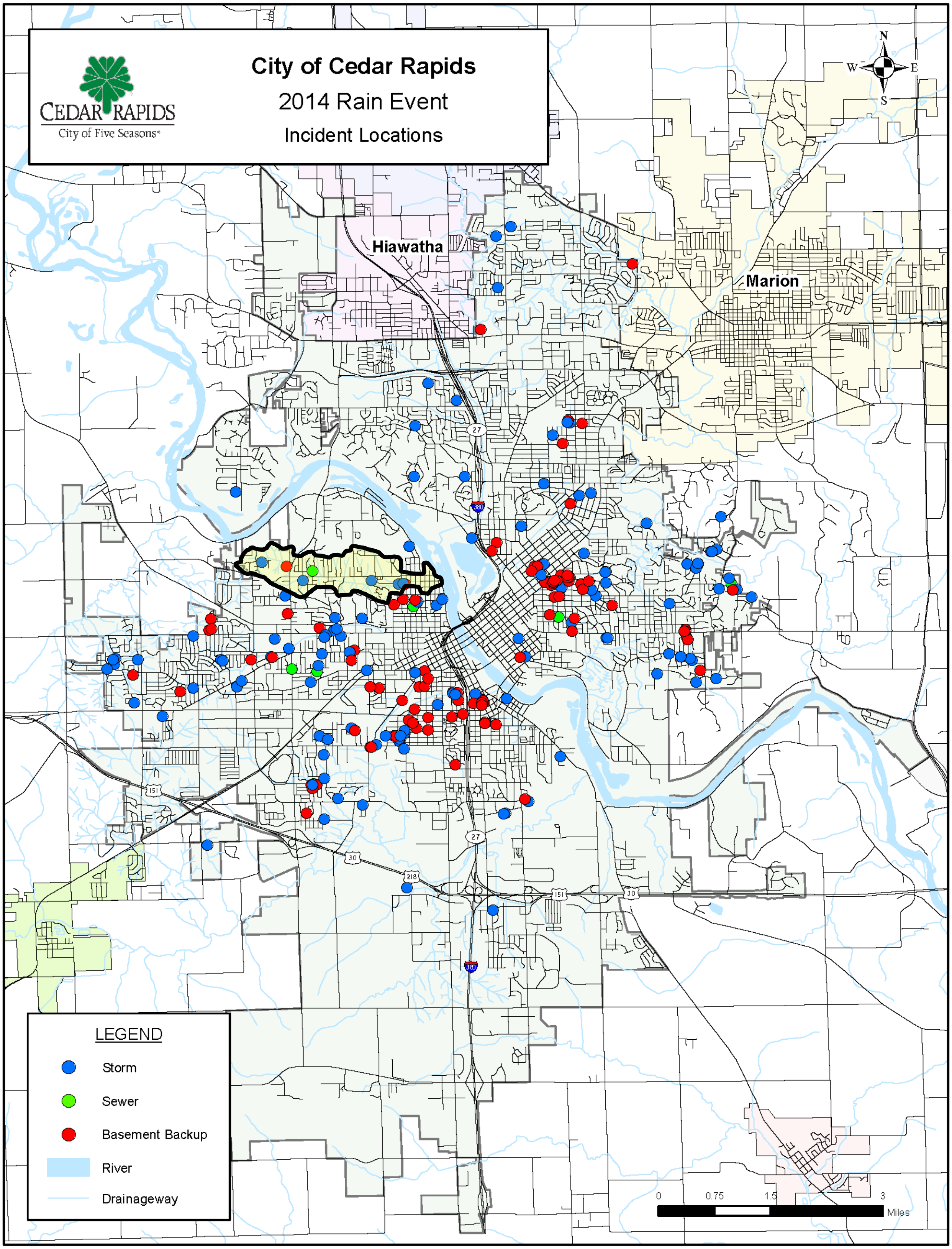


Figure 3: Summary of Reported Stormwater Flooding Incidents, June 29-30, 2014 (Approximate O Avenue Basin Location Highlighted)

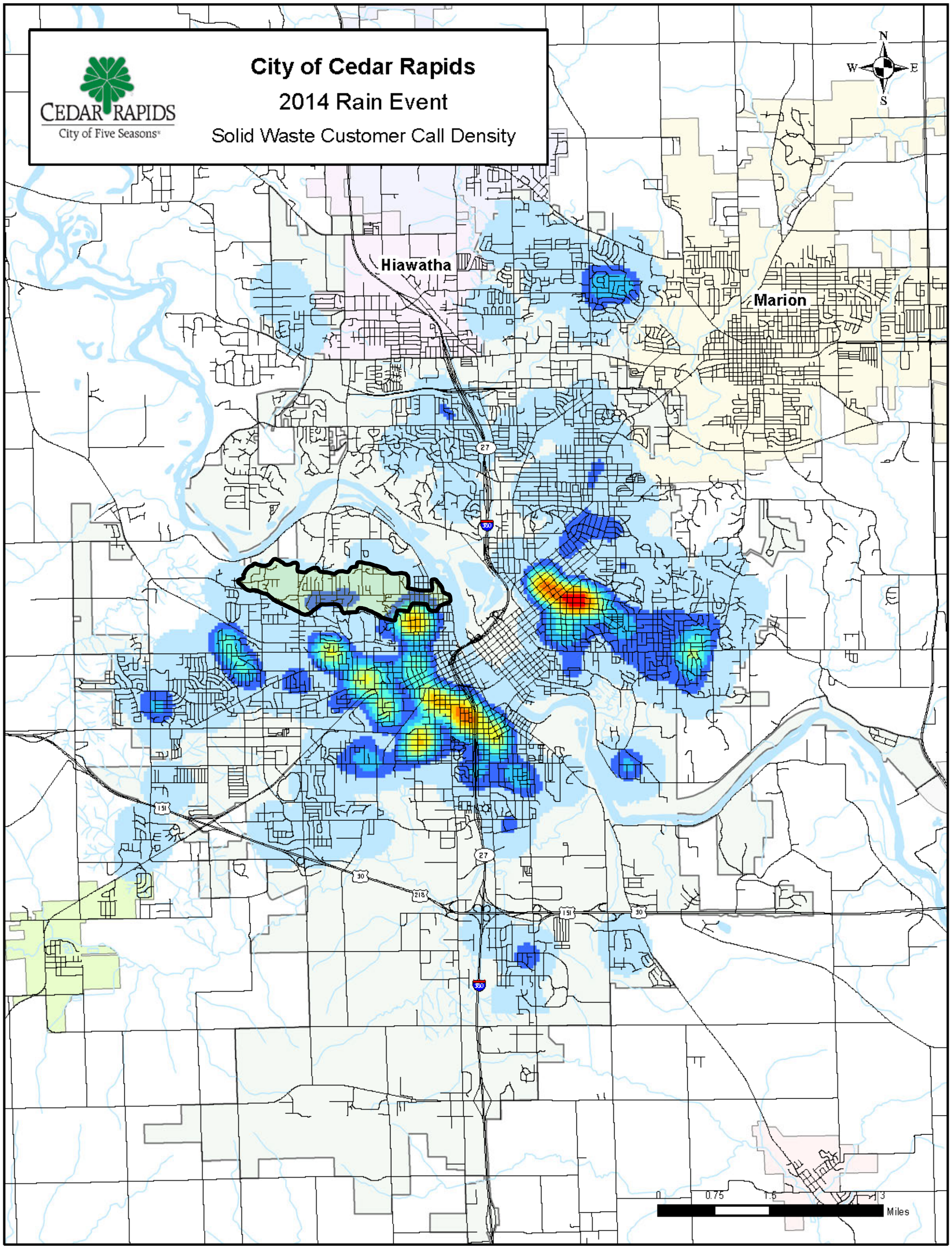


Figure 4: Heat Map of Extra Solid Water Pickups Following June 29-30, 2014 Rainfall (Approximate O Avenue Basin Location Highlighted)

Model Development

Software

InfoWorks ICM software was selected for the stormwater master plan modeling effort. InfoWorks ICM, from Innovyze, provides a comprehensive, GIS-based, computational engine that is both stable and efficient. The model capabilities and HDR's experience with this software make this selection a good and fitting platform to analyze the City's stormwater and sanitary collection systems. The software selection process is documented in the "Model Software Selection" Technical Memorandum, Appendix A to the Stormwater Masterplan TM 3.1 (HDR 2016).

Catchment Characteristics

47 catchments within the O Avenue basin were delineated manually based on LiDAR topography, storm sewer data, and open channel alignment. These catchments were used for the O Avenue basin model and analysis.

TOPOGRAPHY (LIDAR)

LiDAR data collected in October of 2012 was used to develop a digital elevation model (DEM) with a 3-foot grid cell size. The DEM, along with city-provided GIS data representing the City's storm pipe network and open channels, were used to confirm catchment delineation and generate the computational mesh for simulation of overland flow.

SOIL TYPE (HYDROLOGIC SOIL GROUP)

The USDA Soil Survey Geographic (SSURGO) Database for Linn County, Iowa, published on August 19th 2014, was used to characterize hydrologic soil group conditions for each catchment. Table 2 summarizes hydrologic soil groups by area. The majority of the basin soils (93%) are classified as Type C (slow infiltration rate) or D (very slow infiltration rate). The spatial distribution of soil types is shown in Figure 5.

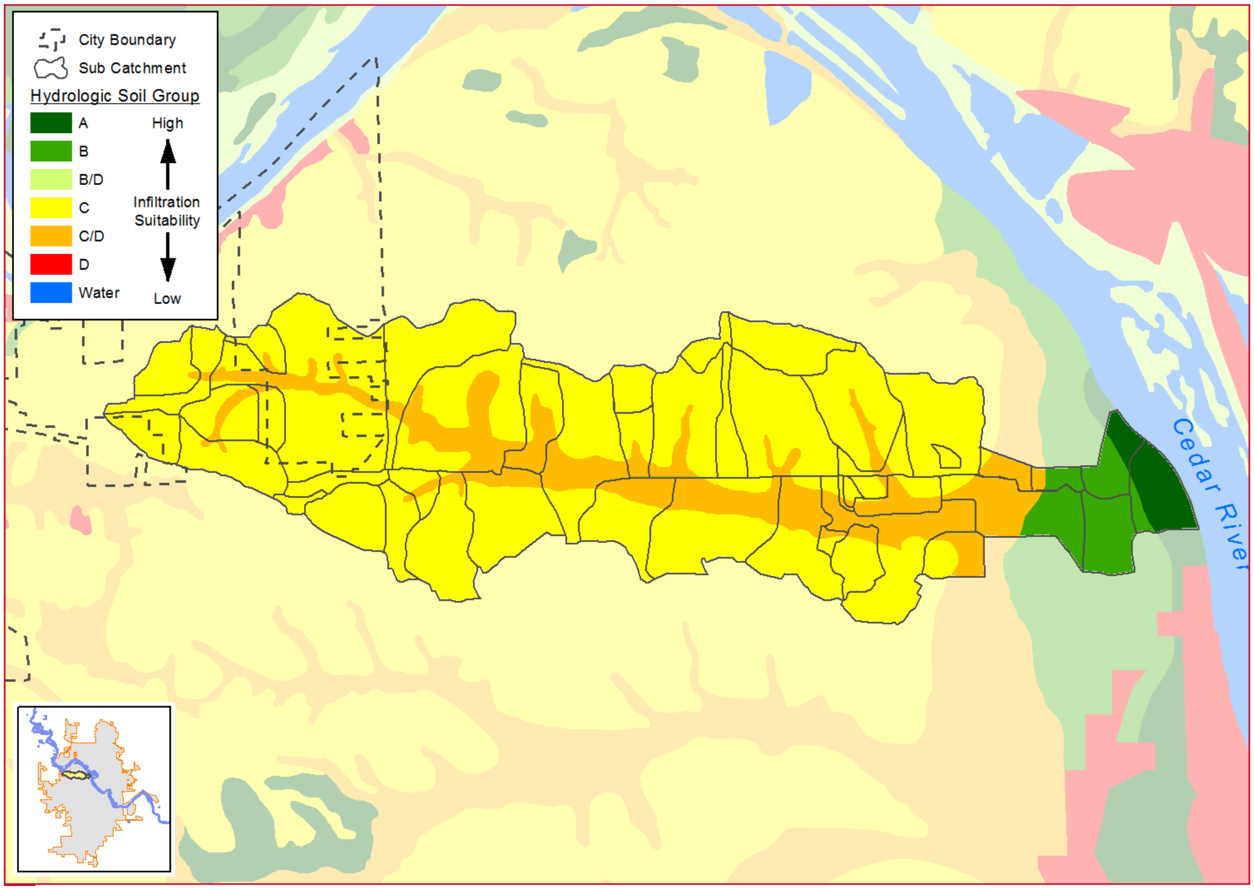


Figure 5: Hydrologic Soil Group Type

Table 2 - Hydrologic Soil Group (HSG) Summary

HSG	% of O Avenue Basin Area
A	2.4
B	5.1
B/D	0.0
C	73.2
C/D	19.3
D	0.0
Water	0.0

COVER TYPE (LAND USE)

Existing land use GIS data was provided by the City from the Envision CR report. The data is maintained at the parcel level and includes descriptions of the associated land use category and links to the Envision CR website.

RIVERS, CREEKS, AND CHANNELS

There are approximately 2.1 miles of open channels within the O Avenue basin. The open channels were used along with the City's pipe network data to confirm the catchment delineation.

WINDSHIELD SURVEY

HDR conducted a windshield survey of several key locations within the O Avenue basin on April 4, 2016. The information from this survey was used to verify field data collected by the survey crew and GIS data from the City's database. The summary of this windshield survey is included in Appendix A.

Catchment Hydrology

Two hydrologic conditions were evaluated as part of the master planning effort. Existing hydrologic conditions were used for validation of the model, and future hydrologic conditions were used to evaluate system deficiencies and identify capital improvements.

CURVE NUMBERS

The NRCS SCS curve number method was used to estimate direct runoff resulting from rainfall in each catchment based on rainfall amount, land use, and the hydrologic soil group. Composite (area-weighted) curve numbers were calculated for each catchment by intersecting hydrologic soil group and existing land use GIS data with catchment boundaries. The curve number is an empirical parameter describing the soil moisture retention characteristics of an area. A lower curve number indicates that the land area will retain more water and produce less runoff than an area with a higher curve number. Impervious areas have a curve numbers approaching 100. An aerial photo taken on September 18th, 2014 was used to compare existing land use GIS data. Based on this review, some existing land use types were classified to represent hydrologic conditions. Specifically, land use types such as civic and agricultural were classified to better match land use descriptions from the NRCS TR-55 manual. In addition, the parcel-based land use layer was "flattened" to remove duplicate and overlapping polygons.

These instances typically occur at multifamily (condominium) locations. Raw curve number data are shown in Figure 6, and the existing composite curve numbers for each catchment are shown in Figure 7.

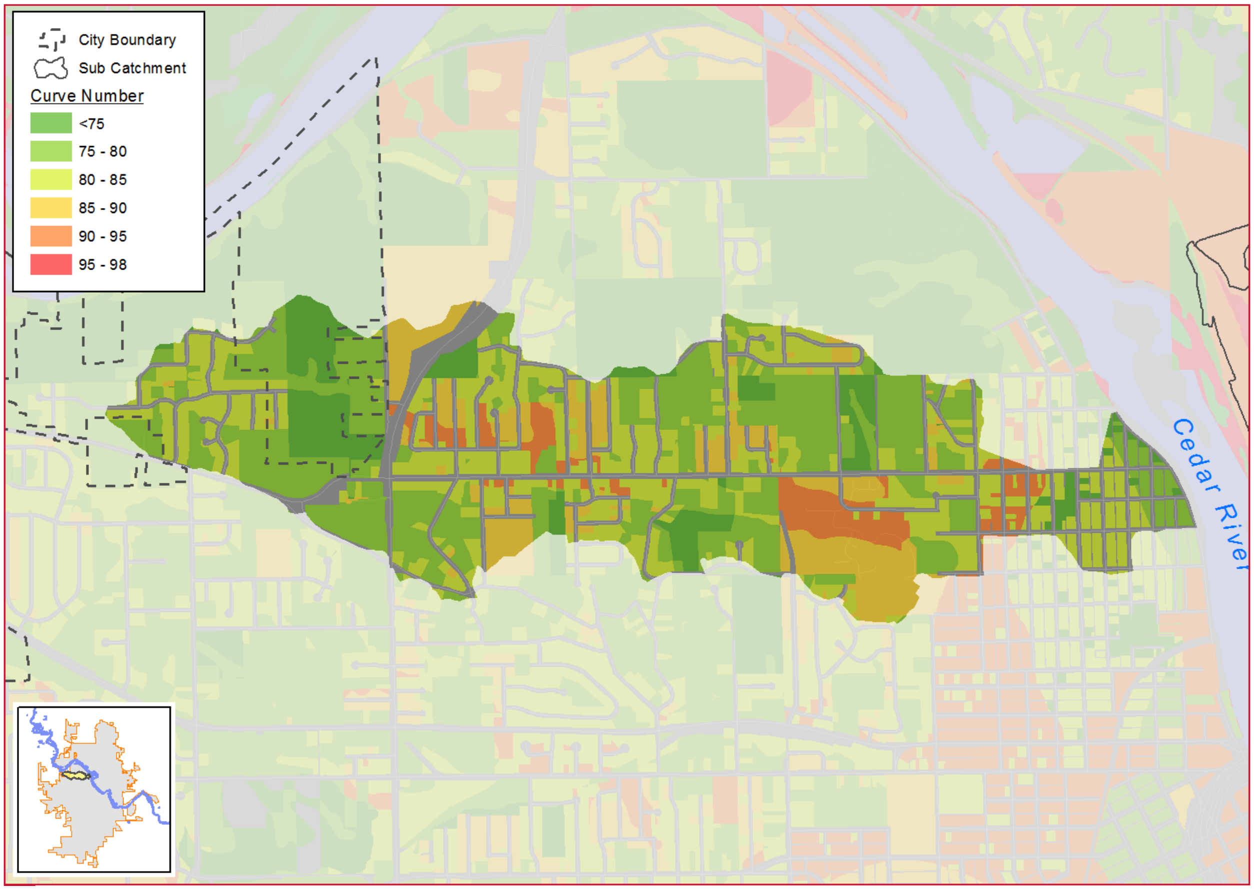


Figure 6: Curve Numbers

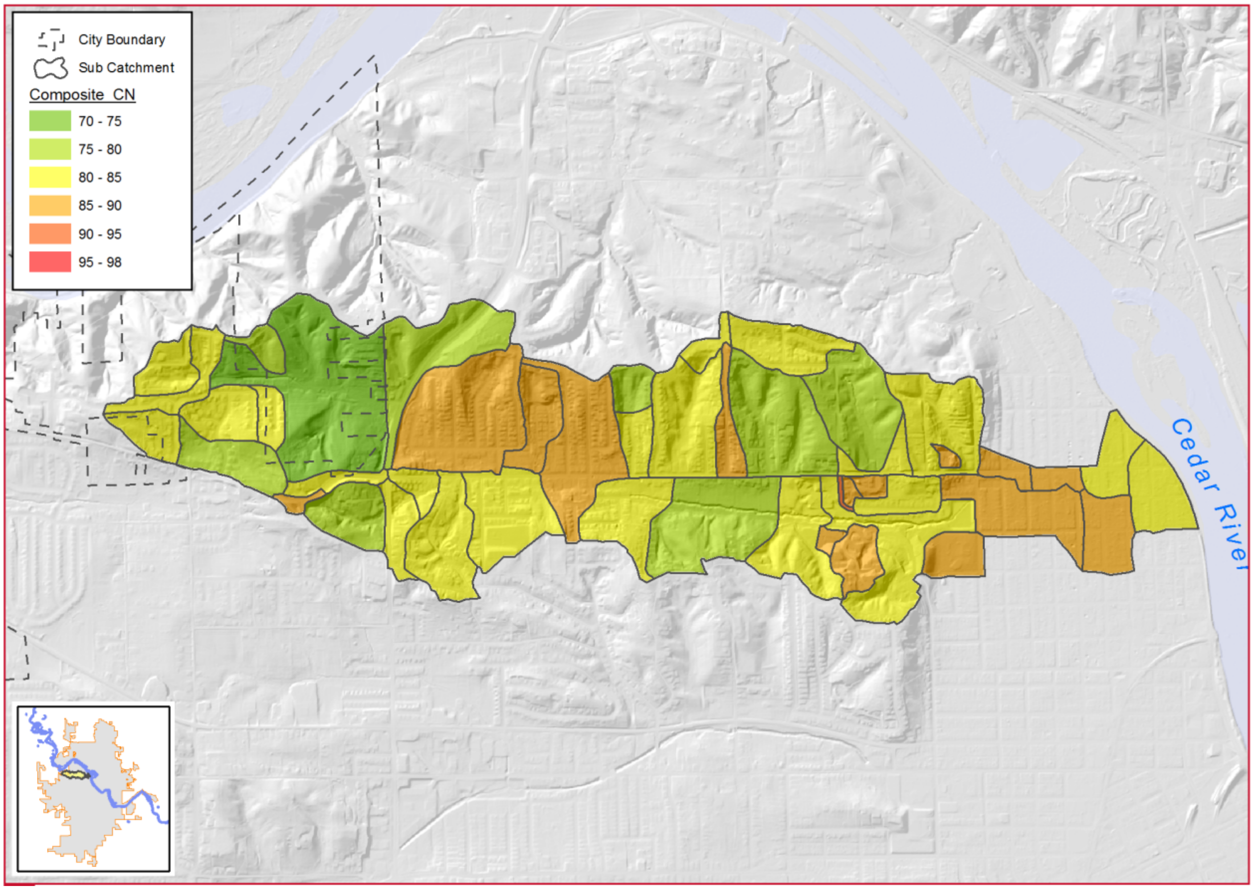


Figure 7: Existing Conditions Composite Curve Number, by Subcatchment

RUNOFF METHOD

The SCS runoff curve number transform method (NRCS TR-55) was used to develop hydrographs from each of the catchments. This method generates the runoff hydrograph based in the rainfall intensity and curve numbers.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \ , \ I_a = 0.2S, \ S = \frac{1000}{CN} - 10$$

where

Q = runoff (in)

P = rainfall (in)

$S =$ potential maximum retention after runoff begins (in)

$I_a =$ Initial abstraction and

CN = Curve number

TIME OF CONCENTRATION

The peak runoff rate and shape of the runoff hydrograph is influenced by the time of concentration. The time of concentration for each subcatchment was computed using surface characteristics, slopes, and basin geometry as outlined in NRCS TR-55. The time of concentration included components to represent the sheet flow, shallow concentrated flow, and channel flow, as applicable. Overland sheet flow was assumed to become shallow concentrated flow at a maximum of 100 ft.

