Assessment of Augusta County as a Headwaters Zone and Associated Risk Posed by Pipeline Construction

Augusta County, Virginia

Prepared for:

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1.0 INTRODUCTION

Sullivan International Group, Inc. (Sullivan) is pleased to provide the following report to Augusta County Service Authority (ACSA), which documents our methodologies and findings related to the following: (1) an estimation of the annual water volume being contributed from Augusta County to adjoining counties and (2) an assessment of risks associated with the construction of the proposed Dominion Pipeline. The proposed path of the Dominion Pipeline can be observed in Figure 1. It was important to assess the risks associated with construction of the proposed Dominion Pipeline because Augusta County is uniquely situated as a geographic headwaters zone. As such, water in the county, including both surface water and groundwater, is supplied by precipitation that falls within the county. This water is not only an essential and valuable resource for Augusta County, but is also an important resource to counties downgradient from Augusta County. Figure 2 shows the regional hydrography of Augusta County, including named streams and subbasin boundaries, and depicts the county's position as a geographic headwaters zone.

Sullivan estimated the annual water volume being contributed from Augusta County to adjoining counties by utilizing a mass-balance approach to estimate the county's annual hydrologic budget. This allowed Sullivan to assess individual inflows and outflows to/from Augusta County. Findings from this assessment are documented in Section 2.0, below. Sullivan also performed an assessment of potential risks to the county's water resources that should be considered prior to construction of the Dominion Pipeline. This risk assessment included the development of Sensitive Area Maps (Figures 3a–3g), which depict identified sensitive areas that are in proximity to the proposed pipeline corridor. General descriptions of potential risks associated with pipeline construction, both within identified sensitive areas and throughout the path of the pipeline, have also been included. Findings from the risk assessment portion of this study are documented in Sections 3.0 and 4.0, below.

The findings of this study highlight the quantity and value of water resources originating within Augusta County and identify potential risks to the county's water resources associated with pipeline construction. These findings demonstrate the importance and necessity for groundwater protection planning during any pipeline construction within Augusta County. This planning should include the formulation of a monitoring plan designed to identify impacts to water resources as a result of pipeline construction activities. Mitigation plans should also be formulated to address and remedy any impacts resulting from pipeline construction activities.

2.0 ESTIMATE OF WATER OUTFLOW TO ADJOINING COUNTIES

2.1 Water Outflow Assessment Methodology

To better understand the annual volume of water that originates in Augusta County and flows to downgradient regions beyond its borders, Sullivan has calculated Augusta County's annual hydrologic inflows and outflows using a mass-balance approach. A U.S. Geological Survey (USGS) Scientific Investigations Report by Sanford et al. (2012), wherein components of the hydrologic cycle were quantified throughout Virginia, was an essential resource that was used as part of this study. Sullivan personnel spoke with David Nelms, a hydrologist with the USGS and second author of the Sanford et al. (2012) publication, to discuss the applicability of data within their publication to the Augusta County study. Mr. Nelms concurred that these data could appropriately be used for planning purposes to provide an estimate of average annual groundwater and surface water outflows from Augusta County.

The inflows and outflows comprising Augusta County's hydrologic budget are as follows: (1) inflow from direct precipitation, (2) outflow from subsurface groundwater flow and the component of streamflow contributed from groundwater discharge (i.e. baseflow), (3) outflow from groundwater and surface water withdrawn for consumptive use (i.e. human, agricultural, industrial, etc.), (4) outflow from the stormwater runoff component of streamflow, and (5) outflow from evapotranspiration. All of these hydrologic budget components were accounted for within Sullivan's hydrologic budget calculations.

Sullivan performed two iterations of the mass-balance calculations; average hydrologic conditions were used for the first iteration and drought conditions were used for the second iteration to provide an estimated range of hydrologic inflows and outflows under variable climactic conditions. Sullivan utilized an annual direct precipitation value of 65 percent of normal precipitation conditions to represent drought conditions. A 35 percent reduction to normal precipitation conditions was utilized to assess drought conditions because the Virginia Drought Response Technical Advisory Committee states that an indicator of extreme drought is the occurrence of a 12-month period where normal precipitation is reduced by 35 percent or more (Virginia Technical Advisory Committee 2003). Detailed descriptions of the assessed hydrologic components and calculation methodology has been provided in Appendix A.

2.2 Results

The utilization of a mass-balance approach to estimate Augusta County's annual hydrologic inflows and outflows yielded the volumes included in Table 1. This table includes estimated volumes under both average and drought precipitation conditions. Under normal precipitation conditions, the calculated groundwater outflow volume via subsurface flow and baseflow was approximately 190,403 million gallons (Mgal) per year and the calculated storm water runoff component of streamflow was 82,848 Mgal/year, for a combined outflow volume totaling 273,251 Mgal/year. Under drought conditions, the calculated groundwater outflow component via subsurface flow and baseflow was 120,214 Mgal/year and the storm water runoff component of streamflow was 53,598 Mgal/year, for a combined outflow volume totaling 173,812 Mgal/year. Based on these results, Sullivan estimates that between 173,812 Mgal/year and 273,251 Mgal/year are contributed to adjoining counties on an annual basis via groundwater flow and streamflow.

Table 1. Summary of Augusta County's mass-balance hydrologic budget calculations

Hydrologic Component	Hydrologic Parameter	Parameter Component	Average Precipitation Conditions		Drought Precipitation Conditions[a]	
			Augusta County Value[b] (inches/year)	Annual Volume (Mgal/year[c])	Augusta County Value[d] (inches/year)	Annual Volume (Mgal/year[c])
Inflow	Precipitation	Total Precipitation	43.2	730,416	28.08	474,770
Outflow	Evapotranspiration	Total Evapotranspiration	26.6	449,747	17.27	291,997
	Storm Streamflow	Runoff to streams	4.9	82,848	3.17	53,598
	Groundwater Outflow	Subsurface flow and stream baseflow	11.24	190,043	7.11	120,214
	Groundwater and Surface Water Withdrawal	Consumptive use	0.56[e]	9,468	0.56[e]	9,468
Net Difference	Not Applicable	Not Applicable	-0.1	-1,690	-0.03	-507

[a]It is assumed that drought conditions are represented by 65 percent of normal precipitation conditions
[b]Parameter values obtained from Sanford et al. (2012)
[c]Mgal/year = million gallons per year
[d]Parameter value from Sanford et al. (2012) that has been modified to account for drought conditions
[e]Parameter value from Sanford et al. (2012) that has been modified to account for returns to the hydrologic system

3.0 ASSESSMENT OF RISKS POSED BY PIPELINE CONSTRUCTION

Sullivan has identified several potential risk conditions posed by pipeline construction activities that should be considered. These risk conditions could potentially impact Augusta County's groundwater and surface water resources. While these risks have the potential to affect the sensitive areas identified within Figures 3a–3g, they may also affect, on a broader scale, any surface water and groundwater resources encountered during construction of the proposed pipeline, including resources servicing individual property owners (i.e. wells and springs).

3.1 Occurrence of Bedrock Outcrops, Shallow Bedrock, and Karst Terrain

Bedrock geology in Augusta County varies in depth and in physical character. Generally, the western portion of the county is underlain by clastic shale, siltstone and sandstone, the central "valley" portion is underlain by carbonates (limestone and dolostone) and shale, and the eastern portion is underlain by sandstone and metamorphic crystalline rock (Figure 1). Geologic mapping, including detailed formation descriptions, of Augusta County can be found online at the Virginia Department of Mines, Minerals, and Energy's website (http://www.dmme.virginia.gov/dgmr/augusta.shtml).

Approximately 61 percent of the Augusta County-portion of the planned Dominion Pipeline path extends across carbonate bedrock. Dissolution of the carbonate bedrock leads to the development of karst features and subsurface karst aquifers. Karst aquifers are characterized as having complex flow pathways that can transmit groundwater at significantly higher flow rates than that of typical clastic or crystalline aquifers. As a result of their typically high hydraulic conductivities, karst aquifers have the ability to rapidly transmit contamination through the aquifer. According to the Virginia Department of Conservation and Recreation (VDCR), the most important current and future environmental issue with respect to karst is the sensitivity of karst aquifers to groundwater contamination, since water can travel rapidly through solution conduits with relatively little time for natural filtering (VDCR 2015).

Localized areas of bedrock outcrops, as well as areas with shallow depths to bedrock, are widespread throughout Augusta County in areas underlain by both carbonate and non-carbonate bedrock. The presence of exposed or shallow bedrock is often associated with drainage incisions in the landscape where overlying soils have been transported away by erosional forces, but it can also be associated with higher topographic settings where the physical properties of the bedrock result in greater resistance to weathering. Based on the variety of both landscape positions and bedrock types throughout Augusta County, shallow depths to bedrock would be expected to be encountered frequently during construction of the Dominion Pipeline, which is expected to be buried to depths of 30–60 inches below the land surface. Such occurrences may require blasting to accommodate pipeline construction.

3.2 Water Quality

Groundwater wells and springs can be susceptible to impacts from blasting activities. Contamination of groundwater can occur from exposure to, or from a release of, chemicals used in bedrock blasting. Increased turbidity of groundwater can also be caused by agitation of the subsurface as a result of blasting. Blasting vibrations can shake loose silt, rock particles and chemical precipitates that line fracture surfaces in the subsurface, which can increase groundwater turbidity (Kernen 2010). Blasting vibrations in proximity to a well may also have the potential to compromise a well's sanitary seal by creating cracks within the grout seal. The introduction of turbidity or contaminants to groundwater can impair its quality (Emery & Garrett Groundwater Investigations, LLC [EGGI] 2014).

