ATLANTIC COAST PIPELINE, LLC
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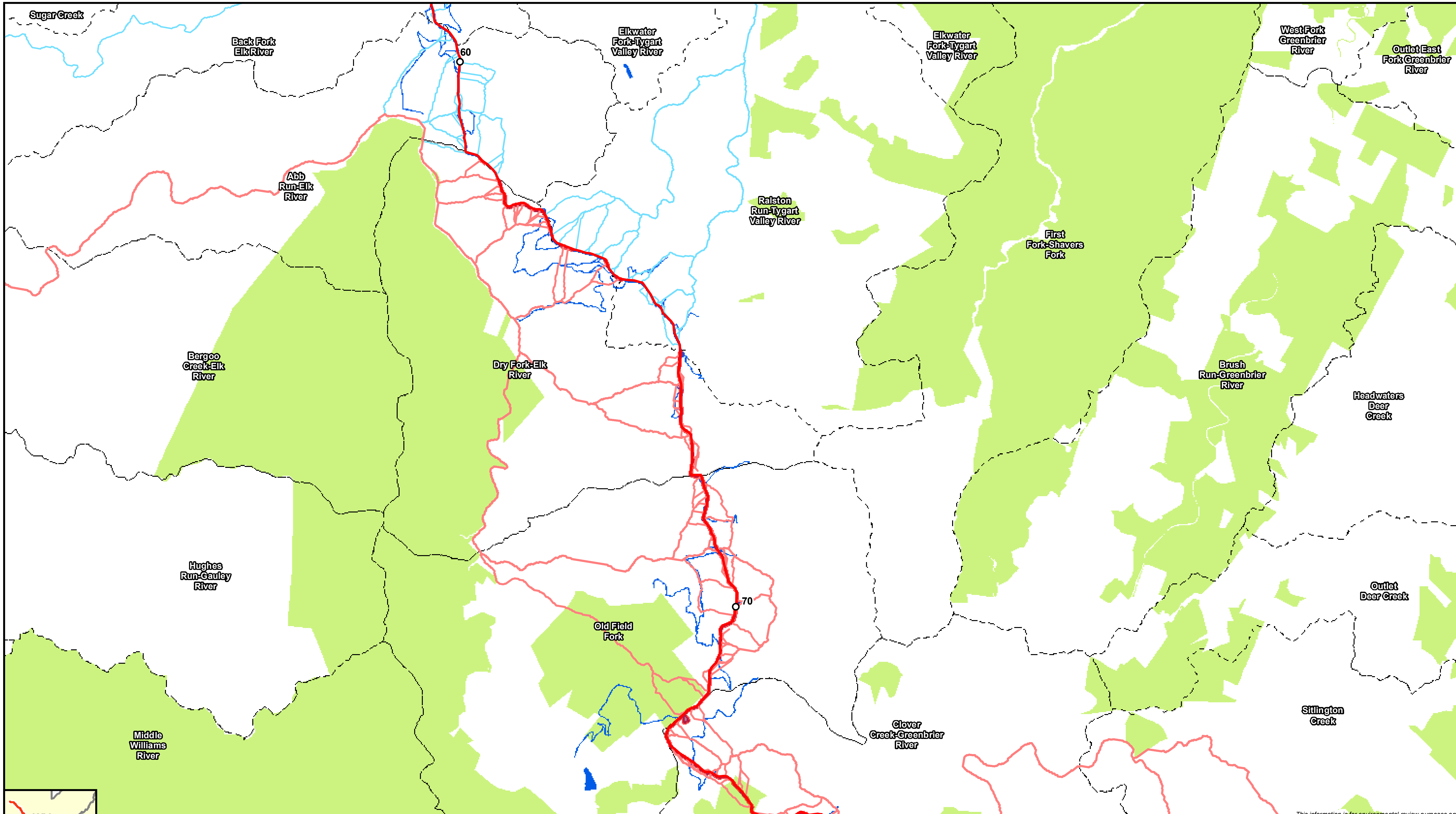
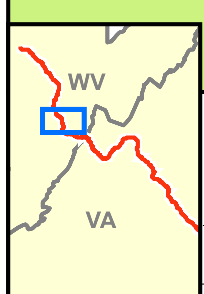
Soil Erosion and Sedimentation Modeling Report

Monongahela National Forest and George Washington National Forest

APPENDIX D – FLOW PATHS FOR IDENTIFED SEGMENTS





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Miles

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1 inch = 2 miles

- Milepost
- Construction Impact Footprint (CIF)
- Watershed Boundaries
- National Forest Owned Land (NF)
- Flow Paths that Intersect NF-Owned Land
- All Flow Paths
- Segments Identified from CIF

Atlantic Coast Pipeline

Appendix D
Construction Site Analysis
Identified Segments

ERM

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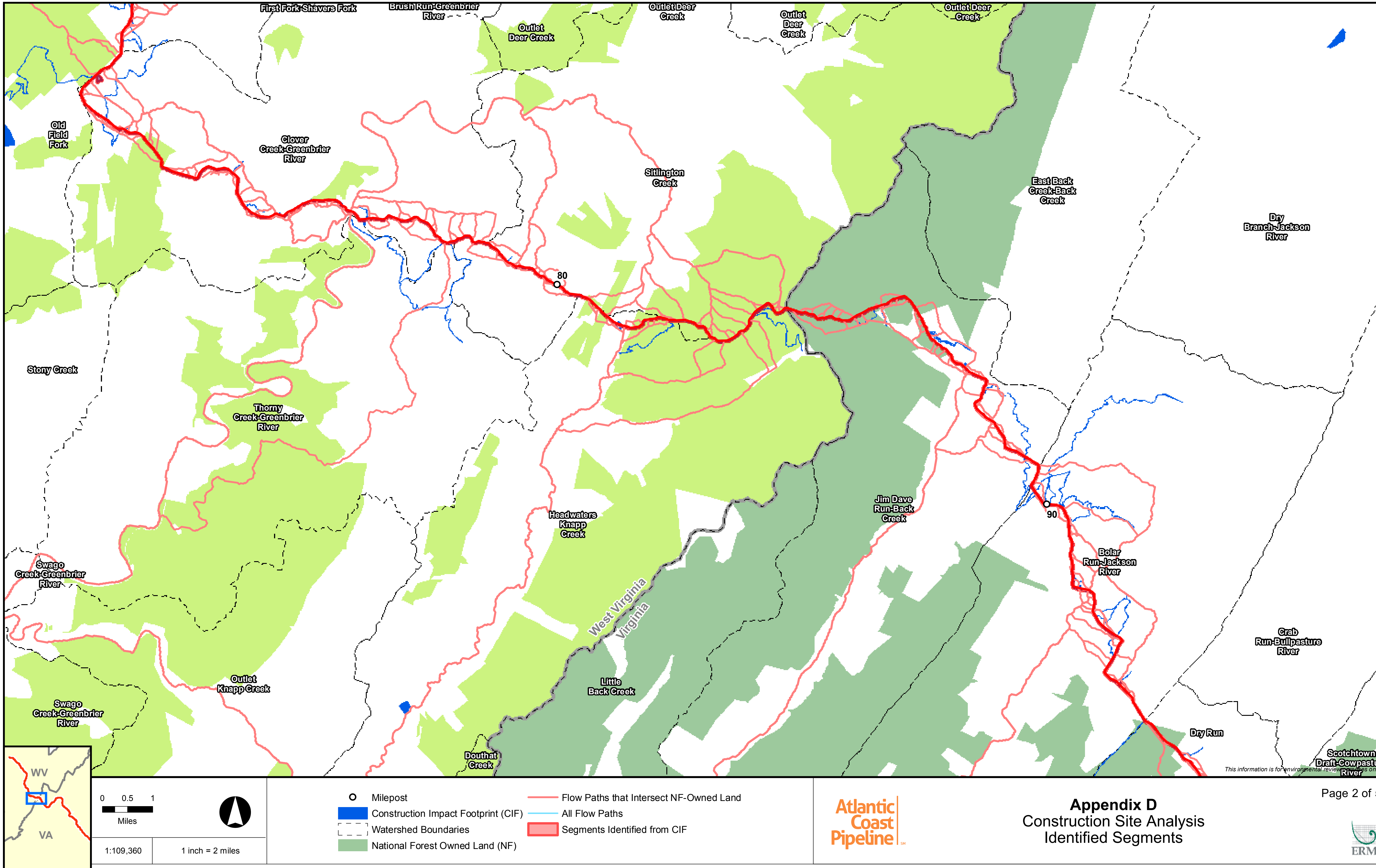

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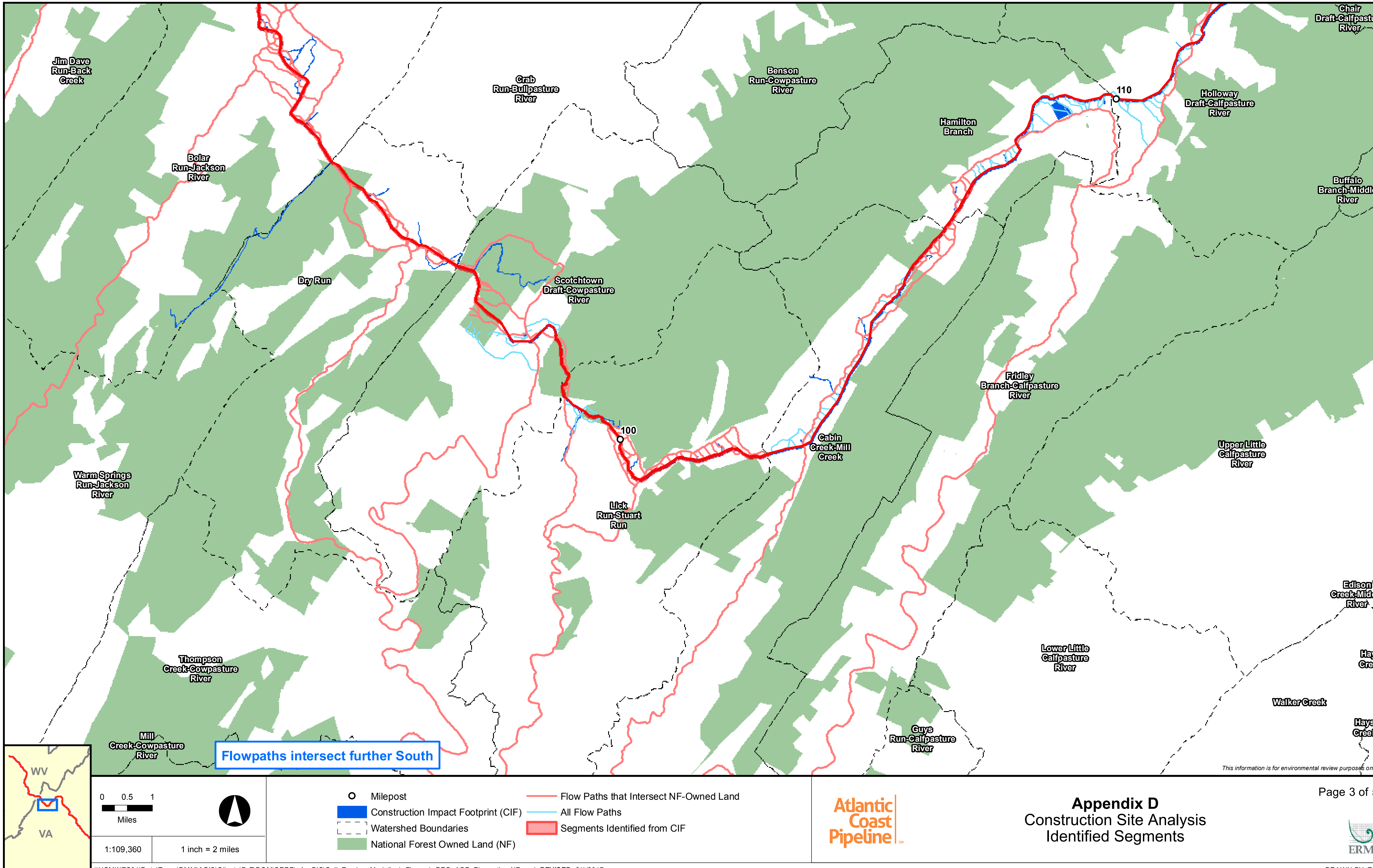

