Stantec

Final Report

Flood Mitigation along Tripps Run near Barrett Road

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Prepared for:

Fairfax County DPWES
Stormwater Planning Division

Prepared by:

Stantec

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Table of Contents

LIST OF APPENDICES

Executive Summary

Stantec is providing this Final Report outlining the Field Visit, the stream restoration Preliminary Concept Plan, Modeling, Floodplain mapping, technical memo, and the associated preliminary flood elevations. This Final Report includes:

1. General Location Map (Figure 1)
2. GIS-based Existing Conditions Map (Figure 2)
3. Sections related to background information, description of Scenarios, modeling, and results
4. Preliminary concepts for Scenarios 2, 3 and 4
5. Comparison of the Scenarios to include a table with 1-percent annual chance water surface elevations for existing conditions and the Scenarios
6. Comparison of the structures' lowest adjacent grade (determined from County GIS or elevation certificate) to the modeled storm event elevations to determine depth of flooding
7. Fairfax County Stormwater Planning Division Preliminary Analyses
8. Documentation of planning, design, and modeling assumptions
9. Project benefits and planning level cost estimates
10. Conclusions, recommendations, next steps, and additional data needs

Stantec completed a desktop and field assessment of existing conditions of the Tripps Run near Barrett Road site.

1.0 INTRODUCTION AND BACKGROUND

This project involves an area of historic flooding along Barrett Road which is currently in the FEMA designated 1-percent annual chance floodplain and designated “Zone AE”, whereby the base flood elevations (BFEs) have been determined (Flood Insurance Rate Map: Fairfax County, Virginia and incorporated Areas”, Number 51059C0285E, Panel 285 of 450, effective date September 17, 2010). Additionally, this area has been identified by Fairfax County (County) as one of 21 repetitive loss areas based on FEMA’s list of properties that have experienced repetitive loss from flooding (communication with County). The general area encompasses the segment of Tripps Run between Annandale Road and Sleepy Hollow Road and the stream length is approximately 3,700 linear feet (refer to Appendix A, or Figure 1).

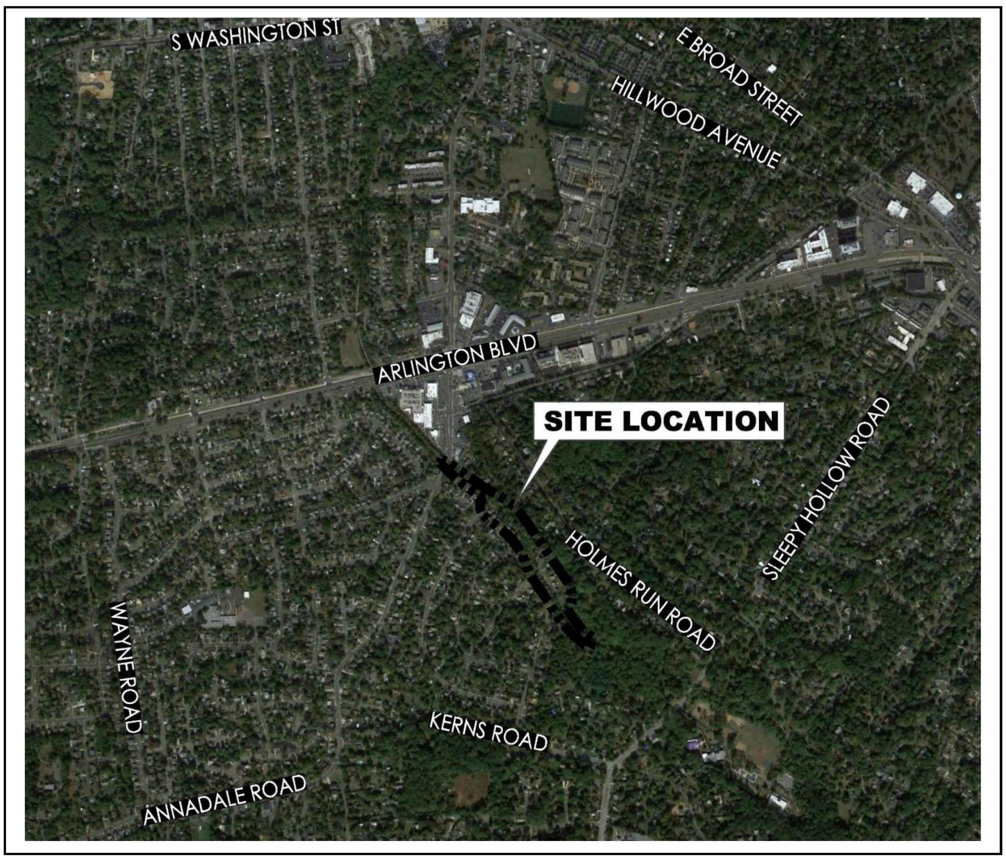

Figure 1 - General Location Map

Most recently, several structures in this area experienced flooding during a rainfall event on July 8, 2019 and another event on July 7, 2020 including flooding within main floor living areas. This project will evaluate flood hazard mitigative Scenarios inclusive of obtaining flood-prone properties paired with environmental corridor and restorative stream enhancements from upstream near the confluence of Tripps Run with an unknown tributary continuing downstream to Sleepy Hollow Park.

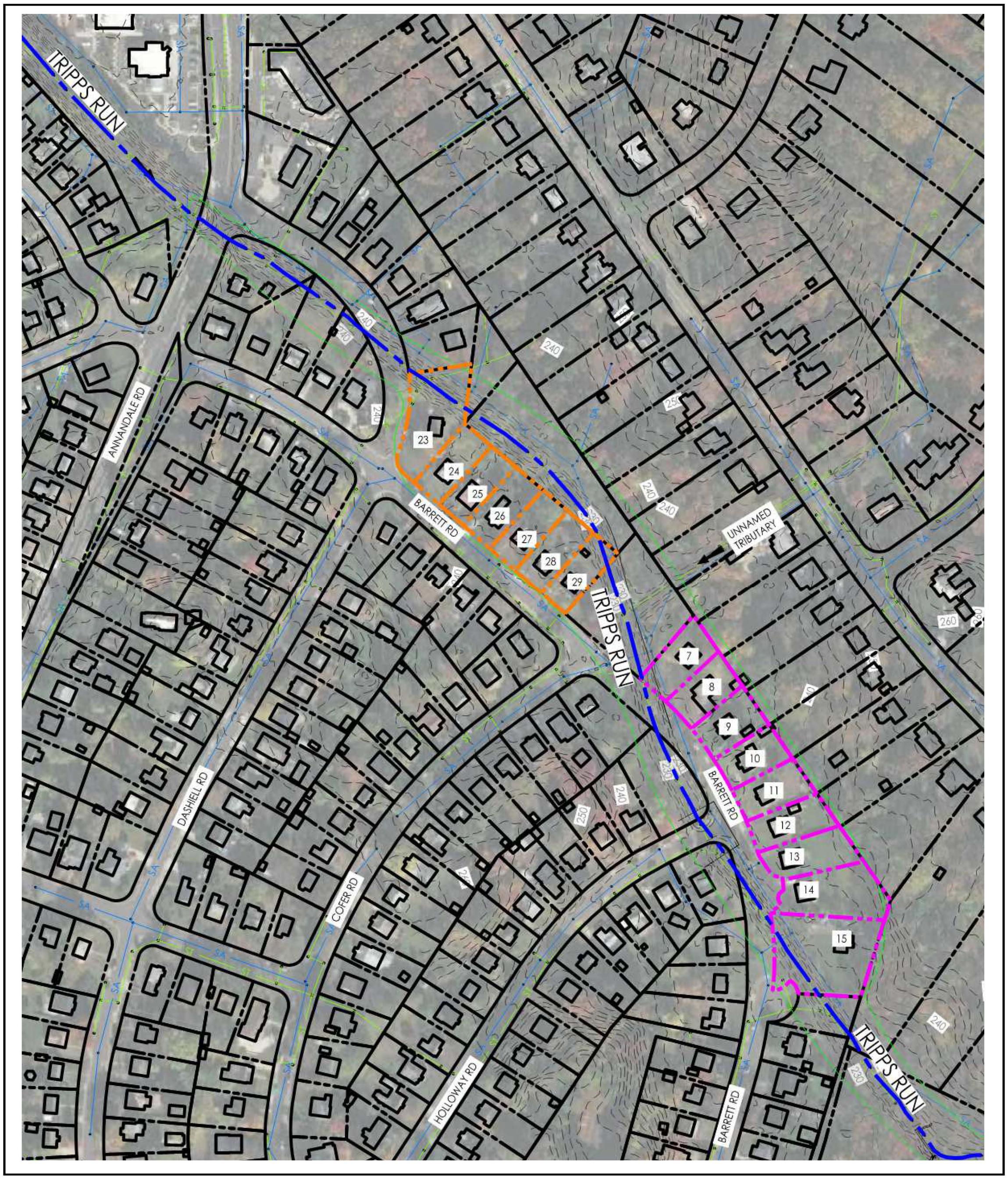

Figure 2 – Existing Conditions Map (Also refer to Appendix A)

1.1 PROJECT GOALS AND OBJECTIVES

The project goal is to mitigate flooding from a 1-percent annual chance storm event in the repetitive loss areas. The objectives of this project are to:

1. Assess the feasibility of the various flood mitigation Scenarios.
2. Develop a corresponding environmental corridor (beyond both banks and within the existing County easement) and restorative stream enhancement design features.
3. Quantify the associated flood reduction benefits.
4. Develop planning level cost estimates.

1.2 PROJECT CONSTRAINTS

There are several project constraints identified that will directly affect the selection of project treatments, and were considered in developing conceptual design/modeling:

1. The existing stream runs through private property. As such, this project will require substantial landowner coordination and potentially several easements.
2. Mature and native vegetation exists throughout the stream and floodplain which proposed treatment disturbances should avoid where practicable.
3. Access throughout the project is limited. The project boundaries are currently restricted to existing County easements merged with associated Scenario-specific property acquisitions.
4. Existing utilities including, but not limited to:
    a. Sanitary sewer lines and manholes
    b. Contributing stormwater conveyances and outlets
    c. Overhead and underground power and data lines
    d. The existing downstream VDOT-maintained bridge crossing at Sleepy Hollow Road
    e. The adjacent sewer trunk line (and probable service connections) along Tripps Run
5. Project objective of flood hazard mitigation may indicate potential private property encroachment. Future design refinements will attempt to avoid or minimize such encroachments.

