EASTERN PANHANDLE EXPANSION PROJECT
POTOMAC RIVER CROSSING

PROJECT 6493

KARST MITIGATION PLAN

Columbia Gas Transmission

2930 Eskridge Road
Fairfax, VA 22031
phone: (703)-698-9300
fax: (703) 698-4414
intertek.com/building
psiusa.com

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1. INTRODUCTION

PSI understands that the proposed project will consist of the installation of a natural gas transmission pipeline beneath portions of Fulton County, Pennsylvania; Washington County, Maryland; and Morgan County, West Virginia.

The Eastern Panhandle Expansion Project will consist of approximately 3.37 miles of new greenfield 8-inch diameter pipeline; three valves and two new tie-in assemblies. Approximately two thirds of the pipeline will be installed a minimum of 3 feet below the ground surface (i.e. conventional cut and cover installation) and approximately one third will be installed using Horizontal Directional Drilling (HDD) to tunnel and lay the pipeline under the Potomac River and Interstate I-68 at a depth deeper than 3 feet.

EnSite USA is providing engineering services for Columbia Gas Transmission for the proposed pipeline and requested that PSI perform an assessment of the potential for the presence of karstic limestone bedrock along the alignment.

Mitigation is being utilized to minimize karst related issues that may arise during construction and operation of the Project. Karst conditions and sinkhole development are potential issues at various locations along the proposed pipeline alignment and at pipeline facilities.

Avoidance was used as the primary mitigation measure during the planning and selection of the proposed alignment. Where avoidance is not feasible, the karst features identified were further evaluated and remediation measures developed. In addition, field survey, testing and evaluations were conducted at horizontal directional drilling (HDD) locations to evaluate design and support of the proposed facilities and assess the potential for sinkhole development. Response plans for sinkholes, depressions or other karst related issues that may arise during construction or operation of the Project have also been prepared and have been included as part of the overall mitigation plan.

This report has been reviewed and edited by several of our Florida based engineers who are in the process of providing similar support during construction of a gas pipeline through South Georgia and North Florida in karst areas. This plan has been used several times to deal with sinkholes that have occurred during construction of that particular pipeline.

2. KARST RISKS ASSOCIATED WITH PIPELINE CONSTRUCTION

Sinkholes are naturally occurring phenomena in areas underlain by carbonate bedrock, such as the limestone formations associated with Ridge and Valley Province between South Mountain in Washington County, Maryland and Dans Mountain in western Allegany County, Pennsylvania. The Ridge and Valley Province contains strongly folded and faulted sedimentary rocks. The Potomac river flows in a valley called the Great Valley and is formed on Cambrian and Ordovician limestone and dolomite. Some of the valleys in this region are underlain by Silurian and Devonian limestones.

Most sinkholes are triggered by external factors such as significant or prolonged rainfall, periods of drought, heavy groundwater pumping, or stormwater management practices. Experience with pipeline installation in Karst Sensitive areas of the country such as South Georgia and North Florida has shown that the frequency of localized subsidence occurrences is typically low and the scale of the features small enough for non-complicated remediation efforts. The bedrock in this area of the country is significantly harder and stronger than the softer and more porous limestone in South Georgia and North Florida resulting in a reduced likelihood of sinkhole features due to the pipeline installation. The following addresses the risks associated with different aspects of Project construction.

2.1. Pipeline

Approximately two-thirds of the proposed pipeline will be constructed with conventional cut and cover techniques, where a length of trench is excavated, the pipe is placed and connected to the previous section, and the trench is backfilled with material excavated from the trench. While, there is the potential for unknown karst features to be encountered during pipeline installation, the probability that these features will negatively impact pipeline installation or result in the formation of sinkholes or surface depressions is extremely low. Karst features discovered during pipeline installation can be readily identified, evaluated and remediated during the construction process.

Hydrostatic testing performed during pipeline construction can introduce significant amounts of water to the area. Mitigation measures for managing hydrostatic test water in the vicinity of karst features are discussed in the Remediation Section (Section 7) of this report.

