THE ASSESSMENT OF NINE MILE LANDSLIDE AREA THROUGH GEOPHYSICAL INVESTIGATION IN EAST DISTRICT, SIKKIM.

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Abstract

Landslide in Sikkim has been reported since 1957, and Nine mile is one of them. It is at entrance gate of Gangtok- capital of Sikkim, along NH-31A. It possess disturbance to traffic movement along NH31-A, close to instable hill slope at western bank of Rohini chhua-tributary of Tista river. The various kinds of water has played typical role in triggering of nine mile landslide, in different seasons under neo-tectonic activity.

Geophysical investigation has been conducted through temporal resistivity survey during successive pre-monsoon, monsoon & post-monsoon seasons. Twelve instrumentation sites have been selected at five different portions of landslide area for objective to decipher-causes, mode of occurrence and remedial measures. The continuous sinking of partial NH 31-A in the area posses an unique feature.

It has been observed that- the cause of sinking is an account of developing negative groundwater pore pressure due to absent of hard rock formation beneath the area. The non-structural remedial measure as cultivation of LAPSI vegetation at vulnerable sites seems to most successful cheap and eco-friendly technique for Nine mile landslide area.

Introduction

Nine mile landslide has been studied by several prestigious and reputed organisations during the past. Central Road Research Institute [CRRI] New Delhi has concluded during 1960, that main causes of landslide are rotational failure along hill slope and toe erosion beneath road alignment adjacent to river.[1] CPWD, New Delhi has put remedial measures-as construction of retaining wall during Indo-china war of 1962, along central & toe portion. Central Building Research Institute [CBRI] Roorkee has concluded during 1985,that mode of occurrence for landslide is the down dip of phyllite rock formation along foliation and weak geological plane in association with slip surface. Geological Survey of India [GSI] Kolkata has carried out systematic mapping of crown and toe portion during 2001-2002. I I T Kharagpur has conducted modelling of landslide in 2003 through DST, sponsored project.

The present study has been executed during 2005-2007 by CIMFR, Dhanbad [erstwhile Central Mining Research Institute] as part of consultancy project, sponsored by Border Road Organisation [BRO] New Delhi, Government of India.

Area of study

It is located at NINETH mile- stone [about 12 Km] in southern direction of Gangtok along NH 31A. It is almost at entrance gate to the capital of state and also known as Ranipul landslide area, as per

name of locality. It belongs to Survey of India topo-sheet no. 78A/11, at scale of 1:50,000 and corresponds to western bank of Rohini chhu-a tributary of Tisa river.

NH 31A is the only road link [no air/rail link] from Siliguri.[rest of India] for Sikkim. The other available road route for North district of Sikkim is via Singtam to Rangrang, without touching Gangtok, covering longer distance with more number of landslide areas as well as crowded with NHPC vehicles for ongoing hydroelectric projects.

The area of study has geographic coverage of 0.20 Sq. Km with elevation range- 840 m RL to 175 m RL, with NHA 31 alignment at 375 m RL. Nine mile landslide at a glance from Gangtok to Singtam [Siliguri] with frequent vehicle movement is illustrated as Fig.1.

Fig.1 Location map of area under

Methodology & Objectives

Two conventional approaches have been evolved namely: Field study and Lab study. The field study includes collection of relevant auxiliary information for selection of suitable instrumentation sites, conducting temporal resistivity survey in pre-monsoon, monsoon & post monsoon period using schlumberger electrode configuration. The lab study deals with calibration of D C resistivity meter, maintenance of necessary accessories required for field experimentation, interpretation of field data with matching standard master curves along-with subsequent analysis of data for obtaining the following objectives:-

- Estimation of upper level of saturation zone in area of study
- Estimation of lower level of saturation zone in area of study
- Deciphering the role of Rohini chhu' meander along bottom of NH 31A road alignment during monsoon period.
- Delineation of solid rock verse weathered formation for sinking zone in the surrounding area for all seasons.

- Causes of sinking with suggestion for economically effective remedial measures.