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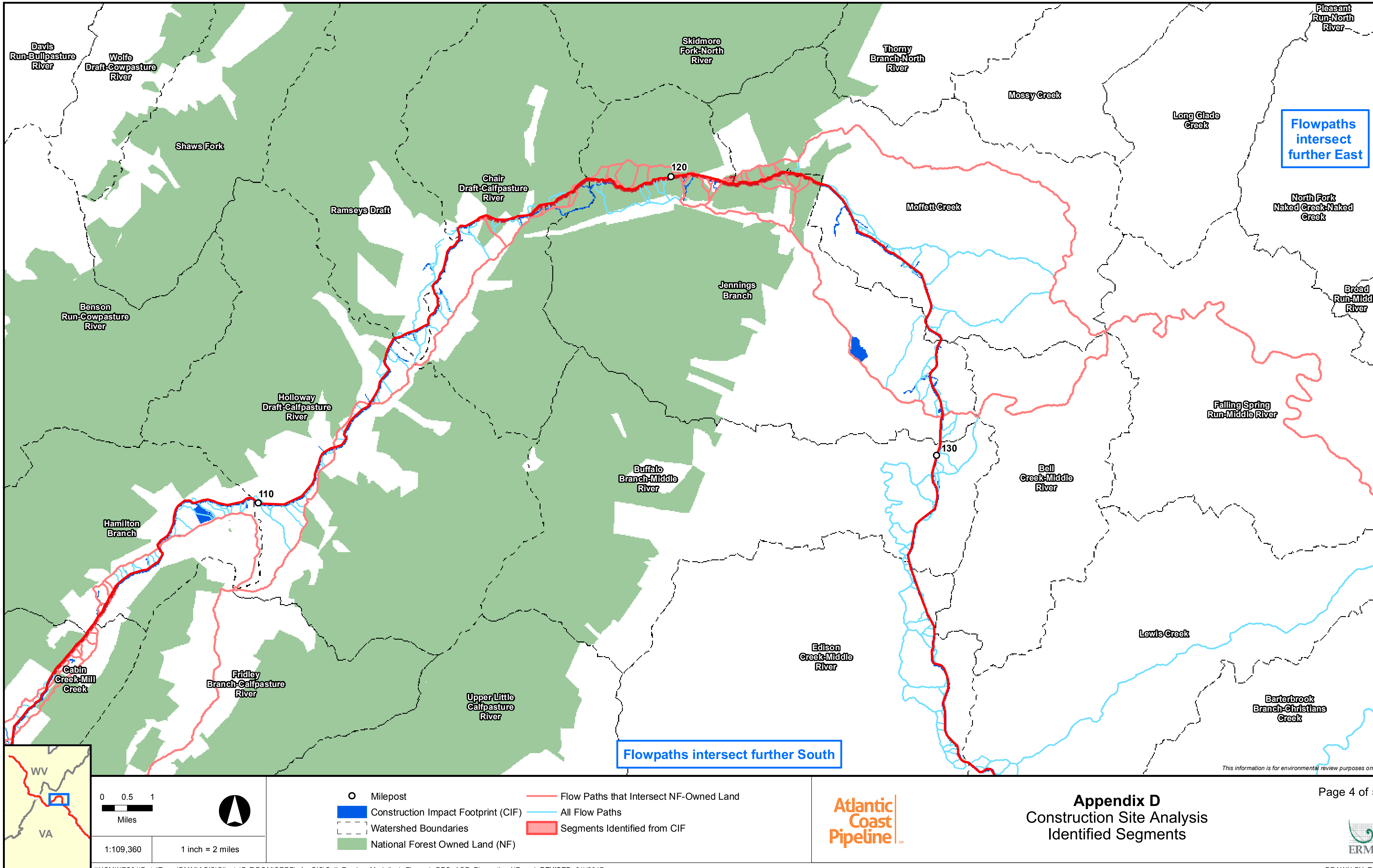

Davis Run-Bullpasture River
Wolfe Draft-Cowpasture River
Shaws Fork
Skidmore Fork-North River
Thorny Branch-North River
Mossy Creek
Long Glade Creek
Pleasant Run-North River
Flowpaths intersect further East
Chair Draft-Calfpasture River
Ramseys Draft
120
Moffett Creek
North Fork Naked Creek-Naked Creek
Jennings Branch
Broad Run-Middle River
Benson Run-Cowpasture River
Holloway Draft-Calfpasture River
Falling Spring Run-Middle River
130
Buffalo Branch-Middle River
Bell Creek-Middle River
110
Hamilton Branch
Lewis Creek
Edison Creek-Middle River
Cabin Creek-Mill Creek
Fridley Branch-Calfpasture River
Upper Little Calfpasture River
Barterbrook Branch-Christians Creek
Flowpaths intersect further South
This information is for environmental review purposes only.
WV
VA
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Miles
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Milepost
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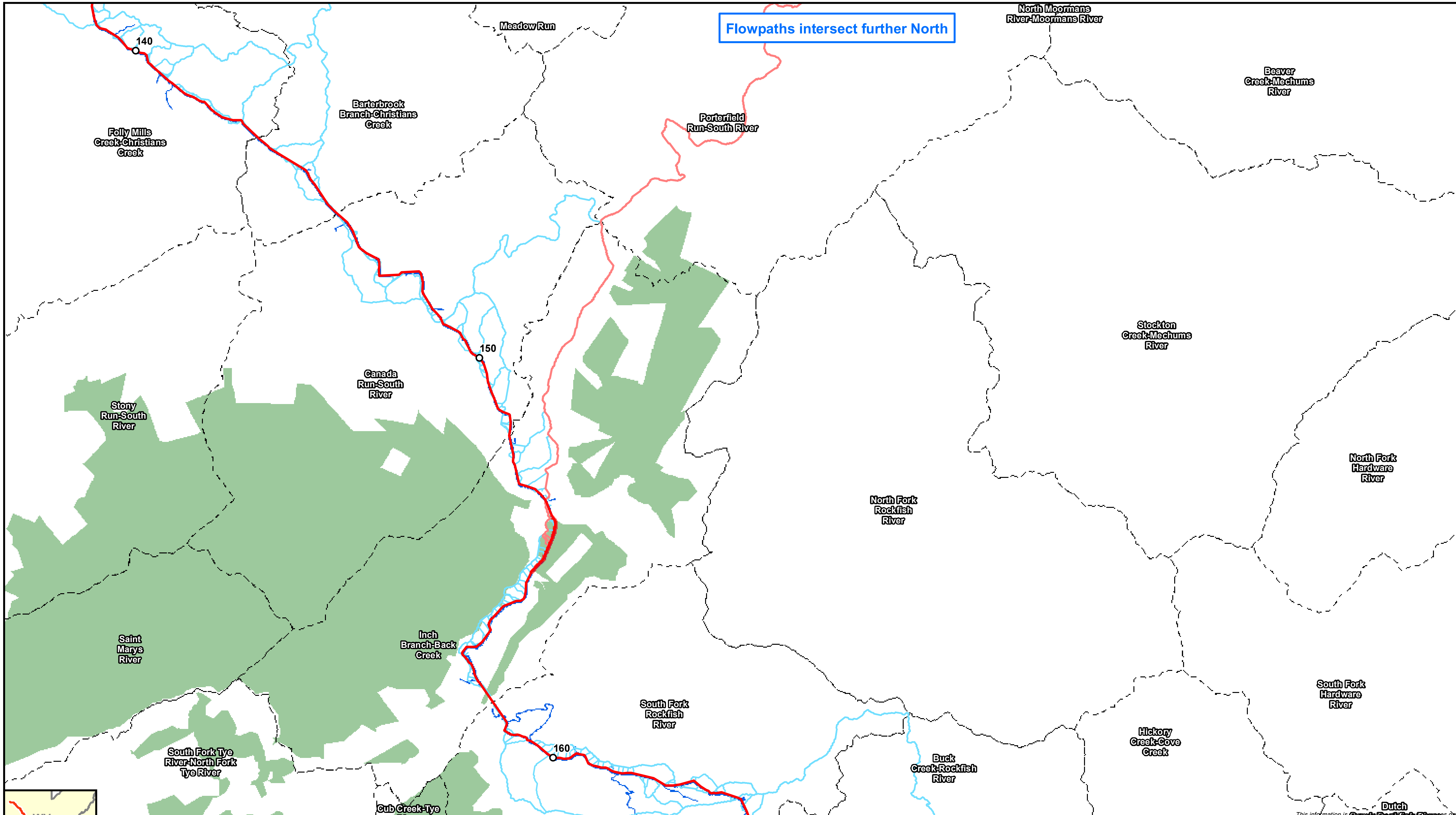

0 0.5 1
Miles

1:109,360 | 1 inch = 2 miles

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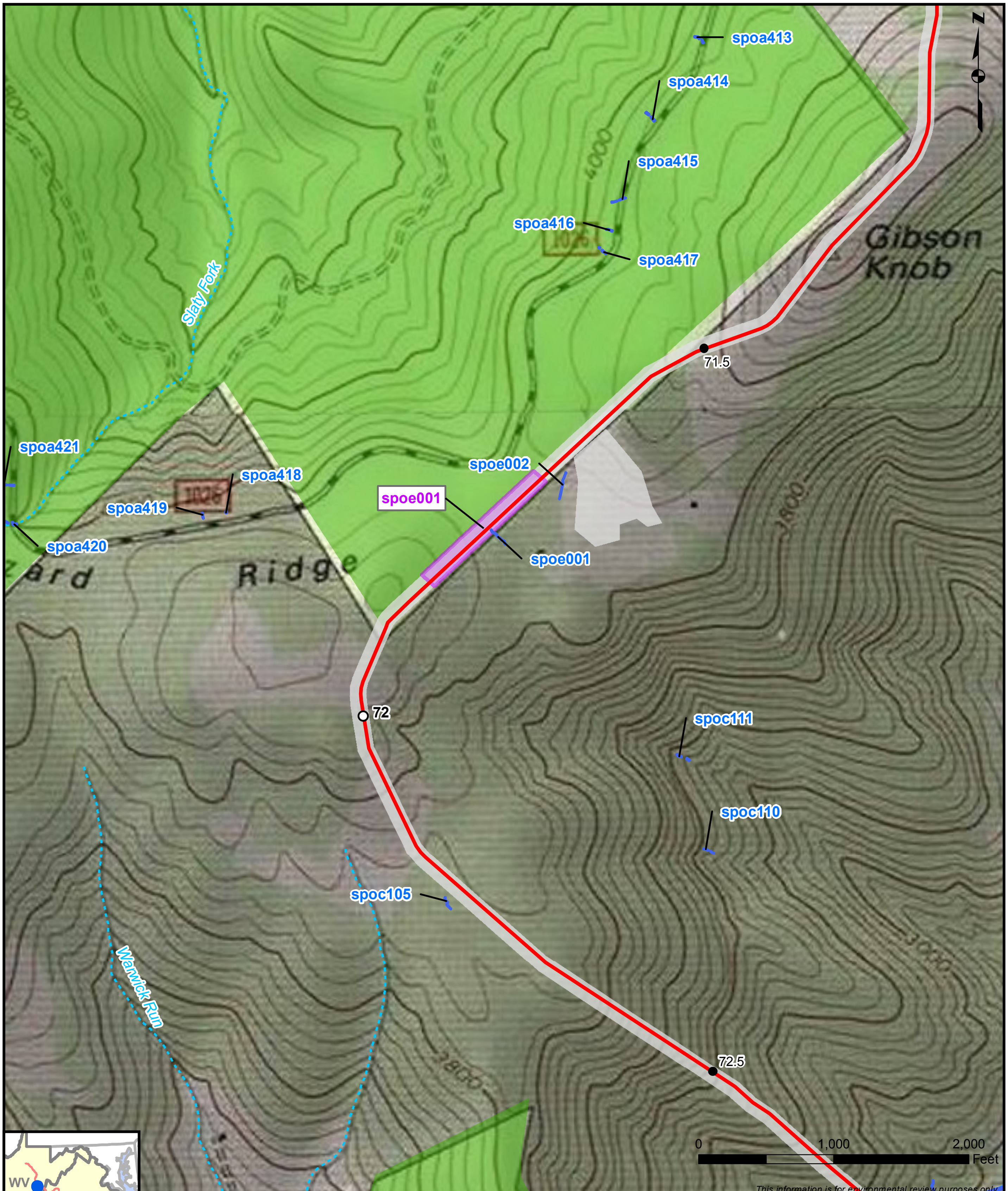
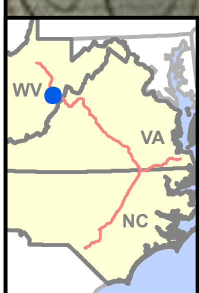
APPENDIX E – STREAM CROSSING SEGMENTS





- Milepost
- Current Centerline
- Intermittent Stream
- Surveyed Waterbody
- Stream Crossing Segment
- Workspace
- National Forest Land

Atlantic Coast Pipeline

Atlantic Coast Pipeline

Stream Crossing Analysis Area

ERM

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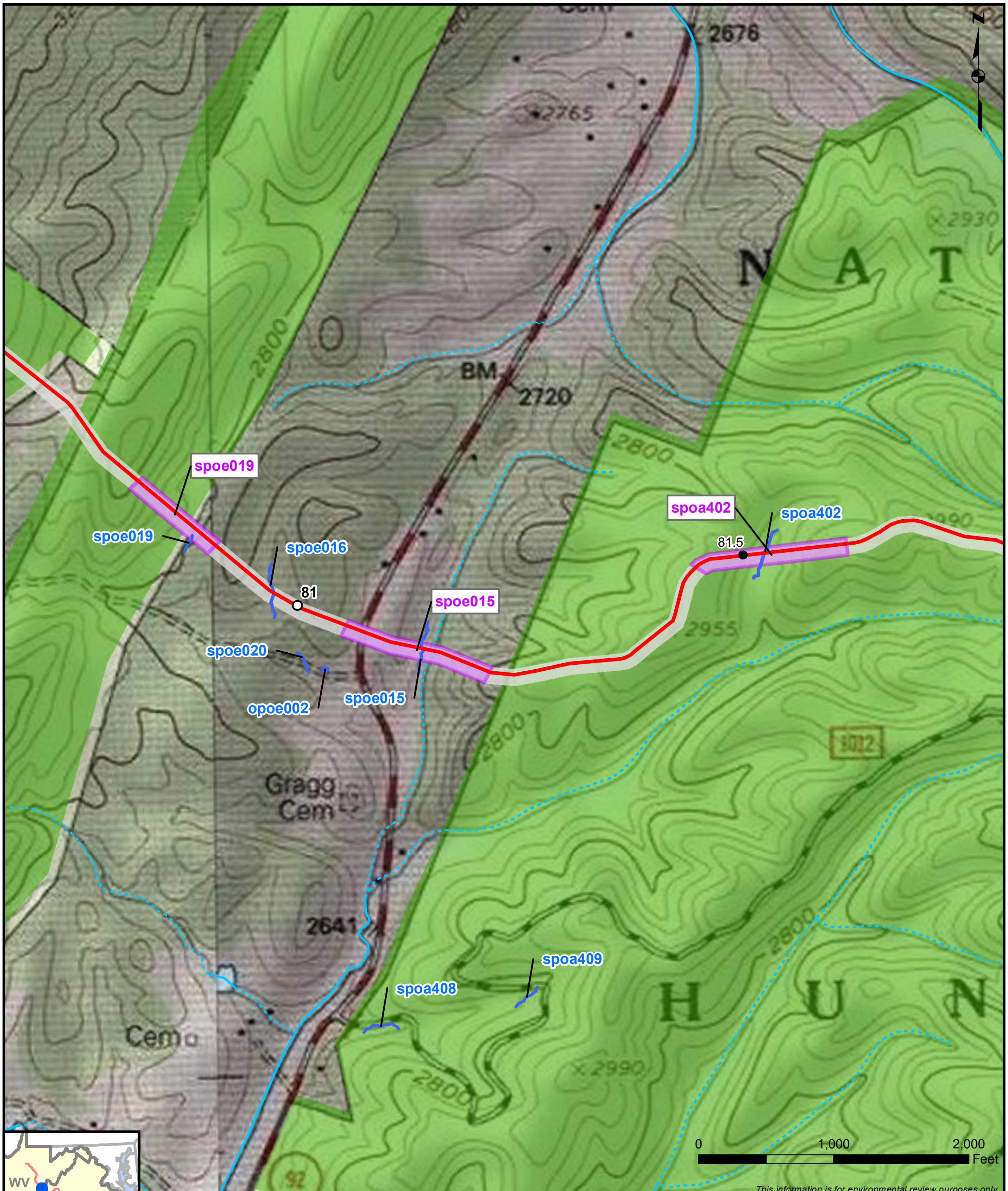