2.2. HDD Crossings

Columbia Gas Transmission has consulted with nationally recognized horizontal directional drilling (HDD) contractors with experience completing HDD installation in the Project's region, as well as other karst areas, to help evaluate the potential risks to the Project and to develop mitigation measures that may be employed during construction.

The general risks associated with HDD construction methods in karst areas include difficulties arising from very loose unstable soils and open voids along the drill path. More specifically, these risks include:

- Loss of drilling fluid into open conduits and inadvertent drilling fluid returns leading to turbidity in nearby wells, springs, and rivers.
- Ground subsidence and possible sinkhole formation due to excavating zones of loose unstable soils.
- Stuck drill tooling and the possibility of the carrier pipe becoming stuck in loose unstable zones during pullback.

The exploration completed for this HDD crossing did indicate the presence of some voids, they were typically very minimal (a few inches in size) and most likely discontinuous and localized. No other conditions often associated with sinkhole risk/potential were observed in the borings.

2.2.1. Lost Drilling Fluid Returns

Drilling fluid which is primarily a combination of water (about 95%) mixed with bentonite (about 5 %) to form a slurry is circulated through the drilled hole during horizontal directional drilling operations. Water based bentonite drilling fluids are an integral part of a successful HDD operation and are used to lubricate and cool the downhole tooling, suspend and transport cuttings to the surface, and stabilize the borehole by forming a thin layer of clay on the inside of the hole (wall cake). Additionally, water based bentonite drilling fluids help maintain the open hole condition by offsetting the formation’s geostatic pressure with increased hydrostatic pressure. The clay in drilling fluid utilized for HDD operations is composed of bentonite, which is a naturally occurring clay mineral that absorbs several times its weight in water. When mixed with water in measured quantity, bentonite augments and optimizes the engineering properties of the mixture to support HDD operations in specified geological conditions.

While drilling fluid loss to conduit and cave systems is possible in karst affected areas, site characterization of the HDD sites does not suggest that cave systems will be directly encountered along the HDD profiles. In addition, springs were not identified in the vicinity of the proposed HDD crossings. It is recognized that small conduits feeding cave systems could be encountered along the HDD profiles; however, these conduits are not typically “open” but are filled with permeable sediments that create a preferential pathway for groundwater flow. In some instances, loss of drilling fluid from the borehole to these conduits will subside over time as the drilling fluid builds a layer of bentonite in the borehole and seals it to further flow. Drilling fluid properties will be managed, on a site specific basis, to ensure that they are optimal for the conditions being encountered.

The partial or full loss of drilling fluid may also occur as a result of encountering loose unstable zones of soil that have in-filled pre-existing sinkholes or by intersecting conduits or voids. In zones of loose unstable soil, the properties of drilling fluid may be augmented to aid in stabilizing the soils and in maintaining drilling fluid returns to the entry and/or exit pits. If open voids are encountered along the HDD path, a temporary loss of drilling fluid returns can be expected until the fluid being pumped into the borehole fills the cavity and drilling fluid returns are restored.

In the event that drilling fluid circulation is reduced or lost in the borehole, additives may be used to attempt to seal the conduits and allow for the reestablishment of drilling fluid returns to the entry and/or exit pits. Many types of inert and environmentally benign additives or materials are available for use with HDD operations which include wood fibers, cotton seed husks, ground walnut shells and other natural materials.

Special polymers that swell to several times their original size when introduced to water can also be used to seal the borehole should a partial loss of drilling fluid occur during HDD installation. These products are readily available to contractors should the need arise.

Grout and concrete plugs have been successfully utilized to fill subsurface voids and conduits to restore drilling fluid returns and stabilize the borehole during HDD operations. The details of how grout plugs are installed are highly dependent on conditions encountered during HDD operations. There are many types of equipment, methods and materials to successfully install a grout plug and their use will be determined on a case by case basis by a specialty grouting contractor. Potential short-term impacts to groundwater quality resulting from grout plug installation would be negligible because the grout will typically begin setting up within 24 to 48 hours.

