

# *Rio-Watch 2001: the Rio de Janeiro landslide alarm system*

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**ABSTRACT:** The City of Rio de Janeiro has installed in 1996 the *watch system* for warning against landslides triggered by severe rainfall. The system consisted of a raingauge network and one automatically instrumented slope. In 1999 the system was enhanced by a meteorological Doppler radar, operated by meteorologists. This is a result of a nearly 10-year long project conducted by *GeoRio*, the Rio de Janeiro Geotechnical Engineering Office, which is responsible for the slopes and in charge of the project. This paper describes the Rio-Watch project, which is aimed at giving an early warning some two hours in advance.

## 1 INTRODUCTION

The City of Rio de Janeiro presents a unique fascinating scenery due to the contrast of high steep slopes and the beaches. In between this flat land live many of its 6 million inhabitants who are exposed to a high risk of slope failure.

The catastrophes striking Rio in 1966, 1967 and 1988, and more recently in 1996, are vivid reminders of the seriousness of landslides triggered by severe rainfall. The Government's policy to keep the landslide risk within an acceptable level has been to carry out a large number of slope stabilisation works and risk mapping (Barros et al. 1991). The work described in this paper started back in 1991 with a pilot automatic instrumentation project. It consisted of three instrumented slopes with piezometers and raingauges (Ortigao et al. 1994). The data were transmitted and analysed at GeoRio. The success of this preliminary programme has led GeoRio to deploy the raingauge network for the *Rio-Watch* alarm system (d'Orsi et al. 1997). The aim of this programme was an early alarm system for heavy rains and its potential landslip

consequences. The project included a fully automatic instrumented slope (Ortigao et al. 1997). In 1999, the *Rio-Watch* was significantly enhanced by the addition of a meteorological Doppler radar and a team of meteorologists to analyse the data and issue two-hour advance warnings.

The *Rio-Watch* system, the precedent studies for its deployment and the criteria to issue an alarm are presented in the paper.

## 2 ALARM SYSTEM CONCEPTS

Landslip alarm system based on instrumented slopes is an accepted concept for the geotechnical profession. This idea has been applied successfully in man-made slopes, such as those of dams or embankments. Geotechnical engineers are able to assess the margin of slope safety by means of trends shown by the instrumentation. However, most natural slopes in residual and other tropical soils may not show any obvious signs of an imminent failure condition until it fails under a severe rainstorm. Therefore, the concept

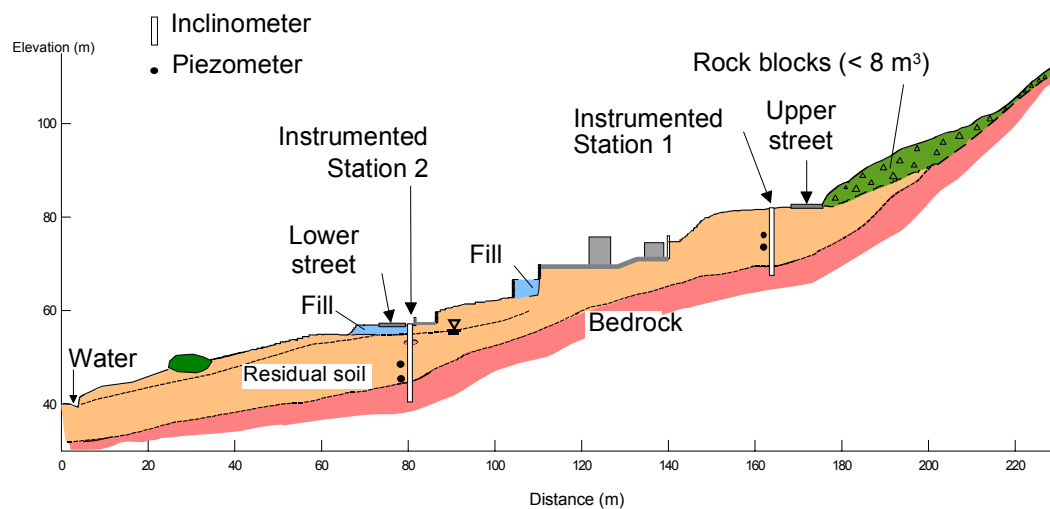


Figure 1. Instrumented slope at the Itanhangá Hill (Ortigao et al. 1997).

