Technical Memorandum

Date:	Thursday, May 05, 2016
Project:	Stormwater Master Plan Update
To:	City of Cedar Rapids
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Subject:	TM 3.2 Basin Scale Modeling - Kenwood

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

- Objective
- Summary
- Critical Area Identification
- 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 one more detailed basin-scale model.

The first modeling effort focuses 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 (12" and larger), will be developed to enable evaluation of mitigation strategies in the context of the entire system. At the October 14, 2015 workshop, the City decided that the Kenwood basin was the highest-priority critical basin-scale model to develop. The Kenwood 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 Kenwood basin-scale model. This document will be incorporated in the Final Stormwater Master Plan Technical Memorandum.

Summary

HDR has developed a basin-scale model of the City's stormwater conveyance system in the Kenwood 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. 379 catchments were developed based on previously delineated boundaries and reconciled with 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. Of the pipe junctions in the model, approximately 50% of the inverts and pipe diameters were either confirmed or documented with survey data. 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, building, and roadway GIS data. The resulting mesh polygons generally represent the elevations present in overbank areas and roadways, but do not represent curb flowlines 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 three 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 Kenwood 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.

With this and further validation, the model can be used to assist in developing flooding mitigation strategies within the Kenwood basin. These improvement strategies can be applied

and prioritized based on magnitude of overflow and flooding in the areas of the system capacity constraints.

Critical Area Identification

A workshop with the City was conducted on October 14, 2015. Macro-scale model development and preliminary results were presented and discussed. Following this presentation, the group discussed which of the 15 basins would be most beneficial to evaluate with the initial critical basin-scale modeling effort. The Kenwood sub-watershed was identified as the primary basin of interest for several reasons. City staff indicated that following the June 2014 rainfall event, the Kenwood basin had the highest reported densities of incidents and extra solid waste calls (refer to Figures 1 and 2) as well as a loss-of-life. City staff also indicated that the issues in the Kenwood basin and plans to address them are not well understood at this time. Furthermore, the Kenwood area is among the older neighborhoods, which presents the greatest number of restrictions to making improvements (due to the fully-built nature of the area). This area also has many sanitary inflow and infiltration sources, which when mitigated, would increase flow in the stormwater system. This condition could be modeled in anticipation of anticipated changes. Finally, this area has the largest contribution to Cedar Lake, and developing stormwater alternatives may impact or influence any potential Cedar Lake restoration goals.

In summary, the frequency and severity of stormwater-related damages and the potential usefulness of a tool for understanding the root causes of these damages were compelling arguments for evaluating the Kenwood basin in greater detail. As a result, the Kenwood basin was selected as a critical basin to be modeled. Other critical basins (such as O Ave, E Ave, Rockford Rd, and Czech Village) should be modeled in subsequent efforts.

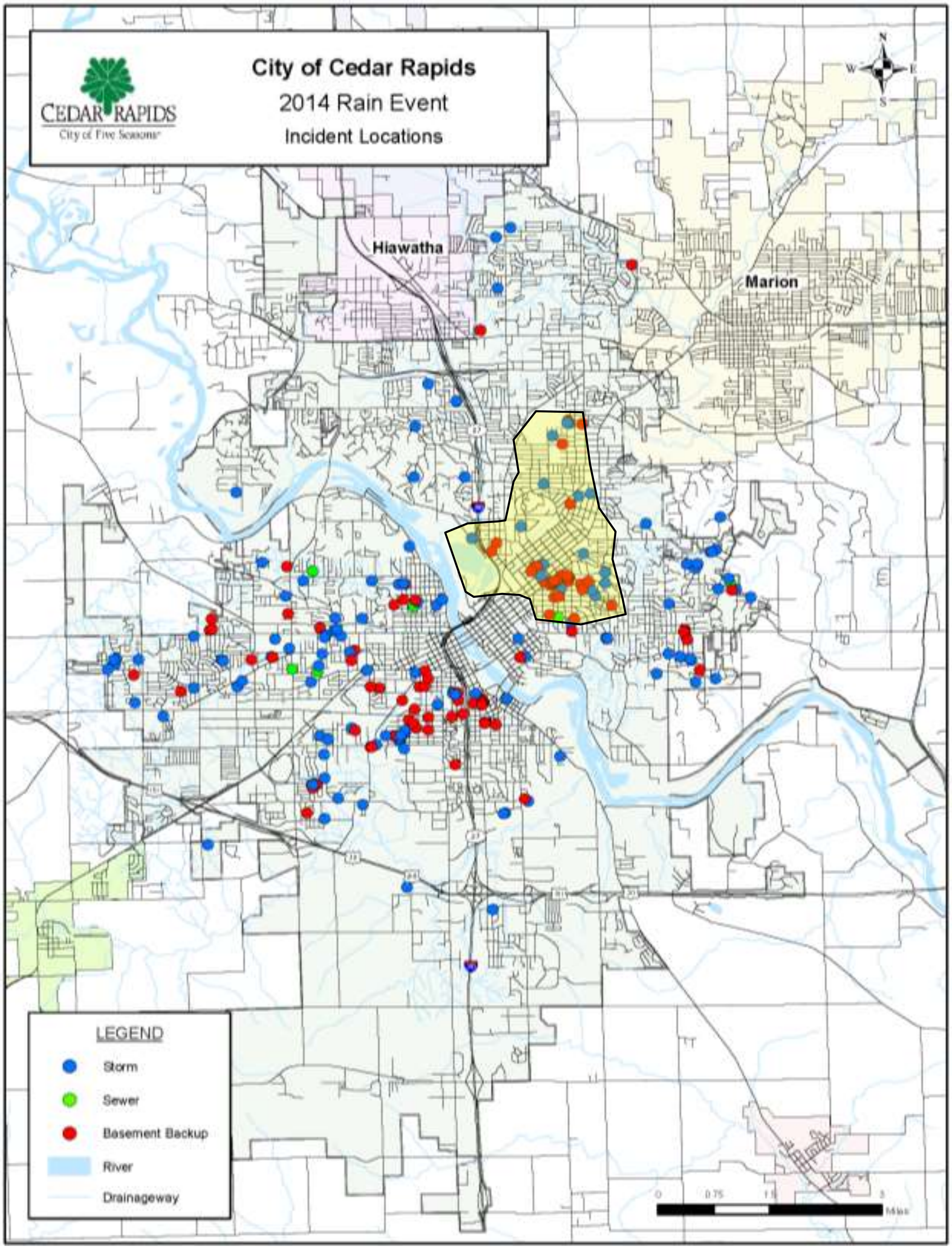


Figure 1: Summary of Reported Stormwater Flooding Incidents, June 29-30, 2014 (Approximate Kenwood Basin Location Highlighted)

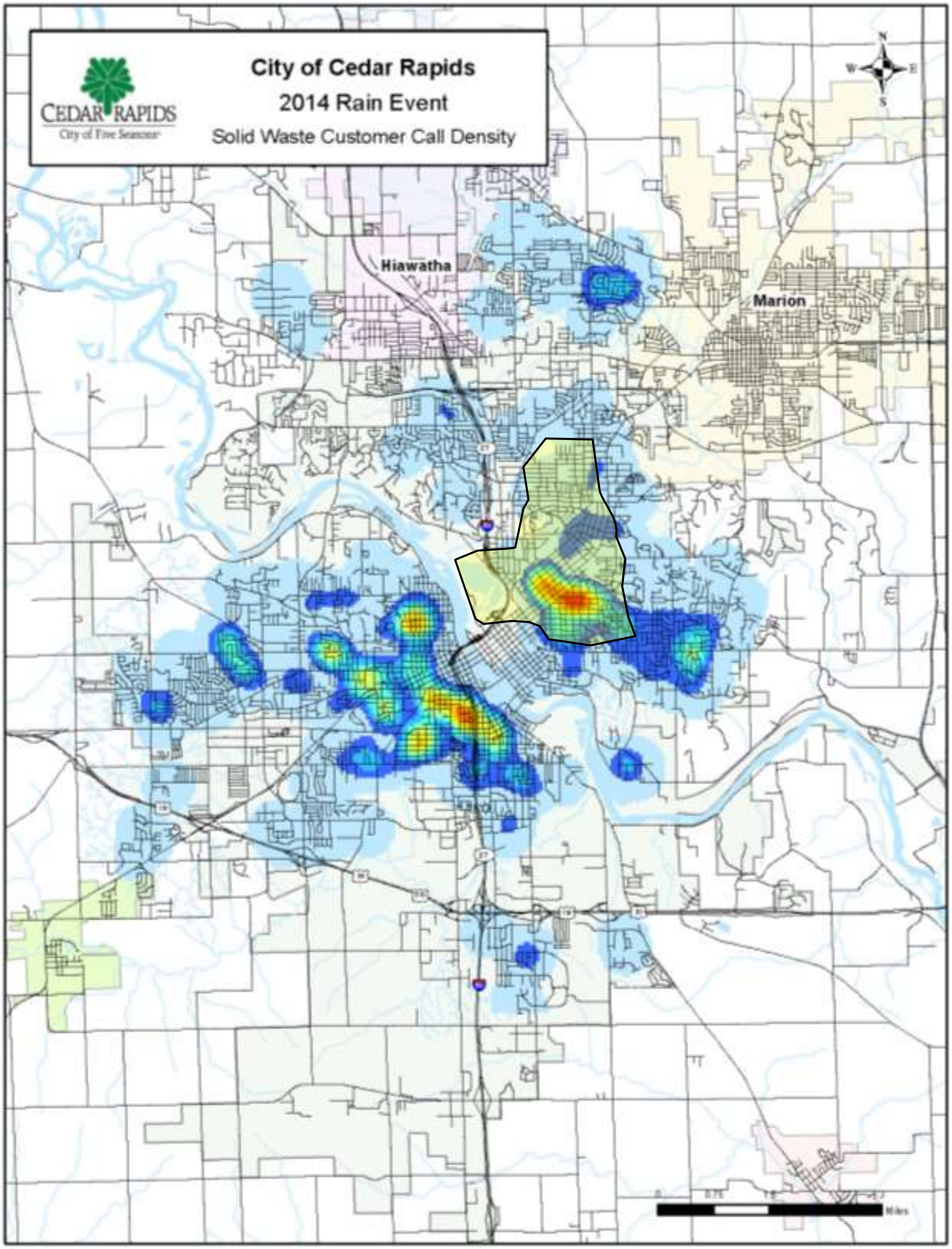


Figure 2: Heat Map of Extra Solid Water Pickups Following June 29-30, 2014 Rainfall (Approximate Kenwood Basin Location Highlighted)

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 TM 3.1.

Basin Characteristics

SUMMARY OF BASIN

The Kenwood subwatershed or basin is in parts of the SE and NE quadrants of Cedar Rapids (refer to Figure 3). It flows generally from the east to the west and north to south, discharging from an 18 by 10 feet box structure into Cedar Lake. The total drainage area in the Kenwood basin is 3,019 acres. It is bounded by the McCloud Run watershed on the NW and Indian Creek watershed on the east. On the south, it flows to Mt Vernon Rd SE and includes the Vernon Heights area. The land uses consist of fully developed residential areas, one golf course, two colleges, commercial areas along 1st Ave East and a smaller industrial area along I Ave NE. Figure 4 shows an overview map of the Kenwood basin.

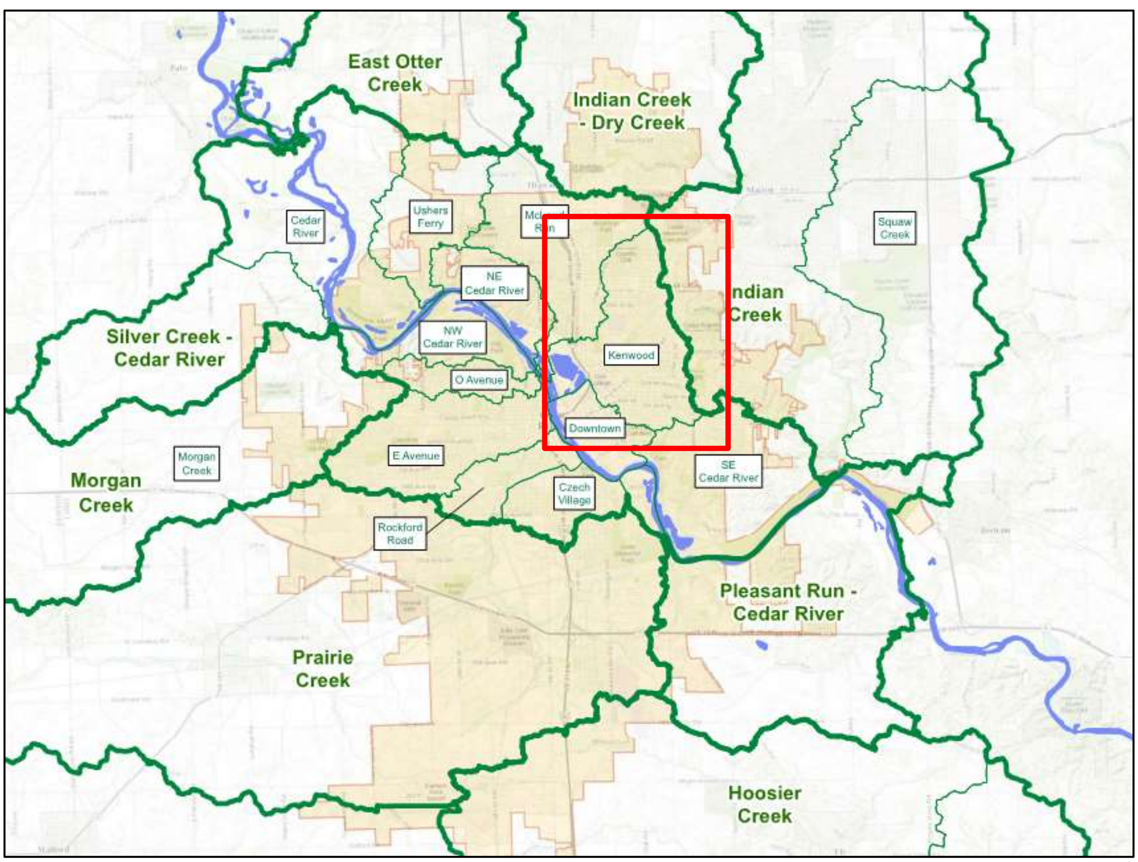


Figure 3: Location of Kenwood Basin within Cedar Rapids

Figure 4: Overview of Kenwood Basin

This basin has a history of significant damages during flash rains in 1971, 1993, 2008 and 2014. The specific damaged areas noted by City staff include:

- Rockwell Collins Plant NE on 35th ST NE
- 37th ST NE by Elmhurst Golf Course
- A and B Ave NE at 15th ST
- Bever Ave at Meadow Brook SE
- Grande and Forest Ave SE

Following the 1971 flooding, capacity was increased by adding a storm sewer along16th ST NE to parallel the 15th St NE brick line. The magnitude of the 2014 event exceeded the capacity of the system and backed up flows into a low area at A and B Ave at 15th ST NE. Based on previous estimates by City staff, many of the pipes are limited to conveying less than the 5 to 10 year rain event flows. Additionally, some overland flow paths are blocked resulting in street ponding in excess of 3 feet in depth in 2014.

DATA SOURCES AND ASSUMPTIONS

GIS Catchments

Catchments delineated by the Iowa Flood Center for a previous project were the starting point for the catchments for the current study. Those catchments were delineated using automated methods which consider the topography of the project area and the existing stormwater pipe network. These catchments were refined for the Kenwood 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 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 1 summarizes hydrologic soil groups by area. The majority of the basin soils (85%) 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.

