North Grounds Stream Restoration

A Technical Report submitted to the Department of Civil and Environmental Engineering

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Patrick Brown

Spring, 2024

Technical Project Team Members
Karin Brett
Lucas Bushey
Dorian Gaines
Nora Levasseur
Shayla Utzinger

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Jonathan Goodall, Department of Civil and Environmental Engineering

North Grounds Stream Restoration

01 INTRODUCTION

Design Problem Statement

Our team, the UVA Stream Restoration Capstone Group, worked in conjunction with Biohabitats, an environmental consulting company, to assess an unnamed tributary stream to Meadow Creek located in Albemarle County and the City of Charlottesville. This assessment allowed us to compose a design proposal to restore and remediate the erosion, pollution, and stress imposed by nearby human development on the stream. Our research and design also provide insight into cost and pollution reduction credit opportunities for UVA.

The stream is 5,000 feet long, running parallel to the US 250/Route 29 bypass, near UVA's North Grounds, and contains a portion of the Rivanna Trail. These attributes make it an important waterway to protect, especially for stakeholders such as UVA, VDOT, the City of Charlottesville, and the Rivanna Trails Foundation.

The UVA Capstone group will focus on two specific reaches in this project: Reach 3 and Reach 5. The inlets of Reach 3 and 5 are outfalls from culverts that run beneath Route 29. In restoring these streams, there is potential to earn large reduction credits. Because the budget is reliant on external factors like grant funding, the project will be broken into stages, with research and modeling analysis as the first step. After a comprehensive understanding of the current state and challenges facing these reaches, the UVA team will generate a restoration design.

Design Objectives

Scope

This stream has been divided into reaches by the Biohabitats team according to topographic features and the current state of various stretches.

Figure 1-1. Biohabitats Division of Reaches

As is shown in Figure 1-1, reaches (3 and 5) are tributaries to the stream fed by outfalls that run under US 250/Route 29 Bypass. These reaches are of particular interest because there is concern about the influence of increased flow contributions on sediment load and phosphorus and nitrogen concentrations. Therefore, our research and design are primarily centered around Reach 3 and Reach 5. Figure 1-2 provides a more detailed view of these reaches.

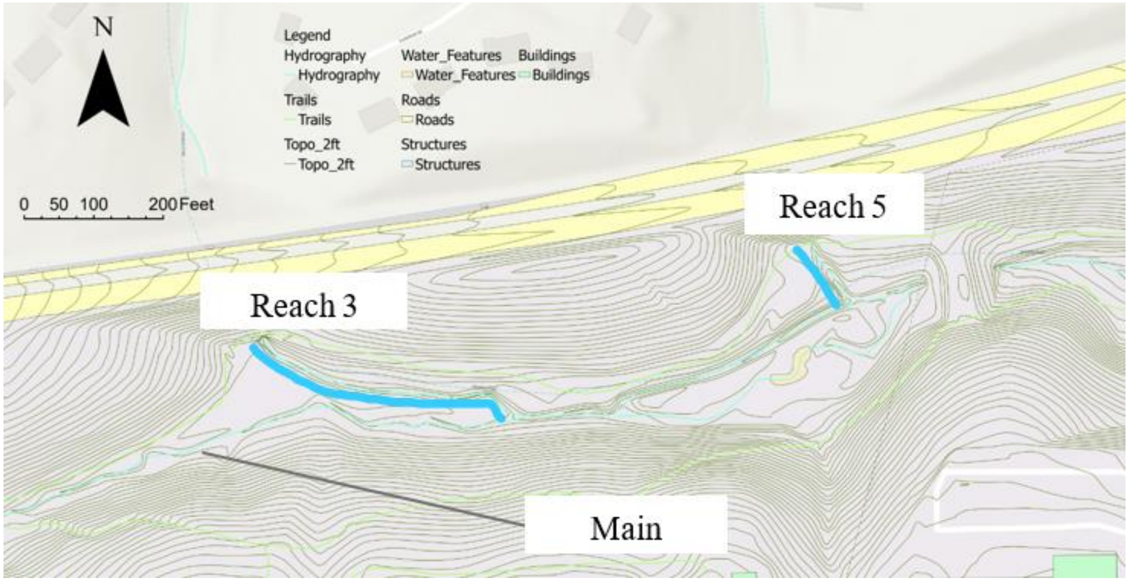


Figure 1-2. ArcGIS Topographical Map of Reach 3 and 5

The scope of our research and analysis is best understood in phases: water quality, existing conditions modeling, AutoCAD design, post-restoration modeling, and construction planning.

Our team collected water quality grab samples (analyzing TSS, total phosphorus, and nitrate concentrations) in dry weather and wet weather to set a baseline water quality for the site. Samples were collected within and upstream of each reach in the stream's main channel. The water quality data is compared to standards for streams of this size established by the National Stormwater Quality Database.

To model existing conditions, a Hydrologic and Hydraulic (H&H) Analysis was conducted on these two reaches. This involved the development of two HEC-RAS models and a HEC-HMS model for the greater watershed. Furthermore, on-site cross sections were taken for both reaches to augment the data necessary for the HEC-RAS model.

The results from the H&H Analysis and water quality testing informed the development of a restoration design for Reaches 3 and 5 in AutoCAD. The design components address sediment load, nutrient concentrations, and embankment erosion concerns. Another H&H model was generated for the reaches to analyze the restoration improvements and calculate potential VA Sediment and Nutrient Credits to be allocated to UVA. These credits are classified under MS4 and TMDL credits for the university. Along with this, a cost analysis for the work budget compared to the Sediment and Nutrient Credits attained was performed.

Our scope includes preliminary construction planning. The schedule of the stream restoration project was established to minimize the impact on the local community. The proposed design of the Rivanna Trail along the stream, during and after the construction process, was also be generated. The plan-view map and cross sections of trail network were developed.

Metrics of Success

To ensure the successful attainment of our scope objectives, we frequently monitor and adjust our schedule, facilitating timely progress in both research and design phases. Further details on the project schedule can be found in Appendix A. Furthermore, collaboration with Biohabitats and other advisors has enabled us to confirm the quality of our research and design.

02 BACKGROUND

River restoration, initially pursued for aesthetic and recreational purposes, has a rich history spanning over a century. Communities alongside rivers often engage in restoration efforts to enhance the natural beauty of their surroundings. In turn, this increases fish diversity and populations for leisure activities such as fishing and boating. However, historical restoration practices sometimes inadvertently compromised river health by focusing solely on facilitating passage and thus neglecting broader ecosystem needs (Wohl, 2015). In the late 1900s, river restoration evolved with the emergence of techniques like channel formation and bioengineering using vegetation. Today, a significant shift is observed towards restoration efforts aimed at ecological balance, biodiversity, and water quality improvement (Choudhury, 2022).

Our project is deeply rooted in the connection to the Rivanna River, one of Charlottesville, Virginia's oldest rivers and the largest tributary to the Upper James River. We would like to acknowledge that this watershed lies within the traditional land of the Monacan People. After European settlement, the Rivanna was crucial to settler agricultural activities. Thomas Jefferson's efforts to enhance the river's navigability during his time in Charlottesville facilitated the transportation of goods like wheat and tobacco from Monticello and neighboring farms. Today, the scenic Rivanna River and its tributaries remain integral to Charlottesville, offering diverse recreational opportunities such as kayaking and tubing, and supporting hundreds of fish species. Given its significance to history, the city, and surrounding areas, it's imperative to continually enhance the quality of both the main river and its tributaries, as they significantly influence overall stream health.

An important historic aspect of river restorations is the Municipal Separate Storm Sewer System (MS4) permitting program (VA DEQ, n.d.). In 1987, the Clean Water Act was amended to address specifically stormwater discharges and regulate stormwater runoff from municipalities by way of the National Pollutant Discharge Elimination System (NPDES) permitting. Three years later the Environmental Protection Agency (EPA) introduced the MS4 permitting program. MS4 is a framework that treats stormwater conveyance systems as point source discharge. The permit program addresses challenges uniquely associated with urban and suburban areas where the water is subject to pollution from multiple sources. The MS4 program is a multifaceted program that covers almost everything in the realm of water quality. Many of the program components include stormwater management plans, runoff control, pollution control, and water quality monitoring.

In 2010, the EPA established the Chesapeake Bay Total Maximum Daily Load (TMDL) framework as a comprehensive plan to address pollution in the bay and its tributaries (EPA, 2023). Tributaries and water bodies within the watershed can earn credit for reductions in nutrients and sediments. These credits can be traded and transferred to other projects related to nutrient pollution and runoff. A TMDL is the maximum concentration of a pollutant allowed to enter a body of water daily. The Chesapeake Bay TMDL framework also identified point source and non-point source target locations for pollutant reduction.

03 WATER QUALITY

Reaches 3 and 5 flow into a tributary to Meadow Creek, which feeds into the Rivanna River, and eventually Chesapeake Bay. UVA could earn nutrient and sediment credits for restoring the North Grounds tributary, including Reaches 3 and 5. To determine the magnitude of improvement, it was necessary to establish baselines for nutrient load and total suspended sediment concentrations (TSS) in these reaches.

Methods

To understand the nutrient and sedimentation impact of Reaches 3 and 5 on the North Grounds tributary, grab samples were collected from the locations displayed in Figure 3-1.

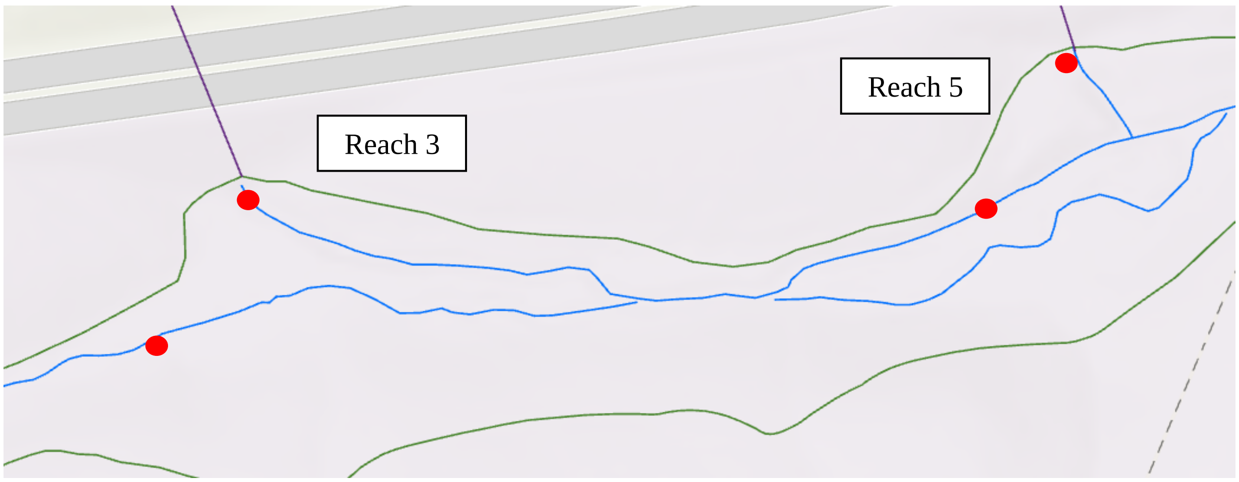


Figure 3-1. Grab Sample Collection Locations

Grab samples were collected both within the reaches and upstream from their outfalls into the main. Five rounds of water sampling and testing were completed to understand the existing nutrient loads and total suspended solids (TSS) in Reach 3 and 5. Samples were collected after both dry weather and wet weather. It is important to note that the first round of TSS tests encountered challenges with improper storage of filters, so turbidity tests were introduced as a second measure of suspended solids.

To measure nitrate concentrations, a TNT835 testing kit with a detection range of 0.23-13.50 mg/L NO_3-N was utilized. To measure total phosphorus concentrations, a TNT843 testing kit with a detection range of 0.05-1.50 mg/L PO_4-P was utilized. Testing kits were used with a Hach Spectrophotometer DR3900 machine. To measure turbidity, a Hach 2100Q turbidimeter was used. And lastly, the TSS test was conducted using a Welch turbo vacuum pump attached to a volumetric flask. This process isolated the sediment from the sample water through a filter.

