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**DETAILED SITE SPECIFIC STUDY OF THE KADWAD LANDSLIDE,
KARWAR TALUK, UTTAR KANNADA DISTRICT, KARNATAKA
(Progress Report for Field Season 2010-2012)
Code No.: EG/SR/KG/2010/058**



BY

**K.V.MARUTHI, SENIOR GEOLOGIST
K.V.CHANDRAN, SENIOR GEOLOGIST**

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**Project: Engineering Geology
State unit: Karnataka and Goa**

**BANGALORE
2012**

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ABSTRACT

On October 2, 2009, the most destructive and disastrous landslide took place in Kadwad village, Karwar Taluk, Uttar Kannada district, killing 19 persons and destroying nine houses. A preliminary post-disaster study was carried out by GSI in October 2009 and subsequently, a detailed site-specific study was taken up as a service item during the FS 2010-12 to assess slide characteristics, causative factors of landslide and to suggest remedial measures.

The landslide site at Kadwad (14° 50' 35.6"N latitude and 74° 10' 36.4"E longitude in Toposheet No 48J/1) is situated nearly 6 km northwest of Karwar. The litho-unit exposed at the site is mainly laterite (as capping) over granite. The laterite is vesicular in nature with tubular cavities. The granite is mostly weathered. The ferruginous/lateritised soil and lithomarge clay are the other litho-constituents. An area of about 0.10 km² on 1:1000 scale was mapped in detail and a site plan was prepared. Three cross sections and one longitudinal section were drawn. The slide material in the zone of accumulation and depletion are largely lateritic fragments, lateritic soil and weathered granitic material. Accordingly, the dislodged masses vary in size from boulders to clay size. Three UDS (Undisturbed Soil Sample) and six disturbed samples were collected and analyzed for various geotechnical parameters. The analytical results reveal that all the three undisturbed samples fall in MH category of Unified Soil Classification System, reflecting silty nature of sediment with high plasticity.

The main causes for the Kadwad landslide appear to be improper slope modification due to anthropogenic activity at crown as well the toe parts, presence of clayey soil layer between Laterite and saprolite layers. Increase in pore water pressure owing to a heavy rain fall appears to be a triggering factor. As per the geotechnical evaluation of the site the suggested remedial measures includes slope gradation of crown part, improving drainage network with proper drainage system and planting appropriate vegetation on the slope. Preparation of a Landslide Hazard Zonation of Karwar area by GSI in future is also suggested.

जिले के कारवार तहसील में कड़वाड भूस्खलन स्थान विशेष विस्तृत अध्ययन

(प्रगति प्रतिवेदन कार्य वर्ष 2010-12)
(क्रमांक इजी/एस.आर/के.जी/2010/058)

द्वारा

के. वी. मारुति, वरिष्ठ भूवैज्ञानिक
के. वी. चन्द्रन, वरिष्ठ भूवैज्ञानिक

सारांश

उत्तर कन्नडा जिले की कारवार तहसील में 02 अक्टूबर 2009 के दिन अत्यधिक हानीकारक भूस्खलन आपदा आई, जिस में 19 व्यक्तियों की मृत्यु व 09 घर तहस-नहस हुए। इस भूस्खलन क्षेत्र में भारतीय भूवैज्ञानिक सर्वेक्षण द्वारा भूस्खलन पश्चात प्रारंभिक अध्ययन किया गया/इस क्षेत्र का स्थान विशेष पर विस्तृत अध्ययन कार्य वर्ष 2010-12 में किया गया ताकि भूस्खलन भी विशेषता, कारण और क्षेत्र विशेष के लिए उपचारी उपाय बताए जा सकें।

कड़वाड भूस्खलन $14^{\circ} 50'35.6''$ अक्षांश व $74^{\circ}10'36.4''$ देशांश पर स्थलाकृति मानचित्र 48J/1 में कारवार में 6 कि. मि. उत्तर पश्चिम में स्थित हैं। इस क्षेत्र के मुख्यतः मखरला (लेटेराइट) आच्छादित है। यह लेटेराइट कूप सटित (वेसीकुलर) व लम्बी गुटाओं के साथ उपस्थित है। क्षेत्र में उपस्थित ग्रेनाइट अपरवित हैं। लोहयुक्त/मखरला युक्त मिट्टी व मुरम भी इस क्षेत्र के पायी जाती है। इस क्षेत्र में करीब 0.1 वर्ग कि. मी. का क्षेत्र का मानचित्र 1:1000 पैमाने पर किया गया/इस क्षेत्र में 3 अनुभाग व 01 अनुदैर्घ्य काट का अध्ययन किया गया। भूस्खलन क्षेत्र से मलवे के अलग होने व एकत्र होने के स्थान में अधिकतर लेटेराइट के खंड, अपरदित ग्रेनाइट व मृदा पाई गई है। भूस्खलन क्षेत्र से अलग होने वाली सामग्री का आकार बोल्टर में क्ले के मध्य है। क्षेत्र की भूअभियांत्रिकी मापदंडों के अध्ययन हेतु 3 अपरवर्तित व 06 परिवर्तित नमूने लिए गए। अपरवर्तित नमूने एकीकृत मृदा वर्गीकरण में एम एच श्रेणी में आते हैं। अतः यह नमूने अत्यधिक नमनीयता के साथ - साथ अधिक गाद वाले पाए गए हैं।

कड़वाड भूस्खलन का मुख्य कारण मानवीय गतिविधियों द्वारा शीर्ष व पाद क्षेत्र में ढाल परिवर्तन एवं लेटेराइट व संप्रोलाइट तलों के मध्य मृदा की उपरीस्थित अत्यधिक वर्षा के समय सरंध्रो में पानी की उपरिस्थित ने उत्प्रेरक का कार्य किया है। इस क्षेत्र के भूअभियांत्रिकी अध्ययन के असधार पर भूस्खलन के शीर्ष में ढलान का समतलीकरण, प्रभावी जलनिकासी व वृक्षारोपण द्वारा क्षेत्र में भूस्खलन को कम करने की आवश्यक उपाय हो सकते हैं। कारवार क्षेत्र में भूस्खलन आपदा वर्गीकरण का कार्य किया जाना चाहिए।

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I. INTRODUCTION

Landslides, around the world, take a heavy toll on life and property every year. Landslide is one of the main natural hazards disrupting communication modes in the affected terrain such as Western Ghats every year during monsoon period. With increase in population, the anthropogenic activity also increases in Western Ghats resulting in slope cutting in an unscientific way for plantation purposes as well as for settlements and making roads. The landslides during every monsoon in Western Ghats are a common phenomenon and are of great concern for general public as well as local administration.

On 2nd October 2009, the coastal region of Karwar Taluk in Uttar Kannada district witnessed a series of landslides, following heavy rain. A destructive and disastrous landslide took place in Kadwad village, 6 km northwest of Karwar town, at 1615hrs, killing 19 people and destroying nine houses, coconut plantation and livestock. Many people were reported buried alive and their houses destroyed. There was also a series of landslides all along the hills obstructing the traffic flow on NH-17 at several locations. The preliminary post-disaster study was carried out by the Geological Survey of India and a detailed site-specific study was proposed to assess the slide characteristics and to propose long term remedial measures (Mishra, 2009). Accordingly, a detailed site specific study was taken up as a service item during the FS 2010-12 (Code No.: EG/SR/KG/2010/058) to understand of the slide characteristics, causative factors of landslide & suggest remedial measures.

I.1.LOCATION: The Kadwad landslide site (latitude 14° 50' 35.6" N and longitude 74° 10' 36.4"E) is located in the Survey of India Toposheet no 48J/1 about 6 km NW of Karwar Town. (Plate-1).

I.2.PREVIOUS WORK: Preliminary post-disaster investigation of the Kadwad landslide carried out during 2009 (Mishra, 2009) reveals a deep seated (depth of failure > 20m) nature of rotational debris slides. The slide is classified as a "Large slide" (>20,000 sq.m area) and as per the rate of movement, the slide was also classified as a "very fast slide". Grading of the slope and crown with benches, & planting vegetation on the slope were suggested to stabilize the slope. Detailed site specific study for suggesting long term remedial measures was also recommended.

The objective of the present study is to evaluate the slide risks if any, mechanism of failure, triggering mechanism, stability of the slope, risk associated with the slide and to propose suitable long term remedial and/ or precautionary measures to stabilize the slope.

I.4. NATURE AND QUANTUM OF WORK

NATURE OF WORK	Work proposed for FS. 2010-12	Total work Completed in Current FS. 2010-12
Detailed study of the landslide and slope stability analysis for identifying the Causative factors and suggesting remedial measures. Detailed mapping of 0.1 sq.km of slide area	0.10 sq.km	0.10 sq.km.
Geological section a) Longitudinal section on 1:1000 b) Cross section on 1:1000	3 Profiles 3 Profiles	1 Profiles 3 Profiles
SMPL a) Undisturbed b) Disturbed	As necessary	3 samples collected 6 Samples collected

I.5. ACKNOWLEDGEMENTS: The authors extend their sincere thanks to Shri. R. Panduranga, the then Director EG Division, SU: Karnataka & Goa, GSI, Bangalore for his guidance during investigation, and to Dr.B.R.Venkatesh, Director, EG Division, SU: Karnataka & Goa, GSI, Bangalore for scrutiny of the report. They also extend their thanks to the Director in-Charge, SU: Karnataka. & Goa, GSI, Bangalore for his encouragements and support. Thanks are due to the Deputy Commissioner, Uttar Kannada district, the Village Accountant and Asst. Village Accountant, Kadwad village and other district administrative staffs for providing necessary help during the field work. Thanks are also due to the residents of Kadwad village for rendering co-operation during investigation.

II. PHYSIOGRAPHY AND CLIMATE

II.1. TOPOGRAPHY AND GEOMORPHOLOGY: Kadwad village is situated towards east of Karwar town and south of the Kali River estuary and a large inlet of the estuary could be seen separating the town and Sunkeri village towards its north-east from Kadwad. The landslide occurred in the northeast slope of a NW-SE trending mound. The maximum height of the mound is 65m above msl with a slope angle of ~30°. The foot hill is habituated all around. The spur of the mound runs into the marshy land near the bank of Kali River on its three sides. As from the toposheet the original hill profile shows small streams draining into Kali River from northeast and southwest direction. Geomorphologically, the valley area is considered a paleochannel that formerly drained into the Kali River that flows in the north of Kadwad. The Konkan Railway track (Photo 3) passes through this Kadwad paleochannel, connecting Karwar town with Goa and many other places. The railway track is also situated very close to the study area (Photo 1, 2, 3 & 4). The drainage in the area shows a sub-dendritic to trellis pattern (Plate-1 & 2).

ER: The area in and around Kadwad is characterized by the in farms, rice fields, marshes and small inlets of the estuary towards north, north-east and west of Kadwad landslide site. The hills are covered with dense scrubby vegetation - mainly cashew, thorny bushes, herbs, grasses and climbers. The zone between lowlands and the hills is densely populated. The houses are generally abutting the lower slopes of hills and bordering the normal flood line of river. The slope has been modified for the purpose of settlements and also for plantation (Photo 6) since a long time. As per the information gathered from local residents and observed from the study, the slope is modified to accommodate three levels of benching with construction of houses and plantation of coconut trees. The slope is moderately vegetated with shrubs and cashew plants, both having low root and shoot ratio.