FUTURE CONDITIONS HYDROLOGY

Hydrologic parameters which represent future development within the watershed were determined by assuming the development of undeveloped areas to similar zoning and density of adjacent developed areas. Assumptions about future land use were informed by the City's parcel data, which include zoning information about the type of use (residential, commercial, etc.) and the density of development. No reduction in runoff was assumed for local site detention.

ASSUMPTIONS

Further Refinements

Modeling efforts were focused on utilizing available data from the City's GIS database to estimate runoff hydrology. Further refinements could be made to the hydrologic parameters in the model based on field verification and inclusion of specific data from stormwater flooding events as these become available. These refinements, which may result in changes to runoff rates would likely improve the model representation of the condition resulting from rainfall events and may affect model findings. However, the methods used in determining the hydrologic parameters are adequate for the planning purposes of this study.

West Side Flood Protection Interior Drainage

The area downstream of Harrison Basin will be changing with the construction of the Cedar River Flood Control System west-side levee and floodwall. As a result, detailed evaluation of results was not performed in the area downstream of Harrison Basin as part of this study. Further refinement of the hydrology and additional detail of the pipe network, including proposed improvements, would be required to evaluate drainage issues in this area. Proposed conditions will likely result in very different stormwater ponding impacts at the line of protection. Changes to this area, which is downstream of Harrison Basin, would have minimal impact to the upstream routing evaluated in this study.

1D Flow Network

SUMMARY OF ELEMENTS

The 1D flow network in the basin-scale model includes approximately 5.5 miles of pipe, over 350 pipe junctions (connections), 2.1 miles of open channel, 12 stormwater ponds, and 1 outfall to the Cedar River (refer to Figure 8). Inflow hydrographs determined for each catchment are applied directly to the 1D flow network at the appropriate location. Where the pipe is conveyance-limited, water surcharges and flows in the 2D domain. The downstream boundary for the model was an outfall to the Cedar River at the N Avenue Outfall.

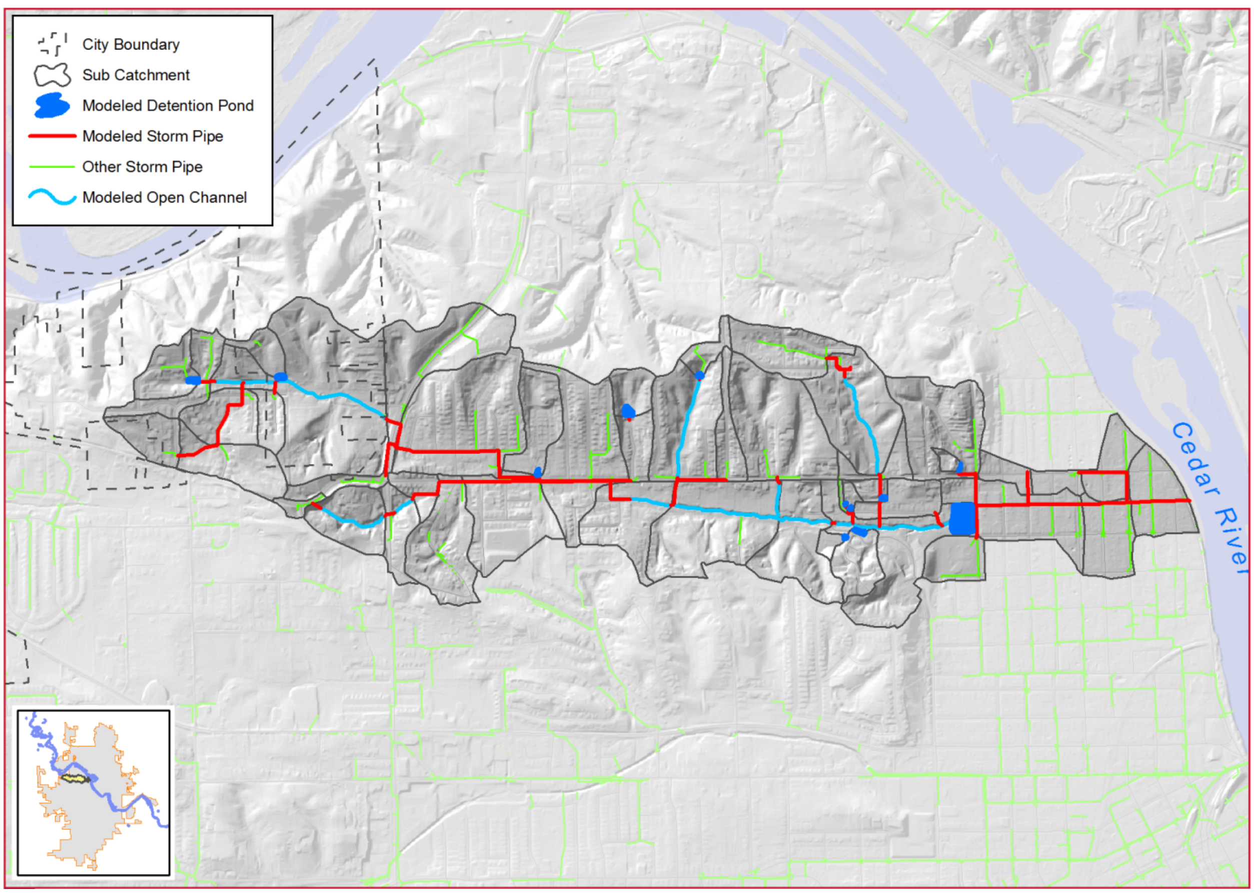


Figure 8: 1D Flow Network

DATA SOURCES

Several data sources were used to develop the 1D flow network for the basin scale hydraulic model. They include GIS data and survey data for the closed conduits and LiDAR, aerial photography, and survey data for open channels. Design drawings and additional survey provided by the City were utilized to confirm or update data related to the pipe network and detention facilities in the model. Generally, pipe diameter and invert data were provided for approximately 30% of the pipe junctions in the GIS database. Select inverts and pipe diameters were either confirmed or documented with survey data. In instances where data were not provided from the GIS database or survey, pipe characteristics were inferred from the connecting pipe segments.

City Stormwater Network GIS Data

The City's GIS database of the storm sewer network was provided to HDR as the primary data source for development of the hydraulic model. The most applicable information in the GIS data for the hydraulic model is the network connectivity, pipe invert elevations and pipe shapes and sizes.

As-Built Drawings

The City provided as built drawings from several detention ponds and larger sewers in the basin. These data were incorporated into the 1D flow network.

Supplemental Survey Data

Supplemental survey data was collected for the current project to fill in gaps in the GIS data or replace the GIS data where applicable. The survey data included pipe invert elevations, pipe shapes and sizes, and notes describing unique pipe configurations or conflicts between field observations and the GIS data. Photographs were also taken of each structure that was accessed during the survey and provided to HDR. These photographs were used where needed to confirm connectivity or otherwise inform the model development.

Open Channel Data

Stormwater in the O Avenue basin is conveyed through a series of pipes and open channels, ultimately draining to the Cedar River. For the basin-scale hydraulic model, open channels between closed conduits were included in the model. The most significant open channel in the basin is Meth-Wick Creek. Meth-Wick Creek is the receiving watercourse for much of the basin. Cross sections of the Creek were surveyed at hydraulic structures (such as bridges and culverts). Beyond the channel areas and between surveyed cross sections, overbank elevations were determined using LiDAR data.

Detention Facilities

Twelve detention facilities were included in the hydraulic model. The detention facilities ranged in area from less than one tenth of an acre to 3.1 acres and had total storage volumes ranging from one tenth to 14.2 acre-feet at high water level. Basin characteristics were taken from design drawings where available and supplemented with LiDAR data when necessary. Outlet structure information was taken from GIS data and supplemented with survey data, HDR staff observations, design drawings or other hydraulic information provided by the City.

Energy Losses

Major losses in open channels and pipes were represented using Manning's equation. The roughness coefficients that were used are summarized in Table 3.

Table 3: Manning's Roughness Coefficients

Classification	Manning's Roughness
Pipes	0.013
Grass Swale	0.03 to 0.04
Long grass, scattered brush	0.05
Wooded areas	0.08

Energy losses at junctions are calculated using the InfoWorks built-in normal head loss relationship. This method calculates energy losses based on the velocity in the pipes upstream and downstream of the junction and ratio of flow surcharging from the junction compared to the flow conveyed through the junction in the pipe. Additional losses based on pipe entry or exit angles to the junctions were not applied. This is believed to provide a reasonable approximation of headloss given that junctions in the GIS data can include a variety of connection types. Based on GIS data and field investigation, these connection types can include well-constructed manholes, custom built transitions between box culvert segments, sweeping bends, 'blind taps' where smaller pipes are tapped directly into large box culverts, and other connection types. The difference in losses between various types of junctions is anticipated to be significantly smaller than the losses in the pipe segments of the system. For these reasons, this simplifying assumption should provide a reasonable approximation throughout this basin.

Boundary Conditions

The outfall to the Cedar River is upstream of the 5-in-1 dam and is typically submerged as a result. The water surface elevation for this outfall was determined using the City's HEC-RAS model of the Cedar River for a discharge of 3,050 cubic feet per second (cfs), which represents the 50% duration exceedance (median) flow. This water surface elevation is 717.0 feet and was modeled accordingly in the O Avenue basin model.

Open Channels

There are 2.1 miles of open channel included in the O Avenue basin model. Open channels are represented by irregular cross sections, with elevation data determined using channel surveys and supplemented with LiDAR data. Each channel segment has an associated cross section and slope. Channel segments were chosen to provide a reliable estimate of water surface elevation at sewer outfalls and to capture macro features of the floodplain (such as major expansions in the width of the floodplain or obstructions in the floodplain).

Detention Facilities

The in-line or other major detention facilities that were included in the O Avenue basin model are shown in Table 4.

Table 4: O Avenue Basin Model Detention Facilities

Detention Facility	Basin ID	Estimated Storage Volume (ac-ft)
APPLEWOOD HILLS ESTATES	C-224	0.9
HARRISON ELEMENTARY SCHOOL	C-206	14.2
APPLEWOOD HILLS 11TH	6103	0.3
SPIRIT HOLLOW	61	0.3
METH-WICK MANOR #3	493	0.2
UNNAMED – 2714 O AVE. NW	236	0.6
HIGHLAND PARK #3	1181	0.3
HIGHLAND PARK #1	1180	0.1
HIGHLAND PARK #2	1179	0.1
UNNAMED – CEDAR CREST	11335	0.1
UNNAMED – 24TH ST NW		0.8
UNNAMED – METH-WICK MANOR		0.5

An elevation-area table was defined for each detention facility to represent the basin storage above the bottom of the pond for dry ponds or above the normal water level for wet ponds (with normal water level taken from LiDAR). The influence of other smaller detention facilities not included in Table 4 were not captured, but are partly accounted for in the 2D flow surface.

ASSUMPTIONS

Network Development

The 1D Flow network was developed using the best available information from GIS and survey data. In some cases, the survey data conflicted with the GIS data or both sources seemed questionable. The following procedures and assumptions were used to simplify the flow network.

- If a dimension, such as 48"x72" was reported in notes within the GIS data, it was assumed that the height was reported first based on information from City GIS staff. Similarly, for supplemental survey data, it was assumed that height was recorded first, then width, based on information provided by the surveyor that gathered the data for the basin scale model.
- If only one dimension was provided in City GIS data for pipes indicated to be arch, oval, or elliptical pipe, it was assumed that the size represented an equivalent circular pipe (e.g. a 36" arch pipe was assumed to be 43"W x 26"H). If one dimension was provided in the supplemental survey data, it was assumed that the dimension represented a height based on the method of survey (measuring the pipe size from ground level). This assumption was typically confirmed with the photographs that accompanied the survey.
- In some cases, conflicts existed between survey data and GIS data. Generally GIS data was given preference over survey data based on the rationale that in many cases it can be difficult to measure pipe diameters without entering the adjoining manhole. At pipe endwalls or for box culverts, preference was given to survey data. Additionally, in areas where the GIS data seemed suspect and survey data made more sense, the survey data was used. For example, if a GIS shows a 54" pipe flowing into a 48" pipe and survey data indicated the 54" should be a 48", the 48" was used.

Modeling efforts were focused on utilizing available data from the City's GIS database and supplemental survey data. Additional improvements to the storm sewer model could be made by incorporating additional as-built data, especially in the larger sewers and other significant facilities. Also, any additional survey or field verification data could be incorporated as it becomes available. However, the level of detail incorporated in the model is assumed sufficient for the development of project recommendations for the City's stormwater CIP.

Inlet Capacity

Inlet details at each manhole (size, type), were either not included or not detailed completely in the City's GIS database. Significant field work would be required to document and confirm the size, type, and condition of every inlet. Furthermore, debris impacts are very difficult to predict accurately. The assumption has been made for this CIP planning-level model to utilize a grouped-inlet approach, in which individual inlet limitations are not considered. This approach eliminates the possibility of a local inlet capacity limitation leading to surface ponding which may eventually mask a conveyance capacity limitation downstream. For this reason, the grouped-inlet approach is useful for evaluating storm sewer conveyance independent of inlet capacity. If surface ponding is observed in an area that the model does not predict ponding, this ponding may be resulting from inadequate inlet capacity.

Inlet capacity is generally evaluated and designed based on Statewide Urban Design and Specifications (SUDAS). The model detail and additional field survey required to include each inlet in a stormwater model would require a significant effort. This level of effort is likely only warranted on a project-scale with complex street level flow or some other exceptional case where traditional methods may need refinement.

Representation of Open Channel Sections

Open channels were represented in this model as 1D flow segments used to route runoff hydrographs through the system. Detailed water surface elevations were not mapped within the 1D channel segments. The 1D channel segments were connected to the 2D domain at select locations to capture and route overland flow that surcharges the storm sewer system and would flow to the 1D channel.

2D Flow Domain

DATA SOURCES

The 2D domain was developed from GIS data provided by the City. The 2D surface was developed to represent ponding/storage and overland conveyance that occurs and interacts with the 1D storm sewer system. This 2D flow domain incorporated recent LiDAR topography, buildings, and pavement layers to depict the ponding and flow conditions at the ground surface in the O Avenue basin.

LiDAR Data

Terrain elevation data for this study area were provided to HDR by the City's geographic information system (GIS) staff. This dataset was collected for the City during the fall of 2012 using light detection and ranging (LiDAR) and was processed for ground points and provided as a raster dataset. Vertical accuracy for individual LiDAR point elevations was reported by the City's contractor to be within approximately 0.15 meters (6 inches), with points generally at a

0.7-meter (2.3-foot) horizontal spacing. This accuracy was not verified as part of this study, and is assumed adequate for the purposes of this planning-level study.

City GIS Planimetric Data

Planimetry data within the study area were provided to HDR by the City's GIS staff. These data detailed the plan-view spatial extent of pervious and impervious areas including buildings, sidewalks, roads, parking lots, and open areas. An example of the roadway coverage within the O Avenue basin is shown in Figure 9.

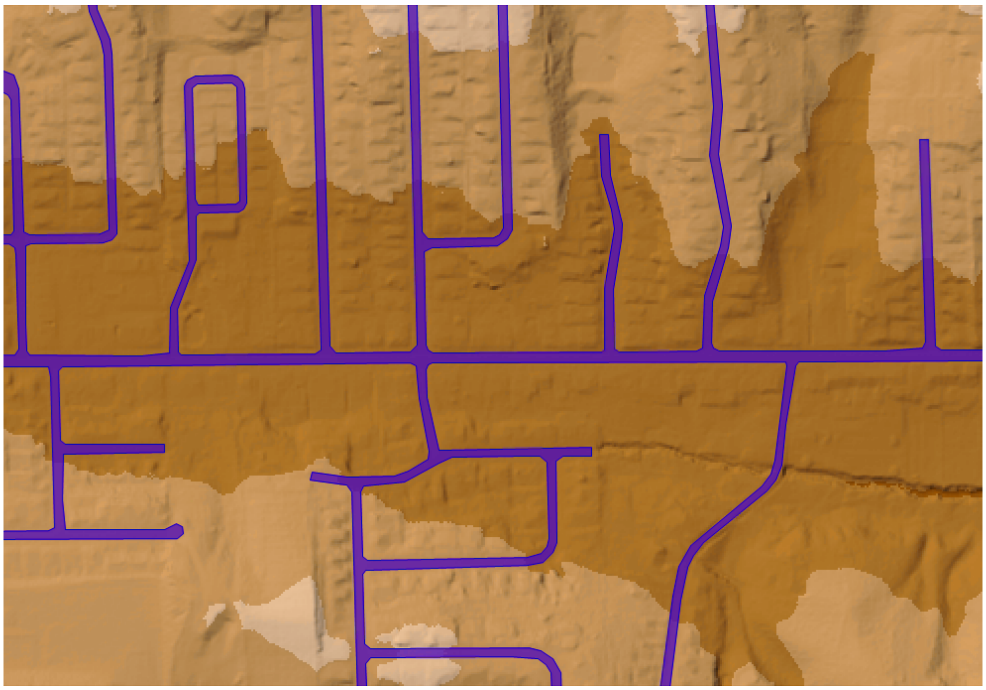


Figure 9: Sample of LiDAR (hillshade and background) and Roadway Planimetric Data (blue)

2D DOMAIN DEVELOPMENT AND FUNCTION

The 2D flow domain was created from the GIS data. Elevations are based on the LiDAR raster dataset provided by the City. Planimetry data were used to help define the roadways areas. Roadway data were used to define areas with finer computational mesh and associated Manning's roughness coefficient of 0.015. Beyond roadway areas, a Manning's roughness coefficient of 0.05 was assigned to approximate overland roughness features. An example of the 2D mesh within the O Avenue basin is shown in Figure 10.

Figure 10: Sample of 1D/2D Domain

Flow is applied to the 2D domain when the flow in the pipe or open channel section exceeds capacity. Flow will be conveyed within the 2D domain and enter the 1D domain elsewhere if pipe or open channel capacity is available at that location. Incorporation of a 2D domain is especially useful in characterizing water flowing and ponding in streets or other overland areas. The 2D domain is necessary to evaluate system performance for events that will not be conveyed entirely within the storm sewer system.

The resulting mesh polygons generally represent the elevations present in overbank areas and roadways, but do not represent curb flow lines or other influential flow features. Resolution in roadway areas was increased (compared to other overland areas) to better represent the geometry. Most roadway sections were represented by a minimum of two mesh elements across the width.

ASSUMPTIONS

No buildings were included in the 2D mesh due to the limited number of buildings in the 2D mesh over 5000 square feet. Buildings account for a small percentage of the total area of the basin. Therefore, this assumption is not expected to impact results significantly.

An assumption was also made that the 2D surface was entirely drained at the beginning of the simulation. This assumption does not account for the influence of ponded water beyond ponds, and other wet detention facilities in the basin. This assumption provides a reasonable starting condition for a design event, but would result in an underestimation of runoff volumes that would result from consecutive events.

Rainfall

The nested design storm hyetographs were developed from NOAA Atlas 14[1] rainfall depths for recurrence intervals of 5 and 100 years. The 5 year storm hyetograph produces a total of 3.8 inches of rain with a peak intensity of 6.5 inches/hour. The 100 year storm hyetograph produces a total of 7.4 inches of rain with a peak intensity of 11.5 inches/hour.

A nested storm hyetograph embeds the rainfall totals for multiple durations, creating a storm with a single steep curve (that is, the most intense 1 hour in the nested storm would generate the rainfall depth entered for the 1-hour duration). The hyetograph for the 5- and 100-year, 24-hour storm is shown in Figure 11. The simulated 24-hour hyetographs were generated using HEC-HMS using NOAA Atlas 14 rainfall depths for durations of 5 minutes, 15 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, and 24 hours.

With a non-nested hydrograph, the maximum flow rates are generated when the storm duration matches the time of concentration for a location in the model based on upstream catchments and flow routing. A short-duration storm would be required to generate the high-intensity rainfall periods observed in the historical storms, but may not create the rainfall depths of a longer storm, which would create higher flow rates at some locations.

Using a nested storm pattern eliminates the need to run multiple simulations of different durations, producing a short, high-intensity period with the appropriate 24-hour storm rainfall depth. For these reasons, the nested 24-hour distribution was used in this analysis.

[1] Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffrey Bonnin (2013). NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States. NOAA, National Weather Service, Silver Spring, MD.