Milepost
Current Centerline
Intermittent Stream
Perennial Stream
Surveyed Waterbody
Stream Crossing Segment
Workspace
National Forest Land

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Stream Crossing Analysis Area

ERM

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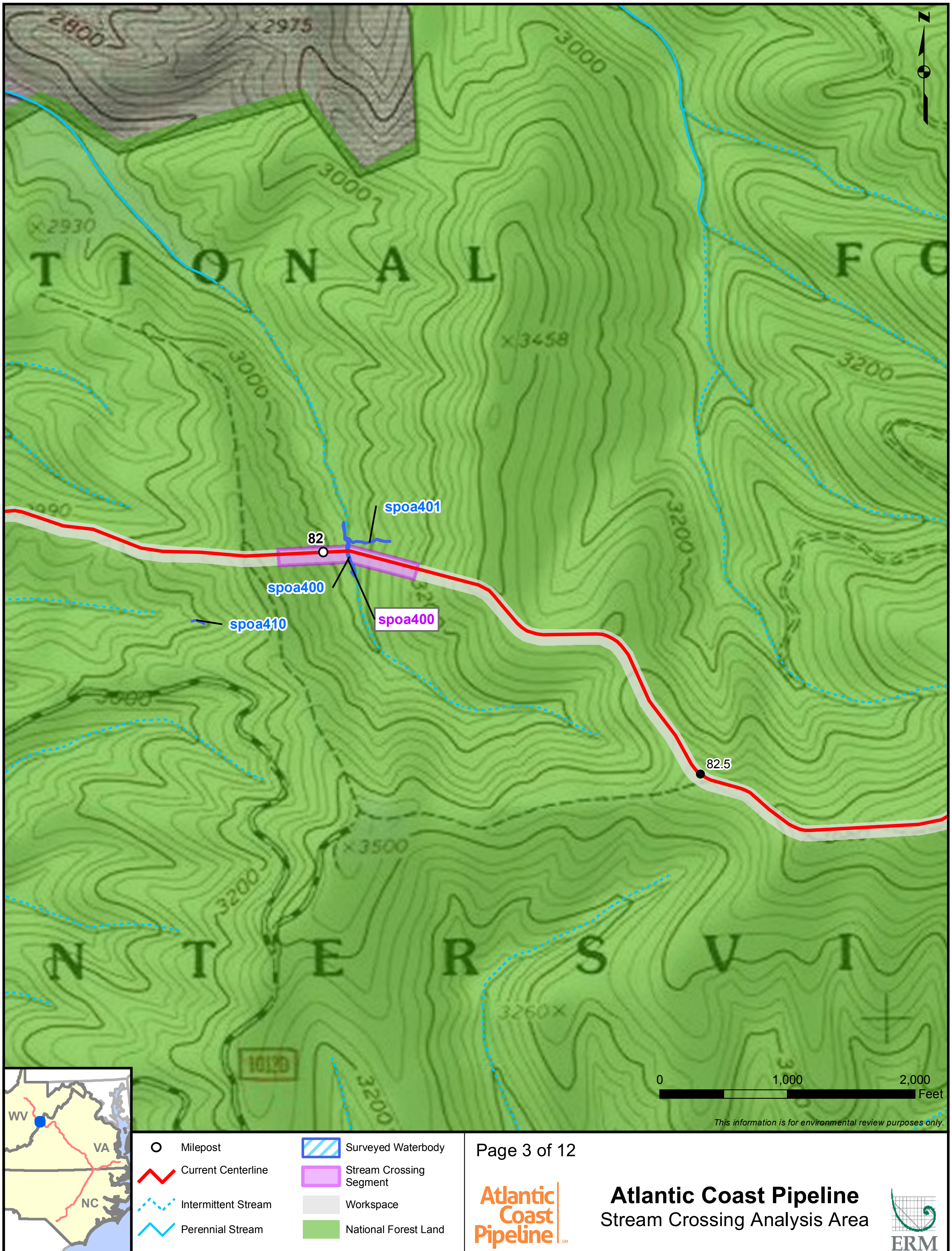

Atlantic Coast Pipeline

Stream Crossing Analysis Area

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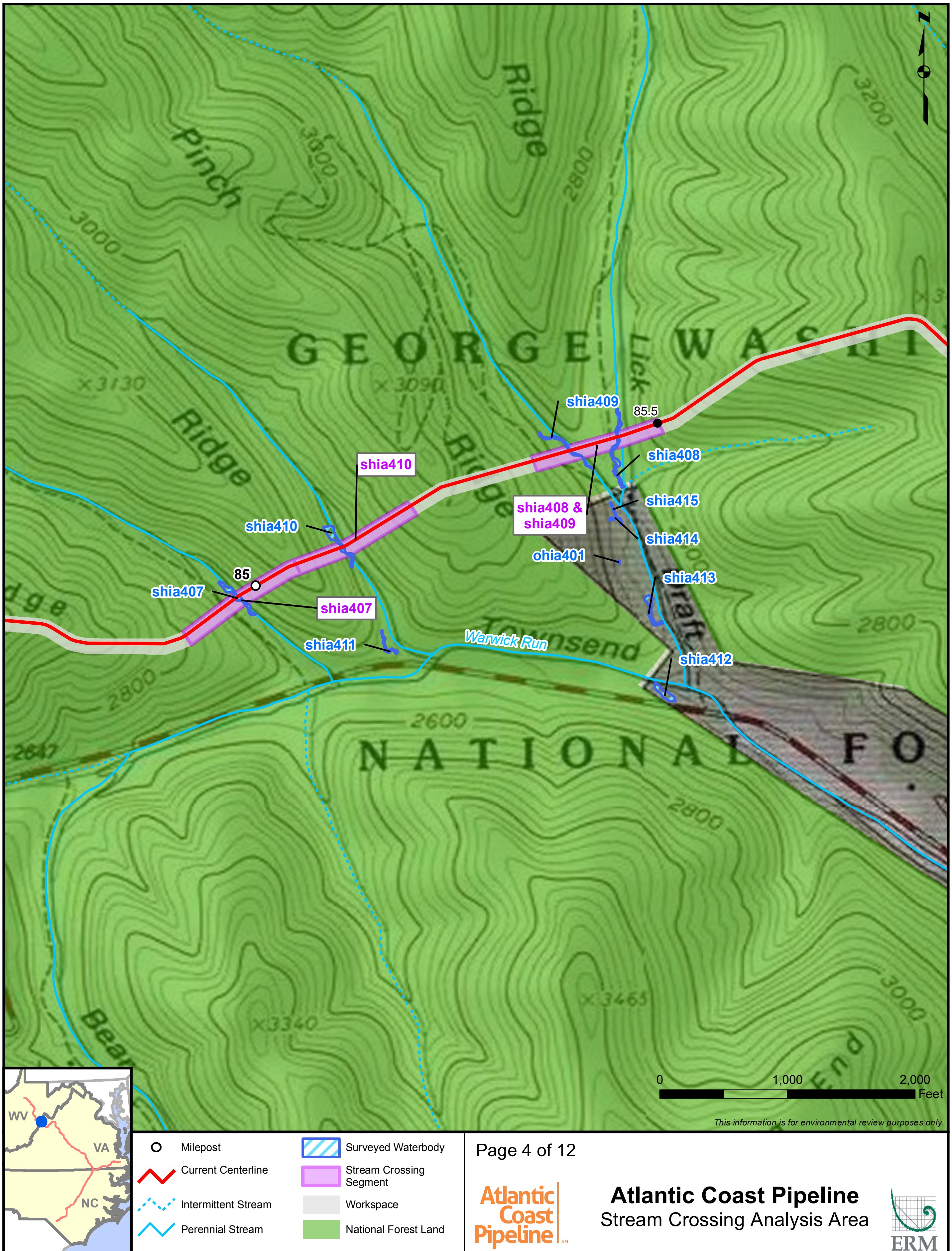

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Milepost	Surveyed Waterbody
Current Centerline	Stream Crossing Segment
Intermittent Stream	Workspace
Perennial Stream	National Forest Land

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Atlantic Coast Pipeline

Stream Crossing Analysis Area

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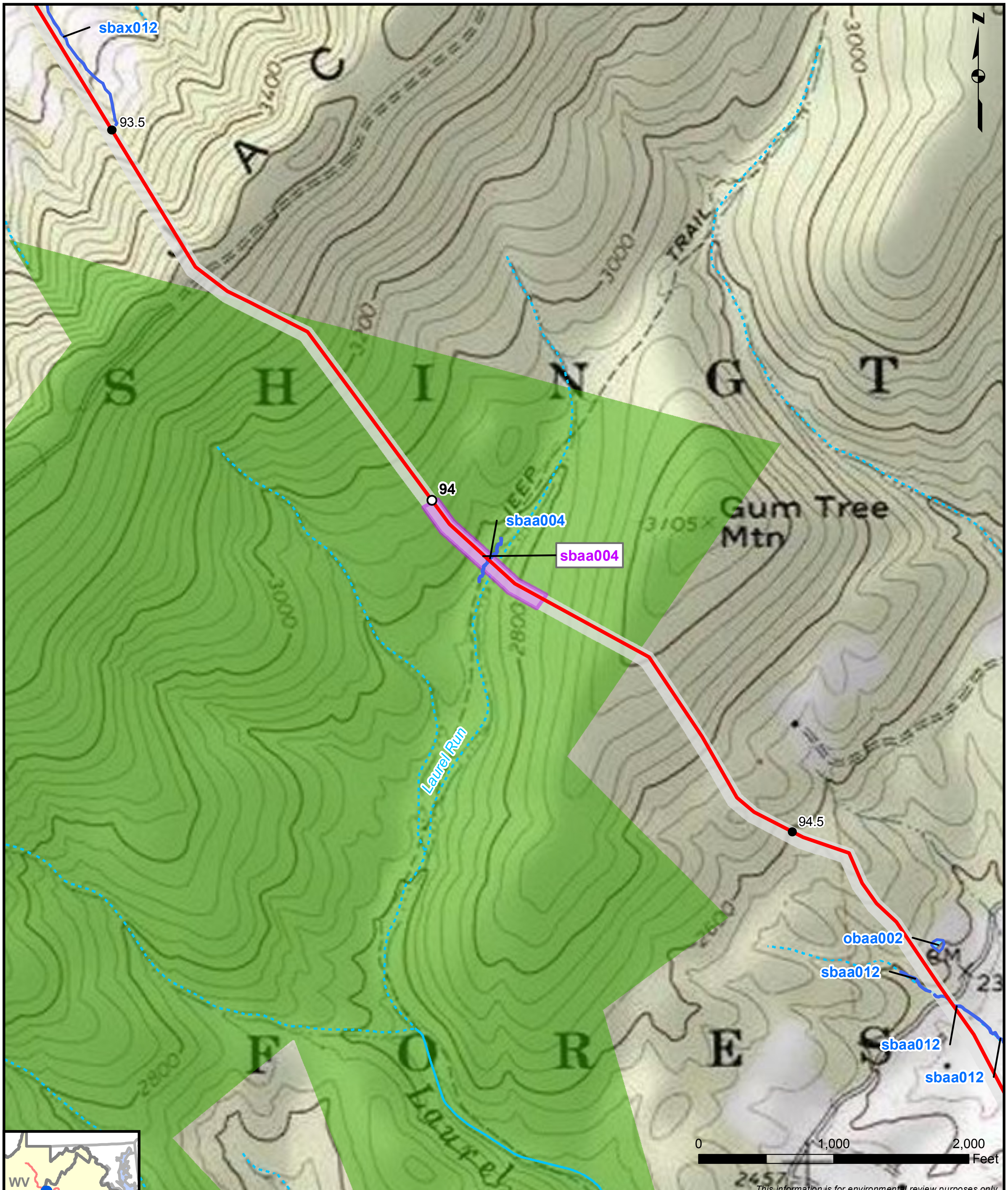

Milepost
Current Centerline
Intermittent Stream
Perennial Stream
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Stream Crossing Segment
Workspace
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Atlantic Coast Pipeline

