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GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

A REPORT ONLANDSLIDE HAZARD ZONATION ON MACRO SCALE OF CHARMUDI GHAT SECTION FROM CHARMUDI TO KOTIGEHARA, KOTIGEHARA TO KALASA AND SAKLESHPUR TO UPPINANGADI IN DAKSHIN KANNADA AND CHIKMAGALUR DISTRICTS, KARNATAKA

(Field Season 2008-2009 & 2009-2010)

Code No.: LHZ/SR/KG/2008/044

BY

A.K. MISHRA, SENIOR GEOLOGIST
U.K.PRADHAN, GEOLOGIST
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GEOLOGICAL SURVEY OF INDIA

Project: ENGINEERING GEOLOGY
State Unit: Karnataka and Goa
BANGALORE

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GEOLOGICAL SURVEY OF INDIA

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GEOLOGICAL SURVEY OF INDIA

ABSTRACT

The landslide hazard zonation (LHZ) of an area aims at identifying the landslide potential zones and ranking them in order of the degree of hazard from landslides. Landslides in Western Ghat has been a continuing problem for years, causing disruption in communication routes, damaging properties and killing people. The menace of this hazard has been restricted to the monsoon season only. The investigation was carried out in GIS platform using proposed guidelines of GSI which includes preparation of slope map, slope morphometry, lithology, structure, land use, land cover, relative relief, slope erosion condition, landslide incidences, average rainfall and finally preparation of Landslide Hazard Zonation map. Factors responsible for landslides and their ratings as envisaged in the guidelines was adhered to calculate the TEHD value and classifying the zones.

The Landslide Hazard Zonation in Macrosacle (1:25,000 scale) covering a buffer of 1 km on either side of the transportation routes were taken up during FS 2008-09 and FS 2009-2010 in two sections. Section -1 includes Charmudi ghat section from Charmudi to Kotigehara and Kotigehara to Kalasa, Dakshina Kannada and Chikmagalur districts of Karnataka and section-2 includes Shiradi ghat section from Sakleshpur to Gundiya (Uppinangadi taluk) along with Sakleshpur –Subramanya road and railway sections, Hassan and Dakshina Kannada districts of Karnataka. A total area of 120 L Km and 240 sq km (60 L Km & 120 sq km in each section) was covered and 152 landslide incidences were studied in the two sections. During investigation it is observed that majority of the landslides are debris or earth slumps and slides occurred due to cutting of the natural slope for making road. The vertical cut slopes have failed due to heavy rain in the ghat section during monsoon. The maximum portion of the study area has a very gentle slope with general slope angle <15º. The lithology of the area is granite, biotite gneiss, meta basalt and granulite.

In both the ghat sections, three hazard zones are identified as per the total estimated hazard value viz. Very Low Hazard zone, Low Hazard zone and Moderate Hazard zone as per the analysis of data and creation of the model using ILWIS 3.3. The recommendation suggested includes, removal of the unstable crown part in some landslides, easing of vulnerable slopes, use of bio-technical measures of slope protection and proper drainage.

A REPORT ON LANDSLIDE HAZARD ZONATION ON MACRO SCALE OF CHARMUDI GHAT SECTION FROM CHARMUDI TO KOTIGEHARA, KOTIGEHARA TO KALASA AND SAKLESHPUR TO UPPINANGADI IN DAKSHIN KANNADA AND CHIKMAGALUR DISTRICTS, KARNATAKA

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1. INTRODUCTION

1.1. Background information

In Karnataka, Western Ghats forms a divide between the cities located in the coastal areas and in the inland areas. For development of these cities a good network of transportation lines is a prerequisite. In recent years a number of roads have been cut through the Western Ghats. This coupled with the changes in agricultural practices from orthodox seasonal crops to plantation (cash crops) such as coffee, tea and rubber have put tremendous pressure on the slopes of the Western Ghats. The adverse effect of this development is the increase in landslide disaster leading to loss of human lives and properties. In order to minimize the landslide risk more work is therefore required in identifying slopes that are prone to landslides. This will help to identify precautionary and preventive measures requires to mitigate future landslide disaster.

Every year monsoon triggers numerous landslides on the Western Ghats. These not only cause direct loss to the roads and railroads but also the indirect loss by blocking of the transportation lines and by disrupting the traffic. The four major transportation routes i.e., SH-64 (state highway passing through Charmudi ghat), SH-66 (state highway connecting Kotigehara and Kalasa), NH-48 (national highway passing through Shiradi ghat), and the Bangalore- Mangalore railroad (between Sakleshpur and Subrahmanya) have been affected by landslides every year.

During FS 2006-07 a preliminary post disaster studies along Charmudi ghat section and the Kalasa-Kotigehara section was carried out by GSI. The landslide inventory of SH-66, SH-64 and NH-48 was prepared by GSI during FS 2007-08 and 2008-09. In pursuance of the item code LHZ/SR/KG/2008/044 of the Geological Survey of India annual programme of field season 2008-2009 and 2009-2010, landslide hazard zonation on macrosacle (1:25,000 scale) on both side of the transportation route of Charmudi ghat section from Charmudi to Kotigehara, Kotigehara to Kalasa, Shiradi ghat section from Sakleshpur to Gundiya (Uppinangadi taluk) and Sakleshpur – Subrahmanya railroad section were taken up during FS2008-09 and FS2009-2010 in parts of Hassan, Dakshina Kannada and Chikmagalur districts of Karnataka. The study involved preparation of thematic maps on slope forming material, slope morphometry, slope, relative relief, landuse, landcover, hydro geological, slope erosion and landslide incidences, based on which landslide zonation has been attempted using modified BIS method. The study included identification of factors contributing to slope instability and assigning weightage to each factor as per the rating given in the modified BIS code.

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1.2. Scope and objectives of the investigation

The landslide hazard zonation (LHZ) of a corridor/ road section aims at identifying the landslide potential zones and ranking them in order of the degree of hazard from landslides.

The objectives of the present study are as follows:

- Preparation of thematic maps on geology, land use, land cover, slope, etc.
- Preparation of landslide inventory,
- Preparation of landslide hazard zonation map using modified BIS method using GIS.

