# The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)

# EXHIBIT 21

**February 21, 2023**

FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, D.C. 20426
OFFICE OF ENERGY PROJECTS

In Reply Refer To:
OEP/DG2E/Gas 3
Mountain Valley Pipeline, LLC
Mountain Valley Pipeline Project
Docket No. CP16-10-000

October 19, 2022

VIA Electronic Mail

Matthew Eggerding, Counsel
Mountain Valley Pipeline LLC
meggerding@equitransmidstream.com

**Re: Comments on Updated Supplement to the Biological Assessment**

Dear Mr. Eggerding,

On July 29, 2022, Mountain Valley Pipeline, LLC (Mountain Valley) submitted an Updated Supplement to the Biological Assessment (Updated SBA) to the U.S. Fish and Wildlife Service (FWS or Service). The Updated SBA addresses the comments by the U.S. Court of Appeals for the Fourth Circuit in their decision of February 3, 2022, to vacate and remand the previously approved 2020 Biological Opinion as well issues raised by Project opponents. The Updated SBA was prepared by Mountain Valley to help aid the Federal Energy Regulatory Commission (FERC or Commission) and the Service in the reinitiated consultation under Section 7 of the Endangered Species Act. FERC staff and the Service have reviewed the Updated SBA. Enclosed are FERC staff and the Service's comments. **Please file responses as appropriate within 14 days of the date of this letter.** Note that the Service and FERC are continuing to review Appendix L, which was filed on October 13, 2022, and may provide additional comments at a later date. If you have any questions concerning this matter, please contact me at (202) 502-8045 or Amanda Mardiney, Project Biologist, at (202) 502-8081.

Sincerely,

James Martin, PhD
Chief, Gas Branch 3
Division of Gas –
Environment and Engineering

Enclosure

**Mountain Valley Pipeline Project (Project)**
**Updated Supplement to the Biological Assessment (Updated SBA)**
Docket No. CP16-10-000

FERC Comments

1. The tricolored bat (*Perimyotis subflavuswas*) was proposed for listing as endangered on September 14, 2022 (87 FR 56381). Provide an analysis of the Project's potential effects on the tricolored bat, including a description (and quantification as appropriate) of habitat present in the Project area and a summary of anticipated effects on habitat and individuals from activities necessary to complete the Project. Further, describe any mitigation measures that MVP would implement to minimize impacts on the tricolored bat.

2. Section 1.2.2.1 of updated (2022) Supplement to the Biological Assessment (Updated SBA) refers to a "revised Action Area" for aquatic species. Indicate any revisions subsequent to the 2020 Biological Opinion (BO), the dimensions and location of the revision, and indicate the reason(s) for the revision.

3. Section 1.3.3.1 of the Updated SBA states that "post-construction Roanoke logperch habitat monitoring October 16-19, 2020, at the Project's North Fork Roanoke River open-cut crossing location" and that "four suitable habitat patches were identified, and 18% of the habitat patches provided high-quality (i.e., Good to Excellent) habitat for Roanoke logperch". Is there pre-construction (prior to 2018) assessment of these four habitat patches and if so, what percentage of them provided high-quality habitat.

4. Section 4.1.7 addresses the effects of climate change on candy darter viability and focuses on stream temperature and flow. Indicate if erosion and sedimentation caused by future extreme weather events could also modify suitable habitat.

5. Using the data collected from the tributary monitoring stations, describe any relationships between precipitation event magnitude and flow response. Would the data suggest a precipitation event size that should be a trigger for monitoring or inspection of erosion control devices?

U.S. Fish and Wildlife Service October 4, 2022 Comments on the Updated Supplement to the Biological Assessment

# United States Department of the Interior

FISH AND WILDLIFE SERVICE

Virginia Field Office
6669 Short Lane
Gloucester, VA 23061

October 4, 2022

James Martin, PhD
Chief, Gas Branch 3
Division of Gas – Environment and Engineering
Office of Energy Projects
Federal Energy Regulatory Commission
Washington, D.C. 20426

Attn: Amanda Mardiney

Re: Mountain Valley Pipeline, LLC; Docket Number CP 16-10-000; Project #05E2VA00-2016-F-0880 and #05E2WV00-2015-F-0046

Dear Dr. Martin:

This responds to Mountain Valley Pipeline, LLC's (Mountain Valley) Updated Supplement to the Biological Assessment (SBA2) dated July 2022 prepared for the Mountain Valley Pipeline project (MVP or project) and provided to the U.S. Fish and Wildlife Service (FWS) on July 29, 2022. The SBA2 addresses updates to the project and new information regarding affected species since FWS issued the September 4, 2020, non-jeopardy biological and conference opinion.

The FWS has reviewed the SBA2 and requests clarification and/or additional information as described below. The FWS requests that responsive information be provided as soon as available. After all requested clarifications and additional information have been provided, provide an updated SBA2 that contains all revised information.

| Comment # | Page # | Section or Table # | Comment |
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| 1 | 123, 283 | Gray bat Updates to Habitat 5.3.2, Effects Determination 6.3.3.3 | FWS agrees with the gray bat NLAA determination (page 283) for VA and WV. Page 123 states "No known gray bat habitat occurs within the Action Area in West Virginia (A. Silvis, pers. comm. May 2022). Recent coordination with VDWR confirmed no new or currently known gray bat habitat occurs within the Action Area in Virginia (Rick Reynolds pers. comm. May 2022)." FWS agrees that the analysis in the July 2022 updated Supplement to the Biological Assessment (SBA2) reflects the best available data for gray bat for VA and WV. |
| 2 | 129-130, 283-284 | Virginia big-eared bat 5.4.2, Effects Determination 6.3.4.4 | FWS agrees with the Virginia big-eared bat NLAA determination (page 284) for VA, page 129 states "Likewise, VDWR confirmed that there are no new records of Virginia big-eared bat captures or habitat in the Action Area in Virginia (Rick Reynolds pers. comm. May 2022)." Page 130 states "The Project does not cross any counties in Virginia containing known occurrence records for Virginia big-eared bats. As described in the 2017 BA, no Virginia big-eared bats were captured during summer efforts in 2015 and 2016." FWS agrees with NLAA determination for WV. From SBA2, page 129, "As detailed in the 2017 BA, no known Virginia big-eared bat captures, summer roosts, or winter hibernacula are known in the Action Area (Craig |

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| | | | Stihler pers. comm. February 2017). WVDNR confirmed that there are no new captures and no known habitat for the Virginia big-eared bat within seven miles of the Project Area in West Virginia (A. Silvis, pers. comm. May 2022).” Additionally, page 283 states “The Project will not impact any caves occupied by Virginia big-eared bats within in Fayette, Monroe, Nicholas, and Summers counties, West Virginia; the only portion of the species’ range within the Action Area.” FWS agrees that the analysis in the SBA2 reflects the best available data for Virginia big-eared bat for VA and WV. |
| 3 | 191, 324 | RPBB Updates to Habitat 5.9.2, Effects Determination 6.3.10.3 | FWS agrees with the rusty patched bumble bee (RPBB) NE determination (page 324) for VA and WV. Page 191 states “Coordination with WVDNR confirmed there are no known occurrences of rusty patched bumble bee within the Project’s Action Area in West Virginia (A. Silvis, pers. comm. [May 13, 2022]). Likewise, coordination with VDCR (E. Orcutt, pers. comm. [May 3, 2022]) confirmed there are no known occurrences of rusty patched bumble bee occurrences within the Project’s Action Area in Virginia. As a result, and as confirmed by the best available information from USFWS (discussed below), no rusty-patched bumble bee HPZs overlap with the Project’s Action Area in West Virginia or Virginia.”<br><br>The action area goes through a RPBB Low Potential Zone in Monroe County, WV, according to 2022 RPBB zones (https://www.arcgis.com/home/webmap/viewer.html?webmap=2716d871f88042a2a56b8001a1f1acae&extent=-100.6667%2c29.7389%2c-48.8551%2c50.9676). However, FWS agrees with the analysis for RPBB in WV as no current HPZs are affected and the analysis follows Service Section 7 guidance related to RPBB (https://www.fws.gov/media/esa-section-7a2-voluntary-implementation-guidance-rusty-patched-bumble-bee). |
| 4 | 195, 324 | Northeastern Bulrush Updates to Occurrence 5.10.3 Effects Determination 6.3.11.3 | FWS agrees with the northeastern bulrush NE determination (page 324) for VA and WV. Page 195 states “No new populations of northeastern bulrush have been documented in the Project’s Action Area or in surrounding counties. (B. Streets (WVDNR) email to J. Spaeth [May 11, 2022]; Virginia Natural Heritage Program 2022). Northeastern bulrush remains absent from the Project’s Action Area, consistent with USFWS’s conclusions in the 2017 and 2020 BOs.” FWS agrees that the analysis in the SBA2 reflects the best available data for northeastern bulrush for VA and WV. |
| 5 | 200, 325 | Shale Barren Rock Cress Updates to Occurrence 5.11.3, Effects Determination 6.3.12.3 | FWS agrees with the shale barren rock cress NE determination (page 325) for VA and WV. Page 200 states “Shale barren rock cress remains absent from the Project Area, consistent with USFWS’s conclusions in the 2017 and 2020 BOs. This conclusion is further supported by the absence of any new species occurrence data for shale barren rock cress anywhere within or near the Project’s Action Area. (B. Streets (WVDNR) email to J. Spaeth [May 11, 2022]’ Virginia Natural Heritage Program 2022).” FWS agrees that the analysis in the SBA2 reflects the best available data for shale barren rock cress for VA and WV. |
| 6 | 210 | Smooth coneflower Updates to Habitat 5.13.3 | Provide FWS a copy of the habitat assessment from February 28, 2019, in Montgomery County, VA and a copy of the August 20, 2021, survey from within the 0.34-acre and 0.07-acre areas associated with the variance areas adjacent to Mt. Tabor Road that flank each side of the pipeline ROW near milepost 222.67. |
| 7 | 43-56 | Updates to the Action Area 3 | On page 56, Figure 3 is captioned “Overview of the Action Area as defined by updates to construction and operational impacts of the Mountain Valley Pipeline.” Provide GIS shapefile(s) of the terrestrial and aquatic action area to FWS to facilitate review of the SBA2. In addition, provide the aquatic impact area shapefiles (e.g., the suspended sediment impact areas and instream crossing impact areas) used in the maps in the SBA2, such as Figures 19, 20a and b, and 21 to FWS. |
| 8 | 5 | Yellow lance and Yellow critical habitat 1.1 | FWS agrees with not evaluating yellow lance and yellow lance critical habitat further in the SBA2. The best available information does not indicate that the yellow lance or its critical habitat occurs at or downstream of the pipeline crossing of Craig Creek or any other pipeline stream crossings, or in the action area (which includes upland sedimentation effects). FWS agrees that the proposed project will have no effect on the yellow lance and its critical habitat. |
| 9 | 5 | Atlantic pigtoe and Atlantic | FWS agrees with not evaluating Atlantic pigtoe and Atlantic pigtoe critical habitat further in the SBA2. The best available information does not indicate that the Atlantic |

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| | | pigtoe critical habitat 1.1 | pigtoe or its critical habitat occurs at or downstream of the pipeline crossing of Craig Creek or any other pipeline stream crossings, or in the action area (which includes upland sedimentation effects). FWS agrees that the proposed project will have no effect on the Atlantic pigtoe and its critical habitat. |
| 10 | 312-314 | James spinymussel Effects to Individuals 6.3.7.2, Effects Determination 6.3.7.3 | FWS agrees with the James spinymussel NLAA determination (page 313). Page 312 indicates that there will no instream work because "in February 2021, Mountain Valley changed the Craig Creek pipeline crossing method to a conventional bore, and the temporary access road crosses Craig Creek via a single-span bridge, which avoids disturbance of instream substrates." In addition, the SBA2 provided information (pages 313-314) to support that impacts due to sedimentation/turbidity from construction activities in the upland areas are not likely in areas of Craig Creek where James spinymussel is assumed to occur:<br>• "The Sediment Deposition Impact Area and LOD total 3.27 kilometers and occur near the headwaters of Craig Creek, all of which are areas James spinymussel is not expected to occupy.<br>• Project-specific mussel surveys completed in 2015, 2019, and 2021 covering 1.274 kilometers of Craig Creek were negative for any mussel species, including James spinymussel.<br>• The Project's mussel surveyors rated the mussel habitat throughout the survey area as marginal at best.<br>• The Project's mussel surveyors identified no natural or anthropogenic stream characteristics present in the unsurveyed portion of Impact Area that would suggest a positive change (i.e., improvement in mussel habitat quality) between the terminus of mussel survey area and the unsurveyed portion of Impact Area.<br>• The nearest known occurrence of James spinymussel in Craig Creek is approximately 25.4 stream kilometers downstream of the ROW crossing near the confluence of Trout Creek (i.e., tributary to Craig Creek) (https://dwr.virginia.gov/gis/werms/ Accessed June 9, 2022). That occurrence is based on identification of a single live James spinymussel individual in 1987. The nearest known occurrence in Craig Creek of live mussels of *any* species was approximately 20.3 stream kilometers downstream of the ROW crossing (https://dwr.virginia.gov/gis/werms/, Accessed June 9, 2022). That occurrence was recorded in 1991 in Craig County, and included only non-listed mussel species (e.g., *Villosa constricta*, *Strophitus undulatus*, *Elliptio complanata*). S. Watson (VDWR) email to J. Spaeth [May 19, 2022]).<br>• Nineteen mussel survey efforts, both those related and unrelated to the Project, have been completed between the headwaters of Craig Creek and the nearest downstream James spinymussel occurrence (i.e., inclusive of the Project crossings). Of these, 13 were completed between the headwaters of Craig Creek and nearest downstream non-listed mussel species occurrence. All were negative for James spinymussel (http://www.dgif.virginia.gov/gis/ werms.asp, Accessed June 9, 2022).<br>• The headwaters of Craig Creek, where the Impact Area occurs, experience natural flow regimes (i.e., prone to drought and flash flooding events). In contrast, James spinymussel populations have been reported from headwater streams such as Little Oregon and Johns Creeks where stream flow regimes are modulated due to small reservoirs located upstream of James spinymussel populations. Small, headwater reservoirs, such as those in Little Oregon and Johns Creeks, provide hydrologic retention and may reduce dramatic stream flow surges during storm events. Furthermore, sunlight exposed to impounded surface water in the system increases primary productivity and decreases nutrient loss through a slow, regulated water release; thereby increasing unionid food availability (Hoch 2012). Based on discussions with VDWR and USFWS, the headwater impoundments in Johns and Little Oregon Creeks are imperative to local James spinymussel populations by stabilizing the environment. Such stable regulated flows, water temperatures, and trophic productivity do not exist in the headwaters of Craig Creek. As a result, the Impact Area in Craig Creek is not expected to contain James spinymussel."<br>FWS agrees that the analysis in the SBA2 reflects the best available data for James spinymussel. However, FWS did not take into consideration the results of the eDNA |

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| | | | analysis for the mussels because the methodology was not tested on sites with known occurrences. |
| 11 | 222-223 | Suspended Sediment and Mussels 6.1.2.2, Suspended Sediment Modeling 6.1.2.3 | FWS did not state that (page 222) "adverse effects to mussels are likely to occur when mussels are exposed to increased concentrations of Project-related sediment >20 mg/L continuously for five days or more (J. Stanhope personal communication [Aug. 20, 2020])." In the August 20, 2020 email from J. Stanhope to P. Moore, FWS asked these follow-up questions: "<br>1) For the following blue stars, do you anticipate TSS concentrations to be greater than 20 mg/L in the tributaries above background:<br>a. Fishing Creek - FID 0 (the GIS shapefile identifier)<br>b. West Fork - FID 8, 10, 11, and 13<br>c. Little Kanawha River - FID 14 and 12<br>2) If yes to any of the above, do you anticipate that the tributary's TSS concentrations would exceed 20 mg/L above background for more than 5 days?"<br>Mountain Valley incorrectly inferred from the email that this is the FWS's impact threshold duration. Revise this sentence (and any other reference to this duration, for example see pages 238-242 related to round hickorynut) to indicate that Mountain Valley is basing their determination/assumption on the Gascho Landis and Stoeckel (2015) paper or remove the above referenced statement. |
| 12 | 355 | Literature Cited 8 | There are two references provided for the Virginia Spiraea (VASP) 5-Year Review:<br>• Virginia Spiraea (Spiraea virginiana Britton) 5-Year Review: Summary and Evaluation, at 26 (Oct. 2021).<br>• Virginia Spiraea (Spiraea Virginiana Britton) 5-Year Review: Summary and Review at 31 (Dec. 20, 2021).<br>Remove the 2nd reference. Add FWS 2021 as the author in the first reference.<br>Also, references do not appear to be in alphabetical order in different portions of the section and should be reorganized to be in alphabetical order. |
| 13 | 226-229 | Roanoke logperch (RLP) Monitoring Results and Candy Darter (CD) Monitoring Results 6.1.2.4.2, Appendix L | Appendix L is indicated as pending and not provided in the submission of the SBA2. (1) FWS needs to receive and review Appendix L to complete our review of the SBA2. (2) As the FWS does not have the technical expertise to fully review Appendix L, the FWS is relying on FERC to review this document for adequacy and accuracy and to verify the conclusions on pages 227-229. The FWS will not be relying on the analysis in Appendix L as used in the SBA2 until we receive the results of FERC's review, and we complete our internal review. |
| 14 | 132 | RLP Environmental Baseline and Stressors 5.5.1 | The statement (page 132) "Each of the known populations is protected from present and foreseeable threats that may interfere with the species' survival (USFWS 2007c)." is inaccurate. The RLP 2007 status review states... "Based on limited monitoring information, it is difficult to determine whether protection from threats for each population has improved since the species was listed (See section 2.3.2.1 for known and potential threats to Roanoke logperch)." This statement was written to address how each recovery criterion has or has not been met. The recovery criteria it was referencing is: "Each of the known population is protected from present and foreseeable threats that may interfere with the species' survival." This information is accurately reflected in the SBA2 on page 153. |
| 15 | 135 | RLP Environmental Baseline and Stressors, North Fork Roanoke River 5.5.1 | The last sentence of the second bullet references the wrong year for the RLP status review, "...or the 2009 5-Year Review (USFWS 2007c)." Replace with: "...or the 2007 5-Year Review (USFWS 2007c)." |
| 16 | 136 | RLP Environmental Baseline and Stressors, Pigg | The last sentence of the last bullet references the wrong year for the RLP status review, "...or the 2009 5-Year Review (USFWS 2007c)." Replace with: "...or the 2007 5-Year Review (USFWS 2007c)." |

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| | | River 5.5.1 | |
| 17 | 148 | RLP Updates to Occurrence 5.5.3 | This statement, “No other observations have been reported on the Roanoke River within the Project’s Action Area or at least 12 river kilometers upstream or downstream of that Project crossing. Likewise, no new observations have been reported in Bradshaw Creek, Pigg River, or any other portion of the Project’s Action Area since the USFWS issued the 2020 BO (VDWR WERMS Database https://dwr.virginia.gov/gis/werms/, Accessed June 9, 2022; P. Angermeier email to J. Spaeth [June 15, 2022]; S. Watson (VDWR) email to J. Spaeth [May 19, 2022]).” is contradicted by earlier statements on page 146, “Similarly, on October 20, 2021, at the Roanoke River Project ROW crossing, seven live Roanoke logperch (including six adults and one juvenile) individuals were documented (independent, non-duplicative observations) by Mountain Valley consultants snorkeling along a 100-meter stream reach. As discussed above, Mountain Valley consultants also observed two adult Roanoke logperch in 2020 at the North Fork Roanoke River crossing during post-construction habitat monitoring efforts.” Update the statements on page 148 to include the reported observations from October 20, 2021, and the observations from 2020. |
| 18 | 152 | RLP Five-Year Status Review 5.5.5.4 | Add the citation for “(USFWS 2018x)” to the literature cited. |
| 19 | 30 | Excavated Material Treatment 2.4.2 | “Any treatment water that is used will be collected in an isolated, “zero-discharge” collection pond within the existing LOD. Collected water either will be recirculated for additional soil treatment or removed from the site in a sealed water tank.” Will the collection pond be open, such that bats (and birds, etc.) in the area could drink from the water? If so, describe any potential contaminants that could be present in the treatment water and the potential to adversely affect bats should they consume the water. How long will this feature be present within the LOD? |
| 20 | 216 | VASP Updates to Occurrence 5.14.3 | Page 216 states that “Previous surveys of portions of the Gauley River crossing have expired (Table 15) but it was unnecessary to resurvey those areas in light of USFWS’s evaluation of the best available science, which indicates that the Virginia spiraea occurs along the Gauley River only in Fayette and Nicholas counties, and the occurrence in Nicholas County is limited to Summersville Dam to Swiss (USFWS 2018a). The Project’s Action Area on the Gauley River is upstream of Summersville Dam, outside the recognized range of the Virginia spiraea.” The FWS (2018a) citation is not the most up-to-date information on the range of VASP and should not be cited. The action area is within FWS’s current area of influence (IPaC layer) and range of VASP. Amend the SBA2 to reflect current information.<br><br>The work area was previously assessed as having potentially suitable habitat for VASP, and as noted in the SBA2, the 2017 survey results have expired. However, WVDNR does not have any known occurrences of the VASP upstream of the Gauley River crossing; therefore, it is unlikely that VASP has colonized this area since the last survey (J. Burkhardt, WVDNR pers. comm. to B. Smrekar, Service, 8/26/2022). FWS does not recommend that new surveys of the Gauley River work area be conducted for VASP. |
| 21 | 216, 328 | VASP 5.14.2 and 6.3.15.1 | Provide copies to FWS of all reports for habitat assessments, surveys, and supplemental reports for VASP that are referenced in the SBA2 from 2017, 2018, and 2022. |
| 22 | 216-217 | VASP 5.14.3 | The last paragraph on page 216 is not related to VASP, it references smooth coneflower. Remove this paragraph.<br><br>The first paragraph on page 217 states “no suitable habitat or occurrences of Virginia spiraea are found within the Project Action Area itself,” which is incorrect. The Gauley River crossing was assessed by Mountain Valley as having suitable habitat, although no individuals were found. Also, see comment #24 regarding the results of the July 2022 habitat assessment and survey for VASP at the Greenbrier River crossing and whether any project activities have begun/have occurred in this site that may affect the reliability of the negative survey results for that site. |
| 23 | 328 | VASP 6.3.15.1 | Page 328 states “Virginia spiraea surveys were completed on July 14, 2022 (i.e., during the approved survey season), and no suitable habitat or individuals were |

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| | | | located.” Provide FWS a survey report that includes who performed the survey, survey methods and extent of the survey, and results. Provide FWS site photos that are sufficient for FWS to review the results. |
| 24 | 328-329 | VASP 6.3.15.1 | There is a change in effects determination for VASP from LAA to NLAA. This is based on the negative surveys for the species that were completed in July 2022 at the Greenbrier River crossing and because in the 2020 BA and 2020 BO, “it was mistakenly claimed that construction (i.e., clearing, timber mat placement) had been completed throughout the majority of the parcel and, consequently, USFWS (and FERC) determined that the Project was likely to adversely affect the species. However, construction has not been completed on the referenced parcel, and surveys had not been updated on the parcel.”<br><br>Has any work activity been started or occurred at the project site WV-SU-046 (Greenbrier River crossing) prior to the July 2022 VASP habitat survey? Provide FWS a copy of the original mistaken documentation from Mountain Valley stating that tree clearing and timber mats had been placed in this site (from August 12, 2020), as well as new documentation (including site photos and a report or email where this mistake is corrected) showing that the site has not had any work of any kind started or performed prior to the July 2022 surveys.<br><br>If work has occurred, provide FWS a description of what type and where in the site it has been started or has occurred; include a map of disturbed areas within this work site. Include all activities associated with the project, including access roads.<br><br>VASP surveys that are performed after work has begun or has occurred on WV-SU-046 may not be used to reliably determine whether potentially suitable habitat for the species was present or if individuals were present prior to any work that has begun in this area, especially given this is a small area. |
| 25 | 227 | RLP monitoring results 6.1.2.4.2 | The first bullet states “The Project at most contributes trivial amounts of sediment to Roanoke logperch streams that are well below the concentrations at which USFWS concluded the Roanoke logperch would be impacted (>20 mg/L).” Replace “(>20 mg/L)” with “>20 mg/L above background levels.” Explain the above statement in relation to previous Virginia state water quality violations. In particular, explain the July 21, 2019 photograph of Bradshaw Creek showing the creek heavily impacted by sediment (the photograph was provided to FWS by Elly Benson, Sierra Club on August 13, 2022.).<br> |
| 26 | 49 | Delineation of aquatic action area 3.4.2 | There has been discussion of terminating the aquatic action area “at the downstream point at which the stream becomes impounded to an extent that water velocity slows and sediment settles out” particularly regarding very small features (e.g., individual logs, small low water bridges with culverts, etc.). The discussion on “impoundments” is unclear and unsupported. The term impoundment could be applied to a range of structures in the streams of interest. If using impoundments to determine that sediments will be trapped and not be transported further downstream, describe each |

| Comment # | Page # | Section or Table # | Comment |
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| | | | type of impoundment referenced for each location of interest (i.e., a dam, low river crossing with or without pipes, etc.), discuss the research and other justifications or methods used to determine that the particular type of impoundment will act as a sediment trap in the stream of interest, and for how long or under what flow conditions. Has this been demonstrated in the sediment models? It is not necessarily accurate to describe an impoundment as a sediment trap if it will temporarily trap sediments that will then be released during a typical high water or storm event. |
| 27 | 58-59 | CD Newly listed species and newly designated critical habitat 4.1.3 | The results from McBaine et al. (2022) provide a quantifiable estimate of the movement potential of CDs and demonstrate that it is much higher than previously suspected. McBaine et al. (2022) also demonstrate the importance of multiple habitat types used at various life stages. This new information needs to be considered and addressed in section 6.3.6.2 of the SBA2, where Mountain Valley relies heavily upon the assumption that CD do not use stream segments that occasionally go dry. Also, important to note that the study expects even higher movement rates in the WV portion of the species range. |
| 28 | 61 | CD Newly listed species and newly designated critical habitat 4.1.3 | "Dunn (2013) suggested that potential causes for the reduction of candy darter populations in Virginia are increased stream temperature and increased sedimentation in streams." This statement is provided on page 61 but is contradicted/ignored in subsequent sections (such as 4.1.6, 4.1.7, 4.1.9, etc.) where the document repeatedly emphasizes the role of hybridization and minimizes the importance of other stressors. Revise those sections to appropriately include the role of other stressors, besides hybridization, to the CD. |
| 29 | 63 | CD Climate Change 4.1.7 | "To date, the candy darter and its habitat are not known to have experienced effects attributable to climate change. (P. Angermeier email to J. Spaeth [June 15, 2022])." Context for this statement is important and the email itself should be provided as part of the SBA2. The SBA2 needs to be clear that while there is not empirical data examining and establishing impacts to CD from climate change, that does not warrant a conclusion that the impacts of climate change are irrelevant to the status of the species and its habitat. Similarly, the statement that follows, "climate-change-related stressors are not considered a primary risk to the candy darter's viability" is an example related to comment #28. This statement is somewhat misleading. While introgressive hybridization is identified by the CD Species Status Assessment (SSA) as the primary and most immediate threat to the species' survival, sedimentation and habitat degradation have played a major role, particularly in the VA populations. |
| 30 | 64 | CD Climate Change 4.1.7 | "However, USFWS has also continuously emphasized that hybridization, not climate change, has had and "will continue to have the greatest influence on candy darter populations and the candy darter's overall viability." This statement is minimizing the importance of sedimentation, temperature, and other habitat/water quality parameters to both the species' historic decline and its future probability of persistence. Between the New River, Greenbrier River, and Gauley River populations, the relevance of hybridization to CD populations is highest in the Greenbrier, where MVP is not impacting CD populations, and lowest in the New River (within VA), followed by the Gauley River. These populations are more largely protected from the spread of hybridization by physical barriers. The scenarios modeled in the SSA for multiple 25-year projections indicate that even under the worst scenarios for the spread of variegate darters, the difference between the Stony Creek population maintaining a population condition score of 1 versus a score of 33 (as compared to the current condition score of 49) is based entirely on the variables related to habitat conditions and water quality. Likewise, dismissing the importance of maintaining high habitat quality in the Upper Gauley because the spread of hybridization is a foregone conclusion is not an appropriate approach to an analysis of the effects of the project. Revise the SBA2 to correct the inaccuracies detailed above. |
| 31 | 64 | CD Climate Change 4.1.7 | "The best available science indicates that, although cool- or cold-water streams may be its preferred habitat, the species tolerates warm-water conditions and flow variability." This statement is taken from the CD SSA, which states "the species prefers cool or cold water temperatures, but that warm water conditions **may also be tolerated**." (emphasis added). The statement regarding tolerance of flow variability also comes from the CD SSA, which states "**Given other suitable habitat conditions** (e.g., water temperature, water chemistry, connectivity, and patch size), candy darter populations **tolerate natural stream flow variability**, including |

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| | | | lowflow conditions in the late summer and early fall.” (emphasis added). Citing the SSA as support that CD tolerate warm water conditions and the kinds of increased flow variability associated with climate change and anthropogenic change is, at best, misleading. Revise the SBA2 to accurately reflect information provided in the CD SSA. |
| 32 | 67 | CD Environmental baseline and stressors 4.1.9 | “Even so, other minor stressors such as sedimentation, water temperature and quality, water flow, water chemistry and stream acidification, spills or releases, habitat fragmentation, and nonnative competition and predation have previously and may continue to affect the species (USFWS 2018).” These items are not minor stressors. Further, the following sentence: “Although the best available science recognizes that habitat-related stressors did not lead to candy darter population declines, there is some evidence that variegate darter may better tolerate such, which could benefit the variegate darter to the detriment of the candy darter.” The first part of the first quoted statement is entirely false. Within the 7 historic CD metapopulations, extirpation of at least 9 of the 17 populations are attributed to water quality and habitat stressors alone, with no indication of any effect from variegate darter hybridization. The second quoted statement is relevant in that it emphasizes that habitat degradation and reductions in water quality are expected to exacerbate the impacts of variegate darter hybridization on CD populations.<br><br>Similarly, the statement under the “hybridization” bullet incorrectly states that “It is recognized as the lone population-level threat to the species that created the basis to list the species.” The **combined** and cumulative effects of habitat, water quality, and hybridization stressors are what created the need to list the species as endangered.<br><br>Revise the SBA2 to correct the inaccuracies detailed above. |
| 33 | 68 | CD Environmental baseline and stressors 4.1.9 | “Therefore, stream acidification does not pose a significant risk to the candy darter, although stream acidification may be a localized stressor. Id.at 41” This is a misinterpretation of the CD SSA, which states: “In streams maintaining favorable habitat conditions, through natural or managed condition, candy darters can be abundant throughout the stream continuum. Examples of managed stream conditions include the State of West Virginia’s “stream liming” projects that add calcium carbonate sand or gravel to streams to neutralize acidic water conditions in the Upper Gauley watershed (see Chapter 3—Water Chemistry), and the U.S. Forest Service’s implementation of a variety of stream restoration projects in the Monongahela National Forest specifically to reduce sedimentation in the Greenbrier watershed (see Chapter 3—Sedimentation).”<br><br>The active management of these systems to ameliorate the effects of acidification and sedimentation is the primary basis upon which the CD populations are expected to continue thriving. Revise the SBA2 to accurately reflect information provided in the CD SSA. |
| 34 | 228 | CD Suspended sediment monitoring results and conclusions 6.1.2.4.2 | The data generated and analyzed from the relevant CD watersheds need to be discussed alongside an explicit discussion of the exact condition of the watershed and the project at the time the data was collected. While construction was halted and the project site temporarily stabilized, it is critical to place it in proper context by discussing how much of the project (including site restoration) had been started/completed in the area when work was halted. For example, if no project work was completed, then the data collected do not represent potential effects to the watersheds from the project. |
| 35 | 296 | CD effects determination 6.3.6 | FWS cannot evaluate any of the statements in this or subsequent sections without reviewing the monitoring data and analysis which support the conclusions. See comment #13. |
| 36 | 298 | CD effects to individuals 6.3.6.2 | “In Stony Creek (VA), it is likely that there are no candy darters perennially occupying the dry stream reach near the confluence with the New River, which is consistent with a statement made by Mike Pinder (VDWR, personal communication April 8, 2015) that there are few candy darters occupying the lower portions of Stony Creek, downstream of Kimballton, Virginia.”<br><br>This statement is unsupported by any data, but also relies upon the word “perennially” which negates its usefulness. FWS understands that CD do not occupy |

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| | | | stream segments that are dried during low flow periods. In a similar sense, no sedimentation is ever mobilized during dry conditions with no precipitation. The relevant question is whether CD might occupy these stream areas when they are wetted, the same time as which sediment might be mobilized. Mountain Valley has relied on anecdotal accounts of limited portions of Stony Creek running dry during summer conditions. If this concept of dried stream reaches is integral to Mountain Valley's analyses of CD impacts and the associated effects determination, the extent and duration of stream lost to drying needs to be quantified or described with some level of evidence. |
| 37 | 299 | CD effects to individuals 6.3.6.2 | "None of those stations have measured any appreciable suspended sediment concentrations attributable to the Project (e.g., runoff from temporarily stabilized right of way), let alone any Project-related sediment concentrations in the tributary or mixing zone Impact Area approaching or exceeding the TRC." The accuracy and utility of this statement depends upon 1) the condition of the project ROW during the monitored time period and 2) the data underlying the conclusions attributed to Appendix L. See comment #13 and #35. |
| 38 | 236 | RLP Table 19 | Explain why rivers in the Blackwater drainage are included in this table, which is a summary of streams of interest. In Section 5.5.3 there is a summary regarding why the Blackwater is no longer considered likely to support RLP. |
| 39 | 286-287 | Figures 18 & 19 | The legends of both figures state "Detailed action area and depositional zone..." however the description in the figures themselves states "Detailed action area and mixing zones...." Explain the discrepancy. |
| 40 | 288 | RLP Effects to Habitat due to Incremental Increase in Sediment Deposition | The first sentence states "Potentially occupied habitats within the Roanoke and Blackwater River drainages may be temporarily impacted by incremental increase in sediment deposition." The Blackwater River drainage is not considered potentially occupied RLP habitat. Revise the SBA2 to correct the inaccuracy detailed above. |
| 41 | N/A | All species | Provide FWS a GIS layer showing where trees have been felled, where trees need to be felled, areas where the pipeline has been laid and restored, and areas where the ground will be disturbed (e.g., clearing herbaceous vegetation and ground cover, upgrading access roads, new temporary and permanent access roads trenching, grading) to lay the pipe. |
| 42 | N/A | Ibat | To assist FWS in analyzing the amount of acres cleared or to be cleared for each Ibat habitat category, update Tables 3-6 and 8-9 from the 2020 BO with the following information and then add the updated tables to the SBA2. Total acres<br>• cleared for the project to date;<br>• not yet cleared (but included in the previous SBA);<br>• cleared to date for variances;<br>• approved for variances, but not yet cleared;<br>• cleared to date for slips;<br>• approved for slips, but not yet cleared;<br>• downed due to slips; and<br>• future slip repair.<br><br>It appears that more acreage was added for future unknown slips (2020: 234.9 acres vs 2022: 247.25 acres. Confirm that this is accurate (and if so, update this in Table 5 from 2020 BO in the appropriate Ibat habitat category). |
| 43 | 246 | Ibat Table 21 | Table 21 has different values for acreages in each category of Ibat habitat impacted than those assessed in the 2020 BO. Were there more or less acres of habitat cleared in each category than was provided for in the incidental take statement of the 2020 BO? Revise the SBA2 to explain the discrepancies. |
| 44 | 292 | Effects to Individuals due to Increases in Sediment | "Stream segments where the incremental increase in delivered sediment load attributable to the Project exceeds 20 mg/L were identified as potential impact areas to threatened, endangered, and sensitive aquatic species.56" Replace "20 mg/L" with ">20 mg/L above background levels." |
| 45 | 204 | Small whorled pogonia (SWP) | SBA2 states that suitable habitat for SWP was found in the project area on 232.2 acres during surveys in 2018, but that "No further surveys have been warranted for the project." Provide support for this statement in the SBA2. Explain what activities |

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| | | Updates to Habitat 5.12.2 and Updates to Occurrence 5.12.3 | have occurred on the 232.2 acres of suitable SWP habitat to date. Plant surveys in WV are valid for 2 years unless there is evidence that the habitat is no longer suitable (i.e., all suitable habitat found in the 2018 surveys has been disturbed by project activities). Because SWP can go dormant underground for a long period of time and then appear again, FWS recommends an additional survey for this species in areas of suitable habitat identified previously. Surveys for the species can occur in WV until September 30. |
| 46 | 248 | Bats Summer Habitat, Total Tree-clearing Impacts 6.3.1.1.4 | The numbers in this section do not match the numbers in Table 21. Update the table and/or the paragraph with the correct acreage numbers. |
| 47 | 249 | Ibat Effect to Hibernating individuals 6.3.1.2.1 | The numbers referenced in these 2 sentences do not sum to the total. "...there are 64 potential winter hibernacula features within the Project Action Area. Of these, two are Priority 3/4 hibernacula (Greenville Saltpeter Cave and Tawney's Cave) known to support Indiana bats, and 63 features are presumed occupied by Indiana bats based on potential suitability but lack of occupancy data (Table 10)." Make the appropriate corrections. |
| 48 | 250 | Bats Effect to Hibernating individuals, Noise 6.3.1.2.1 | The numbers referenced in this section do not sum to the total. "The model determined noise levels at 51 feature openings will not rise above existing ambient conditions during construction activities, and thus disturbance to bats potentially using these features for hibernation will be avoided. The remaining 37 feature openings investigated have or will experience an increase above ambient noise levels at their entrances during construction activities (Table 22)." 51 + 37 = 88; however earlier in section 6.3.1.2.1 64 potential hibernacula are referenced. Make the appropriate corrections. |
| 49 | 251-252 | Bats Table 22 | Explain why Greenville Saltpeter Cave is not included in this table. Is this because an increase over ambient sound levels at this hibernaculum is not expected from the proposed project? |
| 50 | N/A | Round hickorynut, longsolid | Clarify in the SBA2 which of the WV streams with round hickorynut and longsolid have been included in the sediment modeling. |
| 51 | 78-96, 238-242 | Round hickorynut 4.2, Newly Proposed Species 6.2 | The SBA2 states that there are multiple streams occupied by round hickorynut within the action area. The SBA2 describes the closest known occurrence of the round hickorynut in each of the stream reaches (based on communications with the WVDNR) and states the distances downstream that sediment is expected to impact the streams from work areas, then makes a NLAA determination based on the sediment modeling (which I do not believe occurred in these streams) not reaching, or just reaching/slightly overlapping (in the case of Fink Creek and Kincheloe Creek) those known occurrences. Distance of mussels from work location alone is not sufficient to support a NLAA. The SBA2 needs to include a discussion as to whether there is the potential for suitable habitat for the species in stream reaches that are downstream of work areas and within the sediment impact areas. Confirm that there have not been any surveys or habitat assessments for round hickorynut in these areas or provide the survey/habitat assessment results. Specify what type of stream crossing method will be used in each instance and if the stream crossing has occurred or will occur in the future. Justification/rationale for NLAA determination should provide discussion on why sediment is not expected to affect mussels (e.g., number of tributaries that will not carry project-related sediment and that enter b/w the crossing and the known mussel locations, stream characteristics that would lead to sediment settling out or continuing downstream, type of stream crossing method, etc.). Also see comment #26 if using impoundments as part of the rationale. Be sure to include any water withdrawals and discuss the potential for that activity to have an effect (or explain why not). Provide the email communications from the WVDNR that are referenced in the SBA2. See also comment #50.<br>After the above items have been addressed, FWS will evaluate the NLAA determination. |
| 52 | 80, 241 | Round hickorynut Site-Specific | Provide further citation/documentation for assuming extirpation of round hickorynut from Sand Fork in the SBA. Currently, justification/rationale for assuming extirpation is insufficient in the SBA. |

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| | | Data 4.2.3, 6.2.1 | There have only been a handful of surveys for mussels in the aquatic action area in Sand Fork. While salvage efforts have been conducted and none have been found at the locations of the stream crossing, there is currently not enough information provided to support a determination that the effects of sedimentation are not likely to affect the species downstream. Likewise, there is not enough information provided to support an assumption that the species is not present elsewhere in the Sand Fork aquatic action area, where surveys have not been conducted to determine if the species may be present or if suitable habitat is present. |
| 53 | 238-242 | Round Hickorynut 6.2.1 | See comment #26. |
| 54 | N/A | Round hickorynut Appendix D, Appendix J | The maps provided in Appendix D are not detailed enough and the maps in Appendix J (which are more zoomed in/detailed) do not include all relevant information. Provide FWS a map (and shapefiles) for each location where the aquatic action area includes streams with round hickorynut occurrences or where round hickorynut proposed critical habitat could be affected (i.e., Buckeye Creek, Meathouse Fork, Middle Island, Leading Creek, Fink Creek, Sand Fork, Kincheloe Creek, and other potential streams in the aquatic action area). These maps should be zoomed in (like the maps in Appendix J) to see details on the following items/areas:<br>• locations of known occurrences of the species or occupied areas noted in the SSA (as referenced in this section),<br>• locations of other surveys with non-detections of the species,<br>• locations of any water withdrawals for the project,<br>• proposed critical habtiat,<br>• locations of the pipeline crossing/type of crossing,<br>• impact areas for the crossing,<br>• mixing zones (i.e., blue stars), and<br>• location of any impoundment and type that may be being used to describe curtailment of sediment.<br>Also provide a shapefile for blue mixing zones for areas with round hickorynut. |
| 55 | N/A | Bats Appendix I, Variances | Include additional columns showing:<br>• the acreage of tree clearing associated with each variance,<br>• if TOYR for tree clearing was implemented,<br>• which bat habitat category each variance is affecting,<br>• when each tree clearing occurred or that it has not happened yet, and<br>• if there were positive detections of any of the species surveyed for in each variance.<br>For variances other than slip repairs (which are included in the 2020 BO), is there tree clearing associated with these actions? If yes, include acreage that is being affected in the SBA2. |
| 56 | 22 | Bats Updates to the Project Route 2.1 | An additional 234.9 acres of tree clearing is included in the project, which includes the same acreage as 2020 BO, plus:<br>• additional clearing that has occurred since 2020 BO,<br>• future tree clearing associated with known variances and slips, and<br>• future tree clearing to repair unknown slips.<br>In the SBA2 clarify how much of the additional 234.9 acres is included in the categories above and which bat habitat category is affected. |
| 57 | 29 | Bats Blasting 2.3 | Confirm in the SBA2 that the following measures will be incorporated for any future blasting (2020 BO, page 76):<br>• All blasting activities within close proximity to known and assumed occupied hibernacula will occur outside of the bat hibernating season.<br>• Site-specific blasting plans will be developed for all blasting activities proposed within 0.5 mile of any known or assumed occupied hibernacula to avoid adverse overpressure or vibration impacts to any bats occupying the features and to ensure the structural integrity of both the aboveground and subsurface features of a cave or portal during blasting events. |
| 58 | 40-42 | Updates to Voluntary Conservation | Proposal to update the use of pesticides in the ROW, such that pesticides could be used almost anywhere (some buffers described) and anytime (except within 12 hours of rainfall) in the ROW when Mountain Valley determines there is a pest threatening |

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| | | Measures 2.7 | revegetation efforts. In the SBA2 provide support/research discussing why a 150 ft. buffer is considered sufficient for pesticide applications near streams, wetlands, and ponds, as well as drains, culverts (i.e., pesticide not expected to enter the water through runoff, traveling through soil, or otherwise) and a discussion of how long the proposed pesticides are expected to persist in the environment. FWS recommends fall mowing as a treatment be the first option. Alternatively, FWS recommends Mountain Valley commit to treating just army cutworm in the known area of concern as opposed to the broad change of pesticide use described in the SBA2. Clarify if either of these options will be utilized and if not, provide an explanation as to why not. |
| 59 | 243-244 | Ibat 6.3.1 | Page 11 of the 2020 BO included an area 0.24 acres in size in unknown use spring staging/fall swarming habitat near MP 119.7 as not yet cleared. Clarify in the SBA2 if this area has been cleared or should be included in the section Future Clearing for Known Project Components.<br><br>The SBA2 includes ATWS-1304 (0.33 acres in size) as yet to be cleared. On page 244, Mountain Valley states that it will adhere to the remediation for future slips guidance for tree removal in this area, with citations from 2019 documents. The process outlined on page 244 appears to be outdated as compared to the 2020 BO. Clarify in the SBA2 if Mountain Valley commits to following the process for tree clearing as discussed on pages 13-14 of the 2020 BO for the area ATWS-1304 and for all future slips: "When responding to future slips in known Ibat buffers, Mountain Valley will complete all tree clearing between November 15 and March 31 of any given year whenever possible (M. Hoover, Mountain Valley, email to T. Lennon, Service, June 30, 2020). In addition, in all areas of the MVP, Mountain Valley commits that it will not cut trees May 1 – July 31 to address future slips barring an unforeseen emergency arising (M. Hoover, Mountain Valley, email to T. Lennon, Service, June 30, 2020). Should an emergency arise that would require tree clearing during that period, Mountain Valley will coordinate with the Service and FERC on potential emergency consultation (M. Hoover, Mountain Valley, email to T. Lennon, Service, June 30, 2020)." |
| 60 | 37 | Federally Listed Aquatic Species 2.6.3 | Provide an update to any known failures of E&S controls by updating Table 7 of the 2020 BO and adding it to the SBA2. |
| 61 | 38-39 | Federally Listed Aquatic Species 2.6.3 | From the 2020 BO: "To reduce the potential impacts of withdrawing water from these streams, Mountain Valley anticipates installing holding tanks near the withdrawal points to pull water over a longer period, instead of a more acute withdrawal (M. Eggerding, Mountain Valley, letter to J. Martin, FERC, May 13, 2020)." This statement is not included in the SBA2. Confirm that this measure will be incorporated to reduce stream impacts and add it to the SBA2. |
| 62 | 103 | Ibat Updates to Habitat 5.1.2 | Incorrect math in the first paragraph. Make the appropriate corrections. |
| 63 | 104 | Bats Winter Hibernation, Autumn Swarming, and Spring Staging Habitat 5.1.2.2 | 125 features were excluded as described in the 2020 BO. 124 features are excluded in the SBA2. Make the appropriate corrections or explain the discrepancy in the SBA2. |
| 64 | 104, 106 | Bats Winter Hibernation, Autumn Swarming, and Spring Staging Habitat 5.1.2.2 and Winter, Autumn Swarming, and Spring Staging Occurrence 5.1.3 | Page 104 states "62 features (81 openings) are presumed occupied…." Page 106 states "63 suitable, unsurveyed portal and cave features within the Action Area...." Make the appropriate corrections or explain the discrepancy in the SBA2. |
| 65 | 249 | Bats Effects to | The numbers in this section do not add up. Make the appropriate corrections in the |

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| | | Hibernating Individuals 6.3.1.2.1 | SBA2. |
| 66 | 117 | NLEB Updates to Habitat 5.2.2 | The number of unsurveyed portals is not consistent with number of Ibat portals, as indicated here. Make the appropriate corrections. |
| 67 | 271, 273 | NLEB Fall Swarming and Spring Staging Habitat 6.3.2.1.2 and Summer Habitat 6.3.2.1.3 | To assist FWS in understanding the location and status of the tree clearing in this statement "...the overwhelming majority of this tree removal for the Project already has been completed." provide a table in the SBA2 with the following:<br>• acreage of tree clearing completed where incidental take was exempted under the NLEB 4d rule,<br>• acreage of tree clearing not completed where incidental take was exempted under the NLEB 4d rule,<br>• acreage of tree clearing completed where incidental take was provided in the 2020 BO ITS (i.e., not exempted under the 4d rule),<br>• acreage of tree clearing not completed where incidental take was provided in the 2020 BO ITS (i.e., not exempted under the 4d rule),<br>• total acreage of tree clearing not completed, and<br>• the acreage, location, and habitat category of each area where tree clearing will occur in the future, including planned project activities and anticipated slips.<br>Provide FWS maps showing areas that remain to be cleared and a shapefile of these areas. |
| 68 | 267 | NLEB Effects to Habitat 6.3.2.1 | Add a table to the SBA2 (format similar to Ibat Table 5 on page 15 of the 2020 BO or Table 21 of the SBA2) with acreages of trees cleared associated with:<br>• NLEB hibernacula that are within 5 miles of the action area (known use winter),<br>• any NLEB roosts within the action area or within 1.5 miles of the action area,<br>• any NLEB captures within 3 miles of the action area (known use summer), and<br>• the amount of acreage that remains to be cleared within these buffers.<br>We recommend Mountain Valley coordinate with VDWR and WVDNR to determine what buffers the pipeline intersects. |
| 69 | 116, 267-271, 275 | NLEB Updates to Habitat 5.2.2, Hibernacula 6.3.2.1.1, Effects to Individuals During Spring Staging and Fall Swarming 6.3.2.2.2 | Provide information on the number of hibernacula in the action area and the number within 5 miles of the action area. We recommend Mountain Valley coordinate with VDWR and WVDNR to determine what buffers the pipeline intersects. Include this information in the SBA2, then update the numbers, tables, and analysis as appropriate. For example, for Kelly Tank in Mercer County, WV; Laurel Creek in Monroe County, WV; and Honacker Cave in Mercer County, WV:<br>• clarify the number of suitable hibernacula that are within the project action area, and<br>• the number that are within 5 miles of the action area for NLEBs<br>Provide information on the acreages of tree clearing in each habitat category and specify how much of this acreage has not yet been cleared of trees. |
| 70 | 269-270 | NLEB Table 24 | Clarify in the SBA2 if hibernacula assessments or bat surveys on these potentially suitable NLEB hibernacula (66) within the action area are planned or if presence of hibernating NLEBs is assumed. |
| 71 | 275-276 | NLEB Hibernacula 6.3.2.2.1 | "...the best available information indicates that the four known, occupied hibernacula in the Project's Action Area are each currently occupied by no more than one northern long-eared bat in the winter, it is highly likely that the potentially suitable hibernacula (Table 24) contain, at most, a few individuals each." This is inconsistent with the best available information (see the 2020 BO pages 88 and 134). FWS assumes up to 17 NLEBs may be overwintering in each hibernaculum in the 2020 BO. Make the appropriate corrections in the SBA2. |
| 72 | 277 | NLEB Effects to Individuals During Summer Season of | Only one known maternity roost for NLEB is mentioned here; however, a juvenile was also captured and tracked to roost 791-1. Although this maternity colony was not located, we know that there is likely to be one nearby (see 2020 BO, page 88). Include this information in this section of the SBA2. |

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| | | Reproduction 6.2.2.2.3 | |
| 73 | 6 | Longsolid 1.1 | On page 6, it states "Likewise, no portion of the proposed critical habitat for the longsolid occurs within the Project's Action Area (J. Stanhope email to J. Spaeth [May 13, 2022])." This email only addresses species in Virginia. Add "in Virginia" to the end of the sentence and delete "Likewise." There is proposed critical habitat for longsolid in the aquatic action area in Middle Island Creek in Doddridge County, WV. Review known locations of longsolid in WV, locations of mussel surveys with non-detections for longsolid in WV, and location of longsolid proposed critical habitat in WV and provide an analysis of the potential for project-related effects on the species and its habitat and its proposed critical habitat in the SBA2. |
| 74 | 6 | Running Buffalo Clover 1.1 | FWS agrees that running buffalo clover does not need to be assessed due to delisting of the species in 2021. |
| 75 | 39 | Water Withdrawals 2.6.3 | Provide a shapefile to FWS showing streams that will be affected by water withdrawals and the anticipated locations of the withdrawals. |
| 76 | N/A | Tricolored bat | On September 14, 2022, FWS published a proposal in the Federal Register to list the tricolored bat (*Perimyotis subflavus*) as endangered under the ESA. A conference with the Service on proposed species or proposed critical habitat is required where an action is likely to jeopardize the continued existence of a proposed species or result in the destruction or adverse modification of proposed critical habitat (50 C.F.R. 402.10).<br><br>The FWS has up to 12-months from the date the proposal published to make a final determination, either to list the tricolored bat under the ESA or to withdraw the proposal. The FWS determined the bat faces extinction primarily due to the rangewide impacts of white-nose syndrome (WNS), a deadly fungal disease affecting cave-dwelling bats across North America. Because tricolored bat populations have been greatly reduced due to WNS, surviving bat populations are now more vulnerable to other stressors such as human disturbance and habitat loss. Species proposed for listing are not afforded protection under the ESA; however, as soon as a listing becomes effective (typically 30 days after publication of the final rule in the Federal Register), the prohibitions against jeopardizing its continued existence and "take" will apply. Therefore, if your future or existing project has the potential to adversely affect tricolored bats after a potential final listing goes into effect, the FWS recommends that the effects of the project on tricolored bat and their habitat be analyzed to determine whether authorization under ESA Section 7 or 10 may be necessary. Projects with an existing Section 7 biological opinion may require reinitiation of consultation, and projects with an existing Section 10 incidental take permit may require an amendment to provide uninterrupted authorization for covered activities.<br><br>The tricolored bat is a small insectivorous bat that typically overwinters in caves, abandoned mines and tunnels, and road-associated culverts (southern portion of the range) and spends the rest of the year in forested habitats, typically roosting among live and dead leaf clusters. For more information on tricolored bats and the proposed rule, see: https://www.fws.gov/species/tricolored-bat-perimyotis-subflavus and for more information on WNS, see: https://www.whitenosesyndrome.org/ |
| 77 | N/A | NLEB | The 2020 BO stated all tree removal within 0.25 mile (of Tawney's Cave, Canoe Cave, and PS-WV3_y-P1) occurred in 2018. In the SBA2, clarify what activities (tree clearing, pipe installation, restoration, etc.), if any, are proposed within 5 miles of any of these areas. |
| 78 | 24-28 | Table 2 Updated Stream crossing methods | Update Table 2 to provide information for the following stream crossings and the associated stream crossing methods that are not listed in Table 2 for Lewis County, WV:<br>• Sand Fork near MP 55.2,<br>• Oil Creek near MP 62.3, and<br>• Clover Fork near MP 65.6. |
| 79 | N/A | Round hickorynut, | Describe the activity that is occurring in the Granny Creek portion of the aquatic action area and how the length of this aquatic action area was determined. |

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| | | longsolid | |

Please provide responses to comments and all requested information to cindy_schulz@fws.gov. If you have any questions or require additional information, please contact me at (804) 654-1842 or via email at cindy_schulz@fws.gov.

Sincerely,

Cindy Schulz
Field Supervisor
Virginia Ecological Services

cc: Beveridge and Diamond, Washington, DC (Attn: Parker Moore)
Equitrans Midstream, Canonsburg, PA (Attn: Matt Hoover, Megan Neylon)

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 22

**February 21, 2023**

FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, DC 20426
OFFICE OF ENERGY PROJECTS

In Reply Refer To:
OEP/DG2E/Gas 3
Mountain Valley Pipeline, LLC
Mountain Valley Pipeline Project
Docket No. CP16-10-000

January 26, 2023

VIA Electronic Mail

Cindy Schulz
U.S. Fish and Wildlife Service
Virginia Field Office
cindyschulz@fws.gov

**Subject:** Updated Effects Determinations for the Mountain Valley Pipeline Project

Dear Ms. Schulz:

On July 10, 2017, the Federal Energy Regulatory Commission (FERC) initiated formal consultation with the U.S. Fish and Wildlife Service (FWS) under Section 7 of the Endangered Species Act (ESA) regarding the Mountain Valley Pipeline Project (Project). Our Biological Assessment for the Project was issued on July 7, 2017, along with additional technical information, including maps, biological survey reports, and other supplemental materials separately provided by the Project sponsor, submitted to the FWS separately from the final environmental impact statement (EIS) issued on June 23, 2017.[1] On November 17, 2017, the FWS transmitted its Biological Opinion (BO) for the Project to the FERC.

On August 28, 2019, FERC reinitiated consultation with the FWS due to the listing of the candy darter and new information regarding potential effects of the Project on certain species (Roanoke logperch, Indiana bat, and northern long-eared bat). As part of the reinitiation, on July 2, 2020, Mountain Valley Pipeline, LLC (Mountain Valley) submitted a final draft of its supplement to the 2017 Biological Assessment, which included revised effect analyses for all federally listed species (including the candy darter) affected by the Project. FERC sent a letter to the FWS on July 8, 2020 confirming its revised effects determinations to assist the FWS with revising its BO. FWS issued a new BO and conference opinion on September 4, 2020 that replaced in its entirety the FWS 2017 BO.

Since issuance of the 2017 Biological Assessment, there have been various changes to the Project as well as litigation that included: October 11, 2019, the United States Court of Appeals for the Fourth Circuit issued an order granting a stay of the November 2017 BO and Incidental Take Statement issued by the FWS for the Project and granting the Department of the Interior's

[1] The final EIS summarized the findings of our subsequent Biological Assessment.

motion to hold the litigation in abeyance until completion of ESA re-consultation[2]; and the same court's vacatur and remand of FWS' 2020 BO on February 3, 2022.[3] Following the vacatur, on June 24, 2022, the FERC requested reinitiation of consultation so that updates to the Project (including changes to waterbody crossing methodologies, variances, etc.) could be assessed and to provide support to the FWS as it responds to issues raised by the Fourth Circuit Court of Appeals decision.[4]

Mountain Valley submitted an Updated Supplement to the Biological Assessment to the FWS on July 29, 2022 (July 2022 SBA) that includes revised and/or additional information on listed species potentially affected by the Project and revised effect determinations for several species. This document was supplemented on October 13, 2022; and revised on December 22, 2022. Since the submittal of Mountain Valley's July 2022 SBA, FERC has been in discussions with the FWS regarding the information provided and the subsequent effects determinations for the subject species. FWS and FERC provided comments on October 19, 2022 and November 18, 2022 to Mountain Valley to clarify and supplement information presented in the July 2022 SBA. Mountain Valley provided responses to these comments on a rolling basis. As of January 19, 2023, Mountain Valley has responded to all the comments provided by FERC and the FWS including filing a revised version of the July 2022 SBA to address some of the comments (referred to herein as the 2022 SBA).

In order to facilitate the consultation process, FERC is providing FWS with confirmation of its updated determinations of effect for the species listed in table 1, including determinations for newly proposed species, as further discussed below. We are maintaining our prior determinations that the Project *May Affect, and is Likely to Adversely Affect* the Roanoke logperch, Indiana bat, northern long-eared bat, candy darter, and Virginia spiraea. We are also maintaining our prior determinations that the Project *May Affect, but is Not Likely to Adversely Affect* the gray bat, Virginia big-eared bat, James spinymussel, clubshell, snuffbox, smooth coneflower, and small whorled pogonia. There is also no change to the *No Effect* determinations for the shale barren rock cress, rusty patched bumble bee, northeastern bulrush, yellow lance, and Atlantic pigtoe.

There is one species that was delisted and three species that have been proposed for listing since the issuance of the 2020 BO. We note that Mountain Valley's 2022 SBA made the determination that the Project *May Affect, but is Not Likely to Adversely Affect* the candy darter and the Virginia spiraea based on new data regarding the Project's potential impacts on the species and completion of surveys. However, based on further discussions with FWS, FERC is not changing its prior determination that the Project *May Affect, and is Likely to Adversely Affect* the candy darter and Virginia spiraea.

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2 *Wild Virginia, Inc. v. Dep't of the Interior*, No. 19-1866 (4th Cir. Oct. 11, 2019) (order granting stay and holding case in abeyance).

3 *Appalachian Voices v. U.S. Dep't of the Interior*, 25 F. 4th 259 (4th Cir. 2022).

4 *See* June 24, 2022 Letter from the FERC to the FWS (eLibrary accession number 20220624-3028).

| Table 1<br>Effects Determinations for the Mountain Valley Pipeline Project | | | |
|---|---|---|---|
| **Species Common Name** | **Species Scientific Name** | **ESA Status** | **Effects Determination [a]** |
| Indiana bat | *Myotis sodalist* | Endangered | LAA |
| Northern long-eared bat | *Myotis septentrionalis* | Threatened | LAA |
| Roanoke logperch | *Percina rex* | Endangered | LAA |
| Candy darter | *Etheostoma osburni* | Endangered and Critical Habitat | LAA |
| Virginia spiraea | *Spiraea virginiana* | Threatened | LAA |
| Gray bat | *Myotis grisescens* | Endangered | NLAA |
| Virginia big-eared Bat | *Corynorhinus townsendii virginianus* | Endangered | NLAA |
| James spinymussel | *Pleurobema collina* | Endangered | NLAA |
| Clubshell | *Pleurobema clava* | Endangered | NLAA |
| Snuffbox | *Epioblasma triquetra* | Endangered | NLAA |
| Smooth coneflower | *Echinaceae laevigata* | Endangered | NLAA |
| Small whorled pogonia | *Isotria medeoloides* | Endangered | NLAA |
| Shale barren rock cress | *Arabis serotina* | Endangered | No effect |
| Rusty patched bumble bee | *Bombus affinis* | Endangered | No effect |
| Northeastern bulrush | *Scirpus ancistrochaetus* | Endangered | No effect |
| **Running buffalo clover** | ***Trifolium stoloniferum*** | **Delisted** | **N/A** |
| Yellow lance | *Elliptio lanceolata* | Threatened and Critical Habitat | No effect |
| Atlantic pigtoe | *Fusconaia masoni* | Threatened and Critical Habitat | No effect |
| **Round hickorynut** | ***Obovaria subrotunda*** | **Proposed Threatened and Proposed Critical Habitat** | **Not likely to jeopardize the continued existence; Not likely to adversely modify critical habitat** |
| **Tricolored bat** | ***Perimyotis subflavus*** | **Proposed Endangered** | **Not likely to jeopardize the continued existence** |
| **Longsolid** | ***Fusconaia subrotunda*** | **Proposed Threatened and Proposed Critical Habitat** | **Not likely to jeopardize the continued existence** |
| [a] NLAA = May affect, but is not likely to adversely affect; LAA = May affect, and is likely to adversely affect; N/A = Not applicable<br>**Bold text indicates species for which effect determinations have changed since the 2020 consultation or newly proposed species.** | | | |

**Running Buffalo Clover**

Mountain Valley performed additional surveys for running buffalo clover in 2018 and 2019 due to pipeline route changes and variance requests. No running buffalo clover individuals were observed within the limits of disturbance even though potentially suitable habitat was present. However, on September 7, 2021, running buffalo clover were delisted. Therefore, consultation for this species is no longer required.

**Round Hickorynut**

On September 29, 2020, the FWS proposed to list the round hickorynut as a federally threatened species with proposed critical habitat. Round hickorynut populations and habitat in the Project area are in Meathouse Fork, Buckeye Creek, Middle Island Creek, Leading Creek, Fink Creek, Kincheloe Creek, and Sand Fork. Round hickorynut individuals are not expected within the limits of disturbance for the Project. Mountain Valley's updated sedimentation analysis did not show a measurable increase in sedimentation in round hickorynut occurrence locations. After further discussions with FWS, we have determined the Project is not likely to jeopardize the continued existence of the round hickorynut or adversely modify the proposed critical habitat for the round hickorynut.

**Longsolid**

On September 29, 2020, the FWS proposed to list the longsolid as a federally threatened species with proposed critical habitat. There are historic reports of longsolid occurrence within Meathouse Fork within the Project's Action Area. However, there are no modern records of longsolid occurrence within the Project's Action Area. In addition, longsolid proposed critical habitat does not occur within the Project's Action Area. After further discussions with FWS, we have determined the Project is not likely to jeopardize the continued existence of the longsolid or on the proposed critical habitat for the longsolid.

**Tricolored Bat**

The tricolored bat, proposed for listing as endangered on September 13, 2022, can be found within forested habitat roosting in live or recently dead hardwood trees; and winters in caves, abandoned mines, and road-associated culverts. Because the tricolored bat may be found in similar habitat as the Indiana bat and northern long-eared bat within the Project area, we expect the Project to result in similar impacts on the tricolored bat as for the Indiana bat and northern long-eared bat. For species that have been recently proposed for listing, the action agency is required to evaluate impacts on the species that occurred or will occur since the issuance of the proposal to list the species. Nearly all of the necessary tree clearing has already been completed for the Project aside from isolated patches totaling less than four acres. While the 2020 BO estimates that up to 247.68 additional acres of tree clearing may be required to remediate unknown future slips, Mountain Valley committed to continuing to implement its stepwise protocol before cutting any trees in those areas to avoid adverse effects to tree-roosting bat species. No adverse effects to tricolored bat winter (hibernation), spring, summer, fall, or migration habitat are expected related to future tree clearing or Project operation and maintenance activities. Mountain Valley also has committed to continue abiding by the avoidance and minimization measures described in the 2017 Biological Assessment and the 2020 BO, which originally were developed for the Indiana bat and northern long-eared bat. Mountain Valley has also committed to voluntary bat conservation measures for other bat species that will provide similar benefits for tricolored bat. Based on these factors and the fact the Project would affect only a part of the species range, our determination is that the Project is not likely to jeopardize the continued existence of the tricolor bat.

FERC will request a conference with FWS at a later date, as appropriate, for the three species and critical habitat proposed for listing. If construction of the Project is not completed by the time the species' become listed, Mountain Valley may be required to pause construction activities, if necessary, until FERC staff completes ESA consultation. We request that you provide your concurrence with our new and modified species determinations for the Project or formally inform us of your nonconcurrence. If you have any questions concerning this matter, please contact me at (202) 502-8045 or Amanda Mardiney, Project Biologist, at (202) 502-8081.

Sincerely,

James Martin, PhD
Chief, Gas Branch 3
Division of Gas Environment and Engineering
Office of Energy Projects

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

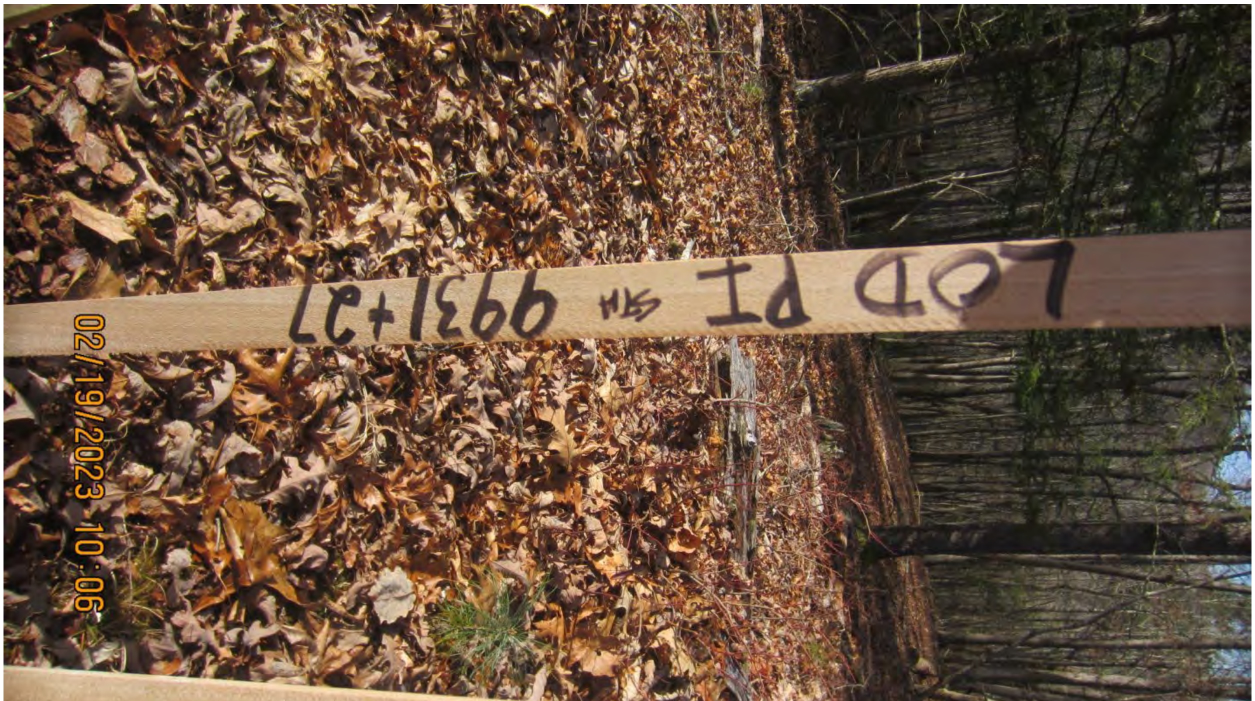
# EXHIBIT 23

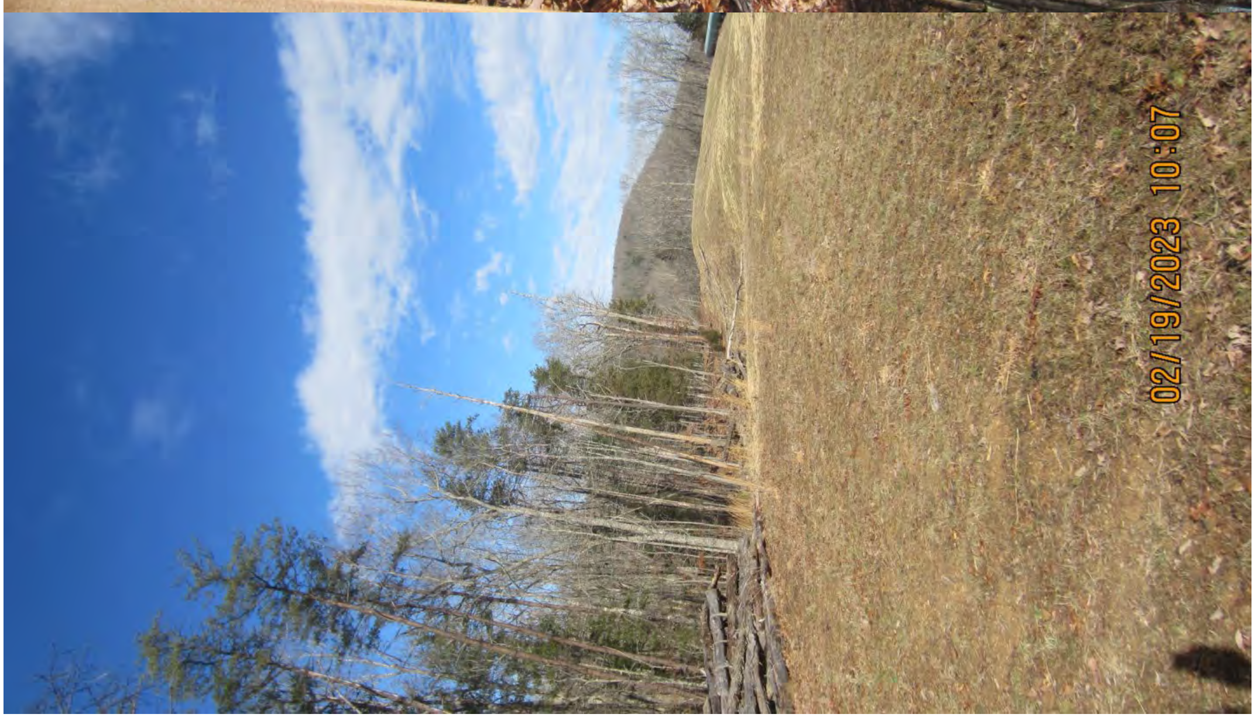
**February 21, 2023**

MVW Report Narrows of Hans Creek

February 19, 2023

The south side on the MVP ROW is steep. The north side is very steep and probably twice as long.



LOD PI STA 9931+27
02/19/2023 10:06


02/19/2023 10:07



The pictures above show that MVP has removed all the silt fences and silt sock from this area. This will be a problem if the resume construction. You will see why when I file my complaint in a couple of days.


02/19/2023 10:13


02/19/2023 10:08


02/19/2023 10:15


02/19/2023 10:18


02/19/2023 10:18

02/19/2023 10:19

ABOVE: The silt fences at the base of the bridge is in disrepair.


02/19/2023 10:29


02/19/2023 10:29


02/19/2023 10:32


02/19/2023 10:32


02/19/2023 10:32


02/19/2023 10:40


02/19/2023 10:43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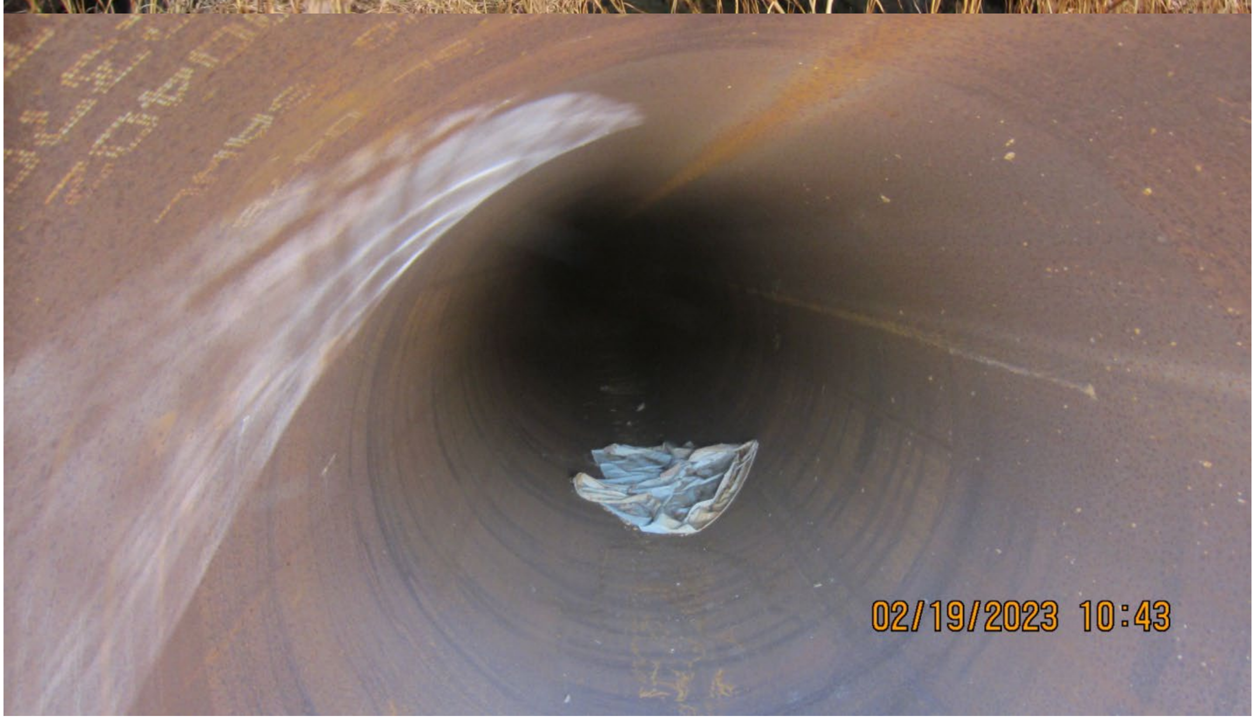
02/19/2023 10:43


02/19/2023 10:43

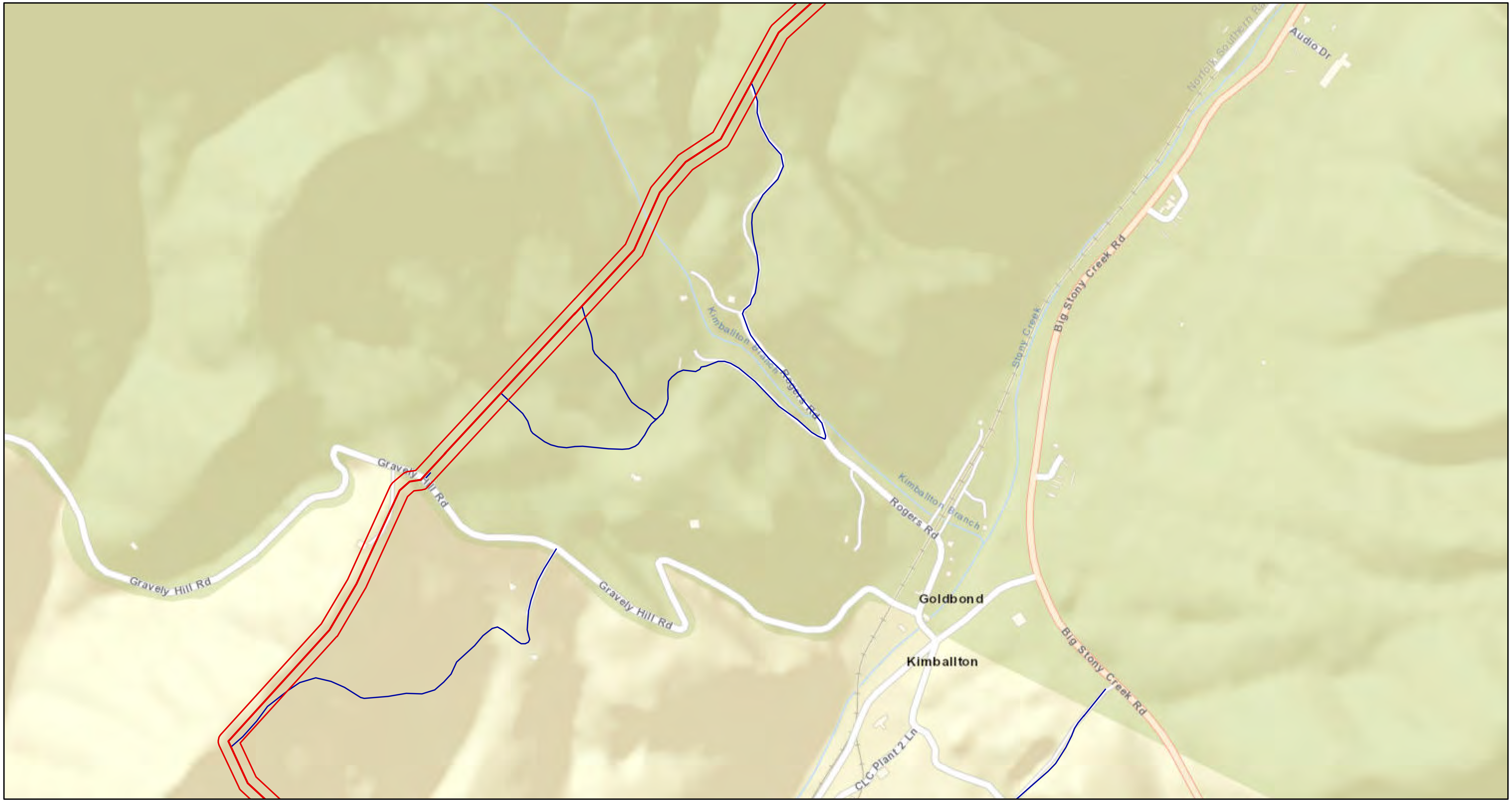

All of the pipe seen here was brought into this area in late 2018. It is also seen in Paula's video made in September. If you have questions please ask.

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 24

**February 21, 2023**

# Rogers Road,Kimballton Branch, Stony Creek area - MVP pipeline




1/28/2023, 2:32:56 PM

MVP proposed route

MVP proposed route right of way

MVP access roads

1:9,028

0 0.07 0.15 0.3 mi

0 0.13 0.25 0.5 km

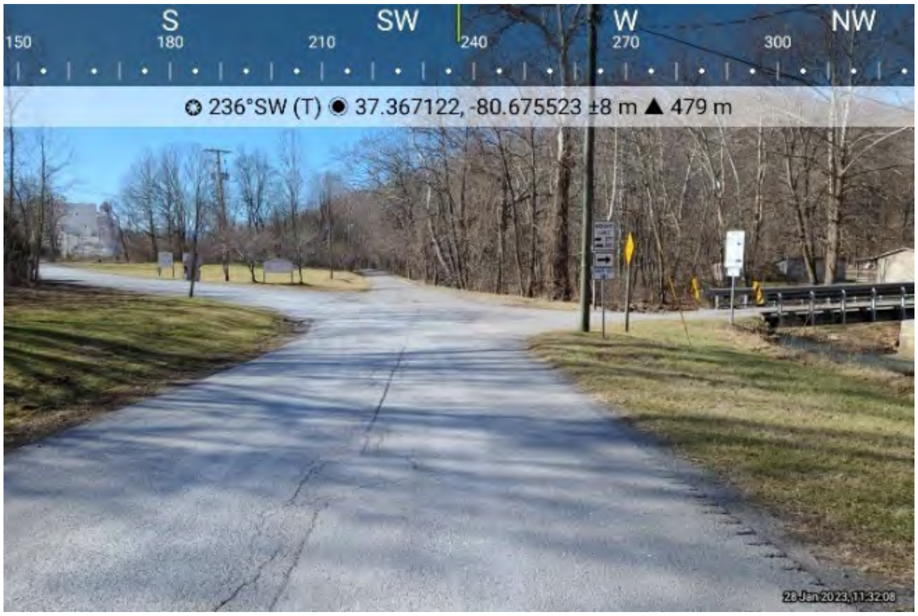
VITA, Esri, HERE, Garmin, INCREMENT P, Intermap, NGA, USGS

Web AppBuilder for ArcGIS

National Park Service Appalachian Trail Park Office and Appalachian Trail Conservancy | VITA, Esri, HERE, Garmin, INCREMENT P, Intermap, NGA, USGS |

## Photos of Rogers Road Access Route to MVP ROW and JNF on Peters Mountain

Approach from Big Stony Creek Rd (Rte 435) on Norcross Rd. Tight right turn onto bridge across Stony Creek to get to Rogers Road.





One-lane bridge over Stony Ck, 12 ft wide


Source: All photographs taken on January 28, 2023 by Indian Creek Watershed Association

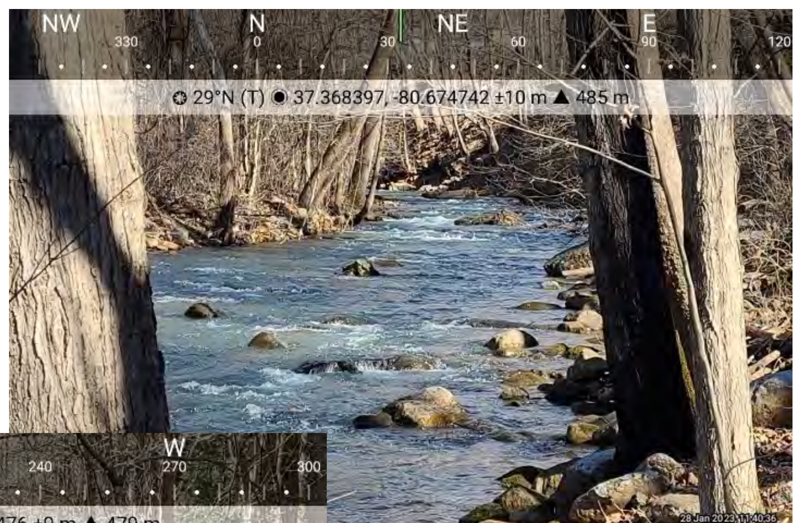
Stony Creek upstream from bridge

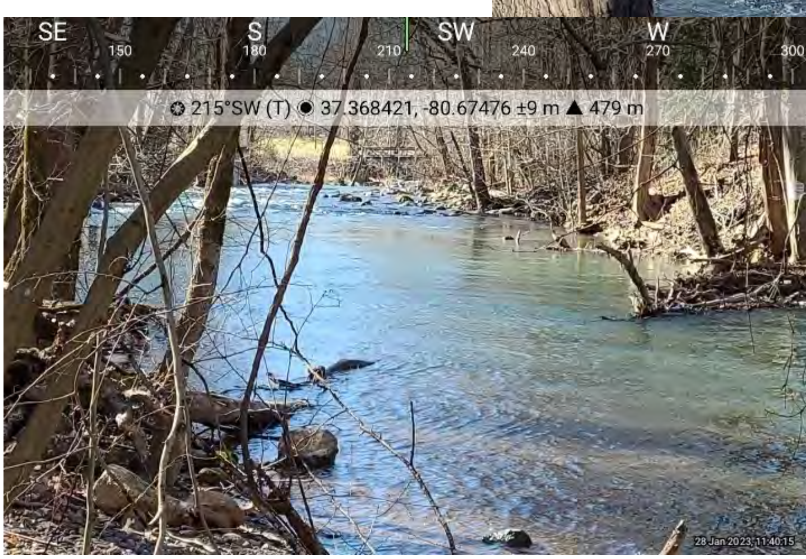

Stony Creek downstream from bridge

Kimballton Branch entrance to Stony Creek (center). Appears to be debris caught around entrance area.


Right: Stony Ck above Kimballton Branch entrance

Below: Stony Ck below Kimballton Branch entrance

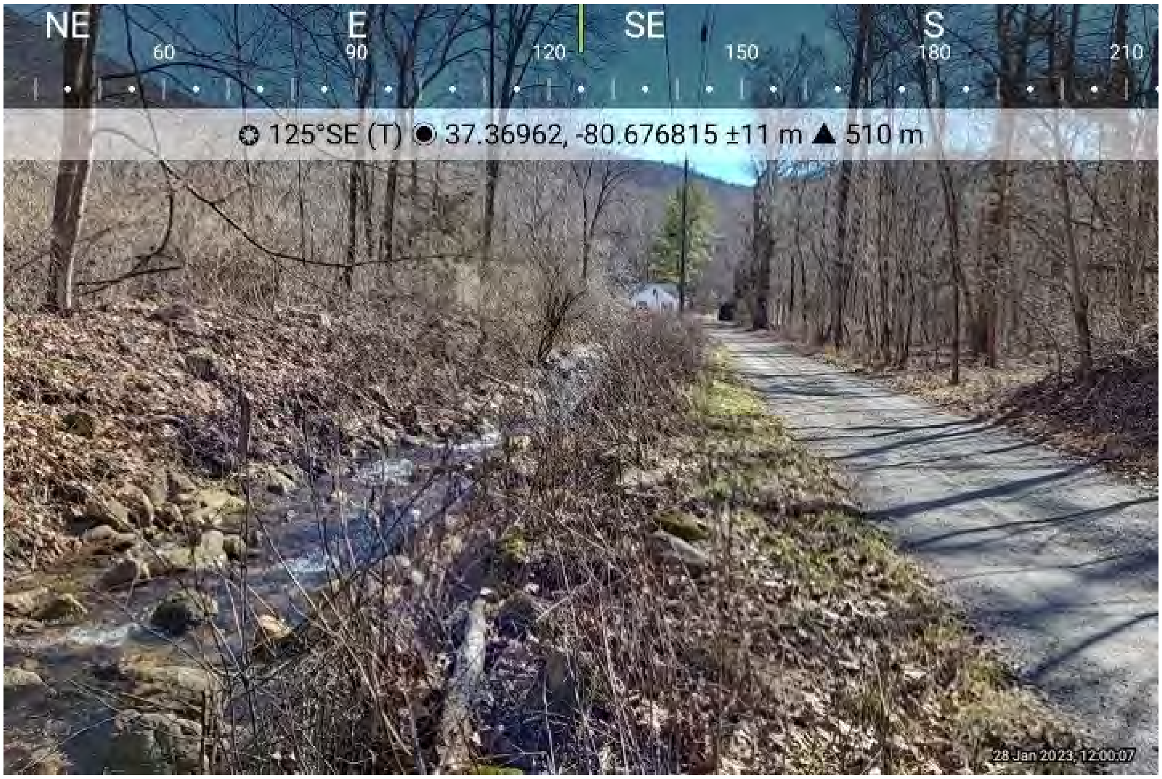


Rogers Road is paved for short distance between bridge and railroad crossing

Rogers Road continues as gravel 12-ft road from RR crossing towards Peters Mountain

Looking back toward RR crossing, with Kimballton Branch on left




Looking toward Peters Mountain,  Kimballton Branch on right.

Roger Road ends as state road and forks about 300 yards from RR crossing.  Right, Rogers Road continues as private drive. It crosses Kimballton Branch just above the fork, past the white sign. Identified as a permanent Access Rd for MVP and will likely carry most or all of the equipment, etc. to be transported up the ROW to the JNF. Left fork is a rougher road, also planned for Access Rd (temporary). Kimballton Branch runs between the two Access Roads for about 250-300 yds. KB will be crossed by open-cut method at the base of Peters Mountain. Its subwatershed extends up on Peters Mountain close to the bore site and ROW.

Kimballton Branch on left, above the culvert under Rogers Rd.

Kimballton Branch below the Rogers Rd culvert. Pipes for monitoring station can be seen on right by trees. See next photos.

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 25

**February 21, 2023**

# Site-Specific Design of Stabilization Measures in Selected High-Hazard Portions of the Route of the Proposed Mountain Valley Pipeline Project in the Jefferson National Forest

Prepared by:


**Mountain Valley Pipeline, LLC**

625 Liberty Avenue, Suite 1700

Pittsburgh, PA 15222-3111


**December 20, 2016**

# Contents

**Appendix A – Figures**



**Appendix B – Typical Drawings**

**Appendix C – Slope Stability Output**

# Introduction

The following analyses are in response to the October 24, 2016, *Request for Site-Specific Design of Stabilization Measures in Selected High-Hazard Portions of the Route of the proposed Mountain Valley Pipeline Project in the Jefferson National Forest* letter.

Six JNF Priority Sites were identified in the letter and are addressed herein. These sites are shown on the Jefferson National Forest Priority Sites map of Figure 1.

Potential hazards and associated mitigations are discussed on an individual basis for each Priority Site. Monitoring strategies are discussed following the site-specific discussion.

Mitigation measures prescribed in this document are comparable to those recommended in *Mitigation of Land Movement in Steep and Rugged Terrain for Pipeline Projects* by the Interstate Natural Gas Association of America (INGAA) published in May 2016. The mitigation measures described in the INGAA report have been successfully implemented on numerous pipeline projects in the Appalachian region.

Figures depicting construction conditions show a soil swell of 25 percent for topsoil and 50 percent for spoil (based on bedrock as the primary excavated material), which will actually be less as the spoil piles will be compacted. Nonetheless, a conservative swell volume was chosen to depict worst-case conditions during construction. Soil swell will be negligible in the final configuration as backfill will be placed in compacted lifts via tracked heavy equipment. Any excess soil generated due to soil swell or displacement by the pipeline itself will be tracked in across the temporary workspace area and then the topsoil will be placed on top of that surface. The original ground surface contours will be restored as practicable during reclamation activities and the replaced soil will be graded to meet the existing contours at the edge of the right of way.

During construction, Mountain Valley will deploy a landslide inspection team to identify geohazards encountered along the pipeline alignment. The landslide inspection team will develop mitigation schemes for the identified geohazards using Mountain Valley's landslide mitigation typical drawings. These drawings are included in Appendix B. The use of all included typical drawings is not prescribed herein, but Mountain Valley's landslide inspection team may implement these schemes as necessitated by subsurface conditions revealed during construction. If subsurface conditions are not conducive to the use of the included typical drawings, additional mitigation schemes will be developed by the landslide inspection team for use in the field.

# 1.0 JNF Priority Site #1

*Coordinates: (37.384428, -80.679174) to (37.381628, -80.677097)*

## 1.1 Site Description and Geology

This site is located on private property adjacent to National Forest Service lands, on the lower downslope south side of Peters Mountain, approximately between milepost (MP) 198.15 to 198.35 on the October 2016 Proposed Route.

Slopes along this portion of the right-of-way (ROW) in the near vicinity of the JNF Priority Site #1 range from 13 to 76 percent (with an average slope of 34 percent), and generally become more gradual further downslope. As shown on the plan view slope map of Figure 2, the steepest part of the proposed right of way in the JNF Priority Site #1 area is approximately between MP 198.15 and 198.20

A profile of the site is shown on Figure 3. The pipeline will be approximately three feet below grade at this location, with the bottom of the pipeline trench located approximately seven feet below grade. The trench will be backfilled with select backfill, which will be shaker bucket material from the native soil and rock. Cross section 1A is shown on Figures 4, 5, and 6, showing the anticipated extent of trenching and stockpiled material before, during, and after construction, respectively.

According to Rader and Gathright (1986) and Schultz and Stanley (2001) the geology of general area of the JNF Priority Site #1 area is highly folded and thrust-faulted, northeast striking and steeply dipping (generally 50-60$^{o}$) Silurian to Cambro-Ordovician age bedrock. The upslope vicinity of the JNF #1 area is underlain by the undivided Tonoloway Limestone and Keefer Sandstone. A splay fault of the Narrows thrust fault is mapped in the upslope vicinity of the JNF Priority Site #1 location. Colluvial overburden obscures bedrock outcrop in the vicinity of the JNF Priority Site #1 area, where underlying bedrock is mapped as Silurian age Rose Hill and Tuscarora Formations (red shales, mudstone, fine to medium red to gray to white sandstones and quartzite) conformably overlying upper Ordovician age Juniata Formation bedrock further downslope. The Juniata Formation conformably contacts Ordovician age undivided Reedsville Shale and Trenton Limestone (interbedded gray calcareous shale, fossiliferous limestone and minor calcareous sandstone, thin gray shale beds). The ancient, inactive Narrows thrust fault is an unconformable contact between the Ordovician Reedsville and Trenton strata and older Cambro-Ordovician age Knox Group (predominantly dolostone) that underlies the valley floor.

*Photo 1: Red and brown sandstones characteristic of the Rose Hill Formation were observed as float upslope of the JNF Priority Site #1 area (view is toward north-northwest)*

*Photo 2: White to gray sandstone talus blocks characteristic of the Tuscarora Formation observed as abundant float near the vicinity of the JNF Priority Site #1 (view is upslope toward the west)*

*Photo 3: The JNF Priority Site #1 situated on an ancient colluvial fan composed primarily of Tuscarora sandstone (view is sideslope to the southwest)*

Schultz et al (1986) map these characteristic areas as "Colluvium undifferentiated: boulders, gravel, sand and silt; includes rock fall, talus, debris train, and block field deposits".

## 1.2 Potential Slope Failure Hazards

Potential slope failure hazards that were considered for this area included rock failure, debris flow, remobilization of colluvial deposits, shallow failure of stockpiled trench/topsoil, slope failure subjacent to stockpiles, failure of cut slopes created during construction, post-construction erosion of the reclaimed right of way, shallow sloughing failure of the trench backfill, and water intrusion from seeps and springs encountered in the trench.

A slope failure in this vicinity could impact streams S-Q10 and S-Q11, which are tributaries to Big Stony Creek and are at least 275 feet east-southeast from the proposed temporary right of way.

These slope failure hazards and associated mitigation and avoidance strategies are discussed below.

### 1.2.1 Rock Failure

Rock-block failure involves gravity-induced movement of large, relatively intact blocks of bedrock on steep slopes. The bedrock mass is typically a complex geological body resulting from variable lithology, tectonic stresses and weathering that lead to differential loading and unloading. Rock-block failures typically occur where stronger bedrock units transition to weaker or weathered units and become undercut. Rock falls or topples entail abrupt movements of bedrock mass or boulders that detach along discontinuities (fractures, joints, bedding planes) or the forward rotation of a unit or units about some pivotal point. Movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water. Field reconnaissance of the JNF Priority Site #1 did not reveal conditions that would lead to potential rock block failure. Bedrock is not exposed as over-steepened cliffs or ledges, is covered by soil overburden, and is likely stable in-place. Therefore, based on field observations of the JNF Priority Site #1 and planned construction activities, Mountain Valley considers the potential for rock failure to be so remote as to be negligible. No mitigation measures for rock failure are prescribed at JNF Priority Site #1.

### 1.2.2 Debris Flow / Colluvial Deposit

Debris flows are generally considered to be high-energy, rapid downslope movement of earth material that can entrain trees and other large objects in the flow path.  A debris flow differs from rock-block slide in that there are no well-defined blocks moving along shear surfaces. Instead, the mass flows downhill, with shear strains present everywhere.  Debris flows generally occur during intense precipitation events, and travel rapidly downslope along existing drainage channels or stream valleys, transporting and depositing mud, sand, gravel, and boulders where the slope gradient flattens. Multiple debris flows may coalesce into a central channel downslope from the points of initiation.

Colluvial deposits observed in the vicinity of the JNF Priority Site #1 may be derived from past debris flow(s), or other forms of mass wasting. However, this analysis groups debris flow with colluvial deposits because pipeline construction within, or in the vicinity of an observed colluvial deposit entails similar precautions to that for a debris flow.

Major controls on the potential to initiate a debris flow include topographic gradient and orientation of the slope, bedrock structure, and the accumulation of historic debris flows in topographic drainage features that concentrate surface and subsurface water during intense precipitation events. Field observations of the JNF Priority Site #1 suggest that topographic and bedrock conditions are not likely susceptible to generating a new debris flow at the JNF Priority #1 site. However, colluvial deposit(s) observed at, and in the near vicinity of, the site (as described above), coupled with the potential for extreme precipitation events, warrant consideration for construction and long-term operation of the pipeline.

Field observations indicated that the colluvium in the vicinity of the JNF Priority Site #1 generally accumulates in topographic drainage features below the south-sloping ridgeline where the proposed alignment is situated.  The pipeline trench in the vicinity of JNF Priority Site #1 will be located in thin overburden overlying bedrock forming a downslope ridge.  Nonetheless, adjacent colluvial deposit(s) may be encountered within the overall limit of disturbance (LOD) during construction, and is therefore being evaluated for slope stability.  The landslide mitigation specialists deployed by Mountain Valley during construction will determine if additional mitigation measures need to be implemented based on the depth of the colluvial deposit and its position relative to the pipeline. If the pipeline must be located within the colluvial deposit due to the deposit's depth, the implementation of additional measures will be dependent upon the direction of the mass movement and steepness, where encountered. If movement follows the pipeline longitudinally, no additional measures will be required to protect the pipe. If movement is transverse or oblique to pipeline orientation, the trench may be backfilled with deformable material or wrapped in a protective sleeve to attenuate potential strain on the pipeline.

### *Slope Stability and Pipeline Integrity Analyses*

As discussed above, the JNF Priority Site #1 is situated adjacent to colluvial deposits overlying clastic sedimentary bedrock. Activities within the LOD may encounter the colluvial deposit. Soil test pits conducted in the vicinity of the JNF Priority Site #1 indicated that bedrock is more than three feet deep, and based on field observations (e.g., incised drainages, local road cuts) depth to bedrock increases toward the central portion of the drainage where colluvium tends to accumulate.

Existing slope stability at the JNF Priority Site #1 was evaluated by establishing safety factors using a numerical model with input from field observations, probabilistic analysis of material properties and analyst experience. Slope failure risk analysis was approximated using the peer-reviewed slope stability program SLIDE (RocScience, Inc.). This model incorporates Bishop, Janbu and Spencer methods, generates circular, non-circular, and optimized shaped failure planes with seismic and boundary loads.

Observations of historical slope failures in other areas suggest that the likely slip plane will occur at the overburden-bedrock interface resembling an infinite slope failure. However, the depth of the slip surface within the colluvium material has a minimal effect on the Factor of Safety (FoS) (i.e., difference of less than 0.05). Therefore, the model simulates a failure surface near the overburden-bedrock interface to represent a failure with an adverse effect and not shallow, surficial sloughs.

A probabilistic model was applied to the colluvial soil's shear strength (friction angle) and unit weight using highest and lowest conceivable values (Duncan, 2000). Stability analyses were run for slope angles ranging from 15% (9 degrees) to 76% (37 degrees), which bracket the range of existing slopes observed at and near the JNF Priority Site #1. Modeling also accounted for saturated conditions and seismic loading (0.16 g; see Mountain Valley Pipeline Resource Report #6, seismic hazards analysis). Examples of the sensitivity analysis are shown below for a 30 percent slope with saturated soils.

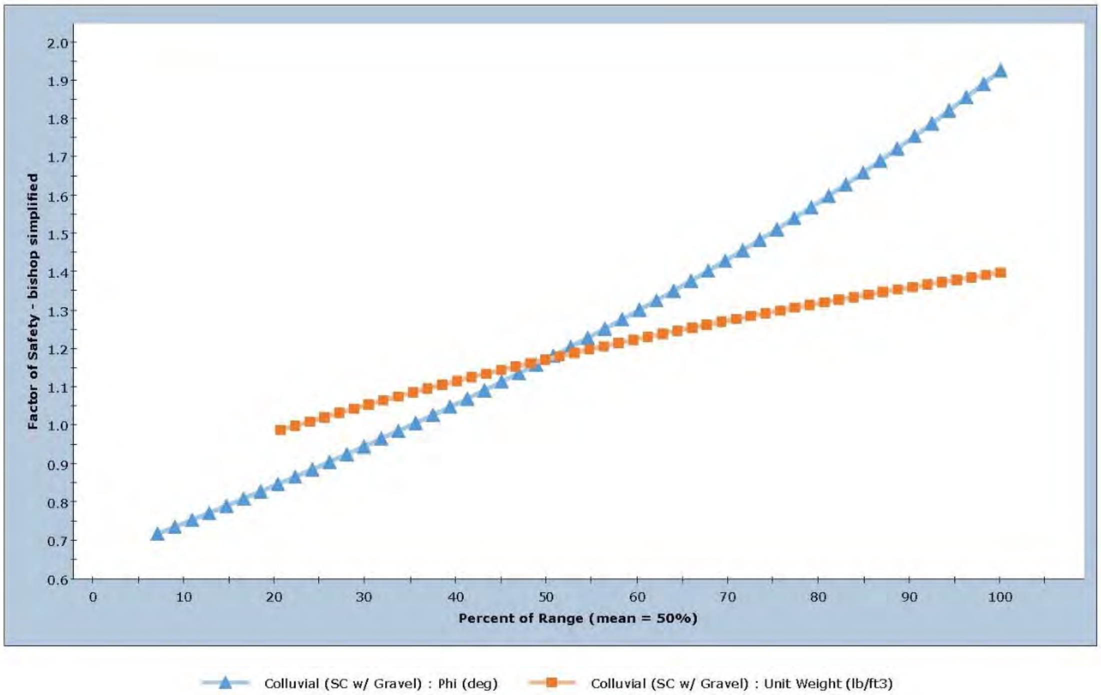



*Photo 4: Example of sensitivity plot for the shear strength and unit weight of colluvium versus factor of safety*

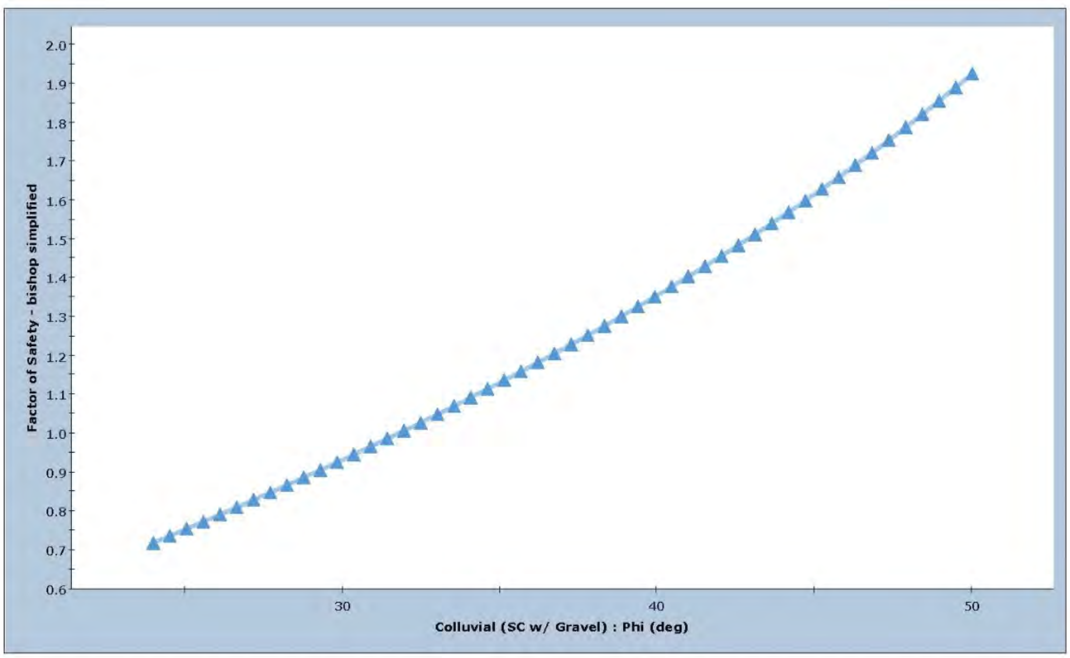



*Photo 5: Example sensitivity plot for the shear strength of the colluvium versus factor of safety (likely (mean) phi=36°, lower limit=24°, upper limit=50°)*

The output files for results of each analysis at the likely soil parameters are included in Appendix C. Table C-1 in Appendix C summarizes the full range of stability analysis results given the probabilistic analyses for input parameters soil density and friction angle, under increasing slope, saturated and unsaturated conditions, and with and without seismic loading.

In summary from Table C-1, based on likely colluvial material density and friction angle values, the existing colluvial deposit slopes at JNF Priority Site #1 are stable (minimum FoS of 1.1) up to at least 65% (33 degrees) native slopes under unsaturated conditions with no seismic loading, and 45% (24 degrees) native slopes with seismic loading. Under saturated conditions, risk for slope failure increases substantially.

The slope stability model suggests that colluvial slopes in the near vicinity of the JNF Priority Site #1 are stable within FoS values under unsaturated conditions. The model also confirms what Mountain Valley has already accounted for in construction practices, that the largest effect on the FoS is soil saturation from groundwater intrusion, or surface water infiltration, to the colluvial deposit (i.e., as soils become saturated, stability decreases). As discussed, Mountain Valley is aware of the need to prevent accumulation of storm water during construction, permanently divert subsurface springs or seeps from the pipeline bedding and near vicinity if encountered during construction, and to properly grade and reclaim the ground surface in the LOD after construction. Preventing saturated conditions on these steep slope environments is a critical factor in maintaining slope stability. The project stormwater management plans and subsurface drains implemented during construction will address the issue of overburden saturation.

The analysis suggests there is minimal risk of ground displacement. From the perspective of pipeline integrity and safety, D. G. Honegger Consulting (2015) indicated that slope displacements parallel to the proposed alignment can be screened out as not representing a significant hazard if the length of pipeline exposed to ground displacement is less than 1,150 feet (Class 1 pipe) to 1,640 feet (Class 3 pipe) from the top of the slope (screening approach assumes a relatively straight line with no connections or insulated joints in the screening distance). While Mountain Valley does not anticipate any slope failure to occur, it is even more unlikely that failure on the magnitude of 1,000's of feet will occur. Thus the effects of displacement on the pipeline have not been analyzed. As discussed later in this document, Mountain Valley will implement a post-construction slope monitoring program. If future monitoring observations suggest slope movement is occurring, Mountain Valley will take appropriate actions to stabilize the slope and will evaluate pipeline response to the nature and degree of observed ground displacement using the recommendations provided in PRCI (2009).

### 1.2.3 Soil Stockpile and Subjacent Slope Failure

Soil stockpiles will be compacted via rolling with dozers on site. Excavation and backfilling will be completed as quickly as possible to minimize the duration of stockpiling. At JNF Priority Site #1, the contractor will install a temporary diversion, such as reinforced silt fence, to prevent rocks from rolling off of the ROW. In areas of the ROW steeper than about 65%, spoil may be moved downhill to a flatter area temporarily during construction, then moved back uphill during final restoration.

In steeper areas of the ROW, spoil stockpiles will be stored on bedrock. Thus, overloading the slope in the steeper regions of the JNF Priority Site #1 does not present a technical concern for construction in this area. Temporary spoil stockpiles will be stable with a factor of safety of at least 1.2 as demonstrated in Appendix C.

Colluvial deposits were observed in the flatter portions of the site. Stability of the native material underlying spoil stockpiles is of concern. The spoil will be spread out across the workspace to the extent practicable to avoid overloading the in-situ colluvial soils. Stockpiles will be compacted via rolling with dozers to prevent water infiltration and thus minimize the weight of the stockpiled soil.

The landslide inspection team deployed by Mountain Valley during construction will evaluate the subgrade to determine whether or not it is appropriate to stockpile soils in the vicinity of the colluvial deposit. The exact thickness of the colluvial deposit will not be fully determined until excavation is initiated, but as previously described, as colluvial debris generally follow ravines and drainage paths and the pipeline ROW is located on a ridge, it is unlikely that the colluvial deposit is extremely thick in the workspace area. Therefore, soils may be sufficiently thin that instability due to stockpiled material is not a concern. If colluvial deposits exceed about five feet, spoil stockpiles will be moved up or downslope to a more stable area to avoid overloading the colluvial deposit and initiating a failure.

### 1.2.4 Temporary Cut Failures

Cut slopes created during construction at JNF Priority Site #1 are anticipated to be minor (less than about five feet in height) and located in rock. Cut slopes will not exceed the maximum safe angle per OSHA standards for the type of material being excavated. Temporary rock cuts are anticipated to be stable in the long-term following reclamation as they will be protected by compacted native material placed to original contours as practicable.

### 1.2.5 Erosion

Erosion hazards will be mitigated by following the project Erosion and Sediment Control Plan (E&SCP). Refer to the E&SCP for details.

### 1.2.6 Trench Backfill Failures

The pipeline trench will be provided with trench breakers at locations specified in the project E&SCP. These trench breakers will act as gravity retaining walls within the trench to hold the backfill in place during construction and will slow the velocity of water running through the trench, preventing subsurface erosion. Every third trench breaker at this location will be provided with daylight drains, as shown on typical drawing MVP-35, discharging water building up in the trench to water dissipation devices at the ground surface. All trench breakers not provided with daylight drains will be provided with pass-through drains as shown on typical drawing MVP-43.

As the trench backfill will be placed in compacted lifts, the trench backfill will be at least as stable as the distal extent of in-situ colluvial deposits, if encountered. Slope stability analysis of the trench backfill is included in Appendix C. Up to approximately 65 percent slope, backfill is anticipated to be stable with a safety factor of at least 1.5. In areas steeper than 65 percent (which are likely rock outcrop areas), additional slope breakers should be installed in the trench backfill, spaced a maximum of 25 feet apart. Larger rocks from the excavation should be placed in the upper two feet of backfill at these steep areas to armor the backfill between the trench breakers.

### 1.2.7 Seeps and Springs

As the presence of seeps/springs encountered in the pipeline trench will not be known until the trench is excavated, their location and extent cannot be determined at this time. At JNF Priority Site #1, seepage (if any is encountered) will be captured by daylight drains behind the trench breakers, as shown on typical drawing MVP-35. These drains will outlet to energy dissipation devices at the right-of-way ground surface and any resulting discharge will be directed downslope to prevent accumulation within the LOD. Trench breaker locations are shown on the project E&SCP.

## 1.3 Mitigation Measures

Overall best management practices include:

- controlling surface runoff from the limit of disturbance and the reclaimed construction area to prevent direct flow into exposed debris flow or colluvial deposit;
- intercepting and controlling subsurface drainage from the excavation during construction and post-construction to prevent subsurface infiltration into the underlying debris flow or colluvial deposit;
- constructing in a timely fashion to reduce the amount of time when the limit of disturbance is exposed to the elements and not under final grade;

- and installing additional trench breakers (minimum 25-foot spacing) in areas steeper than 65 percent slope and armoring the ground surface in these steep areas with larger rocks from the trench excavation.

Subsurface conditions observed during construction may dictate the use of enhanced mitigation measures. Site-specific observations made by the Mountain Valley landslide inspection team during construction may result in the team's recommendation for deployment of additional specific mitigation measures, which consider potential native ground movement around or below the ROW, disturbed temporary ground surface movement from initial grading and subsequent construction work and finished and restored ROW surface.

Based on field observations during construction, Mountain Valley may implement slope breakers, water bars, additional grading, French drains, armored slopes and/or ditches as enhanced drainage control measures to promote slope stability.  Mountain Valley does not anticipate that structures will be required to stabilize bedrock within the trench excavation, or adjacent native soils or colluvium, however highwall/steep slope revetments or geogrid may be implemented to increase the stability of backfilled areas if soils do not exhibit the strength parameters modeled herein.

## 1.4 Post-Construction Monitoring and Intervention

See the discussion on post-construction monitoring and potential for intervention for the JNF Priority Sites that is presented in the last section of this document. Slope monitoring is a critical element of post-construction operations of the pipeline and the recommended procedures (including potential reclamation measures) are applicable to all of the JNF Priority Sites.

# 2.0 JNF Priority Site #2

*Coordinates: (*37.30601, -80.397099*) to (*37.30346, -80.394457*)*

## 2.1 Site Description and Geology

This site is on the north side of Brush Mountain from approximately MP 220.5 to MP 220.75 as shown on the October 2016 Proposed Route. The October 24, 2016, *Request for Site-Specific Design of Stabilization Measures in Selected High-Hazard Portions of the Route of the proposed Mountain Valley Pipeline Project in the Jefferson National Forest* letter requested that "the route variation to another ridge on the north side of Brush Mountain" be addressed in addition to the area described above. This ridge is not addressed herein; however, it exhibits similar geologic features to the ridge analyzed in this document.

Slopes along this portion of the right of way range from nearly flat to 46 percent (averaging 26 percent), and are generally steeper in the middle portion of the site. As shown on the plan view slope map of Figure 7, the pipeline route follows a narrow ridge in this area, with side slopes generally about 2H:1V, but in some areas as steep as 1.5H:1V. The site is immediately subjacent to FR 188 – Brush Mountain Road.

A profile of the site is shown on Figure 8. The pipeline will be approximately 8 feet below grade, with the bottom of the pipeline trench located approximately 12 feet below grade. The trench will be backfilled with select backfill, which will be shaker bucket material from the native soil and rock. Cross section 2A is shown on Figures 9, 10, and 11, depicting the anticipated extent of trenching and stockpiled material before, during, and after construction.

According to the Geologic Map of Virginia (1993) the geology of the general vicinity of the JNF Priority Site #2 is highly folded and thrust-faulted, northeast striking and steeply dipping (generally 50-60$^{o}$) Mississippian to Devonian age clastic sedimentary bedrock. The Mississippian Age Price Formation sandstone, conglomeratic sandstone and shale typically forms the Brush Mountain ridge line. West-northwest and downslope from the ridgeline, the proposed alignment overlies Devonian age Chemung Formation sandstone, shale, thin quartz-pebble conglomerates and red beds. Field reconnaissance confirmed that there are no observed bedrock outcrops below the ridgeline in the vicinity of JNF Priority Site #2 and further downslope until the valley floor. Residual soil overburden is present on the northwest slope of Brush Mountain and is likely 10 feet thick or less near the JNF Priority Site #2.

*Photo 6: Exposure of the Price sandstone outcrop at the ridge line near JNF Priority Site #2*

*Photo 7: Downslope exposure of bedrock was not observed, but the steep slopes in the vicinity of the JNF Priority Site #2 suggest only a thin overburden mantle overlies the downslope Devonian age bedrock (view is to the north)*

## 2.2 Potential Slope Failure Hazards

At this site, potential slope failure hazards that were considered included rock failure, unconsolidated overburden failure, shallow failures of the stockpiled trench/topsoil, slope failures subjacent to stockpiles, failure of temporary slopes created during construction, post-construction erosion of the reclaimed right of way, shallow sloughing failures of the trench backfill, and water intrusion from seeps and springs encountered in the trench.

No aquatic resources have been identified in the vicinity of Priority Site #2.

These hazards and associated mitigation and avoidance strategies are discussed in detail below.

### 2.2.1 Rock Failure

Rock-block failure involves gravity-induced movement of large, relatively intact blocks of bedrock on steep slopes. The bedrock mass is typically a complex geological body resulting from variable lithology, tectonic stresses and weathering that lead to differential loading and unloading. Rock-block failures typically occur where stronger bedrock units transition to weaker or weathered units and become undercut. Rock falls or topples entail abrupt movements of bedrock mass or boulders that detach along discontinuities (fractures, joints, bedding planes) or the forward rotation of a unit or units about some pivotal point. Movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water. Field reconnaissance of the JNF Priority Site #2 did not reveal conditions that would lead to potential rock block failure. Bedrock is not exposed as over-steepened cliffs or ledges, is covered by soil overburden, and is likely stable in-place. Therefore, based on field observations of the JNF Priority Site #2 and planned construction activities, Mountain Valley considers the potential for rock failure to be so remote as to be negligible. No mitigation measures for rock failure are anticipated at JNF Priority Site #2.

### 2.2.2 Unconsolidated Overburden Failure

Field observations and geologic mapping indicate that the JNF Priority Site #2 is underlain by a residual soil mantle that overlies clastic sedimentary bedrock. Based on field observations overburden is likely 10 feet thick or less. As discussed above, the pipeline trench in the vicinity of JNF Priority Site #2 will be located as deep as 12 feet below grade, likely below the residual overburden and into the upper reaches of stable shallow bedrock.

Major controls on the potential to initiate a landslide (unconsolidated overburden failure) include topographic gradient and orientation of the slope, bedrock structure, and topographic drainage features that concentrate surface and subsurface water during intense precipitation events. Mountain Valley evaluated overburden observed (as described above) at the JNF Priority Site #2, coupled with the potential for extreme precipitation events, for consideration of failure risk during construction and long-term operation of the pipeline.

#### *Slope Stability and Pipeline Integrity Analyses*

Existing slope stability at the JNF Priority Site #2 was evaluated by establishing safety factors using a numerical model with input from field observations, probabilistic analysis of material properties and analyst experience. Slope failure risk analysis was approximated using the peer-reviewed slope stability program SLIDE (RocScience, Inc.). This model incorporates Bishop, Janbu and Spencer methods, generates circular, non-circular, and optimized shaped failure planes with seismic and boundary loads.

Observations of historical slope failures in other areas suggest that the likely slip plane will occur at the overburden-bedrock interface resembling an infinite slope failure. However, the depth of the slip surface within the colluvium material has a minimal effect on the Factor of Safety (FoS) (i.e., difference of less than 0.05). Therefore, the model simulates a failure surface near the overburden-bedrock interface to represent a failure with an adverse effect and not shallow, surficial sloughs.

A probabilistic model was applied to the colluvial soil shear strength (friction angle) and unit weight using highest and lowest conceivable values (Duncan, 2000). Stability analyses were run for slope angles ranging from 15% (9 degrees) to 76% (37 degrees), which bracket the range of existing slopes observed at and near the JNF Priority Site #2. Modeling also accounted for saturated conditions and seismic loading (0.16 g; see Mountain Valley Pipeline Resource Report #6, seismic hazards analysis). Slope stability model output is provided in Appendix C. Table C-1 in Appendix C summarizes the full range of stability analysis results given the probabilistic analyses for input parameters soil density and friction angle, under increasing slope, saturated and unsaturated conditions, and with and without seismic loading.

In summary from Table C-1, based on likely residual soil density and friction angle values, the existing native overburden slopes at JNF Priority Site #2 are stable (minimum FoS of 1.1) up to at least 65% (33 degrees) native slopes under unsaturated conditions with no seismic loading, and 45% (24 degrees) native slopes with seismic loading. The JNF Priority Site #2 slopes are nearly level to 46%, such that the analysis results suggest the slopes are stable at an acceptable FoS under unsaturated conditions.

Under saturated conditions, risk for slope failure increases substantially. The model confirms what Mountain Valley has already accounted for in construction practices, that the largest effect on the FoS is soil saturation from groundwater intrusion, or surface water infiltration, to the colluvial deposit (i.e., as soils become saturated, stability decreases). As discussed, Mountain Valley is aware of the need to prevent accumulation of storm water during construction, permanently divert subsurface springs or seeps from the pipeline bedding and near vicinity if encountered during construction, and to properly grade and reclaim the ground surface in the LOD after construction. Preventing saturated conditions on these steep slope environments is a critical factor in maintaining slope stability. The project stormwater management plans and subsurface drains implemented during construction will address the issue of overburden saturation.

The analysis suggests there is minimal risk of ground displacement. From the perspective of pipeline integrity and safety, D. G. Honegger Consulting (2015) indicated that slope displacements parallel to the proposed alignment can be screened out as not representing a significant hazard if the length of pipeline exposed to ground displacement is less than 1,150 feet (Class 1 pipe) to 1,640 feet (Class 3 pipe) from the top of the slope (screening approach assumes a relatively straight line with no connections or insulated joints in the screening distance). While Mountain Valley does not anticipate any slope failure to occur, it is even more unlikely that failure on the magnitude of 1,000's of feet will occur. Thus the effects of displacement on the pipeline have not been analyzed. As discussed later in this document, Mountain Valley will implement a post-construction slope monitoring program. If future monitoring observations suggest slope movement is occurring, Mountain Valley will take appropriate actions to stabilize the slope and will evaluate pipeline response to the nature and degree of observed ground displacement using the recommendations provided in PRCI (2009).

### 2.2.3 Soil Stockpile and Subjacent Slope Failure

Soil stockpiles will be compacted via rolling with dozers on site. Excavation and backfilling will be completed as quickly as possible to minimize the duration of stockpiling. At JNF Priority Site #2, the contractor will install a temporary diversion, such as reinforced silt fence, to prevent rocks from rolling off of the ROW. The contractor will install temporary shoring along the edge of the ROW to prevent downslope movement of spoil (as depicted on Figure 10). Temporary stockpile side slopes will not exceed 1. 5H:1V except in areas where temporary shoring is installed subjacent to the soil stockpile. Temporary spoil stockpiles will be stable with a factor of safety of at least 1.2 as demonstrated in Appendix C.

Field observations indicate the likelihood of a thin soil mantle at the site and spoil stockpiles will be stored on rock. Thus, overloading the subjacent slope at JNF Priority Site #2 does not present a technical concern for construction in this area.

### 2.2.4 Temporary Cut Failures

Cut slopes created during construction at JNF Priority Site #2 may approach 15 feet in height and are anticipated to be cut into rock. Cut slopes will not exceed the maximum safe angle per OSHA standards for the type of material being excavated, and as such are expected to be stable during construction. As any cuts made temporarily during construction will be reclaimed with native material (buttressing the cut slope) placed to original contours as practicable, cut slopes are anticipated to be stable in the long term.

### 2.2.5 Erosion

Erosion hazards will be mitigated by following the project E&SCP. Refer to the E&SCP for details.

### 2.2.6 Trench Backfill and Reclaimed Sideslope Failures

The pipeline trench will be provided with trench breakers at locations specified in the project E&SCP. These trench breakers will act as gravity retaining walls within the trench to hold the backfill in place during construction and will slow the velocity of water running through the trench, preventing subsurface erosion. Every third trench breaker at this location will be provided with daylight drains, as shown on typical drawing MVP-35, discharging water building up in the trench to water dissipation devices at the ground surface. All trench breakers not provided with daylight drains will be provided with pass-through drains as shown on typical drawing MVP-43.

Trench backfill is anticipated to be stable with a factor of safety of at least 1.5 as demonstrated in Appendix C.

Along the ridge where JNF Priority Site #2 is located, sideslopes approach 1:5H:1V. The excavated material will be replaced in compacted lifts not exceeding 12 inches in thickness. The stability of the reclaimed slope was modeled using GSTABL7 software. Slope stability analysis presented in Appendix C show that the backfill is stable with a factor of safety of at least 1.5. The landslide inspection team will evaluate this area during reclamation and may prescribe the use of geogrid (as shown on typical drawing MVP-42) to further stabilize areas of the hillside if the excavated and replaced material does not demonstrate the strength parameters modeled herein.

To maintain long-term stability of the backfill, the fill should be kept as dry as possible by means of subsurface drains. Transverse trench drains, as shown on typical drawing MVP-38, will be installed at 100-foot intervals throughout JNF Priority Site #2.

A thin residuum overburden mantle overlies bedrock in the vicinity of the JNF Priority Site #2, such that Mountain Valley anticipates the proposed pipeline trench will be installed in bedrock (if practical). In the unlikely event of a slope failure, the thin unconsolidated mantle would release parallel to the pipeline and trench axes (i.e., downslope) and there would be no anticipated effect to the bedrock hosting the pipeline.

### 2.2.7 Seeps and Springs

As the presence of seeps/springs encountered in the pipeline trench or temporary construction excavation will not be known until the trench is excavated, their location and extent cannot be determined at this time. At JNF Priority Site #2, seepage (if any is encountered) will be captured by daylight drains behind the trench breakers, as shown on typical drawing MVP-35, or with transverse trench drains as shown on typical drawing MVP-38. These drains will outlet to energy dissipation devices at the right-of-way ground surface. Trench breaker locations are shown on the E&SCP.

## 2.3 Mitigation Measures

Overall best management practices include:

- controlling surface runoff from the limit of disturbance and the reclaimed construction area to prevent direct flow into exposed debris flow or colluvial deposit;
- intercepting and controlling subsurface drainage from the excavation during construction and post-construction to prevent subsurface infiltration into the underlying debris flow or colluvial deposit;
- constructing in a timely fashion to reduce the amount of time when the limit of disturbance is exposed to the elements and not under final grade.
- and embedding the pipeline completely with in the bedrock trench, as practical.

Subsurface conditions observed during construction may dictate the use of enhanced mitigation measures. Site-specific observations made by the Mountain Valley landslide inspection team during construction may result in the team's recommendation for deployment of additional specific mitigation measures, which consider potential native ground movement around or below the ROW, disturbed temporary ground surface movement from initial grading and subsequent construction work and finished and restored ROW surface.

Based on field observations during construction, Mountain Valley may implement slope breakers, water bars, additional grading, French drains, armored slopes and/or ditches as enhanced drainage control measures to promote slope stability. Mountain Valley does not anticipate that structures will be required to stabilize bedrock within the trench excavation, or adjacent native soils or colluvium, however highwall/steep slope revetments or geogrid may be implemented to increase the stability of backfilled areas if soils do not exhibit the strength parameters modeled herein.

## 2.4 Post-Construction Monitoring and Intervention

See the discussion on post-construction monitoring and potential for intervention for the JNF Priority Sites that is presented in the last section of this document. Slope monitoring is a critical element of post-construction operations of the pipeline and the recommended procedures (including potential reclamation measures) are applicable to all of the JNF Priority Sites.

# 3.0 JNF Priority Site #3

*Coordinates: (37.401887, -80.689491) to (37.400977, -80.687575)*

## 3.1 Site Description and Geology

This site is located on the southeast slope of Peters Mountain, downslope from the bore pit from approximately MP 196.4 to 196.55 as shown on the October 2016 Proposed Route.

Slopes along this portion of the right of way range from nearly flat to 41 percent (averaging 27 percent), and are generally steeper at the northern portion of the site near the bore pit. Sideslopes are generally about 3H:1V or shallower except in limited areas where slopes approach 2.5H:1V. As shown on the plan view slope map of Figure 12, the pipeline route runs generally east-west and slightly sidehill upon exiting the bore pit and then turns south, where the ground surface slopes gently.

A profile of the site is shown on Figure 13. The pipeline will be approximately 10 feet below grade in the sidehill portion of the alignment and three feet below grade in the flatter area. The trench will be backfilled with select backfill, which will be shaker bucket material from the native soil and rock. Cross section 3A is shown on Figures 14, 15, and 16, depicting the anticipated extent of trenching and stockpiled material before, during, and after construction in the sidehill portion of JNF Priority Site #3. The flatter portion of the site will resemble the drawings associated with JNF Priority Site #1.

According to Rader and Gathright (1986) and Schultz and Stanley (2001) the geology in the general vicinity of the JNF Priority Site #3 vicinity is highly folded and thrust-faulted sedimentary bedrock. Underlying the site is the Devonian age Rose Hill Formation (red shales, mudstone, fine to medium sandstones), striking northeast-southwest with a moderate southeast dip of (generally $30^{o}$). North of the JNF Priority Site #3 the slope becomes steeper as it ascends to the ridgeline (i.e., thin soil mantle over weather-resistant bedrock outcrop with southeast dip). Downslope from the site, a large colluvial deposit is mapped (Schultz and Stanley, 2001), and observed in the field to be predominantly comprised of Rose Hill bedrock float that has weathered and sloughed from the outcrop on the topographically higher ridge. The colluvial overburden obscures bedrock outcrop on the slope at JNF Priority Site #3.

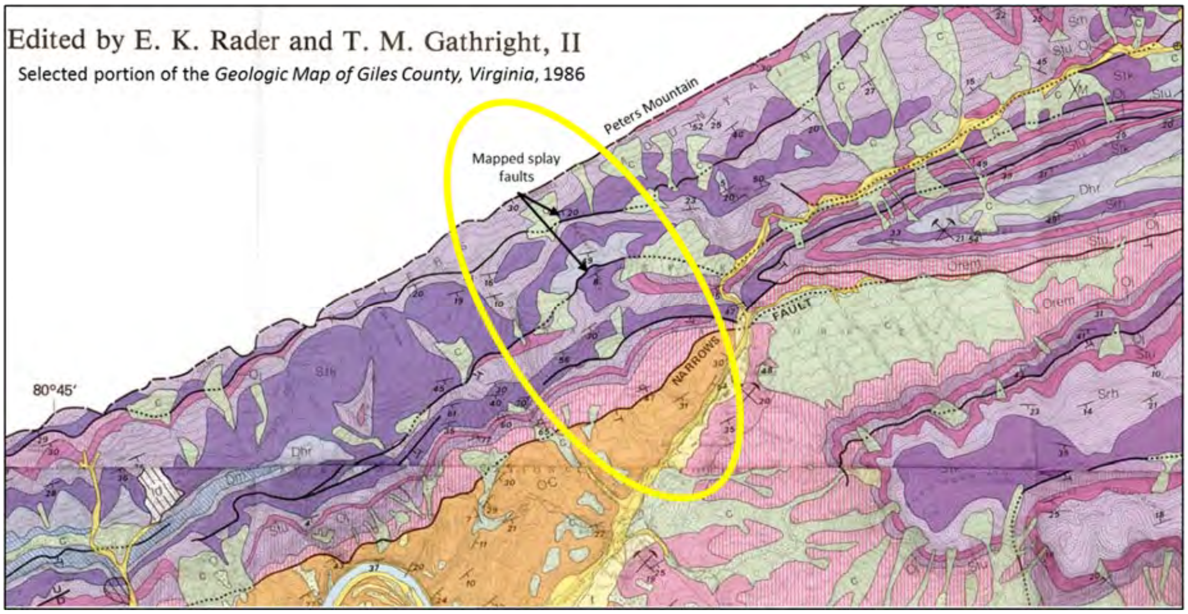
*Photo 8: Rose Hill sandstone outcrop on ridge top north of the JNF Priority Site #3, dipping to the south (view to northeast)*

*Photo 9: Rose Hill sandstone outcrop on ridge top north of the JNF Priority Site #3, dipping to the south (view to the southwest)*

*Photo 10: Slope approximately 800 feet south of the ridge line*

*Photo 11: Colluvial deposit float (predominantly Rose Hill sandstone) at ground surface in the near vicinity of the JNF Priority Site #3 (view is to the west toward the upslope ridgeline)*

The exhibit presented below was excerpted from Rader and Gathright (1986) showing the mapped geology of the Mystery Ridge area of Giles County, Virginia (encompassing JNF Priority Sites #1, #4, #3 and #5) and is intended to highlight the following discussion.




The yellow ellipse in the image above demarks the general area of the proposed alignment (not shown). The mapped locations of three splay faults of the Narrows thrust fault, and the fault itself, are mapped downslope (southeast) of JNF Priority Site #3. The fault zone is no longer active as the tectonic processes that led to thrust faulting are no longer active on the eastern margin of North America. However, the remnant fault zone may have some measure of effect on surface and groundwater flow rate and direction, and may also be comprised of relatively weak brecciated bedrock. Also, the proposed alignment in this area passes over and near colluvial deposits, which are indicative of ancient (Pleistocene) mass movement.

In general, on steep slopes on JNF property, regardless of the specific geologic conditions, Mountain Valley recognizes that a key factor in maintaining slope stability is to control surface and subsurface water flow such that saturated soil and overburden conditions do not occur. Mountain Valley will take all appropriate actions during construction and after reclamation to manage surface and subsurface water to prevent saturated conditions on native and engineered slopes. Caution will be used to avoid reactivation of unstable deposits, and appropriate management of surface and subsurface drainage is crucial. The extent and character of the breccia zones, if observable at the ground surface, will be investigated by the landslide inspection team during initial land clearing and grubbing, and appropriate recommendations made to ensure construction stability and long-term pipeline integrity.

## 3.2 Potential Slope Failure Hazards

At this site, potential slope failure hazards that were considered included rock failure, debris flow, remobilization of colluvial deposits, shallow failures of the stockpiled trench/topsoil, slope failures subjacent to stockpiles, failure of temporary slopes created during construction, post-construction erosion of the reclaimed right of way, shallow sloughing failures of the trench backfill, and water intrusion from seeps and springs encountered in the trench.

Stream S-KL24 is located immediately southwest of the temporary LOD and could be impacted in the event of a failure.

These hazards and associated mitigation and avoidance strategies are discussed in detail below.

### 3.2.1 Rock Failure

Rock-block failure involves gravity-induced movement of large, relatively intact blocks of bedrock on steep slopes. The bedrock mass is typically a complex geological body resulting from variable lithology, tectonic stresses and weathering that lead to differential loading and unloading.  Rock-block failures typically occur where stronger bedrock units transition to weaker or weathered units and become undercut. Rock falls or topples entail abrupt movements of bedrock mass or boulders that detach along discontinuities (fractures, joints, bedding planes) or the forward rotation of a unit or units about some pivotal point. Movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water. Field reconnaissance of the JNF Priority Site #3 did not reveal conditions that would lead to potential rock block failure. Bedrock is not exposed as over-steepened cliffs or ledges, is covered by soil overburden, and is likely stable in-place. Therefore, based on field observations of the JNF Priority Site #3 and planned construction activities, Mountain Valley considers the potential for rock failure to be so remote as to be negligible. No mitigation measures for rock failure are anticipated at JNF Priority Site #3.

### 3.2.2 Debris Flow / Colluvial Deposit

Debris flows are generally considered to be high-energy, rapid downslope movement of earth material that can entrain trees and other large objects in the flow path.  A debris flow differs from rock-block slide in that there are no well-defined blocks moving along shear surfaces. Instead, the mass flows downhill, with shear strains present everywhere.  Debris flows generally occur during intense precipitation events, and travel rapidly downslope along existing drainage channels or stream valleys, transporting and depositing mud, sand, gravel, and boulders where the slope gradient flattens. Multiple debris flows may coalesce into a central channel downslope from the points of initiation.

Colluvial deposits observed in the vicinity of the JNF Priority Site #3 may be derived from past debris flow(s), or other forms of mass wasting. However, debris flows are grouped with colluvial deposits for this analysis because pipeline construction and boring within, or in the vicinity of an observed colluvial deposit entails similar precautions to that for a debris flow.

Major controls on the potential to initiate a debris flow include topographic gradient and orientation of the slope, bedrock structure, and the accumulation of historic debris flows in topographic drainage features that concentrate surface and subsurface water during intense precipitation events. As noted above, pipeline construction in the vicinity of the JNF Priority Site #3 will be as much as 10 feet below grade. Field observations of the JNF Priority Site #3 suggest that pipeline construction will possibly remain within the colluvial deposits, but may encounter the upper reaches of shallow, stable bedrock. Topographic and bedrock conditions are likely not susceptible to generating a new debris flow at the JNF Priority #3 site. However, colluvial deposit(s) observed at, and in the near vicinity of, the site (as described above), coupled with the potential for extreme precipitation events, warrant consideration for construction, boring and long-term operation of the pipeline.

### *Slope Stability and Pipeline Integrity Analyses*

Existing slope stability at the JNF Priority Site #3 was evaluated by establishing safety factors using a numerical model with input from field observations, probabilistic analysis of material properties and analyst experience. Slope failure risk analysis was approximated using the peer-reviewed slope stability program SLIDE (RocScience, Inc.). This model incorporates Bishop, Janbu and Spencer methods, generates circular, non-circular, and optimized shaped failure planes with seismic and boundary loads.

Observations of historical slope failures in other areas suggest that the likely slip plane will occur at the overburden-bedrock interface resembling an infinite slope failure. However, the depth of the slip surface within the colluvium material has a minimal effect on the Factor of Safety (FoS) (i.e., difference of less than 0.05). Therefore, the model simulates a failure surface near the overburden-bedrock interface to represent a failure with an adverse effect and not shallow, surficial sloughs.

A probabilistic model was applied to the colluvial soil shear strength (friction angle) and unit weight using highest and lowest conceivable values (Duncan, 2000). Stability analyses were run for slope angles ranging from 15% (9 degrees) to 76% (37 degrees), which bracket the range of existing slopes observed at and near the JNF Priority Site #3. Modeling also accounted for saturated conditions and seismic loading (0.16 g; see Mountain Valley Pipeline Resource Report #6, seismic hazards analysis). Slope stability model output is provided in Appendix C. Table C-1 in Appendix C summarizes the full range of stability analysis results given the probabilistic analyses for input parameters soil density and friction angle, under increasing slope, saturated and unsaturated conditions, and with and without seismic loading. In summary from Table C-1, based on likely residual soil density and friction angle values, the existing native overburden slopes at JNF Priority Site #3 are stable (minimum FoS of 1.1) up to at least 65% (33 degrees) native slopes under unsaturated conditions with no seismic loading, and 45% (24 degrees) native slopes with seismic loading. The JNF Priority Site #3 slopes are approximately 41%, such that the analysis results suggest the slopes are stable at an acceptable FoS under unsaturated conditions.

Under saturated conditions, risk for slope failure increases substantially. The model confirms what Mountain Valley has already accounted for in construction practices, that the largest effect on the FoS is soil saturation from groundwater intrusion, or surface water infiltration, to the colluvial deposit (i.e., as soils become saturated, stability decreases). As discussed, Mountain Valley is aware of the need to prevent accumulation of storm water during construction, permanently divert subsurface springs or seeps from the pipeline bedding and near vicinity if encountered during construction, and to properly grade and reclaim the ground surface in the limit of disturbance after construction. Preventing saturated conditions on these steep slope environments is a critical factor in maintaining slope stability. The project stormwater management plans and subsurface drains implemented during construction will address the issue of overburden saturation.

The analysis suggests there is minimal risk of ground displacement. From the perspective of pipeline integrity and safety, D. G. Honegger Consulting (2015) indicated that slope displacements parallel to the proposed alignment can be screened out as not representing a significant hazard if the length of pipeline exposed to ground displacement is less than 1,150 feet (Class 1 pipe) to 1,640 feet (Class 3 pipe) from the top of the slope (screening approach assumes a relatively straight line with no connections or insulated joints in the screening distance). While Mountain Valley does not anticipate any slope failure to occur, it is even more unlikely that failure on the magnitude of 1,000’s of feet will occur. Thus the effects of displacement on the pipeline have not been analyzed. As discussed later in this document, Mountain Valley will implement a post-construction slope monitoring program. If future monitoring observations suggest slope movement is occurring, Mountain Valley will take appropriate actions to stabilize the slope and will evaluate pipeline response to the nature and degree of observed ground displacement using the recommendations provided in PRCI (2009).

### 3.2.3 Soil Stockpile and Subjacent Slope Failure

Soil stockpiles will be compacted via rolling with dozers on site. Excavation and backfilling will be completed as quickly as possible to minimize the duration of stockpiling. At JNF Priority Site #3, the contractor will install a temporary diversion, such as reinforced silt fence, to prevent rocks from rolling off of the ROW. Temporary spoil stockpiles will be stable with a factor of safety of at least 1.2 as demonstrated in Appendix C.

Colluvial deposits were observed in the flatter portions of the site. Stability of the native material underlying spoil stockpiles is of concern. The spoil will be spread out across the workspace to the extent practicable to avoid overloading the in-situ colluvial soils. Stockpiles will be compacted via rolling with dozers to prevent water infiltration which will minimize the weight of the stockpiled soil.

The landslide inspection team deployed by Mountain Valley during construction will evaluate the subgrade to determine whether or not it is appropriate to stockpile soils in the vicinity of the colluvial deposit. The exact thickness of the colluvial deposit will not be fully determined until excavation is initiated, but as previously described, colluvial debris generally follow ravines and drainage paths and the pipeline ROW is located on a ridge, it is unlikely that the colluvial deposit is extremely thick in the workspace area. Therefore, it may be sufficiently thin that instability due to stockpiled material is not a concern. If colluvial deposits exceed about five feet, spoil stockpiles will be moved up or downslope to a more stable area to avoid overloading the colluvial deposit and initiating a failure.

### 3.2.4 Temporary Cut Failures

Cut slopes created during construction at JNF Priority Site #3 may approach 10 feet in height and are anticipated to be cut into rock. Cut slopes will not exceed the maximum safe angle per OSHA standards for the type of material being excavated, and as such are expected to be stable during construction. As any cuts made temporarily during construction will be reclaimed with native material (buttressing the cut slope) placed to original contours as practicable, cut slopes are expected to be stable in the long term.

### 3.2.5 Erosion

Erosion hazards will be mitigated by following the project Erosion and Sediment Control Plan (E&SCP). Refer to the E&SCP for details.

### 3.2.6 Trench Backfill and Reclaimed Sideslope Failures

The pipeline trench will be provided with trench breakers at locations specified in the project E&SCP. These trench breakers will act as gravity retaining walls within the trench to hold the backfill in place during construction and will slow the velocity of water running through the trench, preventing subsurface erosion. Every third trench breaker at this location will be provided with daylight drains, as shown on typical drawing MVP-35, discharging water building up in the trench to water dissipation devices at the ground surface. All trench breakers not provided with daylight drains will be provided with pass-through drains as shown on typical drawing MVP-43.

Trench backfill is anticipated to be stable with a factor of safety of at least 1.5 as demonstrated in Appendix C.

Through the sidehill portion of JNF Priority Site #3, sideslopes approach 2:5H:1V. The excavated material will be replaced in compacted lifts not exceeding 12 inches in thickness. The stability of the reclaimed slope was modeled using GSTABL7 software. Slope stability analysis presented in Appendix C show that the backfill is stable with a factor of safety of at least 1.5. The landslide inspection team will evaluate this area during reclamation and may prescribe the use of geogrid (as shown on typical drawing MVP-42) to further stabilize areas of the hillside if the excavated and replaced material does not demonstrate the strength parameters modeled herein.

To maintain long-term stability of the backfill, the fill should be kept as dry as possible by means of subsurface drains. Transverse trench drains, as shown on typical drawing MVP-38, will be installed at 100-foot intervals throughout JNF Priority Site #3.

### 3.2.7 Seeps and Springs

As the presence of seeps/springs encountered in the pipeline trench or temporary construction excavation will not be known until the trench is excavated, their location and extent cannot be determined at this time. At JNF Priority Site #3, seepage (if any is encountered) will be captured by daylight drains behind the trench breakers, as shown on typical drawing MVP-35, or with transverse trench drains as shown on typical drawing MVP-38. These drains will outlet to energy dissipation devices at the right-of-way ground surface. Trench breaker locations are shown on the E&SCP.

## 3.3 Bore Pit

It should be noted that stability of the bore pit is not considered herein. Temporary shoring will be developed by the bore contractor to all applicable safety standards to protect both the open bore pit and the stockpiled spoil material excavated from the bore pit. The landslide inspection team will evaluate the site to determine if any mitigation measures, in addition to those proposed by the contractor, are necessary.

## 3.4 Mitigation Measures

Overall best management practices include:

- controlling surface runoff from the limit of disturbance and the reclaimed construction area to prevent direct flow into exposed debris flow or colluvial deposit;

- intercepting and controlling subsurface drainage from the excavation during construction and post-construction to prevent subsurface infiltration into the underlying debris flow or colluvial deposit;
- constructing in a timely fashion to reduce the amount of time when the limit of disturbance is exposed to the elements and not under final grade;
- and embedding the pipeline completely with in the bedrock trench, if practical.

Subsurface conditions observed during construction may dictate the use of enhanced mitigation measures. Site-specific observations made by the Mountain Valley landslide inspection team during construction may result in the team's recommendation for deployment of additional specific mitigation measures, which consider potential native ground movement around or below the ROW, disturbed temporary ground surface movement from initial grading and subsequent construction work and finished and restored ROW surface.

Based on field observations during construction, Mountain Valley may implement slope breakers, water bars, additional grading, French drains, armored slopes and/or ditches as enhanced drainage control measures to promote slope stability. Mountain Valley does not anticipate that structures will be required to stabilize bedrock within the trench excavation, or adjacent native soils or colluvium, however highwall/steep slope revetments or geogrid may be implemented to increase the stability of backfilled areas if soils do not exhibit the strength parameters modeled herein.

## 3.5 Post-Construction Monitoring and Intervention

See the discussion on post-construction monitoring and potential for intervention for the JNF Priority Sites that is presented in the last section of this document. Slope monitoring is a critical element of post-construction operations of the pipeline and the recommended procedures (including potential reclamation measures) are applicable to all of the JNF Priority Sites.

# 4.0 JNF Priority Site #4

*Coordinates: (37.387563, -80.682672) to (37.38578, -80.681428)*

## 4.1 Site Description and Geology

This site is located on the steepest slopes downslope from the bore pit on the south side of Peters Mountain from approximately MP 197.75 to 197.95 on the October 2016 Proposed Route. This portion of the right of way is located at the southern extent of Mystery Ridge.

Slopes along this portion of the right of way range from nearly flat to 58 percent (averaging 23 percent), and are generally steeper on the southeastern side of Mystery Ridge. Sideslopes are generally 3H:1V or shallower throughout the site. As shown on the plan view slope map of Figure 17, the pipeline in this area parallels and then crosses Mystery Ridge Road on a gentle sidehill, then turns southeast.

A profile of the site is shown on Figure 18. The pipeline will be up to approximately seven feet below grade, with the bottom of the pipeline trench located approximately eleven feet below grade. The trench will be backfilled with select backfill, which will be shaker bucket material from the native soil and rock. Cross section 4A is shown on Figures 19, 20, and 21, and cross section 4B is shown on Figures 22, 23, and 24, depicting the anticipated extent of trenching and stockpiled material before, during, and after construction.

According to Rader and Gathright (1986) and Schultz and Stanley (2001) the geology of the JNF Priority Site #4 vicinity is highly folded and thrust-faulted sedimentary bedrock (typical of the Valley and Ridge geologic province of Virginia). Bedrock underlying the JNF Priority #4 site is mapped to be northeast striking and moderately dipping (generally 30-40$^{o}$) upper Silurian age undivided Tonoloway Limestone and Keefer Sandstone. A splay fault of the Narrows thrust fault is mapped downslope of the JNF Priority Site #4, as an unconformable contact between the Tonoloway and Keefer bedrock and Silurian age Rose Hill sandstone. JNF Priority Site #4 is located approximately 1,000 feet upslope from JNF Priority Site #1 (downslope and older bedrock was described previously for the JNF Priority Site #1). Bedrock outcrops of the Tonoloway Limestone or Keefer Sandstone were not observed during field reconnaissance of the JNF Priority Site #4.

## 4.2 Potential Slope Failure Hazards

At this site, potential slope failure hazards that were considered included rock failure, debris flow, remobilization of colluvial deposits, shallow failures of the stockpiled trench/topsoil, slope failures subjacent to stockpiles, failure of temporary slopes created during construction, post-construction erosion of the reclaimed right of way, shallow sloughing failures of the trench backfill, and water intrusion from seeps and springs encountered in the trench.

No aquatic resources were delineated in this area.

These hazards and associated mitigation and avoidance strategies are discussed in detail below.

### 4.2.1 Rock Failure

Rock-block failure involves gravity-induced movement of large, relatively intact blocks of bedrock on steep slopes. The bedrock mass is typically a complex geological body resulting from variable lithology, tectonic stresses and weathering that lead to differential loading and unloading. Rock-block failures typically occur where stronger bedrock units transition to weaker or weathered units and become undercut. Rock falls or topples entail abrupt movements of bedrock mass or boulders that detach along discontinuities (fractures, joints, bedding planes) or the forward rotation of a unit or units about some pivotal point. Movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water. Field reconnaissance of the JNF Priority Site #4 did not reveal conditions that would lead to potential rock block failure. Bedrock is not exposed as over-steepened cliffs or ledges, is covered by soil overburden, and is likely stable in-place. Therefore, based on field observations of the JNF Priority Site #4 and planned construction activities, Mountain Valley considers the potential for rock failure to be so remote as to be negligible. No mitigation measures for rock failure are prescribed at JNF Priority Site #4.

### 4.2.2 Unconsolidated Overburden Failure

Field reconnaissance of the JNF Priority Site #4 and vicinity revealed bedrock outcrops, thin soil mantle and no notable topographically overlying overburden or bedrock exposure, which indicate negligible potential for debris flow activation. Based on field observations, the residual overburden is less than 10 feet deep. As discussed above, the pipeline trench in the vicinity of JNF Priority Site #4 will be approximately 7 to 11 feet below grade, likely below the residual overburden and into the upper reaches of stable shallow bedrock.

Major controls on the potential to initiate a landslide (unconsolidated overburden failure) include topographic gradient and orientation of the slope, bedrock structure, and topographic drainage features that concentrate surface and subsurface water during intense precipitation events. Mountain Valley evaluated overburden observed (as described above) at the JNF Priority Site #4, coupled with the potential for extreme precipitation events, for consideration of failure risk during construction and long-term operation of the pipeline.

### *Slope Stability and Pipeline Integrity Analyses*

Existing slope stability at the JNF Priority Site #4 was evaluated by establishing safety factors using a numerical model with input from field observations, probabilistic analysis of material properties and analyst experience. Slope failure risk analysis was approximated using the peer-reviewed slope stability program SLIDE (RocScience, Inc.). This model incorporates Bishop, Janbu and Spencer methods, generates circular, non-circular, and optimized shaped failure planes with seismic and boundary loads.

Observations of historical slope failures in other areas suggest that the likely slip plane will occur at the overburden-bedrock interface resembling an infinite slope failure. However, the depth of the slip surface within the colluvium material has a minimal effect on the Factor of Safety (FoS) (i.e., difference of less than 0.05). Therefore, the model simulates a failure surface near the overburden-bedrock interface to represent a failure with an adverse effect and not shallow, surficial sloughs.

A probabilistic model was applied to the colluvial soil shear strength (friction angle) and unit weight using highest and lowest conceivable values (Duncan, 2000). Stability analyses were run for slope angles ranging from 15% (9 degrees) to 76% (37 degrees), which bracket the range of existing slopes observed at and near the JNF Priority Site #4. Modeling also accounted for saturated conditions and seismic loading (0.16 g; see Mountain Valley Pipeline Resource Report #6, seismic hazards analysis). Slope stability model output is provided in Appendix C. Table C-1 in Appendix C summarizes the full range of stability analysis results given the probabilistic analyses for input parameters soil density and friction angle, under increasing slope, saturated and unsaturated conditions, and with and without seismic loading.

In summary from Table C-1, based on likely residual soil density and friction angle values, the existing native overburden slopes at JNF Priority Site #4 are stable (minimum FoS of 1.1) up to at least 65% (33 degrees) native slopes under unsaturated conditions with no seismic loading, and 45% (24 degrees) native slopes with seismic loading. The JNF Priority Site #4 slopes are nearly level to approximately 58% (average of 23%), such that the analysis results suggest the slopes are stable at an acceptable FoS under unsaturated conditions, and given that the pipeline will be bedded in stable bedrock with negligible risk for slope failure under seismic loading.

Under saturated conditions, risk for slope failure increases substantially. The model confirms what Mountain Valley has already accounted for in construction practices, that the largest effect on the FoS is soil saturation from groundwater intrusion, or surface water infiltration, to the colluvial deposit (i.e., as soils become saturated, stability decreases). As discussed, Mountain Valley is aware of the need to prevent accumulation of storm water during construction, permanently divert subsurface springs or seeps from the pipeline bedding and near vicinity if encountered during construction, and to properly grade and reclaim the ground surface in the LOD after construction. Preventing saturated conditions on these steep slope environments is a critical factor in maintaining slope stability.  The project stormwater management plans and subsurface drains implemented during construction will address the issue of overburden saturation.

The analysis suggests there is minimal risk of ground displacement. From the perspective of pipeline integrity and safety, D. G. Honegger Consulting (2015) indicated that slope displacements parallel to the proposed alignment can be screened out as not representing a significant hazard if the length of pipeline exposed to ground displacement is less than 1,150 feet (Class 1 pipe) to 1,640 feet (Class 3 pipe) from the top of the slope (screening approach assumes a relatively straight line with no connections or insulated joints in the screening distance). While Mountain Valley does not anticipate any slope failure to occur, it is even more unlikely that failure on the magnitude of 1,000’s of feet will occur. Thus the effects of displacement on the pipeline have not been analyzed. As discussed later in this document, Mountain Valley will implement a post-construction slope monitoring program. If future monitoring observations suggest slope movement is occurring, Mountain Valley will take appropriate actions to stabilize the slope and will evaluate pipeline response to the nature and degree of observed ground displacement using the recommendations provided in PRCI (2009).

### 4.2.3 Soil Stockpile and Subjacent Slope Failure

Spoil stockpiles will be compacted via rolling with dozers on site.  Excavation and backfilling will be completed as quickly as possible to minimize the duration of stockpiling.  At JNF Priority Site #4, the contractor will install a temporary diversion, such as reinforced silt fence, to prevent rocks from rolling off of the ROW.  Temporary spoil stockpiles will be stable with a factor of safety of at least 1.2 as demonstrated in Appendix C.

Field observations revealed a thin soil mantle and spoil stockpiles will be stored on bedrock.  Thus, overloading the subjacent slope at JNF Priority Site #4 is not anticipated to occur and does not present a technical concern for construction in this area.

### 4.2.4 Temporary Cut Failures

Cut slopes created during construction at JNF Priority Site #4 may approach 15 feet in height and are anticipated to be cut into rock.  Cut slopes will not exceed the maximum safe angle per OSHA standards for the type of material being excavated, and as such are expected to be stable during construction.  As any cuts made temporarily during construction will be reclaimed with native material (buttressing the cut slope) placed to original contours as practicable, cut slopes are expected to be stable in the long term.

### 4.2.5 Erosion

Erosion hazards will be mitigated by following the project Erosion and Sediment Control Plan (E&SCP). Refer to the E&SCP for details.

### 4.2.6 Trench Backfill and Reclaimed Sideslope Failures

The pipeline trench will be provided with trench breakers at locations specified in the project E&SCP. These trench breakers will act as gravity retaining walls within the trench to hold the backfill in place during construction and will slow the velocity of water running through the trench, preventing subsurface erosion. Every third trench breaker at this location will be provided with daylight drains, as shown on typical drawing MVP-35, discharging water building up in the trench to water dissipation devices at the ground surface. All trench breakers not provided with daylight drains will be provided with pass-through drains as shown on typical drawing MVP-43.

Trench backfill is anticipated to be stable with a factor of safety of at least 1.5 as demonstrated in Appendix C.

Through the sidehill portion of JNF Priority Site #4, sideslopes approach 2:5H:1V. The excavated material will be replaced in compacted lifts not exceeding 12 inches in thickness. The stability of the reclaimed slope was modeled using GSTABL7 software. Slope stability analysis presented in Appendix C show that the backfill is stable with a factor of safety of at least 1.5. The landslide inspection team will evaluate this area during reclamation and may prescribe the use of geogrid (as shown on typical drawing MVP-42) to further stabilize areas of the hillside if the excavated and replaced material does not demonstrate the strength parameters modeled herein.

To maintain long-term stability of the backfill, the fill should be kept as dry as possible by means of subsurface drains. Transverse trench drains, as shown on typical drawing MVP-38, will be installed at 100-foot intervals throughout JNF Priority Site #4.

In this area, the pipeline should be fully embedded in the bedrock trench to prevent damage to the pipeline in the unanticipated event of a slope failure.

### 4.2.7 Seeps and Springs

As the presence of seeps/springs encountered in the pipeline trench or temporary construction excavation will not be known until the trench is excavated, their location and extent cannot be determined at this time. At JNF Priority Site #4, seepage (if any is encountered) will be captured by daylight drains behind the trench breakers, as shown on typical drawing MVP-35, or with transverse trench drains as shown on typical drawing MVP-38. These drains will outlet to energy dissipation devices at the right-of-way ground surface. Trench breaker locations are shown on the E&SCP.

## 4.3 Mitigation Measures

Overall best management practices include:

- controlling surface runoff from the limit of disturbance and the reclaimed construction area to prevent direct flow into exposed debris flow or colluvial deposit;
- intercepting and controlling subsurface drainage from the excavation during construction and post-construction to prevent subsurface infiltration into the underlying debris flow or colluvial deposit;
- constructing in a timely fashion to reduce the amount of time when the limit of disturbance is exposed to the elements and not under final grade;
- and embedding the pipeline completely within the bedrock trench, as practicable.

Subsurface conditions observed during construction may dictate the use of enhanced mitigation measures. Site-specific observations made by the Mountain Valley landslide inspection team during construction may result in the team's recommendation for deployment of additional specific mitigation measures, which consider potential native ground movement around or below the ROW, disturbed temporary ground surface movement from initial grading and subsequent construction work and finished and restored ROW surface.

Based on field observations during construction, Mountain Valley may implement slope breakers, water bars, additional grading, French drains, armored slopes and/or ditches as enhanced drainage control measures to promote slope stability. Mountain Valley does not anticipate that structures will be required to stabilize bedrock within the trench excavation, or adjacent native soils or colluvium, however highwall/steep slope revetments or geogrid may be implemented to increase the stability of backfilled areas if soils do not exhibit the strength parameters modeled herein.

## 4.4 Post-Construction Monitoring and Intervention

See the discussion on post-construction monitoring and potential for intervention for the JNF Priority Sites that is presented in the last section of this document. Slope monitoring is a critical element of post-construction operations of the pipeline and the recommended procedures (including potential reclamation measures) are applicable to all of the JNF Priority Sites.

# 5.0 JNF Priority Site #5

*Coordinates: (37.406782, -80.693608) to (37.403354, -80.690408)*

## 5.1 Site Description and Geology

This site is located on the northwest side of Peters Mountain downslope from the bore pit, mostly subjacent to US Forest Service property on private lands, from approximately MP 196.0 to 196.3 on the October 2016 Proposed Route.

Slopes along this portion of the right of way range from 13 to 60 percent (averaging 41 percent), and are generally steeper at the southern portion of the site, approaching the crest of Peters Mountain. The ridge is relatively wide and gently sloping with side slopes no steeper than 4H:1V. As shown on the plan view slope map of Figure 25, the pipeline in this area follows a wide ridge with gentle side slopes up Peters Mountain.

A profile of the site is shown on Figure 26. The pipeline will be approximately three feet below grade, with the bottom of the pipeline trench located approximately seven feet below grade. The trench will be backfilled with select backfill, which will be shaker bucket material from the native soil and rock. Cross section 5A is shown on Figures 27, 28, and 29, depicting the anticipated extent of trenching and stockpiled material before, during, and after construction.

While separated by less than approximately 1,500 feet, the JNF Priority Site #3 is located in Virginia while the JNF Priority Site #5 is in West Virginia. Geologic mapping of Monroe County, West Virginia is not as well developed as that for Virginia. According to the Geologic and Economic Map of Monroe County, West Virginia (1925), the JNF Priority Site #5, located on the north-northwest facing slope of Peters Mountain within approximately 800 feet of the ridgeline, is underlain by the upper Ordovician Age Red Medina Formation and Martinsburg Series, which correspond to the Juniata Formation and undivided Reedsville Shale / Trenton Limestone, respectively, in Virginia. Closer to the ridge line, the White Medina and Red Medina Formation (corresponding to the Silurian Tuscarora and Rose Hill Formations in Virginia) form a series of steep slope benches. Consistent with the conditions observed at JNF Priority Site #3, bedrock strike is to the northeast (parallel to the Peters Mountain ridgeline), dipping to the south-southeast toward Virginia. In a general but not exact analog, JNF Priority Site #5 is consistent with JNF Priority Site #2, where the area is located north-northwest and downslope from the ridge line on bedrock that dips back into the mountain to the south-southeast.

*Photo 12: White Medina (Tuscarora) sandstone forming ridgeline, dipping south-southeast back into the ridge (view is to the north)*

*Photo 13: Downslope to the north-northwest from the ridgeline near where slopes are reduced toward JNF Priority Site #5 (below bore pit), underlain by Martinsburg Series bedrock (view is to the west-southwest)*

As noted above, the JNF Priority Site #5 is located downslope from the ridge line and downslope from the bore pit. This site is analogous to JNF Priority Site #2, with relatively thin residual soil overburden overlying clastic sedimentary bedrock.

## 5.2 Potential Slope Failure Hazards

At this site, potential slope failure hazards that were considered included rock failure, debris flow, remobilization of colluvial deposits, shallow failures of the stockpiled trench/topsoil, slope failures subjacent to stockpiles, failure of temporary slopes created during construction, post-construction erosion of the reclaimed right of way, shallow sloughing failures of the trench backfill, and water intrusion from seeps and springs encountered in the trench.

No aquatic resources were delineated in this area.

These hazards and associated mitigation and avoidance strategies are discussed in detail below.

### 5.2.1 Rock Failure

Rock-block failure involves gravity-induced movement of large, relatively intact blocks of bedrock on steep slopes. The bedrock mass is typically a complex geological body resulting from variable lithology, tectonic stresses and weathering that lead to differential loading and unloading. Rock-block failures typically occur where stronger bedrock units transition to weaker or weathered units and become undercut. Rock falls or topples entail abrupt movements of bedrock mass or boulders that detach along discontinuities (fractures, joints, bedding planes) or the forward rotation of a unit or units about some pivotal point. Movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water. Field reconnaissance of the JNF Priority Site #5 did not reveal conditions that would lead to potential rock block failure. Bedrock is not exposed as over-steepened cliffs or ledges, is covered by soil overburden, and is likely stable in-place. Therefore, based on field observations of the JNF Priority Site #5 and planned construction activities, Mountain Valley considers the potential for rock failure to be so remote as to be negligible. No mitigation measures for rock failure are prescribed at JNF Priority Site #5.

### 5.2.2 Unconsolidated Overburden Failure

Field observations and geologic mapping indicate that the JNF Priority Site #5 is underlain by a residual soil mantle that overlies clastic sedimentary bedrock, generally similar to conditions observed at JNF Priority Site #2. As discussed above, the pipeline trench in the vicinity of JNF Priority Site #5 will be approximately seven feet below grade, likely within residual overburden and possibly upper reaches of stable shallow bedrock.

Major controls on the potential to initiate a landslide (unconsolidated overburden failure) include topographic gradient and orientation of the slope, bedrock structure, and topographic drainage features that concentrate surface and subsurface water during intense precipitation events. Mountain Valley evaluated overburden observed (as described above) at JNF Priority Site #5, coupled with the potential for extreme precipitation events, for consideration of failure risk during construction and long-term operation of the pipeline.

#### *Slope Stability and Pipeline Integrity Analyses*

Existing slope stability at the JNF Priority Site #5 was evaluated by establishing safety factors using a numerical model with input from field observations, probabilistic analysis of material properties and analyst experience. Slope failure risk analysis was approximated using the peer-reviewed slope stability program SLIDE (RocScience, Inc.). This model incorporates Bishop, Janbu and Spencer methods, generates circular, non-circular, and optimized shaped failure planes with seismic and boundary loads.

Observations of historical slope failures in other areas suggest that the likely slip plane will occur at the overburden-bedrock interface resembling an infinite slope failure. However, the depth of the slip surface within the colluvium material has a minimal effect on the Factor of Safety (FoS) (i.e., difference of less than 0.05). Therefore, the model simulates a failure surface near the overburden-bedrock interface to represent a failure with an adverse effect and not shallow, surficial sloughs.

A probabilistic model was applied to the colluvial soil shear strength (friction angle) and unit weight using highest and lowest conceivable values (Duncan, 2000). Stability analyses were run for slope angles ranging from 15% (9 degrees) to 76% (37 degrees), which bracket the range of existing slopes observed at and near the JNF Priority Site #5. Modeling also accounted for saturated conditions and seismic loading (0.16 g; see Mountain Valley Pipeline Resource Report #6, seismic hazards analysis). Slope stability model output is provided in Appendix C. Table C-1 in Appendix C summarizes the full range of stability analysis results given the probabilistic analyses for input parameters soil density and friction angle, under increasing slope, saturated and unsaturated conditions, and with and without seismic loading.

In summary from Table C-1, based on likely residual soil density and friction angle values, the existing native overburden slopes at JNF Priority Site #2 are stable (minimum FoS of 1.1) up to at least 65% (33 degrees) native slopes under unsaturated conditions with no seismic loading, and 45% (24 degrees) native slopes with seismic loading. The JNF Priority Site #5 slopes are approximately 13% to 60% (average 41%), such that the analysis results suggest that average slopes at JNF Priority Site #5 are stable at an acceptable FoS under unsaturated conditions.

Under saturated conditions, risk for slope failure increases substantially. The model confirms what Mountain Valley has already accounted for in construction practices, that the largest effect on the FoS is soil saturation from groundwater intrusion, or surface water infiltration, to the colluvial deposit (i.e., as soils become saturated, stability decreases). As discussed, Mountain Valley is aware of the need to prevent accumulation of storm water during construction, permanently divert subsurface springs or seeps from the pipeline bedding and near vicinity if encountered during construction, and to properly grade and reclaim the ground surface in the LOD after construction. Preventing saturated conditions on these steep slope environments is a critical factor in maintaining slope stability. The project stormwater management plans and subsurface drains implemented during construction will address the issue of overburden saturation.

The analysis suggests there is minimal risk of ground displacement, thus the effects of displacement on the pipeline have not been analyzed. As discussed later in this document, Mountain Valley will implement a post-construction slope monitoring program. If future monitoring observations suggest slope movement is occurring, Mountain Valley will take appropriate actions to stabilize the slope and will evaluate pipeline response to the nature and degree of observed ground displacement using the recommendations provided in PRCI (2009).

### 5.2.3 Soil Stockpile and Subjacent Slope Failure

Spoil stockpiles will be compacted via rolling with dozers on site. Excavation and backfilling will be completed as quickly as possible to minimize the duration of stockpiling. At JNF Priority Site #5, the contractor will install a temporary diversion, such as reinforced silt fence, to prevent rocks from rolling off of the ROW. Temporary spoil stockpiles will be stable with a factor of safety of at least 1.2 as demonstrated in Appendix C.

Field observations revealed a thin soil mantle and spoil stockpiles will be stored on rock. Thus, overloading the subjacent slope at JNF Priority Site #5 is not anticipated to occur and does not present a technical concern for construction in this area.

### 5.2.4 Temporary Cut Failures

Cut slopes created during construction at JNF Priority Site #5 are limited to the pipeline trench and associated side slopes. Cut slopes will not exceed the maximum safe angle per OSHA standards for the type of material being excavated. As any cuts made temporarily during construction will be reclaimed with native material (buttressing the cut slope) placed to original contours as practicable, cut slopes are expected to be stable in the long term.

### 5.2.5 Erosion

Erosion hazards will be mitigated by following the project Erosion and Sediment Control Plan (E&SCP). Refer to the E&SCP for details.

### 5.2.6 Trench Backfill Failures

The pipeline trench will be provided with trench breakers at locations specified in the project E&SCP. These trench breakers will act as gravity retaining walls within the trench to hold the backfill in place during construction and will slow the velocity of water running through the trench, preventing subsurface erosion. Every third trench breaker at this location will be provided with daylight drains, as shown on typical drawing MVP-35, discharging water building up in the trench to water dissipation devices at the ground surface. All trench breakers not provided with daylight drains will be provided with pass-through drains as shown on typical drawing MVP-43.  Trench backfill is anticipated to be stable with a factor of safety of at least 1.5 as demonstrated in the slope stability analysis in Appendix C.

### 5.2.7 Seeps and Springs

As the presence of seeps/springs encountered in the pipeline trench or temporary construction excavation will not be known until the trench is excavated, their location and extent cannot be determined at this time.  At JNF Priority Site #5, seepage (if any is encountered) will be captured by daylight drains behind the trench breakers, as shown on typical drawing MVP-35, or with transverse trench drains as shown on typical drawing MVP-38.  These drains will outlet to energy dissipation devices at the right-of-way ground surface.  Trench breaker locations are shown on the E&SCP.

## 5.3 Bore Pit

It should be noted that stability of the bore pit is not considered herein.  Temporary shoring will be developed by the bore contractor to all applicable safety standards to protect both the open bore pit and the stockpiled spoil material excavated from the bore pit.  The landslide inspection team will evaluate the site to determine if any mitigation measures, in addition to those proposed by the contractor, are necessary.

## 5.4 Mitigation Measures

Overall best management practices include:

- controlling surface runoff from the limit of disturbance and the reclaimed construction area to prevent direct flow into exposed debris flow or colluvial deposit;
- intercepting and controlling subsurface drainage from the excavation during construction and post-construction to prevent subsurface infiltration into the underlying debris flow or colluvial deposit;
- and constructing in a timely fashion to reduce the amount of time when the limit of disturbance is exposed to the elements and not under final grade.

Subsurface conditions observed during construction may dictate the use of enhanced mitigation measures. Site-specific observations made by the Mountain Valley landslide inspection team during construction may result in the team’s recommendation for deployment of additional specific mitigation measures, which consider potential native ground movement around or below the ROW, disturbed temporary ground surface movement from initial grading and subsequent construction work and finished and restored ROW surface.

Based on field observations during construction, Mountain Valley may implement slope breakers, water bars, additional grading, French drains, armored slopes and/or ditches as enhanced drainage control measures to promote slope stability.  Mountain Valley does not anticipate that structures will be required to stabilize bedrock within the trench excavation, or adjacent native soils or colluvium, however highwall/steep slope revetments or geogrid may be implemented to increase the stability of backfilled areas if soils do not exhibit the strength parameters modeled herein.

## 5.5 Post-Construction Monitoring and Intervention

See the discussion on post-construction monitoring and potential for intervention for the JNF Priority Sites that is presented in the last section of this document. Slope monitoring is a critical element of post-construction operations of the pipeline and the recommended procedures (including potential reclamation measures) are applicable to all of the JNF Priority Sites.

# 6.0 JNF Priority Site #6

*Coordinates: (37.324447, -80.415421) to (37.320149, -80.412061)*

## 6.1 Site Description and Geology

This site is located near the crest of Sinking Creek Mountain from approximately MP 218.5 to 218.9 on the October 2016 Proposed Route.

Slopes along this portion of the right of way range from nearly flat to 63 percent (averaging 34 percent), and are generally steepest approaching the crest of Sinking Creek Mountain. As shown on the plan view slope map of Figure 30, the pipeline follows a ridge just downslope of the mountain's crest. This ridge generally has side slopes shallower than 4H:1V, but in limited instances is as steep as 2.5H:1V.

A profile of the site is shown on Figure 31. The pipeline will be approximately three feet below grade, with the bottom of the pipeline trench located approximately seven feet below grade. The trench will be backfilled with select backfill, which will be shaker bucket material from the native soil and rock. Cross section 6A is shown on Figures 32, 33, and 34, depicting the anticipated extent of trenching and stockpiled material before, during, and after construction.

According to Rader and Gathright (1986) the geology of the JNF Priority Site #6 vicinity is highly folded and thrust-faulted sedimentary bedrock (typical of the Valley and Ridge geologic province of Virginia). Bedrock underlying the JNF Priority #6 site is mapped as northeast striking and moderately-to-steeply dipping (generally 45-50$^{o}$) Silurian age Rose Hill Formation conformably in contact with the older Tuscarora Formation (red shales, mudstone, fine to medium red to gray to white sandstones and quartzite). Both the Rose Hill and Tuscarora Formations were observed to outcrop on the ridge line in different exposures (see Photo 15 and Photo 16, below). The older Tuscarora Formation is conformably in contact with the Rose Hill downslope to the south-southeast.

*Photo 14: Tuscarora Formation sandstone observed to outcrop at the ridge line (view is to the southwest)*

*Photo 15: Further to the southwest, the Rose Hill Formation sandstones outcrop at the ridge line (view is to the southwest)*

Field reconnaissance of the JNF Priority Site #6 confirmed a near-horizontal portion of the slope within approximately 800 feet downslope (south) of the ridge line that corresponds to the rock-block slump, and a steep slope leading up to the ridge line (north-northwest) that is primarily the result of a release of the rock-block when it slumped.

*Photo 17: View of the shallow slope apparently formed by rock-block slump, viewed toward the ridge line that is somewhat visible by trees in background defined by skyline approximately 800 feet to the west (view is to the west-southwest)*

*Photo 16: South extent of the shallow slope formed by an apparent rock-block slump downslope from the ridge line (view is to the northeast)*

The rock-block slump is mapped as Tuscarora Formation sandstone by Schultz (1993). See the exhibit presented below, excerpted from Schultz (1993), showing the proposed alignment as the red dashed line, crossing the approximately 1,500 by 500 feet ancient rock-block slump (Stk) on the southeast slope of Sinking Creek mountain.

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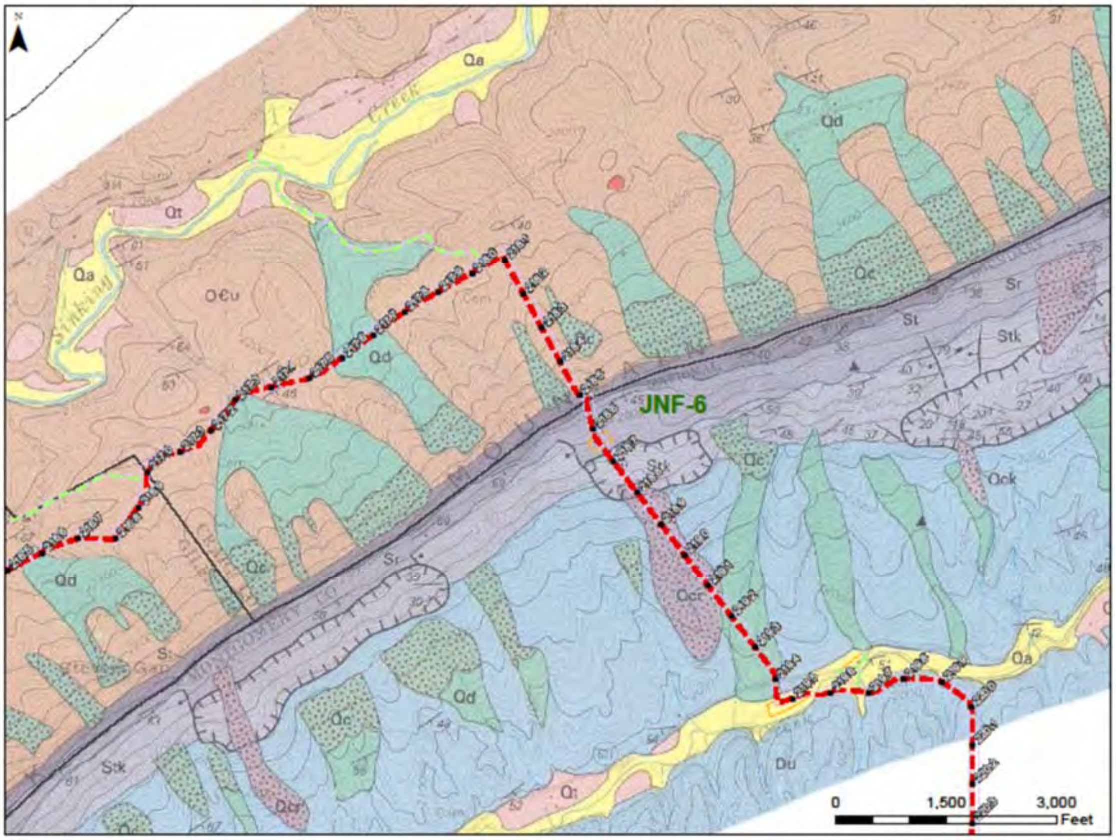


Base map: Schultz, 1993

Continuing downslope, the pipeline is mapped as crossing colluvium (Qcr in the exhibit above), derived from the Rose Hill Formation and consisting of debris transported downslope ridgeline and rock-block slide. Field reconnaissance revealed hummocky terrain, abundant Rose Hill and Tuscarora float at the ground surface and a well graded agglomeration of fine-to-coarse sand, pebbles, cobbles and boulders of Rose Hill and Tuscarora (observed in tree-fall root balls) that are characteristic of the ancient debris flow (see Photo 19, below).

*Photo 17: Hummocky ground with variable size float (boulders, cobbles, pebbles, sand, silt) that corresponds to a mapped debris flow downslope (to the south-southeast) from the rock-block slump feature (view is to the south-southeast)*

## 6.2 Potential Slope Failure Hazards

At this site, potential slope failure hazards that were considered included continued rock-block slumping, debris flow, remobilization of colluvial deposits, shallow failures of the stockpiled trench/topsoil, slope failures subjacent to stockpiles, failure of temporary slopes created during construction, post-construction erosion of the reclaimed right of way, shallow sloughing failures of the trench backfill, and water intrusion from seeps and springs encountered in the trench.

Stream S-PP22 has been delineated near the southern portion of the site.

These hazards and associated mitigation and avoidance strategies are discussed in detail below.

### 6.2.1 Rock Failure

Rock-block failure involves gravity-induced movement of relatively intact blocks of bedrock overlying weaker or weathered units on critical slopes. The bedrock mass is typically a complex geological body resulting from variable lithology, tectonic stresses and weathering that lead to differential loading and unloading.  Rock-block failure is commonly controlled by discontinuities or failure planes (e.g., bedding, folds, joints, and faults) within the rock mass. The distribution of discontinuities affects the mechanical strength of the rock mass (i.e., bonding force and friction coefficient). Trigger events for rock falls are primarily associated with pore pressure effects from sustained long-duration or short-duration intense precipitation events, and freeze-thaw weathering (Schultz and Southworth, 1987, 1989; Wieczorek and Snyder, 2009). Some researchers postulate that seismic shaking may trigger slope failure, but no direct evidence is available to support this suggestion. D.G. Honegger Consulting (2015) presents an analysis and recommendations for mitigating seismic-induced risks to the pipeline.

Field reconnaissance of the JNF Priority Site #6 reveal conditions that confirm the presence of an ancient rock-block failure structure. Pipeline construction in the vicinity of the slumped rock-block will entail trenching to approximately seven feet below grade and will likely remain within overlying residual overburden or possibly encounter the upper reaches of the weathered bedrock. The particular rock-block near JNF Priority Site #6 is approximately 1,500 feet by 500 feet in dimension, and these blocks are typically dozens of feet think. It is not anticipated that pipeline construction will affect the stability of the rock-block, given that failure conditions have already occurred (in ancient times) and the rock-block is likely stable at its current repose. Therefore, Mountain Valley considers the risk for activation of the rock-block to be negligible, and no further analysis was conducted.

Upslope of the rock-block, in the vicinity of JNF Priority Site #6, pipeline construction will encounter the Silurian Age ridge-forming sandstones (Rose Hill and Tuscarora Formations). As noted, pipeline construction at the ridge line will likely only be seven feet below grade, and Mountain Valley anticipates being able to rip these jointed, dipping bedrock exposures. Under this relatively controlled construction practice, Mountain Valley does not anticipate increased risks for rock fall or tumble at this location.

### 6.2.2 Debris Flow / Colluvial Deposit

Schultz (1993) mapped a debris flow downslope (south-southwest) of the JNF Priority Site #6. Debris flows are generally considered to be high-energy, rapid downslope movement of earth material that can entrain trees and other large objects in the flow path. A debris flow differs from rock-block slide in that there are no well-defined blocks moving along shear surfaces. Instead, the mass flows downhill, with shear strains present everywhere. Debris flows generally occur during intense precipitation events, and travel rapidly downslope along existing drainage channels or stream valleys, transporting and depositing mud, sand, gravel, and boulders where the slope gradient flattens. Multiple debris flows may coalesce into a central channel downslope from the points of initiation.

Colluvial deposits are also mapped downslope of the JNF Priority Site #6, which may be derived from past debris flow(s), or other forms of mass wasting. Debris flows are grouped with colluvial deposits for this analysis because pipeline construction within, or in the vicinity of an observed colluvial deposit entails similar precautions to that for a debris flow.

Major controls on the potential to initiate a debris flow include topographic gradient and orientation of the slope, bedrock structure, and the accumulation of historic debris flows in topographic drainage features that concentrate surface and subsurface water during intense precipitation events. Field observations of the JNF Priority Site #6 suggest that topographic and bedrock conditions are not susceptible for generating a new debris flow at the JNF Priority #6 site. However, debris flow and colluvial deposit(s) observed at, and in the near vicinity of, the site (as described above), coupled with the potential for extreme precipitation events, warrant consideration for construction and long-term operation of the pipeline.

### *Slope Stability and Pipeline Integrity Analyses*

Existing slope stability at the JNF Priority Site #6 was evaluated for potential debris flow conditions, and colluvial deposit failure, by establishing safety factors using a numerical model with input from field observations, probabilistic analysis of material properties and analyst experience. Slope failure risk analysis was approximated using the peer-reviewed slope stability program SLIDE (RocScience, Inc.). This model incorporates Bishop, Janbu and Spencer methods, generates circular, non-circular, and optimized shaped failure planes with seismic and boundary loads.

As discussed above, the JNF Priority Site #6 is situated near an ancient debris flow mapped downslope of a rock-block slump. The debris flow and what is interpreted to be either related or younger colluvial deposits, overlie clastic sedimentary bedrock. Pipeline trenching in the vicinity of JNF Priority Site #6 will be approximately seven feet below grade, and is anticipated to remain within the debris flow (i.e., we anticipate that the debris flow is deeper than seven feet; no bedrock outcrops were observed in the vicinity). Observations of historical slope failures in other areas suggest that the likely slip plane will occur at the overburden-bedrock interface resembling an infinite slope failure. However, the depth of the slip surface within the debris flow and related colluvium has a minimal effect on the FoS (i.e., difference of less than 0.05). Therefore, the model simulates a failure surface near the overburden-bedrock interface to represent a failure with an adverse effect and not shallow, surficial sloughs.

A probabilistic model was applied to the debris flow and colluvial soil shear strength (friction angle) and unit weight using highest and lowest conceivable values (Duncan, 2000). Stability analyses were run for slope angles ranging from 15% (9 degrees) to 76% (37 degrees), which bracket the upper range of the existing slope observed near the JNF Priority Site #6. Modeling also accounted for saturated conditions and seismic loading (0.16 g; see Mountain Valley Pipeline Resource Report #6, seismic hazards analysis).

The output files for results of each analysis at the likely soil parameters are included in Appendix C. Table C-1 in Appendix C summarizes the full range of stability analysis results given the probabilistic analyses for input parameters soil density and friction angle, under increasing slope, saturated and unsaturated conditions, and with and without seismic loading.

In summary from Table C-1, based on likely colluvial material density and friction angle values, the existing colluvial deposit slopes at JNF Priority Site #6 are stable (minimum FoS of 1.1) up to at least 65% (33 degrees) native slopes under unsaturated conditions with no seismic loading (the maximum slope near JNF Priority Site #6 is 63%, with an average of 34%). Under seismic loading, unsaturated native slopes are stable (minimum FoS of 1.1) up to 45% (24 degrees). See discussion below on post-construction monitoring of native slopes.

Under saturated conditions, risk for slope failure increases substantially. The model confirms what Mountain Valley has already accounted for in construction practices, that the largest effect on the FoS is saturation from groundwater intrusion, or surface water infiltration, to the colluvial deposit (i.e., as soils become saturated, stability decreases). As discussed, Mountain Valley is aware of the need to prevent accumulation of storm water during construction, permanently divert subsurface springs or seeps from the pipeline bedding and near vicinity if encountered during construction, and to properly grade and reclaim the ground surface in the LOD after construction. Preventing saturated conditions on these steep slope environments, particularly under conditions of an ancient debris flow, is a critical factor in maintaining slope stability. The project stormwater management plans and subsurface drains implemented during construction will address the issue of overburden saturation.

The analysis suggests there is minimal risk of ground displacement. From the perspective of pipeline integrity and safety, D. G. Honegger Consulting (2015) indicated that slope displacements parallel to the proposed alignment can be screened out as not representing a significant hazard if the length of pipeline exposed to ground displacement is less than 1,150 feet (Class 1 pipe) to 1,640 feet (Class 3 pipe) from the top of the slope (screening approach assumes a relatively straight line with no connections or insulated joints in the screening distance). While Mountain Valley does not anticipate any slope failure to occur, it is even more unlikely that failure on the magnitude of 1,000’s of feet. Thus the effects of displacement on the pipeline have not been analyzed. As discussed later in this document, Mountain Valley will implement a post-construction slope monitoring program. If future monitoring observations suggest slope movement is occurring, Mountain Valley will take appropriate actions to stabilize the slope and will evaluate pipeline response to the nature and degree of observed ground displacement using the recommendations provided in PRCI (2009).

### 6.2.3 Soil Stockpile and Subjacent Slope Failure

Soil stockpiles will be compacted via rolling with dozers on site. Excavation and backfilling will be completed as quickly as possible to minimize the duration of stockpiling. At JNF Priority Site #6, the contractor will install a temporary diversion, such as reinforced silt fence, to prevent rocks from rolling off of the ROW. In the steepest reaches of the site, spoil may be moved downhill to a flatter area temporarily during construction, then moved back uphill during final restoration.

In steeper areas of the ROW, spoil stockpiles will be stored on bedrock. Thus, overloading the slope in the steeper regions of the JNF Priority Site #6 does not present a technical concern for construction in this area. Temporary spoil stockpiles will be stable with a factor of safety of at least 1.2 as demonstrated in Appendix C.

Colluvial deposits were observed in the flatter portions of the site. Stability of the native material underlying spoil stockpiles is of concern. The spoil will be spread out across the workspace to the extent practicable to avoid overloading the in-situ colluvial soils. Stockpiles will be compacted via rolling with dozers to prevent water infiltration to minimize the weight of the stockpiled soil.

The landslide inspection team deployed by Mountain Valley during construction will evaluate the subgrade to determine whether or not it is appropriate to stockpile soils in the vicinity of the colluvial deposit. The exact thickness of the colluvial deposit will not be fully determined until excavation is initiated, but as previously described, colluvial debris generally follow ravines and drainage paths and the pipeline ROW is located on a ridge, it is unlikely that the colluvial deposit is extremely thick in the workspace area. Therefore, it may be sufficiently thin that instability due to stockpiled material is not a concern. If colluvial deposits exceed about five feet, spoil stockpiles will be moved up or downslope to a more stable area to avoid overloading the colluvial deposit and initiating a failure.

### 6.2.4 Temporary Cut Failures

Cut slopes created during construction at JNF Priority Site #6 are anticipated to be minor (less than about five feet in height) and located in rock. Cut slopes will not exceed the maximum safe angle per OSHA standards for the type of material being excavated. If temporary cut slopes encounter colluvium, the slopes will be appropriately sloped to mitigate slope failure. Temporary rock cuts are anticipated to be stable in the long-term following reclamation as they will be protected by compacted native material placed to original contours as practicable.

### 6.2.5 Erosion

Erosion hazards will be mitigated by following the project Erosion and Sediment Control Plan E&SCP. Refer to the E&SCP for details.

### 6.2.6 Trench Backfill Failures

The pipeline trench will be provided with trench breakers at locations specified in the project E&SCP. These trench breakers will act as gravity retaining walls within the trench to hold the backfill in place during construction and will slow the velocity of water running through the trench, preventing subsurface erosion. Every third trench breaker at this location will be provided with daylight drains, as shown on typical drawing MVP-35, discharging water building up in the trench to water dissipation devices at the ground surface. All trench breakers not provided with daylight drains will be provided with pass-through drains as shown on typical drawing MVP-43.

As the trench backfill will be placed in compacted lifts, Mountain Valley anticipates that the trench backfill will be at least as stable as the distal extent of in-situ colluvial deposits, if encountered. Backfill is anticipated to be stable with a safety factor of at least 1.5 as demonstrated in the slope stability analysis of Appendix C. The landslide inspection team may recommend installing additional slope breakers or steep slope revetments in the trench backfill in steeper portions of the site if backfill does not exhibit the strength parameters used in the slope stability model.

### 6.2.7 Seeps and Springs

As the presence of seeps/springs encountered in the pipeline trench will not be known until the trench is excavated, their location and extent cannot be determined at this time. At JNF Priority Site #6, seepage (if any is encountered) will be captured by daylight drains behind the trench breakers, as shown on the typical drawing MVP-35. These drains will outlet to energy dissipation devices at the right-of-way ground surface and any resulting discharge will be directed downslope to prevent accumulation within the limit of disturbance. Trench breaker locations are shown on the project E&SCP.

## 6.3 Mitigation Measures

Overall best management practices include:

- controlling surface runoff from the limit of disturbance and the reclaimed construction area to prevent direct flow into exposed debris flow or colluvial deposit;
- intercepting and controlling subsurface drainage from the excavation during construction and post-construction to prevent subsurface infiltration into the underlying debris flow or colluvial deposit;
- and constructing in a timely fashion to reduce the amount of time when the limit of disturbance is exposed to the elements and not under final grade.

Subsurface conditions observed during construction may dictate the use of enhanced mitigation measures. Site-specific observations made by the Mountain Valley landslide inspection team during construction may result in the team's recommendation for deployment of additional specific mitigation measures, which consider potential native ground movement around or below the ROW, disturbed temporary ground surface movement from initial grading and subsequent construction work and finished and restored ROW surface.

Based on field observations during construction, Mountain Valley may implement slope breakers, water bars, additional grading, French drains, armored slopes and/or ditches as enhanced drainage control measures to promote slope stability. Mountain Valley does not anticipate that structures will be required to stabilize bedrock within the trench excavation, or adjacent native soils or colluvium, however highwall/steep slope revetments or geogrid may be implemented to increase the stability of backfilled areas if soils do not exhibit the strength parameters modeled herein.

### 6.4 Post-Construction Monitoring and Intervention

See the discussion on post-construction monitoring and potential for intervention for the JNF Priority Sites that is presented in the last section of this document. Slope monitoring is a critical element of post-construction operations of the pipeline and the recommended procedures (including potential reclamation measures) are applicable to all of the JNF Priority Sites.

## 7.0 Topsoil

During construction, topsoil will be segregated throughout the Jefferson National Forest. It will be stockpiled along the edge of the temporary workspace. Spoil piles will be temporarily stabilized with seed and mulch in accordance with the USFS guidance documents (*Suggested Seed Mixes for Pipeline Right-of-Ways and Associated Disturbances on the Monongahela and George Washington – Jefferson National Forests* – November 2016; and *Suggested Seeding Techniques for Pipeline Right-of-Ways and Associated Disturbances on the Monongahela and George Washington – Jefferson National Forests* – November 2016). Stockpiled soils and areas to remain inactive (excluding the travel lane) for a period exceeding 30 days shall be stabilized within 14 days of initial disturbance. During final restoration, the temporary workspace ground surface will be roughened and the topsoil will be replaced across it. The surface will be seeded within 14 days of final reclamation to stabilize the topsoil and promote vegetation growth. Mountain Valley has received recommended seed mixes from the USFS and plans to implement those mixes throughout the JNF.

## 8.0 Slope Stability Monitoring Program

After pipeline construction and land reclamation are completed, Mountain Valley will implement a monitoring program to verify slope stability and provide Mountain Valley with early-warning detection of subtle ground movement that may indicate incipient slope failure. If subtle ground movement is detected, the monitoring program will trigger Mountain Valley's post-construction slope evaluation and mitigation, described below. Recommendations for slope failure mitigation are discussed in Section 8.3, below. More specific mitigation measures will depend upon the results of the monitoring program, and the landslide inspection team's field observations on actual conditions.

Mountain Valley will construct the pipeline with safeguards to prevent slope failure under the various potential mechanisms addressed at the Priority Sites. Mountain Valley does not consider it sound practice to establish a construction area that requires repeated interim measures to maintain slope stability.

## 8.1 LiDAR Surveys

Given the remote access and steep slopes in the vicinity of the Jefferson National Forest, Mountain Valley proposes to utilize aerial LiDAR surveys on a prescribed periodic basis (discussed below) to monitor the ROW for changes in ground topography that could be indicators of potential slope movement.

LiDAR works by emitting multiple laser pulses over the same area, such that some pulses are reflected off intermediate surfaces (i.e. variable height vegetation, buildings, power lines, etc.) and some of the pulses find the underlying ground surface. The resulting data are processed to classify data that represent the ground surface (i.e., generate a bare Earth model), providing a detailed topographic and geomorphic landform model to detect subtle ground morphologies that define natural and human-triggered landslide and erosion hazards (i.e. scarps, settlement, hummocky terrain, depletion zones, accumulation zones, sag ponds, disrupted drainage, etc.).

A progression of LiDAR data collected over time on a slope of concern will be compared to historical data in order to identify whether subtle landform chances are occurring that could correspond with possible land movement or subsidence. The sequential LiDAR models of the area of concern will be configured as a "heat map" to more clearly identify slope changes.

## 8.2 Monitoring Schedule

Mountain Valley's monitoring program will use LiDAR data to provide detailed ground surface mapping on slopes after construction is complete. LiDAR data detects subtle ground movement that can be used to surveille for potential impending slope failure.  If ground movement is perceived via LiDAR monitoring (analysis is discussed below), direct slope inspection will take place.  The intent is to mitigate subtle slope movements before larger failures occur.

Mountain Valley will conduct semiannual aerial LiDAR monitoring during an initial two-year period after construction is complete. This spans a critical period of time post-construction to confirm that land reclamation is established, and that slopes are stable through two freeze-thaw cycles. Continued monitoring described below will used to confirm these conclusions.

If the slopes in the area of concern are demonstrated to be stable by sequential LiDAR monitoring data for the initial two years of semiannual monitoring (described above), the frequency of LiDAR survey will be reduced to annually for another two consecutive years. This will provide six LiDAR monitoring events over the span of four years in order to detect potential subtle slope movement.

If the slopes are demonstrated to be stable by sequential LiDAR monitoring data for the combined four years of monitoring (i.e., the initial two years of semiannual monitoring, followed by two years of annual monitoring), the frequency of LiDAR surveys will be further reduced to a five-year periodicity throughout the life of the pipeline.

As each new sequential LiDAR survey is completed (see monitoring schedule above), the data will be processed and compared to all historical LiDAR data (i.e., to produce a "heat map" of slope movement) to evaluate for potential ground movement over time.

If slope reclamation is required in the area of concern, Mountain Valley will remediate the area per the landslide inspection team's recommendations, and re-start the six-month / annual / five-year monitoring frequency to document that slope stability is achieved.

## 8.3 Slope Stability Mitigation Measures

If slope movement is detected by the LiDAR monitoring program, Mountain Valley will notify the appropriate U.S. Forest Service representative, and then engage a landslide inspection team to complete field verification and confirm actual conditions and governing reasons for the topographic changes. Recommendations for slope stability remedial measures will be provided to Mountain Valley based on the landslide inspection team's observations.

Once Mountain Valley has received recommendations from the landslide inspection team, Mountain Valley will notify the U.S. Forest Service of planned remediation activities, and offer the proposed remediation to the U.S. Forest Service for review.

Examples of potential redial measures:

- If slope movement is confirmed in surficial backfill in the ROW, enhanced backfill compaction (or replacement with engineered materials), enhanced water management, and aggressive revegetation will be implemented.

- If slope movement in native earth material outside of the ROW is confirmed, the landslide inspection team will provide recommendations to Mountain Valley for remediation measures.
- If the movement may have stressed the pipe, a stress relief excavation may be required to allow the pipeline to rebound to the non-stress condition prior to slope movement. Stress relief excavations typically start in the middle of the area where slope movement is observed, and extend in either direction until no rebound is observed, and generally continue for a minimum of an additional 50 feet. Surveys may be required during the excavation work to track pipeline rebound, and to confirm before and after pipeline location and elevation. Stress relief excavations would only be contemplated for relatively large-scale movement scenarios.
- Mountain Valley may also consider installing strain gauges on the pipeline during stress-relief excavation. The strain gauges would monitor potential accumulated pipeline strain in the future if differential ground movement continues. Strain gauge monitoring would be conducted manually on a yearly basis, unless LiDAR monitoring under the post-remediation timeframe continues to identify large-scale slope movement, in which case the strain gauges will be monitored on a six-month basis. Strain gauges would only be contemplated for relatively large-scale movement scenarios.