Atlantic Coast Pipeline

Stream Crossing Analysis Area

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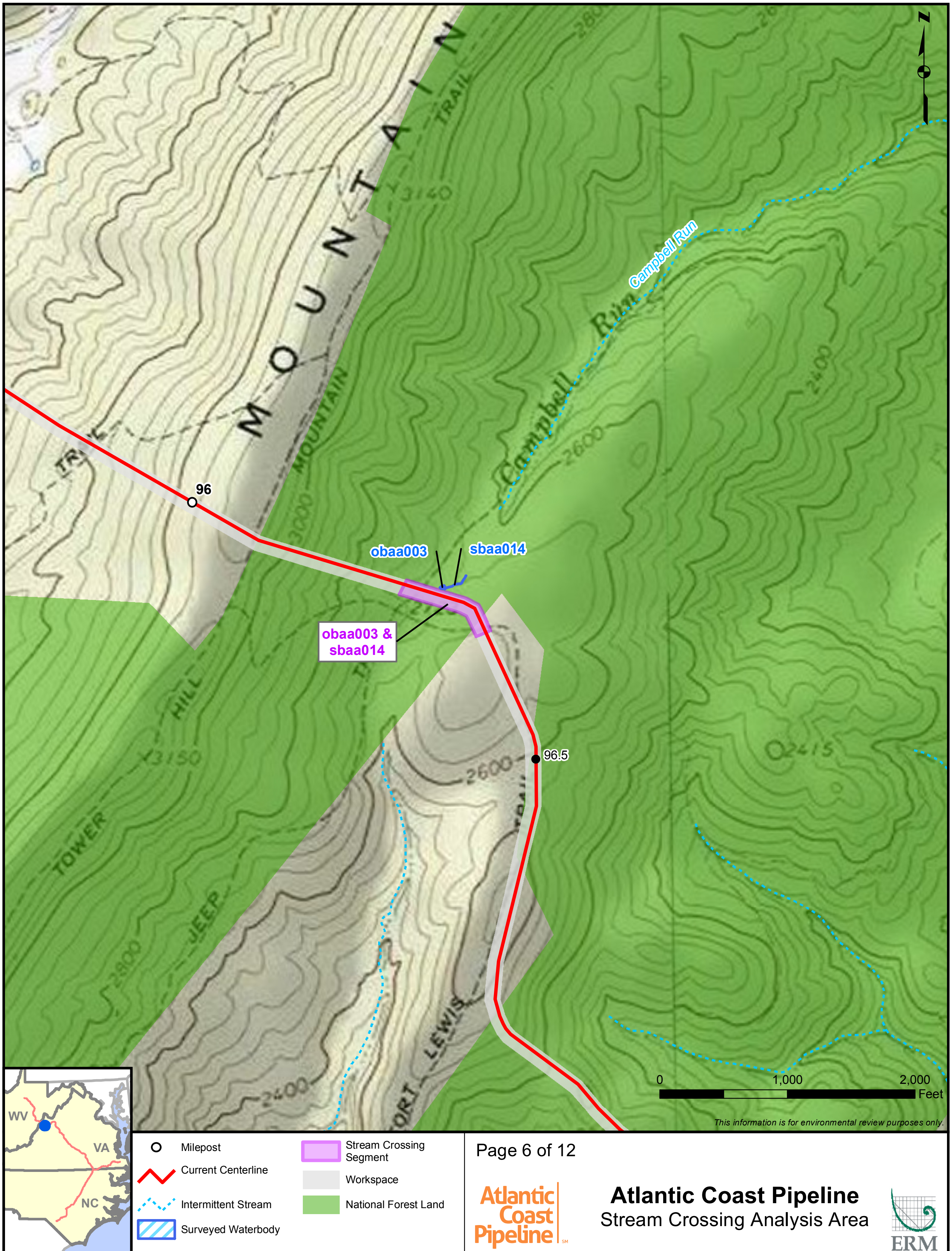

Milepost

Current Centerline

Intermittent Stream

Surveyed Waterbody

Stream Crossing Segment

Workspace

National Forest Land

Atlantic Coast Pipeline

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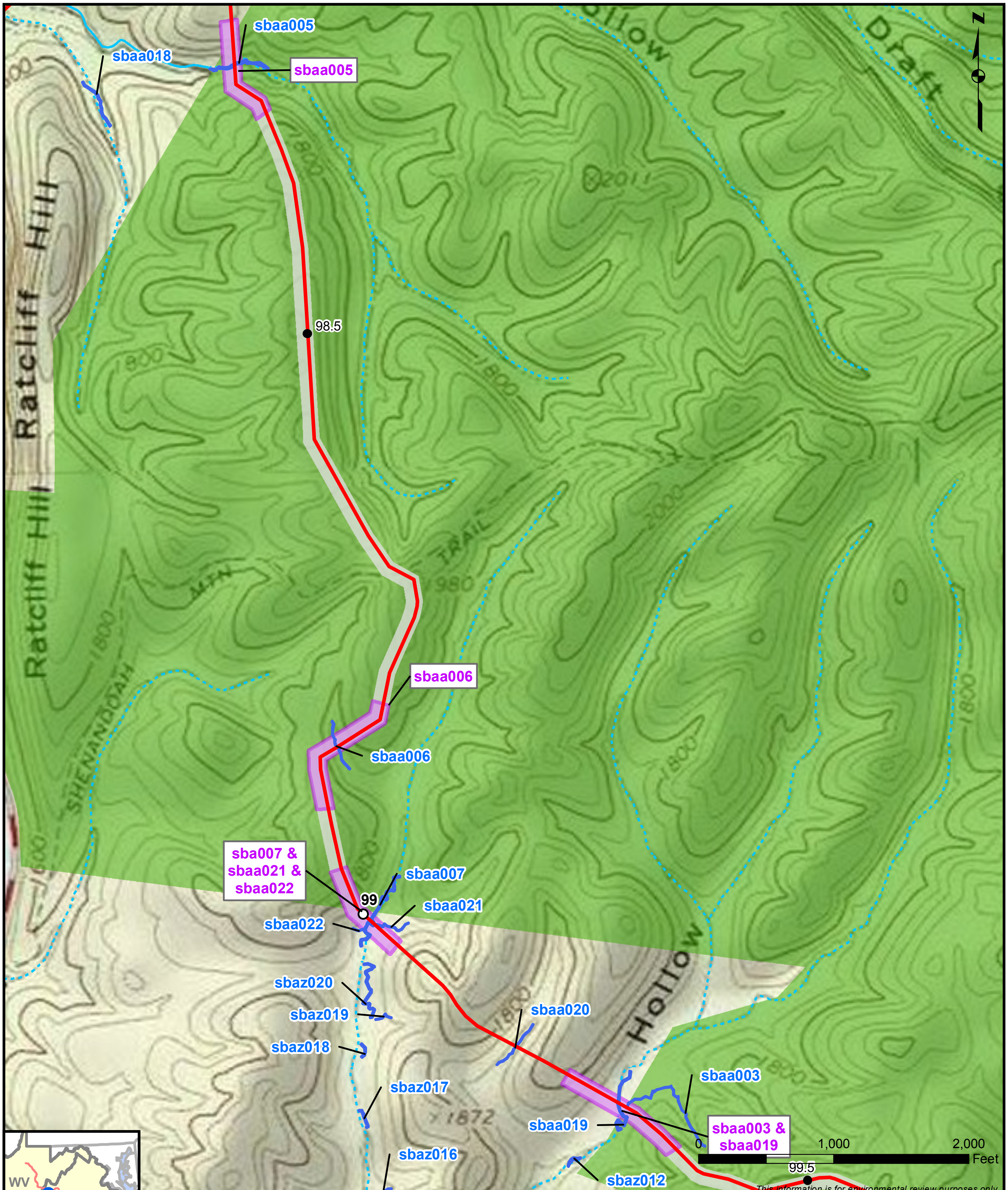

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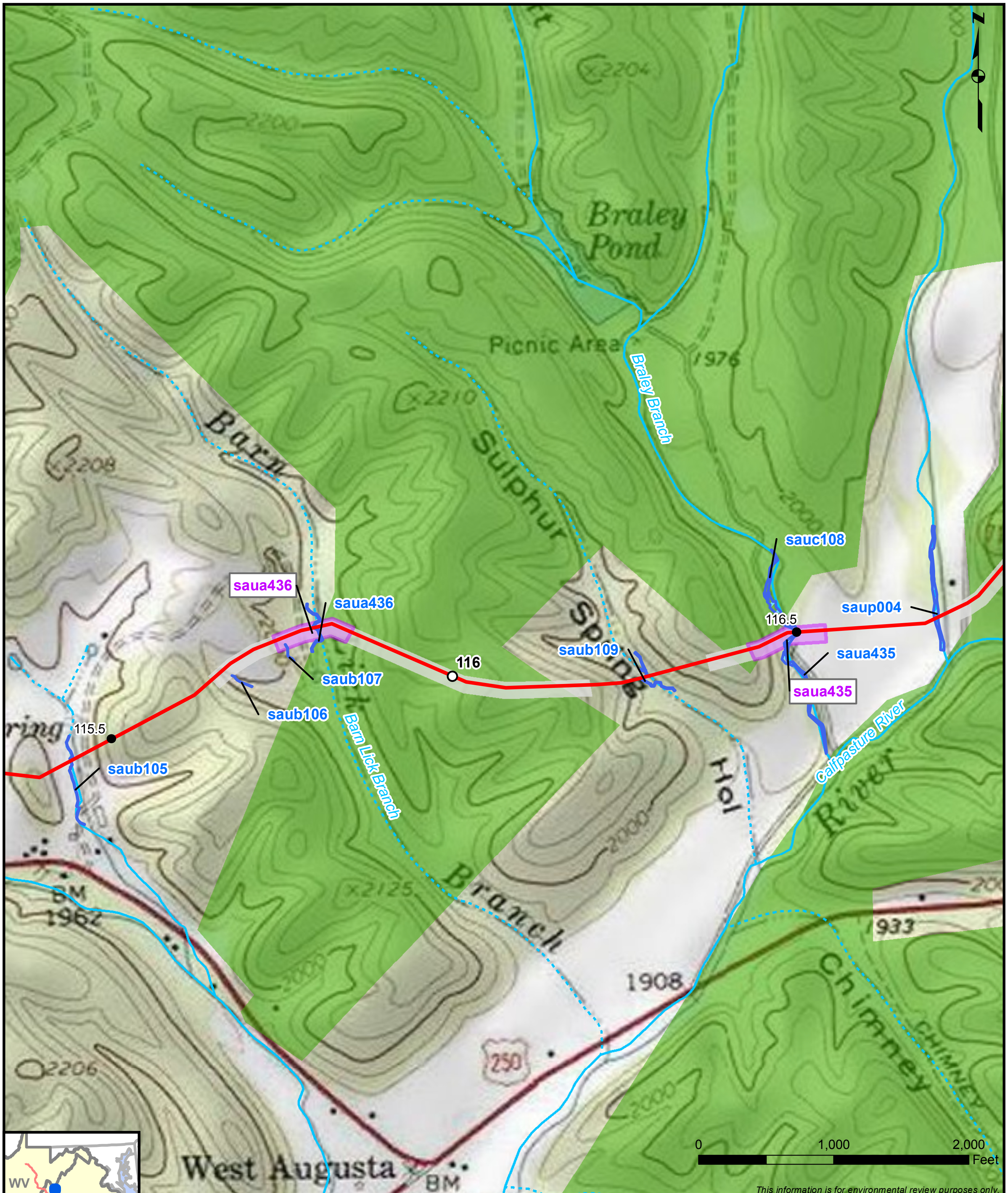

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Stream Crossing Analysis Area

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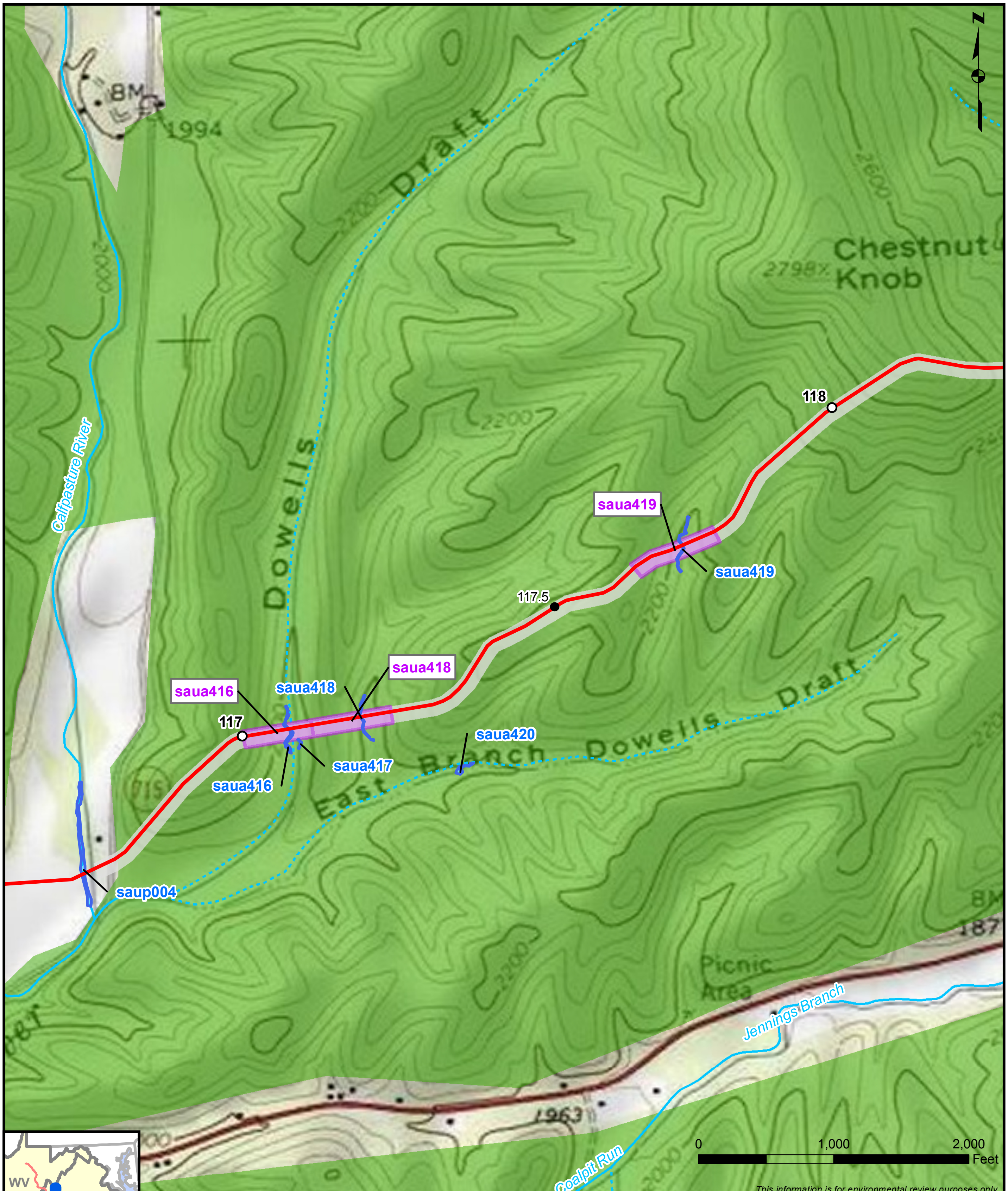

