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Pipeline Integrity Management for Ground Movement Hazards

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Technical Status

Activities undertaken through the seventh 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.

Task 1: Definition of Large Ground Displacement Hazards

Technical Status

Work this quarter focused on Tasks 1.7 and 1.8.

Results and Conclusions

- Task 1.7: Obtain review comments from outside experts
- Task 1.8: Prepare final draft recommendations on hazard definition

A revised draft of recommended practices for hazard definition was distributed to three external topic area experts not involved with the draft preparation near the end of February. Review comments are being incorporated into a third draft (Task 1.8) as they are being received; all comments are expected to be received by the end of March. Once all comments have been received, it is expected that a meeting will be held in Vancouver to finalize the response to review comments such that Task 1.8 can be completed shortly thereafter. A meeting date around mid- to late-April is being considered.

Task 2: Improved Pipeline-Soil Interaction Models

Technical Status

Progress on Task 2 continued this quarter and focused on subtask 2.4

Results and Conclusions

- Task 2.7: Interim reports on physical modeling, numerical analysis and improved interaction models

The report summarizing Task 2 activity has been drafted internally and will be finalized after review by the participants during the next reporting period.

Task 3: Improved Pipeline Response Modeling

Technical Status

Efforts have concluded on Task 3 looking at alternative soil and pipeline formulations and the draft report is nearly complete.

Results and Conclusions

- Task 3.4: Interim report on improved engineering models for pipeline response analysis

The report summarizing Task 3 activity has been drafted internally and will be finalized after review by the participants during the next reporting period.

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

Background

An algorithm for deducing the total longitudinal strain in a displaced pipeline based on curvature established from geometry pig measurements has been developed as described in previous quarterly reports. The extensional strain ε_e can be expressed as:

$$\varepsilon_e = sign(c) \cdot D|K|/\pi + c$$

in which D is the pipe diameter and K is the change in curvature of the pipeline. The constant of integration c is determined such that ε_e equals the extensional strain in the straight (boundary) length of the pipe joint immediately adjacent to the displaced region of the pipeline. Note that the sign of the deduced extensional strain must be tied to the *sign* of the constant of integration (i.e., + for gross tension, – for gross compression).

Technical Status

Work during this quarter included more efforts on Task 4.2 (validation of axial extensional strain algorithm). The work performed under Task 4.2 expanded the matrix of analysis cases for buried pipelines subjected to ground movement scenarios to include pipeline configurations with bends. A write up describing the bend analyses cases and results is currently being finalized. The effects of noise in the pipeline pitch or azimuth data is still being investigated. We are currently projecting completion of Task 4.2 by approximately 4/30/2008.

During this quarter we initiated work on Task 4.3 (measurement considerations). This work began with the development of a list of questions related to measurement accuracy for submission to geometry pig vendors with inertial geometry monitoring capability. We are currently waiting for responses from the geometry pig vendors. The work performed under Task 4.3 also included a theoretical development of a curvature and bending strain measurement error measure based on geometry pig measurements for a cosine-shaped transverse pipe deflection

profile. The theoretical development considers that the pitch and azimuth angles measured by geometry pigs are measured over the support-to-support (i.e., cup-to-cup or wheel-to-wheel) length of the pig canister containing the angle measurement instrument (i.e., gyroscopes for inertial measurement pigs or accelerometers for accelerometer based pigs). The error analysis utilizes a central difference formulation wherein the gage length for curvature calculation L_{gage} is set equal to the pig length L_{pig}. It can be shown that the relative curvature or bending strain error varies with the square of the ratio of the pig length to the length of the deformation feature of interest. Previously reported simulations of geometry pig runs over pipeline profiles established from finite element analyses will be reviewed in the context of this error analysis approach. We are currently pursuing an extension of the theoretical error analysis to consider relatively abrupt, ramp-like pipeline deflection profiles such as those that might occur at fault crossings or at the boundaries of wide landslides. We are currently projecting completion of Task 4.3 by approximately 5/31/2008.

Results and Conclusions

The main result from this work is the development of the extensional strain algorithm outlined above. Analyses that consider the effect of the gage length for curvature calculations as well as the error analysis outlined above have lead us to the use of a curvature calculation gage length L_{gage} that is set equal to the supported length of the geometry pig canister L_{pig} over which the inclination of the pig is measured (i.e., use $L_{gage}=L_{pig)}$. This result may be refined once the investigation of the effects of noise in the geometry pig data is complete, since the effects of noise tend to be amplified in curvature profiles computed using shorter gage lengths. For many of the ground movement scenarios considered, an abrupt transition ramp was used wherein the transition from 0% movement to 100% ground movement occurred over a very short distance (typically 1 foot). Abrupt transitions are on the conservative side of the range of possible ground movement assumptions. The degree of sharpness of the profile transitions has a strong influence on the differences between the finite element model results vs. “digitally pigged” results and on how accurately a geometry pig can estimate curvature and bending strain. The use of less abrupt profiles (such as the cosine functions recommended in the PRCI seismic guidelines document) results in significant improvements in the comparison between finite element results vs. the “digital pigged” results.

