Quarterly Report - Public

Date of Report: *6th Quarterly Report – March 31, 2024*

Contract Number: *693JK32210010POTA*

Prepared for: *DOT PHMSA*

Project Title: ***Risk-Based Decision Support for Rehabilitation of Natural Gas Distribution Pipelines***

Prepared by: *GTI Energy*

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For quarterly period ending: *March 31, 2024*

1: Work Performed During this Quarterly Period

Work on Task 4 – Risk Assessment Tool. This task involves evaluating the causal relationship between system properties and events that derive soil movement and corrosion potentials. This quarter's work involved demonstrating the approach used in the analysis. Further work is in progress and will continue in the following two quarters.

Technical and Deliverable Milestone Schedule					
Item No.	Task No.	Activity/Deliverable	Quarter No.	Expected Completion Date/Mos	Payable Milestone
	(per proposal)	ACTIVITY/DELIVERABLE			TITLE
10	8	Quarterly Status Report	6	18 months	Submit 6th quarterly report
		Sixth Payable Milestone	**6**	**18 months**	**SUBTOTAL**

Figure 1 – 6th Quarterly Deliverable

2: Project Schedule

Figure 2 shows the project schedule and progress as of the end of the 6th Quarter. No time-related issues are reported in this quarter.

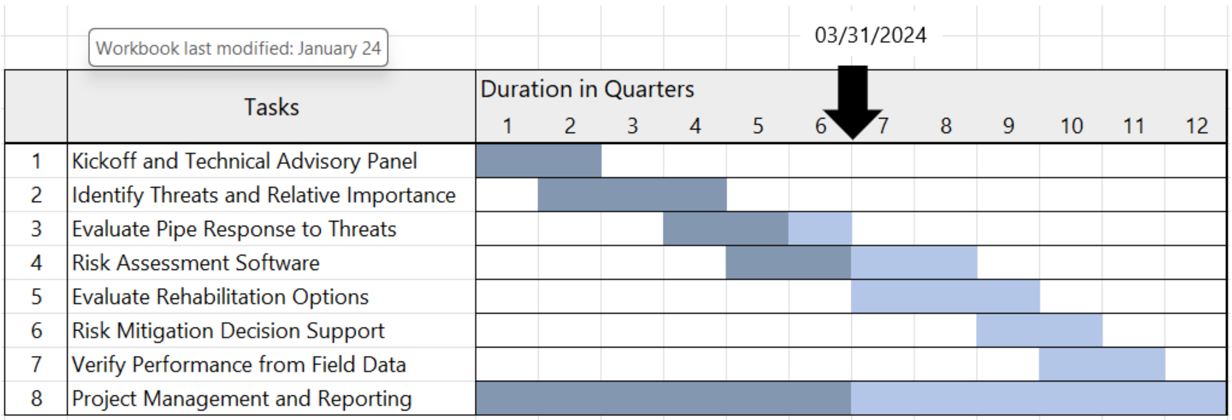

Figure 2 - Project time schedule

Interim Work on Task 4 – Risk Assessment Tool

Introduction

Preliminary examples of the application of risk approach are described here for the assessment of pipeline risk resulting from vertical ground movement and an assessment of pipe risk due to corrosion potential.

The examples provide a description of the causal relationship between system properties and events that derive soil movement and corrosion potentials. They demonstrate the approach used in the analysis and they are not meant to cover all the parameters associated with ground movement and corrosion potential. Further work is in progress in this task.

Ground Movement

Surface ground movement (such as soil heave) would result in a pipe deformation within the moving soil zone as shown in the cross section in Figure 1.

