Infrastructure Management Based on Vulnerability to Landslides

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Abstract. This study analyzed the vulnerability of the assets of an oil field exposed to landslides, based on the potential loss of value due to damage to people, the environment, property and/or business, with the objective of making visible, prioritizing, planning, and executing actions to address risk areas, through the application of digital technologies.

This infrastructure management plan is determined from the study of landslides that occurred in the area, which are references to carry out a relative and quantitative analysis of the geological, geomorphological, environmental, and geotechnical characteristics of the roads, locations, or central processing facilities (CPF) of the oil field under study. The implemented methodology consists of taking advantage of public and free information (lithology and structure of surface geology, relief, location of bodies of water, geomorphology and its evolution over time seen in historical aerial photographs, and the ease of visualization and analysis in geographic information systems (GIS)), and the weighting and qualification of these attributes according to geotechnical engineering criteria in each area analyzed.

As a result of this vulnerability study, it was possible to identify 14 zones, corresponding to 7% of the studied area, (access roads, locations and/or central process facility) classified as highly vulnerable, which require more attention due to the potential to impact the environment. Environment and the property or affectations to the production of hydrocarbon fluids estimated at 767 BOPD, suspension of injection of 9.888 BWPD and limitation of the use of a central with a capacity of more than 100.000 BFPD (Cuéllar in Thesis master's in advanced management of the promotion and exploitation of Infrastructure, Madrid, 2019).

Keywords: landslides · vulnerability · infrastructure management

1 Introduction

In two oil production fields in the area under study, three landslides on roads occurred, one of which had to suspend the flow line and production of wells, with production delays reaching 150 BOPD and loss of asset value (lower Net Present Value), accordingly. The cause of this landslide is associated with the geological condition of the area (presence of colluviums) and as a detonating event a precipitation peak, low predictability event whose probability of impact could be reduced with a vulnerability study associated with the condition of its infrastructure, to make areas of interest visible and prioritize action plans to reduce the risk of landslides.

R. E. Hammah et al. (Eds.): RIC 2023, AHE 19, pp. 119–126, 2023.
https://doi.org/10.2991/978-94-6463-258-3_12

It also seeks to highlight the importance of applying the conclusions of numerous studies published by organizations such as the World Bank and the Inter-American Development Bank, about the advantages and the imperative of the organizations to manage the infrastructure for the sake of its conservation, avoiding its deterioration and its costly repair or reconstruction, or even to increase its resilience to possible natural events.

Paper presented here combines geotechnical analysis with elements of quantitative and qualitative validation, exponentially motivating decisions for validating operational risk, which can encourage asset management organizations to proactively and preventively protect their systems aligned with best practices in process safety.

2 Glossary

Vulnerability: The degree of probability of loss of a specific element or group of elements within the area affected by the landslide[1].

Landslide susceptibility: Generally, it expresses the ease with which a phenomenon can occur based on local terrain conditions. Susceptibility is a property of the terrain that indicates how favorable or unfavorable the conditions are for landslides to occur.

For the purposes of this paper, the meaning of the following terms is clarified:

Active: refers to the company's property in the oil field, such as its wells, locations, roads, pipes, central processing facilities and its oil production.

BOPD: barrels of oil per day / BWPD: barrels of water per day / BFPD: barrels of fluids per day.

3 Asset Characterization

The oil field under study generates relevance from the point of view of geotechnical and asset management by the following characteristics:

- Geology: presents a combination of inverse faults and anticlinal and syncline folds, related to the Chusma fault system, which are interpreted as the structures responsible for lifting the eastern flank of the central mountain range in Colombia. In the field of study, colluvial deposits emerge, intercalations of sludge and lutites with sandstones, formations that drop towards the axis of excavations, altered discontinuities are highly susceptible to landslides.
- Relief: Formed by mountainous area with inclinations that go up to 50°.
- Seismicity: Hazard high
- Condition of the infrastructure: Cuts in slopes to half slope of lengths greater than 100 m, with scarce drainage works or no maintenance and failed retaining walls.
- Vulnerability: The oil field has at least 200 drilled wells, with the presence of important communities and natural resources in influence where operations are carried out.

[1] Terms defined by the International Union of Geological Sciences (IUGS) for use in the quantitative analysis of hazard and risk for slopes and landslides [2].

4 Infrastructure Evaluation

4.1 Collection Information

Geological information was established based on information published by the Colombian Geological Service (SGC) scale 1:100,000 geological cartography 323 Neiva - Huila and the different attributes sent by the SGC. Information related to the location of the wells, capacity of facilities and hydrocarbon production flows or water injection into the wells, is public information reported by the owner of the asset.

