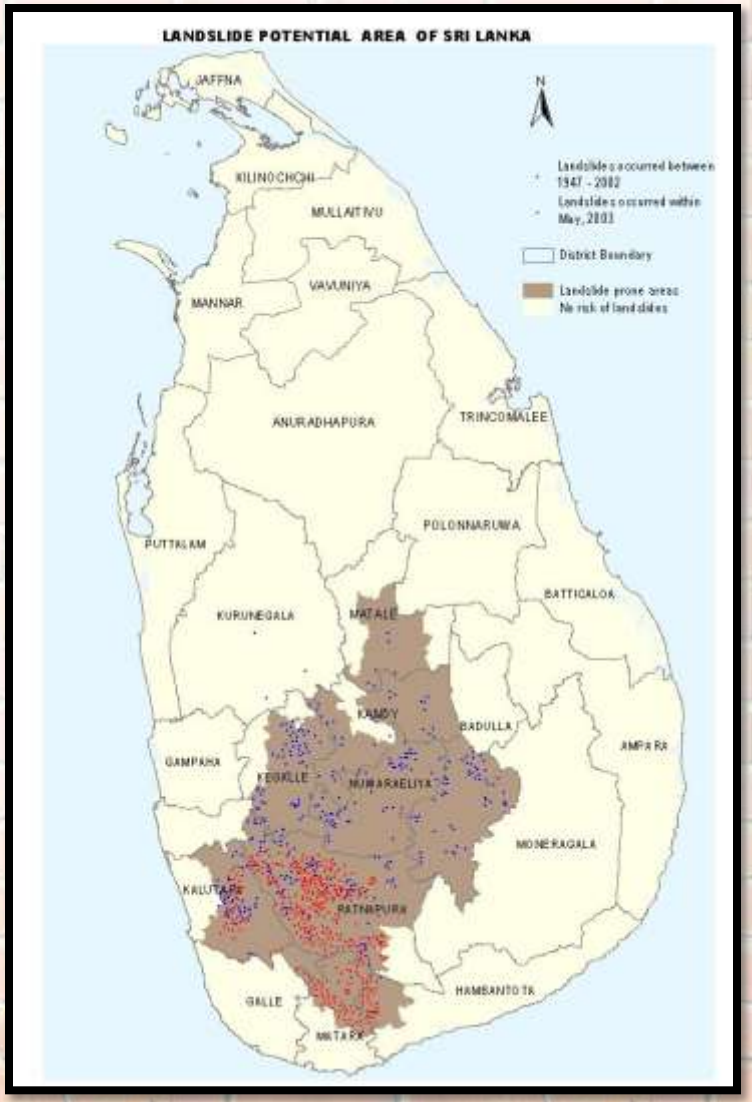
Landslide

- Most of landslides in SL are rain-induced landslides
- Hilly terrain in the central part of the country is most vulnerable
- Major periods of the landslides occurred in every years
  - North-East monsoon (November-February)
  - South-West monsoon (May-August)