The potential for increased turbidity and susceptibility to chemicals associated with blasting represents a risk to groundwater throughout Augusta County. However, areas underlain by carbonate bedrock possessing karst characteristics are considered more vulnerable to such risks. Active sinkholes, which are typical of karst conditions, can provide a direct conduit from the surface to the underlying bedrock aquifer. The use of chemicals that are frequently used at construction sites, such as diesel fuel, gasoline, antifreeze, etc., represents an additional risk to groundwater quality within the karst aquifer due to the potential for rapid contaminant migration and the resulting long-lasting effects to water quality.

Sinkholes can develop in a variety of ways. Dissolution sinkholes form naturally by the slow downward dissolution of carbonate rock, whereas collapse sinkholes form suddenly when overlying rock collapses into a dissolution cavern. According to the Virginia Department of Emergency Management's (VDEM's) Hazard Mitigation Plan (VDEM 2013), sinkhole development can also be human-induced by alterations to local hydrology, as inadequate drainage and increased runoff can lead to sinkhole development. Proper stormwater management is an essential component of protecting groundwater and surface quality. According to Figure 3.14-1 in VDEM's Hazard Mitigation Plan, titled Karst Regions and Historical Subsidence, the entire portion of Augusta County that is underlain by carbonate rock is recognized as an area that has experienced historical subsidence, which is further defined as having extensive sinkhole development. This figure also identifies the type of karst in Augusta County as being of the "long" variety, which is characterized by fissures, tubes, and caves over 1,000 feet in length with vertical extents of 50 feet to greater than 250 feet. Figure 3.14-1 in the Hazard Mitigation Plan has been included as Appendix B in this report. Finally, the Hazard Mitigation Plan recognizes karst terrain as a risk to energy pipelines, stating that "pipeline infrastructure, underlain by karst terrain, can be damaged by collapse in the supporting soil" (VDEM 2013).

3.3 Water Yield

Blasting-induced vibrations have the potential to affect fragile bedrock fracture systems within the bedrock aquifer underlying Augusta County, which could result in diminished well yields. Diminished well yields can occur as a result of the collapse of a water bearing feature, or by increased sedimentation effectively clogging a water-bearing feature contributing water to a well or spring (EGGI 2014). Substantial changes within a fragile karst aquifer system also have the potential to lower the water table, which can result in reduced yields to wells and springs (EGGI 2014).

3.4 Dam Safety

The potential for blasting vibrations to threaten the integrity of dams within the county has created concerns from the Headwaters Soil and Water Conservation District (HSWCD). The HSWCD outlined their concerns for dam safety in a correspondence to the Federal Energy Regulatory Commission (FERC) dated December 17, 2014. A copy of this correspondence has been included as Appendix C. In this correspondence, the HSWCD requested that blasting be prohibited within 0.75 mile of any dams to avoid potential damage to the dam embankments. The HSWCD further requested that a monitoring plan be prepared for any blasting occurring between 0.75–1.25 mile of any dams to monitor for potential damage.

4.0 SENSITIVE AREA MAPPING

Sullivan has prepared a series of Sensitive Area Maps that show identified sensitive areas in proximity to the planned route of the Dominion Pipeline (Figures 3a–3g). Figure 3a depicts identified sensitive areas throughout Augusta County on a countywide-scale, Figure 3b depicts the boundaries of map "subsets" that show large-scale mapping of identified sensitive areas along the path of the pipeline, and Figures 3c–3g show these large-scale subset maps. The Sensitive Area Maps depict the route of the pipeline, mapped geologic faults, carbonate and non-carbonate bedrock areas, sinkholes, ACSA well heads, potable water supply production springs, source water protection zones associated with ACSA wells and water supply production springs, areas planned for future groundwater development, mapped non-municipal springs, and dams. Available published resources and mapping data provided by Augusta County, ACSA, HSWCD, Virginia Department of Environmental Quality (VDEQ), and USGS were used to develop these maps. While the intent of the Sensitive Area Maps is not to relieve Dominion Power of their own obligation to perform due diligence regarding risk assessment associated with pipeline construction, the mapping does provide a screening-level assessment that identifies sensitive areas that could be susceptible to impact during pipeline construction. Any such impact could result in impairment to Augusta County's water resources.

There will undoubtedly be numerous domestic wells located in proximity to the planned path of the pipeline. With the exception of public water supply wells utilized by ACSA, the Sensitive Area Maps do not identify groundwater wells. Any domestic well, community supply well, or other public water supply well that lies in proximity to the planned path of the pipeline would be deemed as sensitive. An additional site-specific inventory would be required to determine the locations of any wells that may lie in proximity to the planned pipeline.

4.1 Discussion of Mapping Methodology

Sullivan utilized Geographic Information Systems (GIS) mapping and shapefile data to identify sensitive areas located in proximity to the path of the proposed pipeline. A 500-foot buffer distance from both sides of the pipeline was utilized to select the mapped sinkholes and non-municipal supply springs. A larger 2,640-foot (0.5-mile) buffer

Table 2: Summary of sensitive features in proximity to the proposed Dominion Pipeline.

Sensitive Feature	Buffer Distance from Pipeline	Number of Features Within Buffer Distance	Notes
Mapped Sinkholes	500 ft on each side	27	Pipeline directly crosses over 4 of the 27 sinkholes located within 500 ft of the pipeline
ACSA Wells and Production Springs	0.5 mile on each side	0	---
City of Staunton Production Springs	0.5 mile on each side	0	---
Non-Municipal Springs	500 ft on each side	0	4 springs are located within 1,000 ft of the pipeline
Geologic Faults	Crossings	7 crossings	---
Dams	1.25 mile on each side	4	Inch Branch Dam, Robinson Hollow Dam, Happy Hollow Dam, and Waynesboro Nurseries Dam. All of these dams except Inch Branch Dam are located within 0.75-mile of the pipeline
Streams (named)	Crossings	12 crossings	From west to east: Barn Lick Branch, Braley Branch, Calfpasture River, Stoutameyer Branch, Jennings Branch, Middle River, Lewis Creek, Folly Mills Creek, Christians Creek, Barterbrook Branch, South River, Back Creek
Wellhead Protection Areas	0.5 mile on each side	3	Pipeline directly crosses through the Lyndhurst Well and Gardner Spring Wellhead Protection Areas, and is within 0.5 mile of the HHR Wells Wellhead Protection Area
Potential Future Groundwater Development Areas	0.5 mile on each side	2	Pipeline directly crosses through both of these future groundwater development areas

distance from both sides of the pipeline was utilized to assess public water supply sources used by ACSA or the City of Staunton, Wellhead Protection Areas associated with these wells and springs, and potential future groundwater development areas. This buffer distance was selected based on criteria utilized by the state code of Massachusetts (Massachusetts State Code 2009) for interim wellhead protection area delineation. A buffer distance of 1.25 mile was utilized to select dams in proximity to the pipeline. This distance was chosen to correspond with the aforementioned HSWCD concerns related to the threat of blasting vibrations on dam stability. Table 2 shows a summary of assessed sensitive features, buffer distances from the pipeline, and the number of features located within the buffer distance. Analysis of the sensitive area mapping results is provided below.

4.2 Geologic Faults

The proposed pipeline crosses seven (7) mapped geologic faults. The majority of geologic faults in Augusta County have a general northeast-southwest orientation. As such, the generally east-west trend of the proposed pipeline leads to a propensity for fault crossings. Preferential weathering of bedrock often occurs along geologic faults, which can provide enhanced means for subsurface groundwater movement (De Simone and Gale 2009). Springs are also often found along geologic faults, particularly in karst regions of Augusta County. The most prominent mapped fault in the region is the Staunton Fault, which the proposed Dominion Pipeline would cross at a location approximately two miles southwest of the City of Staunton (Figure 3d). Although they are not located within the 0.5-mile buffer zone, it is of interest that three (3) significant springs (Gardner Spring, Berry Farm Spring, and Dices Spring) are located along or are likely supplied water from the Staunton Fault. Each of these springs are used for public water supply by either the ACSA or the City of Staunton.

4.3 Sinkholes

As much of Augusta County is underlain by carbonate geology, it is not unexpected that 27 sinkholes were identified within the 500-foot pipeline buffer zone. These sinkholes are outlined in red in Figures 3c–3g. Four (4) of the 27 sinkholes actually underlie the planned path of the pipeline, all of which are located within the extent of Figure 3e. It is important to note that mapped sinkhole data obtained during this assessment are representative of work performed by Hubbard (1984), who identified sinkholes using stereoscopic analysis. Certainly other sinkholes that may not have been clearly visible are absent from this mapping. Likewise, any new sinkhole development that has occurred from the date of this mapping (1984) would not be shown.

The locations of sinkholes within 500 feet of the planned pipeline are deemed important because sinkhole development often occurs in clusters, as evidenced by sinkhole mapping in Figures 3a–3g. Also, active sinkholes possess the ability to rapidly transmit water and potential contaminants from the surface to the underlying bedrock aquifer. The potential for disturbance to soil arches and/or fragile weathered solution channels that are typically associated with sinkholes should be carefully considered during any pipeline construction activity, since damage to these systems can affect the flow pathways, yield, and quality of groundwater in karst aquifers. The potential risk of damage to the proposed pipeline must also be considered within karst portions of Augusta County, since pipeline infrastructure underlain by karst terrain can be damaged by collapse in the supporting soil (VDEM 2013).