Nutrient Loads

In Tables 3-1 and 3-2, the results of the dry and wet weather nutrient testing in Reach 3 and 5 are presented. Note that the total phosphorus and nitrate concentrations were below the kits' detection limits. This highlights the limitations of the nutrient testing performed during this project. Furthermore, only four rounds of nutrient testing were performed, which is not enough to draw statistically significant conclusions. However, the preliminary data allowed our team to make inferences on the current state of nutrients and TSS in the stream. The 24-hour rainfall data for each collection date and corresponding results are presented in Tables 3-1 and 3-2.

Table 3-1. Nutrient Testing in Reach 3

Date	Weather	24-hr Cumulative Rainfall (in)	Nitrate (mg/L NO3-N)	Total Phosphorus (mg/L PO4-P)
10/27/2023	Dry	0	0.664	BDL
L11/15/2023	Dry	0	0.644	BDL
1/29/2024	Wet	0.126	--	BDL
2/13/2024	Wet	0.680	0.461	BDL
		Average	0.589	--

Table 3-2. Nutrient Testing in Reach 5

Date	Weather	24-hr Cumulative Rainfall (in)	Nitrate (mg/L NO3-N)	Total Phosphorus (mg/L PO4-P)
10/27/2023	Dry	0	0.822	BDL
11/15/2023	Dry	0	0.515	BDL
1/29/2024	Wet	0.126	--	BDL
2/13/2024	Wet	0.680	0.366	BDL
		Average	0.751	--

The National Stormwater Quality Database (NSQD) performed a similar analysis in Anne Arundel County, MD (Maester and Pitt, 2005). Benchmarks in runoff concentrations of TSS, total nitrogen, and total phosphorus were established for various land uses. Given the geographic proximity, their results provide insight into the water quality of the Meadow Creek tributary and Reaches 3 and 5. The NSQD analysis established various land uses. The sites of Reach 3 and 5 are most consistent with deciduous forest and brush conditions. The standard concentrations of TSS, total nitrogen, and total phosphorus for that category are presented in Table 3-3.

Table 3-3. NSQD Nutrient Baselines for Deciduous Forest and Brush Land Use

Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
1.5	0.1	90

Note that the NSQD baselines are for concentrations during storm events and are typically compared to *wet* weather testing results. In the analysis on Reaches 3 and 5, total nitrogen (nitrate + nitrite + Total Kjeldahl Nitrogen) was not measured. However, the NSQD total nitrogen benchmark is still significantly larger than the concentrations of nitrate in Reaches 3 and

5 on average. As for total phosphorus, the values within Reach 3 and 5 were below the NSQD benchmark and the detection range of the kit. Regardless of weather or the magnitude of storms, our data does not imply that nutrient loads worsen with heavy precipitation. **According to this limited dataset, the nutrient levels of Reaches 3 and 5 were low and of minimal concern.** To further corroborate this, the nutrient testing performed *within* and *upstream* of each reach was compared.

In Figure 3-2, the nitrate concentrations are presented for upstream and in-stream of both reaches.

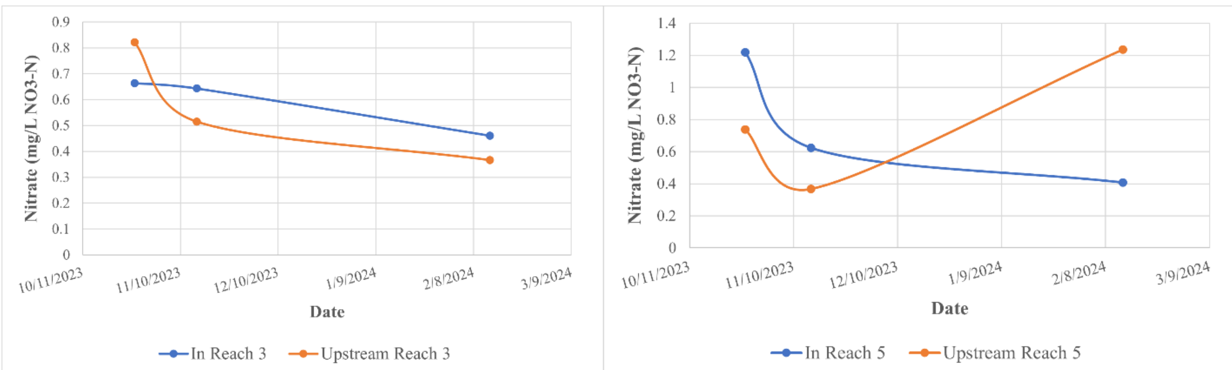


Figure 3-2. Upstream and In-Stream Nitrate Concentrations

These graphs indicate that there are no discernible trends between upstream nitrate concentrations versus in-stream for both reaches. This implies that the reaches did not contribute a disproportionate amount of nutrients to the main tributary on those dates.

Sediment Loads

In Tables 3-4 and 3-5, the results of the dry and wet weather sediment testing in Reach 3 and 5 are presented. As previously mentioned, the first round of TSS testing performed on the 10/27/2023 grab sample utilized improperly stored filters. In the following data tables, it is evident that some of these values are of disproportionate magnitude or even negative, which is not possible for sediment concentrations. The disproportionately large TSS concentration is likely the result of agitating the stream bed during the grab sample collection, dislodging more settled sediment. Furthermore, a negative TSS concentration also occurred for the 1/29/2024, In-Reach-5 sample. To address these errors, turbidity tests were introduced as a second measure of total sediment.

Table 3-4. Sediment Testing in Reach 3

Date	Weather	24-hr Cumulative Rainfall (in)	Turbidity (NTU)	TSS (mg/L)
10/27/2023	Dry	0	2.48	1.78

11/15/2023	Dry	0	1.15	1.06E-06
11/25/2023	Dry	0	1.73	4.50E-07
1/29/2024	Wet	1.49	--	4.65E-06
2/13/2024	Wet	2.17	--	1.79E-05
		Average	1.79	0.357

Table 3-5. Sediment Testing in Reach 5

Date	Weather	24-hr Cumulative Rainfall (in)	Turbidity (NTU)	TSS (mg/L)
10/27/2023	Dry	0	1.47	BDL
11/15/2023	Dry	0	1.03	1.04E-07
11/25/2023	Dry	0	1.02	2.94E-07
1/29/2024	Wet	1.49	--	BDL
2/13/2024	Wet	2.17	--	2.48E-05
		Average	1.17	8.39E-06

The average TSS concentrations in both Reach 3 and Reach 5 (0.357 mg/L and 0.00000469 mg/L, respectively) were insignificant in comparison to the benchmark of 90 mg/L established by the NSQD. There was also no significant change in TSS concentrations because of precipitation. Furthermore, the average turbidities were relatively small given that turbidity values can be in the 100s.

Acknowledging the error and small sample size, the TSS and turbidity results were low and of minimal concern on these dates. To further corroborate this, the sediment testing performed *within* and *upstream* of each reach was compared. In Figure 3-3, the TSS concentrations are presented for upstream and in-stream of both reaches.

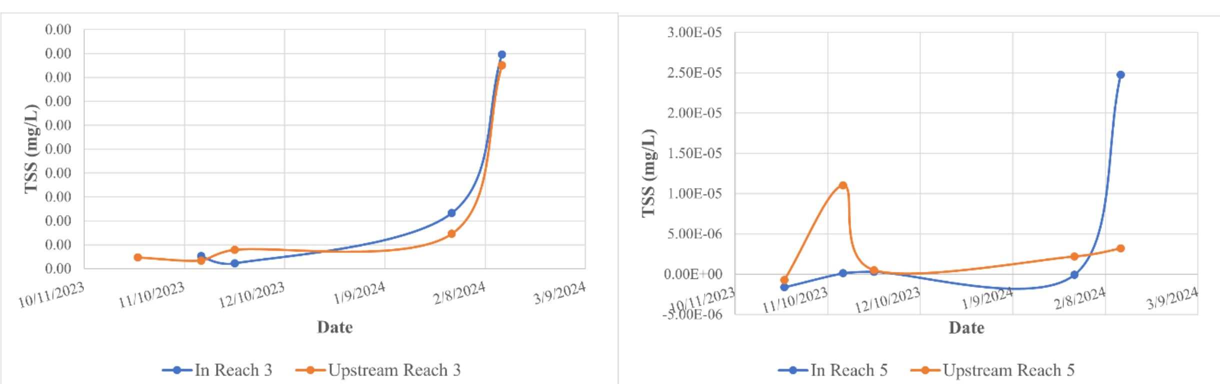


Figure 3-3. Upstream and In-Stream TSS Concentrations

Again, there are no discernible TSS trends upstream or in-stream for Reach 3 and 5. This implies that the reaches did not add much sediment to the main tributary on these dates.

Bank Erosion Hazard Index Methods

The previous water quality datasets imply that sediment and nutrients are not actively being conveyed by Reaches 3 and 5. However, the severe physical incising (Figure 3-4) is indicative of historical erosion in the reaches and probable erosion during future, larger storm events. Therefore, to accurately determine the extent of erosion and inform TMDL and MS4 credit calculations, a Bank Erosion Hazard Index (BEHI) of Reaches 3 and 5 was employed.

Figure 3-4. Incised Banks on Reach 3

The BEHI and Near-Bank Stress (NBS) assessments were developed by Dave Rosgen of Wildland Hydrology, Inc to quantify streambank erosion condition and potential (Rosgen, 2001). Reach 3 is longer and has more variable bank conditions. Therefore, the assessments were performed on bank lengths of similar characteristics, for both the left and right banks. Utilizing an Excel template from Stream Mechanics, ten BEHI and NBS assessments were performed on Reach 3 and two were performed on Reach 5, which is shorter with more consistent conditions (Stream Mechanics, n.d.).

For the BEHI, bank lengths, angles, and heights along with bankfull height were measured in the field. Root depth, root density, and surface protection were estimated as percentages. Soil type was assumed to be clay/silt loam for every bank as indicated by the Web Soil Survey (USDA, n.d.). By inputting these attributes into the Excel template, a conditions rating was assigned to each specific stretch of the bank. The BEHI has the following ratings for erosion: low, moderate, high, very high, and extreme which is based on the factors listed above and the degree to which they allow the stream to resist further erosive activities.

For the NBS, a Level I assessment was performed. The levels of assessment were established by Rosgen, where Level I is “Reconnaissance”. Typically, Level II and V are the most common levels of assessment, which involve measurements of the stream radius of curvature, average slope, near-bank maximum depth, and near-bank mean depth. Level I assessments are performed when there is clear evidence of very high or extreme near-bank stress (extensive deposition, chute cutoffs, down-valley meander migration, converging flow, etc.). In our case, there was little evidence of that extreme, however due to time and resource constraints, reconnaissance was the highest degree of assessment that could be performed. Each bank stretch was assigned a high or moderate NBS rating.

Each combination of BEHI and NBS characterizations has a corresponding rate of erosion (ft/year), established by Rosgen. Factoring in the bank height and length, a volume of sediment contributed by each existing bank stretch was calculated. Following our restoration design's completion, a second BEHI and NBS assessment was completed to quantify the reduction in erosion per year. Based on cross-sections from the HEC-RAS design model, which is further discussed in the following sections, the bank height and bank angle for each station were determined. The design bank angle was assumed to be 45°, based on a design of 2:1 bank slopes. The root depth, density, and surface protection were established as conservative values that still ensure a "Low" rating on the BEHI for that parameter, according to Figure 3-5.