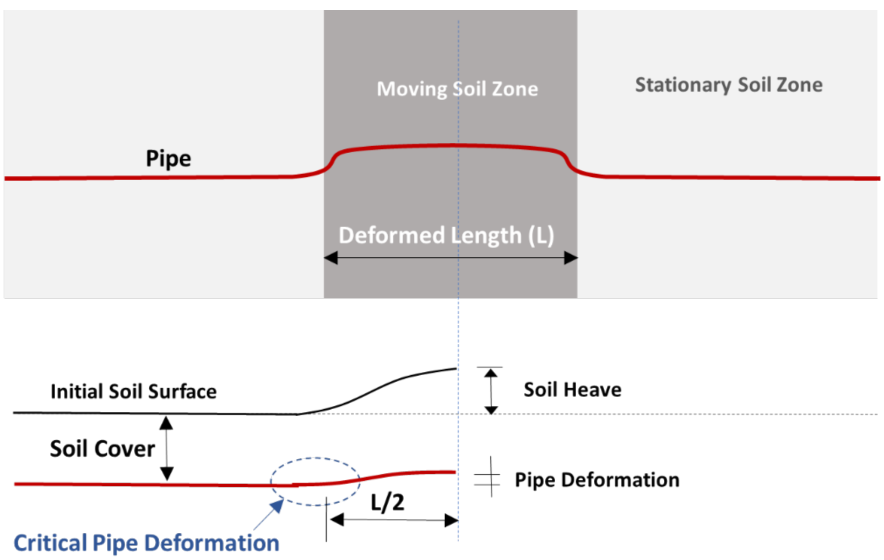

Figure 11. Soil Vertical Movement and Resulting Pipe Deformation

The threat of ground movement (‘*Primary Threat*’ in the example) is evaluated by estimating the magnitude of vertical soil movement and its probability of occurrence (frequency) as shown in Figure 2. This threat results in the development of a corresponding magnitude of pipe deformation and frequency, thus identifying a ‘risk of damage to pipelines’ as shown in the figure.

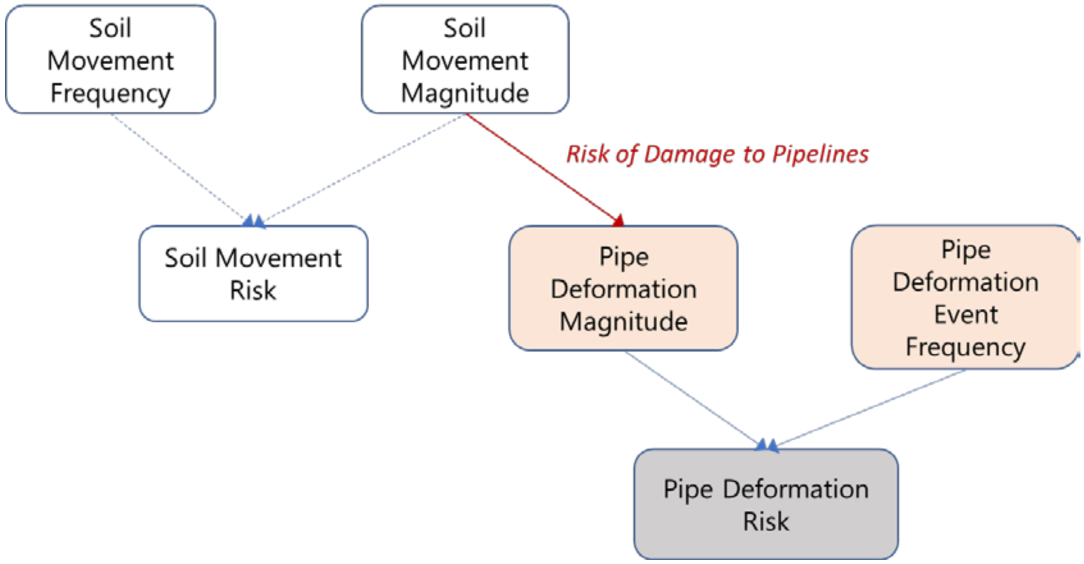

Figure 22. Layout of Primary Threat and Risk to Pipelines

In the figure, *Pipe Deformation Event Frequency is* the probability of occurring pipe deformation due to soil movement potential as shown in A-2. The *Deformation Magnitude* is the consequence of soil movement and may be calculated based on sol properties and represented by deformations in inches. The loss magnitude may also be represented by other tangible consequences (such as leak and pipe rupture) depending on the objective of the risk analysis. *Pipe Deformation Risk* is calculated from these two parameters in a Bayesian Analysis and is evaluated against permissible values for risk tolerance.

