City of Kinston Flood Resiliency Study

KINSTON

NORTH CAROLINA

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Prepared for:

EDF
ENVIRONMENTAL DEFENSE FUND®
Finding the ways that work

Prepared by:

EPR
Ecosystem Planning & Restoration

Evaluating Flood Mitigation Needs for Adkin Branch – Summary

- Problem: More frequent, lower volume storm events lead to road flooding in the Adkin Branch watershed, particularly at certain road crossings.
    - Recent storm events in August and November 2020.

- Solution: Conduct updated hydrologic and hydraulic modeling to determine potential causes of the problem and prioritize actions to address them.

1. Model Development:
    - Model accounts for % impervious surface and watershed shape.
    - Model has similar peak discharge results for 10-yr storm as compared to effective FEMA model, though 100-yr storm discharge varies significantly.
    - Adkin Branch watershed is long and thin—this shape routes water to Adkin Branch faster and all at once, leading to amplification of peak flows.

2. Model Analysis and Results
    - Focuses on 10-yr storm event; similar to targeted storm type.
    - Culverts at N. Heritage St., N. Queen St., and MLK Blvd would not pass the modeled 10-yr storm flows, even using a modeled minimum bridge deck elevation greater than the actual culvert top elevation.
    - Lincoln St. bridge passes the modeled 10- and 25-yr storm flow.

3. Flood Mitigation – Detention Scenarios
    - Determine the volume of water going over the roadway rather than through the culvert for the modeled 10-yr discharge at affected crossings → initial storage volumes to prevent road over topping.
    - Moderate Detention Scenario [Scenario #1]:
        - Evaluate watershed for open space along Adkin Branch for detention locations, upstream of MLK Blvd.
        - Detention options are not sufficient to prevent road overtopping at the culvert locations for the modeled 10-yr storm, using 8-inch average depth of detention.
    - Aggressive Detention Scenario [Scenario #2]:
        - Theoretical exercise to determine storage volume needed to produce a no flooding result.
        - Approximately 10% of the drainage area upstream of MLK Blvd. would be required for storage to meet flood reduction needs.
        - Significant backwater effects would still occur.

4. Flood Mitigation -- Modified Crossing Scenarios
   - Modified Crossings Only [Scenario #3]
     - Replace culverts at Crawford St., N. Heritage St., N. Queen St., E. Highland Ave., and MLK Blvd. with a simplified full-span bridge in the model.
     - Drastic reductions in flood stage seen at N. Heritage St. and MLK Blvd. and moderate reductions seen at E. Highland Ave. and Crawford St. for 10-yr storm.
     - No decrease in flooding at N. Queen St., as the cause of constriction is the channelization upstream and not the culvert.
     - Effects greatest at crossings, more muted system-wide.
   - Modified Crossings with Moderate Detention [Scenario #4]
     - Replaced culverts stated above and layered in moderate detention [Scenario 1] in upper watershed
     - Similar results seen: greatest effect at the crossings but minor system wide reductions are also apparent in the downstream area

5. Flood Mitigation – Floodplain Excavation Scenarios
   - Looked at undeveloped, wooded areas along Adkin Branch between N. Heritage St. and N. Queen St. only.
     - First analysis included excavation on both banks to fullest extent possible [Scenario #5]
     - Second analysis included excavation on both banks to fullest extent possible with moderate detention [Scenario #1] layered in [Scenario #6]
   - Road overtopping still occurs with 10-yr storm at N. Queen St. with excavation + moderate detention [Scenario #6], but it occurs in two peaks, with the water surface receding below the road elevation in between.
   - Benefits may be more significant for more frequent (less than the 10-yr) events, including the event in August 2020.
   - Benefit may increase if used in conjunction with modified crossings [Scenario #3] instead of moderate detention [Scenario #1]

6. Conclusions and Recommendations
   - Aggressive Detention [Scenario #2] shows the greatest flood reduction potential throughout the entire system; however, this scenario may not be practically applied.
   - Moderate detention [Scenario #1], crossing modifications [Scenario #3], and floodplain excavation [Scenarios #5] have similar overall flood reduction benefits to the system, though exact effects differ spatially.
   - Recommendation is to discuss with community and leaders potential impacts with most practical application being a combination of floodplain excavation along with select crossing modifications in vicinity of N. Heritage and N. Queen Streets.

TECHNICAL MEMORANDUM

Evaluating Flood Mitigation Needs for Adkin Branch

Date: February 26, 2021

Prepared For: Environmental Defense Fund and City of Kinston

Prepared By: Tami Norton, PE & CFM and Cidney Jones, PE & CFM
Ecosystem Planning and Restoration

This technical memorandum describes EPR's work in developing hydrologic and hydraulic models for the Adkin Branch watershed and evaluating options for alleviating flood risk. The modeling performed by EPR evaluated possible alternatives to address the critical flooding issues being experienced by the City. EPR has completed: 1) data collection and processing; 2) hydrologic model development using HEC-HMS v4.6.1, including a review of the basin delineations and stormwater networks within the City; 3) hydraulic model development using HEC-RAS v5.0.7; 4) hydrologic and hydraulic (H&H) model calibration using the best available data; and 5) an evaluation of hydraulic and hydrologic alternatives for flood mitigation. The exhibits provided in **Attachment 1** depict the modeling results showing inundation limits for the following hydrologic and hydraulic scenarios:

Exhibit 1 – Existing Conditions Floodplain Mapping – includes August 2020 rainfall event, 10-, 25-, and 100-year return frequencies for existing conditions

Exhibit 2 – August 10, 2020 Rainfall Event, Detention Only – includes moderate and aggressive detention scenarios compared to the existing conditions

Exhibit 3 – 10-year Floodplain, Detention Only – includes moderate and aggressive detention scenarios compared to the existing conditions

Exhibit 4 – August 10, 2020 Rainfall Event, Crossing Modification – includes removal/enlargement of channel crossing only and removal/enlargement of channel crossing with moderate detention scenarios compared to the existing conditions

Exhibit 5 – 10-year Floodplain, Crossing Modification - includes removal/enlargement of channel crossing only and removal/enlargement of channel crossing with moderate detention scenarios compared to the existing conditions

Exhibit 6 – August 10, 2020 Rainfall Event, Floodplain Excavation – includes floodplain excavation only and floodplain excavation with moderate detention scenarios compared to the existing conditions

Exhibit 7 – 10-year Floodplain, Floodplain Excavation - includes floodplain excavation only and floodplain excavation with moderate detention scenarios compared to the existing conditions

Details for each step of model development are summarized in the following sections.

Data Collection and Processing

Various data sets were conditioned by our modeling staff in ESRI's Geographic Information System (ArcGIS) environment to determine the Adkin Branch watershed size and characteristics, flow paths and sub-catchment connectivity, precipitation, evaporation, and infiltration estimations. A digital elevation model (DEM) of the Adkin

Branch watershed was created from the U.S. Geological Survey (USGS) 3m National Elevation Dataset (LiDAR 2014, downloaded from the National Map). Flow accumulation and stream raster datasets were created to show overland flow paths and delineate the overall watershed and subbasins within the Adkin Branch watershed. These products were reviewed alongside the City stormwater network and waterways shapefiles to further define drainage networks for hydrologic routing in the HEC-HMS model. It was noted in the proposal that drainage ditches under Villa Drive and near Crestwood Drive may introduce flow into Adkin Branch; however, through discussions with the City it was determined the drainage ditches are not to be included in the Adkin Branch watershed.

A hydraulic model for Adkin Branch, previously developed by others utilizing HEC-RAS v4.0.0 in 2013, was used to determine base flood elevations for the current Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) panels. The model was revised with a Letter of Map Revision (LOMR) 13-04-6410P in 2014 to incorporate a stream restoration project between MLK Blvd (Highway 11) and Lincoln Street, which added a pedestrian bridge but also generally lowered flood water surface elevations. With the acceptance and integration of the LOMR results into the current FEMA Flood Insurance Study (FIS) and FIRM, the associated hydraulic model is considered the effective model. Detailed study methods were utilized to develop the model, meaning all bridges and culverts were field surveyed and bathymetric data were collected on Adkin Branch to inform the model. Therefore, EPR began with this effective hydraulic model as a baseline while conditioning current, available data sets in ArcGIS to prepare an existing conditions model for evaluating the hydraulics of Adkin Branch. The existing conditions model was georeferenced for ease of comparing the conditioned data sets and reviewed for accuracy. The 2014 DEM for the watershed was used to revise the overbank areas of the cross-sections. Roughness values in the effective FEMA model were evaluated using recent aerial imagery and were found to be reasonable. The flow path, channel shape, channel roughness, floodplain extent, floodplain roughness, and structure locations were confirmed against recent aerial imagery and pictures from site visits.

Precipitation data for the 10-, 25-, and 100-year, 24-hour frequency events were obtained from the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14, Volume 2, Version 3. Additionally, hourly precipitation data were downloaded from the KINS Cunningham Research Station located in Kinston for July 30, 2020 through November 14, 2020.[1] City officials had reported recent flood events on August 3, 2020; August 10, 2020; October 25, 2020; and November 12, 2020. Analysis of the available hourly rainfall data for these events indicated that:

- The event on August 10, 2020 was 2.56 inches in 3-hours, which corresponds to between a 2- and 5-year recurrence interval event (20-50 percent annual chance).
- The event on November 12, 2020 was 5.91 inches in 24-hours, which corresponds to between a 5- and 10-year recurrence interval event (10-20 percent annual chance).

The August and November rainfall events were used as calibration events as described in the Hydraulic Model Calibration section below and in **Attachment 2**.

[1] NC State Climate Office of North Carolina, NC State University CRONOS database.

Hydrologic Model Development

The subbasin delineation of the Adkin Branch watershed is shown in Figure 1.

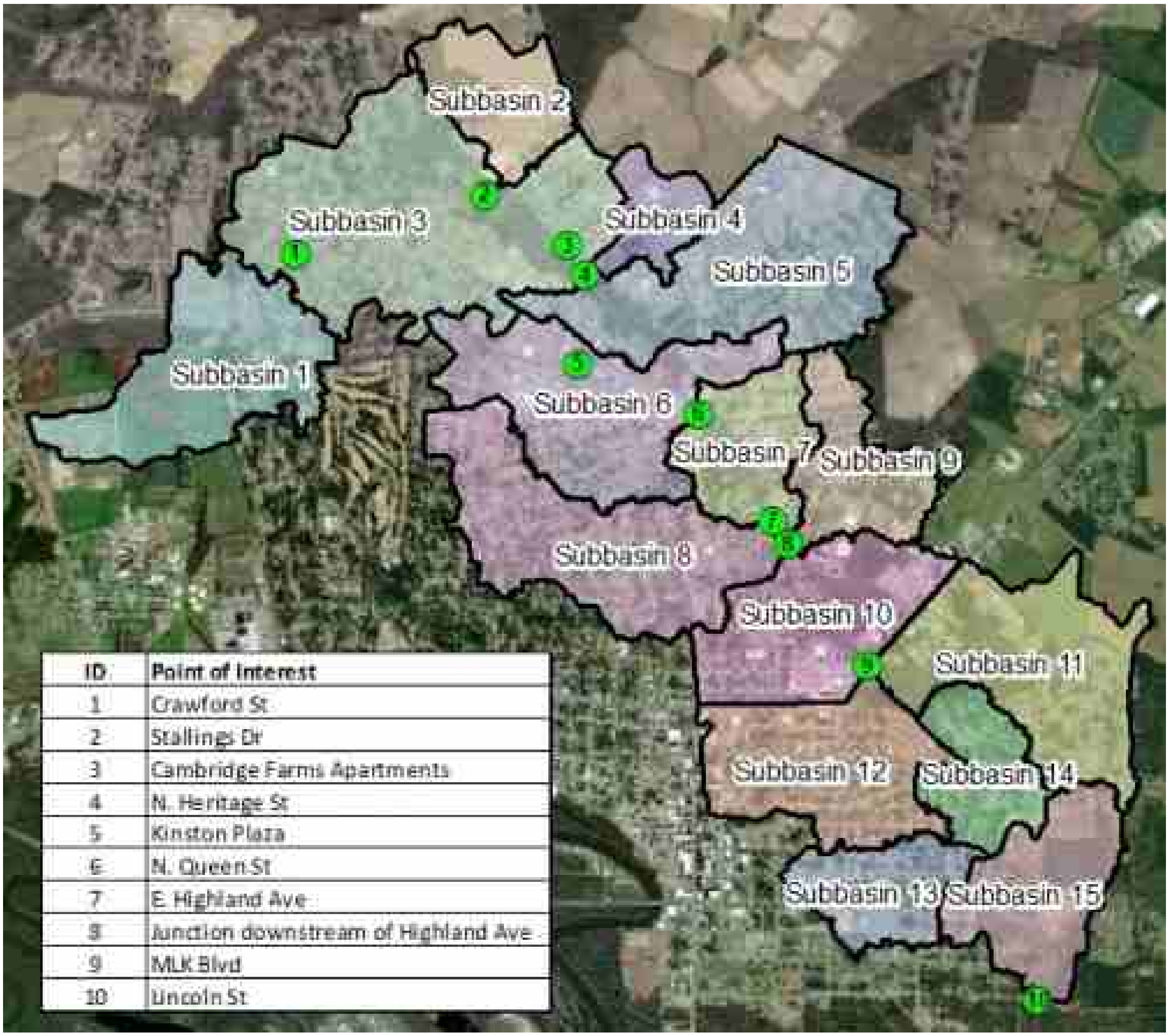

Figure 1. Subbasin Delineation for Adkin Branch HEC-HMS Model

The SCS Curve Number method was used to estimate infiltration losses based on land use and hydrologic soil group. Curve numbers were determined for each subbasin following the methodology laid out in Doll et al. (2020) using the 2016 National Land Cover Dataset (NLCD) and the U.S. Department of Agriculture Natural Resources

Conservation Service Web Soil Survey.[2] Initial abstraction was calculated from the resulting curve numbers. The Soil Conservation Service (SCS) Unit Hydrograph transform method was used to calculate lag times for each sub-basin. Flow paths were delineated using GIS based tools and revised to reflect existing stormwater system data, where available. The Muskingum-Cunge flood routing method was used to route flows from combination point to combination point in the model for all reaches except Reach 2, between North Heritage Street and North Queen Street. The Modified Puls routing method was used for Reach 2 in order to investigate the benefits of floodplain excavation. All values used to develop the hydrologic model are provided in **Attachment 3**. Due to lack of available data, baseflow was not incorporated into the hydrologic model.

Hypothetical storms were used to model 24-hour duration flood events for the 10-year, 25-year, 50-year, and 100-year events using SCS Storm Type II. Specified hyetographs were also used to model the recent storm events on August 10 and November 12, 2020. The specified hyetographs from these two recent storm events and precipitation depths from NOAA Atlas 14 for each storm event are provided in **Attachment 3**.

Note that the hydrologic model focuses on flooding in Adkin Branch only and is not sufficiently detailed to predict street flooding or evaluate stormwater drainage network capacity.

<u>Hydrologic Model Calibration</u>

The Adkin Branch watershed is an ungauged watershed and the nearest USGS gages are located on the Neuse River, Contentnea Creek, and the Trent River. The characteristics of the contributing watersheds upstream of these gages differs significantly from the Adkin Branch watershed and are not relevant for calibration of the Adkin Branch hydrologic model.

To date, there has been considerable variation in the available hydrology data for Adkin Branch. According to the Lenoir County FIS dated April 16, 2013, the effective flowrates for Adkin Branch were derived from USGS urban regression equations (USGS 1996).[3] The peak flowrates published in the June 19, 2020 FIS match the 2013 FIS published flowrates and it is therefore assumed that the 2020 peak flowrates were derived from the same USGS regression equations. Urban peak flowrates from StreamStats for Adkin Branch are derived from 2014 USGS regression equations (USGS 2014)[4] and are approximately half of the peak flowrates published in the 2013 and 2020 FIS. This variability in datasets has likely caused some uncertainty in floodplain management for the City in the past.

EPR's hydrologic model provides a more comprehensive analysis of the watershed compared to regional regression equations, providing more detailed, watershed-specific hydrologic routing. Flow rates from the effective FEMA FIS, USGS regression equations, and hydrologic model of Adkin Branch at four (4) crossing of interest are summarized and compared in Table 1.

[2] Doll, B., D. Line, and J. Kurki-Fox. 2020. Evaluating the Capacity of Natural Infrastructure for Flood Abatement at the Watershed Scale: Goldsboro, NC Case Study. Final Report. Environmental Defense Fund. Raleigh, NC.

[3] USGS 1996. Estimation of flood-frequency characteristics of small urban streams in North Carolina. Water Resources Investigations Report 96-4084.

[4] USGS 2014. Methods for estimating the magnitude and frequency of floods for urban and small, rural streams in Georgia, South Carolina, and North Carolina, 2011 (ver. 1.1, March 2014). Scientific Investigations Report 2014-5030.

Table 1 - Model Calibration Peak Discharges (cfs)

Crossing of Interest	Drainage Area (mi^2)	10-year				100-year			
		HEC-HMS	FEMA Effective Model	USGS 2014 - Upper 95% Prediction Interval	USGS 2014	HEC-HMS	FEMA Effective Model	USGS 2014 - Upper 95% Prediction Interval	USGS 2014
North Heritage Street	1.9	1,165	739 (63%)	735 (63%)	367 (32%)	2,450	1,458 (60%)	1,420 (58%)	640 (26%)
North Queen Street	2.48	1,584	1,211 (76%)	928 (59%)	571 (36%)	3,423	2,220 (65%)	2,090 (61%)	928 (27%)
MLK Blvd.	3.75	1,777	1,420 (80%)	1,540 (87%)	759 (43%)	4,286	2,548 (59%)	2,750 (64%)	1,220 (28%)
Lincoln Street	5.21	1,837	1,918 (105%)	1,890 (103%)	933 (51%)	4,399	3,282 (75%)	3,370 (77%)	1,490 (34%)

Note – Percentages shown are of the predicted HEC-HMS flow with 100% being an exact match.

The initial hydrologic model results for conditions in the Adkin Branch watershed more closely match the values from the FEMA effective modeling than those generated by StreamStats and the 2014 USGS regression equations. Lincoln Street is the most downstream location of the HEC-HMS model and shows similar peak discharge for the 10-year flood event compared to the FEMA value and the upper prediction interval for the USGS (2014) regression equations. For the 100-year, however, the modeled results vary significantly from the FEMA values and the USGS (2014) upper prediction interval. This is not unusual for hydrologic modeling of urban watersheds, and for Adkin Branch specifically. Regression equations are predictions based on percent impervious cover and do not account for watershed shape (time of concentration) and relative arrival time of runoff at the receiving waters (coincident peaks flows). The Adkin Branch watershed is relatively long and thin; therefore, during a rainfall event, water is quickly transported directly to Adkin Branch, causing large volumes of water to arrive at the stream at the same moment in time, resulting in an amplification of peak flows. Figure 2 shows the model results for the 10-year flood event at five junctions within the hydrologic model: the four (4) crossings of interest and the junction with the highest peak flood value – located downstream of Highland Avenue where the storm drain that runs through Emma Webb park joins Adkin Branch (see Figure 1). The peak flow for North Heritage St, North Queen St, and the Highland all occur around 1300 and even though North Queen Street is downstream of the North Heritage Street crossing, the peak at the North Queen Street culvert occurs before the peak flow occurs at the North Heritage Street culvert. This occurs because the North Queen Street culvert is the recipient of the highest percent impervious cover coming in from the mall/shopping plaza (Kinston Plaza; Subbasin 6 in Figure 1) and a relatively short time of concentration (see Attachment 2). The coincident timing of these watersheds creates the magnitude amplification in flow seen in the graph at North Heritage St, N Queen St, and the Highland Ave Junction whereas the downstream graphs (MLK Blvd and Lincoln St) accommodate the additional flow through longer residence time of the event instead of flow amplification. Therefore this watershed timing analysis explains why when comparing to the regression equations, the HEC-HMS model is predicting larger flows in the upper watershed while becoming more congruent in the lower watershed when all impervious surface has been fully accounted.

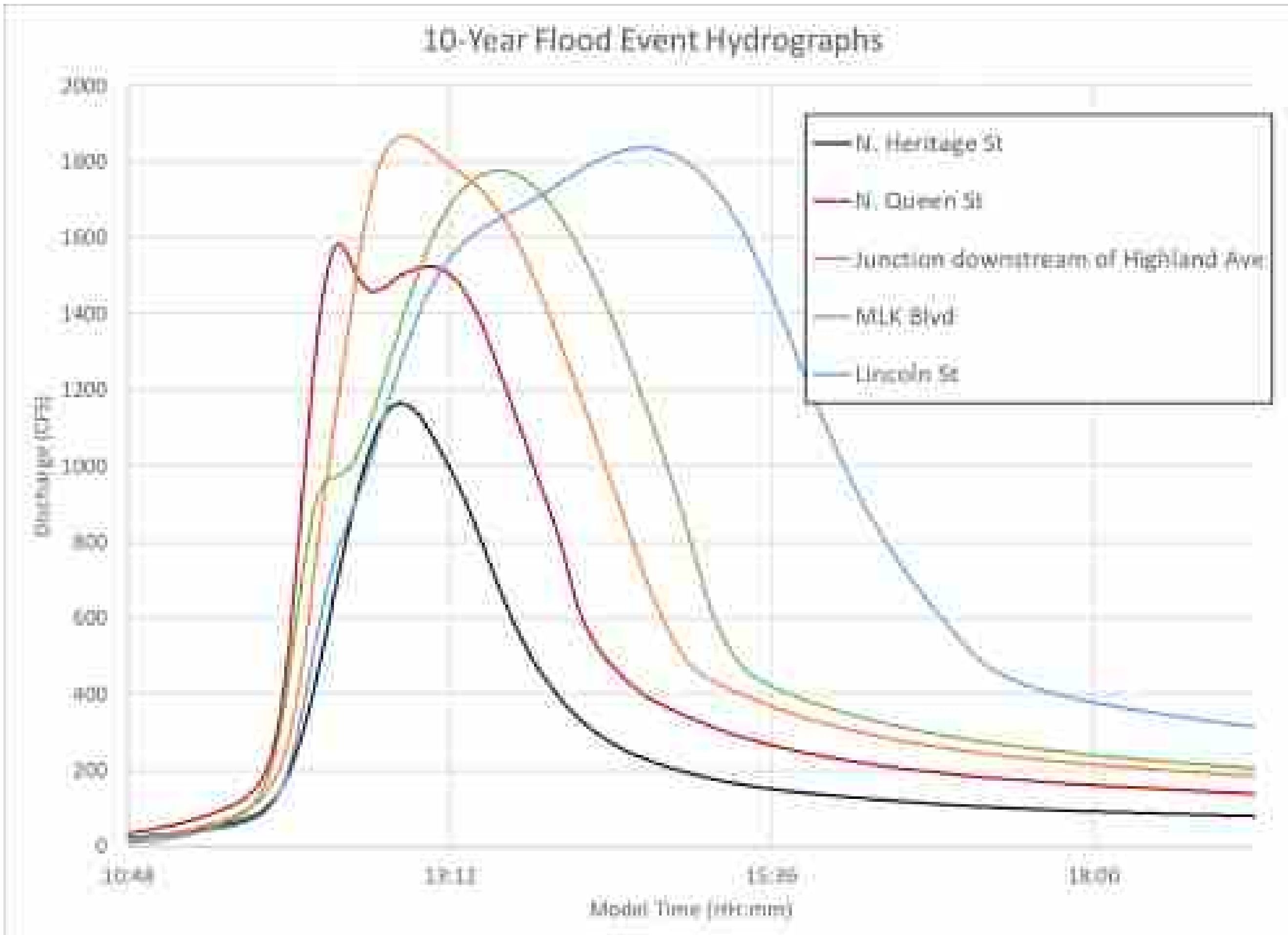

Figure 2. 10-year Flood Event Hydrographs at key locations for the Existing Condition

Hydraulic Model Development and Calibration

EPR updated the effective hydraulic model using the latest version of HEC-RAS (v5.0.7), georeferencing model components, revising overbank topography from recent LIDAR data, and incorporating the results of the detailed hydrologic modeling. Preliminary maps were provided to EDF and the City showing the modeled inundation limits of the two recent storm events that occurred on August 10 and November 12, 2020. The City provided feedback on the preliminary mapping that identified a few locations where the flood mapping was inconsistent with observed conditions. Alterations to the model performed as part of calibration are described in **Attachment 2** which resulted in predicted floodplain extents more consistent with observed conditions.

Modeling Analyses and Results

Baseline analyses were performed to evaluate the peak flow and water surface elevations for the 10-year, 25-year, and 100-year storm events (Tables 2 and 3). Most of the analyses performed focused on the August 10, 2020 and 10-year results since the goal of this analysis was to focus on more frequent, lower volume events where downstream effects from the Neuse River are not experienced. Per the RFP, the model analyses focused on conditions at North Heritage Street, North Queen Street, MLK Boulevard, and Lincoln Street. From the existing conditions model, the low chord elevation of a bridge or top of culvert, the point at which the conveyance is flowing at capacity, along with the minimum elevation of the roadway, or the point at which a road would begin flooding, are noted in Table 3. For comparison, the depth of water in relation to the minimum roadway elevation has been provided from the water surface elevations modeled using HEC-RAS for each flow event. The North Heritage Street culvert has a water surface elevation more than 1.2 feet higher than the minimum roadway elevation for the 10-year event, meaning there are significant backwater effects resulting from this culvert. Similarly, the North Queen Street culvert and MLK Boulevard culverts report WSE more than 0.5 feet higher than the minimum bridge deck elevation for the 10-year while the Lincoln Street bridge passes the 10-year and 25-year runoff events.

Table 2- HEC-HMS Hydrologic Modeling Results for Peak Flow (cfs) – Existing Condition

Crossing of Interest	Drainage Area (mi^2)	Aug 10, 2020	Nov 12, 2020	10-year	25-year	100-year
North Heritage Street	1.9	514	348	1,165	1,614	2,450
North Queen Street	2.48	858	572	1,584	2,129	3,423
MLK Blvd.	3.75	959	708	1,777	2,547	4,286
Lincoln Street	5.21	1,095	859	1,837	2,633	4,399

Table 3 –Hydraulic Model Results – Existing Conditions

Location	Culvert Top or Low Chord Elev (ft)	Minimum Roadway Elevation (ft)	Depth of Water Over (+) or Under (-) Roadway (ft)*					
			Aug 10, 2020	Nov 12, 2020	10-year	25-yr	50-year	100-year
North Heritage Street	55.31	58.34	-2.8	-4.4	1.2	1.7	1.9	2.2
North Queen Street	50.34	51.94	-1.0	-2.7	0.9	1.4	1.7	2.3
MLK Blvd.	41.99	43.66	-2.5	-3.9	0.5	1.2	1.5	1.9
Lincoln Street	29.14	29.26	-3.7	-4.3	-2.4	-1.1	0.8	0.8

*Depth of water has been calculated as a reference to the minimum roadway elevation. Under the current condition, North Heritage would experience 1.2 ft of water over the road during a 10-year storm event.

Detention Scenarios

Given the urban land uses, first efforts for flood mitigation examined the storage capacity necessary to address flooding concerns. For the purpose of this evaluation, road overtopping was considered to be flood stage since buildings and structures generally exist at street level. Thus, EPR evaluated the amount of storage required to prevent overtopping of the road crossings at each crossing identified in Table 3. Initial storage values that would prevent road overtopping were estimated for each flood event and are shown in Table 4. Using the hydraulic model, a discharge value that did not exceed the minimum elevation on the roadway was identified. EPR calculated the volume of water in the hydrograph above the identified flow value, which is approximately the volume of water that goes over the roadway rather than through the bridge or culvert. This approach assumes it is possible to preferentially detain water only when it is above a certain stage (possible for some offline detention options). These values, which are initial storage volumes to prevent road overtopping, focus on the existing conditions for each bridge or culvert individually; therefore, implementing reductions upstream of North Heritage Street will reduce the amount of storage needed at subsequent downstream crossings.

With the volume of storage required to eliminate road overtopping known, EPR evaluated two detention scenarios. The first scenario, Moderate Detention Scenario, evaluated the watershed for open space along Adkin Branch and within each subbasin that could be used to achieve the estimated levels of water storage. These locations, along with notes, are provided in **Attachment 4**. A likely average depth for retention was estimated as 8 inches using the average 'annual minimum depth to groundwater' for the underlying soils and the average storm drain diameter for the identified locations. An estimate of detention volume for each location was calculated by multiplying the average depth by the available surface area at the location and then modeled using diversions within subbasins 1 through 9 (Figure 1). The diversions fill up to a specified volume ("Detention Volume in Watershed" in Table 4) during the rising limb of the hydrograph (Figure 3).

The second scenario, an Aggressive Detention Scenario, was a theoretical scenario to determine the volume of storage need within the watersheds to produce a no flooding result. This scenario was an iterative process in which detention volumes were manipulated in the HEC-HMS model to produce the Road Overtopping Discharge value shown in Table 4. The result indicated roughly 10% of the drainage area for subbasins 1 through 9 at an 8-inch depth would be required for storage to meet the flood reduction need. The resulting hydrographs of these two detention scenarios (Moderate and Aggressive) are shown in Figure 3.

Table 4 - Storage Capacity Analyses for the 10-year Flood Event.

Crossing of Interest	Road Overtopping Discharge (cfs)	Existing	Moderate Detention			Aggressive Detention		
		Water Volume over Road (AC-FT)	Detention Volume in Watershed (AC-FT)	Water Volume over Road with Detention (AC-FT)	*Change in Water Volume over Road (AC-FT)*	Detention Volume in Watershed (AC-FT)	Water Volume over Road with Detention (AC-FT)	*Change in Water Volume over Road (AC-FT)*
North Heritage Street	800	19.20	19.40	17.20	*-2.00*	58.00	0.80	*-18.40*
North Queen Street	1,000	57.50	35.80	40.10	*-17.40*	105.00	4.00	*-53.50*
MLK Blvd.	1,450	25.70	48.90	8.50	*-17.20*	144.00	0.00	*-25.70*

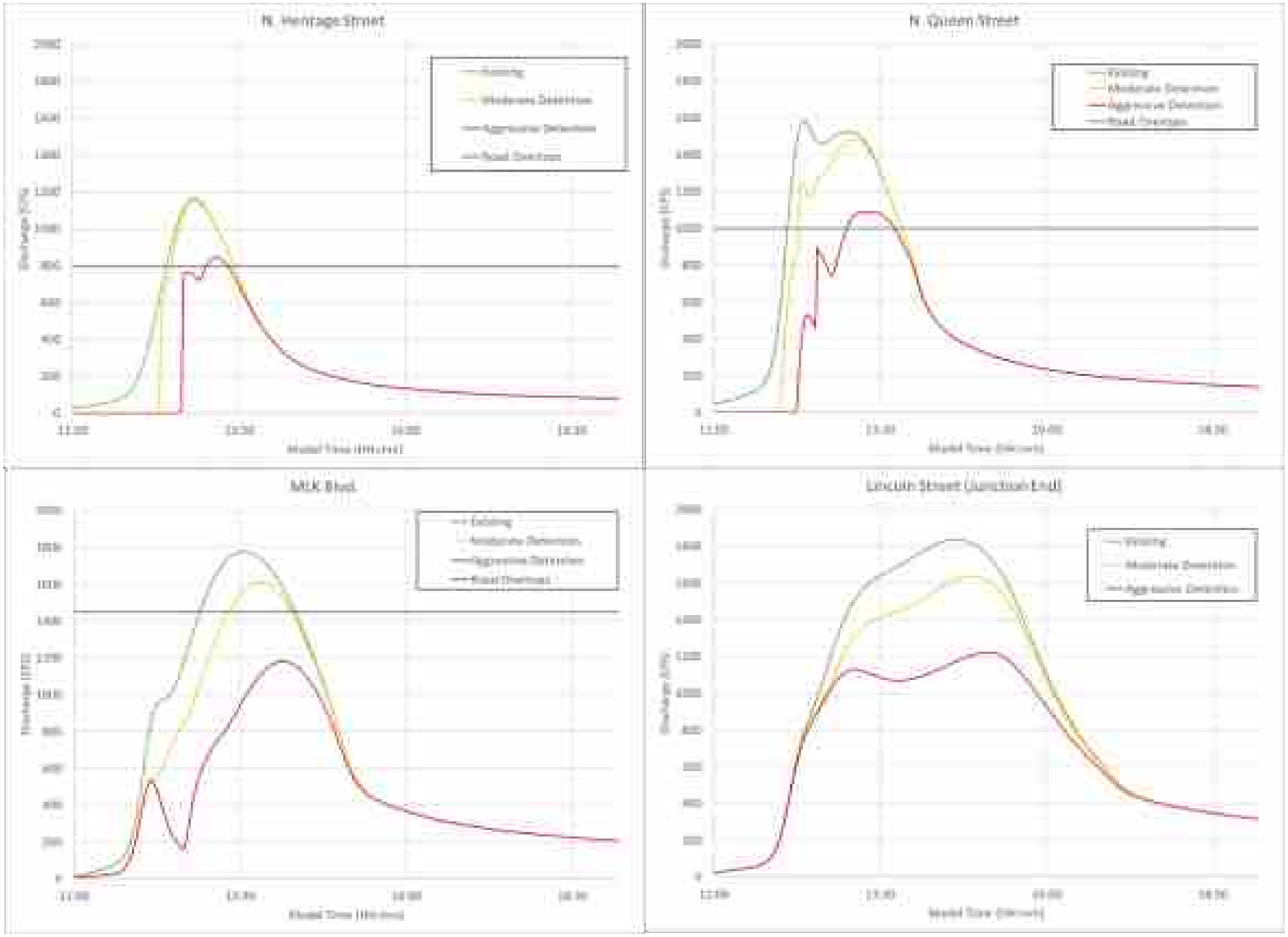

Figure 3. 10-year Hydrographs Showing Hydrologic Detention Scenarios

Modified Crossing Scenarios

While adding detention higher in the watershed will be effective in reducing flooding throughout Adkin Branch, those methods will require additional hydrologic or hydraulic modifications within the watershed to meet the flood reduction need. Even under the aggressive detention scenario with flows reduced to avoid road overtopping, the hydraulic model still shows significant backwater effects from the culverts. Therefore, model results were reviewed to identify physical constraints within the watershed, such as undersized culverts, floodplain obstructions, and other pinch points, that may be negatively affecting the hydraulics of Adkin Branch and worsening flooding conditions.