1.3 EXISTING SITE AND STREAM CONDITIONS

A single one-day site visit was completed by Stantec, accompanied by the County, with the purpose of observing and becoming familiar with the area and documenting pertinent field information. The below is a summary of observations:

Although no data was collected, the existing conditions were evaluated, and the stream behavior realized. Under stable natural conditions, this type of stream (located in the Northern Inner Piedmont, Level IV Ecoregion 45e) would likely classify as a C, B, or Bc (Rosgen, 1994) with substrate consisting primarily sand and gravel, various quantity of cobble and occasional bedrock, depending on the available sediment load. Prior to 1947 (earliest observed aerial), the site appears to have been primarily pasture/agricultural use, which likely initiated channel evolution toward instability. However, since the 1947 portions of this channel, including the project area, have been straightened to accommodate residential development. Subsequently, channel armor (riprap) was introduced to portions of the bed and bank throughout. The upstream contributing reach (north of Annandale Road) is currently a concrete trapezoidal ditch showing little to no natural bed material and therefore suggests very little sediment contribution to the downstream project reach.

As a result of historic modification, the current condition of Tripps Run varies from downstream to upstream, resembling the channel evolution shown in Figure 3.

Figure 3 - Probable Channel Evolution Process (Rosgen, 2007)

In general, current physical conditions may be characterized as follows.

- Upstream (STA 10+00 to STA 20+00) - Located adjacent to Barrett Road (between Cofer Road and Dashiell Road), the existing armored channel contains multiple transverse riffles and appears less stable than downstream. Here, the current channel (refer to Photo 1) appears to have cut into relic alluvium (sand/gravel/cobble) and is actively adjusting dimension where possible, though only slightly as the previously installed armor and bedrock serve to arrest channel development. Based on the irregular geometry, fewer stable inner-berm features, less established vegetation than Midstream, and observed erosion, the threat of active channel adjustment remains. Left unmanaged this reach will not correct itself but instead will continue to present an ongoing risk of erosion and degraded channel function.

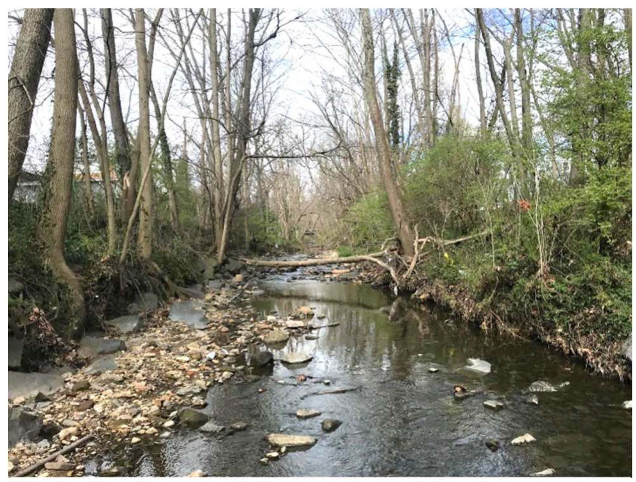

Photo 1 – Representative Upstream Reach

- Midstream (STA 20+00 to STA 31+00) - This channelized, armored reach adjacent (upstream and downstream) to the Holloway Road bridge crossing more resembles Bc3/4 – G3/4 stream types due to moderate-high entrenchment, low sinuosity, and high width to depth ratios. Channel riprap armoring has prevented

Photo 2 – Representative Midstream Reach

further channel downcutting and lateral channel migration (refer to Photo 2). Inner berm features are apparent and stable vegetation, including 8-inch diameter trees and greater, has established along the lower banks in this reach. While much of the understory vegetation is composed of lower seral stage species and invasive species (privet), disturbance of this buffer could be a greater risk than the potential benefit gained. In general, much of the channel in this reach shows low risk of instability and related stream failures or degradation.

- Unnamed Tributary to Tripps Run (enters Midstream reach at ~STA 22+00) – While only the lower 75 feet of this channel was observed, few signs of instability were apparent. This contributing stream appeared to be a desirable haven for aquatic species, with the exception of a single hydraulic barrier to fish (refer to Photo 3).

Photo 3 – Unnamed Tributary to Tripps Run

- Downstream (STA 31+00 to STA 35+00) – Downstream of the armored reach and nearby the northern boundary of Sleepy Hollow Park, the channel has adjusted from an F toward a C/Bc. Current processes include meander deposition paired with outside meander lateral erosion (refer to Photo 4). Left unmanaged, this process will continue to threaten upstream stability.

Photo 4 – Representative Downstream Reach

- Sleepy Hollow Road (downstream of STA 36+00) – Located at the downstream portion of Sleepy Hollow Park, and very much like the Downstream reach, the channel here (refer to Photo 5) has adjusted from an F toward a C/Bc. Current processes include meander deposition paired with outside meander lateral erosion. Exacerbating this process is the presence of the VDOT maintained Sleepy Hollow Road bridge crossing immediately downstream. While treatments at this location were considered, this concept focused on treatments upstream and this location was removed from the project area. If treatments were preferred, then further coordination with VDOT will be required.

Photo 5 – Tripps Run through Sleepy Hollow bridge (downstream, right side of photo). NOTE: panoramic distortion

Field data collection necessary to quantitatively rank stream function was not performed. However, from the perspective of the North Carolina Stream Quantification Tool (Harmon, 2017) we can consider the following four qualitative categories of stream function (refer to summary Table 1) to characterize the reaches observed:

- **Access to floodplain** – Throughout the project reach, the access to floodplain is low. While in some areas, channel armoring has stifled bankfull processes and serve as challenges to establish stable geometry. Overall, the entire stream could benefit physically and ecologically by the introduction of bankfull geometry.
- **Lateral Stability** – As noted, evidence of erosion is most prevalent in the Downstream reach and only slightly Upstream. The more armored Midstream reach has been successfully laterally stabilized by the placed armor.
- **Bedform Diversity** – Bedform diversity is lowest in the Midstream reach, and slightly higher Downstream. The higher bedform diversity Upstream should be noted as temporary, as these unstable features are subject to change during any storm event. That said, throughout all the reaches, schools of minnows were observed and the potential to foster aquatic habitat.
- **Riparian Vegetation** – Noted earlier, the riparian vegetation along the low banks is acceptable, while the upper bank vegetation is challenged by fences and managed backyards. In general, the riparian vegetation is lacking throughout all reaches.

Table 1 - Observed Stream Function

Reach	Access to Floodplain	Lateral Stability	Bedform Diversity	Riparian Vegetation
Downstream	Low	Low	Medium	Medium
Midstream	Low	High	Low	Low
Tributary	Medium	Medium	Medium	Medium
Upstream	Low	Medium	Medium	Low

2.0 SCENARIOS

The specific Scenarios investigated and evaluated during this project align with the County's 2019 Floodplain Management Plan (Fairfax County Stormwater Planning Division, Department of Public Works and Environmental Services, September 2019), which documents numerous flood hazard mitigation actions to address flooding, including seeking voluntary buyouts of FEMA's repetitive loss properties within the floodplain.

2.1 SCENARIO 1

Scenario 1 consists of a model (by others) provided to Stantec by Fairfax County, which *"removed the bridge at Holloway Road"*.

This Scenario makes no changes to the existing conditions other than complete removal the bridge at Holloway Road. The purpose of this Scenario is to evaluate the hydraulic influence of the bridge, associated effect to flooding and realize the conceptual feasibility of either removing the bridge or raising the bridge above the base flood elevation.

Stantec did not perform modeling or Preliminary Concept Plan drawings for this alternative and are only including the County-provided results for comparison with other provided Scenario modeling and drawings.

This report includes a discussion regarding the general "geometric" feasibility of raising the Holloway Road bridge above the 1-percent annual chance water surface elevation (WSEL) through a high-level comparison of the necessary elevation of the bridge (from the Scenario 1 model) and the surrounding topography (using approximate lowest adjacent grade elevations and County GIS terrain data). It is assumed that raising the bridge so that the low chord is above the Scenario 1-percent annual chance WSEL would result in approximately the same WSEL as in Scenario 1.

2.2 SCENARIO 2

Scenario 2 consists of restorative stream enhancements and corresponding grading within VDOT Right-of-Way (ROW), County easements, and Board of Supervisor (BOS) properties only. In this Scenario, the existing Holloway Road bridge shall remain in place with no required property acquisitions.

This Scenario provides for stream channel improvements from STA 12+75 to STA 23+00 (see Figure 7). Floodplain grading along the left overbank and some grading to the bank on the right side near STA 16+00 to STA 22+50 and adjacent to Lots 23 to 29 (see Table below and Figure 2 for lot locations) will occur in this Scenario. This area is within existing VDOT ROW or County easement.

The total assumed length of corridor and stream treatment length is approximately 1,025 linear feet.

This Scenario does not include the removal of any bridges, residential structures, or other structures (see Appendix A).

2.3 SCENARIO 3

Scenario 3 consists of the option to acquire Lots 7 through 15 (see Table below and Figure 2 for lot locations) and develop an environmental corridor within the existing County easements and acquired properties. In this Scenario, the existing bridge at Holloway Road would be removed.

This Scenario provides for stream channel improvements from STA 10+50 to STA 35+10, which is generally between Annandale Road and Sleepy Hollow Park. Floodplain grading along the left overbank starting at STA 15+00 and ending at STA 33+50 will occur in this scenario, along with additional floodplain grading expansion on the left overbank between STA 21+00 and 30+00.

The total assumed length of corridor and stream treatment length is approximately 2,460 linear feet.

Acquired Properties		
Lot	Street Address	
7	6656	Barrett Road
8	6654	Barrett Road
9	6652	Barrett Road
10	6650	Barrett Road
11	6648	Barrett Road
12	6646	Barrett Road
13	6644	Barrett Road
14	6642	Barrett Road
15	6640	Barrett Road

2.4 SCENARIO 4

Scenario 4 consists of the option to acquire Lots 7 through 15, as noted in Scenario 3, and option to acquire Lots 23 through 29 (see Table below and Figure 2 for lot locations). The development of an environmental corridor within the existing County easements and properties, and acquired properties is envisioned. In this Scenario, the existing bridge at Holloway Road would be removed.

This Scenario provides for stream channel improvements from STA 10+50 to STA 35+10, which is generally between Annandale Road and Sleepy Hollow Park. Floodplain grading expands on the right overbank between STA 15+50 and 22+50. Then, floodplain grading will occur along the left overbank starting at STA 15+00 and ending at STA 33+50. Additional floodplain grading expands on the left overbank between STA 21+00 and 30+00.