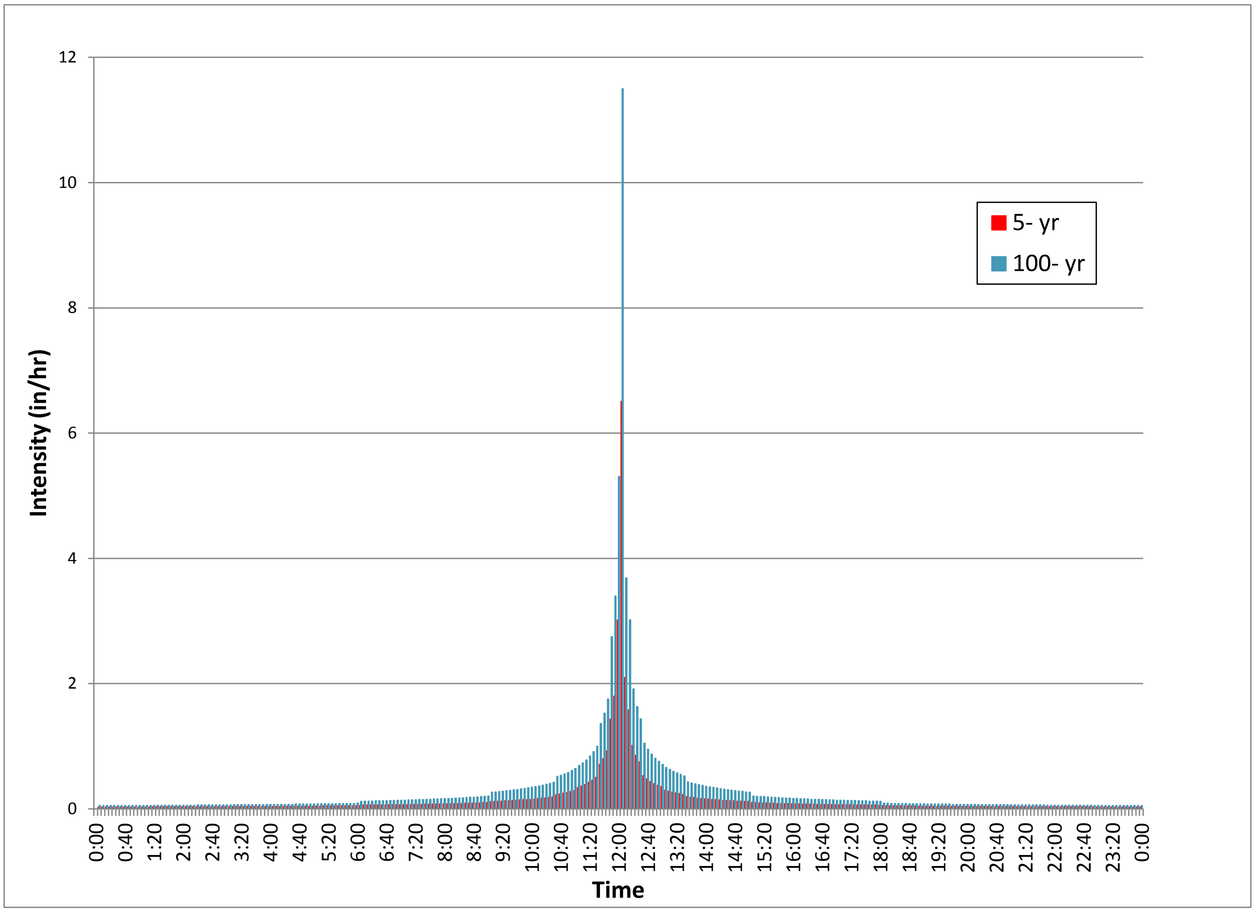


Figure 11: Rainfall Hyetographs for 5- and 100-year Nested Storms

For comparison, the June 29 to June 30, 2014 rainfall hyetograph is shown in Figure 12. The June 2014 event had average rainfall depths of around 4.5 inches in Cedar Rapids, most of which fell in a 1-hour period. The storm event started on June 29th around 9:00 pm with the most significant portion of rainfall falling between 10:50 pm and midnight. The rainfall intensities peaked above 8 inches per hour in some areas compared to the 100-year nested storm with approximately 4 inches falling over 1 hour.

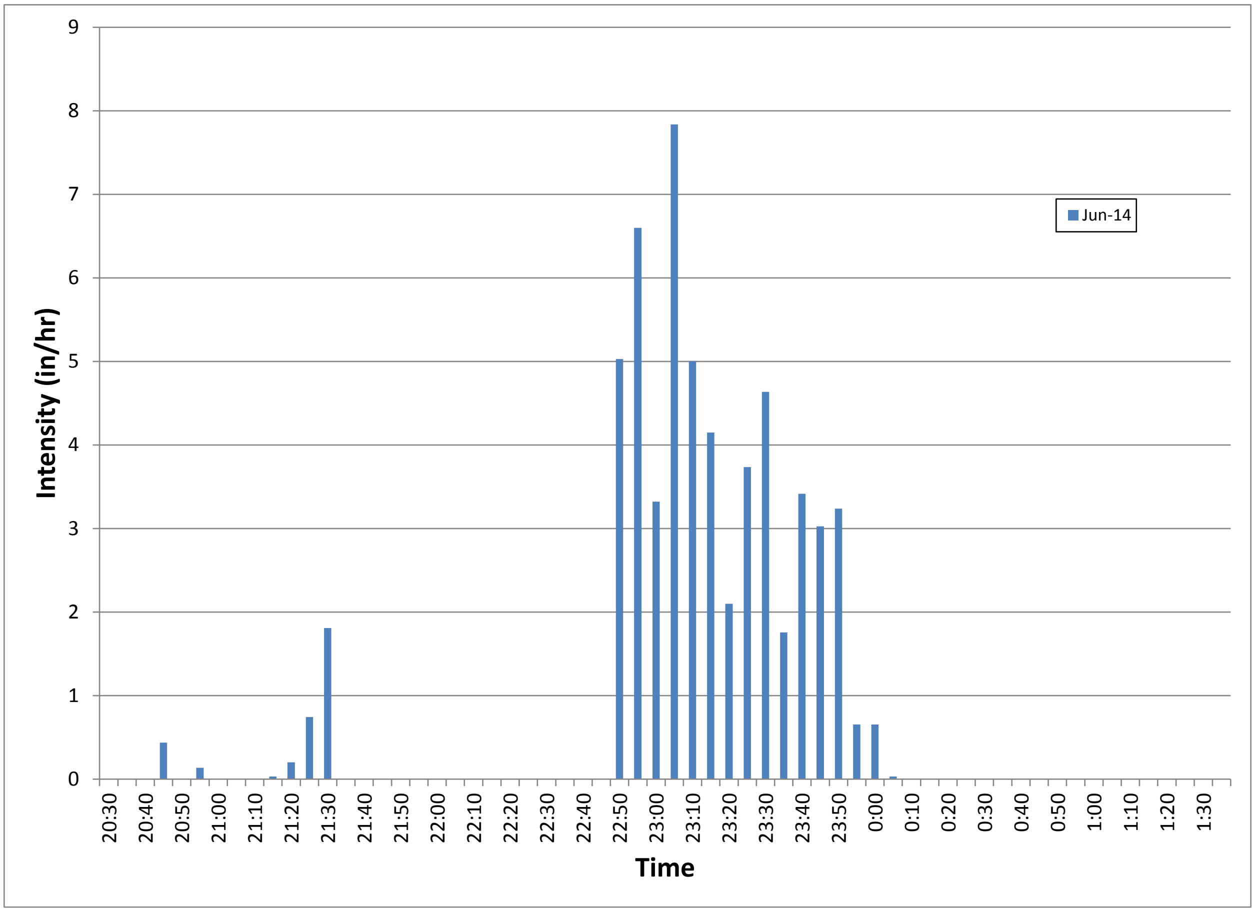


Figure 12: Rainfall Hyetographs for June 29-30, 2014 Event

Model Analysis

The 2014 event was used to qualitatively validate the model results. The simulated model results from the 5-year and 100-year rainfall events were analyzed to evaluate the stormwater conveyance system level of service compared to these two events. Two aspects of the results were evaluated: capacity in the 1D pipe network and surface ponding/flow on the 2D domain (ground surface). Figures and discussion of the results are based on the maximum flow in the sewer system and the maximum depth of ponding/flow on the 2D surface over the entire event. Therefore, the model results figures don't illustrate these conditions at any specific time during the simulation but rather the maximum flow and inundation conditions which occurred at any point during the entire simulation.

Validation

Limited field data (high waterline levels or flow measurements) is available for the O Avenue basin for quantitative validation. However, qualitative validation of the model results was completed through discussions with City staff and comparison to customer complaints received during the June 2014 storm event. Preliminary model results were presented to the City staff on April 20, 2016. During the workshop, problem areas and approximate ponding depths were discussed. In general, City staff was able to confirm that both the location of ponding and the approximate ponding depths predicted in the model were reasonable given the observed ponding during the June 2014 rainfall event. Specifically, the staff noted that predicted ponding was consistent with observed street flooding in the flowing locations:

- 29th and 30th Streets North of O Avenue
- O Avenue between 30th Street NW and 24th Street NW
- Koehler Drive between O Avenue and N Avenue
- Harrison Basin

Model predicted flooding considering the 2014 rainfall event (See Figure 13 and Figure 14 below and Appendix B, Figure B-1) is consistent with the locations of the cases that the current stormwater CIP is founded on as well as customer complaints (debris, storm, and basement backup incidents) documented from the June 2014 storm. Also, previous historic events (1971, 1993, and 2008) noted flooding and damage issues in the same areas of the flooding shown in the model results.

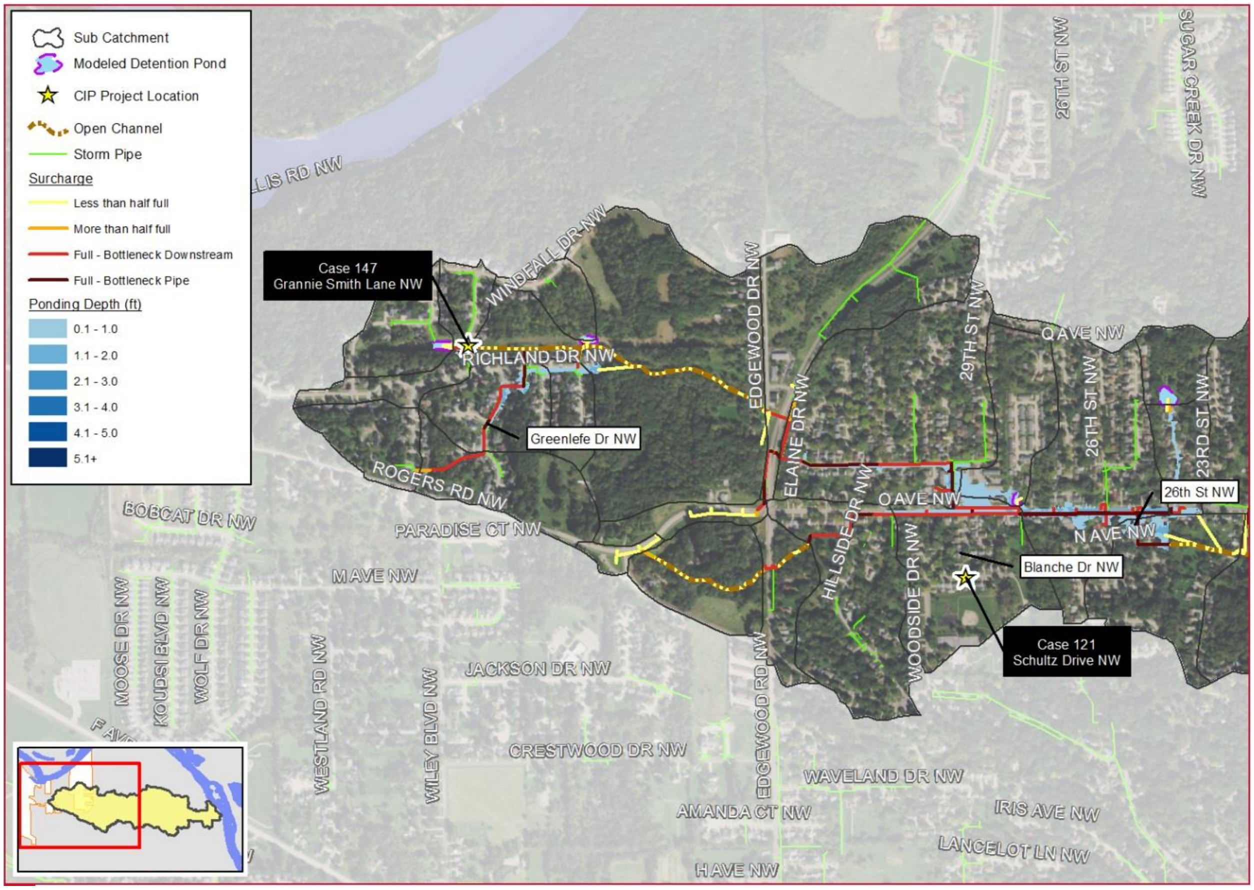


Figure 13: 2014 Event Model Results, West Portion of O Avenue Basin

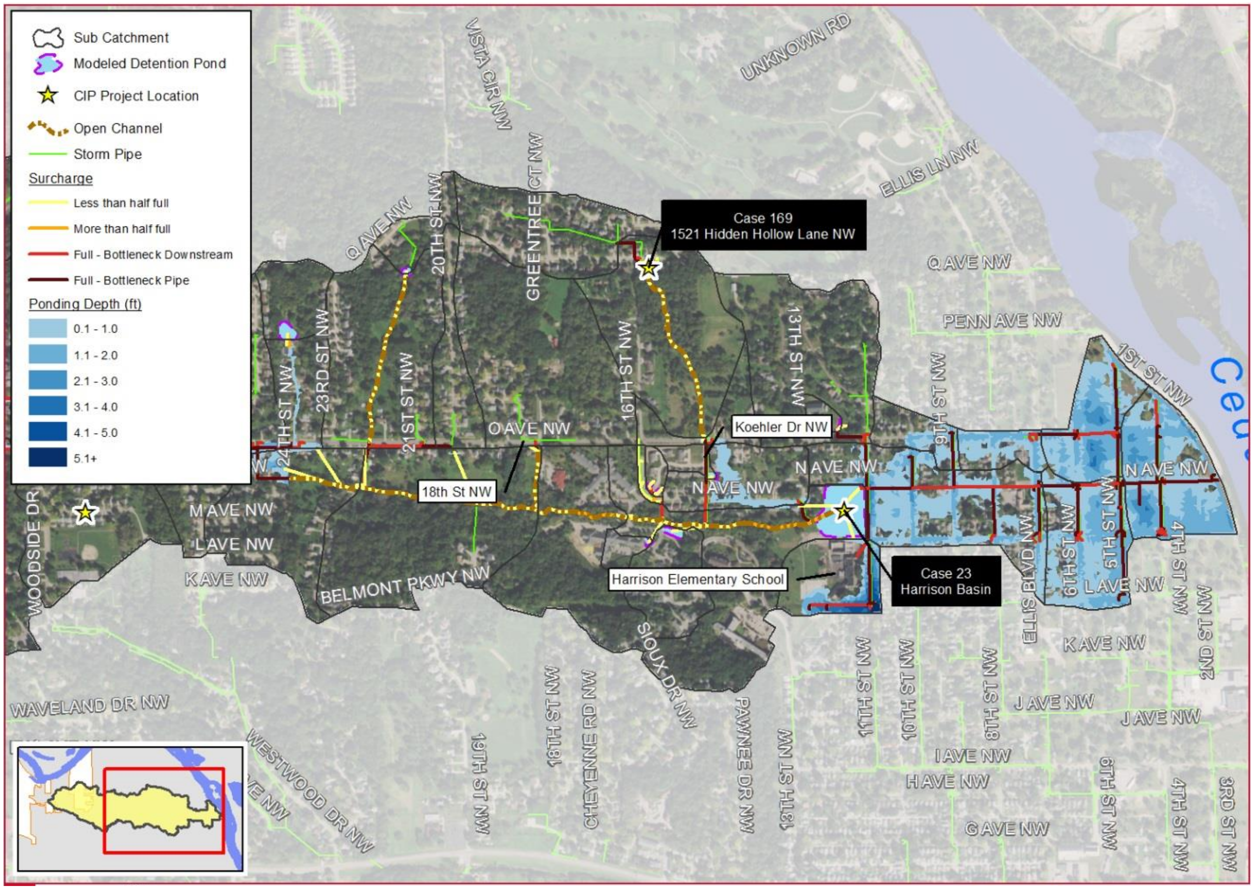


Figure 14: 2014 Event Model Results, East Portion of O Avenue Basin

5-Year Rainfall Event Results

The performance of the stormwater system in the O Avenue basin was evaluated with the 5-year rainfall event. Consistent with Metro Area Standards, new storm sewers are designed to convey the 5-year storm without surcharging or overflows. Older sewers may not provide this level of service. The results for the 5-year rainfall simulation were evaluated in this light. Any pipe flowing at capacity (i.e. bottlenecks) or surface ponding of any level indicates a possible deficiency when compared to this standard level of service.

As Figure 15 and Figure 16 show, results from the 5-year rainfall simulation indicate that there are multiple pipe bottlenecks and areas of ponding. Discussions of the more prominent areas of concern, based on model results and discussions with the City are organized by areas within the O Avenue basin. Figure 15 and Figure 16 also identify current stormwater CIP project locations and case numbers as previously developed by City staff. A larger version of the 5-year results figures is provided in Appendix B, Figure B-2.

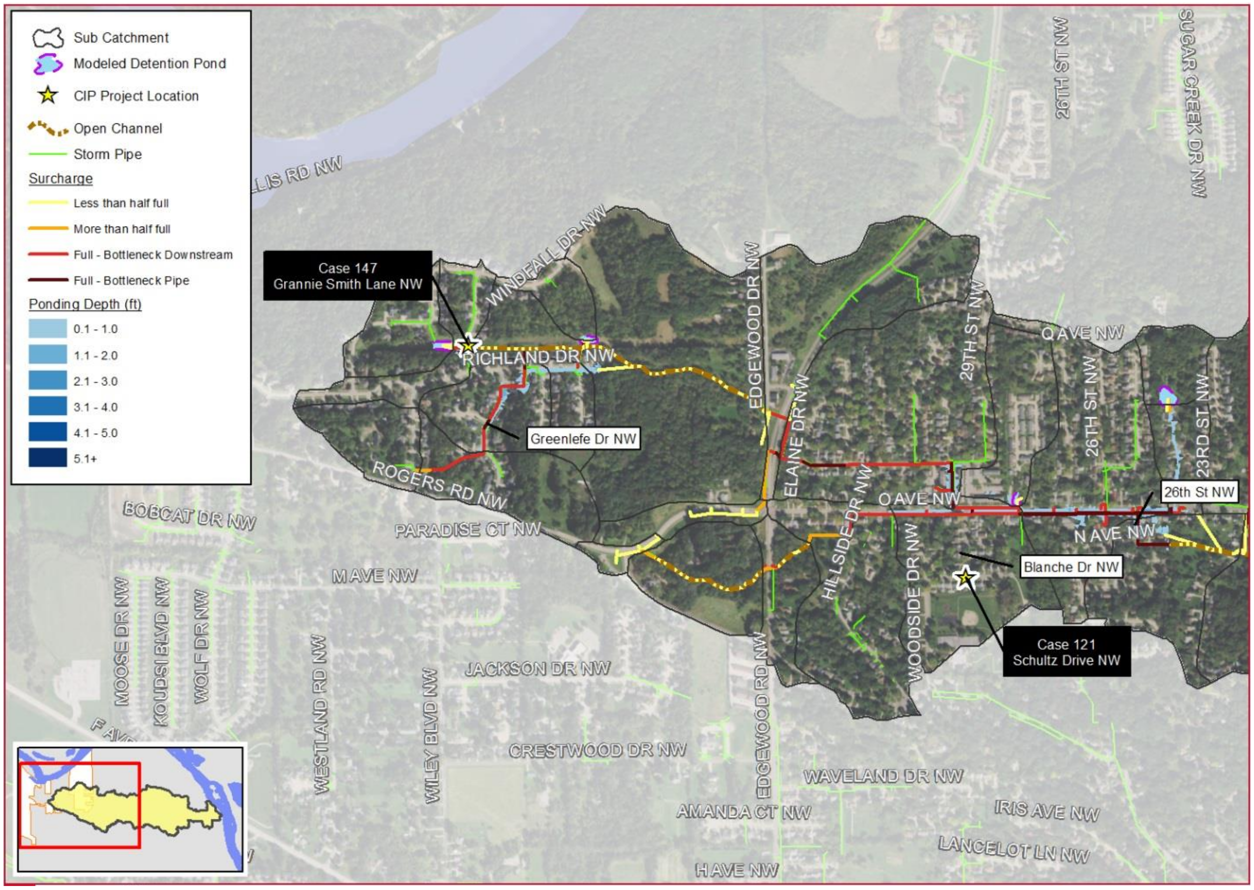


Figure 15: 5-year Model Results, West Portion of O Avenue Basin

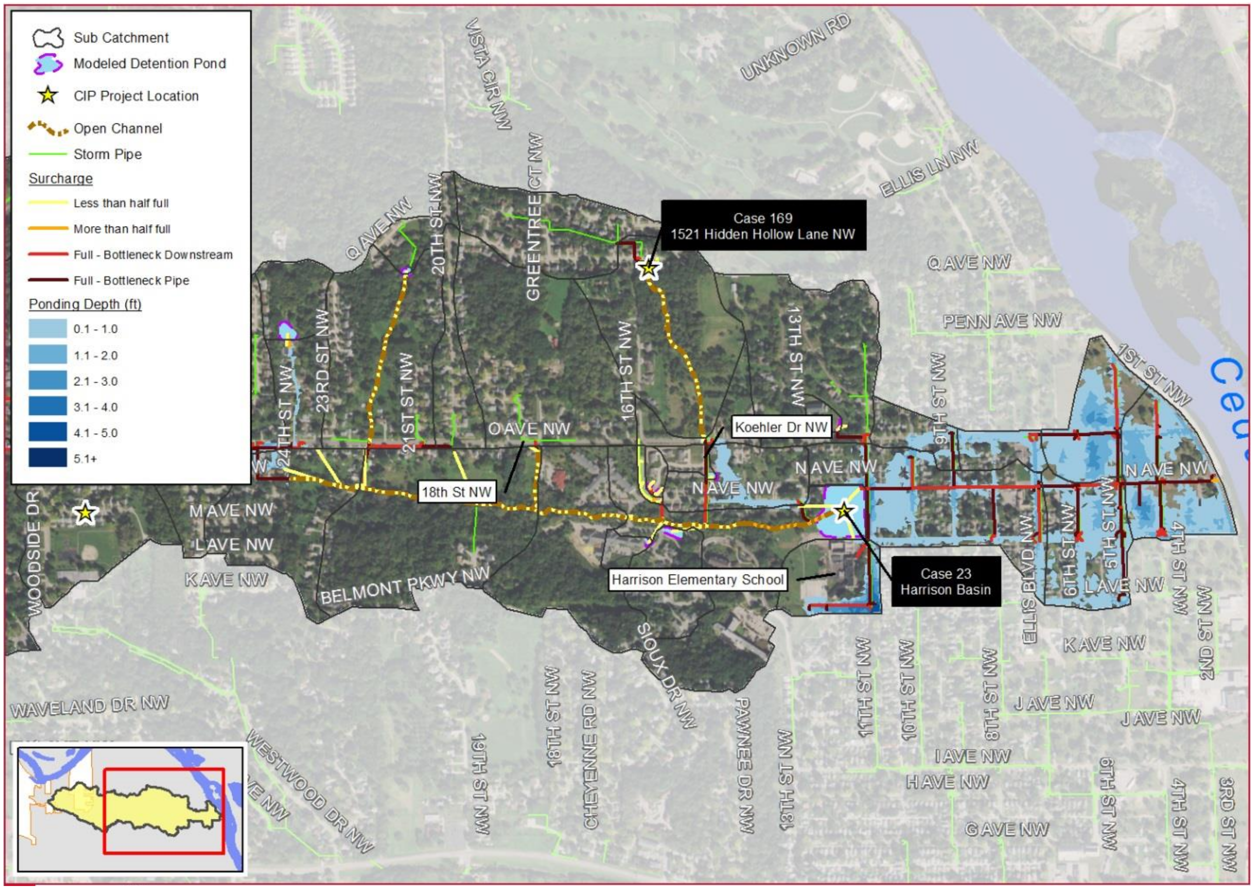


Figure 16: 5-year Model Results, East Portion of O Avenue Basin

GREENLEFE DRIVE NW / RICHLAND DRIVE NW

5-year event results indicate that pipe capacity in portions of the system is approximately 50% less than peak runoff rates. In the model, surcharges resulting from this inadequate capacity flows through lots east of Greenlefe Drive, along Richland Drive, and into the drainageway directly east of Richland Drive. The storm sewers would be impacted by high tailwater in the drainageway north of Richland Drive.