Removing or altering stream crossings has benefits and drawbacks. Culverts provide some attenuation of peak discharges during backwater conditions which can help reduce downstream peak flows; however, there is potential impacts to upstream structures or roads being inundated under the backwater conditions. Thus, EPR altered the hydraulic model to replace undersized culverts with full-span bridges only where the City indicated frequent flooding trouble or where structures are shown within the floodplain associated with the August 10, 2020 event and where flooding is caused by the crossing. As a simplified method for bridge estimation, culverts were replaced with a bridge spanning Adkin Branch following the roadway elevation. Then a deck thickness of 2 feet was assumed with no supporting abutments or piers, thus defining the bridge opening. EPR did not perform any design analysis for these bridges and alterations should not be used as a basis for bridge design. The reductions in water surface elevation for each crossing was modeled and provided in Table 5. The Lincoln Street bridge is the only crossing in the model to pass the 25-year storm without overtopping the road and passes the 10-year storm without significant backwater. Additionally, since this location is the most downstream crossing, it will benefit from the flood mitigation alternatives discussed in this memo and is not likely to need updates to the structure itself.

Table 5 - Reductions in Water Surface Elevations Resulting from Culvert Upgrade for the 10-year Event

Crossing of Interest	Water Surface Elevation (ft)		
	Existing Condition	Upgraded Crossing	*Change*
Crawford Street	75.33	74.80	*-0.53*
North Heritage Street	59.54	57.27	*-2.27*
North Queen Street	52.86	52.96	*0.10*
E. Highland Avenue	49.78	49.51	*-0.27*
MLK Blvd.	44.11	42.21	*-1.90*

Replacing some culverts will result in drastic reductions in flood stage, notably the North Heritage Street and MLK Boulevard culverts, which are causing significant backwater. Upgrading the North Heritage Street culvert will reduce flooding at the Cambridge Farms Apartments off Doctors Drive, as shown in Figure 4, as well as reduce flooding at Stallings Drive (Figure 5). The full-span bridge deck proposed for MLK Boulevard results in reduced flooding on the right bank where existing businesses are currently located (Figure 6).

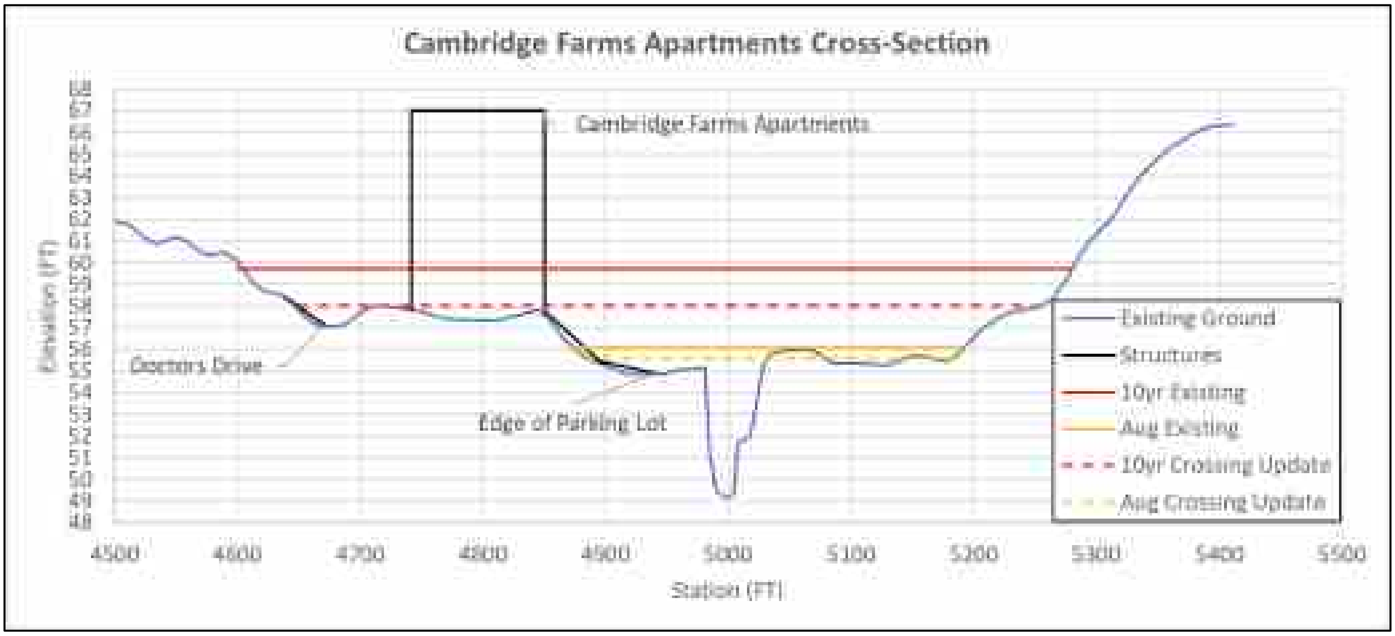

Figure 4. Changes to water surface elevation at Cambridge Farm Crossing with Updated Heritage St. Crossing

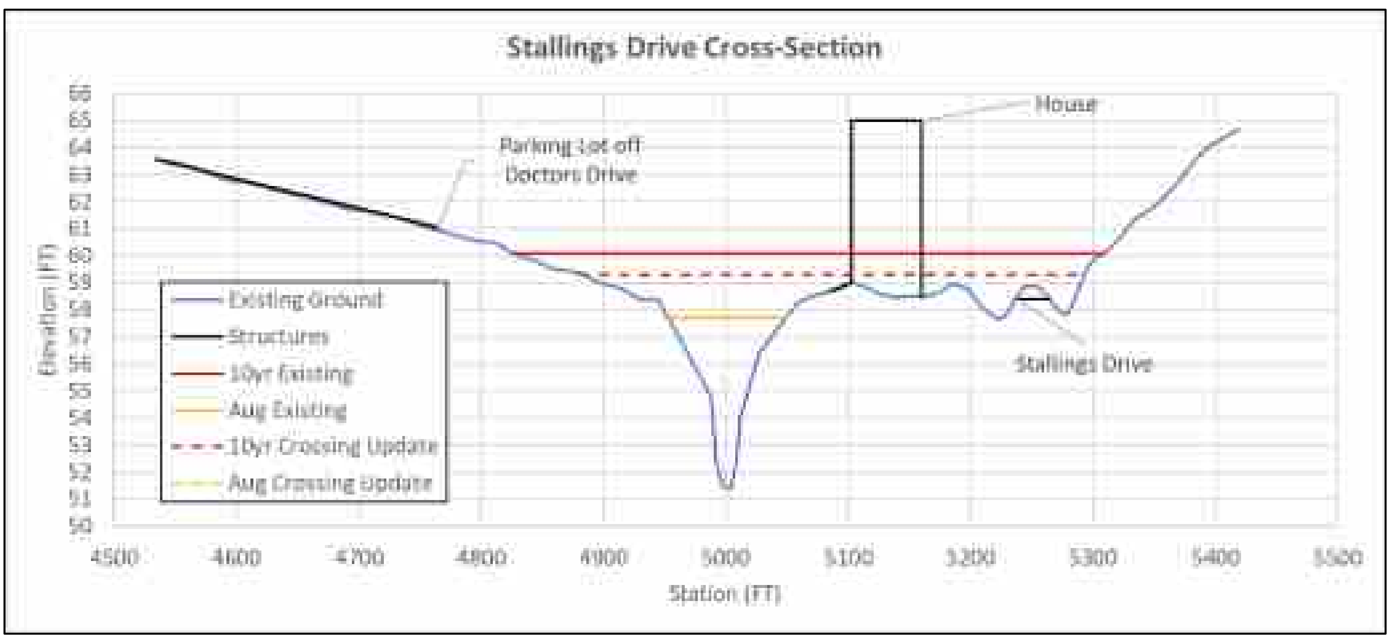

Figure 5. Changes to water surface elevation at Stallings Drive Crossing with updated Heritage St. Crossing

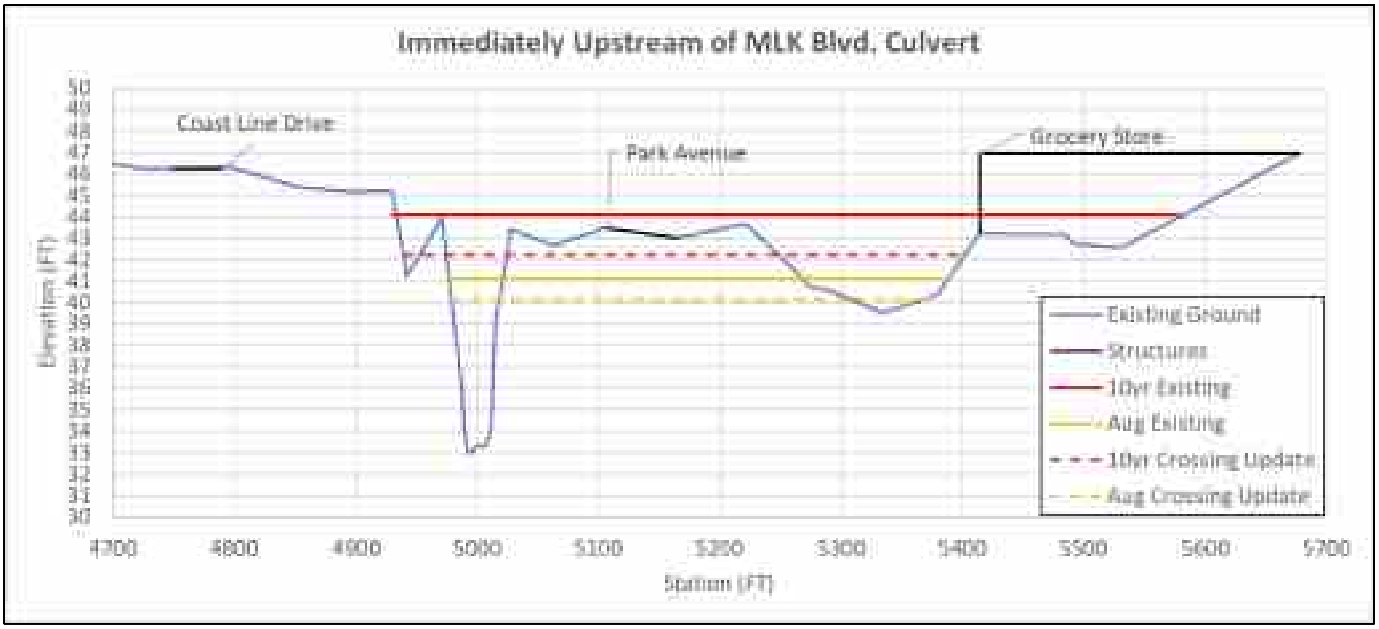

Figure 6. Changes to water surface elevation at MLK Blvd with updated crossing

Crawford Street is at the upstream extent of the model; it is likely upgrading the culvert would relieve flooding on Emerson Drive. Replacing the E. Highland Street culvert results in moderate flood reductions during the 10-year storm. This culvert was explored due to the presence of houses in the floodplain; however, this area is likely benefiting from the detention caused by the E. Daniel Street culvert, which backwaters a wooded area without endangering houses.

Replacing the North Queen Street culvert did not result in a decrease in water surface elevation; this outcome is primarily due to the channelization upstream of the North Queen Street culvert since the culvert is not causing the constriction.

Floodplain Excavation Scenarios

Floodplain excavation alters both hydrologic and hydraulic principles to impact flood potential. Thus, due to the complicated interactions between the two modeling approaches, EPR targeted the wooded areas along Adkin Branch between North Heritage and North Queen street to evaluate. This area consists of undeveloped woodland where there is potential for significant floodplain excavation. The floodplain excavation scenarios were modeled assuming a 3.5-ft deep channel, and excavation in both overbanks at that elevation, with a 4:1 slide slope to existing ground (see **Attachment 5**). The 3.5-ft channel depth was selected based on principles of natural channel design where localized regional curves are utilized to predict an appropriate channel area that promotes floodplain connectivity and ecological uplift. For a comparison of this approach's effect on the hydrologic functions of the system, Figure 7 shows the impacts of the various modeled flood mitigation scenarios on peak flow and volume upstream of North Queen Street, including floodplain excavation with and without moderate detention. Alternatively, Figure 8 depicts the hydraulic response to floodplain excavation through the reduction in water surface elevation for the area upstream of N Queen Street.

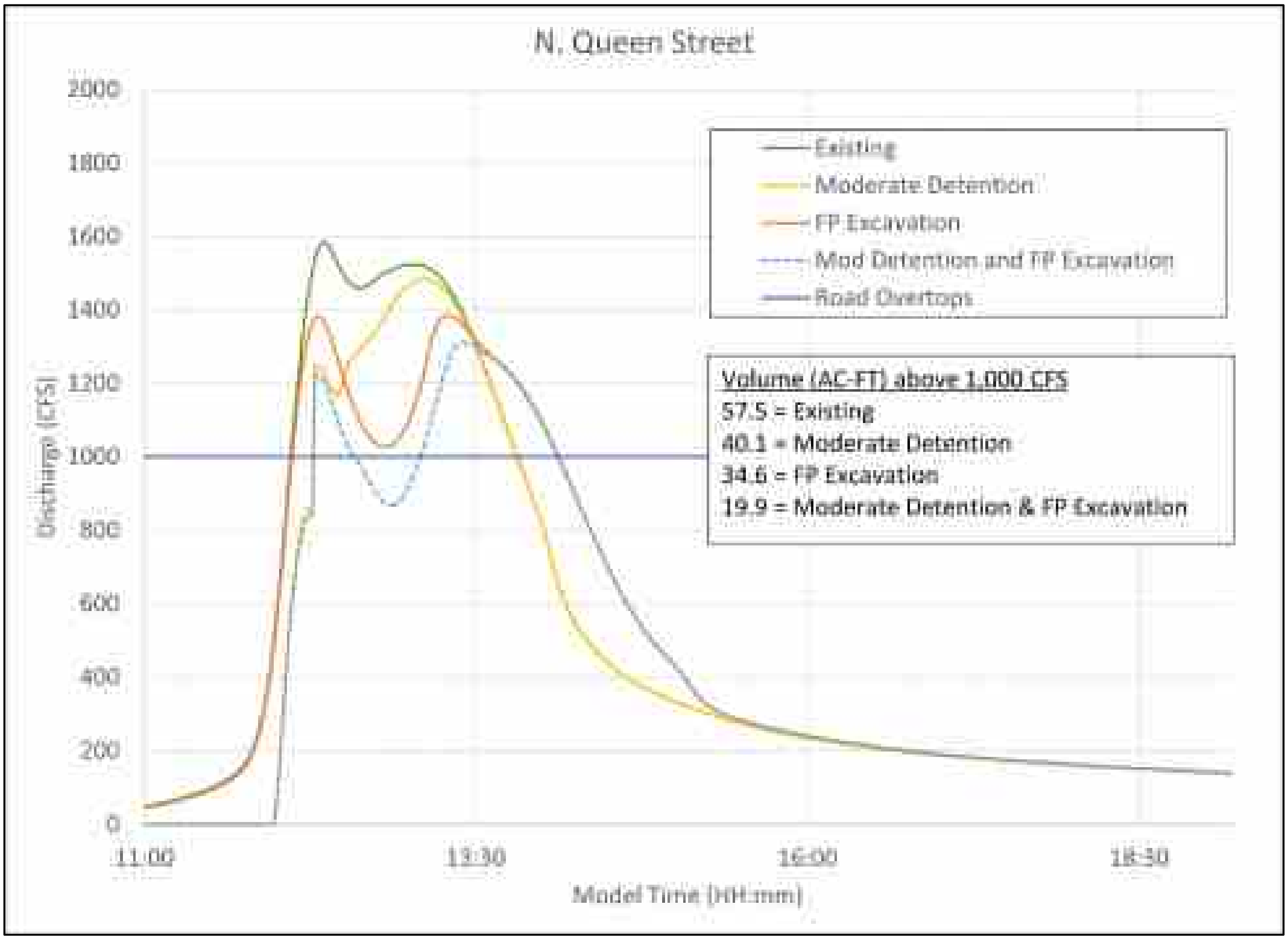

Figure 7. North Queen Street Hydrograph with Flood Mitigation Scenarios

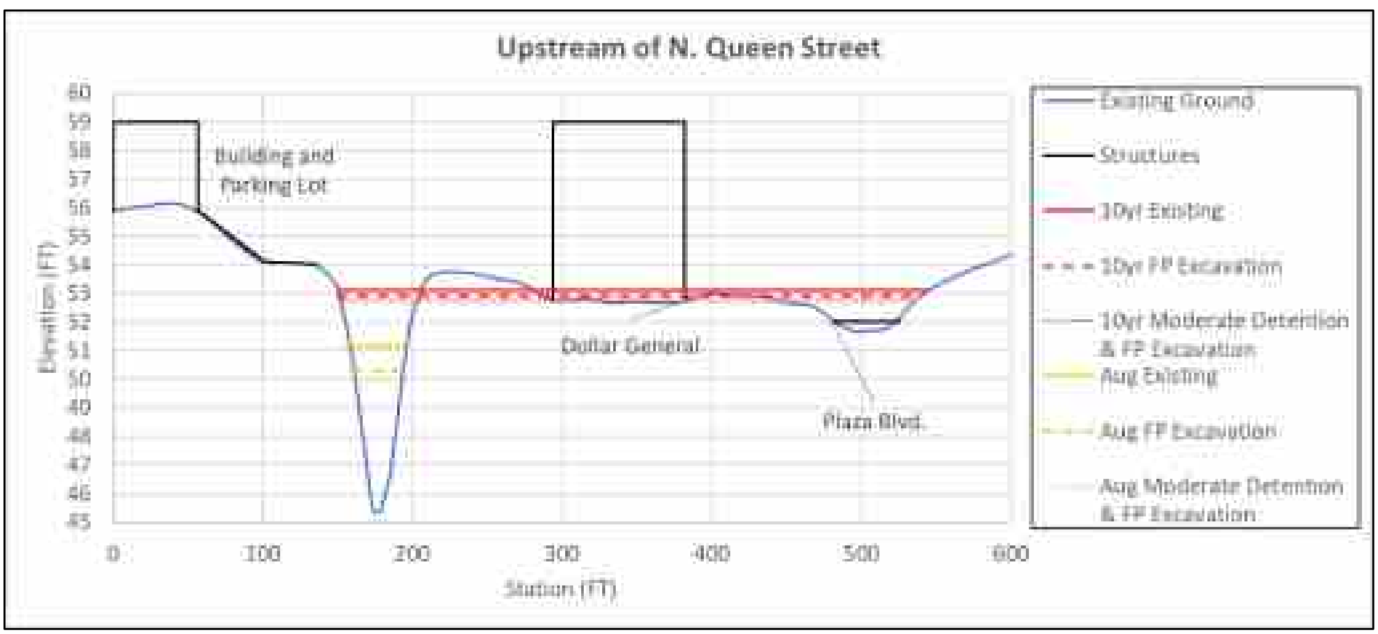

Figure 8. Changes to water surface elevation at North Queen Street with Reach 2 floodplain excavation

For North Queen Street flooding, the floodplain excavation resulted in exacerbating the bimodal peak flow: the earlier peak coming from the runoff attributed to Subbasin 6 while the latter is associated with the upstream drainage traveling down Adkins Branch being delayed as the floodplain bench attenuates. While there is some reduction in water surface elevation (0.2-feet) and floodplain extents for the 10-year storm event, the benefits for more frequent events (less than the 10-year) may be more significant as indicated by the 0.8-foot reduction for the August 2020 rainfall event.

Conclusions and Recommendations

By evaluating the three modes of reducing flood water surface elevations associated with the 10-year and lesser events (i.e. detention within the watershed, crossing modifications, and floodplain excavation), six modeling scenarios were identified as having notable outcomes. Table 6 provides a visual summary of these approaches.

Table 6 – Summary of Modeled Scenarios

Scenario	Moderate Detention	Aggressive Detention	Crossing Modification	Floodplain Excavation
1	x			
2		x		
3			x	
4	x		x	
5				x
6	x			x

Scenario 1 included moderate detention spread throughout the watershed with a focus on storage in the upper part of the basin. This involved a realistic assessment of the where storage could be applied, however it did not include the advanced routing calculations and design necessary to fully comprehend the true effects on the overall watershed that each of the individual detention areas could create. But given the low detention depth and other assumptions about residency, this approach produced a conservative estimate and is a valid estimate for comparing outcomes against the other scenarios. Additionally, this was the one approach to have a system wide response.

Scenario 2 was a theoretical approach to determine the necessary amount of detention within the watershed to produce the desired flooding reduction – no roads overtopped during the 10 year event. Though this scenario is informative by giving an estimated acreage of land needed to produce the result, the reality is acquisition and conversion of that amount of land is likely improbable.

Scenario 3 converted undersized hydraulic structures to more accommodating and effective bridges. This resulted in responses in the vicinity of these structures and when comparing localized water surface elevations had the greatest impact; however, when evaluating the effectiveness throughout the system the response is muted. Therefore, the team decided to evaluate Scenario 4 by taking the crossing modifications of Scenario 3 and layering in the system wide benefits of Scenario 1.

Scenario 5 is the most complicated to evaluate as floodplain excavation effects both hydrology and hydraulics. Because of this and the limitations of computing power and scope of work, this option was confined to the area along Adkin Branch between North Heritage Street and North Queen Street. This approach had the greatest effect in the location of the excavation and immediately upstream because of the hydraulic response to capacity increase. However, smaller deviations were noticeable downstream through the system as a result of the increased detention altering the peak flow. Therefore, as with Scenario 3, the team decided to take Scenario 5 one step farther by layering in the additional system wide benefits from Scenario 1 which resulted in Scenario 6.

The process of comparing these scenarios is complicated. A traditional hydraulic approach is to compare water surface elevations at fixed points for a given event as in Figure 9 for the 10-year event. Hydrologically, a similar approach was assessed using a reduction in overtopping volumes during the 10-year event at the same fixed

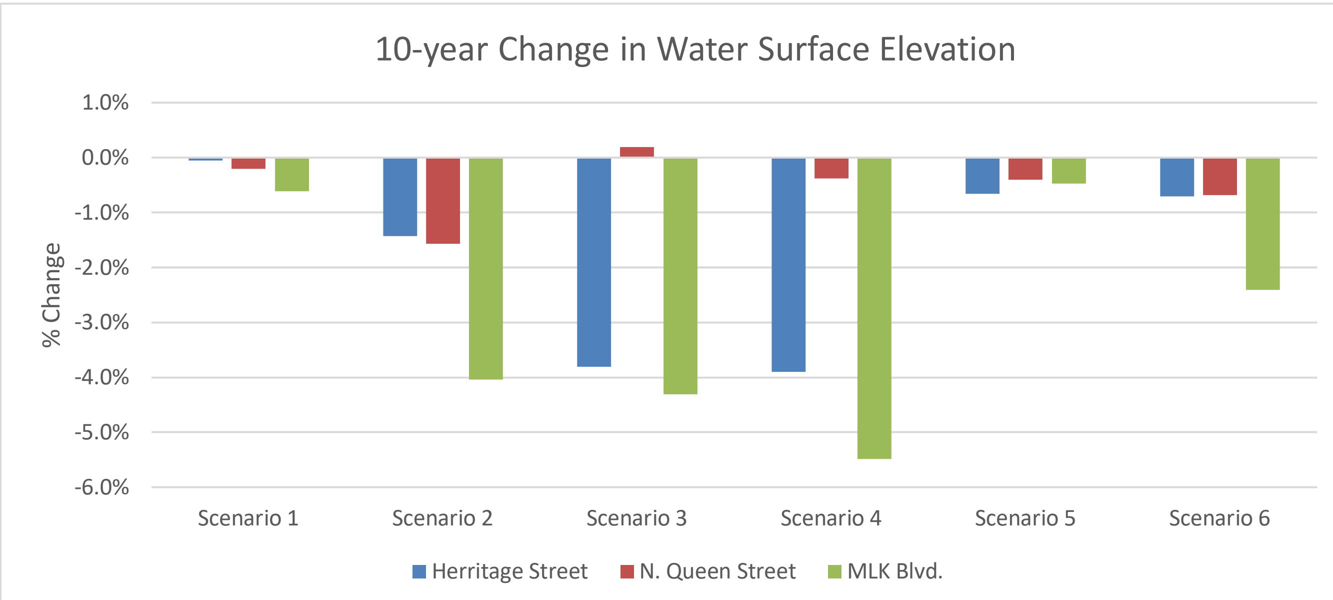

Figure 9. 10-year Percent Change in Water Surface Elevations

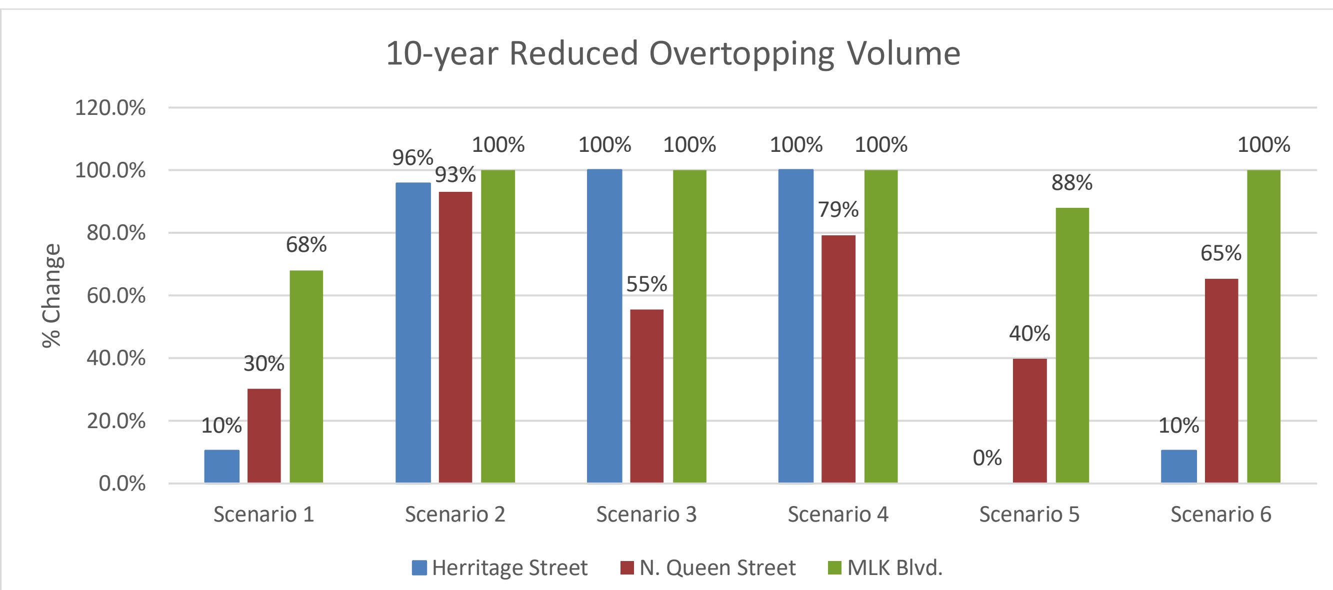

Figure 10. 10-year Percent Reduction in Roadway Overtopping

points for Figure 10. These graphs are useful tools, but they reinforce the assessment techniques used in the study and are spatially finite. For example, Scenario 3 and 4 involved modifying crossings at the assessment points and therefore the expected response is seen in water surface elevation reduction and overtopping volume reduction. Similarly, Scenario 2 iterated a reduction in flow by increasing storage to eliminate road overtopping and therefore the appropriate response is recorded in overtopping volume reduction and thusly in water surface elevation reduction. To overcome the implicit bias and account for responses seen spatially throughout the system, a visual comparison, Exhibit 8, was produced of Scenario 1 (Moderate Detention), 3 (Crossing Modification), and 5 (Floodplain Excavation). While Exhibit 8 provides the detail and breadth of information desired, there is no concrete evidence as to which Scenario is providing the greatest benefit. Take the MLK Blvd crossing, from Figures 9 and 10, the response from Scenario 3 should indicate water surface reductions and they are clear on the upstream side of the crossing with the Scenario 3 line (green) inside the existing floodplain (filled blue). However just downstream of the crossing, Scenario 1 and Scenario 5 provide the greater benefit for what appears to be a larger portion of the system. Therefore, to provide a concrete metric for comparison across scenarios, the entire floodplain extent or surface area was determined and normalized to the length of the evaluation reach. Figure 11 presents this normalized floodplain extent comparison as a departure from the existing floodplain or baseline condition with increasing negative values indicating a greater benefit.