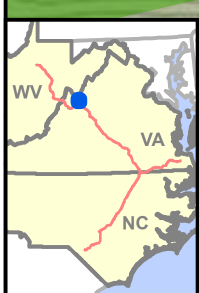

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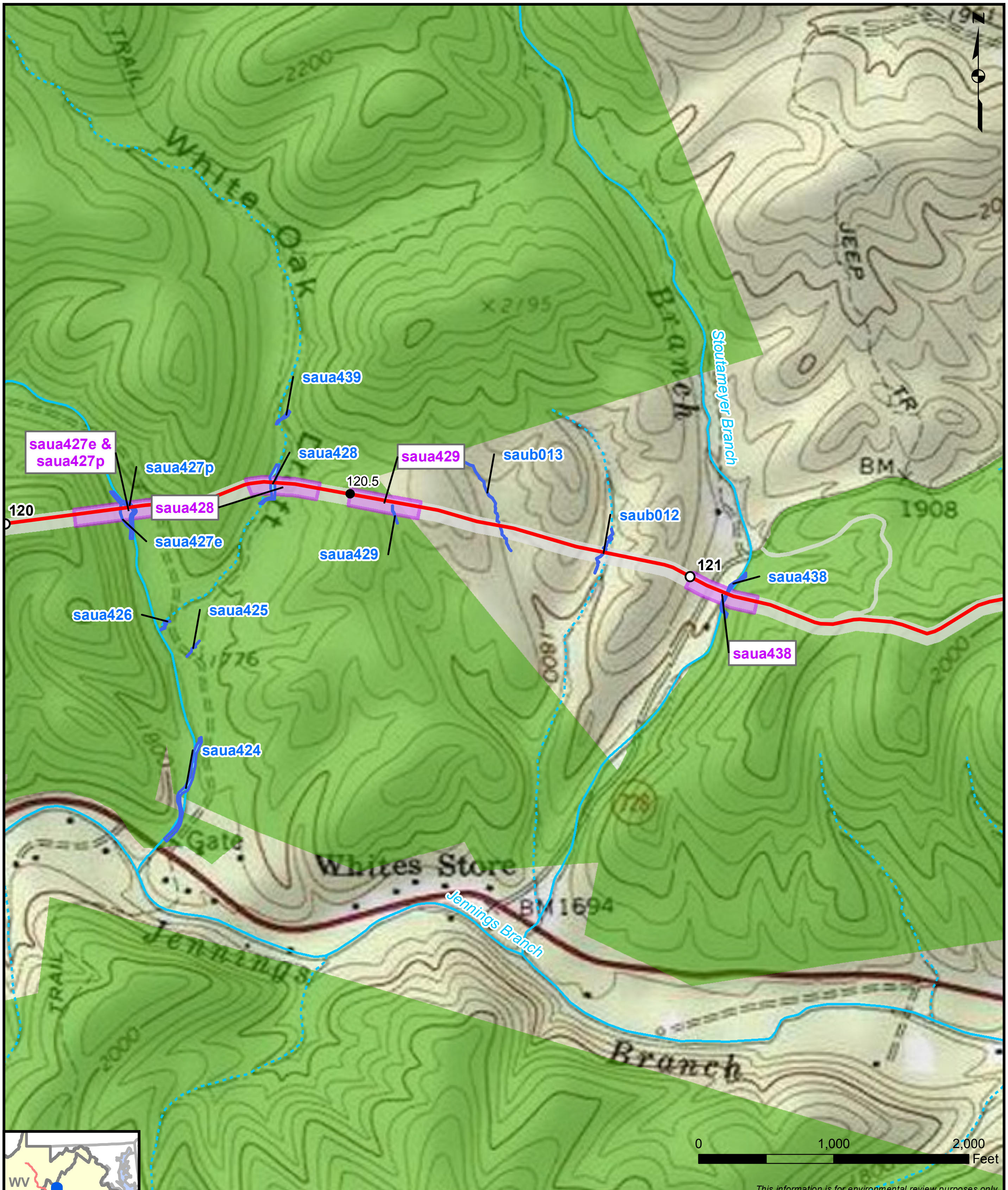

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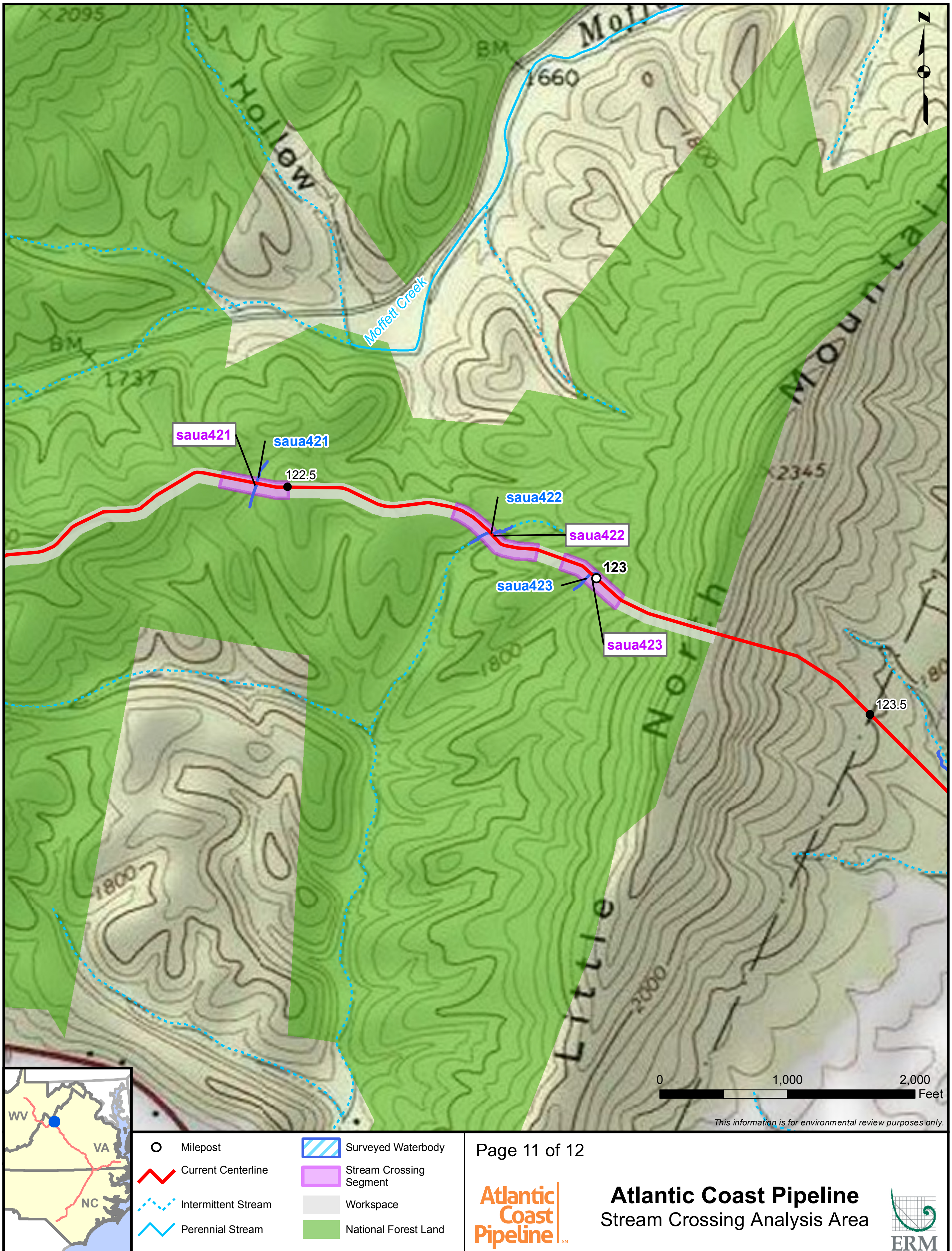

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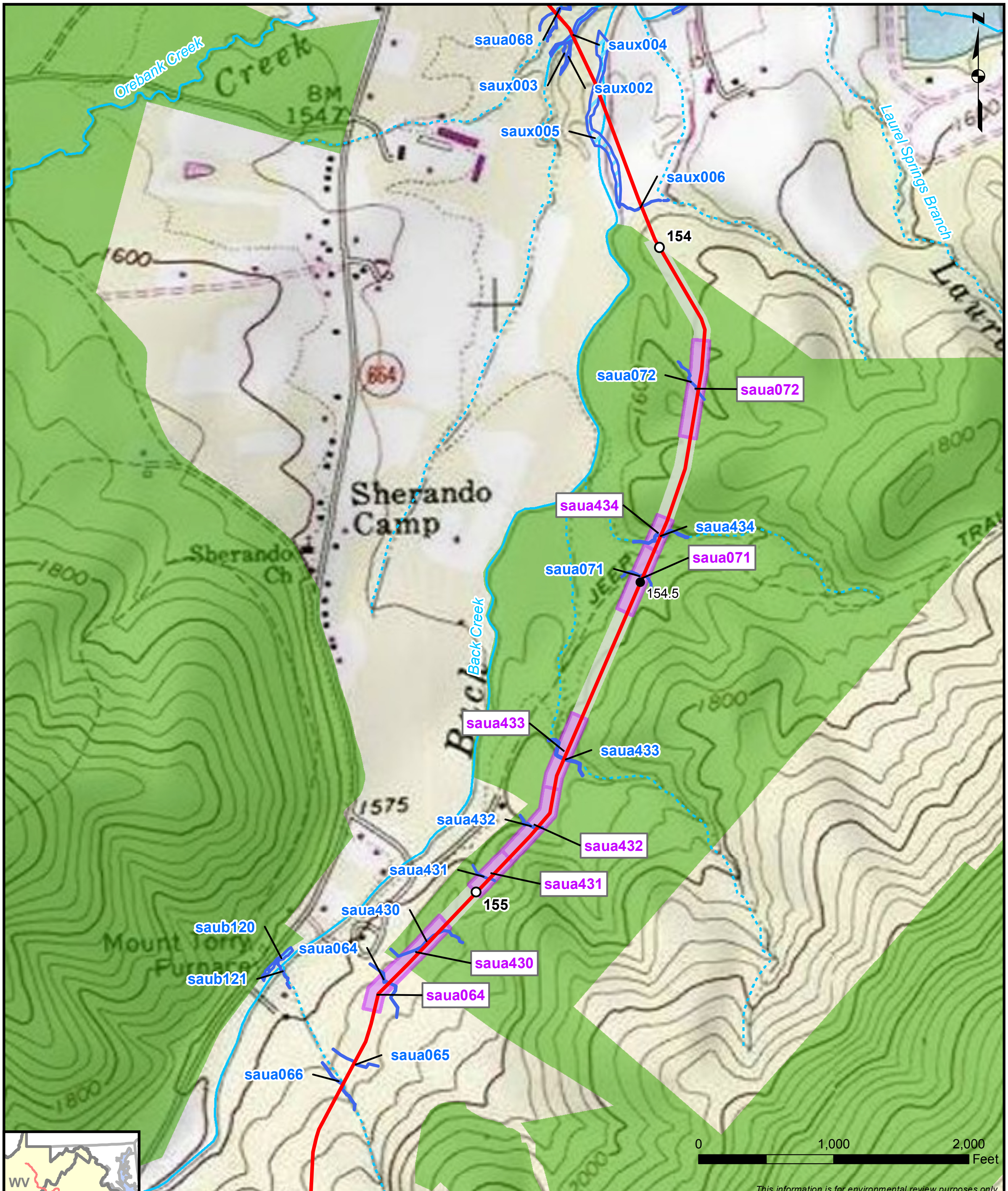

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APPENDIX F – WATERSHED ANALYSIS

1.0 WATERSHED ANALYSIS

1.1 MODELING APPROACH

The Atlantic Coast Pipeline construction area spans West Virginia and Virginia, crossing through both the Monongahela National Forest (MNF) and George Washington National Forest (GWNF). The eroded sediments have the potential to not only impact the U.S. Forest Service-owned lands, but also the streams of the broader watersheds. Accordingly, an analysis was performed for the entire Hydrologic Unit Code 12 (HUC12) watersheds which contain any portions of the ACP corridor and access roads and also contain any streams that lie within the MNF and GWNF. Watersheds in this study include the 28 HUC12 subwatersheds that include both the Atlantic Coast Pipeline construction footprint and U.S. Forest Service-owned lands. These 28 subwatersheds are presented in Figure 1.1-1 and their geographical characteristics are presented in Table 1.1-1.

Atlantic Coast Pipeline, LLC (Atlantic) used the Revised Universal Soil Loss Equation (RUSLE) incorporated into Geographical Information System (GIS) to evaluate sediment loads for baseline (existing) conditions in the subwatersheds crossed. The RUSLE-GIS model provides estimates of erosion rates and sediment delivery based on climate, soil, topography, and cover management factors.