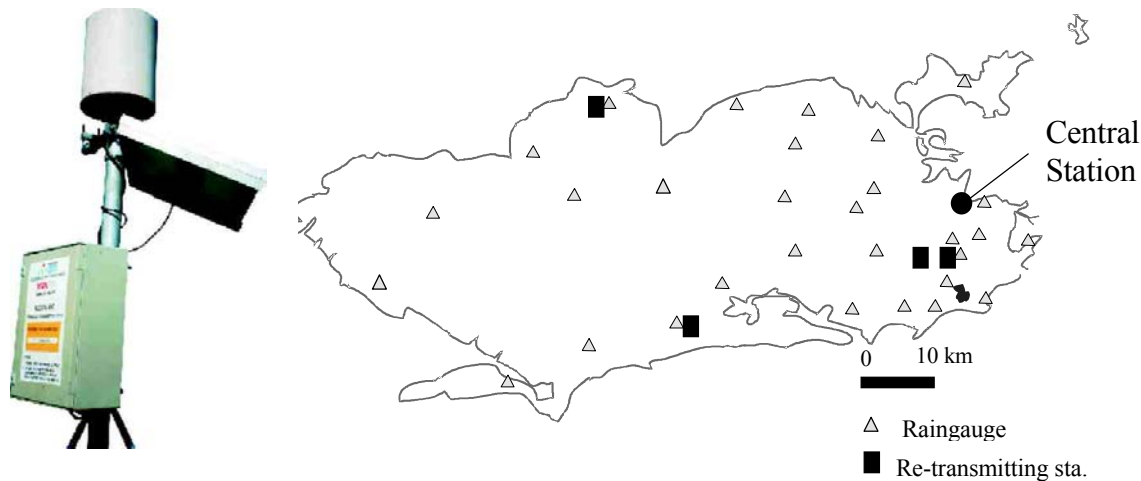


Figure 2. The automatic rain gauge.

Figure 3. Location of rain gauges.

applied to the design of Rio-Watch was based on:

- A few specific instrumented slopes, used for research and to gain insight into the phenomena.
- A rain gauge network which, instead of measuring the *effect*, measures the main landslide *cause*.
- In 1999 this system was enhanced with a meteorological radar and meteorological analyses, which enable the issuance of alarms a few hours before the severe storm.

Figure 1 shows an example of a fully automated instrumented slope in Rio de Janeiro (Ortigao et al. 1997) with piezometers and inclinometers. This slope was instrumented because soil movements occurred in the past and damaged several houses. Also due to the

fact that it is very gentle, unlike many slopes in Rio.

Automated slope instrumentation aimed at getting insight into the dominating phenomena. It cannot be regarded as a practical tool for a large area such as Rio. It would be too expensive to have a hundred instrumented slopes and the cost of analysis and data interpretation would be enormous. Therefore, the concept of measuring just the landslide cause, *i.e.* rainfall, came into play.

### 3 THE RAINGAUGE NETWORK

The rain gauge network in Rio de Janeiro consists of 30 automatic rain gauges of the type shown in Figure 2. Figure 3 shows the locations of the rain gauges. This network became operational in December 1996. The

data are transmitted at 15 minutes intervals to a Central Station fitted with a microcomputer network to handle the data.

important variables like: accumulated antecedent rainfall in different time windows, slope and ground characteristics. Therefore,