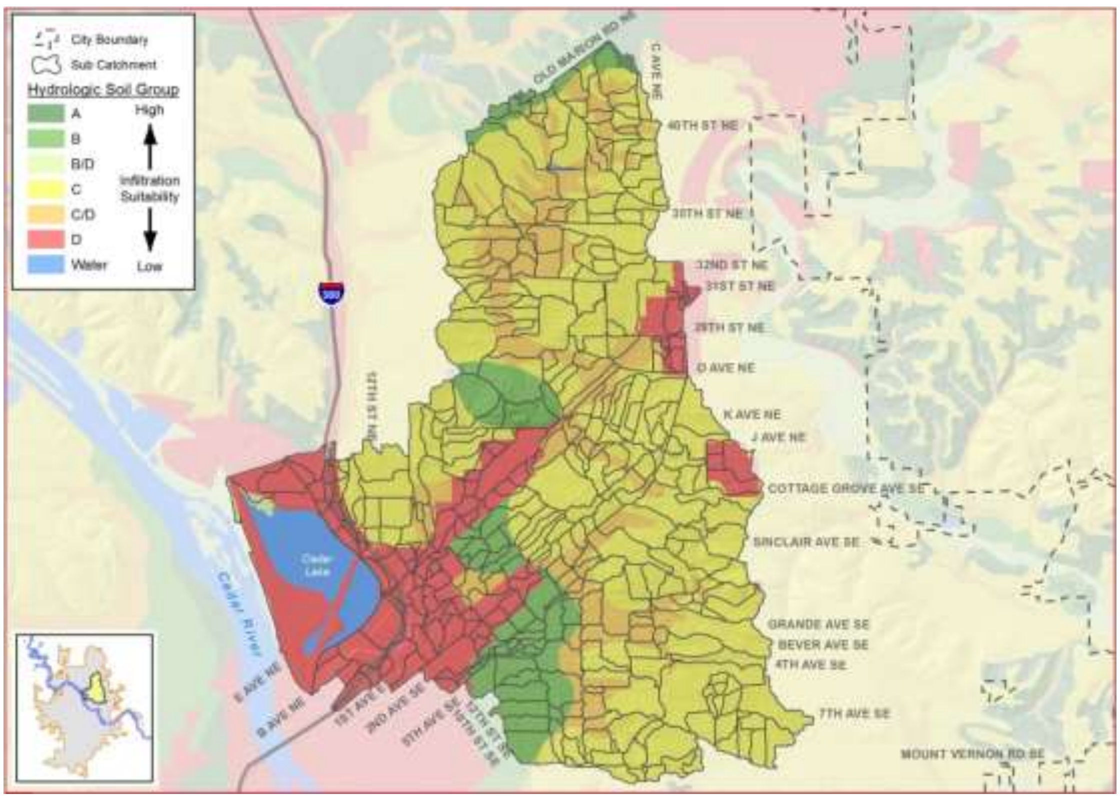


Figure 5: Hydrologic Soil Group Type

Table 1 - Hydrologic Soil Group (HSG) Summary

HSG	% of Kenwood Basin Area
A	0.2
B	10.2
B/D	0.3
C	50.6
C/D	16.2
D	18.7
Water	3.8

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 900 linear feet of open channels within the Kenwood 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 Kenwood basin on November 25, 2015. The information from this survey was used to verify field data collected by the survey crew and GIS data from the City's database. Some debris was observed around private detention pond outlet risers, in the McLoud Run inflow into Cedar Lake and in the channel upstream of the Cedar Lake outlet. To assist in achieving optimal performance of the City's stormwater infrastructures, these areas should be routinely cleaned and maintained to remove the debris and any blockages and help prolong infrastructure life. The summary of this windshield survey is included in Appendix A.

CATCHMENT HYDROLOGY

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. An aerial photo taken on September 18th, 2014 was used to verify existing land use GIS data. Based on this review, some existing land use types were modified to better represent existing conditions. Specifically, land use types such as civic and agricultural were revised 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 composite curve numbers for each catchments are shown in Figure 7.

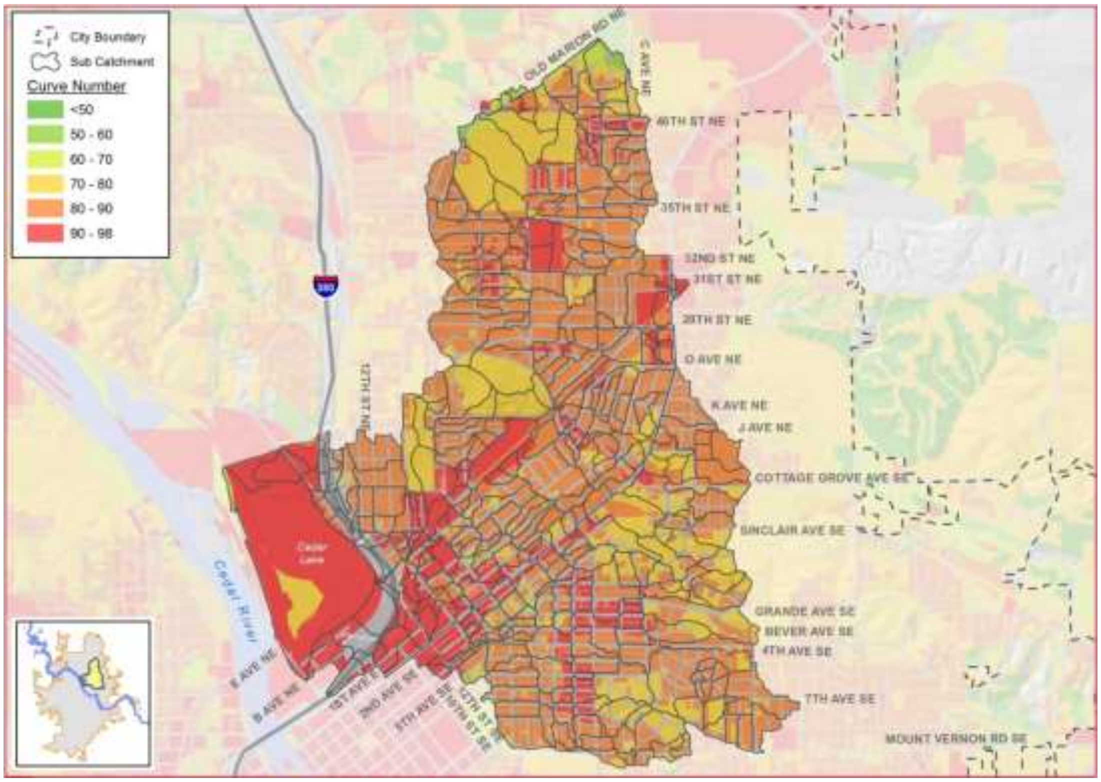


Figure 6: Curve Numbers

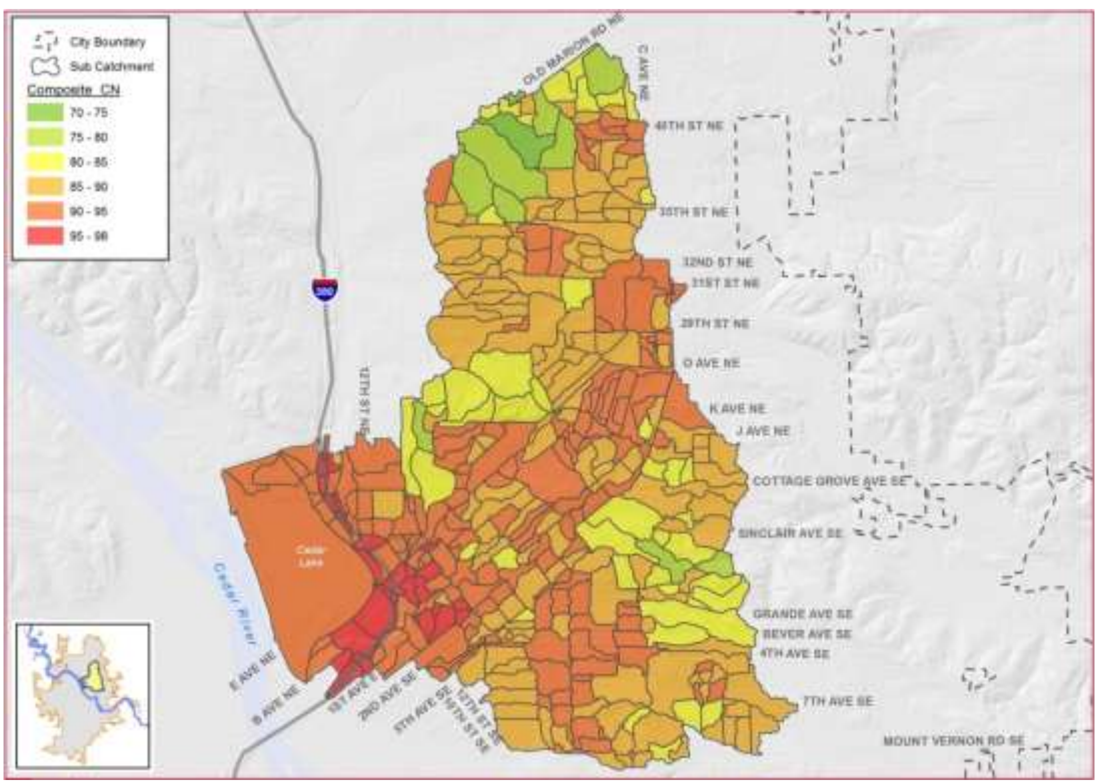


Figure 7: Composite Curve Number, by Subcatchment

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.

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

where

Q = runoff (in)

P = rainfall (in)

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

$I_a =$ Initial abstraction

ASSUMPTIONS

Mt. Mercy Geothermal System

Mt. Mercy University operates a geothermal heating system which is a closed system and does not connect to the stormwater system. This was modeled with the assumption that this system is not directly connected to the storm sewer system.

Elmcrest Country Club

The storm sewer GIS database did not indicate any sewer connection to the ponds in the Elmcrest Country Club golf course. City staff have indicated that the lack of connection via storm sewer is likely accurate. At this time, the model was developed with the assumption that the Elmcrest Country Club ponds are not directly connected to the storm sewer system. Any flow leaving the Elmcrest Country Club golf course would do so once the downstream pond overtops and water flows overland to the storm sewer system.

Further Refinements

Preliminary 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.

1D Flow Network

SUMMARY OF ELEMENTS

The 1D flow network in the basin-scale model includes approximately 27 miles of pipe, over 900 junctions, 900 linear feet of open channel, 4 stormwater ponds, Cedar Lake, and the associated outfalls to Cedar Lake and 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 condition for the model was an outfall to the Cedar River at the northwest corner of Cedar Lake. The normal water level in Cedar Lake results in partial submergence of the 10’ x 18’ RCB outfall.

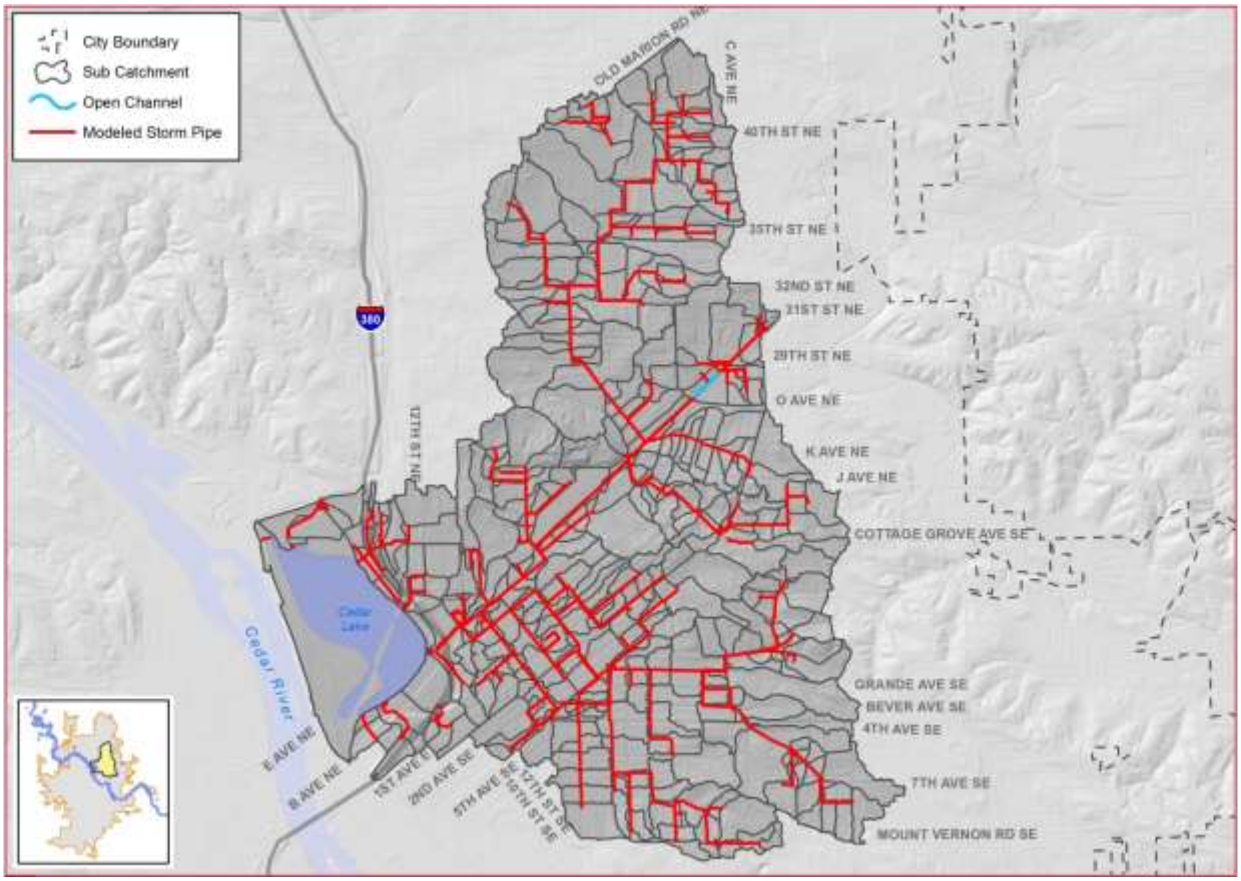


Figure 8: 1D Flow Network

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 and aerial photography 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. Of the pipe junctions in the model, approximately 50% of the 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. Approximately 50% of the pipe connections in the model 1D flow network were surveyed as part of this data collection effort.

Open Channel Data

Stormwater in the Kenwood basin is conveyed through a series of pipes and open channels, ultimately draining to Cedar Lake. For the basin-scale hydraulic model, open channels between closed conduits were included in the model. The outfall to Cedar Lake is via a ten by eighteen feet box structure.

Detention Facilities

Four major detention facilities and Cedar Lake were included in the hydraulic model. The detention facilities ranged in area from a tenth to one acre and had total storage volumes ranging from a fourth to five 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 design drawings or other hydraulic information provided by the City.

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.

Preliminary 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.

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.

1D NETWORK HYDRAULICS

Energy Losses

Major losses in open channels in pipes were represented using Manning's equation. The roughness coefficients that were used are summarized in Table 2.

Table 2: 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 was done 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 from Cedar Lake discharges to the Cedar River 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 Kenwood basin model.

Detention Facilities

The in-line or other major detention facilities that were included in the Kenwood basin model are shown in Table 3. Cedar Lake was also included in the model.

Table 3: Kenwood Basin Model Detention Facilities

Detention Facility	Basin ID	Estimated Storage Volume (ac-ft)
DISCOVERY LIVING	1249	0.25
CRYSTAL ESTATES	1242	1.03
PRIVATE	409	5.01
ELMCREST COUNTRY CLUB		4.72

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 smaller detention facilities, such as the I-380 depression under the highway overpass were not captured, but are partly accounted for in the 2D flow surface.

Preliminary modeling efforts were focused on utilizing available data from the City's GIS database and supplemental as-built data. Additional improvements could be made by incorporating additional as-built and survey data, especially at larger facilities. Any additional field verification data from stormwater flood events could be incorporated as it becomes available.

