Otterdale Road Drainage Improvements

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

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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

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Problem Statement

Project details: Otterdale Road crosses over Otterdale Branch. There has been a history of flooding along the existing two-lane undivided road and single-span bridge. The creek flows through a double box culvert under the bridge but fails to properly convey flow during heavy storm events. The current roadway, which is classified as an urban collector, exhibits sharp curvature, which is more representative of a rural roadway.

Purpose and need: Chesterfield County has requested that our team alleviate flooding and improve roadway safety where Otterdale Road crosses Otterdale Branch. In the event of rain, this segment of Otterdale Road often becomes too dangerous to drive through. This means that local residents, emergency vehicles, etc. lose vital access into and out of the area. Moreover, due to the growth of adjacent neighborhoods and commercial businesses in the area, traffic is steadily increasing over time and the number of impacted individuals is rising.

Design Objectives

Goals: The overall goal is to develop a set of deliverables that would typically be presented at a public hearing, which combines both technical and digestible content to describe our proposed solution to the Otterdale Road flooding problem. This solution will be broken down into three main disciplines: water, roadway, and traffic. Our current aim is to redesign this segment of Otterdale Road as a rural collector to better tie in with existing road geometry and with improved stormwater management capabilities to handle a 100-year storm event.
Acceptance criteria: Evaluation of feasibility – if the project meets appropriate technical, monetary, and time constraints, we can be confident that this solution would effectively address the issues on Otterdale Road.

Activities & Deliverables

Roadway: CAD drawings of alternative roadway alignment/design.
Water Resources: Watershed Analysis using Contour Data and StreamStats, HEC-RAS model of existing culverts and proposed roadway changes, VRRM spreadsheet, CAD drawings of BMPs and drainage design, bridge scupper assessment.
Traffic: CAD drawings of traffic rerouting during construction for roadway alternatives and associated outputs showing measures of effectiveness (delay, level of service) derived from microsimulation data based upon existing and rerouted roadway data and VDOT guidelines.
Structural: CAD drawings of typical bridge sections and bridge implementation into roadway.
Project Management: Project overview, project schedule, budget estimate.
Public Display Board: Use CAD files and other refined deliverables to develop and display key printed visuals showing features of our design, hydrologic and hydraulic modeling and stormwater analysis to highlight major flooding solutions and Best Management Practices, maintenance of traffic plans for the duration of construction, and project management information to explain the process all in an easily-digestible board aimed at the general public.

Background

Our goal is to redesign this segment of Otterdale Road as a rural collector to better tie in with existing road geometry and with improved stormwater management capabilities to handle a higher degree of storm events. This challenge requires addressing conflicting issues of the technical design of the roadway, which has sharp curvature and alignments that pose safety risks, and the design of the stormwater management on the site, which is the cause of flooding in the area. The design of the roadway must consider how the stormwater is to be impacted, and the stormwater design must account for the proposed roadway. The solution to this problem is not obvious because the safety and accessibility of Otterdale Road can be addressed by multiple unique roadway designs coupled with different forms of stormwater management.

In terms of design constraints, the environmental and hydrologic aspects need to be balanced with the roadway and traffic elements. For project management, budget, time, and right of way are conflicting factors. Another complexity of this problem is the involvement of diverse stakeholders. The project will have an ongoing impact on not only residents of surrounding neighborhoods, but any non-locals who may need to use the road for travel as well; additionally, emergency vehicles need access to the road in order to fulfill their vital roles to the community, so the local administration would also be considered an important stakeholder. As VDOT is responsible for the maintenance of Otterdale Road, this organization is also a stakeholder. When assessing the multiple disciplines needed to solve this problem, there will be roadway, water resource, and traffic components necessary to address safety and accessibility concerns on Otterdale Road. Besides the major problem of solving the flooding on this roadway, the selected alternative for the redesign of Otterdale Road will impact the methods in which stormwater can be managed and traffic will be redirected.

Design Constraints

The major constraints of the project are the existing conditions, right of way, budgetary limitations, environmental regulations, and timeframe. The existing conditions of the roadway and right of way will impact what kind of roadway alignment we are able to design. The utilities within and around the project limits will constrain the design we create. The existing conditions of the landscape and wetlands will constrain the kind of stormwater management that is put in place. Budgetary limitations and timeframe are going to impact the amount of design work able to be completed. Environmental regulations surrounding the Otterdale Branch will constrain the impact the final design and the construction of the design can have on the area.

The major regulatory constraints that our project faces deal with the standards set by the VDOT. Such standards include The VDOT Road and Bridge Standards, VDOT Road Design Manual, VDOT Drainage Manual, Virginia Work Area Protection Manual, and VDOT Structure and Bridge Manual. These standards/manuals give regulatory guidance for roadway geometry and material, structure specifications, water surface elevation, beam selection/spacing, work zone signage, and guardrail guidance. Additionally, the Federal Emergency Management Association (FEMA) standards regarding 100-year storm events were used to determine the design storm used. The minimum bridge depth was determined based on regulatory requirements located in the AASHTO LRFD Bridge Design Specifications.

Design

In order to begin designing the roadway and structural components of the project, the HEC-RAS model of the existing conditions of the site, as well as the HEC-RAS model of an ultimate land use condition in which the surrounding areas of the site were fully developed, were analyzed. The model of the existing condition was used to understand the current box culverts and the cause of the flooding in the area. The reason for using the ultimate land use condition is that, since we are going to be redesigning the roadway, it is more efficient to consider a scenario where there is a lot more development because of the inevitability of growth in the area. From the ultimate land use condition HEC-RAS models, we were able to gather information on the cross sections of stations at and around the culverts. The water surface level elevations for a 100 year storm at the culvert locations were noted and will be used as a reference for the elevation of the proposed roadway, so that the roadway would not be overtopped if a 100 year storm event were to occur. We chose this design storm based upon determination of the project area being in Zone A according to FEMA floodplain maps and FEMA standards for Zone A. The total volumetric flow rate of the stream was collected from the HEC-RAS model to be used as reference for design of the structural component and the proposed hydraulic model. Profile and cross section views of the culverts as well as a plan and surface view of the stream were obtained to give context to the ultimate land use conditions we are designing for.

Initial preparations for creating the proposed hydraulic model were conducted. A StreamStats report was generated to determine the drainage area of the water at the roadway crossing and the current peak flow statistics for different storm events within the drainage basin. Virginia GIS Clearinghouse data was downloaded to verify the StreamStats report and to serve as another reference for the drainage area contributing to the stream crossing. GIS aerial and DEM slope tiles were recreated in OpenRoads Designer to see where water was flowing. Plots were then created, showing the drainage area overlaid with aerial and topographic maps to confirm StreamStats was accounting for the proper flows. The drainage area determination and peak flow information are useful for verifying the proper flows to the project site. The land use information from the Chesterfield Comprehensive plan was gathered to help inform our design of the model as well. The HEC-RAS existing conditions modeling analysis, drainage area determination, and watershed analysis findings are detailed more in Appendix D, Sections 1 and 2.

After obtaining more data on the topography of the watershed surrounding the Otterdale Road Crossing over Otterdale Branch, the 5’ Contours for the region were imported into OpenRoads Designer. The drainage area that flows into the Otterdale Branch Creek at the Otterdale Road Crossing was then delineated by hand in OpenRoads Designer using the drawing tools. The final drainage area drawing with the 5’ Contours after some feedback from Rinker Design Associates advisors can be found in Appendix D, Section 2. This step allowed for a more accurate determination of the drainage area than previous delineations which is useful for verifying the proper flows in the hydraulic modeling on the project.

In regards to the roadway elements, the functional classification, ADT, and design speed of Otterdale Road were first determined. These are rural collector, over 2000, and 45 miles per hour, respectively. Once this information was established, the preliminary design could begin. To appropriately tie in with the existing geometric design, the concept started as a two-lane undivided roadway with a width of 11’ per lane and standard slope of 2%. Next, in accordance with the geometric standards set by the Virginia Department of Transportation (VDOT), adding a minimum total shoulder width of either 6’ or 10’ depending on the use of guardrail was necessary. Although a paved shoulder was not specifically required because the amount of truck/bus usage in the area did not exceed 5%, it was included as a potential design choice due to the client’s intention of making the area more accessible to other means of transportation. A 5’ paved shoulder with a slope of 5% would suffice for both the ADT and any potential bikers in the area. This would then leave the remainder of the 6’ total width to be filled by 1’ of graded shoulder, also at a slope of 5%. For the proposed design that excluded paved shoulders entirely, the mainline pavement structure was extended by 1’ to protect the pavement edges from wear and an additional 6’ of graded shoulder was substituted. This concluded the shoulder design for concepts without guardrail. However, given that the existing project site has guardrail in certain areas, another typical section was created to reflect this. VDOT guidance states that a total shoulder width of 10’ is necessary for rural collectors with guardrail, so the aforementioned 5’ paved shoulder design was accompanied by 5’ of matching graded shoulder. The placement of the guardrail, as determined by VDOT’s Road and Bridge Standards manual, was 1’ off the edge of the pavement to the face of the guardrail. The 1’ was then followed by an additional 3’ to meet the 4’ minimum total distance required between the edge of pavement to the slope hinge point; i.e., the point at which the shoulder ‘ends’ and a road-side ditch or median would typically begin. This leaves 1’ remaining in the total 10’ width, which was filled in by additional graded shoulder. The typical section selected for the proposed design was the 5’ graded shoulder without a guardrail because the graded shoulder made the roadway accessible to bikers and not using guardrail was applicable for most areas of the project. The final proposed typical section is shown below in Figure C.1.1. Previous designs that were considered for the typical section can be found in Appendix B, Section 2. Finally, in terms of pavement composition, our design was based on recommendations given to Rinker Design Associates by professional geotechnical engineers. As such, the mainline is composed of 2” of asphalt concrete surface course, 2” of asphalt concrete intermediate course, 4” of asphalt concrete base course, and 6” of aggregate base material. The shoulder design consists of 2” asphalt concrete surface course, 2” of asphalt concrete intermediate course, and 10” of aggregate base material. Moreover, in areas of graded shoulders with guardrail, the 4’ minimum total distance between the edge of pavement slope hinge point would be modified to include a 2” layer of asphalt underneath. This was chosen with consideration to future maintenance, given that mowing would be difficult to complete in the graded shoulders when obstructed by guardrail. The full pavement design can be found in Figure C1.2. below.

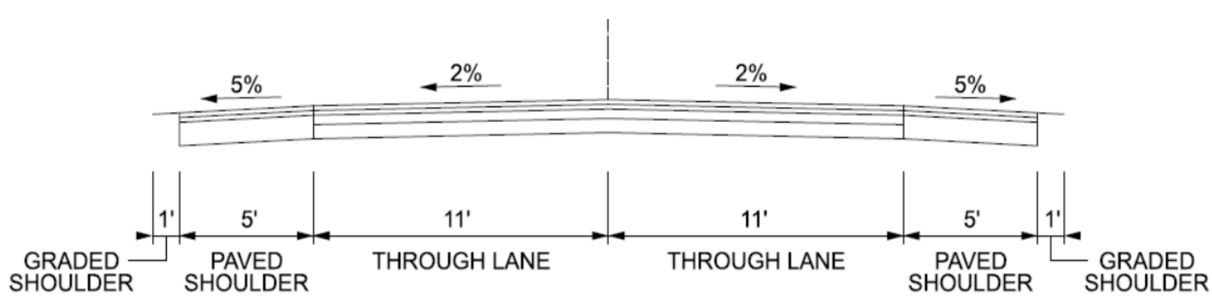

Figure C1.1. Proposed Roadway Typical Section

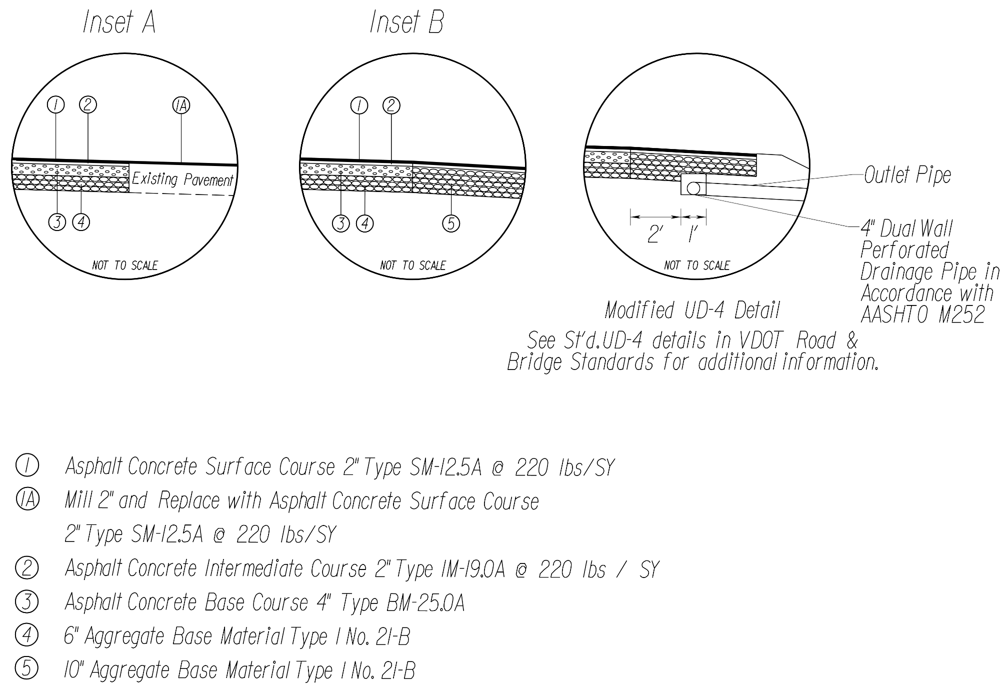

Figure C1.2. Pavement Design for Mainline and Shoulders (Source: Rinker Design Associates)

Initial preparations regarding traffic management plans during construction were made. After transferring an existing TrafficSynchro network provided by RDA into PTV Vistro and implementing minor geometric changes, delay and level of service were determined for intersections that will be impacted during traffic rerouting. These values were obtained for both the AM and PM peak hours, and will be useful in providing the community with rough estimates of delay that can be expected during rerouting. Additionally, an initial traffic rerouting plan that will be implemented during construction was laid out in a simple graphic which can be found in Appendix D, Section 3 (R3.2). Prioritizing traffic in and out of the residential development directly south of the site, Woolridge Road will be used to redirect traffic to and from Genito Road and Otterdale Road. This plan will be analyzed in PTV Vistro to optimize traffic management during construction, with the goal of minimizing delay at intersections performing poorly in the existing condition. The two signalized intersections in the network (4: Otterdale Road and Woolridge Road, 7: Woolridge Road and Genito Road) will be prioritized, as delays exceed 25 seconds across both intersections in the AM and PM peak hour in the existing condition.

Advancements in the second half of the fall semester yielded results on the impact of traffic rerouting on the study intersections. With help from Rinker Design Associates, an excel spreadsheet for both AM and PM scenarios was used to reroute traffic with a road closure at Otterdale Branch. The rerouting was done by starting at the road closure, evaluating origin-destination patterns of trips to and from residential access points south of Otterdale

Branch, and the Otterdale-Genito roundabout north of Otterdale Branch. From here, traffic was able to be rerouted accordingly, connecting origins to destinations via alternate routes where Otterdale Branch was previously crossed. This resulted in increased volumes at all intersections, leading to increased delays. Overall network delays were 28.35 seconds in the AM peak hour and 37.68 seconds in the PM peak hour. In the AM peak hour, intersection 6 (Woolridge Road and Timber Bluff Parkway) saw the largest increase in delay (7.53 seconds), while the PM peak hour saw intersection 4 (Otterdale Road and Woolridge Road) saw the largest increase in delay (8.18 seconds). All intersections analyzed in the network saw an increase in delay for both the AM and PM peak hour scenarios. However, difference in delays under 10 seconds between the existing and rerouted condition at each study intersection does not warrant signal timing adjustments, as was initially presumed would be the case. Essentially, the detour route analyzed in PTV Vistro by rerouting volumes around the road closure can be proceeded with in the following semester. This will involve drafting a public facing document to inform the public of detour routes they will be following, along with a design of the signage type and location throughout the network during construction.

The intersection analysis summaries after rerouting for the AM and PM scenarios are shown in Table C2.1, where only delay is considered. This is because no failing intersections were observed, and delay is more practical for detour purposes to come in the following semester. Excel sheets used for rerouting of existing volumes for the AM and PM scenarios are in Appendix D, Section 3 (R3.3, R3.4), accompanying analysis of the existing conditions and traffic rerouting directional plan.

Table C2.1. Intersection Analysis Summary

Intersection	Delay (seconds)					
	AM (Existing)	AM (Reroute)	Difference - AM	PM (Existing)	PM (Reroute)	Difference - PM
1. Otterdale Road and Genito Road (Roundabout)	4.72	5.7	0.98	5.12	9.9	4.78
2: Otterdale Road and Summer Lake Drive/Benmore Road (Two-Way Stop)	13.29	14.4	1.11	9.76	13.9	4.14
3: Otterdale Road and Duval Road (Two-Way Stop)	10.61	11.1	0.49	11.24	13.5	2.26
4: Otterdale Road and Woolridge Road (Signalized)	26.77	30.4	3.63	28.92	37.1	8.18
5: Woolridge Road and Fox Light Parkway/Fox Club Road (Two-Way Stop)	12.87	18.9	6.03	13.14	20.5	7.36
6: Woolridge Road and Timber Bluff Parkway (Two-Way Stop)	14.17	21.7	7.53	14.87	21	6.13
7: Woolridge Road and Genito Road (Signalized)	30.67	36.7	6.03	39.58	44.4	4.82
8: Genito Road and Water Overlook Boulevard/Heron Pointe Boulevard	12.05	14.6	2.55	10.19	10.2	0.01
	Rerouted Network Delay		28.35			37.68

Once the existing conditions were analyzed using HEC-RAS modeling software, the design process of the new roadway and structure began. The existing box culverts on the site were modeled as having 100 year storm event flows that overtopped the roadway significantly. This led to the design decision to create a larger hydraulic opening by creating a bridge across the creek crossing instead. The elevation of the roadway was adjusted using several iterations to create a model in HEC-RAS with a bridge that did not have water that overtopped the roadway. During the iterative design process, it was discovered that Microsoft Copilot was a useful tool for generating new points across the upstream and downstream roadway crossings. By analyzing the existing conditions, the lowest point and the points needed to remain constant to tie in with the existing roadway were noted. Using this information and the expected water surface elevation, Microsoft Copilot could then be prompted to generate points between the existing roadway points that were to remain constant and the desired new lowest point on the roadway with a constant slope between them. The responses provided were all checked for accuracy and adjusted when necessary. At times there were follow up prompts inputted to fix the errors. An example of a prompt and response are provided in Appendix D in Section 4 as well as an example of a follow up prompt. This led to efficiency in generating points that would work with a constant slope and allowed for changes to be made quickly. However, the program would sometimes provide points that were unwanted, so it was found to be easier for some bridge iterations to calculate the new points using excel calculations of the slope instead. Through this process, a bridge model was found that did not have water that overtopped the roadway, but the water surface elevation was greater than the existing water surface elevation for a 100 year storm event.

The next step taken to address the high water surface elevation was adjusting the ground elevation under the bridge. The lowest stream elevation points upstream and downstream were kept constant to ensure the natural flow of water would remain. The surrounding points were changed to allow for a larger opening for the water to flow through. When the ground elevations below the bridge were adjusted in HEC-RAS, the water surface elevation was lowered significantly which meant the roadway elevation could be lowered as well. Several bridge and roadway elevations were modeled in HEC-RAS to then find the lowest the roadway could be to reduce fill volume requirements. Around this time, the desired bridge structure dimensions were being calculated and it was determined that a superstructure depth, or the distance between the high chord and low chord of the bridge, of 3’ should be used. This was input into the model and the roadway elevation was adjusted to keep the 100 year storm event model from flooding. Profile and cross section views created in HEC-RAS of all the previous designs mentioned can be found in Appendix B. After further analysis, it was determined that a larger superstructure depth of 3.38’ should be used and this was input into the HEC-RAS model. This change in superstructure height along with the need to meet hydraulic requirements of not raising the water surface elevation from existing conditions and to have a minimum freeboard, or distance from the water surface elevation of design storm event to low chord of bridge, of at least 4” required adjustments to the HEC-RAS model through the increase in bridge span and further changes to the ground elevations under the bridge. Details on the standards used for these requirements can be found in Appendix C. The current proposed HEC-RAS model of the bridge and roadway that meets hydraulic requirements, structural requirements, and passes the goal of a 100 year design storm event is shown in Figure C3.1, Figure C3.2, and Figure C3.3 below. This model has a 50’ bridge span, freeboard of over 4” for both upstream and downstream cross sections, and has lower upstream and downstream water surface elevations for a 100 year storm event than in the existing conditions.

