Report on Technical Trip and Proposed Studies of the Risks of Floods and Mudflows due to a Volcanic Eruption of Nevado del Huila

prepared for

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Nevado del Hulla

1.0 Introduction

This is a report on a trip by Dr. Norman H. Crawford to the Nevado del Huila, Río Páez, and Río Magdalena on December 4 and 5, 1990, made on behalf of the National Office of Disaster Prevention and Assistance in Colombia. The purpose of the trip was to investigate the potential for mudslides and floods, damaging to villages on the Río Páez or Río Magdalena, or to the hydroelectric project at Betania. The possibility of a tragedy similar to the Nevado del Ruiz eruption in 1985 is of concern for the Nevado del Huila region.

This report describes the similarities and differences between Nevado del Huila and Nevado del Ruiz, and recommends studies to establish the magnitude of flood flows and mud flows that may result from an eruption of Nevado del Huila. When the hazards of volcanic activity at Nevado del Huila are better defined, measures can be taken to prevent loss of life and limit damage to property.

This report was prepared for Camilo Cárdenas Giraldo, Jefe Oficina Nacional Para Prevención Y Atención de Desastres. Professor Juan Guillermo Saldarriaga, Jefe Depto. de Ingeniería Civil, Universidad de Los Andes traveled with Dr. Crawford to the Nevado del Huila, and provided technical assistance in the preparation of this report.

2.0 Volcanology, Geography and Hydrology

The characteristics of Nevado del Huila and Nevado del Ruiz are as follows:

	Nevado del Huila	Nevado del Ruiz
Elevation	5350 m.	5399 m.
Activity	Active fumarolas. Historic reports of "red glow" on the mountain in the late 19th century. Lava flows, rather than eruptions of ash are typical.	Last eruption in 1985 of volcanic ash, similar to Mt. St. Helens (USA). Eruptions of ash are typical.
Glacial Ice[1]	710 Mm^3.	1700-2000 Mm^3.
Potential for Mudflows	Mountain slopes are very erodible with limited vegetation.	Mountain slopes are very erodible with limited vegetation.
Rivers that may be affected by Floods or Mudslides	Río Páez Río Símbola	Río Gualí. Río Lagunillas Río Chinchiná
Unique Concerns	Betania reservoir and dam	

[1] Mm^3 is millions of cubic meters.

Nevado del Ruiz erupted volcanic ash in 1985, similar to the Mount St. Helen's eruption in the U.S.A. Ash falling on the surface of the glacier on Nevado del Ruiz melted about three percent of the volume of the glacier. Glacial runoff, combined with runoff from rainfall that was occurring when Nevado del Ruiz erupted, eroded soils on the mountain slopes and created a disastrous mudslide at Armero.

Nevado del Huila is different geologically, and is expected to 4.
produce lava flows rather than ash. Lava flows under the glacier would rapidly melt glacial ice, although the entire volume of the glacier would be unlikely to melt.