II.3. CLIMATE AND RAINFALL: The area lies in the coastal tract bound on eastern side by the Western Ghats. The area enjoys tropical climate with hot and humid summers between March and May and a moderate cold winters from November to February. Between June and October, the area has heavy monsoonal rainfall. The annual rainfall is in excess of 3000 mm. Most of the rainfall is received during the peak monsoon period of June to September (Table-1, Fig-1 and Annexure-1)

Table-1: Rainfall data of Karwar rain gauge station over last decade

Year wise Monthly rain fall (in mm) at Karwar rain gauge station													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	0.0	0.0	0.0	0.6	471.5	991.8	1216.6	566.0	217.8	132.7	0.0	5.4	3602.4
2001	10.4	0.0	0.0	39.7	281.7	744.7	838.9	434.4	138.3	147.5	0.0	0.0	2635.6
2002	0.0	0.0	0.0	8.3	183.4	1030.3	394.0	581.0	149.2	432.4	0.0	0.0	2778.6
2003	0.0	0.0	0.6	0.0	0.2	1268.1	1174.8	555.6	272.4	66.8	0.0	0.0	3338.5
2004	0.0	0.0	0.0	0.0	271.0	732.4	678.4	664.8	273.6	123.7	69.8	0.0	2813.7
2005	0.0	0.0	0.0	91.6	56.1	956.3	1146.2	351.8	374.3	157.6	0.0	0.2	3134.1
2006	0.0	0.0	4.3	0.0	569.3	973.5	637.9	670.6	543.7	293.0	38.2	0.0	3730.5
2007	0.0	0.0	0.0	2.0	111.4	1336.9	730.6	914.4	653.3	66.9	4.1	4.4	3824.0
2008	0.0	3.3	86.3	2.7	62.7	943.3	556.2	666.8	469.8	13.4	1.5	26.1	2832.1
2009	0.0	0.0	15.0	0.0	86.6	780.9	1318.1	441.2	518.9	688.4	157.5	3.9	4010.5
2010	1.3	0.0	0.0	11.0	123.5	920.3	1381.8	617.0	575.2	306.4	403.4	3.2	4343.1
Total	11.7	3.3	106.2	155.9	2217.4	10678.5	10073.5	6463.6	4186.5	2428.8	674.5	43.2	37043.1

Data Source: Dy. Commissioner's office, Uttar Kannada Dist., Karwar

Karwar over the years

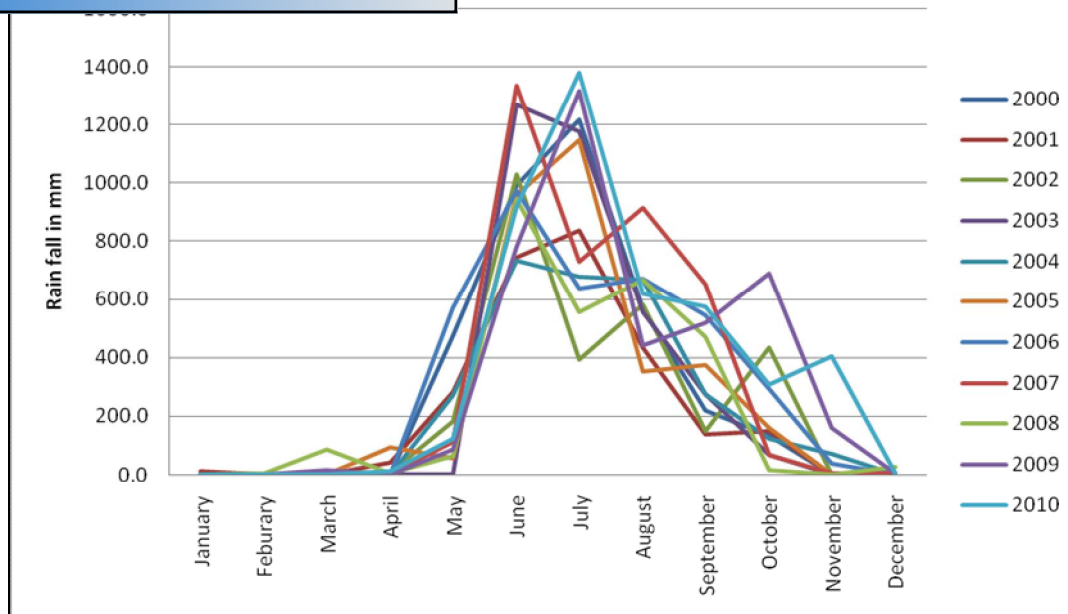


Fig 1: Rainfall data of Karwar rain gauge station over the years

II.4. GROUND WATER: The seasonal fluctuation of the Water Table is not high in the area. The Water table is shallow in the Kadwad village and even during summer months, the level in dug wells is within a few meters. The groundwater regime is in general influenced by the Kali river estuary. The Ground water level, observed in the dug wells (Photo 17) distributed at the toe part of the slide is given below (Table-2, Plate-3). During the time of investigation i.e., December 2010 Depth to water table (DTW) in the wells was at 1.5 to 2.5 m indicating shallow depth of water table (Photo 18).

Table-2: Depth to water table in the dug wells at the time of investigation

Well number	Location	Depth to water table(DTW) at the time of investigation
W-1	20 m east of survey station 5	1.53 m
W-2	20 m west of survey station 5	1.50 m
W-3	23 m west of survey station 7	2.45 m
W-4	10 m east of survey station 7	2.50 m
W-5	16 m west of survey station 6	1.87 m
W-6	16 m west of survey station 6 on the other side of the road	1.89 m

III.GEOLOGY

III.1.REGIONAL GEOLOGY: Regionally, the area comprises rocks of Sargur Group, Peninsular Gneissic Complex (PGC), older granitoids and rocks belonging to the Chitradurga Group under the Dharwar Supergroup of Archaean age as well as dolerites of Palaeoproterozoic age intruding these rocks. The older metamorphics of Sargur Group of rock are represented by amphibolite occurring as enclaves within granite. The rocks belonging to the PGC are represented by granitic gneiss and granodiorite. The granite gneiss at places is migmatitic in nature. The Dharwar Supergroup of rocks and PGC-I are intruded by older granitoids locally referred as 'Karwar Granite'. The granite is massive, generally coarse grained, porphyritic in shades of grey and pink consisting of quartz, K-feldspars, plagioclase and biotite. The Goa belt represented by Chitradurga Group is exposed in the area as 'Barcem Formation' consisting of metabasalt (schistose), BMQ and acid volcanics. The area is also intruded by numerous swarms of dolerite dykes (Ramakrishna, 1967; Shafeeq Ahmed, 1990; Subramanian, 1968; Subramanian, 1969).

III.2. LITHOLOGY AT SITE: The litho units exposed at the site includes vesicular laterite as cappings over granite. Lateritic soil/clay, lithomarge clay and saprolite (weathered granite) are also present. The details are given below.

III.2.1. Vesicular Laterite: The top part of the Kadwad slide area is characterized by the presence of hard ferruginous, vesicular laterite, which also occurs as cap/sheet rock at the top with thickness varying from 2 to 10 m. The Laterite is hard with brownish to reddish brown colour having a vesicular texture. The freshly slid slope debris is reddish brown and appears highly ferruginous. Laterite is exposed all along the scarp and beyond the Crown part as sporadic boulders (Photo 12).

III.2.2. Lateritic soil/clay: Lateritic soil occurs all along the top portion between laterite exposures and in slide scar, lateritic clay is seen just below the laterite cap. The lateritic clay is brownish to reddish brown in colour.

III.2.3. Lithomarge clay: A small lensoid body of lithomarge clay layer occurs near the head scarp at the left flank (Photo 5, 11). The lithomarge is buff white to grey, soft and is seen to have fine, smooth texture.

III.2.4. Saprolite (Weathered granite): Saprolite or weathered granite is exposed below the lateritic clay in the scarp and found extensively in the debris material (Photo 14). Saprolite is yellowish to grey in colour (Photo 16).

III.2.5. Granite: Two minor granite exposures are exposed in the right flank of the slide scar. The granite is grey, massive exposing three sets of joints (Photo 13). Petrographically, the granite is coarse grained, consisting of quartz, K-feldspars, plagioclase and biotite. The characteristics of the joints are given in Table-3.

Granite

Joint set	Attitude	Spacing	Opening / Filling	Characteristics
J1	N20°W/ 84°NE	10-30 cm	Tight	smooth, uneven, seepage of water seen
J2	N80°W/Vertical	10-30 cm	Tight	Smooth, uneven seepage of water seen
J3 (Foliation plane)	N10°E/71°NW	10-20 cm	Tight	-

III.3. WEATHERING: The nature and degree weathering of litho units on the slope and nature and extent of weathering determines

- The amount of pore space available and the permeability of the material present in the slope
- Clay content of the material in the slope and
- Material retention on the slope.

The depth of the weathering was estimated up to depth of 20-30 m. and the role of weathering at the site appears to have played an important role in the formation of lithomarge and lateritic clay. The laterite profile at Kadwad area is top surface has a thin mantle of highly weathered laterite and lateritic soil which is brownish red in colour denoting a non-hydrated iron oxide (FeO₃) in the soil. In middle and lower slopes, hydrated iron oxides mainly limonite with reddish brown to brown yellow clay are seen. Lower-slope is typically brown yellow in colour, as are the better drained soils developed here.

IV. LANDSLIDE CHARACTERISTICS

IV.1. MEDIA REPORTS OF SLIDE EVENT: The Kadwad landslide was widely covered in the media and some excerpts from the media reports are as follows.

Deccan Chronicle (Oct. 5, 2009):

“The most disastrous and ferocious of all the landslides that ever happened in the history of Karnataka in which 19 people lost their lives happened on 02.10.2009. The hill ruptured at about 40 m height and the soil, mud and water rushed towards the habitation below at around 4.30 pm on October 2. Horrified on hearing the rumble and seeing the mudslide rushing towards them along with uprooted trees and palms most residents ran for safety along the flooded road. However, unfortunately, eight houses were totally destroyed, with 19 of their inmates buried alive. Eight members of Talekar family lost their lives. The rescue operation is shown in Photo 7, and 8.

Santosh Uma Vaingankar (51) and many others are reported to have made allegation and blamed the Konkan Railway for the Kadwad tragedy as the latter had “unscientifically” dug the hill for laying the Konkan Railway track through the adjoining lowlands, thereby disturbing the natural gradient of the hill. Mr. Vaingankar, who lost everything in the calamity, says that a small landslide occurred on the same hill over ten years ago, just a few days after the Railways excavated a portion of this hill.” However, other residents, like Satir Belurkar alleged that the “the real culprits of the October 2 tragedy are the several unauthorized miners operating in the area.” Ullas Govekar, another resident conferred to *The Hindu* that the blasting conducted in the mines here created tremors in a radius of several kilometers. It was reported that similar landslides had occurred in the Kadwad area, during the year 1959”.

IV.2.INFORMATION FROM THE IMAGERY: The slide appears to represent reactivation of old slide that could also be conformed to the Google image wherein the old Palaeo scar line could be marked. The elderly locals also confirmed that a landslide was occurred during late fifties (Fig-2).



