MVP Southgate Amendment Project

Docket No. CP25-60-000

Attachment IP-4

Revised *Mountain Valley Southgate Pipeline Stream Burial Recommendations*

January 2026

MOUNTAIN VALLEY SOUTHGATE PIPELINE STREAM CROSSING BURIAL RECOMMENDATIONS

Revision 1

Prepared for

Mountain Valley Pipeline, LLC
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Prepared by

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Geosyntec Project No. GHZ1121

Report No. GHZ1121-01-R-001 Rev. 1B (for use)

November 21, 2025

MVP SOUTHGATE

Geosyntec consultants

Geosyntec Consultants of NC, P.C.

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Report No. GHZ1121-01-R-001 Rev. 1B (for use)

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ACRONYMS AND ABBREVIATIONS

1-D	one-dimensional
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
cfs	cubic feet per second
DEM	digital elevation model
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
ft	feet
ft/s	feet per second
Geosyntec	Geosyntec Consultants, Inc.
HEC-RAS	Hydrologic Engineering Center River Analysis System
HSA	horizontal setback analysis
LiDAR	light detection and ranging
LWD	large woody debris
mm	millimeter
Mountain Valley	Mountain Valley Pipeline, LLC
NLCD	National Land Cover Database
OHWM	ordinary high water mark
PHMSA	Pipeline and Hazardous Materials Safety Administration
pipeline	Mountain Valley Southgate pipeline
PRCI	Pipeline Research Council International
sq mi	square mile
TOB	top of bank
USGS	United States Geological Survey

1. INTRODUCTION

Mountain Valley Pipeline, LLC (Mountain Valley) intends to permit, design, construct, and operate an extension of the Mountain Valley Pipeline, called Mountain Valley Southgate (pipeline), from its currently approved end point in Pittsylvania County, Virginia, to an interconnect facility called the Dan River Interconnect, in Rockingham County, North Carolina. The proposed pipeline will consist of approximately 31 miles of 30-inch diameter pipe. The pipeline alignment as of 13 February 2025 is shown in Figure 1-1.

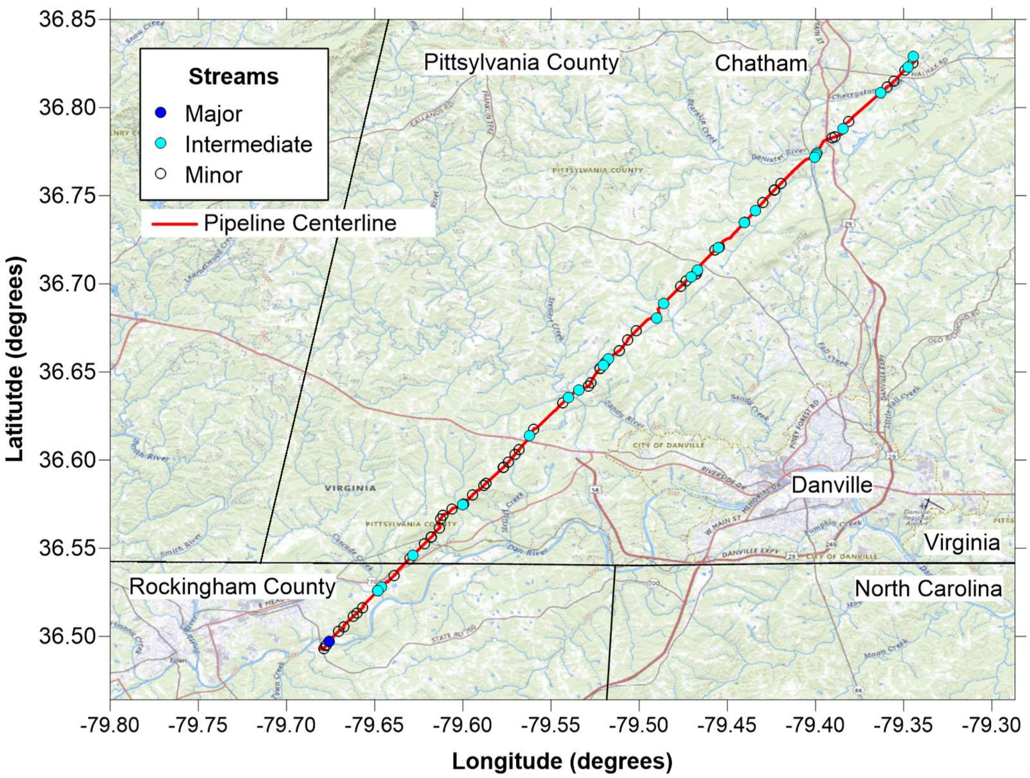

Figure 1-1. MVP Southgate 31-mile (Approximately) Long Pipeline Alignment (dated 13 February 2025) and Stream Crossing Locations

The route for the new pipeline traverses perennial, intermittent, and ephemeral streams. Over time, streams migrate horizontally and vertically; therefore, the pipeline needs to be buried sufficiently away from the existing banks and sufficiently deep below the thalweg to minimize pipeline exposure during the design life. The pipeline will be buried underneath the streams to mitigate against exposure that can lead to hydrotechnical hazards that could compromise the integrity of the structure, such as hydrodynamic loading, debris impact, and fatigue caused by vortex induced vibration. Mountain Valley requested that Geosyntec Consultants of NC, P.C. (Geosyntec) develop recommendations for pipeline burial that will reduce the risk of exposure during the lifetime of the project.

As summarized in Table 1-1, the pipeline route crosses 80 streams, of which 56 are defined by the Federal Energy Regulatory Commission (FERC) as Minor (i.e., exhibit a width of less than 10 feet

[ft]), 23 are Intermediate (i.e., exhibit a width between 10 and 100 ft), and 1 is Major because it exhibits a width of more than 100 ft.[1] This technical report documents Geosyntec's methods and recommendations for stream crossing burial depth and stream bank setback for all the stream crossings along the pipeline route.

Table 1-1. Classification of Stream Crossings Along the Pipeline Route

FERC Steam Classification	Total Number of Streams	Number of Streams in Virginia	Number of Streams in North Carolina
Minor	58	48	10
Intermediate	23	21	2
Major	1	0	1

[1] The stream width as defined by Mountain Valley is the length of the pipeline crossing between the right and left bank ordinary high-water marks (OHWM) that were delineated by others. The measurement was taken along the proposed pipe alignment, which in some cases was not perpendicular to the stream or waterbody, resulting in a larger reported stream width than the actual bankfull stream width, which is typically measured perpendicular to flow at a riffle. The "right" and "left" bank designation is based on orienting yourself facing downstream at a crossing and assigning the bank label from that perspective.

2. CONSIDERATIONS FOR DESIGN AT STREAM CROSSINGS

There is no specific regulatory guidance that defines the methods that should be followed for selecting pipeline burial depths adjacent to and below stream crossings, and little is provided regarding minimum pipeline burial. API RP 1133 (2017) provides some recommendations and guidance for overall risk management, but no specifics regarding burial depth. Therefore, operators are given flexibility to define the pipeline burial depth. Guidance from the Pipeline Hazardous Materials Safety Administration (PHMSA) and the Bureau of Land Management (BLM) and PHMSA regulations relevant to the issue are summarized below. While the BLM has no role in Mountain Valley, its guidance is instructive, nevertheless.

2.1 PHMSA Advisory Bulletin

PHMSA Advisory Bulletin ADB-2015-01 indicates that

> *"operators are urged to take the following actions to prevent and mitigate damage to pipeline facilities and ensure public and environmental safety in areas affected by flooding:*
>
> 1. *Utilize experts in river flow, such as hydrologists or fluvial geomorphologists, to evaluate a river's potential for scour or channel migration at each pipeline river crossing.*
> 2. *Evaluate each pipeline crossing of a river to determine the pipeline's installation method and determine if that method (and the pipeline's current condition) is sufficient to withstand the risks posed by anticipated flood conditions, river scour, or river channel migration. In areas prone to these conditions and risks, consider installing pipelines using horizontal directional drilling to help place pipelines below elevations of maximum scour and outside the limits of lateral channel migration.*
> 3. *Determine the maximum flow or flooding conditions at rivers where pipeline integrity is at risk in the event of flooding (e.g., where scour can occur) and have contingency plans to shut down and isolate those pipelines when those conditions occur."*

2.2 Bureau of Land Management Guidance

The BLM (Fogg and Hadley 2007) developed guidance for placing pipelines that cross below the surface of stream channels to prevent inundation or exposure of the pipe to the hydraulic forces of flood events. The BLM indicates that

"an analysis of channel degradation and scour should be completed to ensure the pipelines are not exposed and broken during extreme runoff events. Without such analysis, channels should be excavated to bedrock and pipelines placed beneath all alluvial material."

"Once a determination is made on how to bury the pipeline at the stream crossing, the elevation of the pipe should be held constant across the floodplain."

Thus, the BLM recommends either (1) conducting a scour and degradation analysis to estimate the burial depth and pipeline elevation within the floodplain at a stream crossing, or (2) foregoing such analysis and excavating to bedrock such that the pipeline is placed below all alluvial material.

2.3 PHMSA Regulations on Pipeline Cover

PHMSA's regulations 49 CFR §192.327 provides minimum pipeline burial depths in soil and rock according to class location (as defined in 49 CFR Part 192 §192.5). No guidance is provided for "streams", other than for "navigable rivers or streams" where the minimum burial in soil is 4 ft and in consolidated rock is 2 ft. The minimum burial across "drainage ditches of public roads" is 36 inches in soil and 24 inches in consolidated rock.

2.4 Approach for Burial Depth Design

In this study, Geosyntec implemented the following approach to address vertical and horizontal migration of streams at pipeline stream crossings, respectively:

- Select the pipeline burial depth as equal to, or greater than, the estimated depth of scour calculated using the 100-year return period stream flow parameters, which has approximately 26% probability of exceedance in 30 years.
- Select the location of sagbends, which are the locations at which the pipe curves vertically upwards and define the constant elevation interval below a stream, at stream crossings based on geomorphological analyses (i.e., review of historical imagery and LiDAR data) of the stream and an assumed 30-year design life for the project.

The scour depth calculations will be conducted for all the crossings at Intermediate (23 streams) and Major (1 stream) streams because the Minor streams can be designed with standard burial depths, such as what is defined in PHMSA's regulations (Section 2.3). Minor streams exhibit relatively small channel width and are unlikely to lead to exposures that are long enough to cause pipeline integrity hazard. However, the sagbend locations for these streams were also selected by conducting a geomorphological analysis.

This approach and the methods described in subsequent sections of this report are consistent with the guidance in PHMSA Advisory Bulletin ADB-2015-01 and guidance by the BLM. Minimum burial recommendations proposed for the stream crossings would meet the requirements of 49 CFR §192.327.

Additionally, the PHMSA regulations (49 CFR §192.705) require periodic pipeline patrols on a schedule based on class location to observe any factors affecting safety and operation over the life of the pipeline. Monitoring over the life of the pipeline may identify the need for mitigation measures or redesign of the crossing to mitigate exposure. These future measures are not described in this report.

3. CHARACTERISTICS OF THE STREAMS ALONG THE PIPELINE

Characteristics of the stream crossings along the proposed pipeline are summarized below based on key factors that influence channel morphology, including hydrology, channel geometry, and bed and bank material. These characterizations serve as inputs to the horizontal setback analysis (HSA) described in Section 4.1 and vertical scour analysis described in Section 4.2.

3.1 Hydrology

The hydrology of each stream crossing location (i.e., site) was characterized using the drainage area, urbanization, and peak flows specific to each site. A summary of the site-specific characteristics is provided in the following subsections.

3.1.1 Drainage Area

The drainage area tributary to the 24 stream crossings evaluated (i.e., 1 Major and 23 Intermediate as described in Section 2.4) was calculated using United States Geological Survey (USGS) StreamStats Batch Processing Tool (https://www.usgs.gov/streamstats/streamstats-batch-processing-tool) and refined with manual edits where necessary. Drainage area for the 24 stream crossings ranges between 0.0001 square miles (sq mi) and 1,720 sq mi. A histogram of drainage area for the stream crossings of interest is provided on Figure 3-1.

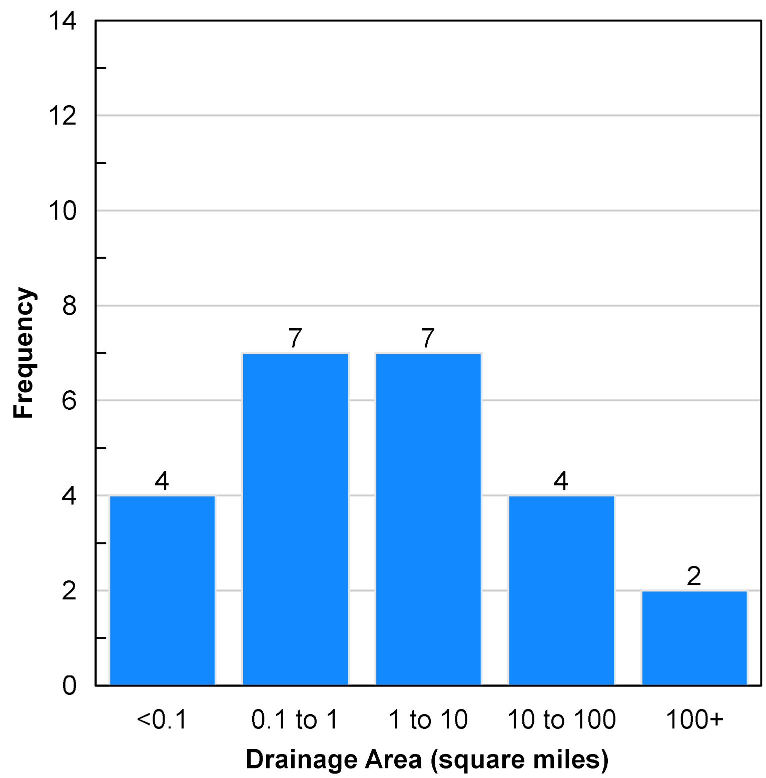

Figure 3-1. Histogram of Drainage Area Tributary for Intermediate and Major Stream Crossings

3.1.2 Urbanization

When present in the watershed, urbanization can be an important factor that influences geomorphic change of streams. Land development modifies natural watershed and stream hydrologic (water) and geomorphic (landform) processes by introducing impervious surfaces and drainage infrastructure that in turn changes runoff volume, timing, duration, frequency, and increases in peak discharge. These changes to runoff patterns caused by land use modifications are referred to as "hydromodification." Unless managed, hydromodification can cause channel erosion, channel migration, or sedimentation (referred to as "hydromodification impacts"). Such impacts may be associated with degradation of stream conditions and eventually pipeline exposure.

The imperviousness of the drainage areas tributary to the stream crossings evaluated was assessed using the drainage area delineations and the 2011 National Land Cover Dataset (NLCD). Watershed imperviousness ranges between 0% and 11%. Only one of the 24 crossings has tributary imperviousness greater than 5%, indicating that urbanization is not significant for the vast majority (96%) of the crossings. A histogram of watershed imperviousness is provided on Figure 3-2.

