APPENDIX E
Contingency Plan for the Proposed Crossing of the Appalachian National Scenic Trail

Mountain Valley Pipeline Project

Docket No. CP16-10-000

Contingency Plan for the Proposed Crossing of the Appalachian National Scenic Trail

May 10, 2023

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1.0 INTRODUCTION

Mountain Valley Pipeline, LLC (Mountain Valley), a joint venture between EQM Midstream Partners, LP; NextEra Capital Holdings, Inc.; WGL Midstream; RGC Midstream, LLC; and Con Edison Midstream, LLC, is the owner of the Mountain Valley Pipeline Project (Project or MVP), an approximately 303-mile, 42-inch-diameter natural gas pipeline traversing 17 counties in West Virginia and Virginia. The Project extends from the existing Equitrans transmission system and other natural gas facilities in Wetzel County, West Virginia to Transcontinental Gas Pipe Line Company, LLC's (Transco) Zone 5 compressor station 165 in Pittsylvania County, Virginia. In addition to the pipeline, the Project includes approximately 171,600 horsepower (hp) of compression at three compressor stations along the route, as well as measurement, regulation, and other ancillary facilities required for the safe and reliable operation of the pipeline. The pipeline is designed to transport up to 2.0 million dekatherms per day of natural gas.

2.0 PURPOSE

Mountain Valley has proposed to cross underneath the Appalachian National Scenic Trail (ANST), located on U.S. Forest Service (FS) lands, using trenchless (or bore) installation technology. The ANST is a significant recreational resource. Trenchless technology would allow the Project to cross under the ANST while protecting the ground surface used for the ANST footpath and significant buffer areas on each side of the trail from disturbance.

The proposed crossing is 600 feet in length, and approximately 90 feet below the ANST. Mountain Valley has completed a geologic analysis, described in the following section, that has determined the bore path will encounter primarily solid rock. Mountain Valley's trenchless technology consultant, Michels, expects with a high degree of confidence that the pipeline can be successfully installed using Manned Tunnel Boring technology. However, in the unlikely event that this method fails, Mountain Valley has identified a set of alternative means to achieve the goal of constructing the pipeline without trenching or other disturbance to the ANST footpath and adjacent woodlands. The following sections of this document describe the contingency measures Mountain Valley has identified. No matter the construction method used, no trenching will occur, and no motor vehicle traffic will be permitted between the bore pits.

3.0 SITE GEOLOGY

The ANST bore crossing is located in the folded and thrust-faulted Valley and Ridge geologic province, on the crest of Peters Mountain at the border between West Virginia and Virginia. The geologic formations that underlie the Peters Mountain ridgeline are the Ordovician-age Juniata Formation and the Silurian-age Tuscarora and Rose Hill Formations that dip moderately (30 degrees) to the southeast (note that the latter two formations generally correspond to the White Medina Formation and Red Medina Formation in West Virginia). A professional geologist visited the site to confirm the mapping and geological conditions in the area, as described in the attached May 12, 2020, memo from Draper Aden Associates.

The Juniata Formation is composed mainly of fine-grained gray-red commonly crossbedded sandstone, with minor red shale interbeds in the lower part of the unit and minor gray-red fissile siltstone and silty shale in the upper part. It generally occupies steep outcrop slopes below ridgelines commonly formed by the overlying Tuscarora sandstone.

The Tuscarora and Rose Hill Formations are found throughout the Valley and Ridge province, as thrust faulting has resulted in repeated geologic sections throughout. The Tuscarora is the dominant ridge-former in the vicinity of this bore, with the Rose Hill being somewhat less weather resistant than the Tuscarora, but nonetheless also a ridge-former as they are both hard, competent rocks. The following descriptions of these formations were taken from various sources at different locations within the Valley and Ridge province, in order to provide a comprehensive geologic description. The boring would proceed at the prescribed 2-degree angle along the bedrock formations that dip at 30 degrees and therefore would penetrate several units of the Tuscarora and Rose Hill formations.

The Tuscarora Formation sandstone and conglomerate units consist of thin to very thick-bedded, white to light-gray, medium to coarse-grained sandstone and strongly welded quartzite. The Tuscarora quartzite is typically the most weather-resistant (i.e., hardest) rock-type in this province. The Tuscarora sandstone and conglomerate units can be quite hard, particularly where it demonstrates low-grade metamorphism to a welded quartzite.

The Rose Hill Formation is composed of deep-red hematitic sandstones, brown to tan medium-grained sandstones with clay galls, and red and green sandy and micaceous shales. The shales and hematitic sandstones are distinctive and permit ready identification of the unit. The hematitic sandstone is bounded above and below by greenish-gray to red shale with thin gray sandstone interbeds, some of which have abundant brachiopod fossils. Ripple marks are common on the sandstone beds. The Juniata Formation and the Rose Hill Formation are generally observed to be less weather-resistant (i.e., less hard) than the Tuscarora, with more frequent occurrences of shale and siltstone units. The hematite-cemented sandstone units of the Rose Hill are relatively hard compared to the Formation shale and siltstone units, but are generally less indurated than the Tuscarora Formation. Therefore, the Tuscarora quartzite is the dominant ridge-forming unit in the region surrounding the bore.

Mountain Valley has identified four different boring techniques capable of tunneling under the ANST: (1) manned tunnel boring, (2) microtunneling, (3) direct pipe, and (4) guided pilot conventional boring. The following section briefly describes the alternative construction techniques appropriate to the geology of the proposed bore location and highlights the relative merits of the different techniques. After outlining the different techniques, this document describes how Mountain Valley intends to respond to contingencies that may arise during the boring operations.

4.0 MANNED TUNNEL BORING: OPTION 1

Manned tunnel boring uses a machine that is propelled forward by jacked pipe or by thrusting itself forward off fixed conventional tunnel supports installed within the tail can of the tunnel boring machine (TBM). It can be referred to as “Analog Age Tunneling” because in all cases the operator rides underground within the TBM and uses his or her hands to operate machine controls and visually follows a laser beam to control the direction of TBM. TBMs are manned and have complete face access allowing for accurate line and grade tolerances as well as adaptability to changing conditions.

Manned tunnel boring’s major advantage over other boring technologies is that the cutting face to the bore path is always accessible, facilitating removal of obstructions, modifications, and mechanical repairs without significant interference with bore progress. The product pipe is installed as the boring is advanced, leaving no unsupported hole that could potentially collapse. Manned tunnel boring requires construction of launching and receiving pits on either side of the bore, but has a smaller footprint than other typical trenchless technologies. The TBM does not use a slurry to move material, thus significantly reducing the risk of inadvertent returns. This method is guided and steered as it progresses in a single step process.

Cutting heads and teeth are changeable throughout the bore. This method utilizes less equipment than slurry microtunneling or direct pipe.

It is estimated that the manned tunnel bore under the ANST will take approximately 10 weeks to complete. However, there are many factors (such as weather and equipment malfunctions) that may extend this duration. Mountain Valley intends to complete the bore as quickly as possible. Cuttings (spoil) generated by boring operations may be stockpiled temporarily at the site but will ultimately be reused as backfill in the pipeline right of way or transported offsite to an appropriate disposal site.

The manned tunnel bore method (utilizing the appropriate cutting head based on site conditions) described above is an appropriate method for penetrating the geologic formations previously described.

5.0 ALTERNATE TRENCHLESS CROSSING METHODS

5.1 Microtunneling: Option 2

Microtunneling (MT) is a pipeline installation method that consists of jacking a pipe behind a remotely-controlled, steerable, guided, articulated microtunnel boring machine (MTBM). MT projects can range in diameter from 10 to 136 inches. Drive lengths for MT installations can range from 200 to 1,500 feet in length. A wide range of soil types are suitable for installation by MT, including boulders and rock. Boulders and cobbles up to one-third the diameter of the installed pipe can be accommodated by the MTBM. MT activities will only be conducted during daylight hours and will require only one bore pass.