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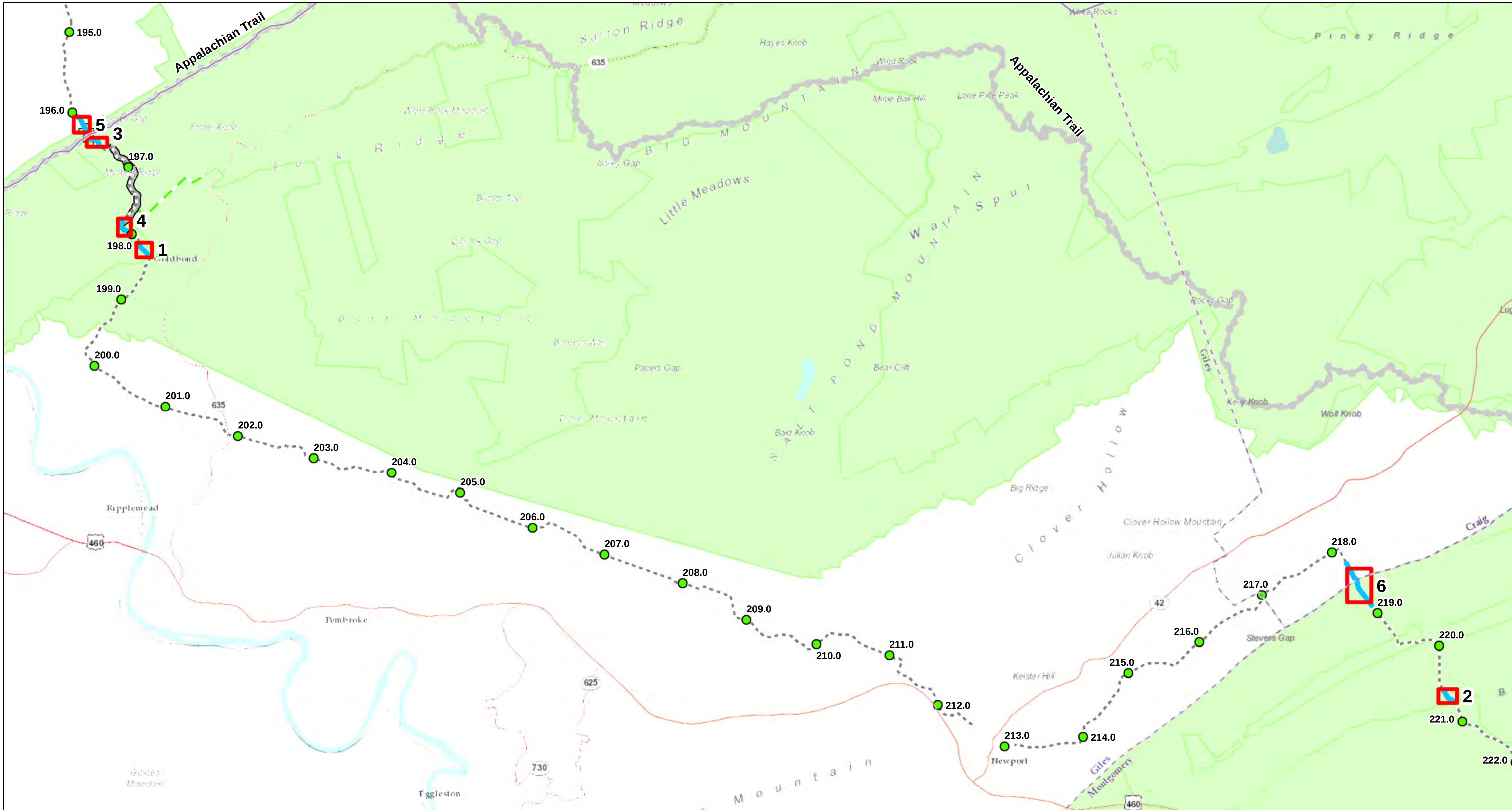
# Appendix A – Figures




Mountain Valley PIPELINE

SLOPE MAP - FIGURE 1
JEFFERSON NATIONAL FOREST
PRIORITY SITE OVERVIEW

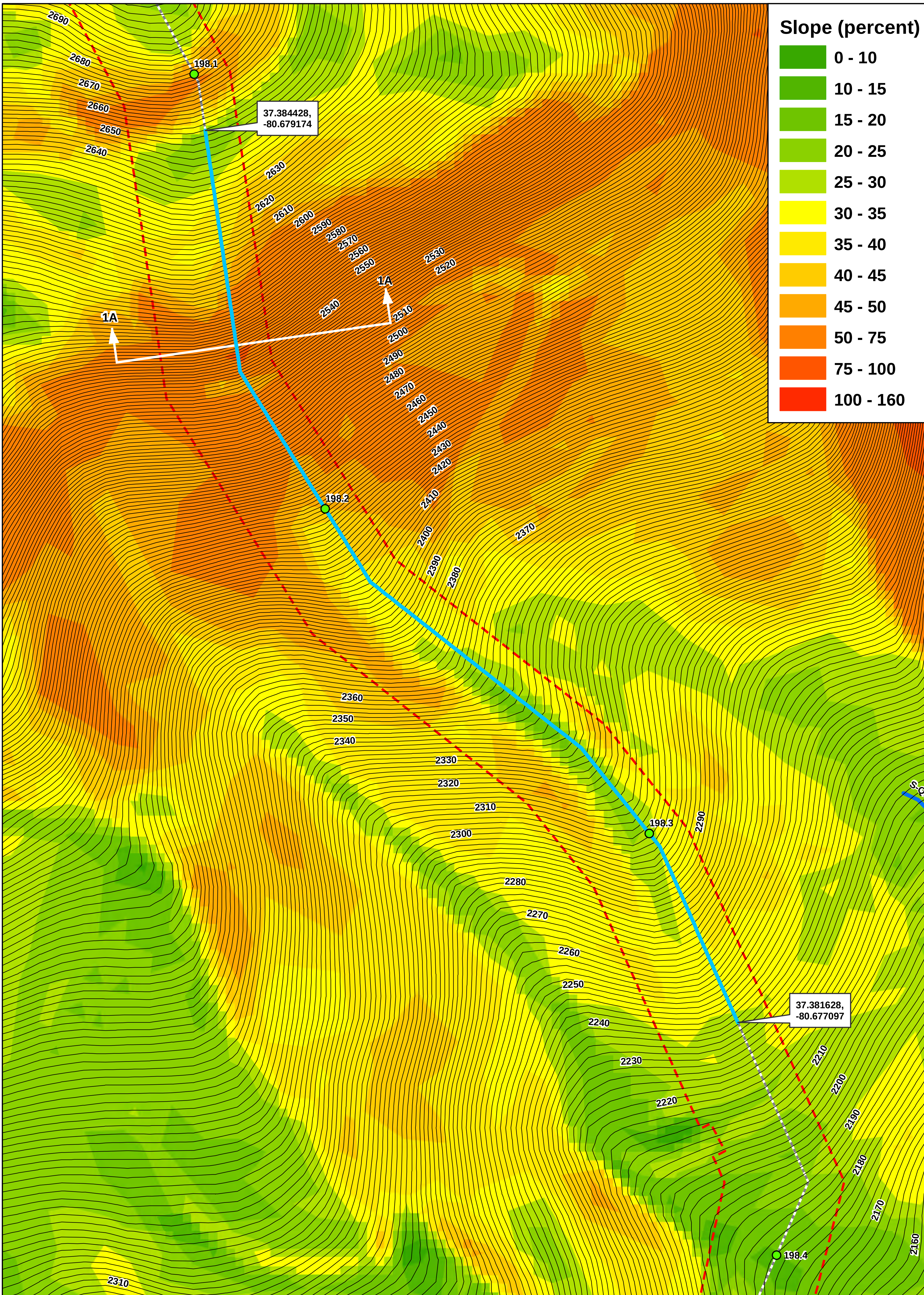
0 1 2 3 Miles

11/30/2016

N S E W

LEGEND

Jefferson National Forest Review Sites
October 2016 Proposed Route Milepost
October 2016 Proposed Route




Mountain Valley PIPELINE

**SLOPE MAP - FIGURE 2**
**JEFFERSON NATIONAL FOREST**
**PRIORITY SITE 1**

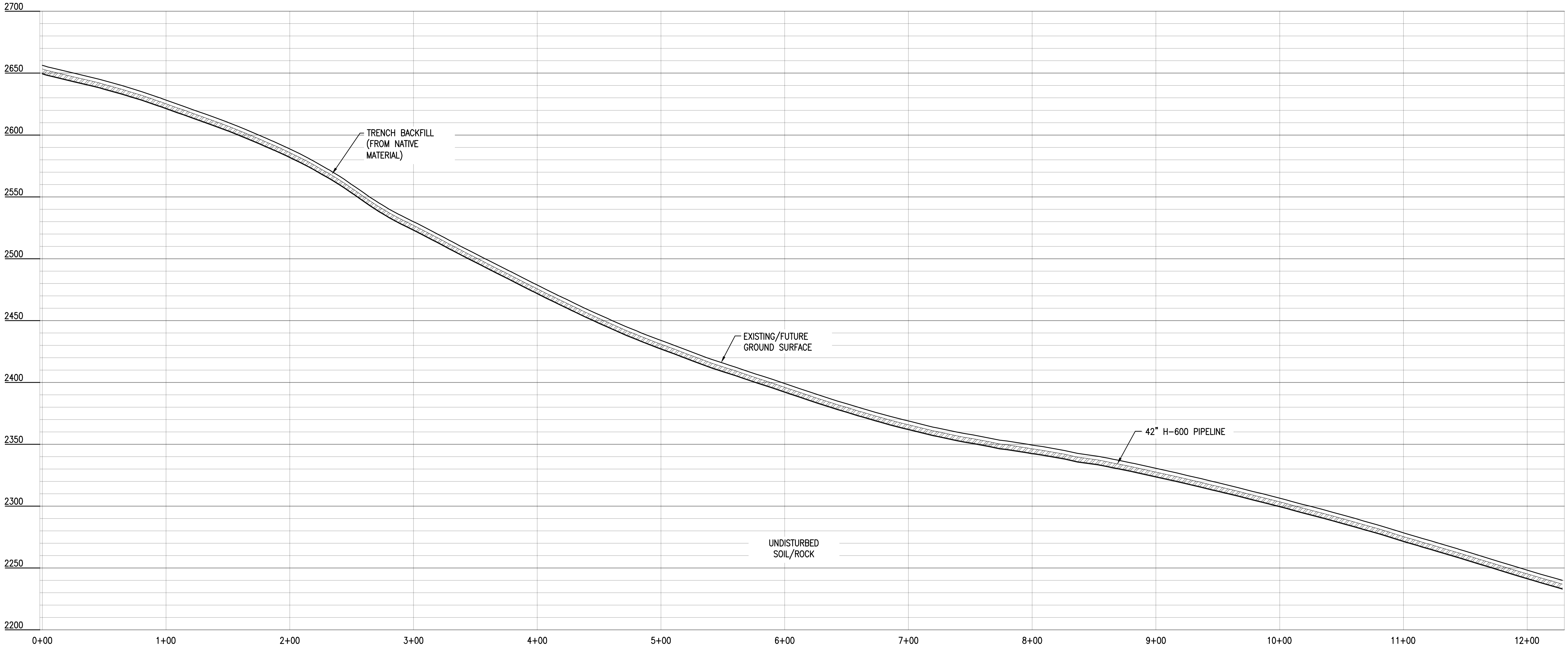
0 0.025 0.05 Miles

12/13/2016

N S E W

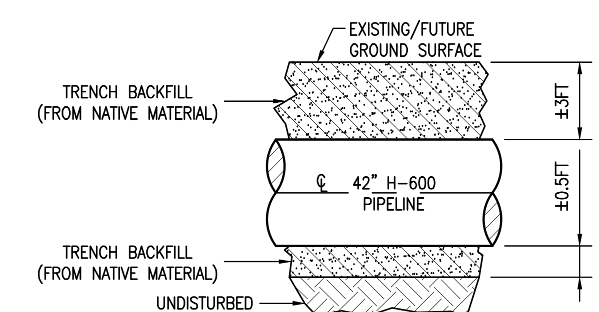
**LEGEND**

- JNF Priority Site #1
- October 2016 Proposed Route (Revised)
- October 2016 Proposed Route MP (Revised)
- Temporary Work Space
- Permanent Easement




(STATIONING IS RELATIVE TO START OF JNF PRIORITY SITE #1)

PROFILE




TYPICAL TRENCH BACKFILL

(NOT TO SCALE)

| REFERENCE DRAWINGS | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

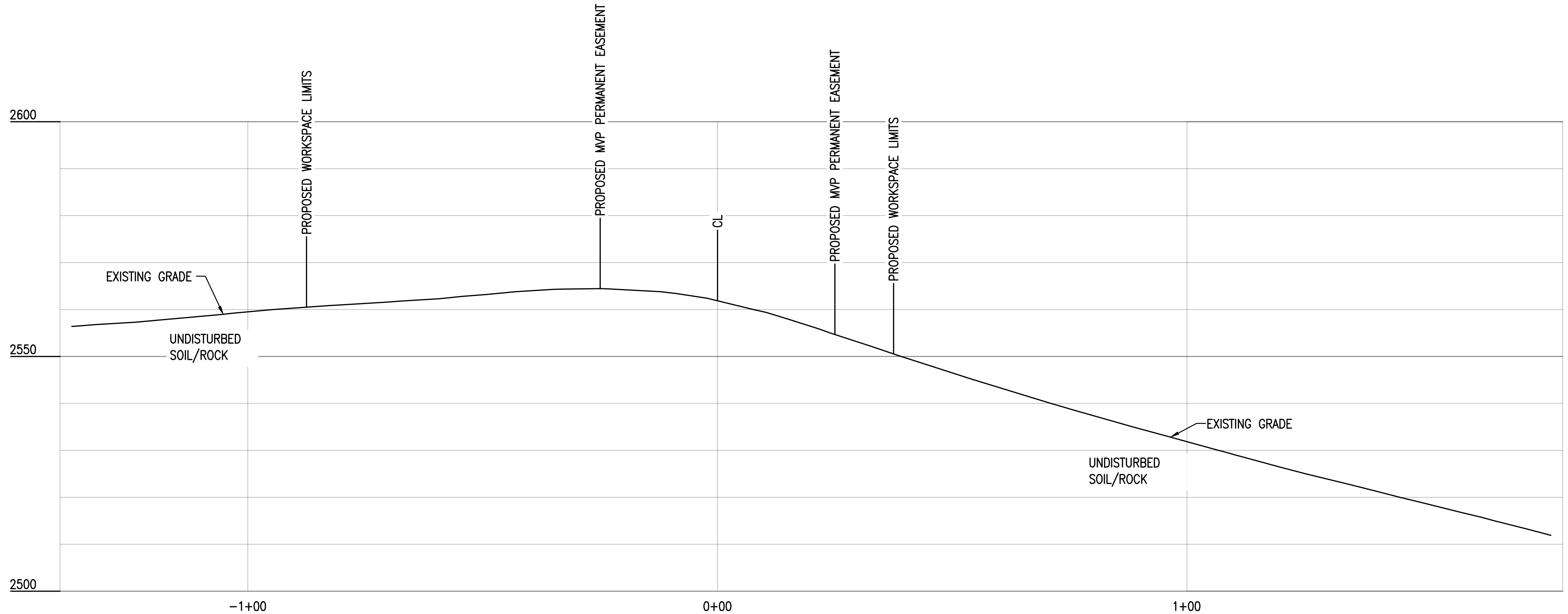
PROJECT ID: –

DRAWING SCALE: 1"=80'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #1 PROFILE – FIGURE 3

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS1 | 01 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS1-01.dwg




PRE-CONSTRUCTION SECTION 1A
THIS DWG
SCALE: 1"=30'-0"

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

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MECHANICAL DESIGN ENGINEER
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DATE
–
ELECTRICAL DESIGN ENGINEER
–
DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

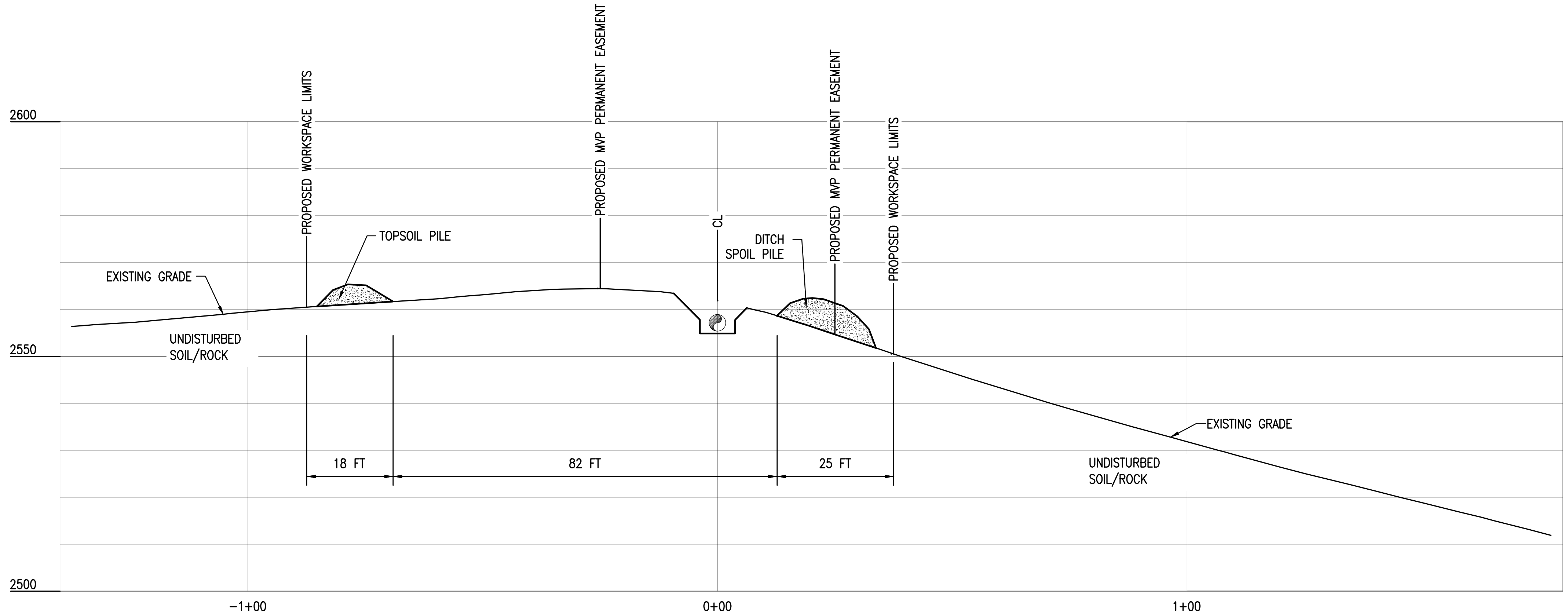
PROJECT ID
–

DRAWING SCALE:
1"=30'

DRAWING TITLE:
MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #1
PRE-CONSTRUCTION SECTION – FIGURE 4

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS1 | 02 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS1-02.dwg




CONSTRUCTION PHASE

SECTION 1A

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

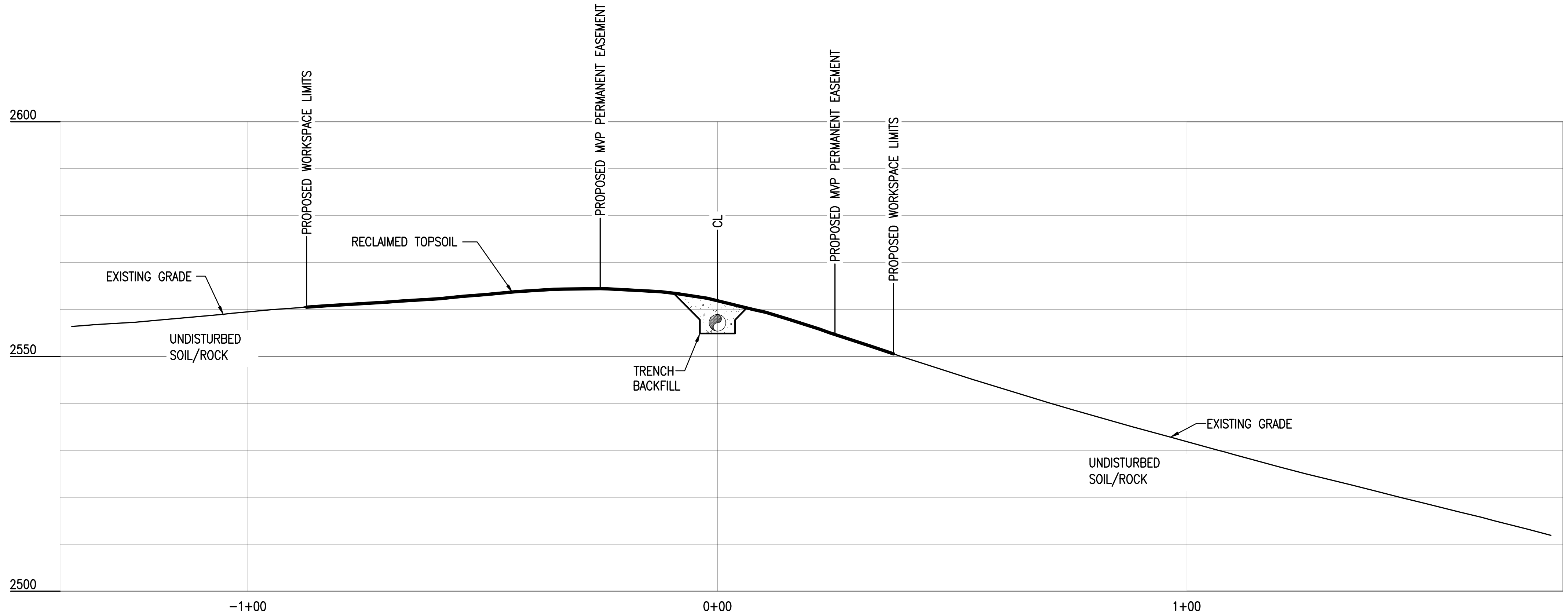
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #1
CONSTRUCTION PHASE SECTION – FIGURE 5

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS1 | 03 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS1-03.dwg




POST-CONSTRUCTION PHASE

SECTION 1A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #1
POST-CONSTRUCTION SECTION – FIGURE 6

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
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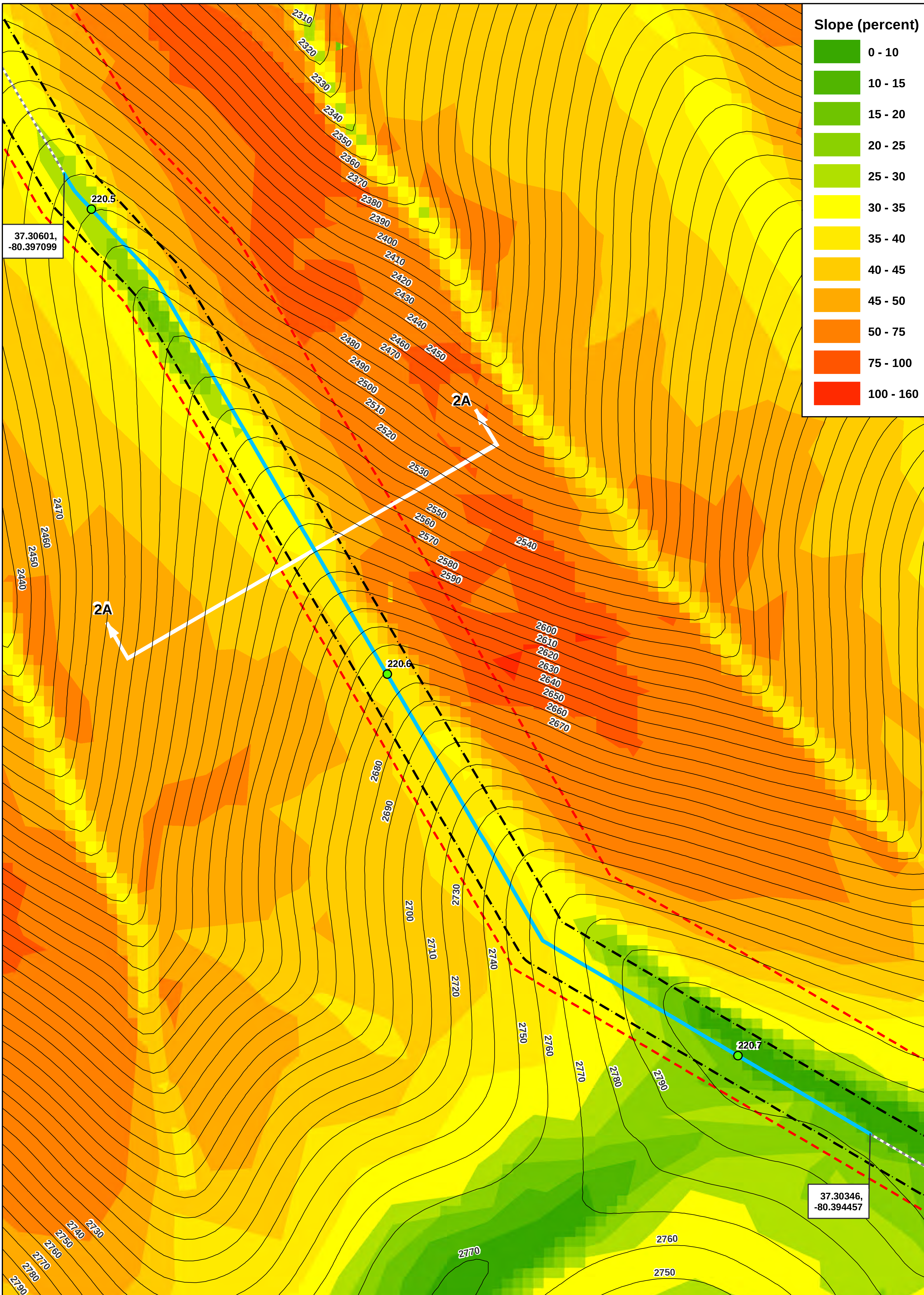
| P | V | H600 | PS1 | 04 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS1-04.dwg




Mountain Valley PIPELINE

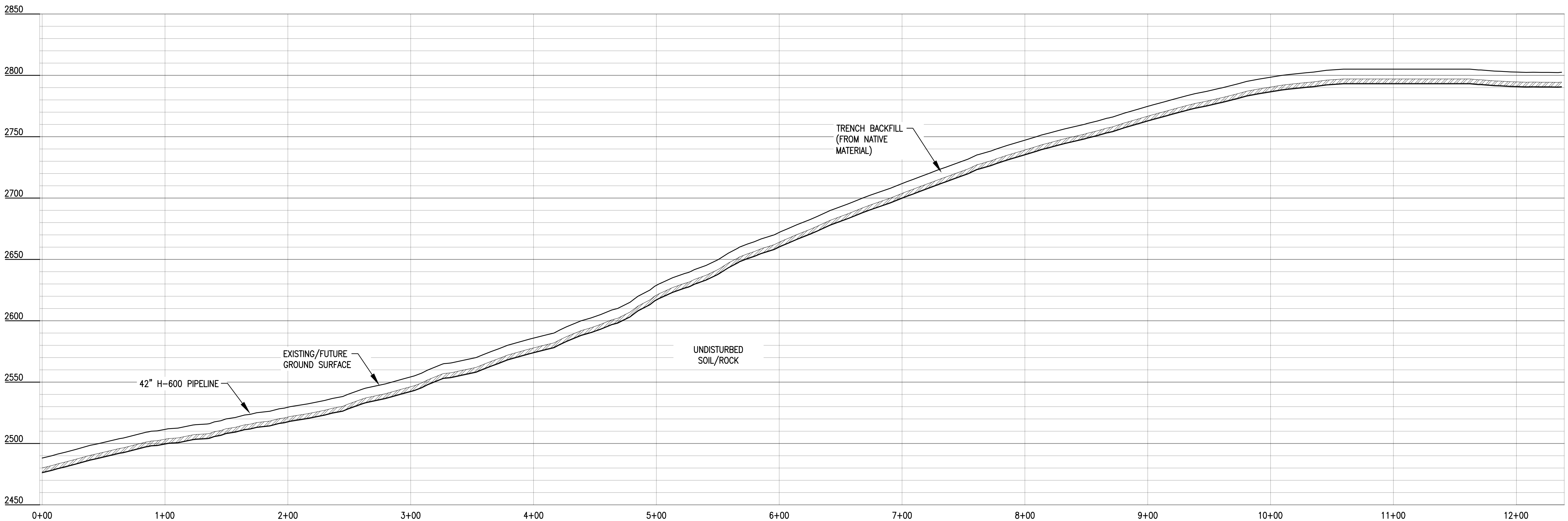
# SLOPE MAP - FIGURE 7
# JEFFERSON NATIONAL FOREST PRIORITY SITE 2

0 0.02 0.04 Miles

12/13/2016

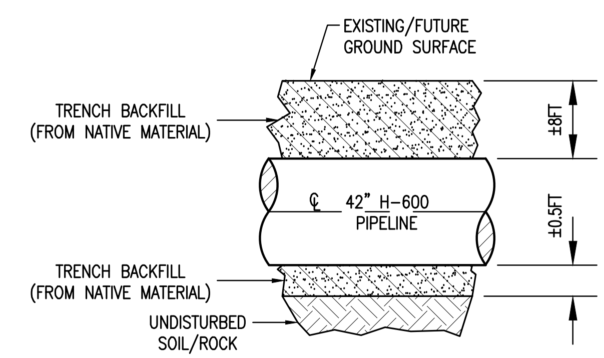
LEGEND

- JNF Priority Site #2
- October 2016 Proposed Route (Revised)
- October 2016 Proposed Route MP (Revised)
- Temporary Work Space
- Permanent Easement




(STATIONING IS RELATIVE TO START OF JNF PRIORITY SITE #2)

PROFILE




TYPICAL TRENCH BACKFILL
(NOT TO SCALE)

| REFERENCE DRAWINGS | | | | | | | | | | | | | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

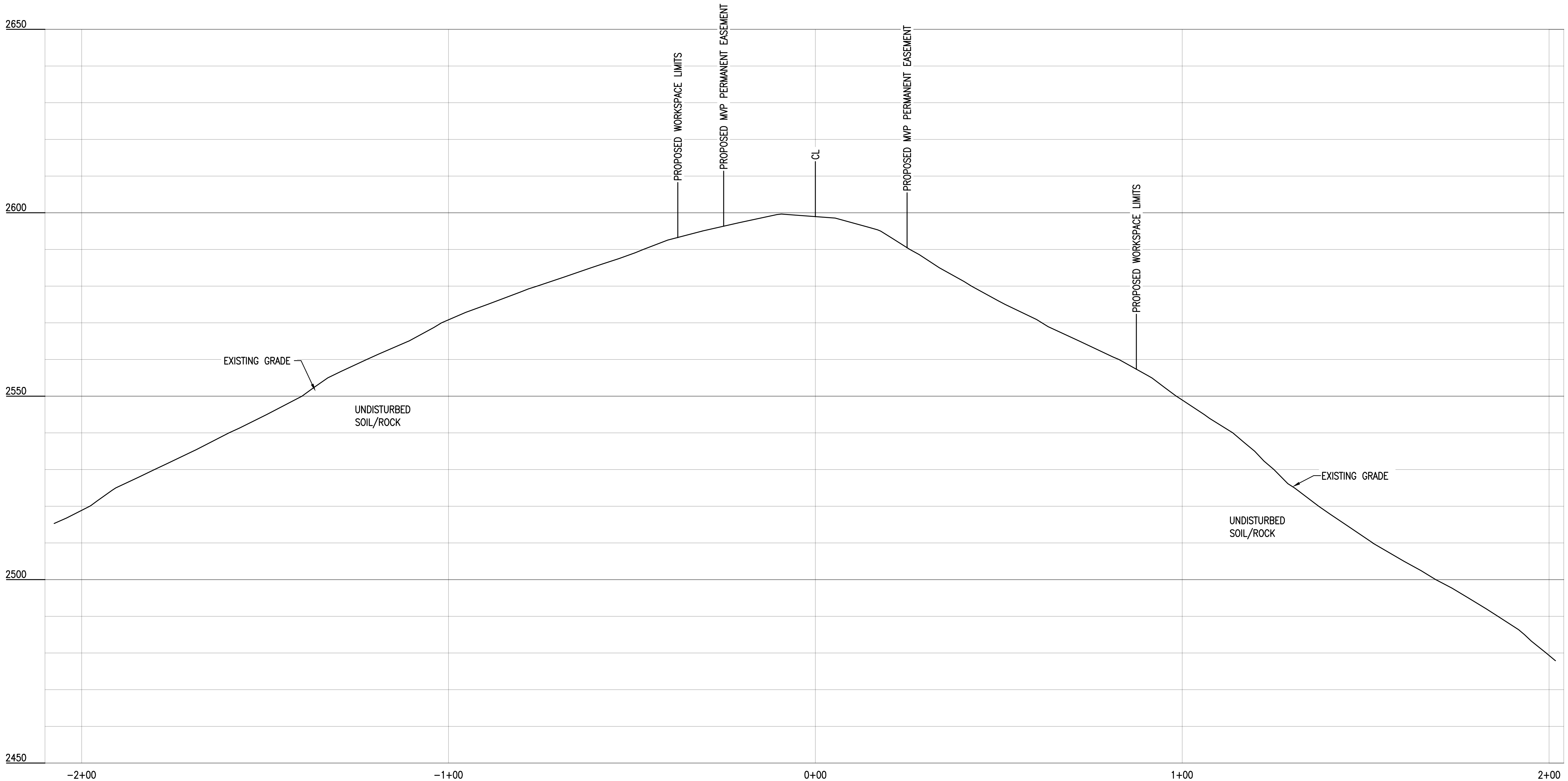
PROJECT ID: –

DRAWING SCALE: 1"=80'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #2
PROFILE – FIGURE 8

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS2 | 01 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS2-01.dwg




PRE-CONSTRUCTION SECTION 2A

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

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– ELECTRICAL DESIGN ENGINEER – DATE

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Mountain Valley PIPELINE LLC

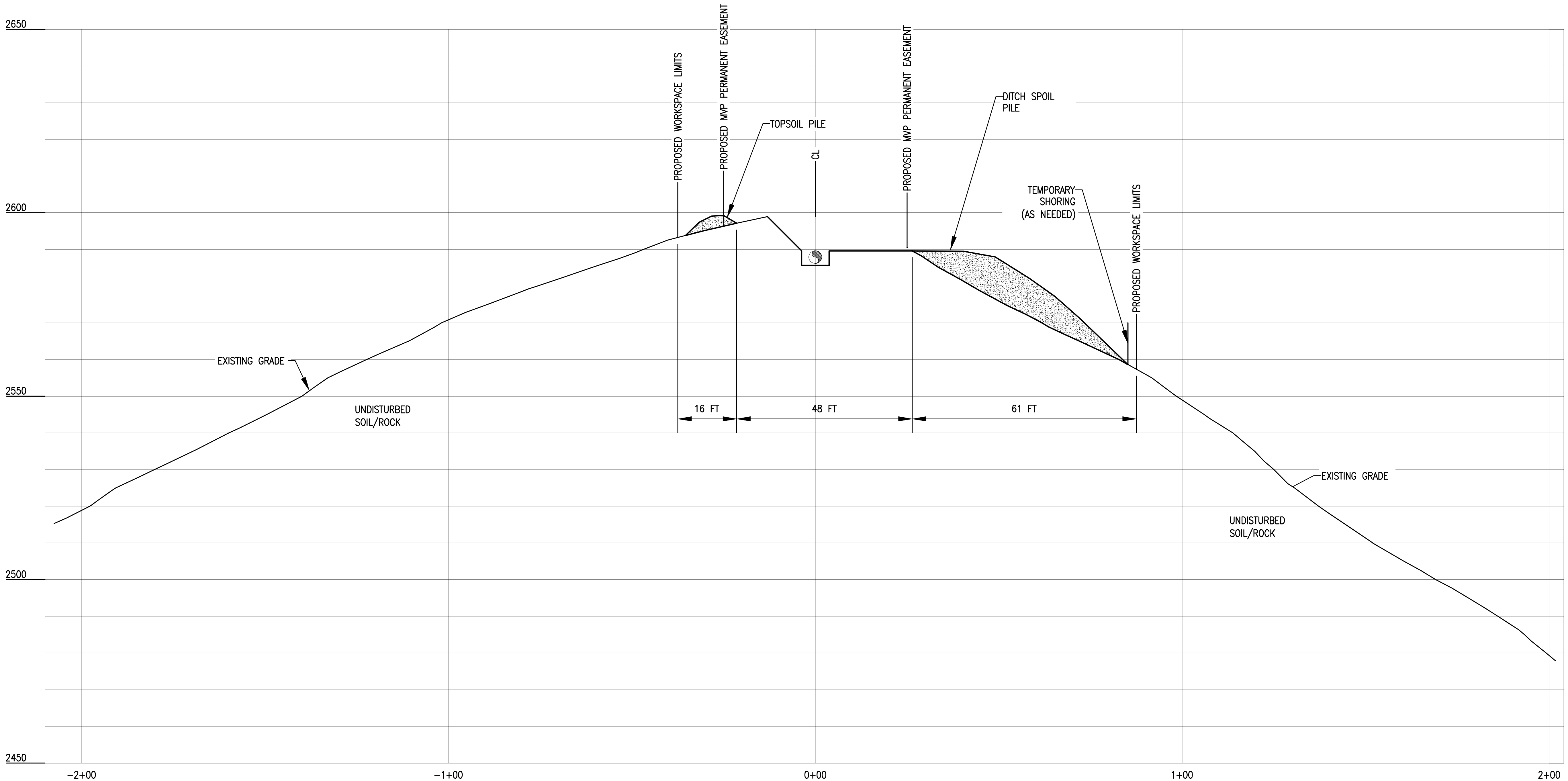
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #2 PRE-CONSTRUCTION SECTION – FIGURE 9

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS2 | 02 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS2-02.dwg




CONSTRUCTION PHASE

SECTION 2A

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #2 CONSTRUCTION PHASE SECTION – FIGURE 10

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
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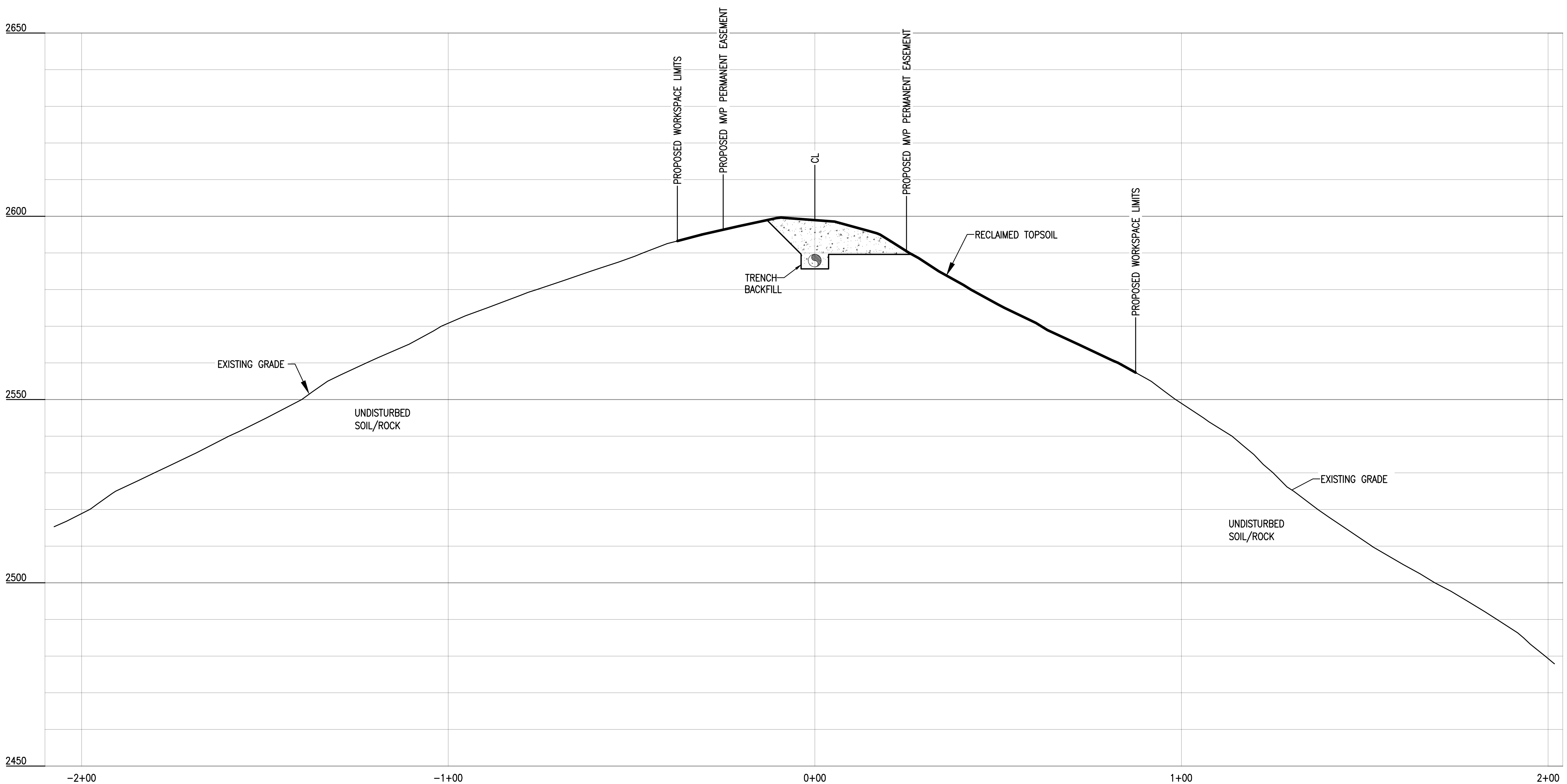
| P | V | H600 | PS2 | 03 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS2-03.dwg




POST-CONSTRUCTION PHASE

SECTION 2A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

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| ELECTRICAL DESIGN ENGINEER | DATE |

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

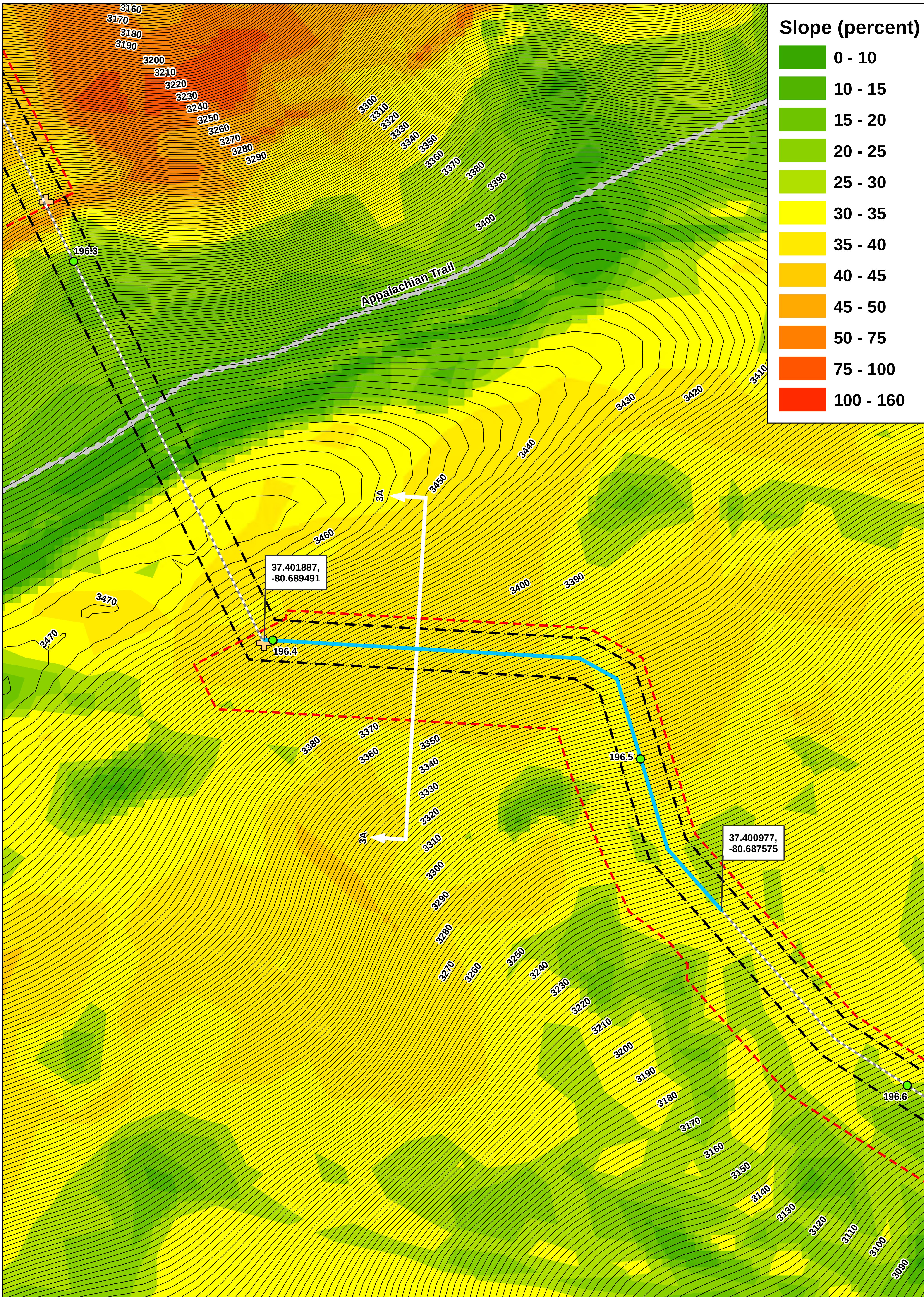
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #2
POST–CONSTRUCTION SECTION – FIGURE 11

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS2 | 04 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS2-04.dwg




Mountain Valley PIPELINE

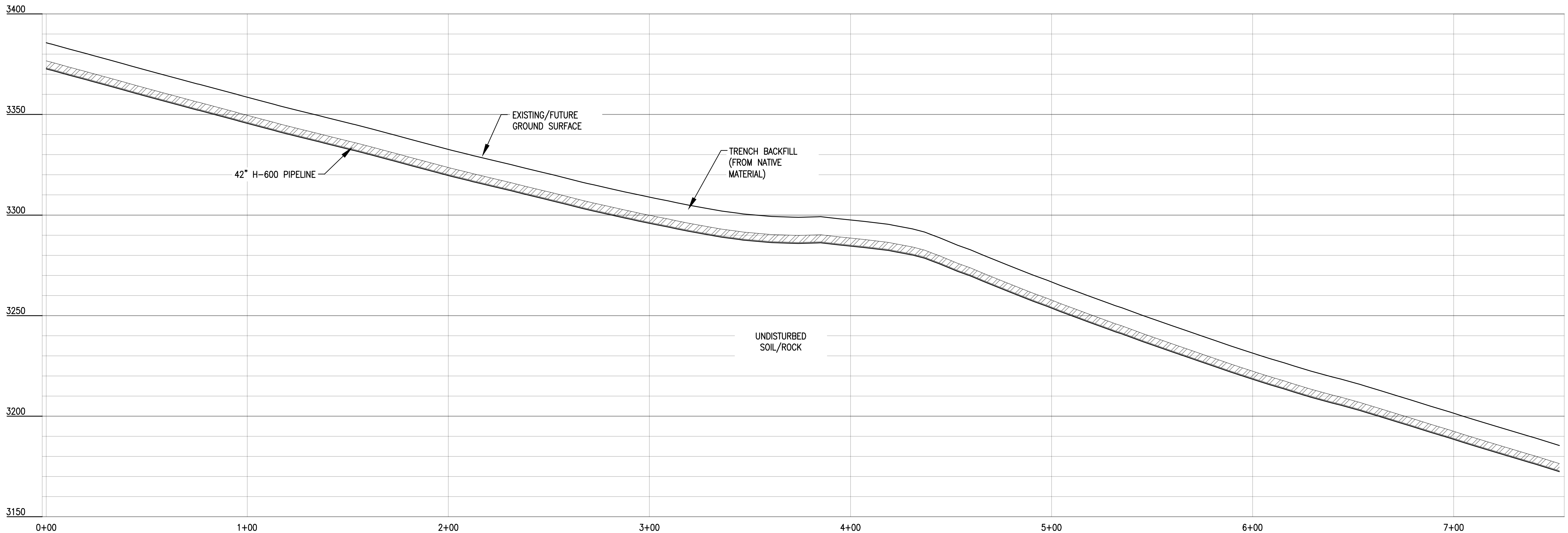
**SLOPE MAP - FIGURE 12**
**JEFFERSON NATIONAL FOREST**
**PRIORITY SITE 3**

0 0.025 0.05 Miles

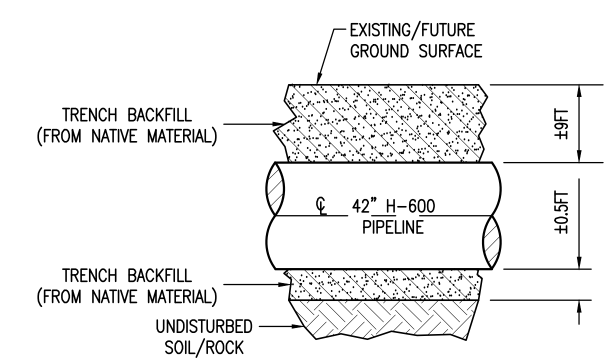
12/16/2016

**LEGEND**

- JNF Priority Site #3
- October 2016 Proposed Route (Revised)
- October 2016 Proposed Route MP (Revised)
- Temporary Work Space
- Permanent Easement
- Bore Pit




(STATIONING IS RELATIVE TO START OF JNF PRIORITY SITE #3)




TYPICAL TRENCH BACKFILL
(NOT TO SCALE)

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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

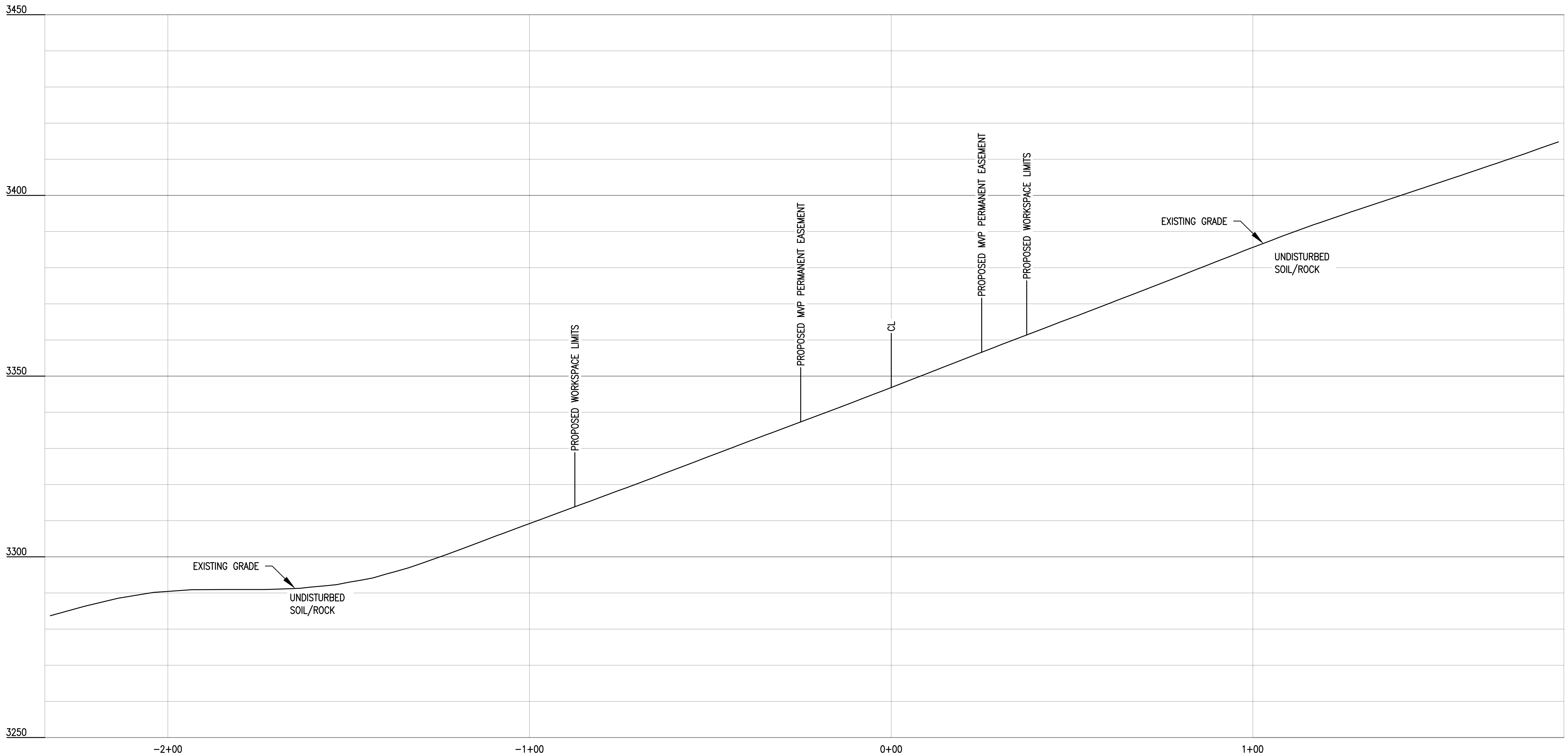
PROJECT ID –

DRAWING SCALE: 1"=50'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #3
PROFILE – FIGURE 13

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS3 | 01 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS3-01.dwg




PRE-CONSTRUCTION SECTION 3A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

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– ELECTRICAL DESIGN ENGINEER — – DATE

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Mountain Valley PIPELINE LLC

PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #3 PRE-CONSTRUCTION SECTION – FIGURE 14

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
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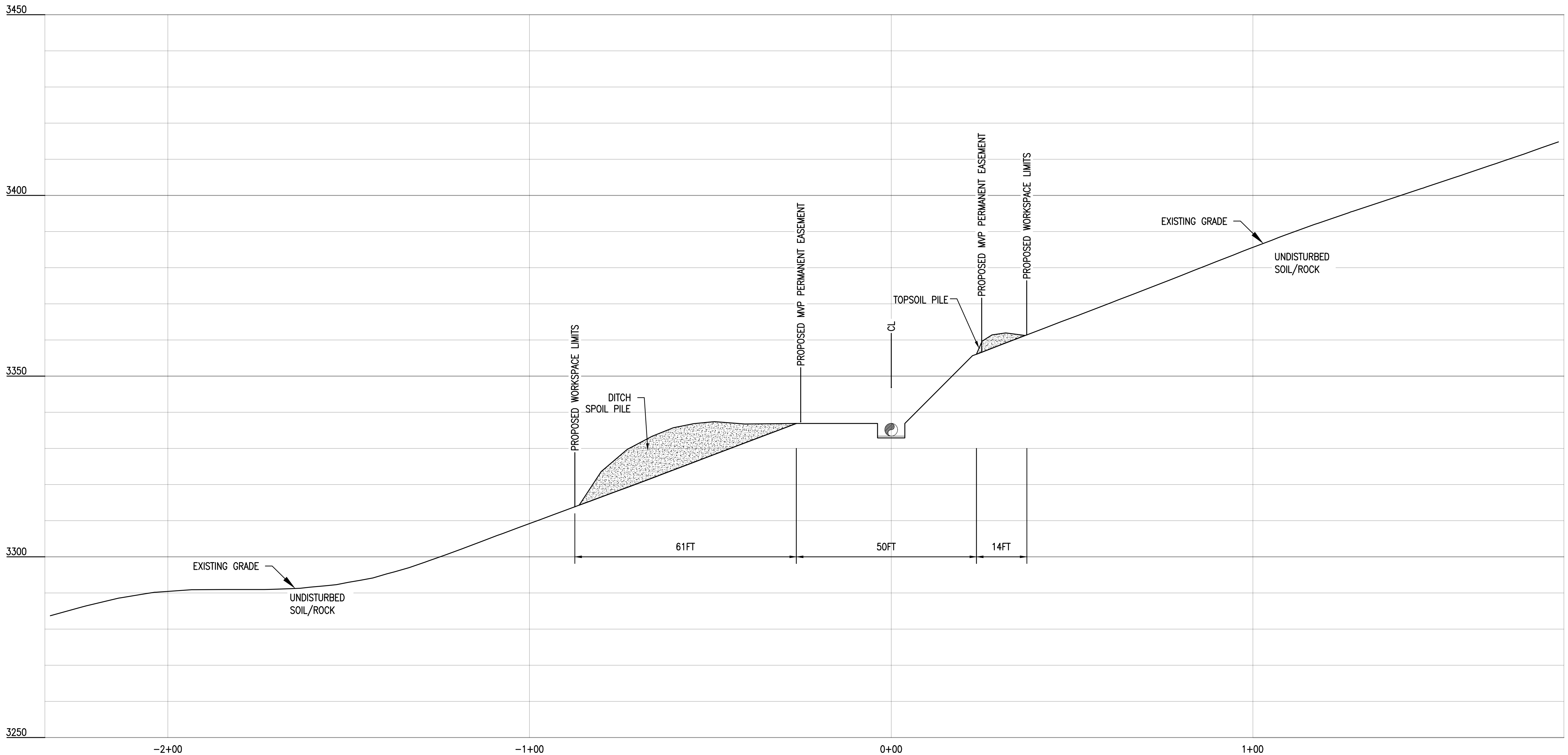
| P | V | H600 | PS3 | 02 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS3-02.dwg




CONSTRUCTION PHASE

SECTION 3A

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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| DWG NUMBER | DRAWING TITLE | P | - | PRELIMINARY ISSUE | EPG | MMF | | - | | | | | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

- MECHANICAL DESIGN ENGINEER — - DATE

- ELECTRICAL DESIGN ENGINEER — - DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

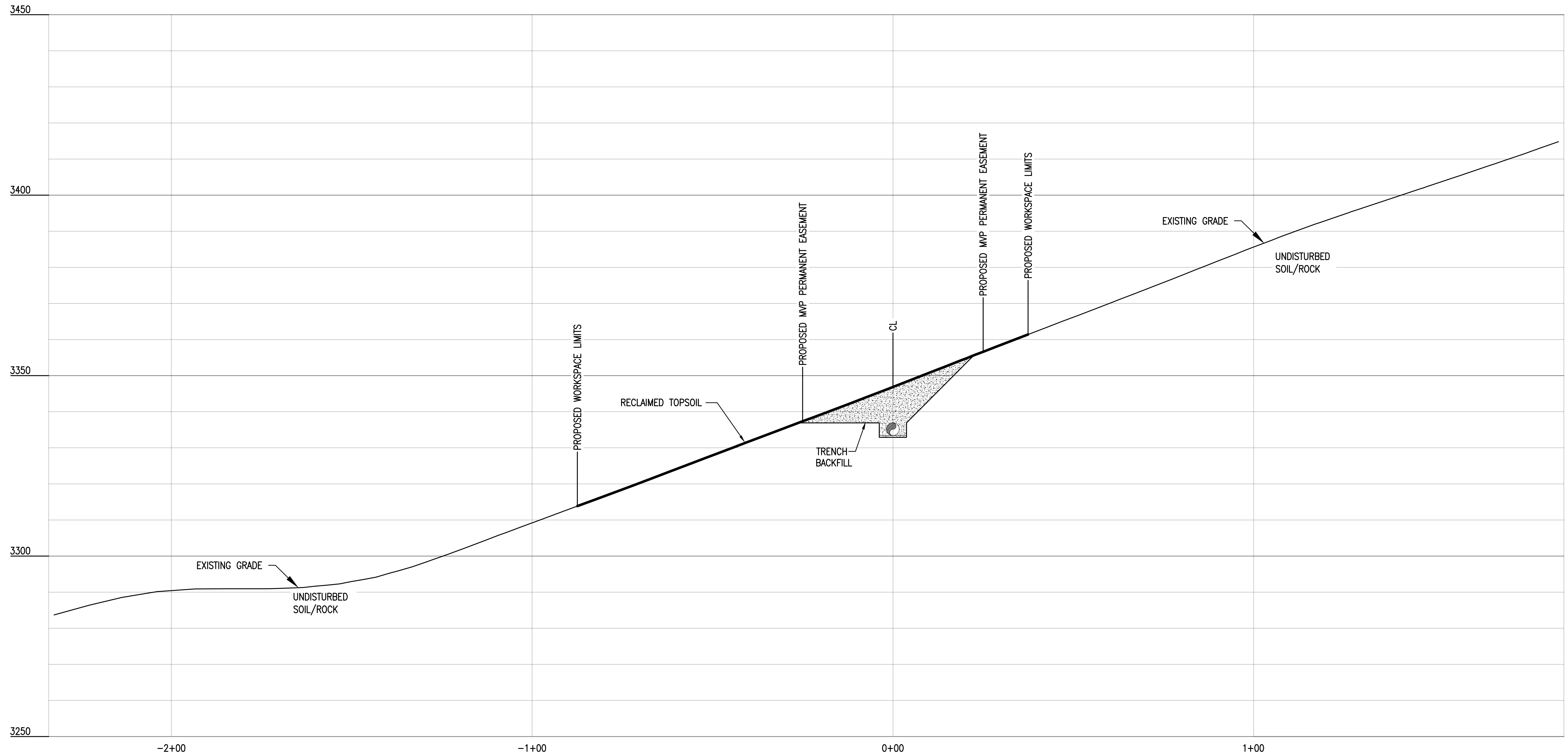
PROJECT ID: -

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #3
CONSTRUCTION PHASE SECTION – FIGURE 15

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS3 | 03 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS3-03.dwg




POST-CONSTRUCTION PHASE

SECTION 3A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | |
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| DWG NUMBER | DRAWING TITLE |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

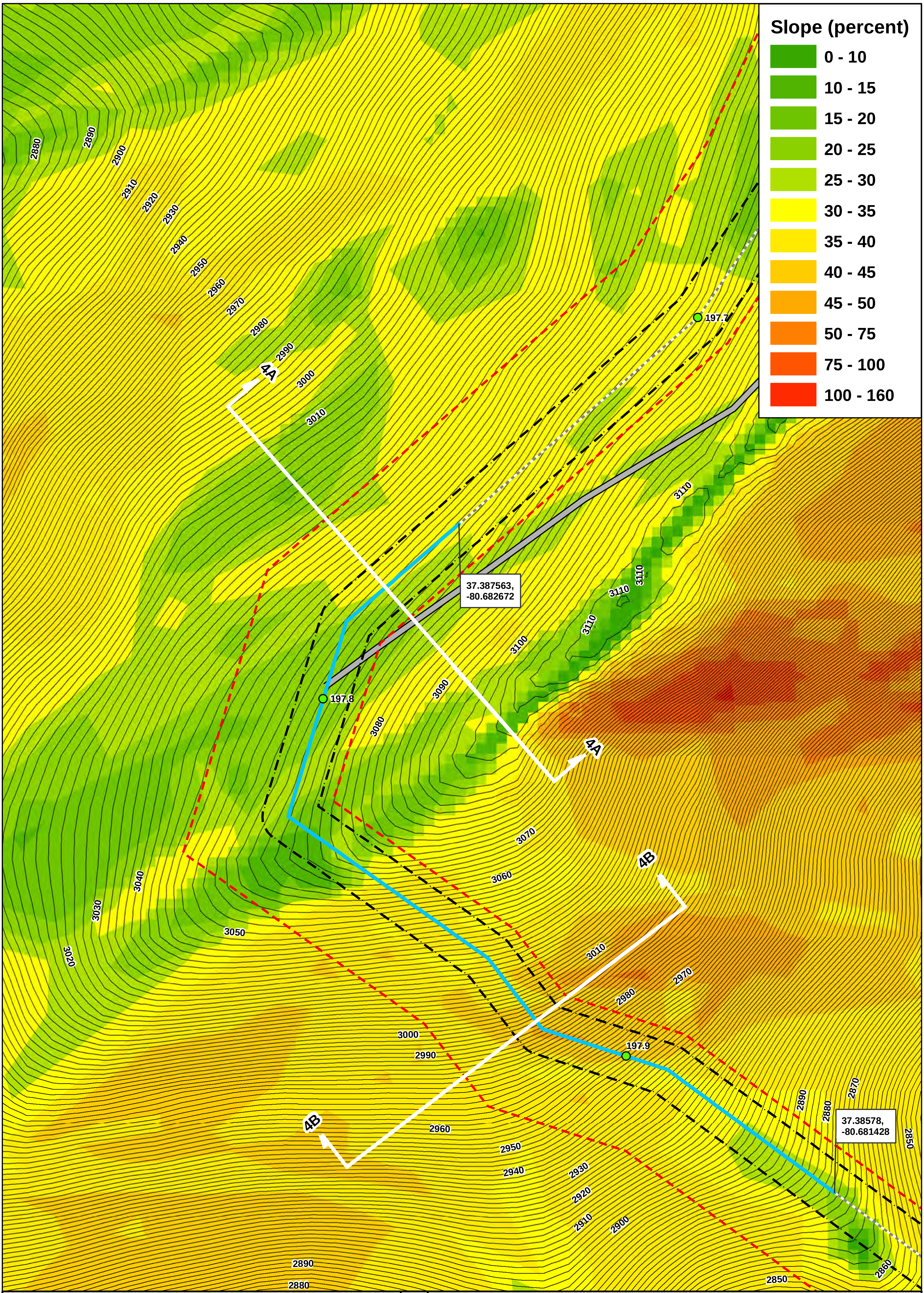
PROJECT ID: –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #3
POST-CONSTRUCTION SECTION – FIGURE 16

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS3 | 04 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS3-04.dwg




Mountain Valley PIPELINE

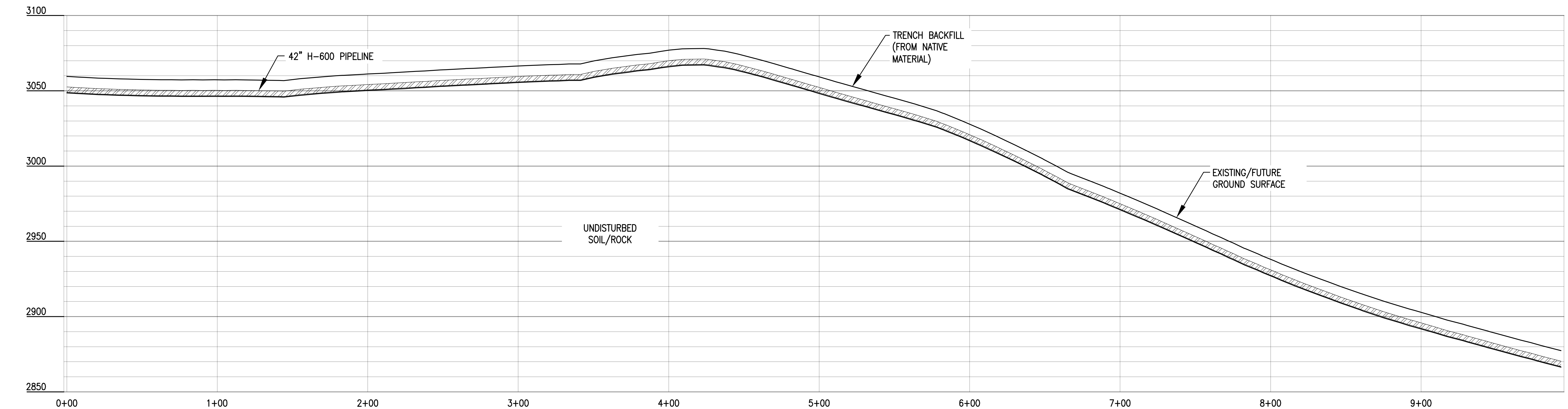
# SLOPE MAP - FIGURE 17
# JEFFERSON NATIONAL FOREST
# PRIORITY SITE 4

0 0.02 0.04 Miles

12/13/2016

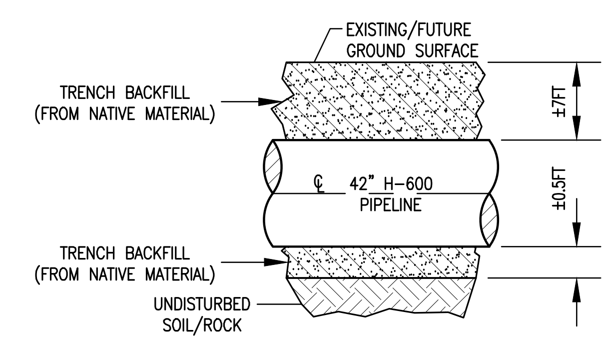
LEGEND

- JNF Priority Site #4
- October 2016 Proposed Route (Revised)
- October 2016 Proposed Route MP (Revised)
- Temporary Work Space
- Permanent Easement




(STATIONING IS RELATIVE TO START OF JNF PRIORITY SITE #4)

PROFILE




TYPICAL TRENCH BACKFILL
(NOT TO SCALE)

| REFERENCE DRAWINGS | |
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| DWG NUMBER | DRAWING TITLE |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

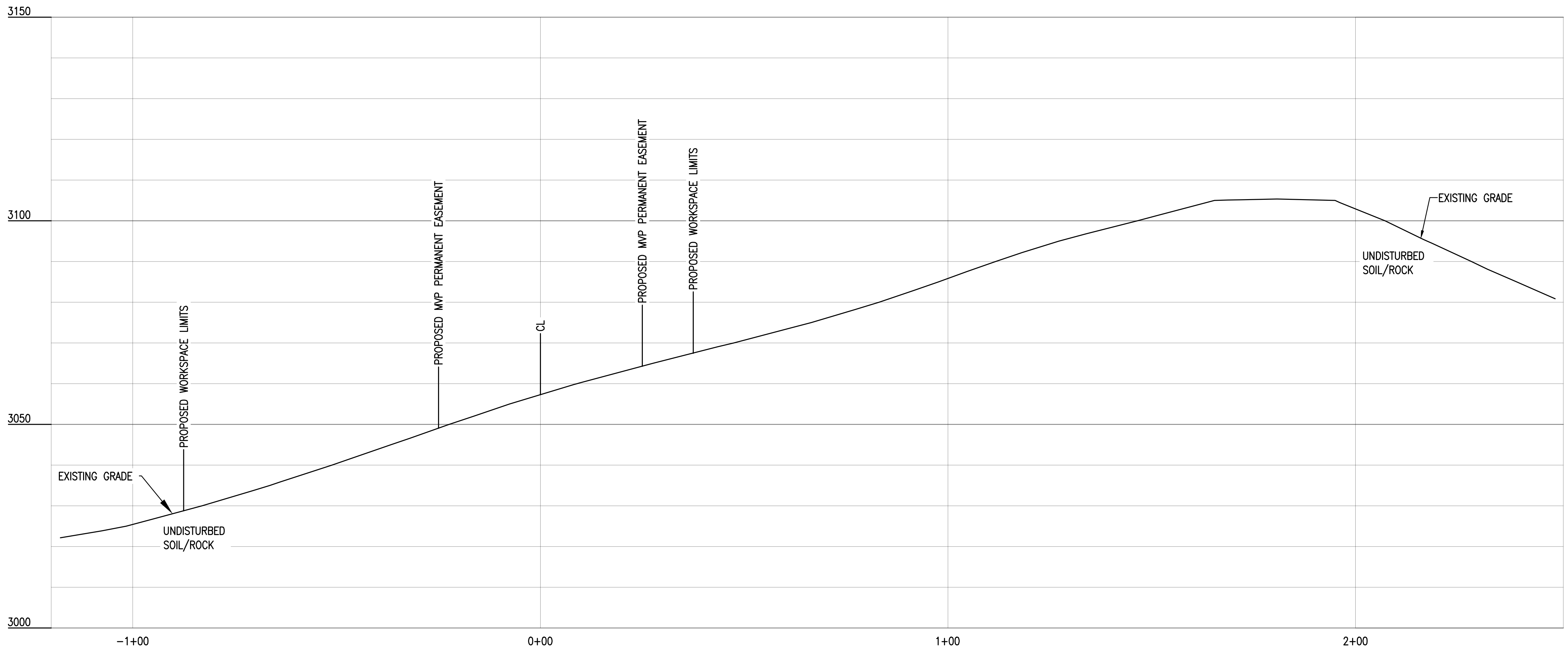
PROJECT ID –

DRAWING SCALE: 1"=70'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #4
PROFILE – FIGURE 18

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS4 | 01 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS4-01.dwg




PRE-CONSTRUCTION
SECTION 4A
SCALE: 1"=30'−0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

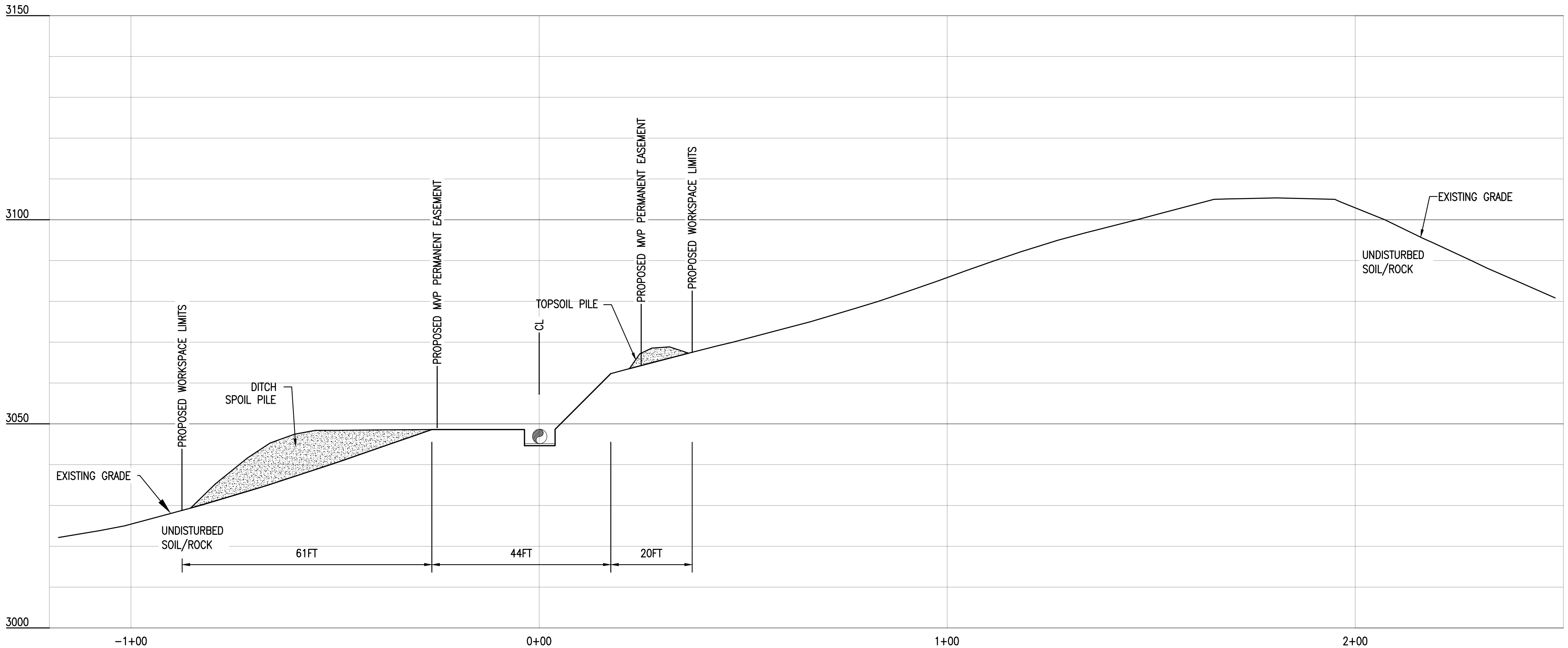
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #4
PRE−CONSTRUCTION SECTION − FIGURE 19

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS4 | 02 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS4-02.dwg




CONSTRUCTION PHASE

SECTION 4A THIS DWG

SCALE: 1"=30'-0"

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

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| ELECTRICAL DESIGN ENGINEER | DATE |

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

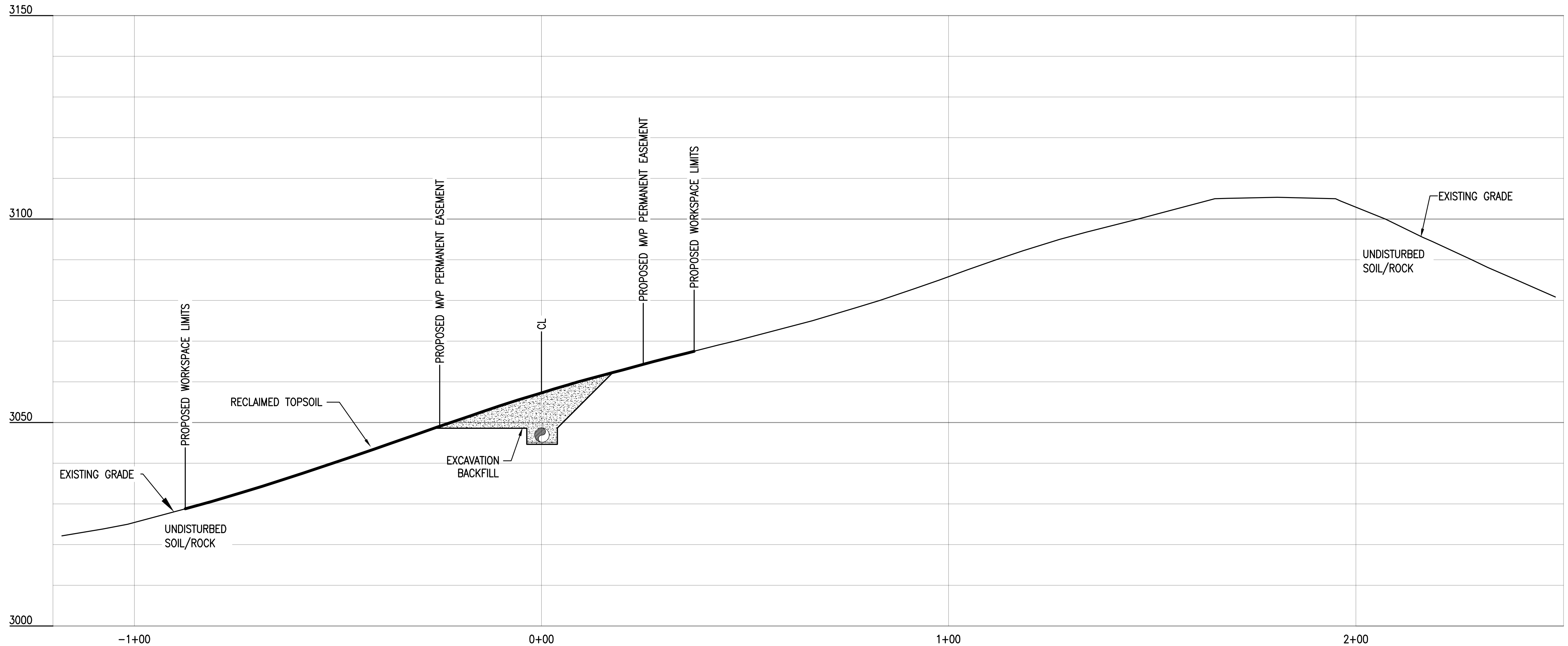
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #4 CONSTRUCTION PHASE SECTION – FIGURE 20

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS4 | 03 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS4-03.dwg




POST-CONSTRUCTION PHASE

SECTION 4A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

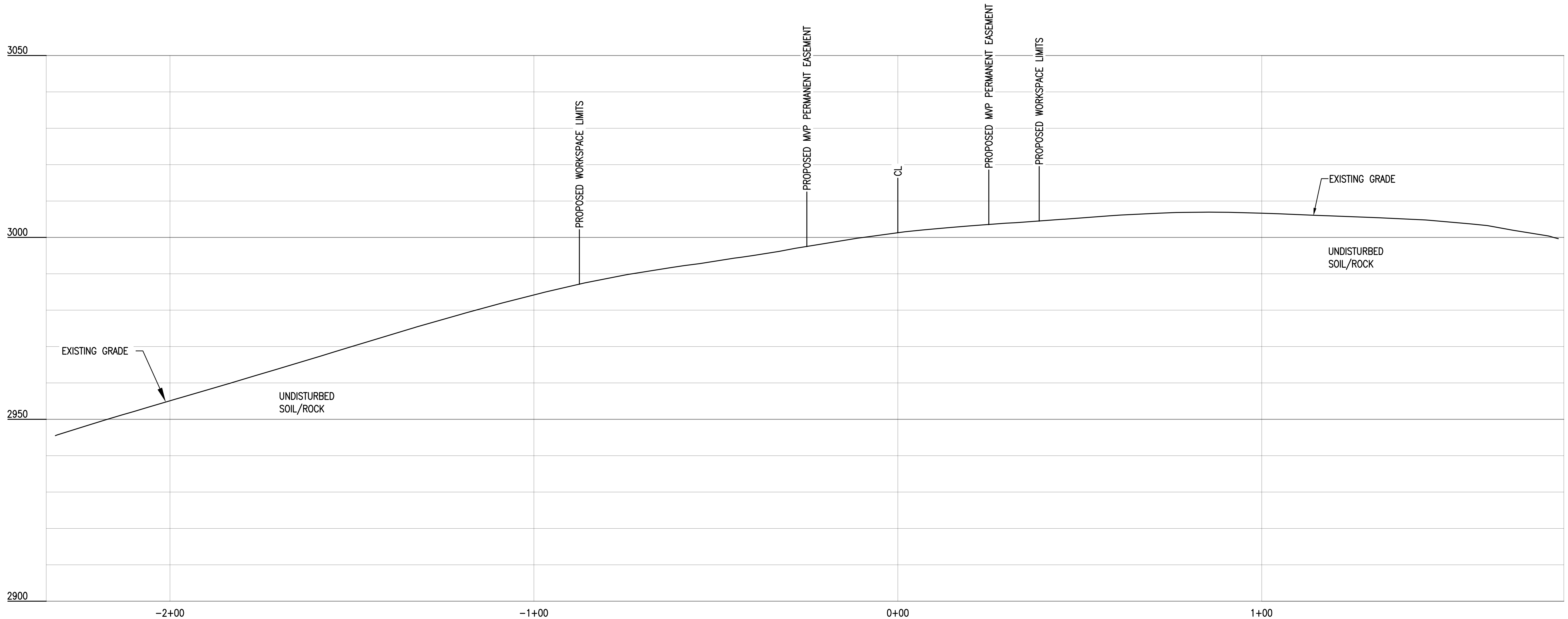
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #4
POST-CONSTRUCTION SECTION - FIGURE 21

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS4 | 04 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS4-04.dwg




PRE-CONSTRUCTION SECTION 4B

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

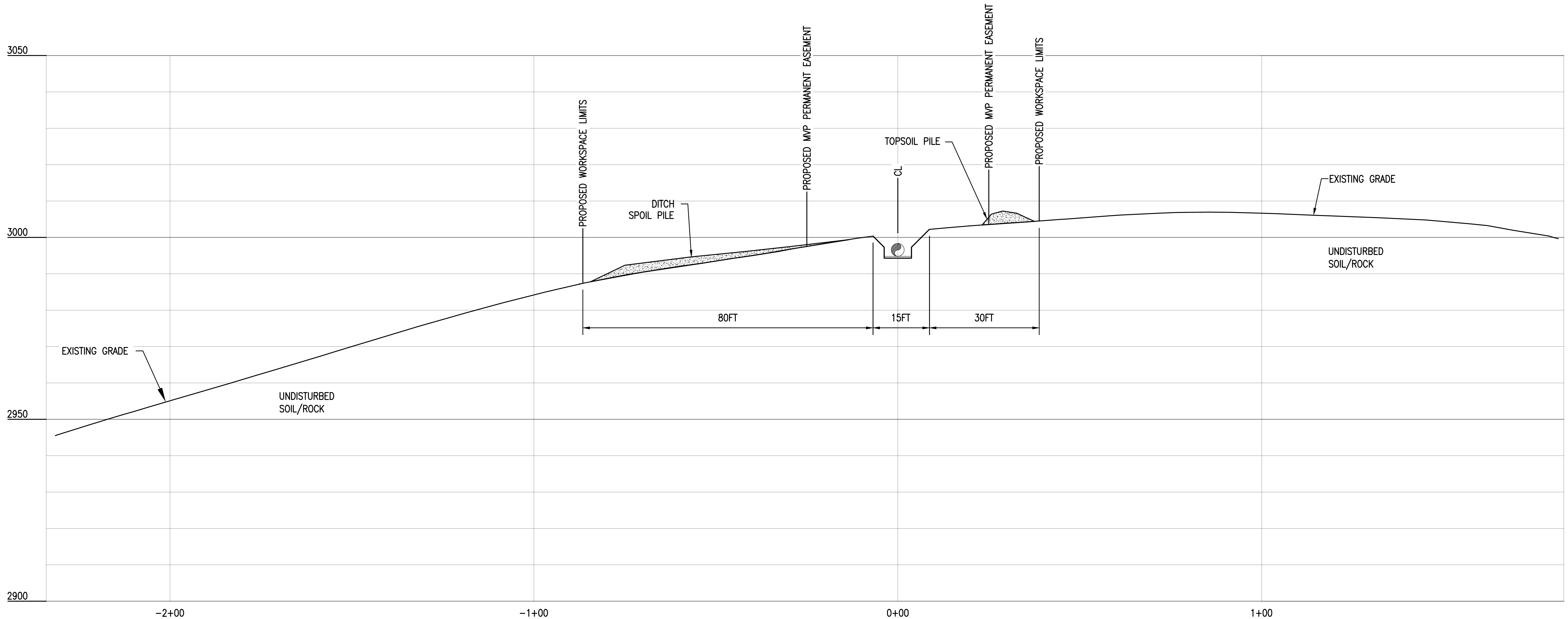
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #4 PRE-CONSTRUCTION SECTION – FIGURE 22

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS4 | 05 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS4-05.dwg




CONSTRUCTION PHASE

SECTION 4B
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

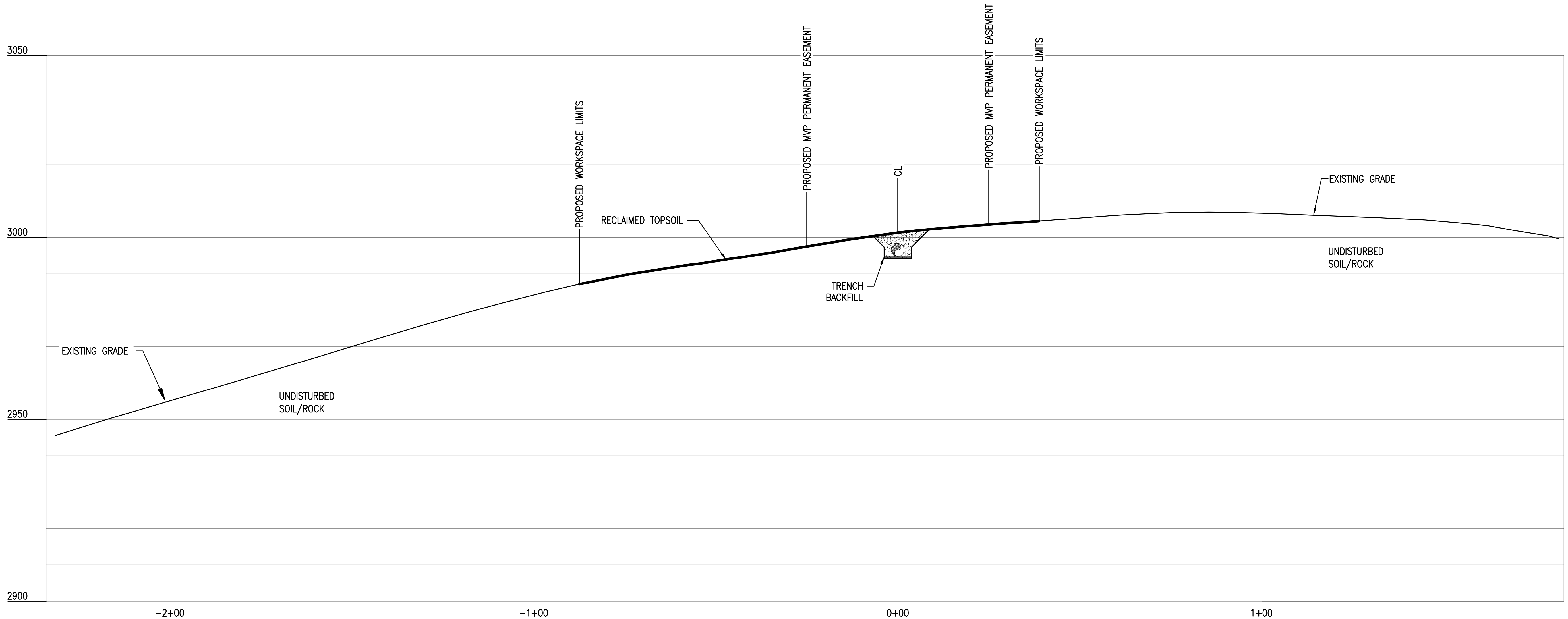
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #4
CONSTRUCTION PHASE SECTION – FIGURE 23

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS4 | 06 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS4-06.dwg




POST-CONSTRUCTION PHASE

SECTION 4B
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

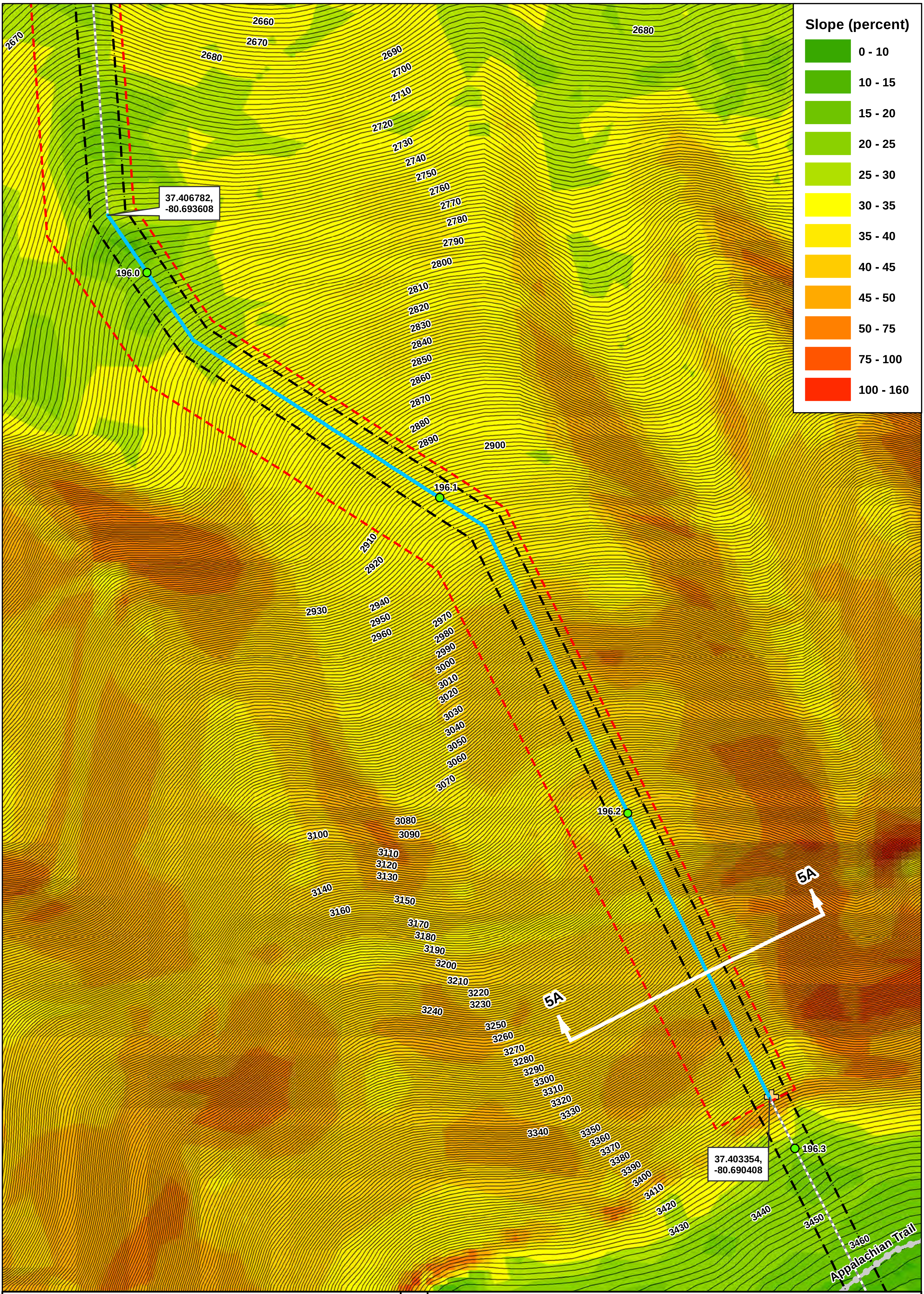
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #4
POST-CONSTRUCTION SECTION – FIGURE 24

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS4 | 07 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS4-07.dwg




Mountain Valley PIPELINE

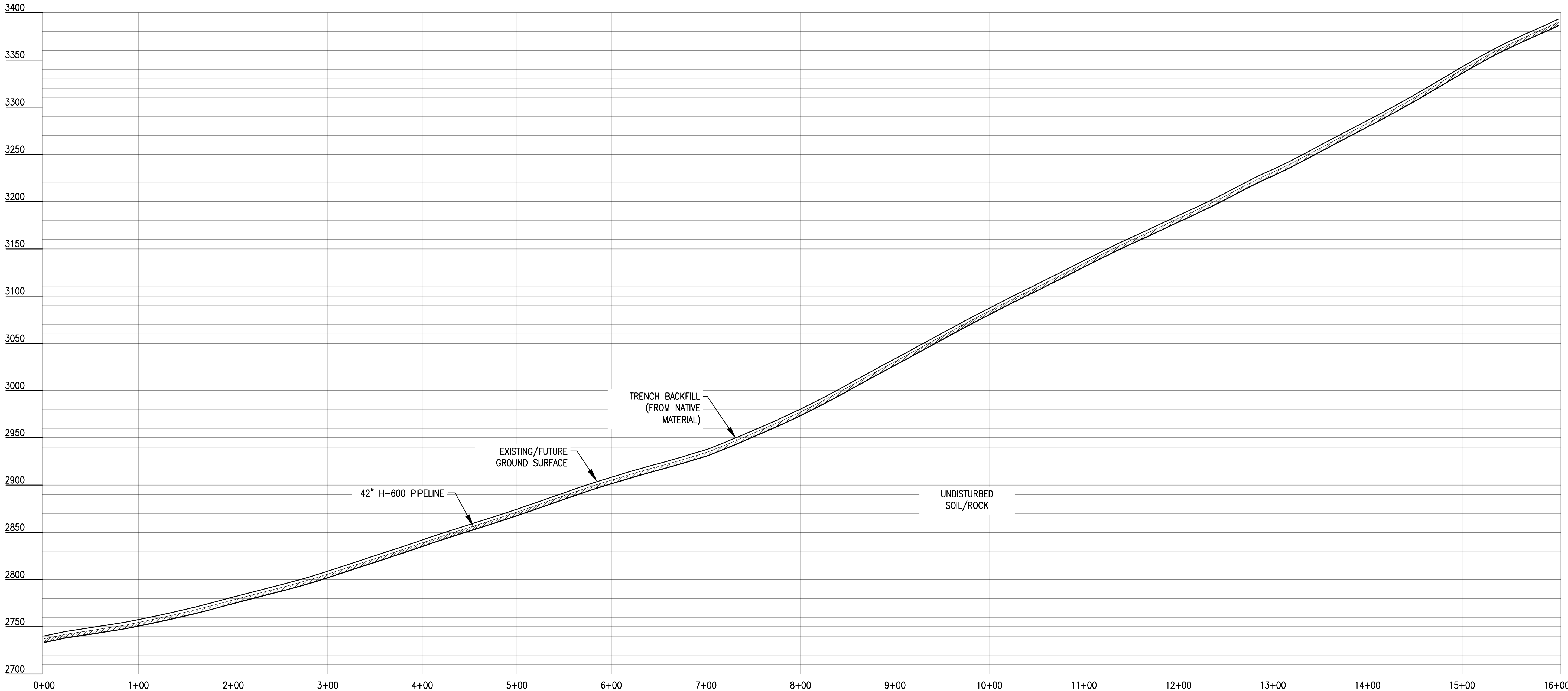
**SLOPE MAP - FIGURE 25**
**JEFFERSON NATIONAL FOREST**
**PRIORITY SITE 5**

0 0.025 0.05 Miles

12/16/2016

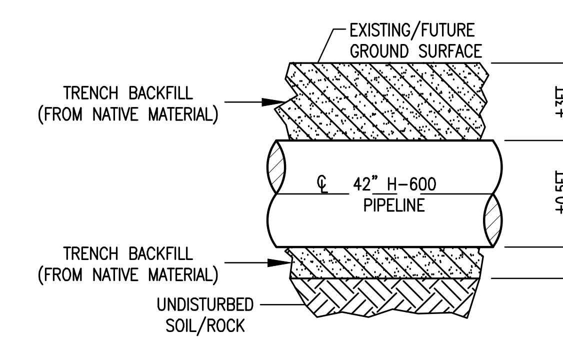
**LEGEND**

- JNF Priority Site #5
- October 2016 Proposed Route (Revised)
- October 2016 Proposed Route MP (Revised)
- Temporary Work Space
- Permanent Easement
- Bore Pit




(STATIONING IS RELATIVE TO START OF JNF PRIORITY SITE #5)

PROFILE




TYPICAL TRENCH BACKFILL

(NOT TO SCALE)

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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

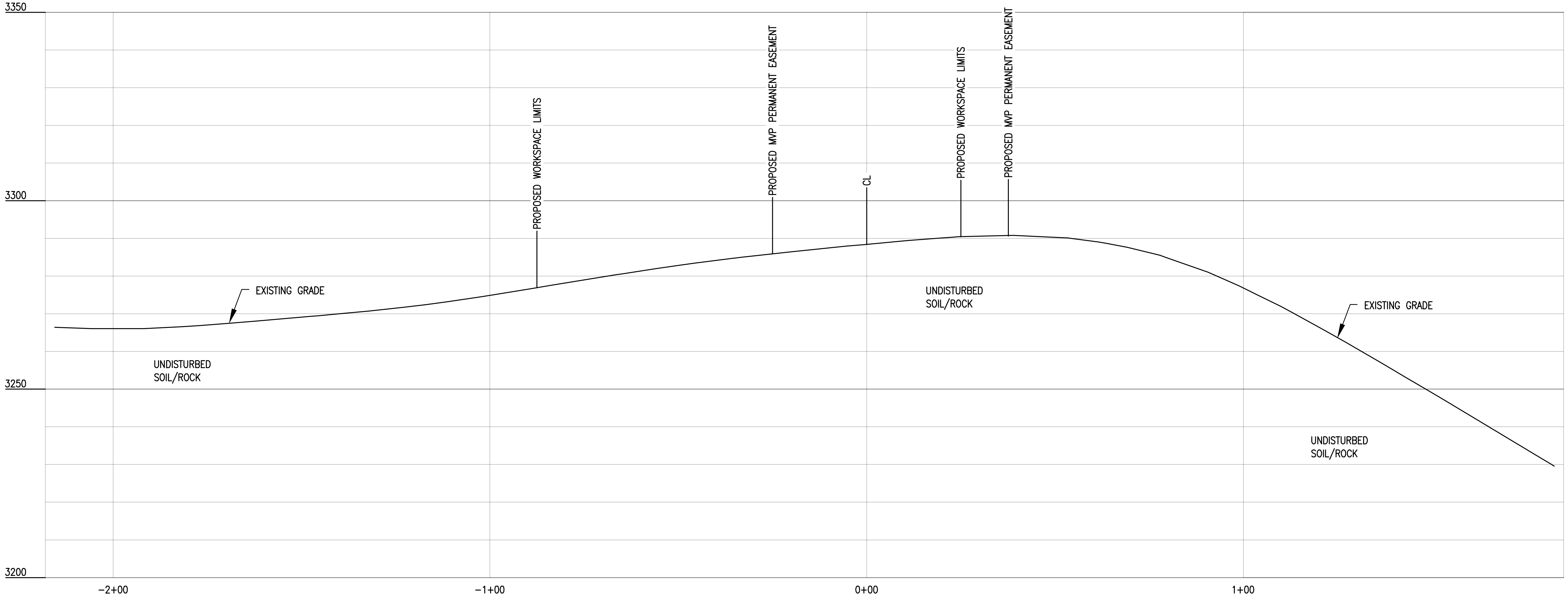
PROJECT ID: –

DRAWING SCALE: 1"=110'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #5 PROFILE – FIGURE 26

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS5 | 01 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS5-01.dwg




PRE-CONSTRUCTION SECTION 5A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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| DWG NUMBER | DRAWING TITLE | P | – | PRELIMINARY ISSUE | EPG | MMF | | – | | | | | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

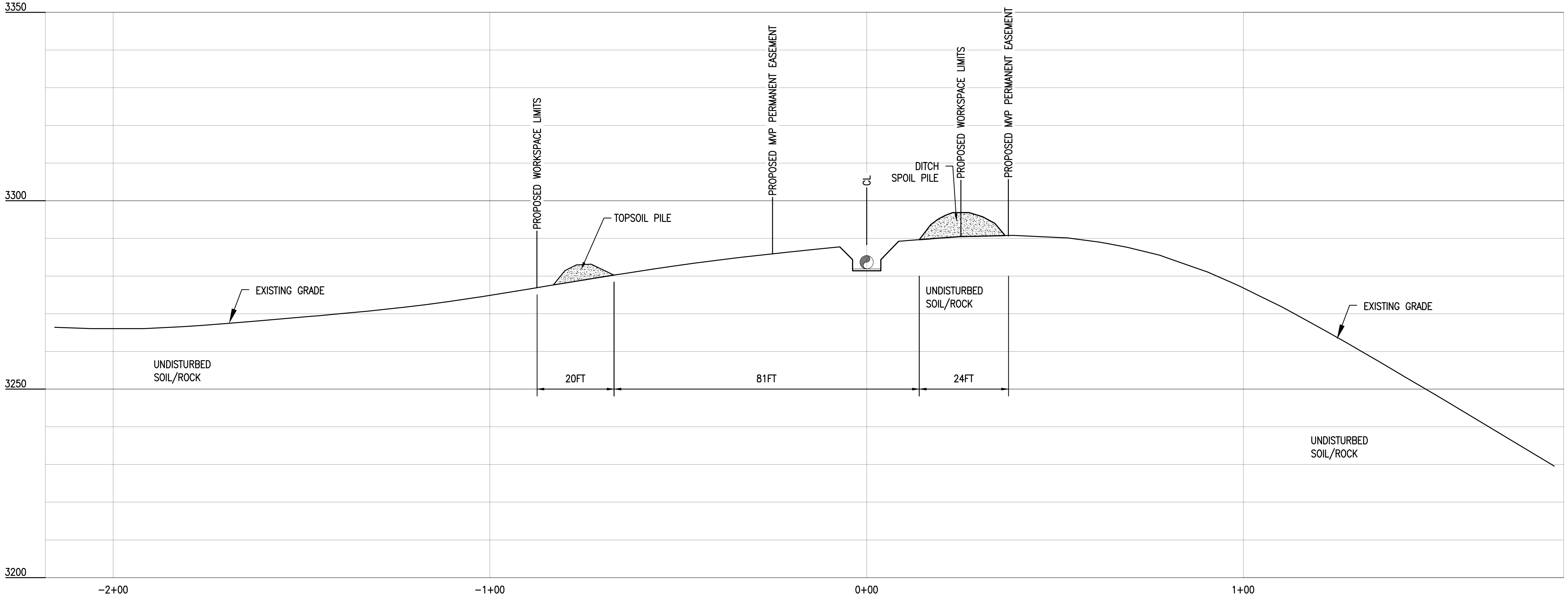
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #5
PRE-CONSTRUCTION SECTION – FIGURE 27

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS5 | 02 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS5-02.dwg




## CONSTRUCTION PHASE

SECTION 5A

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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| DWG NUMBER | DRAWING TITLE | P | – | PRELIMINARY ISSUE | EPG | MMF | | – | | | | | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER    – DATE

– ELECTRICAL DESIGN ENGINEER    – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

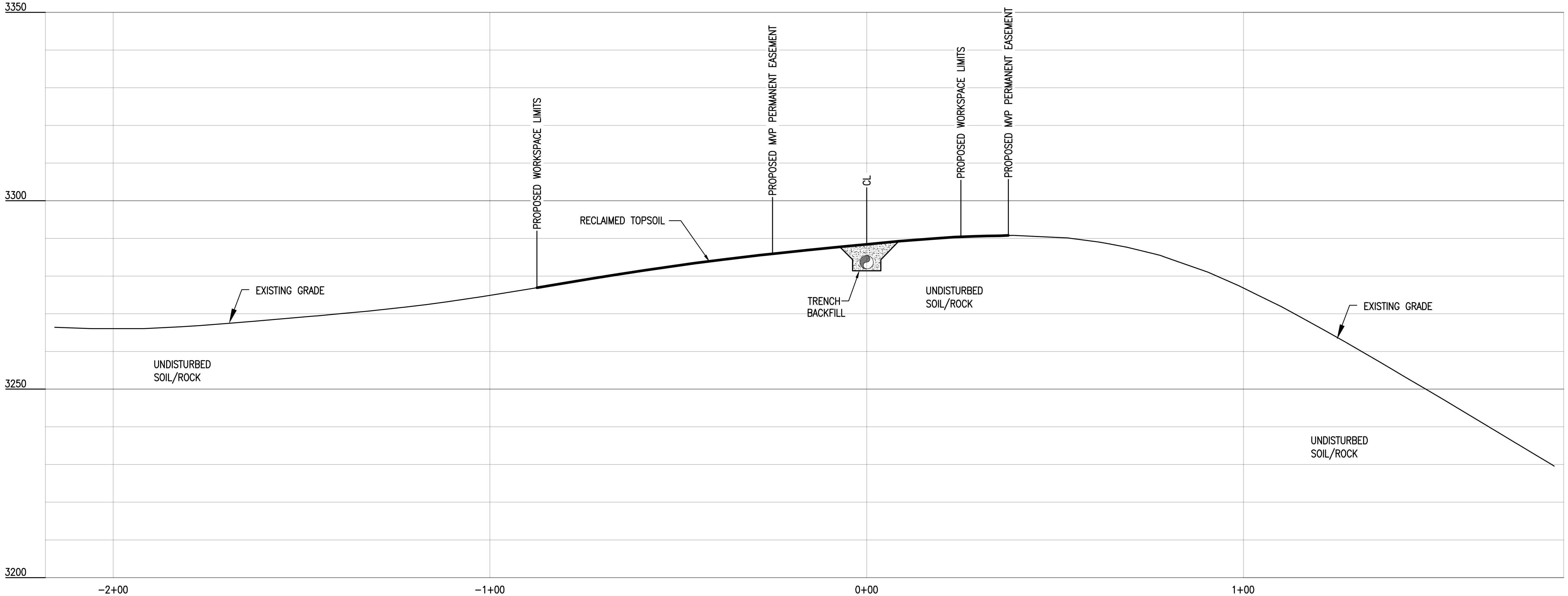
PROJECT ID: –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #5 CONSTRUCTION PHASE SECTION – FIGURE 28

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS5 | 03 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS5-03.dwg




POST-CONSTRUCTION

SECTION 5A

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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| DWG NUMBER | DRAWING TITLE | P | – | PRELIMINARY ISSUE | EPG | MMF | | – | | | | | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

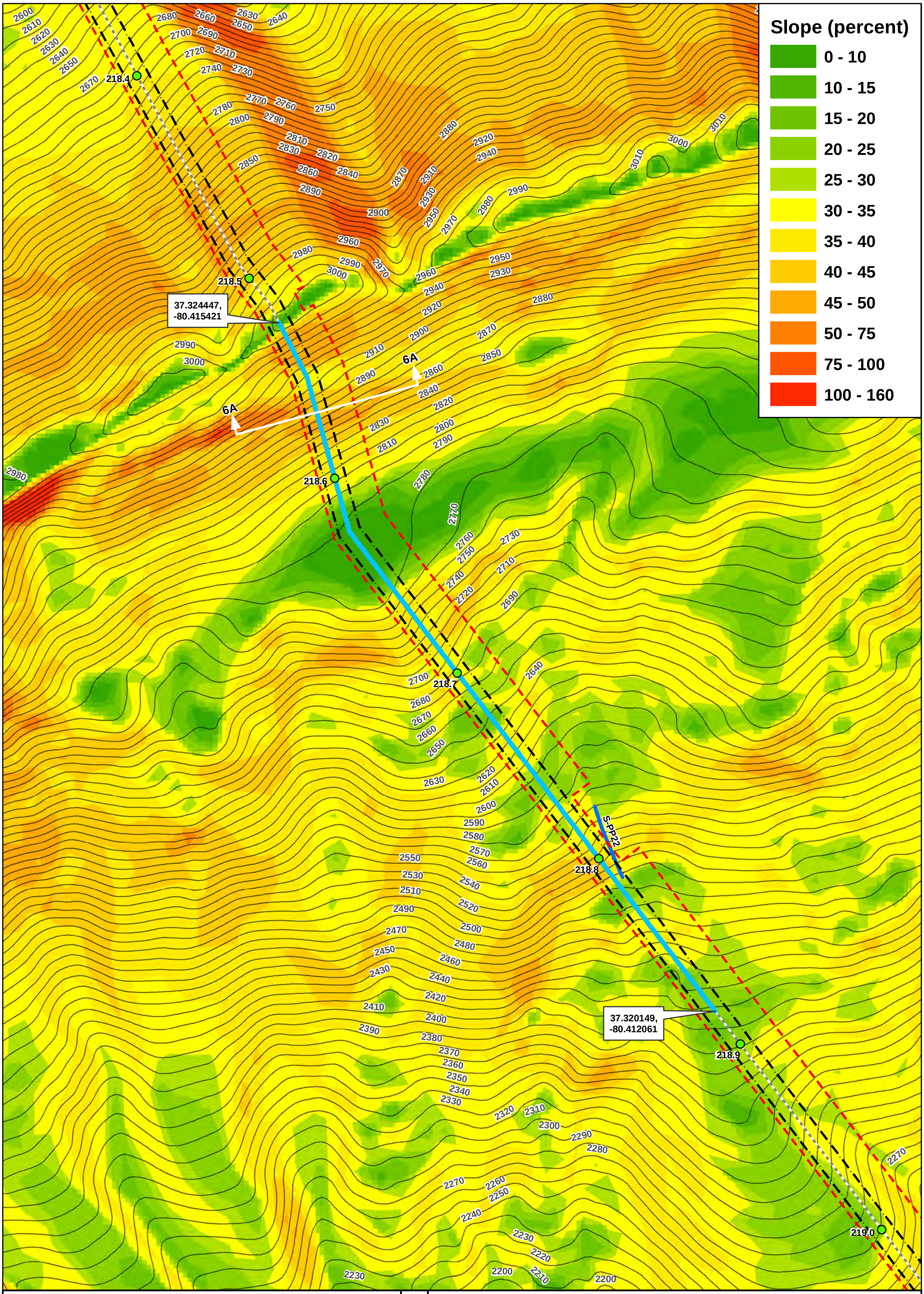
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #5 POST-CONSTRUCTION SECTION – FIGURE 29

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS5 | 04 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS5-04.dwg




Mountain Valley PIPELINE

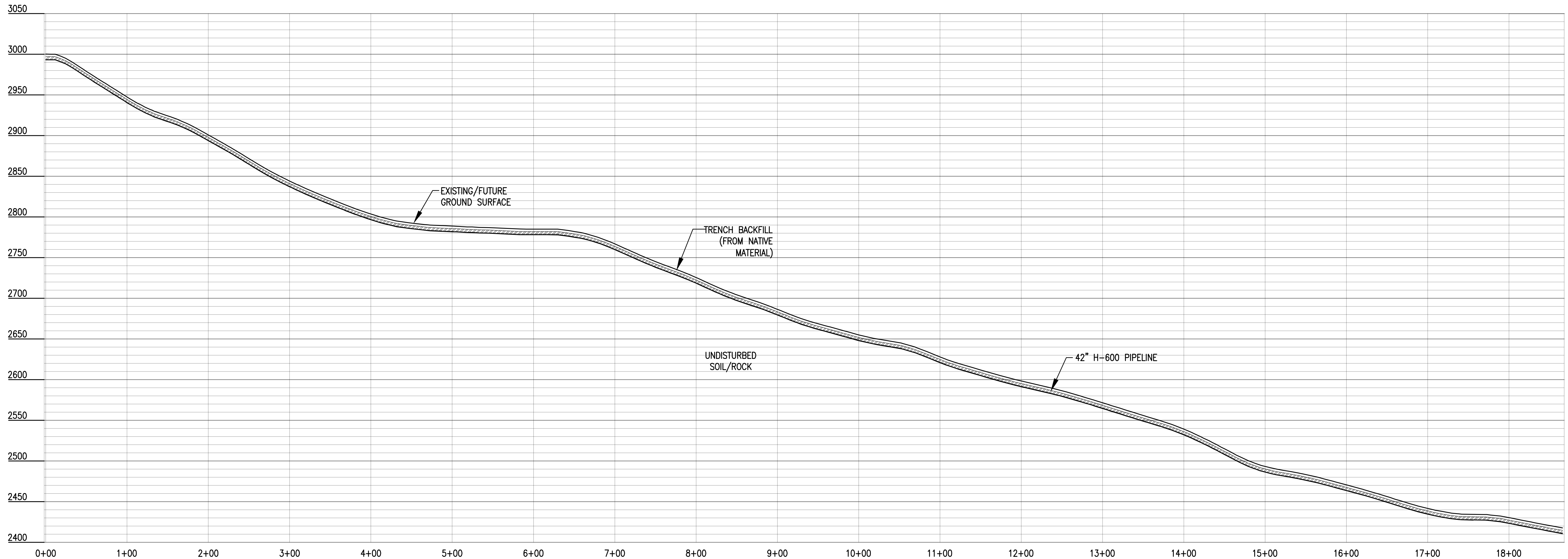
**SLOPE MAP - FIGURE 30**
**JEFFERSON NATIONAL FOREST**
**PRIORITY SITE 6**

0 0.05 0.1 Miles

12/13/2016

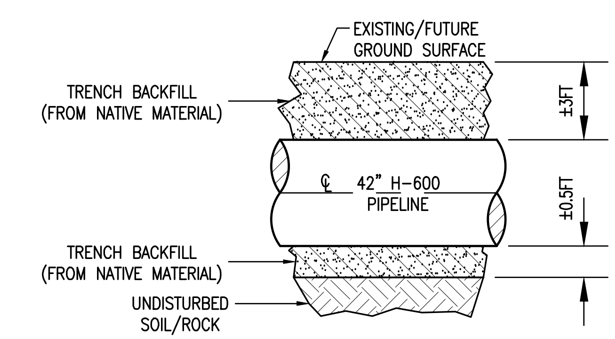
**LEGEND**

- JNF Priority Site #6
- October 2016 Proposed Route (Revised)
- October 2016 Proposed Route MP (Revised)
- Temporary Work Space
- Permanent Easement




(STATIONING IS RELATIVE TO START OF JNF PRIORITY SITE #6)

PROFILE




TYPICAL TRENCH BACKFILL
(NOT TO SCALE)

| REFERENCE DRAWINGS | |
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| DWG NUMBER | DRAWING TITLE |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER   – DATE

– ELECTRICAL DESIGN ENGINEER   – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

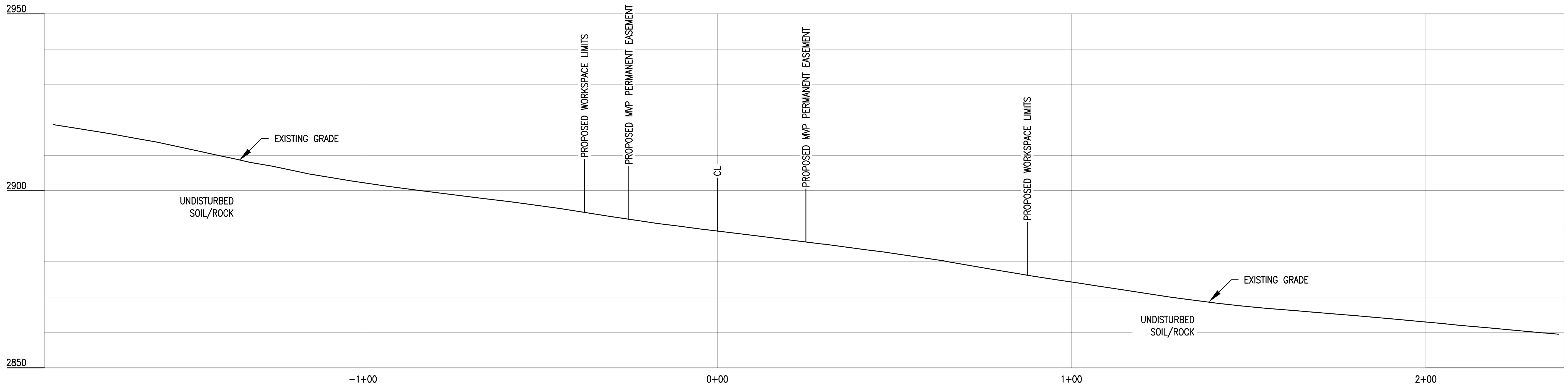
Mountain Valley PIPELINE LLC

PROJECT ID: –

DRAWING SCALE: 1"=125'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #6 PROFILE – FIGURE 31

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS6 | 01 | P |




PRE-CONSTRUCTION SECTION 6A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

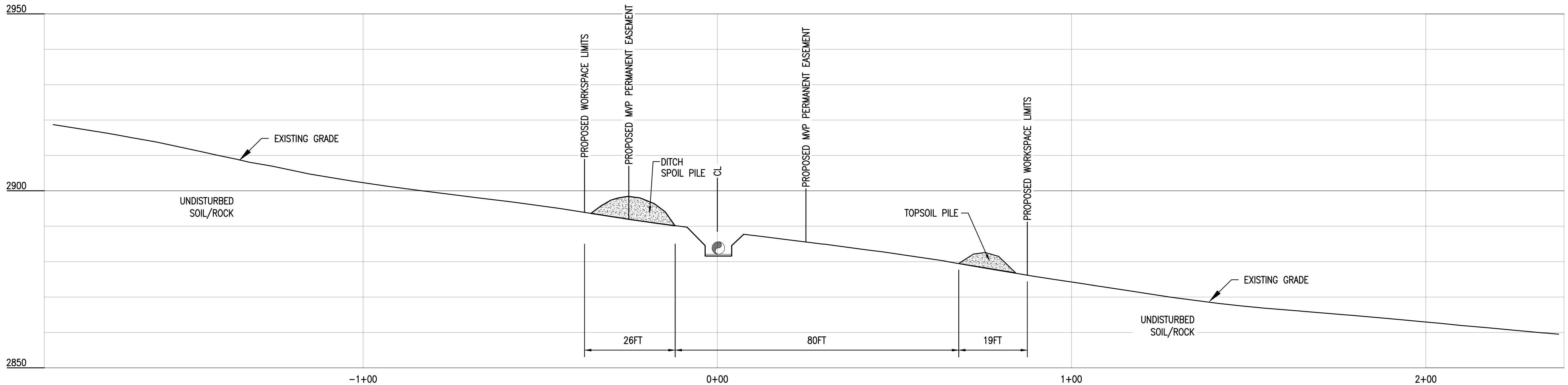
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #6 PRE-CONSTRUCTION SECTION – FIGURE 32

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS6 | 02 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS6-02.dwg




CONSTRUCTION PHASE

SECTION 6A
SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER – DATE

– ELECTRICAL DESIGN ENGINEER – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

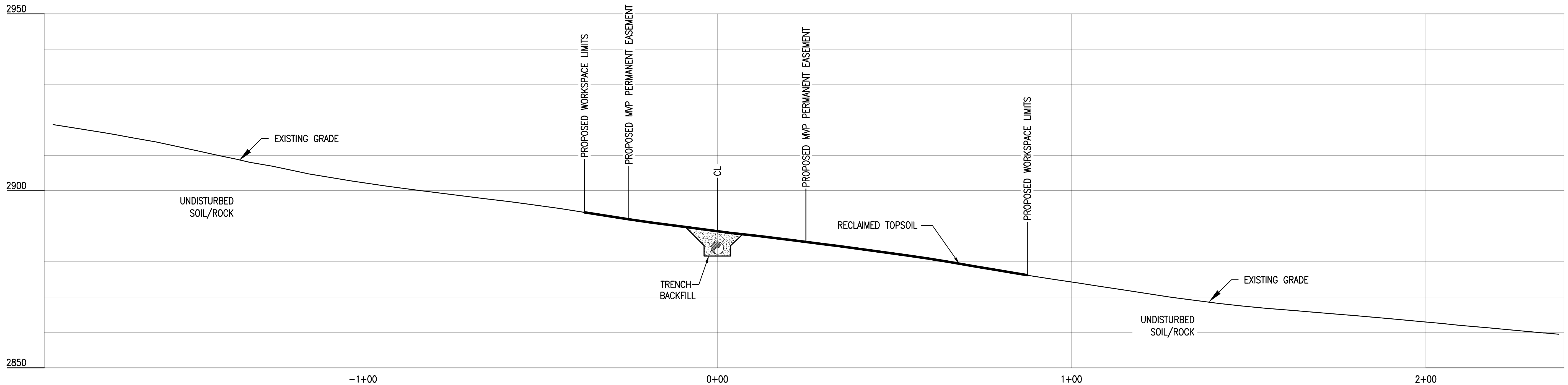
PROJECT ID –

DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE JEFFERSON NATIONAL FOREST PRIORITY SITE #6 CONSTRUCTION PHASE SECTION – FIGURE 33

| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS6 | 03 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS6-03.dwg




POST-CONSTRUCTION

SECTION 6A

SCALE: 1"=30'-0" THIS DWG

NOTE:

1. ALL DIMENSIONS ARE APPROXIMATE AND DEPENDENT ON PIPELINE FIELD LOCATION.

| REFERENCE DRAWINGS | | NO. | DATE | REVISION | BY | CHK | APPD | NO. | DATE | REVISION | BY | CHK | APPD |
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| DWG NUMBER | DRAWING TITLE | P | – | PRELIMINARY ISSUE | EPG | MMF | | – | | | | | |
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TO THE BEST OF MY KNOWLEDGE, ALL COMPONENTS OF THIS DRAWING ARE DESIGNED IN ACCORDANCE WITH APPLICABLE GUIDELINES AND SPECIFICATIONS

– MECHANICAL DESIGN ENGINEER — – DATE

– ELECTRICAL DESIGN ENGINEER — – DATE

NOTE: ANY CHANGES TO THE DESIGN SHOWN ON THIS DRAWING MUST BE APPROVED BY THE DESIGN ENGINEER.

Mountain Valley PIPELINE LLC

PROJECT ID: –

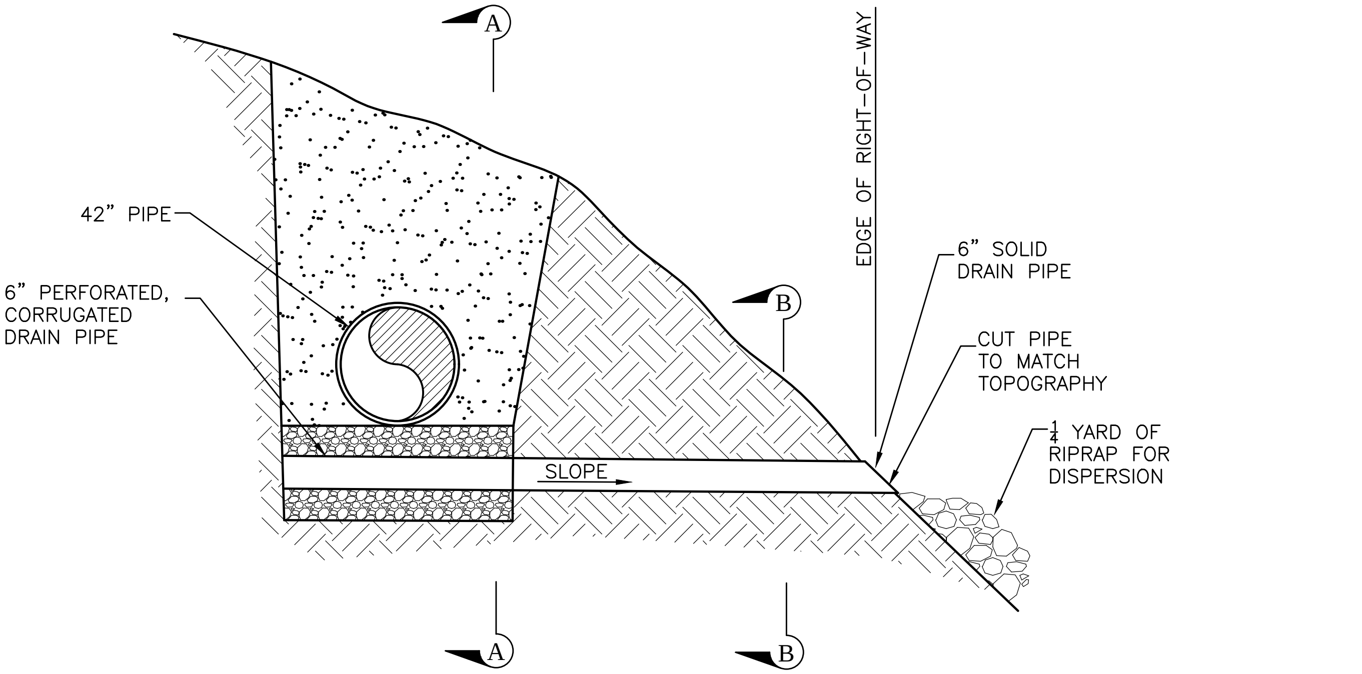
DRAWING SCALE: 1"=30'

DRAWING TITLE: MOUNTAIN VALLEY PIPELINE
JEFFERSON NATIONAL FOREST
PRIORITY SITE #6
POST CONSTRUCTION SECTION – FIGURE 34

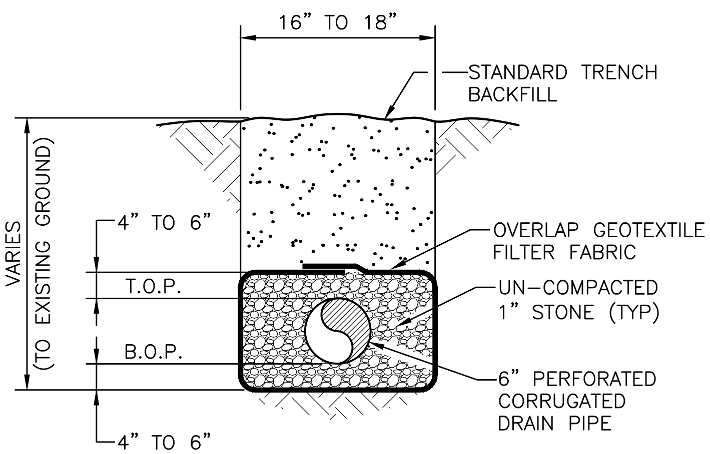
| FACILITY | STATE | IDENTIFICATION | SERIES | SHEET | REVISION |
|---|---|---|---|---|---|
| P | V | H600 | PS6 | 04 | P |

le Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Civil\JNF Site Specific Design_Nov 2016\P-V-H600-PS6-04.dwg

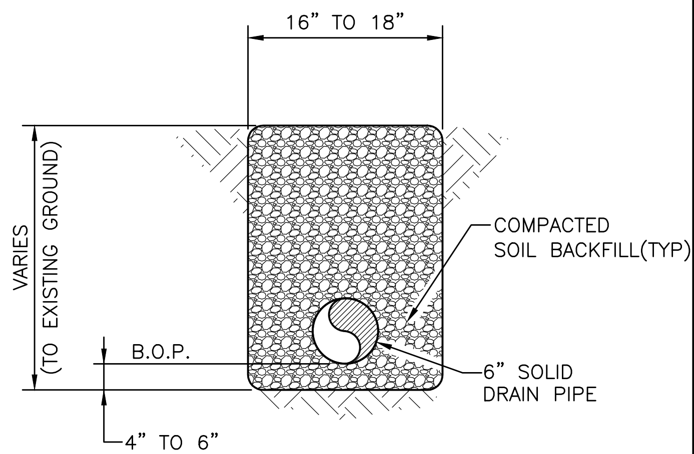
# Appendix B – Typical Drawings




MAINLINE CROSS SECTION




SECTION A-A




SECTION B-B

NOTES

1. LOW POINT DITCH DRAINS SHALL BE INSTALLED AT LOCATIONS SPECIFIED IN THE APPROVED EROSION & SEDIMENTATION CONTROL PLAN, AND AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
2. FILL STONE SHOULD BE 1" AGGREGATE WITHOUT FINES, CRUSHER RUN WITHOUT FINES, OR EQUIVALENT.
3. DRAIN PIPE TO BE CONNECTED USING STANDARD PIPE COLLARS.

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN | JIL | DATE | 10/6/2016 |
| CHECKED | MMF | DATE | 10/6/2016 |
| APP'D | XXX | DATE | 10/6/2016 |
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| JOB NO. | | | |
| PROJECT ID: PXXXX | | | |

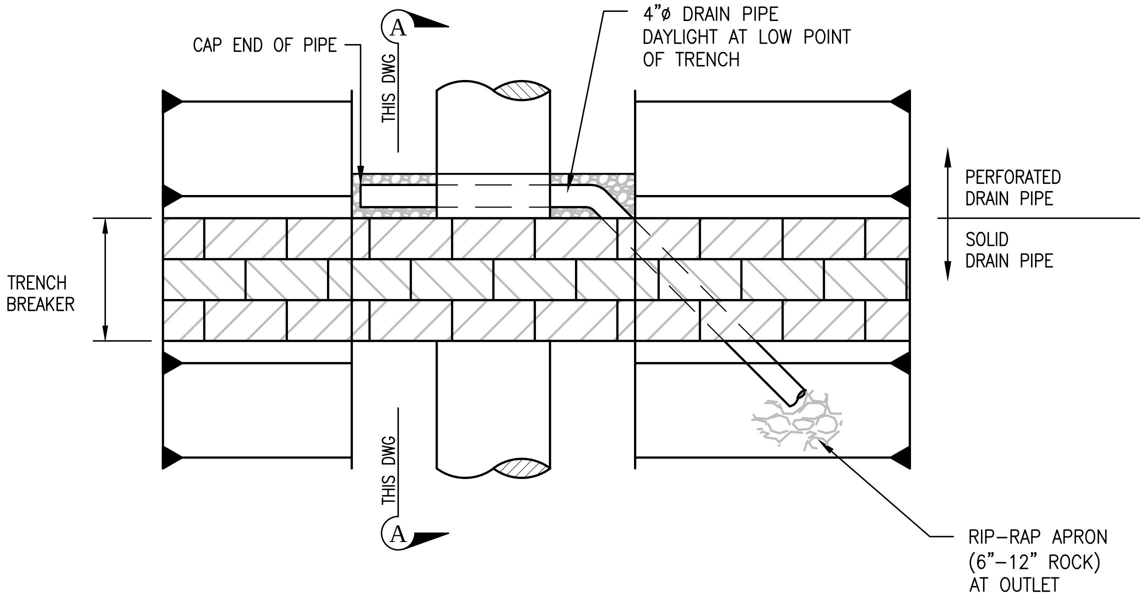
Mountain Valley PIPELINE

DESIGN ENGINEERING

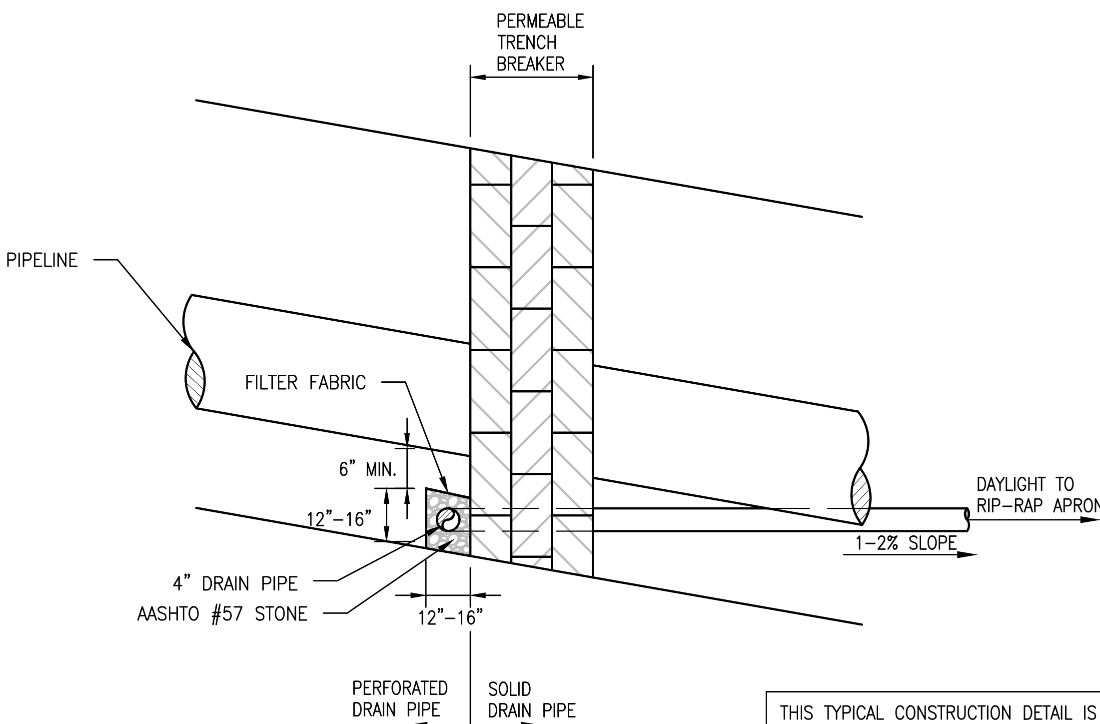
**TYPICAL CONSTRUCTION DETAIL**

SIDEHILL LOW-POINT DRAIN TYPICAL

| DRAWING NO. | REV. |
|---|---|
| MVP-24 | 0 |




PLAN
SCALE: NOT TO SCALE




SECTION A-A
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 1 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

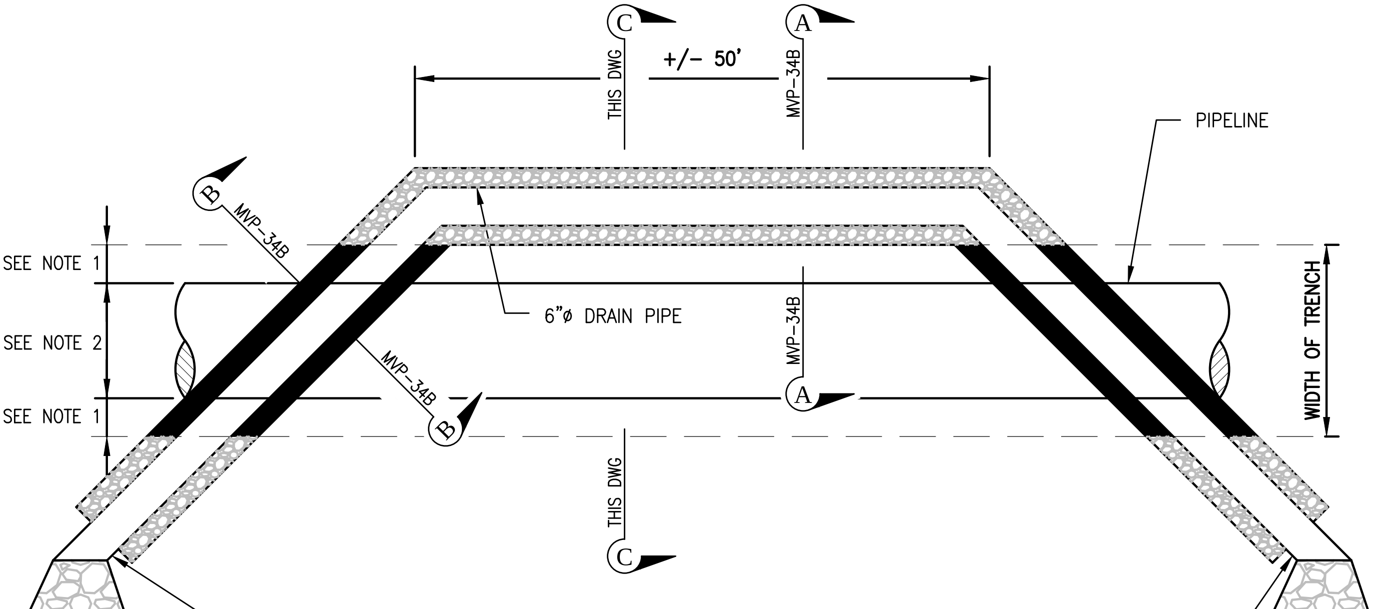
TYPICAL CONSTRUCTION DETAIL

TRENCH BREAKER DAYLIGHT DRAIN

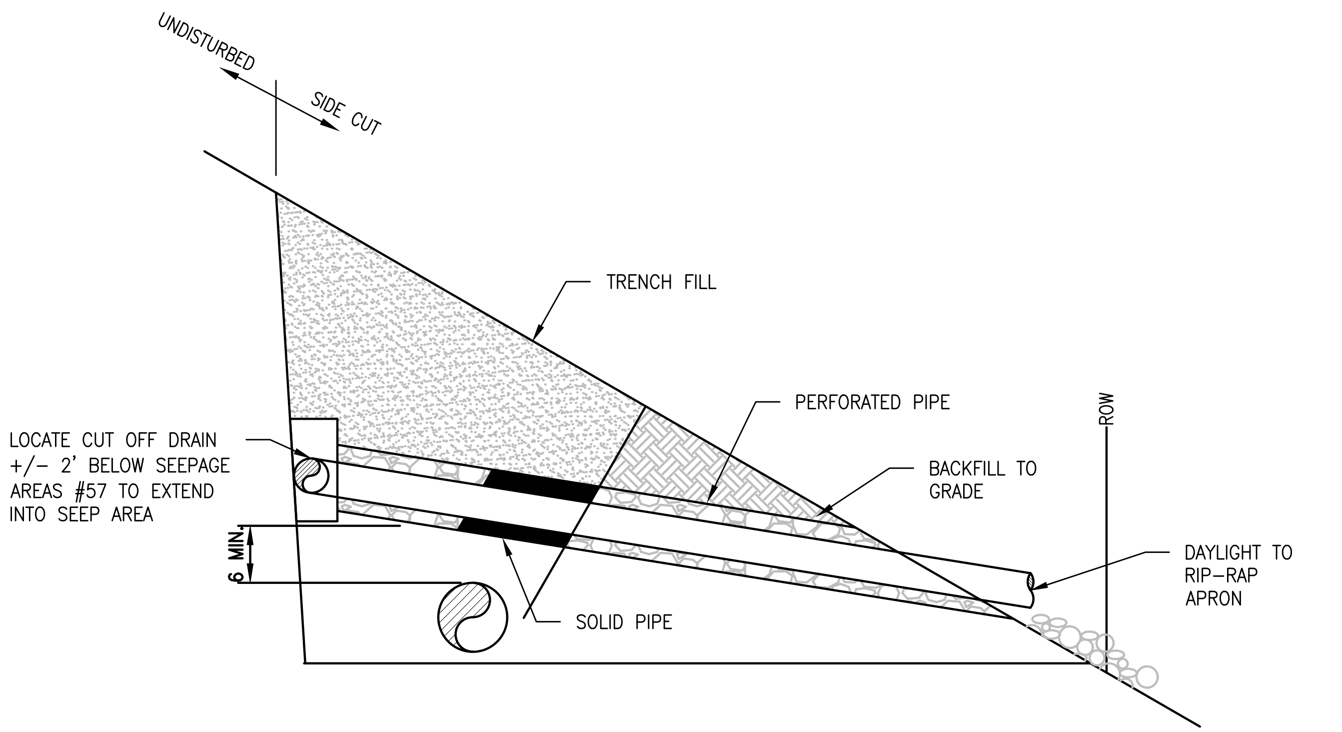
| DRAWING NO. | REV. |
|---|---|
| MVP-35 | 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-35.dwg




PLAN
SCALE: NOT TO SCALE




SECTION C-C
SCALE: NOT TO SCALE

NOTES:
1. PERFORATED PIPE SURROUNDED BY #57 STONE.
2. SOLID PIPE (IN TRENCH) SURROUNDED BY TRENCH BACKFILL.

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 2 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

# TYPICAL CONSTRUCTION DETAIL

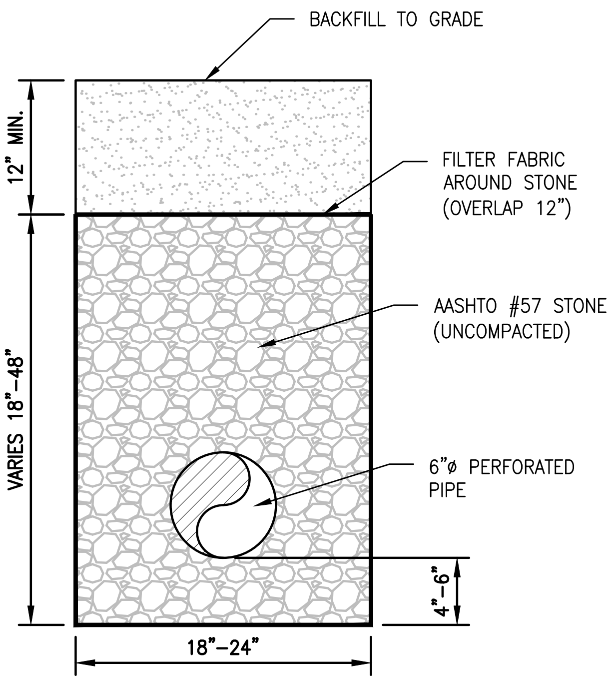
CUTOFF DRAIN-SIDEHILL

DRAWING NO. MVP-36A

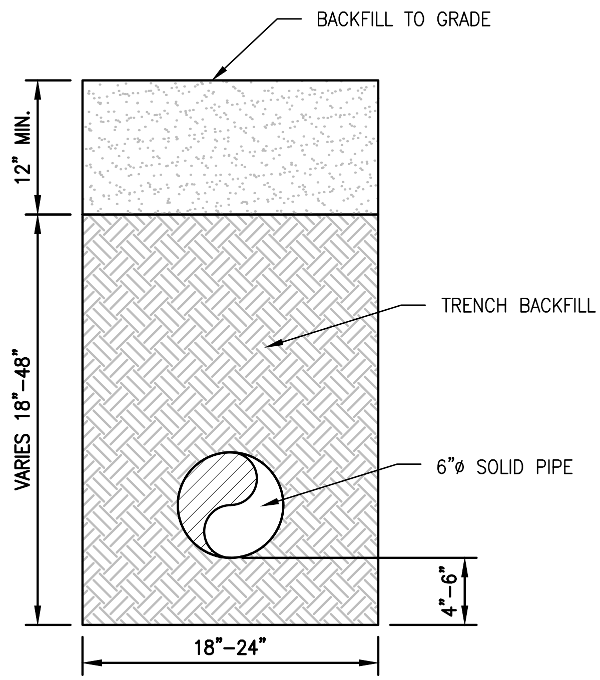
REV. 0

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-36a.dwg




SECTION A-A
SCALE: NOT TO SCALE
FROM MVP–34A




SECTION B-B
SCALE: NOT TO SCALE
FROM MVP–34A

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
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| SCALE N.T.S. | SHEET 2 OF 2 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

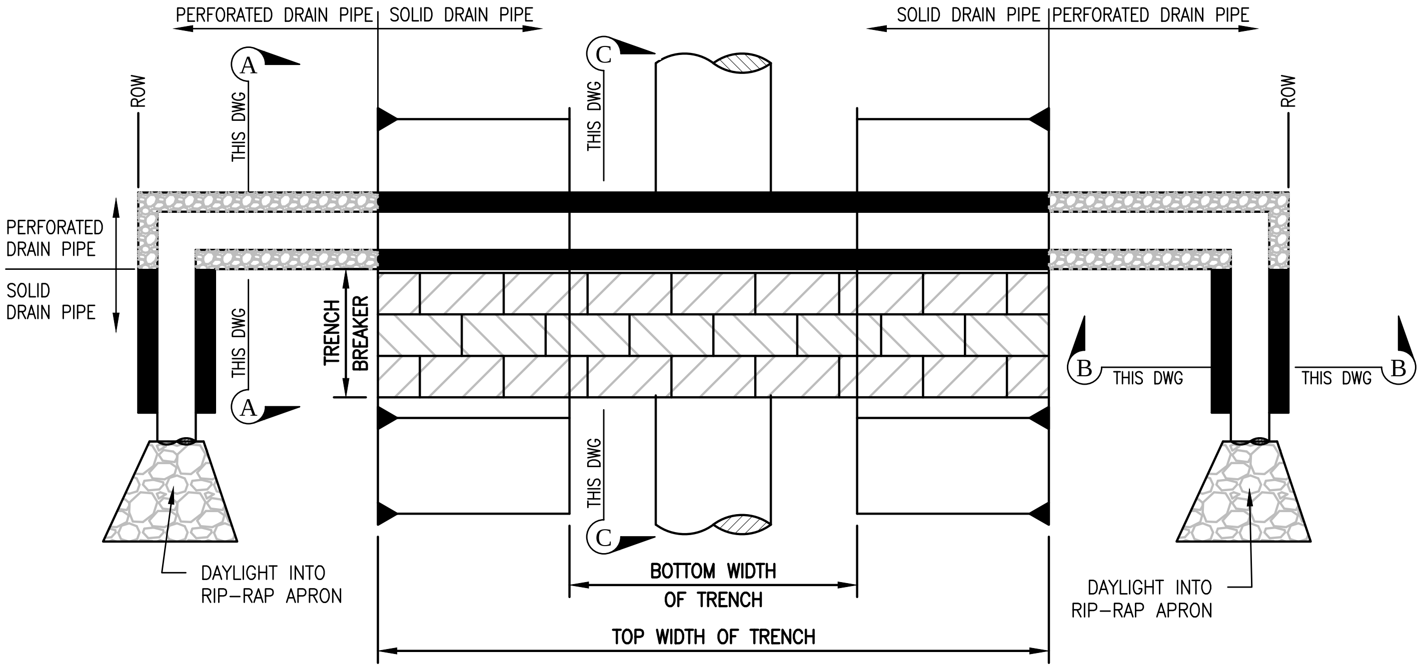
Mountain Valley PIPELINE

DESIGN ENGINEERING

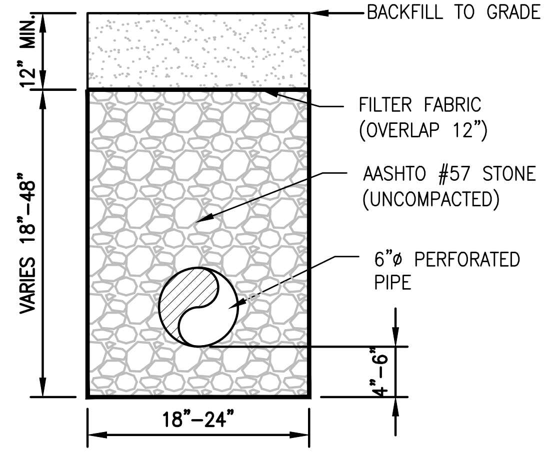
# TYPICAL CONSTRUCTION DETAIL

CUTOFF DRAIN–SIDEHILL

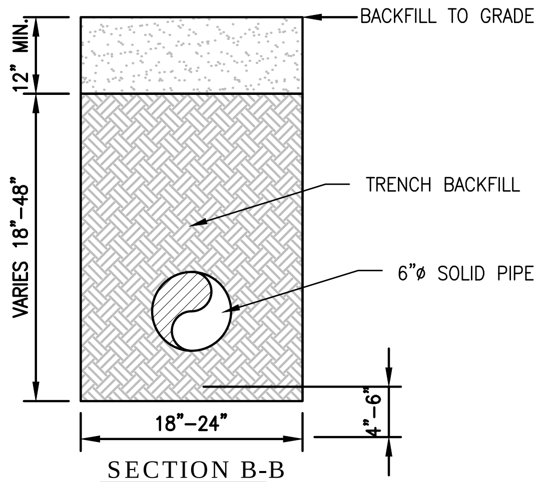
| DRAWING NO. | REV. |
|---|---|
| MVP–36B | 0 |




PLAN
SCALE: NOT TO SCALE

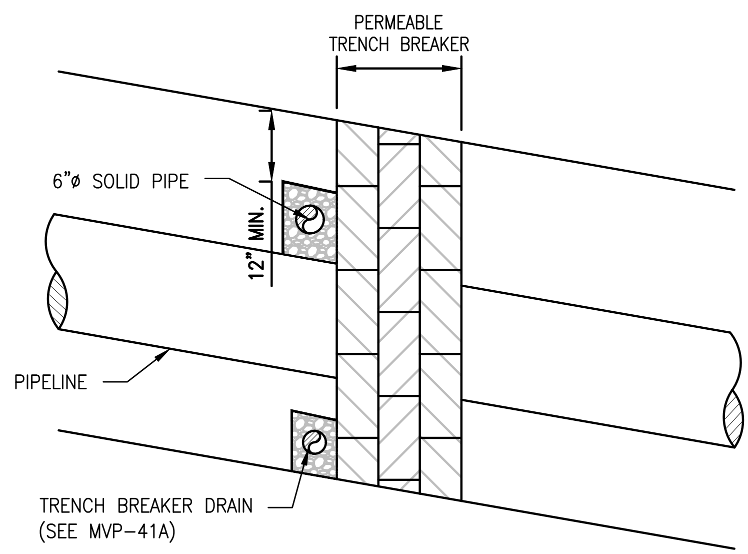



SECTION A-A
SCALE: NOT TO SCALE




SECTION B-B
SCALE: NOT TO SCALE

NOTES:
1. EACH CUTOFF DRAIN SHALL UTILIZE A TRENCH BREAKER DRAIN (SEE DETAIL 1) TO DRAIN THE TRENCH.




SECTION C-C
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 1 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

TYPICAL CONSTRUCTION DETAIL

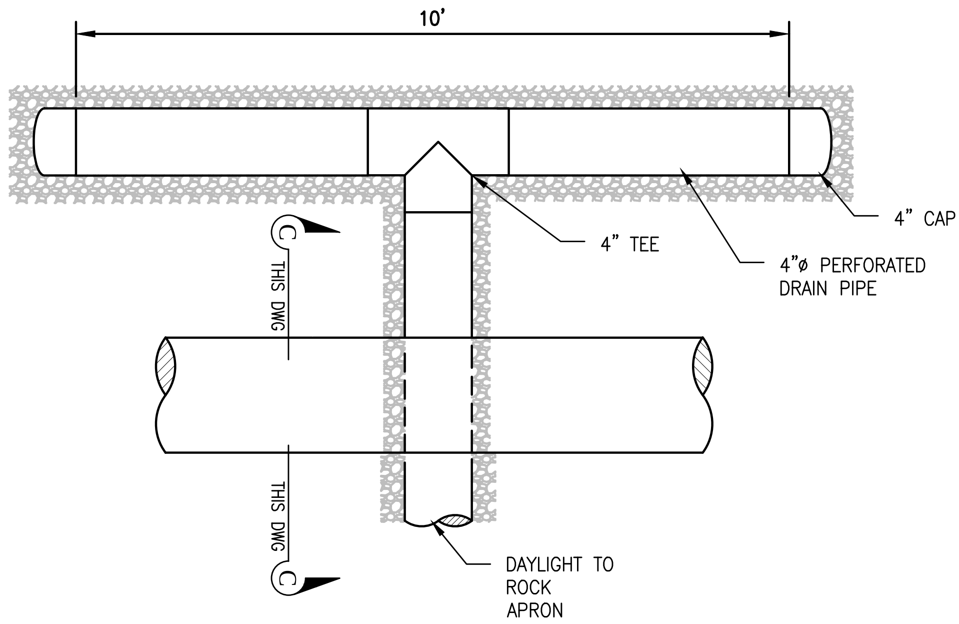
CUTOFF DRAIN–PLANAR

DRAWING NO. MVP–37

REV. 0

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-37.dwg

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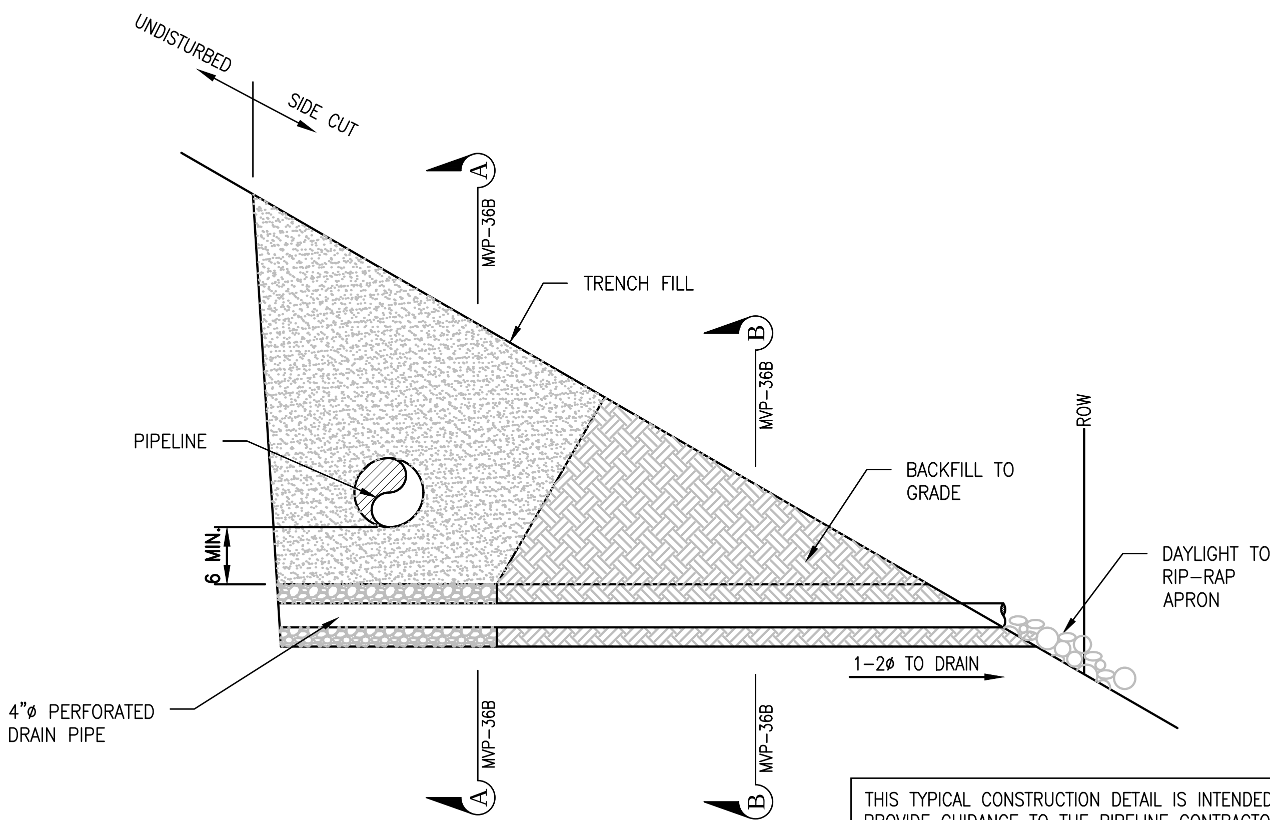
SCALE: NOT TO SCALE




C-C
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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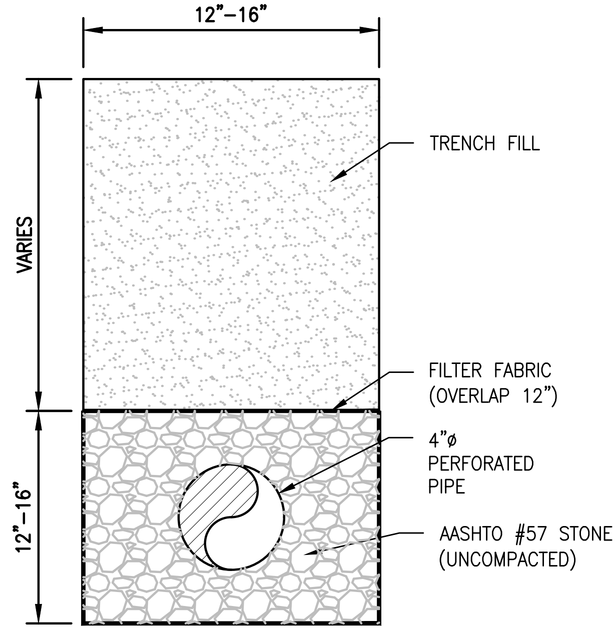
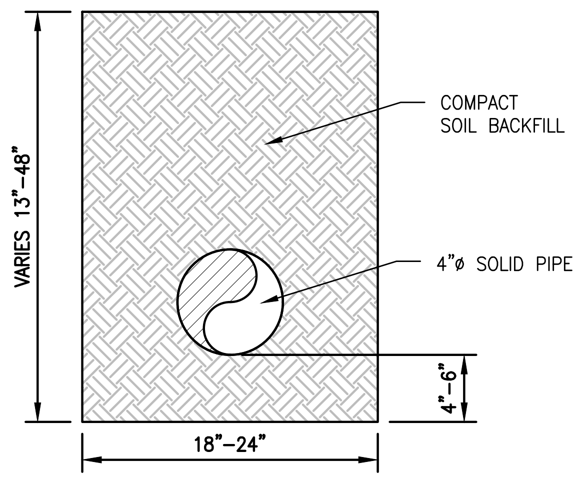
| DRAWN TDD | DATE 2/03/2016 | Mountain Valley PIPELINE | TYPICAL CONSTRUCTION DETAIL |
| CHECKED MMF | DATE 2/03/2016 | | TRANSVERSE TRENCH DRAIN |
| APP'D | DATE | | |
| SCALE N.T.S. | SHEET 1 OF 2 | | |
| JOB NO. | | | |
| PROJECT ID: PXXXX | | DESIGN ENGINEERING | DRAWING NO. MVP-38A / REV. 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-38A.dwg




SECTION A-A
SCALE: NOT TO SCALE
**FROM MVP–36A**




SECTION B-B
SCALE: NOT TO SCALE
**FROM MVP–36A**

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|---|---|---|---|
| DRAWN | TDD | DATE | 2/03/2016 |
| CHECKED | MMF | DATE | 2/03/2016 |
| APP'D | | DATE | |
| SCALE | N.T.S. | SHEET | 2 OF 2 |
| JOB NO. | | | |
| PROJECT ID: | PXXXX | | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

# TYPICAL CONSTRUCTION DETAIL

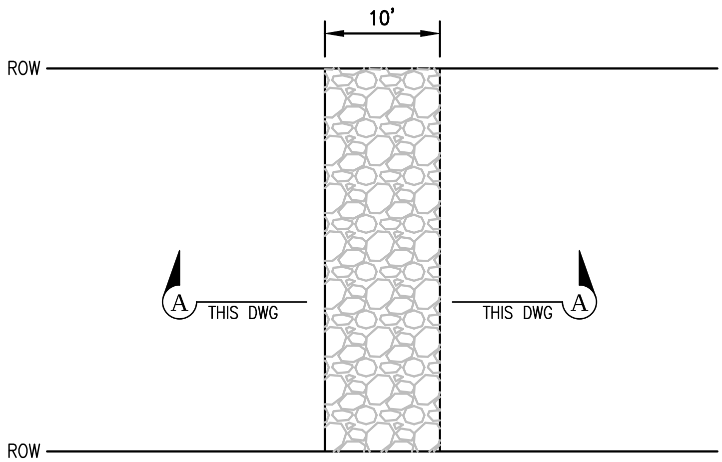
TRANSVERSE TRENCH DRAIN

DRAWING NO. MVP–38B

REV. 0

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-38B.dwg

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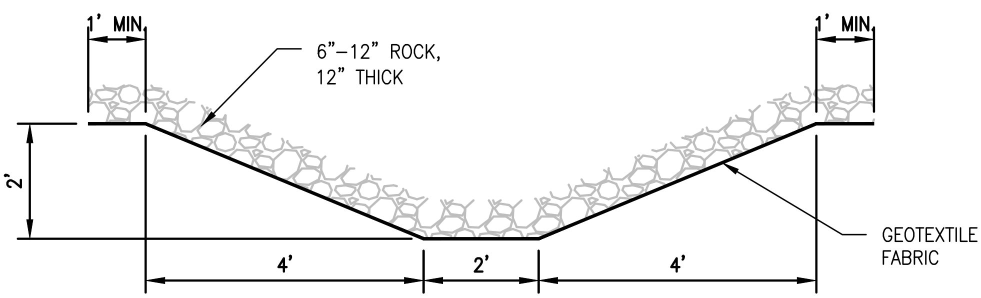
SCALE: NOT TO SCALE




SECTION A-A
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 1 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

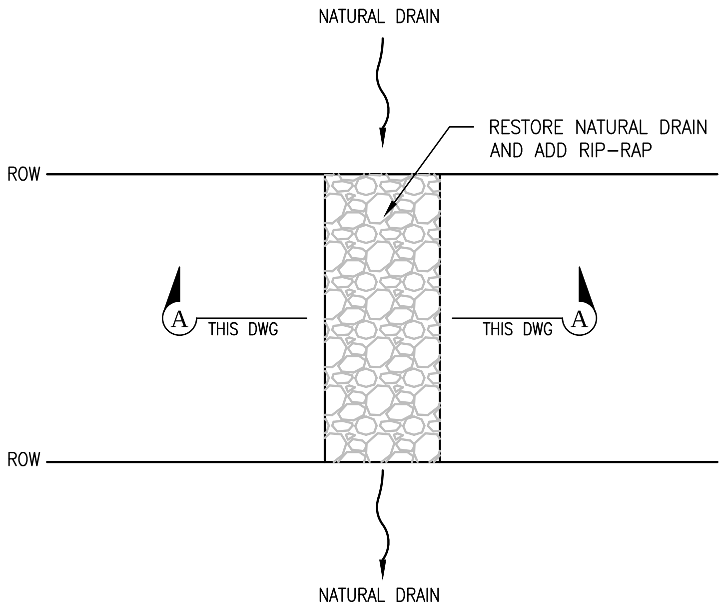
TYPICAL CONSTRUCTION DETAIL

ROCK LINED SWALE

| DRAWING NO. | REV. |
|---|---|
| MVP–39 | 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-39.dwg




PLAN
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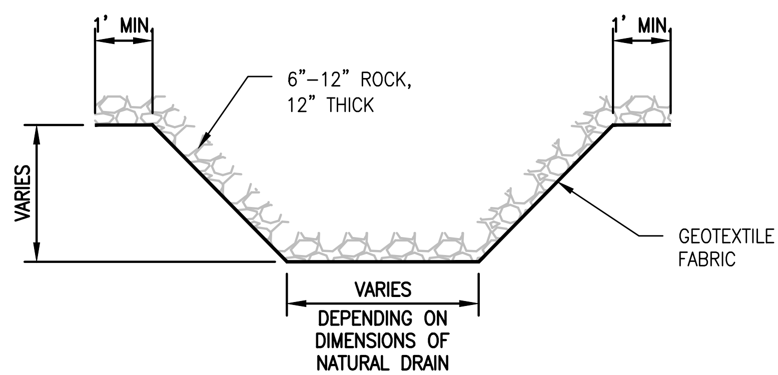


SECTION A-A
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 1 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

TYPICAL CONSTRUCTION DETAIL

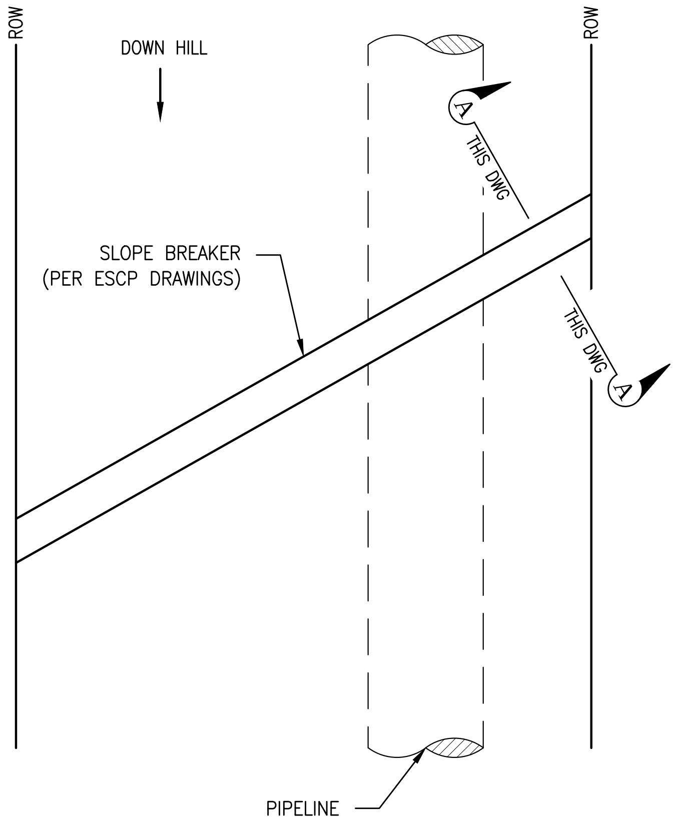
RIP-RAP NATURAL DRAIN

DRAWING NO. MVP-40

REV. 0

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-40.dwg




PLAN
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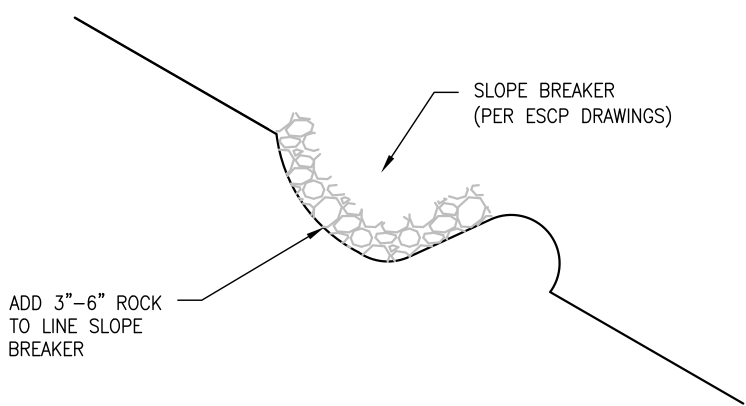


SECTION A-A
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 1 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

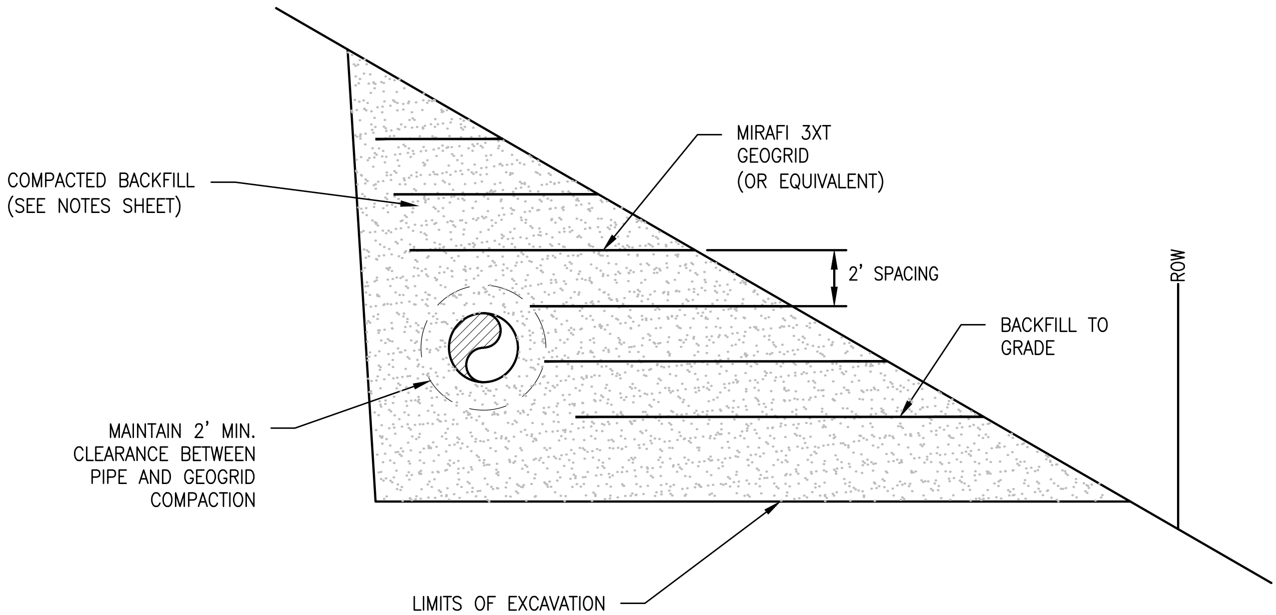
**TYPICAL CONSTRUCTION DETAIL**

RIP–RAP SLOPE BREAKERS

| DRAWING NO. | REV. |
|---|---|
| MVP–41 | 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-41.dwg




THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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|---|---|
| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 3 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

DESIGN ENGINEERING

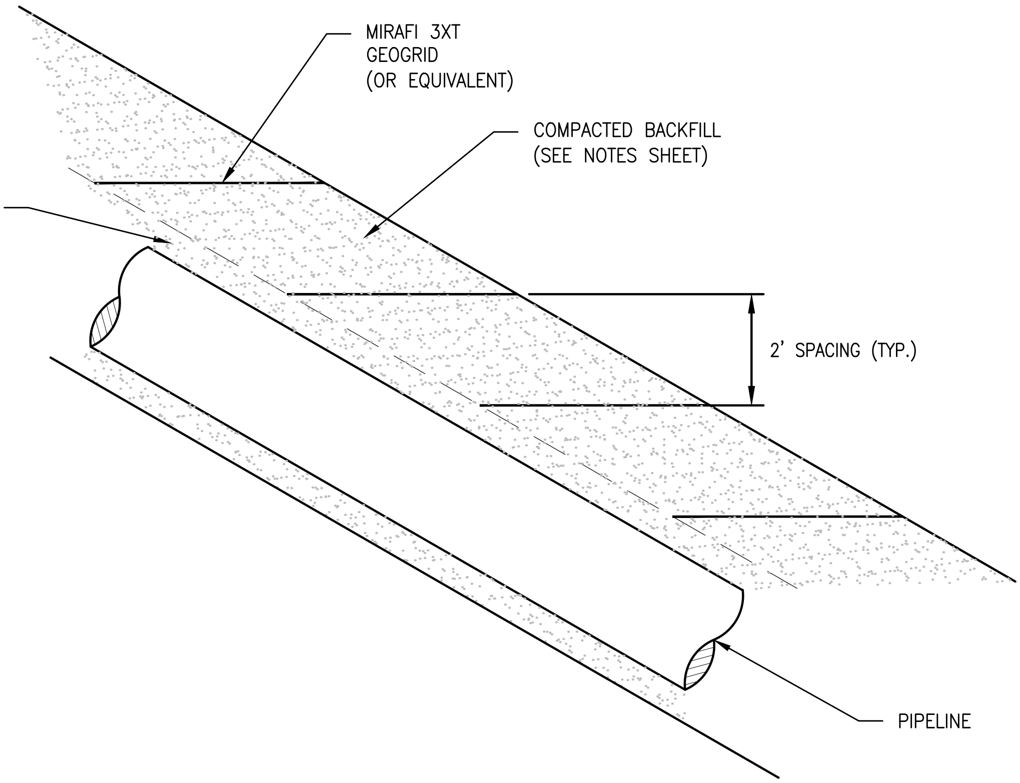
# TYPICAL CONSTRUCTION DETAIL

GEOGRID–SIDEHILL

| DRAWING NO. | REV. |
|---|---|
| MVP–42A | 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-42A.dwg




SECTION VIEW
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

| | | | |
|---|---|---|---|
| DRAWN TDD | DATE 2/03/2016 | Mountain Valley PIPELINE | SLIDE MITIGATION DETAIL |
| CHECKED MMF | DATE 2/03/2016 | | GEOGRID—PLANAR |
| APP'D | DATE | | |
| SCALE N.T.S. | SHEET 2 OF 3 | | |
| JOB NO. | | | |
| PROJECT ID: PXXXX | | DESIGN ENGINEERING | DRAWING NO. MVP—42B / REV. 0 |

COMPACTION NOTES

1) ALL ROCKS LARGER THAN 6 INCHES IN SIZE, AND MORE THANK 10 PERCENT BY VOLUME SHOULD BE REMOVED AND PROPERLY DISPOSED FROM THE BACKFILL MATERIAL.
2) THE SUBGRADE AT THE BASE OF THE EXCAVATION SHOULD BE PROOFROLLED WITH A PNEUMATIC TIRED ROLLER OR VEHICLE.
3) THE EXCAVATED AREA SHALL BE BACKFILLED WITH THE CLEANED EXCAVATED SOIL MATERIAL AND COMPACTED IN PLACE.
4) BACKFILL OPERATIONS SHALL BE PERFORMED WHEN SOIL IS SUITABLE FOR COMPACTION (I.E., NOT IMMEDIATELY FOLLOWING A LARGE RAIN, SNOW, OR ICE EVENT). FROZEN FILL SHALL NOT BE USED.
5) THE BACKFILL SHALL BE PLACED IN COMPACTED LIFTS NO GREATER THAN 12 INCHES.
6) MAINTAIN A MINIMUM 2FT CLEARANCE BETWEEN COMPACTION ACTIVITY AND THE GAS PIPELINE.

GRAVEL DRAIN NOTES

1) GEOTEXTILE FABRIC SHALL BE TENCATE MIRAFI 140N OR APPROVED EQUIVALENT.
2) THE GEOTEXTILE FABRIC SHALL BE STORED UNDAMAGED PURSUANT TO MANUFACTURERS RECOMMENDATIONS.
3) DO NOT OPERATE CONSTRUCTION EQUIPMENT DIRECTLY ON THE GEOTEXTILE FABRIC.
4) DRAINAGE AGGREGATE SHALL MEET THE REQUIREMENTS OF AASHTO NO. 57 STONE.
5) DRAINAGE AGGREGATE SHALL NOT BE COMPACTED.

GEOGRID NOTES

1) GEOGRID REINFORCEMENT SHALL BE TENCATE MIRAFI 3XT OR APPROVED EQUIVALENT.
2) THE GEOGRID MATERIAL SHALL BE STORED UNDAMAGED PURSUANT TO MANUFACTURERS RECOMMENDATIONS.
3) GEOGRID SHALL BE PLACED HORIZONTALLY ON THE BACKFILL WITH THE PRINCIPAL STRENGTH DIRECTION PERPENDICULAR TO THE FACE OF THE SLOPE. ADJACENT PIECES OF PRIMARY GEOGRID SHALL NOT OVERLAP BUT ARE TO BE BUTTED SIDE TO SIDE.
4) REMOVE ALL SLACK IN THE GEOGRID MATERIAL AND ANCHOR AS NECESSARY WITH PINS, OR BAGS TO PREVENT SLACK FROM DEVELOPMENT DURING FILL PLACEMENT AND COMPACTION.
5) FILL IS TO BE PLACED AND SPREAD DIRECTLY ON THE GEOGRID MATERIAL WITH RUBBER TIRED EQUIPMENT ONLY. SPEEDS ARE TO BE KEPT SLOW WITH AS FEW STOPS AND TURNS AS PRACTICAL.
6) DO NOT OPERATE TRACKED EQUIPMENT DIRECTLY ON THE GEOGRID MATERIAL.
7) MAINTAIN A MINIMUM 2FT CLEARANCE BETWEEN GEOGRID MATERIAL AND THE GAS PIPELINE.

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN | TDD | DATE | 2/03/2016 |
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| SCALE | N.T.S. | SHEET | 3 OF 3 |
| JOB NO. | | | |
| PROJECT ID: PXXXX | | | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

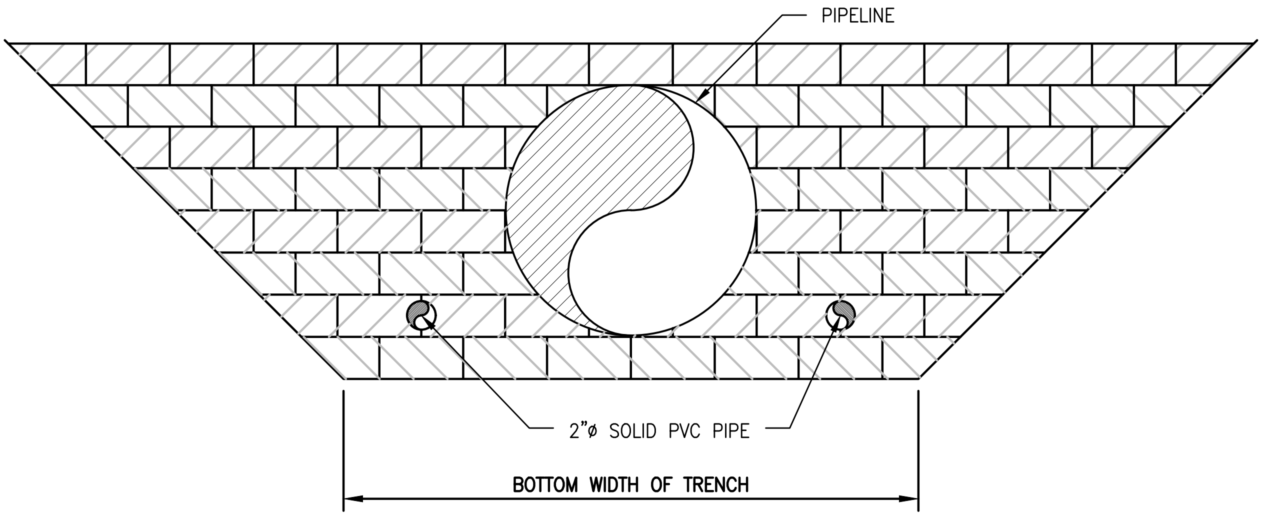
TYPICAL CONSTRUCTION DETAIL

GEOGRID NOTES

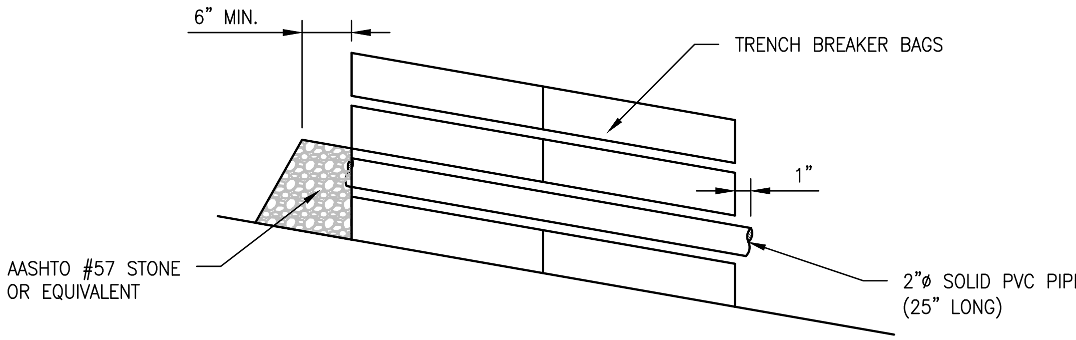
| DRAWING NO. | REV. |
|---|---|
| MVP-42C | 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-42C.dwg




FRONT VIEW
SCALE: NOT TO SCALE




SECTION VIEW
SCALE: NOT TO SCALE

NOTES:
1. PLACE PVC DRAIN PIPE ON FIRST LAYER OF TRENCH BREAKER BAGS.
2. PLACE PVC DRAIN PIPE EQUADISTANT FROM THE OUTSIDE EDGE OF THE 30" GAS PIPE AND THE BOTTOM LIMITS OF THE TRENCH.
3. EXTEND PVC PIPE THROUGH ENTIRE TRENCH BREAKER AND EXTEND APPROX. 1" PAST END OF BREAKER.
4. AASHTO#57 STONE SHALL BE PLACED TO A MINIMUM 6" THICKNESS UPSLOPE OF THE DRAIN PIPE.

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN | TDD | DATE | 4/14/2016 |
| CHECKED | MMF | DATE | 4/14/2016 |
| APP'D | | DATE | |
| SCALE | N.T.S. | SHEET | 1 OF 2 |
| JOB NO. | | | |
| PROJECT ID: | PXXXX | | |

Mountain Valley PIPELINE

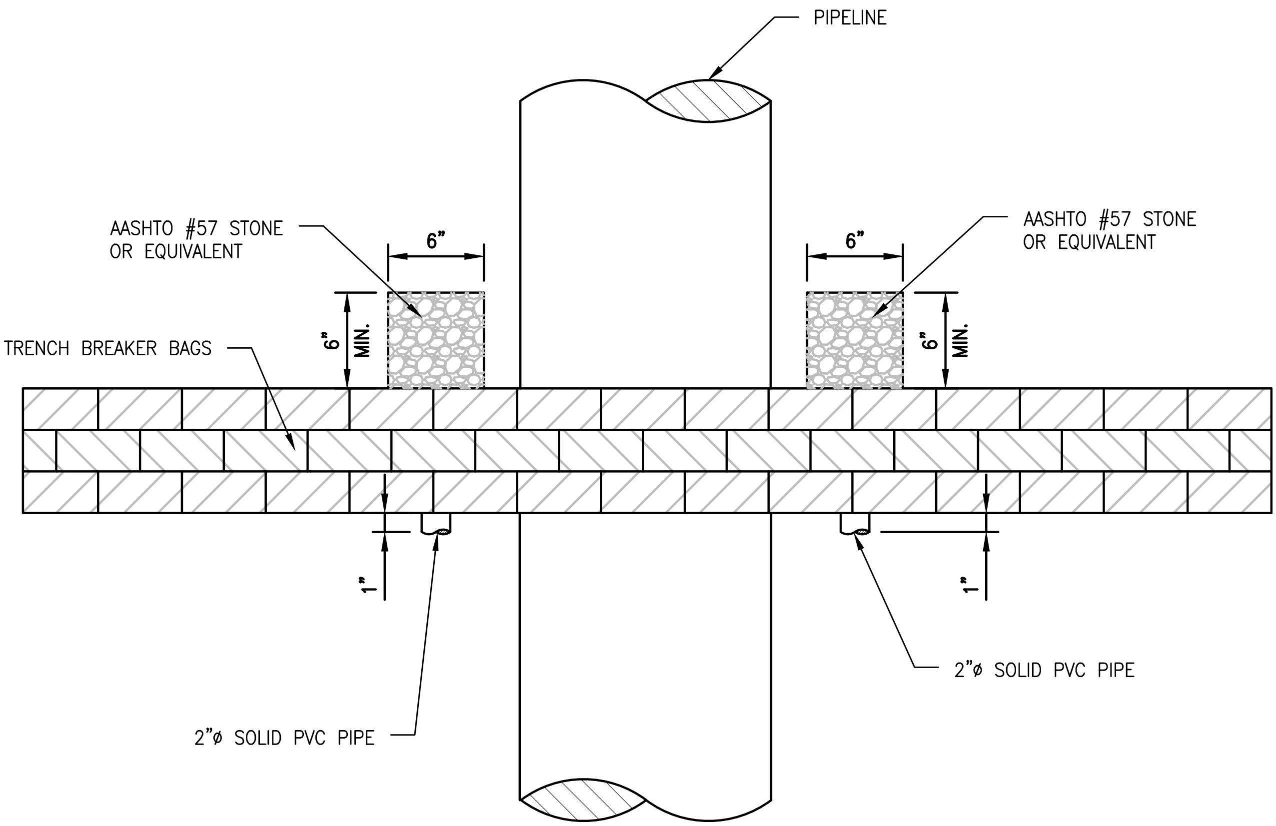
DESIGN ENGINEERING

# TYPICAL CONSTRUCTION DETAIL

TRENCH BREAKER
PASS–THROUGH DRAIN

DRAWING NO. MVP–43A

REV. 0




PLAN VIEW
SCALE: NOT TO SCALE

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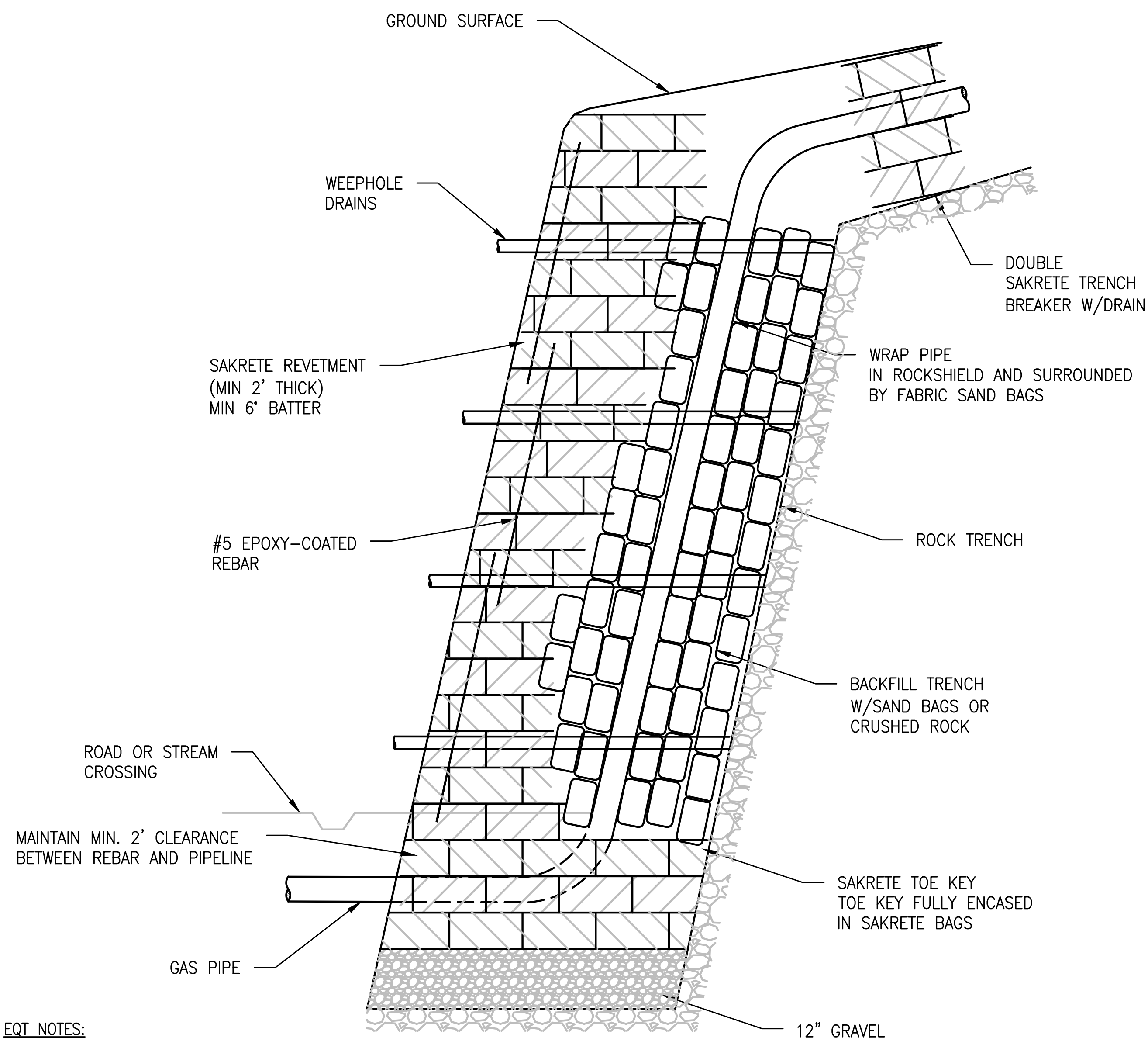
| DRAWN TDD | DATE 4/14/2016 | Mountain Valley PIPELINE | TYPICAL CONSTRUCTION DETAIL |
| CHECKED MMF | DATE 4/14/2016 | | TRENCH BREAKER PASS-TROUGH DRAIN |
| APP'D | DATE | | |
| SCALE N.T.S. | SHEET 2 OF 2 | | |
| JOB NO. | | | |
| PROJECT ID: PXXXX | | DESIGN ENGINEERING | DRAWING NO. MVP-43B / REV. 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-43B.dwg




SIDE VIEW
SCALE: NOT TO SCALE

EQT NOTES:

1. SAKRETE BAGS SHOULD EXTEND 4 BAGS DEEP PIPE SHOULD BE COMPLETELY SURROUNDED BY SAND BAGS, OR CRUSHED ROCK (MAX 6").
2. SAKRETE BAGS SHOULD BE STAGGERED IN A MASONRY FASHION. THE FACE OF THE WELL SHALL BE INCLINED 6°-10° FROM VERTICAL.
3. #5 REBAR SHOULD BE DRIVEN THROUGH THE SAKRETE BAGS (SEE DETAIL 1).
4. 2"ø PVC WEEPHOLE DRAINS SHALL BE INSTALLED EVERY 15 FT.

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN OL | DATE 6/29/2016 |
| CHECKED MMF | DATE – |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 2 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

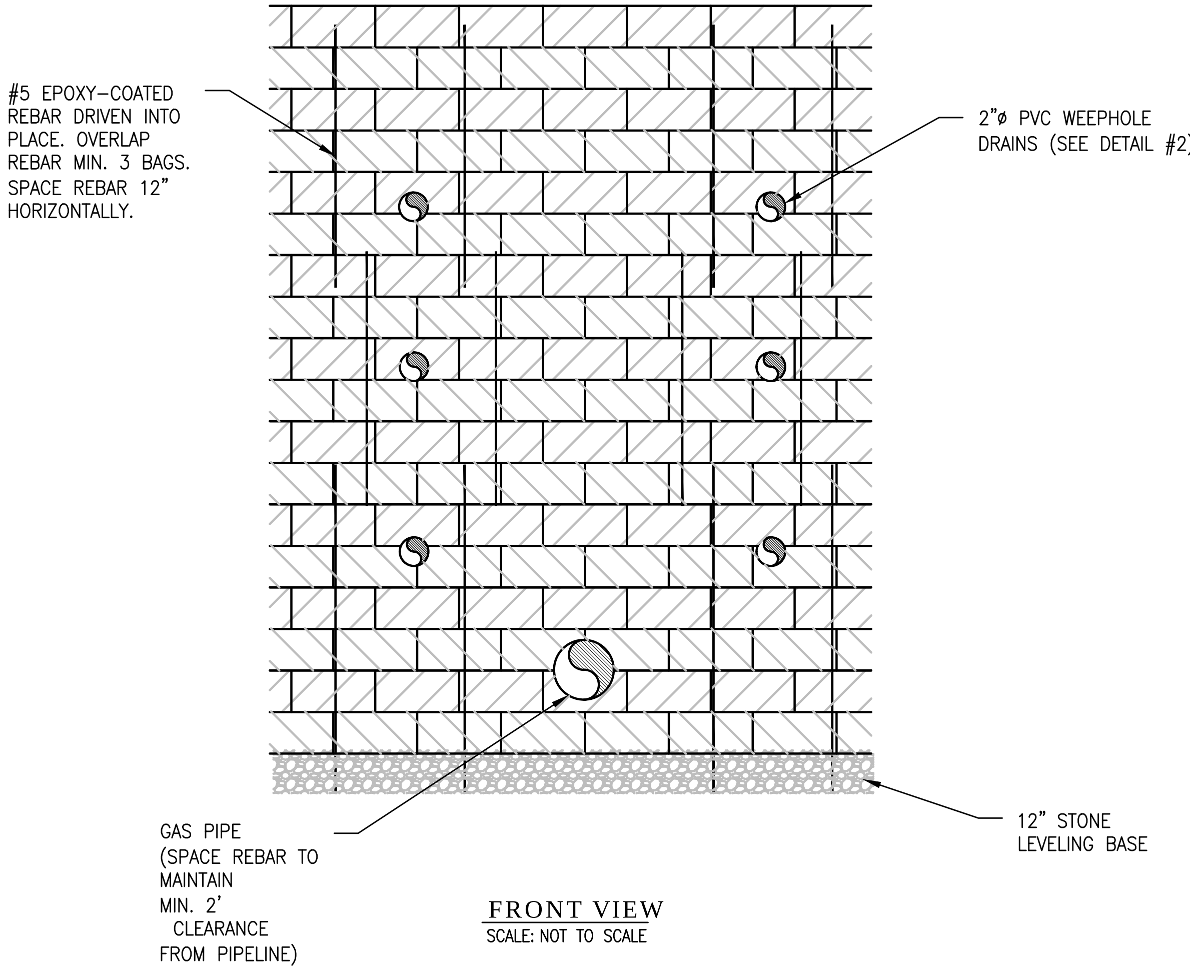
TYPICAL CONSTRUCTION DETAIL

SLIDE MITIGATION
HIGHWALL REVETMENT
SIDE VIEW

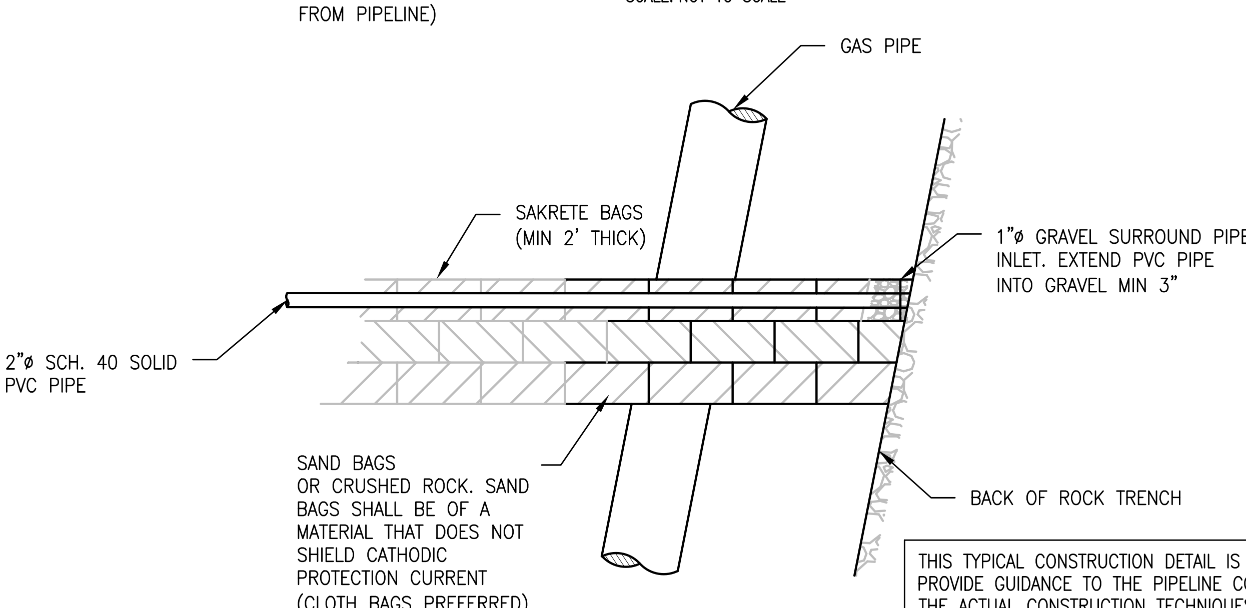
| DRAWING NO. | REV. |
|---|---|
| MVP-44A | 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-44A.dwg




FRONT VIEW
SCALE: NOT TO SCALE




DRAIN DETAIL
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN | OL | DATE | 6/29/2016 |
| CHECKED | MMF | DATE | – |
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| JOB NO. | | | |
| PROJECT ID: PXXXX | | | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

# TYPICAL CONSTRUCTION DETAIL

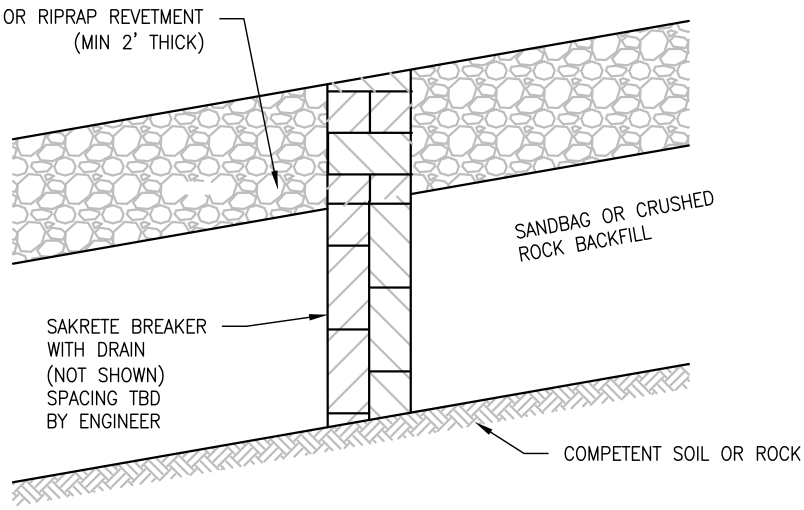
SLIDE MITIGATION
HIGHWALL REVETMENT
FRONT VIEW AND DRAIN DETAIL

DRAWING NO. MVP–44B

REV. 0

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-44B.dwg




SIDE VIEW
SCALE: NOT TO SCALE

THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 2/03/2016 |
| CHECKED MMF | DATE 2/03/2016 |
| APP'D | DATE |
| SCALE N.T.S. | SHEET 1 OF 1 |
| JOB NO. | |
| PROJECT ID: PXXXX | |

Mountain Valley PIPELINE

DESIGN ENGINEERING

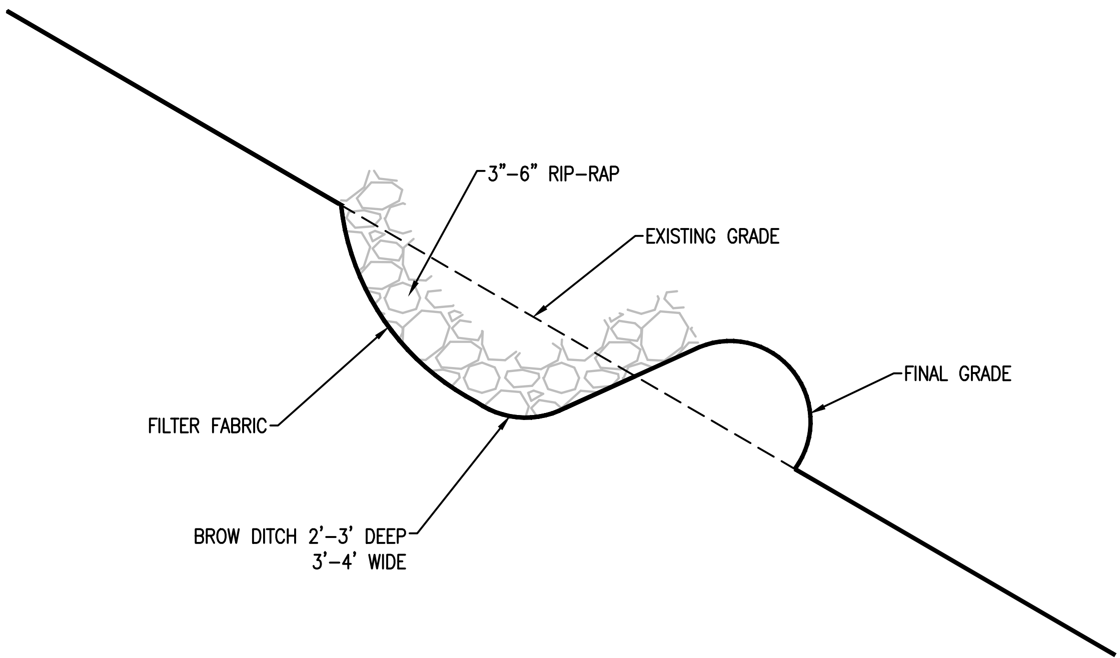
TYPICAL CONSTRUCTION DETAIL

STEEP SLOPE REVETMENT

| DRAWING NO. | REV. |
|---|---|
| MVP-45 | 0 |

Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-45.dwg




THIS TYPICAL CONSTRUCTION DETAIL IS INTENDED TO PROVIDE GUIDANCE TO THE PIPELINE CONTRACTOR. THE ACTUAL CONSTRUCTION TECHNIQUES MAY DIFFER DEPENDING UPON FIELD CONDITIONS AND OR REGULATORY REQUIREMENTS.