Ratnapura-Elapatha

- 74 people were dead, 14 houses were totally damaged

Walapane

- 63 people were dead
- 30- 35 houses were totally damaged

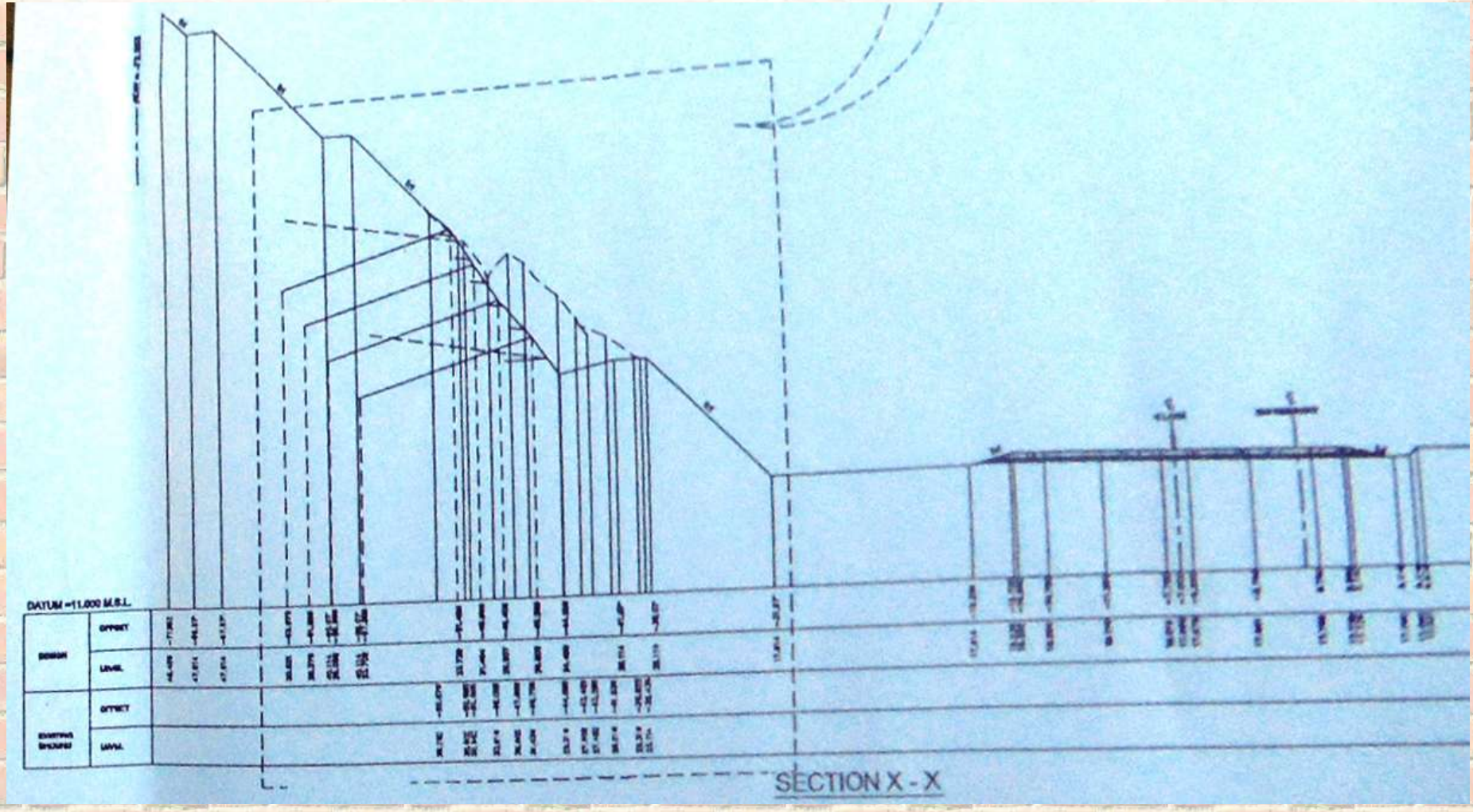
Meeriyabedda

Watawala land slide

No death records but it was totally damaged to the railway line

Kokmaduwa (114km) in Southern Express Way

Design of mitigation measures for Kokmaduwa (114km)



Applying of advanced investigation and monitoring techniques to mitigate slow moving landslides in Sri Lanka

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Geotechnical Engineering Division, National Building Research Organisation

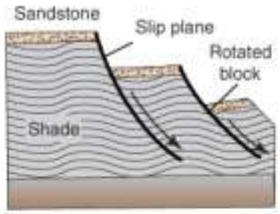
Introduction

- Landslide and other ground failures cause substantial damage and loss of life
- Landslide are naturally occurred and also affected by human activities
  - Triggering factors

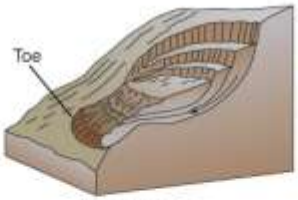
    Heavy rains

    Earthquakes

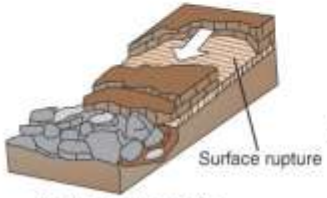
- The assessment and controlling of stability conditions of a slope and to predict its future movement is a big challenge.
  - Deep Seated landslides
  - Shallow landslides



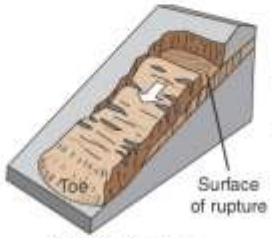
(a) Rock slump



(b) Soil slump

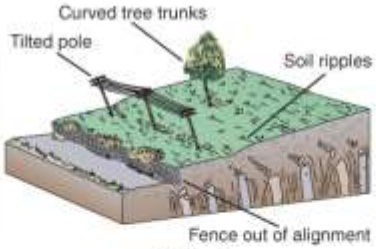


(c) Rock slide



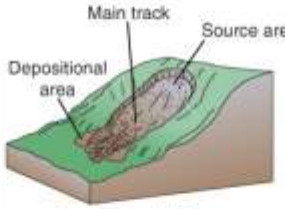
(d) Soil slide


(e) Rockfall

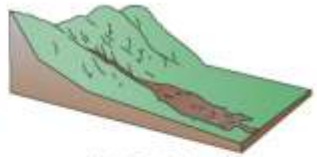


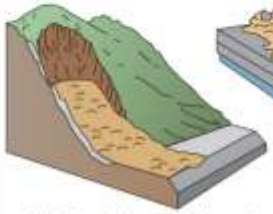
(f) Soil creep

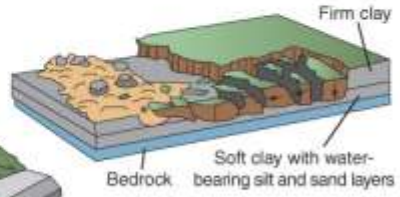
Type of Movement	Materials	
	Rock	Soil
Landslides with variable water content and rate of movement	Rotational	
	Slump(a)	Slump(b)
	Translational	
	Rock slide(c)	Soil slide (slip)(d)
Falls	Rock fall(e)	Soil fall
Flows — Slow	Rock creep	Soil creep(f)
Flows	Unconsolidated rock and soil (saturated)	
Flows — Rapid	Earth flow(g)	
Flows — Rapid	Debris flow / mud flow(h)	
Flows — Very rapid	Debris avalanche(i)	
Lateral spread	Rock(j)	Soil
Subsidence	Rock(k)	Soil
Complex	Combination of slides, slumps, and flows(l)	



