ATTACHMENT 5

CSO 44 GREEN INFRASTRUCTURE / UPPER SPLITLOG CREEK WATERSHED STORMWATER IMPROVEMENTS

B&V PROJECT NO. 415853

PREPARED FOR

Unified Government, WYCO/KCK

22 JANUARY 2024

BLACK & VEATCH

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1.0 Introduction

This Technical Memorandum for the Splitlog Creek Storm Water Model has been prepared by Black & Veatch for the United Government of Wyandotte County & Kansas City, Kansas (UG). The objective of this study is to provide hydrologic and hydraulic modeling support to the Stormwater Program at the UG. More specifically, the work evaluates the existing conditions in the watershed and supports conceptual design of solutions to mitigate flooding in the northern portion of the Splitlog Creek watershed, as shown in **Figure 1-1**.

The project area is located in Kansas City, Kansas in eastern Wyandotte County within the Splitlog Creek watershed. Splitlog Creek watershed encompasses over 700-acres. The project boundary covers the northeastern portion of the Splitlog Creek watershed, approximately 203 acres as shown in **Figure 1-1**. The project encompasses the area approximately bounded by North 11th Street to the west, State Avenue to the north, North 6th Street to the east, and Tenny Avenue to the south.

The project area is primarily residential development with some commercial areas. There are three parks within the project boundary: Eighth Street Park, Northrup Park, and Splitlog Park as shown in **Figure** 1-2**.** These parks have open turfed space which could be utilized as temporary storage for stormwater to alleviate flooding in the watershed.

Combined sewers serve as the stormwater management and conveyance system in the watershed, and the pipe network modeled only includes those combined sewer pipes 24 inches and larger that carry storm water. No modeling of base sanitary sewer flows was completed, as the focus of this study was to improve the level of service of stormwater management within the study area.

1.1.1 Consent Decree Requirements

In 2022, the UG entered into a revised agreement with EPA, called the 'Integrated Overflow Control Program' (IOCP), which is a revised agreement under the UG's consent decree issues by the Department of Justice. This agreement requires that improvements be made to address water quality issues related to the UG's combined sewer system and amongst other projects, it requires that by December 31, 2024, a project which constructs '[s]ewer separation and green infrastructure to provide wet weather storage for 0.5" rainfall event and stormwater control for the 1.4" rainfall event' be completed within 8th Street Park.

This study describes improvements which both meet this minimum requirement to improve water quality at 8th Street Park via a structural green infrastructure facility, and it investigates means by which a project at the park could benefit stormwater management for the Splitlog Creek watershed. Improvements at 8th Street Park required by the Consent Decree. This project is referred to as 'CSO 44 Green Infrastructure / Stormwater Facility' throughout this document.

This report also encompasses improvements outside of the CSO 44 Green Infrastructure / Stormwater Facility which provide improvements to stormwater conveyance to reduce flooding. These improvements are not driven by any requirement in the consent decree, and have been developed to provide a holistic set of solutions to stormwater issues throughout the upper portion of the Splitlog Creek watershed.

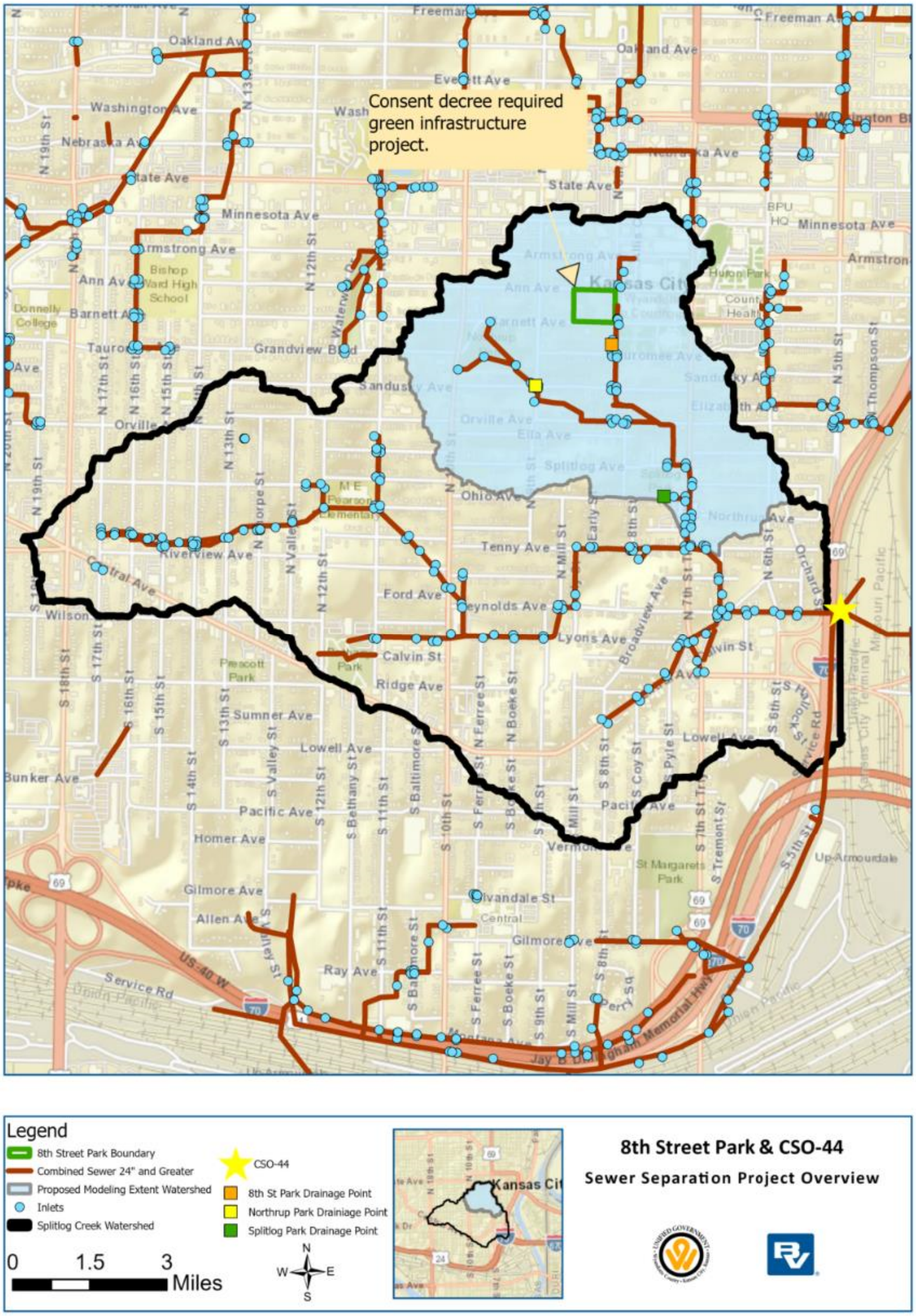


Figure 1-1 Splitlog Creek Watershed Overview

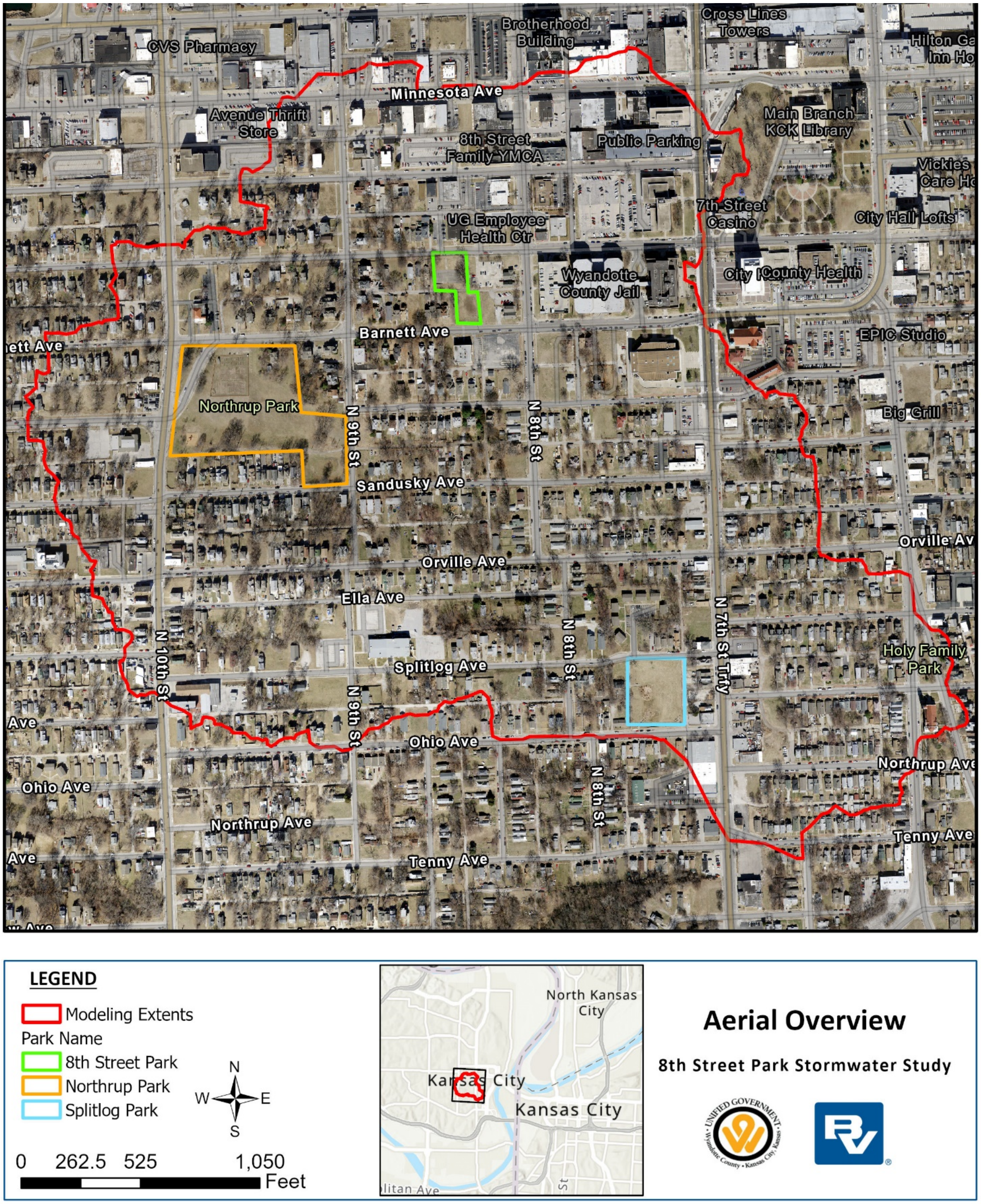


Figure 1-2 Project Aerial Overview

2.0 Data Collection and Preparation

A GIS data collection was performed to characterize the watershed, evaluate the project area and prepare model data inputs. Files were extracted from UG's Geoportal website (UG, 2023), United States Department of Agriculture's (USDA's) Web Soil Survey portal (USDA, 2021) and Kansas' Department of Transportation (KSDOT) LiDAR grid (KSDOT, 2018). Further, the City provided hydraulic data including a stormwater inventory and a network of an existing ICM model. **Table 2-1** lists existing data that was reviewed and used for the current study.

Table 2-1 Data Source Information

Name	Data Type	Source	Date
Aerial Imagery	Photographs	UG https://www.wycokck.org/Departments/Knowledge/Maps-and-GIS/Geoportal	2018
Building Footprints	GIS Shapefile	UG https://www.wycokck.org/Departments/Knowledge/Maps-and-GIS/Geoportal	2020
Elevation DEM	LiDAR	KSDOT https://ksdot.maps.arcgis.com/apps/mapviewer/	2018
Land Cover Data	GIS Shapefile	UG https://www.wycokck.org/Departments/Knowledge/Maps-and-GIS/Geoportal	2014
Rainfall Data	Excel File	NOAA https://hdsc.nws.noaa.gov/pfds/pfds_map_cont.html?bkmrk=ks	2023
Road Centerlines	GIS Shapefile	UG https://www.wycokck.org/Departments/Knowledge/Maps-and-GIS/Geoportal	2018
Soils Data	GIS Shapefile	USDA's Web Soil Survey https://websoilsurvey.sc.egov.usda.gov/app/WebSoilSurvey.aspx	2021
1D Pipe Network	GIS Shapefile	Existing IOCP model (Infoworks ICM)	2023

Aerial Imagery

Aerial imagery was extracted from UG's Geoportal GIS data (**Figure 1-2**). The data was exported as photographs in a TIFF file. The published date of the aerial imagery is 2018 (UG, 2018).

Building Footprints Data

Building footprints data was downloaded from UG's Geoportal GIS data. The data was published in 2016 and last modified in 2020. The building footprints provide base data input for extrusions in the ICPR model. The buildings encompass about 37 acres of the project area (18% of the project area). There are seven different types of buildings. Houses and apartments make up the majority with over 20 acres of buildings, commercial and retail the second largest area with about seven acres of footprints. At less than one acre, education buildings make up the smallest category. **Figure 2-1** depicts the buildings within the study area (UG, 2020).

Elevation DEM Data

DEM data for the project was extracted from KSDOT's LiDAR grid data. The data was collected in 2018 and has a 1 m (3.28 ft) resolution. Within the project boundary, elevations range from 769 ft to 913 ft (KSDOT, 2018). The watershed has ridges around the west, north and east side of the project boundary, drainage occurs from these to the center and then southeast. The southeast section is the low spot of the project area, both overland flow and stormwater routing occurs further southwards into Splitlog Creek watershed.

Land Cover Data

Land cover data from 2014 for the project area was exported from UG's Geoportal GIS data. An overview analysis of the data was conducted against the aerial imagery to ensure data accuracy. The project area consists of two different land uses: pervious turf and impervious. Impervious surfaces cover 114 acres and have a curve number of 98. Pervious turf covers 88 acres, with a curve number of either 69 (59 acres) or 79 (29 acres). The project area does not have any waterbodies, streams, channels or other features of flowing or standing water. The entire area is developed. **Figure 2-2** depicts the land cover for the study area (UG, 2014).

Rainfall Data

Rainfall data for the project area was obtained from the NOAA Atlas 14 website (NOAA, 2023). Rainfall depths for the Water Quality, 5-, 10-, 25-, 50- and 100-year storms were all downloaded. A rainfall distribution for the project area was also downloaded and used to develop a dimensionless unit hydrograph based on the 1st Quartile, 10% distribution for a 6hr rainfall event. Refer to **Table 3-6** for rainfall depths.

Road Centerlines Data

Road centerlines data was extracted from UG's Geoportal GIS data. The data was exported as a GIS shapefile. According to the metadata information, the data was published in 2015. The attribute table shows the data was modified in 2018. There are three different levels of road in the project area: collector, local, and minor arterial. Local roads cover much of the length with over 44,000 ft or about eight miles. **Figure 2-1** depicts the roads within the study area (UG, 2018).

The road centerlines were used to develop breaklines for the ICPR model. Breaklines serve to refine the triangular mesh in the model and support the accurate development of the surface flow paths in the 2D mesh. For roads with distinct curbs additional breaklines along the curb locations were added. These are typically along arterial roads in the project area. There are about 72,000 ft or about 14 miles of breaklines in the project area that encompass roads and curbs.

Soils Data

Soils data for the project area was extracted from the United States Department of Agriculture's (USDA) Web Soil Survey. The soil dataset is from 2021. The project area consists of two different soil types: knox silt loam with 7 to 12 percent slopes and Ladoga silt loam with 3 to 8 percent slopes. The Knox silt loam encompass 118 acres of the project area. This loam is within the hydrologic soil group B. Ladoga silt loam covers the remaining 85 acres, it is within the hydrologic soil group C. **Figure 2-3** depicts the soils within the study area (USDA, 2021).

1D Pipe Network

1D pipe network for the project area was developed from the ICM model and UG's Geoportal GIS data. The data included nodes and conduits of the pipe network. The ICM model includes pipes of 24 inch and larger diameter, in addition to selected smaller pipes that connect the larger pipes. The ICM model data contains pipe locations, dimensions, material and invert elevations as well as manhole location and invert elevations. UG GIS data includes the full pipe network of the project area, regardless of the pipe diameter. It contains pipe diameter, dimensions, and some invert elevations. Further, it shows manhole and inlet locations. **Figure 2-4** depicts the model network showing the different sources used for the 1D pipe network in the project area (UG, 2023). Refer to **Figure 1-1** to see the full 1D network from the ICM model.