2.2.2. Fracture and Conduit Size Limitations for HDD

Successful installation of pipelines using HDD methods requires sufficient stability of the borehole to allow the passage of the pipe during pullback operations. In mature karst areas, fractures and conduits can be present within the limestone bedrock units that could pose risks to the successful completion of the pipeline installation. When designing HDD installations in rock formations, the key characteristic of the bedrock which determines how stable the formation will be during drilling and pullback operations is the rock quality designation (RQD). Rock core samples are typically recovered from exploratory hole in 5 to 10-foot intervals referred to as core runs. RQD is a measure of the fracture spacing of the formation and is expressed as a percentage value. RQD is calculated by dividing the total length of rock core pieces over 4 inches in length recovered from a core run by the total length of the core run.

In competent rock formations, RQD values less than 50 percent provide evidence that borehole stability during HDD operations may be compromised, which introduces risk of difficulties during construction. Based on the subsurface exploration performed high core recoveries and RQD values suggest a low instance of sinkholes or issues with borehole stability. Lower RQD values may be due to reduced core recovery in weathered and poorly cemented/in-filled zones of the formation that wash away or are broken during the coring process are not necessarily detrimental to overall borehole stability during HDD operations. More than 80% of the rock cored for the geotechnical exploration had RQD values in excess of 50.

Open conduits can present a risk of stuck and/or lost tooling in the borehole during HDD operations. In karst-sensitive areas, conduits in the limestone formations feed groundwater to springs in the region. Essentially, the springs are fed by irregular networks of smaller conduits that become increasingly smaller with distance from the spring. Because of the distance the HDD sites are from the nearest documented springs, it is anticipated that any conduits encountered will be less than a few feet in size. Additionally, evidence of large open voids or conduits was not observed during site characterization activities.

When estimating the type and width of subsurface voids that can be successfully spanned, consideration must be given to the type, strength and rigidity of drilling tooling and mainline pipe. During consultations with HDD contractors experienced in karst-sensitive areas, it has been determined that open conduits or voids of approximately 15 feet or less in diameter have been successfully spanned utilizing similar tooling and in similar conditions as those expected on the proposed Project. Voids of this nature can be successfully spanned because the stiffness/strength of the downhole tooling and mainline pipe is sufficient to allow drilling operations to continue without compromising the geometry of the hole, the integrity of the tooling or mainline pipe.

2.2.3. Sinkhole Development from HDD Operations

HDD operations could trigger or reactivate sinkhole activity where the borehole passes through loose, unstable soils that have in-filled existing sinkholes, where the borehole passes through the throat of an in-filled sinkhole, or where soil in-filling in conduits is removed by circulation of drilling fluid. This occurs through a process of over-mining where the loose soil continues to flow into the drilled hole, similar to how sand passes through the constriction in an hourglass. As drilling fluid is circulated through the borehole, loose soils are entrained into the drilling fluid and carried out of the hole. This process can eventually lead to the activation or reactivation of ground settlement. Proven techniques, as developed by the HDD industry, will be implemented on this particular project.

In summary we believe that the potential for sinkhole development at this particular HDD site will be low and that if such conditions become apparent during construction they may be dealt with on a reactive basis as noted herein and as construction progresses.

3. IDENTIFICATION OF KARST FEATURES

A review of readily available published information was conducted to identify possible karst features in close proximity to the proposed pipeline alignment and HDD crossings. The results of the geologic literature review indicate that the rock formations along the project alignment are not mapped as having karst features. In our opinion this again suggests the potential for sinkhole risk as low and the need for remediation / restoration unlikely.

4. EVALUATION OF THE POTENTIAL FOR SINKHOLE DEVELOPMENT

Four borings were completed for the Potomac River crossing (GO-1, GO-7, GO-2R and GO-3R), two borings for the Interstate I-68 crossing (GO-4 and GO-5), one for the proposed Tie-in-Facility (GO-10) and one for the proposed Point-of-Delivery Facility (GO-6). The borings generally encountered five to twenty-three feet of overburden soil materials over the weathered rock and rock. The overburden deposits thicken toward the Potomac river.