(g) Earthflow

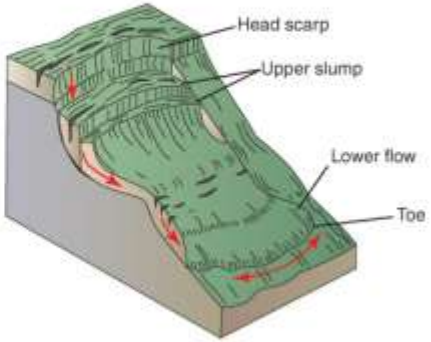

(h) Debris flow


(i) Debris avalanche



(j) Lateral spread


(k) Subsidence



(l) Complex slide

Preventing landslides

1. Drainage control;

   Surface, subsurface

2. Reshaping

   Reducing the overall slope

3. Reducing infiltration

   Cement Grouting, weeding

4. Reinforcement measure

   Large diameter walls, Anchors,

   Networks of micro-piles,

   Nailing, Geo-grids, shot creating

- For the purpose of designing those mitigation measures, we must have adequate information on sub surface condition rather than having just surface information.

  1. Visual signs by site inspection
     (tension cracks, seepages, tilting of trees etc.)
  2. Typical (assumptions) soil parameters are used for analysis works
  3. Laboratory test results conducted for the soil samples collected from surface or shallow depths

- Therefore, in order to improve landslide mitigation process in Sri Lanka a project was implemented with the financial and technical corporation from the Japanese International Cooperation Agency (JICA).

Study Area


A005-043
(B Rank)
A005-044
(B Rank)
A005-046
(C Rank)
A113-015
Nawalapitiya
Nawalapitiya
A007-045
(B Rank)
A005-063
(B Rank)
A005-167
Lunugala
Hotel
Badulla
A005-135
(C Rank)
2nd Mile Post
A007-031
(B Rank)
A007-054
(B Rank)
A007-057
(B Rank)
Nuwara Eliya
Sri Lanka
Keppatipola
A016-010
(C Rank)
Kahagalla
A004-173
Uvatenna
A004-154
(B Rank)
A004-174
(B Rank)
Hotel
Imbulpe
2

Objectives

- To understand the overall subsurface conditions to identify, assess and ascertain the engineering geological and geotechnical aspects of the subsurface.
- To identify slip surfaces, weak zones or any other geotechnical criteria leading for mass movement processes.
- To install instruments to monitor movements of landslide and to assess fluctuation of groundwater level before and after adaptation of mitigation measures.
- To understand the effectiveness of proper soil investigation and monitoring program towards the mitigation of slow moving landslides in Sri Lanka.