Task 5: Options to Mitigate Risks of Large Ground Displacement

Technical Status

Work this quarter focused on Tasks 5.4 through 5.8. Tasks 5.4 through 5.6 were completed this quarter.

Results and Conclusions

- Task 5.4: Prepare initial draft of recommended practice
- Task 5.5: Assess initial recommendations with constraints typical of pipeline construction
- Task 5.6: Prepare second draft of recommendations

The initial draft of recommended practice (Task 5.4) was generated this quarter and distributed for review. As a result of the review (Task 5.5), considerable modification of the organization of the material was undertaken and incorporated into a second draft of recommendations (Task 5.6).

- Task 5.7: Obtain review comments from outside experts
- Task 5.8: Prepare final draft of recommended mitigation options

A revised draft of recommended practices for hazard definition was distributed to three external topic area experts not involved with the draft preparation near the end of February. Review comments are being incorporated into a third draft (Task 5.8) as they are being received; all comments are expected to be received by the end of March. Once all comments have been received, it is expected that a meeting will be held in Vancouver to finalize the response to review comments obtained under Tasks 1.7 and 5.7 such that Task 5.8 can be completed with Task 1.8 shortly thereafter. A meeting date around mid- to late-April is being considered.

Task 6: Prepare Overall Guidance Document

Technical Status

Work this quarter focused on Tasks 6.1.

Results and Conclusions

Work under Task 6 involved 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 that could be sent out review under Tasks 1.7 and 5.7. Further progress on this task is awaiting input from Tasks 2, 3, and 4.

Plans for Future Activity

Activities for Tasks 1 through 6 will continue in the next quarter (milestone period). Planned activities for these six tasks are presented below.

Task 1: Definition of Large Ground Displacement Hazards

Technical Progress
Efforts will focus on completing the following subtasks during the next quarter:

- Task 1.7: Obtain review comments from outside experts

The review of the latest draft of guidelines for identifying slope movement and subsidence hazards is expected to be completed by the end of March.

- Task 1.8: Prepare final draft recommendations on hazard definition

Incorporating review comments is ongoing as comments are received. It is anticipated that the resolution of some comments will require discussions with the reviewers which is expected to require a face-to-face meeting. The resolution of comments into a final draft is expected to be completed mid-way through the next quarter.

Meeting and Presentations
A working meeting of the Douglas G. Honegger Consulting team is anticipated near the end of April to discuss comments from topic area experts.

Task 2: Improved Pipeline-Soil Interaction Models

Technical Progress
The planned activities for next three months include:

- Task 2.7: Prepare interim engineering reports
  - This report will be completed.

Meeting and Presentations
No related meetings, conferences, or presentations are planned for upcoming quarter.

Tests and Demonstrations
Tests are planned as outlined under Tasks 2.5 above.

Task 3: Improved Pipeline Response Modeling

Technical Progress
- Task 3.4: Prepare interim engineering reports
  - This report will be completed

Meeting and Presentations
No related meetings, conferences, or presentations are planned for upcoming quarter.

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

Technical Progress
Testing of the deduced strain algorithm under Task 4.2 is essentially complete with some additional work required to complete the write up on bends and evaluation of the effect of noise in curvature profiles. We are currently waiting for responses to questions sent to geometry pig vendors. We are currently working on extension and refinement of a theoretical geometry pig error analysis to consider relatively abrupt, ramp-like pipeline deflection profiles such as those that might occur at fault crossings or at the boundaries of wide landslides. We will also be assembling an overall report on our portion of the work (Task 4) during the next 8 to 10 weeks.

Task 5: Hazard Mitigation Strategies

Technical Progress

Efforts will focus on completing the following subtasks during the next quarter:

- Task 5.7: Obtain review comments from outside experts

The review of the latest draft of guidelines for identifying slope movement and subsidence hazards is expected to be completed by the end of March.

- Task 5.8: Resolve comments from outside experts and prepare final draft report

Incorporating review comments is ongoing as comments are received. It is anticipated that the resolution of some comments will require discussions with the reviewers which is expected to require a face-to-face meeting. The resolution of comments into a final draft is expected to be completed mid-way through the next quarter.

Meeting and Presentations

A working meeting of the Douglas G. Honegger Consulting team is anticipated during the next quarter to discuss topic area expert review comments

Task 6: Comprehensive Guidance Document

Work will continue next quarter on the following subtasks:

- Task 6.1: Assemble 1st draft of guideline from task reports

In addition to incorporating revisions resulting from Tasks 1.7 and 1.8 and Tasks 5.7 and 5.8, efforts will include incorporating available results from Tasks 2 and 3.

- Task 6.2: Distribute first draft of guidelines document and obtain review comments

A first draft of the comprehensive guidance document will be distributed to all project personnel for review and comment in Quarter 8. This first draft to be distributed will be incomplete as Task 4 is not scheduled to be complete until sometime in the 8th quarter. However, this review allows full comment on the majority or Task 1 and a review of the proposed guidelines organization.

Meeting and Presentations

No meetings or presentations are planned.