Figure 3 presents *Pipe Deformation Frequency* in further detail, in an example of expansive soil movement. In the figure, The '*Difficulty*' of threat occurring in a region is defined by site characteristics which affect soil volume change. These characteristics include overburden loads over the soil, type of cover, and thickness of clay layer. High overburden loads, impermeable and well-drained covers (such as concrete pavement), and small layer thickness reduce soil movment potential. These parameters may increase or reduce the probability of the threat and result in an overall "*Vulnerability*' estimate of the region to ground movement.

The interaction of the threat with the 'time-dependent' environmental actions in the region results in an estimation of the '*Expansive Soils Frequency*'. These actions include the frequencies of soil moisture, wet/dry cycles, and water table changes which affect the frequency of vertical soil movement.

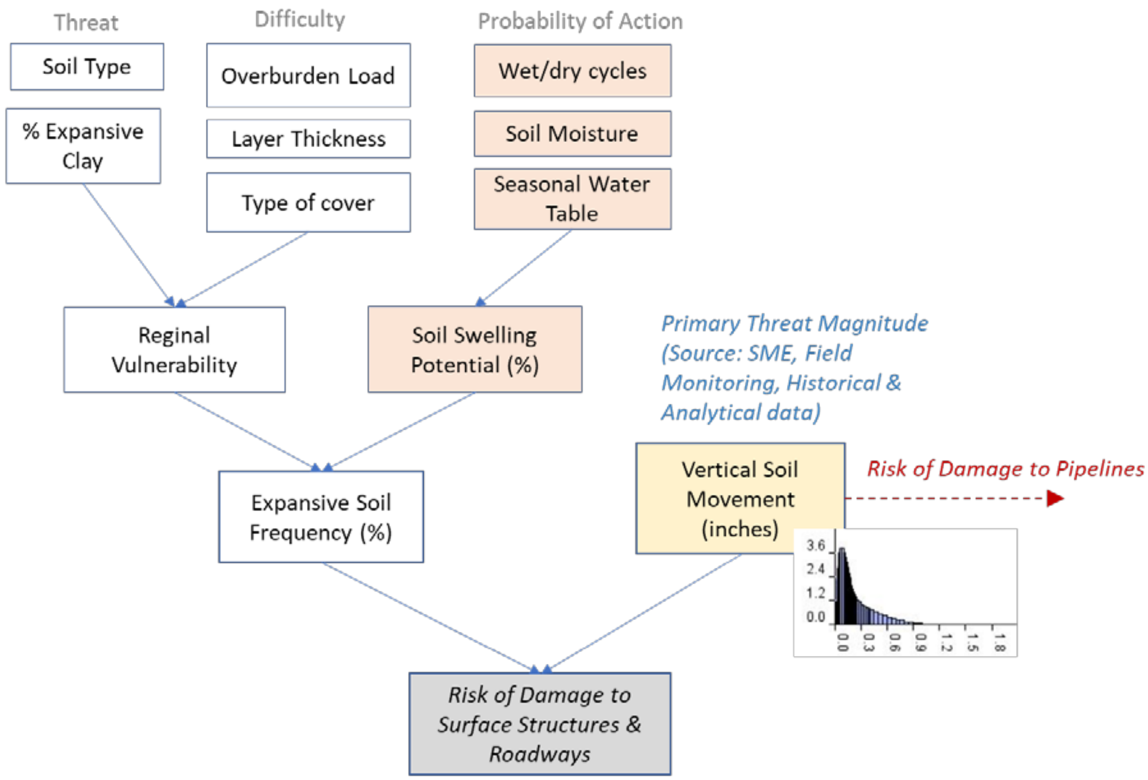

Figure 33. Threat of Soil Vertical Deformation

The "*Threat Magnitude*' of vertical soil movement is a tangible value (or more appropriately, a distribution) which can be defined by inches of vertical soil movement. Its magnitude is based on analytical estimates