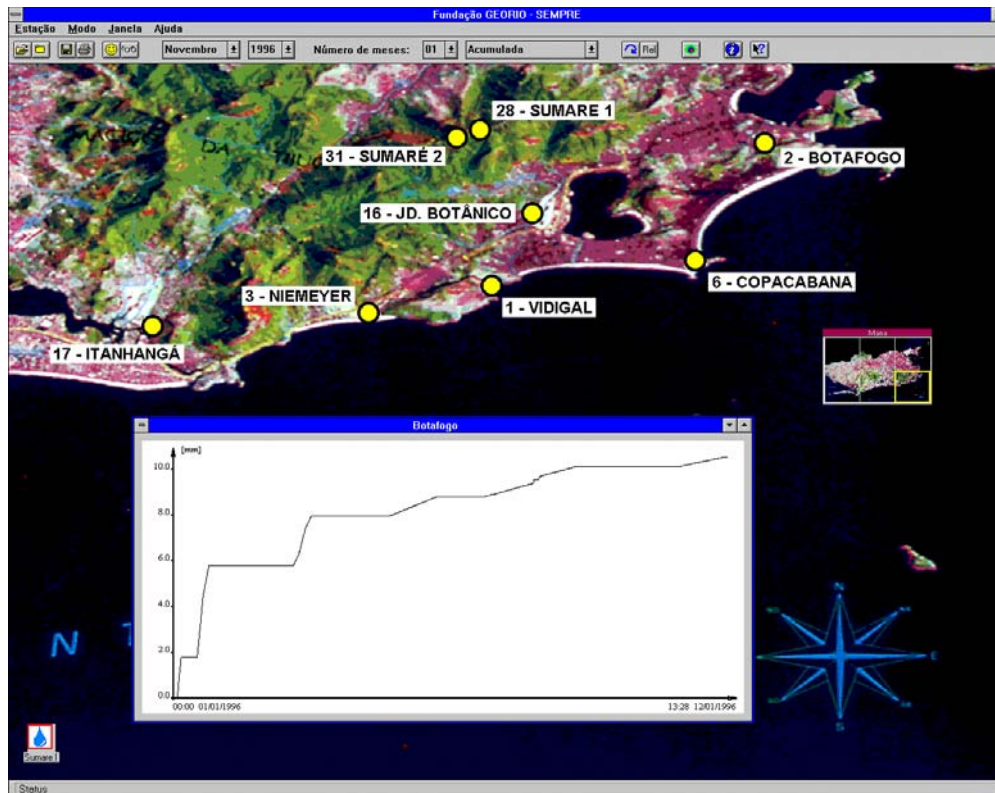


Figure 4. Windows software at the Central Station.

#### 4 SOFTWARE

The Central Station consists of a PC based computer network operating under NT environment with a server and three PC workstations, employing Windows 98. The dedicated Windows software (Figure 4) receives, analyses, stores, backs-up and displays the data. At any time, however, the operator can look at the data from a particular raingauge just by clicking the mouse on its location.

#### 5 CRITICAL PRECIPITATION LEVELS

D'Orsi et al. (1997) presented a comprehensive study of the relationship between rainfall and landslips for Rio de Janeiro based on 65 landslips and precipitation data from five raingauges only. This preliminary study led to GeoRio's criteria for the landslide level. The criteria relate daily or hourly precipitation to 4-day antecedent rainfall and disregard several

these empirical relationships are rather limited, but they constitute a preliminary approach for Rio de Janeiro.

This work was recently reassessed using new landslide and rainfall data from the raingauge network and the results are given in Figure 5. The maximum daily precipitation level is about 180 mm/day, decaying as a function of the antecedent 4-day rainfall.

#### 6 WEATHER FORECAST

In 1999 GeoRio decided to enhance the Rio-Watch system by adding a team of meteorologists and a digital Doppler radar aimed at obtaining early warnings of heavy precipitation.

Meteorological analyses consist of three phases: *regional scale basis*, preliminary analyses of data available at the Internet, *mesoscale basis* which is based on the radar imagery and finally a *comparison* between prediction and actual rainfall measurements through the raingauge network.

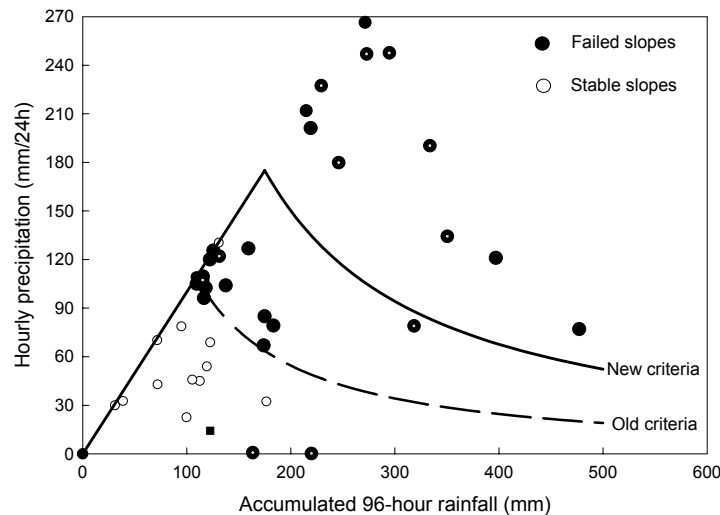


Figure 5. Landslip based on the daily rainfall rate against accumulated rainfall in 96 hours.