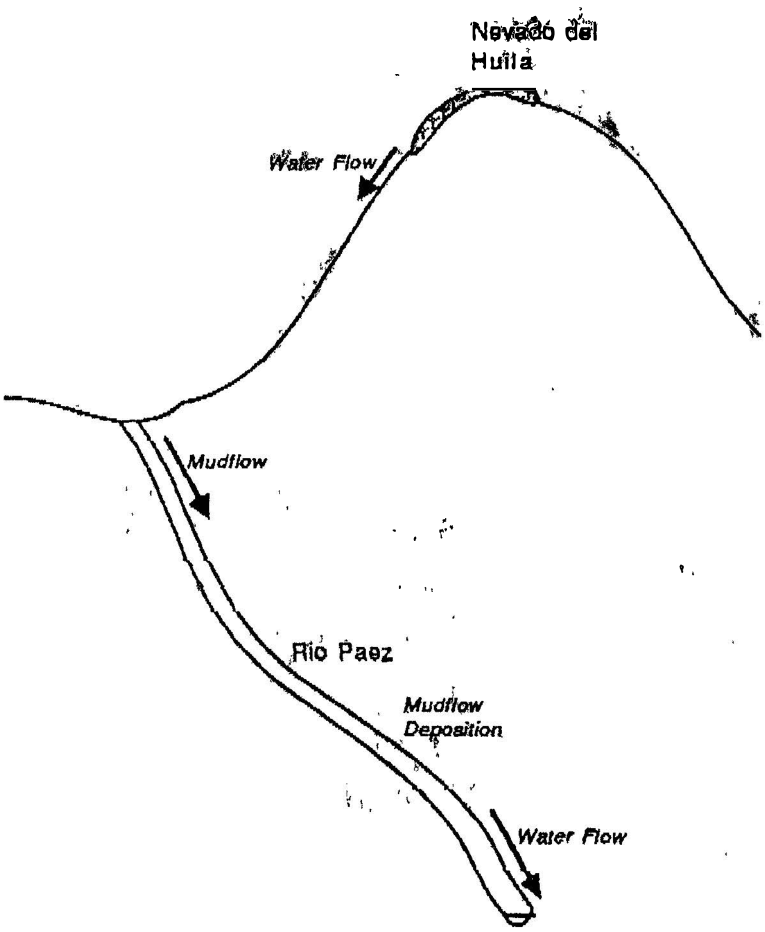
Soil conditions on the slopes of Nevado del Huila are similar to 5.
Nevado del Ruiz, so a mudslide could develop, and historic mudslides on the Río Páez below Nevado del Huila have been found.

The Betania reservoir and dam are of concern, because high
spillway flows or failure of this important hydroelectric dam would 6.
cause high flows in the city of Neiva, and in downstream cities on the Río Magdalena.

3.0 Analysis of Floods and Mudflows

The most critical condition on Nevado del Huila is an eruption that causes rapid glacial melt, producing large meltwater flows. Rainfall may be concurrent with an eruption.

On Nevado del Ruiz in 1985, 3 percent of the ice at high elevations melted as hot ash fell on the surface of the glacier. On Nevado del Huila different melt rates are expected since lava flows will melt ice from the bottom of the glacier. Since the magnitude and timing of lava flows are unknown, an analysis would assume moderate, large, and "worst expected" lava flows. Glacial melt would be estimated for each case.



Sketch of Mudslide and Floods at Nevado del Huila
Figure 1

A water flow leaving the glacier on Nevado del Huila would erode soils, creating a mudflow into the Río Páez and its tributaries. At some location downstream, as the velocity of the mud and water flows decrease, most of the sediments will deposit. A flood with much lower sediment content will continue downstream.

