Geo-Hazards and Pipeline Safety

Presented By:
Scott A. Wendling, PG
Vice President, Chief Operating Officer
ARM Group Inc.
Hershey, PA

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Pipelines Are in the Public Interest

PA PUC Mission Statement:

The Pennsylvania Public Utility Commission balances the needs of consumers and utilities; ensures safe and reliable utility service at reasonable rates; protects the public interest; educates consumers to make independent and informed utility choices; furthers economic development; and fosters new technologies and competitive markets in an environmentally sound manner.
American Petroleum Institute:

Pipelines are an extremely safe way to transport energy across the country. A barrel of crude oil or petroleum product shipped by pipeline reaches its destination safely more than 99.999% of the time. The number of releases greater than 500 barrels is down 32% since 2011.
## Agenda

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## What Are Geo-Hazards?

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How Can Geo-Hazards Impact Pipelines?

“Landslide caused West Virginia pipeline explosion, TransCanada reports“ Pittsburgh Post Gazette, July 2018
How Can Geo-Hazards Impact Pipelines?

“Officials believe landslide may have triggered massive gas pipeline explosion in Beaver County” Pittsburgh Post Gazette, September 2018
How Can Geo-Hazards Impact Pipelines?

“Another sinkhole appears in Chester County neighborhood, exposing pipeline “
Philadelphia Inquirer, January 2019
How Can Geo-Hazards Impact Pipelines?

“Neighbors concerned after latest sinkhole…”
WPVI TV Philadelphia, January 2019
What Can We Do to Evaluate Geo-Hazards?

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Geo-Hazards May be Dictated by Construction Technique
Potential Issues with Improper HDD Practices

- Inadvertent Returns (IRs)
- Ground surface heaving/subsiding
- Lost borehole (borehole collapse)
- Pullback failure
- Impacts to sensitive areas (water)
Inadvertent Return (IR)

“Inadvertent Return” (IR) formerly known as “Frack Out”

Two primary causes:

1. Preferential Pathways
2. Improper Drilling Practices
Focus on IR’s

Cause #1 - Preferential Pathways
Focus on IR’s

Eliminating IR via Preferential Pathways

1. Avoid them!
   1. Good geotechnical data, conservative bore planning

2. Drilling fluid additives (with small aperture openings)
   1. Thick bentonite drilling fluid can help, to a point
   2. LCM

3. Grout from Surface & Drill on
Focus on IR’s

Eliminating IR via Preferential Pathways

4. Casing off the zone
Some IRs are expected

- When soil/rock pressures can’t support the fluid pressure
  - Entry, Exit, Too thin of cover
- Managing the fluid return where it is occurring, by setting up the transfer of fluid via pumping or occasionally, trucking.
- Drilling may continue if IR is contained and managed
- Relief wells
Sinkholes & HDD
What is Karst?

Karst terrain is defined as a type of topography that is present in areas underlain by carbonate bedrock (limestone or dolomite). It is caused by dissolution and erosion and is characterized by surface depressions, sinkholes, caves, and subsurface drainage (Kochanov, 1990).
Sinkhole Development

- During an IR, mud flow up and out of the bore can carry soil/sediment up and to the surface, leaving a preferential pathway for fluid flow, and potentially, a sinkhole.
Sinkholes May Be Karst-Related
Not all Sinkholes are Karst-Related!

• Geologic contacts
• Fractures
• Faults
• Mining Subsidence (i.e., Centralia)
• Utilities (i.e., City of Harrisburg)
Not all Sinkholes are Karst-Related
Not all Sinkholes are Karst-Related
Not all Sinkholes are Karst-Related
What Can We Do to Evaluate Geo-Hazards?