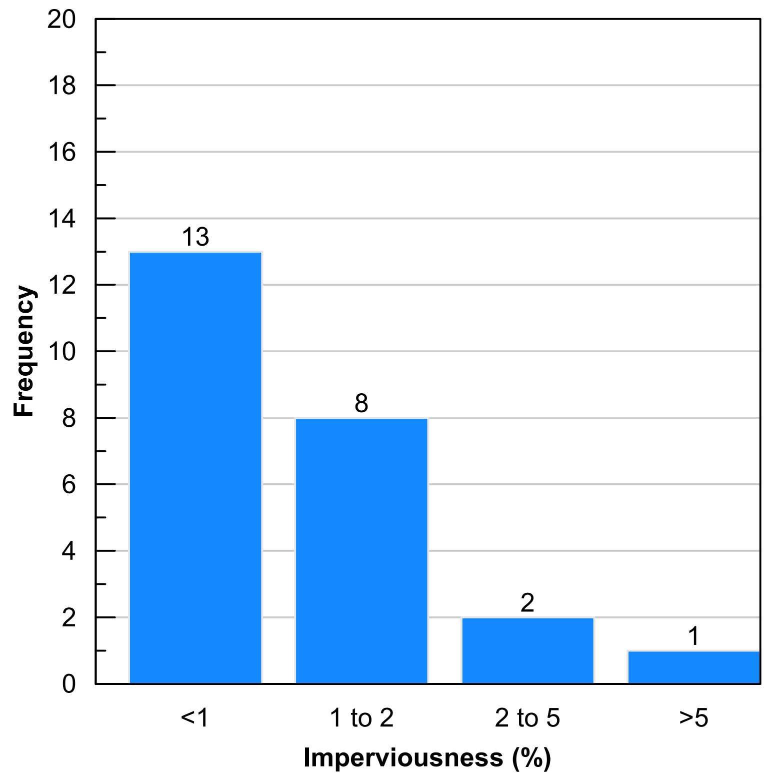

Figure 3-2. Histogram of Imperviousness Tributary for Intermediate and Major Stream Crossings

3.1.3 Peak Flows

Peak flows associated with the 2-, 5-, 10-, 25-, 50-, 100-, and 200-year return periods were calculated using empirical relationships derived for Virginia (Austin et al. 2011) and North Carolina (Weaver et al. 2009) streams. Additionally, peak flows associated with bankfull conditions were calculated using regional hydraulic geometry relationships empirically derived for

Virginia (Lotspeich 2009) and North Carolina (Harman et al. 2000) streams. The proposed pipeline alignment resides entirely in the Piedmont physiographic province, so the equations associated with this province were used. The peak flow relationships for Virginia and North Carolina are shown on Figure 3-3 and Figure 3-4, respectively, and are expressed as a function of drainage area, which is that area of the watershed upstream of the location of the pipeline stream crossing.

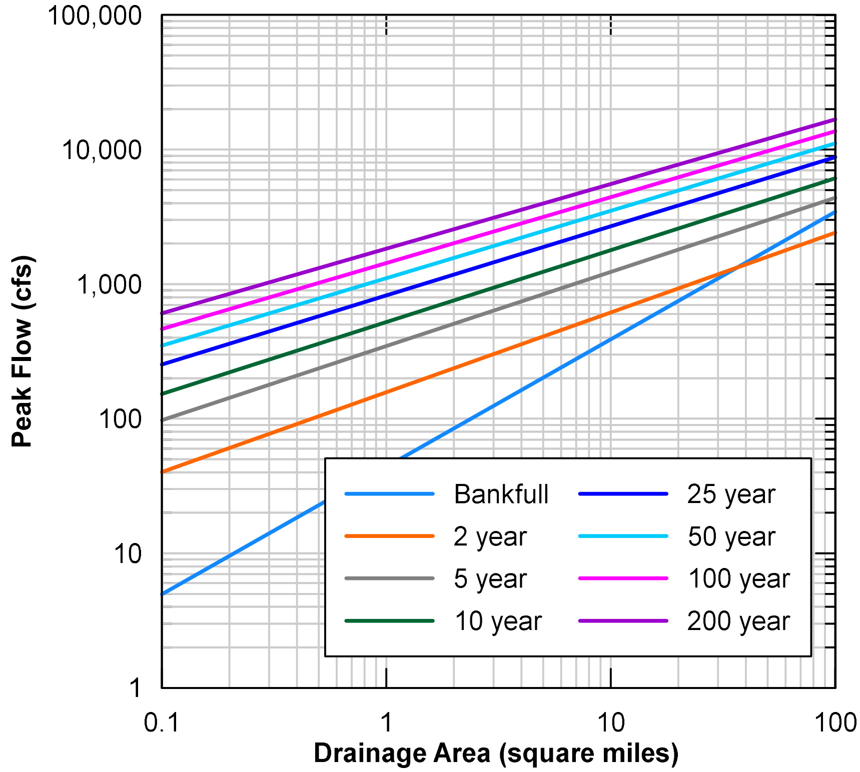

Figure 3-3. Empirical Peak Flow Relationships for Virginia (based on Austin et al. 2011)

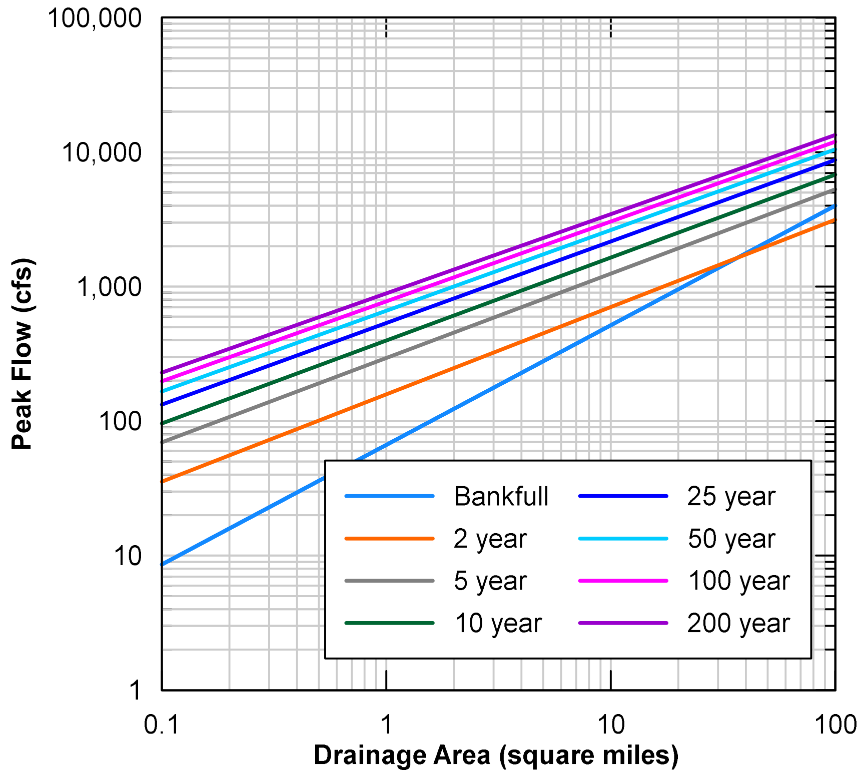

Figure 3-4. Empirical Peak Flow Relationships for North Carolina (based on Weaver et al. 2009)

3.2 Channel Geometry

Channel geometry was characterized by the planform, longitudinal slope, and cross-section of each waterway crossing site. A summary of the site-specific characteristics is presented in the following subsections.

3.2.1 Planform

Planform geometry was characterized by measuring the radius of curvature for stream meanders at or nearby (i.e., within one wavelength in planform) the pipeline stream crossings of interest. Measured radius of curvature range between 11 and 1,100 ft. The plot of radius of curvature as a function of drainage area is shown on Figure 3-5, where a positive correlation, as expected, is noticeable (i.e., radius of curvature increases as drainage area increases).

Active channel[2] width at stream crossings was also characterized based on reviewing aerial imagery and the light detection and ranging (LiDAR) digital elevation model (DEM) hillshade image in plan view[3]. This is discussed further in Section 3.2.3.

[2] The active channel represents the break in topography associated with the top of bank or nearest high bank, which is the most recent abandoned terrace or predominant floodplain in the topography surrounding the stream crossing.
[3] Geosyntec used LiDAR data provided by Mountain Valley from a survey conducted in 2019 and publicly available LiDAR-derived hillshades from USGS.

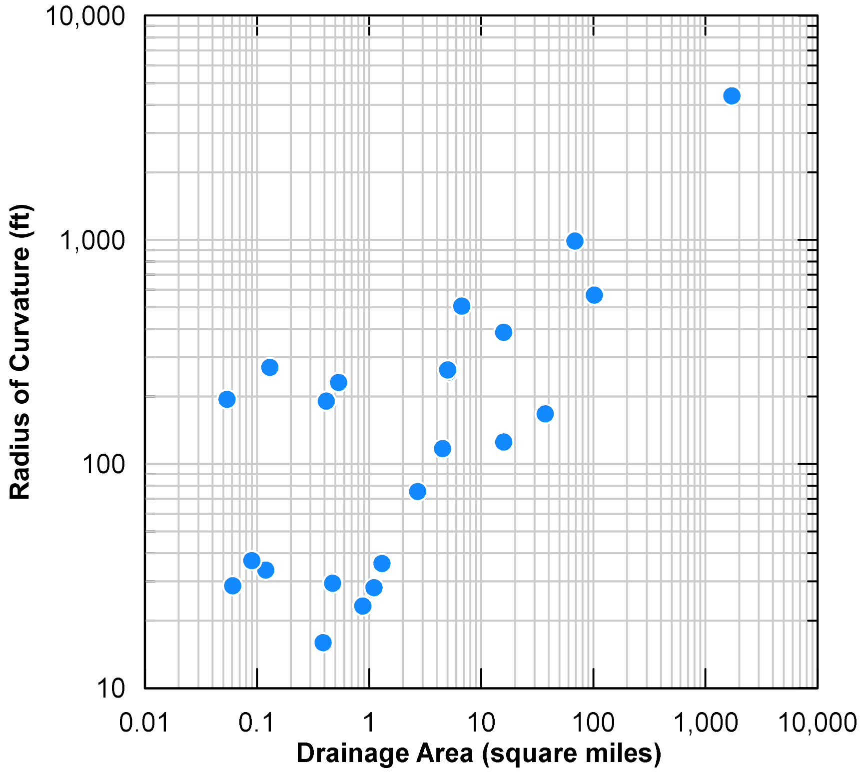

Figure 3-5. Plot of Radius of Curvature vs. Drainage Area for Intermediate and Major Streams

3.2.2 Longitudinal Slope

Longitudinal slope was calculated using a publicly available LiDAR-based DEM provided by USGS and stream flow path in vicinity to the pipeline crossings. Calculated longitudinal slope ranges between 0.09% and 3.61%. The distribution of longitudinal slope is shown on Figure 3-6 and has a negative correlation with drainage area (i.e., slope decreases as drainage area increases). This is an expected trend.

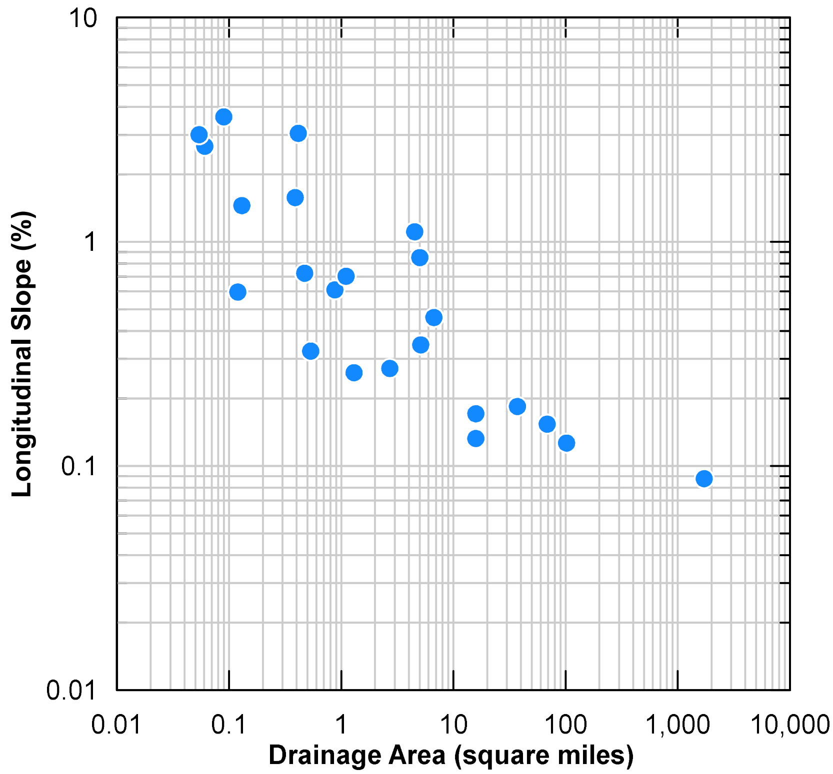

Figure 3-6. Plot of Longitudinal Slope vs. Drainage Area for Intermediate and Major Streams

3.2.3 Cross Section

Cross section dimensions (i.e., bankfull width and depth) were calculated for each stream crossing in two ways. First, regional hydraulic geometry relationships were used to calculate empirical bankfull width and depth for both Virginia (Lotspeich 2009) and North Carolina (Harman et al. 2000). These hydraulic geometry relationships are based on data collected from non-urban streams. Second, site-specific width and depth dimensions of the active channel were estimated by (1) cutting cross sections from the LiDAR-based DEM at each crossing perpendicular to flow; (2) defining the horizontal limits of the active channel (i.e., top of bank [TOB] width) by reviewing available aerial imagery and the DEM hillshade in plan view as well as reviewing the cross section geometry; and (3) subtracting the minimum elevation of the top of active channel (i.e., TOB, terrace, or floodplain) by the thalweg elevation (i.e., low point) to calculate the active channel depth[4].

Distributions of the active channel measurements and empirical bankfull dimensions are shown in Figure 3-7 and Figure 3-8. Both channel width and depth have a positive correlation with drainage area, which is the expected trend. Additionally, the active channel dimensions are generally greater than the mean values of the empirically derived bankfull dimensions. This is particularly the case

[4] Because the aerial LiDAR did not penetrate the water surface, the bed elevation was lowered in cross section for those crossings where substantial water surface was present at the time of the LiDAR survey.

for crossings with smaller drainage area and is typically indicative of channel degradation or prediction error in the empirical formula.