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| DRAWN TDD | DATE 7/12/2016 | Mountain Valley PIPELINE | TYPICAL CONSTRUCTION DETAIL |
| CHECKED MMF | DATE 7/12/2016 | | |
| APP'D | DATE | | BROW DITCH DETAIL |
| SCALE N.T.S. | SHEET 1 OF 1 | | |
| JOB NO. | | | |
| PROJECT ID: PXXXX | | DESIGN ENGINEERING | DRAWING NO. MVP–46 / REV. 0 |

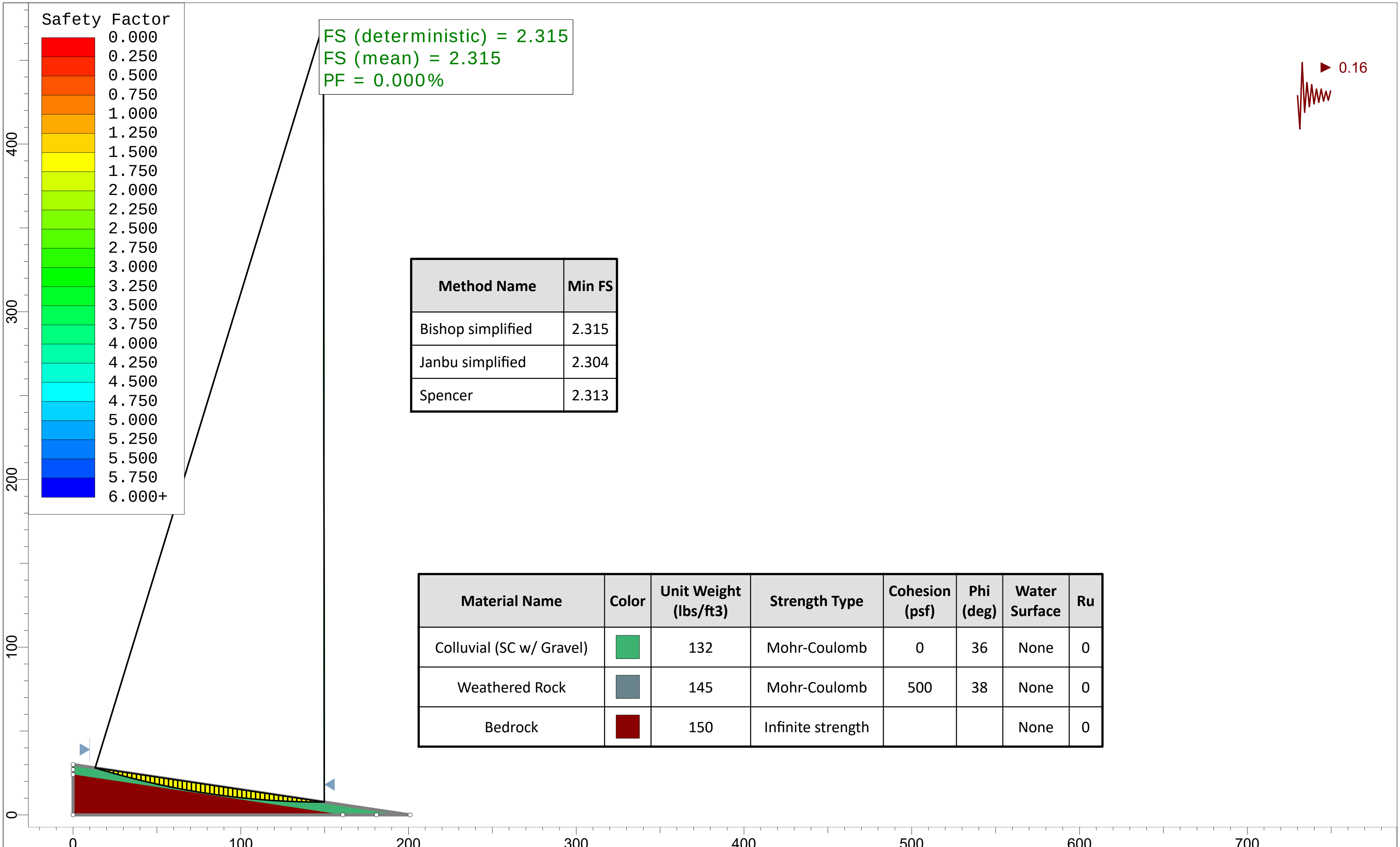
Plotted by: Lee, Joshua I. on: October 6, 2016 - 1:41 PM

File Path: C:\Vault Working\Systems\MVP\H-600\H-600 Bid Package\Drawing Files\Design Files\Mechanical\Construction Typicals\MVP-46.dwg

# Appendix C – Slope Stability Output

## Table C-1. Summary of Slope Stability Analysis

| Slope (% and Ratio) | Groundwater / Precipitation Model | Seismic Load Applied (g) | Density (pcf) Low 115 | Density (pcf) Likely 132 | Density (pcf) High 161 | Friction Angle (°) Low 24 | Friction Angle (°) Likely 36 | Friction Angle (°) High 50 | FS (Bishop) |
|---|---|---|---|---|---|---|---|---|---|
| 15% 6.7:1 | Saturated (Perpindicular & $h_w$=h) | 0 | | X | | | X | | **2.6** |
| | | 0.16 | | X | | | X | | **1.2** |
| | No GW | 0 | | X | | | X | | **4.9** |
| | | 0.16 | | X | | | X | | **2.3** |
| 30% 3.3:1 | Saturated (Perpindicular & $h_w$=h) | 0 | | X | | | X | | **1.2** |
| | | | X | | | | X | | 1.0 |
| | | | | | X | | | X | 1.4 |
| | | | | X | | X | | | 0.7 |
| | | | | X | | | | X | 1.9 |
| | | 0.16 | | X | | | X | | **0.7** |
| | | | X | | | | X | | 0.6 |
| | | | | | X | | | X | 0.8 |
| | | | | X | | X | | | 0.4 |
| | | | | X | | | | X | 1.1 |
| | No GW | 0 | | X | | | X | | **2.4** |
| | | 0.16 | | X | | | X | X | **1.5** |
| 45% 2.2:1 | Saturated (Perpindicular & $h_w$=h) | 0 | | X | | | X | | **0.7** |
| | | | X | | | | X | | 0.6 |
| | | | | | X | | | X | 0.9 |
| | | | | X | | X | | | 0.5 |
| | | | | X | | | | X | 1.2 |
| | | 0.16 | | X | | | X | | **0.4** |
| | | | X | | | | X | | 0.4 |
| | | | | | X | | | X | 0.6 |
| | | | | X | | X | | | 0.3 |
| | | | | X | | | | X | 0.8 |
| | No GW | 0 | | X | | | X | | **1.6** |
| | | | X | | | | X | | 1.6 |
| | | | | | X | | | X | |
| | | | | X | | X | | | 0.7 |
| | | | | X | | | | X | 1.9 |
| | | 0.16 | | X | | | X | | **1.1** |
| | | | X | | | | X | | 1.1 |
| | | | | | X | | | X | |
| | | | | X | | X | | | 1.0 |
| | | | | X | | | | X | 2.7 |
| 65% 1.5:1 | Saturated (Perpindicular & $h_w$=h) | 0 | | X | | | X | | **0.4** |
| | | 0.16 | | X | | | X | | **0.2** |
| | No GW | 0 | | X | | | X | | **1.1** |
| | | | X | | | | X | | 1.1 |
| | | | | | X | | | X | |
| | | | | X | | X | | | 0.7 |
| | | | | X | | | | X | 1.8 |
| | | 0.16 | | X | | | X | | **0.8** |
| | | | X | | | | X | | 0.8 |
| | | | | | X | | | X | |
| | | | | X | | X | | | 0.5 |
| | | | | X | | | | X | 1.3 |
| 76% 1.3:1 | Saturated (Perpindicular & $h_w$=h) | 0 | | X | | | X | | **0.3** |
| | | 0.16 | | X | | | X | | **0.1** |
| | No GW | 0 | | X | | | X | | **1.0** |
| | | | X | | | | X | | 1.0 |
| | | | | | X | | | X | |
| | | | | X | | X | | | 0.6 |
| | | | | X | | | | X | 1.6 |
| | | 0.16 | | X | | | X | | **0.7** |
| | | | X | | | | X | | 0.7 |
| | | | | | X | | | X | |
| | | | | X | | X | | | 0.4 |
| | | | | X | | | | X | 1.1 |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 2.315 |
| Janbu simplified | 2.304 |
| Spencer | 2.313 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Weathered Rock | | 145 | Mohr-Coulomb | 500 | 38 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

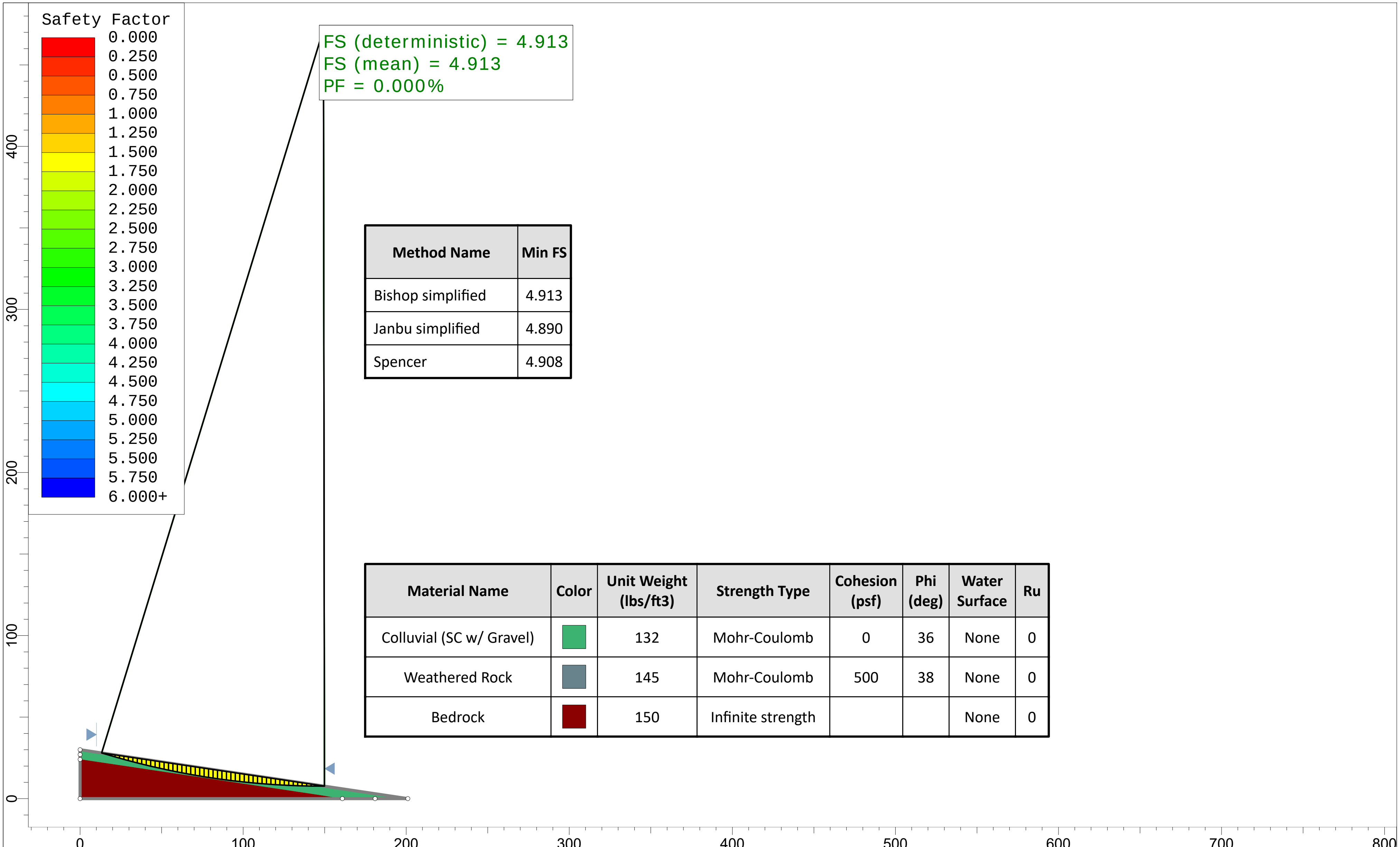
SLIDEINTERPRET 7.018

*Project* MVP Debris Stability

*Analysis Description* 15% Slope - Moist with 0.16g Seismic Load

*Drawn By* PTJ | *Scale* 1:950 | *Company* DAA

*Date* 11/30/2016, 4:07:45 PM | *File Name* MVP Debri - 15 Slope.slmd

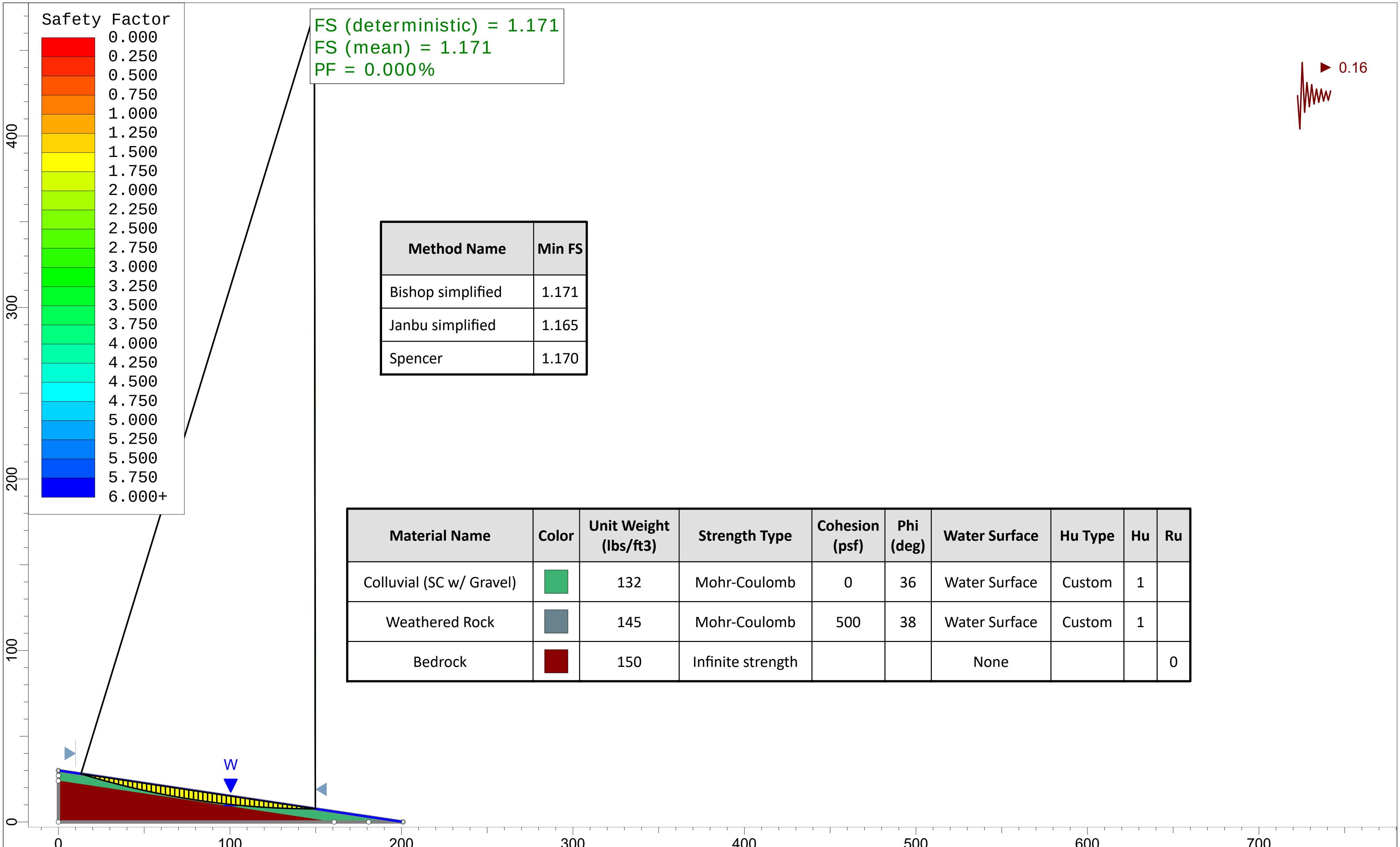



| Method Name | Min FS |
|---|---|
| Bishop simplified | 4.913 |
| Janbu simplified | 4.890 |
| Spencer | 4.908 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Weathered Rock | | 145 | Mohr-Coulomb | 500 | 38 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 15% Slope - Moist Soils |
| *Drawn By* | PTJ |
| *Scale* | 1:977 |
| *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM |
| *File Name* | MVP Debri - 15 Slope.slmd |

SLIDEINTERPRET 7.018

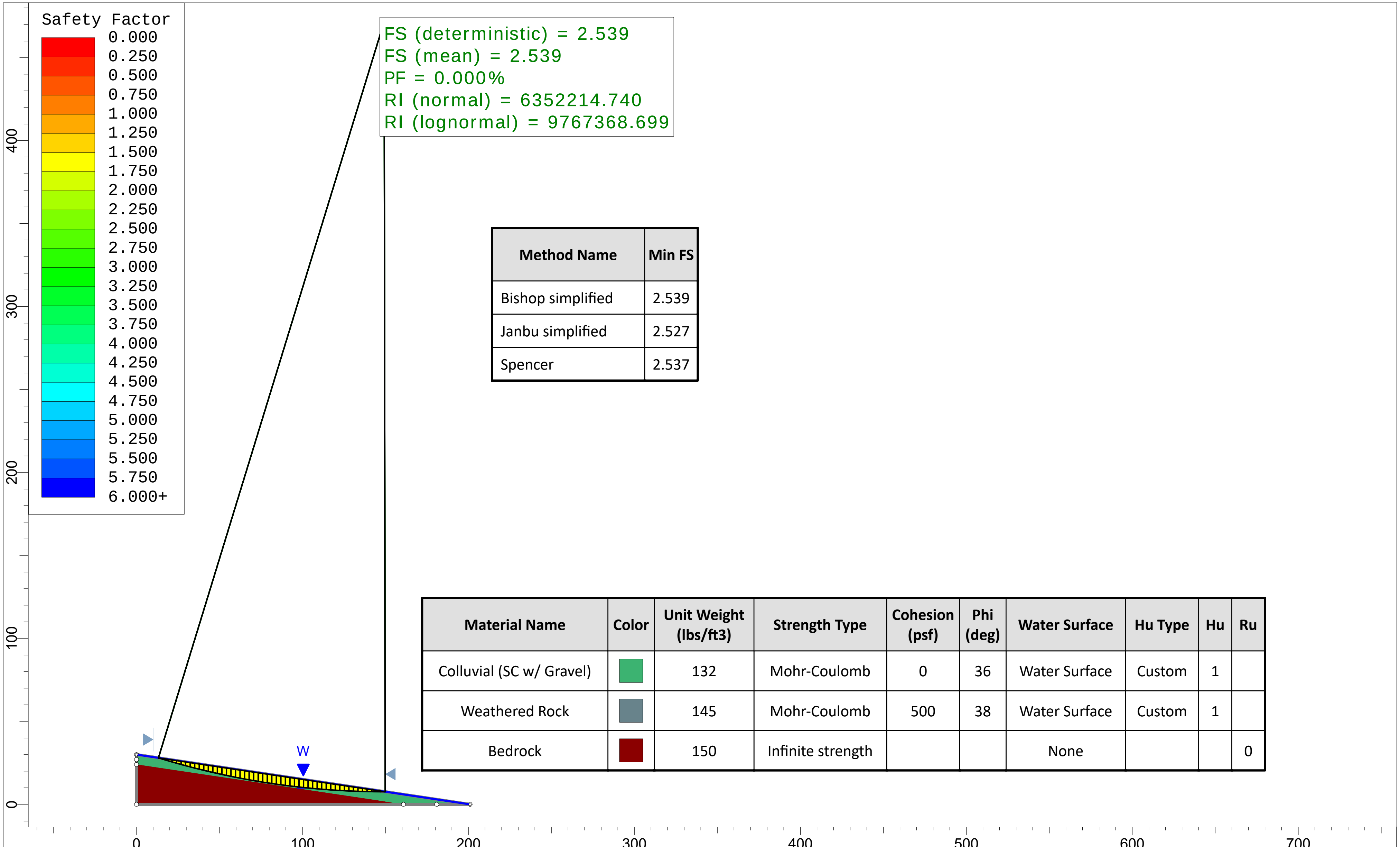



| Method Name | Min FS |
|---|---|
| Bishop simplified | 1.171 |
| Janbu simplified | 1.165 |
| Spencer | 1.170 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Weathered Rock | | 145 | Mohr-Coulomb | 500 | 38 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

SLIDEINTERPRET 7.018

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 15% Slope - Saturated Soils with 0.16g Seismic Load | | |
| *Drawn By* | PTJ | *Scale* 1:929 | *Company* DAA |
| *Date* | 11/30/2016, 4:07:45 PM | *File Name* | MVP Debri - 15 Slope.slmd |

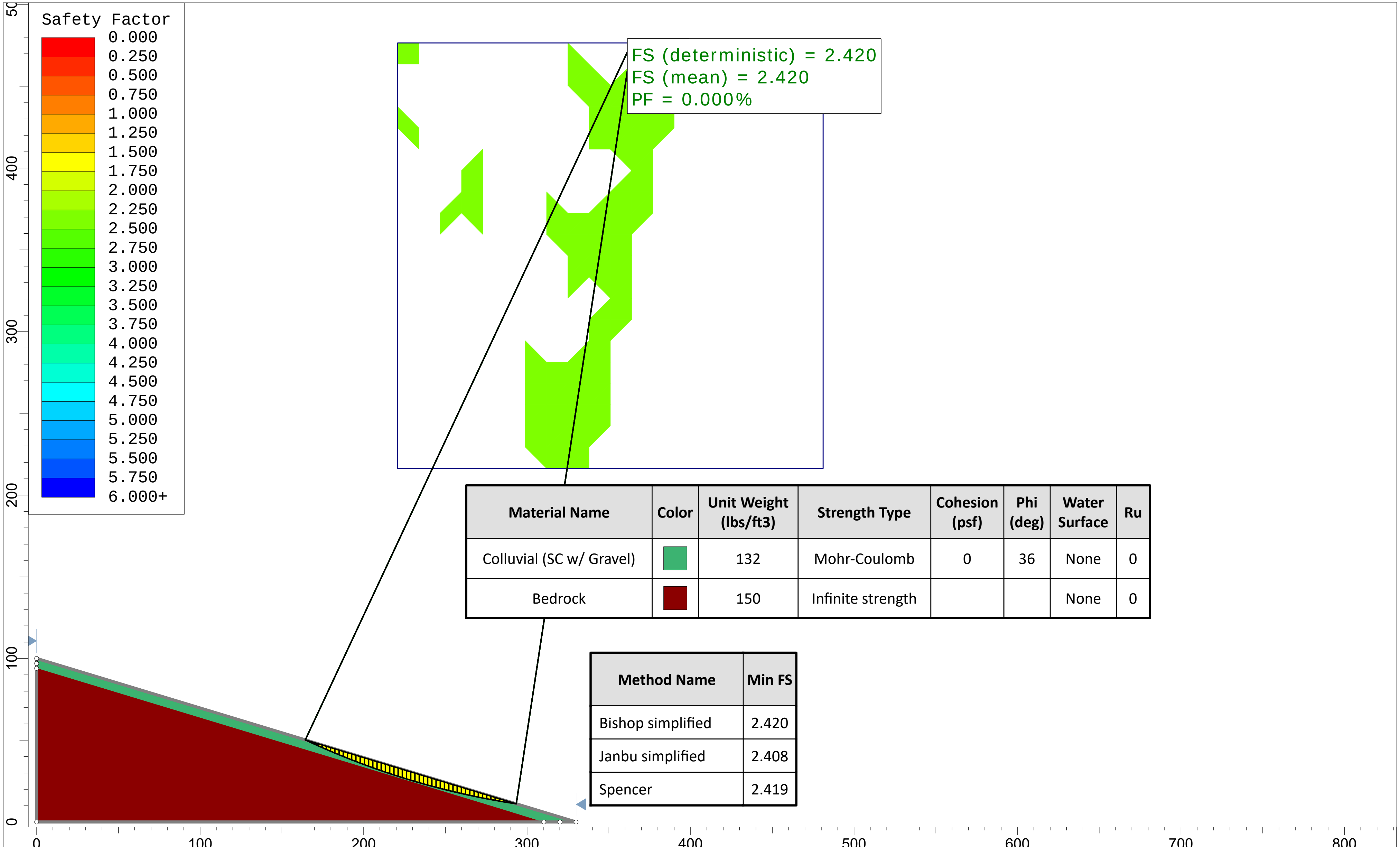



| Method Name | Min FS |
|---|---|
| Bishop simplified | 2.539 |
| Janbu simplified | 2.527 |
| Spencer | 2.537 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Weathered Rock | | 145 | Mohr-Coulomb | 500 | 38 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 15% Slope - Saturated Soils | | |
| *Drawn By* PTJ | *Scale* 1:960 | *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM | *File Name* | MVP Debri - 15 Slope.slmd |

SLIDEINTERPRET 7.018




| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

| Method Name | Min FS |
|---|---|
| Bishop simplified | 2.420 |
| Janbu simplified | 2.408 |
| Spencer | 2.419 |

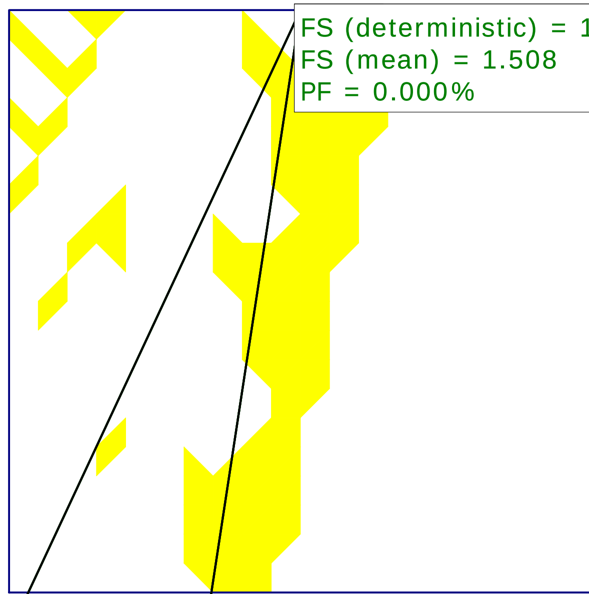
| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 30% Slope - Moist Soils |
| *Drawn By* | PTJ |
| *Scale* | 1:974 |
| *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM |
| *File Name* | MVP Debri - 30 Slope.slmd |

SLIDEINTERPRET 7.018

Safety Factor

| Safety Factor |
|---|
| 0.000 |
| 0.250 |
| 0.500 |
| 0.750 |
| 1.000 |
| 1.250 |
| 1.500 |
| 1.750 |
| 2.000 |
| 2.250 |
| 2.500 |
| 2.750 |
| 3.000 |
| 3.250 |
| 3.500 |
| 3.750 |
| 4.000 |
| 4.250 |
| 4.500 |
| 4.750 |
| 5.000 |
| 5.250 |
| 5.500 |
| 5.750 |
| 6.000+ |

| Method Name | Min FS |
|---|---|
| Bishop simplified | 1.508 |
| Janbu simplified | 1.500 |
| Spencer | 1.505 |

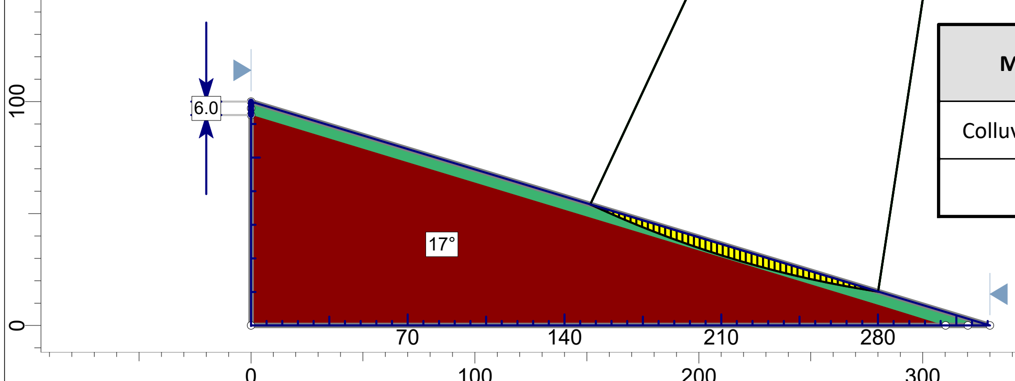


FS (deterministic) = 1.508
FS (mean) = 1.508
PF = 0.000%

0.16

Project Summary
Project Title: MVP NFS
Analysis: 30% Slope
Moist Soils
Seismic Load = 0.16g

Results
Analysis Method: bishop simplified
Surface Type: Circular
Search Method:Grid Search
Radius Increment:10
Composite Surfaces:Enabled
Reverse Curvature:Create Tension Crack
Minimum Elevation:Not Defined
Minimum Depth []:5
Minimum Area:Not Defined
Minimum Weight:Not Defined
Every available surface
1.508




| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

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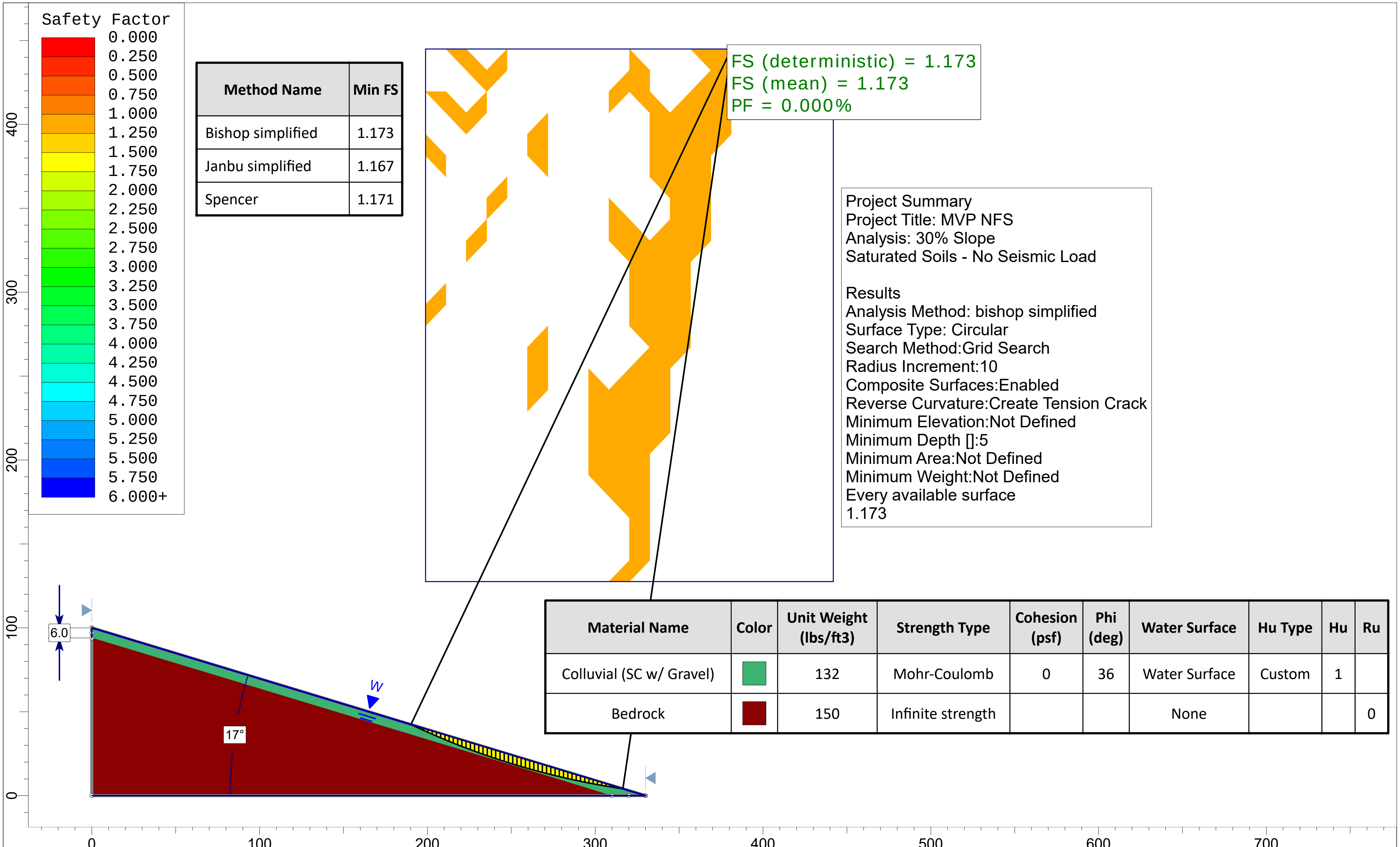
SLIDEINTERPRET 7.018

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 30% Slope - Moist Soils with 0.16g Seismic Load | | |
| *Drawn By* PTJ | *Scale* 1:1029 | *Company* | DAA |
| *Date* 11/30/2016, 4:07:45 PM | | *File Name* | MVP Debri - 30 Slope.slmd |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 1.173 |
| Janbu simplified | 1.167 |
| Spencer | 1.171 |

FS (deterministic) = 1.173
FS (mean) = 1.173
PF = 0.000%

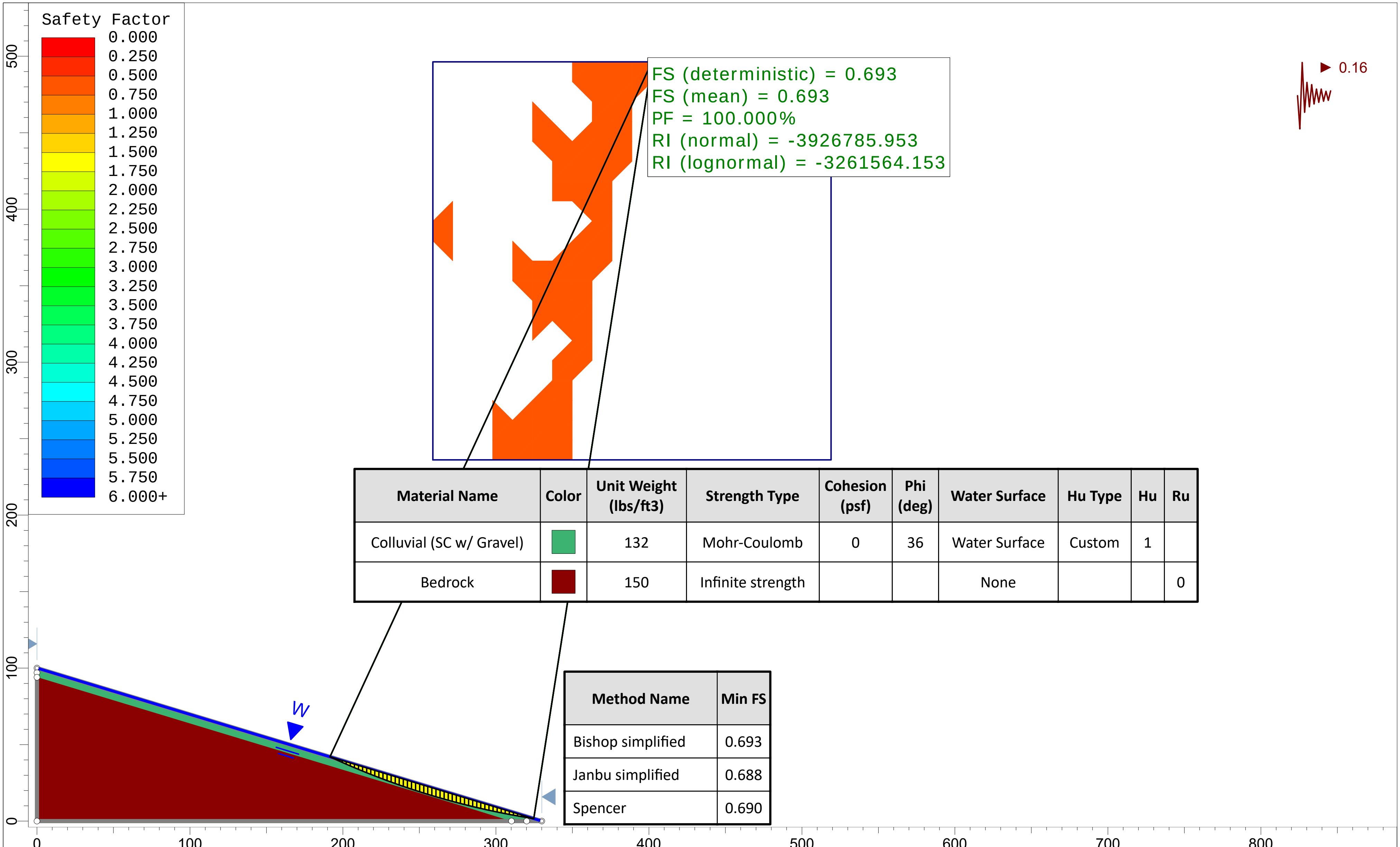
Project Summary
Project Title: MVP NFS
Analysis: 30% Slope
Saturated Soils - No Seismic Load

Results
Analysis Method: bishop simplified
Surface Type: Circular
Search Method:Grid Search
Radius Increment:10
Composite Surfaces:Enabled
Reverse Curvature:Create Tension Crack
Minimum Elevation:Not Defined
Minimum Depth []:5
Minimum Area:Not Defined
Minimum Weight:Not Defined
Every available surface
1.173

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 30% Slope - Saturated Soils with No Seismic Loading | | |
| *Drawn By* PTJ | *Scale* 1:949 | *Company* DAA | |
| *Date* 11/30/2016 | | *File Name* MVP Debri - 30 Slope.slmd | |

SLIDEINTERPRET 7.018

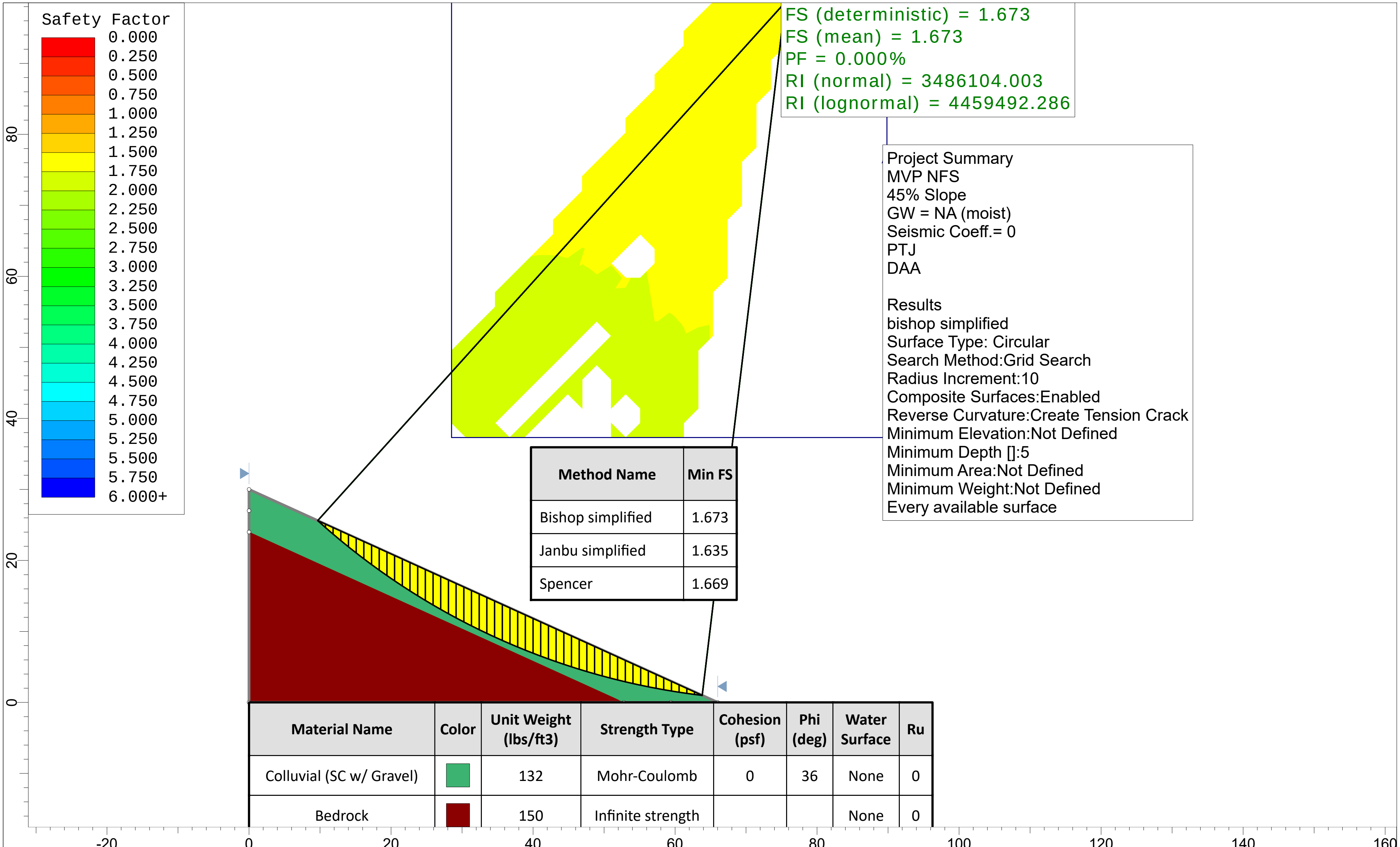



| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.693 |
| Janbu simplified | 0.688 |
| Spencer | 0.690 |

SLIDEINTERPRET 7.018

| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 30% Slope - Saturated Soils with 0.16g Seismic Load |
| *Drawn By* | PTJ |
| *Scale* | 1:1041 |
| *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM |
| *File Name* | MVP Debri - 30 Slope.slmd |

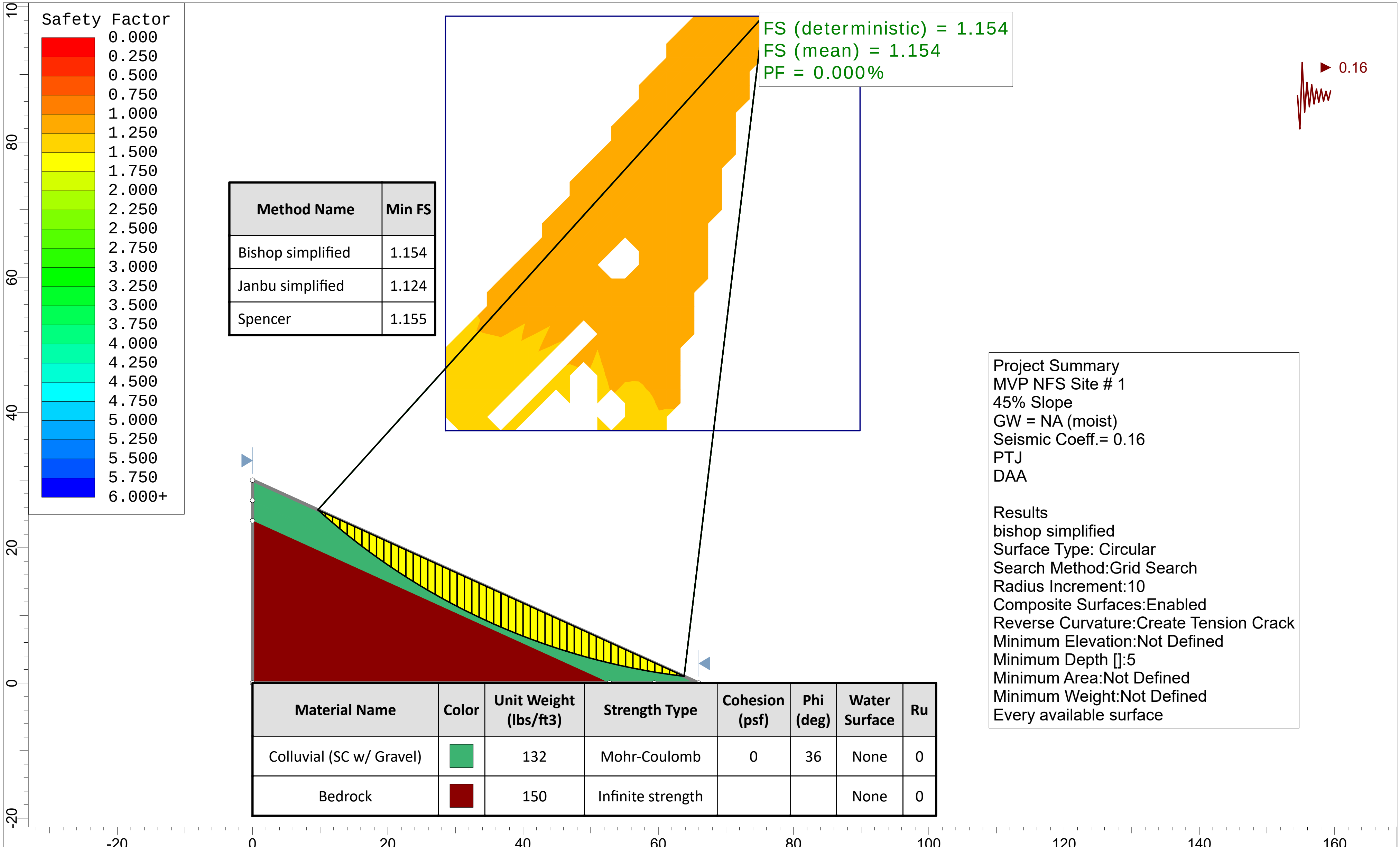



| Method Name | Min FS |
|---|---|
| Bishop simplified | 1.673 |
| Janbu simplified | 1.635 |
| Spencer | 1.669 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

SLIDEINTERPRET 7.018

| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 45% Slope - Moist Soils |
| *Drawn By* | PTJ |
| *Scale* | 1:224 |
| *Company* | DAA |
| *Date* | 11/30/2016 |
| *File Name* | MVP Debri - 45 Slope.slmd |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 1.154 |
| Janbu simplified | 1.124 |
| Spencer | 1.155 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

Project Summary
MVP NFS Site # 1
45% Slope
GW = NA (moist)
Seismic Coeff.= 0.16
PTJ
DAA

Results
bishop simplified
Surface Type: Circular
Search Method:Grid Search
Radius Increment:10
Composite Surfaces:Enabled
Reverse Curvature:Create Tension Crack
Minimum Elevation:Not Defined
Minimum Depth []:5
Minimum Area:Not Defined
Minimum Weight:Not Defined
Every available surface

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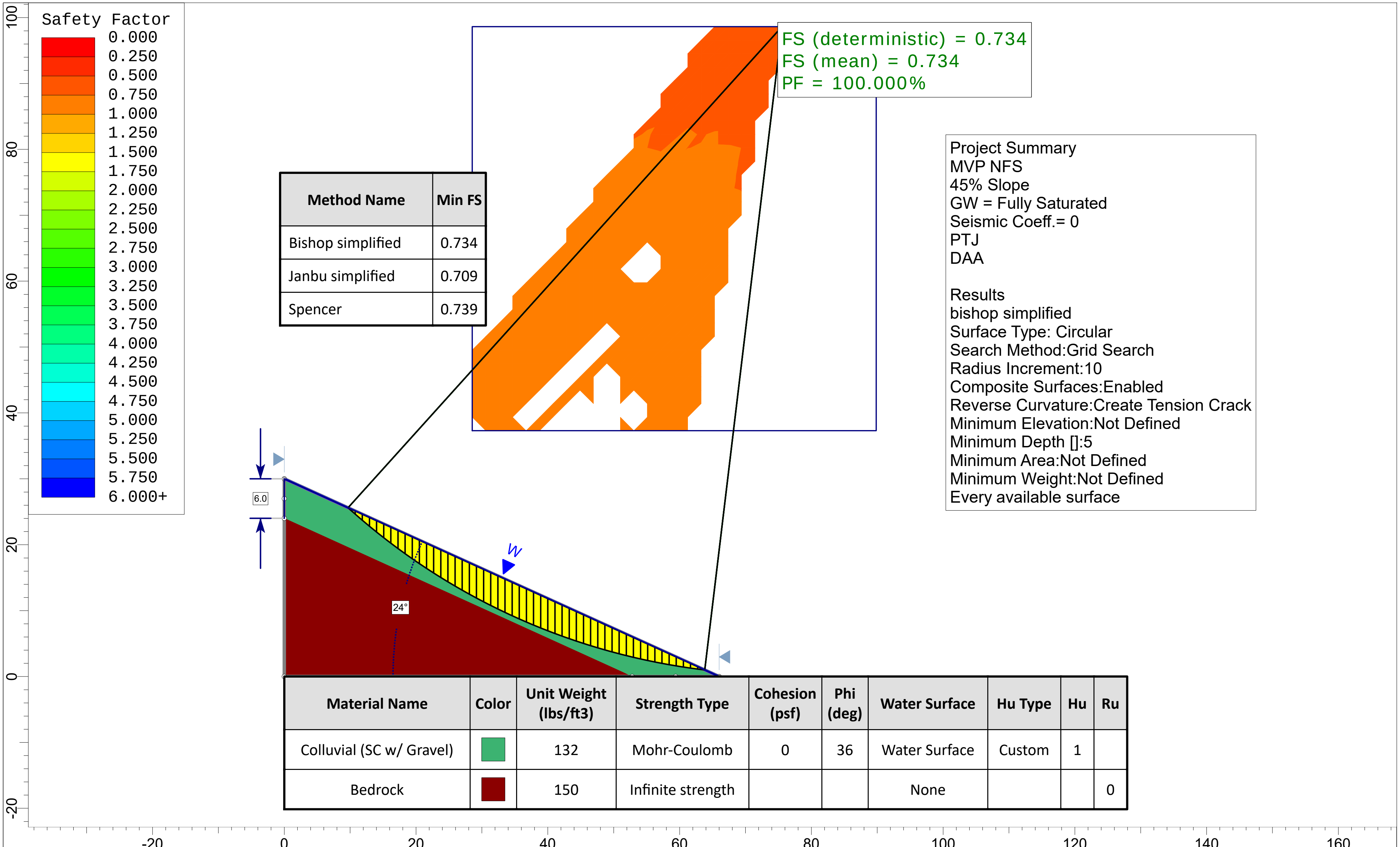
SLIDEINTERPRET 7.018

| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 45% Slope - Moist Soils with 0.16g Seismic Load |
| *Drawn By* | PTJ |
| *Scale* | 1:236 |
| *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM |
| *File Name* | MVP Debri - 45 Slope.slmd |



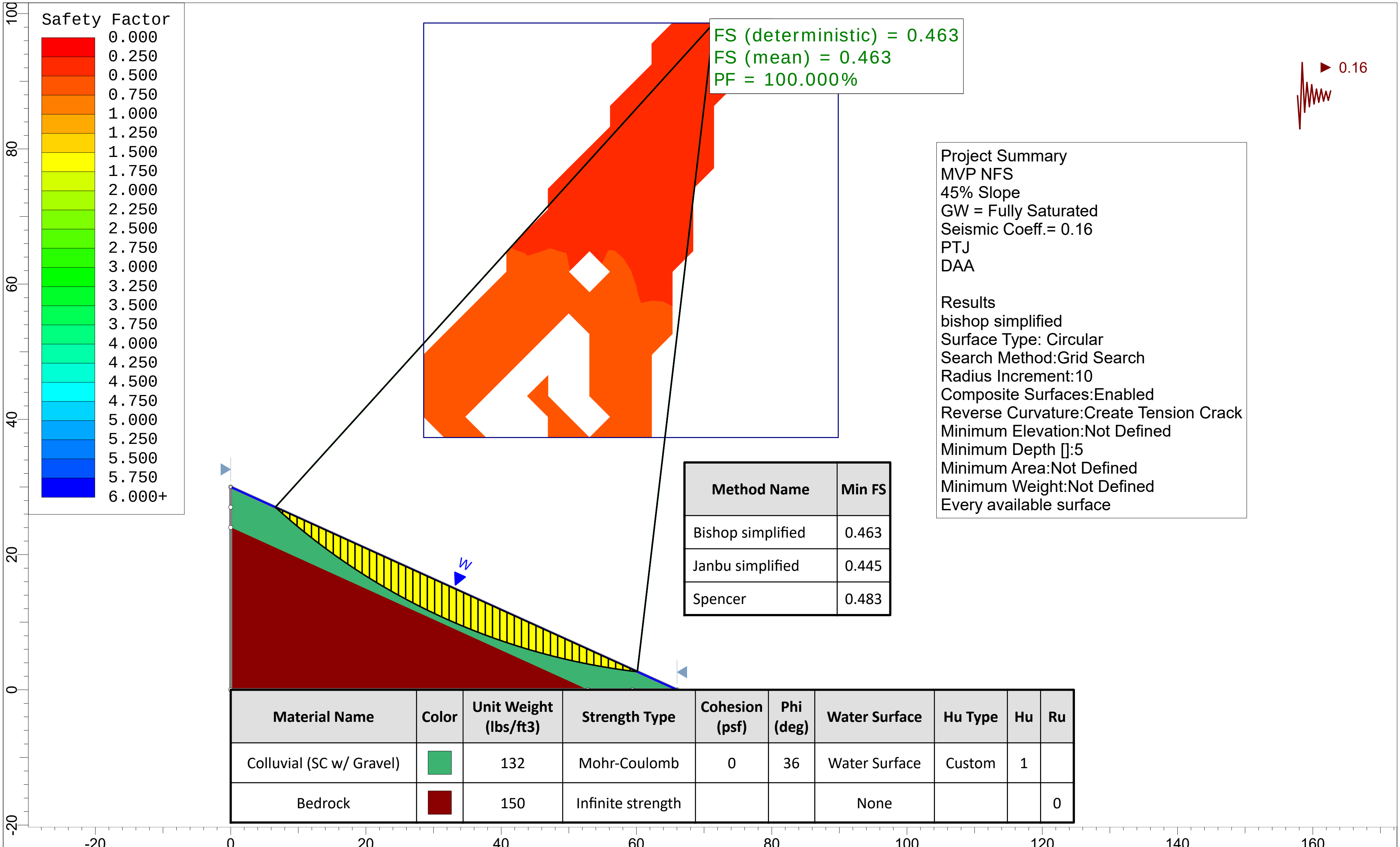

| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.734 |
| Janbu simplified | 0.709 |
| Spencer | 0.739 |

Project Summary
MVP NFS
45% Slope
GW = Fully Saturated
Seismic Coeff.= 0
PTJ
DAA

Results
bishop simplified
Surface Type: Circular
Search Method:Grid Search
Radius Increment:10
Composite Surfaces:Enabled
Reverse Curvature:Create Tension Crack
Minimum Elevation:Not Defined
Minimum Depth []:5
Minimum Area:Not Defined
Minimum Weight:Not Defined
Every available surface

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

| | | | |
|---|---|---|---|
| rocscience | *Project* MVP Debris Stability | | |
| | *Analysis Description* 45% Slope - Saturated Soils | | |
| | *Drawn By* PTJ | *Scale* 1:242 | *Company* DAA |
| SLIDEINTERPRET 7.018 | *Date* 11/30/2016, 4:07:45 PM | | *File Name* MVP Debri - 45 Slope.slmd |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.463 |
| Janbu simplified | 0.445 |
| Spencer | 0.483 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

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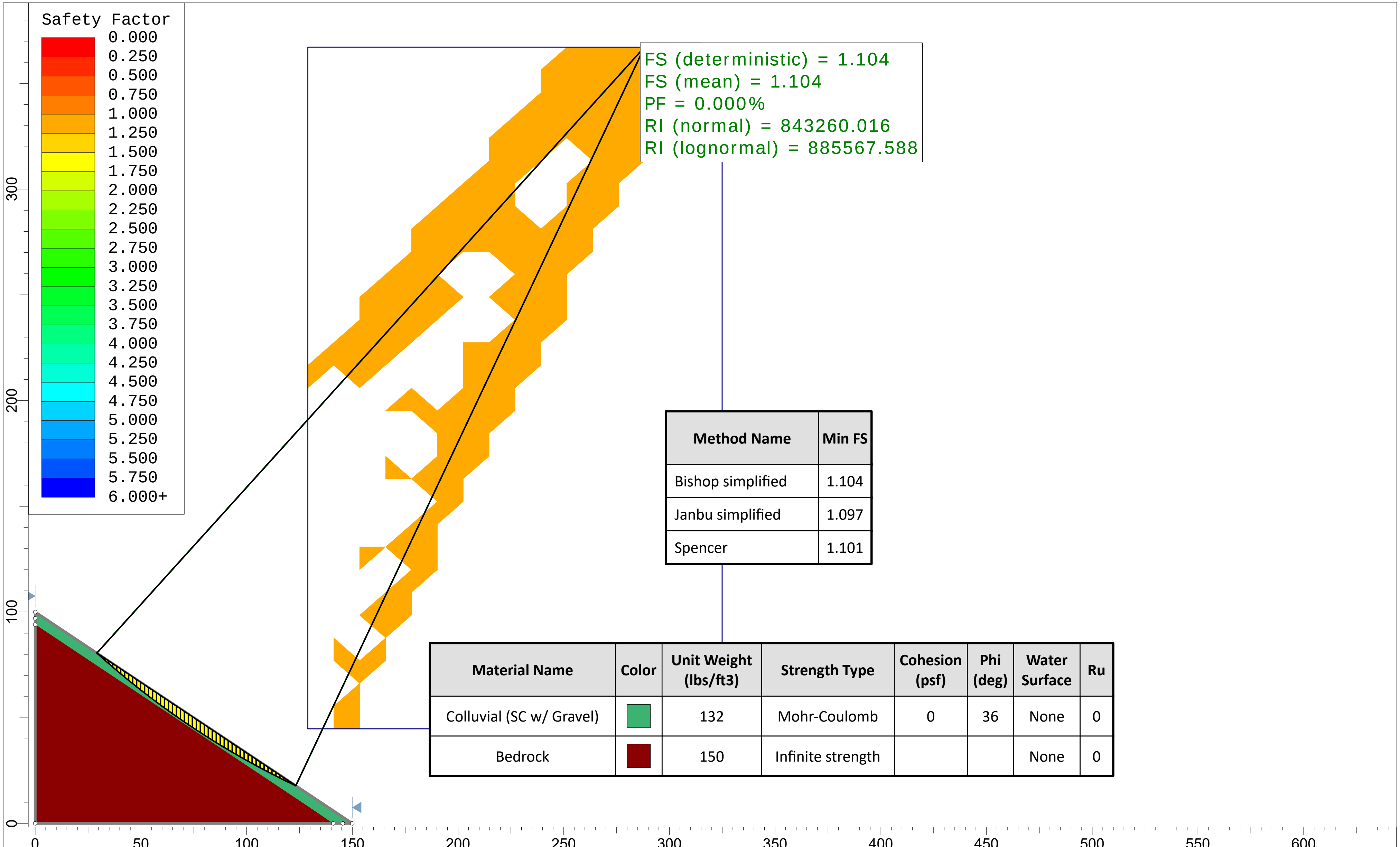
SLIDEINTERPRET 7.018

| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 45% Slope - Saturated Soils with 0.16g Seismic Load |
| *Drawn By* | PTJ |
| *Scale* | 1:236 |
| *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM |
| *File Name* | MVP Debri - 45 Slope.slmd |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 1.104 |
| Janbu simplified | 1.097 |
| Spencer | 1.101 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

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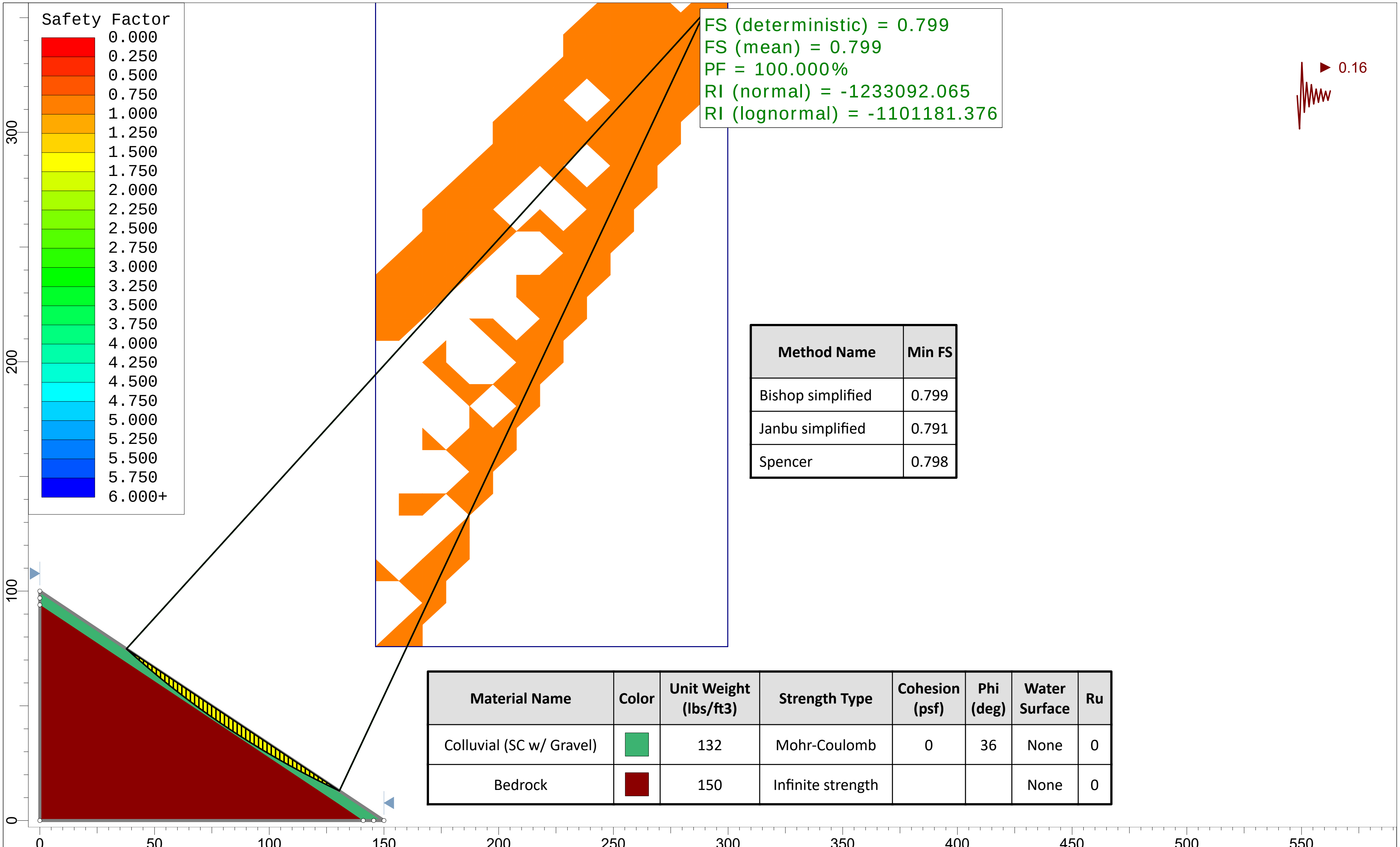
| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 65% Slope - Moist Soils | | |
| *Drawn By* PTJ | *Scale* 1:754 | *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM | *File Name* | MVP Debri - 65 Slope.slmd |

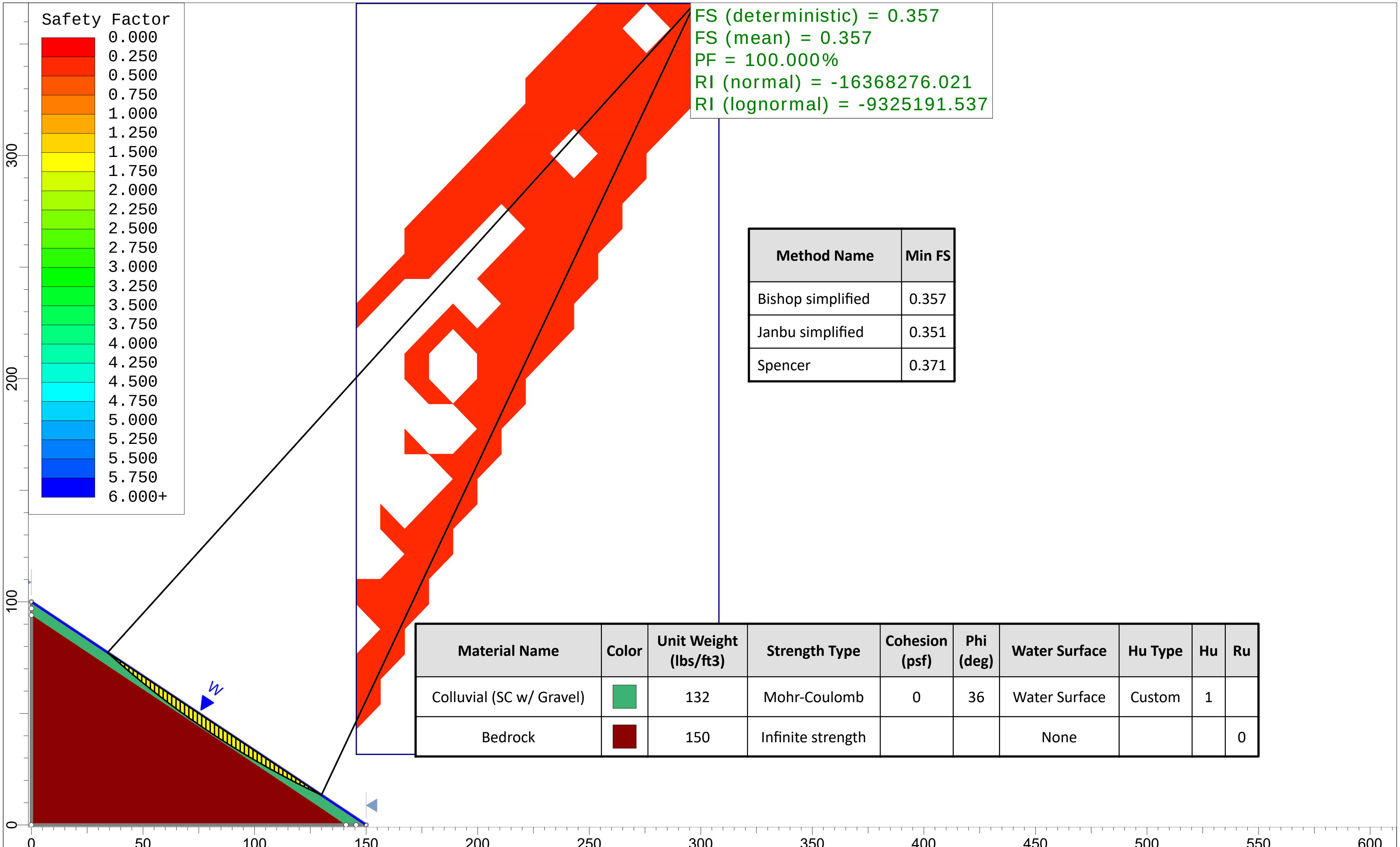



| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.799 |
| Janbu simplified | 0.791 |
| Spencer | 0.798 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

SLIDEINTERPRET 7.018

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 65% Slope - Moist Soils with 0.16g Seismic Load | | |
| *Drawn By* | PTJ | *Scale* | 1:694 |
| *Company* | DAA | | |
| *Date* | 11/30/2016, 4:07:45 PM | *File Name* | MVP Debri - 65 Slope.slmd |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.357 |
| Janbu simplified | 0.351 |
| Spencer | 0.371 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

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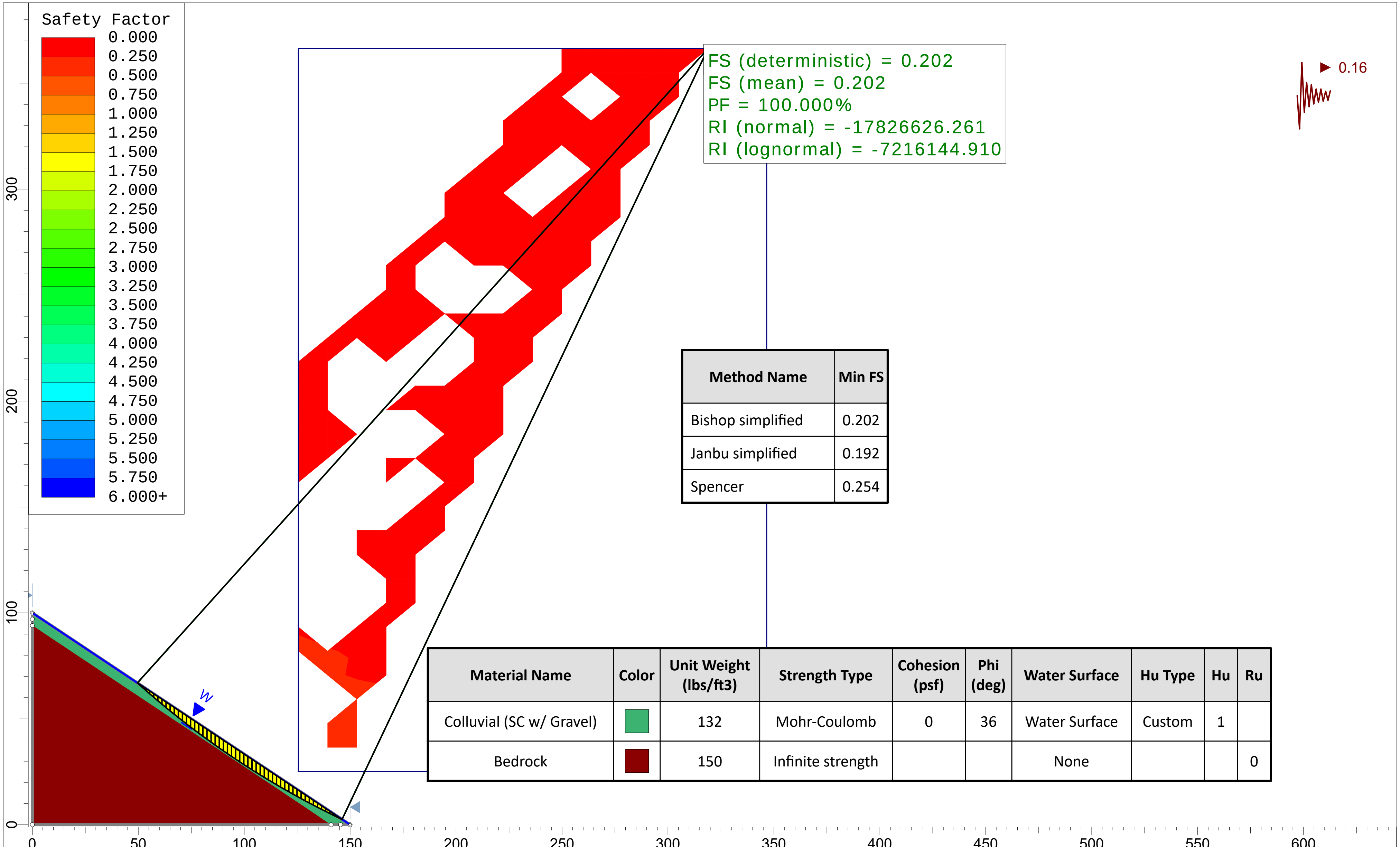
SLIDEINTERPRET 7.018

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 65% Slope - Saturated Soils | | |
| *Drawn By* PTJ | *Scale* 1:714 | *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM | *File Name* | MVP Debri - 65 Slope.slmd |

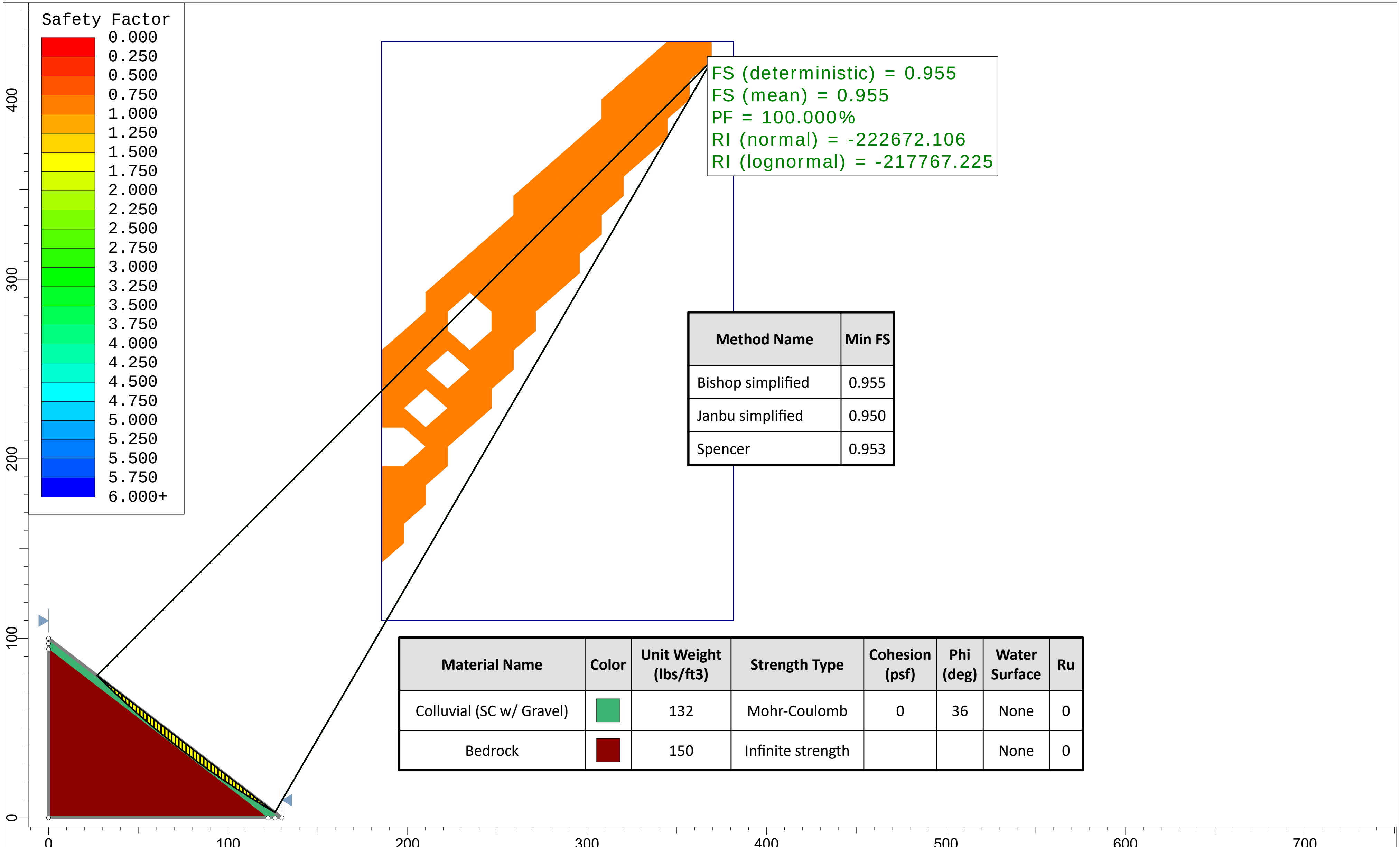



| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.202 |
| Janbu simplified | 0.192 |
| Spencer | 0.254 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 65% Slope - Saturated Soils with 0.16g Seismic Load | | |
| *Drawn By* PTJ | *Scale* 1:752 | *Company* | DAA |
| *Date* 11/30/2016, 4:07:45 PM | | *File Name* | MVP Debri - 65 Slope.slmd |

SLIDEINTERPRET 7.018




| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.955 |
| Janbu simplified | 0.950 |
| Spencer | 0.953 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

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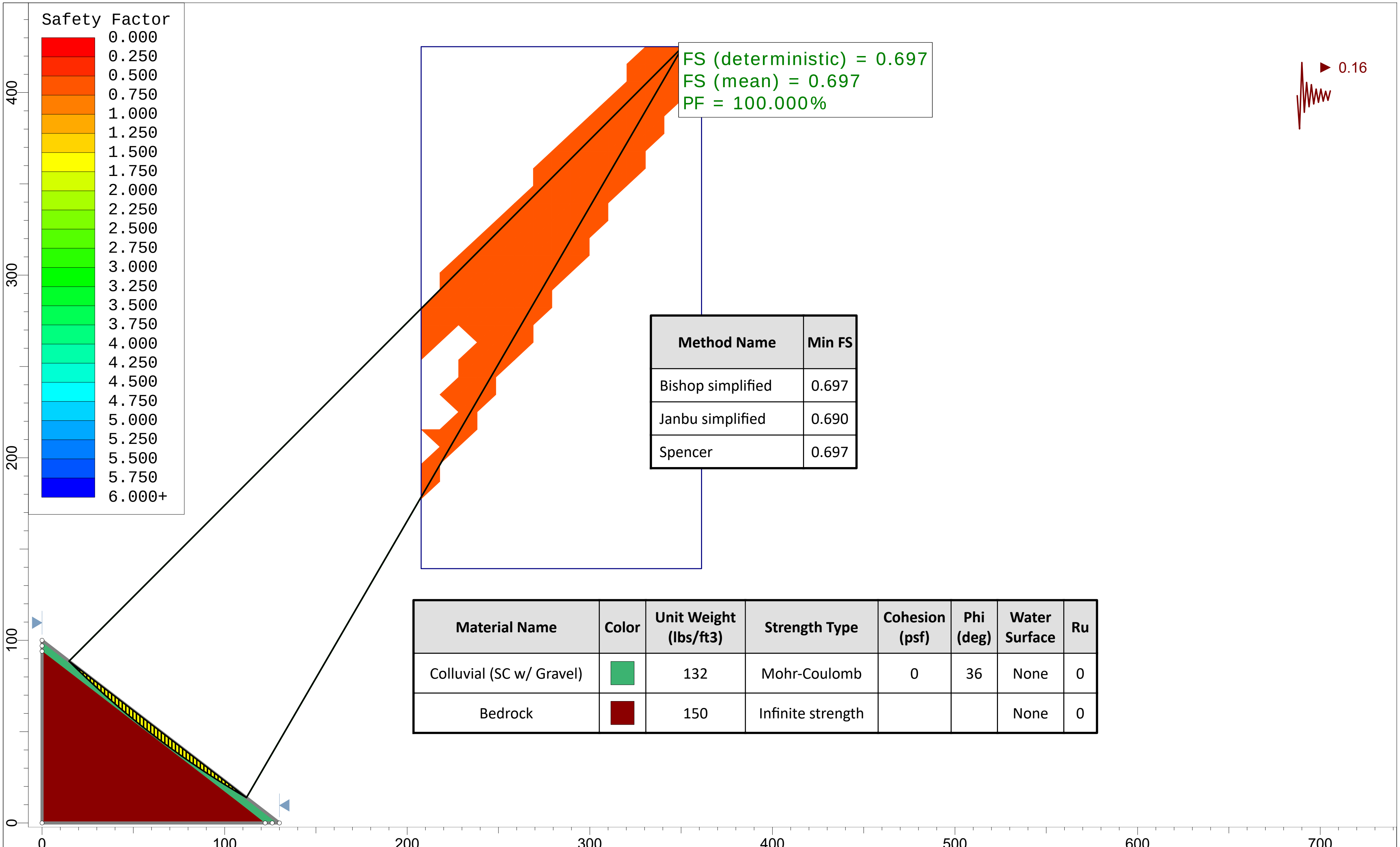
SLIDEINTERPRET 7.018

| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 76% Slope - Moist Soils |
| *Drawn By* | PTJ |
| *Scale* | 1:887 |
| *Company* | DAA |
| *Date* | 12/02/2016 |
| *File Name* | MVP Debri - 76 Slope.slmd |



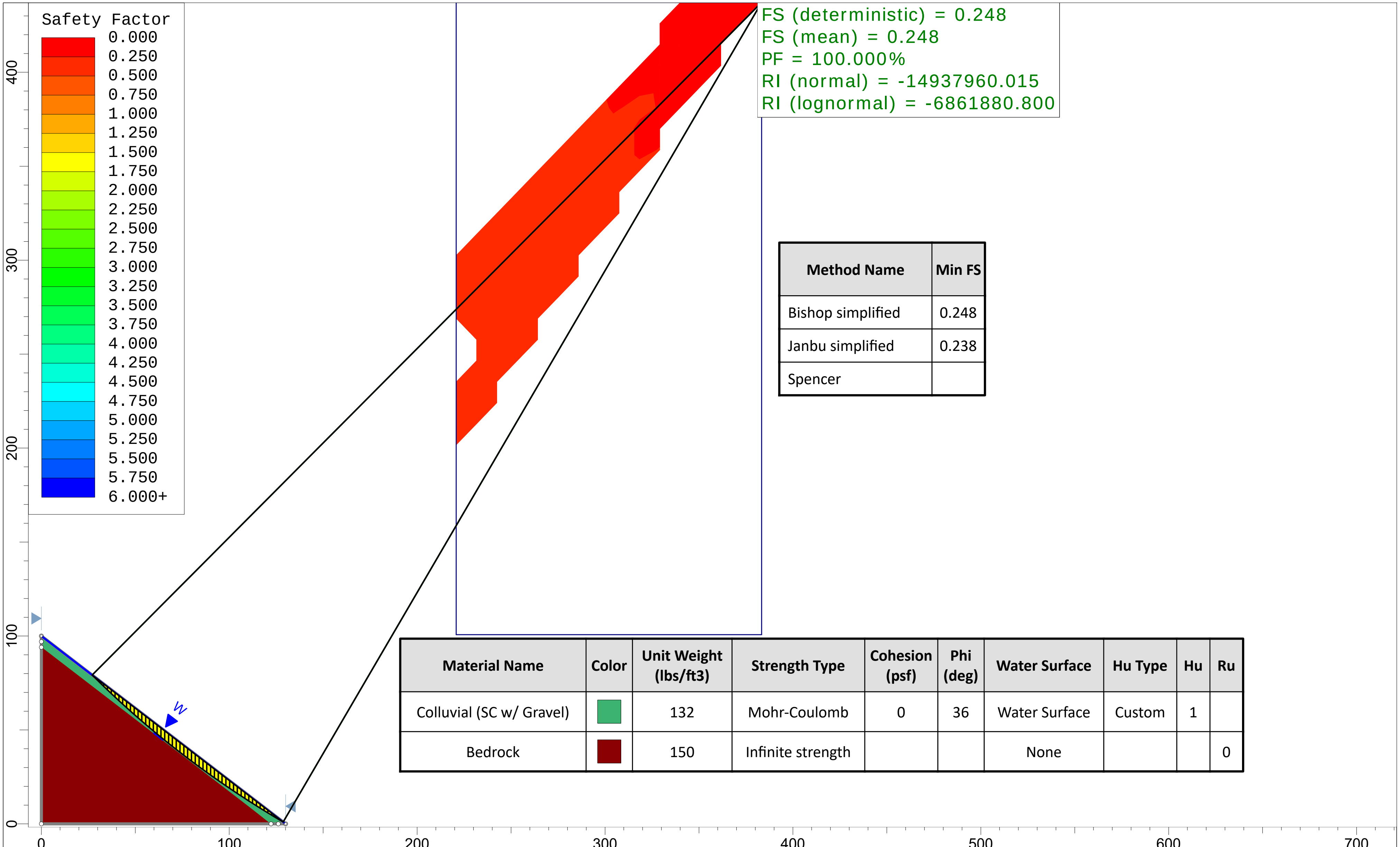

| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.697 |
| Janbu simplified | 0.690 |
| Spencer | 0.697 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru |
|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | None | 0 |
| Bedrock | | 150 | Infinite strength | | | None | 0 |

rocscience

SLIDEINTERPRET 7.018

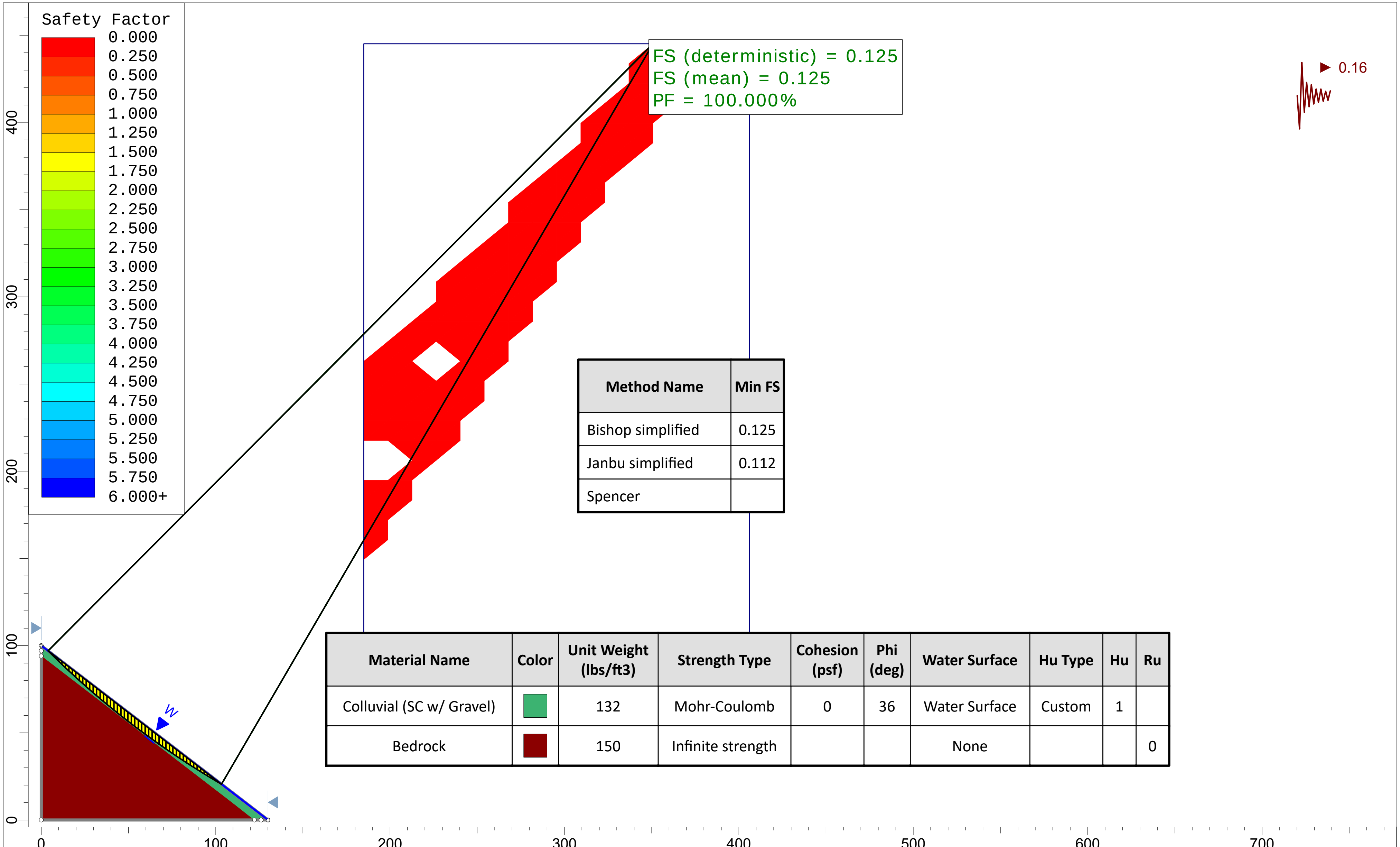
| | |
|---|---|
| *Project* | MVP Debris Stability |
| *Analysis Description* | 76% Slope - Moist Soils with 0.16g Seismic Load |
| *Drawn By* | PTJ |
| *Scale* | 1:872 |
| *Company* | DAA |
| *Date* | 11/30/2016, 4:07:45 PM |
| *File Name* | MVP Debri - 76 Slope.slmd |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.248 |
| Janbu simplified | 0.238 |
| Spencer | |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

| | | | |
|---|---|---|---|
| rocscience<br>SLIDEINTERPRET 7.018 | *Project* MVP Debris Stability | | |
| | *Analysis Description* 76% Slope - Saturated Soils | | |
| | *Drawn By* PTJ | *Scale* 1:848 | *Company* DAA |
| | *Date* 11/30/2016, 4:07:45 PM | | *File Name* MVP Debri - 76 Slope.slmd |




| Method Name | Min FS |
|---|---|
| Bishop simplified | 0.125 |
| Janbu simplified | 0.112 |
| Spencer | |

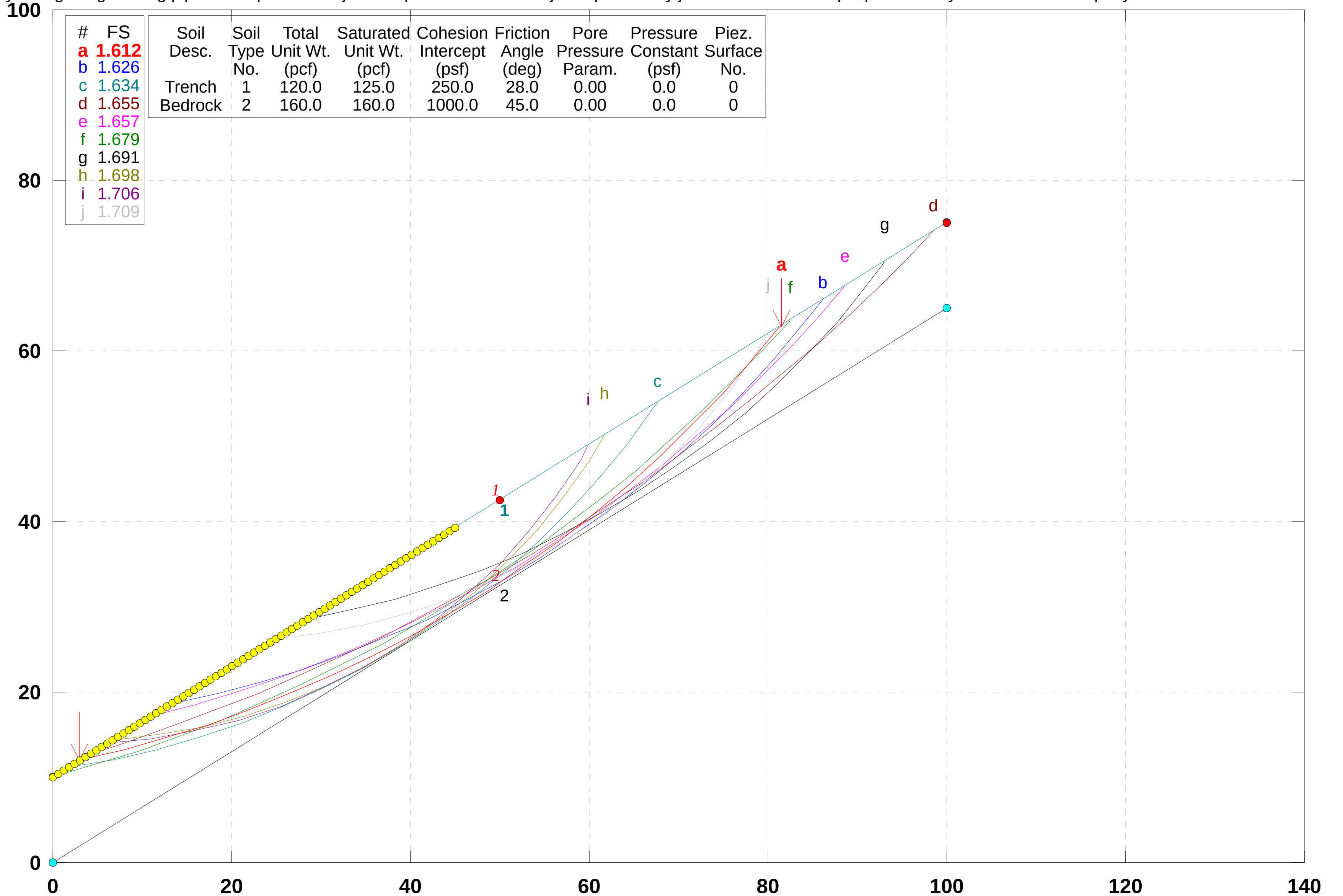
| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Hu Type | Hu | Ru |
|---|---|---|---|---|---|---|---|---|---|
| Colluvial (SC w/ Gravel) | | 132 | Mohr-Coulomb | 0 | 36 | Water Surface | Custom | 1 | |
| Bedrock | | 150 | Infinite strength | | | None | | | 0 |

| | | | |
|---|---|---|---|
| *Project* | MVP Debris Stability | | |
| *Analysis Description* | 76% Slope - Saturated Soils with 0.16g Seismic Load | | |
| *Drawn By* PTJ | *Scale* 1:913 | *Company* | DAA |
| *Date* 11/30/2016, 4:07:45 PM | | *File Name* | MVP Debri - 76 Slope.slmd |

SLIDEINTERPRET 7.018

## JNF1: Trench Backfill Stability - 65% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf1 trench backfill 65pct.pl2 Run By: Insert Name/company Here 12/16/2016 11:38AM



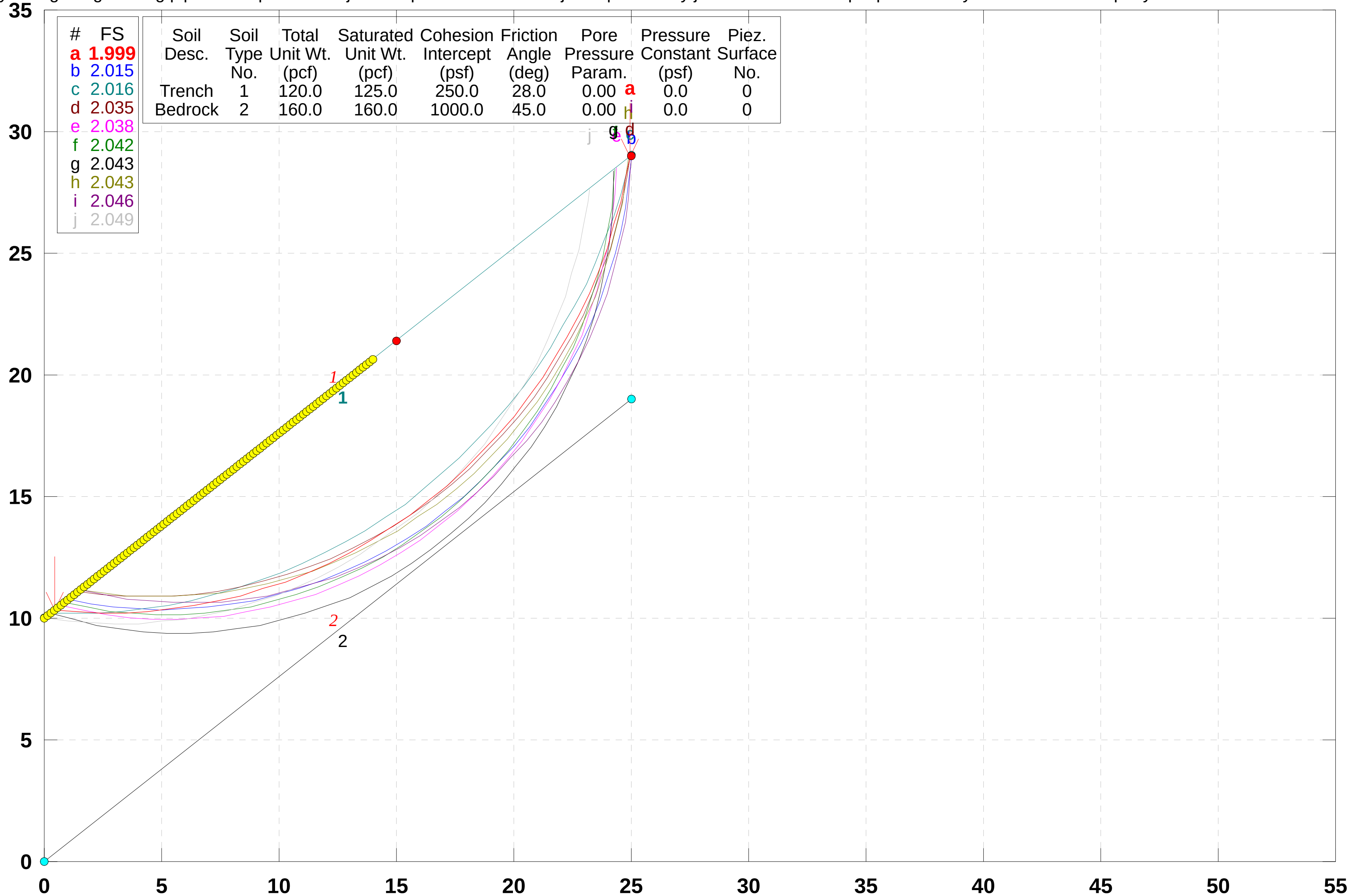

**GSTABL7 v.2 FSmin=1.612**

**Safety Factors Are Calculated By The Modified Bishop Method**

# JNF1: Trench Backfill Stability - 25' Breaker Spacing, 76% Slope

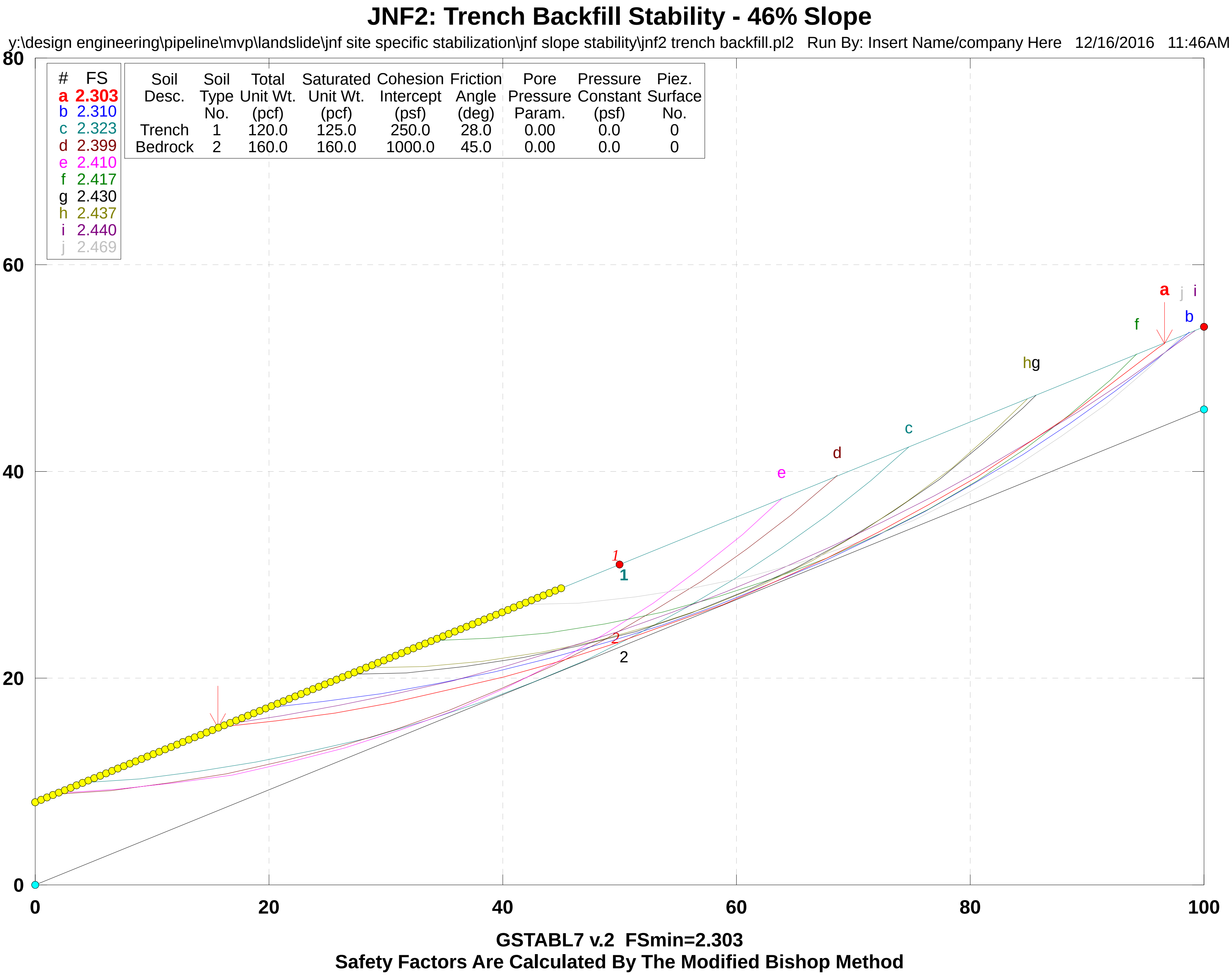
y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf1 25f breakers 76pct.pl2   Run By: Insert Name/company Here   12/15/2016   04:27PM

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Trench | 1 | 120.0 | 125.0 | 250.0 | 28.0 | 0.00 | 0.0 | 0 |
| Bedrock | 2 | 160.0 | 160.0 | 1000.0 | 45.0 | 0.00 | 0.0 | 0 |



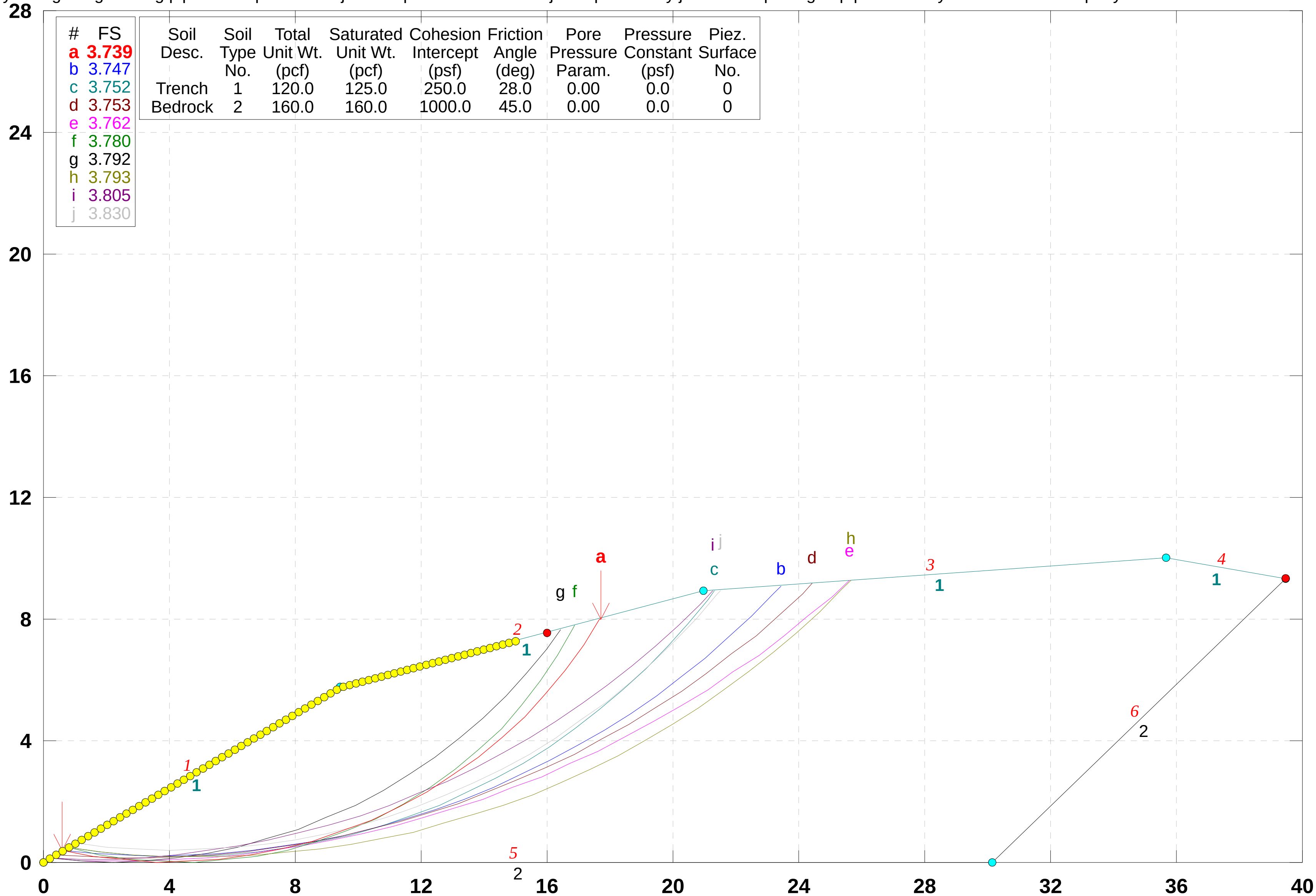

GSTABL7 v.2  FSmin=1.999

Safety Factors Are Calculated By The Modified Bishop Method


JNF2: Trench Backfill Stability - 46% Slope
y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf2 trench backfill.pl2 Run By: Insert Name/company Here 12/16/2016 11:46AM
# FS
a 2.303
b 2.310
c 2.323
d 2.399
e 2.410
f 2.417
g 2.430
h 2.437
i 2.440
j 2.469
Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No.
Trench 1 120.0 125.0 250.0 28.0 0.00 0.0 0
Bedrock 2 160.0 160.0 1000.0 45.0 0.00 0.0 0
0
20
40
60
80
100
GSTABL7 v.2 FSmin=2.303
Safety Factors Are Calculated By The Modified Bishop Method

## JNF2: Sideslope Stability - 1.5H:1V

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf2 sideslope ridgetop.pl2 Run By: Insert Name/company Here 12/16/2016 11:42AM



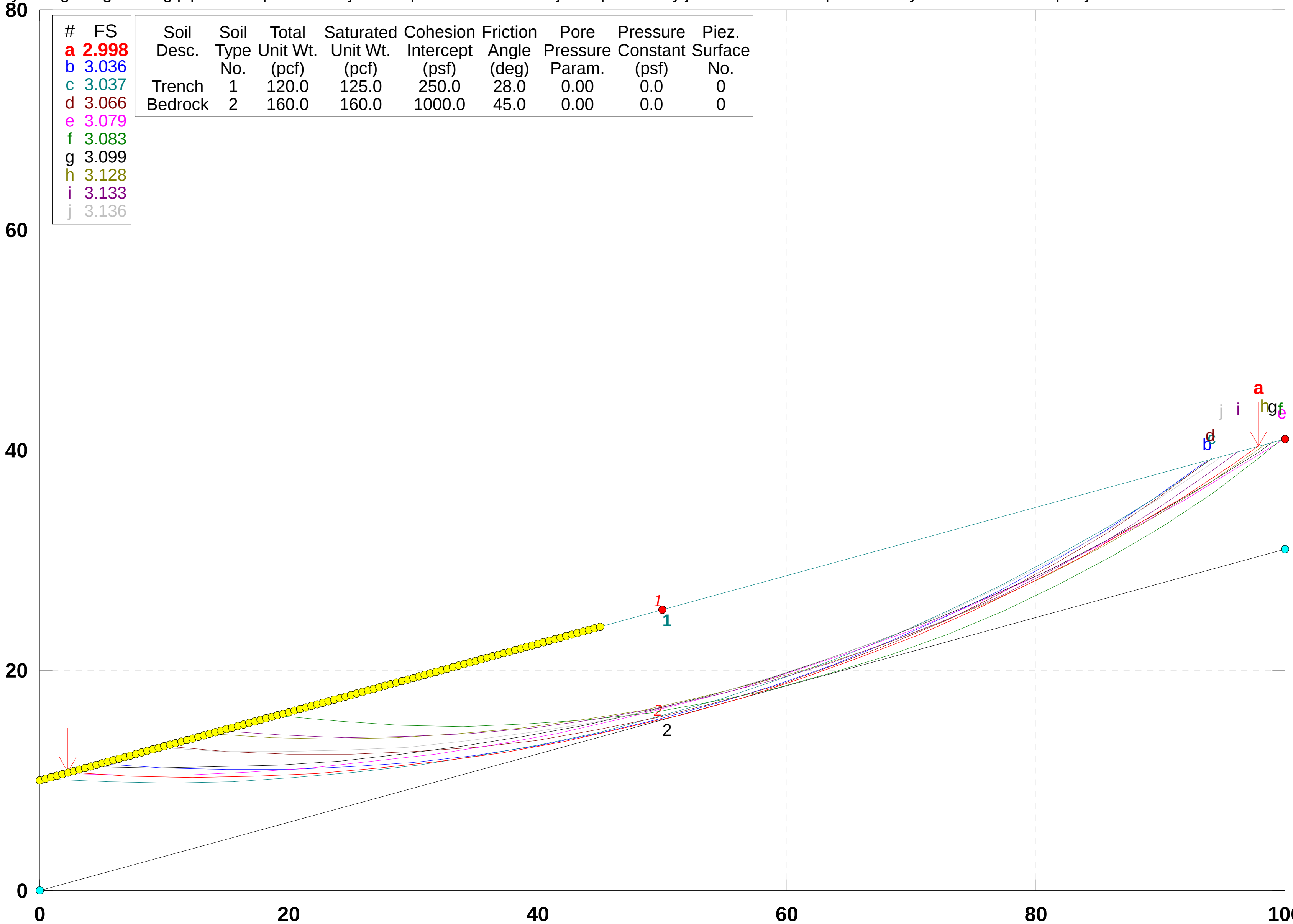

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Trench | 1 | 120.0 | 125.0 | 250.0 | 28.0 | 0.00 | 0.0 | 0 |
| Bedrock | 2 | 160.0 | 160.0 | 1000.0 | 45.0 | 0.00 | 0.0 | 0 |

**GSTABL7 v.2 FSmin=3.739**

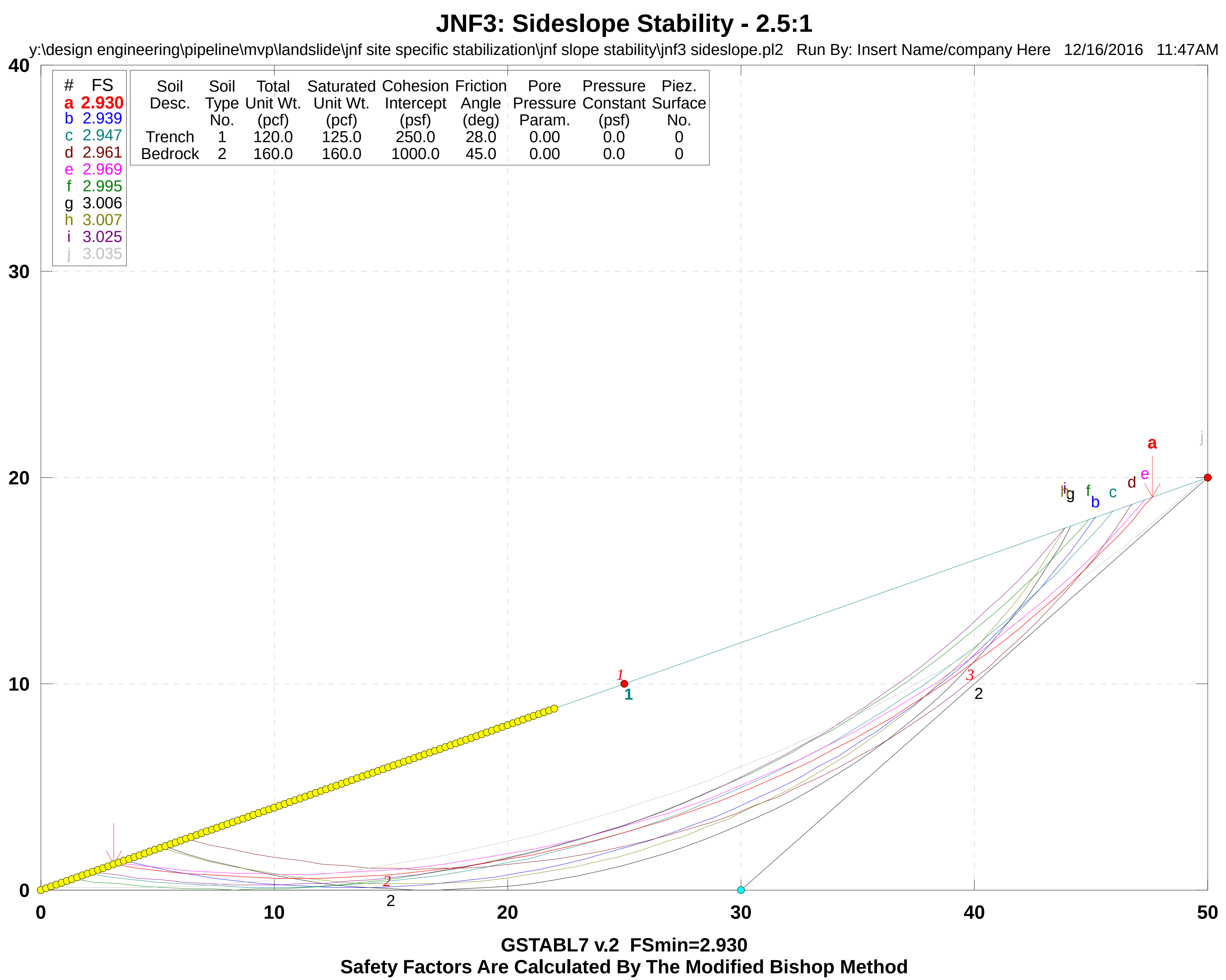
**Safety Factors Are Calculated By The Modified Bishop Method**

# JNF3: Trench Backfill Stability - 41% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf3 trench backfill.pl2 Run By: Insert Name/company Here 12/16/2016 11:48AM

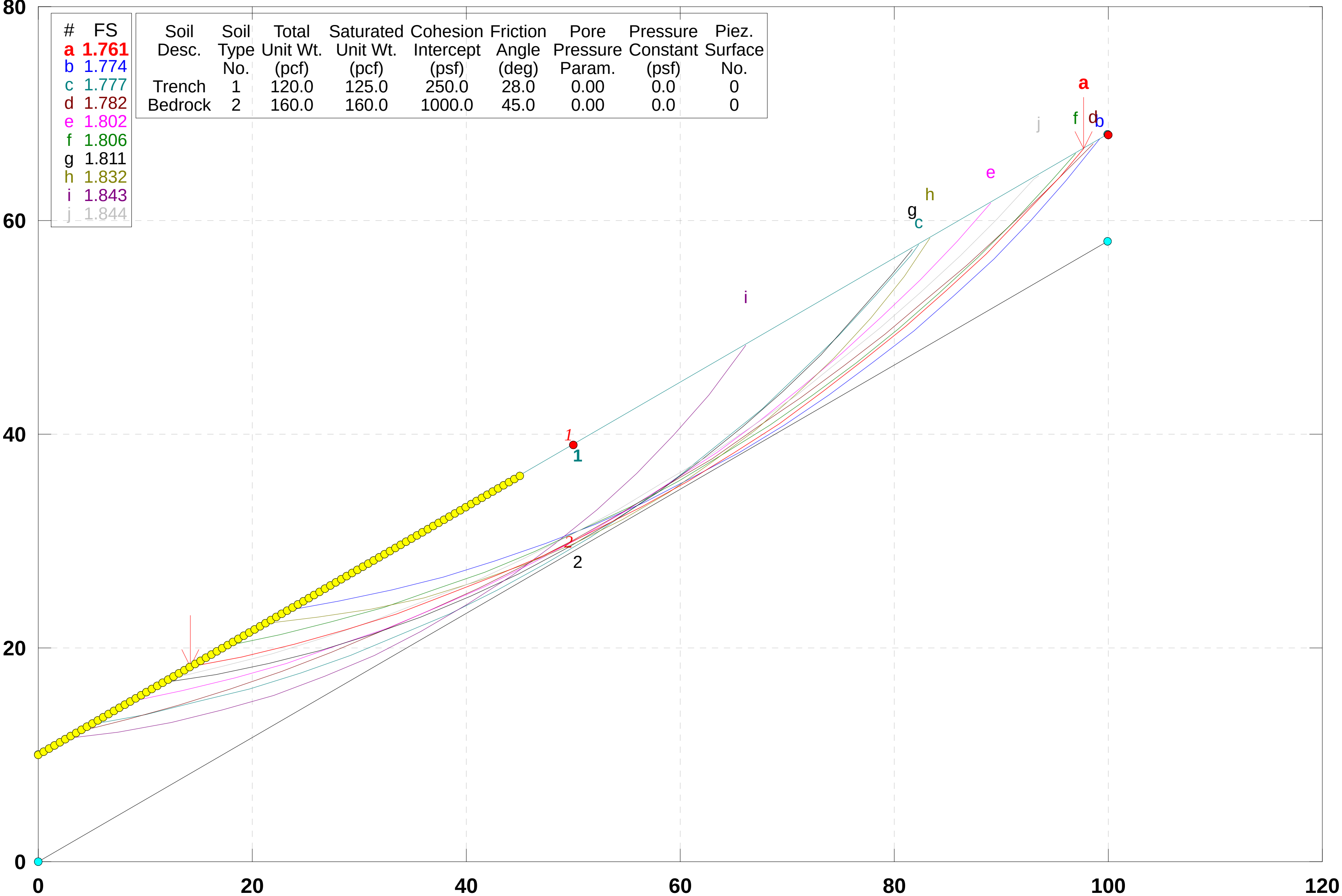



**GSTABL7 v.2 FSmin=2.998**
**Safety Factors Are Calculated By The Modified Bishop Method**


JNF3: Sideslope Stability - 2.5:1
y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf3 sideslope.pl2 Run By: Insert Name/company Here 12/16/2016 11:47AM
# FS
a 2.930
b 2.939
c 2.947
d 2.961
e 2.969
f 2.995
g 3.006
h 3.007
i 3.025
j 3.035
Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No.
Trench 1 120.0 125.0 250.0 28.0 0.00 0.0 0
Bedrock 2 160.0 160.0 1000.0 45.0 0.00 0.0 0
0
10
20
30
40
50
GSTABL7 v.2 FSmin=2.930
Safety Factors Are Calculated By The Modified Bishop Method

# JNF4: Trench Backfill Stability - 58% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf4 trench backfill.pl2 Run By: Insert Name/company Here 12/16/2016 11:52AM

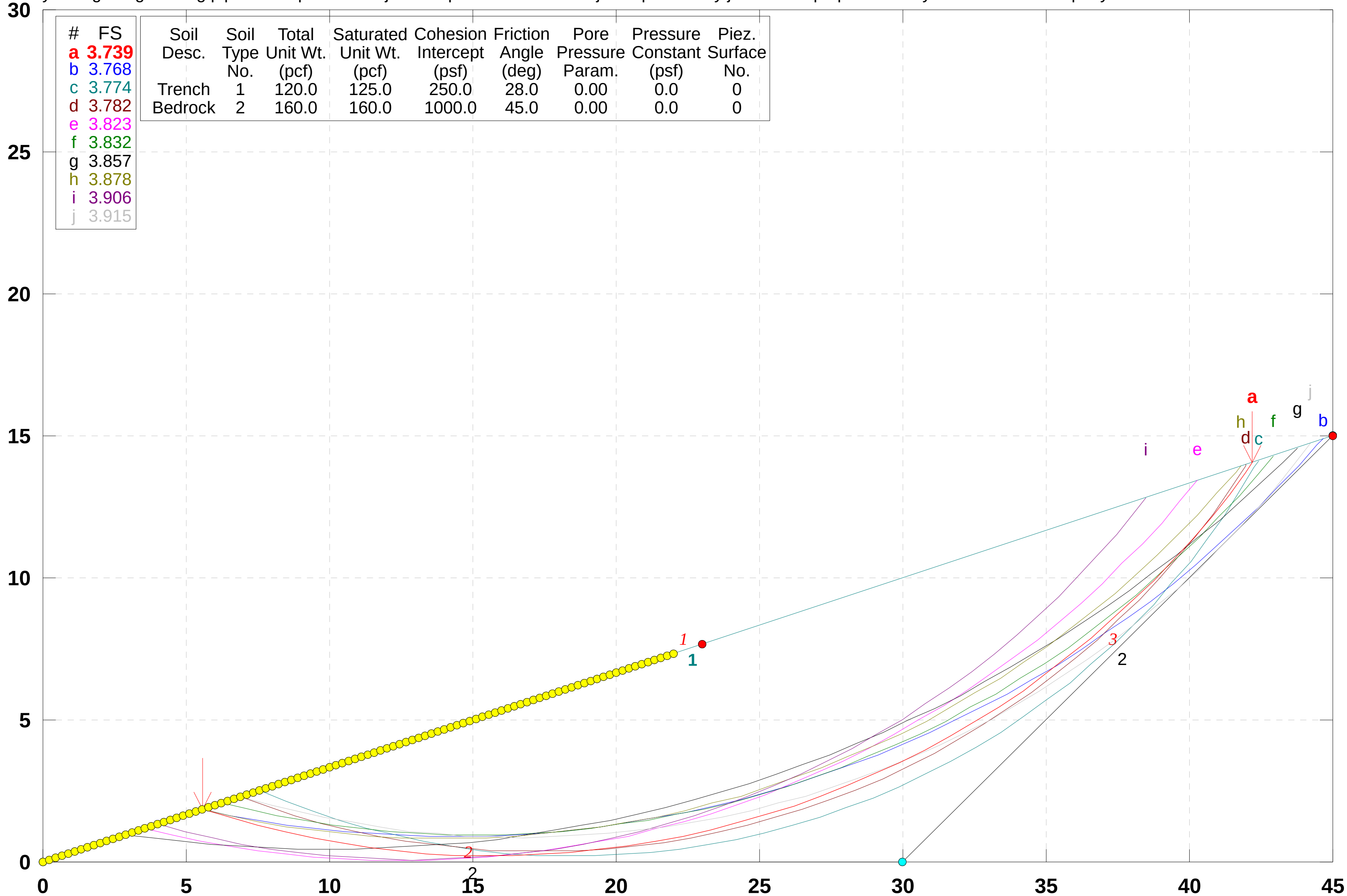



GSTABL7 v.2 FSmin=1.761

Safety Factors Are Calculated By The Modified Bishop Method

## JNF4: Sideslope Stability - 3:1

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf4 sideslope.pl2   Run By: Insert Name/company Here   12/16/2016   11:50AM



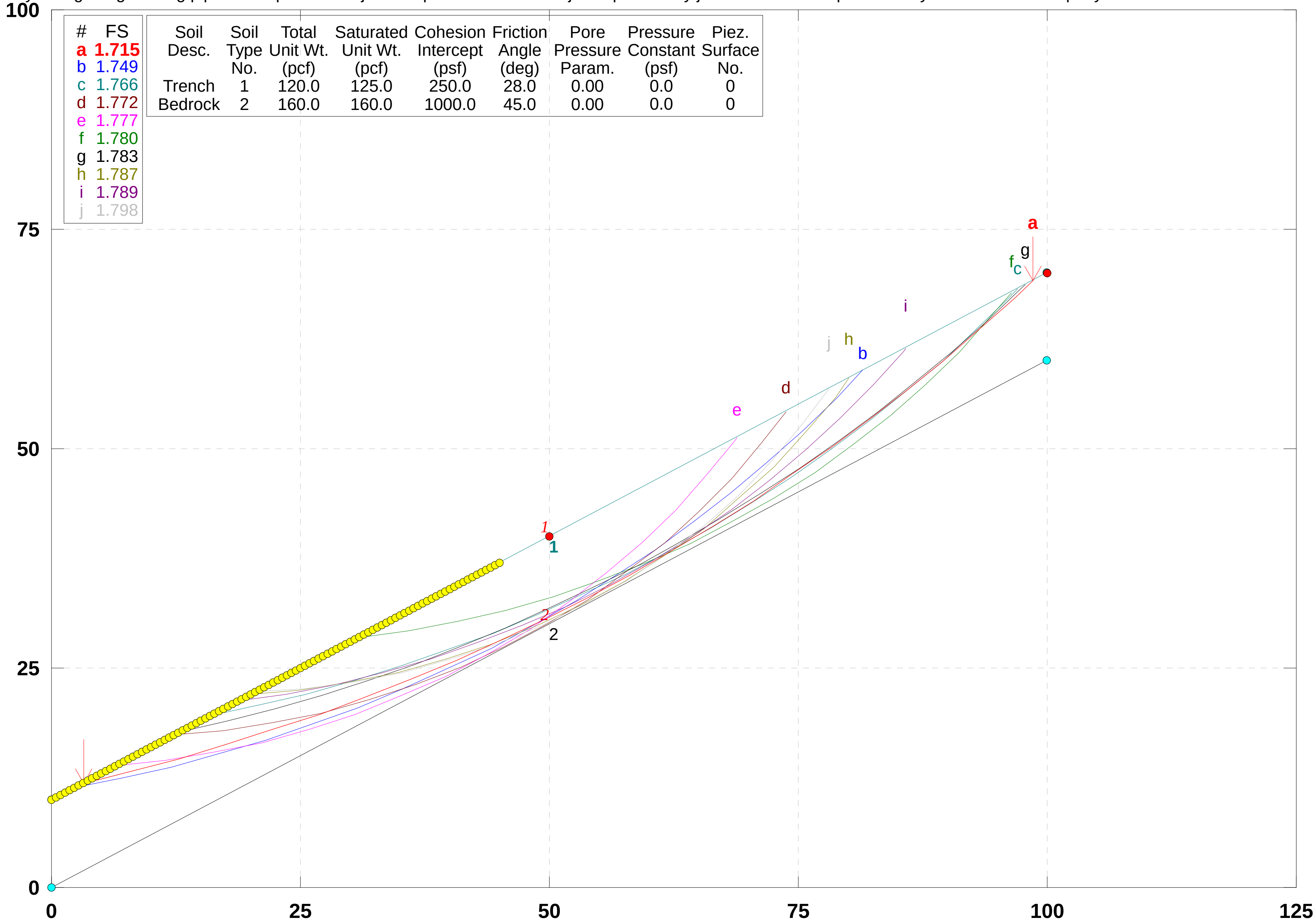

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Trench | 1 | 120.0 | 125.0 | 250.0 | 28.0 | 0.00 | 0.0 | 0 |
| Bedrock | 2 | 160.0 | 160.0 | 1000.0 | 45.0 | 0.00 | 0.0 | 0 |

**GSTABL7 v.2 FSmin=3.739**

**Safety Factors Are Calculated By The Modified Bishop Method**

# JNF5: Trench Backfill Stability - 60% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf5 trench backfill.pl2 Run By: Insert Name/company Here 12/16/2016 11:53AM

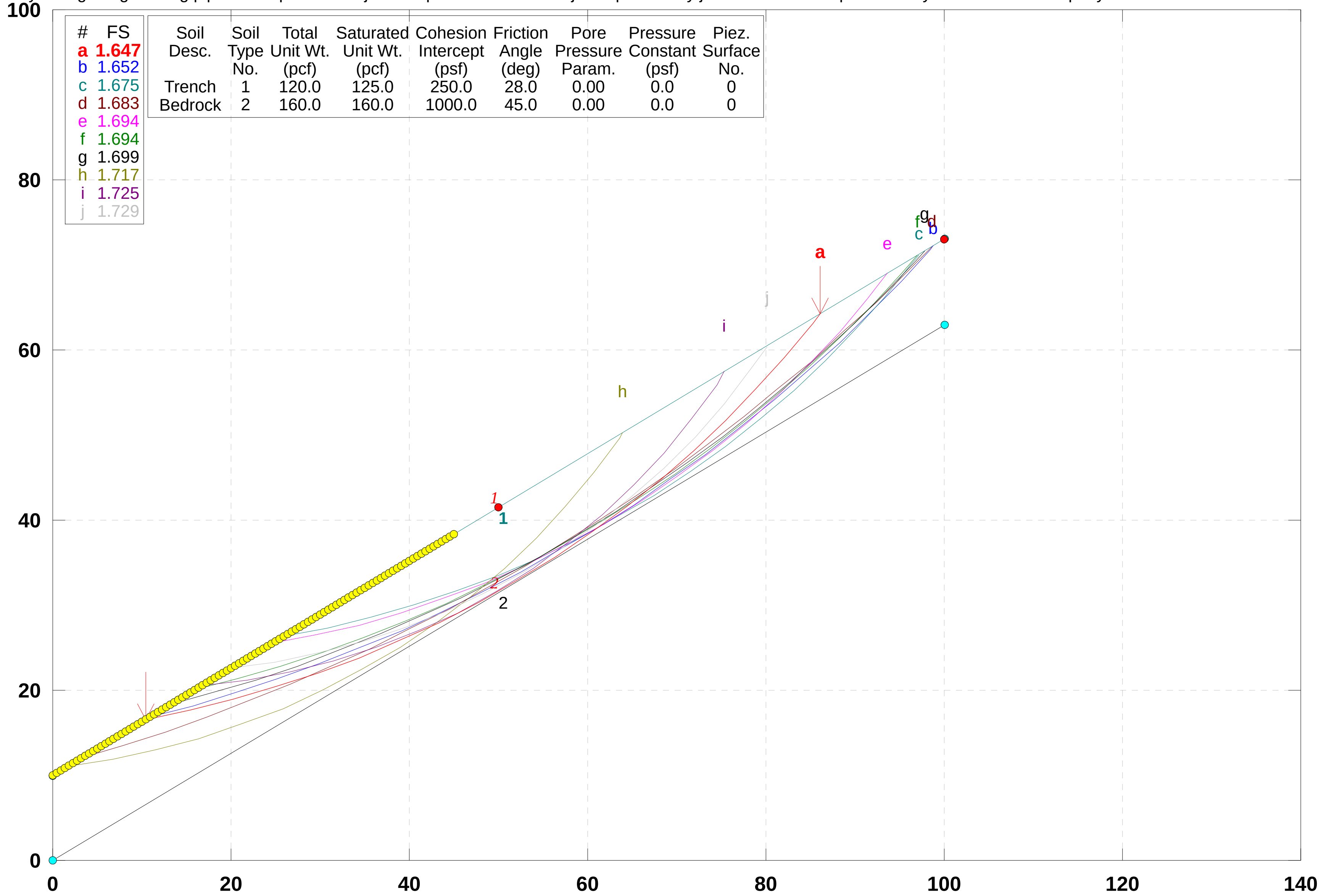



**GSTABL7 v.2 FSmin=1.715**

**Safety Factors Are Calculated By The Modified Bishop Method**

# JNF6: Trench Backfill Stability - 63% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf6 trench backfill.pl2 Run By: Insert Name/company Here 12/16/2016 11:54AM



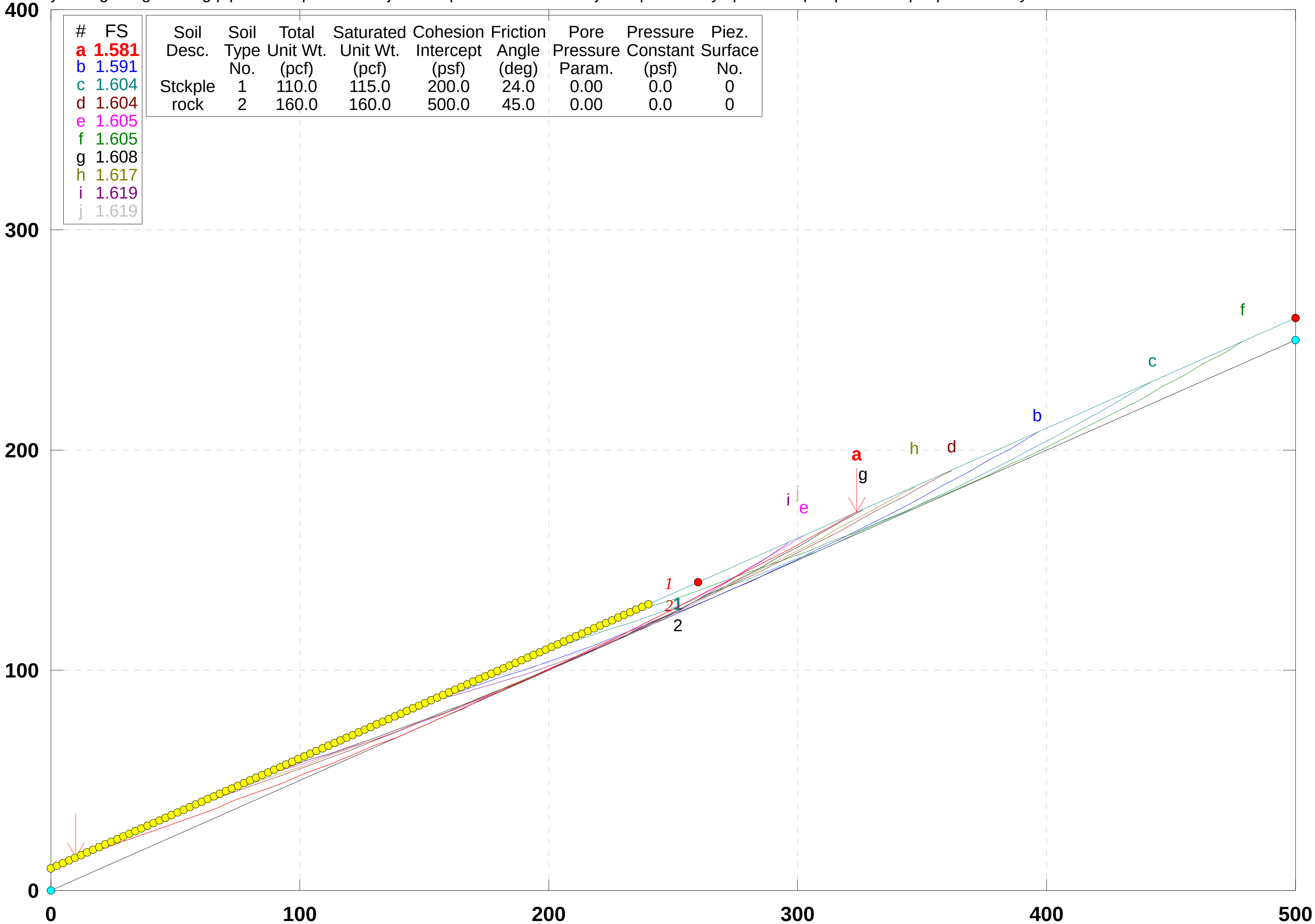

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Trench | 1 | 120.0 | 125.0 | 250.0 | 28.0 | 0.00 | 0.0 | 0 |
| Bedrock | 2 | 160.0 | 160.0 | 1000.0 | 45.0 | 0.00 | 0.0 | 0 |

**GSTABL7 v.2 FSmin=1.647**

**Safety Factors Are Calculated By The Modified Bishop Method**

# Spoil Stockpile Profile - 50% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\spoil stockpile profile 50 pct.pl2   Run By: Username   12/20/2016   02:30PM



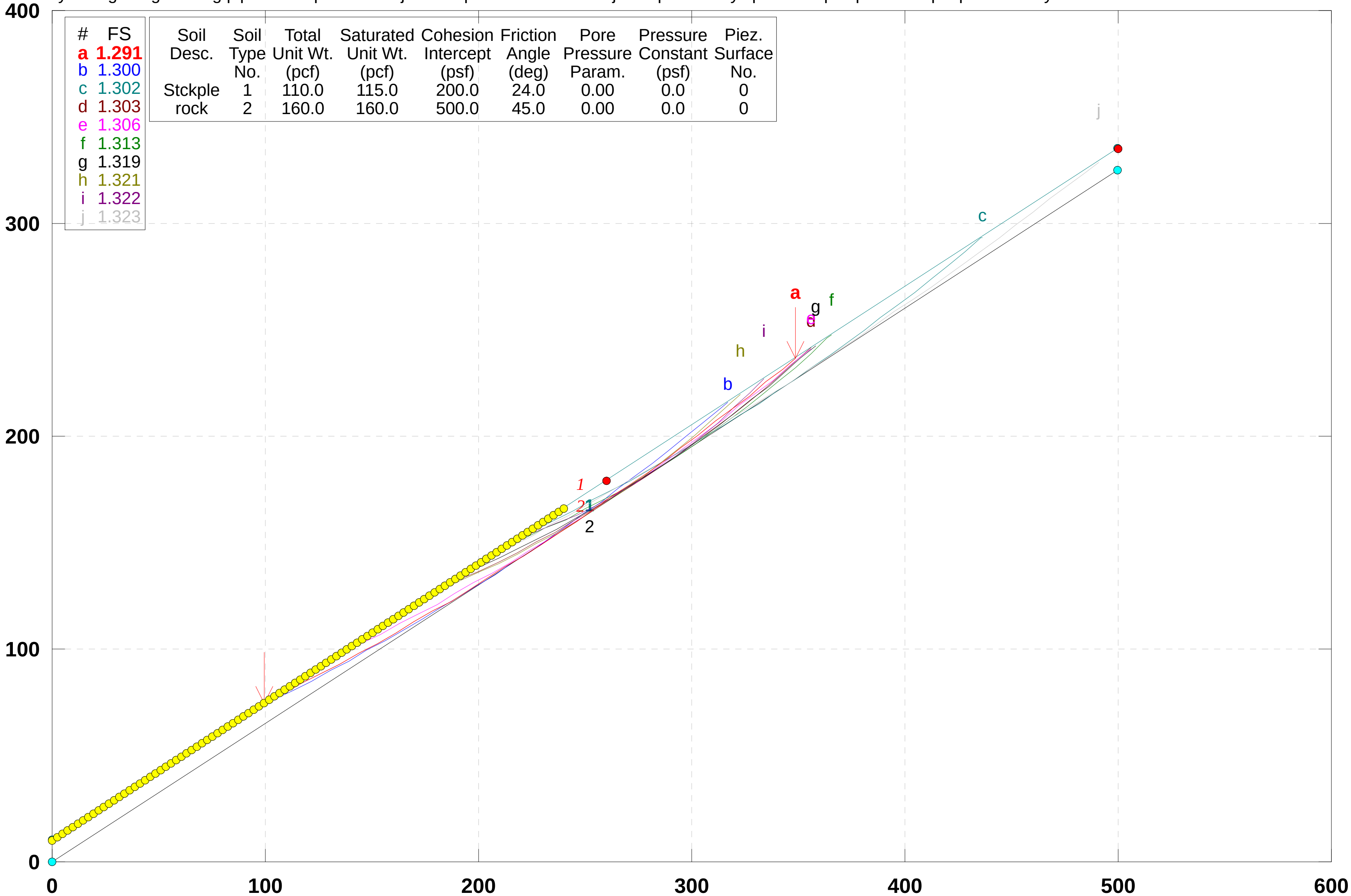

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Stckple | 1 | 110.0 | 115.0 | 200.0 | 24.0 | 0.00 | 0.0 | 0 |
| rock | 2 | 160.0 | 160.0 | 500.0 | 45.0 | 0.00 | 0.0 | 0 |

GSTABL7 v.2  FSmin=1.581

Safety Factors Are Calculated By The Modified Bishop Method

## Spoil Stockpile Profile - 65% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\spoil stockpile profile 65 pct.pl2 Run By: Username 12/20/2016 02:27PM

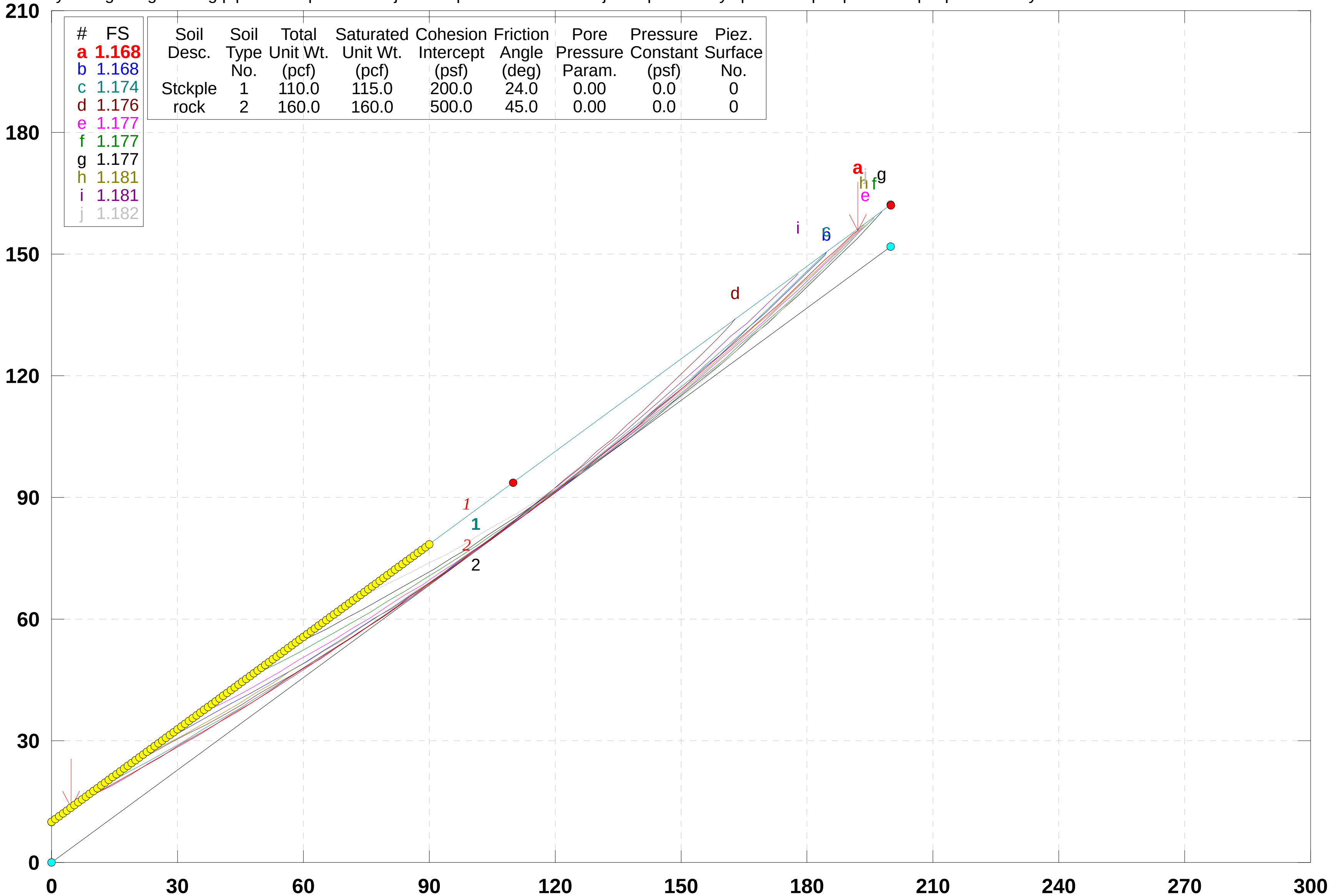



**GSTABL7 v.2 FSmin=1.291**

**Safety Factors Are Calculated By The Modified Bishop Method**

# Spoil Stockpile Profile - 76% Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\spoil stockpile profile 76 pct.pl2   Run By: Username   12/20/2016   02:23PM



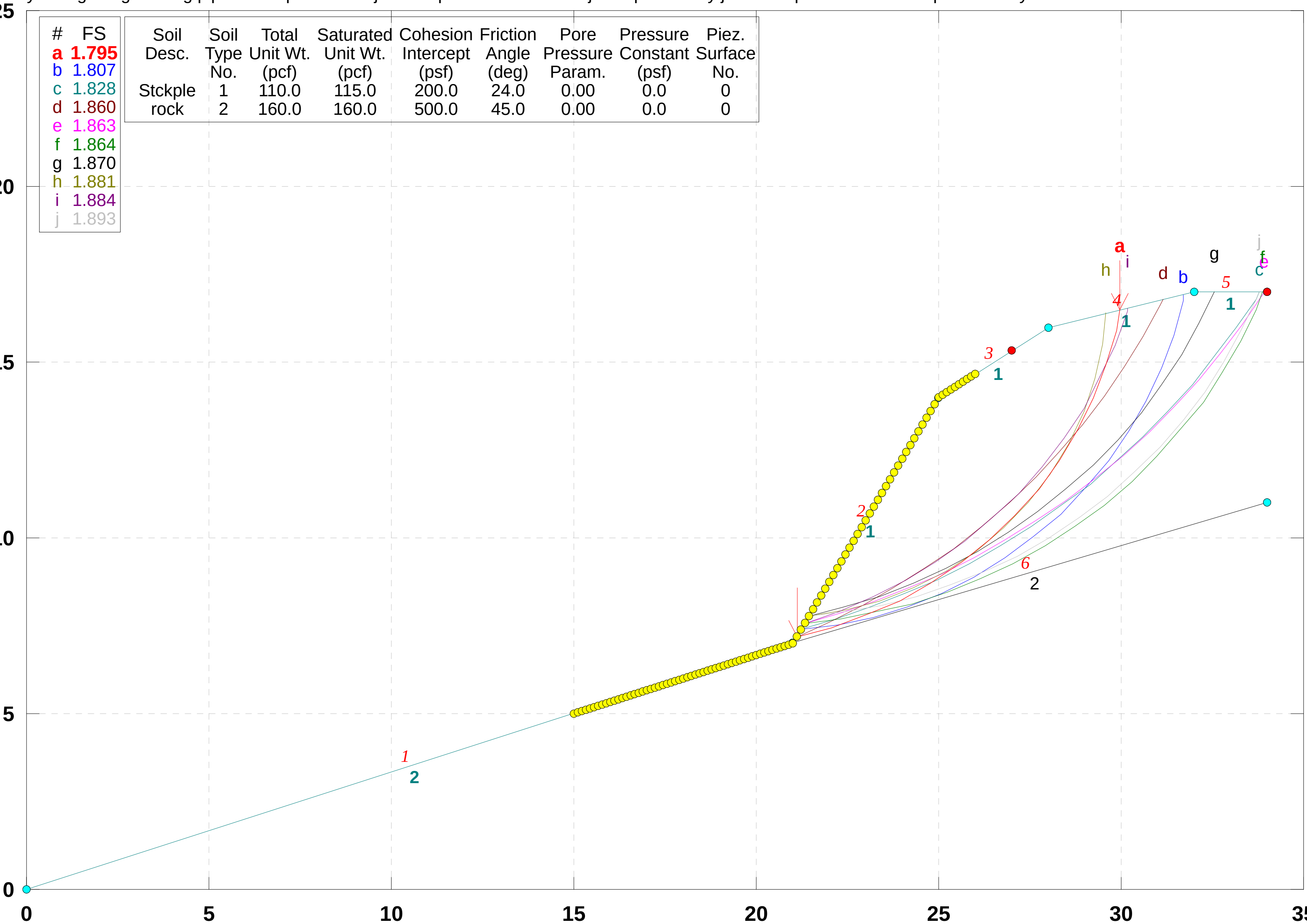

**GSTABL7 v.2 FSmin=1.168**

**Safety Factors Are Calculated By The Modified Bishop Method**

## Spoil Stockpile Cross Section - Trench Material on Gentle Slope

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf1 stockpile cross section.pl2 Run By: Username 12/20/2016 11:22AM

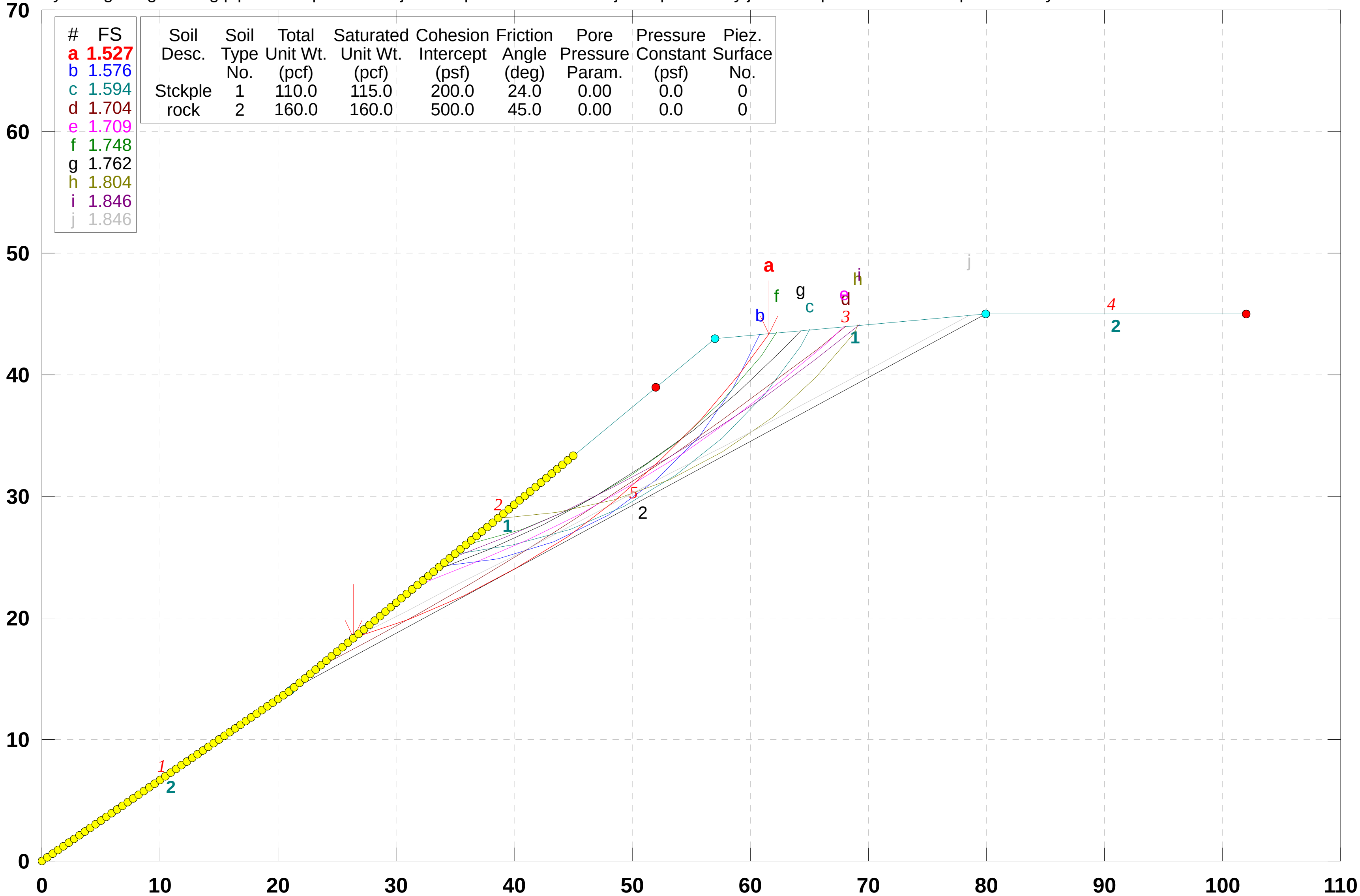
| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Stckple | 1 | 110.0 | 115.0 | 200.0 | 24.0 | 0.00 | 0.0 | 0 |
| rock | 2 | 160.0 | 160.0 | 500.0 | 45.0 | 0.00 | 0.0 | 0 |




GSTABL7 v.2 FSmin=1.795
Safety Factors Are Calculated By The Modified Bishop Method

# Spoil Stockpile Cross Section - Narrow Ridge

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf2 stockpile cross section.pl2   Run By: Username   12/20/2016   11:22AM



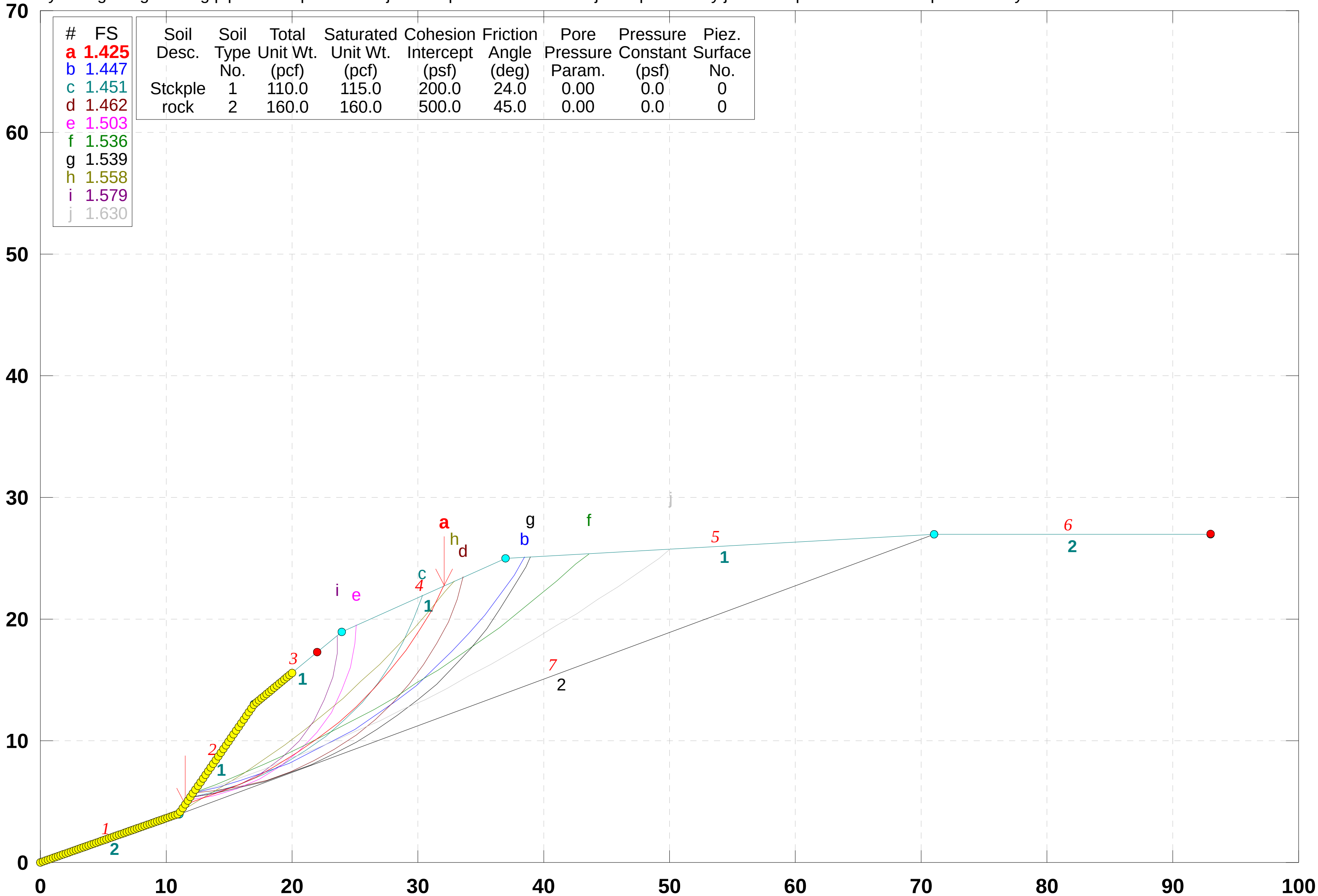

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|---|
| Stckple | 1 | 110.0 | 115.0 | 200.0 | 24.0 | 0.00 | 0.0 | 0 |
| rock | 2 | 160.0 | 160.0 | 500.0 | 45.0 | 0.00 | 0.0 | 0 |

**GSTABL7 v.2  FSmin=1.527**

**Safety Factors Are Calculated By The Modified Bishop Method**

# Spoil Stockpile Cross Section - Sidehill

y:\design engineering\pipeline\mvp\landslide\jnf site specific stabilization\jnf slope stability\jnf3 stockpile cross section.pl2 Run By: Username 12/20/2016 11:23AM




GSTABL7 v.2 FSmin=1.425

Safety Factors Are Calculated By The Modified Bishop Method

# The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)

# EXHIBIT 26

**February 21, 2023**

June 20, 2017

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission

Washington, DC 20426

Re: Docket CP16-10-000
Mountain Valley Pipeline
Hazards and visual impacts of proposed Mountain Valley Pipeline crossing of Appalachian National Scenic Trail (ANST) on Peters Mountain

Dear Ms. Bose,

Thank you for the opportunity to comment again on this project.

Mountain Valley Pipeline proposes to cross the Appalachian National Scenic Trail (ANST) on the crest of Peters Mountain on or near the boundary between Monroe County, West Virginia and Giles County, Virginia. On behalf of the Roanoke Appalachian Trail Club (RATC), one of the 31 maintaining clubs that build, maintain and protect the ANST and its interests, I am writing to provide the Commission with information regarding the likely hazards and visual impacts of the proposed crossing.

Applicants and agencies are required to use the best available scientific information about the route being proposed and its potential impacts. I am attaching two presentations that I shared with the applicant and federal agencies at a meeting in Salem, Virginia on June 15, 2017. The narrative in this letter describes the contents.

Presentation #1 – "Columbia/Celanese 12" Pipeline: Peters Mountain, Va/W Va, 2017 ($4^{th}$ year)
The ten slides were shown at the end of a discussion regarding potential visual impacts of the pipeline from the ANST. The applicant stated confidence in being able to reduce visual impacts from the 125-foot construction zone to a 50-foot impact zone within a few years after construction. The 12" Columbia/Celanese pipeline illustrated is in its $4^{th}$ year of operation. The route and construction were collaboratively agreed upon with the US Forest Service and the Appalachian Trail Conservancy, and applicant agreed to use Best Management Practices for construction. Yet 2017 Google Earth photos show a very poor result.

Figure 1 Celanese/Columbia pipeline right of way in fourth year (Google Earth 2017)

The presentation slides include a map of the pipeline route, photos taken during construction, a photo approximately one year after construction and a series of Google Earth 2017 screenshots of the current appearance of the pipeline right of way (ROW) such as the one on the left.

It is apparent that the ROW is as wide as it was at the time of construction and that there are large areas of disturbance outside the ROW that may be associated with construction. <u>The pipeline can be found on Google Earth: 37.367491° -80.772918°</u>

<u>We would assert that despite close collaboration with the USFS and a commitment to follow BMPs, this project has created a major scar on the same mountain where Mountain Valley Pipeline proposes to build a 42" pipeline that would probably have a significantly larger footprint.</u>

<u>In addition, on the West Virginia side of Peters Mountain, construction of this pipeline contaminated the Red Sulphur Public Service District's primary water source.</u> The details of this pollution event including maps, photos, and abatement reports are contained in the comment re pipeline/sinkhole pollution of Red Sulphur Public Water District drinking water. (Accession #20151127-5151). According to a May 5, 2017 filing by the Indian Creek Watershed Association, the applicant still has not responded to concerns about impacts of Mountain Valley Pipeline on ground and surface water in this area (Accession #20170505-5117(32147159)).

<u>Presentation #2 – "High Hazard Areas: Mountain Valley Pipeline and Appalachian National Scenic Trail, June 2017</u>. The 38 slides in this presentations focused on the applicant's study titled "Site-Specific Design of Stabilization Measures in Selected High-Hazard Portions of the Route Of the Proposed Mountain Valley Pipeline Project in the Jefferson National Forest" (Accession # 20161222-5442(31856030)). Using the best available scientific information, we would assert that:

- Due to cumulative and interactive risk factors, the proposed Peters Mountain crossing is too hazardous for safe construction and operation of a very large natural gas pipeline with a very large impact area.
- Due to the magnitude of potential impacts, there is no logical basis for mitigation of impacts.
- Little or no concern has been demonstrated for the safety of the thousands of people who hike this section of the ANST each year.

The slides tell the story:

(Slides 2-3) RATC is a trail-maintaining club founded in 1932 with bylaws that require it to "use all legal means to protect and defend the Appalachian Trail and its related interests."

(Slide 4) RATC played an important role in the 2002 Record of Decision by the US Forest Service rejecting an AEP request to cross Peters Mountain with a 765 kV transmission line. The ROD stated that the line "would cross the National Forest in areas where there are few existing linear disturbances. The construction of a transmission line and its associated access roads would substantially reduce the value of these areas for the remote recreation setting they afford…" RATC was repeatedly referenced in the decision. Instead the transmission line was constructed near Interstate 77, not adjacent to a Wilderness area.

(Slides 5 to 9) We believe that the applicant understands that the proposed pipeline poses very high consequence risks if it should leak or rupture. We would cite some of our specific concerns based on real events, most of them quite recent:

- The proposed pipeline would have a blast zone (incineration) of approximately 1,000 feet on each side and an evacuation zone (risk of serious injury) of at least 3,600 feet on each side. A recent filing on behalf of Roanoke and Giles counties (Accession #20170602-5147(32197198)) includes a study by Paul Rubin concluding a safe evacuation distance from such a pipeline would be a minimum of 7,544 feet on each side. ANST hikers and campers would be fully exposed to these risks, with no easy escape route – and they would be on foot.
- Drought conditions such as those that prevailed in 2016 on the southern ANST would magnify even pipeline leakages if there were forest fires. In 2016, much of the ANST between Georgia and the Virginia border was closed due to forest fires as well as a portion of the trail in Shenandoah National Park. It took 4 days for the National Park Service to put out a 1-acre fire below McAfee Knob on the RATC section due to steep terrain and difficult access. A small fire that had been smoldering in Smoky Mountains National Park erupted into a firestorm that quickly swept through Gatlinburg, Tennessee. It caused 14 deaths, damaged or destroyed 1,684 structures and required the evacuation of about 14,000 people.
- A rupture could cause a huge forest fire that would threaten many communities; a leak along the pipeline in an area of forest fire would be a significant additional risk.
- Extreme rain events have been common in the region where Mountain Valley Pipeline proposes this project.
  - The City of Roanoke had four 25-year floods in just over a year.
  - Greenbrier County, West Virginia (on the proposed route) received 10 inches of rain in 12 hours in June 2013 – considered to be a1,000-yr flood
  - Virginia suffered 3 hurricanes in a row in September 2004, causing 50 to 100-year floods, depending on location
  - Roanoke endured the largest flood in its history in November 1985
- Climate scientists agree that <u>more severe droughts and more severe rainfall events are likely as the atmosphere heats up.</u> Infrastructure projects should therefore be examined with much more carefully before approval.

(Slides 8 and 9) High profile failures such as that of the 20" Columbia Gas pipeline near Sissonville, West Virginia in 2012 illustrate the long-term risks to the ANST and local communities. The rupture melted part of I 77. And pipelines built since 2010 have disturbingly high failure rates, much worse than at any time since before World War II.

(Slides 10 to 11) RATC considers the High-Hazard study done by MVP to be a very important document, but its filing was so untimely and obscure that even the FERC did not seem to be aware of it.

- On January 26, 2017, FERC inquired about the FS request for data to show the effectiveness of its proposed measures in high hazard areas.
- Applicant responded that they filed it on December 22, 2016. (Accession # 20170217-5199)
- The December 22, 2016 filing was made after 4 pm on the final day of the comment period, after everyone had already filed their comments. It was one of 28 separate documents totaling perhaps 1,000 pages and had an innocuous title ("Attach C_JNF Priority Sites") that did not mention High Hazards.
- Existence of this document was not known to RATC, ATC, NPS staff and landowners we talked with until May 2017.

(Slides 12 to 18) Applicant references "Mitigation of Land Movement in Steep and Rugged Terrain for Pipeline Projects" by the Interstate Natural Gas Association of America (INGAA) published in May 2016 as basis for proposed construction in High Hazard areas of JNF.

- The reference document states that it applies to <u>low plateau</u> of West Virginia, not to the high plateau where this project is proposed. Applicant stated in June 15, 2017 meeting in Salem, Virginia that "steep slopes are steep slopes," and it does not matter whether they are in low plateau or high plateau.
- The reference document and the applicant's own study show a map of high landslide potential construction areas in West Virginia. RATC noted that two reputable studies demonstrate that the applicant could reach the Transco pipeline through a more northerly route that avoids these major hazards.[1]
- The reference document does not discuss seismic activity (proposed crossing is almost in epicenter of active Giles County Seismic Zone) or karst (Peters Mountain and plain below it on West Virginia side contain abundant karst, as do areas around Sinking Creek and Brush Mountain).

(Slides 19 to 28) Peters Mountain/Mystery (4 High Hazard areas)

- Two of the six High Hazard areas in JNF are immediately adjacent to the ANST – within 300 to 400 feet on each side.
- If the applicant needed to use a Contingency Plan such as microtunneling, the platform for boring and assembly would be located within the High Hazard area. In the June 15, 2017 meeting, applicant indicated that they did not consider this to be a concern.

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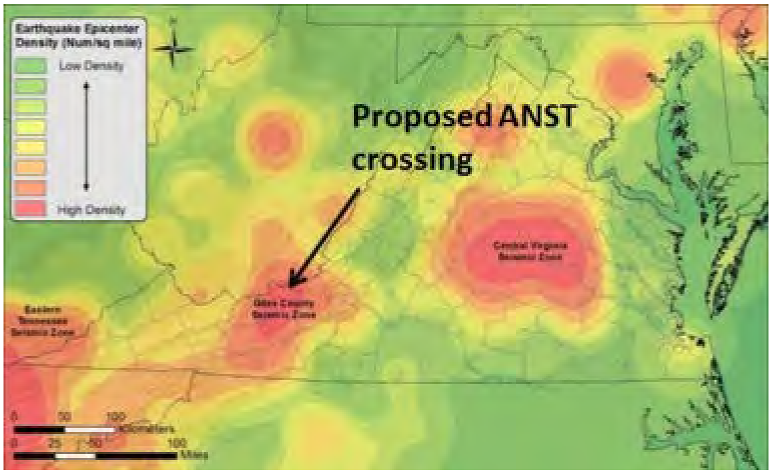
[1] https://www.dropbox.com/s/zw1u0on00840hmx/Are%20Pipelines%20Needed%20Synapse_9-12-16.pdf?dl=0 "Are the Atlantic Coast Pipeline and the Mountain Valley Pipeline Necessary? Synapse Energy Economics, September 12, 2016; https://www.dropbox.com/s/h3ie7nrnku01phc/Risks-Associated-With-Natural-Gas-Pipeline-Expansion-in-Appalachia-_April-2016.pdf?dl=0 "Risks Associated with Natural Gas Pipeline Expansion in Appalachian," Institute for Energy Economics and Financial Analysis, April 2016.




- Applicant has stated in response to questions from EPA that "<u>the risk for lower-magnitude earthquakes "affecting land displacement is infinitesimal</u>." (Accession #20170224-5038(31988524)
- Applicant would cross the ANST virtually in the epicenter of the active Giles County Seismic Zone, scene of the largest earthquake in Virginia history.
- On May 12, 2017, a magnitude 2.8 earthquake occurred near Narrows, Virginia, approximately 10 miles from the proposed ROW. On May 13, 2017, a landslide occurred approximately 6.2 miles from the earthquake. It is quite possible that the earthquake caused the landslide. (Accession # 20170619-5063(32222851)).
- In addition, applicant has co-located a permanent access road on the ANST itself due to use of an incorrect map of the ANST. RATC has already filed comments regarding this problem in December 2016.

(Slides 29-33) Both Peters Mountain and the Sinking Creek Mountain/Brush Mountain portion of JNF include or are bounded by land with a large amount of karst.

- The word "karst" does not appear in the applicant's "Site-Specific Design of Stabilization Measures in Selected High-Hazard Portions of the Route of the Proposed Mountain Valley Pipeline Project in the Jefferson National Forest" nor in the study that it referenced for Best Management Practices.
- The Sinking Creek Valley, including the pipeline ROW, has numerous karst features as does the Mt. Tabor area near Brush Mountain. Numerous FERC filings have addressed these issues.
- At Peters Mountain, karst issues have been thoroughly addressed and filed to FERC in "Hydrological Assessment of Karst Area Impacts Caused by Construction of the Mountain Valley Gas Pipeline Across Peters Mountain, Monroe County, West Virginia," Pam Dodds for Indian Creek Watershed Association, December 2016.
- A major concern would be <u>sinkhole collapse causing a pipeline rupture</u>. In fact, such a collapse occurred in Adair County, Kentucky on February 13, 2014. The 30" natural gas pipeline under 996 psig expelled 80 feet of carbon steel pipe in large pieces up to 380 feet and left a crater 105 feet long, 44 feet wide, and 25 feet deep.[2]

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[2] FERC filing of lawyer for Giles and Roanoke counties, June 2, 2017 ( Accession #20170602-5147(32197198))

- RATC asks that ROW on both sides of both Sinking Creek Mountain and Brush Mountain be examined as High Hazard areas, given the large amount of karst present and the fact that Sinking Creek Mountain is the scene of the largest known large block landslide in North American history.[3]


Figure 1-1: Landslide incidence and susceptibility across the US (Radbruch-Hall, et al., 1982, USGS Professional Paper 1183)

(Slide 34) As has been stated many times in FERC filings, the concern is not for any one factor that might be addressed by the combination of factors that could contribute to a very hazardous and costly situation whose main costs would be borne by local citizens and governments, not by the applicant, if there were a serious failure of any kind. These include

- The size of the proposed pipeline, the explosive nature of its contents under more than 1,400 psig, and the magnitude of the disaster if it failed.
- The long active life span and the permanent presence of the pipeline on the ANST and close to it for many miles.
- Deforestation and its impact on slope stability as well as erosion and sediment and visual impacts as seen with the 12” Celanese/Columbia pipeline on Peters Mountain.
- Very steep, landslide prone slopes in poor soils
- Location of the proposed ANT crossing in the epicenter of the Giles County Seismic Zone that experienced an earthquake and perhaps a related landslide as recently as May 2017.
- Extensive presence of karst, which is not even mentioned in the High Hazard report nor in the reference document supplied by the applicant. Sinkhole collapse alone could cause a pipeline rupture.

Each of these hazards is significant in its own right. When combined with each other and with the impacts of either sustained draught or major rainfall events, the plan to work in such challenging, landslide-prone terrain seems very questionable.

Thank you again for the opportunity to comment. I hope that FERC will seriously consider the impacts of the proposed project.

Sincerely,

Dr. Diana Christopulos
President
Roanoke Appalachian Trail Club

[3] https://pubs.usgs.gov/gip/mountain/mountain.pd

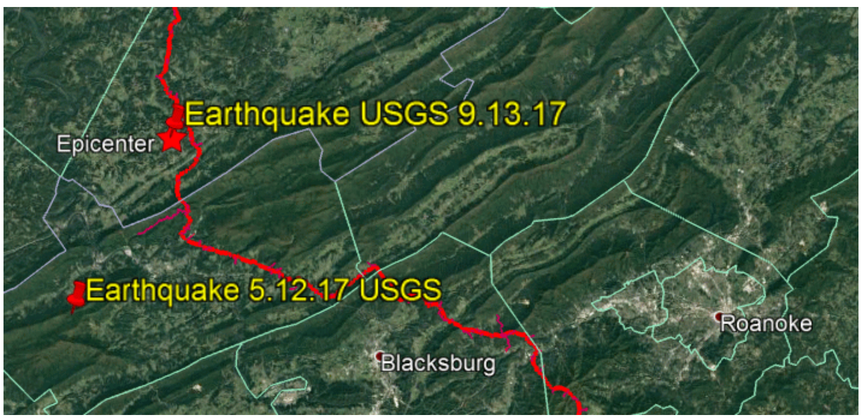
# The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)

# EXHIBIT 27

**February 21, 2023**

# Earthquakes and pipelines: recipe for disaster

DIANA CHRISTOPULOS - POSTED ON SEPTEMBER 18, 2017 - POSTED IN APPALACHIAN TRAIL, MOUNTAIN VALLEY PIPELINE - TAGGED WITH MOUNTAIN VALLEY PIPELINE, NATURAL GAS PIPELINES




*Red line = proposed route of Mountain Valley Pipeline*

**On September 13, 2017, Monroe County, West Virginia experienced the largest earthquake in decades, with the epicenter 1.5 mile from the proposed Mountain Valley Pipeline route.**

The Roanoke Times reported that more than 200 calls came into the Giles County Sheriff's Office dispatch in the half hour after the quake. Within a day, over 500 citizens notified the USGS that they had felt the earthquake.

The Virginia Tech Seismological Observatory rated it a magnitude 3.7 earthquake, while the US Geological Survey pegged it at 3.2 (they use slightly different measurement strategies).

Wednesday's earthquake is the second one that was felt within 4 months in the GCSZ, with another on May 12, 2017 near Narrows, Virginia (magnitude 2.8).

***WHY PIPELINES AND EARTHQUAKES DON'T MIX***

Well, these weren't huge earthquakes, so what's the problem? Very simply, Mountain Valley Pipeline has chosen to place a very large (42"), explosive pipeline under enormous pressure (1,440 pounds of pressure per square inch) on a very dangerous route. Threats to communities near and downstream from the pipeline include:

- Increased **leakage of hazardous materials** such as methane, particulate matter, volatile organic compounds, and radon from the pipeline into drinking water wells and public water supplies.
- Increased risk of pipeline failure, producing **catastrophic damage** within as much as 7,700 feet on each side of the pipeline. WANT TO SEE WHAT A MUCH SMALLER 20 ″ PIPELINE LOOKED LIKE WHEN IT EXPLODED AND MELTED PART OF INTERSTATE 77? THIS IS THE SISSONVILLE, WV PIPELINE IN DECEMBER 2012.
- Increased risk of major **wildfires** due to potential explosions on a route that is very heavily forested.


**WORST POSSIBLE LOCATION: PROPOSED CROSSING OF APPALACHIAN TRAIL**

If you were going to combine all possible risk factors for the Mountain Valley Pipeline in one location, the proposed crossing of the Appalachian Trail could be that spot. **The September 13, 2017 earthquake was only 5-6 miles from the proposed crossing of the AT** on top of Peters Mountain, immediately next to the Peters Mountain Wilderness on the Virginia/West Virginia border.

The US Forest Service identified numerous High Hazard Areas in Jefferson National Forest associated with construction of Mountain Valley Pipeline. Two of the High Hazard areas are immediately adjacent to the Appalachian Trail (300 feet away on each side) on both sides of Peters Mountain (see visual above).

Risk factors include:

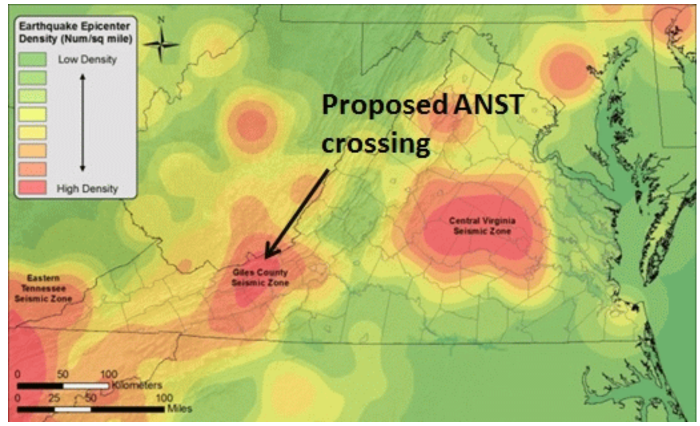
- Location in the middle of the very active Giles County Seismic Zone.
- Location between what the US Forest Service has identified as two High Hazard zones that combine very steep slopes, with landslide prone soils, and high exposure to seismic action.
- All of the dangers are increased if the soil is wet.
- The bottom of the slope on the West Virginia side is full of karst, as noted by Dr. Kastning, so that a failure would impact a wide area.

**At a live meeting in Salem, Virginia on June 15, 2017, I asked an MVP construction supervisor to cite one example of a pipeline this size that was successfully constructed in an environment of steep slopes, landslide prone soils, karst and an active earthquake zone. His answer was: "*FLORIDA*." Obviously, Florida has karst. But none of the other hazards are present.**

Mountain Valley Pipeline seems largely unaware of or unconcerned about the risks. ***They seem to believe that stating there is no problem in fact means there is no problem***. Since the company itself is not being required to post any bond nor pay the cost of any damage that is done to the surrounding area, it is not surprising. All of the costs would be borne by those who are most directly impacted and who have the least resources to spare.

### *WHY MOUNTAIN VALLEY PIPELINE IS ESPECIALLY RISKY*

Unlike the 20" pipelines currently supplying the much of the East, Mountain Valley would not follow existing utility and transportation routes through relatively flatter ground. Instead, it would combine the following risks:




- It would run right through the middle of the **Giles County Seismic Zone** (GCSZ), site of the huge 5.8 magnitude earthquake in 1897 that was felt in 12 states, including Ohio, Georgia and Indiana. It actually cracked the rocks on "Angel's Rest" above Pearisburg (now on the Appalachian Trail). The shocks of earthquakes are often amplified on ridges when they cross under mountains.
- **STEEP SLOPES**. In the area of the recent earthquake, average maximum vertical slopes of the proposed pipeline route are 40 to 60%, creating a high risk of slippage or failure.
- **POOR SOILS.** The slopes often have landslide-prone soils, exposing the pipe to greater failure risks, especially when it rains.
- **KARST**. In valleys, the route is often in karst, limestone/dolomite formations filled with unseen sinkholes, creeks and rivers. Large pipelines that fail in karst can create a 3-mile-wide disaster zone.
- **HEAVY RAINFALL.** Mountain Valley Pipeline admits that wet slopes have a very significantly increased risk of slippage. Extreme rain events have been common in the region where Mountain Valley Pipeline proposes this project, and climate change will mean stronger events in the future:
  - Greenbrier County, West Virginia (on the proposed route) received **10 inches of rain in 12 hours in June 2013** – considered to be a 1,000-yr flood
  - Virginia suffered **3 hurricanes in a row in September 2004**, causing 50 to 100-year floods, depending on location
  - Roanoke endured the **largest flood** in its history in **November 1985**
  - The City of Roanoke had **four 25-year floods in just over a year**.

Yet Mountain Valley Pipeline has proposed to use a 2" rainfall as the standard for heavy precipitation.

Each of these risks is significant by itself, but they also amplify each other. An earthquake shakes steep, landslide-prone soils – encouraging leakage, slippage and failure. In his widely lauded summary of the geologic risks associated with Mountain Valley Pipeline, karst expert Dr. Ernst Kastning repeatedly noted that the earthquake activity (**seismicity**) of the region was most dangerous because it was **combined** with other very serious risk factors. Writing specifically about Monroe County, West Virginia where the September 13, 2017 earthquake occurred (p.32), Dr. Kastning observed that:

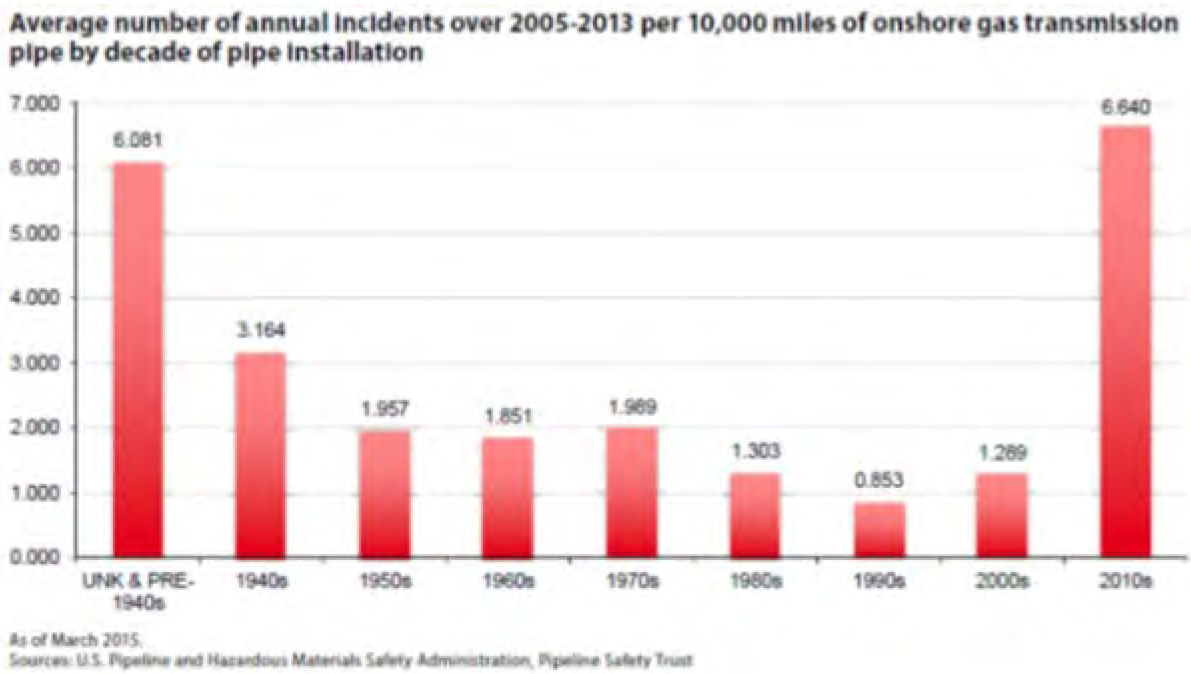
> ***The preferred route of MVP passes through the center of the Giles County Seismic Zone . . . Should a potential magnitude 4 to 6 earthquake occur once the pipeline is operational, there may well be a triggering of landslides on unstable or metastable slopes that could potentially disrupt the pipeline and cause significant collateral damage. Perhaps the pipeline itself may be directly broken by ground motion during an earthquake. It is clear that steep mountain slopes in the area of Monroe, Giles, Montgomery, Craig, and Roanoke counties are subject to mass movement including large landslides. Seismicity and severe runoff from storms have triggered these events in the past and can easily do so in the future. Earthquakes do not necessarily have to be large to do damage to the pipeline. Small events can easily trigger mass movement on metastable slopes. The Mountain Valley Pipeline would be most subject to these hazards in the many areas having steep slopes.***

In karst, found in the valleys along much of the proposed route, an earthquake can encourage sinkhole-induced pipeline failure. A sinkhole failure occurred in Adair County, Kentucky on February 13, 2014, tossing 80 feet of carbon steel pipe in large pieces up to 380 feet away even though it had been buried 4.7 to 8.5 feet deep. The rupture created a crater approximately 105 feet long, 44 feet wide, and 25 feet deep.

Desktop calculations based on experience with smaller pipelines suggests that Mountain Valley Pipeline would have a blast zone (incineration) of approximately 1,100 feet on each side and an evacuation zone (risk of serious injury) of at least 3,600 feet on each side. A filing to the Federal Energy Regulatory Commission on behalf of Roanoke and Giles counties includes a study by Paul Rubin concluding **a safe evacuation distance from such a pipeline in karst would be a minimum of 7,544 feet on each side**.

### *WHY ARE NEW NATURAL GAS PIPELINES SO UNSAFE?*

**Pipelines built since 2010 have a much higher failure rate than at any time since before World War II.** Experts suggest that this poor performance is due to hasty construction in unsatisfactory terrain, a description that fits Mountain Valley Pipeline.




The graph above goes through 2015. The data have not improved since then. According to data collected by the US DOT Pipeline and Hazardous Material Safety Administration (PHMSA) for gas pipelines:

- From 1997 to 2016, there were 11,462 significant incidents costing $7,058,024,527.13 These incidents killed 324 people and injured another 1,331.
- In just the first five months of 2017, there were 201 incidents costing $44,031,235. The damage caused by each incident is significantly higher than in the past.

### *MOUNTAIN VALLEY PIPELINE WOULD USE INADQUATE SAFETY PRACTICES*

At a live meeting in Salem, Virginia on June 15, 2017, I asked an MVP construction supervisor to cite one example of a pipeline this size that was successfully constructed in an environment of steep slopes, landslide prone soils, karst and an active earthquake zone. His answer was: "***Florida***." Obviously, Florida has karst. But none of the other hazards are present.

**Mountain Valley Pipeline is using construction practices that were not designed to withstand seismic zones, karst or long, steep slopes in this region.** They reference a document called "Mitigation of Land Movement in Steep and Rugged Terrain for Pipeline Projects" by the Interstate Natural Gas Association of America (INGAA) published in May 2016 as the basis for construction of the project. However:

- This document is designed for the low plateau of West Virginia, not to the high plateau where this project is proposed.
- It does not even contain the word "seismic" in it, so it is clearly not addressing earthquake zones.
- Nor does it contain the word "karst," even though the lowlands of the project are full of karst.

Let's conclude with a few more comments from Prof. Kastning's work, "An Expert Report on Geologic Hazards in the Karst Regions of Virginia; Investigations and Analysis Concerning the Proposed Mountain Valley Gas Pipeline"

> *With or without a significant seismic event, **slope failure is in itself a significant continuing concern**. In commenting to FERC on March 30, 2015, Dr. Robert Tracy (Professor of Geosciences at Virginia Tech) states: "Even holding constant the seismic hazards, along the MVP route most subject to seismic activity, **there is a very high probably of differential slope failure**, with slide masses moving at differential rates with abrupt boundaries (effectively soil faults) separating masses."*

***Even though a very-high-magnitude earthquake (Richter magnitude 5.0 or greater) has not occurred in the GCSZ since 1897, the more time that elapses, the more likely it is that such event may occur.***

> *. . . **continuing seismic activity in the GCSZ (a high frequency of magnitude 2.5 or larger earthquakes), produces a major risk when compounded with the already co-existing problems of karst, slope, and soil hazards** at sensitive locations along the proposed pipeline route. This poses severe engineering challenges in constructing the pipeline, and **calls into***

***question whether the pipeline should be built at all.***

*Compounding of hazards along the preferred route alone suggests that* ***avoidance of the region altogether is in the best interest of MVP and FERC, and certainly to the overwhelming majority of residents of Giles and adjacent counties.***

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SHARE THIS:

‹ Hands Across the AT Celebration, Saturday, August 19 in Pearisburg
Graceful farewell from Duncan Adams, Roanoke Times reporter ›

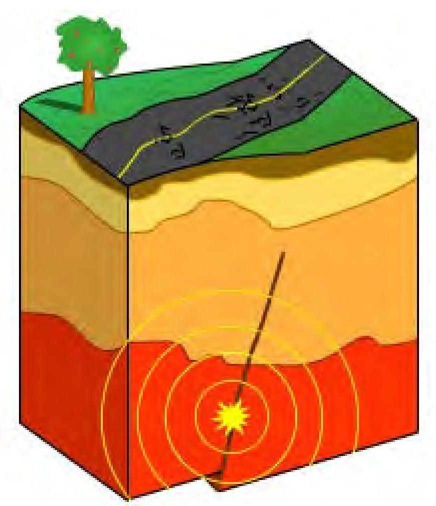
**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 28

**February 21, 2023**

# What is an Earthquake ?

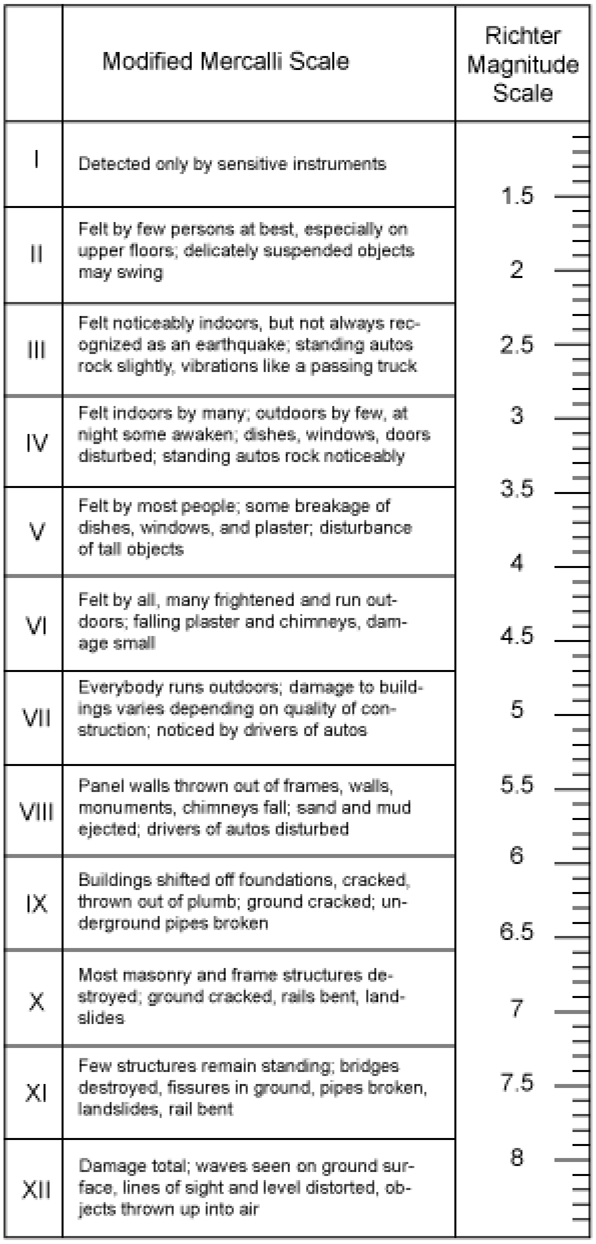
An earthquake is the sudden release of accumulated stress within the Earth's crust that causes the ground to shake. When stress that has accumulated over time eventually exceeds the rock's strength, rupture occurs, generally along a plane of weakness called a fault. As the fault ruptures, built-up energy is released, producing undulating forces in the rock known as seismic waves. Some faults displace the ground surface, while others remain concealed underground.



*Earthquakes in Virginia commonly occur on blind faults that do not reach earth's surface.*

Earthquakes vary greatly in strength. Most are small and imperceptible, and can occur almost anywhere around the world. Larger magnitude earthquakes occur less frequently but can affect thousands of square miles with disastrous results such as collapsed structures, landslides, compromised water supplies, and widespread fires from ruptured gas and electrical lines, not to mention devastated infrastructure and near-complete disruption of the local economy. Losses can run into the tens of billions of dollars.

The severity of an earthquake can be measured by either *magnitude* or *intensity*. *Magnitude* is the amount of energy that is released by an earthquake. *Intensity* is a subjective measure that describes how an




*Earthquakes are measured by the amount of energy they release (Richter scale) and by the amount of damage they can cause (modified Mercalli scale)*

earthquake affected people and structures at a particular location.

There are a number of different ways that earthquake magnitude came be calculated. Probably the most familiar is the "Richter scale," developed by Charles Richter in 1935. Even though the original calculations developed by Richter to estimate earthquake magnitude have gone out of favor, newer formulae still retain the familiar Richter reporting methodology: a dimensionless number from 0.0 to 10.0. Currently, the moment magnitude scale (MMS) is the primary reporting method used by the U.S. Geological Survey. The MMS is a quantitative, logarithmic measure of energy released and each unit corresponds to a ten-fold increase in wave amplitude. Earthquakes less than 3.5 on this scale are generally not felt at the surface, but can be detected by sensitive instruments called seismometers. Earthquakes from 3.5 up to 5.5 are felt but there is little structural damage; above 6.0, damage increases dramatically.

The perceived intensity of an earthquake is measured using the modified Mercalli scale, which is based on qualitative descriptions, such as the type and extent of property damage, and changes in groundwater and surface water flows. The Richter scale uses Arabic numerals, while Mercalli levels are typically described using Roman numerals, with I corresponding to imperceptible events up to XII for total destruction. The Mercalli scale is a measure of the effects of an earthquake at a particular place and depends not only on the strength (magnitude) of the quake, but also the distance from the epicenter of the quake and the local geology at the observation point. Thus, a given event will have only one magnitude, but many intensity values, which tend to decrease with distance from the epicenter.

Earthquake intensity is considerably greater over soft soils than solid rock. In loose material, the shaking can increase the pressure of shallow groundwater, mobilizing sand and silt deposits, a process known as *liquefaction*. As a result, ground displacement increases by a factor of four or five. As the liquefied earth loses strength, buildings sink or topple over and underground utility lines rupture. Liquefaction is more likely to occur in loose, saturated granular soils with poor drainage, usually Holocene-age (less than 10,000 years old) alluvial deposits found along floodplains, or in other areas where thick, unconsolidated deposits of sand and silt have accumulated. Areas of land reclamation are often prone to liquefaction, which was a major factor in the destruction in San Francisco's Marina District during the 1989 Loma Prieta earthquake.

Other local factors can amplify incoming seismic waves. Mountains and ridges may enhance ground vibrations by a factor of two or three as wavelengths become “tuned” to the distance between ridges. The Coastal Plain near the Fall Line is a wedge of soft sediment forming a feather edge overlying hard basement rock, and such a circumstance focuses the destructiveness of seismic waves. Many of Virginia’s taller buildings are located along the Fall Line.

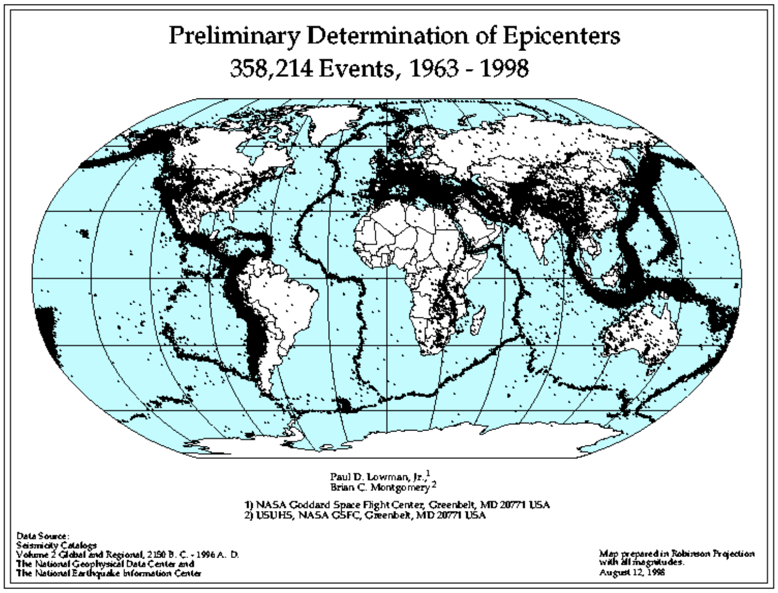
# What Should I do in the Event of an Earthquake?

Most of Virginia's recorded earthquakes have been magnitude 4.5 or less, and the associated damage has been minor (cracks in foundation, tumbling chimneys, etc.). However, due to modern development, if Virginia experienced an earthquake with a magnitude 6.0 or greater, the consequences could be serious. Richmond, Charlottesville, Petersburg, and Lynchburg are situated on the periphery or within the Central Virginia seismic zone. A worst-case scenario would include the collapse of bridges and tall buildings, flash-flooding from breached reservoirs, widespread electrical fires and exploding gas pipelines, and potentially compromised nuclear power plants at North Anna. Damage is compounded as ruptured water lines hinder fire abatement and disrupted transportation systems delay the evacuation of seriously injured persons.

Despite the potential for a damaging earthquake in the future, few engineering studies or emergency response plans have been devised specifically for our region. Studies of features left by prehistoric earthquakes, called paleoseismology, can reveal a great deal about what to expect in the future. Further research into the geologic control of earthquakes in Virginia could greatly lessen the impact of a destructive event by 1) improved predictability and characterization of damages, and 2) delineation of earthquake-susceptible substrates in urban areas such as Richmond, as well as for situating critical emergency response facilities throughout the state. The typical homeowner's insurance policy does not cover damage from earthquakes.

# What earthquakes have occurred in Virginia?

Most earthquakes occur along tectonic plate boundaries where stress is greatest. Unlike the West Coast, the East Coast is situated near the center of a tectonic plate and resides on what geologists call a passive margin. This is not to say that earthquakes don't occur in Virginia, but they are much different than the earthquakes that occur in California. West Coast earthquakes can be very shallow and often break the ground surface, while in Virginia they usually occur at depths of anywhere from three to fifteen miles and it is not always possible to associate a specific earthquake with a specific fault. In general, East Coast earthquakes are less energetic than those on the West Coast, but due to the coherency of the basement rock (think concrete slab vs. brick patio) they are felt much farther away. In Virginia, the affected area can be up to ten times larger than it would have been for a similar magnitude event occurring in the western United States.




*Earthquakes are extremely common along tectonic plate boundaries, but also occur at passive continental margins, such as the eastern United States.*

James R. Martin II, former director of the Earthquake Engineering Center for the Southeastern United States, has said, “Recent seismological studies suggest that the southern Appalachian highlands have the potential for even larger earthquakes than have occurred in the past. But now those events would take place in much more highly populated areas.” He believes that "we are under a significant threat of large, damaging earthquakes." Martin goes on to say that earthquakes don't occur as often in the East as they do along the West Coast because the tectonic strain rates are different and our region "tends to experience large earthquakes isolated by long periods of quiet." There's another difference. "The earth's crust is stronger here," explains Martin Chapman, director of the Virginia Tech Seismological Observatory. "So shock waves moving from the epicenter of an earthquake don't lose as much energy as during quakes in California. When a magnitude 7.0 earthquake occurs in the Southeast, the waves affect a larger area and can cause more damage at a greater distance than when a similar shock hits California.

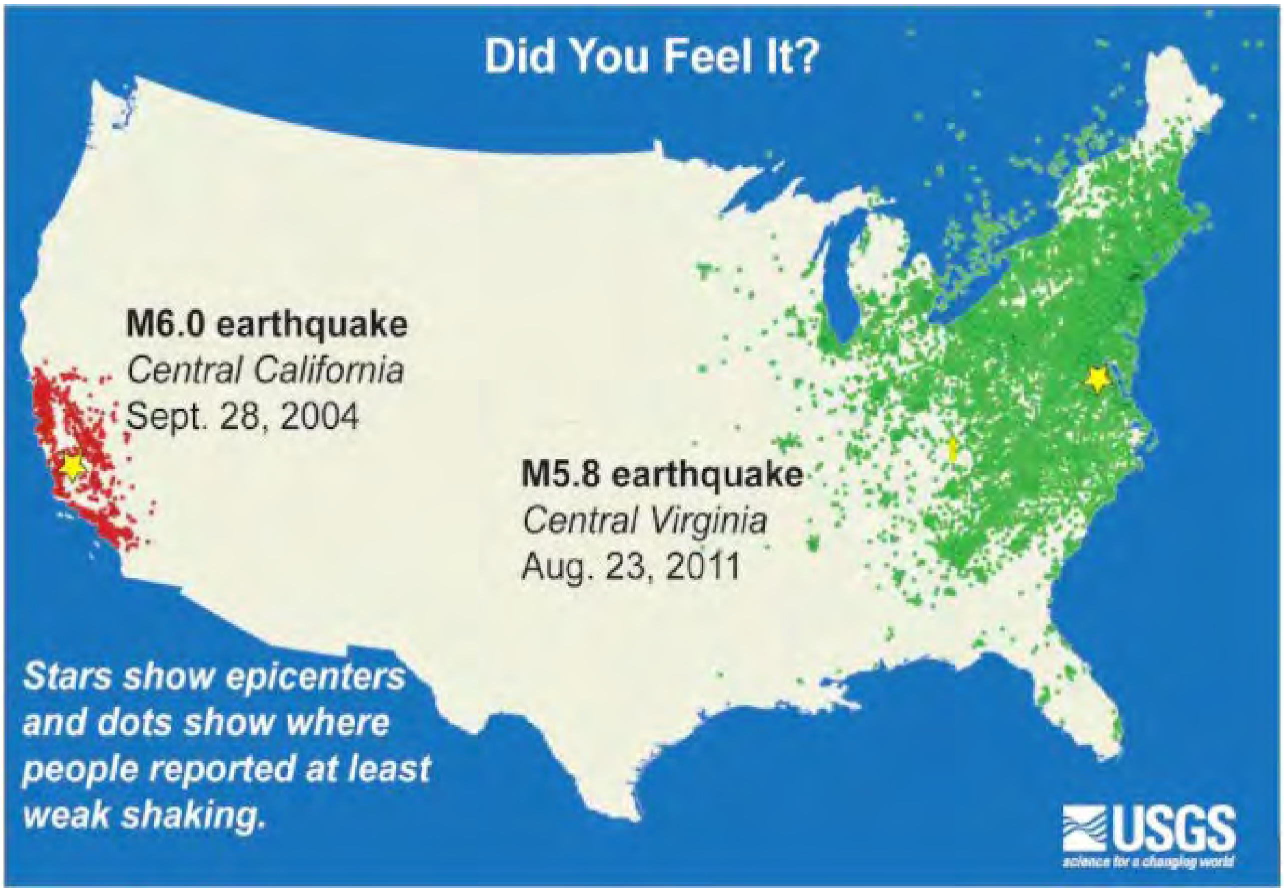
Earthquake activity in Virginia has generally been, with a few exceptions, low-magnitude but persistent. The first documented earthquake in Virginia took place in 1774 near Petersburg, and many others have occurred since then, including an estimated magnitude 5.5 (VII) event in 1897 centered near Pearisburg in Giles County. A Roanoke attorney who was in Pearisburg said that for nearly fifty miles from that place he saw hardly a sound chimney standing. In his opinion, If the buildings throughout Giles had been largely of brick, the damage would have been very great, and serious loss of life would have occurred. The largest recorded earthquake in Virginia occurred in Louisa County on August 23, 2011 and had a magnitude of 5.8 (VII). It was felt all along the eastern seaboard by millions of people, causing light to moderate damage in central Virginia, Washington, D.C. and into southern Maryland. Since 1977, more than 195 quakes have been detected as originating beneath Virginia. Of these, at least twenty-nine were large enough to be felt at the Earth's surface. This averages out to about six earthquakes per year, of which one is felt.

Find out more about major earthquakes that have occurred in Virginia.

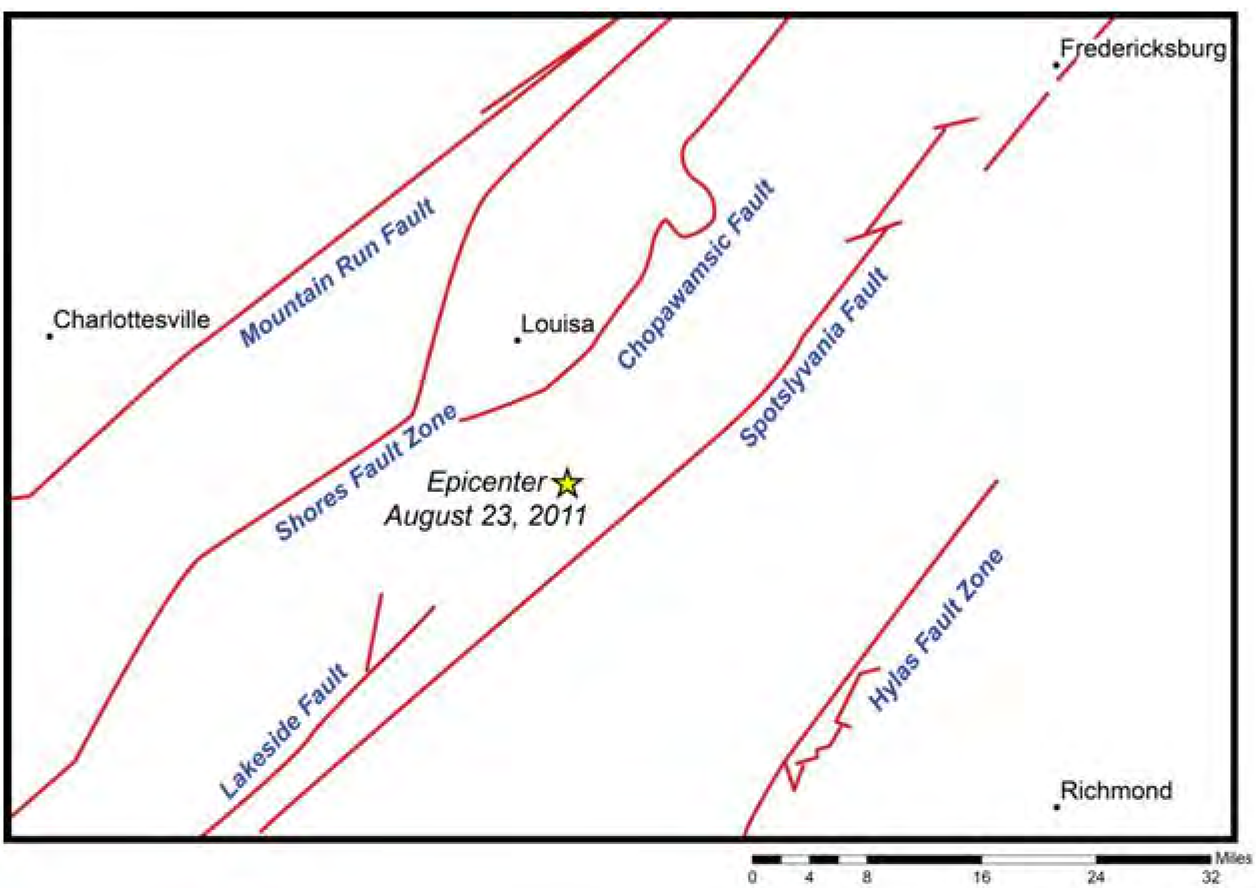
# The August 23, 2011 Magnitude 5.8 Mineral, VA Earthquake

At 1:51 p.m. eastern daylight time on Tuesday, August 23rd 2011, the most damaging earth¬quake ever felt in Virginia was recorded. According to the U.S. Geological Survey, the epicenter of the quake was in central Virginia near the town of Mineral, in Louisa County. Approx¬imately 150,000 individuals reported feeling the earthquake through the U.S. Geological Survey Earthquake Hazard Program, "Did You Feel It?" website . The earthquake was felt over the entire eastern United States and into Canada, potentially making it the earthquake felt by more people than any other in United States history.

Scientists have determined that the Mw 5.8 shock was actually a complex earthquake of three subevents. Faulting initiated approximately four miles underground and progressed upward and to the northeast. The rupture occurred along a previously unknown fault, now named the Quail Fault, but did not break the ground surface. The northeastward progression of rupture may account for the fact that ground motions were much stronger to the northeast, toward the Washington, D.C. area, as compared to shaking experienced in other directions from the epicenter.



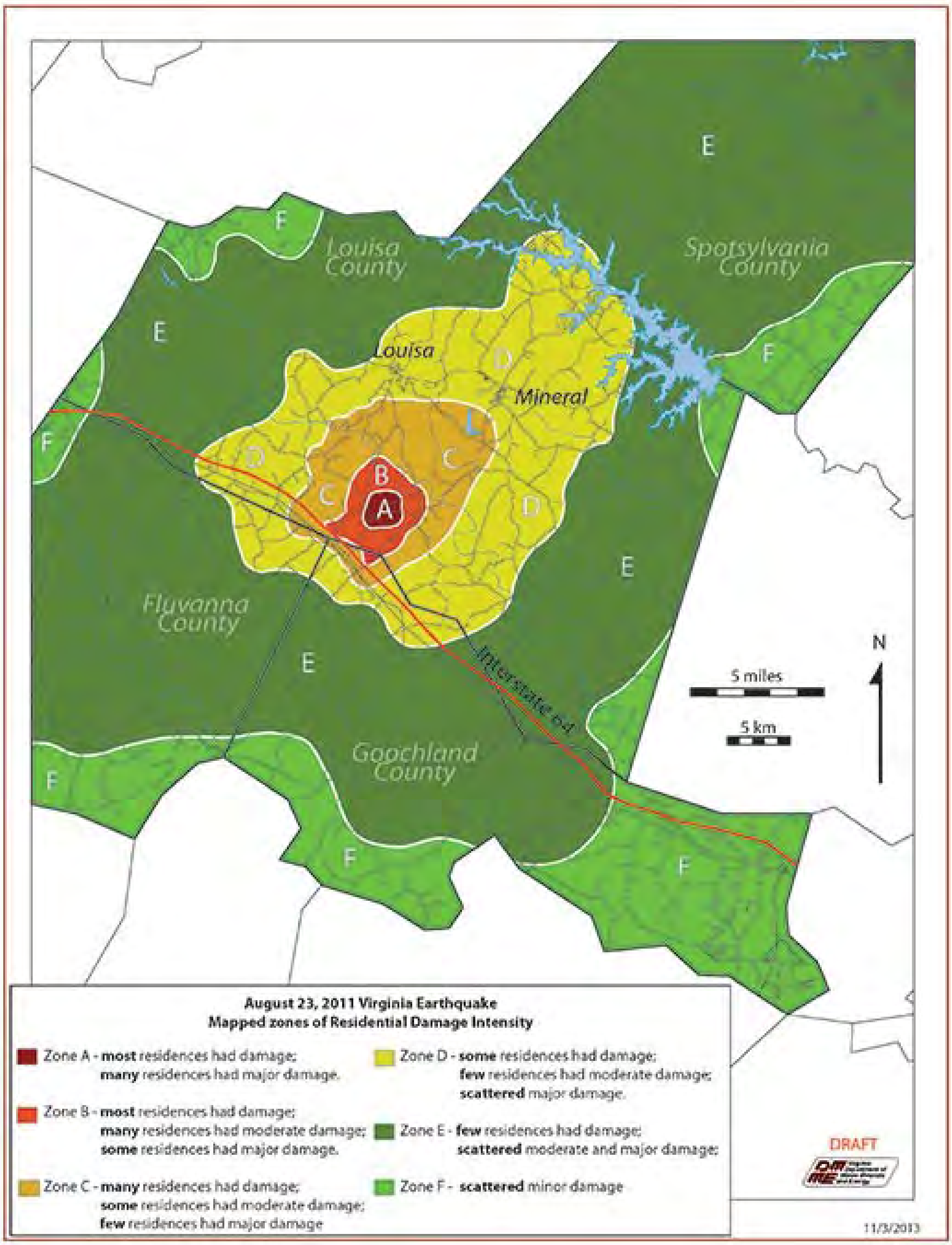

*The U.S. Geological Survey reports that the August 23, 2011 earthquake was the most widely-felt earthquake in U.S. history.*



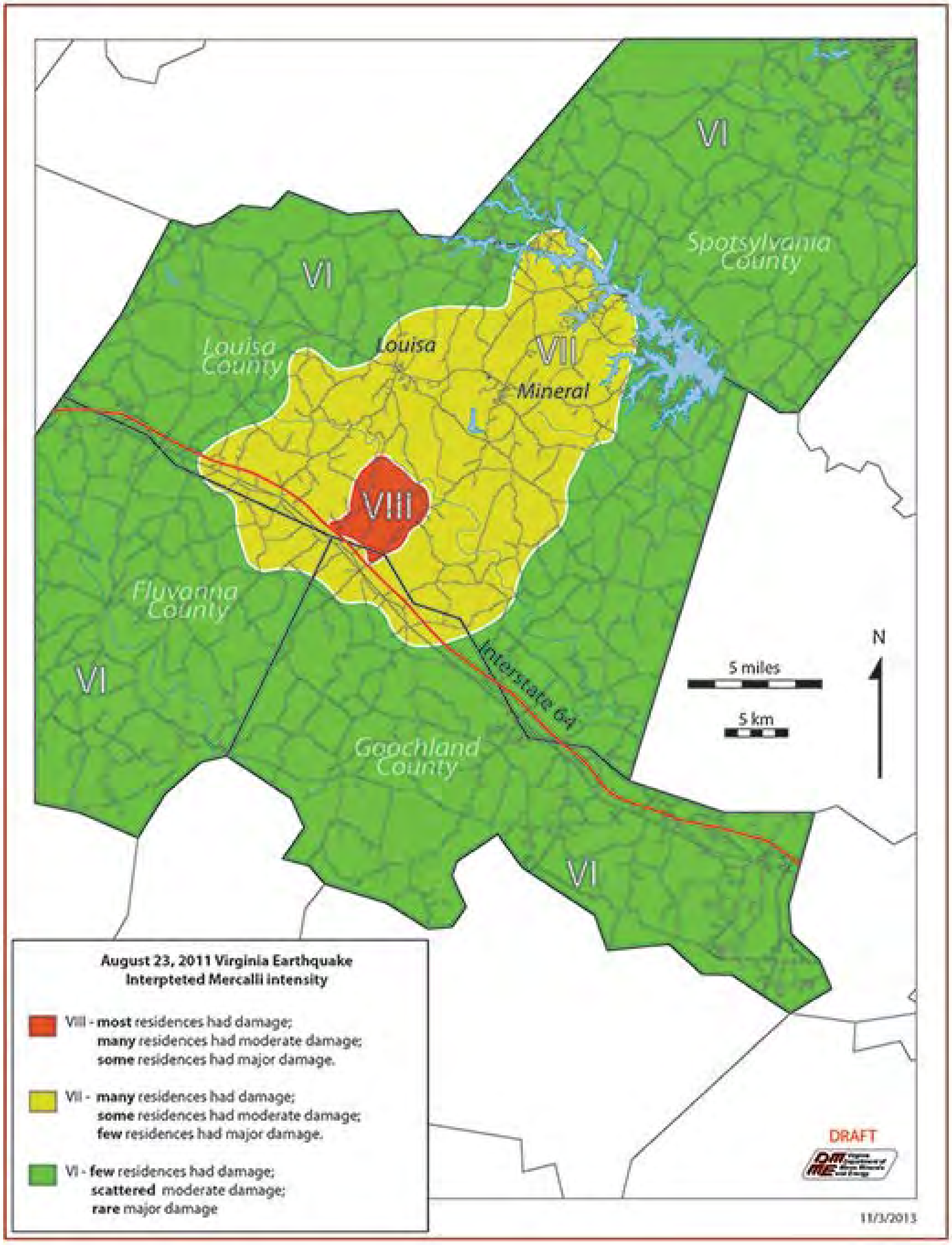

*Location of the epicenter of the August 23, 2011 earthquake and the locations of mapped faults at the Earth's surface.*

*The 2011 earthquake occurred along a fault that has no surface expression.*

Geologists from our Geology and Mineral Resources Program (GMR) and the U.S. Geological Survey gathered immediately following the earthquake to record intensity measurements across the area. From the data collected GMR created damage intensity maps (below). Some homes in the epicentral area were shifted off of their foundations, had chimneys that toppled, and sustained damage to exterior and interior walls and framing. Total damages resulting from the 2011 earthquake reached at least $300 million. Eight counties in Central Virginia were included in the federally-declared disaster area; Louisa County alone received almost 1,500 damage reports from residents. The entire Louisa County school system closed down for weeks following the earthquake, and two schools were considered damaged beyond repair.



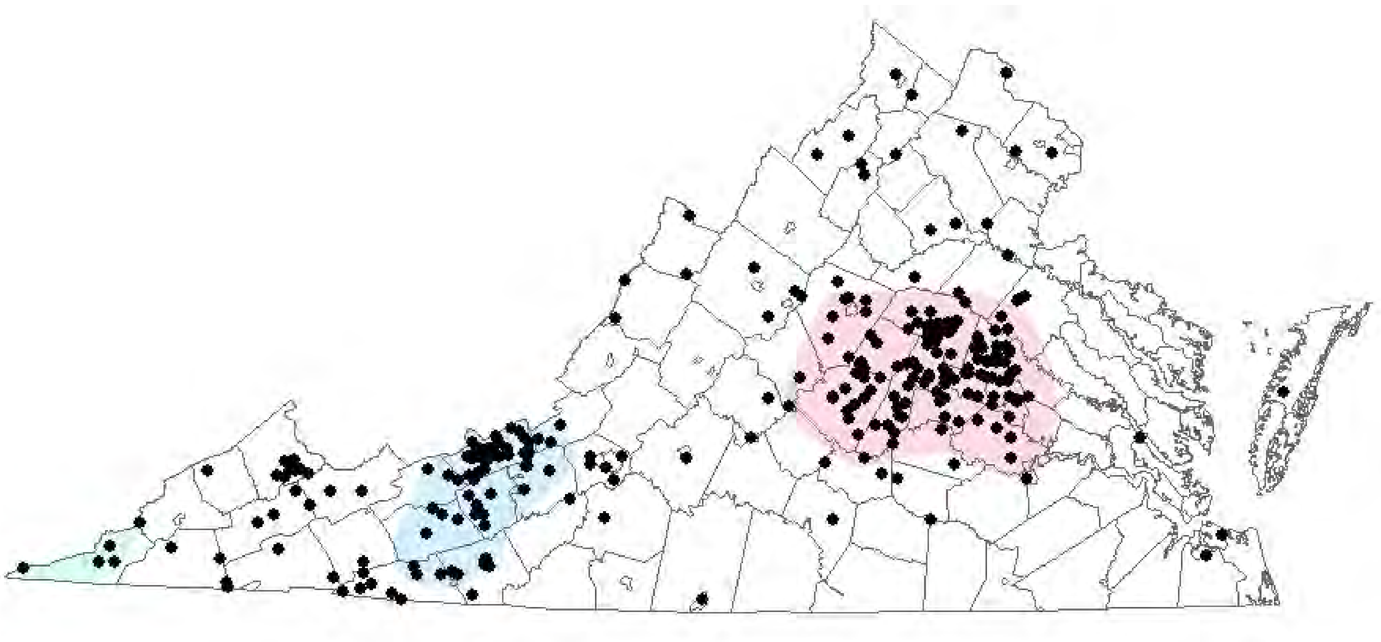

*Damage Zone Intensity map for the 5.8M Earthquake (click on image to view full size line)*




*August 23, 2011 Virginia Earthquake Interpreted Mercalli intensity (click on image to view full size line)*

# Virginia's Seismic Zones

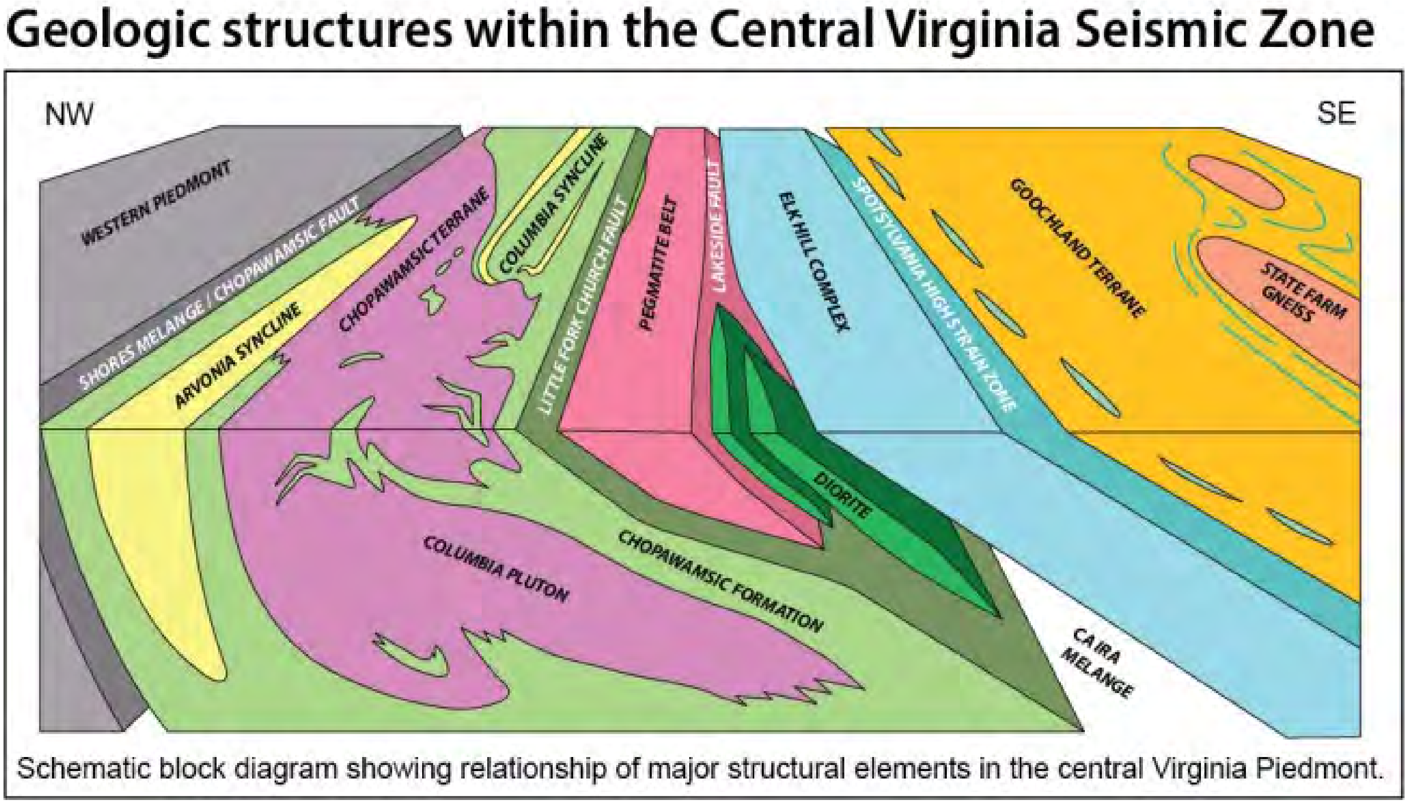
Virginia's past seismic activity is concentrated in three primary areas: the Central Virginia seismic zone (CVSZ), the Giles County seismic zone (GCSZ), and the Eastern Tennessee seismic zone (ETSZ). The CVSZ is located within the central Piedmont along the James River and includes the counties of Fluvanna, Goochland, Cumberland, Powhatan, Louisa, Albemarle, Buckingham, Hanover, and Chesterfield, and the cities of Richmond and Charlottesville. The GCSZ is along the New River Valley in Giles County, and extends to the southwest, and includes parts of Pulaski, Bland, Wythe, Montgomery, Grayson, and Carroll Counties. The ETSZ stretches from northern Alabama and Georgia north through eastern Tennessee and includes a small portion of far southwestern Virginia in Lee County. Although these three seismic zones delineate the greatest concentration of earthquake events that have occurred in Virginia, all parts of the Commonwealth should be considered susceptible to earthquake shaking, as the entire state has experienced seismic activity in the past.



*This map shows the locations of known earthquake epicenters in Virginia.*
*The Eastern Tennessee seismic zone is shown in green, the Giles County seismic zone is shown in blue and the Central Virginia seismic Zone is shown in pink.*

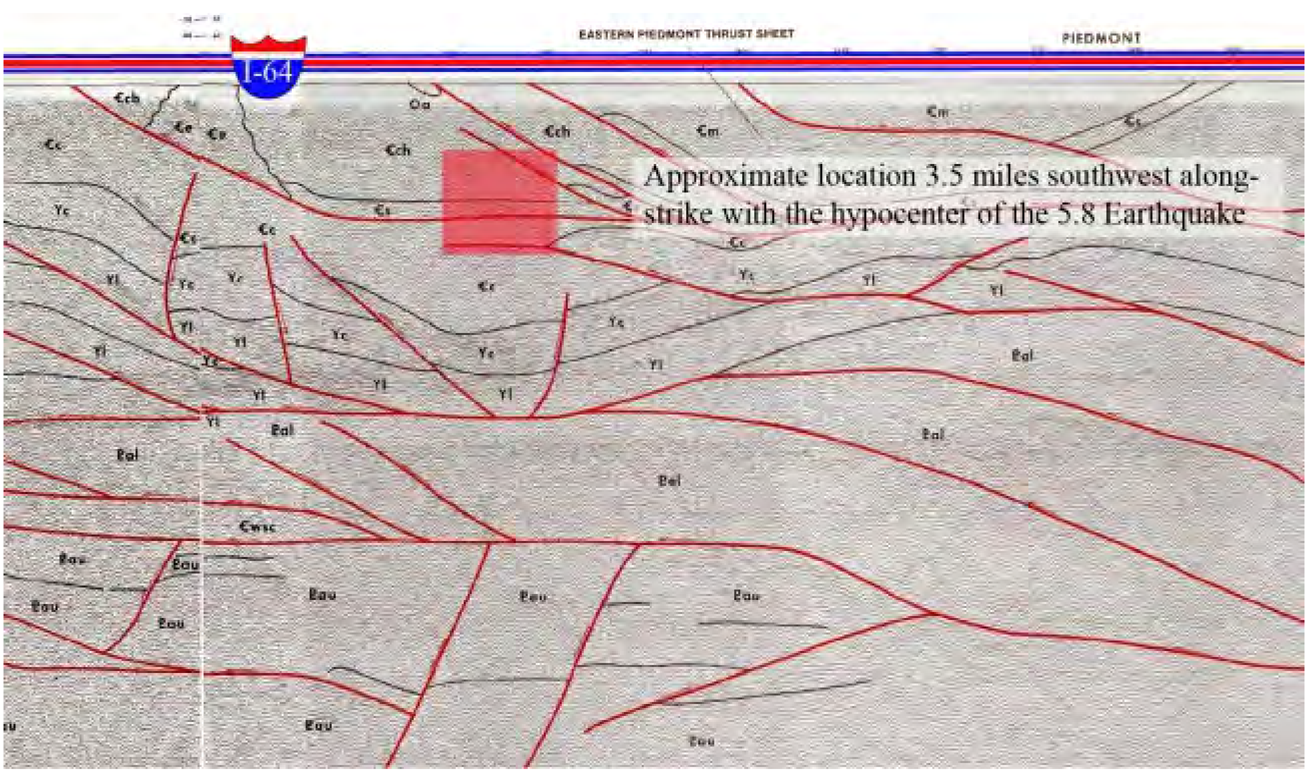
The exact mechanisms of Virginia's earthquakes are not clearly understood. The Piedmont has been assembled piece-by-piece through geologic time and is laced with numerous faults of varying ages. Residual stress may cause these faults to reactivate on occasion, but patterns are unclear. The Giles County seismic zone may be associated with the Narrows Fault, the Saltville Fault, and/or an extension of the Holston Valley Fault, or all three. These faults trend toward eastern Tennessee, which is one of the most seismically active areas in the continental U.S.

The epicenter of the 2011 5.8M Mineral earthquake falls within the Central Virginia Seismic Zone. Several known faults are present in the area: the Chopawamsic Fault, the Lakeside Fault, and the Spotsylvania Fault. These are old faults, related to plate tectonic events that closed and then reopened the Atlantic Ocean about 200 million years ago. Even though these faults are quite old and considered to be inactive, occasional earthquakes continue to occur.




*Geologic structures within the Central Virginia Seismic Zone, Virginia Department of Energy*

Geology and Mineral Resource's Publication 66 is an interpretation of the seismic profile line along Interstate-64 in Central Virginia. This publication proves helpful in showing the fault structure of the Central Virginia Seismic Zone. Interpretation by geologists on the image below shows several scallop faults in an overthrust regime. Using two way travel time, the small red bounding box shows the proposed location 3.5 miles southwest along-strike of the 5.8M earthquake.



*Interpreted 2-D seismic line along I-64 across the Central Virginia Seismic Zone (Publication 66 ) (click on image to view full size line)*

# Earthquake Monitoring and Mapping

The Virginia Tech Seismological Observatory (VTSO) is one of the primary sources for data on seismic activity in the central East Coast. In 1963, as part of the worldwide program, seismometers were installed at Blacksburg. In 1977, several more seismometers were stationed in the Commonwealth and operated by the Virginia Division of Geology and Mineral Resources. Along with the Center for Earthquake Research and Information (CERI) and the U.S. National Seismic Network, VTSO contributes to seismic hazard assessment in the southeastern United States and compiles a Southeastern U.S. Earthquake Catalog.

Click on this link to see a listing of active seismic stations in the southeast and look at real-time data.

In 2014, the Geology and Mineral Resources Program received a 3-year Federal Emergency Management Agency (FEMA) funded grant to identify and map faults in the seismically active regions of Virginia, including the Central Virginia and Giles County seismic zones. This project was completed in 2017. Deliverables included an ArcGIS geodatabase of faults and earthquake locations, a report on Virginia's earthquake history (Publication 185), a general earthquake hazard assessment, and outreach materials for planners and emergency management.