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<th>Geophysical &amp; Geotechnical Investigations</th>
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<td>Borehole Logging</td>
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Seismic MASW for HDD

Vertical MASW Profile M4

- Top of Competent Rock
- Rippable Rock
- Proposed Alignment Along Top of Rock; Not Optimal

Subsurface Shear Wave Velocity Scale:
- Soft Clay Soil
- Stiff Soil
- Very Dense Soil and Soft Rock
- Rock
Seismic MASW for HDD Pipeline Investigation

MASW & ER Geophysical Survey Points

Vertical MASW Profiles M1, M2, M3

Estimated Top of Weathered Bedrock (~1,200 feet/second contour on MASW profiles)
Potential Dense Shaley Soil

Subsurface Shear Wave Velocity Scale

(Potential IR Area)
(Non-Rippable Rock)
Electrical Imaging for Sinkhole

Example Earth Resistivity Profile Over a Potential Sinkhole

This earth resistivity profile was collected over a circular depression at the ground surface that was suspected to be a potential sinkhole. The profile indicates that a soil/water filled solution cavity had developed in the bedrock beneath the circular surface depression representing a hazardous condition for this site. Early detection of solution cavities allows for remediation and removal of these hazards prior to sinkhole formation.
ER Survey for Geo-Hazards

ER4

ER Anomaly #4
Saturated Zone / Potential Coal Mine Workings
60' to 170' bgs

ER Anomaly #3
Potential Coal Mine Workings or Shale Bed
25' to 80' bgs

(Planned HDD Alignment)

ER5

ER Anomaly #6
Higher Moisture Content @ 50' to 70' bgs

ER Anomaly #5
Higher Moisture Content @ 20' to 45' bgs

(Possible Mine Shaft)
ER Survey for HDD Pipeline

3D ER Survey Results

Projected HDD Path (white translucent line)
Southwest HDD Exit

ER Cross-Section (Vertical Profile)
*Black Transect on Basemap*

Stream Crossing

E1
E2
E3
E4
E5
HDD Entry

Ground Surface (brown line)

Potential Fracture Zones (high-transmissivity pathways)

Resistivity Color Scale (ohm-feet)

Massive Bedrock/Dry Soils

Moist Soil/Fractured or Shaly Bedrock

Distance (feet)

Vision. Partnership. Results.
MASW Survey for HDD Pipeline
Geophysical Results - HDD Pipeline

- No subsurface voids identified.

- Multiple near-vertical bedrock fracture zones in area of proposed HDD. Fractures correspond to fracture zones identified by ARM on aerial and LiDAR imagery, and to the mapped contact between geologic formations based on information from the Pennsylvania Geologic Survey.

- Potential for significant groundwater volumes to be present on both sides of the stream. The anomalies identified are representative of the types of zones ARM commonly seeks when exploring for commercially-viable groundwater resources (i.e., well yields >> 100 gallons per minute).

- Potential for a groundwater seep/spring on the hillside approximately 100- to 150-feet southwest of the stream along the proposed pipeline alignment.
Geophysical Results - HDD Pipeline

• Soft soils & apparent fracture zones appear to be associated with zones of structural weakness and are likely to be problem areas during an HDD construction project. For example, these zones of weakness are areas where inadvertent returns (IRs) may occur.

• Potential for significant groundwater volumes also poses a risk to proposed HDD construction. Significant groundwater volume at a higher elevation to the southwest of the stream could result in water flowing through the HDD bore and discharging to the surface at the proposed HDD entry point. The artesian conditions observed in test borings B-2 and B-3 support this conclusion.

• The potential risks associated with HDD activities should be carefully considered when determining if HDD methods or open-cut trench methods are to be used to cross the stream.
Borehole Logging
Evaluating Coal Seams

<table>
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<tr>
<th>Optical Image</th>
<th>Depth 1m/2ft</th>
<th>Virtual Core</th>
<th>Virtual Core with Caliper</th>
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<tbody>
<tr>
<td>0° 90° 180° 270° 0°</td>
<td>Coal</td>
<td>305°</td>
<td>0°</td>
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<tr>
<td>80</td>
<td>87</td>
<td>88</td>
<td>89</td>
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[Image of coal seam analysis]
Televiewer Imaging

Open Fracture

Filled Fracture
Methane Intrusion Investigation

Gas bubbles start at 231.4’ on the SE side (150 deg) of borehole, from a fracture with dip & dip direction of 7/217.
Geo-Hazards Can Be Managed

With proper planning and due diligence, geo-hazards may be identified and managed, allowing safe operation of pipelines.

Deploying the proper geophysical & geotechnical tools can be a cost-effective approach to managing risks associated with pipeline construction.
Thank You!

Contact Information:

Scott Wendling, PG
ARM Group Inc.
1129 West Governor Road
PO Box 797
Hershey, PA

Phone: 717-508-0583
Email: swendling@armgroup.net
Website: www.armgroup.net