The total assumed length of corridor and stream treatment length is approximately 2,460 linear feet.

Acquired Properties					
Lot	Street Address		Lot	Street Address	
7	6656	Barrett Road	15	6640	Barrett Road
8	6654	Barrett Road	23	3045	Dashiell Road
9	6652	Barrett Road	24	6672	Barrett Road
10	6650	Barrett Road	25	6670	Barrett Road
11	6648	Barrett Road	26	6668	Barrett Road
12	6646	Barrett Road	27	6666	Barrett Road
13	6644	Barrett Road	28	6664	Barrett Road
14	6642	Barrett Road	29	6662	Barrett Road

This Scenario provides for all of the treatments proposed in Scenario 3, plus additional floodplain grading for the right floodplain overbank.

2.5 FAIRFAX COUNTY PRELIMINARY ANALYSES

When the project modeling results indicated a large volume of water ponding upstream of the of Sleepy Hollow Road Bridge, Fairfax County Stormwater Planning Division staff realized the need to obtain a better understanding of the bridge's impact on the upstream flooding. Using a variation of the model previously developed by Stantec, Fairfax County staff independently conducted (and ran) another simulation reflecting complete removal of the Sleepy Hollow bridge deck, allowing for comparison of water surface elevations both with and without the bridge deck.

Additionally, Fairfax County speculated whether the 1-percent annual chance storm event could be contained within the channel if there were only minimal constraints related to channel enlargement. As a result, Fairfax County independently staff also developed several model simulations reflecting concrete channels of various volume capacities to preliminary evaluate the feasibility of conveying the 1-percent annual chance storm event within the channel.

A memorandum prepared by Fairfax County discussing these analyses and the corresponding results can be found in Appendix D.

3.0 STREAM RESTORATION/ENHANCEMENT CONCEPT

Toward the project goal of developing an environmental corridor (within the existing County easements and potentially acquired properties) and restorative stream enhancements, Stantec developed a Stream Restoration/Enhancement Preliminary Concept strategy and shared with the County for their concurrence.

Following County review and comment, Stantec approximated dominant channel-forming bankfull flow (approximately between the 1- and 2-year peak flow), and applied preliminary design parameters (treatment priority, stream type, bankfull width/depth, horizontal geometry). Further geometry refinements and treatment types (refer to details, Appendix A) were incorporated into Preliminary Concept Design and applied to further hydraulic flood mitigation modeling purposes.

3.1 BANKFULL FLOW

Drawing from a variety of resources (USGS gage data, January 2017 FEMA flood study, regional curve data, Stantec reference reach repository, and other anecdotal data), Stantec approximates channel-forming bankfull flow between ~400 cubic feet per second (cfs) Upstream to ~475 cfs Downstream, with the greatest increases below the Unnamed Tributary (near STA 22+00). Other discharges considered in developing the conceptual design include those provided in "Section 4.0 – Hydraulic Model Development".

3.2 DESIGN PARAMETERS

Design parameters were developed primarily using empirical data consisting of an urban mini-regional curve (unknown tributary to Toby Creek and Long Creek) paired with a relevant reference reach, Neabsco Creek located in nearby Prince William County, VA. Relationships for bankfull area, depth, width, and discharge were considered (refer to sample relationship, Figure 4).

Additionally, selected design parameters (specifically bankfull cross section area) were compared against published regional curves: 1) *"Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region"* (McCandless, 2002), 2) "*Development of regional curves of bankfull-channel geometry and discharge for streams in the non-urban, Piedmont Physiographic Province, Pennsylvania and Maryland"*, (Cinotto, 2003), and 3) *"Regional Curves of Bankfull Channel Geometry for Non-Urban Streams in the Piedmont Physiographic Province, Virginia"* (Lotspeich, 2009). Because these curves were developed using non-urban sites, an urban enlargement ratio (Caraco, 2000) was applied to the non-urban watershed parameters to reflect the impact of urbanization.

Comparison of empirical data with that of regional curves (modified for urban enlargement) provided consistent results, enabling confident selection of preliminary design parameters.

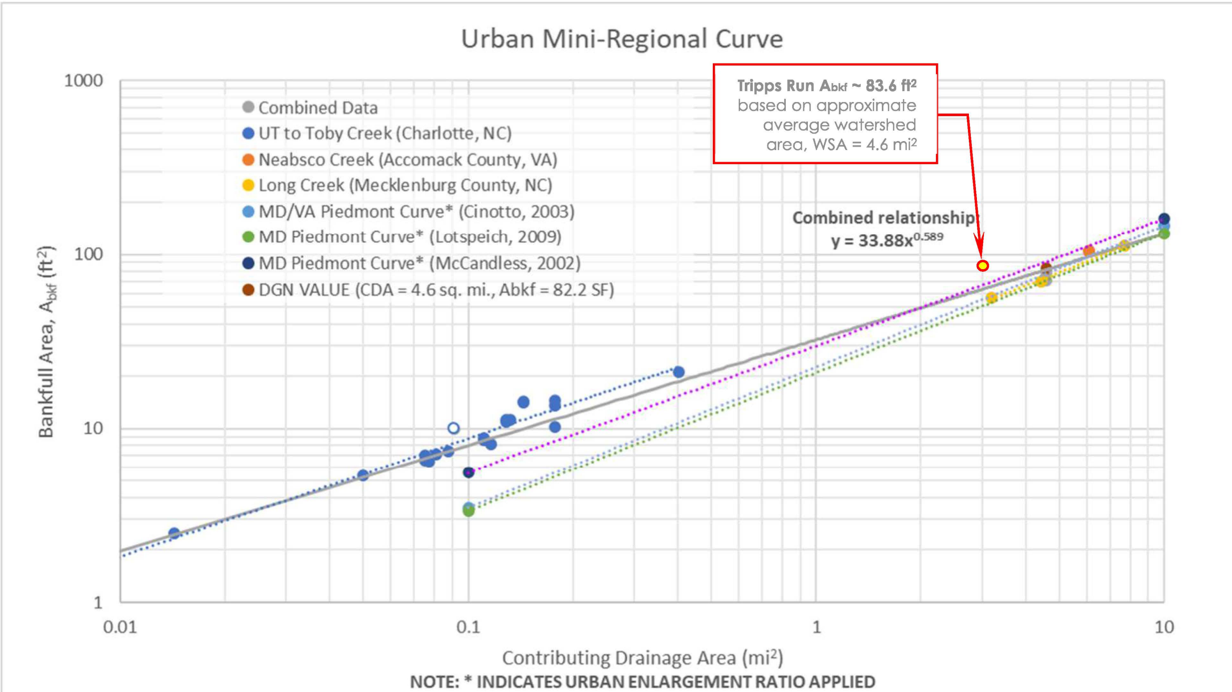

Figure 4 - Urban Mini-Regional Curve

From the provided Urban Mini-Regional Curve, preliminary design parameters applied at this phase of work are as follows:

Table 2 - Preliminary Concept Design Parameter Target Values

Design Parameter	Target Range	Actual Design Value (rounded)
Approximate Average Watershed Area, mi² (*WSA*)	**4.6**	
Riffle Cross-Sectional Area, ft² (A_{bkf})	**80 - 85**	**83**
Riffle Width/Depth Ratio (W_{bkf}/d_{bkf})	**10 - 16**	**10.3**
Riffle Width, ft (W_{bkf})	**25 – 30**	**29**
Riffle Mean Depth, ft (d_{bkf})	**2.5 – 3.0**	**2.8**
Riffle Maximum Depth (d_{max})	**3 - 5**	**4.0**
Riffle Maximum Depth to Riffle Mean Depth (d_{max}/d_{bkf})	**1.1 – 1.5**	**1.3**
Riffle Inner Berm Width, ft (W_{ib})	**16 - 22**	**19**
Riffle Inner Berm Width to Riffle Width (W_{ib}/W_{bkf})	**0.6 – 0.9**	**.8**
Riffle Inner Berm Mean Depth, ft (d_{ib})	**0.9 – 1.3**	**1.1**
Riffle Inner Berm Mean Depth to Riffle Mean Depth (d_{ib}/d_{bkf})	**0.3 – 0.5**	**0.4**

Design Parameter	Target Range	Actual Design Value (rounded)
Riffle Inner Berm Width/Depth Ratio (W_{ib}/d_{ib})	**14 - 18**	**17**
Riffle Inner Berm Cross-Sectional Area (A_{ib})	**27.1**	**27.1**
Riffle Inner Berm Cross-Sectional Area to Riffle Cross-Sectional Area (A_{ib}/A_{bkf})	**0.25 – 0.50**	**0.32**
Pool Length, ft (Lp)	**18 - 27**	**20 - 28**
Pool Length to Riffle Width (L_p/W_{bkf})	**0.7 – 1.0**	**0.65 – 0.90**
Pool Spacing, ft (S_{P-P})	**64.4**	**60 - 70**
Pool Spacing to Riffle Width (S_{P-P}/W_{bkf})	**1.5 – 2.0**	**1.8**

3.3 PRELIMINARY CONCEPT DESIGN

In general, the concept includes the following elements:

- **Floodplain Structure Demolition** – For Scenarios 3 and 4, the bridge at Holloway Road will be demolished and removed. Other specific structures scheduled for removal for each scenario are indicated on the Preliminary Concept Plan, in Appendix A.

- **In-Stream Structures** – Fairfax County-provided habitat assessment data of a nearby representative channel (*"Index of Benthic Integrity"* performed on Cameron Run in 2010; email correspondence 06/25/2020) which proved supportive of reconnaissance observations. In general, the greatest opportunities for stream riparian and aquatic improvement largely include alterations that promote: 1) improved epifaunal substrate, 2) increased hydraulic variability (depth/velocity) throughout the stream, and 3) increased frequency of riffles and sinuosity.

  Toward this interest, riffles or other grade control composed of rock, logs, or a mixture are proposed to serve as grade control structures placed where modeled energy losses are expected to increase. Other structural placement includes step-pool features, specifically near the Unnamed Tributary to relieve physical barriers to aquatic organisms. Additionally, incorporation of these instream structures serves to diversify bedform, transforming portions of the channel dominated by run-pool morphology and promoting more diverse facets characteristic of glide-riffle-run-pool morphology, consistent with the potential channel type.

- **Floodplain Grading** – In areas where possible, and consistent with Scenarios 3 and 4, overbank access is improved, by grading a floodplain and bankfull overflow channel, features activated only at bankfull events and higher. While general grading of these features was incorporated into the hydraulic modeling, specific floodplain outlets (weirs) reconnecting flows with have not yet been designed.