4.4 Non-Municipal Springs

The locations of mapped springs within Augusta County were obtained from the VDEQ. There were no mapped springs identified within the defined buffer zone, however, it should be noted that four (4) springs were identified within 1,000 feet of the planned pipeline. Other unmapped springs could exist in proximity to the pipeline that are not included within the VDEQ database.

4.5 Public Supply Source Water Protection Areas

Review of the sensitive area mapping indicated that two (2) source water protection areas that have previously been delineated for existing public water supplies used by the ACSA or City of Staunton lie within the path of the planned pipeline and an additional source water protection area is within 0.5 mile of the proposed pipeline. The source water protection areas that would be crossed by the proposed pipeline are the Lyndhurst Well and the Gardner Spring areas. The HHR Wells wellhead protection area is within 0.5 mile of the proposed pipeline. A source water protection area can be defined as the landscape area which is deemed to supply groundwater to the well or spring. Their delineation typically involves hydrogeologic mapping, which considers underlying geology, fracture orientation, and landscape position. Construction activity within a source water protection area must consider the sensitive nature of these areas, as the potential for impact to both water quality and yield associated with public water supplies could exist.

4.6 Future Groundwater Development Areas

Areas that are deemed important for potential future development of groundwater have been previously delineated in Augusta County. Just as it is important to protect existing public water supplies, it is likewise prudent to protect areas that may provide future water supply. Sensitive area mapping indicated that two (2) such areas are located within the 0.5 mile buffer zone from the pipeline, both of which are crossed by the proposed pipeline.

4.7 Streams

The locations of named streams throughout the county have been depicted in Figure 2. Review of this figure shows that the planned path of the pipeline crosses 12 of these streams. From west to east, these streams are as follows: Barn Lick Branch, Braley Branch, Calfpasture River, Stoutameyer Branch, Jennings Branch, Middle River, Lewis Creek, Folly Mills Creek, Christians Creek, Bartbrook Branch, South River, and Back Creek. It should be noted that crossing of other unnamed streams will likely occur. During any stream crossing, the risk of impact to surface water and potentially groundwater quality exists.

4.8 Dams

A review of dams proximal to the planned path of the pipeline was also conducted. Dams located within 1.25 mile of the proposed pipeline were identified to be consistent with requests previously made by the HSWCD (Appendix C). Four (4) dams (Inch Branch Dam, Robinson Hollow Dam, Happy Hollow Dam, and Waynesboro Nurseries Dam) were identified as being located within 1.25 mile of the proposed pipeline. With the exception of Inch Branch Dam, all of these dams are located within 0.75 mile of the planned pipeline. As previously discussed, concerns related to blasting vibrations and the potential effects of such vibrations on the integrity of the dams have been raised by the HSWCD. Their concerns were highlighted within correspondence to the Federal Energy Regulatory Commission, where a request was made to prohibit blasting within 0.75 mile of any dams. They also requested that a monitoring plan be prepared for any blasting occurring between 0.75–1.25 mile of any dams to monitor for potential damage.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The findings of this report demonstrate the value of Augusta County's groundwater and surface water resources, as demonstrated by the large annual volume of water outflow being contributed to adjoining counties (Table 1). A discussion of general risks posed by pipeline construction, along with the creation of Sensitive Area Maps (Figures 3a–3g) and analysis of these maps, has provided a screening-level assessment of risks specific to Augusta County that could be encountered during pipeline construction. Numerous sensitive areas lying within or near the path of the planned pipeline have been identified. Impacts to the county's water resources could potentially occur during any pipeline construction activities in these areas.

In an effort to protect the water resources of Augusta County, it will be imperative to have proper groundwater protection planning in place during any pipeline construction activities. This planning should include site-specific monitoring plans designed to identify impacts to groundwater and surface water resources resulting from pipeline construction activities. Adequate storm water management would also be necessary to avoid sinkhole development. In the event that impacts to water resources are identified, adequate mitigation planning should be available to clearly address and remedy any such impact conditions.

Sensitive area mapping provided within this report has utilized readily-available mapping resources to aid in identifying areas deemed to potentially be at risk from impacts resulting from pipeline construction. Analysis of mapping results was conducted on a countywide scale and was focused along the path of the proposed pipeline. Locations of mapped sensitive features should be considered approximate. This assessment is not intended to replace a site-specific inventory of sensitive conditions that may exist along the planned path of the pipeline. Site-specific sensitive area inventory and site specific monitoring and mitigation planning is recommended.

6.0 LIMITATIONS

The work performed in conjunction with this study, and the data developed, are intended as a description of available information. This report does not warrant against future operations or conditions, nor does it warrant against operations or conditions present of a type or at a specific location not investigated. Generally accepted industry standards were used in the preparation of this report. Stated opinions and conclusions are not intended as a guarantee.

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Figures

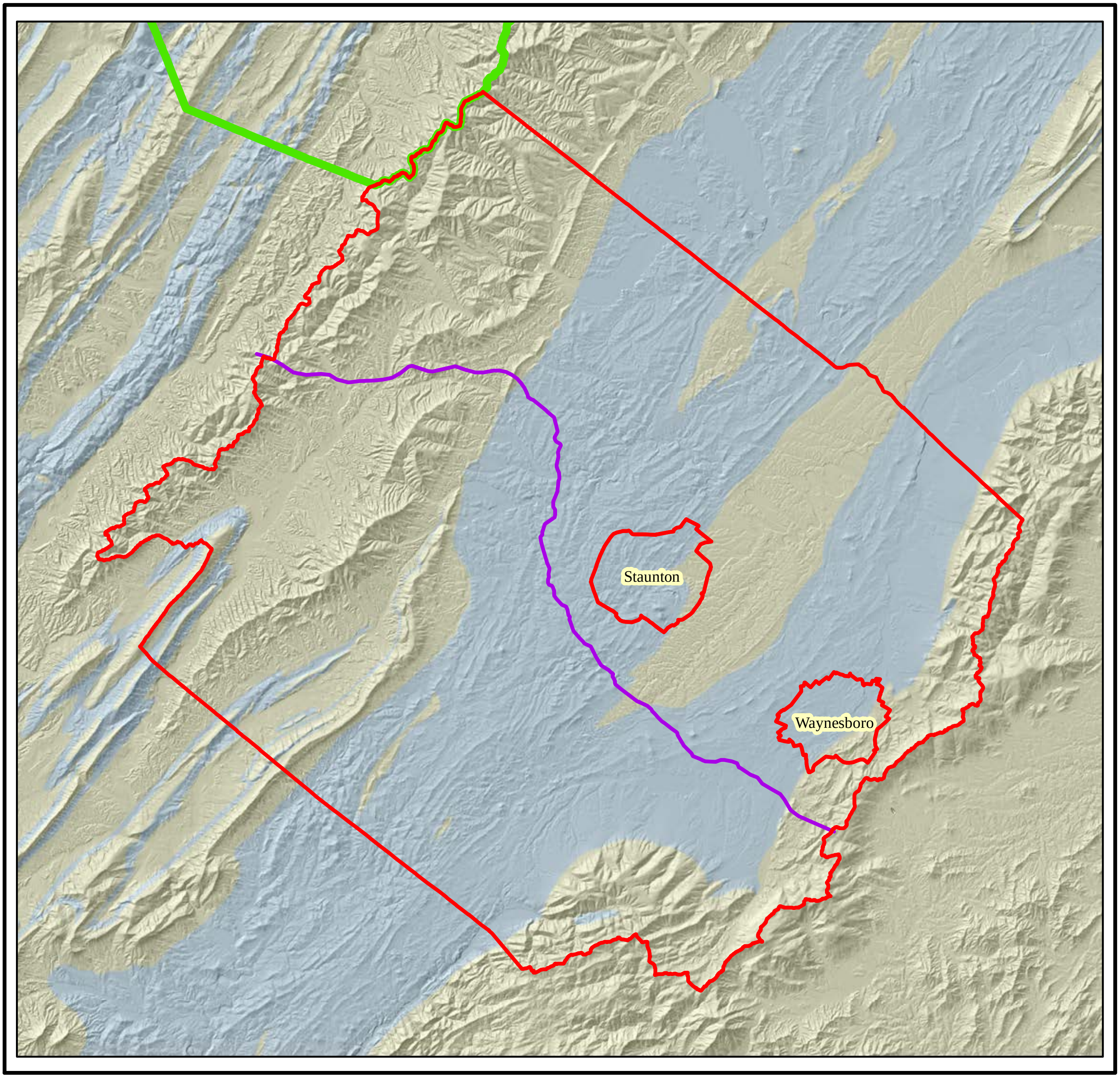

Figure 1: Proposed Pipeline Corridor

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Virginia-West Virginia Border
- Proposed Pipeline
- Carbonate Rock
- Non-Carbonate Rock