Adjective Hazard or risk rating categories		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%	Totals
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80	
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	5-9.5
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55	
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	10-19.5
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30	
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	20-29.5
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15	
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	30-39.5
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10	
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	40-45
EXTREME	Value	>2.8	<0.05	<5	>119	<10	
	Index	10	10	10	10	10	46-50

*Figure 3-5. Streambank Characteristics Used to Develop BEHI (*Rosgen, 2001*)*

The NBS ratings for the post-restoration BEHI assessment were assumed to be "Low" as our restoration was designed to meet that characterization.

Bank Erosion Hazard Index Results

Based on the data collected in the field, predicted erosion amounts (tons/year) were calculated using the Stream Mechanics spreadsheet, which is presented in Table 3-6. The resultant BEHI and NBS ratings for each bank stretch were in the range of moderate or high erosion potential. Depending on the bank stretch length and BEHI/NBS rating combination, the predicted sediment contribution ranged from 1 to 14 tons/year for pre-restoration Reach 3. The total predicted erosion for pre-restoration Reach 3 is 65.04 tons/year. The predicted sediment contribution for each bank stretch length and BEHI/NBS combination ranged from 4 to 8 tons/year for pre-restoration Reach 5. The total predicted erosion amount for Reach 5 pre-restoration is 11.97 tons/year.

Table 3-6. Pre-Restoration Predicted Erosion Amount

Reach	Bank	Length (ft)	Height (ft)	BEHI Rating	NBS Rating	Predicted Erosion Amount (tons/year)	Predicted Erosion Amount (tons/year)
3	00+50 LB	50.0	5.0	Moderate	High	5.70	65.04
	00+50 RB	50.0	5.0	Moderate	High	5.70	
	00+100 LB	50.0	6.4	High	Moderate	5.83	
	00+100 RB	50.0	5.5	High	Moderate	5.01	
	00+180 LB	80.0	5.0	High	High	11.40	
	00+180 RB	80.0	6.0	Moderate	High	13.68	
	00+230 LB	50.0	4.0	High	Moderate	3.65	
	00+230 RB	50.0	7.5	High	Moderate	6.84	
	00+370 LB	140.0	3.5	Low	Moderate	1.26	
	00+370 RB	140.0	5.0	Moderate	Moderate	5.98	
5	00+30 LB	30.0	5.5	Moderate	High	4.70	11.97
	00+30 RB	30.0	8.5	Moderate	High	7.26	

The predicted erosion amounts (tons/year) for post-restoration Reach 3 and 5 are presented in Table 3-7.

Table 3-7. Post-Restoration Predicted Erosion Amount

Reach	Bank	Length (ft)	Height (ft)	BEHI Rating	NBS Rating	Predicted Erosion Amount (tons/year)	Predicted Erosion Amount (tons/year)

3	00+50 LB	50.0	5.6	Moderate	Low	1.00	8.02
	00+50 RB	50.0	5.6	Moderate	Low	1.00	
	00+100 LB	50.0	5.2	Moderate	Low	0.92	
	00+100 RB	50.0	5.2	Moderate	Low	0.92	
	00+180 LB	80.0	4.6	Moderate	Low	1.30	
	00+180 RB	80.0	4.6	Moderate	Low	1.30	
	00+230 LB	50.0	2.8	Moderate	Low	0.49	
	00+230 RB	50.0	2.8	Moderate	Low	0.49	
	00+370 LB	140.0	3.8	Low	Low	0.30	
	00+370 RB	140.0	3.8	Low	Low	0.30	
5	00+30 LB	30.0	2.7	Low	Low	0.05	0.33
	00+30 RB	30.0	2.7	Moderate	Low	0.28	

To understand the annual erosion improvements attributable to our restoration design, the results in Tables 3-6 and 3-7 are compared side-by-side in Table 3-8.

Table 3-8. TMDL Credit Attributable to Restoration Design

Reach	Predicted Erosion Amount Pre-Restoration (tons/year)	Predicted Erosion Amount Post-Restoration (tons/year)	Δ Predicted Erosion Amount (tons/year)
3	65.04	8.02	57.02
5	11.97	0.33	11.64

According to pre- and post- restoration BEHI assessments, the implementation of our design may earn UVA 68.66 tons/year of sediment credit with the Virginia Department of Environmental Quality (VA DEQ, 2023).

04 EXISTING CONDITIONS MODELING

ARC-GIS Model

To model Reaches 3 and 5, Digital Elevation Models (DEMs), 2-ft topography data, land cover and hydrologic soil group (HSG) data was acquired from UVA Facilities and the United States

Geological Survey (USGS) website. These files were compiled to create an accumulation grid and watershed delineation for the site. Subbasins were created for each reach defined in the initial project scope provided to us by Biohabitats. For our work, we focused on the subbasins contributing to Reaches 3 and 5. The initial delineation created did not account for the area north of Route 29 and the culvert beneath the highway. Our team decided to burn in the culverts to the original DEM file to show that flow would continue under the highway into Reaches 3 and 5. This new burned in DEM file was used for the rest of the project. The new file generated an accurate watershed and subbasin boundaries for each reach of the stream. The delineation of subbasins within the watershed can be found in Figure 6 in Appendix B.

Curve numbers were assigned based on a layer created by combining the land cover/use GIS layer and the Hydrologic Soil Group (HSG) layer. We created a coding system that would assign a unique number to each pixel based on their HSG and land use classification combination. Certain ranges of numbers were given specific curve numbers. This coding system created an entirely new raster that was able to clip to the delineations of the subbasins. After clipping the coded layer in, an average curve number value was calculated for each subbasin, which was then used later in the HEC-HMS model. A slope layer was also created using the DEM file uploaded to GIS. Clipping the slope layer to the subbasin delineation gave us the ability to determine an average slope of the subbasin to inform subbasin characteristics in the HEC-HMS model. The GIS model also calculated the flow lengths within each subbasin. The flow length correlated to the distance a stream extended in a subbasin, characterizing the true length of each reach.

HEC-HMS Model

This information was applied to the basin model in HEC-HMS, which requires inputs for each subbasin. The necessary inputs for the HEC-HMS model were subbasin areas, curve numbers, and lag time. These values were either taken directly from GIS data or were calculated using GIS data and equations from the Virginia Stormwater Management Handbook (VA DEQ, 2023). The HEC-HMS model layout is presented in Figure 4-1. This layout shows which subbasins contribute to which junction and provides a clear image of the water flow within the entire stream.

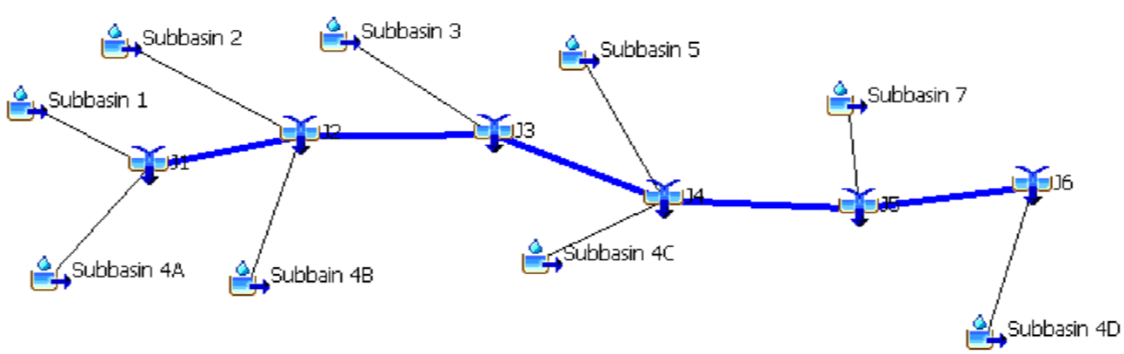


Figure 4-1. HEC-HMS Model for Entire Stream

Junction 6 (J6) represents the outfall for the entire stream. The subbasins are labeled according to the reaches they correlate to. Subbasin 3 is the watershed contributing to Reach 3, and subbasin 5 is the watershed contributing to Reach 5.

Using rainfall data acquired from the National Oceanic and Atmospheric Association, 1-Year, 2-Year, 5-Year, 10-Year, 50-Year, and 100-Year storms were modeled. Below in Table 4-1 are the results of the storm event simulations run in HEC-HMS to determine peak discharge and runoff volume by the main stem for each storm. More figures of the ArcGIS Pro model and the HEC-HMS basin created can be found in Appendix B.

Table 4-1. HEC-HMS Peak Discharge and Runoff Volume Results for Total Stream (Figure 4-1, J-6)

Storm Event	Precipitation Depth (in)	Peak Discharge (cfs)	Runoff Volume (in)
1-Year	3.04	28.5	0.59
2-Year	3.68	42.9	0.93
5-Year	4.70	76.5	1.57
10-Year	5.55	109.6	2.16
50-Year	7.92	216.4	4.00
100-Year	9.11	275.2	4.99

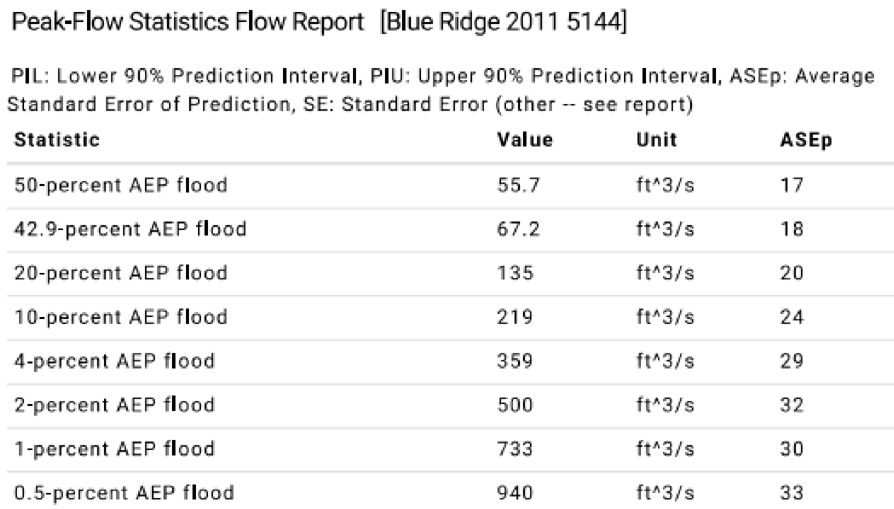
The output provided data for each storm event simulation and was further broken down by subbasin. This allows for contributions to be determined for each subbasin in every storm event. Because the purpose of this project is restoring sections of the stream, knowing the breakdowns of the peak discharges for each reach is important. Below, in Table 4-2, is an example of this data for a 5-Year storm event.

Table 4-2. HEC-HMS Peak Discharges and Runoff Volumes for Subbasins in a 5-Year Storm Event

Subbasin	Precipitation Depth (in)	Peak Discharge (cfs)	Runoff Volume (in)
1	4.70	0.9	0.78
2	4.70	5.6	1.33
3	4.70	51.3	1.67
5	4.70	8.9	1.07
7	4.70	21	1.33
4A	4.70	1.3	1.39
4B	4.70	3.4	1.25
4C	4.70	27.6	1.81
4D	4.70	3.2	1.81

Comparison to Existing Data

Using the tool StreamStats by the USGS the results that were shown in Table 4-1 can be compared to current data that they provide (USGS, n.d.). In StreamStats, the delineation area is chosen by the user and is very sensitive. Because of this, the area of delineation was slightly bigger but similar in shape to our watershed delineation in ArcGIS. The StreamStats values are shown below in Figure 4-2. The larger watershed delineation could account for the higher values in StreamStats compared to that of our calculated values from HEC-HMS.



