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ESTABLISHING PIPELINE GEOHAZARD MITIGATION PROTOCOLS

Prior to an unexpected ground movement event, such as from land subsidence, landsliding, or an earthquake, hazard mitigation protocols should be established. Where these protocols do not exist, an unprepared operator is in a reactionary, all hands mode to mitigate the potential peril and ultimate damage when such an event would occur. Therefore, when there is an unexpected ground movement event which can affect a pipeline, this situation should be avoided where possible given the potential catastrophe, massive expense from repair/mitigation measures and an out-of-service line, and any resulting regulatory issues.

Ahead of such an event, the protocols should be established by the operator and the geohazard specialist. Important factors in establishing geohazard protocols are:

- The nature of the ground movement,
- The integrity of pipe and associated structure,
- Alert driven action items, and
- The ground movement/line monitoring tools.

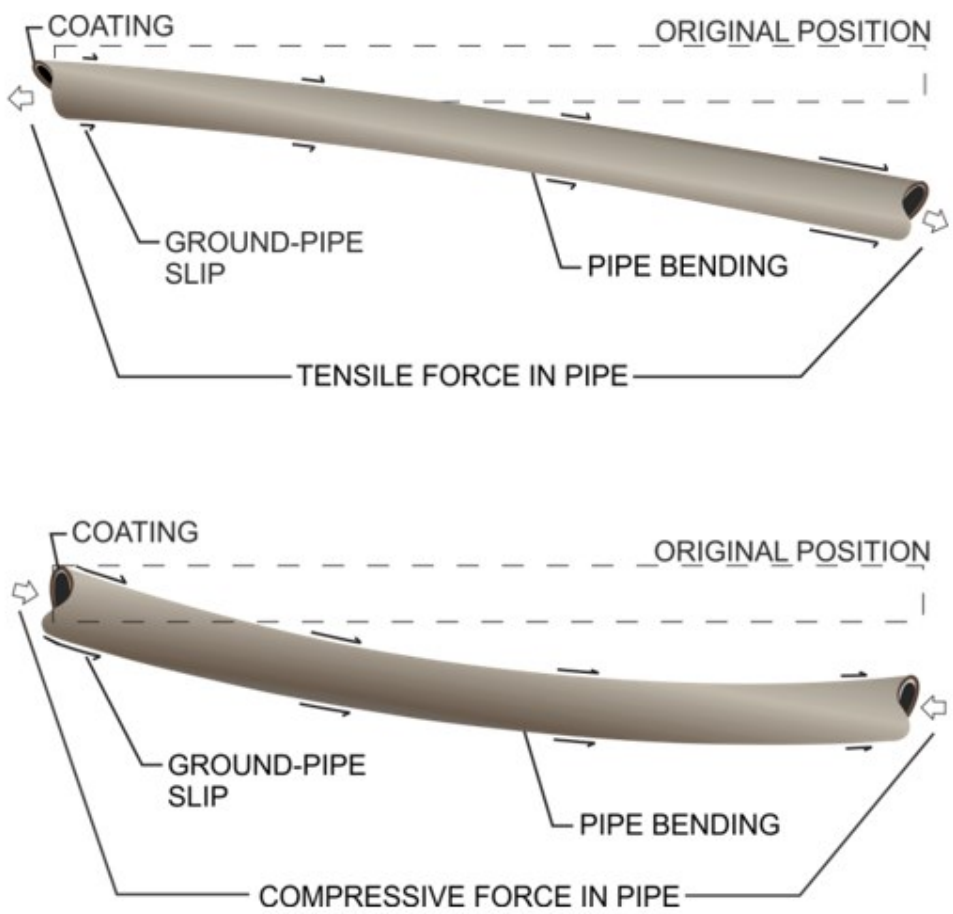

FIGURE 1 ILLUSTRATION OF POTENTIAL STRESSES IN A PIPELINE FROM GROUND MOVEMENT

Nature of the Ground Movement: Pipelines exposed to geohazards which are typically of the greatest concern are related to land subsidence due to underground mining and karst, landsliding and earthquake movements. These types of events can represent ground movements which occur at creep to rapid rates and can induce various stress and deformation conditions into the line. The various failure modes and associated critical stresses related to ground movement are given below and are illustrated in Figure 1.