Boring	Approximate Termination Depth (feet)	Ground Surface Elevation (feet, NAVD)	Approximate Depth/Elevation of recorded VOIDS Depth/Elevation (Feet)	Approximate Depth/Elevation of recorded Sand Seams Depth/Elevation (Feet)	Material Washed Away During Coring Depth/Elevation (Feet)
GO-1	305	624	N/A	10-foot sand seam from 264feet, EL ±360MSL to 274feet, EL ±350MSL	N/A
GO-2R	154	411	1-inch void at 51.3 feet, EL ±359.7MSL 1-inch void at 53.1 feet, EL ±357.9MSL 7-inch void at 53.4 feet, EL ±357.6MSL	29-inch sand seam from 131.6 feet, EL ±279.4MSL to 134feet, EL ±277MSL 8-inch sand seam at 136 feet, EL 275MSL 6-inch sand seam at 138.5 feet, EL ±272.5MSL	N/A
GO-3R	277	591	N/A	N/A	N/A
GO-4	60	435	N/A	N/A	N/A
GO-5	70	447	N/A	N/A	N/A
GO-6	40	590	N/A	N/A	N/A
GO-7	100	402	9-inch void at 58.2 feet, EL ±343.8MSL	N/A	17-inch clay seam from 72.6 feet, EL±329.4MSL to 74feet, EL±328MSL 18-inch clay seam from 107feet, EL±295MSL to 108.5feet, EL±293.5MSL
GO-10	20	581	N/A	N/A	N/A

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The borings did not have a very soft active weathering zone just above the bedrock which is a characteristic of sites with active karst feature development. In addition, the limestone encountered in the rock cores was interbedded with shale. Karst features are more likely to develop in massive limestone than in more thinly bedded limestone that is interbedded with shale. Although some voids were observed in the rock cores, they were typically small and well above the expected depth of the pipeline.

The general geologic conditions traversed by the alignment were evaluated and assigned a risk ranking of **LOW** based on the following scale:

LOW The probability of an occurrence is unlikely. Although historical occurrences may have been reported or documented in the area, they are infrequent and recent activity is low or insignificant.

MEDIUM Historical occurrences are well documented and conditions favorable to development are believed to be present.

HIGH Historical occurrences are common and frequent and conditions favorable to development are present and well documented.

Natural factors that influence sinkhole risk in any given area include the depth to rock, the composition of the overburden soils above the rock (confined with clayey soils present over the rock or unconfined with essentially sands from the ground surface to top of rock), recharge potential, presence and concentration of fractures, and the potentiometric surface elevation of the aquifer. In addition, the proposed HDD installation is not anticipated to intercept or penetrate any known aquifer system in the area of the project. These factors were taken into consideration while assessing the sinkhole risk.

5. EVALUATION OF KARST FEATURES

At each HDD site, geotechnical investigations were conducted to characterize subsurface conditions that could be experienced during HDD operations. The geotechnical investigations consisted of completing borings offset from the pipeline alignment utilizing rotary wash and rock coring techniques to advance the borings and sample the subsurface strata. The interval between samples was reduced where deemed necessary. The risk of sinkhole formation is considered LOW. Data collected during the site investigation phase of the project was utilized during the design phase to evaluate the HDD geometry to maximize the likelihood of successful installation and reduce the risk of impacting areas along the alignment of the HDDs.

More specifically, the following methodologies, where possible, were employed during the design phase:

- The depth of HDD was designed to avoid zones that were interpreted to represent the largest potential risk to the successful installation of the pipeline while minimizing the risk of inadvertent drilling fluid returns to the surface.
- The length of each HDD was developed to ensure that its associated surface workspace would avoid impacts to environmentally sensitive areas while minimizing the length of the HDD drill path.

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6. EVALUATION OF RESULTS

The results of geotechnical investigations are included in Table 1. The results of these investigations were used to assist with the development of the mitigation measures outlined in section 7.