0 4 8 16 Miles

N

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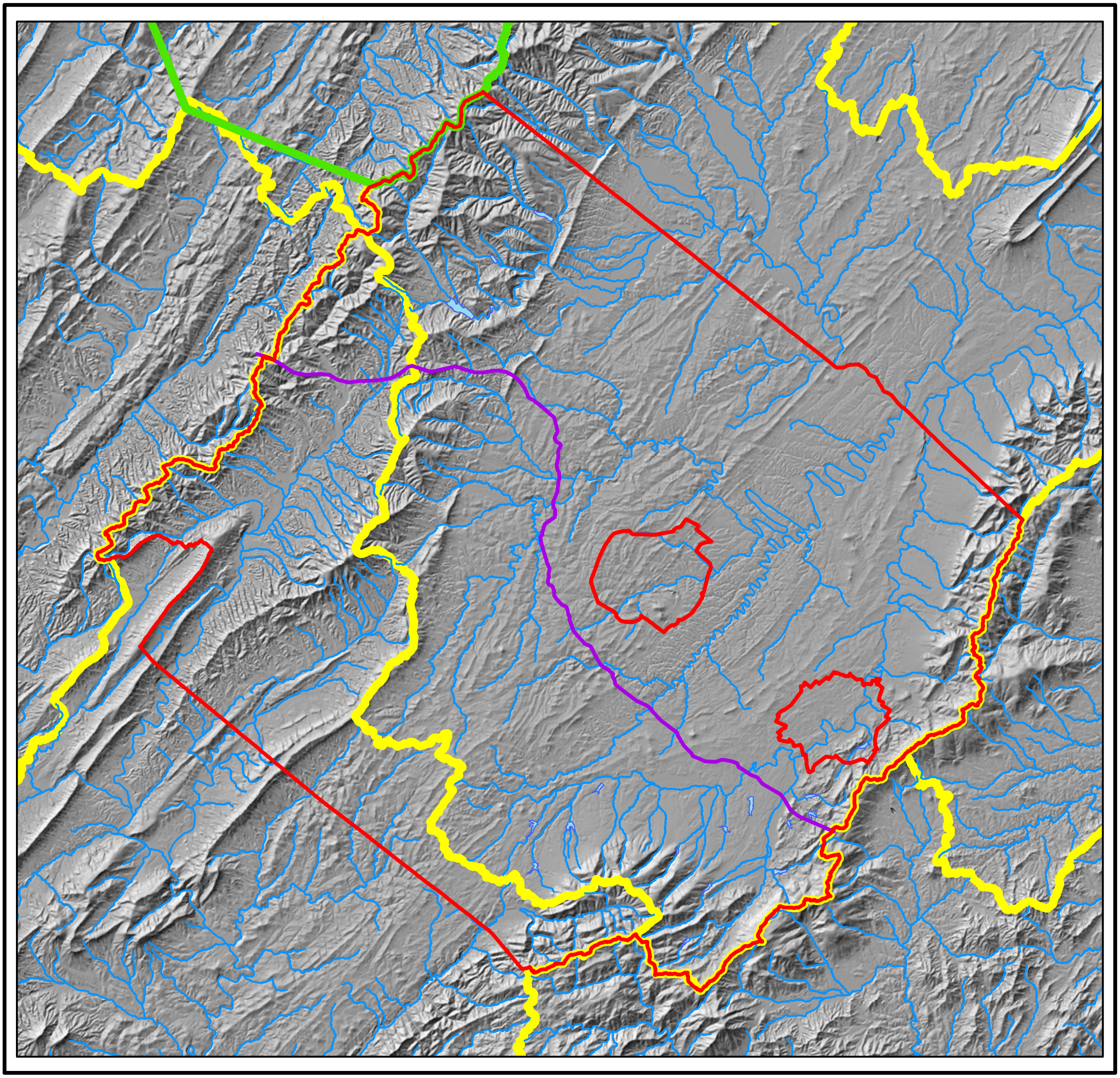

Figure 2: Regional Hydrography

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Virginia-West Virginia Border
- Proposed Pipeline
- Stream
- Reservoir
- Subbasin Boundary

0 4 8 16 Miles

N

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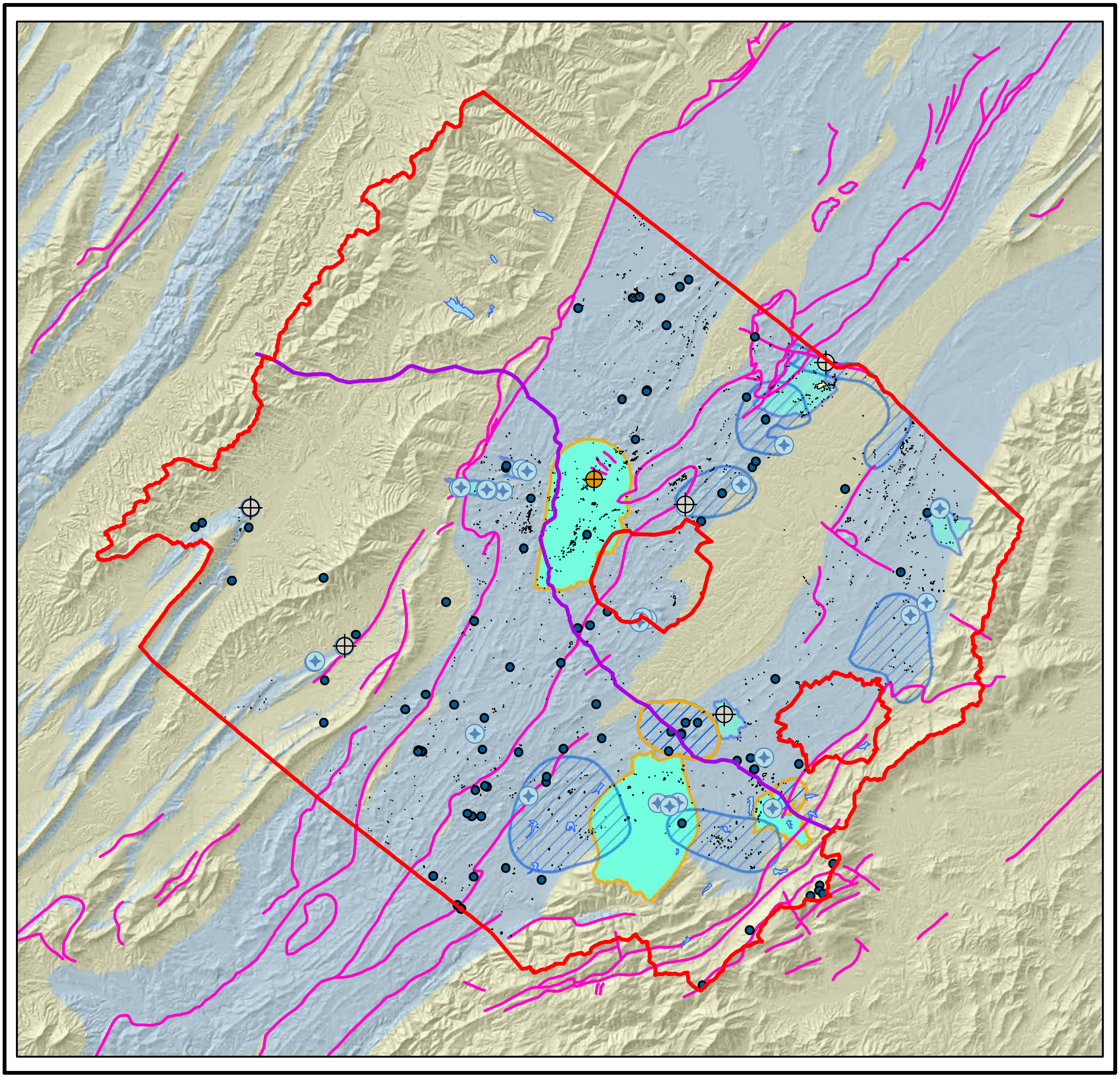

Figure 3a: Countywide Map of Sensitive Areas

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Proposed Pipeline
- ACSA Well
- ACSA Potable Spring
- City of Staunton Potable Spring
- Non-Municipal Spring
- Geologic Fault
- Carbonate Rock
- Non-Carbonate Rock
- Mapped Sinkhole
- Dammed Reservoir
- Wellhead Protection Area
- Potential Future Groundwater Development Area

Map Notes: (1) Sensitive areas located within assigned buffer distances of the proposed pipeline are outlined in orange. (2) Mapped sinkholes generally appear as small dots due to the map's countywide scale.