Click here to learn more about this study and to download project deliverables.

## Selected References:

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Bollinger, G. A., Snoke, J. A., Chapman, M. C., and Sibol, M. S.,1989, Estimates of the occurrence and resulting effects of damaging earthquakes in Virginia: Virginia Minerals, v. 35, n. 3.

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Coruh, C., Bollinger, G. A., and Costain, J. K. 1988, Seismogenic structures in the central Virginia seismic zone: Geology, v.16, p.748-751

Mixon, R. B. and Newell, W. L., 1977, The Stafford fault system-structures documenting Cretaceous and Tertiary deformation along the Fall Line in northeastern Virginia: Geology, v. 5, p. 437-440.

Paliser, L. C., 1991, Earthquakes: U. S. Geological Survey pamphlet, 20 p.

Spears, D. B., and Bailey, C. M., 2002, Geology of the central Virginia Piedmont between the Arvonia syncline and the Spotsylvania high-strain zone: 32nd Virginia Geological Field Conference Guidebook, 36 p.

Stover, Carl W., and Coffman, Jerry L., 1993, Seismicity of the United States, 1568- 1989, USGS Professional Paper 1527.

## Additional Resources:

Earthquake Fact Sheet

Earthquake Hazard Mapping Project

USGS "Did you Feel it?"

Earthscope U.S. Seismic Array

College of William & Mary Geology of Virginia Web site, details of the 2011 earthquake

ScienceBlog, “Virginia earthquake not a fluke in the seismically active Southeast.”

The USGS Earthquake Hazards Program

Virginia Tech Seismological Observatory

Site with map showing earthquakes in the eastern US within the last six months

VIRGINIA Energy

Email:
vaenergy@energy.virginia.gov

## Virginia Energy Programs

- Energy Efficiency
- Clean Energy
- Offshore Wind
- Mineral Mining
- Gas and Oil
- Mined Land Repurposing
- Geology and Mineral Resources
- Coal Mine Safety

## Other Links

- Web Policy
- VITA Large File Transfer
- Strategic Plan

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 29

**February 21, 2023**

# Giles County Earthquake of May 31, 1897
# News Reports

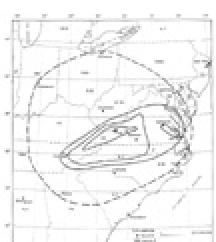
Because the 1897 Giles County earthquake preceded seismic networks, there were few direct measures of the ground motion resulting from the earthquake. For this, and other pre-network events, one determines intensities for the event and infers from that a magnitude, or some other measure of size.

The earthquake **intensity** is a measure of the effects of an earthquake at a particular place on humans and (or) structures. The intensity at a point depends not only upon the strength of the earthquake (magnitude) but also upon the distance from the point of observation to the epicenter and the local geology at that point. Note that a given event will have only one magnitude, but many intensity values. Intensities tend to decrease with distance from the epicenter, but local site conditions or focusing effects can produce anomalies. Also, the lower intensities depend upon human perception, which is subjective and subject then to variability.

The Modified Mercalli Intensity Scale (MMI) is the one used in North America. It is expressed by Roman numerals. MMI = III is generally the threshold for a "felt" event at that location. Architectural damage comes with MMI = VI. MMI values of VII-IX are applied for increasing degrees of structural damage.

The reports given below are taken from **Earthquake History of Virginia 1774 - 1900** by M. G. Hopper and G. A Bollinger, 1971, pages 55-66, and are based primarily on newspaper accounts. The reports are given here in the order of decreasing intensities, and for each intensity value they are ordered alphabetically within each state. Entries in parentheses refer to newspapers -- mostly in 1897.

A special note: chimneys in 1897 were not as well constructed as they are now, so less horizontal shaking would damage a chimney in 1897 more than it would today.



Clicking on the map shows the outline of the MMI zones. MMI=VIII is the maximum intensity for this event. The felt area estimated to be 280,000 square miles.

**MMI VIII**

<u>Giles County, Va. and Pearisburg, Va</u>: Report that "Angels Rest", a high mountain near Pearisburg, was cracked. (RD 6/l/97)

From Roanoke, Va.: Telegram from Giles County that Mountain Lake still intact. "Advices from Giles County, however, still report much uneasiness there. The courthouse at Pearisburg was badly cracked by the earthquake shock, and numerous chimneys were thrown down or badly damaged. In other parts of the county, it is said, several brick houses were seriously damaged, and some shaken down completely. Along the railroad track tons of rock fell from the overhanging cliffs. In one instance derailing a freight train, and causing a delay to traffic for five hours or more. At Pearisburg bricks rolled from the chimneys to the roof of the courthouse in such numbers and to such an extent that Judge Jackson, who was holding Circuit Court when the shock occurred, left the building, along with the lawyers and others present. For a week or more before the shock people throughout Giles County were much disturbed by subterranean noises, and all day Monday detonations like the explosion of distant artillery were heard throughout the county. As to the crack in Angels Rest Mountain reports are so conflicting that it is hard to get at the truth. For several days after the shock last Monday the water in many of the springs and branches were muddy. An attorney of this city who was in Pearisburg on Monday bears out some of the above statements, and says that for nearly fifty miles from that place he saw hardly a sound chimney standing. In his opinion, if the buildings throughout Giles had been largely of brick, the damage would have been very great, and serious loss of life would have occurred."

From Pulaski, Va.: "From what can be learned, all reports about cracks in the earth in Giles, etc., are fictitious. Your correspondent saw yesterday a lawyer from there who said there were no holes in Angels Rest Mountain or elsewhere there, that any one had seen, but people are afraid to go in the mountain to investigate. There was a great scare, as the earthquake was very severe, there having been four separate shocks on May 31st between 2 and 5 o'clock p.m." (RD 6/4/97)

From McDonald's Mill: "I have been reliably informed that in Giles County, near Pearisburg (the county seat) earthquake shocks have daily occurred for some time past, and the citizens along the base of a lofty part of a mountain called Angels Rest are considerably excited." (RD 6/3/97)

Dr. Goodride Wilson, writing of the Town of Pearisburg: "While court was in session on Monday, May 31, 1897, Pearisburg experienced a moderately severe earthquake. The judge summarily adjourned court, jumped over the railing and ran out of the courtroom along with the lawyers and spectators. A number of chimneys were toppled in the town and some brick walls were cracked. The shocks were felt throughout the county and in several other counties in Southwest Virginia."

Mr. J. H. Hardy, in a letter, reports that his father-in-law, Mr. Sam D. May, was an attorney trying a case in Pearisburg at the time of the earthquake: "He told me that the quake was really severe there. Some thought Mountain Lake had caved in. I think the water did go down some but if there was a crack in the bottom it evidently filled up gradually." (Hardy, 1969)

Earthquake "especially strong at Pearisburg, where the walls of old brick houses were cracked and bricks were thrown from chimneys which had been damaged. A few earth fissures and small landslides were reported from this area, but no serious damage.... At Narrows (Va.) large rocks rolled down the mountains. The sounds were compared by veterans to those made by seige guns in action.... Minor tremors continued from time to time until June 6." (MacCarthy, 1964)

"There were fissures in the ground and small landslides in places where they were easy to start. At the Narrows ( Va.) it was claimed that a motion like the ground swell of the ocean was observed." (Eppley, 1965, p. 25).

"Earthquake shocks nightly in Giles County since the 25th; large fissures have been made." (MWR)

Noises heard from May 3 to May 31 and after. Shock most severe near Pearisburg. No serious damage, but old brick houses badly shaken and many chimneys cracked and top bricks knocked off. Much noise. Many people "terror stricken." Surface "rolled like the groundswells of the ocean" and springs were muddied and one large landslide started at the Narrows. (Campbell, 1898)

Roanoke, Va.: Crockery rattled, windows shaken, doors opened and closed, furniture moved in many houses. Several chimneys knocked down; frame buildings "seen to sway back and forth." In the business district "many persons rushed into the streets, fearing that the buildings would fall.... Felt by everybody and frightened many people." (RD 6/l/97)

Terry Building was "noticed to sway perceptibly and doors standing open in the Masonic Temple and Commercial Bank building were swung back and forth." Pictures shaken from walls and bottles from shelves. -- "People rushed out of their houses expecting them to fall." Shock scared "a great many people nearly out of their wits." Several chimneys "shaken to the ground." Tops shaken off some chimneys and others "partly demolished." (RT 6/l/97)

**MII VII**

Bedford City, Va.: Earthquake "severest ever felt here, and caused considerable consternation . . . . Rocking vibration . . . accompanied by a dull detonation like that of heavy thunder and a report like that of a cannon." (RD 6/l/97) "Chimneys of the courthouse, bank, Windsor Hotel, and several private houses were shaken down. The walls of several dwellings were cracked, and people rushed terrified into the streets." (RD 6/l/97)

No serious damage. "Four or five chimneys toppled over." (RT 6/l/97)

Pulaski, Va.: "Very severe earthquake shock.... Shook down chimneys greatly alarming the citizens who rushed from their houses and places of business." No other damage. (RD 6/l/97)

Radford, Va.: "No less than twenty chimneys shaken or split and in some instances... nearly leveled to the houses." Roofs of some houses "looked as if mortar and lime had been scattered all over them." Buildings rocked so much that no shocks were noticeable in the open ground. "The earth seemed to rise and fall in waves.... Heaviest earthquake ever known in this section." (RD 6/l/97)

"Heavy earthquake shocks.... A great deal of excitement was occasioned at the time, as chimneys were falling, houses rocking like cradles, and women and children screaming in terror about the streets." Preceded by "a heavy rumbling." (RT 6/l/97)

Houston, Va.: "Quite a severe earthquake shock" - Several chimneys partly demolished. (RD 6/l/97)

Bristol, Tenn. - Va.: "Shook the buildings so that the people ran into the streets." Several chimneys "thrown to the ground." (RD 6/l/97)

Time - 13:15, duration - 30 seconds. (MWR)

Bluefield, W.Va.: "A heavy seismic disturbance, with buildings rocking and chimneys failing." (RD 6/l/97)

**MMI VI-VII**

Wytheville, Va.: Many people "were panic-stricken, running from their houses." Bricks were thrown from chimneys; in some cases "chimneys were cracked and thrown several inches out of plumb.... Terrifically loud" report accompanied the shock. One large tree "was precipitated down a steep cliff into the creek." (RD 6/l/97)

Knoxville, Tenn.: Felt throughout the city - "Several large buildings were badly shaken and two chimneys fell. " (RD 6/l/97)

"Startled the citizens nearly out of their wits." Little damage. (RT 6/l/97)

Several chimneys shaken down. (NYT 6/l/97)

**MII VI**

Christiansburg, Va.: A "rumbling noise" preceded the shock. Houses rocked, doors opened, bricks thrown from chimneys. People "rushed into the streets much excited." Severity of the earthquake "exceeded any in the recollection of the oldest inhabitant." (RD 6/l/97)

"It was a warm sunshiny day in early summer when, without warning, buildings along Main Street begun a rocking movement and the dry timbers in their frames popped and cracked and the air became full of dust. Many people ran out of the houses into the street, some whitefaced, and stared upward where the dust, shaken from the buildings was slowly settling toward the ground. The tremor lasted only a few minutes before the panic was over and normal business was resumed along the street. This earthquake was felt in several counties adjoining Montgomery, but little damage was reported beyond the cracking of plaster in a few homes." (NMI Centennial Edition, 12/31/1969)

Dublin, Va.: "Severe." Houses shaken, horses frightened, bricks thrown from chimneys. "Rumbling noise" preceded and followed the shock. (RD 6/l/97)

Lynchburg, Va.: Felt "very perceptible.... Many badly frightened, and rushed into the streets, and great excitement prevailed for awhile." (RD 6/l/97)

Bricks fell from chimneys and "furniture and crockery jostled." (MacCarthy, 1964)

Time - 13:58 (MWR)

Richmond, Va.: "The vibrations lasted for several seconds and were so violent that many people ran out of their homes, fearing their collapse." No material damage. Hotel guests "ran out of their rooms under the impression that a boiler had burst." Noise "Loud and startling." Pictures were shaken, shutters "rattled as if blown by a violent wind" and "furniture was moved in a number of instances." Many suddenly sick just before the shock was felt; symptoms "like nausea and swimming of the head." Convicts at the penitentiary tried to break out. "The most serious and alarming (earthquake) ever experienced here." (RD 6/l/97)

Windows, pictures, glassware rattled violently and unstable objects overthrown. Hundreds of people left their houses in alarm. (from Washington Post, June 1) (MacCarthy, 1964)

An earthquake shook "buildings and rattled windows, but no damage was done. The people in many buildings were badly frightened." (NYT 6/l/97)

Time - 13:59. "Violent vibrations and loud noises; two shocks, at 13:59 and 14:1l."

(MWR)

Rocky Mount, Va.: "Severe" Felt by "the entire community." Accompanied by "rumbling sound, much like that made by the rapid moving of a wagon or wagons upon the streets." Many "rushed into the streets from their houses and offices." Loose bricks thrown from chimneys. (RD 6/l/97)

Salem, Va.: Just before the shock, "a peculiar noise... resembling the reverberation of thunder" was heard. Bricks shaken from chimneys, goods thrown from shelves of stores, no damage. "People rushed pale and frightened from their houses." (RD 6/l/97)

Houses "were trembling like autumn leaves in a stiff breeze." (RT 6/l/97)

Letter from Mr. J. H. Hardy who was a boy of 17 at the time of the earthquake: "Was seated on a stool at the kitchen table eating when all of a sudden everything began shaking including the stool I was seated on. My first thought was that there was a heavy explosion somewhere in the neighborhood. I didn't get excited -- but finished eating and went down to the street where everybody was talking about the earthquake." (Hardy, 1969)

Stuart, Va.: "A severe and prolonged earthquake shock". . . . Accompanied by a loud, rumbling noise. Windows rattled, houses shook, and furniture was overturned. (RD 6/l/97)

Tazewell, Va.: "Strong" shock. Bricks shaken from tops of some chimneys. People "rushed into the streets to ascertain the cause of the vibrations." Accompanied by "a perceptible roar." (RD 6/l/97)

Asheville, N.C.: Felt. (RD 6/l/97]

"An earthquake shock shook Asheville perceptibly. Hundreds of occupants of buildings ran into the streets. No damage." (NYT 6/l/97)

Time - 13:59. (MWR)

Durham, N.C.: "Distinct." Houses shaken and plastering knocked from the ceilings. (RD 6/l/97)

Lenoir, N.C.; Time - 13:58. "Loud roar, chimneys injured." (MWR)

Oxford N.C.: "Very perceptible." Bricks thrown from chimneys. No damage. (RD 6/l/97)

Raleigh, N.C.: Plastering knocked down. Doors closed. One public building cracked. (RD 6/l/97)

"Quite a severe shock of earthquake." No damage. (RT 6/l/97)

A few chimneys damaged. (MacCarthy, 1964)

"Two shocks, each lasting 30 seconds; chimneys thrown down." (MWR)

Salisburg, N.C.: "A distinct shock of an earthquake." Walls cracked, plaster fell, and glass rattled. No general damage. (RD 6/l/97)

Weldon, N.C.: Many "badly frightened and ran out of their houses." "Quite severe."

Walls of several houses "seen to move, and others rocked like a cradle. . . . Crockery and other things rattled together, and many small things were thrown down."

Winston, N.C.: "The most severe earthquake of any experienced in this section since the memorable Charleston earthquake in 1886....

A general exodus from stores and residences to the streets, and consternation reigned supreme for a few minutes." Some nausea. Bricks shaken off chimneys at several houses. (RD 6/l/97)

Caused "wild excitement." (RD 6/l/97)

No damage. . . beyond shaking down a few chimneys." (RT 6/l/97)

Jonesboro, Tenn.: "The shock was quite severe." (RD 6/l/97)

The people ran out into the streets. (NYT 6/l/97)

**MMI V-VI**

Burkeville, Va.: A well caved in; a little plastering fell. Very little damage. (RD 6/l/97)

Danville, Va.: People "greatly alarmed, and rushed very generally from houses into the streets." (RD 6/1/97)

Time - 13:58 (MWR)

Lexington, Va.: "The largest buildings were shaken and people ran out of their houses in their fright." No damage. "A severe earthquake shock." (RD 6/l/97 NYT 6/l/97)

Newport News, Va.: "Frightened a great many people." More perceptible "near the edge of the water, where it caused the piers and buildings to rock." No damage. (RD 6/l/97)

"About 2 p. m. - brief but violent." (MWR)

Petersburg, Va.: "Sufficiently severe to jar the heaviest building, though causing no damage." Houses "considerably shaken," crockery rattled, families so frightened they rushed out into the street as a means of safety. Large factories "were quickly emptied of their workmen." Vases broken, gas globes shaken from chandeliers, crockery moved on shelves. Telephone and telegraph wires violently shaken. (RD 6/l/97)

Some glassware broken and goods knocked from shelves; people rushed from houses and factories (from Raleigh Press - Vista, June 2).

Time - 13:59. "Quite severe, the first since August 31, 1889." (MWR)

Smithville, Va.: "A very strong earthquake shock." People frightened from their houses. (RD 6/l/97)

**MMI V**

Abingdon, Va.: Shock was "very distinct and severe". No damage. "Considerable scare." (RT 6/l/97)

Ashland, Va.: Shock "quite severe here". Houses shaken, crockery overturned, people "pretty generally scared.... Some few ran from their houses, looking appalled at the sudden visitation." No damage. Crockery and furniture "were put in motion." (MacCarthy, 1964)

Big Stone Gap, Va. and Gate City, Va.: "A severe earthquake shock.... Even houses were shaken, clocks stopped and furniture was jostled about." (RD 6/l/97)

Crewe, Va.: "Houses trembled and china and glassware turned over in some of them. Many persons were alarmed, and some ran out of their houses." (RD 6/l/97)

Floyd Courthouse, Va.: Eyewitness remembers the "great excitement it caused among the school children." (NM, Centennial Edition, 12/31/1969)

"Severest shock ever felt here; brick and stone walls were cracked." (MWR)

Fredericksburg, Va: "A heavy earthquake shock-" Some "ran from the houses badly frightened." (RD 6/l/97)

Greenbay, Va. (Prince Edward County): "A distinct shock of an earthquake" - The crockery and other articles in the stores "were badly shaken up." (RD 6/l/97)

Manassas, Va.: "Shook buildings so that windows rattled and doors swayed to and fro on their hinges." (RD 6/l/97)

Millboro, Va.: "Very severe." Felt by "almost everyone in the place." Some people "ran from their house, fearing they would fall." (RD 6/1/97)

Warm Springs, Va. and Hot Springs, Va.: "Shook the houses and rattled the windows, and made moveable things totter." Some frightened. (RD 6/l/97)

Cincinnati. Ohio: Felt "here and in the suburbs.... The printers ran out of the Times-Star office. The occupants of other buildings were alarmed, and at Coney Island, Chester Park, the Zoo gardens, and elsewhere there was consternation among the holiday crowds. At the Lagoon, on the Kentucky side, there was a panic among several thousand people on the grounds. The waters in the Lagoon were so rough that the life-saving crew went to the relief of those out on the electric pleasure boats." (RD 6/l/97)

No damage reported. (RT 6/l/97)

"The shock was general throughout the State." (NYT 6/l/97)

"Weather Bureau Station, 13:02 - A wave of water started at the southwest extremity of the lake at Ludlow Lagoon, which by the time it reached the eastern shore of the lake was over 3 feet high. The earthquake lasted 1 1/2 minutes.- Shock rarely noticed inside the city." (MWR)

Zanesville, Ohio: The Courier Building "experienced decided vibrations" to such an extent that "the employees on the fourth and third floors deserted their posts, greatly frightened." (RD 6/l/97) (DL 5/31/97)

Felt. (RT 6/l/97)

The Zanesville, Ohio Times-Recorder does not mention an earthquake at that time.

"About 1 p.m., alarming vibrations." (MWR)

Grafton, W.Va.: "Windows broken and officials panic-stricken." (MWR)

**MMI V?**

Chesterfield County, Dinwiddie County, Va.: Shock "very decided.... Large buildings felt the tremor." A general rattling of windows. No damage. Accompanied by "a deep, low rumbling noise." (RD 6/l/97)

**MMI IV-V**

Chase City, Va.: A "violent earthquake shock." Windows rattled and buildings shook. "Some heard a roaring sound and few were frightened." (RD 6/l/97)

Norfolk, Va. and Portsmouth, Va.: "A distinct shock of an earthquake followed immediately by a heavier shock.... People rushed into the streets panic-stricken.... Great excitement prevailed." Many clocks stopped. No damage. (RD 6/i/97)

"Everybody got a good scare." No damage. (RT 6/l/97)

Time - 13:57 (MWR)

Suffolk, Va.: "A slight but very decided earthquake shock". . . felt throughout Suffolk. Made some dizzy. Windows shaken "as though by wind." Some ran from their house "startled." No damage. (RD 6/l/97)

Washington, D.C. : Chandeliers swayed and floors trembled perceptibly. "It was noticed at the capitol, in the Telephone Exchange, and in several of the high buildings. In the Associate Press office, in the Post Office Building, the vibrations were felt very distinctly." (RD 6/l/97)

"Many buildings were considerably shaken." No damage. (RT 6/l/97)

"What was supposed to have been an earthquake was felt here.... The vibrations were felt very distinctly." Self-recording instrument at the Weather Bureau shows it began at 1:58 1/4 and lasted five minutes. (NYT 6/l/97)

"Weather Bureau seismograph recorded continuous series of shocks from 13:58:15 to 14:03:15." (MWR)

Charlotte, N.C.: Felt. (RD 6/l/97

Very little damage. (RT 6/l/97)

"A distinct earthquake shock.... No damage, but created much excitement." (NYT 6/l/97)

Time - 13:45. "Throughout the mountain district a violent shock." (MWR)

**MMI IV**

Amherst, Va. - "Houses shook, windows rattled, and the earth trembled with a convulsive motion." Accompanied by a "low rumbling sound." (RD 6/l/97)

Chesterfield County (Bon Air, Va.) - "A slight shock of an earthquake... The store buildings shook, causing things hanging against the walls to rattle." (RD 6/l/97)

Greenwood, Va. - "Felt over the entire county of Albemarle, shaking houses and causing general alarm." Men at large brick freight depot "rushed out to see what was wrong." (RD 6/l/97)

Nottoway Courthouse, Va.: -"A very perceptible earthquake ... distinctly felt by many persons." No damage. Preceded by a "loud rumbling sound which seemed to roll from southwest to northeast." (RD 6/l/97)

Staunton, Va.: "Perceptibly felt." Heavy rumble, rattling of windows. People "distinctly saw the sway of a brick building." (RD 6/l/97)

Felt. (RT 6/l/97)

Time - 13:59. Heavy rumble (MWR)

Waynesboro, Va.: "A distinct earthquake shock." (RD 6/l/97)

Williamsburg, Va.: Felt by "nearly everybody in town." All recognized it. (RD 6/l/97)

Chattanooga, Tenn.: "A slight earthquake shock. . . felt throughout East Tennessee from Bristol to Chattanooga." No damage. (NYT 6/l/97)

"Very slight shock at 1 p.m., duration of 10 seconds, soon followed by second shock." (MWR)

Wheeling, W.Va.: "A distinct earthquake shock... felt all over Wheeling and surrounding towns.... Shook brick buildings slightly. No damage." (RD 6/l/97)

"Violent enough to shake brick buildings slightly." (NYT 6/l/97)

**MMI IV?**

Fincastle, Va.: Vibrations "preceded by a noise resembling that made by the rumbling of cars." Houses shaken. Shaking of doors and windows "distinctly heard". (RD 6/l/97)

Cleveland Ohio: "A severe earthquake shock was felt at this point." (RD 6/1/97) (DL 5/31/97)

Very little damage. (RT 6/l/97)

"Time - 12:32. Adelbert College seismograph recorded vibrations as being from northeast to southeast and about 0.01 inch in extent." (MWR)

**MMI III-IV**

Luray, Va.: "A very perceptible shock of an earthquake....Articles of furniture and some buildings vibrated slightly." (RD 6/l/97)

Spartanburg, S.C.: "A distinct earthquake, shaking buildings and rattling windows.... As severe as that of August, 1886." (Charleston earthquake) (RD 6/l/97)

**MMI III**

Lester Manor, Va. (King William County) - "Quite a distinct earthquake shock." Windows and doors rattled. No damage. (RD 6/l/97)

Atlanta, Ga.: "Clearly felt." Trembling "not severe.... There was no excitement." (RD 6/1/97)

"Alarming shake, most severe since 1884; the quake seems not to have extended into the Piedmont region." (MWR)

Louisville, Ky.: "A distinct earthquake shock." (RD 6/l/97

Lasted about five seconds. Passed north to south. (NYT 6/l/97)

Shortly after 2 p.m.; duration - seconds. (MWR)

Wilson, N.C.: "An earthquake shock was plainly felt here." Windows rattled. (RD 6/l/97)

Pittsburgh, Pa.: "A slight earthquake shock.... Quite perceptible in high buildings." (RD 6/l/971

Felt. (NYT 6/l/97)

"13:54 to 13:55, slight shock; perceptible in buildings, but not on street." (MWR)

**MMI III?**

Greenville, N.C.: "A distinct earthquake shock." (RD 6/l/97)

Huntington, W.Va.: "An earthquake shock was felt here distinctly and throughout Southern West Virginia." (DL 5/31/97)

**MMI II-III**

Indianapolis, Ind.: "A slight earthquake shock.... Most noticeable in the fire-tower and in high buildings." (RD 6/l/97)

Baltimore, Md.: "A slight earthquake.... Not noticeable, except in the high buildings." (RD 6/l/97)

In high buildings a distinct vibration was felt lasting nearly a minute. (NYT 6/l/97)

New Bern, N.C.: "A decided shock of an earthquake.... Persons in the upper part of buildings felt it quite sensibly, while those on the lower floors and-ground did not perceive it." (RD 6/l/97)

**FELT**

Carson, Va.: Felt. (RD 6/l/97)

Jarratts, Va. (Sussex County): Felt. (Rd 6/l/97)

Oak, Va. (New Kent County): Vibrations "as distinct as those of the earthquake of 1886." (1886 was the Charleston, S.C. earthquake.) (RD 6/l/97)

Stony Creek, Va.: Felt. (R D 6/1 /97)

Covington, Ga. : Time - 14:00. (MWR)

Elberton, Va.: Felt; no time given. (MWR)

Hepzibah, Ga.: Time - 14:05, duration - 2 seconds. (MWR)

Savannah, Ga.: "A slight earthquake." Windows and doors shaken throughout the city. Many made dizzy. (RD 6/l/97)

Toccoa, Ga.: Felt; no time given. (MWR)

Barboursville, Ky.: Felt (RD 6/l/97)

Covington, Ky.: "Waters in lagoon dangerously rough." (MWR)

Greensboro, Ky.: Time 14:00, "severe." (MWVR)

Middlesboro, Ky.: Felt. (RD 6/l/97)

Baltimore, Eastern Shore, Southern Md.: "Three distinct felt shocks" (MWR)

Biltimore, N.C.: Time - 14:00. Duration - 15 seconds. (MWR)

Concord, N.C.: Felt. (RD 6/i/97)

Greensboro, N.C.: Time - 14:00 (MWR)

Linville, N.C.: Perceptible. (MWR)

Murphy, N.C.: Duration - 2 seconds. (MWR)

New London, N.C.: Felt. (RD 6/l/97]

Reidsville, N.C.: "An earthquake shock was felt here." (RD 6/l/97)

Soapstone Mt., N.C.: "Rumbling noises." (MWR)

Waynesville, N.C.: "Perceptible." (MWR)

Columbus, Ohio: "A slight shock of an earthquake was felt here." (RD 6/l/97)

Time - 13:02. Duration - 40 to 50 seconds. Two distinct shocks. (MWR)

South Carolina: Felt. (RD 6/l/97)

Statesburg, S.C.: Time - 13:55 (MWR)

"13:57:30 - Motion of floor and its creaking were very distinct." (MWR)

Greenville, Tenn.: Time - 14:10 (MWR)

Harriman, Tenn.: Time - 10:00 p.m. (?), oscillations for two minutes. (MWR)

Tullahoma, Tenn.: Time - 13:15; duration - 30 seconds (MWR)

Time - 12:57 (MWR)

Charleston, W.Va.: Time - 13:00 (MWR)

Clarksburg, W.Va.: Time - 14:02, duration - 12 seconds (MWR)

Hinton, W.Va.: No details. (MWR)

Newburg, W.Va.: "Severe shock." (MWR)

Parkersburg, W.Va.: "Two shocks between 1 and 2 p.m." (MWR)

**OTHER**

Saltville, Va.: From Roanoke, Va.: Telegram received from Saltville denying that the saltwells had gone dry since the earthquake shock. (RD 6/4/97)

Lexington, Ky.: The Lexington Daily Leader carries the story of the earthquake for other cities, but does not mention its being felt in Lexington. (DL 5/31/97)

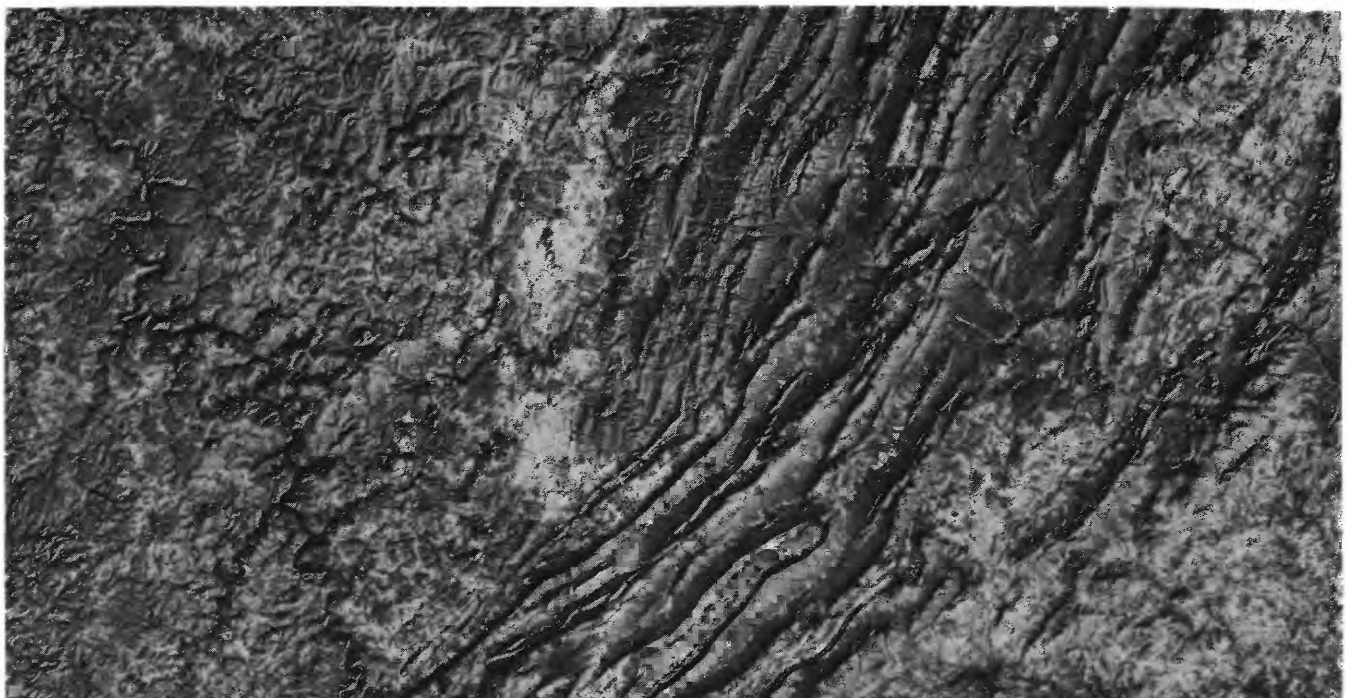
Williamsport, Pa.: "Four or five wells went dry during quake." (MWR)

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 30

**February 21, 2023**

# THE GILES COUNTY, VIRGINIA, SEISMIC ZONE—
## SEISMOLOGICAL RESULTS AND GEOLOGICAL INTERPRETATIONS




U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1355

Landsat multispectral image showing Giles County, Virginia, and surroundings. Image number 2654-15090-7, taken November 6, 1976. The solid circle locates Pearisburg, Virginia, seat of Giles County and the presumed epicenter of the earthquake of May 31, 1897.

Cover designed by Norma J. Maes

## THE GILES COUNTY, VIRGINIA, SEISMIC ZONE— SEISMOLOGICAL RESULTS AND GEOLOGICAL INTERPRETATIONS


Angel's Rest promontory (center foreground, elevation 3633 ft [1107 m] above sea level) of Pearis Mountain with the town of Pearisburg and the New River (elevation 1581 ft [482 m] above sea level) at its base. View is toward the southwest. This mountain was erroneously reported to have cracked during the May 31, 1897, earthquake centered in the vicinity. The Narrows seismograph station (code: NAV) is located in Mill Creek Valley, this side of Sentinel Point promontory extending to the right (north). Refer to Narrows, Virginia-West Virginia 7.5 minute topographic map for details.

# The Giles County, Virginia, Seismic Zone— Seismological Results and Geological Interpretations

*By* G. A. BOLLINGER *and* RUSSELL L. WHEELER

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1355

*A description of a newly recognized seismogenic zone, with contributions towards evaluation of its seismic hazard*

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# CONTENTS



# ILLUSTRATIONS

# TABLES

# THE GILES COUNTY, VIRGINIA, SEISMIC ZONE—SEISMOLOGICAL RESULTS AND GEOLOGICAL INTERPRETATIONS

By G. A. BOLLINGER[1] and RUSSELL L. WHEELER[2]

ABSTRACT

A newly recognized 40-km-long seismic zone is described and interpreted. The zone is inferred to have been the locus of a damaging earthquake in 1897. That shock was the second largest known to have occurred in the Southeastern United States (MMI=VIII, $m_b$ estimated at 5.8, felt over 725,000 km$^2$). It struck Giles County in southwestern Virginia, and a recurrence would affect populous regions on and near the central Atlantic seaboard. The seismic zone presents a hazard. We attempt to aid in evaluating the hazard by presenting and synthesizing new seismological data with geological inferences and deductions.

A five-station, 60-km aperture seismic network has been in operation in the Giles County locale since early 1978. For the subsequent 3-year monitoring period, 12 microearthquakes (M<2) have been detected. Hypocenters of eight of those 12 events, plus an additional four older, relocated, felt earthquakes ($3.2 \leq M \leq 4.1$; 1959–76), have a tabular distribution centered at Pearisburg, Va. That distribution is about 40 km long, 10 km wide, strikes N. 44° E., and has a nearly vertical extent of 5–25 km in depth. Thus, the Giles County seismic zone is defined presently by 12 earthquakes that span four orders of earthquake magnitude ($0 \leq M \leq 4$) and two decades of time (1959–80). We conclude that the 1897 earthquake occurred on that seismic zone. From the orientation of the zone, from evidence that greatest horizontal compressive stress trends east-northeast at seismogenic depths in and near Giles County, and from sparse *P*-wave first-motion data, we infer that the monitored microseismicity probably occurs by right-reverse motion on steep faults in the seismic zone, with the southeast side dropping down with respect to the northwest side.

In the Giles County locale, the upper 3–6 km of the crust are Paleozoic sedimentary rocks that have moved some tens of kilometers northwest on nearly horizontal thrust faults. The previously mentioned hypocenters for the region lie below the deepest likely thrust fault, indicating that Giles County seismicity probably has no simple relationship to surface geology.

Since Precambrian time, three deformational episodes could have formed steep faults under the present surface structures, at the observed hypocentral depths. These episodes were as follows: (1) As the Iapetus Ocean (Atlantic's predecessor) opened in late Precambrian or early Paleozoic time, northeast-striking normal faults formed, probably at the inferred Iapetan continental edge in central Virginia and at least as far northwest of that locus as Giles County. (2) In late Paleozoic time, thrust faults loaded the crust with several kilometers of overthrust sedimentary rocks, perhaps forming northeast-striking thrust-load faults in a brittle analog of isostatic depression caused by thrust masses and much lighter continental glaciers. (3) As the Atlantic Ocean opened in Mesozoic time, other northeast-striking normal faults formed on the present continental margin and inland of it.

The seismic zone seems most likely to have resulted from compressional reactivation of an Iapetan normal fault, which also may have been reactivated by late Paleozoic compression and Mesozoic extension. Two arguments support this conclusion. First, the seismic zone probably does not occur on a thrust-load fault. The zone underlies the thrust structures of southern Appalachian orientations (east-northeast), but those structures are not known to be displaced where they cross the zone. Thus, if the zone occurs on a thrust-load fault, the fault and its coeval causative central Appalachian thrusts would predate the southern Appalachian structures. That deduction contradicts stratigraphic and structural estimates of relative ages of southern and central Appalachian thrusting. Second, the zone probably does not result from a Mesozoic normal fault, because known locations of Mesozoic normal faults and grabens are well to the southeast of Giles County.

Not yet known is where else in the East reactivated Iapetan normal faults might generate shocks similar to that of 1897. However, our analysis enables us to suggest specific geological and geophysical investigations that may produce results useful in answering that question. Such investigations can concentrate on defining the area of probable occurrence of other Iapetan normal faults, and on determining whether the one inferred to underlie Giles County is uniquely active or is typical of others that might exist elsewhere.

## INTRODUCTION

On May 31, 1897, a damaging earthquake struck Pearisburg, the seat of Giles County in southwestern Virginia (fig. 1). The shock was erroneously reported to have cracked Pearis Mountain, whose Angel's Rest promontory rises more than 600 m above Pearisburg and the New River. (See frontispiece.) The earthquake is especially important in the seismic history of the Southeastern United States, for the following reasons:

1. It is the largest shock known to have occurred in Virginia, and the second largest earthquake known in the entire Southeastern United States (Modified Mercalli Intensity (MMI)=VIII, body-wave magnitude ($m_b$) = 5.8, felt area = 725,000 km$^2$; Bollinger and Hopper, 1971; Nuttli and others, 1979; Street, 1979; see fig. 1).
2. It serves as the design earthquake for critical facilities sited in the Valley and Ridge and Blue Ridge provinces of the southeastern United States.

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[2]U.S. Geological Survey, P.O. Box 25046, Denver Federal Center, MS 966, Denver, Colo. 80225.

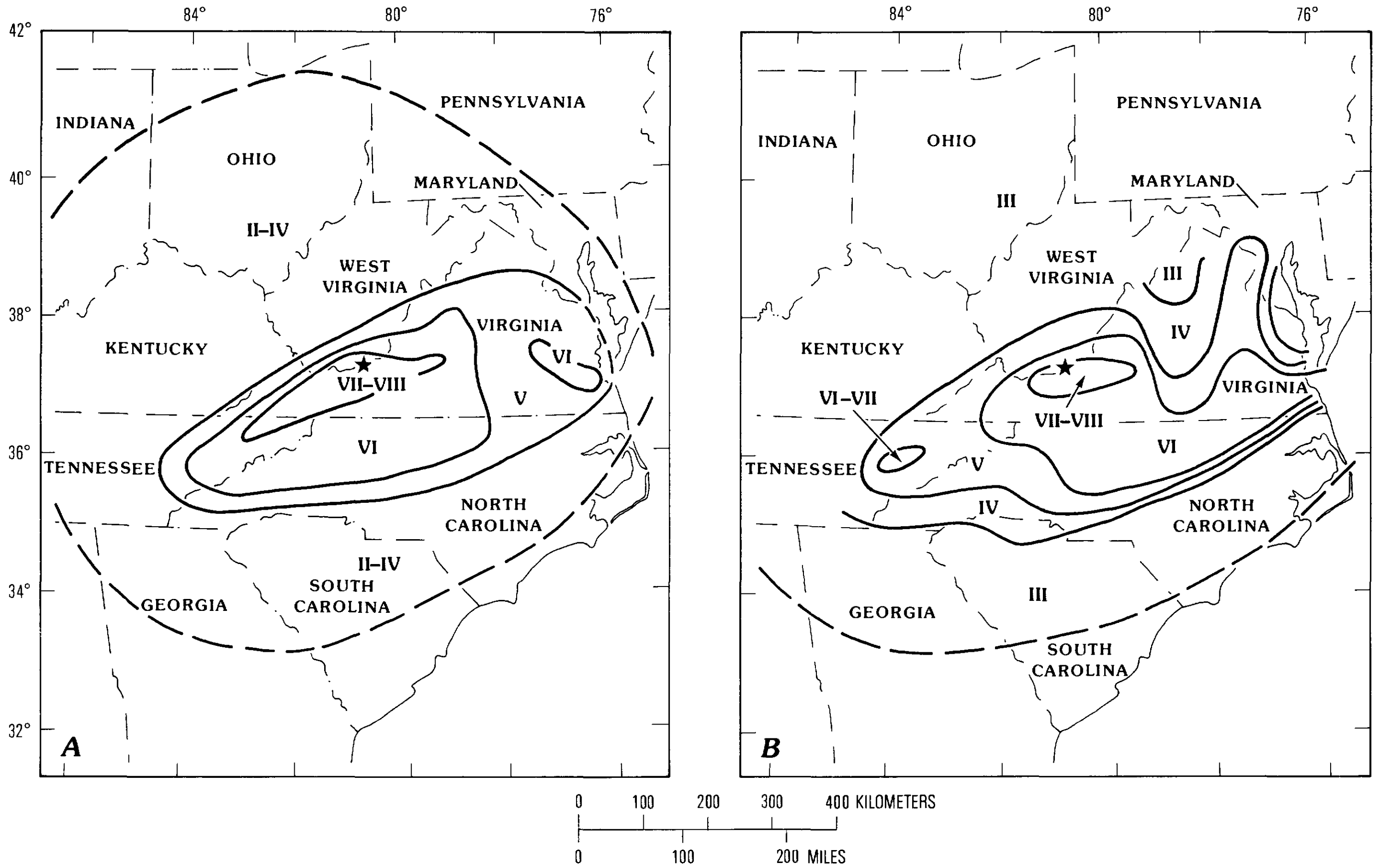



FIGURE 1.—Intensity maps for the May 31, 1897, Giles County, Va., earthquake. *A*, modified from Law Engineering Testing Company (1975); *B*, modified from Bollinger and Hopper (1971). Differences between the two maps reflect difference in data bases (Law Engineering Testing Company's was the larger) and in the interpreters. Star indicates the location of Pearisburg, Va., the presumed epicenter of the shock. Contours are drawn on values of intensity reported from various places. Typical intensity values for areas between or within contours are shown as Roman numerals. Dashed contours show approximate limits of data: earthquake was felt at least that far from the epicenter. Reproduced from Bollinger (1981a) with permission.

3. No earthquake activity prior to 1897 has been definitely assigned to the Giles County locale (Hopper and Bollinger, 1971; Reagor and others, 1980a, b). However, a foreshock-aftershock sequence did occur in conjunction with the May 31, 1897, main shock from May 3 to at least June 6 (Bollinger and Hopper, 1971). A local resident estimated that there were at least 250 distinct shocks observed at Pearisburg subsequent to May 3, 1897 (Campbell, 1898).

The felt aftershocks apparently ended in 1902 (MMI=V shock on May 18 near Pearisburg, the presumed epicenter of the main shock of 1897; table 1) or perhaps in 1917 (southwestern Virginia earthquake reported on April 19, MMI=II; Reagor and others, 1980a). There followed a quiescent period of 4–6 decades that ended in 1959 with the occurrence that year of three felt shocks (MMI=VI, IV, IV). In the following 2 decades (1960–79), six additional felt earthquakes (MMI≤VI) were reported from within 50 km of Pearisburg. The largest of those six shocks was the $m_b$=4.6, MMI=VI, Elgood, W. Va., earthquake of November 20, 1969 (felt area=324,000 km$^2$). Elgood is a small community just north of the Virginia–West Virginia border north of Giles County. Thus, there has been an apparent modern renewal of seismic activity (nine felt earthquakes in 1959–76) in or near Giles County (table 1).

This report has three purposes:

1. It presents and interprets results of a recent seismic monitoring program in the Giles County locale. (We define the Giles County locale as that area within 50 km of Pearisburg.) The first section of the report achieves this purpose.
2. The report attempts to integrate those results of the seismic monitoring program with what is known or reasonably inferred about local and regional geologic structure at seismic focal depths, which is accomplished in the second and third sections

TABLE 1.—*Chronological listing of earthquakes that occurred prior to 1978 in the Giles County, Va., locale (within 50 km of Pearisburg, Va.)*

[Data sources: Reagor and others (1980a, b). Letter code for "Quality" column is defined as follows: Determination of instrumental hypocenters is estimated to be accurate within the ranges of latitude and longitude listed; each range is letter coded as indicated--A, 0.0°-0.1°; B, 0.1°-0.2°; C, 0.2°-0.5°; D, 0.5°-1.0°; E, 1.0° or larger. Determination of noninstrumental epicenters from felt data is estimated to be accurate within the ranges of latitude and longitude listed below; each range is letter coded as indicated--F, 0.0°-0.5°; G, 0.5°-1.0°; H, 1.0°-2.0°; I, 2.0° or larger. Body-wave magnitude ($m_{bLg}$) (Nuttli, 1973; Bollinger, 1979); MM, Modified Mercalli intensity rating in Roman numerals (Wood and Newmann, 1931). Leaders (---) indicate no value available]

| Date | | | Locality | Origin time (UTC) | | | Latitude (north) | Longitude (west) | Depth (km) | Quality | Magnitude ($m_{bLg}$) | Intensity (MM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Month | Day | | Hours | Minutes | Seconds | | | | | | |
| 1876 | Dec. | 21 | Wytheville, Va. | 15 | 30 | -- | 36.9° | 81.1° | -- | G | ---- | II |
| 1879 | Sept. | 1 | ----do---------- | 12 | -- | -- | 36.9° | 81.1° | -- | G | ---- | II |
| 1885 | Feb. | 2 | ----do---------- | 12 | 10 | -- | 36.9° | 81.1° | -- | G | ---- | IV |
| 1897 | May | 3 | Pulaski, Va.---- | 17 | 18 | -- | 37.1° | 80.7° | -- | G | [1]4.3 | VII |
| 1897 | May | 3 | ----do---------- | 19 | -- | -- | 37.1° | 80.7° | -- | G | ---- | III |
| 1897 | May | 3 | ----do---------- | 21 | 10 | -- | 37.1° | 80.7° | -- | G | ---- | III |
| 1897 | May | 3 | ----do---------- | 23 | -- | -- | 37.1° | 80.7° | -- | G | ---- | III |
| 1897 | May | 31 | Pearisburg, Va. | 18 | 58 | -- | 37.3° | 80.7° | -- | G | [1]5.8 | VIII |
| 1897 | June | 29 | ----do---------- | 03 | -- | -- | 37.3° | 80.7° | -- | G | [1]4.0 | IV |
| 1897 | Sept. | 4 | Wytheville, Va. | 11 | -- | -- | 36.9° | 81.1° | -- | G | ---- | III |
| 1897 | Oct. | 22 | ----do---------- | 03 | 20 | -- | 36.9° | 81.1° | -- | G | ---- | V |
| 1898 | Feb. | 5 | ----do---------- | 20 | -- | -- | 37.0° | 81.0° | -- | G | [1]4.3 | VI |
| 1898 | Feb. | 6 | ----do---------- | 02 | -- | -- | 37.0° | 81.0° | -- | G | ---- | II |
| 1898 | Nov. | 25 | ----do---------- | 20 | -- | -- | 37.0° | 81.0° | -- | G | [1]4.6 | V |
| 1899 | Feb. | 13 | ----do---------- | 09 | 30 | -- | 37.0° | 81.0° | -- | G | [1]4.7 | V |
| 1902 | May | 18 | Blacksburg, Va. | 04 | -- | -- | 37.3° | 80.4° | -- | G | ---- | V |
| 1917 | Apr. | 19 | Wytheville, Va. | -- | -- | -- | 37.0° | 81.0° | -- | I | ---- | II |
| 1959 | Apr. | 23 | Virginia-West Virginia border. | 20 | 58 | 40.2 | 37.40° | 80.68° | 1 | A | [2]3.8 | VI |
| 1959 | July | 7 | Pearisburg, Va. | 23 | 17 | -- | 37.3° | 80.7° | -- | F | ---- | IV |
| 1959 | Aug. | 21 | ----do---------- | 17 | 20 | -- | 37.3° | 80.7° | -- | F | ---- | IV |
| 1968 | Mar. | 8 | Narrows, Va. | 05 | 38 | 15.7 | 37.28° | 80.77° | 8 | A | 4.1 | IV |
| 1969 | Nov. | 20 | Elgood, W.Va. | 01 | 00 | 09.3 | 37.45° | 80.93° | 3 | A | 4.6 | VI |
| 1974 | May | 30 | Virginia-West Virginia border. | 21 | 28 | 35.3 | 37.46° | 80.54° | 5 | A | 3.6 | V |
| 1975 | Mar. | 7 | Blacksburg, Va. | 12 | 45 | 13.5 | 37.32° | 80.48° | 5 | A | 3.0 | II |
| 1975 | Nov. | 11 | Giles-Bland Counties, Virginia, border. | 08 | 10 | 37.6 | 37.22° | 80.89° | 1 | A | 3.2 | VI |
| 1976 | July | 3 | Virginia-West Virginia border. | 20 | 53 | 45.8 | 37.32° | 81.13° | 1 | A | [3]2.1 | --- |

[1]Nuttli and others (1979).
[2]J. W. Dewey and D. W. Gordon (written commun., 1980).
[3]G. A. Bollinger (unpub. data, 1976).

of the report. Our goal of integrating results from diverse portions of seismology and geology has required us to write for two audiences. Thus, we have included some material that may seem unnecessary to members of one audience or the other. As geologists and seismologists reviewed drafts of this report, some specialists in each discipline questioned inclusion of some of the details. So, we have relegated highly specialized material to appendixes, but in general we have preferred to risk too much detail rather than to chance omitting something of interest or importance.

3. To the extent that the second purpose is fulfilled, the report can contribute to improved evaluation of seismic hazard. Throughout much of the Western United States, many known or suspected seismic faults are exposed for study, together with the geologic evidence of their past activity. The best known example is the San Andreas fault zone. There, the geologic record forms an important

adjunct to records of historical and instrumental seismicity, and the resolution and reliability of hazard evaluation benefit markedly. In sharp contrast, throughout most of the East any seismic faults are buried beneath sediments, sedimentary rocks, or thrust sheets. Thus, evaluation of seismic hazard in the East often must be based mostly or entirely on the historical seismic record. However, in most Eastern areas, evaluation would benefit if seismicity could be associated with individual faults or classes of faults, whether buried or exposed. The geological characteristics of such faults could then be used to infer where else in the East similar faults might occur, and might also be subject to seismic reactivation like that which occurred in 1897. In this way an evaluation of the seismological and geological characteristics of Giles County may lead eventually to enhanced evaluation of seismic hazard for urban centers, critical facilities, and lifelines far removed from semirural Giles County itself.

Since 1962, a Worldwide Standard Seismograph Network (WWSSN) Observatory (call letters: BLA) has been in operation at Blacksburg, Va., some 35 km southeast of Pearisburg, the county seat of Giles County. Operation of a five-station network, centered in Giles County, began in April 1978. (See fig. 2 and frontispiece.) That network was designed to enclose the aforementioned concentration of historical and recent epicenters. Following discussions of terminology and local geology, we will present the results of that network monitoring.

A reviewed but mostly unedited draft of this report was published by Bollinger and Wheeler (1982) and summarized by Bollinger and Wheeler (1983). This report and that of Bollinger and Wheeler (1982) differ only in editorial details, the addition of explanatory material dealing mostly with regional geology and seismological matters, addition or completion of citations of references that were unpublished in 1982, changes of 1-2 km in earthquake locations and their locational uncertainties as more data have become available, and the revision and expansion of Appendix D. Monitoring and analysis of earthquakes after December 1980 (Munsey and Bollinger, 1984; Bollinger and others, 1985; Gresko, 1985; Viret and others, 1986) support and build on the conclusions of this report and those of Bollinger and Wheeler (1982, 1983) and suggest no reason to change those conclusions.

## TERMINOLOGY

Some of the terms used in this report should be defined and their usage explained, because usage differs from one specialty to another, usage changes rapidly, and in some contexts the terms have economic and legal implications. Some abbreviations are also defined.

**balanced cross section** A cross section that has been drawn so that the structures depicted satisfy certain geometric rules. Balancing is usually applied to sections that are drawn through a thrust belt (Dahlstrom, 1969; Hossack, 1979). The goal is to produce a section that accurately depicts the geometries of buried structures, at depths where direct information about the geometries is sparse. Balancing involves comparison between two cross sections: (1) an undeformed section that represents the lengths and thicknesses of strata as they are inferred to have been before the deformation, and (2) a deformed section that shows structures as they are inferred to be now. Mass must be conserved between the two sections. This required conservation of mass, and appropriate assumptions, are expressed as geometric rules that the deformed section must satisfy. One rule that is commonly used is that the cross sectional area of each stratigraphic unit must be conserved so that the deformed section can be pulled apart into an undeformed section without producing gaps or overlaps. Another common rule specifies that bed length across the deformed section must be the same for all units that have buckled and faulted but have not flowed internally. A deformed section that matches the corresponding undeformed section, according to the geometric rules and within the limits of available data, is said to be balanced. Subsurface data are usually sparse, and different assumptions can produce different geometric rules, so several different deformed sections may balance a particular undeformed section. Thus, balancing cannot guarantee that a particular deformed section is correct. However, if a deformed section is unbalanced, and if the imbalance cannot be explained, then the deformed section must be wrong. Thus, at the least, balancing can narrow the range of possible geometries of subsurface structures. Balancing by hand is tedious, so some workers balance their sections only partly, for example by balancing bed lengths but not cross sectional areas, or by balancing shallow structures but not deep ones. The recent advent of interactive computer programs is a great aid to balancing.

**confidence ellipsoid** A measure of the locational uncertainty of a calculated earthquake hypocenter. The size, shape, and orientation of the ellipsoid are measures of the uncertainty of the latitude, longitude, and depth of the calculated hypocenter. The equation of the ellipsoid is calculated so that there is a specified probability, usually 0.68, 0.90, or 0.95, that the true hypocenter falls within the ellipsoid (J. W. Dewey and D. W. Gordon, written commun., 1980; Dewey and Gordon, 1984). Then the ellipsoid is referred to as, for example, the 0.90 confidence ellipsoid or the 90-percent confidence ellipsoid. Most confidence ellipsoids are tilted, so that their semimajor axes are not vertical or horizontal. The projection of the ellipsoid onto a plane, such as a horizontal map or a vertical cross section, is a confidence ellipse. Equivalent terms are error ellipsoid and error ellipse, and hypocenter ellipsoid and epicenter ellipse.

**dB** Decibels.

**ERH, ERZ** Measures of the locational uncertainty of a calculated earthquake hypocenter, in terms of the confidence ellipsoid (Lee and Lahr, 1975). ERZ is half the length of a vertical line that spans the ellipsoid and passes through its center. ERH is half the greatest width of a horizontal cross section through the center of the ellipsoid. Thus, ERZ measures depth uncertainty, and ERH, map or epicentral uncertainty. Because most confidence ellipsoids are tilted, ERZ and ERH generally do not correspond to semiaxes of the ellipsoids.

**felt area** The size of the area over which an earthquake was sensibly felt or otherwise noticed by humans.

**hazard** or **risk** These concepts have been expressed as verbal descriptions, numerical values, and probabilities that a specified value will be exceeded in a specified time at a specified site. However, one distinction is common and we shall follow it here: Hazard refers to the geologic effects of an earthquake; whereas, risk refers to its societal effects (Hays, 1979; Earthquake Engineering Research Institute Committee on Seismic Risk, 1981, 1984). Because we do not use the term "risk" herein, that distinction will suffice for our needs.

**hypocenter** The three-dimensional location of an earthquake within the Earth, usually specified by latitude, longitude, and depth below some datum.

**intensity** A standardized, qualitative measure of the effects of an earthquake at a particular place. Intensity is expressed as a Roman numeral and determined for that place by comparing the earthquake's effects there with written lists of effects on man-made structures, natural systems, and human behavior. The most commonly used list of effects gives Modified Mercalli Intensity (MMI) with 12 divisions, I-XII. For example, people usually feel earthquakes of MMI=II or III or greater, and structural damage to buildings usually does not occur below MMI=VI or VII (Wood and Newmann, 1931).

**interference structure** A complex structure formed when a younger structure deforms an older one. Examples include folded folds, folded faults, faulted folds, and faulted faults. Two interfering structures bear an interference relationship to each other.

**magnitude** A measure of the strength or size of an earthquake, usually expressed in Arabic numerals. Magnitude is a measure of the energy released by the earthquake as elastic waves. Two earthquakes whose magnitudes differ by 1 differ by a factor of 10 in the amplitude of their elastic waves and by a factor of about 30 in the energy released. Various ways of calculating magnitudes produce slightly different results, because different seismic waves of the seismograms are measured. The types of magnitudes used in this report are $M$ (unspecified type of magnitude), $M_L$ (Richter magnitude, measured on a specific type of seismograph), $m_b$ (magnitude calculated from body waves of distant earthquakes), $M_S$ (magnitude calculated from surface waves of distant earthquakes), and $m_{bLg}$ (also written $m_b(L_g)$; similar to $m_b$ but modified to use a short-period type of surface wave; for application to Eastern earthquakes).

**microearthquake** A small earthquake not felt by humans. In this report, an earthquake with a magnitude of less than or equal to 2.

**seismogenic fault** A fault that generates earthquakes.

**seismic zone** This term has two different meanings. One refers to engineered structures, and is "a generally large area within which seismic-design requirements for structures are constant" (Earthquake Engineering Research Institute Committee on Seismic Risk, 1984). The other meaning refers to a volume or area defined by a group of hypocenters or epicenters that are presumed to be related because they are considered to form a single spatial pattern. We will use seismic zone in its second meaning, as in "seismicity of the Giles County seismic zone."

**structure** We will use this term in accordance with the usage common in structural geology: "1. The way in which a rock, a rock-mass, or a whole region of the earth's crust is composed of its component parts: the form and mutual relations of the parts of a rock * * * 2. Structural discontinuity of any kind occurring in rock bodies" (Dennis, 1967, p. 145). For example, the structure of the Valley and Ridge province of the Appalachians can be described as a complex of thrusting-related folds and mostly shallowly dipping faults. Also, a discontinuity in rock properties, such as an igneous or erosional contact that cuts across beds, is a structure. Such a discontinuity could concentrate enough stress to cause seismicity at a point, line, or surface, but the presence of such a structure is not in itself grounds for inferring the presence of a fault or the likelihood of seismicity. We will not use structure as a synonym for fault.

**velocity model** A mathematical representation of vertical changes in the velocity of seismic waves through the Earth. In the models of this report, the Earth is represented by several horizontal layers overlying an infinite half-space. Each layer or half-space of the model has its own constant velocity. The velocity layers usually bear little relation to the stratigraphic units of the geologist, because most of these units are too thin, differ too little in velocity to be resolvable by the seismic wavelengths of interest, or both. For example, most velocity models used in the Southeastern United States have the several kilometers of sedimentary rock represented by one to three velocity layers, and the entire velocity model typically has three to five layers to represent the crust and upper mantle.

## GEOLOGIC SETTING

### INTRODUCTION

This report uses the widely accepted division of the Appalachians into structural provinces, each characterized by a distinctive combination of exposed stratigraphy, structural styles, and degree of metamorphism. Geologic aspects of this report deal with structures and stratigraphy that are exposed at ground level, and with structures that are inferred to exist in the subsurface. Accordingly, the division into structural provinces is more appropriate for our purposes than is the older division into physiographic provinces, which we will not use. For more detailed descriptions of the structural provinces than are appropriate here, see Rodgers (1970).

From northwest to southeast in southwestern Virginia and adjacent States, the structural provinces are the Appalachian Plateau, Valley and Ridge, Blue Ridge, and Piedmont Plateau provinces. The LANDSAT image on the cover shows the characteristic topographic expressions of the rock types, structural styles, and levels of metamorphism that characterize each province.

The strongly defined, linear ridges that cross the center of the cover image from southwest to northeast identify the western Valley and Ridge province. The ridges are limbs of breached anticlines, some cut by southeast-dipping thrust faults. The ridges and intervening valleys expose unmetamorphosed sedimentary rocks. Most are sandstones, siltstones, shales, and some limestones, of middle Paleozoic age. Southeast of the ridges lies the Great Valley or eastern Valley and Ridge province. Structural style is similar to that in the western part of the province, but the rocks exposed in the Great Valley are mostly unmetamorphosed to slightly metamorphosed limestones and dolomites of early Paleozoic age. In the humid climate of this region, these rocks weather to form flat to rolling farmland, mostly light colored in the image. Here and there in the Great Valley are steep ridges, supported by middle Paleozoic sandstones preserved in synclinoria.

Because the topography of the Valley and Ridge province reflects structural style and orientation so clearly, the province best shows the junction of the central and southern Appalachians. In the north-central part of the image, north-northeast-trending structures of the central Appalachians interfinger with and are replaced southwestward by east-northeast-trending structures of the southern Appalachians.

The Blue Ridge and Piedmont Plateau provinces lie southeast of the Valley and Ridge province. Their topographic expressions are varied in the image, but the expressions are mostly finely lineated, with subdued topography and structural grain. Exposed in these two provinces are metamorphic rocks of diverse Precambrian and Paleozoic ages, origins, and degrees of metamorphism.

Northwest of the Valley and Ridge province lies the Appalachian Plateau province, a rugged, heavily dissected region that exposes mostly sandstones, shales, and coals of late Paleozoic age. Most beds lie flat in the northwest corner of the image, but bed dips increase southeastward toward the Valley and Ridge province. Here and there in the easternmost Appalachian Plateau province are anticlines whose amplitudes and limb dips give them a structural style between the tighter folding of the Valley and Ridge province and the gentler folding of the Appalachian Plateau province. Where such anticlines are present, topographic expression alone makes the Valley and Ridge province seem unusually wide. Examples occur in the northern third and at the western edge of the cover image. However, most workers place such structures in the Appalachian Plateau province because of their structural style and the age of the exposed rocks. We follow such usage here, using the boundary between the two provinces as that of Rodgers (1970, p. 5–8). At the latitude of Giles County, the province boundary is so sharp structurally, stratigraphically, and topographically that it forms most of the northwestern county line and the West Virginia–Virginia border.

Thus, Giles County, Va., lies at the western edge of the Valley and Ridge province (fig. 2). The Giles County locale, defined previously as the area within about 50 km of Pearisburg, lies mostly in the Valley and Ridge province but overlaps into the Appalachian Plateau province. Ground elevation ranges from about 0.6 km to about 1.2 km above sea level but is about 1 km in most places. Figure 2 shows locations of the five seismograph stations of the Virginia Polytechnic Institute seismic network that form a subnetwork in the Giles County locale.

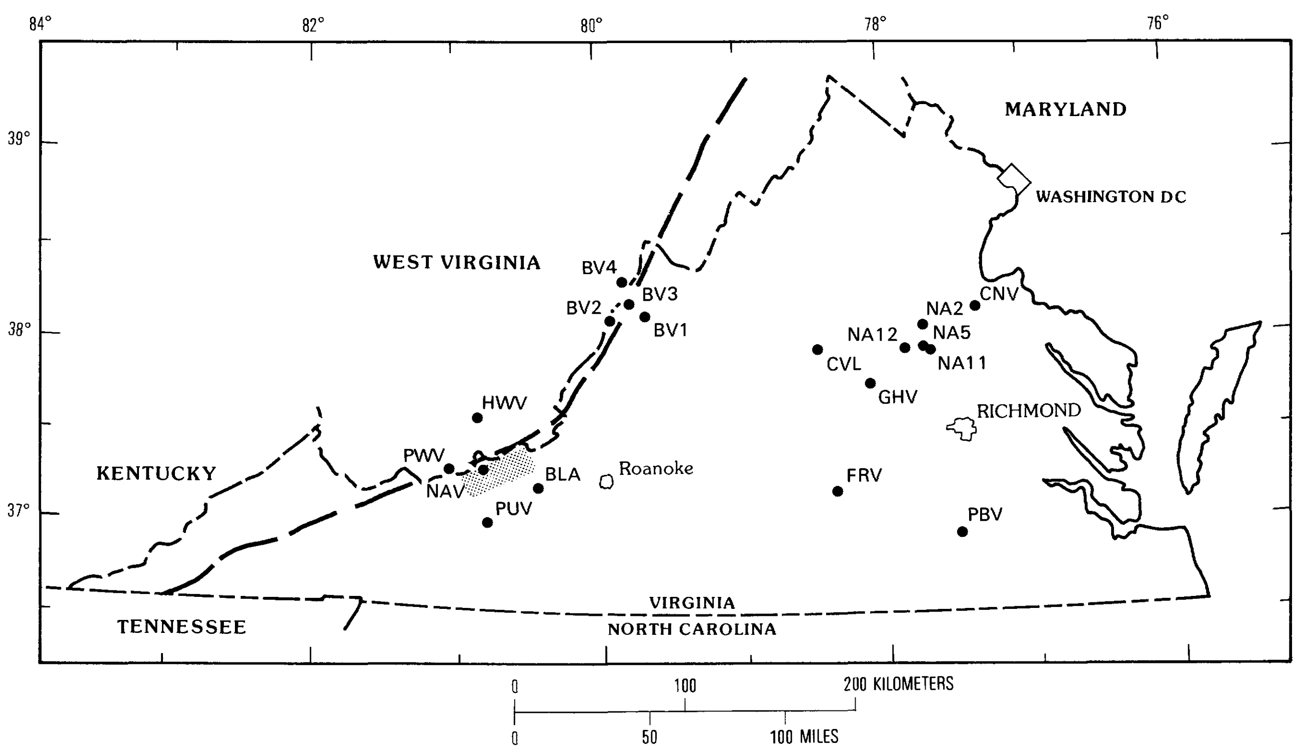



FIGURE 2.—Map showing the Virginia Polytechnic Institute Seismic Network. Modified from Bollinger (1981a) with permission. Locations of individual seismograph stations are shown by solid circles. Stations are identified by their three- or four-character formal names. Dashed line divides Appalachian Plateau (on northwest) and Valley and Ridge (on southeast) provinces (Rodgers, 1970, pl. 1A). Solid lines are State boundaries. Shaded area defines Giles County.

## STRATIGRAPHY AND STRUCTURE

Most of the stratigraphic units and structures that are exposed in and near the Giles County locale are not pertinent to an interpretation of seismicity under that locale. The reason is that all pre-Mesozoic near-surface rocks from the eastern Appalachian Plateau province southeastward have been thrust to the northwest during Paleozoic deformation, and the earthquakes occur below the deepest known thrust faults. Evidence to support those statements will be given in following sections of this report, but their consequence is that whatever structures cause the earthquakes have nothing obvious to do with exposed structures or stratigraphic units.

Accordingly, descriptions of stratigraphy, structures, and tectonic evolution will be confined to general summaries and to details that will be used in subsequent discussions and arguments. Most structures and stratigraphic units of the Giles County locale and environs will not be mentioned because they have no bearing on our discussion. Also, most of the geological arguments of this report deal with stratigraphic units and structures that, in and near Giles County, remain buried under thrust sheets or have been removed by erosion. Our arguments will draw on evidence from areas where those units and structures are exposed or preserved. Some of those areas are distant from the Giles County locale; for example, up to several hundred kilometers away in western West Virginia. Thus, what may seem like a tendency to ignore the study area arises from the need to determine what is under Giles County, not what is exposed in it.

Stratigraphy and rock type have strongly influenced structural style in the parts of the Valley and Ridge and Appalachian Plateau provinces near Giles County. That influence is summarized in figure 3. Column *B* of figure 3 summarizes the rock types that dominate various parts of the stratigraphic column, as exposed throughout Virginia and West Virginia. The Precambrian basement complex is overlain by the Late Proterozoic to Lower Cambrian basal clastic rocks of the Appalachians. The lower Paleozoic rocks are mostly a thick sequence of carbonate rocks of Cambrian and Ordovician ages. Most of the rest of the preserved sequence is clastic, although limestones occur in the Silurian and Devonian part. Clastic wedges of Ordovician, Devonian, and late Paleozoic ages contain the erosional record of parts of the Taconic, Acadian, and Alleghany orogenic episodes. Mississippian and older rocks are mostly marine; younger rocks are mostly continental. The youngest preserved rocks are Permian, which overlie the Pennsylvanian coal measures of West Virginia and adjacent States.

Column *C* of figure 3 shows what might be termed a structural stratigraphy. The Paleozoic sequence has been thrust northwestward during Paleozoic deformational episodes. The distance of northwestward transport decreases to the northwest, because the thrust masses telescoped as they moved. Thrust faults occur preferentially in shaley, thin-bedded parts of the sequence. Paired arrows show the four places in the stratigraphic sequence in which large thrust faults most commonly formed. The deepest thrusts are found in the Lower Cambrian shales (locally named the Rome Formation). Rocks below the Rome Formation form structural basement, which is not known to have been thrust northwestward. Shallower rocks have ridden northwestward on one or more of the intervals indicated in figure 3, on smaller thrust faults elsewhere in the section, or on both. Which thrust faults were active at a particular time and place varies in complex fashions. Not all thrusts formed or moved at once, and facies changes cause the shaley sequences that localize the thrusts to rise and fall stratigraphically, and to thicken and thin both along and across strike. Such complexity does not alter the important fact that rocks above the Rome

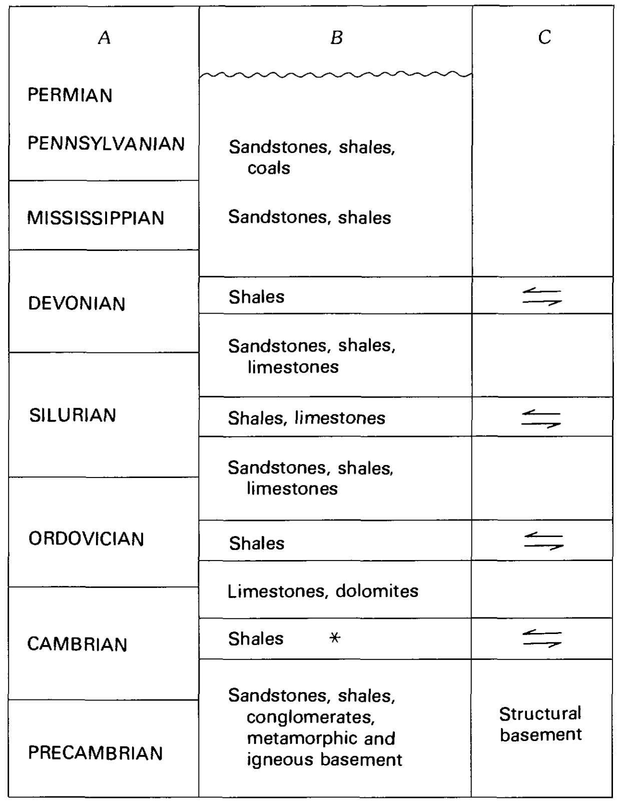



FIGURE 3.—Sketch summarizing the stratigraphy of the central and southern Appalachians in and near Giles County, Va., and its relationship to the dominant structure there. *A*, The age range of units exposed in and near the Giles County locale. *B*, Dominant rock types in various portions of the stratigraphic column. Asterisk identifies the shales of the Lower Cambrian Rome Formation. *C*, Paired arrows identify the stratigraphic and lithologic positions that commonly contain the largest thrust faults.

Formation, including all exposed rocks older than Mesozoic in and near the Giles County locale, have been thrust northwestward.

### INDEPENDENCE OF SEISMOGENIC AND EXPOSED STRUCTURE

Interpretations of data from public and proprietary wells and reflection seismic surveys show that the sedimentary rocks are underlain by metamorphic and igneous basement at depths of 10,000–19,000 ft (3–6 km) subsea (section *F-F'* of Cardwell and others, 1968; Shumaker, 1977, and in Negus-deWys, 1979, and Negus-deWys and Renton, 1979; Kulander and Dean, 1978b; Compudepth map of Seay, 1979; Perry and others, 1979; Kelly, 1978). Those depths correspond to 4–7 km below ground level. Accordingly, structures in rocks shallower than 4–7 km are unrelated to deeper structures (for example, see fig. 4 of Perry and others, 1979, and the more generalized section V3 of Roeder and others, 1978). In particular, we know of no reason to suspect any simple relationship between (1) outcropping faults or other obvious aspects of surface geology and (2) structures at the depths of the seismicity in the Giles County locale (at least 5 km, as documented later in table 4).

On a scale of hundreds of kilometers, most large exposed, shallow subsurface and deeper crustal structures in the Appalachians, adjacent craton, and Coastal Plain are roughly parallel to each other. They are roughly parallel because the Atlantic Ocean opened approximately where an older ocean had opened and then had closed to form the Appalachians (Wilson, 1966; p. 28–37 of this report). Parallelism on such a scale is too general to be of much aid in geological interpretation of seismicity within small areas like Giles County and, indeed, may hinder such interpretation because it limits our ability to distinguish structures by their azimuthal orientations. Thus, such parallelism of structures in eastern North America does not affect our conclusion that we expect no simple relationship between surface structures and seismicity in or near Giles County.

Two lines of evidence might appear to conflict with that conclusion, but on examination, do not. First, independence of structure above and below the thrust faults is best established farther north, in the central Appalachians (Gwinn, 1964; Rodgers, 1963). The possibility remains of subtle control of Paleozoic depositional systems by ancient topography created by movement on then-active faults in the underlying basement. Then, the thicknesses of Paleozoic sedimentary units would reflect that ancient topography (Cooper, 1961, p. 100–118, 1964; Thomas, 1982b). Such control is perhaps more likely in the southern than in the central Appalachians although there are clear examples in western West Virginia, near the cratonward edge of the Appalachians (Schaefer, 1979; Shumaker and others, 1979; Donaldson and Shumaker, 1981; Nuckols, 1981). However, Geiser (1977) pointed out that the same sedimentological patterns could be produced by thrust-related anticlines that were growing during deposition of the sediments in question. Thus, any such sedimentological patterns would not necessarily be evidence that basement faults are reflected in surface geology.

Second, J. W. Dewey and D. W. Gordon (written commun., 1980) calculated the location of the 1969 Elgood, West Virginia, earthquake ($m_b = 4.6$, event J of table 7). They obtained a depth of 2.5 km below ground level for the hypocenter. All other reliable hypocentral depths in the Giles County locale are deeper, within the basement. The top of basement near Elgood is at an approximate subsurface depth of 4–5 km, so the Elgood focal depth is apparently well within the sedimentary rocks. However, from J. W. Dewey's and D. W. Gordon's results (written commun., 1980), the vertical semiaxis of the 90-percent confidence ellipsoid about the hypocenter is estimated to be 6 km. Thus, the probability is 0.90 that the depth of the Elgood earthquake was about 8.5 km or less. Furthermore, near Elgood the deepest thrust faults are only from 3 km to about 3.5 km below the surface (fig. 4 of Perry and others, 1979; W. J. Perry, Jr., oral commun., 1980). As much as another 3 km of unthrust sedimentary rocks underlie those deepest thrust faults, separating the faults from the top of metamorphic and igneous basement (Perry and others, 1979). Those sedimentary rocks beneath the thrust faults are structurally part of the basement (fig. 3, column *C*). Thus, the depth calculated by Dewey and Gordon for the Elgood earthquake, taken with the 6-km uncertainty implied by the confidence ellipsoid, is not inconsistent with the earthquake having occurred either in the metamorphic and igneous basement, or in the unthrust sedimentary rocks below the deepest thrust faults. In addition, Herrmann (1979) calculated a depth of 5 km for the Elgood earthquake, using surface-wave data, and Carts (1981) calculated a well-constrained depth of 13.6 km using the computer program HYPO71 (Lee and Lahr, 1975). The associated vertical location error parameter, ERZ, was 1.4 km using a locale-specific velocity model. Thus, of the three depths calculated for the Elgood earthquake, two place it below the thrust structures and the third has too large an uncertainty to contradict such a depth. We, therefore, retain our conclusion that seismicity in the Giles County locale appears to bear no simple relationship to surface geology. Later, we shall consider faults or classes of faults that are known or inferred to exist in the basement and that lack obvious expression in the surface geology, and which thus could be responsible for the observed seismicity.

# SEISMICITY OF THE GILES COUNTY, VIRGINIA, LOCALE

## NETWORK MONITORING PROGRAM

The Giles County network is a five-station subnetwork of the Virginia Polytechnic Institute's Seismic Network. The subnetwork is capable of detecting and locating accurately microearthquakes in the nearby area (fig. 2, table 2). Its central station is at Narrows, Va. (station call letters NAV), about 6 km west of Pearisburg, Va., and is located in Mill Creek Valley on the east side of Sentinel Point promontory. (See frontispiece.) The subnetwork aperture (greatest distance between stations) is about 60 km. Monitoring was initiated at NAV in October 1977, and the network installation was completed by mid-April, 1978. All stations have short-period (1 Hz), vertical (SPZ) transducers; however, the Pulaski, Va., (PUV) station also has two short-period horizontals (oriented north-south and east-west, and has been operational since early in 1980). Signals from all five stations are telemetered to a central recording facility on the Virginia Polytechnic Institute

TABLE 2.—*Site, instrumentation, and operation information for the Giles County, Va., subnetwork of the Virginia Polytechnic Institute Seismic Network*

[SPZ, short-period vertical seismometer; $T_o$, free period of seismometer; $T_g$, free period of galvanometer. Timing System: Systron-Donner Time Code Generator 8120[5]. Direction of motion of records: up on record for up on ground. System response curves (see fig. 4). Two horizontal sensors added at PUV early in 1980. Magnifications listed are for the visual recorders]

Site information

| Code | Station name | Latitude (north) | Longitude (west) | Elevation (meters) | Date opened | Foundation geologic age |
|---|---|---|---|---|---|---|
| NAV | Narrows, Va.----- | 37.3157° | 80.7935° | 610 | 10/77 | Ordovician clastics. |
| PUV | Pulaski, Va.----- | 37.0235° | 80.8158° | 652 | 2/78 | Devonian clastics. |
| HWV | Hinton, W. Va.--- | 37.5905° | 80.8408° | 521 | 4/78 | Mississippian clastics. |
| PWV | Princeton, W. Va. | 37.3348° | 81.0488° | 820 | 3/78 | Do. |
| BLA | Blacksburg, Va.-- | 37.2114° | 80.4211° | 634 | 1962 | Cambrian carbonates. |

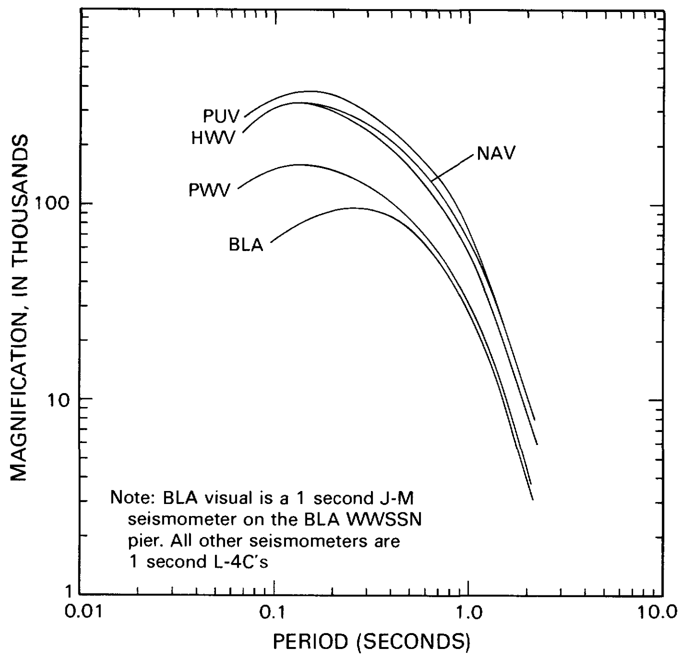
Instrumentation

| Code | SPZ seismometer | $T_o$ (seconds) | $T_g$[1] (seconds) | Type recording[2] | Magnification at $T_o$ | Maximum magnification |
|---|---|---|---|---|---|---|
| NAV | (L4-C)[3] | 1.0 | 0.1 | V,F,T | 65K | 310K at 0.15 s |
| PUV | (L4-C)[3] | 1.0 | .1 | F,T | 75K | 390K at .15 s |
| HWV | (L4-C)[3] | 1.0 | .1 | F,T | 53K | 320K at .15 s |
| PWV | (L4-C)[3] | 1.0 | .1 | F,T | 32K | 160K at .15 s |
| BLA | (J-M)[4] | 1.0 | .1 | V,F,T | 30K | 97K at .30 s |

Operation (To June 1, 1980)

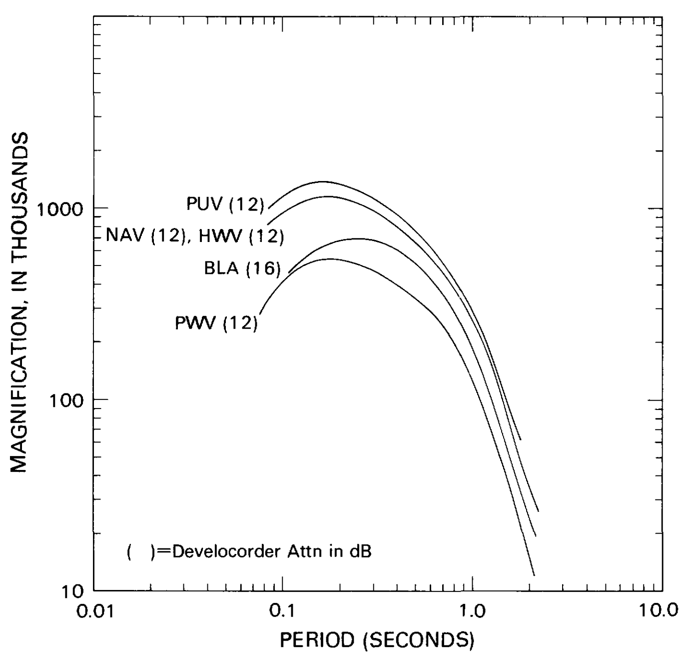
| Code | Years of operation | Total down days | Percent down time |
|---|---|---|---|
| NAV | 2.60 | 33 | 3.5 |
| PUV | 2.24 | 29 | 3.5 |
| HWV | 2.13 | 4 | .5 |
| PWV | 2.21 | 27 | 3.3 |
| BLA | 2.60 | 1 | .1 |

[1]High-cut filter setting.
[2]V, visual; F, 16-mm film; T, FM magnetic tape.
[3]Mark Products design[5].
[4]Johnson-Matheson design[5].
[5]Use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

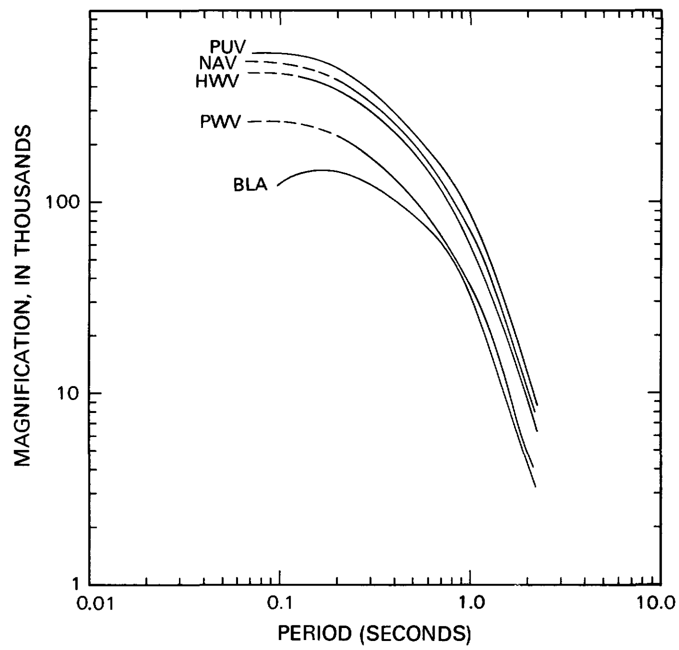



*A.* MAGNIFICATION CURVES – GILES COUNTY, VIRGINIA NETWORK. VISUAL RECORDER CALIBRATION – JANUARY 1979

Direction of motion (all stations): Up on record=Up on ground



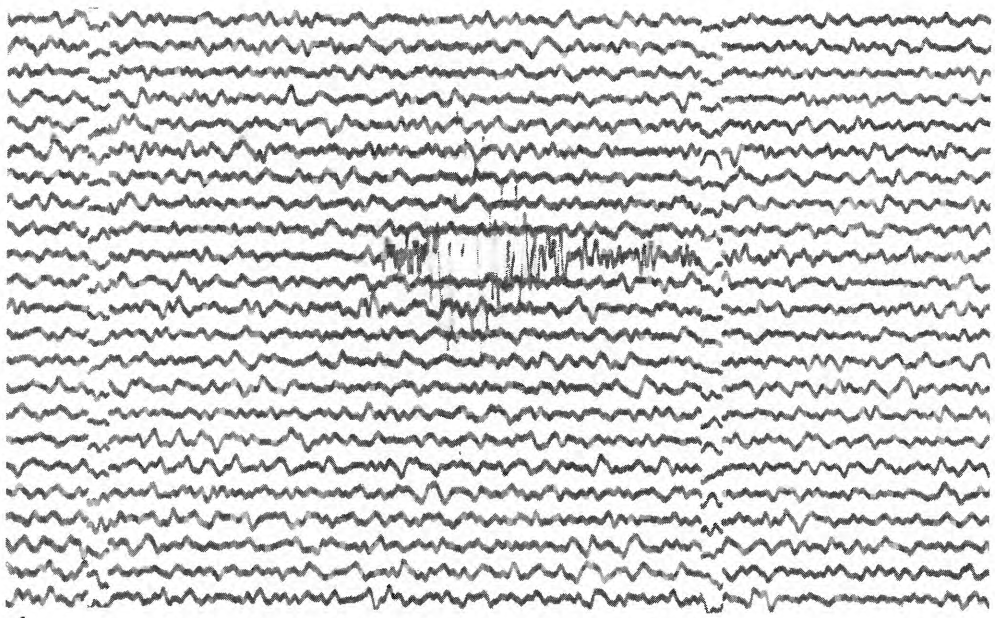

*B.* MAGNIFICATION CURVES – GILES COUNTY, VIRGINIA NETWORK. DEVELOCORDER CALIBRATION – JANUARY, 1979



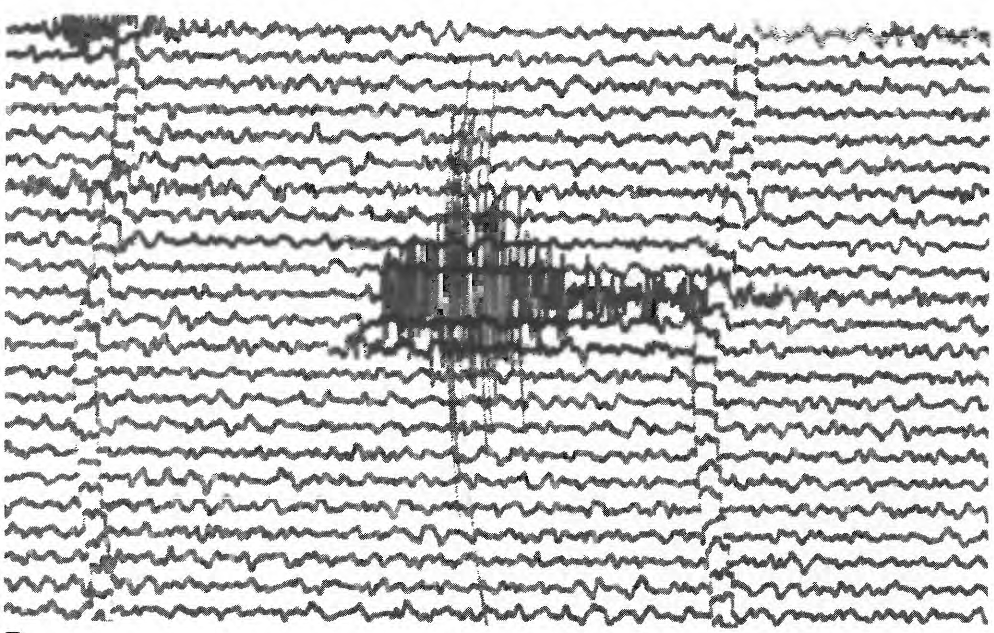

*C.* MAGNIFICATION CURVES – GILES COUNTY, VIRGINA NETWORK. ANALOG TAPE RECORDER CALIBRATION, JANUARY 1979

FIGURE 4.—Magnification curves for the seismographs comprising the Giles County subnetwork of the Virginia Polytechnic Institute Seismic Network. Seismograph stations located in Virginia (BLA-Blacksburg, PUV-Pulaski and NAV-Narrows) and in West Virginia (HWV-Hinton and PWV-Princeton). The magnification is the amount by which the seismograph magnifies the ground motion. Thus, a magnification of 100,000 (100K) means that a ground motion of 1 micron (0.001 mm) would appear (be magnified) on the seismogram as 10 cm (100 mm). The calibration of the seismographs necessary to determine these magnification curves was performed during January 1979. *A*, Visual (pen-and-ink) recorders; seismograph polarities set so that an upward motion of the seismogram trace corresponds to an upward motion of the ground beneath the seismometer. *B*, 16-mm-film recorder. Develocorder Attn in dB gives the attenuation switch setting on the 16-mm-film recorder. Magnifications shown are for the use of a film viewer with its own magnification of 20 times; *C*, Analog tape recorder-playback system. See table 2 for general network information.

campus where they are recorded on 16-mm film and on frequency-modulated (FM) analog magnetic tape. Signals from the central station (NAV) are also recorded on a visual recorder (pen-and-ink) and as an additional, low-gain (30-decibel (dB) reduction) channel on the tape recorder. Seismograph magnifications at the individual stations range from 30 to 300 K at 1 Hz, depending on station and recorder mode and are specified by individual magnification curves. (See fig. 4.) The frequency passband for all recording channels is set by filters at 1–10 Hz. Average microseismic levels, as measured on the 16-mm film records, range from 1 to 60 nanometers at 0.6–3.4 Hz (Sibol, 1980; Appendix A of this report). Figure 5 shows seismograms from a magnitude 1.6 event that occurred near Narrows, and which was recorded on both the BLA WWSSN SPZ (short-period vertical seismograph and the network BLA SPZ (1–10 Hz passband). The increased efficiency of microearthquake



A



B

FIGURE 5.—Sample seismograms for a microearthquake. Two different, short-period, vertical seismograms for the same microearthquake that occurred near Narrows, Va. (January 28, 1978; event no. 32, table 4; magnitude=1.6; minute marks every 60 mm on original seismograms. Scale here is 1 mm on the figure equals about 1.4 mm and 1.4 s on the original seismogram). Both seismometers located on the same pier at Blacksburg, Va. *A*, BLA WWSSN SPZ: magnification is 50K at 1 Hz and 4.5K at 10 Hz. *B*, BLA network SPZ visual: magnification is 28K at 1 Hz and 65K at 10 Hz. (See fig. 4*A*.) Note the increase in signal-to-noise ratio achieved by the increased magnification of the higher ground frequencies by the network station.

recording provided by the network passband is apparent in the figure. That increase is accomplished by emphasizing the higher (5–10 Hz) Earth frequencies.

The capability for detection and location of microearthquakes by the entire Virginia network, according to Tarr (1980), is illustrated in figures 6 and 7 (threshold

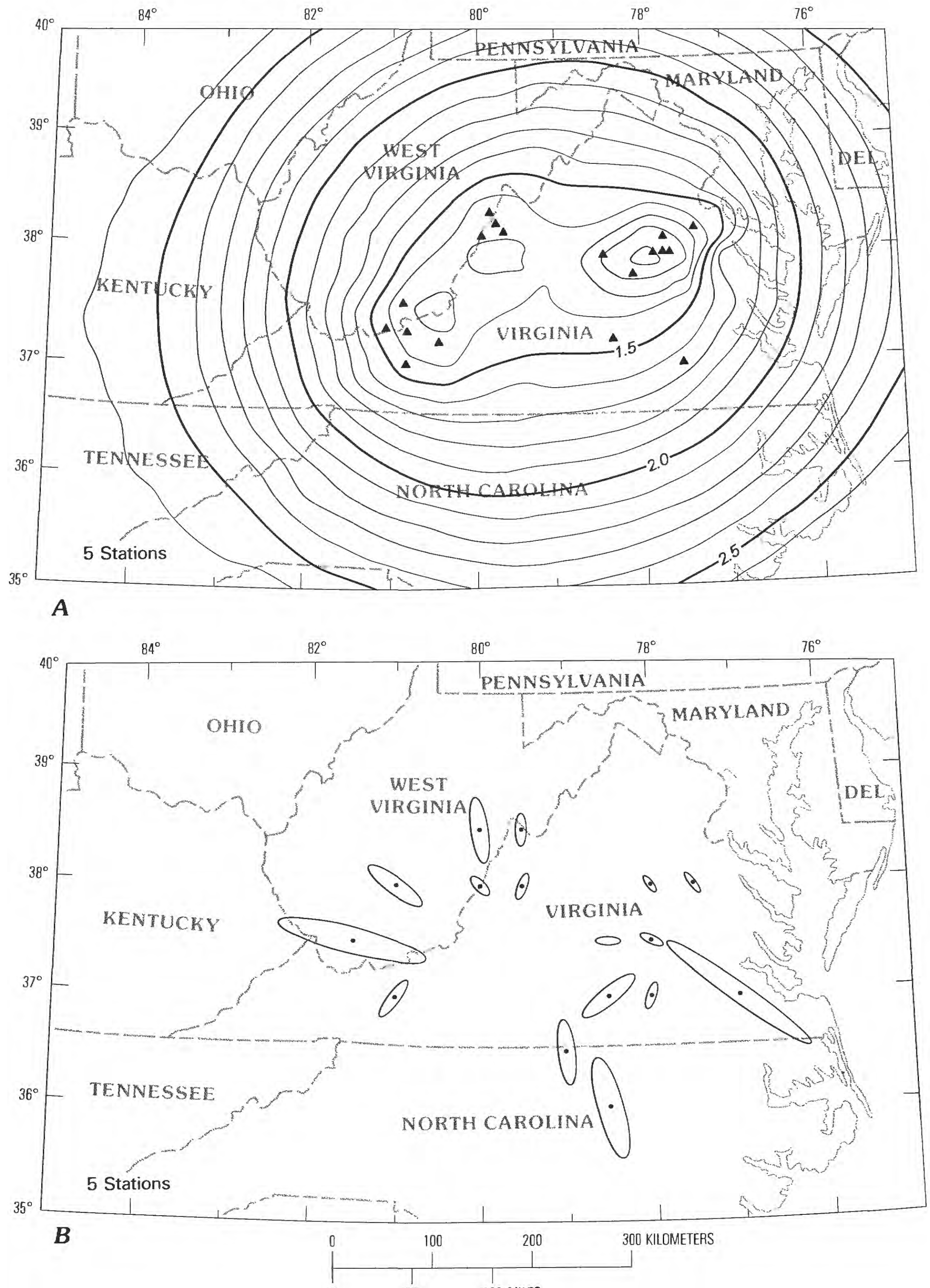



FIGURE 6.—Maps showing capability for detection and location of hypothetical microearthquakes by any 5 stations (solid triangles) of the Virginia Polytechnic Institute Seismic Network (Tarr, 1980). *A*, Ninety-percent probability threshold $m_b$ magnitudes for detection by five or more stations. Contour interval 0.1 $m_b$ unit. *B*, Ninety-percent confidence location ellipses, on a 0.5° latitude and longitude grid, for events detected by five or more stations. Ellipses are calculated for each 0.5° grid point but are not plotted if their semimajor axes are greater than 100 km or if their 95-percent confidence intervals on the focal depth are greater than 100 km. Interpolate only between adjacent grid points; do not extrapolate to grid points at which no ellipses are shown.

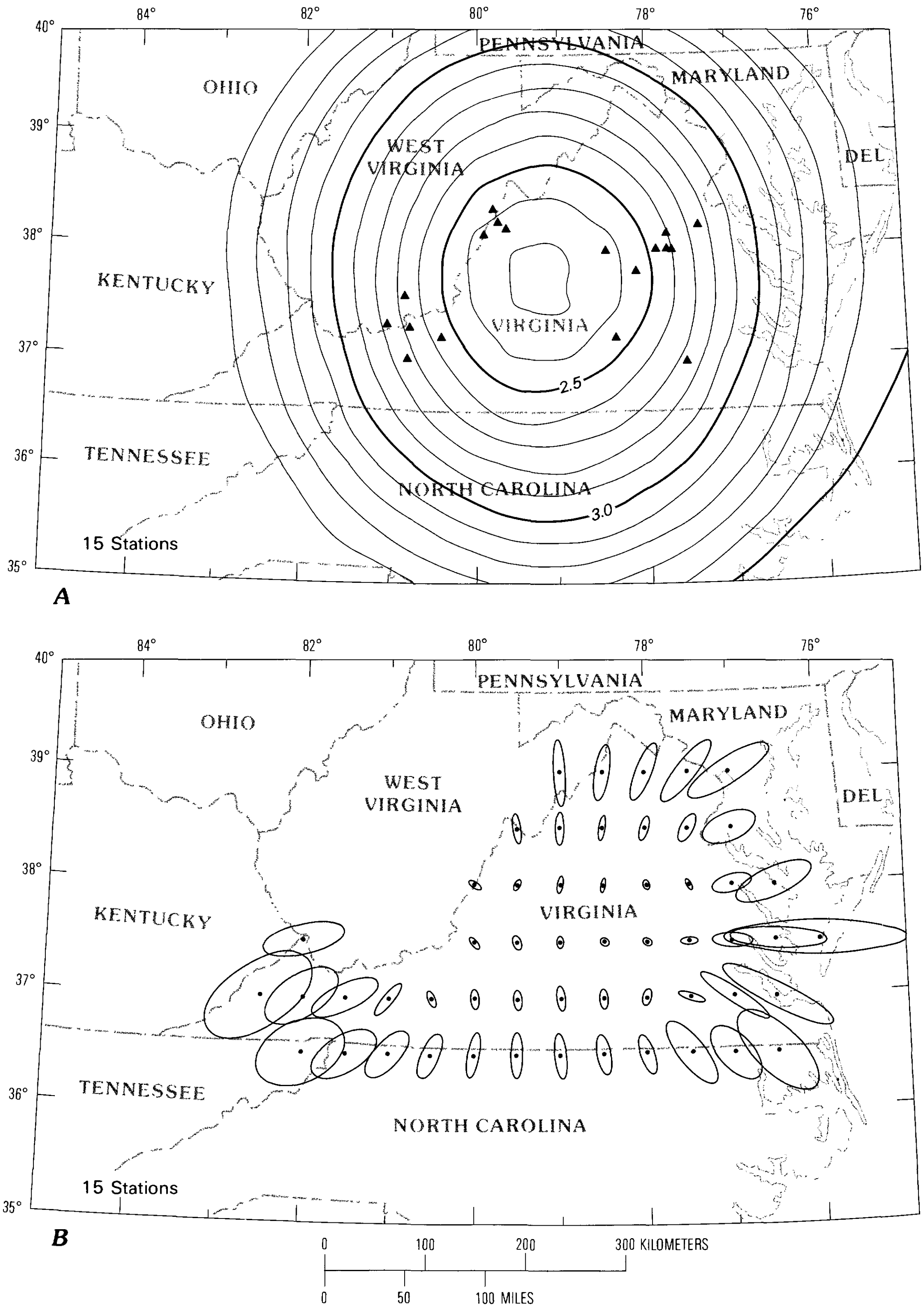



FIGURE 7.—Maps showing capability for detection and location of hypothetical microearthquakes by any 15 stations (solid triangles) of the Virginia Polytechnic Institute Seismic Network (Tarr, 1980). *A*, Ninety-percent probability threshold $m_b$ magnitudes for detection by 15 or more stations. Contour interval 0.1 $m_b$ unit. *B*, Ninety-percent confidence location ellipses, on a 0.5° latitude and longitude grid, for events detected by 15 or more stations. Ellipses are calculated for each 0.5° grid point but not plotted if their semimajor axes are greater than 100 km or if their 95-percent confidence intervals on the focal depth are greater than 100 km. Interpolate only between adjacent grid points; do not extrapolate to grid points at which no ellipses are shown.

body wave ($m_b$) magnitudes and 90-percent confidence ellipses for detection by 5 or more and 15 or more network stations). Note that inside the five-station Giles County network (see fig. 2), detection is complete down to a magnitude somewhat less than 1.5. Figure 8 shows the 90-percent confidence ellipses for $m_b=2$ and $m_b=3$ events detected by five or more network stations. For the Giles County locale, the location capability is seen to be quite good (small error ellipses).

Event size for locally recorded microearthquakes is determined by a duration magnitude relationship established for the Virginia Polytechnic Institute network by Viret (1980; See Appendix B, this report). For larger events, at distances greater than about 45 km, Nuttli's (1973) $m_b$ formulas that use the short-period surface waves (*Lg* phase) are used.

A crustal velocity model for the Giles County network was determined by Moore (1979). He used conventional refraction techniques with local quarries and regional earthquakes serving as seismic sources. He also used a modification of the classical tripartite technique, perturbed to account for wave-front curvature of signals from regional quarry and mine blasts (Chapman, 1979), as an aid in determining the local velocity structure. Moore (1979) obtained two- and three-layer crustal models. A comparison of the error statistics estimated for the hypocentral locations derived from those as well as other available velocity models (Carts, 1980; Appendix C, this report) indicated that Moore's three-layer model, TPM2 (table 3), gave the smallest error estimates for hypocentral parameters. That velocity model has been used throughout this investigation.

## ANALYSIS OF NETWORK EVENTS FROM JANUARY 1978 THROUGH DECEMBER 1980

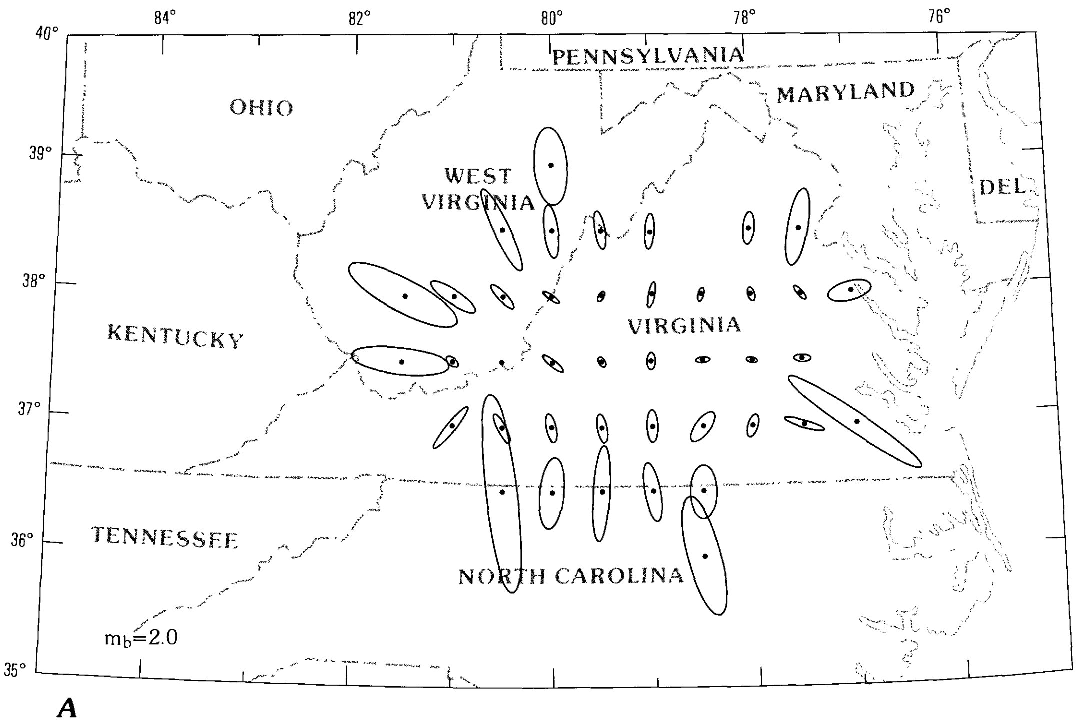
Using the TPM2 velocity model, hypocenters were recalculated using HYPOELLIPSE (Lahr, 1980) for all the seismic events that had occurred since the beginning of network operation. Twelve of these events occurred in the area shown in figure 9. The reductions in the hypocentral errors, as compared to their pre-TPM2 values, were substantial, and 8 of the 12 epicenters (table 4, nos. 32, 33, 35, 37, 38, 46, 58, 63) coalesced to form a northeasterly trending alignment approximately 10 km in width and some 45 km in length (fig. 9). Four epicenters (table 4, nos. 34, 39, 40, 60) lie off the alignment and are interpreted not to have occurred in the Giles County seismic zone but to be part of the background seismicity of the surrounding region. The depth distribution of the 8 foci depicts a nearly vertical zone that extends from about 5 to 26 km in depth (table 4). These rough dimensions of 45 × 10 × 21 km (length × width × depth) define a seismic zone that is tabular (as opposed to planar or volumnar) in configuration.

## TESTS OF THE SEISMIC ZONE

Because the seismic zone is defined by so few foci, evidence that is more objective than the simple visual impression of figures 9 and 13 is required. Appendix D contains discussions of statistical tests and other procedures that provide such evidence. The results of those tests and procedures allow us to conclude that the tabular zone is not random and that we have correctly estimated its orientation.

In addition to use of the hypocenters' statistical error measures to specify the geometry of the Giles County microearthquake zone, another form of testing can be done. By locating known quarry or construction blast sites from the arrival times of their *P* and *S* waves at the network stations and then comparing those calculated locations with the actual locations, the locational capability of the Giles County network can be demonstrated. Thus, the procedure is to pretend that the quarry explosion is an earthquake at an unknown location. Actually, only the epicenter (the horizontal coordinates of latitude and longitude) is tested in such a procedure, because the blasts are only at the surface and not at the deeper earthquake focal depths. But, if the hypocenters determined from the blast data indicate the correct very shallow focal depths, then this is evidence that the velocity model is suitable.

Such a test of the Giles County network and the velocity model (TPM2) was performed. Blasting for a highway bypass being constructed around Pearisburg, Va., was first monitored during December 1979 and then again during May 1980 as a confirming experiment. HYPOELLIPSE (Lahr, 1980) locations were calculated using only network *P* and *S* arrival times. Next, the actual blast locations were spotted on 7.5-minute topographic maps by the shooter. Figure 10 shows the blast locations (designated as A, B, C) and their HYPOELLIPSE locations. Tables 5 and 6 give the small epicenter errors (0.5, 0.9, 2.0 km), and they also show that, although there was lower accuracy in the focal-depth determinations, all determinations that were started well below the surface tended to become shallower than their starting trial focal depths. We interpret the results of these tests to indicate that our earthquake locational capability within the Giles County network is excellent. Blast C, which gave the largest error and the largest uncertainty, consisted of a significantly smaller explosive change than the other two blasts (A and B). The network signals of blast C as a result were not as clear (smaller signal to noise ratio), and thus its calculated location was



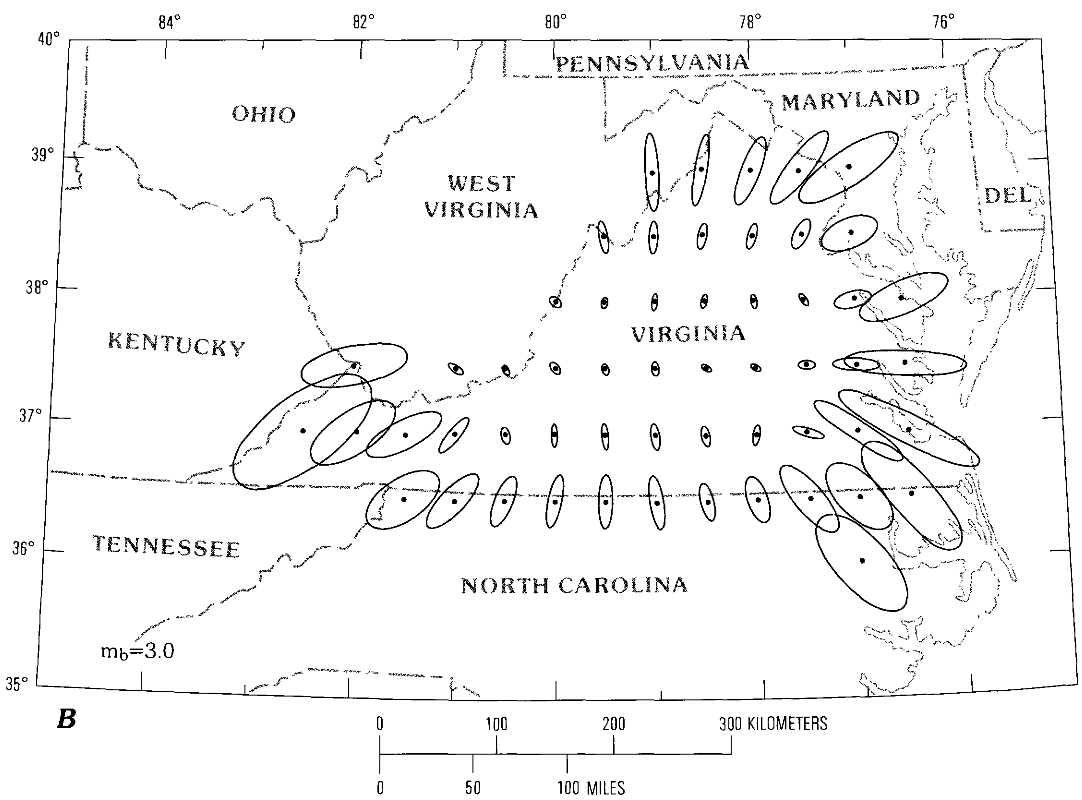




FIGURE 8.—Maps showing 90-percent confidence location ellipses. Ellipses are on a 0.5° latitude and longitude grid, for magnitudes $m_b$=2.0 (in *A*) and $m_b$=3.0 (in *B*) hypothetical events detected by five or more of the Virginia Polytechnic Institute Seismic Network stations (Tarr, 1980). Ellipses are calculated for each 0.5° grid point but are not plotted if their semimajor axes are greater than 100 km or if their 95-percent confidence intervals on focal depth are greater than 100 km. Interpolate only between adjacent grid points; do not extrapolate to grid points at which no ellipses are shown.

TABLE 3.—*Velocity model (TPM2) developed for the Giles County, Va., locale by Moore (1979)*

[km, kilometers; km/s, kilometers per second]

| Depth (km) | P velocity ($V_P$, km/s) | S velocity ($V_S$, km/s) | $V_P/V_S$ |
|---|---|---|---|
| 0 | 5.63 | 3.44 | 1.64 |
| 5.7 | 6.05 | 3.52 | 1.72 |
| 14.7 | 6.53 | 3.84 | 1.70 |
| 50.7 | 8.18 | 4.79 | 1.71 |

expectably not as certain as those with the larger explosive charges.

An additional and important corroboration of the entire northeast-striking zone of microearthquakes was obtained from J. W. Dewey and D. W. Gordon (written commun., 1980). As part of their project to use Joint-Hypocenter-Determination (JHD) techniques (Dewey, 1971) to relocate historical Eastern United States earthquakes, they had relocated six events in the Giles County locale (table 7 and fig. 11). These were all events that were sensibly felt by people ($2.1 \leq M \leq 4.6$) and that occurred between 1959 and 1976, which is prior to the installation of the Giles County seismic network. Four of those six earthquakes relocated directly (within locational uncertainties) on the northeast-striking zone (figs. 11–15; note that the location of station NAV serves as a visual key from one figure to the next).

With the addition of the Dewey and Gordon (written commun., 1980) results, the definition of the Giles County seismogenic zone consists of 12 earthquakes that span four orders of seismic magnitude ($0 \leq M \leq 4$), span some 20 years of occurrence (1959–80), and have locations that were determined by two different research projects. Our judgment is that this constitutes a strong

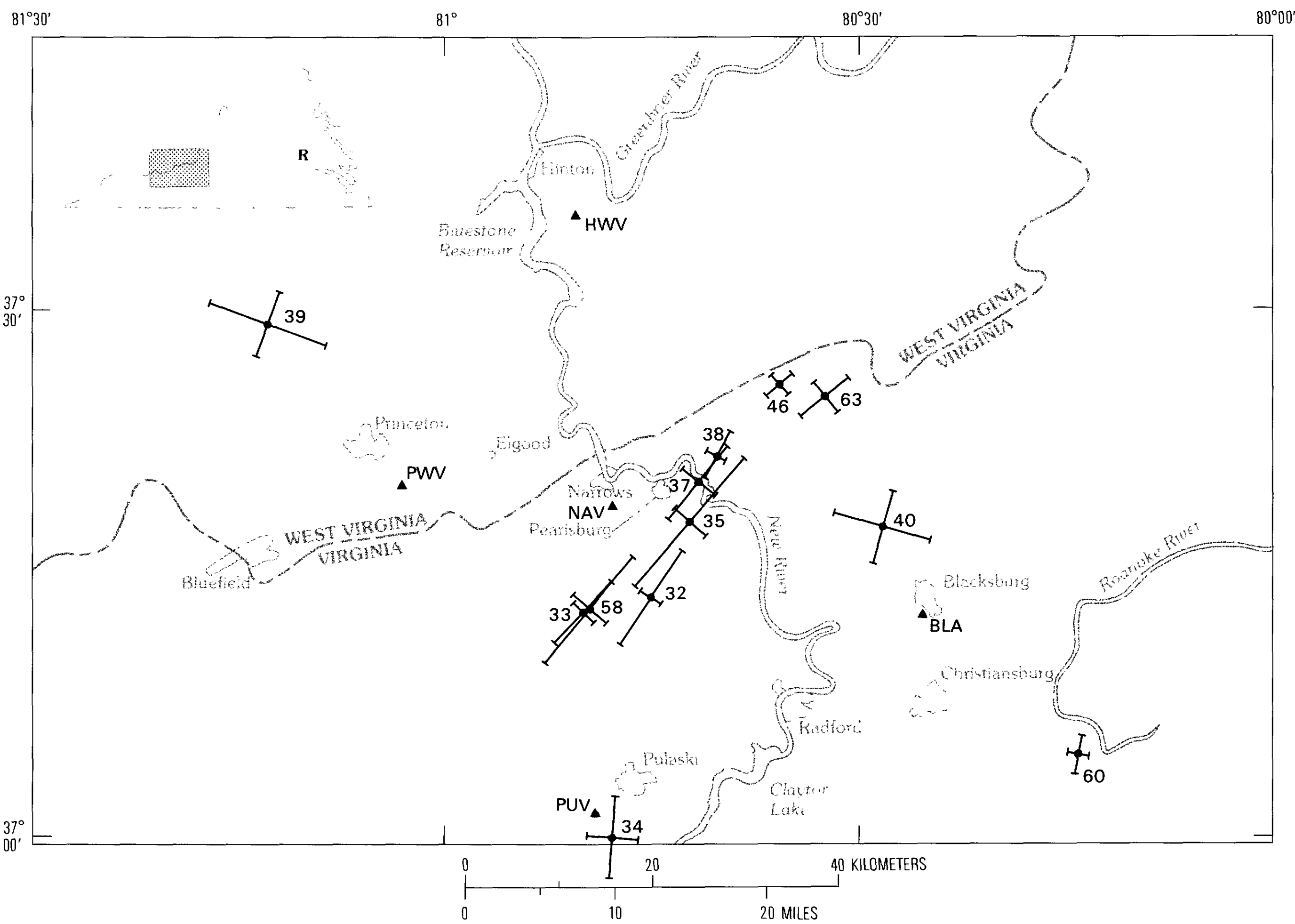



FIGURE 9.—Epicenter map for microearthquakes located with data from the Giles County, Va., subnetwork. Event identification numbers refer to the listing given in table 4. Sixty-eight-percent confidence-ellipsoid axes plotted at each epicenter (Lahr, 1980). Network seismic stations shown by solid triangles with three-letter codes. Inset map shows area of this figure and location for Richmond (R).

TABLE 4.—*Chronological listing of earthquakes that occurred subsequent to 1977 in the Giles County, Va., locale and were located using network data and the HYPOELLIPSE program*

[km, kilometers; s, seconds. Location within 50 km of Pearisburg, Va. HYPOELLIPSE from Lahr, 1979]

| Event No. | Date | | | Origin time (UTC) | | | Latitude (north) | Longitude (west) | Depth (km) | Magnitude[1] ($M_D$) | RMS[2] (s) | Projection[3] | | | | | Quality[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Horizontal | | | | Vertical | |
| | Year | Month | Day | Hours | Minutes | Seconds | | | | | | Length (km) | Trend (degrees) | Length (km) | Trend (degrees) | Length (km) | |
| 32 | 1978 | Jan. | 28 | 23 | 13 | 23.4 | 37°13.68' | 80°44.80' | 4.5 | 1.6 | 0.10 | 1.3 | -56 | 5.9 | 34 | 3.0 | C |
| 33 | 1978 | May | 10 | 4 | 19 | 9.6 | 37°12.80' | 80°49.82' | 26.2 | .3 | .09 | 1.5 | -46 | 4.4 | 44 | 3.0 | B |
| 34 | 1978 | May | 25 | 8 | 30 | 25.1 | 37°00.01' | 80°47.65' | 12.1 | 1.5 | .23 | 2.7 | -86 | 4.3 | 4 | 3.8 | B |
| 35 | 1978 | June | 1 | 1 | 33 | 1.0 | 37°17.99' | 80°41.98' | 17.3 | -0.2 | .17 | 2.1 | -49 | 8.8 | 41 | 9.1 | C |
| 37 | 1978 | July | 28 | 8 | 39 | 40.7 | 37°20.22' | 80°41.41' | 11.8 | .6 | .27 | 2.2 | -51 | 4.9 | 39 | 8.1 | C |
| 38 | 1978 | Aug. | 30 | 2 | 19 | 38.2 | 37°21.71' | 80°40.06' | 8.4 | .5 | .09 | 1.0 | -62 | 3.1 | 28 | 6.4 | C |
| 39 | 1978 | Sep. | 14 | 19 | 37 | 6.6 | 37°29.22' | 81°12.80' | 9.9 | -0.4 | .17 | 3.6 | 20 | 6.6 | -70 | 17.4 | D |
| 40 | 1978 | Oct. | 14 | 1 | 50 | 51.0 | 37°17.68' | 80°28.03' | 20.1 | .3 | .06 | 3.8 | 16 | 5.3 | -74 | 17.2 | D |
| 46 | 1980 | Feb. | 18 | 3 | 58 | 55.3 | 37°25.78' | 80°35.54' | 13.0 | 1.1 | .25 | 1.2 | -41 | 1.7 | -131 | 3.6 | B |
| 58 | 1980 | Oct. | 9 | 1 | 47 | 1.1 | 37°13.01' | 80°49.32' | 23.5 | -0.2 | .25 | 2.3 | -50 | 7.2 | 40 | 4.9 | C |
| 60 | 1980 | Oct. | 14 | 1 | 20 | 4.6 | 37°04.69' | 80°13.82' | 11.0 | 1.7 | .35 | 1.1 | -77 | 2.0 | 13 | 3.1 | B |
| 63 | 1980 | Dec. | 2 | 7 | 47 | 38.2 | 37°25.08' | 80°32.25' | 12.2 | .4 | .34 | 2.0 | -39 | 3.2 | -129 | 7.4 | C |

[1]Average network magnitude: $M_D$=-3.38+2.74 log ($D$) where $D$=average duration (seconds) at network stations from the onset of the *P* wave until return of vibrations to background microseismic level.

[2]Root-mean-square error of the travel-time residuals (observed seismic-wave traveltime minus calculated seismic-wave traveltime).

[3]Projection onto the Earth's surface (horizontal) and onto a vertical plane of the 68-percent confidence ellipsoid on the hypocentral coordinates. These projections are specified by giving the lengths and trends (plus-and-minus from north) of the semimajor and semiminor axes along with the length of the vertical semiaxis.

[4]Quality factor according to HYPOELLIPSE (Lahr, 1979): Lengths and azimuths of the axes of this ellipse are calculated as described in footnote 3. The greatest vertical deviation of the ellipsoid from the hypocenter is also calculated. Then a quality is calculated based on the largest of these three distances according to the following criteria:

| Quality | Largest distance |
|---|---|
| A | Less than or equal to 2.5 km |
| B | Less than or equal to 5.0 km |
| C | Less than or equal to 10.0 km |
| D | Greater than or equal to 10.0 km |

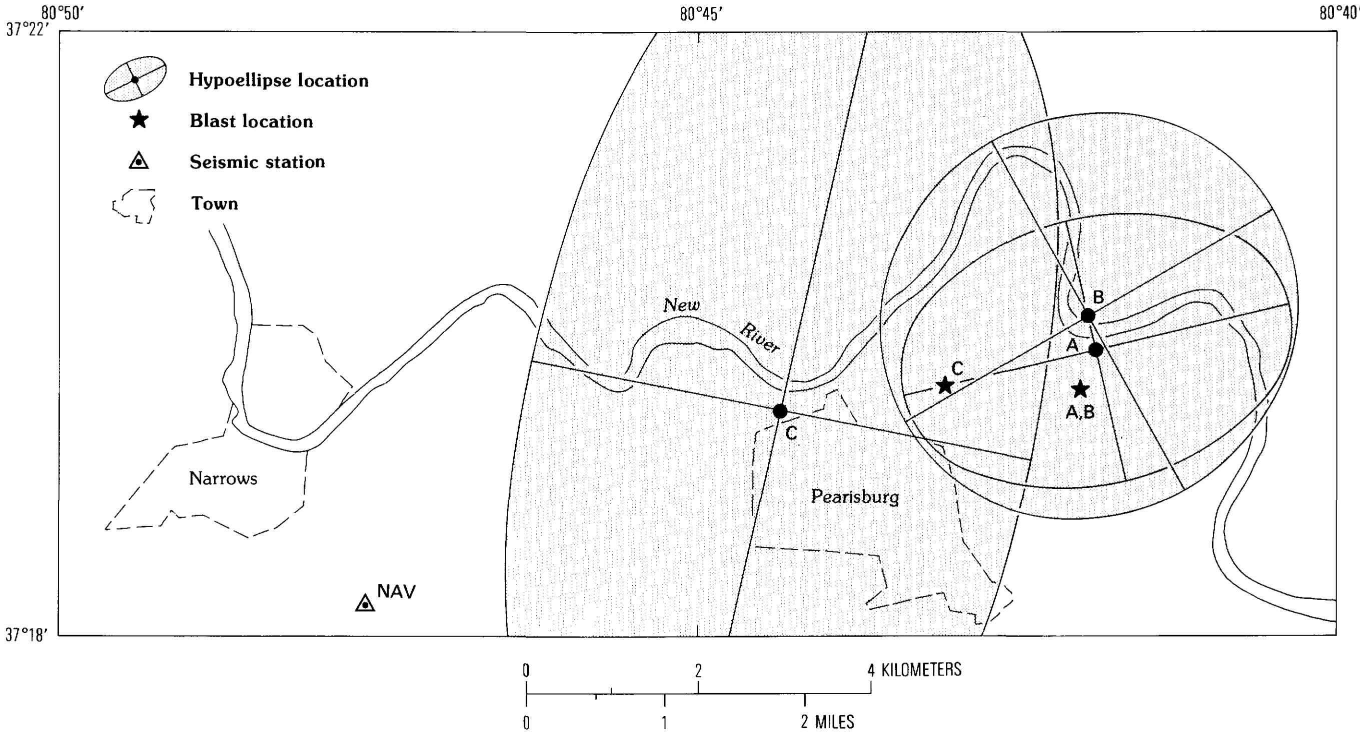



FIGURE 10.—Map showing a comparison of actual blast locations with those calculated using data from the Giles County, Va., subnetwork. Actual locations of blasts A, B, and C shown by stars. Computed locations shown by dots at the center of the error ellipses (projection onto a horizontal plane of the error ellipsoid). Location of Narrows, Va., seismic station (NAV) shown by open triangle with center-dot symbol.

TABLE 5.—*HYPOELLIPSE epicenter location errors for Giles County, Va., blasts*

[ERH, semimajor axis of the error ellipse that results from projection of the error ellipsoid onto a horizontal plane; km, kilometers]

| Blast | Date of blast (Year Month Day) | Difference between actual and calculated epicenter (km) | ERH (km) |
|---|---|---|---|
| A | 1979 Dec. 3 | 0.5 | 2.2 |
| B | 1979 Dec. 6 | .9 | 2.4 |
| C | 1980 May 20 | 2.0 | 5.7 |

TABLE 6.—*HYPOELLIPSE determination of focal depths for Giles County, Va., blasts*

[ERZ, greatest vertical deviation of the error ellipsoid from the hypocenter; km, kilometers]

| Blast | Date of blast (Year Month Day) | Trial focal depth (km) | Solution focal depth (km) | ERZ (km) |
|---|---|---|---|---|
| A | 1979 Dec. 3 | 4.0 | 0.5 | 57.7 |
| | | [1]10.0 | .2 | 99.0 |
| B | 1979 Dec. 6 | .0 | .0 | 99.0 |
| | | [1]5.0 | 2.5 | 16.7 |
| C | 1980 May 20 | 4.0 | 2.2 | 14.3 |

[1]Two trial focal depths were tested for blasts A and B.

case for the existence of the zone as we have described it even though the data base is not large.

## FAULT AREA

Epicenter maps and vertical-section plots of foci are given by figures 11, 13, and 14. Figures 12 and 15 are illustrations designed to portray specific characteristics of the hypocenter data set in the horizontal (fig. 12) and vertical (fig. 15) planes. Figure 12 presents the epicenters, scaled according to magnitude, without any geography (except the location of the station NAV) or error ellipse axes so as to portray the seismicity in as direct a manner as possible. Figure 14 is a side view of the 12 earthquake hypocenters in vertical section, and figure 13 is an end view of those same 12 hypocenters, plus two off-zone hypocenters (nos. 34 and 40). In both figures two of the earthquakes (D and S) do not have vertical error semiaxes on the figure, because there were insufficient arrival-time data available to determine

TABLE 7.—*Chronological listing of earthquakes that occurred prior to 1978 in the Giles County, Va., locale and were relocated using joint hypocenter determination techniques*

[From J. W. Dewey and D. W. Gordon, written commun., 1980. Some of these data appear in table 1]

| Event No. | Date | | | Locality | Origin time (UTC) | | | Latitude (north) | Longitude (west) | Depth (km) | Magnitude ($m_{bLg}$) | Projection[1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year | Month | Day | | Hours | Minutes | Seconds | | | | | Trend (degrees) | Semilengths (km) |
| D | 1959 | Apr. | 23 | Virginia-West Virginia border. | 20 | 58 | 40.2 | 37°23.70' | 80°40.92' | [2]5 | 3.8 | 98.1 | 12.9, 7.7 |
| H | 1968 | Mar. | 8 | Narrows, Va.---- | 5 | 38 | 15.7 | 37°16.86' | 80°46.44' | 7.7 | 4.1 | 133.5 | 6.5, 6.1 |
| J | 1969 | Nov. | 20 | Elgood, W. Va.-- | 1 | 00 | 9.3 | 37°26.94' | 80°55.92' | 2.5 | 4.6 | 132.7 | 6.2, 4.4 |
| R | 1974 | May | 30 | Virginia-West Virginia border. | 21 | 28 | 35.3 | 37°27.42' | 80°32.40' | 5.4 | [3]3.7 | 122.7 | 8.6, 5.1 |
| S | 1975 | Nov. | 11 | Giles-Bland Counties, Va., border | 8 | 10 | 37.6 | 37°13.02' | 80°53.52' | [2]1.0 | 3.2 | 144.8 | 11.6, 6.7 |
| X | 1976 | July | 3 | Virginia-West Virginia border. | 20 | 53 | 45.8 | 37°19.26' | 81°07.62' | [2]1.0 | [4]2.1 | 141.3 | 13.7, 6.5 |

[1]Projection onto the Earth's surface of the 90-percent-confidence ellipsoid on the hypocentral coordinates. This projection is specified by the trend of the semimajor axis and the lengths of the semimajor and semiminor axes, respectively.
[2]Focal depth fixed.
[3]Reagor and others (1980a) give a value of 3.6.
[4]Magnitude according to G. A. Bollinger (unpub. data, 1976).

adequately a focal depth even though the data were sufficient for calculation of an epicenter. In such cases, the depth is fixed at some arbitrary, but geologically reasonable depth, by the geophysicist performing the calculations. Figure 15 illustrates the range of fault areas allowed by the 10 hypocenters. That range, from 80 km$^2$ to 800 km$^2$, was determined by first projecting the hypocenters onto a vertical plane (*A-A'*; see figure 11) and then arbitrarily moving the hypocenters inside their error ellipses in the following manner:

Figure 15*A*—All hypocenters shifted toward the centroid of the hypocentral distribution. Note the superposition of groups of two and three hypocenters. A minimal area (80 km$^2$) is defined by the shallowest eight hypocenters (shaded area). If the deepest two hypocenters are included (shaded plus hachured areas), then the area specified is 250 km$^2$.

Figure 15*B*—All hypocenters shifted away from the centroid of the hypocentral distribution, restricted to a minimum focal depth of 5 km, or both. A maximal area of some 800 km$^2$ (shaded area) is thereby defined.

Other ways of connecting the dots in figure 15 would produce slightly different inferred fault areas, but those areas could still vary by a factor of 10 times and yet be consistent with the locational accuracy of the hypocenters as specified by the error ellipsoids. Therefore, we do not have, at this time, an accurate estimate of the area of the Giles County, Va., seismogenic zone.

The definition of fault-plane area, 80–800 km$^2$, can be used to estimate the magnitude of an associated earthquake: M6–7. Thus, a variation of 10 times in the fault plane area implies a change of one in the magnitude of an associated earthquake (Wyss, 1979, 1980; Singh and others, 1980; Bonilla, 1980). However, the published plots of earthquake magnitude against the logarithm of fault-plane area contain approximately one unit of dispersion in each variable. We and Bollinger (1981a) have used the regression line of magnitude on log (fault-plane area) to estimate magnitude from area and so have not explicitly incorporated this variability. One could argue that that is wrong, because we are estimating the magnitude of the largest shock likely to occur on the seismic zone. However, we have already chosen an extreme value for the area that is consistent with locational uncertainties. The regression line gives the most probable magnitudes expectable from those extreme values of the area. We consider that if we added the uncertainty in the regression to the uncertainty of the area, the resulting magnitude range would be needlessly wide and conservative.

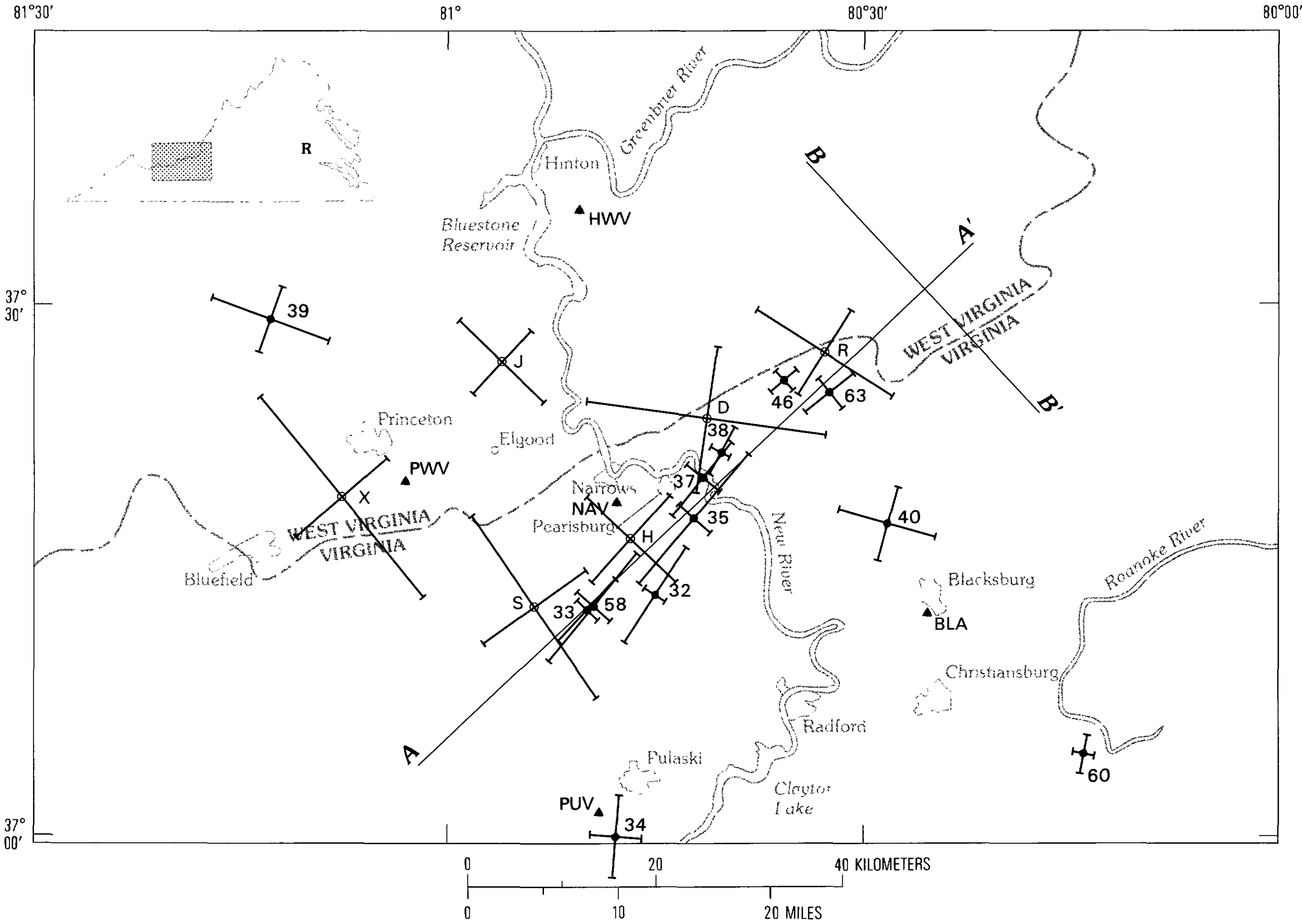



FIGURE 11.—Epicenter map for microearthquakes located by data from the Giles County, Va., subnetwork and for felt earthquakes relocated by J. W. Dewey and D. W. Gordon (written commun., 1980). The epicenters of felt earthquakes are designated by letters and listed in table 7. The epicenters of the microearthquakes are designated by numbers and listed in table 4. The six epicenters of felt earthquakes are shown by open circles and 90-percent confidence ellipsoidal axes, four of which are located on the northeast-striking zone. The locations of the vertical profiles are shown; the northeast-striking *A*-*A*′ line is shown in figure 14, and the northwest-striking *B*-*B*′ line is shown in figure 13. Inset map shows area of this figure and location for Richmond (R). Modified from Bollinger (1981a) with permission.

There are subjective aspects to the specification of seismogenic fault-plane area and estimation of the associated potential magnitude that bear further discussion.

1. Seismic rupture of the ground surface is unknown in or near Giles County. In such cases elsewhere that lack surface evidence, areas of fault planes are usually estimated from spatial distributions of aftershocks. We use here the spatial distribution of seismicity detected during an extended period of time because no aftershock sequences have been detected during our monitoring. However, the existence, orientation, and shape of the seismic zone as defined by the microseismicity are supported by the distribution of felt events. The zone has had nine felt events since 1959 (table 1). Four of the nine (events D, H, R, S in table 7) were relocated within the seismic zone by J. W. Dewey and D. W. Gordon (written commun., 1980; see also figs. 11–14) and events X and J were relocated outside the seismic zone.
2. The confidence ellipsoids used to estimate minimal and maximal fault-plane areas (fig. 15) are of two different types. Locations derived from the Giles County network were calculated using the HYPO-ELLIPSE program, which produces 68-percent confidence ellipsoids. These locations are shown as solid dots in figures 9–14. The relocations of Dewey and Gordon were calculated using the Joint-Hypocenter-Determination (JHD) techniques,

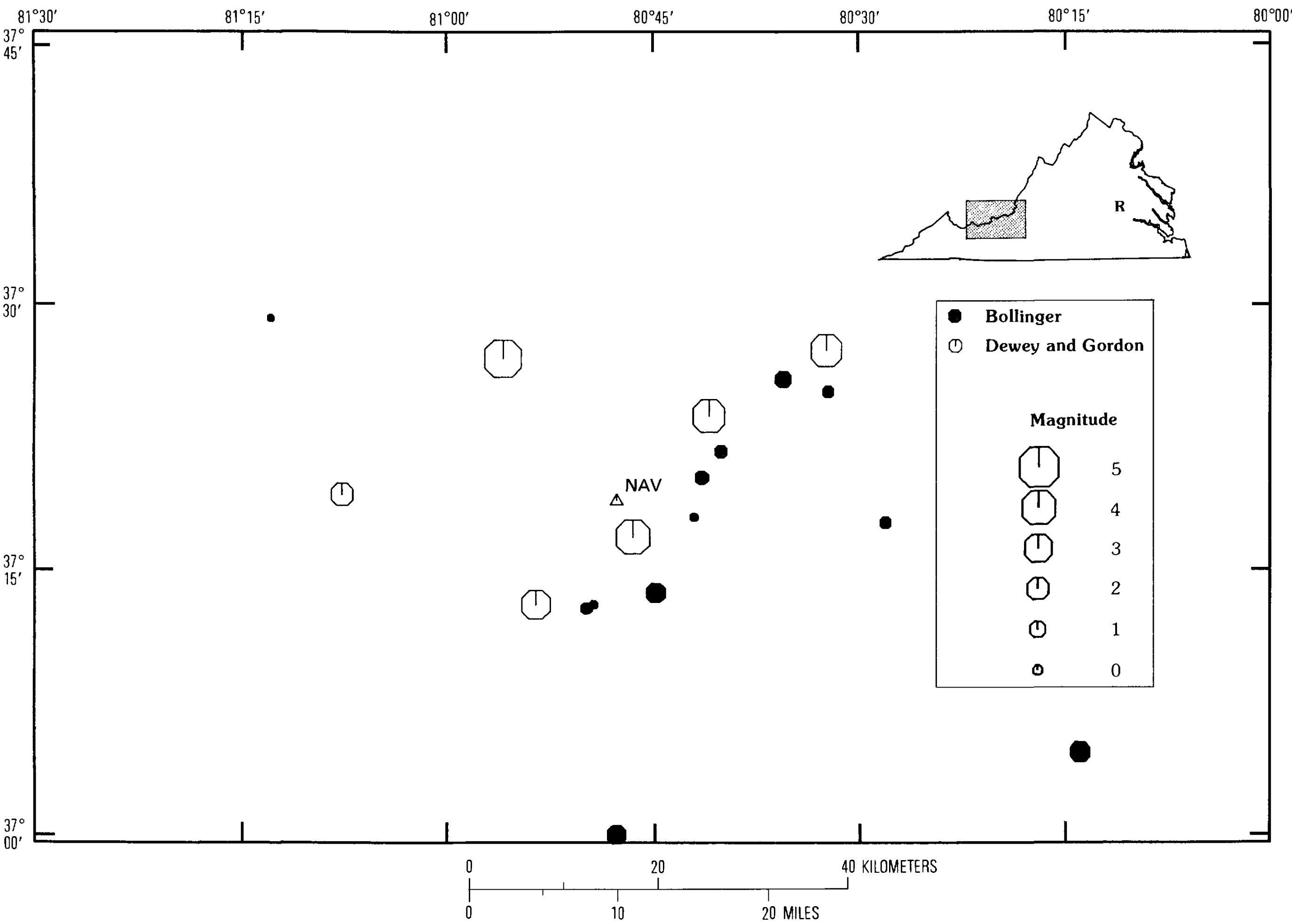



FIGURE 12.—The 18 epicenters of figure 11 scaled according to magnitude. The magnitudes are listed in tables 4 and 7. The epicenters are separated according to locational authority: Open symbols for epicenters according to J. W. Dewey and D. W. Gordon (written commun., 1980; see table 7); solid symbols for epicenters according to this study (see table 4). Inset map shows area of this figure. Modified from Bollinger (1981a) with permission.

which produces 90-percent confidence ellipsoids. These relocations are shown as open circles in figures 11–14. To combine the two properly, the eight 68-percent ellipsoids should be expanded, which would increase the estimated fault plane area, or the four 90-percent ellipsoids should be contracted, which would decrease the area. However, we consider that the resulting changes in the ellipsoid sizes, in the estimated areas, and in the resulting magnitudes would be negligible for our purposes. A recent study that applied the JHD technique to all 12 Giles County events in the seismic zone showed that the hypocenters relocated by the JHD technique have the same general location and trend as do those presented herein (Viret and others, 1981, 1986; Bollinger and others, 1982).

3. The confidence ellipsoids are three-dimensional shapes with various orientations in space. Figure 15 uses only the elliptical projections of the ellipsoids into horizontal and vertical planes. This distorts the estimates of fault plane area. A crude estimate of the amount of distortion may be obtained from a two-dimensional analogy that uses figure 15. The ellipses of figure 15 are drawn using vertical and horizontal semiaxes. Consider how the ellipses would be distorted if they were drawn using semiaxes obtained by projection of the ellipses of figure 15 into two other perpendicular lines lying in the plane of figure 15, say lines plunging 45° to the southwest and to the northeast. Such projected axes would allow fault planes with different orientations but whose areas would not be much different from those shown in figure 15.

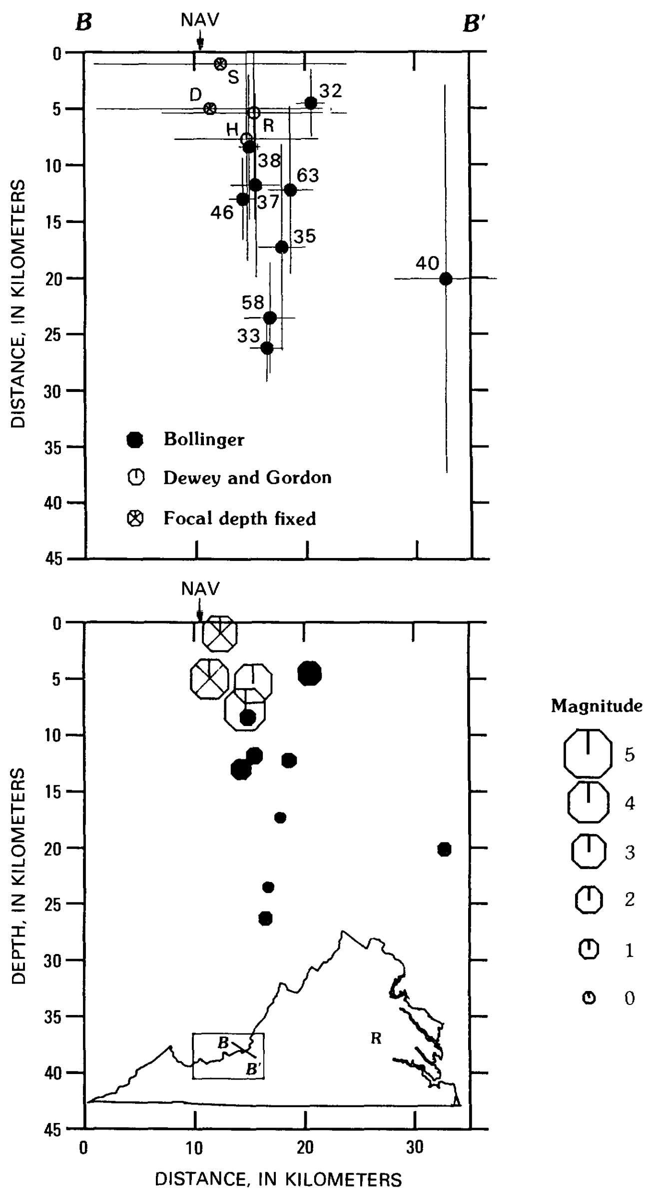



FIGURE 13.—Sections showing vertical distribution of the hypocenters projected perpendicularly into a northwest-striking plane *B-B'* (see fig. 11 for location of *B-B'*). Solid symbols, this report; open symbols, J. W. Dewey and D. W. Gordon (written commun., 1980) with focal-depth control; open symbols with X's, J. W. Dewey and D. W. Gordon (written commun., 1980) without focal-depth control (not enough arrival-time data), indicating depths shown were arbitrarily fixed during calculations. Top part of the figure shows error ellipse axes and event numbers and letters; in bottom part of the figure, hypocenter symbols are scaled according to magnitude (<1 to >4) of the individual earthquakes. Event numbers and letters refer to tables 4 and 7, respectively. Confidence ellipsoidal axes shown are at a 68-percent level for numbered events (from Giles County network) and a 90-percent level for lettered events (from J. W. Dewey and D. W. Gordon, written commun., 1980). Location of seismic station NAV shown by arrow on both parts of figure. The inset map shows the profile location and Richmond (R). Modified from Bollinger (1981a) with permission.

Thus, the effect of such a projection on the minimal and maximal fault plane areas would be negligible. Analogously, after consideration of the elliptical shapes as indicated by the semiaxes of figures 11 and 13–15 and after consideration of the ellipsoidal semiaxes of table 4, we conclude that this effect is also negligible for our purposes in three dimensions.

Recently, Bollinger (1981a) has presented an assessment of the potential hazard for use by public officials and emergency planners, but this assessment is not detailed enough to be of use in defining engineering specifications of structures. Such an assessment involves two major factors: (1) specification of a fault-plane area for use in estimating the potential earthquake magnitude; and (2) development of a hypothetical intensity map. The initial factor (1) has been discussed. The second factor (2), development of a hypothetical intensity map, attempts to utilize the geometric characteristics of local and regional isoseismal maps along with magnitude-intensity relationships and intensity-distance attenuation functions (Bollinger, 1981a). Application of these various characteristics, relationships, and functions to the Giles County data could, in principle, yield a range of possible results depending on initial assumptions and objectives. The specific results developed by Bollinger (1981a) for the study area were as follows: Potential earthquake size: $M_S$=7, $I_o$=IX (MMI); Hypothetical intensity map—all isoseismals elliptical in shape with principal zones of damage having areas of 785 km$^2$ (IX), 4,500 km$^2$ (VIII) and 31,700 km$^2$ (VII). The innermost isoseismals (VIII, IX) are postulated to have long dimensions that trend with the seismogenic zone (N. 44° E.), but the lower level isoseismals (VII and below) are to trend with the tectonic fabric of the surrounding portion of the Appalachians (N. 75° E.)(Bollinger, 1981a, p. 285).

Bollinger's (1981a) estimate of the size of the largest shock possible on the Giles County seismic zone is consistent with two suggestions of Nuttli (1981a, b). Nuttli compared Eastern and Western United States seismicity and suggested that (1) large Eastern shocks can arise from structures of only moderate size, and (2) most Eastern regions have probably not experienced their largest possible shock yet in historic times.

## FOCAL MECHANISM STUDIES

A composite focal-mechanism solution (CFMS; fig. 16) was attempted for those 8 microearthquakes that have the most accurate locations and form the tightest spatial distribution in map view. According to our interpretation, they occurred on the same fault or fault

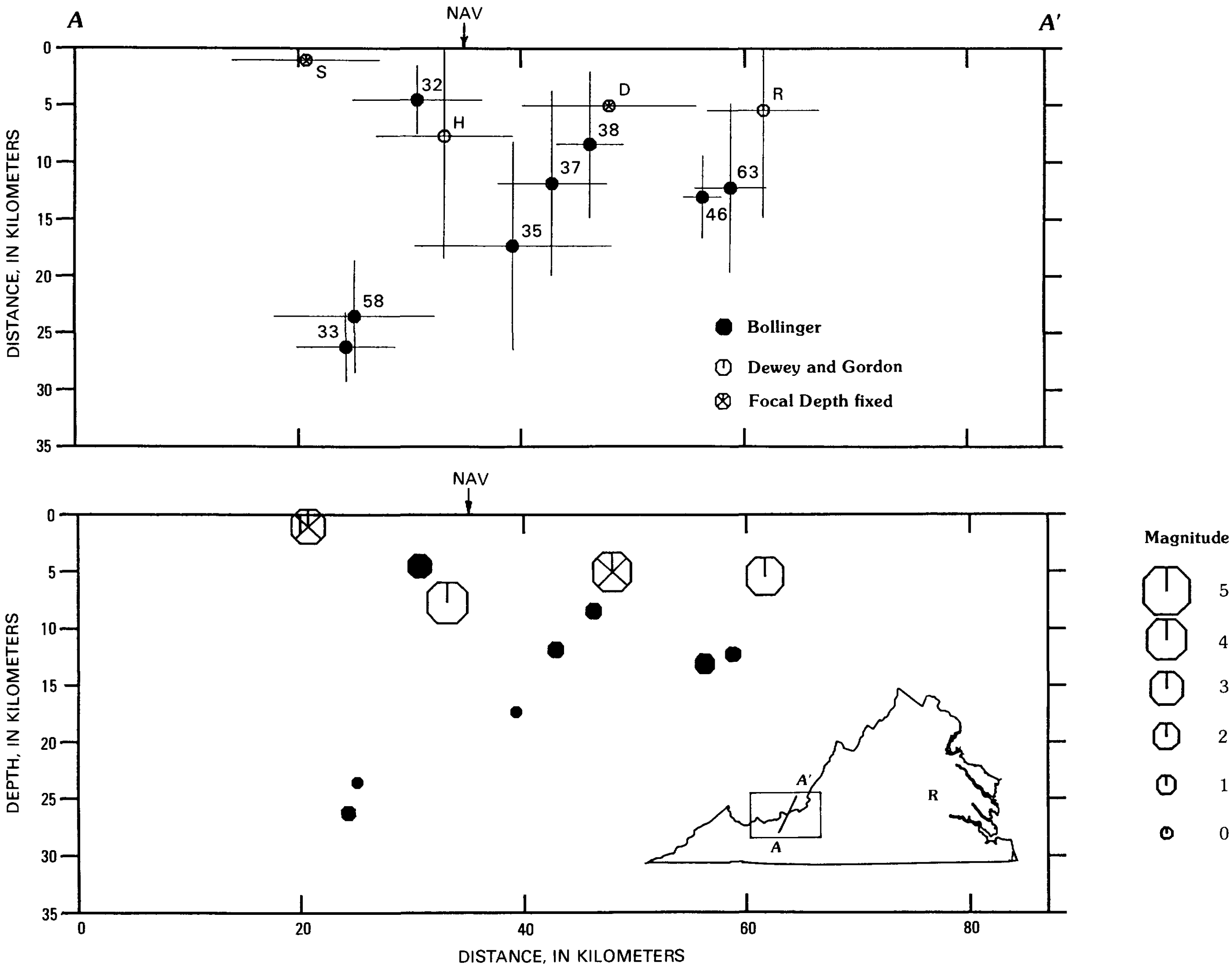



FIGURE 14.—Section showing vertical distribution of the hypocenters that define the seismic zone, along a northeast-striking plane *A*-*A'* (see fig. 11 for location of *A*-*A'*). Solid symbols, this paper; open symbols, J. W. Dewey and D. W. Gordon (written commun., 1980) with focal-depth control; open symbols with X's, J. W. Dewey and D. W. Gordon (written commun., 1980) without focal-depth control; therefore, depths shown were arbitrarily fixed during calculations. Upper half of the figure shows error ellipse axes and event numbers and letters; in lower half of the figure, hypocenter symbols are scaled according to magnitude (<1 to >4) of the individual earthquakes. Event numbers and letters refer to tables 4 and 7, respectively. Confidence ellipsoidal axes shown are at a 68-percent level for numbered events (from Giles County network) and a 90-percent level for lettered events (from J. W. Dewey and D. W. Gordon, written commun., 1980). Inset figure shows the profile location and Richmond (R). Modified from Bollinger (1981a) with permission.

zone. Because of the small size (low energy level) of the individual shocks, only 14 *P*-wave polarities could be obtained (six impulsive, eight emergent; see table 8). A unique focal mechanism could not be obtained from the data set (we easily obtained three different solutions). Figure 16 gives a provisional composite focal-mechanism solution for these 8 well-located microearthquakes. To construct figure 16, we take the strike of that zone to be N. 44° E. and the dip to be 80° NW. The strike has been discussed previously, and the dip is our subjective visual fit to the foci in figure 13.

To glean as much as possible from the *P*-wave data set, the following procedures were employed to develop a focal-mechanism solution:

1. We used the microearthquake hypocenter distribution (figs. 9, 13) to define subjectively the preferred nodal plane as striking N. 44° E. and dipping 80° northwest, as follows. In Appendix D, we have noted that statistical analysis yielded a dip of 40° for the tabular seismic zone. However, we concluded there that the dip estimate was not clearly reliable. Further, if we had used a 40° dip for the

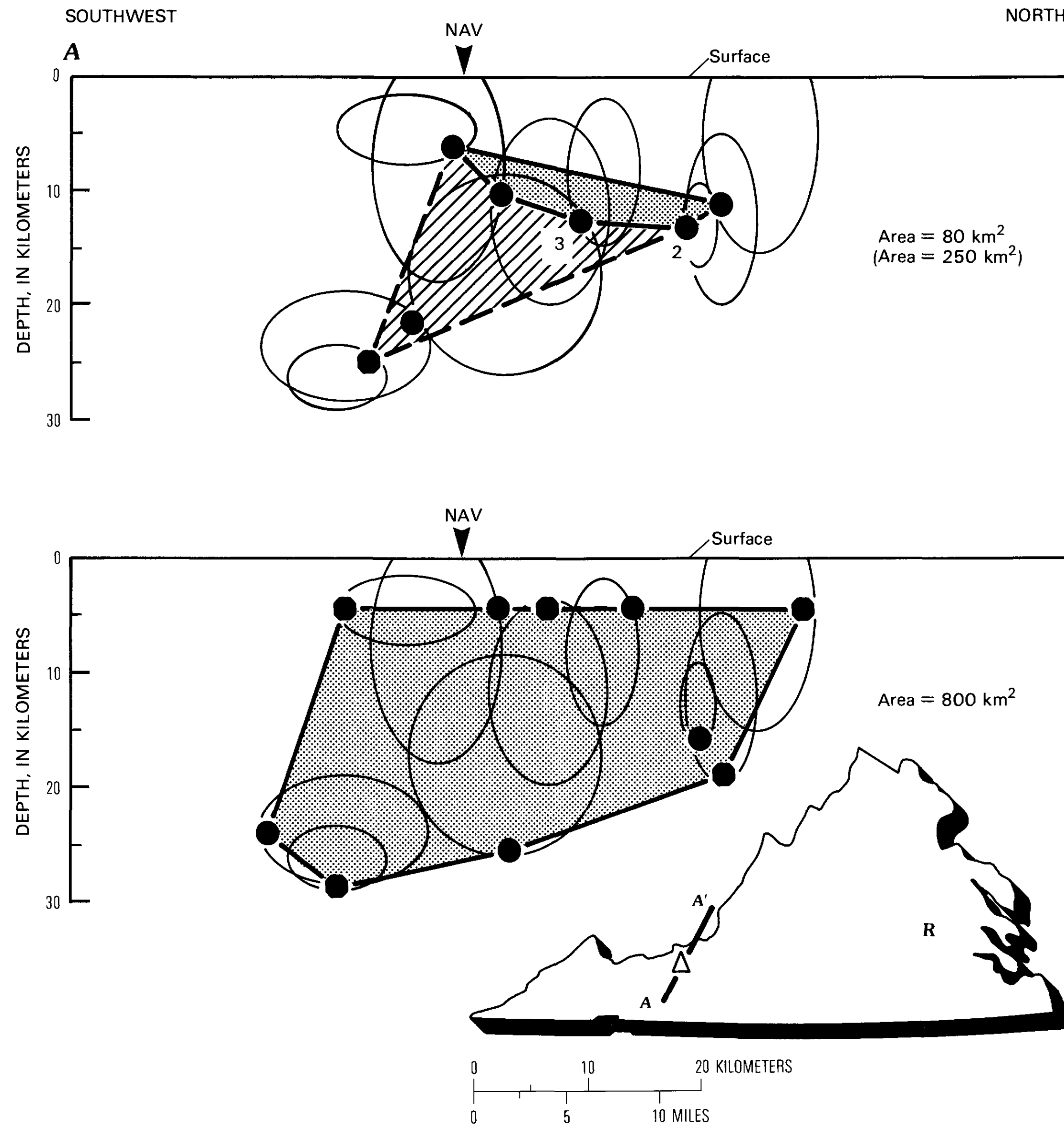



FIGURE 15.—Sections showing definition of possible fault-plane areas. Examples of hypocenter (solid dots; each with an associated error ellipse) distributions and interpretations of fault-plane areas that can be derived by first projecting the hypocenters onto a vertical plane (*A*–*A*′; see fig. 11) and then arbitrarily moving the hypocenters of figure 14 to various positions inside their error ellipses: Top—Minimal area (80 km$^2$, shaded region) and an intermediate size area (250 km$^2$, shaded plus hachured regions). Numerals indicate the number of hypocenters moved to the same point. Bottom—Maximal area (800 km$^2$, shaded region). Inset map shows locations of profile, the NAV station (open triangle) and Richmond (R). Note that events S and D have unknown focal depths (see figs. 13 and 14), so they were not used here; thus, only 10 points are plotted. Modified from Bollinger (1981a) with permission.

preferred nodal plane, the resulting CFMS would have predicted normal movement on that nodal plane. Such normal movement would be inconsistent with a maximum horizontal compressive stress trending east-northeast which is the orientation we shall infer in a later section on "State of Stress." Accordingly, we used a dip for the preferred nodal plane of 80° NW., estimated from a visual fit of a line to the foci of figure 13. We then found, by graphical means, an auxiliary plane that encompasses the compressional field (9 of 11 compressional *P*-wave polarity readings: table 8) observed in the northeast to south azimuths. Figure 16 shows that auxiliary plane to strike north-south

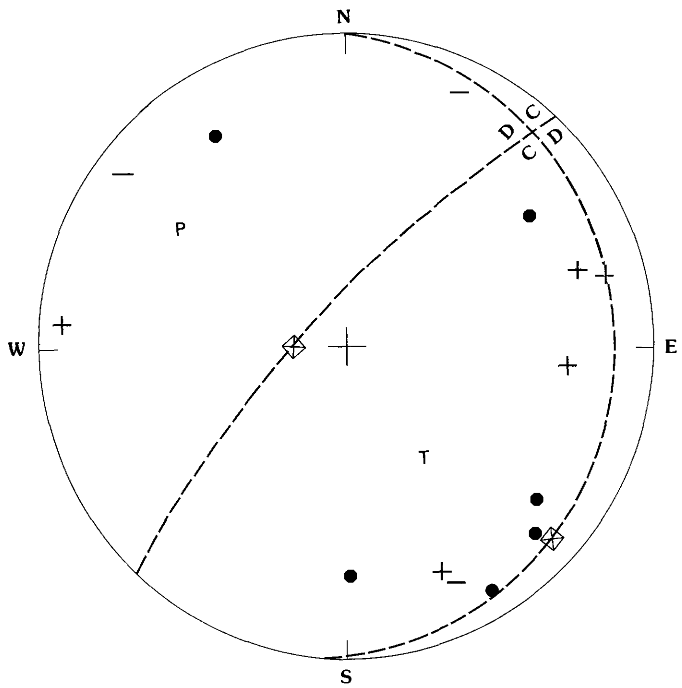



FIGURE 16.—Provisional composite focal-mechanism solution for events in the Giles County, Va., seismic zone. Lower-hemisphere equal-area projection. Symbols: Large plus, center of projection; solid circles, definite (impulsive) compressions; small plus signs, indefinite (emergent) compressions; minus signs; indefinite (emergent) dilatations; P and T, pressure and tension axes at the source, respectively; boxes with X's, nodal plane poles; dashed lines, nodal planes; C and D, quadrants about the source where the *P*-wave arrivals show compressional (away from source) and dilatational (toward source) first motions, respectively.

and to dip 14° to the east. The resulting CFMS (fig. 16) indicates right-reverse motion on the preferred nodal plane. The CFMS suggests that the reverse component is larger than the right-slip component of motion. However, we do not actually know which component is larger. That is because the relative magnitudes of the two components depend on the orientation of the auxiliary nodal plane. That orientation is uncertain, partly because the first motions are too few and too poorly distributed on the focal hemisphere to restrict the orientation of the auxiliary nodal plane (fig. 16), and partly because the hypocenters do not tightly constrain the dip of the preferred nodal plane (fig. 13; Appendix D).

2. Two of the four Dewey and Gordon (written commun., 1980) relocations in the seismic zone (table 7; fig. 11) have fixed focal depths (events D and S) and the other two (H, R) have rather large horizontal and vertical error estimates. Thus, it would be somewhat questionable to combine data

TABLE 8.—*P-wave polarity data for Giles County, Va., earthquakes*

[Event No., listing as shown in table 4; AZM, epicenter-to-station azimuth (in degrees); AIN, angle-of-incidence (measured from the downgoing vertical) at the focus (in degrees). P-wave polarity: C, compression; D, dilatation; e, emergent beginning of P wave; i, impulsive beginning of P wave. Station abbreviations are defined in table 2]

| Event No. | Date | | | Station | AZM | AIN | P-wave polarity |
|---|---|---|---|---|---|---|---|
| | Year | Month | Day | | | | |
| 32 | 1978 | Jan. | 28 | BLA | 274 | 81 | eC |
| | | | | NAV | 157 | 67 | eC |
| 33 | 1978 | May | 10 | HWV | 179 | 63 | iC |
| 37 | 1978 | July | 28 | HWV | 155 | 73 | eD |
| 38 | 1978 | Aug. | 30 | BLA | 307 | 80 | eD |
| | | | | HWV | 149 | 81 | iC |
| 40 | 1978 | Oct. | 14 | NAV | 95 | 61 | eC |
| | | | | HWV | 135 | 75 | iC |
| 46 | 1980 | Feb. | 18 | BLA | 328 | 69 | iC |
| | | | | NAV | 55 | 62 | iC |
| | | | | HWV | 129 | 68 | iC |
| | | | | PWV | 75 | 76 | eC |
| | | | | PUV | 24 | 79 | eD |
| | | | | CVL | 72 | 68 | eC |

from those shocks with data from the more precisely located microearthquakes. However, we note that the WWSSN Observatory BLA is always in the northwestern (dilatational) quadrant of the focal sphere (because we are considering a lower focal hemisphere; table 8). A check of the BLA seismograms for the D, H, R, and S events revealed only one clear reading (an impulsive dilatation from the event S) and one somewhat indefinite reading (a compression for event H). Thus, the single check we are able to make tends to agree with the CFMS, but not without some ambiguity. Resolution will come only with more data from larger earthquakes ($M>3$).

3. We can evaluate the solution with binomial tests. Details are in Appendix E. Statistical results discussed there provide objective support for our subjective opinion that the CFMS of figure 16 is valid, despite being based on a small number of first motions with several inconsistencies.

4. We compared the Giles County, Va., CFMS with other, nearby focal-mechanism solutions. With no previous focal-mechanism solutions for events in the seismic zone, a direct comparison of this type is not possible. There are, however, two nearby focal-mechanism solutions that will provide a measure of comparative value. Those solutions are for

the 1969 Elgood, W. Va., shock (event J in fig. 11 and table 7) and the 1973 Knoxville, Tenn., earthquake (epicenter: 35.8° N. 84.0° W.; origin time (UTC): 0748:41.2; $m_b$=4.6).

Herrmann (1979) used *P*-wave first motions and surface-wave amplitude and phase data from Love and Rayleigh waves to obtain a focal-mechanism solution for the 1969 Elgood, W. Va., shock. That solution showed predominately strike-slip motion. The nodal plane strikes were northeast and northwest, and the dips were near vertical. The northeast-striking plane (N. 33° E., 80° SE.) exhibited a left-lateral motion, with a small normal component. Thus, the strike and dip (but not the sense of movement) of one of the solution's nodal planes are similar to those for the Giles County, Va., zone. Note that the 1969 Elgood, W. Va., shock was not directly in the Giles County zone, but rather some 25 km to the northwest of that zone (fig. 11).

Focal mechanism solutions for the 1973 earthquake were obtained by Bollinger and others (1976) and by Herrmann (1979). The former investigators found a dip-slip mechanism, but could not, because of meager polarity data, differentiate between normal and reverse modes of faulting. That is, they obtained two equally likely solutions, one showing normal faulting (NE.- and NW.-striking nodal planes) and the other defining reverse faulting (both nodal planes had NW. strikes). The northeast-striking nodal plane (N. 49° E.; dip 70° SE.) has an orientation roughly similar to the strike and nearly vertical dip of the Giles County, Va., zone. Bollinger and his coauthors (1976) favored the reverse-faulting solution based on other data (trend of aftershock epicenters, the vertical distribution of the aftershock hypocenters, and the trend of regional in situ stress measurements). Interestingly, Herrmann obtained a predominately strike-slip mechanism for this shock (nodal planes with NNE. and WNW. strikes and steep dips). He rated the solution quality as "C" (average) and noted that, because of the skimpy data base, he had little faith in either his solution or that by Bollinger and others (1976). The 1973 Knoxville earthquake was located some 320 km along strike and to the southwest from Pearisburg, Va.

Thus, from other focal-mechanism studies we find some supporting evidence for seismically active, northeast-striking, steeply dipping seismic zones in the general area and in the same geologic province as the Giles County, Va., zone. The evidence favors right-reverse motion but is far too mixed and uncertain to be definitive at this stage.

# TYPES OF FAULTS POTENTIALLY RESPONSIBLE FOR THE GILES COUNTY SEISMIC ZONE

## INTRODUCTION

We shall now determine the type of fault that is most likely to be responsible for the seismicity of Giles County, including the earthquake of 1897, and estimate the portion of the East in which similar faults might be expected to occur. The discussion to follow is long and involved because pertinent data are sparse. However, the effort is worthwhile: We conclude that (1) the seismicity of Giles County probably occurs by compressional reactivation of a fault that formed when an ocean called Iapetus opened, in Late Proterozoic or early Paleozoic time, and (2) similar faults may occur under most of the western portion of the southern and central Appalachians and adjacent craton.

What is known of the geologic evolution of southeastern North America indicates that the crust beneath the region that includes Giles County has undergone four deformational episodes. Each episode is known or can reasonably be inferred to have produced faults that may have been reactivated under present-day stresses to produce the Giles County seismic zone. Each episode was caused by movements of the North American plate and other plates and is known or inferred to have produced faults with specific and predictable properties throughout all or portions of the region now occupied by the Appalachians and the Coastal Plain. Those fault properties can be compared to properties of the crust under Giles County and surrounding areas, to characteristics of the seismicity of Giles County, and to geological data. Of the four kinds of faults produced by the four deformational episodes, the one whose properties best match those of the Giles County locale is the one most likely to include the structure that produces the seismicity of Giles County.

The four deformational episodes occurred (1) about a billion years ago during the Grenville orogeny, (2) during crustal extension in the Late Proterozoic or early Paleozoic, as the Iapetus Ocean began to open, (3) during crustal loading later in the Paleozoic as Appalachian thrusting reached the Giles County locale, and (4) during renewed crustal extension in the early Mesozoic as the Atlantic Ocean began to open (Wheeler and Bollinger, 1980).

## CRUSTAL PROPERTIES AND SEISMICITY

We have documented that the current seismicity in the Giles County locale is concentrated in a nearly vertical, tabular zone that strikes N. 44° E. and extends from 5 to 25 km in depth; we have argued that that zone is probably the source of the 1897 shock; and we have concluded that structures responsible for the seismic zone lie in the basement, beneath exposed and near-surface rocks, folds, and thrust faults.

The Giles County seismic zone involves the upper half of the continental crust beneath the thrust faults. The best estimate of local crustal thickness is 51 km, which is based on traveltime analyses of local and regional earthquakes and quarry blasts and on an unreversed refraction survey (Moore, 1979; model TPM2 of Appendix C, of this report). That thickness estimate is consistent with a previous one of 50–55 km derived from regional analysis of seismic traveltime terms (James and others, 1968). Sbar and Sykes (1977), Dewey and Gordon (1980), and Acharya (1980b; but see Stevens, 1981) suggested that small earthquakes occurring deeper than about 10 km indicated a potential for large earthquakes. That is consistent with the suggestion by Bollinger (1981a) that the Giles County seismic zone could generate a large shock. Also, the depth distribution of hypocenters of the seismic zone is consistent with a suggestion by Chen and Molnar (1981) that continental regions are characterized by an aseismic lower crust. The lower crust could be aseismic because it is too ductile to support high stresses (Meissner and Strehlau, 1982), perhaps because the grains of common minerals that support stress recrystallize in the lower crust (Toriumi, 1982).

Because of the size of the seismic zone, any structure or structures responsible for the zone must be of crustal scale. It seems reasonable to expect that any such large, nearly vertical, presumably planar structures are faults or fault zones that had their origins in processes operating on regional, continental, or plate scales. Only such processes could stress the entire upper crust and cause it to fail. Eventually, data with which to identify clearly such deep, seismogenic faults in the Giles County locale may result from interpretation of deep seismic-reflection lines, from detailed modeling and interpretation of new and existing gravity and aeromagnetic data, from new geologic mapping and analyses, or from analysis of future seismicity beneath the Giles County network. In the meantime, consideration of the geologic history of the Giles County locale and its surroundings can help to define the probable type, age, and motion of such seismogenic faults, as well as the geographic area within which there may occur analogous faults with similar potential for seismic hazard.

Here, we should note an assumption that underlies most of our geological interpretation of the seismological data. We assume that if the Giles County seismic zone does occur on a fault or fault zone, then that fault or fault zone is an old one that is being reactivated in the present stress field. It is not a fresh crustal break formed in unfractured rock in direct response to today's stress field. There are two reasons for making this assumption.

First, where continental basement is exposed, it is commonly cut by old faults and shear zones of various ages, sizes, orientations, and movement histories. For instance, Odom and Hatcher (1980) described examples from the Appalachians, and Isachsen and McKendree (1977) mapped similar features in the Adirondacks. Many geologists have long argued that, in intraplate regions, reactivation of older faults may be the rule and formation of new faults, the exception. Recently, Hamilton (1981) has summarized evidence that suggests that large Eastern earthquakes occur on reactivated rather than new faults.

Second, regardless of the stress state at the fault, a weak zone that is at or near the optimum failure orientation will yield before fresh rock will. The following sections demonstrate that ancient, crustal-scale faults probably formed in the region that is now occupied by Giles County, with the orientation and size that we observe for the seismic zone. Some of those ancient faults formed in Late Proterozoic or early Paleozoic time, as an ocean called Iapetus opened. Since then, no events are known to have affected Giles County that are likely to have significantly deformed, annealed, or otherwise strengthened most such faults. Thus, it is probable that some of the ancient faults are still weak and would be reactivated in preference to forming new faults.

## GRENVILLE OROGENY

Roughly in middle Middle Proterozoic time (about a billion years ago) the Grenville orogeny occurred. The metamorphic and igneous basement rock under and near Giles County lies in that part of eastern North America that was deformed or recrystallized, or both, during the Grenville orogeny (Ammerman and Keller, 1979, p. 344; Bass, 1960; Bayley and Muhlberger, 1968; Black and Force, 1982; Lidiak and Zietz, 1976; Lidiak and others, 1981). Glover and others (1978) have identified rocks of Grenville age in the thrust sheets of the Piedmont province in central Virginia. Pertinent data are sparse, but any high-angle faults that formed during or before the local Grenville deformational or metamorphic peak(s) should have been sufficiently deformed or annealed, or both, by Grenville events that they no longer constitute important strength discontinuities. R. C. Shumaker (1982; written commun., oral communs., 1978–81) is analyzing published and unpublished structural, stratigraphic, geophysical, and oil- and gas-production data from central and southwestern West Virginia and eastern Kentucky. He has suggested that basement faults of Grenville age have been reactivated in that region throughout Paleozoic time. However, all the areas in which such reactivation is known to have occurred lie west of the New York–Alabama magnetic lineament (King and Zietz, 1978; Zietz and others, 1980), which crosses central West Virginia about 100 km northwest of Giles County (fig. 17). The magnetic lineament lies approximately along the ill-defined southeastern edge of a large Paleozoic graben called the Rome trough (this report, fig. 25; Harris, 1975, 1978; Shumaker, 1977). Reactivated basement faults in central and southwestern West Virginia and eastern Kentucky are probably parts of the Rome trough and probably are not analogs of the Giles County seismic zone.

Odom and Hatcher (1980) discussed the potential for reactivation of faults formed before, during, and after the occurrence of Paleozoic metamorphic peaks of the Appalachian orogenies. Those Paleozoic metamorphic peaks occurred tens of kilometers southeast of Giles County, and so did not affect the rocks under consideration here.

## IAPETAN NORMAL FAULTS

Late Proterozoic or early Paleozoic normal faults could be the sources of Giles County seismicity. Such faults formed in North American cratonic crust as an ancient ocean opened, early in the development of a passive (Atlantic-type) continental margin. Features in the Bouguer gravity field over the Appalachians are used here to suggest the extent and limits of the area beneath which such faults may be expected to occur. We will argue that the southeastern limit of such faults is probably a large eastward rise in the Bouguer anomaly field that runs the length of the Appalachians. We will also suggest that the likelihood of encountering such faults decreases gradually to the northwest of the gravity rise, over a distance of several tens to several hundreds of kilometers.

### IAPETUS OCEAN

The predecessor ocean of the Atlantic began opening in Late Proterozoic time, and closed progressively throughout the middle and late Paleozoic to produce the various Appalachian and Atlantic Caledonide orogens from Alabama, U.S.A., to Spitsbergen, Norway. The ocean was named the proto-Atlantic by Wilson (1966). However, the same term applies to the early stage of the Atlantic Ocean. Accordingly, Harland and Gayer (1972, p. 305) took the less confusing name Iapetus (from Greek mythology) for the northern part of the Paleozoic ocean, which separated the Eurasian and North American cratons. (See also reviews by McKerrow and Ziegler, 1972a; Cocks and others, 1980.) South of New England, the Paleozoic ocean opened and closed later than did Iapetus proper (Harland and Gayer, 1972), because of the involvement of a plate carrying the African and South American cratons rather than the Baltic craton (McKerrow and Ziegler, 1972b). The evolution of the southern Paleozoic ocean was further complicated by microplates caught between the converging cratons. Regardless, Williams (1978) and Williams and Max (1980) applied the name Iapetus to the area from Spitsbergen south to the southernmost Appalachians, and we follow that simplifying usage here.

### GRAVITY MAPS AND THE IAPETAN CONTINENTAL EDGE

A steep gravity gradient runs the length of the Appalachians, with Bouguer gravity values rising eastward across the gradient as much as 80 mGal (Woollard and Joesting, 1964; Earth Physics Branch, 1974; Haworth and others, 1980). Figure 18 shows the part of the gradient in the region of interest here, near Giles County. The base of the gradient is shown by the –60 mGal contour in central Virginia, and the –80 mGal contour in western North Carolina. The top of the gradient is shown by the O mGal contour throughout the area of figure 18. The position of the gradient is clear from central Alabama to southern Vermont, but farther north the shape of the Bouguer field becomes more complex (Woollard, 1948; Griscom, 1963; Woollard and Joesting, 1964; Diment, 1968; Diment and others, 1972; Earth Physics Branch, 1974; Haworth, 1975; Haworth and others, 1980). Because of the complexity of the Bouguer field in New England and because New England lies beyond the geographic scope of this report, we shall restrict the following discussion to the central and southern Appalachians, and mostly to the area of figure 18. However, where pertinent, we shall cite papers and observations from elsewhere in the Appalachians.

R. W. Simpson, M. F. Kane, and coworkers have produced a set of gravity maps that show considerably more detail and complexity in the Bouguer field than is visible on most of the maps just cited (Simpson, Bothner, and Godson, 1981; Simpson and Godson, 1981; Simpson, Godson, and Bothner, 1981; Kane and Simpson, 1981; Kane and others, 1981; Kane, 1982). Their maps are derived from digitized Bouguer gravity values, contain computer corrections for terrain more than 0.895 km from the stations, are computer contoured and plotted in color, and show the Bouguer

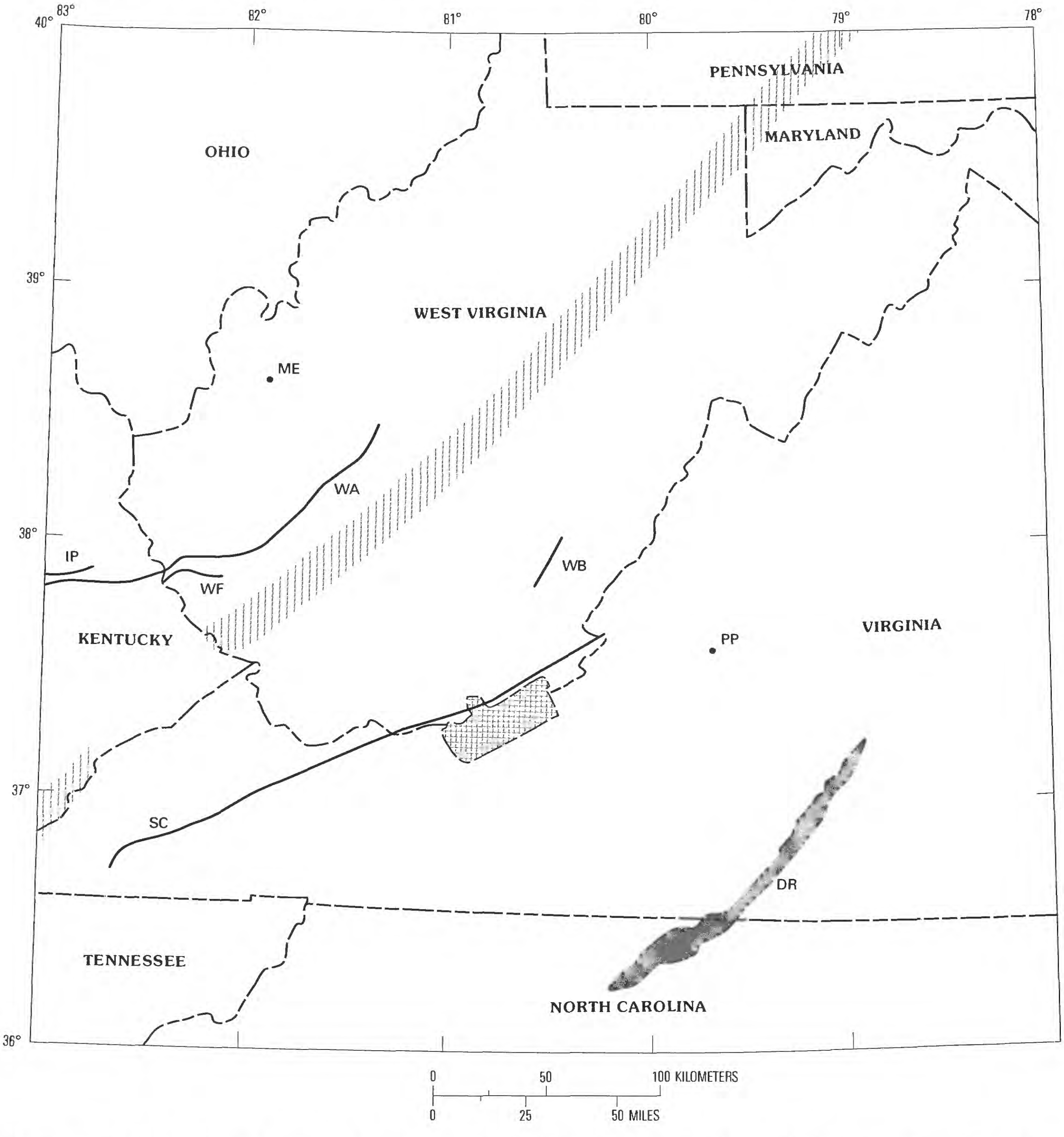



FIGURE 17.—Index map showing locations of some structures and other features named in the text. Hachured band approximates location of New York-Alabama magnetic lineament. Cross-hatched area is Giles County. DR, Dan River basin; IP, Irvine-Paint Creek fault; ME, Midway-Extra gas field; PP, interference structure formed by Pulaski thrust sheet and Purgatory Mountain anticline; SC, St. Clair fault; WA, Warfield anticline; WB, Williamsburg anticline; WF, Warfield fault. Modified from Rodgers (1970, pl. 1A), Cardwell (1976), Calver and others (1963), King and Zietz (1978).

anomaly field and several derivative fields calculated from the Bouguer values. The colored maps show that the gradient, part of which is shown in figure 18, is a geometrically complex eastward rise in Bouguer values. The rise and the portions of the Bouguer field on either side of the rise consist mostly of numerous irregularly

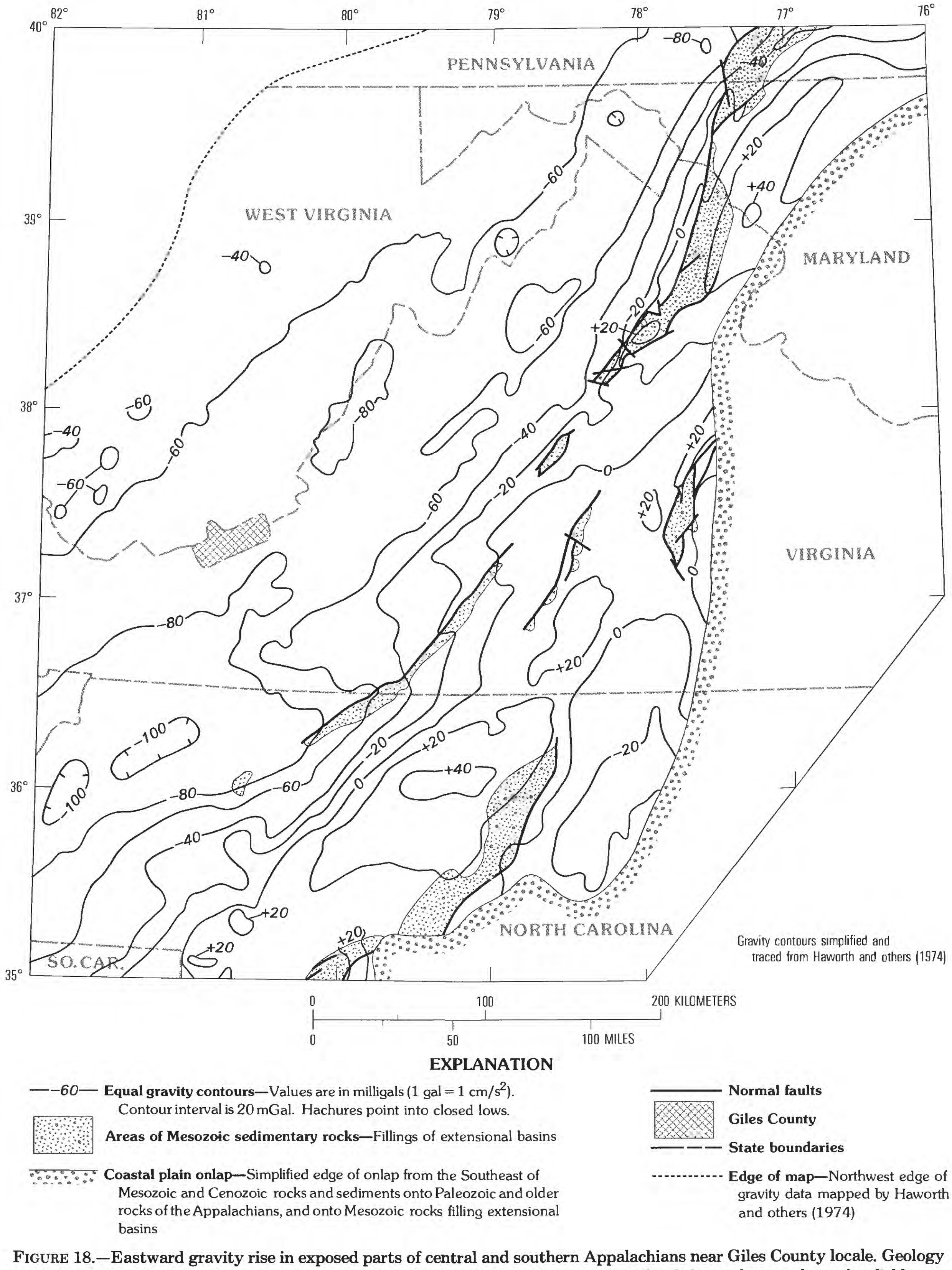



FIGURE 18.—Eastward gravity rise in exposed parts of central and southern Appalachians near Giles County locale. Geology from Williams (1978). Gravity from Haworth and others (1980). For more details of the geology and gravity field over larger areas, see maps of King and Beikman (1974), Woollard and Joesting (1964), Williams (1978), Haworth and others (1980), Simpson, Bothner, and Godson (1981), and Simpson and Godson (1981).

linear, anastamosing highs and lows. Anomalies of many widths are superimposed. The individual anomalies are separated across strike by second-order gradients of several milligals to several tens of milligals and replace each other along strike. Accordingly, rather than refer to a single gradient like that shown in figure 18, we shall refer to the eastward rise in the Bouguer anomaly field: The rise has as much internal structure as the parts of the Bouguer field that it separates, but the part of the gravitational field east of the rise generally has more positive Bouguer values than does the part west of the rise (R. W. Simpson, oral and written communs., 1981).

Simpson and coworkers used Fourier transform techniques to digitally separate the Bouguer anomaly field into a regional part, comprising all anomalies with wavelengths exceeding 100 km, and a residual part, made up of all anomalies with wavelengths less than 100 km. They performed a similar separation at a wavelength of 250 km (Simpson, Bothner, and Godson, 1981, their figs. 4, 5; Simpson and Godson, 1981, their figs. 4, 5). This process is called wavelength filtering. The two maps of residual (short-wavelength) fields, and especially the two maps of regional (long-wavelength) fields, all reflect the same presence and position of the rise as seen in the unfiltered field, from Vermont to Alabama. Figure 19 summarizes this spatial stability of the gravity rise for the region near Giles County.

A common interpretation of the prominent eastward rise in the Bouguer anomaly field is that it marks the southeastern edge of relatively intact North American continental crust. The edge is a relic of the early opening of the Iapetus Ocean (in addition to many of the papers already cited, see, for example, Fleming and Sumner, 1975; Rankin, 1975, p. 327–328; Long, 1979; Hatcher and Zietz, 1980; Price and Hatcher, 1980; Iverson, 1981; Kumarapeli and others, 1981; Cook and Oliver, 1981; Iverson and Smithson, 1982; Odom and Fullagar, 1982; Schwab, 1982; Thomas, 1982a). W. H. Diment (oral commun., 1981) noted that the rise could have different causes along different parts of its length. Interpretations of the rise by various authors previously cited include (1) eastward crustal thinning, caused by a change from continental crust to buried oceanic crust, or caused by an uplift of the upper mantle and lower crust on steep faults, and (2) eastward change to denser crust (oceanic, denser continental, or transitional) of the same or lesser thickness.

For example, several workers have computed geological models whose density distributions are consistent with the shape and amplitude of the rise. Diment (1968) suggested that the rise in Vermont could be caused by uplift east of the rise of dense lower crustal rocks along a steep fault. For northeast Georgia, Long (1979) suggested that the rise marks the west edge of a terrane of continental fragments separated from each other and the craton by remnants of a Paleozoic rift or rifts. For the same area, Cook and Oliver (1981) showed that a model based on density distributions typical of the modern Atlantic continental margin is consistent with the shape, position, and amplitude of the rise. Further, Kean and Long (1981) estimated from seismic-refraction arrival-time data that crustal thickness decreases about 13 km southeastward across the gravity rise in parts of Tennessee, the Carolinas, and Georgia. They showed a decrease of crustal thickness from a mean of 49 km northwest of the rise, to a mean of 36 km southeast of the rise, with a value of 33 km for the region immediately southeast of the rise. Their thickness estimate of 50 km at Blacksburg, Va., northwest of the rise, is in excellent agreement with the 51 km determined for the Giles County locale, about 25 km west of Blacksburg (Moore, 1979; see model TPM2 of Appendix C of this report). Similar eastward decreases in crustal thickness across the region of the rise were suggested by James and others (1968; decrease from 45 to 50 km to 35 to 40 km, as derived from seismic traveltime terms and corroborated by Chapman (1979)) and by Carts and Bollinger (1981; averaged thicknesses decrease from 40 to 33 km, as derived from an updated crustal velocity model based on recent earthquake arrival-time data).

Regardless of local causes of the eastward gravity rise, it is important for our purposes to note that we interpret the two maps of long-wavelength Bouguer gravity anomalies of Simpson, Bothner, and Godson (1981), and of Simpson and Godson (1981) to indicate that the North American craton extends at least as far east as the rise in the unfiltered Bouguer anomaly field, which is east of Giles County (fig. 19). This is presumed to be true for all crustal levels below the Appalachian thrust sheets, including those at the depths of Giles County seismicity (5–25 km). That interpretation is made because the process of wavelength filtering can be thought of in terms of the depths of the rock masses (sources) that produce gravity anomalies of various wavelengths (fig. 20). For sources of the same sizes and density contrasts, deeper sources produce broader (longer wavelength) anomalies. That correspondence between source depth and anomaly wavelength is not perfect because broad, shallow sources can also produce long-wavelength anomalies. However, in general, the process of wavelength filtering, which separates the total field into a short-wavelength (residual) part and a long-wavelength (regional) part, can be thought of as separating gravity anomalies that are caused by sources within different depth ranges. That is, the residual field from the 120-km wavelength filter is regarded as composed mostly of anomalies caused by sources at upper

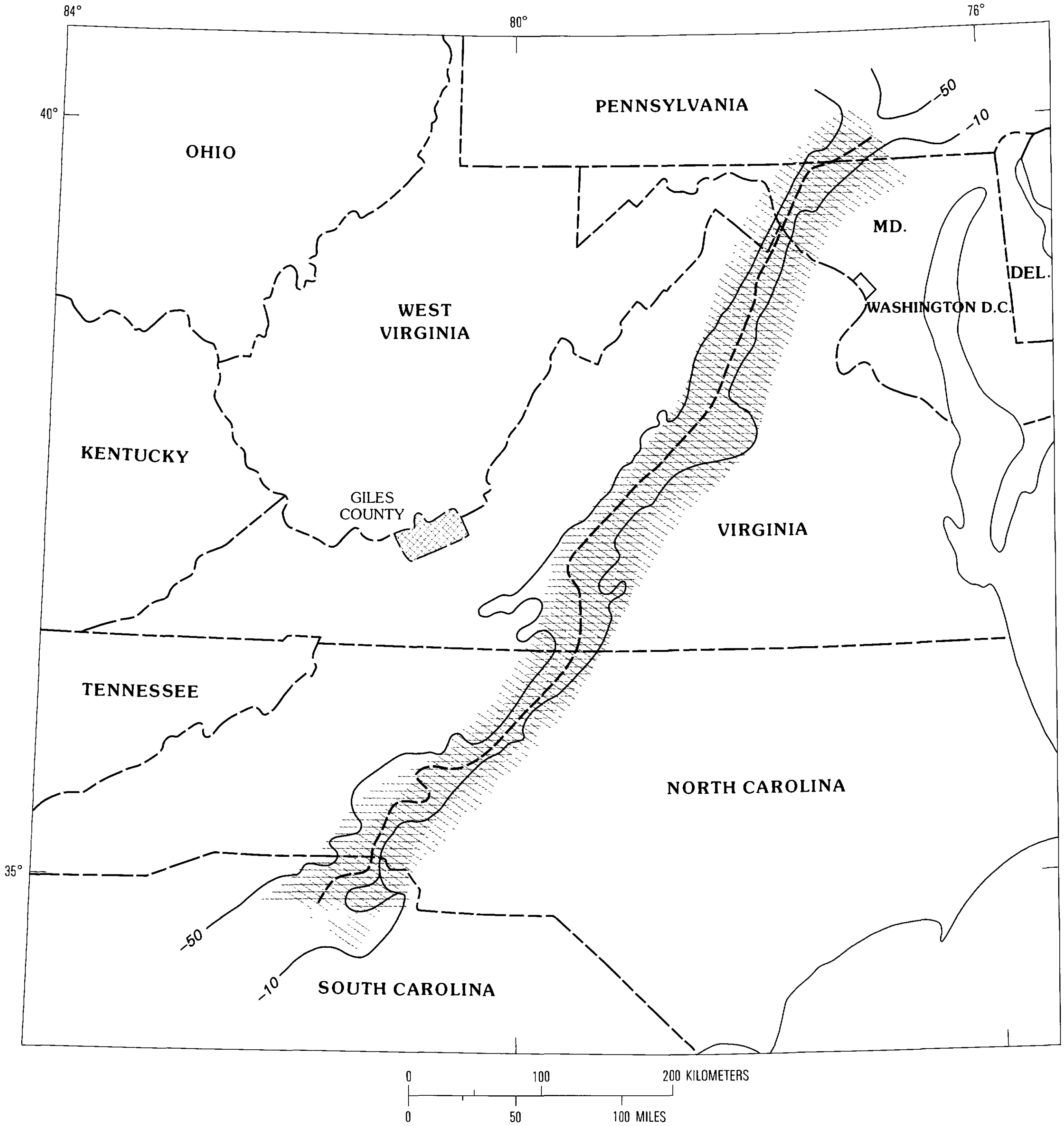



FIGURE 19.—Positions of eastward gravity rise in wavelength-filtered Bouguer anomaly fields. Isogal values of -50 mGal and -10 mGal define the bottom (northwest side) and top (southeast side) of the rise, respectively, in the unfiltered Bouguer field. Halfway in value, the -30 mGal isogal is shown by a heavy dashed line. Horizontal ruling shows position of gravity rise as it appears on map of anomalies with wavelengths longer than 125 km (ruling covers the area between -40 mGal and +10 mGal isogals). Diagonal ruling shows position of rise as it appears on map of anomalies with wavelengths longer than 250 km (ruling covers the area between -30 mGal and 0 mGal isogals).

Gravity data simplified and traced from unpublished maps supplied by R. W. Simpson (written commun., 1981), which combine the maps of Simpson, Bothner, and Godson (1981), and Simpson and Godson (1981), but use 125 km-wavelength instead of 100 km-wavelength.

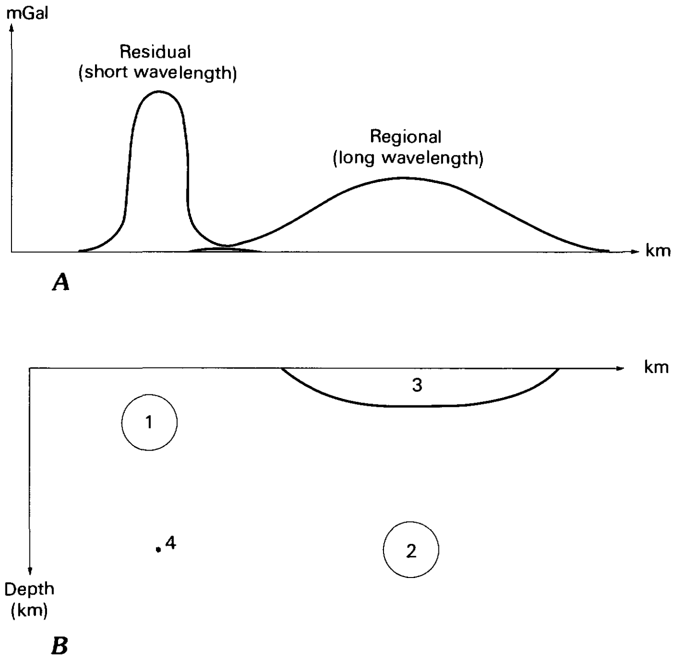



FIGURE 20.—Sketch illustrating interpretation of wavelengths of gravity anomalies in terms of the depths of the sources of the anomalies. *A*, Narrow (residual, or short wavelength) and wide (regional, or long wavelength) anomalies, respectively on the left and the right. *B*, Vertical cross section showing types of sources that might underlie and produce the anomalies of *A*. Sources 1–4 are denser than surrounding rock, and produce positive anomalies. Negative anomalies would be interpreted in the same way, but with sources that are less dense than surrounding rock. As the source of an anomaly deepens, the anomaly broadens. Source 2 is deeper than source 1 but otherwise identical, and produces a long-wavelength anomaly. However, such a long-wavelength anomaly can also be produced by a wide source like 3, at about the same depth as source 1. It is unlikely that a short-wavelength anomaly, such as that above source 1, could be produced by a deep source, such as 4. Such a deep source would have to be improbably small, improbably dense, or both. In practice, qualitative statements like the preceding ones are sharpened with numerical models calculated from specific values of densities, source depths and dimensions, and anomaly sizes and shapes.

crustal or shallower depths. The corresponding regional field contains anomalies from deeper sources, as well as those from shallow, wide sources, such as the sedimentary filling of the Appalachian Basin. Similarly, the residual field from the 250-km wavelength filter contains mostly anomalies arising from lower crustal and shallower sources; whereas, the corresponding regional field reflects deeper sources as well as shallow, wide sources (Simpson, Bothner and Godson, 1981; Simpson and Godson, 1981; Kane and others, 1981; R. W. Simpson, M. F. Kane, and W. H. Diment, oral and written communs., 1980, 1981).

Given that general association between anomaly wavelength and source depth, it is important for our purposes to note that the eastward rises in the unfiltered Bouguer field, in the regional field obtained from the 125-km filter, and in the regional field obtained from the 250-km filter, all coincide in map view in the region near Giles County (fig. 19). Locational mismatches between the eastward rises in the three fields have map dimensions usually less than half the map width of the rises themselves. We attribute such mismatches to the smoothing effects of the filtering process. We see no indication that the source of the rise migrates northwestward or southeastward with depth, although small amounts of such migration may be unresolvable at the scale of the maps we examined (1:5,000,000: R. W. Simpson, written commun., 1981). Thus, the source of the eastward gravity rise, which we and others infer to be the southeastern edge of relatively intact North American continental crust left from Iapetan opening, occurs at the same map position in both the upper and lower crust.

## AREA OF EXPECTED OCCURRENCE OF IAPETAN NORMAL FAULTS

If a reactivated Iapetan normal fault or fault zone is responsible for the seismicity of the Giles County locale, where else in the Southeast might similar faults have formed? A foundation on which to build an answer is provided by the eastward gravity rise, and by its interpretation as the southeastern edge of the relatively intact continental crust that was left after Iapetan opening. The answer will consist of two estimated distances: how far to the southeast of the gravity rise, and how far to the northwest, Iapetan normal faults might have formed and been preserved until today.

### SOUTHEASTWARD EXTENT OF IAPETAN NORMAL FAULTS

Recall that seismicity in and near Giles County occurs west of the gravity rise (fig. 19), beneath the sedimentary rocks that form the local thrust complex of the Valley and Ridge province (p. 5–8). That complex is the western tip of the much thicker thrust sheets of mostly metamorphic and igneous rocks that involve much of the upper crust of the southern Appalachians (Clark and others, 1978; Cook and others, 1979; Costain and Glover, 1980a; Cook and others, 1981; Cook and Oliver, 1981; Iverson and Smithson, 1982; Pratt and others, 1982) and perhaps farther north (Harris and Bayer, 1979, 1980, with discussion by Williams, 1980; Granger and others, 1980; Costain and Glover, 1980b;

but see also Ando and others, 1982; Taylor and Toksöz, 1982). If Giles County seismicity occurs on Iapetan normal faults, such faults will lie beneath the thrust complex and may be masked by thrusts on which upper crustal and shallower rocks have been transported to the west. Thus, Iapetan normal faults could exist at all crustal levels beneath the thrust sheets and at least as far east as the edge of relatively intact North American cratonic crust, which edge we consider to underlie the gravity rise.

We now consider whether an eastern boundary can be found for the area in which Iapetan normal faults may occur in cratonic crust. It is necessary for us to estimate separately regions of likely occurrence for Iapetan and Atlantic normal faults, even though both faulting episodes probably produced structures of comparable size, orientation, and style. The Appalachian thrustings and metamorphisms followed the Iapetan normal faulting but preceded the Atlantic normal faulting. Thus, the Iapetan and Atlantic normal faults could differ in properties, such as degree or type of annealing, which would affect their abilities to be reactivated in the present-day stress field. We will suggest that, in general, the eastward rise in the unfiltered Bouguer anomaly field is the eastern limit for Iapetan normal faults and that most such faults occur in the relatively intact North American crust west of the gravity rise. Local exceptions are possible, because the crust east of the rise is probably a heterogeneous mixture of many crustal pieces of many types. Some pieces may be parts of North American crust thinned or dissected by Iapetan normal faults. Most pieces may have been reworked by deformation and metamorphism during various Paleozoic subduction episodes. The reworking may have been so extensive that preexisting faults are no longer zones of crustal weakness.

Although the composition, thickness, and history of the crust east of the gravity rise are known only locally and approximately, it is now clear that much of that crust is not cratonic. For more than a decade (Brown, 1970), terranes of various sizes throughout the Appalachians have been shown or suggested to consist of Paleozoic island arcs, pieces of marginal or back-arc basins, or cratonic fragments with or without superimposed volcanic-plutonic edifices of Andean type. Examples of such terranes include Armorica (Van der Voo, 1979b, 1980a, 1982b) and various pieces of Avalon (for example, Simpson, Shride, and Bothner, 1980; Skehan and Murray, 1980; see review by Rast, 1980). Hatcher (1978), Long (1979), and Hatcher and Zietz (1980) inferred that various blocks of mafic, granitic, and mixed deep crust compose much of the southern Appalachians, including the region southeast of the gravity rise opposite Giles County. Osberg (1978) concluded that an island arc terrane comprises most of New England, and more terranes are being found or suggested at a quickening pace (Rowley, 1981; Spariosu and Kent, 1981; Williams and Hatcher, 1981; Zen and Palmer, 1981; Hatcher and Williams, 1982; Iverson and Smithson, 1982; Sinha and Zietz, 1982; Williams and Hatcher, 1982). Indeed, several workers (for example, Irving, 1979; Cook and others, 1981; Zen, 1981) considered a possible analog to be the mélange of over 50 distinct tectono-stratigraphic terranes that accreted onto western North America in Cenozoic, Mesozoic, and perhaps Paleozoic time after traveling unknown distances across the Pacific. (See reviews by Coney and others, 1980; and Ben-Avraham and others, 1981.) Some of these workers suggested, as a modern example, the complex of telescoping microplates and lithospheric shreds now caught between converging Australia and southeast Asia. (See maps by Hamilton, 1974a, b, c, 1978; Hayes, 1978.) Hatcher (1978) suggested, as another modern analog, the Pacific coast of Asia from Kamchatka to Japan and Korea, with its complex of peninsulas, island arcs, and marginal seas.

Further, the converging North American and Gondwanan continental margins of the Paleozoic were probably as irregular in map view as are present-day margins. If so, then geometric and geologic complexities like those inferred to be still developing in and around the Aegean Sea (Dewey and Şengör, 1979) may underlie one or more areas east of the gravity rise, opposite Giles County. Finally, the converging overall motion of the North American and Gondwanan plates may well have had irregular or strike-slip components. Such components would be most likely to occur as convergence ended and global plate motions began to reorganize to accommodate the loss of thousands of kilometers of subductive plate boundaries. If so, then much of the region east of the gravity rise may have evolved and accumulated throughout a history as complex as that suggested by Dewey and others (1973) for the Mediterranean region and the Alpine system.

Such known and suggested complexities in the tectonic evolution of the Appalachians can be used to postulate a resolution of an ostensible conflict. On the one hand, we hypothesize that the gravity rise marks the eastern edge of relatively intact North American continental crust, mostly formed in the Middle Proterozoic when the Grenville orogeny occurred. On the other hand, Glover and others (1978) identified exposed metamorphic rocks of Grenville age in central Virginia that lie east of the gravity rise. The rocks are involved in the thrust sheets of the Piedmont province, and so before thrusting they lay still farther east of the gravity rise. If these Grenville rocks were originally part of North America, they could have arrived east of the rise in various ways: the Grenville rocks could have remained attached to the relatively intact North American crust but linked to it by continental crust thinned by Iapetan normal faults; alternatively, the Grenville rocks could have been entirely separated from North America, by being rifted away (Hatcher, 1978; Hatcher and others, 1981; Glover and others, 1982), by strike-slip separation from a North American promontory, or by both, and later sutured back onto North America in their present relative position.

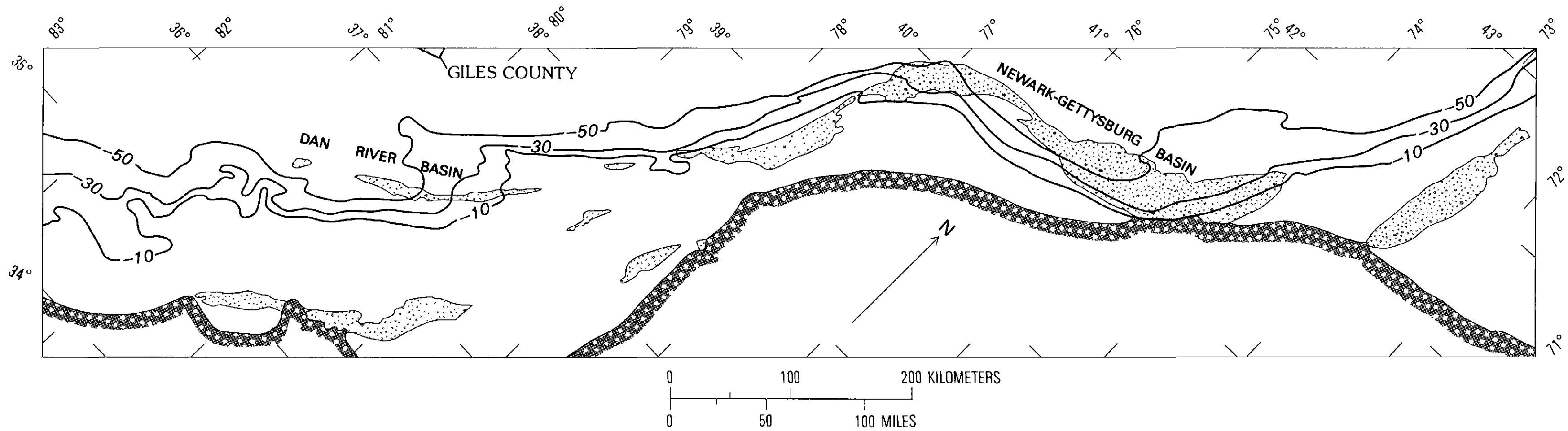
East of the gravity rise, such tectono-stratigraphic terranes could be of many sizes, shapes, and compositions. They are likely to be bounded and perhaps internally fragmented by plate-scale shear zones. Edges of pieces of continental crust could be further modified by Andean-type metamorphic and igneous activity. Further, any Iapetan normal faults that formed east of the gravity rise might no longer have an orientation suitable for reactivation in today's ambient stress field. That is, small plates could have been rotated when caught between larger plates carrying the North American and other cratons. Further rotation could have occurred during the many hundreds to several thousands of kilometers of left slip that is inferred to have occurred mostly or entirely in Carboniferous time (Kent and Opdyke, 1978, 1979; Van der Voo and others, 1979; Irving, 1979; Harland, 1980; Van der Voo, 1980a, b, 1981, 1982a, b; Kent, 1981; Van der Voo and Scotese, 1981; Williams and Hatcher, 1982). LeFort and Van der Voo (1981) suggested a model in which that left slip is consistent with the much smaller amount of coeval right slip inferred from the compilation of Bradley (1982). It seems unlikely that Iapetan normal faults would survive in such activity, at least not as weak zones of crustal size on which stress might be preferentially released by seismic slip.