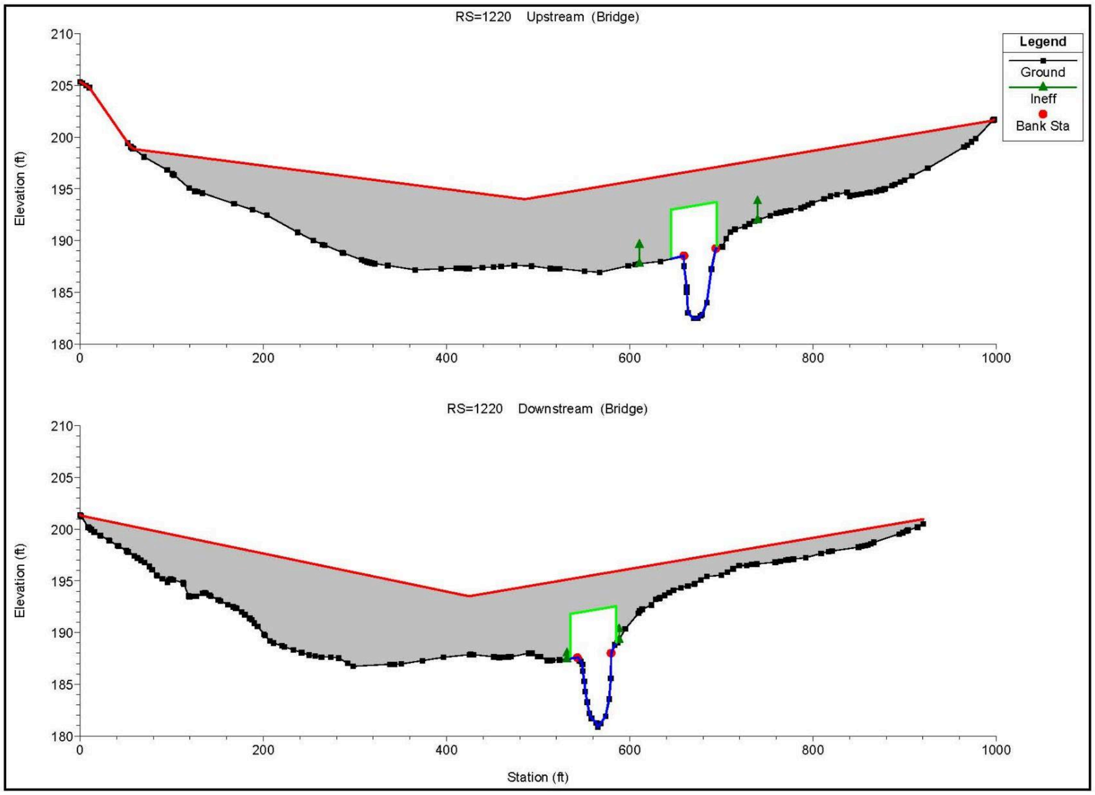

Figure C3.1. Upstream and Downstream Profile view of Proposed Bridge Structure at Otterdale Road, Otterdale Creek Crossing in HEC-RAS
Details: 50’ Bridge Span, 3.38’ Superstructure Height, and Stream Bed Grading

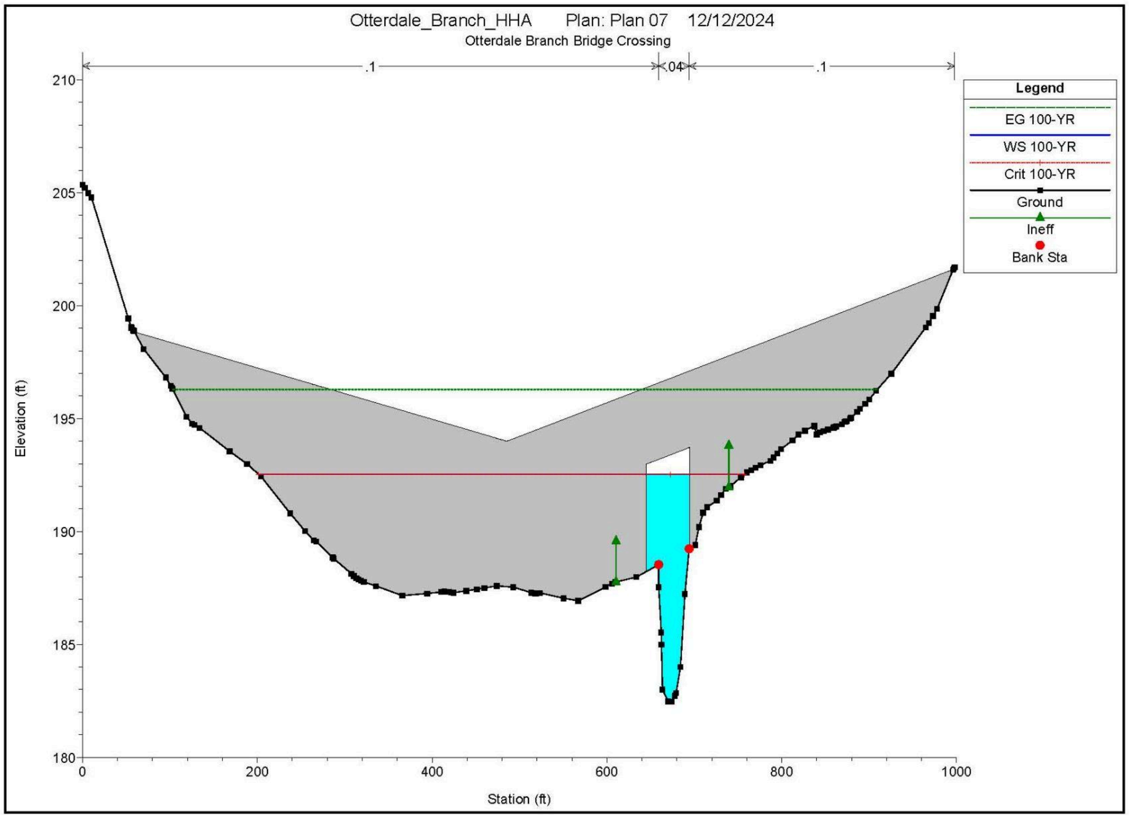

Figure C3.2. Upstream Cross Section of 100 year storm flow
Details: Water Surface elevation: 192.53’, Freeboard: 5.52”

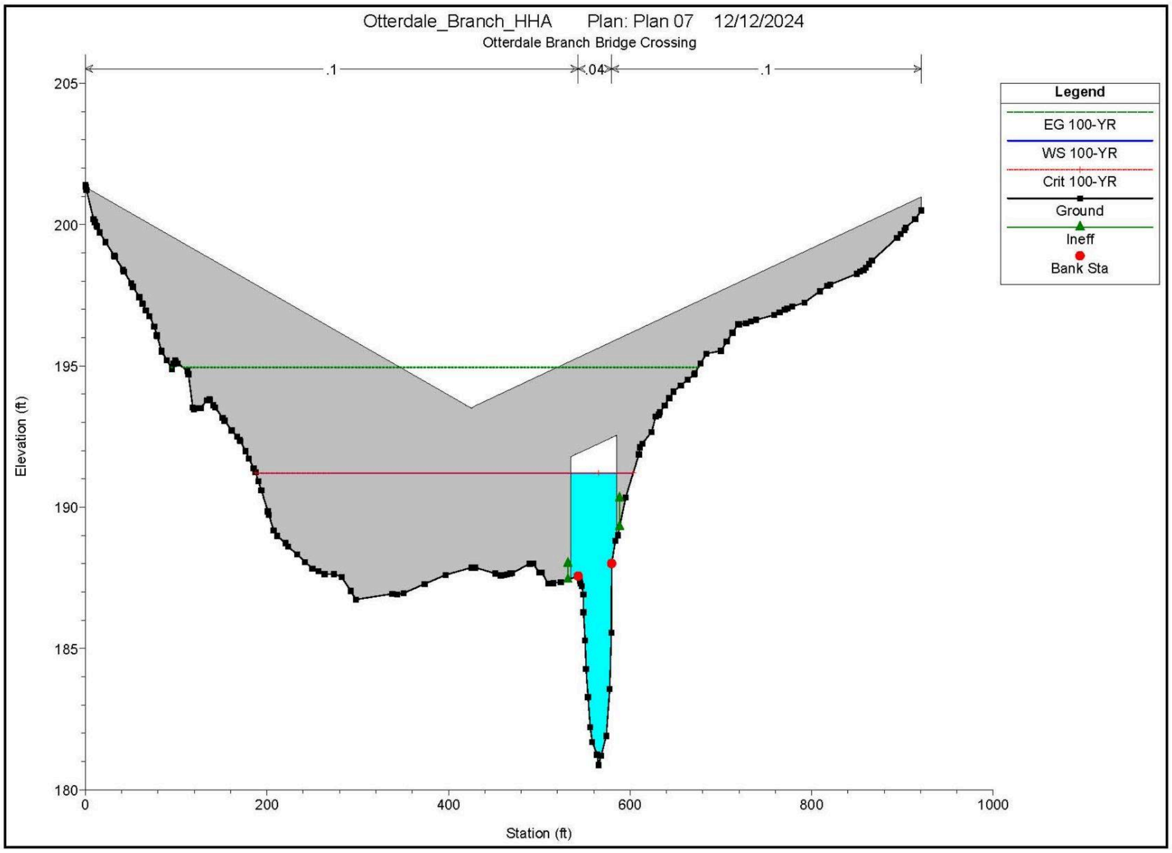

Figure C3.3. Downstream Cross Section of 100 year storm flow
Details: Water Surface elevation: 191.21', Freeboard: 6.96"

A visualization of how this bridge structure would be placed in reference to the existing roadway was drawn out in OpenRoads Designer, depicted in Figures C4.1 and C4.2 below. Previous iterations of the placement of this structure can be found in Appendix B. The location of our bridge in plan view was determined by creating parallel offsets from the existing double box culvert. We placed the bridge along the roadway such that the distance between the border of our bridge and the sides of the existing culvert aligns closely with our HEC-RAS bridge stations, ensuring that the physical bridge will successfully pass a 100-year storm. The position of the bridge with respect to the width of the roadway was selected to ease the transition between the existing roadway and the narrower bridge. The final bridge can be seen relative to the new roadway centerline in Figure C4.3 below.

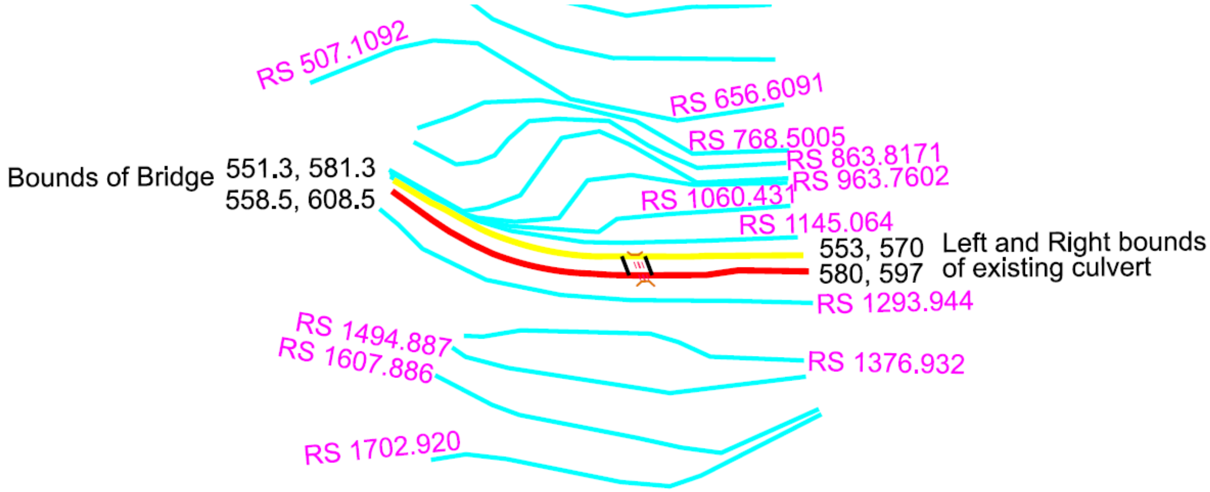

Figure C4.1. Outline of Bridge Placement Relative to Roadway Stations in OpenRoads

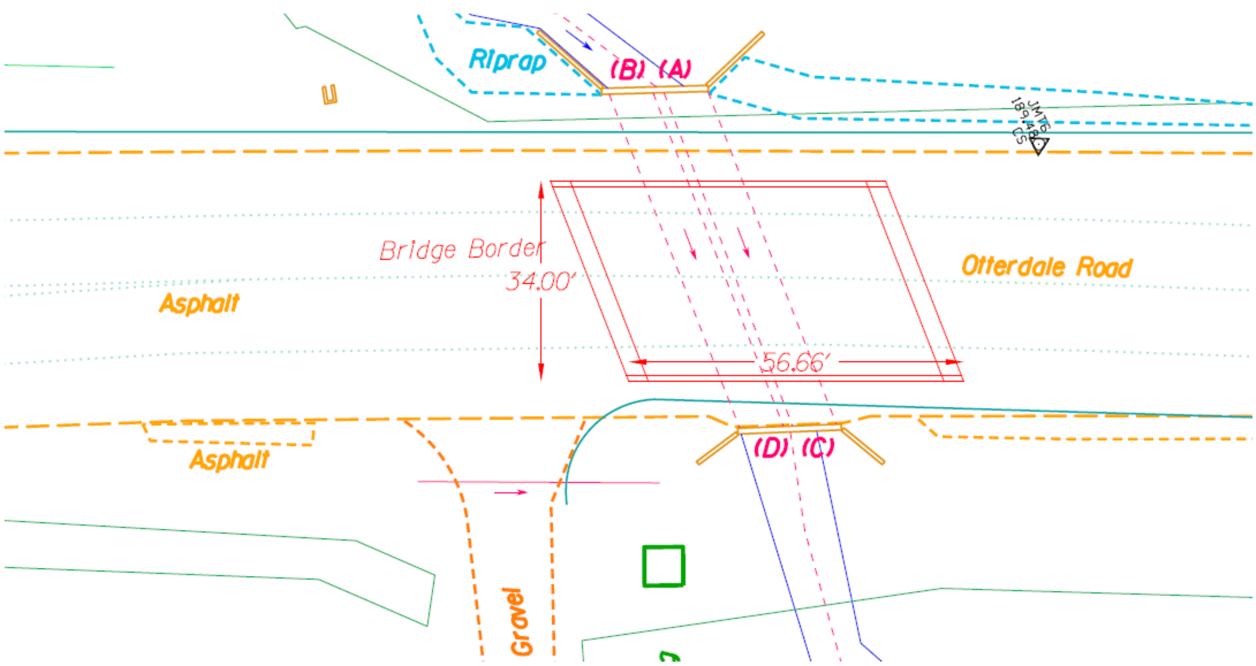

Figure C4.2. Outline of Proposed Bridge Relative to Existing Roadway in OpenRoads

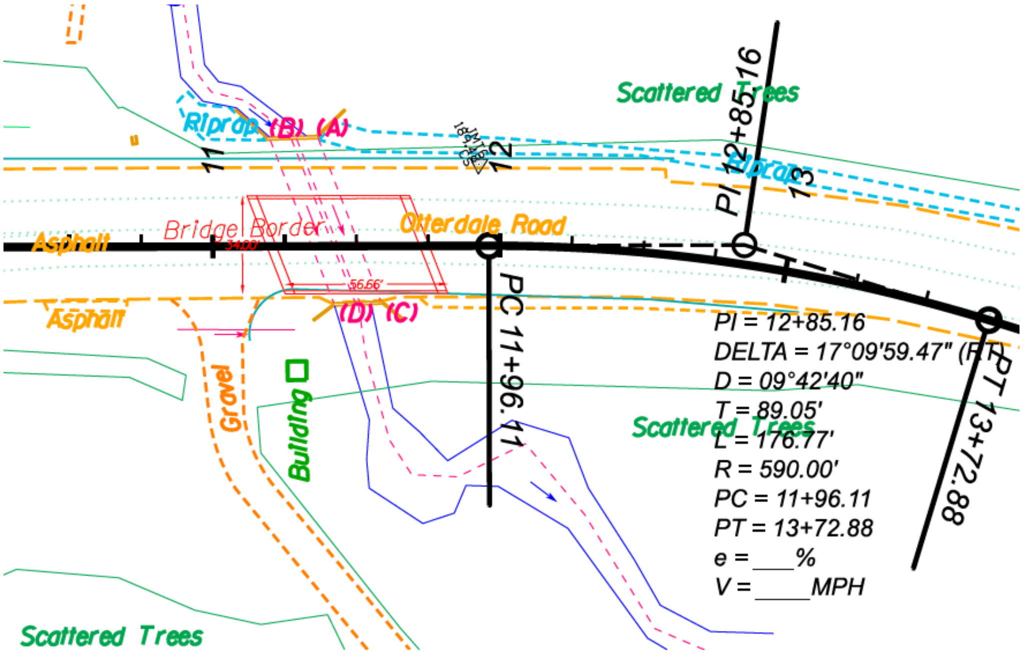

Figure C4.3. Final Bridge Placement Relative to New Roadway Centerline in OpenRoads

Initial structural determination was conducted within a design manual produced by Contech Engineered Solutions, where precast structures are recommended for crossings based on applications. These can vary from expected span, rise, and waterway range, shape, and aesthetic. However, investigation into integration and design of these precast structures revealed complications with a smaller span and high water levels, as seen at Otterdale Branch. This led to an investigation into simpler span bridges with concrete or steel makeups. Using the AASHTO LRFD manual, a minimum superstructure depth could be determined, proving useful in constructing a HEC-RAS model that integrates a bridge structure.

With guidance from Rinker Design Associates and the AASHTO LRFD Manual, an excel sheet, seen in R5.1, was created to iterate through basic design layouts based on overall span length and height from the roadway to the water elevation. With a primary focus on concrete and steel I beams, determinations on the clear height for opening along with the opening area of each iteration was found. Using the height from proposed final grade to the water elevation, determined by through existing HEC-RAS modeling, and minimum superstructure depth formulas from the AASHTO LRFD Manual, the clear height for opening was able to be determined by subtracting the minimum superstructure depth from the height from proposed final grade to the water elevation, and this value was multiplied by the span length to generate a predicted opening area. Despite steel composite I-beams providing larger clear height for opening and opening area by a small margin, concrete I-beam values were used in modeling, as concrete holds a superior compressive strength and provides more resistance to corrosion when water inevitably comes into contact with the bottom of the bridge structure.

An initial span length of 40.77 feet was tested in the HEC-RAS model, with corresponding superstructure depth, clear height for opening, and opening area, and met requirements for the 100-year storm. Using chapter 12 of the VDOT Structure and Bridge

Manual, beam spacing and designation were determined using road width and span length. Before undergoing design, it was evident that the superstructure depth with the smallest prestressed concrete bulb-T beam (PCBT-29) available in the manual would be larger than the minimum value calculated using AASHTO LRFD manual, which was inputted into the HEC-RAS model with a 40.77 span length. Understanding that the span length, even if exceeding 55 feet, would call for the PCBT-29 to be used, it became clear that the superstructure depth used in the HEC-RAS model was an underestimate. Because the deck slab thickness of 8.5 inches would remain constant for beam spacing feasible for this structure, and a haunch (member that connects beam to underside of deck slab) depth of 3 inches is assumed by VDOT, a superstructure depth of 3.38 feet would likely be used in this structure. The HEC-RAS model was updated to reflect this, and resulted in a 50 foot bridge span necessary. With this span length, and a 34 foot road width, a 9.5 foot spacing of beams was necessary to meet requirements (such as deck slab overhang) as noted in file 12.03-1 in the VDOT Road and Bridge Manual. File 12.03-6 in the VDOT Road and Bridge Manual calls for a 8.5 inch deck slab thickness at this spacing, and file 12.03-8 calls for a PCBT-29 at a compressive strength of 6 ksi at specified beam spacing and span length. This results in the same superstructure depth deemed necessary (3.38’), which was used in the HEC-RAS model that passed the 100-year storm at a 50 foot span length.

A typical section of this design is shown in Figure C5.1. and Figure C5.2, and the iterative excel table is found in Appendix D, Section 5. The Contech Engineered Solutions Structures Reference Guide, AASHTO LRFD manual and VDOT Structure and Bridge Manual are linked in the design standards.

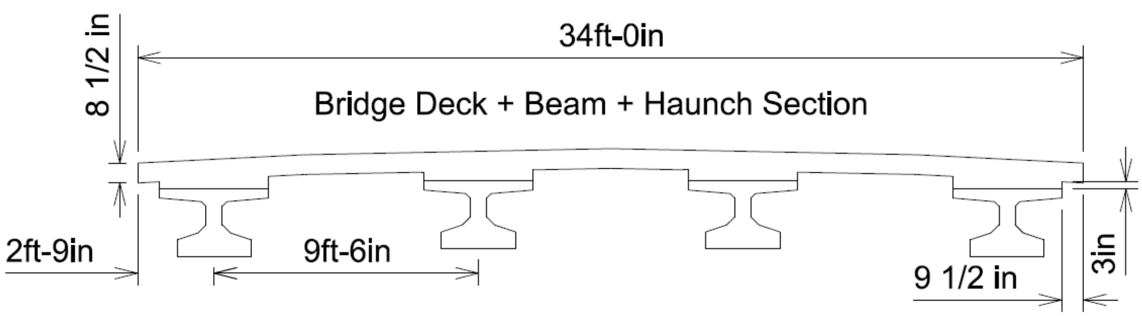

Figure C5.1. Typical Section of Proposed Structure

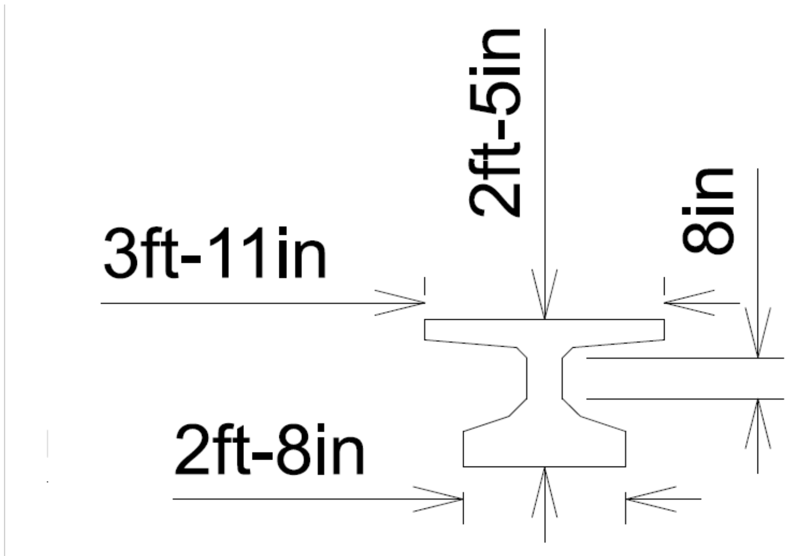

Figure C5.2. Typical Section of Proposed Structure's Beams - Prestressed Bulb-T PCBT-29

While the width of the bridge is 34' with two 11' travel lanes, two 5' paved shoulders, and two 1' graded shoulders to mirror the geometry of the roadway, a graded shoulder on each side is not necessary on a bridge deck. The updated 34' bridge deck width will include two 11' travel lanes, two 5' paved shoulders, and a 1' barrier on each side. The beam spacing and sizing remains unchanged beneath the bridge deck. In accordance with VDOT Structures Manual: CPSR-1 design standards, a crash tested and VDOT approved 42" CPSR-1 barrier will be implemented across the span of the bridge deck. Because the CPSR-1 barrier is one foot in width, it will simply replace the graded shoulder in the road-bridge transition. An updated profile sketch of a typical section of the bridge width can be found in Figure C6.1. below.