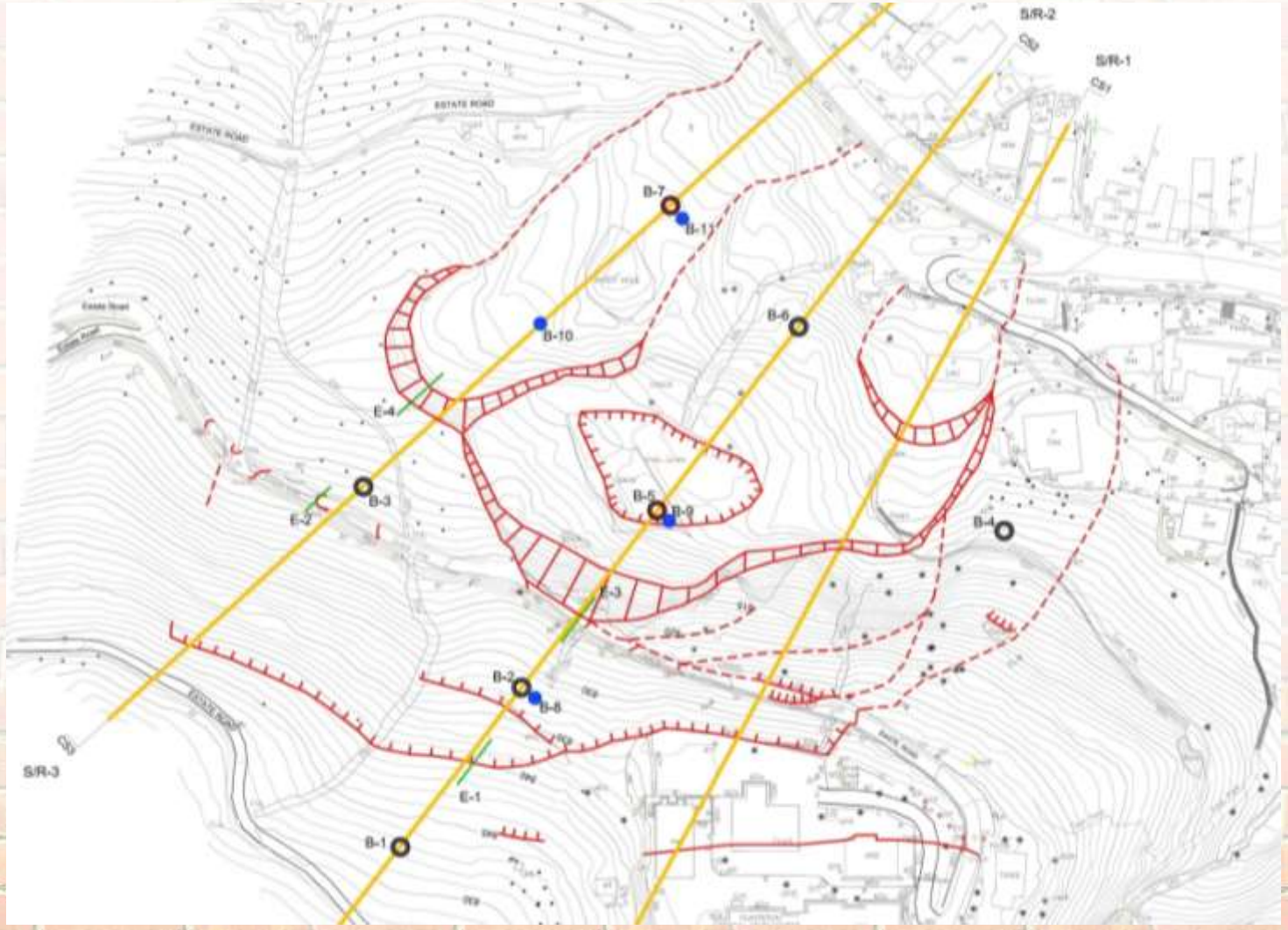
Methodology

1. Reconnaissance survey

- Extent, slope, vulnerability
- Tension cracks
- Existing surface drainage system
- Surface water bodies
- Soil type
- Land use, buildings or any other constructions
- Large trees and boulders
- And finally study the national importance of each site

Contd...

1. Demarcation of borehole locations



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2. Investigation of sub-surface condition in each landslide site, constructing adequate boreholes along the centre line of landslide.

Contd...

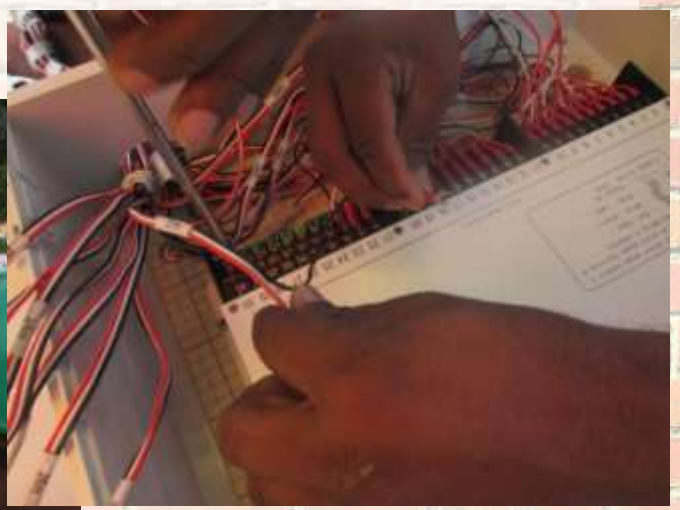
3. Collect disturbed and undisturbed soil samples from the existing ground level to termination depth of each borehole location.


SPT 15.00-15.45
ONT 16.40-16.90

Contd...

4. Installation of monitoring equipments in each borehole location.

   And Installation of extensometer at selective locations, where the maximum surface movements were recorded



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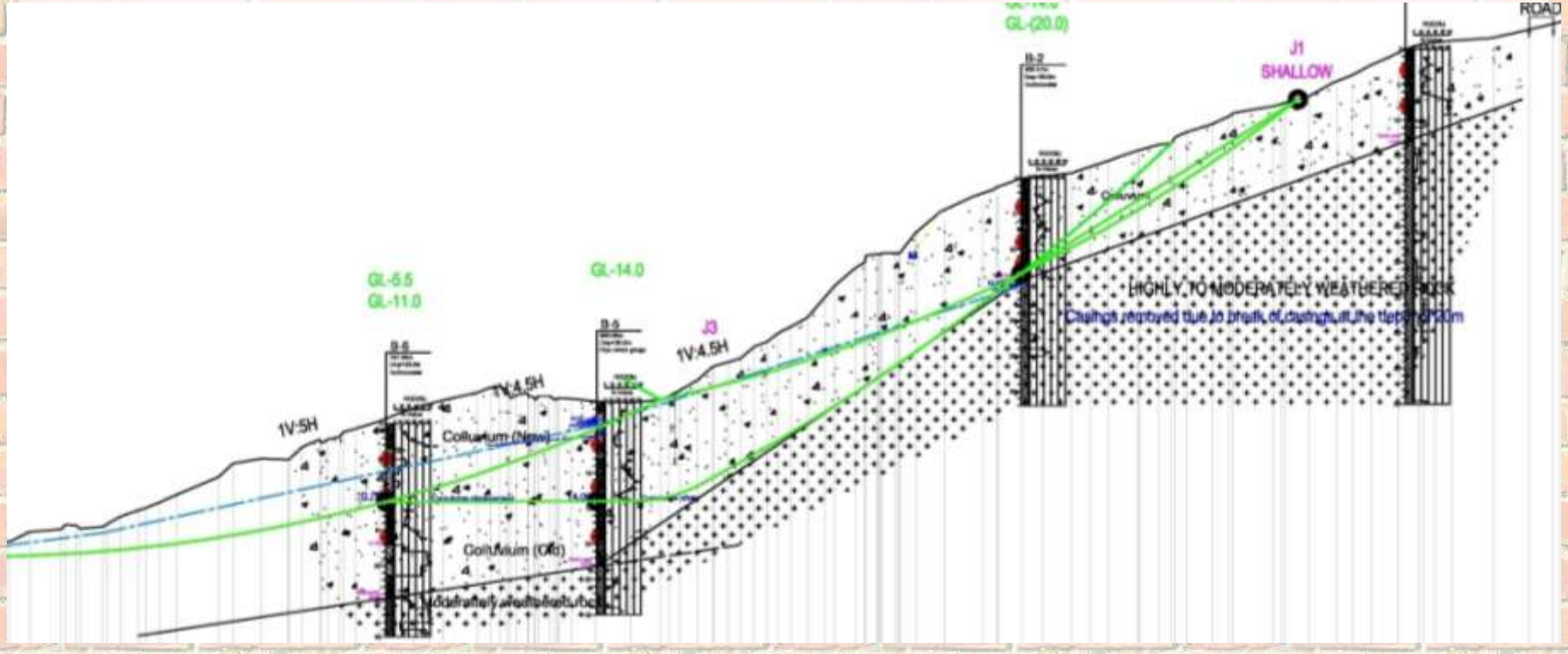
5. Preparation of sub-soil profile along the centre line of the land slide using borehole logs in each landslide sites.