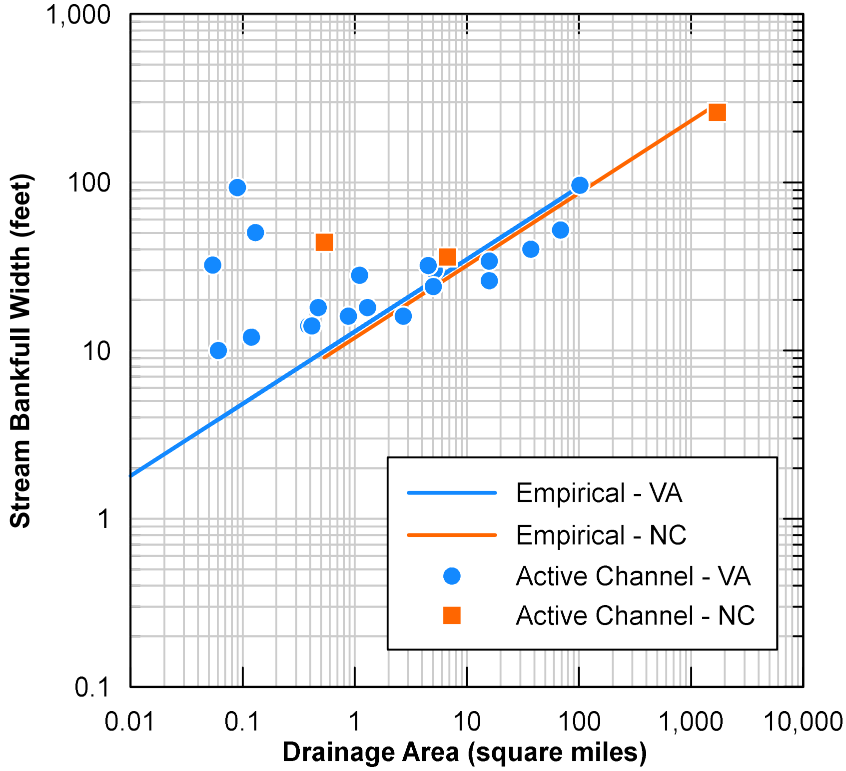

Figure 3-7. Plot of Active Channel and Empirical Bankfull Width vs. Drainage Area for Intermediate and Major Streams

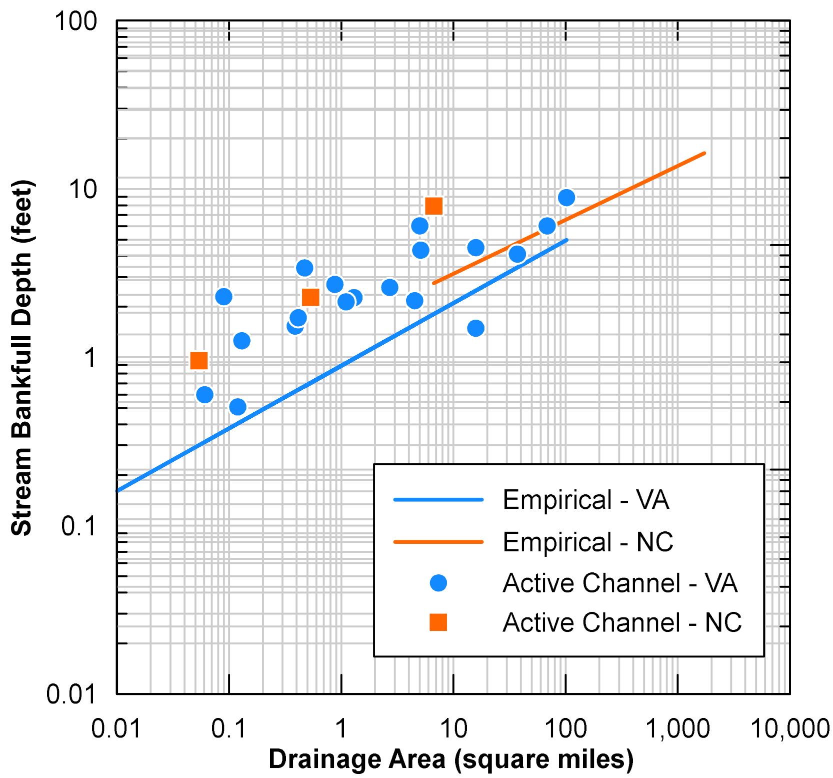

Figure 3-8. Plot of Active Channel and Empirical Bankfull Depth vs. Drainage Area for Intermediate and Major Streams

3.3 Bed and Bank Material

Bed and bank material were characterized by the stream bed particle size, presence of bedrock in the stream bed, and hydraulic roughness for each site. A summary of the site-specific characteristics is presented in the following subsections.

3.3.1 Stream Bed Particle Size

Grain size distribution data of the stream bed, which are needed as input in scour analyses, were not available for this desktop analysis. However, Geosyntec's past stream observations during field reconnaissance in the region conducted during the development of recommendations for the previous alignment of the pipeline indicate that streams beds in the Piedmont physiographic province typically consist of a mix of sand and gravel with bedrock exposure at some locations. The fraction of sand comprising the bed sediment generally increases with drainage area. Given the lack of available data for bed material at the stream crossings of interest, a sand bed was conservatively assumed for all stream crossings.

3.3.2 Bedrock in Stream Bed

Data on exposed or shallow bedrock along the stream bed were not available for this desktop analysis; however, the lack of data does not impede the ability to calculate recommended burial depths but rather provides depths that may be more conservative. Burial depth adjustments can be made during pipeline construction as the characteristics of the stream bed are discovered.

3.3.3 Hydraulic Roughness

Manning's hydraulic roughness (n-value) was assigned to the land surface based on review of the aerial imagery, provided by Mountain Valley, at the crossings of interest. The n-values outside of the active channel were assigned based on land cover type (Chow 1959), as follows:

- Pasture or crops, $n = 0.035$
- Brush, $n = 0.06$
- Trees, $n = 0.10$

The n-values associated with the active channel were assigned based on Rosgen Level 1 stream classifications. As shown on Figure 3-9, overall there is a slight negative correlation between the n-values assumed and drainage area (i.e., lower n-value for larger drainage area).

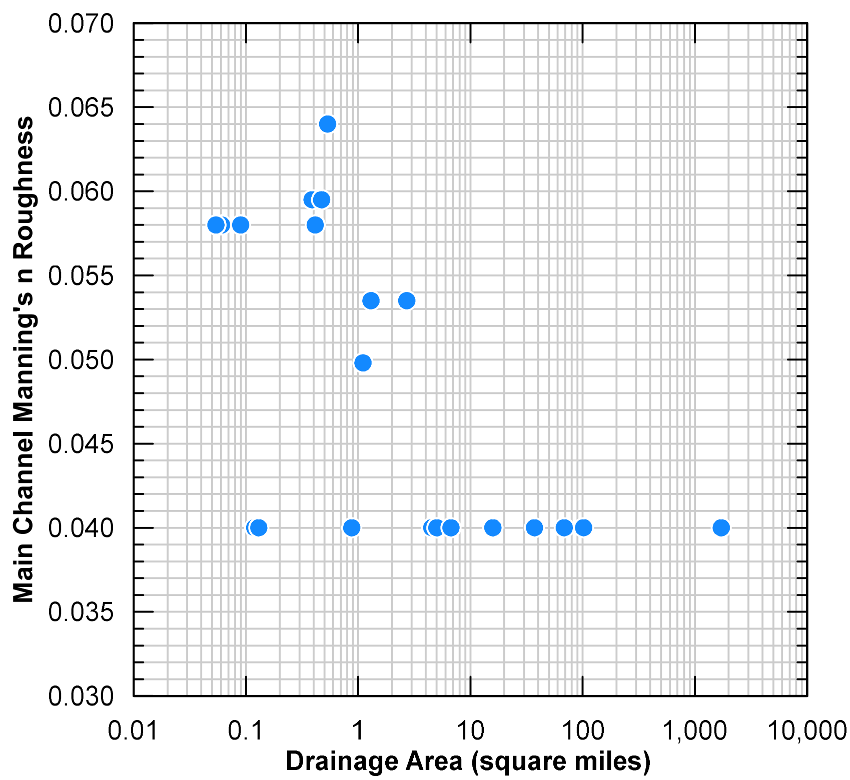

Figure 3-9. Plot of Main Channel Manning's Roughness vs Drainage Area for Intermediate and Major Streams

4. SETBACK ANALYSIS AND BURIAL DEPTH CALCULATIONS

This section summarizes the method and results used by Geosyntec to estimate the location of the sagbends and the vertical scour depth.

4.1 Horizontal Setback Analysis

Geosyntec conducted an HSA to characterize the horizontal limits for lateral channel migration and channel avulsion with potential to affect the pipeline alignment over the anticipated design life of the project (assumed to be 30 years). The fluvial processes associated with avulsion can be unpredictable stemming from the channel seeking a topographic advantage (steeper gradient) during flood stage or due to random events such as debris accumulations, debris jamming, or sediment infilling of the main channel. Other fluvial processes, such as channel bend or meander development (response due to historical straightening of many of the streams), lateral bank migration, down-valley meander migration, and meander belt extension, are associated with the measured rates of erosion derived from observed changes from aerial image records. It is with these processes in mind that the HSA described below was performed.

4.1.1 Basis of Design

As part of the HSA, Geosyntec evaluated the lateral setback from the subject stream crossings generally following the principals and concepts identified in (1) Chapter 6 of HEC-20 (Federal Highway Administration [FHWA] 2012) for plan view analysis and (2) the State of Washington Department of Ecology's *A Methodology for Delineating Planning-Level Channel Migration Zones* (Olson et al. 2014). This analysis was conducted using Mountain Valley-provided LiDAR collected in 2019 and publicly available USGS LiDAR from 2022. Therefore, it is possible that stream morphology may have changed since then, affecting the HSA; however, the majority of the assessed streams do not pose a significant lateral migration hazard (see Appendix A-2), and therefore changes to the setback positions are unlikely. Where there was a lateral migration concern, setback locations were conservatively assigned to include the distance of an average meander belt width based on the immediate upstream and downstream channel morphology, where deemed appropriate (i.e., where the channel is not geomorphologically confined). The setback positions are provided in Appendix A-2. To determine if the setback recommendations should be adjusted, the TOB positions determined from the LiDAR review and geomorphological assessment for all streams should be referenced (Appendix A-2). If stream TOB deviation is observed in the field during construction, modifications should be made where deemed appropriate.

The guiding objective for the HSAs is to provide the location and length of pipeline segments at stream crossings whose burial depth, defined as the depth from the channel thalweg to top of pipeline, should be consistent with that recommended by the vertical scour assessment described in Section 4.2. The elevation of the pipeline for the extent of the pipeline segment identified should be constant between horizontal setbacks.

4.1.2 Implementation of HSA

For the analysis of fluvial landforms and past and ongoing channel migration, Geosyntec relied on LiDAR-based topographic data (hillshade DEM and 2 ft contours were available) collected by

Mountain Valley on an approximately 1,070-ft-wide path along the project alignment as well as publicly available hillshade DEMs provided by USGS. Historical aerial imagery sourced from the USGS EarthExplorer database[5] (1946–1986) was also supplemented with contemporary historical imagery available in Google Earth Pro (1990–2018). For crossings where vegetation restricted observation of the stream channel in aerial imagery, only LiDAR-based topographic data were used for the HSA.

Setback distances for Intermediate and Major channels were described as distances from the TOB, measured along the pipeline alignment. For Minor channels, the recommended extents of the pipe at the proposed burial depth are provided. Setback recommendations for all stream channels are provided in Appendix A-2.

When the setback was based on geomorphic features observed on the DEM and aerial imagery, those features were used to define the setback limits. The following terms were used to describe geomorphic setback locations: ordinary high-water mark (OHWM) line (*MVP_Streams* kmz file provided by TRC, a consultant to Mountain Valley), active channel belt width, terrace, adjacent floodplain channel, and valley wall (slope transition point between hillslope and valley floor, channel, or floodplain). Valley wall to valley wall burial was typically applied to crossings located in confined valleys (i.e., valley width less than two to three times the stream width). For stream crossings where historic channel migration was observed in aerial imagery, channel bank migration rates (distance of channel bank migration per year) were evaluated to define horizontal setbacks that provide near-term and long-term protection.

The results of the desktop study HSA may require field modification during construction to suit the unique geomorphic and hydraulic attributes of a stream crossing and the field conditions encountered in the temporary and permanent workspace.

4.1.3 Proposed Horizontal Setbacks

The HSA was performed on 24 stream crossings. For 20 of the 24 crossings, the HSA was previously applied in 2019 adjacent to the current crossing, as the pipeline alignment was in a similar location. The new pipeline alignment shifted the stream crossings approximately 1 to 410 ft away from the previous alignment. The setback distances for the previously assessed streams remained largely similar apart from one location (SC_018). For 4 of the 24 crossings, the HSA was performed for the first time as these areas had not been previously assessed.

As described schematically in Figure 4-1, the burial depth requirements at most of the streams that Geosyntec analyzed are defined by the coordinates (latitude and longitude) of the two sagbend points and the burial depth. The coordinates of the proposed sagbends are provided in Appendix A (Table A-2) in tabular format.

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[5] https://earthexplorer.usgs.gov/

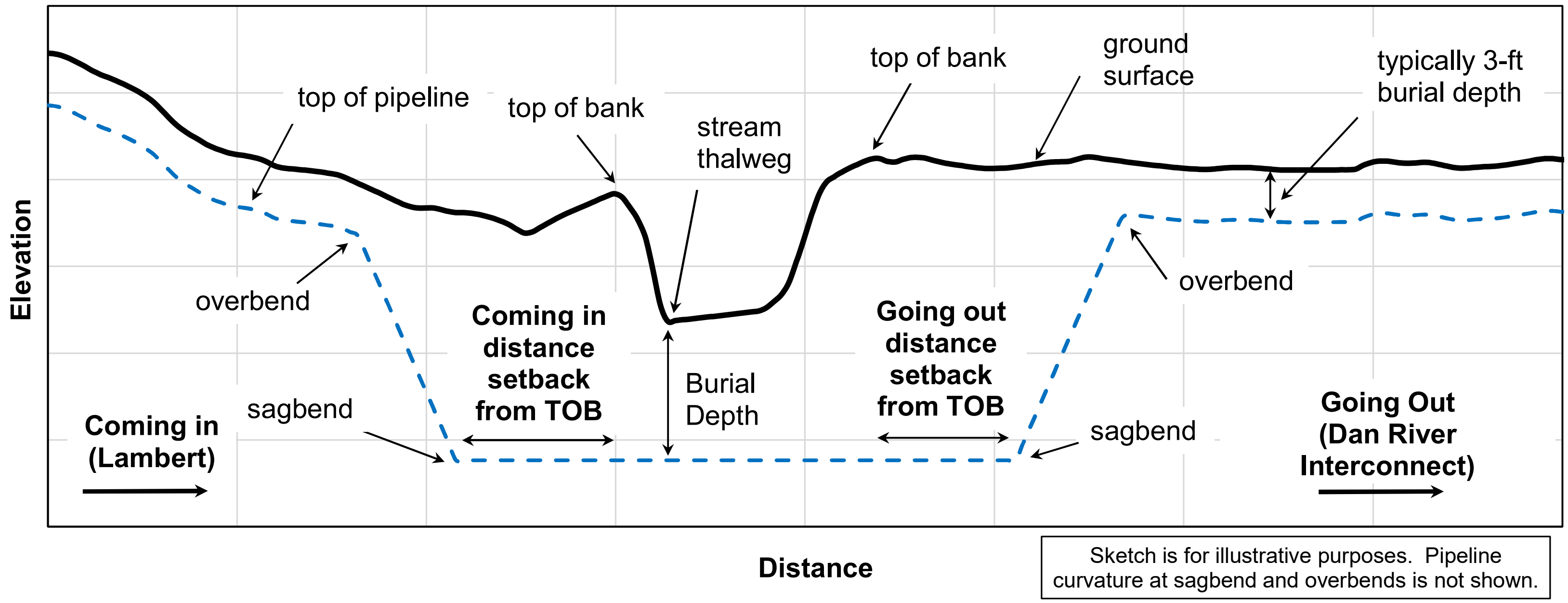

Figure 4-1. Sketch of Pipeline Setback Showing Lateral and Vertical Burial Design Parameters at Streams with One Set of Setbacks

4.2 Vertical Scour Analysis

Geosyntec's vertical scour analysis consisted of evaluating appropriate burial depths based on the depth of anticipated total (vertical) scour at the 24 pipeline stream crossings. These 24 crossing locations included 1 Major stream and 23 Intermediate streams. Scour calculations required hydraulic analysis for each crossing. The methodology and results of the hydraulic, scour, and burial depth analyses are summarized in the following sections.