If the crust east of the gravity rise is indeed an assemblage of heterogeneous terranes, it may be less cohesive or weaker than the cratonic crust west of the rise. Comparison of geologic and Bouguer gravity maps of the Eastern United States produces observations consistent with that suggestion (fig. 21). South from lat 43° N., Mesozoic extensional basins, most of them bounded by normal faults, lie on or east of the gravity rise, with two exceptions. The larger exception is the western part of the Newark-Gettysburg basin. However, there and elsewhere the western limit of the province of Mesozoic faults and associated basins follows faithfully abrupt bends in the gravity rise. The smaller exception is at about lat 37° N. where a sharp offset in the rise crosses the middle of the Dan River basin. Thus, the Mesozoic fragmentation of this part of the late Paleozoic supercontinent, Pangea, apparently followed and was restricted to the region suggested to be underlain by heterogeneous lithospheric fragments. It may be that those fragments are relatively weakly attached to each other and to the North American craton. Indeed, Grow and others (1982) independently suggested control of Mesozoic extensional faults by Paleozoic compressional structures.

### NORTHWESTWARD EXTENT OF IAPETAN NORMAL FAULTS

It is reasonable to expect Iapetan normal faults to occur under and near the Giles County locale itself. The center of the rise in the unfiltered Bouguer anomaly field lies 50–100 km southeast of the locale (figs. 18, 19, 21). If the rise marks the eastern edge of relatively intact and unthinned North American cratonic crust, then analogies drawn from examination of present passive continental margins show that, in early Iapetan time, the locale was close enough to the lithospheric break that finally grew into the Iapetus Ocean that the Giles County locale could have experienced normal faulting. For example, on the edges of the Red Sea, Lowell and Genik (1972, their fig. 5) mapped normal faults that cut continental crust. On traverses across the Red Sea, as one approaches active and once-active spreading centers, such faults become abundant enough to have extended and thinned the crust. Lowell and Genik (1972) showed such faults occurring to about 100 km toward the craton from the seaward edge of relatively unthinned continental crust, and to some 270 km from the inferred boundary between new oceanic crust and old, fault-thinned continental crust.

Similarly, on and near the present-day United States continental margin off the central and southern Appalachians, the western edges of exposed, partly fault bordered Mesozoic basins show approximately how far into the pre-Atlantic continental crust of North America large normal faults formed when the Atlantic began to open. Continental crust is herein taken as extending east no farther than the western edge of the East Coast Magnetic High, which roughly follows the 2,000-m isobath between lat 31° and 40° N., 50–150 km offshore (Schouten and Klitgord, 1977; Grow and others, 1982). Over most of that area, continental crust is faulted but still relatively intact because it was apparently unthinned by Atlantic normal faults at least as far east as the overlap of the Coastal Plain onto Paleozoic rocks (boundary between Coastal Plain and Piedmont; James and others, 1968; Grow and others, 1982). However, offshore there are more normal faults (Sheridan, 1976; compilations by Wentworth and Mergner-Keefer, 1981a, b, c), and rift-stage crust becomes abundant at and east of the coast, or within 100–200 km of the East Coast Magnetic High (Klitgord and Behrendt, 1979). Thus, when the Atlantic opened, normal faults formed as




**EXPLANATION**

**Areas of Mesozoic sedimentary rocks**—Fillings of extensional basins

**Southeast edge of exposed Paleozoic and Older rocks of Appalachians**—South of about latitude 41°, the edge is at the onlap of Mesozoic and Cenozoic rocks and sediments of the Coastal Plain. North of that latitude, the edge is at the shoreline

—-10— **Selected contours of equal Bouguer gravity values**—Values are in milligals (1 gal = m/s$^2$). Contour interval is 20 mGal

**Southeastern corner of Giles County**

FIGURE 21.—Relationship of eastward rise in Bouguer gravity field to western edge of Mesozoic extension in central and southern Appalachians. Simplified and traced from Williams (1978) and Haworth and others (1980). Maps of Williams (1978) and King and Beikman (1974) show no Mesozoic extensional basins south or west of the area shown here. The three gravity contours that are shown are those that best depict the location and shape of the eastward gravity rise in the map area.

much as about 250 km to about 450 km inland from the present edge of the continental crust, and at least one-third to one-half of that distance represents normal faults in relatively intact continental crust. Similar values come from the margins of the Labrador Sea (Van der Linden, 1975), the Moroccan margin (Schlee, 1980), and several Australian, Red Sea, African, and Brazilian passive margins (Falvey, 1974; Talwani and others, 1979).

Thus, the area in which Iapetan normal faults are expected to exist and might experience seismic reactivation is bounded on the southeast by the eastward gravity rise, but has no sharp northwestern boundary. Southeast of the gravity rise, it is possible, but unlikely, that single Iapetan normal faults are preserved in a reactivatable state. To the northwest, Iapetan normal faults are expected to decrease in size, abundance, and slip gradually and irregularly northwestward into the North American craton over a distance of perhaps 100–200 km.

By analogy with other normal faults formed on passive continental margins, most Iapetan normal faults in eastern North America may be expected to strike northeast to north-northeast, particularly if they had not formed by reactivation of still older faults of diverse orientations. The Iapetan faults should dip steeply to either the northwest or the southeast. Where senses of net dip slip can be determined, most should still be normal. However, because the faults were properly oriented to have been reactivated in later compressional episodes of the Appalachian orogenies, some net dip slips could have been changed from normal to reverse if the original dip slips were small. Because today's greatest horizontal compressive stress trends northeasterly and not perpendicularly to the ancient Iapetan continental margin (Zoback and Zoback, 1980, 1981; this report, p. 51), seismic reactivation of such faults may (but need not) have a strike-slip component, probably right-slip. Such faults formed as the upper portions of fault systems that acted to extend the continental crust, and so should have dimensions comparable to the thickness of at least the brittle upper part of the crust.

#### SUMMARY

Of the three types of Paleozoic and Mesozoic basement faults that reasonably could have formed under the Giles County locale and that may be responsible for much of its present seismicity, we consider an Iapetan normal fault to be the most probable. Before considering the other two fault types, we summarize here reasons for favoring Iapetan normal faults. The Giles County locale is well within the region of North American continental crust expected to have undergone such faulting: west of but within 100–200 km of the Iapetan continental edge that is inferred to underlie the steep eastward rise in the unfiltered Bouguer anomaly field. The Giles County seismic zone has the proper orientation, shape, size, and depth range to be occurring on such a fault—reactivated in today's ambient stress field. Sparse direction-of-motion data on *P* waves are unable to give a composite focal mechanism by themselves but are consistent with right-reverse reactivation of such a fault (fig. 16). Finally and reassuringly for the evaluation of such subtly expressed and well-hidden structure, we know of no evidence that is inconsistent with the hypothesis that an Iapetan normal fault is responsible for the Giles County seismic zone.

## ALLEGHANY THRUST-LOAD FAULTS

Late Paleozoic faults of a type here named "thrust-load" could be sources of Giles County seismicity. The likelihood that a thrust-load fault is responsible for the Giles County seismic zone will be evaluated by comparing relative ages of central and southern Appalachian thrusting in and near Giles County. The hypothesis of a thrust-load fault allows relative ages to be deduced from observed map relations, and that deduction can be tested against relative ages of thrusting inferred from stratigraphic and structural observations.

Thrust-load faults are hypothesized to form in front of or beneath recently emplaced thrust sheets, as the crust fractures under their weight in a brittle analog of the foredeeps known to form under and in front of thrust masses and continental ice sheets. Alternatively, thrust-load faulting may occur by reactivation of older basement faults that are suitably oriented, again under the load imposed by newly emplaced detached masses (W. G. Brown, oral communs., 1980, 1981; Berry and Trumbly, 1968; Buchanan and Johnson, 1968; Hopkins, 1968; Beiers, 1976; Bush and others, 1978; M. K.-Seguin, oral and written communs., 1981; Seguin, 1982).

### A TESTABLE DEDUCTION FROM THE THRUST-LOAD HYPOTHESIS

The Giles County locale and its N. 44° E. striking seismic zone lie in the western part of the Valley and Ridge province (fig. 2) of the southern Appalachians. The locale is also near the juncture of the southern and central Appalachians. The southern Appalachians are characterized by east-northeast-trending thrust faults and related structures (fig. 22); in contrast, the central Appalachians are characterized by north-northeast

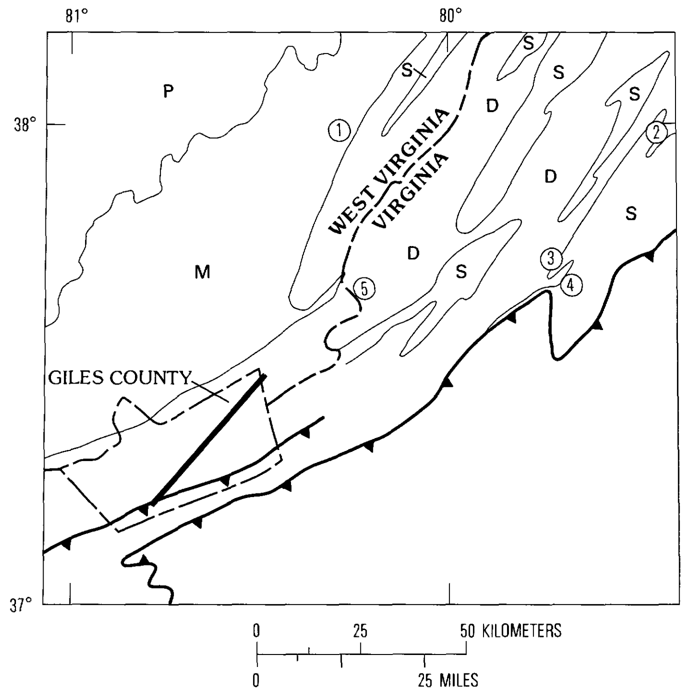



FIGURE 22.—Approximate orientations of Giles County seismic zone and of central and southern Appalachian thrust structures. Thick solid line trending about N. 44° E. shows approximate center of the seismic zone. Southern Appalachian structures trend east-northeast as indicated by traces of outcrops of main thrust faults (solid lines with sawteeth on upper plates). Central Appalachian structures trend north-northeast as indicated by main folds as outlined by traces of systemic boundaries (S, Silurian and older rocks; D, Devonian rocks; M, Mississippian rocks; P, Pennsylvanian rocks). Systemic boundaries southeast of thrust-fault traces are complex and not shown here. Geology and structure simplified from compilation of Willden and others (1968). Circled numbers show localities discussed in text.

trending thrust-related folds and other structures. Thrust faults and folds of both central and southern Appalachians involve Mississippian and older rocks, and to the northwest of Giles County, Pennsylvanian and Permian rocks. Many of the pre-Pennsylvanian rocks contain polymictic conglomerates that record the formation and erosion of substantial structural and topographic relief at several times and places. However, in and near the Giles County locale only the Pennsylvanian and Permian strata contain abundant, immature synorogenic clastic debris: molasse, derived from the southeast. Accordingly, the thrust masses presently exposed above the seismic zone are regarded as having been emplaced in the Giles County locale during the Alleghany orogeny of Pennsylvanian and Permian time. Older thrusts are known or possible, especially farther southeast, because thrusting developed successively northwestward (Perry, 1978). Any such older thrusts could have propagated northwestward, under Giles County, as blind thrusts (Boyer and Elliott, 1982, p. 1197). Thus, the thrusts now exposed in Giles County may have begun to form and move before Alleghany time. However, such earlier events would not affect the conclusion that the thrust-transported near-surface rocks and structures of the Giles County locale probably arrived above the seismic zone in Pennsylvanian or Permian time.

If the seismic zone occurs on a thrust-load fault, then that fault is probably either an Iapetan normal fault reactivated in Alleghany time, or a fresh crustal break of Alleghany age; recall that the introduction to this section suggests that high-angle faults older than Iapetan are unlikely to have survived under Giles County in any form able to be reactivated seismically. If thrust loading reactivated an Iapetan normal fault, the basement beneath the thrust masses would have to extend horizontally, in a direction at high angles to the strike of the reactivated normal fault. Fleitout and Froidevaux (1982, p. 43, figs. 5, 7) suggested a theoretical mechanism by which gravitational loading could produce a small amount of horizontal extension. Their suggestion is that emplacement of a thrust sheet would load and depress the lithosphere. Depression of the lower crust into the upper mantle would create a buoyant effect. However, if thrust loading and depression occurred fast enough that the depression occurred adiabatically, then depression of the upper mantle into the warmer, underlying mantle would create a sinking effect. If the sinking effect exceeded the buoyant effect, the crust could be drawn slightly in toward the center of the loaded area. The result could be horizontal extension under or near the loading thrust sheet. We do not argue that such horizontal extension under thrust loading actually occurred under Giles County, but we note that it is theoretically possible, and so must be considered here.

On the other hand, if the hypothesized thrust-load fault formed as a fresh Alleghany-age fracture, its strike should follow approximately the strike of the causative load gradient. In turn, the strike of the load gradient should follow the trends of thickness contours of the causative thrust complexes. Thickness contours follow trends of depth to basement, stratigraphic levels exposed today by erosion, and sedimentary facies, none of which change abruptly along strike in the region surrounding Giles County (Colton, 1970; King and Beikman, 1974). Consequently, the strike of any thrust-load fault that formed as a fresh Alleghany-age fracture should follow the general structural and stratigraphic trends of the exposed remnants of the causative thrust sheets.

The strike of the seismic zone is of an unambiguous central Appalachian orientation, rather than of a southern Appalachian one (fig. 22), so the hypothesized thrust-load fault would have been caused by emplacement of central Appalachian thrust sheets. However, the thrust and related structures now exposed in and near Giles County have southern Appalachian orientations (fig. 22). Those southern Appalachian structures are not known to be cut or otherwise affected by movement on the hypothesized thrust-load fault. Therefore, the thrust-load fault would have formed before arrival of the southern Appalachian thrust sheets that now overlie the seismic zone. This reasoning implies that central Appalachian thrust sheets arrived in or near Giles County first and were eroded before arrival of the southern Appalachian sheets, or were rotated by them or buried by them. Thus, the thrust-load hypothesis leads to the deduction that, in the Giles County locale, arrival of central Appalachian thrust sheets predates that of southern Appalachian thrust sheets.

This deduction can be tested. Relative ages of central and southern Appalachian thrusting are not clearly known, but several independent lines of structural and stratigraphic evidence are summarized in the following paragraphs. All favor southern Appalachian thrust sheets as having reached the vicinity of Giles County slightly before those of central Appalachian orientations. This conclusion contradicts the faulting sequence as deduced from the thrust-load hypothesis and, therefore, negates that hypothesis.

### STRATIGRAPHIC TESTS

The straightforward stratigraphic approach of constraining the age of thrusting by determining the ages of youngest folded and oldest unfolded rocks cannot work here. Youngest folded rocks are Early Permian in the central Appalachians and are Middle or Late Pennsylvanian in the southern Appalachians (King and Beikman, 1974). However, Permian rocks are wholly eroded or were never deposited in the southern Appalachians, and Middle and Upper Pennsylvanian rocks are nearly as sparse there (Colton, 1970, p. 42; King and Beikman, 1974). On the other hand, more subtle stratigraphic arguments are fruitful. Arkle (1969, 1972, 1974) presented isopach and facies maps and current-direction data for units of middle Mississippian through latest Pennsylvanian or Early Permian ages. These maps and related information allow us to estimate relative ages of thrusting, by dating the main influxes of Pennsylvanian molasse. The following analysis and interpretation are consistent with those done independently by Donaldson and Shumaker (1981). Their analysis is more detailed and covers more of the Paleozoic and a larger region than does ours.

Pennsylvanian and Permian rocks of the central and adjacent southern Appalachians are "a series of shales and fine- to coarse-grained sandstones, locally conglomeratic, arranged in repetitious sequences with thinner coals, clays, lacustrine and marine limestones, chert and ironstone" (Arkle, 1974, p. 5). Pertinent stratigraphic names are summarized in figure 23. The sandstones are immature, and the various lithologies record terrestrial, fluvial, deltaic, and some shallow marine deposition (Meckel, 1970; Donaldson, 1974; Arkle, 1974; Horne and others, 1978). The sequence is synorogenic and records the topographic and erosional effects of emplacement of late Paleozoic Alleghany thrust sheets. At least the parts of those sheets that were close to areas of molasse deposition must have been the tops of the detached sedimentary fold-and-thrust complexes now exposed in the eastern Appalachian Plateau and the Valley and Ridge provinces. Farther southeast, the metamorphic and igneous rocks of the Appalachians were also being unroofed and dissected (Presley, 1981). Davis and Ehrlich (1974) inferred from petrography of metamorphic and igneous grains and rock fragments in the Pennsylvanian sandstones that, in Early Pennsylvanian time, sedimentary and volcanic debris accumulated from initial unroofing of the metamorphic and igneous rocks. Next, successively deeper erosion and the required kilometers of uplift shed debris first from low-grade metamorphic rocks, then from batholithic complexes, and finally by Late Pennsylvanian time, from the underlying migmatitic terrane.

The deposition of Pennsylvanian and Permian sediments occurred in two overlapping basins separated by a wide, diffuse hinge line (fig. 24; Arkle, 1969, 1972; Horne and others, 1978). Upper Mississippian (Englund and others, 1982) and Lower to Middle Pennsylvanian clastic debris flowed in from the southeast and accumulated mostly in a subsiding trough called the Pocahontas basin, southeast of the hinge line (fig. 24*A*, *B*). Lower Pennsylvanian rocks of the Pottsville Group (figs. 23, 24) north of the hinge line are much thinner than are correlative rocks south of the hinge line (fig. 24*B*, *C*). In Middle and Late Pennsylvanian time, the clastic sources lay to the east and northeast and much thinner units accumulated mostly on a stable platform called the Dunkard basin, northwest of the hinge line (fig. 24*D*). Williams and Bragonier (1974) documented a southeastern source for Early Pennsylvanian time in much of western Pennsylvania, but, even so, thicknesses were much less there than southeast of the hinge line in southeastern West Virginia.

The Pottsville Group and the overlying units of the northern coal field both have northeastern sediment sources, and isopach lines indicate southwestward

| System | Series | Stratigraphic Units | |
|---|---|---|---|
| | | Northern coal field | Southern coal field |
| Permian | Lower | Dunkard Group | |
| Permian or Pennsylvanian | | | |
| Pennsylvanian | Upper | Monongahela Formation ⑦ | |
| | | Conemaugh Formation ⑥ | |
| | Middle | Allegheny Formation ⑤ | Charleston Sandstone ③ |
| | | | Kanawha Formation ② |
| | Lower | Pottsville Group ④ | New River Formation, Pocahontas Formation ① |
| | | NW SE | NW SE |

FIGURE 23.—Permian and Pennsylvanian stratigraphy of West Virginia coal fields. Sources: Englund and others (1979) and Arkle (1974); also Berryhill and Swanson (1962) and Cardwell and others (1968), unless there is a conflict with the two newer sources. Nondeposition and erosion followed deposition of the Dunkard Group and Charleston Sandstone. In both coal fields, basal Pennsylvanian strata are conformable on Mississippian beds southeast of the hinge line of figure 24 and unconformable northwest of it. Circled numbers refer to isopachs of figure 24. Note that "Allegheny Formation" is spelled with an e; whereas, "Alleghany orogeny" takes an a (Rodgers, 1970, p. 30).

thinning for both sequences (fig. 24*C*, *D*). However, in western Pennsylvania the Pottsville Group also resembles the approximate correlative units in the southern coal field, because both received sediments from the southeast and both have isopachs that show northward thinning (fig. 24*B*, *C*). Thus, the Pottsville represents a transition between an older sediment source in the southern Appalachians, and a younger source in the central Appalachians.

Thus, the sedimentary record of Alleghany tectonism indicates an older, Early and Middle Pennsylvanian (Pocahontas, New River, and Kanawha Formations, and Charleston Sandstone) age in the southern Appalachians near Giles County, but a younger, Middle and Late Pennsylvanian (Alleghany, Conemaugh, and Monongahela Formations) age in the central Appalachians.

The greater age of the southern Appalachian deformation compared to that of the central Appalachians can be demonstrated by additional stratigraphic evidence. First, in eastern Pennsylvania, a central Appalachian synclinorium contains tightly folded coal measures of Middle and Late Pennsylvanian age—all deformed by the oldest of the Alleghany structures (Wood and Bergin, 1970). Thus, in that portion of the central Appalachians, Alleghany deformation occurred during or after Late Pennsylvanian time.

Second, Horne and others (1978) and Cavorac and others (1964) reported an abrupt southward thickening of lowest Pennsylvanian (lower Pottsville Group) strata across the east-striking Irvine–Paint Creek fault system

FIGURE 24 (facing page).—Distributional patterns of Pennsylvanian units in West Virginia and parts of adjacent States. See figure 23 for stratigraphy. Double broken line shows position of hinge line of Arkle (1969, 1972), separating northern and southern coal fields of central Appalachians and figure 23. Location of hinge line is approximate: Donaldson (1974) gives its width as 25–50 mi (50–80 km). In parts *B*, *C*, and *D* heavy lines show isopachs selected from the maps of Arkle (1974). Circled numerals at ends of isopachs match the isopachs with their units, numbered in figure 23 from oldest to youngest. Isopachs shown here were selected to summarize the approximate present shapes and thinning directions of the units as shown in the more detailed maps of Arkle (1974). Thickness values of the selected isopachs are shown next to them, and for Parts *B*, *C*, and *D* are variously one-third to three-fourths the largest values shown on Arkle's maps. Boxed numerals show approximate locations of maximum thicknesses of indicated units in the area shown here, as inferred from map patterns of facies distributions and from the isopach patterns shown and discussed by Arkle (1969, 1972, 1974). Arrows on isopachs indicate approximate directions of sediment flow and unit thinning.

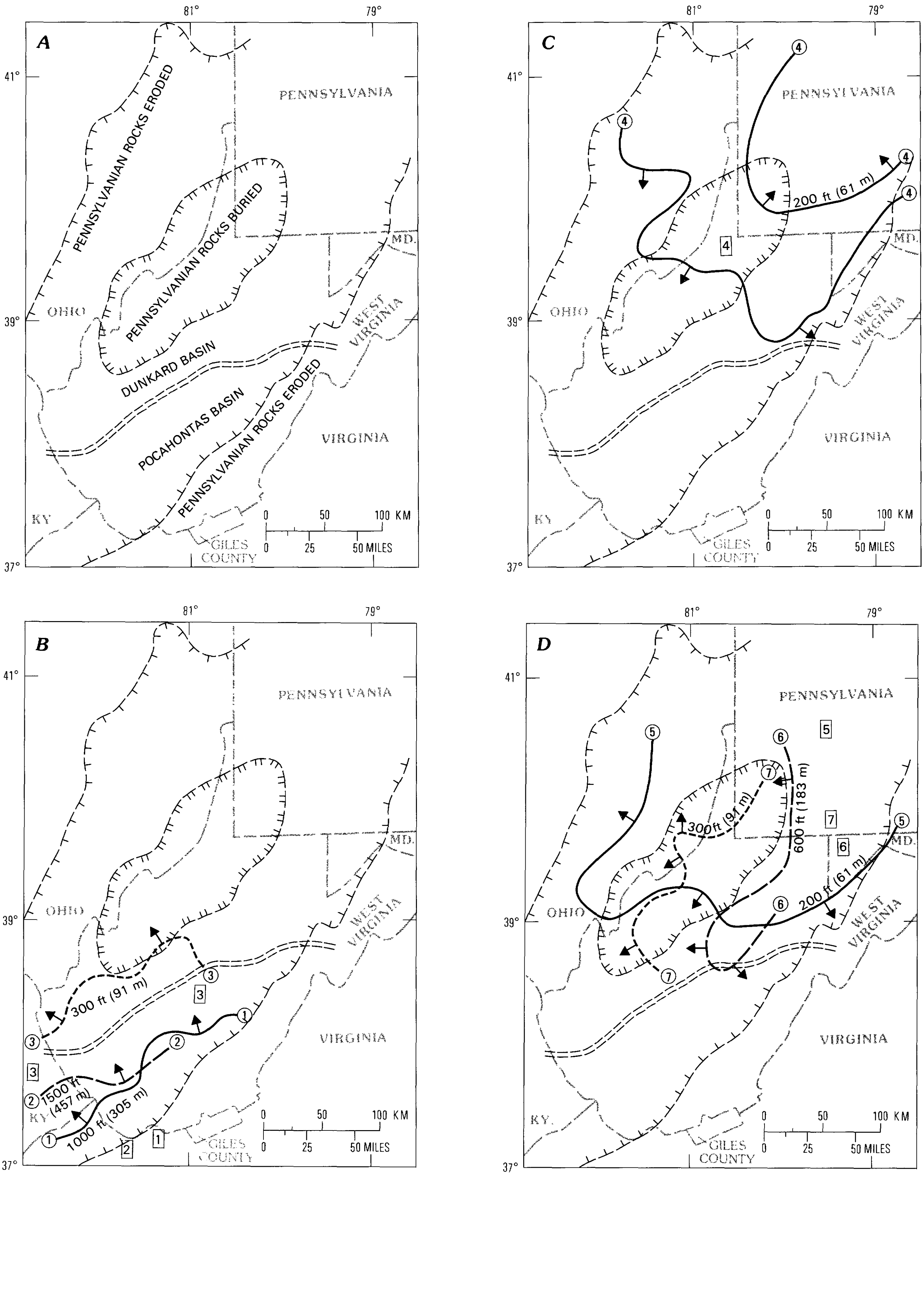
*A*. Locations of outcrops of base (single hachures) and top (double hachures) of Pennsylvanian System, greatly simplified. Hachures point inward toward center of late Paleozoic Dunkard basin.

*B*. Distributional patterns of Lower and Middle Pennsylvanian units, which entered the southern coal field of the Pocahontas basin from a southeastern source.

*C*. Distributional patterns of Lower and lower Middle Pennsylvanian Pottsville Group of the northern coal field, which is approximately correlative with most of the sequences represented in part *B*. Sediment entered the northern coal field of the Dunkard basin mostly from a northeastern source, but also with influx from a source in the southeast in western Pennsylvania (Williams and Bragonier, 1974).

*D*. Distributional patterns of Middle and Upper Pennsylvanian units, which entered the northern coal field of the Dunkard basin from eastern and northeastern sources. Arkle (1974) also shows isopach and facies maps of two Permian units. Their distributional patterns are consistent with those shown here but the Permian units are preserved over such small areas that they are not represented here.

of eastern Kentucky (fig. 17). Moreover, the southeastward tilting of depositional surfaces south of the hinge line occurred in Early Pennsylvanian time. The southeastward tilting possibly was a crustal response to loading by advancing southern Appalachian thrust sheets, and the activity on the Irvine–Paint Creek faults possibly was reactivation of older faults by thrust-loading. Later, a marine transgression, known to have occurred in Conemaugh time, could have been a response to formation of a foredeep by central Appalachian thrust-loading (Merrill, 1981). Such early southeastward tilting in front of advancing southern Appalachian thrust sheets, and later, northeast-trending depression in front of advancing central Appalachian thrust sheets, would be consistent with observations of Kulander and others (1980). Within the outcrop belt of Mississippian rocks that is shown in figure 22, Kulander and others mapped extension


A
B
C
D
81°
79°
41°
39°
37°
PENNSYLVANIA
OHIO
WEST VIRGINIA
VIRGINIA
MD.
KY
GILES COUNTY
PENNSYLVANIAN ROCKS ERODED
PENNSYLVANIAN ROCKS BURIED
DUNKARD BASIN
POCAHONTAS BASIN
0 50 100 KM
0 25 50 MILES
300 ft (91 m)
1500 ft (457 m)
1000 ft (305 m)
200 ft (61 m)
600 ft (183 m)

fractures that strike north-northeast and east-northeast. The fractures formed later than middle Mississippian time because they occur in limestone of that age. However, the extension fractures formed before Alleghany folding of the limestone because they are overprinted by stylolites that are a precursor of that folding. The extension fractures may record tilting and flexing of the crust in response to thrust-loading (S. L. Dean, oral commun., 1981). Thus, we have evidence which can be interpreted to indicate that the southern Appalachian thrust sheets were emplaced earlier in Pennsylvanian time than were the central Appalachian thrust sheets.

Finally, Babu and others (1973) compiled and mapped data on compositions of West Virginia coals. Coal rank and fixed-carbon content are properties whose values are affected mostly by postdepositional processes, such as burial, tectonism, and metamorphism. Accordingly, one would expect contours based on coal rank and fixed-carbon content to follow Appalachian structural trends—and they do (Babu and others, 1973, fig. 2). Values of both variables increase to the south-southeast in southeastern West Virginia, adjacent to the east-northeast-trending southern Appalachians, and values increase to the east-southeast in northern West Virginia, adjacent to and in the north-northeast-trending central Appalachians. However, ash and sulfur contents are known to reflect the local depositional environment and details of paleotopography in the coal swamp, and so ash and sulfur contents can record trends of thrust-related anticlines that were growing during deposition (Donaldson, 1974, p. 73). Figures 3 and 4 of Babu and others (1973) are too generalized to reflect locations and orientations of individual folds, but contours derived from ash and sulfur contents have crude southern Appalachian trends in the southern coal field, where most coals are of Early Pennsylvanian age, and the contours have crude central Appalachian trends in the northern coal field (see also Kent and Gomez, 1971), where most coals are of Middle and Late Pennsylvanian age. Thus, the combined data on coal composition and age support the evidence of a paleotopography that was created by growth of thrust-related anticlines formed in Early and Middle Pennsylvanian time in the southern Appalachians, and in Middle and Late Pennsylvanian time in the central Appalachians.

### STRUCTURAL TESTS

Sparse structural information supports or is consistent with the relative ages inferred from interpretations of stratigraphic results. The clearest structural information is that from the Mississippian Greenbrier Limestone in both the central and southern Appalachians, along a strike belt about 120 mi (190 km) long roughly centered at the location indicated by the circled numeral 1 in figure 22 (Dean and Kulander, 1977, 1978; Dean and others, 1979; Skinner, 1979; S. L. Dean, oral commun., 1981). Along the strike belt, stylolites formed in the Greenbrier Limestone on preexisting systematic joints. Stylolites and joints were rotated by folds that are visible on maps at scales from 1:24,000 to 1:250,000. Stylolites form as the rock dissolves under compressive stress, and the teeth on the stylolite seam form with their long axes parallel to that compressive stress. The stylolites in the Greenbrier Limestone have slickenlines (grooves or striae on slickensided surfaces (Fleuty, 1975)) parallel to the teeth. Over a large area extending about 50 mi (80 km) into the central Appalachians, stylolite teeth trend north-northwest and so they parallel other southern Appalachian structures. In the central Appalachians, in the southwestern part of the Williamsburg anticline (locality 1, fig. 22; and fig. 17), the stylolites have a southern Appalachian orientation and are folded by the anticline. Further, central Appalachian stylolites and slickenlines overprint those of southern Appalachian orientation, and a central Appalachian axial cleavage can be traced southwest, and there cuts obliquely and with constant orientation across southern Appalachian folds (S. L. Dean, oral commun., 1981).

However, interpretations of larger interfering structures are still too few to be conclusive. Perry (1978, p. 525–526) reinterpreted map patterns published by Bick (1973) at scales of about 1:40,000 to about 1:100,000 (localities 2–4, fig. 22 of this report). For locality 2, Perry concluded that the map by Bick records a thrust fault of southern Appalachian orientation that has been folded by an anticline of central Appalachian orientation. Bick agrees with this conclusion (written communs., 1978, 1981). For localities 3 and 4, Perry interpreted Bick's maps to show other central and southern Appalachian structures interfering with each other; however, subsequent mapping indicates that the interpreted interference does not or may not occur at those two localities (K. F. Bick, written commun., 1981). More recently near locality 4 (fig. 22), Bick (1982, 1986) and Henika and others (1982) interpreted an interference structure involving the Purgatory Mountain anticline and the Pulaski thrust sheet (fig. 17). They deduced different relative ages using different data. In another study of the area at the junction of the southern and central Appalachians, Olson (1979) mapped, at a scale of 1:24,000, folds of central Appalachian orientation lying northwest of and trending into the southern Appalachian St. Clair fault (figs. 17, 22, locality 5). Olson (1979, p. 88) concluded that one such unnamed anticline-syncline pair is not truncated by the thrust, but his map (his plate 1A, northeast half) suggests to Wheeler that the thrust may cut the fold pair. At the northeast end of the thrust, a second fold pair mapped by Olson may be folded, though not necessarily cut, by the thrust. Reconnaissance mapping by McDowell tends to support the interpretation of Olson (R. C. McDowell, 1981; oral commun., 1981). Thus, of six places where map-scale structures of southern and central Appalachian orientations are known or suspected to interfere, one shows an older southern Appalachian structure and five are inconclusive at present.

Such inconclusive relative ages as determined from map-scale structures are discouraging but, on reflection, not surprising. The sequence of deformation in the sedimentary parts of the central Appalachians and adjacent parts of the southern Appalachians is known to have been long and complex on both map and outcrop scales (Geiser, 1977, 1981; Perry and deWitt, 1977, p. 39–40; Perry, 1978; Bartholomew, 1979; Nickelsen, 1963, 1979, 1980; Van der Voo, 1979a, b; Berger and others, 1979; Hatcher and Odom, 1980; Roeder and Boyer, 1981; Wright, 1981; Bartholomew and others, 1982; Bick, 1982; Gray, 1982; Henika and others, 1982; Webb, 1982; Wheeler, 1982, 1986). Dahlstrom (1970) documented type examples in the foothills of the Canadian Rockies where the typical sequence of relative ages of thrusts, becoming younger toward the craton, is locally reversed. Roeder and others (1978) and Witherspoon and Roeder (1981) interpreted a series of partly balanced cross sections through the southern Appalachians as recording complex polyphase thrusting with similar local reversals. Given such complex internal deformation of a thrust complex like the Valley and Ridge and eastern Appalachian Plateau provinces, it seems likely that many more local map relations will be needed before relative ages of structures become clear. Such structural complexity is compounded because the central and southern Appalachians overlapped in time for part of their growth. Overlap can be inferred with particular clarity from the paleogeographic maps of Donaldson and Shumaker (1981). Mapping underway by several workers, such as K. F. Bick, S. L. Dean, B. R. Kulander, and R. C. McDowell (oral and written communs., 1978–1982), will eventually produce the clearest, most detailed determinations of relative ages. However, now and for our purposes, the chronology of folded stylolites of Dean and Kulander (1977, 1978), and conclusions drawn from the stratigraphic data mapped by Arkle (1969, 1972, 1974) and compiled by Donaldson and Shumaker (1981), probably give more reliable relative ages because both approaches average the results over large areas.

#### SUMMARY

The thrust-load hypothesis leads to the deduction that central Appalachian thrust sheets entered or formed in Giles County before those of the southern Appalachians. However, that conclusion is contradicted by relative ages inferred from stratigraphic and outcrop-scale structural data. We conclude that the Giles County seismic zone did not form originally as a fresh Alleghany fracture or fracture zone under thrust loading. Recall that this line of reasoning assumes that such a fresh break would parallel the causative thrust front. Thrust loading by southern Appalachian thrust sheets could have reactivated an older basement fault. If such an older fault were weak enough, it could be reactivated even if it made an angle of several tens of degrees with the front of the loading thrust sheets. Such an older fault would probably have originated as an Iapetan normal fault, according to the arguments and conclusions previously stated in this report (p. 27–28).

### ATLANTIC NORMAL FAULTS

Mesozoic normal faults could be sources of Giles County seismicity. Such faults formed to extend Pangean continental crust as the Atlantic Ocean began to open. The faults now bound Mesozoic grabens and half grabens that are exposed at least from Massachusetts to South Carolina (for instance see figure 18; King and Beikman, 1974). The normal faults are known or inferred to bound Mesozoic basins. The basins have been detected as far east as the edge of the continental shelf by geophysical methods and by drilling through younger sediments and sedimentary rocks. (See compilation of Wentworth and Mergner-Keefer, 1981a, b, c, and references cited there.) The faults can be high angle, with net normal slip. Most strikes trend from east-northeast to north-northeast, but a few short segments strike northwesterly and subdivide or terminate some of the basins (King and Beikman, 1974). Dips can be to either side of the strike. At least some faults formed by reactivation of older faults (Ratcliffe, 1971). Near New York City, Aggarwal and Sykes (1978) inferred that some such Mesozoic faults are seismically active, although Ratcliffe (1981a, b, c) questioned that inference.

Atlantic normal faults of Mesozoic age are unlikely to occur in or under the Giles County locale for four reasons: First, exposures of Mesozoic sedimentary rocks of the types that fill the Mesozoic grabens and half-grabens are unknown as far northwest as the Giles County locale (fig. 18; this has also been noted by Bollinger, 1981a). Second, large faults with normal slip that cut Alleghany thrust structures are unknown as far northwest as the Giles County locale; a Mesozoic normal fault of small enough extent to have escaped detection thus far would probably be too small to generate a damaging earthquake, even if erosion had removed all evidence of any Mesozoic sediment that might have accumulated on the downdropped block. Third, as noted previously under "Iapetan Normal Faults," most Mesozoic faults and basins in the Eastern United States lie on or east of the steep eastward rise in the Bouguer anomaly field. (For the region near the Giles County locale, figure 21 shows this relationship.) We have previously suggested that Mesozoic extensional faulting was restricted to weaker, more heterogeneous crust east of the gravity rise; therefore, the Mesozoic faults should not be expected in the relatively intact North American cratonic crust inferred to lie west of the rise. Giles County is about 50 mi (80 km) northwest of the gravity rise, and the nearest known Mesozoic basin is the fault-bounded Dan River basin, about 70 mi (110 km) southeast of Giles County (figs. 17, 21). Fourth, it is possible, although structurally and stratigraphically improbable, that beneath the Giles County locale the very last movements on Alleghany thrust faults occurred in earliest Mesozoic time and buried Permian or very early Mesozoic basins that have bounding faults. However, we know of no evidence for such Permian or Mesozoic basins under the thrust sheets—The sedimentary fillings of Mesozoic basins of the Atlantic seaboard of the Southeastern United States have compressional velocities from 4.4 km/s (or less) to 4.85 km/s, although higher velocities are possible with admixtures of basalt (Stewart and others, 1973; Daniels, 1974; Ackermann, 1977; Talwani, 1977; Behrendt and others, 1981); however, for the Giles County locale, Bollinger and others (1980) found no compressional velocities less than 5.33 km/s, and the velocity usually used for depths down to 5.7 km is 5.63 km/s (table 3, this report). For these four reasons, we reject the hypothesis that Atlantic normal faults could be responsible for Giles County seismicity.

## OTHER FAULT TYPES

Other fault types that cannot be conclusively ruled out as candidates for Giles County seismicity include (1) those associated with formation of a back-arc basin in response to subduction connected with one of the Appalachian Paleozoic orogenies, and (2) a continental rift such as that associated with present seismicity in the head of the Mississippi embayment (Russ, 1981). However, we know of no data to suggest that either process operated near the Giles County locale. The nearest fault of either type is the graben known as the Rome trough of western Pennsylvania, western West Virginia, and eastern Kentucky (fig. 25; Harris, 1975, 1978; Shumaker, 1977; Kulander and Dean, 1978b; Ammerman and Keller, 1979). However, the southeastern border fault or faults of the Rome trough have a striking aeromagnetic signature that trends northeasterly and forms part of the New York–Alabama magnetic lineament (fig. 17) of King and Zietz (1978) and Zietz and others (1980). The magnetic lineament is about 60 mi (100 km) northwest of Giles County (U.S. Geological Survey, 1978).

It seems worth stating explicitly that we know of no reason to suspect that any seismicity in or near Giles County occurs on thrust faults such as those known or suggested to be sources of earthquakes elsewhere (Suppe, 1981; Seeber and Armbruster, 1979, 1981; Armbruster and Seeber, 1981; Behrendt and others, 1981). There are three arguments against seismic reactivation of thrust faults in the Giles County locale: First, all well-determined hypocentral depths in the locale lie in pre-Appalachian metamorphic and igneous basement, below the deepest known Appalachian thrusts. Second, a deeper Appalachian thrust, in basement, such as thrusts found farther south and southeast and in other mountain ranges, is unknown in or near Giles County. Third, the Giles County seismic zone itself dips too steeply over too great a depth range—and is too tabular—to be part of a thrust complex.

There is other seismicity in the Giles County locale that is not a part of the Giles County seismic zone itself. It is possible that some of that other seismicity could occur on a pre-Appalachian thrust fault within the basement below any Appalachian thrusts. Presumably, such a deeper detachment would have originated during the Grenville orogeny of Middle Proterozoic age. Although the existence of such a fault cannot be ruled out by present evidence, neither can we see any seismological, geological, or geophysical reason to postulate it.

## SUMMARY

Of the four kinds of faults that might have been reactivated to produce the Giles County seismic zone, Iapetan normal faults best fit local geological, geophysical, and locational evidence. Faults formed during the Grenville orogeny or older faults are unlikely to have survived until now in a condition that would allow them to generate earthquakes. The stratigraphic and structural arguments against a seismogenic thrust-load fault are not conclusive. However, we are not aware of any place where thrust loading has been clearly shown to have formed fresh fractures in previously unfaulted crust. Rather, two other responses to thrust loading seem to occur instead or in addition: the formation of broad foredeeps by crustal downwarping and reactivation of older normal faults that date from the early opening of an ocean. For the Giles County locale, the Pocahontas basin may be such a foredeep and any reactivated faults would, therefore, be Iapetan normal faults. Finally, Mesozoic normal faults are still less likely candidates for the source of Giles County seismicity because they only occur far to the southeast of the Giles County locale.

# STATE OF STRESS IN THE GILES COUNTY, VIRGINIA, LOCALE

## INTRODUCTION

The orientation of the greatest horizontal compressive stress acting today on the Giles County seismic zone is estimated from selected stress measurements. We show the estimated orientation of greatest stress is consistent with the orientation and sense of seismic slip on the zone, as inferred from *P*-wave polarities and hypocentral distributions.

## STRESS ORIENTATIONS

We are aware of three compilations of measurements of stress orientations for part or all of the region surrounding Giles County. Overbey (1976) compiled stress orientations measured at sites from southwestern New York State to eastern Kentucky, all in the Appalachian Plateau province and adjacent foreland. His review paper does not evaluate the different methods used, and his tabled and mapped orientations range over 61° of azimuth. Because the reliability of stress orientations and their applicability to seismogenic depths are more important for our purposes than the number of sites at which the orientation is measured, we did not investigate the original sources of Overbey. We relied instead on the two more recent compilations.

Zoback and Zoback (1980) reviewed and evaluated measurements and estimates of stress orientations for the conterminous United States. They compiled and annotated those that they considered reliable. Two of the orientations meet all the criteria that we imposed, which we will discuss later. The measurements at well OH-1 in southeastern Ohio, and at well 20402 in Lincoln County, W. Va., meet our criteria (fig. 25; table 9). Both measurements were obtained by hydraulic fracturing of wells at depths exceeding 800 m (about 2,600 ft).

The other six wells and well measurements shown in figure 25 and table 9 are from the analyses and compilation by Evans (1979). He examined oriented cores of parts or all of a sequence of gas-bearing Middle and Upper Devonian shales, taken in 13 gas wells drilled in Pennsylvania, Ohio, West Virginia, Kentucky, and Virginia. The cores are fractured, in many cases, intensively. They were collected to evaluate the fracture permeability of gas reservoirs in the shales, and it was crucial to determine which fractures are natural and which induced by the coring operation, including drilling. Evans examined the cores with techniques developed by ceramicists and later applied to rocks in work funded by the U.S. Department of Energy (Kulander, Dean, and Barton, 1977; Kulander, Barton, and Dean, 1979). Evans concluded that most unmineralized, unslickensided fractures in most cores are induced by coring. Of the three types of fractures induced by the coring operation, only that called petal-centerline is of interest here. Petal-centerline fractures are described, figured, and interpreted by Kulander, Dean, and Barton (1977), Kulander, Barton, and Dean (1979), Dean and Overbey (1980), and GangaRao and others (1979). Those authors concluded that the fractures form in advance of the downcutting drill bit, as extensional fractures in an orientation not distorted by the core or hole but determined by ambient stress at core depth. The result is one or several mostly vertical, planar fractures that parallel the axis of the core. The petal-centerline fractures form perpendicular to the least compressive stress, and so record the orientation of the least stress at all cored depths at which such fractures are observed. By inference, the vertical fractures also strike parallel to the trend of the greatest horizontal compressive stress.

GangaRao and others (1979, p. 686) reported that in some cores petal-centerline fractures dip steeply but not vertically. In such cases, the principal stresses would not have been vertical or horizontal. However, even in those cases, the orientation of the fractures would be interpreted as defining the orientation of the least compressive principal stress, and defining the orientation of a steeply dipping plane that contains the orientations of the greatest and intermediate compressive principal stresses.

We consider petal-centerline fractures to give accurate and precise estimates of the orientations of greatest and least horizontal compressive stresses for five reasons:

1. The oriented cores come from depths from 290 to 2,027 m (table 9), well below the near-surface zone of weathering and intensified jointing that may be responsible for the notorious complexity of individual stress determinations from shallow depths (for example, see Zoback and Zoback, 1980, p. 6128).
2. Cores can be hundreds of feet (meters) long, and so their fractures can average out variations in

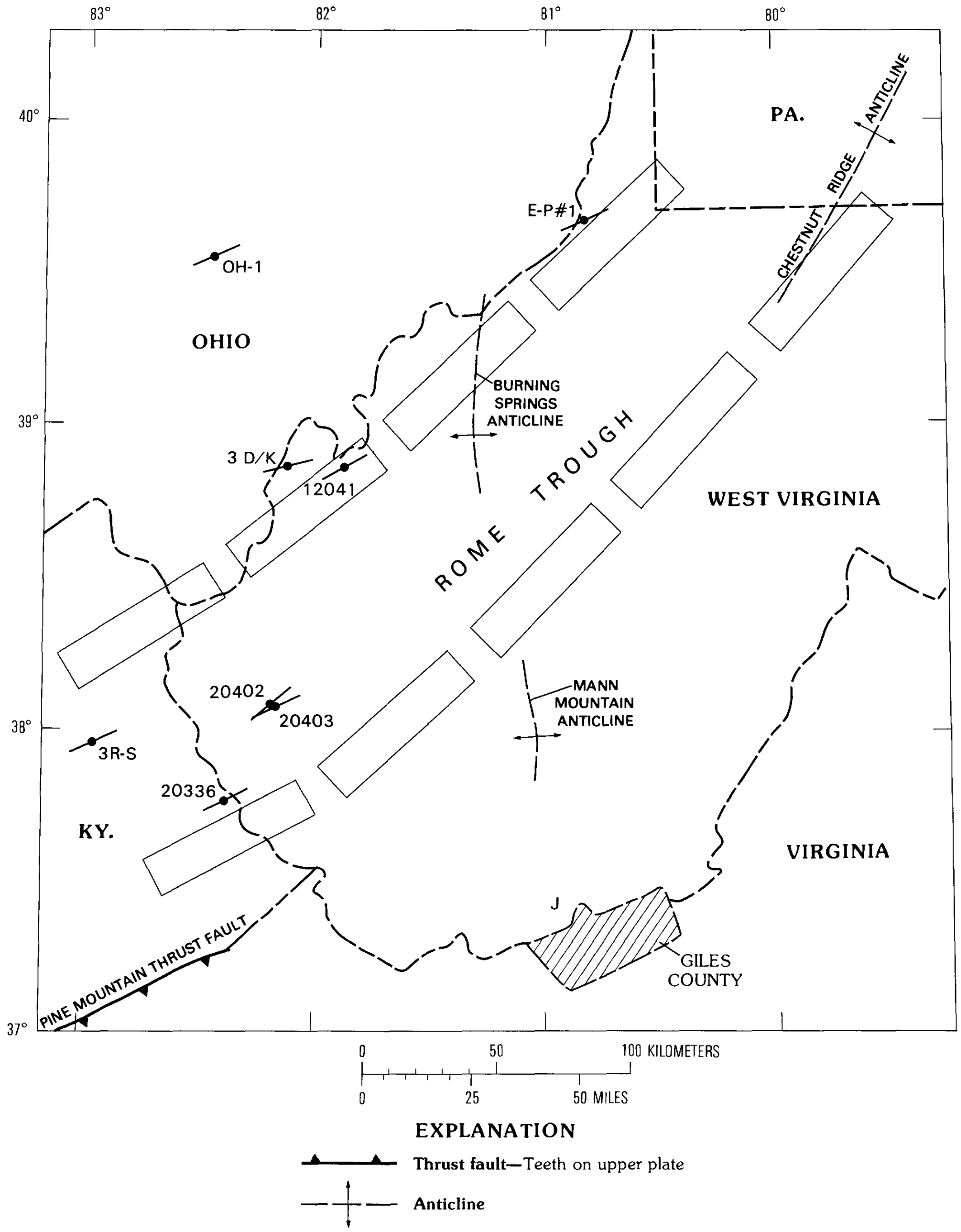



FIGURE 25.—Orientations of maximum horizontal compressive stress. Solid circles and lines through them show well locations and orientations of selected stress determinations from well cores (see text and table 9). Dashed lines show approximate locations of westernmost structures known to us to show significant thrust transport: Chestnut Ridge, Burning Springs, and Mann Mountain anticlines, and outcrop of Pine Mountain thrust fault. J shows approximate location of Elgood earthquake (table 7). Aligned open rectangles show approximate locations of southeast and northwest border faults of Rome trough: compiled from Ammerman and Keller (1979), Harris (1975, 1978), Kulander and Dean (1978b), and Shumaker (1977).

stress orientation between individual beds or groups of beds.

3. Such an oriented core can contain tens to many hundreds of individual petal-centerline fractures, many of which extend through several meters of core, so that orientations can be averaged over the entire cored interval.
4. Even cores with few petal-centerline fractures can

TABLE 9.—*Locations, sources, and values of selected stress orientations*

[Well code: usually permit number. Source, Zoback and Zoback (1980, Z in table) and Evans (1979, E in table). Code: parentheses after Z or E are well designators used by those authors. Method: HF, stress orientation obtained by hydrofracturing the well and then determining strike(s) of vertical cracks in hole wall. PCL, orientation determined by measuring strikes of vertical portions of petal-centerline fractures (defined in text) in an oriented core. n: Number of petal-centerline fractures used, leaders (----) indicate information not applicable or not given. Depth: Below ground level. References: Source of further information about the wells]

| County and State | Well code | Source and code | Method | Stress orientation | Depth Meters | Depth Feet | n | References |
|---|---|---|---|---|---|---|---|---|
| Hocking, Ohio--- | ----- | Z(OH-1) | HF | N. 64° E. | 808 | 2650 | ---- | Haimson, 1974. |
| Martin, Ky.----- | 20336 | E(KY3) | PCL | N. 63° E. | 758-1038 | 2486-3404 | 1573 | Evans, 1979, p. 244-260; Wilson and others, 1980. |
| Johnson, Ky.---- | 3 R-S | E(KY4) | PCL | N. 65° E. | 290- 457 | 950-1500 | 3 | Evans, 1979, p. 261-276. |
| Wetzel, W. Va.-- | E-P No. 1 | E(WV7) | PCL | N. 67° E. | 1859-2027 | 6100-6650 | 11 | Evans, 1979, p. 161-176. |
| Mason, W. Va.--- | 3 D/K | E(WV5) | PCL | N. 75° E. | 826-1042 | 2711-3420 | 1268 | Evans, 1979, p. 125-146. |
| Jackson, W. Va. | 12041 | E(WV2) | PCL | N. 60° E. | 981-1125 | 3220-3690 | 738 | Evans, 1979, p. 67-84. |
| Lincoln, W. Va. | 20402 | Z(WV-1) | HF | N. 50° E. | 835- 839 | 2738-2752 | ---- | Evans, 1979, p. 106-124; Haimson, 1977; Abou-Sayed and others, 1978. |
| Do---------- | 20403 | E(WV3) | PCL | N. 65° E. | 829-1227 | 2720-4025 | 1215 | Evans, 1979, p. 85-105. |

give stress orientations that are consistent within the core and that match orientations from nearby wells (table 9). Indeed, in the cores described by Evans (1979), preferred orientations of petal-centerline fractures are exceptionally strong, with few fractures falling more than 10° away from the orientations listed in table 9.

5. If the core is preserved, it can be reexamined for stratigraphic and structural evidence with which to evaluate any changes along the core in the strike of the petal-centerline fractures. For example, we do not include stress orientations determined from petal-centerline fractures in a core from a well in southwestern Virginia (Wise County, well No. 20338). Evans (1979) and Wilson and others (1980) examined this core. They studied the vertical distributions and orientations of slickensides and slickenlines in the core, and structural, stratigraphic, and drilling information from the region surrounding the well. They concluded that the core bottomed in the sheared rock of the Pine Mountain thrust fault. The stress orientation of N. 57° E. from the core of well No. 20338 is consistent with other values obtained nearby (table 9; fig. 25), but to use such a result from rocks known to be thrust would violate one of the criteria of data selection that we shall discuss next.

## CRITERIA USED TO SELECT DATA

Within about 300 mi (500 km) of Giles County, Zoback and Zoback (1980, plate 2; 1981, fig. 1) compiled 27 stress-orientation measurements made by various workers using various methods. Evans (1979) examined cores from 13 wells. These 40 measurements from Zoback and Zoback (1980, 1981) and Evans (1979) were reduced by us to the eight of table 9 by using the four following criteria:

1. We use only measurements likely to reflect stress orientations in the North American continental crust that is inferred to underlie Giles County at seismogenic depths, whether or not that crust has been reworked by Grenville metamorphism or fractured by Iapetan normal faults.
2. We use only stress orientations measured near Giles County, in the eastern parts of Tennessee, Ohio,

and Kentucky, in the western parts of Virginia and North Carolina, and anywhere in West Virginia.

3. We use only stress orientations likely to be representative of the stress field at seismogenic depths under Giles County. This means that measurements from rocks in thrust sheets are suspect because such rocks may be mechanically decoupled from underlying rocks.
4. We avoid stress orientations determined from measurements made at or within several tens of meters of the Earth's surface. Such measurements are notoriously variable and difficult to evaluate.

Criteria 1 and 3 require explanation. Criterion 1 restricts us to measurements made west of the steep rise in the unfiltered Bouguer anomaly field (fig. 18). East of that rise, we have suggested (p. 35) that the crust is an assemblage of pieces of various sizes, shapes, compositions, thicknesses, and origins. Thus, the stress field at seismogenic depths east of the rise may be more varied than, and differently oriented from, that under Giles County.

The stress data themselves contain support for this criterion. Zoback and Zoback (1980, 1981) divided the Eastern United States (apart from the Gulf Coast) into two stress provinces. In the region surrounding Giles County (fig. 19), the boundary between the two stress provinces coincides with the eastward rise in the Bouguer gravity field. To the east of the rise lies the Atlantic Coast stress province and to the west lies the Midcontinent stress province. The Atlantic Coast province is characterized by a variable but generally northwesterly trending greatest horizontal compressive stress, with the least compressive stress being vertical. From this, Zoback and Zoback inferred the existence of a coastal domain of reverse faulting involving compression at high angles to the Appalachians and continental margin. (Wentworth and Mergner-Keefer (1980, 1981a, b, c) arrived at the same conclusion.) Zoback and Zoback (1980, 1981) assigned the middle portion of the United States to the Midcontinent stress province, characterized by northeasterly trending greatest horizontal compressive stress. From this, they inferred the existence of a domain of reverse and strike-slip faulting. The eastward rise in the Bouguer anomaly field consistently separates data sites of the Midcontinent and Atlantic Coast stress provinces (also noted independently by Seeber and Armbruster, 1981). Thus, stress orientations measured east of the gravity rise are interpreted to come from a different stress province than that containing Giles County.

Criterion 3 restricts us to stress measurements made in rocks below the deepest thrust faults, or west of the westernmost rocks involved in thrusting, because thrust sheets might be mechanically decoupled from underlying rocks. Structural data consistent with such decoupling of Paleozoic stresses across thrust faults in the area shown in figure 25 are given by Wheeler (1980, p. 2173–2174), Werner (1980), and Wilson and others (1980). Seeber and Armbruster (1981) suggested similar decoupling for the modern stress field across a deeper thrust fault in Georgia. On the other hand, Zoback and Zoback (1980, p. 6136) pointed out that modern stress orientations in thrust rocks of the Appalachian Plateau province of western New York State and adjacent Pennsylvania are nearly parallel to those in nearby and underlying rocks not involved in thrust sheets. Thus, the question of decoupling remains open, and it seems possible that thrust rocks could be partly decoupled from underlying basement in some places and not in others.

In the region shown in figure 25, the deepest thrust faults cut upsection to the northwest. This is known from the dominant southeastward dips of outcropping thrust faults; from observing that more southeasterly thrusts expose older rocks that have been brought up from greater depths; and from abundant well and seismic-reflection data. For examples, see the cross sections of Rodgers (1963), Cardwell and others (1968), Gwinn (1970), Perry (1978), Roeder and others (1978), and Boyer and Elliott (1982, fig. 29). Because the deepest thrusts climb stratigraphically to the northwest, there is a western limit to rocks that have been involved in thrusting or anticlines produced by thrusting. Figure 25 locates westernmost structures known to us to have experienced important thrusting: Chestnut Ridge, Burning Springs, and Mann Mountain anticlines, and the outcrop of the Pine Mountain thrust fault. Small amounts of thrusting, or simple shear distributed over a stratigraphic interval without loss of cohesion, may occur west of those indicated structures (for example, see Shumaker, 1980). That situation may be most likely at shallow stratigraphic levels, such as within the Pennsylvanian and Permian rocks that are exposed around the wells shown in figure 25. Accordingly, we use only stress measurements made appreciably to the west of rocks likely to be thrust, or well below thrusted rocks, or both.

Other considerations apply to only one or a few cores, and cause us to discard data from those cores: Some cores examined by Evans (1979) contain no petal-centerline fractures, so stress orientation cannot be measured. Other cores have such fractures, but they exhibit no strong preferred orientation. Again, stress orientation cannot be measured on such cores. In examining one core, early workers did not distinguish natural from core-induced fractures. The core of well No. 20336 in Martin County, Ky., has 1573 petal-centerline fractures and preferred orientations of N. 33° E.,

N. 47° E., and N. 63° E. (Evans, 1979, p. 250). We use only the N. 63° E. orientation because that is most representative of fracture orientations in the bottom part of the core, below the effects of any near-surface thrusting in front of the outcrop of the Pine Mountain thrust fault.

Petal-centerline fractures in the core of well No. 20402 in Lincoln County, W. Va., present a problem. The 1,627 fractures give a strong preferred orientation of N. 33° E. (Evans, 1979, p. 114). That is anomalously more northerly than any of the other orientations shown in figure 25 or listed in table 9. However, a hydrofracturing experiment in the upper portion of the cored interval gives a stress orientation of N. 50° E. (Abou-Sayed and others, 1978), and the strike of petal-centerline fractures is N. 65° E. at well No. 20403, only 1 mi (1.6 km) away. Therefore, for well No. 20402 we use the hydrofracturing result (N. 50° E.) rather than that from the petal-centerline fractures (N. 33° E.), for the following reasons: First, the anomalously oriented fractures of well No. 20402 are not ubiquitous in the cored interval; the topmost 46 feet (14 m) of the 614 ft (187 m) cored contain petal-centerline fractures that strike N. 49° E. (Evans, 1979, p. 107, 116), in agreement with the hydrofracture result from that interval and with the orientation of petal-centerline fractures from the nearby well No. 20403 and the other wells of figure 25 and table 9. Second, both wells are within the Rome trough (fig. 25); as mentioned previously, some of the basement faults of that structurally complex graben were active intermittently throughout Paleozoic time. We speculate that the present-day stress field in the lower and larger part of the rock volume cored by well No. 20402 is distorted by past movement of some underlying fault associated with the Rome trough. We suggest that the top part of the cored volume of well No. 20402, and all the volume cored by well No. 20403, sample the regional and undistorted stress field.

This suggestion that stress fields have been distorted locally by past movement on basement faults, and have remained distorted, draws support from results of other workers. Such basement faults are known to be nearby and are inferred to have affected structures in the overlying sedimentary sequence. The Warfield fault and its associated Warfield anticline are about 15 mi (24 km) south of wells Nos. 20402 and 20403 (figs. 17, 25). At the Midway-Extra gas field, about 30 mi (48 km) northeast of wells Nos. 20402 and 20403 (figs. 17, 25), gas is produced from a fractured reservoir at the inflection line between an anticline and a syncline that are inferred to overlie another basement fault (Evans, 1979, p. 107; Schaefer, 1979; Cardwell, 1976). Further, distorted stress orientations in sedimentary rocks overlying basement faults of the Rome trough have been predicted from finite-element modelling, if the downdropped block is on the east side of the fault (Advani and others, 1977). Distortions are also inferred from anomalous orientations of cleat (planar fractures; systematic joints) in exposed coals, if the downdropped block is on the west side of the fault (Kulander, Dean, and Williams, 1977). Accordingly, we will use the hydrofracture result (N. 50° E.) instead of that from the petal-centerline fractures (N. 33° E.) for well No. 20402.

## RESULTS

Orientations of greatest horizontal compressive stress that meet all the criteria just described are listed in table 9 and mapped in figure 25. They span about 170 mi (250 km) along the northeast trend of the Appalachians and about 110 mi (170 km) across the trend. They are in the western Appalachian Plateau province and adjacent foreland, from about 90 to 190 mi (150–300 km) west to north of Giles County.

Our selection criteria have produced a set of eight consistent estimates of stress orientations that cover a large area. The median trend is N. 64° E., with a range of 25° from N. 50° E. to N. 75° E. (fig. 26*A*). This median orientation agrees with the east-northeasterly orientations that Zoback and Zoback (1980) found for the eastern part of their Midcontinent stress province. Zoback and Zoback (1980, p. 6136) also suggested the existence of a transition zone about 200 km wide, comprising the eastern edge of the Midcontinent stress province and containing stress orientations that are roughly east-west, from Pennsylvania to Tennessee. We find no evidence of such a transition zone and suggest that the absence may be attributed to two factors. First, petal-centerline fractures can provide valid and accurate estimates of in situ stress orientation if measurements are made below the near-surface zone. However, some of the transition zone of Zoback and Zoback is based on measurements made at or near ground level. Second, perusal of the stress orientations in the hypothesized zone of transition indicates that most, but not all, are in thrust rocks. Thus, much of the transition zone may be caused by partial, local decoupling of rocks in thrust sheets from underlying rocks. The thrust rocks perhaps partly reflect stresses transmitted cratonward from the Atlantic Coast province. Both factors could produce a transition zone that reflects only near-surface stresses.

The result from the eight selected measurements can be improved slightly. We weight the measurements for geographic independence by averaging pairs of orientations determined in adjacent wells, which yield the results of figure 26*B*. For example, the two wells in Lincoln County, W. Va., are 1 mi (1.6 km) apart (Evans,

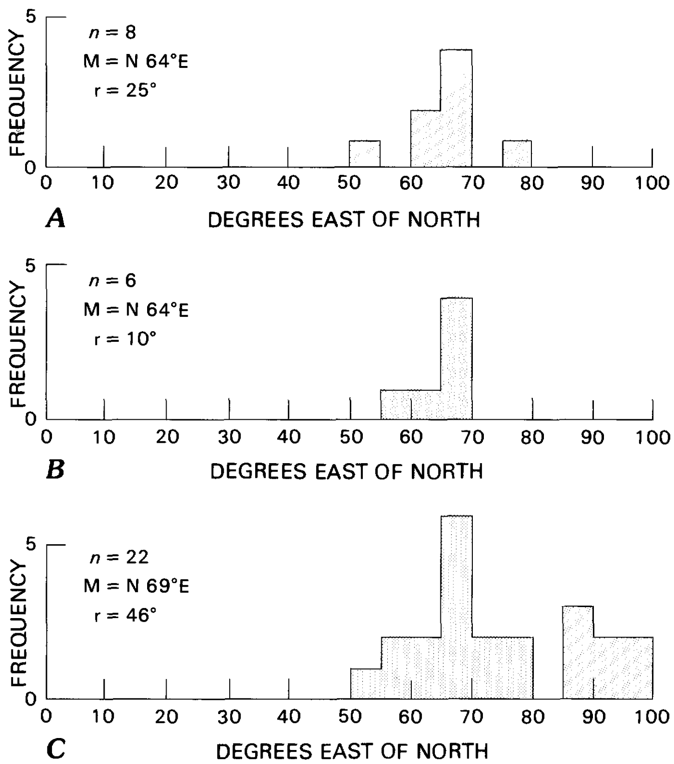



FIGURE 26.—Orientation distributions of measurements of greatest horizontal compressive stress. Class interval is 5 degrees, and $n$ = number of measurements in a given set of orientations, M = median, r = range. *A*, The eight measurements that passed the selection criteria described in the text. *B*, The six measurements derived from those of *A* by averaging measurements from pairs of nearby wells. These six measurements are our preferred results. *C*, The 22 measurements obtained by adding to those of part *A*, 10 from Overbey (1976), 3 from Zoback and Zoback (1980), and 1 from Evans (1979).

1979, p. 92). The hydrofracturing determination from well No. 20402 averages with the determination from petal-centerline fractures in well No. 20403 to give a stress orientation of N. 58° E. The two wells in Mason and Jackson Counties, W. Va., are about 13 mi (21 km) apart (Evans, 1979, p. 72); their two determinations from petal-centerline fractures average to give N. 68° E. The resulting six estimates of the trend of greatest horizontal compressive stress still have a median of N. 64° E., but the range has decreased to 10°. The two extreme values are the two average orientations just described. This median and range are our preferred estimates for the stress orientation at and around the Giles County seismic zone (fig. 26*B*).

The selection criteria that we have used to produce table 9 and figure 25 have not changed the median stress orientation much, but the criteria have narrowed the range of individual site orientations considerably. Those results are shown by comparing medians and ranges between the three parts of figure 26. Figure 26*C* was obtained by including 14 other orientations that did not pass our selection criteria. In compiling figure 26*C*, we first include 10 of the orientations compiled by Overbey (1976). Those 10 orientations are mostly in the area shown in figure 25 and are apparently results of hydrofracturing at depth rather than near-surface strain-relief experiments. These 10 orientations are consistent with other nearby measurements and do not duplicate any individual results tabulated by Zoback and Zoback (1980) or Evans (1979). However, we have not determined whether any of those 10 measurements satisfy any of our criteria except the first, which is that they lie west of the gravity gradient.

The second group of orientations used in figure 26*C* are the three orientations compiled by Zoback and Zoback (1980, TN-3, OH-2, and WV-4) and one orientation by Evans (1979, VA-1 from well No. 20338 in Wise County, extreme southwestern Virginia). In compiling figure 26*A*, we originally deleted these four measurements because OH-2 is too far north, and the other three are known or suspected to have been measured in rocks that are shallow, thrusted, or both.

All 22 stress orientations together have a median of N. 69° E., only 5° more easterly than that of our preferred measurements (fig. 26*B*). However, the 22 measurements of figure 26*C* range over 46°, from N. 50° E. to N. 84° W. Thus, selection criteria that are designed with considerations of local and regional geology and structure, and which are combined with stress orientations measured by reliable methods can greatly improve the precision of estimates of stress over a large area. The accuracy of the estimate of stress orientation was also improved, but only slightly.

Another encouraging conclusion can be drawn from the consistency of stress orientations over the area shown in figure 25. This conclusion is that the Rome trough apparently has little effect on present-day stress orientations, at least over an area as large as that shown in figure 25. (Recall that we suggest a local effect for all but the top part of the interval cored by Lincoln County well No. 20402). This lack of effect on present-day stresses is noteworthy because some of the faults of the Rome trough were active from Cambrian through at least Pennsylvanian and perhaps Permian time, at least in eastern Kentucky (Cavorac and others, 1964; Black and Haney, 1975; Dever and others, 1977; Harris, 1978; Horne and others, 1978; Ammerman and Keller, 1979) and perhaps in central West Virginia (Kulander and Dean, 1978a; Kulander, Dean, and Williams, 1977, 1980). Of the eight well sites shown in figure 25, well OH-1 and probably wells E-P Nos. 1 and 3 D/K are northwest of the Rome trough. The other wells are within the limits of the trough. Apparently this major, long-lived crustal structure has not distorted the stress orientations of figure 25. The stress orientations determined by Evans (1979) from petal-centerline fractures indicate that the N. 64° E. orientation persists across the complex and long-active basement faults of the Rome trough.

The criteria that we used to select the eight measurements of figures 26*A* and 26*B* indicate that the N. 64° E. stress orientation represents the orientation of stresses at mid-crustal depths, under the thrust sheets of the Giles County locale. Such mid-crustal stresses would be those that cause the earthquakes of Giles County. The eight wells at which the stress measurements of figures 26*A* and 26*B* were made are separated from Giles County by some or all of the faults of the Rome trough, but we have just noted that the Rome trough does not appear to distort the regional stress field over the area of about 170 km by about 250 km that is covered by the wells plotted in figure 25. Thus, we shall extrapolate the N. 64° E. stress orientation 150 km to the southeast, across the Rome trough, to mid-crustal depths under Giles County. It now remains to test the N. 64° E. stress orientation for consistency with available seismological data from the Giles County seismic zone; we shall do that next.

## CONSISTENCY WITH FOCAL MECHANISMS

Figure 27 illustrates an evaluation of the consistency of stress orientations deduced from the composite focal mechanism of figure 16, with those deduced from estimates of in situ stress that are shown in figure 25 and table 9. The in situ stress estimates are lines of zero plunge, parallel to strikes of vertical petal-centerline fractures. The vertical fractures formed by extension against the least compressive principal stress ($S_3$), which is also the least horizontal compressive principal stress ($S_h$) because the fractures are vertical. If we assume that the estimates can be extrapolated southeastward and downward to the Giles County seismic zone, the only constraint they provide is that $S_h$ of figure 27 is parallel to $S_3$. The greatest and intermediate compressive principal stresses ($S_1$ and $S_2$, respectively) are constrained only to lie somewhere in the vertical plane perpendicular to $S_h$ (represented by the dash-dot great circle of figure 27). Thus, $S_1$ and $S_2$ cannot be plotted directly in figure 27.

We concluded that the seismic zone probably occurs on an Iapetan normal fault that is being reactivated in today's stress field. For reactivation of an old fault that is weaker than surrounding rock, the angle between the reactivated fault and $S_1$ can depart from the ideal value of 30° that is typical of unfractured, homogeneous, brittle rock. Estimates of the size of the departure vary.

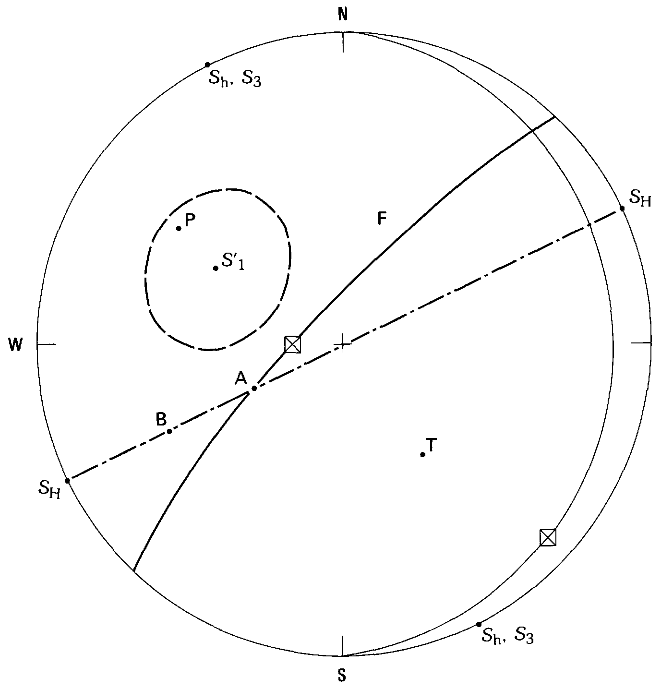



FIGURE 27.—Consistency of in situ stress orientation with orientation deduced from composite focal mechanism. Lower-hemisphere equal-area projection. Elements of focal mechanism of figure 16: solid curves show nodal planes, and boxed X's, their poles; F identifies preferred nodal plane, assumed to represent the orientation of the seismogenic fault or fault zone, which strikes N. 44° E., and dips 80° NW.; P and T locate compressional and tensional axes, respectively, at the seismic source. Elements of in situ stress field of figure 25 and table 9: $S_H$ shows orientation of greatest horizontal compressive stress, a line that trends N. 64° E. and plunges 00° NE.; $S_h$ shows orientation of least horizontal compressive stress, a line that trends N. 26° W. and plunges 00° NW.; dash-dot great circle shows plane perpendicular to $S_h$. Elements of greatest principal compressive stress, estimated from focal mechanism as recommended by Raleigh and others (1972): $S_1'$ orients the stress; broken line is a small circle enclosing all orientations within 20° of $S_1'$; $S_3$ is least principal compressive stress. Points A and B are defined in text.

McKenzie (1969) noted that, in the most general case, $S_1$ determined from a focal mechanism is constrained only to lie within the compressional quadrant of the focal sphere. Thus, in principle, $S_1$ could lie as far as 90° from the P axis of figure 27. Raleigh and others (1972) suggested a procedure for estimating the probable orientation of $S_1$ from a focal mechanism. That estimate is $S_1'$ of figure 27. It lies 15° from the P axis in the direction toward the preferred nodal plane. Raleigh and others suggested that in most cases the true orientation of $S_1$ should lie within 20° of $S_1'$. That range of orientations is enclosed by the broken line that defines the projection of a small circle in figure 27.

For strict consistency between the two orientations of $S_1$ deduced from the composite focal mechanism and from the in situ measurements, the dash-dot great circle of figure 27 should intersect the small circle around $S_1'$. Then, that intersection would define the possible range of orientations of $S_1$.

Thus, it appears that the stress orientations deduced from the in situ measurements are inconsistent with those deduced from the composite focal mechanism of figure 16. Further, a focal mechanism published by Herrmann (1979), for event J of our figure 11, appears to be inconsistent with both of our deduced stress orientations. Herrmann's solution will be discussed later. (Note: Event J occurred only about 25 km northwest of the Giles County seismic zone (fig. 11)). From these apparent inconsistencies, one could conclude that the stress state at seismic depths under and near Giles County changes markedly over horizontal distances as short as 25 km; such a conclusion is premature. In particular, the uncertainties in the sparse data allow the hypothesis that the in situ measurements, the first motions from the Giles County seismic zone (fig. 16), and at least some aspects of Herrmann's focal mechanism for event J might all reflect the same stress field, for the following reasons:

First, the 20° radius of the small circle is not an inflexible limit. Experimental data tabulated by Raleigh and others (1972) show considerable variation in the value of the angle between $S_1$ and the resulting reactivated fault. At least some of the variation can be attributed to differences in mean compressive stress, in the smoothness of the fault surface, and in lithology of the faulted rock. The dash-dot great circle of figure 27 lies only 13° from the small circle and consistency (point A is the point of closest approach).

Second, recall that the range of trends of $S_H$ is 10°. Using the most easterly trending of the 6 orientations of figure 26*B*, point A would move another 2° closer to consistency.

Third, and most important, the discrepancy between the two estimates of the orientation of $S_1$ depends mostly on the orientation of the auxiliary nodal plane of figures 16 and 27. In particular, the orientation of the auxiliary nodal plane constrains the orientation of $S_1'$. That plane is constrained to include the pole of the fault nodal plane, but the dip of the auxiliary plane here is poorly constrained. For example, there are only six impulsive first motions from the seismic zone (fig. 16; table 8). If one uses only the five northeast- to southeast-plunging impulsive first motions, one could easily draw a steeper dipping auxiliary plane that would fit the five data about as well as does the shallowly dipping plane used here. If the auxiliary nodal plane were to steepen and strike more to the west in figure 27, $S_1'$ and its enclosing small circle would be moved to the southwest to intersect the dash-dot great circle. If the auxiliary plane were to steepen from a dip of 14° to about 50°, the small circle would touch the great circle about at point B of figure 27, and the two stress estimates would be consistent within the limits suggested by Raleigh and others (1972). Then point B would represent the orientation of $S_1$.

Therefore, within the limits of our data, we can conclude that the in situ stress estimates are roughly consistent with the estimates deduced from the seismological data. $S_1$ probably plunges southwestward, toward points A and B of figure 27. Recall that the preferred nodal plane strikes northeast and dips steeply northwest (fig. 16). Motion on a fault with the orientation of the preferred nodal plane, and driven by compressive stress parallel to $S_1$, would be a combination of right slip and reverse slip. Because the orientation of the preferred nodal plane is determined by seismological data, Giles County seismicity is also produced by right-reverse slip. Such slip is consistent with the Midcontinent domain of reverse and strike-slip faulting suggested by Zoback and Zoback (1980). It is also consistent with most focal mechanisms compiled by them or given by Herrmann (1979) for unthrust rocks of the eastern craton of the United States. The relative importance of the reverse and right-slip components of motion on the Giles County seismic zone cannot be determined until the orientation of the auxiliary nodal plane is better constrained by more numerous impulsive *P*-wave first motions.

Herrmann (1979) used surface-wave data to derive a focal mechanism solution for the Elgood, W. Va., earthquake. That shock was located near but northwest of the Giles County seismic zone (fig. 25; Herrmann, 1979, event 11; our event J of fig. 11). His solution has a compression (P) axis trending northerly at low plunge and strike-slip motion on two steeply dipping nodal planes: left slip on a northeasterly striking plane and right slip on a northwesterly striking plane. Our selected stress orientations (fig. 25), extrapolated southeast to Elgood, are not consistent with the solution of Herrmann (1979, event 11). Our estimate of the orientation of greatest horizontal compressive stress (figs. 26, 27) falls near the dilatation (T) axis of Herrmann (1979). The most likely orientation of $S_1$ (fig. 27) also falls within the T field of Herrmann. However, the pattern of polarities of *P*-wave first motions in the northwest-to-northeast quadrant (dilatation) and the northeast-to-southeast quadrant (compression) are the same in both our and Herrmann's focal mechanism solutions. Applying the criteria of McKenzie (1969) and Raleigh and others (1972) to that similarity will allow a small area (about 1 percent of the focal hemisphere) wherein the $S_1'$ about our P axis could include Herrmann's P axis. That is, Herrmann's P field includes roughly the northeastern quarter of the area in figure 27 that is enclosed by the small circle about $S_1'$. Thus, the markedly different focal mechanisms are not completely at odds with each other. However, resolution of the significant disparity that does exist lies beyond our scope here.

### SUMMARY

The trend of greatest horizontal compressive stress has been measured at many places within several hundred kilometers north and west of the Giles County locale. The measured trends show much scatter, and were obtained in various geologic settings by methods of different reliability. We have formulated criteria based on considerations of local geology and structure, and on the reliability of the various methods that were used to obtain the stress measurements. Eight measurements satisfy these criteria. The eight measurements come from wells that were drilled 150–350 km north and west of Giles County, northwest of the thrust sheets that cover the Giles County locale and overlie its earthquakes. After averaging two pairs of duplicate measurements, the greatest horizontal compressive stress is estimated to trend N. 64° E., with little variability over the region covered by the wells. This orientation represents stress in the continental crust into which the wells were drilled and which extends southeast, under the thrust sheets of the Appalachians, to the location and depths of the seismicity beneath Giles County. The orientation of N. 64° E. is roughly consistent with stress orientations inferred from seismological data from the Giles County seismic zone, and it is partly consistent with stress orientations inferred from another earthquake that occurred near, but northwest of, the seismic zone. This consistency and the observed strike and dip of the seismic zone itself indicate that the seismicity of Giles County, including the damaging earthquake of 1897, probably occurs by right-reverse motion, in compression that trends about N. 64° E.

## CONCLUSIONS

Our conclusions consist of specific statements, and of more general observations that should be borne in mind by users of the specific statements.

### GENERAL OBSERVATIONS

This report presents the first direct instrumental evidence for a tabular seismic zone in Virginia, in the form of accurate and precise hypocenters that scatter but little about a plane. Additionally, by combining seismological and geological information, this report presents the first documentation of a seismically active basement fault or fault zone in the Southeast that does not parallel the trend of the known tectonic fabric of the host locale.

The excellent earthquake-location capability within the Giles County seismic network resulted in defining a seismic zone. The definition of the zone has two bases. First, the locale-specific velocity model (TPM2) has measured *P*- and *S*-wave velocities. Second, many of the microearthquakes are characterized by impulsive *P*- and *S*-wave phases (fig. 5), thereby allowing precise arrival-time determinations. Thus, accurate (*S–P*) time intervals from earthquakes within the network strongly constrain the hypocenter determinations in a manner that *P*-wave data alone cannot achieve. This situation is somewhat analogous to the independent determination of the origin-time procedure discussed by James and others (1969).

We have implicitly assumed throughout this report that the seismic zone we have defined is the same one that was the source of the 1897 shock. Clearly, the weight of evidence supports that assumption, but it cannot be proved. The intensity data are adequate to demonstrate that the greatest effects were, indeed, in Giles County (fig. 1; Bollinger and Hopper, 1971; Hopper and Bollinger, 1971; Law Engineering Testing Company, 1975). However, the presumption that Pearisburg was the probable epicentral locale is partly based on the fact that, as the county seat, it was the largest town in the county. Thus, the most numerous and detailed intensity reports came from there. Additionally, Campbell (1898), a U.S. Geological Survey geologist who visited the region in the early part of June, 1897, noted that: "The shock of May 31 was probably more severe in and about Pearisburg than any other point from which I have information."

There were two reasons for demonstrating the range of fault-plane areas that is allowed by the hypocenter data set to date (fig. 15). First, the demonstration conveys graphically the uncertainty of calculated fault-plane areas when a given level of statistical confidence is used as an error measure for the hypocentral locations. Second, in this case the demonstration shows that there can be a variation of a factor of ten in the implied fault plane area. Such uncertainty in the fault-plane area carries the potential for a change of one full unit in an associated earthquake's magnitude (Wyss, 1979; Singh and others, 1980). Realization of that potential would require that (1) the collection of individual hypocenters actually represents a single fault plane or zone, and (2) the entire plane or zone slips seismically all at once. However, we do know that in 1897 the locale experienced a shock roughly comparable in size to that associated with the minimum hypocentral area of 80 km$^2$ ($m_b = 5.8$, $M_S = 6$; Geller, 1976; O. W. Nuttli, written commun., 1980).

## SPECIFIC STATEMENTS

The data presented and analyzed herein constitute a detailed instrumental and geological description of an individual seismic zone in the Southeastern United States. In our judgment, the evidence presented warrants the following conclusions:

1. A seismic zone has been defined in Giles County, Va., with the following seismological characteristics:
   - A. Strike—northeast; present data indicate N. 44° E.; Dip—near vertical; Depth range—from 5 to 25 km;
   - B. Horizontal length—40 km; centered at Pearisburg, Va.; Horizontal width—10 km.
2. The seismic zone also has the following geological characteristics:
   - A. Located within the basement and beneath the Appalachian thrusts;
   - B. Though the zone is in the southern Appalachians, it is subparallel in strike to the surface and near-surface structures of the central Appalachians to the north, and is at an angle of some 30° to the thrust-faulted tectonic fabric of the southern Appalachian host region.
3. Although conclusive evidence is lacking for the following aspects of the zone, we favor their likelihood:
   - A. The present-day motion on the inferred northeast-striking fault or fault zone is such that the southeast side is moving down relative to the northwest side;
   - B. High-angle reverse motion of the fault is more likely than is normal motion. At this time, it is impossible to determine which motion has occurred; nevertheless, high-angle reverse motion is the more likely because the seismic zone probably dips steeply northwest and because the region is probably under east-northeasterly trending compression at seismogenic depths;
   - C. Any strike-slip component of the motion is probably right-slip, though of unknown magnitude relative to the dip-slip component;
   - D. The zone defined in this report is the source of the 1897 shock. This implies an apparent resumption of strain energy release after a seismic quiescence of 4 to 5 decades;
   - E. The N. 44° E. seismic zone has probably resulted from compressional reactivation of a Late Proterozoic or early Paleozoic Iapetan normal fault or fault zone. Fault reactivation by late Paleozoic compression and Mesozoic extension is also possible.
4. Although flat or low-dip detachment faults have been found to or suggested to produce large earthquakes elsewhere, that is apparently not true for the Giles County seismic zone. Neither is it likely to be true for other earthquakes with well-determined depths in or near Giles County.

## FUTURE WORK NEEDED FOR HAZARD ZONING

Our familiarity with the seismicity and geology of Giles County and the surrounding region enables us to offer suggestions that may be useful in guiding future workers who build on the conclusions of this report. The following suggestions in no way indicate that our findings here are preliminary, or that we expect future work to change these findings. It is unlikely that future seismicity in the Giles County locale will differ much from the seismicity analyzed in this report. The location of Giles County hypocenters below the Appalachian thrust sheets, and the lack of known surface ruptures associated with the 1897 shock, make it equally unlikely that important new geological or other geophysical data can be obtained quickly or at low cost. Therefore, we expect that future results will amplify and extend the conclusions of this report—but will not change them. Accordingly, the following suggestions are based partly on these conclusions, and partly on our more general experience with the geology, seismology, and hazard evaluation of the Southeast.

Our findings lead to three questions that must be answered to contribute to improvement of the existing hazard evaluations. At present, we know of no way to answer these questions quickly, but the following paragraphs suggest avenues of investigation that may eventually produce reliable answers:

1. Is a single fault or a single fault zone responsible for the Giles County seismic zone? Our only evidence for the existence of the seismic zone itself is the distribution of hypocenters shown in figures 11–14. From that distribution, one may infer the existence of a single fault or single fault zone. For example, figure 15 and the arguments based on it stem from such an inference.

Such an inference would be strengthened if the existence, orientation, and slip of one or more faults could be inferred from independent geophysical data, especially reflection seismic profiles. To test the existence of a fault or faults responsible for seismicity in Giles County, a reflection field experiment must be carefully designed to fit the reflector depths and geometries and fault offsets that are expected. Otherwise, equipment or processing may be selected that cannot resolve any fault offset that is present. For example, three-dimensional shooting geometries may be required to detect faults with very small offsets (J. K. Costain, oral communs., 1981).

Actual documentation of any outcropping fault or fault zone may be obtainable only through structural and other geologic mapping at scales more detailed than most hitherto done in the Giles County locale. Such mapping could seek and document small, systematic offsets of sharp contacts and structural elements or locate zones of unusually high intensity of joints and other fractures (Wheeler and Dixon, 1980).

Identification of a fault or fault zone responsible for Giles County seismicity is complicated by lack of any known rupture of the ground surface from the 1897 shock—or indeed from any accumulated motion on the seismic zone over time. However, we know of only one detailed search for such rupture and that is still in progress (McDowell, 1982, and his six preceding semiannual reports in the same series). Such a search is hindered by the comparatively moist climate, thick vegetation, and rapid erosion characteristic of the region and by the consequent sparseness of young and dateable geological materials that could record such rupture (Houser, 1981). Acharya (1980a, b) suggested that large earthquakes in eastern North America that do not rupture the ground surface must occur deeper than about 10 km. Such a depth would be consistent with instrumentally determined depths of microseismicity on the Giles County seismic zone (5–25 km) and would be consistent with the best estimate of the depth of the nearby Elgood earthquake of 1969 (table 1; Carts, 1981, depth 13.6 km). So, lack of known surface rupture from the 1897 shock is bothersome but not necessarily surprising.

A greater potential problem is the lack of any known surface offset that could be attributed to slip accumulated by the seismic zone by repeated activity over millions of years. However, the problem is still only a potential one because the problem is so poorly defined. For example, the seismic basement is overlain by several kilometers of complexly layered and faulted sedimentary rocks, and several thick shale sequences of largely unknown mechanical properties are contained within those rocks. It is not clear to us how fault slip would be transmitted through or dissipated within such a complex. Alternatively, the Giles County seismic zone might be only intermittently active. Such intermittent activity could arise from regular reactivation at long intervals. Such intermittent activity could also arise if the zone occurs on a fault that is but one element of a network of mechanically linked faults, which could relieve stresses imposed on the boundary of the network by concentrating them in turn at constantly changing points within the network. If the recoverable vertical strains within the crustal blocks of such a network were of about the same size as dip slips on the faults that bounded the blocks, and if the shifting stress concentrations within the network allowed such strains to alternately accumulate and relax, then the faults might experience alternating normal and reverse slip. Little or no net slip would accumulate, so little or no net slip would be visible at the surface. Therefore, the lack of known surface offset in Giles County is a complex enough problem that its further consideration lies beyond our scope here.

2. Are there other seismic zones structurally analogous to that in Giles County that lie along strike to the northeast or southwest? An eventual answer to this question will take one of two forms. One answer is that the Giles County seismic zone is unique in eastern North America. However, in addition to suggesting uniqueness, one should be able to explain it. For example, one might be able to show the presence of a northerly to westerly trending cross structure, under the thrust sheets, which might act to concentrate seismic release of stress on the Giles County seismic zone. Such cross structures could be of several kinds. For instance, the gradient in the unfiltered Bouguer field has a sharp S-shaped bend southeast of Giles County (figs. 18, 21). That bend may express the presence of an Iapetan transform fault. From analyses of gravity and aeromagnetic data, Phillips and Daniels (1982) suggested a marked change in the type of subthrust rock across that possible transform fault. Alternatively, Wheeler (1980) and Wheeler and others (1979) described a class of complex structures called cross-strike structural discontinuities (CSD's). Some CSD's apparently overlie basement faults of unknown or multiple ages and origins in structural settings similar to that of

Giles County. To our knowledge, CSD's have not yet been sought in Giles or most of its adjacent counties.

The alternative answer is that the Giles County seismic zone is not unique but is a presently active member of a class of similar zones that cover part of the terrane west of the gravity gradient. Before recommending this alternative answer, one should be able to suggest where other such zones might occur. This will be difficult. The Southeast is sparsely enough covered by seismograph networks that, over most of the region, such zones might not be recognizable. For example, of the 12 events that define the Giles County seismic zone, only the four that were relocated by J. W. Dewey and D. W. Gordon (written commun., 1980) exceed $M=2$ (fig. 12), and reliable location of smaller events is feasible only over a small area (fig. 6).

3. How far west or northwest of the rise in the unfiltered Bouguer gravity field may one expect to find Iapetan normal faults? An answer to this question is likely to be only approximate and might be expressed as the probability of finding such faults at specified distances from the rise. Such faults might not have a sharp cratonward limit but instead might decrease gradually in slip and in abundance away from the inferred Iapetan continental edge.

Estimates of the spatial distribution to be expected of Iapetan normal faults may be obtained from modern Atlantic-type continental margins. A bound on such an estimate may be derived from the distribution of Mesozoic normal faults in eastern North America. That bound could be conservative from the viewpoint of hazard zoning by erring on the side of safety, overestimating the area underlain by Iapetan normal faults. If the crust east of the gravity rise is weaker than that to the west (as we have suggested), then normal faults might have formed farther inland from the Atlantic continental edge than they did from the Iapetan edge. Thus, an estimate derived from the Mesozoic faults might overestimate sizes, abundances, and area of occurrence of Iapetan faults. On the other hand, a nonconservative bound may be obtained from other modern margins, on which normal faults are commonly buried under younger sedimentary rocks and sediments. That estimate might be nonconservative because the more cratonward faults on such margins might be too small, too few, or both, to be resolved readily by standard geologic and geophysical techniques. Thus, both the numbers and cratonward extent of such faults could be underestimated. The two estimates might provide useful bounds for an estimate of the cratonward extent of Iapetan normal faults.

A test of such estimates may be possible soon. Davies and others (1982) made numerous partly balanced cross sections across the Valley and Ridge and Appalachian Plateau provinces of the southern Appalachians. The sections were drawn to show numerous basement faults under the thrust sheets. By the arguments of this report, those basement faults are probably Iapetan normal faults.

Questions 2 and 3 posed in the preceding paragraphs deal with the uniqueness of Giles County seismicity in the Southeast. One hypothesis that bears on both questions is that of gravitationally induced stresses, which might reactivate Iapetan normal faults in the area that is outlined by the long Bouguer gravity low that flanks the steep eastward gravity rise on the northwest (Woollard and Joesting, 1964; Haworth and others, 1980; this report, fig. 18). The Giles County locale is in that long gravity low, and the rise passes 50–100 km southeast of the locale (fig. 18). Gibb and Thomas (1976) developed a composite model of crustal density distribution to fit Bouguer gravity profiles across four boundaries between Precambrian structural provinces in the Canadian Shield; Goodacre and Hasegawa (1980) used finite-element calculations based on that model to estimate shear stresses in the crust. Goodacre and Hasegawa applied their results to the Bouguer gravity rise where it passes through southeastern Quebec. They observed that seismicity in southeastern Quebec is concentrated in free-air gravity lows adjacent to free-air highs, where their calculations predicted that gravitationally induced shear stresses would be greatest. They hypothesized that the induced stresses have reactivated preexisting faults.

The hypothesis of Goodacre and Hasegawa (1980) is a possible explanation for the seismicity in the Giles County locale. Some of the largest, steepest parts of the Bouguer rise in the central and southern Appalachians are near Giles County. Also, the Giles County locale is in or near the long Bouguer gravity low, an area where the Goodacre-Hasegawa hypothesis predicts the greatest shear stresses at the depths of Giles County seismicity.

However, the hypothesis needs more detailed testing before being accepted for the Giles County locale for two reasons. First, there are several exceptionally steep parts of the rise and unusually strong positive and negative anomalies atop and at the bottom of the rise, between northern Virginia and northwestern South Carolina (Haworth and others, 1980). Indeed, Giles County itself is in a saddle between the two strongest negative anomalies, instead of within a negative anomaly as would be expected from a direct application of the results of Goodacre and Hasegawa (1980). Therefore, the hypothesis of gravitationally induced stresses requires further development to answer the question: Why is seismicity concentrated in and near Giles County, rather than at one of those other locales? Second, the models of Goodacre and Hasegawa and of Gibb and Thomas both attribute the induced stresses to lateral density contrasts that persist down to the base of the crust. From Pennsylvania southward, much of the size and steepness of the gravity rise is caused by the long gravity low adjacent to the rise on the northwest (Haworth and others, 1980; this report, fig. 18). That low lies about along the structural axis of the Appalachian basin, in which the sedimentary rocks are thickest, and the contours of the low approximately follow the mapped shape of the basin. How much of the rise is attributable to the sedimentary fill of the basin, rather than to density contrasts at the depths of Giles County seismicity? If the gravitational effect of the sedimentary rocks were removed by appropriate modeling, would finite-element calculations similar to those performed by Goodacre and Hasegawa predict large gravitationally induced shear stresses at the positions and depths of Giles County seismicity? Could induced stresses be further concentrated by cross structures similar to those mentioned in this section?

We suggest that the preceding questions and concepts be considered in designing future work on or near the Giles County seismic zone. The questions and their eventual answers will be important in drawing source zones for estimating seismic hazard, as well as in understanding the structural evolution of large parts of the North American continental crust. Currently, we have too few pertinent data to justify attempting to answer any of the questions. However, we know of no reason why carefully designed investigations should not eventually produce usably reliable answers to all of the questions we have posed.

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# APPENDIXES

# APPENDIX A

## A NOTE ON MICROSEISMIC LEVELS FOR THE VIRGINIA POLYTECHNIC INSTITUTE SEISMIC NETWORK

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ABSTRACT

Six hundred amplitude and period measurements were made of the seismic waves comprising the short-period microseismic background at the World Wide Standard Seismograph Network (WWSSN) station in Blacksburg (BLA) and at eight Virginia network stations. The overall average amplitude level at BLA was 3 nm (daytime) and 5 nm (nighttime) at frequencies of 0.9–3.1 Hz. At the network sites, the average daytime amplitude level was 5 nm at 2.3 Hz; during the nighttime, it was 10 nm at 2.3 Hz.

### INTRODUCTION

Noise surveys are usually employed to select sites for seismograph stations. However, follow-up measurements after a station or a network is installed and operational, are seldom made. There is normally little need for such measurements. However, if detection thresholds and network capability studies are to be made, knowledge of the ambient microseism levels is required. Additionally, specification of such levels can be useful for selection of additional sites in the region, and for engineering purposes related to radio telescopes, stable platforms, and other structures.

The Virginia Polytechnic Institute Seismic Network is perhaps representative of one class of network: short-period vertical transducers, with recording passband approximately 1–10 Hz. Stations are sited in four of the five major geologic provinces present in the Southeastern United States: Coastal Plain, Piedmont, Valley and Ridge, and Allegheny Plateau. Thus, noise measurements from the network could be used as approximations for expectable levels throughout the region.

### PROCEDURE

A spectral analysis would be the optimum manner to specify microseismic levels. However, for many purposes, simple amplitude-period measurements are entirely adequate. Such a procedure was utilized for this study. A total of 600 such measurements were made from ten different station sites. Film seismograms, using a viewer (1 s of time=10 mm on the viewer screen) were employed for all measurements. These measurements were made according to the following scheme:

1. Choose the months of January, March, June, September, and December, 1979, as representative of seasonal variations.
2. For each month, select a "typical" day and for each day select typical 2-hour periods (for example, $07^h$–$09^h$ UTC, 2–4 a.m. EST; and $19^h$–$21^h$ UTC, 2–4 p.m. EST). Within those periods, select typical but arbitrary 2-minute periods.

For each 2-minute period, make measurements for the noisiest and quietest stations for the Giles County subnetwork and the central Virginia subnetwork. Also make measurements for WWSSN BLA. This procedure yielded 600 amplitude-period measurements at nine different stations. The average values at each of the stations are presented in table 10. Values missing in that table occur when a given station is neither noisiest nor quietest during a given month or during the day-to-night time frame.

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TABLE 10.—*Average microseismic amplitude levels and frequencies*

[Dash (-) indicates no record, see text explanation. Station abbreviations are HWV, Hinton, W. Va.; PWV, Princeton, W. Va.; NAV, Narrows, Va.; PUV, Pulaski, Va.; BLA, Blacksburg, Va.; CVL, Charlottesville, Va.; GHV, Goochland, Va.; FRV, Farmville, Va.; PBV, Petersburg, Va.]

| Province | Station | January Day/Night | March Day/Night | June Day/Night | September Day/Night | December Day/Night |
|---|---|---|---|---|---|---|
| | | Amplitude level (nanometers) | | | | |
| Plateau--------- | HWV | -/- | -/- | -/- | 3/- | 18/- |
| Do---------- | PWV | 11/15 | 3/3 | 2/- | 3/3 | 4/5 |
| Valley and Ridge | NAV | -/- | -/- | -/1 | -/- | -/- |
| Do---------- | PUV | 23/60 | 2/3 | 2/1 | -/9 | -/32 |
| Do---------- | BLA | 5/8 | 2/2 | 2/1 | 2/2 | 3/12 |
| Piedmont-------- | CVL | 11/- | 3/2 | -/1 | 2/- | 11/8 |
| Do---------- | GHV | -/12 | -/- | -/- | -/- | -/- |
| Do---------- | FRV | 13/50 | -/- | 1/- | -/1 | -/- |
| Coastal Plain--- | PBV | -/- | 2/2 | 2/2 | 1/1 | 3/4 |
| Average----------- | | 13/29 | 2/2 | 2/1 | 2/3 | 8/12 |
| | | Microseismic frequency (Hertz) | | | | |
| Plateau--------- | HWV | -/- | -/- | -/- | 2.3/ - | 0.8/ - |
| Do---------- | PWV | 1.1/1.0 | 2.9/3.1 | 3.1/ - | 3.0/2.9 | 3.1/1.7 |
| Valley and Ridge | NAV | -/- | -/- | - /3.2 | -/- | -/- |
| Do---------- | PUV | 0.8/0.6 | 2.8/1.4 | 2.5/3.4 | - /0.9 | - /0.7 |
| Do---------- | BLA | 1.5/1.3 | 2.4/3.1 | 2.7/2.9 | 2.4/2.4 | 2.0/0.9 |
| Piedmont-------- | CVL | 1.0/ - | 2.7/3.4 | - /3.0 | 2.7/ - | 1.0/1.1 |
| Do---------- | GHV | - /1.0 | -/- | -/- | -/- | -/- |
| Do---------- | FRV | 1.1/0.7 | -/- | 2.9/ - | - /3.1 | -/- |
| Coastal Plain--- | PBV | -/- | 4.5/6.7 | 3.1/2.6 | 2.9/4.0 | 2.4/1.9 |
| Average----------- | | 1.1/0.9 | 3.1/3.5 | 2.9/3.0 | 2.7/2.7 | 1.9/1.3 |

# APPENDIX B

## DETERMINATION OF A DURATION MAGNITUDE RELATIONSHIP FOR THE VIRGINIA POLYTECHNIC INSTITUTE SEISMIC NETWORK

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(Modified from Viret (1980))

### INTRODUCTION

For the Virginia Polytechnic Institute Seismic Network, magnitudes of local and regional earthquakes are calculated using body-wave magnitude equations according to Nuttli (1973) and Bollinger (1979):

$$m_b(L_g) = 1.90 + 0.90 \log \Delta + \log (A/T) \quad 50 \text{ km} \le \Delta \le 400 \text{ km} \qquad (1a)$$

$$m_b(L_g) = -0.10 + 1.66 \log \Delta + \log (A/T) \quad 400 \text{ km} \le \Delta \le 2000 \text{ km}, \qquad (1b)$$

where Δ is the epicentral distance in kilometers, A is the sustained maximum ground motion, from center to peak, in microns, and $T$ is the corresponding period in seconds.

Equation 1a does not apply for distances less than 50 km. In that distance range, Richter's local magnitude equation,

$$M_L = \log A - \log A_o + \log (G(WA)/G(Net)) \qquad (2)$$

is used (Richter, 1958). The log (G(WA)/G(Net)) is an adjustment term to allow for differences in magnification: G(WA) is the magnification of the Wood-Anderson seismograph (2800) and G(NET) is the Virginia Polytechnic Institute Network station magnification. $A$ is the trace amplitude (half of the maximum peak to peak amplitude in mm), and $A_o$ is Richter's standard earthquake amplitude (dependent on distance). The quantity ($-\log A_o$) is tabulated by Richter (1958, p. 342).

There are several sources of possible error in various schemes of magnitude determinations. That is, application of the available formulas in an uncritical manner can result in large errors. Possibly the most significant of the error sources are the following:

1. *Near distances.*—At epicentral distances less than 50 km, the use of $M_L$ here includes no adjustment for differences in seismograph response between the mechanical-optical Wood-Anderson system (involved in the definition of $M_L$) and the electromagnetic seismographs used by the network. Additionally, there is no adjustment for the differences in seismic-wave attenuation between California and Virginia. However, with the small distances involved, the attenuation factor probably does not cause too large a disparity.
2. *Wave Frequency.*—The $m_b(L_g)$ formula is based on waves whose periods are within 0.2 s of 1 s. Any observed waves whose periods depart from that range carry the potential for large error. Also, the network seismograph's passband (fig. 4) has a much greater emphasis of the higher Earth frequencies than does the Wood-Anderson seismograph (Anderson and Wood, 1925). This emphasis could result in the use of a different seismic phase, or a different portion of the same phase, for magnitude determination than would have been considered had a Wood-Anderson seismograph been used.
3. *Different Interpreters.*—When the maximum vibrational amplitudes exceed the recording range of the instrument, none of the aforementioned magnitude equations can be used. It then becomes necessary to use a magnitude relationship based on the

duration of vibration. There is considerable subjectivity involved in the estimation of the duration of vibrations on a seismogram. Whitehurst (1977) estimated that a variation of only about 0.1 magnitude unit up or down is attributable to this factor. There were at least three different interpreters involved in the collection of the data set being considered here. In principle, then, we have the potential for 0.2 magnitude units variation from this source.

Several investigators have found empirically that a linear relationship between magnitude and the logarithm of duration of vibrations was adequate to specify earthquake size at near distances. As epicentral distances increase, however, a distance term must be added to this relationship. Because of the nature of seismic coda waves[1] as backscattering waves from numerous, randomly distributed heterogeneities in the Earth (Aki, 1969; Aki and Chouet, 1975), a theoretical basis for the empirical linear relationship can be described (for a review, see Whitehurst, 1977, p. 9–16). Thus, using equations 2, 1b, and 1a to calculate amplitude magnitudes for local and regional earthquakes, a relationship between the duration of vibrations and the magnitude of the causal earthquake can be established over a rather wide range of seismic energy release.

## PROCEDURE

The magnitude-duration relationship is that of a straight line:

$$M_D = \mathrm{A} + \mathrm{B} \log (D) \tag{3}$$

where $M_D$ is the average network duration magnitude, $D$ is the average duration of vibrations (usually in seconds) for the event, and A and B are constants to be determined. How duration is defined can affect the magnitude determined from the relationship of equation 3. Some authors define the duration as the time interval from the onset of the $P$-wave until the time when the earthquake vibrations return to the ambient microseismic noise level. That definition was used in this study. Another definition uses the same beginning but fixes the end of duration at the time the trace amplitude returns to a predetermined arbitrary peak-to-peak amplitude (Whitehurst, 1977).

[1]Seismic coda waves are the "tail" or final portions of a seismogram of a local earthquake; they are that part on a seismogram after the arrival of major wave types such as $P$, $S$, and surface waves (Aki and Chouet, 1975; Whitehurst, 1977).

For this study, there were three sources of data. One source was a data set compiled from durations and magnitudes ($M_L$ or $m_b(L_g)$) measured on the Virginia Polytechnic Institute Seismic Network. The other two sources used durations and magnitudes ($M_L$ or $m_b(L_g)$) measured on the Phase-I (P1) and Phase-II (P2) networks used for seismic monitoring at the North Anna site (Dames and Moore, 1976). The instruments used at that site were similar, and in some cases identical, to those now in use at Virginia Polytechnic Institute. Thus, given the same host region and the same general class of instrumentation, the data sets should be from the same general population. In all cases, the durations and magnitudes for a single event are averaged at all network stations to produce a network average.

The Virginia Polytechnic Institute Network magnitude data were combined with the North Anna magnitudes (VPI+P2+P1) to produce the input data set. A least-squares best-fit line was first determined for all the data points and then every point more than one standard deviation from that line was arbitrarily deleted to reduce excessive scatter. Finally, a new line was fit to the remaining points. The result of the above procedure is the equation:

$$M_D = (-3.38 \pm 0.09) + (2.74 \pm 0.06) \log (D). \tag{4}$$
$$n = 102$$
$$(\mathrm{SD}) = 0.25$$

where $n$ is the final number of points used to calculate the equation of the line and (SD) is the standard deviation of the points about that line. The plus-minus values refer to the standard deviations of the estimates of the slope and the intercept. See table 11 for a listing of these 102 input data pairs.

## SUMMARY

We chose as a provisional duration magnitude relation the following equation derived from 102 data points:

$$M_D = -3.38 + 2.74 \log (D) \tag{5}$$

Figure 28 shows a plot of this curve. It is interesting to note that equation 5 gives values similar to those derived from the WWSSN station BLA's equation: $M_D = -2.87 + 2.44 \log (D)$ as determined by Whitehurst (1977). Table 12 presents a list of the recalculated magnitudes for the Virginia microearthquakes located to date.

TABLE 11.—*Data set used in the determination of average network duration magnitude* ($M_D$) *when* $M_D = -3.38+2.74 \log D$ *and* n=102

[Duration D is in seconds. Leaders (----) indicate no data available]

| D | $M_L$ | $m_b$ | D | $M_L$ | $m_b$ | D | $M_L$ | $m_b$ |
|---|---|---|---|---|---|---|---|---|
| 15 | 0.3 | --- | 16 | -.2 | --- | 188 | 3.3 | --- |
| 16 | .5 | --- | 16 | -.3 | --- | 209 | 3.2 | --- |
| 21 | .9 | --- | 16 | .1 | --- | 232 | 3.5 | --- |
| 30 | .8 | --- | 17 | -.2 | --- | 361 | 4.0 | --- |
| 30 | .9 | --- | 18 | .3 | --- | 361 | 3.7 | --- |
| 30 | 1.2 | --- | 19 | .0 | --- | 8 | -.4 | --- |
| 40 | 1.1 | --- | 19 | .2 | --- | 8 | -.5 | --- |
| 44 | --- | 1.2 | 20 | .5 | --- | 10 | -.6 | --- |
| 120 | --- | 2.5 | 21 | .2 | --- | 10 | -.6 | --- |
| 120 | --- | 2.6 | 24 | .4 | --- | 10 | -.3 | --- |
| 15 | .1 | --- | 24 | .1 | --- | 11 | -.3 | --- |
| 16 | .0 | --- | 25 | .3 | --- | 11 | -.7 | --- |
| 16 | .1 | --- | 26 | .4 | --- | 11 | -.6 | --- |
| 20 | .3 | --- | 26 | .5 | --- | 30 | .3 | --- |
| 20 | .4 | --- | 26 | .1 | --- | 31 | .5 | --- |
| 21 | .2 | --- | 26 | .2 | --- | 32 | .4 | --- |
| 22 | .1 | --- | 26 | .2 | --- | 35 | .6 | --- |
| 23 | .2 | --- | 26 | .3 | --- | 36 | .9 | --- |
| 23 | .5 | --- | 27 | .4 | --- | 37 | .8 | --- |
| 23 | .6 | --- | 29 | .5 | --- | 38 | .8 | --- |
| 23 | .6 | --- | 34 | .7 | --- | 42 | .8 | --- |
| 25 | .4 | --- | 36 | .7 | --- | 44 | .9 | --- |
| 26 | .7 | --- | 37 | .7 | --- | 51 | .9 | --- |
| 28 | .5 | --- | 39 | .8 | --- | 86 | 1.6 | --- |
| 29 | .6 | --- | 39 | .7 | --- | 117 | 2.7 | --- |
| 29 | .5 | --- | 42 | .8 | --- | 137 | 2.4 | --- |
| 30 | .7 | --- | 51 | .9 | --- | 160 | 2.2 | --- |
| 12 | -.4 | --- | 52 | 1.3 | --- | 179 | 3.0 | --- |
| 12 | -.7 | --- | 53 | 1.4 | --- | 180 | 2.9 | --- |
| 13 | -.5 | --- | 62 | 1.7 | --- | 232 | 2.8 | --- |
| 13 | -.3 | --- | 64 | 1.2 | --- | 287 | 3.4 | --- |
| 13 | -.3 | --- | 100 | 2.3 | --- | 294 | 3.1 | --- |
| 14 | -.4 | --- | 159 | 3.1 | --- | 392 | 3.7 | --- |
| 15 | .2 | --- | 174 | 2.8 | --- | 545 | 4.3 | --- |

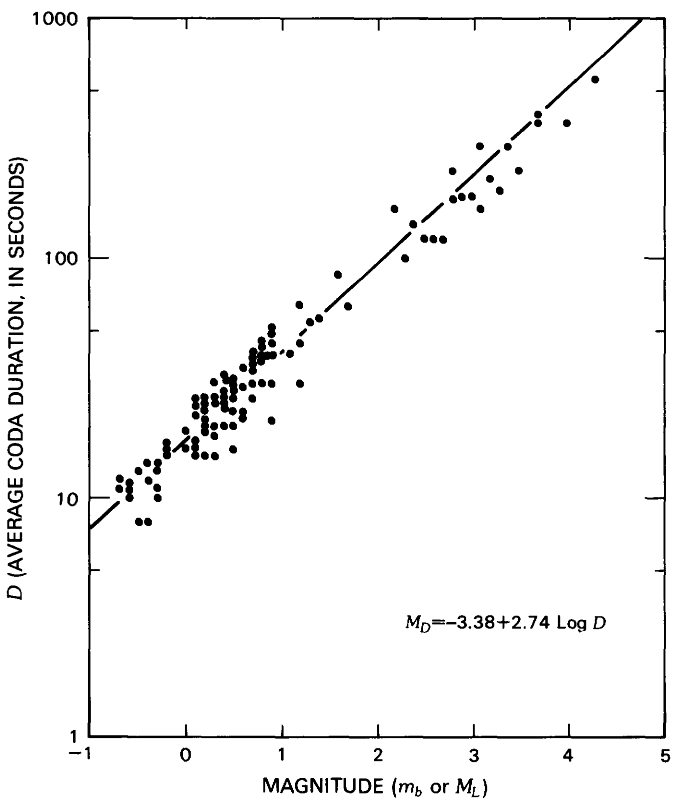


FIGURE 28.—Plot of average coda duration versus magnitude for earthquakes recorded by the Virginia Polytechnic Institute Seismic Network.

TABLE 12.—*Recalculated average network duration magnitudes using* $M_D = -3.38 + 2.74 \log D$

[Duration D is in seconds; leaders (---) indicate no data available]

| Map No.[1] | Date: Year | Date: Month Day | Time (UTC) | Average duration (D) | $M_D$ | $m_b(L_g)$[2] | $M_L$[2] |
|---|---|---|---|---|---|---|---|
| 21 | 1976 | Sept.13 | 18:54 | 193 | 2.9 | 3.1 | --- |
| 32 | 1978 | Jan. 28 | 23:13 | 66 | 1.6 | (2.9) | (2.4) |
| 32A | 1978 | Mar. 17 | 18:26 | 152 | 2.6 | 2.8 | --- |
| 33 | 1978 | May 10 | 4:19 | 22 | .3 | --- | .6 |
| 34 | 1978 | May 25 | 8:30 | 59 | 1.5 | --- | 1.0 |
| 35 | 1978 | June 1 | 1:33 | 14 | -0.2 | --- | ( .5) |
| 36 | 1978 | June 22 | 6:42 | 43 | 1.1 | (2.27) | 1.5 |
| 37 | 1978 | July 28 | 8:39 | 28 | .6 | --- | .6 |
| 38 | 1978 | Aug. 30 | 2:19 | 25 | .5 | --- | .7 |
| 39 | 1978 | Sept.14 | 19:37 | 12 | -0.4 | --- | ( .7) |
| 40 | 1978 | Oct. 14 | 1:50 | 22 | .3 | --- | (1.0) |
| 41 | 1978 | Oct. 29 | 12:22 | 44 | 1.1 | --- | 1.6 |
| 42 | 1978 | Nov. 15 | 8:33 | 72 | 1.7 | 2.1 | 2.1 |
| 43 | 1979 | Nov. 6 | 3:04 | 70 | 1.7 | 1.3 | --- |
| 44 | 1979 | Nov. 12 | 7:21 | 44 | 1.1 | 1.2 | --- |
| 45 | 1980 | Jan. 6 | 13:50 | 66 | 1.6 | (1.0) | --- |
| 46 | 1980 | Feb. 18 | 3:58 | 42 | 1.1 | --- | .9 |
| 47 | 1980 | Apr. 10 | 22:33 | 30 | .7 | --- | .9 |
| 48 | 1980 | Apr. 22 | 3:14 | 110 | 2.2 | (2.8) | --- |
| 49 | 1980 | Apr. 26 | 3:59 | 58 | 1.4 | (3.0) | 1.7 |
| 50 | 1980 | May 18 | 3:31 | 36 | .9 | --- | 1.2 |
| 51 | 1980 | May 18 | 22:33 | 13 | -0.3 | --- | (1.2) |
| 52 | 1980 | July 7 | 17:02 | 20 | .2 | --- | (1.4) |
| 53 | 1980 | Aug. 4 | 10:13 | 30 | .7 | --- | 1.0 |
| 54 | 1980 | Sept.18 | 1:28 | 22 | .3 | --- | .7 |
| 55A | 1980 | Sept.21 | 10:02 | 56 | 1.4 | (2.6) | 1.5 |
| 56 | 1980 | Sept.24 | 6:41 | 42 | 1.1 | (2.0) | 1.4 |
| 57 | 1980 | Sept.26 | 1:31 | 89 | 2.0 | (3.5) | 2.2 |
| 57A | 1980 | Sept.26 | 5:04 | 19 | .1 | --- | (1.0) |
| 58 | 1980 | Oct. 9 | 1:47 | 14 | -0.2 | --- | .4 |
| 59 | 1980 | Oct. 11 | 22:40 | 31 | .7 | --- | 1.1 |
| 60 | 1980 | Oct. 14 | 1:20 | 71 | 1.7 | --- | 1.9 |
| 61 | 1980 | Oct. 16 | 3:48 | 44 | 1.1 | --- | 1.5 |

[1]Refers to table 4 and G. A. Bollinger (1980, unpub. data).
[2]Parentheses identify unacceptable values, probably caused by use of an inappropriate wave period or phase. Do not use these values.

# APPENDIX C

## VELOCITY MODEL TEST FOR GILES COUNTY LOCALE

*By* D. A. CARTS *and* G. A. BOLLINGER

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A microearthquake was detected at 04$^h$ UTC, February 18, 1980, by seismograph stations of the Giles County, Bath County, and central Virginia subnetworks. A preliminary location placed the epicenter near the northeast edge of the Giles County seismic subnetwork.

The arrival times for this event were used to test the several velocity models that are available for the Giles County locale. Specifically, there are now five velocity models in use, three of which are "regional" (Southeastern United States) and two of which are "local" (Giles County). One of the regional models (MCC) and the two local models (TPMl, TPM2) were recently published (Bollinger and others, 1980). Each model has 2-4 horizontal layers of uniform velocities and thicknesses. Model names have no significance beyond identifying the models; most are initials of the authors cited in the table below. All the models are as follows:

[km/s, kilometers per second; km, kilometers]

| Model | $V_P$ (km/s) | Depth (km) | $V_P/V_S$ | Remarks |
|---|---|---|---|---|
| GAB | 6.24 | 0.0 | 1.70 | Regional. Bollinger, 1970. |
| | 8.22 | 45.0 | | |
| VPI | 5.7 | .0 | 1.70 | Regional, hybrid. Unpublished. |
| | 6.24 | 10.0 | 1.70 | |
| | 8.22 | 45.0 | 1.70 | |
| MCC | 6.34 | .0 | 1.67 | Regional. Chapman, 1979. |
| | 8.18 | 45.0 | 1.73 | |
| TPM1 | 5.63 | .0 | 1.64 | Local. Moore, 1979. |
| | 6.53 | 10.0 | 1.70 | |
| | 8.18 | 49.0 | 1.71 | |
| TPM2 | 5.63 | .0 | 1.64 | Local. Moore, 1979. |
| | 6.05 | 5.7 | 1.72 | |
| | 6.53 | 14.7 | 1.70 | |
| | 8.18 | 50.7 | 1.71 | |

### COMPARISON OF LOCATION CAPABILITY OF THE VELOCITY MODELS

Arrival time data were read from the seismograms and were used as input to HYPO71 (Lee and Lahr, 1975). Initial runs were made to eliminate arrival times with large traveltime residuals. Next, each model was tried with one or more different ratios of compressional velocity to shear velocity ($V_P/V_S$). All runs had a trial focal depth (TFD) set equal to zero. The results of the eight runs are tabulated:

[Error measures are calculated by HYP071 (Lee and Lahr, 1975): RMS, root-mean-square error of the traveltime residuals in seconds (s); ERH, standard error of the epicenter and ERZ, standard error of the focal depth in kilometers (km)]

| Model | $V_P/V_S$ | RMS (s) | ERH (km) | ERZ (km) | Quality[1] |
|---|---|---|---|---|---|
| GAB | 1.70 | 0.33 | 1 | 386 | C |
| VPI | 1.70 | .26 | 1 | 2 | C |
| MCC | 1.67 | .46 | 1 | 542 | C |
| MCC | 1.73 | .30 | 1 | 357 | C |
| TPM1 | 1.64 | .52 | 2 | 5 | D |
| TPM1 | 1.70 | .48 | 2 | 4 | C |
| TPM2 | 1.64 | .52 | 2 | 5 | C |
| TPM2 | 1.70 | .21 | 1 | 1 | B |

[1]The 68-percent confidence ellipsoid calculated by the HYPOELLIPSE program (Lahr, 1979) is projected onto horizontal and vertical planes, to give lengths and orientations of semimajor, semiminor, and vertical semiaxes. The largest of these three distances determines quality. Quality is A if the largest distance does not exceed 2.5 km, B if the largest distance does not exceed 5.0 km, C if the largest distance does not exceed 10.0 km, and D otherwise.

On the basis of the lowest RMS, ERH, and ERZ values and highest hypocenter quality, model TPM2 with $V_P/V_S$=1.70 appears to be the best model. Also, only the TPM2 and VPI models calculated a focal depth different from zero trial depth.

### STABILITY OF FOCAL DEPTH ESTIMATED WITH CHANGES IN TRIAL FOCAL DEPTHS

The TPM2 velocity model with $V_P/V_S$=1.70 was used with several trial focal depths (TFD's). We observed the stability of the estimated focal depth as it was calculated with HYPO71 (Lee and Lahr, 1975). TFD's were chosen to be in each layer and near some layer boundaries. Results are as follows, in the form of calculated values of origin time, hypocenter coordinates, and error measures for each TFD:

[km, kilometers; s, seconds; min, minutes]

| Trial focal depth (km) | Origin time (0358 + $x$) (s) | Latitude (N.) (37° + $x$) (min) | Longitude (W.) (80° + $x$) (min) | Focal depth (km) | RMS (s) | ERH (km) | ERZ (km) |
|---|---|---|---|---|---|---|---|
| 00 | 55.28 | 25.68 | 35.37 | 13.1 | 0.21 | 0.8 | 1.5 |
| 3 | 55.34 | 25.72 | 35.36 | 12.1 | .20 | .8 | 1.5 |
| 4 | 55.27 | 25.70 | 35.37 | 13.2 | .21 | .8 | 1.5 |
| 5 | 55.35 | 25.63 | 35.34 | 12.1 | .20 | .8 | 1.5 |
| 6 | 55.34 | 25.57 | 35.42 | 12.6 | .20 | .8 | 1.5 |
| 10 | 55.24 | 25.62 | 35.44 | 13.9 | .20 | .7 | .8 |
| 12 | 55.21 | 25.60 | 35.44 | 14.4 | .19 | .6 | .8 |
| 13 | 55.21 | 25.56 | 35.45 | 14.6 | .20 | .6 | .6 |
| 14 | 55.18 | 25.73 | 35.41 | 14.7 | .19 | .6 | 1.9 |
| 15 | 55.17 | 25.74 | 35.36 | 15.0 | .19 | .6 | .8 |
| 18 | 55.17 | 25.66 | 35.31 | 14.9 | .19 | .6 | 1.8 |
| 20 | 55.17 | 25.71 | 35.21 | 14.5 | .19 | .6 | .6 |
| 25 | 55.18 | 25.78 | 35.42 | 14.7 | .19 | .6 | 1.9 |
| 30 | 55.16 | 25.75 | 35.20 | 14.4 | .19 | .6 | .6 |

It is seen that regardless of the initial depth estimate, a final focal depth near 14-km depth is obtained. Origin time and hypocenter coordinates vary little. All runs had B-quality solutions, RMS values of 0.20±0.01 and ERH values of 0.7±0.1. Runs with TFD near a layer boundary of the model TPM2 either tended to give ERZ values that were relatively large or did not change the focal depth from the TFD. Expectably, deeper focal depths are related to earlier origin times, but the latitude and longitude values were virtually independent of the focal depth.

## PRELIMINARY CONCLUSIONS

The preliminary indications based on this one test are as follows: (1) The TPM2 model with $V_P/V_S=1.70$ is the best model for the Giles County area, (2) epicenter estimation is relatively stable with changing TFD, (3) shallower and deeper TFD's tend to produce slightly shallower and deeper focal depths, respectively, (4) TFD's near layer boundaries should be avoided, and (5) a TFD should be tried from each layer to ascertain stability of focal depth.

# APPENDIX D

## STATISTICAL TESTS OF THE GILES COUNTY SEISMIC ZONE

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### INTRODUCTION

The nearly vertical, tabular seismic zone beneath Giles County, Va., is defined by only eight microearthquakes out of the 12 that have been located in and near Giles County during 1978-80. It is possible that the zone is only an artifact of the small sample size and would disappear with more data. The 12 microearthquakes recorded during 1978-80 are a sample of a population that might contain hundreds or thousands of earthquakes. The population consists of all the earthquakes that have occurred in or near Giles County during the past decades, centuries, and millenia, and all the earthquakes that will occur for a similar time into the future. The next few decades to millenia is the span of time about which evaluators of seismic hazard must be concerned. Accordingly, this appendix must evaluate the likelihood that a 3-year sample of 12 microearthquakes is an adequate basis for characterizing the population.

Properly chosen statistical methods that are applied to a representative sample can evaluate this likelihood, because such methods incorporate the effect of sample size. In particular, the methods lose power as sample size decreases. This power loss means that for small samples the methods used below will produce valid but conservative results. The methods may fail to detect associations that are only weakly significant, but the methods will not overemphasize the significance of marginal associations.

In Appendix D of Bollinger and Wheeler (1982), Wheeler attempted a straightforward statistical analysis of microearthquake locations. That analysis fell into a pitfall that might be called "the one-sample problem". Proper statistical procedure is to collect a sample of data and examine the structure of the sample. Results of the examination aid in the formulation of an hypothesis to be tested. Then the examined sample is set aside and the statistical test is performed on a second, unexamined sample of data. If examination and testing are both performed on the same sample, then the formulation of the hypothesis is likely to reflect vagaries in the sample more strongly than it reflects the structure of the population. The results of the statistical test are likely to be distorted toward statistical significance. In general, the amount of such distortion cannot be determined.

Only one sample of microearthquake locations exists for the Giles County locale. This sample consists of the 12 microearthquakes that were recorded during 1978-80. The sample is too small to divide into two parts. In Appendix D of Bollinger and Wheeler (1982), Wheeler used this single sample of 12 microearthquake locations for both examination and testing, and concluded that eight of these locations define a statistically significant spatial pattern. This conclusion might be correct, but the methods that Wheeler used in Bollinger and Wheeler (1982) cannot determine that because results of the analysis have been distorted by prior inspection of the tested sample.

Methods are needed that do not require inspection of data before performing a statistical test. This appendix applies such methods, in the third of the following four steps: (1) Arguments are presented that the sample is representative of the population from which it was drawn. (2) The epicentral alignment to be examined is shown to be the most appropriate alignment among the several that might be perceived among the 12 microearthquake locations. (3) A procedure that does not depend on prior inspection of the data allows evaluation of the suggested concentration of earthquakes in the Giles County seismic zone and allows evaluation of the suggested northeast alignment of locations of these earthquakes. (4) The strike and dip of the tabular seismic zone are calculated.

The 12 microearthquakes to be considered are represented in figures 9, 11, and 13. The microearthquakes are characterized by the data of table 4. Pertinent parts of these figures and data are included in the figures of this appendix.

## REPRESENTATIVENESS

The 3-year sample of microearthquakes cannot be used to characterize the longer term seismicity of the Giles County seismic zone unless the sample is representative of that longer term seismicity. The sample must be representative in both space and time and must also be what is called complete. Representativeness in space means that earthquake detection and location have not been biased against earthquakes outside the Giles County seismic zone. Representativeness in time means that the sampled time interval, 1978–80, has not been anomalous in its seismicity. Completeness means that no earthquakes that occurred in the area of interest during 1978–80 have been missed, except perhaps earthquakes smaller than those in the sample. Because there is only one sample, and because it is small, quantitative demonstrations of representativeness and of completeness cannot be made. However, the following arguments suffice for our purposes.

The goals of this report do not require that the 3-year sample of microearthquakes perfectly represent the longer term seismicity of the Giles County locale. These goals only require that the sample be representative enough in time that the map pattern of the epicenters is defined clearly enough to justify geological interpretation. The geological and seismological arguments of the next two paragraphs support the conclusion that the sample achieves this level of representativeness in time.

The seismicity of Giles County occurs when existing faults are reactivated in an existing stress field (Hamilton, 1981). Probably important new faults are not formed, so the geologic structures that are responsible for the seismicity do not change over decades to millenia. The present stress field arises from motions and mechanical properties of the North American plate and from the interactions of the plate with adjacent and underlying material; these factors can change over millions of years but are unlikely to change appreciably over decades to millenia. Thus, it is geologically reasonable to regard the earthquakes sampled during 1978–80 as a representative sample of several decades to millenia of seismicity.

Seismicity of the Giles County locale is likely to change with time in two ways. First, earthquakes that are large enough for their recurrence intervals to exceed 3 years will occur in some 3-year samples but not in others. As an extreme example, only samples that include the year 1897 would sample an earthquake of intensity VIII. However, earthquakes that are large enough to have remained unsampled during 1978–80 will change the observed map pattern of epicenters only if they occur on faults that have not generated detectable microearthquakes during 1978–80. The geological arguments of the preceding paragraph make such variable activity unlikely. Second, the abundance of small earthquakes and microearthquakes can rise and fall with time, although locations of these earthquakes tend to remain more or less the same. The historical record of seismicity indicates that the number of earthquakes observed in and near Giles County does fluctuate over several decades (Bollinger, 1975). However, such fluctuations can be regarded as variations in the accumulation and seismic release of stress about a long-term average. Such fluctuations do not appear to indicate changes in the long-term level of seismicity or changes in which fault or group of faults are reactivated over decades to millenia. For these geological and seismological reasons, it is reasonable and safe to assume that the sampled microearthquakes are representative in time to a degree that justifies interpretation of their locations.

Whether the sampled microearthquakes are representative in space depends on whether the ability to detect and locate small earthquakes is the same throughout the area in and around Giles County. Figure 29 shows locations of the 12 microearthquakes that constitute the sample. The Giles County seismic zone is defined by the map locations of 8 of the 12 microearthquakes: nos. 32, 33, 35, 37, 38, 46, 58, and 63. The other four microearthquakes occurred outside the zone: nos. 34, 39, 40, and 60. Is a small earthquake as likely to be detected and located if it occurs outside the zone as if it occurs in the zone? An answer is obtained by comparing magnitudes and estimates of the quality of hypocentral locations for two groups of microearthquakes, the eight that lie in the seismic zone and the four that lie outside of it. Figure 30 makes this comparison graphically.

Figure 30 shows several relationships. As expected, there is a general improvement in the quality of hypocentral locations with increasing magnitude. This improvement occurs because larger earthquakes are more clearly recorded at more stations. However, there is no clear difference in locational quality between the microearthquakes inside the seismic zone and those outside the zone. Both groups of earthquakes have median quality of C. Also, there is no indication that earthquakes recorded inside the zone are preferentially smaller than those recorded outside the zone, as would be expected if detection ability and locational ability decrease away from the zone. The median magnitude of the earthquakes outside the zone is half a magnitude unit larger than is the median magnitude of earthquakes inside the zone, but for such small samples this difference is not important. In fact, the smallest earthquake of the 12 is no. 39, which occurred farthest from the seismic zone (figs. 29, 30). Therefore, it seems

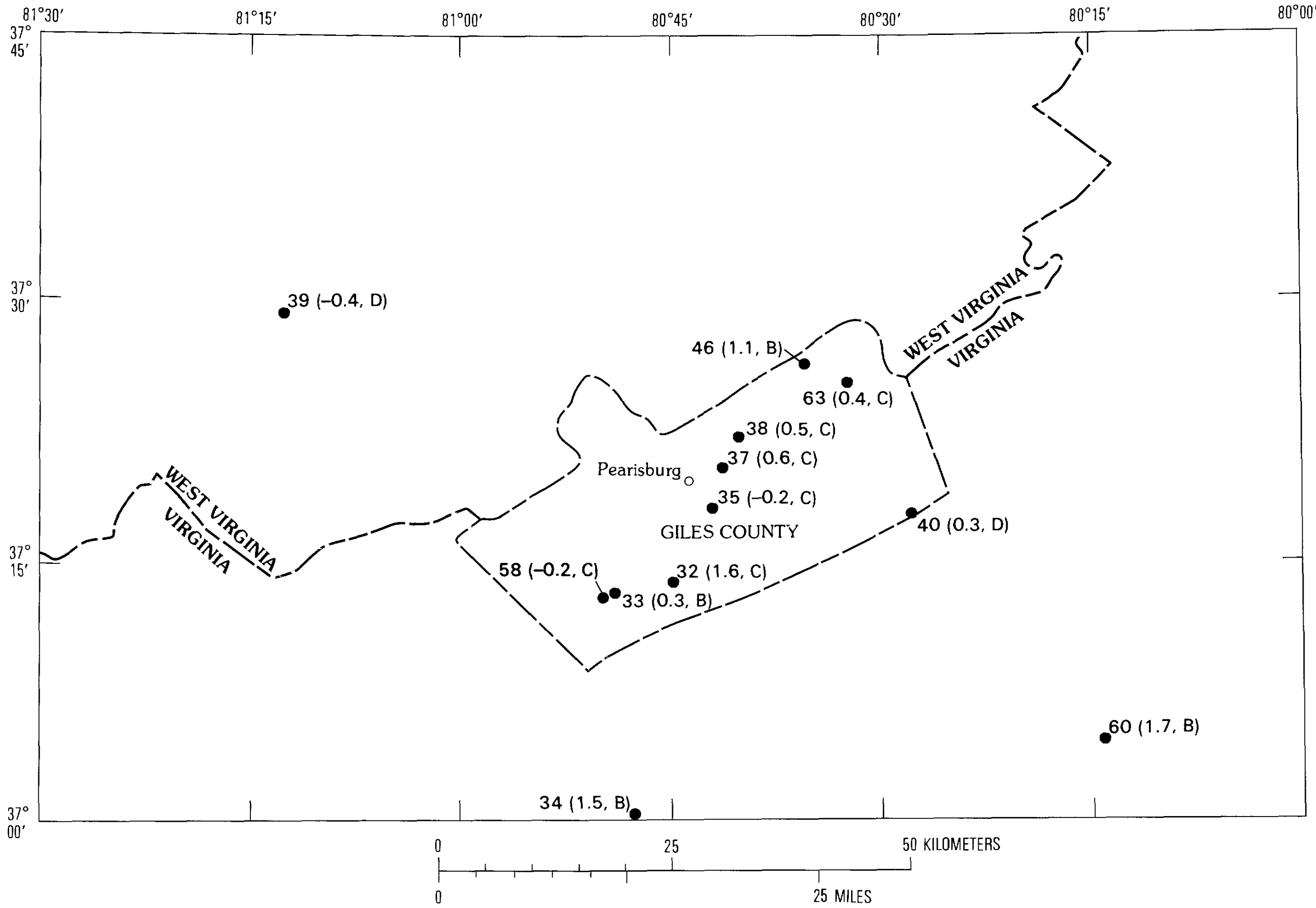


FIGURE 29.—Locations, magnitudes, and estimates of locational quality for the 12 microearthquakes that occurred in the Giles County locale in 1978–80. The locale is defined as the area within 50 km of Pearisburg. Dots locate calculated epicenters. To the right of each epicentral location appear three items: (1) the catalog number of the earthquake, (2) in parentheses, a decimal fraction giving the calculated magnitude ($M_D$) of the earthquake to the nearest tenth of a magnitude unit, and (3) also in parentheses, a letter indicating the quality of the calculated hypocentral location. Quality is determined from the largest of the horizontal and vertical dimensions of the 68-percent confidence ellipsoid (Lahr, 1979). A, B, and C quality locations have this largest dimension less than or equal to 2.5, 5.0, and 10.0 km, respectively; D quality solutions have this largest dimension greater than 10.0 km. Data from figure 9 and table 4 of this report.

reasonable to assume that the ability to detect and locate earthquakes is more or less constant across the Giles County locale. This assumption implies that the sample of 12 microearthquakes is representative in space and that sampling has not been biased against earthquakes occurring outside the seismic zone.

If the ability to detect and locate microearthquakes was about the same throughout the Giles County locale during 1978–80, then probably all earthquakes above some minimum size were detected and located, wherever in the locale they occurred. Judging from the magnitudes and locations of microearthquakes represented in figures 29 and 30, that minimum size is probably about magnitude -0.2, and perhaps as small as magnitude -0.4. Thus, the sample of 12 earthquakes is probably complete above a magnitude of about -0.2. Because the sample can be assumed to be representative in space and time, and because the sample is probably complete, the sample represents the population and can be used to characterize it. One aspect of the population that cannot be characterized by the 3-year sample of microearthquakes is the abundance of larger earthquakes.

## THE MOST APPROPRIATE ALIGNMENT

I know of no statistical test that is generally appropriate for detecting and evaluating single alignments

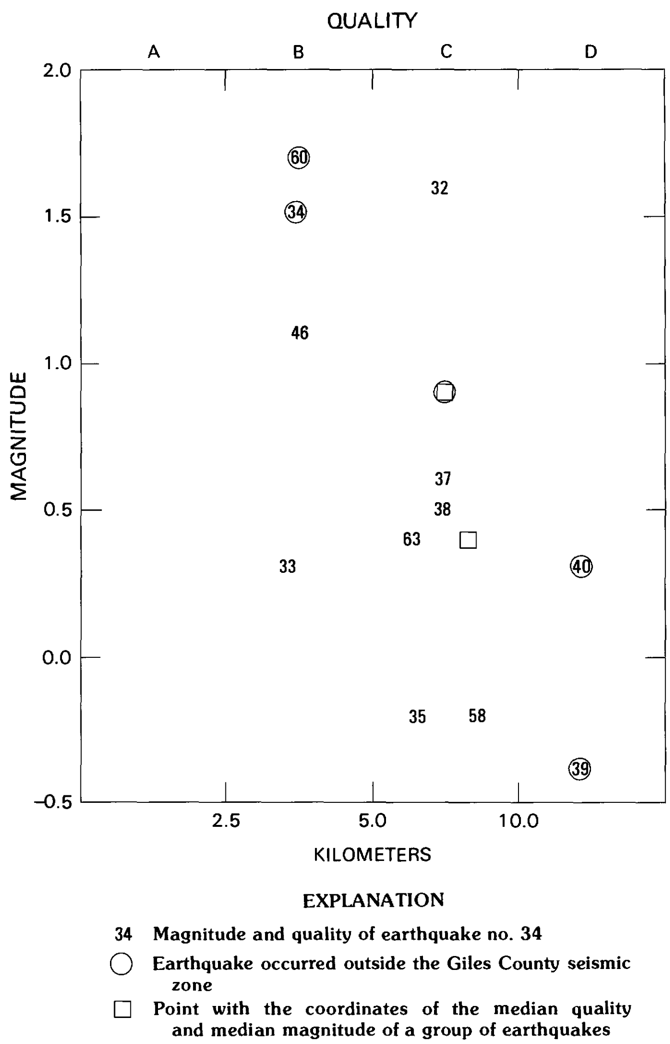


FIGURE 30.—Relationship between earthquake magnitude and locational quality for the 12 earthquakes represented in figure 29. Uncircled box shows median of coordinates of 8 earthquakes inside the seismic zone and circled box does the same for 4 earthquakes outside the zone.

of points in a plane. For example, one problem is the difficulty of constructing mathematical expressions of such perceptual concepts as alignment, the maximum allowable gap between aligned points, and the effect of the mean areal density of all points in the sample. However, for the present case only, such problems of quantifying perceptions can be ignored. This is because many geologists and seismologists have examined figures 9 and 13. None have objected to the suggestion that if there is a significant tabular zone of microearthquakes, it is the one defined by earthquakes 32, 33, 35, 37, 38, 46, 58, and 63 in figures 9 and 13. It remains to determine whether we are all correct in assuming that the tabular zone did not arise randomly.

## SIGNIFICANTLY CONCENTRATED EPICENTERS

In the discussions of representativeness and of appropriateness of the alignment, the sample of 12 microearthquakes was examined. Any subsequent statistical tests that are based on the findings of this examination would produce distorted results. Accordingly, the procedure summarized next does not use those findings and would be performed in the same way whether or not the sample had been examined.

The area represented in figure 29 can be divided into 18 rectangular cells, each measuring in minutes 15×15. The 12 epicenters fall into various cells. We wish to determine which cells contain significantly large numbers of epicenters. Such significantly overpopulated cells will occur independently of each other. If significantly overpopulated cells cluster along the alignment of eight epicenters in Giles County, then the alignment can be considered as a real and reliable feature of the population.

Cell significance is evaluated with the Poisson distribution and Chi-squared test, following procedures and examples of Lewis (1977, p. 76–78, 228) and Feller (1957, p. 146–154). The cell boundaries are drawn along the lines of latitude and longitude that are indicated around the boundaries of figure 29. To avoid distortion peculiar to any one choice of cell boundaries, the calculations are repeated for three other sets of cells, with boundaries moved successively 7.5 minutes east, 7.5 minutes south, and both.

Results vary among the four sets of cell boundaries (fig. 31). Three choices of cell boundaries found significantly many epicenters in one cell per choice; these three cells are hachured in figure 31 and overlap in the center of Giles County. The fourth choice of cell boundaries found significantly many epicenters in each of the three adjacent 15′×15′ cells that together cover most of the area inside the dashed lines of figure 31. For all choices of cell boundaries taken together, most cells contained either no or one epicenter, and the largest concentration of epicenters in any cell was six. Concentrations of four or more epicenters in a cell were significant and, for one choice of cell boundaries, so were concentrations of three or more epicenters in a cell. This variability can be overcome by summing results for all four choices of cell boundaries. Figure 31 does this.

Patterned areas in figure 31 show cells or parts of cells that contain significant concentrations of epicenters for two or more of the four different choices of cell boundaries. These cells overlap the alignment of eight epicenters that define the Giles County seismic zone, and align northeast-southwest along the zone.

The observations of the preceding paragraph are not subject to a numerical test of significance, but they

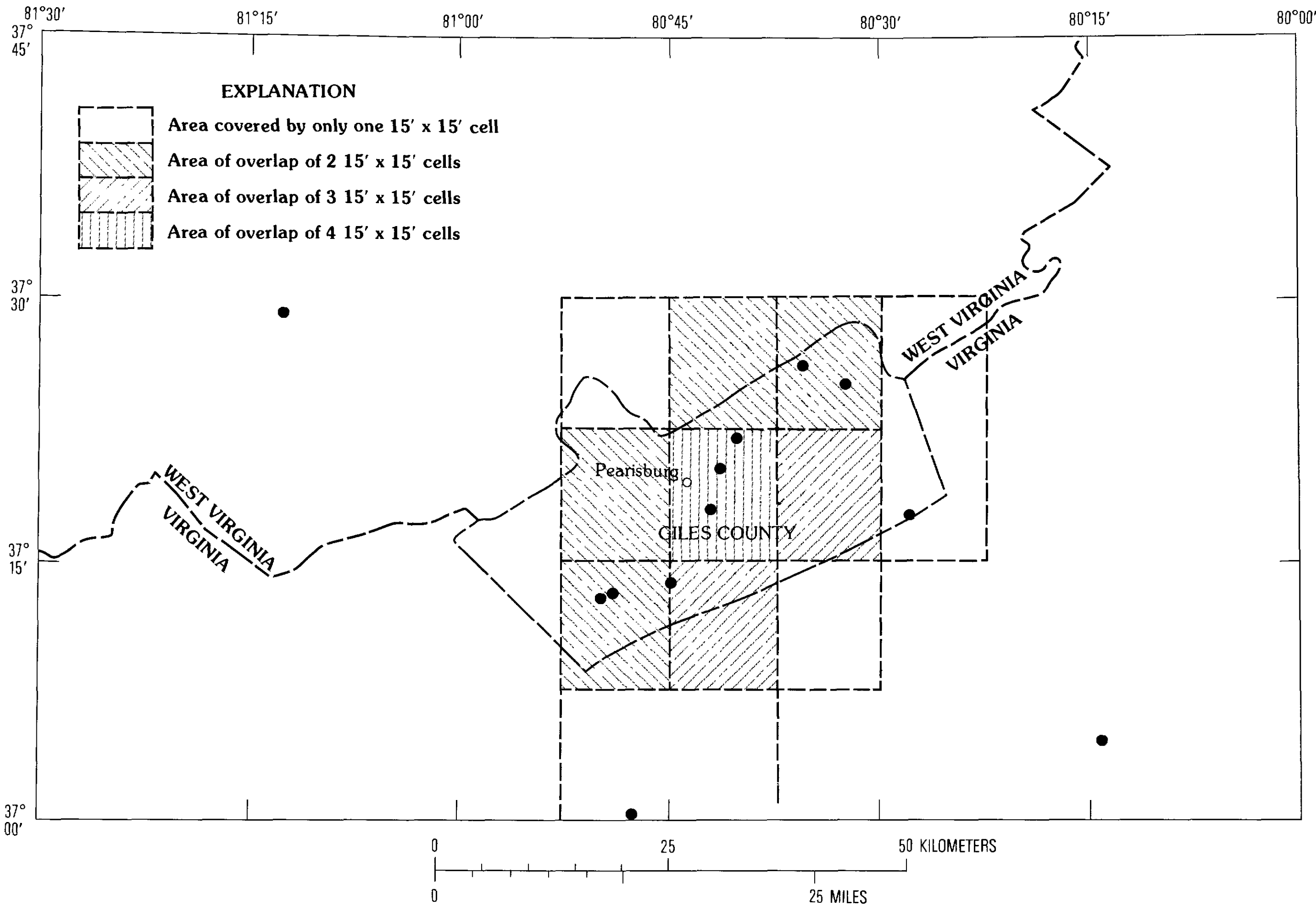


FIGURE 31.—Significant concentrations of the 12 epicenters represented in figure 29. Dots locate the epicenters. Dashed lines outline the 15′×15′ cells that contain significantly many epicenters.

provide support for concluding that (1) the earthquakes of figure 29 are concentrated into Giles County, (2) the earthquakes in Giles County define an elongated zone that trends northeast, and (3) the concentration, its elongation, and the trend of the elongation characterize a representative sample, and so also characterize the population of earthquakes from which the sample of 1978–80 was drawn.

## STRIKE AND DIP OF THE SEISMIC ZONE

The eight hypocenters in the seismic zone define a tabular zone. The zone is presumed to reflect a fault or fault zone, and its strike and dip can be estimated. Earthquakes 34, 39, 40, and 60 lie outside the zone. These four earthquakes are presumed to have occurred on some other fault or faults, and will not be considered further.

To measure the northeasterly strike of the seismic zone, the eight hypocenters are projected up into a horizontal map at ground level (fig. 32*A*). Although deep hypocenters tend to occur farther northwest than do shallow hypocenters (fig. 32*B*), this upward projection will not distort the strike of the seismic zone much because the dip is steep. A straight line fitted to the epicentral locations will allow measurement of a numerical value of the strike of the seismic zone. To measure the dip of the seismic zone, the eight hypocenters are projected into a vertical plane that lies about perpendicular to the strike of the tabular zone (fig. 32*B*). Within the vertical plane, a straight line fitted to the hypocentral projections will allow measurement of a numerical value of the dip of the seismic zone.

In three dimensions, the eight hypocenters are somewhat scattered. No single straight line in figure 32*A* can pass through all eight earthquake locations, and the same is true of figure 32*B*. The regression coefficients that are calculated below allow qualitative estimates of whether that scatter is small enough that

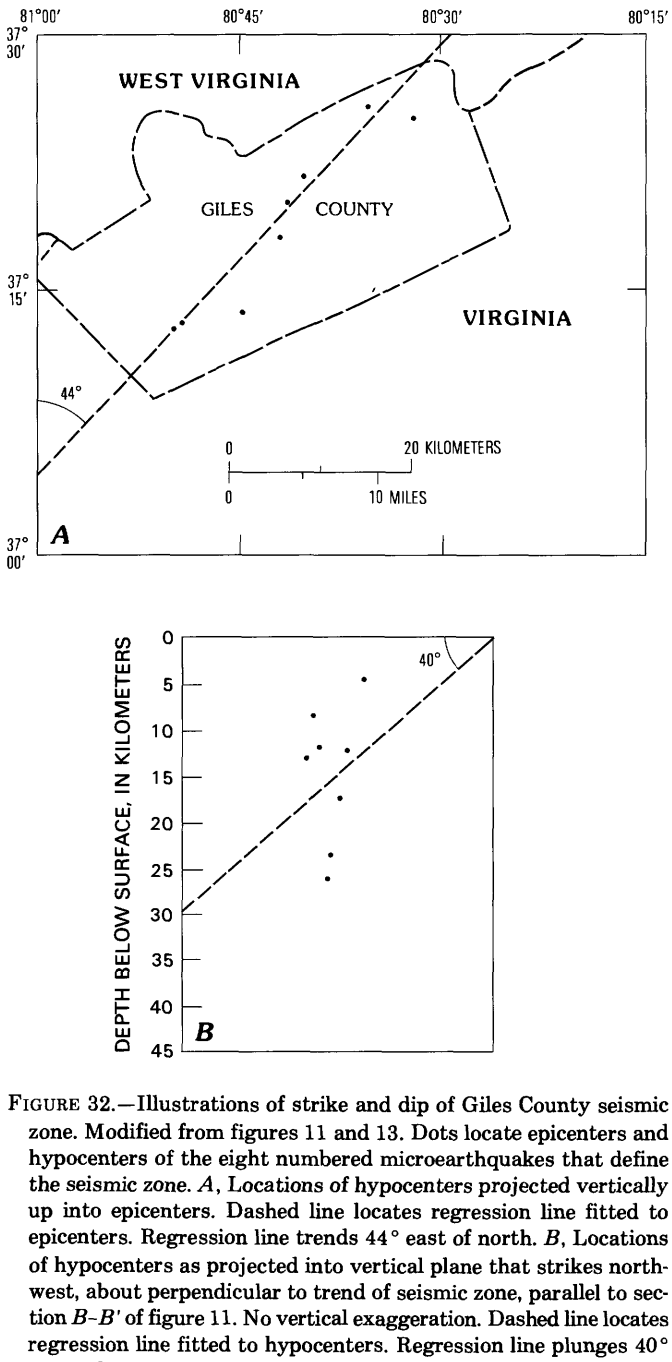


FIGURE 32.—Illustrations of strike and dip of Giles County seismic zone. Modified from figures 11 and 13. Dots locate epicenters and hypocenters of the eight numbered microearthquakes that define the seismic zone. *A*, Locations of hypocenters projected vertically up into epicenters. Dashed line locates regression line fitted to epicenters. Regression line trends 44° east of north. *B*, Locations of hypocenters as projected into vertical plane that strikes northwest, about perpendicular to trend of seismic zone, parallel to section *B–B'* of figure 11. No vertical exaggeration. Dashed line locates regression line fitted to hypocenters. Regression line plunges 40° to northwest.

it can be ascribed to random factors, such as uncertainty in calculated locations of hypocenters and irregular shapes of the faults that underlie Giles County.

The two straight lines that have been fitted to the points in figures 32*A* and 32*B* are regression lines. Although regression is a statistical technique, it is used here merely as a method of fitting lines to points. Several considerations govern the applications of regression methods to the points represented in figure 32: (1) The straight lines are fitted to the points of figure 32 by regression rather than by eye and ruler, because regression is more objective and its results are more reproducible. (2) The regression calculations provide values for Pearson's product-moment correlation coefficient $r$. Consideration of these values can provide qualitative estimates of the confidence that can be placed in the regression lines and of the degree to which the fitted points adhere to the regression lines. Such qualitative estimates are aided by visual examination of figure 32. (3) The values of $r$ cannot be tested for significance, so standard numerical estimates of the goodness of fit of the points by the regression lines cannot be made. Significance testing is ruled out by the one-sample problem. Inspection of the distribution of the hypocenters in map and section views led to the observation that the seismic zone is tabular. This observation led to the desire to fit straight lines to the hypocenters as they are represented in figures 32*A* and *B*. Therefore, results of any significance tests would be distorted. (4) Full quantitative use of the simple linear regression used here is inappropriate for points that have uncertainty in all coordinates (Bolt, 1978). Use of the full panoply of regression techniques may also be inappropriate if it is not clear which coordinate should vary as a function of the other (Williams, 1983). Both problems occur here. The hypocentral locations of figure 32 have small uncertainties in all directions. In both parts of figure 32, it is unclear which coordinate ought to depend on the other. (5) Simple linear regression and testing $r$ for significance require ten assumptions, which range from representativeness of the sample to statements about statistical properties of the scatter of data points about the regression lines (Kmenta, 1971, chaps. 7, 8; H. W. Rauch, R. F. Lamb, and P. A. Lentz, oral communs., 1973–79). For the data represented by the points in figure 32, the net effect of most of these assumptions is that the regression lines and the values of $r$ remain mostly valid, but any tests of significance will produce unreliable results. Spearman's rank-correlation coefficient $r_s$ does not require most of the assumptions that cause problems with $r$, so values of $r_s$ are also calculated.

In map view (fig. 32*A*), the regression line trends N. 44° E., which is therefore the estimated strike of the seismic zone. $r$=0.95, and $r_s$=0.98. For both coefficients, values may range from −1 to +1, with values near either extreme indicating reliable fits of the data to the dashed lines of figure 32, and values near zero indicating little evidence for such fits. Thus, the alignment of the eight epicenters of figure 32*A* appears to be strong, despite the small sample size. Scatter of the eight points about the regression line may be attributed to random effects. The seismic zone strikes about

N. 44° E., although inspection of figure 32*A* suggests that this value could vary a few degrees either way with more data. For example, Bollinger and Wheeler (1980a, b), Wheeler and Bollinger (1980), Bollinger (1981a, b), and Hamilton (1981) cited strikes of N. 36° E. and N. 37° E. These strikes were calculated before the occurrences of earthquakes nos. 58 and 63. Similarly, added data caused the strike to increase one degree from the N. 43° E. of Bollinger and Wheeler (1982). The changes of strike are not large enough to alter any conclusions of those reports.

In section view, the regression line plunges 40° NW., which would therefore be the estimated dip of the seismic zone. However, $r$=-0.23 and $r_s$=-0.12. Neither coefficient has a value close to -1, so there is no strong relationship between distance to the northwest in figure 32*A* and hypocentral depth. These equivocal values of $r$ and $r_s$ could arise in one of three ways, all consistent with the strong epicentral alignment of figure 32*A*: (1) The earthquakes could be occurring in a linear or cylindrical zone that is oriented horizontally; (2) the source of the earthquakes could be tabular but elongate in a northeast-southwest direction and nearly horizontal; or (3) the source of the earthquakes could be tabular and nearly vertical. Figure 32*B* favors the third interpretation and indicates that the dip is steeper than the calculated 40°. The eight hypocenters occur on a nearly vertical tabular zone of unknown dip, but a steep northwest dip is more likely than a dip to the southeast.

## SUMMARY

Results of statistical tests and other statistical procedures, when applied to the hypocenters of the eight microearthquakes of the Giles County seismic zone, allow the following conclusions. The sample of microearthquakes collected during 1978–80 is probably representative of the larger population of earthquakes that have occurred in and near the seismic zone over the past decades to millenia—and which will occur there for a similar time into the future. Accordingly, these microearthquakes may be used to characterize expected future seismicity of the seismic zone. Earthquakes larger than those sampled can be characterized by probable location but not by probable abundance.

Earthquakes concentrate in the seismic zone and are distributed tabularly. The tabular zone strikes N. 44° E. and dips steeply, probably to the northwest. The strike may vary a few degrees with more data but is not expected to change any large amount.

# APPENDIX E

## STATISTICAL TESTS OF THE COMPOSITE FOCAL MECHANISM SOLUTION

*By* R. L. WHEELER

U.S. Geological Survey
P.O. Box 25046, Denver Federal Center, Mail Stop 966
Denver, Colorado 80225

The composite focal-mechanism solution (fig. 16) is based on a small number of first motions. We wonder whether the observed pattern in the data could have arisen by chance. The statistical test that can determine the significance of the observed pattern is the binominal test (Lewis, 1977, p. 59–64; Mosteller and Rourke, 1973, p. 24–25). The binomial test requires that each first motion shown in figure 16 and listed in table 8 be independent of the others; that each first motion be either consistent or inconsistent with the solution, but not both; and that each first motion has the same probability $p$ of being consistent under the null hypothesis.

These three requirements are met. The first motions are independent because no seismograph influences records produced at another. Each first motion is either consistent or inconsistent, and first motions that cannot be classified as compressions or dilatations have not been used. Under the null hypothesis discussed in the next paragraph, $p=0.5$ for each first motion.

The null hypothesis must be carefully worded in order to eliminate distorted results as explained below. Our null hypothesis is that compressional and dilatational first motions are equally distributed over the focal hemisphere, so that they show no preference for the southeast side of the fault that corresponds to the preferred nodal plane of figure 16 having moved either up or down with respect to the northwest side. Then, the one-sided alternative hypothesis is that first motions reflect reverse motion on the steeply dipping nodal plane in which the northwest side moved up relative to the southeast side. Because the neutral axis of the composite focal-mechanism solution is nearly horizontal (fig. 16), that motion is predominantly dip slip. As argued in the main text (p. 24), the movement is more likely to be high-angle reverse than high-angle normal.

Any statistical test produces distorted results if the null and alternative hypotheses are designed by first inspecting the data on which the test will be performed. Such biased hypotheses will reflect structure in the sample that may not be present in the population from which the sample was drawn. That danger persists even if sampling is rigorously representative, because the characteristics of the sample will always differ from those of the population by some (usually small) random amount. In practice, a test of such biased hypotheses produces anomalously low significance values, and the test may appear to find significance where an undistorted result would not. The standard protection against such distortion is to run the test on a second, uninspected sample. Clearly, no such second sample is available here.

We argue that such protection is unnecessary because the steeply dipping nodal plane is unbiased, and the shallowly dipping one is biased in a way that does not affect our results. The steeply dipping plane was determined by inspection of hypocentral locations of several earthquakes (figs. 9, 13) and not from inspection of the first motions of figure 16. The shallowly dipping plane was determined by (1) the constraint that the two planes be orthogonal, which does not introduce bias of the type under discussion and (2) further adjusting the plane's orientation to minimize or eliminate inconsistent first motions. Step 2 introduces bias, but because the shallowly dipping plane is not involved in the null or alternative hypotheses as we have worded them, that plane is not involved in the binomial tests and its bias does not distort results of the tests.

A binomial test, with $p=0.5$ and using all 14 first motions, gives a level of significance of 0.029. A conservative test using only the six impulsive first motions gives 0.109. The conservative result is not significant at the habitual level of 0.05, but both results provide some support for our conclusion of high-angle, mostly dip-slip motion, probably reverse, on the steeply dipping nodal plane. In particular, the tests suggest that there is no more than 1 chance in 9 or 10 that first motions located randomly on the focal hemisphere would produce P (pressure or compression) and T (tension or dilatation) fields as well defined as, or better defined than, those observed.

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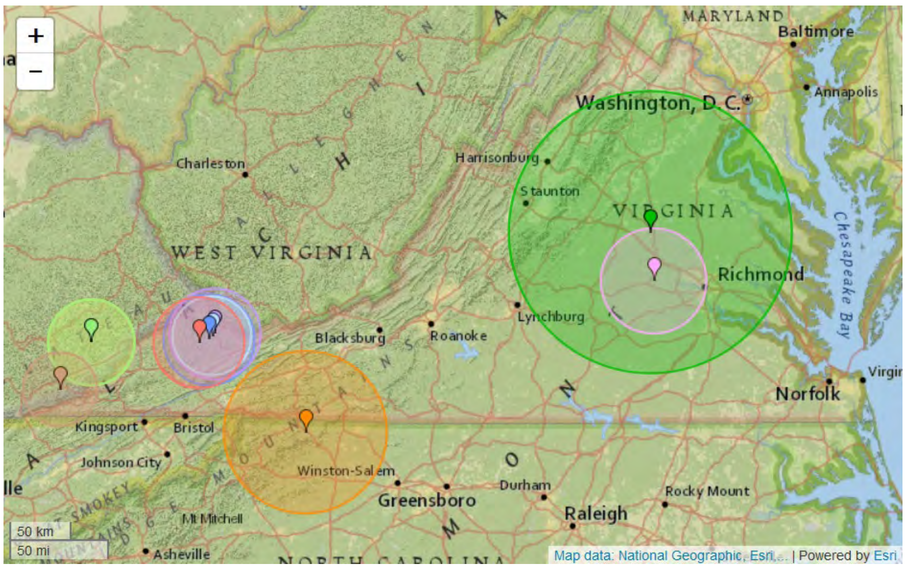
**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 31

**February 21, 2023**

# Virginia Earthquakes

## Most Recent Earthquakes to Shake Virginia




*Above image from earthquaketrack.com shows Magnitude 4+ earthquakes affecting Virgina over the last 30 years. Last updated 2020-08-10, click image for current data.*

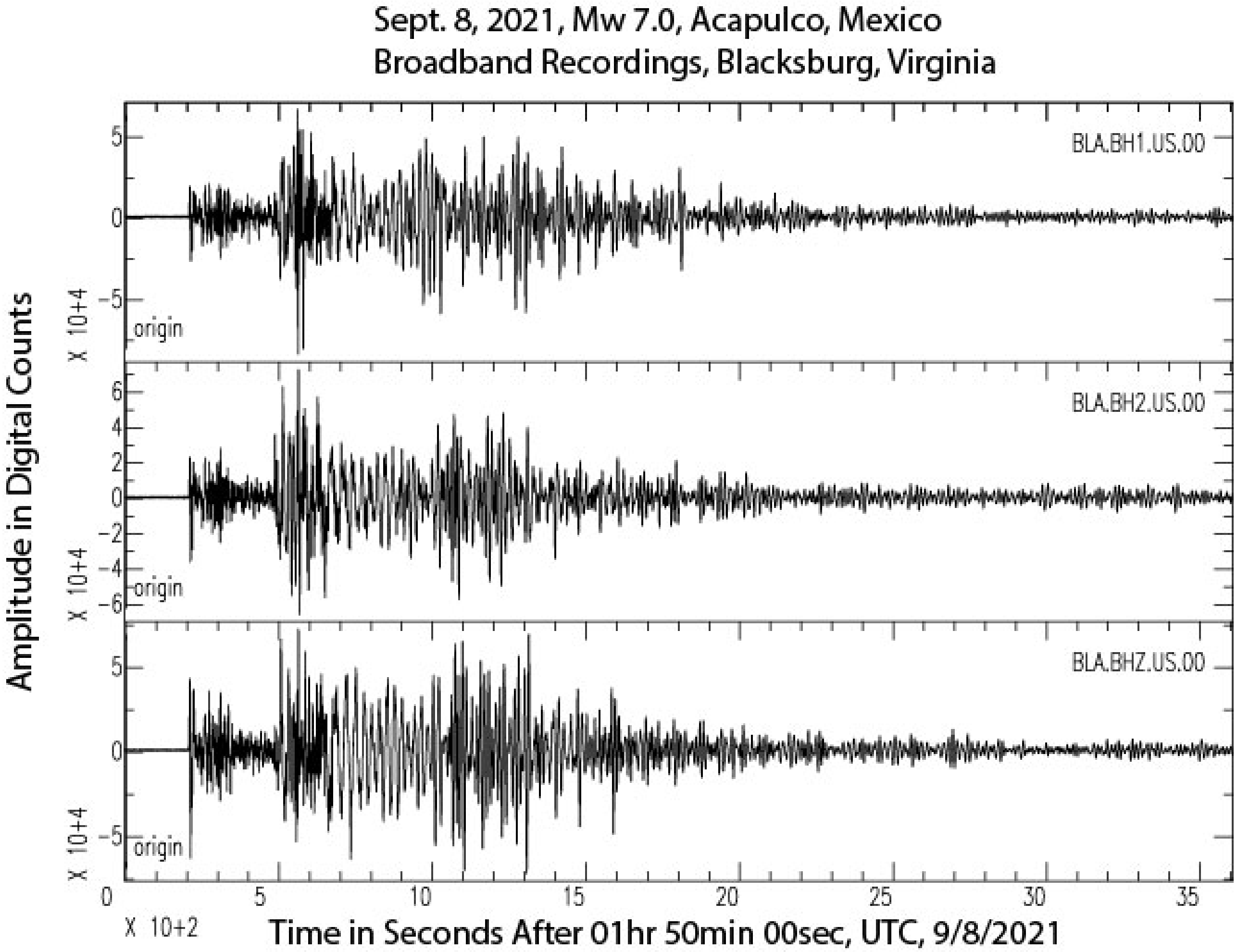
Check out live seismic data from VTSO seismic stations.

## Recent earthquakes near VTSO:

August 9, 2020: Earthquake near Sparta, NC (Md 5.1) (More Details)

## September 8, 2021, Acuapulco, Mexico Earthquake

Preliminary information from various sources:

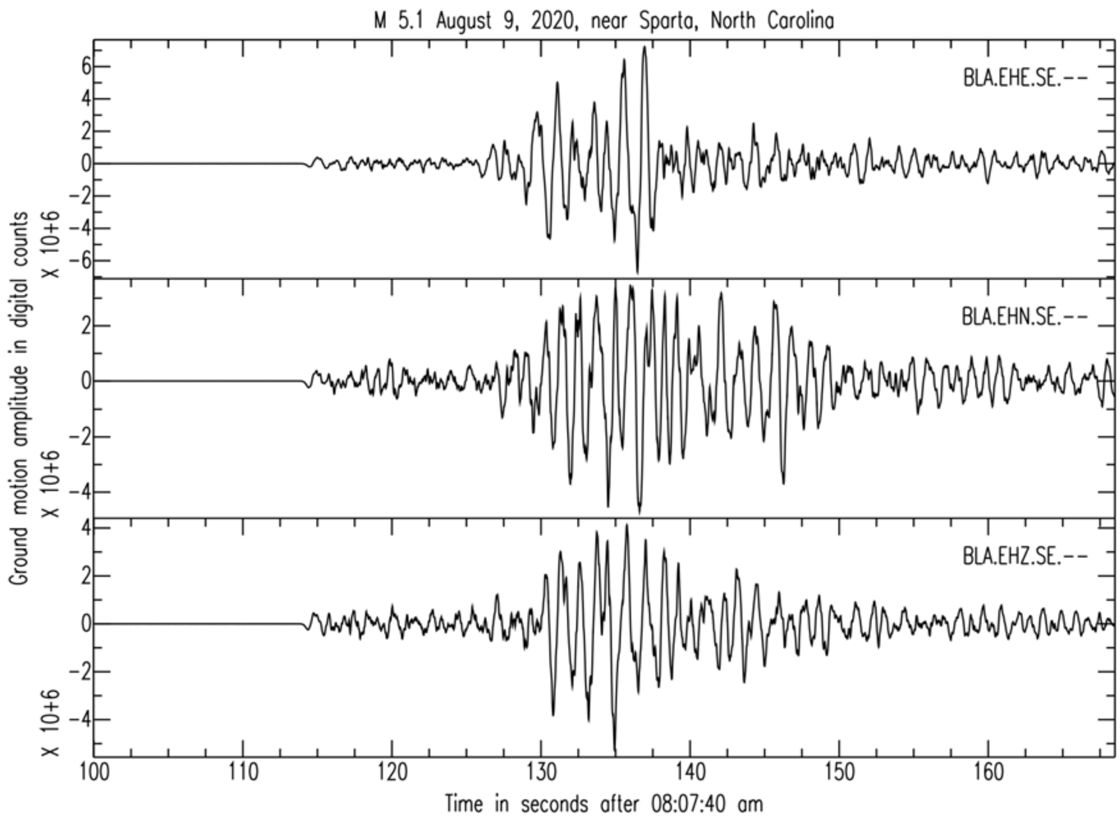



The plot shows the seismograms recorded in Blacksburg, Virgina (Station BLA on the Virgina Tech Campus) from the September 8, 2021 M7.0 earthquake near Acuapulco, Mexico. The top, middle, and bottom traces show the East-West, North-South, and Vertical ground motions (proportional to ground velocity), in digital counts. The intensity of the quake resulted in a strong signal even at this distance.

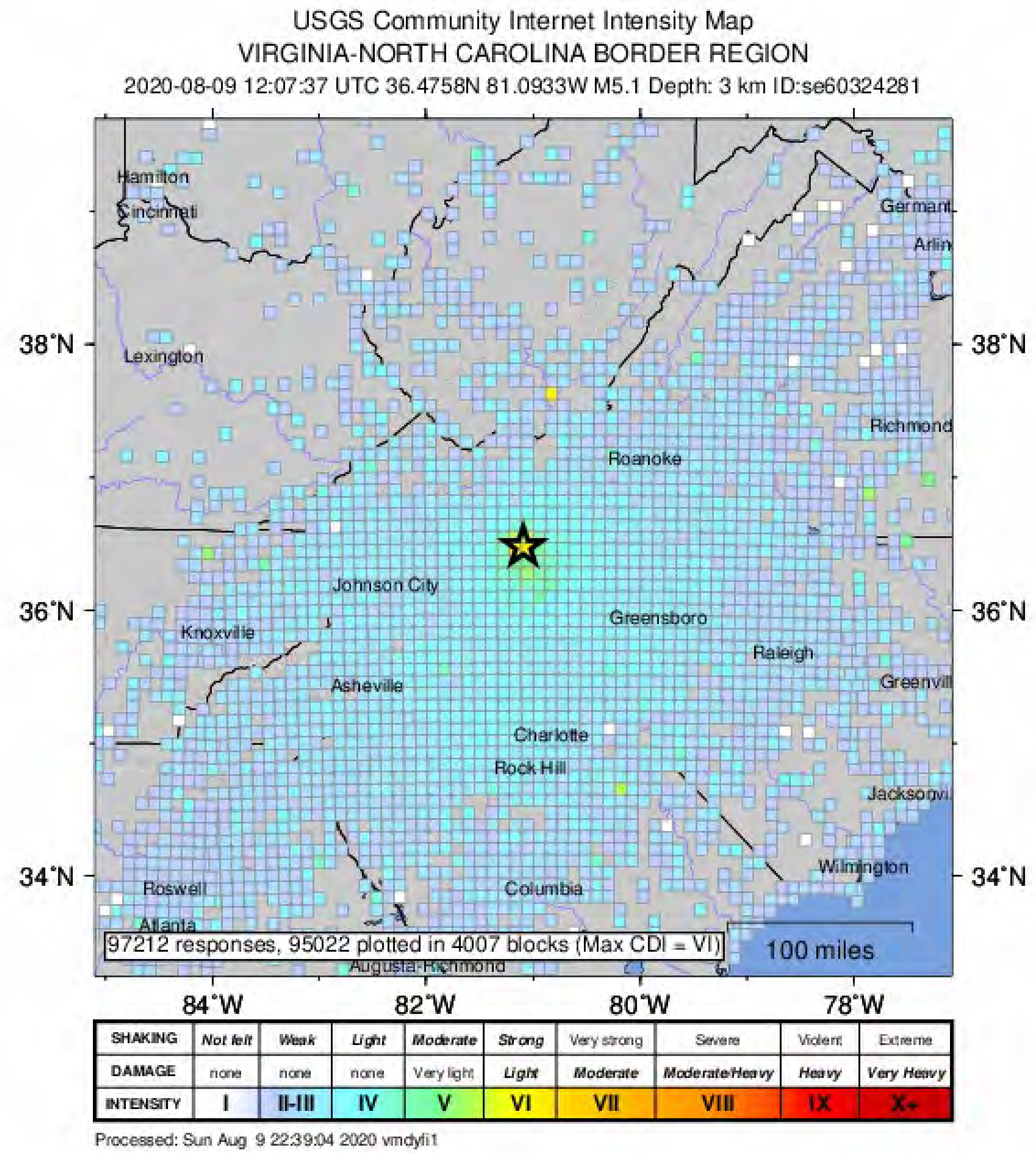
More information coming soon.

## August 9, 2020, Sparta, North Carolina Earthquake

Preliminary information from various sources:




The plot shows the seismograms recorded in Blacksburg, Virgina (Station BLA on the Virgina Tech Campus) from the August 9, 2020 M5.1 earthquake near Sparta, North Carolina. The top, middle, and bottom traces show the East-West, North-South, and Vertical ground motions (proportional to ground velocity), in digital counts. The first motion is due to the seismic P-wave. The largest motions are due to the seismic S-wave, followed by surface waves.

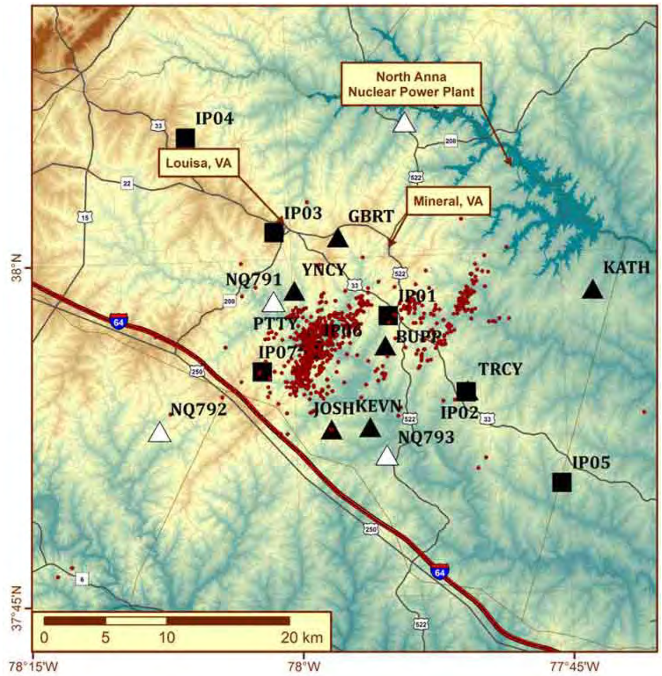



Intensity map of the August 9, 2020 earthquake near Sparta, North Carolina (from the US Geological Survey). Colors show Modified Mercalli Intensity, from felt reports submitted by the public to "Did You Feel It". Maximum intensity is VI–VII MM near the epicenter.

More information coming soon.

## August 23, 2011, Mineral Virginia Earthquake & Aftershocks

The Mineral earthquake had a very prolific




aftershock sequence, which is still being studied. In the days following the earthquake seismologists from VTSO, University of the Memphis, Columbia University, Lehigh University, IRIS and the U.S. Geological Survey installed many seismograph stations in the epicentral area. The small red symbols show the epicenters of 876 aftershock epicenters occurring from August 25, 2011 until January 1, 2012 (Wu and Chapman, 2013). The black symbols show the locations of temporary seismic stations deployed to record the aftershocks.

More information coming soon.

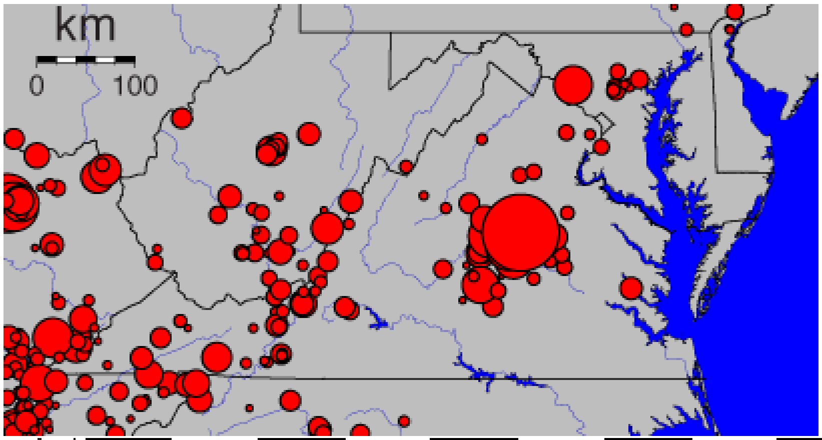
## References:

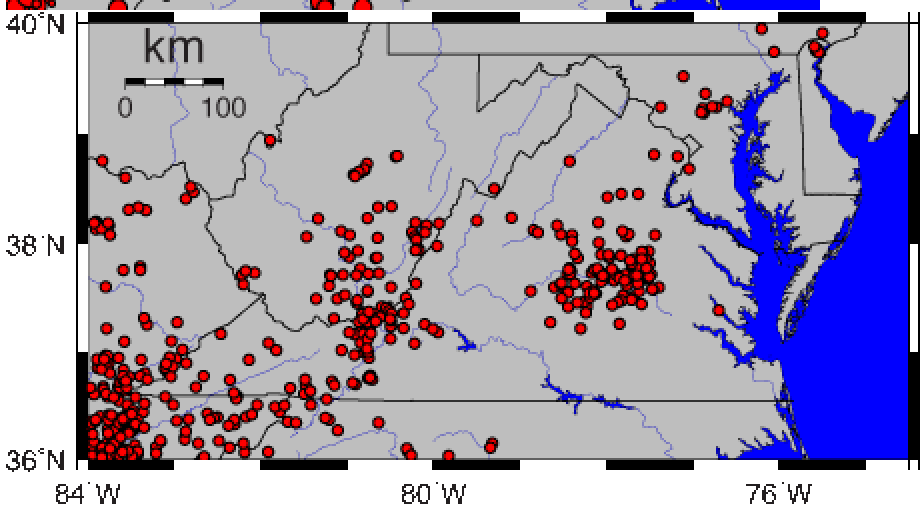
Wu, Qimin and *M.C. Chapman* (2014). Automatic detection and hypocenter determination of the August 32, 2011Mineral, Virginia earthquake aftershock sequence, /_Seismological Research Letters_/, 85, p. 241.

McNamara, D.E., H.M. Benz, R.B. Herrmann, E.A. Bergman, Paul Earle, Anne Meltzer, Mitch Withers and *Martin Chapman*, (2014). The Mw 5.8 Virginia, earthquakes of August 2011 and aftershock sequence: constraints on earthquake source parameters and fault geometry, /_Bulletin of the Seismological Society of America_/, 104, 40-54.

*Chapman, M.C.,*(2013). On the Rupture Process of the 23 August 2011 Virginia Earthquake, /_Bulletin of the Seismological Society of America_,/103, 613-628.

## A Brief History of Virginia Earthquakes




More information coming soon.

## Earthquakes Recorded in Virginia: A Primer

In the theory of plate tectonics, the earth's outermost layer is composed of plates that move relative to each other. Most of the world's earthquakes occur at the plate boundaries. Since places like the California coast are on a boundary between two plates, they have many more earthquakes than places like Virginia, which is near the center of the North American plate (Figure 1a). Yet earthquakes still occur in Virginia (Figure 1b).

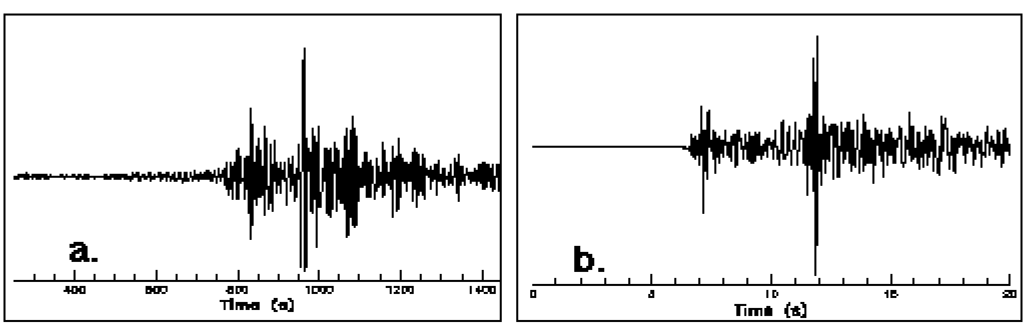
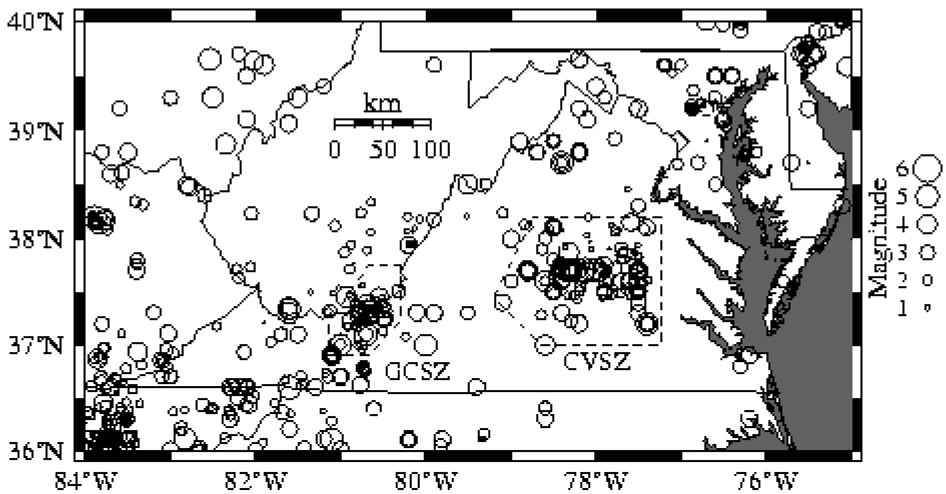



Figure 1: (a)Seismogram of the January 17, 1994 Northridge earthquake, magnitude 6.8. (b) Seismogram of the January 22, 1995 Pulaski earthquake, magnitude 2.9. Both events were recorded on a seismograph in Blacksburg, Virginia.

Virginia has had over 160 earthquakes since 1977 of which 16% were felt. This equates to an average of one earthquake occurring every month with two felt each year. Click here for a summary of the largest earthquakes in Virginia.

Until the magnitude 5.8 earthquake in 2011, the largest earthquake to occur in Virginia was the 1897 magnitude 5.8 Giles County earthquake. This earthquake is the third largest in the eastern US in the last 200 years and was felt in twelve states. Click here for a discussion on the observed effects of this event.

Seismic activity (seismicity) has been known for several decades to be strongest in and around Giles County and in central Virginia. This led researchers at the VTSO to concentrate seismic monitoring stations in these two areas, as shown in Figure 2, which shows earthquakes (circles, scaled to) in and near Virginia from 1774 through 1994.




## Useful Links

More information coming soon.

Questions? Contact us!

# The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)

# EXHIBIT 32

**February 21, 2023**

Earthquake Track

# 2.8 magnitude earthquake 6 km from Narrows, Virginia, United States

## 5 years ago

**UTC time:** Friday, May 12, 2017 04:31 AM
**Your time:** Friday, May 12, 2017 at 12:31 AM EDT
**Magnitude Type:** md
**USGS page:** M 2.8 - 6km SSW of Narrows, Virginia
**USGS status:** Reviewed by a seismologist
**Reports from the public:** 18 people




Map data: National Geographic, Esri,... | Powered by Esri

5 years ago 2.8 magnitude, 4 km depth
Narrows, Virginia, United States

## This earthquake is close to these areas:

Virginia N Carolina Border

Eastern Tennessee

Eastern Kentucky

Potomac Shenandoah

Youngstown Warren Area, Ohio

Georgia, USA

Lake Erie, Ohio

Greater Philadelphia Area, New Jersey

Greater Philadelphia Area, Pennsylvania

East Coast Of United States

Western Kentucky

Greater New York Area, New Jersey

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 33

**February 21, 2023**

Monitoring

Research

# M 3.2 - 11 km NE of Peterstown, West Virginia

2017-09-13 17:33:10 (UTC) | 37.473°N 80.703°W | 17.8 km depth

## Interactive Map


Contributed by SE [1]

## Regional Information


Contributed by SE [1]

## Felt Report - Tell Us!

0 0 0 5 2 9

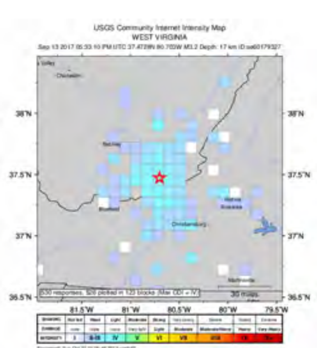
Responses

Contribute to citizen science. Please tell us about your experience.

Citizen Scientist Contributions

## Did You Feel It?

IV



## Origin

Review Status

REVIEWED

Magnitude

3.2 md

Depth

17.8 km

## View Nearby Seismicity

Time Range

± Three Weeks

Search Radius

Community Internet Intensity Map

Contributed by US [2]

Time

2017-09-13 17:33:10 UTC

Contributed by SE [1]

250.0 km

Magnitude Range

≥ 1.0

### For More Information

- Impact Summary
- Technical Summary

### Contributors

1. Center for Earthquake Research and Information
2. USGS National Earthquake Information Center, PDE

### Additional Information

- ANSS Comprehensive Earthquake Catalog (ComCat) Documentation
- Technical terms used on event pages

Questions or comments?

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**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 34

**February 21, 2023**

THE ROANOKE TIMES
https://roanoke.com/news/local/blacksburg/most-signficant-earthquake-in-decades-shakes-parts-of-new-river/article_0f4233cf-afee-5493-8c46-c59ab75ad8bb.html

**Most signficant earthquake in decades shakes parts of New River Valley**

By Robby Korth (540) 381-1679
Sep 13, 2017

art of the New River Valley was shaken by an earthquake Wednesday that started shortly after 1:30 p.m.

A Virginia Tech seismograph showed the epicenter just over the state line in West Virginia with a magnitude between 3.7 and 4.0. That's a big enough earthquake to make it the largest in the area since 1968, said Martin Chapman, the director of the Virginia Tech Seismological Observatory.

The earthquake was felt by people across the New River Valley. Near its epicenter, the quake was loud and shook the earth dramatically, witnesses said.

"It was like an explosion went off," said Roger Jones, town manager of Rich Creek, a Giles County town northwest of Pearisburg.

Jones said there was a loud noise alongside the shake followed by a second loud noise and shake that was felt by workers inside town hall.

More than 200 calls came into the Giles County Sheriff's Office dispatch in the half hour after the quake, according to the department. Giles County Administrator Chris McKlarney said county workers immediately went to check on school buildings and other county properties.

The last measurable earthquake in the area was in May. That one was a 2.8 magnitude quake with an epicenter near Narrows. It was 10 times smaller than Wednesday's.

The quakes are part of what's known as the Giles County seismic zone, an area of fault lines that surrounds the New River.

The Giles County seismic zone is relatively active but its quakes are not often at a level that can be felt. Between the mid-1970s until the late 1990s, Virginia Tech researchers measured between one or two quakes per month.

Chapman said earlier this year that the quakes have become less frequent in the last two decades.

Both quakes were less intense than the "big one" that hit Pearisburg on May 31, 1897. That quake still registers as one of the strongest known quakes in the Southeast. It cracked the mortar of the Giles County courthouse, derailed a train engine and several cars and knocked several chimneys to the ground.

A June 2016 report by geologist Ernst Kastning described the Giles County zone as one of the most active earthquake zones in the mid-Atlantic. Kastning's report, commissioned by pipeline opponents, suggested the active zone, combined with features of the local karst landscape, posed "severe engineering challenges."

The Mountain Valley Pipeline's final environmental impact statement, released in

June by the Federal Energy Regulatory Commission, acknowledged the potential exists for a magnitude 5.8 earthquake in the Giles County zone. The statement noted, “The MVP would be able to withstand seismic events of the historical and projected magnitude” in the zone.

The U.S. Geological Survey measured the quake as a 3.1, amended down from a 3.2 earlier in the day. The USGS and the Tech group have a wide discrepancy in their measurements because of different styles of measurement and different ways of calculating seismological readings, Chapman said. He said people on Tech’s campus were able to feel it.

Pulaski County’s 911 Center reported getting several calls. Director of the center Chris Akers said that people in the town of Pulaski felt a “little jolt.”

So far, no damage has been reported.

Staff writers Sara Gregory and Duncan Adams contributed to this report.The day after, The Roanoke Times reported that damage was minimal but “it succeeded in scaring a great many people nearly out of their wits.”

The potential for an earthquake has been pointed to by opponents of the Mountain Valley Pipeline, a 42-inch diameter, buried natural gas transmission pipeline, as a concern for the project.

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 35

**February 21, 2023**

RELATED TOPICS

Virginia

Earthquakes

# Small earthquake shakes southwest Virginia

September 27, 2021

LAFAYETTE, Va. (AP) — A small earthquake shook southwestern Virginia on Monday morning, according to the U.S. Geological Survey.

The quake with a preliminary magnitude of 2.6 happened around 9:37 a.m. It was centered about 2.5 miles (4 kilometers) north of Lafayette, and was about 8 miles (12.4 kilometers) people in nearby Salem reported feeling the ground shaking, but there were no immediate reports of damage.

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**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 36

**February 21, 2023**

BY AMANDA WHEELOCK

# Celebrating the National Trails System Act

SEPTEMBER 30, 2022

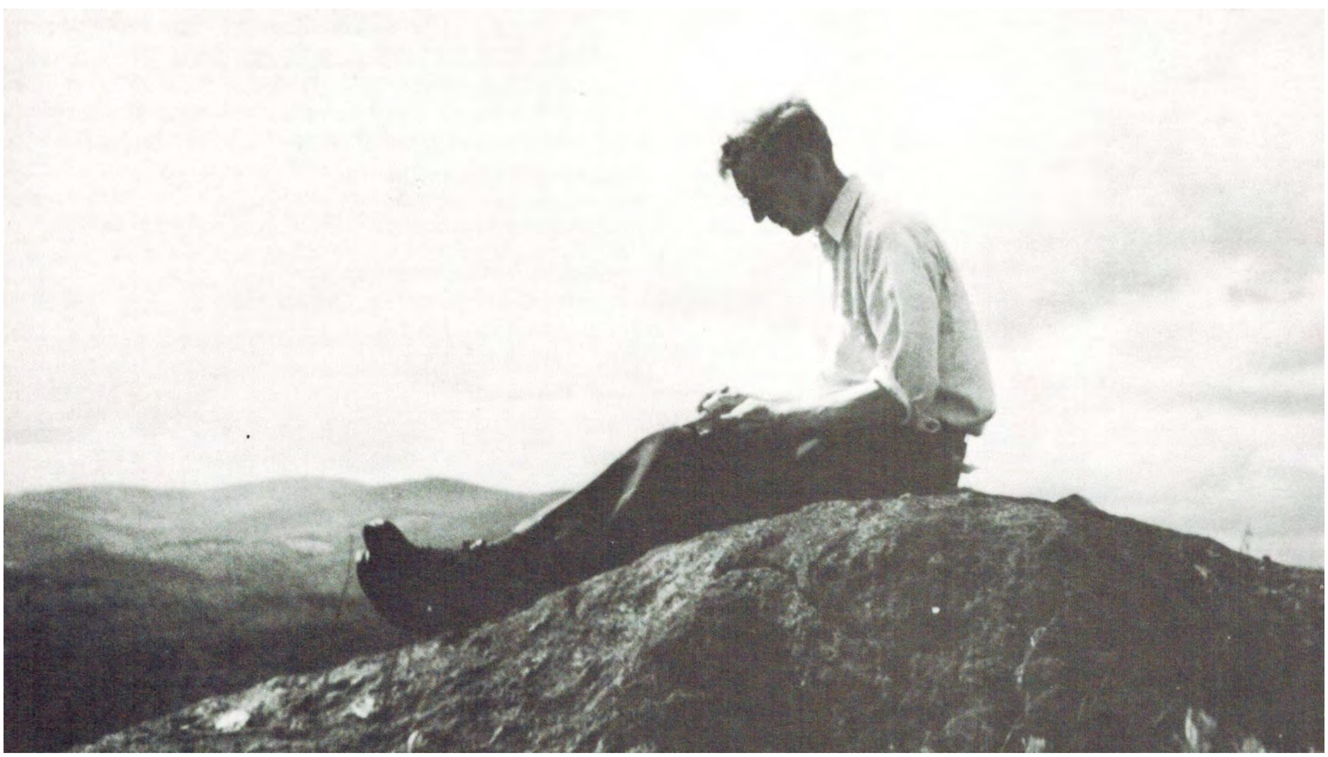
**October 2, 1968, the Appalachian National Scenic Trail was born.** Not with the nailing of a sign or the tread of a boot, as one may have imagined, but with the stroke of a pen. On a busy day of bill signing engineered to distract or, less cynically, unite the nation during a time of anti-war protests and a hotly contested presidential election, President Lyndon B. Johnson signed the National Trails System Act into law, officially designating the Appalachian Trail as America's first National Scenic Trail.

Of course, the Appalachian Trail had existed on the ground for decades by this point. The Trail had been completed in 1937, just 12 years after the first meeting of what was then the Appalachian Trail Conference, and by 1968, almost 50 "end-to-enders" had hiked all 2,000 miles in one go or several. But its rebirth as the Appalachian National Scenic Trail — a trail codified in federal law as a resource of national significance — was a pivotal moment for those who loved the A.T. as well as for trail enthusiasts across the country. Passage of the National Trails System Act, wrote Benton MacKaye, was "unrivaled by any other single feat in the development of American outdoor recreation." October 2, 1968 marked the start of a new era for the A.T., as well as the creation of a system of trails that today traverses more miles of our countryside than the entire interstate highway system.

## The A.T. in All Parts of America

In February 1965, President Johnson addressed a joint session of Congress (in a written "special message") with words that ring just as true in 2018 as they did 53 years ago. "More of our people are crowding into cities and being cut off from nature…modern technology, which has added much to our lives, can also have a darker side… The air we breathe, our water, our soil, and wildlife are being blighted by the poisons and chemicals, which are the by-products of technology and industry." To combat this blight, Johnson called upon Congress to undertake a new and creative conservation effort — one that didn't stop at "a few more parks and playgrounds," but rather involved the whole of the American public in protecting and restoring the country's natural beauty. One focus of this effort, Johnson declared, would be a national system of trails developed for those who liked to walk, ride horseback, and bicycle. "We need to copy the great Appalachian Trail in all parts of America," Johnson said, tasking the Secretary of the Interior with developing recommendations for how to implement such a system.

### 1931



*In 1921, Benton MacKaye pitched the A.T. as a resource that would "extend acquaintance with the scenery and serve as a guide to the understanding of nature."*

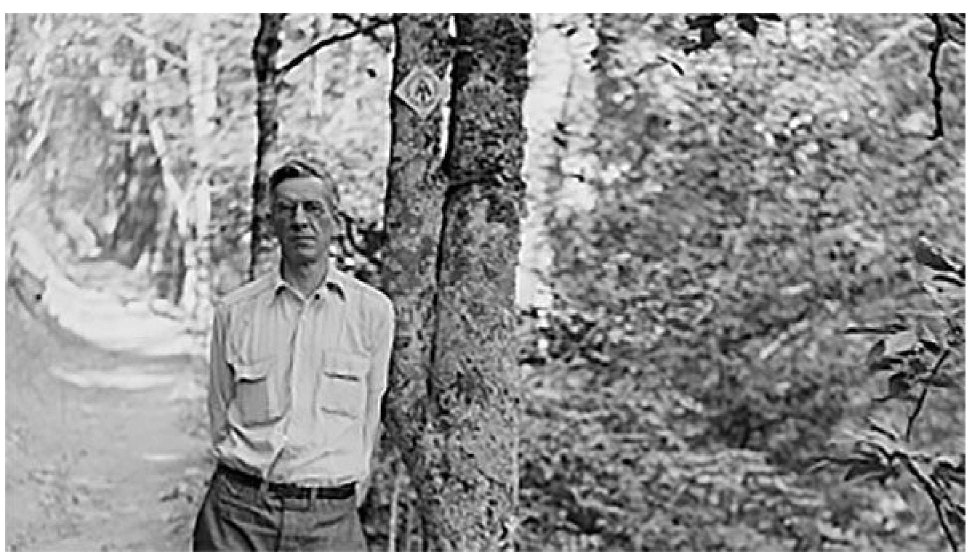
- In October 1921, regional planner Benton MacKaye went public with his proposal for "An Appalachian Trail: A Project in Regional Planning." With publicity from a New York newspaper columnist (who himself blazed the first specifically A.T. section of trail), he then spent years working his network of trail and government contacts from Washington to Boston.

- MacKaye and his supporters organize the Appalachian Trail Conference and present more specific plans for a hiking trail.
- Toward the end of the 1920s, retired Connecticut Judge Arthur Perkins of the Appalachian Mountain Club took over the reins of the ATC from MacKaye after years of relatively little progress beyond linking existing trails and new footpaths in New York. Perkins soon drew the attention of federal admiralty lawyer Myron H. Avery and a small band of Washingtonians who had formed the Potomac Appalachian Trail Club (PATC) and started blazing the path in West Virginia and northern Virginia. Avery succeeded Perkins as head of the ATC (as well as PATC) and efforts to recruit more volunteer clubs and put the A.T. truly on the ground accelerated.
- Myron H. Avery is elected to the first of seven consecutive terms as the ATC's chair.

"

OCTOBER 2, 1968 MARKED THE START OF A NEW ERA FOR THE A.T., AS WELL AS THE CREATION OF A SYSTEM OF TRAILS THAT TODAY TRAVERSES MORE MILES OF OUR COUNTRYSIDE THAN THE ENTIRE INTERSTATE HIGHWAY SYSTEM.

It's easy to imagine how the National Trails System could have developed without the influence of the Appalachian Trail Conservancy (ATC), Trail clubs, and their dedicated volunteer leaders. With the passage of the National Trails System Act, the A.T. became a unit of the National Park System. The federal government could have easily decided to manage



*A.T. visionary Benton MacKaye on the Trail* the Trail like any other park service unit, relying exclusively on federal staff and resources, and in essence, saying to the volunteers that had built the A.T., "thanks for your hard work — we'll take it from here." Our national trails could be managed like any other federal land — no ATC or Pacific Crest Trail Association needed.

But the men and women who had created the A.T. knew how integral volunteers were to the Trail. They were integral to its construction and maintenance, of course, but more importantly, the passion of those volunteers was integral to the spirit of the Trail itself, and to Johnson's vision (as well as Lady Bird Johnson's, who along with her staff was an unheralded driving force behind the vision, the 1965 message, and the 1968 act) for the entire national system of trails — one that involved the American people in protecting and enjoying our beautiful places.

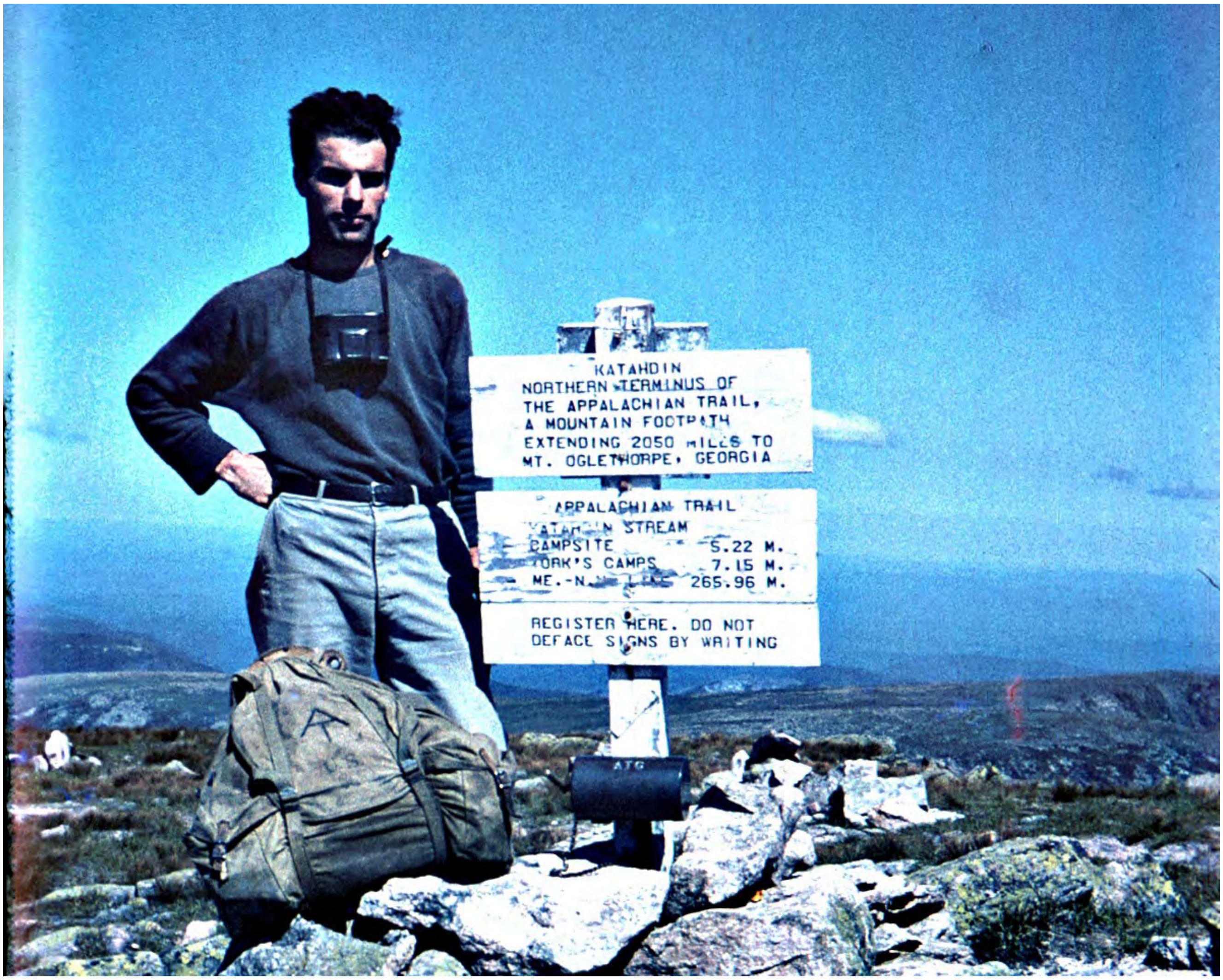
So, after Johnson's address, the ATC — still, at this point, an organization completely run by volunteers — pulled together a committee to work with the government in crafting the legislation that would create a national system of trails.

## 1937

*Myron Avery is pictured here with one of his constant companions: a measuring wheel used to tally the length of the A.T.*

In August 1937, the footpath was complete from Maine to Georgia, and Avery and National Park Service allies were well into a plan for overnight shelters along the 2,000-mile length of it, with some formal measure of federal protection on either side.

## 1948




*Earl Shaffer stands atop Katahdin at the end of his 1948 A.T. thru-hike.*

In 1948, young WWII veteran Earl Shaffer became the first person to hike the entire length of the Appalachian Trail from Georgia to Maine in one continuous journey.

This committee played a pivotal role in helping Congress understand the importance of volunteers in the A.T.'s creation and management. As such, by the time the National Trails System Act was passed three years later, language was included that gave the ATC a formal seat at the table in managing the Trail. And while this formal partnership is unique to the A.T., the success of this grassroots management structure was obvious. So obvious, in fact, that it continues to underlie the management of all of our National

Scenic Trails, and many of our National Historic Trails, through public-private partnerships between land managers and organizations like the Continental Divide Trail Coalition and the Florida Trail Association. Today, in an age of consistently cash-strapped federal land management agencies and a $12 billion maintenance backlog across our national parks, it is easy to be grateful for the foresight of the A.T.'s leaders, who fought for the inclusion of such non-federal partners in the management of these new national trails.

## The Growth of the National Trails System

When the National Trails System Act was passed, the A.T. and the Pacific Crest Trail (PCT) were designated as the first two trails in the system. At the time, the PCT was still far from complete, and over 1,000 miles of the A.T. were still located on either private lands or roads. Through the act, the federal government committed to purchasing the lands necessary to form the A.T. corridor, which meant lots of work in identifying tracts and relocating trail, and it quickly became clear that the ATC could no longer operate on volunteer power alone. Within less than a month, Lester Holmes was hired as the ATC's first paid employee — a part-time "administrative officer" — and a year later he would become its first executive director.

> "WE NEED TO COPY THE GREAT APPALACHIAN TRAIL IN ALL PARTS OF AMERICA."
> -PRESIDENT LYNDON B. JOHNSON

However, as sometimes happens when working with the federal government, progress was slow. Several other trails had been recommended for study when the National Trails System Act was passed, but no one seemed in any rush to examine their potential routes, let alone add them to the system. The National Park Service was slow to act on the A.T. land acquisition powers that had been authorized by the act; in fact, by 1978, none of the of the NPS lands necessary to protect the A.T. had been acquired. Once more, it was up to volunteers to lead the way. But unlike during the decades leading up to 1968, the A.T.'s volunteer leaders now had a law they could point to when working with land managers to protect the Trail. The A.T. was no longer just any old trail, but rather, one of national significance, and by 1978, momentum was in their corner.

That March, a law commonly referred to as “the A.T. bill” was passed, which essentially forced the park service into action in protecting the A.T. corridor. Later that year, another bill would create the Continental Divide National Scenic Trail, stretching over 3,000 miles from Canada to Mexico along the spine of the Rocky Mountains, as well as our first four National Historic Trails — the Oregon, Mormon Pioneer, Lewis and Clark, and Iditarod National Historic Trails. The National Trails System had begun to grow in earnest.

## The National Trails System Today

Fast forward to 2018, and the National Trails System has grown to 11 National Scenic Trails and 19 National Historic Trails that together span over 52,000 miles across 49 states (sorry, Indiana). And those numbers don’t even begin to include the countless National Recreation Trails, rail trails, and side trails that are also part of the National Trails System, allowing a large number of Americans to enjoy national trails within just a few miles of their homes.

The National Trails System gives Americans the opportunity to experience everything from the historic Pony Express to Revolutionary battles, from the quaint New England countryside to 14,000-foot peaks. The diversity of landscapes, communities, and ecosystems showcased by our national trails is truly astounding. And as befits a system built from the ground up by volunteers, it is volunteers who have led the way in celebrating the 50th anniversary of the National Trails System Act in ways that both honor the past and celebrate the future of these trails.

# 1968

*For years the ATC worked with Congress to provide federal protection for the A.T., which culminated in 1968 when President Lyndon B. Johnson signed the National Trails System Act into law. Image courtesy of Jack Rottier.*

A pair of leaders — Murray Stevens of New York and Stanley Murray of Tennessee — followed Avery in the 1950s and 1960s, convinced that only federal ownership of the land on which the footpath twisted could truly protect it for future generations of backpackers, hikers, and birders. Murray, becoming the ATC's chair in 1961, shifted that talk and planning into high gear, building the ATC from 380 members to more than 10,000 while leading a small group working on federal legislation. With little-noticed direction from the office of First Lady, Lady Bird Johnson, the legislation succeeded in 1968, and President Johnson signed into law the National Trails System Act 47 years after MacKaye's original proposal was published. The A.T. became the first national scenic trail.

# 1972


*In 1972, Harpers Ferry became the home of the Appalachian Trail Conservancy Headquarters and Visitor Center.*

The National Trails System Act called for state and federal purchases of a corridor for the footpath. In preparation for much more closely working with state and federal agencies, the ATC hired its first (and for a while only) employee and moved out of Potomac Appalachian Trail Club headquarters in Washington, D.C., to the close-to-the-Trail town of Harpers Ferry, West Virginia.

*A rare photo of Benton MacKaye and Myron Avery from 1931, several months after Avery was elected Chairman of the ATC.*

## 1984

The National Park Service gives the ATC responsibility for managing the Trail corridor lands.

## 2005

APPALACHIAN TRAIL CONSERVANCY®

The ATC has never had just one job as the project leader when it came to the protection, promotion, and management of the A.T. However, the accomplishment of the land-acquisition priority and the more elevated responsibilities given to it by the 1968 and 1978 acts, along with unprecedented federal and state agreements under it, called for a repositioning. Years of discussions came to fruition in July 2005 when the leadership changed the ATC's name to the Appalachian Trail Conservancy. This name change reflects the priority of preservation of the Trail corridor and its natural and cultural resources, which is essential to enhancing the A.T. experience.

On the A.T., trail-maintaining clubs have hosted a variety of celebrations this year focused on improving the Trail. In North Carolina, the Carolina Mountain Club worked with the ATC, the U.S. Forest Service, REI, and local businesses to perform badly-needed restoration at Max Patch, a beautiful Southern Appalachian bald that sees extraordinary levels of day use due to its iconic views of the Smokies and an easy hike to the top. The A.T. Community of Fontana Dam worked with the Smoky Mountain Hiking Club, Tennessee Valley Authority, and land managers to "Kill the Dam Invasives." And in Pawling, New York, the New York-New Jersey Trail Club worked with the local A.T. Community as well as newer A.T. partners like Groundwork Hudson Valley to perform a variety of Trail improvements.

Overall, these events and many others like them have helped raise awareness for A.T. maintaining clubs and the huge job that they have in maintaining the Trail. These events have also highlighted the value of new, diverse partnerships that will be critical to the A.T. in the decades to come as the Trail community expands and diversifies. Partners like A.T. Communities, local businesses, outdoor retailers such as REI, and other non-profits like Groundwork and the Nature Conservancy have brought new volunteers and fresh ideas to reinvigorate the A.T. as it celebrates such a milestone.