- **Upper Bank Grading** – Throughout the project, the existing channel upper banks will be graded to a gentler slope, enabling a better connection to the existing (or graded) floodplain. Any associated existing riprap requiring removal shall be salvaged/repurposed throughout the project (riffles, floodplain outlets).
- **Revegetation** – All disturbed areas will be revegetated with native riparian species corresponding to the appropriate planting zone (to be determined) following further refinements beyond Concept.

In addition to applying design parameters to the preliminary concept design, additional considerations were also incorporated into the Preliminary Concept Plan.

1. Extent of project, including start and end of project
2. Existing planimetrics (roads, parcels, easements) and utility information (per County GIS)
3. Typical cross-section with dimensions incorporating a nested multistage design (bankfull bench and floodplain), where possible. Lower flow features shall be incorporated into final design refinements.
4. Horizontal alignment adjustments were made in accordance with the Preliminary Concept strategy. Vertical areas of interest are visible on the profile. Actual vertical adjustments are not shown, due to accuracy of existing conditions topographic data (County provided LiDAR GIS data), but shall be incorporated into final design refinements, which is outside of the current scope of work
5. Preliminary rough grading depicting only bankfull channel grading and approximate floodplain grading. Detailed grading within the channel (i.e. riffle/run/glide/pool) due to accuracy of data, but shall be incorporated into final design refinements, which is outside of the current scope of work
6. Type of restoration/stabilization/enhancement
7. Location of potential staging and access locations
8. Existing and approximate proposed flood elevations
9. Preliminary (planning level) approximate location of public use trail

Stantec then applied these treatments into a proposed condition hydraulic model simulation using hydrology representative of the dominant channel-forming process (between the 1- and 2-year peak flow) and representative hydraulic geometry (typical riffle and average slope), per the Preliminary Concept Plan. The resultant flow profiles and stream hydraulics were acknowledged and incorporated, into design geometry refinement (revised dimension and geometry) for each Scenario.

The net effect of these proposed treatments not only decreases the flood stage by adding storage and improving conveyance, but also provides for ecological stream function improvements. The following tables provides a qualitative comparison of possible functional uplift:

Table 3 – Qualitative stream function uplift for Scenarios 3 and 4 (NOTE: Scenario 4 would result in additional improvements to Floodplain Access for the Upstream Reach, and associated increase in benefit)

Reach	Access to Floodplain	Lateral Stability	Bedform Diversity	Riparian Vegetation
Downstream	No Δ	Improved	Improved	Improved
Midstream	Improved	No Δ	Improved	Improved
Tributary	No Δ	No Δ	Improved	No Δ
Upstream	No Δ / Improved	Improved	Improved	Improved

4.0 HYDRAULIC MODEL DEVELOPMENT

The hydraulic model was developed based on a review of the FEMA effective hydraulic modeling (FEMA, 2010) and the hydraulic modeling obtained from a new study of Tripps Run completed in 2017 (FEMA, 2017). The 2017 model was used as a baseline for the existing conditions and proposed conditions model development.

4.1 HYDROLOGY

The discharges used in the hydraulic model were selected by reviewing the following sources of information:

1. Effective FEMA discharges (FEMA, 2010), which are based on a model developed using the Massachusetts Institute of Technology catchment model (MITCAT) to determine discharges (Harley 1975);
2. FEMA recurrence interval discharges (10-, 2-, 1-, and 0.2-percent annual chance (AC)) based on the Virginia urban regression equations (Austin, 2014) and computed as part of the 2017 study;
3. Rainfall data from Lake Barcroft during the July 8th, 2019 rainfall event; Note that photographs of the flooding event were used to estimate approximate high water marks and compare to hydraulic results;

This comparison of the effective discharges and the regression discharges are shown in Table 4 below. As can be seen from the table, the effective discharges are generally greater than the regression discharges.

Table 4 - Comparison of Effective Discharges and Regression Discharges

Flooding Source and Location	Drainage Area	Effective Discharges (cfs)				Regression Discharges (cfs)				Pct. Diff. (%)
Tripps Run	Sq. Miles	10-pct. AC	2- pct. AC	1-pct. AC	0.2-pct. AC	10-pct. AC	2- pct. AC	1-pct. AC	0.2-pct. AC	
Downstream of State Route 613 (Sleepy Hollow Road)	4.49	3,777	5,410	6,740	8,400	1,870	3,168	4,178	8,973	38

*AC (annual chance)

As shown in the table, the effective discharges are approximately 38% greater than those computed using the urban regression equations. The effective methodology utilized a MITCAT model which is a more detailed rainfall-runoff method that incorporates the impacts of urbanization, land-use and structural and non-structural controls for mitigating the impacts of flooding. The effective discharges have been used in the hydraulic model for this study.

Stantec understands that the County is also interested in computing discharges for the July 8, 2019 rainfall event. Stantec has completed an analysis by developing a limited detail rainfall-runoff model using

HEC-HMS version 4.3 (USACE, 2000). The model incorporated the entire Tripps Run drainage basin and allowed for an analysis and comparison of the 2019 storm event.

The model was developed using an abbreviated approximate methodology. Using this model, Stantec was able to use rainfall gage data to quantify the discharges in Tripps Run resulting from the July 2019 rainfall event. Since that event had a duration of only an hour and not 24-hours, it produced a discharge that was lower than the 24-hour 1-percent annual chance discharge data from the effective data.

Hydrologic analysis for flood hazard analysis is typically completed by using a 24-hour rainfall events for large drainage basins such as Tripps Run, which has a drainage area of 4.5 square miles. However, shorter duration events can produce very large peak discharge depending on drainage basin size, characteristics, and the intensity of the rainfall. The storm event that occurred on July 8, 2019 produced a total of 4.5 inches of rainfall in a period of 1 hour. That rainfall intensity is greater than 0.2-pct annual chance intensity of 4.0 inches in one hour based on point precipitation frequency estimates obtained from NOAA Atlas 14 (Bonin 2006).

This result can be seen in Table 5 below, where the peak from the July 2019 event of 5,258 cfs is greater than the 0.2-pct annual chance discharge of 4,956 for that one-hour duration. This is still less than the 1-pct. annual chance , 24-hour discharge of 6,740 cfs from the effective data.

Table 5 - Comparison of Discharges Including the July 2019 Storm Event

Flooding Source and Location	Drainage Area	Effective Discharges (MITCAT) 24-Hour Duration (cfs)		Regression Discharges (cfs)		Rainfall-Runoff (HEC-HMS) Discharges 24-Hour Duration (cfs)		Rainfall-Runoff (HEC-HMS) 1-Hour Duration (cfs)		
Tripps Run	**Sq. Miles**	**1-pct. AC**	**0.2-pct. AC**	**1-pct. AC**	**0.2-pct. AC**	**1-pct. AC**	**0.2-pct. AC**	**1-pct. AC**	**0.2-pct. AC**	**July 8th, 2019 Storm Event**
Downstream of State Route 613 (Sleepy Hollow Road)	4.49	6,740	8,400	4,178	8,973	6,831	9,547	3,277	4,956	5,258

*AC (annual chance)

It is Stantec's understanding that Fairfax County currently agrees with utilizing effective discharges in the hydraulic analysis of mitigation effects on base flood elevations (BFEs). A hydraulic analysis of the 2019 event has also been provided for comparison purposes.

It should be noted that the peak discharge from the July 8, 2019 storm event varies by location within the watershed. The comparisons above only show the discharges downstream of Sleepy Hollow Road where the July 2019 peak (5,258 cfs) is slightly less than the 2-pct annual chance discharge. However upstream of Holloway Road, that peak is slightly greater than the 2-pct annual chance discharge. This comparison can be found in Table 6 below. This variation can be attributed to differences in the hydrology methodology and refinement.

At US Route 50, the July 2019 peak (5,258 cfs) is actually less than the 10-pct annual chance event. This variability can also explain why the approximate high water mark observations tend to match closer to the water surface elevation (WSEL) from the 10-pct annual chance event than the 2-pct annual chance event. This is discussed further in section 4.4

Table 6 - Comparison of MITCAT Discharges with the July 2019 Storm Event at Different Locations

Flooding Source and Location	Drainage Area	Effective Discharges (MITCAT) (cfs)				July 8th, 2019 Storm Event
Tripps Run	**Sq. Miles**	**10-pct. AC**	**2- pct. AC**	**1-pct. AC**	**0.2-pct. AC**	
At US Route 50	2.86	2,814	4,102	5,048	6,700	2,716
Upstream of Holloway Road	3.46	3,301	4,694	5,663	7,200	4,798
Downstream of State Route 613 (Sleepy Hollow Road)	4.49	3,777	5,410	6,740	8,400	5,258

*AC (annual chance)

4.2 EXISTING CONDITIONS MODEL

The 2017 FEMA Tripps Run model was used as the baseline model. This model will be released as part of the FEMA preliminary map products in December of 2020. Updates were made to the model to ensure adequate detail to provide a comparison of flood mitigation Scenarios.

Revisions to the baseline model included:

1. Adding flood-prone residential structures as blocked obstructions as shown in the data provided by Fairfax County, but not included in the previous model;
2. Adding model cross-sections at key locations related to the proposed flood mitigation measures;
3. Incorporation of restrictions and other encroachments observed during the field visit; and
4. Updating channel roughness values associated with the materials used for channel lining based on data gathered during the field visit. Roughness values were selected based on judgement from field observation.

The LiDAR data provided with the model was obtained from FEMA and was flown in 2014 as part of the Hurricane Sandy Supplemental for National Capital Region, Delivery Lot 5; 0.7-meter nominal spacing; Vertical Accuracy: 11.5 cm; USGS 3DEP QL2. Horizontal datum North American Datum 83 and vertical datum North American Vertical Datum 88.

4.3 PROPOSED CONDITIONS MODELS

The proposed conditions models were developed based on Scenarios 2, 3 and 4 Preliminary Concept Plan. These updates included the removal of the designated structures (assumed as those associated with buyout properties), removal of the Holloway Road bridge, proposed stream geometry, and proposed adjacent topography.

The models were developed using the same cross-section layout. This allows for an easy comparison between Scenarios by directly comparing cross-section outputs.