Fig-2: The Google image showing the slope prior to failure and the probable old slide scar

IV.3. SLIDE MORPHOMETRY: The slide morphometry was calculated from the plan (Plate-3) and sections prepared in the field using *total station* on 1:1000 scale. The slide is relatively large, exceeding 30,000 sq.m. The slide also appears *very fast*, and *deep seated* with a depth

ing a "Rotational debris slide" (Plate-3 & 4). Various
are as follows.

- | | | | |
|--|---------------|---|-----------------------|
| a. Maximum length of the flow from crown to frontal lobe | (Lm) | : | 270.5m. |
| b. Maximum width of the slide zone from the left flank to the right flank boundary | (Wm) | : | 80.0m |
| c. Maximum depth of the failed mass from the surface of the slide to the failure surface | (Dm) | : | ~ 10.0m |
| d. Area of the debris flow in plan | (A) | : | ~32000m ² |
| e. Debris flow Volume | (V) | : | ~54,000m ³ |
| f. Slope angle after failure | ($\bullet$) | : | 10° -15° |
| g. Slope angle before failure | | : | 30° |
| h. Scarp width | | : | 60.0m |
| i. Scarp depth | | : | ~20.0m |
| j. Scarp angle | | : | 85° -90° |
| k. Runout distance | | : | ~300.0m |

IV.4. TYPE AND SIZE OF SLIDE MATERIAL: The slide material in the zone of accumulation and depletion is "Debris" comprising different size fractions of laterite, sandy lateritic soil, clayey soil and weathered granitic material. The size varies from boulders to clay size. The slope material predominantly consists of coarse material hence it may be classified as "Debris" following the classification of Varnes (1978) and Cruden and Varnes (1996).

IV.5. CLASSIFICATION: The parameters generally used to classify landslides are

- Type of material involved,
- Geomorphic attributes of the slope,
- Landslide geometry,
- Type of movement,
- Climate,
- Water content of the slided material,
- Speed of movement of the slide,
- Triggering mechanism etc.

Landslides can either be rapid or slow, or occur in a wide variety of geologic environments.

As per the observations, the Kadwad slide is found to be a reactivated slide and is classified as a large deep seated rotational debris flow as per Varnes' classification (Varnes 1978). The Debris flow is distinguished from mudflow on the basis of particle size, the former containing a high percentage of coarse fragments, while the latter contains finer fragments. The

It is evident from the fact that the movement resembles that of a debris flow. The site was difficult to trace as the debris flown down the slope was still lying as a huge pile. Bishop (1973) also opines that in debris flows, the slip surfaces are usually not visible or short lived, and the boundary between the flow and the material over which it moves may be sharp or may be represented by a zone of plastic flow.

The rate of movement of the slide was arrived after a due interaction with the locals and also through media reports. One of the RCC houses (which were constructed on load bearing columns) was carried away from its original location to about 15 m away, where it stood collapsed at the time of our survey (Photo 9). As per the rate of movement, the slide may be classified as an "Extremely Rapid flow". As per Fell (1994) size classification for landslides, the Kadwad slide can be grouped in "class 4 medium". The Kadwad debris flow can also be classified as a "Class 3 debris flow" with volume ($\sim 54,000\text{m}^3$) as per Jacob (2005).

V.SAMPLE ANALYSIS

Three UDS and six disturbed samples were collected during investigation and analyzed for various geotechnical properties at the Geotechnical laboratory, GS, SR, Hyderabad. Out of three UDS samples collected, one is from crown, second from just below the crown (Photo 15) and third - at middle reaches below the lithomarge clay exposure. The six disturbed samples were collected from various places from the zone of accumulation (Plate-3).

The undisturbed samples were analyzed for density, moisture content, specific gravity, void ratio and porosity. Size analysis was done to know the percentage distribution of gravel, sand silt and clay. The Atterbergs limits including liquid limit, plastic limit, plasticity index and shrinkage limit were analyzed. Shear parameters including cohesion index and angle of internal friction were determined. The details are given in Table-4.

The disturbed samples were analyzed for distribution of gravel, sand, silt and clay fractions and to decipher Atterbergs limits. The analytical results are given in Table-5.

All the disturbed samples fall in MH category of Unified Soil Classification System (USCS) as given in the Appendix-1. Accordingly, the samples may be termed "Fine grained soil" with fairly a high silt and clay content having a liquid limit of >50 .

undisturbed samples

Sample No.	Density gm/cm ³	Moisture content	Specific gravity	Void ratio	Porosity	Grain size analysis				Atterbergs Limits				Shear parameters		Group Symbol	Group Name
						Gravel %	Sand %	Silt %	Clay %	Liquid Limit %	Plastic Limit %	Plasticity Index	Shrinkage Limit %	Cohesion Index	Angle of Internal friction		
UDS-1	1.26	30.70	3.23	2.36	0.70	15	17	31	37	66	52	14	14	0.28	29	MH	Sandy Elastic Clay
UDS-2	1.71	18.31	3.13	1.16	0.54	26	16	23	35	62	47	15	33	0.30	31	MH	Gravely elastic silt with sand
UDS-3	1.54	29.49	3.33	1.80	0.64	3	27	57	13	66	54	12	47	0.21	30	MH	Sandy Elastic Clay

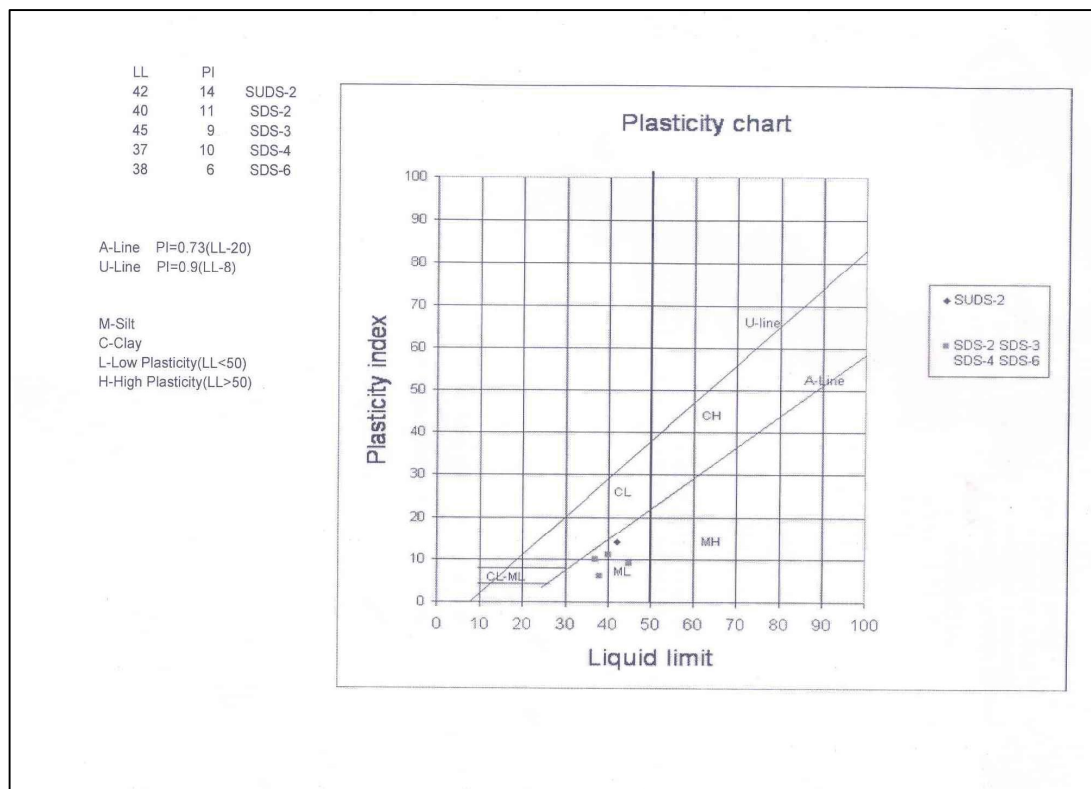


Fig-3: plasticity chart with plasticity index for Kadwad landslide

Disturbed samples

Sample No.	Grain Size Analysis				Atterbergs Limits				Group Symbol	Group Name
	Gravel %	Sand %	Silt %	Clay %	Liquid Limit %	Plastic Limit %	Plasticity Index	Shrinkage Limit %		
DSK-1	12	17	35	36	60	49	11	35	MH	Elastic silt with sand
DSK-2	40	26	12	22	55	39	16	28	GM	Silty gravel with sand
DSK-3	2	22	49	27	61	48	13	40	MH	Elastic silt with sand
DSK-4	3	17	61	19	82	61	21	51	MH	Elastic silt with sand
DSK-5	4	18	58	20	58	49	9	39	MH	Elastic silt with sand
DSK-6	0	9	61	30	68	50	18	40	MH	Elastic silt

V.1. DISCUSSION: In general, the geotechnical analysis of disturbed samples (Table 5) shows relatively lesser clay fraction, perhaps due to the washout of the clay fraction after failure. The plasticity index indicates that the material flow strength was relatively high. The grain-size distribution indicates the categorization under MH category of the USCS indicating the nature of fine-grained soils with relatively a high silt and clay content having a liquid limit of >50. One sample however has fallen in the GM category indicating an admixture of silty gravel with sand component.

In the UDS samples (Table-4), it may be seen from the shear parameters, that the angle of internal friction is higher than the cohesion. The results reveal that the presence of a clayey soil horizon of about 10-15m thickness between laterite and saprolitic layers, being impervious might have become oversaturated during the antecedent rainfall, resulting in building up a high pore pressure. The pore-water pressure coupled with lateral pressure perhaps due to swelling of oversaturated clay rich horizon might have been a driving force resulting in slope distress. The above assumption is supported by the results of grain size analysis wherein the UDS show relatively high silt and clay contents, between 58 and 70% indicating thereby a high water content and low permeability. Relatively a high pore-water pressure build-up, especially during heavy and prolonged rains would have resulted in increasing overburden pressure due to over-saturation and development of pore-pressure.

As angle of internal friction is less than the slope angle (Table-4), a 'high risk' still persists as the failed slope in the scarp is near-vertical. The angle of internal friction is between 29-31° and since the slope angle is more than 40° and cut slope angle is very steep (>80°), unstable slope condition might have resulted in slope failure.

ring a variety of soils, Casagrande (Casagrande, 1953) in which an empirical boundary known as the ωA line separates inorganic clays from silty and organic soils. Soils of the same geological origin usually fall on the plasticity chart as straight lines parallel to the ωA line. Larger the plasticity index, the greater will be the volume change of materials. The plot distinguishes ω Fat ω or plastic clays from organic soils, silts and clays containing a large portion of "rock flour" (finely ground non-clay minerals).

VI. CAUSES AND TRIGERRING MECHANISM

The instability of any slope increases over a period of time due to various factors like slope modification, quality and density of slope forming material, weathering depth and conditions, ground water variation etc. affecting independently or simultaneously. These factors are difficult to quantify but there are a number of other factors which may be operating either to increase the shear stress or to decrease the shearing resistance of the material (e.g. by decreasing the normal shearing resistance because of pore pressure increase) causing the slope failure.