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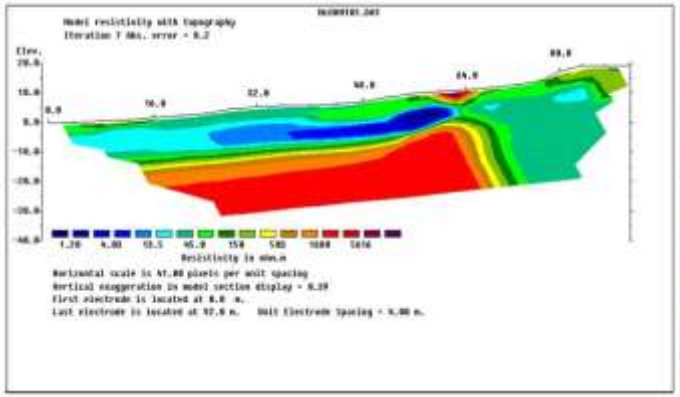
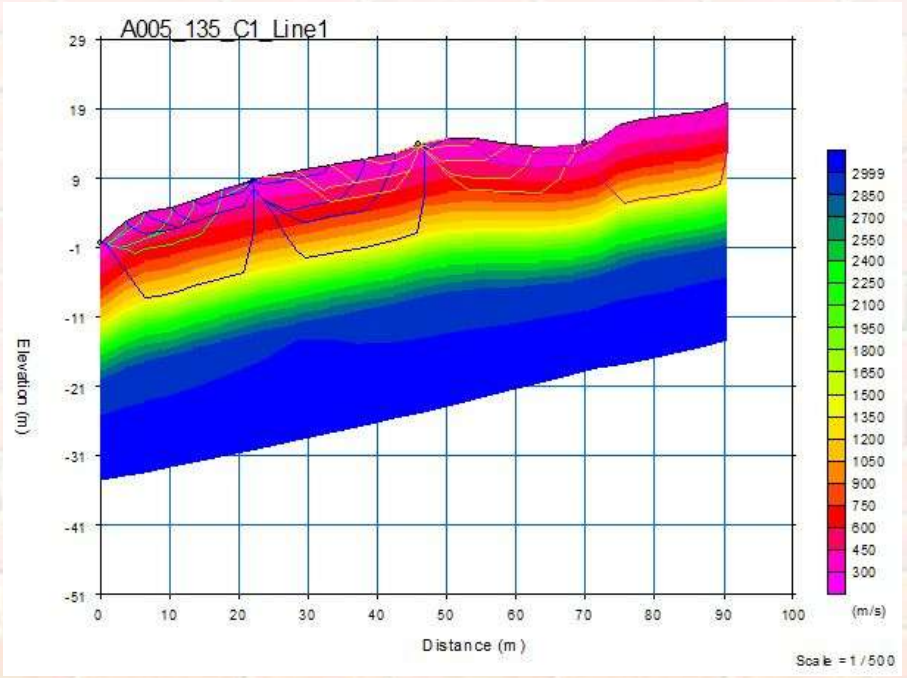
6. Conducting of Geophysical survey along the centre line of each landslide and comparative study with borehole data.