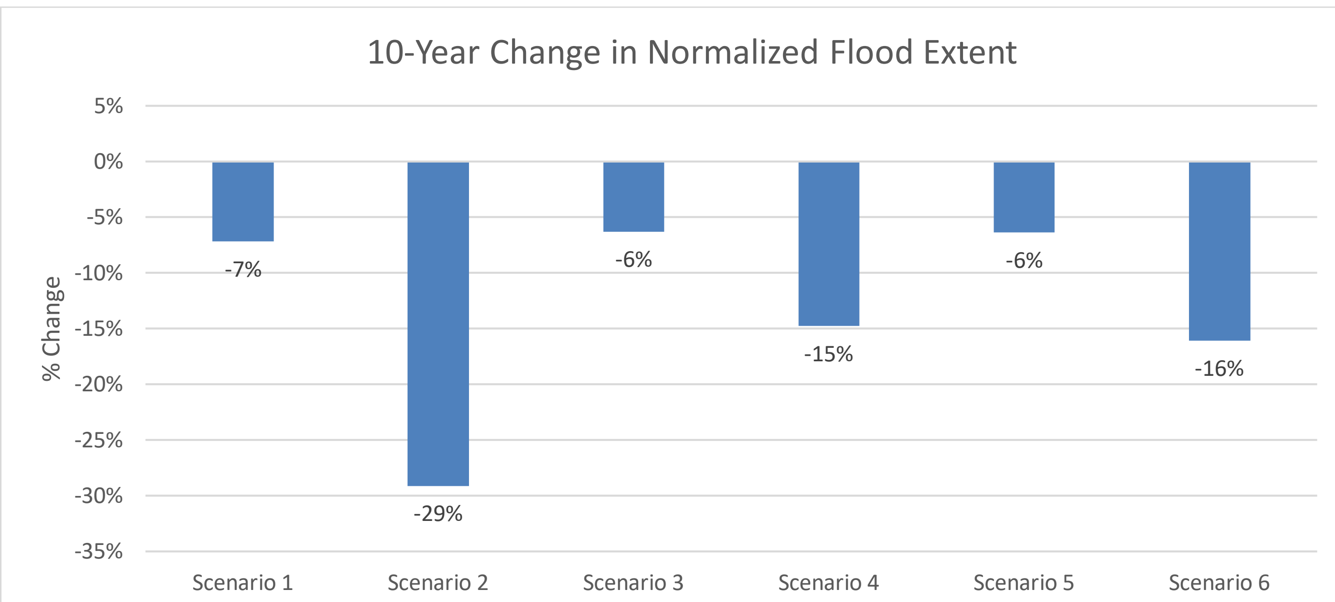

Figure 11. 10-year Change in Normalized Floodplain Extents

Predictably, the result of this evaluation found Scenario 2 (Aggressive Detention) to have the greatest benefit as detention throughout the watershed effects the entire system. However, another notable consideration is Scenario 1 (Moderate Detention), Scenario 3 (Crossing Modification), and Scenario 5 (Floodplain Excavation) have a similar impact on flood reductions for the entire system. By reviewing Exhibit 8, it is clear the crossing modifications have localized impacts surrounding the structure, but this analysis would indicate the benefits from detention and floodplain excavation are very similar though spread throughout the system.

Combining all the evaluations above, some relative conclusions can be made about Adkins Branch specifically, but also about the flood reduction mechanisms. Adkins Branch is a flashy system where the peak flows stack upon one another, particularly in the upper watershed. This phenomenon increased flooding potential in the downstream direction because the peak of the hydrograph amplifies instead of the residency time of the flood expanding to accommodate the additional flow. While the study identified the best mechanism to alleviate the concern is aggressive detention, the practicality of implementing this strategy is limiting. When looking at finite points in the watershed, the modification of crossings to improve flow capacity provides significant improvements in both the volume of water overtopping the road and in water surface elevations. However, this is a very localized solution with a dramatic effect in the vicinity of the structure but has little effect system wide. Finally, floodplain excavation provides a combination of storage and capacity, seen in the overtopping volume reduction. But due to the flat nature of the landscape resulting in expansive floodplain widths, this volume reduction does not translate into water surface elevation reductions with the constrictions remaining in place. Therefore, for Adkins Branch specifically, the recommendation for implementing flood reduction practices would be a combination of floodplain excavation along with select crossing modifications in the vicinity of North Heritage Street and North Queen Street. However, to determine the exact extent of the benefit, additional design and modeling efforts would be required to parse out individual structure modifications and the suitable floodplain excavation extents and depths to create a consistent flow path. However, it must be noted that even this combination approach will not alleviate all flooding throughout the system. The limited down valley grade coupled with the flat, expansive floodplain widths will require alternative measures to prevent flooding of structures in the floodplain. And finally, as to the flood reduction mechanisms, this study indicates moderate detention, crossing modifications, and floodplain excavation have similar overall benefits to the system. Therefore, practitioners need to be aware of the system constraints when approaching these methodologies. Watershed detention is beneficial and practical in settings where the entire watershed can be manipulated. Crossing modifications will alleviate localized flooding concerns. But under the right circumstances, floodplain excavation has potential to provide localized flood reductions through capacity along with system wide benefits associated with attenuation.

ATTACHMENT 1 – Exhibits

Exhibit 1 – Existing Conditions Floodplain Mapping

Exhibit 2 – August 10, 2020 Rainfall Event, Detention Only

Exhibit 3 – 10-year Floodplain, Detention Only

Exhibit 4 – August 10, 2020 Rainfall Event, Crossing Modification

Exhibit 5 – 10-year Floodplain, Crossing Modification

Exhibit 6 – August 10, 2020 Rainfall Event, Floodplain Excavation

Exhibit 7 – 10-year Floodplain, Floodplain Excavation

Exhibit 8 – Scenario Comparison – Moderate Detention, Crossing Modification, and Floodplain Excavation

- Streamline
- Existing 10Aug2020 FP Extents
- Existing 10yr FP Extents
- Existing 25yr FP Extents
- Existing 100yr FP Extents
- Building Footprints

ADKINS BRANCH MODELING

Existing Conditions

Exhibit 1

Kinston, Lenoir County, North Carolina

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Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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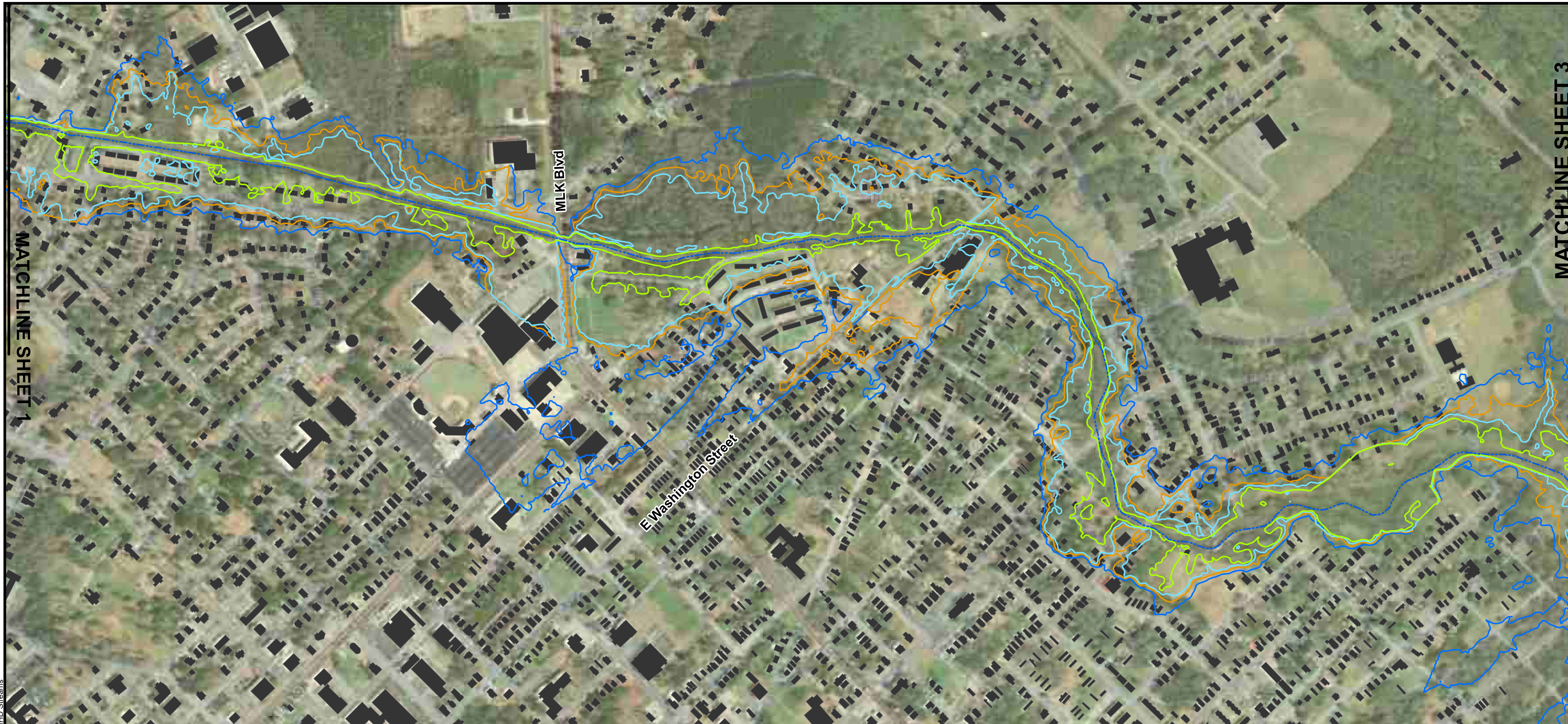

- Streamline
- Existing 10Aug2020 FP Extents
- Existing 10yr FP Extents
- Existing 25yr FP Extents
- Existing 100yr FP Extents
- Building Footprints

ADKINS BRANCH MODELING

Existing Conditions
Exhibit 1

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Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
- Existing 10Aug2020 FP Extents
- Existing 10yr FP Extents
- Existing 25yr FP Extents
- Existing 100yr FP Extents
- Building Footprints

ADKINS BRANCH MODELING

Existing Conditions
Exhibit 1

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Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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Streamline
10Aug2020 Scenario 1 -Moderate Detention - FP Extents
10Aug2020 Scenario 2 - Aggressive Detention - FP Extents
10Aug2020 Rainfall Event - FP Extents
Building Footprints

ADKINS BRANCH MODELING

AUGUST 10, 2020 RAINFALL EVENT

EXHIBIT 2 - DETENTION ONLY

KINSTON, LENOIR COUNTY, NORTH CAROLINA

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Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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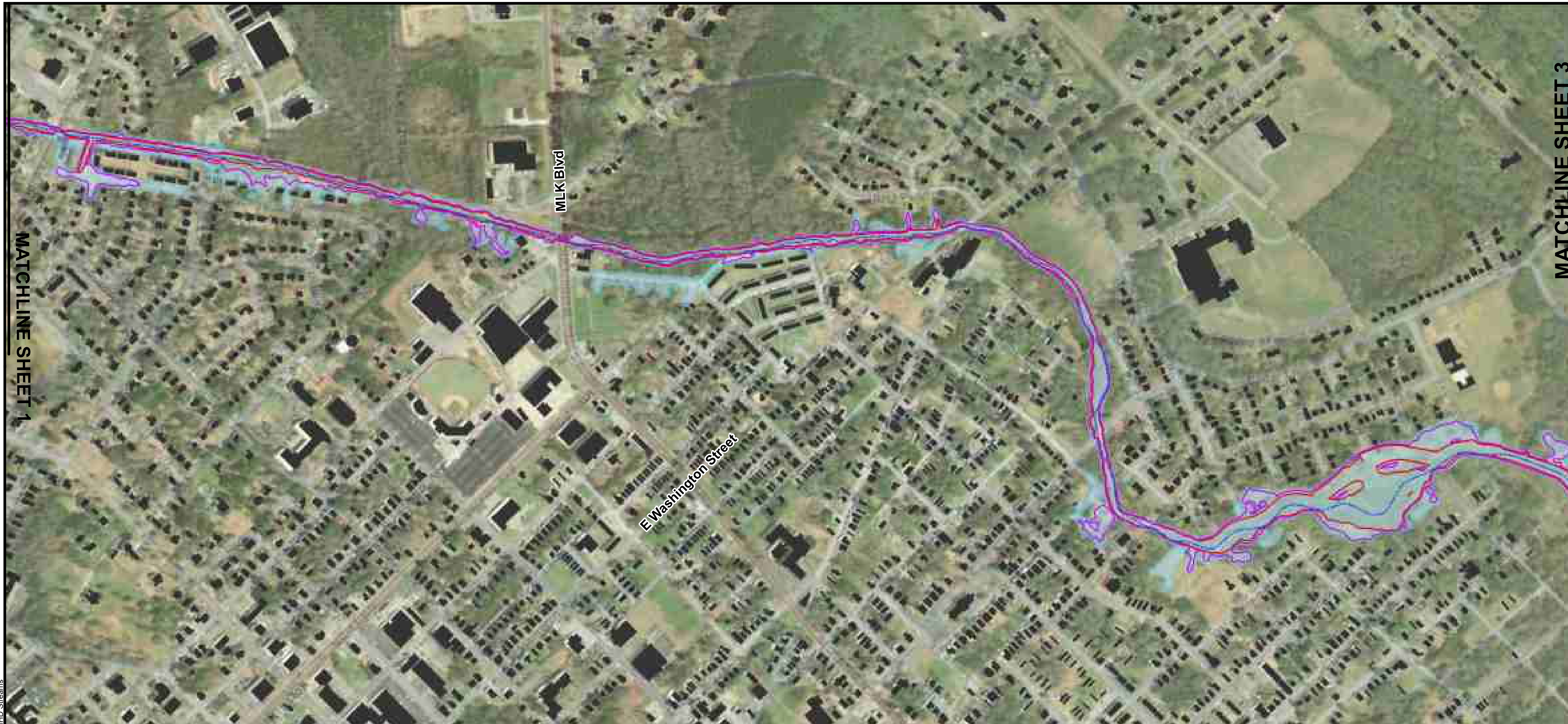

- Streamline
- 10Aug2020 Scenario 1 - Moderate Detention - FP Extents
- 10Aug2020 Scenario 2 - Aggressive Detention - FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

AUGUST 10, 2020 RAINFALL EVENT
EXHIBIT 2 - DETENTION ONLY

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Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
- 10Aug2020 Scenario 1 - Moderate Detention - FP Extents
- 10Aug2020 Scenario 2 - Aggressive Detention - FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event
Exhibit 2 - Detention Only

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Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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Streamline
10yr Scenario 1 - Moderate Detention - FP Extents
10yr Scenario 2 - Aggressive Detention - FP Extents
Existing 10yr - FP Extents
Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 3 - Detention Only
Kinston, Lenoir County, North Carolina

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Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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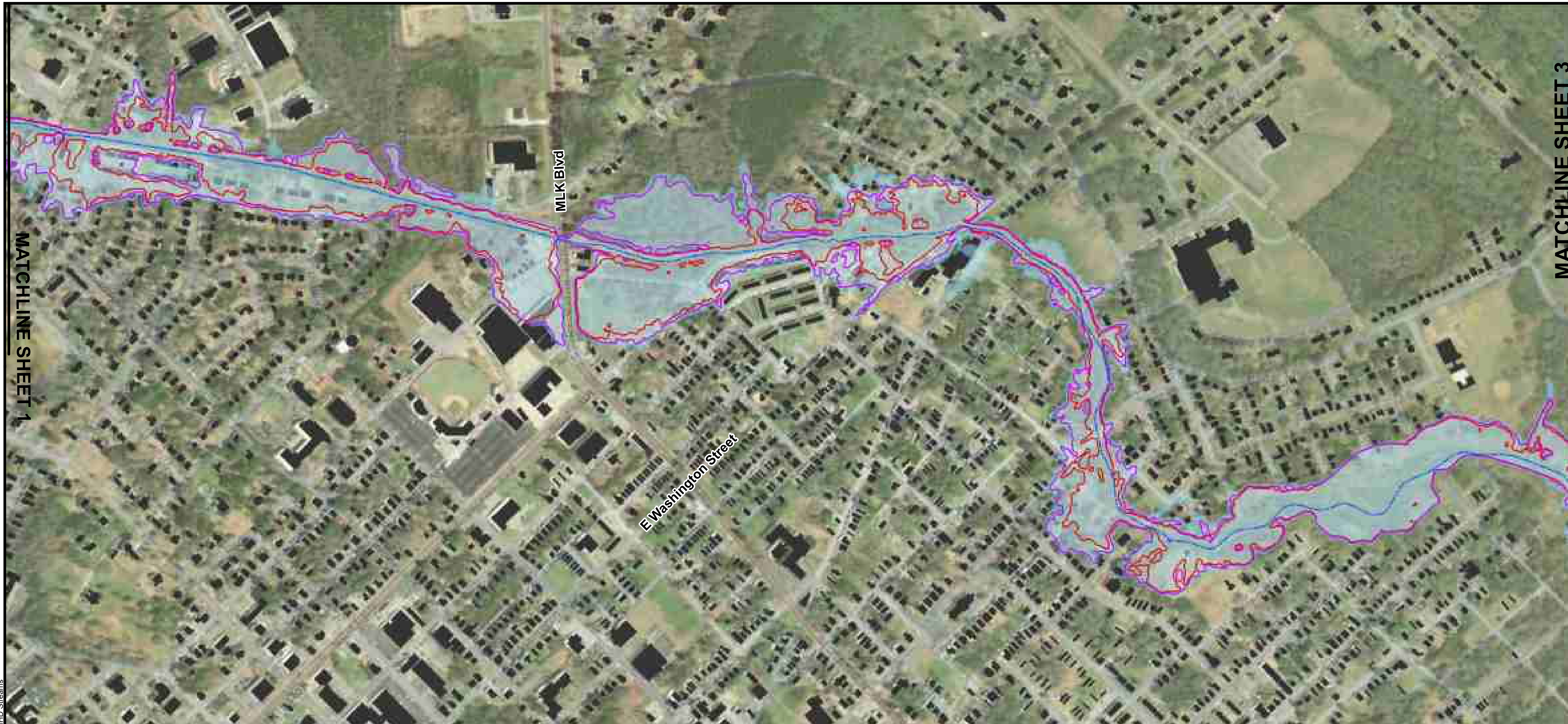

- Streamline
- 10yr Scenario 1 - Moderate Detention - FP Extents
- 10yr Scenario 2 - Aggressive Detention - FP Extents
- Existing 10yr - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 3 - Detention Only

Kinston, Lenoir County, North Carolina

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DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
- 10yr Scenario 1 - Moderate Detention - FP Extents
- 10yr Scenario 2 - Aggressive Detention - FP Extents
- Existing 10yr - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exihibit 3 - Detention Only

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DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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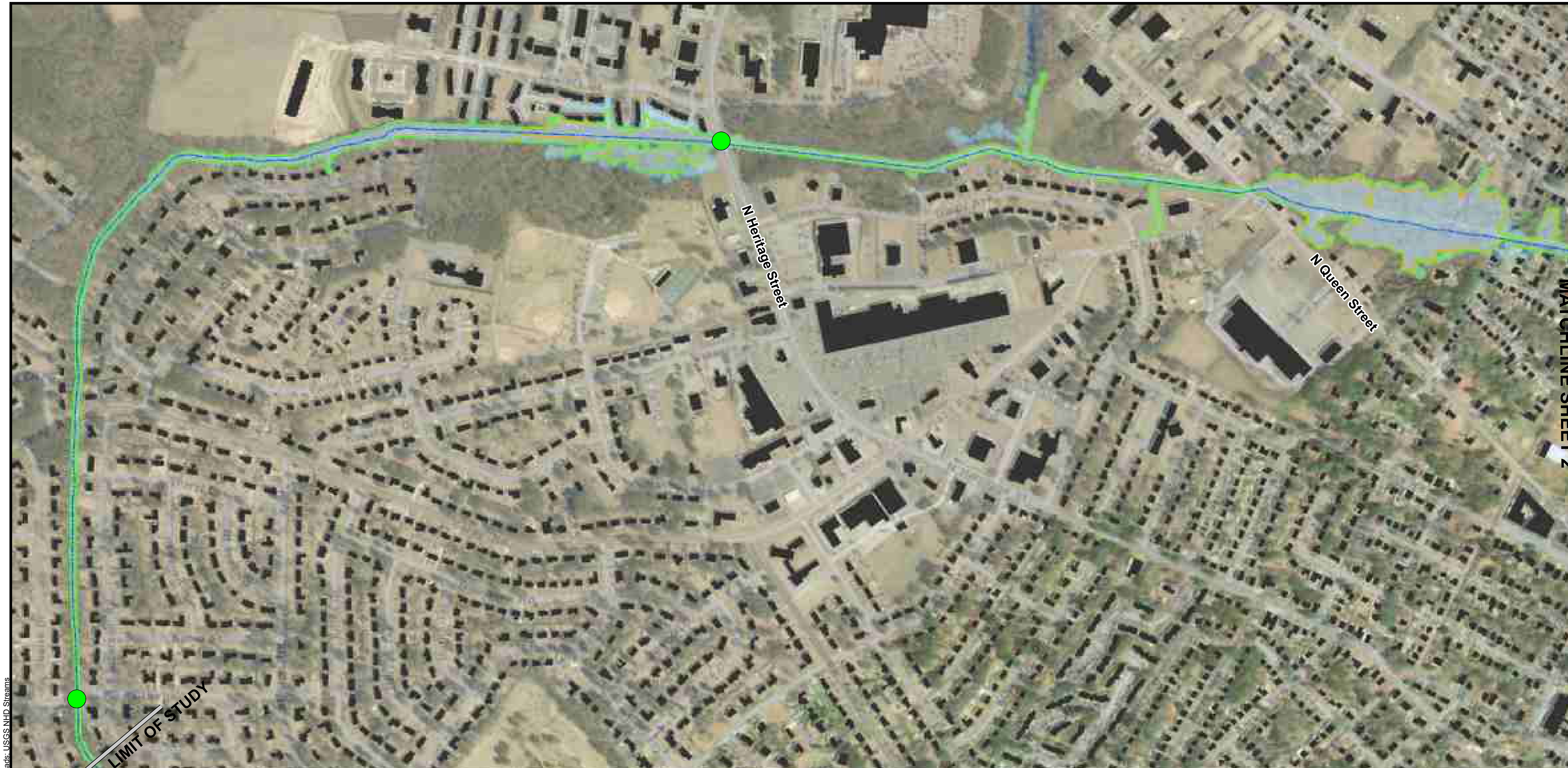

- Streamline
- 10Aug2020 Scenario 3 – Crossing Modification Only - FP Extents
- 10Aug2020 Scenario 4 – Crossing Modification & Moderate Detention - FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event
Exhibit 4 - Crossing Modification
Kinston, Lenoir County, North Carolina

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DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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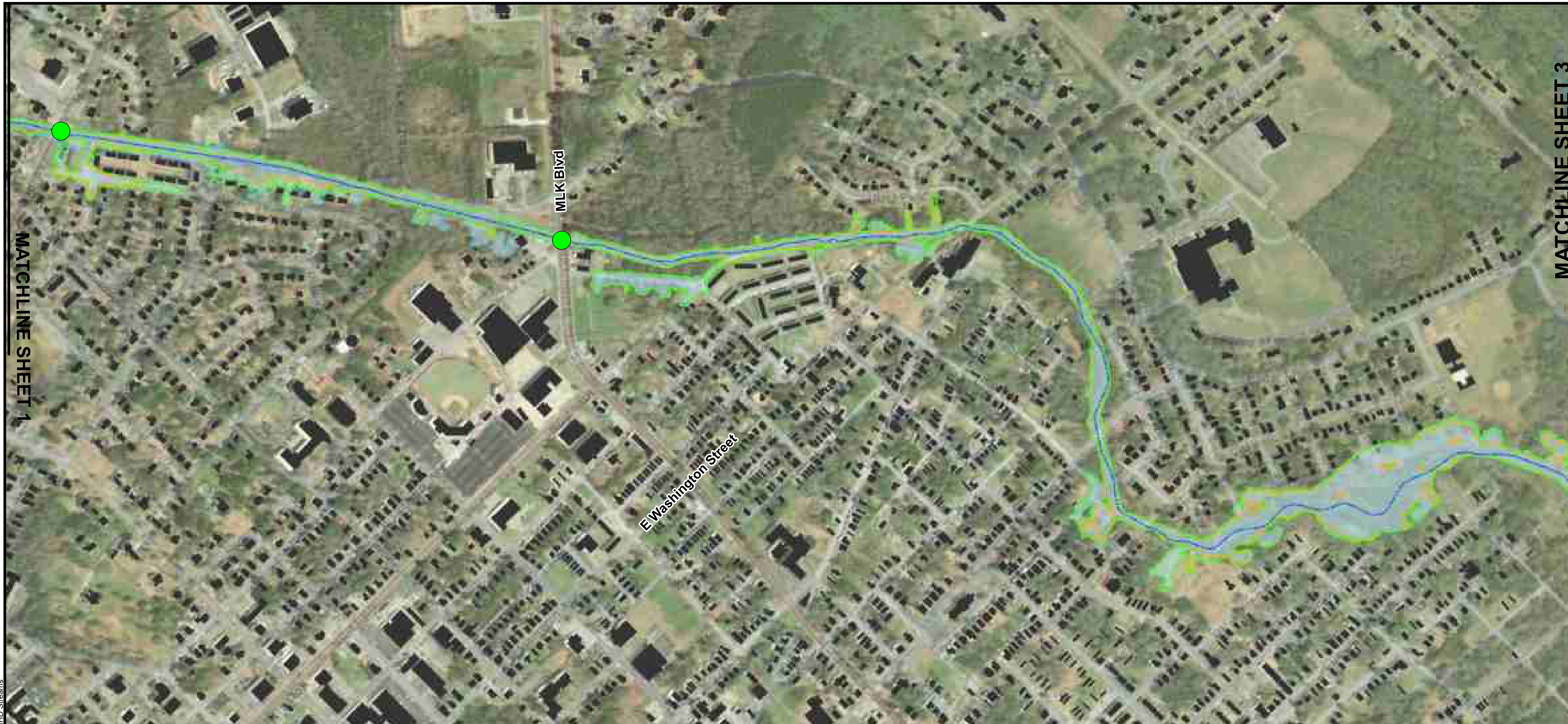

Streamline
10Aug2020 Scenario 3 - Crossing Modification Only - FP Extents
10Aug2020 Scenario 4 - Crossing Modification & Moderate Detention - FP Extents
10Aug2020 Rainfall Event - FP Extents
Crossing Modification
Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event
Exhibit 4 - Crossing Modification

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DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
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- 10Aug2020 Scenario 4 - Crossing Modification & Moderate Detention - FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event
Exhibit 4 - Crossing Modification

Kinston, Lenoir County, North Carolina

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DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
- 10yr Scenario 3 - Crossing Modification - FP Extents
- 10yr Scenario 4 - Crossing Modification & Moderate Detention - FP Extents
- 10yr Existing Conditions - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain

Exhibit 5 - Crossing Modification

Kinston, Lenoir County, North Carolina

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DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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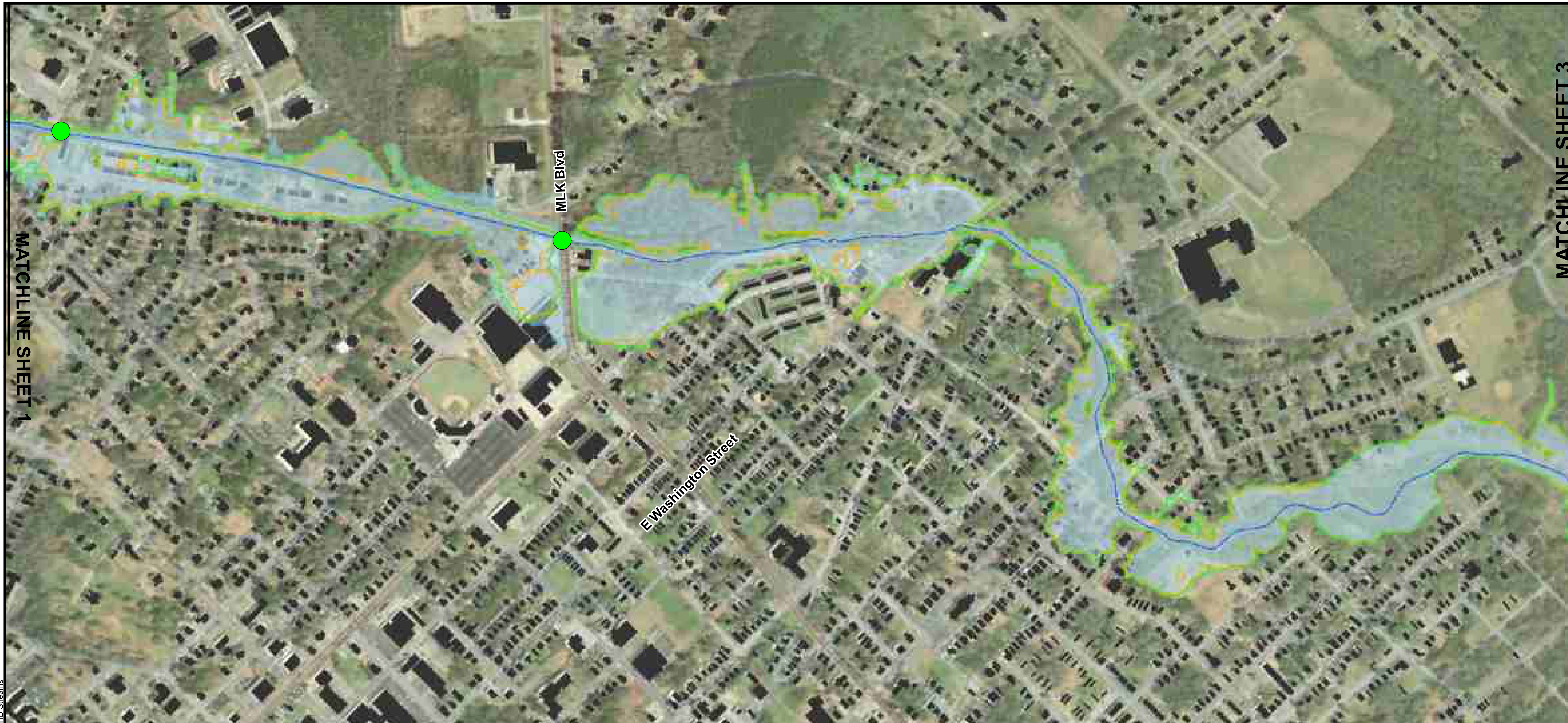

Streamline
10yr Scenario 3 – Crossing Modification - FP Extents
10yr Scenario 4 – Crossing Modification & Moderate Detention - FP Extents
10yr Existing Conditions - FP Extents
Crossing Modification
Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 5 - Crossing Modification

Kinston, Lenoir County, North Carolina

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DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
- 10yr Scenario 3 – Crossing Modification - FP Extents
- 10yr Scenario 4 – Crossing Modification & Moderate Detention - FP Extents
- 10yr Existing Conditions - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 5 - Crossing Modification

Kinston, Lenoir County, North Carolina

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DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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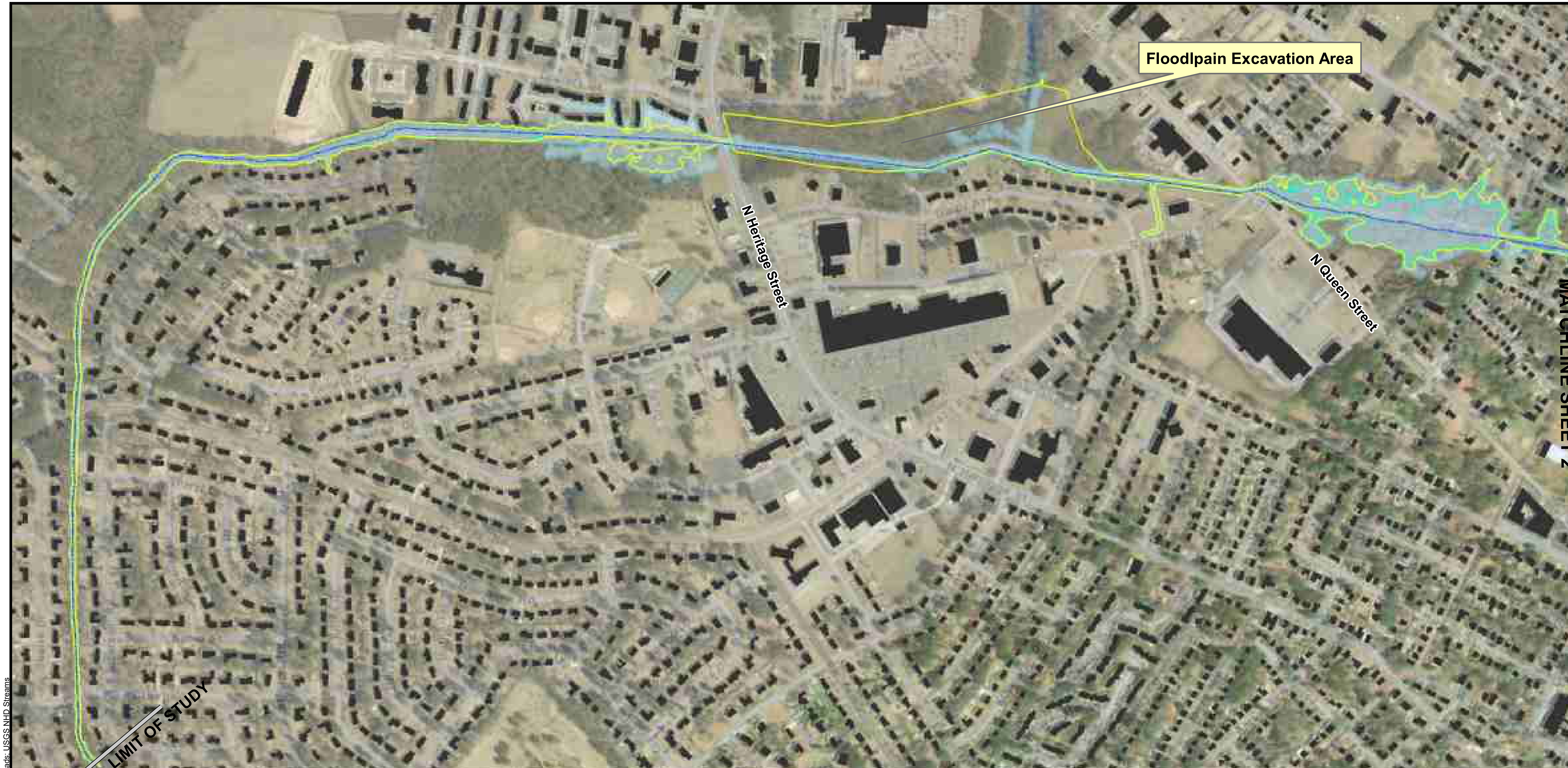