Result & Discussion

Geologically, the area of study has soft metamorphic rock of un-classified Dailing group- phyllite. The country rock has been under dominant weathering process with development of geological weak plane, fissile to foliation along steep hilly portion in the range of 20-85 degree. [4] The varied nature of foliation plane under different cycle of erosion and weathering, on-going neo-tectonic activity has developed several slip surfaces [visible to hidden] and poor soil cover has been responsible for slope failure. [5]

Geo-morphologically, the area of study belongs to Rohini chhu watershed formed during inter-glacial period. It is associated with series of terraces with variety of vegetation cover. The Rhodohendron conifer forest cover has been confined to upper hill range, possessing high sedimentation rate of 40-140 tonnes /hectare/year.[3].The river bed of Rohini chhu has been dominant with unsorted sediments including boulder.

Hydro-logically, the area under study has average annual rainfall of 1200 mm during monsoon period. The total rainfall during monsoon period of 2005 has been recorded in the area as 1485 mm, with **cloud burst on 21 July 2005 pouring 95 mm rainwater and corresponding sinking of 6 mm of NH 31A.**

The concave shaped meander of Rohini chhu has been active to western direction during monsoon and post monsoon period and prominent factor for toe erosion as well under cutting the base of NH 31A The panoramic view of it has been obtained through eastern bank along Peekyong-Tandong road and illustrated as Fig.2.