Peak-Flow Statistics Flow Report [Blue Ridge 2011 5144]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	ASEp
50-percent AEP flood	55.7	ft^3/s	17
42.9-percent AEP flood	67.2	ft^3/s	18
20-percent AEP flood	135	ft^3/s	20
10-percent AEP flood	219	ft^3/s	24
4-percent AEP flood	359	ft^3/s	29
2-percent AEP flood	500	ft^3/s	32
1-percent AEP flood	733	ft^3/s	30
0.5-percent AEP flood	940	ft^3/s	33

Figure 4-2 StreamStats Peak Flow Discharges for Delineated Area

Surveying

Multiple surveys were conducted on Reaches 3 and 5 to augment topographic data and collect specific cross-section information. The initial survey methods using a total station were unsuccessful. Equipped with a laser level, 110’ tape measure, and an extendable leveling rod, four cross-section measurements were conducted on Reach 3. Approximately six elevation points on lateral sections of the stream, roughly 100’ apart, were collected. The locations of the survey sections were selected at spots that most accurately represented the different bank shapes along the reach. After setting up the tape perpendicularly across the stream, cumulative horizontal measurements and vertical depth could be taken working from the left headpin to the right. Survey points were taken at the left and right headpins, top of bank, bottom of bank, and the thalweg of the stream (deepest point). Any additional points where the slope of the bank changed significantly were also measured and recorded. Similar methods were employed for surveying Reach 5, but only three cross-sections were conducted. The cross-section data was imported into HEC-RAS and values are in Appendix C.

HEC-RAS Models

Two HEC-RAS models were created using cross-section data for each reach. The models for each reach used the elevations obtained from point elevations on the Civil3D project DEM. Using this data, profile and plan views of both reaches were created and used for simulations. Figure 4-3 below shows the HEC-RAS models for both Reach 3 and Reach 5. The cross-section stations are shown across each.

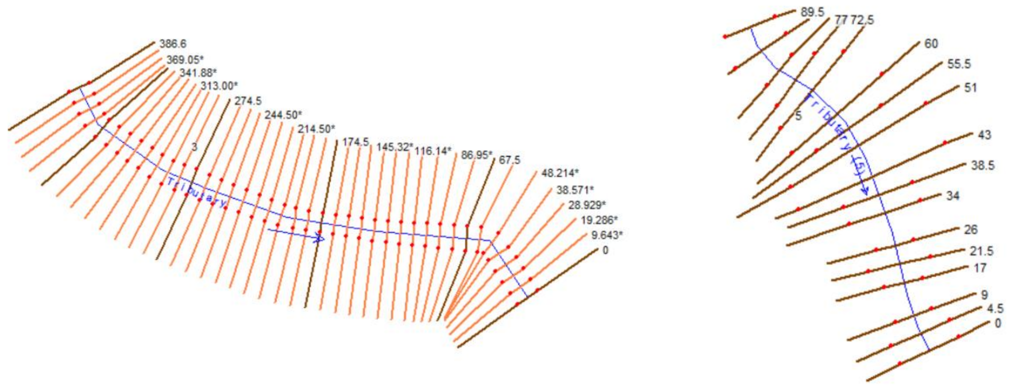


Figure 4-3. HEC-RAS Model for Reach 3 (left) and 5 (right)

Taking the peak discharge values from the HEC-HMS simulations for the six storm types (1-Year, 2-Year, 5-Year, 10-Year, 50-Year, and 100-Year), the HEC-RAS model was run. The outputs taken from this model were peak flows at each cross section, surface water levels at cross sections for each storm type, information about subcritical or supercritical flow throughout the reach, maximum shear stress, and maximum channel velocity. This data informed the parameters for the proposed design of the restoration of the stream. Figure 4-4 is an example of one cross section in Reach 3 after a simulation storm was run and the surface water level is shown for a 1-Year Storm Event.

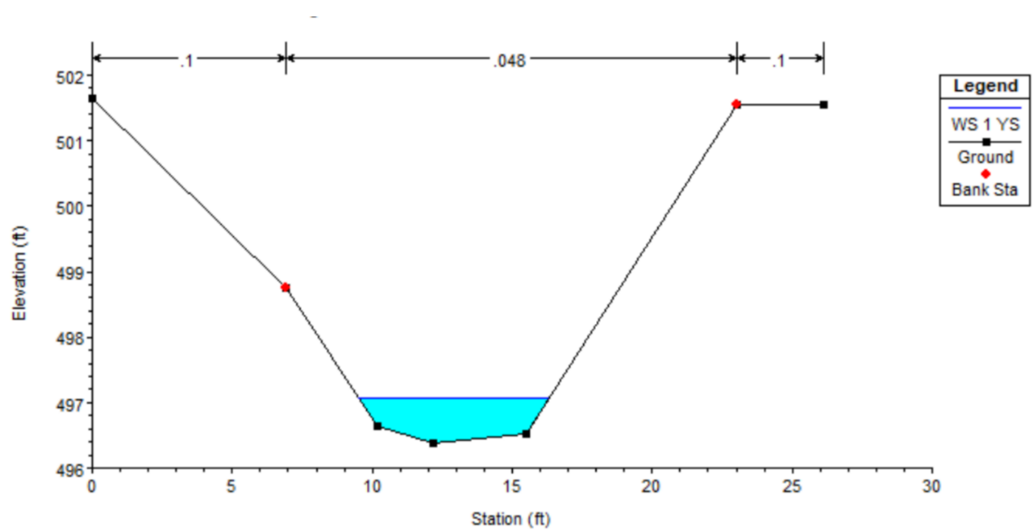


Figure 4-4. Cross Sectional View in Reach 3 of Surface Water Level from 1-Year Storm

05 DESIGN

Considering the modeling results from HEC-HMS and HEC-RAS, as well as the minimal nutrient pollution but extensive embankment erosion, a Step Pool Conveyance System (SPCS) was employed for Reaches 3 and 5. The design specifications were calculated and confirmed according to the Anne Arundel County Bureau of Watershed Protection & Restoration Guidelines provided by the industry advisors at Biohabitats. Anne Arundel County is in

Maryland, but their guidelines are being used because Virginia does not provide a set of design guidelines for SPC Systems. These guidelines provide a spreadsheet with design parameters for the step pools to be used in each reach, using the peak discharge values for a 2, 10, and 100-Year storm. The riffle sizing for Reach 3 is provided below in Figure 5-1.

Riffle Weir Sizing			
	Q_{100}	Q_{10}	Q_2
Design Flow (cfs)	169.9	71.9	29.4
Width (ft)	20.0	20.0	20.0
L, Length (ft)	20.0	20.0	20.0
H, Height (ft)	1.0	1.0	1.0
Design Depth of flow (ft)	1.80	1.80	1.80
D50 (in)	12	12	12
P_D, Parabolic Depth (ft)	1.33	1.33	1.33
Width Depth Ratio (W/P_D)	15.0	15.0	15.0
Manning's n Value	0.057	0.057	0.057
Slope (ft/ft)	5.00%	5.00%	5.00%
Rock Unit Weight (lbs/cf)	165.0	165.0	165.0
Top Width at Depth	23.2	23.2	23.2
Flow area (sf)	27.9	27.9	27.9
Hydraulic Radius	1.18	1.18	1.18
Froude	0.87	0.87	0.87
Isbash Maximum Velocity (ft/s)	12.35	12.35	12.35
Depth ("A") at TW/4 offset from centerline	1.00	1.00	1.00

Figure 5-1. Riffle Sizing Spreadsheet for Reach 3

To determine how many riffle/ pool systems are needed in each reach, the total vertical displacement between the most upstream and most downstream points was calculated. Using the total feet of displacement allowed us to divide up the vertical drop into increments of 1-foot. We also used each reach's length to ensure the number of riffle/ pool systems fits in the stream length. A cascade system was added at the top of Reach 5 due to the short stream length and higher vertical displacement to account for a deeper drop using less horizontal distance across the stream.

Due to the high volume of discharge coming from the culvert under the highway into Reach 3, a plunge pool will also be constructed at the most upstream point of the reach (just after the culvert). This plunge pool was designed according to the guidelines established by the U.S. Department of Agriculture Natural Resources Conservation Service and the Maryland Department of Environment Water Management Administration. The general construction of a plunge pool is included in Figure 5-2.

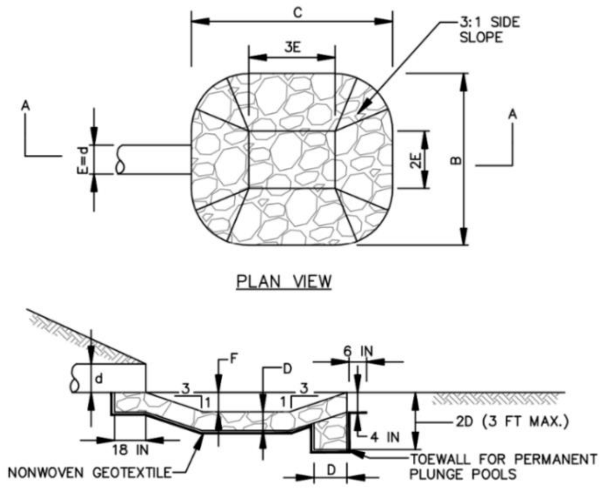


Figure 5-2. Plunge Pool Design

The values for each of these parameters were calculated using a spreadsheet that Biohabitats created from Maryland DEQ's D-4-2 Standards and Specifications for Plunge Pools (MA DEQ, 2012). Inputting parameters of the culvert's span, the tailwater depth, and the peak discharge for a 10-Year storm for Reach 3, dimensions were found for the designed plunge pool for the site. The Type-1 design of the plunge pool was chosen as the most feasible design because of the relative narrowness of Reach 3's channel. The pool will be 30.5 feet (B) by 36.6 feet (C) by 3.05 feet (F).

Each reach's alignment has been mapped in Civil3D and each component of the SPCS positioned. The previously generated DEMs were imported to the Civil3D file and profile views for the design were produced. Finally, cross sections at key locations in each reach were plotted, corresponding to the previously surveyed cross-sections. The cross-sections show typical arrangements of the components of the SPCS, like attenuation ponds, the sand seepage filter, riffle weirs, and cascade weirs. Below is a profile view image of the stream Civil3D file created. Figures 5-3 and 5-4 show the plan view layout of the attenuation ponds, riffles, cascades, and plunge pools

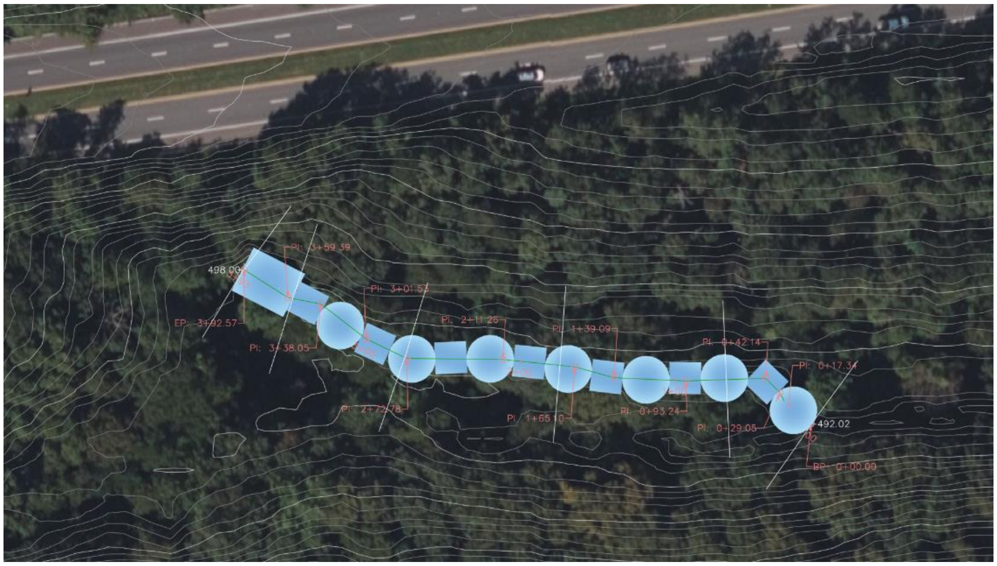


Figure 5-3. Reach 3 Design Layout

Figure 5-4. Reach 5 Design Layout

06 POST-RESTORATION MODELING

To quantify the impacts of the design on the hydraulics and hydrology of the reaches in the stream, we created a HEC-RAS file that demonstrated the design components in the cross sections of the file. We created 3 cross section modifying files: riffles, pools, and a plunge pool. These modifying files rely on input of the general shape of the structures, the slope required to meet the existing banks, and the amount of cut or fill to accomplish these alterations. We set bottom (invert) elevations to create the correct profile view and the correct step pool system. In Figure 6-1 and 6-2 below, you can see the Reach 3 existing profile view from RAS and the proposed profile view for the reach.