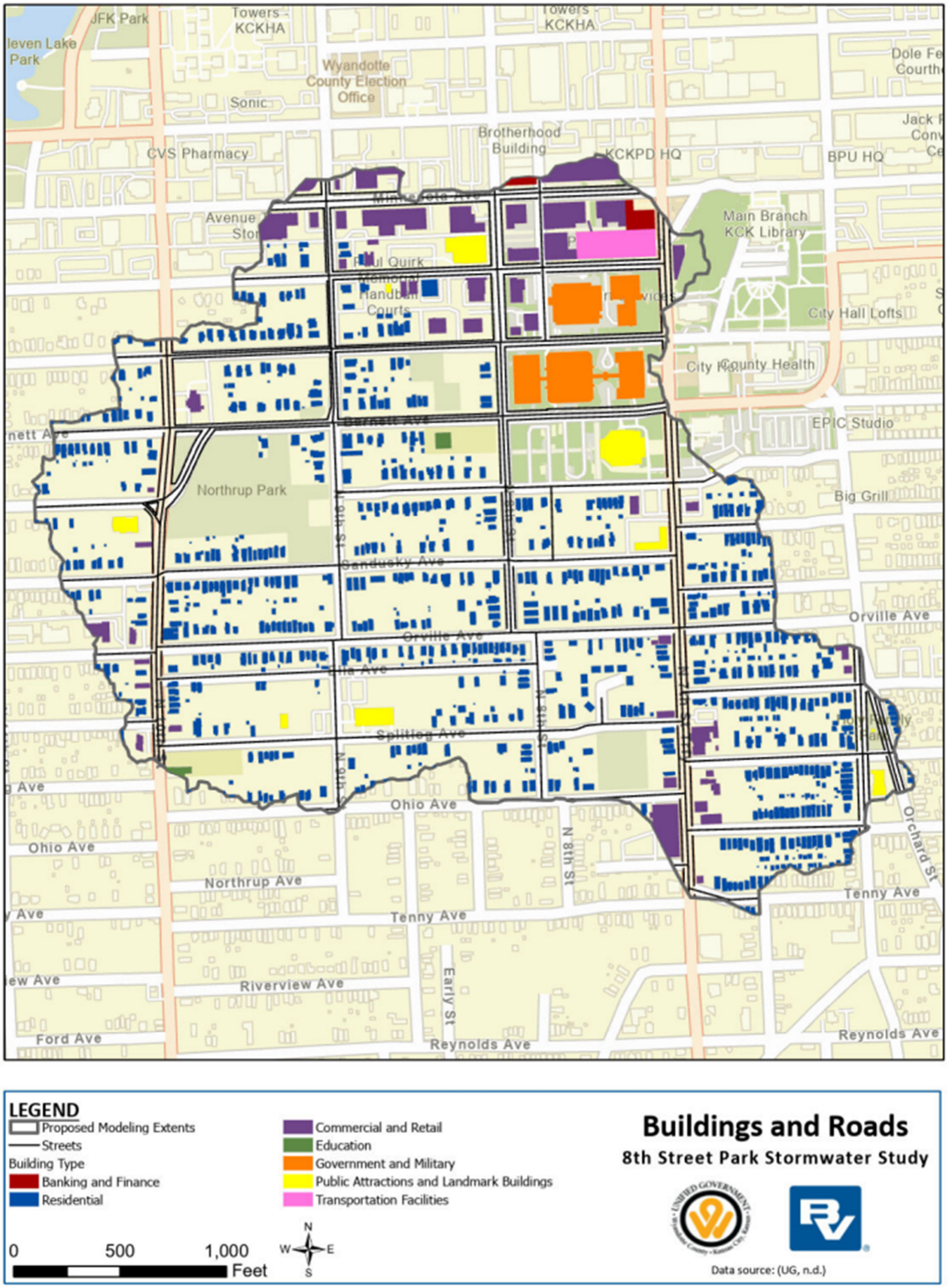


Figure 2-1 Buildings and Roads

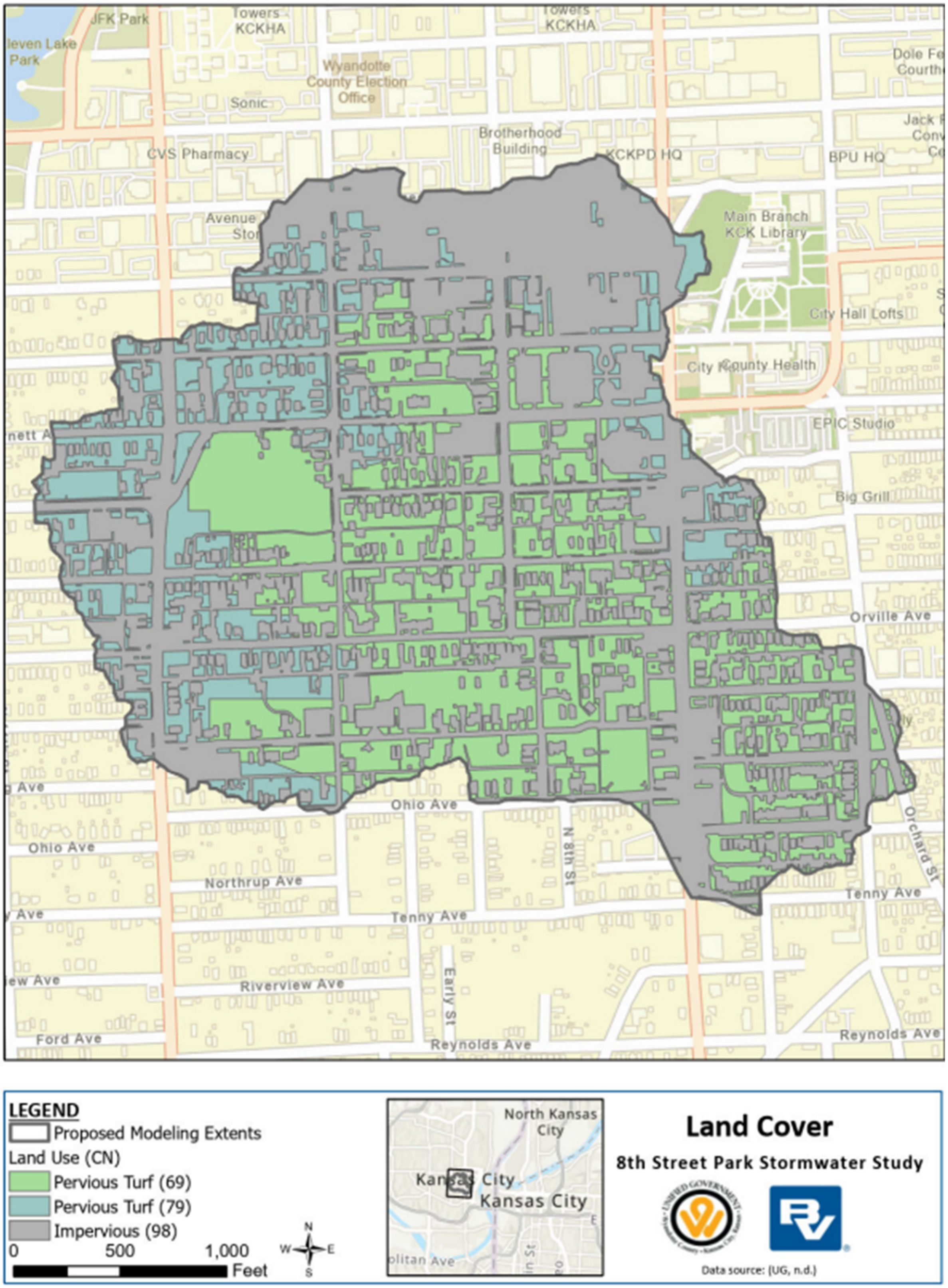


Figure 2-2 Land Cover

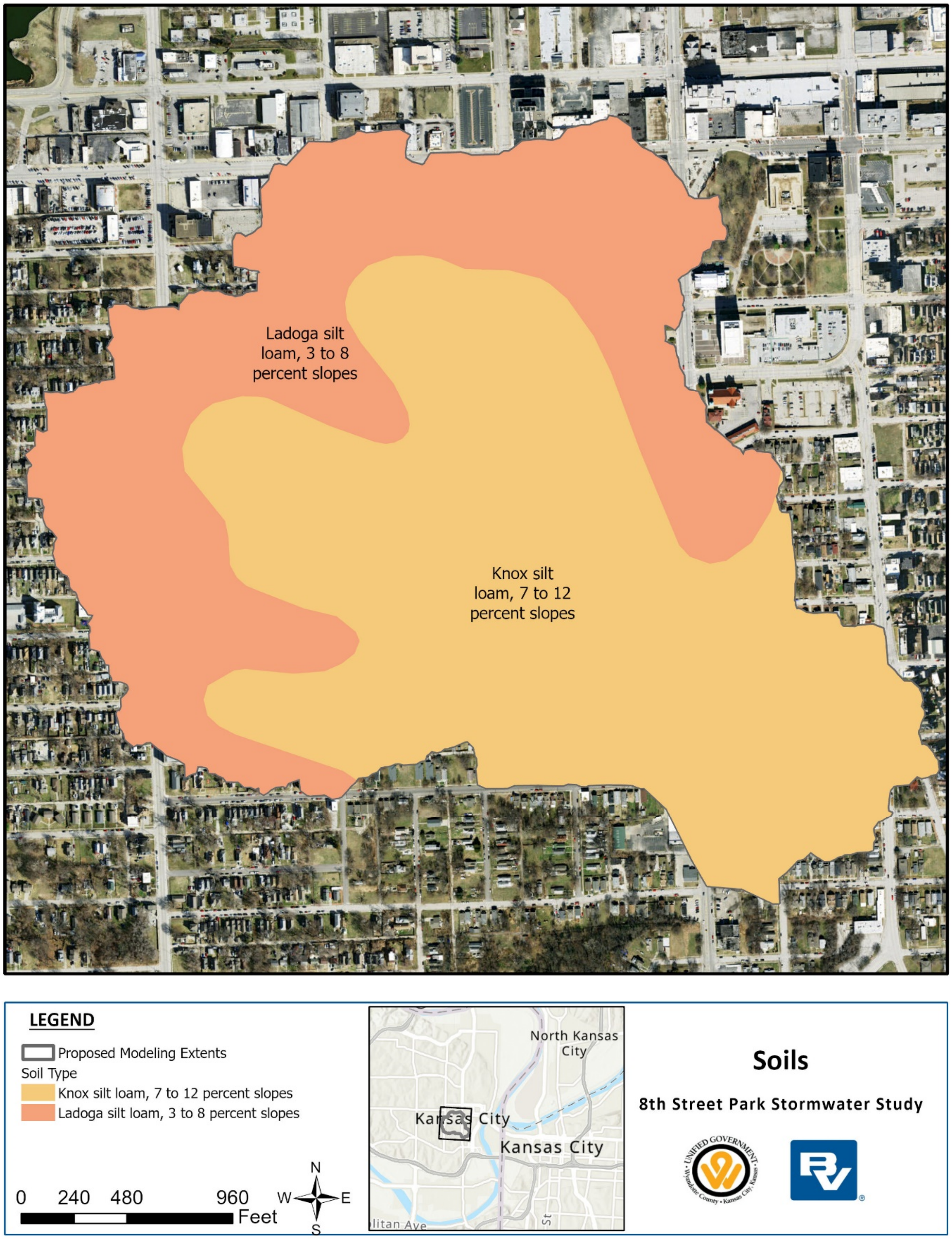


Figure 2-3 Soils

Figure 2-4 1D Network Sources

3.0 Stormwater Model Development

3.1 Introduction

An existing conditions combined stormwater model of a portion of Splitlog Creek watershed was created using version 4 of the Interconnected Channel and Pond Routing (ICPR4) modeling software by Streamline Technologies (Streamline Technologies, 2023).

The proposed project boundary covers 203 acres of the northeastern portion of this watershed. A larger boundary with a 90 ft buffer was drawn around the project boundary to limit boundary instabilities in the model. The ICPR boundary has a size of about 233 acres.

The boundary was smoothed to minimize the number of vertices in the model boundary and optimize computational integrity in the mesh development. The proposed boundary extent in comparison to the ICPR boundary of the stormwater model is shown in **Figure 3-1**. The ICPR model boundary was used to calculate stormwater runoff and evaluate the level of service provided by the existing sewer conveyance.

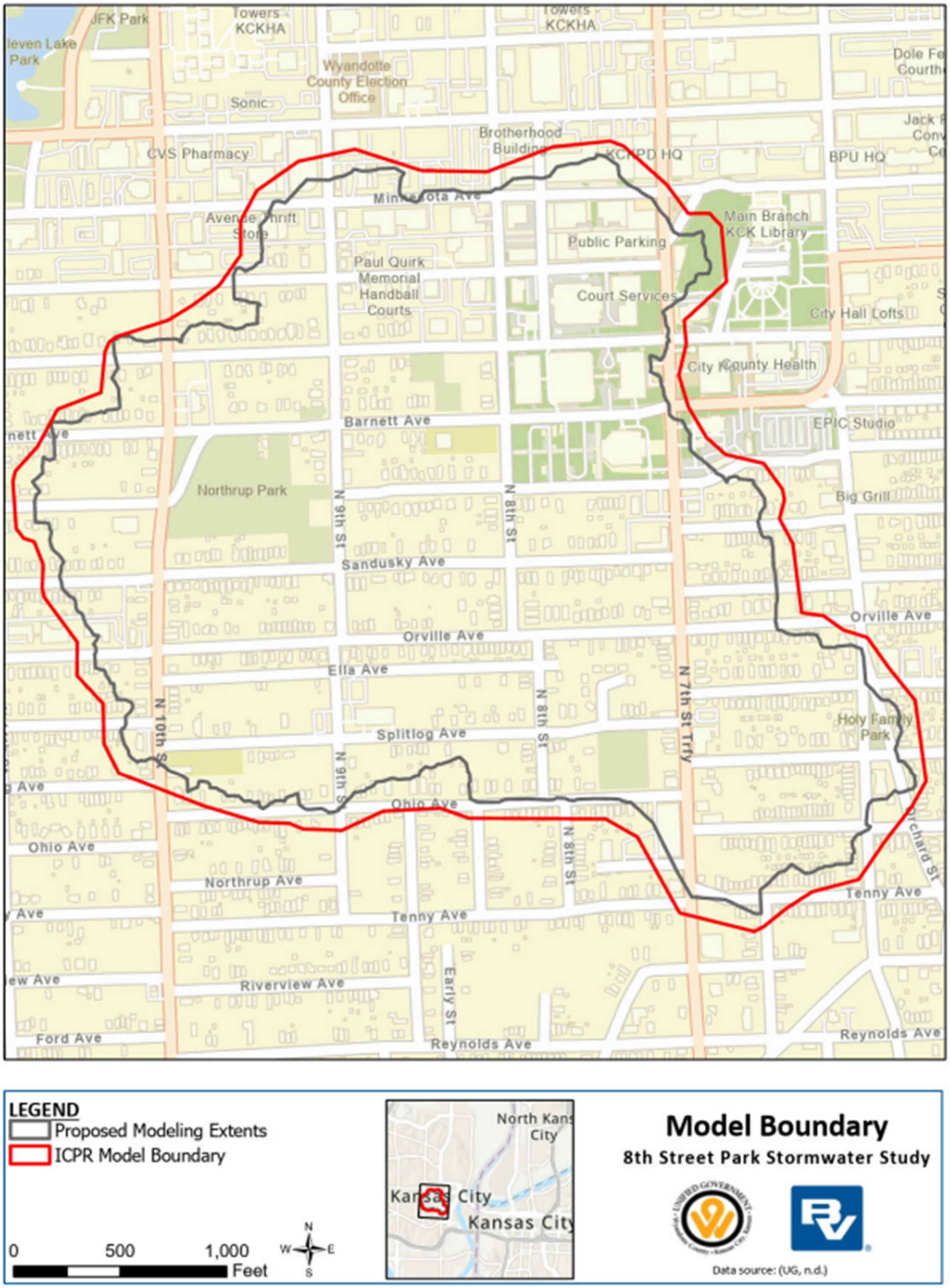


Figure 3-1 Model Extent

3.2 2D Module Computational Mesh

A 2D computational mesh was developed using the compiled elevation, land use, and soil infiltration data. This mesh simulates the surface flow and runoff routing within the project area. It calculates the soil losses, excess runoff volumes and rates, and routes excess stormwater runoff downgradient. These calculations are supported by lookup tables including roughness, impervious, and curve number data. The 2D elements used for this model include the overland flow region, extrusions, breaklines, and breakpoints. The 2D elements are modeled to overland flow region boundary which is slightly larger than the proposed modeling extents boundary.

3.2.1 Overland Flow Region

The overland flow region encompasses the previously mentioned ICPR model boundary. The map layers include the model boundary, soil zone, and land cover zone. The soil zone is utilized to analyze the infiltration parameters for the pervious areas by intersecting the honeycomb mesh with the rainfall excess method. The land cover zone is utilized to analyze the total impervious percentages, DCIA percentages, and initial abstraction amounts by intersecting the honeycomb mesh with the impervious and curve number table sets.

3.2.2 Soil and Land Use Lookup Tables

Lookup tables for the ICPR model were developed from the soil and land use data described in section 2.0. The Rainfall Excess method used in the model is the Curve Number method; the curve number table set is shown in **Table 3-1**. Roughness and impervious data were developed from existing land use data and standard model values and procedures outlined in the ICPR manual (UG, 2014). The roughness table set is shown in **Table 3-2**, and the impervious table set is shown in **Table 3-3**.

Table 3-1 Curve Number Table Set

Land Cover Zone	Soil Zone	Curve Number
69	Knox silt loam, 7 to 12 percent slopes	69
69	Ladoga silt loam, 3 to 8 percent slopes	69
79	Knox silt loam, 7 to 12 percent slopes	79
79	Ladoga silt loam, 3 to 8 percent slopes	79
98	Knox silt loam, 7 to 12 percent slopes	98
98	Ladoga silt loam, 3 to 8 percent slopes	98
Void	Knox silt loam, 7 to 12 percent slopes	98
Void	Ladoga silt loam, 3 to 8 percent slopes	98
*Void areas are very small land use polygons that ICPR was not able to rasterize. The number of void areas were manually reduced and represent only a small fraction of the modeled land use.		

Table 3-2 Roughness Table Set

Roughness Zone	Shallow Manning's N	Deep Manning's N	Depth Range	Damping Threshold	Area Reduction Factor
69	0.2	0.1	3	0	1
79	0.2	0.1	3	0	1
98	0.06	0.03	3	0	1
Void	0.06	0.03	3	0	1
*Void areas are very small land use polygons that ICPR was not able to rasterize. The number of void areas were manually reduced and represent only a small fraction of the modeled land use.					

Table 3-3 Impervious Table Set

Land Cover Zone	% Impervious	% DCIA	% Direct	Ia Impervious	Ia Pervious
69	0	0	0	0	0
79	0	0	0	0	0
98	100	100	0	0	0
Void	100	100	0	0	0
*Void areas are very small land use polygons that ICPR was not able to rasterize. The number of void areas were manually reduced and represent only a small fraction of the modeled land use.					

3.2.3 Extrusions

Extrusion polygons in ICPR allow for stormwater runoff but do not permit overland flow. Acknowledging this flow behavior characteristic of buildings represents the surface flow paths more accurately.
The building footprints are used as extrusions in the existing conditions model. There are 393 different extrusions that cover about 36 acres of area. ICPR assumes that extrusions are 100% impervious with no initial abstraction. The extrusions do not allow overland flow to pass through, so the flow is diverted around the polygons. The extrusions are an input for the 2D mesh is built. The building footprints data were simplified with the objective to optimize computational performance and to reduce over triangulation in boundary areas and around buildings. This included removing building polygons that touched the modeling boundary or were outside the project boundary. Further, building polygons with complex shapes were transformed into simpler shapes of the same area. Additionally, groups of buildings in close proximity to each other were aggregated into single polygons; space between buildings is generally graded to direct flow away from the buildings rather than encourage routing it through those tight spaces. A review of the model results included potential glass walling around building extrusions and suggested no issues with the aggregation. With these modifications, the triangular mesh was developed evenly and avoided overrefinement. **Figure 3-2** depicts the modified extrusions layer.

3.2.4 Breaklines and Breakpoints

Breaklines and Breakpoints were used as additional 2D features used for building the 2D surface mesh. Breaklines serve to refine the triangular mesh in the model and support the accurate development of the surface flow paths in the 2D mesh. The breaklines in the existing conditions model were developed form the centerline layer. For roads with distinct curbs additional breaklines along the curb locations were added. These are typically along arterial roads in the project area. There are about 72,000 ft or about 14 miles of breaklines in the project area that encompass roads and curbs. **Figure 3-2** depicts the modified breaklines layer.

Breakpoints were created throughout the Overland Flow Region using a fixed rectangular pattern with an entity buffer of 10 ft and a minimum triangle side length of 100 ft. The breakpoints support a proportional development of the triangular mesh. **Figure 3-2** depicts the breakpoints layer.

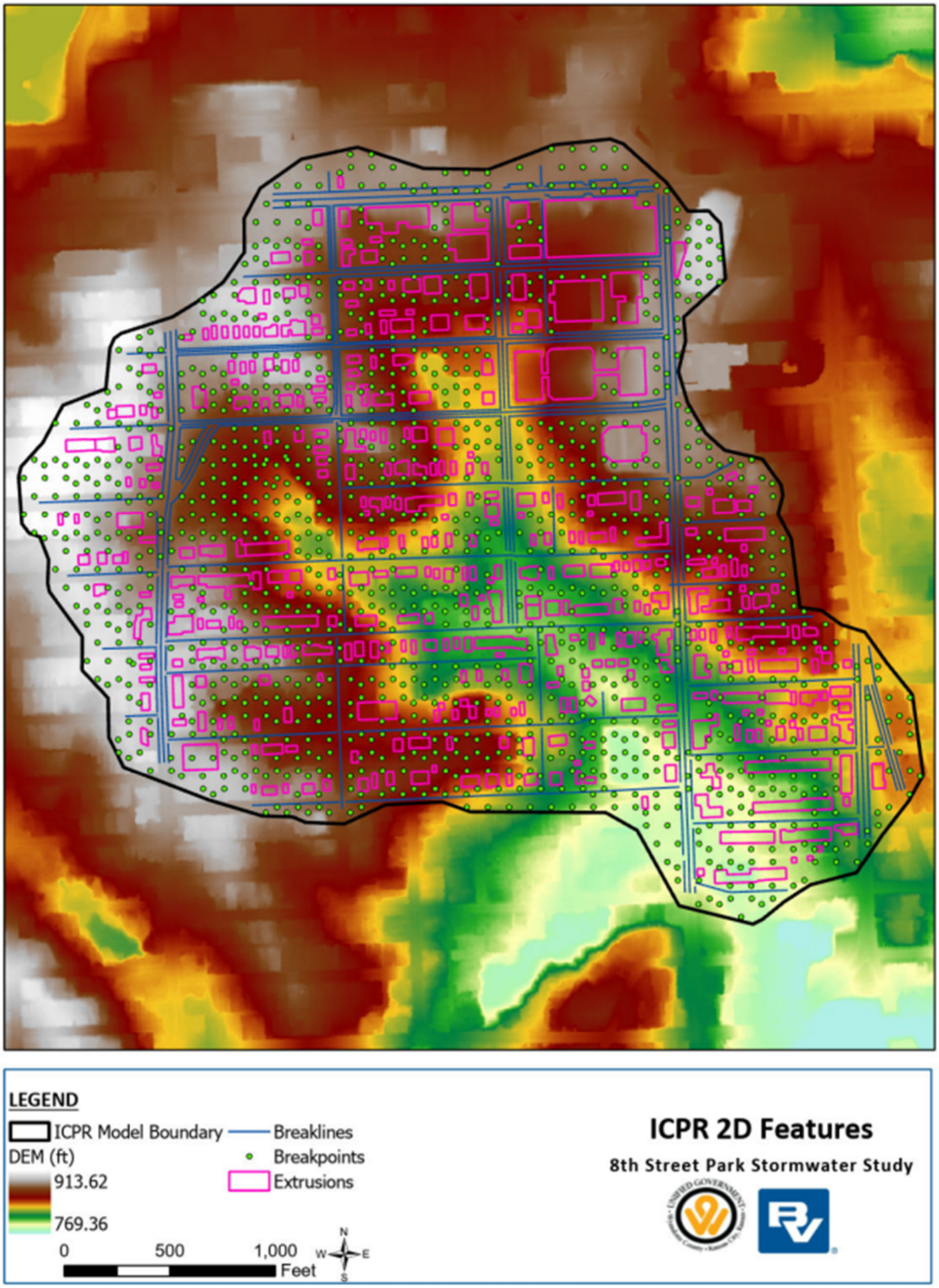


Figure 3-2 ICPR 2D Features

3.3 Model Network

A hydraulic network was created to simulate the existing sewer system that conveys stormwater within the project boundary. The network is made up of four module elements: 1D nodes and links that represent the modeled pipes and connecting manholes, 1D node interface points at inlets that allow surface flow to enter the 1D network, and weir links that are connecting 2D surface flow and 1D subsurface drainage. **Figure 3-3** depicts the nodes, links, and 1D node interface points used in the existing conditions model.