Although unmanned, the MT method, due to its advanced control and guidance system, is capable of installing pipelines to accurate line and grade tolerances. Also, the borehole or tunnel is continuously supported by the installed pipe. Finally, the bentonite slurry (clay and water) collection/recycling system and pressure control features at the excavation face minimize the potential for drilling fluid loss.

Primary disadvantages of the MT method are the necessary use of a slurry and the extended lengths of pipe segments causing more workspace area to be utilized. These factors were the reason why Mountain Valley selected the manned tunnel bore method as the primary ANST crossing method and identified the MT method as an alternate installation choice.

5.2 Direct Pipe: Option 3

Direct Pipe is a trenchless installation method that combines features of Horizontal Directional Drilling (HDD) and MT. Direct Pipe was developed by the HerrenKnecht Company in Germany to provide a one-step pipe jacking method that offered the advantages of both HDD and MT. Direct Pipe utilizes an MTBM connected to the leading edge of an assembled length of pipe and a pipe thruster to jack the pipeline into place, similar to, but in the opposite direction of HDD pullback operations.

Direct Pipe projects can range in diameter for 30 to 60 inches. Drilling lengths for Direct Pipe projects can reach up to 4,900 feet. A wide range of soil types are suitable for installation by Direct Pipe, including boulders and rock. Boulders and cobbles up to one-third the diameter of the installed pipe can be accommodated by the MTBM at the front end of the pipeline.

During Direct Pipe operations, the tunnel face is excavated by an MTBM similar to the MT and pipe-jacking method. The tunnel face is slurry-supported using a bentonite (clay) suspension. The excavated material is removed via a slurry circuit with separation plant in order to separate the spoil from the slurry liquid before feed pumps transport the liquid back to the tunnel face. The MTBM is controlled from the operating container located on the surface adjacent to the pipe thruster. A gyro compass is used for steering control of the MTBM, allowing a drill radius similar to HDD to be completed. If used, Direct Pipe activities would only be conducted during daylight hours and would require only one bore pass.

An advantage of Direct Pipe system is one-step jacking method, which allows the pipe to be installed in one pass. Also, the installation of the pipe directly behind the MTBM provides constant support to the bore hole. The receiving-side footprint for Direct Pipe is small compared to other methods since all materials and equipment are located on the launch side. The advance control and guidance system provides high-precision target control. Finally, as with MT, the slurry collection/recycling system and pressure-control features at the excavation face minimize the potential for drilling fluid loss.

One disadvantage of Direct Pipe is that the technique requires a large work area on the launch side of a proposed crossing to accommodate the Pipe Thruster, supporting equipment, and long lengths of welded product pipe. Also, this is a relatively new technology to the industry. For these reasons, Mountain Valley did not select Direct Pipe as the ANST primary crossing technique.

5.3 Guided Pilot Conventional Boring: Option 4

Pilot guided conventional boring, or auger boring, is one of the most popular trenchless methods and has been used for more than 50 years. It consists of a jacking pipe that is advanced ("jacked") and a rotating cutting head that is attached to the leading edge of the auger string. The spoil is transported back by the rotation of auger flights within the steel jacking pipe. Auger boring can be used to install pipes ranging from 4 to 60 inches in diameter. Drive lengths for typical auger boring projects range from about 40 to 600 feet. Auger bores can be successfully completed in a range of soil types from dry sand to firm clay to hard rock. Boulders and cobbles up to one third of the diameter of the installed pipe can be accommodated. If used, conventional bore activities will only be conducted during daylight hours. A conventional bore would require a pilot pass followed by the main bore pass. Figure 1 illustrates the process of completing a conventional bore.

Auger boring's major advantage over some other boring technologies is that the pipe is installed as the boring is advanced, leaving no unsupported hole that could potentially collapse. Auger boring requires construction of launching and receiving pits on either side of the bore, but has the least amount of areal footprint required of the trenchless technologies. The launch pit, where the jacking machine is located, would be on the Virginia side of the bore and would be 20 feet wide by 60 feet long. The receiving pit, on the West Virginia side of the bore, would be 20 feet wide by 30 feet long, in plan (see Figure 2). A summary table of the bore pit lengths and widths is included at Table 1. It is estimated that the conventional bore under the ANST would take approximately 10 weeks to complete. However, there are many factors (such as weather and equipment malfunctions) that may extend this duration. Mountain Valley would complete the bore as quickly as possible. Cuttings (spoil) generated by boring operations may be stockpiled temporarily at the site but would ultimately be reused as backfill in the pipeline right-of-way or transported offsite to an appropriate disposal site.

The horizontal auger bore method (utilizing the appropriate cutting head) described above is an appropriate method for penetrating the geologic formations previously described. If the conventional auger bore encounters excessively hard rock, an air driven rock hammer drill can be deployed at the bore face, substituting for the auger as needed.

The conventional auger bore method is the least favorable because the length of the bore under the ANST is at the outer limits of this method's typical application.

6.0 CONTINGENCY PLAN

If insurmountable issues are encountered during the manned tunnel boring process, Mountain Valley, in consultation with Michels and the FS, intends to perform corrective actions, such as selecting a new drill path, within the approved corridor or may implement an alternate trenchless crossing method as outlined in this plan. The following list, which is illustrative, not exhaustive, provides examples of issues that could require the implementation of this contingency plan:

- Mechanical failures of MTB Equipment - If a catastrophic failure of the MTB equipment occurs and it is not possible to repair or rebuild, a substitute boring unit will be installed.
- Deviation from planned bore path - If the deviation from the bore path is significant enough that the field engineer determines it cannot be corrected or made up in the remaining bore length, the bore will be considered a failure. The amount of acceptable deviation is dependent upon the angle of deflection and the remaining distance to be drilled.
- Unanticipated geological or hydrological conditions in which ground or surface water affects construction or the geologic materials become unstable or collapse.
- Unexpected soil contaminants or conditions posing a safety hazard to the MTB methodology.

Mountain Valley will not use open-cut methods to install the pipeline under the ANST. Mountain Valley will notify and seek approval from Federal Energy Regulatory Commission (FERC) inspectors and FS representatives prior to implementing this contingency plan or making any adjustments to the boring plans and procedures. Abandonment procedures and alternative crossing measures will be discussed with appropriate permitting, regulatory, and land-managing agencies, and required approvals will be obtained prior to implementing any alternative crossing measures.

While all FS-approved contingency options are viable at the ANST crossing, manned tunnel boring is the most effective method. Microtunneling and Direct Pipe are a more complex process and will require larger entry and exit workspaces, and the length of a conventional auger bore underneath the ANST would be at the outer limits of this method's typical application. Either of the three contingency methods are estimated to take approximately 10 weeks to complete. However, there are many factors (such as weather and equipment malfunctions) that may extend this duration. Mountain Valley intends to complete the bore as quickly as possible.

6.1 Initial Contingency Plan – Reattempt Bore

In the event that the bore is determined to be unsuccessful based on encountering one or more issues identified above, or other obstacles, Mountain Valley will notify and seek approval from FERC inspectors and FS representatives prior to shifting the bore entry to the east or west of the original bore entry and attempting another bore. Should a bore failure involve stuck pipe following known engineered recovery techniques, any pipe from a failed bore will be abandoned in place and backfilled with grout. Should Mountain Valley and technical consultants determine that the manned tunnel bore is not appropriate based on the initial attempts, Mountain Valley will propose to use a different trenchless crossing method. Three alternatives are discussed below, with microtunneling being the most feasible and Mountain Valley's preferred contingency method.

6.2 Microtunneling Installation

In the event that the manned tunnel bore reattempt is determined to be unsuccessful based on encountering one or more issues identified above, Mountain Valley will notify and seek approval from

FERC inspectors and FS representatives prior to making any adjustments, abandoning the process, and moving to the MT method. The MT bore will be attempted in the same location as the manned tunnel bore, and similarly offset to the east and west in the event that the first MT attempt is not successful.