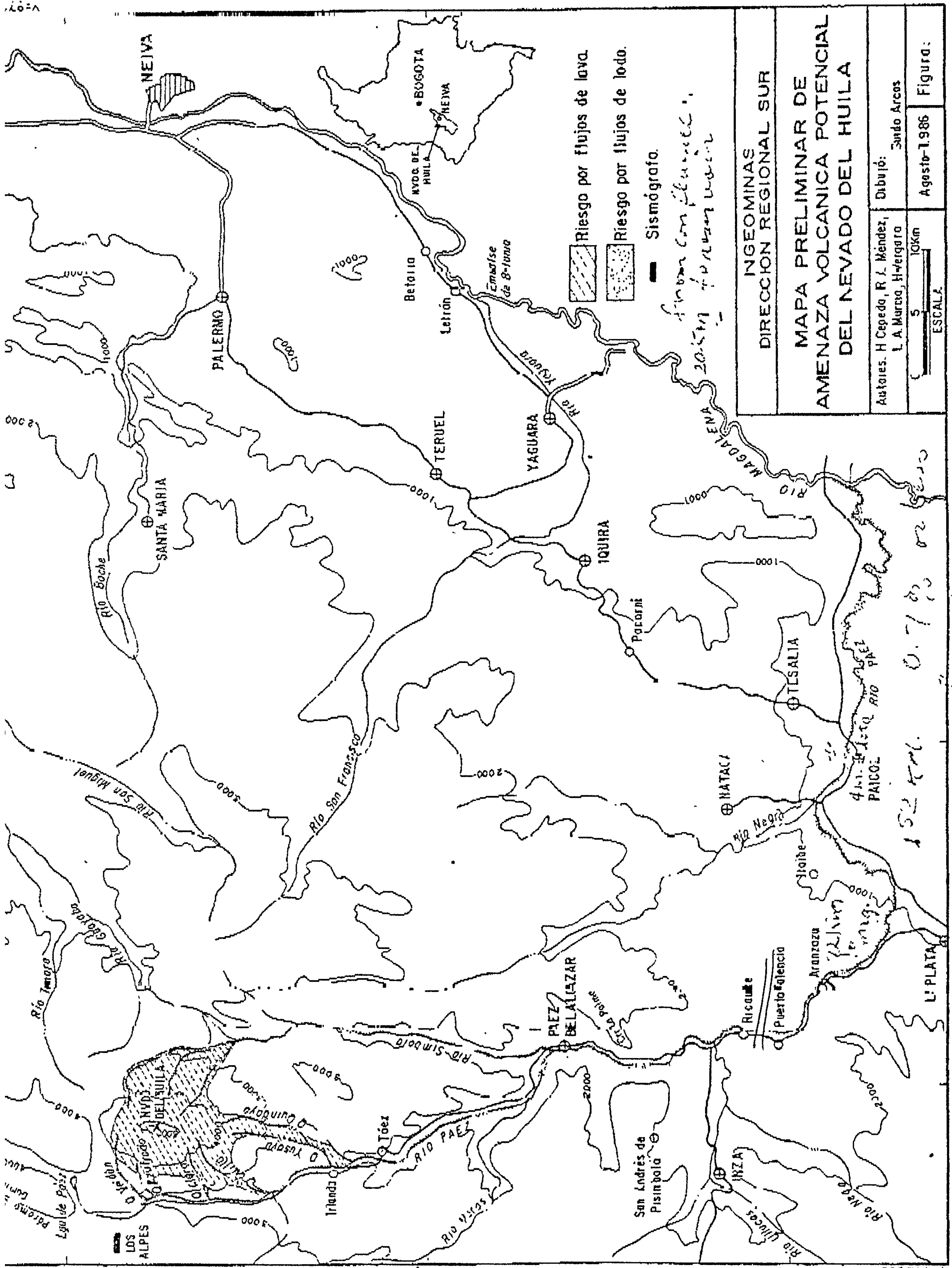
3.1 Mudflows

The slopes of the Nevado del Huila are highly erodible, similar to the soils on the slopes of Nevado del Ruiz. The composition of the Nevado del Ruiz mudflow at Armero was estimated to be 70 percent solid material. The technical analysis of water and mudflows on extremely steep slopes such as Nevado del Huila is approximate. Either the complete continuity and momentum equations, or kinematic wave routing, could be used for this analysis. The complete equations of motion tend to be unstable and are difficult to use on very steep slopes, and for channels that are dry as a flood or mudslide begins. Kinematic wave[2] flow routing is preferable because this technique is robust, and is no less accurate given the uncertain physical characteristics of mudflows.

A water and mudflow from Nevado del Huila would move either (Or both) into the Río Páez or Río Símbola along small creeks as the Q. Yusayu and Q. Quilla. Río Páez receives all the water from the western slopes of the volcano; Río Símbola runs to the east receiving water from the eastern slopes of the mountain. Río Símbola meets Río Páez just upstream the town of Belalcazar. Figure 2 is a map of the Nevado del Huila region. Topographic barriers should prevent significant water and mudflows into Río Moras, Río Tamara and Río Guayabo. Thus, Río Páez and its tributaries have the greatest risk. Mudflows are likely to deposit along Río Páez above Ricaurte.

Mudflows will deposit when the slope of the river or floodplain

[2] Kinematic wave flood routing is based on the continuity equation, and the friction slope of the flow is assumed equal to the channel slope. (Henderson, Open Channel Flow, MacMillan Publishing Co., New York, pp. 367-369)


INGEOMINAS
DIRECCION REGIONAL SUR
MAPA PRELIMINAR DE
AMENAZA VOLCANICA POTENCIAL
DEL NEVADO DEL HUILA
Riesgo por flujos de lava.
Riesgo por flujos de lodo.
Sismógrafo.
Autores: H Cepeda, R. L. Mendez, L. A. Murcia, H. Vergara
Agosto-1.986
Figura:
ESCALA
NEIVA
PALERMO
TERUEL
YAGUARA
SANTA MARIA
IQUIRA
TESALIA
PAICOL
LA PLATA
INZA
Río Magdalena
Río Paez
Río San Francisco
Río Simbola
Río Negro

become mild, as happened at Armero below Nevado del Ruiz. Modeling flow characteristics along the Río Páez will provide hydraulic data that might indicate where mudflow sediments are most likely to deposit. When the larger particles in the mudflow deposit, a flood with more limited sediment load will move downstream.