0 4 8 16 Miles

N

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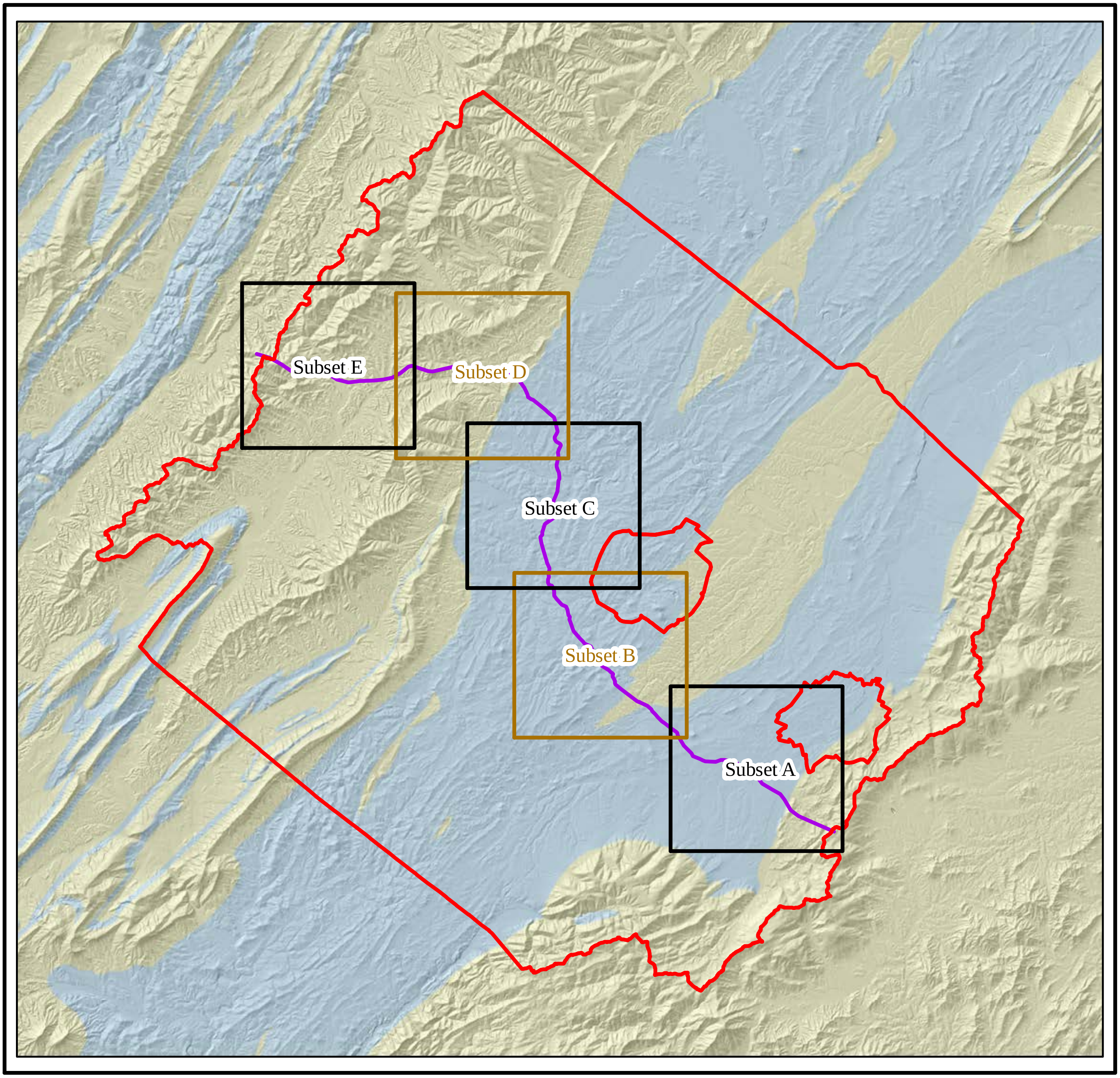

Figure 3b: Sensitive Area Map Subset Boundaries

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Proposed Pipeline
- Carbonate Rock
- Non-Carbonate Rock
- Subset Boundary

0 4 8 16 Miles

N

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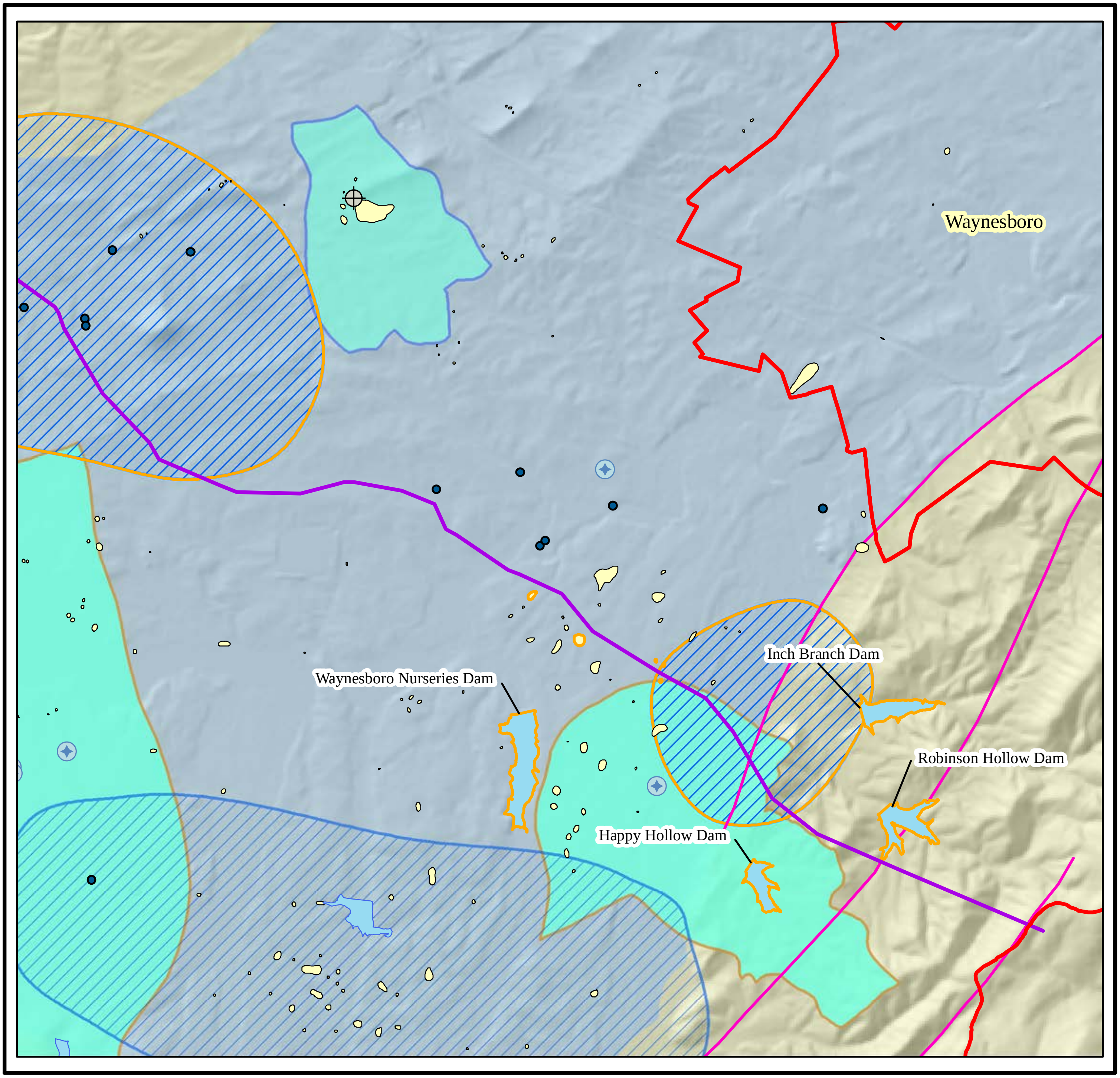

Figure 3c: Sensitive Area Map, Subset A

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Proposed Pipeline
- ACSA Well
- ACSA Potable Spring
- City of Staunton Potable Spring
- Non-Municipal Spring
- Geologic Fault
- Carbonate Rock
- Non-Carbonate Rock
- Mapped Sinkhole
- Dammed Reservoir
- Wellhead Protection Area
- Potential Future Groundwater Development Area

0 0.5 1 2 Miles

Map Note: Sensitive areas located within assigned buffer distances of the proposed pipeline are outlined in orange