As stated above, MT is a pipeline installation method that consists of jacking a pipe behind a remotely-controlled, steerable, guided, articulated MTBM. The MT method most common in the United States is the slurry method. Mountain Valley recognizes that drilling fluids may not be spread onsite as a means of disposal; they will be hauled offsite to an appropriate disposal site. Cuttings (spoil) separated from the drilling fluid may be stockpiled temporarily at the site but will ultimately be transported offsite to an appropriate disposal site. Assuming a swell factor of 34% for sandstone, boring operations will generate approximately 329 cubic yards of cuttings.

The equipment needed for a successful microtunnel, in addition to the MTBM and jacking machine, includes the lubricant/recycling tank and pumps, control container, and supply and storage trailers. In addition, a crane or large side boom will be needed for pipe handling and to lower the MTBM in place as well as the pipe sections. Figure 3 illustrates the process of completing MT.

In the event that the MTBM gets stuck and cannot move forward, it will be pulled out of the bored hole using track-mounted equipment. No additional excavation is anticipated.

The typical workspace footprint of microtunnel setup for this Project is anticipated to be a minimum of approximately 125 feet wide by 250 feet long on the launch side, with a bore pit 20 feet wide by 55 feet long (see Figure 4). Control containers and support equipment are placed adjacent to the launch pit. The exit side workspace required for this method is approximately 125 feet in width by 125 feet in length, with a bore pit 20 feet wide by 30 feet long. A summary table of the bore pit lengths and widths is included in Table 1.

Table 1.

Bore Pit Dimensions for the Proposed and Alternative ANST Bore Methods

Method	Bore Pit Dimensions (Entry/Exit)	Workspace Dimensions (Entry/Exit)
Manned Tunnel Bore	20’ wide x 60’ long / 20’ wide x 30’ long	125’ wide x 125’ long / 125’ wide x 125’ long
Microtunneling	20’ wide x 60’ long / 20’ wide x 30’ long	125’ wide x 125’ long / 125’ wide x 125’ long
Direct Pipe	20’ wide x 60’ long / 20’ wide x 30’ long	125’ wide x 250’ long / 125’ wide x 125’ long
Conventional Bore	20’ wide x 80’ long / 20’ wide x 30’ long	125’ wide x 600’ long / 125’ wide x 125 long’

6.3 Direct Pipe Installation

In the event that the manned tunnel bore and microtunnel bores are determined to be unsuccessful in the designed location based on encountering one or more issues identified above, Mountain Valley will notify and seek approval from FERC inspection and FS representatives prior to making any adjustments abandoning the process and moving to the Direct Pipe method. The Direct Pipe bore will be attempted in the same location as the manned tunnel bore, and similarly offset to the east and west in the event that the first Direct Pipe attempt is not successful.

During Direct Pipe operations, the tunnel face is excavated by an MTBM similar to the MT method. The excavated material is removed via a slurry circuit with separation plant in order to separate the spoil from the slurry liquid before feed pumps transport the liquid back to the tunnel face. The MTBM is controlled from the operating container located on the surface adjacent to the Pipe Thruster. A gyro compass is used for steering control of the MTBM allowing drill radii similar to HDD. Mountain Valley recognizes that drilling fluids may not be spread onsite as a means of disposal; they will be hauled offsite to an appropriate disposal site. Cuttings (spoil) separated from the drilling fluid may be stockpiled temporarily at the site but will ultimately be transported offsite to an appropriate disposal site. Assuming a swell factor of 34% for sandstone, boring operations will generate approximately 329 cubic yards of cuttings.. Figure 5 illustrates the process of completing a Direct Pipe bore.

In the event that the MTBM used in Direct Pipe operations gets stuck and cannot move forward, it will be pulled out of the bored hole using track-mounted equipment. No additional excavation is anticipated.

Direct Pipe typically requires a large area on the launch side. The recommended minimum work area for a Direct Pipe installation of this magnitude is approximately 125 feet wide and at least the length of the crossing on the launch side (over 600 feet at this site) due to need to string assembled pipe. The exit side workspace required for this method is approximately 125 feet in width by 125 feet in length. The entry and exit bore pits are approximately 20 feet by 80 feet and 20 feet by 30 feet, respectively (See Figure 6). A summary table of the bore pit lengths and widths is included in Table 1. The equipment needed for a successful direct-pipe installation is similar to MT: MTBM and thruster, lubricant/recycling tank and pumps, control container, and supply.

6.4 Guided Pilot Conventional Bore

In the event that the manned tunnel bore, microtunneling, and direct pipe attempts are determined to be unsuccessful in the designed location based on encountering one or more issues identified above, Mountain Valley will notify and seek approval from FERC inspection and FS representatives prior to making any adjustments abandoning the process and moving to the guided pilot conventional bore method. The guided pilot conventional bore will be attempted in the same location as the other methods, and similarly offset to the east and west in the event that the first guided pilot conventional bore attempt is not successful.

This option is the least favorable due to the overall length of the bore, which is near the outer limits of the distance typically bored in this manner.

FIGURES

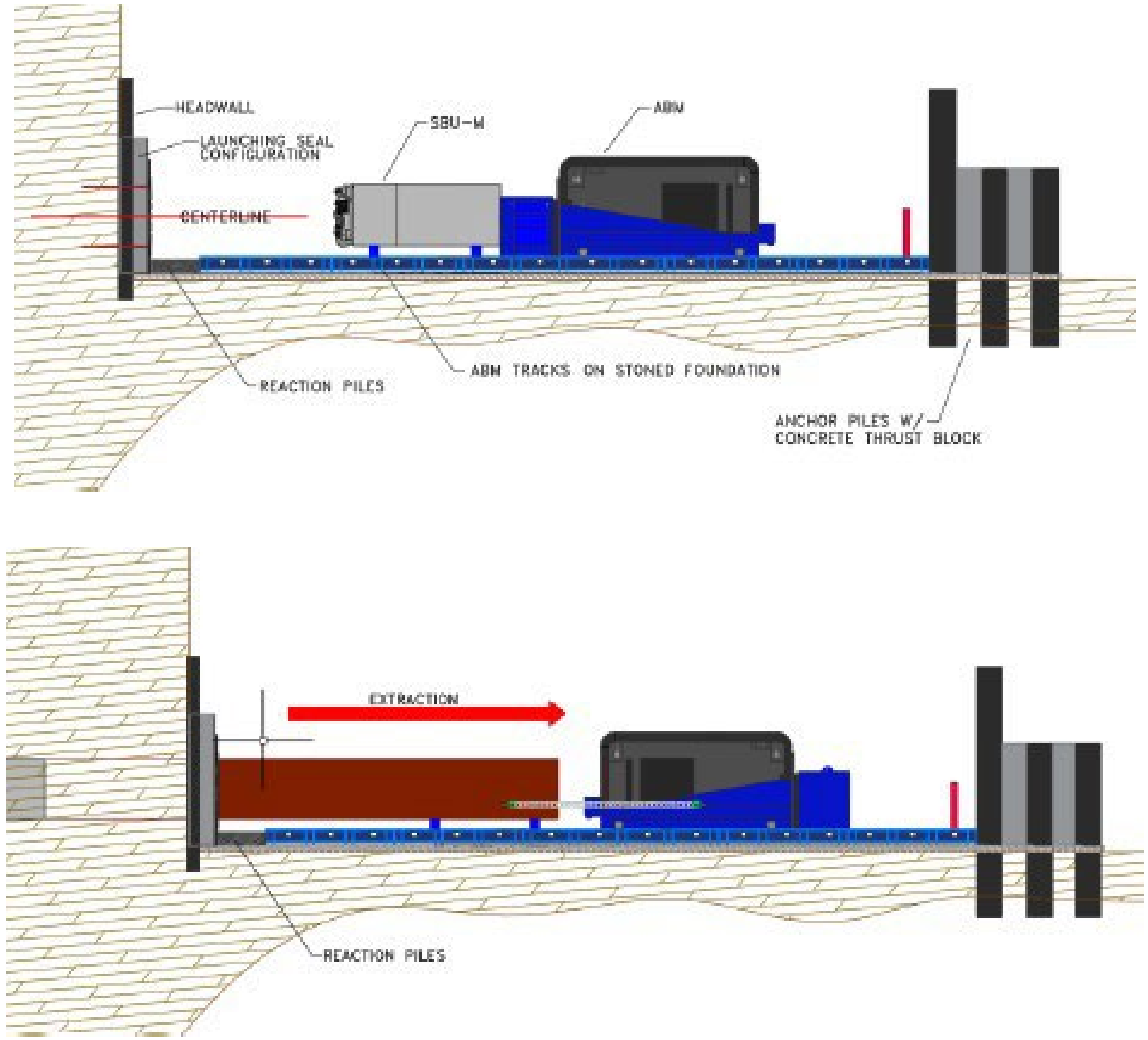

Figure 1. Appalachian National Scenic Trail Crossing – Manned Tunnel Bore Typical Drawings