With the RUSLE-GIS model, the subwatersheds were broken into grid cells (9.16 meter x 9.16 meter) and over each cell, the RUSLE inputs were generated and RUSLE equation was applied to estimate Erosion Rate from each cell. Model results were then aggregated by HUC12 subwatersheds to get the Total Erosion Rate from the subwatershed. Once in streams, eroded sediments will begin to be deposited; not all eroded sediments within the subwatershed result in Sediment Delivery downstream. A Sediment Delivery Ratio, which is the fraction of Total Erosion Rate delivered to the outlet of the subwatershed, was calculated. Sediment Delivery expected at the outlet of the subwatershed was calculated by multiplying the Total Erosion Rate with the Sediment Delivery Ratio.

1.2 MODEL APPLICATION

RUSLE computes the average annual erosion by using a functional relationship of several factors, expressed in an equation as:

$$\boldsymbol{A} = \boldsymbol{R} \times \boldsymbol{K} \times (\boldsymbol{LS}) \times \boldsymbol{C} \times \boldsymbol{P} \qquad \text{Eq. 1}$$

where:

A = erosion flux, i.e., computed spatial average soil loss and temporal average soil loss per unit of area (tons/acre/year).

R = rainfall-runoff erosivity factor (hundreds of foot-ton inches per acre per hour).

K = soil erodibility factor.

L = slope length factor.

S = slope steepness factor.

C = cover-management factor.

P = support practice factor (e.g., contouring, strip-cropping, or terracing).

While RUSLE was initially developed to access erosion from small (less than 1000 feet) tracts of land, application to watershed scale erosion can be achieved by discretizing the watershed into smaller tracts and performing individual calculations in GIS. This approach is described in detail in Kim (2014) and serves as the basis for the approach taken. Individual components are explained in subsequent sections below. The Digital Elevation Model (DEM) served as the basis of the model grid. All GIS data used to determine RUSLE factors were mapped onto the same 9.16 meter x 9.16 meter resolution grid as the DEM.

1.2.1 Erosivity Factor

The climate component in RUSLE is represented by the rainfall-runoff erosivity factor (R-factor). The R-factors are determined by Cooper (2011) from the annually averaged precipitation values using:

$$R = 1.24 \times p^{1.36} \quad \text{Eq. 2}$$

where:

p = mean annual precipitation (inches)

R = R-factor (hundreds of foot-ton inches per acre per hour)

Eq. 2 was used in this analysis to determine the R-Factor. Yearly normal (average annual conditions) based on 30 years of spatially variable precipitation data from 1981 to 2010 with the resolution of 800 meter x 800 meter was obtained from PRISM Climate Group (2016) in the form of ArcGIS raster images. Precipitation data processed into R-factors using the "Raster Calculator" in ArcGIS are presented in Figure 1.2.1-1.

1.2.2 Erodibility Factor

The soil component in RUSLE is represented by the soil erodibility factor (K-Factor). Data from Order 1 Soil Survey conducted by Atlantic in the MNF and GWNF was used in analysis where available. Data from the Natural Resources Conservation Service's Soil Survey Geographic (SSURGO) database provides Rock-Free K values for the entire subwatersheds (Soil Survey Staff, 2016). K-factor values from SSURGO were used in areas outside the Order 1 Soil Survey corridor. K-Factor data processed for HUC12 subwatersheds of this study is presented in Figure 1.2.2-1. In a few small areas K-Factors were not available in SSURGO datasets. Those data were replaced based on the K-Factors provided for similar soils. The effect of filling-in these missing values is assumed to be insignificant because the total area of missing values is quite small compared to the area of the HUC12 subwatersheds. It is understood that K-Factors for steep slopes (greater than 30 percent) are more uncertain than more moderate slopes; however if the SSURGO database contains values of K for a particular area, it is assumed that those values are valid and sufficient for the analysis objective of identifying potential impacts and evaluating erosion control plans.

1.2.3 Slope Length and Steepness

The topography component in RUSLE is represented by the slope length (L) and steepness (S) factors, generally combined into one LS-Factor. LS-Factor is estimated using:

$$\mathrm{LS} = (\mathrm{m}+1)\left(\frac{\lambda_A}{22.13}\right)^{\mathrm{m}}\left(\frac{\sin(0.01745\times\theta)}{0.09}\right)^{\mathrm{n}} \quad \text{Eq. 3}$$

where:

λ_A = specific catchment area, i.e., the upslope contributing area per unit width of contour (or rill), in m^2/m. In Arc GIS calculations, it is calculated using the function called "flow accumulation" multiplied by the area of the raster cell size and divided by the raster cell width.

m, *n* = erosion exponents m and n values can be found in the literature. In general, m varies between 0.4 and 0.6 and n varies between 1.2 and 1.3. For this analysis, m = 0.4 and n = 1.4 was selected based on Kim (2014).

Θ = slope (degrees)

Methodology explained in Pelton (2014) to determine spatially varying LS-Factors using DEM data and ArcGIS software is employed in this analysis. DEM data for this analysis was obtained from United States Geological Survey (USGS) 10 Meter DEM (USGS, 2016). Variation of LS-Factor is shown in Figure 1.2.3-1.

1.2.4 Cover Management Factor

The land cover management component in RUSLE is represented by the cover management factor (C-Factor) which represents the effects of both groundcover and canopy. Present vegetative cover (land cover class) for the HUC12 subwatersheds is available from the 2011 National Land Cover Database (USGS, 2011). This spatially variable data on vegetative cover with the resolution of 30 meter x 30 meter was obtained in the form of an ArcGIS raster image and is presented in Figure 1.2.4-1. C-Factors used for different land cover classes in the HUC12 subwatersheds in this analysis are decided based on Kim (2014) and are presented in Table 1.2.4-1.

1.2.5 Practice Factor

An additional practice factor (P) value may be applied if the soil conservations methods used are known. A default value of 1, which provides a conservative (i.e., maximum) estimate of soil loss, was used in this analysis.

1.2.6 Erosion Rate, Sediment Delivery Ratio, Sediment Delivery, and Sediment Yield

Erosion Rate (*e*) for a grid is calculated using:

$$e = A \times a \qquad \text{Eq. 4}$$

where:

a = area of a single grid cell (acres).

A = expected sediment loss at a grid cell based on the RULSE from Eq. 1 (tons/acre/year)

e = erosion rate for a grid cell (tons/year)

Total Erosion Rate (*E*) for a subwatershed is calculated using:

$$\boldsymbol{E = \sum_{i=1}^{n} e_i} \qquad \text{Eq. 5}$$

where:

i = index of the raster cells

n = number of raster cells within the subwatershed

E = total erosion rate (tons/year)

According to Rosa, et al. (2016) and Boyce (1975), Sediment Delivery Ratio (SDR), which is the fraction of Total Erosion Rate resulted in the outlet of the subwatershed, can be estimated by using:

$$\mathrm{SDR} = 0.375 \times \mathrm{A_w^{-0.2382}} \qquad \text{Eq. 6}$$

where:

A_w = area of the subwatershed (km^2)

Sediment Delivery (D), sediment load expected at the outlet of subwatershed, is estimated by using:

$$D = SDR \times E \qquad \text{Eq. 7}$$

where:

D = sediment delivery (tons/year)

Sediment Yield (Y), sediment delivery from a unit area of the subwatershed, is determined by using

$$Y = D/A_w \qquad \text{Eq. 8}$$

where:

Y = sediment yield ($tons/mile^2$)

1.3 RESULTS AND DISCUSSION

Erosion flux for baseline (existing) conditions is presented in Figure 1.3-1. Total Erosion Rate and Sediment Delivery for each subwatershed during baseline conditions are presented in Table 1.3-1. Also shown in this table are the model results from the site-specific RUSLE2 analysis discussed in the main body. Sediment yield for subwatersheds are presented in Table 1.3-2. The main findings of this analysis can be summarized as follows.

- Total Erosion Rate varies among subwatersheds between 9,000 tons/year and 282,000 tons/year under the baseline conditions.
- The Total Erosion Rate predicted by the site-specific RUSLE2 analysis represents from 0.2 to 2.3 percent of the baseline conditions.
- Approximately 11 percent to 15 percent of Total Erosion Rate from each subwatershed results in the Sediment Delivery at the subwatershed outlet.
- Sediment Delivery ranges among subwatersheds between 1,100 tons/year and 32,500 tons/year under the baseline conditions.
- Sediment Yield of the baseline condition ranges between 28 $tons/mi^2/year$ and 761 $tons/mi^2/year$ approximately. The wide variation in Sediment Yield is due to local variations in soil type, slope, and, to a lesser extent, rainfall.

It can be concluded that construction has the potential to increase erosion within subwatersheds resulting in higher sediment delivery at the outlets of the subwatershed. However, the overall increase of erosion and sediment delivery on the watershed scale is relatively modest.

2.0 REFERENCES

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TABLE 1.1-1

Geographical Characteristics of HUC12 Subwatersheds of Study Area

No.	Area [acres]	State	County	Watershed ID (HUC12)	Watershed Name
1	22,785	VA	Augusta	20700050103	Jennings Branch
2	17,214	VA	Augusta	20700050105	Moffett Creek
3	26,609	VA	Augusta	20700050703	Inch Branch-Back Creek
4	35,644	VA	Bath, Highland	20802010102	Bolar Run-Jackson River
5	34,776	VA	Bath	20802010103	Warm Springs Run-Jackson River
6	37,220	VA	Bath, Highland	20802010202	Jim Dave Run-Back Creek
7	22,287	VA	Bath	20802010701	Scotchtown Draft-Cowpasture River
8	17,258	VA	Bath	20802010702	Dry Run
9	31,659	VA	Bath	20802010704	Lick Run-Stuart Run
10	14,373	VA	Augusta	20802020101	Chair Draft-Calfpasture River
11	13,741	VA	Augusta	20802020102	Ramseys Draft
12	24,449	VA	Augusta	20802020103	Holloway Draft-Calfpasture River
13	29,042	VA	Augusta, Bath, Rockbridge	20802020106	Cabin Creek-Mill Creek
14	30,478	WV	Pocahontas	50500030202	Headwaters Knapp Creek
15	31,871	WV	Pocahontas	50500030401	Sitlington Creek
16	24,736	WV	Pocahontas	50500030402	Clover Creek-Greenbrier River
17	34,747	WV	Pocahontas	50500070101	Old Field Fork
18	19,068	VA	Augusta	20700050102	Buffalo Branch-Middle River
19	12,217	VA	Augusta	20802020104	Hamilton Branch
20	35,186	VA	Augusta, Rockbridge	20802020402	Upper South River
21	21,151	WV	Pocahontas, Randolph	50500070102	Dry Fork-Elk River
22	20,524	WV	Randolph, Webster	50500070103	Abb Run-Elk River
23	28,360	WV	Randolph	50200010101	Ralston Run-Tygart Valley River
24	27,254	WV	Randolph	50200010102	Elkwater Fork-Tygart Valley River
25	28,884	WV	Randolph	50200010104	Becky Creek-Tygart Valley River
26	25,566	VA	Augusta	20700050702	Canada Run-South River
27	21,969	VA	Nelson	20802030902	South Fork Rockfish River
28	30,006	WV	Pocahontas	50500030404	Thorny Creek-Greenbrier River

TABLE 1.2.4-1

C-Factors Used in the Erosion Analysis for Different Land Cover Classes

Value	Land Cover Class	C-Factor
11	Open Water	0.000
21	Developed, Open Space	0.003
22	Developed, Low Intensity	0.013
23	Developed, Medium Intensity	0.200
24	Developed, High Intensity	0.450
31	Barren Land	1.000
41	Deciduous Forest	0.003
42	Evergreen Forest	0.003
43	Mixed Forest	0.003
52	Shrub/Scrub	0.009
71	Herbaceous/Grassland	0.013
81	Hay/Pasture	0.003
82	Cultivated Crops	0.003
90	Woody Wetlands	0.001
95	Emergent Herbaceous Wetlands	0.003

TABLE 1.3-1 **Average Annual Soil Loss and Sediment Load for Subwatersheds**											
							Baseline Analysis		Site-Specific RUSLE2 Analysis		
Number	Watershed ID (HUC12)	Watershed Name	Watershed Area [acres]	Area of Workspace [acres]	Percentage of Workspace [%]	SDR	Baseline Total Erosion Rate [tons/year]	Baseline Sediment Delivery [tons/year]	Identified Construction Area [acres]	First Year Erosion Rate in Identified Construction Areas [tons/year]	Percentage of Existing Erosion [%]
1	20700050103	Jennings Branch	22,785	183	0.80	0.1277	45,500	5,800	56	222	0.49
2	20700050105	Moffett Creek	17,214	96	0.56	0.1365	13,800	1,900	21	66	0.48
3	20700050703	Inch Branch-Back Creek	26,609	120	0.45	0.1230	69,000	8,500	19	59	0.09
4	20802010102	Bolar Run-Jackson River	35,644	166	0.47	0.1148	82,400	9,500	99	420	0.51
5	20802010103	Warm Springs Run-Jackson River	34,776	99	0.28	0.1154	68,100	7,900	-	-	-
6	20802010202	Jim Dave Run-Back Creek	37,220	150	0.40	0.1136	198,200	22,500	114	489	0.25
7	20802010701	Scotchtown Draft-Cowpasture River	22,287	77	0.34	0.1283	47,500	6,100	33	123	0.26
8	20802010702	Dry Run	17,258	74	0.43	0.1364	33,600	4,600	51	152	0.45
9	20802010704	Lick Run-Stuart Run	31,659	108	0.34	0.1180	86,600	10,200	88	361	0.42
10	20802020101	Chair Draft-Calfpasture River	14,373	82	0.57	0.1425	41,200	5,900	33	129	0.31
11	20802020102	Ramseys Draft	13,741	31	0.22	0.1440	46,500	6,700	-	-	-
12	20802020103	Holloway Draft-Calfpasture River	24,449	96	0.39	0.1255	62,000	7,800	-	-	-
13	20802020106	Cabin Creek-Mill Creek	29,042	107	0.37	0.1205	47,300	5,700	21	55	0.12
14	50500030202	Headwaters Knapp Creek	30,478	147	0.48	0.1191	124,000	14,800	63	367	0.3
15	50500030401	Sitlington Creek	31,871	83	0.26	0.1179	167,800	19,800	47	351	0.21
16	50500030402	Clover Creek-Greenbrier River	24,736	199	0.81	0.1252	151,900	19,000	163	1301	0.86
17	50500070101	Old Field Fork	34,747	172	0.50	0.1155	281,600	32,500	86	675	0.24
18	20700050102	Buffalo Branch-Middle River	19,068	48	0.25	0.1332	32,900	4,400	-	-	-
19	20802020104	Hamilton Branch	12,217	138	1.13	0.1481	43,800	6,500	13	28	0.06
20	20802020402	Upper South River	35,186	41	0.12	0.1151	53,200	6,100	-	-	-
21	50500070102	Dry Fork-Elk River	21,151	129	0.61	0.1300	146,100	19,000	74	477	0.33
22	50500070103	Abb Run-Elk River	20,524	67	0.33	0.1309	186,300	24,400	-	-	-
23	50200010101	Ralston Run-Tygart Valley River	28,360	59	0.21	0.1212	216,600	26,200	-	-	-