The hydraulic network was developed based on the ICM model network and further developed for the purpose of this project, including a refinement throughout Northrup Park and Splitlog Park, using the UG stormwater inventory. One objective of the model development was to explore existing and potential storage capacity in the park areas. Northrup Park, Splitlog Park and 8th Street Park have depressed areas that can receive stormwater runoff during wet weather events. The model network was refined throughout the parks areas adding additional smaller pipes and inlets to determine existing conditions ponding in the parks and stormwater conveyance downstream from these areas. Eighth Street Park does not have any inlets that would capture stormwater from the overland flow and convey through pipe network. However, this pipe network was kept in the model to allow for proposed condition analysis in form of stormwater rerouting.

3.3.1 Nodes

There are 65 nodes in the existing conditions model. These are manholes representing the main drainage network, inlets are modeled as 1D Interface Nodes (see section 3.3.3). Each node has a unique name as developed in the UG stormwater inventory. Important parameters for the nodes include the type of node, invert elevation, and location. All manholes are modeled as stage/area nodes, except the boundary node which is a time/stage node; it is representing the model's discharge point. The boundary node ("044-047-FT") is located furthest downstream of the existing model and serves as an outlet for the drainage system. This is where the pipe network ties into the rest of Splitlog Creek watershed's pipe network.

There were nine nodes that did not have invert elevations, so an invert elevation was estimated for each node. Further, four nodes and corresponding 1D Node Interface points were added by BV at pipe junctions with grate inlets. Invert elevations were estimated for each of those nodes. These data estimates are documented in the model in the comment's column. **Table 3-44** expands on each comment made for the nodes. Invert elevations are used as the initial stage value for each node. The nodes are assumed to be in static condition, so using an initial stage allows the node to account for water that is held back in the system. The warning stage is set at ground level to indicate when water is staging up above the manhole rim and potentially flooding is occurring.

Table 3-4 Nodes Comment Log

Element Type	Comment	Description
Node	BV estimated invert because UG did not	The UG GIS data does not include invert elevation data for the node. Therefore, invert elevations were calculated by subtracting 18 inches and the diameter of the pipe connecting to the manhole from the DEM value at that node. 18 inches

Element Type	Comment	Description
	provide invert.	represents the minimum ground cover over the pipe, and the diameter of the pipe will calculate the elevation at the bottom of the pipe.
Node	UG inlet location; BV created node for model.	Several inlets and associated pipes of the stormwater network not modeled in the ICM model were added to the ICPR4 model to refine drainage routing throughout Northrup Park and Splitlog Park. In ICPR, the inlets are modeled as 1D node interface element and linked by a weir to a node, representing the pipe junction. Invert elevations were calculated using DEM and pipe diameter as described above. To differentiate between the UG nodes in the GIS data, these nodes are labeled as “BV_MH0#.”

3.3.2 Links

The existing InfoWorks ICM model was utilized to construct a model of the storm sewer conveyance system which included pipes with a diameter of 24 inches and larger. Some sections of the ICM network were omitted from the existing conditions model when not conveying stormwater or at pipe sizes below 24 inches in diameter.

There are 64 pipe links in the existing conditions model conveying stormwater through the drainage network. Each link has a unique name as assigned by the UG stormwater inventory. Important parameters for the links are material, diameter, length, and the connecting upstream and downstream nodes. The flow direction is set to “both” in the model to allow flow reversals. Most of the links in the model are reinforced concrete pipes (RCP) or vitrified clay pipe (VCP) material and 24 inches or larger in diameter. There are 10 to 18 inches in diameter pipes included in this model. These smaller pipes are kept in the model to either convey stormwater through Northrup Park, Eighth Street Park, or Splitlog Park or connect larger diameter pipes.

3.3.3 1D Node Interface Points

There are 76 inlets in the existing conditions model. These inlets are located along the pipe network to capture the stormwater from the overland flow and transport it through the pipe network. In ICPR 2D models, storm inlets are represented as 1D node interface points where water is transferred from the 2D computational mesh to the 1D node network. 2D overland flow is routed through those 1D node interface points and a connecting weir to the stage/area nodes within the pipe network. Each 1D Node Interface point has a unique name, the inlet ID from the UG stormwater inventory. Important parameters for the inlets include the type of inlet, dimensions, elevation, location, and the node the inlet connects to.

In the existing conditions model, there are 56 curb inlets and 20 surface grates inlets. These were verified with Google Earth aerial and street view imagery. Some inlets in the model differ from the type of inlet labeled in the UG GIS data, these inlets are documented in the comment’s column. **Table 3-5** expands on each comment made for the 1D node interface. The dimensions of the curb inlets are assumed to have a height of 0.5 ft and the width is approximated using aerial imagery. The dimensions of the surface grates inlets are two-by-two ft based off the UG GIS data and aerial imagery. ICPR uses the street elevation that is obtained from the DEM at the 1D node interface as the initial stage at that location. A weir link is used to connect each storm inlet to the appropriate node.

Table 3-5 1D Node Interface Comment Log

Element Type	Comment	Description
1D Node Interface	UG lists as curb inlet. Aerial shows grate inlet.	The UG GIS inlet data includes the type of inlet. Using Google Earth aerial and street view imagery, these inlets are mislabeled as a curb inlet instead of a surface grate inlet in the UG GIS data.
1D Node Interface	Inlet does not exist in UG data.	The UG did not have these inlets in their inlet GIS data set. These inlets were found in Google Earth aerial and street view imagery. To differentiate between the UG inlets in the GIS data, these inlets are labeled as “BV_IT0#.”

3.3.4 Weir Links

Weir links connect the 1D node interface element to the 1D node. Therefore, there are 76 weir links, from each 1D node interface (inlet) to the corresponding 1D node (manhole) receiving its runoff. The required parameters for the weir links are the weir type, geometry and dimensions, elevation, node to and node from, and discharge coefficients. There are two types of weirs in the existing model. Curb inlets are classified as a vertical, sharp crested weir, and surface grate inlets are classified as a horizontal weir. All weird have a rectangular geometry. The dimensions for the weirs match the inlets dimensions. ICPR uses the street elevation that is obtained from the DEM at the 1D node interface as the invert elevation for the weir. This is the elevation at which the weir begins to flow. The weir discharge coefficient and orifice discharge coefficients are set at 2.8 and 0.6, respectively.

3.4 Model Simulation

Six simulations were created for each model scenario, one simulation for each design storm.

- Water Quality Storm
- 5-Year Storm
- 10-Year Storm
- 25-Year Storm
- 50-Year Storm
- 100-Year Storm

Each simulation was run for 48 hours to provide observation of post-storm flood conditions in the existing and improved condtion scenarios. All simulations have a unique boundary condition and rainfall depth.

3.4.1 Boundary Conditions

Boundary conditions were developed for both the 1D pipe network and the 2D overland flow at the downstream end of the project area. The 1D boundary condition is represented by a boundary stage curve assigned to node 044-047-FT at N 7th Street and Tenny Ave. The existing pipe network drains south to a larger trunk line outside of the model boundary. A boundary stage curve was created for each storm event by running each storm simulation in the existing Integrated Overflow Control Plan Infoworks ICM model. The time stage curve was copied from the ICM model node 044-047-FT to the ICPR model node 044-047-FT to accurately model backwater conditions.

A boundary stage line is required along the model boundary at the downstream end to allow 2D overland flow out of the project area and not cause artificial ponding. It was assumed that there is no overland flow backwater at the downstream end of the project. The boundary stage line was set to equal or lower than existing ground elevation to allow surface flow out of the system.

3.4.2 Storm Events

ICPR requires a dimensionless unit hydrograph, rainfall depth, and storm duration as simulation inputs. A dimensionless unit hydrograph was developed from the 1 Quartile, 10% distribution, 6hr rainfall duration data downloaded from the NOAA Atlas 14 website. This dimensionless unit hydrograph was assigned to each simulation as was a storm duration of 6hrs. See **Table 3-6** for each design storm and the corresponding rainfall depth.

Table 3-6 NOAA Atlas 14 Rainfall Data

Design Storm	Rainfall Depth	Rainfall Duration
Water Quality	1.4in	6hr
5-Year	3.42in	6hr
10-Year	4.08in	6hr
25-Year	5.04in	6hr
50-Year	5.81in	6hr
100-Year	6.62in	6hr

Figure 3-3 **1D Network**

4.0 Existing Conditions Modeling Results

Flooding was observed in the existing conditions model during the 5-year and larger storm events in three primary areas.

- 8th Street Park
- N 8th Street & Orville Ave intersection
- N Coy St. & Splitlog Ave Apartment Complex

4.1 8th Street Park

Existing flood depths of approximately 4 ft were observed for both the 5-year and 10-year storms within the 8th Street Park boundary. This was expected due to the topography of the park acting as a detention basin. The existing conditions model confirmed that the park already captures overland flow from surrounding areas. This flooding is not a concern since the intent of the chosen solution is to use the detention area in the park for additional stormwater storage.

4.2 N 8th Street & Orville Avenue Intersection

Extensive flooding was observed throughout the intersection and surrounding residential properties for both the 5-year storm and 10-year storm. This intersection is a low area in the overland flow path and collects water from the street in all four directions. Historical flooding appears to be an issue in this area, and there are four stormwater inlets in the intersection to capture flow. The model suggests that flooding is the result of insufficient capacity in the existing 36-in combined storm sewer within the intersection as well as upstream along N 8th street and Orville Avenue.

4.2.1 5-Year Results

Maximum flood depths 3.5 ft were observed on the street within the intersection and depths of 4.9 ft were observed adjacent to the intersection where grate inlets within a sump area collect stormwater. Maximum flood depths greater than 2 ft were observed at surrounding residential property (**Figure 4-2**). Additionally, a maximum velocity of 4.4 ft/s with an average velocity of 0.8 ft/s were observed. As peak flows within the combined storm sewer subside, the four inlets in the intersection allow ponding to enter the storm sewer. However, the flooding is observed for approximately 3 hours.

4.2.2 10-Year Results

Flood depths of 5.2 ft above the street were observed for the 10-year storm within the intersection and depths greater than 2.5 ft were observed at surrounding residential property (**Figure 4-3**). Additionally, a maximum velocity of 7.4 ft/s with an average velocity of 0.9 ft/s were observed. As peak flows within the combined storm sewer subside, the four inlets in the intersection allow ponding to enter the storm sewer. However, the flooding is observed for approximately 3.3 hours.

4.3 N Coy Street & Splitlog Avenue Apartment Complex

Extensive flooding was observed throughout this complex and surrounding residential properties for both the 5-year storm and 10-year storm. The apartment complex is within a topographic low area where overland flow can enter but is unable to drain due to the grading around the complex (**Figure 4-1**). Historical flooding appears to be an issue in this area and there one surface grate inlet identified by Google Earth imagery within the apartment complex parking lot. Survey would be required to correctly identify the dimensions of the inlet and storm pipe as well as tie-in location to the combined storm sewer. Flooding at N 8th Street & Orville Avenue contributes to the flooding within the complex as does the insufficient inlet and storm pipe capacity.

4.3.1 5-Year Results

Maximum flood depths of 7.4 ft were observed for the 5-year storm within the parking lot and depths greater than 2 ft were observed around the apartment buildings (**Figure 4-2**). As peak flows within the combined storm sewer subside, the 1 inlet in the parking lot allows ponding to enter the storm sewer. The flooding is observed for approximately 6 hours.

4.3.2 10-Year Results

Flood depths of 11.7 ft were observed for the 10-year storm within the parking lot and depths greater than 3 ft were observed around the apartment buildings (**Figure 4-3**). As peak flows within the combined storm sewer subside, the one inlet in the parking lot allows ponding to enter the storm sewer. However, the flooding is observed for approximately 12 hours.