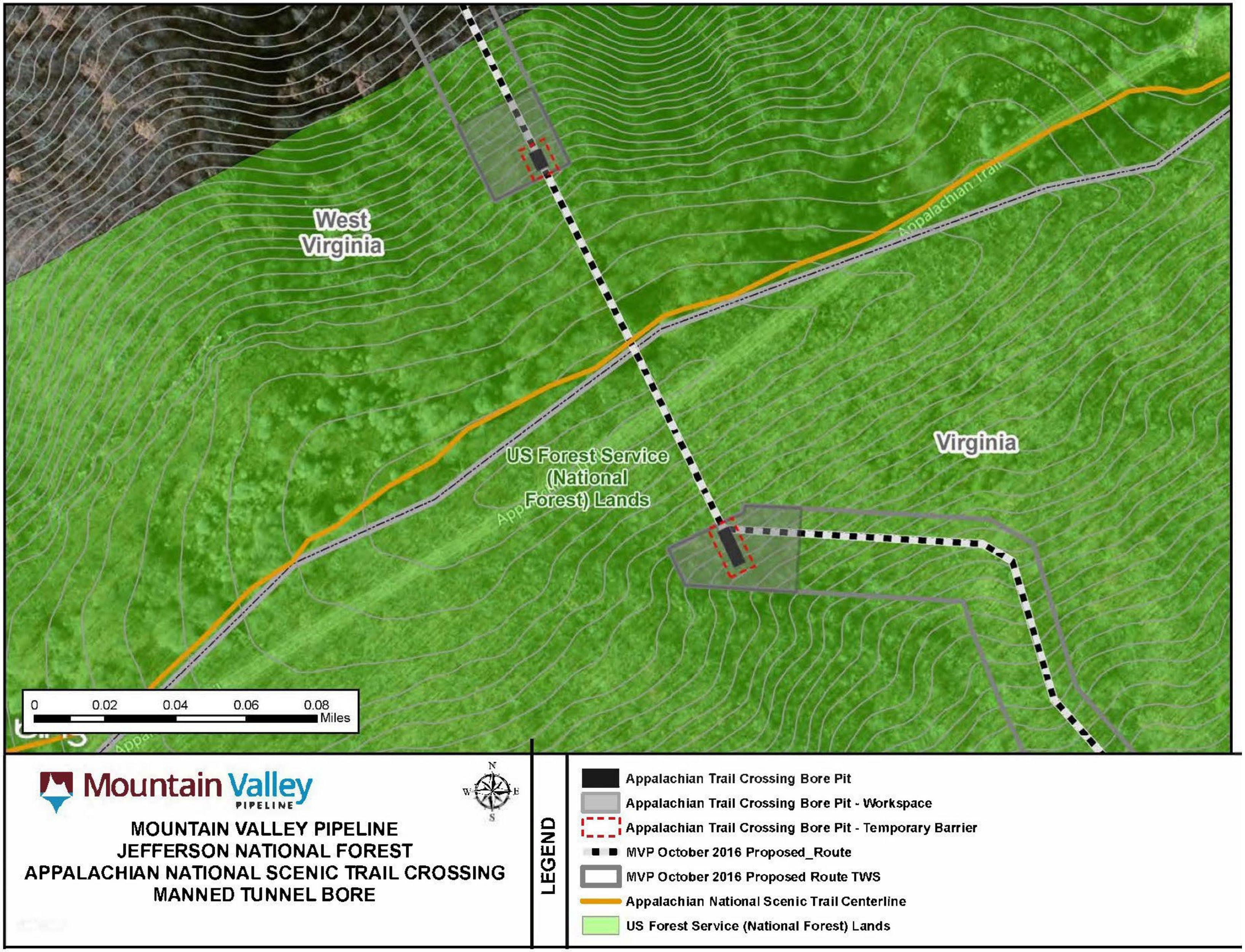

Figure 2. Appalachian National Scenic Trail Crossing – Manned Tunnel Bore

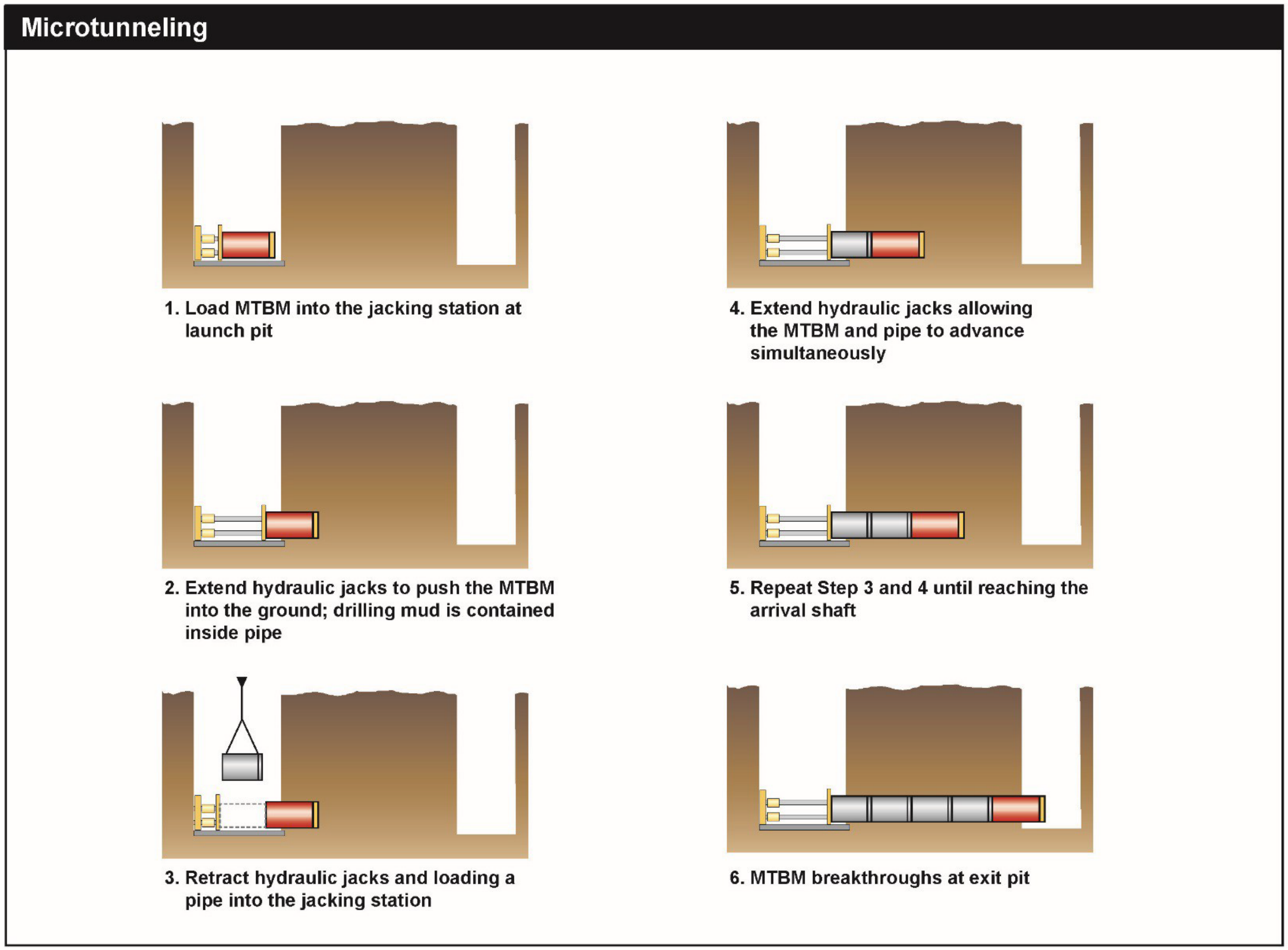

Figure 3. Appalachian National Scenic Trail Crossing – Microtunneling Process Drawing

