# FORECAST OF MUDFLOWS BY USING A SIMPLE RUNOFF MODEL IN PERU

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## 1. Introduction

The huaicos are very common phenomenon of mudflow disasters due to sliding land and stones with great destructive power in Peru. They are formed in the high parts of the micro basins due to the existence of soil layers that can be removed from the surface or unconsolidated deposits of soil, which are removed by the rains.
Like the floods, the huaicos occur during the rainy season, between December and April. In El Niño years the number and magnitude of these mud torrents is increased, due to the intense rains that fall on the coastal basins putting many ravines into operation, being able in some cases to dam the river to which they discharge its flow the Huaicos devastate homes and crops, destroy sections of roads and sanitary infrastructures.
Although various countermeasures such as constructing Sabo dams have been taken, the mudflow disasters have not been able to perfectly prevent since the occurrence area is too large. On the other hand, it has been pointed out that increasing the water contents in soil layers may cause mudflow phenomenon[1)] and the drainage systems to reduce water contents in soil layers may become effective in the recent years. This study has been conducted to categorize mudflow phenomenon to obtain useful knowledge to forecast the occurrence them with the limited data.

## 2. Outline of target area

The study area is located in an area of mountainous relief, with slopes of medium to high slope, corresponding to the flanks of a young valley eroded in the form of V-shape (river of the Santa Eulalia sub-basin) and developed on volcanic rocks that dominate much of the landscape of the region.
The height varies in a range between 1,000 and 5,000 meters above sea level. In the low zones the temperature varies from 10°C to 24°C, due to the height, the climate is characterized by cold days and nights. The maximum temperature occurs in the months of September and April, when it reaches above 15°C, sporadically and during the day it reaches 22°C (with the presence of solar intensity).

## 3. Precipitation data and mudflow events

The Rímac River Basin (the most important in Lima) is formed by two sub-basins; the sub-basin of the San Mateo River and the sub-basin of the Santa Eulalia River.
Precipitation occurs in the form of periodic rains, from December to March, that is, during the summer months. These levels of rainfall can increase in the presence of the atmospheric phenomenon of El Niño.
The huaicos occur in the study area occasionally but can be very destructive since some villages are settled on the mudflow roads. In 2017, with the occurrence of El Niño Costero, there were 3 events that seriously damaged the infrastructures of the area (roads, bridges, houses, crops).
**Fig. 1** shows the location of the target sub basin in this study and the weather stations at which daily precipitation data have been observed. The river discharge data have not been obtained in this sub basin and there are missing periods in the precipitation data. A multiple regression analysis is applied to interpolate and complete missing data by using correct data at other weather stations.

## 4. Rainfall - runoff simulation

A lumped runoff model based on a compartment type[2)] has been applied to evaluate the water content in soil layers as the numerical simulations. The vertical soil structure is composed of three soil layers; layer A, from which infiltrated water rapidly runoff, is the shallowest one; layer B is the second one with a slower runoff; and layer C, the deepest and thickest one. As wet season and dry

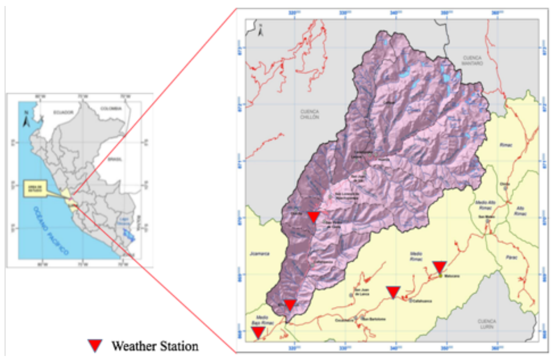


**Figure 1.** Location of the Santa Eulalia sub basin and weather stations

one are cyclically repeated in the target year, the water content variation curve of layer C must have a cyclic behavior throughout the hydrological year. So, although the river discharge data have not been obtained, runoff simulations can be conducted on this condition. **Fig. 2** shows an example of the hyetograph and the simulated variations of water content in the three soil layers in a precipitation event occurring a mudflow. The vertical black line is the date of mudflow; there can be shown the water contents in the layer C is rapidly increasing with the precipitation in this case.

## 5. Discussion

There were ten cases of mudflow occurring in the target period and area. As the results of investigations with the simulated water contents in each soil and the gradients of water contents variations, shown in **Fig. 3**, just before occurring mudflow. When the ground is "dry", the rains penetrate layer A and the moisture is concentrated in a specific area and mudflows occur. Sometimes it doesn't take much rain to happen.

When the ground is "wet", the rains saturate it and a mudflow is much more likely to occur.

As shown in **Tab.1**, in most of the cases analyzed, there is a rapid increase in the height of water in the surface layers in the days prior to the occurrence of the events.

## 6. Conclusions

- Most of the results are in the "wet" and "rapidly increasing" zone (70%).
- Half of the results are rapid increases in layer A (50%).
- The most contributing layer according to the results obtained is layer A.

- A large amount of precipitation is not necessary for a mudflow to occur. The natural humidity of the soil and the temperature of the environment are also factoring to consider.

## References


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2) Matsui, Y., S. Itoshiro, M. Buma, T. Matsushita, K. Hosogoe, A. Yuasa, S. Shinoda, T. Inoue: Predicting pesticide concentrations in river water with a hydrologically calibrated basin-scale runoff model, Water Science and Technology, 45(9), 141-148, 2002.


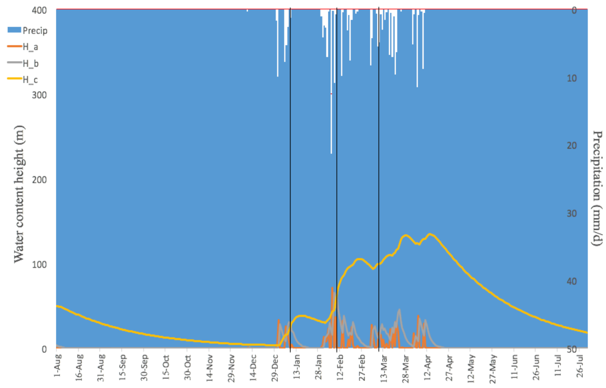


**Figure 2.** Water content variations in the three layers of soil

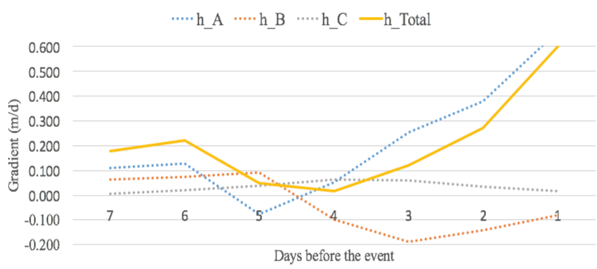


**Figure 3.** Gradients of variations in one week before the mudflow event

**Table 1.** Categorizing the occurrence of mudflows

| Season | Gradually increasing | | | Rapidly increasing | | |
|---|---|---|---|---|---|---|
| | Event code | Essential layer | Days of increasing | Event code | Essential layer | Days of increasing |
| DRY | 1 | A | 7 | 4 | B | 1 |
| | 2 | B | 7 | | | |
| WET | X | | | 3 | A | 1 |
| | | | | 5 | A | 1 |
| | | | | 6 | A | 1 |
| | | | | 7 | B | 1 |
| | | | | 8 | B | 1 |
| | | | | 9 | A | 1 |
| | | | | 10 | A | 1 |