Streamline

10Aug2020 Scenario 5 – Floodplain Excavation - FP Extents

10Aug2020 Scenario 6 – Floodplain Excavation & Moderate Detention - FP Extents

10Aug2020 Rainfall Event - FP Extents

Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event

Exhibit 6 - Floodplain Excavation

Kinston, Lenoir County, North Carolina

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SHEET 1

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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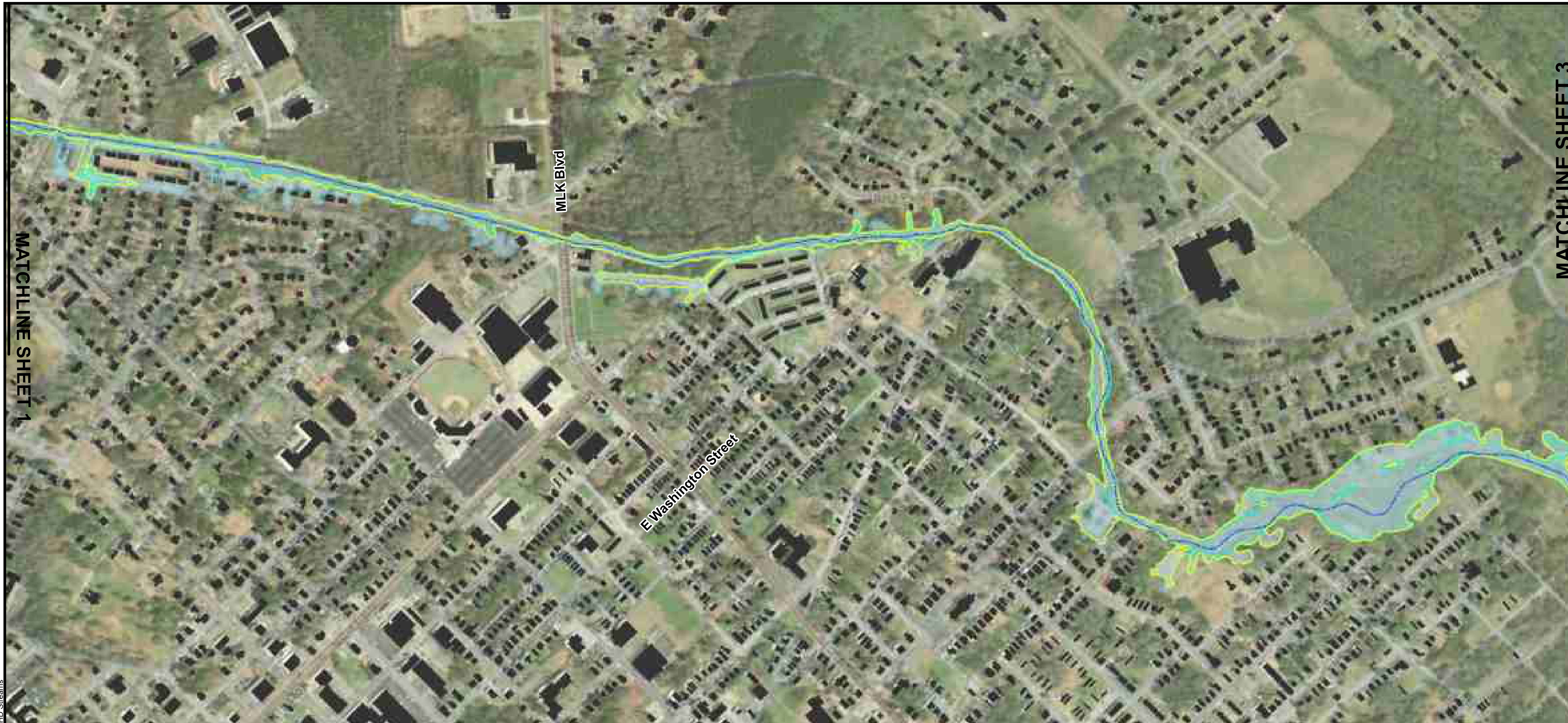

- Streamline
- 10Aug2020 Scenario 5 – Floodplain Excavation - FP Extents
- 10Aug2020 Scenario 6 – Floodplain Excavation & Moderate Detention - FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event
Exhibit 6 - Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund — Finding the ways that work

Ecosystem Planning & Restoration — EPR

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SHEET 2

DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
- 10Aug2020 Scenario 5 – Floodplain Excavation - FP Extents
- 10Aug2020 Scenario 6 – Floodplain Excavation & Moderate Detention - FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event
Exhibit 6 - Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund – Finding the ways that work

Ecosystem Planning & Restoration (EPR)

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SHEET 3

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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Streamline
10-Year Scenario 5 – Floodplain Excavation - FP Extents
10-Year Scenario 6 – Floodplain Excavation & Moderate Detention - FP Extents
Existing 10-Year - FP Extents
Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain

Exhibit 7 - Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund

Ecosystem Planning & Restoration

0 300 600 Feet

1:7,200

SHEET 1

DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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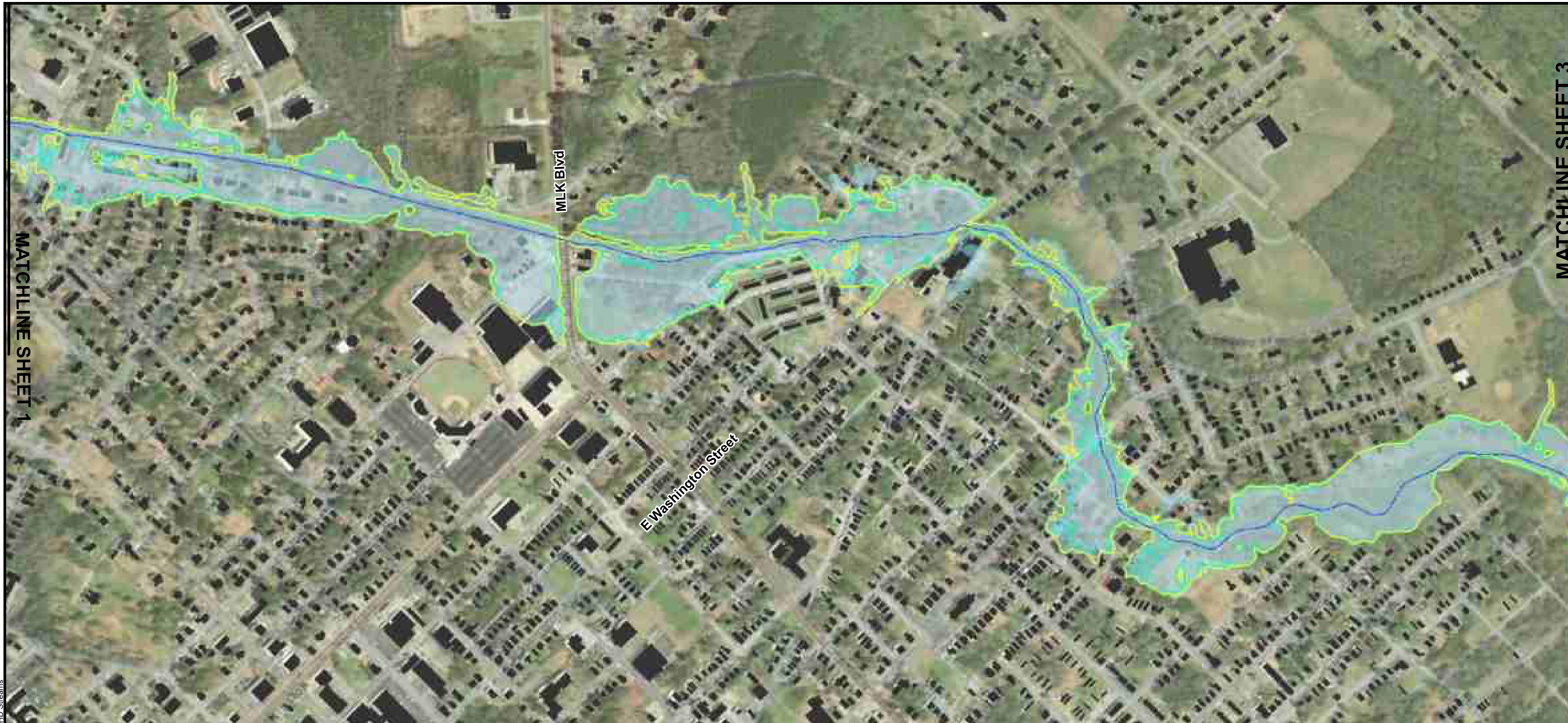

- Streamline
- 10-Year Scenario 5 – Floodplain Excavation - FP Extents
- 10-Year Scenario 6 – Floodplain Excavation & Moderate Detention - FP Extents
- Existing 10-Year - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 7 - Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work

EPR Ecosystem Planning & Restoration

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SHEET 2

DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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Streamline
10-Year Scenario 5 – Floodplain Excavation - FP Extents
10-Year Scenario 6 – Floodplain Excavation & Moderate Detention - FP Extents
Existing 10-Year - FP Extents
Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 7 - Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work

EPR Ecosystem Planning & Restoration

N

0 300 600 Feet

1:7,200

SHEET 3

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

Path: R:\Projects\RDU0141_EDF-Kinston Flood Study\GIS\Maps\Figure 7 - 10yr_FP_Excav_sheet3.mxd | Date: 3/29/2021 | Time: 8:48:56 AM | User Name: mkoon

- Streamline
- 10yr Scenario 1 – Moderate Detention - FP Extents
- 10yr Scenario 3 – Crossing Modification - FP Extents
- 10-Year Scenario 5 – Floodplain Excavation - FP Extents
- Existing 10yr - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain

Exhibit 8 - Scenario Comparison

Kinston, Lenoir County, North Carolina

EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work

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SHEET 1

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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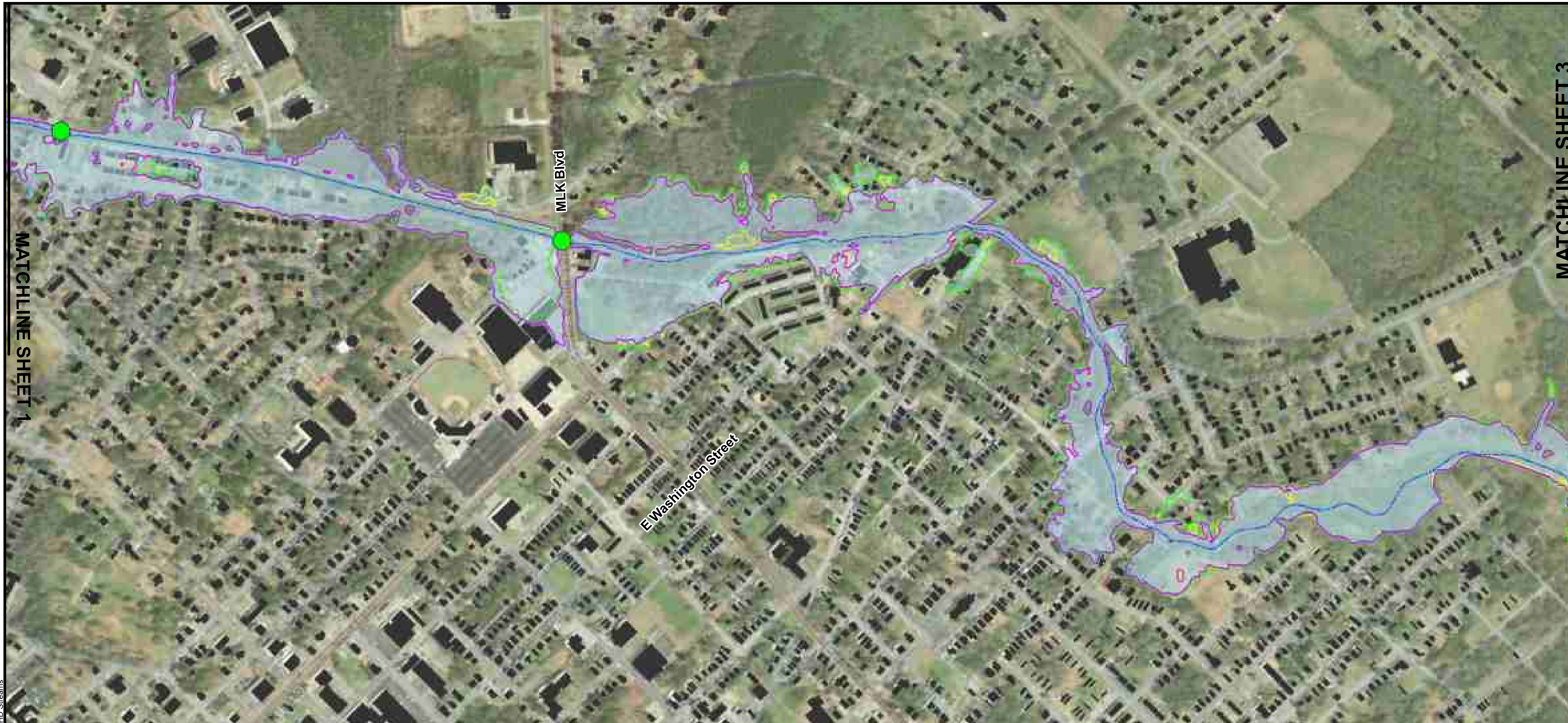

- Streamline
- 10yr Scenario 1 – Moderate Detention - FP Extents
- 10yr Scenario 3 – Crossing Modification - FP Extents
- 10-Year Scenario 5 – Floodplain Excavation - FP Extents
- Existing 10yr - FP Extents
- Crossing Modification
- Building Footprints

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 8 - Scenario Comparison

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund — Finding the ways that work

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SHEET 2

DATE:
March 2021

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- Streamline
- 10yr Scenario 1 – Moderate Detention - FP Extents
- 10yr Scenario 3 – Crossing Modification - FP Extents
- 10-Year Scenario 5 – Floodplain Excavation - FP Extents
- Existing 10yr - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 8 - Scenario Comparison

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund — Finding the ways that work

Ecosystem Planning & Restoration

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0 300 600 Feet

1:7,200

SHEET 3

DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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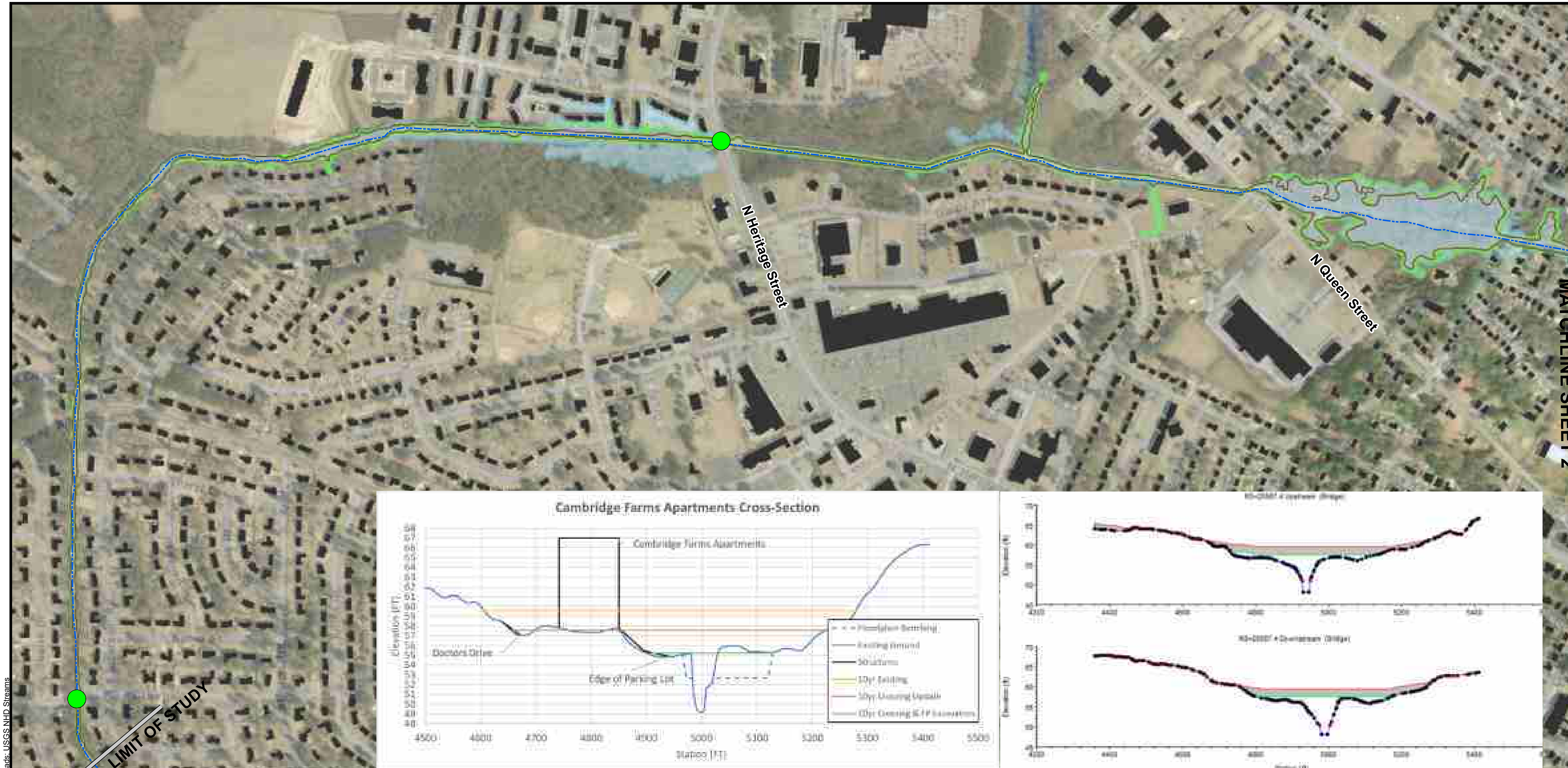

- Crossing Modification
- Streamline
- 10Aug2020 Scenario 7 – Crossing Modification & Fldpln Excavation – FP Extents
- 10Aug2020 Scenario 3 – Crossing Modification Only – FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event

Exhibit 9 - Crossing Modification & Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund

Ecosystem Planning & Restoration

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0 300 600 Feet

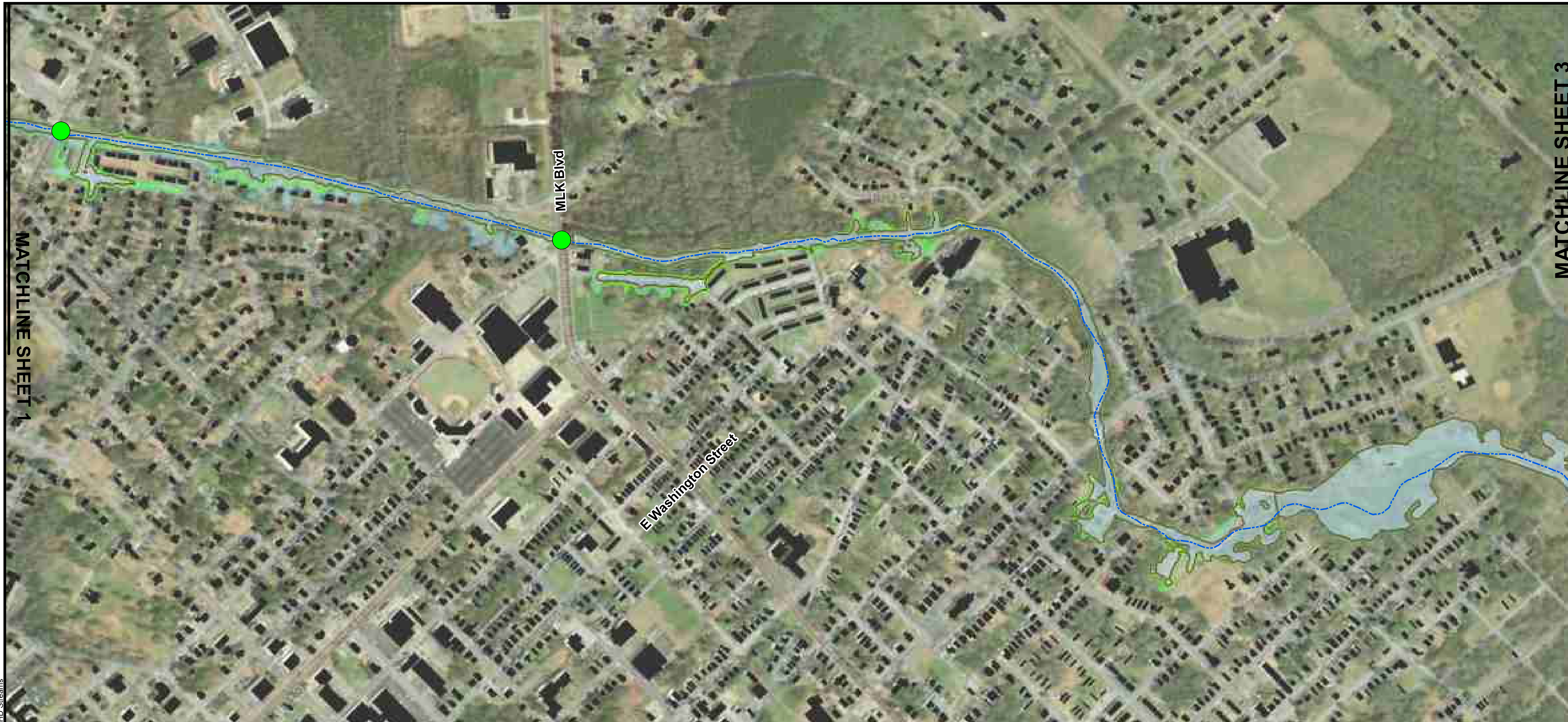
1:7,200

SHEET 1

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

Path: R:\Projects\RDU0141_EDF-Kinston Flood Study\GIS\Maps\Figure 9 - Aug2020_Crossing_FP_sheet1.mxd | Date: 3/29/2021 | Time: 9:06:00 AM | User Name: mkoon



Crossing Modification
Streamline
Building Footprints
10Aug2020 Scenario 7 – Crossing Modification & Fldpln Excavation – FP Extents
10Aug2020 Scenario 3 – Crossing Modification Only – FP Extents
10Aug2020 Rainfall Event - FP Extents

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event
Exhibit 9 - Crossing Modification & Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund — Finding the ways that work

Ecosystem Planning & Restoration

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0 300 600 Feet

1:7,200

SHEET 2

DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

Path: R:\Projects\RDU0141_EDF-Kinston Flood Study\GIS\Maps\Figure 9 - Aug2020_Crossing_FP_sheet2.mxd | Date: 3/29/2021 | Time: 9:08:35 AM | User Name: mkoon

- Streamline
- 10Aug2020 Scenario 7 – Crossing Modification & Fldpln Excavation – FP Extents
- 10Aug2020 Scenario 3 – Crossing Modification Only – FP Extents
- 10Aug2020 Rainfall Event - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

August 10, 2020 Rainfall Event

Exhibit 9 - Crossing Modification & Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work

ECOSYSTEM PLANNING & RESTORATION EPR

N

0 300 600 Feet

1:7,200

SHEET 3

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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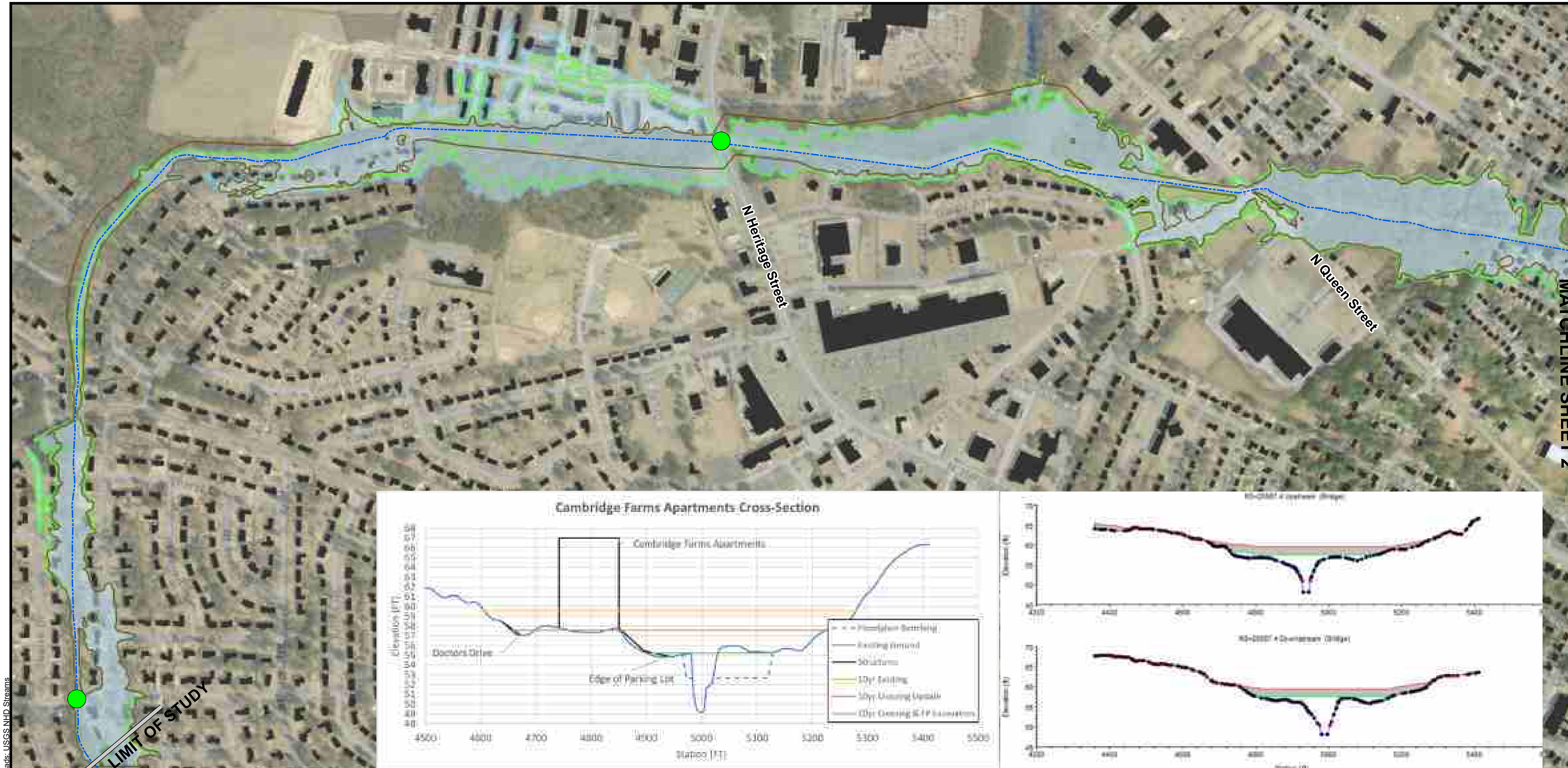

- Streamline
- 10yr Scenario 3 – Crossing Modification Only – FP Extents
- 10yr Scenario 7 – Crossing Modification & Fldpln Excavation – FP Extents
- 10yr Existing Conditions - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain

Exhibit 10 - Crossing Modification & Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund — Finding the ways that work

Ecosystem Planning & Restoration

0 300 600 Feet

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SHEET 1

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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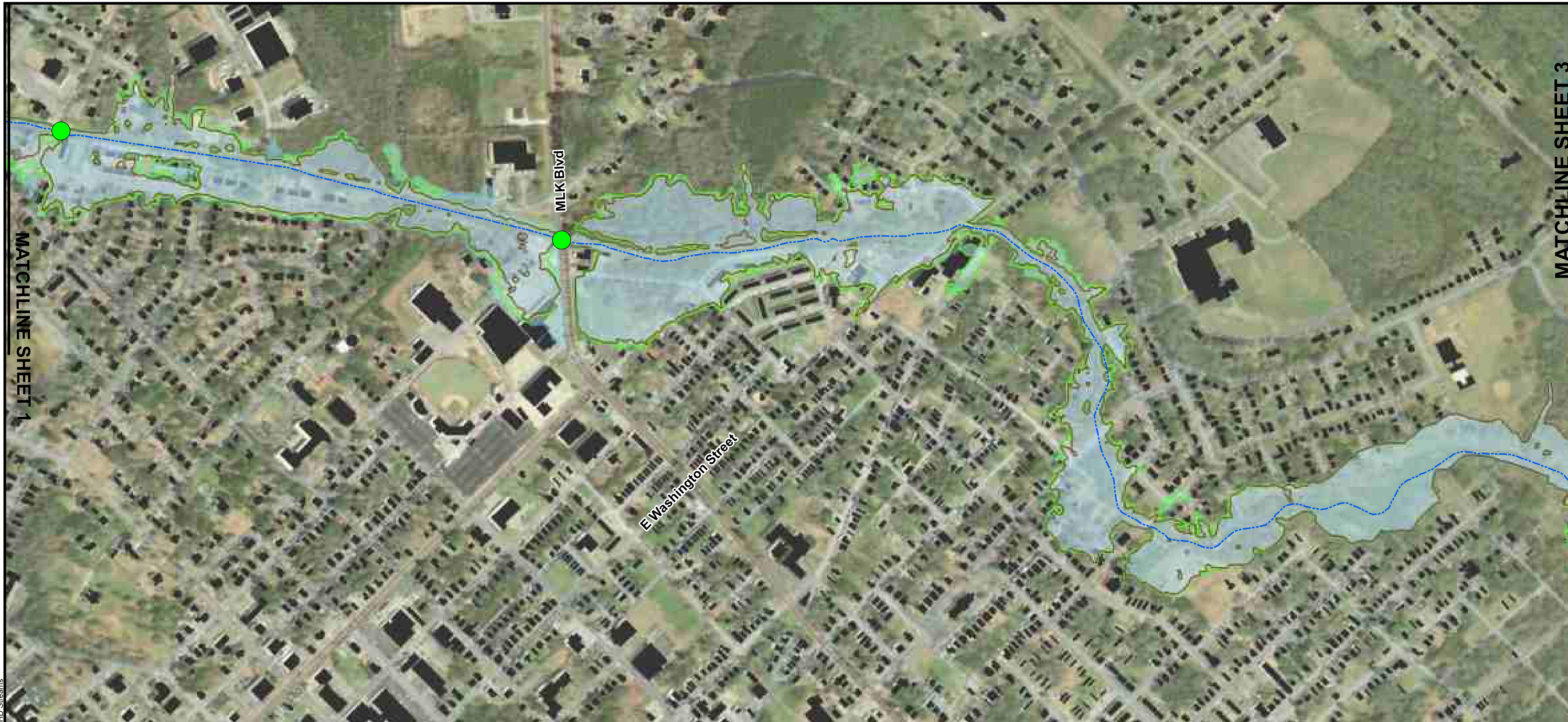

- Streamline
- 10yr Scenario 7 – Crossing Modification & Fldpln Excavation – FP Extents
- 10yr Scenario 3 – Crossing Modification Only – FP Extents
- 10yr Existing Conditions - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 10 - Crossing Modification & Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund — Finding the ways that work

Ecosystem Planning & Restoration (EPR)

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1:7,200

SHEET 2

DATE: March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

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- Streamline
- 10yr Scenario 7 – Crossing Modification & Fldpln Excavation – FP Extents
- 10yr Scenario 3 – Crossing Modification Only – FP Extents
- 10yr Existing Conditions - FP Extents
- Crossing Modification
- Building Footprints

ADKINS BRANCH MODELING

10-Year Floodplain
Exhibit 10 - Crossing Modification & Floodplain Excavation

Kinston, Lenoir County, North Carolina

EDF Environmental Defense Fund

Ecosystem Planning & Restoration

EPR

N

0 300 600 Feet

1:7,200

SHEET 3

DATE:
March 2021

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

Path: R:\Projects\RDU0141_EDF-Kinston Flood Study\GIS\Maps\Figure 10 - 10yr_Crossing_FP_sheet3.mxd | Date: 3/29/2021 | Time: 9:19:33 AM | User Name: mkoon

ATTACHMENT 2 – Calibration Notes

Calibration

A resident reported that during the August event water was coming out of the Adkin Branch upstream of Crawford Street, running down Emerson Rd and then re-entering across a yard somewhere upstream of Carey Street.