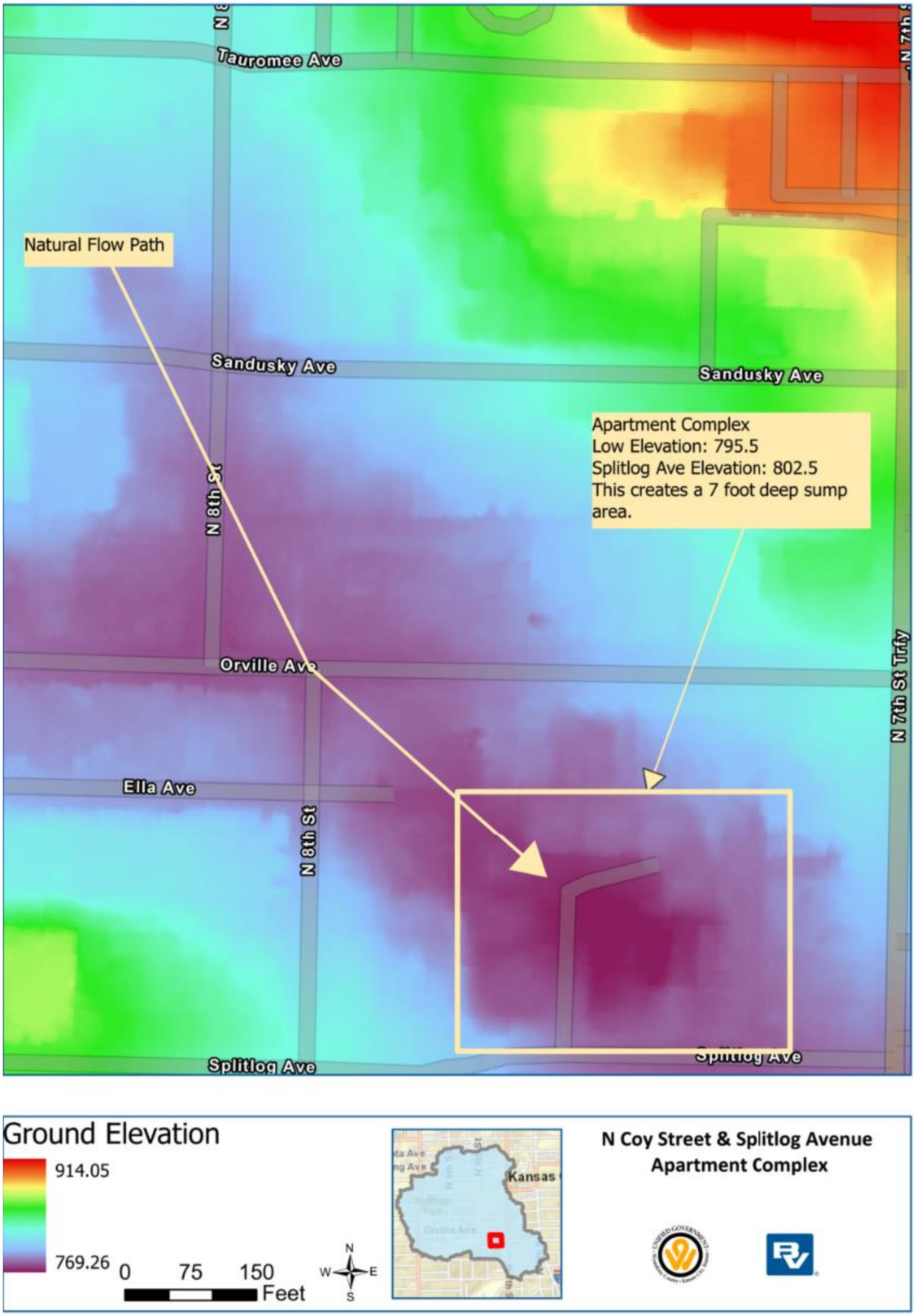


Figure 4-1 N Coy Street & Splitlog Avenue Apartment Complex Topography

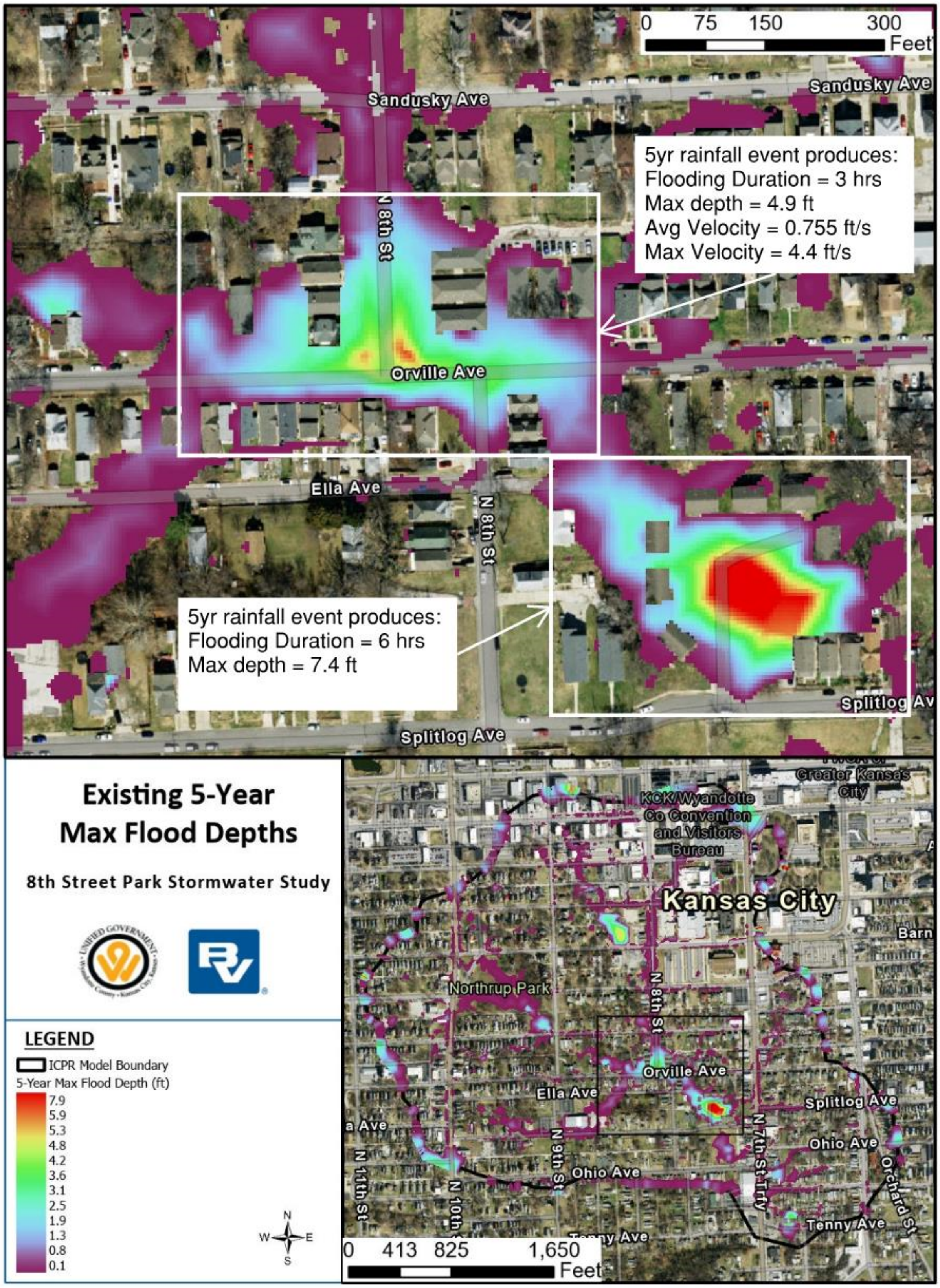


Figure 4-2 Existing 5-Year Flood Depths

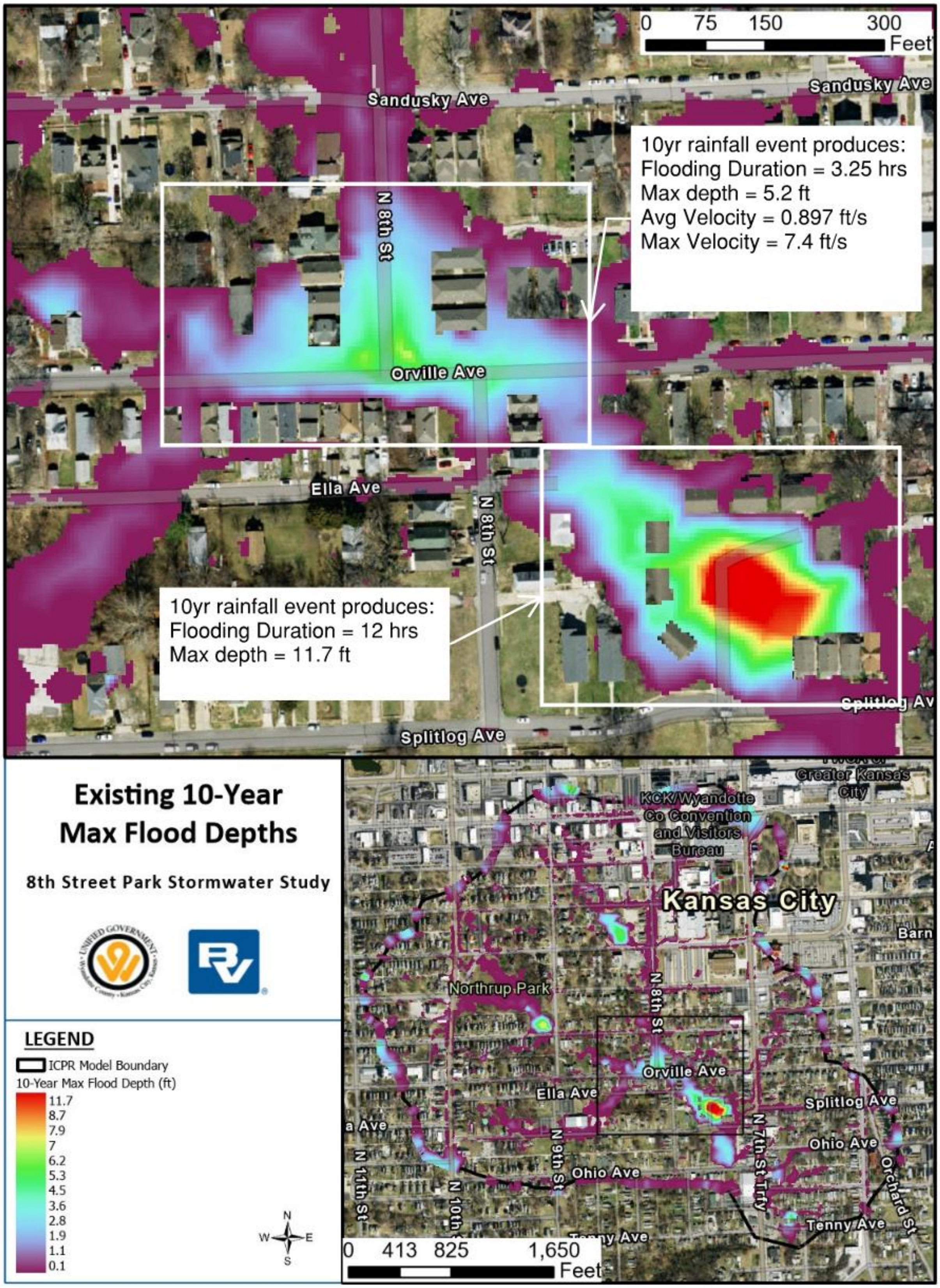


Figure 4-3 Existing 10-Year Flood Depth

5.0 Improved Conditions Analysis

Two solutions were considered with the primary purpose of providing stormwater benefit to the flooding areas identified in the existing conditions model.

5.1 Potential Solution – Enclosed Conveyance

The potential solution included new stormwater pipe throughout the project area to capture overland flow and route stormwater to the downstream end of the project where it would tie back into the combined system. Two primary issues arose early on with this solution:

- First, upon review of the existing ICM model which extends outside of our project area to the outfall on the Kansas River, we found the majority of the downstream combined sewer is already surcharged and lacks capacity (**Figure 5-1**). **Figure 5-2** shows the pipe profile beginning at N 7th Street and Tenny Avenue downstream to the Kansas River outfall. This profile is immediately downstream of our tie in location (node 044-047) for the ICPR model to the rest of the system. The profile shows the existing combined sewer surcharged above the pipe crown by an average of 10 ft for the 5-year storm. Routing new storm pipe to this point would potentially alleviate flooding upstream but likely would create additional flooding or reduced capacity downstream.
- Second, proposing all new storm pipe would be prohibitively expensive. This solution also failed to incorporate 8th Street Park as a stormwater collection point in fulfillment of the requirements of the consent decree.

Due to these limitations, further modeling of the enclosed conveyance solution was not pursued.

5.2 Chosen Solution – Green Infrastructure / Stormwater Retention Facilities

The chosen solution includes additional stormwater detention at 8th Street Park (to fulfill the requirements of the consent decree) and Northrup Park as well as new storm sewer to route stormwater to the parks. A new reinforced concrete box is also proposed at N 8th Steet and Orville Avenue to improve flooding identified in the existing conditions model. Further opportunity is available for stormwater capture utilizing green stormwater infrastructure along N 8th Steet and Orville Avenue. In addition, to alleviate flooding in the apartment complex located at N Coy Street & Splitlog Avenue, additional storm sewer and a detention facility is proposed at Splitlog Park.

An overview of the chosen solution is shown in **Figure 5-3**, further detail is provided in **Sections 5.2.1** to **5.2.3**.

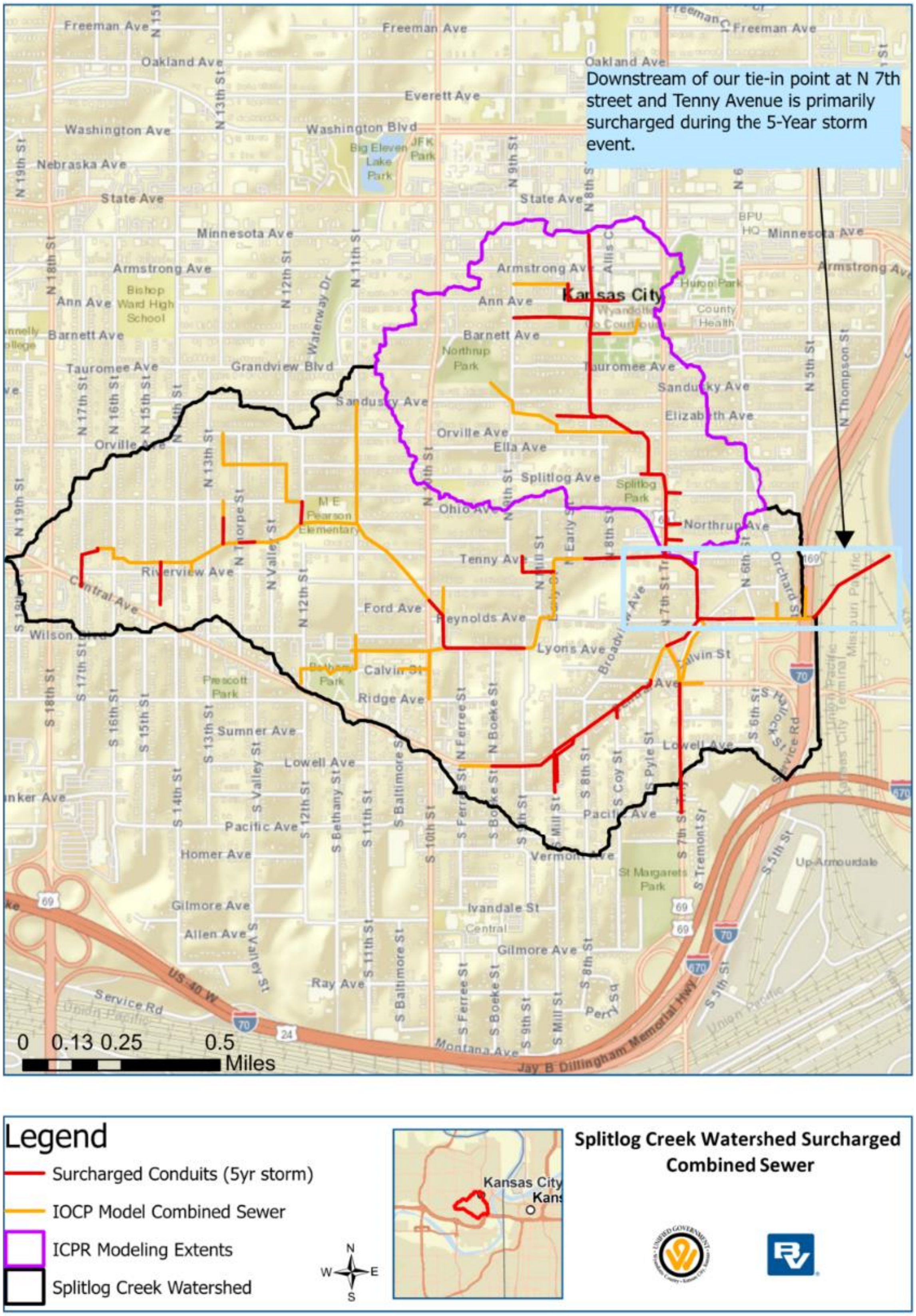


Figure 5-1 ICM Model Results for 5-Year Storm Event

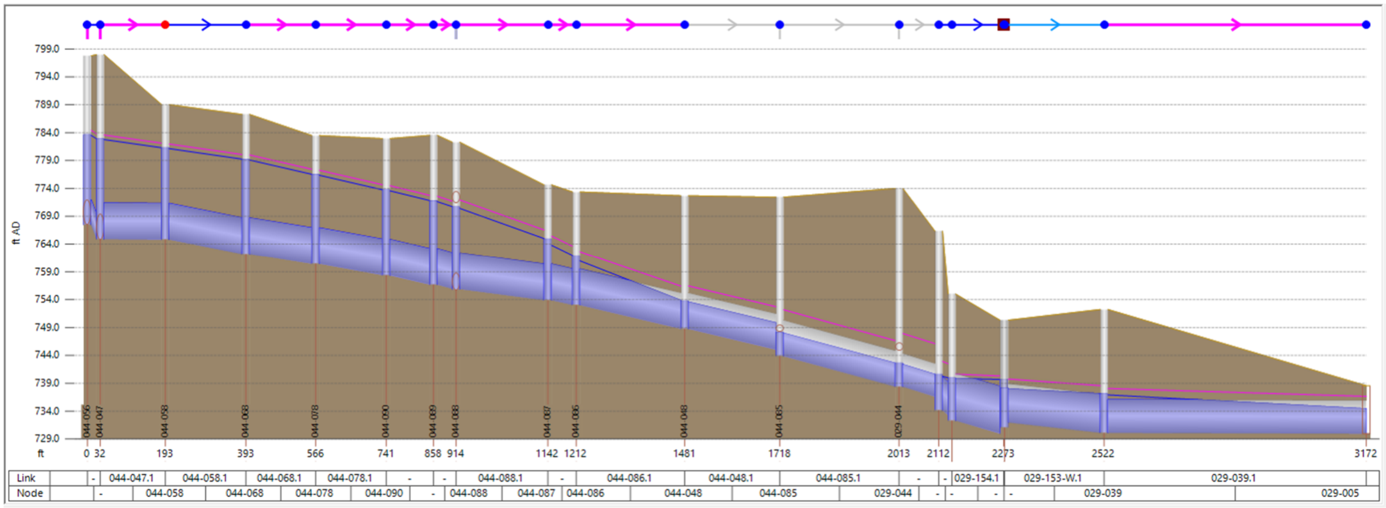


Figure 5-2 ICM Model Downstream Profile

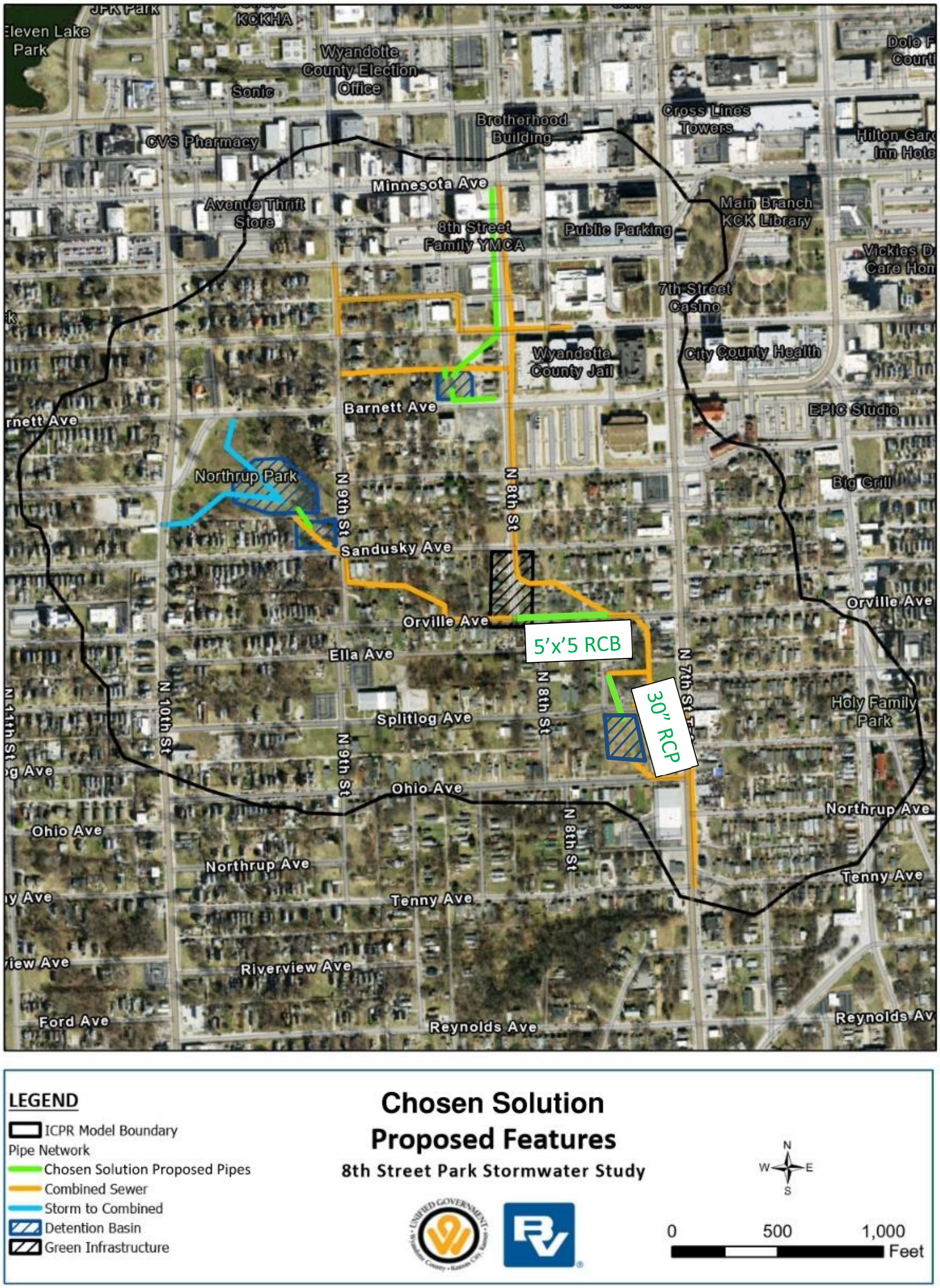


Figure 5-3 Chosen Solution Proposed Features

5.2.1 CSO 44 Green Infrastructure / Stormwater Facility Improvements and Costs

Excavation of 0.8 ac-ft was proposed to create a larger detention basin with capacity to capture the 5-year and 10-year storm events (**Figure 5-4**). New storm pipe was proposed along 8th Street from Minnesota Avenue south to Ann Avenue to capture flow from all the existing storm inlets and direct the flows into 8th Street Park. New storm pipe was also proposed along Barnette Avenue to capture flows at the 8th Street & Barnett Avenue intersection and direct them into the new detention area (**Figure 5-4**). Capturing all the upstream stormwater provides maximum benefit to the surcharged combined sewer downstream. A 10-inch underdrain allows stormwater to slowly drain back into the existing combined storm sewer after peak flows have already passed.