Boring	Approximate Termination Depth (feet)	Ground Surface Elevation (feet, NAVD)	Approximate Depth/Elevation of Top of Weathered Rock	Approximate Depth/Elevation of Auger Refusal
GO-1	305	624	23 feet, EL ±601MSL	24 feet, EL ±600MSL
GO-2R	154	411	20 feet, EL ±391MSL	24 feet, EL ±387MSL
GO-3R	277	591	9 feet, EL ±582MSL	23 feet, EL ±568MSL
GO-4	60	435	6.5 feet, EL ±428.5 MSL	10 feet, EL ±425 MSL
GO-5	70	447	8.5 feet, EL ±438.5 MSL	13.5 feet, EL ±433.5 MSL
GO-6	40	590	19 feet, EL ±571MSL	30 feet, EL ±560MSL
GO-7	100	402	6 feet, EL ±396	6 feet, EL ±396MSL
GO-10	20	581	5 feet, EL ±576MSL	20 feet, EL ±561MSL

The vast majority of the materials cored had recovery in excess of 90 percent and RQD values in greater than 75 indicating good to excellent rock quality from an engineering perspective.

Summary of Soil Boring Results						
Boring	Drilled Rock Depth (feet)	Range of Rock Core Recovery (%REC)	Average Rock Core Recovery (%REC)	Range of RQD Values	Average RQD Value	Percentage of Rock with RQD <50
POTOMAC RIVER CROSSING						
GO-1	23 – 305	87 - 100	99	45 - 100	80	6
GO-2R	30 - 154	55 – 100	94	17 – 98	67	17
GO-3R	30 - 277	53 – 100	95	7 - 100	73	14
GO-7	15 - 134	72 – 100	96	24 - 100	61	23
I-68 CROSSING						
GO-4	6 - 60	83 - 100	98	0 - 86	69	28
GO-5	9 - 70	100	100	61 - 97	81	0

7. MITIGATION OF CONSTRUCTION RELATED KARST ISSUES

The following is a discussion of mitigation measures that will be employed to reduce the frequency, magnitude, and severity of karst related issues that may arise during construction of the pipeline and above ground facilities and during HDD operations.

7.1. Pipeline Construction

7.1.1. Hydrotesting

To reduce the potential for sinkhole development during hydrostatic testing, the test water from the new pipe will not be discharged directly into the vicinity of a known karst feature open to the surface. The water will be discharged down-gradient of identified karst features (if any). If site conditions prevent a down- gradient discharge, the water will be discharged as far from the karst feature as practicable with a discharge and sediment and erosion control features detailed in the Project Erosion and Sediment Control Plan (ESCP). Post- construction monitoring will ensure proper re-vegetation and restoration of these areas.

7.1.2. Ground Subsidence or Sinkhole Formation

As required by Code 49 of Federal Regulations, Part 192.613, route surveillance will be conducted during construction and operation of the facilities, along with training of surveillance personnel, to monitor the pipeline alignment for evidence of subsidence, surface cracks, or depressions which could indicate sinkhole formation. Signs of sinkhole formation, ground subsidence or surface depressions will be immediately and clearly marked. Work will be temporarily halted and the immediate area around the depression evacuated until it is deemed safe and stable. The project geotechnical engineer will also be notified of the occurrence.

If open holes are found to have been sinkhole related they should be filled following local practices. The area may be backfilled with clean sand fill to temporarily stabilize the area until further evaluation can be conducted.

In some cases, pipeline construction will necessitate the backfilling of closed depressions without visible openings/voids at the ground surface and depressions with karst voids or openings exposed to ground surface. A common approach in Florida is to infill these features with clean sand. Backfill activity would consist initially of vegetation removal and placement of a clean sand fill. If it is an “open hole” with no readily visible bottom, an effort should be made to use water to aid in the filling process.

