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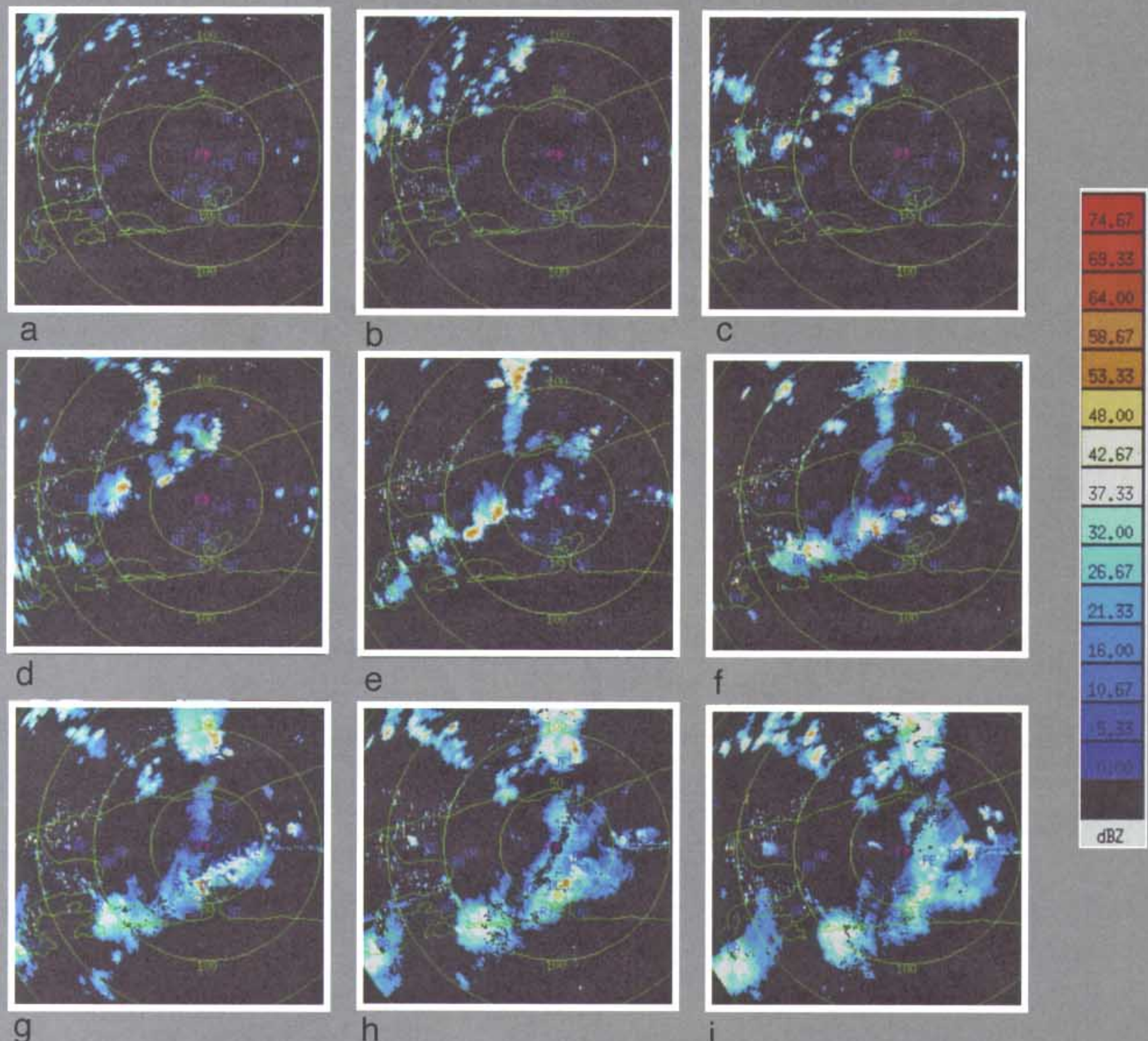

Rio-Watch: the Rio de Janeiro Landslide Alarm System

Shallow Water Cover Technology for Reactive Sulphide Tailings Management

Rio-Watch: the Rio de Janeiro Landslide Alarm System

Beto Ortigao and Maria G Justi

Abstract

In 1996 the City of Rio de Janeiro, Brazil, installed the *Rio-Watch* system for warning of 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 part of a 10-year long project conducted by *GeoRio*, the Rio de Janeiro Geotechnical Engineering Office. This article describes the Rio-Watch project, which is aimed at giving an early warning some two hours in advance of a risk of landslides.