An Engineer's Opinion of Probable Construction Cost was developed for the chosen solution to estimate the costs of providing a 5-year level of service. The cost includes construction for detention at 8th Street Park as well as new storm sewer to capture flows and direct them into the park. The cost estimate can is provided in **Table 5-1.**

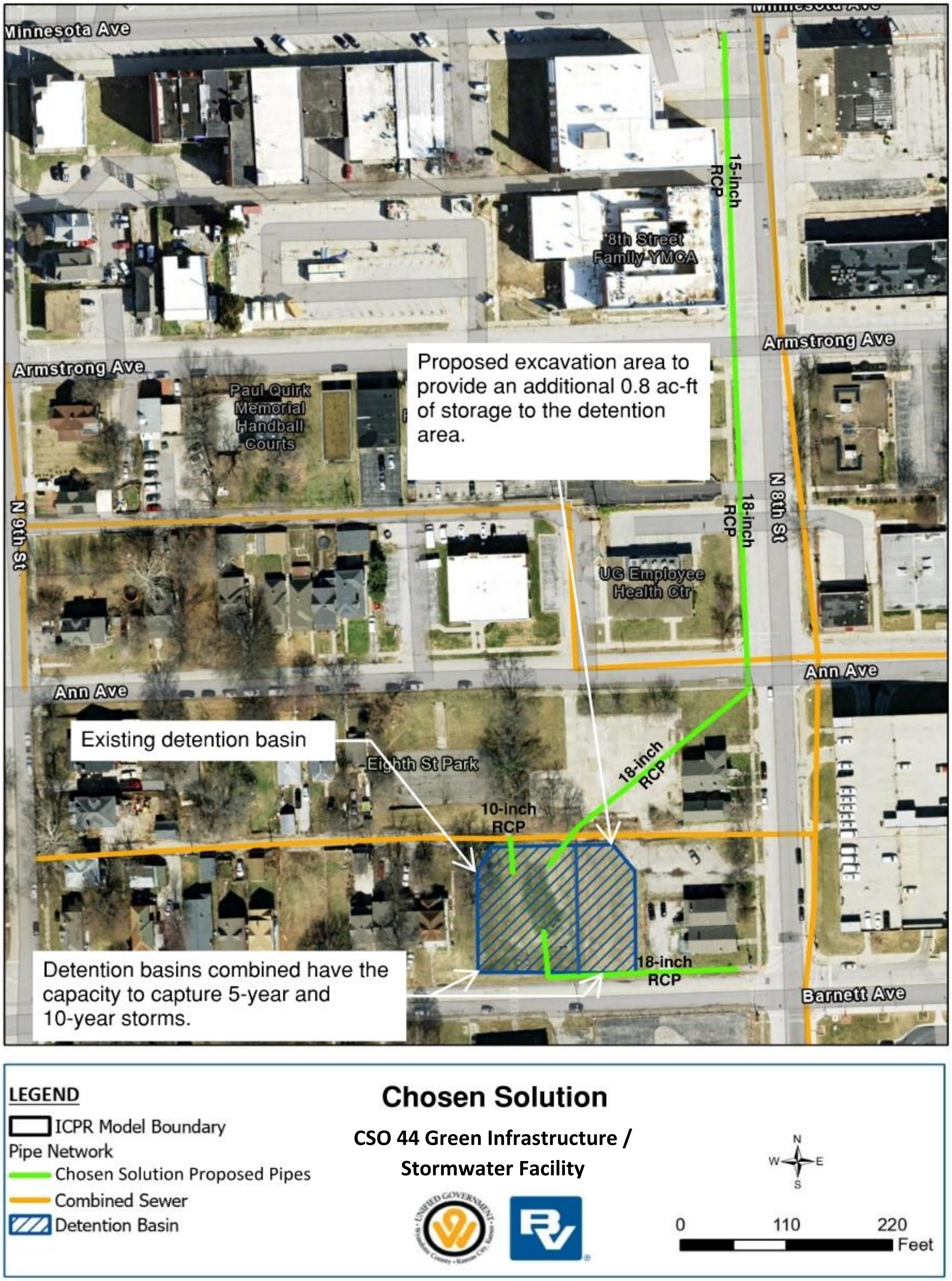


Figure 5-4 Chosen Solution - CSO 44 Green Infrastructure / Stormwater Facility

Table 5-1 Cost Estimate for Chosen Solution - CSO 44 Green Infrastructure / Stormwater Facility

ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	OPCC
CSO 44 Green Infrastructure / Stormwater Facility -- 5 Year Level of Service				
10" Drain Pipe	40	LF	$60	$2,400
15" RCP Inlet Connections	540	LF	$72	$38,900
15" Storm RCP	310	LF	$72	$22,400
18" Storm RCP	850	LF	$77	$65,300
Concrete Flared End Section, 30"	2	EA	$945	$1,900
Field Inlet, 6' x 4'	1	EA	$6,499	$6,500
Manhole, 4' Diameter	6	EA	$5,908	$35,500
Flowable Mortar	1970	CY	$200	$394,000
Pavement removal	770	SY	$18	$13,700
Asphalt paving	770	SY	$89	$68,300
Concrete Curb, Type 1	770	LF	$42	$32,200
Subbase patch	770	SY	$35	$27,300
Sidewalk	375	SY	$89	$33,300
Driveway	270	SY	$89	$24,000
Excavation, Dry	1300	CY	$30	$39,000
Seeding and Fertilizing (Urban)	1	AC	$5,147	$5,200
Riprap Protection	20	TON	$89	$1,800
Traffic Control Allowance	1	LS	$15,000	$15,000
Erosion Control	1	LS	$15,000	$15,000
			Subtotal	**$841,700**
			Allowances (7%)	$58,900
			General Requirements (13.5%)	$113,600
			Contractor Fee (12%)	$101,000
			Insurance and Bond (2%)	$16,900
			Construction Contingency (30%)	$252,400
			Engineering (10%)	$84,200
			Total Construction Cost (rounded to nearest $10,000)	**$1,470,000**
* Excavation costs include cost to haul offsite. Spoils are not stockpiled onsite.				

5.2.2 Northrup Park Improvements and Costs

Northrup Park was identified as available green space that could be used for stormwater detention. The presence of existing storm sewer within the park as well as the topography makes it an attractive location for stormwater improvements.

Figure 5-5 depicts existing conditions, where a depressed area acts as a detention basin in the southeast corner of the park that captures overland flow and allows flow back into the combined storm sewer through a surface grate inlet.

Excavation of 14.8 acre-feet is proposed to create a larger detention basin within the park. The combination of the existing basin with the new basin has enough storage capacity to capture both the 5-year and 10-year storm events.

The storm to combined pipes in the park were disconnected from the downstream combined storm sewer and directed to outfall in the larger detention basin. Capturing all the upstream stormwater provides maximum benefit to the surcharged combined sewer downstream. A 6-inch underdrain allows stormwater to slowly drain over 48 hours from the larger detention basin under the existing alley street and into the smaller detention basin. The stormwater enters back into the existing combined sewer after peak flows have already passed.

An Engineer's Opinion of Probable Construction Cost was developed for the chosen solution at Northrup Park to estimate the costs of providing a 5-year level of service. The cost includes construction for detention at Northrup Park as well as new storm sewer to capture flows and direct them into the park. The cost estimate can be seen in **Table 5-2**.

While no field investigations have been completed to confirm, it is believed that the park has been filled with rubble from I-70 during a reconstruction project completed in the 1990s. Depending on the extent, nature, and condition of this rubble, this could represent a cost risk not accounted for in **Table 5-2**, as excavation of clean material was assumed.

Table 5-2 Cost Estimate for Chosen Solution at Northrup Park

ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	OPCC
Northrup Park -- 5 Year Level of Service				
6" Drain pipe	100	LF	$40	$4,000
Concrete Flared End Section, 30"	3	EA	$945	$2,900
Field Inlet, 6' x 4'	1	EA	$6,499	$6,500
Excavation, Dry	23,900	CY	$30	$717,000
Seeding and Fertilizing (Urban)	1	AC	$5,147	$6,700
Riprap Protection	30	TON	$89	$2,700
Traffic Control Allowance	1	LS	$15,000	$15,000
Erosion Control	1	LS	$15,000	$15,000
			Subtotal	**$769,800**
			Allowances (7%)	$53,900
			General Requirements (13.5%)	$104,000
			Contractor Fee (12%)	$92,400
			Insurance and Bond (2%)	$15,400
			Construction Contingency (30%)	$231,000
			Engineering (10%)	$77,000
			Total Construction Cost (rounded to nearest $10,000)	**$1,343,500**
* Excavation costs include cost to haul offsite. Spoils are not stockpiled onsite.				

Figure 5-5 Chosen Solution at Northrup Park

5.2.3 N 8th Street & Orville Avenue Improvements and Costs

Approximately 460 ft of new 5 ft x 5 ft reinforced concrete box (RCB) is also included in the chosen solution. This RCB extends from the N 8th Street & Orville Avenue to the East 460 ft where a new junction box will connect the 5 ft x 5 ft RCB to the existing combined storm sewer. The new RCB will replace the existing 36-inch combined sewer in the intersection and provide additional capacity where the existing line is surcharged.

There is opportunity to control the remaining flood volume for the 5-year storm at N 8th Street & Orville Avenue with green stormwater infrastructure in this area. GSI would need to capture 0.46 ac-ft to provide a 5-year level of service. The approximate location for green infrastructure solutions is depicted in **Figure 5-3.**

An Engineer's Opinion of Probable Construction Cost was developed for the chosen solution at N 8th Street and Orville Avenue to estimate the costs of providing a 5-year level of service. The cost includes construction for the new 5 ft x 5 ft RCB at N 8th Street and Orville Avenue intersection for increased conveyance. The cost estimate can be seen in **Table 5-3**.

Table 5-3 Cost Estimate for Chosen Solution at N 8th Street and Orville Avenue

ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	OPCC
N 8th Street and Orville Avenue -- 5 Year Level of Service				
5'X5' RCB	460	LF	$868	$399,300
Manhole, 6' Diameter	3	EA	$11,816	$35,500
Drop Structure, 6' x 8'	1	EA	$70,000	$70,000
Pavement removal	500	SY	$18	$8,900
Asphalt paving	500	SY	$89	$44,400
Concrete Curb, Type 1	500	LF	$42	$20,900
Subbase patch	500	SY	$35	$17,800
Traffic Control Allowance	1	LS	$15,000	$15,000
			Subtotal	**$611,800**
			Allowances (7%)	$42,900
			General Requirements (13.5%)	$82,600
			Contractor Fee (12%	$73,400
			Insurance and Bond (2%)	$12,300
			Construction Contingency (30%)	$183,500
			Engineering (10%)	$61,200
			Total Construction Cost (rounded to nearest $10,000)	**$1,067,700**

5.3 Improved Conditions Modeling Results

5.3.1 CSO 44 Green Infrastructure / Stormwater Facility Results

Eighth Street Park provides maximum stormwater benefit by capturing all upstream overland flow and flows from the new storm sewer for both the 5-year and 10-year storms. For the 5-year storm, 8th Street Park has a maximum flood depth of 3.7 ft that draws down over approximately 6 hours. For the 10-year storm, 8th Street Park has a maximum flood depth of 4.3 ft that draws down over approximately 7 hours. Detaining the 5- and 10-year storm volumes reduce peak flows downstream and provides additional capacity in the combined storm sewer to help mitigate flooding at N 8th Street & Orville Avenue intersection.

5.3.2 Northrup Park Results

Northrup Park provides maximum stormwater benefit by capturing all upstream overland flow and flows from the existing storm sewer in the park for both the 5-year and 10-year storms. For the 5-year storm, Northrup Park has a maximum flood depth of 5.3 ft that draws down over approximately 48 hours. For the 10-ear storm, Northrup Park has a maximum flood depth of 6.7 ft that draws down over approximately 48 hours. Detaining the 5 and 10-year storm volumes reduce peak flows downstream and provides additional capacity in the combined storm sewer to help mitigate flooding at N 8th Street & Orville Avenue intersection.

5.3.3 N 8th Street & Orville Avenue Intersection Results

Upstream detention at 8th Street Park and Northrup Park and new 5 ft x 5 ft RCB contribute to noticeable improvements in flood depth, velocity, and duration at N 8th Street & Orville Avenue. As seen in **Figure 5-6**, maximum flood depth for the 5-year storm event is reduced from 3.5 ft to 1.3 ft compared to existing conditions. Additionally, maximum flood velocity is reduced from 4.4 ft/s to 2.7 ft/s and flood duration is reduced from 3 hours to 2.3 hours. Flooding near residential property is also reduced to less than half a foot.

Figure 5-7 depicts results for the 10-year storm event. The chosen solution maximum flood depths are reduced from 4 ft to 3 ft compared to existing conditions. Maximum flood velocity is reduced from 7.4 ft/s to 5.7 ft/s and flood duration is reduced from 3.3 hours to 3 hours. While there is improvement for the 10-year storm, substantial flooding remains. Further analysis was done to see if increasing the size of the RCB under Orville Avenue would help resolve flooding for the 10-year storm, but it was determined that there would be minimal benefit from a larger RCB. A 10-year level of service is unlikely unless further downstream improvements are made to increase capacity in the combined storm sewer.

5.3.4 N Coy Street & Splitlog Avenue Apartment Complex Results & Further Improvements

Upstream improvements at 8th Street Park, Northrup Park, and N 8th Street & Orville Avenue contribute to noticeable improvements in flood depth at the N Coy Street & Splitlog Avenue Apartment Complex. As seen in **Figure 5-6**, maximum flood depth for the 5-year storm event is reduced from 6.5 ft to 1.7 ft compared to existing conditions. Additionally, flood duration is reduced from 12 hours to 2.3 hours. Flooding near the apartment buildings is also reduced to less than half a foot. There is opportunity to control the remaining flood volume for the 5-year storm by increasing inlet capacity and storm sewer capacity in the complex or with combined storm sewer improvements downstream to create additional capacity.

Figure 5-7 depicts results for the 10-year storm event. The chosen solution flood depths are reduced from 7.8 ft to 4 ft compared to existing conditions. Additionally, flood duration is reduced from 12 hours to 3 hours. While there is improvement for the 10-year storm, substantial flooding remains. A 10-year level of service is unlikely unless further downstream improvements are made to increase capacity in the combined storm sewer.

Additional improvements are proposed to further reduce flooding at the Apartment complex. Preliminary model results indicate significant improvements by constructing a new storm sewer which collects ponded stormwater in the apartment complex and routing it south to Splitlog Park to be detained in an engineered facility. Conceptual layout of these improvements has been completed which are estimated to provide a 5-year level of service are shown in **Figure 5-8**, and a cost estimate for this solution is provided in **Table 5-4**.

Modeling of these improvements is not reflected in **Figures 5-6**, **5-7**, or **Appendix B**.

Table 5-4 Cost Estimate for Conceptual Solution - N Coy Street & Splitlog Avenue Apartment Complex

ITEM DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	OPCC
N Coy Street & Splitlog Avenue Apartment Complex -- 5 Year Level of Service				
10" Drain Pipe	40	LF	$60	$2,400
15" RCP Inlet Connections	50	LF	$72	$3,600
30" Storm RCP	300	LF	$125	$37,500
Concrete Flared End Section, 30"	1	EA	$945	$945
Area Inlet, 6' x 4'	1	EA	$6,499	$6,499
Curb Inlet, 6’ x 4’	2	EA	$5,317	$10,634
Manhole, 4' Diameter	2	EA	$5,908	$11,816
Pavement removal	70	SY	$18	$1,260
Asphalt paving	70	SY	$89	$6,230
Concrete Curb, Type 1	50	LF	$42	$2,100
Subbase patch	770	SY	$35	$26,950
Sidewalk	50	SY	$89	$4,450
Excavation, Dry	1,000	CY	$30	$30,000
Seeding and Fertilizing (Urban)	1	AC	$5,147	$5,147
Riprap Protection	20	TON	$89	$1,780
Traffic Control Allowance	1	LS	$15,000	$15,000
Erosion Control	1	LS	$15,000	$15,000
			Subtotal	**$182,000**
			Allowances (7%)	$13,000
			General Requirements (13.5%)	$25,000
			Contractor Fee (12%)	$22,000
			Insurance and Bond (2%)	$4,000
			Construction Contingency (30%)	$55,000
			Engineering (10%)	$19,000
			Total Construction Cost (rounded to nearest $10,000)	**$320,000**
* Excavation costs include cost to haul offsite. Spoils are not stockpiled onsite. No cost for restoration of private property has been included.				

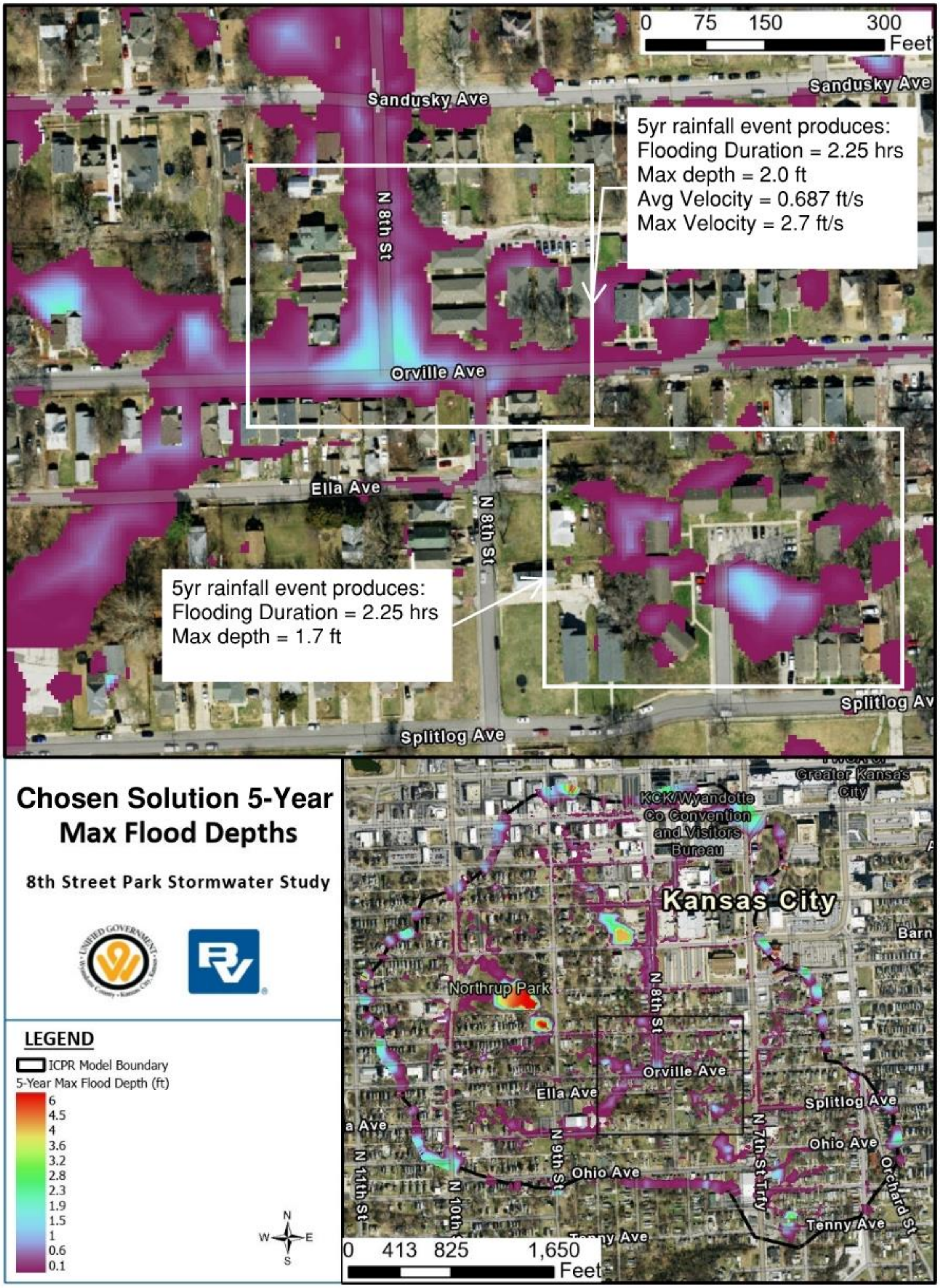


Figure 5-6 Chosen Solution 5-Year Flood Depths

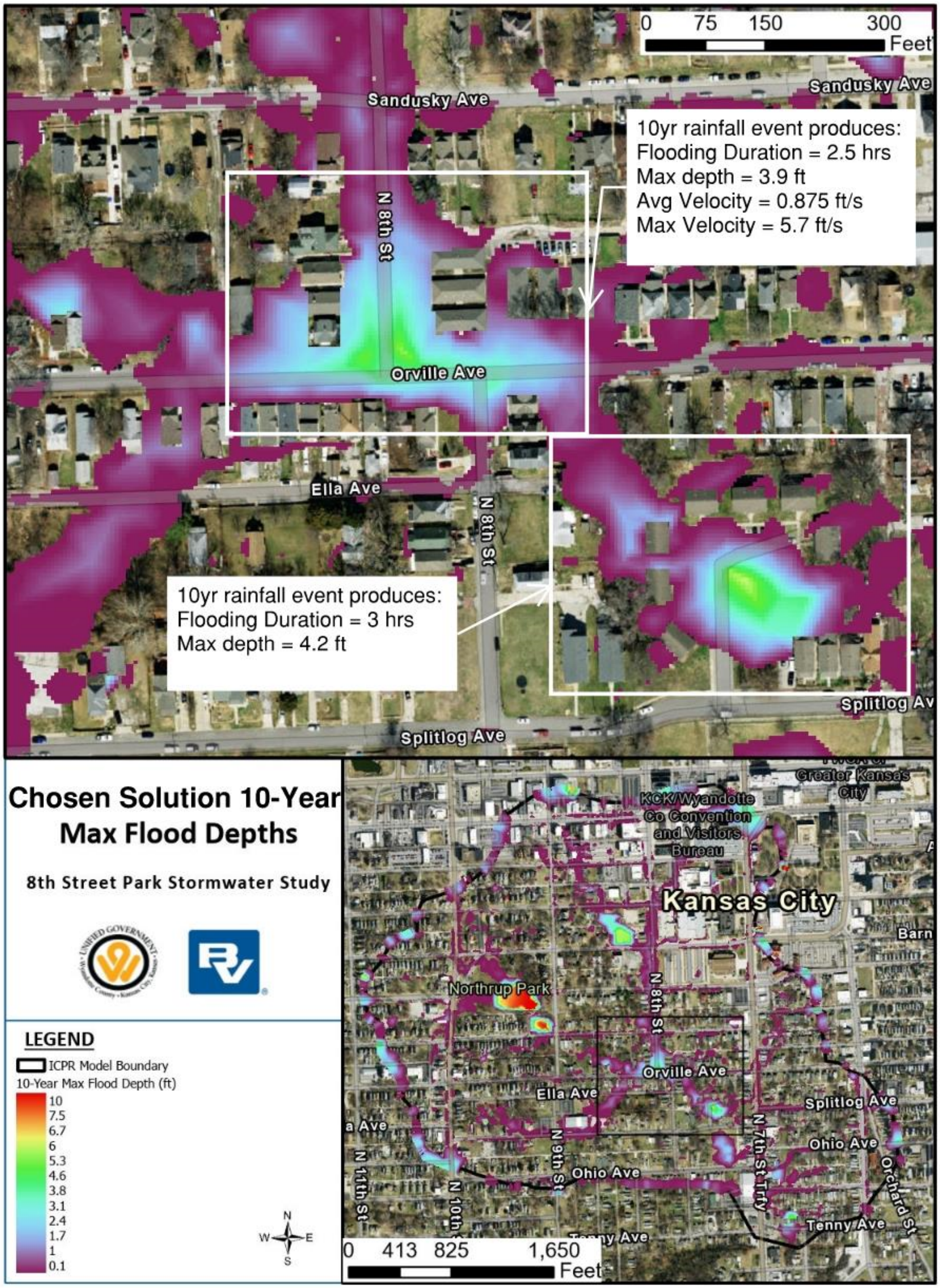


Figure 5-7 Chosen Solution 10-Year Depths

Figure 5-8 Conceptual Improvements at Apartment Complex

6.0 Safety Analysis

In the existing model, there are two areas that portray potential safety concerns to the community during a rain event. The areas of concern are the 8th Street and Orville Avenue intersection and the apartment complex off N Coy Street and Splitlog Avenue. The severity of these safety concerns can be measured by the flood depth and flood velocity. Certain flood depths paired with certain flood velocities can produce different safety hazards. Examples of the type of hazards from the modeling results are described below. The proposed conditions model presents stormwater solutions that will provide safety benefits by diverting and storing stormwater flows. This will alleviate flooding in the areas of concern which will decrease the severity of these safety concerns.