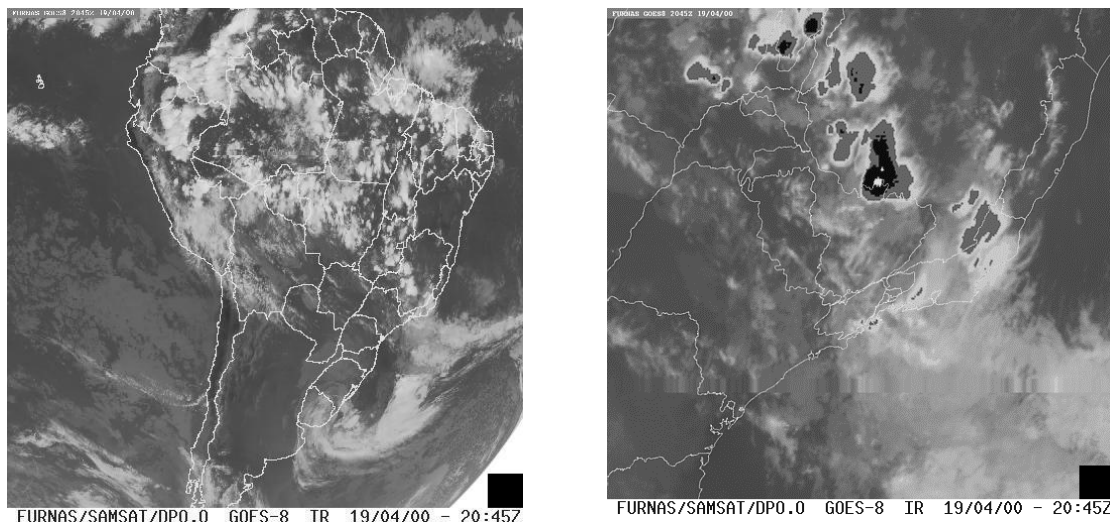


Figure 6. Satellite images (a) South America; (b) Digitally enhanced.

### 6.1 Regional scale analysis

Rio-Watch staff receive twice a day the results of numerical weather predictions of the CPTEC, the Brazilian Centre for Weather Forecasting and Climate Studies. Weather data on surface and upper-air measurements of temperature, pressure, moisture, winds and air density are gathered by many stations and fed into high speed computers running numerical models of the atmosphere.

Another important tool is images from geostationary satellites (Figure 6a), which provide extremely valuable information even over areas where there are no ground-based observations. The Rio-Watch staff analyse

these images to follow weather systems affecting the South America, like extra tropical cyclones and cold fronts, observing their arrival in Rio de Janeiro some days before. These satellites have infrared sensors that enable photography at night, therefore continuous information is obtained. Photographs can be enhanced by computer, as shown in Figure 6b, which indicates the highest and thickest clouds in a particular storm.

## 7 METEOROLOGICAL DOPPLER RADAR

A digital Doppler radar is the tool to investigate mesoscale weather systems, within

300 km radius from the radar antenna. Radar stands for *Radio detection and ranging*. In the computer era it became digital and offers a wide range of possibilities for weather forecasting. It gathers information about storms and precipitation in previously inaccessible regions. Meteorologists use weather radar to examine inside of a cloud

encounters an obstacle like clouds - called a target - a fraction of the energy is scattered back towards the transmitter and is detected by a receiver. The returning signal is amplified and displayed on a screen, producing an image or *echo* from the target. The elapsed time between transmission and reception indicates the target's distance. The brightness of the