1.3. Location and accessibility

The study area covers approximately one km buffer zone on either side of the transportation roads in parts of toposheet no 48O/8/SE, 48O/12/NW, 48O/8/NW, 48O/8/NE, 48O/12/SW (Charmudi to Kotigehara, Kotigehara to Kalasa) and 48P/13/NW, 48P/10/NW, 48P/9/NE, 48P/9/SE, 48P/9/SW (Shiradi ghat section from Sakleshpur to Gundia, Uppinangadi taluk and Sakleshpur to Subrahmanya railroad section). The route details are given in table below.

Sl.No	Major road/rail	Description	Length (Km)
1	SH-64	Highway connecting Kadur with Kannagad via Chikmagalur, Mudigere, Beltangady, Bhantwal and Kalladka.	137.15
2	SH-66	Highway connecting Gangamula with Kotigehara via Malleshwara, Kalasa and Magundi	94
3	NH-48	National highway connecting Bangalore and Mangalore	40
4	Railroad	Sakleshpur-Subrahmanya railroad	80

Charmudi ghat section

The Charmudi ghat section has been named after the nearest place Charmudi village. This SH-64 passes through Western ghat connecting Dakshina Kannada with Chikmagalur district. The 10.56 km ghat road passes through Beltangady taluk of Dakshina Kannada district and Mudigere taluk of Chikmagalur district. It also connects Dharmasthala, which is one of the revered shrines of Karnataka.

Kotigehara-Kalasa section

This SH-66 is a major road connecting Kotigehara and Gangamula via religious places like Hornadu, Sringeri and Kalasa. The study was undertaken only in section passing through Mudigere taluk of Chikmagalur district.

Sakleshpur to Gundia section (Uppinangadi taluk)

This NH-48 connects Bangalore with Mangalore transecting the Western Ghat between Sakleshpur in Hassan District to Gundia in Uppinangadi taluk in Dakshina Kannada district. The ghat section of Western ghat through which the NH-48 passes is called Shiradi Ghat.

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Sakleshpur –Subrahmanya railroad section

Fig. 1 shows the schematic cross section of the railroad between Sakleshpur and Subrahmanya. The railroad has an elevation difference of 854 m and has an average gradient of 1 in 50.

Fig: 1 Sakleshpur –Subrahmanya railroad section.

1.4. Nature and quantum of work done

The table below shows the nature of work carried out and the quantum achieved.

Sl. No.	Nature of Work	Total work envisaged	Achievements
1	Landslide hazard zonation/ Susceptibility mapping on mesoscale (1: 25,000 scale) using GSI proposed guidelines which includes preparation of DEM, Slope facet map, slope morphometry, Lithology, structure, Land use, Land cover, Relative Relief, Slope Erosion condition ,Landslide incidences, Average annual rainfall, seismicity etc,	100 L. km 200 sq. km	120 L. km 240 sq. km
2	Landslide inventory	As necessary	152 nos

1.5. Climate and rainfall

The area receives heavy rainfall during June to September with an average annual rainfall of about 2500 mm. The area experiences a mild summer with temperature varying between 30°C and 20°C and mild winter with temperature varying between 20°C and 16°C.

1.6. Acknowledgements

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2. REGIONAL GEOLOGY

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2.1 Charmudi-Kotigehara-Kalasa section

The area exposes rocks belonging to Sargur Group, Peninsular Gneiss-I, Western Ghat schist belt, Shimoga schist belt and Bababudan schist belt.

Sargur Group is represented by amphibolite and kyanite-muscovite schist, which occurs as minor lensoidal enclaves within PG-I. Peninsular Gneiss is represented by gneiss and older granitoids, and occupies vast area. At places the PG-1 is migmatitic (Bruce Foote, 1900)

Western Ghat schist belt represented by Kudremukh and Kodchadri formations of Bababudan Group occupies the central and western part of the study area. Kudremukh Formation comprises amphibolite, quartzite, metabasalt, metaultramafite and banded magnetite quartzite. Kodchadri Formation consists of folded sequence of quartz-chlorite schist with persistent bands of banded magnetite quartzite exposed in the northwestern segment of the area. The quartz-chlorite schist with bands of banded magnetite quartzite have folded in antiform and the corresponding synform within metabasalt is located south of Malleshwara.

The western linear strip of Bababudan Group, represented by the lower and the upper most lithounits, is designated as Kalasapura and Mullayyangiri Formations, respectively. These occupy the northeastern corner of the study area. Kalasapura Formation consists of only amphibolite and occurs as a thin linear band along the eastern margin of the belt. Mullayyangiri Formation consists of metabasalt, ferruginous phyllite and bands of banded magnetite quartzite. Granite intrudes into schist's and gneiss in the northwestern segment. It is coarse grained, grey coloured consists of quartz feldspar and minor amounts of accessories. Basic intrusive represented by few dolerite dykes trending mostly in NW-SE directions is confined to northeastern segment of the area. Laterite body is exposed in the southwestern part of the area.

In Banded magnetite quartzite bedding is observed to be NW-SE with steep dip to east along eastern margin of the Western Ghat schist belt. Bedding is NNW-SSE to N-S is noted in Bababudan belt. Schistosity varies from N20^{o}E-S20^{o}W to NE-SW and dip 40^{o}-50^{o} either side in Western Ghat schist belt. It varies from NE-SW dipping westerly to NW-SE dipping easterly in Shimoga schist belt indicating synformal axis and NNW-SSE dipping steep easterly in Bababudan belt. Gneissosity in gneiss trends NW-SE dipping 60^{o} westerly.

2.2 Sakleshpur-Gundia- Subrahmanya section

This section exposes the rocks of Sargur Group, Peninsular Gneiss-I of PGC, Charnockite suite of Archaean age traversed by basic intrusive of Palaeoproterozoic age.

Sargur Group comprise sillimanite schist ± garnet and graphite, amphibolite, banded magnetite quartzite and Meta ultramafites occur as enclaves within PG-I.

Sillimanite schist, with or without garnet and graphite occurring as lensoidal bodies within PGC, is exposed west of Kagneri, two km east of Maranhalli and three km north and 1.5 km NW of Kadmane. Amphibolite occurs as thin lensoidal bodies within PGC in south and southeastern corner i.e., around Attihalli and 2 km SW of Makangadde. Banded magnetite quartzite occurring as tabular bodies within PGC, is exposed in the SW corner, east and SE of Shiradi (12^{o}49'40": 75^{o}36'30") and 2 km east of Herike (12^{o}55'40": 75^{o}31'50"). This body is trending N-S, N20^{o}E-S20^{o}W with vertical

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dips. Meta ultramafites occurring as irregular enclaves within PGC is fine grained, dark grey consisting talc, actinolite and tremolite as exposed north of Ganadahalli ($12^{o}57'30''$: $75^{o}44'40''$) and 2 km south of Kagneri (Chappell & White, 1974; Tom & Prasad, 2010)

PGC occupies 80% of the area and is represented by granitic gneiss, which is migmatitic at places. At places, migmatite shows banding and feature like shleron.