VI.1.CAUSES: The main causes for the Kadwad debris flow may be summarized as follows

- The original slope angle being very low $\sim 20^\circ$, the slope was stable prior to human interference. The modification of the slope by cutting 15-20m vertical slope (as observed on either flanks of the slide zone) for settlement as well as plantation purposes, have increased instability (Photo 6).
- The presence of a 10-15m thick clayey soil layer, between laterite and saprolitic layers, being impervious might have become oversaturated during the antecedent rainfall resulting in building up of pore-pressure (Photo 11). The pore-water pressure coupled with lateral pressure perhaps due to swelling of oversaturated clay-rich horizon might have increased the driving force.
- Although the slope was moderately vegetated with shrubs and cashew plantation, the vegetation might have added dead weight on the failed slope as these plants do not have deep penetrating root system to hold the slope material intact (as the plane of failure of the slide is more than 10m).
- As per the information from a few local residents, there was excavation in front of the slope for providing soil for the construction of the embankment for Konkan Railway alignment. Even though the excavation depth could not be confirmed, its location is closer to the front portion of the slope. The instability might have been induced due to the excavation (toe cutting into the slope) which has increased the relative slope height, the volume and weight of material above the toe. The rise in the stagnated water level in the marshy area in front of the mound during the ensuing rainfall might have decreased the volume of water drained out of the mound, thereby increasing the water content of the slope-forming material with subsequent rise of water table.
- Even though percolation through lateritic soil is high, the area did not have any drainage facility to drain out the infiltrating water from the slope.
- The Konkan Railway track connecting Karwar town with Goa and other places passes through the Kadwad valley which is a paleo-channel. The vibration generated by

ve resulted in the loosening of the soil (subsequent to soil

VI.2. POSSIBLE TRIGGERING MECHANISM OF KADWAD LANDSLIDE: Rainfall is known to be the triggering factor for most of the landslides in Western Ghats (Mishra & Pradhan 2010, Mishra & Dharuman 2010). Prolonged heavy showers are known usually to cause saturation of overburden material on hill slopes which in turn may increase the pore-water pressure either in overburden material or in the underlying weathered bedrock thereby triggering landslide many a times. The annual rainfall in general in Uttar Kannada District is mostly in excess of 3000 mm (Annexure-1). Also, most of the rainfall is received during the peak monsoon period between June and October. Incidentally, there has been very heavy rainfall in the coastal regions of Karnataka and whole of North Karnataka during 2009 and that too extending into early October (Annexure-1, Table-6 and Fig-4). Heavy rainfall had contributed substantially towards floods, particularly in northern Karnataka. Incessant rains started at Karwar on 29th September and continued upto 3rd of October had created serious flooding problems. Rainfall of nearly 800 mm was received during the five days (118 mm recorded on 30th September, 40 mm on 1st October, 179 mm on 2nd October and 423 mm on 3rd October) and the cumulative antecedent rainfall for the year on October 2nd morning had already reached 3370 mm. Addition of yet another heavy rainfall on the same day appear to have triggered a massive landslides not only in Kadwad village but also in other places surrounding Karwar. In the process, there might have been substantial increase in the pore water pressure due to impermeable clayey soil horizon resulting in massive slope distress.

Table 6: Rainfall data from 1st September 2009 to 13th October 2009 from Karwar rain gauge station

Date	Rainfall (in mm)	Date	Rainfall (in mm)	Date	Rainfall (in mm)
1-Sep-09	19.9	16-Sep-09	4.7	1-Oct-09	39.5
2-Sep-09	57.9	17-Sep-09	0	2-Oct-09	179.6
3-Sep-09	30	18-Sep-09	0	3-Oct-09	423.6
4-Sep-09	38.4	19-Sep-09	8.2	4-Oct-09	34.9
5-Sep-09	64	20-Sep-09	0	5-Oct-09	1
6-Sep-09	49.6	21-Sep-09	4.4	6-Oct-09	10.4
7-Sep-09	26.4	22-Sep-09	0	7-Oct-09	0
8-Sep-09	8.8	23-Sep-09	0	8-Oct-09	0
9-Sep-09	1	24-Sep-09	2.5	9-Oct-09	0
10-Sep-09	17.3	25-Sep-09	0.7	10-Oct-09	0
11-Sep-09	2.4	26-Sep-09	4.4	11-Oct-09	0
12-Sep-09	41.8	27-Sep-09	0.6	12-Oct-09	0
13-Sep-09	0	28-Sep-09	0	13-Oct-09	0
14-Sep-09	0	29-Sep-09	6		
15-Sep-09	10.7	30-Sep-09	118.2		

Data Source: Dy. Commissioner's office, Karwar

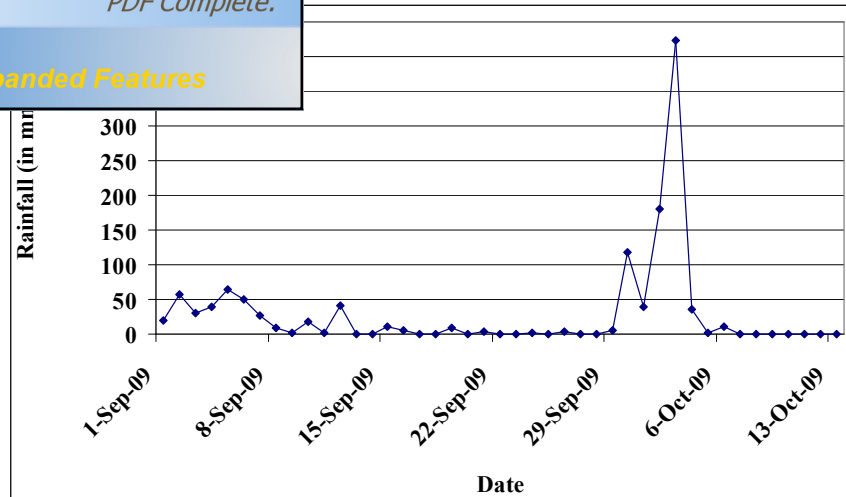


Fig-4: Antecedent rainfall pattern of Kadwad landslide

VII. SUMMARY

Kadwad landslide near Kadwad village, Karwar taluk, Uttar Kannada district occurred on 02.10.2009 killing 19 people and completely destroying 9 houses. The site specific study was taken up to get insight of the slide characteristics, causative factors of landslide and to suggest remedial measures. Detailed mapping over an area of 0.10 sq.km on 1:1000 scale was carried out and 3 cross sections and 1 longitudinal section were drawn. A total of 3 UDS and 6 disturbed samples were taken for geotechnical analysis. On integration of field data and analytical results, following conclusions were drawn.

1. Kadwad slide is classified as a large & Deep seated Rotational Debris flow
2. The litho-units exposed at the site include vesicular laterite with predominantly tubular cavities, lateritic soil, lithomarge clay, saprolite (weathered granite) and granite.
3. The Ground Water Table is shallow with depth to water table at 1.5 to 3.0 m. Weathering was estimated up to a depth of 20-30 m.
4. The analysis of geotechnical parameters reveals that all the three undisturbed samples fall in MH category of Unified Soil Classification System (USCS) implying that the samples represent fine grained soils with relatively a high silt and clay content and a liquid limit >50. From the shear parameters it may be seen that the angle of internal friction is higher than the cohesion. In general the disturbed samples show less clay fraction perhaps due to washout of the clay fraction after failure.
5. The main causes for the failure appear to be
 - i. The slope grading / human interference
 - ii. Presence of a 10-15m thick clayey soil layer, between laterite and saprolitic layers could have been responsible for development of high pore water pressure in the overburden material.
 - iii. Toe cutting and removal of soil.
6. The triggering mechanism appears to be mostly, heavy antecedent rain fall.
7. As per the site condition and geotechnical evaluation of the factors responsible for the debris flow remedial measures have been proposed.

RECOMMENDATIONS

As per the site condition and evaluation of the factors responsible for the Debris flow, the flowing remedial measures are proposed.

1. The hanging crown part needs to be graded as it is still unstable (as subsidence and crown cracks were observed) The major part of the intact slope exposed is either Laterite or clayey soil hence the vertical, 20m high crown scarp (Photo 10) should be graded to 35°-45° slope.
2. Improving drainage connectivity:
Prolonged rainfall over many days might have enhanced the pore water pressure. As such, a proper drainage system may be planned to prevent water accumulation at the fallen debris material. The water from the present slope (pounding of water in the midslope and the rills developed near the head scarp) is to be diverted or suitably drained out of the slope. Catch-water drains and contour drains may be provided at Crown part.
3. Plantation in the slide zone with deep rooted plants in staggered manner is essential to stop future landslides of local nature in the slide debris. Monoculture plantations are to be discouraged.
4. Aforestation is to be prioritised with the native species of flora. Cashew plantation at hazardous slopes needs to be discouraged. Planting Vetiver grass all along mid section to reduce further erosion (mostly gully erosion) may be enforced which may even provide economy for the locals.
5. Illegal soil as well as granite mining on the hills needs to be banned. It is pertinent to note that the soil from the toe part had been removed and supplied to Konkan Railway while lying of the track.
6. For a long-term stability of the distressed and adjoining slopes, a detail LHZ (Landslide Hazard Zonation) study of the whole area as a single unit is recommended to delineate hazard zones. The study also would assess the impact of environment by the anthropogenic activities, suggesting hazard free areas for developmental activities

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PSIS OF WORK DONE

1		Title of the report		DETAILED SITE SPECIFIC STUDY OF THE KADWAD LANDSLIDE, KARWAR TALUK, UTTAR KANNADA DISTRICT, KARNATAKA	
2		Item No.		Code No.: EG/SR/KG/2010/058	
3		Field Season		2010-12	
4		Date of commencement		13.12.2010	
5		Date of completion		26.12.2010	
6		Officers Associated with investigation and No. of days spent in the field		K.V.Maruthi, Senior Geologist K.V.Chandran Senior Geologist (13 days)	
7		Quantum of work done			
		NATURE OF WORK		Work proposed for FS2010-12	Total work Completed
		Detailed study of the landslide and slope stability analysis for identifying the Causative factors and suggesting remedial measures. Detailed mapping of 0.1 sq.km of slide area		0.1sq.km	0.1sq.km.
		Geological section a)Longitudinal section on 1:1000 b)Cross section on 1:1000		3 Profiles 3 Profiles	1 Profiles 3 Profiles
		SMPL a)Undisturbed b) Disturbed		As necessary	3 samples collected 6 Samples collected
8		Analysis carried out 1) AAS-MIBK for Au 2) ICP-AES		NA	
9		Elements analysed		NA	
		Expenditure (1) POL (2) Wages (3) Misc./Other charges		- (* Vehicle was outsourced) Rs. 6701=00 Rs. 14400=00	
10		Other information if any			
		(K.V.MARUTHI) Senior Geologist		(K.V.CHANDRAN) Senior Geologist	
(Dr. B.R.VENKATESH) Director					