N

Sullivan Project Number: 3386-002

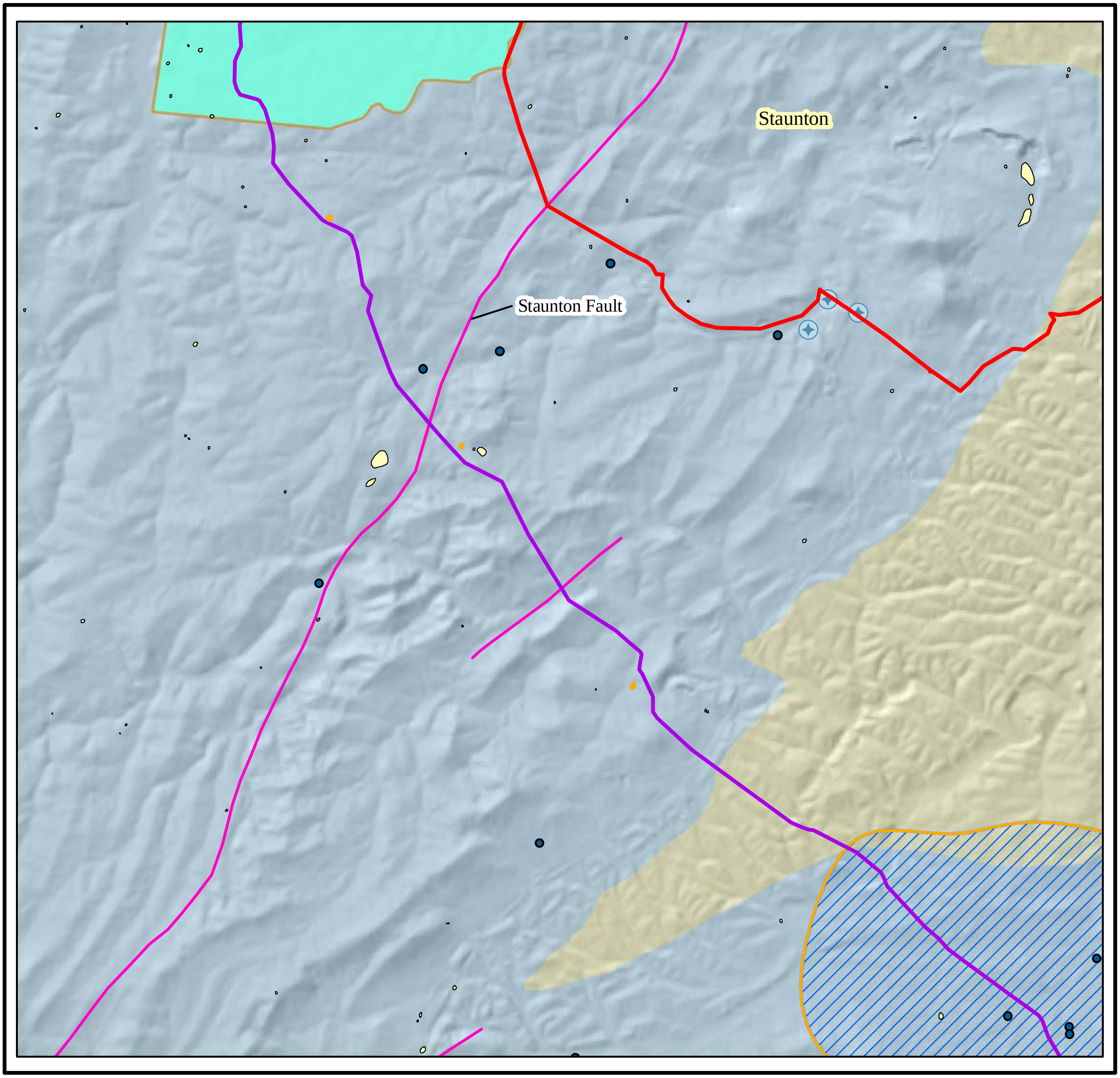

Figure 3d: Sensitive Area Map, Subset B

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Proposed Pipeline
- ACSA Well
- ACSA Potable Spring
- City of Staunton Potable Spring
- Non-Municipal Spring
- Geologic Fault
- Carbonate Rock
- Non-Carbonate Rock
- Mapped Sinkhole
- Dammed Reservoir
- Wellhead Protection Area
- Potential Future Groundwater Development Area

Map Note: Sensitive areas located within assigned buffer distances of the proposed pipeline are outlined in orange

0 0.5 1 2 Miles

N

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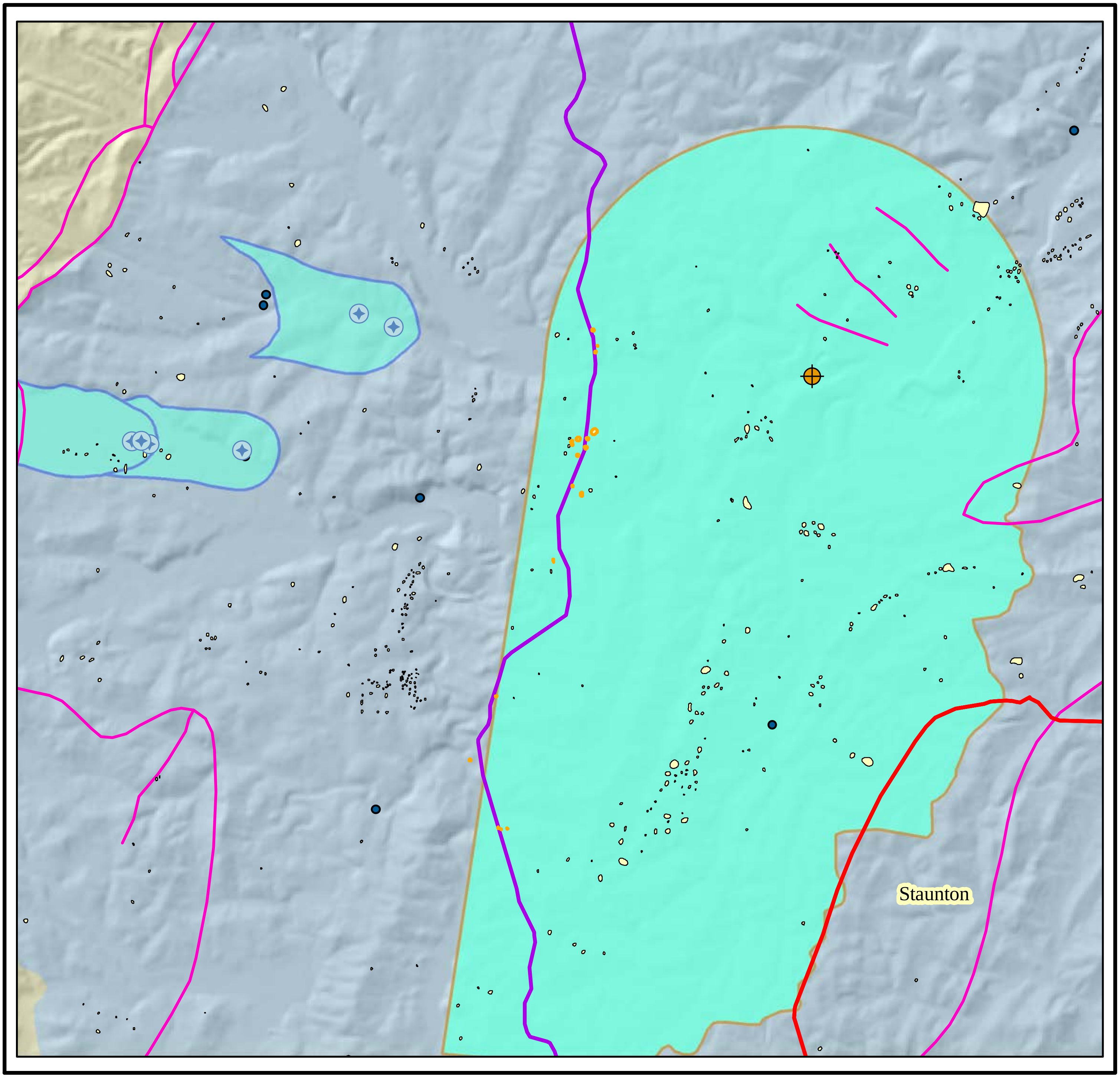


Figure 3e: Sensitive Area Map, Subset C

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Proposed Pipeline
- ACSA Well
- ACSA Potable Spring
- City of Staunton Potable Spring
- Non-Municipal Spring
- Geologic Fault
- Carbonate Rock
- Non-Carbonate Rock
- Mapped Sinkhole
- Dammed Reservoir
- Wellhead Protection Area
- Potential Future Groundwater Development Area

Map Note: Sensitive areas located within assigned buffer distances of the proposed pipeline are outlined in orange