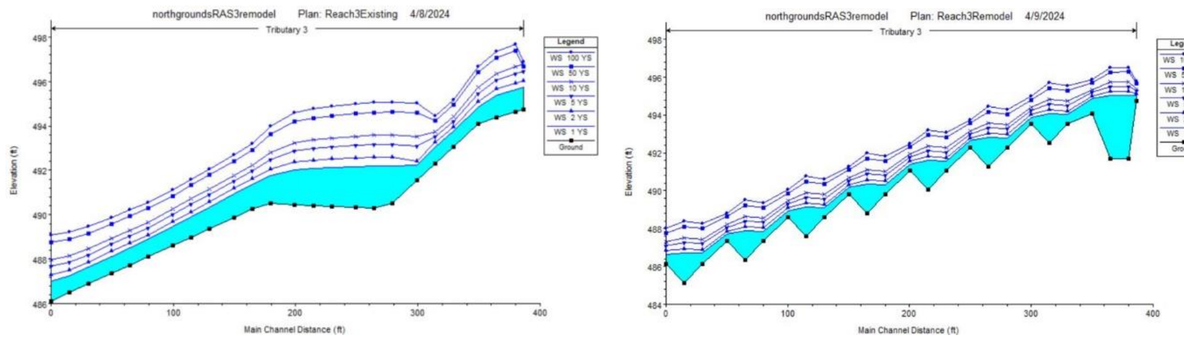


Figure 6-1. Reach 3 HEC-RAS Profile Views, Existing (left) and Proposed (right)

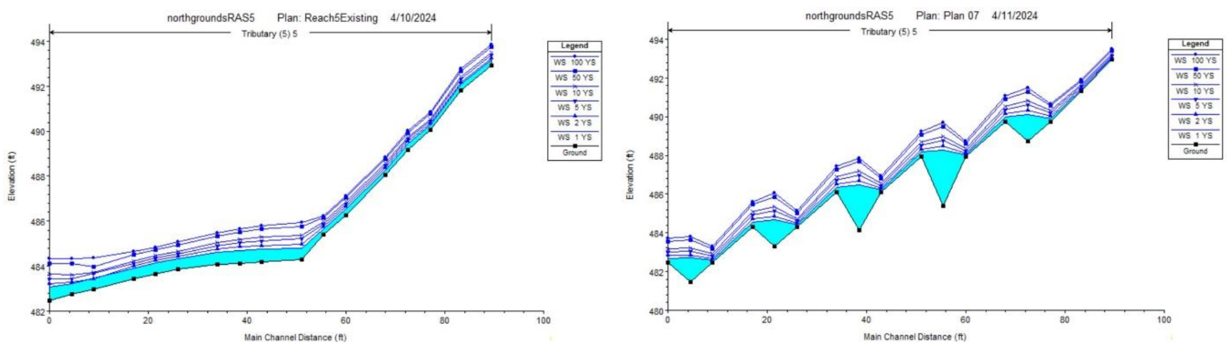


Figure 6-2. Reach 5 HEC-RAS Profile Views, Existing (left) and Proposed (right)

The results of the design were promising. The shear stress of the Reach 3 design was 4 pounds per square foot. This influenced the designed rock size requirement for the riffles and plunge pool across the reach. Using a spreadsheet provided by Biohabitats, the median rock size (D50) for Reach 3 was 10.4 inches. For Reach 5, with a shear stress of 10.06 pounds per square foot, the median rock size requirement for a factor of safety of 1 is 26.1 inches. Figure 6-3 shows the rock sizing diagram, with the shielding line. Both designs are safely below the shields line.

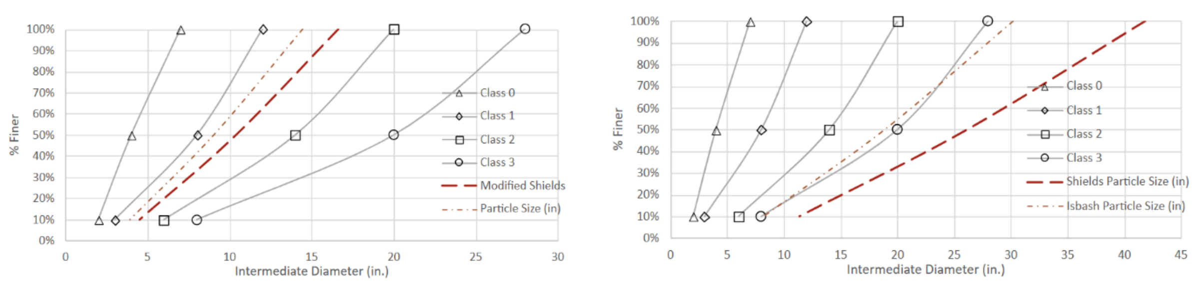


Figure 6-3. Reach 3 (left) and Reach 5 (right) Rock Sizing Diagram

07 CONSTRUCTION PLANNING

The construction plan was dictated by the practical needs of the project and the requests of the Rivanna Trail Foundation (RTF), who manages a trail system that runs along the project site.

In a kickoff meeting with the RTF, they requested that the construction not overlap with their annual “Loop de ’Ville” event, which takes place on the last weekend in September. To provide ample time for this project's construction, work will begin as soon as possible after this event. The RTF also requested that trail users be offered an adequate detour during construction, as well as prioritizing the “rustic” feel of the trail, with a more accessible trail in addition, if possible.

Phases of Construction

To ensure minimal impact on Rivanna Trail users and efficient workflow, the following construction order has been planned.

- Preparation of the site – removal of trees and plants along construction access corridor.
- Install water diversions between reaches and main stem.
- Grade and stabilize steep banks.
- Construct step pool conveyance system (attenuation ponds, sand seepage filter, riffle weirs, cascade weirs).
- Remove water diversions.
- Planting.

A similar project in the Charlottesville area, the restoration of Schenk’s Branch by Hazen & Sawyer, was completed in 135 days. Schenk’s Branch included 830 linear feet of stream, while this project includes 460 linear feet, when Reach 3 and 5 are combined. This project should take about 75 days, but potentially longer if certain mobilization and demobilization processes do not scale linearly with the project's size. A timeline of the Schenk’s Branch project is found in Figure 7-1 below. This timeline fits well within our constraints of not overlapping with RTF events and will be completed primarily during the winter months while the trail is less active and rainfall levels are lower.

SEQUENCE OF CONSTRUCTION:

PHASE 1: MOBILIZATION AND SITE PREPARATION (30 DAYS)

1. THE LIMITS OF WETLANDS MUST BE FLAGGED IN THE FIELD (SURVEY LOCATED) WITH OPTIC ORANGE SAFETY FENCE PRIOR TO ISSUANCE OF A LAND DISTURBANCE PERMIT.
2. PROVIDE THE CITY INSPECTOR 48 HOURS NOTIFICATION TO SCHEDULE AN ON-SITE PRE-CONSTRUCTION MEETING FOR THE ISSUANCE OF THE LAND DISTURBANCE PERMIT. THE PRE-CONSTRUCTION MEETING MUST INCLUDE THE CONTRACTOR'S CERTIFIED RESPONSIBLE LAND DISTURBER (CRLD), OWNER, ENGINEER, VSMP CONSTRUCTION ACTIVITY OPERATOR, AND ENVIRONMENTAL INSPECTOR (OR AUTHORIZED REPRESENTATIVE).
3. PRIOR TO THE PRE-CONSTRUCTION MEETING, THE CONTRACTOR IS TO HAVE ALL LIMITS OF DISTURBANCE (LOD), ACCESS ROADS, TREES EARMARKED FOR STREAM STRUCTURES AND SEDIMENT AND EROSION CONTROL DEVICE LOCATIONS STAKED OUT IN THE FIELD FOR REVIEW AND APPROVAL BY THE CITY INSPECTOR AND ENGINEER.
4. AT THE TIME OF THE PRE-CONSTRUCTION MEETING, TWO STANDARD SIGNS MUST BE INSTALLED ON EACH SIDE OF THE CONSTRUCTION ACCESS. THESE SIGNS SHOULD STATE EITHER "CONSTRUCTION ENTRANCE AHEAD" OR "TRUCKS ENTERING HIGHWAY"
5. THE CONTRACTOR SHALL CONTACT VIRGINIA 811 AT PHONE NUMBER 811 OR 1-800-552-7001 TO REQUEST UNDERGROUND UTILITY LOCATION MARK-OUT AT LEAST THREE (3) WORKING DAYS BUT NO MORE THAN TEN (10) WORKING DAYS PRIOR TO BEGINNING EXCAVATION. THE CONTRACTOR SHALL ALSO CONTACT AND REQUEST UTILITY LOCATION MARK-OUT FROM BURIED UTILITY OWNERS WITH UTILITIES ON THE PROJECT SITE THAT ARE NOT PARTICIPANTS OF VIRGINIA 811.
6. INSTALL THE TEMPORARY CONSTRUCTION ENTRANCE AS SHOWN ON THE DRAWINGS.
7. INSTALL EROSION AND SEDIMENT CONTROL (ESC) MEASURES AS SHOWN ON THE DRAWINGS IN ACCORDANCE WITH THE VIRGINIA EROSION AND SEDIMENT CONTROL HANDBOOK (VESCH).
8. INSTALL FOREST CONSERVATION MEASURES INCLUDING, BUT NOT LIMITED TO, TREE SAVE FENCING AND TREE PROTECTION PLANKING.
9. THE CITY ENVIRONMENTAL ENGINEERING INSPECTOR MUST APPROVE PHASE 1 PRIOR TO CONTINUING TO THE NEXT PHASE OF CONSTRUCTION.

PHASE 2: CONSTRUCTION (60 DAYS)

10. FELL AND SECTION TREES AT APPROPRIATE LENGTHS THAT ARE EARMARKED FOR RE-USE IN THE J-HOOK VANE AND ROOT WAD STRUCTURES. STORE ON SITE.
11. DEMOLISH EXISTING FEATURES AS SHOWN ON THE DRAWINGS AND COMPLETE SITE PREPARATION.
12. INSTALL PUMP AROUND #1 AND CONSTRUCT STREAMBANK STABILIZATION FROM STATION 99+50 TO 103+28.
13. ONCE WORK FROM PROPOSED STREAM STATION 99+50 TO 103+28 IS STABLE (TEMPORARY SEED COVERAGE OF 75% OR GREATER AND COIR MATTING INSTALLED/ACCEPTED), INSTALL PUMP AROUND #2 AND #3 CONSTRUCT STREAM WORK FROM STATION 103+28 TO 105+78 ALONG THE MAINSTEM AND FROM STATION 200+00 TO 200+62 ALONG THE TRIBUTARY.
14. ONCE WORK FROM PROPOSED STREAM STATION 103+28 TO 105+78 AND 200+00 TO 200+62 IS STABLE (TEMPORARY SEED COVERAGE OF 75% OR GREATER AND COIR MATTING INSTALLED/ACCEPTED), INSTALL PUMP AROUND #4 AND CONSTRUCT STREAM WORK FROM STATION 105+78 TO 107+69.
15. THE CITY INSPECTOR MUST APPROVE EACH PHASE PRIOR TO CONTINUING TO THE NEXT PHASE OF CONSTRUCTION.