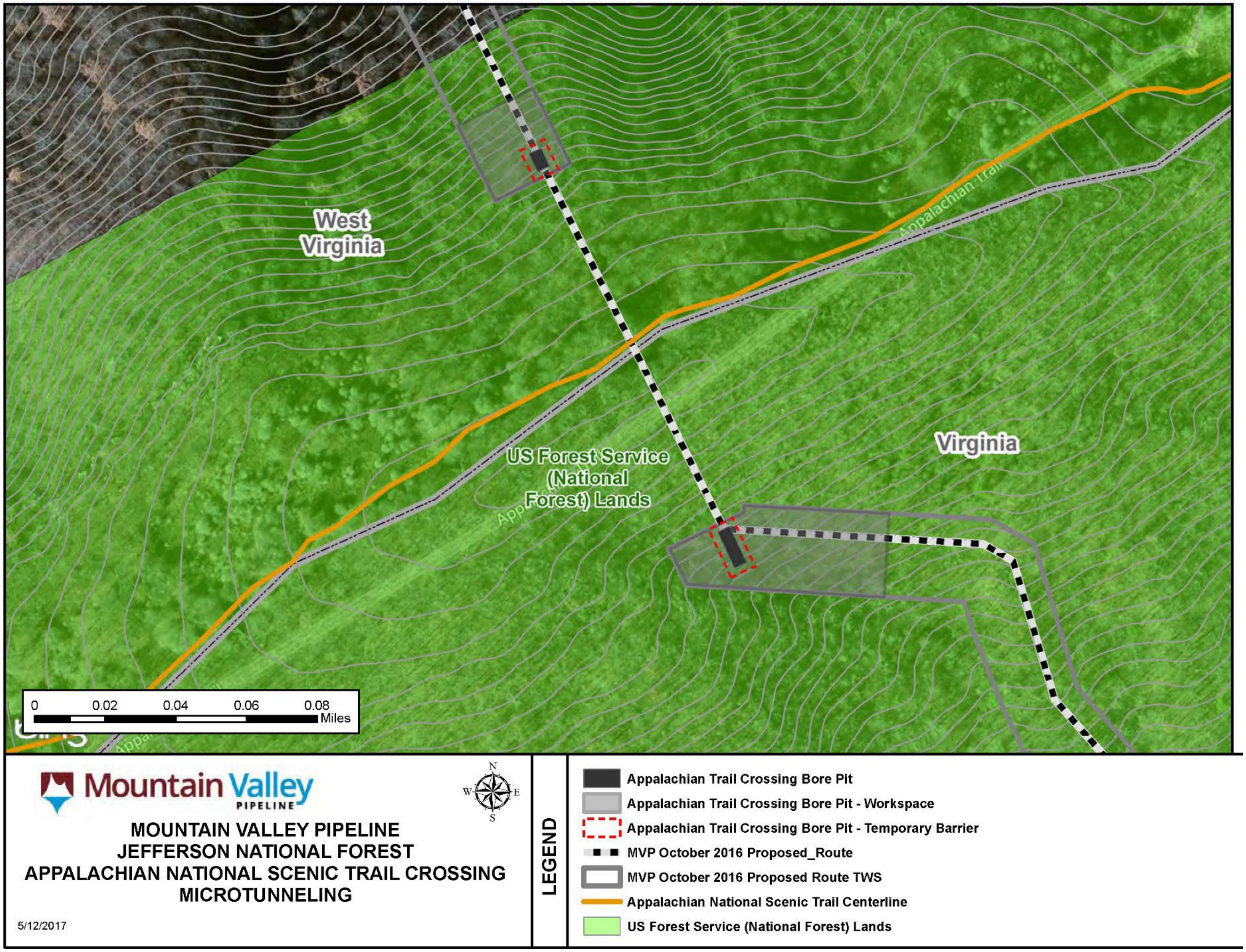

Figure 4. Appalachian National Scenic Trail Crossing – Microtunneling

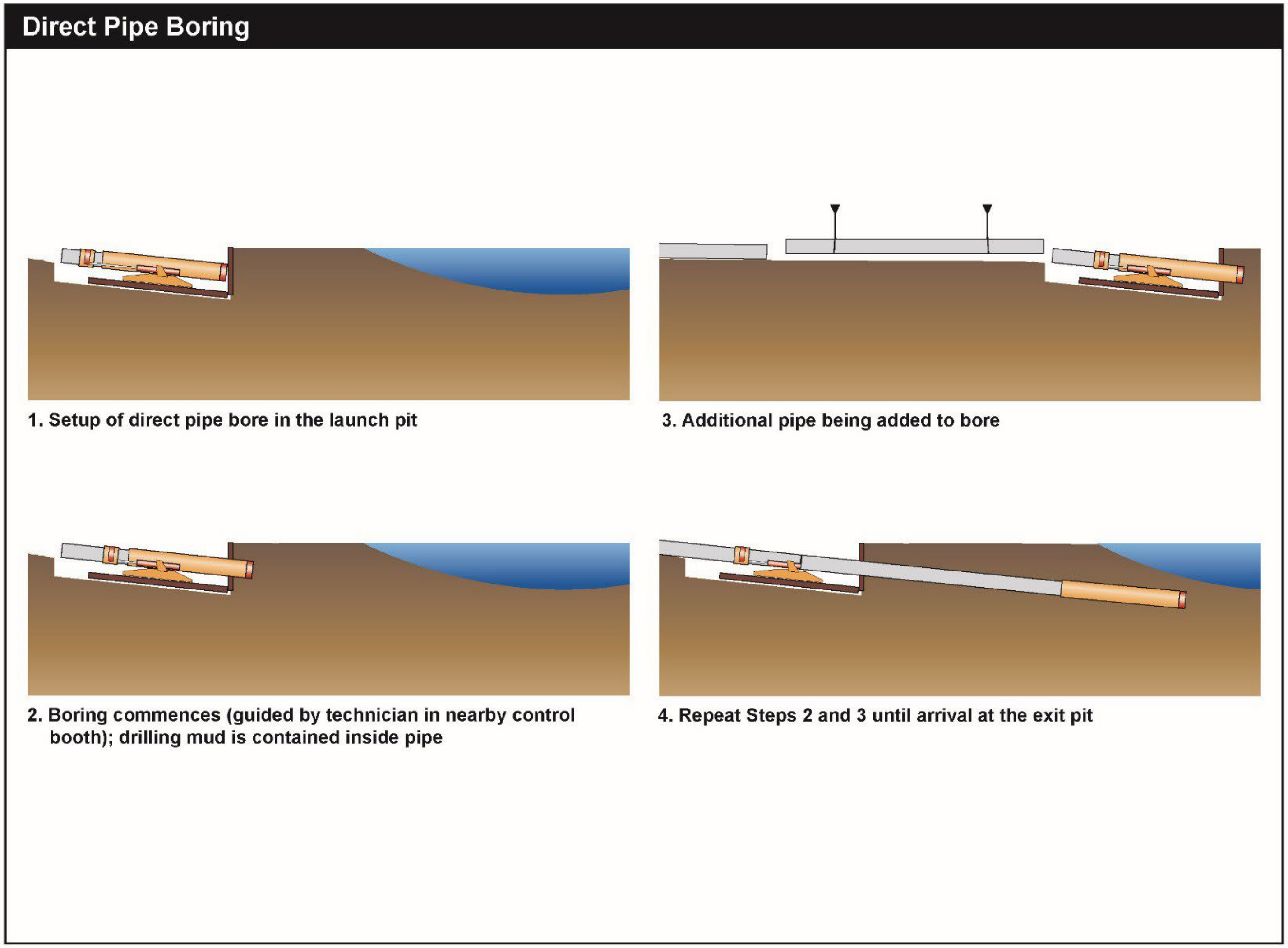

Figure 5. Appalachian National Scenic Trail Crossing – Direct Pipe Process Drawing