0 0.5 1 2
Miles

N

SULLIVAN

Sullivan Project Number: 3386-002

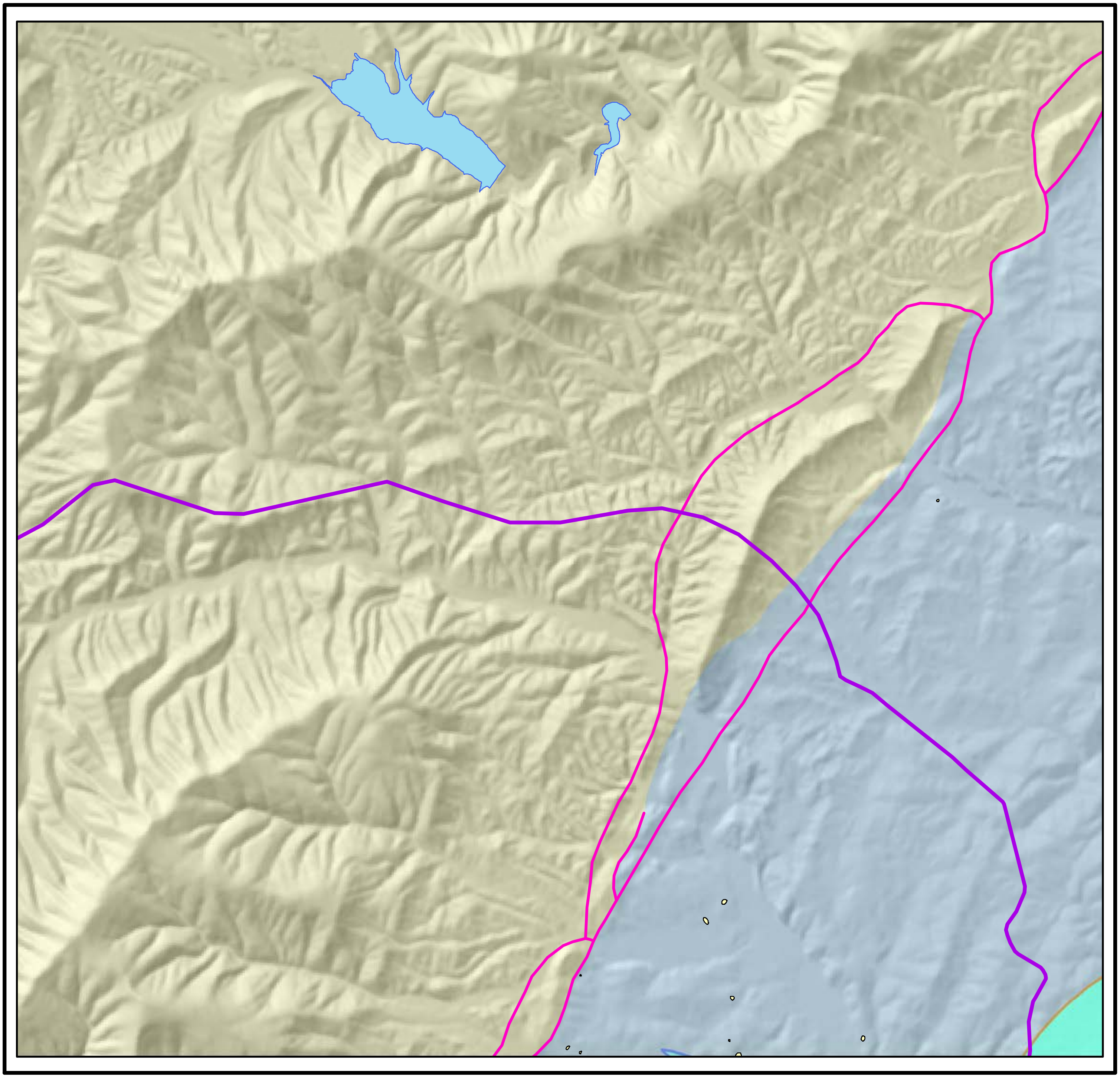


Figure 3f: Sensitive Area Map, Subset D

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Proposed Pipeline
- ACSA Well
- ACSA Potable Spring
- City of Staunton Potable Spring
- Non-Municipal Spring
- Geologic Fault
- Carbonate Rock
- Non-Carbonate Rock
- Mapped Sinkhole
- Dammed Reservoir
- Wellhead Protection Area
- Potential Future Groundwater Development Area

Map Note: Sensitive areas located within assigned buffer distances of the proposed pipeline are outlined in orange

0 0.5 1 2 Miles

N

SULLIVAN

Sullivan Project Number: 3386-002

Figure 3g: Sensitive Area Map, Subset E

Augusta County Service Authority
Augusta County, Virginia

Legend

- Augusta County
- Proposed Pipeline
- ACSA Well
- ACSA Potable Spring
- City of Staunton Potable Spring
- Non-Municipal Spring
- Geologic Fault
- Carbonate Rock
- Non-Carbonate Rock
- Mapped Sinkhole
- Dammed Reservoir
- Wellhead Protection Area
- Potential Future Groundwater Development Area

0 0.5 1 2 Miles

N

Map Note: Sensitive areas located within assigned buffer distances of the proposed pipeline are outlined in orange

SULLIVAN

Sullivan Project Number: 3386-002

Appendix A

Augusta County Hydrologic Budget Description and Calculations

Detailed Description of Hydrologic Budget Assessment

Hydrologic Budget Calculation Methodology

Sullivan utilized a mass-balance approach to calculate annual hydrologic inflows and outflows to/from Augusta County. The following equation was used to perform the calculations: Total Inflow = Total Outflow + Change in Storage. The annual change in water storage within the county, which is primarily a function of fluctuations in groundwater storage, was assumed to be negligible. As such, the aforementioned mass-balance equation was reduced to the following: Total Inflow = Total Outflow.

A U.S. Geological Survey (USGS) Scientific Investigations Report by Sanford et al. (2012), wherein components of the hydrologic cycle were quantified throughout Virginia, was an essential resource that was used as part of this study. Sullivan personnel spoke with David Nelms, a hydrologist with the USGS and second author of the Sanford et al. (2012) publication, to discuss the applicability of data within their publication to the Augusta County study. Mr. Nelms concurred that these data could appropriately be used for planning purposes to provide estimates of average annual groundwater and surface water outflows from Augusta County.

Sullivan performed two iterations of the mass-balance calculations, where average hydrologic conditions were used for the first iteration and drought conditions were used for the second iteration, to provide an estimated range of hydrologic inflows and outflows under variable climactic conditions. Sullivan utilized an annual direct precipitation value of 65 percent of normal precipitation conditions to represent drought conditions. A 35 percent reduction to normal precipitation conditions was utilized to assess drought conditions because the Virginia Drought Response Technical Advisory Committee states that an indicator of extreme drought is the occurrence of a 12-month period where normal precipitation is reduced by 35 percent or more (Virginia Technical Advisory Committee 2003).

All of the Hydrologic inflow to Augusta County is assumed to be from direct precipitation, as a result of it being a geographic headwaters zone. To conduct the first iteration of mass-balance calculations, Sullivan utilized the average annual direct precipitation value for Augusta County (43.2 inches/year), as presented in the Sanford et al. (2012) publication, to calculate the total annual volume of direct precipitation that falls within Augusta County under normal conditions. To conduct the second iteration of calculations that represent drought conditions, Sullivan utilized an annual direct precipitation value of 65 percent of normal precipitation conditions (28.08 inches/year). Calculations of total inflow volumes to Augusta County under normal and drought conditions are included in Appendix A.

Hydrologic outflow components from Augusta County include evapotranspiration, streamflow contributed from stormwater runoff, subsurface groundwater flow, streamflow contributed from baseflow, and groundwater and surface water withdrawn for consumptive use. Calculations of total outflow volumes from Augusta County under normal and drought conditions are included in Appendix A, and are discussed further below.

The average total evapotranspiration rate of Augusta County (26.6 inches/year), as provided in Sanford et al. (2012), was utilized to assess the total annual volume of evaporative outflow. Sanford et al. (2012) state that Augusta County's annual total evapotranspiration is approximately 61.5 percent of the total direct precipitation annual rate. As such, a value of 17.27 inches/year was used to simulate evapotranspiration outflow under drought conditions.

The Sanford et al. (2012) publication states that a total of 0.91 inch/year is withdrawn from groundwater and surface water in Augusta County annually. Although this value only comprises a very minor segment of Augusta County's annual hydrologic budget, Sullivan has estimated the portion of this water that would return to the hydrologic system via septic systems, direct discharges, injection, etc. Sullivan has assumed that a portion of this withdrawn water would leave the hydrologic system via evaporation and the remaining portion would be input back into the hydrologic system via groundwater recharge. To account for the portion of water removed from the hydrologic system via evaporation, Sullivan multiplied the 0.91 inch/year consumptive use rate by the ratio of total annual evapotranspiration to total annual direct precipitation (26.6 inches/year ÷ 43.2 inches/year), which yielded a consumptive use evaporative removal rate of 0.56 inch/year. The remaining 0.35 inch/year was assumed to recharge back into the groundwater system. These values were utilized to simulate outflow under both average and drought precipitation conditions. The aforementioned consumptive use groundwater recharge rate provides a conservative estimate of the volume of water returned to the groundwater system, since much of the consumptive use water would not be subjected to evaporative processes (i.e. water returned to the hydrogeologic system via septic systems or injection).

The average component of streamflow contributed from stormwater runoff in Augusta County (4.9 inches/year), as provided in Sanford et al. (2012), was utilized to assess the total annual outflow volume of this streamflow component. Sanford et al. (2012) state that Augusta County's annual runoff component of streamflow is approximately 11.3 percent of the total direct precipitation annual rate. As such, a value of 3.17 inches/year was used to simulate outflow from the stormwater runoff component of streamflow under drought conditions.

The average outflow of groundwater from Augusta County via subsurface flow and the baseflow component of streamflow (11.8 inches/year), as provided in Sanford et al. (2012), was modified to account for consumptive-use withdrawals to assess the total annual volume of groundwater outflow from the county. As previously discussed, Sullivan has estimated that 0.91 inch/year is removed from groundwater and surface water annually in Augusta County. Of this 0.91 inch/year, 0.56 inch/year was estimated to be lost from the system via evaporative processes and the remaining 0.35 inch/year was assumed to recharge back into the groundwater system. As such, the total annual groundwater outflow via subsurface flow and baseflow was assumed to be equal to the average groundwater outflow value (11.8 inches/year) less consumptive-use losses to evaporation (0.56 inch/year). This resulted in a total annual groundwater outflow via subsurface flow and baseflow of 11.24 inches/year under average precipitation conditions. To simulate groundwater outflow under drought conditions, the average groundwater outflow value (11.8 inches/year) was reduced by a factor of 35 percent, yielding a value of 7.67 inches/year. This value was then reduced by 0.56 inch/year to account for consumptive-use losses, since consumptive-use losses during drought conditions were assumed to be the same as losses under normal precipitation conditions, yielding a drought-conditions total annual groundwater outflow via subsurface flow and baseflow of 7.11 inches/year.

Results from Hydrologic Budget Calculations

The utilization of a mass-balance approach to estimate Augusta County's annual hydrologic inflows and outflows yielded the volumes included in Table 1, within the main body of this report. This table includes estimated volumes under both average and drought precipitation conditions. Under normal precipitation conditions, the calculated groundwater outflow volume via subsurface flow and baseflow was approximately 190,403 million gallons (Mgal) per year and the calculated storm water runoff component of streamflow was 82,848 Mgal/year, for a combined outflow volume totaling 273,251 Mgal/year. Under drought conditions, the calculated groundwater outflow component via subsurface flow and baseflow was 120,214 Mgal/year and the storm water runoff component of streamflow was 53,598 Mgal/year, for a combined outflow volume totaling 173,812 Mgal/year. Based on these results, Sullivan estimates that between 173,812 Mgal/year and 273,251 Mgal/year are contributed to adjoining counties on an annual basis via groundwater flow and streamflow.