Geological attributes such as formations, dips, folds, faults, and other information provided by SGC were converted into a KMZ file to be viewed in the Google Earth program, along with the identification of wells.

Reports of visits and studies carried out to address landslides in the field [1]. Geotechnical parameters of the reference cases are taken from geotechnical exploration by drilling and standard penetration tests (SPT).

4.2 Visualization and Analysis Information

Considering the size study area approximately 45 km^2, the geomorphology and characterization of the slopes (height and slope) will be based on images of Google Earth, making visits only in sites reported with movements, to verify conditions of slopes and/or geological characterization, identify dips, characteristics of discontinuities, folds and geotechnical works and their status.

Use Google Earth to determine movement history by analyzing historical photos of locations and access roads, slopes, and slopes heights.

For this case study a relative analysis technique was selected, comparing each criterion with real situations, which will serve as a basis and reference for the study; therefore, no Safety Factors will be determined.

With layers of well locations, geological formations, folds, dips, geological faults, drains, contours visualized in Google Earth (see Fig. 1), together with historical images, begins the in-plant and profile assessment and allocation of scores for each location and its path; capturing images and consolidating a well-to-well review file that serves as memory to the assessment assigned in the most important places that require a more detailed review on the site for their susceptibility to landslides.

4.3 Analysis of Sliding Base or Reference Cases

Following are two cases of landslides in access roads that are correlated in the field of study, the first slip was presented on the road to the location of the well AB-05 and the second slip was presented on the road to the location of well AA-18.

Sliding access road to well location AB-05. This sector is affected by a rotational slide presenting a midslope escarpment of the upper slope of the road with depth between 2.5 m and 3.0 m (see Fig. 2). Causes of the landslide basic: colluviums in high slope without drainage works. Detonating cause: strong rains saturated the colluvium.

Geological formations: in the upper part of the sandstone slope of the formation La Tabla (Kt), in the middle part of the Olini Group (Ko) and slope deposits of colluvial type (Qc) formed by the activity of the Bache fault.

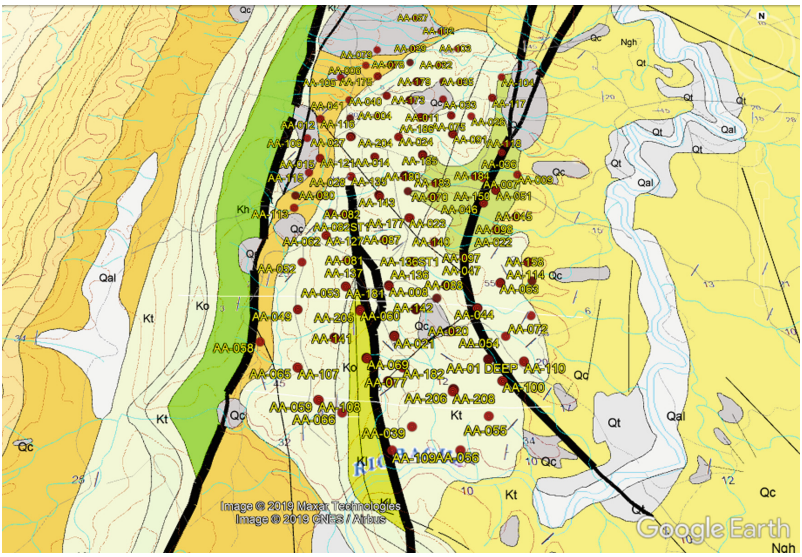

Fig. 1. Google Earth@ visualization of the location of field wells and geological attributes in cartography 323 Neiva – Huila

Fig. 2. Slip access road well AB-05

Sliding access road to well location AA-18: according to the classification of movements by Cruden & Varnes (1978) [2, 3], the studied slip is translational of blocks and detritus with planar fault surface, active, and is typical to present with fast speeds, two states are identified with zone A and zone B. The slope has an average inclination angle of 29° and the rock layer underlying the slide is competent and stable evidence (see Fig. 3) and simulated planar fault surface in Slide® (see Fig. 4).