Charnockite suite represented by charnockite and pyroxene granulite are massive to foliated, occurring as small to large lensoidal bodies within PGC. This unit is seen exposed as small lenses in the western part and as a big enclaves in the SE corner and another one at 3 km west of Kadmane.

Profuse basic intrusive represented by dolerite are seen trending N-S to NNW-SSE confined to mostly eastern part. It is fine to medium grained, dark green and consists of mainly pyroxene and plagioclase.

Primary structures observed in the area include colour banding and bedding in banded magnetite quartzite's. Foliation recorded in schist rocks and gneisses trend NE-SW and NNW-SSE dipping either side varying from 60^{o}-75^{o}. Minor folds recorded within the gneiss in the southeastern part of the area.

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3. METHODOLOGY

Landslide Zonation is being carried out using a number of methods. These can be a probabilistic-based method where landslide incidences are used to assign weightage to landslide causal factors or it can be heuristic-based method where weightage is given by experts. An example of the heuristic method is the landslide hazard zonation methodology given by the *BUREAU OF INDIAN STANDARD (BIS) -Doc CED 56(5423).* Geological Survey of India has recently proposed a new method which is a slight modification of original BIS code and in this study the Modified BIS method has been adopted for Landslide zonation along the transportation corridors.

The Modified BIS method of zonation is based on the rating system. Major causative factors considered responsible for the instability under this method are:

Sl no	***Causative factors***	***Maximum LHEF rating***
1	Slope Morphometry	2
2	Lithology	2
3	Structure	2
4	Relative relief	1
5	Land cover	1
6	Land use	1
7	Rainfall	1
8	Hydrological condition	1
9	Landslide incidence	2
10	Slope erosion	1
	Total	*14*

These factors are responsible independently or interdependently for making a slope unstable. Landslide hazard evaluation factor (LHEF) rating being a numerical system, each factor is assigned a maximum rating on the basis of its estimated significance causing instability. Based on such estimates the maximum LHEF rating assigned to various causative factors are given in the above table.

In this study analysis was carried out in GIS platform using ILWIS 3.3 software. At first the study area was demarcated encompassing a buffer area of about one kilometer around the transportation routes. The contours within the study area were digitized and DEM was generated using contour interpolation. From DEM the derivative layers like slope and aspect were generated using ILWIS 3.3. Other layers such as the Landslide inventory, Lithology, Structure, Hydrogeology, Landuse and Landcover were compiled, validated in the field, and then digitized and rasterised. To perform GIS analysis all the layers were projected in UTM (Zone 43) taking WGS84 as spheroid and datum.

3.1. Rating assigned to different thematic (causal factor) variables

Geology /Lithology

Geology of the study area has already been discussed in the above chapter on Regional Geology. The study under this aspect involves preparation of thematic map, which depicts the slope forming material of the area. The slope forming material map for this purpose has been compiled from the available geological map on 1:50,000 scale. The Modified BIS code provides the following ratings to the lithology:

Lithology (LHEF rating-2)

Description	*Category*	*Rating*	*Remarks (Correcting*

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				factor for weathering)
1.Type of rock	Type I	i. Quartzite/Limestone/BHQ etc ii. Granite/Basalt/Charnokite etc iii. Gneiss	0.2 0.3 0.4	i. Highly weathered rock, discolored, joints open with weathered products *Correction Factor C1* ii. Moderately weathered rock discolored with fresh rock patches, weathering more along joint planes, but rock intact in nature. *Correction Factor C2* iii. Slightly weathered rock slightly discoloured along joint planes but intact in nature *Correction Factor C3* *For rock type I-* C1=4, C2=3,C3=2 *For rock type II* C1=1.5, C2=1.25,C3=1.0
	Type II	i. Well cemented terrigenous sedimentary rocks dominantly sandstone with minor beds of claystone ii. Poorly cemented terrigenous sedimentary rocks dominantly sand rock with minor clay shale beds	1.0 1.3	
	Type III	i. Slate and Phyllite ii. Schist iii. Shale with inter bedded clayey and non clayey rocks iv. Highly weathered shale, phyllite and schist	1.2 1.3 1.8 2.0	
2. Soil type		i. Older well compacted alluvial fill material(Old river terraces ii. Clayey soil over bedrock iii. Sandy soil over bedrock iv. Older compacted colluvial material v. Poorly compacted younger loose material or slide debris	0.6 0.8 1.2 1.4 2.0	

These ratings are valid for normal rock conditions. For weathered conditions, correction factors C1, C2, and C3 are to be incorporated. The correction for weathering to be multiplied with the fresh rock rating. For rock Type-1, values for C1, C2 and C3 are 4, 3 and 2 respectively for highly weathered, moderately weathered and slightly weathered conditions. For rock type-2 these values are 1.5, 1.25, and 1.0 respectively for C1, C2 and C3.

Structure

Orientation and disposition of discontinuity planes in the slope forming material has considerable influence in the stability of slopes. Following three relations of discontinuity with slope are considered important:

Structure (LHEF rating -2)

Description	*Category*	*Rating*	*Remarks*
Relationship of structural discontinuity with slope			Discontinuity refers to the planar discontinuity or line of intersection of two planar

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i. Relationship of parallelism between slope and discontinuity(RS) Planar(œj-œз) Wedge(œi-œз) œ	I.>30° II. 15°-30° III. 5°-15° IV. <5°	0.20 0.30 0.40 0.50	discontinuities which ever is important from point of view of stability Œj- Dip direction of joint Œi- Direction of intersection of two discontinuities Œs-Direction of slope inclination
ii. Relationship of discontinuity and inclination of slope(RI) Planar(ßj-ßs) Wedge(ßi-ßs)	I.>15° II. 0°-15° III. -1°-(-15)° IV. >(-15)°	0.3 0.5 0.8 1.0	ßj-Dip of joint ßi-Plunge of line of two discontinuities ßs-Inclination of slope
iii.Dip of discontinuity Planar(ßj)(DP) Wedge(ßi)	I.<15° II. 16°-30° III. 31°-45° IV. >45°	0.20 0.25 0.35 0.50	