3.2 Flood Wave Movement

A flood caused by an eruption of Nevado del Huila will move downstream in Río Páez and enter Río Magdalena.

The lower Río Páez has a unique channel morphology. The channel meanders extensively, but the meanders are now deeply incised. This channel morphology may have developed when a downstream geologic control was eliminated by the river. Now, the meanders in the lower Río Páez are incised 20 or more meters, creating a canyon at many locations.

A floodwave generated by an eruption at Nevado del Huila must move along the meandering Río Páez channel. There are two effects of this channel configuration. First, the many meanders in the channel cause high energy losses and increase the distance that the floodwave must travel. Secondly, the narrow canyon-like channel allows the floodwave to move with relatively little attenuation.

Numerical integration of the complete equations of motion is the most accurate technique available for calculating the movement and possible attenuation of a flood wave in a river channel[3], and is appropriate to model flows that are primarily water with limited sediment content. The same method is applicable to model surge or dynamic wave movement in reservoirs.

The lower Río Páez, from 1,000 meters elevation to the Río Magdalena, has an average channel slope of 0.7 percent. The

[3]Henderson, Open Channel Flow, MacMillan Publishing Co., New York, pp. 285 324.

floodwave velocity along the lower Río Páez may be 15 to 25 kilometers per hour.

The Río Magdalena channel below the confluence with the Río Páez is geologically similar to Río Páez. The channel meanders extensively although it is not incised as deeply as Río Páez. Twenty kilometers below the confluence with Río Páez, Río Magdalena enters the Betania reservoir.

3.3 Betania Reservoir

The Betania reservoir is large with a length of approximately 26 Km. at full pool, and an average width of 3 Km. Its storage volume is 1,971 Mm^3. Figure 3 is a map on the reservoir. The reservoir has a southern and a northern arm and Río Magdalena enters the southern arm of the reservoir. The drainage area of Río Magdalena at Betania is 13,572 Km^2. The average inflow from Río Magdalena to Betania reservoir is 470 cubic meters per second.

The reservoir has an overflow spillway at 561.2 meters elevation, and a gated spillway at 548 meters elevation. The total discharge capacity of these spillways is 11,000 m^3/sec at a reservoir elevation of 569 meters. The surcharge storage in the reservoir between 561.2 meters elevation and 569 meters elevation is 1000 Mm^3. There is approximately 250 Mm^3 of surcharge storage between 561.2 meters elevation and 563 meters elevation. Flooding of the town of Yaguará on the northern arm of the reservoir begins at 563 meters elevation.

There are two possible consequences of an eruption that could affect the Betania reservoir:

1) the volume of water entering the reservoir could increase the reservoir level for "level pool" conditions, and cause high downstream releases from the reservoir[4].

[4]Spillway 1 is gated, with a sill elevation of 548 meters, and a dischage capacity of

2) a dynamic wave or surge wave may be generated in the reservoir due to a rapid inflow from Río Páez via Río Magdelena. The height of a dynamic wave does not depend on the volume of inflow to the reservoir since the water surface in the reservoir is not level.

