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**PRCI Project Ref: ENV-1**

## QUARTERLY PUBLIC REPORT

## Pipeline Integrity Management for Ground Movement Hazards

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## Project Background

Land use policies increasingly prevent pipelines from obtaining right-of-way for pipeline corridors that avoid ground movement hazards. Where ground displacement hazards cannot be avoided, the potential risks must be managed by suitable combination of design and operational strategies.

*Objectives:* Develop a comprehensive set of guidelines and recommended practices, in a format that can be implemented within the industry, for evaluating pipelines in areas subjected to large-scale ground movements.

*Technical Approach:* The Pipeline Research Council International, Inc. (PRCI), in concert with a research team drawn from C-CORE, D. G. Honegger Consulting (DGHC), SSD, Inc. (SSD), the USGS, PRCI industry sponsors that includes the Southern California Gas Company, TransCanada, El Paso, Marathon Pipelines, Williams Gas Pipeline, and Gaz de France, and the California Energy Commission are assessing and recommending current landslide risk management methods and practices for use within the pipeline industry. In addition, research activities are being carried out to address known deficiencies in current techniques for assessing pipeline response to large ground displacements. These guidelines will be made available from the PRCI publications web site at no charge. PRCI is supporting regular updates to the guidance document as necessary to incorporate future technological developments.

The broad technical tasks involved in the study include:

- definition of large ground displacement hazards,
- development of pipeline/soil interaction models,
- improved pipeline response modeling,
- utilization of pipeline geometry monitoring to assess pipeline condition and,
- options to mitigate risks of large ground displacement.

The result of this work will be a concise set of unified guidelines that can be readily implemented within the pipeline industry and serve as a basis for demonstrating that reasonable measures have been taken to address potential risks from large ground displacements.

## Technical Status

Activities undertaken through the sixth quarter focused on the following tasks:

Task 1: Definition of Large Ground Displacement Hazards
Task 2: Improved Pipeline-Soil Interaction Models
Task 3: Improved Pipeline Response Modeling
Task 4: Use of Pipeline Geometry Monitoring to Assess Pipeline Condition
Task 5: Hazard Mitigation Strategies
Task 6: Assembly of Overall Guidelines Document

A summary of the technical status and results or conclusions to date are presented below for each of these tasks.

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**Task 1: Definition of Large Ground Displacement Hazards**

As reported in the previous quarter, preparation of a second draft of recommended practices for hazard definition was been delayed pending receipt of revised USGS documents. In addition, substantial modification of the preliminary working version of the revised draft was necessary to incorporate the basic concepts identified in the previous quarterly report.

The material from USGS was received in October and was incorporated into a second draft of recommended practice for hazard definition. As noted later in this report, our strategy for getting back on schedule is to combine the external review of Tasks 1 and 5 in a review of a single document organized in a format that will be a starting point for the organization of the overall guidance document to be refined in Task 6.

An internal review of the revised draft material related to Task 1.6 was conducted in November and resulted in a number of recommendations for reorganization to streamline the presentation of similar topic areas (e.g., slope stability methods used for hazard identification and hazard mitigation) and improve the presentation for an audience that is not expected to include topic-area experts. The reorganization of the document is expected to be completed this quarter with a revised document, suitably complete to be reviewed by external experts, to be completed by the end of January, 2008.

**Task 2: Improved Pipeline-Soil Interaction Models**

A set of physical model tests were undertaken in medium silty clay to evaluate the interaction of lateral and axial resistance of pipeline sections to oblique loading. The undrained resistance mobilized along the pipe in clay indicates a clear interaction between the axial and lateral resistance. The 20 and 60 degree tests mobilize a much higher axial resistance than the purely axial test due to additional frictional resistance provided by the mobilized lateral resistance.

**Task 3: Improved Pipeline Response Modeling**

Analyses have been completed of 2 further ground movement – pipeline response examples provided by the project team. The analysis conclusions are consistent with those presented in the last quarterly report. These results and conclusions will be reviewed by the project team.

The evaluation of alternative pipeline formulations identified potential alternatives to current practice in finite element modeling of pipe-soil interaction during ground movement. Beam-Spring models are typically used for this purpose.

Analyses have been conducted comparing a continuum finite element with that from a structural finite element simulation of a large ground movement event over a` buried pipeline. These comparisons are being processed and will be presented in the next quarterly report.

**Task 4: Use of Pipeline Geometry Monitoring to Assess Pipeline Condition**

Work this quarter was focused entirely on Task 4.2 (validation of axial extensional strain algorithm) with the expansion of the matrix of analysis cases for buried pipelines subjected to ground movement. The remaining work efforts under this task include additional study and error analysis on gage length effects, the effect of progressive softening of the edges of the ground movement profiles, application to pipeline bends, and the effects of noise in the pipe pitch or azimuth data.

**Task 5: Options to Mitigate Risks of Large Ground Displacement**

As noted in the previous quarterly report, mitigation through pipeline design focuses on analytical methodologies to incorporate soil-pipeline interaction into an assessment of pipeline response using a methodology similar to that presented in PRCI seismic design guidelines.

Efforts on Task 5.2 during this quarter have focused on determining the level of detail on engineering methodologies for implementing geotechnical remediation of potentially unstable slopes these practices that is needed. An approach that is being developed will rely upon the required reliability of potential geotechnical mitigation measures. This approach will require a definition of reliability (e.g., less than X% chance of failure in Y years) and some level of probabilistic estimate of the variability in factors affecting slide movement and the capacity of the mitigation measure being considered. As an example, if the uncertainty in soil stratigraphy through a slide zone introduces an unacceptable level of uncertainty, additional field investigations are warranted to reduce this uncertainty.

**Task 6: Prepare Overall Guidance Document**

Work under Task 6 involves combining the results of Tasks 1 through 5 into a comprehensive guidance document. Efforts during this quarter focused on the organization of the overall document and incorporating products from Tasks 1 and 5 into the overall document organization.