O AVENUE BETWEEN 30TH STREET NW AND 24TH STREET NW

5-year event model results indicate that up to a foot of water would pond in and along O Avenue between 30th Street NW and 24th Street NW. This surcharging would occur as a result of capacity deficiencies of 25-50% along O Avenue and between O Avenue and N Avenue, near 25th St NW just upstream of the start of Meth-Wick Creek.

KOEHLER DRIVE BETWEEN O AVENUE AND N AVENUE

5-year event model results indicate that a small drainageway north of O Avenue would overtop O Avenue near Koehler Drive. Runoff would be conveyed southward to N Avenue, and eastward to the storm inlet at the bend in N Avenue. The overtopping of O Avenue would occur as a result of pipe capacity which is approximately 50% less than peak runoff rates for the storm sewer running from O Avenue to Meth-Wick Creek.

HARRISON BASIN

5-year model results indicate that water in Harrison Basin would overtop and flow over 11th Street NW for an event of this magnitude. Approximately 19 acre-feet would overtop the basin, which has an existing capacity of 14 acre-feet, during this event. This overtopping would lead to significant inundation in the downstream (east) side and south of the basin and reenters the storm sewer system downstream.

ELLIS BOULEVARD TO CEDAR RIVER

5-year model results indicate a significant amount of ponding and surcharging between Ellis Boulevard and the Cedar River. This results from the limited conveyance capacity in the storm sewers draining this area as well as the upstream basin overtopping.

100-Year Rainfall Event Results

In addition to the 5-year rainfall event, the performance of the stormwater system in the O Avenue basin was also evaluated with the 100-year rainfall event. Consistent with Metro Area Standards, new stormwater detention basins and drainageways are designed to maintain the 100-year rainfall runoff within City right-of-way (ROW) to reduce private property damage. Older facilities may not comply with this standard. In this light, evaluation of 100-year rainfall results was focused on surface flow and ponding that extends beyond the City ROW.

Since the storm sewer system has bottlenecks at the 5-year event, the peak flows and surcharging seen in the storm sewer under 100-year event conditions will not be much different than during the 5-year event. The 100-year event results can be used to identify locations where ponding may occur during this event. The 100-year simulation model results are shown in Figure 17 and Figure 18. Again, Figure 17 and Figure 18 also identify current stormwater CIP project locations and case numbers as previously developed by City staff. A larger version of the 100-year results figures is provided in Appendix B, Figure B-3.

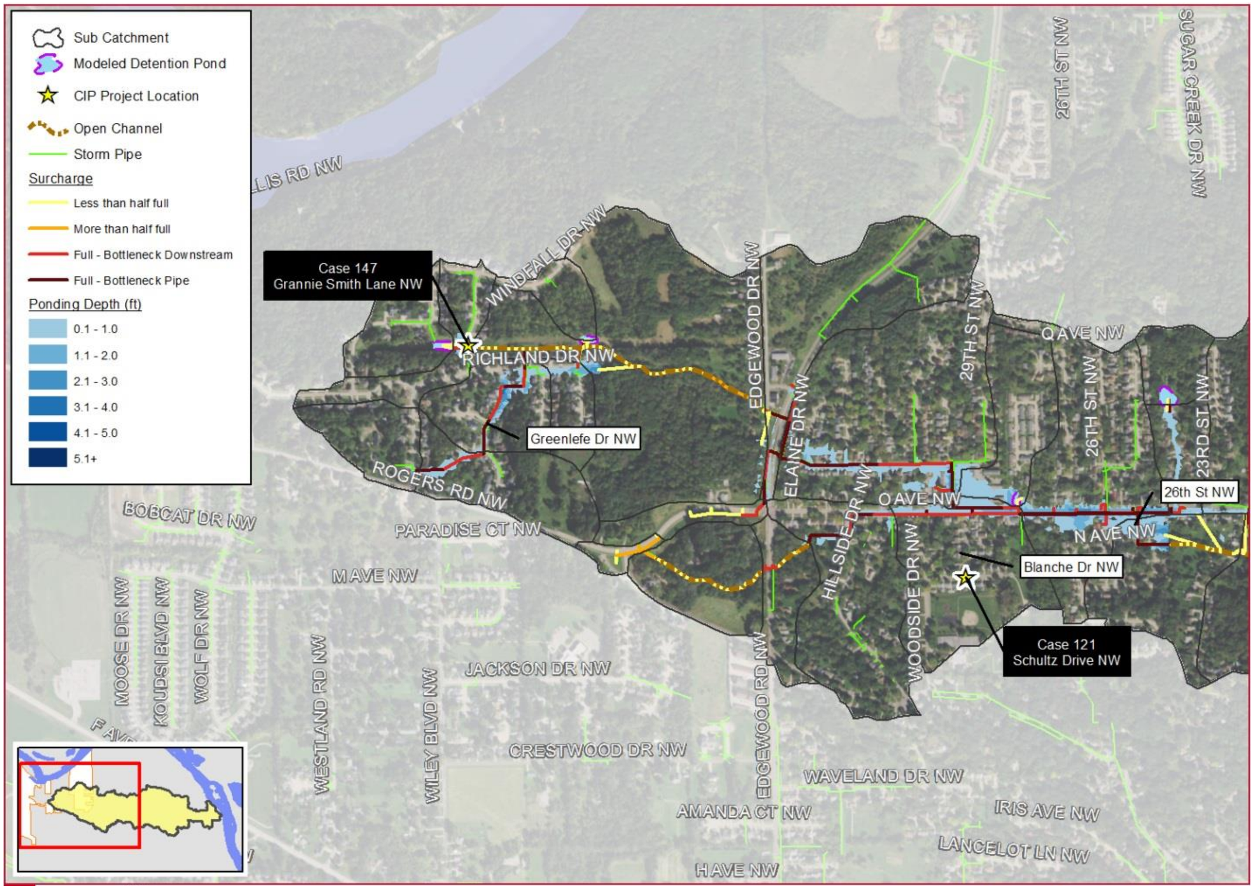


Figure 17: 100-year Model Results, West Portion of O Avenue Basin

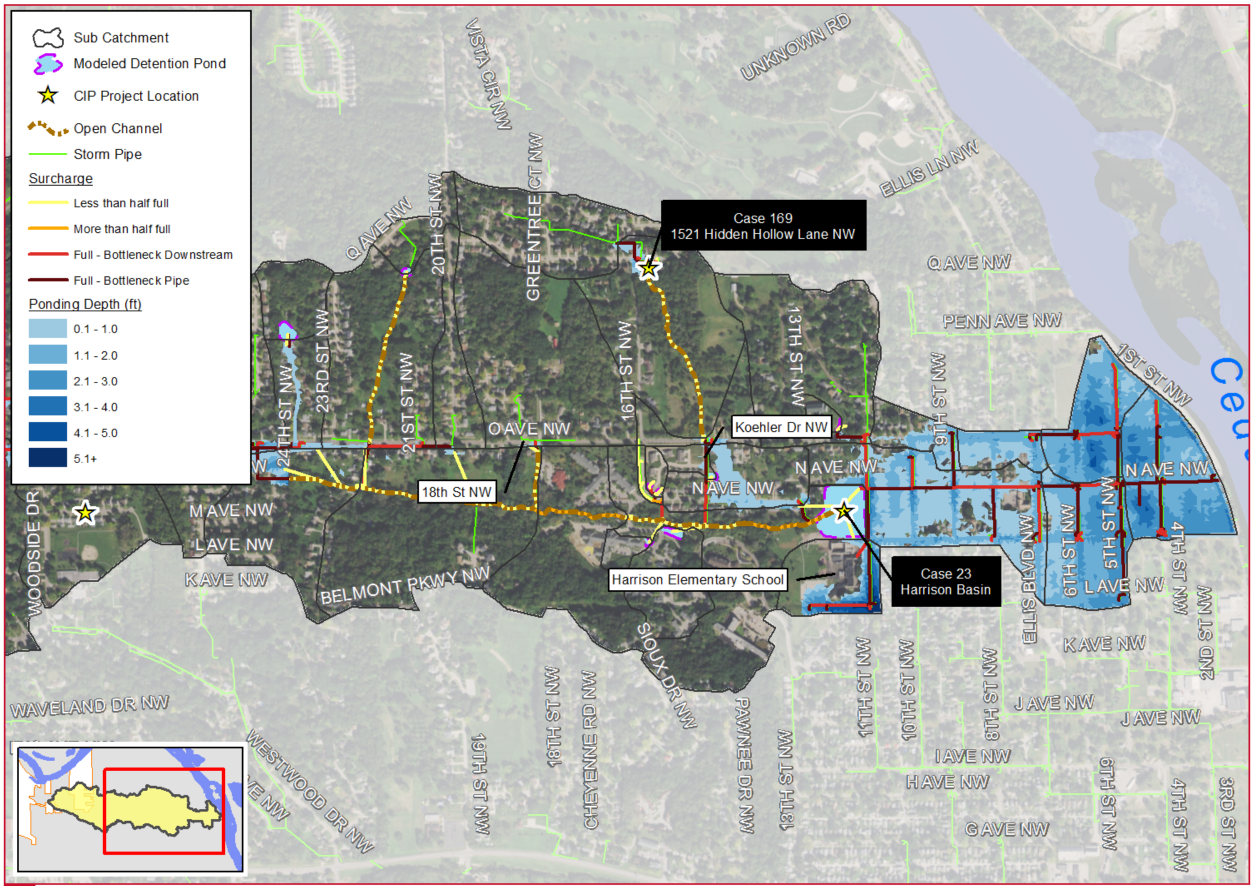


Figure 18: 100-year Model Results, East Portion of O Avenue Basin

GREENLEFE DRIVE NW / RICHLAND DRIVE NW

100-year event results indicate that ponding beyond the ROW would occur along Greenlefe Drive. Inundation depths up to 3 feet would occur on and along Greenlefe Drive. In the model, this runoff flows through lots east of Greenlefe Drive, along Richland Drive, and into the drainage way directly east of Richland Drive. This is the prevailing overland flow path to the drainage way east of Richland Drive.

29TH AND 30TH STREETS NORTH OF O AVENUE

100-year event model results indicate that overland flow depths of 0-2 ft would occur north of O Avenue between 29th Street and 30th Street. This overland flow would occur because this is the primary overland flow path to convey runoff that exceeds the storm sewer capacity at this location.

O AVENUE BETWEEN 30TH STREET NW AND 24TH STREET NW

100-year event model results indicate that up to 2-3 feet of water can pond and flow overland in and along O Avenue between 30th Street NW and 24th Street NW. This overland flow would occur because there is not an alternative overland flow path to convey runoff that exceeds the storm sewer capacity at this location. This overland flow enters Meth-Wick Creek at N Avenue Near 25th Street.

KOEHLER DRIVE BETWEEN O AVENUE AND N AVENUE

100-year event model results indicate that a small drainage way north of O Avenue overtops O Avenue near Koehler Drive. Runoff would be conveyed southward to N Avenue, and eastward to the storm inlet at the bend in N Avenue. The overtopping of O Avenue occurs because this is the prevailing overland flow path for runoff volumes that exceed the storm sewer capacity at Koehler Drive and O Avenue.

HARRISON BASIN

100-year model results indicate that water in Harrison Basin overtops and flows over 11th Street NW during the 100-year event. Approximately 121 acre-feet would overtop the basin during this event. This overtopping would lead to significant inundation in the downstream (east) side and south of the basin and reenters the storm sewer system downstream.

ELLIS BOULEVARD TO CEDAR RIVER

100-year model results indicate a significant amount of ponding and surcharging between Ellis Boulevard and the Cedar River. This would result from the limited ability to convey storm water over the existing trail to the Cedar River, as well as the upstream basin overtopping.

Recommendations

Potential Basin Improvement Strategies
In general, there are four primary improvement strategies that can be employed to reduce overland flow and flooding in the O Avenue basin:

- Capacity improvements through infrastructure retrofits or additions
  - Conveyance (closed and open channel) upsizing
  - Sewer extensions
  - Inlet additions or enlargements
  - Stormwater pump stations
- Storage improvements through infrastructure retrofits or additions
  - Regional stormwater detention facilities
  - Local detention ponds retrofits or additions
  - Bioretention retrofits or additions
- Retention, peak reduction and water quality improvements through green infrastructure retrofits or additions
  - Bioswales and rain garden retrofits
  - Disconnected downspouts (rain barrels) retrofits
  - Permeable pavement retrofits
  - Green alley and roof retrofits
  - Right-of-way green infrastructure (tree box filters) retrofits
- Retention, peak reduction and water quality improvements through low impact development
  - For new or redeveloped areas, integrated management practices for stormwater should be used

Development of Basin Stormwater Mitigation Strategy
The O Avenue basin model results were used to consider alternatives and develop a preliminary stormwater management strategy for the O Avenue Watershed. The strategy was developed systematically, based on a logical evaluation of model results in 47 catchments within the Watershed. These catchments are shown in Figure 19 along with projects in the current CIP noted with stars and case numbers.

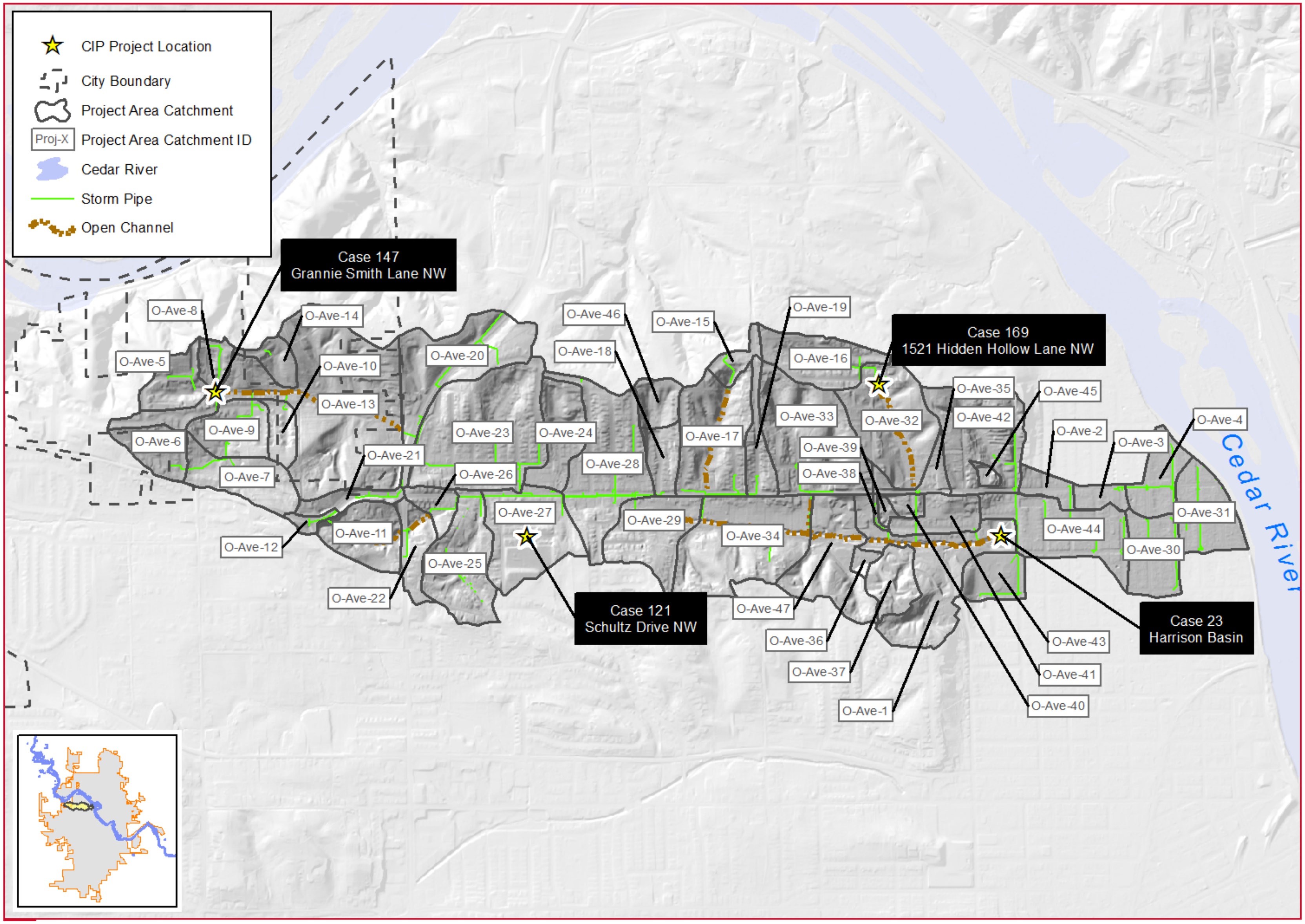


Figure 19: Project Area Catchments, O Avenue Watershed

The process, which is consistent with the process used in previous stormwater master plan studies, prioritizes strategies that reduce the amount and intensity of runoff through storage and/or green infrastructure, considers the effectiveness in reducing stormwater management issues downstream, and then addresses remaining issues through conveyance improvements. In other words, it categorizes strategies as green infrastructure, local distributed detention, regional detention, and conveyance improvements with an emphasis on the first three.

GREEN INFRASTRUCTURE RETROFITS

Green infrastructure (GI) would include a number of retrofit measures that reduce runoff and increase infiltration, including bio-retention, permeable/green pavement, and downspout collection or redirection (i.e. rain barrels). The measures would have the added benefit of improving water quality. For this preliminary screening, areas where GI would be most effective in reducing runoff volume were characterized as having a high percentage of impervious area (>30%) and a significant amount of hydrologic soil types A or B (greater permeability). For this evaluation, it was assumed that areas with these characteristics could experience a runoff reduction of one inch over the project area basin through GI implementation. In developed areas with less-suitable soils, GI retrofits (such as downspout collection/redirection and permeable pavers) can still be used to reduce runoff. An approximation was made that such GI retrofits in areas with less suitable soils could capture the first inch of runoff from impermeable areas within the catchment with approximately 50% efficiency.

LOCAL DISTRIBUTED STORAGE

Local distributed storage was considered to account for the possibility of incorporating any depressions or structures intended to capture local runoff. These would include local detention ponds, swales, depressions, or underground storage. Each could provide a reduction in peak flow and volume with an added water quality benefit. Areas where implementing these strategies would be most feasible were identified as having greater than 1% of the entire area as city owned land or parks or large (>3 acre) parcels with significant (>50%) impervious areas. This strategy would be most suitable in basins with a conveyance constriction downstream, so this was considered as well. For a volumetric evaluation, an estimate was made that 25% of land suitable for local distributed storage retrofit could be converted to capture 4 feet of water (1 acre-foot per acre of suitable area).

REGIONAL DETENTION

Regional detention is included to account for the potential to construct a large detention facility that would collect and store stormwater runoff from several basins to reduce peak flows to alleviate a downstream issue. Configured properly, regional detention would also provide a water quality benefit. Areas where such a facility would be constructed were identified as large (generally greater than 5 acre) open spaces with a significant bottleneck downstream.

CONVEYANCE IMPROVEMENTS

Areas for conveyance improvements were identified based on conveyance capacity deficiency and overland flow or ponding resulting from capacity deficiency. Model results were reviewed to identify which bottleneck segments had surface flow or ponding at or near the segment indicating that existing overland conveyance could be conveyed underground. Conveyance improvements are often the most immediate solution, but may also be the most expensive and least resilient. Conveyance improvements can result in capacity issues downstream and do not provide the water quality benefits that other strategies do. In cases where the basin is located behind a levee or floodwall such as the O Avenue basin, this may result in the need for a larger stormwater pumping station at the Cedar River Flood Control System line of protection.

STRATEGY ASSUMPTIONS

Key assumptions reflected in the Strategy Evaluation are summarized in Table 5.

Table 5: Summary of Evaluation Assumptions

Green Infrastructure Retrofits	
Assumption	Notes
Impervious areas are from city planimetric data.	Input data for modeling, provided by city
Hydrologic soil group type A and B soils are considered most suitable for improving infiltration.	From NRCS national soil survey data
1" of rainfall can be achieved through green infrastructure implemented in an area with favorable soil	Volume reductions observed in HDR projects in New York.
Local Detention	
Assumption	Notes
Areas with Parks and City-owned land (excluding golf courses and cemeteries) greater than 1% of the entire basin are potentially available for local distributed storage.	From City's GIS database, potential to store water on City-owned property
Private parcels 3 acres or larger with greater than 50 percent impervious are potentially available for local distributed storage.	Potential to convert parking area or other large area to detention
Local distributed storage can provide volume calculated assuming an average 4' storage depth over 25% of total area.	Based on approximation of land that could be converted to detention
Regional Detention	
Assumption	Notes
Open areas were identified manually	From aerial imagery dated June 2014 and the City's GIS database.
Conveyance Improvements	
Assumption	Notes
Overland flow indicates areas where flow could be conveyed underground	Based on flow continuity

Strategy Application to the O Avenue Basin

The 47 project areas in the O Avenue Basin were screened separately for suitability based on the above criteria. The results of the screening process are shown in Table 6 and a summary of the screening process and proposed concepts for each strategy are provided in the following sections.