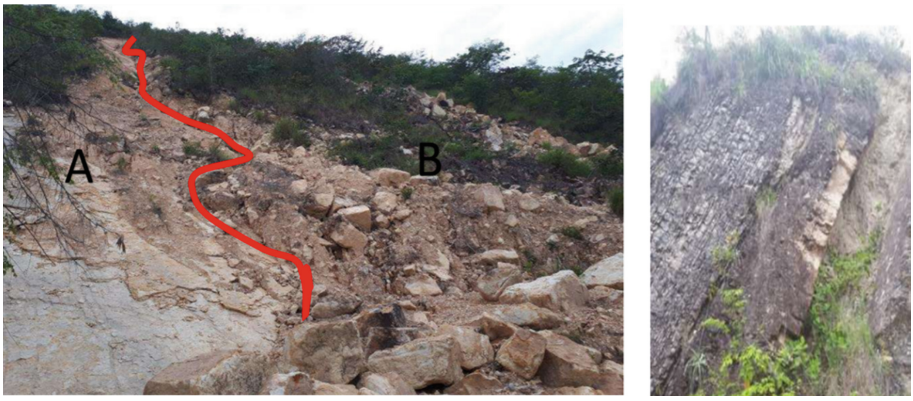

Fig. 3. Slip access road well AA-18 / rocks exposed in the slopes of the road

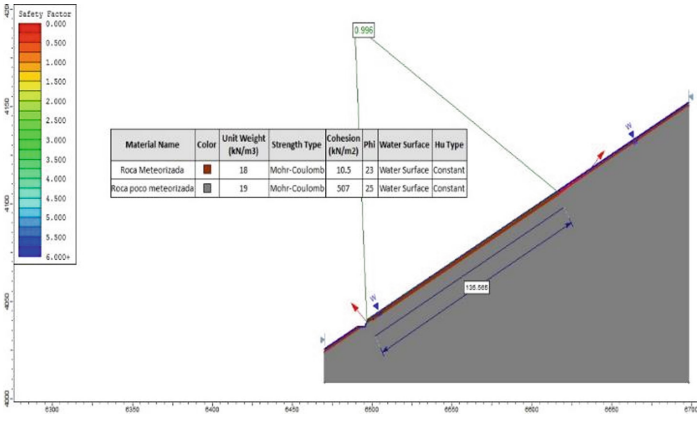

Fig. 4. Slope of access road to AA-18 well with simulated planar fault surface in Slide®

4.4 Susceptibility to Landslides

The following are the weights of the different analyzed factors: geology, geomorphology, and geotechnics, using as a reference the Modified Ambalagan method, 1992; Ali Jawaid, 2000; Mendoza and Dominguez, 2005 [3] and the analysis of cases in the study area.

– Geology:

○ Lithology: formations
○ Structure: Fault distance

– Geomorphological:

○ Topographic: Slope and long of slopes
○ Environmental: Plant cover and presence of water (near natural drains or flood zones)

– Geotechnical characteristics:

○ Adverse dip: based on the dipping of the layers according to the cutting of the excavation.
○ Slope height
○ Mass of soil in motion

4.5 Vulnerability of the Asset and Results

Vulnerability of the asset is associated with damage to people, environment or property or business; in the latter case because of the impact on the value that they produce to the company in case of a landslide or earthworks that will generate a stop of the asset and not to the investment of the same.

5 Conclusions and Recommendations

- Of the 89 areas with high vulnerability, 14 areas have considerable susceptibility to landslides, which are recommended for further study, corresponding to areas with 767 BOPD producing wells, areas with injection wells totaling 9.888 BWPD and a central processing facility (CPF1) with a capacity of more than 100.000 BFPD.
- It is advisable to intervene in the short term and in the related order below, making a visit and studies in greater detail with the purpose of determining and specifying the causes of the movements, and designing the measures, only monitoring or construction works to improve their condition of stability, decrease the probability of occurrence of landslides and avoid the consequent losses in the environment or company.

Well	Tipo	Prod - Inj (BOPD - BWPD)	Vulnerability	Geological Formations	Susceptibility	Observations
AA-117	Inj	4169	High	Kt	12,7	Check access road and location
AA-018	Prod	117	High	Kt	12,3	Reference case, access road
CPF1			High	Qc	11,7	Check moving slope - colluvial
AA-053	Prod	93	High	Kt	11,15	Track check, location appears stable
AA-104	Inj	1994	High	Kh-Kl	10,9	Access road with 4 possible movements
AA-059	Prod	89	High	Kt	10,9	Access route with possible movements
AA-02	Prod	79	High	Kh-Kl	10,7	Check access road adjacent to location
AA-139	Prod	66	High	Kt	10,65	Check the eastern side of the location
AA-154	Prod	68	High	Kt	10,5	Possible movement on eastern side of location
AA-102	Inj	2213	High	Qc	9,6	Check access roads, unprotected areas
AA-01	Inj	1512	Medium	Kt	9,45	Access route with possible movements
AA-042	Prod	121	High	Qc	9,4	Check road, presents change in vegetation in colluvial zone
AA-024	Prod	60	High	Kt	5,3	Check western slope, water supply on track
AA-078	Prod	74	High	KPgs	3,6	Access route with possible movements

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