4.4 APPROXIMATE HIGH WATER MARKS

Fairfax County has provided Stantec with photographs of the flood damage immediately after the July 2019 storm event. From those photographs, field reconnaissance and LiDAR data, Stantec was able to estimate approximate high-water marks and compare them to the results of the hydraulic model. It can be shown from that analysis, that the approximate peak WSEL were closest to the 10-percent annual chance rainfall event of the existing conditions model. See Figures 5 and Figure 6 below. Figure 5 shows an example of some of the photographic evidence that was used to determine the approximate high-water mark and their approximate elevations. Figure 6 shows the location of the approximate high-waters marks and compares them to the 10-percent annual chance 24-hour WSEL of the existing conditions model. All the approximate high-water marks were within 0.4 feet of the approximate 10-percent annual chance modeled elevation.

This analysis is very approximate and variability is expected. However, there are three reasons why the approximate high water marks tend to be closest to the 10-percent annual chance model elevations rather than the higher return interval events:

- The event duration makes a big difference, the July 8, 2019 event had a 3-hour duration and the model events have a 24-hour duration. The 24-hour duration events will often produce higher peak discharges than shorter duration events of the same return period.
- The current hydraulic model assumes steady-state discharge which tends to produce more conservative results. A hydraulic model using an unsteady hydrograph would factor in floodplain storage which can have a major effect especially in shorter duration events.
- As discussed and shown in Table 6 above, the peak discharge from the July 8, 2019 storm event varies by location within the watershed at Sleepy Hollow Road the 2019 peak is slightly less than the 2-pct annual chance discharge. upstream of Holloway Road, that peak is slightly greater than the 2-pct annual chance discharge and above that, at US Route 50, the peak is actually less than the 10-pct annual chance event.

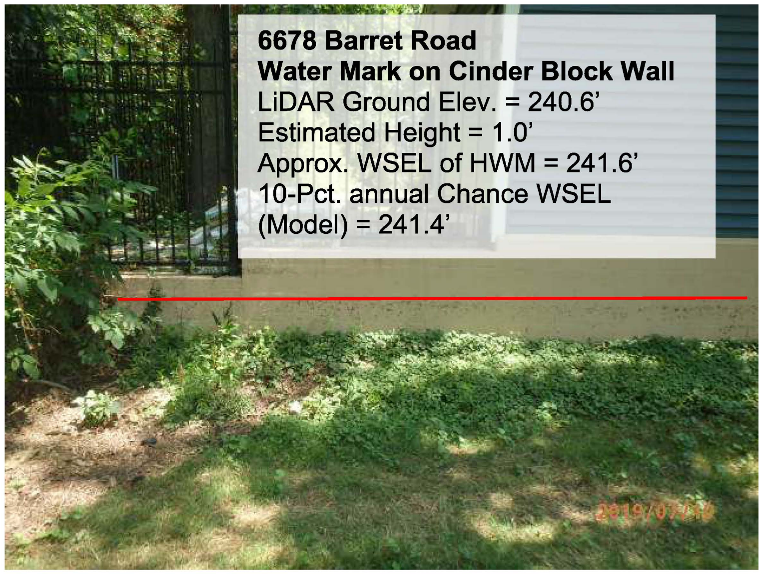

Figure 5 -- Example of an Approximate High Water Mark (HWM)

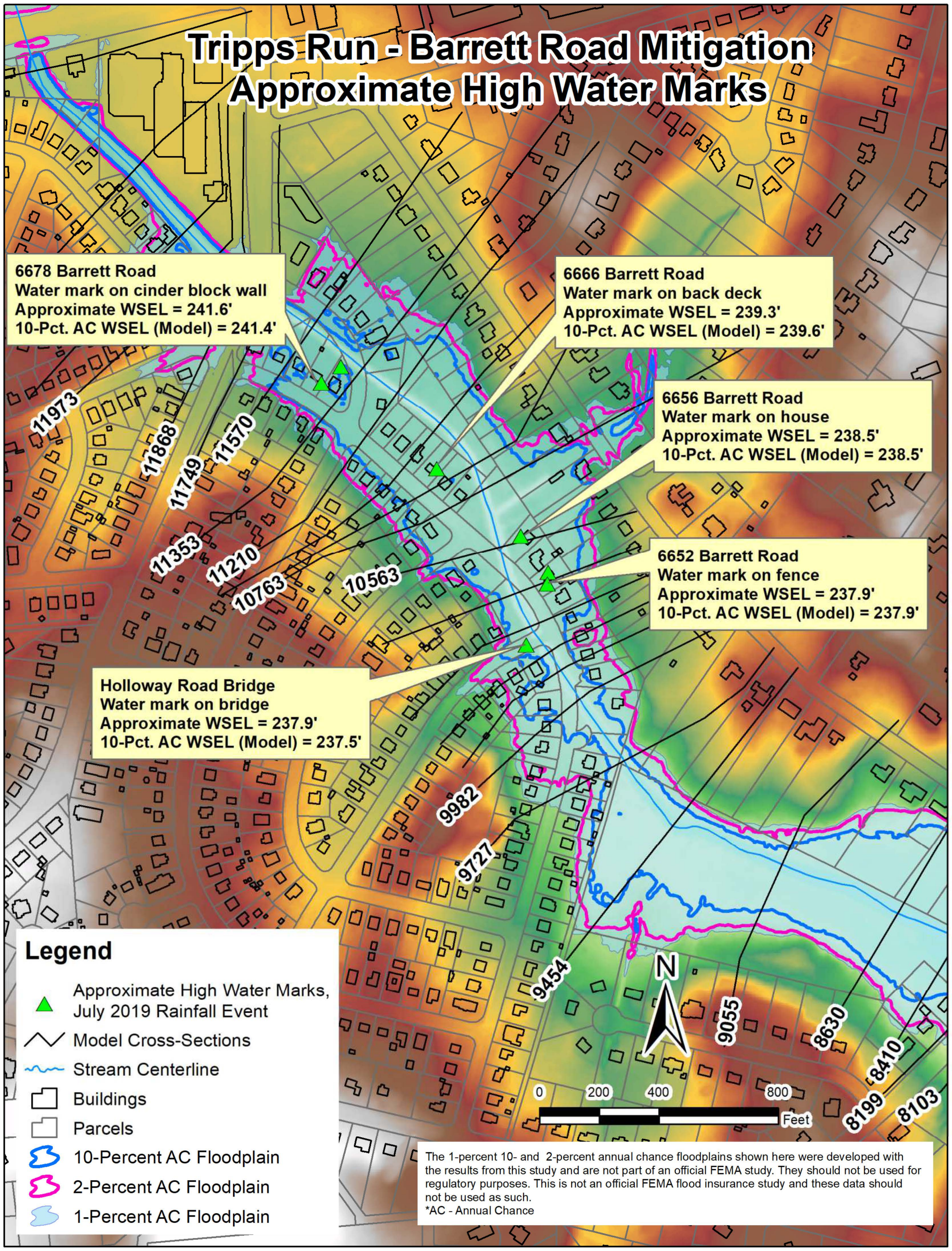

Figure 6 – High Water Mark Map

5.0 HYDRAULIC RESULTS

Once the existing and proposed model runs were complete, they were compared to evaluate the effects of the proposed flood mitigation measures on WSELs in the floodplain. All presented water surface elevations were computed using the 1-percent annual chance and 0.2-percent annual chance discharges with an event duration of 24-hours.

The proposed grading plans were used to update the cross-section geometry accounting for the addition of the proposed overbank channels and other proposed modifications.

5.1 SCENARIO RESULTS

Based on the Scenario 1 hydraulic results, the removal of the Holloway Road Bridge provides drop in WSEL of approximately 0.4 feet. Scenario 2 provides an approximate reduction in water surface elevation up to 0.8 feet in the vicinity of the floodplain grading within the existing storm water right-of-way. Both Scenarios 3 and 4 include property acquisition and provide a reduction in WSEL up to 4.7 feet in places.

A comparison of the WSELs the 1-percent annual chance events are provided in Table 7a and 7b on the following pages. Figure 7 shows the project stationing for the concept plans as well as the hydraulic model cross-section layout and stationing so that they can be cross-referenced.

The maps in Appendix B show the extents of the 1-percent and 0.2-percent annual chance floodplains as well as quantify the impacts to properties for each scenario.