Annexure-1

gauge station over the years

Year- 2000

Month Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	4.8	50.7	0.0	50.6	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	97.2	3.4	0.0	37.7	27.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	43.0	45.2	0.0	63.6	9.6	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	24.5	12.6	0.0	0.0	11.8	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	36.8	109.1	0.0	0.0	1.6	0.0	5.4
6	0.0	0.0	0.0	0.0	4.4	185.4	158.6	0.0	0.2	0.6	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	36.2	201.8	3.4	0.0	5.3	0.0	0.0
8	0.0	0.0	0.0	0.0	14.3	67.8	148.9	27.2	0.0	1.2	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	19.8	95.0	28.6	1.8	3.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	15.8	43.4	25.4	12.6	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	51.4	64.9	73.7	1.8	0.8	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	98.1	38.2	48.6	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	17.5	60.9	12.6	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	11.4	26.8	4.2	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.1	2.8	11.1	0.0	0.0	1.0	0.0	0.0
16	0.0	0.0	0.0	0.0	60.4	0.0	12.0	1.8	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	13.8	5.2	0.2	34.5	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	64.6	2.7	13.2	19.8	5.2	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	97.6	51.9	20.4	12.2	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	16.8	13.6	29.4	7.9	0.0	19.1	0.0	0.0
21	0.0	0.0	0.0	0.0	31.4	26.5	1.2	4.4	3.9	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.5	0.0	3.9	19.2	2.8	5.2	0.0	0.0
23	0.0	0.0	0.0	0.0	2.8	8.0	0.4	29.1	1.5	46.5	0.0	0.0
24	0.0	0.0	0.0	0.6	0.2	1.1	0.0	30.6	3.2	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	5.6	13.7	51.5	4.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	4.1	2.2	0.3	75.3	7.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	75.1	11.8	2.4	4.9	17.8	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	28.7	7.8	37.6	10.7	0.7	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	15.7	61.6	11.3	9.4	3.4	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	10.8	81.3	0.0	27.9	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	30.2	0.0	0.0	3.1	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.6	471.5	991.8	1216.6	566.0	217.8	132.7	0.0	5.4
Annual rainfall in mm					3602.4							

Year- 2001

Month Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	8.0	0.0	0.0	0.0	0.0	0.0	57.0	3.2	1.0	64.4	0.0	0.0
2	2.4	0.0	0.0	0.0	0.0	0.5	83.1	21.2	0.0	0.0	0.0	0.0



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PDF Complete. to upgrade to Pages and Expanded Features					0	0.0	0.0	2.8	122.3	0.3	0.0	0.0	0.0
					4	0.0	0.4	3.7	6.8	0.0	0.0	0.0	0.0
					0	0.0	0.0	42.6	27.8	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	14.6	4.0	0.0	0.7	20.8	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	82.9	16.2	10.2	6.6	1.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	23.4	11.0	4.1	0.0	13.6	0.0	0.0
9	0.0	0.0	0.0	0.2	0.0	0.0	20.2	67.6	11.6	0.0	14.5	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	16.2	11.0	8.2	0.0	0.9	0.0	0.0
11	0.0	0.0	0.0	6.2	0.0	0.0	16.0	15.4	1.7	0.0	0.9	0.0	0.0
12	0.0	0.0	0.0	21.4	0.0	0.0	64.2	4.0	7.4	0.0	3.2	0.0	0.0
13	0.0	0.0	0.0	11.5	0.0	0.0	12.5	13.4	3.9	0.0	1.9	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	21.8	29.0	18.2	0.0	20.6	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	17.0	10.5	5.6	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	7.9	14.0	6.0	0.0	0.2	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	3.4	8.2	20.6	2.5	1.3	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	1.2	15.5	30.5	0.0	3.2	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	1.3	8.1	18.8	29.1	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.9	19.7	2.4	5.3	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	10.8	34.9	3.1	20.8	0.5	1.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	20.2	140.0	7.1	16.2	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	75.0	6.6	30.0	1.9	7.6	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	50.5	0.0	14.7	18.4	30.4	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	32.8	20.4	60.5	11.1	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	46.4	4.6	61.6	6.5	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	2.2	4.6	61.1	2.1	3.8	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	8.0	36.0	9.8	8.9	17.7	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	29.2	109.0	75.6	0.2	1.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	1.3	58.6	65.6	2.4	66.2	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	3.1	0.0	19.6	2.2	0.0	0.0	0.0	0.0
Total	10.4	0.0	0.0	39.7	281.7	744.7	838.9	434.4	138.3	147.5	0.0	0.0	0.0
Annual rainfall in mm					2635.6								



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Year- 2002												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	48.6	12.8	8.4	5.6	20.2	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	12.5	10.1	12.7	25.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	60.8	9.9	12.9	22.4	0.0	0.0	0.0
4	0.0	0.0	0.0	6.7	0.0	2.8	1.6	45.5	7.8	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	14.7	16.3	0.3	0.0	0.0
6	0.0	0.0	0.0	0.0	0.3	0.0	3.2	10.7	42.5	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	11.2	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	4.0	0.0	7.4	11.7	1.0	9.8	0.0	0.0
9	0.0	0.0	0.0	0.0	2.0	0.4	21.4	119.6	9.0	10.1	0.0	0.0
10	0.0	0.0	0.0	0.0	1.3	7.7	14.8	133.2	0.0	9.7	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	43.7	141.0	19.8	4.6	19.6	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	4.7	2.6	42.3	0.0	52.9	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	8.2	1.4	12.9	1.2	190.2	0.0	0.0
14	0.0	0.0	0.0	0.0	0.2	297.2	3.7	0.6	0.0	1.6	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	77.9	1.7	18.0	0.0	1.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	98.0	12.2	11.9	0.0	40.7	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	48.6	13.0	39.0	0.0	36.4	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	37.8	2.5	6.7	0.0	6.0	0.0	0.0
19	0.0	0.0	0.0	0.0	105.0	125.0	1.5	2.8	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	18.0	39.4	0.7	5.2	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	4.2	33.1	38.4	8.9	0.0	2.5	0.0	0.0
22	0.0	0.0	0.0	1.6	0.0	11.4	16.8	1.2	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	26.9	17.8	1.9	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	6.7	3.9	2.6	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	1.1	11.4	29.3	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.4	15.6	8.3	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	2.3	35.0	12.3	0.2	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	28.2	1.6	7.9	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.4	6.7	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	16.4	0.4	0.5	0.0	0.0	10.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	2.6	21.4	0.0	0.0
Total	0.0	0.0	0.0	8.3	183.4	1030.3	394.0	581.0	149.2	432.4	0.0	0.0
Annual rainfall in mm					2778.6							



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Year- 2003												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	0.0	85.8	12.9	35.5	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	36.0	21.0	4.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	38.9	10.9	16.9	3.2	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	69.2	21.4	3.6	11.4	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	97.2	105.8	1.1	2.5	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	49.9	4.3	43.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	3.0	159.5	36.6	9.5	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	26.2	20.9	10.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	19.6	25.3	12.9	14.1	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	3.7	52.9	0.0	2.7	2.6	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	37.4	34.9	1.4	0.6	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	30.4	11.2	15.6	10.2	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	52.6	7.3	2.8	3.5	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	12.2	153.2	0.8	13.4	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	69.4	66.8	13.7	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	133.4	74.8	24.2	25.3	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	95.0	12.9	5.6	25.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	83.1	1.0	15.4	2.4	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.2	39.4	6.8	69.1	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	204.6	7.2	21.5	1.6	0.8	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	107.2	1.2	30.5	0.0	32.6	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	195.8	1.8	3.5	0.0	5.2	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	14.8	41.7	5.0	0.5	8.5	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	33.6	16.2	7.2	0.6	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	11.8	16.0	8.4	18.7	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	6.0	20.4	14.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.6	0.0	0.0	87.8	23.9	2.0	0.3	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	4.4	13.4	0.0	29.9	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	4.6	12.4	3.1	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	18.3	7.8	29.9	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	3.0	35.2	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.6	0.0	0.2	1268.1	1174.8	555.6	272.4	66.8	0.0	0.0
Annual rainfall in mm					3338.5							



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Year- 2004												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	47.6	0.0	47.8	1.6	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	82.6	10.2	24.6	0.0	1.8	14.4	0.0
3	0.0	0.0	0.0	0.0	1.0	0.0	11.5	90.8	0.0	8.7	53.4	0.0
4	0.0	0.0	0.0	0.0	0.0	1.4	6.2	45.3	0.0	62.2	0.0	0.0
5	0.0	0.0	0.0	0.0	2.4	21.0	1.2	6.4	0.0	51.0	0.0	0.0
6	0.0	0.0	0.0	0.0	13.0	35.2	31.8	6.8	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.2	3.2	0.0	13.2	4.8	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	12.0	79.8	0.0	27.0	29.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	2.4	101.7	30.2	8.1	14.3	0.0	2.0	0.0
10	0.0	0.0	0.0	0.0	2.3	72.4	9.5	24.2	43.6	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	3.0	17.5	39.2	10.0	24.8	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.8	8.7	46.2	29.4	24.1	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.8	13.0	45.1	142.5	2.7	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	19.6	22.5	12.1	34.0	0.2	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	14.5	13.3	6.7	4.1	6.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	46.2	19.5	30.2	16.9	1.7	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	6.9	15.3	22.0	29.0	0.4	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	71.6	2.2	2.0	28.4	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	26.2	2.9	15.6	8.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	19.2	0.0	46.8	2.2	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	2.2	0.0	48.3	14.2	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	2.4	0.0	12.2	1.8	61.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	2.9	0.0	20.2	13.4	2.4	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	5.0	0.0	35.4	14.8	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	1.4	7.2	7.2	15.8	0.5	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	101.5	42.4	0.6	0.5	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.4	38.1	19.0	4.0	42.2	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	2.7	11.4	5.5	1.3	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	1.6	15.6	0.2	11.6	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	9.8	12.8	45.6	0.0	2.2	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	2.1	0.0	60.5	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	271.0	732.4	678.4	664.8	273.6	123.7	69.8	0.0
Annual rainfall in mm					2813.7							



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Year- 2005												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	13.2	8.8	3.5	0.4	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	19.9	28.2	20.3	0.0	0.0	0.0	0.2
3	0.0	0.0	0.0	0.0	0.0	0.0	14.8	5.1	1.6	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	8.6	6.4	12.5	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	121.7	6.5	2.5	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	1.2	28.8	5.1	42.1	0.0	0.0	0.0
7	0.0	0.0	0.0	3.2	0.0	36.3	5.0	6.4	2.5	0.0	0.0	0.0
8	0.0	0.0	0.0	5.8	0.0	12.0	2.6	35.0	1.3	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	2.4	94.6	6.8	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	2.1	3.0	18.1	10.3	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	18.4	10.3	4.3	7.7	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	17.8	124.5	0.8	33.4	38.6	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	68.7	0.0	20.2	36.9	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	5.4	39.1	4.3	23.8	32.9	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	2.5	0.0	6.1	4.8	1.6	0.0	0.0
16	0.0	0.0	0.0	58.2	0.0	24.2	0.8	0.4	6.5	6.4	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	19.2	1.9	29.9	2.1	10.6	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	81.0	20.4	57.4	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	26.3	0.9	3.4	18.0	30.2	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	90.4	58.6	0.4	52.9	0.3	0.0	0.0
21	0.0	0.0	0.0	23.6	0.0	122.8	13.1	5.5	8.9	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	234.9	54.0	8.5	43.5	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	104.2	72.3	0.5	59.6	0.0	0.0	0.0
24	0.0	0.0	0.0	0.8	0.0	23.4	145.8	0.7	9.9	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	4.5	159.0	14.6	1.8	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	11.2	3.0	14.3	14.0	1.2	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	4.1	12.6	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	15.2	37.1	0.0	0.0	0.1	0.0	0.0
29	0.0	0.0	0.0	0.0	28.5	48.8	39.4	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	16.4	25.5	47.7	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	91.6	56.1	956.3	1146.2	351.8	374.3	157.6	0.0	0.2
Annual rainfall in mm					3134.1							