Introduction

The City of Rio de Janeiro presents unique fascinating scenery due to the contrast of high steep slopes and beaches. Many of its six million inhabitants live on the lower slopes where they are exposed to a high risk of landslides and slope failures.

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. To keep landslide risk within an acceptable level the Government's policy has been to carry out a large number of slope stabilisation works and risk mapping (Ortigao and Sayao, 2004). The work described in this article started in 1991 with a pilot automatic instrumentation project, consisting of three instrumented slopes with piezometers and raingauges (Ortigao et al. 1994). The data were transmitted and analysed at GeoRio. The success of the pilot project led GeoRio to deploy the full raingauge network for the Rio-Watch alarm system (d'Orsi et al. 1997). The aim of this programme was an early warning system for heavy rains and its potential landslip consequences. The project included a fully automatic instrumented slope (Ortigao et al. 1997). In 1999, Rio-Watch was significantly enhanced by the addition of a meteorological Doppler radar with a team of meteorologists to analyse the data and issue warnings two hours before heavy rain. In 2003 numerical modelling of the atmosphere on a regional (small) scale has proved to be an accurate tool, being able to predict the weather conditions up to four days in advance. The radar, on the other hand, can be used to follow up the atmosphere during the event and compare with numerical predictions. Based on GeoRio's experience, guidelines for risk mapping, design of stabilisation works and slope instrumentation have been recently published in the form of a handbook of slope stabilisation (Ortigao & Sayao, 2004).

This article presents the development and implementation of the Rio-Watch system.

Alarm System Concepts

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

- A few specific instrumented slopes, for research and to gain insight into the phenomena.
- A raingauge network which, instead of measuring the *effect*, measures the main landslip *cause*.
- In 1999 this system was enhanced with a meteorological radar and meteorological analyses, to predict heavy rainfall a few hours in advance.

Figure 1 shows an example of a fully automated instrumented slope in Rio de Janeiro (Ortigao et al. 1997) with piezometers and in-place inclinometers. This slope was instrumented because soil movements occurred in the past and damaged several houses, and because it is very gentle, unlike many slopes in Rio.

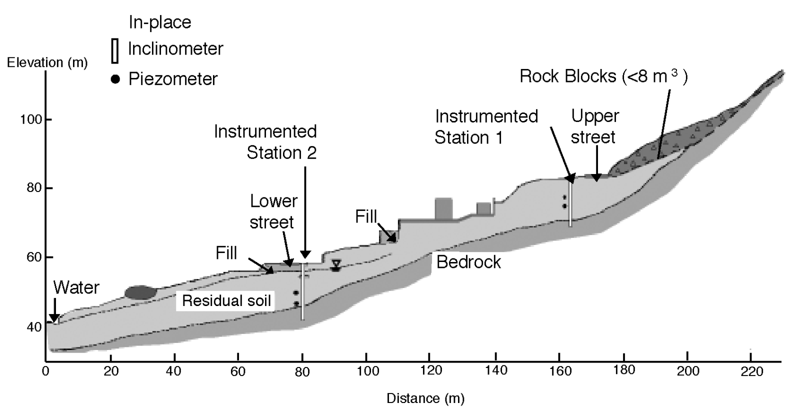

Figure 1. Instrumented slope at the Itanhanga Hill (Ortigao et al. 1997).

Such automated slope instrumentation is aimed at understanding what is controlling slope stability. It cannot be regarded as a practical advance warning tool for a large area such as Rio. It would be too expensive to have a hundred instrumented slopes and the cost of data analysis and interpretation would be enormous. Therefore, the concept of measuring the cause of the landslip, *i.e.,* rainfall, and not the effect, came into play.

The Raingauge Network

The raingauge network in Rio de Janeiro consists of 30 automatic raingauges of the type shown in Figure 2. Figure 3 shows the locations of the raingauges. 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.

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 rain gauges. This preliminary study led to GeoRio's criteria for the landslip risk level. The criteria relate daily or hourly precipitation to 4-day antecedent rainfall. They disregard several important variables such as: accumulated antecedent rainfall in different time windows, slope and ground characteristics. Therefore, these empirical relationships are rather limited in scope, but they constitute a preliminary approach for Rio de Janeiro.