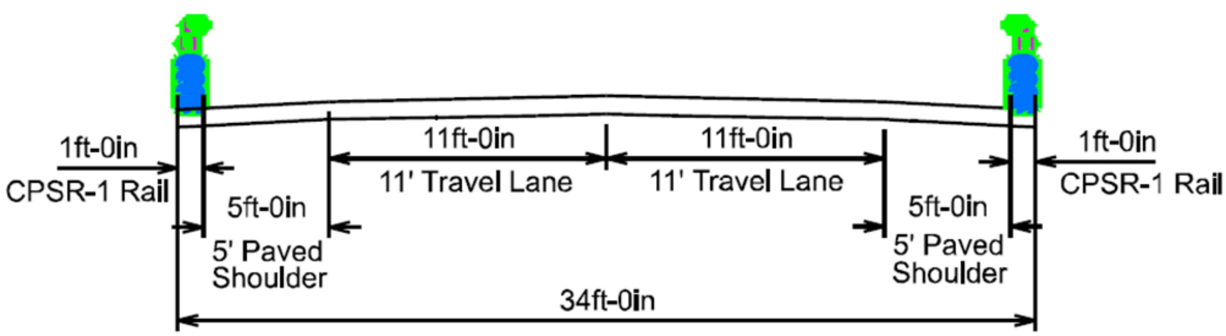

Figure C6.1. Updated Deck Width Profile View: Typical Section without Beam

Initial bridge deck span dimensions were incorrect. A total span length of 50' will not pass the design storm, as the opening area will be less than 50' after implementation of abutments. With the help of RDA and the VDOT Structures Manual, an estimation was made on abutment sizing in accordance with similarly sized structural designs in the past. This was done with the beam type, PCBT-29 Bulb-T in mind. The height of the back wall of the abutment was calculated by subtracting the top flange of the PCBT-29 and 6" for bearing from the overall PCBT-29 element height, leaving a back wall height of 2' 7". The back wall is set to be aligned on the left side of the abutment stem, with 1' in width. The centerline of bearing, where the last beam will be placed on both sides, is 1' adjacent to the outer edge of the back wall. The stem of the abutment, centered on the footing of the abutment, will be 3' in height and 3' in width. The footing of the bearing will be 5' in width and 3' in height. These dimensions will ensure a 50' opening to pass the storm, which is observed from the inside of the stem wall to the inside of the stem wall. In accordance with VDOT, the bridge deck must overhang the back wall of the abutment by 4" on each side. Thus, an updated total bridge deck span of 56' 8" will be used moving forward. An updated sketch of the profile view of the span of the bridge can be found in Figure C6.2. below. This profile view was established as the final bridge design, with measurements in C6.2 used for final hydraulic, roadway, and stormwater calculations and considerations.

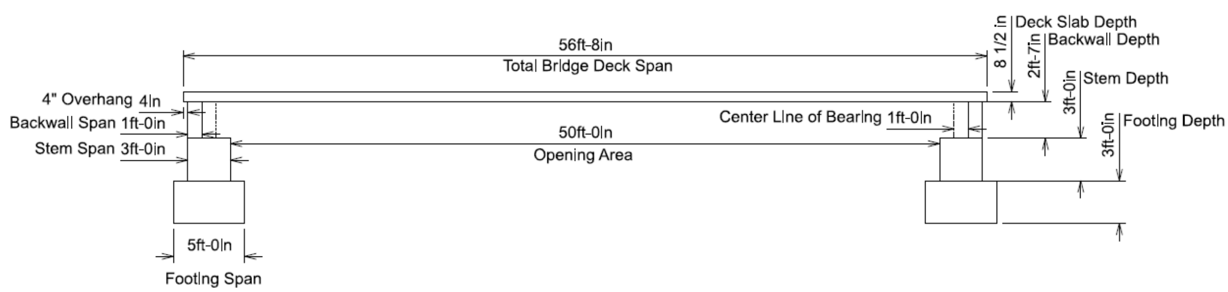

Figure C6.2. Updated (Final) Bridge Span Profile View

The environmental impact that the project will have is of high importance. To assess the nutrient loads before and after the proposed design, CAD files of the survey data were analyzed. The impervious, managed turf, mixed open, and forested areas were quantified by making shapes of each type within the designated limits of disturbance of the project in OpenRoads Designer. The Web Soil Survey online tool by the United States Department of Agriculture (USDA) was used to delineate the soil types on the site which were found to have HSG soil types B, C, and D. This allowed for the impervious, managed turf, mixed open, and forested areas to be separated into their respective soil types and input into the Virginia Runoff Reduction Method (VRRM) 4.1 Redevelopment spreadsheet. Supportive spreadsheets and CAD drawings of this process can be found in Appendix D, Section 6. The results from both the existing conditions and proposed conditions in the VRRM spreadsheet will guide the decision making for the stormwater management practices to include into the design. After further review, the limits of disturbance initially drawn were expanded an additional 15 feet out to consider grading changes that will need to be made for the new roadway. Also, managed turf areas were changed to be mixed open areas to be more representative of the properties of the existing land cover. The revisions to this are shown in Appendix D, Section 6 and the new areas were updated in the VRRM spreadsheet for the Pre-Redevelopment Land Cover section. The same limits of disturbance were used in the context of the proposed roadway design and the impervious, managed turf, mixed open, forested areas of the proposed land cover were quantified in the same method as was done for the existing conditions. These values were input from OpenRoads Designer into the Post Development Land Cover section of the VRRM spreadsheet. The impervious land cover that was impervious in the existing conditions on the project and is going to remain impervious after the proposed design is implemented does not need to be accounted for in VRRM so that area of impervious land cover that will be unchanged was quantified and subtracted from the impervious areas in the VRRM spreadsheet. The information on land cover pre- and post- redevelopment allowed for the determination of the required Post-Development Total Phosphorus(TP) Load Reduction for the site which is 0.6 lb/yr. The VRRM spreadsheet and figures of the land cover can be found in Appendix D, Section 6.

Based upon the Post-Development TP Load found using the VRRM spreadsheet, Best Management Practices (BMPs) will need to be implemented to manage the pollutants in the stormwater on the site. The terrain of the project site was assessed to determine proper location and type of BMP to be used on the site. The design is proposing a bioretention garden at a low elevation point near Otterdale Branch Creek. The drainage area showing the water that will flow into the bioretention garden was delineated in OpenRoads Designer and the drainage area land cover types were input into the Drainage Area A tab of the VRRM spreadsheet to assess nutrient removal capabilities. The visual of the drainage area and calculations of specifics of drainage area land cover types can be found in Appendix D, Section 7.

After delineating the appropriate drainage area (Drainage Area A, or D.A. A), sizing specifications from the VDOT BMP design manual informed the design of the bioretention garden. We elected to design a Level 1 Bioretention system in order to benefit from its more lenient constraints around geometry; it is important that the BMP fit in the area of disturbance already established. The requisite surface area and storage depth were calculated using equations 7.1 and 7.2 from the manual. From the VRRM spreadsheet, we were able to determine that D.A. A had a total Phosphorus loading of 1.8 lb./yr. available to be removed with BMP treatment. Our total removal goal for the site is to treat and remove 0.6 lb./yr.; after sizing the bioretention to be placed in D.A. A, the VRRM was used to determine that approximately 1 lb./yr. P is treated by the bioretention garden, surpassing our minimum treatment goal of 0.6 lb./yr. More detailed analysis of the sizing calculations can be found in Appendix D, Section 7.

Analysis was conducted to determine if the bridge deck would be in need of scuppers to prevent water from pooling up on the deck and spreading into the travel lanes which may cause hydroplaning. A spreadsheet provided by Rinker Design Associates including the variables and functions for Spread, the width of flow, was used. The values of each variable were input and the findings showed the Spread was below the Allowable Spread, indicating there would be no need for scuppers. The spreadsheet with detailed information can be found in Appendix D, Section 8.

The impact of the proposed design on existing utilities is an important factor to be considered. The proposed design was overlaid with existing utilities in OpenRoads Designer and conflicts of the proposed designs with utilities were identified. For the proposed design, there will need to be a relocation of part of an existing water pipe, three power poles, and one communication system junction box. An existing communication system line will also need to be extended. Estimated costs of these changes were obtained from the professional advisors to find a total of approximately $280,000. More detailed information and visuals of these utility conflicts can be found in Appendix D, Section 9.

Updates have been made to the detour route, and initial signage has been proposed with guidance from the Virginia Work Area Protection Manual. Minimal changes have been made to the routing during construction proposed in R3.2, with Woolridge Road being used to connect trips between Otterdale Road and Genito Road. The proposed detour route, which was tested in PTV Vistro (vehicular inputs in R3.3 & R3.4) to ensure traffic delay did not warrant network failure, is shown in C7.1. Green arrows throughout the network represent the detour in practice.

Signage recommendations are shown in C7.1 and C7.2. Sections TTC 34.2 and TTC 48.2 from the Virginia Work Area Protection Manual provide direction on street closure operation with detour. Drafting focused on detour route signage, which included detour ahead (W20-2), road closed ahead (W20-3), end detour (M4-8a), and directional detour (M5-V1, M4-V3R, M4-V3L) signage where recommended along routing by the manual. C7.1 will serve as a public facing document, informing road users of signage/routing while construction is underway. C7.2 portrays example in-field signage from the intersection with the highest vehicular volumes (Genito Road and Woolridge Road). Directional detour signage was implemented shortly before turn lanes, with at-intersection detour signage to remind users. Detour ahead signage was implemented where sight distance allowed, based on google earth imagery. For a 45 mph roadway, which was the consistent speed limit throughout the network, the Virginia Work Area Protection Manual requires 500-800 feet prior to the intersection. This was mirrored across the network, along with end detour signage where necessary.

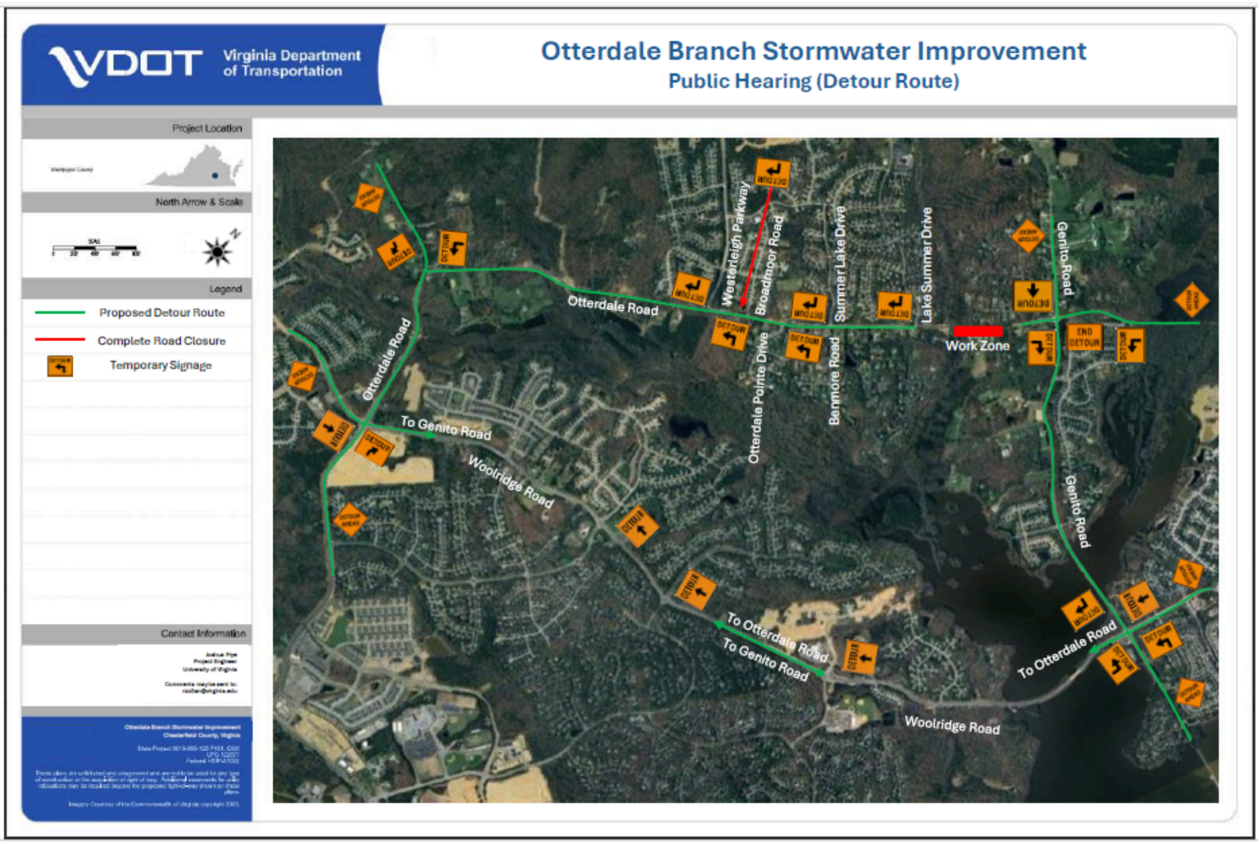

Figure C7.1. Detour Route - Public Facing

Figure C7.2. Example Detour Signage, Mirrored Across the Network

The final components of the proposed design including the horizontal alignment of the roadway, bridge structure, and bioretention garden were drawn in OpenRoads Designer and can be found in Figure C8.1. below. To ensure the proposed design and major results were clearly presented, a zoomed in view of the bridge and bioretention garden is shown including dimensions of each element. The key features of each element of design are highlighted through the use of labels and arrows for clarity.

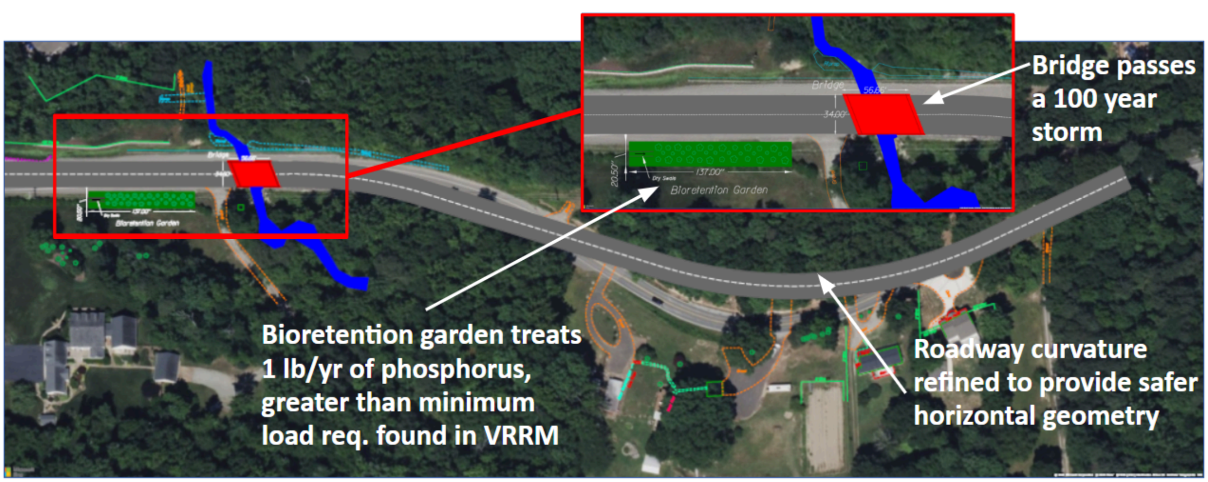

Figure C8.1. Plan View of Proposed Roadway, Bridge Structure, and Bioretention Garden

Conclusion and Discussion

When conducting a construction project for the benefit of a local community, a major concern is the cost. The total estimated cost for the project is $7,090,000. This estimate was developed using the VDOT Pre-Quantity Tool for overall quantities and the VDOT PCET for bridge-specific components. To inform cost allocations, data from VDOT's SPECC tool on bridge reconstruction projects with added capacity near Richmond, VA, was utilized—particularly for elements like grading and earthwork. A complexity contingency was applied to reflect design uncertainty: 35% for most items, 40% for those with higher uncertainty, and 30% for more predictable components. Our final value of $7,090,000 constitutes a total construction estimate without construction engineering and inspection costs, and does not include a construction contingency. The final estimation summary can be found in Appendix D, Section 10.

Otterdale road was redesigned using industry-standard methods, procedures, and techniques to alleviate flooding and ease community safety concerns. Hydraulic, roadway, structural, traffic, and stormwater solutions were developed interdependently; impacts on the surrounding neighborhoods, networks, and utilities were minimized where possible. The key goals of designing a roadway as a rural collector to tie in with the existing roadway, a structure that passes a 100 year storm, and stormwater management techniques that follow Best Management Practices were all met. The community will see improved roadway safety and have fewer disruptions to their daily travel due to this proposed design's changes in horizontal roadway geometry and reduced flooding over the Otterdale Branch Creek crossing. The environmental impacts of the project were considered by ensuring Virginia Department of Environmental Quality Standards were met for nutrient load reduction that is required when doing a redevelopment project. This nutrient load reduction was done through the design of a bioretention garden nearby to Otterdale Branch Creek crossing along Otterdale Road. During construction, a traffic management plan including detour routes will include clear and visible signage so that the community will be safely and efficiently guided to their destination. Although design plans are still in need of further development to arrive at plans that, by engineering standards, can be considered 100 percent complete, strides have been made to determine key elements of the proposed design based on analysis from hydraulic, roadway, structural, traffic, and stormwater disciplines of engineering. Given time and design constraints, progress on Otterdale Road redesign is satisfactory in eventually achieving the golden standard of 100 percent completion.

Acknowledgements
Professional Advising Group - Rinker Design Associates Team: Aaron DeLong, Jane Long, Wyatt Yoder, Mariah Pitts, Nikhil Deshpande, and Katie Flood

Appendix A: Detailed Schedule

The following link (Otterdale Spring Schedule Gantt) should lead to a detailed schedule.

Appendix B: Design Evolution

Previous Designs

Section 1. Previous HEC-RAS Models

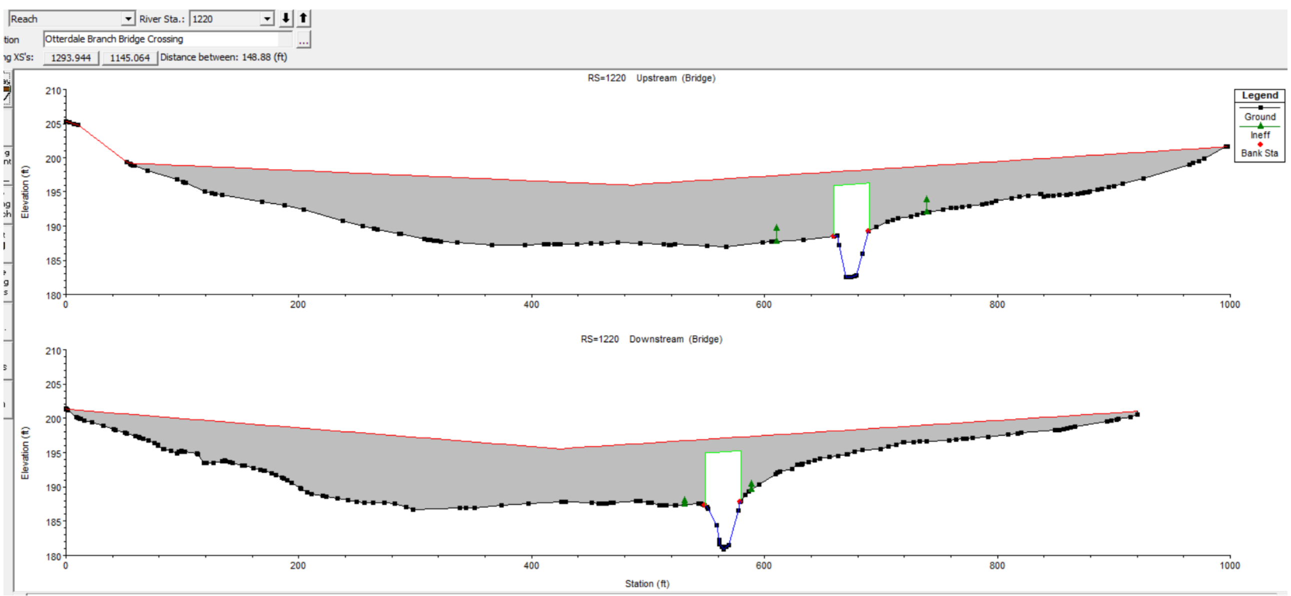

Figure P1.1. Initial Bridge Model Profile View Without Flooding but High Water Surface Elevation

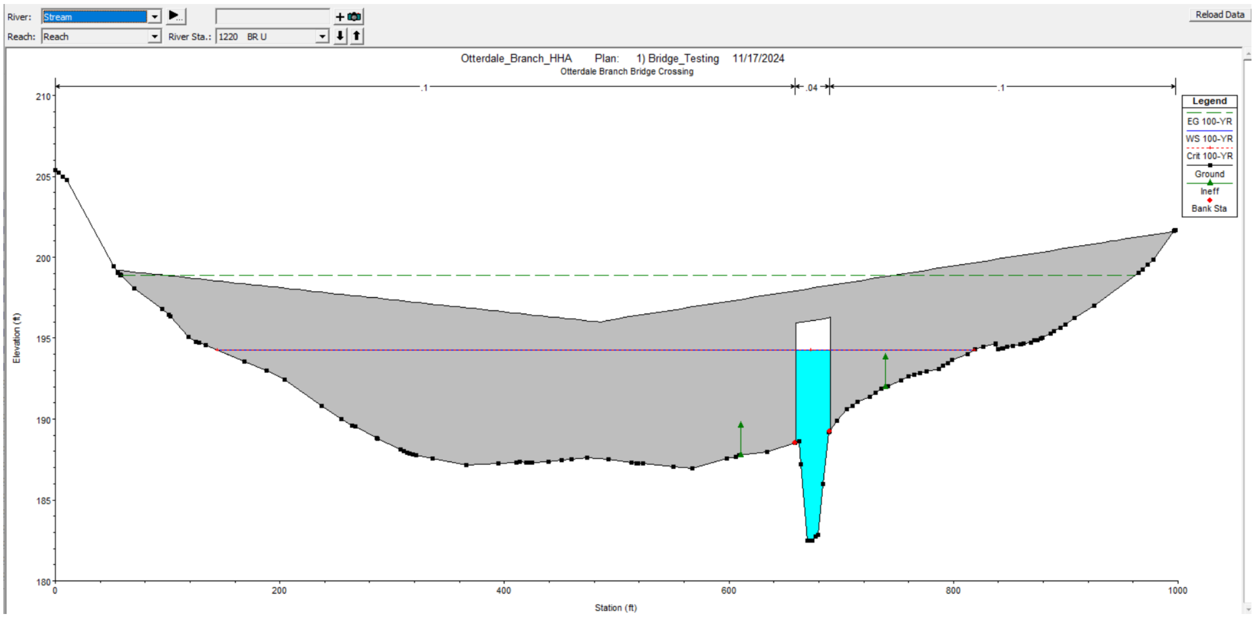

Figure P1.2. Initial Bridge Model Upstream Cross Section View Without Flooding but High Water Surface Elevation