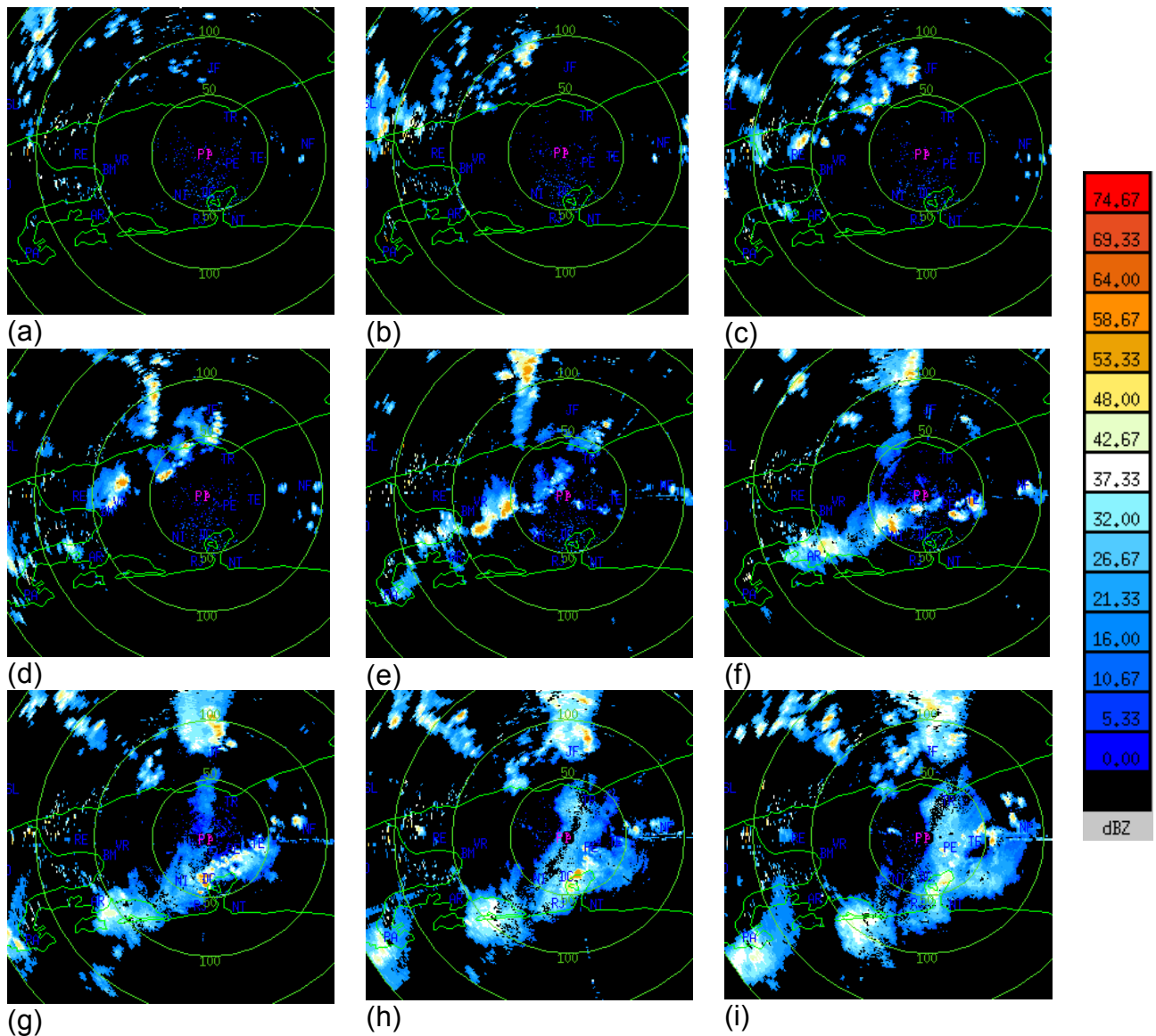


Figure 7. Radar imagery gathered on 25 January 2000 at several times (a) 14:11Z, (b) 16:11Z, (c) 17:11Z, (d) 18:11Z, (e) 19:11Z, (f) 20:11Z, (g) 21:11Z, (h) 21:41Z and (i) 22:11Z.

much like physicians using X-rays to examine the inside of a human body. Some kinds of weather storms, like squall lines, mesoscale convective systems and severe thunderstorms, are much better studied and followed by means of a radar.

Essentially, the radar unit consists of a transmitter that sends out short, powerful microwave pulses. When this energy

echo is directly related to the amount (intensity) of rain falling in the cloud. So, the radar screen shows not only where the precipitation is occurring but also how intense it is. In recent years, the radar image has been displayed using various colours to denote the intensity of precipitation within the range of radar unit. Figure 7 shows a set of images obtained on 25 January 2000 at several times

from 14:11Z to 22:11Z, where Z stands for *Zulu time*, a meteorology jargon for GMT (Greenwich Mean Time).

## 8 ALAAAAAARM ...

On 25 January 2000 weather conditions led to an alarm issued by GeoRio. It is certainly not among those severe cases faced by Rio de Janeiro, but its imagery shows interesting features (Figure 7) like its development, path and duration. The storm originated in the NW and propagated towards SE. The image sequence shows all phases of the storm: formation, propagation and maturing.

Once the Rio-Watch's meteorologists detect the alarm condition, GeoRio contacts the Civil Defence Division of the Rio Government in order to assess the situation before the final decision to issue an alarm. Once it is issued, faxes are sent to the media informing about the high risk of landslips and the Government takes a series of preventive measures. These measures include: information to the people about the current situation, areas or roads that should avoided, notice to hospitals, fire, rescue brigades, etc.

The alarm on 25 January 2000 was issued by GeoRio at 17:30 Z time (Zulu time). Within four hours severe rainfall struck West Rio, as predicted.

No casualty or landslip was recorded on this night. The alarm was cancelled at 23:00 Z time.

## 9 CONCLUSIONS

*Rio-Watch* system has been an outstanding tool in the risk management programme in Rio de Janeiro. It is based on data from the following sources:

- Regional-scale studies by other parties
- Satellite imagery
- Doppler radar
- Automatic raingauge network

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