In case of the overburden areas, the depth of soil cover is observed to have a directly proportional relation with the instability of the slope. More is the thickness of the overburden cover; greater is the chance of failure. The following ratings is suggested in the code for depth of soil cover:

Description	*Category*	*Rating*	*Remarks*
Depth of soil cover	<5m	0.65	*Category I* Very favourable
	6-10m	0.85	*Category II* favourable
	11-15m	1.20	*Category III* Fair
	16-20m	1.50	*Category IV* Unfavourable
	>20m	2.0	*Category V* Very unfavourable

Slope morphometry

Slope Morphometry exhibits the general slope of the area irrespective of the direction. The slope morphometry or slope angle map was obtained from the DEM using GIS. For convenience of correlation with other factors/ parameters the slopes are further categorised into five categories on the basis of their angle of inclination, following the modified BIS classification:

Slope Morphometry (LHEF rating-2)

Description	*Category*	*Rating*	*Remarks (No. of contour lines of 20m interval over 100m length on 1:50,000)*	*Slope angle*

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i. Escarpment/cliff	>45°	2.0	>25	>45°
ii. Steep slope	36°-45°	1.7	19-25	36°-45°
iii. Moderately steep slope	26°-35°	1.2	13-18	26°-35°
iv. Gentle slope	16°-25°	0.8	8-12	16°-25°
v. Very Gentle slope	<15°	0.5	<7	<15°

Land use and Land cover

Land use and Land cover maps were prepared from the Survey of India (SOI) toposheets 48P/13/NW, 48P/10/NW, 48P/9/NE, 48P/9/SE, 48P/9/SW (for road section from Charmudi to Kotigehara and from Kotigehara to Kalasa) and 48O/8/SE, 48O/12/NW, 48O/8/NW, 48O/8/NE, 48O/12/SW (for the Shiradi ghat section from Sakleshpur to Gundia, Uppinangadi taluk, and the railroad section from Sakleshpur to Subrahmanya.

Land cover protects the slope from the effects of the weathering and the erosional agencies. A well spread root system increases the shearing resistance of the slope forming material. Four categories of land cover are considered in the modified BIS code as given below:

Land cover (LHEF rating-1)

Description	*Category*	*Rating*	*Remarks*
i. Thickly vegetated forest area		0.4	
ii. Moderately vegetated area		0.6	
iii. Sparsely vegetated area with lesser ground cover		0.8	
iv. Barren land		1.0	

Anthropogenic activities over slopes has a far more instant effect in causing instability as evident from the large number of landslide incidences resulting from slope cutting during the road construction activities. Even modification of slopes by large scale excavation for mere purpose of settlement also induces instability to the slopes. For zonation purpose a Landuse map showing the following Landuse types has been considered and rated as per the guidelines:

Land use (LHEF rating-1)

Description	*Category*	*Rating*
i. Agricultural land/populated flat land		0.2
ii. Moderately populated slope/village roads		0.5
iii. Thickly populated slope modified by large scale excavation		0.7
iv. Major communication routes involving extensive slope cutting		1.0

Relative relief

Relief represents maximum height of the slope between its crown and its toe measured in the slope direction. Three categories of slopes are suggested in the guidelines on the basis of their relief.

Relative relief (LHEF rating-1***)***

Description	*Category*	*Rating*	*Remarks*
i. Low	<100m	0.3	In seismic zone II & III the maximum rating for relative relief be multiplied by 0.5.It is also
ii. Medium	101-300m	0.6	

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iii. High	>300m	1.0	considered 5.No correction is required for Zones IV &V

Hydrological condition

Presence of water in a slope considerably influences the shearing resistance if the slope forming material. Under wet conditions the same material offers less resistance than in the dry conditions. In a hilly terrain, water does not have a uniform flow pattern, nor enough data are available on this aspect. Therefore, for the purpose of a quick appraisal three categories of generalised hydro-geological conditions are assumed:

Hydrology (LHEF rating-1)

Description	*Category*	*Rating*	*Remarks*
i. Dry		0.2	
ii. Wet		0.5	
iii. Flowing/spring		1.0	

Rainfall data

Landslides are greatly influenced by the presence of ground water in the sub-soil. It plays a different role during dry spells and at the onset of rainfall. The variation in the depth of groundwater is directly related to the amount of rainfall. Therefore, the guidelines suggest the following categories of rating as per the annual rainfall:

Average annual rainfall (LHEF rating-1)

Description	*Category*	*Rating*	*Remarks*
i. Low	<500mm	0.2	
ii. Medium	500-2000mm	0.4	
iii. High	>2000mm	0.6	
iv. History of cloud bursts		1.0	

Soil erosion

Erosional aspect of a hill slope is an important factor in determining its stability condition. It is observed that deep gully, toe erosion by nalas and rivers alarmingly destabilize slopes. Erosional feature is grouped into three categories for rating purposes:

Slope erosion condition (LHEF rating-1)

Description	*Category*	*Rating*	*Remarks*
i.	Deep gully erosion/rill erosion of hill slope	0.5	
ii.	Severe toe erosion by nala and river	1.0	

Landslide incidences

Presence of landslide, even though it is not a causative factor of slope destabilization but is a direct manifestations of slope instability. For this factor the guidelines suggest the following four groups

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for the purpose of rating. The detail description of landslide type and their morphometry along different sections is given below.

Landslide incidence (LHEF rating-2)

Description	*Category*	*Rating*	*Remarks*
i.	No landslide	0	
ii.	Dormant landslide	0.5	
iii.	One active landslide	1.0	
iv.	More than one slide or one very large active slide(material dislodged>100 cu.m)	2.0	

Landslides along Kotigehara-Charmudi ghat section (SH-64): A total of 45 landslides were recorded within the 15 km stretch of this ghat section. Most of the landslides are shallow debris slumps and earth slumps resulted due to toe cutting of the slope for road construction. Most landslides have been reactivated due to lack of remedial measures. The lithology is mainly granite and biotite gneisses. The vertical (70° to 80°) cut slopes have failed due to heavy rain in the ghat section during monsoon. It was observed that the slopes are moderately to thickly vegetated with slope varying from 10° to 20°. The depth of overburden, consisting of soil and weathered rock, varies from 0.5 to 2.0 m. Six rock slides with wedge failures are also observed (Pradhan & Mishra, 2010; Maruthi et.al 2010).