TABLE 1.3-1

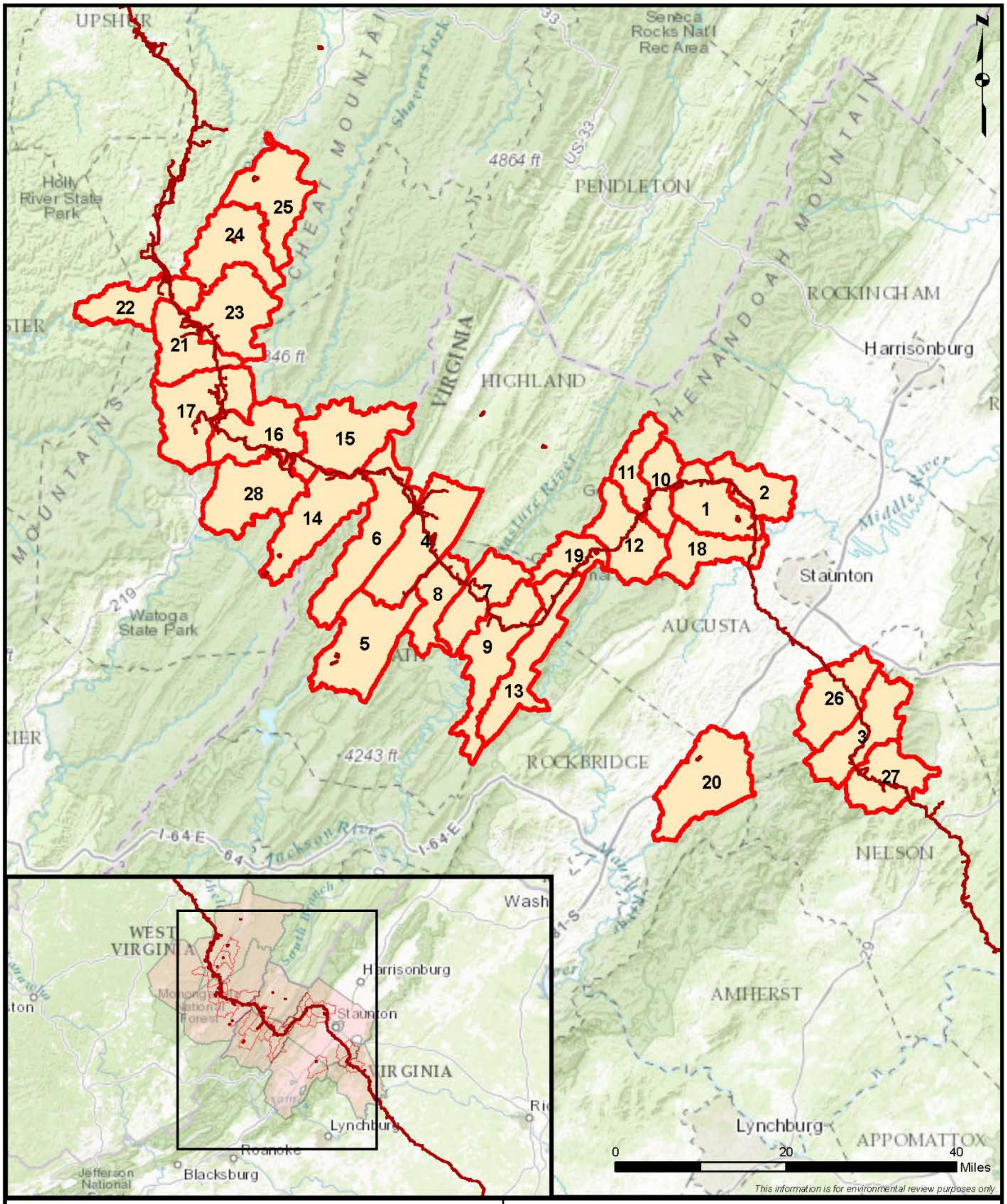
Average Annual Soil Loss and Sediment Load for Subwatersheds

Number	Watershed ID (HUC12)	Watershed Name	Watershed Area [acres]	Area of Workspace [acres]	Percentage of Workspace [%]	SDR	Baseline Analysis		Site-Specific RUSLE2 Analysis		
							Baseline Total Erosion Rate [tons/year]	Baseline Sediment Delivery [tons/year]	Identified Construction Area [acres]	First Year Erosion Rate in Identified Construction Areas [tons/year]	Percentage of Existing Erosion [%]
24	50200010102	Elkwater Fork-Tygart Valley River	27,254	48	0.18	0.1223	174,100	21,300	-	-	-
25	50200010104	Becky Creek-Tygart Valley River	28,884	78	0.27	0.1207	230,500	27,800	-	-	-
26	20700050702	Canada Run-South River	25,566	112	0.44	0.1242	8,900	1,100	-	-	-
27	20802030902	South Fork Rockfish River	21,969	125	0.57	0.1288	84,900	10,900	-	-	-
28	50500030404	Thorny Creek-Greenbrier River	30,006	24	0.08	0.0012	103,400	12,400	-	-	-

TABLE 1.3-2

Average Sediment Yield for Subwatersheds

Number	HUC12	Name	Area [$mile^2$]	Baseline Sediment Yield [$tons/mile^2/year$]
1	20700050103	Jennings Branch	35.6	163
2	20700050105	Moffett Creek	26.9	70
3	20700050703	Inch Branch-Back Creek	41.6	204
4	20802010102	Bolar Run-Jackson River	55.7	170
5	20802010103	Warm Springs Run-Jackson River	54.3	145
6	20802010202	Jim Dave Run-Back Creek	58.1	388
7	20802010701	Scotchtown Draft-Cowpasture River	34.8	175
8	20802010702	Dry Run	27	170
9	20802010704	Lick Run-Stuart Run	49.4	207
10	20802020101	Chair Draft-Calfpasture River	22.5	262
11	20802020102	Ramseys Draft	21.5	312
12	20802020103	Holloway Draft-Calfpasture River	38.2	204
13	20802020106	Cabin Creek-Mill Creek	45.3	126
14	50500030202	Headwaters Knapp Creek	47.6	310
15	50500030401	Sitlington Creek	49.8	398
16	50500030402	Clover Creek-Greenbrier River	38.6	492
17	50500070101	Old Field Fork	54.3	599
18	20700050102	Buffalo Branch-Middle River	29.8	147
19	20802020104	Hamilton Branch	19.1	340
20	20802020402	Upper South River	55	111
21	50500070102	Dry Fork-Elk River	33	575
22	50500070103	Abb Run-Elk River	32	761
23	50200010101	Ralston Run-Tygart Valley River	44.3	593
24	50200010102	Elkwater Fork-Tygart Valley River	42.6	501
25	50200010104	Becky Creek-Tygart Valley River	45.1	617
26	20700050702	Canada Run-South River	39.9	28
27	20802030902	South Fork Rockfish River	34.3	318
28	50500030404	Thorny Creek-Greenbrier River	46.9	264



Huc-12 Subwatersheds

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Figure 1.1-1
Watershed Analysis
Subwatersheds of Study Area

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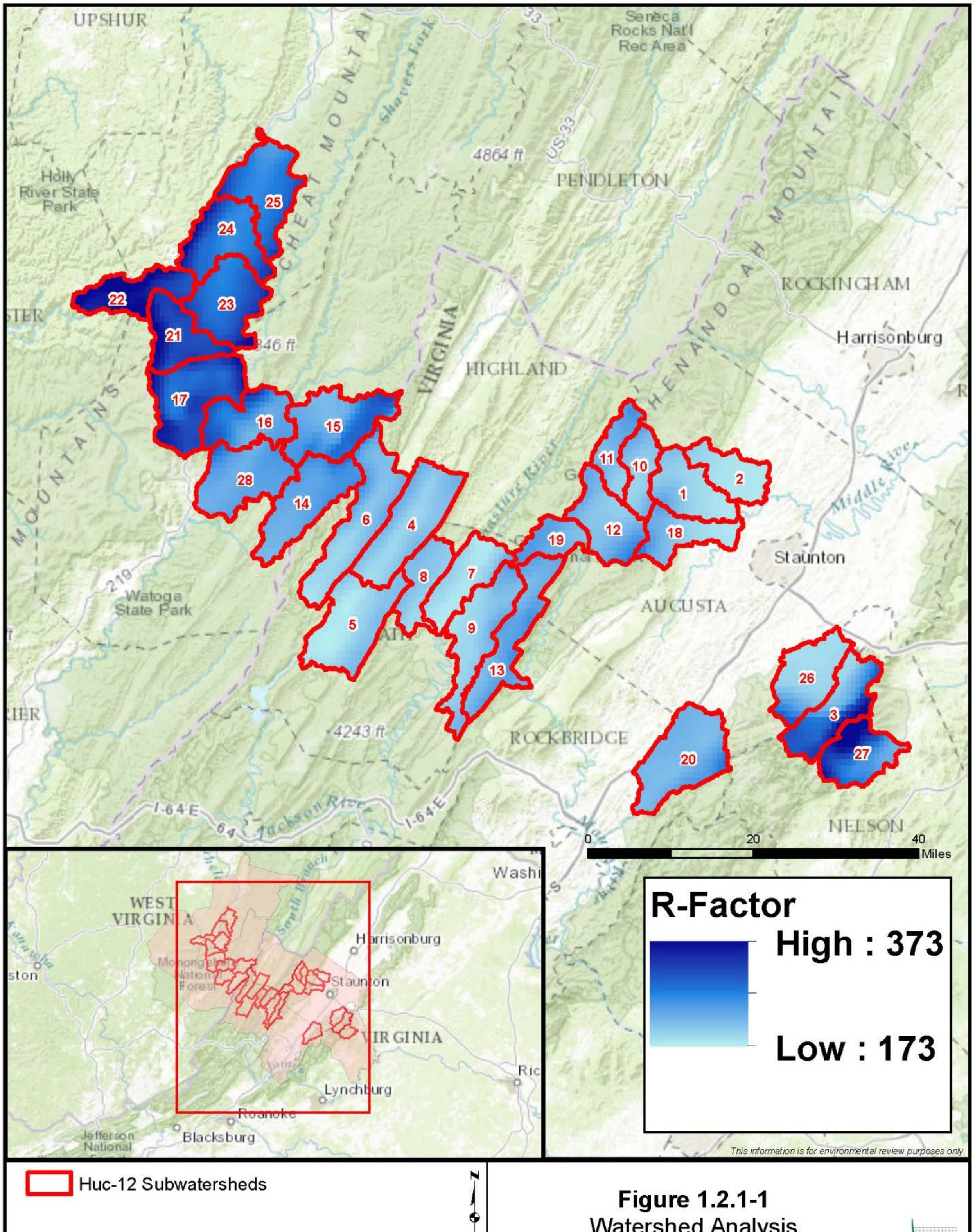

Figure 1.2.1-1
Watershed Analysis
R-Factors

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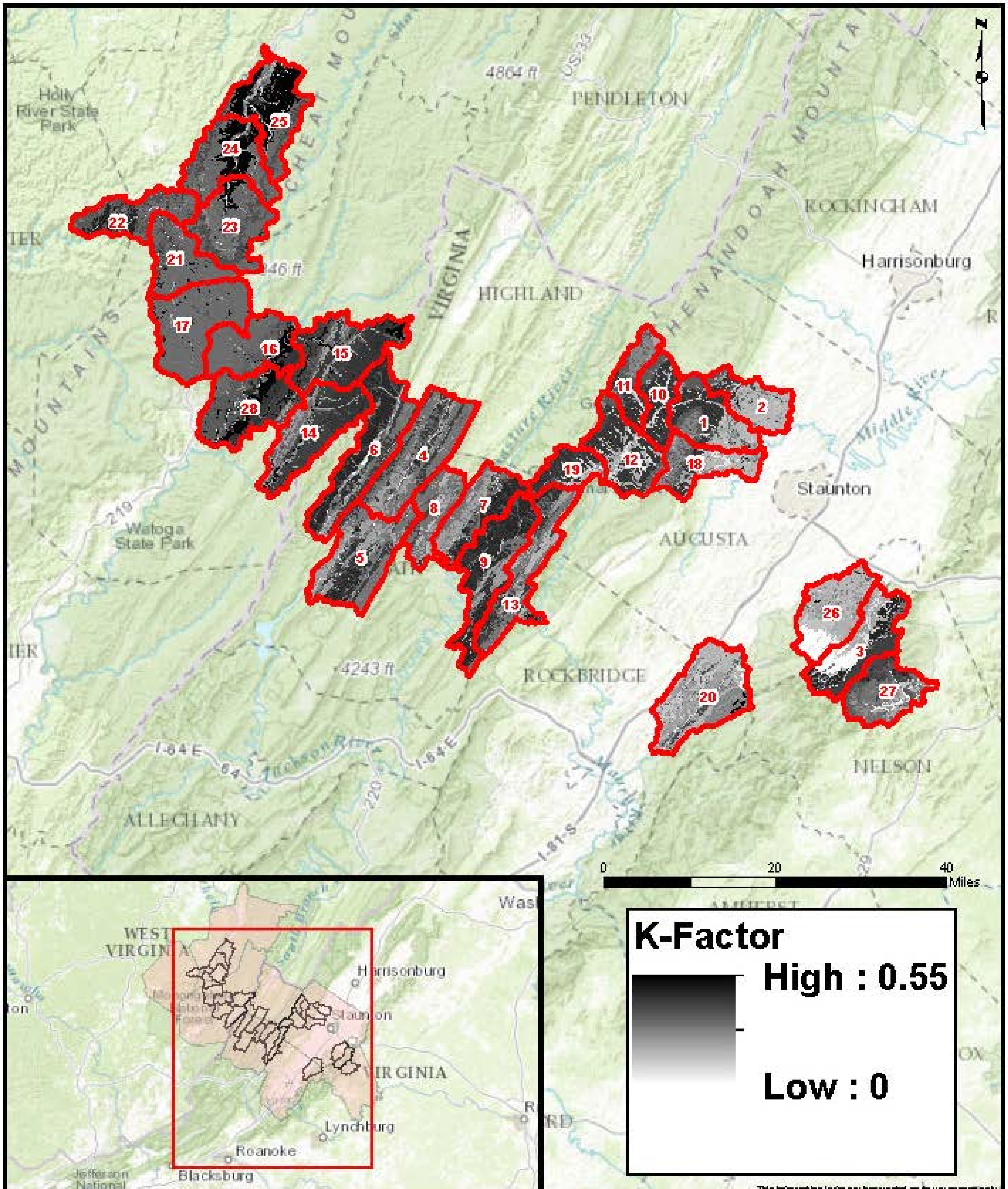