4.2.1 Hydraulic Analysis

Hydraulic analysis was performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software program to calculate hydraulic parameters (e.g., flow depth, flow width, velocity, and effective shear stress) for the peak flows derived from the hydrologic analysis, per Section 3.1.3. The flow profiles modeled include peak discharges associated with empirical bankfull conditions and 2-, 5-, 10-, 25-, 50-, 100-, and 200-year return periods. The 24 one-dimensional (1-D) HEC-RAS models were populated with channel geometry parameters (i.e., longitudinal slope and cross section), described in Section 3.2, and Manning's roughness, described in Section 3.3.3. The HEC-RAS models are representative of normal flow depth calculations at each stream crossing and contain three cross sections. The middle cross section is representative of the stream crossing at the pipeline alignment whereas the upstream and downstream cross sections have the same geometry as the middle, but with elevations adjusted to represent the longitudinal slope. Normal depth boundary conditions were assigned at both the upstream and downstream cross sections and were set to the longitudinal slope.

Once HEC-RAS models were developed and successfully run, Geosyntec observed the flow profile for each stream crossing that results in a flow stage most representative of the active channel conditions. Understanding the approximate return period associated with the active channel is indicative of the level of the channel's entrenchment. A higher return period means that the active channel is more entrenched, has less floodplain connectivity, and is likely more unstable. The distribution of the 24 active channel return periods is shown on Figure 4-2.

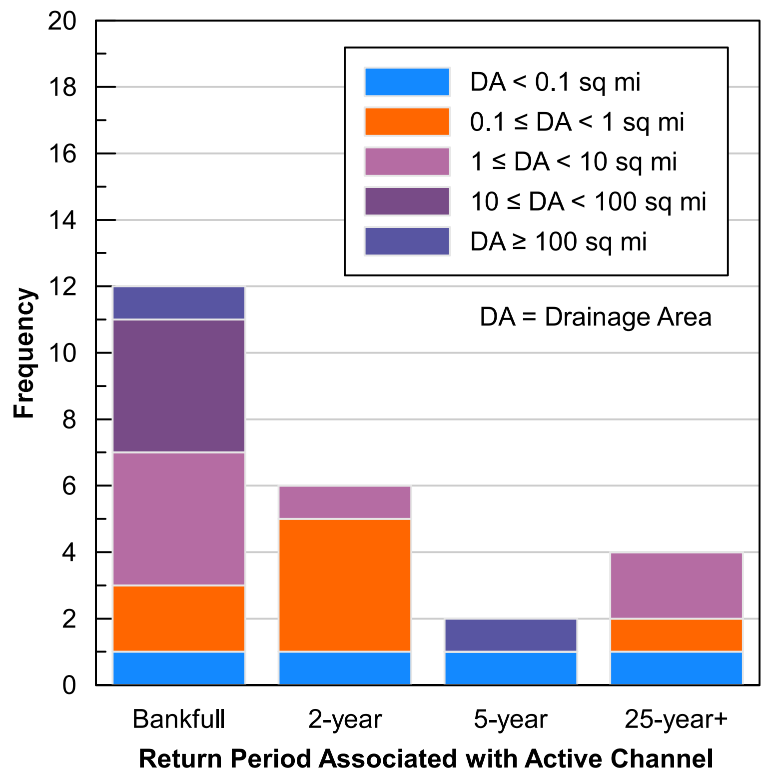

Figure 4-2. Histogram of Active Channel Return Period

4.2.2 Scour Analysis

Total scour (z_{ts}) is the total depth of scour at a given location. It is applied to the thalweg of the channel and is the sum of all scour components that are applicable for the given location. Scour components considered herein include the following, which are described in the subsequent sections:

- Long-Term Degradation (z_{lt})
- General Scour (z_{gs})
- Local Scour (z_{ls})
- Bend Scour (z_{bs})
- Bed Form Scour (z_{bf})

4.2.2.1 Long-Term Degradation (zlt)

Long-term degradation (z_{lt}) is the progressive lowering of the channel bed due to scour. This permanent, or continuing, degradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place. Geosyntec estimated degradation associated with both observed natural geomorphic processes and urbanization (or hydromodification). This approach is described further in the following subsections. Long-term degradation was considered the sum of the two. Calculated long-term degradation ranges between 1.0 and 2.0 ft.

4.2.2.1.1 Natural Degradation

Geosyntec estimated natural degradation by applying observed head cut and knickpoint heights from previous field reconnaissance in the region. These estimates assume that anthropogenic changes to the conditions of the drainage basin upstream and downstream of the crossing, such as installation of dams and changes to the imperviousness of the ground, will be minor. Armoring was not considered, which is conservative. As part of previous field reconnaissance efforts, Geosyntec identified head cuts in various streams in the region with heights ranging from 0.5 to 2 ft. Thus, based on the previous information gathered in the region, the depths provided in Table 4-1 were utilized to estimate potential natural degradation.

Table 4-1. Estimated Natural Degradation Depths

Drainage Area (square miles)	Degradation (feet)
< 1	2
1 to 4	1.5
> 4	1

4.2.2.1.2 Degradation Caused by Urbanization

Degradation caused by urbanization in the tributary drainage area, also termed hydromodification, was calculated by evaluating the difference between the potential channel enlargement associated with watershed imperviousness, as shown by the trend line in Figure 4-3 (Center for Watershed Protection 2000), and the observed channel enlargement in the vertical direction. The equations used are as follows.

$$z_{hm} = Y_{bf} \cdot (A_{rp} - A_{ro})$$ **Equation 1**

$$A_{rp} = 0.0012 \cdot Imp^2 + 0.0233 \cdot Imp + 1.005$$ **Equation 2**

$$A_{ro} = Y_{ac}/Y_{bf}$$ **Equation 3**

Where:

z_{hm} = Degradation associated with urbanization (ft)

Y_{bf} = Empirical bankfull depth (ft)

A_{rp} = Potential channel enlargement ratio (urban/non-urban) (unitless)

A_{ro} = Observed channel enlargement ratio (urban/non-urban) (unitless)

Imp = Imperviousness (%)

Y_{ac} = Active channel depth (ft)

If the potential channel enlargement (A_{rp}) is less than that observed (A_{ro}), then the long-term degradation associated with urbanization was estimated as zero.

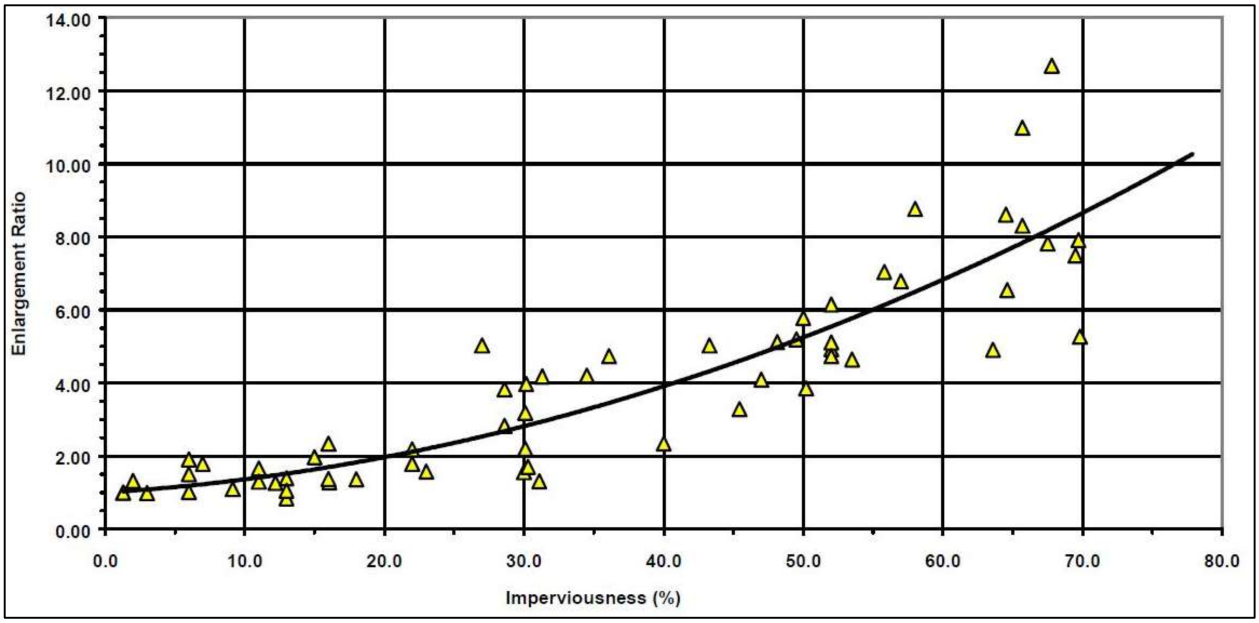

Figure 4-3. Channel Enlargement as a Function of Impervious Cover in Alluvial Streams in Maryland, Vermont, and Texas (MacRae and DeAndrea 1999, Brown and Claytor 2000)

4.2.2.2 General Scour (z_{gs})

General scour is the lowering of the stream bed across the channel over relatively short time periods and is associated with the passing of a single flood. The Lacey Regime Equation (ASCE 2005) was used to calculate general scour for this study. The Blench, Neil, and Pemberton and Lara (competent velocity) equations were also calculated and considered in this study. The Lacey Regime equation was used because it provides scour depths that are within Geosyntec's expectations based on professional judgment and experience in the region. The Lacey Regime Equation is expressed as:

$$z_{gs} = Z \cdot 0.47 \cdot (Q/f)^{1/3}$$

Equation 4

Where:

Z = multiplying factor (unitless), here assumed as 0.25 for a straight reach

Q = design discharge (cubic feet per second [cfs]), here assumed as the 100-year peak flow

f = Lacey's silt factor = $1.76 \cdot D_m^{1/2}$

D_m = mean grain size of bed material (millimeter [mm]), here assumed as 1 mm

Calculated general scour ranges between 0.2 and 3.9 ft.

4.2.2.3 Local Scour (z_{ls})

Local scour is the scour that results from an obstruction and abrupt change in the direction of flow. It is caused by an acceleration of flow and resulting vortices induced by the obstruction. Two components of local scour considered in this analysis are large woody debris (LWD) and confluence scour, as described below. Local scour from LWD was applied for every stream crossing to consider the potential for accumulation of LWD at or near the crossing that could lead to scour and pipeline exposure. Confluence scour was only applied to those stream crossings located in the vicinity of where two stream channels combine into one. Local scour was considered the sum of these two components. Calculated local scour ranges between 0.0 and 5.6 ft.

4.2.2.3.1 Large Woody Debris (z_{lwd})

Large woody debris was considered as part of this analysis due to the prevalence of forested land cover throughout the pipeline alignment and in vicinity to the stream crossings. Geosyntec's previous experience indicates that LWD is prevalent in this region. An equation for pier scour, based on Hydrologic Engineering Circular No. 18 (FHWA 2012), was used as a basis for estimating scour associated with in-stream LWD. This equation is as follows:

$$z_{lwd} = 2.0 \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot a^{0.65} \cdot y_1^{0.35} \cdot F_r^{0.43}$$

Equation 5

Where:

z_{lwd} = local scour associated with LWD (ft)

K_1 = correction factor for pier nose shape (unitless), here assumed as 1.1

K_2 = correction factor for angle of attack of flow (unitless), here assumed as 1.0

K_3 = correction factor for bed condition (unitless), here assumed as 1.0

K_4 = correction factor for armoring of bed material, here assumed as 1.0

a = pier width (ft), here assumed as 1 ft

y_1 = flow depth directly upstream of the pier (ft), here assumed as the channel hydraulic depth associated with the empirical bankfull flow

F_r = Froude Number directly upstream of pier (unitless)

4.2.2.3.2 Confluence Scour (z_{con})

Confluence scour was calculated using the following equation (Sutherland 1986):

$$z_{con} = 0.642 \cdot Q_T^{0.395}$$

Equation 6

Where:

z_{con} = local scour associated with steam confluence (ft)

Q_t = total discharge through confluence (cfs)

4.2.2.4 Bend Scour (z_{bs})

Bend scour is associated with meandering channels that can induce transverse or secondary currents. It is the scour associated with the outside of a bend. Bend scour was calculated as follows (Maynord 1996):

$$z_{bs} = Z \cdot (y_{mxb} - y_u)$$

Equation 7

$$y_{mxb} = y_u \cdot \left[1.8 - 0.051 \cdot \left({}^{r_c}/_{W_u}\right) + 0.0084 \cdot \left({}^{W_c}/_{y_u}\right)\right]$$

Equation 8

Where:

z_{bs} = bend scour depth (ft)

y_{mxb} = maximum water depth in bend (ft)

y_u = average water depth in crossing upstream of bend (ft), here assumed as the hydraulic depth in the main channel for the empirical bankfull peak flow

Z = safety factor (unitless), here assumed as 1.08

r_c = radius of curvature of bend (ft)

W_u = water surface width at upstream end of bend (ft), here assumed as the active channel width

If r_c/W_u < 1.5, then r_c/W_u = 1.5 was assumed.

If W_u/y_u < 20, then W_u/y_u = 20 was assumed.

Calculated bend scour ranges between 0.1 and 6.1 ft.

4.2.2.5 Bedform Scour (z_{bf})

Sand-bedded streams develop ripples, dunes, and anti-dunes at specific levels of shear stress. Dunes and anti-dunes in sand beds can result in additional scour, since they migrate by a systematic process of erosion and deposition[6], controlled by flow velocities (USDA 2007). The scour produced by the passage of a dune is described as bedform scour and, according to Van Rijn (1984), develops when $D_* > 10$ and $3 < T_{ts} < 15$.

$$D_* = D_{50} \cdot \left(\frac{1.65g}{\nu^2}\right)^{\frac{1}{3}}$$ **Equation 9**

$$T_{ts} = \frac{\tau_s^* - \tau_c^*}{\tau_c^*}$$ **Equation 10**

Where:

$$\tau_s^* = \frac{\rho g u^2}{\left[18log\left(\frac{12R}{3D_{90}}\right)\right]^2}$$ **Equation 11**

D_*	=	dimensionless sediment size
D_{50}	=	median grain size (ft)
g	=	acceleration of gravity (32.2 feet per square second)
υ	=	kinematic viscosity of water ($1 \cdot 10^{-5}$ square feet per second)
T_{ts}	=	dimensionless transport-stage parameter
D_{90}	=	size larger than 90% of the bed material by weight (ft)
R	=	hydraulic radius (ft)
u	=	mean flow velocity (ft/s)

$$\tau_c^* = 103 \cdot \theta \cdot D_{50}$$ **Equation 12**

θ = dimensionless Shields stress ranging from 0.02 to 0.10 for sands and larger sediments

$$\theta = \frac{0.24}{D_*} + 0.055 \cdot [1 - exp(-0.02 \cdot D_*)]$$ **Equation 13**

The dune height may be computed by:

$$\Delta = 0.11 \cdot D_{50}^{0.3} \cdot y^{0.7} \cdot \left(1 - exp(-0.5T_{ts})\right)(25 - T_{ts})$$ **Equation 14**

[6] Ripples are considered too small to be significant concern for scour evaluation purposes.

$$z_{bf} = \frac{\Delta}{2}$$ **Equation 15**

Estimates of bedform scour herein used the hydraulic output associated with the empirical bankfull flow. Three iterations of D_{50} and D_{90} were calculated, with the greatest resulting depth assumed as the bed form scour. The three iterations are as follows:

- Small: D_{50} = 0.5 mm, D_{90} = 0.75 mm
- Medium: D_{50} = 1.0 mm, D_{90} = 1.5 mm
- Large: D_{50} = 2.0 mm, D_{90} = 3 mm

Calculated bedform scour ranges between 0.0 and 0.9 ft.