PHASE 3: PLANTING, PUNCH LIST AND DEMOBILIZATION (45 DAYS)

16. UPON COMPLETION OF CONSTRUCTION, ALL DISTURBED AREAS SHALL BE FINE GRADED AND PERMANENTLY STABILIZED PER THE VESCH AND PLANTING PLANS, AS APPROPRIATE, PRIOR TO SCHEDULING FINAL INSPECTION.
17. SCHEDULE AND CONDUCT A PRE-PLANTING MEETING; SEE PLANTING PLAN.
18. PLANT AREAS DURING THE SPRING OR FALL GROWING SEASONS PER THE PLANTING PLANS, EXCEPT FOR LIVE STAKES WHICH CAN ONLY BE INSTALLED DURING THEIR DORMANCY (DECEMBER 1 TO MARCH 30). SOME PLANTINGS (E.G. PERMANENT SEEDING) WILL NEED TO OCCUR DURING EARLIER PHASES AS CONSTRUCTION AND STABILIZATION IS COMPLETED IN EACH AREA.
19. SCHEDULE AND CONDUCT AN ON-SITE PUNCHLIST WALK-THROUGH MEETING AND CORRECT ANY OUTSTANDING ITEMS.
20. ESC MEASURES SHALL NOT BE REMOVED UNTIL CONSTRUCTION IS COMPLETE AND APPROVAL IS OBTAINED FROM THE CITY INSPECTOR.
21. ONCE APPROVAL IS OBTAINED, REMOVE SEDIMENT CONTROL DEVICES INCLUDING TREE PROTECTION FENCE, PLANKING AND ANY MULCH USED IN THE ACCESS PATHS DOWN TO 4 INCHES WITHIN FOREST AREA.
22. SCEHDULE AND CONDUCT A FINAL PUNCH LIST WALK.

TOTAL ESTIMATED WORKING DAYS: 135 DAYS

Figure 7-1. Construction Activities Timeline

Planning and Trail Design

Currently, the established Rivanna Trail runs north of the creek while the North Field Spur Loop runs south of the creek. The most common route that trail users take is the trail north of the creek, which is a rustic trail with many difficult sections along it. It is intended to be traversed primarily by experienced hikers, runners, and mountain bikers, and is not accommodating to those with mobility impairments.

During construction, a temporary detour will take the route of the North Field Spur Loop, which has a similar difficulty to the Rivanna Trail in terms of length, elevation change, and trail surface. The plan view of the existing and detour trail is presented in Figure 7-2 and the CAD drawing in Figure 7-3.

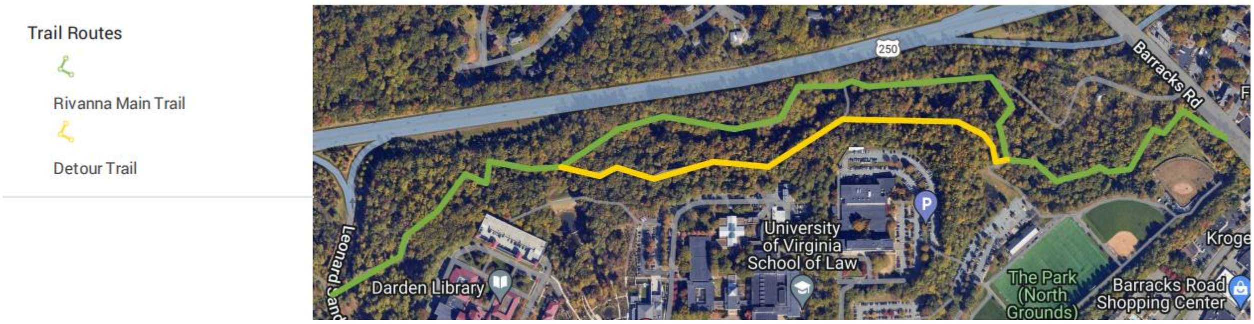


Figure 7-2. Plan View of Main and Detour Trail Alignments

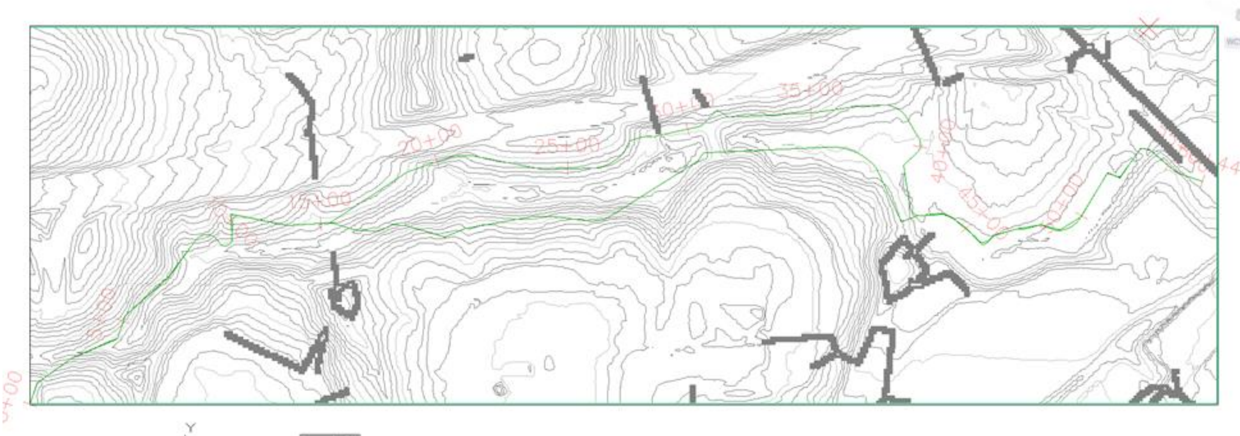


Figure 7-3. AutoCAD Drawing of Trail Alignments

The profiles of the existing and detour trails are displayed in Figure 7-4.

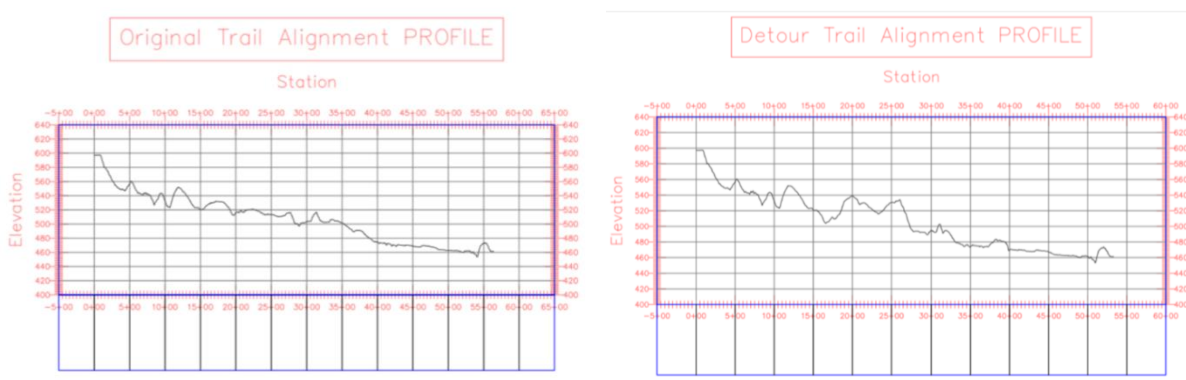


Figure 7-4. Profile Views of Existing and Detour Trails

Trail users will be rerouted via signs at the points where the trails split, merge, and branch off. An example of said signage can be found in Figure 7-5. This is to ensure that trail users can find their way along a trail segment they might not typically travel, as well as avoid the construction area.

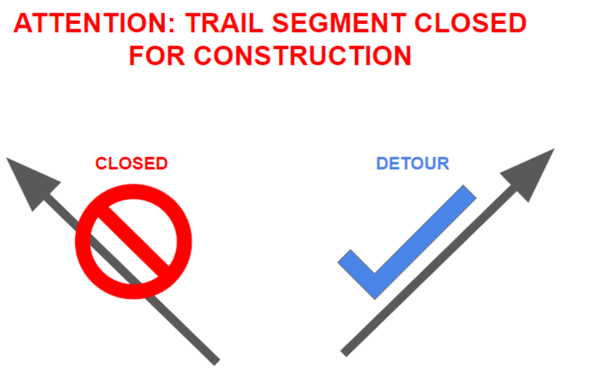


Figure 7-5. Example Signage

To prevent damage to the trail and other areas that the equipment will need to traverse, mulch will be laid down. Trees will need to be cleared in some areas adjacent to the trail and through sections of woodland where the construction trail must deviate from the Rivanna Trail. These trees should be mulched on-site and spread across the trail to reduce demand for mulch to be delivered to the project site.

To meet the interest in ADA accessibility by the RTF, our design initially brought the north trail up to ADA compliance, while keeping the south side detour trail rustic. However, to install an ADA compliant trail, the scope of this project would need to be adjusted. The required grading and paving to meet official standards would exceed the budget. The scope of this project is limited to ensuring that the trail is in similar quality or slightly improved after construction, not an entire upgrade. Since the north trail will be cleared and mulched during construction, and then regraded afterwards, it will likely be more accessible to those with moderate mobility impairments, so this is still an improvement by increasing the range of people who can utilize this amenity.

08 DISCUSSION AND CONCLUSION

A tributary of the greater Meadow creek watershed runs behind UVA's North Grounds and has been severely impacted by human activity and increases in impervious surface in the surrounding watershed. A series of modeling and analysis was conducted to analyze the existing stream conditions to inform the team's final restoration design to restore and remediate stream conditions. Grab bag samples from both reaches were collected in dry and wet weather and analyzed for quality indicators including nitrate, total phosphorus, turbidity, and TSS. A Bank Hazard Erosion Index was also performed to inform Chesapeake Bay TMDL and MS4 credit calculations. HEC-HMS modeling was performed to delineate watersheds and the subbasins within the site area to determine peak discharge and runoff volume. A survey of the two reaches was then conducted to collect cross section data to use as inputs into the HEC-RAS modeling, which provides a more detailed view of the volumes and flows in each individual reach.

Water Quality Discussion and Limitations

Water quality testing in both Reach 3 and 5 revealed nutrient and sediment levels far below typical levels for a stream and basin of this size. Therefore, water quality was not specifically considered in the restoration design. Our dataset was not large enough of a sample size to draw statistically significant conclusions about the quality of the stream. Additionally, the nutrient levels fell out of the detection ranges of the kits. The use of total phosphorus kit did not allow our testing to pick up amounts of phosphorus loads that were attached onto sediments in the water, further limiting the breadth of these results. If time had allowed, collecting additional sampling would provide more well-rounded dataset and make way for a more robust view of the water quality in the tributary. Furthermore, while the BEHI was introduced to improve the certainty of erosion occurring, it was not without error. The necessary reconnaissance and assumptions imposed a higher degree of human error.

Modeling Discussion and Limitations

To inform our HEC-RAS model, a cross-section survey was conducted by the team on both reaches. The accuracy of our survey was limited by human and tool error. While surveying, the team relied primarily on visual cues to determine locations of the top of bank, changes in slope, deepest point in the channel and other key survey points. Because many parts of the bank were covered in vegetation or rip rap, these points were difficult to determine, potentially causing discrepancies in the survey data. Visual tape readings became difficult in parts of the stream that were deep, as measurements had to be read from a distance. Other discrepancies may have come from slacking in the tape and not holding the surveying rod exactly level. There was also significant interpretation done by surveyors as to what areas along the stream accurately represented the channel's overall shape. The extrapolation of these cross sections to reflect the entire length of the reach could create problems as it is a generalization rather than an exact measurement of the banks of the stream.

Conclusions

While acknowledging the previously identified limitations of our analysis and design, conclusions can still be drawn. According to the water quality testing, nutrients (nitrate and total phosphorus) are not of huge concern in Reaches 3 and 5. The levels were well below established NSQD baselines. Sediment loads were also well below the Anne Arundel County baselines according to our TSS testing. To quantify historical and future erosion, the Bank Erosion Hazard Index (BEHI) was introduced. If UVA were to implement our design, up to 68.66 tons/year of sediment credit can be earned with the Virginia Department of Environmental Quality. These credits can be put towards future stormwater management projects, land development, and construction.