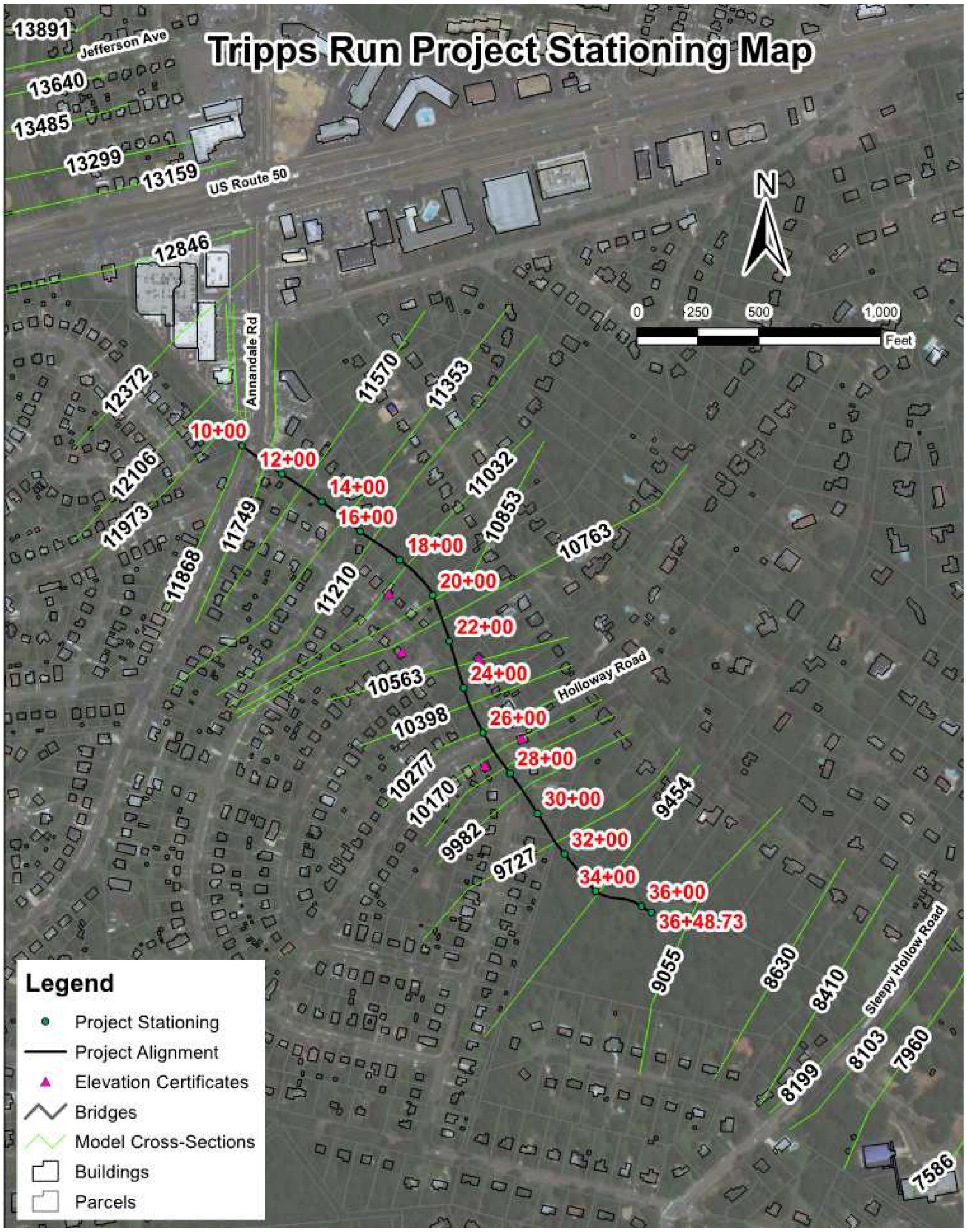

Figure 7 – Map of Project Stationing and HEC-RAS Cross-Sections

5.2 COMPARISON OF SCENARIOS

Scenario 1 considers no changes to the existing conditions other than removal and/or elevation of the Holloway Road Bridge. Scenario 2 includes floodplain grading within existing public and County government easements (i.e. VDOT ROW or County storm drain easement). Proposed grading is located between model cross-section 11570 through 10563.

Table 7a. Comparison of 1- Percent Annual Chance WSEL – Scenario 1 and 2

Cross-Section Station	WSEL Existing Conditions (feet NAVD 88)	WSEL Scenario 1 (feet NAVD 88)	Difference (feet)	WSEL Scenario 2 (feet NAVD 88)	Difference (feet)	Notes
12106	249.7	249.7	0.0	249.7	0.0	
11973	249.7	249.7	0.0	249.7	0.0	
11868	249.8	249.8	0.0	249.8	0.0	
Annandale Road Bridge						
11749	246.3	246.3	0.0	246.2	-0.1	
11570	244.7	244.7	0.0	244.3	-0.4	
11353	243.5	243.4	(-0.1)	242.8	(-0.8)	
11210	243.1	243.0	(-0.1)	242.7	(-0.4)	
11032	242.8	242.7	(-0.1)	242.5	(-0.3)	
10853	242.0	241.8	(-0.2)	241.9	(-0.1)	
10763	241.9	241.8	(-0.1)	241.9	0.0	
10563	240.7	240.5	(-0.2)	240.7	0.0	
10398	240.3	239.9	(-0.4)	240.3	0.0	
10277	239.8	239.4	(-0.4)	239.8	0.0	
Holloway Road Bridge (Raised above the 1%- annual chance WSEL for Scenario 1)						
10170	238.2	238.2	0.0	238.2	0.0	
10099	237.9	237.9	0.0	237.9	0.0	
9982	237.8	237.8	0.0	237.8	0.0	
9727	236.4	236.4	0.0	236.4	0.0	
9454	235.9	235.9	0.0	235.9	0.0	
9055	235.4	235.4	0.0	235.4	0.0	
8630	235.2	235.2	0.0	235.2	0.0	
8410	235.2	235.2	0.0	235.2	0.0	
8199	234.7	234.7	0.0	234.7	0.0	
Sleepy Hollow Road Bridge						
8103	228.9	228.9	0.0	228.9	0.0	
7960	227.0	227.0	0.0	227.0	0.0	

Scenario 3includes the acquisition of properties as noted in Section 2.2 and development of an environmental corridor and restorative stream enhancements beginning near Annandale Road and continuing downstream to Sleepy Hollow Park. Proposed grading is located between model cross-section 11570 through 9454. Scenario 4includes the acquisition of properties as noted in Section 2.3 and the development of an environmental corridor and restorative stream enhancements beginning near Annandale Road and continuing downstream to Sleepy Hollow Park. Proposed grading is located between model cross-section 11570 through 9454.

Table 7b. Comparison of 1-Percent Annual Chance WSEL – Scenario 3 and 4

Cross-Section Station	WSEL Existing Conditions (feet NAVD 88)	WSEL Scenario 3 (feet NAVD 88)	Difference (feet)	WSEL Scenario 4 (feet NAVD 88)	Difference (feet)	Notes
12106	249.7	249.5	(-0.2)	249.6	(-0.1)	
11973	249.7	249.5	(-0.2)	249.5	(-0.2)	
11868	249.8	249.6	(-0.2)	249.6	(-0.2)	
Annandale Road Bridge						
11749	246.3	245.9	(-0.4)	245.9	(-0.4)	
11570	244.7	244.6	(-0.1)	244.7	0.0	Limit of Project
11353	243.5	241.1	(-2.4)	240.8	(-2.7)	
11210	243.1	241.0	(-2.1)	238.7	(-4.4)	
11032	242.8	240.0	(-2.8)	238.5	(-4.3)	
10853	242.0	238.1	(-3.9)	238.3	(-3.7)	
10763	241.9	238.0	(-3.9)	238.2	(-3.7)	
10563	240.7	237.8	(-2.9)	237.8	(-2.9)	
10398	240.3	237.8	(-2.5)	237.8	(-2.5)	
10277	239.8	237.7	(-2.1)	237.7	(-2.1)	
Holloway Road Bridge (Removed in Scenario 3 and Scenario 4)						
10170	238.2	237.7	(-0.5)	237.7	(-0.5)	
10099	237.9	237.6	(-0.3)	237.6	(-0.3)	
9982	237.8	237.6	(-0.2)	237.6	(-0.2)	
9727	236.4	236.3	(-0.1)	236.3	(-0.1)	
9454	235.9	235.9	0.0	235.9	0.0	Limit of Project
9055	235.4	235.4	0.0	235.4	0.0	
8630	235.2	235.2	0.0	235.2	0.0	
8410	235.2	235.2	0.0	235.2	0.0	
8199	234.7	234.7	0.0	234.7	0.0	
Sleepy Hollow Road Bridge						
8103	228.9	228.9	0.0	228.9	0.0	
7960	227.0	227.0	0.0	227.0	0.0	

5.3 FLOODPLAIN MAPPING

Floodplain boundaries were developed for the 1-, and 0.2-percent annual chance floods for existing conditions and all four proposed condition Scenarios.

Floodplain boundaries were developed for each Scenario to quantify the number of structures located within the floodplain under each Scenario. Structures for this purpose have been defined as principal structures of a property only (i.e. residential structures) and not accessory structures such as garages, sheds or similar outbuildings. The results of this analysis are summarized below:

- **Existing Conditions** – 62 residential structures located in the 1-pct annual chance floodplain
- **Scenario 1** – 62 residential structures located in the 1-pct annual chance floodplain, no change
- **Scenario 2** – 60 residential structures located in and 2 residential structures no longer in the 1-pct annual chance floodplain, no residential structures acquired by the County
- **Scenario 3** – 40 residential structures located in and 13 residential structures no longer in the 1-pct annual chance floodplain, 9 residential structures would be acquired by the County
- **Scenario 4** – 29 residential structures located in and 17 residential structures no longer in the 1-pct. annual chance floodplain, 16 residential structures would be acquired by the County

For maps detailing the floodplain extents and impacts to residential structures, see Appendix B.

5.4 COMPARISON OF THE STRUCTURES' LOWEST ADJACENT GRADE

Fairfax County has provided available elevation certificates that can be found in Appendix B. Table 8 on the following page provides a comparison of these lowest adjacent grade (LAG) elevations and the adjacent BFEs for the existing conditions and all four proposed conditions Scenarios. The comparison provides a summary of the effects of each scenario on BFEs.

The effects are summarized below:

- Many of the properties are below the BFE by 1 to 5 feet in the existing conditions scenario.
- In Scenario 1, removing the Holloway Road bridge would only reduce the BFEs marginally and would therefore not make a significant difference in BFE.
- The potential flood mitigation efforts in Scenario 3 would affect some upstream properties, particularly 6668 Barrett Road, 6661 Barret Road, and 3131 Holloway Road. Although, all three properties would still have LAG elevations that are below the BFE.
- The floodplain grading of Scenario 4 does provide some reductions in BFEs for some of these properties

Table 8 – Existing Conditions Comparison of BFEs and Lowest Adjacent Grade Elevations

		Existing Conditions		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Property Location	Lowest Adjacent Grade (LAG) (feet)	BFE (feet*)	Diff. (LAG - BFE) (feet*)	BFE (feet*)	Diff. (LAG - BFE) (feet*)	BFE (feet*)	Diff. (LAG - BFE) (feet*)	BFE (feet*)	Diff. (LAG - BFE) (feet*)	BFE (feet*)	Diff. (LAG - BFE) (feet*)
6668 Barrett Road (XS 11032) (Removed in Scenario 4)	237.9	242.8	(-4.9)	242.7	(-4.8)	242.5	(-4.6)	240.0	(-2.1)	238.5	(-0.6)
6661 Barrett Road (XS 10763)	237.4	241.9	(-4.5)	241.8	(-4.4)	241.9	(-4.5)	238.0	(-0.6)	238.2	(-0.8)
6656 Barrett Road (XS 10563) (Removed in Scenario 3)	236.2	240.7	(-4.5)	240.5	(-4.3)	240.7	(-4.5)	237.8	(-1.6)	237.8	(-1.6)
6646 Barrett Road (XS 10170) (Removed in Scenario 3)	237.1	238.2	(-1.1)	238.2	(-1.1)	238.2	(-1.1)	237.7	(-0.6)	237.7	(-0.6)
3131 Holloway Road (XS 10170)	235.3	238.2	(-2.9)	238.2	(-2.9)	238.2	(-2.9)	237.7	(-2.4)	237.7	(-2.4)
6644 Barrett Road (XS 10099) (Removed in Scenario 3)	235.6	237.9	(-2.3)	237.9	(-2.3)	237.9	(-2.3)	237.6	(-2.0)	237.6	(-2.0)

5.5 PLANNING, DESIGN AND MODELING ASSUMPTIONS

Planning assumptions include but are not limited to the following:

- County-provided data (utilities, parcel data, LiDAR, etc.) is true and accurate
- Holloway Road bridge to be demolished for Scenarios 3 and 4
- Additional stakeholder input to be obtained at a later point in the process
- All necessary easements are acquired and properties are acquired
- Approximate location of public use trail has not been assessed and/or designed and is only intended to provide a preliminary planning-level idea of one possibility

Design assumptions include but are not limited to the following:

- Construction access is feasible
- Channel formation process is dominated by higher frequency bankfull flow events with recurrence interval of 1-2 years
- While incidental to the primary goal of flood hazard mitigation, ecological benefits including improved stream and riparian function are assumed to be limited due to the urban nature of the watershed and receiving stream
- Existing conditions are as reflected in the County-provided LiDAR data and the 2017 Flood Study Existing Conditions HEC-RAS model
- Proposed conditions stability is evaluated and design refined in consideration of modeled range of flows

Modeling assumptions include but are not limited to the following:

- Effective discharges are still valid and hydrologic basin parameters have not changed significantly since the analysis was completed
- Bridge and structure conditions as provided in the FEMA provided hydraulic model are accurate and have not changed
- LiDAR data in the 2017 FEMA model is accurate, current, and appropriate for the analysis

6.0 PROJECT BENEFITS

With each specific scenario treatment (Appendix A), different levels of benefit can be realized. In the interest of selecting the hazard mitigation alternative that best satisfies the project goals (refer to Section 1.1), relative project benefits are described as low, moderate, and high (with text color reflective of desirability). The below table provides a summary of project benefits for each scenario, in comparison with each other, followed by brief qualitative descriptions of rating justification.