Table 6: Preliminary Stormwater Management Strategy Screening Matrix

		Green Infrastructure		Local Detention			Regional Detention			Conveyance Improvements	
Catchment ID	Area Description	>30% Impervious	>40% Type A or B soils	Parks or Municipal Land (>1%)	Private Parcels > 3 ac	Downstream Bottleneck	Large Open Areas	Significant Area Upstream	Downstream Bottleneck	Overland Conveyance	Section Bottleneck
O-Ave-1	Harrison Basin			●	●	●	●	●	●	●	●
O-Ave-2	O Ave NW and 10th St NW	●	●			●			●	●	●
O-Ave-3	O Ave NW and Ellis Blvd NW	●	●	●		●			●	●	
O-Ave-4	O Ave NW and 5th St NW		●	●		●			●	●	●*
O-Ave-5	Mary Beth Ave NW and Andrew Charles Ln NW			●		●	●		●		
O-Ave-6	Morris Ave NW					●			●		
O-Ave-7	Greenlefe Dr NW				●	●	●		●		
O-Ave-8	Wendy Lee Ln NW	●				●			●		
O-Ave-9	Richland Dr NW	●				●			●	●	●
O-Ave-10	Aaron Dr NW and Richland Dr NW	●				●			●	●	
O-Ave-11	Upstream of Edgewood Rd NW, South of O Ave NW				●	●	●	●	●		
O-Ave-12	Rogers Rd NW	●				●			●		
O-Ave-13	Upstream of Edgwood Dr NW, North of O Ave NW				●	●	●	●	●	●	
O-Ave-14	Windfall Dr NW				●	●			●		
O-Ave-15	Q Ave NW and 20th St NW	●				●			●		
O-Ave-16	Hollow Ln NW and 15th St NW	●				●			●		
O-Ave-17	O Ave NW and Highwood Dr NW					●	●	●	●		●
O-Ave-18	O Ave NW and 24th St NW	●				●			●	●	
O-Ave-19	O Ave NW and 20th St NW	●				●			●		●
O-Ave-20	Edgewood Rd NW, North of O Ave NW				●	●			●		
O-Ave-21	Rogers Rd NW and Edgewood Rd			●	●	●			●		
O-Ave-22	Edgwood Rd NW South of O Ave NW	●				●			●		
O-Ave-23	North of O Ave, West of 30th St NW	●				●			●	●	●
O-Ave-24	O Ave NW west of 27th St NW	●			●	●			●	●	
O-Ave-25	Hillside Dr NW and O Ave NW					●	●	●	●		
O-Ave-26	O Ave NW, East of Edgewood Rd NW	●		●		●			●		
O-Ave-27	South of O Ave NW and Blanche Dr NW	●			●	●	●		●	●	
O-Ave-28	O Ave NW and 26th St NW	●			●	●			●	●	●
O-Ave-29	Methwick Creek upstream of Highwood Dr NW					●			●	●	●
O-Ave-30	N Ave NW and 5th St NW	●	●	●		●			●	●	●*
O-Ave-31	O Ave NW and 4th St NW		●	●		●			●	●	●*
O-Ave-32	North of O Ave and Koehler Dr				●	●	●	●	●		
O-Ave-33	North of O Ave and 18th St NW				●	●	●	●	●		
O-Ave-34	Methwick Creek upstream of 18th St				●	●	●	●	●	●	●
O-Ave-35	O Ave NW and Koehler Dr NW					●			●	●	
O-Ave-36	Brendelwood Dr NW	●				●			●		
O-Ave-37	Brendelwood Dr NW and Brendel Hill Dr NW	●			●	●			●		
O-Ave-38	16th St NW	●				●			●		
O-Ave-39	Koehler Dr NW and N Ave NW					●			●		
O-Ave-40	Koehler Dr NW and O Ave NW				●	●			●		●
O-Ave-41	N Ave NW and 12th St NW	●				●			●	●	
O-Ave-42	O Ave NW and 11th St NW				●	●			●	●	●
O-Ave-43	M Ave NW and 11th St NW	●			●	●			●		●*
O-Ave-44	N Ave NW and Ellis Blvd NW	●	●			●			●	●	●*
O-Ave-45	Private Development north of O Ave NW	●				●			●		
O-Ave-46	North of 24th St NW				●	●			●		
O-Ave-47	Methwick Creek upstream of Brendelwood Dr NW				●	●	●		●	●	

* Pipe capacity not directly evaluated using model. Bottleneck due to downstream effects only.

GREEN INFRASTRUCTURE

Soil data in the NRCS national soil database (see Figure 5) indicates the soils in the O Avenue basin, like much of Cedar Rapids, are mostly type C and D. This limits the amount of infiltration / runoff reduction that can be achieved by incorporating GI retrofits throughout the basin. GI could still be incorporated in portions of the basin with type C and D soils with some reduction of runoff and improved water quality benefits. More than likely, over excavation and imported soils would be necessary to incorporate GI in these areas.

Areas where GI retrofits are feasible are shown on Figure 20 and summarized in Table 7. The most significant benefits can be realized in areas with a high percentage of impervious area and Type A or B soils. In the O Avenue Basin, these areas are located near the Cedar River and the proposed line of protection for the Cedar River Flood Control System west-side levee and floodwall alignment. GI could be leveraged in these areas to improve infiltration, which reduces runoff and improves water quality. Based on the assumptions outlined above, retrofits in these areas, approximately 54 acres in total, could reduce runoff volumes by roughly 4.5 acre-feet. This reduction in runoff volume could be realized downstream of Harrison Basin, so would not directly address overtopping risk at that location, but GI could be considered in the design of interior drainage improvements as part of the design of the Cedar River Flood Control System.

Additionally, several other areas with less favorable soils but a high percentage of impermeable surfaces could benefit to a lesser degree from GI retrofits such as disconnections of downspouts from the storm sewer system and installation of permeable pavement. In the O Avenue basin, these areas exist between Edgewood Road and 24th Street North of O Avenue and in the vicinity of Schultz Drive and Blanche Drive south of O Avenue. If implemented over the approximately 260 acres in total, these measures could reduce runoff by an estimated 4.0 acre-feet.

The potential reduction in runoff volume is relatively small in comparison to the overtopping volume at Harrison Basin during major events and the storage volume of proposed regional detention facilities, but GI retrofits in the O Avenue Basin still provide water quantity reductions and improve water quality during minor rainfall events. GI retrofits should be part of the City's stormwater management strategy.

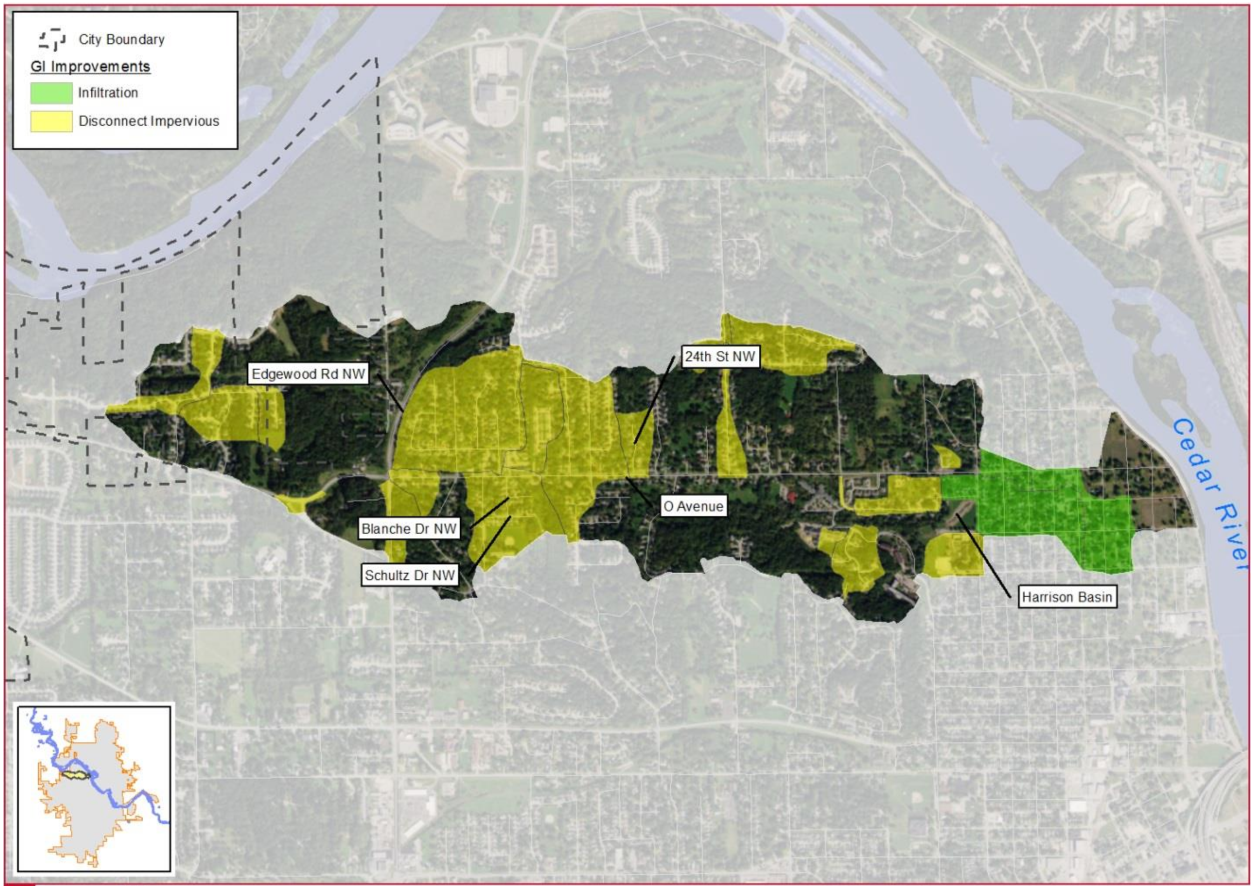


Figure 20: Catchments where Green Infrastructure is Feasible

Table 7: Green Infrastructure Runoff Reduction Estimates

Catchment ID	Area Description	>30% Impervious	>40% Type A or B soils	Green Infrastructure Infiltration	Green Infrastructure Impervious Disconnection	Estimated Runoff Reduction (acre-ft)
O-Ave-2	O Ave NW and 10th St NW	●	●	●		0.44
O-Ave-3	O Ave NW and Ellis Blvd NW	●	●	●		0.39
O-Ave-8	Wendy Lee Ln NW	●			●	0.19
O-Ave-9	Richland Dr NW	●			●	0.20
O-Ave-10	Aaron Dr NW and Richland Dr NW	●			●	0.08
O-Ave-12	Rogers Rd NW	●			●	0.04
O-Ave-15	Q Ave NW and 20th St NW	●			●	0.06
O-Ave-16	Hollow Ln NW and 15th St NW	●			●	0.30
O-Ave-18	O Ave NW and 24th St NW	●			●	0.12
O-Ave-19	O Ave NW and 20th St NW	●			●	0.15
O-Ave-22	Edgwood Rd NW South of O Ave NW	●			●	0.12
O-Ave-23	North of O Ave, West of 30th St NW	●			●	0.80
O-Ave-24	O Ave NW west of 27th St NW	●			●	0.24
O-Ave-26	O Ave NW, East of Edgewood Rd NW	●			●	0.08
O-Ave-27	South of O Ave NW and Blanche Dr NW	●			●	0.40
O-Ave-28	O Ave NW and 26th St NW	●			●	0.64
O-Ave-30	N Ave NW and 5th St NW	●	●	●		1.31
O-Ave-36	Brendelwood Dr NW	●			●	0.04
O-Ave-37	Brendelwood Dr NW and Brendel Hill Dr NW	●			●	0.15
O-Ave-38	16th St NW	●			●	0.02
O-Ave-41	N Ave NW and 12th St NW	●			●	0.16
O-Ave-43	M Ave NW and 11th St NW	●			●	0.16
O-Ave-44	N Ave NW and Ellis Blvd NW	●	●	●		2.33
O-Ave-45	Private Development north of O Ave NW	●			●	0.03

LOCAL DETENTION

Catchments were screened based on the criteria described above to determine locations in which distributed storage would be beneficial. Several catchments were identified for which local distributed storage could be implemented to reduce peak runoff volumes. These catchments are shown in Figure 21 and summarized in Table 8.

Evaluation of the list of catchments indicates that 8 of these catchments have the potential to reduce runoff by at least 1 acre-ft. Of these 8 catchments, catchments 1, 43, and 47 already have either regional or local distributed detention ponds incorporated, and 4, 30, and 31 are on the river-side of the proposed Cedar River Flood Control System levee alignment. These locations are not viable for implementing distributed storage. Catchments 24 (O Ave West of 27th St) and 27 (South of O Ave NW and Blanche Drive NW) are the two catchments that would benefit most from implementation of local detention. Beyond these two locations, available land for this use is limited. Land purchase to acquire suitable property would be required to incorporate greater distributed storage in the O Avenue basin. There are not enough adequate locations suitable for distributed storage in the O Avenue basin to address the large-scale deficiencies.

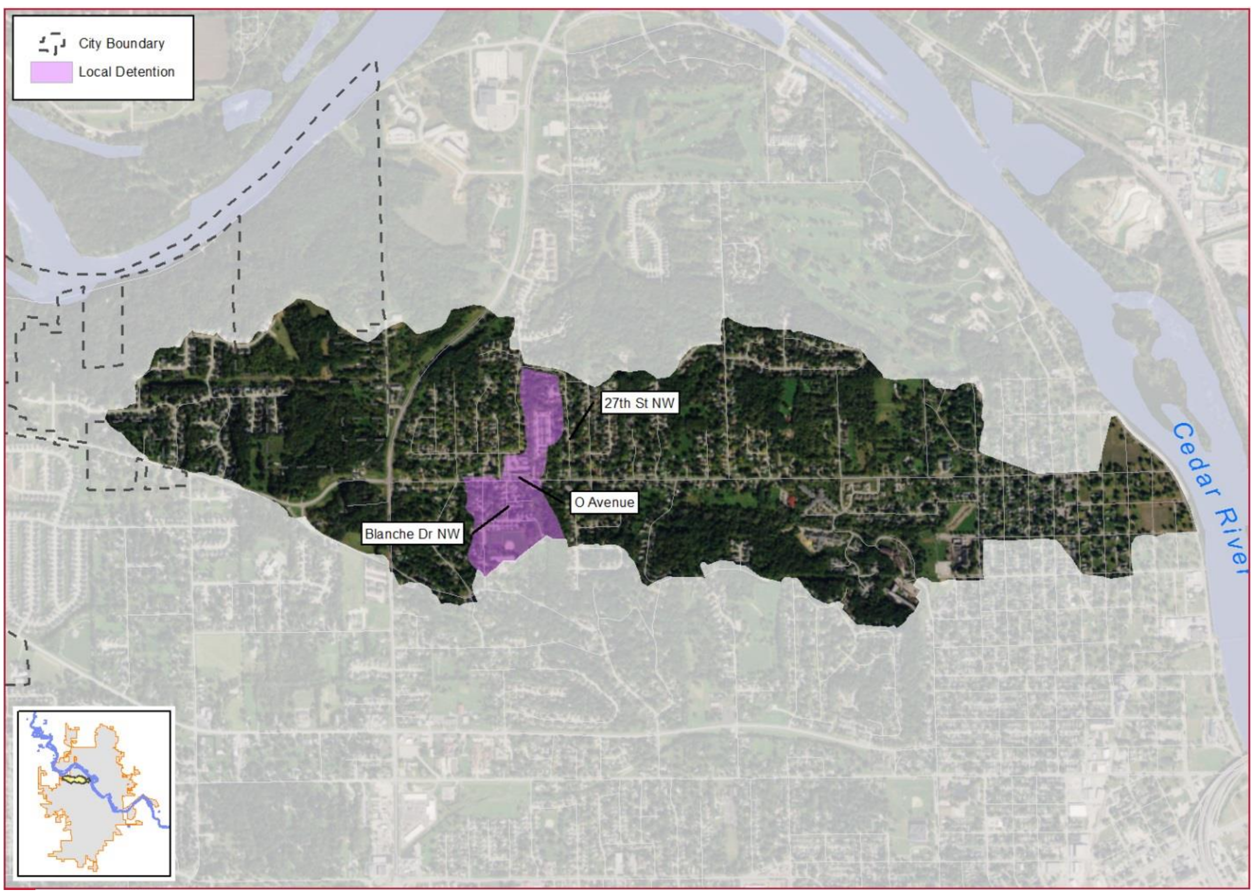


Figure 21: Catchments where Local Detention is Feasible

Table 8: Local Distributed Storage Runoff Reduction Estimates

Catchment ID	Area Description	Local Detention			
		Parks or Municipal Land (>1%)	Private Parcels > 3 ac	Downstream Bottleneck	Potential Runoff Volume Reduction (ac-ft)
O-Ave-1	Harrison Basin	●	●	●	19.8
O-Ave-3	O Ave NW and Ellis Blvd NW	●		●	0.3
O-Ave-4	O Ave NW and 5th St NW	●		●	7.2
O-Ave-5	Mary Beth Ave NW and Andrew Charles Ln NW	●		●	0.4
O-Ave-21	Rogers Rd NW and Edgewood Rd	●		●	0.2
O-Ave-24	O Ave NW west of 27th St NW		●	●	5.4
O-Ave-26	O Ave NW, East of Edgewood Rd NW	●		●	0.1
O-Ave-27	South of O Ave NW and Blanche Dr NW		●	●	6.1
O-Ave-28	O Ave NW and 26th St NW		●	●	0.2
O-Ave-30	N Ave NW and 5th St NW	●		●	6.1
O-Ave-31	O Ave NW and 4th St NW	●		●	10.4
O-Ave-32	North of O Ave and Koehler Dr	●		●	0.4
O-Ave-37	Brendelwood Dr NW and Brendel Hill Dr NW		●	●	0.9
O-Ave-43	M Ave NW and 11th St NW		●	●	6.1
O-Ave-44	N Ave NW and Ellis Blvd NW	●		●	0.3
O-Ave-47	Methwick Creek upstream of Brendelwood Dr NW		●	●	3.7

REGIONAL DETENTION

Model results indicate that approximately 121 acre-feet overtop Harrison Basin during the 100-year event. This is the most significant detention deficit in the O Avenue Basin. Additionally, roadway overtopping and overland flow beyond the public right-of-way occurs at O Avenue near Koehler Drive and O Avenue between 30th Street and 24th Street.

Based on the screening criteria, four sites were identified in the O Avenue basin to incorporate regional detention. These sites included west of Edgewood Road (north of O Ave), upstream of 18th Street along Meth-Wick Creek, North of O Avenue Near Koehler Avenue, and near Harrison Basin. Based on the amount of land that could be available for developing detention facilities, more than 160 acre-feet of regional storage could be realized in the basin. Regional detention facilities are important to the overall stormwater mitigation strategy for O Avenue.

Regional detention concepts were evaluated based on guidance provided by the Iowa DNR and SUDAS. Three of the detention concepts include the construction of earthen dams. Flood pool elevations and top of dam elevations were approximated based on planning-level hydrologic routing calculations. These approximations were completed to provide a high-level estimate of earthwork quantities and required land impacts and acquisitions. Final flood pool and top of dam elevations should be calculated as part of the design of these facilities.

The figures for the detention concepts include a region, shown in blue, which indicates the extent of the design flood pool. For example, if the concept has a 100-year level of service, the outline shows the maximum extent of the flooded area for the 100-year event. In the case of the Harrison basin expansion and the 18th Street basin, this boundary also shows the grading limits for the pond excavation. The City should expect to purchase or obtain perpetual drainage easement to properties within this blue boundary, based on the assumption that these properties will be flooded as part of the normal operation of the basin. Construction and usage of structures for human habitation within this boundary would also be prohibited.

The concepts which include construction of earthen dams also have a larger region, shown in red, which indicates the ground elevation contour equal to the top of dam elevation. The top of dam elevation is higher than the design flood elevation to provide freeboard, also known as a factor of safety. This factor of safety is incorporated to prevent the dam from overtopping for extreme rain events. Specifically, the extreme event is often assumed to be the probable maximum flood, which is the flood resulting from the most rainfall that could theoretically ever occur within the watershed. In Cedar Rapids, this is nearly 33 inches of rain over a 24 hour period. This design standard is used to identify properties for which increased flood risk exists due to the dam. Properties located above the top of dam elevation would not have an increased risk of flooding from the theoretical largest rainfall possible in the basin. In the event that water upstream of the dam exceeds the top of dam elevation, the water overflows the top of the dam rather than continuing to rise. Between the design flood pool elevation (boundary of blue shading) and the top of dam elevation (boundary of red shading), the risk of flooding decreases drastically as elevation increases. However, the risk is still present. As a result, the Iowa DNR requires that dam owners purchase or obtain perpetual drainage easements for this area, as well. This includes prohibiting the construction and usage of structures for human habitation.

The City should expect to purchase or obtain perpetual easement to any properties and structures within this red boundary.

The regional detention concepts were developed with the intent of providing the desired level of service downstream of the detention facilities while minimizing the existing structures that would have an increased risk of flooding due to the presence of the dam. Some yards and existing structures are within the limits of the top of dam, and therefore have an increased flood risk during extreme events. As stated above, City would be required to purchase or maintain perpetual drainage easement for properties that would have an increased flood risk. The evaluation provided is a planning-level estimate of the top of dam elevation. This elevation may be modified during the design process.

Harrison Basin Expansion

The open area to the west and northwest of Harrison Elementary School was identified as potential land that could be used to expand Harrison Basin. The footprint of a conceptual expansion is shown in Figure 22. Based on a conceptual grading plan, the expanded basin would have approximately 36 acre-feet of storage, increasing the storage in Harrison basin by approximately 22 acre-feet. The concept is assumed to be a dry basin, consistent with the existing design.