Our design involves the implementation of step pool conveyance systems in both Reaches 3 and 5, as well as the regrading of the incised banks. The sizing of the riffles and pools, the plunge pool in Reach 3 and the cascade in Reach 5, let us determine the resulting shear stress imposed on the channel banks by the water flow. The required rock sizes were calculated using a spreadsheet provided to us by Biohabitats and concluded our preliminary design.

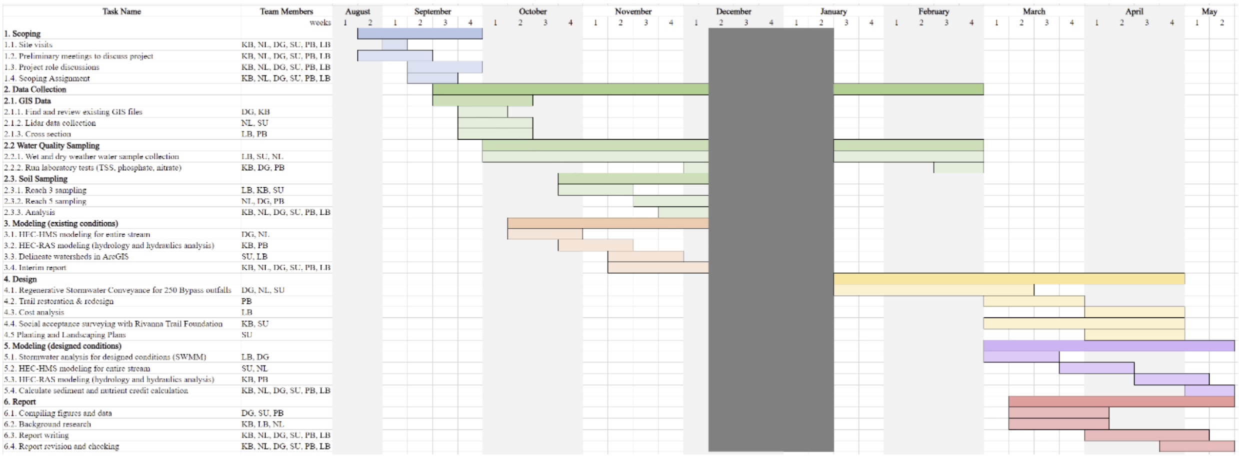
The construction process will follow a similar timeline to the Schenk’s Branch restoration project. It is expected to take roughly 75 days, as this project is about half the linear length of the

Schenk's Branch restoration. Furthermore, there are other factors that complicate the timeline related to community involvement, the number of separate reaches, specificity of the planting plan, and the management of trail traffic.

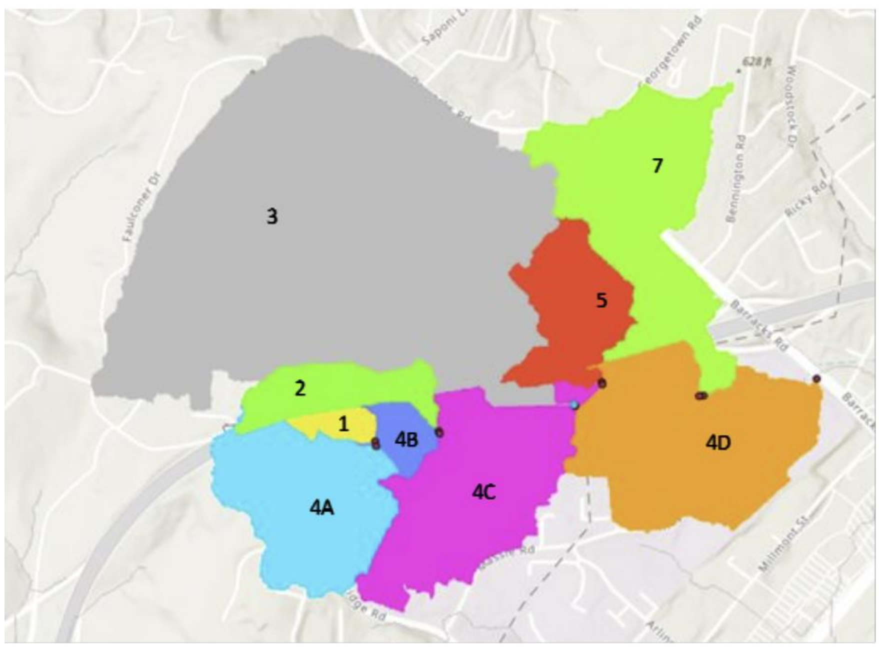
During construction, a detour trail route will be mobilized to meet the requests of the Rivanna Trail Foundation. Construction will begin in the late fall to minimize disruption of Foundation events and enable planting in the spring. Signage, mulching, and short bridges over ponding sections will be constructed along the detour trail to ensure that walkers, runners, and cyclists have a safe and enjoyable experience throughout the construction process.

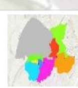
APPENDIX

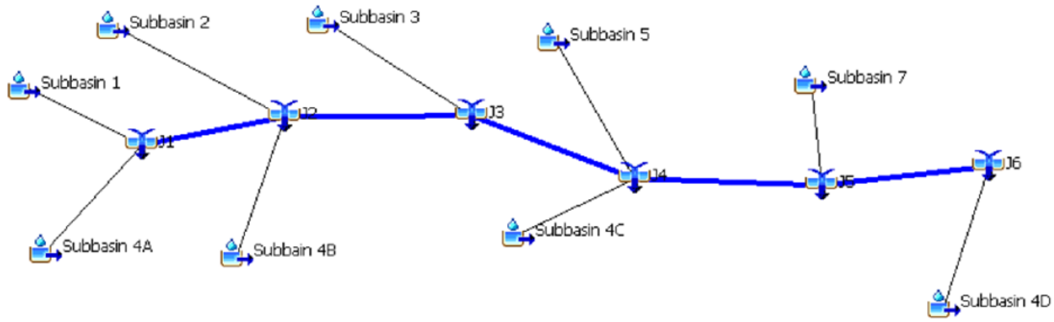
Appendix A – Project Schedule Gantt Chart



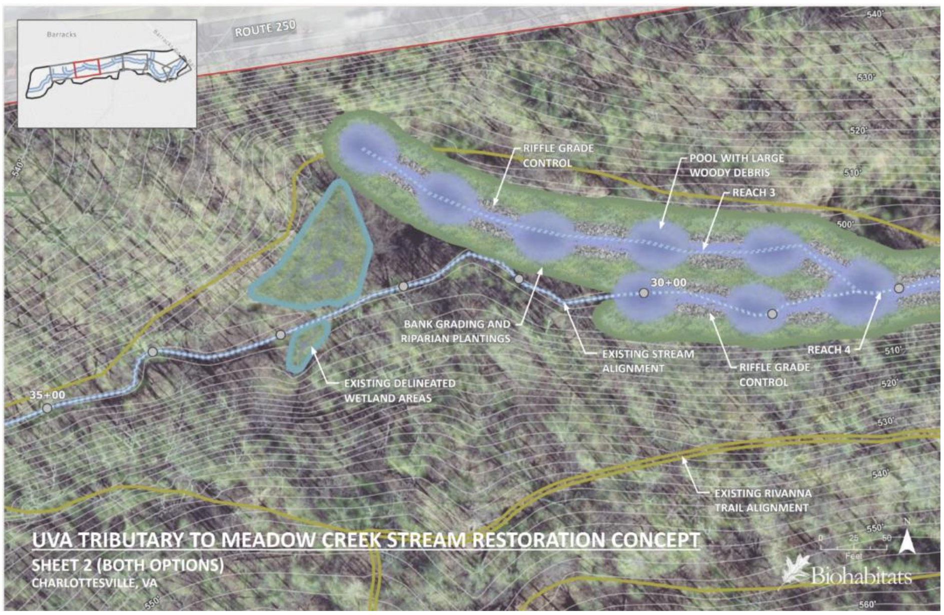
Appendix B – Examples of Previous Designs



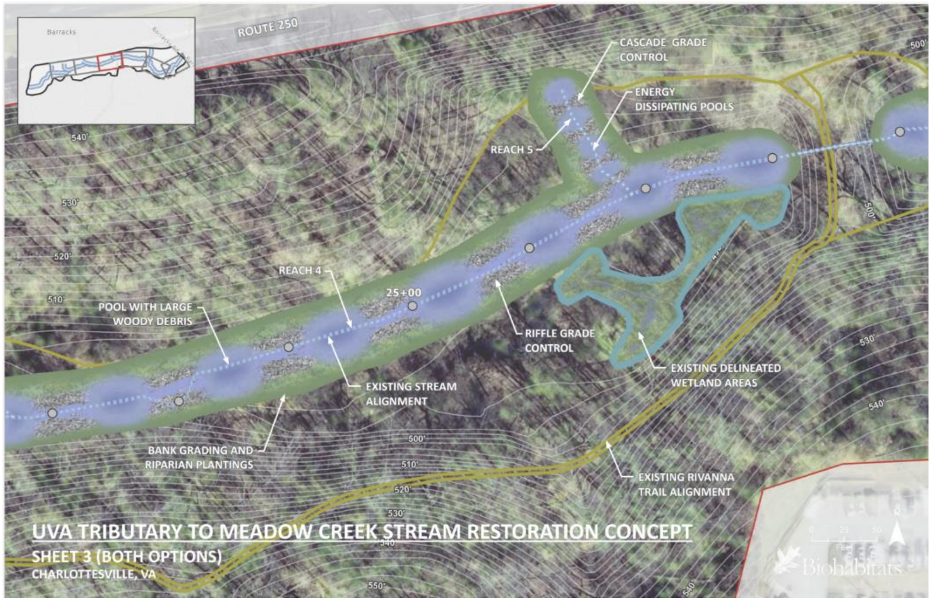




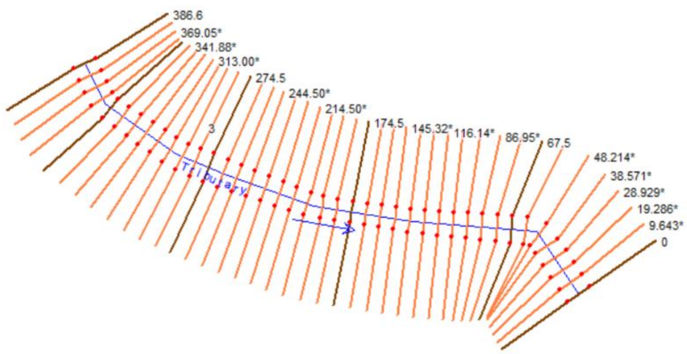
HEC-HMS Model Layout for Existing Hydraulics Information



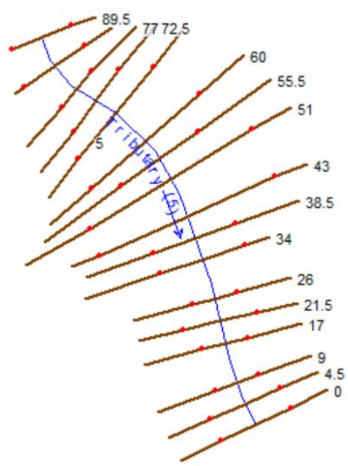
Reach 3 Initial Design Provided by Biohabitats