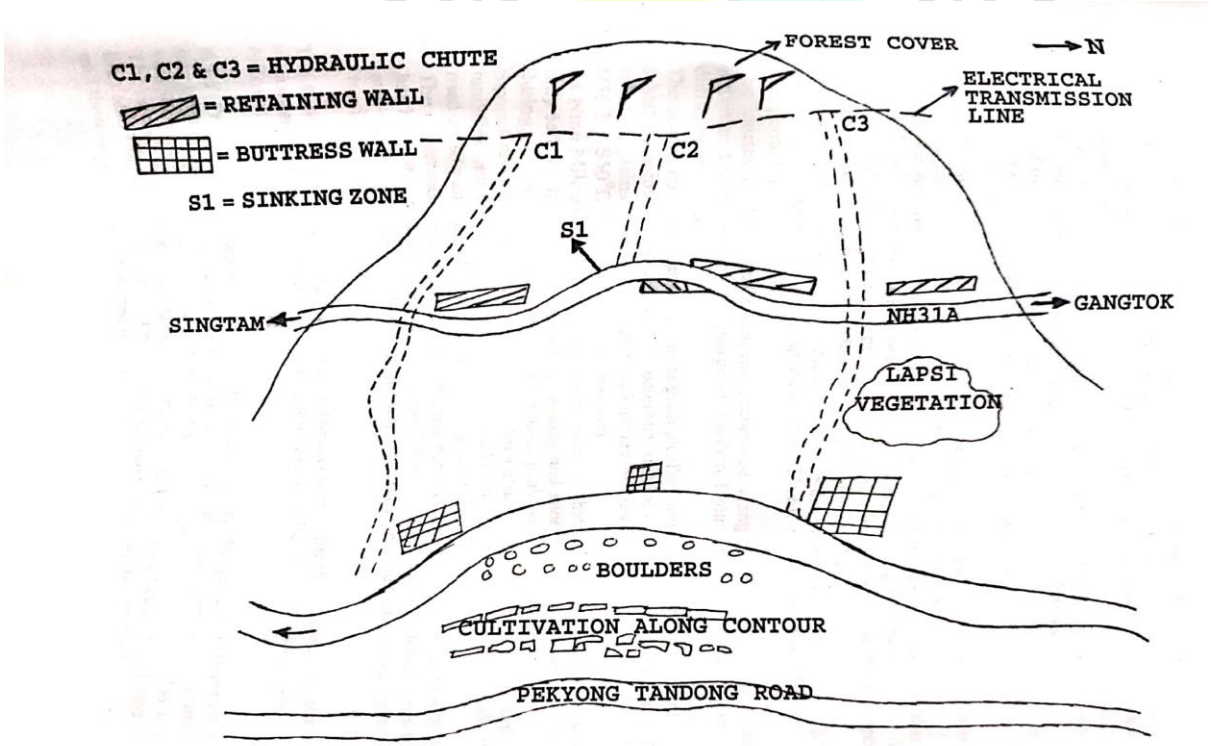

Figure 4: Panoramic view of Nine Mile area

FIG.2 Panoramic view of Nine mile landslide area

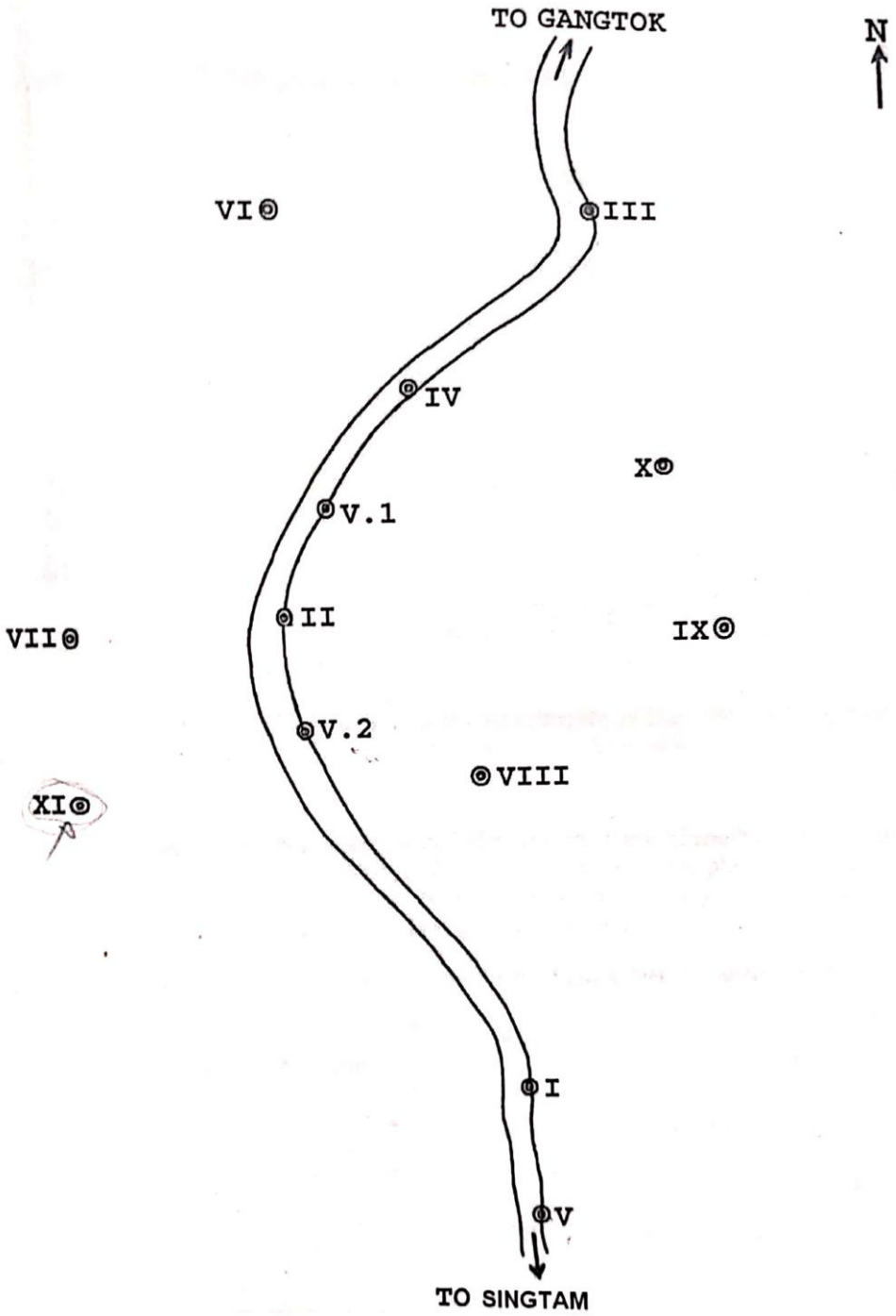

Figure 7: Instrumentation sites location at Nine Mile area

FIG.3 Location map of all twelve instrumentation sites

Geo-physically, the area of study has been investigated through temporal resistivity survey for successive pre-monsoon, monsoon & post-monsoon period. Twelve instrumental sites have been selected for entire area of study and illustrated as Fig. 3. [2]

The specific location of all instrumentation sites along different prominent zones of landslide area pertaining to pre-monsoon, monsoon & post monsoon season is summarised as Table 1.