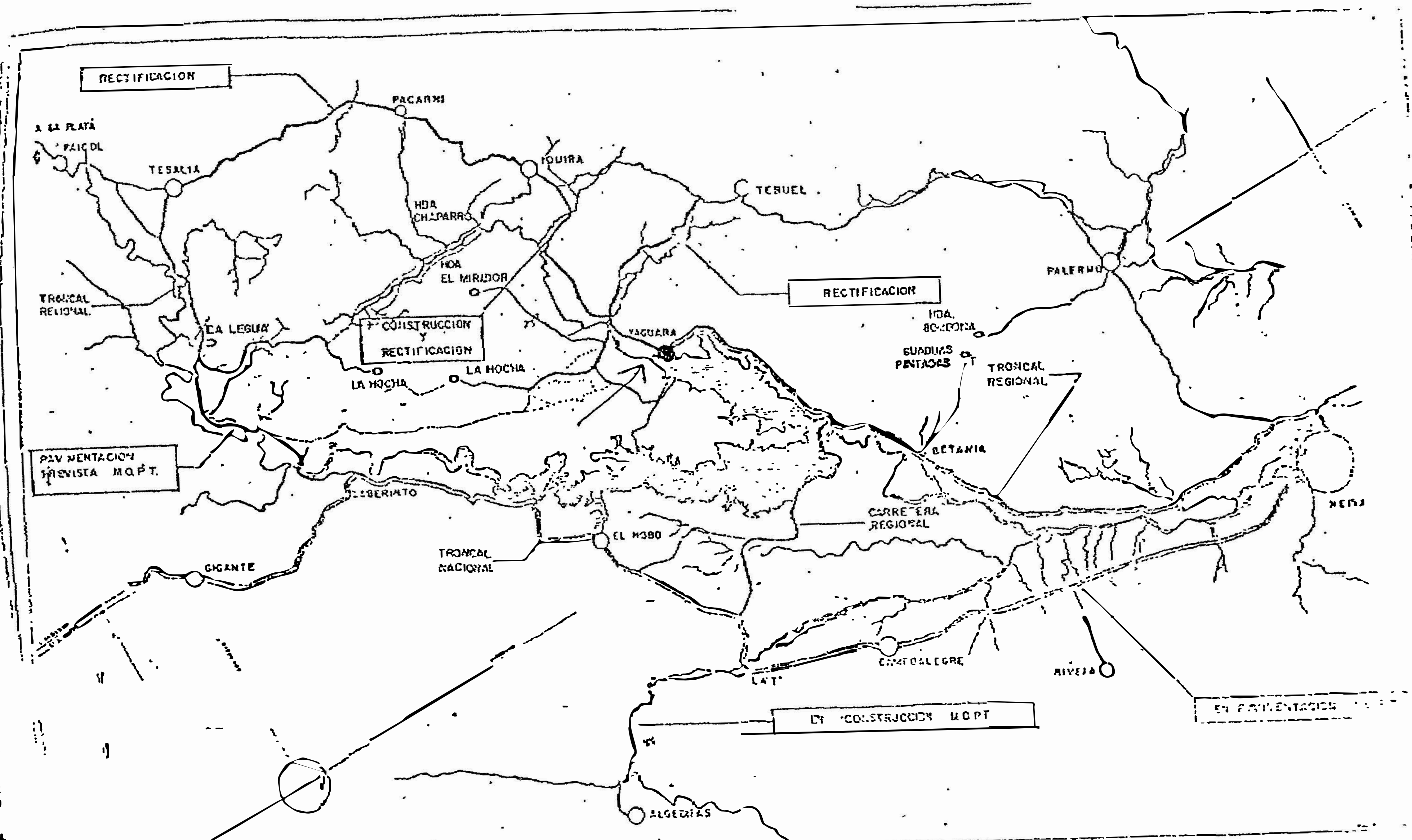
Since the surcharge storage in the Betania reservoir exceeds the total volume of ice in the glacier on Nevado del Huila, there is no danger of overtopping the dam due to glacial melt in a volcanic eruption, if "level pool" conditions prevail in the reservoir. High releases of water from the reservoir is a possibility that should be investigated.

If a flood entering the reservoir creates a dynamic wave, this wave would reach the dam at Betania and would be reflected upstream along the northern arm of the reservoir. It would be unlikely that a dynamic wave would exceed 11 meters and overtop the dam, but this possibility should be investigated with complete equations or full equations routing.

The possibility that a dynamic wave, reflected up the northern arm of the reservoir, could flood the town of Yaguará should be investigated. Yaguará is only two meters above the normal full pool reservoir level.