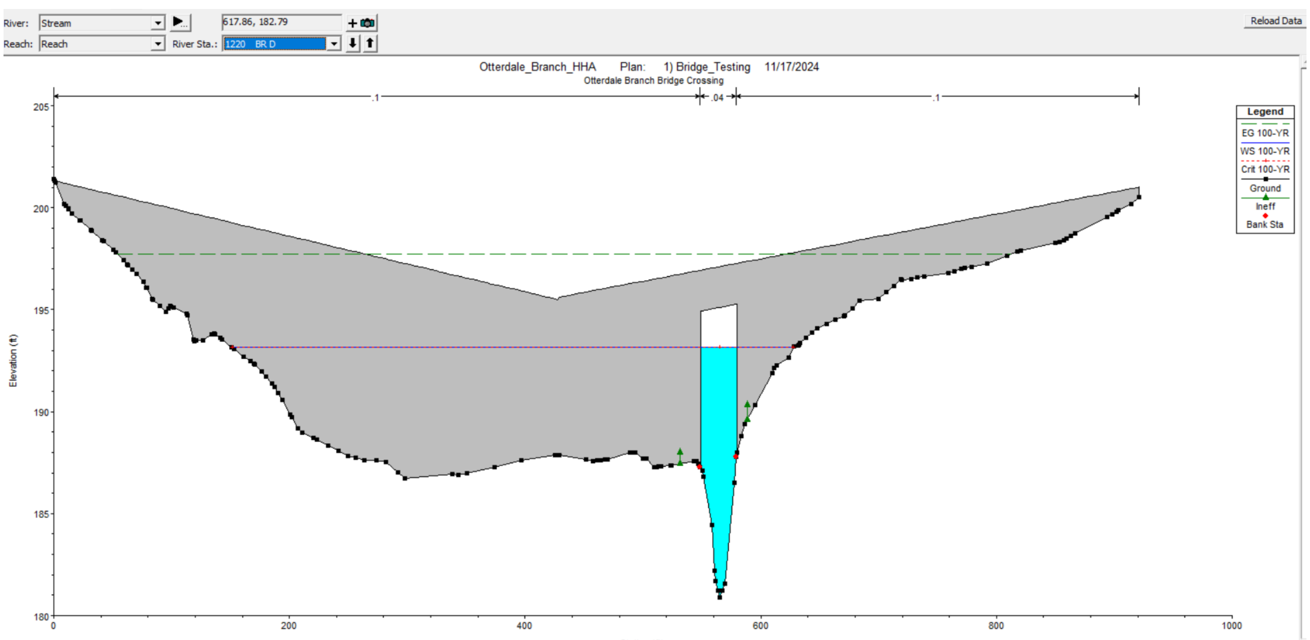

Figure P1.3. Initial Bridge Model Downstream Cross Section View Without Flooding but High Water Surface Elevation

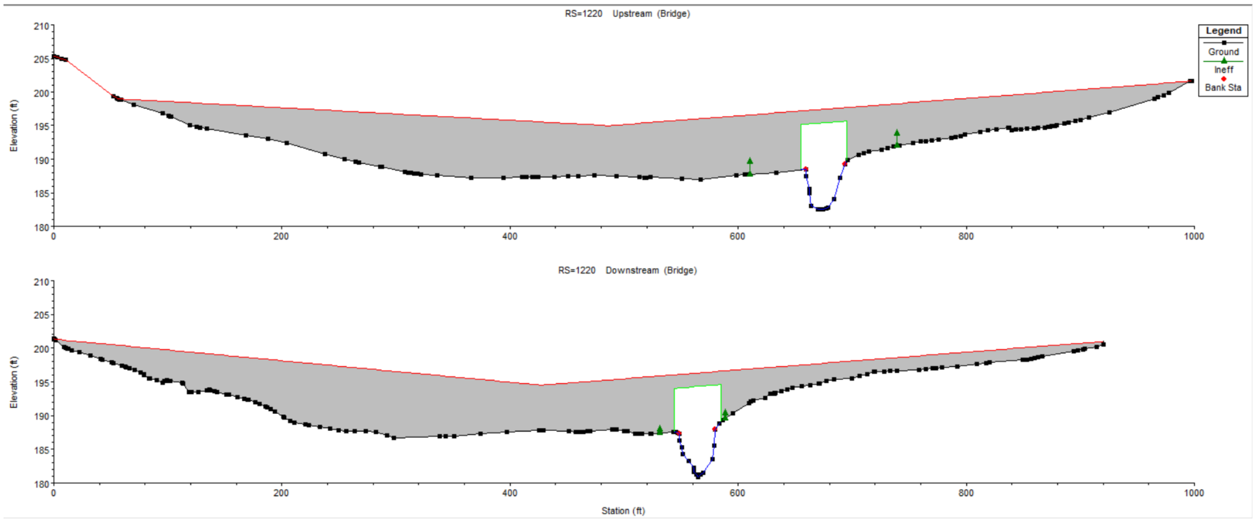

Figure P1.4. Bridge Model Profile View with Adjusted Stream Bed to Lower Water Surface Elevation

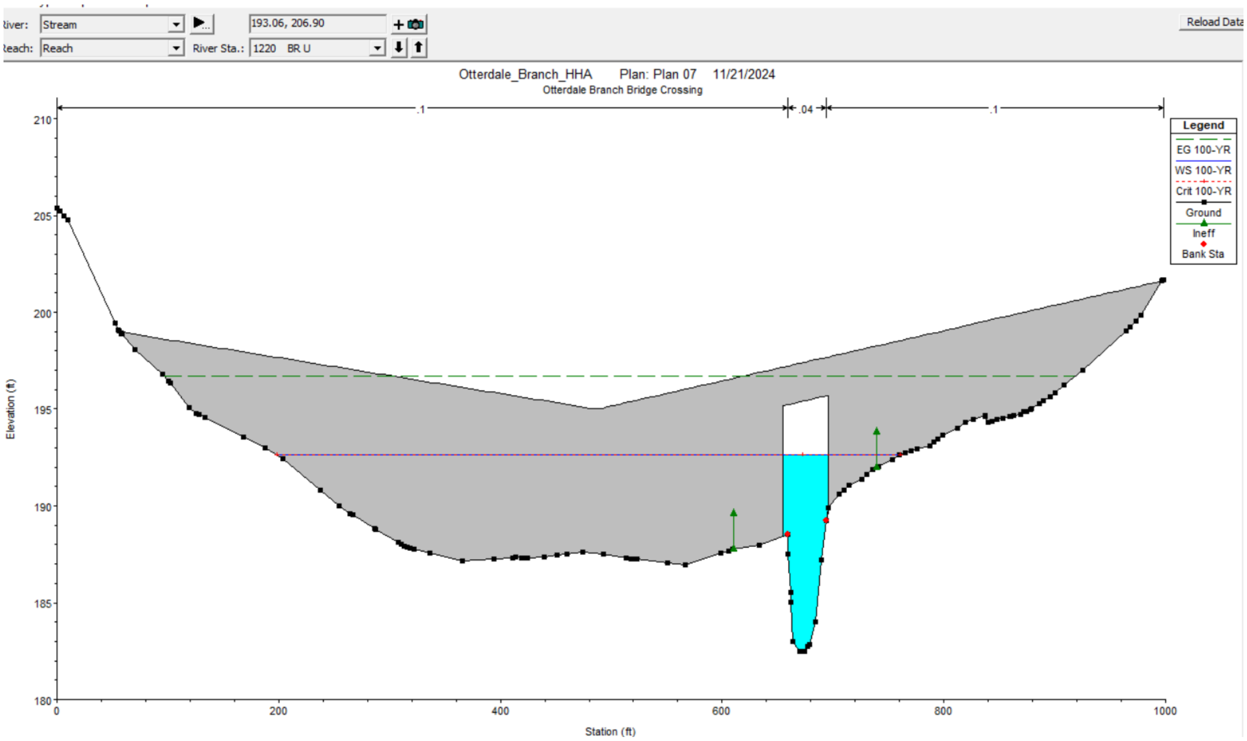

Figure P1.5. Bridge Model Upstream Cross Section with Adjusted Stream Bed to Lower Water Surface Elevation

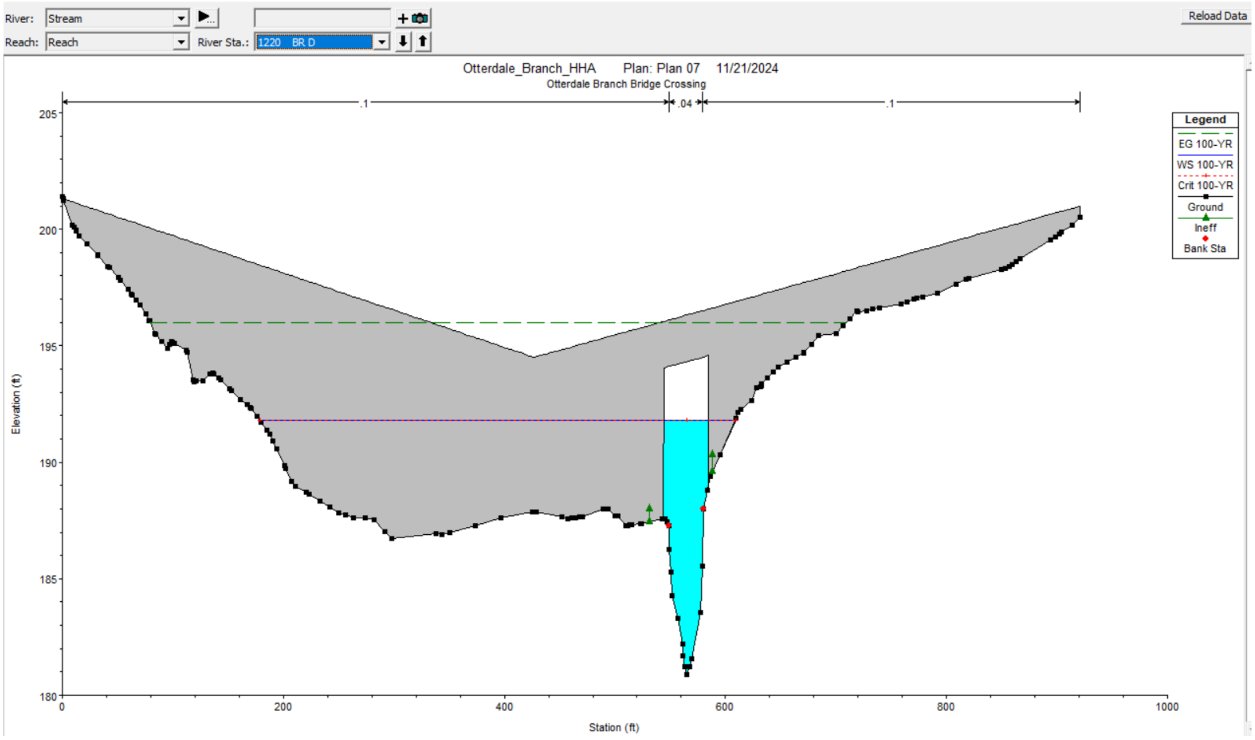

Figure P1.6. Bridge Model Downstream Cross Section with Adjusted Stream Bed to Lower Water Surface Elevation

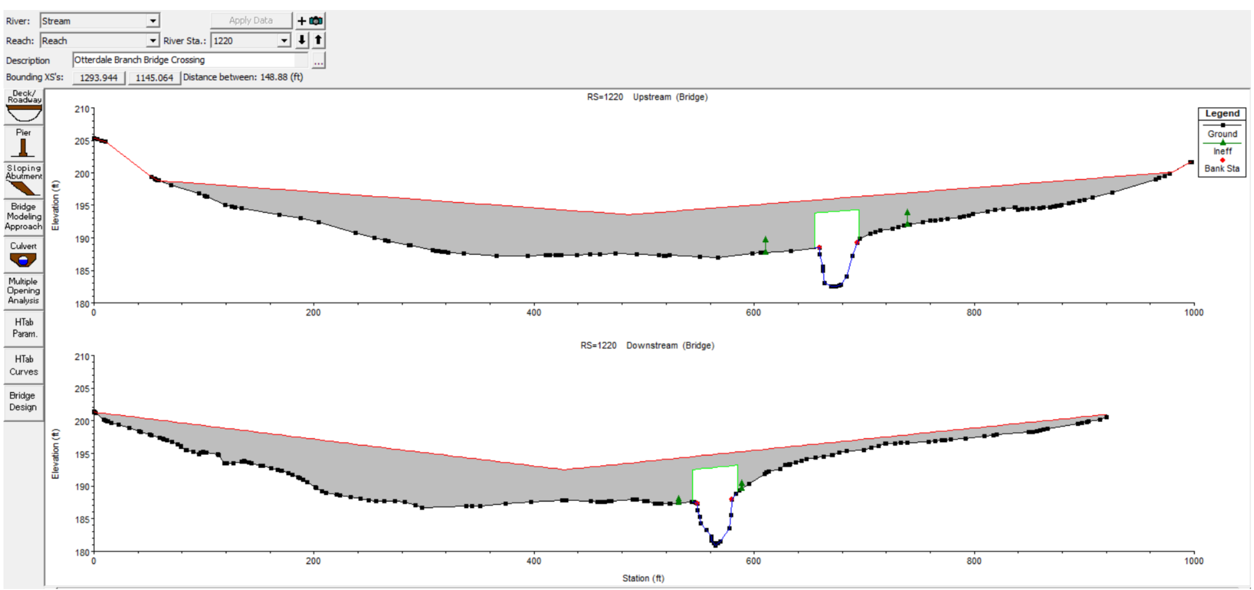

Figure P1.7. Bridge Model Profile View with Lowered Road Elevation and Adjusted Streambed

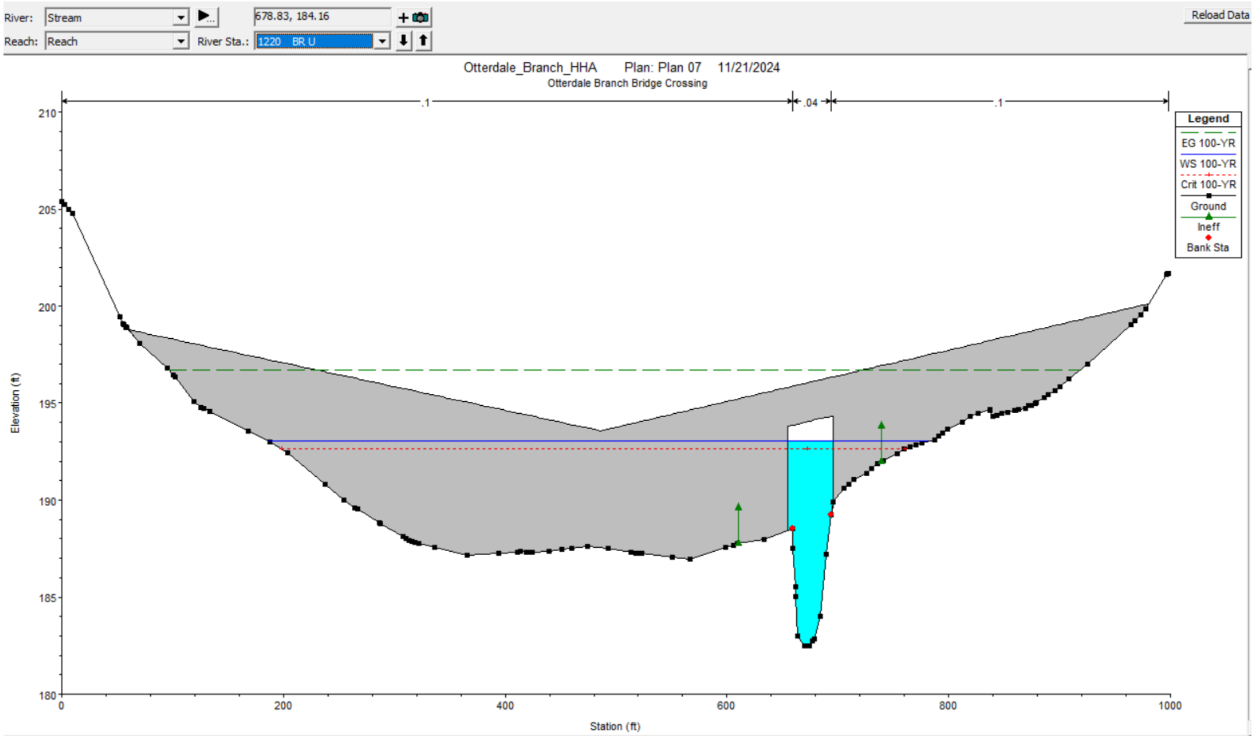

Figure P1.8. Bridge Model Upstream Cross Section with Lowered Road Elevation and Adjusted Streambed

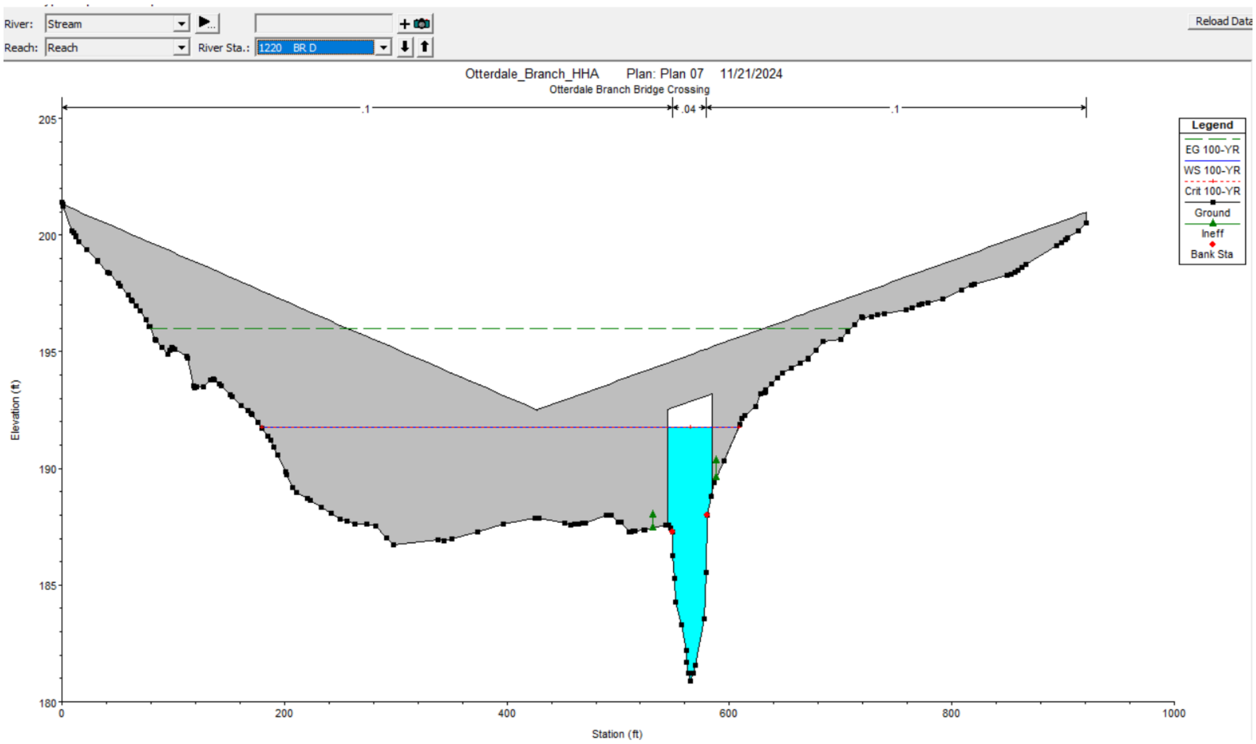

Figure P1.9. Bridge Model Downstream Cross Section with Lowered Road Elevation and Adjusted Streambed

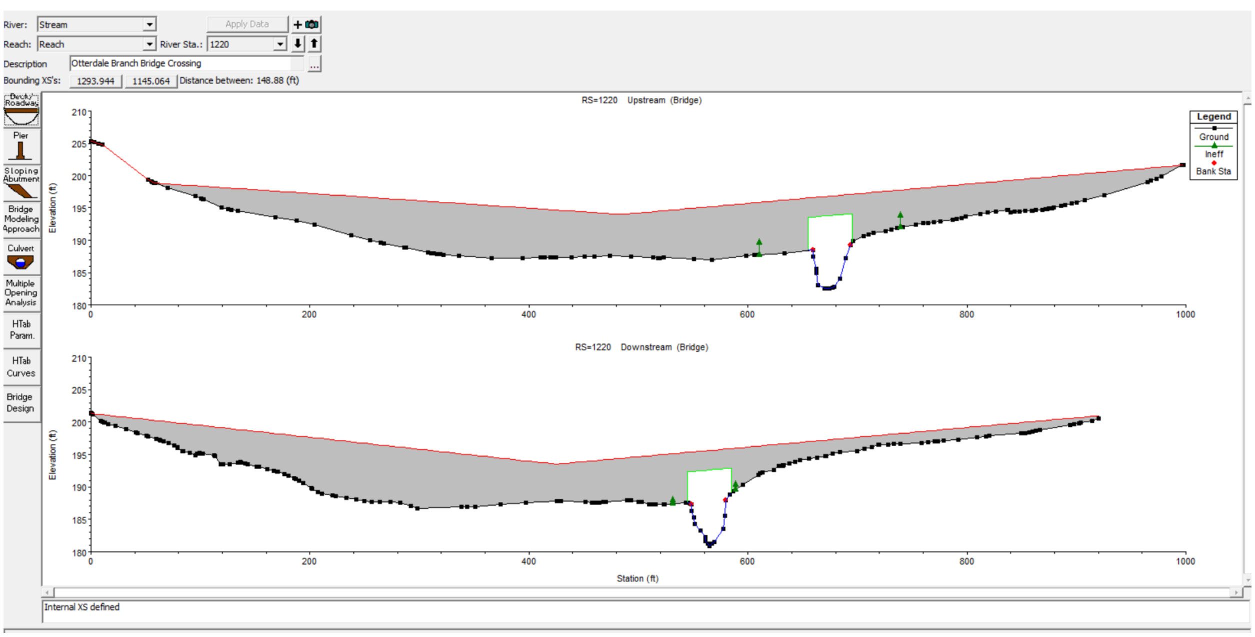

Figure P1.10. Bridge Model Profile View with 3’ Bridge Superstructure Height

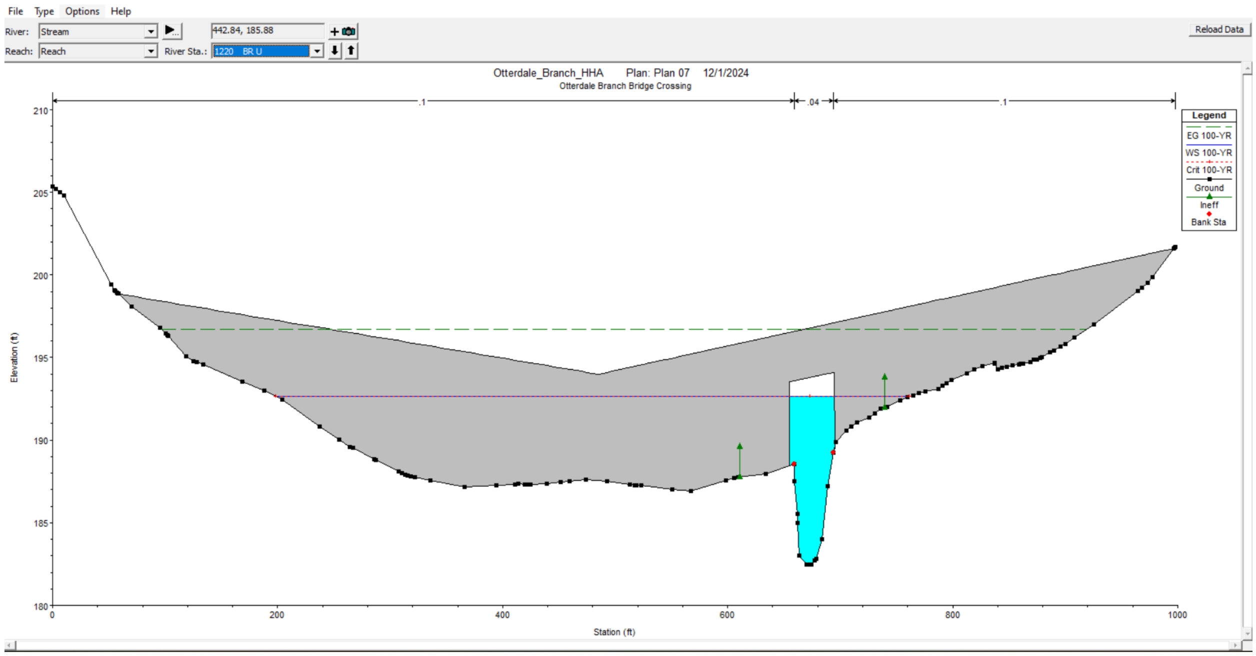

Figure P1.11. Bridge Model Upstream Cross Section with 3' Bridge Superstructure Height