S N	Name of major portion	Number of Instrument -ation sites	Name of Instrument -ation site	Pre-monsoon	Monsoon	Post-monsoon
1	Along NH 31A	3	I II III	Yes Yes Yes	- - -	- - Yes
2	Central	2	IV V.1	Yes -	- -	 Yes
3	Crown	2	VI VII	Yes Yes	Yes Yes	Yes Yes
4	Toe	2	IX X	Yes Yes	- -	- -
5	Sinking	3	V V.2 VIII	- - Yes	- - -	Yes Yes -

Table 1: Details of Instrumentation sites along prominent zones in different seasons

ALONG NH 31A PORTION

It is in between B78/3 [southern end] and B78/12 [northern end] along NH 31A. The resistivity survey has been conducted at three instrumentation sites namely: I, II & III. The instrumentation sites I & II have studied during pre-monsoon period, while the instrumentation site III has studied during pre-monsoon as well as post monsoon period, up to 50 m depth of investigation. The temporal resistivity experiment along this portion, has deciphered the saturation zone with it's lower and upper limit, disposition of unconfined aquifer, confined aquifer, besides the presence of river water at instrumentation site III during post monsoon period at depth range of 35-40 m. It has demonstrated the undercutting of NH31A by meandering activity not only in monsoon period, but also in post monsoon period.

The relevant inferred information for along NH 31A portion of Nine mile landslide has been summarised as Table 2.

S N	Depth range [m]	Charact -eristic app. resistivity [ohm/m]	Instrument -ation site I Pre monsoon	Instrument -ation site II Pre monsoon	Instrument -ation site III Pre	Post	Remark
1	5-6	0.6	USZ	USZ	0.9	1.1	USZ= **Upper Level of Saturation Zone**
2	20	2.1	LSZ	70-110	80-100	60-	LSZ= **Lower Level**

				[WF]	[WF] 90	**of Saturation Zone** WF= Weathered Formation
3	35-40	4.5	UA	1.2-4.5 [UA]	6 8 [RW]	UA= **Unconfined Aquifer**
4	48-50	4.8	CA	3.4[CA]	6 8 [RW]	CA= **Confined Aquifer** RW= **River Water**

Table 2: Relevant inferred information along NH 31A portion through temporal resistivity survey of Nine mile area

CENTRAL PORTION

It is in between two hydraulic chute of good and bad condition along NH 31A. It has two instrumentation sites namely IV & V.1. These sites have been investigated through temporal resistivity survey up to depth of 50 m. The instrumentation site IV has been studied during pre monsoon and post monsoon period, with **no occurrence of groundwater.** The instrumentation site V.1 has been studied during post monsoon period with the occurrence of groundwater at depth of 35m, on account of rainfall infiltration. Both instrumentation sites have been influenced by surface drainage characteristics of crown portion.

CROWN PORTION

It is in between Namli social Forest site and NH 31A along hill with moderate slope and variety of vegetation cover including cardamom cultivation. It has two instrumentation sites namely VI & VII and studied up to depth of 50 m through temporal resistivity investigation during pre-monsoon, monsoon and post-monsoon period. The hill is under unstable condition due to presence weak geological planes, several sets of foliation among weathered formation as visible facts. The hill is dominated with rain- wash creep during monsoon period. The hill is associated with neo-tectonic activity as tilting of trees.

The hill, belonging to majority of crown portion has been more prone to slope failure **due to absence of hard rock formation and presence of negative groundwater pore pressure; along-with saturated weak plane & foliation planes, beyond 40 m depth-the hidden facts, observed through geophysical instrumentation.** The inferred information through temporal resistivity survey has been summarised as Table 3.

S N	Depth range [m]	Character -stic app. resistivity [ohm/m]	Instrumentation site VI Pre M Post	Instrumentation site VII Pre M Post	Remark
1	15	10-12	- - -	GW - -	GW = Ground Water
2	20	10-15	- - -	GW WF - [80-90]	GW = Ground Water WF = Weathered Formation
3	25	8-10	- - -	- - GW -	
4	35	9-12	- GW -	- WF - [90-100]	WF = Weathered Formation

5	40	9-12	- - GW	WF" WF" WF" [110-130]	WF"= Weak & Foliation Plane
6	45	110-130	WF" WF" WF"	WF" WF" WF"	WF"= Weak & Foliation Plane
7	50	110-130	WF" WF" WF"	WF" WF" WF"	WF"= Weak & Foliation Plane

Pre = Pre-monsoon, M-M0nsoon, Post = Post-monsoon

Table 3: Inferred information through temporal resistivity investigation for crown portion