of soil movements, historical data in similar conditions, SME input, and field monitoring in locations of potential threats. This estimate is used to evaluate the risk of pipe deformations as shown in Figure 4.

Pipelines may experience high bending strains and joint displacements in the event of soil movement. Several guidelines and design manuals provide procedures for estimating pipe strains when subjected to large soil deformations [1]. Analytical procedures using Finite Element (FEA) analysis are typically performed to estimate pipe deformations resulting from soil movement for various pipe material, sizes, and soil-pipe interface properties. Examples of these parameters are shown in Figure 4 for the estimation of the pipe deformation magnitude.

[1] Guidelines for the Design of Buried Steel Pipe, American Lifelines Alliance (ALA), American Society of Civil Engineers, July, 2001.

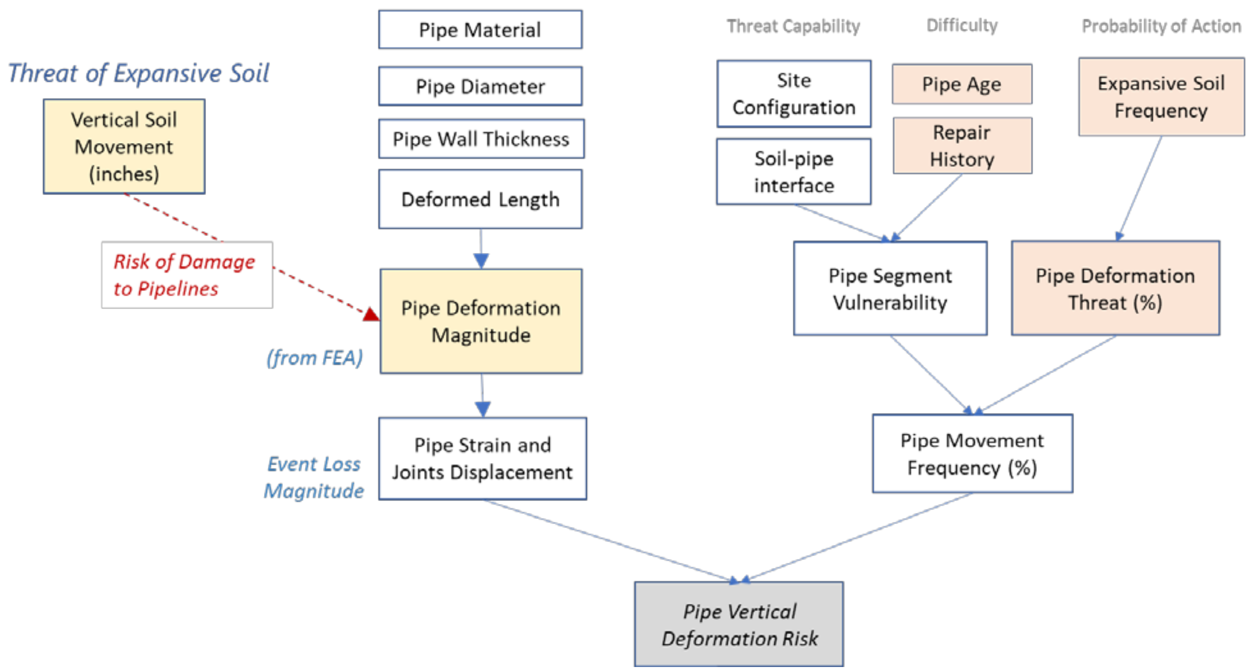

Figure 44. Layout of Pipeline Deformation Risk

Pipe strains and joint displacements are multiplied by the frequency of pipe movement to obtain a risk estimate. The frequency of pipe movement depends on several factors that determine pipeline probability of soil movement and its vulnerability to the corresponding loss.