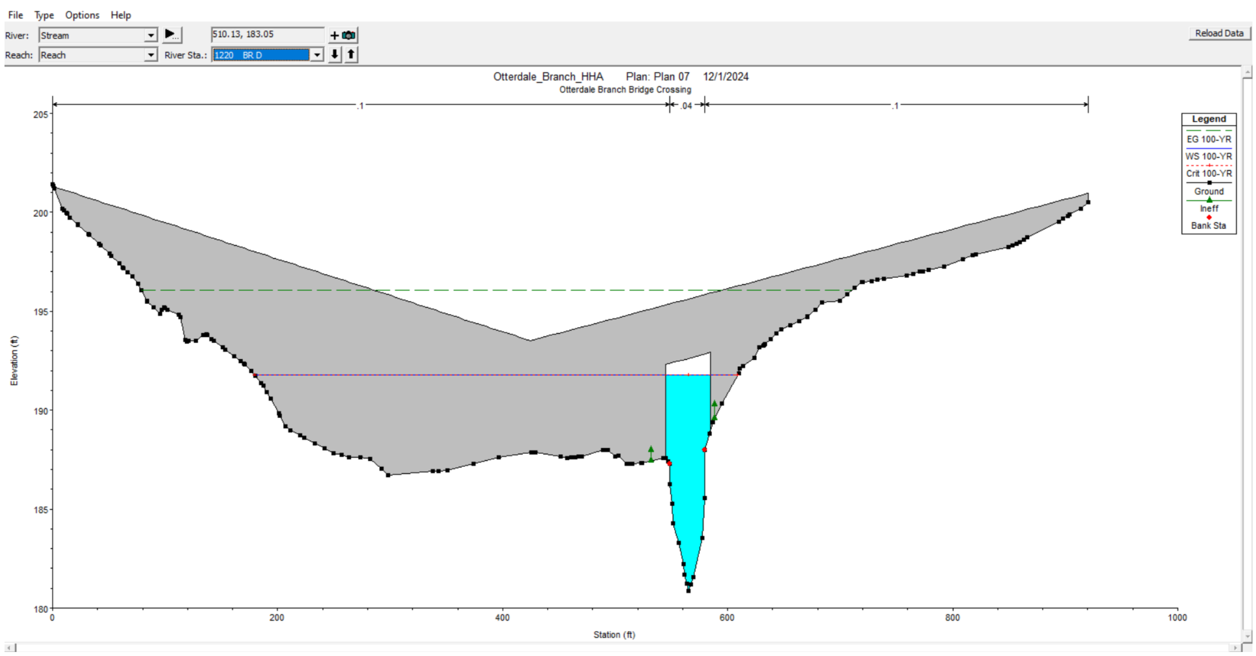

Figure P1.12. Bridge Model Downstream Cross Section with 3' Bridge Superstructure Height

Section 2. Preliminary Proposed Roadway Designs

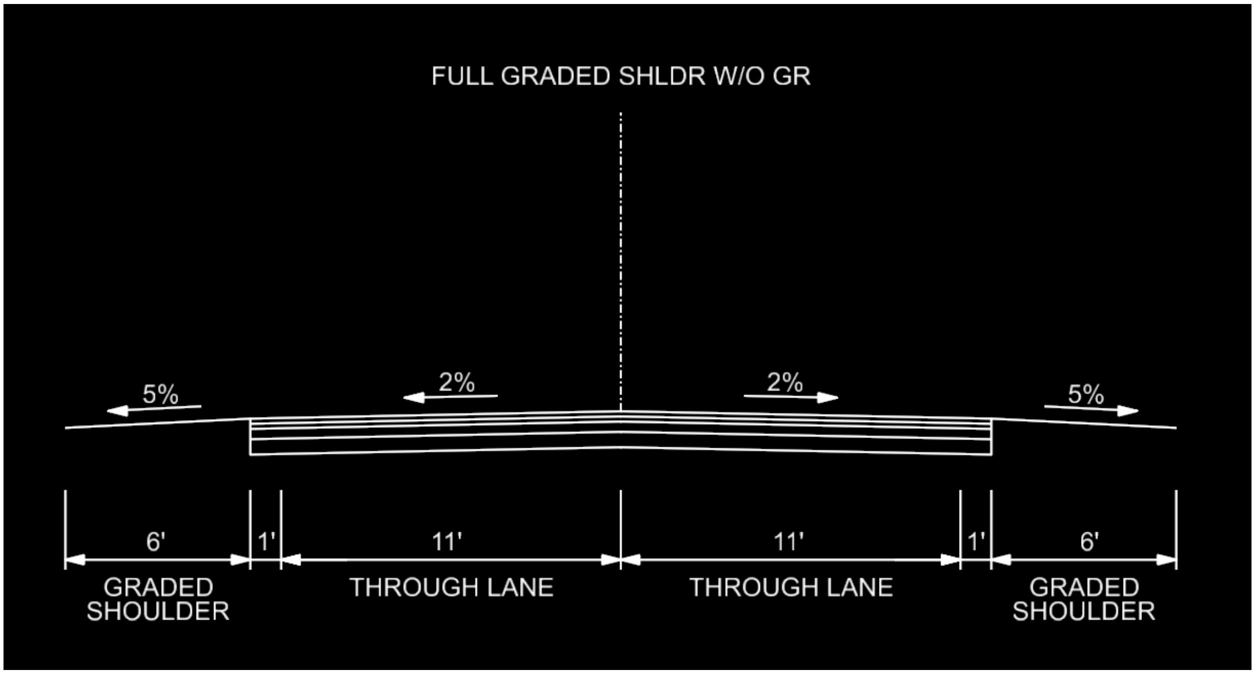

Figure P2.1. Typical Section of Undivided Two-Lane Rural Collector with Full Graded Shoulder, No Guardrail

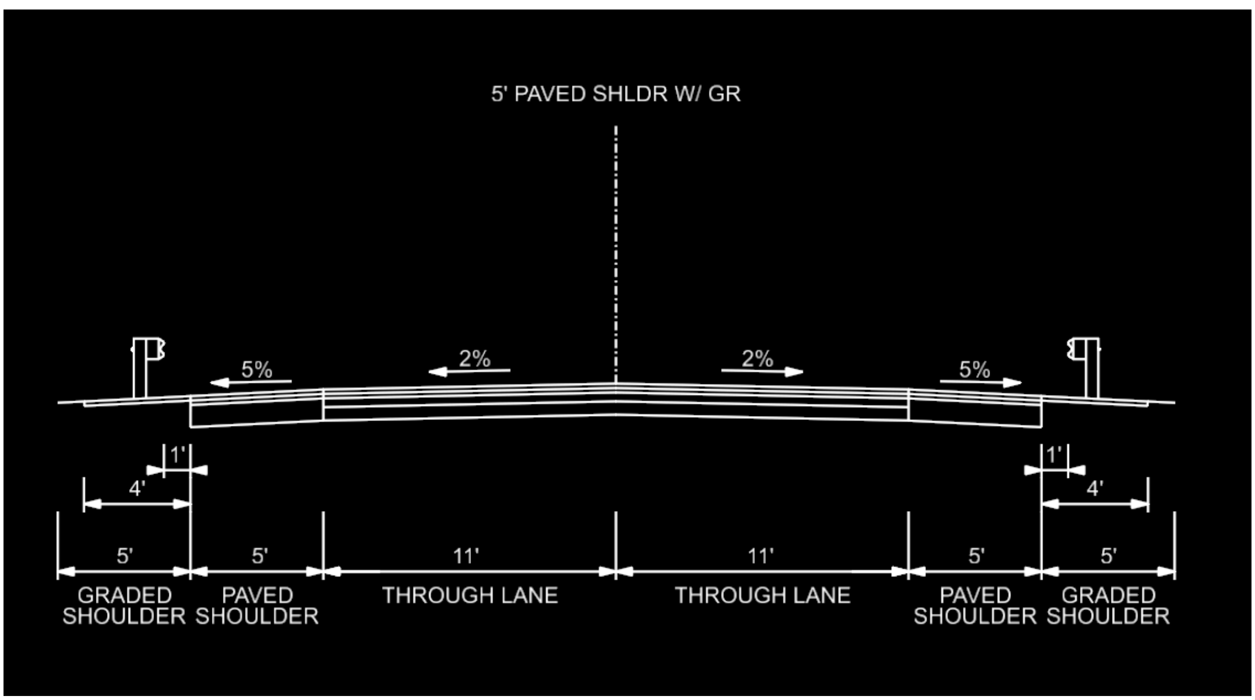

Figure P2.2. Typical Section of Undivided Two-Lane Rural Collector with Paved Shoulder and Guardrail

Section 3. Structure Placement

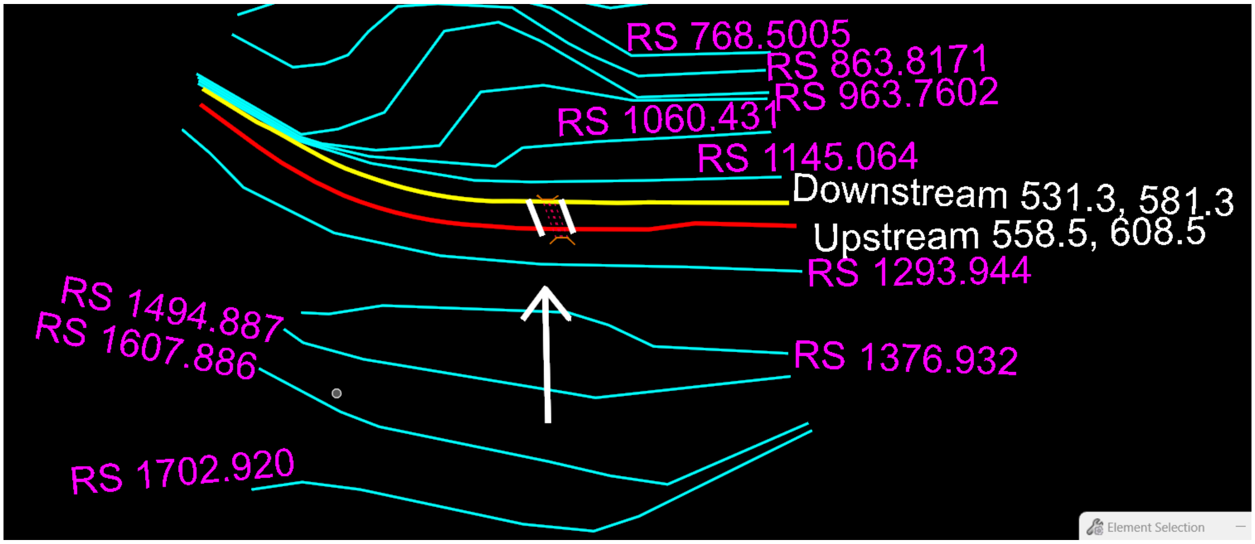

Figure P3.1. Outline of Bridge Placement Relative to Roadway Stations in OpenRoads

Appendix C: Design Standards

To determine if the 100 year storm was what we wanted to design for, we used standards from the Federal Emergency Management Association (FEMA). By looking at the FEMA floodplain maps, we found that the project area fell under Zone A and must be designed to a 100 year storm event.

- Link to standards: https://www.fema.gov/sites/default/files/documents/fema_approx-zone-a-guide.pdf
- Link to floodplain map of project site: https://msc.fema.gov/portal/search?AddressQuery=otterdale%20road%2C%20chesterfield%2C%20virginia

In order to determine the functional classification of Otterdale Road, VDOT's map based on LRS 22.1 was vital. This map contains data of all of the roads in the Commonwealth of Virginia, assigns a classification to each, and provides general statistics.

- Link to the map: https://vdot.maps.arcgis.com/home/item.html?id=19a0da5cfafb4c7ebf1473c222d5ec6f

The typical sections and all preliminary designs of the proposed roadway followed several procedures and guidance set by VDOT. In particular, the Road and Bridge Standards and Road Design Manual were utilized the most. These documents gave insight to design criteria, such as minimum lane widths, guardrail installation, shoulder types, grading, etc.

- Link to Road and Bridge Standards: https://www.vdot.virginia.gov/doing-business/technical-guidance-and-support/technical-guidance-documents/road-and-bridge-standards/

- Link to Road Design Manual: https://www.vdot.virginia.gov/doing-business/technical-guidance-and-support/technical-guidance-documents/road-design-manual/

When assessing the HEC-RAS proposed model for whether it passed the 100 year storm, the water surface elevation was checked based upon FEMA Standards for Allowable Base Flood Elevation Increases. These standards were found in VDOT Drainage Manual Chapter 17 in Table 17-1. Allowable Base Flood Elevation(BFE) Increases

- FEMA Zone A Area: Increase in BFE: 1.0'
- Client requested even more stringent requirements of no base flood elevation increase, which required us to not raise the water surface elevation at all from existing to proposed model
- Link to Chapter 17 of VDOT Drainage Manual: https://www.vdot.virginia.gov/media/vdotvirginiagov/doing-business/technical-guidance-and-support/technical-guidance-documents/location-and-design/migrated/drainagemanual/chapter17_acc10172023_PM.pdf

Chesterfield County Client had a requirement of 4" of freeboard, or distance from the water surface elevation of design storm event to low chord of bridge. This was confirmed when modeling the bridge structure in HEC-RAS.

Calculation of minimum superstructure depth, useful in determining clear height for opening and opening area of a desired structure, was done using formulas from AASHTO LRFD Bridge Design Specifications Table 2.5.2.6.3-1

- Link to AASHTO LRFD Bridge Design Specifications https://s36d44bae16611495.jimcontent.com/download/version/1650043778/module/11581789993/name/AASHTO_LRFD_Bridge_Design_Specifications.pdf

Selection of beams used to support the bridge structure was based on the VDOT Structure and Bridge Manual. After selection of a bulb-T beam, 12.03-1 was used to determine beam spacing and number of beams, 12.03-5 was used to determine the beam designation, directly influencing beam depth. 12.03-6 was used to determine deck slab thickness.

- Link to Chapter 12 of VDOT Structure and Bridge Manual https://www.vdot.virginia.gov/media/vdotvirginiagov/doing-business/technical-guidance-and-support/technical-guidance-documents/structure-and-bridge/manuals-of-structure-and-bridge-acc/part2/Chapter12.pdf
- Link to Contech Engineered Solutions Structures Reference Guide (investigated initially, proved to not be useful at Otterdale Branch) https://www.conteches.com/media/u5cesoyb/structures-reference-guide.pdf

The Virginia Runoff Reduction Method(VRRM) or a similar method in compliance with the Department of Environmental Quality(DEQ) standards is required by the Virginia Stormwater Management Program(VSMP) for redevelopment projects in Virginia. The VRRM 4.1 Redevelopment spreadsheet will be used to determine the necessary stormwater management practices needed on the site and is attached as an appendix in Appendix D, Section 6.

The 42”-CPSR Railing (CPSR-1) design standards are located in the VDOT Structures Manual, and provide exact dimensions for implementation. The CPSR-1 is crash tested & VDOT approved, includes reflectors, and has an opening in the railing to pass overtopping stormwater. An openroads compatible design (.dgn) file was able to be obtained displaying the exact specifications of the CPSR-1, and implemented into the typical section.

-Link to the 42”-CPSR Railing (CPSR-1) Design Standard
chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.vdot.virginia.gov/media/vdotvirginiagov/doing-business/technical-guidance-and-support/technical-guidance-documents/structure-and-bridge/manuals-of-structure-and-bridge-acc/part3/CPSR-1.pdf

According to the VDOT Drainage Manual, Chapter 11, Section 11.4.2.1 standard that says that if the site’s contributing drainage area is less than 1% of the total watershed area, the additional water quantity of flow from the project does not need to be managed. This was found to be true in this project’s case, so additional stormwater management practices for quantity were not designed.

Street closure operations with detour standards are located in the 2011 VDOT Virginia Work Area Protection Manual. Sections TTM 34.2 and TTM 48.2 indicate where detour/road closure signage is placed temporarily during construction, and how workers will be protected from traffic.

-Link to 2011 VDOT Work Area Protection Manual:
chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.vdot.virginia.gov/media/vdotvirginiagov/doing-business/technical-guidance-and-support/technical-guidance-documents/traffic-operations/2011_WAPM_REV_2_1_acc03252025_RM.pdf

When designing the on-site BMP, we did so in accordance with the design specifications listed in the VDOT BMP Design Specification Manual; Bioretention specifications are listed in Chapter 7 Section 7.3.

Appendix D: Technical Deliverables

Folder with All Supporting Files: Supporting Materials

Relevant Design Work
Section 1. HEC-RAS Existing Conditions Model Analysis

Table R1. Cross Sections for Ultimate Land Use

Station	WS elevations(ft)
1494.887	193.02
1376.932	192.7
1293.944	192.58
1220 Culv U	192.58
1220 Culv D	191.31
1145.064	191.28
1060.431	191.11
963.7602	190.85

Table R2. Steady Flow Peak Flow Analysis of Existing Land Use

Design Storm (yr)	Peak Flow(cfs)
2	678
10	1660
50	3111
100	3885
500	6126

Table R3. Steady Flow Peak Flow Analysis of Ultimate Land Use

Design Storm (yr)	Peak Flow(cfs)
2	1174
10	2346
50	3929

100	4747
500	7036

Table R4. HEC-RAS Reach Profile Information for 100 year Storm in Ultimate Land Use Conditions

HEC-RAS Plan: Exist_Ult_Land_Use River: Stream Reach: Reach Profile: 100-YR

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	3644.775	100-YR	4747.00	191.01	199.18		199.54	0.003225	7.28	1683.90	427.91	0.49
Reach	3446.826	100-YR	4747.00	188.95	198.04		198.70	0.005399	9.27	1306.49	363.39	0.64
Reach	3234.580	100-YR	4747.00	188.64	197.58		197.85	0.002348	6.23	2013.22	533.32	0.42
Reach	2981.468	100-YR	4747.00	188.16	197.31		197.42	0.001089	4.56	2780.55	580.33	0.29
Reach	2730.851	100-YR	4747.00	187.48	196.67		197.04	0.002652	6.88	1655.78	387.86	0.46
Reach	2478.311	100-YR	4747.00	187.12	196.16		196.40	0.002196	6.03	1974.26	463.42	0.41
Reach	2305.541	100-YR	4747.00	186.53	195.71		195.97	0.002492	6.48	1771.02	358.20	0.44
Reach	2220.263	100-YR	4747.00	185.01	195.15		195.70	0.003183	7.33	1275.04	291.14	0.49
Reach	2119.902	100-YR	4747.00	185.14	194.59		195.33	0.004870	8.98	1175.85	292.71	0.61
Reach	2016.316	100-YR	4747.00	184.25	194.33		194.76	0.003900	7.60	1474.41	361.34	0.53
Reach	1912.924	100-YR	4747.00	185.02	193.94		194.32	0.004300	7.95	1601.91	431.71	0.55
Reach	1808.303	100-YR	4747.00	184.39	193.75		193.97	0.002129	5.90	2071.41	492.59	0.39
Reach	1702.920	100-YR	4747.00	183.67	193.56		193.70	0.001846	4.95	2284.46	515.22	0.36
Reach	1607.886	100-YR	4747.00	183.77	193.30		193.50	0.002196	5.97	2101.25	488.96	0.40
Reach	1494.887	100-YR	4747.00	183.20	193.02		193.25	0.002539	6.39	1966.70	463.82	0.43
Reach	1376.932	100-YR	4747.00	182.67	192.70		192.96	0.002970	6.50	1723.68	387.93	0.46
Reach	1293.944	100-YR	4747.00	182.47	192.58	189.93	192.73	0.001726	5.42	2365.70	558.58	0.35
Reach	1220		Culvert									
Reach	1145.064	100-YR	4747.00	180.87	191.28	190.10	191.74	0.004095	8.25	1549.41	417.35	0.54
Reach	1060.431	100-YR	4747.00	180.15	191.11		191.55	0.002516	7.18	1667.71	424.96	0.43
Reach	963.7602	100-YR	4747.00	181.03	190.85		191.33	0.003826	7.90	1578.63	451.94	0.52
Reach	863.8171	100-YR	4747.00	181.27	190.59		190.92	0.003688	7.22	1745.18	486.19	0.51
Reach	768.5005	100-YR	4747.00	181.21	190.31		190.66	0.004416	7.45	1609.90	458.48	0.55
Reach	656.6091	100-YR	4747.00	180.90	190.09		190.38	0.004275	7.09	1674.98	454.62	0.53
Reach	507.1092	100-YR	4747.00	180.70	189.95		190.16	0.002853	6.31	2078.11	577.11	0.45
Reach	425.9626	100-YR	4747.00	181.02	189.73		189.87	0.002117	5.54	2445.56	652.26	0.39
Reach	353.1680	100-YR	4747.00	180.51	189.59		189.70	0.001701	4.81	2658.59	666.08	0.34
Reach	247.4904	100-YR	4747.00	180.49	189.40		189.53	0.001943	5.08	2414.38	604.53	0.37
Reach	148.1003	100-YR	4747.00	179.25	189.21		189.35	0.001782	5.37	2434.58	581.18	0.35
Reach	78.09373	100-YR	4747.00	181.34	189.03	187.02	189.22	0.002304	5.79	2180.94	559.01	0.41