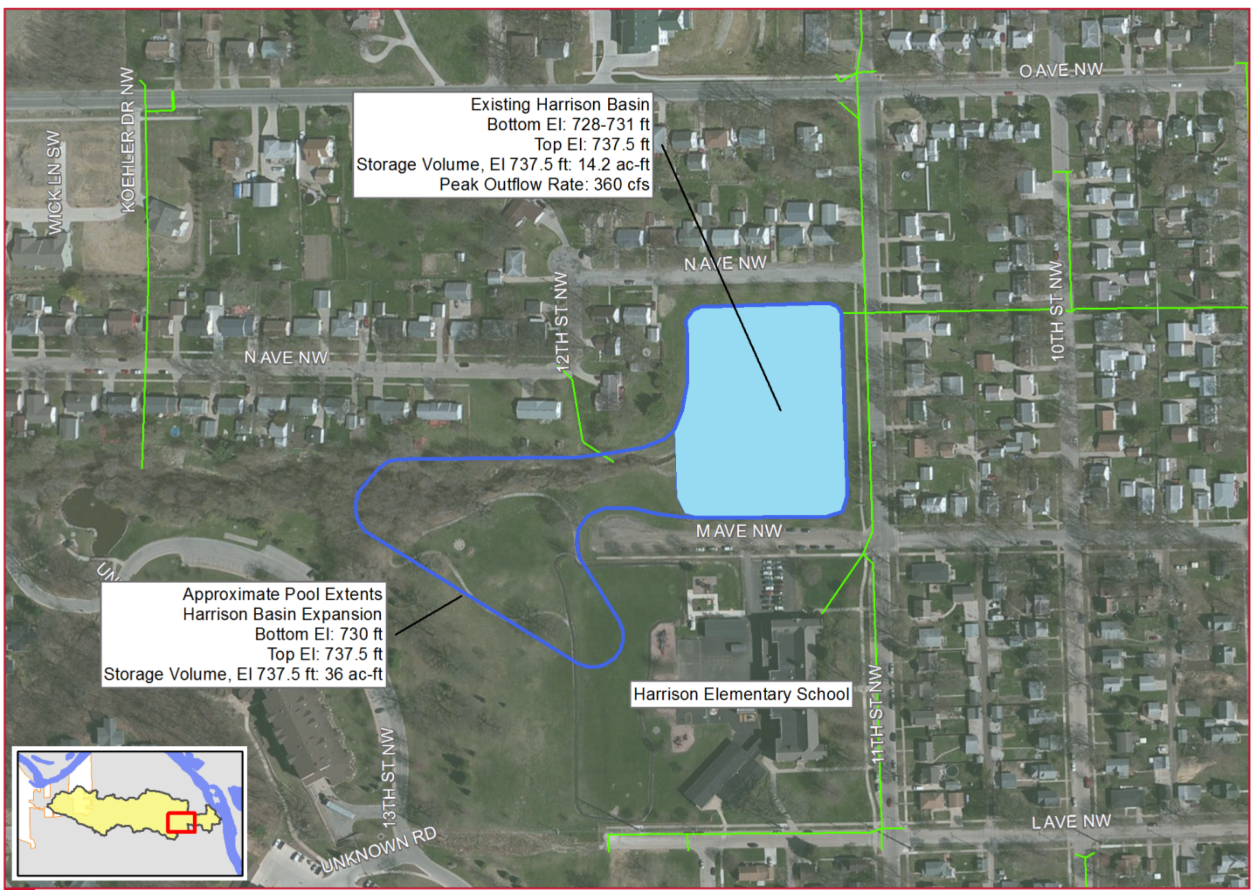


Figure 22: Harrison Basin Expansion Concept

Upstream of 18th Street

The open area along Meth-Wick Creek upstream of 18th Street was identified as a possible regional detention facility location. This large open area along the main receiving watercourse in the basin is approximately one-half mile upstream of the Harrison Basin. Incorporating the basin would require the construction of a dam to impound water in this area. This location was originally proposed in the Shive-Hattery 1983 O Avenue Drainage Study.

Two basic detention facility concepts were considered in the current study: a dry pond that would have a benched (excavated) overbank with channel in place and a wet pond where the bottom of the pond would be excavated below the existing Meth-Wick Creek profile and invert. Based on preliminary grading plans, a 66 ac-ft dry-pond, and a 101 ac-ft wet-pond could be constructed without the grading limits impacting the existing structures on the south side of O Avenue backing up to Meth-Wick Creek.

A wet pond was determined to be the preferred approach because it would allow for accumulated sediment storage, be easier to maintain, provide opportunities for incorporation of water quality improvements, and provide more flood storage. Model results indicate that expansion of Harrison Basin to 36 ac-ft and construction of approximately 101 ac-ft of storage at the 18th Street basin would reduce the risk of overtopping of Harrison basin to less frequently than a 50-year event. If 127 acre-feet of flood storage is provided in the 18th Street basin and Harrison Basin is expanded to 36 ac-ft, a 100-year level of service at Harrison Basin is achievable. The additional 26 ac-ft to achieve a 100-year level of service could be added with the full acquisition of approximately eight properties with existing structures along O Avenue. More details about how the 101 acre-feet and 127 acre-feet pond concepts could function with other improvements in the O Avenue Basin is provided in the Recommendation section. The 18th Street Basin concepts are shown in Figure 23**Error! Reference source not found.**.

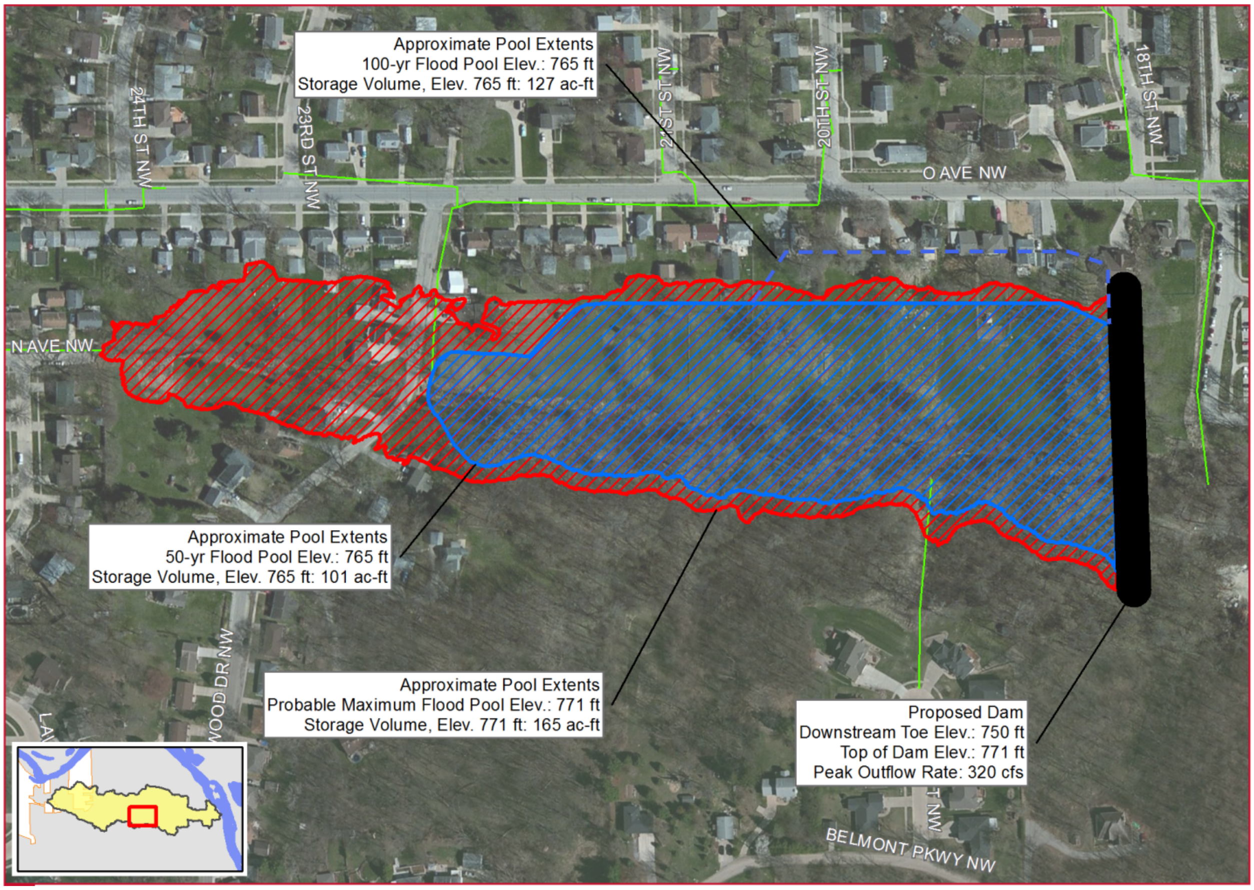


Figure 23: 18th St Basin Detention Concept

West of Edgewood Drive

The area west (upstream) of Edgewood Drive and north of O Avenue was identified as another possible regional detention facility location. The existing Edgewood Drive roadway embankment impounds water in the area. Based on hydraulic modeling, this area already provides natural stormwater detention, and limits downstream flow to roughly 315 cfs. Further reductions in peak flow rate to less than 100 cfs would reduce downstream flood risk along O Avenue for all events, including the 5-year event, and could work with proposed detention elsewhere in the basin to provide a 100-year level of service.

A detention facility at this location could be incorporated several ways. One way would be to modify the existing intake upstream of Edgewood Drive to limit inflows. Reducing inflows would require raising and retrofitting the existing Edgewood Drive roadway embankment to provide a primary function of impoundment and the acquisition of up to three structures upstream of Edgewood Drive. Another option, presented in Figure 24, would require construction of a dam embankment 300 feet upstream of Edgewood Drive. This option would eliminate the need to retrofit Edgewood Drive and provide protection to the properties along the road rather than require the buy out of those properties. For these reasons, construction of a dam upstream of Edgewood would be the recommended approach if modifications are made in this area.

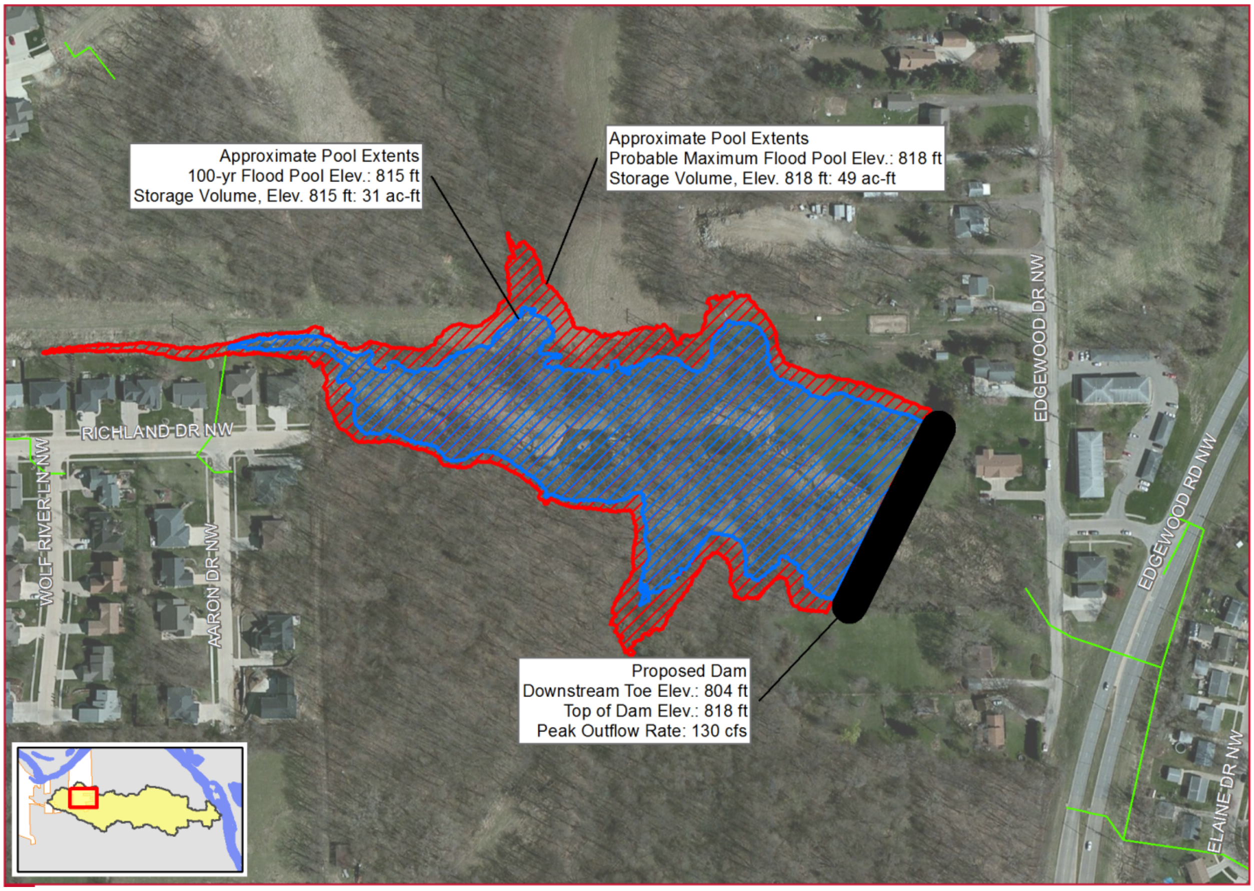


Figure 24: Edgewood Drive Basin Detention Concept

North of O Avenue near Koehler Road

The open area north of O Avenue (near Koehler Road) was identified as potential regional detention facility. This detention facility would receive stormwater runoff that flows into the open channel drainageway from Hidden Hollow Lane and the surrounding area, and require the construction of a dam to impound stormwater runoff. This basin would have to be constructed to store approximately 9 acre-feet of water to reduce the risk of O Avenue overtopping for the 5- and 100-year event. The Koehler Basin concept is shown in Figure 25.

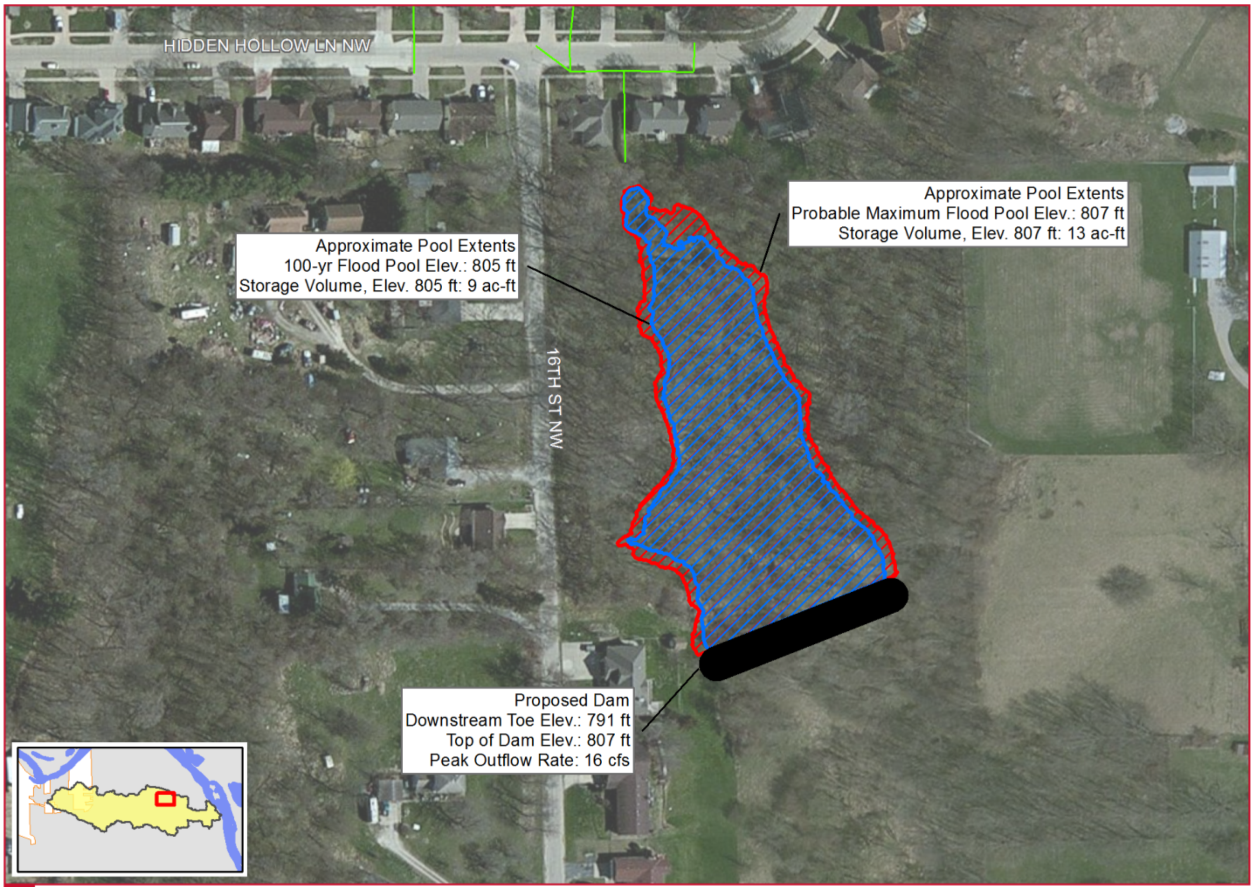


Figure 25: Koehler Basin Concept

CONVEYANCE IMPROVEMENTS

In areas where the above concepts may not fully mitigate deficiencies in the stormwater conveyance system, conveyance improvements will be required to prevent surface ponding. This is the case in locations that are fully-developed and incorporation of upstream detention is difficult. These locations are shown on **Error! Reference source not found.** and summarized below.

Greenlefe Drive NW / Richland Drive NW

The area around Greenlefe Drive NW and Richland Drive NW is developed with little area to incorporate local detention. Conveyance improvements to the bottleneck storm sewers and open-channel drainageway north of Richland Drive are recommended to reduce surcharging during the 5-year rainfall event. Model results indicated that several pipe segments along Greenlefe Drive SW are below the required capacity. However, detailed pipe invert information was not available in this area to determine exact pipe flow rates. For planning purposes, it was assumed that additional pipe capacity would be required between Greenlefe Drive NW and the drainageway north of Richland Drive NW. Costs associated with 417 LF of 36” storm sewer were included in the cost of conveyance improvements. Additionally, general maintenance of the drainageway including removal of obstructions should be conducted regularly. See Appendix A for general drainageway observations.

The idea of providing a secondary conveyance path to divert flood water from the drainageway north of Richland Drive northward to the Cedar River from this general area was proposed in early project discussions with the city. From the evaluation of the topography in the area, this alternative does not appear feasible. A 90-ft slope exists to the north of the drainageway. Excavation required to divert significant flow would be difficult to construct and likely cost-prohibitive.

30th Street NW and O Avenue Between 30th Street NW and 24th Street NW

5-year event model results indicate that up to a foot of water can pond in and along 30th Street NW between O Avenue and Elaine Drive and along O Avenue between 30th Street NW and 24th Street NW. Conveyance improvements are necessary to mitigate the bottleneck storm sewer segments along O Avenue, as well as the storm sewer that runs south between O Avenue and N Avenue, near 26th St NW just upstream of the start of Meth-Wick Creek. These storm sewers should be sized to provide capacity for the 5-year rainfall event. Any additional capacity would help mitigate the ponding and overland flow at this location and upstream that are observed during the 100-year event.

If the Edgewood Drive basin is constructed, peak runoff rates to O Avenue from the northwest are reduced approximately 130 CFS. This basin would reduce the conveyance improvements required along 30th Street and O Avenue. Table 9 summarizes the planning level estimates of required pipe size to convey the 5-year event at these locations. Final sewer upgrades (pipe size, locations, replacement of existing lines or addition of parallel lines, etc.) should be determined during design.

Table 9 – Planning Level Conveyance Improvement Estimate for 30th Street and O Avenue (5-year event)

Location	Option 1 – Edgewood Basin Constructed	Option 2 – Edgewood Basin Not Constructed
30th Street NW between O Avenue and Elaine Drive	Not required	350 LF of 42” RCP
O Avenue West of 26th Street NW	950 LF of 42” RCP	950 LF of 54” RCP
O Avenue East of 26th Street NW	270 LF of 24” RCP	270 LF of 24” RCP
Between O Avenue and Meth-Wick Creek	510 LF of 54” RCP	510 LF of 60” RCP

Additional conveyance capacity would be required to manage the runoff for the 100-year event. The peak runoff rate draining to 30th Street between O Avenue and Elaine Drive NW for the 100-year event is 330 cfs. This exceeds the available pipe capacity (considering flow rates from the west in Elaine Drive NW of 230 cfs for 5-year Option 1) by 240 cfs. The lack of conveyance capacity results in ponding elevations of approximately 790.3 feet on 30th Street. Lidar elevations indicate that ground elevations near the boundary of the right of way are approximately 789.0 feet.

To reduce ponding at this low area on 30th Street, peak runoff rates to the area would need to be reduced by 170 cfs or 170 cfs of additional capacity would need to be provided to drain this area and reduce ponding elevations to less than 789.0 feet. Due to topography, roadway alignments, and development, there is not an easy way to provide an overland flow route to drain this area, so additional pipe would be likely required. At existing pipe slopes, a 54” pipe would be required. This assumes that ponding within the right-of-way is acceptable. To completely convey the peak runoff from this area, an additional 70 cfs of pipe capacity would be required for a total of 240 cfs of added capacity.

There is also street-level ponding related to excess runoff along O Avenue for the 100-year event. With incorporation of improvements from 5-year Option 1 in table 9, model results indicate that peak overland flow rates along O Avenue near 26th Street would be approximately 410 cfs from the west. When flows from the north and east are considered, total overland flow rates draining to the low point along O Avenue between 24th Street and 26th Street would be 460 cfs. Ponding would be confined to the street until curb elevations are overtop.

When the curb overtops, overland flows would continue south through an existing drainage swale following the storm sewer alignment, flow into the back lots of the homes along O Avenue, and then flow east to Methwick Creek. Elevation data for the drainage swale and homes along O Avenue is not available, but it is likely that ponding elevations would exceed the elevations within the drainage easement and flow uncontrolled onto private property.

