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A case study of the Bungmati Landslide on fluvio-lacustrine sediments of the Kathmandu Valley

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ABSTRACT

The main water supply pipeline of the Lalitpur District passes through the Bungmati Landslide, which occurs on soft fluvio-lacustrine sediments of the Kathmandu Valley. The landslide study was carried out during the two rainy seasons (i.e. in 1992 and 1993). In the landslide zone, the Lukundol Formation is overlain by the Chapagaon Formation. The Lukundol Formation includes beds of peat, clayey diatomite, and fine sand, whereas the Chapagaon Formation consists mainly of gravel and sand. The detailed study of the landslide included engineering geological mapping, soil test, Rod Driving Test, and measurement of the displacement by the Vertical Wire Extensometer. The depth and total displacement of the slip surface were 6–7 m and 5–25 cm, respectively. The main cause of sliding was the compositional difference between the Lukundol Formation and Chapagaon Formation. Percolation of water through the gravel beds resulted in the formation of pore water pressure and the development of the slip surface along the contact of the Lukundol Formation.

INTRODUCTION

The Department of Mines and Geology (DMG), HMG Nepal, is carrying out landslide studies in the Kathmandu Valley, and the Bungmati area is chosen as on of the test sites (Fig. 1) for studying the nature, kinematics, and cause of failure on fluvio-lacustrine slopes.

The Bungmati Landslide is one of the critical natural hazards in the Kathmandu Valley, as the main water supply pipeline of the Lalitpur District passes through it. The pipeline was periodically damaged due to the landslide movement, especially in the rainy season. The study focuses on the causes and mechanism of failure of the landslide. For this purpose, detailed engineering geological mapping and geotechnical investigations were carried out at the landslide site.

The altitude of the landslide area ranges from 1,300 to 1,440 m. The general aspect of the failed slope is due northeast and its slope angle is 10°–17°. The landslide occupies an area of about 0.240 sq km. The length of the slide is about 480 m and the width is about 500 m. The landslide zone around the pipeline is relatively wet.

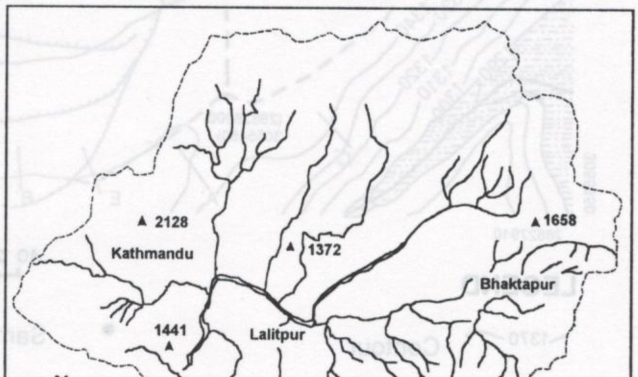

Fig. 1: Location of the study area

GEOLOGY

The Bungmati area is made up of soft fluvio-lacustrine sediments (Fig. 2). In the landslide zone, the Lukundol Formation of Pliocene age is overlain by the Chapagaon Formation of Pleistocene age (Yoshida and Igarashi 1984; Shrestha et al. 1993). The grey and dark grey Lukundol Formation is highly carbonaceous and includes beds of peat, clayey diatomite, and fine sand with plant and animal fossils. Bioturbation and oxidation/reduction zones are frequent in this formation. The clays of the Lukundol Formation are semi-consolidated and fissile. The pale yellow coloured Chapagaon Formation consists mainly of gravel and sand with a few intercalations of silt and clay. The clasts in the gravel are rounded to subrounded and the matrix is made up of silty clay.

ENGINEERING GEOLOGICAL STUDIES

A reconnaissance survey of the landslide area was carried out on 1:10,000 scale aerial photographs taken in