Landslides along Kotigehara- Kalasa section (SH-66): A total of 24 landslides are recorded in this 40 km stretch of the ghat section. Most of the landslides are shallow debris slumps and earth slumps, which have resulted due to toe cutting of the slope for making road (Pradhan & Mishra, 2010; Maruthi et.al 2010). Out of 24 landslides 20 are located in cut slopes above the road and four in fill slopes below the road. During rains the loose material from fill slopes are removed and flows down causing risk to the State Highways. Failures are common in cut slopes having cut height more than 5 m. The lithology is mainly granite and gneisses. It was observed that the slopes are moderately to thickly vegetated and covered by tea, coffee and spices plantations. General slope angle varies from 10° to 20°. The depth of overburden, consisting of soil and weathered rock, varies from 0.5 to 2.0 m.

Landslides along Shiradi Ghat (NH-48): A total of 54 landslides are recorded in this 40 km stretch of the ghat section. Most of the landslides are shallow debris slides resulted due to toe cutting of the slope for making road (Pradhan & Mishra, 2010; Maruthi et.al 2010). Few old and reactivated slides are also observed. The lithology is granite, biotite gneisses and granulite. The loose and non-cohesive materials overlying the bed rock have failed due to increase in pore water pressure during rain. It was observed that the slopes are moderately vegetated and general slope angle varies from 10° to 25°.The overburden depth varies from 1-5m. One rock slides with planner failures is also observed.

Landslides along SH-64 between Chikmagalur district boundary and Beltangady road sections: A total of 29 landslides are recorded along 34 km stretch of this ghat section. Most of the landslides are shallow debris slides and slumps caused mainly due to toe cutting for road construction. The general slope angle varies from 25° to 35°. The slopes are moderately vegetated. The overburden thickness varies from 1-5 m and consists of soil and weathered rock. The cut slope angle is 70° to 80° with height varying from 2-15 m. geologically, the section comprises of granite and gneisses.

Landslide Hazard Zonation

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The Landslide Hazard Zonation Map is prepared according to Total Estimated Hazard (TEHD) of each facet by superimposing the slope facet map successively one by one over all thematic maps. The THED of the facet is calculated after adding the Landslide Hazard Evaluation Factor (LHEF) values of all ten geoenvironmental parameter encompassing the particular facet. The following table has been adopted for the preparation of the Landslide hazard Map. For obtaining Total Estimated Hazard (TEHD) of a slope the ratings of the different causative factors are added up. TEHD has been divided into five zones in increasing order of susceptibility. The analysis is performed in GIS.

Zone	*THED Value*	*Description of zone*
I	<4.9	Very Low Hazard Zone(VLHZ)
II	4.91-7.0	Low Hazard Zone(LHZ)
III	7.1-8.4	Moderate Hazard Zone(MHZ)
IV	8.41-10.5	High Hazard Zone(HHZ)
V	>10.5	Very High Hazard Zone(VHHZ)

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4. MACROSCALE LANDSLIDE HAZARD ZONATION

4.1 Section between Charmudi-Kotigehara-Kalasa, Chikmagalur and Dakshina Kannada districts, Karnataka

4.1.1 Thematic maps

Facet map

The BIS defines the smallest map unit for zonation as "facet". A facet is a part of the hill slope which has more or less similar characters of slope showing consistent direction and inclination. In this study facets are represented by grid of uniform size, obtained by integrating slope and aspect maps (Plate-4 and 7). The direction component of a facet is obtained from the aspect map, which is a derivative of DEM. In this section the number of facets is more or less uniformly distributed in seven classes. Maximum (39%) number of facets is southerly facing (Fig. 2).

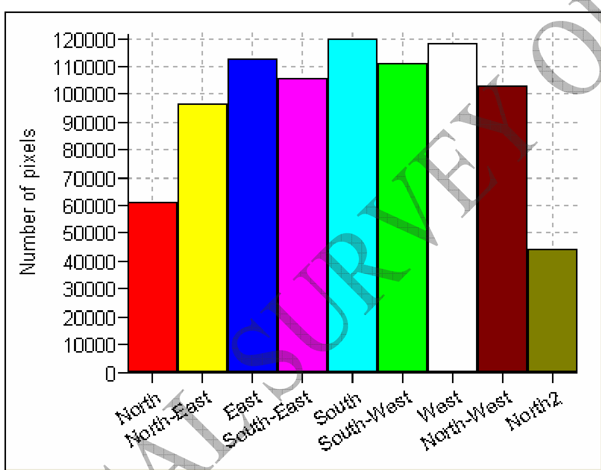

Fig.2. Distribution of slope direction between Charmudi-Kotigehara-Kalasa.

Slope morphometry map

The slope map of the area was created from the DEM and was reclassified into five classes as per modified BIS code (Plate-3). The maximum (90%) of the study area is covered by very gentle slope (slope angle <15º), Fig. 3.

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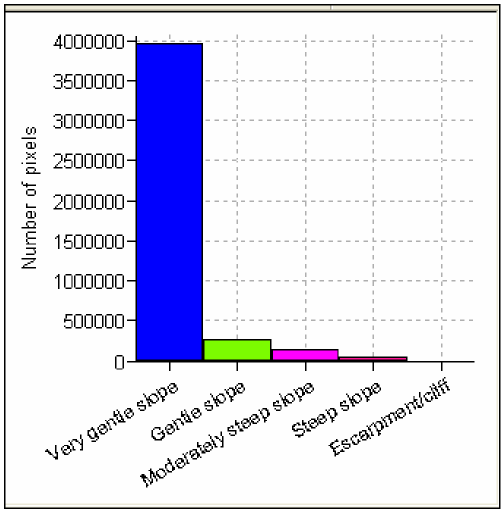

Fig.3. Distribution of slope between Charmudi-Kotigehara-Kalasa.

Lithology

The lithological classification of the area has been carried out using the available geological maps. Each facet is rated based on the type of lithology or depth of overburden/soil present as indicated in the modified BIS code.