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 Kenwood 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 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 these data within the Kenwood basin are shown in Figure 9.

Figure 9: Sample of LiDAR (hillshade and background) and Planimetric Data- Roadways (blue) and Buildings (Red)

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 and buildings on the surface. 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 Kenwood basin is shown in Figure 10.

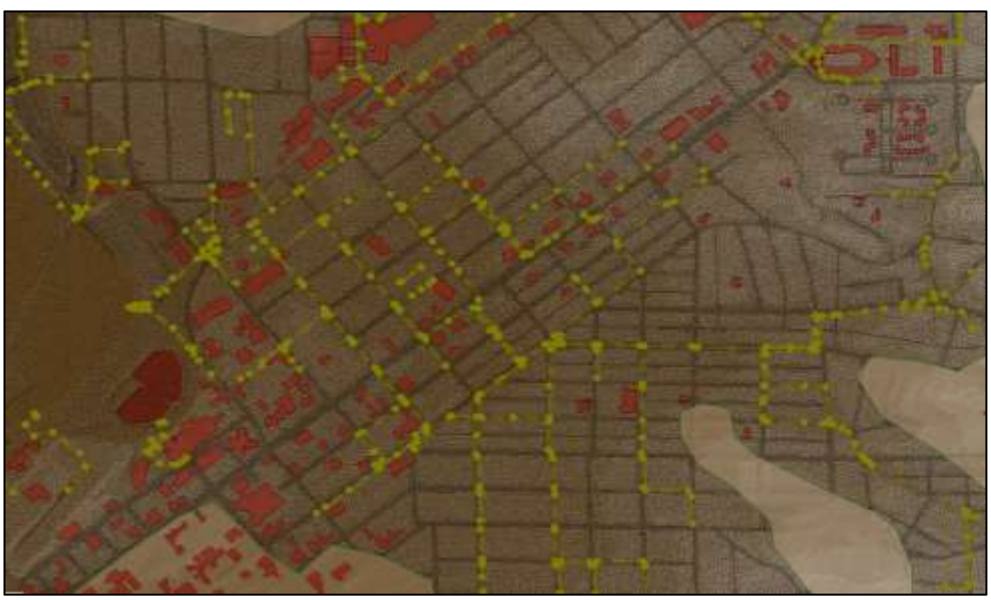


Figure 10: Sample of 1D/2D Domain, Kenwood Basin

Flow is applied to the 2D domain when the flow in the pipe section exceeds capacity. Flow will be conveyed within the 2D domain and enter the 1D domain elsewhere if pipe 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 flowlines 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 three mesh elements across the width.

ASSUMPTIONS

Buildings with footprints larger than 5,000 square feet (from the planimetry “building” layer) were treated as voids in the 2D flow domain. This assumption prevents flow from moving into or through these building structures. It is anticipated that this will result in a slightly conservative but reasonable approximation of the inundation near building structures.

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 Cedar Lake, ponds, and other wet detention facilities in the basin.

Rainfall

The nested design storm hyetographs were developed from NOAA Atlas 14 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.

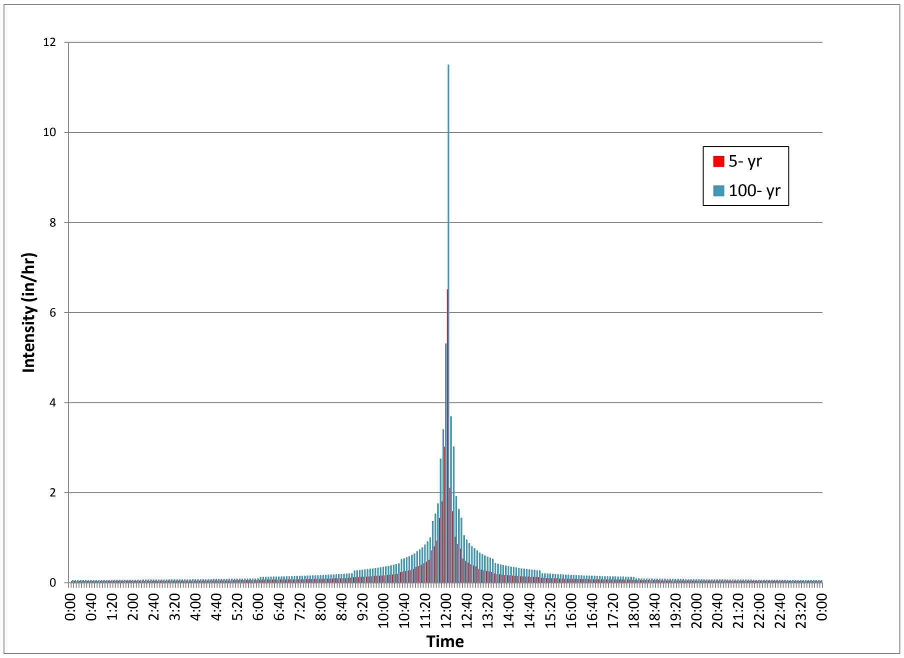


Figure 11: Rainfall Hyetographs for 5- and 100-year Nested Storms

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.

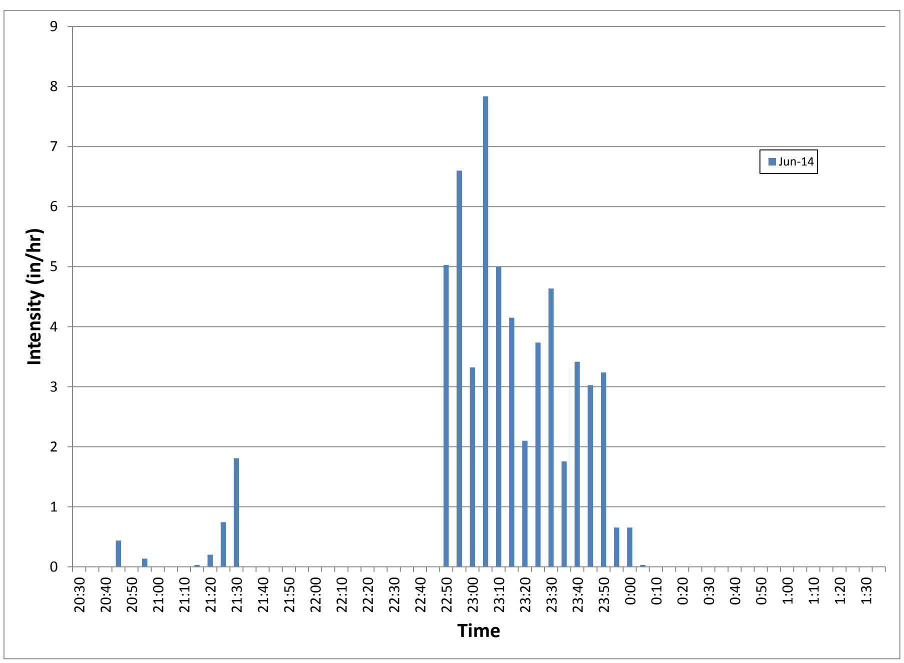


Figure 12: Rainfall Hyetographs for June 29-30, 2014 Event

Model Analysis

The 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 don't indicate these conditions at any specific time during the simulation but the worst case conditions over the entire simulation.

The results from the 5-year and 100-year rainfall event simulations are shown in Appendices B and C. The Capital Improvements Plan TM will take this analysis a step further by further quantifying the conveyed versus overflow volume of stormwater. This in turn will be used to further characterize the modeled capacity constraints by type of sewer (truck, collector, local), by number and volume of overflow from manholes, upstream catchment characteristics, peak flows, inundated structures, and network input data confidence.

5-Year Rainfall Event

The 5-year rainfall event was evaluated against the capacity of the stormwater system in the Kenwood basin. Consistent with Metro Area Standards, the City has a goal of providing a 5-year level of service by the storm sewer system without surcharging or overflows. The results for the 5-year rainfall simulation were evaluated in light of this goal. Any pipe flowing at capacity (i.e. bottlenecks) or surface ponding of any level indicates a possible deficiency in comparison to this level of service.

As Figure 13 shows, 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 Kenwood basin. Figure 13 also identifies current stormwater CIP project locations and case numbers as previously developed by City staff.

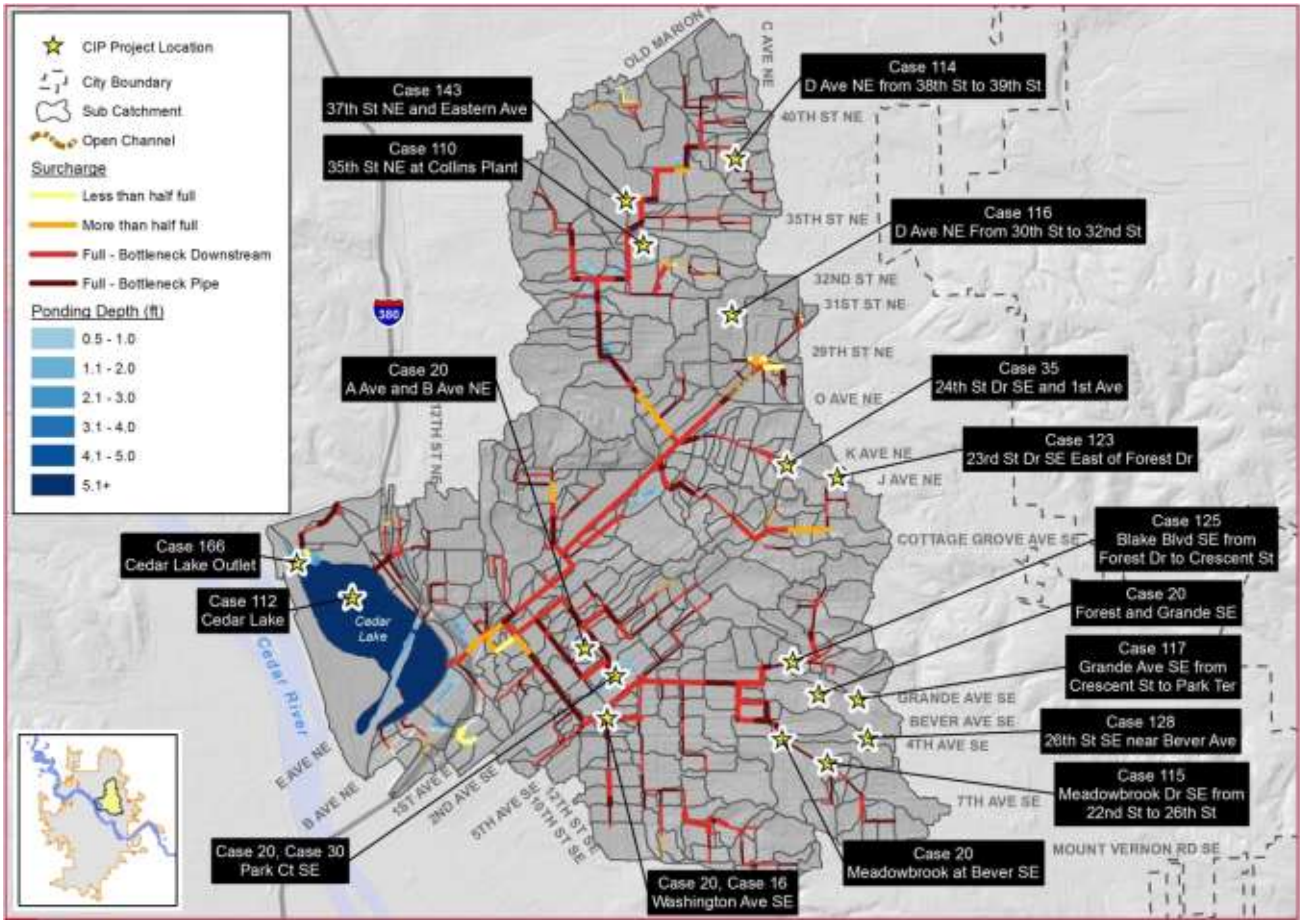


Figure 13: 5-Year Model Results Overview

FOREST AVE SE AND GRAND AVE SE

Model results indicate that conveyance limitations along Forest Ave SE and Grande Ave SE result in surcharging and overland street flow. Water from this area flows downstream to the 15th St NE and B Ave NE. This may further worsen ponding in this downstream area. Results are shown in Figure 14.

MOUND VIEW/ WELLINGTON HEIGHTS NEIGHBORHOODS

Model results show significant ponding between 2nd Ave SE & B Ave NE and 15th St NE &16th St NE, with depths between 3-4 feet at the intersection of Park Ct SE and 2nd Ave SE. The model results suggest that this ponding may result from downstream sewer conveyance limitations and could be worsened by upstream overland flow to this area. This area has been identified by the City as an on-going problem area. City staff completed a flooding evaluation from the June 2014 storm of this area (specifically 15th St NE, 16th St NE, A Ave NE and B Ave NE) which can be found in Appendix D.

Flooding was also predicted near Washington Ave SE / 15th St SE, Blake Blvd SE and along Meadowbrook Dr. These areas, which are noted as on-going problem cases by the city, each appear to have local conveyance limitations that result in street-level ponding.

Model results of the southeast and southwest portions of the Kenwood basin are shown in Figures 14 and 15, respectively.