TOE PORTION

It is in between NH 31A road alignment and western bank of Rohini chhu,& below. It has steep slope [more than 80 degree], unusual up-down with several kinds of vegetation including LAPSI. It has two instrumentation sites namely: IX & X. The resistivity survey has been conducted during pre-monsoon period up to 90 m depth of investigation. The meandering of Rohini Chhu with it's activation process during monsoon and post-monsoon period has developed it's westerly shifting pattern, which seems to be responsible for toe erosion. It has been evidenced by broken Breast wall, Sausar wall at the western bank of river meandering, as field observation. The pre-monsoon resistivity survey for toe portion has revealed **the absence of groundwater below river bed. But, the presence of hard rock formation [Biotite hornblende gneiss] at depth range of 85-90m.** The other inferred relevant information have been summarised as Table 4 for toe portion.

S N	Depth range [m]	Characteristic App. resistivity [ohm/m]	Instrumentation site IX	Instrumentation site X	Remark
1	5	60-70	No Groundwater	No Groundwater	Boulder of various size with unsorted sediment
2	15-20	8-10	River water	River water	Water of Rohini chhu meandering
3	25-60	80-120	WF	WF	WF= Weathered Formation
4	65	130-150	PS	PS	PS=Phyllite Schist
5	85-90	410-450	HF	HF	**HF =Hard rock Formation**

Table 4: Inferred information through pre-monsoon resistivity survey for toe portion

SINKING PORTION

It is in between central portion and southern end of Nine mile landslide area. It has three instrumentation sites namely: V, V.2 & VIII and studied through resistivity survey up to 200 m depth of investigation. The instrumentation sites V & V.2 have been surveyed during post-monsoon period and instrumentation site VIII has been studied during pre-monsoon period. The terrain condition for

instrumentation site V.2 has been maximum sinking has recorded on 09 September 2005. The downward portion of instrumentation site VIII has LAPSI vegetation.

The causes of sinking in association with landslide has been deciphered the presence of negative groundwater pore pressure as well as the absence of hard rock formation. beneath NH 31A road, as per conducted temporal resistivity investigation. The relevant inferred information has been summarised as Table 5.

S N	Depth range [m]	Characteristic App. resistivity [ohm/m]	Instrument-ation site VIII Pre-monsoon	Instrument-ation site V Post monsoon	Instrument-ation site V.2 Post monsoon	Remark
1	20	8-10	GW	GW	GW	GW = Ground Water[Unconfined Aquifer]
2	35-40	6-8	GW	GW	GW	Confined Aquifer
3	60	9-12	CA	CA	CA	CA= Confined Aquifer
4	90-200	100-150	NHR	NHR	NHR	NHR= No Hard Rock

Table 5: Inferred information through resistivity investigation for sinking portion

Conclusion

Nine mile landslide area is one of the critical landslide prone of Sikkim State. It has been studied through temporal geophysical investigation for fulfilling the desired objectives. The major finding as summarised view, are as follows:

- Crown portion belongs to middle-top of hill having unstable slope condition for NH 31A road alignment. The reason responsible for unstable slope condition has been due to three prevailing factors, namely: Geology, Hydrology & Social. Geologically, the hill has weathered Phyllite schist, with absence of hard rock formation. The weathered formation has several sets of weak planes, foliation planes and slip planes-which have been saturated by rain water during monsoon & post-monsoon period. The hill has been under the influence of neo-tectonic activity, as additional factor for slope failure. Hydro-logically, the surface water drainage is being regulated unscientifically for social forestry and vegetable cultivation purpose by local residents.

- Toe portion belongs to bottom of hill, having NH 31A road alignment. It has been under the influence of shifting trend of river meandering-accelerating the under cutting of hill during monsoon and post-monsoon period. There has been no presence of groundwater, but hard rock formation occurs at depth range of 85-90 m.

- Sinking portion belongs to central & southern end of Nine mile landslide area along NH 31A road. It has been associated with frequent bumbling among to continuous moving vehicles. It is due to negative groundwater pore pressure with absence of hard rock formation up-to greater depth. The slow sinking process has correlation with neo-tectonic activity and high intensity of rainfall occurrence for the whole stretch.

- The cheap, eco-friendly, economically viable and successful remedial measure for checking the slope failure at vulnerable sites is the cultivation of LAPSI vegetation, which has been sustained successful by nature at the bottom side of NH 31A road alignment at southern end.

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