The upstream extent of the hydraulic model is about 500 feet upstream of the Crawford Street culvert and examination of the LiDAR indicates that if flow is getting out of Adkin Branch then it is likely occurring upstream of the model extents. The most likely flow path for water to flood Emerson Drive was also examined and it was noted that the water surface elevation at the upstream model extent was not high enough to get over to Emerson Drive. The roughness values in the model were reviewed and revised from the FEMA model values (0.035) to be consistent with the rest of the hydraulic model (0.055). The floodplain roughness values were reasonable and consistent with the rest of the hydraulic model. The increased channel roughness raised the WSE at the cross section by 0.2 feet but was still insufficient to access Emerson Drive.

The model was showing that Laura Lane, downstream of MLK Boulevard, was flooded via backwater for these small flood events. This is not consistent with field conditions during these events.

The hydraulic model and LiDAR data were reviewed. Ineffective flow areas were added for multiple cross-sections to reflect that flow does not access Laura Lane until the bank is overtopped. The mapping of this location as flooded is due to a low spot in the LiDAR data at E. Vernon Ave. Subsequent mapping has removed this area from flood inundation boundaries until the berm next to the channel is overtopped (i.e., the 5-year).

There was noted flooding near the lift station at the downstream extent of the model.

EPR investigated whether the Neuse was causing flooding in this area during the recent storm events and found that the Neuse flood stage was relatively low and not likely flooding Adkin Branch during the August 10 and November 12 flood events. However, the model conditions that would cause flooding near the lift station were not reasonable alterations to make to the model. EPR suspects the flooding of low areas near the lift station may be due to overland flow.

ATTACHMENT 3 – Hydrologic Model Inputs

(1) Summary table of HMS Components and Inputs
(2) Land Use Table
(3) Weighted Land Use Table
(4) Curve Numbers
(5) Lag Time Table
(6) Routing Table
(7) Routing Values for Reach 2 – Modified Puls
(8) Storm Hyetographs

Summary of HEC-HMS Components
Existing Condition

HMS Subbasin ID	Name/Notes	Area (mi^2)	Area (AC)	CN Value	Initial Abstraction (in)	Lag (min)	Downstream Component
1	Hydraulic Headwaters	0.4091	262	75.98	0.63	31.83	Reach 1a
2	UT - Heritage Court Apartments	0.1910	122	73.42	0.72	38.95	Reach 1b
3	LDA - Heritage Street	0.7851	502	71.57	0.79	43.75	Junction 1
4	SD - Heritage Street	0.1073	69	74.55	0.68	29.19	Junction 2
5	LDA - Hospital	0.5458	349	68.98	0.90	17.53	Junction 3
6	LDA - Dollar General	0.4465	286	70.32	0.84	35.84	Junction 4
7	LDA - Highland Ave	0.2140	137	67.60	0.96	31.64	Junction 5
8	UT - Morningside Dr	0.4896	313	59.46	1.36	45.50	Junction 5
9	UT - Hyman Ave	0.2100	134	59.59	1.36	28.06	Junction 5
10	LDA - MLK Blvd	0.3573	229	66.59	1.00	17.13	Junction 6
11	UT - Liberty Hill	0.4479	287	65.40	1.06	37.39	Junction 7
12	LDA - Chestnut Street	0.3637	233	79.05	0.53	24.52	Junction 8
13	LDA - Lovitt Hires Park	0.1821	117	76.54	0.61	17.14	Junction 9
14	LDA - Gordon Street	0.1832	117	70.84	0.82	26.40	Junction 8
15	LDA - Lincoln Street	0.2825	181	65.23	1.07	27.24	Junction -END
	Total Drainage Area	**5.2151**	**3338**				

UT = Unnamed Tributary

LDA = Lateral Drainage Area

SD = Storm Drain

Reach ID	Name/Notes	Length (FT)	Routing Method	Downstream Component
1a	Adkin Branch Mainstem	7588	Muskingum-Cunge	Junction 1
1b	Adkin Branch Mainstem	2275	Muskingum-Cunge	Junction 1
2	Adkin Branch Mainstem	1974	Modified Puls	Junction 3
3	Adkin Branch Mainstem	1379	Muskingum-Cunge	Junction 4
4	Adkin Branch Mainstem	2945	Muskingum-Cunge	Junction 5
5	Adkin Branch Mainstem	2719	Muskingum-Cunge	Junction 6
6	Adkin Branch Mainstem	1344	Muskingum-Cunge	Junction 7
7	Adkin Branch Mainstem	3012	Muskingum-Cunge	Junction 8
8	Adkin Branch Mainstem	964	Muskingum-Cunge	Junction 9
9	Adkin Branch Mainstem	3281	Muskingum-Cunge	Junction-END

Land Uses from NLCD 2016

Land Use and HSG	Subbasin ID - Area (Acres)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cultivated Crops															
Assumed A					0.88										
A	32.43	33.33	20.75	3.44	27.90	0.02	2.66		3.18	5.11	26.83			0.44	11.98
A/D	52.01	16.09	2.61	3.70	5.95		0.67			0.22	5.71				0.02
B	0.00	13.28	0.65	4.04	2.33				0.47		12.82	0.22			1.37
B/D	17.91	1.47	0.09	1.20	3.84						5.34				
C		2.27	3.30												
C/D		0.20													
D											16.03				
Deciduous Forest															
Assumed A					0.05										
A			2.27		0.30			6.09							3.12
A/D	1.37		0.84		1.21										
B									0.48		0.01				
B/D	0.00				3.11										
Developed, High Intensity															
A		0.64	1.01	2.56	8.34	31.04	7.55	1.48	1.40	7.41	1.36	3.83	0.17	0.43	1.13
A/D			1.41		1.39	7.63	0.39	0.75		1.22		0.20			
B			0.22			1.14				1.51		14.84	4.54		
B/D				2.95	0.11	1.94		0.22							
C		0.00	0.37							7.91		5.46	0.37		
Developed, Low Intensity															
A	0.16	0.76	39.33	8.50	44.43	75.37	42.96	129.88	42.63	35.88	18.88	8.49	11.16	10.96	36.37
A/D	20.24	0.38	50.69	0.44	11.98	18.78	5.16	4.34	2.71	5.55	0.54	5.71	2.81	10.44	2.39
B	4.98	1.60	8.51	0.50	14.57	4.61				5.44	19.17	81.61	46.27	10.10	12.78
B/D	0.00	1.48	23.18	4.70	14.59	10.06	0.27	14.95	7.83	0.55	8.60				
C		0.46	7.57							14.26		11.69	0.24		
C/D			23.64												
D											2.56			5.43	

Land Uses from NLCD 2016

Land Use and HSG	Subbasin ID - Area (Acres)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Developed, Medium Intensity															
A		0.51	15.92	10.29	30.17	37.46	11.39	14.57	7.82	16.36	12.46	14.09	4.29	2.65	4.33
A/D	2.89	0.17	6.50	0.24	7.67	2.52	1.49	0.97	0.01	3.43	0.30	1.23	0.48	0.56	
B		1.72	0.47	0.00		4.61				2.02	0.22	47.39	26.32	2.31	1.88
B/D		0.68	0.67	6.40	1.90	1.92	0.06	1.69	1.10	0.16					
C		1.63	9.46							7.85		9.74	0.86		
C/D			0.39												
D											0.46				
Developed, Open Space															
A	2.61	4.25	55.71	8.39	55.55	46.28	32.73	113.74	26.89	41.58	18.91	1.59	0.83	10.43	41.88
A/D	64.27	1.99	57.23	0.56	19.64	12.79	10.03	3.42	4.48	8.70	2.09	1.59	3.32	19.43	20.26
B	12.72	6.12	10.55	1.39	22.30	4.19			0.89	1.03	13.82	16.25	14.67	6.59	14.79
B/D	1.44	2.88	25.56	8.06	26.96	7.64	1.99	12.49	5.65	0.02	4.57				
C		1.75	6.36							8.16		6.02	0.20		
C/D			33.31												
D											4.36			8.83	
Emergent Herbaceuous Wetlands															
A/D	18.01														
Evergreen Forest															
A			20.49		8.20	3.42	0.06	5.21	2.26	20.50	13.90			2.17	0.35
A/D	12.12	1.95	23.71		3.74	2.96			1.29	1.24	11.81	0.21		5.34	0.05
B	1.86		0.01		0.41				0.21		4.62				
B/D	0.04		1.05		8.32				1.22		5.89				
C			0.05							0.15					
C/D			2.38												
D											6.02			5.45	
Hay/Pasture															
A															1.83
B															0.62

Land Uses from NLCD 2016

Land Use and HSG	Subbasin ID - Area (Acres)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Herbaceous															
A			0.53			1.11			0.09		0.80				1.20
A/D					0.89										
B											1.15				
C/D			0.83												
D											0.05				
Mixed Forest															
Assumed A					0.10										
A		0.63	5.17		1.42	2.67		2.09	8.31	3.14	5.67			1.16	6.62
A/D	1.72	6.68	10.37		2.53	0.09			1.99	2.62	11.94	0.29		3.48	
B	0.74	0.53							1.73			0.16			
B/D									0.07						
C		0.00	0.00												
C/D		0.62													
D											1.88			1.22	
Shrub/Scrub															
A			3.31	1.28	1.72	1.61	2.01	1.49	10.38	6.62	14.67			2.31	
A/D	1.16		0.71		3.13	0.83	1.33		0.68	1.78	2.54	1.30		0.89	
B	1.51										7.43	0.66			
B/D	0.00				0.70						0.91				
D											1.50			2.92	
Woody Wetlands															
A		0.00	5.13		0.60	0.84	2.63		0.19	10.03	9.93			0.06	17.82
A/D	11.60	11.85	19.30		12.36	4.21	13.60		0.47	8.20	5.90	0.21		1.62	
B		1.98	0.87								0.52			0.38	
B/D		0.00									0.88				
C/D		4.34	0.01												
D											3.60			1.64	
TOTAL (ACRES)	261.80	122.24	502.46	68.65	349.28	285.76	136.97	313.37	134.43	228.69	286.65	232.78	116.54	117.25	180.78
Total (sq.mi.)	0.41	0.19	0.79	0.11	0.55	0.45	0.21	0.49	0.21	0.36	0.45	0.36	0.18	0.18	0.28

Weighted Land Use

Land Use and HSG	Subbasin ID - Weighted Subbasin Area (%)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cultivated Crops															
Assumed A					0.3%										
A	12.4%	27.3%	4.1%	5.0%	8.0%	0.0%	1.9%		2.4%	2.2%	9.4%			0.4%	6.6%
A/D	19.9%	13.2%	0.5%	5.4%	1.7%		0.5%			0.1%	2.0%				0.0%
B	0.0%	10.9%	0.1%	5.9%	0.7%				0.4%		4.5%	0.1%			0.8%
B/D	6.8%	1.2%	0.0%	1.8%	1.1%						1.9%				
C		1.9%	0.7%												
C/D		0.2%													
D											5.6%				
Deciduous Forest															
Assumed A					0.0%										
A			0.5%		0.1%			1.9%							1.7%
A/D	0.5%		0.2%		0.3%										
B									0.4%		0.0%				
B/D	0.0%				0.9%										
Developed, High Intensity															
A		0.5%	0.2%	3.7%	2.4%	10.9%	5.5%	0.5%	1.0%	3.2%	0.5%	1.6%	0.1%	0.4%	0.6%
A/D			0.3%		0.4%	2.7%	0.3%	0.2%		0.5%		0.1%			
B			0.0%			0.4%				0.7%		6.4%	3.9%		
B/D				4.3%	0.0%	0.7%		0.1%							
C		0.0%	0.1%							3.5%		2.3%	0.3%		
Developed, Low Intensity															
A	0.1%	0.6%	7.8%	12.4%	12.7%	26.4%	31.4%	41.4%	31.7%	15.7%	6.6%	3.6%	9.6%	9.4%	20.1%
A/D	7.7%	0.3%	10.1%	0.6%	3.4%	6.6%	3.8%	1.4%	2.0%	2.4%	0.2%	2.5%	2.4%	8.9%	1.3%
B	1.9%	1.3%	1.7%	0.7%	4.2%	1.6%				2.4%	6.7%	35.1%	39.7%	8.6%	7.1%
B/D	0.0%	1.2%	4.6%	6.8%	4.2%	3.5%	0.2%	4.8%	5.8%	0.2%	3.0%				
C		0.4%	1.5%							6.2%		5.0%	0.2%		
C/D			4.7%												
D											0.9%			4.6%	

Weighted Land Use

Land Use and HSG	Subbasin ID - Weighted Subbasin Area (%)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Developed, Medium Intensity															
A		0.4%	3.2%	15.0%	8.6%	13.1%	8.3%	4.6%	5.8%	7.2%	4.3%	6.1%	3.7%	2.3%	2.4%
A/D	1.1%	0.1%	1.3%	0.4%	2.2%	0.9%	1.1%	0.3%	0.0%	1.5%	0.1%	0.5%	0.4%	0.5%	
B		1.4%	0.1%	0.0%		1.6%				0.9%	0.1%	20.4%	22.6%	2.0%	1.0%
B/D		0.6%	0.1%	9.3%	0.5%	0.7%	0.0%	0.5%	0.8%	0.1%					
C		1.3%	1.9%							3.4%		4.2%	0.7%		
C/D			0.1%												
D											0.2%				
Developed, Open Space															
A	1.0%	3.5%	11.1%	12.2%	15.9%	16.2%	23.9%	36.3%	20.0%	18.2%	6.6%	0.7%	0.7%	8.9%	23.2%
A/D	24.6%	1.6%	11.4%	0.8%	5.6%	4.5%	7.3%	1.1%	3.3%	3.8%	0.7%	0.7%	2.8%	16.6%	11.2%
B	4.9%	5.0%	2.1%	2.0%	6.4%	1.5%			0.7%	0.5%	4.8%	7.0%	12.6%	5.6%	8.2%
B/D	0.6%	2.4%	5.1%	11.7%	7.7%	2.7%	1.5%	4.0%	4.2%	0.0%	1.6%				
C		1.4%	1.3%							3.6%		2.6%	0.2%		
C/D			6.6%												
D											1.5%			7.5%	
Emergent Herbaceuous Wetlands															
A/D	6.9%														
Evergreen Forest															
A			4.1%		2.3%	1.2%	0.0%	1.7%	1.7%	9.0%	4.8%			1.8%	0.2%
A/D	4.6%	1.6%	4.7%		1.1%	1.0%			1.0%	0.5%	4.1%	0.1%		4.6%	0.0%
B	0.7%		0.0%		0.1%				0.2%		1.6%				
B/D	0.0%		0.2%		2.4%				0.9%		2.1%				
C			0.0%							0.1%					
C/D			0.5%												
D											2.1%			4.7%	
Hay/Pasture															
A															1.0%
B															0.3%

Weighted Land Use

Land Use and HSG	Subbasin ID - Weighted Subbasin Area (%)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Herbaceous															
A			0.1%			0.4%			0.1%		0.3%				0.7%
A/D					0.3%										
B											0.4%				
C/D			0.2%												
D											0.0%				
Mixed Forest															
Assumed A					0.0%										
A		0.5%	1.0%		0.4%	0.9%		0.7%	6.2%	1.4%	2.0%			1.0%	3.7%
A/D	0.7%	5.5%	2.1%		0.7%	0.0%			1.5%	1.1%	4.2%	0.1%		3.0%	
B	0.3%	0.4%							1.3%			0.1%			
B/D									0.0%						
C		0.0%	0.0%												
C/D		0.5%													
D											0.7%			1.0%	
Shrub/Scrub															
A			0.7%	1.9%	0.5%	0.6%	1.5%	0.5%	7.7%	2.9%	5.1%			2.0%	
A/D	0.4%		0.1%		0.9%	0.3%	1.0%		0.5%	0.8%	0.9%	0.6%		0.8%	
B	0.6%										2.6%	0.3%			
B/D	0.0%				0.2%						0.3%				
D											0.5%			2.5%	
Woody Wetlands															
A		0.0%	1.0%		0.2%	0.3%	1.9%		0.1%	4.4%	3.5%			0.1%	9.9%
A/D	4.4%	9.7%	3.8%		3.5%	1.5%	9.9%		0.4%	3.6%	2.1%	0.1%		1.4%	
B		1.6%	0.2%								0.2%			0.3%	
B/D		0.0%									0.3%				
C/D		3.5%	0.0%												
D											1.3%			1.4%	

Curve Numbers

Land Use and HSG	CN	Subbasin ID - Curve Number														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		75.98	73.42	71.57	74.55	68.98	70.32	67.60	59.46	59.59	66.59	65.40	79.05	76.54	70.84	65.23
Cultivated Crops																
Assumed A	71					0.18										
A	71	8.79	19.36	2.93	3.56	5.67	0.00	1.38		1.68	1.59	6.64			0.27	4.71
A/D	71	14.10	9.35	0.37	3.82	1.21		0.35			0.07	1.41				0.01
B	80	0.00	8.69	0.10	4.71	0.53				0.28		3.58	0.08			0.61
B/D	80	5.47	0.96	0.01	1.40	0.88						1.49				
C	87		1.61	0.57												
C/D	87		0.14													
D	90											5.03				
Deciduous Forest																
Assumed A	36					0.01										
A	36			0.16		0.03			0.70							0.62
A/D	36	0.19		0.06		0.12										
B	60									0.21		0.00				
B/D	60	0.00				0.53										
Developed, High Intensity																
A	89		0.47	0.18	3.32	2.13	9.67	4.90	0.42	0.93	2.89	0.42	1.46	0.13	0.32	0.56
A/D	95			0.27		0.38	2.54	0.27	0.23		0.51		0.08			
B	92			0.04			0.37				0.61		5.87	3.59		
B/D	95				4.08	0.03	0.65		0.07							
C	94		0.00	0.07							3.25		2.20	0.30		
Developed, Low Intensity																
A	61	0.04	0.38	4.77	7.55	7.76	16.09	19.13	25.28	19.35	9.57	4.02	2.23	5.84	5.70	12.27
A/D	87	6.73	0.27	8.78	0.56	2.98	5.72	3.28	1.20	1.75	2.11	0.16	2.13	2.10	7.75	1.15
B	75	1.43	0.98	1.27	0.55	3.13	1.21				1.78	5.02	26.30	29.77	6.46	5.30
B/D	87	0.00	1.05	4.01	5.95	3.63	3.06	0.17	4.15	5.07	0.21	2.61				
C	83		0.32	1.25							5.18		4.17	0.17		
C/D	87			4.09												
D	87											0.78			4.03	

Curve Numbers

Land Use and HSG	CN	Subbasin ID - Curve Number														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		75.98	73.42	71.57	74.55	68.98	70.32	67.60	59.46	59.59	66.59	65.40	79.05	76.54	70.84	65.23
Developed, Medium Intensity																
A	77		0.32	2.44	11.55	6.65	10.09	6.40	3.58	4.48	5.51	3.35	4.66	2.84	1.74	1.84
A/D	92	1.02	0.13	1.19	0.32	2.02	0.81	1.00	0.28	0.01	1.38	0.10	0.49	0.38	0.44	
B	85		1.20	0.08	0.00		1.37				0.75	0.06	17.30	19.19	1.68	0.88
B/D	92		0.51	0.12	8.58	0.50	0.62	0.04	0.50	0.76	0.07					
C	90		1.20	1.69							3.09		3.77	0.67		
C/D	92			0.07												
D	92											0.15				
Developed, Open Space																
A	49	0.49	1.71	5.43	5.99	7.79	7.94	11.71	17.78	9.80	8.91	3.23	0.34	0.35	4.36	11.35
A/D	84	20.62	1.37	9.57	0.68	4.72	3.76	6.15	0.92	2.80	3.20	0.61	0.57	2.39	13.92	9.41
B	69	3.35	3.46	1.45	1.40	4.40	1.01			0.46	0.31	3.33	4.82	8.68	3.88	5.65
B/D	84	0.46	1.98	4.27	9.87	6.48	2.25	1.22	3.35	3.53	0.01	1.34				
C	79		1.13	1.00							2.82		2.04	0.14		
C/D	84			5.57												
D	84											1.28			6.32	
Emergent Herbaceuous Wetlands																
A/D	91	6.26														
Evergreen Forest																
A	36			1.47		0.84	0.43	0.02	0.60	0.60	3.23	1.75			0.66	0.07
A/D	36	1.67	0.57	1.70		0.39	0.37			0.35	0.19	1.48	0.03		1.64	0.01
B	60	0.43		0.00		0.07				0.09		0.97				
B/D	60	0.01		0.13		1.43				0.54		1.23				
C	73			0.01							0.05					
C/D	73			0.35												
D	79											1.66			3.67	
Hay/Pasture																
A	39															0.39
B	61															0.21

Curve Numbers

Land Use and HSG	CN	Subbasin ID - Curve Number														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		75.98	73.42	71.57	74.55	68.98	70.32	67.60	59.46	59.59	66.59	65.40	79.05	76.54	70.84	65.23
Herbaceous																
A	30			0.03			0.12			0.02		0.08				0.20
A/D	30					0.08										
B	58											0.23				
C/D	71			0.12												
D	78											0.01				
Mixed Forest																
Assumed A	36					0.01										
A	36		0.19	0.37		0.15	0.34		0.24	2.23	0.49	0.71			0.36	1.32
A/D	36	0.24	1.97	0.74		0.26	0.01			0.53	0.41	1.50	0.04		1.07	
B	60	0.17	0.26							0.77			0.04			
B/D	60									0.03						
C	73		0.00	0.00												
C/D	73		0.37													
D	79											0.52			0.82	
Shrub/Scrub																
A	35			0.23	0.65	0.17	0.20	0.51	0.17	2.70	1.01	1.79			0.69	
A/D	35	0.15		0.05		0.31	0.10	0.34		0.18	0.27	0.31	0.20		0.27	
B	56	0.32										1.45	0.16			
B/D	56	0.00				0.11						0.18				
D	77											0.40			1.92	
Woody Wetlands																
A	88		0.00	0.90		0.15	0.26	1.69		0.12	3.86	3.05			0.05	8.67
A/D	91	4.03	8.82	3.50		3.22	1.34	9.04		0.32	3.26	1.87	0.08		1.26	
B	89		1.44	0.15								0.16			0.29	
B/D	91		0.00									0.28				
C/D	91		3.23	0.00												
D	91											1.14			1.27	

SCS Transform Method
Lag Calculations

Sub-basin	Type	Length (ft)	Ele High (ft)	Ele Low (ft)	Slope	n-value	P2	Cover	Velocity	Tc (hr)	Tc (min)	Lag (min)	Total Lag (min)
Headwaters	Sheet Flow	100	107.8	107.2	0.005	0.06	3.89	n/a	n/a	0.12	7.3	4.4	
1	Shallow Conc Flow 1	3077	107.2	83.2	0.008	n/a	n/a	unpaved	1.43	0.60	35.9	21.6	
	Channel Flow	2000	83.2	76.8	0.003	0.035	n/a	n/a	4.16	0.13	8.0	4.8	
	Pipe Flow (36")	280	76.8	75.9	0.003	0.013	n/a	n/a	5.68	0.01	0.8	0.5	
	Channel Flow - HW3	924	75.9	68.6	0.008	0.013	n/a	n/a	15.14	0.02	1.0	0.6	**31.8**
UT - Heritage Apartments	Sheet Flow	100	79.5	79.2	0.004	0.06	3.89	n/a	n/a	0.14	8.5	5.1	
	Shallow Conc Flow 1	1095	79.2	70.1	0.008	n/a	n/a	unpaved	1.47	0.21	12.4	7.5	
2	Shallow Conc Flow 2	609	70.1	66.0	0.007	n/a	n/a	unpaved	1.32	0.13	7.7	4.6	
	Shallow Conc Flow 3	1413	66.0	61.7	0.003	n/a	n/a	unpaved	0.89	0.44	26.3	15.8	
	Channel Flow - UTHA1	741	61.7	59.4	0.003	0.035	n/a	n/a	3.09	0.07	4.0	2.4	
	Channel Flow - UTHA2	779	59.4	57.4	0.003	0.045	n/a	n/a	2.18	0.10	5.9	3.6	**38.9**
UT - Hospital	Sheet Flow	100	76.2	75.2	0.060	0.06	3.89	n/a	n/a	0.05	2.8	1.7	
5	Channel Flow	730	75.2	74.9	0.000	0.035	n/a	n/a	1.37	0.15	8.9	5.3	
	Pipe Flow (15")	73	74.9	73.5	0.019	0.013	n/a	n/a	8.05	0.00	0.2	0.1	
	Channel Flow	506	73.5	72.5	0.002	0.035	n/a	n/a	3.78	0.04	2.2	1.3	
	Pipe Flow (15")	33	72.5	72.2	0.010	0.013	n/a	n/a	5.98	0.00	0.1	0.1	
	Channel Flow	572	72.2	68.3	0.007	0.035	n/a	n/a	7.02	0.02	1.4	0.8	
	Pipe Flow (15")	33	68.3	68.2	0.004	0.013	n/a	n/a	3.49	0.00	0.2	0.1	
	Channel Flow	522	68.2	65.9	0.004	0.055	n/a	n/a	4.44	0.03	2.0	1.2	
	Channel Flow	1967	65.9	55.4	0.005	0.055	n/a	n/a	4.47	0.12	7.3	4.4	
	Channel Flow	367	55.4	53.5	0.005	0.04	n/a	n/a	6.05	0.02	1.0	0.6	
	Channel Flow - UTH1	1036	53.5	47.7	0.006	0.055	n/a	n/a	5.25	0.05	3.3	2.0	**17.5**

SCS Transform Method
Lag Calculations

Sub-basin	Type	Length (ft)	Ele High (ft)	Ele Low (ft)	Slope	n-value	P2	Cover	Velocity	Tc (hr)	Tc (min)	Lag (min)	Total Lag (min)
Dollar General	Sheet Flow	100	81.7	81.4	0.003	0.41	3.89	n/a	n/a	0.70	41.9	25.1	
6	Shallow Conc Flow 1	103	81.4	80.4	0.010	n/a	n/a	paved	2.00	0.01	0.9	0.5	
	Pipe Flow (24")	1408	80.4	80.3	0.005	0.013	n/a	n/a	4.13	0.09	5.7	3.4	
	Pipe Flow (30")	307	80.3	78.7	0.005	0.013	n/a	n/a	6.53	0.01	0.8	0.5	
	Pipe Flow (36")	3574	78.7	58.7	0.006	0.013	n/a	n/a	7.59	0.13	7.8	4.7	
	Pipe Flow (54")	349	58.7	53.1	0.005	0.013	n/a	n/a	9.29	0.01	0.6	0.4	
	Channel Flow - DG1	413	52.6	49.9	0.006	0.045	n/a	n/a	7.87	0.01	0.9	0.5	
	Channel Flow - DG2	671	48.0	46.4	0.002	0.045	n/a	n/a	9.45	0.02	1.2	0.7	**35.8**
Liberty Hill Ave	Sheet Flow	100	79.1	78.6	0.005	0.24	3.89	n/a	n/a	0.37	22.2	13.3	
11	Shallow Conc Flow	413	78.6	77.6	0.002	n/a	n/a	unpaved	0.79	0.14	8.7	5.2	
	Channel Flow	299	77.6	75.0	0.009	0.035	n/a	n/a	3.95	0.02	1.3	0.8	
	Pipe Flow (15")	899	75.0	73.0	0.002	0.013	n/a	n/a	2.80	0.09	5.3	3.2	
	Pipe Flow (24")	46	73.0	72.9	0.002	0.013	n/a	n/a	3.77	0.00	0.2	0.1	
	Pipe Flow (18)	640	72.9	71.4	0.002	0.013	n/a	n/a	3.14	0.06	3.4	2.0	
	Pipe Flow (24")	520	71.4	69.3	0.002	0.013	n/a	n/a	3.77	0.04	2.3	1.4	
	Channel Flow	1441	69.3	58.8	0.007	0.045	n/a	n/a	6.30	0.06	3.8	2.3	
	Channel Flow	1560	58.8	49.2	0.006	0.09	n/a	n/a	3.39	0.13	7.7	4.6	
	Channel Flow	1885	49.2	32.1	0.009	0.09	n/a	n/a	4.22	0.12	7.4	4.5	**37.4**
N Heritage St	Sheet Flow	100	79.2	78.7	0.004	0.06	3.89	n/a	n/a	0.13	7.8	4.7	
4	Shallow Conc Flow	800	78.7	78.0	0.001	n/a	n/a	unpaved	0.50	0.45	26.9	16.1	
	Shallow Conc Flow	648	78.0	74.0	0.006	n/a	n/a	paved	1.59	0.11	6.8	4.1	
	Pipe Flow (18")	252	72.3	72.0	0.001	0.013	n/a	n/a	2.06	0.03	2.0	1.2	
	Pipe Flow (24")	382	72.0	71.8	0.001	0.013	n/a	n/a	1.80	0.06	3.5	2.1	
	Pipe Flow (30")	995	71.8	58.3	0.014	0.013	n/a	n/a	10.52	0.03	1.6	0.9	**29.2**
Chestnut	Sheet Flow	100	46.0	44.5	0.015	0.011	3.89	n/a	n/a	0.02	1.2	0.7	
12	Shallow Conc Flow 1	313	44.5	42.6	0.006	n/a	n/a	paved	1.60	0.05	3.3	2.0	
	Pipe Flow (15")	198	40.1	39.9	0.001	0.013	n/a	n/a	1.65	0.03	2.0	1.2	
	Pipe Flow (24")	769	39.9	39.3	0.001	0.013	n/a	n/a	2.22	0.10	5.8	3.5	
	Pipe Flow (21")	495	39.3	38.9	0.001	0.013	n/a	n/a	2.04	0.07	4.0	2.4	
	Pipe Flow (24")	1145	38.9	38.0	0.001	0.013	n/a	n/a	2.22	0.14	8.6	5.2	
	Pipe Flow (36")	200	38.0	37.8	0.001	0.013	n/a	n/a	2.87	0.02	1.2	0.7	
	Pipe Flow (42")	2742	37.8	35.6	0.001	0.013	n/a	n/a	3.17	0.24	14.4	8.7	
	Channel Flow	223	35.6	29.3	0.028	0.055	n/a	n/a	9.81	0.01	0.4	0.2	**24.5**