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Year- 2006												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	68.7	2.0	33.9	14.8	1.2	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	70.4	26.5	8.0	1.1	27.4	31.7	0.0
3	0.0	0.0	0.0	0.0	1.6	5.8	21.8	25.6	0.0	81.3	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	35.3	5.5	5.6	0.0	48.6	5.1	0.0
5	0.0	0.0	0.0	0.0	0.0	3.8	9.5	6.2	0.0	24.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	21.8	20.2	33.8	0.0	37.0	0.4	0.0
7	0.0	0.0	0.0	0.0	0.0	5.2	11.3	16.4	0.0	9.3	1.0	0.0
8	0.0	0.0	0.0	0.0	0.0	15.3	158.2	112.8	0.0	27.9	0.0	0.0
9	0.0	0.0	0.0	0.0	0.2	5.0	10.2	22.0	0.0	36.3	0.0	0.0
10	0.0	0.0	3.3	0.0	0.0	9.0	8.1	24.9	10.4	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	15.3	16.3	26.8	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	5.1	7.4	8.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	5.2	13.5	12.9	52.1	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	16.3	15.6	102.3	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	7.9	31.8	83.7	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	3.2	50.5	73.9	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	3.2	6.2	12.2	34.6	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	49.0	136.4	18.6	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	27.9	31.9	23.5	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	14.0	3.9	3.6	0.0	0.0	0.0
21	0.0	0.0	1.0	0.0	0.0	3.6	8.6	3.7	2.5	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	20.2	15.9	28.8	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.4	0.1	8.3	1.6	36.4	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.7	335.8	43.4	0.1	0.8	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	53.4	6.8	0.0	0.8	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.6	143.0	8.7	0.0	51.4	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	3.3	65.6	42.6	0.0	3.6	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	23.7	18.7	26.7	24.4	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	7.8	69.0	1.7	0.5	0.8	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	439.8	15.2	20.9	4.5	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	91.2	0.0	15.0	0.7	0.0	0.0	0.0	0.0
Total	0.0	0.0	4.3	0.0	569.3	973.5	637.9	670.6	543.7	293.0	38.2	0.0
Annual rainfall in mm					3730.5							



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Year- 2007												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	1.1	13.0	2.0	118.1	16.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	21.8	28.0	96.4	84.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	46.8	26.4	96.1	80.2	2.8	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	2.7	55.3	47.2	63.1	21.8	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.2	22.4	103.6	10.8	0.0	2.5	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	1.2	89.8	10.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	4.8	4.2	73.6	32.9	0.0	1.6	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	24.8	28.3	9.6	0.7	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.5	18.2	9.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	34.6	33.9	4.8	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	11.3	21.7	10.6	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	38.2	0.6	0.8	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	75.8	17.4	7.6	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	21.4	10.2	6.2	3.3	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	37.6	0.3	29.0	18.6	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	103.3	9.8	0.0	22.0	0.0	0.0	0.0
17	0.0	0.0	0.0	2.0	0.0	54.2	23.8	0.0	0.6	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	71.8	0.4	0.0	25.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	29.6	3.4	5.7	5.7	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	89.4	4.3	21.0	7.8	12.1	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	30.8	9.0	32.1	2.6	11.0	0.0	4.4
22	0.0	0.0	0.0	0.0	0.0	143.2	66.8	9.4	2.1	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	2.8	205.8	62.5	58.2	10.5	1.4	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	83.6	6.9	7.2	43.8	0.4	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	44.8	17.6	3.2	26.5	0.7	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	37.2	9.7	42.2	4.5	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	23.5	60.0	16.3	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	6.4	13.0	53.8	14.8	3.8	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	85.0	71.8	38.4	18.3	34.9	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.8	38.1	42.4	30.2	32.9	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	16.4	0.0	44.2	50.8	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	2.0	111.4	1336.9	730.6	914.4	653.3	66.9	4.1	4.4
Annual rainfall in mm					3824.0							



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Year- 2008												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	55.7	28.7	17.3	0.7	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.2	13.9	0.6	3.8	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.2	1.1	9.5	0.0	0.0	0.0	26.1
4	0.0	0.0	0.0	0.0	0.0	1.0	5.8	22.1	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	22.0	12.9	0.6	0.0	1.4	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	31.9	13.9	4.2	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	84.5	13.6	26.4	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	103.7	8.7	41.2	122.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	113.6	8.2	41.7	28.6	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	61.8	4.0	90.4	95.4	6.3	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	103.9	2.2	119.0	66.7	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	48.7	0.0	85.9	37.6	0.0	1.0	0.0
13	0.0	0.0	0.0	0.0	0.0	159.3	4.4	69.9	37.7	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	29.9	1.4	56.2	9.5	0.0	0.0	0.0
15	0.0	1.1	0.0	0.0	0.0	8.7	0.3	40.7	10.1	0.0	0.0	0.0
16	0.0	2.2	0.0	0.0	0.0	18.8	37.8	12.7	26.8	0.0	0.0	0.0
17	0.0	0.0	0.5	0.0	0.0	17.8	1.6	11.7	2.6	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.8	2.5	49.0	0.4	10.5	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	2.6	21.3	11.7	8.2	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	4.0	25.8	0.7	2.8	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	2.2	1.0	2.2	0.3	5.6	0.0	0.0	0.0
22	0.0	0.0	16.8	0.0	5.0	2.4	0.8	0.7	1.2	0.2	0.0	0.0
23	0.0	0.0	5.3	2.7	5.2	2.8	5.8	1.0	0.0	1.7	0.0	0.0
24	0.0	0.0	0.4	0.0	0.8	0.0	5.6	1.6	0.0	3.8	0.0	0.0
25	0.0	0.0	7.1	0.0	0.7	1.2	77.3	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	50.2	0.0	0.2	13.8	51.3	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	6.0	0.0	32.7	6.5	29.3	0.3	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.2	17.4	61.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.1	18.2	19.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	10.9	9.2	31.2	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	3.9	0.0	18.1	0.0	0.0	0.0	0.5	0.0
Total	0.0	3.3	86.3	2.7	62.7	943.3	556.2	666.8	469.8	13.4	1.5	26.1
Annual rainfall in mm					2832.1							



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Year- 2009												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	0.0	32.2	4.0	19.9	38.5	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	1.2	141.0	0.2	57.9	179.6	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	12.8	142.2	4.5	30.0	423.6	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	66.5	4.1	38.4	34.9	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	20.5	83.2	21.6	64.0	1.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	108.6	98.0	39.6	49.6	10.4	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	165.3	71.8	2.8	26.4	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	20.4	102.6	1.6	8.8	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	10.8	108.1	0.4	1.0	0.0	2.6	0.0
10	0.0	0.0	0.0	0.0	0.0	20.6	32.1	0.5	17.3	0.0	8.2	0.0
11	0.0	0.0	0.0	0.0	0.0	19.2	40.9	16.8	2.4	0.0	59.3	0.0
12	0.0	0.0	0.0	0.0	0.0	0.2	5.0	10.4	41.8	0.0	32.9	0.0
13	0.0	0.0	15.0	0.0	0.0	0.6	8.0	11.6	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	28.0	5.5	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	11.9	41.2	1.5	10.7	0.4	0.3	0.0
16	0.0	0.0	0.0	0.0	0.0	10.0	29.9	4.0	4.7	0.0	51.8	0.0
17	0.0	0.0	0.0	0.0	0.0	48.0	3.2	2.0	0.0	0.0	0.4	0.0
18	0.0	0.0	0.0	0.0	2.4	0.0	40.3	23.9	0.0	0.0	2.0	0.0
19	0.0	0.0	0.0	0.0	0.0	7.9	20.5	0.9	8.2	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	19.5	18.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.2	44.4	7.7	0.0	4.4	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	65.0	18.4	10.5	0.5	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	21.4	0.5	23.6	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	12.0	40.0	2.6	70.6	3.5	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	5.7	28.4	19.8	49.6	0.7	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	31.5	0.0	12.7	4.4	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	1.0	30.1	9.1	13.0	0.6	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	27.5	79.4	28.3	0.0	0.0	0.0	2.4
29	0.0	0.0	0.0	0.0	0.3	21.3	47.2	33.4	6.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	40.4	24.8	10.6	118.2	0.0	0.0	1.5
31	0.0	0.0	0.0	0.0	0.0	0.0	3.8	43.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	15.0	0.0	86.6	780.9	1318.1	441.2	518.9	688.4	157.5	3.9
Annual rainfall in mm					4010.5							

					Year- 2010							
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Date												
1	0.0	0.0	0.0	0.0	2.0	6.0	60.2	25.4	13.2	15.4	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	150.2	8.0	10.8	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	1.2	0.0	51.5	2.2	37.5	0.0	22.7	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	25.4	52.3	45.6	33.2	7.8	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	76.2	2.7	5.4	0.0	6.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.8	26.3	5.4	32.6	0.0	25.0	0.0
7	0.0	0.0	0.0	0.0	0.0	15.8	54.4	12.2	23.6	3.2	0.6	0.0
8	0.0	0.0	0.0	0.0	0.0	70.9	14.4	18.6	17.2	0.0	7.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.0	36.4	0.0	207.4	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	9.8	7.4	28.2	0.0	12.8	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.4	24.2	13.5	0.0	1.2	3.2
12	0.0	0.0	0.0	0.0	0.0	1.0	0.6	10.6	2.2	0.0	31.4	0.0
13	0.5	0.0	0.0	0.0	0.0	13.7	17.6	11.8	6.4	1.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	49.7	9.2	1.7	5.7	0.6	0.0	0.0
15	0.8	0.0	0.0	0.0	0.0	64.1	4.2	13.9	6.6	18.4	20.8	0.0
16	0.0	0.0	0.0	0.0	0.0	63.0	57.2	12.8	28.5	1.6	7.2	0.0
17	0.0	0.0	0.0	0.0	0.0	56.0	22.9	70.0	39.0	7.9	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	57.2	71.2	49.8	0.6	12.6	0.0	0.0
19	0.0	0.0	0.0	0.0	7.8	30.8	68.4	32.5	20.0	72.2	5.5	0.0
20	0.0	0.0	0.0	0.0	0.0	10.7	140.8	20.0	0.4	34.8	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	11.6	74.4	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	14.1	64.8	19.6	20.2	18.0	0.8	0.0
23	0.0	0.0	0.0	5.3	0.0	31.4	20.2	0.0	0.0	66.3	41.4	0.0
24	0.0	0.0	0.0	0.0	0.0	44.8	9.2	17.3	70.0	17.6	4.6	0.0
25	0.0	0.0	0.0	0.0	0.0	86.6	36.0	47.3	0.0	0.6	1.0	0.0
26	0.0	0.0	0.0	0.0	0.0	112.4	36.2	52.8	11.8	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	2.7	58.0	8.7	33.9	3.2	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	15.6	34.3	20.6	51.2	0.0	0.0	0.0
29	0.0	0.0	0.0	5.2	0.0	5.9	30.6	10.2	36.8	0.0	0.0	0.0
30	0.0	0.0	0.0	0.5	0.0	100.2	119.3	6.0	8.6	3.0	0.0	0.0
31	0.0	0.0	0.0	0.0	109.8	0.0	73.0	27.8	0.0	0.0	0.0	0.0
Total	1.3	0.0	0.0	11.0	123.5	920.3	1381.8	617.0	575.2	306.4	403.4	3.2
Annual rainfall in mm					4343.1							

Appendix-1

Unified Soil Classification System: The Unified Soil Classification System (USCS) is a soil classification system used in engineering and geology to describe the texture and grain size of a soil. The classification system can be applied to most unconsolidated materials, and is represented by a two-letter symbol. Each letter is described below (with the exception of Pt):

		Second letter	Definition
<u>G</u>	<u>gravel</u>	P	poorly graded (uniform particle sizes)
S	<u>sand</u>	W	well graded (diversified particle sizes)
M	<u>silt</u>	H	high <u>plasticity</u>
C	<u>clay</u>	L	low plasticity
O	<u>organic</u>		

If the soil has 5–12% by weight of fines passing a #200 sieve ($5\% < P_{\#200} < 12\%$), both grain size distribution and plasticity have a significant effect on the engineering properties of the soil, and dual notation may be used for the group symbol. For example, GW-GM corresponds to "well graded gravel *with silt*." If the soil has more than 15% by weight retained on a #4 sieve ($R_{\#4} > 15\%$), there is a significant amount of gravel, and the suffix "with gravel" may be added to the group name, but the group symbol does not change. For example, SP-SM with gravel may refer to "poorly graded sand with silt and gravel."