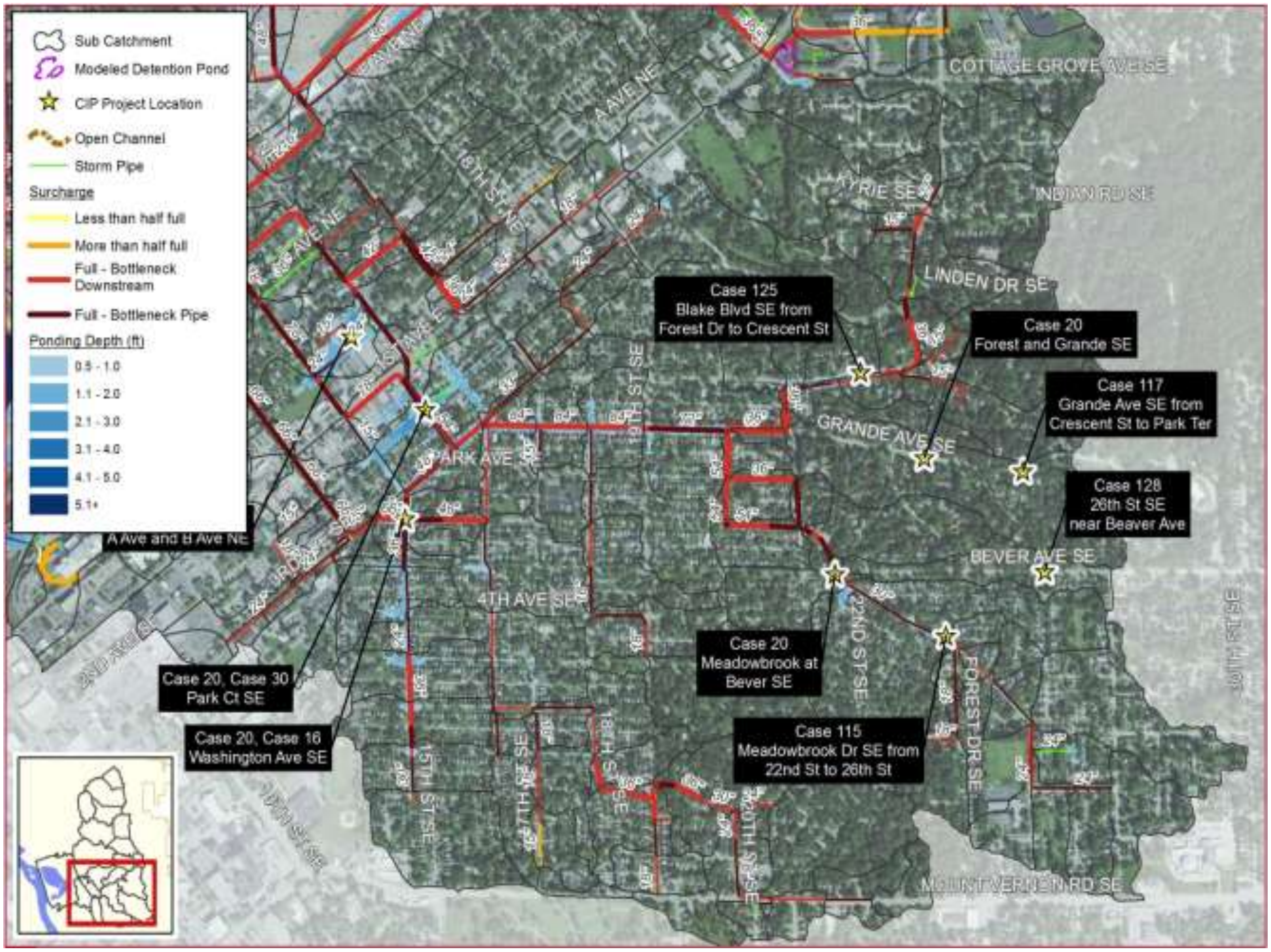


Figure 14: 5-Year Model Results, Southeast Portion of Kenwood Basin

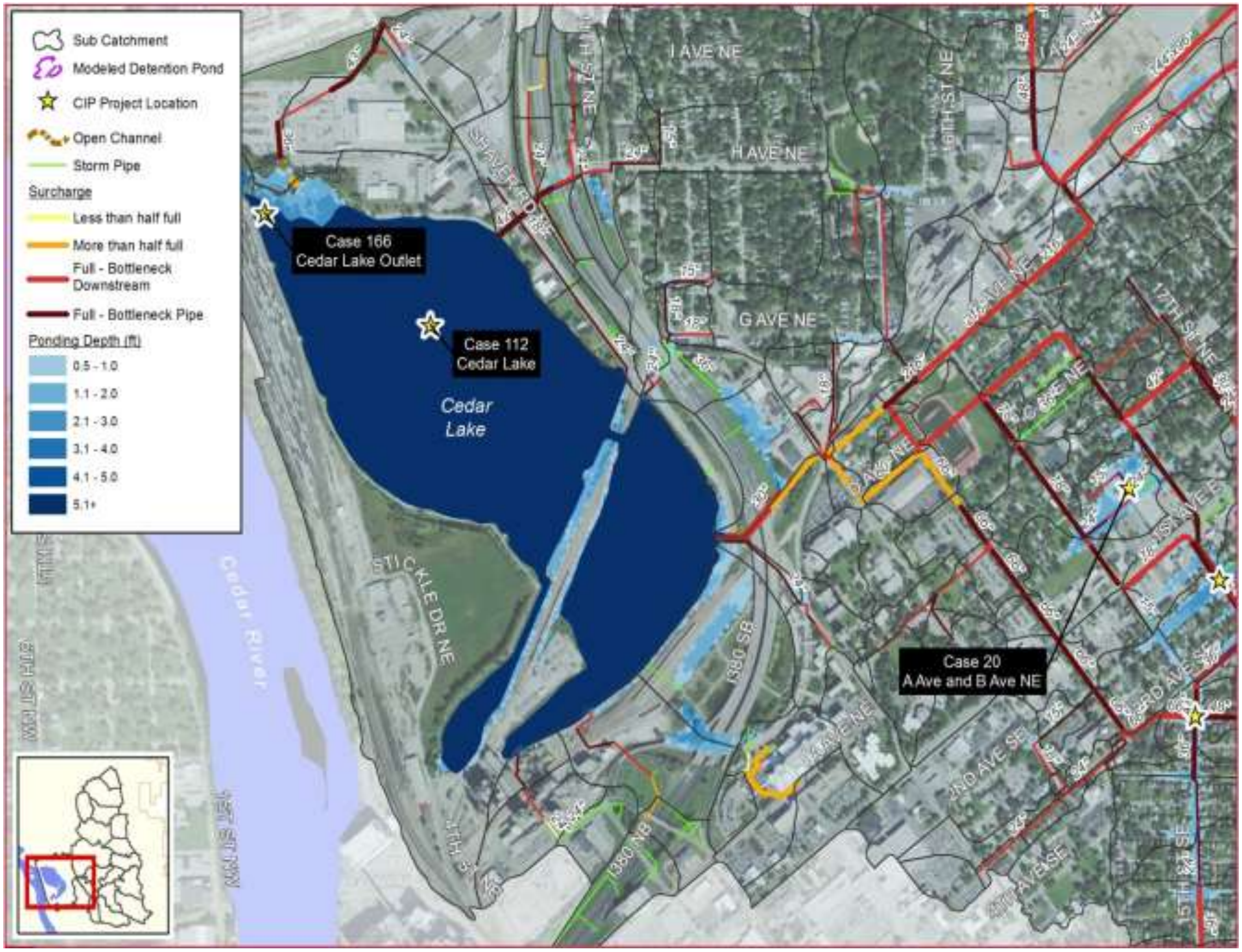


Figure 15: 5-Year Model Results, Southwest Portion of Kenwood Basin

KENWOOD PARK / ROCKWELL COLLINS 35TH STREET CAMPUS

Model results show significant ponding at the Rockwell Collins 35 St Campus, along the west side of the parcel and along 33rd St NE to the west of the parcel. The pipe network results show that although storm sewers are flowing full at these locations, the conveyance capacity is limited downstream (south) along Eastern Ave NE. The results also show ponding at D Ave NE from 38th St to 39th Street. This localized street-level ponding, is a result of insufficient storm sewer capacity at this location. Model results are shown for the northern portion of Kenwood basin in Figure 16.

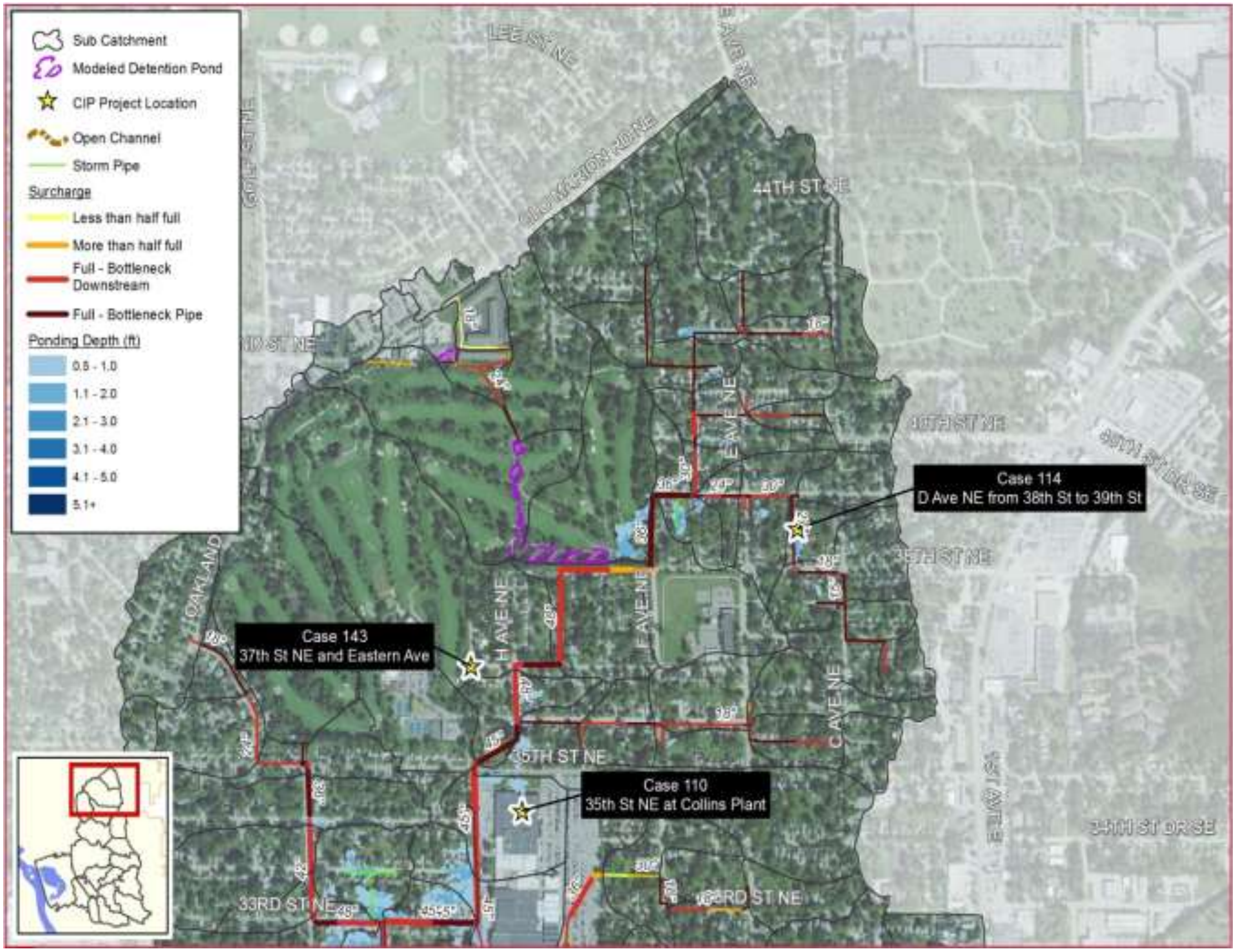


Figure 16: 5-Year Model Results, Northern Portion of Kenwood Basin

EASTERN AVE TRUNK SEWER ALIGNMENT

Model results show ponding at depths of 2-3 feet along the alignment of the Eastern Ave storm sewer line. The most significant ponding is located north of 29th St NE. Model results indicate that much of this portion of sewer is a conveyance constriction. Ponding along the trunkline alignment also exists south of 29th St NE, adjacent to the graded drainage ditch. This ponding (1-2 feet) appears to be a result of overland flow originating upstream. Model results for the central portion of the Kenwood basin are shown in Figure 17.

F AVE NE/24TH ST NE

Model results indicate that significant ponding (4-5 feet in depth) may occur near the intersection of F Ave NE/24th St NE and E Ave NE. In the model, ponding appears to result from a local conveyance limitation in the 40" storm sewer at that location and worsened by upstream overland flow to this area. Model results for the central portion of the Kenwood basin are shown in Figure 17.

24TH ST NE AND 1ST AVE SE

Model results indicate that significant localized ponding occurs near the intersection of 24th St NE and 1st Ave SE. Model results indicate that the localized ponding is due to inadequate capacity in the storm sewer downstream. The location is also a local low-lying area, which worsen maximum ponding depths. Model results for the central portion of the Kenwood basin are shown in Figure 17.

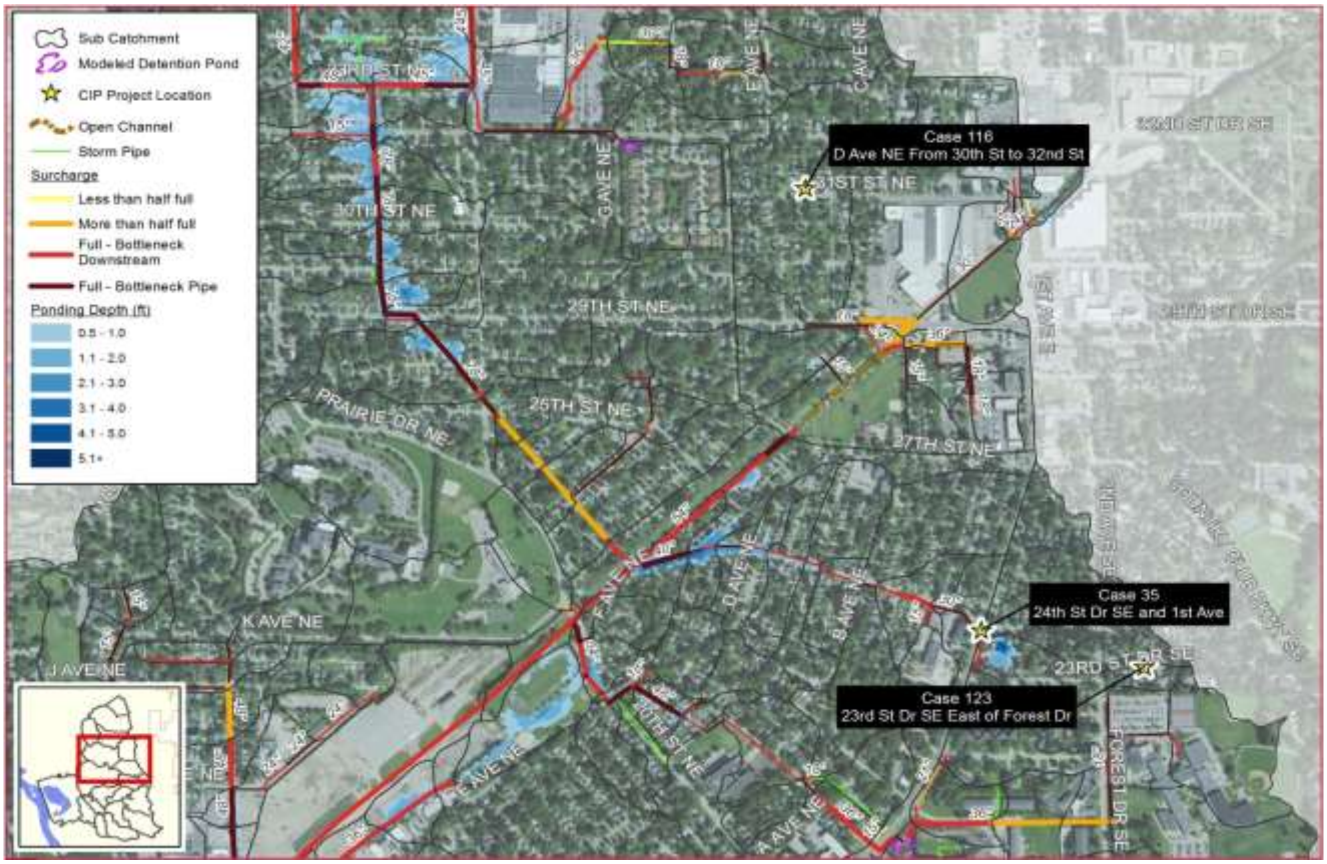


Figure 17: 5-year Model Results, Central Portion of Kenwood Basin

Following the completion of modeling, the City staff provided as-built drawings which indicated that significantly more conveyance may exist along the main trunkline between 33rd St NE and F Ave than was represented in the model (which was based on the City GIS database). The additional conveyance includes a 10'x5' box culvert between F Ave and 29th St NE, and parallel 78" storm sewers between 33rd St NE and 29th St NE. This additional conveyance may alleviate some or all of the predicted stormwater surcharging predicted upstream of this area. The model should be updated incorporating additional data in this vicinity. This should be done prior to implementation and will allow projects in this area to be reevaluated and developed based on the best available data.

100-Year Rainfall Event

In addition to the 5-year rainfall event, the 100-year rainfall event was also evaluated against the capacity of the stormwater system in the Kenwood basin. Consistent with Metro Area

Standards, the City has a goal of maintaining the 100-year rainfall runoff within City right-of-way (ROW). Evaluation of 100-year rainfall results was focused on surface flow and ponding that extends well 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 and to help prioritize the worst case capacity deficiencies. The 100-year simulation model results are shown in Figure 18. Again, Figure 18 also identifies current stormwater CIP project locations and case numbers as previously developed by City staff.