If sand infill or local filling practices do not provide for a stable subgrade for pipe support, compaction grouting may be required. Compaction grouting is a common method of remediating ongoing active or potential sinkhole formation. The process involves installing pipe by driving or drilling into the area of concern and injecting grout under pressure to fill voids, cavities and soft zones within the limestone formation. As the pipe is withdrawn, grout is continually pumped to stabilize any loose or raveled soils in the overburden by compression and compaction. To effectively stabilize the feature without pumping excessive amounts of grout, a volume limit is typically established for each hole. If the limit is reached, secondary or tertiary points are added to ensure the feature is stabilized.

Based upon the final remediation method the alignment of the pipe maybe modified.

7.2 Above-Ground Facilities

Site specific measures to assure structural integrity in the facility areas will be used. Because ground subsidence or sinkhole formation is so rare in the project area, special measures such as reinforced grade beams and slabs capable of spanning small drop outs, or utilizing deep foundations (piles or drilled shafts) that extend into competent rock are not typically employed. Should karst conditions be identified at any above-ground facility location, alternative foundation or remediation measures may be employed.

7.3. HDD Crossings

During construction, the Chief Inspector, HDD Superintendent and other members of Columbia Gas Transmission's inspection staff will maintain close communication regarding daily progress and any potential karst features (zones of concern) that may have been encountered. Close communication between all members of the construction staff will be important to ensure that all possible risks are addressed and accounted for in the drill plan. The following sections outline methods that will be employed during construction to minimize negative impacts associated with HDD activities in karst-sensitive areas.

7.3.1. Pilot Hole

During pilot hole operations, the following measures will be employed to help determine if the condition of the formation along the HDD drill path indicates that a zone of concern has been encountered.

- Rates of penetration and resistance to forward progress will be monitored for zones of loose soils or open voids indicating that zones of concern may be present. A decrease in the resistance required to advance the bottom hole assembly could indicate a zone of loose, unstable soils or open voids.

- The pilot hole driller/surveyor will monitor the steering inputs required to advance the pilot hole along the alignment and profile of the HDD path. Zones where larger steering inputs are required to advance the pilot hole within acceptable tolerance could indicate a zone of loose, unstable soils or open voids.
- Drilling fluid returns will be monitored. A loss of drilling fluid returns may indicate where loose, unstable zones or open voids and/or conduits are located along the drill path and that the bottom hole assembly is entering a karst feature.

The following actions will be taken if, based on the above observations, it is believed that a zone of concern has been encountered along an HDD drill path.

- The location and extent of the zone of concern will be documented so that it can be considered relative to subsequent drilling activities.

- The zone of concern will be targeted for surface monitoring along the HDD alignment during drilling operations.
- Observations made during pilot hole operations will be used to modify the original drill plan for subsequent HDD operations.
- The HDD contractor will make all reasonable attempts to maintain drilling fluid returns. If the integrity of the borehole or the HDD profile geometry becomes compromised through attempts to restore drilling fluid returns, the HDD contractor will notify Columbia Gas Transmission. If it is determined that further attempts to restore drilling fluid returns may compromise the HDD installation or are unlikely to be successful, the HDD contractor will proceed with modified drilling procedures to reduce the risk of inadvertent drilling fluid returns.
- In the event of inadvertent drilling fluid returns, recognized/ acceptable drilling procedures and practices will be followed.
- In the event of ground subsidence, the area will be monitored and backfilled with sand if feasible. Topographic surveys will be conducted if nearby structures may be impacted.
- If drilling fluid loss downhole affects nearby springs or rivers and complete drilling fluid loss to the formation cannot be prevented, all or a portion of the pilot hole would be abandoned and a new pilot hole started at an alternate depth. Drilling will continue and the affected waterbody will be monitored.
- If practical, an increased rate of penetration through zones of loose, unstable soils will be used to limit the risk of inadvertent returns.
- Twenty-four hour HDD operations may be implemented to help maintain stability of the hole within zones of concern.

7.3.2. Reaming and Swabbing

During reaming operations, the following measures will be employed to help determine if the condition of the formation along the HDD drill path indicates that a zone of concern has been encountered.

