

Basic overview towards the assessment of landslide and subsidence risks along a geothermal pipeline network

Introduction

The pipeline network connects various engineering structures (e.g. wells, separator, scrubber, and power station), in the process of transferring geothermal fluids to generate electricity.

Geothermal pipeline may bear a threat to its vicinity through a pipeline failure, related to physical deterioration (e.g. corrosion and fatigue).

The geothermal reservoirs are usually located in mountainous areas that are associated with perilous disaster (e.g. landslides, earthquake, and subsidence).

Geothermal areas record a noteworthy number of disasters, especially due to landslide and subsidence. Therefore, a proper multi-risk assessment along the geothermal pipeline is required.

By considering the risk on loss consequences, as well as the alternatives for mitigation measures, the environmental safety in geothermal working area could be enforced.



Figure 1: Geothermal Field in Wayang Windu.
Source : <http://www.aecom.com/>.



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Objectives

Basic overview towards multi-risk assessment along the geothermal pipelines.
Basic principles on risks analysis in modeling loss consequences.

Keywords

- **Landslide** : soil or rock movement downslope by the force of gravity, which may occur in susceptible slopes, geology, and other precursor events (earthquake, extreme precipitation) (Di Pippo, 2012b; Highland & Bobrowsky, 2008).
- **Subsidence** : surface sinking, that may happen due to natural causes (subsurface erosion, magma process) or human activity (mining, groundwater or gas extraction) (ENV-1 et al., 2009; Highland & Bobrowsky, 2008; Werner & Friedman, 2010).
- **Risk** : probability of adverse consequences due to the exposure to hazardous events (UNISDR, 2009; van Westen et al., 2011).
- **Risk assessment** : to estimate the probability and consequence of risk, by analyzing variables of hazard, vulnerability, and coping capacity; also evaluates the alternative decisions or strategies (UNISDR, 2009; van Westen et al., 2011).

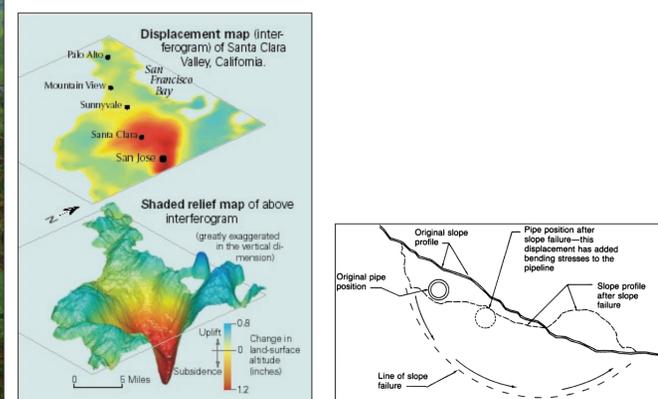


Figure 2: Land Movement Phenomena of Subsidence (Left) and Landslide (Right)
Source : <http://www.usgs.gov/>; Muhlbauer, 2004.

Risk Assessment Components

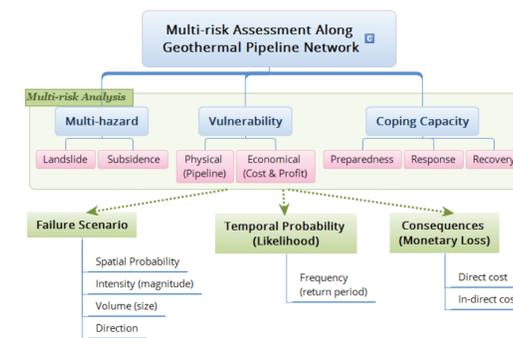


Figure 3: Components of Disaster Risk Assessment.

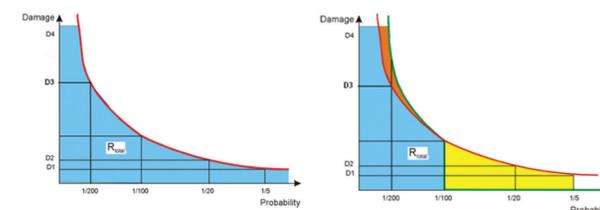


Figure 4: Risk Curve of Monetary Loss (Blue Area), as the Function of Damage Loss over Probability Occurrence: without Risk Mitigation (Left), with Risk Reduction Investment (Right) Source : van Westen et al., 2011.

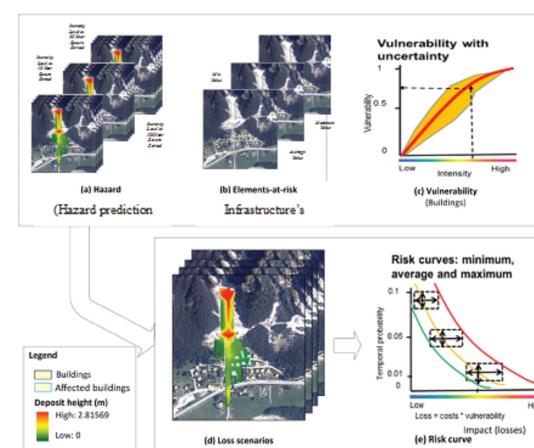


Figure 5: Multi-risk Assessment Approach, Presented as Scenario & Its Loss Value in Return Periods
Source : Aye et al., 2016; Chen et al., 2016.

Approaches for the Risk Assessment

Landslide

Table 1: Approaches for Landslide Susceptibility.

Methods	Approaches
Qualitative	Geomorphological Analysis
	<ul style="list-style-type: none"> ● Landscape observation (field or remote sensing technique) ● Relatively implicit and rapid ● Expert determination
	Variable Weighting & Parameter Scoring
Quantitative	<ul style="list-style-type: none"> ● Indexing the contributing factors through criteria matrix ● Tools, e.g. SMCE ● Expert determination
	Statistical Analysis
	<ul style="list-style-type: none"> ● Parameters comparison for hazard distribution or density, ● Univariate or Bivariate (comparing each parameter influence separately), ● Multivariate (comparing parameters concurrently)
	Geotechnical Modelling (Deterministic / Probabilistic)
	<ul style="list-style-type: none"> ● E.g. slope stability, hydrological analysis ● Scenarios of probable events ● Mathematically model the driving force (soil saturation, pore pressure, rainfall)

Subsidence

Approaches to assess subsidence susceptibility are by field reconnaissance of ground displacement, e.g.:

- Feature and geological observation (sinkhole, fault, wells, submergence),
- Ground-based levelling (geodetic measurement),
- Geophysical or geotechnical analysis for gravity measurement;
- Remote sensing technique by radar or Lidar interpretation.

Future Work

- Developing new methods to address the multi-risk assessment along the geothermal pipelines, to enforce the environmental safety,
- That is taking into account the hazard, vulnerability, and capacity analysis,
- To model the spatial-temporal scenarios of pipeline failure and its possible monetary loss.

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