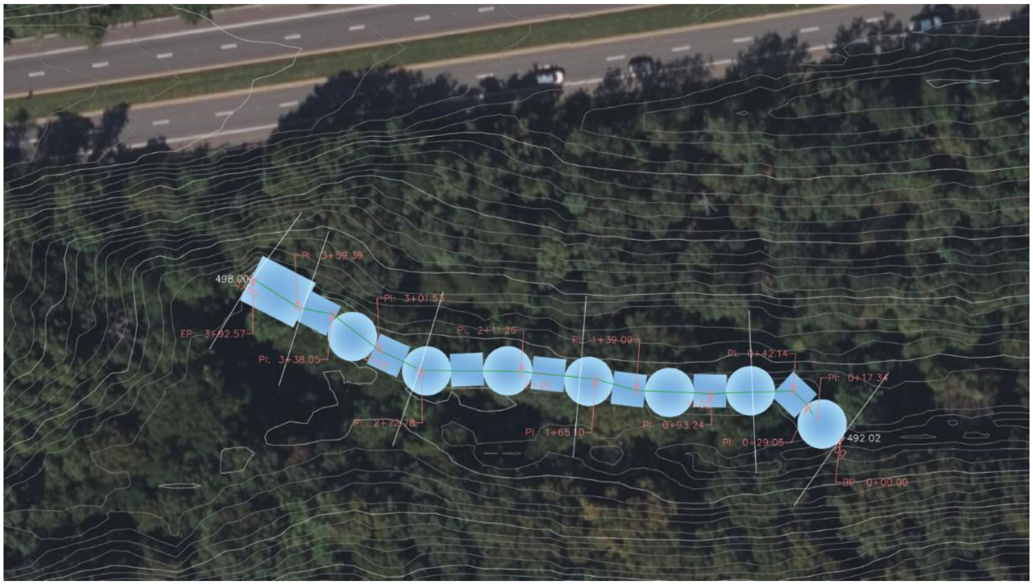
Reach 5 Initial Design Provided by Biohabitats



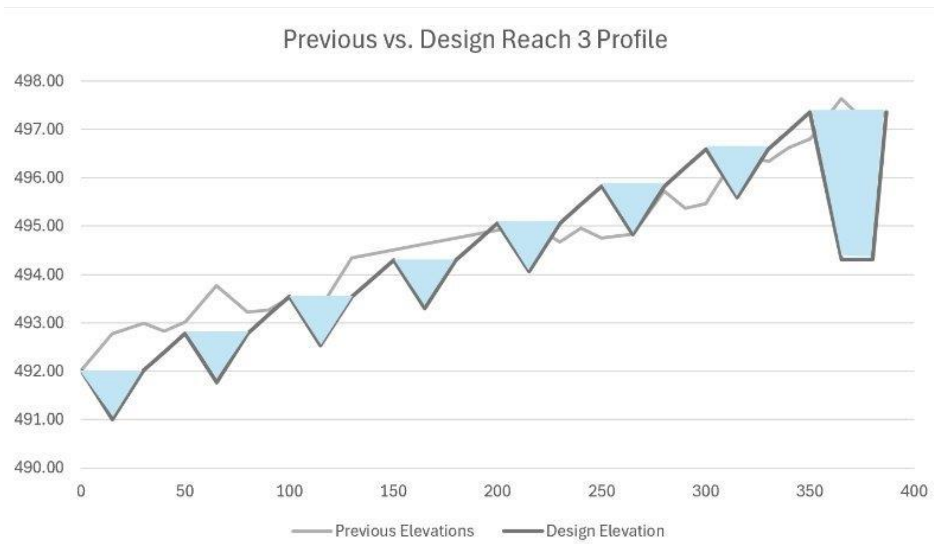
Reach 3 HEC-RAS Model Layout with Cross Sections at Delineated Stations



Reach 5 HEC-RAS Model Layout with Cross Sections at Delineated Stations

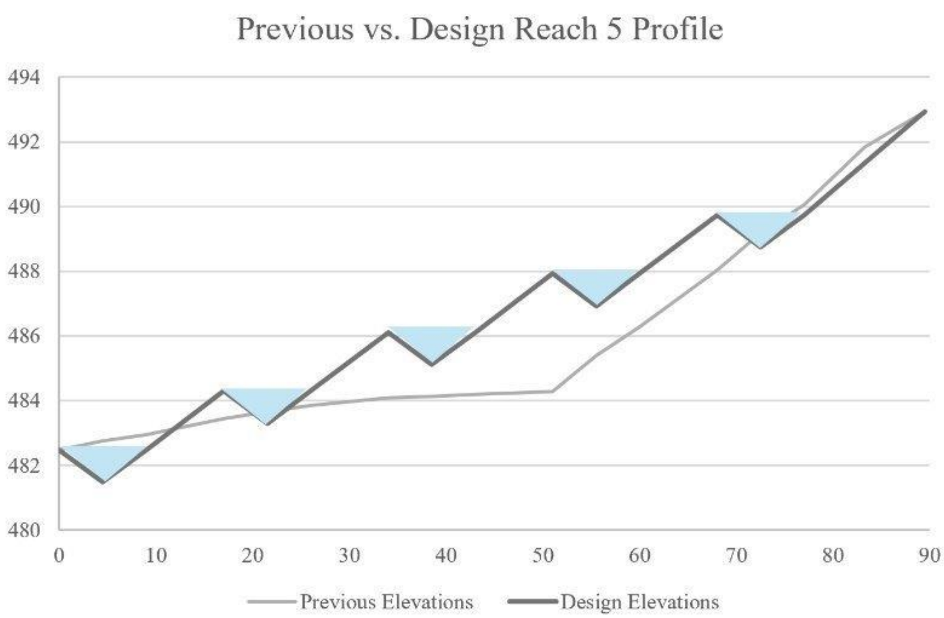


Reach 3 Final Draft Design (Plan View)



Reach 3 Profile View of Existing vs Proposed Elevations

Reach 5 Final Draft Design (Plan View)



Reach 5 Profile View of Existing vs Proposed Elevations

Appendix C – Surveying Results
Survey Reach 3 and 5.xlsx

Appendix D – Engineering Codes and Standards
Water Quality

- The Chesapeake Bay Total Maximum Daily Load (TMDL) Framework was used to quantify potential sediment credits that could be earned by UVA for this restoration project.
- Our team used the National Stormwater Quality Database (NSQD) for Anne Arundel County, MD as a baseline to compare the results of nutrient and sediment testing results. This allowed us to determine the severity of nutrient pollution and sediment loads for a

stream of this size in the Piedmont region. The Virginia Stormwater Management Handbook was similarly used as a second source of comparison for nutrient and sediment loads.

- The Bank Erosion Hazard Index (BEHI) was conducted in accordance with the methods outlined by David Rosgen's *A Practical Method for Computing Streambank Erosion Rate,* published by the EPA. A Stream Mechanics pre-established BEHI Excel template was utilized during the bank assessment. This spreadsheet is also in accordance with the methods outlined by the EPA and Rosgen.
    - BEHI.xlsx

Surveying

To survey cross sections along reaches 3 and 5, the US Army Corp of Engineers Stream Channel Reference Sites: An Illustrated Guide to Field Technique was used. These standards informed our decisions on where to survey cross sections and the sequence of methods used to obtain them. Techniques had to be slightly modified due to equipment type, as our group was utilizing a laser level to take measurements rather than a total station. This resulted in elevations relative to the right headpin rather than from a known elevation benchmark. Actual elevations were derived at a later stage using GIS contours and Lidar.
US Army Corp of Engineers Stream Channel Reference Sites: An Illustrated Guide to Field Technique

Modeling

Design

- For the design of the plunge pool, our team used the Maryland Department of Environment, Water Management Administration specification sheet to determine the dimensions. Taking in information about the sizing of the outfall culvert discharging into the pool, the hydraulic discharge of the flow in a 10 Year Storm, and the tailwater depth for the system, we were able to get length, width, depth, and rock sizing specs, as well as the side slopes for the system.
    - Plunge Pool Sizing.xlsx
- When designing the Step Pool Conveyance System, our team used the Anne Arundel County SPCS Guidelines to influence the sizing of both the riffles and the pools for both reaches. This standard also provided specs for our cascade sizing for Reach 5. These standards are based on several assumptions and observations on the stream's qualities, including 100-, 10-, and 2-Year Storm Design flow, Manning's n value, and unit rock weight.
    - Riffle and Cascade Sizing.xlsx

Construction

Construction plan standards segment The meadow creek restoration construction plan will follow the Virginia Code Article 2.4 - Erosion and Sediment Control (ESC) Law and 9VAC25-840-40 Minimum standards, Responsible Land Disturber (RLD) certificate issued by the Virginia Department of Environmental Quality, The ESC code applies to all construction that has potential for runoff after disturbing the ground surface. The minimum standards are specific to stream restorations in particular and outline the basic requirements for what counts as a restoration and how to prevent is from having negative impacts on the surroundings. The RLD certificate ensures there is a person qualified to implement and supervise ESC devices on the project site. Together, all these standards ensure that the restoration project is done responsibly, not creating more problems than it solves.

Appendix E – Technical Deliverables

Final Presentation.pptx

Civil3D Stream Restoration Design.dwg

HMS Design Parameters.xlsx

Profile Plotting Views.xlsx

HEC-RAS Reach 3.prj

HEC-RAS Reach 5.prj

HEC-HMS North Grounds Project.hms

Appendix F – Peer Review and Member Contributions

- Karin Brett: GIS data acquisition; chloride and bacteria analysis equipment inquiry; Gantt Chart creation, Site Visit Survey, HEC-HMS modeling, GIS modeling, HEC-HMS modeling, HEC-RAS modeling, proposed design parameter calculations, Civil3D modeling, post-restoration modeling
- Patrick Brown: Leading Efforts with the Rivanna Trails Foundation to determine how their impact will fit into our project, Site Visit Survey, Suspended Solids Water Testing
- Lucas Bushey: Water Quality Testing, Water Quality Testing Communications, Scope Assistance, Site Visit Survey, CAD Design
- Dorian Gaines: Coordination for Site Visit, Preliminary Topo Map Creation (Figure 2), Inquiry about surveying tools, Site Visit Survey, GIS Modeling, HEC-HMS Modeling, Site Visit Survey
- Nora LeVasseur: Water Quality Testing, Water Quality Data Analysis, Conducting and Analyzing BEHI, Site Visit Survey, Scope Development, Researching Compliance Standards and Baselines, DEM Acquisition for CAD, Technical Writing and Revisions

- Shay Utzinger: Site Visit Survey, Surveying Tools Collection, Water Testing Meeting, Site Visit Surveying & Data Sheet, Suspended Solids Water Testing, Researching TMDLs

REFERENCES

Anne Arundel County Bureau of Watershed Protection & Restoration. (2022, Mar.). Design Guidelines for Step Pool Stormwater Conveyance (SPCS) Systems.

Choudhury, M. (2022). Human-induced stresses on the rivers beyond their assimilation and regeneration capacity. *Ecological Significance of River Ecosystems*.

EPA (2023, Nov. 13). Environmental Protection Agency. Overview of Total Maximum Daily Loads (TMDLs). www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls#4.

MA DEQ. (2012). Maryland Department of Environmental Quality. Soil Erosion and Sediment Control Regulations.

Maester, A. and Pitt, R. (2005, Sep. 4). The National Stormwater Quality Database, Version 1.1. A Compilation and Analysis of NPDES Stormwater Monitoring Information. *U.S. EPA Office of Water*, p. 192.

Rosgen, D. (2001, Jan.). A Practical Method of Computing Streambank Erosion Rate. Wildland Hydrology, Inc. 2.

Stream Mechanics. (n.d.). BEHI/NBS Calculation Spreadsheet. stream-mechanics.com/wp-content/uploads/2020/10/Bank-Erosion-Summary-Table-w-BEHI-and-NBS-forms-Template_10-20-2020.xlsx

USDA (n.d.). United States Department of Agriculture. Web Soil Survey. Natural Resources Conservation Service.

USGS (2018). United States Geological Survey. StreamStats. streamstats.usgs.gov/ss/

VA DEQ (2023). Virginia Department of Environmental Quality. Virginia Stormwater Management Handbook.

VA DEQ (n.d.). Virginia Department of Environmental Quality. Municipal Separate Storm Sewer System (MS4) Permit – Stormwater. www.deq.virginia.gov/permits/water/ms4.

Wohl, E. (2015, Jul. 24). The science and practice of river restoration. AGU. www.agupubs.onlinelibrary.wiley.com