4.2.2.6 Total Scour (z_{ts})

Geosyntec calculated total scour for two design scenarios:

- Scenario A (More Conservative): this scenario includes the summation of all components of scour (local, general, long-term, bend, and bedform scour). This is a very conservative approach because of the low likelihood of the contemporary colocation of these forms of scour occurring over the life of the pipeline, (e.g., Baird et al. 2015); and
- Scenario B (Conservative): this scenario includes the summation of all components of scour excluding the large woody debris component (z_{lwd}) of local scour, which produces a total scour depth that is less conservative than Scenario A but is an appropriate scenario for design based on standards of practice[7].

The distribution of total scour depth results relative to drainage area is provided in Figure 4-4. There is a positive relationship between total scour depth and drainage area, which is expected. Histograms of calculated total scour depth, with a breakdown by component, are provided for Scenarios A and B in Figure 4-5 and Figure 4-6, respectively. Calculated total scour ranges between 2.8 and 13.0 ft for Scenario A and between 2.5 and 10.3 ft for Scenario B (Appendix A, Table A-3). For either scenario, the confluence scour component of local scour is only present if a confluence exists at the crossing; otherwise, only the LWD component of scour is illustrated (Scenario A only).

Consistent with the recommendation by Baird et al., (2015), Geosyntec did not apply an additional factor of safety to the calculated scour depth as we consider that additional conservatism is not warranted. Conservatism was introduced by adding scour components that would have to be collocated and contemporary to expose the pipeline.

[7] For a given stream reach of interest, z_{lwd} is considered to be localized in spatial extent and potentially short-lived in time because movement and accumulation of woody debris is a dynamic process. While local scour associated with large woody debris is a real process, it is not a scour component commonly considered in practice.

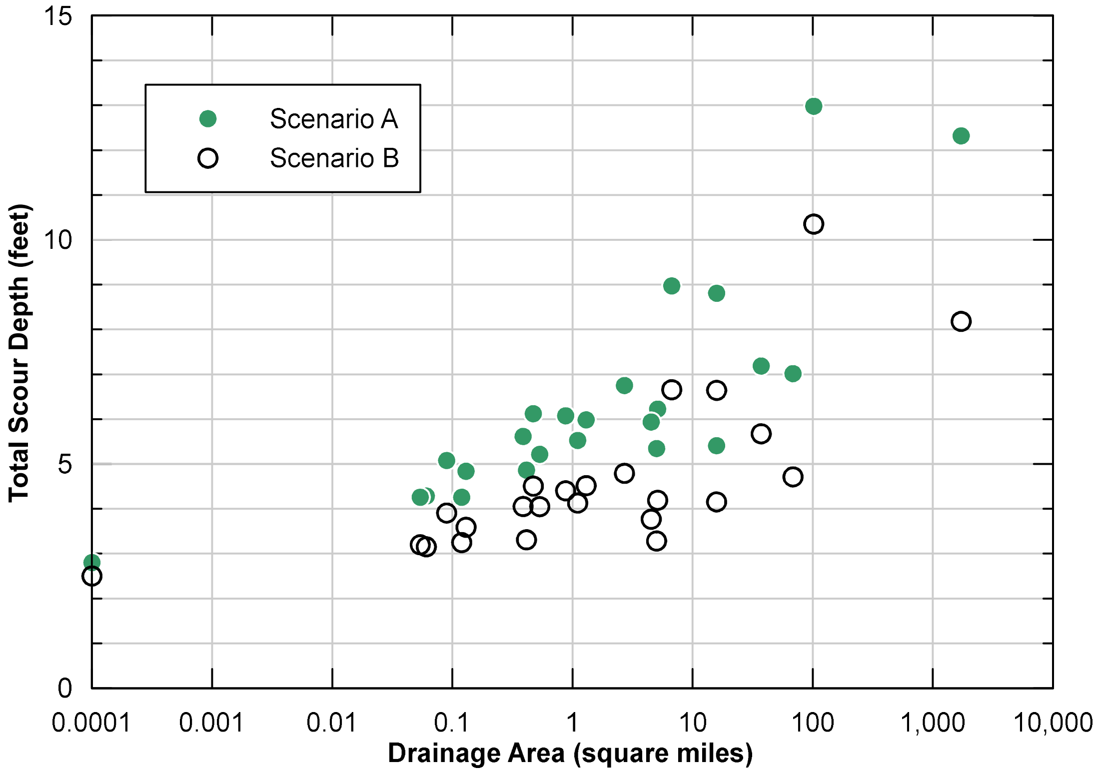

Figure 4-4. Plot of Calculated Total Scour Depth by Scenario vs. Drainage Area

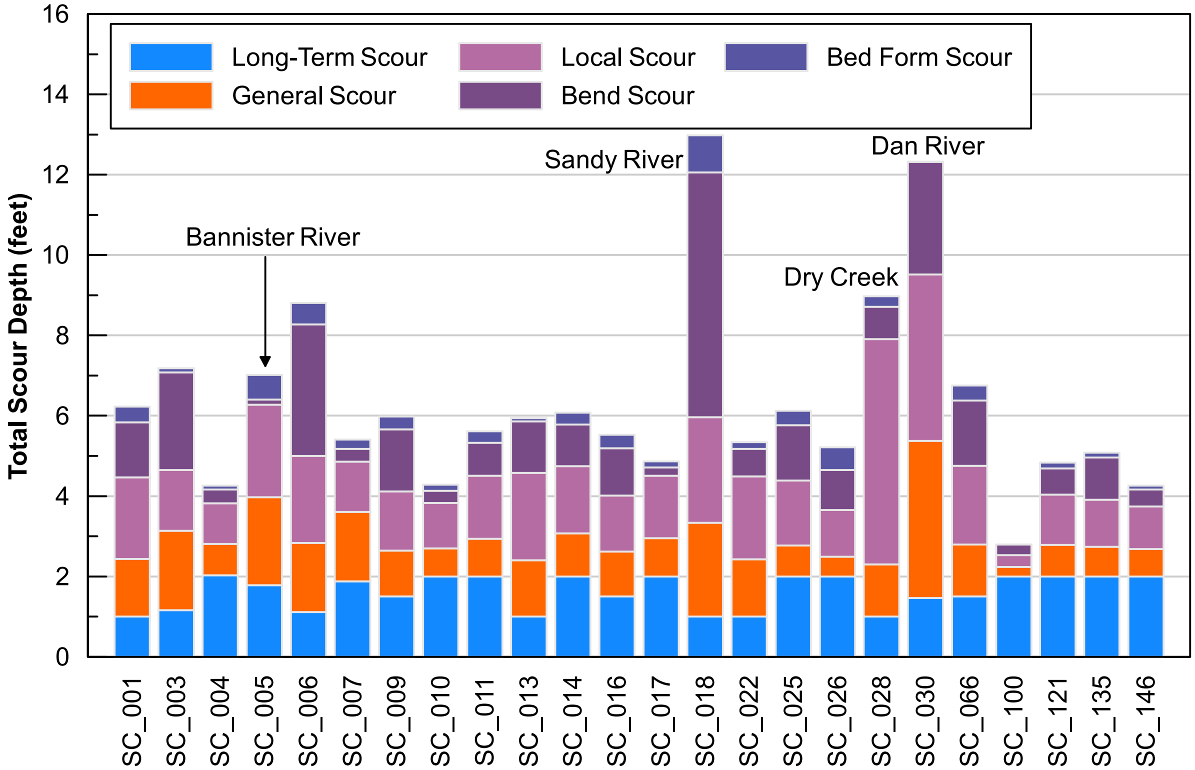

Figure 4-5. Total Scour Depth Results with Component Breakdown for Design Scenario A

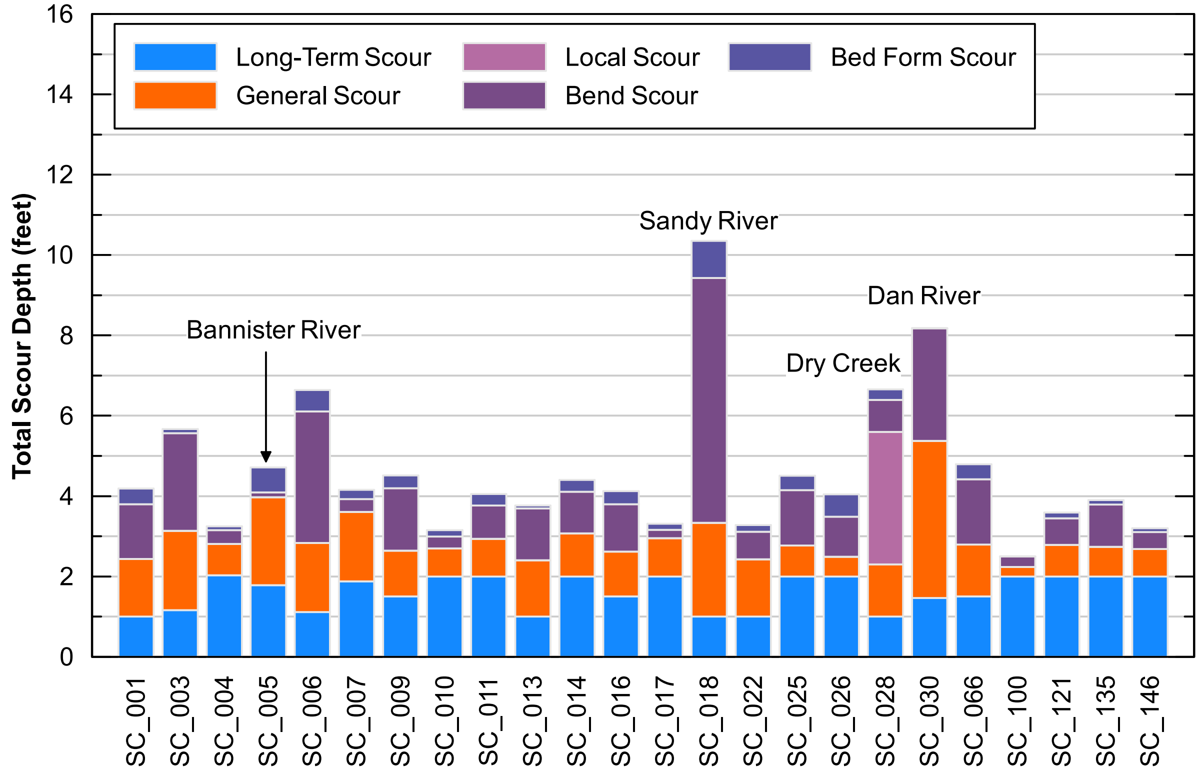

Figure 4-6. Total Scour Depth Results with Component Breakdown for Design Scenario B Burial Depths

Geosyntec recommends that the burial depth of the pipeline at stream crossings be rounded up from the total scour estimates to the next half foot increment, with a minimum burial depth of 5 ft at Intermediate and Major stream crossings. For stream crossings that have consolidated rock shallower than 5 ft, the minimum recommended burial depth at stream crossings is 2 ft into consolidated rock. Appendix A (Table A-2) provides proposed burial depth recommendations for the 80 stream crossings. These recommendations are based on the desktop study described herein.

5. CONSTRUCTION IMPLEMENTATION AND MITIGATION MEASURES

Stream physical attribute data for the 24 streams that were analyzed are included in Table A-1 (Appendix A). Additionally, results and recommendations for proposed setbacks and burial depths for all 80 streams evaluated herein are provided in Table A-2 (Appendix A). An additional reference point at the stream's TOB for measuring setback locations along centerline of pipe alignment has been added to Table A-2 for Intermediate and Major streams (i.e., streams wider than 10 ft.) The setback measurements are referred to as either "Coming In (Lambert)" or "Going Out (Dan River Interconnect)" setback measurements depending on if the setback is on the Lambert or Dan River Interconnect side of the stream/waterbody. The TOB reference point is to provide the construction team with an alternate point to measure the setback labeled as Setback 1 (S1) and Setback 2 (S2) in addition to the provided latitude and longitude coordinates. The TOB point is indicated on Figure 4-1 for visual reference.

As right-of-way clearing and construction proceeds, the crossing setback and burial recommendations may encounter site-specific field conditions that make meeting the recommendation impractical or not possible within existing workspace and time requirements to cross the stream/waterbody. Geosyntec should be consulted if deviations from the recommendations provided herein are needed.

Crossings where a horizontal directional drilling method, or other similar trenchless technology is used, should apply the recommended setbacks and selected burial depth scenario as minimum values to design the bore profile.

A more detailed discussion of how to apply the recommendations to construction conditions, compliance with applicable regulations, and mitigation measures process for seeking regulatory minimums in cases of deviations is provided in the section below.

5.1 Lateral Channel Migration

Geosyntec conducted an HSA described in Section 4.1 to characterize the horizontal limits for lateral channel migration and channel avulsion with potential to affect the pipeline alignment over the anticipated design life of the project (assumed to be 30 years). The recommended horizontal setbacks to mitigate exposure of the pipeline due to these lateral erosion processes are provided in Appendix A, Table A-2.

In some situations, the setback recommendations were located at the edge of the floodplain, at the toe of the hillslope, or edge of stream/waterbody at the hillslope toe. The practicality of achieving these setback locations depends on a number of conditions, principally the depth to bedrock, hillslope angle, soil type, depth of burial, workspace available, landslide triggering hazard, and others. Where the construction team identifies a setback that is not practical to achieve and seeks to reduce the setback recommendation (Appendix A, Table A-2), the practicable extent of the recommendations for setback should be attempted. If bedrock is encountered before the target burial depth along the setback for the crossing, then burial in bedrock per 49 CFR §192.327 would apply for the practicable extent of the setback to achieve the recommended setback length.