Huc-12 Subwatersheds

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Figure 1.2.2-1
Watershed Analysis
K-Factors

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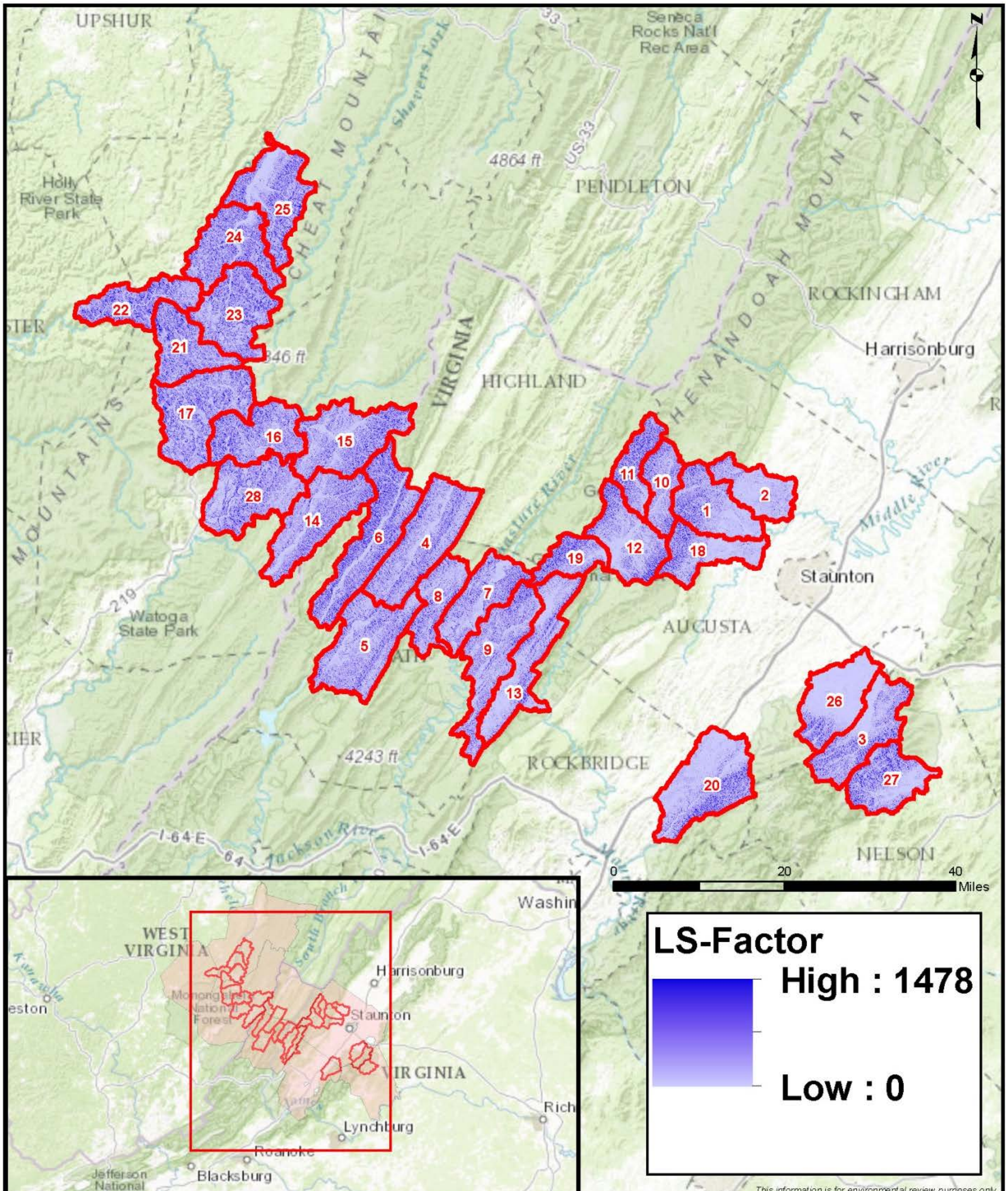

Huc-12 Subwatersheds

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Figure 1.2.3-1
Watershed Analysis
LS-Factors

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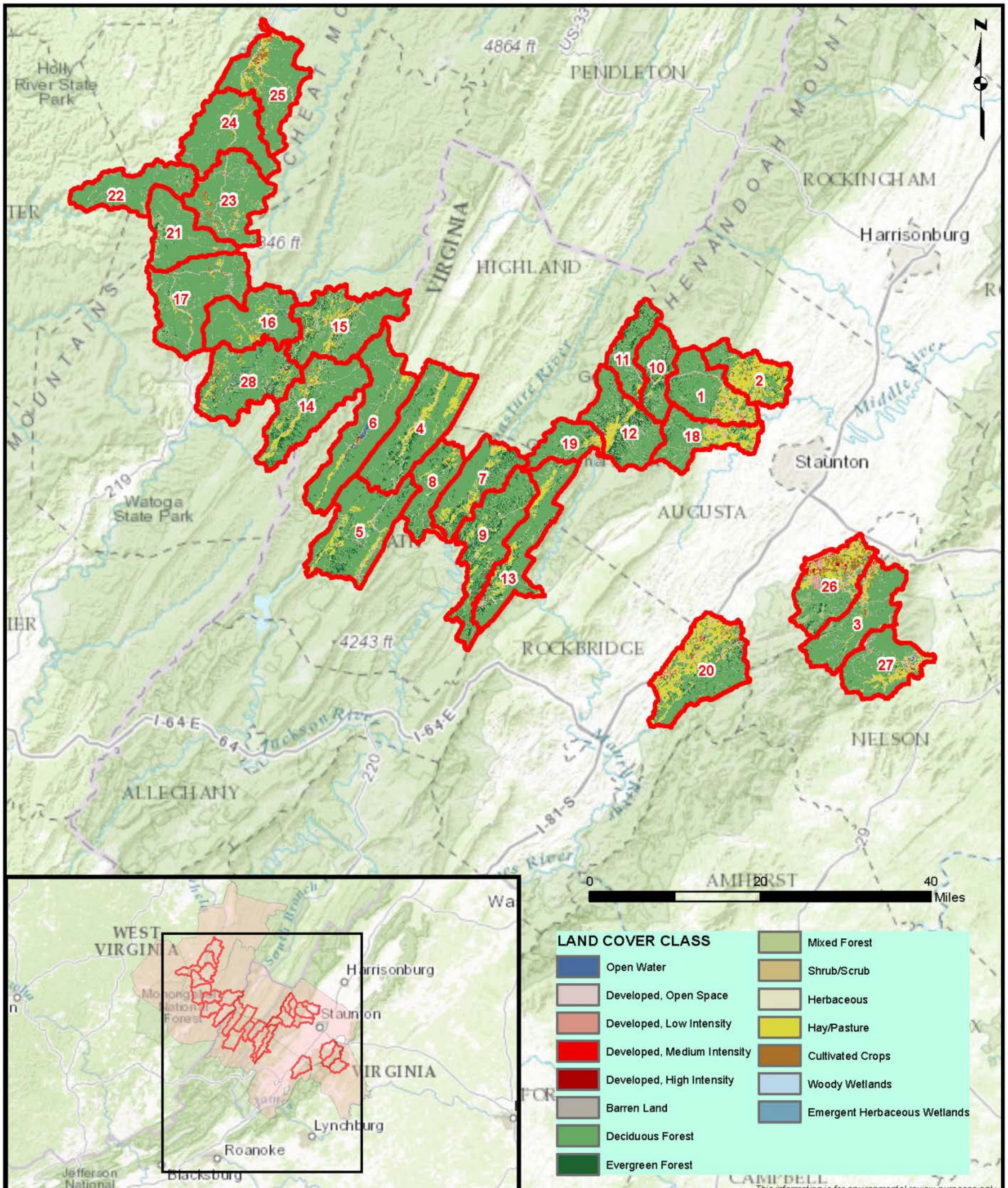

Figure 1.2.4-1
Watershed Analysis
Existing Vegetative Cover

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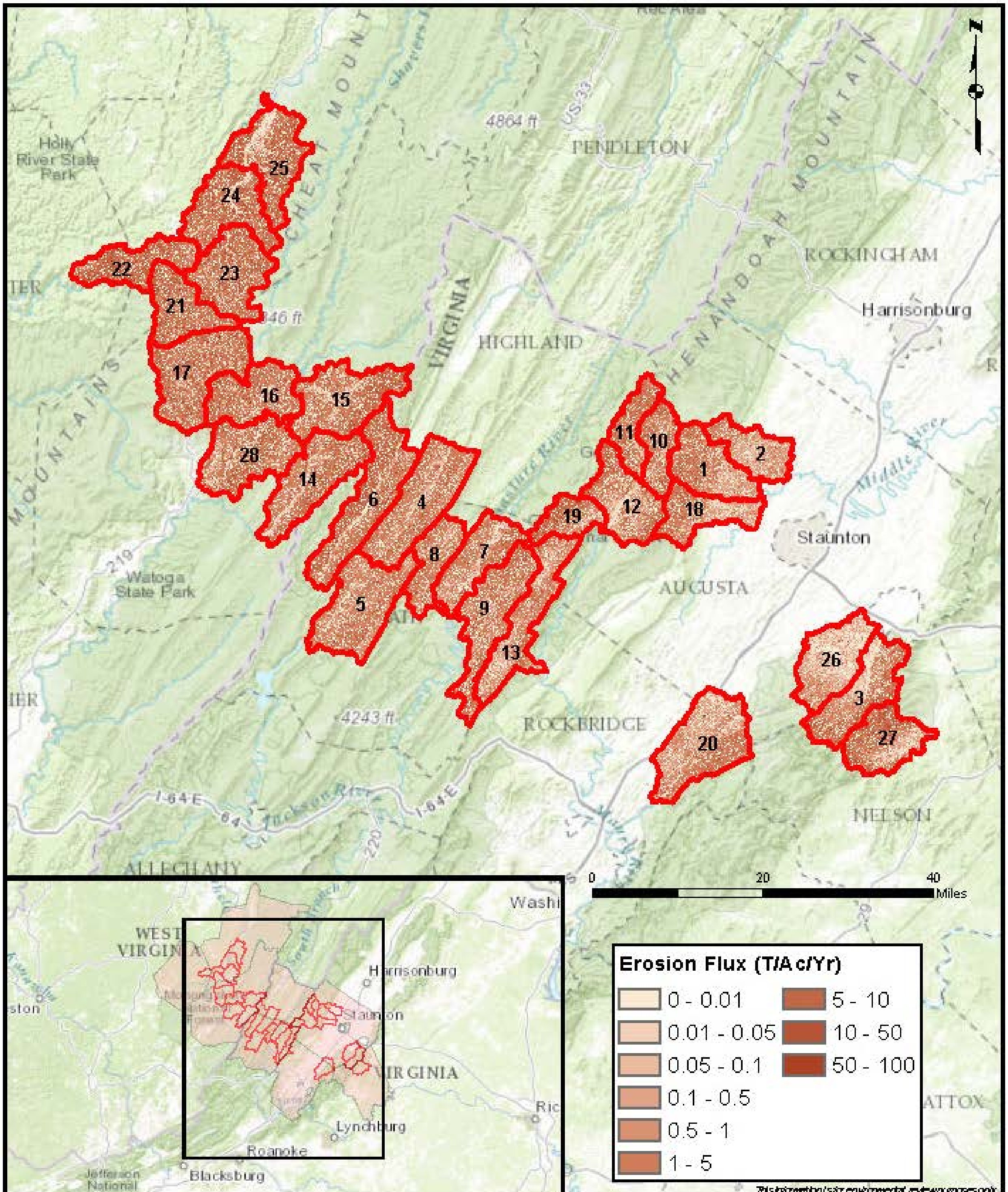

Huc-12 Subwatersheds

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Figure 1.3-1
Watershed Analysis Baseline
Total Erosion Rate

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ATLANTIC COAST PIPELINE PROJECT

BIOLOGICAL EVALUATION

APPENDIX I

Monongahela and George Washington National Forests

Regional Forester's Sensitive Species Downstream Sedimentation Analysis

Contains Privileged Information
Filed Under Separate Cover on March 10, 2017