Table 6-1 lists the flooding results for the 8th Street and Orville Avenue intersection and **Table 6-2** lists the flooding results for the N Coy Street and Splitlog Avenue apartment complex. The 5-year and 10-year storms for the existing conditions and improved conditions are compared in the tables. The flood depths, velocities, and durations all decrease once the proposed conditions for the chosen solution are modeled. This provides safety benefits to the community.

Table 6-1 Intersection at 8th Street and Orville Avenue Flooding Results

	5-Year		10-Year	
Risk Factor	**Existing Conditions**	**Improved Conditions**	**Existing Conditions**	**Improved Conditions**
Depth	4.9 ft	2.0 ft	5.2 ft	3.9 ft
Flooding Duration	3 hrs	2.25 hrs	3.25 hrs	2.5 hrs
Average Velocity	0.8 ft/s	0.7 ft/s	0.9 ft/s	0.9 ft/s
Maximum Velocity	4.4 ft/s	2.7 ft/s	7.4 ft/s	5.7 ft/s

Table 6-2 Apartment Complex at N Coy Street and Splitlog Avenue Flooding Results

	5-Year		10-Year	
Risk Factor	**Existing Conditions**	**Improved Conditions***	**Existing Conditions**	**Improved Conditions***
Depth	7.4 ft	1.7 ft	11.7 ft	4.2 ft
Flooding Duration	6 hrs	2.25 hrs	12 hrs	3 hrs

* These results do not reflect the improvements listed in Section 5.3.4.

"According to [the U.S. Bureau of Reclamation] calculations, flood water depths of 3 ft and 0 flood water velocity pose a high danger to nearly all passenger vehicles" (FEMA, n.d.). An automobile can float in just 2 ft of water (FEMA, n.d.). As seen in Table 6-1 and Table 6-2, the existing intersection and apartment complex can experience maximum flood depths well over 2 ft during a 5- and 10-year storm.

After implementing the proposed infrastructure for the chosen solution, the apartment complex experiences less than 2 ft of maximum flood depth for the 5-year storm. The intersection for the 5- and 10-year storm and the apartment complex for the 10-year storm still experiences a maximum flood depth greater than or equal to 2 ft after implementing the proposed infrastructure. However, the flood depth decreases at both locations from the existing conditions modeling results. Therefore, passenger vehicles are not at a high risk of danger during a 5-year storm at the apartment complex once the chosen solution proposed infrastructure is implemented.

Combining flood water depth and velocity pose a higher risk to vehicles but also humans. The risk for humans is becoming unstable in flood waters which can lead to injury and even death. If the depth times velocity is greater than 4 ft squared per second (ft^2/s) then there is a high risk to humans if they try to navigate through these flood waters (FEMA, n.d.). The existing intersection and apartment complex can experience maximum flood depth times maximum velocity of over 4 ft^2/s during a 5- and 10-year storm.

After implementing the proposed infrastructure for the chosen solution, the apartment complex experiences less than 4 ft^2/s of maximum flood depth times maximum velocity for the 5-year storm. The intersection for the 5- and 10-year storm and the apartment complex for the 10-year storm still experiences a maximum flood depth times maximum velocity greater than 4 ft^2/s after implementing the proposed infrastructure. However, the flood depth times velocity decreases at both locations from the existing conditions modeling results. Therefore, humans are not at a high risk of danger during a 5-year storm at the apartment complex once the chosen solution proposed infrastructure is implemented.

Overall, implementing the proposed infrastructure for the chosen solution will alleviate flooding which will reduce the risk of danger to humans and vehicles. For instance, during a 5-year storm, humans and vehicles are not at a high risk of danger at the apartment complex according to the depths and velocities from the proposed conditions modeling results.

7.0 Conclusion

An existing conditions model for Splitlog creek watershed was developed using version 4 of the Interconnected Channel and Pond Routing (ICPR4) modeling software by Streamline Technologies (Streamline Technologies, 2023). The results from the existing conditions model show extensive flooding for the 5-year and larger storm events at 8th Street & Orville Avenue and at the N Coy Street & Splitlog Avenue Apartment Complex.

An improved conditions analysis was conducted to provide increased stormwater level of service through either enclosed conveyance (potential solution) or stormwater detention in available greenspace (chosen solution). The chosen solution was selected as the most feasible and cost-effective option. It includes stormwater detention at both Northrup Park and 8th Street Park. It also includes new storm sewer to route storm flows into the detention areas and new RCB to mitigate flooding at N 8th street & Orville Avenue Intersection.

Results from the improved conditions modeling show significant improvement in flood depth, velocity and duration for the 5-year storm. Further opportunity was identified to use green stormwater infrastructure facilities to control the remaining flood volume for the 5-year storm at N 8th street & Orville Avenue Intersection. Results from the improved conditions modeling also show some improvement in flood depth, velocity and duration for the 10-year storm. However, flooding during the 10-year storm still remains an issue and a 10-year level of service is unlikely without further improvements downstream to increase conveyance.

7.1 Cost Estimates for Proposed Improvements, by Consent Decree Requirement

The following table summarizes the improvements required by the UG's consent decree described in **Sections 5.2.1** through **5.2.3**.

Table 7-1 Cost Estimates for Proposed Improvements, by Consent Decree Requirement

SOLUTION	REQUIRED BY CONSENT DECREE?	ESTIMATED COST
CSO 44 Green Infrastructure / Stormwater Facility -- 5 Year Level of Service	Yes	$1,470,700
Total Consent Decree Required Improvements		**$1,470,700**
Northrup Park	No	$1,344,000
N 8th Street & Orville Avenue Improvements	No	$1,070,000
N Coy Street & Splitlog Avenue Apartment Complex	No	$320,000
Total Non-Consent Decree Improvements		**$2,734,000**

8.0 References

FEMA. (n.d.). *Flood | Vehicle (Do Not Drive in Floodwaters; "Turn Around, Don't Drown!")*. Retrieved from FEMA Preparedness Community: https://community.fema.gov/ProtectiveActions/s/article/Flood-Vehicle-Do-Not-Drive-in-Floodwaters-Turn-Around-Don-t-Drown

KSDOT. (2018). *KSDOT LiDAR Download Grid*. Retrieved from Kansas DOT: https://ksdot.maps.arcgis.com/apps/mapviewer/index.html?layers=0b27c51ed4e24d01a22fc2952dc3567f

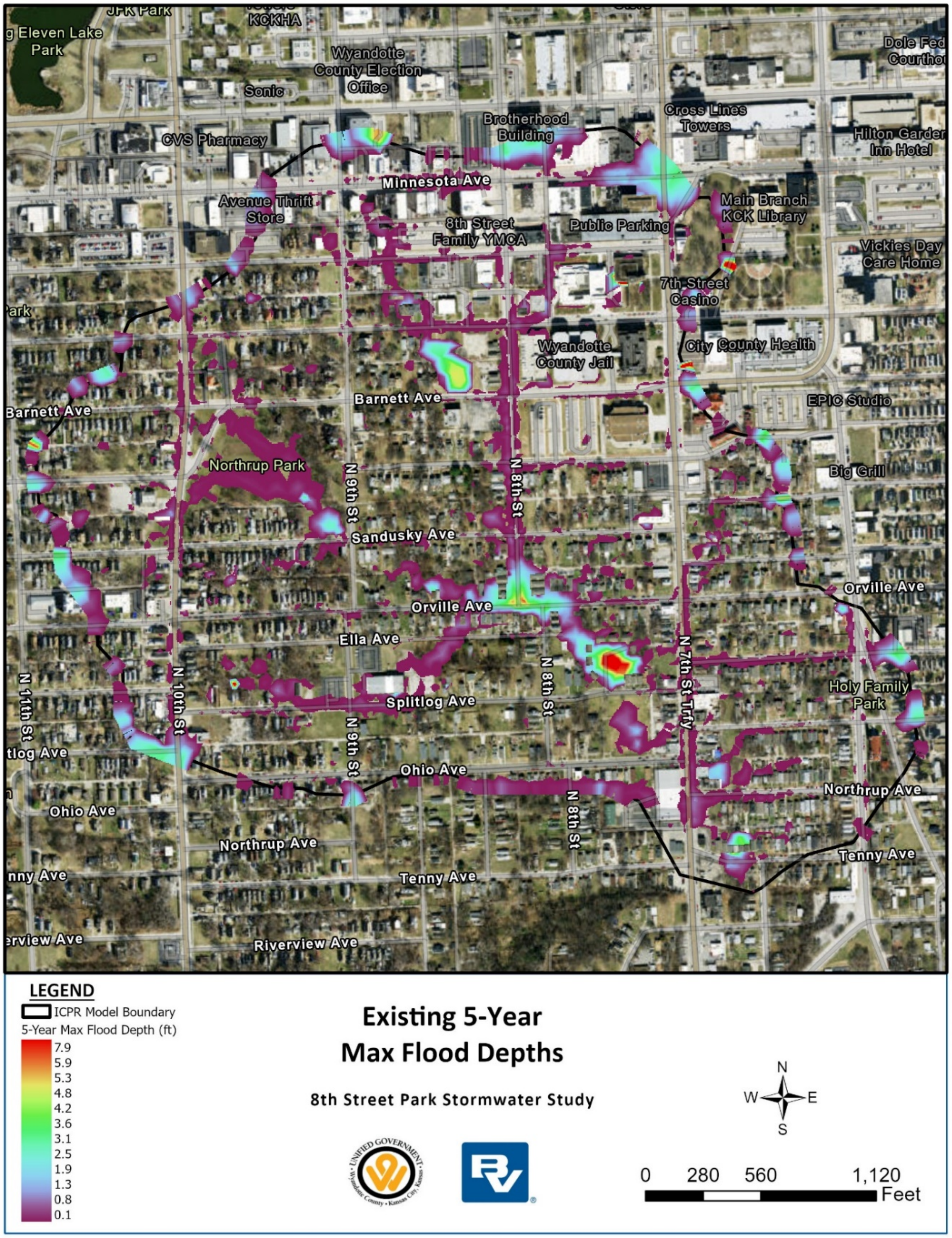
NOAA. (2023). *NOAA Altas 14 Point Precipitation Frequency Estimates: KS*. Retrieved from NOAA's National Weather Service: https://hdsc.nws.noaa.gov/pfds/pfds_map_cont.html?bkmrk=ks

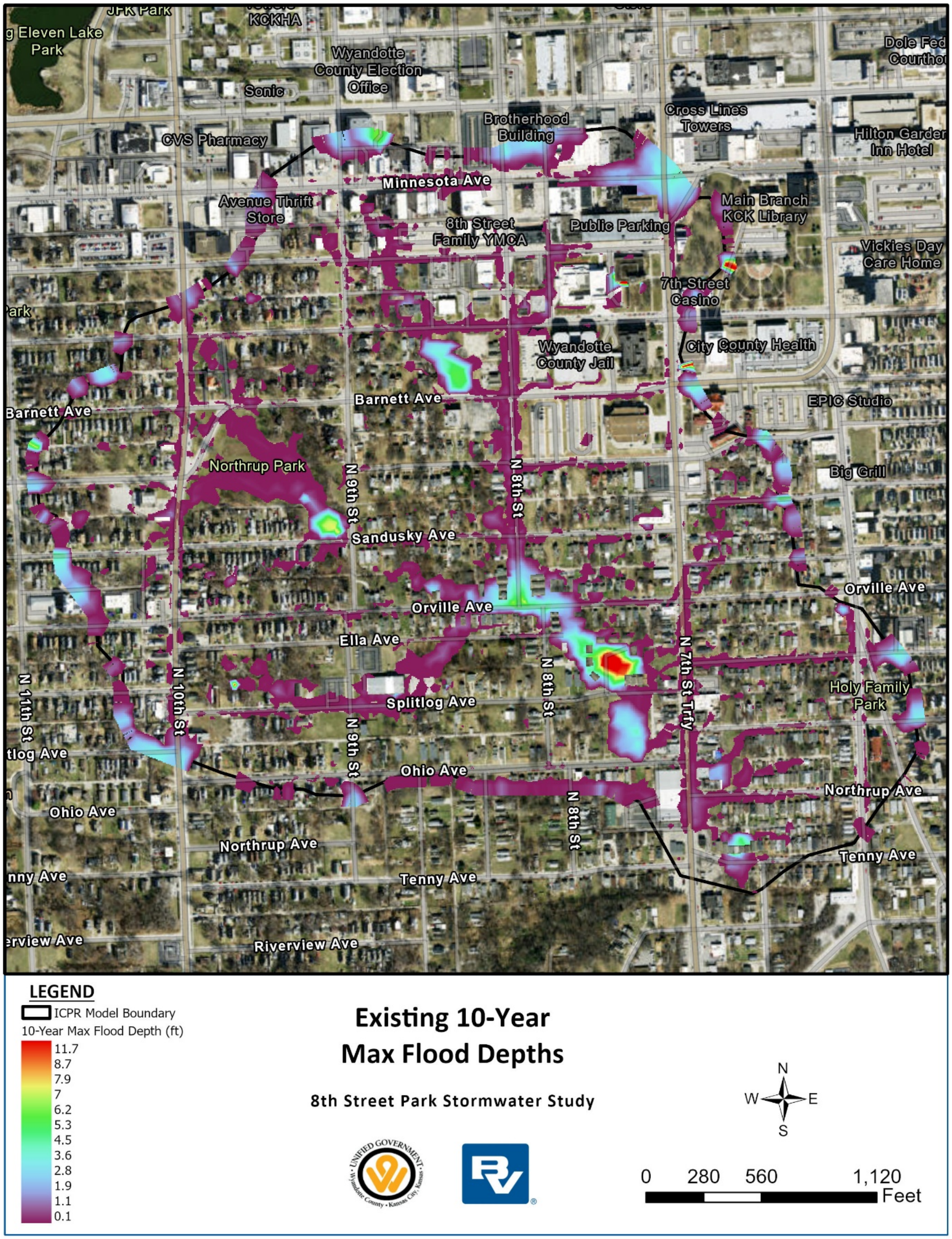
Streamline Technologies. (2023). *1D & 2D Modeling with ICPR4 Expert*. Retrieved from https://streamnologies.com/content/index.php/icpr4-expert/

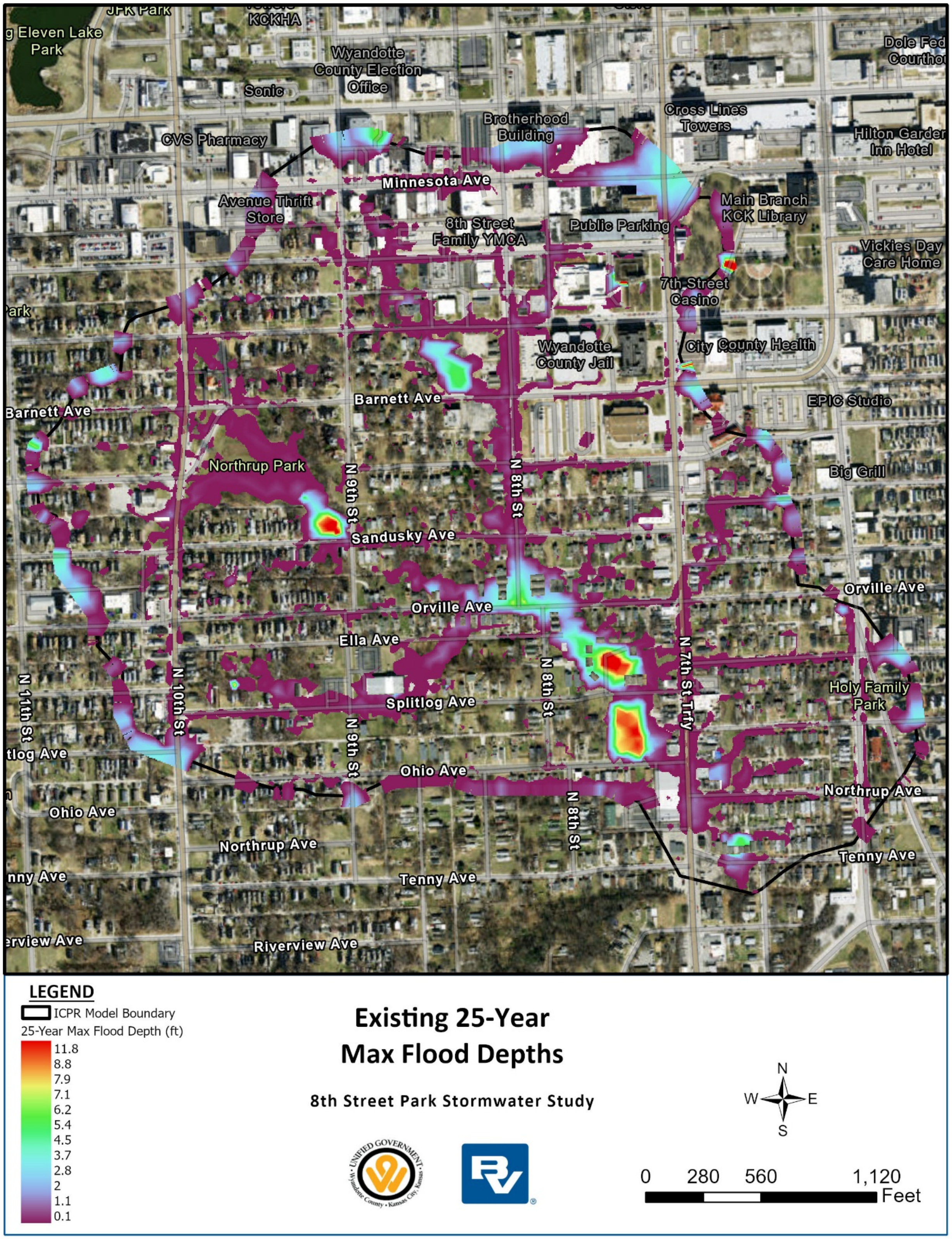
UG. (2023). *Geoportal GIS Digital Data*. Retrieved from UG of Wyandotte County and Kansas City, KS: https://www.wycokck.org/Departments/Knowledge/Maps-and-GIS/Geoportal