THE DIVERSITY OF LANDSCAPES, COMMUNITIES, AND ECOSYSTEMS SHOWCASED BY OUR NATIONAL TRAILS IS TRULY ASTOUNDING. AND, AS BEFITS A SYSTEM BUILT FROM THE GROUND UP BY VOLUNTEERS, IT IS VOLUNTEERS WHO HAVE LED THE WAY IN CELEBRATING THE 50TH ANNIVERSARY OF THE NATIONAL TRAILS SYSTEM ACT IN WAYS THAT BOTH HONOR THE PAST AND CELEBRATE THE FUTURE OF THESE TRAILS.

## The A.T. of the Future

As the saying goes, “the only constant in life is change.” Trails are no exception to this rule. Each year, the A.T. is rerouted here or there, a bridge is replaced, a hillside washed out. Each walk one takes on the A.T., or any of our national trails, is different and new. Yet during this 50th anniversary of our National Trails System, I have been reminded of Benton MacKaye’s reflections on the nature of the Trail in 1971 — 50 years after he first planted such an idea into the public consciousness. “The ultimate purpose?” said MacKaye. “There are three things: to walk; to see; to see what you see.”

Fifty years isn’t a trivial milestone; for many of us, it was more than a lifetime ago that the Appalachian National Scenic Trail was signed into existence at the White House. The National Trails System has grown and changed significantly since that day, and the social and political fabrics of our nation have changed too. But it is comforting to know that the purpose for such a system, the reason why millions of people visit, enjoy, and care about these trails — really hasn’t changed much at all. Perhaps the best way to celebrate such a special year is to take a walk. See. See what you see.

## 2014

*Photo by Christopher Eugene Randall*

The last major stretch of Trail is acquired and permanently protected.

## 2015

*Photo by Brent McGuirt Photography*

The ATC celebrates 90 years of protecting, preserving, and managing the Appalachian Trail.

## 2018

*Photo by Josh Tullock*

The ATC moves into the future of A.T. footpath and landscape conservation: Educating millions of visitors each year as they explore the natural and cultural wonders of the Trail; ensuring the protection of the A.T.'s surrounding lands and waters — including culturally and historically significant landscapes, threatened and endangered species, and migratory routes; emphasizing recreation-driven economies; and empowering the next generation of A.T. stewards.

*For more information about the history of the A.T. visit:* ***appalachiantrail.org/history***

# Discover More

OFFICIAL BLOG

## Not Merely a Trail

As Benton MacKaye discussed in his vision for the Appalachian Trail, we must prioritize conserving a realm of landscapes and experiences in addition to the footpath itself.

OFFICIAL BLOG

## A Deeper Connection

Embracing and encouraging a sense of belonging about the A.T., and turning that feeling into action, is the work of the A.T. Landscape Partnership.

A CENTURY OF INSPIRATION

## Benton MacKaye: Celebrating a Vision

2021 marks the 100-year anniversary of the publication of Benton MacKaye's groundbreaking article proposing the Appalachian Trail. Even after a century, MacKaye's original vision continues to inspire and guide us.

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 37

**February 21, 2023**

# Mountain Valley Pipeline Project

# Docket No. CP16-10-000

# Attachment DR4 Land Use 5

February 2017

## Neylon, Megan

| | |
|---|---|
| **From:** | Adams, Jennifer - FS <jenniferpadams@fs.fed.us> |
| **Sent:** | Friday, February 10, 2017 1:37 PM |
| **To:** | Neylon, Megan; Centofanti, John |
| **Cc:** | Coffman, Ted -FS; Craft, Victoria; Grace Ellis; Lauren Johnston; Irvine, Peter -FS; Faught, Alex R -FS |
| **Subject:** | RE: ANST File Confirmation |

Megan and John,

The FS will not be able to provide you confirmation on the shapefile for the ANST on the date indicated below; the FS will not be able to confirm this information until after Feb. 27 due to scheduling conflicts, the FS and the Appalachian Trail Conservancy. I will be back in touch.

Thank you,
Jennifer


**Jennifer P. Adams**
**Special Project Coordinator**

**Forest Service**
**George Washington & Jefferson National Forests**

**p: 540-265-5114**
**f: 540-265-5145**
**jenniferpadams@fs.fed.us**

5162 Valleypointe Parkway
Roanoke, VA 24019
www.fs.fed.us


**Caring for the land and serving people**

---

**From:** Adams, Jennifer - FS
**Sent:** Thursday, February 09, 2017 5:21 PM
**To:** 'Neylon, Megan' <MNeylon@eqt.com>
**Cc:** Coffman, Ted -FS <tcoffman@fs.fed.us>; 'Craft, Victoria' <vcraft@blm.gov>; Grace Ellis <grace.ellis@galileoaz.com>; Lauren Johnston <lauren.johnston@galileoaz.com>
**Subject:** RE: ANST File Confirmation

Megan,

Ted’s staff is working to answer this for you. Based on the consultation that is necessary to answer these questions—to engage another office and consult with the FS’s GIS specialist—this item will be complete on or about Feb. 17.

Thank you,
Jennifer

**Jennifer P. Adams**
**Special Project Coordinator**

**Forest Service**
**George Washington & Jefferson National Forests**

**p: 540-265-5114**
**f: 540-265-5145**
**jenniferpadams@fs.fed.us**

5162 Valleypointe Parkway
Roanoke, VA 24019
www.fs.fed.us

**Caring for the land and serving people**

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**From:** Neylon, Megan [mailto:MNeylon@eqt.com]
**Sent:** Monday, February 06, 2017 11:35 AM
**To:** Adams, Jennifer - FS <jenniferpadams@fs.fed.us>
**Subject:** ANST File Confirmation

Hi Jennifer,

Please find attached the latest shape file that MVP downloaded from ANST's website at http://www.appalachiantrail.org/home/explore-the-trail on Friday January 27, 2016. Per FERC's data request sent to us under questions "Land Use 5", could you please confirm this file is accurate to use as the current ANST trail for generated maps? See the request below. In order to keep moving, could you or someone from your team confirm by Wednesday (2/8/17 at 5:00 pm) that this is the data that MVP should be utilizing for maps and figures?

FERC Data Request January 27, 2017 Land Use 5 - Utilizing the most correct route of the Appalachian National Scenic Trail (ANST, Forest Trail #1) is critical to visual analyses. Provide current ANST centerline data that is available from the Appalachian Trail Conservancy (ATC), which must be utilized to meet the FS criteria. Obtain FS approval on the data and any updated maps and figures before filing the data with FERC.

Thanks,
Megan

# Mountain Valley Pipeline Project

## Docket No. CP16-10-000

## Attachment DR4 Land Use 6

February 2017

**MOUNTAIN VALLEY PIPELINE PROJECT**

# JEFFERSON NATIONAL FOREST VISUAL IMPACT ASSESSMENT

## FERC DOCKET # CP16-10
## DHR FILE #2014 1194

**Prepared for**

**EQT Plaza, 625 Liberty Avenue**

**Pittsburgh, PA 15222**

**Prepared by**

**160 Federal Street, 3rd Floor**

**Boston, MA 02110**

**February 2017**

## Table of Contents



## List of Tables

## Appendices

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| 3D | Three-dimensional |
| ANST | Appalachian National Scenic Trail |
| BLM | Bureau of Land Management |
| BMP | Best Management Practice |
| Forest Plan | Jefferson National Forest Land and Resource Management Plan |
| GPS | Global Positioning System |
| KOP | Key Observation Point |
| MAP | Management Area Prescription |
| MP | milepost |
| MVP | Mountain Valley Pipeline LLC |
| Project | Mountain Valley Pipeline Project |
| ROW | Right-of-Way |
| RVCCC | Roanoke Valley Cool Cities Coalition |
| SIO | Scenic Integrity Objective |
| SMS | Scenery Management System |
| USFS | United States Forest Service |
| VIA | Visual Impact Assessment |
| VRM | Visual Resource Management |

## 1. INTRODUCTION

The Mountain Valley Pipeline Project (Project) is a natural gas pipeline system that spans approximately 303 miles from northwestern West Virginia to southern Virginia. This Visual Impact Assessment (VIA) for the Jefferson National Forest has been prepared to inform federal agency decisions regarding the issuance of approvals necessary to allow construction and operation of the Project. The Project will be constructed and owned by Mountain Valley Pipeline, LLC (MVP), which is a joint venture of EQT Midstream Partners, LP; NextEra US Gas Assets, LLC; Con Edison Gas Midstream, LLC; WGL Midstream; and RGC Midstream, LLC. EQT Midstream Partners will operate the pipeline. The pipeline will be 42 inches in diameter and will require temporary right-of-way (ROW) during construction that is approximately 125 feet wide. After construction, MVP will maintain a 50-foot-wide permanent ROW.

The Project will cross approximately 3.4 miles of the Jefferson National Forest in Monroe County, West Virginia and Giles and Montgomery counties, Virginia, where it crosses Peters Mountain between mileposts (MPs) 195.3 and 196.9 (1.6 miles), Sinking Creek Mountain between MPs 217.2 and 218.0 (0.8 mile), and Brush Mountain between MPs 218.4 and 219.4 (1.0 mile). The Jefferson National Forest is managed by the U.S. Forest Service (USFS) and, administratively combined with the George Washington National Forest, encompasses nearly 1.8 million acres in West Virginia, Virginia, and Kentucky. The National Forest is managed for multiple uses including camping, hiking, wildlife conservation, and active management for timber and wood product production. This VIA analyzes potential visual impacts of the Project within the Jefferson National Forest, including the Appalachian National Scenic Trail (ANST), Craig Creek Road, and Pocahontas Road.

## 2. ANALYSIS APPROACH SUMMARY

MVP assessed visual impacts using both the USFS's Scenery Management System (SMS) and the Bureau of Land Management's (BLM's) Visual Resource Management (VRM) system. The SMS provides the primary guidance for evaluating landscape character, visual quality (scenic integrity), and impact assessment. BLM's VRM system's rating approach provides guidance for evaluating visual contrast.

Based on the best existing guidance and available data, MVP assessed visual impacts by using both the USFS SMS and BLM VRM systems to analyze visual impacts on USFS lands. Visual impacts resulting from the Project's crossing of the Jefferson National Forest were identified based on estimated changes to existing scenic integrity that would result from the Project. Per USFS practice, the primary focus is to evaluate potential changes to scenic quality and landscape character against the USFS Scenic Integrity Objectives (SIOs) for the Jefferson National Forest. The SIOs define the desired condition and the degree of deviation in visual resources that may occur in a given landscape (USFS 1995). The SIOs for the lands within the analysis area are defined in the Land and Resource Management Plan (Forest Plan) for the Jefferson National Forest. The Forest Plan provides a framework for integrated resource management and guides all project and activity decision making on USFS lands.

While the USFS has a procedure for ranking managed lands and assigning SIOs, the USFS does not have a formal procedure to assess visual impacts. Consequently, a variety of methods may be used by USFS staff for visual impact assessment. However, the USFS's SMS includes landscape character descriptions and scenic integrity objectives for USFS landscapes that can be used to help assess the compatibility of a proposed project with the surrounding landscape (BLM 2016).

Once a landscape character goal and scenic integrity objective have been established for an area, the compatibility of a project proposed for the area can be assessed by evaluating the effect that the addition of the project to the landscape would have on the area's landscape character and the landscape's scenic integrity. Changes to the existing landscape character and scenic integrity are components of the project's visual impact. Assessing these changes requires determination of the likely visual contrasts created by the project, a key component of the project's visual impact.

MVP has determined the visual impacts of the Project through the Jefferson National Forest by evaluating impacts against the desired landscape character and SIO as identified in the Forest Plan. Factors such as visual dominance, degree of deviation from existing landscape character, and intactness of the landscape were considered in this comparison.

## 3. STUDY APPROACH

The main tasks that MVP undertook to prepare this VIA were: (1) establish an understanding of the visual character and qualities of the existing landscape environment in the Project area through viewpoint selection, (2) determine areas from which the proposed Project would be visible, (3) identify visual contrast resulting from changes as they affect the existing landscape character and qualities in the Project area, and (4) assess compliance with USFS SIOs. The following sections describe in more detail how MVP accomplished each of these tasks.

### a. Define Analysis Area

The analysis area for the VIA is generally defined as up to 10 miles from the Project's proposed crossing of the Jefferson National Forest, including the ANST corridor, but may extend further to capture scenic overlooks on the ANST. For instance, the visual impact distance for the

Sugar Run Mountain scenic vista is 12.2 miles.[1] Likewise, the visual impact distance for Sawtooth Ridge is 11 miles.

### b. Identify Key Observation Points

Key Observation Points (KOPs) are viewing locations that are evaluated for potential visual impact and are representative of visually sensitive areas from which viewers may be affected by Project-related changes in the landscape setting. MVP, in consultation with the USFS, selected 14 KOPs on USFS lands and used these KOPs to investigate potential visual impacts of the Project. KOPs for this analysis include popular overlooks along the ANST, sections of the ANST, Craig Creek Road, and the Sugar Camp Trailhead. The KOPs are listed in Table 1 in Section 4 below.

### c. Identify Scenic Integrity Objectives

The SMS uses SIOs to describe the goals of a landscape relative to its assumed natural state in five levels: Very High (Unaltered), High (Appears Unaltered), Moderate (Slightly Altered), Low (Moderately Altered), and Very Low (Heavily Altered). When discussing SIOs, the degree of alteration is measured in terms of visual contrast with the surrounding natural landscape. The objectives of each SIO classification are described below (USFS 1995):

- Very High SIO – Very High scenic integrity refers to landscapes where the valued landscape character "is" intact with only minute deviations, if any. The existing landscape character and sense of place are expressed at the highest possible level.

- High SIO – High scenic integrity refers to landscapes where the valued landscape character "appears" intact. Deviations may be present but must repeat the form, line, color, texture, and pattern common to the landscape character so completely and at such scale that they are not evident.

- Moderate SIO – Moderate scenic integrity refers to landscapes where the valued landscape character "appears slightly altered." Noticeable deviations must remain visually subordinate to the landscape character being viewed.

- Low SIO – Low scenic integrity refers to landscapes where the valued landscape character "appears moderately altered." Deviations begin to dominate the valued landscape character being viewed, but they borrow valued attributes such as size, shape, edge effect and pattern of natural openings, vegetative type changes, or architectural styles outside the landscape being viewed. They should not only appear as valued

[1] This distance was selected based on the Department of the Interior's December 22, 2016 comments on the Project's Draft Environmental Impact Statement.

character outside the landscape being viewed but compatible or complimentary to the character within.

- Very Low SIO – Very Low scenic integrity refers to landscapes where the valued landscape character "appears heavily altered." Deviations may strongly dominate the valued landscape character. They do not have to borrow from valued attributes such as size, shape, edge effect and pattern of natural openings, vegetative type changes, or architectural styles within or outside the landscape being viewed. However, deviations must be shaped and blended with the natural terrain (landforms) so that elements such as unnatural edges, roads, landings, and structures do not dominate the composition.

The existing SIO of the area crossed by the Project that is closest to or seen from each KOP is identified in Table 1 in Section 4.a below.[2] Determining the consistency of the Project with SIOs involves comparing existing landscape integrity with integrity that would occur after construction of the Project. Impacts to landscape scenery were determined by measuring the extent of effects of the pipeline route (e.g., vegetation clearing) on the scenic landscape through USFS scenic attractiveness ratings and scenic quality on private, state, and other federal lands.

### d. Identify Scenic Class Ratings

The Forest Plan divides the Jefferson National Forest into 11 management areas, "which reflect biological, physical, watershed, and social differences in managing each area of land" (USFS 2004). The proposed alignment would cross two of these management areas: Upper James River and New River. Each management area has different attributes that require a slightly different management emphasis. These differences are reflected in the management prescriptions, "which reflect different desired conditions and provide the specific information used to develop projects to implement the Forest Plan" (USFS 2004). The proposed alignment for the Project crosses five separate management prescriptions within the management areas: the Appalachian Trail Corridor (4A), Mix of Successional Habitats in Forested Landscapes (8A1), Old Growth Forest Communities-Disturbance Associated (6C), Urban/Suburban Interface (4J), and Riparian Corridors (11).[3]

[2] Note that, if the Project is approved, the USFS will reallocate the area around the Project right-of-way from the existing management prescriptions (other than management prescription 4A, the ANST) to management prescription 5C, Designated Utility Corridor. Per the terms of the Forest Plan, this will have the effect of reducing some of the existing SIOs from High to Moderate or from Moderate to Low.

[3] Management Prescription 11, Riparian Corridors, is not separately mapped, but rather is embedded in other management prescriptions. Because the Project's crossing of Management Prescription 11 is not visible from any of the KOPs analyzed in this VIA, this management prescription is not discussed further.

Each management prescription also has a scenic class rating. The USFS uses the data gathered and mapped for scenic attractiveness and landscape visibility and then assigns a numerical scenic class rating to all lands within the Jefferson National Forest. These ratings, 1-7, indicate the relative scenic importance, or value, of discrete landscape areas. Mapped scenic classes are used during forest planning to compare the value of scenery with other resources, such as timber, wildlife, old-growth, or minerals. For this VIA, the scenic class ratings are used to assess scenic quality. The scenic class rating(s) for each KOP is identified in Table 2 below.

**e. Identify Visibility Changes Associated with the Proposed Project**

MVP prepared photographic simulations under typical viewing conditions for 11 of the KOPs to demonstrate how the Project, once constructed, would look in the landscape to future viewers (see Appendix B). MVP chose to prepare simulations for these KOPs because they either had high visibility or were a sensitive viewpoint along the ANST. Information from photographic simulations is supported with additional graphic techniques, such as elevations, and construction details to provide a complete understanding of the proposed Project in contrast to the existing landscape conditions. Along with showing how the Project looks from a particular viewpoint, simulations demonstrate where views are effectively screened by topography, surrounding vegetation, and/or structures.

The software used to create the visual simulations includes:

- ArcMap – Used for Project data mapping;
- Promote Systems Global Positioning System (GPS) – Used for photo and modeling location accuracy;
- 3D Studio Max – Used for 3D modeling, texturing, lighting, and rendering;
- PTGui – Used for digital photo panorama creation; and
- Adobe Photoshop CS4 – Used for photo editing and compositing.

The simulations are based on digital photography collected at the selected viewpoint locations. The viewpoint locations were documented with field notes and GPS coordinates. Visual simulations were then prepared by combining site photography with accurate, rendered computer models of Project facilities to predict what would be seen after construction of the Project in the photographed setting. The 3D model includes site-specific reclamation techniques, such as replanting natural seed mixtures, to demonstrate long-term visual impacts after construction. Using a geographic information system to generate a terrain model, the 3D model was placed in real-world coordinates to ensure accuracy. Simulations were developed by aligning each photographic viewpoint with the models and superimposing the models on the photographs. Creation of the simulations also used a real-world lighting system in the model when rendering each of the strategic viewpoints. This lighting system geographically represents lighting as it would appear at the time of day and date the photo was taken. Once complete, the renderings were added to the existing photographs to create a “before and after” product. The simulations demonstrate what the Project ROW would look like post construction but before revegetation. Therefore, it is a worst-case scenario. The visibility of the ROW would diminish once grass and shrubbery has been reestablished within the ROW.

### f. Conduct Viewshed Analyses

Viewshed analyses were conducted to analyze visibility of the Project from each KOP. These analyses examined the extent of visibility without vegetation at each individual location. These bare-earth viewsheds illustrate a worst-case scenario of visibility by not accounting for the screening opportunities offered by dominant hardwood vegetation. Computerized methods were used to identify areas from which the ROW might be visible. This was done by creating a digital elevation model of the area based on United States Geological Survey terrain data and using the visibility function within the computer model Viewshed Analysis for ArcGIS™ Spatial Analyst.

Figures in Appendix A illustrate the visual screening effect of terrain, without taking vegetation into consideration. The figures reflect the elevation within and near the Project area, which is undulating and mountainous. Even without considering the effect of the forested areas surrounding the Project area, potential visibility is effectively limited due to the terrain in the area.

A more detailed analysis was conducted for the ANST crossing due to concerns regarding this resource. This more detailed analysis included three viewshed analyses conducted at different extents (a one-mile radius of the crossing and zoomed-in viewsheds to look at the specific bore locations) and locations (Appendix A, Figures 16-18). One viewshed (Appendix A, Figure 18) was created by digitizing the surrounding vegetation in ArcGIS and setting the vegetation data at a height of 40 feet to mimic the height of surrounding trees.

### g. Conduct Visual Impact Assessment

Visual impact can be defined as the change in visual quality that would result from a proposed action; i.e., the difference between existing visual quality and visual quality with the proposed Project. Visual impact is measured as the amount of contrast with the existing landscape caused by a project; the degree to which a development adversely affects the visual quality of the landscape is directly related to the amount of visual contrast between it and the existing landscape character.

Visual impacts of the Project were determined at each KOP by assessing the amount of visual contrast introduced into the existing landscape and the level of viewer sensitivity from that location. As noted above, visual contrast incorporates the elements of the BLM VRM system rating approach. Contrast in the landscape was determined by the differences in form, line, color, texture, scale, and landscape juxtaposition between the existing conditions and conditions after implementation of the Project. Contrast levels were determined by comparing the entirety of the visual elements present for each KOP with the total amount of contrast resulting from the introduction of Project elements and were assigned an overall rating of strong, moderate, weak, or none. These values and factors that determine impacts were developed by the BLM and were incorporated into the visual impact assessment. Descriptions of each value are listed below (BLM 1986b).

- *None* – The contrast is not visible or perceived. No visual contrast would occur where the visual contrast of activities is not visually evident, where the Project is smaller in scale or design compared to the existing nearby or parallel utility facilities in the landscape, or where manipulation of existing vegetation creates no visual contrast.
- *Weak* – The contrast can be seen but does not attract attention. This level of contrast can be caused, for example, by using existing access or construction roads, where there is minimal vegetation removal, or where existing ROWs of similar scale exist nearby or parallel in the landscape.
- *Moderate* – The contrast begins to attract attention and begins to dominate the characteristic of the landscape. This contrast can be caused, for example, by expansion of existing access roads or construction of new access roads in rolling terrain with occasional short, steep slopes; where agricultural vegetation or grassland is removed for site or access road construction; or where the Project is smaller in scale compared to the existing nearby or parallel utility facilities in the landscape.
- *Strong* – The contrast demands attention and is dominant in the landscape. This contrast can be caused, for example, by construction of access roads in steep terrain, where riparian or forest vegetation is removed for a pipeline ROW clearing or access roads, and where the landscape has no existing visual disturbance.

Other environmental factors can influence the amount of visual contrast introduced by Project components (BLM 1986a).

- *Distance* – The contrast created by a project usually is less as viewing distance increases.
- *Available Panorama* – The amount of visual contrast increases as the proportion of the proposed facilities visible in the available view increases.
- *Angle of Observation* – Viewing the project from different angles can greatly affect the apparent size of a project and the resulting level of visual contrast.
- *Length of Time in View* – The longer the project is in view, the greater the level of visual contrast.
- *Relative Size or Scale* – The level of visual contrast created by a project is directly related to its size and scale compared to the surrounding landscape it is located in.

- *Lighting Conditions* – The direction and angle of the sun affects the color, intensity, shadow, reflection, form, and texture of visual aspects of proposed project components.

With respect to distance, the USFS visual assessment methodology categorizes views into foreground, middleground, and background distance zones. These distance zones provide a frame of reference for classifying the degree to which details of the viewed Project would affect visual resources. The “foreground” area, identified as occurring from 0 to 0.5 mile from the Project, is considered to be the location from which Project element details would be visually clear. In the “middleground,” classified as the area from 0.5 to 4 miles from the Project, viewers still have the potential to distinguish individual forms and can observe some texture and color as well. At a “background” distance, from 4 miles to the horizon, viewers would lose texture and color but may be able to distinguish land patterns.

Visual resource change, or visual contrast, is the sum of the change in landscape character and visual quality. The viewer response to a proposed project is the result of a combination of viewer expectations, duration of view, and use volume (number of viewers). In this VIA, the resulting visual impacts were determined by combining the level of visual resource change with the degree to which people are likely to be impacted and react adversely to the change.

## 4. SUMMARY OF VISUAL IMPACTS

Visual impacts associated with the Project crossing of the Jefferson National Forest would include temporary construction activities such as vegetation clearing; color contrast of soil in the cleared ROW or other ancillary structures such as roads; and the presence of vehicles and workers. Long-term impacts, which would exist for the life of the Project, would result from the existence of a cleared ROW and associated maintained access roads as well as pipeline marking. Short-term impacts, which would occur at regular intervals during the life of the Project, would include maintenance activities and the presence of workers and maintenance vehicles. This section summarizes visual impacts analyzed for each KOP, followed by analyses of visual impacts along Craig Creek Road and Pocahontas Road.

### a. Analysis of Key Observation Points

Table 1 below provides a summary of the impact analysis from and description of each KOP. Each analysis includes a description of existing scenic class rating, scenic inventory objective, potential changes to visual quality (contrast), and resulting visual impact.

**Table 1. Visual Impact Assessment for Each Key Observation Point**

| KOP | Resource Name | Viewers | Scenic Class Rating | SIO[1] | Distance (miles) | Contrast | Impact |
|---|---|---|---|---|---|---|---|
| KOP-OID-92 | ANST Crossing | Recreational | 1 | High | <0.1 | None | None |
| KOP-OID-111 | Angels Rest Overlook | Recreational | 2 | Moderate | 6.0 | Low | Low |
| KOP-OID-113 | Kelly's Knob Overlook | Recreational | 3, 5 | Low, Moderate | 2.0 | Low | Low |
| KOP-OID-114 | Kelly's Knob Overlook | Recreational | 3, 5 | Low, Moderate | 2.0 | Low | Low |
| KOP-OID-115 | Kelly's Knob Overlook | Recreational | 3, 5 | Low, Moderate | 2.0 | Low | Low |
| KOP 125 | Sugar Camp Trailhead | Recreational | 1 | High | 1.6 | Low | Low |
| KOP PT-02 | Peter's Mountain Wilderness | Recreational | 1 | High | 0.4 | None | None |
| KOP-OID-103 | Wind Rock Overlook | Recreational | 2 | Moderate | 6.5 | None | None |
| KOP-OID-22 | Sawtooth Ridge | Recreational | NA | NA | 11.0 | None | None |
| KOP-OID-23 | Dragon's Tooth | Recreational | NA | NA | 7.8 | None | None |
| KOP-OID-85 | Rice Field | Recreational | 1 | High | 4.1 | Low | None |
| Audie Murphy Monument | ANST | Recreational | 2, 3 | Low | 8.0 | None | None |
| Sugar Run Mountain | ANST | Recreational | 2 | Moderate | 12.2 | Low | Low |
| Sinking Creek Mountain | ANST | Recreational | 2, 3, 5 | High | 2.8 | None | None |

1. This is the SIO at the Project location that would be visible from or closest to the KOP.

The majority of visual impacts were rated as none due to distance from the viewer, contrast levels, and screening elements. Low and moderate visual impacts were identified at certain vistas, though impacts would be less than significant.

Described below, and shown in Appendix A, Figure 1, are 14 KOPs representing various views from the ANST that help illustrate what visual impacts can be anticipated once the Project has been constructed. The KOPs are discussed by name or the segment of trail they are associated with. These KOPs are summarized in Table 1 above.

**KOP-OID-92 –** KOP OID-92 is located on the ANST on the Peters Mountain segment looking southeast. The Project crosses the ANST at MP 196.3, approximately 343.0 feet from the KOP, at a location where the trail runs along Peters Mountain between Flat Ridge and Mystery

Ridge. Elevations in this area range from 3,100 feet to over 3,400 feet with vegetation comprised mainly of Appalachian Oak forest.

The location where the Project crosses the Jefferson National Forest and location of the KOP are in Management Prescription 4A, which is the Appalachian Trail corridor. For this management prescription, the Forest Plan states that, "Roads, utility transmission corridors, communication facilities, or signs of mineral development activity exist or may be seen within the prescription area, although the goal is to avoid these types of facilities and land uses to the greatest extent possible and blend facilities which cannot be avoided into the landscape so that they remain visually subordinate" (USFS 2004). All management activities must meet or exceed an SIO of High. The scenic class is rated as a 1, which indicates that the scenic quality is high.

Because MVP has proposed to bore 300 foot under the ANST, vegetation directly adjacent to the ANST will be left in place and the crossing location will remain intact. Therefore, vegetation in the foreground of the view will screen direct visibility of the cleared Project ROW as well as distant views. While the bare-earth viewshed for KOP-OID-92 (Appendix A, Figure 5) indicates a small swath of visibility on Peters Mountain and a much larger area of visibility in the adjacent valley north of Peters Mountain, these views will actually be screened by the dominant hardwood vegetation adjacent to the ANST. The vista was observed in the field during both leaf-on and leaf-off conditions. The view is fully screened by surrounding vegetation (during both conditions) and topography that yield no views of the proposed ROW.

A visual simulation was prepared showing both leaf-off and leaf-on conditions (Appendix B, Figures 1 and 2, respectively). The vegetation with leaf-off conditions would be dense enough to screen views because the bore location is down a ridge on the side of the mountain and is not visible in the simulation. There is a possibility that trees cleared for the ROW would change the density of the forest canopy off the side of the ridge, but that is not apparent in the simulation. The only location where a trail user would be able to see the cleared Project ROW is if the hiker walked approximately 100 feet off the trail and looked off the edge of the ridge that screens the view of the bore location. Otherwise, the ROW will not be visible to hikers on the trail due to the 300-foot buffer of vegetation that will be preserved on each site of the ANST.

The Project crossing will comply with the requirements of Management Prescription 4A, Appalachian Trail corridor, which has a High SIO, because there will be no visual impact at this KOP. The ROW will not be visible from the trail because MVP plans cross the ANST by conventional bore.

**KOP-OID-111 –** KOP-OID-111 is located on the ANST at the Angels Rest lookout point looking north across the New River and city of Pearisburg approximately six miles from the

Project alignment. Elevation at the point is approximately 3,680 feet with vegetation comprised mainly of Appalachian Oak forest.

The land crossed by the Project alignment that is closest to this KOP is in Management Prescription 8A1, Mix of Successional Habitats in Forested Landscapes, which is managed for maintenance, enhancement, and restoration of native forest communities, particularly southern yellow pine and the wide variety of oak forest communities. The landscape character of this area retains a natural, forested appearance. The portion of the Management Prescription crossed by the Project is managed to meet a Moderate SIO. The scenic class is rated as a 2, which is the second highest scenic class and indicates the scenic quality is high. Note, however, that if the Project is approved and constructed on the Jefferson National Forest, the lands within the ROW for the pipeline would be reallocated to Management Prescription 5C - Designated Utility Corridors, except the ANST, which would remain Management Prescription 4A. The SIOs in Management Prescription 5C are either Moderate (for scenic classes 1 and 2) or Low (for scenic classes 3 to 7). Thus, after reallocation, the SIO for the lands crossed by the Project near this KOP would remain Moderate.

The bare-earth viewshed for KOP-OID-111 (Appendix A, Figure 3) indicates high areas of visibility across the valley that would have the potential to see miles of ROW. The vista was observed in the field during leaf-off conditions. A visual simulation (Appendix B, Figure 3) was prepared showing leaf-off conditions, which would be worst-case scenario viewing conditions. The view is broad and open. Elements visible in the simulation include the city of Pearisburg, the New River, various mountains, and industrial elements such as the Celanese industrial plant and numerous ROWs. The ROW is visible in the simulation, but it barely perceptible at this distance. The ROW does not stand out due to the numerous other ROWs in the view. The Project crossing will comply with the Moderate SIO because it will remain visually subordinate to the characteristic landscape being viewed. Contrast levels would be low from this KOP due to distance and numerous existing human-made changes. The low contrast and distance of view would result in low visual impacts to KOP-OID-111.

**KOP-OID-115 –** KOP-OID-115 is located on the ANST at the Kelly’s Knob main lookout point looking south across the Sinking Creek Valley approximately 2.1 miles from the Project alignment (see KOP-OID-114 and KOP-OID-113 below for other KOPs on Kelly’s Knob). Elevation at the point is approximately 3,715 feet with vegetation comprised mainly of Appalachian Oak forest.

The land crossed by the Project alignment that is closest to this KOP falls within Management Prescription 8A1, Mix of Successional Habitats in Forested Landscapes, and Management Prescription 6C, Old Growth Forest Communities-Disturbance Associated. Management Prescription 8A1 is managed for maintenance, enhancement, and restoration of native forest communities, particularly southern yellow pine and the wide variety of oak forest communities. The landscape character of this area retains a natural, forested appearance. The portion of Management Prescription 8A1 crossed by the Project is managed to meet a Moderate SIO and is in scenic class 5, which indicates that existing scenic quality is low.

Management Prescription 6C is managed to emphasize protection, restoration, and management of old growth forests and their associated wildlife, botanical, recreational, scientific, educational, cultural, and spiritual values. Within this management prescription, most of the area contains forest communities where no forest management activities or intervention will take place. Most of the area contains forest canopies that are continuous, interspersed with small gaps from natural causes, with little evidence of past human activity. The landscape character is natural appearing. The portion of Management Prescription 6C crossed by the Project is managed to meet a mix of Low and Moderate SIOs and is in scenic class 3, which indicates existing scenic quality is moderate. However, if the Project is approved and constructed on the Jefferson National Forest, these lands within the ROW for the pipeline would be reallocated to Management Prescription 5C. Because they are in scenic class 3 and 5, their SIO would be Low after the reallocation.

The bare-earth viewshed for the Project alignment (Appendix A, Figure 9) indicates high areas of visibility on the hills and ridges south of the viewpoint, especially where the ROW crosses Sinking Creek Mountain in the middleground of the view. The vista was observed in the field during leaf-off conditions. MVP prepared a visual simulation of KOP-OID-115 (Appendix B, Figure 4) showing leaf-off conditions, which represent the worst-case scenario viewing conditions. The view is broad with few human-made intrusions visible other than clearings in the valley and a high-voltage transmission line in the middleground of the view. The ROW is visible in the simulation, but it barely perceptible at this distance. This simulation demonstrates that the ROW will be visible, but at a distance of 2.0 miles or further from the lookout, the contrast levels appear low.

Roanoke Valley Cool Cities Coalition (RVCCC) independently prepared a simulation for Kelly’s Knob, which it submitted to FERC on January 4, 2017. The location of the RVCCC simulation could not be verified in the field, but additional simulations were prepared at various location around Kelly’s Knob. These additional KOPs (KOP-OID-114 and KOP-OID-113) are discussed below.

The ROW visible in MVP’s simulation of KOP-OID-115 crosses lands managed with a mix of Moderate and Low SIOs. The low visibility of the Project ROW will comply with the Low and Moderate SIOs, because the Project will remain visually subordinate to the characteristic landscape being viewed. Contrast levels would be low from this KOP due to distance and existing human-made changes to vegetation. The low contrast and distance of the view would result in a low visual impact to KOP-OID-115.

**KOP-OID-114 –** KOP-OID-114 (Appendix B, Figure 5) is located at an overlook near a campfire location adjacent to Kelly's Knob where the forest canopy opens up. KOP OID-114 is located adjacent to ANST and the Kelly's Knob lookout point looking south across the Sinking Creek Valley approximately 2.1 miles from the Project alignment. Elevation at the point is approximately 3,715 feet with vegetation comprised mainly of Appalachian Oak forest.

The land crossed by the Project alignment closest to this KOP falls within Management Prescription 8A1, Mix of Successional Habitats in Forested Landscapes, and Management Prescription 6C, Old Growth Forest Communities-Disturbance Associated. Management Prescription 8A1 is managed for maintenance, enhancement, and restoration of native forest communities, particularly southern yellow pine and the wide variety of oak forest communities. The landscape character of this area retains a natural, forested appearance. The portion of Management Prescription 8A1 crossed by the Project is managed to meet a Moderate SIO and is in scenic class 5, which indicates that existing scenic quality is low. Management Prescription 6C is managed to emphasize protection, restoration, and management of old growth forests and their associated wildlife, botanical, recreational, scientific, educational, cultural, and spiritual values. Within this management prescription, most of the area contains forest communities where no forest management activities or intervention will take place. Most of the area contains forest canopies that are continuous, interspersed with small gaps from natural causes, with little evidence of past human activity. The landscape character is natural appearing. The portion of Management Prescription 6C crossed by the Project is managed to meet a mix of Low and Moderate SIOs and is in scenic class 3, which indicates existing scenic quality is moderate. However, if the Project is approved and constructed on the Jefferson National Forest, these lands within the ROW for the pipeline would be reallocated to Management Prescription 5C. Because they are in scenic class 3 and 5, their SIO would be Low after the reallocation.

The bare-earth viewshed for the Project alignment (Appendix A, Figure 11) indicates high areas of visibility on the hills and ridges south of the viewpoint especially where the ROW crosses Sinking Creek Mountain in the middleground of the view. The vista was observed in the field during leaf-off conditions. MVP prepared a visual simulation of KOP-OID-114 (Appendix B, Figure 5) showing leaf-off conditions, which represent the worst-case scenario viewing conditions. The view is partially screened with few human-made intrusions visible other than clearings in the valley and a high-voltage transmission line in the middleground of the view. The simulation is similar to KOP-OID-115 and shows that the ROW will be visible in the valley in the middleground but has low contrast due to its distance from the viewpoint and the existing development and land use patterns in the valley.

The ROW visible in this simulation crosses lands managed with Moderate and Low SIOs. The low visibility of the Project ROW will comply with the Low and Moderate SIOs because the Project will remain visually subordinate to the characteristic landscape being viewed. Where the ROW crosses the hill in the middleground, it would be feathered to soften the edges of the ROW and make the opening in the vegetation appear more natural. The low contrast in this area of low to moderate scenic quality would result in a low visual impact to KOP-OID-114.

**KOP-OID-113 –** KOP-OID-113 is located adjacent to the Kelly's Knob lookout point looking south across the Sinking Creek Valley approximately 2.1 miles from the Project alignment. Elevation at the point is approximately 3,715 feet with vegetation comprised mainly of Appalachian Oak forest.

The land crossed by the Project alignment that is closest to this KOP falls within Management Prescription 8A1, Mix of Successional Habitats in Forested Landscapes, and Management Prescription 6C, Old Growth Forest Communities-Disturbance Associated. Management Prescription 8A1 is managed for maintenance, enhancement, and restoration of native forest communities, particularly southern yellow pine and the wide variety of oak forest communities. The landscape character of this area retains a natural, forested appearance. The portion of Management Prescription 8A1 crossed by the Project is managed to meet a Moderate SIO and is in scenic class 5, which indicates that existing scenic quality is low. Management Prescription 6C is managed to emphasize protection, restoration, and management of old growth forests and their associated wildlife, botanical, recreational, scientific, educational, cultural, and spiritual values. Within this management prescription, most of the area contains forest communities where no forest management activities or intervention will take place. Most of the area contains forest canopies that are continuous, interspersed with small gaps from natural causes, with little evidence of past human activity. The landscape character is natural appearing. The portion of Management Prescription 6C crossed by the Project is managed to meet a mixture of Low and Moderate SIOs and is in scenic class 3, which indicates existing scenic quality is moderate. However, if the Project is approved and constructed on the Jefferson National Forest, these lands within the ROW for the pipeline would be reallocated to Management Prescription 5C. Because they are in scenic class 3 and 5, their SIO would be Low after the reallocation.

The bare-earth viewshed for the Project alignment (Appendix A, Figure 13) indicates high areas of visibility on the hills and ridges south of the viewpoint especially where the ROW crosses Sinking Creek Mountain in the middleground of the view. The vista was observed in the field during leaf-off conditions. MVP prepared a visual simulation of KOP-OID-113 (Appendix B, Figure 6) showing leaf-off conditions, which represent the worst-case scenario viewing conditions. KOP-OID-113 is located off of the main trail with no visible markers to indicate a viewing location. The view is partially screened with few human-made intrusions visible other than clearings in the valley and a high-voltage transmission line in the middleground of the view. The ROW is visible in the simulation, but it barely perceptible at this distance.

As noted above, the location of the RVCCC simulation for Kelly's Knob could not be verified in the field, but this KOP closely resembles the viewing angle of the RVCCC simulation. MVP's simulation for KOP-OID-113 (Appendix B, Figure 6) shows that the ROW is visible as it crosses a hill in the middleground of the view, similar to the RVCCC simulation, though the view for KOP-OID-113 is partially screened by the trees in the foreground. The simulation demonstrates that the ROW will be visible, but at a distance of 2.0 miles or further from the lookout, the contrast levels appear low.

The ROW visible in this simulation crosses lands managed with Moderate and Low SIOs. The low visibility of the Project ROW will comply with the Low and Moderate SIOs because the Project will remain visually subordinate to the characteristic landscape being viewed and partially screened by surrounding vegetation. Where the ROW crosses the hill in the middleground, it may be feathered to soften the edges of the ROW and make the opening in the vegetation appear more natural. Contrast levels would be low from this KOP due to distance and existing human-made changes to vegetation and the partial screening offered by surrounding vegetation. The low contrast and partial screening would result in a low visual impact to KOP-OID-113.

**KOP 125 –** KOP 125 is located at the Sugar Camp Farm Trailhead, which is a trailhead for the Groundhog Trail that connects to the ANST and is part of the George Washington and Jefferson National Forest. Located approximately 2.0 miles north from the ANST, the trailhead is approximately 1.77 miles east from MP 194.4 of the Project. The visual setting is mostly rural residential and agricultural with views dominated by Peters Mountain to the south and southeast of this point. Elevation at the point is approximately 2,157 feet with vegetation comprised mainly of Appalachian Oak forest.

The portion of the Project visible from this KOP that crosses the Jefferson National Forest is located in Management Prescription 4A, which is the Appalachian Trail corridor. For this management prescription, the Forest Plan states that, "Roads, utility transmission corridors, communication facilities, or signs of mineral development activity exist or may be seen within the prescription area, although the goal is to avoid these types of facilities and land uses to the greatest extent possible and blend facilities which cannot be avoided into the landscape so that they remain visually subordinate" (USFS 2004). All management activities must meet or exceed an SIO of High. The scenic class is rated as a 1, which indicates that the scenic quality is high.

The bare-earth viewshed for the Project alignment (Appendix A, Figure 7) indicates high areas of visibility all along the northern side of Peters Mountain in the middleground of the view. The vista was observed in the field during leaf-on conditions. A visual simulation (Appendix A, Figure 6) was prepared showing leaf-on conditions. The view is broad with few human-made visible changes other than trail signage. The ROW is visible in the simulation but is barely perceptible at this distance. The edge of the ROW is visible on the slope of Peters Mountain but blends in with the surrounding vegetation. The simulation demonstrates that the ROW will be visible, but at a distance of 1.6 miles with the dominant hardwood vegetation, contrast levels appear low. The Project ROW will comply with the High SIO, because to the ROW will not be visually evident to the casual observer and the landscape character will appear intact at this crossing. Due to the proposed method of crossing by horizontal bore, the Pipeline ROW will only be visible from the valley below the crossing, and there will be no visible notch in the vegetation at the top of Peters Mountain, leaving the ridgeline vegetation intact. Thus, there would be low visual impacts at KOP 125, and the Project crossing would comply with the USFS management standard.

**KOP-PT-02 –** KOP-PT-02 is located on the ANST at the boundary of Peters Mountain Wilderness, which is located in Giles County in southwest Virginia. Peters Mountain Wilderness, lying on the east slope of Peters Mountain, ranges in elevation from 3,956 feet on the mountaintop to a low of 2,300 feet on the southern border along Big Stony Creek. The vegetation is primarily upland oak with yellow poplar, red oak, and hickory. The wilderness is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted. The Project will not cross Peters Mountain Wilderness. The view at KOP-PT-02 is looking south to southwest toward the crossing of the ANST.

The portion of the Project visible from this KOP that crosses of the Jefferson National Forest is located in Management Prescription 4A, which is the Appalachian Trail corridor. For this management prescription, the Forest Plan states that, “Roads, utility transmission corridors, communication facilities, or signs of mineral development activity exist or may be seen within the prescription area, although the goal is to avoid these types of facilities and land uses to the greatest extent possible and blend facilities which cannot be avoided into the landscape so that they remain visually subordinate” (USFS 2004). All management activities must meet or exceed an SIO of High. The scenic class is rated as a 1, which indicates that the scenic quality is high. The bare-earth viewshed from KOP-PT-02 (Appendix A, Figure 6) indicates high areas of visibility on the northern side of Peters Mountain of Little Mountain and the Dry Creek Valley. The bare-earth viewshed also shows an area on the southern side of Peters Mountain in the middleground of the view. The visibility within the ANST corridor is limited to less than 0.25 mile. A ridge in the foreground of the view screens direct visibility of the Project ROW, though distant views of the ROW will be likely in the adjacent valleys if vegetation is cleared. The vista was observed in the field during leaf-off conditions.

MVP prepared a visual simulation of KOP-PT-02 (Appendix B, Figure 8) showing leaf-off conditions. The view is canopied by vegetation with few human-made visible changes other than USFS signage. The ROW is not visible in the simulation due to screening terrain and vegetation. The simulation demonstrates that the ROW will be effectively screened with the dominant hardwood vegetation; thus, contrast levels are not perceptible. The ROW will comply with the High SIO of Management Prescription 4A because the ROW will not be visually evident to the casual observer and the landscape character will appear intact at this crossing. Due to the screening terrain and vegetation between the viewpoint and the ROW, there will be no visual impact at this KOP.

**KOP-OID-103 –** KOP-OID-103 is located at the Wind Rock overlook on the ANST at the boundary of Mountain Lake Wilderness. Mountain Lake Wilderness, which inside lies a highland plateau resting squarely on the Eastern Continental Divide, ranges in elevation from 2,200 to 4,000 feet. The vegetation is primarily a typical Appalachian hardwood forest with isolated stands of virgin spruce and hemlock. The wilderness is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted. The view at KOP-OID-103 is looking south toward the location of the ROW. The Project will not cross the Mountain Lake Wilderness; at the closest point, the Project will pass approximately 6.5 miles southwest of the wilderness area.

The lands crossed by the Project alignment that are closest to this KOP fall within Management Prescription 8A1, Mix of Successional Habitats in Forested Landscapes. The portion of Management Prescription 8A1 crossed by the Project is managed to meet a Moderate SIO and is in scenic class 2, which indicates that existing scenic quality is high. However, if the Project is approved and constructed on the Jefferson National Forest, these lands within the ROW for the pipeline would be reallocated to Management Prescription 5C. Because they are in scenic class 2, the lands would retain a Moderate SIO after the reallocation. The bare-earth viewshed from KOP-OID-103 (Appendix A, Figure 8) indicates high areas of visibility south of the viewpoint. A series of ridges and mountains in the middleground of the view screens direct visibility of the ROW. The vista was observed in the field during leaf-off conditions.

MVP prepared visual simulation of KOP-OID-103 (Appendix B, Figure 9) showing leaf-off conditions. The view is open and panoramic with few human-made visible changes other than a development in the middleground. The ROW is not visible in the simulation due to screening terrain and vegetation as well as the distance to the ROW. The simulation demonstrates that the ROW will be effectively screened with the vegetation; thus, contrast levels are not perceptible. The Project will comply with the Moderate SIO of Management Prescription 8A1 because the ROW will not be visually evident to viewers at the Wind Rock overlook. Due to the screening terrain and vegetation between the viewpoint and the ROW, there will be no visual impact at this KOP.

**KOP-OID-22 –** KOP-OID-22 is located at the trailhead of Sawtooth Ridge at an elevation of approximately 1,962 feet. The vegetation is primarily a typical Appalachian hardwood forest. The viewpoint is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted. The view at KOP-OID-22 is looking east to southeast toward the location of the ROW. Direct views south are screened by vegetation.

At the closest point, the Project will be 11.0 miles from the viewpoint. This area where the viewpoint is located is not managed by the USFS, so no Management Prescriptions or SIOs apply. The bare-earth viewshed from KOP-OID-22 (Appendix A, Figure 13) indicates high areas of visibility east and south of the viewpoint. A series of mountains in the middleground and background, including Little Brushy and Fort Lewis Mountains, would completely screen the ROW. The vista was observed in the field during leaf-off conditions. The view is canopied by vegetation and partially screened with visible human-made visible changes in the middleground. Due to the screening terrain and vegetation between the viewpoint and the Project, as well as distance, the Project will not be visible. Therefore, there will be no impact on this area.

**KOP-OID-23 –** KOP OID-23 is located at the Dragon's Tooth overlook on the ANST looking south. Elevation at Dragon's Tooth is approximately 3,400 feet, and the vegetation is primarily a typical Appalachian hardwood forest intermixed with pine. Dragon's Tooth is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted.

At its closest point to this location, the ROW will pass approximately 7.8 miles south of the KOP, but this area is not on the JNF. No portion of the Proposed ROW will be visible from this KOP. Where the Project crosses Brush Mountain from MP 219.8 to MP 220.7, it is located on the JNF at a point 12.7 miles from the KOP which is not visible from this location. This area of Brush Mountain is in Management Prescription 4J, Urban/Suburban Interface, west of Blacksburg, Virginia, which emphasizes a "defensible space" that provides a buffer between human developments and forestland, reducing the risk of wildland fire. This prescription recognizes that these areas are people's "backyards" so a long-term goal of high quality, fire-resistant scenery is also emphasized. These landscapes will often appear altered in the short-term while the defensible space is created and a normal fire regime restored. The long-term goal is to maintain a moderate to high scenic integrity. This area is managed with a short-term SIO of Low until the ecosystem and landscape character are rehabilitated. In Management Prescription 4J, there are long-term Moderate and High SIOs; however, the land is currently managed with a Low SIO. If the Project is approved and constructed on the Jefferson National Forest, these lands within the ROW for the pipeline would be reallocated to Management Prescription 5C.

The bare-earth viewshed from KOP-OID-23 (Appendix A, Figure 12) indicates high areas of visibility south of the viewpoint outside the Jefferson National Forest. The viewshed analysis indicated that the Brush Mountain crossing on Jefferson National Forest would be completely screened by terrain. A series of ridges and mountains in the middleground of the view screens direct visibility of the ROW. The vista was observed in the field during leaf-off conditions.

MVP prepared a visual simulation of KOP-OID-23 (Appendix B, Figure 10) showing leaf-off conditions. The view toward the Project is completely screened with few human-made visible changes other than trail signage and development in the valleys surrounding the view. Most views appear to be oriented southeast to Ft. Lewis Mountain, though views would be more open if the hiker climbed to the top of the Dragon's Tooth rock formation. The ROW is not visible in the simulation due to screening terrain and vegetation as well as the distance to the ROW. Thus, contrast levels are not perceptible, and there will be no visual impact at this KOP.

**KOP-OID-85 –** KOP OID-85 is located at the Rice Field section of the ANST looking northeast. Elevation at the Rice Field is approximately 3,371 feet, and the vegetation is primarily a typical Appalachian hardwood forest with the open grassy plain in the foreground and middleground of the view. KOP OID-85 is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted.

The Project will cross the Jefferson National Forest approximately 4.1 miles north of the Rice Field. The portion of the Project visible from this KOP that crosses of the Jefferson National Forest is located in Management Prescription 4A, which is the Appalachian Trail corridor. For this management prescription, the Forest Plan states that, "Roads, utility transmission corridors, communication facilities, or signs of mineral development activity exist or may be seen within the prescription area, although the goal is to avoid these types of facilities and land uses to the greatest extent possible and blend facilities which cannot be avoided into the landscape so that they remain visually subordinate" (USFS 2004). All management activities must meet or exceed an SIO of High. The scenic class is rated as a 1, which indicates that the scenic quality is high.

The bare-earth viewshed from KOP-OID-85 (Appendix A, Figure 4) indicates high areas of visibility north of the viewpoint and in the surrounding valleys. However, a series of ridges in the middleground of the view screens direct visibility of the Project crossing on the Jefferson National Forest on Peters Mountain. The only views of Peters Mountain would be in the immediate foreground and middleground of the view (these views of Peters Mountain do not include the location Project crossing), though middleground and background views are possible in areas north and south of Peters Mountain. The vista was observed in the field during leaf-off conditions.

MVP prepared a visual simulation of KOP-OID-85 (Appendix B, Figure 11) showing leaf-off conditions. The view toward the Project is open and panoramic with human-made visible changes in the valleys surrounding the view. The ROW is visible in the simulation in the distance as it crosses Little Mountain, but the location where the ROW is visible is not on the National Forest. Due to topography, where the ROW is located on f the Jefferson National Forest is not visible from this KOP. Thus, contrast levels where the ROW crosses the National Forest are not perceptible at this KOP, and thus the Project will comply with the High SIO of Management Prescription 4A. Therefore, there will be low visual impacts at this KOP because the ROW is visible only outside of USFS-managed lands, and there are many human-made changes in the valley and hills where the ROW is visible.

**Audie Murphy Monument KOP –** The Audie Murphy Monument is on the ANST on Brush Mountain looking south. Elevation at the monument is approximately 3,101 feet, and the vegetation is primarily a typical Appalachian hardwood forest. The viewpoint is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted.

The Project will cross the Jefferson National Forest approximately 10.2 miles southwest of this KOP on Brush Mountain where the lands are in Management Prescription 4J, Urban/Suburban Interface west of Blacksburg, Virginia. This Management Prescription emphasizes a “defensible space” that provides a buffer between human developments and forestland, reducing the risk of wildland fire. This prescription recognizes that these areas are people’s “backyards” so a long-term goal of high quality, fire-resistant scenery is also emphasized. These landscapes will often appear altered in the short-term while the defensible space is created and a normal fire regime restored. The long-term goal is to maintain a moderate to high scenic integrity. This area is managed with a short-term SIO of Low until the ecosystem and landscape character are rehabilitated. In Management Prescription 4J, there are long-term Moderate and High SIOs; however, the land is currently managed with a Low SIO and a mix of 2 and 3 scenic class. If the Project approved and constructed on the Jefferson National Forest, these lands within the ROW for the pipeline would be reallocated to Management Prescription 5C.

The bare-earth viewshed for the viewpoint (Appendix A, Figure 13) indicates high areas of visibility east and west of Brush Mountain in the surrounding valleys. A series of ridges in the middleground of the view screens direct visibility of the Project crossing on the National Forest. Because the view toward the Project is screened by vegetation, the Project will comply with the Low SIO. The Project will not be visually evident to the casual observer and the landscape character will appear intact. There will be no visual impact on this KOP.

**Sugar Run Mountain KOP –** This KOP is located at a lookout on the ANST on Sugar Run Mountain looking north. Elevation at the lookout is approximately 3,875 feet, and the vegetation is primarily typical Appalachian hardwood forest. The viewpoint is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted. The Project will cross the Jefferson National Forest approximately 12.2 miles north of this location.

The National Forest lands crossed by the Project alignment that are closest to this KOP fall within Management Prescription 8A1, Mix of Successional Habitats in Forested Landscapes. The portion of Management Prescription 8A1 crossed by the Project is managed to meet a

Moderate SIO and is in scenic class 2, which indicates that existing scenic quality is high. However, if the Project is approved and constructed on the Jefferson National Forest, these lands within the ROW for the pipeline would be reallocated to Management Prescription 5C. Because they are in scenic class 2, they would retain a Moderate SIO after the reallocation.

The bare-earth viewshed for this KOP (Appendix A, Figure 2) indicates high areas of visibility across the valley, which would have the potential to see miles of the Project ROW, though these areas where the Project could be visible would not be on the Jefferson National Forest. Though the ROW is visible outside the Jefferson National Forest in the bare-earth viewshed, it would be at such a distance that it would not be perceptible in the view. This assumption is based on the simulation from the Angel's Rest overlook which is 5.6 miles further away from the Project. With bare-earth conditions, Sugar Run Mountain would not have views of the ROW on Jefferson National Forest lands. Because the ROW on the National Forest would not be visible from this KOP, it would comply with the Moderate SIO for Management Prescription 8A1.

For the portion of the ROW that could be visible from the Sugar Run Mountain KOP outside the Jefferson National Forest, visual impacts would be none because the ROW will be collocated between two existing ROWs, which represent an incremental visual contrast, and the distance between the KOP and the ROW is significant. The lack of contrast of the Project at this distance would result in a no visual impacts to the Sugar Run Mountain portion of the ANST.

**Sinking Creek Mountain –** This KOP is located on the ANST on Sinking Creek Mountain looking southwest. The location is not listed as an ANST lookout but was chosen based on where the ANST is within close proximity to the Project on Sinking Creek Mountain. Elevation at the location is approximately 3,258 feet, and the vegetation is primarily typical Appalachian hardwood forest. The viewpoint is located in the Ridge and Valley Ecoregion, which is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted.

The Project will cross the Jefferson National Forest approximately 2.8 miles north of this KOP. The areas within the Forest that the ROW crosses are a mix of management prescriptions. From MP 218.8 to MP 219.4, the ROW is in Management Prescription 8A1, Mix of Successional Habitats in Forested Landscapes, which is managed for maintenance, enhancement, and restoration of native forest communities, particularly southern yellow pine and the wide variety of oak forest communities. The landscape character of this area retains a natural, forested appearance. The portion of Management Prescription 8A1 that crossed by the Project is managed to meet both Low and Moderate SIOs, with scenic class inventory ratings of 3, 5, and 2 as the ROW crosses Sinking Creek Mountain.

From MP 218.5 to MP 218.8, the Project crosses lands within Management Prescription 6C, the Old Growth Forest Communities-Disturbance Associated, which is managed to emphasize protection, restoration, and management of old growth forests and their associated wildlife, botanical, recreational, scientific, educational, cultural, and spiritual values. Within this prescription, most of the area contains forest communities where no forest management activities or intervention will take place. Most of the area contains forest canopies that are continuous, interspersed with small gaps from natural causes, with little evidence of past human activity. The landscape character is natural appearing. The portion of Management Prescription 6C crossed by the ROW is managed to meet a mix of Low and Moderate SIO in a scenic class with a rating of 3.

From MP 219.8 to MP 220.7, the Project crosses lands within Management Prescription 4J, Urban/Suburban Interface, north of Blacksburg, Virginia, which emphasizes a “defensible space” that provides a buffer between human developments and forestland, reducing the risk of wildland fire. This prescription recognizes that these areas are people’s “backyards,” so a long-term goal of high quality, fire-resistant scenery is also emphasized. These landscapes often appear altered in the short-term while the defensible space is created and a normal fire regime restored. The long-term goal is to maintain moderate to high scenic integrity. This area is managed with a short-term SIO of Low until the ecosystem and landscape character are rehabilitated. In Management Prescription 4J, there are long-term Moderate and High SIOs; however, the land is currently managed with a Low SIO.

If the Project is approved and constructed on the Jefferson National Forest, the lands within these three management prescriptions that are within the ROW for the pipeline would be reallocated to Management Prescription 5C, with scenic class 2 areas having a Moderate SIO and scenic class 2, 3 and 5 areas having a Low SIO.

The bare-earth viewshed for Sinking Creek Mountain KOP (Appendix A, Figure 9) indicates high areas of visibility northwest of the location and the western ridge of Brush Mountain to the south, though not directly on Sinking Creek Mountain. The viewshed indicates that the ROW is not visible on Sinking Creek Mountain as there is intervening terrain between the viewpoint and the ROW, but there is the potential to the see the ROW at the very crest of Brush Mountain. However, it is assumed that the dominant hardwood vegetation adjacent to the viewpoint would effectively screen any possible views of the crossing of Brush Mountain.

The Project crossing of the Jefferson National Forest as seen from this KOP will comply with the Moderate and Low SIOs, because the ROW will be effectively screened from the ANST on Sinking Creek Mountain by the surrounding dominant vegetation. The contrast is rated as none due to the vegetative screening. No contrast would result in no visual impacts. A lack of visual impacts will conform with the Low and Moderate SIOs on and adjacent to Sinking Creek Mountain.

### b. Craig Creek Road Analysis

The Project ROW will cross Craig Creek Road between Sinking Creek Mountain and Brush Mountain. MVP intends to cross Craig Creek Road using a conventional bore, with the entry and exit points located approximately 30 feet from the road. Visibility of the Project from various KOPs along Craig Creek Road, both within and outside the Jefferson National Forest, was mapped in December 2016 (Appendix A, Figure 17). Below is a description of the visibility at each KOP as well as a discussion of the Management Prescriptions crossed by this portion of the Project and simulations from each potential visibility location. It should be noted that Craig Creek Road and areas adjacent to the roadway are private and not managed by the USFS.

#### i. Travelers on Craig Creek Road

Viewers traveling eastbound on Craig Creek road will initially have potential visibility of the ROW approximately 0.23 mile from the crossing at KOP PT-28 (Appendix B, Figure 17). Appendix B, Figure 16, KOP PT-26, shows the location of the crossing of Craig Creek Road. Below each KOP is discussed along Craig Creek Road.

- KOP PT-21 (Appendix B, Figure 12) is located on Craig Creek Road approximately 0.6 mile east of the crossing of Craig Creek Road looking west. In the photograph, the road is a typical paved roadway with an adjacent guard rail and an existing power pole ROW. The trees adjacent to Craig Creek Road would screen views even with leaf-off conditions due to a 600-foot buffer of trees between the ROW and the roadway. The visual simulation (Appendix B, Figure 12) confirmed that there would be no visual impact to Craig Creek Road at this location.

- KOP PT-22 (Appendix B, Figure 13) is located on Craig Creek Road approximately 0.5 mile east of the crossing of Craig Creek Road looking west. In the photograph, the road is a typical paved roadway with an adjacent guard rail and signage. The trees adjacent to Craig Creek Road would screen views even with leaf-off conditions due to a 600-foot buffer of trees between the ROW and the roadway. As the visual simulation indicates, there would be no visual impact to Craig Creek Road at this location.

- KOP PT-23 (Appendix B, Figure 14) is located on Craig Creek Road approximately 0.3 miles east of the crossing of Craig Creek Road looking west. In the photograph, the road is a typical paved roadway with a guard rail in the distance. Craig Creek is visible from this portion of Craig Creek Road. The trees adjacent to Craig Creek Road would screen views even with leaf-off conditions due to a 450-foot buffer of trees between the ROW and the roadway. As the visual simulation indicates, there would be no visual impact to Craig Creek Road at this location.

- KOP PT-25 (Appendix B, Figure 15) is located on Craig Creek Road approximately 0.2 mile east of the crossing of Craig Creek Road looking west. In the photograph, the road is a typical paved roadway with an adjacent fence line and pasture. The simulation for KOP PT-25 (Appendix B, Figure 15) shows no visibility of the pipeline ROW but some visibility of a related access road. Therefore, visual impacts at KOP PT-25 would be low and would not be related to the ROW. No portion of the ROW will not be visible for any duration of this roadway segment. The contrast is rated as none for the proposed alignment due to the screening. The visibility of the access road would represent low contrast and low visual impacts for Craig Creek Road.

- KOP PT-26 (Appendix B, Figure 16) is located on Craig Creek Road directly adjacent (96 feet) to the crossing of Craig Creek Road looking east. In the photograph, the road is a typical paved roadway with dense vegetation adjacent on both sides. The trees adjacent to Craig Creek Road would screen views even with leaf-off conditions due to a 30-foot buffer of trees between the roadway and the bore locations, and there are no visible Project elements other than the very end of a gravel access road in the distance. As the visual simulation indicates, there would be no visual impact to Craig Creek Road at this location.

- KOP PT-28 (Appendix B, Figure 17) is located on Craig Creek Road approximately 0.2 miles west of the crossing of Craig Creek Road looking east. In the photograph, the road is a typical paved roadway with adjacent fencing and an open pasture. At this distance the trees adjacent to Craig Creek Road would screen views even with leaf-off conditions, and there are no visible Project elements. As the visual simulation indicates, there would be no visual impact to Craig Creek Road at this location.

#### c. Pocahontas Road Analysis

Pocahontas Road is currently planned as an access road for the construction of the Project. The ANST shares the portion of Pocahontas Road from the ANST approximately 360 feet from the intersection of Pocahontas Road and Clendennin Road. This area is outside of the JNF. MVP will upgrade Pocahontas Road to use it for construction vehicles, including blading and widening in some areas. The upgrades are not anticipated to have any visual impacts to the ANST because there will be minimal changes to the road where it is shared with the ANST. Blading will not start until approximately 340 feet past where the trail exits the shared corridor of the road. The ANST is within the Pocahontas Road corridor from the location where the two meet all the way to Clendennin Road, a distance of approximately 427 feet. This portion of the ANST is on a private road, which has been simulated in Figures and discussed below.

- KOP PR-1 (Appendix B, Figure 18) is located on Pocahontas Road where the roadway corridor is managed as the ANST, looking northeast. In the photograph, the road is a typical gravel road surrounded by hardwood vegetation. There would be no additional road upgrades in the immediate area, and blading will not start on Pocahontas Road for another 300 feet, which is past the viewshed of this KOP and past where the roadway is shared with the ANST. As the visual simulation indicates, there would be no visual impact to the ANST at this location.

- KOP PR-2 (Appendix B, Figure 19) is located on Pocahontas Road where the roadway corridor is managed as the ANST, looking southwest. In the photograph, the road is a typical gravel road with a cattle guard and adjacent fencing. A new culvert will need to be installed approximately 50 feet from the viewer and will be visible. However, there will be no additional road upgrades in the immediate area, and blading will not start on Pocahontas Road for another 300 feet, which is past the viewshed of this KOP and past where the roadway is shared with the ANST. As the visual simulation indicates, there would be no visual impact to the ANST at this location.

- KOP PR-3 (Appendix B, Figure 20) is slightly above the roadway on the ANST as the trail descends down to Pocahontas Road from Peters Mountain. In the photograph, the road is clearly visible from the trail, and road upgrades such as the reinforcement of gravel would occur, though blading would not start on Pocahontas Road for another 300 feet past the viewshed and past where the roadway and ANST are collocated. As the visual simulation indicates, there would be low visual impacts to the ANST at this location.

- KOP PR-4 (Appendix B, Figure 21) is located on Pocahontas Road where the roadway corridor is managed as the ANST, looking northeast. In the photograph, the road is a typical gravel road with adjacent fencing and scattered potholes. It is likely that the potholes would be filed in with fresh gravel, and there will be the installation of a new culvert close to where the photograph was taken. However, there would be no additional road upgrades in the immediate area, and blading would not start on Pocahontas Road for another 500 feet past the viewshed of this KOP and past where the roadway and ANST are collocated. As the visual simulation indicates, there would be no visual impact to the ANST at this location.

- KOP PR-5 (Appendix B, Figure 22) is located on Pocahontas Road where the roadway corridor is managed as the ANST, looking southwest. In the photograph, the road is a typical gravel road with scattered potholes. There would be no upgrades to Pocahontas Road at this location. However, there would be no additional road upgrades in the immediate area, and blading would not start on Pocahontas Road for another 500 feet past the viewshed of this KOP and past where the roadway and ANST are collocated. As the visual simulation indicates, there would be no visual impact to the ANST at this location.

- KOP PR-6 (Appendix B, Figure 23) is located on Pocahontas Road where the roadway corridor is managed as the ANST, looking southwest toward Clendennin Road. In the photograph, the road is a typical gravel road with adjacent fencing, a cattle guard, and scattered potholes. The steps of the ANST are visible on the southwest side of Clendennin Road. It is likely that the potholes would be filed in with fresh gravel. However, there would be no additional road upgrades in the immediate area, and blading would not start on Pocahontas Road for another 620 feet past the viewshed of this KOP and past where the roadway and ANST are collocated. As the visual simulation indicates, there would be no visual impact to the ANST at this location.

Upgrades to Pocahontas Road where the road is managed as the ANST will be minimal, and the gravel roadway will resemble its current appearance. Because the ANST is collocated on Pocahontas Road on private lands outside the Jefferson National Forest, no SIOs or Management Prescriptions apply at the crossing.

## 5. VISUAL MITIGATION MEASURES AND BEST MANAGEMENT PRACTICES

The results of the VIA indicate that construction and operation of the Project will have mostly low or no significant visual impacts to the ANST, including from managed vistas. To ensure compliance with SIOs in the Jefferson National, MVP will implement the following mitigation measures and best management practices (BMPs), which MVP developed in consultation with USFS, to lower potential visual impacts from the Project identified during the analysis.

- In High SIO areas, MVP will feather the ROW to ensure that vegetative openings appear more natural and conform the natural form, line, color, and texture of the existing landscape. Temporary work spaces within forested areas would include some level of shrub plantings or shrub seed mixes to soften the hard edge formed between the existing/undisturbed forest and the maintained ROW. MVP intends to include woody seed mixes within temporary areas where forest regeneration is desired.
- Road or trail crossings will be done at a right angle, where feasible, to ensure the shortest duration of view for the crossing (USFS 1975).
- The ANST will be crossed by the Project by using a conventional bore method to ensure there will be no disruptions to hikers on the ANST. This method will also allow MVP to maintain a 300-foot vegetative buffer between the ROW and the ANST, eliminating visibility of the ROW to trail users at the crossing location.
- MVP has sited the alignment to conform to the natural lines in the landscape and followed existing ROWs, where feasible.

With low or no visual impacts as well as the implementation of the mitigation measures and BMPs listed above, the Project will not result in any significant visual impacts to visual resources on the Jefferson National Forest or popular ANST viewpoints.

## 6. KEY VISUAL STUDY ANALYST

The key analyst for the visual resources study was Robert Evans, Visual Resources Analyst/Task Lead. Mr. Evans has a master's degree in Landscape Architecture and is an active member of American Society of Landscape Architects. He has 10+ years conducting and supported visual assessments in numerous US states including AZ, CA, NV, NM, OR, WA, ID, WY, TX, AK, OK, TN, NH, MA, NY, and HI and has completed the BLM's VRM training in 2008. Mr. Evans is also a member of the Scenic Resources Working Group, which is a subcommittee of the National Association of Environmental Professionals. The group focuses on upcoming and emerging technology that can affect visual resource analysis and mitigation.

## 7. REFERENCES

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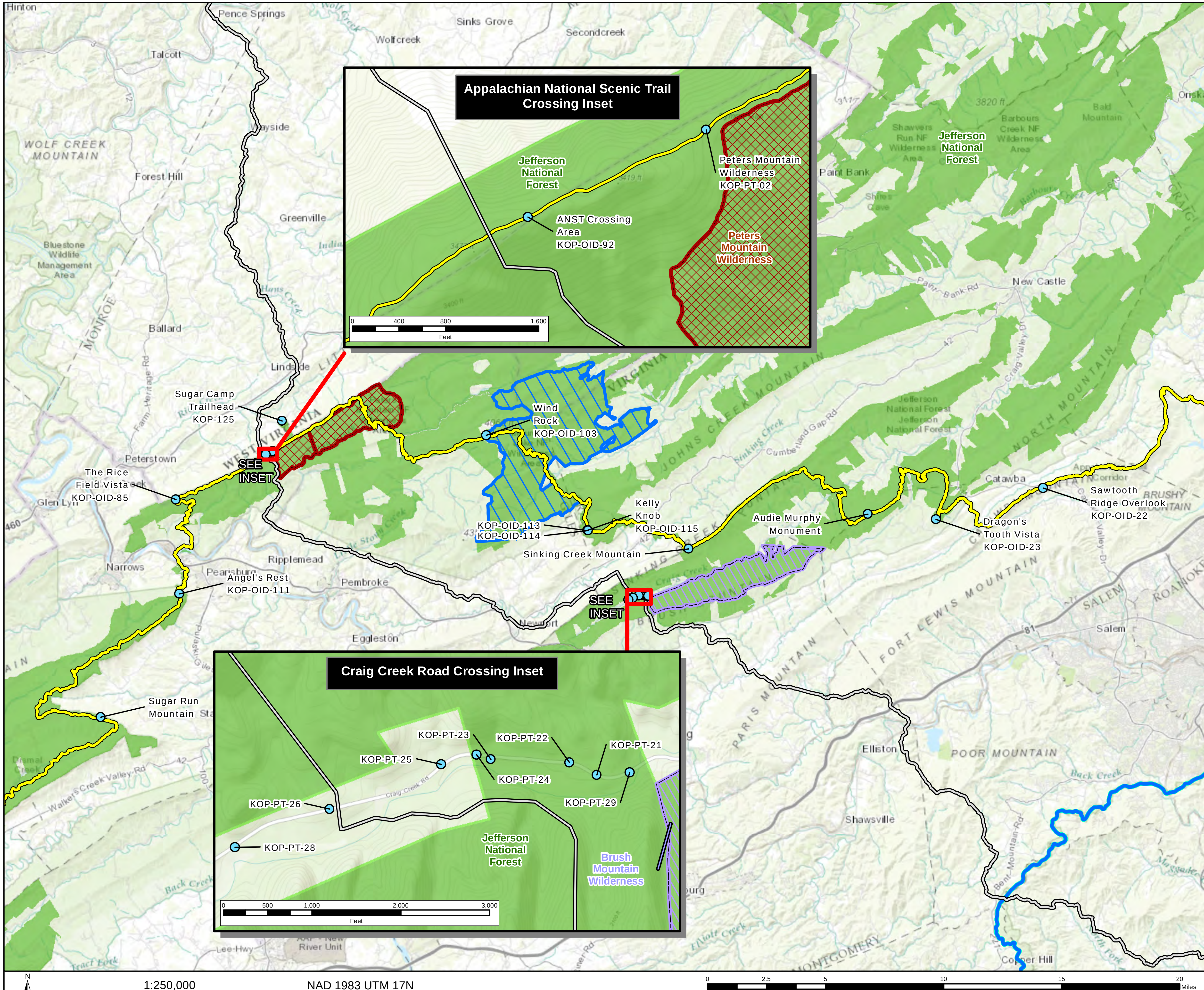
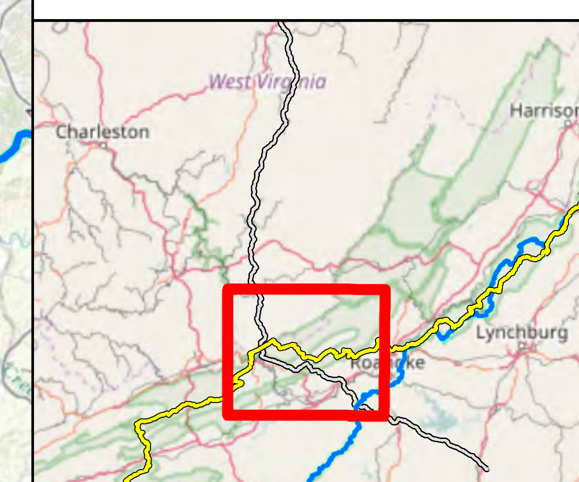
# APPENDIX A

# PROJECT MAPPING




**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

## Key Observation Points Along the Appalachian National Scenic Trail and Craig Creek Road

JANUARY 2017

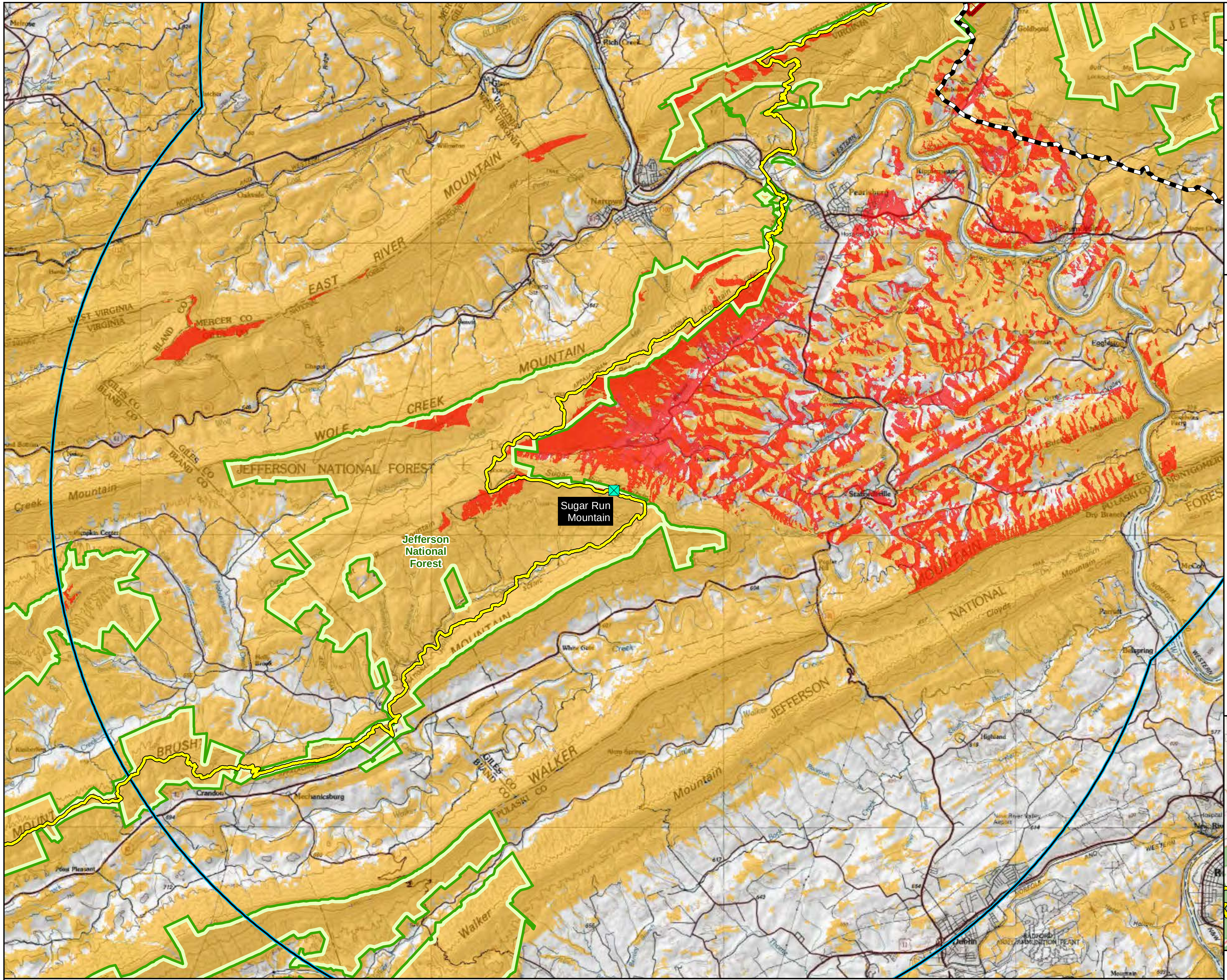
**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Blue Ridge Parkway
- Peters Mountain Wilderness
- Brush Mountain Wilderness
- Mountain Lake Wilderness
- US National Forest Service Boundary

Data Sources: USGS, NPS, ESRI

Figure 1

Document Path: P:\EQT-Equitrans\MVP Project\GIS\Spatial\MXD\2017\0105_USFS_Updated_ANST_Viewsheds\USFS_ANST_KOPs_Overview_20170117.mxd




1:126,720 NAD 1983 UTM 17N 0 2 4 8 12 16 Miles

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

**Bare Earth Viewshed Appalachian National Scenic Trail**

**Sugar Run Mountain**

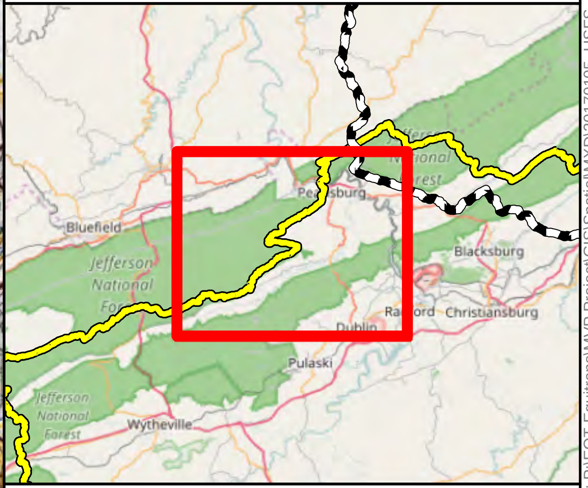
Page 1 of 14

**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 2

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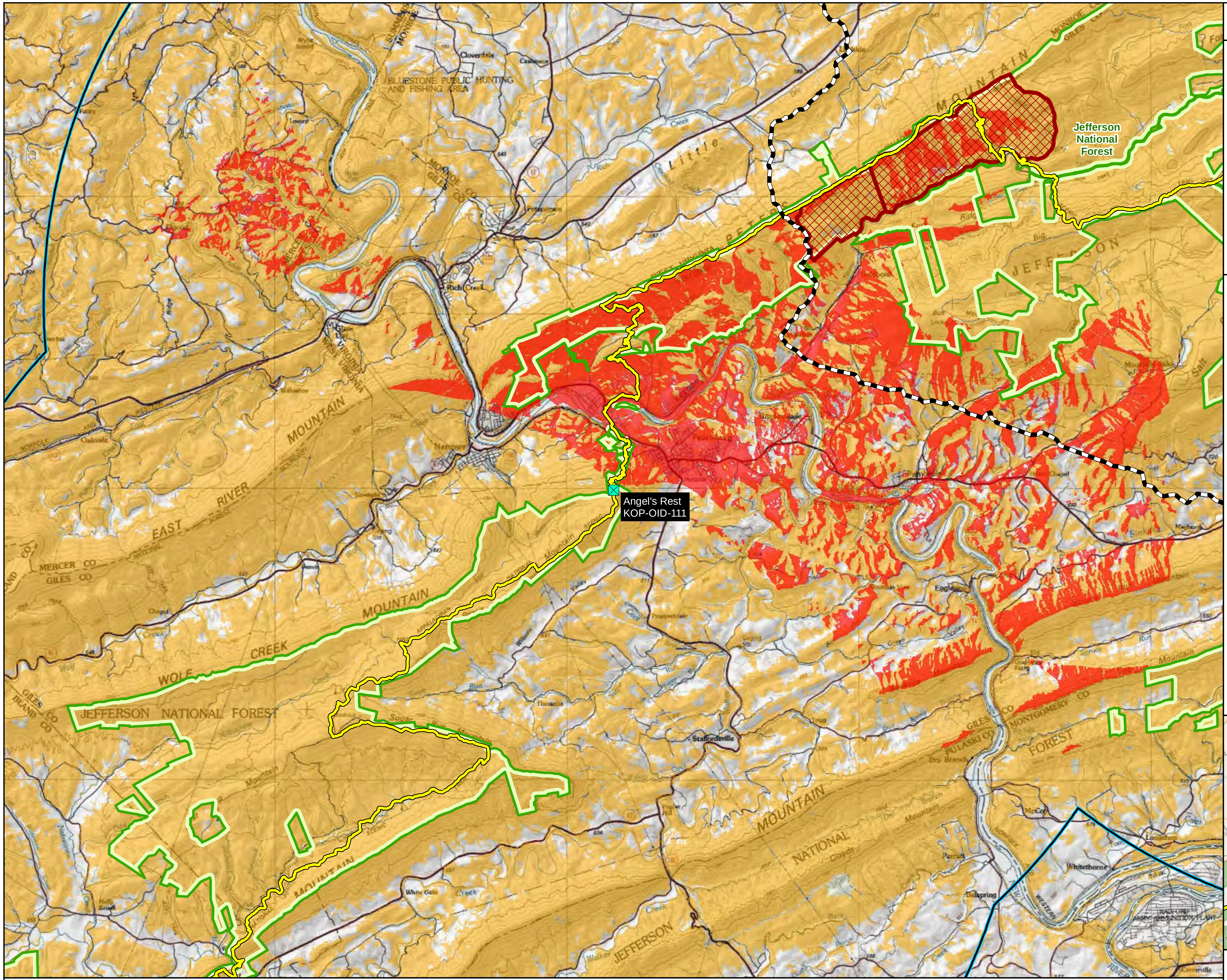



1:126,720 NAD 1983 UTM 17N 0 2 4 8 12 16 Miles

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed
## Appalachian National Scenic Trail

**Angel's Rest**
KOP-OID-111

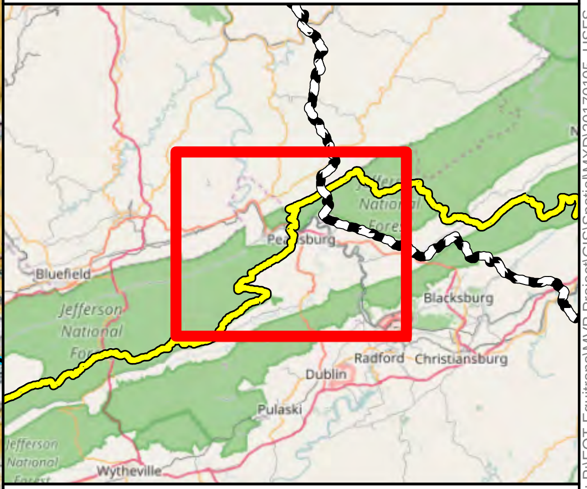
Page 2 of 14

**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 3

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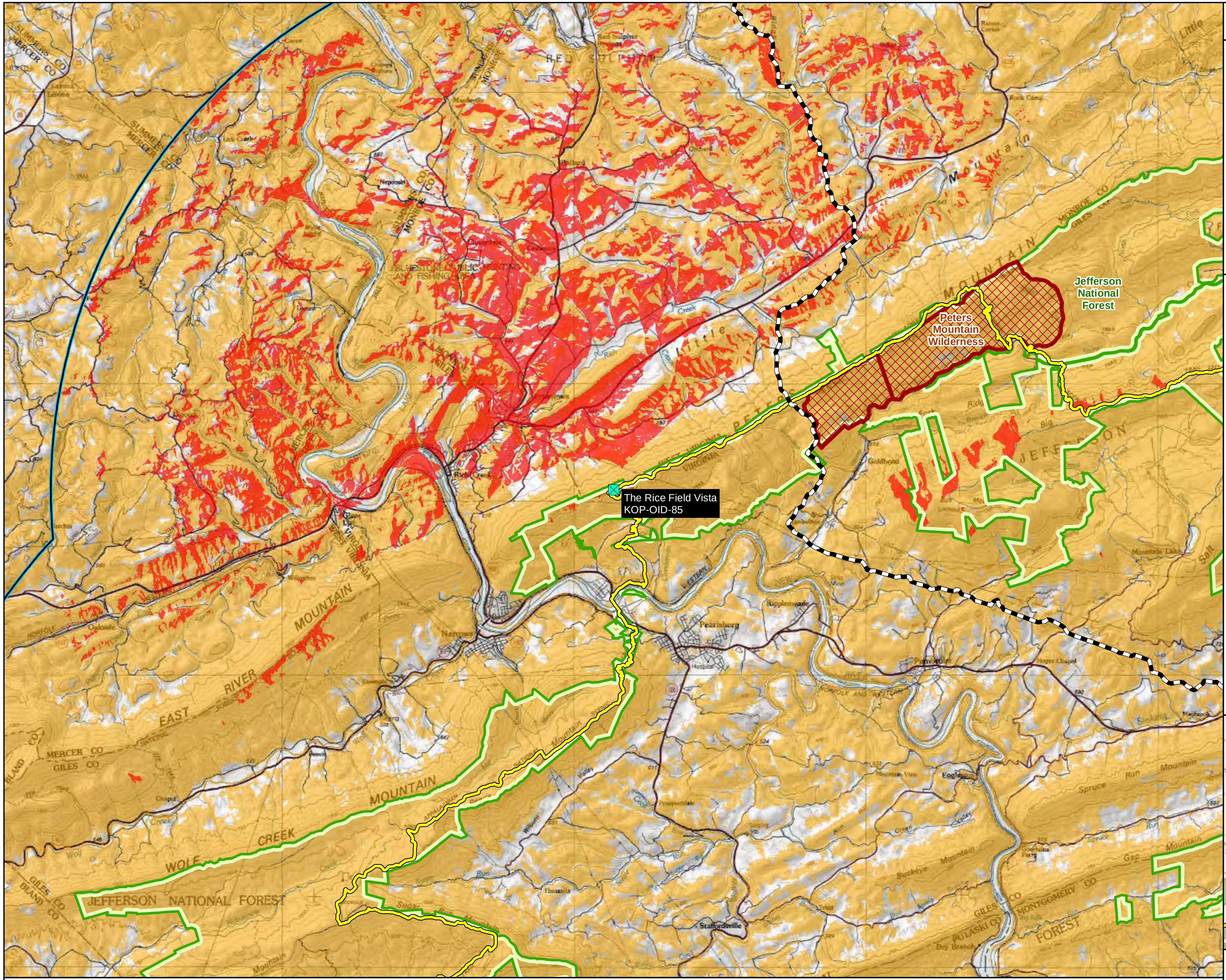



| | | | |
|---|---|---|---|
| N | 1:126,720 | NAD 1983 UTM 17N | 0 2 4 8 12 16 Miles |

## Mountain Valley Pipeline Project

Mountain Valley PIPELINE

**Bare Earth Viewshed**
**Appalachian National Scenic Trail**

**The Rice Field Vista**
KOP-OID-85

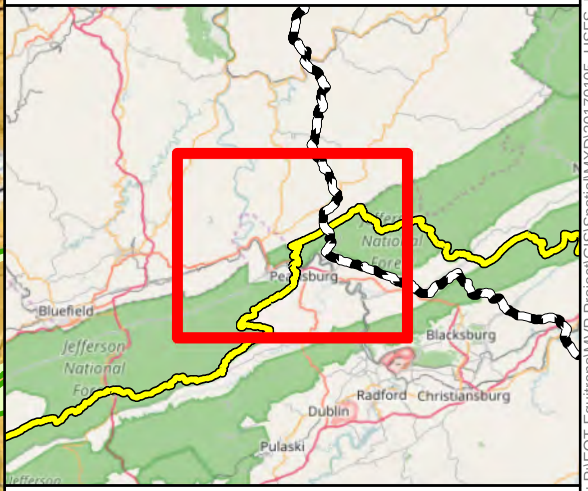


**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 4

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# Mountain Valley Pipeline Project

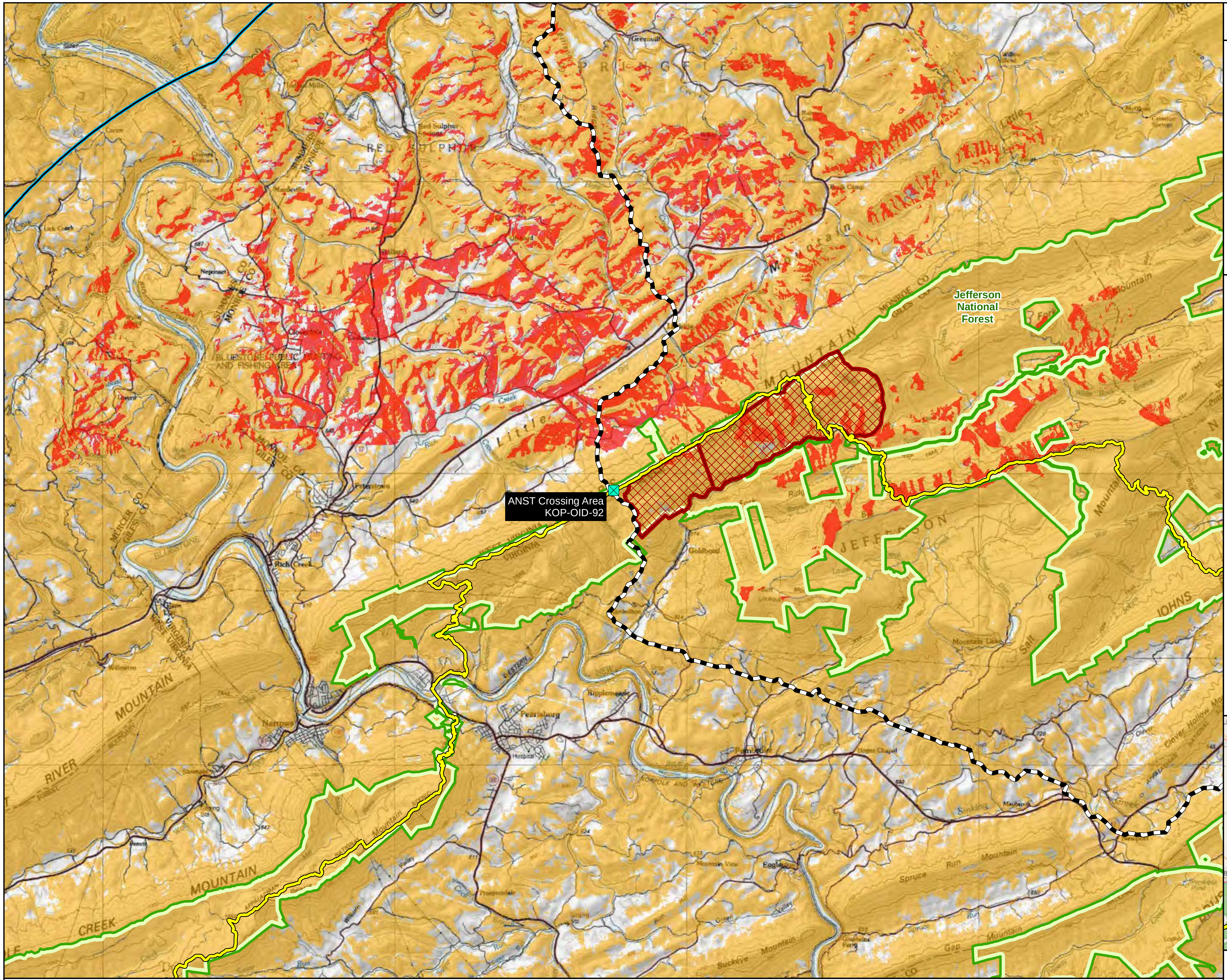
Mountain Valley PIPELINE

**Bare Earth Viewshed**
**Appalachian National Scenic Trail**

**ANST Crossing Area**
KOP-OID-92

Page 4 of 14

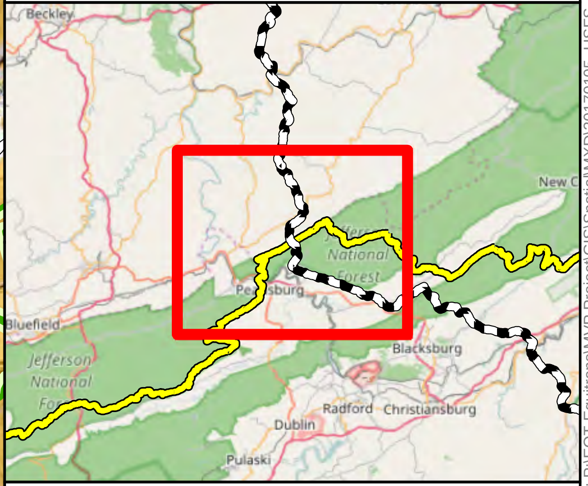
**JANUARY 2017**




**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

N 1:126,720 NAD 1983 UTM 17N 0 2 4 8 12 16 Miles

Figure 5

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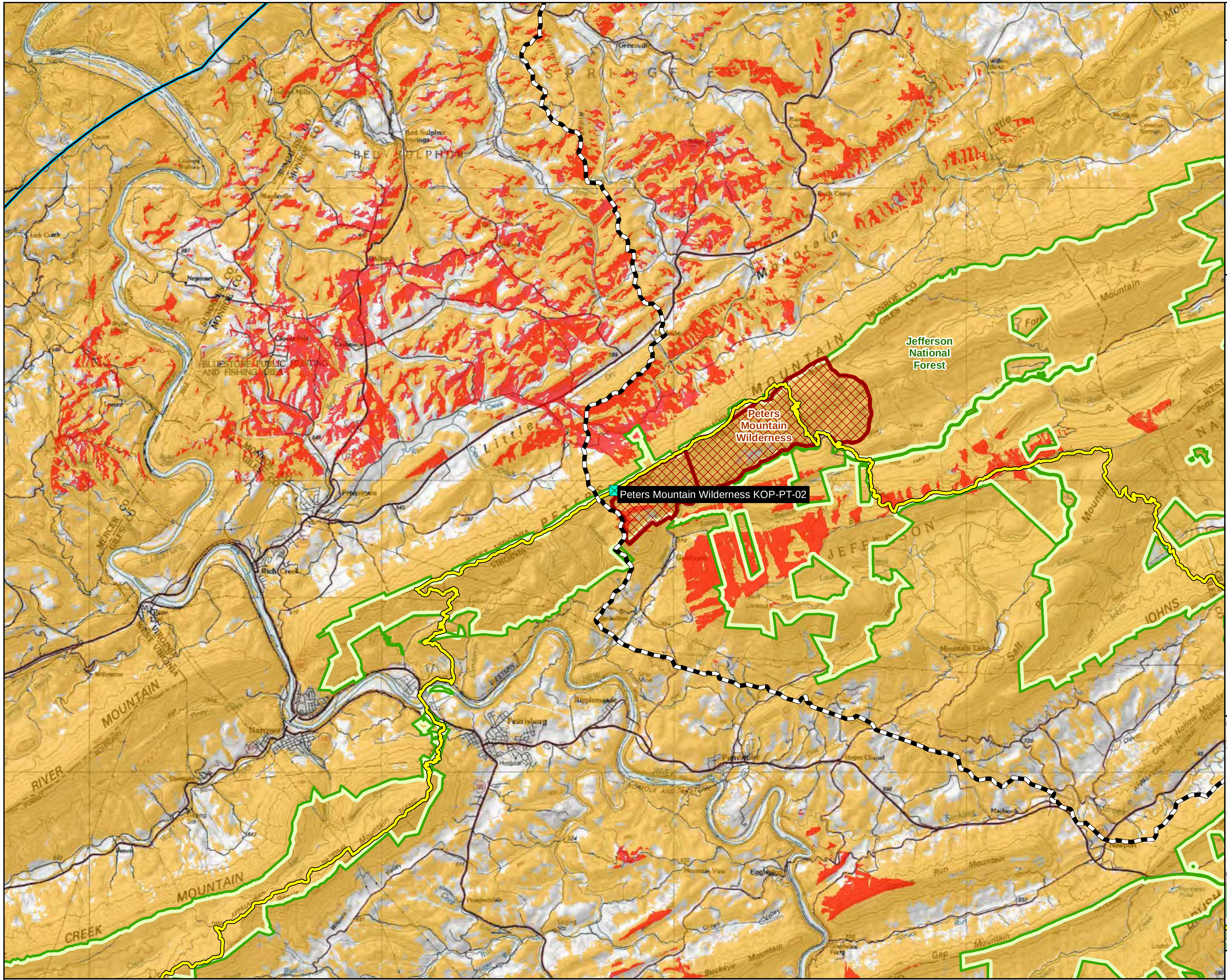



| N | 1:126,720 | NAD 1983 UTM 17N | 0 2 4 8 12 16 Miles |
|---|---|---|---|

## Mountain Valley Pipeline Project

Mountain Valley PIPELINE

### Bare Earth Viewshed Appalachian National Scenic Trail

**Peters Mountain Wilderness**
KOP-PT-02

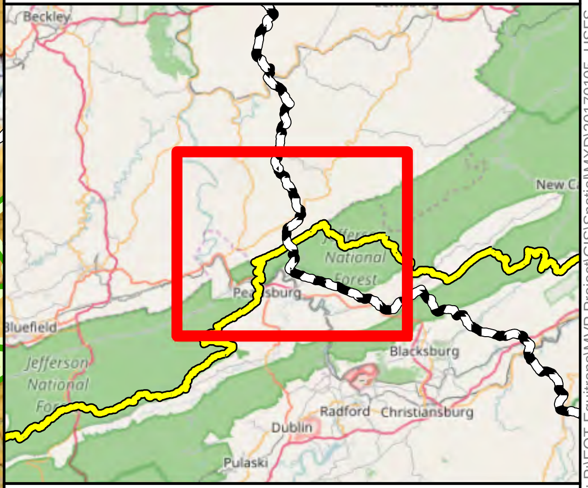
Page 5 of 14

**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

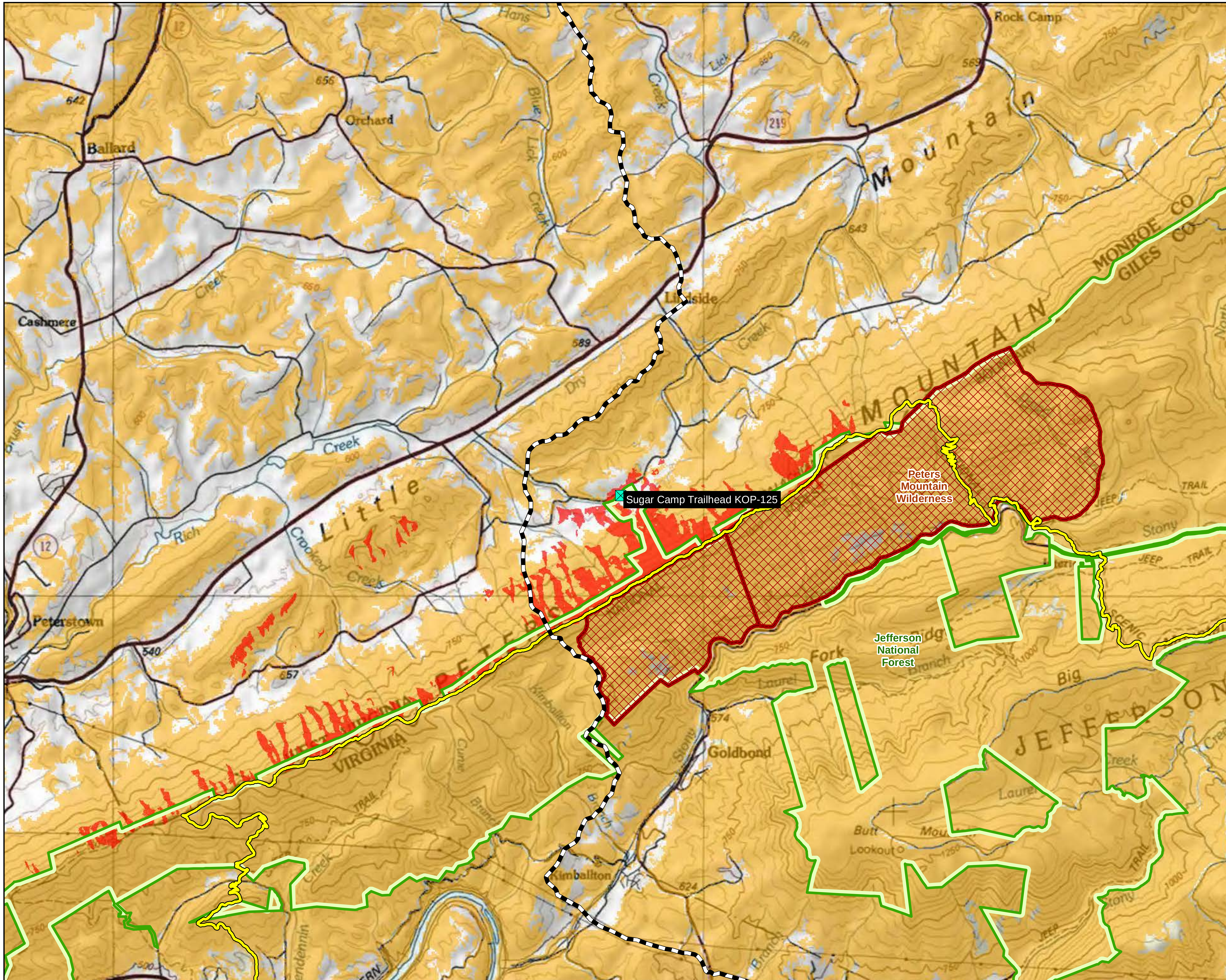
NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 6

Document Path: P:\EQT-Equitrans\MVP Project\GIS\Spatial\MXD\20170105_USFS_Updated_ANST_Viewsheds\USFS_ANST_KOPs_BareEarthViewsheds_20170118.mxd




# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed
## Appalachian National Scenic Trail

**Sugar Camp Trailhead**
KOP-125

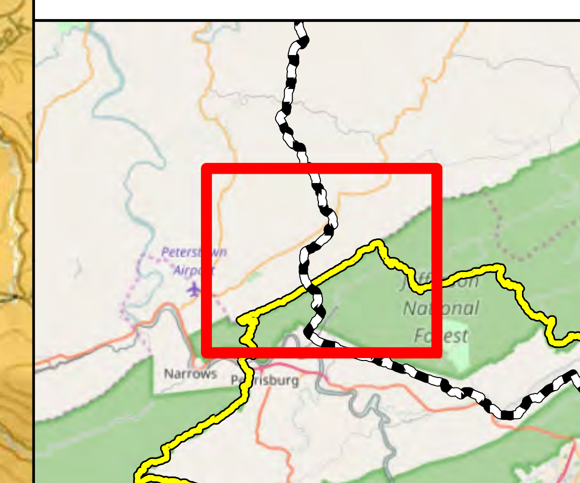
Page 6 of 14

**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

1:63,360 NAD 1983 UTM 17N 0 1 2 4 6 8 Miles

Figure 7

Document Path: P:\EQT-Equitrans\MVP Project\GIS\Spatial\MXD\20170105_USFS_Updated_ANST_Viewsheds\USFS_ANST_KOPs_BareEarthViewsheds_20170118.mxd

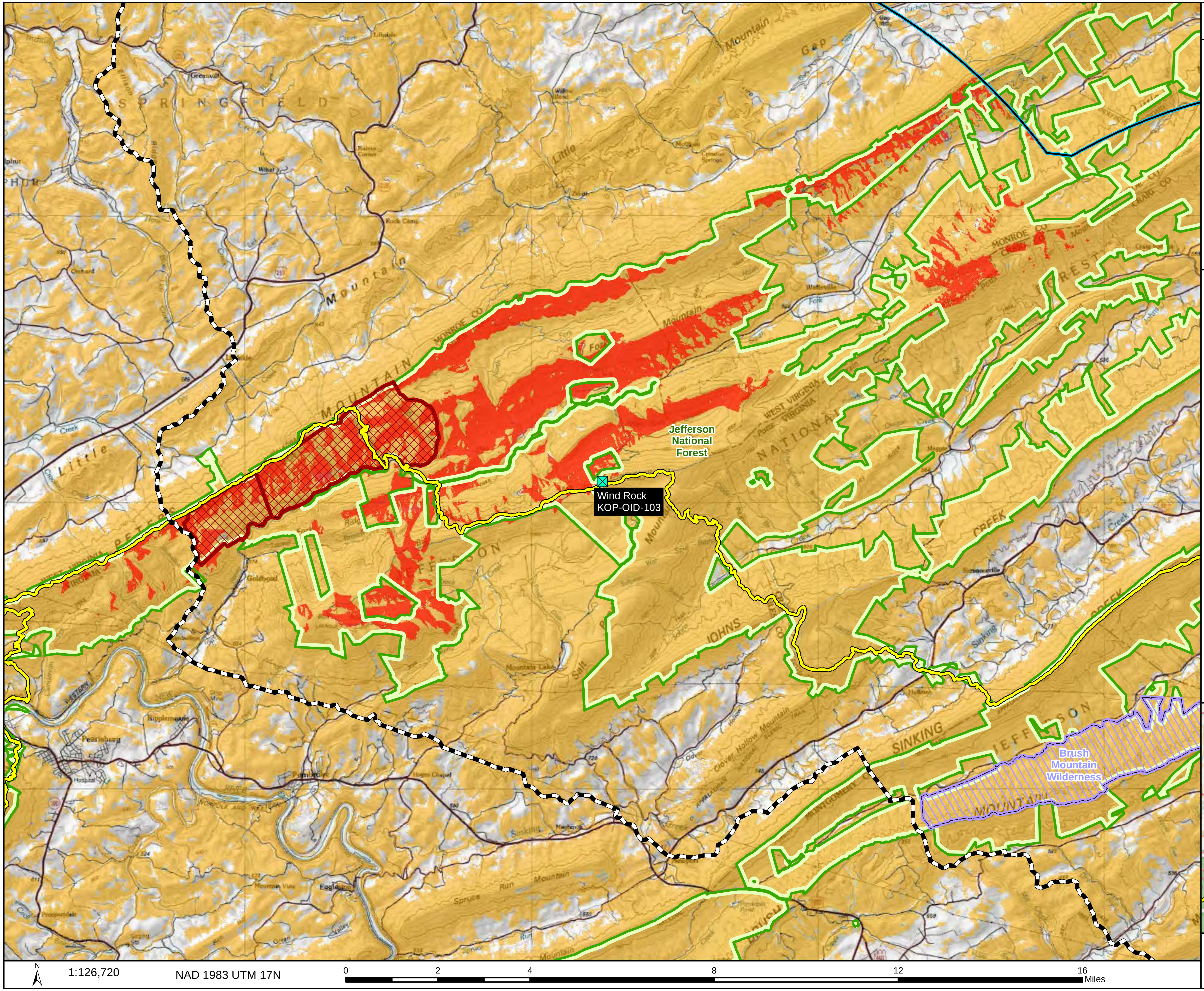
## Mountain Valley Pipeline Project

**Bare Earth Viewshed**
**Appalachian National Scenic Trail**

**Wind Rock**
KOP-OID-103

Page 7 of 14

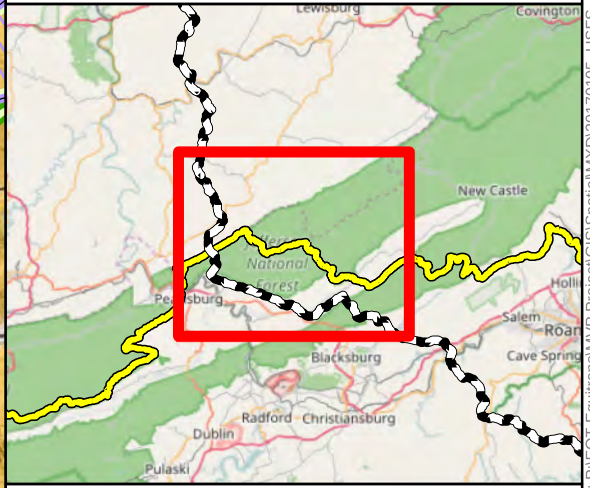
**JANUARY 2017**




**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.



Data Sources: NPS, USGS, NLCD

Figure 8

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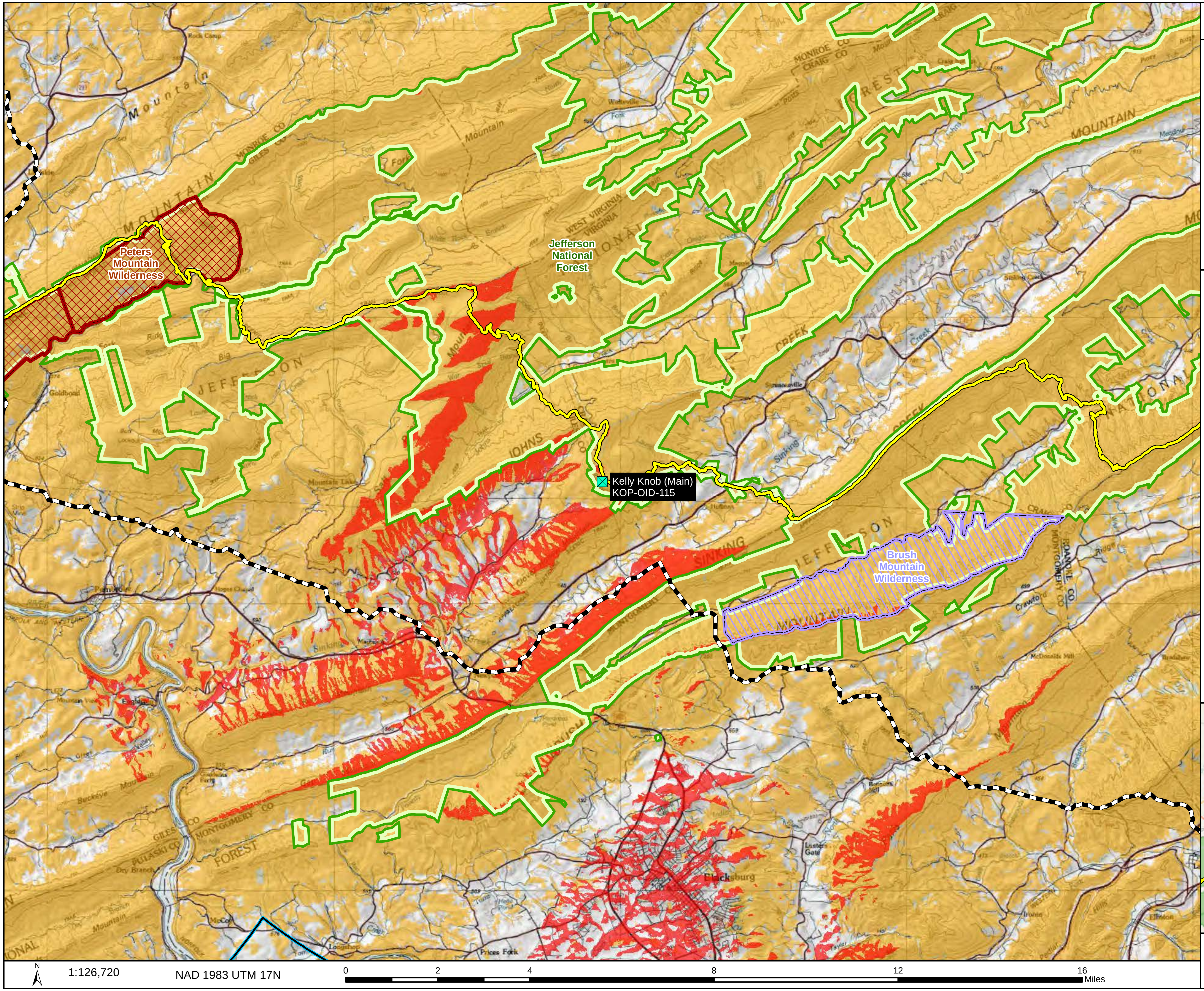



# Mountain Valley Pipeline Project

## Bare Earth Viewshed
## Appalachian National Scenic Trail

**Kelly Knob (Main)**
KOP-OID-115

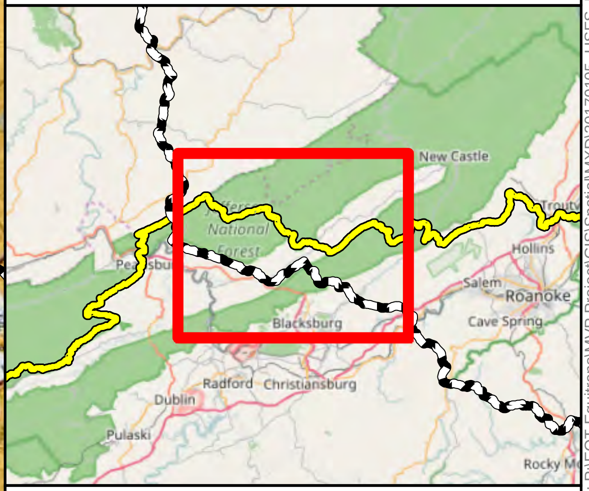
Page 8 of 14

**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 9

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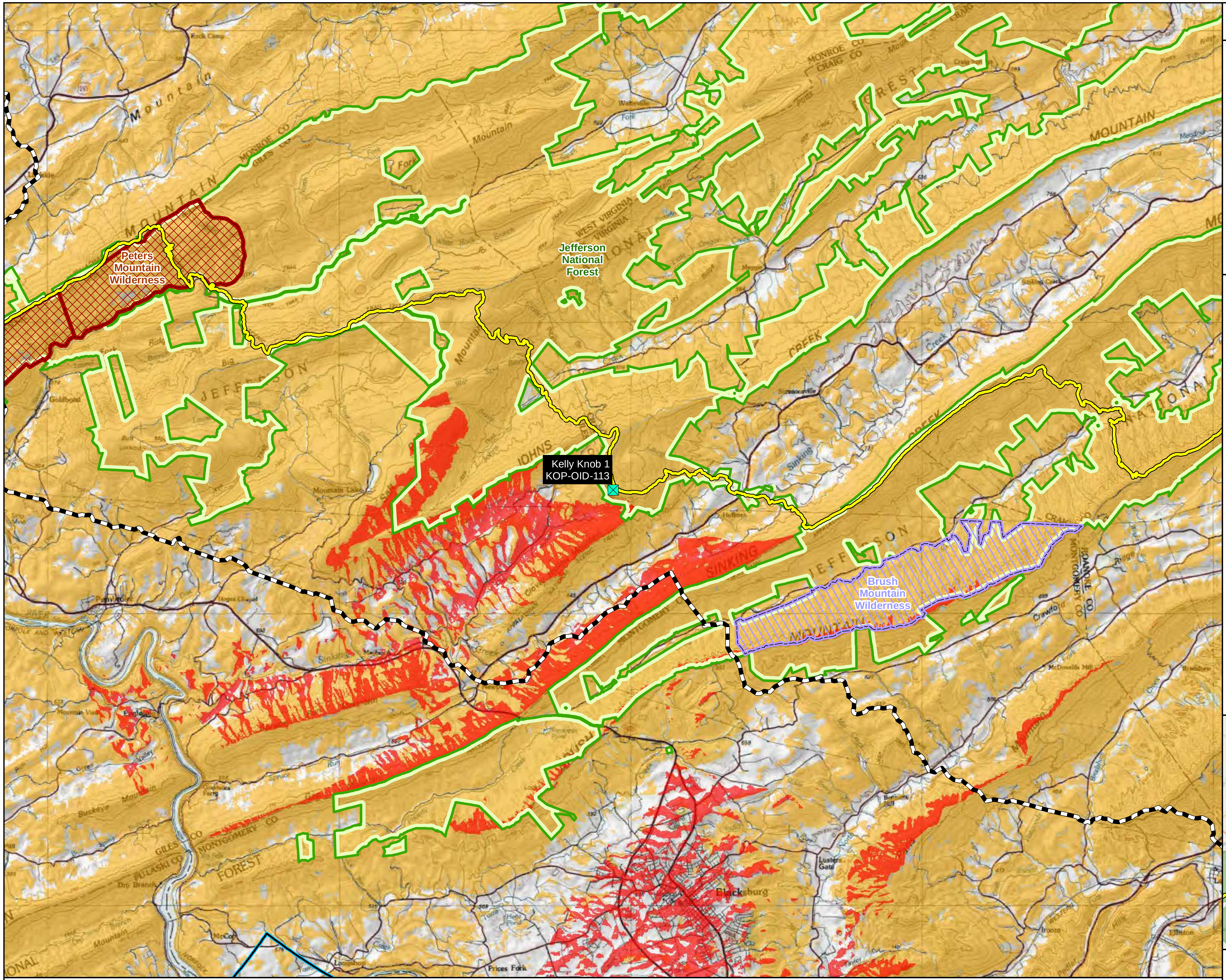



N

1:126,720

NAD 1983 UTM 17N

0 2 4 8 12 16 Miles

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed Appalachian National Scenic Trail

**Kelly Knob 1**
KOP-OID-113

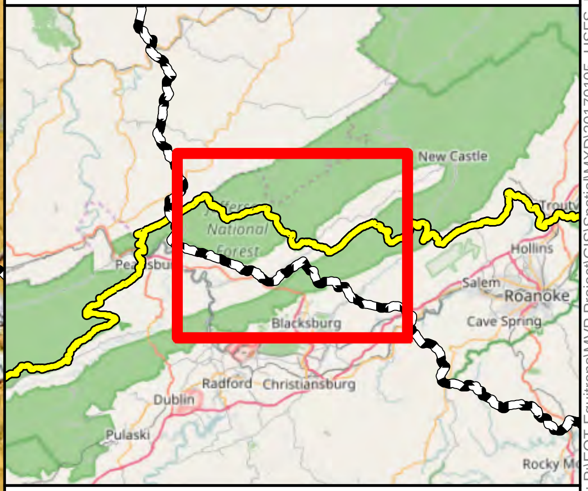


JANUARY 2017

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 10

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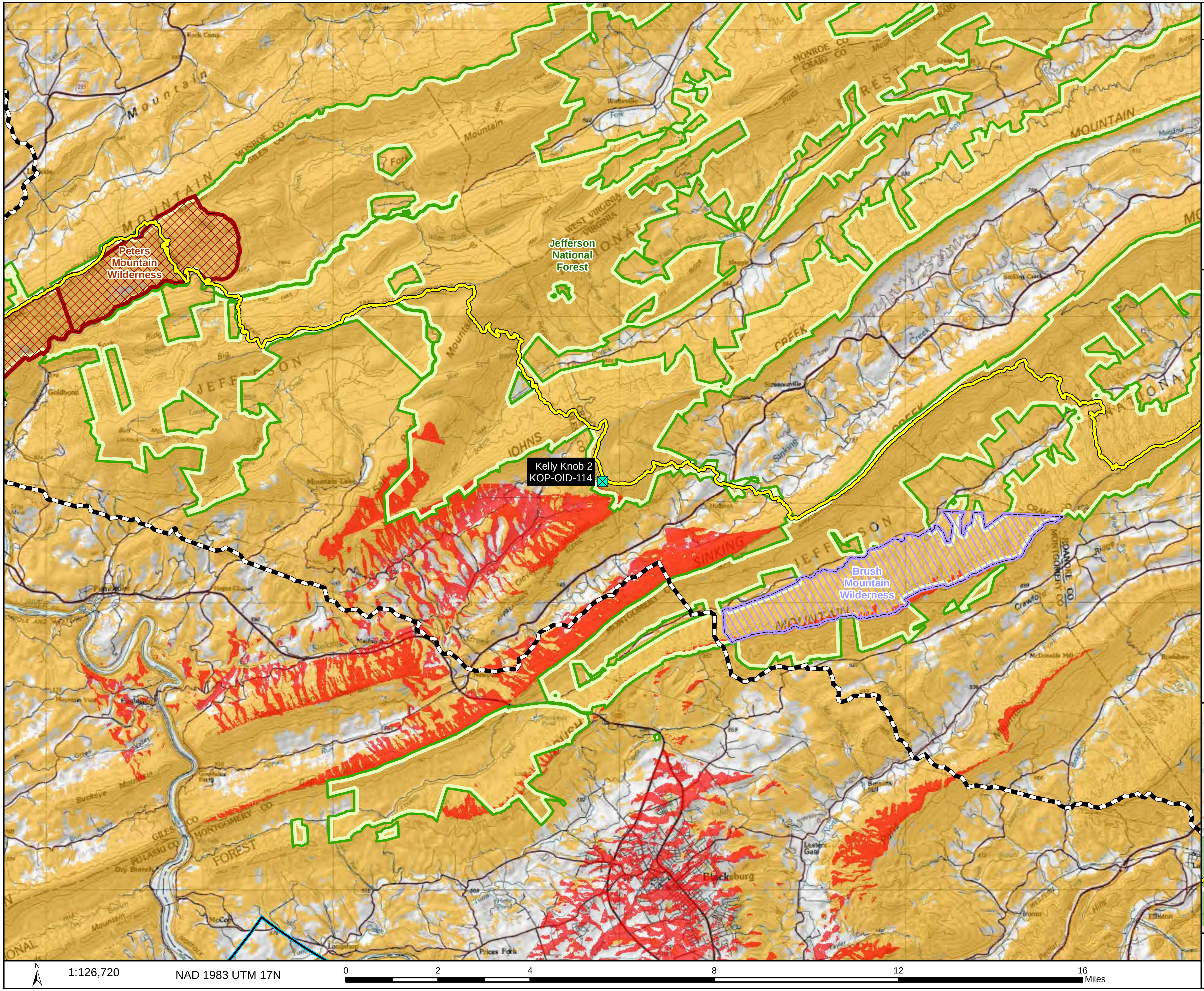



# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed Appalachian National Scenic Trail

**Kelly Knob 2**
KOP-OID-114

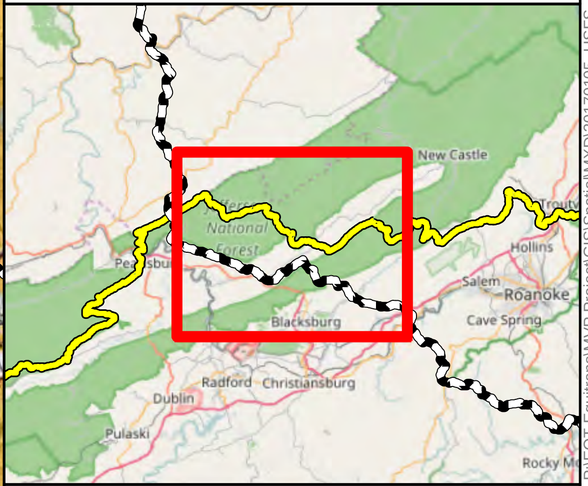


**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 11

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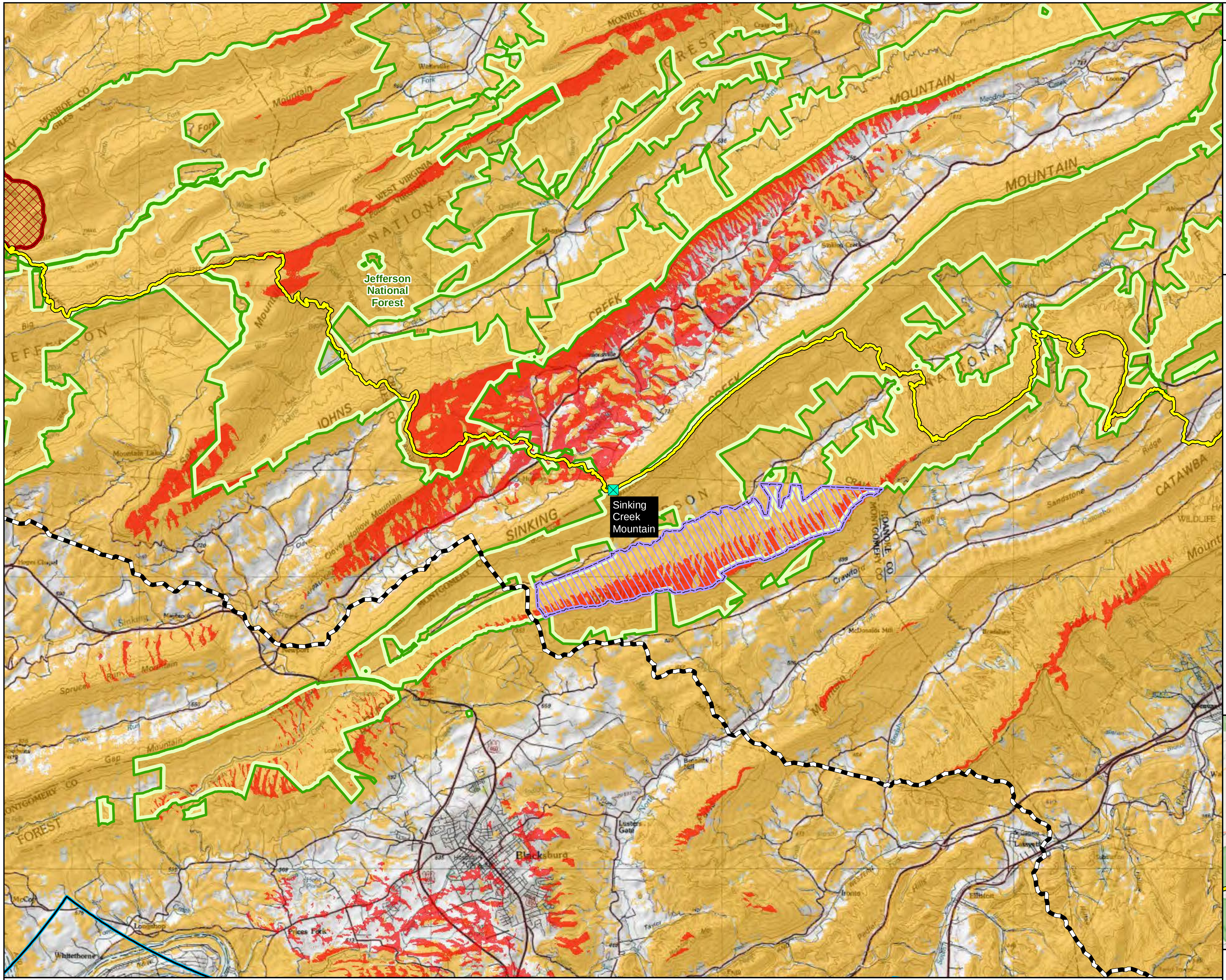



1:126,720

NAD 1983 UTM 17N

0 2 4 8 12 16 Miles

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed Appalachian National Scenic Trail

### Sinking Creek Mountain

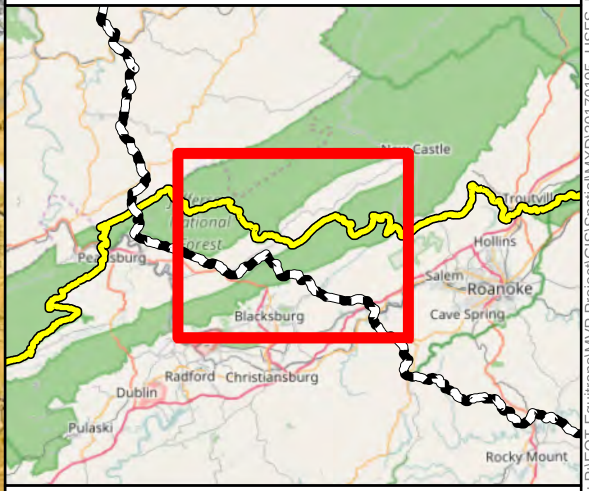


JANUARY 2017

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- Peters Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 12

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# Mountain Valley Pipeline Project

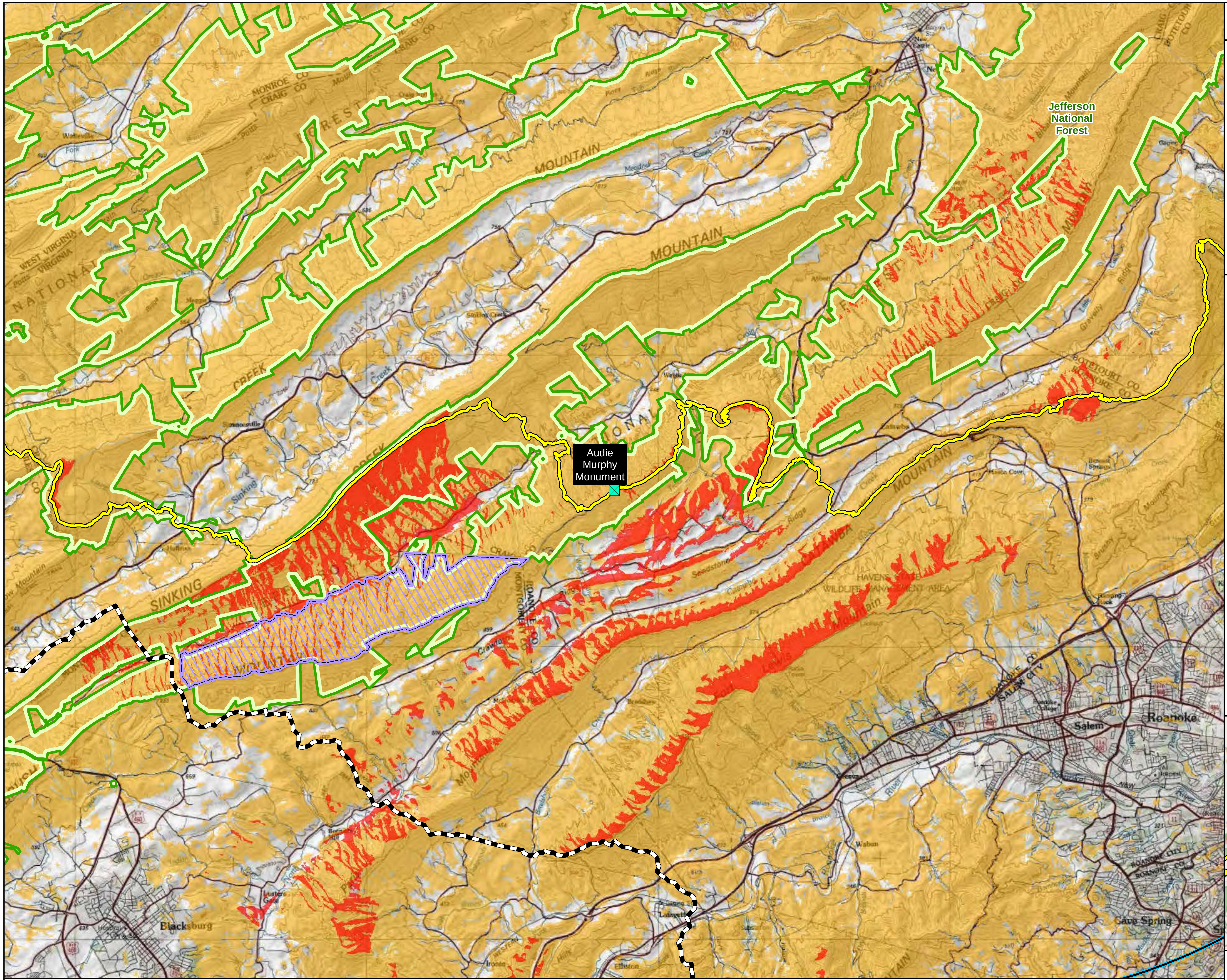
Mountain Valley PIPELINE

**Bare Earth Viewshed**
**Appalachian National Scenic Trail**

**Audie Murphy Monument**

Page 12 of 14

**JANUARY 2017**

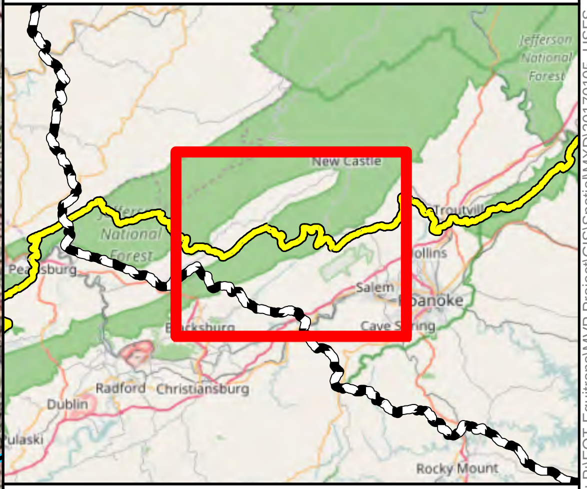



N
1:126,720
NAD 1983 UTM 17N
0 2 4 8 12 16 Miles

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.



Data Sources: NPS, USGS, NLCD

Figure 13

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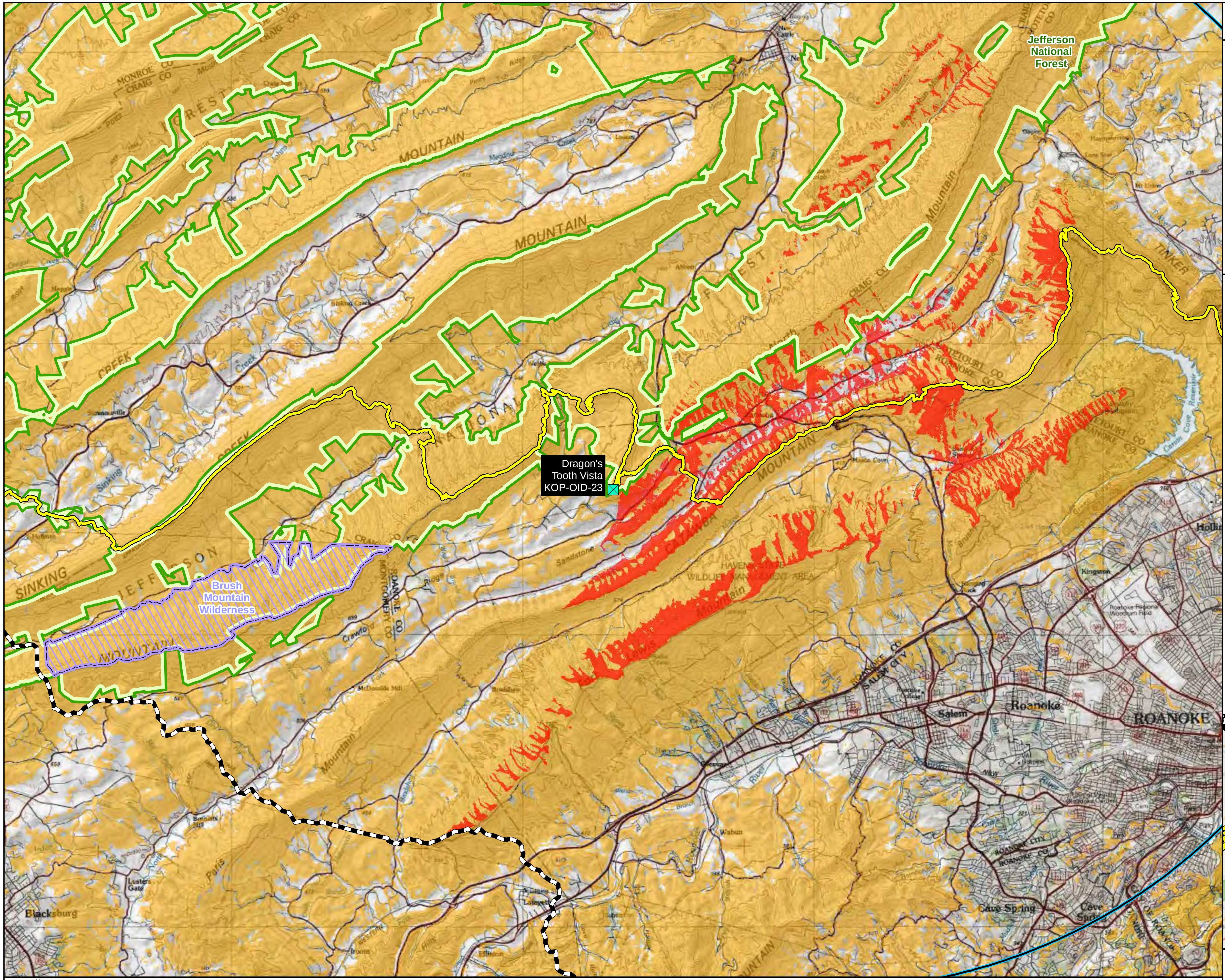



1:126,720

NAD 1983 UTM 17N

0 2 4 8 12 16 Miles

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed Appalachian National Scenic Trail

**Dragon's Tooth Vista**
KOP-OID-23

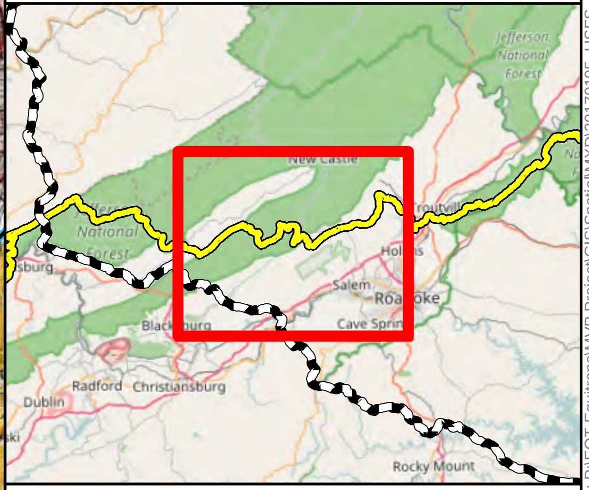


**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

# Figure 14

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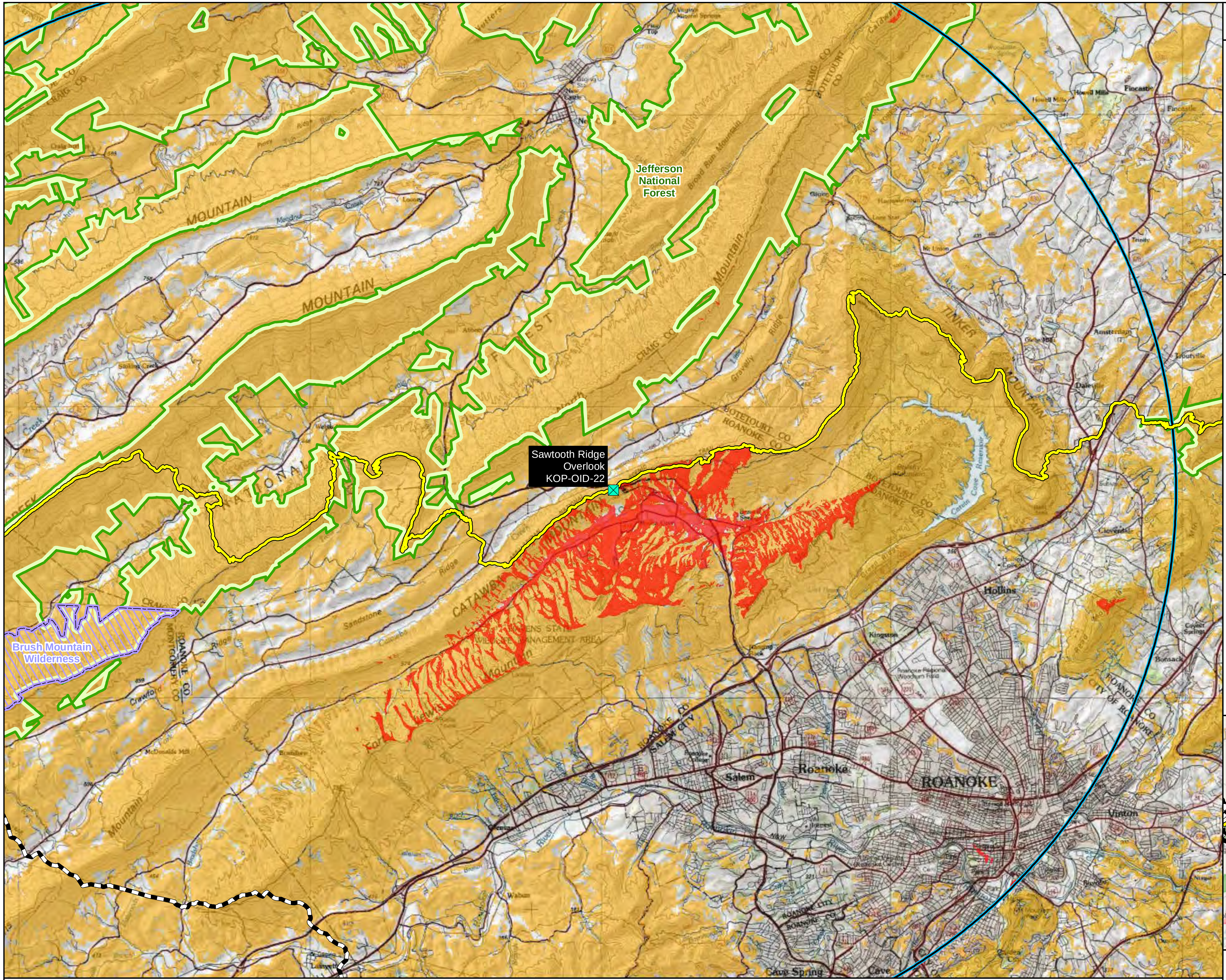



1:126,720

NAD 1983 UTM 17N

0 2 4 8 12 16 Miles

## Mountain Valley Pipeline Project

Mountain Valley PIPELINE

### Bare Earth Viewshed
### Appalachian National Scenic Trail

**Sawtooth Ridge Overlook**
KOP-OID-22

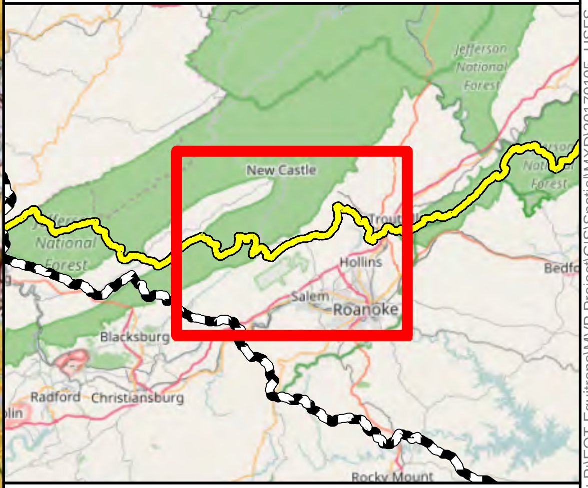
Page 14 of 14

**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Appalachian National Scenic Trail
- Combined Viewshed Extent (12 mi)
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- US National Forest Service Boundary
- Forested Area (NLCD)

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

Figure 15

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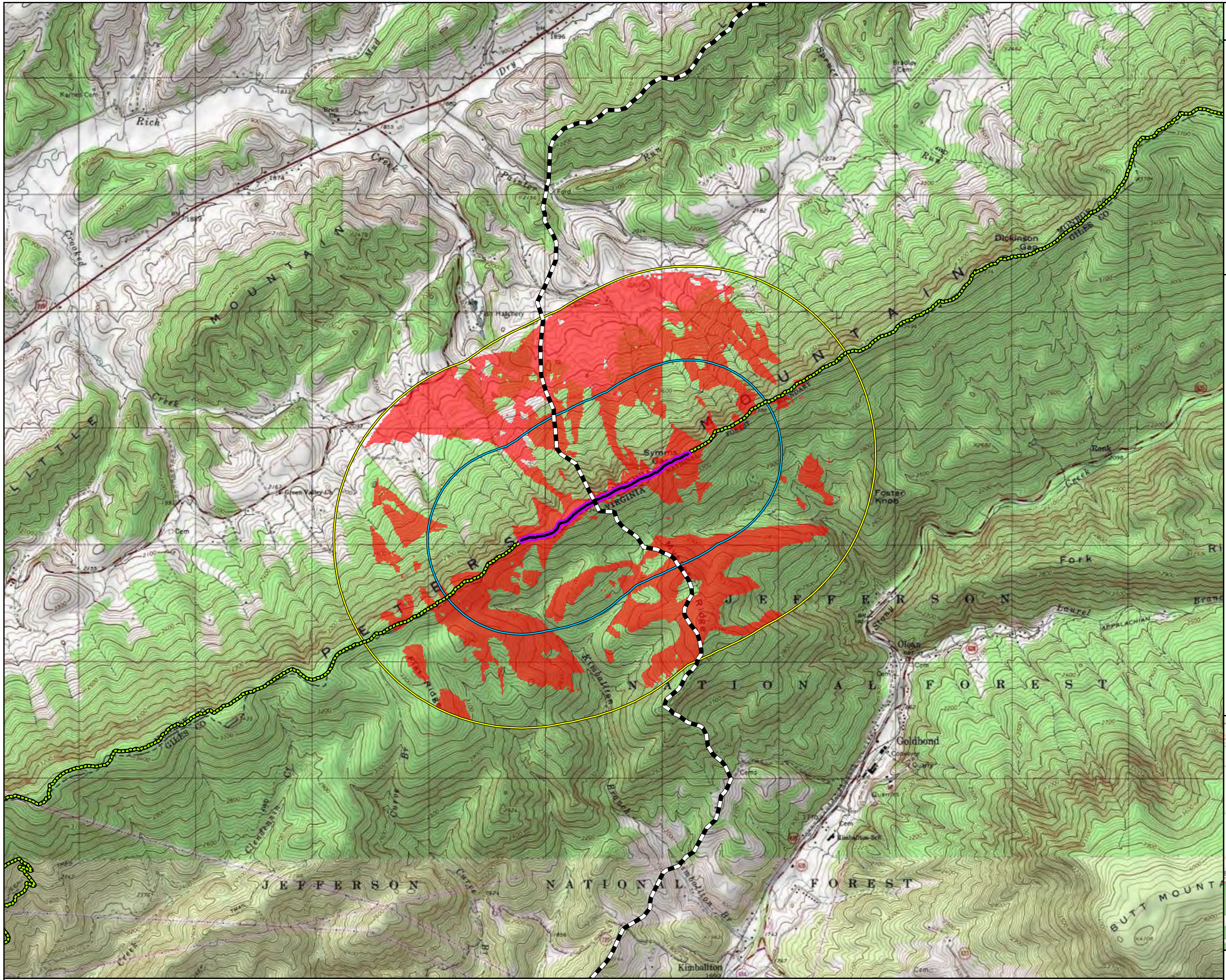



N

1:31,680

NAD 1983 UTM 17N

0 0.5 1 2 3 4 Miles

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed
## Appalachian National Scenic Trail

JANUARY 2017

**Legend**

- Viewer Location (Along Trail)
- Foreground Distance Zone (0.5mi)
- Viewshed Extent (1mi)
- Visible Area (Bare Earth Viewshed)
- October 2016 Proposed Route
- Appalachian National Scenic Trail

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity. Visibility verified during field data collection.


Data Sources: NPS, USGS

Figure 16

Document Path: P:\EQT-Equitrans\MVP Project\GIS\Spatial\MXD\20170105_USFS_Updated_ANST_Viewsheds\Oct2016ProposedRoute_ANST_1mi_Linear_Viewshed_20170109.mxd


# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

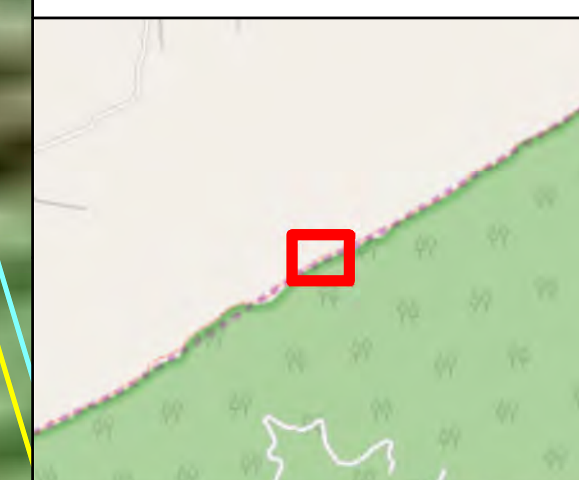
**Bare Earth Viewshed**
**Appalachian National Scenic Trail**

**JANUARY 2017**

**Legend**

- Viewer Location (Along Trail)
- Appalachian National Scenic Trail
- October 2016 Proposed Route
- Permanent Easement
- Temporary Workspace
- Bore Pit Location
- Visible Area (Bare Earth Viewshed)

NOTE: Viewshed does factor in obstructions in visibility caused by vegetation (40-ft tree height assumed). Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity. Visibility verified during field data collection.



Data Sources: NPS, USGS, NLCD

Figure 17

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# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

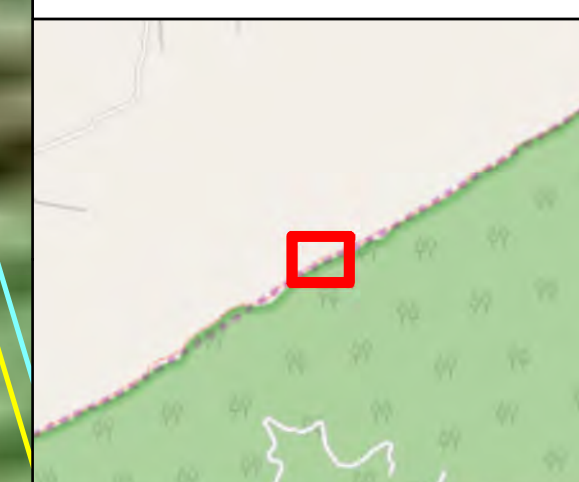
## Vegetation Modeled Viewshed Appalachian National Scenic Trail

JANUARY 2017

Legend

- Viewer Location (Along Trail)
- Appalachian National Scenic Trail
- October 2016 Proposed Route
- Permanent Easement
- Temporary Workspace
- Bore Pit Location
- Visible Area (Vegetation Viewshed)

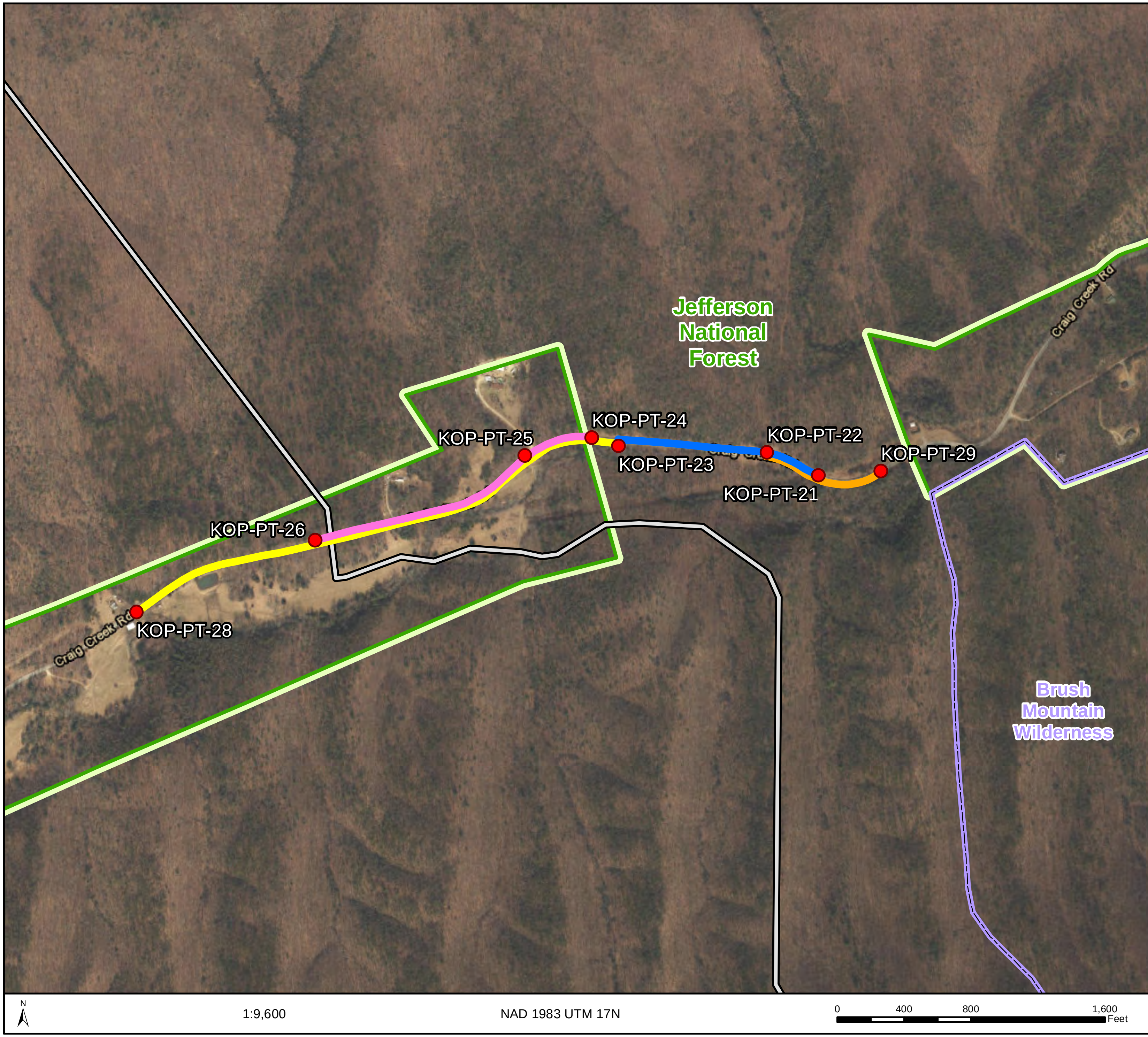
NOTE: Viewshed does factor in obstructions in visibility caused by vegetation (40-ft tree height assumed). Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity. Visibility verified during field data collection.



Data Sources: NPS, USGS, NLCD

Figure 18

Document Path: P:\EQT-Equitrans\MVP Project\GIS\Spatial\MXD\20170105_USFS_Updated_ANST_Viewsheds\ANST_BorePits_Linear_Vegetation_Viewshed_ZoomIn_20170109.mxd




**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

**Craig Creek Road Visibility**
**Jefferson National Forest**

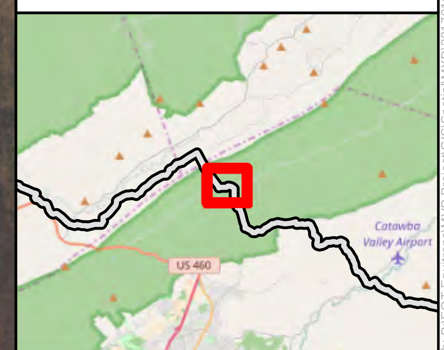
**JANUARY 2017**

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route

**Craig Creek Road Visibility**

- Eastbound 1
- Eastbound 2
- Westbound 1
- Westbound 2
- Brush Mountain Wilderness
- US National Forest Boundary




Data Sources: Appalachian Trail Conservancy, VA DCR, USDA, ESRI Streaming Data.

Figure 19

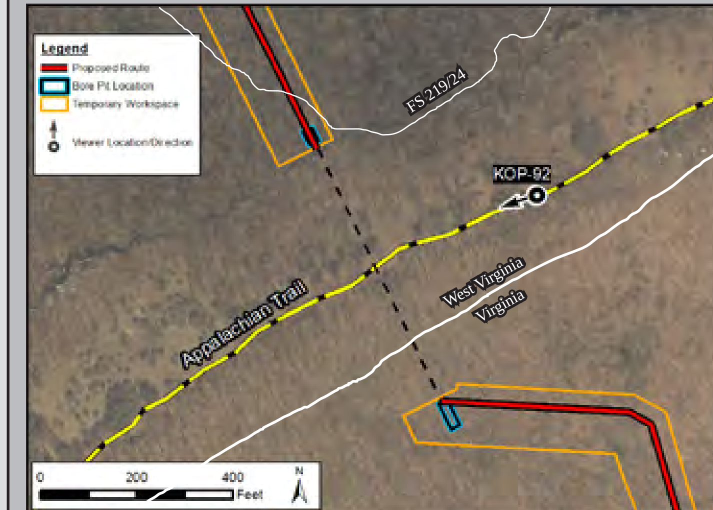
Document Path: P:\EQT-Equitrans\MVP Project\GIS\Spatial\MXD\20170105_USFS_Updated_ANST_Viewsheds\USFS_CraigCkRd_Visibility_20170111.mxd

# APPENDIX B

# SIMULATIONS AND PHOTOGRAPHY

Existing Condition

Post Construction (Leaf-off condition) - Viewers from KOP 92 may see some thinning of trees, depending on trees cleared at the time of construction. The white arrow indicates the location of the bore pit, which would be located approximately 49 feet below the ridgeline.




## Photograph Information

Time of photograph: 1:42 PM

Date of photograph: 12.2.2016

Weather condition: Partly sunny

Viewing direction: Southwest

Latitude: 37°24’10.95”N

Longitude: 80°41’19.74”W

Photo Location: Appalachian Trail corridor on Peters Mountain in West Virginia. Photo taken from a location adjacent to the pipeline crossing the trail. Photo illustrates “leaf-off” conditions.

# Mountain Valley Pipeline Project

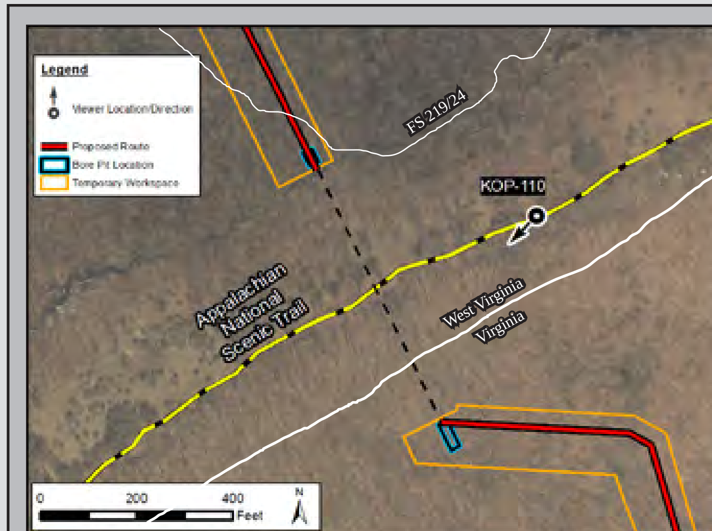
Key Observation Point 92

Mountain Valley    TETRA TECH

Figure 1

Existing Condition

Post Construction (Leaf-on condition) - From KOP 110, the project is not visible as the bore pit and pipeline are completely screened by terrain and vegetation. The red arrows indicate that the bore pits would be located to the north and south of the trail and would be completely screened by terrain and vegetation.




## Photograph Information

Time of photograph: 11:00 AM

Date of photograph: 8.6.2015

Weather condition: Mostly Sunny

Viewing direction: Southwest

Latitude: 37°24'10.89"N

Longitude: 80°41'19.73"W

Photo Location: Appalachian Trail corridor on Peters Mountain in West Virginia. Photo taken from a location adjacent to the pipeline crossing the trail. Photo illustrates "leaf-on" conditions.

# Mountain Valley Pipeline Project

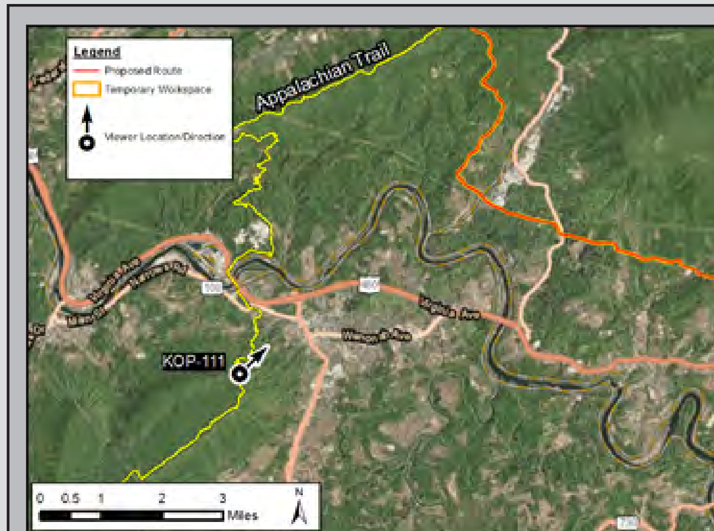
Key Observation Point 110

Mountain Valley    TETRA TECH

Figure 2

Existing Condition

Post Construction - The proposed pipeline would cross over Peters Mountain at a point approximately 6 miles northeast of the Angels Rest overlook. The red arrow indicates where the proposed pipeline would be visible crossing over Peters Mountain.




## Photograph Information

Time of photograph: 1:57 PM

Date of photograph: 12.20.2016

Weather condition: Sunny

Viewing direction: Northeast

Latitude: 37°19'3.46"N

Longitude: 80°45'20.84"W

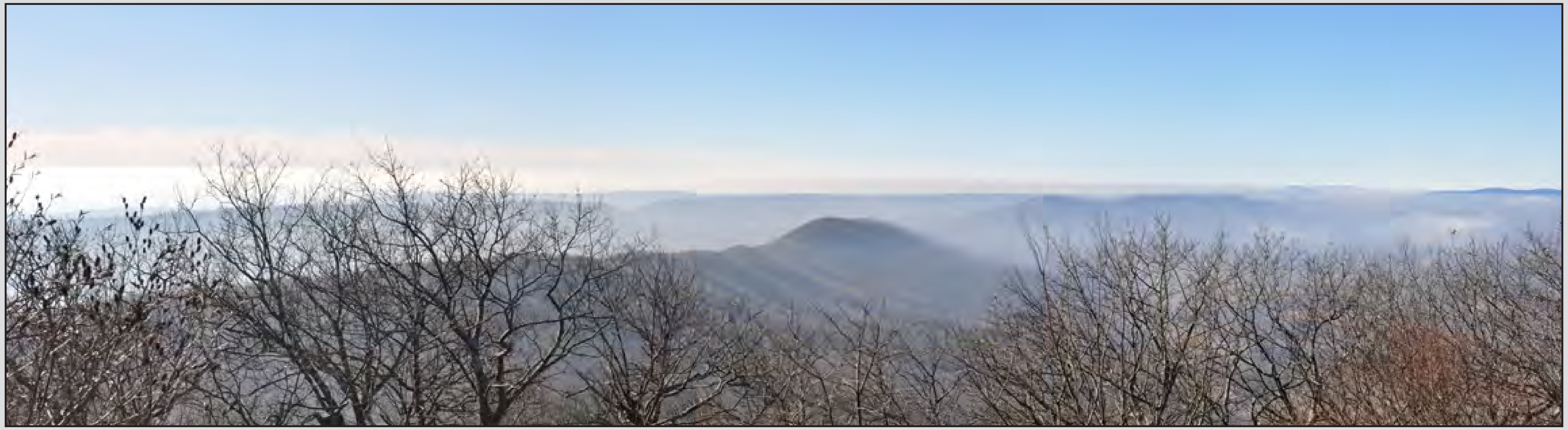
Photo Location: Photo taken from Appalachian Trail corridor at the Angels Rest overlook on Pearis Mountain in Virginia.

# Mountain Valley Pipeline Project

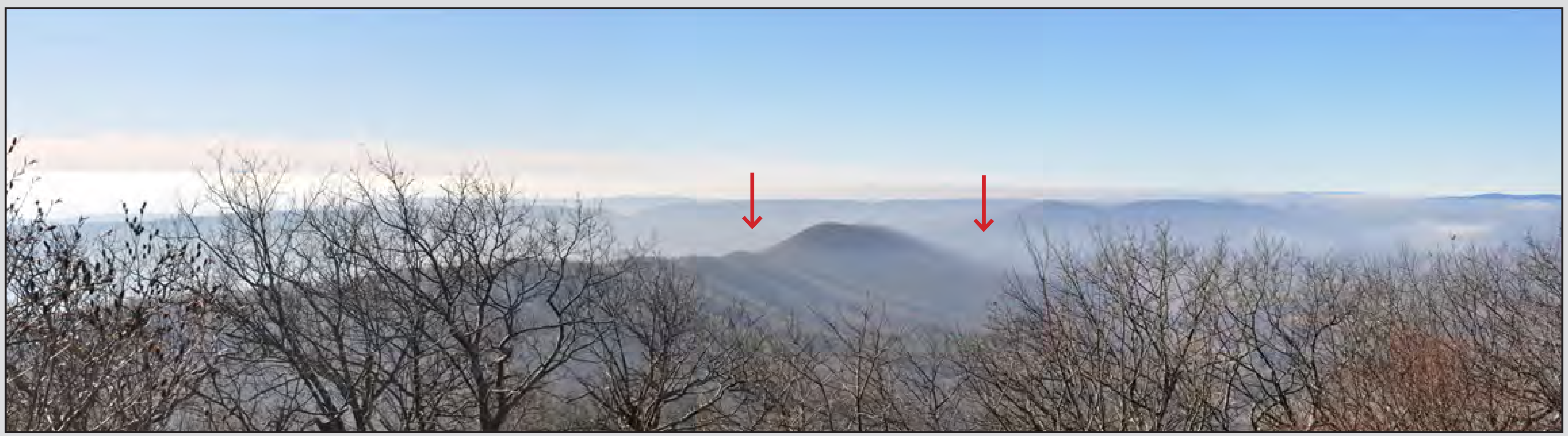
Key Observation Point 111

Mountain Valley    TETRA TECH

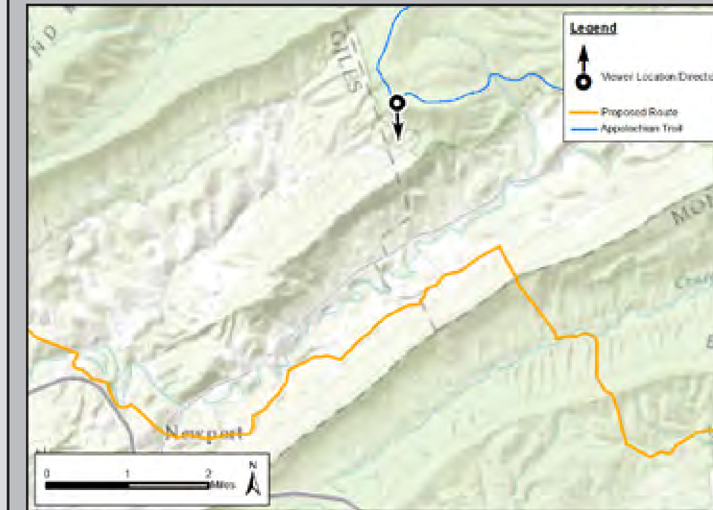
Figure 3



Existing Condition



Post Construction - The proposed pipeline would cross the valley south of Johns Creek Mountain and over Peters Mountain at a point approximately 2 miles southeast of the Kelly's Knob overlook. The red arrows indicate where the proposed pipeline would be visible crossing the valley. The proposed pipeline where is crosses over Peters Mountain is not visible from the overlook.




## Photograph Information

Time of photograph: 9:52 AM

Date of photograph: 12.20.2016

Weather condition: Sunny, foggy conditions in the valley

Viewing direction: South

Latitude: 37°21'20.14"N

Longitude: 80°26'29.96"W

Photo Location: Photo taken from the Appalachian Trail corridor at the Kelly's Knob overlook on Johns Creek Mountain in Virginia.

# Mountain Valley Pipeline Project

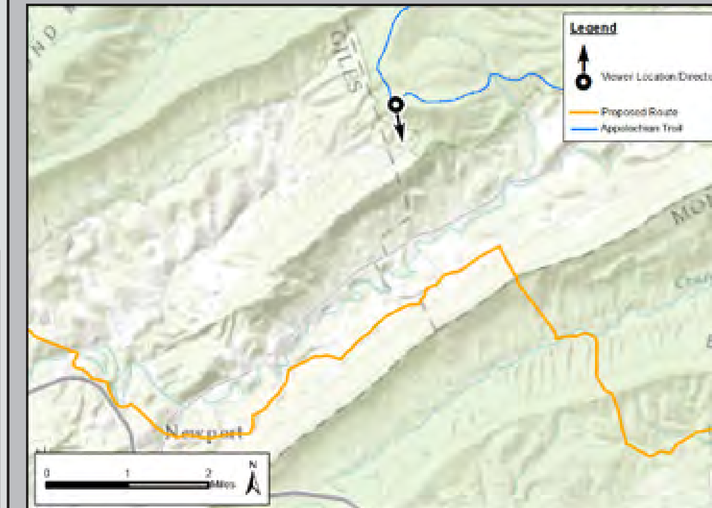
Key Observation Point 115

Mountain Valley

TETRA TECH

Existing Condition

Post Construction - The proposed pipeline would cross over Peters Mountain at a point approximately 2 miles southwest of the overlook near the campsite just east of the main Kelly's Knob overlook. The red arrow indicates where the proposed pipeline would be visible crossing Sinking Creek Mountain through trees in the foreground. The proposed pipeline where it crosses over Peters Mountain is not visible from this viewpoint




## Photograph Information

Time of photograph: 10:18 AM

Date of photograph: 12.20.2016

Weather condition: Sunny, foggy conditions in the valley

Viewing direction: South

Latitude: 37°21'19.57"N

Longitude: 80°26'29.01"W

Photo Location: Photo taken from the Appalachian Trail corridor near the campsite approximately 100 feet east of the Kelly's Knob overlook on Johns Creek Mountain in Virginia.

# Mountain Valley Pipeline Project

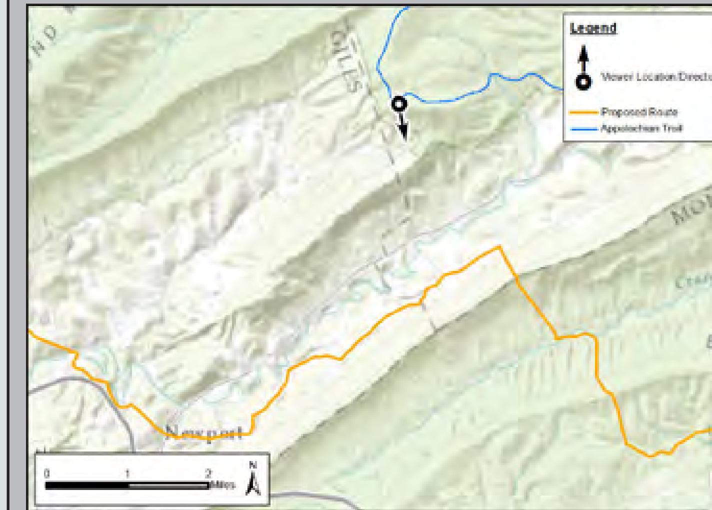
Key Observation Point 113

Mountain Valley TETRA TECH

Figure 5

Existing Condition

Post Construction - The proposed pipeline would cross along the base of Sinking Creek Mountain approximately 2.25 miles from an overlook located east of the Kelly's Knob overlook. The red arrow indicates where the proposed pipeline would be visible crossing in front of Sinking Creek Mountain. The proposed pipeline where it crosses over Peters Mountain is not visible from this viewpoint.




## Photograph Information

Time of photograph: 10:24 AM

Date of photograph: 12.20.2016

Weather condition: Sunny, foggy conditions within the valley

Viewing direction: South

Latitude: 37°21'19.57"N

Longitude: 80°26'29.01"W

Photo Location: Photo taken from the Appalachian Trail corridor approximately 180 feet east of the Kelly's Knob overlook on Johns Creek Mountain in Virginia.

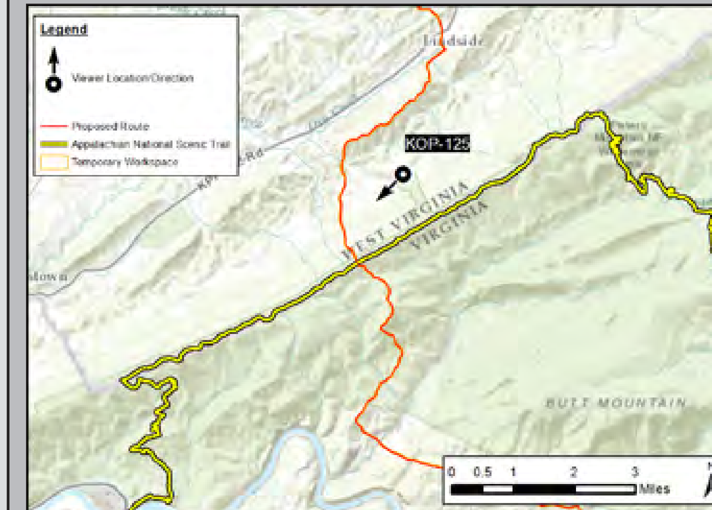
# Mountain Valley Pipeline Project

Key Observation Point 114

Mountain Valley    TETRA TECH

Existing Condition

Proposed Condition - Pipeline right-of-way crossing Peters Mountain




## Photograph Information

Time of photograph: 3:37 PM

Date of photograph: 8.5.2015

Weather condition: Mostly Sunny

Viewing direction: Southwest

Latitude: 37°25'24.73"N

Longitude: 80°40'35.06"W

Photo Location: Sugar Camp Farm Trailhead, Monroe County, West Virginia. Photo taken from the trailhead located approximately 2 miles south of Lindside, West Virginia off of Forest Service Road 219/24.

# Mountain Valley Pipeline Project

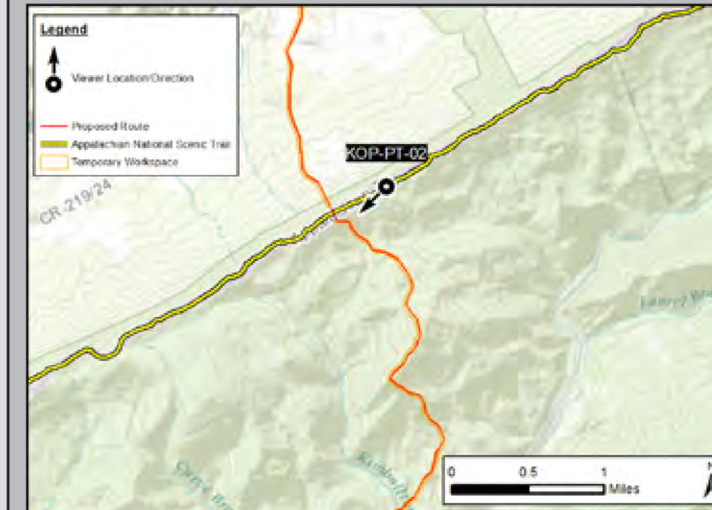
Key Observation Point 125

Mountain Valley TETRA TECH

Figure 7

Existing Condition

Post Construction - The proposed pipeline would cross the Appalachian Trail approximately 0.4 mile southwest from the Peters Mountain Wilderness boundary. From KOP PT-02, the project is not visible as the bore pit and pipeline are completely screened by terrain and vegetation. The red arrow indicates approximately where the proposed pipeline would be located in the distance. The pipeline would be completely screened by terrain and vegetation.




## Photograph Information

Time of photograph: 1:04 PM

Date of photograph: 12.19.2016

Weather condition: Overcast

Viewing direction: Southwest

Latitude: 37° 24' 18.40" N

Longitude: 80° 41' 0.77" W

Photo Location: Photo taken from the Appalachian Trail corridor at the edge of the Peters Mountain Wilderness boundary, approximately 1 mile southwest of the Sugar Trail Camp Trailhead in West Virginia.

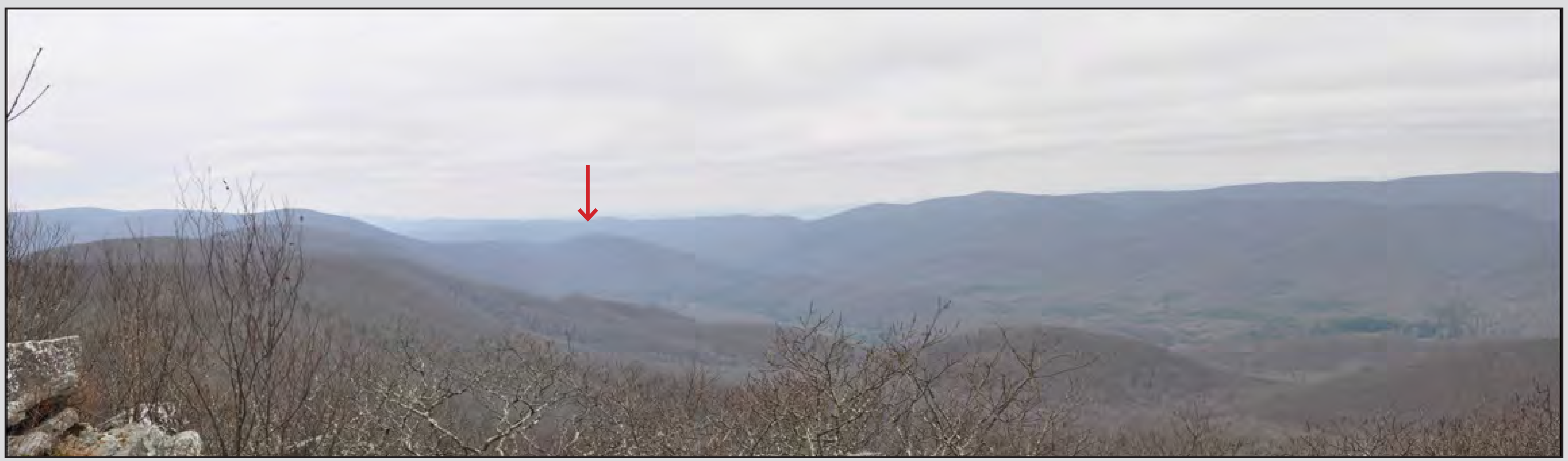
# Mountain Valley Pipeline Project

Key Observation Point PT-02

Mountain Valley TETRA TECH

Figure 8

Existing Condition



Post Construction - The proposed pipeline would cross over Peters Mountain approximately 7 miles from the Wind Rock overlook. The red arrow indicates where the proposed pipeline would be visible crossing over Peters Mountain.


## Photograph Information

Time of photograph: 2:44 PM

Date of photograph: 12.3.2016

Weather condition: Overcast, hazy

Viewing direction: Southwest

Latitude: 37° 24' 51.08" N

Longitude: 80° 31' 9.58" W

Photo Location: Photo taken from the Appalachian Trail corridor from the Windy Rock overlook on Salt Pond Mountain in Virginia.

# Mountain Valley Pipeline Project

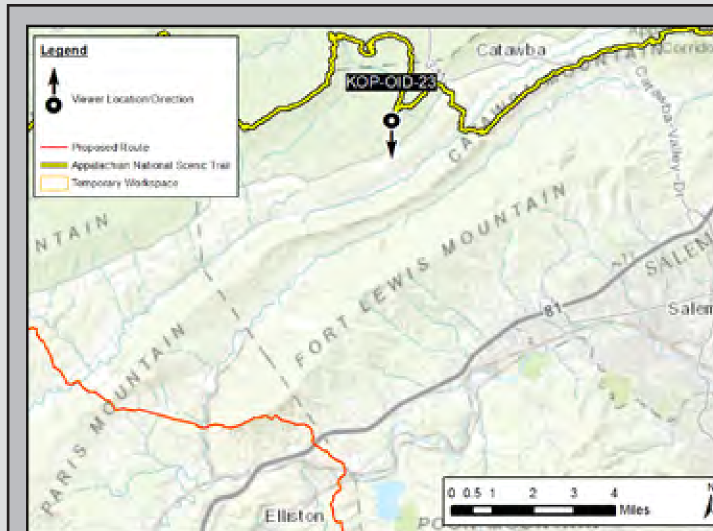
Key Observation Point 103

Mountain Valley    TETRA TECH

Figure 9

Existing Condition

Post Construction - The proposed pipeline would cross over Fort Lewis Mountain approximately 7.8 miles from the Dragon's Tooth Vista. From KOP 23, views toward the project would be screened by vegetation. The red arrow indicates approximately where the proposed pipeline would cross Fort Lewis Mountain in the distance. The proposed pipeline would be completely screened by vegetation and terrain.




## Photograph Information

Time of photograph: 1:29 PM

Date of photograph: 12.5.2016

Weather condition: Overcast, hazy

Viewing direction: South

Latitude: 37°21'38.25"N

Longitude: 80°10'24.83"W

Photo Location: Photo taken from the Appalachian Trail corridor from the Dragon's Tooth Vista on North Mountain in Virginia.

# Mountain Valley Pipeline Project

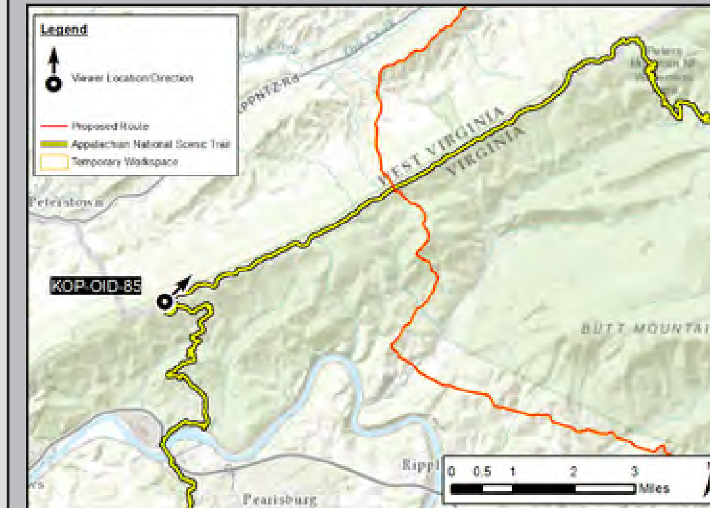
Key Observation Point 23

Mountain Valley TETRA TECH

Figure 10

Existing Condition

Post Construction - The proposed pipeline would cross over Peters Mountain approximately 4.2 miles from the Rice Field Vista. The red arrow indicates where the proposed pipeline would be visible crossing over Little Mountain. Views of the pipeline crossing Peters Mountain would be screened.




## Photograph Information

Time of photograph: 2:48 PM

Date of photograph: 12.5.2016

Weather condition: Overcast, hazy

Viewing direction: Northeast

Latitude: 37°22’32.34”N

Longitude: 80°45’30.29”W

Photo Location: Photo taken from the Appalachian Trail corridor from the Rice Field Vista on Peters Mountain on the border of Virginia and West Virginia.

# Mountain Valley Pipeline Project

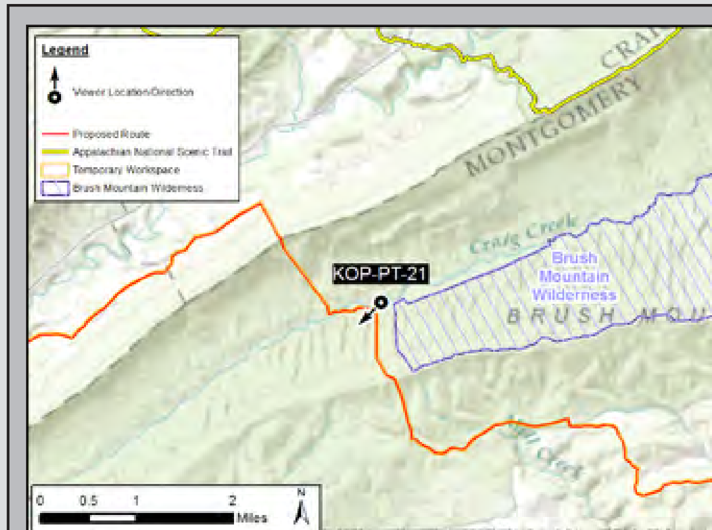
Key Observation Point 85

Mountain Valley TETRA TECH

Figure 11

Existing Condition

Post Construction - The proposed pipeline crossing Sinking Creek Mountain and the adjacent valley would be screened by vegetation. The yellow arrow indicates approximately where the proposed pipeline would be located crossing over Brush Mountain. Views would be completely screened by terrain and vegetation.




## Photograph Information

Time of photograph: 9:14 AM

Date of photograph: 12.21.2016

Weather condition: Mostly Sunny

Viewing direction: Southwest

Latitude: 37°18’53.51”N

Longitude: 80°23’47.44”W

Photo Location: Photo taken from Craig Creek Road approximately 4.1 miles northeast of Highway 460 in Virginia.

# Mountain Valley Pipeline Project

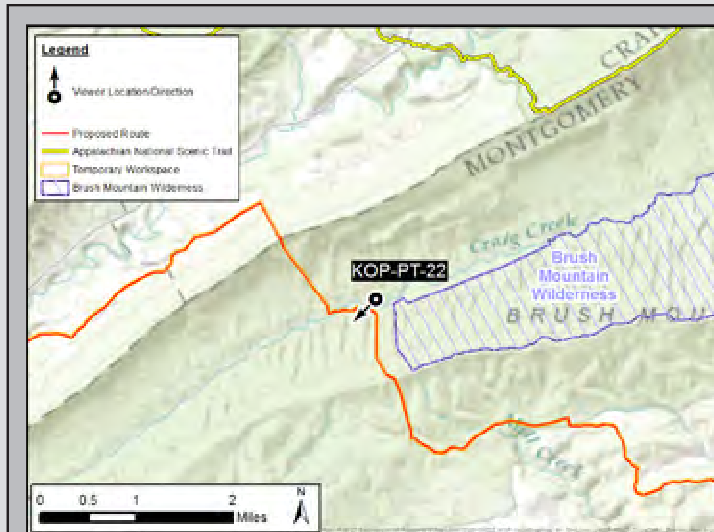
Craig Creek Road KOP PT-21

Mountain Valley    TETRA TECH

Figure 12

Existing Condition

Post Construction - The proposed pipeline crossing Sinking Creek Mountain and the adjacent valley would be screened by vegetation. The yellow arrow indicates approximately where the proposed pipeline would be located crossing Brush Mountain. The red arrow indicates where the pipeline would cross Gap Mountain. Both crossings would be completely screened by terrain and vegetation.




## Photograph Information

Time of photograph: 9:21 AM

Date of photograph: 12.21.2016

Weather condition: Mostly Sunny

Viewing direction: Southwest

Latitude: 37°18'54.90"N

Longitude: 80°23'51.25"W

Photo Location: Photo taken from Craig Creek Road approximately 4 miles northeast of Highway 460 in Virginia.

# Mountain Valley Pipeline Project

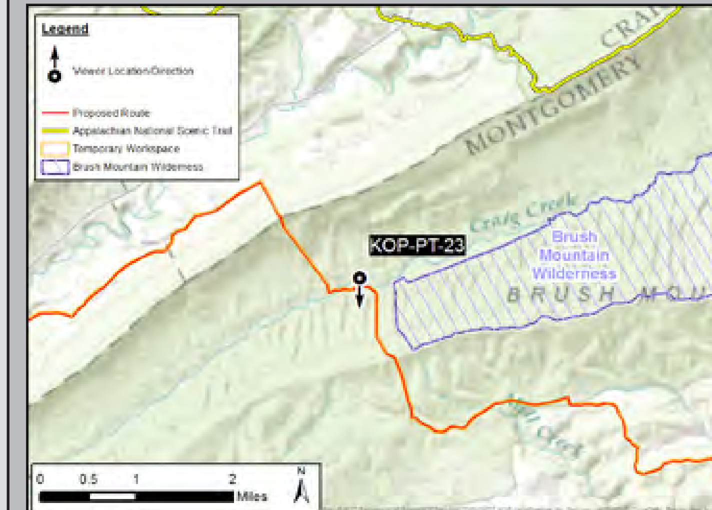
Craig Creek Road KOP PT-22

Mountain Valley    TETRA TECH

Figure 13

Existing Condition

Post Construction - The proposed pipeline crossing Sinking Creek Mountain and the adjacent valley would be screened by vegetation. The yellow arrow indicates approximately where the proposed pipeline would be located crossing the lower slopes of Brush Mountain. Views would be completely screened by terrain and vegetation.




## Photograph Information

Time of photograph: 9:27 AM

Date of photograph: 12.21.2016

Weather condition: Mostly Sunny

Viewing direction: South

Latitude: 37°18'55.33"N

Longitude: 80°24'2.22"W

Photo Location: Photo taken from Craig Creek Road approximately 3.9 miles northeast of Highway 460 in Virginia.

# Mountain Valley Pipeline Project

Craig Creek Road KOP PT-23

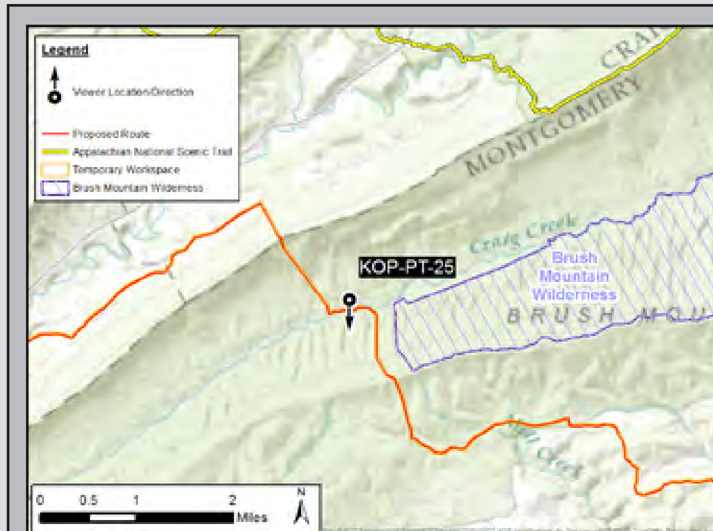
Mountain Valley

TETRA TECH

Figure 14

Existing Condition

Post Construction - The proposed pipeline access road would be visible leading from Craig Creek Road towards the pipeline right-of-way. However, the proposed pipeline crossing and where it crosses the valley adjacent to Craig Creek Road would be screened by vegetation and terrain. The yellow arrow indicates the road upgrades that would be visible from KOP PT-25. The red arrow indicates approximately where the pipeline would cross over Brush Mountain, and would be screened by vegetation from this location.




## Photograph Information

Time of photograph: 9:32 AM

Date of photograph: 12.21.2016

Weather condition: Mostly Sunny

Viewing direction: South

Latitude: 37°18’55.33”N

Longitude: 80°24’2.22”W

Photo Location: Photo taken from Craig Creek Road approximately 3.9 miles northeast of Highway 460 in Virginia.

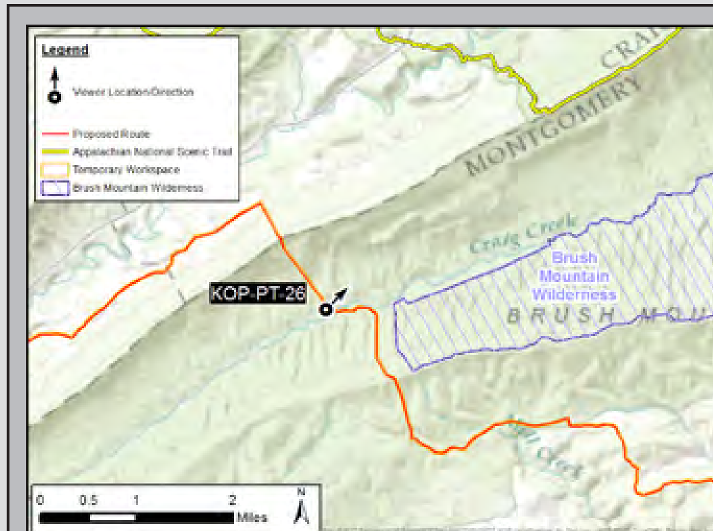
# Mountain Valley Pipeline Project

Craig Creek Road KOP PT-25

Mountain Valley TETRA TECH

Existing Condition

Post Construction - The proposed pipeline would cross Craig Creek Road immediately adjacent to KOP PT-26. However, the pipeline would be bored under the road and the bore pits would be located approximately 60-100 feet from the road and would be screened by vegetation and terrain. The yellow arrows indicate that the bore pits would be located to the north and south of the road and would be completely screened.




### Photograph Information

Time of photograph: 9:37 AM

Date of photograph: 12.21.2016

Weather condition: Mostly Sunny

Viewing direction: Northeast

Latitude: 37°18’49.88”N

Longitude: 80°24’24.54”W

Photo Location: Photo taken from Craig Creek Road approximately 3.6 miles northeast of Highway 460 in Virginia.

# Mountain Valley Pipeline Project

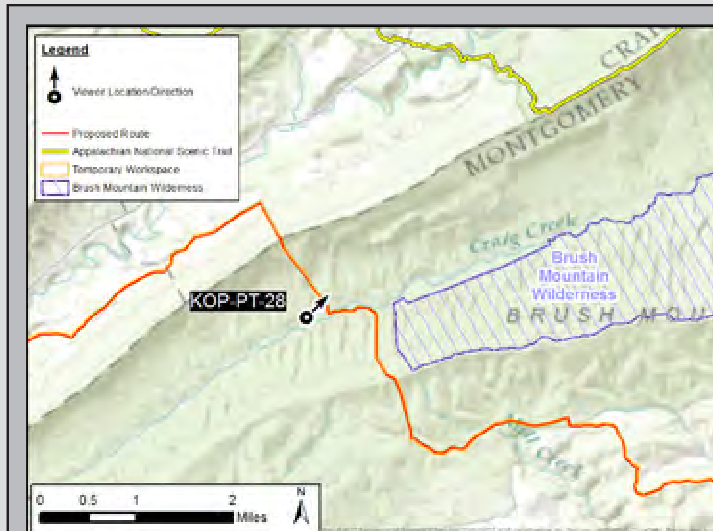
Craig Creek Road KOP PT-26

Mountain Valley TETRA TECH

Figure 16

Existing Condition

Post Construction - The proposed pipeline would cross Craig Creek Road approximately 0.23 mile east of KOP PT-28. The pipeline would be screened by vegetation and terrain. The yellow arrow indicates where the proposed pipeline would be located crossing the open field and over Brush Mountain. Views of the pipeline from this location would be screened by vegetation.




## Photograph Information

Time of photograph: 9:44 AM

Date of photograph: 12.21.2016

Weather condition: Mostly Sunny

Viewing direction: Northeast

Latitude: 37°18'45.53"N

Longitude: 80°24'37.87"W

Photo Location: Photo taken from Craig Creek Road approximately 3.4 miles northeast of Highway 460 in Virginia.

# Mountain Valley Pipeline Project

Craig Creek Road KOP PT-28

Mountain Valley TETRA TECH

Figure 17

Existing Condition

Post Construction - No modifications would be visible from KOP PR-1. Modificiations would be located over the hill and completely screened from this viewpoint.


## Photograph Information

Time of photograph: 9:22 AM

Date of photograph: 1.21.2017

Weather condition: Foggy

Viewing direction: Northeast

Latitude: 37°21’56.43”N

Longitude: 80°44’46.72”W

Photo Location: Photo taken from Pocahontas Road where it crosses the Appalachian Trail, approximately 440 feet north of Route 641 and 2.8 miles northwest of the Town of Pearisburg, Virginia.

# Mountain Valley Pipeline Project

Pocahontas Road KOP PR-1

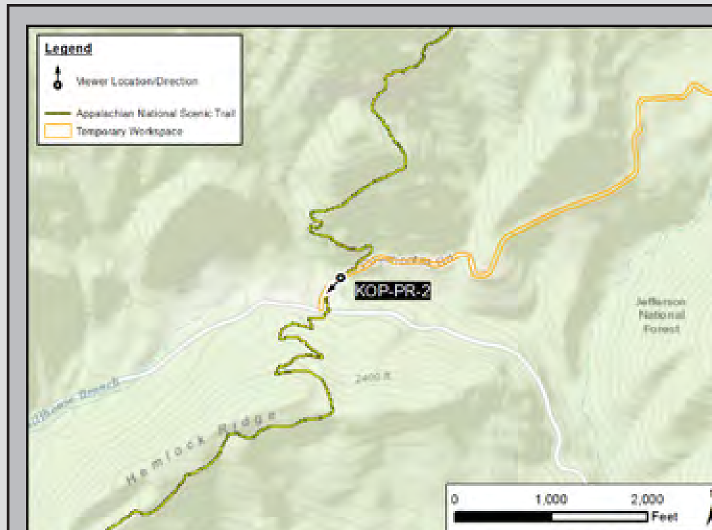
Mountain Valley

TETRA TECH

Figure 18

Existing Condition

Post Construction - From this location modifications to the gravel in the roadway would be apparent where culvert upgrades would occur.




## Photograph Information

Time of photograph: 9:23AM

Date of photograph: 1.21.2017

Weather condition: Foggy

Viewing direction: Southwest

Latitude: 37°21'56.91"N

Longitude: 80°44'46.67"W

Photo Location: Photo taken from Pocahontas Road where it crosses the Appalachian Trail, approximately 440 feet north of Route 641 and 2.8 miles northwest of the Town of Pearisburt, Virginia.

# Mountain Valley Pipeline Project

Pocahontas Road KOP PR-2

Mountain Valley

TETRA TECH

Figure 19

Existing Condition

Post Construction - From this location modifications to the roadway, including reinforcement of gravel along the edge of the roadway, would be apparent.


## Photograph Information

Time of photograph:  9:07 AM

Date of photograph:  2.21.2017

Weather condition:  Foggy

Viewing direction:  East - Southeast

Latitude:  37°21’54.35”N

Longitude:  80°44’45.13”W

Photo Location: Photo taken from along the Appalachian Trail approximately 85 feet north of Pocahontas Road and 630 feet, and 2.8 miles northwest of the Town of Pearisburg, Virginia.

# Mountain Valley Pipeline Project

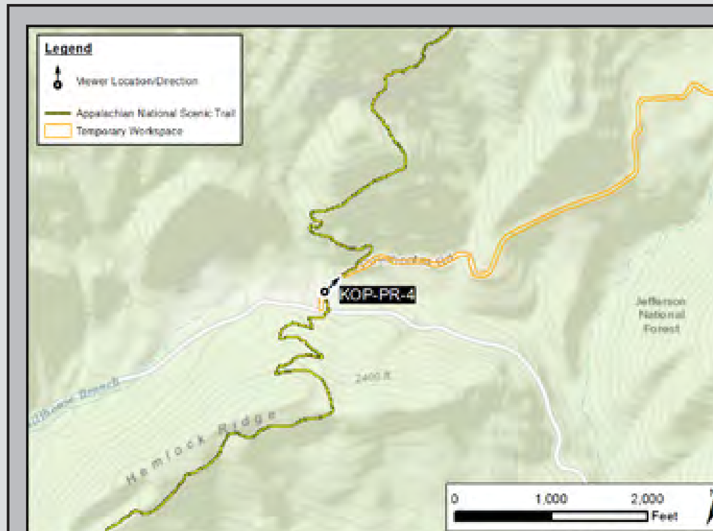
Pocahontas Road KOP PR-3

Mountain Valley    TETRA TECH

Figure 20

Existing Condition

Post Construction - From this location modifications to the gravel in the roadway would be apparent in the immediate foreground where culvert upgrades would occur.




## Photograph Information

Time of photograph: 9:28 AM

Date of photograph: 1.21.2017

Weather condition: Foggy

Viewing direction: North-Northeast

Latitude: 37°21’57.05”N

Longitude: 80°44’48.49”W

Photo Location: Photo taken from Pocahontas Road approximately 200 feet north of Route 641 and 2.8 miles northwest of the Town of Pearisburg, Virginia.

# Mountain Valley Pipeline Project

Pocahontas Road KOP PR-4

Mountain Valley TETRA TECH

Figure 21

Existing Condition

Post Construction - No modifications would be visible from KOP PR-5.


## Photograph Information

Time of photograph: 9:29 AM

Date of photograph: 1.21.2017

Weather condition: Foggy

Viewing direction: South-Southwest

Latitude: 37°21’57.60”N

Longitude: 80°44’48.33”W

Photo Location: Photo taken from Pocahontas Road approximately 200 feet north of Route 641 and 2.8 miles northwest of the Town of Pearisburg, Virginia.

# Mountain Valley Pipeline Project

Pocahontas Road KOP PR-5

Mountain Valley    TETRA TECH

Figure 22

Post Construction - No modifications would be visible from KOP PR-6.


## Photograph Information

Time of photograph: 9:39 AM

Date of photograph: 1.21.2017

Weather condition: Foggy

Viewing direction: South-Southwest

Latitude: 37°21’53.80”N

Longitude: 80°44’59.63”W

Photo Location: Photo taken from Pocahontas Road approximately 85 feet north of Route 641 and 2.8 miles northwest of the Town of Pearisburg, Virginia.

# Mountain Valley Pipeline Project

Pocahontas Road KOP PR-6

Mountain Valley    TETRA TECH

Figure 23

Form 8400-4
(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

1. Project Name
Mountain Valley Pipeline

2. Key Observation Point KOP 110

3. VRM Class NA

4. Location

Township ________________

Range ________________

Section ________________

5. Location Sketch

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Angled and sloping and some distant mountain silhouettes | Vertical, contrasting strip, rough | NA |
| LINE | Undulating and angular | Vertical trees , simple geometric forms | NA |
| COLOR | Browns and greys | Brown, grey, green, some yellow hues, monotone | NA |
| TEX-TURE | Smooth | Course and rough to granular grasses | NA |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | NA | NA | NA |
| LINE | NA | NA | NA |
| COLOR | NA | NA | NA |
| TEX-TURE | NA | NA | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| ELEMENTS | FEATURES: LAND/WATER BODY (1) Strong | Moderate | Weak | None | VEGETATION (2) Strong | Moderate | Weak | None | STRUCTURES (3) Strong | Moderate | Weak | None |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form | | | | X | | | | X | | | | X |
| Line | | | | X | | | | X | | | | X |
| Color | | | | X | | | | X | | | | X |
| Texture | | | | X | | | | X | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No
(Explain on reverse side)

3. Additional mitigating measures recommended?
☐ Yes ☐ No (Explain on reverse side)

Evaluator's Names Date

Robert Evans 1/11/2017

Comments from item 2.

Additional Mitigating Measures (See item 3)

U.S. GOVERNMENT PRINTING OFFICE: 1985-461-988/33094

Form 8400-4
(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

| | | |
|---|---|---|
| 1. Project Name<br>Mountain Valley Pipeline | 4. Location<br>Township ________________<br>Range ________________<br>Section ________________ | 5. Location Sketch |
| 2. Key Observation Point KOP 111 | | |
| 3. VRM Class NA | | |

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Angled and sloping with numerous distant mountain silhouettes , pyramidal, jagged, smooth band of water | Simple geometric forms created by openings in the vegetation | Angular geometric, diverse, contrasting, square |
| LINE | Strong horizon line, angular dendritic lines, strong band of river | Lines and edges created by vegetation clearings | Numerous lines and edges created by structures and roadways |
| COLOR | Browns and greys, yellow hues, glossy blue | Brown, grey, green, olives, some yellow hues, monotone | Metallic, grey, white, tan, pink |
| TEX-TURE | Smooth to course land, smooth water | Contrasting and stippled as well as smooth | Smooth |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Linear diagonal line | Simple geometric form created by vegetation removal | NA |
| LINE | Linear weak band | Simple line created by vegetation removal | NA |
| COLOR | Brown hues | NA | NA |
| TEX-TURE | Smooth | NA | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| | | FEATURES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAND/WATER BODY (1) | | | | VEGETATION (2) | | | | STRUCTURES (3) | | | |
| | | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None |
| ELEMENTS | Form | | | X | | | | X | | | | | X |
| | Line | | | X | | | | X | | | | | X |
| | Color | | | X | | | | | X | | | | X |
| | Texture | | | | X | | | | X | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No (Explain on reverse side)

3. Additional mitigating measures recommended? ☐ Yes ☐ No (Explain on reverse side)

| Evaluator's Names | Date |
|---|---|
| Robert Evans | 1/11/2017 |

Comments from item 2.

Additional Mitigating Measures (See item 3)

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(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

1. Project Name
Mountain Valley Pipeline

2. Key Observation Point KOP 115

3. VRM Class NA

4. Location

Township ____________

Range ____________

Section ____________

5. Location Sketch

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Angled and sloping with numerous distant mountain silhouettes , undulating | Simple geometric forms created by openings in the vegetation | Angular geometric, vertical |
| LINE | Strong horizon line, undulating, sweeping | Lines and edges created by vegetation clearings | Lines and edges created by structures (transmission line) |
| COLOR | Browns and greys, blue hues from atmospheric conditions | Brown, grey, green, olives, monotone | Metallic, grey |
| TEX-TURE | Smooth to course, granular | Stippled and granular | Smooth |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Linear horizontal line | Simple geometric form created by vegetation removal | NA |
| LINE | Linear band | Simple line created by vegetation removal | NA |
| COLOR | Green hues | Green and Brown hues | NA |
| TEX-TURE | Smooth | Smooth | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| | | FEATURES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAND/WATER BODY (1) | | | | VEGETATION (2) | | | | STRUCTURES (3) | | | |
| | | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None |
| ELEMENTS | Form | | | X | | | | X | | | | | X |
| | Line | | | X | | | | X | | | | | X |
| | Color | | | X | | | | | X | | | | X |
| | Texture | | | | X | | | X | | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No (Explain on reverse side)

3. Additional mitigating measures recommended? ☐ Yes ☐ No (Explain on reverse side)

| Evaluator's Names | Date |
|---|---|
| Robert Evans | 1/11/2017 |

## SECTION D. (Continued)

Comments from item 2.

Additional Mitigating Measures (See item 3)

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BUREAU OF LAND MANAGEMENT

# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

| 1. Project Name<br>Mountain Valley Pipeline | 4. Location<br><br>Township ____________<br><br>Range ____________<br><br>Section ____________ | 5. Location Sketch |
|---|---|---|
| 2. Key Observation Point KOP 125 | | |
| 3. VRM Class NA | | |

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Undulating and sloping and some mountain silhouettes | Vertical, rough, solid | Vertical, low, few |
| LINE | Undulating, soft | Vertical trees , simple geometric forms, edge between field and forest | Vertical, weak |
| COLOR | Not apparent | Brown, grey, various greens and olives, some yellow hues, | Brown, grey |
| TEX-TURE | Smooth | Course, clumped, random, contrasting | Smooth |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | NA | Slight edge | NA |
| LINE | NA | Weak line | NA |
| COLOR | NA | Green hues | NA |
| TEX-TURE | NA | Patchy | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| | | FEATURES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAND/WATER BODY (1) | | | | VEGETATION (2) | | | | STRUCTURES (3) | | | |
| | | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None |
| ELEMENTS | Form | | | | X | | | X | | | | | X |
| | Line | | | | X | | | X | | | | | X |
| | Color | | | | X | | | | X | | | | X |
| | Texture | | | | X | | | X | | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No (Explain on reverse side)

3. Additional mitigating measures recommended? ☐ Yes ☐ No (Explain on reverse side)

| Evaluator's Names | Date |
|---|---|
| Robert Evans | 1/11/2017 |

## SECTION D. (Continued)

Comments from item 2.