SCS Transform Method
Lag Calculations

Sub-basin	Type	Length (ft)	Ele High (ft)	Ele Low (ft)	Slope	n-value	P2	Cover	Velocity	Tc (hr)	Tc (min)	Lag (min)	Total Lag (min)
Gorden	Sheet Flow	100	71.9	67.8	0.041	0.8	3.89	n/a	n/a	0.42	25.4	15.3	
14	Shallow Conc Flow 1	848	67.8	40.7	0.032	n/a	n/a	unpaved	2.88	0.08	4.9	2.9	
	Pipe Flow (15")	46	40.7	40.7	0.001	0.013	n/a	n/a	1.65	0.01	0.5	0.3	
	Channel Flow	568	40.7	31.1	0.017	0.045	n/a	n/a	4.31	0.04	2.2	1.3	
	Channel Flow	2508	31.1	26.2	0.002	0.055	n/a	n/a	3.80	0.18	11.0	6.6	**26.4**
Highland	Sheet Flow	100	78.4	77.3	0.011	0.41	3.89	n/a	n/a	0.42	25.2	15.1	
7	Shallow Conc Flow 1	505	77.3	76.4	0.002	n/a	n/a	unpaved	0.68	0.21	12.4	7.4	
	Pipe Flow (15")	42	74.0	73.5	0.011	0.013	n/a	n/a	6.13	0.00	0.1	0.1	
	Pipe Flow (18")	1125	73.5	61.2	0.011	0.013	n/a	n/a	6.87	0.05	2.7	1.6	
	Pipe Flow (30")	1251	61.2	47.4	0.011	0.013	n/a	n/a	9.48	0.04	2.2	1.3	
	Pipe Flow (48")	99	47.4	48.3	0.011	0.013	n/a	n/a	12.78	0.00	0.1	0.1	
	Channel Flow	510	48.3	40.2	0.016	0.055	n/a	n/a	3.42	0.04	2.5	1.5	
	Channel Flow	1566	40.2	37.1	0.002	0.055	n/a	n/a	3.49	0.12	7.5	4.5	**31.6**
Lincoln	Sheet Flow	100	77.5	77.0	0.005	0.24	3.89	n/a	n/a	0.38	22.8	13.7	
15	Shallow Conc Flow 1	124	77.0	74.9	0.017	n/a	n/a	unpaved	2.09	0.02	1.0	0.6	
	Channel Flow	2120	74.9	36.3	0.018	0.09	n/a	n/a	3.65	0.16	9.7	5.8	
	Pipe Flow (18")	197	36.3	36.2	0.011	0.013	n/a	n/a	6.87	0.01	0.5	0.3	
	Channel Flow	1264	36.2	22.2	0.011	0.09	n/a	n/a	3.74	0.09	5.6	3.4	
	Channel Flow	873	22.2	21.4	0.001	0.055	n/a	n/a	2.52	0.10	5.8	3.5	**27.2**
Lovitt	Sheet Flow	67	43.0	42.3	0.010	0.24	3.89	n/a	n/a	0.21	12.6	7.5	
13	Pipe Flow (15")	983	39.3	36.8	0.003	0.013	n/a	n/a	2.98	0.09	5.5	3.3	
	Pipe Flow (18")	527	36.8	35.4	0.003	0.013	n/a	n/a	3.34	0.04	2.6	1.6	
	Pipe Flow (24")	701	35.4	33.6	0.003	0.013	n/a	n/a	4.00	0.05	2.9	1.8	
	Pipe Flow (30")	55	33.6	33.5	0.003	0.013	n/a	n/a	4.61	0.00	0.2	0.1	
	Pipe Flow (36")	382	33.5	32.5	0.003	0.013	n/a	n/a	5.17	0.02	1.2	0.7	
	Pipe Flow (42")	680	32.5	30.7	0.003	0.013	n/a	n/a	5.71	0.03	2.0	1.2	
	Pipe Flow (48")	570	30.7	29.1	0.003	0.013	n/a	n/a	6.21	0.03	1.5	0.9	**17.1**

SCS Transform Method
Lag Calculations

Sub-basin	Type	Length (ft)	Ele High (ft)	Ele Low (ft)	Slope	n-value	P2	Cover	Velocity	Tc (hr)	Tc (min)	Lag (min)	Total Lag (min)
MLKsouth	Sheet Flow	100	80.1	79.0	0.011	0.24	3.89	n/a	n/a	0.27	16.3	9.8	
10	Shallow Conc Flow 1	361	79.0	61.9	0.047	n/a	n/a	paved	4.42	0.02	1.4	0.8	
	Pipe Flow (18")	221	57.8	56.5	0.006	0.013	n/a	n/a	4.95	0.01	0.7	0.4	
	Pipe Flow (15")	776	56.5	52.1	0.006	0.013	n/a	n/a	4.41	0.05	2.9	1.8	
	Pipe Flow (21")	124	52.1	51.4	0.006	0.013	n/a	n/a	5.93	0.01	0.3	0.2	
	Pipe Flow (24")	186	51.4	50.3	0.006	0.013	n/a	n/a	5.93	0.01	0.5	0.3	
	Pipe Flow (30")	1149	50.3	43.8	0.006	0.013	n/a	n/a	5.93	0.05	3.2	1.9	
	Pipe Flow (32")	501	43.8	40.9	0.006	0.013	n/a	n/a	7.11	0.02	1.2	0.7	
	Pipe Flow (36")	416	40.9	38.5	0.006	0.013	n/a	n/a	7.66	0.02	0.9	0.5	
	Pipe Flow (48")	50	38.5	38.2	0.006	0.013	n/a	n/a	9.20	0.00	0.1	0.1	
	Pipe Flow (52")	610	38.2	34.9	0.006	0.013	n/a	n/a	10.94	0.02	0.9	0.6	**17.1**
Morningside Dr UT	Sheet Flow	100	81.8	81.7	0.002	0.24	3.89	n/a	n/a	0.57	34.3	20.6	
8	Shallow Conc Flow 1	564	81.7	81.0	0.001	n/a	n/a	paved	0.72	0.22	13.1	7.9	
	Pipe Flow (15")	55	78.0	77.8	0.003	0.013	n/a	n/a	3.09	0.00	0.3	0.2	
	Pipe Flow (18")	1093	77.8	74.7	0.003	0.013	n/a	n/a	3.47	0.09	5.3	3.2	
	Pipe Flow (24")	604	74.7	73.1	0.003	0.013	n/a	n/a	4.16	0.04	2.4	1.5	
	Pipe Flow (30")	365	73.1	72.0	0.003	0.013	n/a	n/a	4.78	0.02	1.3	0.8	
	Pipe Flow (36")	431	72.0	70.8	0.003	0.013	n/a	n/a	5.37	0.02	1.3	0.8	
	Pipe Flow (36")	100	70.8	70.5	0.003	0.013	n/a	n/a	5.37	0.01	0.3	0.2	
	Pipe Flow (36")	416	70.5	69.4	0.003	0.013	n/a	n/a	5.37	0.02	1.3	0.8	
	Pipe Flow (42")	2492	69.4	62.4	0.003	0.013	n/a	n/a	5.92	0.12	7.0	4.2	
	Pipe Flow (48")	515	62.4	61.0	0.003	0.013	n/a	n/a	6.45	0.02	1.3	0.8	
	Pipe Flow (36")	354	61.0	60.0	0.003	0.013	n/a	n/a	5.37	0.02	1.1	0.7	
	Pipe Flow (42")	228	60.0	59.3	0.003	0.013	n/a	n/a	5.92	0.01	0.6	0.4	
	Pipe Flow (66")	1050	59.3	56.4	0.003	0.013	n/a	n/a	7.90	0.04	2.2	1.3	
	Pipe Flow (36")	72	56.4	56.2	0.003	0.013	n/a	n/a	5.37	0.00	0.2	0.1	
	Pipe Flow (72")	240	56.2	55.9	0.003	0.013	n/a	n/a	8.58	0.01	0.5	0.3	
	Channel Flow	529	55.9	51.2	0.009	0.04	n/a	n/a	7.80	0.02	1.1	0.7	
	Pipe Flow (48")	852	51.2	41.3	0.006	0.013	n/a	n/a	9.20	0.03	1.5	0.9	
	Channel Flow	222	41.3	39.2	0.009	0.055	n/a	n/a	7.01	0.01	0.5	0.3	**45.5**

SCS Transform Method
Lag Calculations

Sub-basin	Type	Length (ft)	Ele High (ft)	Ele Low (ft)	Slope	n-value	P2	Cover	Velocity	Tc (hr)	Tc (min)	Lag (min)	Total Lag (min)
Nheritage	Sheet Flow	100	83.1	80.9	0.022	0.24	3.89	n/a	n/a	0.21	12.4	7.5	
3	Shallow Conc Flow 1	791	80.9	80.0	0.001	n/a	n/a	paved	0.67	0.33	19.5	11.7	
	Pipe Flow (15")	90	77.0	76.6	0.005	0.013	n/a	n/a	4.01	0.01	0.4	0.2	
	Pipe Flow (18")	128	76.6	76.0	0.005	0.013	n/a	n/a	4.49	0.01	0.5	0.3	
	Pipe Flow (24")	1119	76.0	70.7	0.005	0.013	n/a	n/a	5.38	0.06	3.5	2.1	
	Channel Flow	2121	70.7	61.2	0.004	0.055	n/a	n/a	4.73	0.12	7.5	4.5	
	Channel Flow	4905	61.2	49.8	0.002	0.08	n/a	n/a	2.80	0.49	29.2	17.5	**43.7**
Hyman Ave trib	Sheet Flow	100	78.3	77.8	0.005	0.24	3.89	n/a	n/a	0.37	22.1	13.3	
9	Shallow Conc Flow 1	654	77.8	76.0	0.003	n/a	n/a	paved	1.07	0.17	10.2	6.1	
	Channel Flow	384	76.0	74.6	0.004	0.035	n/a	n/a	3.32	0.03	1.9	1.2	
	Pipe Flow (15")	65	74.6	74.8	0.003	0.013	n/a	n/a	3.09	0.01	0.4	0.2	
	Channel Flow	130	74.8	74.0	0.007	0.035	n/a	n/a	4.53	0.01	0.5	0.3	
	Pipe Flow (18")	237	74.0	73.6	0.003	0.013	n/a	n/a	3.47	0.02	1.1	0.7	
	Pipe Flow (24")	66	73.6	73.5	0.003	0.013	n/a	n/a	4.16	0.00	0.3	0.2	
	Channel Flow	145	73.5	72.0	0.011	0.055	n/a	n/a	4.21	0.01	0.6	0.3	
	Pipe Flow (15")	88	72.0	71.3	0.007	0.013	n/a	n/a	4.96	0.00	0.3	0.2	
	Pipe Flow (30")	1736	71.3	58.8	0.007	0.013	n/a	n/a	7.67	0.06	3.8	2.3	
	Pipe Flow (36")	34	58.8	58.7	0.007	0.013	n/a	n/a	8.61	0.00	0.1	0.0	
	Channel Flow	655	58.7	50.7	0.012	0.055	n/a	n/a	6.08	0.03	1.8	1.1	
	Pipe Flow (36")	203	50.7	50.1	0.003	0.013	n/a	n/a	5.37	0.01	0.6	0.4	
	Channel Flow	1243	50.1	38.6	0.009	0.055	n/a	n/a	6.48	0.05	3.2	1.9	**28.1**

Reach Routing

Reach	Length	Slope*	Manning's Roughness**	Index Flow (CFS)***	Left Manning's Roughness**	Right Manning's Roughness**
1a	7588	0.26%	0.055	60	0.14	0.14
1b	2275	0.09%	0.055	73	0.14	0.15
3	1379	0.2%	0.045	227	0.11	0.11
4	2945	0.24%	0.055	300	0.14	0.14
5	2719	0.19%	0.05	376	0.14	0.11
6	1344	0.15%	0.05	407	0.15	0.11
7	3012	0.18%	0.055	414	0.12	0.14
8	964	0.26%	0.055	479	0.11	0.11
9	3281	0.12%	0.055	503	0.11	0.11

**Slope was measured from LiDAR.*

***Manning's roughness values were consistent with HEC-RAS and lag routing.*

****Index flows were initially calculated using the USGS (2014) equations as 2-year flows. These values were revised later in the modeling process but did not impact the model results.*

Modified Puls Routing Tables

Reach 2 Existing

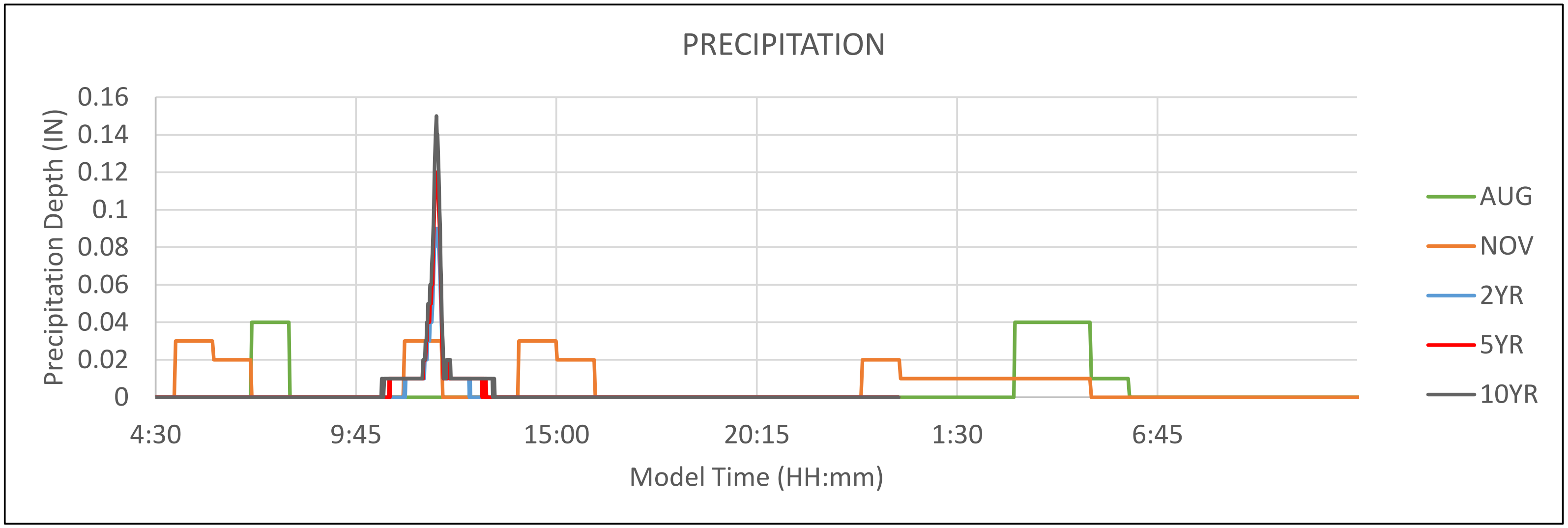
Storage	Discharge	Elevation	Discharge	Length (ft)	Ave. Travel-Time (hrs)	Selected Travel-Time (hr)	Corr. Flows (cfs)	Time Interval	No. of Sub-Reaches
0.00	0	46.80	0	1891	0.24	0.24	283-3108	0.017	10
4.48	269	50.58	269						
7.83	539	52.56	539						
22.09	1077	54.74	1077						
35.87	1617	55.68	1617						
48.04	2155	56.38	2155						
59.60	2694	57.00	2694						
65.10	2963	57.29	2963						

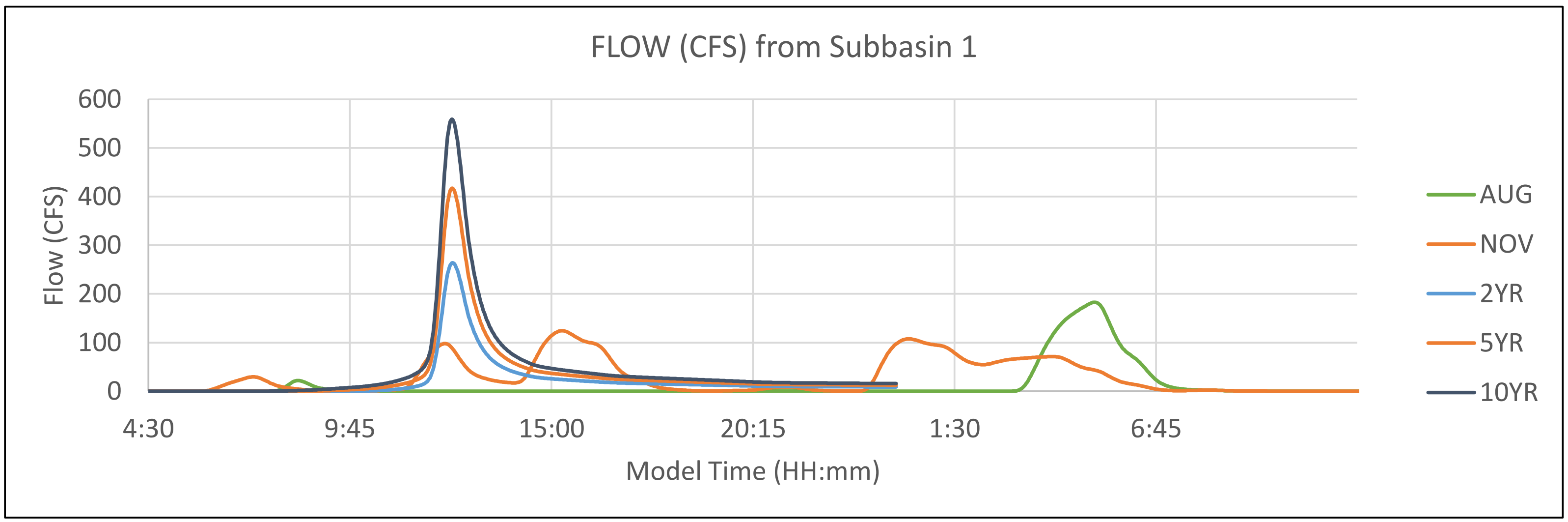
Reach 2 Proposed

Storage	Discharge	Elevation	Discharge	Length (ft)	Ave. Travel-Time (hrs)	Selected Travel-Time (hr)	Corr. Flows (cfs)	Time Interval	No. of Sub-Reaches
0.00	0	46.80	0	1891	0.32	0.23	283-3108	0.017	9
6.83	269	50.52	269						
21.44	539	51.60	539						
52.04	1077	53.52	1077						
65.44	1617	54.36	1617						
75.83	2155	54.98	2155						
86.41	2694	55.59	2694						
91.27	2963	55.86	2963						

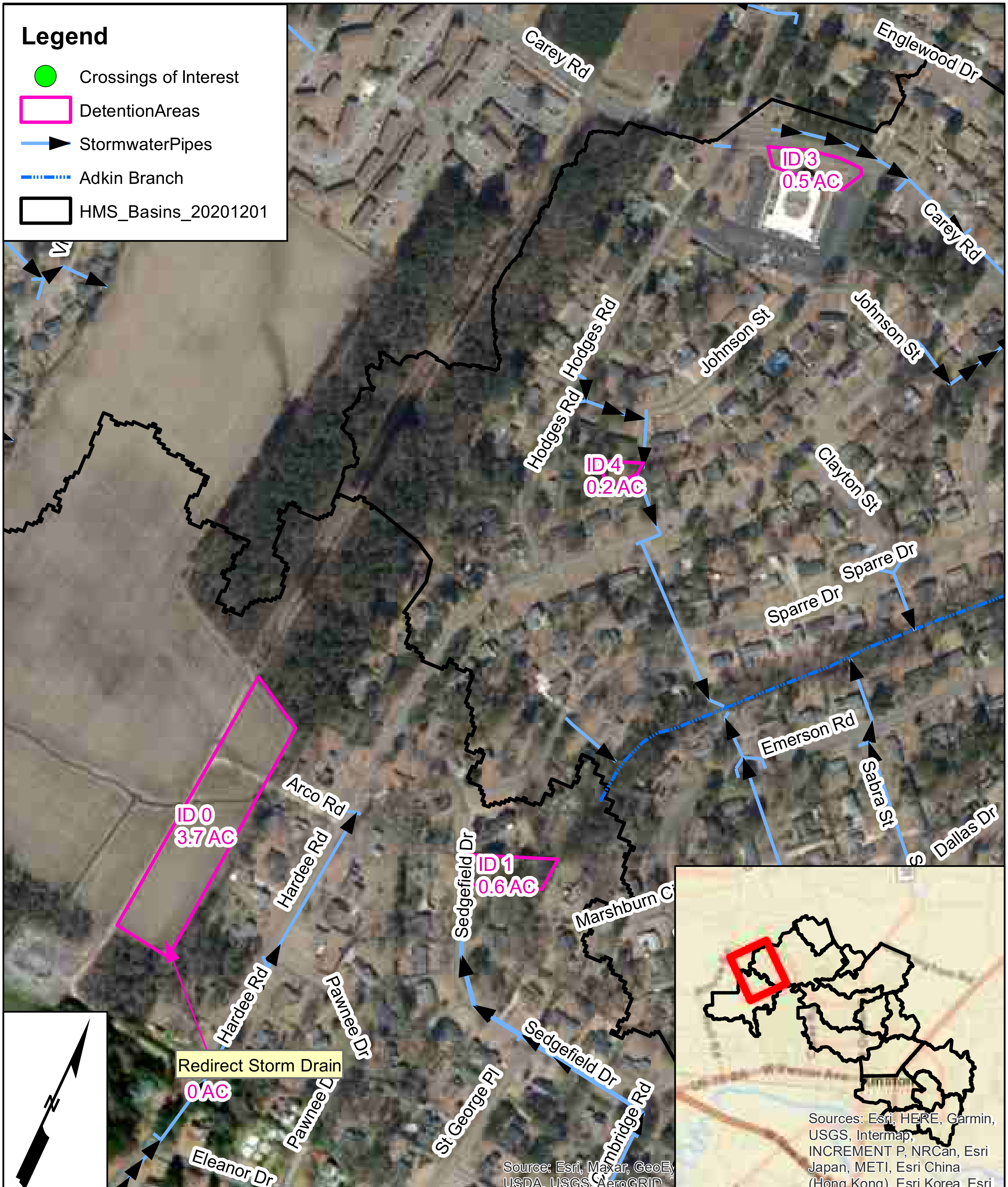
Hyetographs and Subbasin 1 Hydrographs for August and November 2020 Flood Events

Precipitation Record Date/Time			
9-Aug-20	12:00	11-Nov-20	12:00
11-Aug-20	12:00	13-Nov-20	12:00





ATTACHMENT 4 – Potential Detention Sites

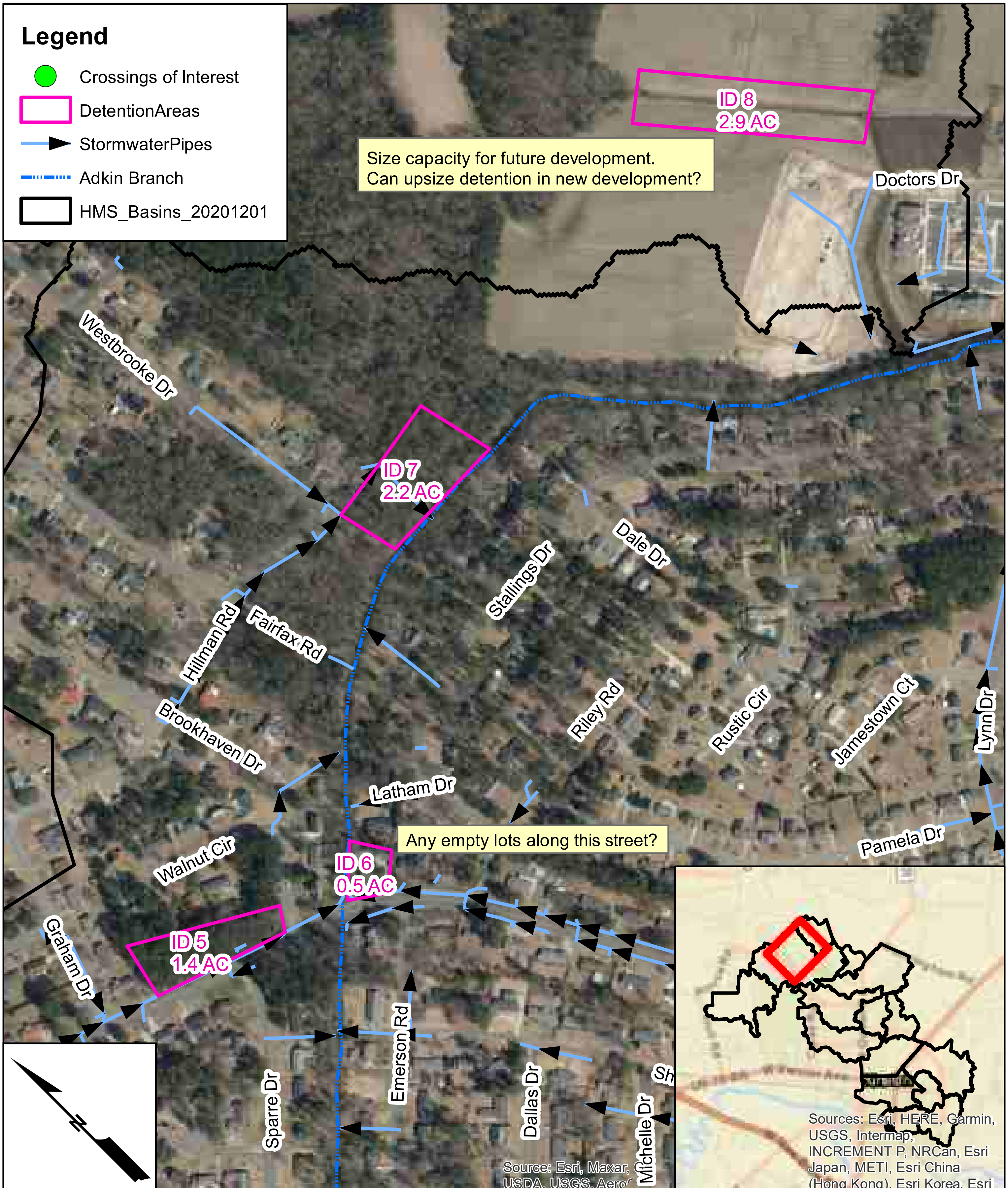


0 200 400 800 Feet

Kinston
Flood Mitigation
Potential Detention Opportunities

Ecosystem Planning & Restoration

1 inch = 400 feet | FIGURE 1 | City of Kinston, NC | Prepared by: EPR | Date: JAN 2021



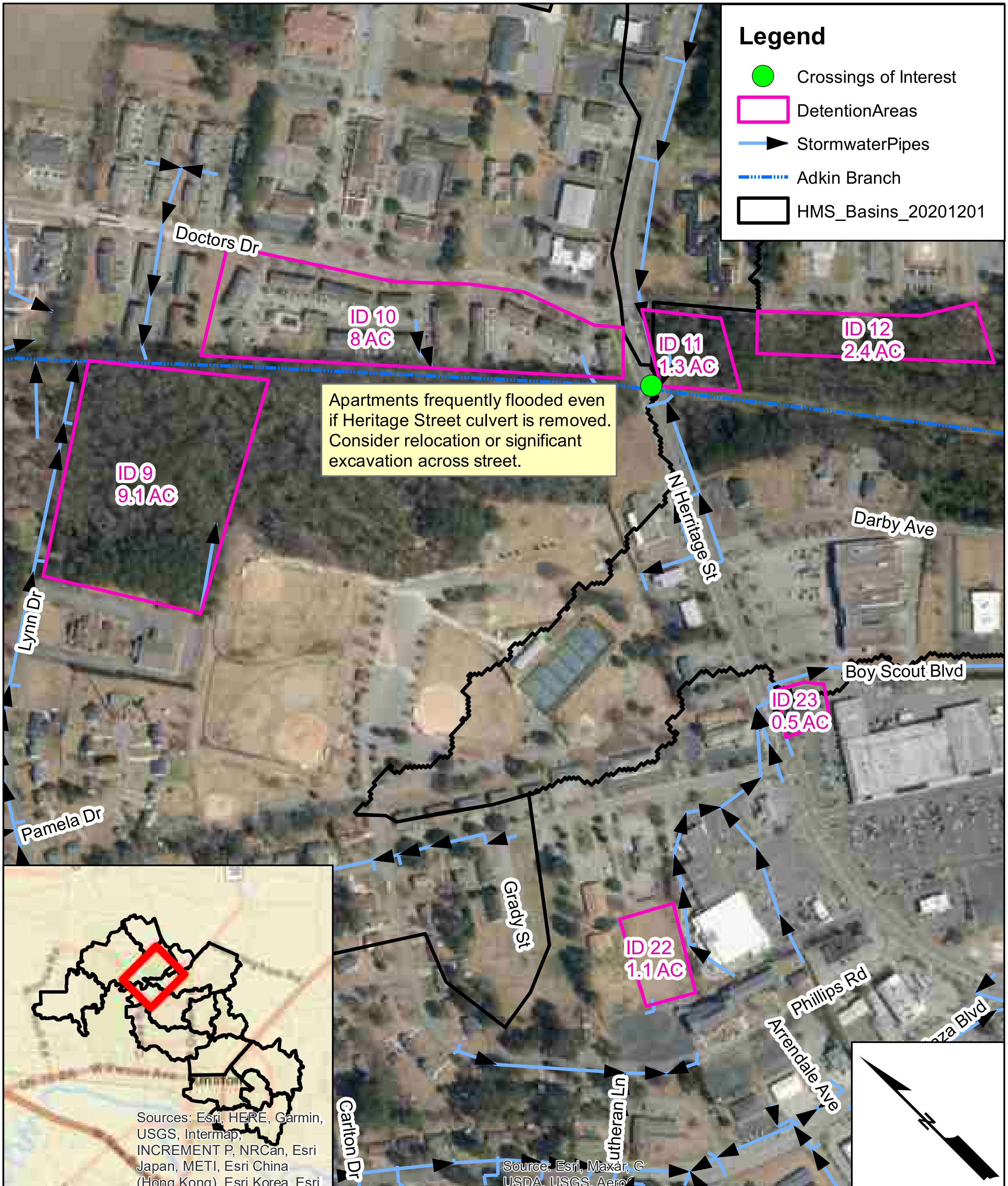
0 200 400 800 Feet

Kinston Flood Mitigation

Potential Detention Opportunities

Ecosystem Planning & Restoration (EPR)