5.1.1 Patrol After Installation

Geosyntec's burial recommendations generally exceed the minimum depth of cover standards of 4 ft in navigable streams (Section 2.3) and as such produce a greater amount of earthwork. The excavated volume required to achieve the setback recommendation for the largest burial depths may be up to four times greater than that required to achieve the minimum standards. This increased volume of earthwork may pose an increased hazard to adjacent environmental resources (i.e., streams, wetlands, and riparian buffers). Situations could include limited workspace to store spoil volume and insufficient workspace for spoil pile storage with sufficient erosion and sediment control measures to protect water quality in the adjacent waterbody. An increased landslide risk may be present when additional excavation would require storing the spoil on native slopes. Other considerations for allowing a reduction in burial setback are when an excavation is impractical due to terrain constraints (e.g., steep slopes at valley edge or at stream/waterbody edge), geology (e.g., blasting or use of special equipment), or adjacent infrastructure.

Should the horizontal setbacks described in Sections 4.1 and presented in Appendix A (Table A-2) pose increased environmental or landslide hazard or be unsafe or impractical due to terrain or geology, Mountain Valley could either protect the bank by hardening it using riprap or revetment mats and/or patrol the streams/waterbodies over the lifetime of the pipeline as a way to identify stream migration and implement a mitigation measure in lieu of maintaining the burial elevation throughout the entire recommended burial setback. Patrols will be performed to assess any channel movement conditions and in accordance with 49 CFR §192.705 for time interval and class location (Table 5-1).

Table 5-1. Maximum Time Interval Between Patrols

Class Location of the Line	At Highway and Railroad Crossings	At all Other Places
1, 2	7 ½ months; but at least twice each calendar year	15 months; but at least once each calendar year
3	4 ½ months; but at least four times each calendar year	7 ½ months; but at least twice each calendar year
4	4 ½ months; but at least four times each calendar year	4 ½ months; but at least four times each calendar year

5.2 Vertical Scour

Geosyntec's vertical scour analysis described in Section 4.2 consisted of evaluating an appropriate burial depth based on the depth of anticipated total (vertical) scour at 80 pipeline stream crossings[8].

[8] Burial depth recommendations for the 24 stream crossing evaluated in the vertical scour analysis were based on the results of the analysis. Burial depth recommendations for the 58 Minor stream crossings (not evaluated in the vertical scour analysis) were based on the minimum depth of 36 inches (3 ft) requirements in 49 CFR §192.327.

Mountain Valley is employing a variety of mitigation strategies to prevent scour from affecting the pipeline at stream crossings. The primary mitigation strategies are to achieve one of the two recommended burial depths (Scenario A – Most Conservative and Scenario B – Conservative) in Appendix A, Table A-3.

This report's recommendations cannot fully contemplate unforeseen conditions during construction that may necessitate deviation from these recommendations. If both of the recommended burial depth scenarios cannot be attained for reasons other than presence of shallow competent bedrock, additional mitigation measures listed in 5.2.2 or 5.2.3, or a combination thereof, could be used to mitigate future exposure assuming that the minimum pipeline burial depth requirements are achieved.

5.2.1 Bedrock

The most common field condition for not achieving recommended burial depth is the presence of shallow consolidated bedrock, which by its nature is a scour inhibitor. Table A-2 (Appendix A) provides recommended burial depths with the assumption that consolidated bedrock is not encountered. Should shallow consolidated bedrock be encountered within the setback and burial recommendations, burial in bedrock per 49 CFR §192.327 would apply for the extent of the recommended setback. However, the burial depth does not have to be deeper than recommended in Table A-2. The resulting potential deviation in burial depth from the recommendation would remain in compliance with 49 CFR §192.327 and meet the intent of this report's recommendations. Therefore, no additional mitigation is required if the pipeline is installed below the bedrock surface. For stream crossings that have consolidated bedrock shallower than 3 ft below the thalweg, the minimum recommended burial depth at stream crossings is 2 ft into consolidated rock. Bedrock depths are to be field verified during construction and documented in as-built records.

5.2.2 Armoring Layer

Vertical scour mitigation methods such as the construction of an erosion/scour-resistant armoring layer may be utilized at the pipeline stream crossing where burial depths exceed 5 ft and bedrock is deeper than 7 ft. The armoring layer would be appropriately sized (i.e., particle sizes are equal to or greater than the 100-year peak discharge design estimate) and would be resistant to vertical scour. The armoring layer would extend upstream and downstream of the pipeline stream crossing to protect the pipeline. The armoring layer would be buried below the stream bed by a minimum of 2 ft and not visible at the surface. The final particle size (or distribution) of the armoring layer will dictate the pipeline burial depth. The design of these armoring layers is outside the scope of this report and should be conducted on a case-by-case basis.

5.2.3 Revetment Mats

On a site-specific basis, Mountain Valley may consider using revetment mats at the pipeline crossing as a mitigation option. Revetment mats are engineered materials designed to provide erosion resistance at the channel bed (i.e., prevent scour) or may be placed below the channel bed to mitigate the potential for exposure in the future. Revetment mats would also be placed upstream and downstream of the pipeline crossing to protect the pipeline and buried below the stream bed by a minimum of 2 ft and not visible at the surface. Pipeline burial depth would be finalized after the size of the revetment mat is assessed.

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APPENDIX A
Results of Burial Setback and Depth Evaluation

MVP SOUTHGATE

Table A-1. Stream Crossing Physical and Waterbody Data

MVP Waterbody ID [1]	MP [1]	State	GEO ID	Key [1]	Waterbody Name	FERC Class	Calculated Stream Type [1]	Physio Province	Latitude	Longitude	DA (sq mi)	Observed OHW Width (ft) [1]	Actual Pipeline Crossing Length (ft) [1, 2]	Active Channel Measured Width (ft)	Bankfull Measured Stream Width (ft)	Slope %	Rosgen Stream Type	Mannings n by Stream Type	Empirical Data Qbkf (ft^3/s)
S-A005	0.10	VA	SC_100		Trib. To Little Cherrystone Creek	Intermediate	Intermittent	Piedmont	36.828987	-79.344561	0.0001	4	13.3	27	13	1.42	C6	0.040	0.01
S-A004	0.70	VA	SC_001	92S-F18-65	Little Cherrystone Creek	Intermediate	Perennial	Piedmont	36.822929	-79.347523	5.11	15	19.28	30	17	0.35	G5	0.040	206
S-A008	2.00	VA	SC_003	334S-D18-18	Cherrystone Creek	Intermediate	Perennial	Piedmont	36.808422	-79.363086	37.22	25	28.10	40	27	0.18	E5	0.040	1350
S-A019	3.90	VA	SC_004	451S-D18-6	Trib. To Banister River	Intermediate	Intermittent	Piedmont	36.787966	-79.384415	0.12	4	11.93	12	6	0.60	C4	0.040	5.9
S-A020	5.30	VA	SC_005	584S-E18-3	Banister River	Intermediate	Perennial	Piedmont	36.774151	-79.399259	68.55	40	46.07	52	42	0.15	E5	0.040	2407
S-A021	5.30	VA	SC_006	3125897S-D18-2	White Oak Creek	Intermediate	Perennial	Piedmont	36.773107	-79.399656	15.86	16	30.03	34	25	0.17	E5	0.040	602
S-A022	5.40	VA	SC_007	312S-D18-2	White Oak Creek	Intermediate	Perennial	Piedmont	36.771802	-79.400505	15.85	24	20.67	26	24	0.13	E5	0.040	601
S-A052	8.30	VA	SC_135		Trib. To White Oak Creek	Intermediate	Perennial	Piedmont	36.741527	-79.434082	0.09	4.5	13.8	93	27	3.61	B6a	0.058	4.5
S-A029	8.90	VA	SC_066	90S-E18-14	Trib. To White Oak Creek	Intermediate	Perennial	Piedmont	36.734738	-79.440383	2.71	11	15.49	16	16	0.27	E5	0.054	113
S-A033a	10.30	VA	SC_009	91S-F18-17	White Oak Creek	Intermediate	Perennial	Piedmont	36.720490	-79.455121	1.30	7	10.15	18	14	0.26	E5	0.054	56.3
S-A036	11.40	VA	SC_010	2965698S-F18-20	Trib. To Sandy Creek	Intermediate	Intermittent	Piedmont	36.707831	-79.466946	0.06	3	39.38	10	4	2.67	B4	0.058	3.09
S-A042	11.70	VA	SC_011	296S-F18-20	Trib. To Sandy Creek	Intermediate	Perennial	Piedmont	36.703911	-79.470539	0.39	6	17.58	14	6	1.57	G4	0.060	17.9
S-A045	13.10	VA	SC_013	471S-D18-21	Sandy Creek	Intermediate	Perennial	Piedmont	36.688828	-79.486182	4.52	15	21.29	32	22	1.11	C4	0.040	183
S-A046	13.80	VA	SC_014	673S-E18-27	Trib. To Sandy Creek	Intermediate	Perennial	Piedmont	36.680582	-79.490095	0.88	6	22.25	16	13	0.61	C4	0.040	38.8
S-A051	16.10	VA	SC_016	686S-D18-37	Trib. To Silver Creek	Intermediate	Perennial	Piedmont	36.657429	-79.517460	1.10	18	16.14	28	14	0.70	F4	0.050	48.2
S-A052	16.40	VA	SC_146		Trib. To Silver Creek	Intermediate	Perennial	Piedmont	36.653784	-79.520360	0.05	3	18.3	32	11	3.00	C6b	0.058	2.77
S-A071	17.70	VA	SC_017	689S-E18-51	Trib. To Sandy River	Intermediate	Perennial	Piedmont	36.639751	-79.534245	0.41	10	17.30	14	10	3.05	B4	0.058	19.1
S-A063a	18.20	VA	SC_018	114S-E18-44	Sandy River	Intermediate	Perennial	Piedmont	36.635512	-79.540133	102	75	83.82	96	75	0.13	E5	0.040	3507
S-B046	20.10	VA	SC_121		Trib. To Pine Lake	Intermediate	Perennial	Piedmont	36.613877	-79.562248	0.13	3	15.1	50	9	1.45	C6	0.040	6.36
S-B029	23.60	VA	SC_022	136S-F18-40	Trotters Creek	Intermediate	Perennial	Piedmont	36.574700	-79.600121	5.02	9	14.08	24	25	0.85	F4	0.040	202
S-B051	26.40	VA	SC_025	685S-C18-90	Trib. To Dan River	Intermediate	Perennial	Piedmont	36.545973	-79.628341	0.47	3	10.49	18	10.5	0.72	G4	0.060	34.1
S-B036	28.00	NC	SC_026	87S-A18-42	Trib. To Cascade Creek	Intermediate	Perennial	Piedmont	36.528020	-79.646199	0.53	5	10.05	44	12	0.33	F5	0.064	38.1
S-B034	28.20	NC	SC_028	580S-A18-40	Dry Creek	Intermediate	Perennial	Piedmont	36.525916	-79.648241	6.71	30	34.23	36	32	0.46	F5	0.040	362
S-B005	30.80	NC	SC_030	146S-A18-17	Dan River	Major	Perennial	Piedmont	36.497121	-79.675825	1720	200	204.87	260	235	0.09	C5	0.040	50454

[1] Data provided by Mountain Valley Pipeline Southgate on 02 June 2025.

[2] Length based on the intersection of the pipeline alignment and the ordinary high water mark delineation.

DA: drainage area

FERC: Federal Energy Regulatory Commission

ft: feet
ft^3/s: cubic feet per second
GEO: Geosyntec
MP: milepost
NC: North Carolina
OHW: ordinary high water
Qbkf: empirical bankfull flow (based on regional hydraulic geometry relationship)
sq mi: square mile
Trib.: tributary
VA: Virginia