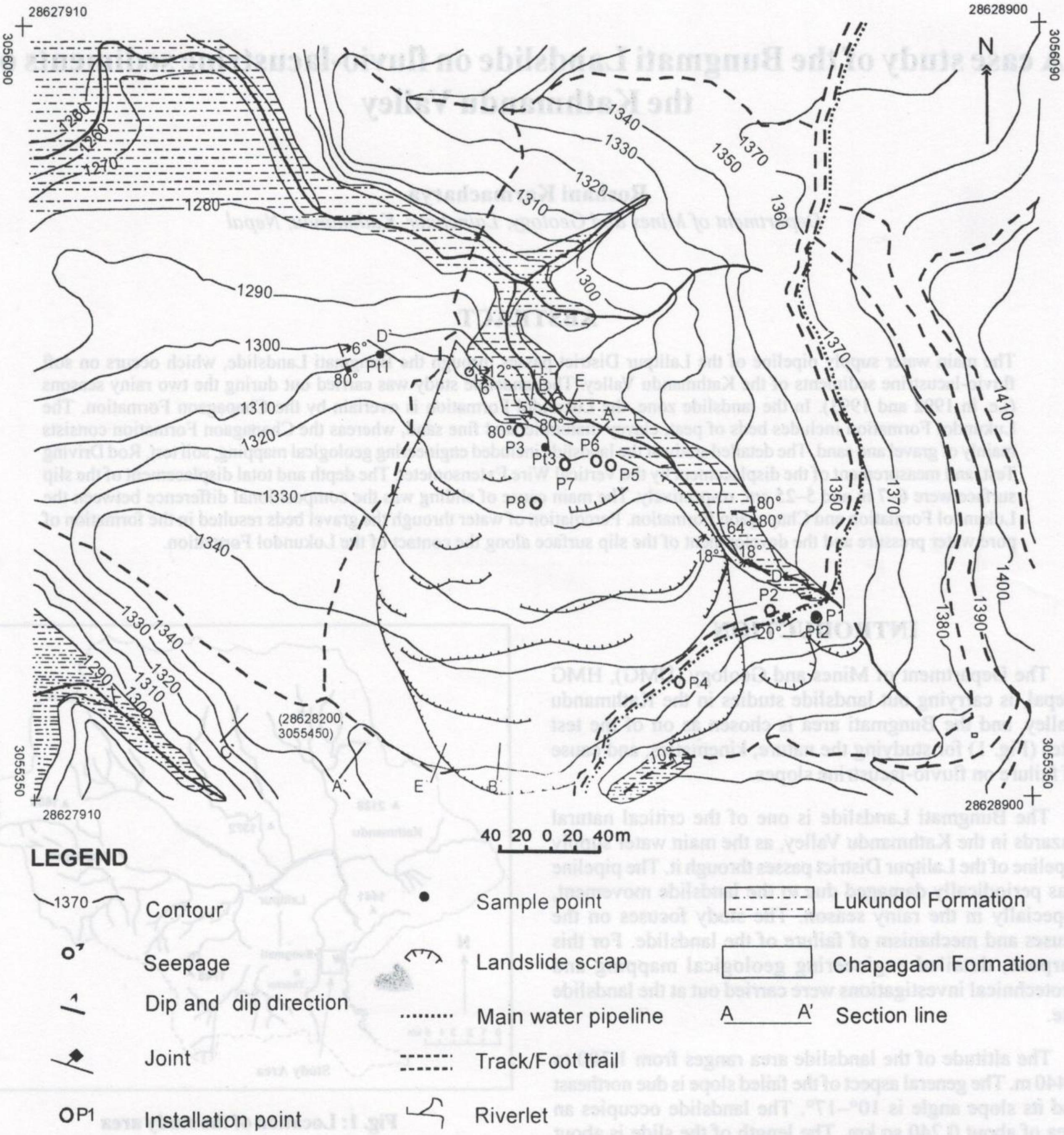

Fig. 2: Engineering geological map of the Bungmati Landslide area, Lalitpur District, Kathmandu Valley

1978. With the help of the aerial photographs, the landslide zone (which exhibited hummocky topography) was delineated, and then transferred onto the topographical map. For the purpose of carrying out detailed engineering geological studies of the landslide area, the topographical map of 1:10,000 scale was enlarged to 1:2,000 scale and used as a base map. The geological contacts, lithological differences, landslide boundary, seepage zones, gullies, streams, and other field data were plotted on the base map (Fig. 2). Many secondary landslide scarps are observed within the major landslide. There are also some small landslides in the vicinity.