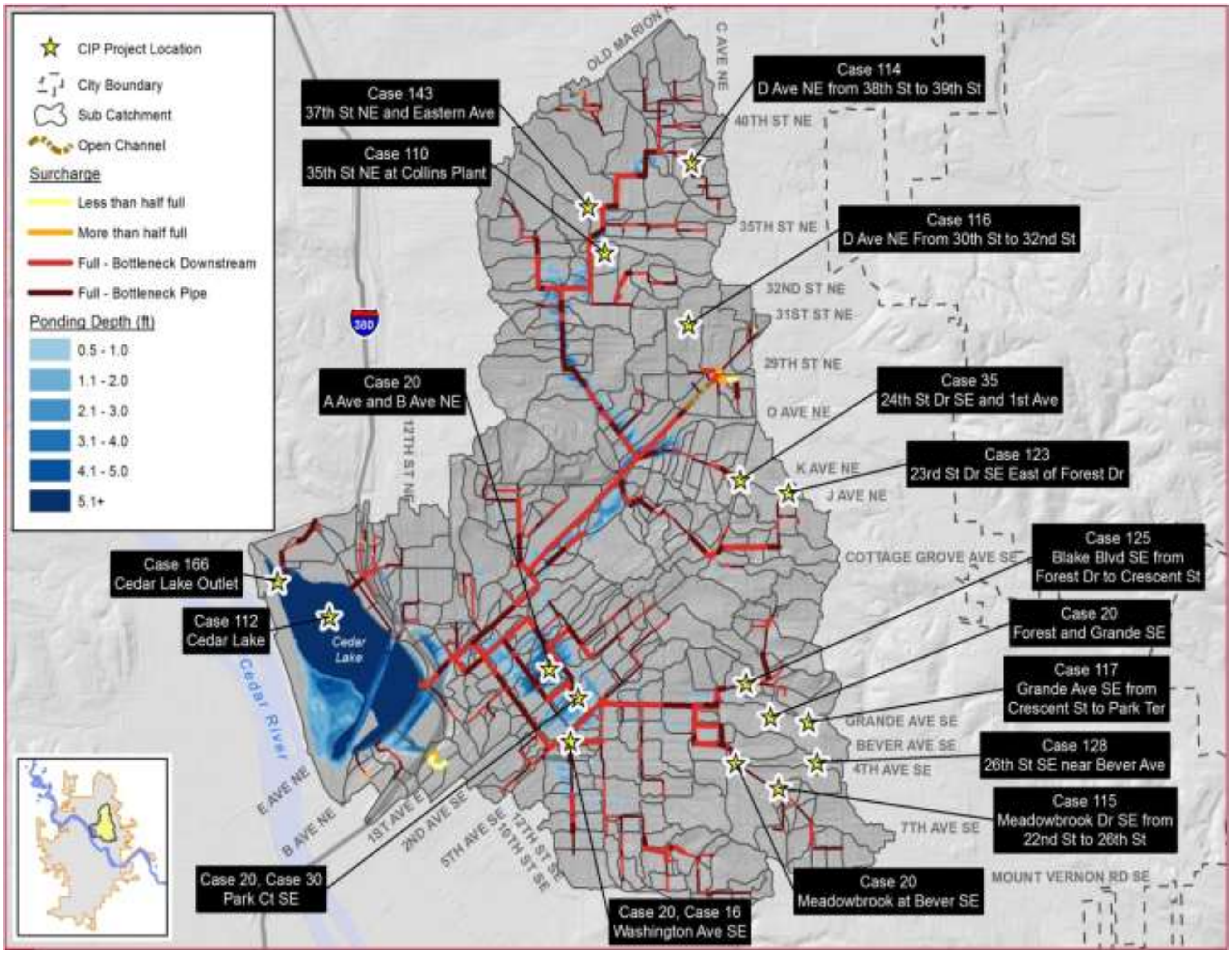


Figure 18: 100-Year Model Results Overview

MOUND VIEW / WELLINGTON HEIGHTS NEIGHBORHOODS

Model results indicate that a 100-year rainfall event may result in expanded ponding in excess of 2 feet across a large portion of several blocks between 3rd Ave SE & B Ave NE and 14th St NE & 17th St NE. The deepest resultant inundation, which exceeds 5 feet, occurs on A Ave NE between 15th St NE and 16th St NE. Most of the local streets in this area experience some overland flow due to downstream capacity constraints in the storm sewer system. The model results for the southeast and southwest portions of the Kenwood basin are shown in Figures 19 and 20, respectively.

AREAS AROUND THE PERIMETER OF CEDAR LAKE

Model results indicate that areas along Cedar Lake may be inundated following a local rainfall event. This inundation results when flow into Cedar Lake exceeds the outlet capacity of the culvert as modeled. Further evaluation of the Cedar Lake outlet culvert and weir may be warranted to confirm flow conditions.

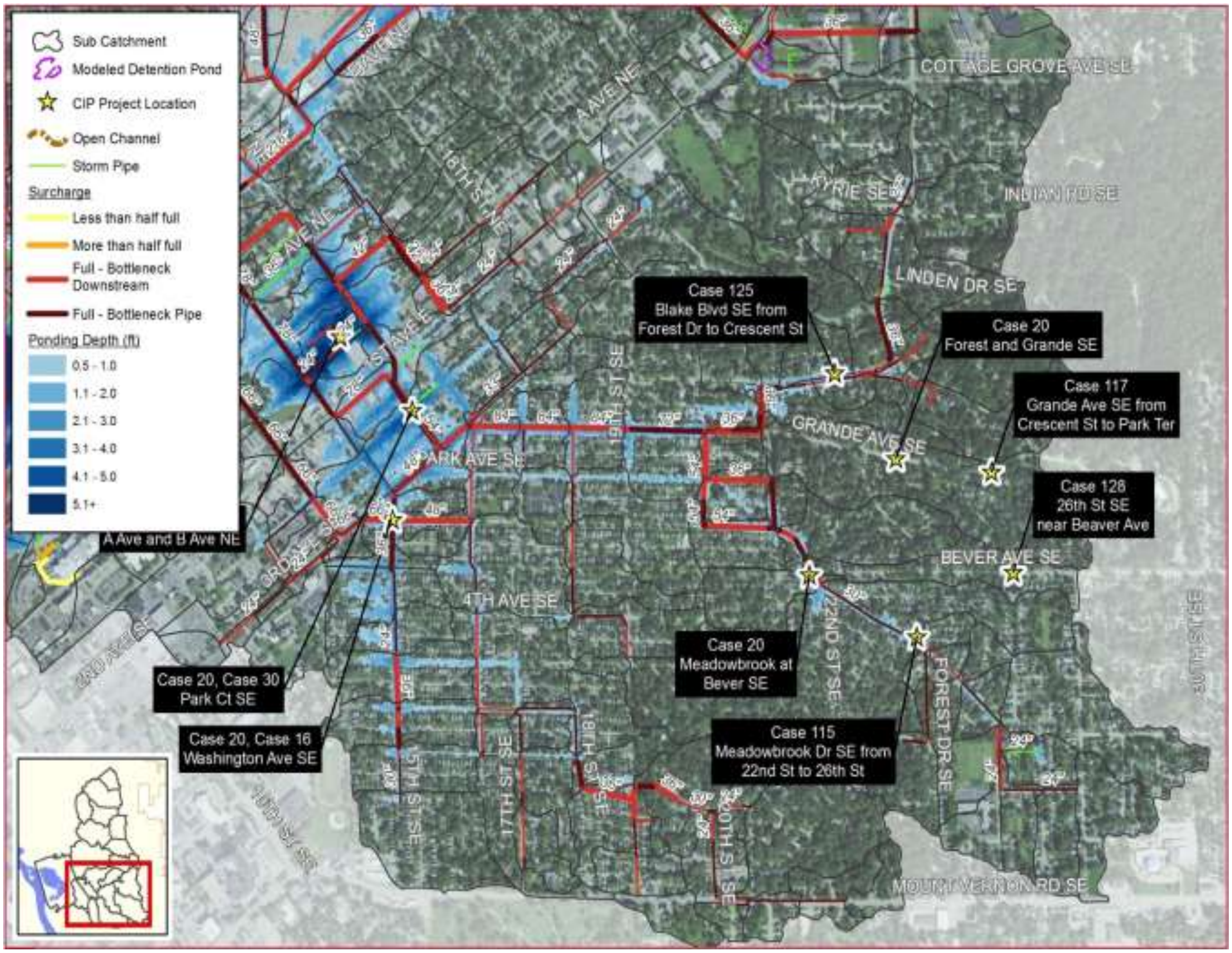


Figure 19: 100-Year Model Results, Southeast Portion of Kenwood Basin

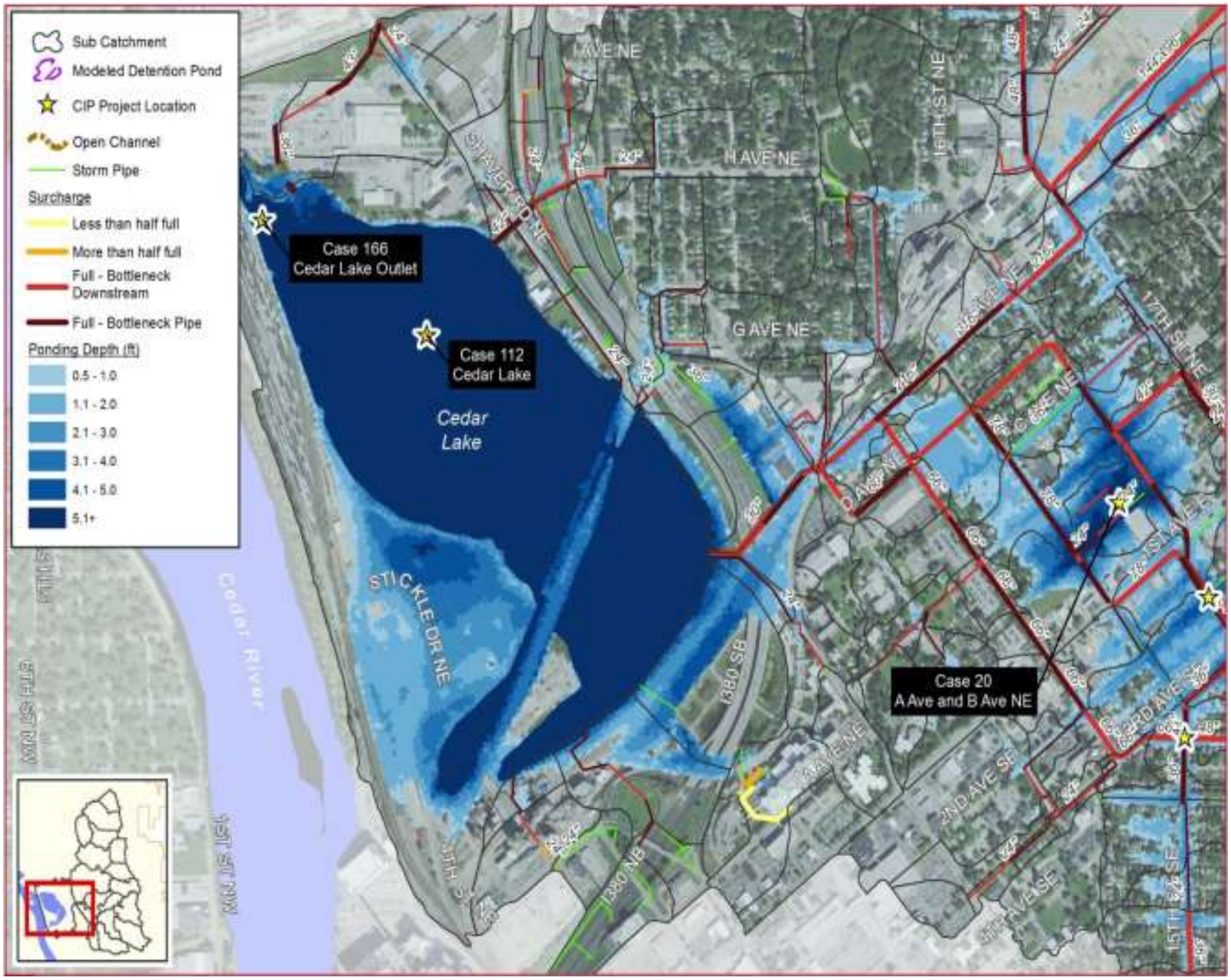


Figure 20: 100-Year Model Results, Southwest Portion of Kenwood Basin

EAST OF ELMCREST COUNTRY CLUB

Results indicate that this event may result in ponding beyond the City ROW in the area east of the Elmcrest Country Club. This ponding and street overland flow ranges in depth between 1-3 feet and occurs in yards and local low-lying areas. Model results for the northern portion of the Kenwood basin are shown in Figure 21.

KENWOOD PARK/ ROCKWELL COLLINS 35TH STREET CAMPUS

Model results indicate that expanded ponding occurs at the Rockwell Collins 35th St Campus and along 33rd St NE between Prairie Drive and Eastern Ave. Depths in this area are generally between 1-3 feet. Model results for the northern portion of the Kenwood basin are shown in Figure 21.

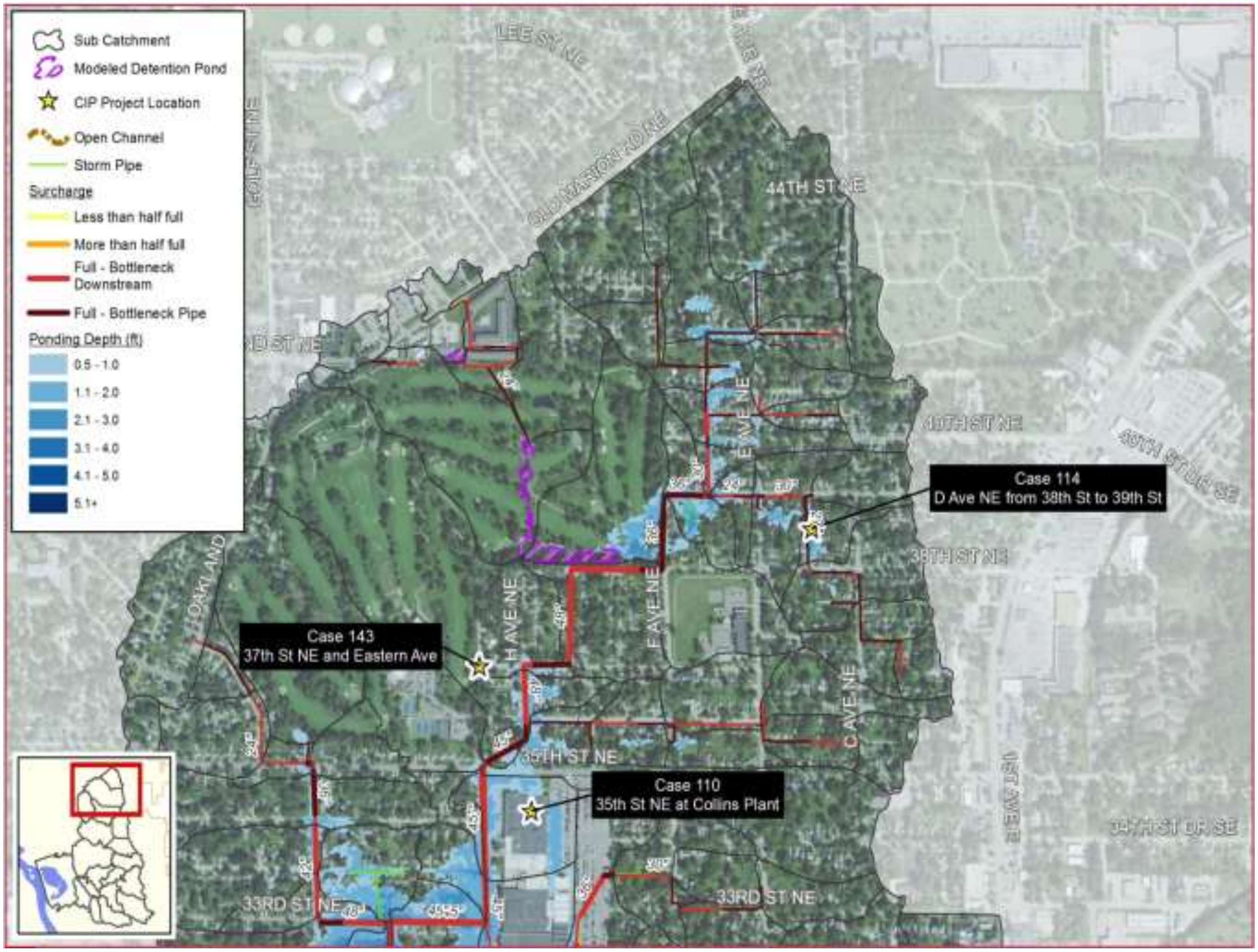


Figure 21: 100-Year Model Results, Northern Portion of Kenwood Basin

EASTERN AVE TRUNK SEWER ALIGNMENT

Model results indicate that significant expanded ponding beyond the City ROW along the alignment of the Eastern Ave storm sewer line from 33rd St NE to the Prairie Drive/K Ave NE intersection. Depths along these sections range generally from 1-4 feet. This area is the primary overland flow path downstream of the Rockwell Collins 35th St Campus. Model results in the central portion of the Kenwood basin are shown in Figure 22.