Model resistivity with topography



Travel-Time diagram of *Seismic Exploration*

Results and Discussion

Identification of most possible slip surfaces with respect to the;

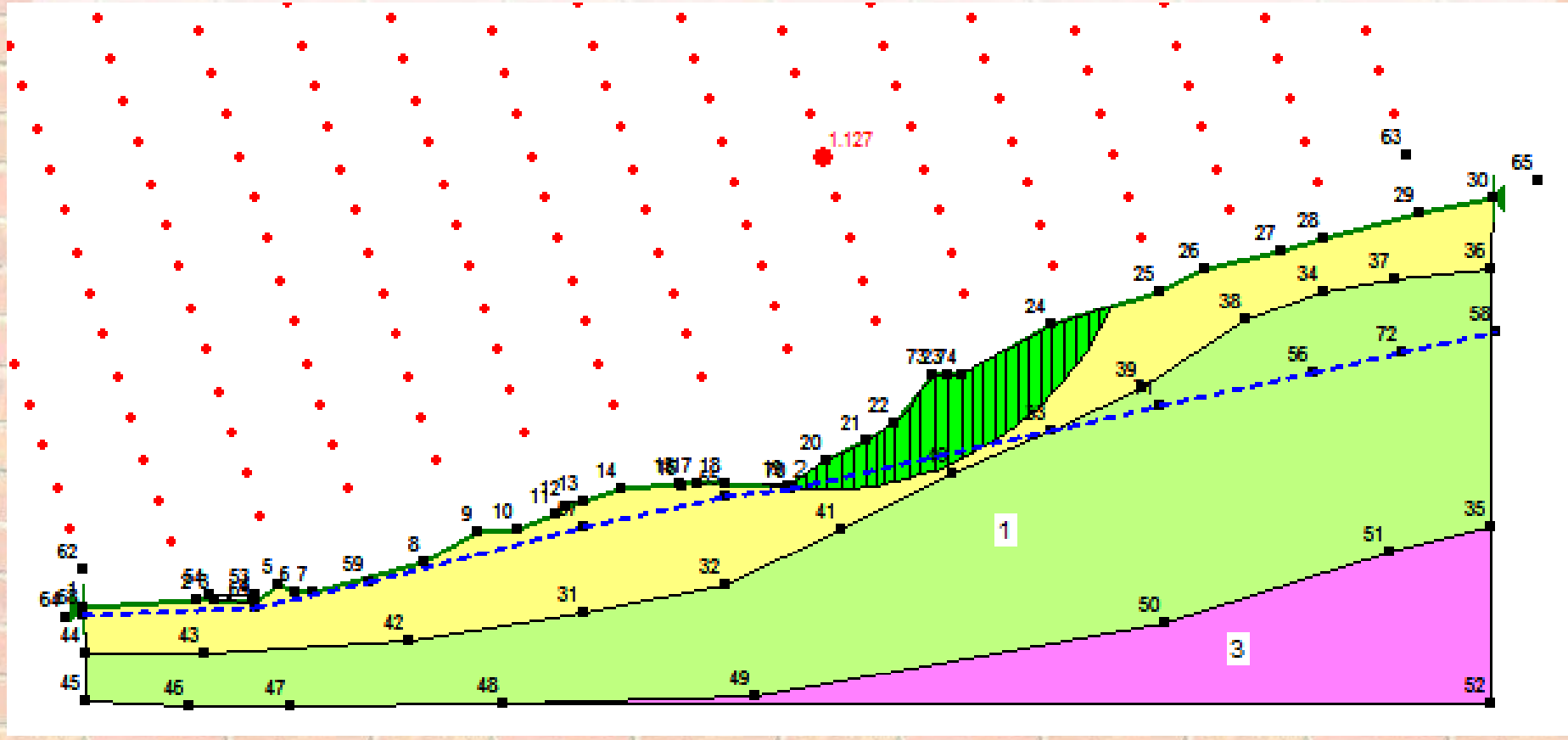
a. Tension cracks observed on ground surface
b. Soil profile and SPT test results
c. Conditions of drilling (drilling ratio, return water etc.)
d. Results of Geophysical survey conducted along the centre line of the each landslide
e. Results of monitoring data

   Extensometer, Water level meter, Inclinometer, Pipe strain gauge

Landslide at 2nd Mile Post

Stability analysis using only soil profile, typical soil parameters and surface observations.