The Bungmati Landslide occurs on the silty clay and shale of the Lukundol Formation, and its slip surface follows the contact with the Chapagaon Formations. The geological cross-sections of the area are shown in Fig. 3. The attitude (dip direction/angle of dip) of beds is 115°–160°/5°–8° at the

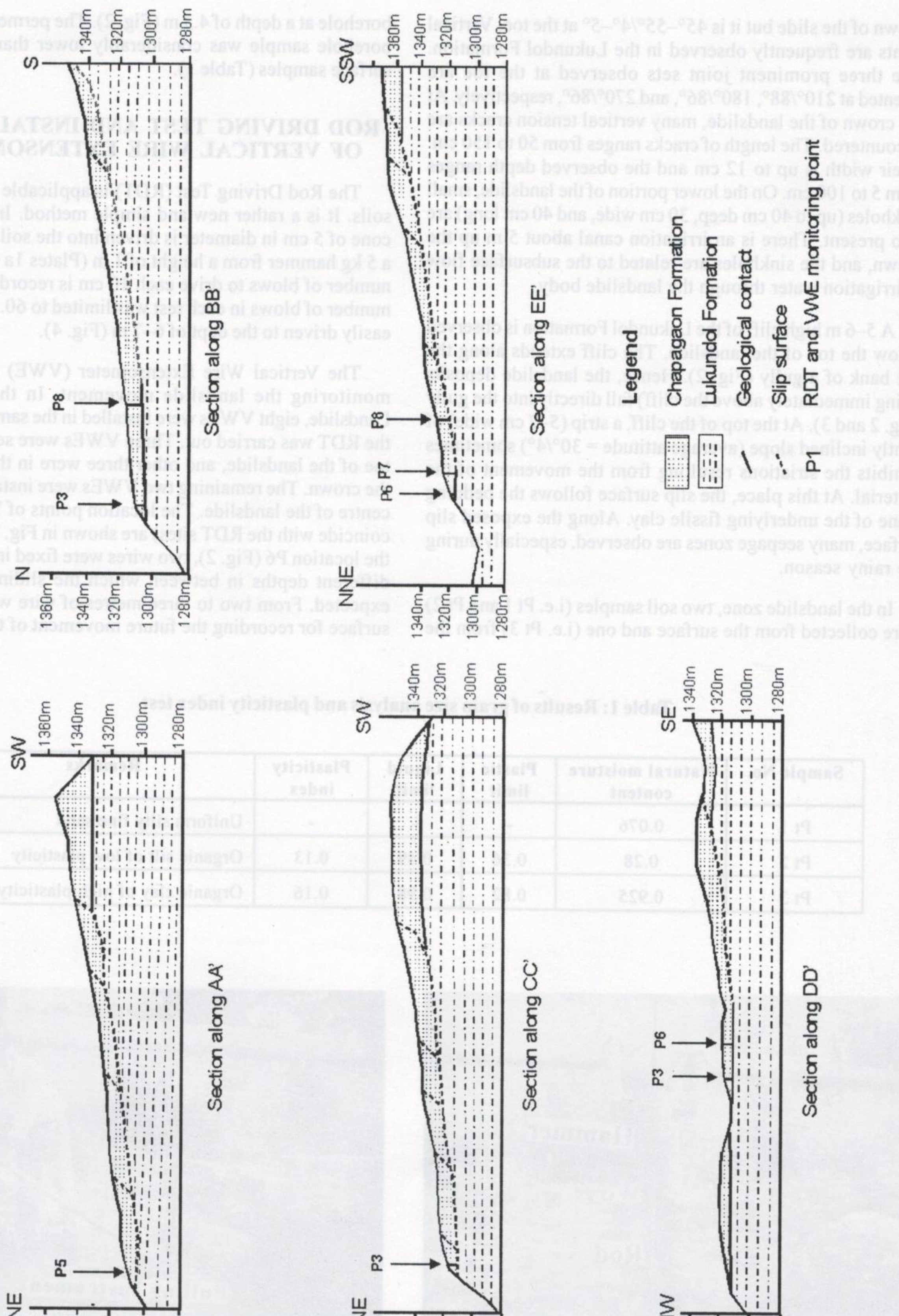

Fig. 3: Geological cross-sections along AA', BB', CC', DD', and EE' (See Fig. 2 for the location of cross-sections)

crown of the slide but it is 45°–55°/4°–5° at the toe. Vertical joints are frequently observed in the Lukundol Formation. The three prominent joint sets observed at the toe are oriented at 210°/88°, 180°/86°, and 270°/86°, respectively. At the crown of the landslide, many vertical tension cracks are encountered. The length of cracks ranges from 50 to 150 cm. Their width is up to 12 cm and the observed depth ranges from 5 to 100 cm. On the lower portion of the landslide, small sinkholes (up to 40 cm deep, 30 cm wide, and 40 cm long) are also present. There is an irrigation canal about 5 m up the crown, and the sinkholes are related to the subsurface flow of irrigation water through the landslide body.