Major divisions			Group symbol	Group name
Coarse grained soils more than 50% retained on No. 200 (0.075 mm) <u>sieve</u>	<u>gravel</u> > 50% of coarse fraction retained on No. 4 (4.75 mm) sieve	clean gravel <5% smaller than #200 Sieve	GW	well graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	GM	silty gravel
			GC	clayey gravel
	<u>sand</u> Ö50% of coarse fraction passes No.4 sieve	clean sand	SW	well graded sand, fine to coarse sand
			SP	poorly-graded sand
		sand with >12% fines	SM	silty sand
			SC	clayey sand
Fine grained soils more than 50% passes No.200 sieve	<u>silt and clay</u> <u>liquid limit</u> < 50	<u>inorganic</u>	ML	silt
			CL	clay
		<u>organic</u>	OL	organic silt, <u>organic clay</u>
	silt and clay liquid limit Ö50	inorganic	MH	silt of high <u>plasticity</u> , <u>elastic</u> silt
			CH	clay of high plasticity, fat clay
		organic	OH	organic clay, organic silt
	Highly organic soils			Pt

Source: From Wikipedia encyclopedia



Geological Survey of India

Data sheet on report movement in connection with its scrutiny

Project/Division Engineering Geology FSP No. 2010-12 Mission IV
Title of the report Geological Survey of the Karkand landslide
Karwar Taluk, Uttara Kannada district, Karnataka

Name of author(s) 1. K.V. Maruthi 2. K.V. Chandran 3. 4.	Date of submission of report to the Supervisory Officer 05.07.2012 Signature of the senior most author K.V. Maruthi
Name of Supervisory Officer Dr. B. R. Venkatesh	Date of receipt of report 05.07.2012 Date of completion of scrutiny 06.08.2012 Date of handing over report to the author after scrutiny 06.08.2012 Signature K.V. Maruthi
Name of author(s) To whom the report has been handed over by the Supervisory Officer K.V. Maruthi	Date of receipt after scrutiny 06.08.2012 Signature K.V. Maruthi Date of resubmission 09.08.2012 Signature K.V. Maruthi
Supervisory Officer Dr. B. R. Venkatesh	Date of receipt after modification 09.08.2012 Date of handing over report to the Regional Mission Head 09.08.2012 Signature Dr. B. R. Venkatesh
Name of Regional Mission Head Dr. K. R. K. PRASAD	Date of receipt of report (by post) 21.08.2012 Date of handing over the report after peer review to the Project Director 03.09.2012 Signature K.V. Maruthi
Name of Supervisory Officer Dr. B. R. Venkatesh	Date of receipt from the Regional Mission Head after peer review 11.09.2012 Date of handing over to author(s) 11.09.2012 Signature Dr. B. R. Venkatesh
Name of author(s) K.V. Maruthi K.V. Chandran	Date of receipt of report from Supervisory Officer 11.09.2012 Date of handing over report after modification to Supervisory Officer 17.09.2012 Signature K.V. Maruthi
Name of Supervisory Officer	Date of receipt of report after



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Dr. B. R. Venkatesh 17.09.2012	from the author(s) Date of handing over report to Regional Mission Head Signature.....<i>[Signature]</i> 17/9
Name of Regional Mission Head Dr. K. R. K. Prasad	Date of receipt after modification from the Project Director.....24.09.2012 Date of handing over the report to the HoD of the Region for approval Signature.....<i>[Signature]</i>
Name of the HoD of the Region S. C. RATH	Date of receipt of report for approval Date of approval.....25.09.2012 Date of sending back report to Project Director.....25.09.2012 Signature of the HoD.....<i>[Signature]</i>
Name of the Project Director	Date of receipt of report after approval of HoD.....26.9.12 Date of circulation of report..... Signature.....



GEOLOGICAL SURVEY OF INDIA

Certificate of Quality of the report

Project/ Division: *Engineering Geology* FSP No.: *2070-12* Mission: *LV*

Title of the report: *Detailed Site Specific Study of Kachwad Landslide
Kannur taluk, Uttara Kannada district, Karnataka.*

Part - A

This is to certify that the following Officer(s) have carried out the above mentioned FSP and are responsible for collection of field data, carrying out required laboratory analysis, compilation and synthesis of field data, collation of the data and writing of the report as per the approved guidelines. The duration of field stay of each Officer is as against his/ her name.

Name and designation of the Officer	Total field stay during the FSP (No. of days)	Signature with date
1. <i>K.V. Maruthi, Sr. Geologist</i>	<i>13 (for this study)</i>	<i>Maruthi K.V. 2/3/12</i>
2. <i>K.V. Chandran, Sr. Geologist</i>	<i>13 (for this study)</i>	
3.		

Part-B

This is to certify that drilling has been carried out and completed as per the table given below: *-NA-*

Drilling Unit No	Date of commencement of drilling	Date of completion of drilling	Name and signature of the Director Drilling
1.			
2.			

Part-C

This is to certify that geophysical component of the item has been carried out as per the table given below *-NA-*

Name(s) Designation of the geophysicist	Date of commencement of work	Date of completion of work	Signature of the Geophysicist with date
1.			
2.			
Name of the Director (Geophysics)			
Signature with date			



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logical samples has been carried out as per the

Name of the Director in charge of the Laboratory	Date of receipt of samples from the Field Officer/ party	Date of providing complete analytical results to the Field Officer/ party	Signature with date

Part –E

This is to certify that the Supervisory Officer(s) mentioned below have supervised the above item and have provided guidance to the Field Officer(s). The number of inspection visits and total duration of field visits is as per the table below. It is also certified that the work carried out under the project is of high standards, the norms of field work, lab work etc. have been followed. It is also certified that thorough scrutiny of the report for maintaining the scientific contents and its quality has been overseen.

Name(s) and designation of the Supervisory Officers	No. of inspection visits	Total No. of days spent on inspection visit	Remarks	Signature with date
Shri R.Panduranga, Director	1	09*	From 1.10.2010 to 31.12.2010	Retired
Dr.S.S.Nayak, Director	1	02*	From 01.01.2011 to 15.05.2011	
Dr. H.S.M. Prakash, Director	Nil	Nil	15.05.2011 to 30.08.2011	
Shri. Muhammad Ahamed, Director	1	1	01.09.2011 to 20.10.2011	Transferred
Shri. Subir Dasgupta, Supt. Geologist	1	2	21.10.2011 to 30.01.2012	
Dr.B.R.Venkatesh, Director	Nil	Nil	01.02.2012 to till date	<i>B.R. Venkatesh</i> 12/8/12

*Supervisory officers visited Kadwad landslide site during their inspection visit.

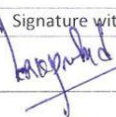


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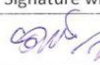
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This is to certify that the report has been thoroughly scrutinized at the Regional Mission Head level. The scientific contents and the quality of the report are certified. The report has been peer reviewed and the needful corrections have been attended to.

Name and designation of the Regional Mission Head	Signature with date
Dr. K.R.K. PRASAD, DIRECTOR (G)	 24.09.2012

Part-G

This is to certify that the report has been scrutinized at various levels and has also been peer reviewed. On being satisfied regarding the scientific content and quality of the report, the undersigned has accorded approval for its circulation.

Name and designation of the Regional HOD	Signature with date
S.C. RATH, Dy.D.G & H.O.D.	 25.09.12

GRPHS OF KADWAD LANDSLDIE

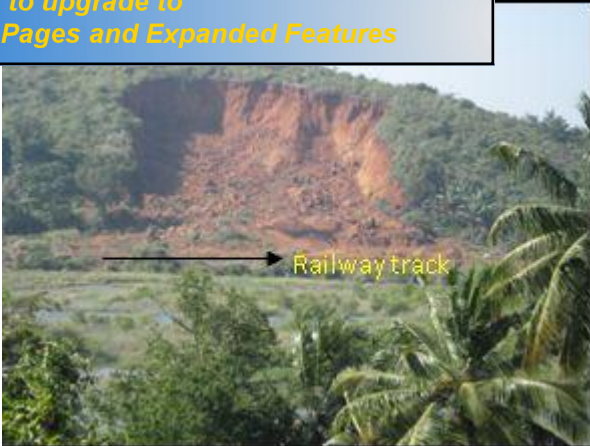


Photo 1: A panoramic view of Kadwad landslide with railway track situated close by



Photo 2: A panoramic view of Kadwad landslide from Konkan railway track



Photo 3: A view of Kadwad landslide from top of crown portion



Photo 4: View of top portion of Kadwad landslide



Photo 5: View of left flank of Kadwad landslide with distinct clay horizon



Photo 6: View of the landslide from the toe of the slide showing the original cut slopes



Photo 7: The body of landslide victim taken out by the rescue team in Kadwad village (Courtesy: www.oneindia.in)



Photo 8: The body of landslide victim taken out by the rescue team in Kadwad village (Courtesy: www.oneindia.in)



Photo 9: The damaged house that has been carried down slope by about 15 m, near the toe part of the Kadwad land slide



Photo 10: Cracks observed in the mid portion of crown



Photo 11: The geological section at the left flank of Kadwad landslide



Photo 12: Vesicular laterite boulder in the debris in the mid slope



Photo 13: Prominent set of joint (J1-N20°W/84°NE) on Granite outcrop on the right flank of the Kadwad landslide



Photo 14: Weathered granite (saprolite) in the slide debris in the mid slope (right flank)



Photo 15: Collection of undisturbed sample (UDS) just below the crown



Photo 16: Weathered granite (saprolite) in the slide debris in the mid slope (left flank)