Additional Mitigating Measures (See item 3)

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BUREAU OF LAND MANAGEMENT

# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

1. Project Name
Mountain Valley Pipeline

2. Key Observation Point KOP OID-22

3. VRM Class NA

4. Location

Township ____________

Range ____________

Section ____________

5. Location Sketch

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Undulating with numerous mountain silhouettes | Vertical, rough, even and balanced | Horizontal |
| LINE | Undulating silhouettes | Vertical trees, simple geometric forms in the middleground | Horizontal band |
| COLOR | Brown with blue hues created by atmospheric conditions | Brown, grey, burnt sienna, some yellow hues | Grey |
| TEX-TURE | Smooth | Course, rough to smooth | Smooth |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | NA | NA | NA |
| LINE | NA | NA | NA |
| COLOR | NA | NA | NA |
| TEX-TURE | NA | NA | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| | | FEATURES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAND/WATER BODY (1) | | | | VEGETATION (2) | | | | STRUCTURES (3) | | | |
| | | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None |
| ELEMENTS | Form | | | | X | | | | X | | | | X |
| | Line | | | | X | | | | X | | | | X |
| | Color | | | | X | | | | X | | | | X |
| | Texture | | | | X | | | | X | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No (Explain on reverse side)

3. Additional mitigating measures recommended? ☐ Yes ☐ No (Explain on reverse side)

| Evaluator's Names | Date |
|---|---|
| Robert Evans | 1/11/2017 |

## SECTION D. (Continued)

Comments from item 2.

Additional Mitigating Measures (See item 3)

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UNITED STATES
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# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

1. Project Name
Mountain Valley Pipeline

2. Key Observation Point KOP OID-23

3. VRM Class NA

4. Location

Township ____________

Range ____________

Section ____________

5. Location Sketch

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Undulating with background mountain silhouettes, large round and vertical bounders in the immediate foreground | Vertical, rough, uneven and patchy | NA |
| LINE | Undulating silhouettes, diverse and numerous | Vertical trees, hard geometric shapes | NA |
| COLOR | Brown, grey, blue hues created by atmospheric conditions | Brown, grey, burnt sienna, some yellow hues | NA |
| TEXTURE | Rough to smooth (gradational) | Course, rough | NA |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | NA | NA | NA |
| LINE | NA | NA | NA |
| COLOR | NA | NA | NA |
| TEXTURE | NA | NA | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| | FEATURES: LAND/WATER BODY (1) | | | | VEGETATION (2) | | | | STRUCTURES (3) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEMENTS | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None |
| Form | | | | X | | | | X | | | | X |
| Line | | | | X | | | | X | | | | X |
| Color | | | | X | | | | X | | | | X |
| Texture | | | | X | | | | X | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No (Explain on reverse side)

3. Additional mitigating measures recommended? ☐ Yes ☐ No (Explain on reverse side)

| Evaluator's Names | Date |
|---|---|
| Robert Evans | 1/11/2017 |

## SECTION D. (Continued)

Comments from item 2.

Additional Mitigating Measures (See item 3)

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(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

1. Project Name
Mountain Valley Pipeline

2. Key Observation Point KOP OID-23

3. VRM Class NA

4. Location

Township ____________

Range ____________

Section ____________

5. Location Sketch

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Undulating with background mountain silhouettes, large round and vertical bounders in the immediate foreground | Vertical, rough, uneven and patchy | NA |
| LINE | Undulating silhouettes, diverse and numerous | Vertical trees, hard geometric shapes | NA |
| COLOR | Brown, grey, blue hues created by atmospheric conditions | Brown, grey, burnt sienna, some yellow hues | NA |
| TEXTURE | Rough to smooth (gradational) | Course, rough | NA |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | NA | NA | NA |
| LINE | NA | NA | NA |
| COLOR | NA | NA | NA |
| TEXTURE | NA | NA | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| | | FEATURES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAND/WATER BODY (1) | | | | VEGETATION (2) | | | | STRUCTURES (3) | | | |
| | | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None |
| ELEMENTS | Form | | | | X | | | | X | | | | X |
| | Line | | | | X | | | | X | | | | X |
| | Color | | | | X | | | | X | | | | X |
| | Texture | | | | X | | | | X | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No
(Explain on reverse side)

3. Additional mitigating measures recommended?
☐ Yes ☐ No (Explain on reverse side)

| Evaluator's Names | Date |
|---|---|
| Robert Evans | 1/11/2017 |

SECTION D. (Continued)

Comments from item 2.

Additional Mitigating Measures (See item 3)

Form 8400-4
(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

# VISUAL CONTRAST RATING WORKSHEET

Date 1/11/2017

District NA

Resource Area NA

Activity (program)

## SECTION A. PROJECT INFORMATION

1. Project Name
Mountain Valley Pipeline

2. Key Observation Point KOP OID-103

3. VRM Class NA

4. Location

Township ____________

Range ____________

Section ____________

5. Location Sketch

## SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | Undulating with numerous mountain silhouettes | Vertical, rough, even and balanced | NA |
| LINE | Undulating, horizontal to convex | Vertical trees, simple geometric forms in the middleground | NA |
| COLOR | Brown with blue hues created by atmospheric conditions | Brown, grey, burnt sienna, some red hues | NA |
| TEX-TURE | Smooth | Course, rough to smooth | NA |

## SECTION C. PROPOSED ACTIVITY DESCRIPTION

| | 1. LAND/WATER | 2. VEGETATION | 3. STRUCTURES |
|---|---|---|---|
| FORM | NA | NA | NA |
| LINE | NA | NA | NA |
| COLOR | NA | NA | NA |
| TEX-TURE | NA | NA | NA |

## SECTION D. CONTRAST RATING ☐ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONSTRAST

| | | FEATURES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAND/WATER BODY (1) | | | | VEGETATION (2) | | | | STRUCTURES (3) | | | |
| | | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None | Strong | Moderate | Weak | None |
| ELEMENTS | Form | | | | X | | | | X | | | | X |
| | Line | | | | X | | | | X | | | | X |
| | Color | | | | X | | | | X | | | | X |
| | Texture | | | | X | | | | X | | | | X |

2. Does project design meet visual resource management objectives? ☐ Yes ☐ No (Explain on reverse side)

3. Additional mitigating measures recommended? ☐ Yes ☐ No (Explain on reverse side)

| Evaluator's Names | Date |
|---|---|
| Robert Evans | 1/11/2017 |

**SECTION D. (Continued)**

Comments from item 2.

Additional Mitigating Measures (See item 3)

# Mountain Valley Pipeline Project

## Docket No. CP16-10-000

## Attachment DR4 Land Use 9a

## KOP Viewsheds
## Proposed Route

February 2017

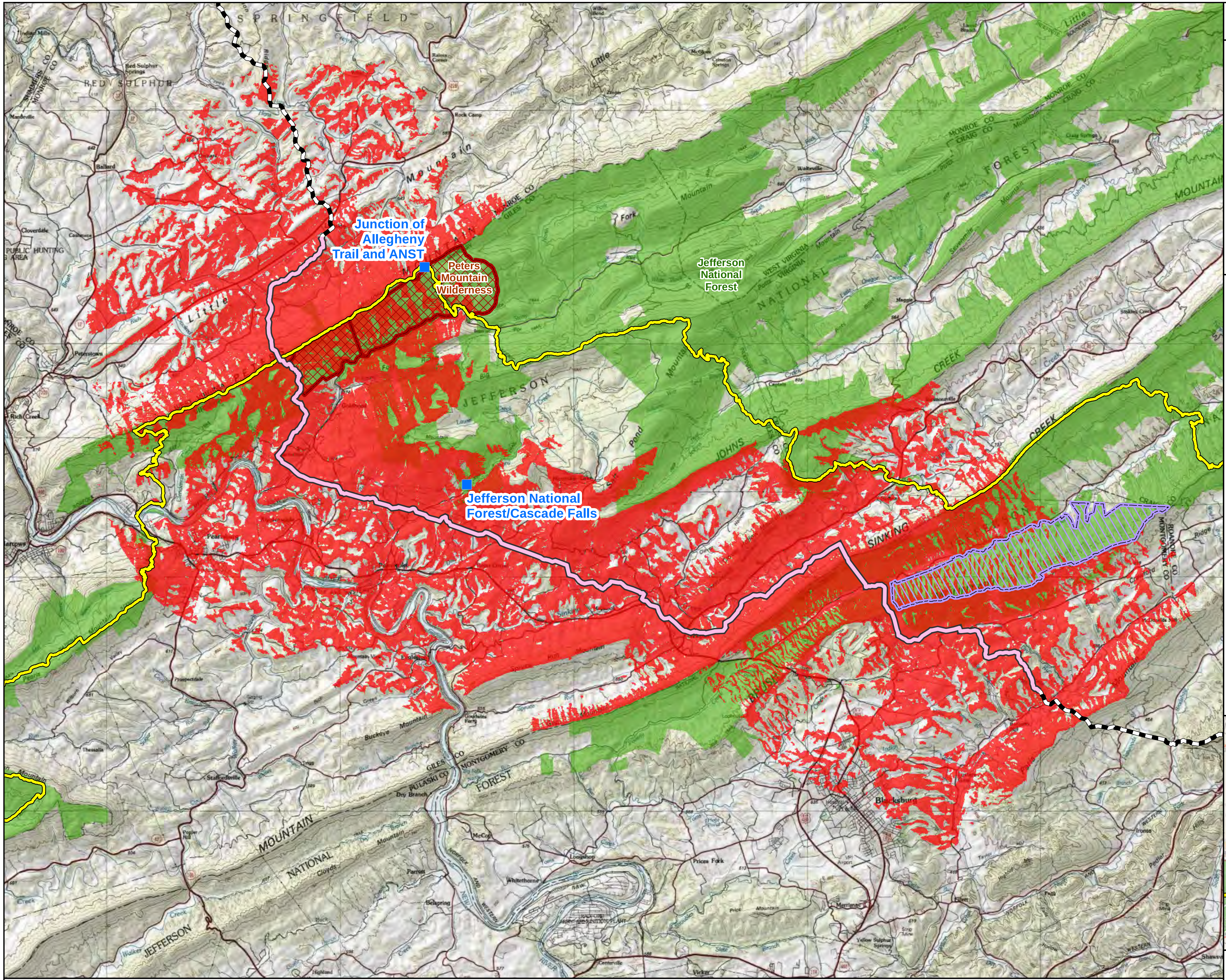
# Mountain Valley Pipeline Project

**Mountain Valley** PIPELINE

## Bare Earth Viewshed

Proposed Route

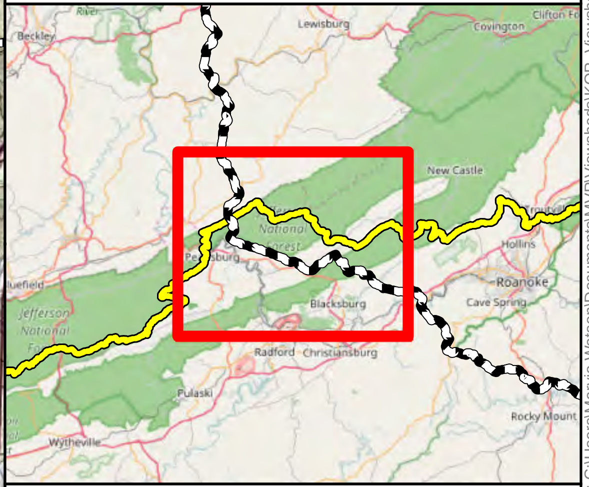
FEBRUARY 2017




**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route Revised December 2016
- Appalachian National Scenic Trail
- Proposed Route Viewshed Feature
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- Peters Mountain Wilderness
- U.S. Forest Service (National Forest) Lands

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.



Data Sources: NPS, USGS, NLCD

N 1:158,400 NAD 1983 UTM 17N 0 2.5 5 10 15 20 Miles

Document Path: C:\Users\Maryjo.Watson\Documents\MVP\Viewsheds\KOP_Viewsheds_20170201.mxd

# Mountain Valley Pipeline Project

## Docket No. CP16-10-000

## Attachment DR4 Land Use 9b

## KOP Viewsheds
## Craig Creek Road

February 2017

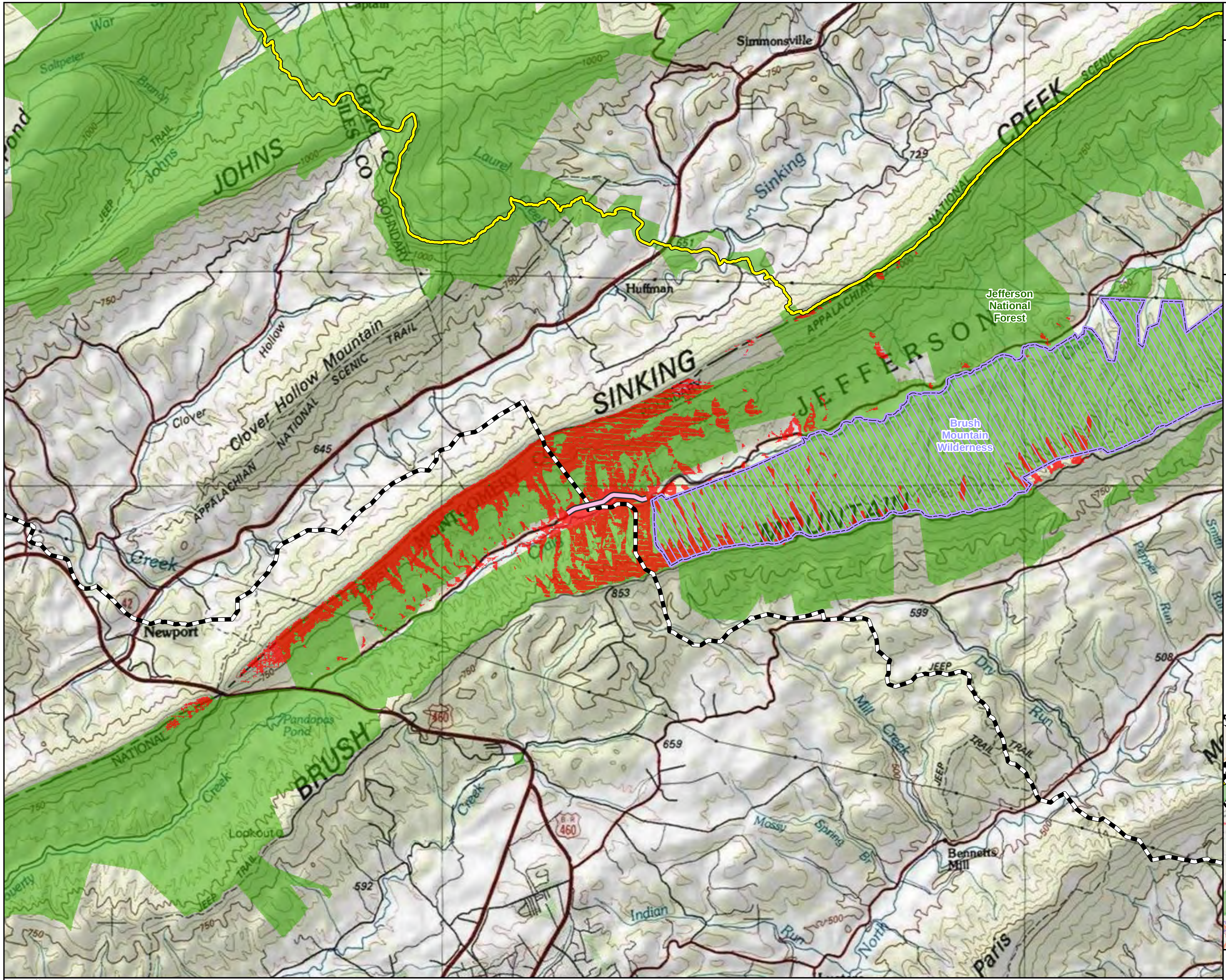
# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed

### Craig Creek Road

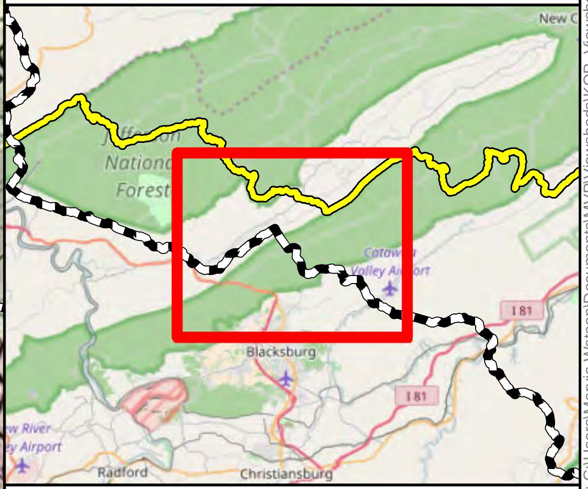
FEBRUARY 2017




**Legend**

- October 2016 Proposed Route Revised December 2016
- Appalachian National Scenic Trail
- Craig Creek Road Viewshed Feature
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- U.S. Forest Service (National Forest) Lands

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

N

1:63,360

NAD 1983 UTM 17N

0 1 2 4 6 8 Miles

Document Path: C:\Users\Maryjo.Watson\Documents\MVP\Viewsheds\KOP_Viewsheds_20170201.mxd

# Mountain Valley Pipeline Project

## Docket No. CP16-10-000

## Attachment DR4 Land Use 9c

## KOP Viewsheds
## State Route 42

February 2017

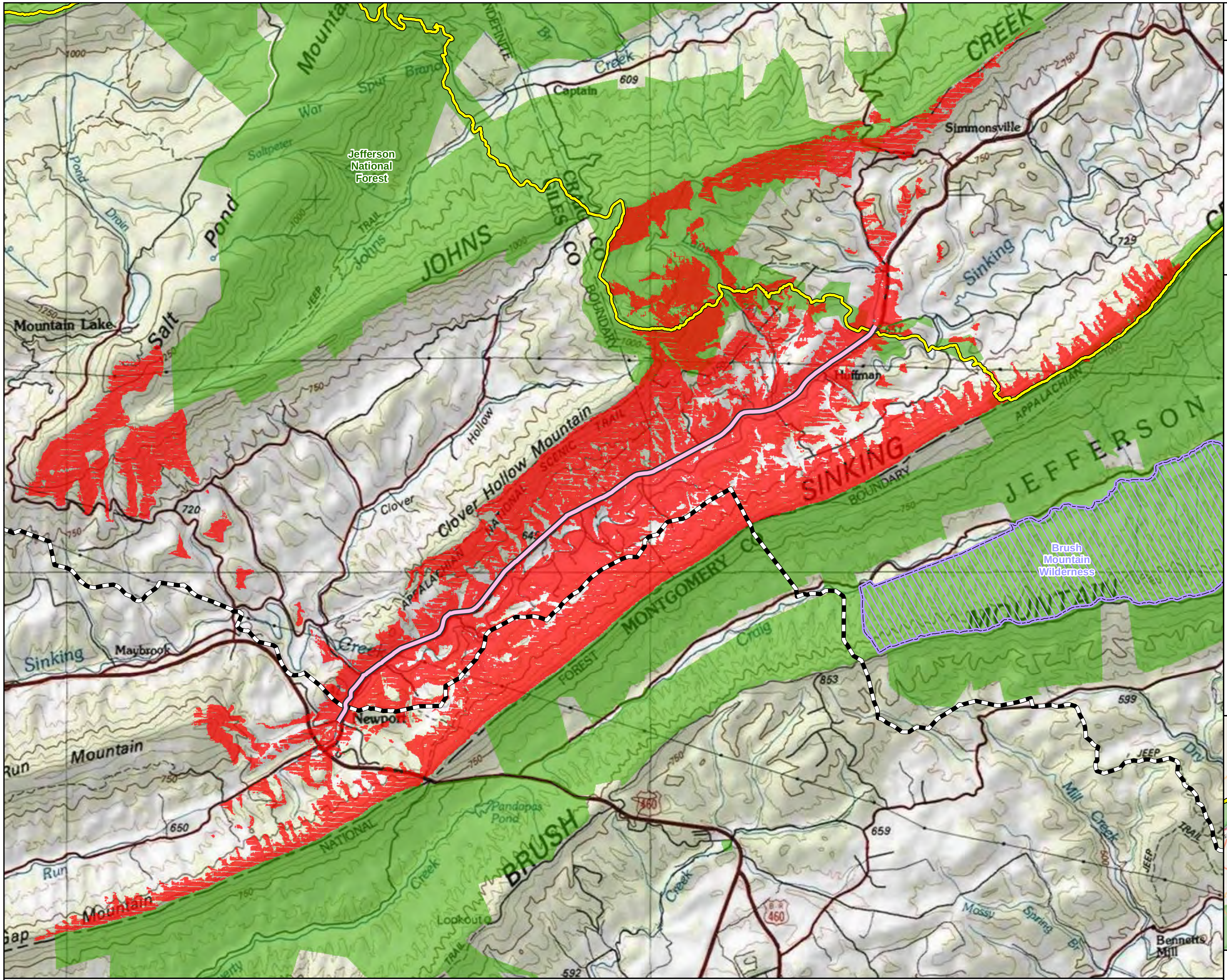
## Mountain Valley Pipeline Project

Mountain Valley PIPELINE

### Bare Earth Viewshed

### State Route 42

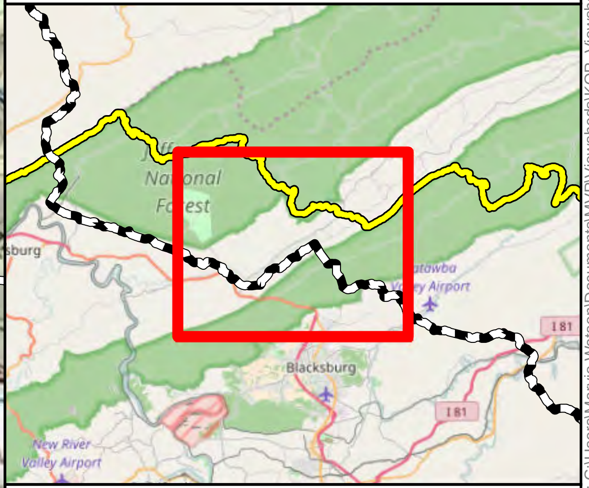
FEBRUARY 2017




**Legend**

- October 2016 Proposed Route Revised December 2016
- Appalachian National Scenic Trail
- State Route 42 Viewshed Feature
- Visible Area (Bare Earth Viewshed)
- Brush Mountain Wilderness
- U.S. Forest Service (National Forest) Lands

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

N 1:63,360 NAD 1983 UTM 17N 0 1 2 4 6 8 Miles

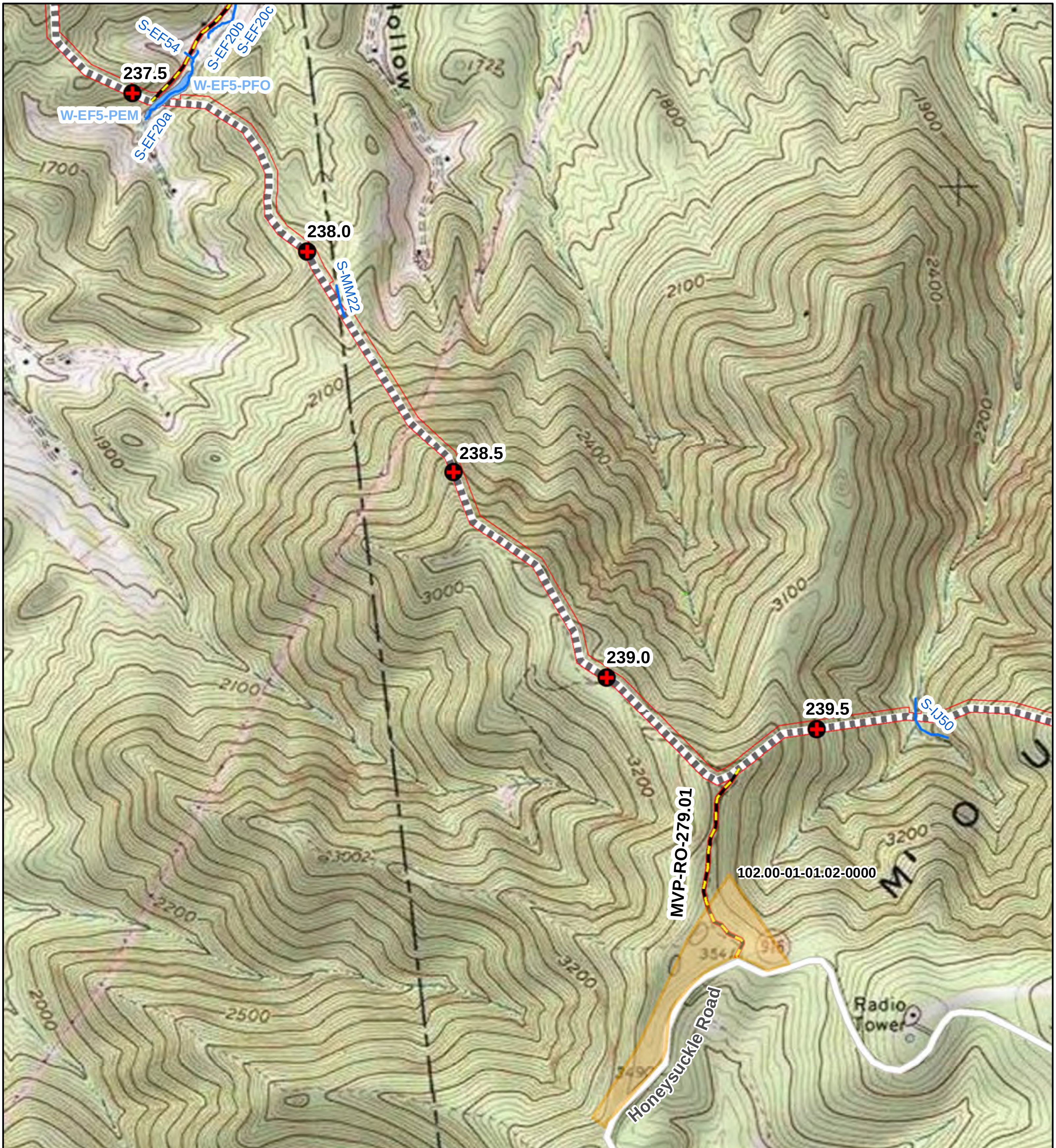
Document Path: C:\Users\Maryjo.Watson\Documents\MVP\Viewsheds\KOP_Viewsheds_20170201.mxd

# Mountain Valley Pipeline Project

# Docket No. CP16-10-000

# Attachment DR4 Land Use 11

February 2017




Mountain Valley PIPELINE

# ACCESS ROAD MVP-RO-279.01

0 0.25 0.5
Miles
1:15,000

2/7/2017

**LEGEND**

- October 2016 Proposed Route
- October 2016 Proposed Route Access Road
- October 2016 Proposed Route Temporary Workspace
- Streams
- Wetlands
- Parcel

# Mountain Valley Pipeline Project

# Docket No. CP16-10-000

# Attachment DR4 Land Use 12

February 2017

DEIS APPENDIX E-1
(Updated for MVP October 2016 Proposed Route, February 2017)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or Upland Forest | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEST VIRGINIA** | | | | | | | | | | | | | | | |
| **Wetzel County** | | | | | | | | | | | | | | | |
| MVP-WE-001 | 0 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.7 | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 89% | 3.07 |
| MVP-WE-000 - | 0 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | ..03 | 40 | 25 | 40 | 15 | Perm. Access to Mobley Interconnect Facility | N/A | 100% | 0.18 |
| ~~MVP-WE-002~~ ~~0.2~~ | 0.2 | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Dirt~~ | ~~RoadwaWidening Grading Stabilization~~ | ~~0.4~~ | ~~25~~ | ~~25~~ | ~~40~~ | ~~15~~ | ~~Mobilizaof construction material. Safely ingress and egress of construction personnel to peak of steep slope.~~ | ~~N/A~~ | ~~100%~~ | ~~2.02~~ |
| MVP-WE-003 | 0.7 | P | Temp | N | Dirt | ~~TBD~~New Construction | 0.0 | 0 | 25 | 40 | 40 | Access from county route to ATWS and road crossing. | TBD | N/A | N/A |
| MVP-WE-004 | 0.8 | P | Temp | N | Dirt | ~~TBD~~New Construction | 0.0 | 0 | 25 | 40 | 40 | Access from county route to stream crossing at toe of slope. | TBD | N/A | N/A |
| MVP-WE-005 | 1.1 | P | Perm | E | Dirt | Roadway– – Widening,– – Grading, Stabilization | 0.66~~0.7~~ | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 75% | ~~2.43~~2.42 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WE 006 | ~~1.4~~1.3 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~ – ~~ Safely ingress and egress of construction personnel.~~ – ~~ Access to north side of stream crossings as well as toe of steep slope. | N/A | 75% | 0.36 |
| ~~MVP-WE-007~~ | ~~1.4~~ | ~~P~~ | ~~Temp~~ | ~~N~~ | ~~Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.1~~ | ~~0~~ | ~~25~~ | ~~40~~ | ~~40~~ | ~~Access to south side of stream crossing~~ | ~~N/A~~ | ~~N/A~~ | ~~N/A~~ |
| ~~MVP-WE-008~~ | ~~1.4~~ | ~~P~~ | ~~Perm~~ | ~~N~~ | ~~Dirt~~ | ~~New Construction~~ | ~~0.1~~ | ~~0~~ | ~~25~~ | ~~40~~ | ~~40~~ | ~~Operations maintenance~~ | ~~TBD~~ | ~~N/A~~ | ~~N/A~~ |
| ~~MVP-WE-008.01~~ | ~~1.5~~ | ~~P~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.2~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel.~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-008.01A | 1.4 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.13 | 8 | 25 | 40 | 32 | Access to south side of road crossing | N/A | 75 | 0.36 |
| MVP-WE-008.02 | 2.7 | S | Perm | E | Dirt | Roadway Widening, Grading Stabilization | 0.8 | 8 | 25 | 40 | 32 | MLV2 Bradshaw CS | N/A | 100% | 3.85 |
| MVP-WE-011 ~~1~~ | ~~4.4~~4.5 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.5 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 75% | 1.75 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or Upland | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WE-012 | 4.8 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 12 | 25 | 40 | 28 | Mobilization of construction material. Safely ingress and egress of construction personnel. Access to mid-point of hill. | N/A | 75% | 1.00 |
| MVP-WE-013 | 5.5 | P | Perm | N | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 75% | 1.43 |
| MVP-WE-014.02 | 6.5 | P | Perm | E | Grass | New Construction | 0.02 | 0 | 25 | 40 | 40 | Access to Ground Bed MVP-CP-GB-01B | N/A | N/A | N/A |
| MVP-WE-014.01 | 6.6 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.20 | 12 | 25 | 40 | 28 | Mobilization of construction material. Safely ingress and egress of construction personnel. | N/A | 50% | 0.48 |
| MVP-WE-014 | 6.8~~.86.9~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 2.0 | 25 | 25 | 40 | 15 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 70% | 6.8 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WE-015 | ~~7.4~~7.3 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 75% | 4.40 |
| MVP-WE-016 | 8.7 | P | Perm | E | Dirt/ Gravel | Roadway Widening, Grading, Stabilization | 0.9 | 8 | 25 | 40 | 32 | Operations maintenance | N/A | 75% | 3.22 |
| **Harrison County** | | | | | | | | | | | | | | | |
| MVP-HA 018 | 9.6~~9.7~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.9 | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 100% | 4.36 |
| MVP-HA-019 | 12~~12.1~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.28~~0.3~~ | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. | N/A | 100% | 1.38 |
| MVP-HA 020 | ~~13.4~~13 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | ~~0.5~~0.46 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 100% | 2.25 |
| MVP-MLV-AR-03.01 | 15.3~~15~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.02 | 8 | 25 | 40 | 32 | MLV3 | Permanent access to MLV 3 | 100% | 0.08 |
| MVP-HA-022 | 15.3~~15~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 30% | 0.44 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~~WV-HA-023~~ | ~~15.5~~ | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.0~~ | | ~~25~~ | ~~40~~ | ~~40~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel.~~ | | ~~100%~~ | ~~0.06~~ |
| MVP-MLV-AR-04 | ~~15.5~~15 | P | Perm | N | Dirt | New Construction | 0.2 | 0 | 25 | 40 | 40 | MLV4 | MLV4 | N/A | N/A |
| MVP-HA-024 | 16.2~~16~~ | S/P | Temp~~P~~ | E | Dirt | Roadway Widening, Grading, Stabilization | ~~1.2~~09 | 12 | 25 | 40 | 28 | Mobilization ~~maintenance~~ | N/A | 50% | 2.86 |
| MVP-HA-025 | 18.5~~18~~ | P | Perm~~T~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 25 | 25 | 40 | 15 | Operations ~~of construction material. Safely ingress and egress of construction personnel~~ | N/A | 100% | 1.66 |
| MVP-HA-026 | ~~19~~18.9 | P | Perm | | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 78% | 1.54 |
| MVP-HA-027 | 20.7 | P | Temp | N | Dirt | Roadway widening, Grading, Stabilization | 0.1 | 0 | 25 | 40 | 40 | N/A | N/A | N/A | N/A |
| MVP-HA-028 | 21.2~~21.3~~ | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.3 | 8~~TBD~~ | 25 | 40 | 32~~TBD~~ | Mobilization of construction material.~~-Safely~~Safe ingress and egress of construction personnel. | TBD | 75%~~TBD~~ | 1.32~~TBD~~ |
| MVP-HA-28.01 | 21.4 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | .07 | 8 | 25 | 40 | 32 | Mobilization of Construction Personnel | N/A | 100% | 0.33 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-HA-029 | 22.3 | P | Perm~~Temp~~ | E | Gravel | Roadway Widening, Grading, ~~Stabilzation~~Stabil | 0.5 | 40 | 25 | 40 | 0 | Operations maintenance | N/A | 100% | 2.23 |
| MVP-HA-029.03 | 22.6 | P | Temp | E | Dirt | Roadway Widening ,Grading, Stabilization | 0.28 | 20 | 25 | 40 | 20 | Mobilization of Construction Personnel | N/A | 100% | 1.36 |
| MVP-HA-029.05 | 23 | P | Perm | E | Dirt | Roadway Widening, grading, Stabilization | 0.04 | 8 | 25 | 40 | 32 | Operations Maintenance | N/A | 100% | 0.22 |
| MVP-HA-029.04 | 23 | P | Temp | E | Gravel/ Grass | Roadway Widening, Grading, Stabilization | 0.09 | 10 | 25 | 40 | 30 | Mobilization of Construction Personnel | N/A | 75% | 0.34 |
| MVP-HA-031 | 23.6 | P | Perm | N | Dirt | New Construction | 0.25 | 0 | 25 | 40 | 40 | Sherwood Int. | Sherwood Int. | N/A | N/A |
| ~~*MVP-HA-029.01*~~ | ~~22.6~~ | ~~P~~ | ~~Perm~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.1~~ | ~~12~~ | ~~25~~ | ~~40~~ | ~~28~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~100%~~ | ~~0.67~~ |
| MVP HA-031.01 | 23.6~~23.7~~ | P | Temp ~~Perm~~ | E~~N~~ | Dirt | Roadway Grading, ~~Construction~~ | 0.36~~0.2~~ | 20~~0~~ | 25 | 40 | 20~~40~~ | Mobilization of Construction Material. Safely ingress and egress of construction personnel ~~Int~~ | Sherwood Int. | N/A | 1.32 N/A |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-HA-032 | 25 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.97~~1.0~~ | 8 | 25 | 40 | 32 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel.~~–~~ Access road provides ridgetop access to north side of US RT 50 | N/A | 50% | 2.35 |
| MVP-HA-032.01 | 25.8 | P | Perm | E | Gravel | Roadway, Widening, Grading, Stabilization | 0.02 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 50% | .06 |
| MVP-HA-033 | 26.7~~26~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel.~~-~~ Access road provides ridgetop access to south side of US RT 50 | N/A | 100% | 2.03 |
| MVP-HA-034 | 28.2~~28.4~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. | N/A | 0% | 0.00 |
| MVP-HA-035 | 29.3~~29.2~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 1.51 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-HA-036 | 29.3~~29.5~~ | P | Temp | N | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.1 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | N/A | N/A |
| MVP-HA-036.01 | 30.1 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization - | 0.05 | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 0.06 |
| MVP-HA-40 | 30.8~~30~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~-~~ Safely ingress and egress of construction personnel | N/A | 0% | 0.00 |
| MVP-DO-041 | ~~31.9~~31.8 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.36~~0.4~~ | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 40% | 0.69 |
| MVP-HA-041.01 | 32.6~~32~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.03 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 0.17 |
| MVP-HA-042 | 32.8~~33~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.02 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 0% | 0.00 |
| MVP-HA-043 | 33.1~~33.2~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.1 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 50% | 0.33 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-DO-044 | 34~~34.1~~ | P | Temp | E~~N~~ | Gravel | Roadway Widening, Grading, Stabilization | 0.3 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 75%~~N/A~~ | 1.16~~N/A~~ |
| **Doddridge** | **County** | | | | | | | | | | | | | | |
| MVP-DO-046 | 34.3~~34.4~~ | P | Perm ~~Temp~~ | E | Gravel | Roadway Widening, Grading, Stabilization | 0.2 | 15 | 25 | 40 | 25 | Operations Maintenance ~~- Mobilization of construction material.– Safely ingress and egress of construction personnel~~ | N/A | 0% | 0.00 |
| MVP-MLV-AR 05 | 34.8~~34.51~~ | P | Perm | N | Dirt | New Construction | 0.00 | 0 | 25 | 40 | 40 | MLV5 | Permanent access to MLV5 | N/A | N/A |
| MVP-DO-047 | 34.6 | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.2 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 0% | 0.00 |
| MVP-DO-048 | 34.9 | P | Temp~~P~~ | E~~N~~ | Dirt | Roadway Widening, Grading, Stabilization ~~- Construction~~ | 0.1 | 25 | 25 | 40 | 15 | Entry of construction personnel, equipment and material.~~–~~ Allows for access to public areas for emergency response if necessary.~~–~~ Improved work area safety. | N/A | 0%~~NA~~ | 0%~~NA~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP DO-049 | 35.8 | P | Perm | E | Dirt | Roadway construction | 0.1 | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 50% | 0.34 |
| MVP-HA-050 | 37.2 | P | Temp | N | Dirt | Roadway Widening, Grading, Stabilization | 0.9 | 0 | 25 | 40 | 40 | N/A | N/A | N/A | N/A |
| MVP-HA-051 | 38.05 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 8 | 25 | 40 | 32 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.34 |
| **Lewis** | **County** | | | | | | | | | | | | | | |
| ~~MVP-HA-052~~ | ~~39.5~~ | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~1.0~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~90%~~ | ~~4.51~~ |
| MVP-LE-054 | 39.8~~40~~ | P | Perm | N | Dirt | New Construction | 0.5 | 0 | 25 | 40 | 40 | Operations maintenance | N/A | N/A | N/A |
| MVP-LE-055 | 41.9~~42~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.6 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. Provides secluded ridgetop access. | N/A | 10% | 0.29 |
| MVP-LE-056 | 42.4~~42.6~~ | P | Perm ~~Temp~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel to north side of road crossing. | N/A | 0% | 0.00 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-LE-057 | 43.2~~43.1~~ | P | Perm | E | Gravel | Roadway Widening, Grading, - Stabilization | 0.8 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 0% | 0.00 |
| MVP-LE-057.01 | 43.6~~43~~ | P | Temp | E | Dirt | Roadway Widening, Grading, - Stabilization | 0.2 | 8 | 25 | 40 | 32 | Mobilization of construction material.– Safely ingress and egress of construction personnel. | N/A | 100% | 0.87 |
| MVP-LE-057.02 | 43.3~~43~~ | P | Temp | E | Dirt | Roadway Widening, Grading, - Stabilization | 0.2 | 8 | 25 | 40 | 32 | Mobilization of construction material.– Safely ingress and egress of construction personnel. | N/A | 100% | 0.73 |
| MVP-LE-057.03 | — 43.3 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.03 | 8 | 25 | 40 | 32 | Mobilization of construction material.– Safely ingress and egress of construction personnel. | N/A | 75% | 0.10 |
| MVP-LE-060 | 44.4~~44.6~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 0% | 0.00 |
| MVP-LE-061 | 44.8~~44.9~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 25 | 25 | 40 | 15 | Mobilization of construction material.– Safely ingress and egress of construction personnel.– Provides access to top of steep slope. | N/A | 10% | 0.08 |

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-LE-062 | 45.1~~46~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.9 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. | N/A | 11% | 0.48 |
| MVP-LE-063 | 45.4~~45~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. | N/A | 60% | 0.61 |
| MVP-LE-064 | 45.8~~45.9~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 25 | 25 | 40 | 15 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. | N/A | 0% | 0.00 |
| MVP-LE-065 | 45.8~~46~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 30 | 25 | 40 | 10 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 0.36 |
| MVP-LE-066 | 46.4~~46.3~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.6 | 25 | 25 | 40 | 15 | Operations maintenance | N/A | 0% | 0.00 |
| MVP-LE-066.02 | 46.3 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 10 | 25 | 40 | 30 | Mobilization of Construction material and personnel | N/A | 25% | 0.15 |
| MVP-LE-066.01 | 46.8~~46.7~~ | P | Temp | E | Gravel/ | Roadway Widening, Grading, Stabilization | 2.6 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. Provides ridgetop access. | N/A | 0% | 0.00 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-LE-067 | 47.8~~48~~ | P | Perm~~Temp~~ | E | Gravel | Roadway Widening, Grading, Stabilization | 0.3~~2~~ | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 0.19 |
| MVP-LE-068 | 48~~48.1~~ | P | Perm | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.6 | 8 | 25 | 40 | 32 | Operations maintenance | N/A | 50% | 1.49 |
| MVP-LE-069 | 51~~50.8~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.5 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 1.18 |
| MVP-LE-069.01 | 50.8~~50.9~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 0.07 |
| MVP-LE-070 | 51.7~~51.8~~ | P | Perm~~Temp~~ | E | Dirt | Operations ~~Roadway Widening, Grading, Stabilization~~ | 1.0 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 1.26 |
| MVP-MLV-AR-006 | 53~~.530~~ | P | Perm | N~~TBD~~ | Dirt~~TBD~~ | New Construction - | 0.08~~0.0~~ | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV6 | Access to MLV-6~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-LE-071 | 53.1~~53~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.0 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 25% | 0.04 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-LE-072 | 53.9~~538~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.0 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 0% | 0.00 |
| MVP-LE-073 | 55~~55.1~~ | P | Perm ~~Temp~~ | E | Gravel | Roadway Widening, Grading, Stabilization | 0.3 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel.~~–~~ Access road provides ridgetop access to north side of road crossing. | N/A | 0% | 0.00 |
| MVP-LE-073.01 | 55.1~~55.2~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.3 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 50% | 0.78 |
| MVP-LE-073.02 | 55.2~~553~~ | P | Temp ~~Perm~~ | E | Gravel | Roadway Widening, Grading, Stabilization | .01 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 50% | 0.25 |
| MVP-LE-074 | 59.2~~593~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.5 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 50% | 1.23 |
| MVP-LE-075.01 | 59.5 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | .03 | 10 | 25 | 40 | 30 | Mobilization of construction personnel and Material | N/A | 0 | 0 |
| MVP-LE-075 | 59.6~~59.7~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.1 | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 2.68 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-LE-076 | 59.7~~598~~ | P | Perm ~~Temp~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 0.9 | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel. Provides necessary access to the north side of Interstate 79. | N/A | 30% | 1.23 |
| MVP-LE-077 | 60.1~~60.2~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 8 | 25 | 40 | 32 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel.~~-~~ Provides necessary access to the north side of Interstate 79. | N/A | 100% | 0.74 |
| MVP-LE-077.01 | 61.1~~60.8~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.7 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 40% | 3.29 |
| MVP-LE-077.02 | | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.0 | 8 | 25 | 40 | 32 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 4.82 |
| MVP-LE-077.03 | 62.8 | P | Perm ~~Temp~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 0.6 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 3.05 |
| MVP-LE-083 | 62.9~~63~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 10 | 25 | 40 | 30 | Operations Maintenance | N/A | 100% | 1.69 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-LE-084 | 65.3 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.7 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 1.78 |
| MVP-MLV-AR-07 | 64.68 | P | Perm | N~~TBD~~ | N~~TBD~~ | New Construction~~TBD~~ | 0.0 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV7 | Access to MLV-07~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| **Braxton** | **County** | | | | | | | | | | | | | | |
| MVP-MLV-AR-08 | 65.4~~65~~ | P | Perm | N~~TBD~~ | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.0 | N/A~~TBD~~ | 25 | 40 | TBD | MLV 8 | Access to MLV-08~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-BR-086.01 | 67 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | .30 | 10 | 25 | 40 | N/A | Operations maintenance | N/A | 50% | 0.75 |
| ~~MVP-BR-086~~ | ~~67.45~~ | ~~P~~ | ~~Perm~~ | ~~E~~ | ~~Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~1.1~~ | ~~8~~ | ~~25~~ | ~~40~~ | ~~32~~ | ~~Operations maintenance~~ | ~~N/A~~ | ~~50%~~ | ~~1.32~~ |
| MVP-BR-087 | 67.7~~67~~ | S | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.6 | `10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 1.32 |
| MVP-BR-088 | 68.5~~68~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.5 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 2.20 |
| MVP-BR-089.01 | 68.8 | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | New Construction ~~TBD~~ | 0.01 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-BR-90.01 | 69.9 | P | Perm | E | Dirt | Roadway Widening, - Grading, Stabilization | 1.00 | 10 | 25 | 40 | 30 | Operations maintenance | TBD | 50% | 2.44 |
| MVP-BR-90.02 | 70.2 | P | Perm | E | Dirt | Roadway Widening, - Grading, Stabilization | 0.61 | 10 | 25 | 40 | 30 | Mobilization of construction personnel. | TBD | 75% | 2.24 |
| MVP-BR-092.01 | 71.6~~71~~ | P | Temp | E | Dirt | Roadway Widening, - Grading, Stabilization | 0.1 | 8 | 25 | 40 | 32 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 25% | 0.14 |
| MVP-BR-095 | 72.2~~72~~ | P | Temp | E | Dirt | Roadway Widening, - Grading, Stabilization | .2~~0.5~~ | 15 | 25 | 40 | 25 | Operations maintenance | N/A | 10% | 0.11~~0.22~~ |
| MVP-BR-095.01 | 72 | P | Temp | E | Dirt | Roadway Widening, - Grading, Stabilization | 0.2 | 15 | 25 | 40 | 25 | Mobilization of construction personnel. | N/A~~TBD~~ | 75% | .80 |
| MVP-BR-094 | 72~~72.1~~ | P | Temp | E | Dirt | Roadway Widening, - Grading, Stabilization | 0.3 | 10 | 25 | 40 | 30 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 25% | 0.35 |
| MVP-BR-093 | 71.9~~72~~ | P | Temp | E | Dirt | Roadway Widening, - Grading, Stabilization | 0.5 | 10 | 25 | 40 | 30 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 25% | 0.54 |
| MVP-BR-097 | 72.6 | P | Temp | E | Dirt | Roadway Widening, - Grading, Stabilization | 0.4 | 8 | 25 | 40 | 32 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 100% | 1.90 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-BR-096 | 72.4~~72.5~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 8 | 25 | 40 | 32 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.51 |
| MVP-BR-098 | 73.3~~73~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.8 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 1.91 |
| MVP-BR-099 | 73.7~~73.9~~ | P | Temp~~Perm~~ | E~~N~~ | Dirt~~TBD~~ | Roadway widening, Grading, Stabilization~~TBD~~ | 0.1 | 18 | 25 | 40 | 22 | Operations maintenance | TBD | 100%~~N/A~~ | 0.40~~N/A~~ |
| MVP-BR-100 | 74~~74.1~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.3 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.69 |
| MVP-BR-101 | 74.4~~74.5~~ | S/P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 50% | 0.39 |
| MVP-BR-103 | 74.7~~74.8~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.5~~1.1~~ | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 10% | 0.71~~0.55~~ |
| MVP-BR-103.01 | 74.9 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.3 | 10 | 25 | 40 | 30 | Mobilization of construction personnel | TBD | 75% | 4.78 |
| MVP-ANC-001 | 75.3 | P | Temp | E | Asphalt | N/A | 0.24 | 17 | 25 | 40 | 23 | Access into ancillary site | TBD | 0 | 0 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or Upland | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-BR-104 | 76.2~~76~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 50% | 1.00 |
| MVP-BR-104.01 | 76.7~~76.8~~ | P | Temp | E~~N~~ | Dirt | Roadway Widening, Grading, Stabilization | 0.03 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100%~~N/A~~ | 0.15~~N/A~~ |
| MVP-BR 105 | 77.2~~77.3~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.1 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 10% | 0.05 |
| MVP-BR-105.03 | 77.3 | P | Perm | N | Dirt | Roadway widening, grading, Stabilization | 0.14 | 0 | 25 | 40 | 0 | Access into Harris compressor station | N/A~~TBD~~ | N/A | N/A |
| MVP-BR-105.02 | 77.5 | P | Perm | N | Dirt | Roadway widening, grading, stabilization | 0.09 | 0 | 25 | 40 | 0 | Access into WB Interconnect | N/A~~TBD~~ | N/A | N/A |
| ~~MVP-BR-105.01~~ | ~~77.5~~ | ~~P~~ | ~~Perm~~ | ~~N~~ | ~~Dirt~~ | ~~New~~ | ~~0.3~~ | ~~0~~ | ~~25~~ | ~~40~~ | ~~40~~ | ~~MLV9 Harris~~ | ~~Permanent~~ | ~~N/A~~ | ~~N/A~~ |
| MVP-BR-106 | 78 | P | Perm | E | Gravel /Dirt~~TBD~~ | TBD | 0.5 | 9 | 25 | 40 | 31 | Operations maintenance | TBD | 100% | 2.53 |
| ~~MVP-ANC-001~~ - | ~~79~~ | ~~P~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.2~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel into ancillary site.~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |

**Webster County**

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WB-107 | 80~~.~~3~~8~~ | P | Perm | E | Dirt | Roadway | 0.3 | 6 | 25 | 40 | 34 | Operations maintenance | N/A | 50% | 0.83 |
| MVP-WB-110.01 | 80.8 | P | Temp | E | Dirt | Roadway widening, Grading, Stabilization | 0.02 | 10 | 25 | 40 | 30 | Mobilization of construction personnel | N/A~~TBD~~ | 50% | 0.09 |
| MVP-WB-110 | 80.8 | P | Temp | E | Dirt | Roadway widening, Grading, Stabilization | 0.15 | 10 | 25 | 40 | 30 | Mobilization of construction personnel | N/A~~TBD~~ | 75% | 0.54 |
| MVP-WB-108 | 81 | P | Temp | E | Grave/Dirt | Roadway widening, Grading, Stabilization | 0.46 | 12 | 25 | 40 | 28 | Mobilization of construction personnel | N/A~~TBD~~ | 25% | 0.56 |
| MVP-WB-111 | 81.7 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel to south side of wetland and stream crossings | N/A | 50% | 0.51 |
| MVP-WB-113 | 82.05 | P | Temp | E | Dirt | New Construction | 0.0 | 0 | 25 | 40 | 40 | Operations maintenance | N/A | N/A | N/A |
| MVP-WB-114 | 82.5~~82.4~~ | P | Temp | E | Rock/Dirt | Roadway Widening, Grading, Stabilization | 0.38~~0.8~~ | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | N/A | 0.921~~.92~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WB-114.01 | 82.3 | P | Temp | N~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization TBD | 0.04 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-WB-116 | 83.1~~8~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.0 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 2.46 |
| MVP-WB-117 | 83.7~~83.7~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 1.6 | 8 | 25 | 40 | 32 | Operations Maintenance | N/A | 50% | 3.91 |
| MVP-WB-117.01 | 83.9~~84~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 10% | 0.17 |
| MVP-WB-119 | 86.2~~85.8~~ | P | Perm | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 3.8 | 16 | 25 | 40 | 24 | Operations maintenance | N/A | 10% | 1.81~~1.83~~ |
| MVP-WB-119.01 | ~~85.7~~ | P | Temp | E | Gravel/Dirt | Roadway Widening, grading, Stabilization | 0.06 | 16 | 25 | 40 | 24 | Mobilization of construction personnel | N/A~~TBD~~ | 10% | 0.03 |
| ~~MVP-WB-120~~ | ~~88.7~~ | ~~P~~ | ~~Perm~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~2.4~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Operations maintenance~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WB-121 | 90.5~~9~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 3.56~~3.0~~ | 10 | 25 | 40 | 30 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 10% | 1.73~~1.45~~ |
| MVP-WB-120.01 | 89.6~~89.1~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 2.9 | 8 | 25 | 40 | 32 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 25% | 3.46 |
| MVP-WB-122 | 90.7~~90.8~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 1.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 25% | 1.39 |
| MVP-WB-123 | 91.8~~91.9~~ | P | Perm | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 6.5 | 15 | 25 | 40 | 25 | Operations maintenance | N/A | 15% | 4.74~~4.69~~ |
| MVP-WB-124 | 92.4 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.37 | 12 | 25 | 40 | 28 | Mobilization of construction personnel to stream crossing | TBD | 75% | 1.35 |
| MVP-WB-125 | 92.7 | S/P | Perm~~T~~ | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 1.0 | 15 | 25 | 40 | 25 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 90% | 4.23 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~~MVP-WB-126~~ | ~~93.1~~ | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Dirt~~ | Roadway Widening, Grading, Stabilization | ~~0.0~~ | ~~10~~ | ~~25~~ | ~~40~~ | ~~30~~ | Mobilization of construction material.– Safely ingress and egress of construction personnel<br>- | | ~~10%~~ | ~~0.00~~ |
| MVP-MLV-AR-010 | 93~~93.1~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | MLV10 | N/A | 10% | 0.12~~0.00~~ |
| MVP-MLV-126.01 | 95.3~~95.4~~ | P | Perm | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization ~~TBD~~ | 0.6 | TBD | 25 | 40 | TBD | Operations maintenance | TBD | 50%~~TBD~~ | 1.35~~TBD~~ |
| MVP-WB-127 | 97.6 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 10 | 25 | 40 | 30 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 25% | 0.14 |
| MVP-WB-128 | 98.1~~98.2~~ | P | Perm~~Temp~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 0.6 | 5 | 25 | 40 | 35 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 50% | 1.35 |
| MVP-MLV-AR-11 | 98.7~~98.3~~ | P | Perm | N | Dirt | New Construction | 0.0 | 0 | 25 | 40 | 40 | MLV11 | N/A | N/A | N/A |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or ... | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WB-129 | 98.8~~98~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 75% | 1.39 |
| MVP-MLV AR-12 | 102.3~~101.78~~ | P | Perm | ~~E~~~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization ~~TBD~~ | 0.10~~0.0~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | MLV 12 | N/A~~TBD~~ | 100%~~TBD~~ | 0.49~~TBD~~ |
| ~~MVP-WB-130~~ | ~~101.8~~ | ~~S~~ | ~~Perm~~ | ~~E~~ | ~~Dirt~~ | Roadway Widening, Grading, Stabilization | ~~0.5~~ | ~~10~~ | ~~25~~ | ~~40~~ | ~~30~~ | ~~Operations maintenance~~ | ~~N/A~~ | ~~70%~~ | ~~1.71~~ |
| MVP-WB-131 | 103.4~~103.2~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 1.0 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 1.24 |
| MVP-WB-131.01 | 103.45 | P | Perm~~Temp~~ | E | Gravel~~Dirt~~ | Operations Maintenance ~~Roadway~~ Widening, Grading, Stabilization | 0.6 | 12~~10~~ | 25 | 40 | 28~~30~~ | Operations maintenance ~~Mobilization of construction material. – Safely ingress and egress of construction personnel~~ | N/A | 10% | 0.31 |
| MVP-WB-131.02 | 103.4 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.06 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 100% | 0.29 |
| MVP-WB-131.03 | ~~103.4~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.38 | 12 | 25 | 40 | 28 | Mobilization of ~~contruction~~construction personnel | N/A | 75% | 1.40 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-WB-132 | 104.9 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.7 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel.~~–~~ Provides access to several miles of ridgetop. | N/A | 25% | 0.87 |
| MVP-WB-132.01 | 104.9 | P | Temp | E | Gravel/ grass | Roadway Widening, Grading, Stabilization | 0.09 | 10 | 25 | 40 | 30 | Mobilization of construction personnel | N/A | 50% | 0.22 |
| MVP-WB-133 | 107.5~~107.3~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.5 | 6 | 25 | 40 | 34 | Operations maintenance | N/A | 50% | 1.14 |
| MVP-WB-134 | 109.6~~109.4~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.49 |
| **Nicholas** | **County** | | | | | | | | | | | | | | |
| MVP-NI-136 | 110 ~~100~~ | P | Temp | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 20% | 0.22 |
| MVP-NI-136.01 | 111.2 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.014 | 10 | 25 | 40 | 30 | Operations maintenance | N/A~~TBD~~ | 10% | 0.07 |
| - MVP MLV AR-13 | 111.3 | P | Perm | N ~~TBD~~ | Dirt ~~TBD~~ | Roadway Widening, Grading, Stabilization | 0.02~~20.0~~ | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV 13 | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or ... | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~~MVP-NI-137~~ | ~~111.4~~ | ~~P~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.3~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-NI-139 | 111.8~~111.9~~ | P | Perm | E~~TBD~~ | Gravel/ Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.26~~0.7~~ | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Operations maintenance | TBD | 20%~~TBD~~ | 0.25~~TBD~~ |
| MVP-NI-140 | 112.7~~112.2~~ | P | Temp | E~~TBD~~ | Asphalt/Gravel~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.66~~0.5~~ | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | TBD | 25%~~TBD~~ | 0.80~~TBD~~ |
| ~~MVP-NI-141~~ | ~~112.7~~ | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Asphalt/Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.8~~ | ~~20~~ | ~~25~~ | ~~40~~ | ~~20~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~50%~~ | ~~1.81~~ |
| MVP-NI-141.01 | ~~113.5~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.23 | 12 | 25 | 40 | 28 | Mobilization of construction material.– Safely ingress and egress of construction personnel | | 50% | 0.56 |
| ~~MVP-NI-145~~ | ~~115.3~~ | P~~P~~ | ~~Perm~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.4~~ | ~~25~~ | ~~25~~ | ~~40~~ | ~~15~~ | ~~Operations maintenance~~ | ~~TBD~~ | | |
| MVP-NI-145.01 | 115.5 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.41 | 8 | 25 | 40 | 32 | Operations maintenance | TBD | 100% | 1.98 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP NI-146 | 116.1~~115.8~~ | P | Temp | E | Dirt/ Asphalt | Roadway Widening, Grading, Stabilization | 0.9 | 8 | 25 | 40 | 32 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 4.50~~4.25~~ |
| MVP-NI-147 | ~~116.511~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.98~~0.6~~ | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 2.37~~1.44~~ |
| MVP-NI-148 | 116.75~~116~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.37 |
| MVP-NI-148.01 | 117.6 | P | Temp | E | Rock | Roadway Widening, Grading, Stabilization | 0.26 | 15 | 25 | 40 | 25 | Mobilization of construction ~~pesonnel~~personnel | N/A | 50% | 0.77~~1.32~~ |
| MVP-NI-149 | 117.6 | P | Temp | E | Rock | Roadway Widening, Grading, Stabilization | 0.26 | 15 | 25 | 40 | 25 | Operations maintenance | N/A | 50% | 0.77~~1.32~~ |
| ~~MVP-NI-150~~ | ~~118.5~~ | ~~S~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.7~~ | ~~30~~ | ~~25~~ | ~~40~~ | ~~10~~ | ~~Mobilization of construction pesonnelpersonnel~~ | ~~N/A~~ | ~~50%~~ | ~~1.76~~ |
| MVP-NI-151 | 119~~118.7~~ | P | Temp | TBD | TBD | TBD | 1.4 | 18~~TBD~~ | 25 | 40 | 22~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | TBD | 10%~~TBD~~ | 0.66~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP~~O~~-NI-151.01 | 119.8 | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.63 | 20 | 25 | 40 | 20 | Mobilization of Construction personnel | N/A | 10% | 0.30 |
| MVP-NI-152 | 119.5~~119.1~~ | P | Temp | N | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 0 | 25 | 40 | 40 | Mobilization of construction personnel~~N/a~~ | N/A | N/A | N/A |
| MVP-NI-153 | 120.2~~119.4~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.68~~0.4~~ | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 1.64~~0.95~~ |
| MVP-NI-153.01 - | 120.2 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.02 | 12 | 25 | 40 | 28 | Mobilization of construction personnel | TBD | 25% | 0.03 |
| ~~MVP-NI-154~~ | ~~119.9~~ | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Gravel/Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.0~~ | ~~15~~ | ~~25~~ | ~~40~~ | ~~25~~ | ~~MLV14~~ | ~~N/A~~ | ~~10%~~ | ~~0.00~~ |
| MVP-MLV-AR-14 | 120.3~~119~~ | P | Perm | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 2.92~~0.4~~ | 12 | 25 | 40 | 28 | MLV14 | N/A | 5% | 0.71~~0.00~~ |
| MVP-NI-154.01 | 120.3~~120~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.3 | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 10% 10% | 0.13 |
| ~~MVP-MLV-AR-14~~ | ~~119.9~~ | ~~P~~ | ~~Pem~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~2.5~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. – Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-NI-155 | 123.2~~122.8~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 75% | 0.85 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-NI-156 | 123.3~~123~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 5.7 | 15 | 25 | 40 | 25 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 27.76 |
| MVP-NI 157 | 124~~123.7~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.8 | 15 | 25 | 40 | 25 | Operations maintenance | N/A | 60% | 2.41 |
| MVP-NI-158 | 124.6~~124.3~~ | P | Temp | E | Gravel/ | Roadway Widening, Grading, Stabilization | 0.13~~0.2~~ | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.31~~0.35~~ |
| MVP-NI-158.01 | 125.3~~125~~ | P | Temp | E | Rock/ | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 40% | 0.36 |
| MVP-NI-160 | 126.8~~126.3~~ | P | Temp~~Perm~~ | E | Gravel | Roadway Widening, Grading, Stabilization | 0.4 | 30 | 25 | 40 | 10 | Operations maintenance | N/A | 5%~~100%~~ | 0.10~~2.03~~ |
| MVP-NI-159 | 126.7~~126.3~~ | P | Perm | E | Gravel/ | Roadway Widening, Grading, Stabilization | 3.5 | 30 | 25 | 40 | 10 | Operations maintenance | N/A | 5%~~100%~~ | 0.85~~17.01~~ |
| MVP-NI-159.01 | 125.9~~125.5~~ | P | Temp | E | Gravel/ | Roadway Widening, Grading, Stabilization | 1.1 | 30 | 25 | 40 | 10 | Mobilization of construction material.~~-~~ Safely ingress and egress of construction personnel | N/A | 75% | 4.02 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-NI-160.01 | 126.8~~126.5~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.3 | 40 | 25 | 40 | 0 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 1.34 |
| MVP-NI-161 | 127~~126.7~~ | P | Perm | E | Asphalt/ Dirt | Roadway Widening, Grading, Stabilization | 1.6 | 30 | 25 | 40 | 10 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 3.77 |
| MVP-NI-163 | 129.7~~128.1~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 20 | 25 | 40 | 20 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 1.14 |
| MVP-NI-164 | 130.5~~128.6~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.7 | 30 | 25 | 40 | 10 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 0.82 |
| MVP-NI-166 | 130.5~~130.1~~ | S/P | Temp | E | Gravel/ | Roadway Widening, Grading, Stabilization | 0.5 | 30 | 25 | 40 | 10 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.24 |
| MVP-NI-167 | 131.2~~4~~ | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.7 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50%~~TBD~~ | 1.59~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-NI-168 | 131.3~~131~~ | P | Perm | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.3 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Operations maintenance | N/A | 50%~~TBD~~ | 0.68~~TBD~~ |
| MVP-NI-170 | 132.9~~132.6~~ | P | Perm | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 90% | 1.73 |
| MVP-NI-171 | 133.4~~133.1~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 75% | 0.59 |
| MVP-NI-172 | | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.2 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25%~~75%~~ | 0.06~~0.59~~ |
| **Greenbrier** | **County** | | | | | | | | | | | | | | |
| MVP-GB-174 | | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.0 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 10% | 0.01 |
| MVP-GB-174.01 | 136.3~~136~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 0.08 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GB-174.03 | 136.8 | P | Temp | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 1.71 | 15 | 25 | 40 | 25 | Mobilization of construction personnel | N/A~~TBD~~ | 10% | 0.83 |
| MVP-GB-176 | 137.6~~137.2~~ | P | Temp | E | Gravel/ Dirt | Roadway Widening, grading, Stabilization | 0.7 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 10% | 0.35 |
| MVP-GB-177 | 138.6~~138.3~~ | P | Temp | E | TBD | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.2 | 8~~TBD~~ | 25 | 40 | 32~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | 25% | 0.26 |
| MVP-MLV-AR-15 | 138.7~~138.35~~ | S/P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.77~~0.6~~ | 15 | 25 | 40 | 25 | MLV15 | N/A | 5% | 0.19~~0.00~~ |
| MVP-GB-178 | 138.7~~139.5~~ | P | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 3.50~~3.4~~ | 20~~TBD~~ | 25 | 40 | 20~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50%~~TBD~~ | 8.49~~TBD~~ |
| MVP-GB-178.01 | 139.3 | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.17 | 20 | 25 | 40 | 20 | Mobilization of construction personnel | N/A | 5% | .04 |
| MVP-GB-179 | 140.2~~140~~ | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway widening, Grading, Stabilization~~TBD~~ | 0.45~~0.7~~ | 15~~TBD~~ | 25 | 40 | 25~~TBD~~ | Mobilization of construction material.~~-~~ Safely ingress and egress of construction personnel | TBD | 50%~~TBD~~ | 1.09~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP GB-179.01 | 140.5 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.55 | 18 | 25 | 40 | 2 | Mobilization of construction personnel | TBD | 70% | 5.24 |
| MVP-MLV-AR-16 | 140.9~~14 0.5~~ | P | Perm | N~~TBD~~ | Dirt~~TBD~~ | New Construction~~Roadway Widening, Grading, Stabilization~~ | 0.03~~0.0~~ | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV16 | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-GB-182 | 143.2~~142.8~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 1.7 | 12 | 25 | 40 | 28 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 30% | 2.46 |
| MVP-GB-183 | 143.9~~143.6~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.07 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~-~~ Safely ingress and egress of construction personnel to north side of highway 60 crossing and river crossing. | N/A | 15% | 0.05 |
| MVP-MLV-AR-17 | 143.9~~143~~ | P | Perm | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.19~~0.2~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | MLV17 | N/A | 30%~~TBD~~ | 0.27~~TBD~~ |
| MVP-MLV-AR-18 | 1144.1~~43.~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.03~~0.0~~ | 20 | 25 | 40 | 20 | MLV 18 | N/A | 25% | 0.01~~0.00~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GB-184 | 145.2~~145~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.80~~0.7~~ | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 25% | 0.97~~0.86~~ |
| MVP-GB-184.01 | 145.2 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.15 | 15 | 25 | 40 | 25 | Mobilization of construction personnel | TBD | 50% | 0.35 |
| MVP-GB-185 | 147~~146~~ | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.2 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 10% | 0.07 |
| MVP-GB-186 | 147.1~~146~~ | P | Perm | E | Gravel/ | Roadway Widening, Grading, Stabilization | 0.1 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 50% | 0.22 |
| MVP-GB-187 | 148.7~~148.2~~ | P | Perm | E | Gravel/ | Roadway Widening, Grading, Stabilization | 0.94~~0.2~~ | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 25% | 1.14~~0.27~~ |
| MVP-GB-187.01 | 148.1~~147.~~ | P | Temp | E | Gravel/ | Roadway Widening, Grading, Stabilization | 0.3 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.83 |
| MVP-GB-187.02 | 148~~147.7~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.1 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 0.51 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GB-187.03 | 148.2~~147.~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.2 | 20 | 25 | 40 | 20 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 50% | 0.39 |
| MVP-GB-188 | 148.9~~148.5~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 50% | 0.39 |
| MVP-GB-189 | 149.9~~149.6~~ | P | Perm | E~~TBD~~ | Gravel/ Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization ~~TBD~~ | 0.6 | 15~~TBD~~ | 25 | 40 | 25~~TBD~~ | Operations maintenance | TBD | 75%~~TBD~~ | 2.27 |
| MVP-GB-190 | 150.6~~150.3~~ | P | Perm | E | Gravel/ | Roadway Widening, Grading, Stabilization | 0.6 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 90% | 2.70 |
| MVP-GB-190.01 | 154.4~~154.1~~ | P | Perm | N | Dirt | New Construction | 0.4 | 0 | 25 | 40 | 40 | MLV19 /Stallworth CS | Permanent access for MLV 19 and Stallworth Compressor Station | N/A | N/A |
| MVP-GB-190.02 | 154.9 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.27 | 12 | 25 | 40 | 28 | Mobilization of construction personnel | N/A | 100% | 1.30 |
| MVP-GB-193.01 | 155.4 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.34 | 10 | 25 | 40 | 30 | Mobilization of construction personnel | N/A | 50% | 0.82 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GB-193 | 155.6~~155.2~~ | P | Perm~~Temp~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 10 | 25 | 40 | 30 | Operations ~~Maointenance~~Maintenance ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | N/A~~TBD~~ | 50% | 0.79 |
| MVP-GB-194 | 156.5~~156.1~~ | S/P | Perm | E~~TBD~~ | Gravel/ Dirt ~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.4 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Operations maintenance | N/A~~TBD~~ | 80%~~TBD~~ | 1.48~~TBD~~ - |
| MVP-GB-196 | 157~~156.6~~ | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.1 | 12 | 25 | 40 | 28 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 50% | 0.21 |
| **Summers** | **County** | | | | | | | | | | | | | | |
| MVP-SU-195 | 157.3~~156.9~~ | S/P | Perm | E | Asphalt | Roadway Widening, Grading, Stabilization | 0.5 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 10% | 0.15~~0.23~~ |
| MVP-SU-197 | 158.7 | P | Perm | N | Dirt | New Construction | 0.1 | 0 | 25 | 40 | 40 | Operations maintenance | N/A | N/A | N/A |
| MVP-SU-197.01 | 161.2~~160.8~~ | P | Temp | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.32 | 15 | 25 | 40 | 25 | Mobilization of construction personnel | N/A | 100% | 1.54 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-SU-198 | 161.2 | P | Temp | E | Rock/Dirt | Roadway Widening, Grading, Stabilization | 1.5 | 12 | 25 | 40 | 28 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 100% | 7.30 |
| MVP-SU-199 | 161.7~~161.3~~ | S/P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 2.0 | 20 | 25 | 40 | 20 | Operations maintenance | N/A | 50% | 4.74 |
| MVP-SU-200 | 162.9~~162.5~~ | P | Temp | TBD | TBD | Roadway Widening, Grading, Stabilization~~TBD~~ | 2.10~~1.7~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | 75%~~TBD~~ | 6.03~~TBD~~ |
| MVP-SU-201 | 165.4~~165~~ | P | Temp | E | Rock/Dirt | Roadway Widening, Grading, Stabilization | 12 | 10 | 25 | 40 | 30 | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A | 100% | 5.90~~5.94~~ |
| MVP-SU-202 | 166.0~~165.6~~ | P | Perm | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.8 | 10%~~TBD~~ | 25 | 40 | 30~~TBD~~ | Operations maintenance | N/A~~TBD~~ | 80%~~TBD~~ | 3.16~~TBD~~ |
| ~~MVP-SU-203~~ | 171.3~~170.5~~ | ~~P~~ | ~~Perm~~ | ~~E~~ | ~~Gravel~~ | Roadway Widening, Grading, Stabilization | ~~0.2~~ | ~~12~~ | ~~25~~ | ~~40~~ | ~~28~~ | ~~Operations maintenance~~ | ~~N/A~~ | ~~10%~~ | ~~0.09~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-SU-205 | 171.3~~170.5~~ | P | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.3 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50%~~TBD~~ | 0.78~~TBD~~ |
| MVP-MLV-AR 20 | 170 | P | Perm | N | Dirt~~TBD~~ | New Construction | 0.0 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV 20~~1~~ | Permanent access to MLV 20 | N/A | N/A |
| MVP-MLV-AR 21 | 171.9 | P | Perm | N | Dirt~~TBD~~ | New Construction | 0.0 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV 21 | Permanent access to MLV 21 | N/A | N/A |
| MVP-SU-207 | 171.7 | P | Perm~~Temp~~ | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.67~~0.0~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | N/A~~TBD~~ | 75%~~TBD~~ | 2.45~~TBD~~ |
| MVP-SU-208 | 172.2 | P | Temp | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.4 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | ~~TBD~~ | 80%~~TBD~~ | 1.64~~TBD~~ |
| MVP-SU-208.01 | 172.4 | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway widening, grading, Stabilization~~TBD~~ | 0.33~~0.4~~ | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | TBD | 85%~~TBD~~ | 1.43~~TBD~~ |
| **Monroe** | **County** | | | | | | | | | | | | | | |
| MVP-MO-210 | 175.1~~173.6~~ | P | Temp~~Perm~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 1.5~~1.4~~ | 10 | 25 | 40 | 30 | Mobilization of construction personnel~~Operations maintenance~~ | N/A | 50% | 3.46~~3.~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-MO-211 | 176.3~~175.2~~ | S | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.5 | 8~~TBD~~ | 25 | 40 | 32~~TBD~~ | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A~~TBD~~ | 90%~~TBD~~ | 2.23~~TBD~~ |
| MVP-MO-212 | 176.8~~175.9~~ | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 1.1 | 8~~TBD~~ | 25 | 40 | 32~~TBD~~ | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A~~TBD~~ | 95%~~TBD~~ | 5.10~~TBD~~ |
| MVP-MO-213 | 177~~176.2~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 1.4 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 70% | 4.59~~4.61~~ |
| MVP-MO-214 | 177.4~~176.5~~ | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 10 | 25 | 40 | 30 | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A | 100% | 1.75~~1.76~~ |
| MVP-MO-215 | 177.7~~176.9~~ | P | Temp~~Perm~~ | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.5 | 15~~TBD~~ | 25 | 40 | 25~~TBD~~ | Mobilization of construction personnel~~Operations~~ | N/A~~TBD~~ | 85%~~TBD~~ | 2.11~~TBD~~ |
| MVP-MO-216 | 179.2~~178.3~~ | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.2 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A~~TBD~~ | 75%~~TBD~~ | 0.82~~TBD~~ |
| MVP-MO-217 | 180.2~~179.1~~ | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.4 | 10 | 25 | 40 | 30 | Operations maintenance | N/A | 25% | 0.44 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-MO-218 | 182.4~~181.5~~ | P | Perm~~Temp~~ | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.5 | TBD | 25 | 40 | ~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50%~~TBD~~ | 1.09~~TBD~~ |
| ~~MVP-MO-219~~ | ~~-~~ | ~~P~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~-~~ | ~~-~~ | ~~25~~ | ~~40~~ | ~~-~~ | - | ~~-~~ | ~~-~~ | ~~-~~ |
| MVP-MO-220 | 184.2~~183.3~~ | P | Perm | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.6 | 15~~TBD~~ | 25 | 40 | 25~~TBD~~ | Operations maintenance | N/A~~TBD~~ | 50%~~TBD~~ | 1.39~~TBD~~ |
| MVP-MO-221 | 185.2~~184.3~~ | P | Temp | E~~TBD~~ | Grass/Dirt ~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.2 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50%~~TBD~~ | 0.54~~TBD~~ |
| ~~MVP-MO-222~~ | ~~184.6~~ | ~~P~~ | ~~Perm~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.3~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Operations maintenance~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-MO 223 | 185.7~~184.8~~ | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.4 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material.~~–~~ Safely ingress and egress of construction personnel | TBD | 75%~~TBD~~ | 1.40~~TBD~~ |
| MVP-MLV-AR-22 | 186.4~~185.4~~ | P | Perm | N~~TBD~~ | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.0 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV-22 | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-MO-224 | 187.2~~186.2~~ | P | Perm | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.5 | TBD | 25 | 40 | TBD | Operations maintenance | TBD | 75%~~TBD~~ | 1.80~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-MO-225 | 187.2~~186.7~~ | P | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.6~~0.4~~ | 15~~TBD~~ | 25 | 40 | 25~~TBD~~ | Mobilization of construction material.– Safely ingress and egress of construction personnel | TBD | 75%~~TBD~~ | 2.12~~TBD~~ |
| MVP-MO-226 | 186.4~~185.4~~ | P | Temp | N~~TBD~~ | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.3 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | Mobilization of construction material.– Safely ingress and egress of construction personnel | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-MO-227 | 188.4 | S | Perm | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.7 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Operations Maintenance | N/A~~TBD~~ | 50%~~TBD~~ | 1.70~~TBD~~ |
| MVP-MO-227.01 | 190 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.15 | 10 | 25 | 40 | 30 | Operations Maintenance | TBD | 75% | 0.56 |
| MVP-MO-227.02 | 190.2 | P | Temp | E | Dirt | Roadway Widening, grading, Stabilization | 0.22 | 8 | 25 | 40 | 32 | Mobilization of construction personnel | TBD | 100% | 1.09 |
| MVP-MO-228 | 189.7 | P~~Private~~ | Temp | E~~TBD~~ | Dirt~~TBD~~ | ROADWAY Widening, Grading, Stabilization~~TBD~~ | 0.92 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Operations Maintenance | N/A~~TBD~~ | 75%~~TBD~~ | 3.35~~TBD~~ |
| MVP-MO-230 | 191.1 | P | Temp | E | Dirt | Roadway Widening, grading, Stabilization | 0.19 | 12.00 | 2 | 40 | 28 | Mobilization of Construction material. Safely Ingress and Egress of Construction personnel | N/A | 50% | 0.47 |
| MVP-MO-231.01 | 193.8 | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.21 | 8.00 | 25 | 40 | 32.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.50 |
| MVP-GI-231 | 195.8 | Private/USFS | TEMP | E | Dirt~~gravel~~ | Roadway widening, Grading, Stabilization | 1.23 | 10.00 | 25 | 40 | 30.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 2.99 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GI-232 | 196.9 | Private/USFS | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 6.25 | 12.00 | 25 | 40 | 28.00 | Operations Maintenance | N/A | 10% | 3.03 |
| ~~MVP-GI-233~~ | ~~197.5~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Rock~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.75~~ | ~~8.00~~ | ~~25~~ | ~~40~~ | ~~32.00~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel. Provides required access to South side of the Appalachain Trail crossing~~ | ~~N/A~~ | ~~25%~~ | ~~0.91~~ |
| MVP-GI-234 | 198.8~~197.8~~ | Private | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.5~~0.46~~ | 11.00 | 25 | 40 | 29.00 | Operations Maintenance | N/A | 60% | 1.40~~1.34~~ |
| MVP-GI-235 | 199.1~~198.2~~ | Private | Temp | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.5~~0.49~~ | 11.00 | 25 | 40 | 29.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 60% | 1.42~~1.29~~ |
| MVP-GI-236 | 199.3~~198.3~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.23 | 11.00 | 25 | 40 | 29.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.56 |
| MVP-MLV-AR-23 | 199.4~~198.46~~ | Private | Perm | New | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.04 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV-23 | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GI-237 | 199.7~~198.8~~ | Private | Temp | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.54~~0.6~~ | 12.00 | 25 | 40 | 28 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 70% | 1.84~~1.87~~ |
| MVP-GI-238 | 200.5~~199.6~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.80 | 15.00 | 25 | 40 | 25 | Mobilization of construction material. Safe ingress and egress of construction personnel. ~~Operations Maintenance~~ | N/A | 10% | 0.39 |
| MVP-MLV-AR-24 | 201.5~~200.5~~ | Private | Perm | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.49 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | MLV-24 | N/A~~TBD~~ | 25%~~TBD~~ | 0.60~~TBD~~ |
| ~~MVP-GI-239~~ | ~~200.5~~ | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.0~~ | ~~10~~ | ~~25~~ | ~~40~~ | ~~30~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~50%~~ | ~~0.05~~ |
| MVP-GI-240 | 201.8~~200.8~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.08 | 18.00 | 25 | 40 | 22 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 0.19~~0.21~~ |
| MVP-GI-241 | 202.2~~201.3~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.10 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.23 |
| MVP-GI-241.01 | 202.3 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.5 | 12 | 25 | 40 | 28 | Operations maintenance | N/A | 25% | 1.24 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GI-241.04 | 202.3 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.5 | 12 | 25 | 40 | 28 | Operations Maintenance | N/A | 25% | 0.66 |
| MVP-GI-241.02 | 204.3 | P | Temp | E | gravel | Roadway Widening, Grading, Stabilization | 0.2 | 10 | 25 | 40 | 30 | Mobilization of Construction material. Safe ingress and egress of construction personnel. | N/A | 10% | 0.10 |
| MVP-GI-241.03 | 204.6 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.57 | 10 | 25 | 40 | 30 | Mobilization of Construction Material. Safe ingress and egress of construction personnel. | N/A | 65% | 1.80 |
| MVP-GI-242 | 207.8 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.43 | 8 | 25 | 40 | 32 | Mobilization of Construction Material. Safe ingress and egress of construction personnel. | N/A | 50% | 1.04~~1.02~~ |
| ~~MVP-GI-243~~ | ~~207~~ | ~~P~~ | ~~Perm~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.4~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Operations Maintenance~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-GI-242.01 | 207.5 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.89 | 10 | 25 | 40 | 30 | Mobilization of construction Material. Safe ingress and egress of construction personnel. | N/A | 90% | 3.86 |
| MVP-GI-243.01 | 208.3~~207.2~~ | Private | Temp | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.62 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | TBD | 75% | 2.26 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GI-244 | 208.5~~207.5~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.46 | 12.00 | 25 | 40 | 28 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 1.11 |
| MVP-GI-245.01 | 209.3~~208.2~~ | Private | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.32 | 12.00 | 25 | 40 | 28 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 75% | 1.16 |
| MVP-GI-245.02 | 209.9~~208.9~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 1.14 | 12.00 | 25 | 40 | 28 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 25% | 1.38 |
| MVP-GI-245.02A | 209.9 | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.01 | 12 | 25 | 40 | 28 | Mobilization of construction material. Mobilization of construction personnel. | N/A | 50% | 0.02 |
| ~~MVP-GI-245.03~~ | ~~209~~ | ~~P~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.2~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel.~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-GI-249 | 210.9~~209.9~~ | Private | Perm | E | Asphalt | Roadway Widening, Grading, Stabilization | 0.4~~0.1~~ | 8.00 | 25 | 40 | 32 | Operations Maintenance | N/A~~TBD~~ | 10% | 0.20~~0.03~~ |
| MVP-GI-249.01 | 210 | Private | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.12 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 0.28 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GI-249.02 | 210.3 | Private | Perm~~Temp~~ | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.1~~0.07~~ | 12~~TBD~~ | 25 | 40 | 28 | Operations Maintenance~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | N/A~~TBD~~ | 25% | 0.08 |
| MVP-GI-249.03 | 211.3~~209.95~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.05 | 10 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 25% | 0.08 |
| MVP-MLV-AR-25 | 212.35~~211.11~~ | Private | Perm. | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.17~~0.03~~ | 15~~TBD~~ | 25 | 40 | 25~~TBD~~ | MLV25 | N/A | 25%~~TBD~~ | 0.03TBD |
| MVP-GI-253.01 | 213.3~~211.7~~ | Private | Perm | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.53 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 25% | 0.64 |
| MVP-GI-253.02 | 213.7~~212.4~~ | Private | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway widening, Grading, Stabilization~~TBD~~ | 0.2~~0.15~~ | 0.8~~TBD~~ | 25 | 40 | 32~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 75% | 0.55 |
| MVP-GI-253.03 | 212.9 | P | Temp | E | Gravel/Dirt | Roadway Widening, grading, Stabilization | 0.30 | 10 | 25 | 40 | 30 | Mobilization of construction material. Mobilization of construction personnel | N/A | 80% | 1.16 |
| MVP-GI-256~~.~~ | 213.1 | Private | Perm | E | Gravel/ Dirt | Roadway Widening, Grading, Stabilization | 0.14~~0.9~~ | 9.00 | 25 | 40 | 31 | Operations Maintenance | N/A~~TBD~~ | 25% | 0.17~~1.14~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-GI-256.01 | 214.9 | P | Temp | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.16 | 9 | 25 | 40 | 31 | Mobilization of Construction material. Mobilization of construction personnel. | N/A | 50% | 0.38 |
| MVP-GI-256.02 | 214.3 | P | Perm | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.81 | 9 | 25 | 40 | 31 | Mobilization of Construction material. Mobilization of construction personnel. | N/A | 50% | 1.96 |
| MVP-CR-258.01 | 215.6 | Private | Temp | E~~TBD~~ | Asphalt/Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.29 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 10%~~TBD~~ | 0.14~~TBD~~ |
| MVP-CR-258.02 | 216.6 | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.78 | 15.00 | 25 | 40 | 25 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 1.88 |
| MVP-MN-258.03 | 218.2 | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.04 | 8.00 | 25 | 40 | 32 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 0.09~~0.13~~ |
| MVP-MN-258.04 | 218.3 | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.12 | 8.00 | 25 | 40 | 32 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 0.30~~0.25~~ |
| MVP-MN-258.05 | 219.7~~218.3~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.05 | 8.00 | 25 | 40 | 32 | Mobilization of construction material. Safely ingress and egress of construction personnel | TBD | 50% | 0.12 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Ownership | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| revisit after Mt Tabor re-route determination | | | | | | | | | | | | | | | 0.00 |
| ~~MVP-MN-260~~ | ~~221.2~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.02~~ | ~~8.00~~ | ~~25~~ | ~~40~~ | ~~32~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~50%~~ | ~~0.06~~ |
| ~~MVP-MN-261~~ | ~~221.7~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.27~~ | ~~8.00~~ | ~~25~~ | ~~40~~ | ~~32~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~25%~~ | ~~0.32~~ |
| MVP-MN-262.01 | 222 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.57 | 10 | 25 | 40 | 30 | Mobilization of construction material and equipment. Mobilization of construction personnel. | N/A | 25% | 0.69 |
| MVP-MLV-AR-26 | 222.11 | Private | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.67 | 12.00 | 25 | 40 | 28 | MLV26 | Permanent access to MLV26 | 25% | 0.81 |
| ~~MVP-MN-263~~ | ~~223.4~~ | ~~Private~~ | | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.43~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Operations Maintenance~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| ~~MVP-MN-26~~4 | ~~223.8~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.83~~ | ~~15.00~~ | ~~25~~ | ~~40~~ | ~~25~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~25%~~ | ~~1.00~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~~MVP-MN-265~~ | ~~224~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.08~~ | ~~12.00~~ | ~~25~~ | ~~40~~ | ~~28~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~50%~~ | ~~0.20~~ |
| MVP-MN-266 | ~~224.3~~227 | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 1.58 | 15.00 | 25 | 40 | 25 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 25% | 1.92 |
| ~~MVP-MN-266.01~~ | ~~225.2~~ | ~~Private~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.04~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-MN-266.02 | 224.3 | P | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.78 | 8 | 25 | 40 | 32 | Mobilization of construction personnel. Mobilization of construction material. | N/A | 75% | 2.83 |
| ~~MVP-MN-267~~ | ~~225.2~~ | ~~Private~~ | | ~~E~~ | ~~Gravel/Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.04~~ | ~~10.00~~ | ~~25~~ | ~~40~~ | ~~30~~ | ~~Operations Maintenance~~ | ~~TBD~~ | ~~10%~~ | ~~0.02~~ |
| MVP-MN-266.03 | 225.6 | P | Perm | E | Gravel | Roadway Widening, Grading, and Stabilization | 0.68 | 10 | 25 | 40 | 30 | Operations Maintenance | N/A | 65% | 2.14 |
| MVP-MN-268 | 227.5~~225.9~~ | Private | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.37 | 10.00 | 25 | 40 | 30 | Operations Maintenance | N/A~~TBD~~ | 100% | 1.87~~1.80~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-MN-270 | 228.6~~227~~ | Private | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.5 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 60%~~TBD~~ | 3.42~~TBD~~ |
| MVP-MV-270.01 | 229.2 | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.28 | 10 | 25 | 40 | 30 | Mobilization of construction materials. Safe ingress and egress of construction personnel. | N/A | 15% | 0.20 |
| MVP-MN-271 | 229.3~~227.7~~ | Private | Perm | E | Asphalt/Dirt | Roadway Widening, Grading, Stabilization | 0.16~~0.1~~ | 6.50 | 25 | 40 | 33.5 | Operations Maintenance | N/A~~TBD~~ | 10% | 0.08 |
| MVP-MN-272 | 229.9~~228.3~~ | Private | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.49 | 8~~TBD~~ | 25 | 40 | 32 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50%~~TBD~~ | 1.18~~TBD~~ |
| MVP-MN-273 | 230.12~~228.5~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.32 | 15.00 | 25 | 40 | 25 | Operations Maintenance | TBD | 75% | 1.17 |
| MVP-MN-274 | 230.8 | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.09 | 8.00 | 25 | 40 | 32 | Mobilization of construction material. Safely ingress and egress of construction personnel | TBD | 25% | 0.11 |
| ~~MVP-MN-274.01~~ | ~~220.1~~ | ~~Private~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.1~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safe ingress and egress of construction personnel~~. | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-MN-275 | 231~~229.3~~ | Private | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.12 | 8.00 | 25 | 40 | 32 | Operations Maintenance | N/A~~TBD~~ | 25% | 0.14 |
| MVP-MN-276 | 231.7~~230~~ | Private | Perm~~Temp~~ | E | Gravel | Roadway Widening, Grading, Stabilization | 2.4~~2.3~~ | 12.00 | 25 | 40 | 28 | Operations Maintenance | N/A~~TBD~~ | 15% | 1.76~~1.67~~ |
| MVP-MN-276.03 | 230 | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 3.38 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 25% | 4.09 |
| MVP-MN-276.02 | 231.3~~230~~ | Private | Perm~~Temp~~ | E | Gravel | Roadway Widening, Grading, Stabilization | 0.11 | 8 | 25 | 40 | 32 | Operations maintenance | N/A | 25% | 0.13 |
| MVP-MN-276.01 | 231.3~~230~~ | Private | Perm~~Temp~~ | E | Gravel | Roadway widening, Grading, Stabilization | 0.06~~2.1~~ | 10 | 25 | 40 | 30 | Operations Maintenance | N/A | 25% | 0.08~~2.57~~ |
| MVP-ANC-002 | 231.3 | Private | Temp | E~~TBD~~ | Asphalt~~TBD~~ | None~~TBD~~ | 0.03 | 25~~TBD~~ | 25 | 40 | 15~~TBD~~ | Entry to Ancillary Site | N/A~~TBD~~ | 0%~~TBD~~ | 0~~TBD~~ |
| ~~MVP-MN-277~~ | ~~232.4~~ | ~~P~~ | ~~Perm~~ | ~~E~~ | ~~Gravel/Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~1.0~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Operations Maintenance to North side of Interstate 81~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-MN-277.02 | 234.1~~232.4~~ | Private | Perm~~Temp~~ | E | Asphalt/Dirt | Roadway Widening, grading, Stabilization | 0.68 | 12 | 25 | 40 | 28 | Operations Maintenance north of Interstate 81 | N/A | 50% | 1.78~~0.00~~ |
| MVP-MLV-AR-027 | 233.35 | Private | Perm | E | Dirt | Roadway widening, grading, Stabilization | 0.28 | 10.00 | 25 | 40 | 30 | Access To MLV-027 | MLV-027 | 75% | 0.99~~1.03~~ |
| ~~MVP-MN-278~~ | ~~233.5~~ | | | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.02~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-MN-279 | 235.4~~233.3~~ | Private | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.36 | 12.00 | 25 | 40 | 28 | Operations Maintenance | N/A~~TBD~~ | 15% | 0.26 |
| MVP-MLV-AR-028 | 236.4~~234.5~~ | Private | Perm | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.56 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | MLV-28 | N/A~~TBD~~ | 75%~~TBD~~ | 2.03~~TBD~~ |
| MVP-MN-278.01 | 237.5~~235.5~~ | Private | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.66~~0.67~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | TBD | 80%~~TBD~~ | 2.56~~TBD~~ |
| MVP-RO-279.01 | 236.5~~237.3~~ | Private | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.41 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | TBD | 100% | 1.97 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-RO-280 | 240.5~~238.5~~ | Private | Temp | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.73 | 18.00 | 25 | 40 | 22 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 1.76 |
| MVP-RO-281 | 241.2~~239.1~~ | Private | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.85~~0.67~~ | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Operations Maintenance | N/A~~TBD~~ | 20%~~TBD~~ | 0.83~~TBD~~ |
| MVP-RO-282 | 241.65~~239.6~~ | Private | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.07~~0.05~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 65%~~TBD~~ | 0.23~~TBD~~ |
| MVP-RO-283 | 242.5~~240.5~~ | Private | Perm | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.89 | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Operations Maintenance | N/A~~TBD~~ | 50%~~TBD~~ | 2.16~~TBD~~ |
| MVP-RO-285 | 244.2~~242.2~~ | Private | Temp | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.40~~0.27~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 65%~~TBD~~ | 1.26~~TBD~~ |
| MVP-RO-286 | 244.6~~242.4~~ | Private | Perm~~Temp~~ | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.43 | 12.00 | 25 | 40 | 28 | Operations Maintenance | N/A~~TBD~~ | 30% | 0.63 |
| MVP-RO-287 | 245.4~~243.3~~ | Private | Temp | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.84~~0.56~~ | 10~~TBD~~ | 25 | 40 | 30~~TBD~~ | Operations Maintenance | TBD | 5%~~TBD~~ | 0.20~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-RO-288 | 245.7~~243.6~~ | Private | Perm | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.42 | 12~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 25%~~TBD~~ | 0.52~~TBD~~ |
| MVP-FR-289 | 246.8~~244.7~~ | Private | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.29~~0.38~~ | 20.00 | 25 | 40 | 20.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.69~~0.91~~ |
| MVP-FR-290 | 247.25~~245.1~~ | Private | Perm | E~~NEW~~ | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.70 | 10.00 | 25 | 40 | 30.00 | Operations Maintenance | N/A | 70%~~N/A~~ | 2.38~~TBD~~ |
| MVP-FR-291 | 248.3~~246.2~~ | Private | Temp | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.62 | 10~~15.00~~ | 25 | 40 | 30~~25~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 60%~~50%~~ | 1.80~~1.50~~ |
| MVP-FR-292 | 248.8~~246.7~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.20 | 8.00 | 25 | 40 | 32.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.49 |
| ~~MVP-FR-293~~ | ~~247.1~~ | ~~P~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.1~~ | ~~10~~ | ~~25~~ | ~~40~~ | ~~30~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~10%~~ | ~~0.03~~ |
| MVP-MLV-AR-29 | 249.8~~247.13~~ | Private | Perm | E/NEW | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.2~~0.0~~ | 15.00 | 25 | 40 | 25.00 | MLV29 | Permanent access to MLV29 | 50% | 0.54~~0.08~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-FR-292.01 | 249.6 | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.13 | 8.00 | 25 | 40 | 32.00 | Mobilization of Construction material. Mobilization of Construction Personnel. | N/A | 75% | 0.47 |
| MVP-FR-293.01 | 251.1 | State | Perm | E~~TBD~~ | Gravel~~TBD~~ | Roadway Widening, Grading, Stabilization | 0.20 | Gravel~~TBD~~ | 25 | 40 | 8'~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50%~~TBD~~ | 0.48~~TBD~~ |
| MVP-FR-293.02 | 254.4~~251.8~~ | Private | Perm | E~~TBD~~ | Dirt~~TBD~~ | Roadway Widening, grading, Stabilization~~TBD~~ | 0.46 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 1.11 |
| MVP-FR-294 | 256~~253.5~~ | Private | Temp | E~~TBD~~ | Asphalt~~TBD~~ | Roadway widening and Stabilization~~TBD~~ | 0.35 | 15.00 | 25 | 40 | 25 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 10% | 0.17 |
| MVP-FR-295 | 257.8~~255.3~~ | ~~State/~~Private | Temp | Existing~~TBD~~ | TBD | Roadway Widening on northern end only, Stabilization~~TBD~~ | 0.98 | 15~~TBD~~ | 25 | 40 | 25~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 10%~~TBD~~ | 0.47~~TBD~~ |
| MVP-FR-296 | 258.9~~256.4~~ | Private | Perm~~Temp~~ | Existing~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.12 | 8.00 | 25 | 40 | 32 | Operations Maintenance | TBD | 20% | 0.12 |
| MVP-MLV-AR-30 | 256.7 | Private | Perm | N~~TBD~~ | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.02 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV 30 | Access to MLV 30~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-FR-297 | 259.4~~256.9~~ | Private | Temp | NEW | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.27 | 0.00 | 25 | 40 | N/A~~40~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-FR-299 | 260.5~~257.9~~ | Private | Temp | E~~TBD~~ | Dirt/Gravel~~TBD~~ | Roadway widening, Grading, Stabilization~~TBD~~ | 0.30 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Safely ingress and egress of construction personnel | TBD | 25% | 0.37 |
| MVP-FR-300 | 260.9~~258.4~~ | Private | Temp | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.30 | 10.00 | 25 | 40 | 40.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | TBD | 50% | 0.73 |
| MVP-FR-302 | 261.75~~259.2~~ | Private | Perm~~Temp~~ | Existing~~NEW~~ | Asphalt~~Dirt~~ | Stabilization~~New Construction~~ | 0.04 | ~~80.00~~ | 25 | 40 | 40.00 | Operations Maintenance | TBD | 10%~~N/A~~ | 0.02~~N/A~~ |
| ~~MVP-FR-301~~ | ~~258.9~~ | ~~Private~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.01~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| ~~MVP-FR-303~~ | ~~259.4~~ | ~~Private~~ | ~~Temp~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ | ~~0.11~~ | ~~TBD~~ | ~~25~~ | ~~40~~ | ~~TBD~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~TBD~~ | ~~TBD~~ | ~~TBD~~ |
| MVP-FR-303.01 | 262.25~~259.7~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.64 | 20.00 | 25 | 40 | 20 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 50% | 1.54 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-FR-305 | 263.9~~261.2~~ | Private | Temp | E~~TBD~~ | Gravel/Dirt~~TBD~~ | Roadway Widening, Grading, Stabilization~~TBD~~ | 0.12 | 12'~~TBD~~ | 25 | 40 | 28~~TBD~~ | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A~~TBD~~ | 75%~~TBD~~ | 0.31~~TBD~~ |
| MVP-FR-306.02 | 265.2 | Private | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.19 | 10.00 | 25 | 40 | 30 | Mobilization of construction material. Mobilization of construction personnel | N/A | 50% | 0.46 |
| MVP-FR-306.03 | 265.2 | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.04 | 12.00 | 25 | 40 | 28 | Mobilization of construction material. Mobilization of construction personnel | | 50% | 0.10 |
| MVP-FR-306.04 | 265.3 | Private | Temp | E | Dirt | Roadway Widening, grading, Stabilization | 0.07 | 12.00 | 25 | 40 | 28 | Mobilization of Construction Material. Mobilization of construction personnel. | | 50% | 0.17 |
| ~~MVP-FR-306~~ | ~~261.9~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.14~~ | ~~10.00~~ | ~~25~~ | ~~40~~ | ~~30~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~10%~~ | ~~0.07~~ |
| MVP-MLV-AR-31 | 265.4~~262.4~~ | Private | Perm | N~~TBD~~ | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.04~~0.44~~ | TBD | 25 | 40 | N/A~~TBD~~ | MLV 31 | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~~MVP-FR-307~~ | ~~263.3~~ | ~~Private~~ | | ~~E~~ | ~~Asphalt/Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.18~~ | ~~12.00~~ | ~~25~~ | ~~40~~ | ~~28.00~~ | ~~Operations Maintenance~~ | ~~N/A~~ | ~~50%~~ | ~~0.45~~ |
| ~~MVP-FR-308~~ | ~~264.5~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.24~~ | ~~12.00~~ | ~~25~~ | ~~40~~ | ~~28.00~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~10%~~ | ~~0.12~~ |
| ~~MVP-FR-308.01~~ | ~~264.5~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Gravel~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.46~~ | ~~12.00~~ | ~~25~~ | ~~40~~ | ~~28.00~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~10%~~ | ~~0.22~~ |
| ~~MVP-FR-309A (same as 309.02)~~ | ~~264.5~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Gravel/Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.15~~ | ~~10.00~~ | ~~25~~ | ~~40~~ | ~~30.00~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~25%~~ | ~~0.19~~ |
| MVP-FR-309 | 267.5~~264.8~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.08 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.04 |
| ~~MVP-FR-309.01~~ | ~~264.6~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Gravel/Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.24~~ | ~~12.00~~ | ~~25~~ | ~~40~~ | ~~28.00~~ | ~~Mobilization of construction material. Safely ingress and egress of construction personnel~~ | ~~N/A~~ | ~~25%~~ | ~~0.29~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-FR-309.05 | 266.2 | P | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.34 | 12 | 25 | 40 | 28 | Operations Maintenance | N/A | 50% | 0.83 |
| MVP-FR-309.06 | 266.4 | P | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.03 | 8 | 25 | 40 | 32 | Mobilization of construction material. Mobilization of construction personnel | N/A | 50% | 0.07 |
| MVP-FR-310 | 268.8~~265.9~~ | Private | Temp | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.31 | 12.00 | 25 | 40 | 28.00 | Operations Maintenance | N/A | 80% | 1.19~~1.22~~ |
| MVP-FR-311 | 266.3269.2 | Private | Temp | E | Asphalt | Roadway Widening, Grading, Stabilization | 0.20 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 0% | 0.00 |
| ~~MVP-FR-312~~ | ~~266.6~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~E~~ | ~~Roadway Widening, grading, Stabilization~~ | ~~0.0~~ | ~~13~~ | ~~25~~ | ~~40~~ | ~~27~~ | ~~Mobilization of construction material. Safe ingress and egress of construction personnel~~ | ~~N/A~~ | ~~0%~~ | ~~0.00~~ |
| MVP-MLV-AR-32 | 269.5~~266.62~~ | Private | Perm | E~~NEW~~ | Dirt | Roadway Widening, Grading, Stabilization~~New Construction~~ | 0.06 | 12.00 | 25 | 40 | 28.00 | MLV32 | Permanent access to MLV32 | 50%~~N/A~~ | 0.15~~N/A~~ |
| MVP-FR-313 | 270.2~~267.3~~ | Private | Temp | E | Asphalt/Dirt | Roadway Widening, Grading, Stabilization | 0.71 | 12.00 | 25 | 40 | 28.00 | Operations Maintenance | N/A | 20% | 0.69 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-FR-314 | 271.9~~269.1~~ | Private | Temp | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.28 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 25% | 0.34 |
| MVP-FR-315 | 272.8~~269.9~~ | Private | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.25 | 12.00 | 25 | 40 | 28.00 | Operations Maintenance | N/A | 25% | 0.30 |
| MVP-FR-316 | 273.7~~270.8~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.08 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.20 |
| MVP-FR-317 | 274.9~~272~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.13 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.06 |
| MVP-FR-317.01 | 275.3~~272.4~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.09 | 8.00 | 25 | 40 | 32.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.021~~0.07~~ |
| MVP-FR-318 | 276.1~~273.2~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.34 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 25% | 0.41 |
| MVP-FR-319.01 | 276.7~~273.8~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.29 | 10.00 | 25 | 40 | 30.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.14 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-FR-319 | 277~~274.1~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.18 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.09 |
| MVP-FR-320 | 277.8~~275~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.41 | 10.00 | 25 | 40 | 30.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.20 |
| MVP-FR-321 | 278.2~~275.8~~ | Private | Perm~~Temp~~ | E | Gravel/Dirt | Roadway Widening, Grading, Stabilization | 0.56~~0.3~~ | 12.00 | 25 | 40 | 28.00 | Operations Maintenance | N/A | 10% | ~~0~~0.27~~.16~~ |
| MVP-FR-321.01 | 278.8 | P | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.23 | 10 | 25 | 40 | 30 | Mobilization of Construction material. Mobilization of construction personnel/ | N/A | 10% | 0.11 |
| MVP-FR-322 | 279.7~~276.8~~ | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.49 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.24 |
| MVP-FR-323 | 277.3 | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.50 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.24 |
| MVP-MLV-AR-33 | 280.8 | Private | Perm | NEW~~TBD~~ | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.03 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV 33 | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-FR-324 | 283.9~~281~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.18 | 10.00 | 25 | 40 | 30.00 | Operations Maintenance | N/A | 25% | 0.22 |
| MVP-PI-325 | 282.6 | Private | Temp | E | Gravel | Roadway Widening, Grading, Stabilization | 0.28 | 14.00 | 25 | 40 | 26.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 10% | 0.14 |
| MVP-PI-326 | 286.9~~283.9~~ | Private | Perm~~Temp~~ | E | Dirt | Roadway Widening, Grading, Stabilization | 0.23 | 12.00 | 25 | 40 | 28.00 | Operations Maintenance | N/A | 50% | 0.55~~0.28~~ |
| MVP-PI-328 | 288.3~~285.5~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.92 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 25% | 1.11 |
| MVP-PI-331 | 289.5~~286.6~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.05 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 75% | 0.19 |
| MVP-PI-330 | 289.5~~286.5~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.49 | 12.00 | 25 | 40 | 28.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 75% | 1.78 |
| MVP-PI-.329 | 289.5~~286.5~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.38 | 10.00 | 25 | 40 | 30.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 75% | 1.39 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-PI-332 | 287.8 | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.15 | 12.00 | 25 | 40 | 28.00 | Operations Maintenance | N/A | 10% | 0.07 |
| MVp-PI-332.01 | 292.9 | P | Temp | E | Dirt | Roadway Widening, grading, Stabilization | 0.14 | 10 | 25 | 40 | 30 | Mobilization of Construction Material. Mobilization of Construction personnel. | N/A | 20% | 0.14 |
| MVP-MLV-AR-34 | 293.4 | Private | Perm | N~~TBD~~ | New Construction~~TBD~~ | New Construction~~TBD~~ | 0.02~~0.03~~ | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV34 | N/A | N/A~~TBD~~ | N/A~~TBD~~ |
| ~~MVP-PI-336~~ | ~~293.8~~ | ~~Private~~ | | ~~E~~ | ~~Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.19~~ | ~~10.00~~ | ~~25~~ | ~~40~~ | ~~30.00~~ | ~~Operations Maintenance~~ | ~~N/A~~ | ~~25%~~ | ~~0.24~~ |
| MVP-PI-336.01 | 296.9~~294~~ | Private | Temp | E | Dirt | New Construction | 0.21 | Dirt | 25 | 40 | N/A | Mobilization of | N/A | N/A | N/A |
| MVP-PI-337 | 297.9~~295~~ | Private | Perm | E | Asphalt/Gravel | Roadway Widening, Grading, Stabilization | 0.14 | 14.00 | 25 | 40 | 26.00 | Operations Maintenance | N/A | 10% | 0.07 |
| MVP-PI-338 | 298.3~~295.4~~ | Private | Perm | E | Gravel | Roadway Widening, Grading, Stabilization | 0.33 | 8.00 | 25 | 40 | 32.00 | Operations Maintenance | N/A | 50% | 0.79 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or ... | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-PI-338.01 | 298.6 | P | Temp | E | gravel | Roadway Widening, Grading, Stabilization | 0.22 | 12 | 25 | 40 | 28 | Mobilization of construction material. Mobilization of construction Personnel | N/A | 50% | 0.62 |
| MVP-MLV-AR-35 | 296.8 | Private | Perm | N~~TBD~~ | Dirt~~TBD~~ | New Construction~~TBD~~ | 0.02 | N/A~~TBD~~ | 25 | 40 | N/A~~TBD~~ | MLV35 | N/A~~TBD~~ | N/A~~TBD~~ | N/A~~TBD~~ |
| MVP-PI-339 | 299.8~~296.9~~ | Private | Temp | E | Dirt | Roadway Widening, Grading, Stabilization | 0.19 | 14.00 | 25 | 40 | 26.00 | Mobilization of construction material. Safely ingress and egress of construction personnel | N/A | 50% | 0.45 |
| MVP-PI-340 | 300.2~~297.3~~ | Private | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.18 | 14.00 | 25 | 40 | 26.00 | Operations Maintenance | N/A | 25% | 0.21 |
| MVP-PI-343.01 | 303.47 | Private | Perm | N | Dirt | New Construction | 0.29 | N/A | 25 | 40 | N/A | Access to Transco Interconnect facility | N/A | N/A | N/A |
| ~~MVP-PI-343.02~~ | ~~300.97~~ | ~~Private~~ | ~~Temp~~ | ~~E~~ | ~~Dirt~~ | - | ~~0.04~~ | - | - | - | - | - | - | - | ~~0.00~~ |
| MVP-PI-343 | 303.47~~300.1~~ | Private | Perm | E | Dirt | Roadway Widening, Grading, Stabilization | 0.42 | 10.00 | 25 | 40 | 30.00 | Access to Transco interconnect | N/A | 100% | 2.02 |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MVP-PI-344 | 303.47 | P | Permanent | N | Dirt | New Construction | 0.01 | N/A | 25 | 40 | N/A | Access to Transco interconnect facility | N/A | N/A | N/A |
| ~~MVP-PI-342~~ | ~~300.8~~ | ~~Private~~ | | ~~E~~ | ~~Gravel/ Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.33~~ | ~~18.00~~ | ~~25~~ | ~~40~~ | ~~22.00~~ | ~~Tranco Interconnect~~ | ~~TBD~~ | ~~10%~~ | ~~0.16~~ |
| ~~MVP-PI-342.01~~ | ~~301~~ | ~~Private~~ | | ~~E~~ | ~~Gravel/ Dirt~~ | ~~Roadway Widening, Grading, Stabilization~~ | ~~0.06~~ | ~~10.00~~ | ~~25~~ | ~~40~~ | ~~30.00~~ | ~~Transco Interconnect/MLV 36~~ | ~~TBD~~ | ~~100%~~ | ~~0.27~~ |

DEIS APPENDIX E-1 (continued)
(Updated for MVP October 2016 Proposed Route)

**Access Roads for the Mountain Valley Project**

| ID | MP | Owner-ship | Type | Status | Existing Surface Type | Proposed Mods. | Length (Miles) | Existing Road Width (Feet) | Proposed Width of Driveway (Feet) | Max. Proposed Width of Easement (Feet) | Land Disturbance Beyond the Existing Footprint of an Existing Road | Site Specific Justification (Permanent and Temporary Access Roads) | Justification for All New Temporary and Permanent Access Roads in Wetlands, Open Water or | Percentage of Existing Road to be Improved | Anticipated Acres of Improvements for Existing Access Roads |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

# Mountain Valley Pipeline Project

# Docket No. CP16-10-000

# Attachment DR4 Land Use 15a

# KOP Viewsheds with Veg.
# Lower Greenbrier River Byway

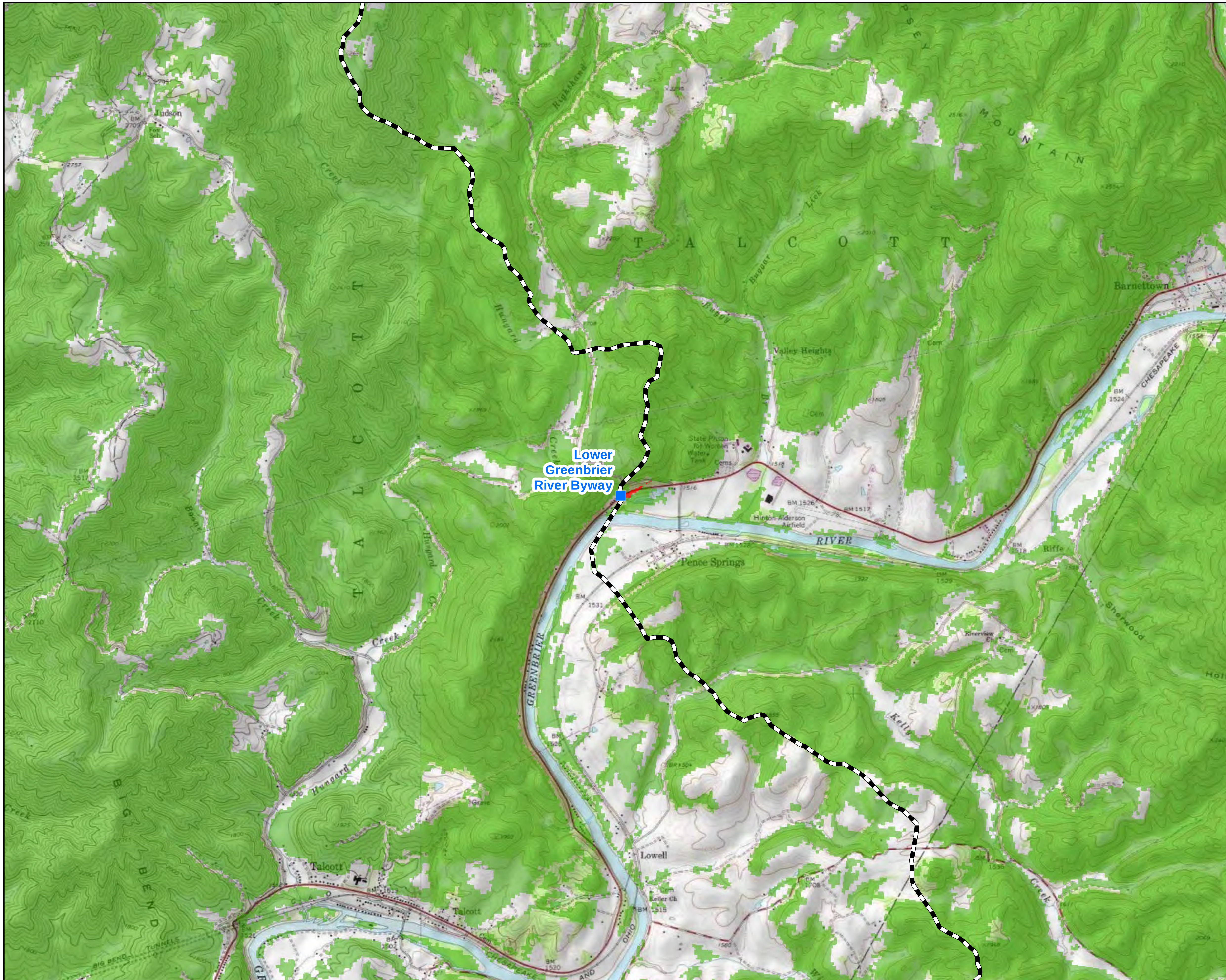
# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Viewshed Results (with Vegetation Heights)

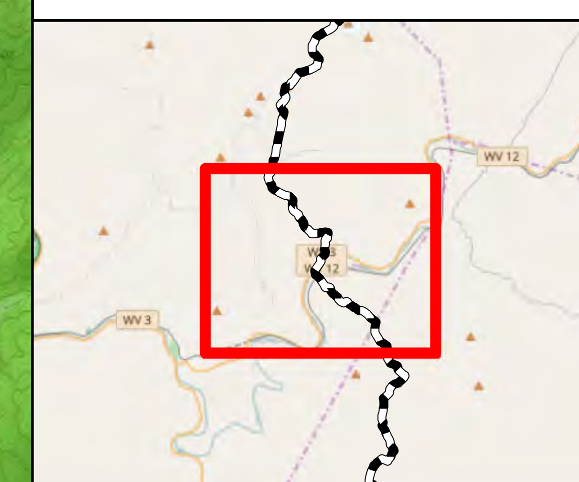
**Lower Greenbrier River Byway**

**FEBRUARY 2017**




**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Visible Area
- Forested Area (NLCD)




Data Sources: NPS, USGS, NLCD

1:31,680 NAD 1983 UTM 17N 0 0.5 1 2 3 4 Miles

Document Path: C:\Users\Maryjo.Watson\Documents\MVP\Viewsheds\KOP_Viewsheds_20170201_withVEG.mxd

# Mountain Valley Pipeline Project

# Docket No. CP16-10-000

# Attachment DR4 Land Use 15b

# KOP Viewsheds with Veg.
# Lowell Backway

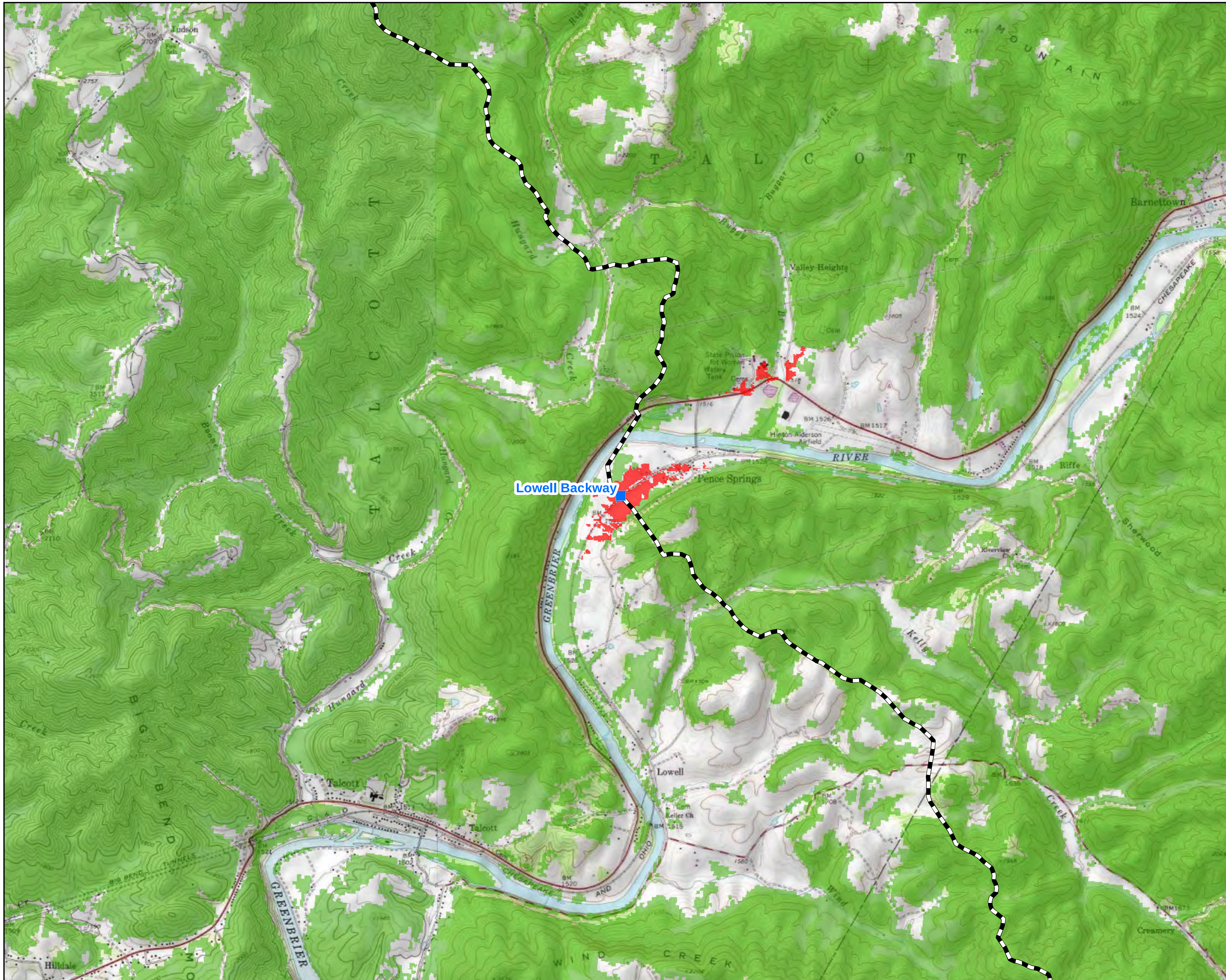
## Mountain Valley Pipeline Project

Mountain Valley PIPELINE

### Viewshed Results (with Vegetation Heights)

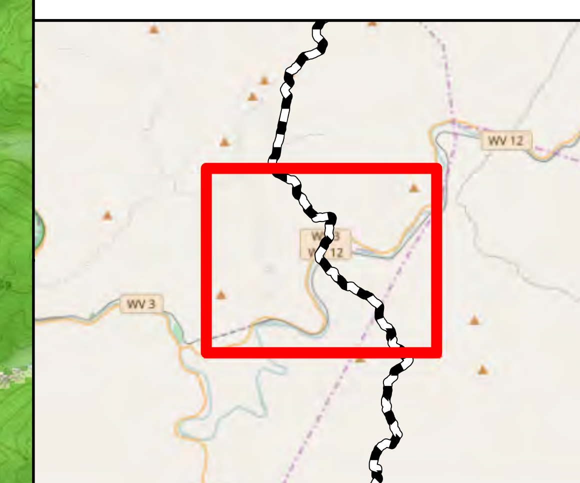
**Lowell Backway**

**FEBRUARY 2017**




**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route
- Visible Area
- Forested Area (NLCD)




Data Sources: NPS, USGS, NLCD

1:31,680 NAD 1983 UTM 17N 0 0.5 1 2 3 4 Miles

Document Path: C:\Users\Maryjo.Watson\Documents\MVP\Viewsheds\KOP_Viewsheds_20170201_withVEG.mxd

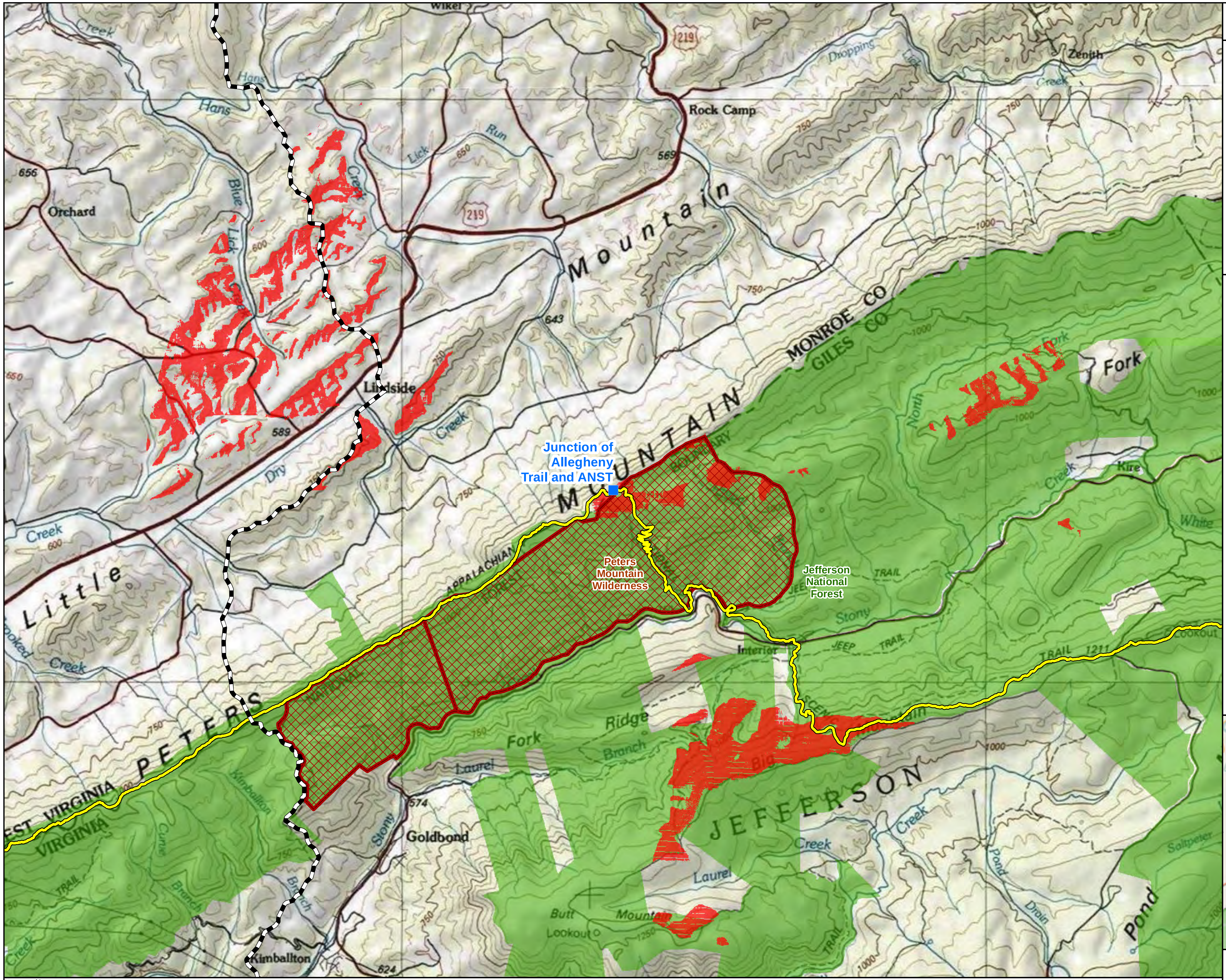
# Mountain Valley Pipeline Project

# Docket No. CP16-10-000

# Attachment DR4 Land Use 16a

# KOP Viewsheds
# Junction of Allegheny Trail and ANST

February 2017




# Mountain Valley Pipeline Project

## Bare Earth Viewshed

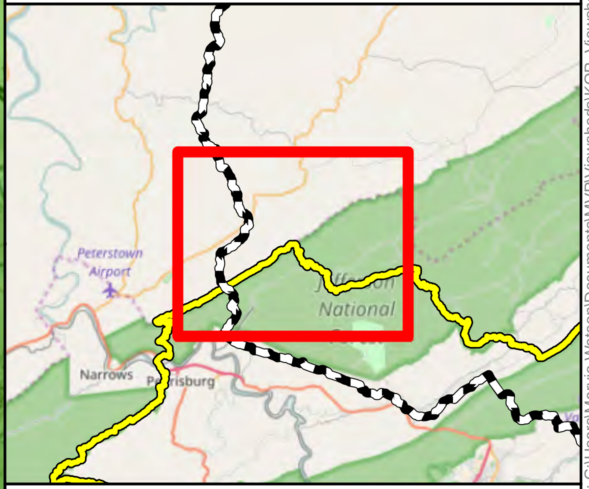
### Junction of Allegheny Trail and ANST

FEBRUARY 2017

**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route Revised December 2016
- Appalachian National Scenic Trail
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- U.S. Forest Service (National Forest) Lands

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

N 1:63,360 NAD 1983 UTM 17N 0 1 2 4 6 8 Miles

Document Path: C:\Users\Maryjo.Watson\Documents\MVP\Viewsheds\KOP_Viewsheds_20170201.mxd

# Mountain Valley Pipeline Project

# Docket No. CP16-10-000

# Attachment DR4 Land Use 16b

# KOP Viewsheds
# Cascade Falls – Jefferson National Forest

February 2017

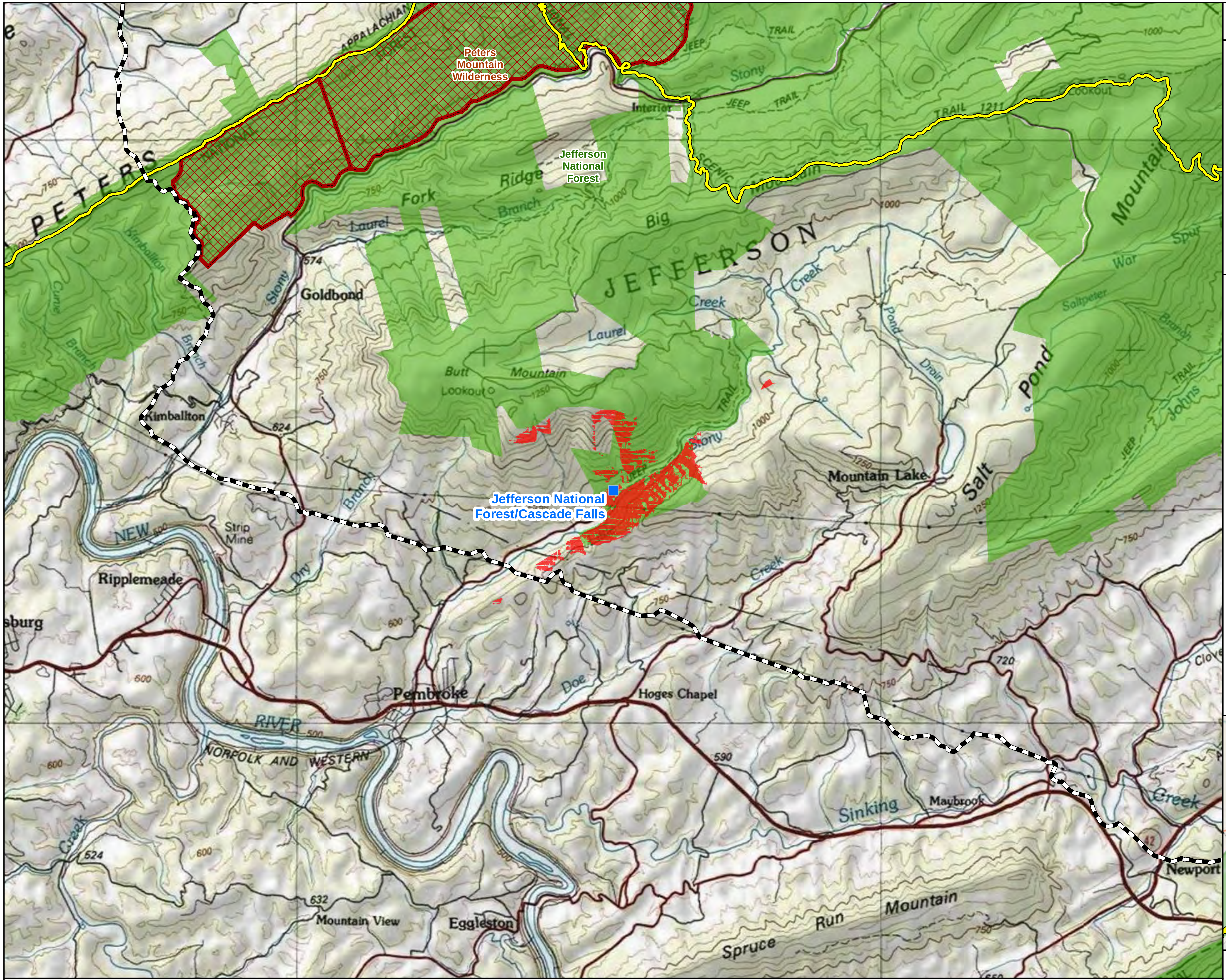
# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Bare Earth Viewshed

### Jefferson National Forest/Cascade Falls

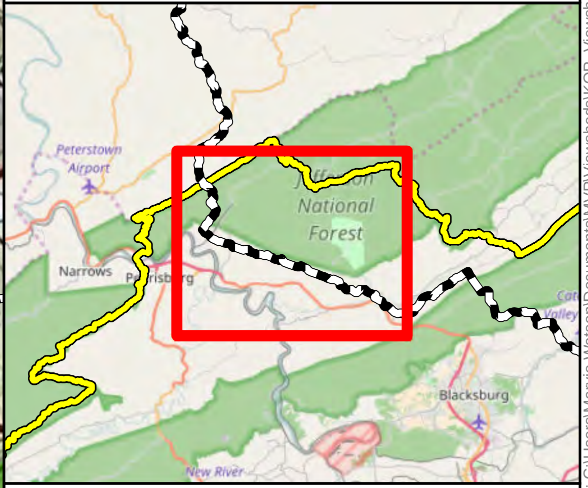
FEBRUARY 2017




**Legend**

- Key Observation Point (KOP)
- October 2016 Proposed Route Revised December 2016
- Appalachian National Scenic Trail
- Visible Area (Bare Earth Viewshed)
- Peters Mountain Wilderness
- U.S. Forest Service (National Forest) Lands

NOTE: Bare earth viewshed does not factor in obstructions in visibility caused by vegetation. Viewer location is within a forested area and will likely not have clear view beyond immediate vicinity.




Data Sources: NPS, USGS, NLCD

N 1:63,360 NAD 1983 UTM 17N

0 1 2 4 6 8 Miles

Document Path: C:\Users\Maryjo.Watson\Documents\MVP\Viewsheds\KOP_Viewsheds_20170201.mxd

# The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)

# EXHIBIT 38

**February 21, 2023**

USDA United States Department of Agriculture | Forest Service | George Washington and Jefferson National Forests | 5162 Valleypointe Parkway
Roanoke, VA 24019
540-265-5100

**File Code:** 2720; 1900
**Date:** March 9, 2016

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First St., N.E., Room 1A
Washington, DC 20426

Dear Ms. Bose:

Subject: Comments on Final Resource Reports for the Mountain Valley Pipeline Project
OEP/DG2E/Gas 3
Mountain Valley Pipeline, LLC
Docket No. CP16-10-000

The Forest Service appreciates the opportunity to review the final resource reports filed by Mountain Valley Pipeline, LLC for the proposed Mountain Valley Pipeline (MVP) Project (Docket No. CP16-10-000). The proposed project would affect National Forest System (NFS) lands on the Jefferson National Forest.

The Forest Service has reviewed the final resource report and identified information and data requirements necessary for the assessment of effects of the proposed MVP Project on NFS lands. The requirements are detailed in the attached document, along with comments and discussions of the Forest Service's concerns about specific aspects of the proposed project.

For questions, please contact Jennifer Adams, Special Project Coordinator, at (540) 265-5114 or by email at jenniferpadams@fs.fed.us.

Sincerely,

JOBY P. TIMM
Forest Supervisor

## Forest Service Comments on Final Resource Reports Dated October 2015

## Mountain Valley Pipeline Project (Docket No. CP16-10)

**GENERAL COMMENTS**

**Federal Lands**

All materials associated with this proposal should depict and explicitly identify the federal lands potentially involved including, but not limited to, the Jefferson National Forest, NPS-Acquired Lands managed by the Jefferson National Forest (JNF), the Appalachian National Scenic Trail, Peters Mountain Wilderness, and Brush Mountain Wilderness, as well as properties owned in fee by the Army Corps of Engineers. Please update diagrams, topographic or quad maps, alignment sheets, details and ancillary sites, etc. accordingly.

**Plans**

Some comments on plans (e.g., revegetation plans) may be included, in part, in the tabled comments below though more detailed comments are forthcoming. Also see comments found in the Forest Service's comments on draft resource reports filed on August 18, 2015 and issued by the Federal Energy Regulatory Commission (FERC) on August 11, 2015.

**Archeology Survey**

In a letter filed with FERC on September 17, 2015, the Forest Service indicated that the archeology survey for the Mountain Valley Pipeline Project (MVP Project or project) would be conducted by the Forest Service. Please note that Mountain Valley Pipeline, LLC (MVP) will now conduct the archeology survey.

**Water withdrawals and discharges**

Per the JNF Land and Resource Management Plan (LRMP), water withdrawals from NFS lands on the JNF are not authorized without analysis of the instream flow or lake level needs sufficient to protect stream processes, aquatic and riparian habitats and communities, and recreation and aesthetic values, and withdrawal is not permissible if any of the above resources are adversely affected. In the event this analysis shows that water withdrawals adversely affect the above resources, then water required for hydrostatic testing, boring, horizontal directional drilling, dust abatement, or any other use during construction, operation, and maintenance of the proposed project will need to be hauled in rather than withdrawn from NFS lands. Any used or unused water will need to be hauled out and disposed of offsite.

The locations and sources of proposed water withdrawals, and the locations of proposed discharges of water or other solutions, should be evaluated within a watershed water-use context in order to identify any off-site effects on sensitive resources. Effects on sensitive resources would be subject to compliance with Forest Service guidance and direction, and laws and regulations including but not limited to the Endangered Species Act and the National Historic Preservation Act.

For each project activity requiring water during the construction, operation, and maintenance of the proposed project on NFS lands, identify the following:

a. volume of water needed;

b. proposed source where water would be withdrawn;

c. volume of water to be discharged;

d. location and details of discharge (transport method, discharge rate, erosion control measures, etc.);

e. number and weights of loads of water that would be hauled from the water source to the site; and

f. number and weights of loads of water to be hauled from the work site to the discharge site.

**Proposed Crossing of the Appalachian National Scenic Trail**

The description of this specific portion of the overall proposal is not comprehensive or sufficiently detailed. There are several critical discrepancies and omissions as discussed in the bullets below.

- It is not clear to the reviewer that the route of the pipeline as shown in Figure 1.11-1, on topo map 36, and on alignment sheets 215 and 216 is the same location, nor exactly where that location is with respect to the actual location of the ANST footpath and the NFS tract boundaries.
- It is not explicitly clear to the reviewer whether MVP plans to follow the original proposed route at this location, the Alternative 200 proposed route, or some other route.
- It is not clear to the reviewer that the proponents are aware that for most of the length of Peters Mountain in the vicinity of the proposed crossing, the westernmost portion of the federal land was actually acquired by the National Park Service for the protection of the Appalachian National Scenic Trail. (See NPS ANST Segment Map 492). The route as shown in Figure 1.11-1 appears to cross only NFS lands, but this is a critical point and must be made explicitly clear.
- Figure 1.11-1 – the legend does not capture or identify the special shading on NFS lands. Peters Mountain should be shown and labelled as Peters Mountain <u>Wilderness</u> on the map and in the legend. The western boundary of Peters Mountain Wilderness is shown incorrectly – per the official Legislative Map, dated April 28, 2008, this portion of the wilderness boundary is officially a 100' offset from the centerline of Forest Road 11080.
- Figure 1.11-2 –the legend does not capture the special shading on NFS lands. Brush Mountain should be shown as Brush Mountain <u>Wilderness</u> on the map and in the legend. The southern boundary of Brush Mountain Wilderness, as shown on the official legislative map dated May 5, 2008 appears to be accurate as shown.
- In Figure 1.11-1, on topo sheet 36, on alignment sheets 215 and 216, in Resource Report-8 pages 8-39 and 8-40, the depiction of the conventional bore location of the proposed pipeline contradicts the statement on Resource Report -1 page 1-66, and elsewhere in the Resource Reports, that the conventional bore underneath the Appalachian National Scenic Trail will result in no surface disturbance within 100 feet of the trail. The dogleg in the depictions is significantly closer than 100' to the ANST. It is important that this measurement be to the closest point of the ANST, not necessarily the point where the bore hole passes under the ANST.
- The description of management prescription 4A (Appalachian National Scenic Trail Corridor) in the 2004 FLRMP defines the corridor as the mapped visual foreground zone visible from the footpath, and lists an absolute minimum distance of 100 feet for protection from social, aural, and other impacts. The proponents should be responsible for mapping that location accurately in the area of their proposed activity. All activities within MRx4A should protect the ANST experience. The proponents do not show anywhere in the Resource Reports a need to conduct any surface disturbance within 4A, or why the proposed conventional bore cannot be significantly more distant from the ANST than shown, keeping it outside of the ANST management prescription, and eliminating the need for a Forest Plan amendment for the purpose of changing the ANST management prescription.
- Throughout all the Resource Reports and supporting documents, the proponents state that there will be no access roads, and no ATWS anywhere on NFS lands. It is not clear whether the northern/western bore pit for the proposed conventional bore under the ANST will be on NFS lands or private lands. It appears clear that the southern/eastern bore pit will be on NFS lands. There are no access roads or ATWS shown or described or quantified to access this bore pit. Please identify whether access roads or ATWS are planned on NFS lands in this area.

Please note that the Forest Service has not agreed to the proposed crossing of the ANST, nor the placement of the bore pits, nor the length of the bored section of the proposal. Please see the Forest Service's letter filed with FERC on September 17, 2015 identifying the Forest Service's concerns about the proposed crossing of the ANST and recommending further consultation regarding the proposed crossing.

Please develop and submit a contingency plan for crossing the ANST in the event that the bore is unsuccessful.

**Evacuation Distance for Natural Gas Pipeline Leaks and Ruptures based on Blast Radius**

Based on the diameter of the pipe and the pressure of the gas contained in the pipe, identify the evacuation feet in distance.

Identify the possible causes of an unanticipated explosion of the pipeline.

Please identify the distance from the proposed pipeline to each facility potentially used by forest users and Forest Personnel on NFS lands.

Discuss the potential effects of an unanticipated explosion on the following:

- sensitive resources in the area;
- forest facilities, forest users, and Forest personnel; and

- the potential for wildfires on NFS lands.

**Groundwater Protection**

Also identify the measures that would be implemented to protect groundwater from potential contamination as a result of the project. The Forest Service has received comments from stakeholders who have cited chemical spill(s) in the news resulting in effects on water district(s) and landowners' wells and springs. Please identify the project-related sources of potential groundwater contamination that could affect users of water from wells and springs in the watershed.

**COMMENTS ON RESOURCE REPORTS AND PLANS**

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| 1 | 1-1 | 1.1.2 | The purpose and need described in this section should be expanded to include a discussion of the necessity to cross Federal lands, in particularly National Forest System lands. Forest Service Manual 2700, Special Uses Management (FSM 2700), §2703.2 describes Forest Service policy relating to the use of National Forest System lands (NFS). §2703.2(2) states to authorize use of NFS lands only if: a) the proposed use is consistent with the mission of the Forest Service to manage NFS lands and resources in a manner that will best meet the present and future needs of the American people; b) the proposed use cannot reasonably be accommodated on non-NFS lands. §2703.2(3) goes on to state not to authorize the use of NFS lands solely because it affords the applicant a lower cost or less restrictive location when compared to non-NFS lands. Therefore, in MVP's discussion, they should clearly articulate why the project cannot reasonably be accommodated off NFS lands. This discussion should not cite lower costs or less restrictive locations as the sole purpose of crossing NFS lands. |
| 1 | 1-23 | 1.4.3 | This section of the report should have a statement that all restoration activities located on NFS lands shall be completed to accepted federal, state, and local Best Management Practices (BMP's) and to the satisfaction of the Forest officer(s) in charge. In addition, as-built drawings of the segments crossing NFS lands will be provided to the Forest Service and all National Forest boundaries disturbed or damaged within the project area will be re-established upon completion of installing the pipe and establishing the right-of-way corridor. |
| 1 | 1-66, more | 1.11 | The Project Description within the Jefferson National Forest is very vague and needs additional specificity and details. Table 1.11-1 should include column totals. JNF is managed under many additional specific regulations and policies than solely the 2004 FLRMP. The length of the MVP proposal crossing on NFS lands as listed in section 1.11 and as shown on Figures 1.11-1 and 1.11-2 conflict with Alignment Sheets 215, 216, second 216 – which appears to be mis-numbered and should be 217 - and 218. Per the alignment sheets, portions of NFS lands past MP 196.9 are clearly impacted. |
| 1 | 1-66, more | 1.11 | Figure 1.11-2 shows the proposed pipeline crossing Craig Creek twice on NFS lands, after its initial crossing of Craig Creek on private land to the west. Alignment sheet 240 appears to show the actual pipeline crossing Craig Creek a total of 5 times – 3 on private land and 2 on NFS lands. Four of these crossings are not necessary and highly impactive on water and aquatics. In addition, the discrepancy leads to questions of which version to consider accurate, and leads reviewers to question the level of critical analysis which was dedicated to developing these "final" products. |
| 1 | | Figure 1.11-2 | This map appears to show MVP proposing to cross Craig Creek three times within a 0.75 mile length of valley bottom. Two crossings very close together on NFS lands as the proposed route takes two very sharp turns within a short distance. This appears to be an unnecessary zig-zag in the line location where one crossing would be sufficient. This extensive work in and near the riparian area and stream channel will increase soil compaction and stream sedimentation probabilities, quantities and areal extent. Please include an alternative that would reduce the number of crossings. |
| Multiple | Multiple | Multiple | It appears that significant materials, including viewshed analyses and maps, have been left out of this comprehensive package of "final" Resource Reports. The proponent should re-review this entire package to ensure completeness. |
| App 1B | 36 & 40 | | The Congressionally designated Wildernesses are not included on the topo maps. The proximity of the proposed pipeline to Wildernesses is important information to consider with regards to the proposed alignment. The potential concern is for noise during construction that would impact the experience and values being sought by visitors to Wilderness and for scenery viewing from the Wilderness during construction and during the life of operations. This can be resolved by adding the Peters Mountain Wilderness and Brush Mountain Wilderness boundaries to the topo sheets. |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| RR1, Giles Co. Align-ment Sheets 1 | 2 | | The aerial photography imagery that helps indicate the land use is clear in some areas and not clear or non-existent in others. An example is sheet 2 of Giles County Alignment Sheets 1. Is satellite imagery available for these portions of the sheets where aerial photography is unavailable or of poor quality making land uses difficult to ascertain? |
| RR1<br><br>Alignment Sheets | All | Legend | The legend includes items that are not described in Resource Report 1. The following symbols that appear on the legend should be clarified as whether they are proposed as part of the pipeline facilities and if so described and their purpose/need stated in Resource Report 1. If the symbols indicate existing features, then clarification is needed as to whether they will be removed as part of the proposal or are anticipated to remain. These items include but may not be limited to Mailbox, PI Symbol, Test Station, Line Marker-Vent Pipe, and Tank. |
| 1 | 1.5.1 | Table 1.5-1 | The inspection/patrol intervals need clarification. Instead of "7.5 months but at least twice per year" should it read "7.5 months but at least twice per *calendar* year"? And instead of "15 months but at least once per year" should it read "15 months but at least once per *calendar* year"? |
| 1 | 1.10 | 1-52 to 1-53 and Table 1.10-1 | The guidelines for past, present and future projects included in the Cumulative Affects analyses is insufficient for considering potential impacts on scenery and related socio-economics. A broader scale analyses is needed for the long-term, cumulative impacts on driving for pleasure and tourism. Tourists drive to enjoy the scenery, particularly for viewing the mountains, along U.S. 11, U.S. 460, Route 42, I-81, and other "through roads" of Virginia. The steady increase in the number and/or size of communication towers, electric transmission lines, gas transmission lines, etc., as viewed during a multiple hour drive through the mountains has the potential to negatively impact the visitors' experience and tourism.<br><br>The National Visitor Use Monitoring Report for the Fiscal Year 2011 visitor surveys that occurred on the GWJeff indicates that about 20% of the national forest visitors traveled 100 miles or more to get to the national forest location where they were surveyed (more than half of those actually travelled more than 200 miles). The top recreation activities of those surveyed, in order, were hiking/ walking, fishing, bicycling, viewing scenery and hunting. These five accounted for almost 2/3 of all national forest visits. [1]<br><br>Table 1.10-1 should include all maintained corridors on the national forests that are visible[2] from major highways, interstates, the Appalachian National Scenic Trail, the Blue Ridge Parkway, and designated State and Forest Service Byways within at least 70 miles (roughly 1.5 hours drive at an average of about 45 m.p.h.) along these same travel routes. Visible corridors to add to the analyses should include electric transmission lines, communications lines (overhead and underground), pipelines, major transportation projects with maintained corridor widths of 40 feet or greater. |
| 1 | 1-61-62 | 1.10 | Section titled *Vegetation, Wildlife and Habitat, and Aquatic Resources* is very general, incomplete, and needs to include a more thorough cumulative effects analysis by alternative. |
| 1 | 1-63 | 1-10<br><br>Visual Resources | The description of potential impacts on scenery is insufficient in that it doesn't provide a discussion about the changes in color, line, form or texture. These are the basic visual elements for determining the degree to which the characteristic landscape of the national forest will be potentially changed by a proposed project. There is an emphasis on above-ground facilities, and not enough detail about the potential impacts to scenery where there are no above-ground facilities. This section should discuss the intrinsic value of the various land-use categories and the potential changes in scenery that would result if the pipeline is constructed and operated, with references to changes (contrasts created) in the characteristic landscape, particularly the mountainous, forested land use type. |
| 1 | 1-61 | 1.10 | There is a one paragraph general discussion on cumulative effects to surface water, and one paragraph on groundwater resources, but no quantitative discussion of pipeline effects in relation to other actions as outlined in Table 1.10-1. |
| 1 | 1-62 | 1.10 | The section titled *Vegetation, Wildlife and Habitat, and Aquatic Resources* does not mention anything about aquatic resources. |

[1] "USDA Visitor Use Report", George Washington-Jefferson NF, USDA Forest Service Region 8, National Visitor Use Monitoring Data Collected FY 2011.

[2] Landscape visibility elements and the process for inventorying/categorizing and mapping visible landscapes are defined in "Landscape Aesthetics: A Handbook for Scenery Management," USDA Forest Service Agriculture Handbook Number 701.

| RR# Or Plan Name | Page # | Section # | Comment |
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| 1 | | 1-B | Each map should reference USGS quadrangle names. |
| 1 | | 1-C | Typical drawings need to include cross section details for steep slopes. |
| 1 | | 1-G | *Project-Specific Erosion and Sediment Control Plan* is absent from the report. |
| 1 | | 1-H | The *Fire Prevention and Suppression Plan* needs to include a section about prescribed fires on NFS lands. The Forest Service often employs prescribed fire as a tool for hazardous fuels reduction and landscape habitat and vegetation treatments. MVP needs to discuss what, if any, effect prescribed fire would have on pipeline facilities or the right-of-way and what restrictions, if any, within or near the pipeline right-of-way might be required for Forest Service prescribed fire planning. For example, are there critical facilities such as valves, stems, signs, etc. associated with the pipeline that would need to be considered in planning for prescribed fire operations? |
| 2 | 2-22 | 2.1.4 | Applicant states "Impacts will be minimized or avoided by implementation of the construction practices outlined in the FERC Plan and Procedures and as described in the mitigation measures detailed below."<br>Needs supporting independent research citation to back up this statement or remove it. Simply stating that mitigations are effective is not sufficient. |
| 2 | 2-23 | 2.1.4.1 | Applicant states "Impacts will be minimized or avoided by implementation of the construction practices outlined in the FERC Plan and Procedures and in this section."<br>Needs supporting independent research citation to back up this statement or remove it. Simply stating that mitigations are effective is not sufficient. |
| 2 | 2-23 | 2.1.4.1 | Applicant states "A depth of 10 feet is above most surficial aquifers utilized as a water source and most existing wells that might be drilled in a shallow aquifer will be cased to at least 20 feet." Please provide citation for the source of this information and explain how this relates to project-related disturbance. |
| 2 | 2-26 | 2.1.4.2 | Applicant states: "Use of controlled blasting techniques should avoid the impacts of blasting and limit rock fracture to the immediate vicinity of detonation along the trench line, and contain impact to within the construction right-of-way."<br><br>Provide credible citation of this limited area of effect from controlled blasting. A statement like this, which can be interpreted as a mitigation of the project's effects, must be supported by credible evidence. |
| | | | Applicant makes the following statement: "The Project will comply with 10 CFR 1022 with no significant loss of flood storage as above ground facilities will displace approximately 1 acres within 100-year flood zones, therefore a floodplain assessment is not necessary."<br>There is no evidence of the project complying with 10 CFR 1022 or that a floodplain assessment is not necessary. A reading of the CFR finds no exceptions for size as the applicant implies in the statement. The conditions necessitating floodplain assessment appear to be contained in § 1022.5 of 10 CFR Parts A through E of the code. These list exceptions to the floodplain assessment that include among others: routine maintenance of existing structures ((d) (1)); site characterization, environmental monitoring, or environmental research activities ((d) (2)); and minor modification of an existing facility or structure in a floodplain or wetland to improve safety or environmental conditions ((d) (3)). Outside of these very narrow circumstances, it appears that the Department of Energy has the authority to decide the necessity of floodplain assessments. The applicant should explain how the proposed facilities meet the exemptions from 10 CFR 1022 or submit the proposal to the appropriate regulating body for a ruling regarding the necessity of a floodplain assessment. |
| 2 | 2-51 | 2.2.3 | Applicant proposes withdrawing millions of gallons of water from streams and discharging them at separate locations. For all withdrawals and discharges on the Jefferson National Forest, the project must comply with Forestwide Standards 3 and 4:<br><br>FW-3: Prior to authorizing or re-authorizing new or existing diversions of water from streams or lakes, determine the instream flow or lake level needs sufficient to protect stream processes, aquatic and riparian habitats and communities, and recreation and aesthetic values.<br><br>FW-4: Water is not diverted from streams (perennial or intermittent) or lakes when an instream flow needs or water level assessment indicates the diversion would adversely affect protection of stream processes, aquatic and riparian habitats and communities, or recreation and aesthetic values.<br><br>Please identify all withdrawals that occur either on or have the potential to effect National Forest Lands (upstream or downstream) and conduct an instream flow analysis for all the beneficial uses as identified in these standards. Simply stating that these withdrawals do not occur on or upstream of the NF is not sufficient. Withdrawals upstream of the NF could decrease flows and have a negative effect on the NF. Withdrawals downstream could lower the water table and cause dewatering of the |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | streams on the NF and have a negative effect. Analysis should include a calculation of the minimum flows to sustain a healthy beneficial use and the demonstration that the proposed removals will not dip below these thresholds. |
| 2 | 2-51 | 2.2.4 | Applicant states "While it is not possible to know how much water would be needed for dust suppression on the pipeline construction right-of-way, during dry seasons, MVP estimates that there would be approximately five 1,000-gallon water trucks per construction spread on a given day."<br><br>The complete lack of an estimate of the water use for dust suppression is unacceptable because it precludes any credible analysis. A credible estimate of ALL water uses, including those for dust suppression, must be made and this amount must be used for the analysis of the effects of water withdrawal on beneficial uses. The cumulative effect of all water withdrawals must be analyzed for all beneficial uses. |
| 2 | 2-51 | 2.2.4 | The report states that "While it is not possible to know how much water would be needed for dust suppression on the pipeline construction right-of-way, during dry seasons, MVP estimates that there would be approximately five 1,000-gallon water trucks per construction spread on a given day. MVP anticipates using 11 construction spreads, which would total 55,000 gallons for 55 water trucks per day". However, it does not specify where the water will be withdrawn from. This information needs to be provided and evaluated within a watershed water-use context. Water will be withdrawn at a time of the year (dry season) when streams already have a low flow, additional withdrawal could impact water quality and aquatic organisms. An instream minimum flow analysis needs to be done and effects analyzed when withdrawal is proposed, so that in informed decision can be made. |
| 2 | 2-51 | 2.2.5 | Applicant states "ATWS will be located at least 50 feet away from the water's edge, except where the adjacent upland consists of actively cultivated or rotated cropland or other disturbed land or as noted with a site specific explanation of the conditions." ATWS locations must comply with the Jefferson Forest Plan (see Riparian Corridors pp 3-178 through 3-187). Ground disturbance is not permitted for these purposes within the core riparian area for all stream types or in a slope adjusted no-equipment zone around intermittent and perennial streams and wetlands. Set-backs could vary up to 150 feet by stream type and side slopes in the immediate area and must comply with the Jefferson Forest Plan. |
| 2 | 2-51 | 2.2.5 | Applicant states "However, there are 5 locations where the pipeline route parallels a waterbody within 15 feet as listed in Table 2-A-4 in Appendix 2A."<br>It appears that Table 2-A-4 does not exist in Appendix 2-4-A or any of the other submitted appendices. Also, paralleling waterbodies within 15 feet will not be allowed on the NF. No substantial parallel routes within the riparian corridor will be allowed on the NF. |
| 2 | 2-52 | 2.2.5 | Applicant states "There are no liquids in the pipeline that would be released to groundwater or surface water in the unlikely event of a leak."<br><br>There is an abundance of evidence that condensates of water and organics occur in natural gas transmission pipelines. Please identify all condensates that could form in the proposed pipeline and be released accidentally by a leak. Discuss the potential effects of a release of condensates. |
| 2 | 2-56 | 2.2.5 | Applicant discusses "temporary impacts" to streams, mentioning only turbidity. Please identify all short term impacts. Also, no mention of effects to long-term stream hydrology is made. Blasting could affect stream hydrology permanently by fracturing aquifers or damaging perched water tables. It could also directly and indirectly affect fish and macroinvertebrates. Please provide a full discussion of blasting effects supported by independent scientific research. |
| 2 | 2-51 | 2.2.5 | Text states that ATWS will be 50 feet from water's edge. The JNF LRMP requires all ground disturbing activities be at least 100 feet from perennial streams; this distance increases with slope. There are likewise set-back distances for ground disturbing activities for intermittent and ephemeral streams, seeps, springs, and lakes. See Tables A1 and A2 in Appendix A in the Forest Plan for required distances from water bodies. |
| 2 | 2-52 to 2-53 | 2.2.8 | There is a general discussion on *Impacts to Waterbodies from Crossings and Mitigation Measures* in this section; however there has been no site specific analysis of potential impacts to waterbodies or aquatic biota. There has not been a sediment analysis done on the pipeline, access roads, or staging areas, therefore there is not quantitative data with which to do an effects analysis or alternative comparison. A sediment analysis should be completed to determine the potential amount of sediment delivered to the stream systems and subsequent effect on fisheries, and downstream mussels. |
| 2 | 2-52 to 2-53 | 2.2.8 | The open cut methods as described in this section is proposed for the crossings on National Forest, including 2 crossings of Craig Creek 0.1 miles apart on National Forest (RR3, page 3-58). The report states that temporary sediment barriers will be installed within 24 hours of completing instream activities. The sediment barriers should be concurrent with activities, not after completion of |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | activities. Erosion and sedimentation is a concern to the stream and downstream aquatic resource, especially in light of the concentration of proposed activities within the riparian corridor. A more thorough analysis of impacts from these crossings needs to be completed for adequate effects determination. The rationale for the multiple crossings of Craig Creek and "dog-leg" of the line within the riparian area of Craig Creek on National Forest needs to be examined and other options or additional alternatives explored. |
| 2 | 2-52 to 2-53 | 2.2.8 | The open cut methods as described in this section is proposed for the crossings on National Forest, including 2 crossings of Craig Creek 0.1 miles apart on National Forest (RR3, page 3-58). The report states that temporary sediment barriers will be installed within 24 hours of completing instream activities. The sediment barriers should be concurrent with activities, not after completion of activities. Erosion and sedimentation is a concern to the stream and downstream aquatic resource, especially in light of the concentration of proposed activities within the riparian corridor. A more thorough analysis of impacts from these crossings needs to be completed for adequate effects determination. The rationale for the multiple crossings of Craig Creek and "dog-leg" of the line within the riparian area of Craig Creek on National Forest needs to be examined and other options or additional alternatives explored. This segment was reviewed in the field, and is considered unacceptable given impact to stream, riparian, and aquatic resources. The line as staked, parallels the stream entirely too close and for too long of a distant. Consider the turn to the east being on top of Brush Mountain, rather in the Craig Creek bottom, or realign the entire crossing of Craig Creek. |
| 2 | 2-54 to 2-55 | 2.2.8 | There is a general discussion on *Impacts to Waterbodies from Turbidity and Sediment Runoff and Mitigation Measures* in this section; however there has been no site specific analysis of potential impacts to waterbodies or aquatic biota. There has not been a sediment analysis done on the pipeline, access roads, or staging areas, therefore there is not quantitative data with which to do an analysis. A sediment analysis should be completed to determine the potential amount of sediment delivered to the stream systems and subsequent effect on fisheries, and downstream mussels. Three pipeline open-cut stream crossings and ¼ mile of access roads, including a road crossing, are all proposed within a ½ mile reach of Craig Creek, in part, on National Forest. One of the pipeline crossings is proposed as downslope with a winch construction method (Figure 1.11-2), meaning it is at the base of a very steep slope. Erosion and sedimentation is a concern to the stream and downstream aquatic resource, especially in light of the concentration of proposed activities within the riparian corridor. A more thorough analysis of potential sedimentation and effects needs to be completed for adequate effects determination. The rationale for the multiple crossings of Craig Creek and "dog-leg" of the line within the riparian area of Craig Creek on National Forest needs to be examined and other options or additional alternatives explored. |
| 2 | 2-55 | 2.2.8 | Report states: "To minimize and/or mitigate potential impacts from pipeline construction and disturbance from other facilities, MVP will implement the FERC Plan and Procedures and our E&SCP, specifically with respect to erosion and sedimentation control, bank stabilization, and bank revegetation, which will minimize impacts related to turbidity and sediment transport into adjacent waterbodies." Recent experience with pipelines on the Forest has shown that frequent E&S inspection and maintenance is necessary to help control off-site erosion. Site specific monitoring and mitigation plans will be necessary to adequately address effects, since just stating that impacts will be minimized or mitigate does not quantify the effects. |
| 2 | 2-58 | 2.2.8 | There is a general discussion on *Impacts to Waterbodies from Rock Blasting and Mitigation Measures* in this section; however there has been no site specific analysis of potential impacts to waterbodies or aquatic biota. The text states that impacts could include increased sediment load and injury from shock wave. One of the pipeline crossings with shallow bedrock is on Craig Creek on National Forest land (table 2.2-11) and is also proposed as downslope with a winch construction method (Figure 1.11-2). Further site specific analysis of effects needs to be done for adequate evaluation and decision. |
| 2 | 2-61 | 2.3 | Applicant states "A Nationwide Permit application will be submitted to the Norfolk District USACE for work in the Waters of the United States (including wetlands) within Virginia."<br>All permits to be submitted to the USACE that propose the destruction or modification of wetlands on NF lands shall be submitted to the FS <u>before</u> submission to the USACE. Mitigation for wetlands destroyed by the construction of this pipeline should be assumed to be in-kind mitigation at a minimum of 2:1. |
| 2 | 2-71 | 2.3.4 | The applicant states "ATWS areas will, to the extent practicable, be located in upland areas a minimum of 50 feet from the wetland edge. In most instances our ATWS is located beyond 50 feet of the wetland. However, there are locations where MVP has located ATWS within 50 feet of the wetland due to topography or other constraints." |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | The Jefferson Forest Plan assigns the same protection to wetlands as it does to perennial streams. Ground disturbance will not be allowed within the 100 foot core area or the slope adjusted area beyond. |
| 2 | 2-72 | 2.4 | This discussion specific to the Jefferson National Forest and list of waterbodies crossed does not include a site specific analysis of sediment and erosion potential. According to Table 2.4-1 there are 11 permanent access road stream crossings, 3 permanent pipeline stream crossings, and 15 temporary access road or workspace crossings within the riparian corridor. Several of the roads are Forest Service roads as identified in Appendix 2-C-6, however, they are not indicated as such in the access roads table in Appendix 1F. An accurate and complete picture of the project needs to be generated and a more thorough analysis of potential sedimentation and effects needs to be done so that an informed decision can be made. |
| 2 | 2-72 | 2.4 | The determination that there will be no water contamination from long term operation and maintenance is unsupported by quantitative analysis of potential sedimentation or other adverse effects, or relevant literature. There was not a readily accessible discussion on acres of exposed soil and miles of road construction/reconstruction, broken down by slope, soil type, and time of the year/length of exposure. These are all things that are necessary when determining the timing and magnitude of effects to aquatic resources. |
| 3 | 3.2.11<br>3.2.10<br>Appendix 3C | 3-23 - 24 | We commend the desire to restore "The areas disturbed by construction…to their original grades, condition and use or better, to the greatest extent practicable" (para. 4, page 3-23). However, it appears from para. 3, page 3-24 that vegetative restoration in the temporary construction zone will rely on "Natural revegetation of shrub and forest cover types… to take significantly longer, with some saplings and nurse trees established within 5 to 10 years, and tree cover then continuing through natural succession of the forest type". Given the age, size, and condition of many of the upland sites coupled with the level of disturbance expected, natural regeneration to current vegetation cover types, is unlikely in most situations.<br><br>The oak species, which dominate the impacted areas, do not readily regenerate from seed on disturbed sites. Oak is an advanced growth dependent species. Natural regeneration certainly does occur, but this most often occurs from a combination of stump sprouts and existing established seedlings that have germinated and developed in the understory over decades (advanced regeneration). Given the level of disturbance in the temporary construction zones, it is highly unlikely that the Oak Forest Community Types would naturally regenerate to eventually achieve their "original condition and use or better". A logical impact of this proposal is the conversion of Oak Forest Community Types to grass and herbaceous in the permanent ROW and Mixed-Mesophytic Forest (mesic sites), red maple ( no real Community Type here, just a Dry Mesic Oak without the Oak on dry sites), to Xeric Pine and Pine Oak (again without the oaks most likely on xeric sites) in the temporary construction zones. The acreages of these expected conversions and loss of hard mast producing habitat (e.g. oaks) should be disclosed in the EIS<br><br>Of course non-native invasive plants are also very likely candidates to revegetate all disturbed areas as recognized in section 3.2.10 and Appendix 3C. We appreciate the emphasis on prevention and monitoring described in Appendix 3C relating to NNIS. However, we question the reluctance to utilize herbicides, especially with regards to woody invasive species (e.g. ailanthus, paulownia, autumn olive, multiflora rose). Hand pulling and/or cutting (Appendix 3C) will not "eradicate" these species. Herbicides have proven to be the safest, most inexpensive, and most effective method of control for species like this. We suggest that MVP recognize the role that herbicide control of invasive species will most assuredly play and to analyze the effects of herbicide treatment in the EIS. The chemicals likely to be used should be identified and the impacts disclosed in the EIS. Herbicides used on the NFS lands must have an appropriate risk assessment on which the disclosure of effects is based. We strongly suggest that MVP adhere to herbicides and application rates for which risk assessments have already been completed (http://www.fs.fed.us/foresthealth/pesticide/risk.shtml). Incorporating a thorough discussion of the use of chemicals and disclosure of impacts relating to those applications in the EIS will allow a decision on the use of herbicides to control NNIS to be made now, rather than creating the need for yet another analysis and decision later when the inevitable need arises. |
| Through-out | Through-out | Through-out | Deficiency: There is no sediment analysis for comparison of effects described or performed in the document. For purposes of analysis and assessment of impacts, the applicant should use a sediment modeling program that includes the delivery estimates of sediment to streams through evaluation of the following variables at a minimum:<br>a. Proposed disturbance area: including the disturbed area of the pipeline corridor, access roads, staging areas, and any other ground disturbance associated with the installation |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | and maintenance of the pipeline and associated facilities. Any sedimentation from illegal use by ATV's, horses, vehicles, or other unauthorized activities that are possible as a direct result of the pipeline construction should also be estimated and modelled. The decision to include these activities in monitoring should be based on the existing legal and illegal uses of FS and adjacent lands in the immediate vicinity.<br>b. Slope (both the slope of the disturbed surface and the side slope in the vicinity of the proposed disturbance)<br>c. Soil type (to include the fine fraction of the soil)<br>d. Distance to a sediment delivering channel (for the FS, this is equivalent to the flow path that begins at an 11-acre watershed<br><br>The analysis should estimate the amount of sediment delivered to the channel (generally expressed in tons), and the fate and impact of that sediment in the context of the natural background sediment of the watershed. Discussions of sediment impacts should be related to the beneficial use of the waterbody and should quantify the amount of sediment produced by the proposed action and its effects on the stream habitat. The analysis should be performed in sufficient detail so that FS specialists can evaluate the impacts to Threatened, Endangered, and the Regional Forester's Sensitive Species (TES) and the stream health. Sufficient stream habitat information should be collected to assess these impacts. These should one or more of the following: pebble counts or other physical habitat assessments, benthic macroinvertebrates monitoring, stream chemistry and turbidity. Selection of the appropriate assessment and monitoring strategy should be coordinated in advance with a FS specialist. Cumulative effects of associated activities and pipeline construction on private property in the analyzed watersheds, past activities, and anticipated future activities in the modeled watersheds on public and private property must be considered and included in the estimated disturbance as is appropriate.<br>Without sediment analysis, no credible statement of impacts or comparison of impacts can be made by the applicant. The FS requires that sediment analysis be performed by the terms above at a minimum. Simply listing the anticipated impacts and promising to mitigate impacts is insufficient for the FS to make an informed and credible decision. |
| 3 | 3-12 | 3.1.4.2 | The statement that "Sediment-related impacts are generally temporary, lasting only during the period of active in-stream construction" does not take into account potential sediment impacts from upslope grubbing, trenching, grading during construction of pipeline corridor and access roads. Impacts from these activities need to be quantitatively evaluated via sediment analysis and effects on water bodies and aquatic biota disclosed. |
| 3 | 3-10 | 3.1.4 | The statement that "no long-term effects on dissolved oxygen, pH, benthic invertebrates, or fish communities are expected to occur due to the construction or operation of the project facilities" is unsupported by quantitative analysis or relevant literature. This information is necessary for adequate evaluation and decision. |
| 3 | 3-13 | 3.1.4.3 | Text states that ATWS will be 50 feet from water's edge. As stated in FS comments, the Jefferson National Forest plan requires all ground disturbing activities be at least 100 feet from perennial streams; this distance increases with slope. This also should be applied when near a stream, and not necessarily just crossing it as specified in the response. See Tables A1 and A2 in Appendix A in the Forest Plan for required distances from water bodies. |
| 3 | 3-13 | 3.1.4.3 | The statement "Implementation of the FERC Plan and Procedures will minimize short and long-term water quality impacts within the waterbodies crossed by the proposed pipeline" is unsupported by quantitative analysis or relevant literature. This information is necessary for adequate review and decision. |
| 3 | 3-24 | 3.2.11 | The report recognizes the potential impacts to forested vegetation (primarily trees) adjacent to the ROW. However, we question the conclusion that such impacts are "anticipated to be minimal", especially considering the potential for stress on these adjacent trees to trigger an oak decline event that could potentially grow far beyond the edges of the ROW. Firstly, you state that trees can spread their root systems "up to 2.9 times beyond the dripline" based upon Gilman, 1988. Upon reading Gilman, we interpret this to mean 2.9 times the distance from the bole of the tree to the edge of the crown, or approximately 3 times live crown radius. Based on this "2.9" number you then conclude that because the trench will be located 37 feet away from the nearest standing tree "impacts are anticipated to be minimal". Based upon equations developed by Bechtold (Crown Diameter Prediction Models for 81 Species of Stand Grown Trees in the Eastern United States, Bechtold W. Southern Journal of Applied Forestry, Vol. 27, No. 4. Nov. 2003) an 18" chestnut oak would be predicted to have a crown width of 30'. The dripline would be approximately 15' and 3 times that dripline in the neighborhood of 45 feet. Thus it seems quite likely that the trench itself is likely to disturb roots of dominant trees located 37 feet away. |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | Secondly, digging of the trench is not the only source of impact to the roots of adjacent trees. Soil compaction from heavy equipment can also have a negative impact on tree roots. Such heavy equipment use in the construction zone directly adjacent to standing trees is likely. Such use would be expected to stress those trees. This stress to mature and overmature oak species (especially black and scarlet oaks) on marginal to poor sites will likely trigger oak decline (see Incidence and Impact of Oak Decline in Western Virginia, 1986. Oak, Steven W., Cindy M. Huber, Raymond M. Sheffield. Southeastern Forest Experiment Station Resource Bulletin SE-123).<br><br>Please improve the effects disclosure with respect to indirect impacts to adjacent trees to be more realistic and include the impacts of compaction as well as trenching in the EIS. While a quantitative analysis of the potential for oak decline may be difficult, please qualitatively address the potential for triggering oak decline due to the proposed construction activities. |
| 3 | 3-30-32 | 3.3.3 | The section of *Migratory Birds* needs more detailed analysis of effects of proposed actions and is missing some high priority species known to occur in the proposed corridor alternatives. Despite previous comments submitted of the existence of a significant wintering golden eagle population in West Virginia, Virginia, and North Carolina, there is no mention of golden eagles or analysis of potential effects of proposed actions on wintering habitat or impacts to individual birds, as required by the Bald and Golden Eagle Act. Cerulean warblers have been documented along the Blue Ridge Parkway and associated slopes below the ridgelines as far south as Floyd County. Potential impacts of the proposed project on habitat on this species should include the area of the Parkway and Blue Ridge Mountains currently being proposed to cross. Potential impacts of this project on high priority migratory bird species should include all life cycles (breeding, post-breeding, migrating, wintering) for the species that utilize habitat along the proposed route, during the time periods they are there. As the golden eagle illustrates, the Appalachians and Piedmont provide important wintering habitat, as well as migratory corridors, for high priority species that may not breed in this area. |
| 3 | 3-34 | 3.3.3 | Thank you for proposing to partner with WHC for vegetation restoration, in particular considering native seed mixes for pollinators, incorporating Integrated Vegetation Management, and restoring a gradual transition of vegetation across the proposed corridor. Especially where the corridor proposes to cross mature forest, a gradual transition of vegetation to the actual pipeline location from each side will minimize a hard edge and help provide cover for species needing to travel across the proposed corridor. |
| 3 | 3-34 through 3-55 | 3.4 and 3.5 | The entire sections of *Endangered, Threatened, and Special Concerns Species*, and associated *Environmental Consequences on Jefferson National Forest Lands* are incomplete, as it does not describe direct, indirect, or cumulative effects of the proposed pipeline, by alternative, on described species found within the area. Please provide a complete analysis for review and decision. |
| 3 | 3-43 through 3-56 | 3.4.3 and 3.5.2 | T&E surveys are incomplete. An analysis of site-specific impacts on species and habitat, and comparison between alternatives, is necessary for adequate review and decision. |
| 3 | 3-54 | 3.4.5 | The statement " the Project corridor has been determined to be unoccupied by state and federally listed species" is incorrect and confusing, based on information provided in other sections, for instance the survey information detailing a number of locations for the threatened northern long-eared bat. And based on statements that multiple surveys are incomplete and ongoing at the time of submission of what have identified as final resource reports. |
| 3 | 3-55 | 3.5 | The entire section of *Environmental Consequences on Jefferson National Forest Lands* is woefully inadequate since it does not describe direct, indirect, or cumulative effects of the pipeline on biotic resources found within the area. Please provide a complete analysis for review and decision. |
| 3 | 3-55 | 3.5.1 | The report provides recognition and inclusion of impacts to old growth communities. However, old growth may not necessarily be limited to just the 6C Mgmt. Rx. While we strive to maintain the accuracy of stand data, we are always refining this data through field surveys when we propose management activities that disturb vegetation. These field surveys are also used to address the operational definition of old growth in areas proposed for disturbance. We are prepared to work with MVP "to schedule the requested vegetation survey and site index measurement for the portions of the Project on USFS lands" as stated on page 3-56. Impacts to old growth should also include the permanent access road along the southeast flank of Peters Mountain. |
| 3 | 3-56 | 3.5.2 | T&E surveys are incomplete. An analysis of site-specific impacts on species and habitat, and comparison between alternatives, is necessary for adequate review and decision. |
| 3 | 3-56 | 3.5.1 | The report discloses impacts in terms of acres by Major Forest Community types, as well as impacts to stands greater than 40 and 100 years old. This will provide the necessary specificity required to make an informed decision as it relates to forested vegetation. We do note, however, that this information is based on geospatial data. While we strive to maintain the accuracy of this data, we |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | are constantly refining this data through field surveys when we propose management activities that disturb vegetation. We are prepared to work with MVP "to schedule the requested vegetation survey and site index measurement for the portions of the Project on USFS lands" as stated on page 3-56. |
| 3 | 3-57 | 3.5.3 | Sensitive species surveys are incomplete. An analysis of site-specific impacts on species and habitat, and comparison between alternatives, is necessary for adequate review and decision. |
| 3 | 3-57 | 3.5.4 | There is no discussion of proposed project and alternative effects to MIS or their habitat. An analysis of site-specific impacts on species and habitat, and comparison between alternatives, is necessary for adequate review and decision. |
| 3 | 3-57 | 3.5.5 | An analysis of site-specific impacts on locally rare species and habitat, and comparison between alternatives, is necessary for adequate review and decision. Example from Table 3.5-4: Hellbender surveys within the project area are still ongoing. |
| 3 | 3-57 | 3.5.3 | Sensitive species surveys are incomplete. An analysis of site-specific impacts on species and habitat, and comparison between alternatives, is necessary for adequate review and decision. |
| 3 | 3-57 | 3.5.4 | There is no discussion of proposed project and alternative effects to MIS or their habitat. An analysis of site-specific impacts on species and habitat, and comparison between alternatives, is necessary for adequate review and decision. |
| 3 | 3-57 | 3.5.5 | An analysis of site-specific impacts on locally rare species and habitat, and comparison between alternatives, is necessary for adequate review and decision. |
| 3 | 3-58 | 3.5.7 | The section on *Stream Crossings within National Forest Land* only discussed 3 pipeline stream crossings on NFS lands although there are additional waterbody crossings on Jefferson National Forest according to Table 2.4-1 (specifically, 29 including access roads and workspace). Of special concern are the 3 pipeline open-cut stream crossings and ¼ mile of access roads, including a road crossing, all proposed within a ½ mile reach of Craig Creek, in part, on NFS lands. One of the pipeline crossings is proposed as downslope with a winch construction method (Figure 1.11-2), meaning it is at the base of a very steep slope. Erosion and sedimentation is a concern to the stream and downstream aquatic resource, especially in light of the concentration of proposed activities within the riparian corridor. Craig Creek has downstream Federally listed, FS Sensitive and locally rare aquatic species. Surveys are incomplete. It is also important to note that it is within the Chesapeake Bay watershed. A more thorough analysis of potential sedimentation and effects needs to be completed for adequate effects determination. The rationale for the multiple crossings of Craig Creek and "dog-leg" of the line within the riparian area of Craig Creek on National Forest needs to be examined and other options or additional alternatives explored. |
| 6 | 6-1 | 6.1 | Section 6.1 provides regional-scale geologic settings. In addition, the Resource Report needs to provide the geologic settings at a scale more relevant to the portions of the Jefferson National Forest (JNF) traversed by the MVP pipeline corridor. Section 6.7 JNF (page 6-49) begins to address the JNF geologic setting but needs more reference to and analysis of existing geologic information. This geologic setting specific to the JNF needs to consider and refer to published geologic reports and maps relevant to portions of JNF to be traversed by the project, such as:<br><br>A.P. Schultz, C.B. Stanley, 2001. Geologic Map of the Virginia portion of the Lindside Quadrangle, Virginia Division of Mineral Resources Publication 160, 1:24,000-scale map.<br><br>Schultz, A.P., Stanley, C.B., Gathright, T.M., II, Rader, E.K., Bartholomew, M.J., Lewis, S.E., and Evans, N.H., 1986, Geologic map of Giles County, Virginia: Virginia Division of Mineral Resources Publication 69, 1:50,000-scale map.<br><br>Schultz, A.P., 1993, Geologic map of large rock block slides at Sinking Creek Mountain, Appalachian Valley and Ridge Province, southwestern Virginia, and comparison with the Colorado Front Range. U.S. Geological Survey I Map 2370, 1:24,000-scale map.<br><br>Display the pipeline corridor (and any project facilities such as access roads) within the JNF surface ownership boundary overlaid on the most detailed scale published geologic maps available.<br><br>The geologic setting specific to the JNF is more than just the geologic units listed by mileposts (Table 6.1-2; Appendix 6-A). Using the most detailed published geologic maps and reports available, the geologic setting needs to discuss the project within the context of geologic materials (lithologies and surface deposits), geologic structures (such as strike and dip of beds, joints, faults, and other discontinuities), geologic processes (such as landslides, floods, etc.), and geomorphic landforms (such as dip slopes, anti-dip slopes) relevant to the construction and operation of the project on the JNF. Based on the types of geology and level of detail in published sources, the geologic setting specific to |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | the JNF would provide an indication of the type and level of detail of geologic field investigations that may be needed to address the issues related to geologic resources and geologic hazards. |
| 6 | 6-4 | 6.1.2 | Section 6.1.2 Topography states: "Topography along the pipeline route varies from flat to slopes exceeding 45 percent…For topographic details along the MVP route, see the U.S. Geological Society (USGS) 7.5-minute series topographic quadrangle excerpts located in Resource Report 1". However, more slope information is need for the National Forest. Because slope steepness is so important in the analysis of the proposed pipeline, provide a detailed display and analysis of slopes on the National Forest relevant to the proposed pipeline. Quantify and classify the slope gradients on the JNF using the best DEM or elevation data available. Prepare a slope map covering the JNF pipeline corridor and the areas upslope and downslope of the corridor that are relevant to assessing 1) potential landslides (including debris flows) that may affect proposed facilities, 2) runout pathway for potential debris flows caused by cut slope or fill slope failures. Prepare similar slope map for areas of potential access road construction on JNF. The slope breaks used to classify slopes on the slope map should include slope breaks relevant to slope stability and/or used in project design. For example, one slope break should be the slope % at which cut-and-fill road construction would change to full bench road construction. Another example, a similar slope break should by the slope % at which cut-and-fill pipeline corridor construction would change to full bench construction. Other examples of slope breaks to include in slope map are the slope % used to determine major differences in types of pipeline corridor construction, such as: a) side hill excavation that is parallel or sub-parallel to slope contours; b) excavation that is perpendicular to slope contours and using winch lines; and c) excavation that is perpendicular to slope contours and not using winch lines. The slope map is also needed to assess slope stability of any proposed disposal sites for excess excavation (such as from full bench construction). |
| 6 | 6-15 | 6.4 | Comment on entire section 6.4.<br>Geologic hazards are geologic processes or conditions (naturally occurring or altered by humans) that may create risks to public health and safety, infrastructure, and resources.<br>Describe the affected environment of existing or potential geologic hazards that the MVP project may affect or be affected by on National Forest lands in a site-specific manner for each geologic hazard discussed in section 6.4. |
| 6 | 6-17 | 6.4.1.2 | Figure 6.4-1 Seismic Hazards map provides a regional setting. In addition, provide a more detailed map showing the Giles County Seismic Zone (GCSZ) and the Pembroke Fault Zone (PFZ) in relation to the JNF traversed by the pipeline corridor. |
| 6 | 6-17 | 6.4.1.2 | This Seismicity section states: "The PFZ is primarily known for being the epicenter of a strong May 31, 1897 earthquake that was subsequently characterized under modern standards of MM-VIII, magnitude 5.8." Since this is a known active earthquake zone, assess the potential for the zone to produce earthquakes with greater than magnitude 5.8 and greater than MM-VIII. Include discussion of magnitude 7 earthquake estimated by Bollinger (1988, 1981).<br>Bollinger, G.A., Wheeler, R.L., 1988, The Giles County, Virginia, Seismic Zone Seismological Results and Geological Interpretations, U.S. Geological Survey Professional Paper 1355.<br>Bollinger, G.A., 198l, The Giles County, Virginia, seismic zone Configuration and hazard assessment, *in* Beavers, J. E., ed., Earthquakes and earthquake engineering; The eastern United States: Knoxville, Tennessee, September 14-16,1981, Proceedings, v. 1: Ann Arbor Science, Ann Arbor, p. 277-308.<br><br>Include discussion of magnitude 7.4 earthquake for Paleozoic extended terrane seismotectonic zone estimated by USGS: Petersen, M.D., et al, 2014, Documentation for the 2014 update of the United States national seismic hazard maps: U.S. Geological Survey Open-File Report 2014–1091, 243 p., *http://dx.doi.org/10.333/ofr2014109*<br>Using the deaggregation tool in Petersen, M.D., et al, 2014, display the contribution of earthquakes of different magnitudes to the 0.14 g estimate for peak acceleration in PFZ. |
| 6 | 6-17 | 6.4.1.2 | Peak ground acceleration for the MVP pipeline crossing the JNF was estimated at 0.14 g in Figure 6.4-1 and Appendix 6-D Table 6.1 (Draper Aden Associates 2015c – Appendix 6-D). However, ridgetop amplification could increase this acceleration number by a factor of two or three times. Whisonant Watts, and Kastning (1991) state: "According to these data, the 1897 Pearisburg earthquake (M = 5.8) would have produced a seismic acceleration in the Sinking Creek Muntain area of approximately 0.12 G. Ridgetop amplification could have enhanced this number by a factor of two or three times along the crest of Sinking Creek Mountain (Bollinger, personal communication)."<br>Whisonant, R.C., Watts, C.F., and Kastning, E.H., 1991. Neotectonic Investigations in the Southeastern United States: Part 1 – Potential Seismic Triggering of Giant Bedrock Landslides and Suspected Mass Movements in the Giles County Seismic Zone. A report prepared of Ebasco Services Incorporated, Greensboro, North Carolina. |

| RR# Or Plan Name | Page # | Section # | Comment |
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| | | | The pipeline corridor crosses three ridgetops on JNF (Peters Mountain, Sinking Creek Mountain, and Brush Mountain). Assess the potential for ridgetop amplification to increase seismic acceleration by a factor of two, three or more times. |
| 6 | 6-17 | 6.4.1.2 | Peak ground acceleration for the MVP pipeline crossing the JNF was estimated at 0.14 g in Figure 6.4-1 and Appendix 6-D Table 6.1 (Draper Aden Associates 2015c – Appendix 6-D). The estimate is based on data from U.S. Geological Survey (Petersen et al, 2014). The USGS tool (Petersen et al, 2014) uses seismotectonic zone models. The zones cover vast areas of the eastern U.S. The Paleozoic extended terrane seismotectonic zone extends from Mississippi to Canada, and includes the Giles County seismic zone or PFZ. The Giles County Seismic Zone (GCSZ) or the Pembroke Fault Zone (PFZ), because it is a known active seismic area at a specific location along the MVP corridor, deserves additional, specific analysis beyond that provided by the seismotectonic zone models of Petersen et al (2014). For example, a detailed analysis of the Giles County Seismic Zone was provided by Bollinger in 1981 and 1988. Provide an updated analysis specific to Giles County Seismic Zone (GCSZ) or the Pembroke Fault Zone (PFZ).<br><br>As part of the updated analysis, consider the more recent correlations of peak ground acceleration and modified Mercalli intensity. For example, Wald et al (1999; Table 1) provide for California earthquakes a range of ground motions for modified Mercalli intensities showing Peak Acceleration (% g) range of 34-65 for an MM intensity of VIII. Similar relationships are discussed in Worden et al (2012). Another example, Atkinson and Kaka, 2007 provide for Oklahoma earthquakes a Peak Acceleration (% g) range of 27 for an MM intensity of VIII. Dangkua and Cramer, 2011 provide similar relationships for modified Mercalli intensities and peak acceleration for eastern North America. The May 31, 1897 earthquake has been characterized as MM-VIII. Provide an estimate of the peak acceleration for the Giles County 1897 MM-VIII earthquake using Dangkua and Cramer, 2011 and other research as appropriate. |
| 6 | 6-17 | 6.4.1.2 | The May 31, 1897 earthquake with MM intensity of VIII has been characterized as a magnitude 5.8 earthquake. The GCSZ or PFZ is a known active seismic zone capable of generating earthquakes of magnitude 6 and 7. Draper Aden Associates 2015c report in Appendix 6-D states that the estimate 0.14 g is "expressed as a fraction of gravitational acceleration, g), with a 2 percent probability of occurring in 50 years (i.e., mean return period of approximately 2,500 years)". Return periods can be modeled and estimated for the GCSZ or PFZ, but the return periods are not known, and cannot be known without earthquake records for thousands of years for the GCSZ or PFZ. Moreover, earthquakes do not occur on regimented, clockwork return periods. Assuming for a moment a 2500 year return period for 0.14 g, it is possible for multiple earthquakes exceeding 0.14 g to occur within a 2500 year return period. The return periods for earthquakes are subject to the same misunderstandings as the return periods for floods. Some people living in a 100 year floodplain are surprised when multiple 100 year flood events occur, sometimes within a few years of each event. So, even assuming a 2500 year return period for 0.14 g, given the active GCSZ or PFZ seismic zone, one might also assume a case for multiple events exceeding .14 g within the 2500 year return period. In such a case, the probability of exceeding 0.14 g would be greater than a 2 percent probability of occurring in 50 years.<br><br>More fundamentally, the relationships of MM Intensity to peak accelerations from some studies, such as Wald et al (1999) and Atkinson and Kaka (2007), suggest that earthquakes with MM intensity of VIII, in general and thus possibly including the May 31, 1897 earthquake, may have peak accelerations significantly greater than 0.14 g. The estimated magnitude 5.8 earthquake was within the magnitude 5 to 6 range of the more common earthquakes that the GCSZ or PFZ might generate compared with the less frequent, higher magnitude 6 or 7 earthquakes. The May 31, 1897 earthquake occurred just over 100 years ago and is in a known active seismic zone. In estimating peak acceleration to use for the MVP pipeline for the next 50 years, it would seem sensible and conservative to use an estimate at least as great as an estimate of the peak acceleration for the May 31, 1897 earthquake. Provide an estimate of the peak acceleration for the 1897 Giles County MM-VIII earthquake using Dangkua and Cramer, 2011 and other research on relationships of MM Intensity to peak accelerations as appropriate. Display median and ranges for peak ground acceleration for these estimates.<br><br>In addition, as another approach, estimate the peak ground accelerations for a M5.8 as a function of distance using ground motion prediction equations (GMPEs) such as Toro, Abrahamson and Schneider (1997) and Tavakoli and Pezeshk (2005). Display median and ranges for peak ground acceleration for these estimates. |

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<tr><td></td><td></td><td></td><td>Compare the estimates from these other approaches with the estimate of 0.14 g. The estimates from these other approaches are needed to provide a check on whether the 0.14 g estimate is reasonable or not for the GCSZ or PFZ in light of the May 31, 1897 earthquake M 5.8 and MM intensity of VIII.<br><br>Also, check on whether the 0.14 g estimate is reasonable or not for the GCSZ or PFZ in light of this following statement from page 6-44:<br>“The effects of the 2011 magnitude 5.8 earthquake near Mineral, Virginia are being widely studied due to the proximity of the North Anna nuclear power station. The USGS estimated that the 2011 earthquake produced a peak ground acceleration of 0.26 g at the NAPS site.”<br><br>Wald, D. J., V. Quitoriano, T. H. Heaton, and H. Kanamori (1999). Relationships between peak ground acceleration, peak ground velocity and modified Mercalli intensity in California, Earthquake Spectra 15, 557–564.<br><br>Worden, C.B., Grettenberger, M. C., Rhoades, D. A. and Wald, D. J. , 2012, Probabilistic Relationships between Ground-Motion Parameters and Modified Mercalli Intensity in California, Bulletin of the Seismological Society of America, Vol. 102, No. 1, pp. 204–221, February 2012, doi: 10.1785/0120110156<br><br>Atkinson, G.M. and I. Kaka, SL.I, 2007, Relationships between Felt Intensity and Instrumental Ground Motion in the Central United States and California, Bulletin of the Seismological Society of America, Vol. 97, No. 2, pp. 497–510, April 2007, doi: 10.1785/0120060154<br><br>Dangkua, D.T. and Cramer, C.H., 2011, Felt Intensity versus Instrumental Ground Motion: A Difference between California and Eastern North America?, Bulletin of the Seismological Society of America, Vol. 101 no. 4, p. 1847-1858 doi: 10.1785/0120100133<br><br>Toro, G.R., N.A. Abrahamson and J.F. Schneider (1997). A Model of Strong Ground Motions from Earthquakes in Central and Eastern North America: Best Estimates and Uncertainties. Seismological Research Letters, v.68, no. 1, pp. 41-57.<br><br>Tavakoli, B and Pezeshk, S, 2005, Empirical-Stochastic Ground-Motion Prediction for Eastern North America, Bulletin of the Seismological Society of America, Vol. 95, No. 6, pp. 2283–2296, December 2005, doi: 10.1785/0120050030</td></tr>
<tr><td>6</td><td>6-17</td><td>6.4.1.2</td><td>In addition, assess the large rock block landslides on Sinking Creek Mountain as evidence for potentially much more powerful and destructive earthquakes than magnitude 5.8 and MM-VIII. The pipeline corridor traverses the JNF on the southeast flank of Sinking Creek Mountain. A series of large rock block slides extends for miles along the southeast flank of Sinking Creek Mountain (Schultz, A.P., 1993). Schultz (1993) states that the analysis shows that the rock block slides may have been emplaced as a single catastrophic event of short duration. Schultz and Southworth (1989) state: “The apparent clustering of large landslides near the Giles County, Virginia seismic zone suggests that seismic shaking may have been an important triggering mechanism.”<br><br>Whisonant, Watts, and Kastning (1991) did a study of landslides in the Giles County Seismic Zone (GCSZ) and identified landslides on Sinking Creek Mountain and elsewhere as landslides likely to be of seismic origin or to contain evidence of seismic events.<br><br>Review and discuss the studies which have considered earthquakes as a triggering mechanism for the large rock block landslides on Sinking Creek Mountain, such as:<br><br>Schultz, A.P., 1993, Geologic map of large rock block slides at Sinking Creek Mountain, Appalachian Valley and Ridge Province, southwestern Virginia, and comparison with the Colorado Front Range. U.S. Geological Survey I Map 2370, 1:24,000-scale map.<br><br>Schultz, A.P., and Southworth, C.S., 1989, Large bedrock landslides of the Appalachian Valley and Ridge of Eastern North America, <u>in</u> Schultz, A.P., and Jibson, R.W. (eds.), Landslide processes of Eastern United States: Geological Society of America Special Paper 236, Chapter 4, p. 57-74.<br><br>Whisonant, R.C., Watts, C.F., and Kastning, E.H., 1991. Neotectonic Investigations in the Southeastern United States: Part 1 – Potential Seismic Triggering of Giant Bedrock Landslides and Suspected Mass Movements in the Giles County Seismic Zone. A report prepared of Ebasco Services Incorporated, Greensboro, North Carolina.</td></tr>
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| RR# Or Plan Name | Page # | Section # | Comment |
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| 6 | 6-19 | 6.4.1.3 | This section on “Active Faults” is focused on active faults with known surface expression (surface faulting). However, there also are active faults with uncertain or no known surface expression. There are several issues for this “Active Faults” to consider.<br><br>First, in the arid and semi-arid western U.S., the ground cracks and scarps of surface faulting produced by some earthquakes are relatively easy see in sparsely vegetated lands; and the evidence of surface faulting can be preserved on the land surface for long periods in the drier climate. In contrast, in the humid eastern U.S., the ground cracks and scarps of surface faulting that might be produced by some earthquakes would be more difficult to find in sparsely populated, and heavily vegetated mountains of western Virginia; and the evidence of surface faulting would be difficult to preserve on the land surface for long periods in the wetter climate.<br><br>Consider changing title of section from “Active Faults” to a title such as “Surface rupture potential from faulting” or “Active surface faults” or “Active surface faults and rupture potential from surface faulting” in order to reflect the specific hazard addressed in this section.<br>Assess potential for 1) surface faulting on known faults and 2) potential for new faulting to rupture the ground surface within the pipeline corridor (Collins, T.K., 1990, New Faulting and the Attenuation of Fault Displacement, Bulletin of the Association of Engineering Geologists, Vol. XXVII, No. 1, pp. 11-22).<br><br>After the August 3, 2011 earthquake of magnitude 5.8 in Louisa, Virginia, geologists from the federal and state agencies were searching for evidence of surface faulting. No known surface faulting was associated with historic earthquakes in the Central Virginia Seismic Zone (CVSZ). Despite the lack of evidence of historic surface faulting in CVSZ, there was recognition that the August 3, 2011 earthquake of magnitude 5.8 might have produced surface faulting. If an earthquake of magnitude 5.8 like the 1897 earthquake were to occur again in Giles County, geologists from the federal and state agencies would be searching for evidence of surface faulting in the GCSZ or PFZ. The geologists would be conducting the kind of intense, scientific search that was not conducted in 1897. Thus, the potential for surface faulting is not a negligible hazard when one recognizes that every damaging earthquake generated by GCSZ or PFZ, such as the 1897 magnitude 5.8, would likely be followed by geological field investigations to see if surface faulting occurred. Moreover, if a damaging earthquake were to occur in the GCSZ or PFZ during the operation of the MVP pipeline, it is likely that MVP would inspect the pipeline to see if surface faulting occurred and displaced and damaged the pipeline. Such surface faulting may occur on preexisting faults or on new faults (Collins, 1990). The potential for surface faulting would be present for each damaging earthquake in the GCSZ or PFZ; the stronger and more damaging the earthquake, the more potential for surface faulting; and the pipeline would be a long, linear feature traversing the GCSZ or PFZ. In this sense, the risk of potential surface faulting to the pipeline in the GCSZ or PFZ ought not to be dismissd as a “negligible risk”. |
| 6 | 6-23 | 6.4.1.5 | Describe historic accounts of landslides from the May 31, 1897 earthquake. It is important to find out as much as possible about these landslides because these types of landslides will likely be common with earthquakes of similar or greater magnitude.<br>In addition, consider potential for landslides generated by earthquakes with epicenters outside the GCSZ or PFZ, such as described by Jibson and Harp, 2012.<br>Jibson, R.W and Edwin L. Harp, E.L., 2012, Extraordinary Distance Limits of Landslides Triggered by the 2011 Mineral, Virginia, Earthquake, Bulletin of the Seismological Society of America, Vol. 102, No. 6, pp. –, December 2012, doi: 10.1785/0120120055 |
| 6 | 6-23 | 6.4.1.5 | Identify the large rock block landslides on Sinking Creek Mountain. The pipeline corridor traverses the JNF on the southeast flank of Sinking Creek Mountain. A series of large rock block slides extends for miles along the southeast flank of Sinking Creek Mountain (Schultz, A.P., 1993). Schultz (1993) states that the analysis shows that the rock block slides may have been emplaced as a single catastrophic event of short duration. Schultz and Southworth (1989) state: “The apparent clustering of large landslides near the Giles County, Virginia seismic zone suggests that seismic shaking may have been an important triggering mechanism.”<br><br>Whisonant, Watts, and Kastning (1991) did a study of landslides in the Giles County Seismic Zone (GCSZ) and identified landslides on Sinking Creek Mountain and elsewhere as landslides likely to be of seismic origin or to contain evidence of seismic events.<br><br>Review and discuss the studies which have considered earthquakes as a triggering mechanism for the large rock block landslides on Sinking Creek Mountain, such as: |

| RR# Or Plan Name | Page # | Section # | Comment |
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| | | | Schultz, A.P., 1993, Geologic map of large rock block slides at Sinking Creek Mountain, Appalachian Valley and Ridge Province, southwestern Virginia, and comparison with the Colorado Front Range. U.S. Geological Survey I Map 2370, 1:24,000-scale map.<br><br>Schultz, A.P., and Southworth, C.S., 1989, Large bedrock landslides of the Appalachian Valley and Ridge of Eastern North America, in Schultz, A.P., and Jibson, R.W. (eds.), Landslide processes of Eastern United States: Geological Society of America Special Paper 236, Chapter 4, p. 57-74.<br><br>Whisonant, R.C., Watts, C.F., and Kastning, E.H., 1991. Neotectonic Investigations in the Southeastern United States: Part 1 – Potential Seismic Triggering of Giant Bedrock Landslides and Suspected Mass Movements in the Giles County Seismic Zone. A report prepared of Ebasco Services Incorporated, Greensboro, North Carolina. |
| 6 | 6-32 | 6.4.3 | This statement is incorrect: "Slope information along the Project is provided in Resource Report 1, Appendix 1-I". Correct statement to show that the slope information is in Appendix 1-J. |
| 6 | 6-32 | 6.4.3. | This reference is incorrect: "Watt 1982". Watt was Secretary of Interior, not the author. Correct reference to show authors of Landslide Overview Map of the Conterminous United States. |
| 6 | 6-34 | 6.4.3 | The Landslide section states: "MVP has performed a preliminary inventory of potential areas of landslide or rockfall concern along the pipeline alignment. This was completed through review of available historic aerial photographs, soils, topographic data to identify indications of potential landslide hazards." The review does not mention a review of geology, which is required to inventory potential landslide or rockfall concerns along the pipeline corridor. Landslides are geologic hazards. Geology is the overarching discipline for considering landslides because geology encompasses not only soils and topography, but a host of surface and subsurface factors relevant to landslides, such as lithology, structure, climate, vegetation, groundwater, and a multitude of landslide type ranging from shallow slides to deep-seated landslides. Correct this deficiency of geologic information by providing a review of geologic setting on the JNF relevant to inventory of potential areas of landslides or rockfalls by a professional geologist or engineering geologist. Consider and refer to published geologic reports and maps relevant to portions of JNF to be traversed by the project, such as:<br><br>A.P. Schultz, C.B. Stanley, 2001. Geologic Map of the Virginia portion of the Lindside Quadrangle,<br>Virginia Division of Mineral Resources Publication 160, 1:24,000-scale map.<br><br>Schultz, A.P., Stanley, C.B., Gathright, T.M., II, Rader, E.K., Bartholomew, M.J., Lewis, S.E., and Evans, N.H., 1986, Geologic map of Giles County, Virginia: Virginia Division of Mineral Resources Publication 69, 1:50,000-scale map.<br><br>Schultz, A.P., 1993, Geologic map of large rock block slides at Sinking Creek Mountain, Appalachian Valley and Ridge Province, southwestern Virginia, and comparison with the Colorado Front Range. U.S. Geological Survey I Map 2370, 1:24,000-scale map.<br><br>Display the pipeline corridor (and any project facilities such as access roads) within the JNF surface ownership boundary overlaid on the most detailed scale published geologic maps available. Identify the types of landslides mapped in the vicinity of the pipeline corridor. Based on existing information, discuss the geologic factors (such as lithology, surficial deposits, structure, discontinuities, etc.) relevant to potential landslides along the pipeline corridor on the JNF. |
| 6 | 6-34 | 6.4.3 | The Landslide section states: "Areas where the alignment crosses steep hill slopes are identified in Table 6.4-6, and Appendix 6-D.3 includes a map set depicting these areas. As shown in the table, the pipeline route traverses approximately 3.8 miles of steep hill slopes that of potential stability or landslide concern." The steep slopes on the JNF are not identified in Table 6.4-6, and Appendix 6-D.3. Identify the steep slopes on the JNF by milepost and slope (%). |
| 6 | 6-36 | 6.4.3 | The Slope (%) column in Table 6.4-6 has a footnote: "a/ Design slope is based on desktop and field review, or range from map analysis of alignment." Specify how the Slope (%) was calculated for the JNF portion of the pipeline corridor. Was Slope (%) calculated using 10 meter DEM or other basis. Define what Slope (%) is considered "steep" for Table 6.4-6, and Appendix 6-D.3. |
| 6 | 6-37 | 6.4.3 | The Landslide section of Resource Report 6 failed to recognize the largest known landslides in eastern North America on Sinking Creek Mountain. The pipeline corridor on the JNF crosses Sinking Creek Mountain which has the largest known landslides in eastern North America (Schultz and Southworth, 1989). The pipeline corridor on Sinking Creek Mountain (MP 217.2 – 218.0) traverses one of the large bedrock landslides mapped by Schultz (1993). The Landslide section of Resource Report 6 failed to identify this large bedrock landslide on a published geologic map (Schultz, 1993). |

| RR# Or Plan Name | Page # | Section # | Comment |
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| | | | The failure of the Landslide section of Resource Report 6 to recognize an existing large bedrock landslide traversed by the pipeline corridor and the failure to assess the potential for large bedrock landslides in the pipeline traverse of Sinking Creek Mountain needs to be corrected by an investigation conducted by an engineering geologist. |
| 6 | 6-37 | 6.4.3 | The pipeline corridor on the JNF crosses Peters Mountain which has some similarities (lithologies, structures, etc.) to Sinking Creek Mountain. The failure of Resource Report 6 to recognize and assess potential for large bedrock landslides (similar to the Sinking Creek Mountain landslides) in the pipeline traversing of Peters Mountain needs to be corrected by an investigation conducted by an engineering geologist. |
| 6 | 6-37 | 6.4.3 | The pipeline corridor on the JNF crosses Peters Mountain, Sinking Creek Mountain, and Brush Mountain. These mountains have the potential for more frequent types of rockslides of lesser dimensions than the large bedrock landslides of Sinking Creek Mountain. The failure of Resource Report 6 to recognize and assess potential more ordinary types of rockslides in the pipeline traverse of Peters Mountain, Sinking Creek Mountain, and Brush Mountain needs to be corrected by an investigation conducted by an engineering geologist. |
| 6 | 6-37 | 6.4.3 | The Landslide section of Resource Report 6 failed to assess the site-specific debris flows hazards for the pipeline corridor traversing the JNF on Peters Mountain, Sinking Creek Mountain, and Brush Mountain. For example, the pipeline corridor on Sinking Creek Mountain (MP 217.2 – 218.0) traverses a debris flow deposit mapped by Schultz (1993). The Landslide section of Resource Report 6 failed to identify the debris flow deposit on a published geologic map Schultz, 1993). The failure of the Landslide section of Resource Report 6 to recognize existing debris flow deposits traversed by the pipeline corridor and the failure to assess the potential for debris flows in the pipeline traverse of Sinking Creek Mountain, Peters Mountain and Brush Mountain, needs to be corrected by an investigation conducted by an engineering geologist. |
| 6 | 6-37 | 6.4.3 | The Landslide section states: "MVP is in the process of conducting field observations at these steep hill slope sites of potential stability issues…These investigations are being conducted by a geotechnical engineer experienced with landslide evaluation." It is essential that investigations also need to be conducted by an engineering geologist (not just a geotechnical engineer) on steep slopes on JNF. An investigation by an engineering geologist is especially important because of the Resource Report 6 major deficiencies in geologic information relevant to potential landslides on JNF.<br><br>For the JNF portions of the pipeline corridor, provide site-specific geologic maps of consolidated and unconsolidated deposits, and geologic structures, such as dip slopes and the orientation of bedrock discontinuities (bedding, joints, and other fractures). Consider the types of landslides relevant to the site-specific geology, such as debris slides, debris flows, slumps, rockfalls, and rockslides including the potential for large bedrock landslides on Sinking Creek Mountain and Peters Mountain. Conduct on-site engineering geologic investigation and mapping such as described by Keaton and DeGraff (1996): Keaton, J.R. and DeGraff, J.V., Surface Observation and Geologic Mapping, pp. 178-230 in Landslides Investigations and Mitigation, Special Report 247, Turner A.K. and Schuster R.L. editors, 1996, Transportation Research Board, National Research Council, National Academy Press, Washington, D.C., pp. 674.<br><br>Identify existing slope stability conditions in the footprint and upslope and downslope of the footprint of the proposed facilities (such as existing landslides; streamside slopes subject to undermining by streams; geologic structures that may be adverse to slope stability such as dip slopes; existing or potential debris flow paths). |
| 6 | 6-37 | 6.4.3 | The Landslide section needs to consider and make reference to such sources of geologic information as:<br><br>Schultz, A.P., 1993, Geologic map of large rock block slides at Sinking Creek Mountain, Appalachian Valley and Ridge Province, southwestern Virginia, and comparison with the Colorado Front Range. U.S. Geological Survey I Map 2370, 1:24,000-scale map.<br><br>Schultz, A.P., Stanley, C.B., Gathright, T.M., II, Rader, E.K., Bartholomew, M.J., Lewis, S.E., and Evans, N.H., 1986, Geologic map of Giles County, Virginia: Virginia Division of Mineral Resources Publication 69.<br><br>Schultz, A.P., Bartholomew, M.J., and Lewis, S.E., 1991, Surficial Geology of the Radford 30x60° quadrangle, Virginia and West Virginia: U.S. Geological Survey I Map 2170A. |

| RR# Or Plan Name | Page # | Section # | Comment |
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| | | | Schultz, A.P., Miller, E.V., Bollinger, G.A., Gathright, T.M., Rader, E.K., and Hubbard, D.A., 1985, Geologic and seismic hazard potential, Giles County, Virginia, including a discussion and map of bedrock geology: Prepared by the Virginia Division of Mineral Resources; the Department of Geological Sciences, Virginia Polytechnic Institute and State University and the United States Geological Survey under contract #14-08-0001-A0076, 44 p., 2 maps at 1:50,000.<br><br>Schultz, A.P., 1986, Ancient, giant rockslides, Sinking Creek Mountain, southern Appalachians, Virginia: Geology, v. 14, no. 1, p. 11-14.<br><br>Southworth, C.S., and Schultz, A.P., 1986, Characteristics of giant rock-slides in the Appalachian Valley and Ridge, Virginia, West Virginia, Maryland, and Pennsylvania: U.S. Geological Survey Open-File Report 86-94, 4 p. with 3 oversized sheets.<br><br>Southworth, C.S., and Schultz, A.P., 1986, Photogeologic interpretation reveals ancient, giant rockslides in Appalachian Valley and Ridge Province, Virginia and West Virginia, in Association of Engineering Geologists Newsletter, v. 29, no. 2, p. 31-33 and back cover.<br><br>Schultz, A.P., 1987, Failure kinematics of ancient giant block slides and rock slumps, southern Appalachian Valley and Ridge Province, in Schultz, A.P., and Southworth, C.S. (eds.), Landslides of eastern North America: U.S. Geological Survey Circular 1008, p. 32-33.<br><br>Schultz, A.P., and Southworth, C.S., 1989, Large bedrock landslides of the Appalachian Valley and Ridge of Eastern North America, in Schultz, A.P., and Jibson, R.W. (eds.), Landslide processes of Eastern United States: Geological Society of America Special Paper 236, Chapter 4, p. 57-74.<br><br>Schultz, A.P. (ed. & compiler), 1989, Roadlog and site description for the 1989 Southeast Friends of the Pleistocene Field Excursion: surficial geology of the New River Valley, southwest Virginia: U.S. Geological Survey Open-File Report 89-635, 72 p.<br><br>Whisonant, R.C., Watts, C.F., and Kastning, E.H., 1991. Neotectonic Investigations in the Southeastern United States: Part 1 – Potential Seismic Triggering of Giant Bedrock Landslides and Suspected Mass Movements in the Giles County Seismic Zone. A report prepared of Ebasco Services Incorporated, Greensboro, North Carolina.<br><br>Whisonant, R.C., Watts, C.F., and Kastning, E.H., 1991. Neotectonic Investigations in the Southeastern United States: Part 2 – Preliminary Investigation of Caves in the Giles County Seismic Zone Possibly Containing Evidence of Seismic Events. A report prepared of Ebasco Services Incorporated, Greensboro, North Carolina.<br><br>Whisonant, R.C. and Watts, C.F., 1991. Comprehensive Stability Analysis of Ancient Giant Landslides, Valley and Ridge Province, (abs), In Proceedings of the 34th Annual Meeting of the Association of Engineering Geologists, Chicago, IL, pp 612-620. |
| 6 | 6-37 | 6.4.3 | The Landslide section states: “MVP is in the process of reviewing areas of potential slope stability issues. This information will be assessed and field evaluations completed. The impacts to the pipeline and vice versa, will be evaluated for each area identified and mitigation measures recommended. The recommendations will be included in the final pipeline design.” The engineering geologic field evaluations and assessments of potential slope stability issues and “impacts to the pipeline, and vice versa” are needed for the Draft Environmental Impact Statement (DEIS), not just for final pipeline design. Provide field evaluations and assessments conducted by an engineering geologist on the JNF for the DEIS. |
| 6 | 6-37 | 6.4.3 | Describe the scope and magnitude of historic debris flows events, such as in:<br>Plate 1 from Hack, J. T., and Goodlett, J. C., 1960, USGS Professional Paper 347.http://pubs.er.usgs.gov/publication/pp347<br><br>Morgan, B.A. et al., 1999, INVENTORY OF DEBRIS-FLOW AND FLOODS IN LOVINGSTON AND HORSESHOE MOUNTAIN, VA: 7.5 MINUTE QUADRANGLES FROM THE AUGUST 19/20, 1969 STORM IN NELSON COUNTY, VA, USGS OFR-99-518.<br>http://geology.er.usgs.gov/eespteam/terrainmodeling/ofr99_518.htm<br><br>Discuss the frequency of debris flow events, including the major debris flow events in Virginia and West Virginia from 1949 to 1996: Figure 1 from Eaton, L.S., Morgan, B. A.,Kochel, R.C. and Howard A. |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | D., 2003, Role of debris flows in long-term landscape denudation in the central Appalachians of Virginia, *Geology* 2003;31;339-342. http://geology.gsapubs.org/content/31/4/339.short<br>Recognize that intense storms can occur outside the hurricane season as well as in hurricane season. |
| 6 | 6-37 | 6.4.3 | Describe any slope instabilities with existing pipelines in the mountainous areas of Virginia and West Virginia, such as the Celanese pipeline traverse of Peters Mountain. Provide details sufficient to characterize the factors involved so that the potential for similar slope instabilities can be assessed on the MVP project. |
| 6 | 6-37 | 6.4 | Add a section under Geologic Hazards titled "Floods and Other Stream Hazards" and describe the affected environment for floods, stream erosion and scour in a site specific manner for the MVP project on the Jefferson National Forest. |
| 6 | 6-37 | 6.4 | Add a section under Geologic Hazards titled "Acid-Producing Rocks" and describe whether acid-producing rocks (lithology) are present along the MVP project on the Jefferson National Forest. |
| 6 | 6-31 | 6.6 | In order to assess impacts on the Jefferson National Forest (JNF), the location and magnitude of the proposed slope modifications (excavations and fills) need to be identified in a site specific manner. Provide plans and typical drawings showing the dimensions of the slope modifications (cut and fill) for each type of MVP project footprint to be located on the JNF such as:<br>Access roads to pipeline right-of-way (ROW) corridor (incudes new construction and reconstruction)<br>Pipeline ROW excavation for trench (ditch).<br>Pipeline ROW excavation for roads (travel area and working area)<br>Pipeline ROW loose material from trench excavation (ditch spoil storage)<br>Pipeline ROW topsoil (topsoil storage).<br>Pipeline ROW loose material from construction road excavation (travel area and working area).<br>Additional Temporary Workspace (ATWS).<br>Contractor yards and equipment staging/storage areas.<br>Disposal areas for excess excavation or other materials.<br><br>For each type of footprint (such as listed above), state whether it will be or will not be located on the JNF. |
| 6 | 6-39 | 6.6.1.2 | Correct this statement: "These techniques and other best management practices are outlined in the typical construction drawings included in Appendix 1-D, Typical Construction Drawings, of Resource Report 1." The typical drawings are in Appendix 1-C1. |
| 6 | 6-39 | 6.6.1.2 | The construction typical drawings of mainline construction in Appendix 1C-1 are largely for flat land, and are not adequate for the steeper slopes typical of the National Forests. Provide construction typical drawings for the range of slopes gradients (%) requiring excavation on NFS lands, including a typical drawing for the maximum slopes (%) to be excavated in the construction right-of-way. Label the loose material from all excavations not just the trench excavation. While additional field information may refine the designs, MVP needs to provide, before or at the start of DEIS process, the typical drawings requested here and in related comments below; the slope and other information currently available should allow MVP to provide initial typical drawings with dimensions suitable for assessing the location and magnitude of construction on National Forests.<br><br>Provide construction typical drawings with dimensions showing a cross-section of original slope and cut-and-fill for each slope class (in 10% increments) where cut-and-fill construction would occur on the National Forest. For example, if cut-and-fill construction is planned on slopes ranging from 10% to 78%, then provide a construction typical drawing for each of these construction slopes: 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 80%. Provide in each typical drawing a cross-section showing the construction details from the top of the cut to the toe of the fill. Because the angle of the cut slope (or cut slope ratio such as 1:1, ¾:1, ½:1 or ¼:1) may vary depending on the geologic site conditions, the typical drawing may include a maximum and a minimum cut-slope to bracket the likely variation in cut-slope angles. Similarly the angle (or slope ratio) of fill slopes may vary, and so, the drawing may include a minimum and maximum fill-slope.<br><br>Provide these typical drawings (at 10% slope intervals) for each of the three types of mainline construction techniques within the JNF as identified on Figures 1.11-1 and 1.11-2 (Resource Report 1) : 1) Typical Overland Construction, 2) Down Slope with Winch, 3) Down Slope without Winch. |
| 6 | 6-39 | 6.6.1.2 | The typical drawing for mainline construction on a ridge (Appendix 1-C1, Drawing No. MVP-8) in Resource Report 1 is inadequate and too generalized to assess the magnitude of the proposed slope modifications (excavations and fills) on ridges in the National Forest. Drawing No. MVP-8 shows ditch spoil storage on a ridge sideslope, but does not identify the slope (%) of the ridge sideslope, nor does |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | it identify the maximum slope (%) of a ridge sideslope that spoil would be allowed for slope stability (for temporary storage or permanent disposal).<br><br>Even more critical, Drawing No. MVP-8 does not show the temporary storage or permanent disposal of the main excavation of the ridge. The main excavation in the construction ROW is much greater volume than the ditch excavation. Provide a range of typical drawings to show the temporary storage or permanent disposal of the main excavation for the range of typical slopes (%) along ridgetops and perpendicular to ridgetops (sideslopes) on the JNF. Where the main excavation will not be stored and/or disposed in the ROW, identify where the excavated material will be stored and/or disposed.<br><br>Provide construction typical drawings with dimensions showing a cross-section with original slope (natural grade) and cut-and-fill for each typical ridgetop where construction would occur on the National Forest. For example, if construction would be on six different slope forms of ridgetops, (such as six ridgetops with symmetric side-slopes of 10%, 20%, 30%, 40%, 50%, 60%), then provide a typical drawing for each of these six types of ridgetops with symmetric slopes. Provide similar construction drawings for each typical ridgetop with asymmetric side-slopes (such 10% on one side-slope and 50% on other side-slope of ridgetop. Of special concern is the potential for failure of loose excavated material during construction and the potential for failure of fill slopes (including fill in reclaimed slopes) in the many years after construction. Display in the typical drawings the maximum extent (dimensions) of the loose excavated material in temporary storage or in permanent disposal or fill.<br><br>For Down Slope Construction with or without winch as identified on Figures 1.11-1 and 1.11-2 (Resource Report 1), two drawings for needed for each typical ridge: 1) a drawing oriented perpendicular to ridge (such as Drawing No. MVP-8), 2) a drawing oriented parallel to the ridgeline showing the original ground and the final grade of the main construction ROW. This information is needed for Down Slope or ridge construction in order to assess the slope stability of cut slopes and fills slopes that may fail parallel to or perpendicular to the linear ROW.<br><br>The need for this type of information is recognized in the following statement on page 6-43: "When steep side slopes are encountered, additional measures will be taken to ensure slope stability. Slope stability will be addressed during Project design and construction for both excessively steep parallel and side slopes." However, what is not recognized is the need for some of this information now in order to identify the scope and magnitude of the proposed slope modifications (excavations and fills) on the JNF and to assess potential effects on slope stability on the JNF for the Draft Environmental Impact Statement (DEIS).<br><br>Provide the mileposts and a map showing the location (length along centerline) to which each typical drawing applies. |
| 6 | 6-39 | 6.6.1.2 | For each typical drawing of mainline construction on JNF, provide a typical drawing for reclamation with dimensions showing a cross-section of reclamation in relation to construction cut-and-fill and original ground surface.<br>The section states: "MVP will minimize impacts by returning contours to pre-construction conditions to the maximum extent practicable…" Recognize that returning to original contour using fill on steep slopes may be unstable and subject to slope failure. Describe criteria that will be used to determine whether excavated material will be stable if returned to original contour. If fill placed to original contour would be unstable, describe alternative reclamation method. Assess the potential for failure of fill slopes resulting from reclamation on steep slopes regardless of whether or not the fill is placed back to original contour. If fill for reclamation on steep slopes would be unstable, describe alternative reclamation method. |
| 6 | 6-39 | 6.6.1.2 | Provide typical drawings for showing the dimensions (magnitude) of proposed modifications on cut slopes and fill slopes along existing Forest Service access road on Peters Mountain. Provide an assessment by an engineering geologist of the proposed slope modifications. |
| 6 | 6-39 | 6.6.1.2 | Provide an engineering geologic assessment of 1) the potential for natural landslides to impact the project, and 2) the potential for failure of project-constructed slopes to impact the project and to impact infrastructure, resources and public safety. Project-constructed slopes include all slope modifications (excavations, cut slopes, fills slopes, backfills, excess excavation or excess fill disposal areas, reclamation fills and slope modifications, etc.). Assess risks to people, facilities, and resources associated with potential failure of slopes modified for the project. Assess short-term slope stability (during construction of the pipeline) and long-term slope stability (during operation of the pipeline and beyond). |