(C=5,∅= 26) FOS=1.127



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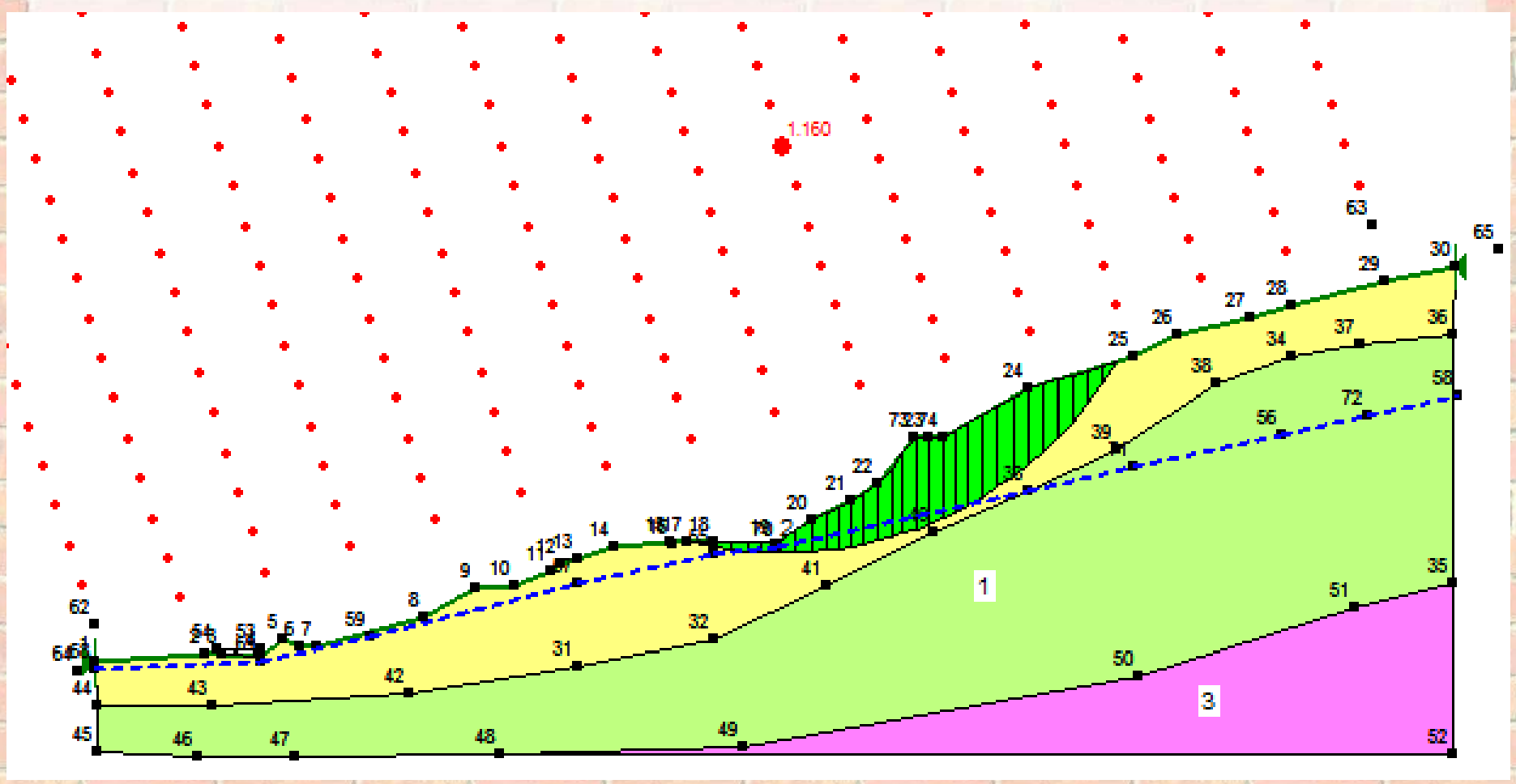
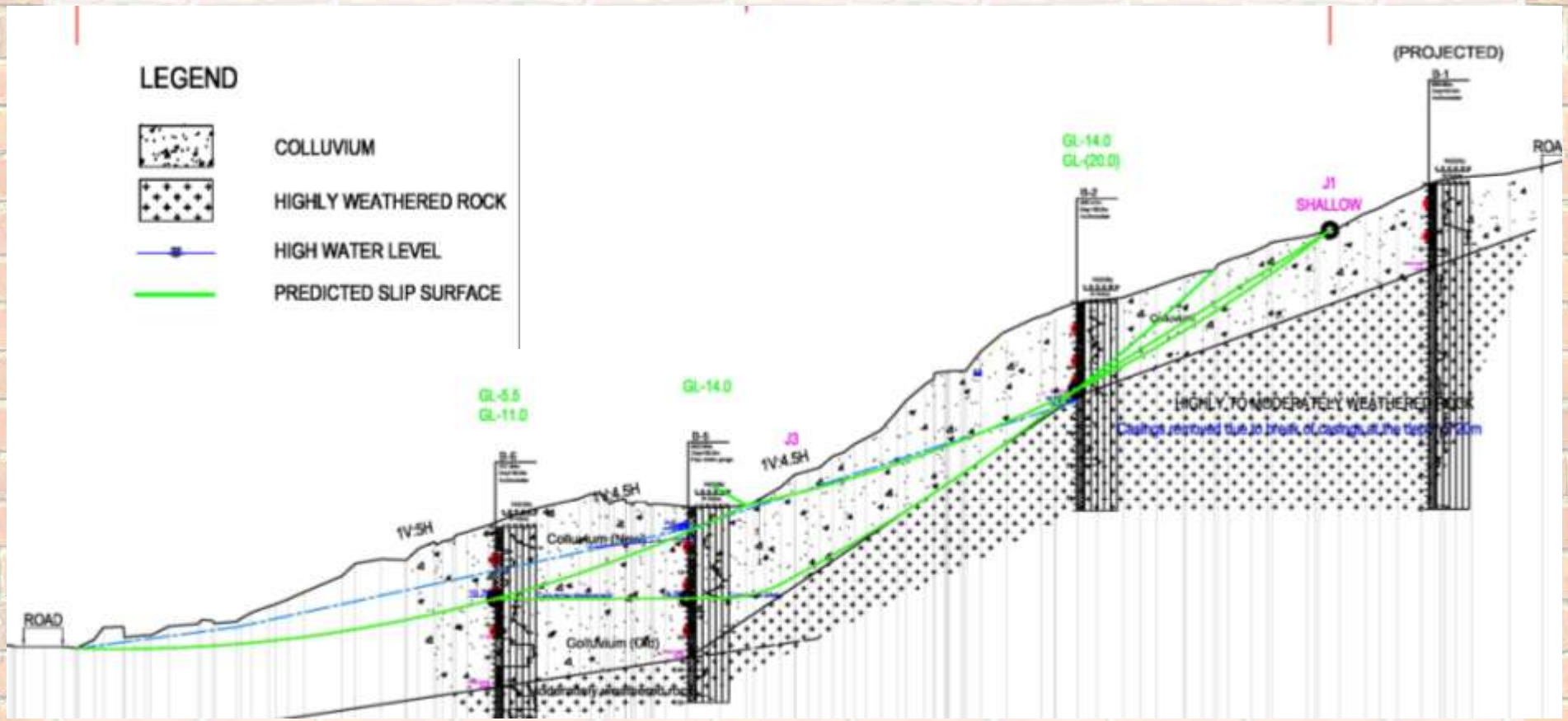
Stability analysis based on soil profile and typical soil parameters (C=5,∅= 26) FOS=1.160