Structure

The structural classification of the area has been carried out from the data collected during field investigation. The structural element studied in the field includes dip direction of joints, dip of joints, direction of slope inclination, inclination of slope, plunge of intersection line of two discontinuities, direction of intersection of two discontinuities. For facets where rock is exposed, the structure rating is given based on the relation of discontinuities with slope as indicated in the modified BIS code.

Relative relief map

The relative relief map was prepared from the 1:25,000 scale Survey of India toposheets. The maximum relative relief is found to be below 100 m throughout the section. The modified BIS code envisages that the influence due to seismicity is to be included into the relative relief factor. As area lies in seismic zone III the rating for the whole area has been given $0.3\times0.5= 0.15$.

Land cover map

The land cover includes dense scrub, Open scrub, Cardamom plantation, Coffee plantation, Open jungle, Eucalyptus plantation and fairly dense mixed jungle. These land cover were grouped into different classes as suggested by modified BIS guidelines. The coffee and cardamom plantation were grouped as thickly vegetated forest area, while the eucalyptus plantation into moderately vegetated area. The thickly vegetated forest area and the sparsely vegetated area cover most part of the study section (Plate-6).

Land use map

The land use pattern of an area depends on two factors viz. the natural set up and the human interference. The natural factors include topography, rainfall and climate, and the human interference is mainly due to the density, occupation of people, extent of technological development and socio-economic factors. Physical factors and human activity influences land use pattern. The different landuse type in this section are agricultural land/populated flat land, major communication route involving extensive slope cutting and moderately populated slope/village road. Thickly

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populated slope modified by large scale excavation is not considered as the study area is restricted to 1 km buffer around the road. The Agricultural land/populated flat land are mainly restricted to the valleys and the modified stream banks. Roads transecting coffee and tea estates have been included in moderately populated slope/village roads class. The major communication route involving extensive slope cutting includes the major NH and state highways and the railroad. The category classed as "major communication routes involving extensive slope cutting" is given the maximum rating (Plate-5).

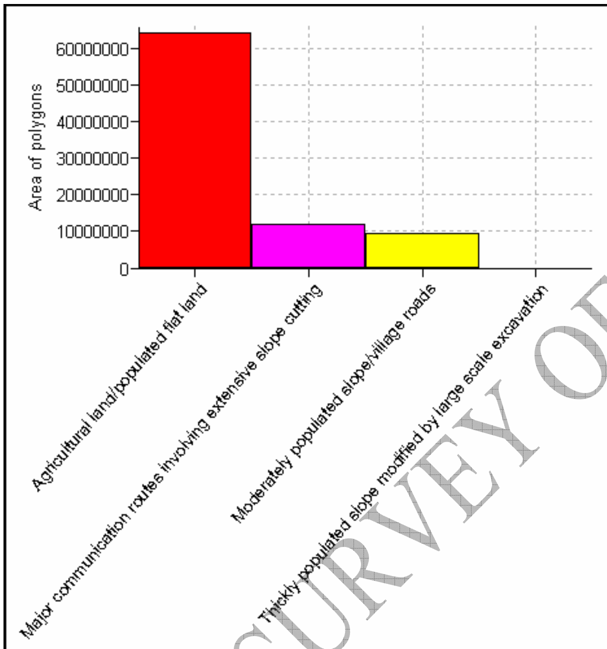

Fig 4. Distribution of different landuse types in the study area.

Hydrogeology

A uniform rating is assigned to all mapping units as no sign of spring is observed along the road. Furthermore, since the area is wet in rainy season and dry during non-rainy season therefore a single rating is reasonable.

Average annual rainfall

The average annual rainfall is more than 4000 mm as noted in the rain gauge stations located in Kotigehara, Kalasa and Javali. The rainfall data of these rain gauges are provided in Annexure - 1. As per the BIS rating the whole area has been kept in high category with a rating of 0.6. Fig. 5 to 10 shows the monthly distribution of rainfall in different years as measured in different rain gauges.

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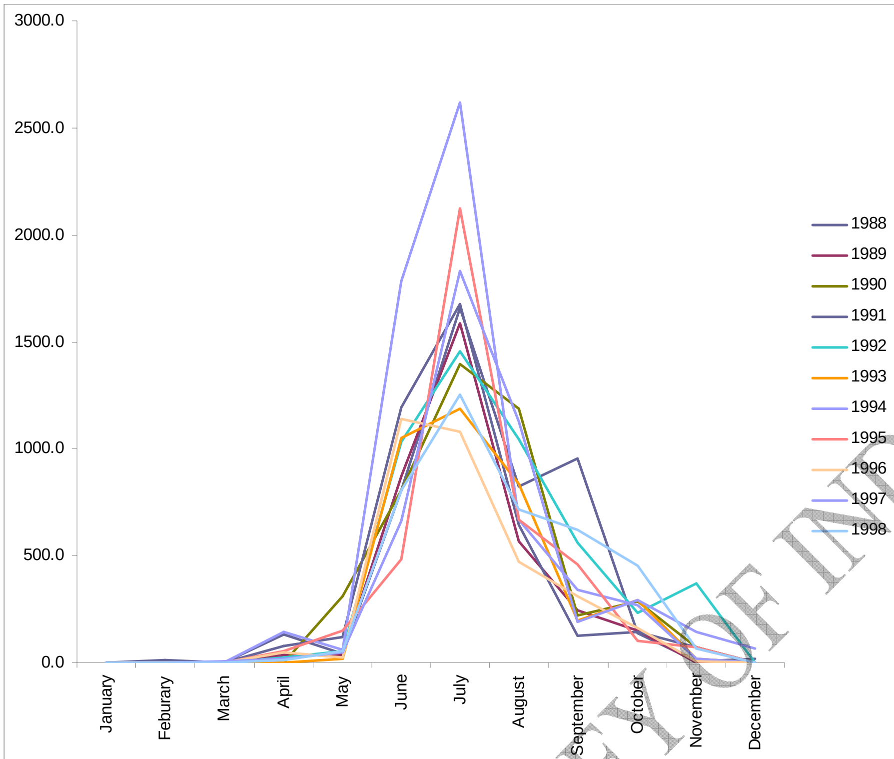

Fig 5. Distribution of rainfall pattern of Kotigehara rain gauge station from 1988 to 1998.