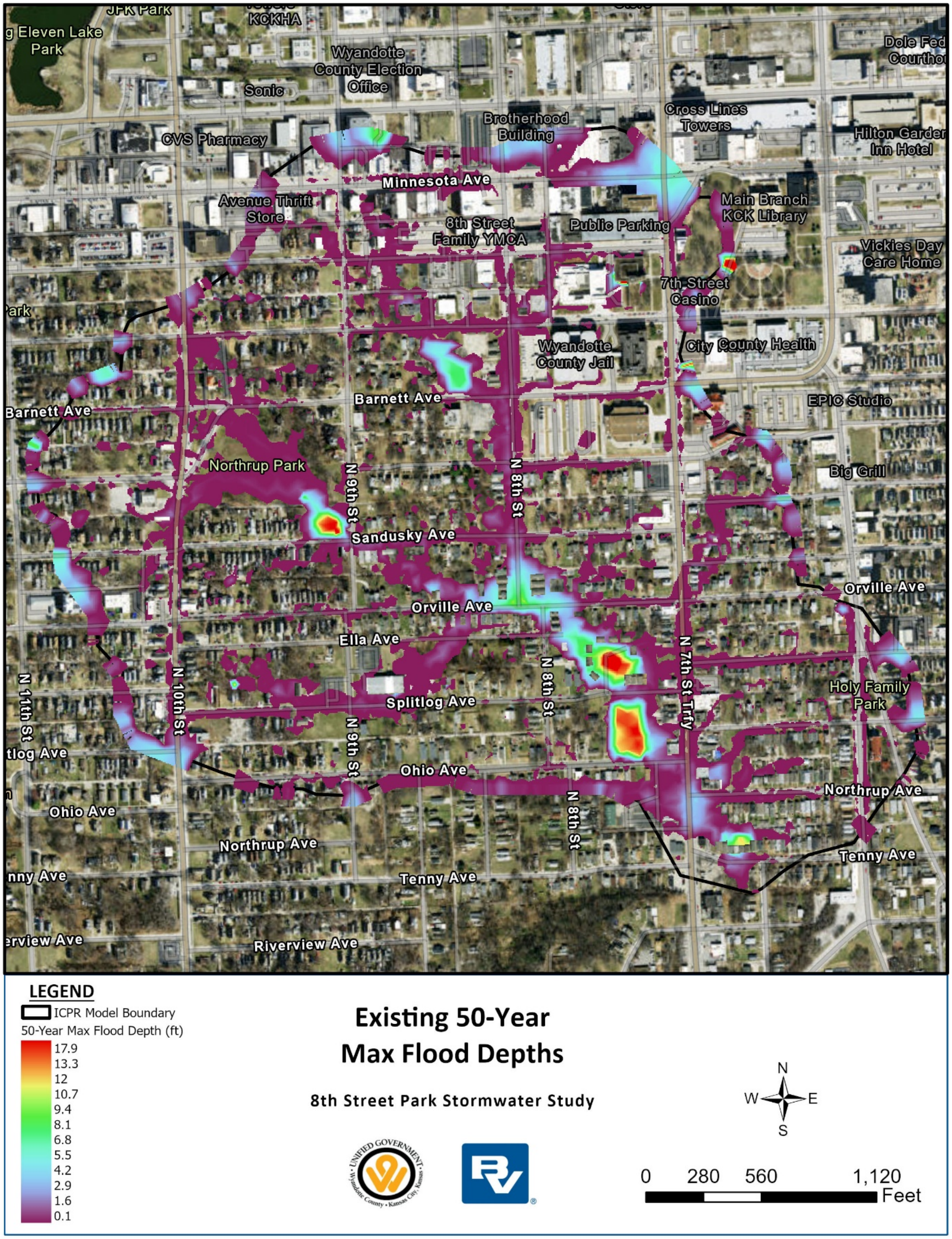
USDA. (2021). *Web Soil Survey*. Retrieved from USDA Natural Resources Conservation Service: https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Appendix A: Existing Conditions Modeling Results


LEGEND
ICPR Model Boundary
5-Year Max Flood Depth (ft)
7.9
5.9
5.3
4.8
4.2
3.6
3.1
2.5
1.9
1.3
0.8
0.1
Existing 5-Year
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet
Minnesota Ave
Barnett Ave
Northrup Park
Sandusky Ave
Orville Ave
Ella Ave
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
N 9th St
N 8th St
N 10th St
N 11th St
N 7th St Trfy
Holy Family Park
Wyandotte County Election Office
Wyandotte County Jail
Brotherhood Building
Cross Lines Towers
Main Branch KCK Library
7th Street Casino
City County Health
EPIC Studio
Big Grill
Public Parking
8th Street Family YMCA
Avenue Thrift Store
CVS Pharmacy
Sonic
Hilton Garden Inn Hotel
Vickies Day Care Home


JFK Park
KCKHA
Eleven Lake Park
Wyandotte County Election Office
Sonic
CVS Pharmacy
Brotherhood Building
Cross Lines Towers
Dole Fed Courthou
Hilton Garden Inn Hotel
Minnesota Ave
Avenue Thrift Store
8th Street Family YMCA
Public Parking
Main Branch KCK Library
Vickies Day Care Home
7th Street Casino
Wyandotte County Jail
City County Health
Barnett Ave
EPIC Studio
Northrup Park
N 9th St
N 8th St
Big Grill
Sandusky Ave
Orville Ave
Ella Ave
N 7th St Trfy
Holy Family Park
N 11th St
N 10th St
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
10-Year Max Flood Depth (ft)
11.7
8.7
7.9
7
6.2
5.3
4.5
3.6
2.8
1.9
1.1
0.1
Existing 10-Year
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet


JFK Park
KCKHA
Eleven Lake Park
Wyandotte County Election Office
Sonic
CVS Pharmacy
Brotherhood Building
Cross Lines Towers
Dole Fed Courthou
Hilton Garden Inn Hotel
Minnesota Ave
Avenue Thrift Store
8th Street Family YMCA
Public Parking
Main Branch KCK Library
Vickies Day Care Home
7th Street Casino
Wyandotte County Jail
City County Health
Barnett Ave
EPIC Studio
Northrup Park
N 9th St
N 8th St
Big Grill
Sandusky Ave
Orville Ave
Ella Ave
N 7th St Trfy
Holy Family Park
N 11th St
N 10th St
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
25-Year Max Flood Depth (ft)
11.8
8.8
7.9
7.1
6.2
5.4
4.5
3.7
2.8
2
1.1
0.1
Existing 25-Year Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet


Wyandotte County Election Office
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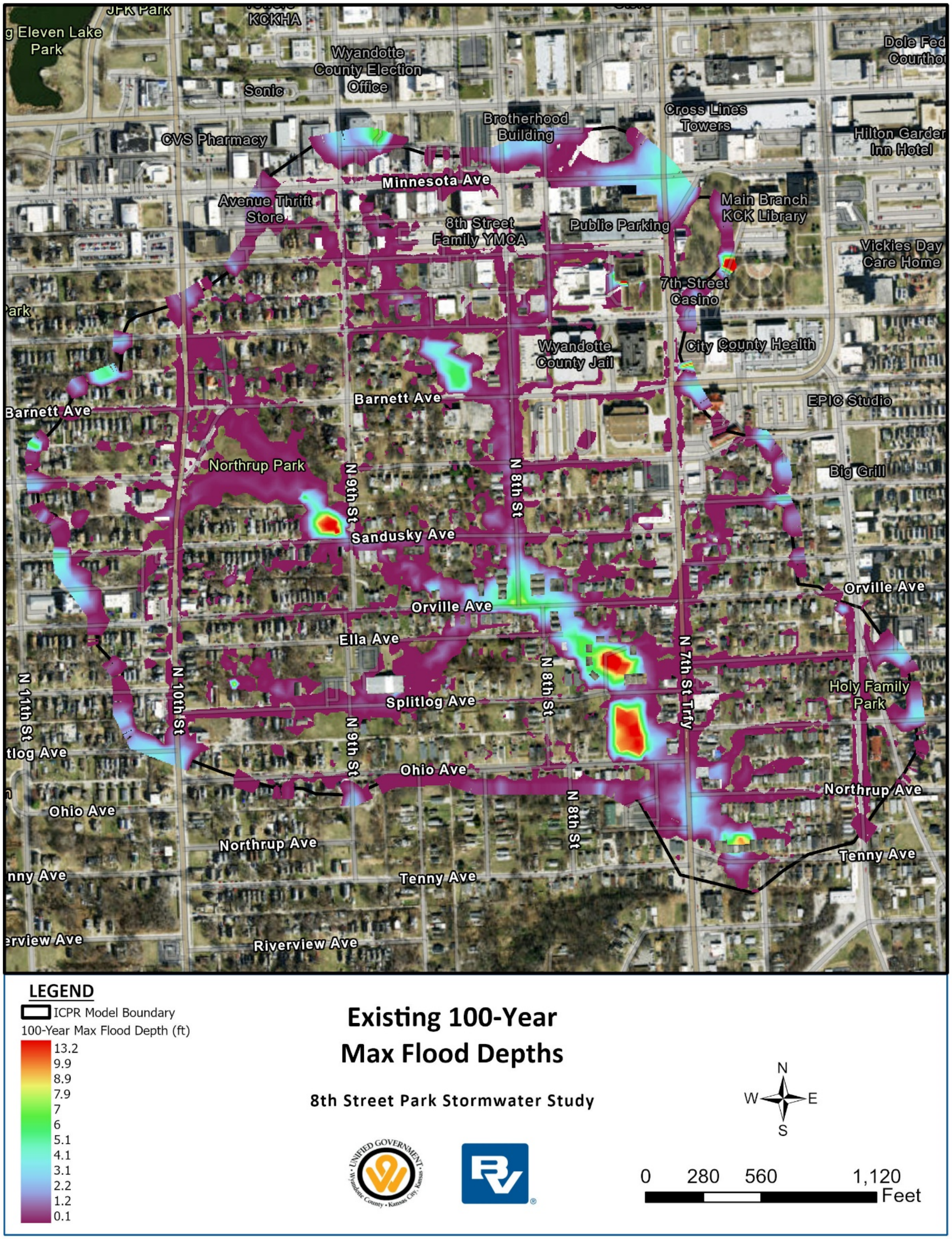
Public Parking
Main Branch KCK Library
Vickies Day Care Home
7th Street Casino
Wyandotte County Jail
City County Health
EPIC Studio
Barnett Ave
Northrup Park
N 9th St
N 8th St
Big Grill
Sandusky Ave
Orville Ave
Ella Ave
N 7th St Trfy
Holy Family Park
N 11th St
N 10th St
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
50-Year Max Flood Depth (ft)
17.9
13.3
12
10.7
9.4
8.1
6.8
5.5
4.2
2.9
1.6
0.1
Existing 50-Year
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet



JFK Park
KCKHA
Eleven Lake Park
Wyandotte County Election Office
Sonic
CVS Pharmacy
Brotherhood Building
Cross Lines Towers
Hilton Garden Inn Hotel
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Avenue Thrift Store
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Public Parking
Main Branch KCK Library
Vickies Day Care Home
7th Street Casino
Wyandotte County Jail
City County Health
EPIC Studio
Barnett Ave
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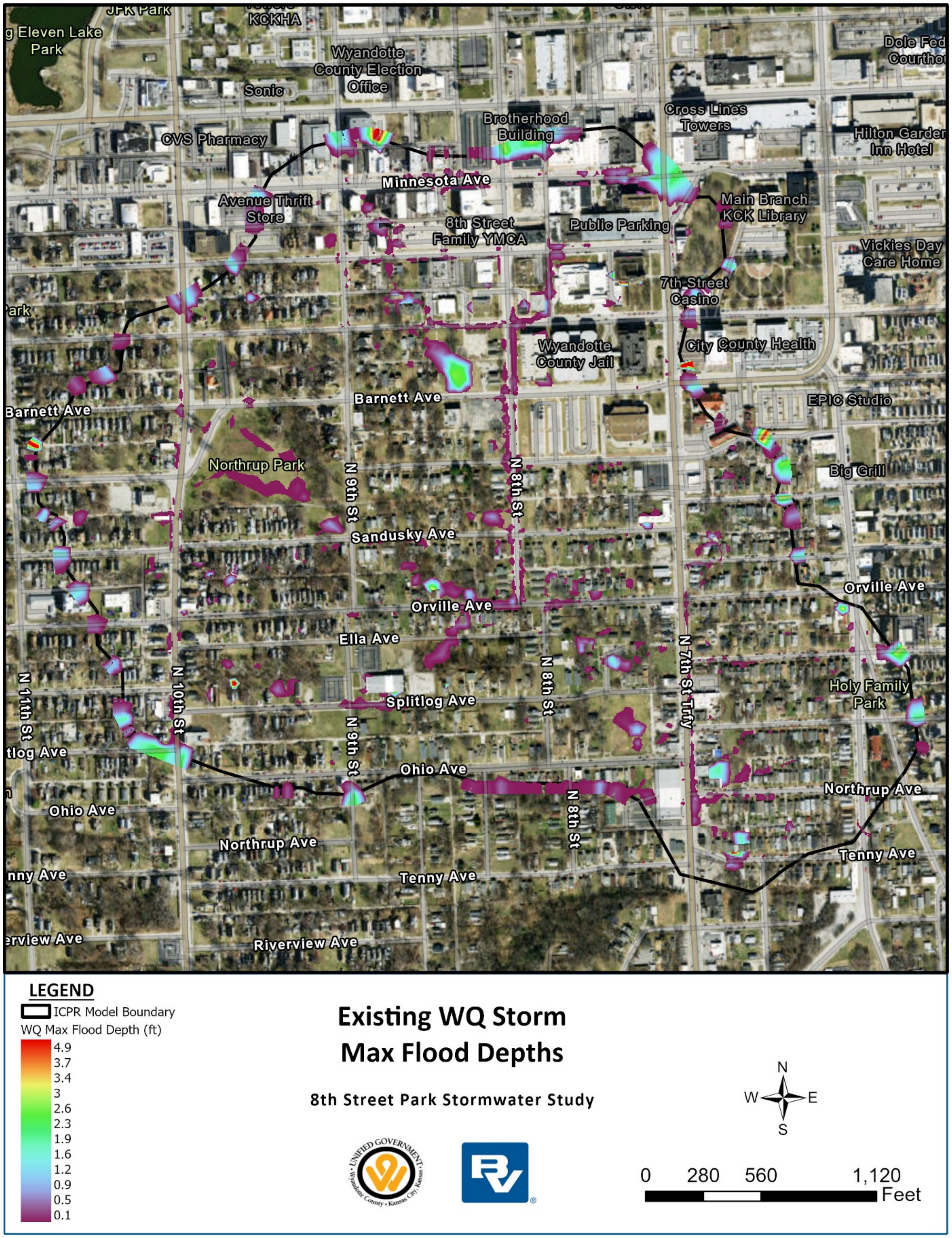
N 9th St
N 8th St
Big Grill
Sandusky Ave
Orville Ave
Ella Ave
N 11th St
N 10th St
Splitlog Ave
N 7th St Trfy
Holy Family Park
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
100-Year Max Flood Depth (ft)
13.2
9.9
8.9
7.9
7
6
5.1
4.1
3.1
2.2
1.2
0.1
Existing 100-Year Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet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Wyandotte County Election Office
Sonic
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Brotherhood Building
Cross Lines Towers
Hilton Garden Inn Hotel
CVS Pharmacy
Minnesota Ave
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Public Parking
Vickies Day Care Home
7th Street Casino
City
County Health
Wyandotte County Jail
Barnett Ave
Barnett Ave
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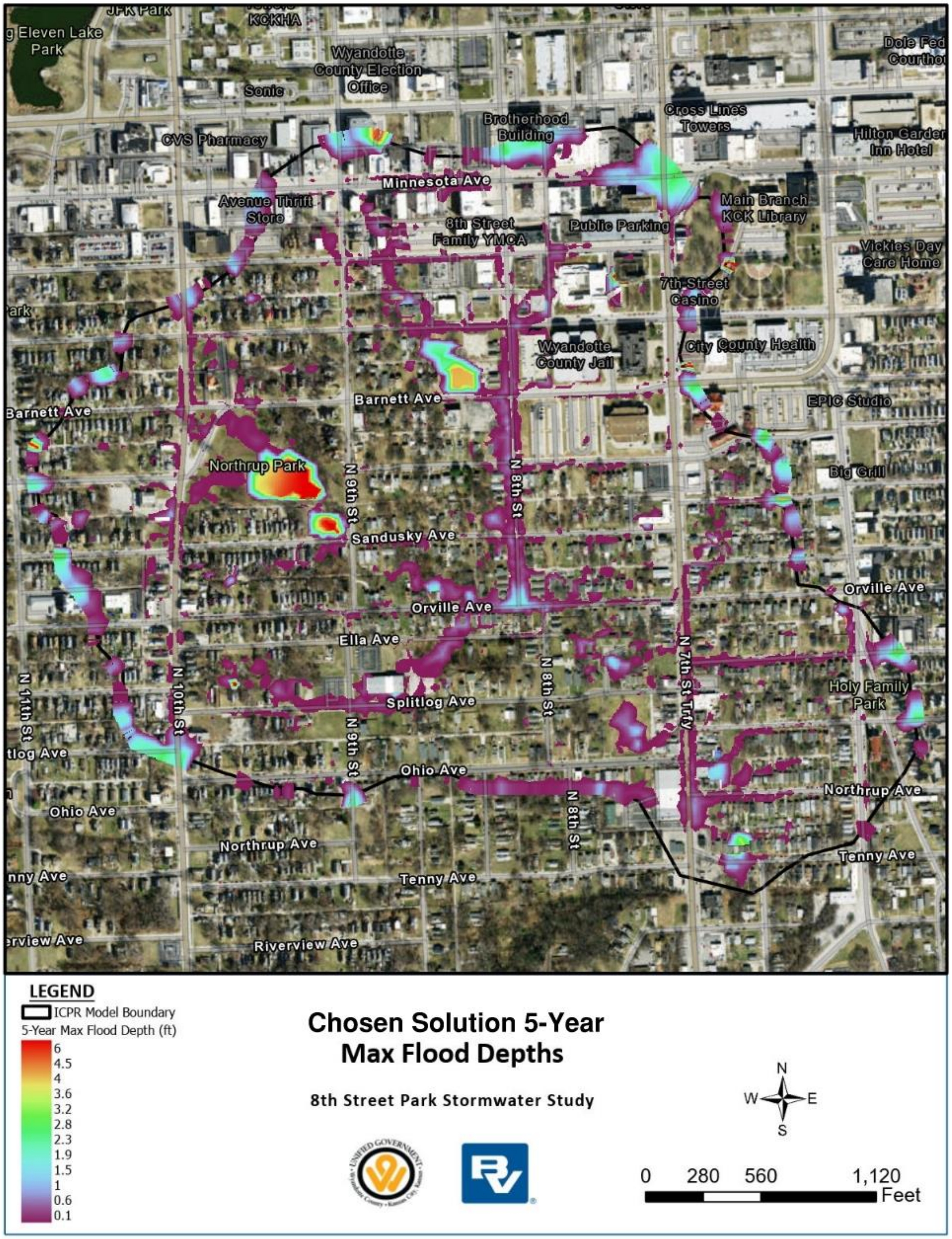
Big Grill
Sandusky Ave
Orville Ave
Orville Ave
Ella Ave
N 7th St Trfy
Holy Family Park
N 11th St
N 10th St
N 8th St
Splitlog Ave
N 9th St
Ohio Ave
Ohio Ave
Northrup Ave
Northrup Ave
N 8th St
Tenny Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
WQ Max Flood Depth (ft)
4.9
3.7
3.4
3
2.6
2.3
1.9
1.6
1.2
0.9
0.5
0.1
Existing WQ Storm
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet