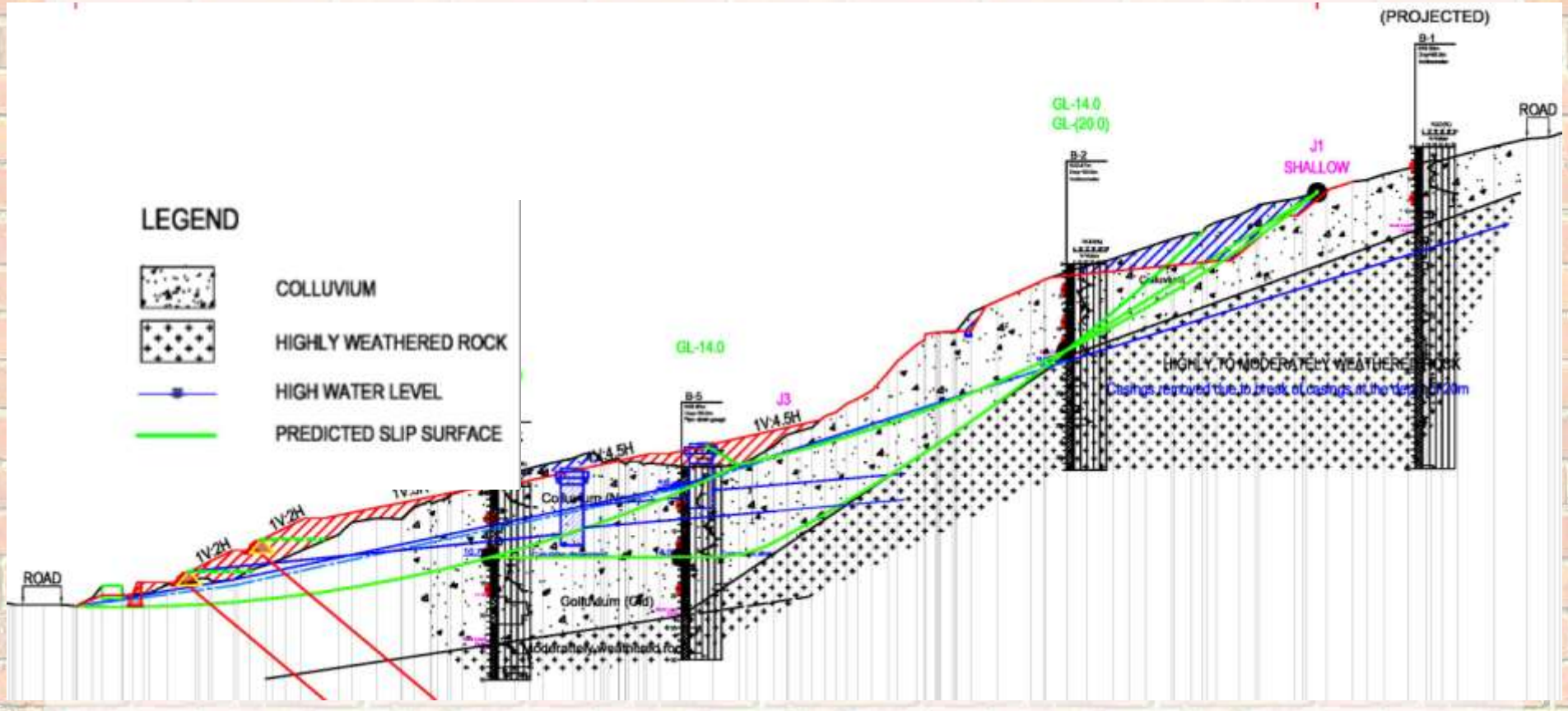


Landslide at 2nd Mile Post



Actual slip surfaces, their rate of movement, direction and influence of GWT fluctuation was identified well using most precise soil profile and monitoring data

Landslide at 2nd Mile Post



The designing of mitigation measures were done in proper and sustainable way. Therefore, it is clear that the design is not a under estimate or over estimate.

Conclusion

Traditional and experienced based mitigation methods can be used to mitigate fast moving land slides especially shallow landslides.

It was shown that the proper soil investigation program associated with well planned monitoring program will be of immense help of minimizing landslide vulnerability.

And this process will help to propose sustainable mitigation methods.

And also having sophisticated monitoring instruments at site will directly function as early warning system.

.. Thank you ..