Table 9 - Summary of Project Benefits

Scenario	**Summary of Project Benefits for Each Scenario** (as compared to each other)		
	Flood Reduction	Stream Function Enhancement	Loss of Existing Structures*
Scenario 1	Low	N/A	Low
Scenario 2	Low	Low	Low
Scenario 3	Moderate	Moderate	Moderate
Scenario 4	High	High	High

* For "Loss of Existing Structures" only, LOW is desirable, HIGH is undesirable

6.1 SCENARIO 1 BENEFITS

A disadvantage of Scenario 1 is that the removal of the Holloway Road Bridge crossing would eliminate access to the residences along Barrett Road, creating the need to construct an additional access. Stantec evaluated raising the bridge to preserve access and replicate a no-bridge water surface elevation. It was determined that the bridge would need to be raised more than seven feet and be subject to excessive constructability constraints on both Holloway and Barrett Road.

- Flood Reduction – The same number of residential structures remain within the 1% annual chance floodplain boundary after implementation of this scenario. The benefits to the approximate peak flooding water surface elevations (WSEL) in Scenario 1 are less when compared to Scenarios 2 through 4. For these reasons, the Flood Reduction benefits are described as "low".
- Stream Function Enhancement – Removal of the crossing would include permanent stabilization of disturbed area, including the associated adjacent stream banks at and around the existing abutments, this scenario does not include proposed stream improvements, and offers very little benefit to the stream ecological function and is therefore described as non-applicable, or "N/A".
- Loss of Existing Structures – Inherent to property acquisition is owner outreach, knowledge-sharing, and coordination, all of which require additional project effort. By considering the number of properties required for acquisition as a surrogate for associated effort, it is assumed

that fewer acquisitions may be realized as a project benefit. For this reason, this scenario provides for the “highest” benefit, or fewest required displacements.

While this scenario was not anticipated to satisfy the project goals, which it does not, this scenario was originally included with intention only to serve as point of reference to better understand specific benefits associated with further treatments proposed in other scenarios.

6.2 SCENARIO 2 BENEFITS

The primary differences between Scenario 2 and the proposed treatments in Scenarios 3 and 4 are the lateral floodplain connections and the longitudinal extent of treatments. Due to the limited availability of properties to incorporate treatments for this scenario (using publicly managed VDOT/County properties only; no acquisitions), the downstream portion of the stream does include stream channel stabilization but does not include floodplain enhancements, as seen in Scenarios 3 and 4. Similarly, without any additional property acquisitions, the public use trail was not needed nor included in Scenario 2.

- Flood Reduction - In Scenario 2 (proposed work only within properties that are currently publicly owned and/or controlled), modeling results indicate that proposed limited floodplain grading would result in a difference to the flood elevations, reducing the depth of flooding, but does not relieve many properties from the 1% probability of flood occurrence. 2 of 62 residential structures are removed from the 1% annual chance floodplain boundary and the remaining 60 continue to be impacted by the 1% annual chance flood compared to existing conditions. The benefits to the approximate peak flooding water surface elevations (WSEL) in Scenario 2 are less when compared to Scenario 3 or 4. For these reasons, the Flood Reduction benefits are described as “low”.
- Stream Function Enhancement – Property constraints associated with this treatment eliminate the opportunity to propose floodplain treatments and therefore, stream enhancements limited to less than that of Scenarios 3 and 4. This scenario does offer some benefit to the stream ecological function, associated with top of bank grading/planting and is therefore described as “low”.
- Loss of Existing Structures – With the exception of possibly requiring Temporary Construction Easements (for all scenarios) this scenario requires no property acquisition or owner displacement and therefore provides for a “low” level of existing structure loss.

6.3 SCENARIO 3 BENEFITS

The potential flood mitigation efforts in Scenario 3 will provide benefit to upstream properties in the form of decreased WSELs, even though some of the properties would still be located within the 1-percent annual chance floodplain boundary. According to their elevation certificates, the residential structures located at 6668 Barrett Road, 6661 Barret Road, and 3131 Holloway Road would remain below the BFE; however, the associated decreases in WSEL range from 0.1 ft to 3.9 ft.

- Flood Reduction - In Scenario 3, modeling results indicate that proposed floodplain grading would result in some difference to the flood elevations, whereby 13 of the 62 residential structures would no longer be located in the 1-percent annual chance floodplain boundary (This does not include the 9 residential structures acquired by the County). Despite this improvement, this scenario accounts for the acquisition of 9 residential structures and the removal of the Holloway Road bridge. The benefits to the approximate peak flooding WSEL in Scenario 3 are greater than Scenario 2, but less than Scenario 4. For these reasons, the Flood Reduction benefits are described as “moderate”.

- Stream Function Enhancement – This scenario includes stream enhancements throughout the longitudinal extent of property acquisitions and beyond. Because this scenario has fewer property constraints and extends further longitudinally (along the stream) to a greater extent than Scenario 2, proposed stream improvements provide for greater cumulative stream function enhancement. As a result, this scenario does offers substantial benefit to the stream ecological function (refer to Table 3) and is therefore described as “moderate”.
- Loss of Existing Structures – This scenario requires acquisition (and displacement) of 9 properties, which is more than Scenario 2, but less than Scenario 4, and was described as “moderate”, accordingly.

While this scenario depicts public use of acquired properties, this benefit has not been fully considered and therefore, not realized at this time.

6.4 SCENARIO 4 BENEFITS

Like Scenario 3, the potential flood mitigation efforts in Scenario 4 will provide benefit to upstream properties but also proposes additional downstream treatments.

- Flood Reduction - In Scenario 4, modeling results indicate that proposed floodplain grading would result in some difference to the flood elevations, whereby 17 of the 62 residential structures are removed from the 1% annual chance boundary. Despite this improvement, this scenario accounts for the acquisition of 16 residential structures and removal of Holloway Road bridge. The benefits to the approximate peak flooding water surface elevations (WSEL) in Scenario 4 are greater than Scenarios 2 and 3. For these reasons, the Flood Reduction benefits are described as “high”.
- Stream Function Enhancement – This scenario proposes more properties acquired and therefore, more stream enhancements beyond that proposed for Scenario 3, specifically in the form of additional floodplain grading throughout the longitudinal extent of property acquisitions. As a result, this scenario offers the greatest benefit to the stream ecological function (refer to Table 9) and is therefore described as “high”.
- Loss of Existing Structures – This scenario requires acquisition (and displacement) of 16 properties, far more than then other scenarios. For this reason, it is ranked as a “high” level of displacements and existing structure loss (undesirable).

7.0 PLANNING LEVEL COST ESTIMATES

Planning level cost estimates are only as accurate as the plan/design level of completion, while still enabling comparison of relative scenario differences. Enumerated engineering opinion of probable quantities of work and unit prices were compiled and summarized in corresponding opinion of probable costs. Planning level cost estimates were prepared for Scenarios 2, 3 and 4 (below):

Table 10 - Summary of Planning Level Cost Estimates

Planning Level Cost Estimates - Engineering Opinion of Probable Cost			
Work Item	**Scenario 2**	**Scenario 3**	**Scenario 4**
Design and Permitting	$ 360,000	$ 930,000	$ 930,000
Mobilization, Site Preparation, Survey, Erosion and Sediment Control, Demobilization	$ 177,000	$ 675,000	$ 801,000
Channel and Floodplain Construction (earthwork, structures, materials/labor)	$ 786,000	$ 4,153,000	$ 5,255,000
Planting / Revegetation	$ 43,000	$ 240,000	$ 319,000
Acquisition of Properties	$ -	$ 5,726,000	$ 9,958,000
Sub-Total	$ 1,366,000	$11,724,000	$17,263,000
Contingency for Design	$ 72,000	$ 186,000	$ 186,000
Contingency for Bidding	$ 60,000	$ 260,000	$ 320,000
Contingency for Construction	$ 110,000	$ 510,000	$ 640,000
TOTAL	**$ 1,608,000**	**$12,680,000**	**$18,409,000**

A summary of these opinions of probable costs are prepared for planning purposes only. The planning level costs include:

- Construction Costs, including: Mobilization, Survey, Site Preparation, Holloway bridge demolition, Erosion and Sediment Control, and Demobilization were evaluated per scenario, based on each corresponding scenario (Appendix A)
- Detailed Channel and Floodplain construction, including earthwork, stream structures and associated materials were calculated based on proposed grading and treatments corresponding to each scenario (Appendix A)
- Planting for each scenario accounts for temporary/permanent seeding, live plantings (live stakes, containerized and/or seedlings)
- Acquisition/purchase of the properties (and associated structure demolition) identified in each scenario. Note that only select residential structures have been identified for County acquisition in

the proposed scenarios. This does not include all residential structures located within the 1-percent annual chance floodplain boundary for any of the scenarios.