A 5–6 m high cliff of the Lukundol Formation is observed below the toe of the landslide. The cliff extends along the left bank of a gully (Fig. 2). Hence, the landslide deposits (lying immediately above the cliff) fall directly into the gully (Fig. 2 and 3). At the top of the cliff, a strip (5–7 cm wide) of gently inclined slope (average attitude = 30°/4°) sometimes exhibits the striations resulting from the movement of the material. At this place, the slip surface follows the bedding plane of the underlying fissile clay. Along the exposed slip surface, many seepage zones are observed, especially during the rainy season.

In the landslide zone, two soil samples (i.e. Pt 1 and Pt 2) were collected from the surface and one (i.e. Pt 3) from the borehole at a depth of 4.3 m (Fig. 2). The permeability of the borehole sample was considerably lower than that of the surface samples (Table 1).

ROD DRIVING TEST AND INSTALLATION OF VERTICAL WIRE EXTENSOMETER

The Rod Driving Test (RDT) is applicable only for soft soils. It is a rather new and simple method. In the RDT, a cone of 5 cm in diameter is driven into the soil by dropping a 5 kg hammer from a height of 1 m (Plates 1a and 1b). The number of blows to drive each 10 cm is recorded. The total number of blows in each test was limited to 60. The rod was easily driven to the dept of 6–7 m (Fig. 4).

The Vertical Wire Extensometer (VWE) is useful for monitoring the landslide movement. In the Bungmati Landslide, eight VWEs were installed in the same hole where the RDT was carried out. Three VWEs were set up near the toe of the landslide, and other three were in the vicinity of the crown. The remaining two VWEs were installed near the centre of the landslide. The location points of VWE (which coincide with the RDT sites) are shown in Fig. 2. Except for the location P6 (Fig. 2), two wires were fixed in each hole at different depths in between which the sliding plane was expected. From two to three metres of wire was left at the surface for recording the future movement of the landslide.

Table 1: Results of grain size analysis and plasticity index test

Sample No.	Natural moisture content	Plastic limit	Liquid limit	Plasticity index	Remarks
Pt 1	0.076	-	-	-	Uniform silty fine sand
Pt 2	0.28	0.36	0.49	0.13	Organic silt of low plasticity
Pt 3	0.925	0.82	0.98	0.16	Organic clay of high plasticity