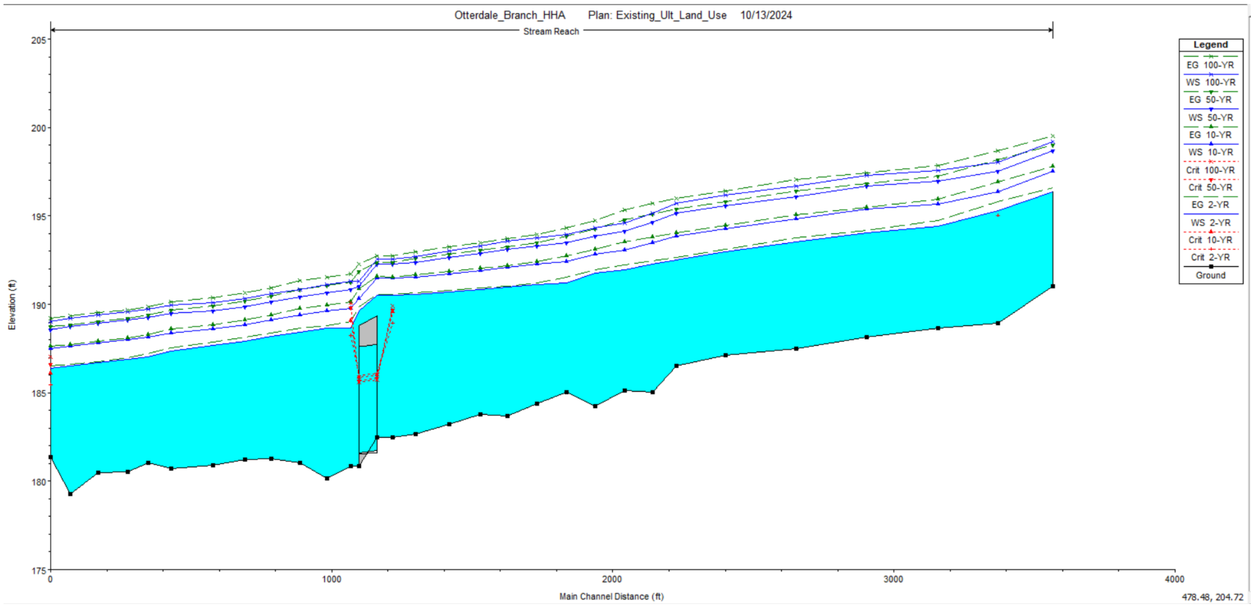

Figure R1.1. Profile View of Channel with Existing Culvert in Ultimate Land Use Conditions

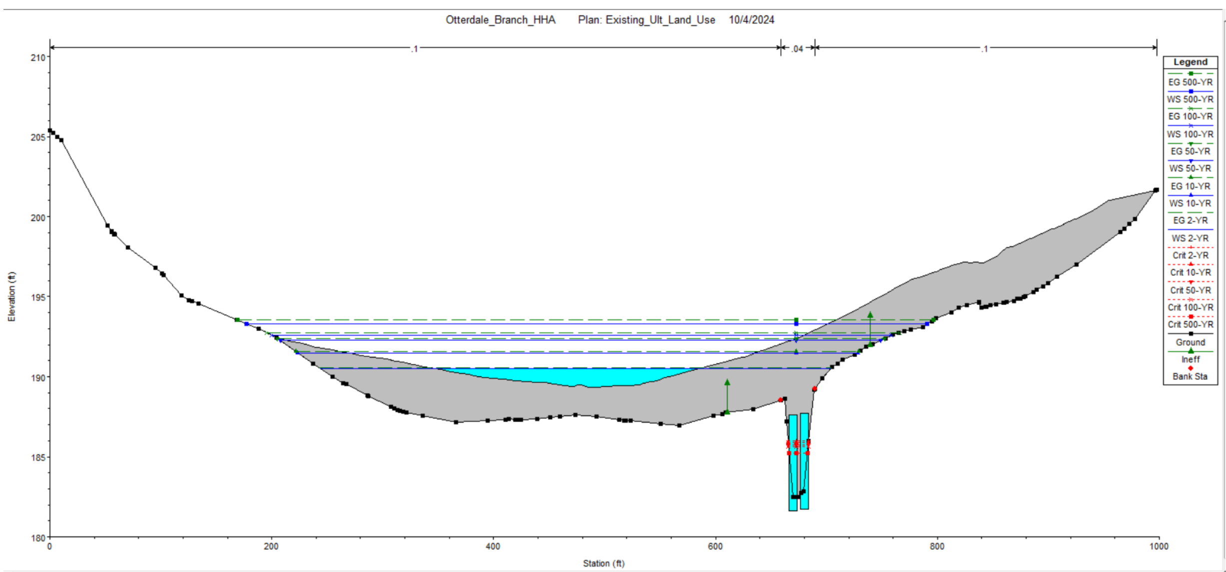

Figure R1.2. Cross Section View of Existing Culverts in Ultimate Land Use Conditions

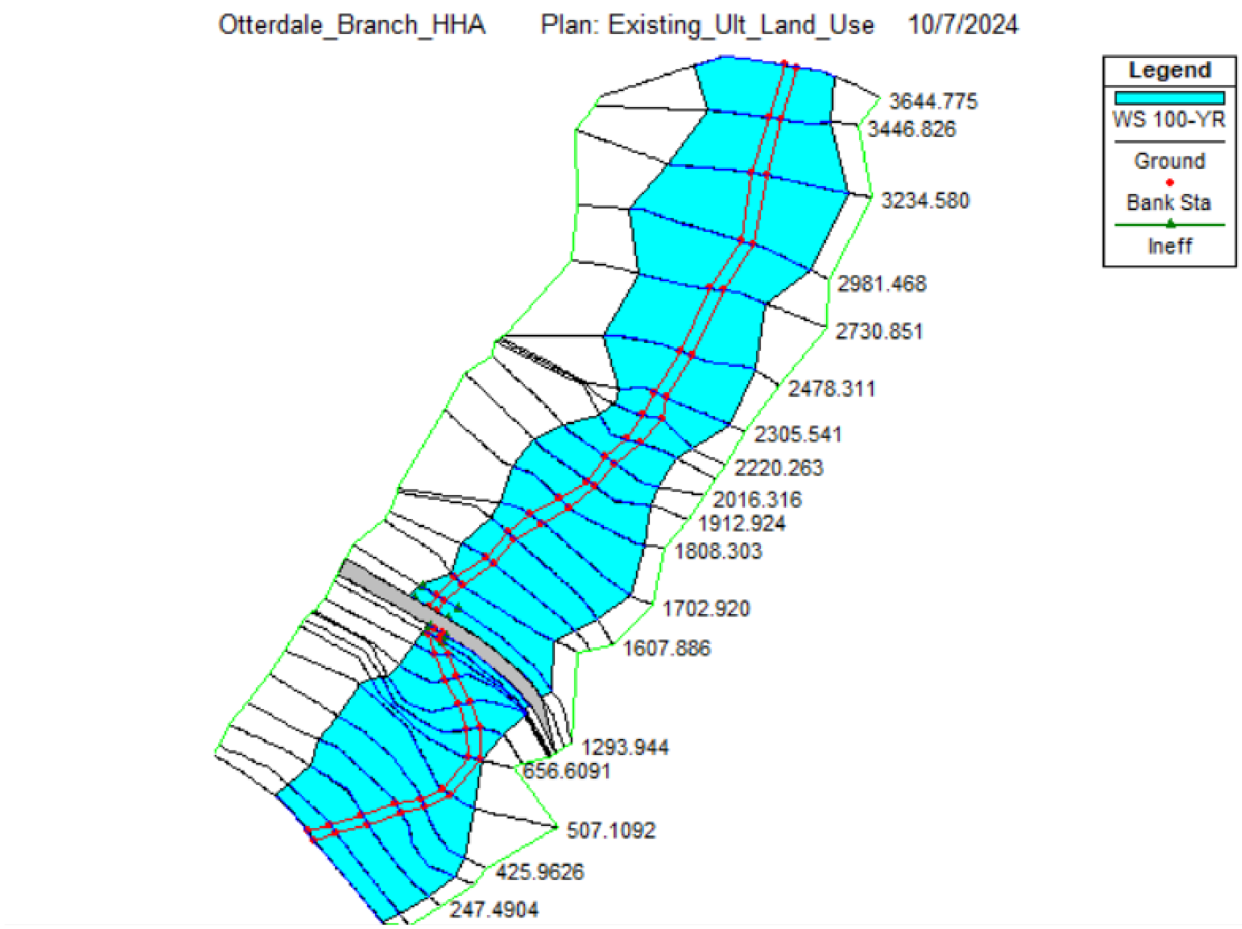

Figure R1.3. Plan View of Stream in Ultimate Land Use Conditions

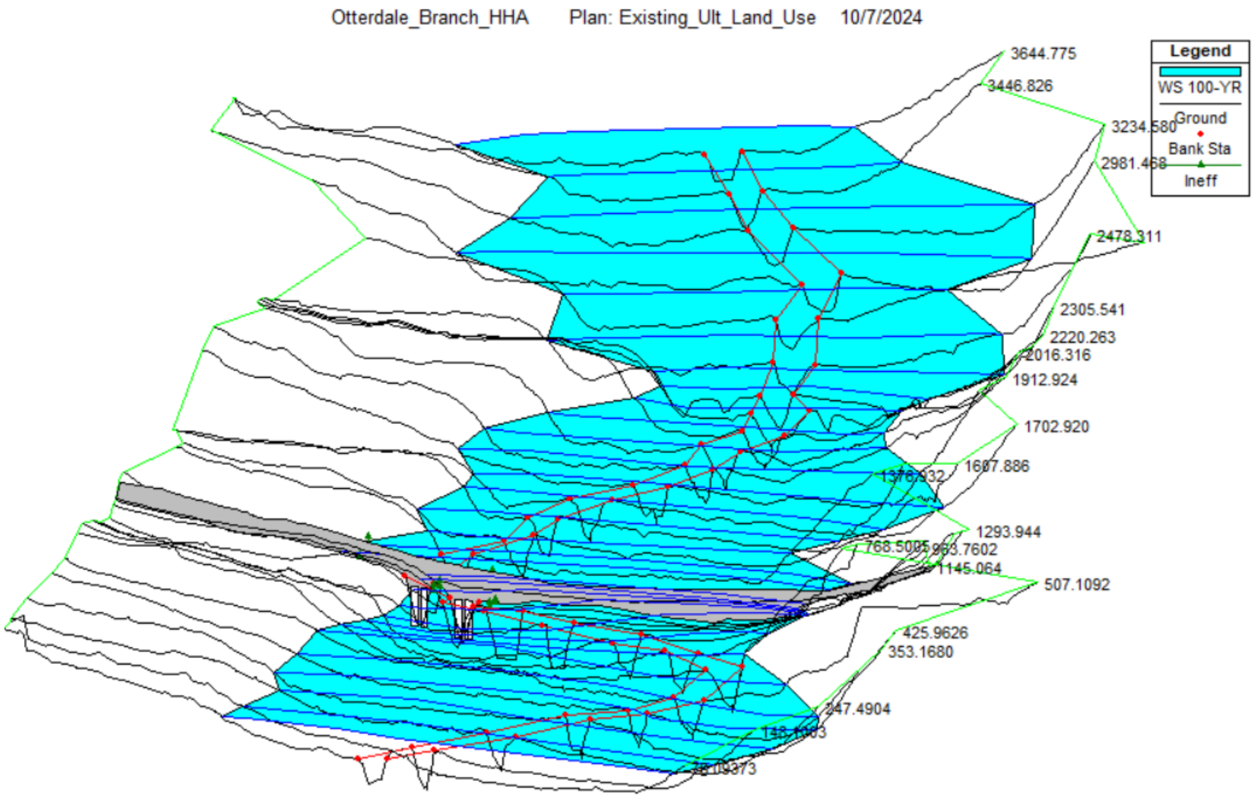

Figure R1.4. Surface view, 15 degree Azimuth angle, of Stream in Ultimate Land Use Conditions

Section 2. Drainage Area Determination and Watershed Analysis

Figure R2.1. Topographic GIS Drainage Area Delineation

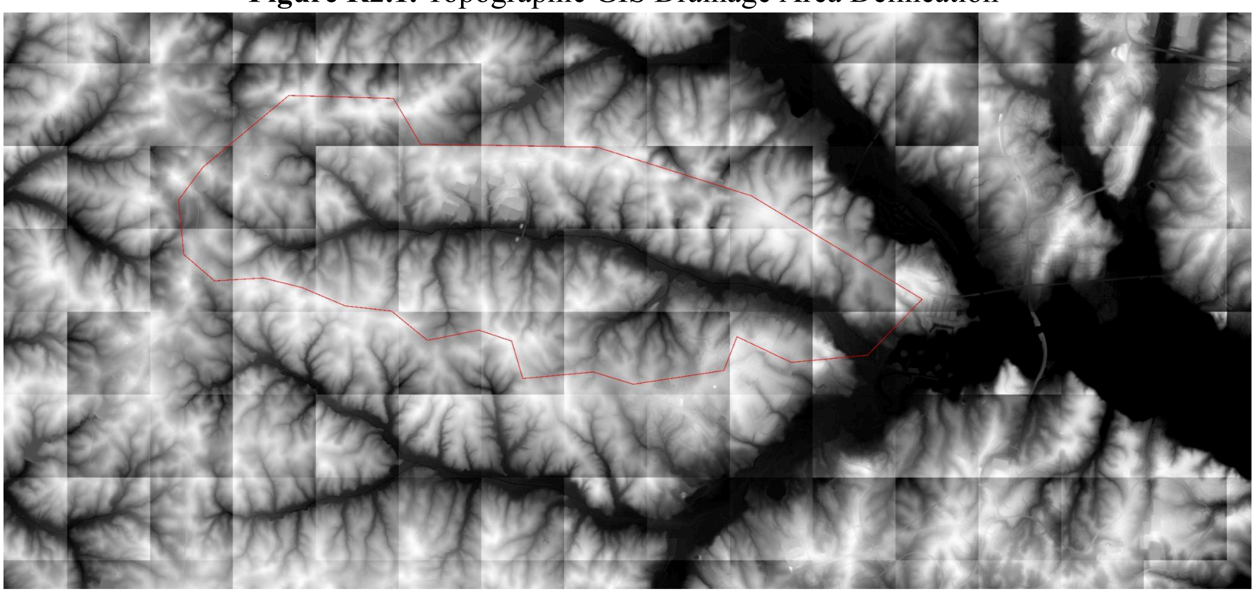

Figure R2.2. DEM(slopes) Drainage Area Delineation

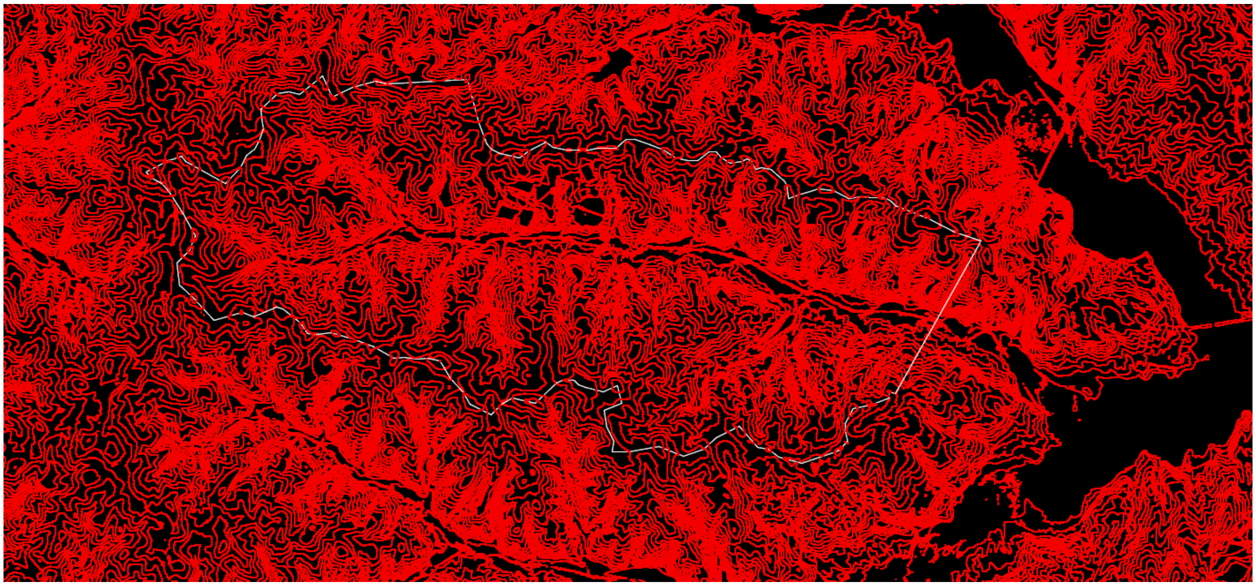

Figure R2.3. 5’ Contours Drainage Area Delineation

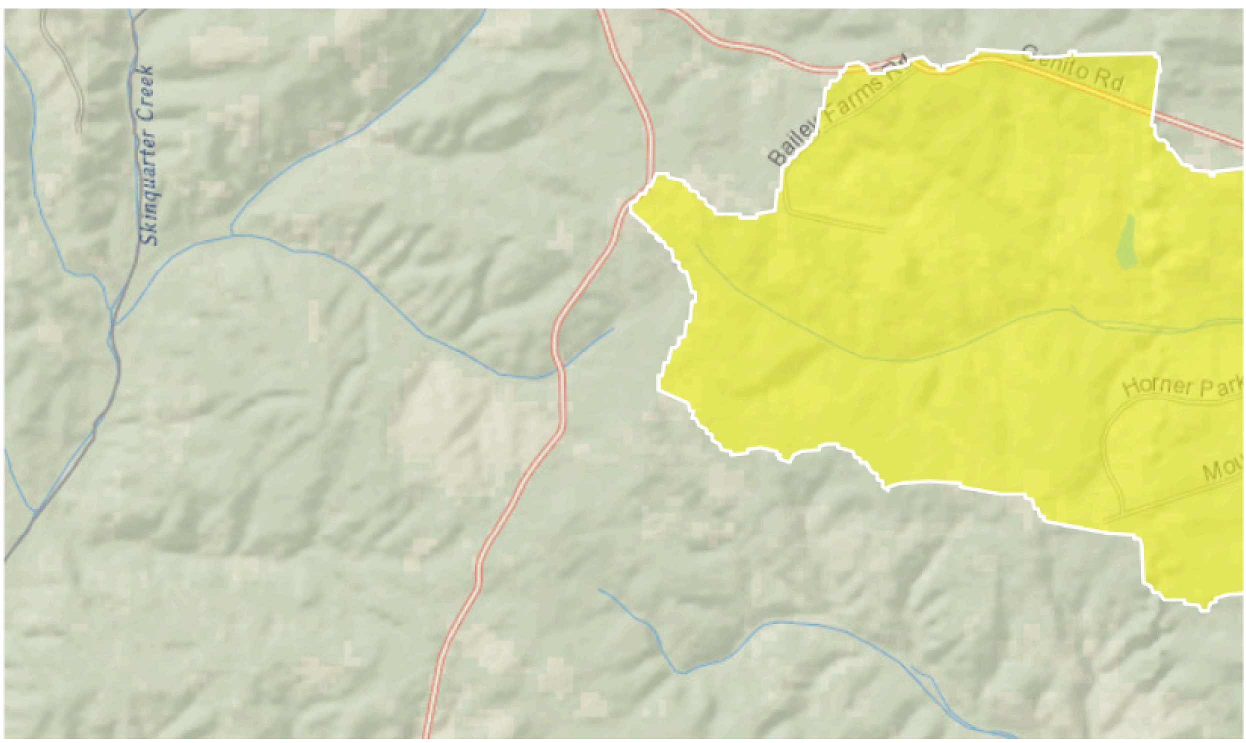

Figure R2.4. StreamStats Drainage Area

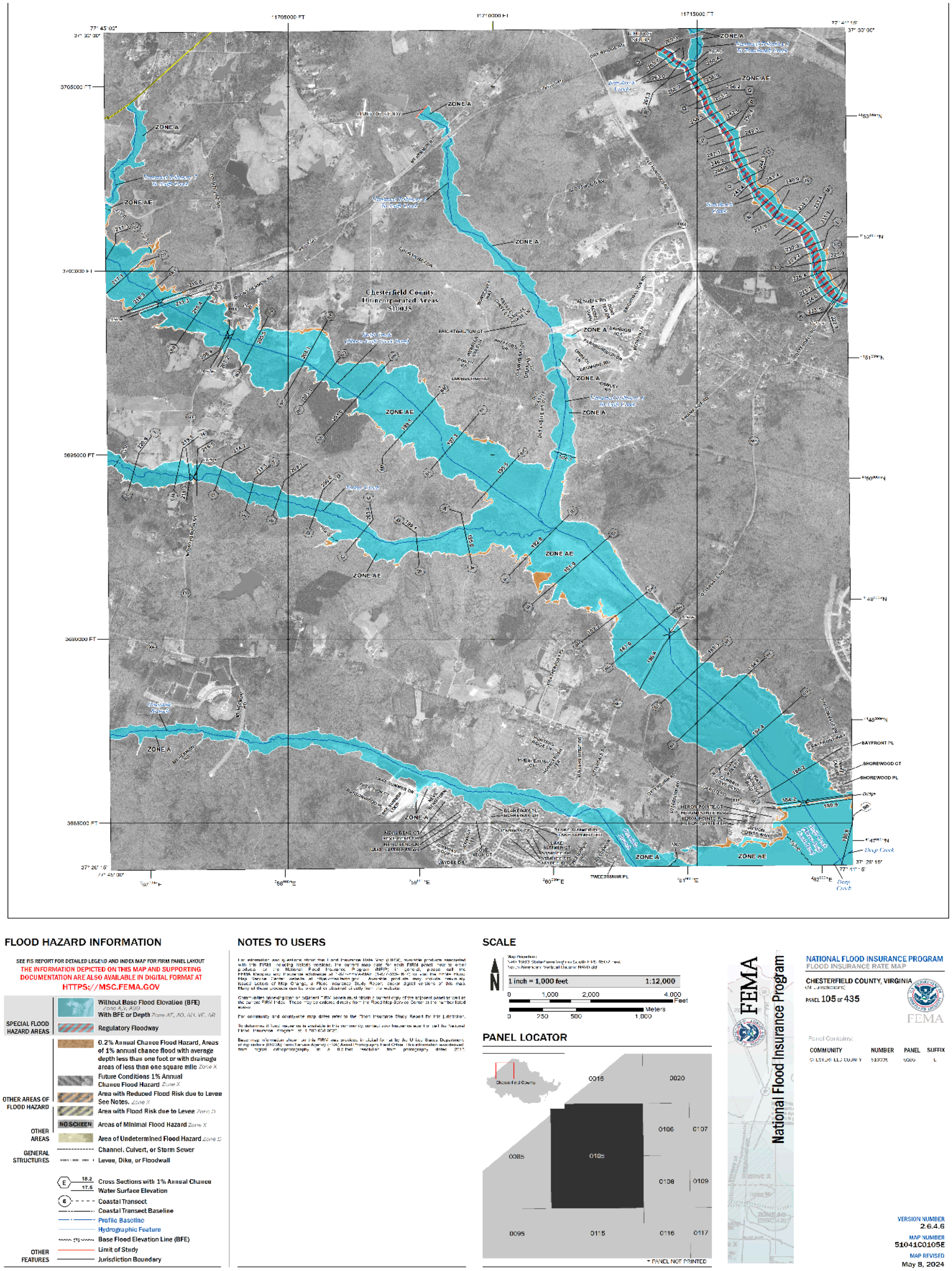

Figure R2.5. FEMA Floodplain Determination (Source: FEMA Flood Map Service Center)