F AVE NE/24TH ST NE

Model results indicate that significant deeper ponding (4-6 feet in depth) may occur near the intersection of F Ave NE/24th St NE and E Ave NE. This is a localized low-lying area. Results are shown in Figure 22.

TOMAHAWK PARK/ F AVENUE

Model results indicate that the area along F Ave (including Tomahawk park) are inundated by 0-3 feet of water. This is a low-lying area in basin.

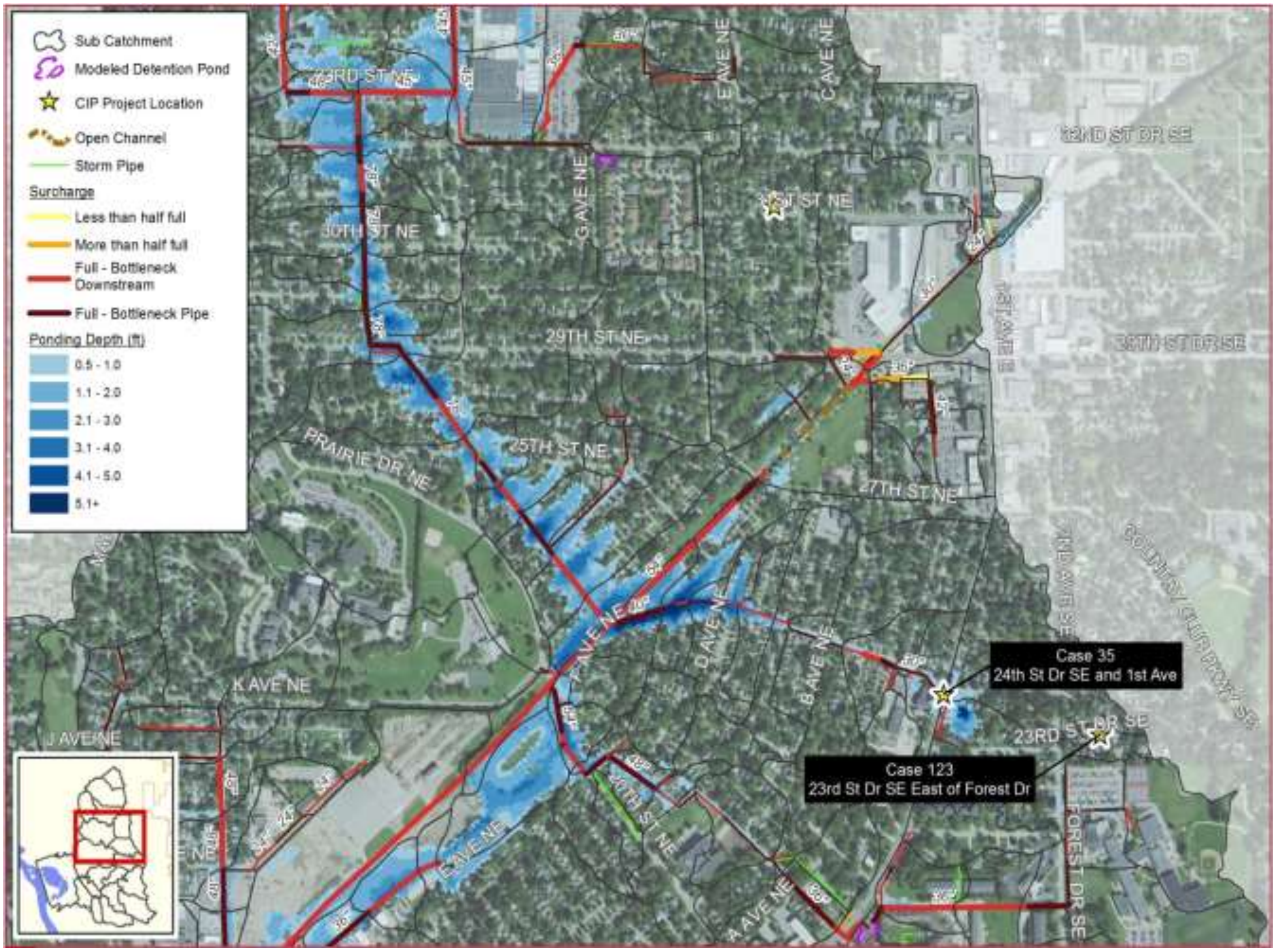


Figure 22: 100-year Model Results, Central Portion of Kenwood Basin

Validation

Limited field data (high waterline levels or flow measurements) is available for the Kenwood 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 December 9, 2015. 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:

- D Ave and 38th St NE-39th St NE
- 15th St and A Ave and B Ave NE
- Rockwell Collins Plant and the Eastern Ave 78" arch pipe alignment
- 24th St NE and 1st Ave SE

Model predicted flooding 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, 2008) noted flooding and damage issues in the same areas of the flooding shown in the model results.

Recommendations

Potential Basin Improvement Strategies

City and HDR staff participated in a workshop on December 9, 2015 to discuss preliminary model results and identify stormwater management projects to mitigate the problems identified by reported damages and complaints which are replicated by model results. At this workshop, the City identified the following potential improvement strategies:

- Upsize the 78-inch sewer along 15th Street from 1st Ave to D Ave NE to provide additional conveyance from the 2nd Ave SE & B Ave NE and 15th St NE &16th St NE area.
- Address capacity issues noted in the model for the 66-inch sewer along 16th Street. City staff noted that the 66-inch sewer had previously been repaired using a shotcrete liner from C Ave NE to 1st Ave, which may have reduced the diameter and also roughened the pipe (both of which would reduce the effective capacity of the pipe) making the modeled issue in this area worse.
- Retrofit or add detention ponds throughout the Kenwood basin to reduce peak flows and downstream capacity requirements. The City is evaluating several options:
    - Take out houses near A & B Avenues and deepen the existing low-spot.
    - Provide detention near 144-inch box near E Ave and 20th Street NE
- An existing industrial site (a large impervious area) south of Mt. Mercy University, near E Ave and 20th Street NE, may be developed into athletic fields reducing impervious surface area and providing an opportunity for incorporating some green infrastructure. Currently the university is planning on constructing a rain garden in the south corner of the property. Discussions with the university are recommended to determine if this can be a joint facility between the university and the City with potential expansion of the currently sized rain garden to help address some of the flooding issues in this area of the City’s stormwater system.
- Two businesses in the basin– Rockwell Collins’ facility near Eastern Ave & 33rd Street NE and D.C. Taylor’s parking lot near B Ave & 29th Street NE – have large impervious areas. Adding detention basins or bioswales to these areas would have water quantity and quality benefits.
- Paving for Progress projects need to be checked for opportunities to incorporate storm water improvements, including underground storage beneath reconstructed roads and curbside bioswales.
- Identify drainage area upstream of A & B Aves and how much detention or bioswale volume would be required to reduce peak flows.

- Consider green infrastructure in areas with higher imperviousness (refer to Figure 5) to encourage retention, peak flow reduction and water quality benefits.
- Consider extending storm sewer to the upper reaches of the Kenwood basin such as the far southeast portion where no storm sewer exists to limit local ponding and street overland flow.
- Consider stormwater pump stations to redirect runoff to an alternative sewer and/or catchment. This strategy would likely be a greater cost improvement but in some areas may be feasible. However, in the Kenwood area most of the stormwater system is at capacity during a 5-year event and therefore likely does not have local excess capacity to use for this purpose. Pumping to adjacent basins could be considered.
- Incorporate the flexibility to modify the Cedar Lake weir outlet elevation during a storm event, which may decrease inundation adjacent to Cedar Lake at the 10'x18' Cedar Lake outfall culvert.
- Make modifications to divert McLoud Run to the Cedar River rather than Cedar Lake.
- Position the existing gate to divert storm sewers along Shaver Road to the Cedar River rather than McLoud Run.

In general, there are four primary improvement strategies that can be employed to reduce overland flow and flooding in the Kenwood 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
    - 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

The condition of inlet structures and pipes was not considered as part of this evaluation. It is possible that stormwater system maintenance, including cleaning the closed conduits and removing debris from inlets and outfall structures, will improve or help sustain the conveyance available within the system existing system.

The Capital Improvements Plan TM will further characterize and prioritize the capacity issues resulting from the model simulations. It will also assists in determining which of the priority bottlenecks may benefit most from which primary improvement strategies.

Modeling Recommendations

In future design development efforts, the validated Kenwood basin model can be utilized to evaluate the effectiveness of the above stormwater management projects. Specific projects can be identified, developed and evaluated with the Kenwood basin model.

Prior to modeling specific improvement projects, planning level analysis should be done to prioritize needs and to evaluate the relative order of magnitude runoff volume reductions that can be expected through land use changes, green infrastructure, or detention basins. This preliminary analysis will significantly reduce the number of model iterations by identifying the degree to which deficiencies in the system can be mitigated or offset with storage, land use changes, and green infrastructure. Accounting for these changes will allow gray infrastructure improvements (i.e. increased conveyance) to be considered in light of a holistic stormwater management strategy for the Kenwood basin.

Limited additional modeling will be conducted once the issue areas in the Kenwood basin have been prioritized to determine how effective the storage and green infrastructure strategies are in reducing downstream capacity constraints and overflows through peak flow and volume reduction. Figure 5 shows the spatial distribution of hydrologic soil type in the Kenwood basin. Areas with A or B soils would be most suitable for improving infiltration to reduce runoff peak flows and volumes.

The preliminary modeling efforts documented in this TM were focused on utilizing available data from the City's GIS database, supplemented with survey and as-built data. Additional improvements to the model could be realized by incorporating more as-built data, especially in the larger sewers and other significant facilities. 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. This model was developed as a starting point for modeling stormwater management in the Kenwood Basin. As additional geometric or hydrologic data become available, the model can be updated and refined.

Additional details, such as individual inlets or full curb-and-gutter sections in roadways, can be added to the model with a significant effort. This level of effort and detail is likely only warranted on a project-scale with complex street level flow or some other exceptional case where traditional methods of analysis and design may need refinement.

Appendix A – Windshield Survey

Memo

Date:	Thursday, December 31, 2015
Project:	Cedar Rapids Stormwater Master Plan Update
To:	City of Cedar Rapids
From:	Michael Butterfield/HDR, Mike Schubert/HDR
Subject:	Windshield Survey of the Kenwood Basin

Background

HDR conducted a windshield survey of several stormwater management features in the Kenwood Basin on November 25, 2015. Photographs were taken and observations were noted at some of the hydraulic features associated with Cedar Lake, and the detention ponds at 1st Ave & Cottage Grove SE and 32nd St & G Ave NE. This was completed to visually confirm field conditions at these locations. The photographs taken and the associated log/notes are attached electronically.

Cedar Lake

Several of the Cedar Lake inflow locations (not including the Kenwood Ditch box culvert) were documented and photographed. These inlets are generally culverts draining smaller adjacent areas. At this time, little of no flow was observed in these culverts (Figure 1). Additionally, the connection from McLoud Run was documented. Three 36” RCPs connect a 4-6’ wide channel section from McLoud Run to Cedar Lake. This channel was actively contributing flow to Cedar Lake. (Figure 2)

The outlet weir was also photographed and documented. Flow from Cedar Lake to the Cedar River over a 6-9” fall was observed (Figure 3). Significant debris was observed in the channel upstream of the weir. (Figure 4)

Figure 1: Example of Small Culvert Inflow to Cedar Lake

Figure 2: McLoud Run Inflow to Cedar Lake

Figure 3: Cedar Lake Outlet Weir

Figure 4: Debris in Channel Upstream of Cedar Lake Outlet

1st Ave & Cottage Grove SE- Private Pond

Three 12” inlets and a 24” (or larger) main inlet were observed and documented in this survey (Figures 5). Additionally, an outlet riser with 16” and 24” ground-level orifices was also documented. Some debris was noted at the outfall pipe. (Figures 6 and 7)

Figure 5: Larger Flared Inflow to Private Pond

Figure 6: Private Pond Outlflow Riser

Figure 7: Orifice in Outflow Riser, Debris

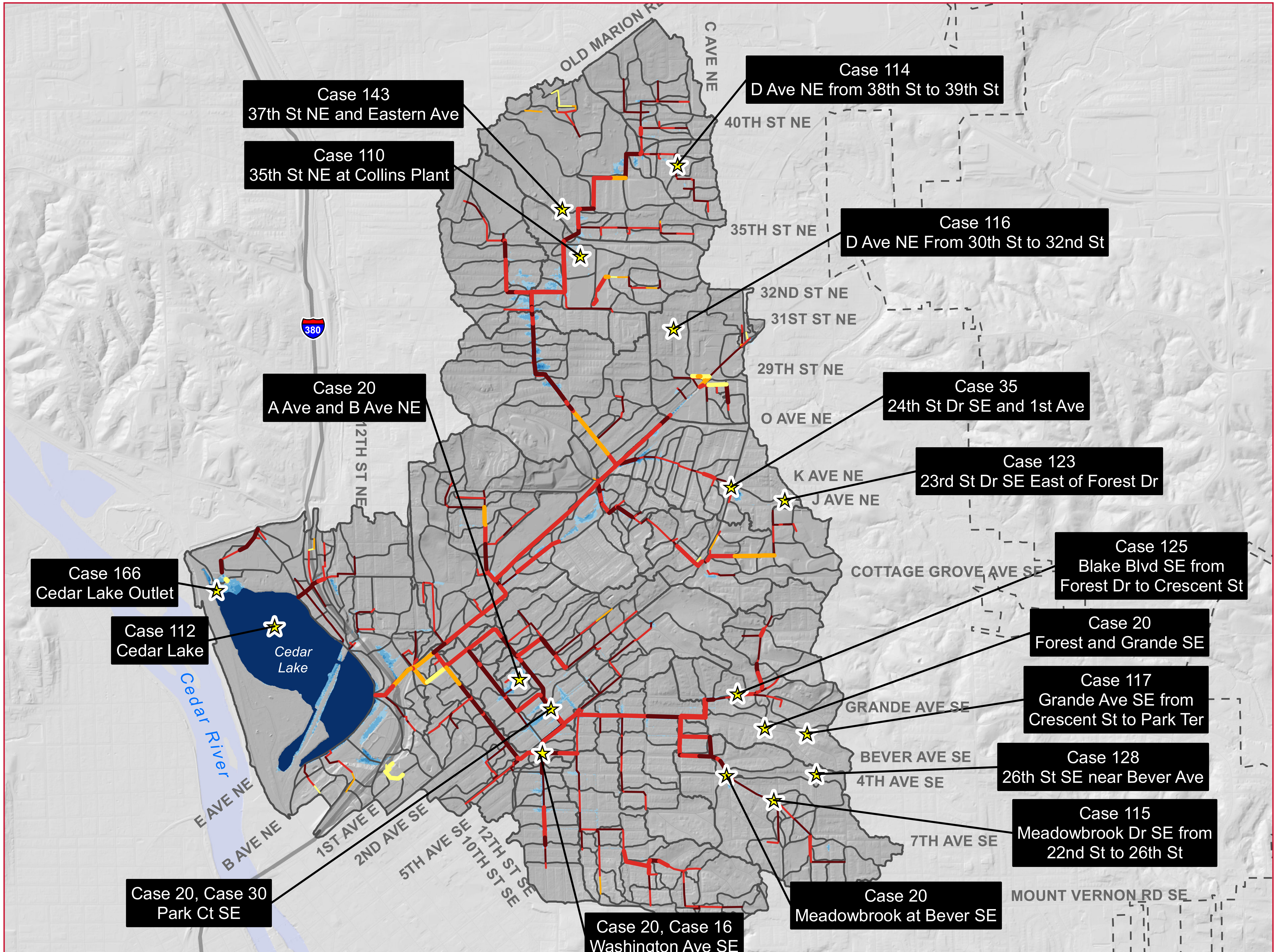
32nd St & G Ave NE- Private Pond

This private “pond” could also be classified as a swale- it has maintained lawn on either side and from visual inspection, can detain several feet of water without impacting adjacent structures. Flow enters this swale via overland flow and exits through a 12-16” outlet pipe.