Plate 1a: Installation of RDT and VWE

Plate 1b: Method of extracting the rod from the ground

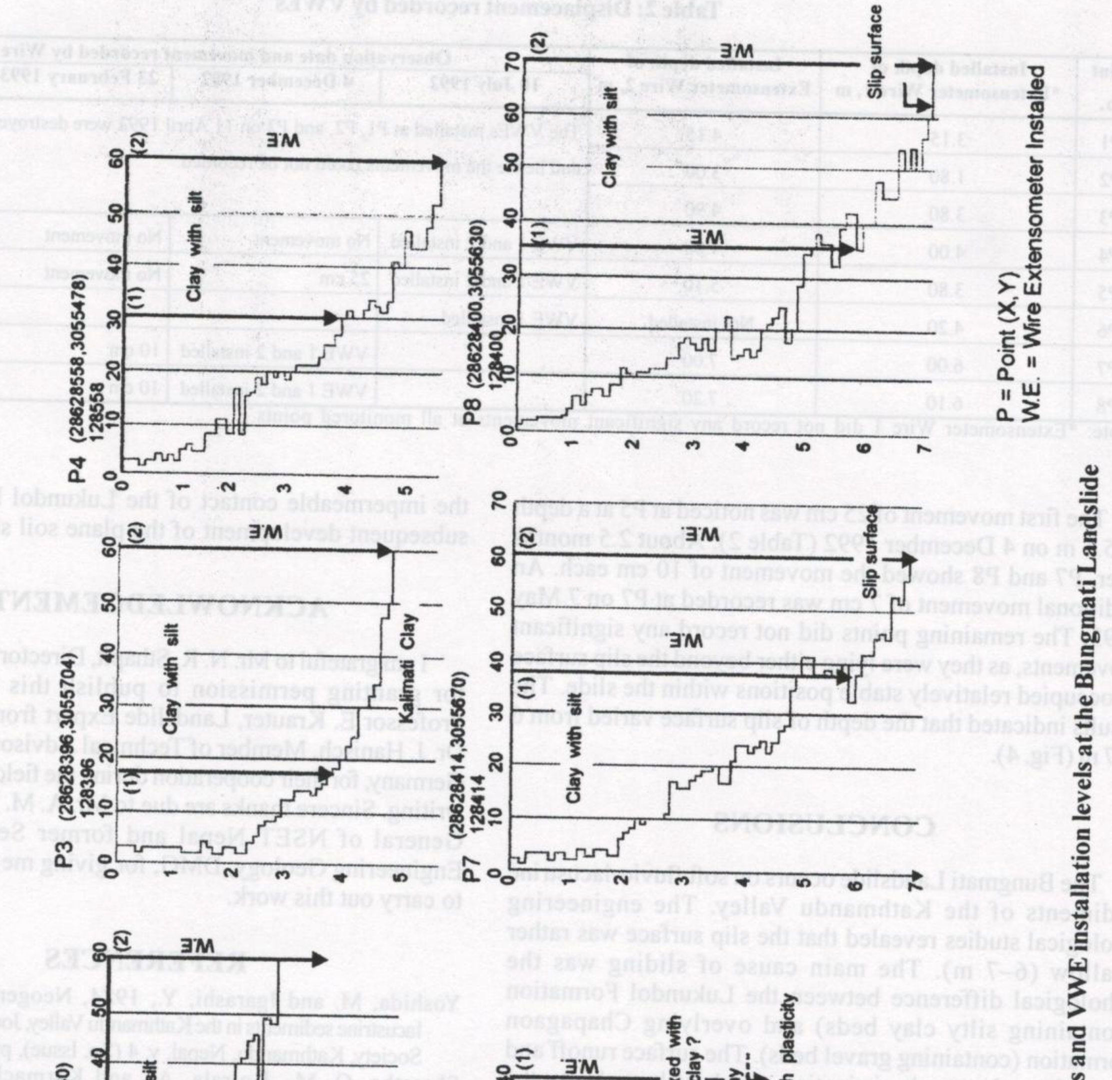

Fig. 4: RDT results and VWE installation levels at the Bungmati Landslide

Table 2: Displacement recorded by VWEs

Point No.	Installed depth of *Extensometer Wire 1, m	Installed depth of Extensometer Wire 2, m	Observation date and movement recorded by Wire 2			
			10 July 1992	4 December 1992	23 February 1993	7 May 1993
P1	3.15	4.15	The VWEs installed at P1, P2, and P3 on 11 April 1992 were destroyed by local people, and hence the movements could not be recorded.			
P2	1.80	3.00				
P3	3.80	4.90				
P4	4.00	4.80	VWE 1 and 2 installed	No movement	No movement	No movement
P5	3.80	5.10	VWE 1 and 2 installed	25 cm	No movement	No movement
P6	4.20	Not installed	VWE 1 installed	–	–	–
P7	6.00	7.00		VWE 1 and 2 installed	10 cm	7 cm
P8	6.10	7.20		VWE 1 and 2 installed	10 cm	No movement

Note: *Extensometer Wire 1 did not record any significant movements at all monitored points.

The first movement of 25 cm was noticed at P5 at a depth of 5.1 m on 4 December 1992 (Table 2). About 2.5 months later, P7 and P8 showed the movement of 10 cm each. An additional movement of 7 cm was recorded at P7 on 7 May 1993. The remaining points did not record any significant movements, as they were lying either beyond the slip surface or occupied relatively stable positions within the slide. The results indicated that the depth of slip surface varied from 6 to 7 m (Fig. 4).

CONCLUSIONS

The Bungmati Landslide occurs on soft fluvio-lacustrine sediments of the Kathmandu Valley. The engineering geological studies revealed that the slip surface was rather shallow (6–7 m). The main cause of sliding was the lithological difference between the Lukundol Formation (containing silty clay beds) and overlying Chapagaon Formation (containing gravel beds). The surface runoff and water from the nearby irrigation canal infiltrated into the permeable gravel beds. Percolation of water through the gravel resulted in the formation of pore water pressure along the impermeable contact of the Lukundol Formation, and subsequent development of the plane soil slide.

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