- Geotechnical efforts and/or utility locate/relocate were not considered as cost factors at this time
- Trails and/or other public use amenities were included for Scenarios 3 and 4.
- Professional services (engineering, design and construction observation) were included

The following summarizes quantity and cost assumptions:

- Mobilization was assumed as 5% of the cost of all other work items
- Survey costs were assumed as follows: Scenario 3 and 4 equal to 50% more effort than Scenario 2.
- Design and permitting costs were assumed as follows: $350 per linear foot for Scenario 2, and $375 per linear foot for Scenario 3 and Scenario 4. Design and permitting costs were based upon the assumed length of channel for each scenario; 1,025 LF for Scenario 2, 2,460 for Scenario 3 and 4.
- LOMR and CLOMR costs were not included
- Holloway bridge demolition costs are constant in Scenarios 3 and 4. The Holloway Road bridge would remain in place in Scenario 2.
- The acquisition cost of the properties is the 2020 Fairfax County assessed value of property (land and structure), plus additional 30%, to adjust for the market rate and demolition costs, and rounded up to nearest 1,000
- All dollar values were rounded up to nearest 1,000
- Utility location/relocation was not included
- Geotechnical engineering/construction was not included

In general, relative scenario cost comparisons may be useful in selecting alternative(s) to advance. Some observations of the comparisons include:

1) The relative cost of Scenario 3 is approximately eight times the cost of Scenario 2,

2) Similarly, the cost of Scenario 4 is approximately 1.5 times the cost of Scenario 3, however

3) The cost-to-benefit increase from Scenario 3 to Scenario 4 is about twice the cost-to-benefit increase from Scenario 2 to Scenario 3. While suggestive of improved value in advancing Scenario 4, Scenario 3 satisfies the original project goals, while avoiding potential limitations of funding.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Four flood mitigation Scenarios have been assessed including the development of corresponding environmental corridors and restorative stream enhancements. The flood reduction benefits have also been quantified for each Scenario and planning level cost estimates have been provided.

The purpose of Scenario 1 was to quantify the hydraulic influence of the bridge at Holloway Road and quickly assess the feasibility of raising the bridge above the 1-percent annual chance WSEL by running a Scenario where the bridge has been removed. Based on that analysis, the bridge removal would provide a hydraulic benefit in WSEL of 0.4 feet or less. Raising the bridge above the BFE would require a lift of 7.1 feet which was deemed infeasible.

Scenario 2 consists of restorative stream enhancements and corresponding grading within VDOT ROW, County easements, and Board of Supervisor (BOS) properties only. In this Scenario, the existing Holloway Road bridge remained in place with no required property acquisitions. Based on the hydraulic model results, this Scenario provides a reduction in WSEL for the 1-percent annual chance event between 0.1-feet and 0.8-feet. The benefits are limited to the reach adjacent to the properties at 6664 through 6672 Barrett Road (lots 23 to 29). Of the 62 properties currently located within the 1-percent annual chance floodplain, only two properties would no longer be located within the floodplain under this Scenario. As noted in section 7.0, the planning level cost estimate for Scenario 2 is $1,608,000.

Scenario 3 includes the acquisition of properties at 6640 through 6656 Barrett Road (lots 7 through 15) and development of an environmental corridor and restorative stream enhancements beginning near 6662 Barrett Road and continuing downstream to Sleepy Hollow Park. The Scenario would provide a reduction in WSEL for the 1-percent annual chance event between 0.1-feet and 3.9-feet. The hydraulic benefits would be more widespread than Scenario 2 and would extend between Annandale Road and Sleepy Hollow Park. Of the 62 properties currently located within the 1-percent annual chance floodplain, 13 properties would no longer be located within the floodplain and 9 properties would be acquired by the County. As noted in section 7.0, the planning level cost estimate for Scenario 3 is $12,680,000.

Scenario 4 includes all of the changes in Scenario 3 with the additional acquisition of properties at 6664 through 6672 Barrett Road (lots 23 to 29) and development of an environmental corridor and restorative stream enhancements beginning from upstream of 3045 Dashiell Road. The Scenario would provide a reduction in WSEL for the 1-percent annual chance event between 0.1-feet and 4.4-feet. The hydraulic benefits would be even more widespread than Scenario 3. Of the 62 properties currently located within the 1-percent annual chance floodplain, 17 properties would no longer be located within the floodplain boundary and 16 properties would be acquired by the County. As noted in section 7.0, the planning level cost estimate for Scenario 4 is $18,409,000.

8.2 RECOMMENDATIONS AND NEXT STEPS

Provided only the information developed to produce this document, Scenario 3 appears to optimize benefits, consistent with stated project goals. However, it is commonly understood that more information can support more informed decision-making. Additional information recommendations are generalized as follows:

- Public Outreach / Property Acquisition – Well known to many municipalities, property acquisitions can often dictate project feasibility beyond technical assessment (e.g. this study). Election of preferred alternatives (scenarios) hinges on individual and community consensus. It is presumed that the required property acquisitions may require substantial coordination, and as such, may require further consideration and knowledge-sharing from the County real estate team. Developing a public outreach strategy, specifically to increase participant (landowner awareness) could enable a clearer perspective of the required effort associated with property acquisition.
- Repetitive Loss Quantification - Of additional importance, repetitive losses should be quantified into cost/unit time for inclusion in refining knowledge of proposed project benefits. Over time, the losses could accumulate to more than the current proposed project costs. Realizing these costs as a deduction against the benefits could provide an alternative perspective of the proposed Scenarios, useful to the decision-makers.
- Scenario Hydrology Refinement - Toward refining the current Scenarios, additional data may be required. Stantec recommends that the hydrologic and hydraulic models be further studied and refined for Tripps Run. This includes developing a refined rainfall-runoff model of the drainage basins to complement and compare to the MITCAT model results and quantify the un-gaged peak discharges during the flooding events of July 8, 2019 and July 7, 2020. Once the historic peak discharges are determined, Stantec recommends that the hydraulic model be calibrated to any available estimated or surveyed high water marks.

8.3 ADDITIONAL DATA NEEDS

In support of Hydrologic Refinement (as noted in above Section 8.2) and further detailed design development, the County should consider acquiring additional data. Specifically, Stantec recommends that Fairfax County survey the high water marks for the July 8, 2019 and July 7, 2020 rainfall events.

Prior to final design, provided the elected preferred scenario involves floodplain grading, geotechnical investigations should be performed to verify material quality and suitability for proposed use, as well as utility locating to accurately realize unseen (underground) constraints. Jurisdictional delineations and cultural/archaeological surveys enable clear USACE permitting. Topographic data, site planimetrics and property boundary survey (detailed survey) will enable more precise design and development of quantities and cost.

Other additional data needs may be driven by specific funding requirements (i.e. FEMA grant, EPA 319 grant, consideration for mitigation, etc.). Further coordination with Fairfax County Park Authority and Recreation should serve to determine public use opportunities, prior to public outreach efforts.

9.0 REFERENCES

Austin, S.H., Krstolic, J.L., and Wiegland, U., 2001. *"Peak-Flow Characteristics of Virginia Streams"*, U.S. Geological Survey Scientific Investigations Report 2011-5144, 106 p.

Austin, S. H., *"Methods and Equations for Estimating Peak Streamflow Per Square Mile in Virginia's Urban Basins"*, 2014, U.S. Geological Survey Scientific Investigations Report 2014-5090.

Bonnin, G., D. Martin, T. Parzybok, B. Lin, D. Riley, and M. Yekta, 2006: "*Precipitation frequency atlas of the United States. NOAA Atlas 14 Volume 2, Version 4.0*," National Weather Service, Silver Spring, Maryland.

Brunner, G. W. *"HEC-RAS River Analysis System. Hydraulic Reference Manual"*. 2016. Version 5.0.3. Hydrologic Engineering Center Davis CA.

Caraco, D. 2000. "The Dynamics of Urban Stream Channel Enlargement", Watershed Protection Techniques 3(3):729-734. The Center for Watershed Protection. Ellicott City, MD.

Cinotto, P. J., 2003. "*Development of regional curves of bankfull-channel geometry and discharge for streams in the non-urban, Piedmont Physiographic Province, Pennsylvania and Maryland: U.S. Geological Survey Water-Resources Investigations Report 2003–4014"*, 27 p., https://pubs.er.usgs.gov/publication/wri034014.

Doll, B. A., *et al.*, 2002. *"Hydraulic Geometry Relationships for Urban Streams throughout the Piedmont of North Carolina"*, JAWRA Journal of the American Water Resources Association, 38: 641–651.

Fairfax County Stormwater Planning Division, Department of Public Works and Environmental Services, 2007. "*Cameron Run Watershed Management Plan: Final";* 770 pp.

Fairfax County Stormwater Planning Division, Department of Public Works and Environmental Services, September 2019. "*Floodplain Management Plan (Part of the Norther Virginia Regional Hazard Mitigation Plan): Progress Report"; 13* pp.

Federal Emergency Management Agency. September 17, 2010. *"Flood Insurance Study, Fairfax County, Virginia"*, FIS Number 51059CV000A.

Federal Emergency Management Agency. January 2017. *"Hydraulic Analyses: Middle Potomac, Anacostia, Occoquan Watershed – Virginia"*, STARR II, Laurel, MD.

Federal Emergency Management Agency. July 2016. *"Hydrologic Analyses: Middle Potomac, Anacostia, Occoquan Watershed – Virginia"*, STARR II, Laurel, MD.

Harley, B., *"MITCAT, Catchment and Simulation Model, Description and User's Manual, version 6"*, September 1975, Resource Analysis, Inc., Cambridge, Massachusetts.

Harman, W.A. and C.J. Jones. 2017. North Carolina Stream Quantification Tool: Data Collection and Analysis Manual, NC SQT v3.0. Environmental Defense Fund, Raleigh, NC.

Lotspeich, R.R. 2009. *"Regional Curves of Bankfull Channel Geometry for Non-Urban Streams in the Piedmont Physiographic Province, Virginia"*, U.S. Geological Survey Scientific Investigations Report 2009–5206, 51 p.

McCandless, T.L., Everett, R.A. 2002. *"Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region"*, U.S. Fish & Wildlife Service cbfo-s02-01, 175 p. (also available online at https://www.fws.gov/chesapeakebay/pdf/piedmont.pdf)

Rosgen, D.L. 1996. *"Applied River Morphology"*, Wildland Hydrology

Rosgen, D.L. 2007. *"Part 654, National Engineering Handbook, Chapter 11: Rosgen Geomorphic Design"*, United States Department of Agriculture, Natural Resources Conservation Service.

U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Coastal Program – Stream Assessment and Restoration Team. 2011. *"Stream Functions Pyramid – A Tool for Assessing Success of Stream Restoration Projects"*

U.S. Army Corps of Engineers. *"Hydrologic Modeling System HEC-HMS, Technical Reference Manual"*, March 2000, U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC, Davis, CA, USA.