Figure 8: Private Pond/Swale

Appendix B – Kenwood 5 Year Result

FIGURE 2
5-YEAR MODEL RESULTS
KENWOOD WATERSHED



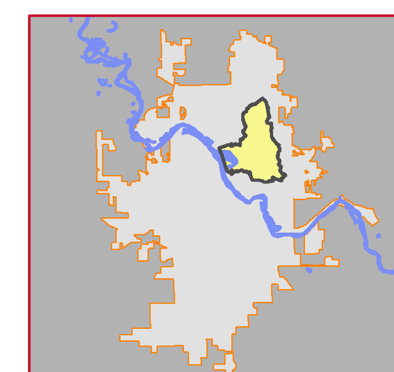
- ★ CIP Project Location
- City Boundary
- Cedar River
- Catchment
- Sub Catchment

Surcharge

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

Ponding Depth (ft)

- 0.5 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1+

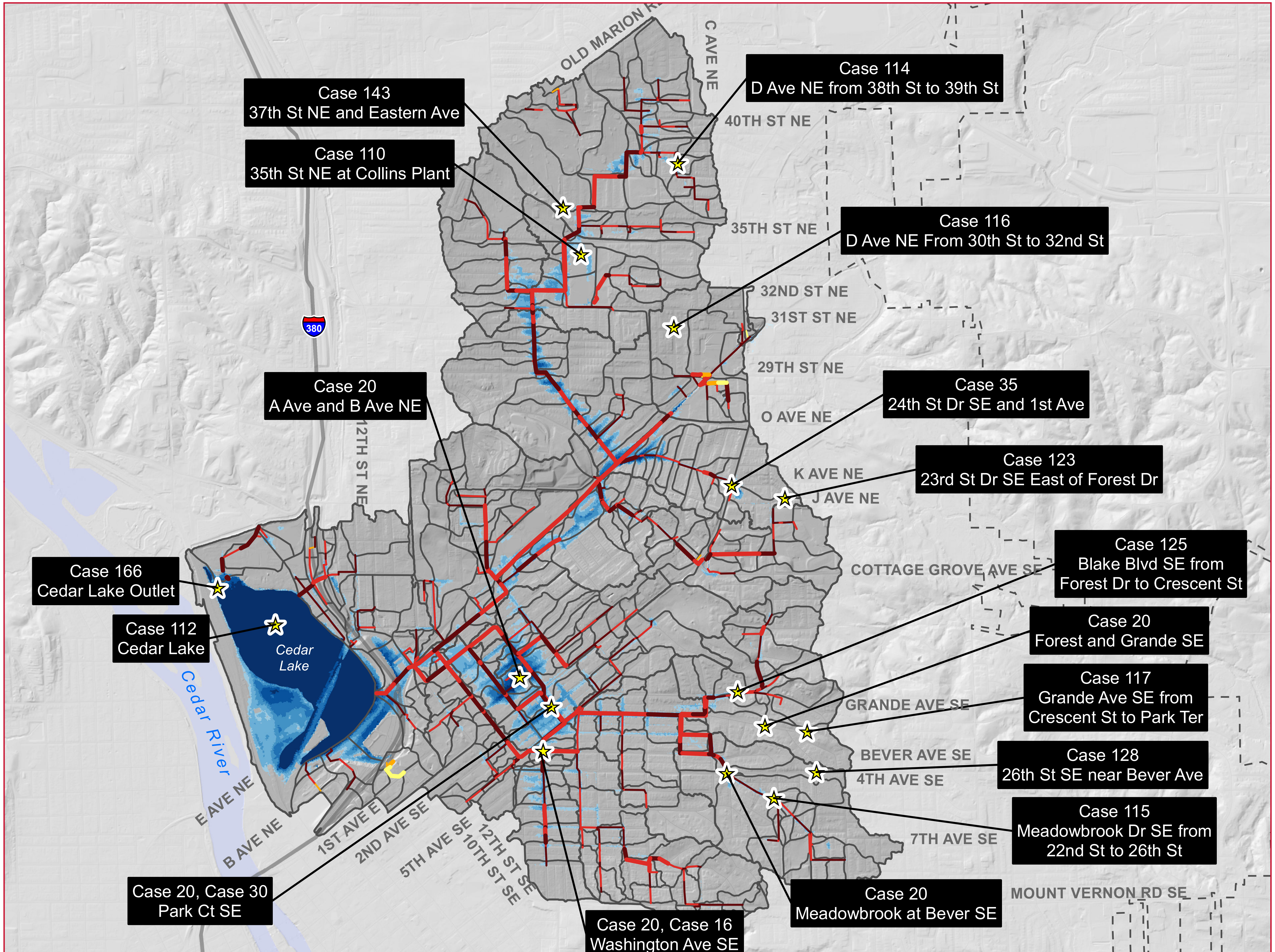


0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

Appendix C – Kenwood 100 Year Results

FIGURE 3
100-YEAR MODEL RESULTS
KENWOOD WATERSHED



CIP Project Location

City Boundary

Cedar River

Catchment

Sub Catchment

Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe

Ponding Depth (ft)

0.5 - 1.0

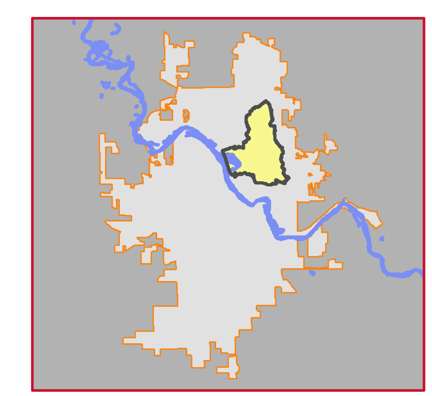
1.1 - 2.0

2.1 - 3.0

3.1 - 4.0

4.1 - 5.0

5.1+



0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

HDR

CEDAR RAPIDS
City of Five Seasons

CITY OF CEDAR RAPIDS
STORMWATER MASTER PLAN

PATH: Z:\PROJECTS\258297-CR_STROMWATER_MASTER_PLAN\MAP_DOCS\MXD\TM_3\MICRO\CR_KENWOOD_100YR_RESULTS_20151230.MXD - USER: WWHEELER - DATE: 12/31/2015

Appendix D – SJP - A Avenue NE, B Avenue NE, 15th Street NE and 16th Street NE

MEMORANDUM

TO: Dave Elgin, PE, PLS, Public Works Department

FROM: Sandy Pumphrey, PE, CFM, Public Works Department

DATE: October 7, 2014

RE: Review of A Ave / B Ave / 15th St / 16th St NE Flooding in light of the June 30th, 2014 Event

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The subject area considered in this document is the residential city block bounded by:

- A Avenue NE
- B Avenue NE
- 15th St NE
- 16th St NE

The subject area is generally located behind the Hy-Vee grocery store and McDonald's restaurant on 1st Avenue E.

General Comments

1. On the evening of June 30th, 2014, the City of Cedar Rapids recorded a high intensity rainfall. The subject area experienced damage to homes, garages, yards and vehicles. Specifically, according to property owners within the subject area, there were numerous basement wall collapses and cars moved by flotation in flood waters.

2. A number of homes were tagged by the City's Building Services Division as unsafe, requiring repair before being habitable once more. Some of the homes that remained structurally intact still experienced basement flooding. Both sanitary sewer backup and overland flooding were reported by property owners.

3. There are 32 primary structures (houses) within the subject area and what appear to be 19 accessory structures (garages/sheds, etc.). Assuming an average value of $75,000 for each of the homes and $20,000 for each of the accessory structures, the estimated value of property affected by this flood event is $2,780,000.

4. The Sewer Division on the Public Works Department reported that they cleared the storm sewer lines shortly after the flood event and found no substantive blockages contributing to the flooding that occurred previously.

5. Our GIS database reports box culverts upstream (between 1st and 3rd Ave SE) and downstream (north of C Ave NE) of the subject site. The storm sewers between these, however, are smaller in size.

6. From analysis of the contours around the subject area, it appears as though there is a regional low area at the intersection of A Ave NE and 15th St NE at an elevation of approximately 738. Should the storm sewers be impeded or surcharged, and the water rise up to the next lowest overflow point, it would need to rise to an overflow elevation of approximately 742 in the vicinity of C Ave NE before it stops rising. This explains the 4-5' of standing water experienced in the subject area, as claimed by the residents, and assuming that the storm sewer was surcharged.

Conclusions

1. The storm experienced on the evening of June 30, 2014 was of high intensity, exceeding the Iowa DOT's definition of the 100-year event. It was not a "normal event."
2. The storm sewers along 16th St NE, C Ave NE and 15th St NE were likely surcharged from stormwater collected upstream in the catchment area during the peak of the storm.
3. There appears to be the absence of an adequate overland flow route serving the subject area, in the event of the storm sewer capacity being exceeded.

Options

		Relative Anticipated Effectiveness (1-low, 5- high)	Estimated Cost of Concept
1.	Increase storm sewer capacity between 1st Ave and D Ave NE to accommodate higher peak discharge from catchment area. The storm sewer pipes along 15th St NE are already large (78"). However, the pipes along 16th St NE and C Ave NE could be added to so as not to act as a bottleneck between the box culverts on Park Ct SE and D Ave NE. (Approximately 5 blocks) The existing pipes would remain in place.	2	$740,163
2.	Locate an area(s) upstream within the catchment area where detention can be provided to mitigate the subject area from flooding as a result of a similar intensity rainfall. E.g. Redmond Park. Maximize the volume used for detention. Further study is required to determine the usable volume available and volume required. The depth of the excavation will depend on the elevation of the existing pipes at the outfall point.	2	$746,844
3.	Install infiltration practices under the pavement of surrounding streets, assuming that soil conditions permit. This option may alleviate the effects of smaller storm events in the future, but will not likely make much of a difference if a repeat of the June 30th flood event were to occur, based on the infiltration rates mentioned earlier. The ground was assumed to be saturated prior to this event.	1	$1,290,540
4.	Elevate homes and garages to accommodate for lack of overland overflow route. In the event of a similar flood event, we would expect standing water	3	$1,920,000

		Relative Anticipated Effectiveness (1-low, 5- high)	Estimated Cost of Concept
	around each of the elevated homes, to be relieved only by the existing storm sewer. Residents would need to be willing to allow floodwaters to rise underneath their homes within the new elevated stem walls of their home, and to sacrifice the enclosed use of their basement. More details can be found at http://www.fema.gov/media-library-data/20130726-1443-20490-7815/fema347_complete.pdf.		
5.	Regrade for an overland flow route downstream of the subject site. Assume this is done via streets and not via privately owned lots, it is assumed that 4 blocks of street profile would be affected (Along 15th St NE from A Avenue to E Avenue NE)	**4**	**$2,452,398**
6.	Buy-out damaged homes and leave graded lots, through a voluntary buy-out program to prevent future damage. There are 32 primary structures (houses) within the subject area and what appear to be 19 accessory structures (garages/sheds etc.). Assuming an average value of $75,000 for each of the homes and $20,000 for each of the accessory structures, the estimated value of property affected by this flood event is $2,780,000. A partial list of homes and accessory structures within the subject area could also be considered.	**4**	**$4,721,930**
7.	Buy out damaged homes and grade for a detention pond for protection of these and other downstream properties, through a voluntary buy-out program. In addition to buying out all properties ($2,780,000), further costs would be needed for the excavation and restoration required to convert the subject area into a detention basin.	**5**	**$7,147,694**

Recommendations

1. Promote the purchase of flood insurance for all property owners, regardless of their FIRM status.
2. Pursue Option #5 - Regrade for an overland flow route downstream of the subject site. Although this would require approximately 3 blocks of street reconstruction, it would greatly reduce the risk of flooding in this vicinity by opening up an overland overflow route, which doesn't rely on the capacity of the storm sewer.
3. Note that if Options #6 or #7 are selected, more study should be done to determine which of the properties in the subject area were in fact badly damaged, warranting a buy-out. For the purposes of this study, it is assumed that all homes within the subject area were significantly damaged.

Appendices

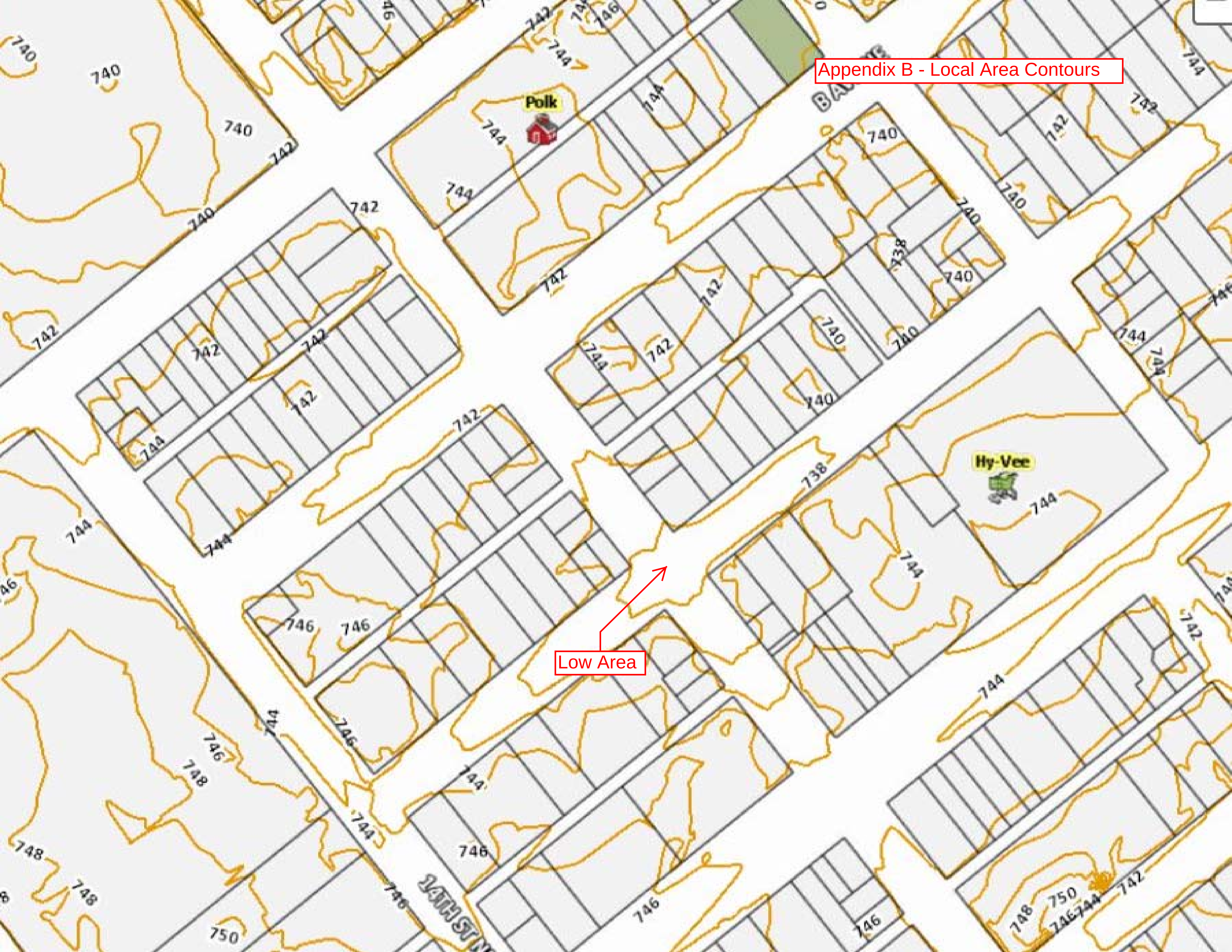
- A – Aerial image of affected area
- B – Local Area Contours
- C – FEMA FIRMette
- D – Cost Estimate Data