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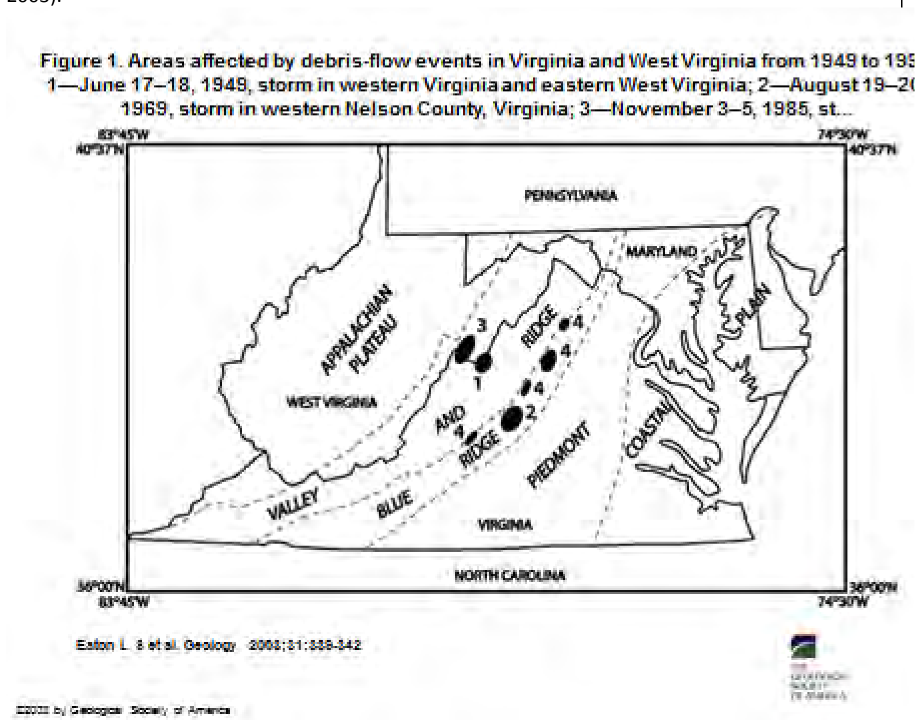
Because of the overarching influence of geologic structures (dip slopes and antidip slopes) on both natural landslides and project-related slope failures, provide engineering geologic assessment divided into 4 sections on JNF: the west flank of Peters Mountain, the east flank of Peters Mountain, the east flank of Sinking Creek Mountain, and the west flank of Brush Mountain.<br>
1. –Natural landslides: Identify existing slope stability conditions in the footprint of, or relevant to, the proposed facilities (such as existing landslides; streamside slopes subject to undermining by streams; geologic structures that may be adverse to slope stability such as dip slopes; debris flow paths). Assess potential for various types of landslides (mass movements, mass wasting) to affect pipelines, access roads,<br>
2. – Natural debris flows: Assess the potential for debris flow type of landslides to impact the pipeline and associated facilities. Consider the frequency of debris flow events, including the major debris flow events in Virginia and West Virginia from 1949 to 1996 (Figure 1 from Eaton, L.S. et. al., 2003).<br>


Credit: Figure 1 from Eaton, L.S., Morgan, B. A.,Kochel, R.C. and Howard A. D., 2003, Role of debris flows in long-term landscape denudation in the central Appalachians of Virginia, Geology 2003;31;339-342.<br>
http://geology.gsapubs.org/content/31/4/339.short<br><br>
3. - Assess the potential impacts on pipeline and access roads of swarms of debris flows, such as occurred in June 1949 in Augusta County (Figure 2) and in August 1969 in Nelson County (Figure 3).
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| RR# Or Plan Name | Page # | Section # | Comment |
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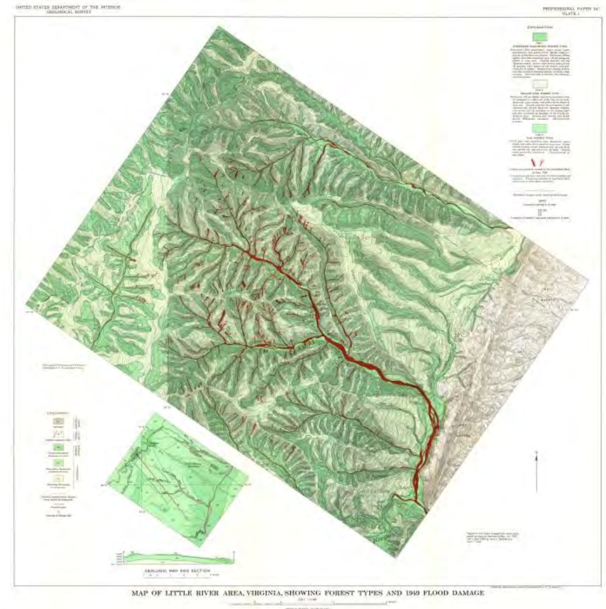
| | | | <br><br>Figure 2 - A June 17-18, 1949 storm triggered more than 100 debris flows in the Little River area on the North River Ranger District in Augusta County, Virginia. Credit: Plate 1 from Hack, J. T., and Goodlett, J. C., 1960, USGS Professional Paper 347.[http://pubs.er.usgs.gov/publication/pp347](http://pubs.er.usgs.gov/publication/pp347)<br><br><br>Figure 3 - Debris flows in Davis Creek area triggered by remnants of Hurricane Camille August 19/20, 1969 in Nelson County, Virginia. Credit: Map excerpt from Morgan, B.A. et al., 1999, INVENTORY OF DEBRIS-FLOW AND FLOODS IN LOVINGSTON AND HORSESHOE MOUNTAIN, VA: 7.5 MINUTE QUADRANGLES FROM THE AUGUST 19/20, 1969 STORM IN NELSON COUNTY, VA, USGS OFR-99-518. [http://geology.er.usgs.gov/eespteam/terrainmodeling/ofr99_518.htm](http://geology.er.usgs.gov/eespteam/terrainmodeling/ofr99_518.htm)<br><br>3a. – **Project-related slope failures (landslides)**: Assess the slope stability of proposed cut slopes and fill slopes during construction and operation of the pipeline, access roads, and associated facilities. Identify any risks to people, facilities, and resources associated with potential failure of slopes modified for the project.<br>3b. –**Access road cut slope and fill slope stability**: Assess the stability of any cut slopes or fill slopes to be modified on existing Forest Service access road on Peters Mountain. Identify methods and locations for disposal of excess excavation. |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | 3c. – **Trench backfill stability**: In considering the stability of fill in pipeline trenches, determine the slope % at which fill in trenches would be unstable and subject to fill slope failure. Prepare a slope map of the project area. Use slope % at which fill in trenches would be unstable as one of the slope breaks in classifying slopes on the slope map. Identify methods and locations for disposal of excess excavation from the trenches.<br>3d. –**Pipeline corridor road slope stability**: The access roads to reach the pipeline corridor are a familiar type of road. In contrast, the road built in the pipeline corridor is a different type of road, cutting a wide swath across the landscape in order to accommodate heavy construction equipment traffic to dig the trench and install the pipeline. While different in scale and layout than an access road, the construction within the corridor is basically a wide road with an adjacent pipeline trench (Figure 4).<br><br>Figure 4 – Example of construction road with adjacent pipeline trench. Material excavated for the road is piled on uphill side of road; material excavated for the trench is piled in a berm on downhill side of trench.<br><br>Assess the slope stability of the corridor road and adjacent pipeline trench during construction and operation of the pipeline. Of special concern is the loose, unconsolidated material (soil, colluvium, weathered or fractured bedrock) resulting from the mainline excavation (not just trench excavation) and stored in temporary piles or berms. Show the volume (cubic yards) of loose, excavated materials in temporary storage, and state how long these piles or berms would remain before some or all of the material is used for backfill or is graded as part of reclamation?<br><br>If a significant rainstorm occurs during the time these temporary piles or berms are present (such as in Figure 4), it could result is a mass failure of the temporary piles or berms, and then, a debris flow that could produce off-site damage downslope and in stream channels. To estimate the volume and stability of these temporary piles or berms, a cross-section of this stage of the construction process is needed. The project design would have three types of cross-sections: 1) original ground surface, 2) final cut-and-fill, 3) cross-section to temporary piles or berms at construction stage of maximum loose excavated material, that is, before the trench is backfilled or pipeline ROW roadway is reclaimed. Longitudinal profiles showing the slope % or grade along the corridor road at this stage of construction would also be needed to assess slope stability.<br><br>3e. – **Project-related debris flows:** Assess the potential for debris flows caused by failure of fill slopes created by the project (such as access roads, pipeline corridor road and pipeline construction, |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | and associated facilities). Assess the potential for debris flows caused by failure of waste disposal areas (such as disposal areas for excess excavation along access roads, corridor road and pipeline). Assess risks to public safety, downslope infrastructure, streams and other resources associated with potential failure of fill slopes or disposal areas for the project. Recognize the potential for fill failures to result in debris flows that can travel hundreds or thousands of feet downslope (Collins, T. K., 2008, Debris flows caused by failure of fill slopes: early detection, warning, and loss prevention. Landslides. 5:107–120). http://link.springer.com/article/10.1007/s10346-007-0107-y#page-1 Provide a slope map covering the mountainside from the ridge above, to the creek below, for the pipeline on the JNF in order to assess the debris flow potential upslope from the pipeline, as well as potential for debris flows caused by fill slope failure from the pipeline project.<br><br>4. –**Seismically induced landslides**: Assess potential for seismically induced landslides to impact the pipeline. Assess potential for large bedrock rockslides, such as found along Sinking Creek Mountain, to occur on Peters Mountain as well as Sinking Creek Mountain. Assess potential for earthquakes to trigger cut slope failure or fill slope failures originating on slopes modified by MVP project. |
| 6 | 6-39 | 6.6.1.2 | The following statement is premature in respect to JNF: "The overall effects of construction and operation of the Project facilities on topography and geology will be minor. Primary impacts will be limited to construction activities and will include temporary disturbance to slopes within the construction right-of-way resulting from grading and trenching operations." Until the geologic information requested in comments on Section 6.4.3 is gathered and then assessed in accord with the comments Section 6.6.1.2, it is premature assess the effects on the JNF. |
| 6 | 6-41 | 6.6.1.2 | This section states: "MVP is in the process of reviewing areas of potential slope stability issues. This information will be assessed and field evaluations completed. The impacts to the pipeline and vice versa, will be evaluated for each area identified and mitigation measures recommended. The recommendations will be included in the final pipeline design." An engineering geologic field evaluations and assessments of potential slope stability issues and "impacts to the pipeline, and vice versa" are needed for the Draft Environmental Impact Statement (DEIS), not just for final pipeline design. Provide the field evaluations and assessments conducted by an engineering geologist for the DEIS. |
| 6 | 6-44 | 6.6.1.3 | This section has two statement claiming that 0.28 g is used for the MVP project: "As noted above, peak seismic loading for the Project alignment in Virginia and West Virginia was estimated to be 0.28 g or less (USGS 2014a)." "Based on the assessed seismic-related risks in West Virginia and Virginia (i.e., no known active faults at surface; probable peak ground acceleration of 0.28 g) it is anticipated that PGD hazards to the Project alignment will remain low."<br><br>However, these statements are inconsistent with Section 6.6.4 Seismic Hazards and the two reports in Appendix 6-D which state that 0.14 g (not 0.28 g) is used for the MVP project. Clarify this inconsistency. |
| 6 | 6-43 | 6.6.1.3 | See several comments on Section 6.6.4 Seismic Hazards, and revise this Section 6.6.1.3 as appropriate. |
| 6 | 6-43 | 6.6.1.3 | See comment about adding a seismically induced landslides section within Section 6.6.1.2. Provide a cross-reference here to the seismically induced landslides section. |
| 6 | 6-49 | 6.6 | See comment about adding a "Floods and Other Stream Hazards" section within Section 6.4. In conjunction, add a "Floods and Other Stream Hazards" section within 6.6. Assess the potential for floods to impact the MVP project and the potential for the MVP project to affect flooding, for example, by failure of constructed slopes resulting in temporary landslide dam in narrow mountain valleys and hollows. Assess potential for flooding to affect pipelines, roads, and associated facilities. |
| 6 | 6-49 | 6.6 | See comment about adding a "Acid-Producing Rocks" section within Section 6.4. In conjunction, add a "Acid-Producing Rocks" section within 6.6. State whether acid-producing rock is identified in the corridor traversing the National Forests. If acid-producing rock is identified, assess the potential for release of sulfuric acid from acid-producing rock into water bodies and wetlands. |
| 6 | 6-49 | 6.6.2 | This section on Operational Impacts and Mitigation mainly describes mitigation. There is only on short sentence to assess impacts: "Operational impacts on geologic resources are expected to be minimal." This is a grossly deficient assessment of the various geologic hazards that may affect, or be affected by, the pipeline projects over the many decades of operations. See all the comments on geologic hazards in Section 6.6.1 Construction Impacts and Mitigation. Apply these same comments to Section 6.6.2 Operational Impacts and Mitigation. |
| 6 | 6-49 | 6.7 | This section states: "The JNF is located in the area with highest seismic hazards as discussed in Section 6.4.1. However, these hazards - including soil liquefaction near water crossings and the |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | potential for landslides and rock falls - are not considered severe and can be mitigated with appropriate construction design."<br><br>Contrary to the above statement, the potential for seismically induced landslides is likely the most severe geologic hazard in terms of potential catastrophic destruction of the pipeline.<br>The Landslide Section 6.4.3 and Section 6.4.1.5 failed to recognize the largest known landslides in eastern North America on Sinking Creek Mountain. The pipeline corridor on the JNF crosses Sinking Creek Mountain, which has the largest known landslides in eastern North America (Schultz and Southworth, 1989). The pipeline corridor on Sinking Creek Mountain (MP 217.2 – 218.0) traverses one of the large bedrock landslides mapped by Schultz (1993). The Landslide section 6.4.3 failed to identify this large bedrock landslide on a published geologic map (Schultz, 1993). The Landslide section 6.4.3 failed to recognize research on the seismic origin of the Sinking Creek Mountain landslides (Whisonant, Watts, and Kastning (1991); Schultz and Southworth (1989); Schultz (1993).<br><br>See the comments on Section 6.4.1, and revise Section 6.7 accordingly. Assess the potential for seismically induced landslides to disrupt large sections of pipeline on Sinking Creek Mountain, Peters Mountain and Brush Mountain. |
| 6 | 6-50 | 6.7.1 | Change "Forests" to "Forest" and change "within the Forests" to "within the pipeline corridor on the Forest" to read:<br>"Communication with Tom Collins, Forest Geologist, revealed that no permits for the collection have been issued for the Forest (Collins, 2015) and that Mr. Collins is not aware of existing paleontological sites (collection sites or "type sections") within the pipeline corridor on the Forest." |
| 7 | FERC Env Info Request Report 7, Aug 11, 2015 | #13 | It appears this request has not been completed regarding 7.3.1.6 and soil amendments and revegetation aids. MVP refers the reader to Section 1.4 and RR-3, which do not have this information. This is important because MVP does not mention fertilizer or lime additions in RRs-7, 1 or 3 nor do they say when they will used these soil amendments or other revegetation aids listed in FERC's Upland Erosion Control Revegetation and Maintenance Plan, May 2013. |
| 7 | FERC Env Info Request Report 7, Aug 11, 2015 | #3 | This request from FERC is not adequately addressed by MVP as they have not identified high water tables, compaction hazard or reclamation potential in the tables displaying the soils by milepost, Appendices 7-A1 and 7-A2. These are soil characteristics which are important in determining potential effects to soils from the project and location potential problem areas for reclamation/revegetation. The reader is referred to Section 7.2, Appendices 7-A1 and 7-A2 and Appendix 7-B, which do not contain the requested information. |
| 7 | | | MVP Final RR-7 does not use the same criteria as NRCS to assess erosion potential. NRCS uses K-factor, slope and rockiness; MVP uses slope, soil capability class. NRCS erosion hazard rating is the standard and should be used on NFS lands These ratings can be found in the NRCS Web Soil Survey website and SSURGO database. |
| 7 | 7-17 | 7.3.1.1 | The timing paragraph on this page states that MVP will attempt to complete final cleanup and install permanent erosion control measures in and area within 30 days after backfilling the trench in that area, weather and soil conditions permitting. This does not comply with FERC's 2013 edition of Upland Erosion Control, Revegetation and Maintenance Plan (UECR&MP), which MVP says it will follow on page 7-1 of Final RR-7. FERC's UECR&MP on page 20 says to complete final grading, topsoil replacement and installation of permanent erosion control structures within 20 days after backfilling the trench. A lot of erosion can occur within 10 days and the chance of a storm event happening while the area is very susceptible to erosion increases.<br><br>Please be advised that the Forest Service may have requirements that exceed FERC's requirements. |
| 7 | 7-18 | 7.3.1.2 | The Forest Service, as the land management agency, requires that topsoil be segregated and used in the reclamation process on Forest Service managed land disturbed by this project. The Forest Service is not included in the list of areas where topsoil will be segregated automatically; please add the Forest Service to this list and ensure topsoil is conserved during construction as described in Section 7.3.1.2, RR-7. This stipulation should be added to Section 7.4, RR-7. |
| 7 | 7-21 | 7.3.1.6 | The last sentence on Page 7-20 beginning with "Unless…" says when grading is completed after the end of a seeding season the area will be seeded "by" the next available seeding season. This word "by" on first line of Page 7-21, is not correct, as this would lead to seeding out of season. Change "by" to "during" to make this statement read correctly. |
| 8 | 3 | Appendix 8-E | Consistency result for *FW-3: Prior to authorizing or re-authorizing new or existing diversions of water from streams or lakes, determine the instream flow or lake level needs sufficient to protect stream processes, aquatic and riparian habitats and communities, and recreation and aesthetic values.* states "N/A – standard refers to FS action". This is not true; the standard refers to any action, |

| RR# Or Plan Name | Page # | Section # | Comment |
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| | | | including special uses. The consistency result should be "NO", since an instream flow analysis has not been done. |
| 8 | 3 | Appendix 8-E | Consistency result for *FW-4: Water is not diverted from streams (perennial or intermittent) or lakes when an instream flow needs or water level assessment indicates the diversion would adversely affect protection of stream processes, aquatic and riparian habitats and communities, or recreation and aesthetic values.* States "N/A. The Project will not withdraw water from streams located on Forest Service land". This is not currently true since section 2.2.4 does not specify where dust control suppression water will come from and an instream flow analysis has not been done. |
| 8 | 8-21 | 8.3.1.1 | The Forest Service understands that MVP's proposed route also crosses federal lands under the jurisdiction of the Army Corps of Engineers in West Virginia. The report needs updating to include this information. |
| 8 | N/A | 8.5 | We submitted a comment on Draft Resource Report 8 relating to the impacts of the pipeline on future use of prescribed fire as a management tool on NFS lands. A word search of RR8 reveals no such discussion. Prescribed fire is a very important tool in managing forests and woodlands to achieve our Desired Conditions set forth in the Forest Plan. In this context, it is a land use. We are concerned that the pipeline itself will impact the ability to use that tool by isolating areas that cannot be feasibly burned. Please evaluate if prescribed fire will still be a viable management tool allowed within and/or adjacent to the corridor in the EIS. |
| 8 | N/A | 8.5 | We submitted a comment on the Draft Resource Report relating to the impacts of the pipeline on Lands Suitable for Timber Production on NFS lands. A word search of RR8 reveals no such discussion. Commercial timber harvest is a very important tool in managing forests and woodlands to achieve our Desired Conditions set forth in the Forest Plan. In this context, it is a land use. We are concerned that the pipeline itself will impact the ability to use that tool by removing lands that are currently suitable for timber production or isolating suitable areas that cannot be feasible harvested. Please disclose the number of acres of lands suitable for timber production that will be removed from production by the pipeline, either directly or indirectly through isolation of currently manageable tracts, in the EIS. |
| 8 | 8-40 | 8.4.3 | **Peters Mountain Wilderness** – The narrative covers foreground views and distant views to the pipeline simultaneously, resulting in confusion as to whether distance alone accounts for the low to no visual impacts to the distant view of the pipeline, or whether vegetation that would mitigate the foreground view will also mitigate the distant view. The discussion about the potential views of the pipeline in the foreground and the potential views to the middleground should be provided as separate sentences or paragraphs. Furthermore, statements about screening vegetation should state whether that vegetation is evergreen or deciduous. If deciduous, MVP needs to assess whether the deciduous vegetation during leaf-off is dense enough to screen views of the pipeline. |
| 8 | 8-40<br>and<br>260 of 260 in RR8 | 8.4.3<br>and<br>App. 8F | **Appalachian National Scenic Trail (ANST) –** Information provided in this report is deficient about the process to choose the location and number of Key Observation Points for the ANST. The number of KOPs is likely insufficient. The report lacks a broader landscape topographic map depicting the proposed pipeline route and the ANST, making it impossible for the reader to get the big picture about the potential impacts and whether the visual assessment is adequate. A "seen area" area map is needed that includes national forest boundaries, topography, the ANST and the preferred route alternative, at a minimum.<br><br>The photo provided in Appendix 8F for the ANST on Peters Mountain is not informative and is deficient for use in determining potential impacts to scenery as viewed from the ANST. The deficiencies include the horizontal cone of vision, the vertical/height of view included in the photograph, the leaf-on condition (clearly deciduous forest, so there is no evergreen visual screen) when the standard protocols for visual assessments is during the leaf-off season. As stated above, additional visual simulations are likely needed to demonstrate whether or not the SIOs would be met for the ANST with a 100 foot buffer of vegetation or not. Also, additional photo simulations may be needed for middleground and background views from the ANST. |
| 8 | | 8.4.3<br>Expansion or new sub-section needed | **Missing from this Report – Other Concern Level 1 Routes/Areas** – The USDA Forest Service's SMS requires that visual resource analysis occurs not only for special areas such as the national scenic trails, scenic byways, resorts, etc., but also for all "primary travelways and use areas." The guidance is provided on pages 4-8 and 4-9 of the SMS Handbook.<br><br>MVP states that the USDA Forest Service's SMS protocols will be utilized for private lands as well as national forest and other public lands (Section 8.4 page 8-29 and Section 8.4.3 page 8-32). |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | At a minimum, the report is deficient in that it does not include visual analysis for highways U.S. 460, U.S. 11 or Interstate 81, all major interstate routes with a Concern Level of 1.<br><br>A broad scale, landscape level map depicting not only roads and trails *crossed* by the pipeline, but also routes and viewing platforms not crossed by the pipeline but potentially within the seen area "viewshed" of the pipeline, so that readers can discern whether all primary, sensitive routes and areas have been considered and included in the report. These could be roads, trails, rivers and streams popular with kayakers or anglers, highly sensitive communities and primary summer home tracts, etc., with views to the national forest. These need to be taken into account during project level analysis, regardless of whether they are included in the forest-level SMS inventory. A higher level of ground-truthing occurs during project level analysis. |
| 8 | 8-51 | 8.5.1 | The report indicates there is a summary of land use impacts to USFS lands, however, there is no analysis of impacts in this section. In addition, this section should clarify if the 80.4 acre temporary construction right-of-way figure includes all ATWS, contractor yards, pipe storage locations, and other work spaces required on NFS lands during the construction phase. |
| 8 | 8-51 | 8.5.2 | The Forest Service understands that the project crosses lands administered by the Army Corps of Engineers in West Virginia. Since the project crosses Federal lands administered by two or more Federal agencies (Forest Service and Army Corps of Engineers), the Bureau of Land Management (BLM) has jurisdictional authority to grant or renew rights-of-way or permits through the Federal lands involved under the Mineral Leasing Act of 1920. Therefore, this section should state that a right-of-way grant application across National Forest System lands will be submitted through the BLM. |
| 8 | 8-53 | 8.5.4 | The format for describing each of the management area prescriptions is somewhat inconsistent. For example, some describe the ROS standard for the M.A. and others do not. |
| 8 | 8-54 | 8.5.4<br><br>SMS Complianc e | Generally, this report summarizes the USDA Forest Service's Scenery Management System (SMS) accurately. However, the part of the narrative pertaining to Scenic Classes is confusing. The SMS Handbook describes how inventoried scenic attractiveness, distance zones and concern levels are used to identify the relative value or importance of scenery for different areas using a range from Scenic Class 1 (highly valued) to Scenic Class 7 (low value, relative to other areas). This section of Resource Report 8 contains only Scenic Classes 1, 2 and 3. It should be stated whether areas of Scenic Classes 4 – 7 exist within the proposed project area. Furthermore, parentheticals contain the words "Very High, High, Moderate, Low". Clarification is needed about what these words represent. Are these the Scenic Integrity Objectives (SIOs) that exist within each of those Scenic Classes? If so, there is a discrepancy between the descriptions on page 8-53 (no Very High SIO in any management areas) and the description of Scenic Classes on page 8-54 (includes Very High for Scenic Classes 1 and 2). If these are references to the relative value of the landscape scenery that needs to be explained in the report and its source referenced (Final LRMP or inventory data of existing scenic integrity). |
| 8 | 8-54 | 8.5.4<br><br>SMS Complianc e | The same concluding statements are made under Scenic Class 1, Scenic Class 2 and Scenic Class 3 (all national forest lands through which the proposed pipeline will pass). These are:<br>• The project elements, the landform, vegetation patterns, and cultural features would still combine to provide the ordinary/common or high scenic quality for the areas.<br>• The landscape has the ability to absorb the visual change.<br><br>Resource Report 8 has not adequately substantiated either of those statements and has not followed the USDA Forest Service's SMS protocols that it claims earlier in the report will be followed. To do so, the descriptions of the site specific landscapes for each of the management areas (page 8-53) must provide more detail regarding the type and level of landscape variety and patterns that exist, and inform about the current level of intactness of the landscape character. The proposed project elements (including any new or expanded access roads and ATWS), need to be described in terms of anticipated changes they would introduce to the existing landscape character and intactness. The latter should be phrased in terms of visible changes to color, line, form and texture in contrast to the existing condition, as provided in the SMS Handbook and described Resource Report 8 section 8.4.3 on page 8-32 ("Contrast is an important assessment criterion on the visual impact assessment to measure the degree of physical change in the landscape with regard to how the change is seen by viewers. Contrast in the landscape is determined by the differences in form, line, color, texture, and landscape juxtaposition between the existing condition and the Project… Factors such as visual |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | dominance, degree of deviation from existing landscape character, and intactness of the landscape were considered in this comparison”).<br><br>Section 8.5.4 needs to provide details about this assessment of contrast and the degree of physical change in the landscape and provide a determination based on the level of deviation defined for each SIO. A broad statement that the project meets the SIOs for each Management Area is deficient. Geographically specific (site specific) determinations are needed. Views can and often do change with movement along a route within a single management area, and that should be described in a narrative and displayed graphically.<br><br>Secondly, there is concern about the broad application of the SMS principle of visual absorption capability. There is not sufficient detail in the description of the landscape character to indicate that a suitable degree of variety and pattern exists to visually absorb the addition of the proposed pipeline corridor (including what patterns, lines, forms, textures and/or colors currently exist that are similar to those that would be introduced by the project). |
| 8 | | Table 8D | The data displayed in this table indicates that MVP analyzed only the “nearest” potential view between project components and the viewing platform. The nearest location of a travelway or area may not be the part that would have the greatest impact on its scenery. Intervening geology or evergreen vegetation may block the view at the nearest location, but further out along that same travelway there could be a clear view to the project area. The table should be updated to include whether other portions of travelways listed, further from the proposed project area, may also have a view of the project area.<br><br>A “seen area” analysis needs to be provided that displays where primary viewing routes and areas, on and off the national forest, may potentially view the proposed project components. Those that lie within five miles, per the MVP process (the FS definition of background is actually four miles to infinity), should be included in Table 8D. Since MVP states it will use the FS process for private lands (up to three miles), those sites that meet the definition of “primary travelway or area” captured in the “seen area” analysis should also be added to the table. Some travelways may have views to the project area from multiple distance zones (foreground, middleground, and/or background). This needs to be revealed in Table 8D. |
| 8 | | Consistency Analysis with FLRMP document | This document is inserted into RR8, but it is not identified as an Appendix to that document. The page numbering starts at 1. It seems that it should either be a Section of Resource Report 8 with continued page numbering from Resource Report 8, or it should be identified as an Appendix to Resource Report 8. |
| 8 | 18 & 19 | Consistency Analysis with FLRMP | **Consistency with FW-154 and FW-158 for ANST.** – As provided in comment to Section 8.4.3 and Appendix 8F Visual Simulation related to the ANST, the claim that the proposed project meets the SIO has not been adequately substantiated. The narrative in this FLRMP consistency review document does not provide any additional information that would substantiate the claim that any of the standards for M.A. 4A are met including the SIO of High. |
| 8 | 19 | Consistency Analysis with FLRMP | **Consistency with FW-161, FW-162 and FW-163 Regarding ROS** - Resource Report 8 is deficient with regards to addressing the Recreation Opportunity Spectrum and the ROS standards for each management area. There is no analysis provided for ROS and no indication of potential impacts to not meeting the ROS, as stated in the Consistency Analysis document for FW-161. A narrative describing the impacts to the settings under the recreation opportunity spectrum, using the guidance provided in the USDA Forest Service’s “1986 ROS Book” is needed in Resource Report 8. It should be accompanied by a map or table clearly depicting the ROS standards and anticipated outcome of ROS inventory changes as a result of this project. |
| 8 | 21 | Consistency Analysis with FLRMP | **Consistency with FW-183, FW-184 and FW-185 Regarding SIOs** – The MVP response to each of these standards is “Yes” and that a project level analysis ***will*** be conducted. However the Resource Report 8 narrative in Section 8.5.4 states that the SIO’s will be met, implying that the project level SIO analysis is complete. There is a discrepancy between these two portions of Resource Report 8.<br><br>If the project level analysis is complete, per Section 8.5.4, then it is deficient as described in response to other sections (above) and in my general comments provided below. The finding that the project |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| | | | is consistent with the FLRMP by meeting SIOs has not yet been determined and the document should not indicate, at this point, "Yes". |
| 8 | 21 | Consistency Analysis with FLRMP | **Consistency with FW-186, Mitigations to Protect Scenery -** The MVP response is deficient in describing where and how the openings in the canopy created by the centerline corridor, ATWS, and road accesses will be shaped, oriented, and edges feathered to reduce the impacts to scenery. There is no indication from the description of the final centerline corridor of 50' that MVP is willing or able to shape the opening or feather the edges. If MVP does intend to incorporate this mitigation measure, a description of how and where they will employ this mitigation should be included. |
| 8 | 21 | Consistency Analysis with FLRMP | **Consistency with FW-189, Mitigation to Protect Scenery -** The MVP response demonstrates a misunderstanding or error in their interpretation of the intent of this standard. The intent is that the proponent must find a means to eliminate or minimize the height of slash after the removal of the trees. MPV needs to describe how they will meet this standard or change their determination regarding consistency with it. |
| 8 | 22 | Consistency Analysis with FLRMP | **Consistency with FW-193, Mitigation to Protect Scenery –** The MVP response addresses only the ANST, but the standard applies to locating bare mineral soil out of view from view of all concern level 1 and 2 travelways, where practical.<br><br>This standard refers to log landings, roads, and bladed skid trails. It is not clear which of these features might be utilized during the removal of trees from the proposed pipeline corridor. The primary purpose of the standard is to make practical attempts to locate mineral soil out of view, therefore the focus should not be on the specific methods utilized. |
| 8 | | | Resource Report 8 lacks a clear map of the proposed route(s) for the MVP pipeline. This is needed to help readers ascertain the adequacy of the number and location of Key Observation Points, and whether the visual simulations in Appendix 8-F include the best direction of view or whether a different direction or multiple directions are needed.<br><br>The Forest Service recommended that a visible or "seen area" analysis be prepared for a distance of five miles from the proposed pipeline centerline. There is no mention of the use of this important analysis tool in Resource Report 8. A "Seen Area Analysis" map for the pipeline crossing of national forest lands should be included in Resource Report 8 as a method used to select Key Observation Points.<br><br>Resource Report 8 lacks a table of Key Observation Points, which should be included. A table should display all KOPs along with elevation, direction of view(s), a description of the view including predominant vegetation in the foreground and middleground (if visible during leaf off) and any distinguishable natural or cultural features, whether the KOP was within the "seen area", the line of sight direction to one or more pipeline segments, the line of sight distance to the pipeline segment(s), and whether photo or visual simulations were prepared.<br><br>Forest Service trails, including the Appalachian National Scenic Trail, some Forest Service roads, and all public roads are open and used year round. Scenic Integrity Objectives need to be met during winter "leaf off" season. It is not clear whether the assessment for meeting SIOs considered this. Visual simulations in Appendix 8F only include summer, leaf-on season. Wherever MVP states in Resource Report 8 that there is vegetation that screens views of the pipeline, additional information is needed including whether the vegetation is evergreen or deciduous. If deciduous, a statement is needed with regards to the density of the vegetation and its capacity to block or screen views during leaf-off.<br><br>Wherever MVP states in Resource Report 8 that viewing distance mitigates the visual impact, that distance should be specified. |
| 8 | 32 | Appendix 8-E | Consistency result regarding Riparian Corridors states "N/A. The Project will not cross this management prescription". This is not true; According to table 2.4-1 (Waterbodies crossed on the Jefferson National Forest) the project crosses 29 streams on the forest, and thus riparian corridors. A consistency review needs to be completed for all of the Standards in Management Prescription 11-riparian corridors. In addition, there is no discussion regarding the Federally Listed Fish and Mussel Conservation Plan, of which this project crosses several watersheds that are included in that plan. |

| RR# Or Plan Name | Page # | Section # | Comment |
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| 8 | General | | A portion of the route on NFS lands is within the Chesapeake Bay watershed. MVP should determine how this project impacts the U.S. EPA's Chesapeake Bay Total Maximum Daily Load (TMDL) pollution limits in the cumulative effects analysis. |
| 10 | 10-9 | 10.5.1 | The report states that one of MVP's primary objectives with respect to pipeline routing was to avoid (if possible) or minimize crossings of national forest. The report, however, does not identify or discuss any routes that avoid National Forest System lands. MVP should identify and discuss one of the early route(s) in their routing process that avoided NFS lands and reasons why that alternative(s) was not considered.<br><br>As discussed in a previous comment, Forest Service Manual 2700, Special Uses Management (FSM 2700), §2703.2 describes Forest Service policy relating to the use of National Forest System lands (NFS). §2703.2(2) states to authorize use of NFS lands only if: a) the proposed use is consistent with the mission of the Forest Service to manage NFS lands and resources in a manner that will best meet the present and future needs of the American people; b) the proposed use cannot reasonably be accommodated on non-NFS lands. §2703.2(3) goes on to state not to authorize the use of NFS lands solely because it affords the applicant a lower cost or less restrictive location when compared to non-NFS lands. Therefore, in MVP's discussion of alternatives, they should clearly articulate why the project cannot reasonably be accommodated off NFS lands. This discussion should not cite lower costs or less restrictive locations as the sole purpose of crossing NFS lands. |
| 10 | 10-9 | 10.5.1 | The report is deficient in displaying an alternative that avoids the Jefferson NF or in providing information about why an alternative that avoids the Jefferson NF is not possible. In Section 10.5.1, a primary MVP objective is identified as avoiding (if possible) the national forests. There is a description of an initial attempt to avoid all cities and towns, the NFs, the NPS, and the ANST, which resulted in a corridor 2,362 miles long. There is no description of any additional attempts to develop a specific alternative or alternative modification that avoids the Jefferson NF. |
| 10 | First= 10-12 | Multiple | Errors in earlier Resource Reports are duplicated here – the proposed route appears to impact some NFS lands between MP 169.9 and MP 180, so total mileage is larger than 3.4 miles. |
| 10 | 10-28 | 10.6.4 | There is no Brush Mountain West Wilderness. There is a Brush Mountain Wilderness, and a Brush Mountain East Wilderness. |
| 10 | 10-54 | 10.6.16 | One example of improper references. Figure 10.6.16 does not appear in Resource Report-10, but rather in Resource Report-10, Appendix 10-B. Better references would facilitate review. |
| 10 | 10-56 | 10.6.17.1 | Per earlier comments, a much more detailed description of a much more detailed analysis must be conducted and documented. Forest Service field review, including a very basic visual analysis, in October 2015 found that the proposed ANST crossing will result in a significant visual impact to users of the Appalachian National Scenic Trail. This unsupported statement raises questions about other weakly-supported statements in the Resource Reports package. |
| 10 | 10-56 | 10.6.17.1 | The proposed crossing of the ANST is a horizontal bore beneath the trail. MVP needs to provide alternatives and/or a contingency plan in the event the bore is not successful. |
| 10, App 10-B | --- | --- | This entire appendix needs significant reworking and addition of detailed notes. For example, the sheet with 4 pictures labelled "Appalachian National Scenic Trail at Proposed Route Crossing Location" should be geo-referenced, dated, with directions shown and locations of proposed bore pits identified.<br><br>The half-sheet satellite views and map views need vicinity mapping, and need to show federal land boundaries, and Wilderness boundaries, and include a legend.<br>For example, the sheet titled "Columbia Gas of Virginia Peters Mountain Variation Appalachian Trail Crossing" does not provide enough context for this reviewer to identify where it actually is located. |
| 10, App. 10-D | Table 10-D-2 | --- | Significant additional explanation of this table is needed. Calling a shift of "east up to 1300 feet" between MP 194.3 – 197.0 a "minor route modification" needs explanation. It may, in fact, shift the pipeline into a federal Wilderness, or shift the proposed pipeline crossing of the ANST to include some NPS-acquired lands.<br><br>Similarly, a statement that a "shift northeast up to 14,441 feet" between MP 213.1 – 221.8 could impact entirely different areas of NFS lands, including a difference federal Wilderness.<br>It is impossible for this reviewer to understand what is meant by this entire table. It appears that it may significantly change the area of NFS lands potentially impacted, necessitating completely different field surveys and review. |

| RR# Or Plan Name | Page # | Section # | Comment |
|---|---|---|---|
| 10 | | App 10A | **Alternative Routes Maps:** The pages containing maps in this Appendix do not have page numbers. Ability to reference specific maps would be improved by the addition of page numbers for the entire Appendix.<br><br>Most of the maps do not graphically indicate lands owned by the national forest. For people interested in potential impacts to the Jefferson NF, these maps are not very informative. NF ownership should be delineated or displayed graphically on the maps at (in the .pdf document as page # of 151) pages 87-90, 92, 96, 116-117. |
| 10 | | Tables | **General Comment:** The tables for the different alternatives are confusing. The data for the proposed route varies from alt to alt and when compared to different alt modifications when it seems to the average reader that the proposed route data would remain constant in each table.<br><br>At a minimum, MVP should add a note to each table describing the segment of the pipeline involved. However, the big picture for the entire pipeline gets lost to the reader who is trying to compare one alternative to another if the pipeline is broken down by segment. For improved clarity about the alternatives, it would be helpful if MVP adds a table that includes all of the alternatives and the data for the entire pipeline proposal. |
| 10 | General | | FERC regulations at § 380.12(l)(1)(2)(ii) requires identification and consideration of route alternatives that avoid impact on sensitive environmental areas and presentation of sufficient comparable data to justify the selection of the proposed route. The report consistently cites a one-to-one relationship of mileage to environmental impact as the primary comparable data. This approach does not measure the environmental effects of different alternatives sufficient for the Forest Service to make an informed decision on whether or not the proposed route would result in the least amount of impacts to National Forest System lands when compared with other alternatives. We understand that MVP remains in process of conducting environmental surveys and look forward to additional comparable data being provided for review. |

# The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)

# EXHIBIT 39

**February 21, 2023**

February 3, 2017

TO: Jefferson National Forest Staff

FROM: Diana Christopulos, President, Roanoke Appalachian Trail Club (RATC)

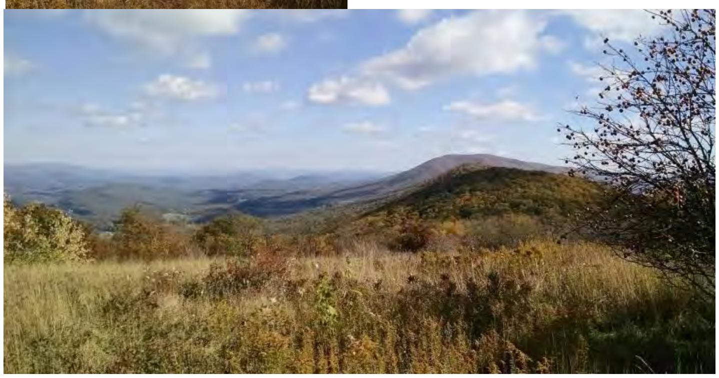
SUBJECT: POTENTIAL IMPACTS OF THE MOUNTAIN VALLY PIPELINE ON THE APPALCHIAN NATIONAL SCENIC TRAIL

Thank you for the opportunity to meet today. Please keep in mind that:

1. RATC does not consider this to be a meeting with the applicant as called for in the Draft Environmental Impact Statement and in the January 26, 2017 letter from the Federal Energy Regulatory Commission (FERC) to Mountain Valley Pipeline, which requires the applicant to, "Document communications with the NPS, FS, ATC, and local clubs that occurred after the release of the draft EIS on September 16, 2016 regarding visual simulations and KOP related to the ANST, that are not already in the public record for this proceeding." A separate meeting that is initiated by the applicant and includes attendance by the applicant would be necessary, we think, to satisfy that request.
2. The only contact that the applicant has ever made with RATC was after the April 28, 2016 site visit to Peters Mountain, responding to our request for a map. A request for an updated centerline after the July 22, 2016 site visit was ignored by the applicant.
3. We would like to have these notes, including the full presentation made by David Hill of Hill Studio at the October 8, 2016 Forum on Natural Gas Pipelines at Roanoke College in Salem, Virginia – "Visual Quality in the Landscape." become part of the record with FERC on the MVP on behalf of the Appalachian Trail Conservancy as an Intervenor in the process.
4. We think it is vital that cumulative impacts of both the proposed Mountain Valley Pipeline and the proposed Atlantic Coast Pipeline be considered, since together they impact a very large percentage of the Appalachian National Scenic Trail in Virginia and set a precedent for ignoring decades of work by hundreds of staff and volunteers as well as the expenditure of millions of dollars to protect scenic resources on a national trail.

**Roanoke Appalachian Trail Club and Potential Visibility of Mountain Valley Pipeline**
**Summary of research from club ~ February 3, 2017**

The Roanoke Appalachian Trail Club (RATC), a Virginia 501.c.3 nonprofit with responsibility for over 120 miles of the Appalachian National Scenic Trail, has been concerned with potential visibility of the proposed Mountain Valley Pipeline since at least October 2015, when an RATC representative accompanied staff from the Appalachian Trail Conservancy (ATC) and the US Forest Service (USFS) as well as pipeline representatives to a proposed crossing location on Peters Mountain. We took the photos shown here (Figures 1 and 2) on the ANST from very close to the proposed crossing, looking into the Peters Mountain Wilderness and Monroe County, West Virginia.



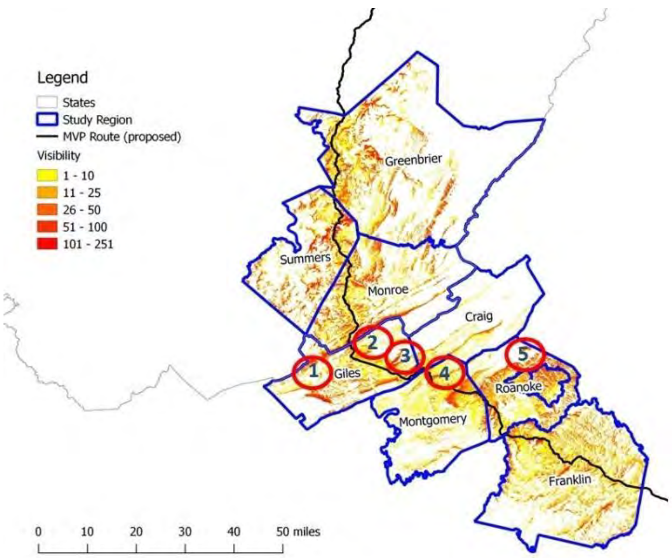
At that time no flagging was visible, so the actual proposed location could not be determined. The probable location was very close to the pictured clearing at Symms Gap.

Much of RATC's understanding of visual impacts is based on the March 9,2016 comments of the USFS on MVP's Resource Reports, and we offer our comments here in that spirit.

On April 28, 2016, three volunteers from RATC (two of them in the middle of an ANST backpack trip from Va 608 in the south to Va 621 in the north) met staff from ATC, the USFS and the pipeline company at a location that was flagged for a conventional bore with pits approximately 100 feet on each side of the ANST.

Although the developer had filed statements that the bore pits would not be visible from the ANST, measurements taken by USFS staff made it quite clear that the bore pits would be extremely visible (and audible) from the ANST. The developer had also mistakenly claimed that there were no clearings in the area, though it was obvious that the location of the proposed bore is largely a clearing. When RATC volunteers reported back on this site visit, the board of the RATC voted unanimously to oppose construction of the MVP. Club members were extremely concerned that the descriptions provided by the developer were not trustworthy, and representatives of the pipeline demonstrated almost no interest in or concern for the ANST. In fact, when an RATC volunteer asked a pipeline representative (the fellow in the red shirt in the photo), where the ANST was located on the map that he was using, he brushed the question off as if it was insignificant, and we do not think that the ANST was shown on the developer's map.

On April 26, just two days before the Peter's Mountain site visit, the two RATC volunteers who were backpacking much of the RATC section took a photo from Angel's Rest, an iconic overlook on the ANST near Pearisburg, Virginia. The center of the photo was approximately aimed at the proposed crossing of the ANST, based on a centerline map from MVP and a compass heading on the ATC's map of the ANST in that section. It seemed likely to RATC that the pipeline's path would be visible from Angel's Rest and perhaps for a very long distance as it came down from Peters Mountain and across the valley below. ATC requested that the USFS include Angel's Rest as a KOP at this time. RATC shared the backpacker photo with both the ATC and the USFS shortly after the site visit. RATC also posted the photo with an arrow drawn in at the approximate point where the MVP would cross the ANST on the RATC website along with the RATC board of directors' resolution opposing MVP on July 18, 2016.




In May 2016, Key-Log Economics published "Economic Costs of the Mountain Valley Pipeline," including (p.30) a visibility study of MVP showing 30m x 30m segments of all lands within 25 miles of the MVP centerline and the number of 100m segments that might be visible from each segment. RATC worked with the study author to determine how much of the MVP (0.1 miles to over 15 miles) might be seen from scenic vista points on the ANST and found that MVP might be visible off and on for approximately 100 miles of the ANST, from Sugar Run Mountain in Giles County to Dragon's Tooth (and possibly as far north as McAfee Knob) in Roanoke County.

By June 23, 2016, RATC and Key-Log had determined that the MVP might be visible from at least 5 important scenic locations (numbers match those on Figure 5 map):

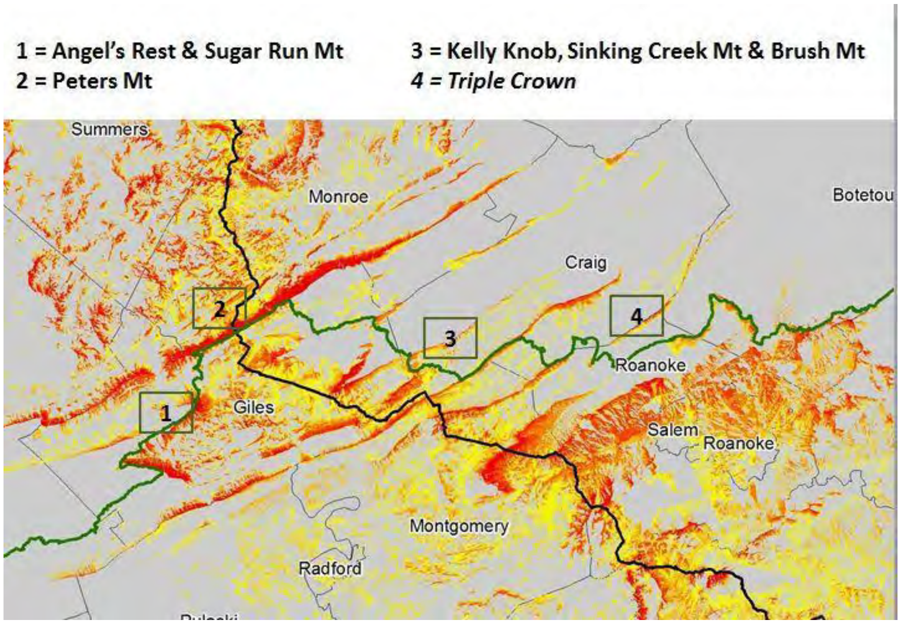
1. Angel's Rest (approximately 7 miles of pipeline might be visible)
2. Peters Mountain (up to 3 miles of pipeline visible on West Virginia side of the AT near the crossing and Symms Gap)
3. Kelly Knob (about 6.5 miles of pipeline visible as it comes through Sinking Creek valley and climbs Sinking Creek Mountain)
4. Sinking Creek Mountain/Brush Mountain (3 to 4 miles of pipeline potentially visible)
5. Triple Crown (Dragon's Tooth, McAfee Knob, Tinker Cliffs). Ground GPS/compass viewing suggested that pipeline might be visible from two different locations on the back side of McAfee Knob (July 31, 2016).

RATC volunteers used the visibility layer shown in Figure 5 along with Google Earth overlays of the MVP centerline and the ANST centerline to begin checking on-the-ground visibility with GPS, compass readings and ATC maps. Our volunteers took over 100 photographs of potential impact locations. This enabled the preparation of a list of potential points on the ANST where the pipeline would be visible along with an estimate of the amount of pipeline that could be visible.

RATC volunteers accompanied staff of ATC, USFS and Cardno on a third trip to Peters Mountain on July 22, 2016 to examine the new proposed site for a conventional bore on Peters Mountain with close to 300 feet between the ANST and each bore pit. Items of note for RATC:

- RATC supported the letters to the FERC record from both the USFS and ATC stating that the applicant should show visual impacts at the crossing at a time when there are no leaves.
- RATC supported the repeated request that MVP show the potential visual impact of MVP from Angel's Rest.
- RATC noted while on top of Peters Mountain that the MVP would likely be visible as it crossed Little Mountain on the West Virginia side, an observation that was later verified by a simulation done for ATC by Hill Studio of Roanoke.

- During that visit, RATC pointed out to the Cardno representative that MVP had stated that there are no man-made clearings within more than 3 miles of the proposed crossing. The Cardno representative agreed with us that this statement was patently untrue and that the facts could be verified by simply looking at Google Earth.




Although the visibility mapping at a 30m x 30m level was helpful, the use of 10m x 10m parcels provides a more detailed understanding of potential visibility. John DeGroot, who worked on the original Key-Log study, was able to complete a study using 10m x 10m segments, an updated MVP centerline, and the centerline of the ANST in September 2016. This greatly improved the ability to identify potential points of visibility and compilation of a list of such locations. This version yielded 4 major areas of impact: Angel's Rest and Sugar Run Mountain, Peters Mountain, Kelly Knob/Sinking Creek Mountain/Brush Mountain, and the Triple Crown (Dragon's Tooth, McAfee Knob and Tinker Cliffs).

Using all of this information and using Google Earth overlays of the new visibility study and an updated MVP centerline,, RATC prepared a preliminary list of significant points from which the MVP might be visible from the ANST. The 19 points identified were shared with the ATC and are listed below.

| **NAME OF VISTA (shown from south to north on AT)** | **Latitude** | **Longitude** | **Estimated pipeline miles visible** |
|---|---|---|---|
| SUGAR RUN MOUNTAIN 1 | 37.26144531 | -80.83596761 | 2.11 |

| | | | |
|---|---|---|---|
| SUGAR RUN MOUNTAIN 2 | 37.24208305 | -80.81641683 | 7.33 |
| UNNAMED OVERLOOK SOUTH OF WILBURN VALLEY OVERLOOK | 37.29293063 | -80.78524343 | 2.92 |
| WILBURN VALLEY OVERLOOK | 37.30962922 | -80.75707475 | 0.37 |
| ANGELS REST | 37.31770981 | -80.75580092 | 7.21 |
| PETERS MOUNTAIN OVERLOOK NEAR RICE FIELD SHELTER - 1 | 37.37998658 | -80.74684553 | 6.28 |
| PETERS MOUNTAIN OVERLOOK NEAR RICE FIELD SHELTER - 2 | 37.37538493 | -80.75875926 | ? |
| SYMMS GAP CAMPSITE AND OPEN AREA | 37.404524° | -80.685259° | 6 |
| PETERS MOUNTAIN - SYMS GAP | 37.37955224 | -80.74347463 | 2.49 |
| WIND ROCK | 37.4139405 | -80.51920419 | 1.62 |
| KELLY'S KNOB | 37.35566363 | -80.44167456 | 2.73 |
| SINKING CREEK MOUNTAIN 1 | 37.35713081 | -80.33793049 | 2.36 |
| SINKING CREEK MOUNTAIN 2 | 37.35761328 | -80.33749886 | 3.29 |
| SINKING CREEK MOUNTAIN 3 | 37.37846376 | -80.31000277 | 1.12 |
| AUDIE MURPHY | 37.35864 | -80.23564 | 6.97 |
| DRAGON'S TOOTH ON AT | 37.3626 | -80.17263 | 0.62 |
| DRAGON'S TOOTH ACTUAL | 37°21'39.02"N | 80°10'24.66" | 2.36 |
| McAFEE KNOB 1 | 37.39083 | -80.03511 | 0.56 |
| McAFEE KNOB 2 | 37.39106 | -80.03609 | 2.42 |

RATC shared this table with the ATC and believes that **all 19 points shown should be seriously considered for visual simulations of the MVP's potential impacts.**

RATC presented much of the information shown here at the September 30, 2016 Triple Crown Planning and ATC regional meeting held at the offices of the George Washington & Jefferson National Forests, with numerous staff from the JNF in attendance. No one from Mountain Valley Pipeline was present.

**We would especially note that a later change in the MVP centerline in Montgomery County, to avoid a Virginia Outdoors Foundation property, has moved the pipeline route even closer to Dragon's Tooth, a part of "Virginia's Triple Crown" – Dragon's Tooth, McAfee Knob and Tinker Cliffs.** We know from an infrared counter that McAfee Knob is already receiving over 75,000 visitors each year, and recent counts of Dragon's Tooth foot traffic suggest that 1/3 to ½ that number (25,000 to 37,500 hikers) are visiting Dragon's Tooth, which lies within Jefferson National Forest.

In addition, RATC was fully informed of the work that a team led by David Hill, a landscape architect in Roanoke, was doing for the Roanoke Valley Cool Cities Coalition through his firm, Hill Studio. Hill has extensive experience with visual impact studies and uses sophisticated strategies to show likely impacts. It is useful to note that:

1. The Hill Studio team used Google Earth, the MVP centerline, the ANST centerline, and the DeGroot 10m x 10m visibility layers to identify likely locations where the pipeline would be visible.
2. The colors that Hill Studio used to portray the likely appearance of the MVP are based on the actual appearance of the three-year-old Celanese pipeline on Peters Mountain, the same mountain where MVP proposes to cross the ANST.
3. The original work that Hill Studio did is completely explained in the presentation at the October 8, 2016 Forum on Natural Gas Pipelines at Roanoke College in Salem, Virginia – "Visual Quality in the Landscape." We submit that this presentation, in its entirety, should be part of the record with FERC on the MVP.

Hill Studio originally identified locations in Giles County and Roanoke County where the MVP would be very visible and later did several visualizations for ATC and for a Bent Mountain group showing visibility from a Blue Ridge Parkway overlook. The before and after versions done for Giles High School are shown below.

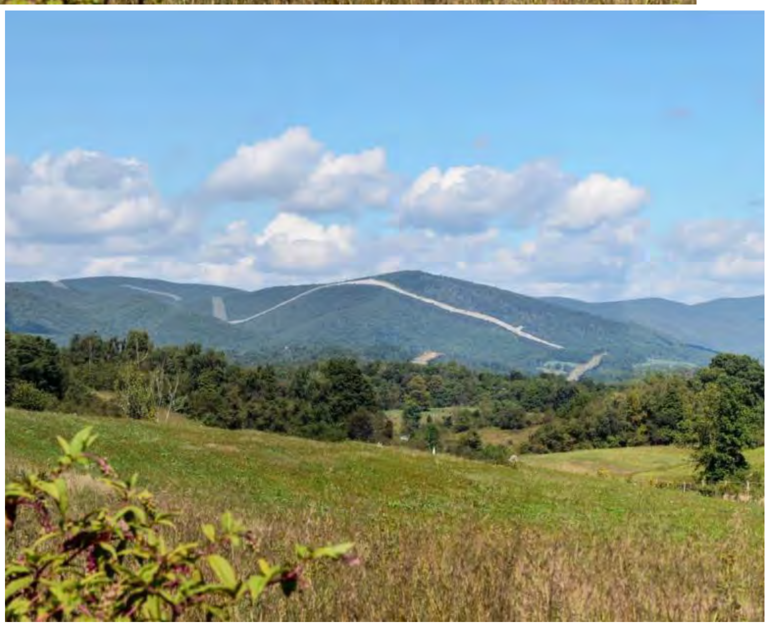


Figure Giles High School - Before Giles High School – After
*Hill Studio*

This photo was taken very close to US 460 in Pearisburg, Virginia and below Angel's Rest on the ANST as well. The simulation done at a later date for the ATC from Angel's Rest reflects a very similar view from a higher vantage point.

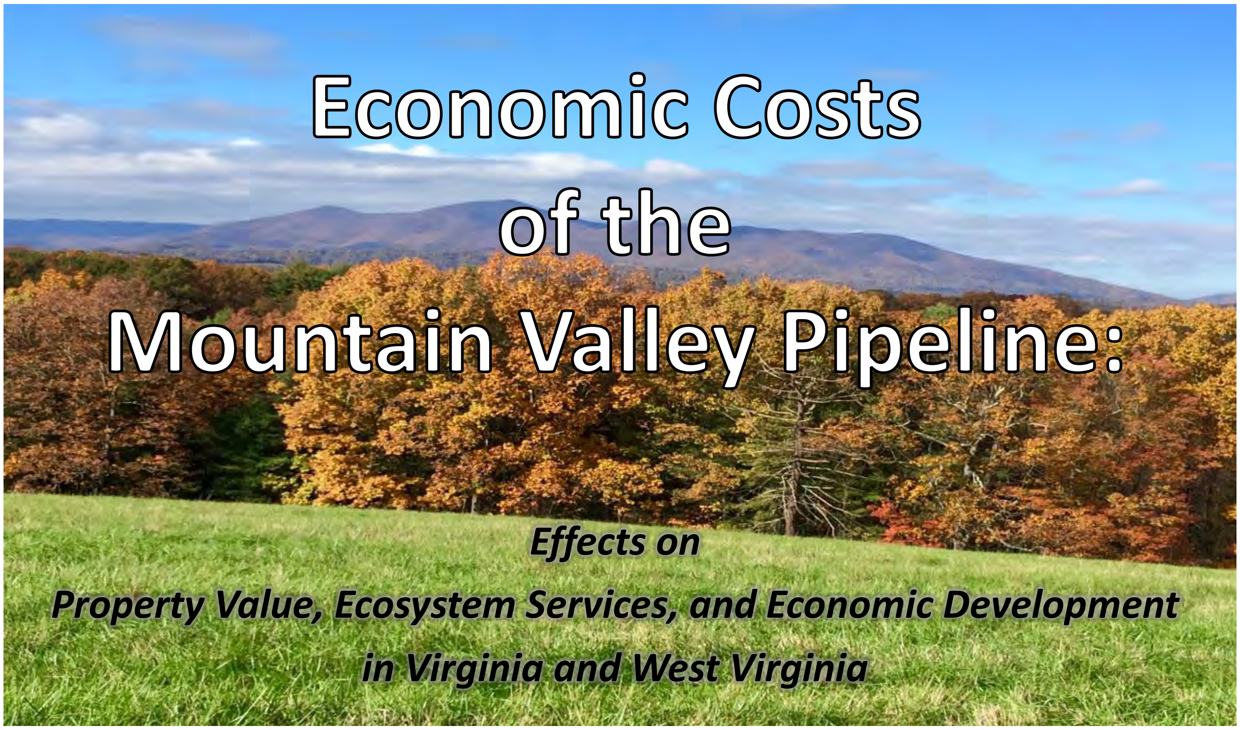
As you can see, RATC has collected a great deal of information about the likely visual impacts of the MVP on the ANST. At no time after July 22, 2016 did the applicant ask for information from us about potential visual impacts of the MVP. Nor did they coordinate with us in planning simulations of the MVP's potential impacts on the ANST. It is our firm belief, based on detailed study with help from volunteers on the ground and from very qualified and reputable third parties, that the Mountain Valley Pipeline would have very negative scenic impacts on the ANST off and on for perhaps 100 miles and would permanently degrade the scenic experience for AT hikers. Given that the current backup plan for the ANST crossing is an open cut, which was frequently referenced in the DEIS, we seriously question this route selection.

President
Roanoke Appalachian Trail Club
February 3, 2017

**The Wilderness Society et al. Comments on the U.S. Forest Service Mountain Valley Pipeline and Equitrans Expansion Project Draft Supplemental Environmental Impact Statement (#50036)**

# EXHIBIT 40

**February 21, 2023**




MAY 2016

*Report to:*
*Protect Our Water, Heritage, Rights (The POWHR Coalition)*
*powhr.org*

Spencer Phillips, PhD
Sonia Wang
Cara Bottorff

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*Research and strategy for the land community.*

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# EXECUTIVE SUMMARY

The Mountain Valley Pipeline (MVP) is proposed to carry natural gas from the Marcellus and Utica Shale approximately 300 miles through 11 West Virginia and 6 Virginia counties before terminating at the existing Transcontinental pipeline compressor station in Pittsylvania County, Virginia. Mountain Valley Pipeline, LLC, which would construct and operate the pipeline as a joint venture of EQT Corporation and NextEra Energy, Inc., and some public officials have promoted the MVP as both environmentally safe and economically beneficial, providing economic opportunity for local communities along the proposed route.

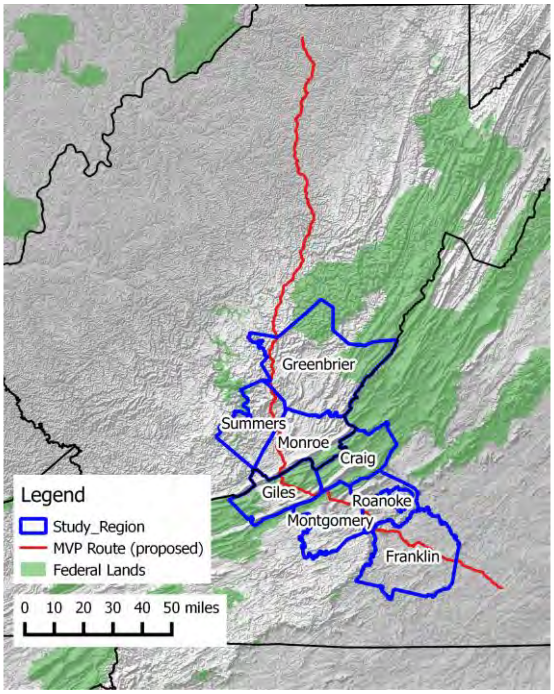


**FIGURE 1: Eight-County Study Region**

Note: Roanoke County includes the independent cities of Salem and Roanoke

Sources: MVP route digitized from online maps and MVP LLC filings (http://mountainvalleypipeline.info/maps/); Study Region (counties), federal lands, and hill shade from USGS and http://nationalmap.gov/small_scale/

Promised economic benefits, however, are only part of the impact the Federal Energy Regulatory Commission (FERC) must review before deciding whether to approve the construction and operation of the pipeline. Under its own policy and the more comprehensive requirements of the National Environmental Policy Act, FERC's review must consider the full range of environmental effects of the proposed pipeline. These include the various ways in which environmental effects would result in changes in human well-being—including economic benefits and costs. While estimates of the positive economic effects, including construction jobs and local tax payments, have been developed and promoted as reasons to move forward with the pipeline, no systematic consideration of the potential negative economic effects—economic costs—of the MVP has been completed.

To help fill the gap in current information, the POWHR (Protect Our Water, Heritage, Rights) coalition of community groups from an eight-county region in West Virginia and Virginia commissioned this independent research into key economic costs of the MVP. This region comprises Greenbrier, Monroe, and Summers Counties in West Virginia and Craig, Franklin, Giles, Montgomery, and Roanoke Counties in Virginia (Figure 1). The MVP's construction, operation, and presence would impose three types of costs on this region. First, the pipeline would impact property values along the approximately 143 miles of pipeline proposed for the study region. Affected properties are those touched by the 50-foot-wide right-of-way, within the 1.4-mile-wide evacuation zone, and throughout the viewshed of the proposed pipeline. Second, construction and the ongoing operation of the pipeline would alter land use/land cover in ways that diminish the value of ecosystem services, such as aesthetics, water supply, and timber and food production. Third, and in part due to a loss of scenic and quality-of-life amenities, there would be decreases in visitation, in-migration, tourism, small business development, plus a loss of jobs and personal income those activities would otherwise support.

Considering this eight-county region alone, estimated one-time costs range from $65.1 to $135.5 million. These one-time costs comprise lost property value and the value of ecosystem services lost during construction. Annual costs following the construction period include lower ecosystem service productivity in the MVP's right-of-way, lower property tax revenue due to the initial losses in property value, and dampened economic development. These total between $119.1 and $130.8 million per year and would persist for as long as the MVP right-of-way exists—that is, in perpetuity. (See "At a Glance," page iii for details.) Putting the stream of costs into present value terms [1] and adding the one-time costs, the total estimated cost of the MVP in the eight counties is between $8.0 and $8.9 billion.

The costs represented by the estimates presented here are what economists call “externalities,” or “external costs,” because they would be imposed on parties other than (external to) the company proposing to build the pipeline. Unlike the private (or internal) costs of the pipeline, external costs borne by the public do not affect the company’s bottom-line. From an economic perspective, the presence of externalities is what demands public involvement in decisions about the MVP. Without consideration of all of the costs of the project, too much pipeline (which may mean any pipeline at all) is the inevitable result. FERC must consider the true bottom line and ensure that the full costs of the pipeline, especially those external costs imposed on the public, are rigorously examined and brought to bear on its decision about whether or not to permit the MVP project to proceed.

For reasons explained in the body of this report, estimates of external costs developed as part of this study and reported here are conservative. One reason is simply that there are categories of impacts that are beyond the scope of the study. These impacts include changes to sites or landscapes that have historical or cultural significance. Like lost aesthetic quality or a decrease in the capacity of the landscape to retain soil, filter water, or sequester carbon, historical and cultural impacts matter to humans and, therefore, can be expressed as monetary value. We have also not included the cost to communities of increased emergency response planning and capacity necessary during the operation of the proposed pipeline or of increased law enforcement, road maintenance and repair, or other costs that would accompany its construction.[2]

Another important category of cost not counted here is “passive use value.” Passive use value includes the value to people of simply knowing an unspoiled natural area exists and the value of keeping such places unspoiled for the sake of some future direct or active use. In light of this, it is important to consider the estimates of economic costs provided here as a fraction of the total economic value put at risk by the proposed Mountain Valley Pipeline.

Finally, while this report covers many of the costs that *will* happen if the MVP is constructed and operated, it does not include an assessment of natural resource damage and other effects that *might* happen during construction and operation. For example, there is some probability that erosion of steep slopes and resulting sedimentation of streams and rivers will occur during construction. Similarly, there is some probability that there will be a leak and explosion somewhere along the length of the MVP during its lifetime. If, when, and where such events occur with the MVP, there will be clean-up and remediation costs, costs of fighting fires and reconstructing homes, businesses, and infrastructure, the cost of lost timber, wildlife habitat, and other ecosystem services, and most tragically, the cost of lost human life and health.[3] The magnitude of these damages, multiplied by the probability that they will occur, yields additional “expected costs,” which would then be added to the more certain costs estimated in this study. The same is true of the costs that could accrue after the MVP is no longer used and maintained.

To be clear, the costs estimated here—the effect on ecosystem services from clearing land for the pipeline corridor, the impact on land values resulting from buyers’ concerns about pipeline safety, and reductions in economic vitality stemming from changes in the landscape—will occur with or without any discreet or extreme events like landslides or explosions ever happening. These impacts and their monetary equivalents are simply part of what will happen in West Virginia and Virginia if the MVP is approved, built, and operated.

[1] The present value of a perpetual stream of costs is the one-year cost divided by the 1.5% real discount rate recommended by the Office of Management and Budget for cost-benefit and cost-effectiveness analysis of public projects and decisions (Office of Management and Budget, 2015).

[2] As of this writing, a pilot study of these cost for one Virginia county in our study region is underway, with results expected in the coming weeks.

[3] While no one was killed in the incident, one need look no further than the recent explosion of Spectra Energy’s Texas Eastern gas transmission line in Pennsylvania to see such impacts. See, for example, https://stateimpact.npr.org/pennsylvania/2016/05/04/pa-pipeline-explosion-evidence-of-corrosion-found/

## At a Glance:

## The Mountain Valley Pipeline in Virginia and West Virginia

*Craig, Franklin, Giles, Montgomery, and Roanoke Counties in Virginia and Greenbrier, Monroe, and Summers Counties in West Virginia*

- Miles of pipeline: 143
- Acres
  - In the construction corridor and temporary roads and workspaces: 2449
  - In the permanent right-of-way (ROW): 861
  - In permanent access roads and other facilities: 76
- Most impacted land cover types (ROW only): forest (664 acres) and pasture (142 acres)
- Parcels touched by ROW: 716
- Parcels in the 1.4-mile-wide evacuation zone: 8,221
- Residents and housing units in the evacuation zone: 20,389 people and 9,700 homes
- Parcels from which the pipeline would be visible: 78,553 or 31% of all parcels in the six counties for which detailed parcel data are available
- Baseline (no pipeline) property value at risk (and expected one-time cost due to the MVP):
  - In the ROW: $125.9 million ($5.3 to $16.4 million)
  - In the evacuation zone: $972.6 million ($37.0 million)
  - In the viewshed: $16.8 billion (to avoid double counting with lost aesthetic value under ecosystem services, this impact is not separately estimated)
- Total property value lost (a one-time cost): $42.2 to $53.3 million
- Resulting loss in property tax revenue (annual): $243,500 to $308,400
- Lost ecosystem service value, such as for water and air purification, recreational benefits, and others:
  - Over the two-year construction period (a one-time cost): between $22.9 and $82.2 million
  - Resulting loss in property tax revenue (annual): between $4.1 and $14.8 million
- Lost economic development opportunities due to the erosion of these counties' comparative advantages as attractive places to visit, reside, and do business. Under the scenarios described below, these could include:
  - Annual loss of recreation tourism expenditures of $96.8 million that supports 1,073 jobs and $24.3 million in payroll and generates $4.8 million in state and $2.6 million in local taxes
  - Annual loss of personal income of $15.6 million due to slower growth in the number of retirees
  - Annual loss of personal income of $2.1 million due to slower growth in sole proprietorships
- Total of estimated costs:
  - One-time costs (lost property value and lost ecosystem service value during construction) would total between $65.1 to $135.5 million
  - Annual costs (costs that recur year after year) would range from $119.1 to $130.8 million
    - Present discounted value of all future annual costs (discounted at 1.5%): $7.9 to $8.7 billion
  - One-time costs plus the discounted value of all future annual costs: $8.0 to $8.9 billion

# CONTENTS

## ABBREVIATIONS AND TERMS

**BTM:** Benefit Transfer Method, a method for estimating the value of ecosystem services in a study region based on values estimated for similar resources in other places

**EIS:** Environmental Impact Statement, a document prepared under the National Environmental Policy Act analyzing the full range of environmental effects, including on the economy, of proposed federal actions, which in this case would be the approval of the Mountain Valley Pipeline

**ESV:** Ecosystem Service Value, the effects on human well-being of the flow of benefits from an ecosystem endpoint to a human endpoint at a given extent of space and time, or more briefly, the value of nature's benefits to people

**FERC:** Federal Energy Regulatory Commission, the agency responsible for preparing the EIS and deciding whether to grant a certificate of public convenience and necessity (i.e., whether to permit the pipeline)

**HCA:** High Consequence Area, the area within which both the extent of property damage and the chance of serious or fatal injury would be expected to be significant in the event of a rupture failure

**MVP:** Mountain Valley Pipeline, which in this report generally refers to the pipeline corridor itself

**MVP LLC:** Mountain Valley Pipeline, LLC, a joint venture of EQT Midstream Partners, LP, NextEra US Gas Assets, LLC, Con Edison Gas Midstream, LLC, WGL Midstream, Vega Midstream LLC, and RGC Midstream, will own and construct the proposed Mountain Valley Pipeline

**NEPA:** National Environmental Policy Act of 1970, which requires the environmental review of proposed federal actions, preparation of an EIS, and, for actions taken, appropriate mitigation measures

**ROW:** Right-of-Way, the permanent easement in which the pipeline is buried

# AUTHOR'S NOTE

We are grateful for the assistance of POWHR—for "Protect Our Water, Heritage, Rights" (information at powhr.org)—coalition members and other groups in identifying local information sources and making contacts in the study region. These groups include Blue Ridge Land Conservancy, Border Conservancy, Chesapeake Climate Action Network, Greenbrier River Watershed Association, Preserve Bent Mountain, Preserve Craig, Preserve Franklin, Preserve Giles County, Preserve Greenbrier County, Preserve Monroe, Preserve Montgomery County, Va., Preserve the New River Valley, Preserve Roanoke, Roanoke Valley Cool Cities Coalition, Save Monroe, Summers County Residents Against the Pipeline, Virginia Chapter, Sierra Club, and Virginia Citizens Consumer Council.

We also thank Professor Stockton Maxwell of Radford University and his students John DeGroot and Bryan Behan for their assistance acquiring and processing spatial (GIS) data for the land value and visibility analyses. Key-Log Economics remains solely responsible for the content of this report, the underlying research methods, and the conclusions drawn. We have used the best available data and employed appropriate and feasible estimation methods but nevertheless make no claim regarding the extent to which these estimates will match the actual magnitude of economic effects if the MVP is built.

*Cover Photo from Franklin County, Virginia courtesy of David Sumrell*

## BACKGROUND

The proposed Mountain Valley Pipeline (MVP) is a high-volume transmission pipeline intended, as described in filings with the Federal Energy Regulatory Commission (FERC), to transport up to two million dekatherms per day of natural gas from the Marcellus and Utica Shale region in West Virginia to markets in the Mid- and South-Atlantic Region of the United States (Mountain Valley Pipeline LLC, 2015a). MVP LLC partners have also indicated that the pipeline could facilitate export of liquefied natural gas to India or other overseas markets (Adams, 2015).

The majority of the pipeline, and the entire portion in the eight-county region considered in this study (Figure 1), would consist of 42-inch diameter pipe and would be operated at a nominal pressure of 1,480 pounds per square inch gauge (PSIG).

Along the way, the MVP would cross portions of the Jefferson National Forest, the Appalachian Trail, the Blue Ridge Parkway, and other public conservation, scenic, and natural areas. Its permanent right-of-way and temporary construction corridor—50 and 125 feet wide, respectively—would also cross thousands of private properties. Pipeline leaks and explosions, should they occur, would cause substantial physical damage and require evacuation of even wider swaths, affecting perhaps tens of thousands of homes, farms, and businesses. Still wider, but more difficult to gauge and estimate, are the zones within which the construction, operation, and presence of the pipeline would affect human well-being by changing the availability of ecosystem services such as clean air, water supply, and recreational opportunities. This would occur as the pipeline creates an unnatural linear feature on a landscape that otherwise remains largely natural or pastoral and dampens the attractiveness of the affected region as a place to live, visit, retire, or do business.

To date, these negative effects and estimates of their attendant economic costs have not received much attention in the otherwise vigorous public debate surrounding the proposed MVP. This report, commissioned jointly by several regional and local groups, is both an attempt to understand the nature and potential magnitude of the economic costs of the MVP in a particular eight-county area, as well as to provide an example for FERC as it proceeds with its process of analyzing and weighing the full effects of the proposed MVP along its entire length and, by extension, throughout the region in which its effects will occur.

### Policy Context

Before construction can begin, the MVP must be approved by FERC. That approval, while historically granted to pipeline projects, depends on FERC's judgment that the pipeline would meet a public "purpose and need." Because the approval would be a federal action, FERC must also comply with the procedural and analytical requirements of the National Environmental Policy Act (NEPA). These include requirements for public participation, conducting environmental impact analysis, and writing an Environmental Impact Statement (EIS) that evaluates all of the relevant effects. Of particular interest here, such relevant effects include direct, indirect, and cumulative effects on or mediated through the economy. As the NEPA regulations state,

> Effects include ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative. Effects may also include those resulting from actions which may have both beneficial and detrimental effects, even if on balance the agency believes that the effect will be beneficial (emphasis added, 36 CFR 1508.b).

It is important to note NEPA does not require that federal actions–which in this case would be approving or denying the MVP–necessarily balance or even compare benefits and costs. NEPA is not a decision-making law, but rather a law requiring decisions be supported by an as full as possible accounting of the reasonably foreseeable effects of federal actions on the natural and human environment. It also requires that citizens have opportunities to engage in the process of analyzing and weighing those effects.

Moreover, FERC's own policy regarding the certification of new interstate pipeline facilities (88 FERC, para. 61,227) requires adverse effects of new pipelines on "economic interests of landowners and communities affected by the route of the new pipeline" be weighed against "evidence of public benefits to be achieved [by the pipeline]" (88 FERC, para. 61,227; Hoecker, Breathitt, & He'bert Jr., 1999, pp. 18–19). Further, "…construction projects that would have residual adverse effects would be approved only where the public benefits to be achieved from the project can be found to outweigh the adverse effects" (p. 23).

In principal, this policy is in line with the argument, on economic efficiency grounds, that the benefits of a project or decision should be at least equal to its cost, including external costs. However, the policy's guidance regarding what adverse effects must be considered and how they are measured is deeply flawed. The policy states, for example, "if project sponsors…are able to acquire all or substantially all, of the necessary right-of-way by negotiation prior to filing the application…it would not adversely affect any of the three interests," which are pipeline customers, competing pipelines, and "landowners and communicates affected by the route of the new pipeline" (Hoecker et al., 1999, pp. 18, 26). The Commission's policy contends the only adverse effects that matter are those affecting owners of properties in the right-of-way. Even for a policy adopted in 1999, this contention is completely out of step with long-established understanding that development that alters the natural environment has negative economic effects.

A further weakness of the FERC policy is that it relies on applicants to provide information about benefits and costs. The policy's stated objective "is for the applicant to develop whatever record is necessary, and for the Commission to impose whatever conditions are necessary, for the Commission to be able to find that the benefits to the public from the project outweigh the adverse impact on the relevant interests" (Hoecker et al., 1999, p. 26). The applicant therefore has an incentive to be generous in counting benefits[4] and parsimonious in counting the costs of its proposal. Under these

[4] MVP LLC has published estimates of economic benefits in the form of employment and income stemming from the construction and operation of the MVP (Ditzel, Fisher, & Chakrabarti, 2015a, 2015b). As has been well documented elsewhere, these studies suffer from errors in the choice and application of methods and in assumptions made regarding the long-run economic stimulus represented by the MVP. Most significantly, the studies make no mention of likely

circumstances, it seems unlikely that the Commission's policy will prevent the construction of pipelines for which the full costs are greater than the public benefits they would actually provide. Indeed, until just recently, FERC has never rejected a pipeline proposal (van Rossum, 2016).

Because MVP LLC failed to acquire a sufficient portion of the right-of-way and other federal agencies, including the US Forest Service, needed to evaluate how the MVP would affect resources under its stewardship, the Commission issued a Notice of Intent to prepare an EIS in February of 2015 (Federal Energy Regulatory Commission, 2015). The process began with a series of scoping meetings where members of the public could express their general thoughts on the pipeline as well as what effects should fall under the scope of the EIS. Interested parties also had the opportunity to submit comments online and through the mail.

Much of what FERC heard from citizens echoed and expanded upon the list of potential environmental effects listed in its Notice of Intent. Of those, several including "domestic water sources…, Appalachian Trail…, Residential developments and property values; Tourism and recreation" and others are particularly important as environmental effects that resonate in the lives of people. These effects can take the form of economic costs external to MVP LLC that would be borne by individuals, businesses, and communities throughout the landscape the MVP would traverse.

Based on a review of written comments submitted to FERC in January through March of 2015, citizens do seem to have emphasized these issues. Key issues include economic impacts, environmental degradation, public safety, property value effects, and issues related to cultural and historical resources (Pipeline Information Network, 2015).

## Study Objectives

Given the policy setting and what may be profound effects of the proposed MVP on the people and communities of Virginia and West Virginia, we have undertaken this study to provide information of two types:

1. An example of the scope and type of analyses that FERC could, and should, undertake as part of its assessment of the environmental (including economic) effects of the MVP.

2. An estimate of the potential magnitude of economic effects in this eight-county subset of the landscape where the MVP's environmental effects will be felt.

We do not claim the estimates below represent the total of all potential costs that would attend the construction, operation, and presence of the pipeline. Specifically, we have included several categories of cost: "passive-use value,"[5] including the value of preserving the landscape without a pipeline for

economic costs, and their projections of long-term benefits extend far beyond the time period (of a year or so) within which economic impact analysis is either useful or appropriate. See Phillips (Phillips, 2015b) for details on these shortcomings.

[5] Passive-use values include *option* value, or the value of preserving a resource unimpaired for one's potential future use; *bequest* value, which is the value to oneself of preserving the resource for the use of others, particularly future generations; and *existence* value, which is the value to individuals of simply knowing that the resource exists, absent any expectation of future use by oneself or anyone else. In the case of the MVP, people who have not yet visited the Blue Ridge Parkway or otherwise spent vacation time and dollars in the region are better off knowing that the setting for their planned activities is

future direct use, increases in the cost of community services like road maintenance and emergency response that may increase due to the construction and operation of the pipeline,[6] and probabilistic damages to natural resources, property, and human health and lives in the event of mishaps during construction and leaks/explosions during operation.

Therefore, our figures should be understood to be conservative, lower-bound estimates of the true total cost of the MVP in the sub-region and, of course, they do not include costs for the remainder of the region proposed for the MVP. We urge that the FERC augment the results of this study with its own similar analysis for the entire region and with additional research to determine the costs of community services and other relevant classes of costs not counted here.

## Current Economic Conditions in the Study Region

Our geographic focus is an eight-county region encompassing Craig, Franklin, Giles, Montgomery, and Roanoke counties in Virginia[7] as well as Greenbrier, Monroe, and Summers counties in West Virginia. This 3,964-square-mile region supports diverse land uses, including wild and pristine forests, both the Appalachian Trail and Blue Ridge Parkway, thriving cities, working farms, and extensive commercial timberland. These natural, cultural, and economic assets are among the reasons more than

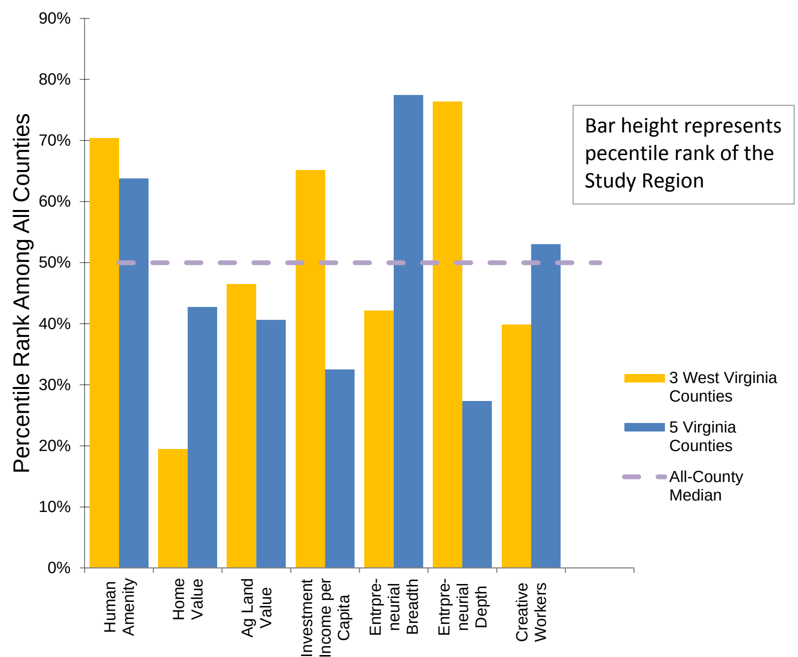


**FIGURE 2: Regional Asset Indicators for Study Region Counties, Relative to their Respective States**
(Source: Federal Reserve Bank of Kansas City)

a beautiful aesthetically pleasing landscape. What future visitors would be willing to pay to maintain that possibility would be part of the "option value" of an MVP-free landscape.

[6] As with communities impacted by the shale gas boom itself, communities along the pipeline can expect spikes in crime as transient workers come and go, more damage to roads under the strain of heavy equipment, increases in physical and mental illnesses including asthma, depression, anxiety, and others triggered by exposure to airborne pollutants, to noise, and to emotional, economic, and other stress. See, for example, Ferrar et al. (2013), Healy (2013), Fuller (2007), Campoy, (2012), and Mufson (2012).

[7] Two independent cities, Salem and Roanoke, lie within the geographic borders of Roanoke County. In this report, subject to some limitations where noted, statistics, estimates, and other information labeled as "Roanoke County" reflect totals for the County plus the two independent cities. The City of Radford at the southern edge of Montgomery County lies on the other side of the New River from the rest of the County, and is considered in this study to be far enough removed from the proposed MVP that it is not included in the statistics or estimates.

342,000 people call this region home and an even larger number visit each year for hiking, boating, sightseeing, festivals, weddings, and other events.

Statistics from the Center for the Study of Rural America, part of the Federal Reserve Bank of Kansas City, highlight the extent to which the region possesses the right conditions for resilience and economic success in the long run (Low, 2004). These data show that the study region has a higher human amenity index (based on scenic amenities, recreational resources, and access to health care), and strong entrepreneurship relative to most West Virginia or Virginia counties (Figure 2).[8] The West Virginia counties are stronger in terms of investment income per capita than the average for other West Virginia counties. The five Virginia counties have slightly more creative workers, as a percentage of the workforce, than the average for the Commonwealth.

More traditional measures of economic performance suggest the region is generally strong and resilient, though there are some differences among the Virginia and West Virginia Counties. From 2000 through 2014, for example:[9]

- Population in the study region grew by 9.6%, compared to a -0.5% loss of population for non-metro Virginia and West Virginia[10]
    - Population in the Virginia section of the study region grew by 10.5%, compared to a -0.2% loss of population for non-metro Virginia
    - Population in the West Virginia section of the study region grew by 0.8%, compared to a -1.1% loss of population for non-metro West Virginia
- Employment in the study region grew by 3.5%, compared to a -4.0% loss for non-metro Virginia and West Virginia
    - Employment in the Virginia section of the study region grew by 3.4%, compared to a -6.7% loss of employment for non-metro Virginia
    - Employment in the West Virginia section of the study region grew by 5.1%, compared to a 2.4% growth of employment for non-metro West Virginia
- Personal income in the study region grew by 20.6%, compared to 15.1% for non-metro Virginia and West Virginia
    - Personal income in the Virginia section of the study region grew by 20.7%, compared to 13.1% growth of personal income for non-metro Virginia

[8] Note that the Kansas City Fed's statistics have not been updated since 2004-2006, and conditions in and outside the study region have undoubtedly changed. Some of these relative rankings may no longer hold.
[9] These data are from Headwaters Economics (2015), US Bureau of Economic Analysis (2015), and US Bureau of the Census (2014, 2015).
[10] "Non-metro Virginia" and "Non-metro West Virginia" comprises those counties that are not a part of a federally defined metropolitan statistical area (MSA). While the Virginia counties in the study region are in MSAs, each of the study region counties are predominantly rural in landscape and character and are much more like other non-metro counties than they are like Northern Virginia or Tidewater, for example. Therefore, we believe that averages for non-metro Virginia provide a more appropriate point of comparison than statistics that include the Commonwealth's more urban areas. None of the West Virginia counties in the study region are part of an MSA.

  - Personal income in the West Virginia section of the study region grew by 19.7%, compared to 19.6% growth of personal income for non-metro West Virginia
- On average, earnings per job in the study region are higher, by about $7,400/year, than the average for non-metro Virginia and West Virginia
  - Earnings per job in the Virginia section of the study region are higher, by about $9,300/year, than the average for non-metro Virginia
  - Earnings per job in the West Virginia section of the study are lower, by about $5,100/year than the average for non-metro West Virginia
- Per capita income is higher in the study region, by $4,100/year, than the average for non-metro Virginia and West Virginia
  - Per capita income in the Virginia section of the study region is higher, by about $4,400/year, than the average for non-metro Virginia
  - Per capita income in the West Virginia section of the study region, while growing, is lower, by about $1,400/year, than the average for non-metro West Virginia
- The unemployment rate in the study region is 2.5%, compared to 2.3% for non-metro Virginia and West Virginia, during 2000-2014
  - The unemployment rate in the Virginia section of the study region is 2.9%, compared to an unemployment rate of 3.2% for non-metro Virginia, during 2000-2014
  - The unemployment rate in the West Virginia section of the study region is 0.3%, compared to an unemployment rate of 1.0% for non-metro West Virginia, during 2000-2014

These trends are consistent with what regional economists McGranahan and Wojan have called the "Rural Growth Trifecta" of outdoor amenities, a creative class of workers, and a strong "entrepreneurial context" (innovation-friendliness) (2010). Individual workers, retirees, and visitors are attracted to the natural beauty of the region while entrepreneurs are attracted by the quality of the environment, by the quality of the workforce, and by existing support from local government. Workers, for their part, are retained and nurtured by dynamic businesses that fit with the landscape and lifestyle that attracted them to the region in the first place. As further indication of this dynamic, consider since 2000:[9]

- The region's population growth has been primarily due to in-migration
- The proportion of the population 65 years and older has increased from 14.5% to 15.5%
- Proprietors' employment is up by 28.9%
- Non-labor income (primarily investment returns and age-related transfer payments like Social Security) is up by 39.0%.

These trends suggest entrepreneurs and retirees are moving to (or staying in) this region, bringing their income, expertise, and job-creating energy with them.

Temporary residents–tourists and recreationists attracted to the natural amenities of the region–and the businesses that serve them are also important parts of the region's economy. Tourists spent more than $1.2 billion in the study region in 2014. The companies that directly served those tourists employed 11,642 people, or 15.4% of all full- and part-time workers (Dean Runyan Associates, 2015; Headwaters Economics, 2015; Virginia Tourism Corporation, 2015).

It is in this context the potential economic impacts of the MVP must be weighed and the apprehension of the region's residents understood. Many believe the construction and operation of the pipeline will kill, or at least dampen, the productivity of the proverbial goose that lays its golden eggs in the region. This could result in a slower rate of growth in the region and worse economic outcomes. More dire is the prospect that businesses will not be able to maintain their current levels of employment. Just as retirees and many businesses can choose where to locate, visitors and potential visitors have practically unlimited choices for places to spend their vacation time and expendable income. If the study region loses its amenity edge, other things being equal, people will go elsewhere, and this region could contract.

Instead of a "virtuous circle" with amenities and quality of life attracting/retaining residents and visitors, who improve the quality of life, which then attracts more residents and visitors, the MVP could tip the region into a downward spiral. In that scenario, loss of amenity and risk to physical safety would translate into a diminution or outright loss of the use and enjoyment of homes, farms, and recreational and cultural experiences. Some potential in-migrants would choose other locations and some long-time residents would move away, draining the region of some of its most productive members. Homeowners would lose equity as housing prices follow a stagnating economy. With fewer people to create economic opportunity, fewer jobs and less income will be generated. Communities could become hollowed out, triggering a second wave of amenity loss, out-migration, and further economic stagnation.

## ENVIRONMENTAL-ECONOMIC EFFECTS AND WHERE THEY WOULD OCCUR

In the remainder of this report, we follow this potential cycle and estimate three distinct types of economic consequences.

First, corresponding to the direct biophysical impacts of the proposed pipeline, are effects on ecosystem services–the benefits nature provides to people for free, like purified water or recreational opportunities, that will become less available and/or less valuable due to the MVP's construction and operation. Second are effects on property value as owners and would-be owners choose properties farther from the pipeline's right-of-way, evacuation zone, and viewshed. Third and finally are more general economic effects caused by a dampening of future growth prospects or even a reversal of fortune for some industries.

We begin with an exploration of the geographic area over which these various effects will most likely be felt.

### Impact Zones within the Study Region

Construction of the pipeline corridor itself would require clearing an area at least 125 feet (38.1 m) wide. (It would be wider in some areas depending on slope.) After construction, the permanent right-of-way (ROW) would be 50 feet wide along the entire length of the pipeline. Within the construction zone and right-of-way is where the greatest disruption of ecosystem processes will occur, so these zones are where reductions in ecosystem service value (ESV) emanate. Since we are estimating ecosystem service values at their point of origin, we will focus on the ROW and the construction zone, as well as temporary and permanent access roads, temporary workspaces, and permanent surface infrastructure.

Operated at its intended pressure and due to the inherent risk of leaks and explosions, the pipeline would present the possibility of having significant human and ecological consequences within a large "High Consequence Area" and an even larger evacuation zone. A High Consequence Area (HCA) is "the area within which both the extent of property damage and the chance of serious or fatal injury would be expected to be significant in the event of a rupture failure" (Stephens, 2000, p. 3). Using Stephens' formula, the HCA for this pipeline would have a radius of 1,095 feet (333.9 m). The evacuation zone is defined by the distance beyond which an unprotected human could escape burn injury in the event of the ignition or explosion of leaking gas (Pipeline Association for Public Awareness, 2007, p. 29). There would be a potential evacuation zone with a radius of at least 3,583 feet (1092.1 m).[11] (See map, Figure 3, for a close-up of these zones in part of the study region.) An explosion would undoubtedly affect ecosystem processes within the HCA and possibly the evacuation zone, but given the probability of an explosion at a particular point along the pipeline at a given time is small, we do not include the additional effects *on ecosystem service value* due to explosion in the cost estimates.

> ***"I saw no other option than to cancel my home building project once the MVP was proposed to cross the property."***
>
> *— Christian Reidys, Blacksburg, VA*

Effects on land value are another matter, and it is reasonable to consider land value impacts through both the high consequence area and the evacuation zone. As Kielisch (2015) stresses, the value of land is determined by human perception, and property owners and would-be owners have ample reason to perceive risk to property near high-pressure natural gas transmission pipelines. Traditional news reports, YouTube, and other media reports attest to the occurrence and consequences of pipeline leaks and explosions, which are even more prevalent for newer pipelines than for those installed decades ago (Smith, 2015). Information about pipeline risks translates instantly into buyers' perceptions and, therefore, into the chances of selling properties exposed to those risks, into prices offered for those properties, and, for people who already own such properties, diminished enjoyment of them (Freybote & Fruits, 2015).

In addition, loss of view quality would be expected for properties both near to and far from the pipeline corridor. Unlike leaks and explosions, view quality impacts will occur with certainty. If the pipeline is built, people will see the corridor as a break in a once completely forested hillside, and their "million-

[11] The maximum operating pressure proposed for the MVP is 1,480 PSIG, but the source data for this evacuation distance is a table with pressure in 100 PSIG increments. The full evacuation distance would be between 3,583 feet and 3,709 feet, the distance recommended for a 42" pipeline operated at 1,500 PSIG. The upshot for this study is a slightly more conservative estimate of the effect of the MVP on property value.

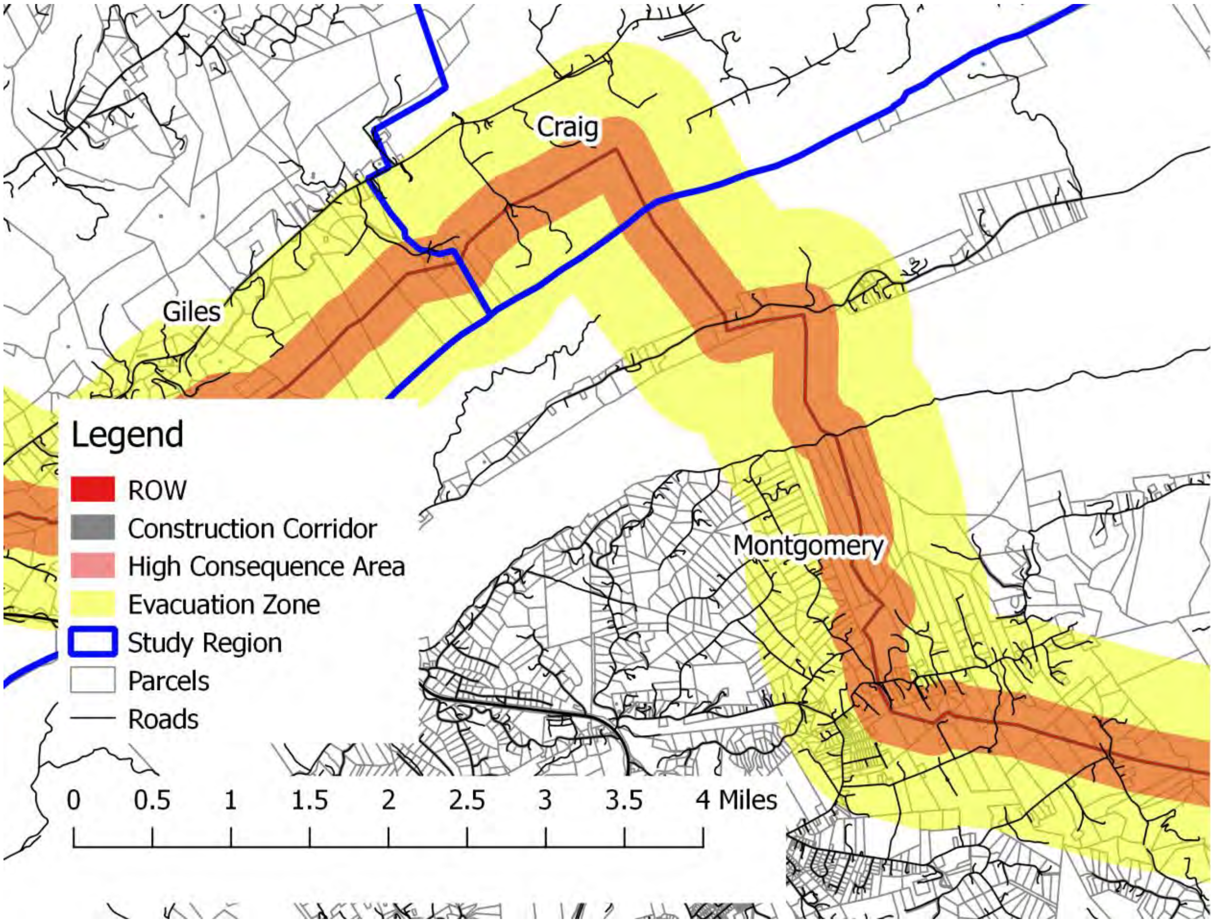


**FIGURE 3: Right-of-Way, Construction, High Consequence, and Evacuation Areas**

Note that the overlay of the HCA (in rose) and the evacuation zone (in yellow) shows up as the orange band in the map. The ROW covers much of the construction corrido, leaving a thin band of grey visible.

Sources: MVP route digitized from online maps and MVP LLC filings (http://mountainvalleypipeline.info/maps/); Counties and roads from USGS (http://nationalmap.gov; Parcels from public records in Giles and Montgomery County, respectively. (Parcel boundaries are not available in electronic form for Craig County.)

dollar" view will be diminished. Therefore, for our analysis of land value, we consider any place where there is considerable potential to see the pipeline corridor to be within its direct impact zone. (See map, Figure 7, in the land value section for the results of the visibility analysis.)

Beyond the loss of ecosystem services stemming from the conversion of land in the ROW, the loss of property value resulting from the chance of biophysical impacts, or the certainty of impacts on aesthetics, the proposed MVP would also diminish physical ecosystem services, scenic amenity, and passive-use value that are realized or enjoyed beyond the evacuation zone and out of sight of the pipeline corridor. The people affected include residents, businesses, and landowners throughout the study region, as well as past, current, and future visitors to the region. The impacts on human well-being would be reflected in economic decisions such as whether to stay in or migrate to the study region, whether to choose the region as a place to do business, and whether to spend scarce vacation time and dollars near the MVP instead of in some other place.

To the extent the MVP causes such decisions to favor other areas, less spending and slower economic growth in the study region would be the result. A secondary effect of slower growth would be further reductions in land value, but in this study we consider the primary effects in terms of slower population, employment, and income growth in key sectors. Table 1 summarizes the types of economic values considered in this study and the zones in which they are estimated.

**TABLE 1: Geographic Scope of Effects**

**A check mark indicates those zones/effects for which estimates are included in this study. The "X's" indicate areas for future study.**

| Values / Effects | Right-of-Way and Construction Zone | High Consequence Area | Evacuation Zone | Pipeline Viewshed | Entire Study Region | The World Beyond the Study Region |
|---|---|---|---|---|---|---|
| **Ecosystem Services** | ✓ | a | a | a,b | ✗[a,b] | ✗ |
| **Land / Property Value** | ✓[c] | ✓[d] | ✓[d] | ✓[e] | ✗ | n/a |
| **Economic Develop-ment Effects** | f | f | f | f | ✓ | n/a |

Notes:

a. Changes in ecosystem services that are felt beyond the ROW and Construction zone may be key drivers of "Economic Development Effects," but they are not separately estimated to avoid double counting.

b. With the exception of the impact on visual quality, we do not estimate the spillover effects of alteration of the ecosystem within the ROW on the productivity of adjacent areas. The ROW, for example, provides a travel corridor for invasive species that could reduce the integrity and ecosystem productivity of areas that, without the MVP would remain core ecological areas, interior forest habitat, etc.

c. We estimate land value effects for the ROW but not for the construction zone.

d. Properties in the HCA are treated as though there is no additional impact on property value relative to the impact of being in the evacuation zone.

e. To avoid double-counting, changes in property value due to an altered view from the property are considered to be part of lost aesthetic value under the "Ecosystem Services" section.

f. Economic development effects related to these subsets of the study region are included in estimates for the study region.

## EFFECTS ON ECOSYSTEM SERVICE VALUE

The idea that people receive benefits from nature is not at all new, but "ecosystem services" as a term describing the phenomenon is more recent, emerging in the 1960s (Millennium Ecosystem Assessment, 2003). "Benefits people obtain from ecosystems" is perhaps the simplest and most commonly heard definition of ecosystem services (Reid et al., 2005). Other definitions abound, including the following from Gary Johnson of the University of Vermont:

> Ecosystem services are the effects on human well-being of the flow of benefits from an ecosystem endpoint to a human endpoint at a given extent of space and time (2010).

This definition is helpful because it emphasizes services are not necessarily things–tangible bits of nature–but rather, they are the effects on people of the functions of the natural world. It also makes clear ecosystem services happen or are produced and enjoyed in particular places and at particular times.

No matter the definition, different types of ecosystems (forest, wetland, cropland, urban areas) produce different arrays of ecosystem services, and/or produce similar services to greater or lesser degrees. This is true for the simple reason that some ecosystems or land uses produce a higher flow of benefits than others.

"Ecosystem services" is sometimes lengthened to "ecosystem goods and services" to make it explicit that some are tangible, like physical quantities of food, water for drinking, and raw materials, while others are truly services, like cleaning the air and providing a place with a set of attributes that are conducive to recreational experiences or aesthetic enjoyment. We use the simpler "ecosystem services" here. Table 2, lists the provisioning, regulating, and cultural ecosystem services included in this study.

At a conceptual level, we estimate the potential effects of the MVP on ecosystem service value by identifying the extent to which the construction and long-term existence of the pipeline would change land cover or land use, resulting in a change in ecosystem service productivity. Lower productivity, expressed in dollars of value per acre per year, means fewer dollars' worth of ecosystem service value produced each year.

Construction would essentially strip bear the 125-foot-wide construction corridor. Once construction is complete and after some period of recovery, the 50-foot-wide right-of-way will be occupied by a different set of ecosystem (land cover) types than were present before construction. By applying per-acre ecosystem service productivity estimates (denominated in dollars) to the various arrays of ecosystem service types, we can estimate ecosystem service value produced per year in the periods before, during, and after construction. The difference between annual ecosystem service value *during* construction and *before* construction is the annual loss in ecosystem service value *of* construction. The difference between the annual ecosystem service value during ongoing operations (i.e., the value produced in the ROW) and the before-construction baseline (no pipeline) is the annual ecosystem service cost that will be experienced indefinitely.

## TABLE 2: Ecosystem Services Included in Valuation

| |
|---|
| **Provisioning Services[a]** |
| **Food Production:** The harvest of agricultural produce, including crops, livestock, and livestock by-products; the food value of hunting, fishing, etc.; and the value of wild-caught and aquaculture-produced fish.<br>**Associated land uses[b]:** Cropland, Pasture/Forage, Forest |
| **Raw Materials:** Fuel, fiber, fertilizer, minerals, and energy.<br>**Associated land uses[b]:** Forest |
| **Water Supply:** Filtering, retention, storage, and delivery of fresh water—both quality and quantity—for drinking, watering livestock, irrigation, industrial processes, hydroelectric generation, and other uses.<br>**Associated land uses[b]:** Forest, Water, Wetland |
| **Regulating Services[a]** |
| **Air Quality:** Removing impurities from the air to provide healthy, breathable air for people.<br>**Associated land uses[b]:** Shrub/Scrub, Forest, Urban Open Space |
| **Biological Control:** Inter- and intra-specific interactions resulting in reduced abundance of species that are pests, vectors of disease, or invasive in a particular ecosystem.<br>**Associated land uses[b]:** Cropland, Pasture, Grassland, Forest |
| **Climate Regulation:** Storing atmospheric carbon in biomass and soil as an aid to the mitigation of climate change, and/or keeping regional/local climate (temperature, humidity, rainfall, etc.) within comfortable ranges.<br>**Associated land uses[b]:** Pasture/Forage, Grassland, Shrub/Scrub, Forest, Wetland, Urban Open Space, Urban Other |
| **Erosion Control:** Retaining arable land, stabilizing slopes, shorelines, riverbanks, etc.<br>**Associated land uses[b]:** Cropland, Pasture/Forage, Grassland, Shrub/Scrub, Forest |
| **Pollination:** Contribution of insects, birds, bats, and other organisms to pollen transport resulting in the production of fruit and seeds. May also include seed and fruit dispersal.<br>**Associated land uses[b]:** Cropland, Pasture/Forage, Grassland, Forest |
| **Protection from Extreme Events:** Preventing and mitigating impacts on human life, health, and property by attenuating the force of winds, extreme weather events, floods, etc.<br>**Associated land uses[b]:** Forests, Urban Open Space, Wetland |
| **Soil Fertility:** Creation of soil, inducing changes in depth, structure, and fertility, including through nutrient cycling.<br>**Associated land uses[b]:** Cropland, Pasture/Forage, Grassland, Forest |
| **Waste Treatment:** Improving soil and water quality through the breakdown and/or immobilization of pollution.<br>**Associated land uses[b]:** Cropland, Pasture/Forage, Grassland, Shrub/Scrub, Forest, Water, Wetland |
| **Water Flows:** Regulation by land cover of the timing of runoff and river discharge, resulting in less severe drought, flooding, and other consequences of too much or too little water available at the wrong time or place.<br>**Associated land uses[b]:** Forests, Urban Open Space, Urban Other |
| **Cultural Services[a]** |
| **Aesthetic Value:** The role that beautiful, healthy natural areas play in attracting people to live, work, and recreate in a region.<br>**Associated land uses[b]:** Forest, Pasture/Forage, Urban Open Space, Wetland |
| **Recreation:** The availability of a variety of safe and pleasant landscapes—such as clean water and healthy shorelines—that encourage ecotourism, outdoor sports, fishing, wildlife watching, hunting, etc.<br>**Associated land uses[b]:** Cropland, Forest, Water, Wetland, Urban Open Space, Urban Other |

Notes:

a. Descriptions follow Balmford (2010, 2013), Costanza et al. (1997), Reid et al. (2005), and Van der Ploeg, et al. (2010).

b. “Associated Land Uses” are limited to those for which per-unit-area values are available in this study.

In addition to the ROW and construction corridor, the MVP would require the construction of various temporary and permanent access roads, temporary work areas, and several areas for maintenance facilities. All temporary roads and temporary work areas are treated as though they are part of the construction zone. Permanent roads and installations are treated separately. Note that many of the access roads already exist and will simply be used for pipeline access. Since there is no change in the land use for those roads, there is no loss in ecosystem service value associated with them. It is only when areas are converted from forest, pasture, or other land covers to the developed use (a road or surface facility) that ecosystem service value is altered.

This overall process is illustrated in Figure 4 and the details of our methods, assumptions, and calculations are described in the following two sub sections.

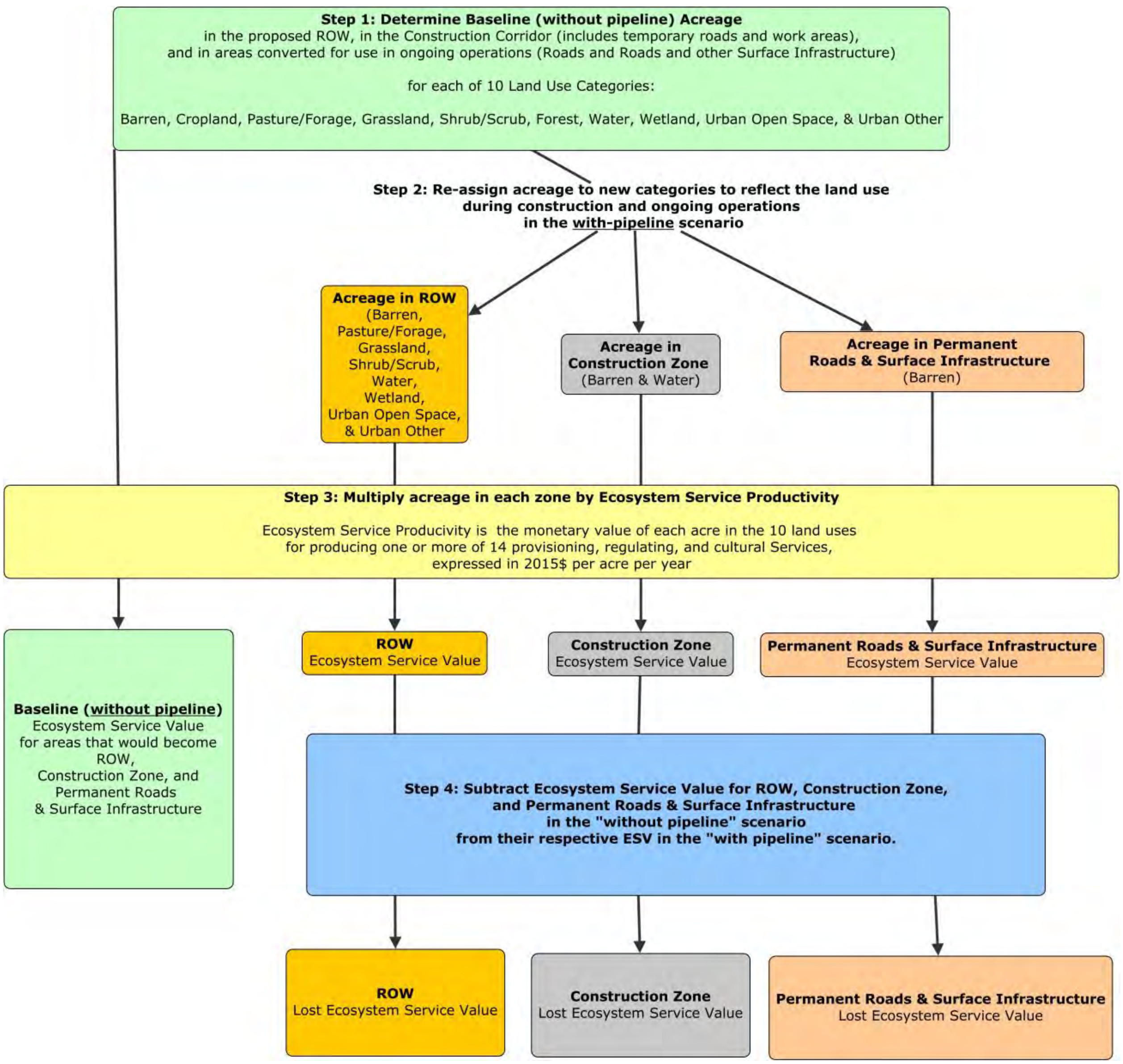


**FIGURE 4: Ecosystem Service Valuation Process**

## Ecosystem Service Estimation Methods

Economists have developed widely used methods to estimate the monetary value of ecosystem services and/or natural capital. The most widely known example was a study by Costanza et al. (1997) that valued the natural capital of the entire world. That paper and many others employ the "benefit transfer method" or "BTM" to establish a value for the ecosystem services produced or harbored from a particular place.[12] According to the Organization for Economic Cooperation and Development, BTM is "the bedrock of practical policy analysis," particularly in cases such as this when collecting new primary data is not feasible (OECD, 2006).

As the name implies, BTM takes a rate of ecosystem benefit delivery calculated for one or more "source areas" and applies that rate to conditions in the "study area." As Batker et al. (2010) state, the method is very much like a real estate appraiser using comparable properties to estimate the market value of the subject property. It is also similar to using an existing or established market or regulated price, such as the price of a gallon of water, to estimate the value of some number of gallons of water supplied in some period of time. The key is to select "comps" (data from source areas) that match the circumstances of the study area as closely as possible.

Typically, values are drawn from previous studies estimating the value of various ecosystem services from similar land cover or ecosystem types. Also, it is benefit (in dollars) per-unit-area-per-year in the source area that is transferred and applied to the number of hectares or acres in the same land cover/biome in the study area. For example, data for the source area may include the value of forest land for recreation. In that case, one would apply the per-acre value of recreation from the source area's forestland to the number of acres of forestland in the study area. Multiplying that value by the number of acres of forestland in the study area produces the estimate of the value of the study area's forests to recreational users. Furthermore, it is important to use source studies that are from regions with underlying economic, social, and other conditions similar to the study area.

Following these principles as well as techniques developed by Esposito et al. (2011), Esposito (2009), and Phillips and McGee (2014, 2016a), and as illustrated in Figure 4, we employ a four-step process to evaluate the short-term and long-term effects of the MVP on ecosystem service value in our study region. The steps are described in greater detail below, but in summary, they are:

1. Assign land and water in the study to one of 10 land uses based on remotely sensed (satellite) data in the National Land Cover Dataset (NLCD) (Fry et al., 2011). This provides the array of land uses for estimating baseline or "without MVP" ecosystem service value.

2. Re-assign or re-classify land and water to what the land cover would most likely be during construction and during ongoing operation.

3. Multiply acreage by per-acre ecosystem service productivity (the "comps,") (in dollars per acre per year) to obtain estimates of annual aggregate ecosystem service value under the baseline/no MVP scenario, for the construction corridor (and period), and for the ROW during

[12] See also Esposito et al. (2011), Flores et al. (2013), and Phillips and McGee (2014) for more recent examples.

ongoing operation.

For simplicity and given the two-year construction period, we assume the construction corridor will remain barren for a full two-year period. We recognize revegetation will begin to occur soon after the trench is closed and fill and soil are returned, but it will still be some time until something like a functioning ecosystem has actually been restored.

4. Subtract baseline (no pipeline) ESV from ESV (with pipeline) for the construction period (and in the construction corridor) and from ESV during ongoing operations (in the ROW) to obtain estimates of the ecosystem service costs imposed annually during the construction and operations period, respectively.

### Step 1: Assign Land to Ecosystem Types or Land Uses

The first step in the process is to determine the area in the 10 land use groups in the study region. This determination is made using remotely sensed data from the National Land Cover Database (NLCD) (Fry et al., 2011). Satellite data provides an image of land in one of up to 21 land cover types at the 30-meter level of resolution;[13] 15 of these land cover types are present in the study region (Table 3 and Figure 5).

**TABLE 3: Land Area Affected By MVP, Study Region Total (See Also Figure 6)**

| Land Use | Baseline acreage in ROW | Baseline acreage in construction corridor, including temp work zones, etc. | Baseline acreage in permanent surface infrastructure |
|---|---|---|---|
| Urban Other | 6.6 | 22.9 | 1.3 |
| Urban Open Space | 23.9 | 85 | 3.3 |
| Wetland | 0.5 | 1.4 | 0 |
| Water | 0.8 | 2.5 | 0 |
| Forest | 663.7 | 1781.4 | 54 |
| Shrub/Scrub | 0.5 | 2 | 0 |
| Grassland | 3.6 | 10.5 | 0.4 |
| Pasture/Forage | 141.5 | 485.3 | 15.6 |
| Cropland | 11.9 | 32.3 | 0.9 |
| Barren | 8.2 | 26.1 | 0.2 |
| **Total** | **861.2** | **2449.4** | **75.7** |

Looking forward to the final step, we will use land use categories to match per-acre ecosystem value estimates from source areas to the eight-county study region. Unfortunately, value estimates are not available for all of the detailed land use categories present in the region. We therefore simplify the NLCD classification by combining a number of classifications into larger categories for which per-acre

[13] Because 30 meters is wider than the right-of-way and not much narrower than the 125-foot construction corridor, we resample the NLCD data to 10m pixels, which breaks each 30m-by-30m pixel into 9 10m-by-10m pixels. This allows for a closer approximation of the type and area of land cover in the proposed ROW and construction corridor.

values are more available. Specifically, low-, medium-, and high-intensity development are grouped as "urban other," and deciduous, evergreen, and mixed forest are grouped as "forest."

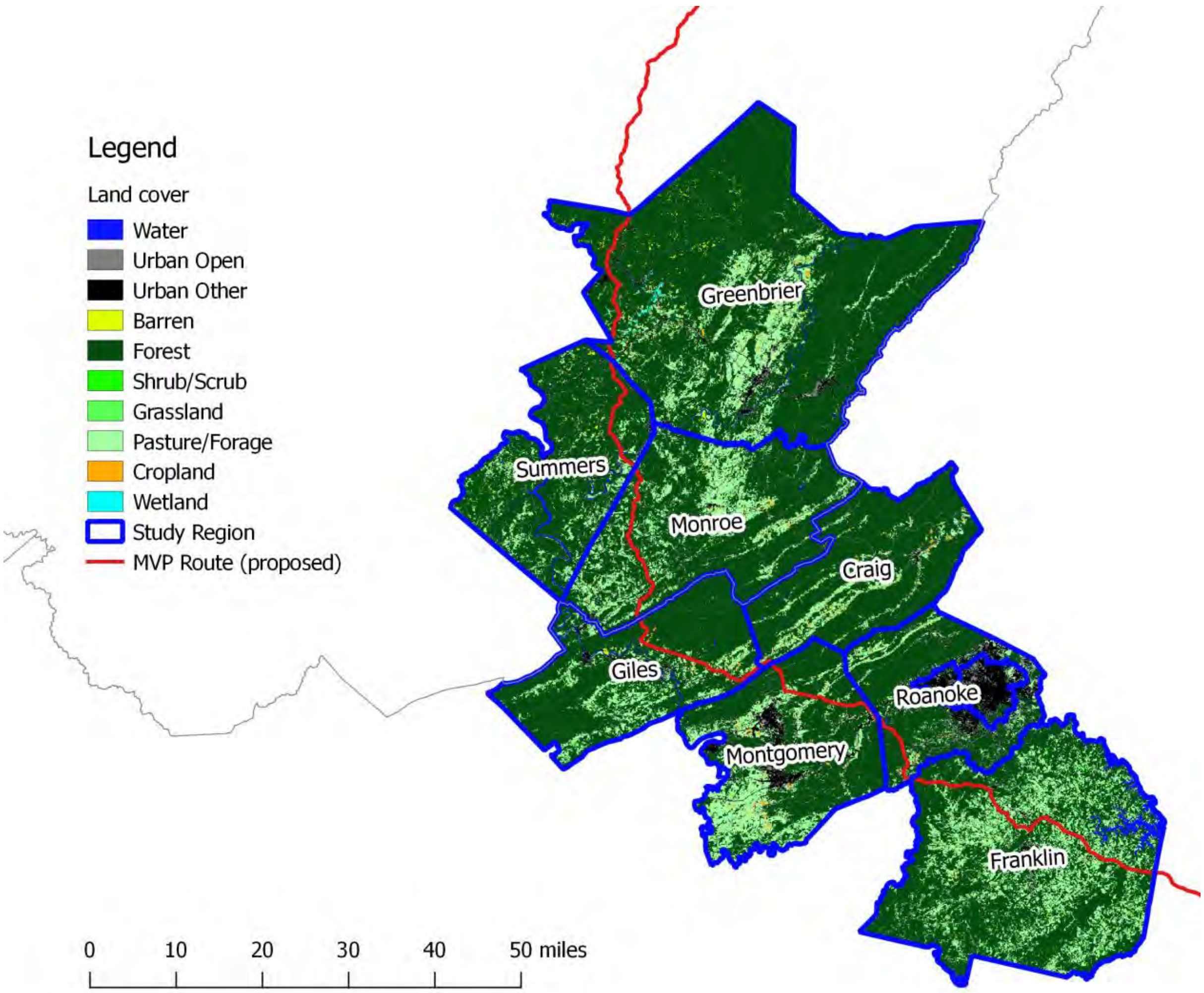


**FIGURE 5: Land Use in the Study Region, as Classified for Ecosystem Service Valuation**

Land cover for the entire study region is shown to display the overall range and pattern of land use. The ecosystem service valuation itself covers only those portions of the study region that would be occupied by the MVP right-of-way and construction corridor.

Sources: Land Cover from National Land Cover Database (Fry, et al. 2011); MVP route digitized from online maps and MVP LLC filings (http://mountainvalleypipeline.info/maps/); Counties from USGS (http://nationalmap.gov).

In addition and for two reasons, we add land in the NLCD category of "woody wetlands" to the "forest" category for two reasons. First, these wetlands would normally become forest in the study region (Johnston, 2014; Phillips & McGee, 2016a). Second, wetlands possess some of the highest per-acre values for several ecosystem services. To avoid over-estimating the ecosystem services contribution of "woody wetlands," we count them as "forest" instead of "wetland."

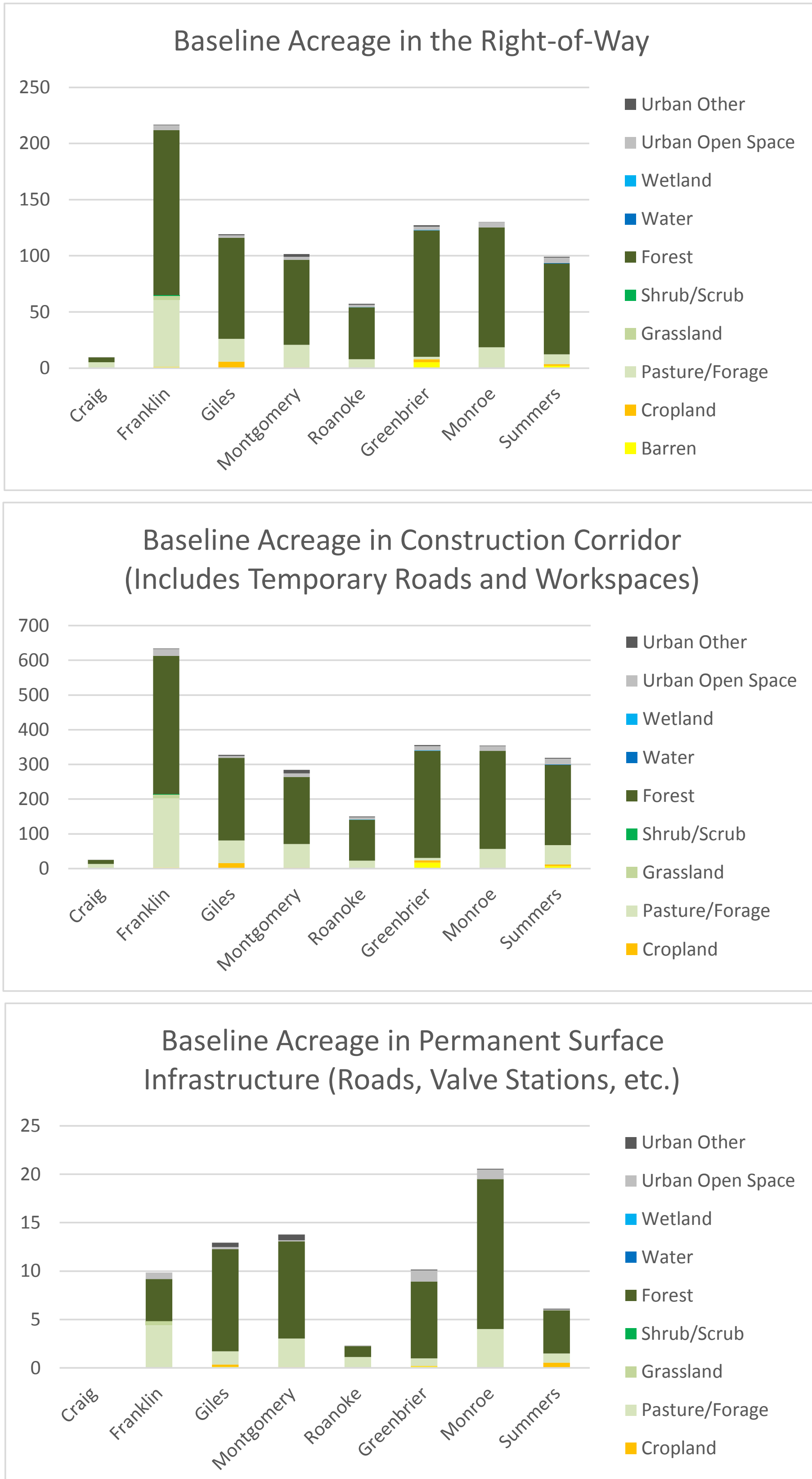


**FIGURE 6: Baseline (Pre-MVP) Land Use, by County, in the Row, Construction Zones, and Permanent Surface Infrastructure. (See also Table 3.)**

In the end, at least for baseline (no pipeline) conditions, we have land in 10 land uses. The total area that would be disturbed in the construction corridor and temporary roads and other work areas is 2,449 acres, of which 861 acres would be occupied by the permanent right-of-way. An additional 76 acres would be devoted to permanent access roads and other installations on the surface. Figure 6 shows the distribution of acreage in the ROW, construction zone, and in land needed for permanent surface infrastructure by county and pre-MVP, or baseline land use.

### Step 2: Re-assign Acreage to New Land Cover Types for the Construction and Operation Periods

We assume all land in the construction corridor will be "barren" or at least possess the same ecosystem service productivity profile as naturally-occurring barren land for the duration of the construction period. Water will remain water during construction. Table 4 lists the reassignment assumptions in detail.

**TABLE 4: Land Cover Reclassification**

| NLCD Category | Reclassification for Baseline | Reclassification for Construction | Reclassification for Ongoing Operation in the ROW | Reclassification for Ongoing Operation Roads and Surface Infrastructure |
|---|---|---|---|---|
| **Barren Land** | Barren | Barren | Barren | Barren |
| **Cultivated Crops** | Cropland | Barren | Pasture/Forage | Barren |
| **Pasture/Hay** | Pasture/Forage | Barren | Pasture/Forage | Barren |
| **Grassland/Herbaceous** | Grassland | Barren | Grassland | Barren |
| **Shrub/Scrub** | Shrub/Scrub | Barren | Shrub/Scrub | Barren |
| **Deciduous Forest** | Forest | Barren | Shrub/Scrub | Barren |
| **Evergreen Forest** | Forest | Barren | Shrub/Scrub | Barren |
| **Mixed Forest** | Forest | Barren | Shrub/Scrub | Barren |
| **Woody Wetlands** | Forest | Barren | Shrub/Scrub | Barren |
| **Open Water** | Water | Water | Water | Barren |
| **Emergent Herbaceous Wetlands** | Wetland | Barren | Wetland | Barren |
| **Developed, Open Space** | Urban Open Space | Barren | Urban Open Space | Barren |
| **Developed, Low Intensity** | Urban Other | Barren | Urban Other | Barren |
| **Developed, Medium Intensity** | Urban Other | Barren | Urban Other | Barren |
| **Developed, High Intensity** | Urban Other | Barren | Urban Other | Barren |

Within the ROW, and for the indefinite period following construction—during ongoing operations—we assume pre-MVP forestland will become shrub/scrub, and cropland will become pasture/forage. We recognize some pre-MVP cropland may be used for crops after construction has been completed, but as expressed in comments to FERC and elsewhere, and as we discovered through personal interviews with agricultural producers in the region, it seems likely that the ability to manage acreage for row crops will be greatly curtailed, if not eliminated entirely by the physical limits imposed by the MVP and by restrictions in easements to be held by MVP LLC. These include limits on the weight of equipment that could cross the corridor at any given point and difficulty using best soil conservation practices, such as tilling along a contour, which may be perpendicular to the pipeline corridor. (This would require extra time and fuel use that could render some fields too expensive to till, plant, or harvest.) Reclassifying cropland as pasture/forage (which is a generally less productive ecosystem service) recognizes these effects while also recognizing some sort of future agricultural production in the ROW (grazing and possibly haying) could be possible.

An additional effect not captured in our methods is long-standing harm to agricultural productivity due to soil compaction, soil temperature changes, and alteration of drainage patterns due to pipeline construction. As agronomist Richard Fitzgerald (2015) concludes, “it is my professional opinion that the productivity for row crops and alfalfa will never be regenerated to its existing present ‘healthy’ and productive condition [after installation of the pipeline]." Thus, the true loss in food and other ecosystem service value from pasture/forage acreage would be larger than our estimates reflect.

Permanent access roads and sites for main line valves are assumed, post construction, to remain in the “barren” land use and produce the corresponding level of ecosystem services.

### Step 3: Multiply Acreage by Per-Acre Value to Obtain ESV

After obtaining acreage by land use in the construction corridor and the ROW, we are ready to multiply those acres times per-acre-per-year ecosystem service productivity (in dollar terms) to obtain total ecosystem service value in each area and for with- and without-pipeline scenarios. Per-acre ecosystem service values are obtained primarily from a database of more than 1,300 estimates compiled as part of a global study known as “The Economics of Ecosystems and Biodiversity” or “the TEEB” (Van der Ploeg et al., 2010).[14] The TEEB database allows the user to select the most relevant per-unit-area values, based on the land use/land cover profile of the study region, comparison of general economic conditions in the source and study areas, and the general “fit” or appropriateness of the source study for use in the study area at hand. After eliminating estimates from lower-income countries and estimates from the U.S. that came from circumstances vastly different from Virginia and West Virginia, we identified 91 per-acre estimates in the TEEB that adequately provide approximations of ecosystem service value in our study region.[15]

[14] Led by former Deutsche Bank economist, Pavan Sukhdev, the TEEB is designed to “[make] nature’s values visible” in order to “mainstream the values of biodiversity and ecosystem services into decision-making at all levels” (“TEEB - The Initiative,” n.d.). It is also an excellent example of the application of the benefit transfer method.

[15] Among those U.S. studies included in the TEEB database that we deemed inappropriate for use here were a study from Cambridge Massachusetts that reported extraordinarily high values for aesthetic and recreational value and the lead author’s own research on the Tongass and Chugach National Forests in Alaska. The latter was excluded due to the vast differences in land use, land tenure, climate, and other factors between the source area and the current study region.

After selecting the best candidate studies and estimates in the TEEB database, we still had some key land use/ecosystem services values (such as food from cropland) without value estimates. To fill some of the most critical gaps, we turned to other studies that examined ecosystem service value in this general region (Phillips, 2015a; Phillips & McGee, 2016b) and to specific data on cropland and pasture/hayland value from Virginia Cooperative Extension and the National Agricultural Statistics Service (Lex & Groover, 2015; USDA National Agricultural Statistics Service, 2016).

For several land cover-ecosystem service combinations, either multiple source studies were available or the authors of those studies reported a range of dollar-per-acre ecosystem service values. We are therefore able to report both a low and a high estimate based on the bottom and top end of the range of available estimates.

In the end, we have 165 separate estimates from 61 unique source studies covering 67 combinations of land uses and ecosystem services. (See Appendix A to this report for a full list of the values and sources that yielded these estimates.) This is still a fairly sparse coverage, given there are 140 possible combinations of the 10 land uses and 14 services. Therefore, we know our aggregate estimates will be lower than they would be if dollar-per-acre values for all 14 services were available to transfer to each of the 10 land use categories in the study region. It is possible to live with that known underestimation, or it is possible to assign per-acre values from a study of one land-use-and-service combination to other combinations. Doing so would introduce unknown over- or perhaps under-estimation of aggregate values. We prefer to take the first course, knowing our estimates are low/conservative and urge readers to bear this in mind when interpreting this information for use in weighing the costs of the proposed MVP.

After calculating acreage and per-acre ecosystem service values, we now calculate ecosystem service value per year for each of the four area/scenario combinations. To repeat, these annual values are:

- Baseline (no pipeline) ecosystem service value in the proposed construction corridor
- Ecosystem service value in the construction corridor during construction
- Baseline (no pipeline) ecosystem service value in the proposed right-of-way
- Ecosystem service value in the right-of-way during the (indefinite) period of ongoing operations[16]

[16] Note that while the ROW and construction corridors overlap in space, they do not overlap in time, at least not from an ecosystem services production standpoint. During construction, the land cover that would eventually characterize the ROW will not exist in the construction corridor. Thus, there is no double counting of ecosystem service values or of costs from their diminution as a result of either construction or ongoing operations.

Value calculations are accomplished according to this formula

$$\text{ESV per year } = \sum_{i,j}[(Acres_j) \times (\$/acre/year)_{i,j}]$$

Where:

| | |
|---|---|
| *$Acres_j$* | is the number of acres in land use (j) |
| *$(\$/acre/year)_{i,j}$* | is the dollar value of each ecosystem service (i) provided from each land use (j) each year. These values are drawn from the TEEB database and other sources listed in Appendix A. |

**Step 4: Subtract Baseline "without MVP" ESV from ESV in "with MVP" Scenario**

With the steps above complete, we now estimate the cost in ecosystem service value of moving from the baseline (no pipeline) or status quo to a scenario in which the MVP is built and operating.

The cost of construction is the ESV from the construction corridor during construction, minus baseline ESV for the construction corridor, multiplied by two. The multiplication by two is due to the conservative assumption that revegetation and restoration to a land use that is functionally different from barren land will take at least two years.

The ecosystem service cost of ongoing operations is ESV from the ROW in the "with MVP" scenario minus the baseline ESV for the ROW. This will be an annual cost borne every year in perpetuity.

## Ecosystem Service Value Estimates

In the baseline or "no pipeline" scenario, the construction corridor and land slated for temporary roads and workspaces produces between $11.4 and $41.1 million per year in ecosystem service value. The largest contributors to this total (at the high end) are aesthetic value, water supply, and protection from extreme events. Under a "with MVP" scenario, and not surprisingly given the temporary conversion to bare/barren land, these figures drop to near zero, or between $451 and $3,552 per year for each of the two years. Taking the difference as described above, estimated per-year ecosystem service cost of the MVP's construction would be between $11.4 and $41.1 million, or between $22.8 and $82.2 million over two years in the eight-county study region (Table 5).

The ecosystem service costs for the ROW are predictably smaller on a per-year basis, but because they will persist indefinitely, the cumulative effect will be much higher. Under the "with MVP" scenario, using minimum values, the annual ecosystem service value from the ROW falls from $4.2 million to about $160,000 for an annual loss of over $4.1 million. At the high end of the range, the ecosystem service value of the ROW would fall from $15.3 million to about $436,000 for an annual loss of $14.8 million in the study region (Table 6).

**TABLE 5: Ecosystem Service Value Lost to the Construction Corridor and Temporary Roads and Workspaces in Each of Two Years, Relative to Baseline, by Ecosystem Service (2015$)**

| | Study Region | | | |
|---|---|---|---|---|
| **Ecosystem Service** | *Baseline (low)* | *Loss (low)* | *Baseline (high)* | *Loss (high)* |
| **Aesthetic Value** | 8,046,503 | (8,046,503) | 32,491,871 | (32,491,871) |
| **Air Quality** | 666,647 | (666,647) | 680,270 | (680,270) |
| **Biological Control** | 12,524 | (12,524) | 30,044 | (30,044) |
| **Climate Regulation** | 209,199 | (209,199) | 228,236 | (228,236) |
| **Erosion Control** | 15,104 | (15,104) | 146,466 | (146,466) |
| **Protection from Extreme Events** | 1,447,945 | (1,447,945) | 1,482,118 | (1,482,118) |
| **Food Production** | 10,929 | (10,929) | 10,929 | (10,929) |
| **Pollination** | 369,769 | (369,769) | 433,706 | (433,706) |
| **Raw Materials** | 43,763 | (43,763) | 297,240 | (297,240) |
| **Recreation** | 64,090 | (63,722) | 967,718 | (965,459) |
| **Soil Formation** | 12,837 | (12,837) | 41,061 | (41,061) |
| **Waste Treatment** | 22,692 | (22,666) | 527,395 | (527,369) |
| **Water Supply** | 84,501 | (84,444) | 2,306,613 | (2,305,346) |
| **Water Flows** | 417,057 | (417,057) | 1,444,340 | (1,444,340) |
| **Total** | **11,423,559** | **(11,423,108)** | **41,088,007** | **(41,084,455)** |

Most of this loss is due to the conversion of forestland to shrub/scrub. Shrub/scrub naturally increases its share of overall ecosystem service value in the “with pipeline” scenario. Those gains are dwarfed, however, by the loss of much more productive forests. Similarly, the ecosystem-service value of cropland falls due to its assumed transition to pasture/forage. While there is some gain in the pasture/forage category, there is a net loss of ecosystem service value from the two agricultural land uses of between $1,000 and $28,000 per year.[17]

**TABLE 6: Ecosystem Service Value Lost Each Year Post Construction in Right-Of-Way, Relative to Baseline, by Ecosystem Service (2014$)**

| | Study Region | | | |
|---|---|---|---|---|
| **Ecosystem Service** | *Baseline (low)* | *Loss (low)* | *Baseline (high)* | *Loss (high)* |
| **Aesthetic Value** | 2,985,838 | (2,945,731) | 12,089,964 | (12,040,073) |
| **Air Quality** | 248,102 | (222,539) | 251,931 | (222,539) |
| **Biological Control** | 4,062 | (1,673) | 10,554 | (8,166) |
| **Climate Regulation** | 68,141 | (32,887) | 75,238 | (39,900) |
| **Erosion Control** | 4,926 | 12,931 | 51,847 | (26,014) |

[17] Note that due to differences in the range of dollars-per-acre estimates available for the various combinations of land use and ecosystem service, there are some instances where an apparent gain at the low end turns into a loss at the high end. For example, and based on the estimates available from the literature, the minimum value for erosion control from shrub/scrub acres is higher than the minimum for forests. Because we assume that forests return to shrub/scrub after the pipeline is in operation, this translates into a net increase in erosion regulation. At the high end, however, available estimates show a higher erosion control value for forests than for shrub/scrub. Thus, the high estimate shows a net loss of erosion control benefits. It is important, therefore, to keep in mind that these estimates are sensitive to the availability of underlying per-acre estimates.

| | | | | |
|---|---|---|---|---|
| **Protection from Extreme Events** | 536,977 | (529,386) | 547,721 | (529,386) |
| **Food Production** | 3,308 | (1,043) | 3,308 | (1,043) |
| **Pollination** | 137,114 | (133,628) | 160,576 | (153,309) |
| **Raw Materials** | 16,306 | (16,278) | 110,739 | (110,711) |
| **Recreation** | 18,729 | 1,738 | 355,391 | (332,073) |
| **Soil Formation** | 4,641 | (4,083) | 15,136 | (14,579) |
| **Waste Treatment** | 8,197 | (7,182) | 194,147 | 37,326 |
| **Water Supply** | 31,478 | (31,450) | 859,334 | (857,620) |
| **Water Flows** | 155,301 | (152,619) | 536,635 | (529,356) |
| **Total** | 4,223,118 | (4,063,831) | 15,262,520 | (14,827,442) |

Finally, the establishment of permanent access roads and other surface installations will entail the conversion of land from various uses to what, from an ecosystem services perspective, will function as barren land. These areas amount to a total of only 76 acres across the study region, so the effect on ecosystem service values are correspondingly small, at least when compared to the impact of the construction zone and ROW. As with the ROW, however, these effects would occur year after year for as long as the MVP exists. The annual loss of ecosystem service value from these areas under a "with MVP" scenario would range from $350,000 to $1.2 million.

It bears repeating the benefit transfer method applied here is useful for producing first-approximation estimates of ecosystem service impacts. For several reasons, we believe this approximation of the effect of the MVP's construction and operation on ecosystem service values is too low rather than too high. These reasons include:

- The estimates include only the loss of value that would otherwise emanate from the ROW, construction corridors, access roads, temporary workspaces, and other surface installations themselves.

  The estimates do not account for the extent to which the construction and long-term presence of the MVP could damage the ecosystem service productivity of adjacent land. During construction, the construction corridor itself could be a source of air and water pollution that may compromise the ability of surrounding or downstream areas to deliver ecosystem services of their own. For example, if sediment from the construction zone that reaches surface waters, the sediment will cause those streams and rivers to lose some of their ability to provide clean water, food (fish), recreation, and other valuable services. This reduced productivity may persist well after construction is complete.[18]

- Over the long term, the right-of-way would serve as a pathway by which invasive species or wildfire could more quickly penetrate areas of interior forest habitat, thereby reducing the natural

[18] This is not a small risk. As noted by the Dominion Pipeline Monitoring Coalition "pipeline construction over steep Appalachian mountains creates significant runoff and slope-failure problems" (Webb, 2015b). In one example, multiple problems during and after construction of a relatively small pipeline on Peters Mountain in Giles County caused extensive erosion and damage to waterways (Webb, 2015a). The coalition points out that "the potential for water resource problems will be greatly multiplied for the proposed larger projects [like the MVP], both in terms of severity and geographic extent."

productivity of those areas and imposing direct costs on communities and landowners in the form of fire suppression costs, lost property, and the costs of controlling invasive species.

- Finally, these estimates reflect only those changes in natural benefits that occur due to changes in conditions on the surface of the land. Particularly because the proposed pipeline would traverse areas of karst topography there is well-founded concern that subsurface hydrology could be affected during construction and throughout the lifetime of the pipeline (Jones, 2015; Pyles, 2015). Blasting and other activities during construction could alter existing underground waterways and disrupt water supply. There is also a risk that sediment and other contaminants could reach groundwater supplies if sinkholes form near the pipeline during construction or afterwards.

## EFFECTS ON PROPERTY VALUE

### Land Price Effects

> ***"I never met a client who would choose, for a family home, a property with a 42" pipeline full of explosive gas over a similar property without such an environmental and personal-safety hazard."***
>
> *– Patricia Tracy, Realtor*
> *Blacksburg, Virginia*

To say the impacts and potential impacts of the MVP on private property value are important to people along its proposed route would be an extreme understatement. The Pipeline Information Network (2015) reviewed all MVP comments submitted to FERC in the first three months of 2015. Some 60% of these comment letters mentioned property value or property rights concerns. Landowners and Realtors along the proposed route of the Mountain Valley Pipeline report have abandoned building plans, seen lower than expected appraisals, and have had buyers walk away from properties potentially affected by the MVP (Adams, 2016). At least one ROW landowner has been told by two insurance agencies that rates would likely increase for properties like hers if, indeed, coverage remains available at all (Roston, 2015).

While it is impossible to know precisely how large an effect the specter of the MVP has already had on land prices, there is strong evidence from other regions that the effect would be negative. In a systematic review, Kielisch (2015) presents evidence from surveys of Realtors, home buyers, and appraisers demonstrating natural gas pipelines negatively affect property values for a number of reasons. Among his key findings relevant to the MVP:

- 68% of Realtors believe the presence of a pipeline would decrease residential property value.
- Of these Realtors, 56% believe the decrease in value would be between 5% and 10%. (Kielisch does not report the magnitude of the price decrease expected by the other 44%.)
- 70% of Realtors believe a pipeline would cause an increase in the time it takes to sell a home. This is not merely an inconvenience, but a true economic and financial cost to the seller.
- More than three quarters of the Realtors view pipelines as a safety risk.

- In a survey of buyers presented with the prospect of buying an otherwise desirable home with a 36-inch diameter gas transmission line on the property, 62.2% stated that they would no longer buy the property at any price. Of the remainder, half (18.9%) stated that they would still buy the property, but only at a price 21%, on average, below what would otherwise be the market price. The other 18.9% said the pipeline would have no effect on the price they would offer.

  Not incidentally, the survey participants were informed that the risks of "accidental explosions, terrorist threats, tampering, and the inability to detect leaks" were "extremely rare" (2015, p. 7).

  Considering only those buyers who are still willing to purchase the property, the expected loss in market value would be 10.5%.[19] This loss in value provides the mid-level impact in our estimates. A much greater loss (and higher estimates) would occur if one were to consider the fact that 62% of buyers are effectively reducing their offer prices by 100%, making the average reduction in offer price for <u>all</u> potential buyers 66.2%.[20] In our estimates, however, we have used the smaller effect (-10.5%) based on the assumption that sellers will eventually find one of the buyers still willing to buy the pipeline-easement-encumbered property.

- Based on five "impact studies" in which appraisals of smaller properties with and without pipelines were compared, "the average impact [on value] due to the presence of a gas transmission pipeline is -11.6%" (Kielisch, 2015, p. 11). The average rises to a range of -12% to -14% if larger parcels are considered, possibly due to the loss of subdivision capability.

These findings are consistent with economic theory about the behavior of generally risk-averse people. While would-be landowners who are informed about pipeline risks and nevertheless decide to buy property near the proposed MVP corridor could be said to be "coming to the nuisance," one would expect them to offer less for the pipeline-impacted property than they would offer for a property with no known risks.

Kielisch's findings demonstrate that properties on natural gas pipeline rights-of-way suffer a loss in property value. Boxall, Chan, and McMillan (2005), meanwhile, show that pipelines also decrease the value of properties lying at greater distances. In their study of property values near oil and gas wells, pipelines, and related infrastructure, the authors found that properties within the "emergency plan response zone" of sour gas[21] wells and natural gas pipelines faced an average loss in value of 3.8%, other things being equal.

The risks posed by the MVP would be different – it would not be carrying sour gas, for example—but there are similarities between the MVP scenario and the situation in the study that makes their finding particularly relevant. Namely, the emergency plan response zones (EPZs) are defined by the health and safety risks posed by the gas operations and infrastructure. Also, in contrast to MVP-cited studies

[19] Half of the buyers would offer 21% less, and the other half would offer 0% less; therefore the expected loss is 0.5(-21%) + 0.5(0%) = -10.5%.

[20] This is the expected value calculated as 0.622*(-100%)+0.189*(-21%)+0.189*(0%).

[21] "Sour" gas contains high concentrations of hydrogen sulfide and poses an acute risk to human health.

showing no price effects (see "Claims that pipelines have no effect on property value may be invalid," below), the Boxall study examines prices of properties for which landowners must inform prospective buyers when one or more EPZs intersect the property.

The MVP has both a high consequence area (HCA) and an evacuation zone radiating from both sides of the pipeline defined by health and safety risks. Whether disclosed or not by sellers, prospective buyers are likely to become informed regarding location of the property relative to the MVP's HCA and evacuation zones or, at a minimum, regarding the presence of the MVP in the study region.

In addition to the emerging body of evidence that there is a negative relationship between natural gas infrastructure and property value, there have been many analyses demonstrating the opposite analog. Namely, it is well-established that amenities such as scenic vistas, access to recreational resources, proximity to protected areas, cleaner water, and others convey positive value to real property.[22] There are also studies demonstrating a negative impact on land value of various other types of nuisance that impose noise, light, air, and water pollution, life safety risks, and lesser human health risks on nearby residents (Bixuan Sun, 2013; Bolton & Sick, 1999; Boxall et al., 2005). The bottom line is that people derive greater value from, and are willing to pay more for, properties that are closer to positive amenities and farther from negative influences, including health and safety risks.

### Claims that pipelines have no effect on property value may be invalid.

Both FERC and MVP LLC have cited several studies purporting to show that natural gas pipelines (and in one case a liquid petroleum pipeline) have at most an ambiguous and non-permanent effect on property values. In its final EIS regarding the Constitution Pipeline, for example, FERC cited two articles concluding, in brief, that effects on property value from the presence of a pipeline can be either positive or negative, and that decreases in values due to a pipeline explosion fade over time (Diskin, Friedman, Peppas, & Peppas, 2011; Hansen, Benson, & Hagen, 2006). In its filing, MVP LLC cites additional studies drawing similar conclusions based on comparison of market and/or assessed prices paid for properties "on" or "near" a pipeline versus those farther away (Allen, Williford & Seale Inc., 2001; Fruits, 2008; Mountain Valley Pipeline LLC, 2015b; Palmer, 2008).

While the studies differ in methods, they are similar in that each fails to take into account two factors potentially voiding their conclusions entirely. First, the studies do not consider that the property value data used do not represent prices arising from transactions in which all buyers have full information about the subject properties. Second, for the most part, the definition of nearness to the pipelines may be inappropriate or inadequate for discerning actual effects on property value of that nearness.

Economic theory holds that for an observed market price to be considered an accurate gauge of the value of a good, all parties to the transaction must have full information about the good. If, on the other hand, buyers lack important information about a good, in this case whether a property is near a potential hazard, they cannot bring their health and safety concerns—their risk aversion—to bear on

[22] Phillips (2004) is one such study that includes an extensive review of the literature on the topic.

their decision about how much to offer for the property. As a result, buyers' offer prices will be higher than they would be if they had full information.

As Albright (2011) notes in response to the article by Disken, Friedman, Peppas, & Peppas (2011):

> The use of the paired-sales analysis makes the assumption of a knowing purchaser, but I believe this analysis is not meaningful unless it can be determined that the purchaser had true, accurate and appropriate information concerning the nature and impact of the gas pipeline on, near or across their property. … I believe that the authors' failure to confirm that the purchasers in any of the paired sales transactions had full and complete knowledge of the details concerning the gas transmission line totally undercut the authors' work product and the conclusions set forth in the article. (p.5)

Of the remaining studies, only Palmer (2008) gives any indication that any buyers were aware of the presence of a pipeline on or near the subject properties. For Palmer's conclusion that the pipeline has no effect on property value to be valid, however, it must be true that **all** buyers have full information, and this was not the case.

The study by Hansen, Benson, and Hagen (2006) actually reinforces the conclusion that when buyers know about a nearby pipeline, market prices drop. The authors found that property values fell after a deadly 1999 liquid petroleum pipeline explosion in Bellingham, Washington. They also found that the negative effect on prices diminished over time. This makes perfect sense if, as is likely, information about the explosion dissipated once the explosion and its aftermath left the evening news and the physical damage from the explosion had been repaired.

We do not think it is appropriate to conclude from this study (as FERC did in the case of the Constitution Pipeline) that natural gas transmission pipelines would have no effect on land prices in today's market. In contrast to Bellingham homebuyers in the months and years after the 1999 explosion, today's homebuyers can query Zillow to see the history of land prices near the pipeline and explore online maps to see what locally undesirable land uses exist near homes they might consider buying. They also have YouTube and repeated opportunities to find and view news reports, citizens' videos, and other media describing and depicting such explosions and their aftermath. Whether the pre-explosion prices reflected the presence of the pipeline or not, it is hard to imagine that a more recent event and the evident dangers of living near a fossil fuel pipeline would be forgotten so quickly by today's would-be homebuyers.

Online based tools have changed the ways people shop for homes. We are now in a real world much closer to the competitive economic model that assumes all buyers have full information about the homes they might purchase. Anyone with an eye toward buying property near the proposed MVP corridor would quickly learn that the property is in fact near the corridor, that there is a danger the property could be adversely affected by the still-pending project approval, and that fossil fuel pipelines and related infrastructure have an alarming history of negative health and environmental effects. Accordingly, the price buyers would offer for a home near the MVP will be lower than the price offered for another farther away or in another community or region entirely.

The second problem with the studies is that while they purport to compare the price of properties near a pipeline to properties not near a pipeline, many or in some cases all of the properties counted as “not near” the pipelines are, in fact, near enough to the subject pipelines that health and safety concerns could influence prices. In both studies written by the Interstate Natural Gas Association of America (INGAA) the authors compare prices for properties directly on a pipeline right-of-way to prices of properties off the right-of-way. However, in almost all cases the geographic scope of the analysis was small enough that most or all of the properties not on the right-of-way are still within the pipelines’ respective evacuation zones (Allen, Williford & Seale Inc., 2001; Integra Realty Resources, 2016).[23]

The 2016 INGAA study suffers from the same problems, including the comparison of properties “on” and “off” the six pipelines analyzed when a majority of the “off” properties are within the pipelines’ evacuation zones. In eight of the case studies—those for which a specific distance from pipeline was reported—an average of 72.5% of the “off” properties were actually within the evacuation zone. (We estimated the evacuation zone based on available information about the pipelines’ diameter and operating pressure.) For the other two pipelines, the study reported a simple “yes” or “no” to indicate whether the property abutted the pipeline in question. For these cases, we assume the author’s methods, while flawed, are at least consistent from one case study to the next meaning it is likely at least 50% or more of the comparison properties (the “off” properties) are in fact within the evacuation zone.

To adequately compare the price of properties with and without a particular feature, there needs to be certainty that properties either have or do not have the feature. It is a case where one actually does need to compare apples to oranges. However, because there is no variation in the feature of interest (i.e., the majority of properties are within the evacuation zone), the study is only looking at and comparing “apples.” In this case, the feature of interest is the presence of a nearby risk to health and safety. With no variation in that feature, one would not expect a systematic variation in the price of the properties. By comparing apples to apples when it should be comparing apples to oranges, the INGAA study reaches the forgone and not very interesting conclusion that properties that are similar in size, condition, and other features <u>including their location within the evacuation zone of a natural gas pipeline</u> have similar prices.

To varying degrees, the other studies cited by FERC and in MVP LLC’s filing suffer from the same problem. Fruits (2008), who analyzes properties within one mile of a pipeline that has a 0.8-mile-wide-evacuation zone (0.4 miles on either side), offers the best chance that a sizable portion of subject properties are in fact “not near” the pipeline from a health and safety standpoint. He finds that distance from the pipeline does not exert a statistically significant influence on the property values, but he does not examine the question of whether properties within the evacuation zone differ in price from comparable properties outside that zone. A slightly different version of Fruits’ model, in other words, could possibly detect such a threshold effect. Such an effect would show up, of course, only if the

[23] This is based on a best estimate of the location of the pipelines derived from descriptions of the pipelines location provided in the study (only sometimes shown on the neighborhood maps) and an approximation of the evacuation zone based on pipeline diameter and operating pressure (Pipeline Association for Public Awareness, 2007).

buyers of the properties included in the study had been aware of their new property's proximity to the pipeline.

In short, one cannot conclude from these flawed studies' failure to identify a negative effect of pipelines on property value that no such effect exists. To evaluate the effects of the proposed MVP on property value, FERC and others must look to studies (including those summarized in the previous section) in which buyers' willingness to pay is fully informed about the presence of nearby pipelines and in which the properties bought are truly different in terms of their exposure to pipeline-related risks.

## Visual Effects and Viewshed Analysis

Information about how the visual effects of natural gas transmission pipelines are reflected in property value is scarcer than information related to health and safety effects. On one hand, we know better views increase property value. Conversely, utility corridors from which power lines can be seen decrease property values (by 6.3% in one study) (Bolton & Sick, 1999). This suggests that a pipeline corridor reduces property value either by impairing a good view or, if like power lines, by simply being unattractive. It is reasonable to conclude that the proposed MVP would have effects on property value that are mediated through visual effects, but the literature to date does not offer clear guidance on how large or strong the effects may be. We therefore have not included separate estimates of the impact of the MVP on property value in the viewshed. Moreover, we do not wish to double-count a portion of the impact of the MVP on "Aesthetics," which is already included among the ecosystem service value effects.

We do want to know, however, how many properties might suffer a portion of that lost aesthetic value. To keep the estimate conservative, we only count properties with a higher-than-average likelihood the MVP corridor could be seen from them. To determine this for each parcel, a GIS-based visibility analysis provides an estimate of how many points along the pipeline could potentially be seen from each 30m-by-30m spot in the study region. To keep the computing needs manageable, we analyzed a sample of points placed at 100m intervals along the proposed MVP route.

Because weather, smog, and other conditions limit the distance at which one can see anything in the mountains and valleys of Virginia and West Virginia, we restricted the scope of analysis for any given point on the pipeline to spots in the study region that lie within a 25-mile radius. We analyzed a section of the MVP beginning 25 miles north of the western boundary of Greenbrier County, West Virginia that extended to a point 25 miles east of the eastern boundary of Franklin County, Virginia.

By tallying the number of points on the pipeline corridor that could be seen from each spot in the study region and then connecting those spots to parcel boundaries, we obtain an estimate of how much of the pipeline could be seen from some spot within a given parcel. In Figure 6, yellow spots on the maps are points where between 1 and 10 points on the pipeline are visible, whereas orange and red spots have a view of up to as many as 251 points. Since each point represents 100 meters of pipeline, there are places in the study region where 25.1 km, or 15.6 miles, of pipeline corridor could be visible.

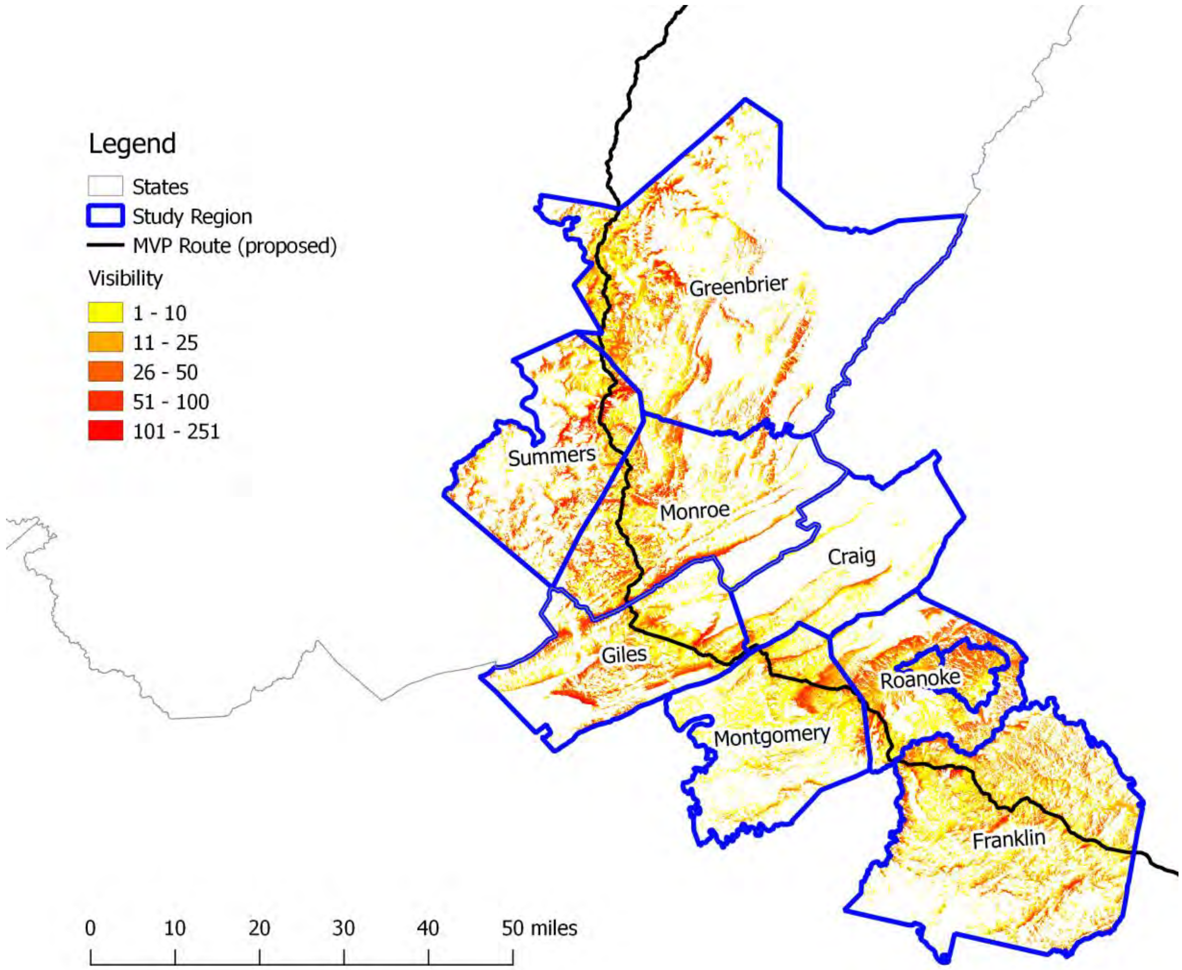


**FIGURE 7: Visibility of the Proposed Mountain Valley Pipeline**

The color of each point on the map indicates the number of waypoints, spaced 100m apart along the MVP route and only those within 25 miles,that could be seen from each point. Note that the analysis is based on elevation only, and does not take into account the extent to which buildings or trees may mask views of the pipeline corridor.

Sources: MVP route digitized from online maps and MVP LLC filings (http://mountainvalleypipeline.info/maps/); Counties from USGS (http://nationalmap.gov); Visibility analysis thanks to Bryan Behan and Stockton Maxwell of Radford University.

Taking into account those spots on nearly every parcel from which the MVP corridor is not visible, the average of the maximum number of points visible from a parcel is 10. This serves as our threshold for identifying parcels from which the pipeline would be "visible." Parcels containing no locations (again each spot is a 30m-by-30m square) from which more than 10 pipeline points are visible are considered to have no view of the pipeline. By this rule, and out of 253,880 parcels in the study region, 78,553 parcels, or just under one-third, would have a potential view of the pipeline.[24] The total value of these properties is currently $16.8 billion.

We call this a potential view of the pipeline because we have not taken other visual obstructions such as trees or buildings into account. In particular, smaller parcels in more densely developed areas could be at elevations relative to the pipeline which would make it possible to see the MVP corridor, but the

[24] Because GIS parcel maps are unavailable for Craig and Monroe Counties, those counties are not included in these figures.

house next door may block that view. The restriction of our analysis to those parcels that have comparatively many spots from which to potentially see the pipeline mitigates this limitation of our GIS analysis. The reason is simply that smaller urban lots have very few 30-meter-square spots to begin with. A parcel has to be at least 10 spots in size (2.2 acres), with the pipeline visible from every spot, to cross the 10-spot threshold.

## Parcel Values

For five of the eight counties in the study region, GIS data on parcel boundaries and corresponding tabular data with parcel value was obtained from the jurisdictions' public records. For the remaining three counties, electronic data on parcel boundaries, parcel values, or both were unavailable. In those cases, we adopted variations on a second-best approach to ensure more complete coverage of land value effects.

- Summers County, WV parcel boundaries were available, but the corresponding parcel values were not. We therefore used median house value from the US Census Bureau's American Community Survey (ACS) (2014) as a proxy. After adjusting the ACS figures for inflation, we attached those values to each parcel, according to which block group the parcel occupies.[25]

- Monroe County, WV parcel boundaries are viewable via the County's online map service, which allowed us to develop a list of parcels crossed by the ROW and those that overlap the evacuation zone. Similar to Summers County, we used median house value from ACS as a proxy for parcel value.

- For Craig County, parcel maps and corresponding parcel values are not available. MVP's route map, however, does show the 10 parcels crossed by the (ROW) through the County's southwest corner. We assume that 10 more parcels would be within the evacuation zone. For parcel value, we use the same proxy from ACS.

Two other features of the parcel data required adjustments prior to performing any land value impact calculations. First, the Giles County data had instances in which two or more individual tracts in different parts of the County are listed on a single tax record with a single property value. The consequence is that the value of all of the land connected to such multi-tract tax records would be swept up with the value of just those tracts actually crossed by the proposed ROW, or in the evacuation zone. To avoid overstating impacts, we split the multi-tract parcels into separate tax records and assigned each tract its own value based on its size and the per-acre value of the original multi-tract parcel.

The second remaining issue deals with public land that is unlikely to be sold and therefore does not possess any market value. To ensure these properties would not inflate overall property value effects, we used the "Protected Areas Database" from the National Gap Analysis Program to identify fee-owned conservation properties, such as portions of the Jefferson National Forest and state, county, and

[25] Because many parcels overlap block group boundaries, each parcel is assigned to a block according to whether its centroid, or geometric center, lies within the block group.

municipal parks (Conservation Biology Institute, 2012). Once identified, we set the value of all such properties equal to zero.

With all of these adjustments made, there remains the comparatively straightforward matter of identifying parcels of six types for which one could expect some effect of the MVP on the value. In order of increasing distance from the pipeline itself, these are:

1. Parcels crossed by the right-of-way
   (716 parcels, with total value (before MVP) of $125.9 million)
2. Parcels crossed by the construction corridor
   (768 parcels, with total value (before MVP) of $132.6 million)
3. Parcels at least partially within the high consequence area (HCA)
   (2,333 parcels, with total value (before MVP) of $320.6 million)
4. Parcels at least partially within the evacuation zone
   (8,221 parcels, with total value (before MVP) of $972.6 million)
5. Parcels from which the pipeline would be visible (as defined in the previous section)
   (78,553, with total value (before MVP) of $16.8 billion, not counting Monroe or Craig County)[26]

Note there is overlap among these zones. All ROW parcels are within the construction, HCA, and evacuation zones, for example. To avoid double counting we apply only one land value effect to any given parcel. ROW parcels are assumed to suffer no further reduction in value due to their location within the evacuation zone.

We have not considered the construction corridor separately this analysis. Even though the additional 52 parcels and $6.7 million in value (relative to parcels in the ROW) are not trivial, we do not have a basis for estimating a change in value that is separate from or in addition to the change due to the parcels' proximity to the ROW or their location within the evacuation zone.

*[Upon learning of the proposed MVP route through my property,] I immediately put the land on the market, disclosing its [bisection] by the pipeline…I was told by a realtor that a sale was out of the question, as the land had lost its value for building…. As of now I have not received any offers except ones that make a purchase contingent on the pipeline not being built. Apparently buyers do care.*

*- Christian M. Reidys, Ph.D.*
*Montgomery County Landowner*

Furthermore, we treat parcels in the HCA and in the evacuation zone the same way and apply a single land value change to all parcels in the evacuation zone. Arguably, there should be a larger effect on parcels in the HCA than those only in the evacuation zone. Living with the possibility of having to evacuate one's home at any time day or night could have a smaller effect on property value than living with the possibility of not surviving a "high consequence" event and, therefore, not having the chance to evacuate at all. We do not have data or previous study

[26] Monroe and Craig County are excluded because we do not have the necessary GIS parcel boundary data.

results that allow us to draw such a distinction, so instead we apply the lower evacuation zone effect to all HCA and evacuation zone parcels.

To summarize, Table 7 repeats a portion of Table 2, but with the property value effects in place of check marks.

**TABLE 7: Summary of Marginal Property Value Effects**

| Values / Effects | Right-of-Way (Low, Medium, & High Effects) | High Consequence Area | Evacuation Zone | Pipeline Viewshed |
|---|---|---|---|---|
| **Land / Property Value** | -4.2%[a]<br>-10.5%[b]<br>-13.0%[c] | -3.8%[d] | | Impact included with Ecosystem Services |

Notes:

a. Kielisch, Realtor survey in which 56% of respondents expected an effect of between -5% and -10% (0.56*-7.5% = -4.2%).
b. Kielisch, buyer survey in which half of buyers still in the market would reduce their offer on a property with a pipeline by 21% (0.50*-0.21 = -10.5%).
c. Kielisch, appraisal/impact studies showing an average loss of between -12% and -14% (-13% is the midpoint)
d. Boxall, study in which overlap with an emergency planning zone drives, on average, a 3.8% reduction in price. We apply this reduction ONLY to those parcels in the evacuation zone that are not also in the ROW or within one half mile of the compressor station.

## Estimated Land Value Effects

Following the procedures outlined in the previous section, our conservative estimate for costs of the proposed MVP would include between $42.2 million and $53.3 million in diminished property value. Some of the most intense effects will be felt by the owners of 716 parcels in the path of the right-of-way, who collectively would lose between $5.3 million and $16.4 million in property value. Some 8,221 additional parcels lie outside the ROW but are within or touching the evacuation zone. These parcels' owners would lose an estimated $37.0 million (Table 8). A far greater number of parcels, 78,553, would experience a loss in value due to diminished quality of the view from their properties.

Based on median property tax rates in each county, these one-time reductions in property value would result in reductions in property tax revenue of between $243,500 and $308,400 per year (Table 9). To keep their budgets balanced in the face of this decline in revenue, the counties would need to increase tax rates, cut back on services, or both. The loss in revenue would be compounded by the likelihood that the need for local public services, such as road maintenance, water quality monitoring, law enforcement, and emergency preparedness/emergency response could increase. The MVP could drive up expenses while driving down the counties' most reliable revenue stream.[27]

[27] We recognize that MVP anticipates making tax payments, but because those payments are tied to net income from the operation of the pipeline, they may fluctuate from year to year or disappear entirely if pipeline operations become unprofitable.

**TABLE 8: Summary of Land Value Effects, by Zone and County**

| | Effects in Right-of-Way | | | Effects in Evacuation Zone |
|---|---|---|---|---|
| **Area** | **Realtor Survey (4.2%)** | **Buyer Survey (10.5%)[a]** | **Impact Studies (13.0%)** | **Boxall Study (3.8%)** |
| ***Study Region*** | -5,288,289 | -13,220,723 | -16,368,514 | -36,958,088 |
| ***Virginia Portion*** | -4,484,041 | -11,210,102 | -13,879,174 | -30,656,302 |
| **Craig** | -60,223 | -150,557 | -186,404 | -54,487 |
| **Franklin** | -2,138,174 | -5,345,434 | -6,618,157 | -14,855,120 |
| **Giles** | -792,099 | -1,980,248 | -2,451,735 | -4,174,604 |
| **Montgomery** | -714,101 | -1,785,252 | -2,210,312 | -7,009,533 |
| **Roanoke** | -779,444 | -1,948,611 | -2,412,566 | -4,562,557 |
| ***West Virginia Portion*** | -804,248 | -2,010,620 | -2,489,339 | -6,301,786 |
| **Greenbrier** | -186,961 | -467,402 | -578,688 | -1,438,278 |
| **Monroe** | -382,228 | -955,571 | -1,183,088 | -3,321,634 |
| **Summers** | -235,059 | -587,647 | -727,563 | -1,541,874 |

**TABLE 8: Continued**

| | Total of ROW and Evacuation Zone Effects | | |
|---|---|---|---|
| **Area** | **Low** | **Medium** | **High** |
| ***Study Region*** | -42,246,377 | -50,178,810 | -53,326,601 |
| ***Virginia Portion*** | -35,140,343 | -41,866,404 | -44,535,476 |
| **Craig** | -114,710 | -205,045 | -240,892 |
| **Franklin** | -16,993,293 | -20,200,554 | -21,473,277 |
| **Giles** | -4,966,703 | -6,154,852 | -6,626,339 |
| **Montgomery** | -7,723,634 | -8,794,785 | -9,219,845 |
| **Roanoke** | -5,342,002 | -6,511,168 | -6,975,123 |
| ***West Virginia Portion*** | -7,106,034 | -8,312,406 | -8,791,125 |
| **Greenbrier** | -1,625,239 | -1,905,680 | -2,016,966 |
| **Monroe** | -3,703,862 | -4,277,204 | -4,504,721 |
| **Summers** | -1,776,933 | -2,129,522 | -2,269,438 |

In addition to factors that make our estimates of the effects on property value conservative,[28] there is one other factor that makes the estimates of effects on property taxes lower than expected if the MVP is permitted. Some portion of properties in the ROW are currently undeveloped but still assessed at a

[28] These factors include using the lower expected price reduction from the buyer survey and applying the same price reduction to the entire evacuation zone (including the HCA).

value that assumes a single house site. Depending on where and how the ROW crosses these properties, it is likely that some will lose their potential usefulness for future residential or other development. In those cases, the assessed value (which by law reflects market value) will fall, and tax revenue generated by future development will never materialize.

**TABLE 9: Effects on Local Property Tax Revenue**

| Area | Median Tax Rate (% of Value)[a] | Lost Property Tax Revenue | | |
|---|---|---|---|---|
| | | Low | Medium | High |
| ***Study Region*** | | -243,476 | -289,966 | -308,414 |
| ***Virginia Portion*** | | -217,097 | -259,111 | -275,783 |
| **Craig** | 0.50% | -574 | -1,025 | -1,204 |
| **Franklin** | 0.47% | -79,868 | -94,943 | -100,924 |
| **Giles** | 0.72% | -35,760 | -44,315 | -47,710 |
| **Montgomery** | 0.67% | -51,748 | -58,925 | -61,773 |
| **Roanoke** | 0.92% | -49,146 | -59,903 | -64,171 |
| ***West Virginia Portion*** | | -26,379 | -30,855 | -32,631 |
| **Greenbrier** | 0.42% | -6,826 | -8,004 | -8,471 |
| **Monroe** | 0.36% | -13,334 | -15,398 | -16,217 |
| **Summers** | 0.35% | -6,219 | -7,453 | -7,943 |

a. Source: Property Taxes By State (Virginia Counties and Independent Cities) (propertytax101.org, 2015).

## EFFECTS ON ECONOMIC DEVELOPMENT

Across the study region, county-level economic development plans recognize the importance of a high quality of life, a clean environment, and scenic and recreational amenities to the economic future of people and communities. Franklin County's Comprehensive Plan, for example, states that "the County wishes to maintain its rural character and scenic views…" (Franklin County Planning Commission, 2007). Greenbrier County's Comprehensive Plan notes the County's melding of old and new economy businesses (farming and high tech, for example) and recognizes that "a healthy environment is central to citizens' health, welfare, and quality of life" (Greenbrier County Planning Commission, 2014).

The MVP would undermine the progress toward these visions if the loss of scenic and recreational amenities, the perception and the reality of physical danger, and environmental and property damage were to discourage people from visiting, relocating to, or staying in the study region. Workers, businesses, and retirees who might otherwise choose to locate along the MVP's proposed route will instead pick locations retaining their rural character, productive and healthy landscapes, and promise for a higher quality of life.

This is already occurring in the region. With the possibility of the MVP looming, business plans have stalled and the real estate market has slowed. Study region residents are also concerned about the effect the MVP could have on the economy. Based on the Pipeline Information Network's review of comment letters submitted in the first three months of 2015, more than half mentioned the economy,

### Forgone Economic Development: Sustainable Agriculture

Owners Patti and Constantine Chlepas describe their 23-acre Birdsong Farm as “pristine land in the heart of Monroe County.” They use organic practices to produce natural raw honey and natural beeswax products. In part because pesticides are threatening honeybee operations worldwide, Birdsong Farm is an oasis from which the Chlepas can sell bees to and serve as mentors for apiarists in other places that have been hit hard. With the proposed MVP right-of-way adjacent to their property—and the likelihood that the ROW would be maintained using chemical defoliants that could harm bees—the owners are concerned that their core business would be wiped out.

The Chlepas have put on hold their planned investment in a pick-your-own strawberry operation and a new line of business selling locally-grown fresh strawberries, strawberry plugs, and value-added products to sell in an on-site store. Birdsong Farm was planning to hire employees to help run their local operation. However, because of the MVP, they cancelled their grant to build a high tunnel greenhouse, and estimate the long-term loss in revenue to the County may run as high as half a million dollars.

with property value, tourism, recreation, and agriculture looming large in citizens’ concerns (Pipeline Information Network, 2015).

These fears are consistent with research results from this region and around the country demonstrating that quality of life is often of primary importance when people choose places to visit, live, or do business. As Niemi and Whitelaw state, “as in the rest of the Nation, natural-resource amenities exert an influence on the location, structure, and rate of economic growth in the southern Appalachians. This influence occurs through the so-called people-first-then-jobs mechanism, in which households move to (or stay in) an area because they want to live there, thereby triggering the development of businesses seeking to take advantage of the households’ labor supply and consumptive demand” (1999, p. 54). They note that decisions affecting the supply of amenities “have ripple effects throughout local and regional economies” (p. 54).

Along similar lines, Johnson and Rasker (1995) found that quality of life is important to business owners deciding where to locate a new facility or enterprise and whether to stay in a location already chosen. This is not surprising. Business owners value safety, scenery, recreational opportunities, and quality of life factors as much as residents, vacationers, and retirees.

It is difficult to predict just how large an effect the MVP would have on decisions about visiting, locating to, or staying in the study region. Even so, based on information provided by business owners to FERC and as part of this research, we can consider reasonable scenarios for how the MVP might affect key portions of the region’s overall economy.

The study region’s residents believe the MVP will harm the travel and tourism industry. In the words of the owner of one recreation and tourism business in Summers County, West Virginia, the MVP would “completely destroy the use, purpose, business operation, well, commercial septic system, two rental houses, and public campground on [the] property,” with one-time losses valued at $800,000, not to mention the owners loss of livelihood and employment (Berkley, 2015). While more systematic research could provide refined estimates of the impact of natural gas transmission pipelines on recreation and tourism spending, one plausible scenario is that the impact is at

> ***Recognizing that a healthy environment is central to citizens' health, welfare, and quality of life, Greenbrier County strongly supports the wise stewardship of our natural environment, including air and water resources, agricultural and forest resources, and geologic resources, with special emphasis on the protection of environmentally sensitive areas and features (springs, sinkholes, caves, other karst features, floodplains, and wetlands) which contribute to overall environmental health and citizens' quality of life.***
>
> *–Greenbrier County Comprehensive Plan*

least as high as the minimum of these business owners' reported expectations. If the MVP were to cause a 10% drop in recreation and tourism spending from the 2014 baseline, the MVP could mean $96.8 million less in travel expenditures each year. Those missing revenues would otherwise support roughly $24.3 million in payroll, $2.6 million in local tax revenue, $4.8 million in state tax revenue, and 1,073 jobs in the eight-county region's recreation and tourism industry each year.[29] In the short run, these changes multiply through the broader economy as recreation and tourism businesses buy less from local suppliers and fewer employees spend their paychecks in the local economy. As with the reduction in local property taxes, lost tax revenue from a reduction in visitation and visitor spending would squeeze local governments trying to meet existing public service needs as well as those additional demands created by the MVP.

Along similar lines, retirement income is an important economic engine that could be adversely affected by the MVP. In county-level statistics from the US Department of Commerce, retirement income shows up in investment income and as age-related transfer payments, including Social Security and Medicare payments. In the study region, investment income grew by 0.8% per year from 2000 through 2014, and age-related transfer payments grew by 5.8% per year. During roughly the same time period (through 2013), the number of residents age 65 and older grew by 15.1% (1.2% per year), and this age cohort now represents 15.5% of the total population.[2]

It is difficult to precisely quantify the effect of the MVP on retirement income, but given the expression of concern from residents about changes in quality of life, safety, and other factors influencing retirees' location decisions, it is important to consider that some change is likely. Here, we consider what just a *10% slowing of the rate of increase* might entail. Such a scenario entails an annual decrease in investment income and age-related transfer payments of approximately $15.6 million. That loss would ripple through the economy as the missing income is not spent on groceries, health care, and other services such as restaurant meals, home and auto repairs, etc.

The same phenomenon also applies to people starting new businesses or moving existing businesses to communities in the study region. This may be particularly true of sole proprietorships and other small businesses who are most able to choose where to locate. As noted, sole proprietors account for a large and growing share of jobs in the region. If proprietors' enthusiasm for starting businesses in the study

[29] Raw data on travel expenditures is from the Virginia Tourism Corporation (2015) and Dean Runyan Associates (2015). This reduction in economic activity would be in addition to the lost recreation benefits (the value to the visitors themselves over and above their expenditures on recreational activity) that are included with ecosystem service costs above.

region were dampened to the same degree as retirees' enthusiasm for moving there, the 10% reduction in the rate of growth would mean 722 fewer jobs and $2.0 million less in personal income.

For "bottom line" reasons (e.g., cost of insurance) or due to owners' own personal concerns, businesses in addition to sole proprietorships might choose locations where the pipeline is not an issue. If so, further opportunities for local job and income growth will be missed.

These are simple scenarios and the actual magnitude of these impacts of the MVP will not be known unless and until the pipeline is built. Even so, and especially because the pipeline is promoted by supporters as bringing some jobs and other economic benefits to the region, it is important to consider the potential for loss.

> ***A pipeline route through here will destroy our farm business. Our customers drive here for the scenery and tranquility as much as for the fresh blueberries. Construction of a pipeline this large does not fit into this picture. Our customers would recoil and take their business elsewhere.***
>
> *–Shirley & Lewis Woodall*
> *Craig County, Virginia*

## CONCLUSIONS

The full costs of the proposed Mountain Valley Pipeline in the eight-county study area and beyond are wide-ranging. They include one-time costs like reductions in property value and lost ecosystem services during pipeline construction, which we estimate to be between $65.1 and $135.5 million. Plus there are ongoing costs like lost property tax revenue, diminished ecosystem service value, and dampened economic growth that would recur year after year for the life of the pipeline. Our estimates of the annual costs range from $119.1 to $130.8 million per year. Most of these costs would be borne by residents, businesses, and institutions in Craig, Franklin, Giles, Montgomery, Roanoke, Greenbrier, Monroe, and Summers Counties.

By contrast, the MVP's one local benefit is much smaller. It is an estimated average tax payment of $6.1 million per year (for the five Virginia counties) and $4.5 million per year (for the 3 West Virginia counties) through 2025 (Ditzel, Fisher, & Chakrabarti, 2015a, p. 15, 2015b, p. 13). Other MVP-promoted benefits, such as jobs from the MVP's construction and operation and those stemming from lower energy costs, would accrue primarily in other places (Ditzel et al., 2015a, 2015b).[30]

The decision to approve or not approve the MVP does not hinge on a simple comparison of estimated benefits and estimated costs. The scope and magnitude of the costs outlined here, however, reflect an important component of the full extent of the MVP's likely environmental effects that must be considered when making the decision. Impacts on human well-being, including but not limited to those that can be expressed in dollars-and-cents, must be taken into account by the Federal Energy Regulatory Commission and others weighing the societal value of the Mountain Valley Pipeline.

If these considerations and FERC's overall review result in selection of the "no-action" alternative and the Mountain Valley Pipeline is never built, most of the costs outlined in this report will be avoided. It

[30] Due to issues with the methods and assumptions used in the MVP-sponsored studies, the benefit estimates they present may be inflated. See Phillips (2015b) for a review.

is *most*, but not *all* costs because there has already been the cost of delaying implementation of business plans, the cost of houses languishing on the market, and the cost to individuals of the stress, time, and energy diverted to concern about the pipeline rather than what would normally (and more productively) fill their lives.

Another possible scenario is that the FERC, considering the impacts of the MVP *as currently proposed* on ecosystem services, property values, and economic development, would conduct a thorough analysis of all possible alternatives. Those alternatives may include using existing gas transmission infrastructure (with or without capacity upgrades), routing new gas transmission lines along existing utility and transportation rights-of-way, and/or scaling down permitted new pipeline capacity to match regional gas transmission needs (as opposed to permitting pipelines on a company-by-company basis). In this case, estimates of these impacts should inform the choice of a preferred alternative that minimizes environmental damage and, thereby, minimizes the economic costs to individuals, businesses, and the public at large.

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## APPENDIX A:
## CANDIDATE PER-ACRE VALUES FOR LAND-USE AND ECOSYSTEM SERVICE COMBINATIONS

As explained under "Effects on Ecosystem Service Value," the benefit transfer method applies estimates of ecosystem service value from existing studies of "source areas" to the "study area," which in this case is the proposed MVP corridor. This application is done on a land-use-by-land-use basis. So, for example, values of various ecosystem services associated with forests in the source area are applied to forests in the study area. The table below lists all of the values from source area studies considered for our calculations.

| Land Use | Ecosystem Service | Minimum $/acre/year | Maximum $/Acre/year | Source Study |
|---|---|---|---|---|
| Cropland | Aesthetic | 35.01 | 89.23 | (Bergstrom, Dillman, & Stoll, 1985) |
| | Biological Control | 15.21 | 15.21 | (Brenner Guillermo, 2007) * |
| | Biological Control | 14.38 | 204.95 | (Cleveland et al., 2006) |
| | Erosion | 27.31 | 72.55 | (Pimentel et al., 2003) * |
| | Food | 33.25 | 33.25 | (Lex & Groover, 2015) |
| | Pollination | 10.14 | 10.14 | (Brenner Guillermo, 2007) * |
| | Pollination | 13.89 | 13.89 | (Robinson, Nowogrodzki, & Morse, 1989) |
| | Pollination | 47.43 | 1,987.97 | (Winfree, Gross, & Kremen, 2011) |
| | Recreation | 18.77 | 18.77 | (Brenner Guillermo, 2007) * |
| | Recreation | 2.16 | 5.02 | (Knoche & Lupi, 2007) |
| | Soil Fertility | 7.28 | 7.28 | (Pimentel, 1998) * |
| | Soil Fertility | 115.23 | 115.23 | (Pimentel et al., 2003) |
| | Waste | 132.26 | 132.26 | (Perrot-Maître & Davis, 2001) * |
| Grasslands | Aesthetic | 102.38 | 116.61 | (Ready, Berger, & Blomquist, 1997) |
| | Biological Control | 15.21 | 15.21 | (Brenner Guillermo, 2007) * |
| | Climate | 3.55 | 3.55 | (Brenner Guillermo, 2007) * |
| | Erosion | 17.48 | 17.48 | (Barrow, 1991) * |
| | Erosion | 68.28 | 68.28 | (Sala & Paruelo, 1997) * |
| | Food | 15.50 | 15.50 | (Lex & Groover, 2015) * |
| | Pollination | 16.23 | 16.23 | (Brenner Guillermo, 2007) * |
| | Soil Fertility | 3.55 | 3.55 | (Brenner Guillermo, 2007) * |
| | Waste | 55.28 | 55.28 | (Brenner Guillermo, 2007) * |
| | Waste | 5.88 | 64.40 | (Ministerie van Landbouw & Natuur en Voedselkwaliteit, 2006) * |
| | Water Flows | 2.54 | 2.54 | (Brenner Guillermo, 2007) * |
| Pasture | Aesthetic | 102.38 | 116.61 | (Ready et al., 1997) |
| | Biological Control | 15.21 | 15.21 | (Brenner Guillermo, 2007) * |
| | Climate | 3.55 | 3.55 | (Brenner Guillermo, 2007) * |
| | Erosion | 17.48 | 17.48 | (Barrow, 1991) * |
| | Erosion | 68.28 | 68.28 | (Sala & Paruelo, 1997) * |
| | Food | 15.50 | 15.50 | (Lex & Groover, 2015) |
| | Pollination | 16.23 | 16.23 | (Brenner Guillermo, 2007) * |
| | Soil Fertility | 3.55 | 3.55 | (Brenner Guillermo, 2007) * |

| Land Use | Ecosystem Service | Minimum $/acre/year | Maximum $/Acre/year | Source Study |
|---|---|---|---|---|
| Pasture, cont'd | Waste | 55.28 | 55.28 | (Brenner Guillermo, 2007) * |
| | Waste | 5.88 | 64.40 | (Ministerie van Landbouw & Natuur en Voedselkwaliteit, 2006) * |
| | Water Flows | 2.54 | 2.54 | (Brenner Guillermo, 2007) * |
| Shrub/Scrub | Air Quality | 37.26 | 37.26 | (Ministerie van Landbouw & Natuur en Voedselkwaliteit, 2006) * |
| | Climate | 7.27 | 7.27 | (Croitoru, 2007) * |
| | Erosion | 22.75 | 22.75 | (Ministerie van Landbouw & Natuur en Voedselkwaliteit, 2006) * |
| | Pollination | 1.41 | 7.10 | (Robert Costanza, Wilson, et al., 2006) |
| | Recreation | 3.95 | 3.95 | (Haener & Adamowicz, 2000) |
| | Waste | 46.35 | 46.35 | (Croitoru, 2007) * |
| | Waste | 0.10 | 324.35 | (Ministerie van Landbouw & Natuur en Voedselkwaliteit, 2006) * |
| Forest | Aesthetic | 4,439.71 | 18,141.99 | (Nowak, Crane, Dwyer, & others, 2002) |
| | Air Quality | 372.57 | 372.57 | (Ministerie van Landbouw & Natuur en Voedselkwaliteit, 2006) * |
| | Biological Control | 8.91 | 8.91 | (Wilson, 2005) * |
| | Biological Control | 2.54 | 2.54 | (Brenner Guillermo, 2007) * |
| | Climate | 67.45 | 67.45 | (Brenner Guillermo, 2007) * |
| | Climate | 56.89 | 56.89 | (Robert Costanza, d'Arge, et al., 2006) |
| | Erosion | 61.87 | 61.87 | (Brenner Guillermo, 2007) * |
| | Erosion | 3.09 | 36.09 | (Zhou, Al-Kaisi, & Helmers, 2009) |
| | Extreme Events | 797.66 | 797.66 | (Weber, 2007) |
| | Food | 0.13 | 0.13 | (Wilson, 2005) * |
| | Pollination | 202.87 | 202.87 | (Brenner Guillermo, 2007) * |
| | Raw Materials | 24.53 | 24.53 | (Wilson, 2005) * |
| | Raw Materials | 166.82 | 166.82 | (Weber, 2007) |
| | Recreation | 152.66 | 152.66 | (Brenner Guillermo, 2007) * |
| | Recreation | 1.29 | 4.55 | (Cruz & Benedicto, 2009) * |
| | Recreation | 1.56 | 1.56 | (Kniivila, Ovaskainen, & Saastamoinen, 2002) * |
| | Recreation | 37.13 | 45.50 | (Prince & Ahmed, 1989) |
| | Recreation | 2.79 | 503.97 | (Shafer, Carline, Guldin, & Cordell, 1993) |
| | Soil Fertility | 6.09 | 6.09 | (Brenner Guillermo, 2007) * |
| | Soil Fertility | 19.97 | 19.97 | (Weber, 2007) |
| | Waste | 55.28 | 55.28 | (Brenner Guillermo, 2007) * |
| | Waste | 8.66 | 8.66 | (Cruz & Benedicto, 2009) * |
| | Waste | 265.79 | 266.89 | (Lui, 2006) |
| | Water | 204.39 | 204.39 | (Brenner Guillermo, 2007) * |
| | Water | 47.39 | 47.39 | (Cruz & Benedicto, 2009) * |
| | Water | 1,292.23 | 1,292.23 | (Weber, 2007) |
| | Water Flows | 230.01 | 230.01 | (Mates, 2007) |
| | Water Flows | 797.66 | 797.66 | (Weber, 2007) |

| Land Use | Ecosystem Service | Minimum $/acre/year | Maximum $/Acre/year | Source Study |
|---|---|---|---|---|
| Water | Recreation | 446.31 | 446.31 | (Brenner Guillermo, 2007) * |
| | Recreation | 155.36 | 914.10 | (Cordell & Bergstrom, 1993) |
| | Recreation | 304.18 | 437.19 | (Mullen & Menz, 1985) |
| | Recreation | 148.68 | 148.68 | (Postel & Carpenter, 1977) |
| | Waste | 10.72 | 10.72 | (Gibbons, 1986) * |
| | Water | 512.74 | 512.74 | (Brenner Guillermo, 2007) * |
| | Water | 22.98 | 22.98 | (Gibbons, 1986) * |
| Wetland | Aesthetic | 38.46 | 38.46 | (Amacher & Brazee, 1989) * |
| | Air Quality | 75.50 | 98.02 | (Jenkins, Murray, Kramer, & Faulkner, 2010) |
| | Climate | 1.84 | 1.84 | (Wilson, 2005) * |
| | Climate | 157.73 | 157.73 | (Brenner Guillermo, 2007) * |
| | Extreme Events | 228.06 | 369.85 | (Wilson, 2005) * |
| | Extreme Events | 110.06 | 4,583.26 | (Brenner Guillermo, 2007) * |
| | Extreme Events | 304.18 | 304.18 | (Robert Costanza, Farber, & Maxwell, 1989) |
| | Extreme Events | 278.77 | 278.77 | (Robert Costanza & Farley, 2007) |
| | Extreme Events | 1,645.59 | 7,513.98 | (Leschine, Wellman, & Green, 1997) |
| | Raw Materials | 50.16 | 50.16 | (Everard, Great Britain, & Environment Agency, 2009) |
| | Recreation | 80.71 | 80.71 | (Bergstrom, Stoll, Titre, & Wright, 1990) |
| | Recreation | 1,716.76 | 1,761.89 | (Brenner Guillermo, 2007) * |
| | Recreation | 109.30 | 429.97 | (Robert Costanza et al., 1989) |
| | Recreation | 1,041.04 | 1,041.04 | (Creel & Loomis, 1992) |
| | Recreation | 88.06 | 994.50 | (Gren & Söderqvist, 1994) * |
| | Recreation | 71.11 | 71.11 | (Gren, Groth, & Sylven, 1995) * |
| | Recreation | 208.01 | 208.01 | (Kreutzwiser, 1981) |
| | Recreation | 209.51 | 209.51 | (Lant & Roberts, 1990) * |
| | Recreation | 648.57 | 4,203.82 | (Whitehead, 1990) |
| | Waste | 141.56 | 141.56 | (Wilson, 2005) * |
| | Waste | 67.02 | 67.02 | (Breaux, Farber, & Day, 1995) |
| | Waste | 1,050.34 | 1,050.34 | (Brenner Guillermo, 2007) * |
| | Waste | 170.05 | 170.05 | (Gren & Söderqvist, 1994) * |
| | Waste | 35.20 | 35.20 | (Gren et al., 1995) * |
| | Waste | 551.02 | 551.02 | (Jenkins et al., 2010) |
| | Waste | 209.51 | 209.51 | (Lant & Roberts, 1990) * |
| | Waste | 5,027.28 | 5,027.28 | (Meyerhoff & Dehnhardt, 2004) * |
| | Waste | 10,881.15 | 10,881.15 | (Lui, 2006) |
| | Water | 1,934.84 | 2,407.52 | (Brenner Guillermo, 2007) * |
| | Water | 622.77 | 622.77 | (Creel & Loomis, 1992) |
| | Water | 18.19 | 18.19 | (Folke & Kaberger, 1991) * |
| | Water Flows | 3,741.87 | 3,741.87 | (Brenner Guillermo, 2007) * |
| | Water Flows | 3,920.69 | 3,920.69 | (Leschine et al., 1997) |
| | Water Flows | 4,329.70 | 4,329.70 | (UK Environment Agency, 1999) |

| Land Use | Ecosystem Service | Minimum $/acre/year | Maximum $/Acre/year | Source Study |
|---|---|---|---|---|
| Urban Open Space | Aesthetic | 1,006.06 | 1,322.31 | (Qiu, Prato, & Boehrn, 2006) |
| | Air Quality | 32.46 | 32.46 | (G. McPherson, Scott, & Simpson, 1998) |
| | Air Quality | 192.35 | 192.35 | (G. E. McPherson, 1992) |
| | Climate | 1,134.38 | 1,134.38 | (G. E. McPherson, 1992) |
| | Extreme Events | 315.52 | 597.01 | (Streiner & Loomis, 1995) |
| | Water Flows | 8.32 | 8.32 | (G. E. McPherson, 1992) |
| | Water Flows | 138.22 | 187.58 | (The Trust for Public Land, 2010) |
| Urban Other | Climate | 420.95 | 420.95 | (Brenner Guillermo, 2007) * |
| | Recreation | 2,670.74 | 2,670.74 | (Brenner Guillermo, 2007) * |
| | Water Flows | 7.61 | 7.61 | (Brenner Guillermo, 2007) |

All values are adjusted for inflation to 2014 dollars.
* Indicates source is from the TEEB database.