Appendix B: Alternative 2 Modeling Results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Brotherhood Building
Cross Lines Towers
Hilton Garden Inn Hotel
Minnesota Ave
Avenue Thrift Store
8th Street Family YMCA
Public Parking
Main Branch KCK Library
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7th Street Casino
City County Health
Wyandotte County Jail
Barnett Ave
EPIC Studio
Northrup Park
Big Grill
N 9th St
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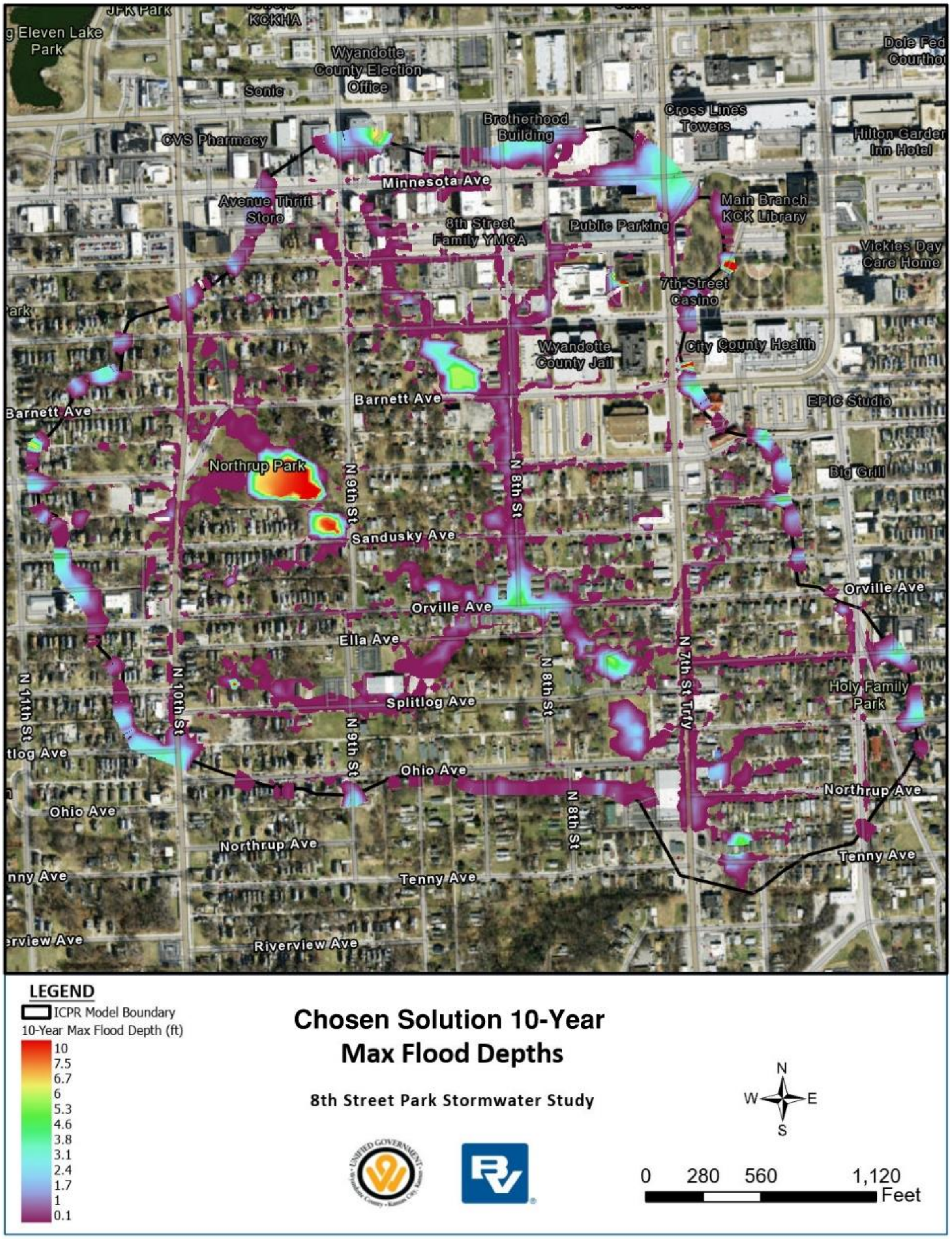
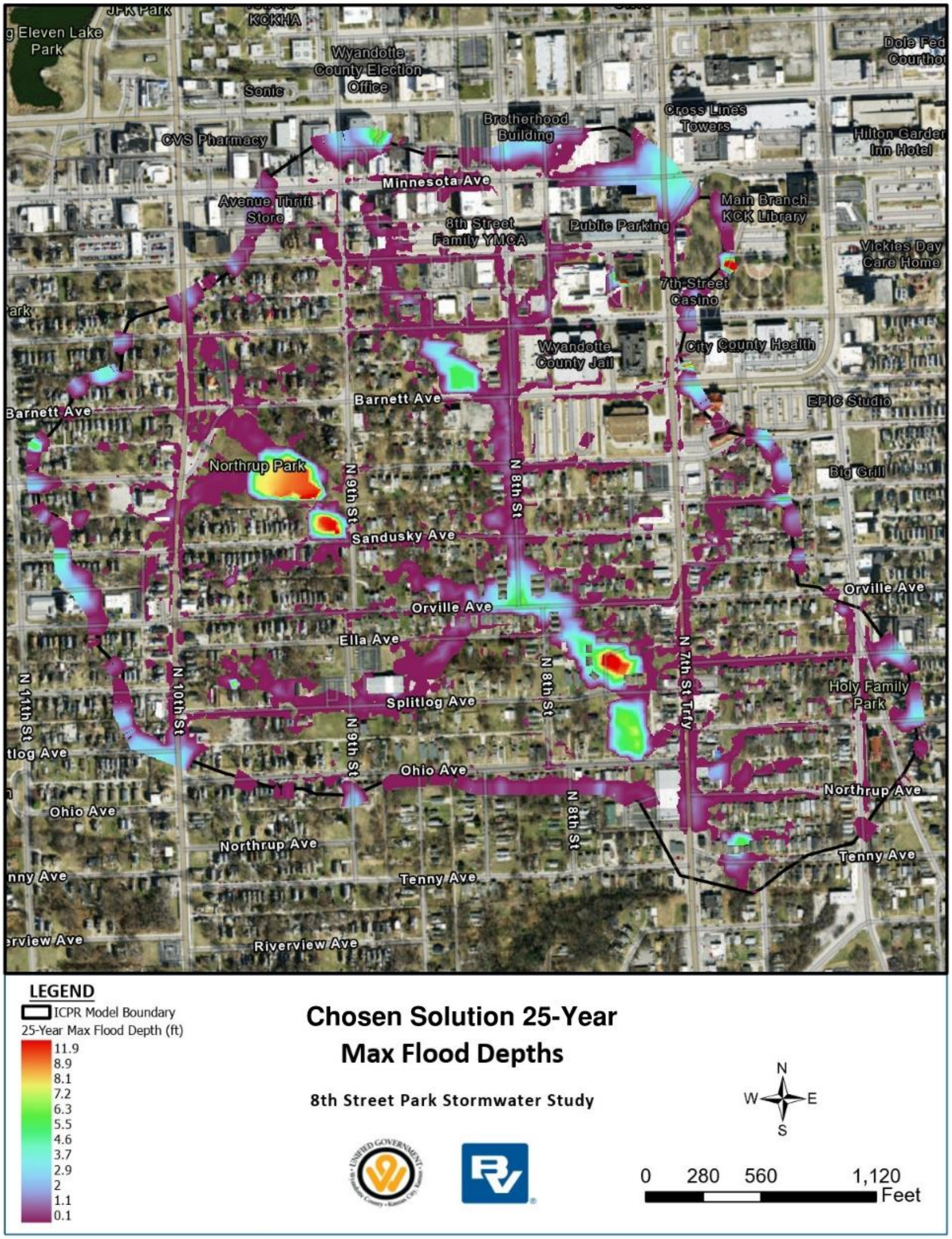
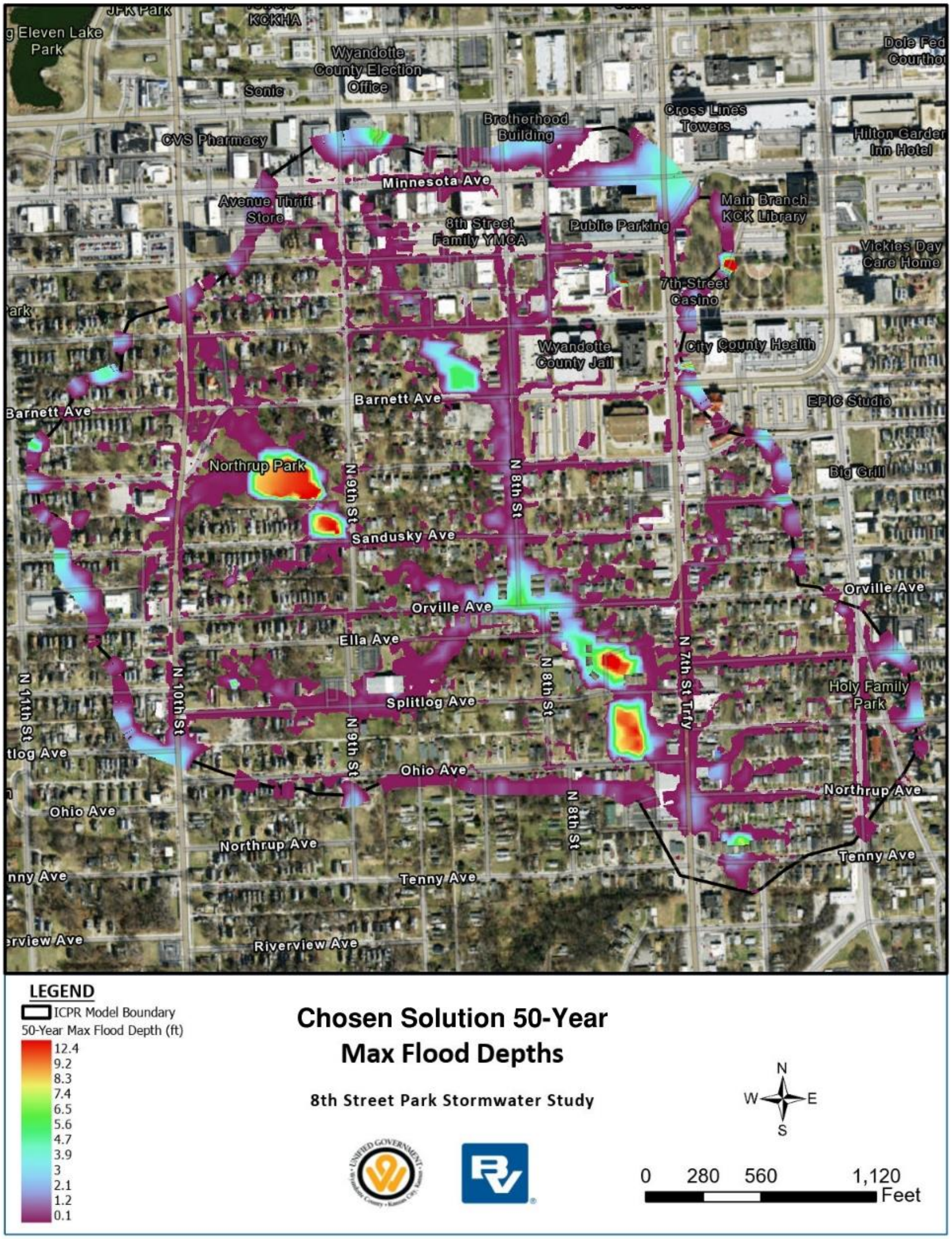
Sandusky Ave
Orville Ave
Ella Ave
N 7th St Trfy
Holy Family Park
N 11th St
N 10th St
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
5-Year Max Flood Depth (ft)
6
4.5
4
3.6
3.2
2.8
2.3
1.9
1.5
1
0.6
0.1
Chosen Solution 5-Year
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet


KCKHA
Wyandotte County Election Office
Sonic
CVS Pharmacy
Brotherhood Building
Cross Lines Towers
Hilton Garden Inn Hotel
Minnesota Ave
Avenue Thrift Store
8th Street Family YMCA
Public Parking
Main Branch KCK Library
Vickies Day Care Home
7th Street Casino
Wyandotte County Jail
City County Health
EPIC Studio
Barnett Ave
Barnett Ave
Northrup Park
N 9th St
N 8th St
Big Grill
Sandusky Ave
Orville Ave
Orville Ave
Ella Ave
N 8th St
N 7th St Trfy
Holy Family Park
N 11th St
N 10th St
Splitlog Ave
N 9th St
Ohio Ave
Ohio Ave
Northrup Ave
N 8th St
Northrup Ave
Tenny Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
10-Year Max Flood Depth (ft)
10
7.5
6.7
6
5.3
4.6
3.8
3.1
2.4
1.7
1
0.1
Chosen Solution 10-Year Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet


LEGEND
ICPR Model Boundary
25-Year Max Flood Depth (ft)
11.9
8.9
8.1
7.2
6.3
5.5
4.6
3.7
2.9
2
1.1
0.1
Chosen Solution 25-Year
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet
Minnesota Ave
Barnett Ave
Northrup Park
Sandusky Ave
Orville Ave
Ella Ave
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
N 10th St
N 9th St
N 8th St
N 7th St Trfy
Wyandotte County Jail
City County Health
Main Branch KCK Library
7th Street Casino
Holy Family Park
Brotherhood Building
Cross Lines Towers
Public Parking
8th Street Family YMCA
CVS Pharmacy
Avenue Thrift Store
Wyandotte County Election Office
Sonic
EPIC Studio
Big Grill
Vickies Day Care Home
Hilton Garden Inn Hotel


Minnesota Ave
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Orville Ave
Ella Ave
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
N 9th St
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N 10th St
N 11th St
N 7th St Trfy
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Public Parking
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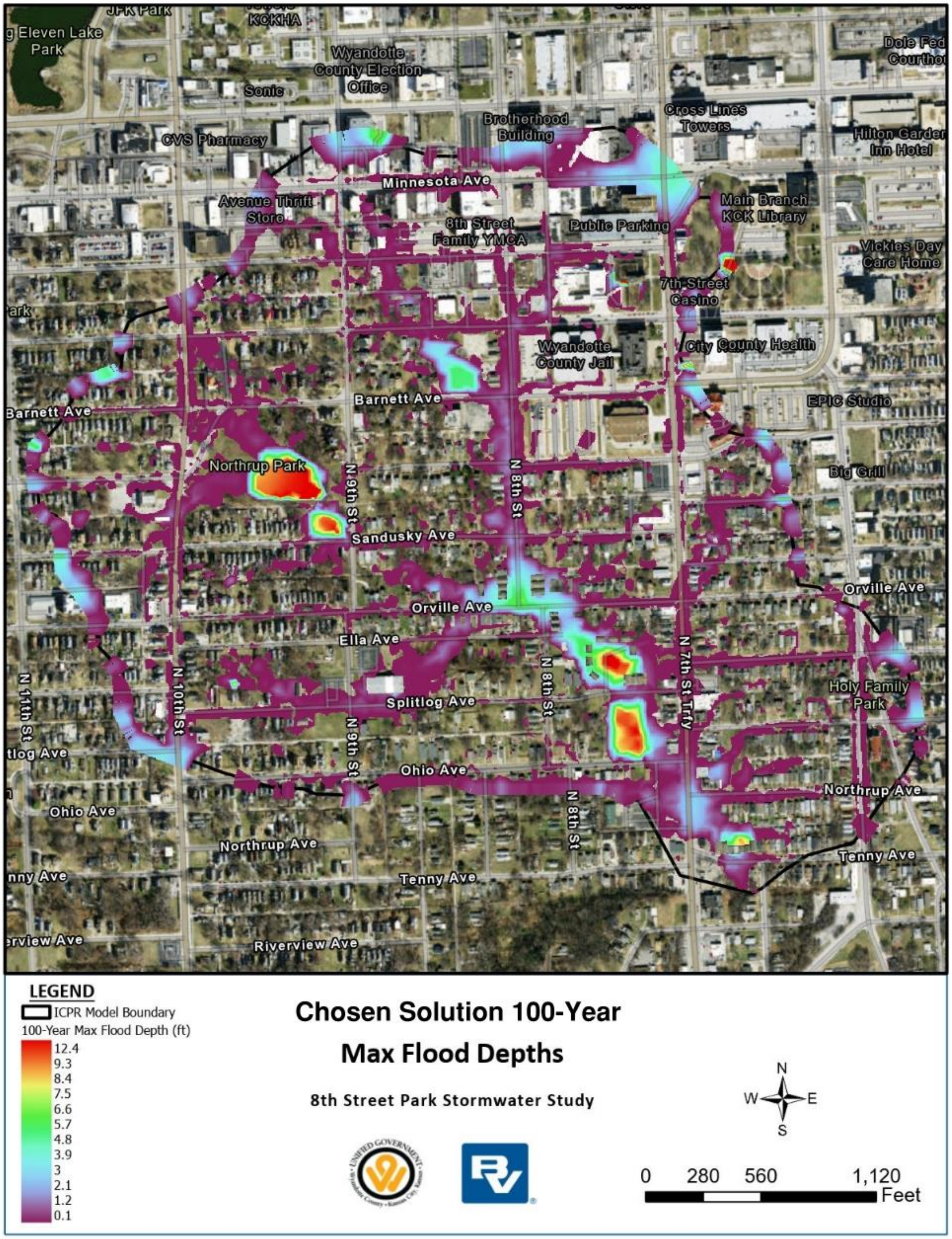
Vickies Day Care Home
7th Street Casino
Wyandotte County Jail
City County Health
EPIC Studio
Big Grill
Holy Family Park
LEGEND
ICPR Model Boundary
50-Year Max Flood Depth (ft)
12.4
9.2
8.3
7.4
6.5
5.6
4.7
3.9
3
2.1
1.2
0.1
Chosen Solution 50-Year
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet



Wyandotte County Election Office
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Hilton Garden Inn Hotel
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N 8th St
Sandusky Ave
Orville Ave
Ella Ave
N 7th St Trfy
Holy Family Park
N 11th St
N 10th St
Splitlog Ave
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
100-Year Max Flood Depth (ft)
12.4
9.3
8.4
7.5
6.6
5.7
4.8
3.9
3
2.1
1.2
0.1
Chosen Solution 100-Year
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet


Eleven Lake Park
KCKHA
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7th Street Casino
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Orville Ave
Ella Ave
Holy Family Park
N 11th St
N 10th St
Splitlog Ave
N 7th St Trfy
Ohio Ave
Northrup Ave
Tenny Ave
Riverview Ave
LEGEND
ICPR Model Boundary
WQ Max Flood Depth (ft)
5.9
4.4
4
3.6
3.2
2.7
2.3
1.9
1.5
1
0.6
0.1
Chosen Solution WQ Storm
Max Flood Depths
8th Street Park Stormwater Study
N
W
E
S
0
280
560
1,120
Feet

Appendix C: Digital Submittal

Digital Submittal Includes:

1. 2D ICPR Model with six simulations for each scenario, one simulation for each design storm:

- Water Quality Storm
- 5-Year Storm
- 10-Year Storm
- 25-Year Storm
- 50-Year Storm
- 100-Year Storm

2. ICPR Model inputs as:

- ArcGIS .mxd files
- ArcGIS .mpk files
- ArcGIS shapefiles
- ArcGIS geodatabase

3. ICPR Model exports as:

- .CSV files