Forward any questions to:
Sandy Pumphrey, PE, CFM – Project Engineer II – Flood Mitigation
Public Works Department
s.pumphrey@cedar-rapids.org or 319-286-5363

SJP/nck

cc: Robert A. Davis, P.E., Engineering Manager
Craig Hanson, P.E., Public Works Maintenance Manager
David Wallace, P.E., Sewer Utility Engineering Manager
Jon Durst, Sewer Superintendent
Scott Sovers, P.E., Project Engineer I
Garrett Prestegard, P.E., Project Engineer I

Appendix A - Aerial Image of Subject Area


Appendix B - Local Area Contours
Polk
Hy-Vee
Low Area
740
742
744
746
748
750
738

MAP SCALE 1" = 1000'

500 0 1000 2000

300 0 300

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0410D

FIRM
FLOOD INSURANCE RATE MAP
LINN COUNTY, IOWA
AND INCORPORATED AREAS

PANEL 410 OF 625

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
CEDAR RAPIDS, CITY OF	190187	0410	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
19113C0410D

EFFECTIVE DATE
APRIL 5, 2010

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

A Avenue / B Avenue / 15th St / 16th St NE
Option 1
Increase Storm Sewer Capacity between 1st Ave and D Ave NE
10/7/2014

Item	STD.	Item Description	Unit	Quantity	Unit Cost	Amount
1	01100-01	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	01100-01	Construction Surveys	LS	1	$ 10,000.00	$ 10,000.00
3	01200-01	Traffic Control	LS	1	$ 10,000.00	$ 10,000.00
4	01400-10	Removal of Existing Pavement	SY	1025	$ 27.00	$ 27,675.00
5	01400-22	Sawcutting of Pavement (Full Depth)	LF	4625	$ 5.00	$ 23,125.00
6	02000-01	Unclassified Excavation (Assume 5 deep')	CY	1700	$ 50.00	$ 85,000.00
7	02000-40	Dispose Unclassified Excavation Off-Site	CY	1700	$ 40.00	$ 68,000.00
8	02400-01	Storm Sewer Main (36" RCP pipe)	LF	2300	$ 100.00	$ 230,000.00
9	02400-50	Storm Intake (RA-5)	EA	10	$ 6,000.00	$ 60,000.00
10	02400-60	Connection to Existing Storm Sewer Structures	EA	2	$ 1,500.00	$ 3,000.00
10	02100-50	Granular Subbase (2' deep over new pipe)	CY	685	$ 11.50	$ 7,877.50
11	02700-02	PCC Pavement, Reimforced	SY	1025	$ 85.00	$ 87,125.00
					Subtotal	$ 616,802.50
					20% Contingency	$ 123,360.50
					TOTAL	**$ 740,163.00**

Note: All quantities are approximate and based on concept plans. Cost estimates should be validated and refined at various milestones through the design process.

A Avenue / B Avenue / 15th St / 16th St NE

Option 2

Locate an Area upstream within the catchment area where detention can be provided

10/7/2014

Item	STD.	Item Description	Unit	Quantity	Unit Cost	Amount
1	01100-01	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	01100-01	Construction Surveys	LS	1	$ 10,000.00	$ 10,000.00
3	01200-01	Traffic Control	LS	1	$ 2,000.00	$ 2,000.00
4	01300-01	Temporary Erosion and Sediment Controls	LS	1	$ 2,000.00	$ 2,000.00
5	01300-10	Silt Fence	LF	1200	$ 1.00	$ 1,200.00
6	01300-12	Filter Socks at Storm Sewer Structures	EA	6	$ 125.00	$ 750.00
7	01400-01	Clearing and Grubbing	LS	1	$ 2,500.00	$ 2,500.00
8	01400-10	Removal of Existing Pavements, Driveways, Curb and Gutter	SY	25	$ 27.00	$ 675.00
9	02000-01	Unclassified Excavation and Embankment	CY	6000	$ 50.00	$ 300,000.00
10	02000-40	Dispose Unclassified Excavation Off-Site	CY	6000	$ 40.00	$ 240,000.00
11	02400-20	Culvert Pipe	LF	50	$ 15.00	$ 750.00
12	02400-40	Storm Sewer Outlet Structure	EA	1	$ 12,300.00	$ 12,300.00
13	02400-60	Connection to Existing Stormsewer	EA	1	$ 1,500.00	$ 1,500.00
14	02600-01	Revetment	SY	2	$ 110.00	$ 220.00
15	02900-01	Imported Topsoil	CY	1000	$ 30.00	$ 30,000.00
16	02900-03	Water	CF	1000	$ 0.50	$ 500.00
17	02900-10	Seeding, Fertilizing, and Mulching	AC	1.25	$ 3,120.00	$ 3,900.00
18	02900-40	Wood Excelsier Mat	SY	6050	$ 1.50	$ 9,075.00
					Subtotal	$ 622,370.00
					20% Contingency	$ 124,474.00
					TOTAL	**$ 746,844.00**

Note: All quantities are approximate and based on concept plans. Cost estimates should be validated and refined at various milestones through the design process.

A Avenue / B Avenue / 15th St / 16th St NE
Option 3
Install Infiltration Practices under pavement of surrounding streets
10/7/2014

Item	STD.	Item Description	Unit	Quantity	Unit Cost	Amount
1	01100-01	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	01100-01	Construction Surveys	LS	1	$ 10,000.00	$ 10,000.00
3	01200-01	Traffic Control	LS	1	$ 5,000.00	$ 5,000.00
4	01300-01	Temporary Erosion and Sediment Controls	LS	1	$ 2,000.00	$ 2,000.00
5	01400-10	Removal of Existing Pavement	SY	5750	$ 27.00	$ 155,250.00
6	01400-22	Sawcutting of Pavement (Full Depth)	LF	240	$ 5.00	$ 1,200.00
7	02000-01	Unclassified Excavation and Embankment (Assume 3')	CY	5750	$ 50.00	$ 287,500.00
8	02000-40	Dispose Unclassified Excavation Off-Site	CY	5750	$ 40.00	$ 230,000.00
9	02100-01	Subgrade Preparation	SY	5750	$ 2.00	$ 11,500.00
10	02100-50	Granular Subbase (3' thick)	CY	5750	$ 11.50	$ 66,125.00
11	02100-35	Geotextile Fabric	SY	5750	$ 3.00	$ 17,250.00
12	N/A	Permeable Pavers	SF	51750	$ 5.50	$ 284,625.00
					Subtotal	$ 1,075,450.00
					20% Contingency	$ 215,090.00
					TOTAL	**$ 1,290,540.00**

Note: All quantities are approximate and based on concept plans. Cost estimates should be validated and refined at various milestones through the design process.

A Avenue / B Avenue / 15th St / 16th St NE
Option 4
Elevate Homes and Garages
10/7/2014

Item	STD.	Item Description	Unit	Quantity	Unit Cost	Amount
1	N/A	Complete Elevation and Foundation Reconstruct	EA	32	$ 50,000.00	$ 1,600,000.00
					Subtotal	$ 1,600,000.00
					20% Contingency	$ 320,000.00
					TOTAL	**$ 1,920,000.00**

Note: All quantities are approximate and based on concept plans. Cost estimates should be validated and refined at various milestones through the design process.

A Avenue / B Avenue / 15th St / 16th St NE
Option 5
Regrade for an overland flow route downstream of the subject site (approximately 4 blocks)
10/7/2014

Item	STD.	Item Description	Unit	Quantity	Unit Cost	Amount
1	01100-01	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	01100-01	Construction Surveys	LS	1	$ 10,000.00	$ 10,000.00
3	01200-01	Traffic Control	LS	1	$ 10,000.00	$ 10,000.00
4	01400-10	Removal of Existing Pavement, Driveway Aprons, Curb, sidewalk	SY	8000	$ 27.00	$ 216,000.00
5	01400-22	Sawcutting of Pavement (Full Depth)	LF	400	$ 5.00	$ 2,000.00
6	01400-40	Removal of Storm Sewer Structures	EA	14	$ 635.00	$ 8,890.00
6	02000-01	Unclassified Excavation	CY	11550	$ 50.00	$ 577,500.00
7	02000-40	Dispose Unclassified Excavation Off-Site	CY	11550	$ 40.00	$ 462,000.00
8	02400-50	Storm Intake (RA-5)	EA	14	$ 6,000.00	$ 84,000.00
9	02100-50	Granular Subbase	CY	5000	$ 11.50	$ 57,500.00
10	02700-02	PCC Pavement, Reimforced	SY	6000	$ 85.00	$ 510,000.00
11	02700-70	PCC Sidewalk	SY	1500	$ 55.00	$ 82,500.00
12	02700-75	PCC Sidewalk Ramp	SY	100	$ 85.00	$ 8,500.00
13	02700-20	PCC Driveway Aprons	SY	115	$ 85.00	$ 9,775.00
					Subtotal	$ 2,043,665.00
					20% Contingency	$ 408,733.00
					TOTAL	**$ 2,452,398.00**

Note: All quantities are approximate and based on concept plans. Cost estimates should be validated and refined at various milestones through the design process.

A Avenue / B Avenue / 15th St / 16th St NE
Option 6
Buy-out damaged homes and leave graded lots
10/7/2014

Item	STD.	Item Description	Unit	Quantity	Unit Cost	Amount
1	01100-01	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	01100-01	Construction Surveys	LS	1	$ 10,000.00	$ 10,000.00
3	01200-01	Traffic Control	LS	1	$ 2,000.00	$ 2,000.00
4	01300-01	Temporary Erosion and Sediment Controls	LS	1	$ 3,000.00	$ 3,000.00
5	01300-10	Silt Fence	LF	1900	$ 1.00	$ 1,900.00
6	01300-12	Filter Socks at Storm Sewer Structures	EA	10	$ 125.00	$ 1,250.00
7	01400-01	Clearing and Grubbing	LS	1	$ 5,000.00	$ 5,000.00
8	01400-10	Removal of Existing Pavements, Driveways, Curb and Gutter	SY	5000	$ 27.00	$ 135,000.00
9	01400-40	Removal of Storm Sewer Structures	EA	2	$ 635.00	$ 1,270.00
10	01400-41	Removal of Storm Sewer and Culvert Pipe	LF	450	$ 12.00	$ 5,400.00
11	01400-43	Removal of Sanitary Sewer Pipe	LF	4000	$ 15.00	$ 60,000.00
12	01400-61	Removal of Valves	EA	32	$ 350.00	$ 11,200.00
13	01400-62	Removal of Existing Watermain	LF	1600	$ 50.00	$ 80,000.00
14	02400-20	Culvert Pipe	LF	300	$ 15.00	$ 4,500.00
15	02400-40	Storm Sewer Outlet Structure	EA	1	$ 12,300.00	$ 12,300.00
16	02400-60	Connection to Existing Stormsewer	EA	1	$ 1,500.00	$ 1,500.00
17	02900-01	Imported Topsoil	CY	4500	$ 30.00	$ 135,000.00
18	02900-03	Water	CF	5000	$ 0.50	$ 2,500.00
19	02900-10	Seeding, Fertilizing, and Mulching	AC	5.6	$ 3,120.00	$ 17,472.00
20	02900-40	Wood Excelsier Mat	SY	27100	$ 1.50	$ 40,650.00
21	N/A	Acquisition and Relocation Costs	EA	32	$ 75,000.00	$ 2,400,000.00
22	N/A	Demolition and Haulage of Homes	EA	32	$ 25,000.00	$ 800,000.00
23	N/A	Demolition and Haulage of Accessory Structures	EA	20	$ 10,000.00	$ 200,000.00
					Subtotal	$ 3,934,942.00
					20% Contingency	$ 786,988.40
					TOTAL	**$ 4,721,930.40**

Note: All quantities are approximate and based on concept plans. Cost estimates should be validated and refined at various milestones through the design process.

A Avenue / B Avenue / 15th St / 16th St NE
Option 7
Buy out Damaged Homes and Grade for a detention pond
10/7/2014

Item	STD.	Item Description	Unit	Quantity	Unit Cost	Amount
1	01100-01	Mobilization	LS	1	$ 5,000.00	$ 5,000.00
2	01100-01	Construction Surveys	LS	1	$ 10,000.00	$ 10,000.00
3	01200-01	Traffic Control	LS	1	$ 2,000.00	$ 2,000.00
4	01300-01	Temporary Erosion and Sediment Controls	LS	1	$ 3,000.00	$ 3,000.00
5	01300-10	Silt Fence	LF	1900	$ 1.00	$ 1,900.00
6	01300-12	Filter Socks at Storm Sewer Structures	EA	10	$ 125.00	$ 1,250.00
7	01400-01	Clearing and Grubbing	LS	1	$ 5,000.00	$ 5,000.00
8	01400-10	Removal of Existing Pavements, Driveways, Curb and Gutter	SY	5000	$ 27.00	$ 135,000.00
9	01400-40	Removal of Storm Sewer Structures	EA	2	$ 635.00	$ 1,270.00
10	01400-41	Removal of Storm Sewer and Culvert Pipe	LF	450	$ 12.00	$ 5,400.00
11	01400-43	Removal of Sanitary Sewer Pipe	LF	4000	$ 15.00	$ 60,000.00
12	01400-61	Removal of Valves	EA	32	$ 350.00	$ 11,200.00
13	01400-62	Removal of Existing Watermain	LF	1600	$ 50.00	$ 80,000.00
14	02000-01	Unclassified Excavation and Embankment	CY	22500	$ 50.00	$ 1,125,000.00
15	02000-40	Dispose Unclassified Excavation Off-Site	CY	22500	$ 40.00	$ 900,000.00
16	02400-20	Culvert Pipe	LF	50	$ 15.00	$ 750.00
17	02400-40	Storm Sewer Outlet Structure	EA	1	$ 12,300.00	$ 12,300.00
18	02400-60	Connection to Existing Stormsewer	EA	1	$ 1,500.00	$ 1,500.00
19	02600-01	Revetment	SY	2	$ 110.00	$ 220.00
20	02900-01	Imported Topsoil	CY	4500	$ 30.00	$ 135,000.00
21	02900-03	Water	CF	5000	$ 0.50	$ 2,500.00
22	02900-10	Seeding, Fertilizing, and Mulching	AC	5.6	$ 3,120.00	$ 17,472.00
23	02900-40	Wood Excelsier Mat	SY	27100	$ 1.50	$ 40,650.00
24	N/A	Acquisition and Relocation Costs	EA	32	$ 75,000.00	$ 2,400,000.00
25	N/A	Demolition and Haulage of Homes	EA	32	$ 25,000.00	$ 800,000.00
26	N/A	Demolition and Haulage of Accessory Structures	EA	20	$ 10,000.00	$ 200,000.00
					Subtotal	$ 5,956,412.00
					20% Contingency	$ 1,191,282.40
					TOTAL	**$ 7,147,694.40**

Note: All quantities are approximate and based on concept plans. Cost estimates should be validated and refined at various milestones through the design process.