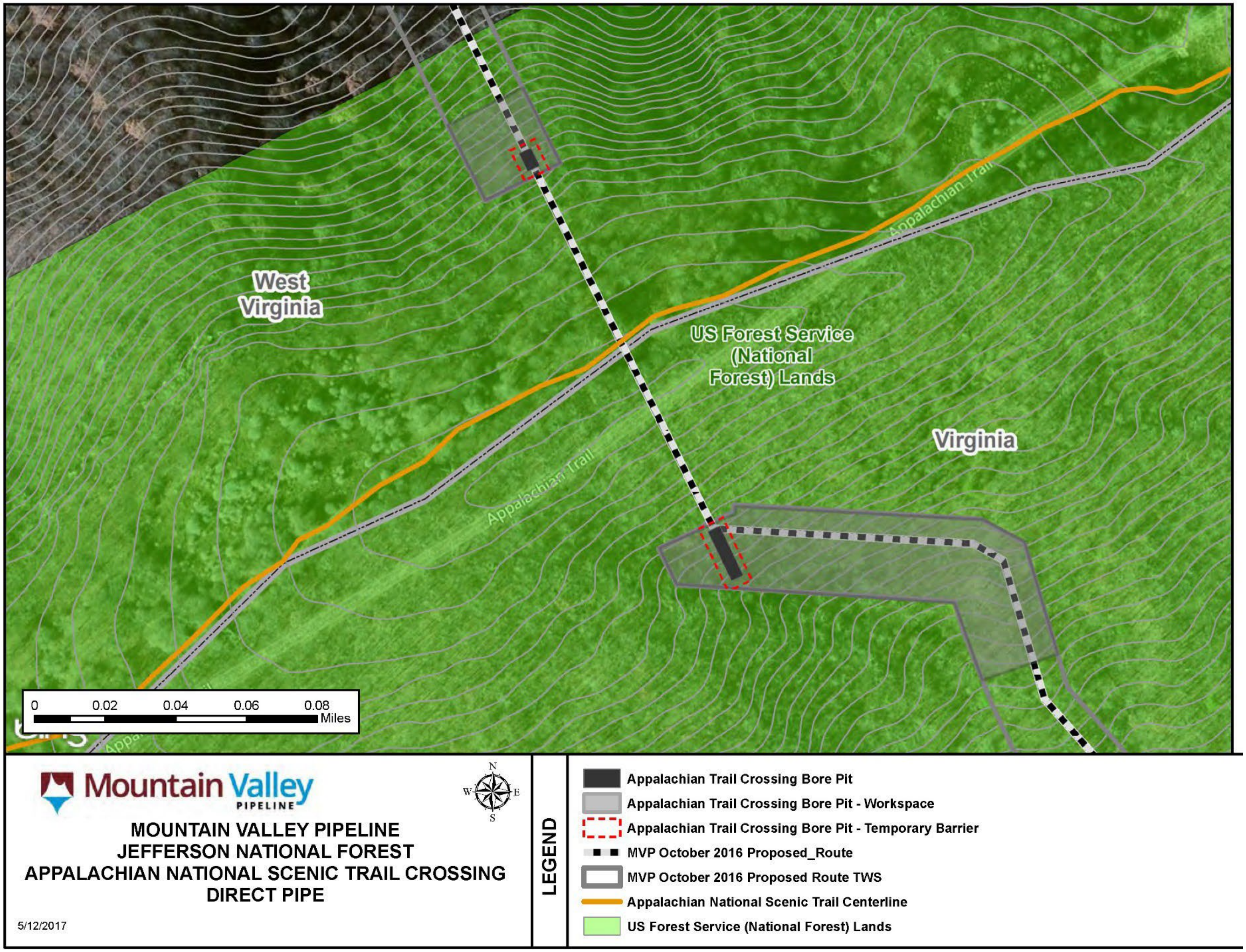

Figure 6. Appalachian National Scenic Trail Crossing – Direct Pipe

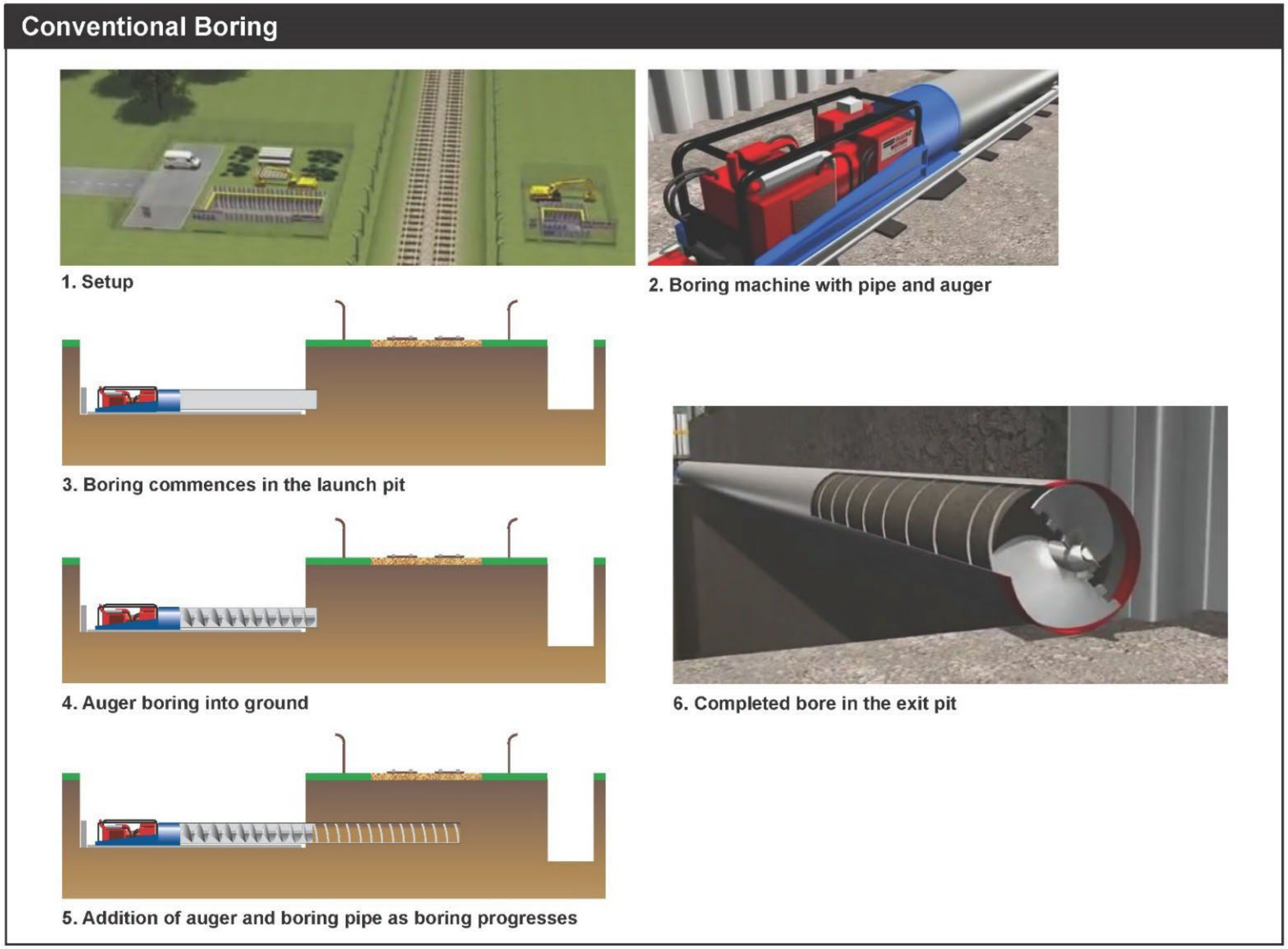

Figure 7. Appalachian National Scenic Trail Crossing – Conventional Bore Process Drawing