MODE	INDUCED STRESS
Buckling	Axial compression/bending
Separation	Axial tension/bending
Upheaval Buckling	Axial compression + bending

An example of upheaval buckling is depicted in Figure 2. These deformation patterns related to various geohazards are summarized in Table 1.

Pipe and Associated Structure Integrity: This aspect of the protocol is determined by the operator's pipe integrity specialist or consultant. This would be determined by the condition and sensitivity of the line to the ground movements. Occasionally this may not be straightforward and would require numerical modeling for more complex line conditions. These associated alert levels are

commonly defined in terms of percentages of MSYS (maximum safe yield strength) of induced total longitudinal and equivalent stresses. These alert levels can set at low, moderate, and high, for example 0-60%, 60-90%, and 90% or higher of MSYS, respectively. Or alternately, alerts can set separately for different stress/deformation conditions. For example for upheaval buckling, the total longitudinal compressive stress may be the only concern. Without these alert levels in place, monitoring an active geohazard event can become a dangerous and uncertain spectator activity.

FIGURE 2 EXAMPLE OF UPHEAVAL BOWING OF A GAS TRANSMISSION FROM MINE SUBSIDENCE

Alert Action Items: Based on how the protocols are set up, and the nature of the geohazard situation, certain monitoring and field measures would be taken at the different established alert levels. These include in approximate order of increasing alert level, periodic monitoring, and report of the rate and intensity of the ground movement and line stress/deformation; frequent monitoring and report of stress/deformation; additional analysis to better quantify stress/deformation conditions; field inspections; prediction of future stress/deformation conditions; and emergency field mitigation measures including decoupling of the line from the ground to relieve the induced stress, and ultimately line shutdown to make the necessary repairs.

Ground Movement/Line Monitoring Tools: Ground and line monitoring tools are necessary to assess the start of an event and to identify the alert level present for an ongoing geohazard event. In areas prone to geohazards, it is crucial to install telemetric devices that accurately assess the impending risk of ground movement events and their potential impact on pipelines and associated structures. The most common instrumentation utilized depending upon the geohazard and line conditions in question include strain or force gauges, tiltmeters, inclinometers, and piezometers. Such instrumentation should have the capability to measure the necessary level of ground or line stress or deformation and in a sufficient number and in proper locations to best identify peak or critical load/deformation in the ground or line installed based on the evaluation of the geohazard and pipe integrity specialists.

TABLE 1 DOMINANT PIPELINE DEFORMATION PATTERNS RELATED TO VARIOUS GEOHAZARDS

Bending	Sinkholes (karst/mining) Fault displacement Landslides (transvere alignment) Earthquake wave propagation
Axial Compression	Gentle subsidence basins (karst/mining)
Axial Compression + Bending	Subsidence basins (karst/mining) Landslides (parallel to alignment) Fault Displacement
Axial Tension	Gentle subsidence basins (karst/mining)
Axial Tension + Bending	Subsidence basins (karst/mining) Landslides (parallel to alignment) Fault Displacement

Other MEA Publications that may be of Interest:

UPDATE #25 — Transmission Pipeline Subsidence From Mining

UPDATE #51 — Upheaval Buckling of Pipelines

Blog — How to Handle Geohazard Risks

ABOUT MEA: Marino Engineering Associates, Inc. focuses on engineering research, practice and expert evaluations and is licensed in 30 states in the U.S. Our projects primarily have an emphasis on Geotechnical Engineering, however, we also have significant experience in projects involving transportation, subsidence engineering, laboratory testing, training, and geophysical exploration. To obtain additional information on MEA, one can also visit our website at www.meacorporation.com.

FOR MORE INFORMATION: There is a significant amount of additional information that is available on the above subject. For more information, please contact MEA at the address listed below.

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