The upper valley of Rio Páez is narrow, with steep slopes along both banks of the river. A landslide, which may or may not be caused by an eruption of Nevado del Huila, could dam the river and form a temporary reservoir. The landslide would be washed out as soon as river flows filled the temporary reservoir, and a flood similar to a glacial melt flood would move downstream in Rio Páez. The risks of flooding along Rio Páez, and the risk of surge waves in Betania reservoir caused by landslides, could be investigated together with the risks caused by a volcanic eruption of Nevado del Huila.

7,500 m^3/sec at a pool elevation of 569 meters. Spillway 2 is ungated, with a sill evevation of 561.2 meters, and a discharge capacity of 3,500 m^3/sec at a pool elevation of 569 meters.



UNIVERSIDAD NACIONAL DE COLOMBIA

CENTRAL HIDROELECTRICA DE BETANIA S.A.

PROYECTO BETANIA

UNIDAD DE ORDENAMIENTO TERRITORIAL

MAPA Nº 27 AREA DE ORDENAMIENTO TERRITORIAL

CONTIENE SISTEMA VIAL REGIONAL PROPUESTO

4.0 Proposed Technical Studies

4.1 Goals

The goal of the proposed technical studies is to define the risks of an eruption of Nevado del Huila.

How much glacial melt could occur and how quickly would it occur?

What mudslide volume could occur?. How quickly would a mudslide move and where might it deposit? What bridges, roads or other structures would be endangered?

How much warning time would be available for a mudslide?

What water flow or flood hydrograph could occur, and how quickly would this flood move into Río Páez and Río Magdelena?. What bridges, roads or other structures would be endangered?

Would a rapid inflow to Betania reservoir create a surge or dynamic wave in the reservoir?. How large might a dynamic wave in the reservoir be, and how would it affect the dam or the town of Yaguará?

Would an eruption lead to high reservoir releases from Betania that would cause downstream floods?

4.2 Tasks, and Time Required for Studies

In summary, the steps required to investigate the effects of a volcanic eruption at Nevado del Huila are as follows.

Task		Technical Specialties	Estimated Professional Time (person-weeks)
1	Estimate the magnitude and timing of lava flows that could occur on Nevado del Huila	Volcanology	4
2	Estimate the magnitude and timing of glacial melt for lava flows of different magnitude	Volcanology, Hydrology	4
3	Calculate the volume and shape of mudflows and flood hydrographs entering Río Paez and its tributaries	Hydrology, Volcanology	6
4	Calculate or estimate areas of deposition for mudflows along the Río Paez valley	Hydrology, Geology	3
5	Route the flood hydrograph, after the mudflow deposition, along Río Paez and Río Magdelena to Betania reservoir.	Hydrology	10

Task		Technical Specialties	Estimated Professional Time (person-weeks)
6	Estimate the "dambreak" flood hydrograph that would occur if a landslide temporarily dammed the upper Río Paez valley, and route this flow along Río Paez and Río Magdelena, and through Betania reservoir.	Hydrology	6
7	Calculate dynamic waves in Betania reservoir, due to the flood hydrograph found in Task 5.	Hydrology	6
8	Calculate the releases from Betania reservoir in a volcanic eruption, given current reservoir operating policy	Hydrology	3
9	Prepare a report[1]	Volcanology, Geology, Hydrology	12

[1]The report would include summaries and results of all studies, maps of the time of arrival and magnitude of mudlides and floods, recommendations for emergency actions for towns affected by mudsides and floods, and recommendations for modifications, if needed, in Betania project operations to limit damages from dynamic waves or downstream flow releases.

5.0 Conclusions

There is no evidence that Betania dam can be significatly affected by a mud flow from Nevado del Huila. It can cause some waves in the reservoir that could afect the town of Yaguará, specially if the pool is full. Also , the flood produced by a mudflow can cause large spillway discharges that can afect Neiva and/or other tows in the Magdalena Basin.

The proposed studies would be done primarily in Colombia by professionals in the Instituto Nacional de Investigaciones Geológico-Mineras, at universities, or by consultants, with assistance from Hydrocomp as necessary.

Hydrocomp has experience with kinematic and complete equations routing for flood flows in streams and reservoirs, and with United States practice in emergency action planning, that might contribute to these studies.