The risk framework in Figure 4 is suitable for a Bayesian Network approach to estimate the conditional probabilities of pipe deformation based on the probabilities of occurrence of soil movement and associated site and pipe characteristics. A graphical representation of the conditional probability using 'AgenaRisk' program is being used to represent the relationships in calculations of the pipe deformation magnitude.

Pipe Corrosion Potential

Pipeline damages resulting from corrosion potential threat is evaluated in a Bayesian Network analysis. The analysis started last quarter using the risk analysis software AgenaRisk.

Figure 5 shows a schematic example of a Bayesian Analysis of the probability of failure resulting from probabilities of occurrence of pipe coating and Cathodic Protection (CP).

The top row of the figure presents a prior knowledge of the pipe characteristics. The second row shows the probability of pipe corrosion. This probability will be weighted in further analysis with other pipeline attributes such as age, leak history, corrosion history, and water intrusion to produce an overall estimate of likelihood of corrosion.

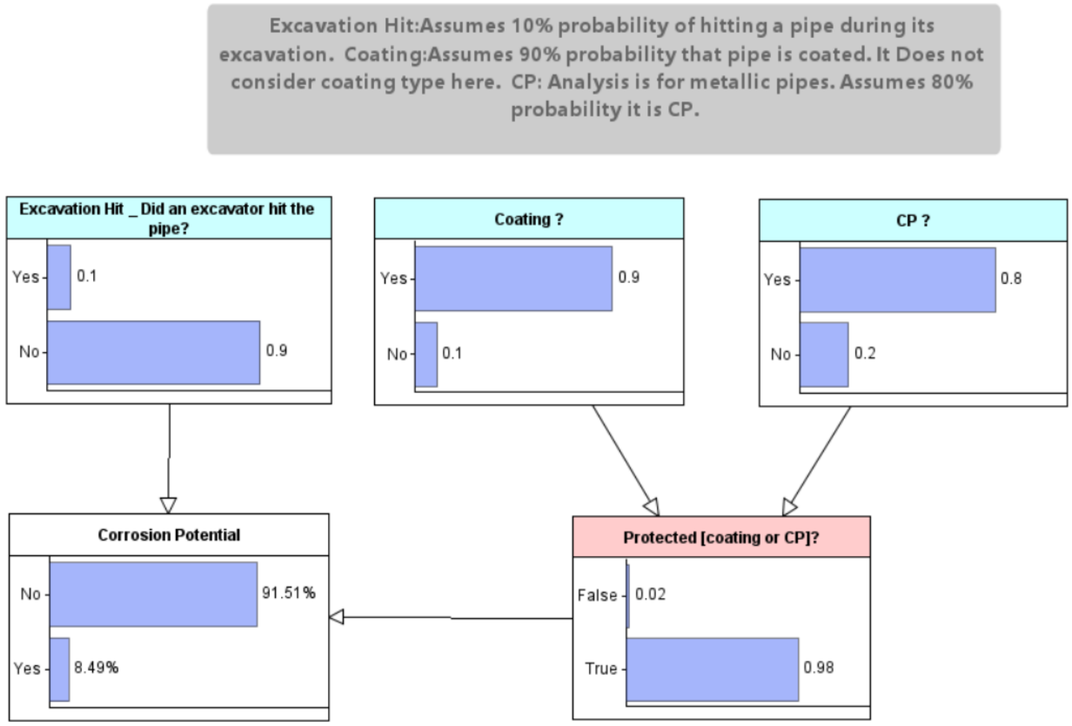

Figure 55. Basic Bayesian Network of the probability of corrosion potential of known distributions of coating and CP probabilities

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