FEMA Flood Map Service Center Source Link:
https://msc.fema.gov/portal/search?AddressQuery=otterdale%20road%2C%20chesterfield%2C%20virginia
Project Area is within FEMA floodplain mapping Zone A which classifies it as being vulnerable to 100 year storms.
Source providing guidance on development in Zone A areas:
https://www.fema.gov/sites/default/files/documents/fema_approx-zone-a-guide.pdf

Existing Land Use Details
From Chesterfield Comprehensive Plan and GIS Supplement:

- Areas surrounding potential development (Otterdale Branch Crossing) classified as Suburban Residential I
- Implies more rural densities, allows for 1 residence per 1 acre land

Section 3. Intersection Analysis & Initial Traffic Rerouting Plan

Figure R3.1. Traffic Analysis Study Area

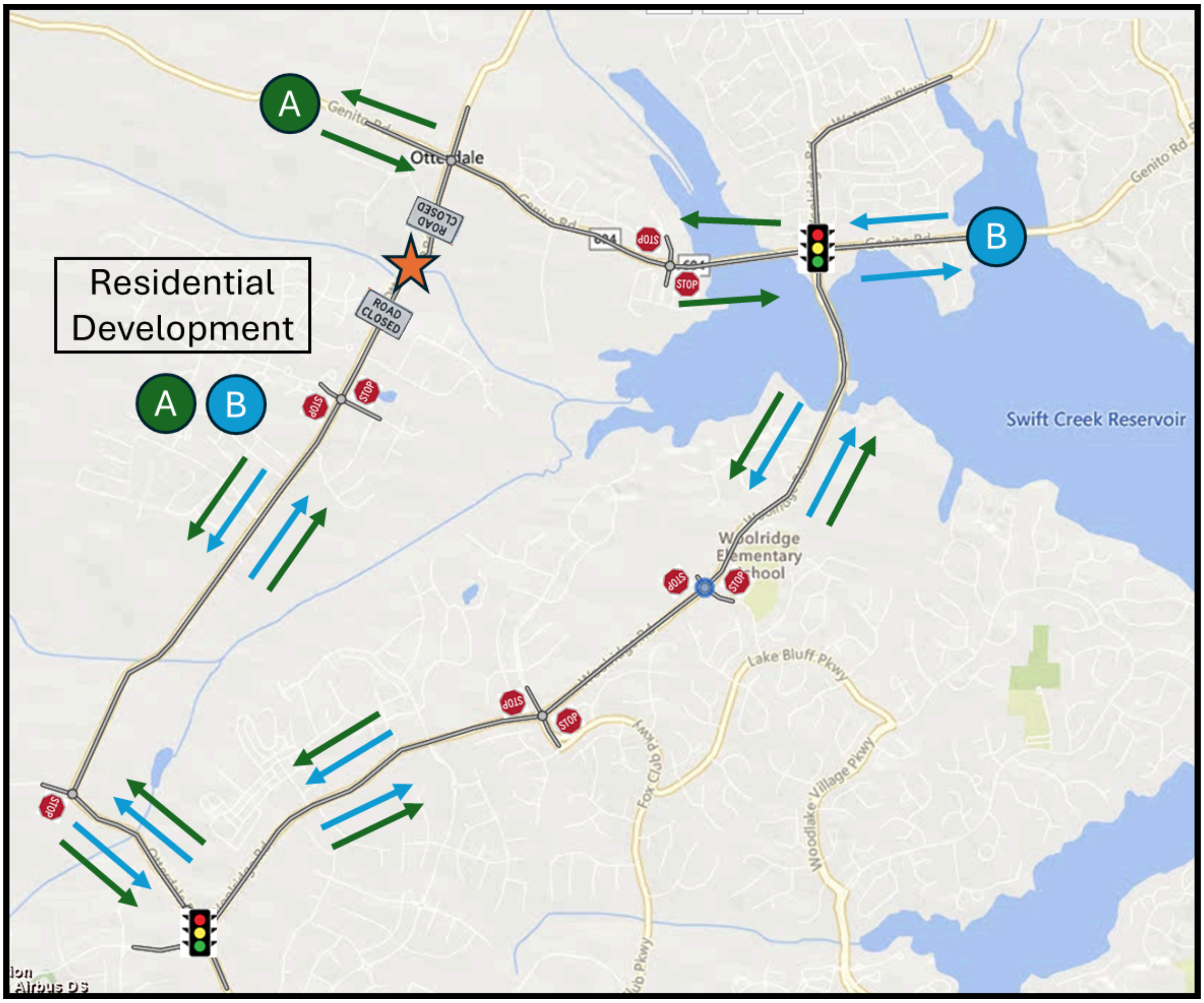

Figure R3.2. Initial Traffic Rerouting Plan

Table R5. Existing Conditions Intersection Analysis

Intersection	Level of Service (LOS)		Delay (seconds)	
	AM	PM	AM	PM
1: Otterdale Road and Genito Road (Roundabout)	A	A	4.72	5.12
2: Otterdale Road and Summer Lake Drive/Benmore Road (Two-Way Stop)	B	A	13.29	9.76
3: Otterdale Road and Duval Road (Two-Way Stop)	B	B	10.61	11.24
4: Otterdale Road and Woolridge Road (Signalized)	C	C	26.77	28.92
5: Woolridge Road and Fox Light Parkway/Fox Club Road (Two-Way Stop)	B	B	12.87	13.14
6: Woolridge Road and Timber Bluff Parkway (Two-Way Stop)	B	B	14.17	13.87
7: Woolridge Road and Genito Road (Signalized)	C	D	30.67	39.58
8: Genito Road and Water Overlook Boulevard/Heron Pointe Boulevard (Two-Way Sto	B	B	12.05	10.19

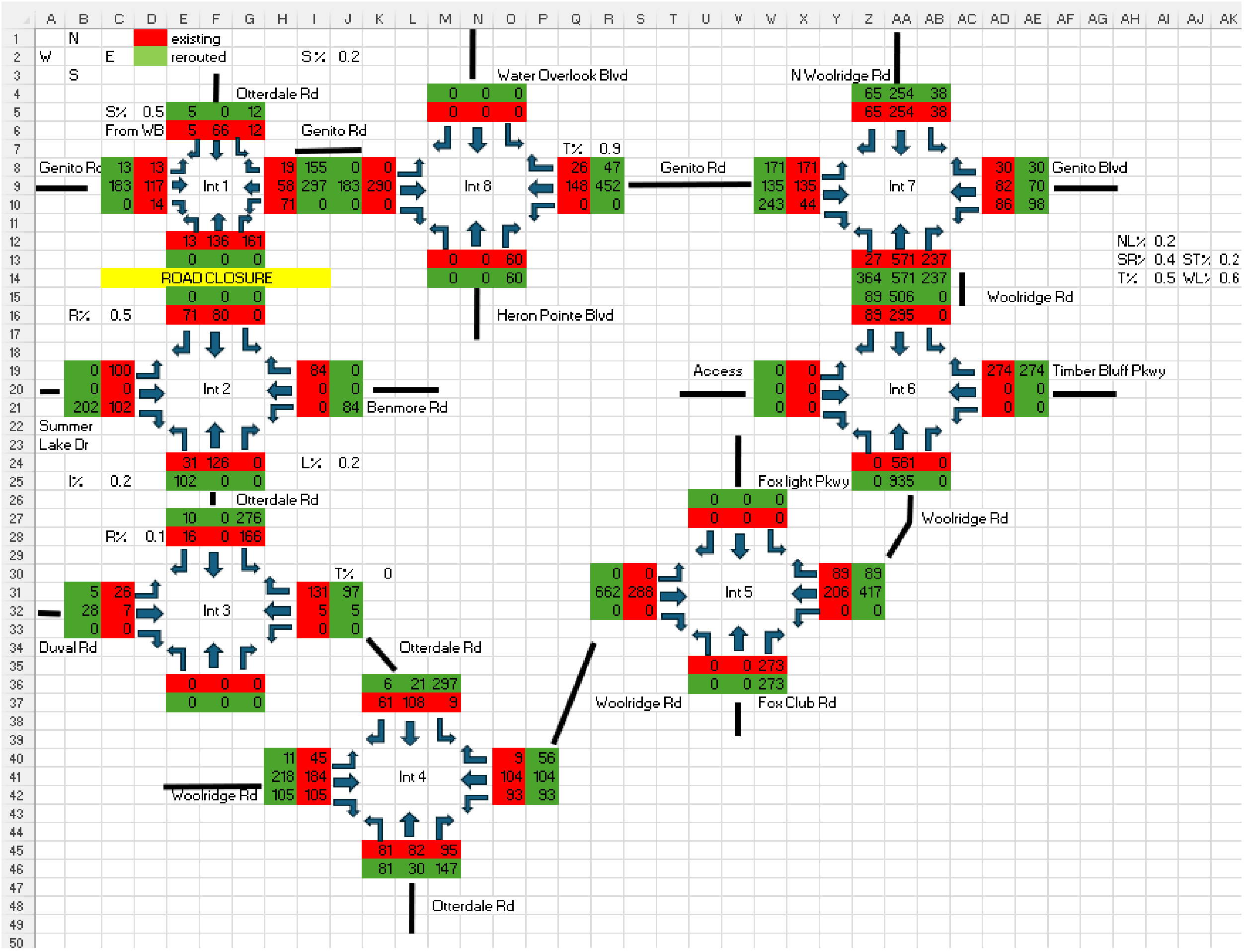

Figure R3.3. AM Rerouting Excel

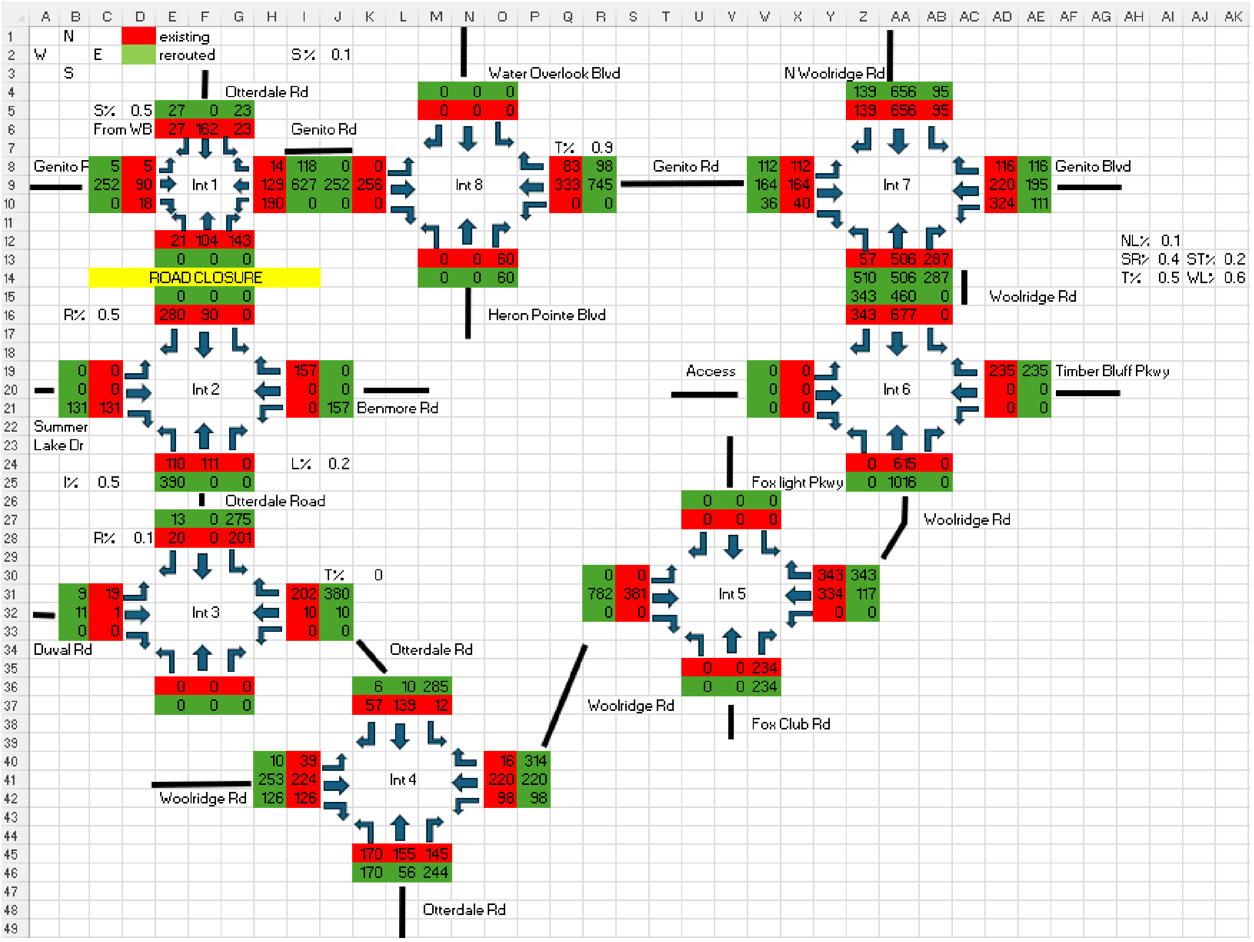

Figure R3.4. PM Rerouting Excel

Section 4. Proposed HEC-RAS Modeling

Current Bridge Deck Data Sheet: Bridge Deck
HEC-RAS files: HEC-RAS files

Copilot Aid of Number Generation

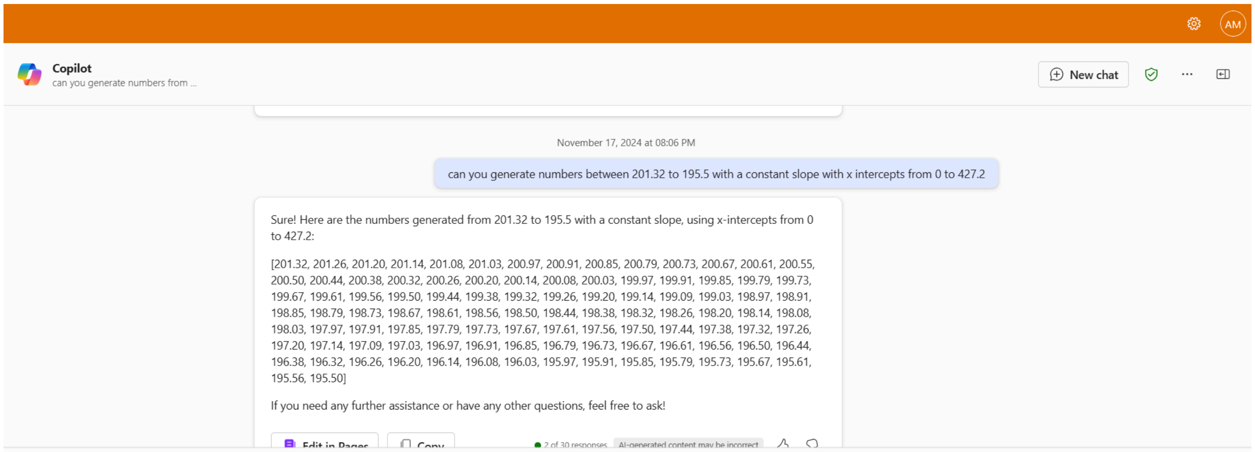

Figure R4.1. Example Microsoft Copilot Prompt and Response

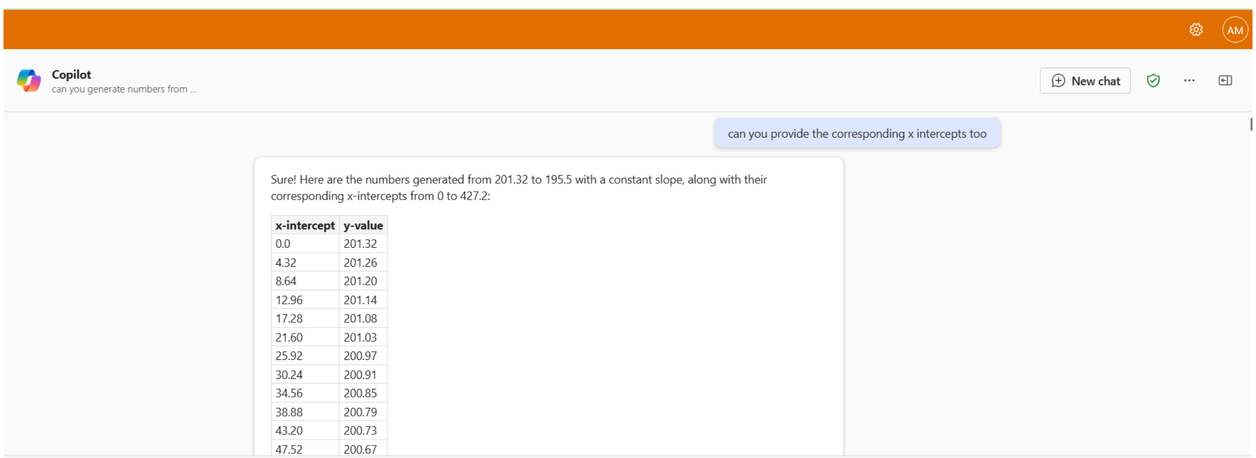

Figure R4.2. Example Microsoft Copilot Follow Up Prompt and Response

Note: All Responses were verified for accuracy and corrected when necessary

Section 5. Structure Dimensions Calculations

Overlall Span Length	40.77	ft				
	Simple Spans Min Superstructure Depth (ft)		Height from Prop. Fin Grade to Water Elev. (ft)		Clear Height for Opening (ft)	Opening Area (sf)
Concrete I-Beams (0.045*L)	1.83465		11.75		9.91535	404.2488195
Steel Composite I-Beam (0.04*L)	1.6308		11.75		10.1192	412.559784
Overlall Span Length	50	ft				
	Simple Spans Min Superstructure Depth (ft)		Height from Prop. Fin Grade to Water Elev. (ft)		Clear Height for Opening (ft)	Opening Area (sf)
Concrete I-Beams (0.045*L)	2.25		11.75		9.5	475
Steel Composite I-Beam (0.04*L)	2		11.75		9.75	487.5
Concrete I-Beam (PCBT-29) - Depth (in)	29					
Haunch depth (in)	3					
Deck Slab Depth (in)	8.5					
Final Superstructure depth (ft)	3.375		11.75		8.375	418.75

Figure R5.1. Structure Determinations based on AASHTO LRFD Manual

Section 6. VRRM Analysis

VRRM 4.1 Redevelopment Spreadsheet:

NEW - VRRM V.4.1 Redevelopment_OTTERDALE.xlsm

Land Type x Soil Type Area Calculations Spreadsheet: Otterdale Web Soil Survey.xlsx

USDA Web Soil Survey Report: OtterdaleRoadXOtterdaleBranch_Soil_Report1.pdf

OpenRoads Designer Initial Existing Conditions CAD file:
ExistingConditionsAnalysisVRRM.dgn

OpenRoads Designer Revised Existing Conditions CAD file:
https://drive.google.com/file/d/17nVCDiO15lkJt6g-hOR-Eeet324kt3A6/view?usp=sharing

OpenRoads Designer Proposed Design CAD file:
https://drive.google.com/file/d/1j8UtAvFxH1uAHRmMxRe11rS2YRW2ZG0M/view?usp=sharing

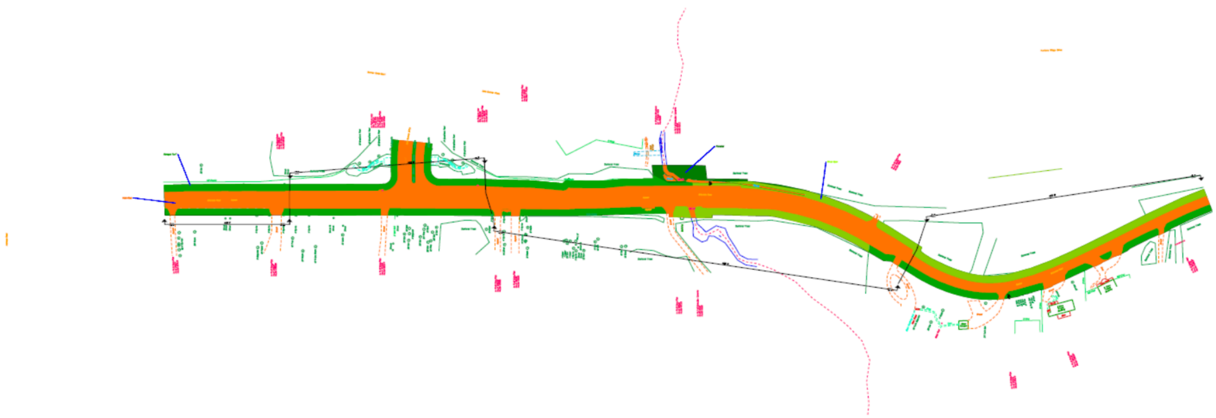

Figure R6.1. Initial Plan View of Existing Conditions Land Types of Entire Project Area