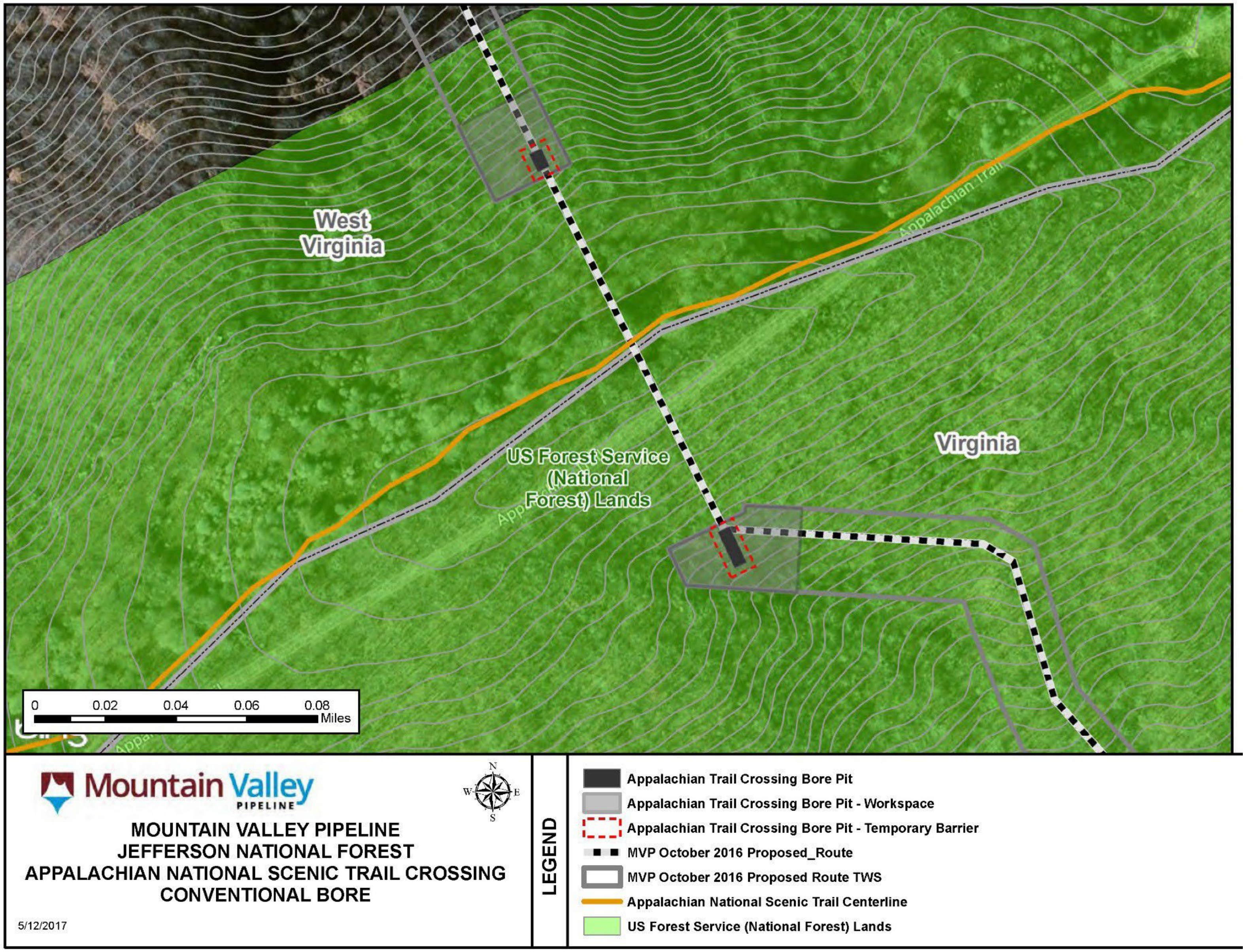

Figure 8. **Appalachian National Scenic Trail Crossing – Conventional Bore**

ATTACHMENT A
MEMORANDUM ON GEOLOGIC FORMATION DESCRIPTIONS AT MVP ANST CROSSING SITE

Memorandum

To: Megan Neylon, Equitrans Midstream

From: William D. Newcomb, P.G., Program Manager

Date: 05/12/2020

Project Name: Mountain Valley Pipeline Project

Project Number: B14188B-01 / 21[G]

Subject: Geologic formation descriptions at ANST crossing site

The following discussion summarizes geologic formations observed in outcrops at one portion of the Mountain Valley Pipeline (MVP) that will entail a manned tunnel boring under one scenic trail, the Appalachian National Scenic Trail (ANST) between Monroe County West Virginia and Giles County, Virginia (starting at MVP Milepost 196.3).

The purpose for completing the manned tunnel boring at this location is to preserve the viewshed at the scenic feature. The purpose for presenting the information included herein is to provide descriptive details of the rock type observed in outcrops at the bore site, in order to assist Mountain Valley in design specifications of the bore.

William D. Newcomb, P.G., a registered professional geologist in Virginia (number 2801000924; expires August 31, 2021) with 30 years of experience in geology, geotechnical assessments and hydrogeology, visited the ANST site on December 7, 2016, to observe bedrock characteristics in outcrops at the ground surface. No subsurface invasive sampling was permitted at this location by the U.S. Forest Service (ANST site).

Appalachian National Scenic Trail (ANST), Monroe County, West Virginia and Giles County, Virginia.

Mountain Valley seeks a permit from the U.S. National Forest Service (NFS), which maintains the right-of-way for the ANST, in order to complete a manned tunnel boring under the ANST at approximately Milepost 196.3 of the MVP (Figure 1).

The ANST bore crossing is located in the folded and thrust-faulted Valley and Ridge geologic province, on the crest of Peters Mountain at the border between West Virginia and Virginia. The geologic formations that underlie the Peters Mountain ridgeline are the Silurian age Tuscarora and Rose Hill Formations that dip moderately (30-degrees) to the southeast (the Juniata Formation conformably underlies the Tuscarora Formation in this area).

The proposed boring would proceed at a 2-degree upward angle from southeast to northwest (i.e., from Virginia into West Virginia). The bore would likely begin in the Rose Hill Formation on the southeast flank of Peters Mountain, penetrate the Tuscarora and then enter the Juniata Formation with the receiving pit likely encountering the Juniata Formation on the northwest slope of Peters Mountain (see Figure 2 for site-photographs of the bedrock formations near the ANST bore site at the ridgeline of Peters Mountain; downslope exposures of bedrock are covered by colluvial deposits). The boring would proceed at the prescribed 2-degree angle along the bedrock formations that dip at 30-degrees. The proposed bore is slated to be approximately 600 feet in length between the bore pit and receiving pit, with a maximum depth of approximately 92 feet below ground at the ridgeline.

The Tuscarora, Rose Hill and Juniata Formations are found throughout the Valley and Ridge province, as thrust faulting has resulted in repeated geologic sections throughout. The Tuscarora and Rose Hill Formations are ridge forming units on Peters Mountain. The following general descriptions of these formations provide a fairly comprehensive geologic description of the bedrock units likely to be encountered by the proposed boring.

The Juniata Formation is composed mainly of fine-grained gray-red commonly crossbedded sandstone, with minor red shale interbeds in the lower part of the unit and minor gray-red fissile siltstone and silty shale in the upper part. It generally occupies steep outcrop slopes below ridgelines commonly formed by the comformably overlying Tuscarora sandstone.