The overland flow along O Avenue could be managed before reaching the low point and overtopping the curb and affecting private property. This could be accomplished by intercepting the flow at 26th Street, re-grading 26th Street to form a low point near the back lots of the homes facing O Avenue, and grading an open swale in the back lots to drain to Methwick Creek.

Table 10 includes costs to manage runoff from the 100-year event.

Table 10 – Planning Level Conveyance Improvement Estimate for 30th Street and O Avenue (100-year event)

Location	Option 1 – Edgewood Basin Constructed	Option 2 – Edgewood Basin Not Constructed
30th Street NW between O Avenue and Elaine Drive	140 LF of 54” RCP	210 LF of 42” RCP 140 LF of 72” RCP
O Avenue from 30th Street to Methwick Creek	580 LF of 54” RCP 950 LF of 66” RCP 510 LF of 72” RCP	580 LF of 66” RCP 1460 LF of 84” RCP
O Avenue East of 26th Street NW	270 LF of 36” RCP	270 LF of 36” RCP
Open swale on back lots along O Avenue	650 LF trapezoidal channel 15-foot wide by 3-foot deep	650 LF trapezoidal channel 15-foot wide by 3-foot deep

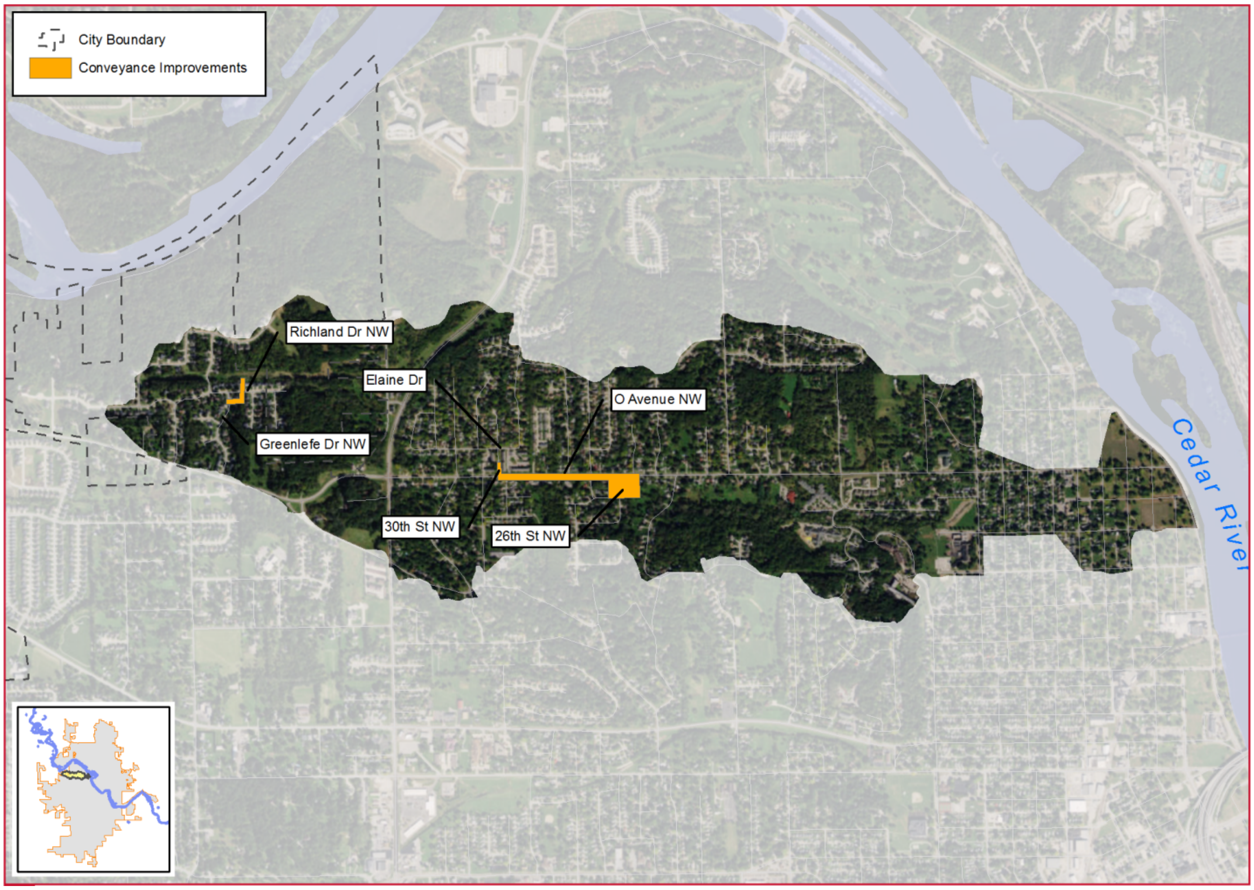


Figure 26: Locations where Conveyance Improvements are Required

Recommendations for O Avenue Stormwater Management Projects

The projects described in the previous section can be combined and constructed incrementally such that an increasing level of service is realized within the O Avenue Basin as projects are constructed. The projects have been organized by level of service in Table 10 and a cost has been provided for each individual concept. Level of service was established based on modeling results which incorporated the component projects. A total cost to achieve a given level of service (5-, 50-, or 100-year) is provided for each collection of concepts.

Table 11 shows than there are two options for the 5- and 100-year level of service. The difference between the options is determined by construction of the Edgewood Basin. If the Edgewood Basin is constructed, peak flows are reduced downstream, reducing the infrastructure needed for conveyance improvements. Construction of the Edgewood Basin also works with the 101 ac-ft pond at 18th Street and expansion of Harrison Basin to provide a 100-year level of service. If the Edgewood basin is not constructed, more significant infrastructure is needed for conveyance improvements to achieve a 5-year level of service and a larger 18th Street Basin is required to achieve a 100-year level of service. If the Edgewood Basin is not constructed and the 101 ac-ft pond is constructed at 18th Street, the overtopping risk of Harrison Basin is reduced to less frequently than a 50-year event. Expansion of Harrison Basin and construction of the Koehler Basin are constants for each level of service. More explanation of the benefit of each concept is provided in the follow sections.

Table 11: Summary of Concept Costs and Level of Service Achieved

Improvement	5-year Option 1	5-year Option 2	50-year	100-year Option 1	100-year Option 2
Conveyance Improvements – 5-year LOS	$0.80 mil	$1.0 mil	$1.0 mil	-	-
Conveyance Improvements – 100-year LOS	-	-	-	$1.3 mil	$1.4 mil
Harrison Basin Expansion	$1.1 mil	$1.1 mil	$1.1 mil	$1.1 mil	$1.1 mil
18th St Basin – 101 ac-ft	-	-	$4.3 mil	$4.3 mil	-
18th St Basin – 127 ac-ft	-	-	-	-	$6.1 mil
Edgewood Basin	$0.37 mil	-	-	$0.37 mil	-
Koehler Basin	$0.35 mil	$0.35 mil	$0.35 mil	$0.35 mil	$0.35 mil
Total Cost	**$2.62 mil**	**$2.45 mil**	**$6.75 mil**	**$7.42 mil**	**$8.95 mil**

Concepts were developed and recommendations made in light of the City's goal to not increase conveyance (and required stormwater pumping) downstream of Harrison Basin. This assumption has been reinforced during HDR's correspondence with the City prior to and during the project. As a result, recommended concepts focus primarily on regional detention with limited use of conveyance improvements. Local detention, green infrastructure, and other O Avenue Basin recommendations are also discussed.

OVERALL RECOMMENDATION

HDR recommends that the City include the collection of concepts identified as 100-year Option 1 in Table 11 in the City's stormwater CIP. This collection of projects, shown in Figure 27, includes construction of stormwater basins near Koehler Drive and Edgewood Drive, expansion of Harrison Basin, and construction of a wet detention pond with a capacity of approximately 101 ac-ft along Meth-Wick Creek near 18th Street. This alternative is the most cost effective method to improve system performance to meet Metro Area Standards with the least negative impact to the homes within the O Avenue watershed. This alternative, which has an estimated cost of $6.46 million, also meets City's goal to not increase peak outflows from Harrison basin.

An incremental approach can be taken when constructing the improvements. Expansion of Harrison Basin would reduce the risk of Harrison Basin overtopping to less frequently than a 5-year event. Construction of the Edgewood Basin and the identified conveyance improvements in the vicinity of O Avenue would achieve a 5-year level of service elsewhere in the O Avenue Basin and 100-year level of service upstream of the 18th Street basin location. Finally, construction of the 18th Street Basin could reduce the risk of Harrison Basin overtopping to less frequently than a 100-year event. Construction of Koehler basin provides an independent benefit of reduction in risk of ponding on O Avenue and risk of overland flow between O Avenue and Meth-Wick Creek. The basis for recommendation of each concept as part of an overall strategy is provided in the following sections.

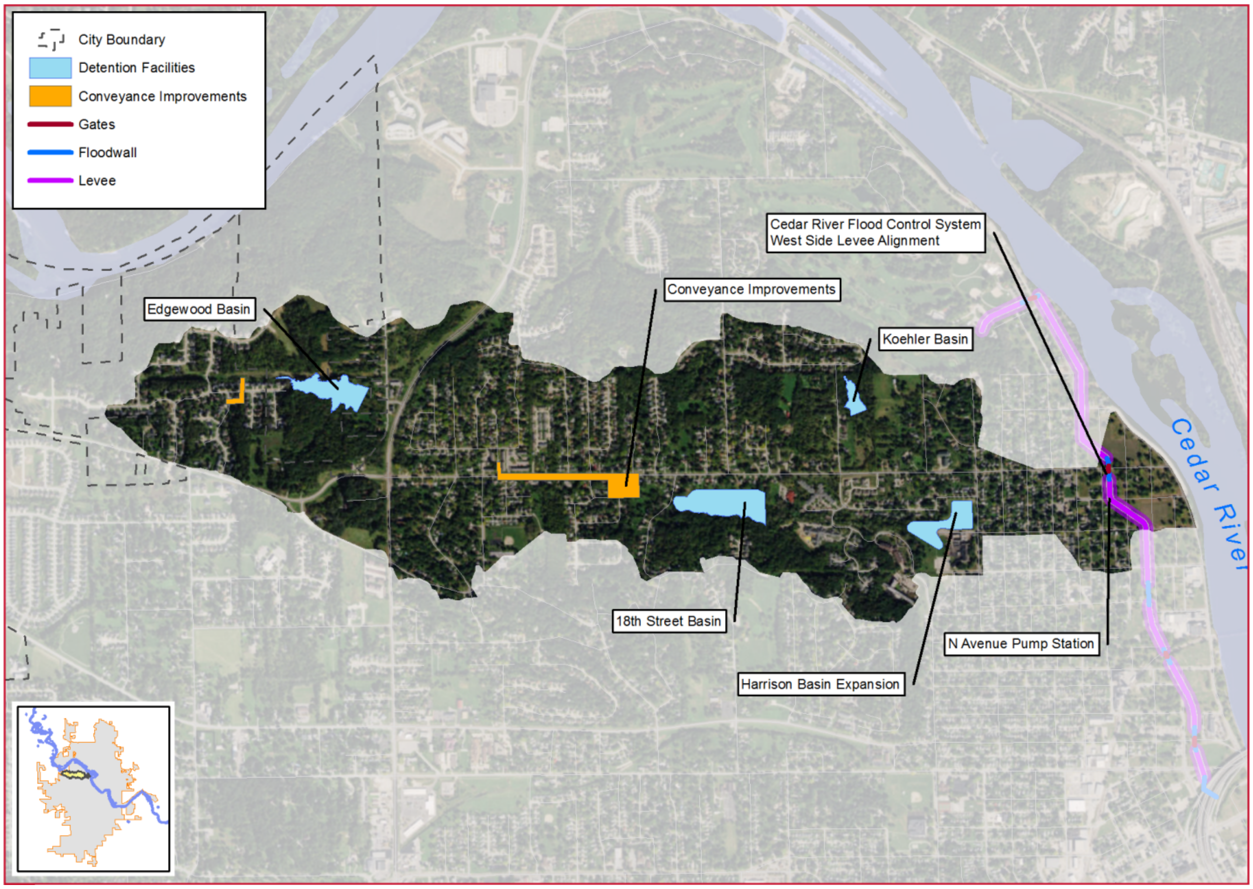


Figure 27: Recommended Improvements

HARRISON BASIN EXPANSION

It is estimated that Harrison Basin can be expanded from 14 ac-ft to 36 ac-ft with no impact to existing structures. This expansion reduces the risk of overtopping of Harrison Basin to less frequently than a 5-year event. If the Edgewood Basin and 18th Street Basin are constructed, an expansion of Harrison Basin can work with those improvements to reduce the risk of Harrison Basin overtopping to less frequently than a 100-year event. HDR recommends making expansion of Harrison Basin the highest priority project within the collection of recommended projects due to the relative ease of design, permitting and construction.

18TH STREET BASIN

Additional detention volume is required upstream of Harrison Basin to reduce the risk of Harrison Basin overtopping to less frequently than a 100-year event. The area upstream (west) of 18th Street along Meth-Wick Creek would have the capacity to provide significant storage. Estimates from preliminary grading plans indicate that roughly 101 acre-feet of storage can be added in this area without the grading limits impacting existing structures. Land acquisitions of open land from private landowners would be required. Greater detention volume can be incorporated at this location with additional land and structure acquisitions.

If Harrison Basin is expanded to 36 ac-ft and a 101 ac-ft pond is constructed at 18th Street, the risk of Harrison Basin overtopping is reduced to less frequently than a 50-year event. With the addition of additional storage upstream of Edgewood Drive, the risk of Harrison Basin overtopping is reduced to less frequently than a 100-year event. The risk of Harrison Basin overtopping could also be reduced to less frequently than a 100-year event through expansion of Harrison Basin to 36 ac-ft and construction of 127 ac-ft of storage at 18th Street.

Construction of the 18th Street basin with temporary storage capacity of 101 acre-feet is recommended to maximize storage without acquiring existing structures. Based on preliminary grading plans, this would be a wet pond requiring acquisition of open land on the south side of O Avenue. The wet pond would be designed to provide sediment storage for the life of the dam, reduce maintenance concerns with associated with a dry pond (mowing, maintaining steep slopes in a wet area), and allow for water quality benefits.

EDGEWOOD DRIVE BASIN

A detention facility constructed upstream of Edgewood Drive provides several benefits. Directly downstream, the basin can reduce flood risk during the 100-year event for several structures along Edgewood Drive. Further downstream, the basin could reduce pipe bottlenecks in the vicinity 30th Street NW and O Avenue between 24th Street NW and 30th Street NW by reducing peak discharges flowing to these areas from Edgewood Drive for all events considered in this study. Finally the basin could work along with an expansion of Harrison Basin and 101 ac-ft basin at 18th Street to reduce the risk of Harrison Basin overtopping to less frequently than a 100-year event. HDR recommends that the City construct the Edgewood Basin as part of a solution to provide adequate detention for the 100-year event and to reduce the required conveyance improvements downstream.

KOEHLER BASIN

The detention basin north of O Avenue near Koehler Drive can be implemented to reduce risk of overtopping at O Avenue for both the 5-year and 100-year event. Construction of the Koehler basin has little effect on storage volumes required to reduce overtopping risk at Harrison basin when compared to the impact of the 18th Street basin and expansion of Harrison Basin. This project can be considered an independent project to reduce the risk of overtopping of O Avenue near Koehler Drive for planning purposes. HDR recommends that the City construct a basin upstream of Koehler Drive, but that it be assigned a lower priority than expanding Harrison Basin, and constructing basins at 18th Street and upstream of Edgewood Drive.

CONVEYANCE IMPROVEMENTS

Several locations were identified where conveyance improvements would be necessary to convey the 5-year event. If the Edgewood Drive basin is constructed, the size of the conveyance improvements required on 30th Street NW between O Avenue and Elaine Drive and those required on O Avenue between 30th Street NW and 24th Street NW is reduced. Additionally, the costs included in Table 10 include surface restoration, which would not be a direct cost if the sewer improvements are constructed as part of the Paving for Progress project currently underway along O Avenue. HDR recommends that sewer upgrades identified as Option 1 in Table 9 be constructed in coordination with the Paving for Progress project.

LOCAL DETENTION AND GREEN INFRASTRUCTURE RETROFITS

Implementing local detention and GI retrofits will reduce runoff volumes more noticeably for minor events (such as the 5-year event) and improve water quality downstream of the improvements, but will not have a significant impact on runoff volumes for the 100-year rainfall event. HDR recommends that the City continue to pursue opportunities for GI retrofits and local detention, but does not count on either strategy as a primary strategy for water quantity reductions in the O Avenue Basin.

OTHER RECOMMENDATIONS

Water Quality Considerations

In addition to the water quality benefits of green infrastructure retrofits, additional water quality improvements could be realized through proper planning of the regional detention concepts recommended in this study. HDR recommends that the City consider opportunities for construction of one or more wet ponds for the proposed detention concepts presented in this study. The 18th Street basin would provide opportunities to incorporate water quality improvements especially given the requirement of sediment storage upstream of the dam, size of the upstream drainage area, and a high likelihood of recharge due to the topography and location on a perennial stream. Wet ponds, also known as retention ponds, can capture suspended sediment and provide an environment which encourages nutrient removal. Proper design consideration at retention facilities can result in decreased sediment and pollutant load to the Cedar River from the O Avenue basin.

Interior Drainage Design at the West side Levee

Significant ponding is observed in the model results for both the 5-year and 100-year events in the lower portion of the basin on either side of Ellis Boulevard. Ponding results from two sources: overflow from Harrison Basin and conveyance limitations in local storm sewers. Significant changes to this area's storm sewer system will be required as part of the Cedar River Flood Control System west-side levee construction to provide interior drainage. Local storm sewer capacity was not considered in this study and should be evaluated as part of the interior drainage design of this levee reach.

Infrastructure Condition Inspection and Assessment

It was assumed as part of this modeling effort that the condition of existing inlet structures and pipes was not a limiting factor in the conveyance of stormwater. As the City moves forward with asset management program implementation, it is possible that stormwater system maintenance will improve or help sustain the conveyance available within the existing system. Given this information, HDR recommends that the City continue to implement the condition inspection and assessment program to realize the full benefit of the recommended capital improvements.

Future Design Considerations

MODEL UTILITY FOR PRELIMINARY AND FINAL DESIGN

The concepts presented in this report are developed at a planning level to inform the City's CIP and should not be considered final designs. Further project development and design is required. The O Avenue basin model developed for this study can be utilized in the design process. For example, proposed conveyance improvements can be checked with the model to ensure they work as intended within the overall system or hydrographs from the model can be used in detailed pond/dam routing and design.

DAM DESIGN

Several concepts presented in this report require the construction of a dam to impound water. Complex design considerations exist for permitting and constructing a dam that can not be considered at a master planning level. These considerations include:

- Hazard Classification of the Dam
- Design of the principal and auxiliary spillways and determination of top of dam elevation
- Required acquisition of land and/or easements
- Evaluation of dam breach
- Sediment Storage
- Rigorous construction standards
- Public Involvement
- Periodic Dam Inspections
- Permitting

Iowa DNR requires any impoundment in urban areas over 5 feet and storing 50 acre-feet or more (to the top of dam) temporarily or 18 acre-feet permanently to be permitted as a dam structure. Further, Iowa DNR defines several dam hazard classes that depend on the risk of damage and loss of human life which could result from failure of the dam. It is likely that one or more of the dam concepts proposed in this report would be classified as a high hazard dam.

Depending on the hazard class of the dam, the dam must be designed to include adequate freeboard for extreme events. For high hazard dams, the dam must be able to discharge the probable maximum flood (PMF) without overtopping. Lower hazard class dams must discharge a less extreme event, but must still include freeboard above the flood pool elevation. The appropriate freeboard for each dam is determined by the flood routing and coordinated design of an emergency spillway and top of dam elevation.

Ownership or easement would be required for all the dam structures and the area occupied by the permanent pool, maximum normal pool, and up to the top of dam elevation. More information about the design criteria for dams can be found in the Iowa DNR Technical Bulletin No. 16 "Design Criteria and Guidelines for Iowa Dams"

PROJECT IMPACTS TO INTERIOR DRAINAGE DESIGN

The recommended improvements impact outflow rates from Harrison Basin. Figure 28 compares the flow hydrographs for the 5-year rainfall event for the following conditions:

- Existing Conditions, Existing Hydrology – Existing stormwater infrastructure and existing development
- Existing Conditions, Future Hydrology – Existing stormwater infrastructure and assumed future development
- Harrison – Assumed future development and expanded Harrison basin
- Harrison, Edgewood, Conveyance – Assumed future development, expanded Harrison basin, Edgewood basin, and Option 1 conveyance improvements to provide 100-yr level of protection
- 100-yr Option 1 – All improvements included in recommended alternative, 100-yr Option 1

The flow hydrographs are taken from model results at the outfall of Harrison basin and include both flows in the box culvert and Harrison basin overtopping flows, where applicable. Figure 28 shows that construction of all of the recommended improvements can reduce peak flows downstream of Harrison basin for the 100-year event by nearly 80%.