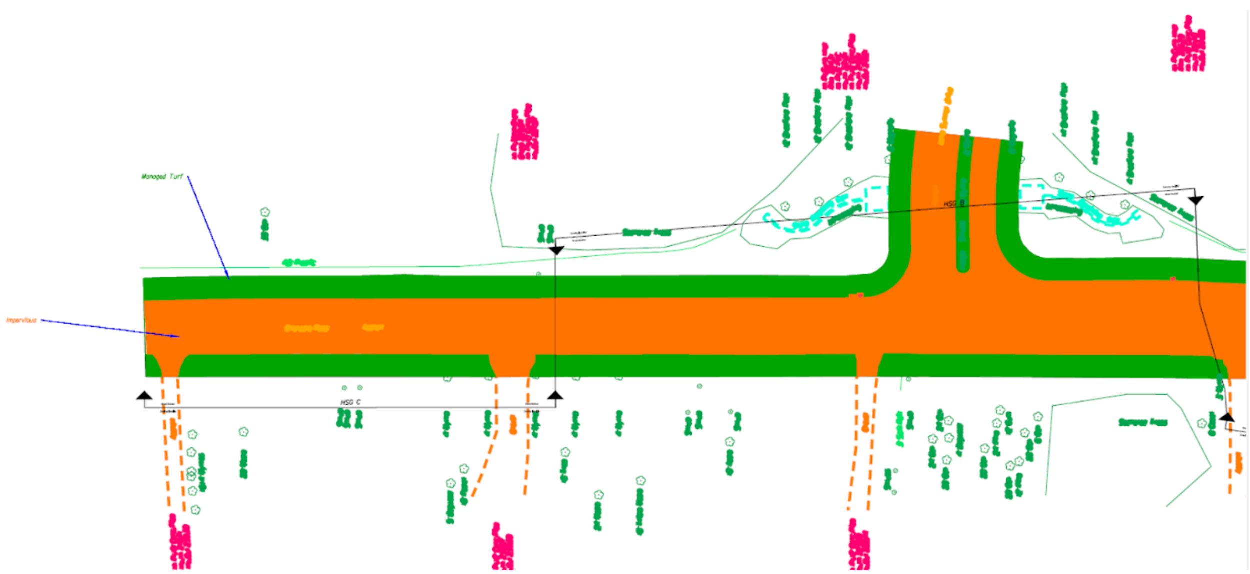

Figure R6.2. Initial Plan View of Existing Conditions Land Types Close Left Side View

Figure R6.3. Initial Plan View of Existing Conditions Land Types Close View Over Creek Crossing

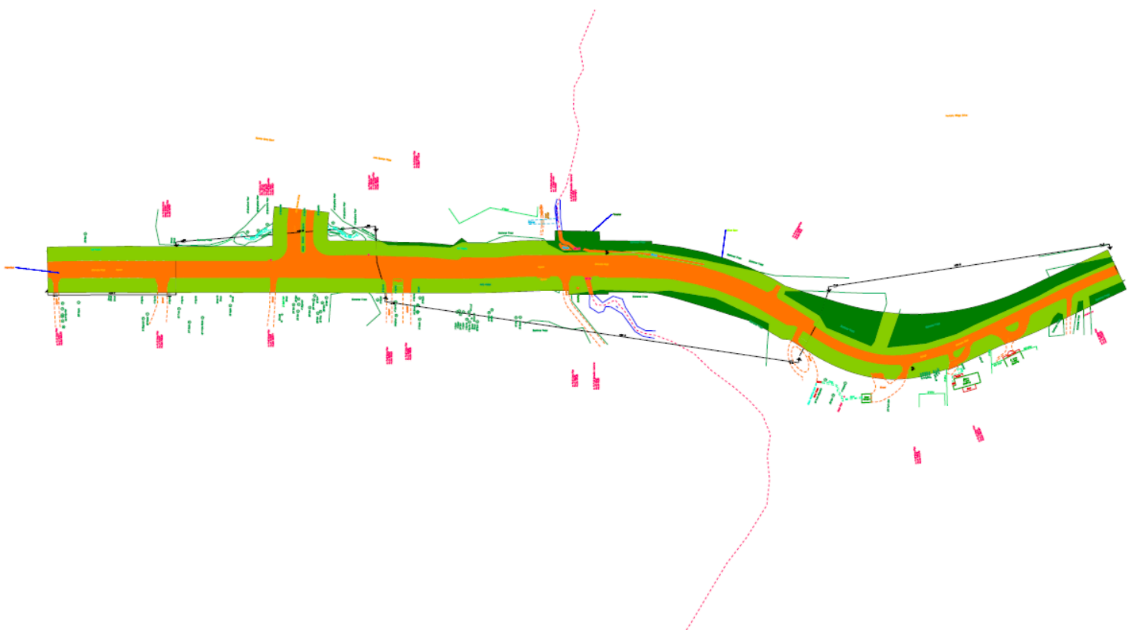

Figure R6.4. Revised Plan View of Existing Conditions Land Types of Entire Project Area

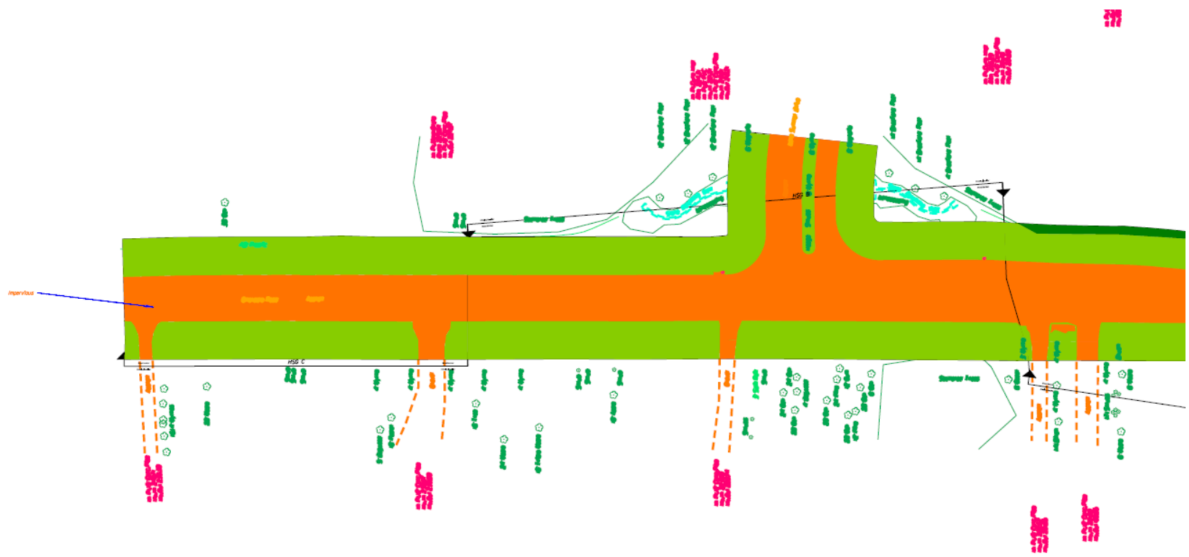

Figure R6.5. Revised Plan View of Existing Conditions Land Types Close Left Side View

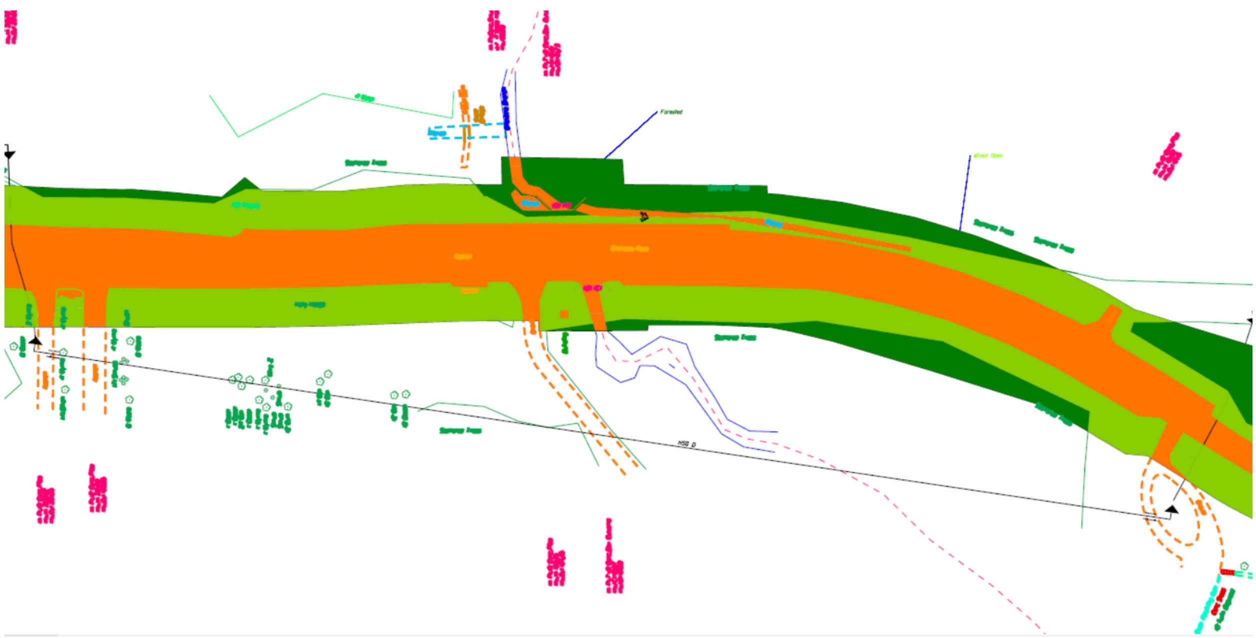

Figure R6.6. Revised Plan View of Existing Conditions Land Types Close View Over Creek Crossing

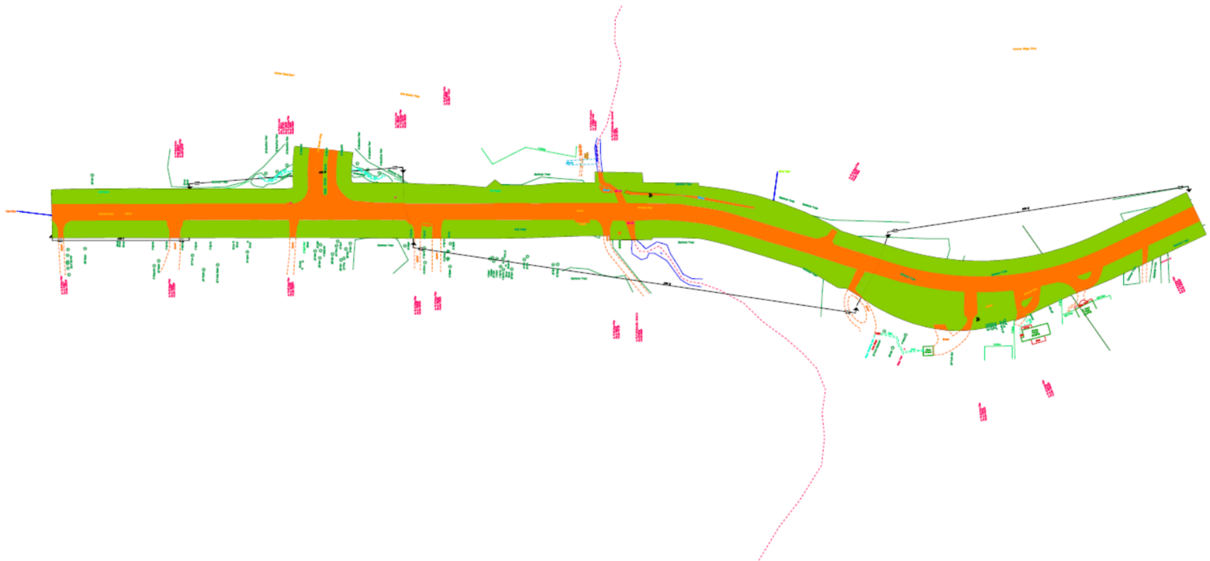

Figure R6.7. Plan View of Proposed Design with Land Types of Entire Project Area

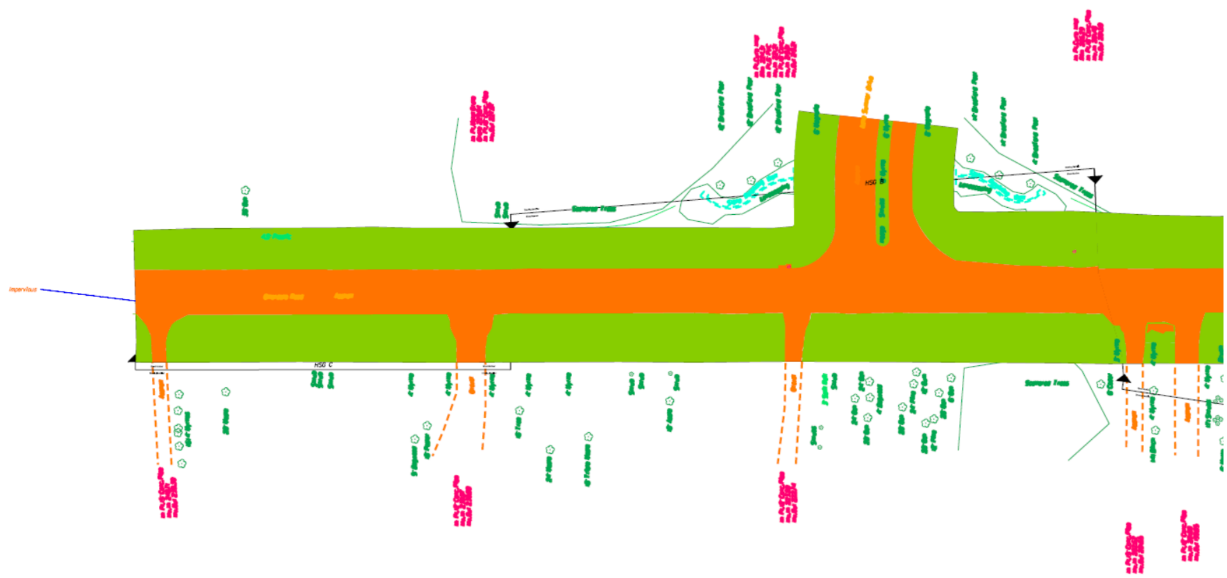

Figure R6.8. Plan View of Proposed Design Land Types Close Left Side View

Figure R6.9. Plan View of Proposed Design Land Types Close View over Creek Crossing

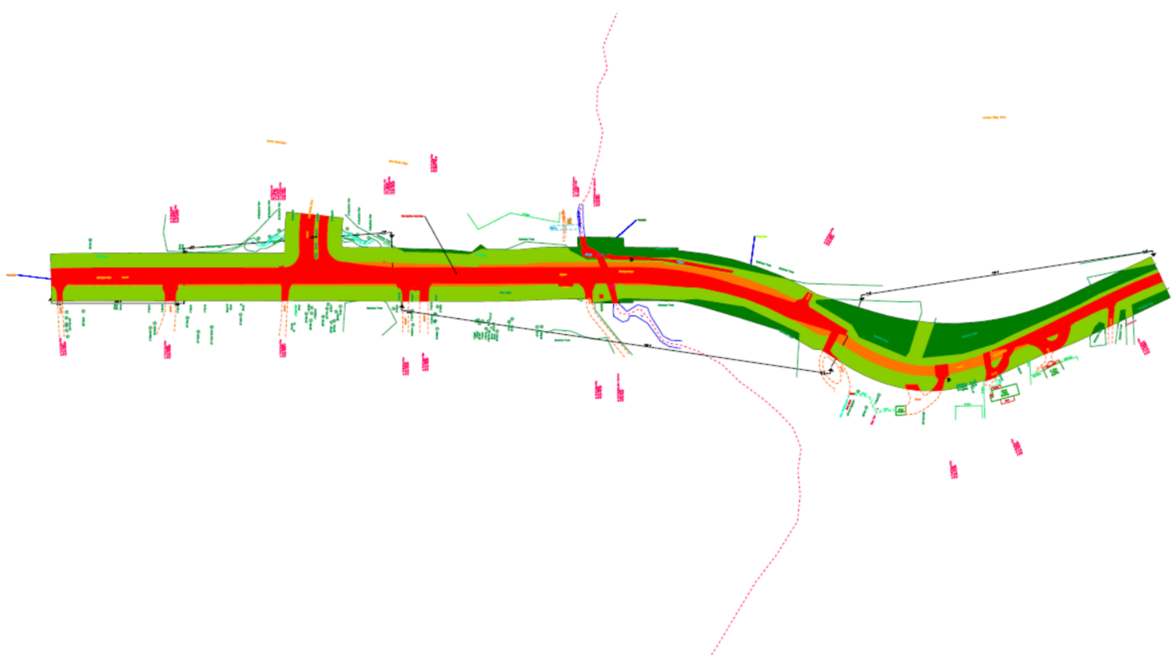

Figure R6.10. Plan View of Impervious Areas Not Included in VRRM (Areas in Red)

Section 7. BMP Design Work

Soil Group Area Calculations: Drainage Area Soil Groups

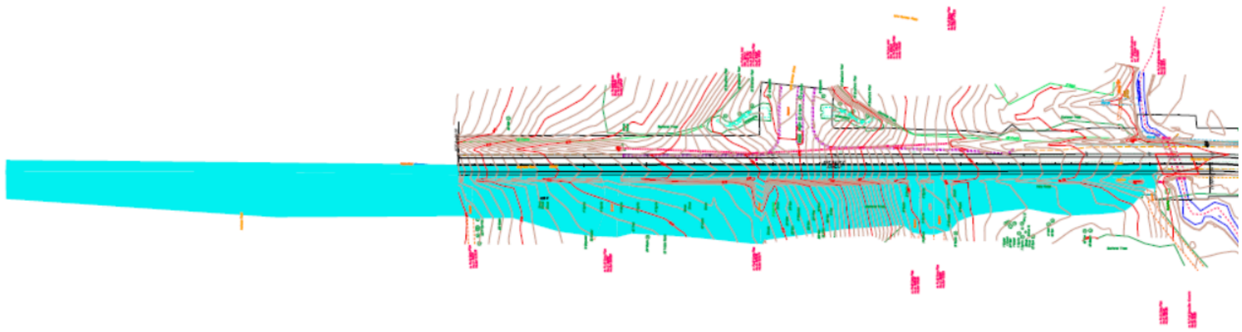

Figure R7.1. Plan View of Drainage Area for Proposed Bioretention Garden

BMP Sizing Calculations and Considerations: BMP Design

Section 8. Scupper Analysis

Scupper Computations: Scupper Comps.xlsx

Section 9. Utility Impact Assessment

Utility Impact Information: Otterdale Road Utility Impacts

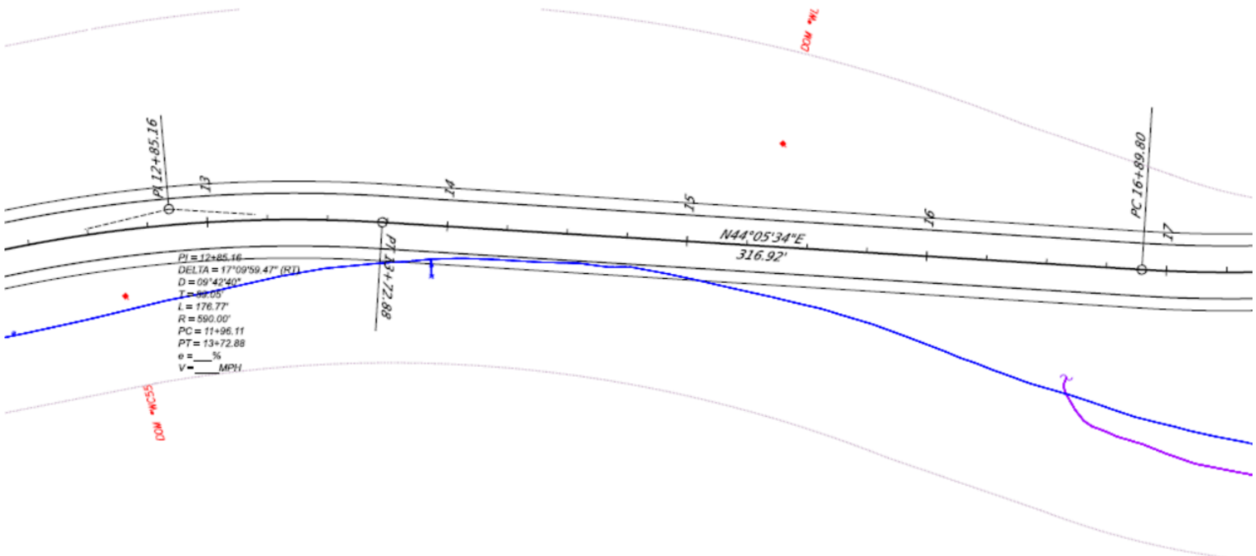

Figure R9.1. Location of Water Pipe Interference (Existing Pipe in Blue)

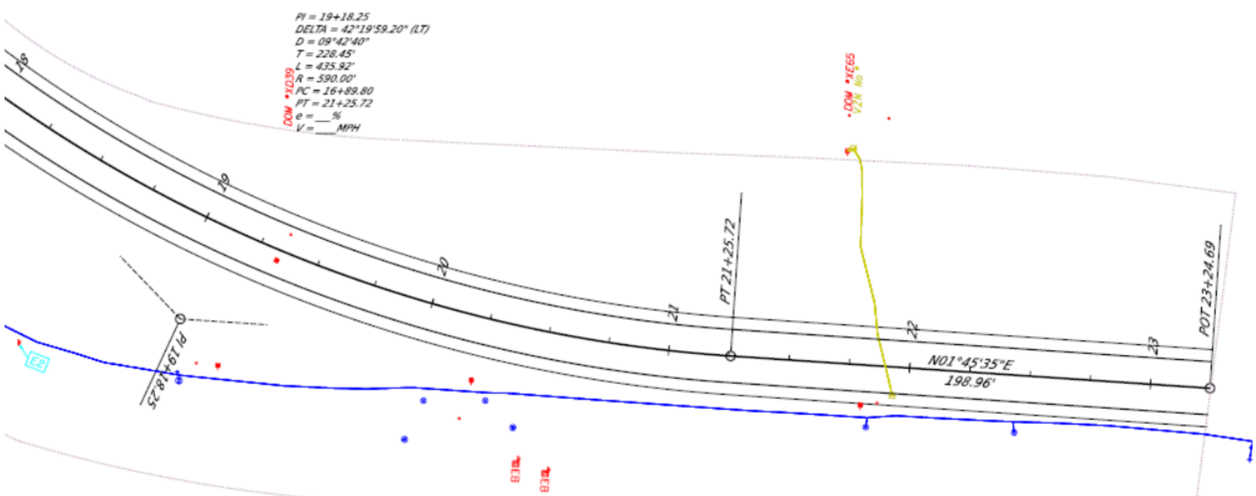

Figure R9.2. Location of Power and Communication Systems Interferences (Power in Red and Communication in Yellow)

Section 10. Cost Estimation

Final Cost Estimation Details: Final Capstone Estimate.pdf