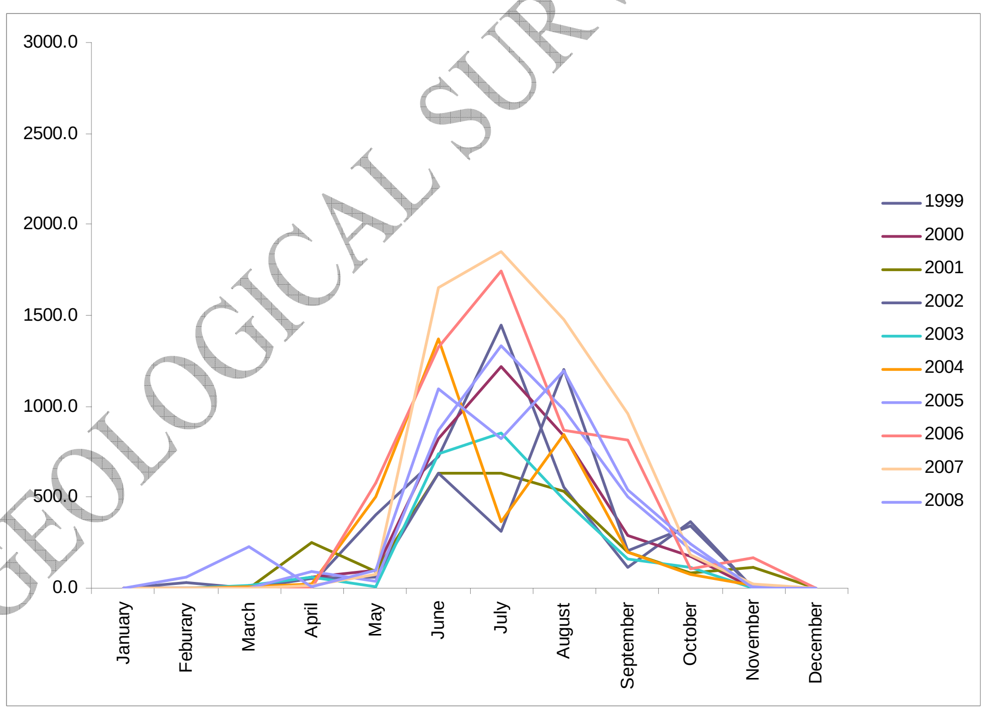

Fig 6. Distribution of rainfall pattern of Kotigehara rain gauge station from 1999 to 2008. The aaverage annual rainfall in Kotigehara is 4041 mm.

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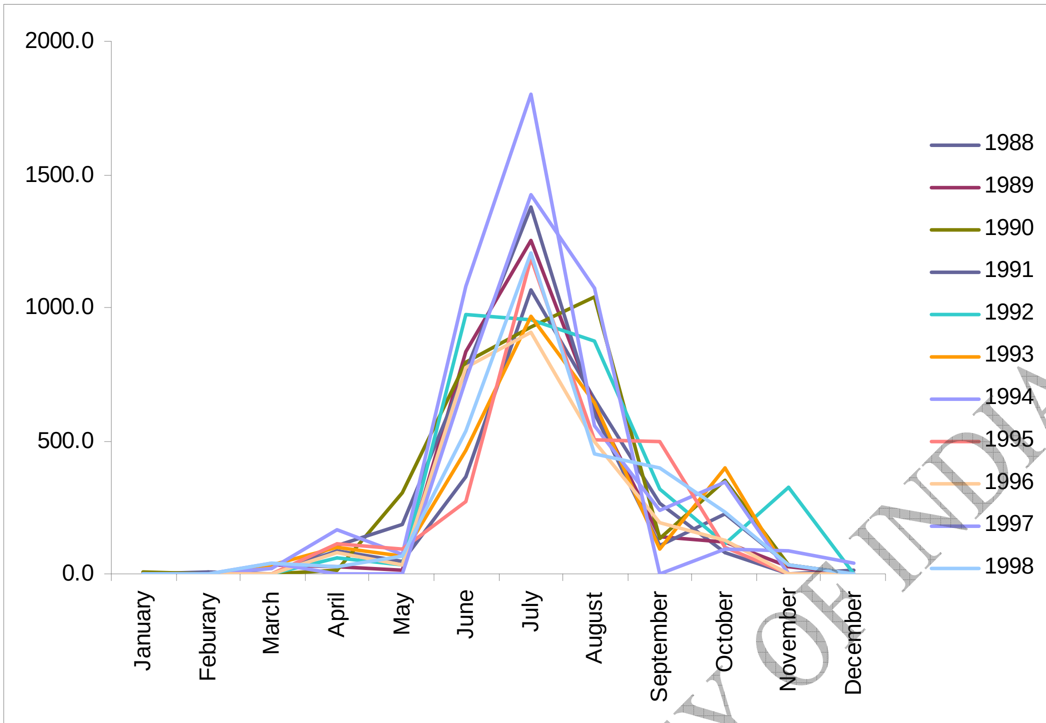

Fig 7. Distribution of rainfall pattern of Kalasa rain gauge station from 1988 to 1998.