- Rates of penetration and rotary torque on the downhole drill pipe string can be monitored for zones of loose material indicating where zones of concern may be present.
- Drilling fluid returns will be monitored. A loss of drilling fluid returns may indicate where loose, unstable zones or open voids and/or conduits are located along the drill path and that the reaming assembly is entering a karst feature.
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The following actions will be taken if, based on the above observations it is believed that a zone of concern is encountered along an HDD drill path.

- The location and extent of the zone of concern will be documented so that it can be considered relative to subsequent drilling activities.
- The zone of concern will be targeted for surface monitoring along the HDD alignment during drilling operations.
- The observations made during reaming operations will be used to modify the original drill plan for subsequent HDD operations.
- The HDD contractor(s) will make all reasonable attempts to maintain drilling fluid returns. If the integrity of the drilled hole becomes compromised through attempts to restore drilling fluid returns, the HDD contractor shall notify Columbia Gas Transmission or their authorized representative. If it is determined that further attempts to restore drilling fluid returns may compromise the HDD installation or are unlikely to be successful, the HDD contractor should proceed with modified drilling procedures to reduce the risk of inadvertent drilling fluid returns.
- In the event of inadvertent drilling fluid returns, measures will be taken to re-establish borehole integrity.
- In the event of ground subsidence, the area will be monitored and backfilled with sand if feasible. Topographic survey will be conducted if nearby structures may be impacted.
- If drilling fluid loss downhole affects nearby springs or rivers and complete drilling fluid loss to the formation cannot be prevented, reaming operations will continue and the affected waterbody will be monitored.
- Increased rate of penetration through zones of loose, unstable soils will be used to limit the risk of inadvertent returns and over- mining of loose soils.
- Twenty-four hour HDD operations may be implemented to help maintain stability of the hole within zones of concern.
- The HDD contractor will employ modified reaming practices to limit impacts and maximize the chances for a successful installation.

7.3.3. Pullback

To maximize the chances of a successful installation, pullback operations will commence immediately following one or more acceptable swab passes which indicate that the hole is in a condition to accept the carrier pipe. The HDD Superintendent, will make the determination as to when the reamed borehole has been adequately prepared for installation of the pipeline. Pullback operations may be carried out on a 24-hour basis until the completion of pipe installation.

8. GLOSSARY

- BLS or BGS – an abbreviation for below surface or below ground surface.
- Carrier Pipe – pipe designated to contain and carry the product, in this context - natural gas
- Compaction Grouting – a grouting technique that displaces and densifies loose granular soils, reinforces fine grained soils and stabilizes subsurface voids or sinkholes, by the staged injection of low-slump, low mobility aggregate grout.
- Cut and Cover – a pipeline construction technique where a trench is excavated, the pipeline is laid in the trench then the trench is backfilled.
- Drill Tooling – HDD tooling used to drill a pilot hole or ream (increase the diameter of) the hole for the carrier pipe installation. This tooling includes the drill pipe, drill bit and or reaming tools and stabilizers.
- Drilling Fluid - a water-based drilling fluid consisting of water and bentonite (a naturally occurring clay mineral). The drilling fluid is pumped downhole during drilling operations to remove soil and rock cuttings from the hole, stabilize the hole and cool and lubricate the downhole tooling.
- Drilling Fluid Returns – Drilling fluid that is pumped downhole through the drill pipe to the drill bit or reaming tool and travels to the entry and/or exit sides of the crossing via the drilled hole.
- DD pullback – A process of pulling the carrier pipe through a previously reamed hole.
- Mitigation – the action of reducing severity or seriousness of something. In the context of this plan, karst mitigation is a set of actions intended to reduce a probability and/or impacts associated with karst terrain.
- Standard Penetration Test (SPT) - an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil.
- Rock Coring – sampling method used for hard materials where an outer barrel is rotated at high speeds to cut the material while samples are recovered from a swivel mounted inner barrel.
- Rock Core Recovery – percentage of the recovered sample compared to the total core length
- Rock Quality Designation (RQD) – defined as the cumulative sum of recovered pieces 4 inches and longer divided by the total length cored. The sample recovery and RQD are a measure of the character and continuity of the material penetrated and are indications of the quality of rock.