The Tuscarora Formation sandstone and conglomerate units consist of thin- to thick-bedded, white to light-gray, medium to coarse-grained sandstone (some areas strongly welded quartzite are observed). Thin beds of quartz-pebble conglomerate occur in the lower half of the formation. The Tuscarora displays cross-bedding and clay rip-ups. The Tuscarora quartzite is typically the most weather-resistant (aka, hardest) rock-type in the Valley and Ridge province of southern West Virginia and southwestern Virginia. As a result, it plays a prominent role in the shaping of the local topography and is well exposed in numerous mountain outcrops.

The Tuscarora is comformably overlain by the Rose Hill Formation (and Keefer sandstone unit) at the top of the last quartz arenite of the Tuscarora. The Rose Hill Formation is composed of deep-red hematitic sandstones, brown to tan medium-grained sandstones with clay galls, and red and green sandy and micaceous shales. The shales and hematitic sandstones are distinctive and permit ready identification of the unit. The hematitic sandstone is bounded above and below by greenish-gray to red shale with thin gray sandstone interbeds, some of which have abundant brachiopod fossils. Ripple marks are common on the sandstone beds.

The Tuscarora sandstone and conglomerate units can be quite hard, particularly where it demonstrates low-grade metamorphism to a welded quartzite. Figure 3 provides a link to several photographs of a rock core through the Tuscarora Formation in West Virginia (depth ranges from 6,775 to 6,819 feet below ground). Figure 4 shows specific close-up photographs of the sandstone and conglomerate units of the Tuscarora. Figure 5 is a descriptive log of the Tuscarora core that is presented at the link provided in Figure 3.

Review of the Tuscarora Formation core (Figure 3) shows intervals of white and gray well- cemented sandstone and conglomerate layers, which form the most weather-resistant (i.e., ridge forming) units in the formation in the Appalachian basin, including the vicinity of the MVP bore at MP 196.3. However, silt and shale partings, joints and fractures are also common to the Tuscarora, which would reduce the overall resistance to boring through the Formation. The photographs of the core sandstone and conglomerate units show a tightly cemented fine to medium-grained sandstone and conglomerate (Figure 4). The data log (Figure 5) does not provide specific information on hardness, but gives a good overall description of the Tuscarora Formation, which is consistent with what is observed in southwestern Virginia, near the bore pits at Peters Mountain.

The Rose Hill and Juniata Formations are generally observed to be less weather-resistant (i.e., less hard) than the Tuscarora, with more frequent occurrences of shale and siltstone units. The hematite-cemented sandstone units of the Rose Hill are relatively hard compared to the shale and siltstone units, but are generally less indurated than the Tuscarora Formation.

In summary, the primary risk for the bore site is penetrating the Tuscarora quartzite, in terms of hardness of the formation. There is also a complication given the 30-degree southeast dip of the formation underlying Peters Mountain, in terms of bore deflection. The length of the bore (approximately 600 feet) also presents a risk to completing the bore at the prescribed receiving pit.

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Figure 1 – MVP bore under ANST at Approximate Milepost 196.3 (geologic basemap from Schultz and Stanley, 2001)

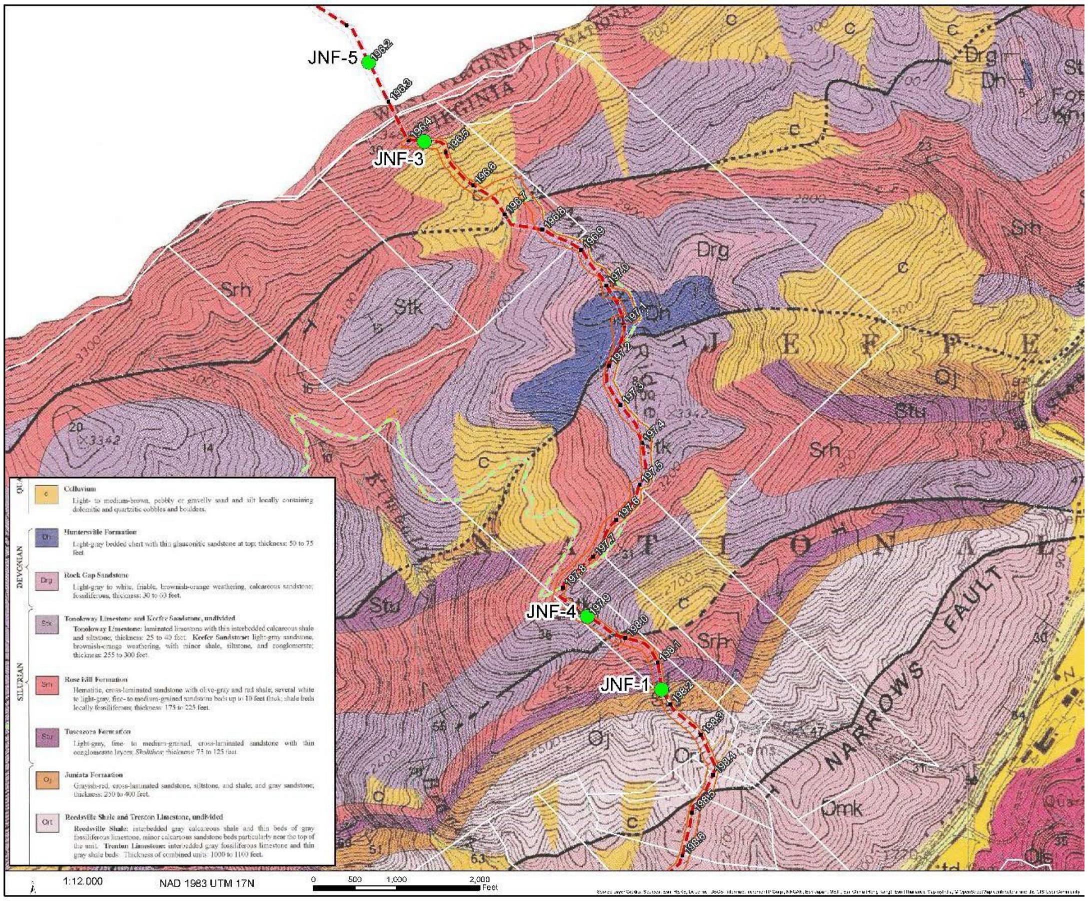

Figure 2 – Representative Site Photographs of Peters Mountain where Rose Hill Formation outcrops at the ridge line and Tuscarora Formation outcrops to the northwest and downslope from the ridge line in the vicinity of the ANST bore (the Juniata Formation underlies the Tuscarora). The bore would likely begin in the Rose Hill Formation on the southeast flank, penetrate the Tuscarora and then enter the Juniata with the receiving pit likely encountering the Juniata Formation on the northwest slope of Peters Mountain.

Figure 3 – This link provides photographs of Tuscarora Formation core from tight-gas exploration in West Virginia (core depth ranges from 6,775 to 6,819 feet below ground**.**

http://www.wvgs.wvnet.edu/atg/CoreViewer.aspx?RO=4&PN=1&api=4703902751

Figure 4 – Photographs of Tuscarora sandstone and conglomerate units from core provided at the link presented in Figure 3

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Differential cementation in the Tuscarora Sandstone

FIG. 25a— Tightly-cemented layers alternating with poorly-cemented layers. Depth in feet.

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FIG. 25b— Narrow horizontal and vertical bands of tightly-cemented sandstone forming a lattice pattern (arrows). Depth in feet.

(Bruner, 1983)

Figure 4 – Continued

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FIG. 25c— Irregular lower digitate boundary, similar to the lower boundaries in poorly cemented disk-shaped lenses found in outcrop. Depth in feet.

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FIG. 25d— Poorly-cemented patches over pebbles and clay clasts (arrows). Depth in feet.

(Bruner, 1983)

Figure 5 – Descriptive data on the Tuscarora core provided in Figure 3