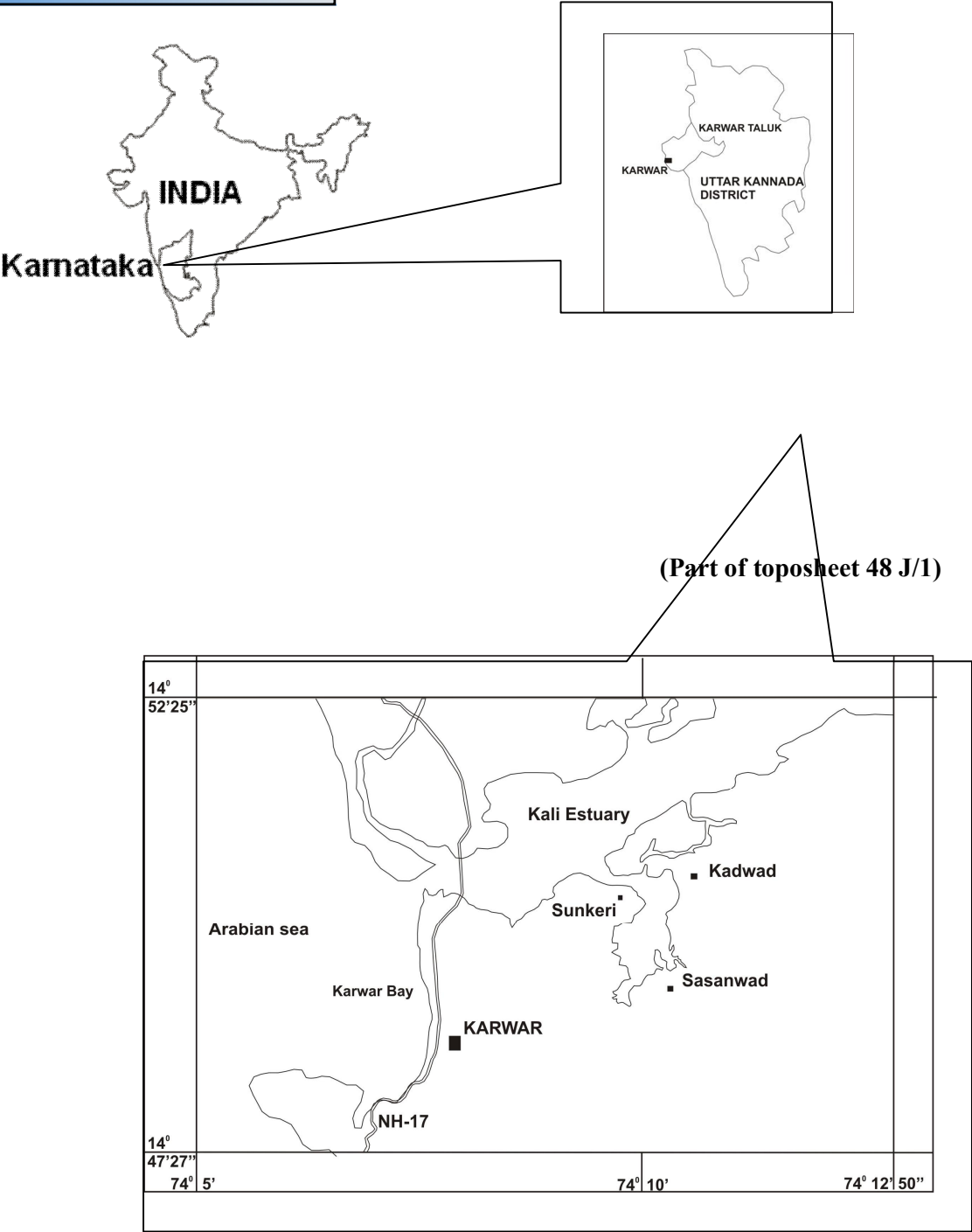


Photo 17: Dug well at the toe



Photo 18: Ground water level in the open dug well at the toe part of the slide

MAP OF KADWAD LANDSLIDE AREA

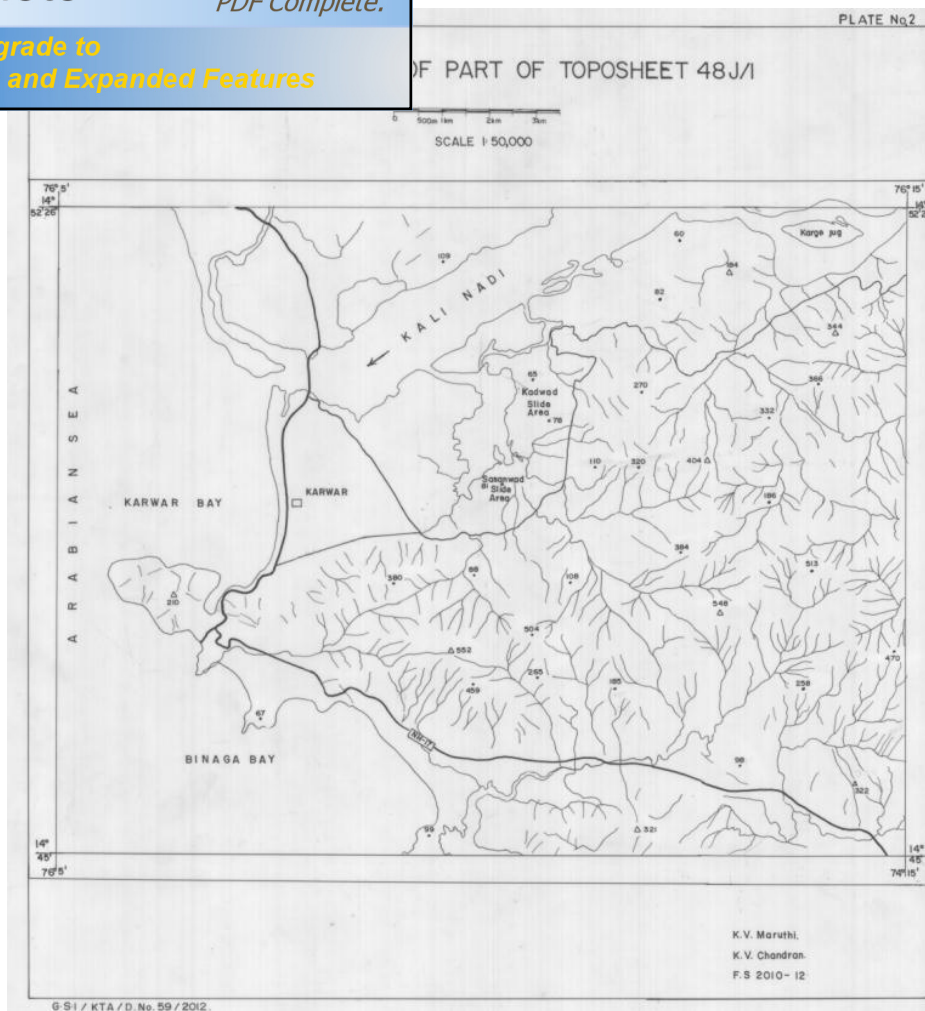


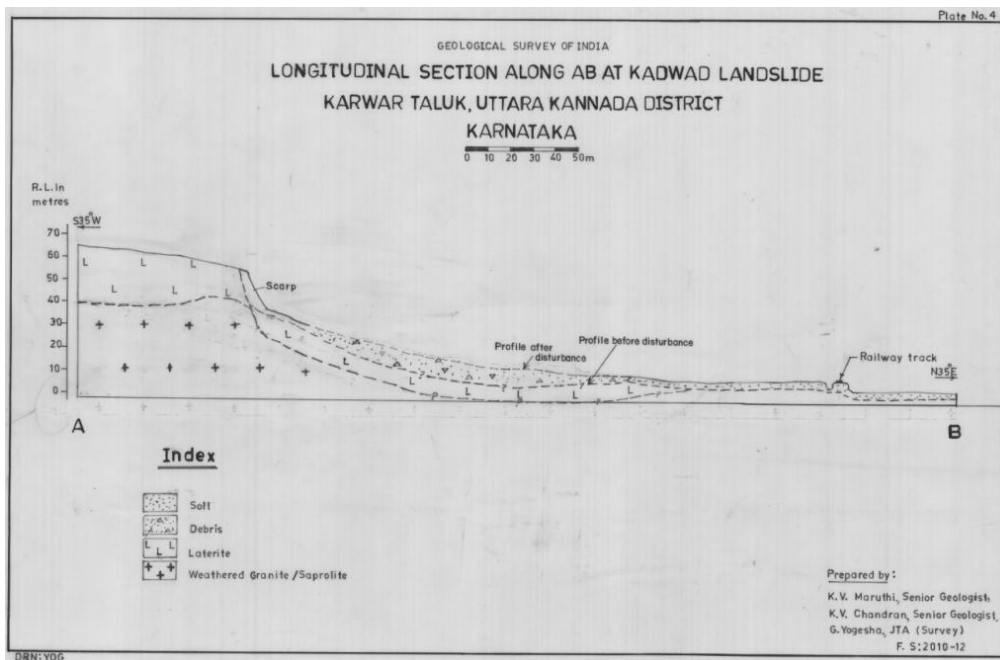
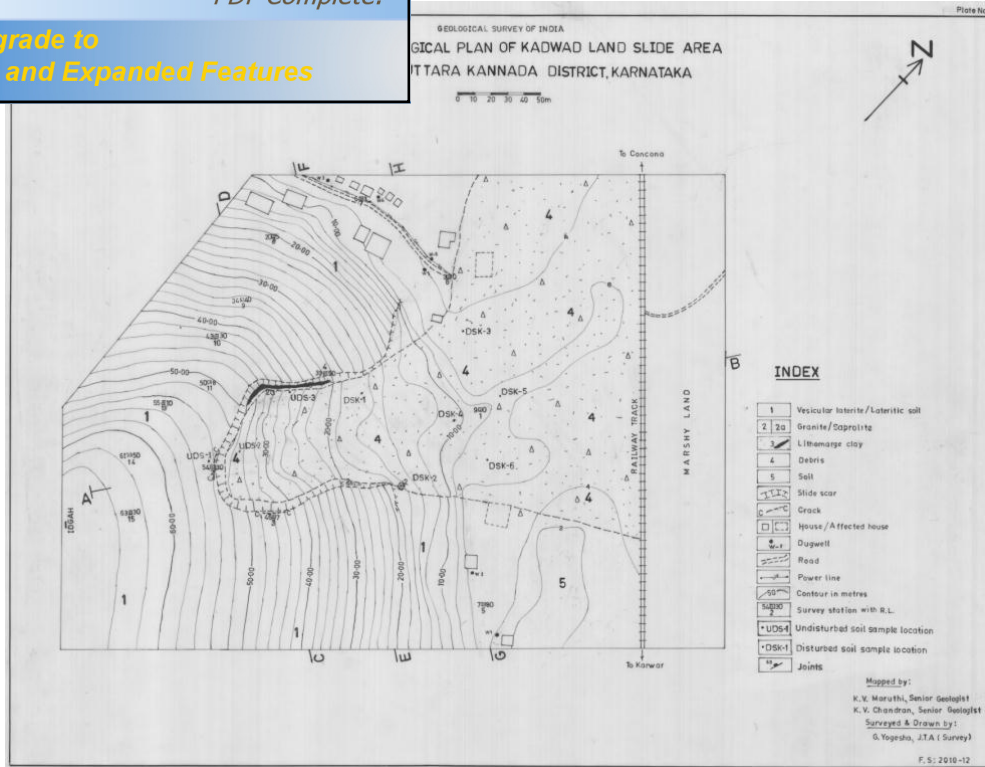


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