This work was reassessed in 2000 (Ortigao et al, 2001) using new landslip and rainfall data from the raingauge network and the results are given in Figure 4. The maximum daily precipitation level is about 180 mm/day, decaying as a function of the antecedent 4-day rainfall.

Weather Forecast

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

Meteorological analyses consist of three phases: *regional scale*, preliminary analyses of data available at the Internet, *mesoscale* which is based on the radar imagery and finally a compari-

Figure 2. The automatic raingauge.

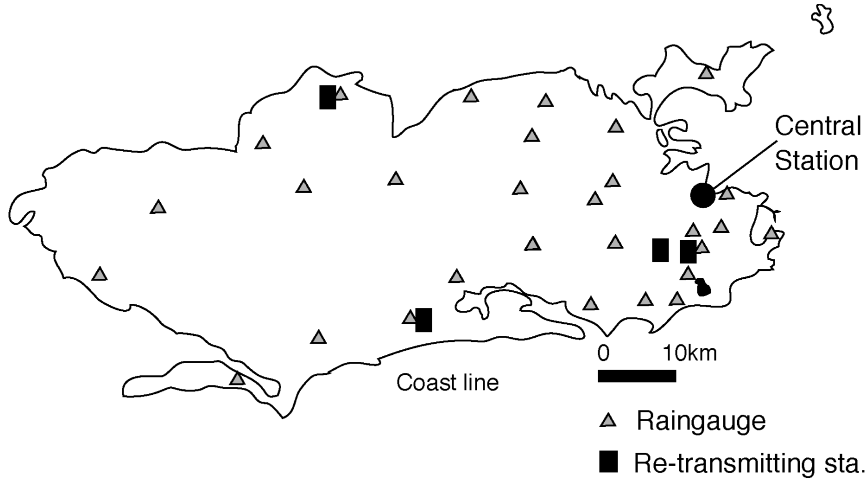

Figure 3. Location of raingauges, metropolitan area of Rio de Janeiro.

son between prediction and actual rainfall measurements through the raingauge network.

Regional Scale Analysis

Rio-Watch staff receives 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. Regional scale numerical models became available in 2003 and run the atmospheric models on small or regional scale. As numerical predictions of weather conditions have proven to be reasonably accurate, this reduces the role intended for the rain gauge network.

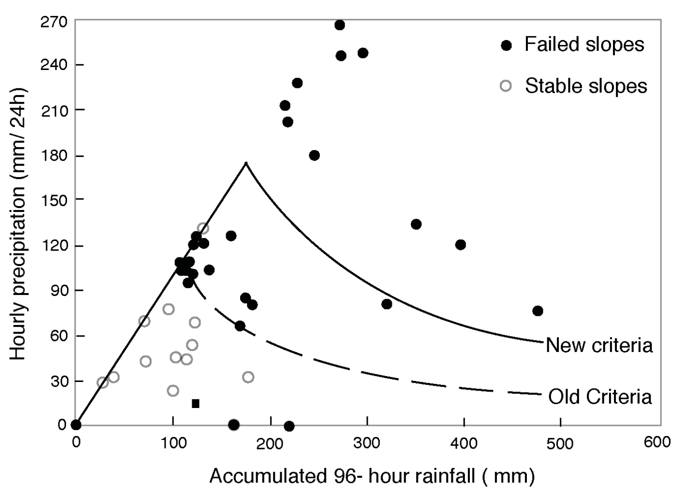

Figure 4. Landslip alarm level based on the daily rainfall rate against accumulated rainfall in 96 hours.

Meteorological Doppler Radar

A digital Doppler radar is used to investigate mesoscale weather systems, within 300 km radius from the radar antenna. It gathers information about storms and precipitation in previously inaccessible regions. Meteorologists use weather radar to examine inside of a cloud much like physicians using X-rays to examine the inside of a human body. Certain kinds of weather storms, like squall lines, mesoscale convective systems and severe thunderstorms, are more easily studied and followed by means of radar.

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 5 shows a set of images obtained on 25 January 2000 at several times from 14:11*Z* to 22:11*Z*, where *Z* stands for GMT (Greenwich Mean Time).