Table A-2. Hydrotechnical Data

MVP Waterbody ID	Approx MP	State	GEO ID	Water Body Name	Proposed Burial Depth (ft)	Burial Distance (ft)	Proposed Setback 1 (Lambert)		Proposed Setback 2 (Dan River Interconnect)		Proposed Setback Measurements from TOB [1]		Top of Bank Position (Lambert)		Top of Bank Position (Dan River Interconnect)		HSA Notes
							Latitude	Longitude	Latitude	Longitude	Coming In (Lambert)	Going Out (Dan River Interconnect)	Latitude	Longitude	Latitude	Longitude	
S-A005	0.1	VA	SC_100	Trib. To Little Cherrystone Creek	5.0	89	36.829151	-79.344512	36.828914	-79.344581	35.0	28.0	36.82905792	-79.34453925	36.82898851	-79.34455938	Questionable ~25 ft of lateral migration visible between 2018 and 2024 aerial imagery; Setbacks from TOB equivalent approximate belt width of meander at crossing.
S-A006	0.4	VA	SC_145	Trib. to Little Cherrystone Creek	3.0	34	36.825265	-79.344730	36.825196	-79.344810	N/A	N/A	36.82523552	-79.34476418	36.82522448	-79.34477691	
S-A004	0.7	VA	SC_001	Little Cherrystone Creek	6.5	145	36.823072	-79.347357	36.822776	-79.347688	46.0	55.0	36.82298267	-79.34746581	36.82289159	-79.34756471	~30 ft of upstream lateral migration observed in aerials between 1994 and 2007 (~ 2.3ft /yr); Bank has not migrated much since 2007 and was straightened between 2016 and 2017; Setbacks placed ~42 ft from TOBs measured perpendicular; which is just outside stable belt width.
S-A002	0.8	VA	SC_002	Trib. To Sandy Creek	3.0	63	36.821232	-79.349247	36.821101	-79.349385	16.0	15.0	36.82119923	-79.34928095	36.8211306	-79.34935331	Crossing located downstream of agricultural impoundment; minimal lateral instabilities observed; standard 15 ft setbacks from TOB.
S-A012	1.4	VA	SC_144	Trib. To Cherrystone Creek	3.0	47	36.815038	-79.355475	36.814944	-79.355583	N/A	N/A	36.8150186	-79.35549726	36.81496251	-79.35556127	
S-A009	1.7	VA	SC_143	Trib. To Cherrystone Creek	3.0	34	36.811685	-79.359347	36.811616	-79.359426	N/A	N/A	36.81166269	-79.35937212	36.81164172	-79.35939628	
S-A008	2.0	VA	SC_003	Cherrystone Creek	7.5	138	36.808618	-79.362877	36.808340	-79.363198	69.0	27.0	36.80847631	-79.36303146	36.80838956	-79.36313044	Upstream belt width ~80-90 ft; minimal lateral migration observed in historic aerials; LB setback 45 ft from LB TOB, outside upstream meander belt width; right bank setback 30 ft from TOB (low migration hazards along right bank); setbacks cover upstream meander belt width.
S-A018	3.5	VA	SC_142	Trib. To Banister River	3.0	45	36.792159	-79.381141	36.792065	-79.381239	N/A	N/A	36.79212728	-79.38117404	36.79210118	-79.38120131	
S-A019	3.9	VA	SC_004	Trib. To Banister River	5.0	40	36.788023	-79.384395	36.787915	-79.384421	14.0	15.0	36.78798598	-79.38440389	36.78795338	-79.38441171	Crossing in backwater of impoundment in a depositional zone; no lateral migration hazard expected; standard 15-ft setbacks from TOB.
S-A015	4.3	VA	SC_141	Trib. To Banister River	3.0	67	36.783452	-79.388833	36.783380	-79.389045	N/A	N/A	36.78340916	-79.38896188	36.78338995	-79.38901777	
S-A017	4.4	VA	SC_140	Trib. To Banister River	3.0	48	36.782847	-79.390504	36.782793	-79.390652	N/A	N/A	36.78281098	-79.39060288	36.78279997	-79.39063301	
S-A020	5.3	VA	SC_005	Banister River	7.5	145	36.774342	-79.399151	36.773979	-79.399352	44.0	41.0	36.77423028	-79.39921413	36.77408301	-79.39929535	Minor lateral migration observed in historic aerial imagery; channel has been straightened repeatedly to prevent meandering; 40 ft (one channel width) setbacks from toe of bank to accommodate lateral migration; one channel width evaluated to be the lateral hazard extent. Cannot identify belt width from aerials.
S-A021	5.3	VA	SC_006	White Oak Creek	9.0	130	36.773295	-79.399618	36.772943	-79.399680	41.0	45.0	36.77318443	-79.39963757	36.77306808	-79.39965799	Lateral migration observed in historic aerial imagery (~15 ft in 22 yrs); Lateral migration observed in LiDAR signature; Potential for meander formation at right bank post construction.
S-A022	5.4	VA	SC_007	White Oak Creek	9.0	52	36.771826	-79.400426	36.771788	-79.400598	14.0	14.0	36.77181622	-79.40047126	36.77179804	-79.4005518	Some lateral migration observed in historic aerials. 15-ft standard setbacks from TOB.
S-A028	7.0	VA	SC_139	Trib. To White Oak Creek	3.0	35	36.757005	-79.419573	36.756931	-79.419648	N/A	N/A	36.75698201	-79.41959674	36.75695355	-79.41962534	
S-A027	7.3	VA	SC_137	Trib. To White Oak Creek	3.0	60	36.753173	-79.423373	36.753044	-79.423502	N/A	N/A	36.75310769	-79.42343817	36.75308157	-79.42346436	
S-A026	7.3	VA	SC_138	Trib. To White Oak Creek	3.0	60	36.753386	-79.423159	36.753258	-79.423287	N/A	N/A	36.75335707	-79.42318824	36.75333556	-79.4232098	
S-A025	7.9	VA	SC_136	Trib. To White Oak Creek	3.0	74	36.746211	-79.429824	36.746047	-79.429974	N/A	N/A	36.7461446	-79.42988503	36.74612598	-79.42990205	
S-A024	8.3	VA	SC_135	Trib. To White Oak Creek	5.5	107	36.741721	-79.433909	36.741485	-79.434124	73.0	12.0	36.74155664	-79.43405811	36.74151095	-79.4340996	Drainage from agricultural pond. Setbacks placed at valley width.
S-A029	8.9	VA	SC_066	Trib. To White Oak Creek	7.0	48	36.734801	-79.440328	36.734696	-79.440425	15.0	14.0	36.73476882	-79.4403577	36.73472698	-79.44039601	Minimal lateral instability and no historic migration signatures observed in LiDAR; Standard 15-ft setbacks from TOB.
S-A001	8.9	VA	SC_134	Trib. To White Oak Creek	3.0	40	36.734949	-79.440193	36.734860	-79.440274	N/A	N/A	36.73491873	-79.44022043	36.73489443	-79.44024269	
S-A032	10.2	VA	SC_147	Trib. To White Oak Creek	3.0	35	36.720667	-79.454603	36.720648	-79.454720	N/A	N/A	36.72066181	-79.4546338	36.72065351	-79.45468733	
S-A033a	10.3	VA	SC_009	White Oak Creek	6.0	66	36.720602	-79.454998	36.720469	-79.455150	33.0	16.0	36.72053689	-79.45507244	36.72050097	-79.4551138	LB setback set beyond observed meander migration history; RB setback ~15 ft from TOB.
S-A034	10.4	VA	SC_133	Trib. To White Oak Creek	3.0	32	36.719198	-79.457044	36.719126	-79.457109	N/A	N/A	36.71917049	-79.45706851	36.71915612	-79.45708155	
S-A036	11.4	VA	SC_010	Trib. To Sandy Creek	5.0	187	36.708029	-79.466901	36.707525	-79.467020	47.0	47.0	36.70790056	-79.46693146	36.70765009	-79.46699018	Pipeline crosses stream obliquely/parallel (runs down channel centerline); Suggest reroute; No lateral instabilities observed, channel laterally confined by valley wall; Standard 15-ft setbacks from TOB.
S-A038	11.4	VA	SC_132	Trib. To Sandy Creek	3.0	32	36.707053	-79.467130	36.706966	-79.467151	N/A	N/A	36.70701188	-79.46713982	36.70700496	-79.46714145	

Table A-2. Hydrotechnical Data

MVP Waterbody ID	Approx MP	State	GEO ID	Water Body Name	Proposed Burial Depth (ft)	Burial Distance (ft)	Proposed Setback 1 (Lambert)		Proposed Setback 2 (Dan River Interconnect)		Proposed Setback Measurements from TOB [1]		Top of Bank Position (Lambert)		Top of Bank Position (Dan River Interconnect)		HSA Notes
							Latitude	Longitude	Latitude	Longitude	Coming In (Lambert)	Going Out (Dan River Interconnect)	Latitude	Longitude	Latitude	Longitude	
S-A039-Braid-1	11.5	VA	SC_131	Trib. To Sandy Creek	3.0	45	36.705639	-79.467601	36.705560	-79.467720	N/A	N/A	36.70559348	-79.46766933	36.70558842	-79.46767697	
S-A039	11.5	VA	SC_150	Trib. To Sandy Creek	3.0	45	36.705639	-79.467601	36.705560	-79.467720	N/A	N/A	36.70561477	-79.46763717	36.705609	-79.46764589	
S-A042	11.7	VA	SC_011	Trib. To Sandy Creek	6.0	62	36.703950	-79.470463	36.703867	-79.470646	13.0	20.0	36.70393252	-79.47050127	36.70389359	-79.47058687	Difficult to see stream in aerials; Stream is moderately entrenched; no historic lateral migration observed in LiDAR signature; 15-ft setbacks from TOB on LB and RB.
S-A043	12.0	VA	SC_130	Trib. To Sandy Creek	3.0	37	36.701676	-79.473382	36.701596	-79.473461	N/A	N/A	36.70164402	-79.47341328	36.70163096	-79.47342639	
S-A044	12.2	VA	SC_012	Trib. To Sandy Creek	3.0	50	36.698595	-79.476448	36.698487	-79.476555	15.0	14.0	36.69856299	-79.47647908	36.69851768	-79.47652428	Setbacks placed ~17 ft from TOB on LB and RB beyond the meander belt width to accommodate the meander migration potential.
S-A045	13.1	VA	SC_013	Sandy Creek	6.0	85	36.688963	-79.486052	36.688780	-79.486234	37.0	15.0	36.68888482	-79.48612968	36.6888111	-79.48620264	Right setback set at ~70 ft from TOB on left bank to accommodate the meander belt width observed upstream and downstream; LB setback at standard 15-ft from TOB.
S-A046	13.8	VA	SC_014	Trib. To Sandy Creek	6.5	83	36.680672	-79.490030	36.680479	-79.490177	15.0	32.0	36.68063641	-79.49005771	36.68055452	-79.49011979	Minimal lateral migration hazard; standard 15-ft setback from TOB on LB, and 25-ft setback from TOB on RB to accommodate oblique crossing.
S-A049	14.7	VA	SC_015	Trib. To Sandy Creek	3.0	40	36.673477	-79.501597	36.673391	-79.501684	12.0	5.0	36.67345275	-79.50162174	36.6734014	-79.50167336	Vegetation restricts view of channel at crossing in aerials; no lateral instabilities or migration observed in aerials within ROW immediately upstream; topographically confined along right bank; Standard 15-ft setbacks from TOB.
S-A048	15.1	VA	SC_129	Trib. To Sandy Creek	3.0	39	36.668223	-79.506515	36.668120	-79.506555	N/A	N/A	36.66818987	-79.50652787	36.66815784	-79.50654045	
S-A070	15.6	VA	SC_128	Trib. To Silver Creek	3.0	39	36.662137	-79.511196	36.662066	-79.511295	N/A	N/A	36.66211306	-79.51122888	36.66208616	-79.51126652	
S-A051	16.1	VA	SC_016	Trib. To Silver Creek	6.0	105	36.657595	-79.517322	36.657357	-79.517526	45.0	16.0	36.65749224	-79.51740998	36.65739283	-79.51749432	Setbacks at 15 ft beyond TOB outside meander migration potential/active belt width.
S-A050	16.3	VA	SC_127	Trib. To Silver Creek	3.0	43	36.655453	-79.519192	36.655360	-79.519281	N/A	N/A	36.65542648	-79.51921756	36.65538519	-79.51925659	
S-A052	16.4	VA	SC_146	Trib. To Silver Creek	5.0	64	36.653826	-79.520297	36.653719	-79.520469	14.0	9.0	36.65380283	-79.52033421	36.65373355	-79.52044589	Small wooded drainage. Unable to assess potential lateral migration at crossing due to vegetation cover in aerial imagery. Standard 15-ft setbacks from TOB.
S-A054	16.6	VA	SC_126	Trib. To Silver Creek	3.0	71	36.652001	-79.522148	36.651841	-79.522286	N/A	N/A	36.65199184	-79.52215578	36.65197346	-79.52217164	
S-A055	16.6	VA	SC_148	Trib. To Silver Creek	3.0	71	36.652001	-79.522148	36.651841	-79.522286	N/A	N/A	36.65187569	-79.52225604	36.65185739	-79.52227184	
S-A057	17.2	VA	SC_125	Trib. To Sandy River	3.0	45	36.643963	-79.527388	36.643841	-79.527364	N/A	N/A	36.6439178	-79.5273793	36.64386873	-79.52736928	
S-A058	17.4	VA	SC_124	Trib. To Sandy River	3.0	35	36.642002	-79.528758	36.641932	-79.528840	N/A	N/A	36.6419837	-79.52877974	36.64194592	-79.52882426	
S-A071	17.7	VA	SC_017	Trib. To Sandy River	5.0	36	36.639770	-79.534209	36.639722	-79.534317	12.0	2.0	36.63975355	-79.53424632	36.63972426	-79.53431309	Stream in a confined valley; setbacks placed at toe of valley wall (approximately elevation 582)
S-A063a	18.2	VA	SC_018	Sandy River	13.0	229	36.635799	-79.539819	36.635329	-79.540340	94.0	44.0	36.63560635	-79.54003246	36.63541986	-79.54023891	Limited channel migration observed at the crossing in aerials between 1967 and 2018; meander at crossing has migrated ~25 ft downstream over 56 years; RB topographically confined against valley wall; LB is a depositional area with setback placed one bankfull width from TOB.
S-A059	18.4	VA	SC_123	Trib. To Hardys Creek	3.0	33	36.632520	-79.543328	36.632451	-79.543401	N/A	N/A	36.63249472	-79.54335468	36.63248634	-79.54336358	
S-B059	19.9	VA	SC_122	Trib. To Pine Lake	3.0	38	36.617539	-79.559831	36.617452	-79.559902	N/A	N/A	36.61750479	-79.55985913	36.61748631	-79.55987403	
S-B046	20.1	VA	SC_121	Trib. To Pine Lake	5.0	69	36.613977	-79.562181	36.613811	-79.562296	34.0	16.0	36.61389603	-79.56223702	36.61384981	-79.56226889	Limited channel migration observed at the crossing in aerials between 2007 and 2024. Variable flows with channel dry at times. Standard 15-ft setbacks from TOB.
S-B045	20.8	VA	SC_019	Trib. To Trayner Branch	3.0	47	36.605991	-79.568099	36.605883	-79.568191	8.0	12.0	36.60596571	-79.56812046	36.60590078	-79.56817577	Crossing located ~30 ft downstream of culvert; RB laterally confined by valley wall; LB and RB standard 15-ft setback from TOB.
S-B044a	21.0	VA	SC_020	Trib. To Trayner Branch	3.0	45	36.603336	-79.570370	36.603235	-79.570458	N/A	N/A	36.60329709	-79.57040406	36.60326299	-79.57043351	
S-B043	21.4	VA	SC_120	Trayner Branch	3.0	41	36.598955	-79.574138	36.598863	-79.574217	N/A	N/A	36.59893685	-79.57415384	36.59887753	-79.57420483	
S-B041	21.6	VA	SC_149	Trib. To McGuff Creek	3.0	76	36.595955	-79.576946	36.595797	-79.577116	N/A	N/A	36.59592675	-79.57697638	36.59590875	-79.57699579	
S-B042	21.7	VA	SC_119	Trib. To McGuff Creek	3.0	76	36.595955	-79.576946	36.595797	-79.577116	N/A	N/A	36.59587291	-79.57703443	36.59582858	-79.57708224	
S-B040	22.0	VA	SC_021	Trib. To Trotters Creek	3.0	86	36.587605	-79.586042	36.587432	-79.586239	N/A	N/A	36.58757513	-79.58607569	36.5874868	-79.58617628	Headwater stream in confined valley; pipeline crosses stream obliquely; standard 15-ft setbacks measured perpendicular from TOB.
S-B032	22.5	VA	SC_118	Trib. To Trotters Creek	3.0	37	36.586865	-79.586853	36.586788	-79.586936	N/A	N/A	36.58684373	-79.58687624	36.58682063	-79.58690122	
S-B033	22.6	VA	SC_117	Trib. To Trotters Creek	3.0	35	36.585643	-79.588094	36.585567	-79.588169	N/A	N/A	36.58561952	-79.58811731	36.58558844	-79.58814797	
S-B039	23.1	VA	SC_116	Trib. To Trotters Creek	3.0	37	36.580318	-79.594469	36.580223	-79.594517	N/A	N/A	36.58027634	-79.59449003	36.5802593	-79.59449875	
S-B029	23.6	VA	SC_022	Trotters Creek	5.5	54	36.574736	-79.600061	36.574650	-79.600212	10.0	16.0	36.57472032	-79.60008945	36.57467592	-79.60016691	Crossing located within confined valley; limited lateral migration potential; Setbacks 15 ft on LB and RB from toe of bank.