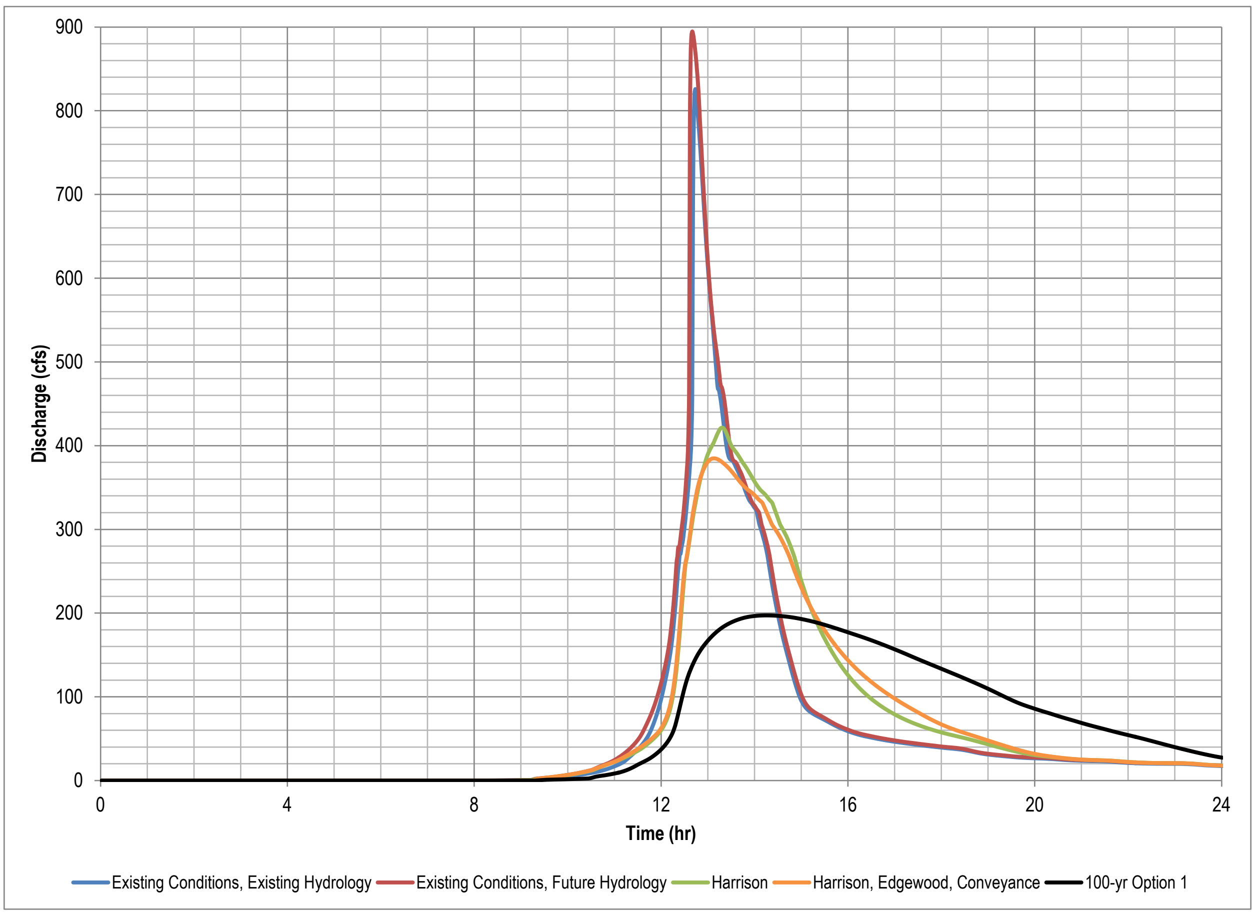


Figure 28: Flow Hydrographs Downstream of Harrison Basin - 5-yr Event

The flow hydrographs shown in Figure 28 provide a planning level estimate of the impact of the recommended improvements on flow rates downstream of Harrison basin. Peak discharges from the 5-year 24-hour event are significantly reduced downstream of Harrison basin as a result of the combination of projects implemented. This would likely reduce the required pumping capacity at the stormwater pumping station at N Avenue. It is expected that, if the improvements are designed and constructed, the hydrographs will change as a result of optimization of the stage-storage-discharge relationship for each facility. It is not recommended to use the hydrographs for design of interior drainage pump stations. Pump station capacities should be determined through evaluation and analysis of the O Avenue Basin based on the projects as they are designed and constructed.

Appendix A – Windshield Survey

Memo

Date:	Friday, July 01, 2016
Project:	O Avenue Basin Stormwater Drainage Study
To:	City of Cedar Rapids
From:	Brice Stafne/HDR, Mike Schubert/HDR
Subject:	Windshield Survey of the O Avenue Basin

Background

HDR conducted a windshield survey of several stormwater management features in the O Avenue Basin on April 4, 2016. Trace (insignificant) rainfall occurred the day before the windshield survey was conducted. Photographs were taken and observations were noted at some of the hydraulic features associated with Meth-Wick Creek and the associated drainageways. The observations are summarized in the memo.

Detention Pond at Grannie Smith Lane

A detention pond is located upstream of the open channel reach north of Richland Drive. This pond collects overland and tiled inflow from the surrounding areas. The pond is vegetated and offset Grannie Smith Lane roughly 100 feet. This pond is shown in Figure 1.

Figure 1: Detention Pond Upstream of Grannie Smith Road

Open Channel Drainageway North of Richland Drive

The drainage way North of O Avenue is a small open channel draining the neighborhood located between O Avenue and Richland Drive as well as some of the wooded area to the north. Less than a foot of flow was observed in the channel. Figure 2 shows the channel. Figure 3 shows a small sediment/detention basin adjacent to the open channel. Figure 4 shows a culvert at a crossing of this drainageway.

Figure 2: Open Channel Drainageway North of Richland Drive

Figure 3: Detention Basin Adjacent to the Drainageway

Figure 4: Culvert at Drainageway Crossing

Area Upstream (West) of Edgewood Drive

The drainageway enters a riser structure (Figure 5) upstream of Edgewood Drive. This low-lying area (Figure 6 and Figure 7Figure 7) stores some stormwater during local high-intensity rainfall events. On the day of the visit, flow entered the riser through a low-flow orifice. Downstream (east) of Edgewood, the flow is contained underground. The drainageway daylights several blocks east of this location.

Figure 5: Riser Structure West of Edgewood Drive

Figure 6: Area West of Edgewood Drive (1)

Figure 7: Area West of Edgewood Drive (2)

N Avenue Outfall

The drainageway daylights as Meth-Wick Creek at N Avenue near 25th Street. On the day of the visit, less than 6” of flow was observed in the elliptical pipe at the outfall. The outfall is shown in Figure 8.

Figure 8: N Avenue Outfall

Highwood Drive NW

Meth-Wick Creek flows through a large culvert under Highwood Drive. Upstream , the channel is somewhat sinuous and has significant wood debris (Figure 9). Downstream of Highwood, the channel is wider and has less vegetative debris (Figure 10).

Figure 9: Meth-Wick Creek Upstream of Highwood Drive

Figure 10: Meth-Wick Creek, Downstream of Highwood Drive

Brendelwood Road Vicinity
Brendelwood Road Crosses Meth-Wick Creek in the Meth-Wick Community area. The creek flows into a culvert that is approximately 12-ft in diameter (Figure 11). There is a pedestrian bridge (Figure 12) upstream of the culvert. There are two smaller detention ponds nearby at the intersection of N Avenue and Koehler. The outlet risers for these ponds are shown in Figure 13 and Figure 14.

Figure 11: Brendelwood Drive Culvert, Meth-Wick Creek

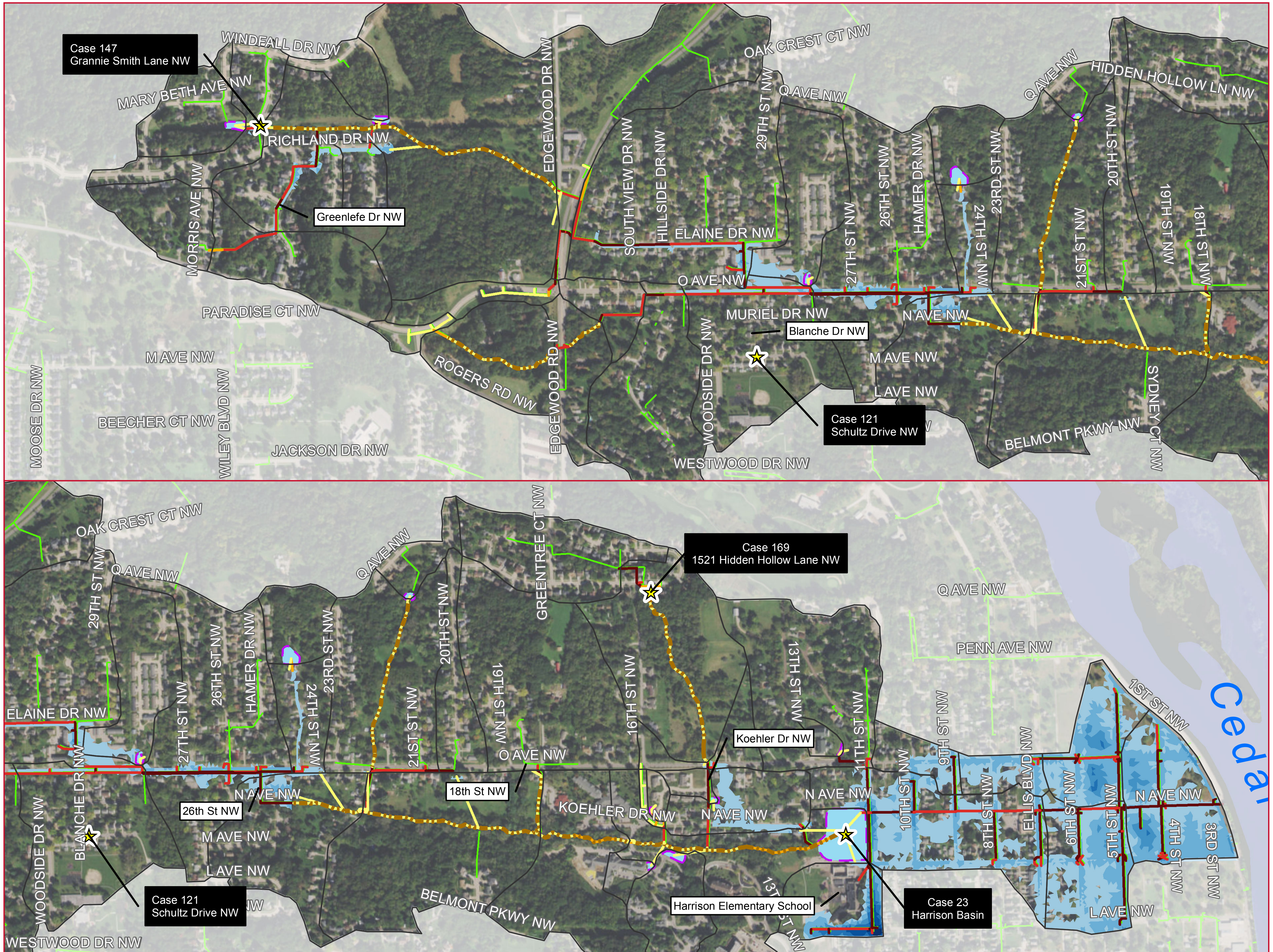
Figure 12: Pedestrian Bridge Upstream (West) of Brendelwood Drive

Figure 13: Outlet Riser in Detention Pond at N Avenue and Koehler Drive (1)

Figure 14: Outlet Riser in Detention Pond at N Avenue and Koehler Drive (2)

Appendix B – Model Results

FIGURE B-1
2014 EVENT MODEL RESULTS
EXISTING CONDITIONS



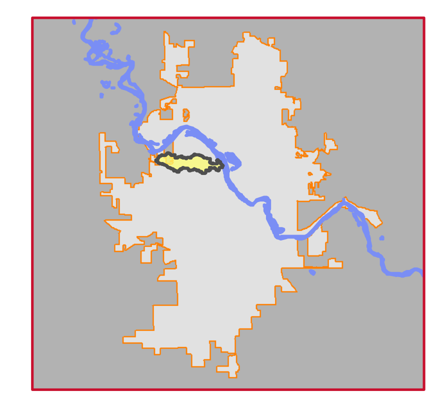
Sub Catchment
Modeled Detention Pond
CIP Project Location
Open Channel
Storm Pipe

Surcharge

Less than half full
More than half full
Full - Bottleneck Downstream
Full - Bottleneck Pipe

Ponding Depth (ft)

0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1+



0 Feet 800

DATA SOURCE: City of Cedar Rapids

HDR
CEDAR RAPIDS City of Five Seasons

CITY OF CEDAR RAPIDS
O AVENUE WATERSHED DRAINAGE STUDY

PATH: L:\CITY_OF_CEDAR_RAPIDS_O-AVENUE_DRAINAGE_STUDY\GIS-MODEL\MAP_DOCS\MXD\TM_FIGURES\EXISTING_2014_RESULTS_20160720_SHEET.MXD - USER: BSTAFNE - DATE: 7/20/2016

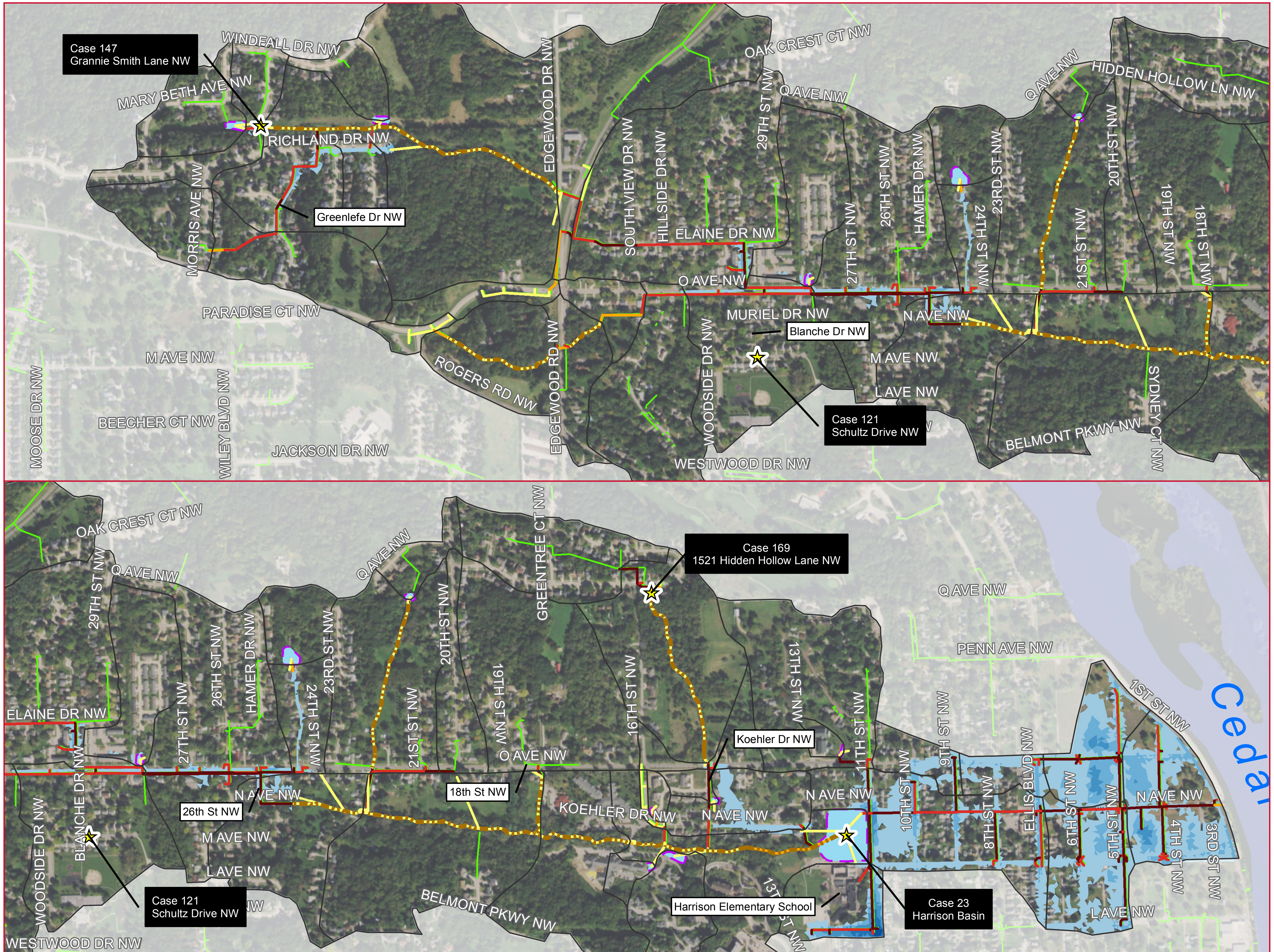


FIGURE B-2
5-YR MODEL RESULTS
EXISTING CONDITIONS

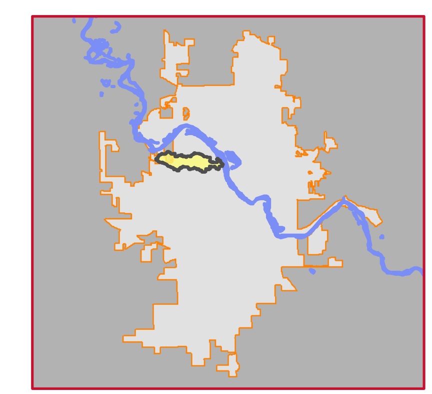
Sub Catchment
Modeled Detention Pond
CIP Project Location
Open Channel
Storm Pipe

Surcharge

Less than half full
More than half full
Full - Bottleneck Downstream
Full - Bottleneck Pipe

Ponding Depth (ft)

0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1+



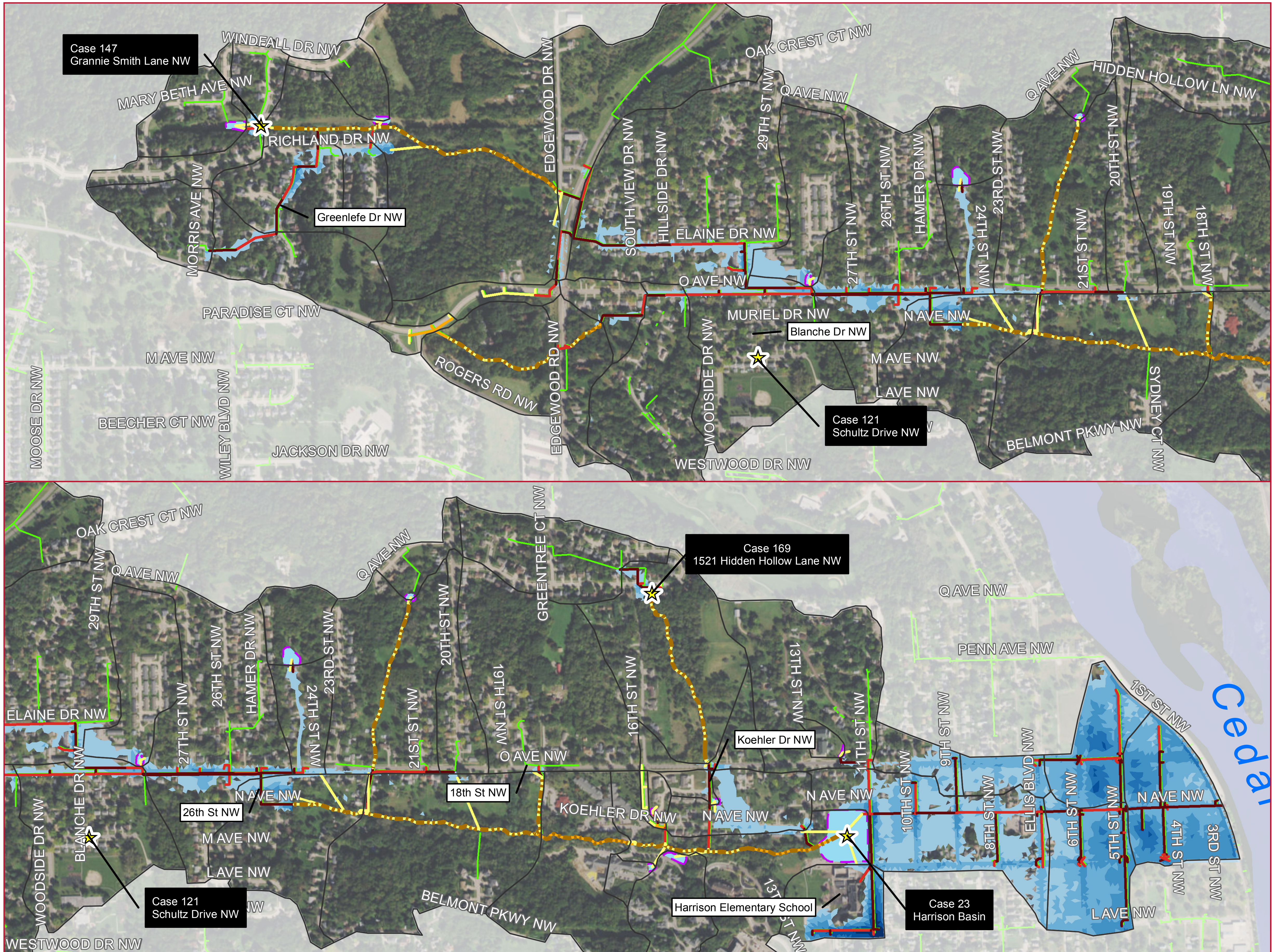
0 Feet 800

DATA SOURCE: City of Cedar Rapids

CITY OF CEDAR RAPIDS
O AVENUE WATERSHED DRAINAGE STUDY

HDR
CEDAR RAPIDS
City of Five Seasons

FIGURE B-3
100-YR MODEL RESULTS
EXISTING CONDITIONS



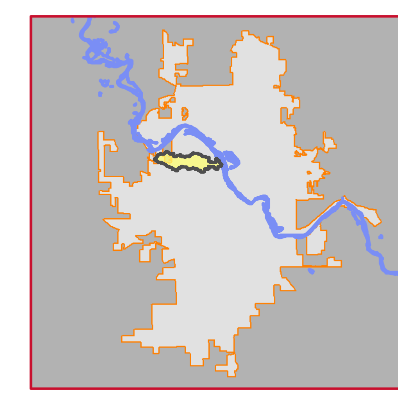
- Sub Catchment
- Modeled Detention Pond
- CIP Project Location
- Open Channel
- Storm Pipe

Surcharge

- Less than half full
- More than half full
- Full - Bottleneck Downstream
- Full - Bottleneck Pipe

Ponding Depth (ft)

- 0.1 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1+



0 Feet 800

DATA SOURCE: City of Cedar Rapids

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PATH: L:\CITY_OF_CEDAR_RAPIDS_O-AVENUE_DRAINAGE_STUDY\GIS-MODEL\MAP_DOCS\MXD\TM_FIGURES\EXISTING_100YR_RESULTS_20160720_SHEET.MXD - USER: BSTAFNE - DATE: 7/20/2016