1 inch = 400 feet	FIGURE 2	City of Kinston, NC	Prepared by: EPR	Date: JAN 2021



0 200 400 800 Feet

1 inch = 400 feet

FIGURE 3

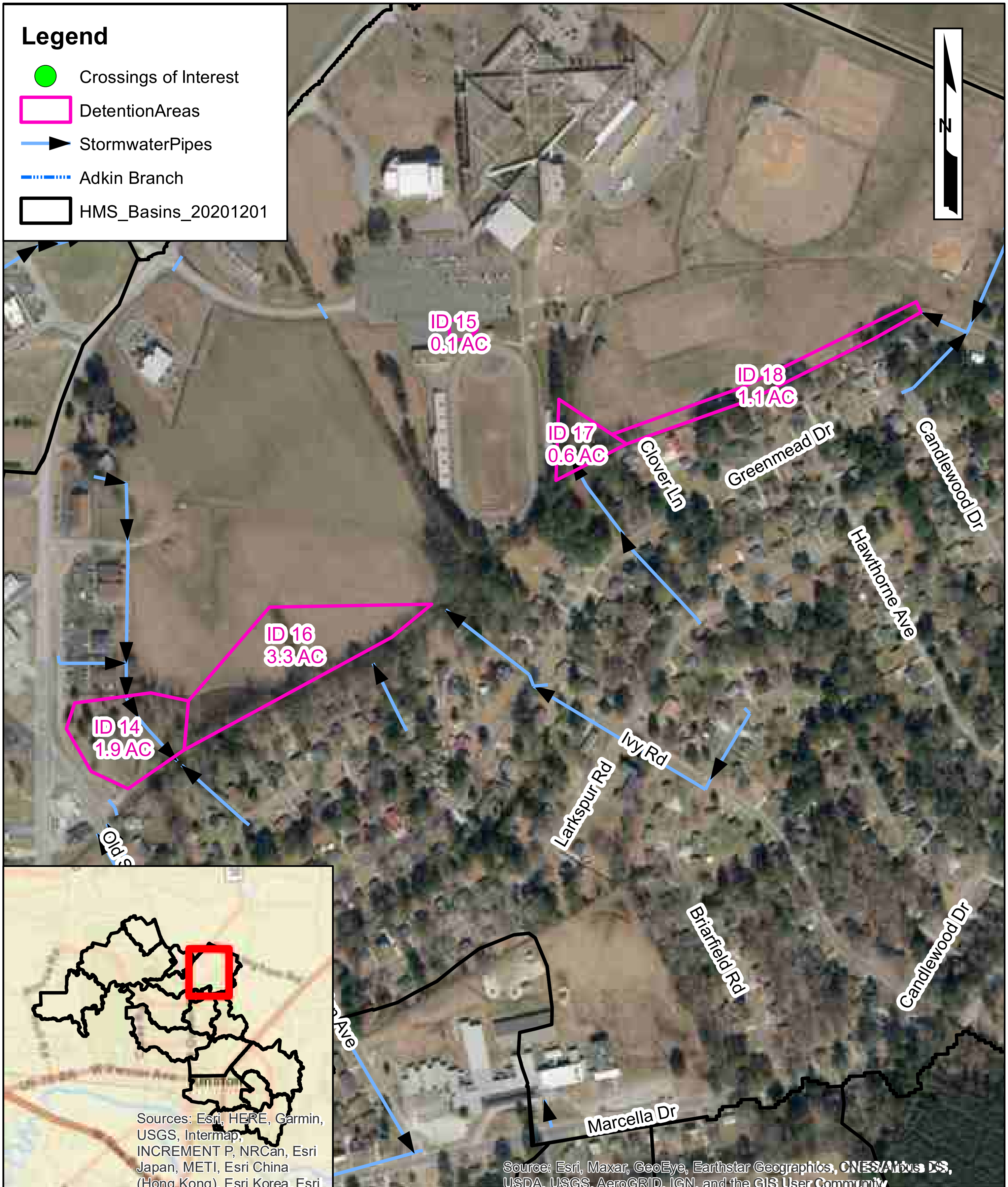
KINSTON
FLOOD MITIGATION
POTENTIAL DETENTION OPPORTUNITIES

CITY OF KINSTON, NC

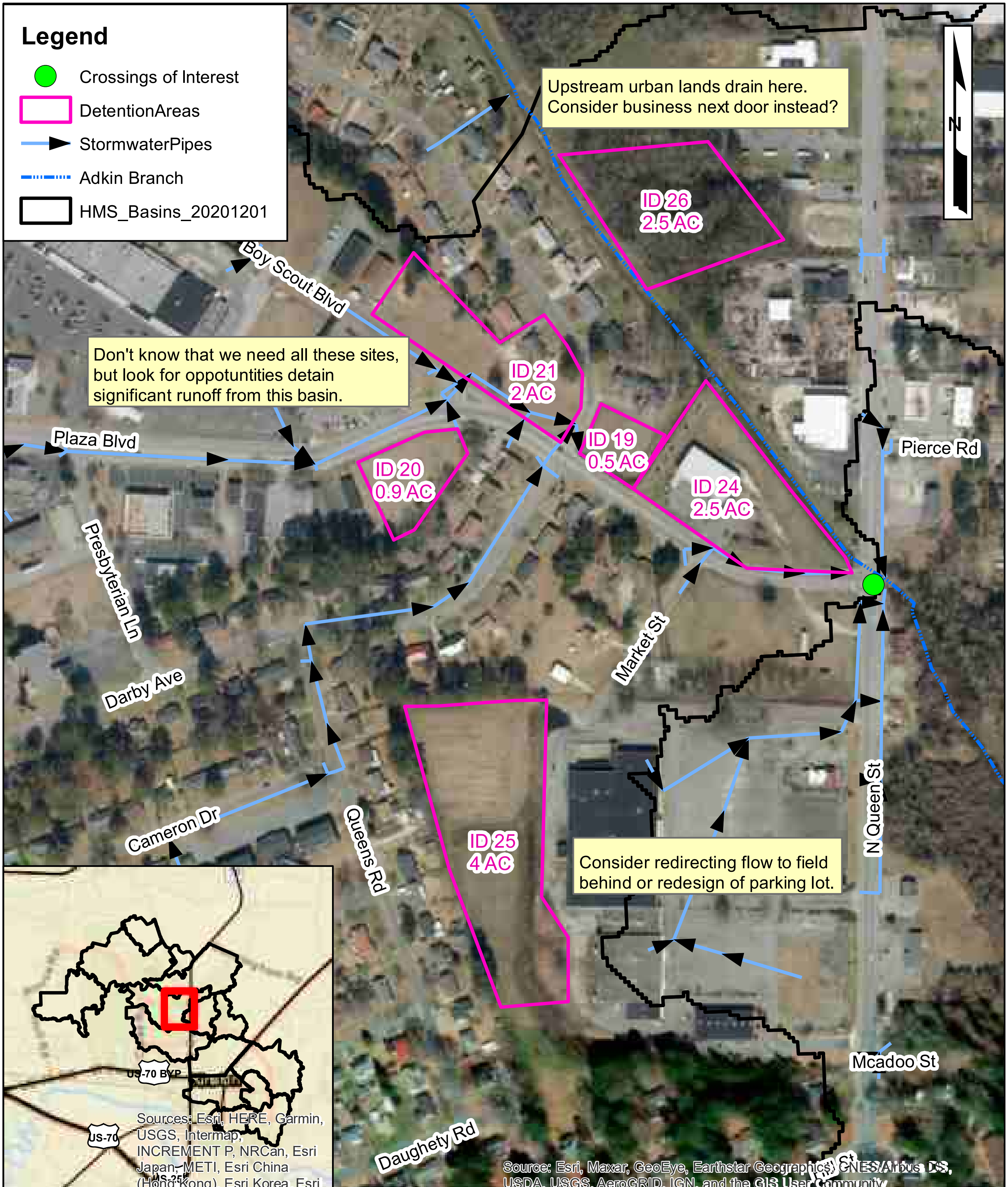
ECOSYSTEM PLANNING & RESTORATION

PREPARED BY: EPR

DATE: JAN 2021



1 inch = 400 feet	FIGURE 4	
KINSTON FLOOD MITIGATION POTENTIAL DETENTION OPPORTUNITIES		ECOSYSTEM PLANNING & RESTORATION
CITY OF KINSTON, NC	PREPARED BY: EPR	DATE: JAN 2021



0 150 300 600 Feet

1 inch = 300 feet

FIGURE 5

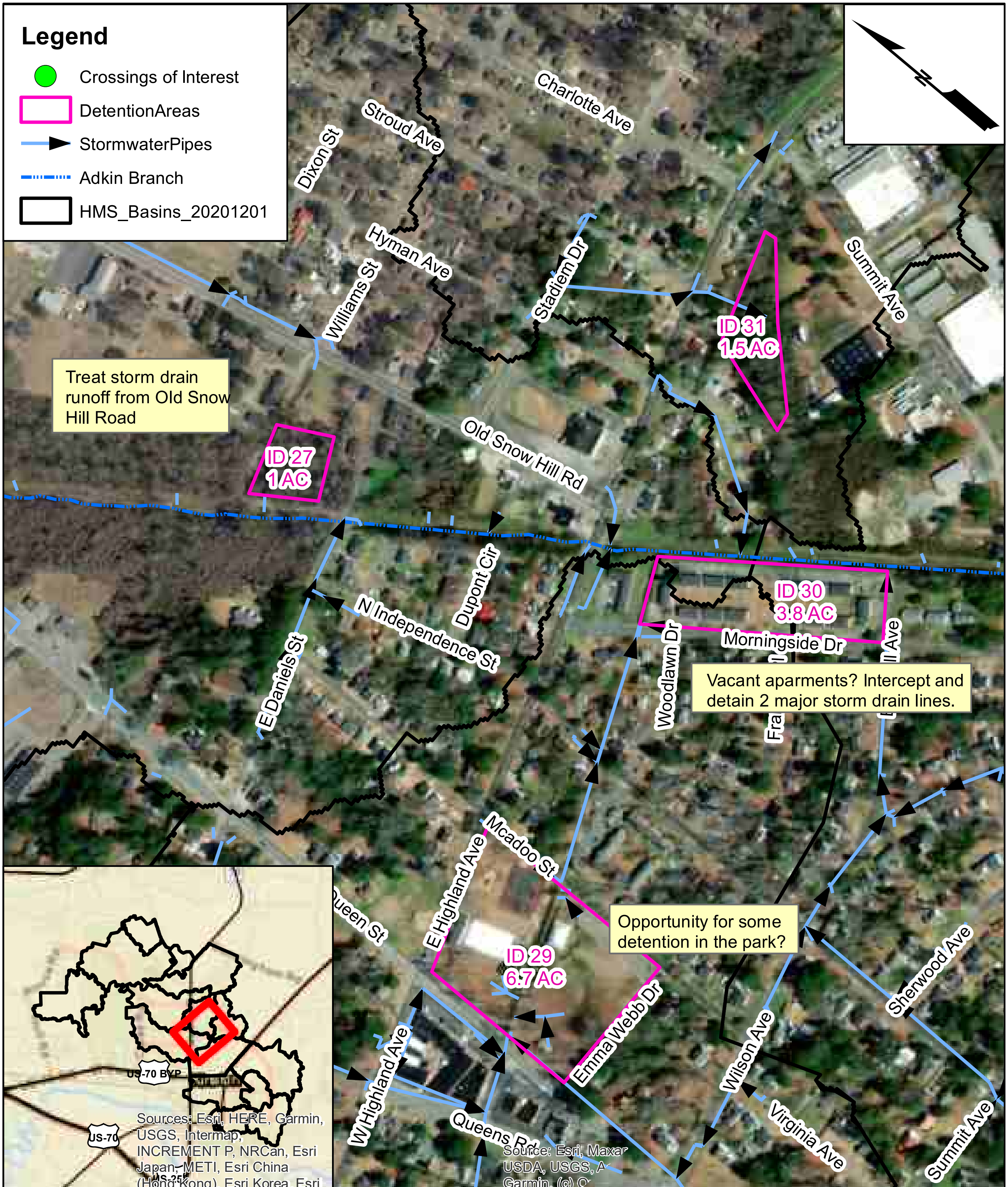
KINSTON
FLOOD MITIGATION
POTENTIAL DETENTION OPPORTUNITIES

ECOSYSTEM PLANNING & RESTORATION

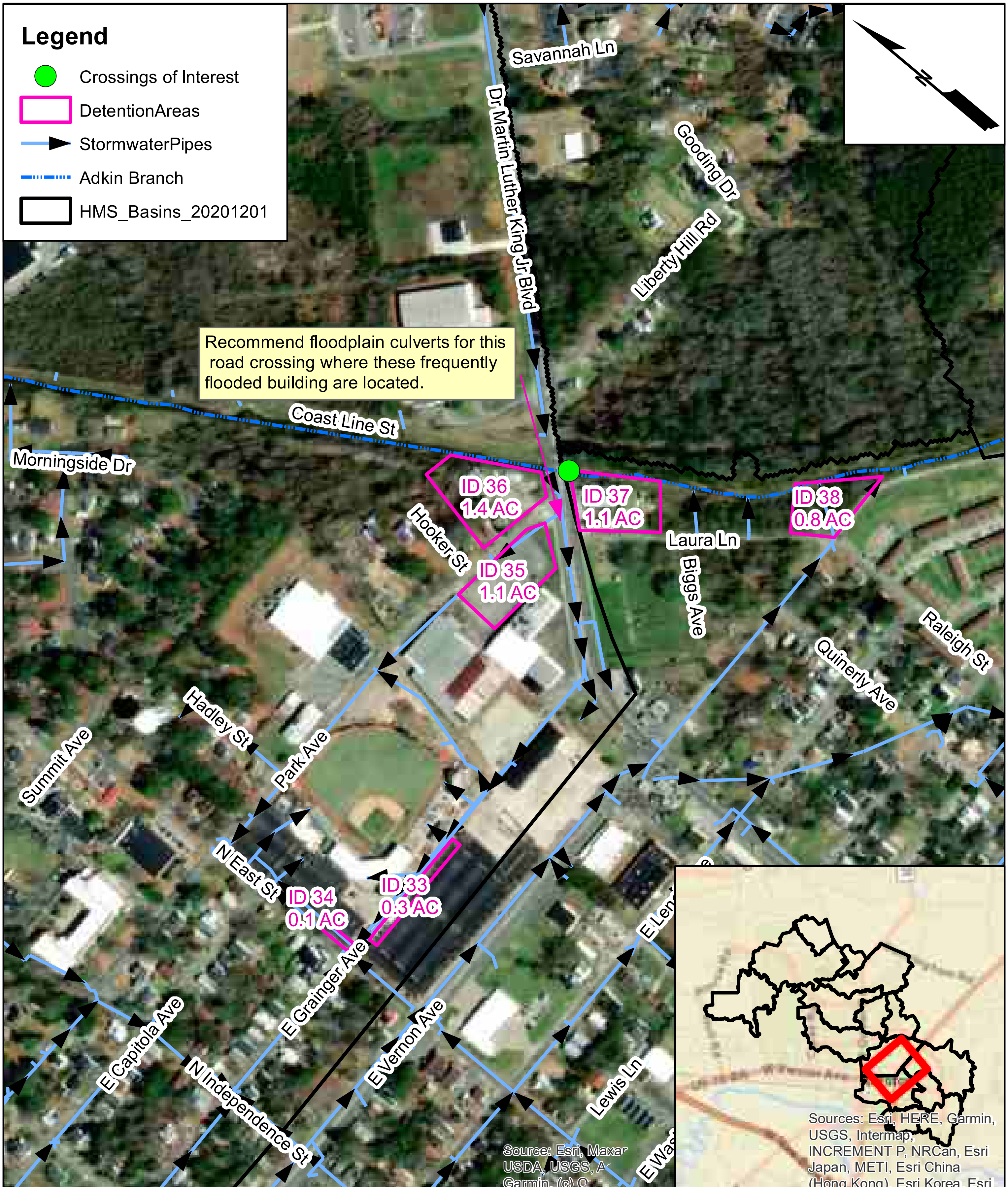
CITY OF KINSTON, NC

PREPARED BY: EPR

DATE: JAN 2021



1 inch = 400 feet	FIGURE 6	KINSTON FLOOD MITIGATION POTENTIAL DETENTION OPPORTUNITIES	ECOSYSTEM PLANNING & RESTORATION
		CITY OF KINSTON, NC	PREPARED BY: EPR / DATE: JAN 2021



0 200 400 800 Feet

Kinston
Flood Mitigation
Potential Detention Opportunities

Ecosystem Planning & Restoration

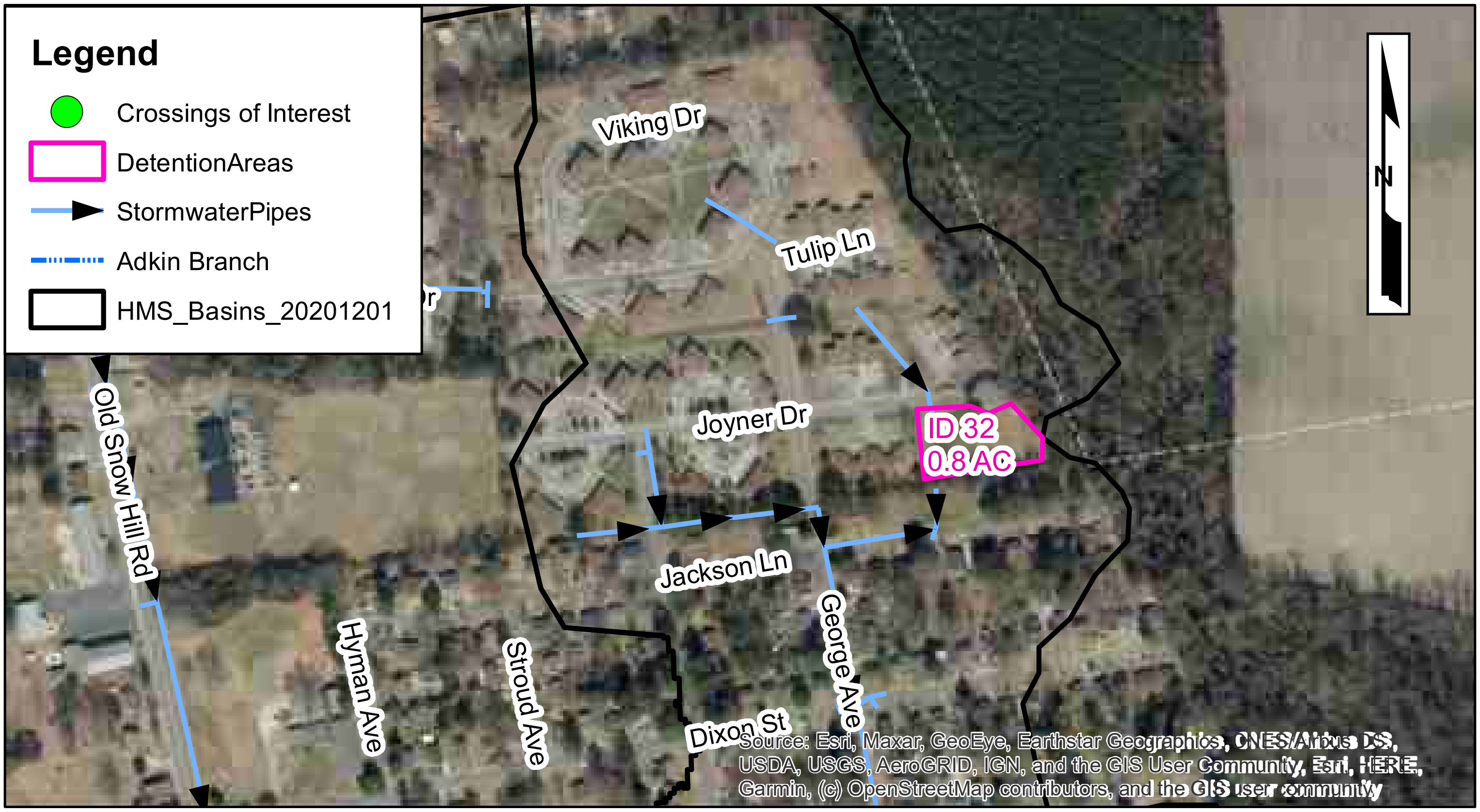
1 inch = 400 feet

FIGURE 7

City of Kinston, NC

Prepared by: EPR

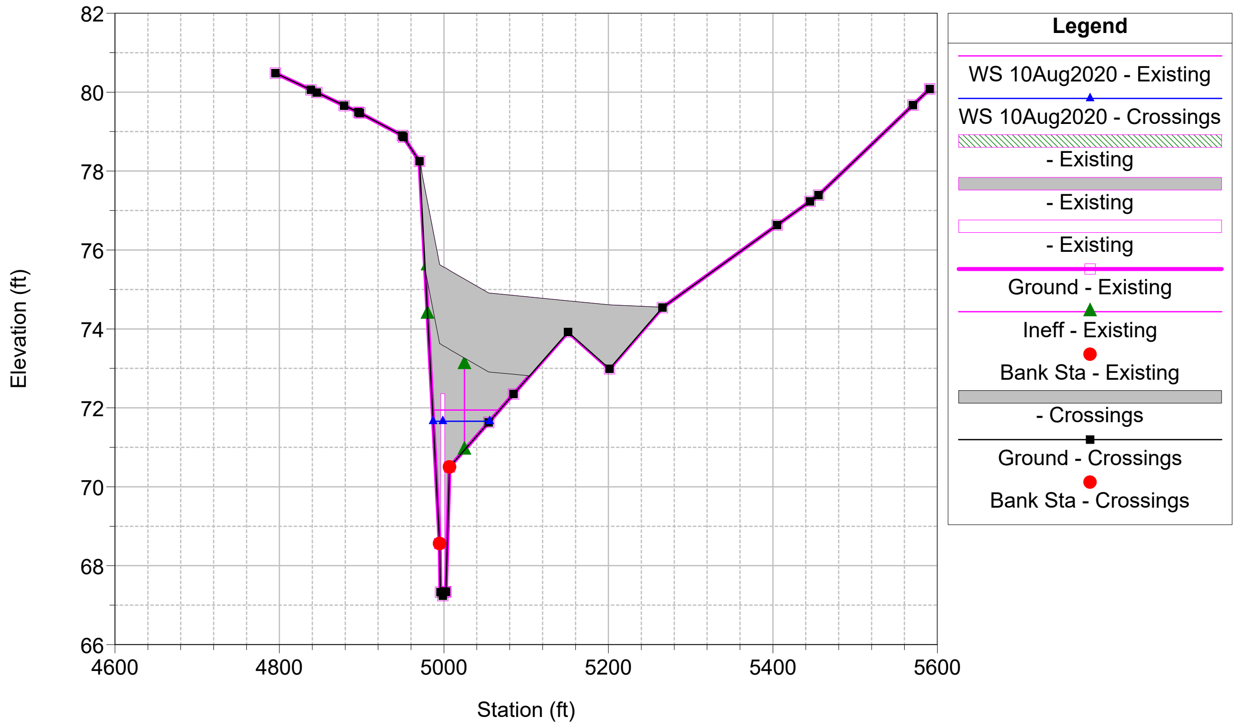
Date: JAN 2021



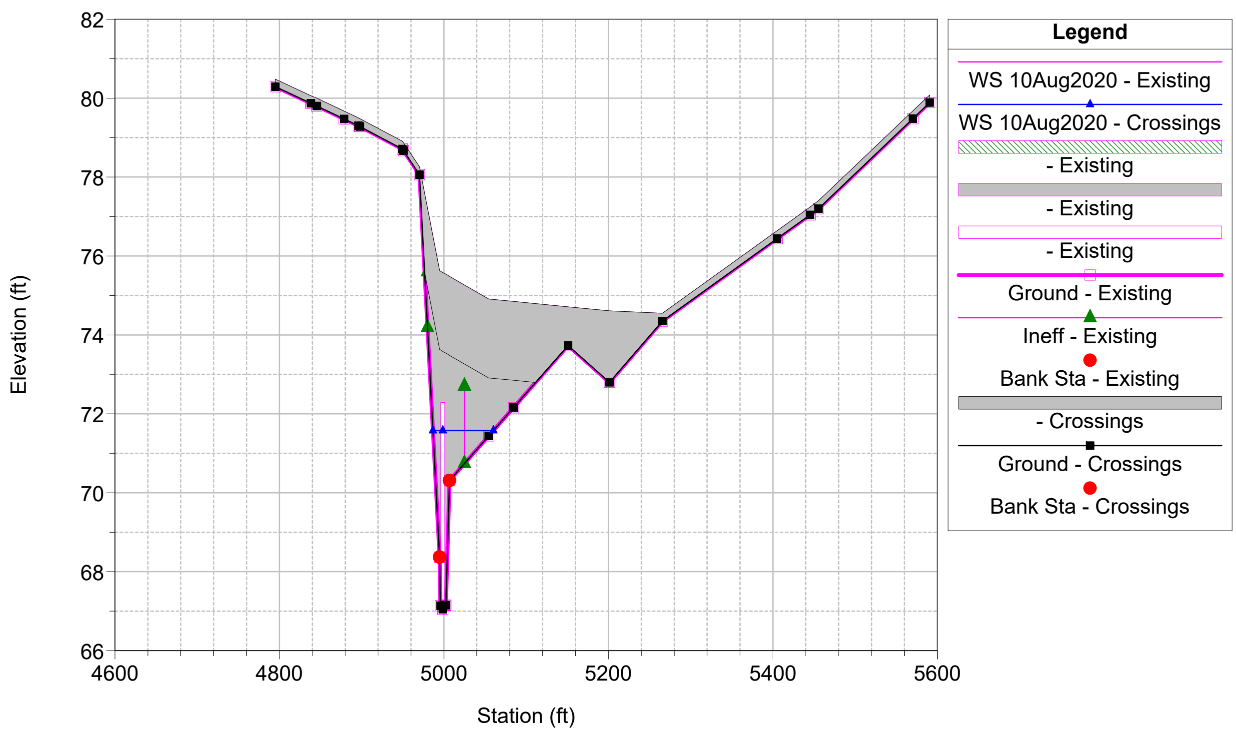
0 200 400 800 Feet	KINSTON FLOOD MITIGATION POTENTIAL DETENTION OPPORTUNITIES		ECOSYSTEM PLANNING & RESTORATION
1 inch = 400 feet	FIGURE 8	CITY OF KINSTON, NC	PREPARED BY: EPR	DATE: JAN 2021

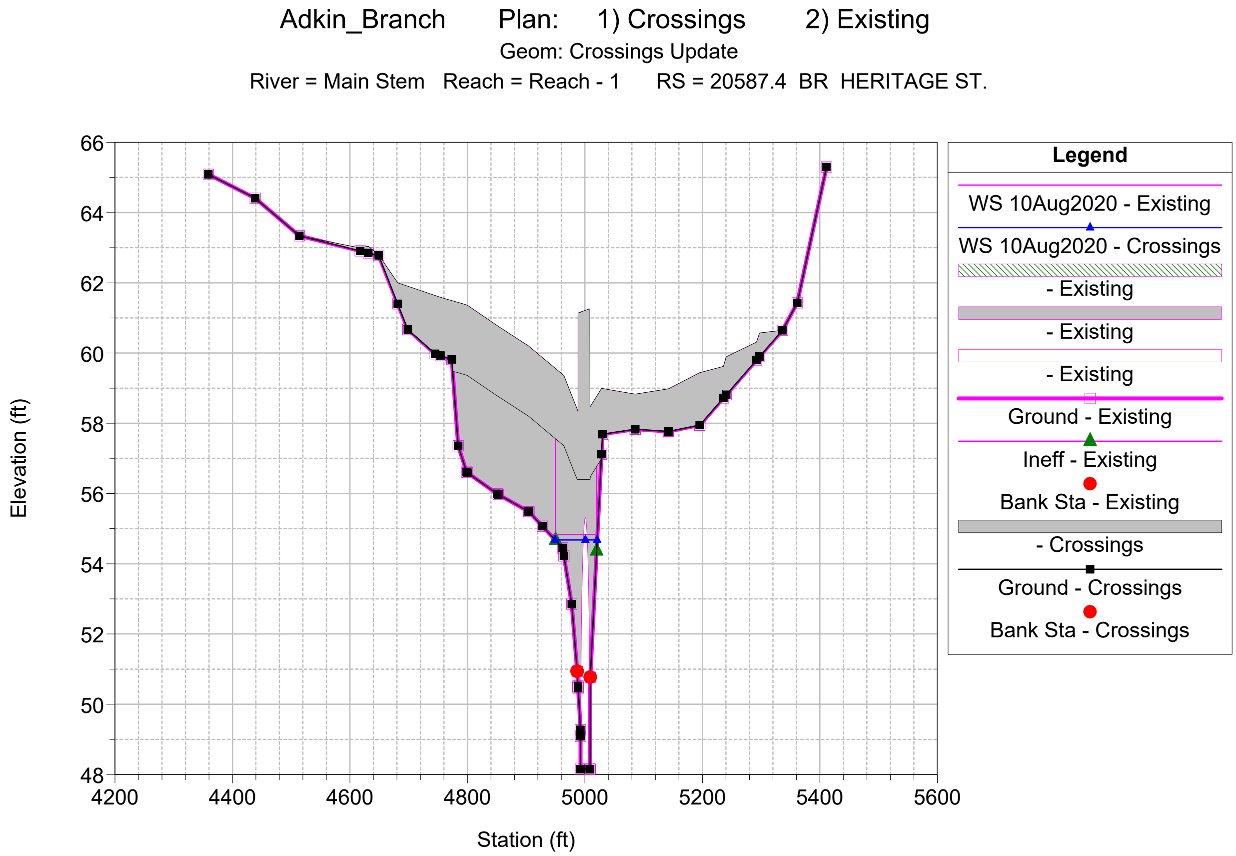
ATTACHMENT 5 - Hydraulic Model Cross-section Plots

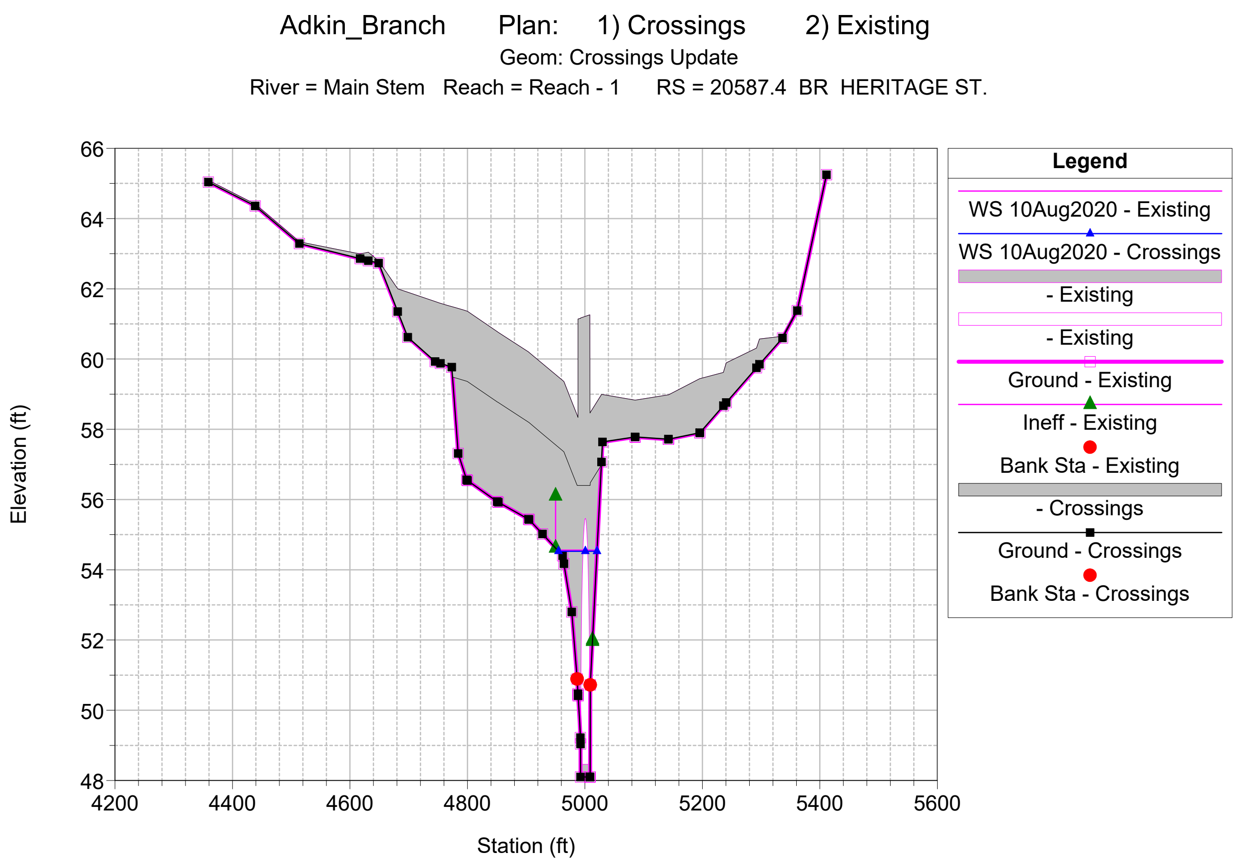
Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 27660.9 BR CRAWFORD ST