Alarm

The 25 January 2000 weather conditions led to an alarm issued by GeoRio. It is certainly not among the severe cases faced by Rio de Janeiro, but the radar image shows interesting features (Figure 5) 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 meteorologists detect an 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. When a warning 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: public warnings 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. 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.

Conclusions

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

- Large scale studies by other parties;
- Regional-scale numerical modelling;
- Doppler radar;
- Automatic raingauge network.
- The cost of Rio-Watch is small as compared to the benefits.

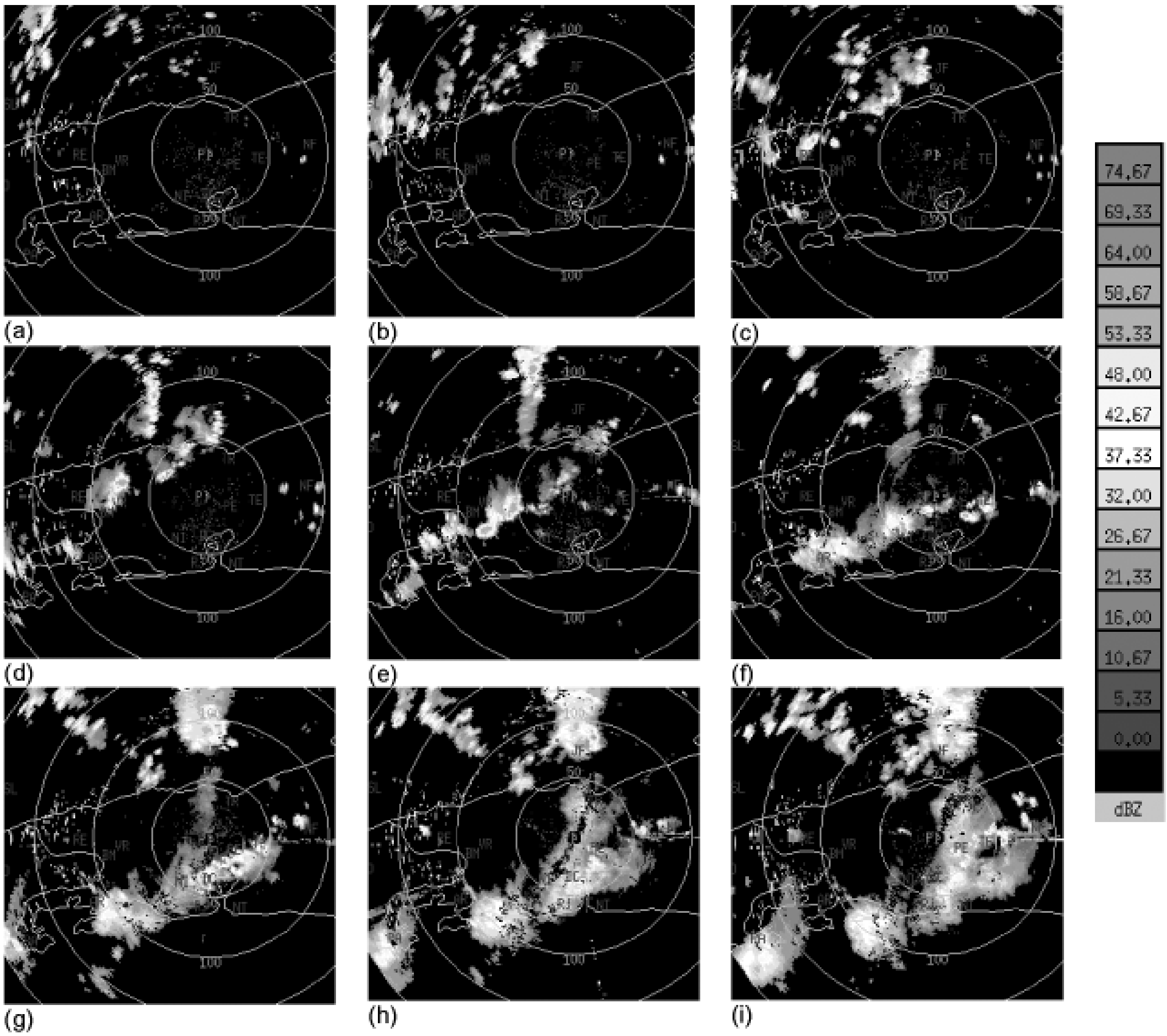

Figure 5. Radar imagery on 25 January 2000.

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