Table A-2. Hydrotechnical Data

MVP Waterbody ID	Approx MP	State	GEO ID	Water Body Name	Proposed Burial Depth (ft)	Burial Distance (ft)	Proposed Setback 1 (Lambert)		Proposed Setback 2 (Dan River Interconnect)		Proposed Setback Measurements from TOB [1]		Top of Bank Position (Lambert)		Top of Bank Position (Dan River Interconnect)		HSA Notes
							Latitude	Longitude	Latitude	Longitude	Coming In (Lambert)	Going Out (Dan River Interconnect)	Latitude	Longitude	Latitude	Longitude	
S-B061	23.6	VA	SC_023	Trib. To Trotters Creek	3.0	35	36.575093	-79.599552	36.575025	-79.599635	N/A	N/A	36.57506221	-79.59958955	36.57504015	-79.59961664	
S-B030	24.0	VA	SC_115	Trib. To Dan River	3.0	33	36.572269	-79.606124	36.572195	-79.606189	N/A	N/A	36.57224065	-79.60614905	36.57222728	-79.60616086	
S-B024	24.4	VA	SC_114	Trib. To Dan River	3.0	36	36.568722	-79.611292	36.568633	-79.611345	N/A	N/A	36.56868954	-79.61131144	36.56866821	-79.611324	
S-B022	24.6	VA	SC_113	Trib. To Dan River	3.0	50	36.566585	-79.612580	36.566472	-79.612677	N/A	N/A	36.56656442	-79.61259759	36.5665085	-79.61264547	
S-B056	25.0	VA	SC_112	Trib. To Dan River	3.0	48	36.561467	-79.613286	36.561365	-79.613390	N/A	N/A	36.56141064	-79.61334388	36.56139284	-79.61336204	
S-B054	25.4	VA	SC_110	Trib. To Dan River	3.0	55	36.556428	-79.617845	36.556314	-79.617967	N/A	N/A	36.55641286	-79.61786166	36.55638902	-79.61788725	
S-B052	25.8	VA	SC_024	Trib. To Dan River	3.0	37	36.552579	-79.621748	36.552500	-79.621827	N/A	N/A	36.55255724	-79.62176972	36.55252847	-79.62179849	
S-B051	26.4	VA	SC_025	Trib. To Dan River	6.5	57	36.546040	-79.628276	36.545918	-79.628397	17.0	19.0	36.54600465	-79.62831096	36.54595928	-79.62835615	Vegetation restricts view of channel at crossing in aerials; No historic migration or lateral instabilities observed in channel in ROW upstream of crossing in; drainage depression present adjacent to LB; Standard 15-ft setbacks from TOB.
S-B020	26.5	VA	SC_109	Trib. To Dan River	3.0	33	36.544391	-79.629920	36.544320	-79.629991	N/A	N/A	36.54436329	-79.62994725	36.54434615	-79.62996436	
S-F005	27.4	NC	SC_151	Trib. To Cascade Creek	3.0	39	36.534563	-79.638930	36.534481	-79.639017	N/A	N/A	36.53452964	-79.63896555	36.53451392	-79.63898229	
S-B036	28.0	NC	SC_026	Trib. To Cascade Creek	5.5	121	36.528210	-79.646016	36.527948	-79.646269	19.0	24.0	36.52816696	-79.64605772	36.52800106	-79.64621803	Vegetation restricts view of channel at crossing in aerials; meander bend present immediately upstream of crossing on RB; Standard 15-ft setbacks from TOB (~15 ft from TOB), beyond upstream belt width.
S-B035	28.2	NC	SC_027	Cascade Creek	9.0[2]	367	36.526488	-79.647641	36.525718	-79.648450	N/A	N/A	36.52816696	-79.64605772	36.52800106	-79.64621803	
S-B034	28.2	NC	SC_028	Dry Creek	9.0	367	36.526488	-79.647641	36.525718	-79.648450	151.0	64.0	36.52616965	-79.64797482	36.52585237	-79.64830846	Setbacks same as setbacks for SC_027; suggest reroute as crossing is oblique to flow and located at a confluence.
S-B015	29.1	NC	SC_108	Trib. To Dan River	3.0	48	36.516267	-79.656854	36.516166	-79.656960	N/A	N/A	36.51623942	-79.65688302	36.51618384	-79.65694153	
S-B017	29.3	NC	SC_107	Trib. To Dan River	3.0	37	36.513241	-79.660018	36.513163	-79.660100	N/A	N/A	36.51320996	-79.6600507	36.5131933	-79.66006809	
S-B011	29.5	NC	SC_106	Trib. To Dan River	3.0	40	36.511403	-79.662104	36.511319	-79.662192	N/A	N/A	36.51137511	-79.66213301	36.51135441	-79.66215463	
S-B009	30.0	NC	SC_105	Trib. To Dan River	3.0	35	36.505457	-79.667486	36.505363	-79.667493	N/A	N/A	36.50541718	-79.66748884	36.50539787	-79.66749041	
S-B008	30.3	NC	SC_104	Trib. To Dan River	3.0	36	36.502906	-79.670468	36.502830	-79.670546	N/A	N/A	36.50288522	-79.67048912	36.50284885	-79.67052635	
S-B005	30.8	NC	SC_030	Dan River	12.5	297	36.497467	-79.675548	36.496781	-79.676097	25.0	24.0	36.49740718	-79.67559563	36.49683844	-79.67605055	~20 feet of migration observed in historic aerial imagery between 1963 and 2018 (55 years at 0.36 ft/year); Setbacks set for 100 yr migration protection at 40 ft from toe of bank on LB and RB.
S-B004	30.9	NC	SC_103	Trib. To Dan River	3.0	34	36.495192	-79.677368	36.495114	-79.677430	N/A	N/A	36.49516556	-79.67738866	36.49514248	-79.67740711	
S-B003	31.0	NC	SC_102	Trib. To Dan River	3.0	34	36.494758	-79.677715	36.494678	-79.677778	N/A	N/A	36.49472753	-79.67773902	36.49470447	-79.67775747	
S-B002	31.1	NC	SC_101	Trib. To Dan River	3.0	35	36.492989	-79.678793	36.492982	-79.678912	N/A	N/A	36.49298625	-79.67883734	36.4929845	-79.67886716	

ft: feet
GEO: Geosyntec
HSA: horizontal setback analysis
LB: left bank
LiDAR: light detection and ranging
MP: milepost
NC: North Carolina
OHWM: ordinary high water mark
RB: right bank
TOB: top of bank
Trib.: tributary
VA: Virgina
yr: year

[1] Setbacks measured from top of bank nearest to stream/waterbody and setback measurements rounded to nearest whole number.

[2] The burial depth recommendation for SC_027 exceeds the recommended burial depth for Minor streams due to its proximity to the SC_028 stream. The recommended burial depth for the SC_027 and SC_028 sites is the greater of the two sites independent recommended burial depths.

Table A-3. Burial Depth Scenarios

MVP Waterbody ID	Approx MP	State	GEO ID	Water Body Name	Estimated Scenario A Scour Depth (ft)	Scenario A Burial Depth (ft)	Estimated Scenario B Scour Depth (ft)	Scenario B Burial Depth (ft)	Burial Distance (ft)
S-A005	0.1	VA	SC_100	Trib. to Little Cherrystone Creek	2.8	5.0	2.5	5.0	89
S-A006	0.4	VA	SC_145*	Trib. to Little Cherrystone Creek	N/A	3.0	N/A	3.0	34
S-A004	0.7	VA	SC_001	Little Cherrystone Creek	6.22	6.5	4.2	5.0	145
S-A002	0.8	VA	SC_002	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	63
S-A012	1.4	VA	SC_144*	Trib. To Cherrystone Creek	N/A	3.0	N/A	3.0	47
S-A009	1.7	VA	SC_143*	Trib. To Cherrystone Creek	N/A	3.0	N/A	3.0	34
S-A008	2.0	VA	SC_003	Cherrystone Creek	7.18	7.5	5.7	6.0	138
S-A018	3.5	VA	SC_142*	Trib. To Banister River	N/A	3.0	N/A	3.0	45
S-A019	3.9	VA	SC_004	Trib. To Banister River	4.26	5.0	3.3	5.0	40
S-A015	4.3	VA	SC_141*	Trib. To Banister River	N/A	3.0	N/A	3.0	67
S-A017	4.4	VA	SC_140*	Trib. To Banister River	N/A	3.0	N/A	3.0	48
S-A020	5.3	VA	SC_005	Banister River	7.01	7.5	4.7	5.0	145
S-A021	5.3	VA	SC_006	White Oak Creek	8.81	9.0	6.6	7.0	130
S-A022	5.4	VA	SC_007	White Oak Creek	5.41	9.0	4.2	7.0	52
S-A028	7.0	VA	SC_139*	Trib. To White Oak Creek	N/A	3.0	N/A	3.0	35
S-A027	7.3	VA	SC_137*	Trib. To White Oak Creek	N/A	3.0	N/A	3.0	60
S-A026	7.3	VA	SC_138*	Trib. To White Oak Creek	N/A	3.0	N/A	3.0	60
S-A025	7.9	VA	SC_136*	Trib. To White Oak Creek	N/A	3.0	N/A	3.0	74
S-A024	8.3	VA	SC_135	Trib. To White Oak Creek	5.08	5.5	3.9	5.0	107
S-A029	8.9	VA	SC_066	Trib. To White Oak Creek	6.75	7.0	4.8	5.0	48
S-A001	8.9	VA	SC_134*	Trib. To White Oak Creek	N/A	3.0	N/A	3.0	40
S-A032	10.2	VA	SC_147*	Trib. To White Oak Creek	N/A	3.0	N/A	3.0	35
S-A033a	10.3	VA	SC_009	White Oak Creek	5.98	6.0	4.5	5.0	66
S-A034	10.4	VA	SC_133*	Trib. To White Oak Creek	N/A	3.0	N/A	3.0	32
S-A036	11.4	VA	SC_010	Trib. To Sandy Creek	4.28	5.0	3.2	5.0	187
S-A038	11.4	VA	SC_132*	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	32
S-A039-Braid-1	11.5	VA	SC_131*	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	45
S-A039	11.5	VA	SC_150*	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	45
S-A042	11.7	VA	SC_011	Trib. To Sandy Creek	5.61	6.0	4.1	5.0	62
S-A043	12.0	VA	SC_130*	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	37
S-A044	12.2	VA	SC_012	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	50
S-A045	13.1	VA	SC_013	Sandy Creek	5.94	6.0	3.8	5.0	85
S-A046	13.8	VA	SC_014	Trib. To Sandy Creek	6.07	6.5	4.4	5.0	83
S-A049	14.7	VA	SC_015	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	40
S-A048	15.1	VA	SC_129*	Trib. To Sandy Creek	N/A	3.0	N/A	3.0	39
S-A070	15.6	VA	SC_128*	Trib. To Silver Creek	N/A	3.0	N/A	3.0	39
S-A051	16.1	VA	SC_016	Trib. To Silver Creek	5.52	6.0	4.1	5.0	105
S-A050	16.3	VA	SC_127*	Trib. To Silver Creek	N/A	3.0	N/A	3.0	43
S-A052	16.4	VA	SC_146	Trib. To Silver Creek	4.26	5.0	3.2	5.0	64
S-A054	16.6	VA	SC_126*	Trib. To Silver Creek	N/A	3.0	N/A	3.0	71
S-A055	16.6	VA	SC_148*	Trib. To Silver Creek	N/A	3.0	N/A	3.0	71
S-A057	17.2	VA	SC_125*	Trib. To Sandy River	N/A	3.0	N/A	3.0	45
S-A058	17.4	VA	SC_124*	Trib. To Sandy River	N/A	3.0	N/A	3.0	35
S-A071	17.7	VA	SC_017	Trib. To Sandy River	4.86	5.0	2.2	5.0	36
S-A063a	18.2	VA	SC_018	Sandy River	12.98	13.0	10.4	10.5	229
S-A059	18.4	VA	SC_123*	Trib. To Hardys Creek	N/A	3.0	N/A	3.0	33
S-B059	19.9	VA	SC_122*	Trib. To Pine Lake	N/A	3.0	N/A	3.0	38
S-B046	20.1	VA	SC_121	Trib. To Pine Lake	4.84	5.0	3.6	5.0	69
S-B045	20.8	VA	SC_019	Trib. To Trayner Branch	N/A	3.0	N/A	3.0	47

Table A-3. Burial Depth Scenarios

MVP Waterbody ID	Approx MP	State	GEO ID	Water Body Name	Estimated Scenario A Scour Depth (ft)	Scenario A Burial Depth (ft)	Estimated Scenario B Scour Depth (ft)	Scenario B Burial Depth (ft)	Burial Distance (ft)
S-B044a	21.0	VA	SC_020*	Trib. To Trayner Branch	N/A	3.0	N/A	3.0	45
S-B043	21.4	VA	SC_120*	Trayner Branch	N/A	3.0	N/A	3.0	41
S-B041	21.6	VA	SC_149*	Trib. To McGuff Creek	N/A	3.0	N/A	3.0	76
S-B042	21.7	VA	SC_119*	Trib. To McGuff Creek	N/A	3.0	N/A	3.0	76
S-B040	22.0	VA	SC_021	Trib. To Trotters Creek	N/A	3.0	N/A	3.0	86
S-B032	22.5	VA	SC_118*	Trib. To Trotters Creek	N/A	3.0	N/A	3.0	37
S-B033	22.6	VA	SC_117*	Trib. To Trotters Creek	N/A	3.0	N/A	3.0	35
S-B039	23.1	VA	SC_116*	Trib. To Trotters Creek	N/A	3.0	N/A	3.0	37
S-B029	23.6	VA	SC_022	Trotters Creek	5.34	5.5	3.3	5.0	54
S-B061	23.6	VA	SC_023*	Trib. To Trotters Creek	N/A	3.0	N/A	3.0	35
S-B030	24.0	VA	SC_115*	Trib. To Dan River	N/A	3.0	N/A	3.0	33
S-B024	24.4	VA	SC_114*	Trib. To Dan River	N/A	3.0	N/A	3.0	36
S-B022	24.6	VA	SC_113*	Trib. To Dan River	N/A	3.0	N/A	3.0	50
S-B056	25.0	VA	SC_112*	Trib. To Dan River	N/A	3.0	N/A	3.0	48
S-B054	25.4	VA	SC_110*	Trib. To Dan River	N/A	3.0	N/A	3.0	55
S-B052	25.8	VA	SC_024*	Trib. To Dan River	N/A	3.0	N/A	3.0	37
S-B051	26.4	VA	SC_025	Trib. To Dan River	6.12	6.5	4.5	5.0	57
S-B020	26.5	VA	SC_109*	Trib. To Dan River	N/A	3.0	N/A	3.0	33
S-F005	27.4	NC	SC_151*	Trib. To Cascade Creek	N/A	3.0	N/A	3.0	39
S-B036	28.0	NC	SC_026	Trib. To Cascade Creek	5.21	5.5	4.1	5.0	121
S-B035	28.2	NC	SC_027*	Cascade Creek	N/A	9.0[1]	N/A	7.0[1]	367
S-B034	28.2	NC	SC_028	Dry Creek	8.97	9.0	6.7	7.0	367
S-B015	29.1	NC	SC_108*	Trib. To Dan River	N/A	3.0	N/A	3.0	48
S-B017	29.3	NC	SC_107*	Trib. To Dan River	N/A	3.0	N/A	3.0	37
S-B011	29.5	NC	SC_106*	Trib. To Dan River	N/A	3.0	N/A	3.0	40
S-B009	30.0	NC	SC_105*	Trib. To Dan River	N/A	3.0	N/A	3.0	35
S-B008	30.3	NC	SC_104*	Trib. To Dan River	N/A	3.0	N/A	3.0	36
S-B005	30.8	NC	SC_030	Dan River	12.32	12.5	8.2	8.5	297
S-B004	30.9	NC	SC_103*	Trib. To Dan River	N/A	3.0	N/A	3.0	34
S-B003	31.0	NC	SC_102*	Trib. To Dan River	N/A	3.0	N/A	3.0	34
S-B002	31.1	NC	SC_101*	Trib. To Dan River	N/A	3.0	N/A	3.0	35

[1] The burial depth recommendation for SC_027 exceeds the recommended burial depth for Minor streams due to its proximity to the SC_028 stream. The recommended burial depth for the SC_027 and SC_028 sites is the greater of the two sites independent recommended burial depths.

*Indicates a minor stream

ft: feet
GEO: Geosyntec
MP: milepost
NC: North Carolina
Trib.: tributary
VA: Virginia