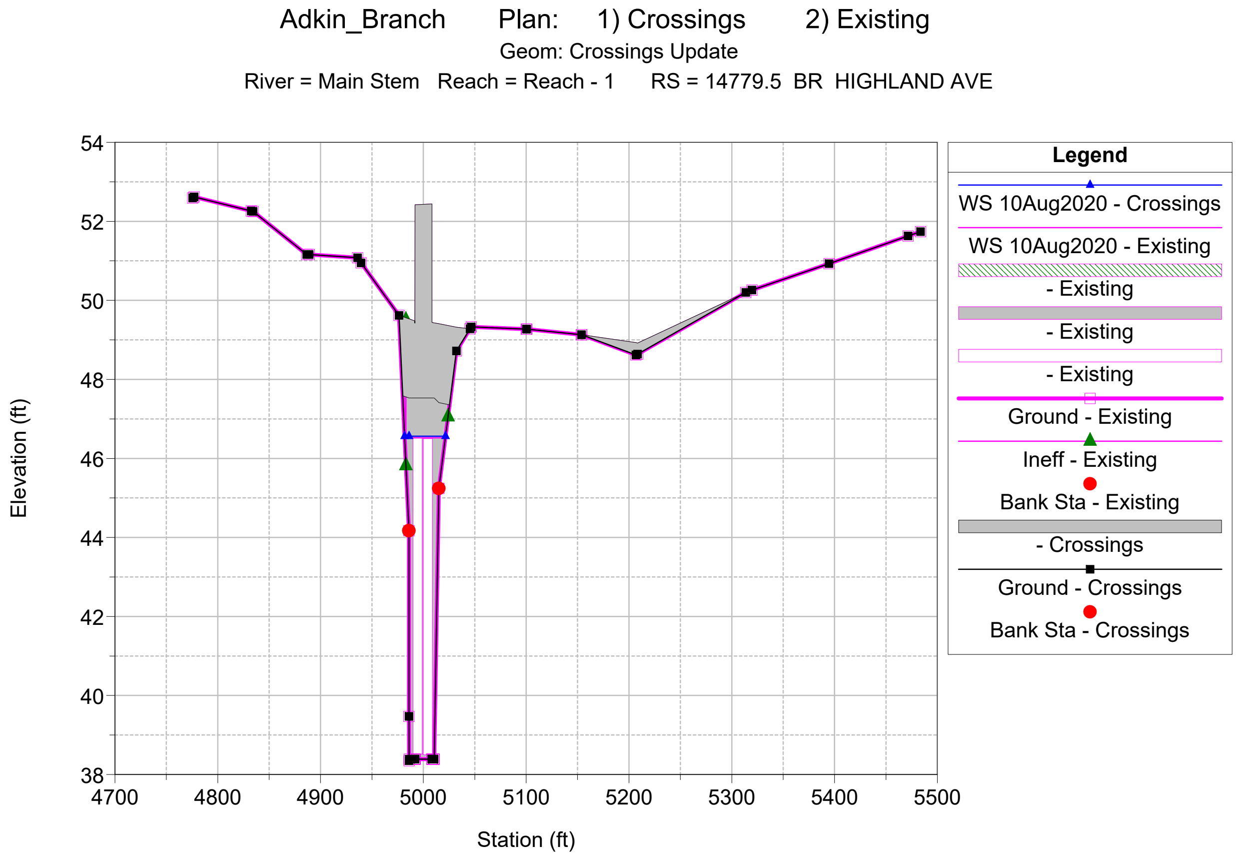


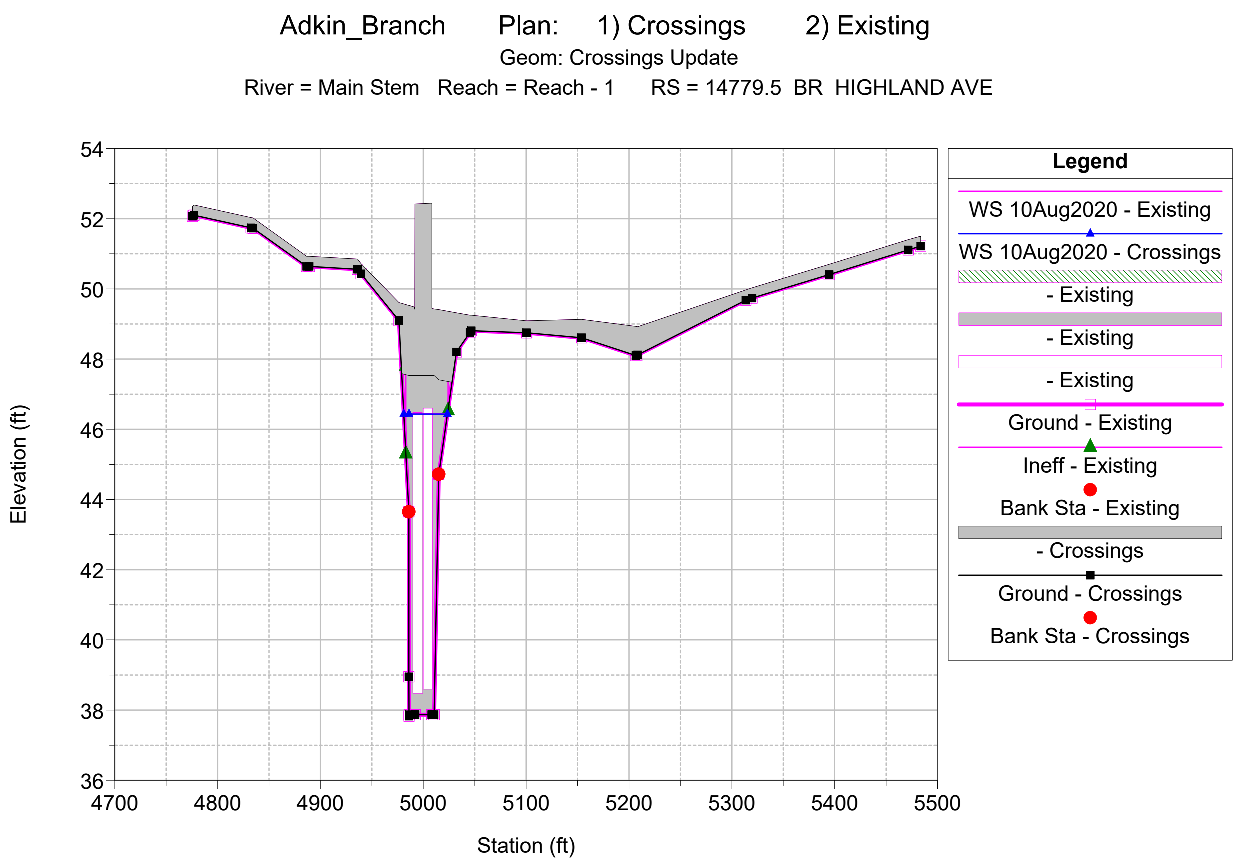
Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 27660.9 BR CRAWFORD ST

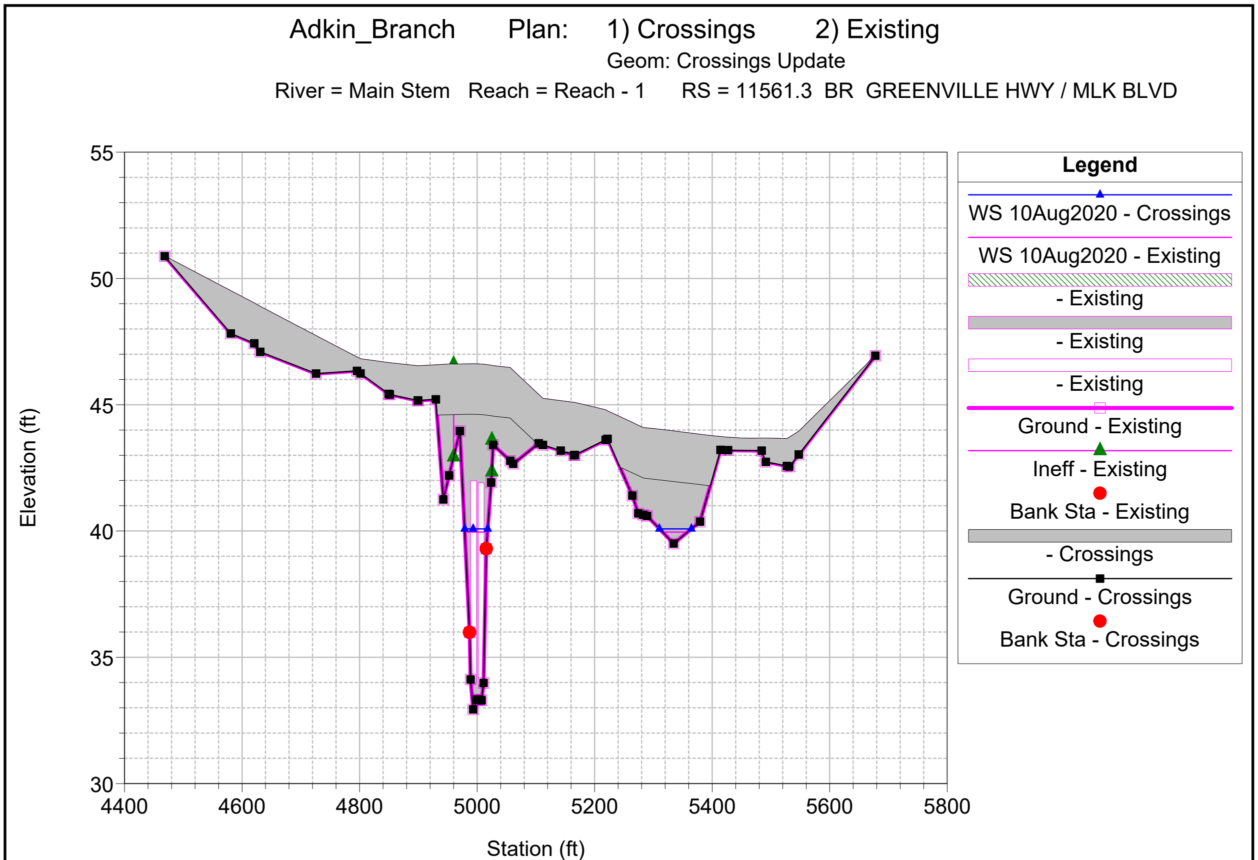



Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 20587.4 BR HERITAGE ST.
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- Crossings
Ground - Crossings
Bank Sta - Crossings
Elevation (ft)
Station (ft)


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 20587.4 BR HERITAGE ST.
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- Crossings
Ground - Crossings
Bank Sta - Crossings
Elevation (ft)
Station (ft)


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 14779.5 BR HIGHLAND AVE
Elevation (ft)
Station (ft)
Legend
WS 10Aug2020 - Crossings
WS 10Aug2020 - Existing
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- Crossings
Ground - Crossings
Bank Sta - Crossings


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 14779.5 BR HIGHLAND AVE
Elevation (ft)
Station (ft)
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- Crossings
Ground - Crossings
Bank Sta - Crossings


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 11561.3 BR GREENVILLE HWY / MLK BLVD
Legend
WS 10Aug2020 - Crossings
WS 10Aug2020 - Existing
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- Crossings
Ground - Crossings
Bank Sta - Crossings
Elevation (ft)
Station (ft)
55
50
45
40
35
30
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4600
4800
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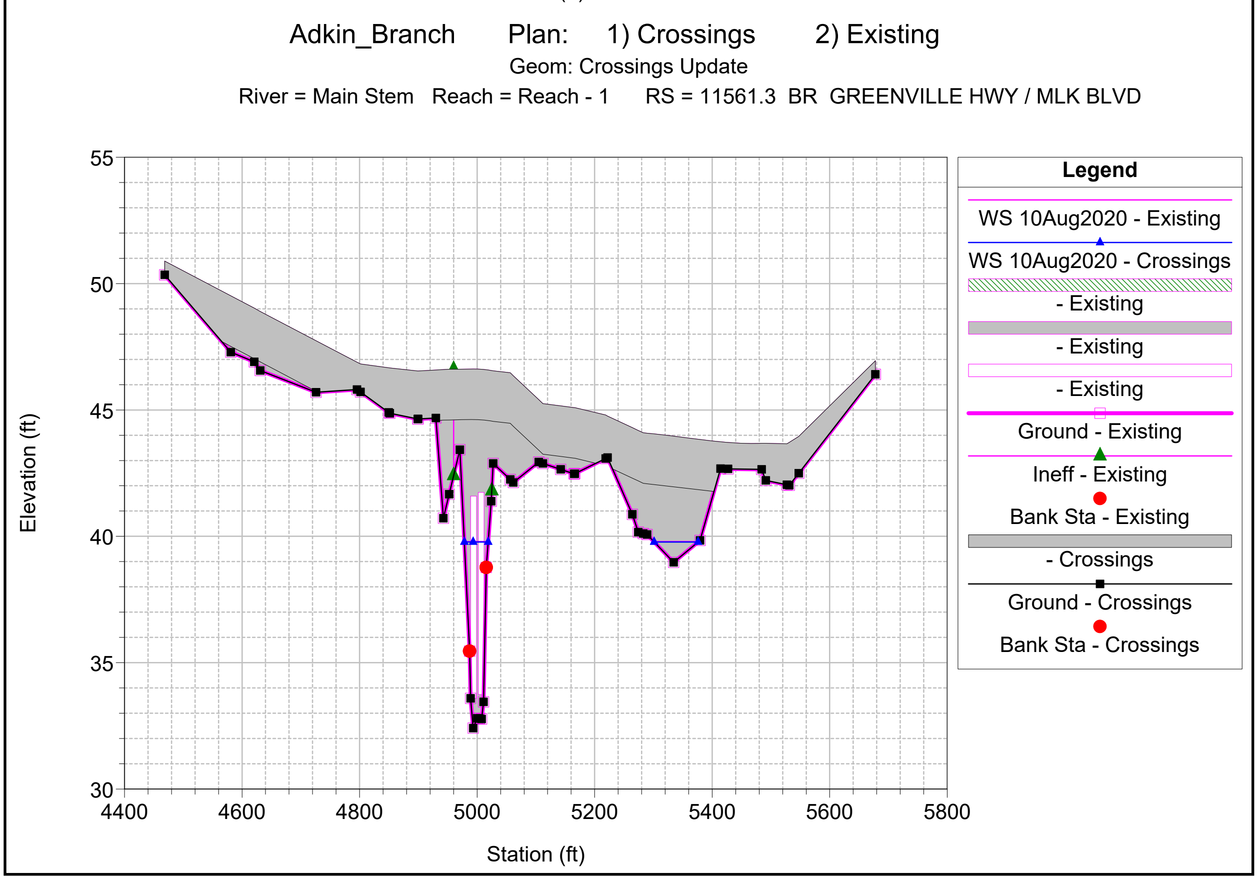
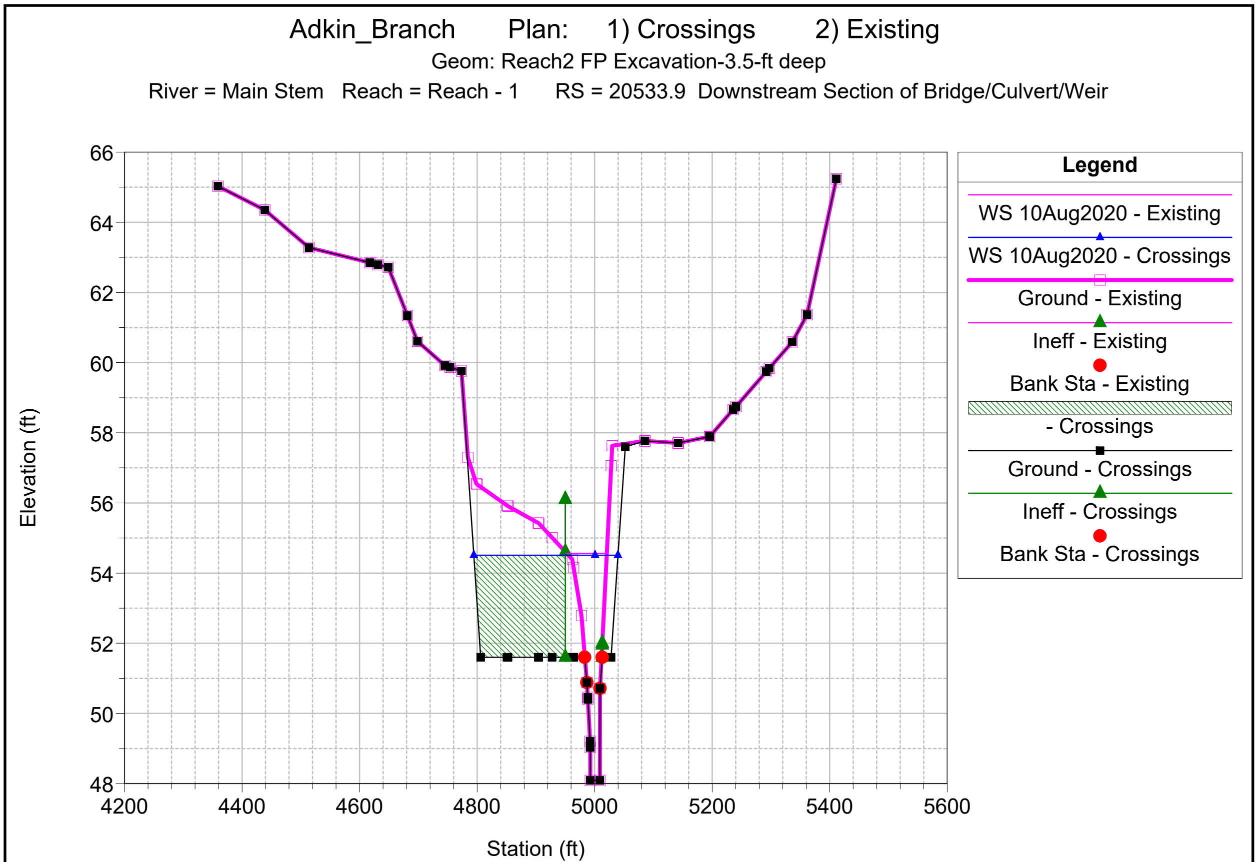
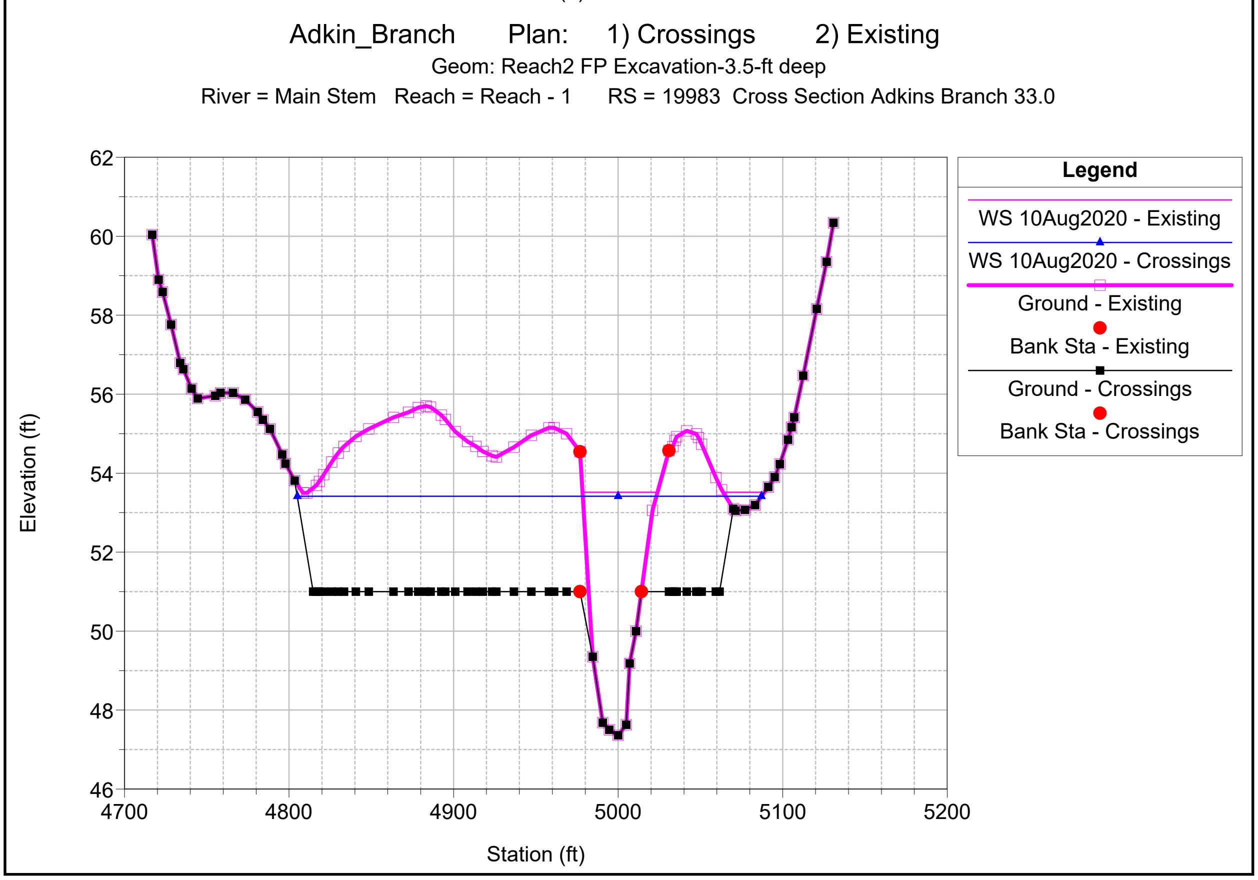
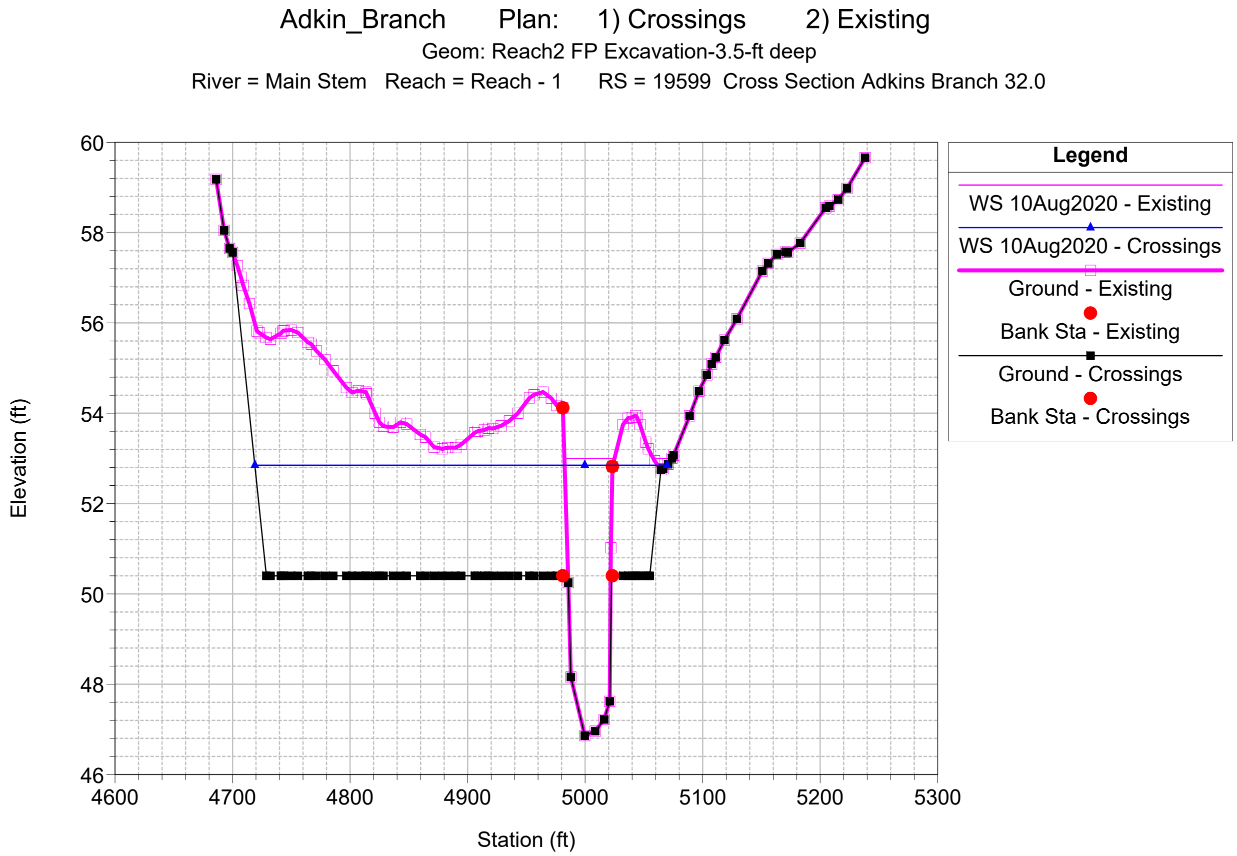
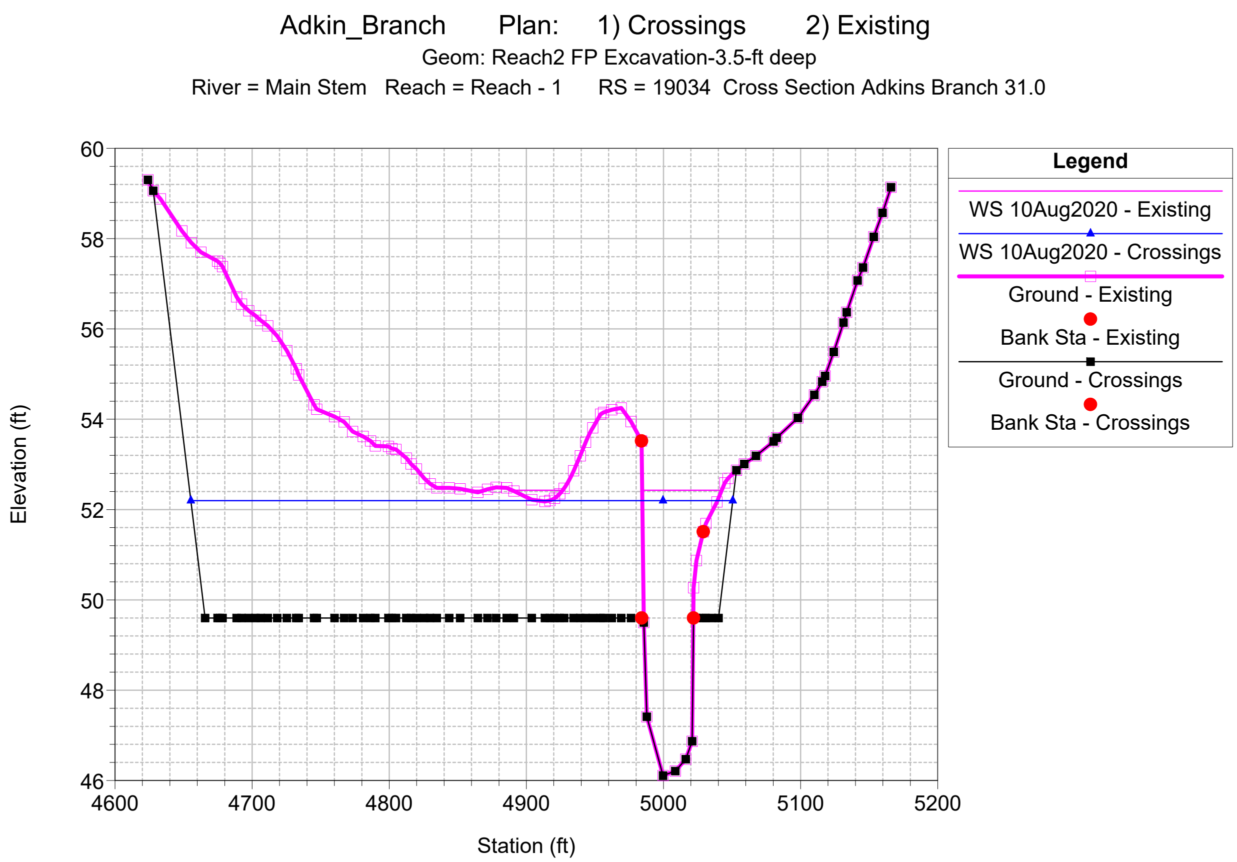
5200
5400
5600
5800

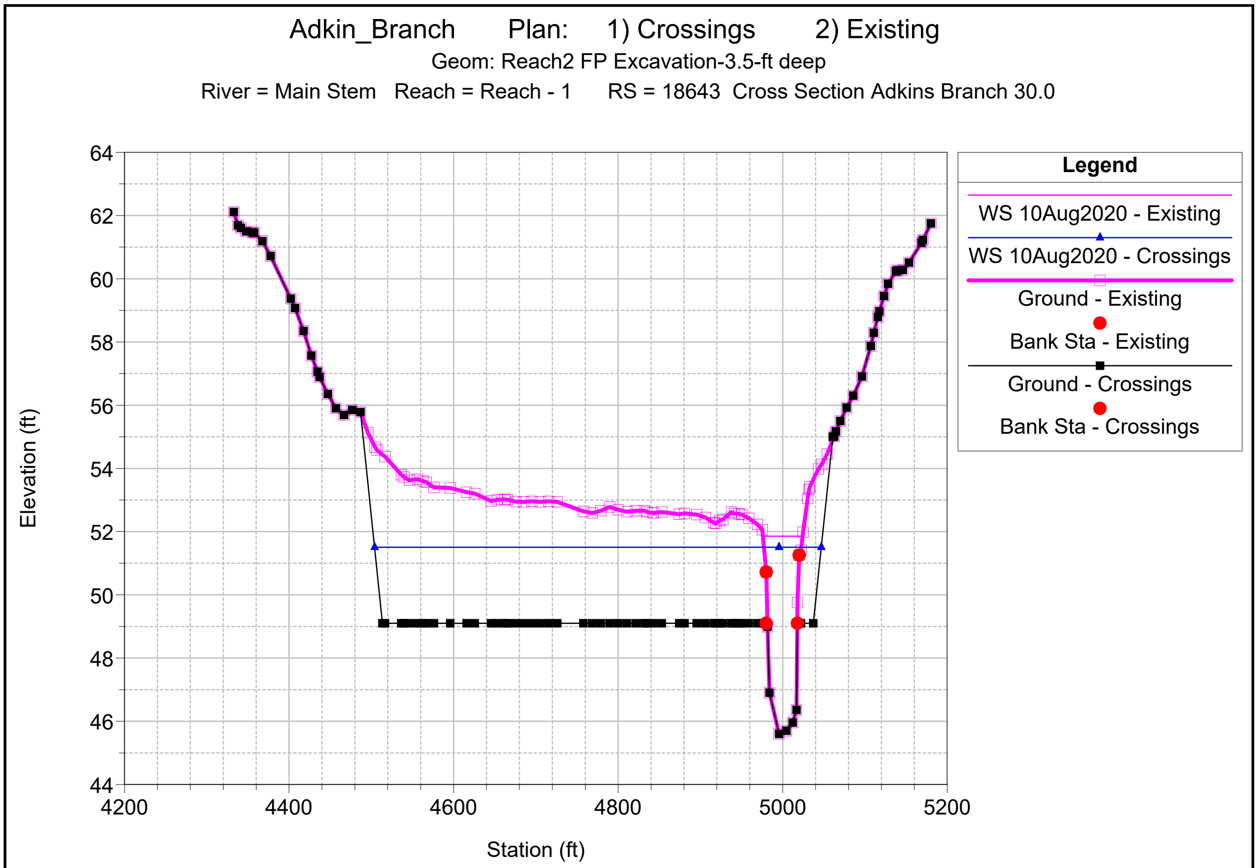

Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Crossings Update
River = Main Stem Reach = Reach - 1 RS = 11561.3 BR GREENVILLE HWY / MLK BLVD
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
- Existing
- Existing
- Existing
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- Crossings
Ground - Crossings
Bank Sta - Crossings
Elevation (ft)
Station (ft)
55
50
45
40
35
30
4400
4600
4800
5000
5200
5400
5600
5800


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Reach2 FP Excavation-3.5-ft deep
River = Main Stem Reach = Reach - 1 RS = 20533.9 Downstream Section of Bridge/Culvert/Weir
Elevation (ft)
Station (ft)
66
64
62
60
58
56
54
52
50
48
4200
4400
4600
4800
5000
5200
5400
5600
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
Ground - Existing
Ineff - Existing
Bank Sta - Existing
- Crossings
Ground - Crossings
Ineff - Crossings
Bank Sta - Crossings


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Reach2 FP Excavation-3.5-ft deep
River = Main Stem Reach = Reach - 1 RS = 19983 Cross Section Adkins Branch 33.0
Elevation (ft)
Station (ft)
62
60
58
56
54
52
50
48
46
4700
4800
4900
5000
5100
5200
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
Ground - Existing
Bank Sta - Existing
Ground - Crossings
Bank Sta - Crossings


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Reach2 FP Excavation-3.5-ft deep
River = Main Stem Reach = Reach - 1 RS = 19599 Cross Section Adkins Branch 32.0
Elevation (ft)
Station (ft)
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
Ground - Existing
Bank Sta - Existing
Ground - Crossings
Bank Sta - Crossings


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Reach2 FP Excavation-3.5-ft deep
River = Main Stem Reach = Reach - 1 RS = 19034 Cross Section Adkins Branch 31.0
Elevation (ft)
Station (ft)
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
Ground - Existing
Bank Sta - Existing
Ground - Crossings
Bank Sta - Crossings


Adkin_Branch Plan: 1) Crossings 2) Existing
Geom: Reach2 FP Excavation-3.5-ft deep
River = Main Stem Reach = Reach - 1 RS = 18643 Cross Section Adkins Branch 30.0
Elevation (ft)
Station (ft)
Legend
WS 10Aug2020 - Existing
WS 10Aug2020 - Crossings
Ground - Existing
Bank Sta - Existing
Ground - Crossings
Bank Sta - Crossings