Hydrologic Budget Calculations

Hydrologic Equation and Assumptions

- General Hydrologic Equation: Inflow = Outflow + Change in Storage
- It is assumed that change in storage is negligible; as such, the general equation can be reduced to the following, which was used to conduct the calculations: Inflow = Outflow
    - Inflow component: total precipitation (P)
    - Outflow components: total evapotranspiration (ET), runoff to streams (R), groundwater outflow from subsurface flow and stream baseflow (GW), and consumptive use (CU)
- Inflow and outflow component values were obtained or modified from Sanford et al. (2012). Augusta County's area (972.9 mi^2 or 2.52×10^9 m^2) was also obtained from Sanford et al. (2012).
- The hydrologic budget was calculated under average and drought precipitation conditions. Drought conditions are represented by a 35 percent reduction to all inflow and outflow components except consumptive use.
- Calculations of component volumes were generally conducted as follows:

- Volume (million gallons per year [Mgal/year]) = Component Value (in/yr) * Unit Conversion (in to m) * Augusta County's Area (2.52 x 10^9 m^2) * Unit Conversion (m^3 to Mgal)

Average Precipitation Conditions Calculations

(1) Hydrologic Inflow Calculations:
   a. P = 41.2 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 730,416 Mgal/yr

(2) Hydrologic Outflow Calculations:
   a. ET = 26.6 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 449,747 Mgal/yr
   b. R = 4.9 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 82,848 Mgal/yr
   c. CU = 0.56 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 9,468 Mgal/yr
   d. GW = 11.24 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 190,043 Mgal/yr

Drought Precipitation Conditions Calculations

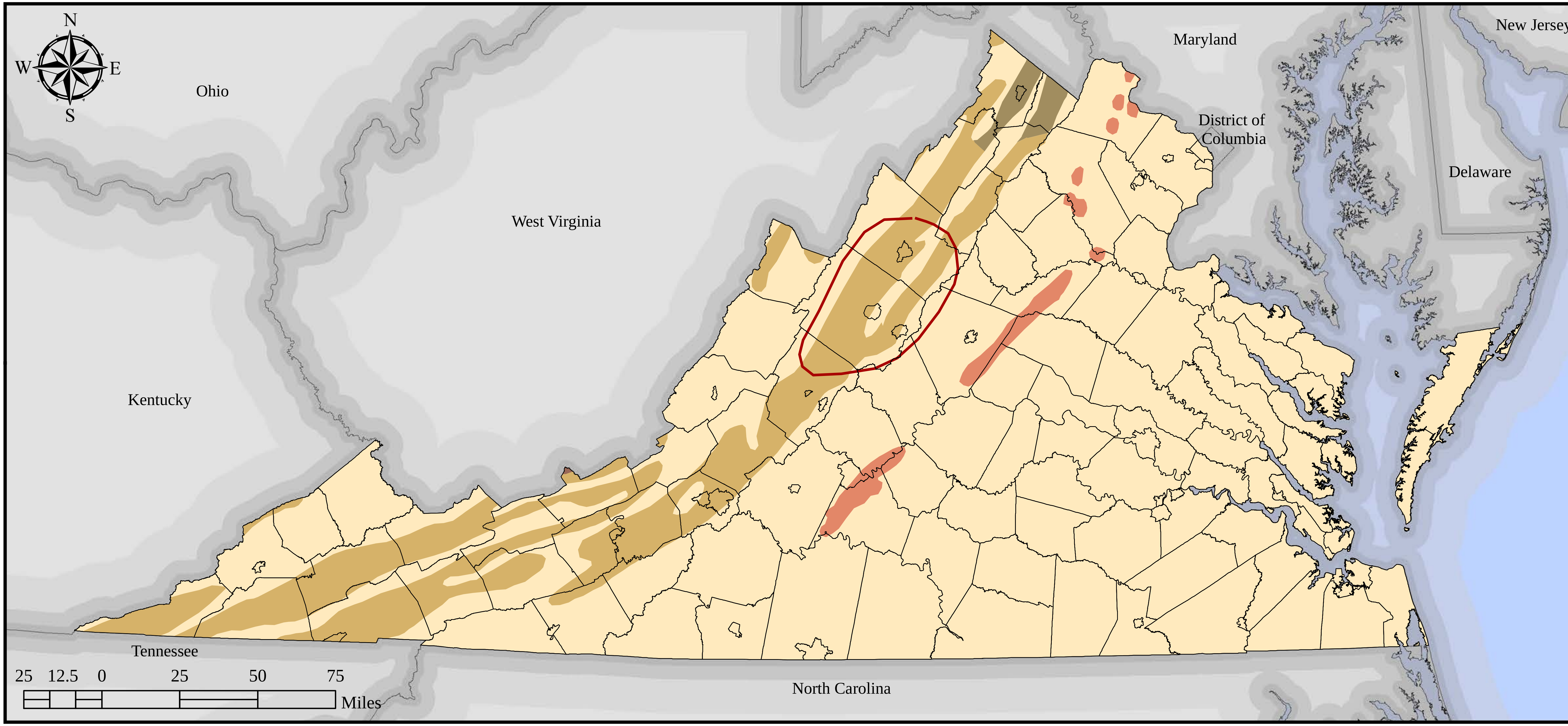
(1) Hydrologic Inflow Calculations:
   a. P = 28.08 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 474,770 Mgal/yr

(2) Hydrologic Outflow Calculations:
   a. ET = 17.27 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 291,997 Mgal/yr
   b. R = 3.17 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 53,598 Mgal/yr
   c. CU = 0.56 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 9,468 Mgal/yr
   d. GW = 7.11 in/yr * 0.0254 m/in * 2.52 x 10^9 m^2 * 2.64172 x 10-4 Mgal/m^3 = 120,214 Mgal/yr

Appendix B

Excerpted Figure from the Virginia Hazard Mitigation Plan (2013), Depicting Karst Regions and Historical Subsidence in Virginia

Figure 3.14-1: Karst Regions and Historical Subsidence



Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

DATA SOURCES:

USGS Engineering Aspects of Karst
VGIN Jurisdictional Boundaries
ESRI State Boundaries

PROJECTION: *VA Lambert Conformal Conic North American Datum 1983*

DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

LEGEND:

Historical Subsidence

Karst Type (Long)

- In moderately to steeply dipping beds of carbonate rock
- In gently dipping to flat- lying beds of carbonate rock

Karst Type (Short)

- In metamorphosed limestone, dolostone, and marble
- In moderately to steeply dipping beds of carbonate rock

HAZARD IDENTIFICATION:

Long Karst Type: Fissures, tubes, and caves over 1,000 ft long; 50 ft to over 250 ft vertical extent
Short Karst Type: Fissures, tubes and caves generally less than 1,000 ft long; 50 ft or less vertical extent

Historical subsidence represents areas of extensive sinkhole development.

Appendix C

Headwaters Soil and Water Conservation District's Letter Addressing Dam Safety in Regard to Pipeline Construction

Headwaters Soil and Water Conservation District
70 Dick Huff Lane
Verona, VA 24482
(540) 248-0148
www.headwatersswcd.org

We work with the people who work the land.

December 17, 2014

Federal Energy Regulatory Commission
888 First Street, NE
Washington, D.C. 20426

Docket#: PF15-6-000
RE: Protection of Flood Control Dams

Headwaters Soil and Water Conservation District (SWCD) received pre-filling notification as a landowner and owner of easements affected within the proposed Atlantic Coast Pipeline.

The Headwaters SWCD has the operation and maintenance responsibility for eleven (11) flood control dams in Augusta County, Virginia. The proposed pipeline will cross a section of the county that has the potential to impact a number of those dams depending on the final route. These dams protect as many as 800 properties and hundreds of lives downstream in Augusta County and the City of Waynesboro.

To protect those properties and lives we request the following protections be a mandatory part of any federal approvals:

- Any easements obtained by Atlantic Coast Pipeline, LLC or its subsidiaries with landowners must protect the rights the district has under the existing easements to construct, operate and maintain the dam.

- The pipeline cannot be installed through the embankment or the auxiliary (emergency) spillway.

- Atlantic Coast Pipeline, LLC or its subsidiaries must avoid impacts such as damage to roads to and from the dams.

- Atlantic Coast Pipeline, LLC or its subsidiaries must adhere to all federal, state and local erosion and sediment control regulations to avoid possible soil erosion that may find its way to the reservoirs and cause deposition issues in the pool.

- Blasting is prohibited within three quarters of a mile (3/4 mile) distance of the dam because of shaking of the embankment caused by the pipeline construction. All rock must be removed within this distance with rock breakers on an excavator in lieu of blasting. Shaking of the embankment may lead to dam failure upon the next storm fill.

- Blasting between three quarters of a mile and one and a quarter mile distance (3/4 – 11/4 mile) of a dam will require a monitoring plan to ensure that nothing happened to the dam's embankment.

Attached is a map with the location of dams within the county. The Headwaters SWCD asks that these safeguards for public safety be included as a part of any approvals.

Sincerely,

Richard Shiflet/cp

Richard Shiflet, Chairman

cc: Carole A. McCoy
Atlantic Coast Pipeline
701 E. Cary Street,
Richmond, VA 23219

Augusta County Board of Supervisors
City of Staunton – Council
City of Waynesboro - Council

Enclosure