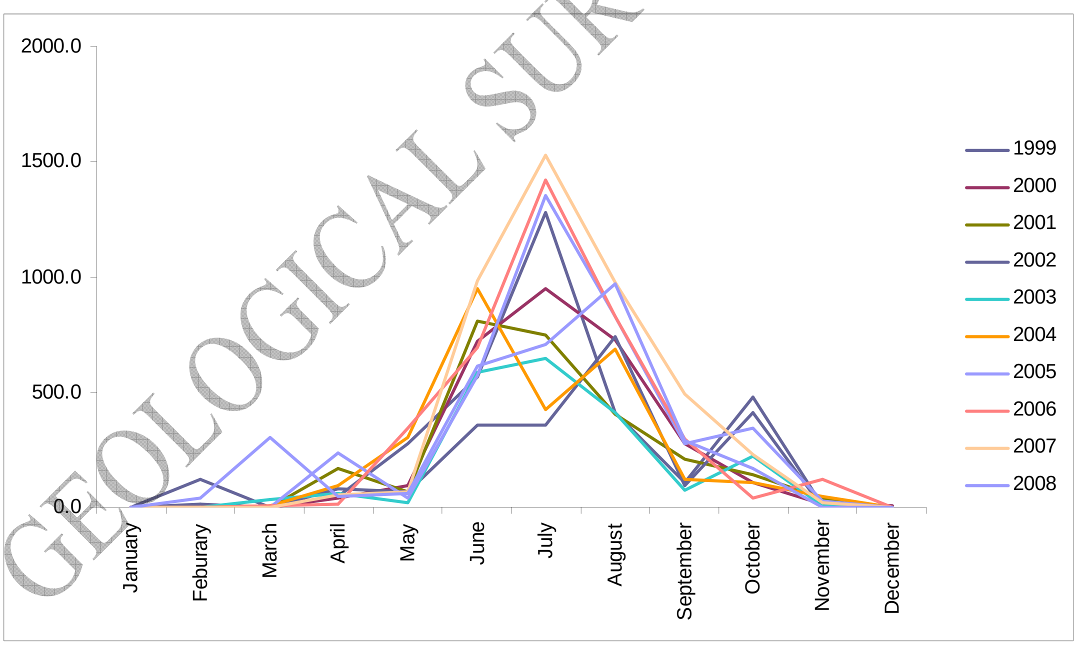

Fig 8. Distribution of rainfall pattern of Kalasa rain gauge station from 1999 to 2008. The average annual rainfall in Kalasa is 3140.2 mm.

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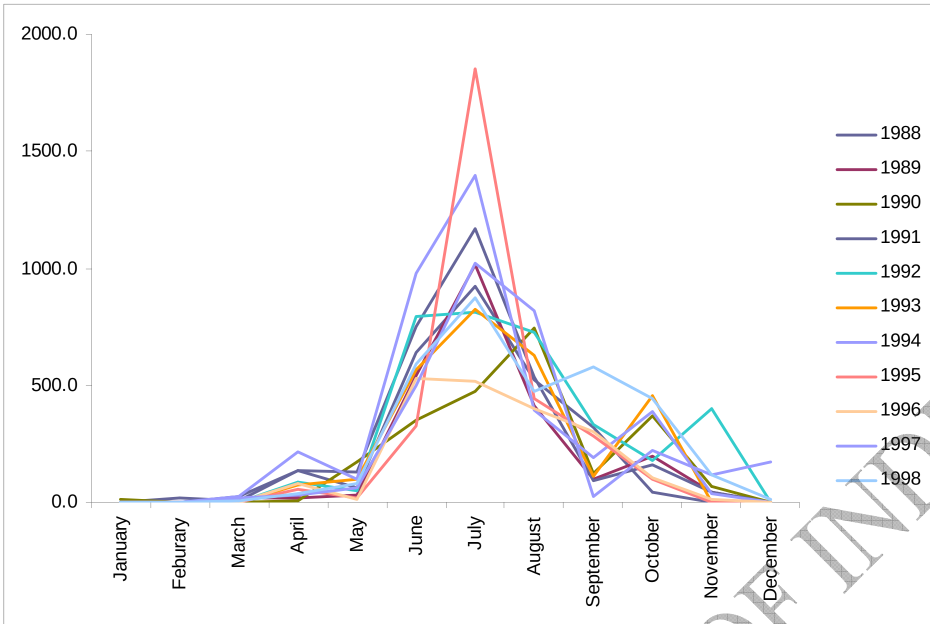

Fig 9. Distribution of rainfall pattern of Javali rain gauge station from 1988 to 1998.

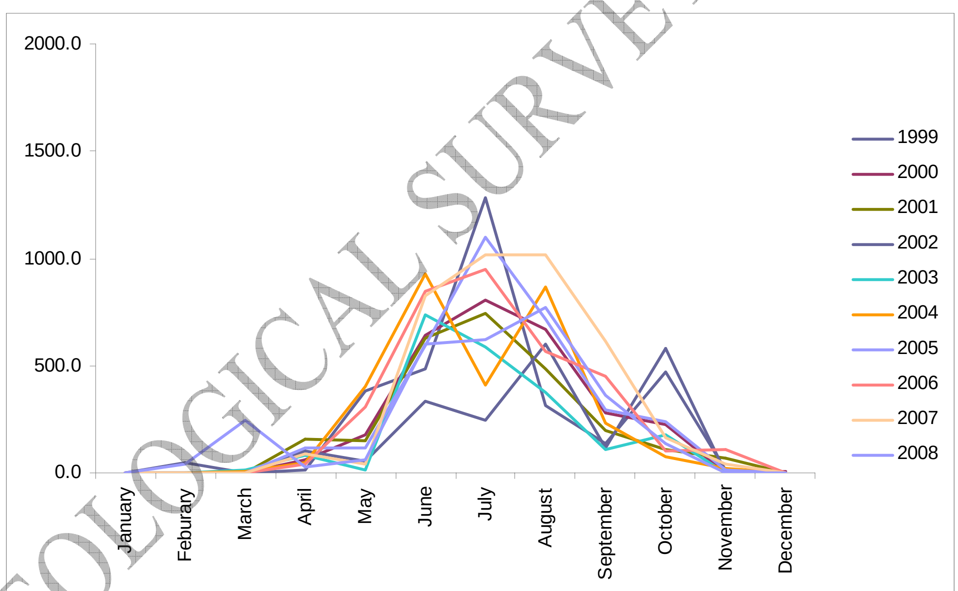

Fig 10. Distribution of rainfall pattern of Javali rain gauge station from 1999 to 2008. The average annual rainfall in Javali is 4255.77 mm**.**

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Slope erosion condition

The Western Ghats are relict mountains having very low relief. The Charmudi lies in the highest part of the Western Ghats and therefore the area is not prone to severe toe erosion by nala or river. However, considering the fact that there is always a possibility of having slope erosion by torrent streams during heavy rains, the whole area has been kept in the category of Deep gully erosion/rill erosion of hill slope with the maximum rating of 0.5.

Landslide incidences
The landslide rating was assigned depending on the presence or absence of landslides in a facet as suggested by the modified BIS guidelines.

4.1.2 Landslide hazard map for Charmudi-Kotigehara-Kalasa section

All the thematic maps after being assigned LHEF ratings for different factors as per the modified GSI code "Total Estimated Hazard value (TEHD value)" was calculated by adding ratings of individual causative factors per facet in GIS. The TEHD values were regrouped to classify the investigated area as 1) very low, 2) low and 3) moderate hazard zones. Palate-8 shows the obtained Landslide Hazard zonation map and Fig 11 shows the statistics.

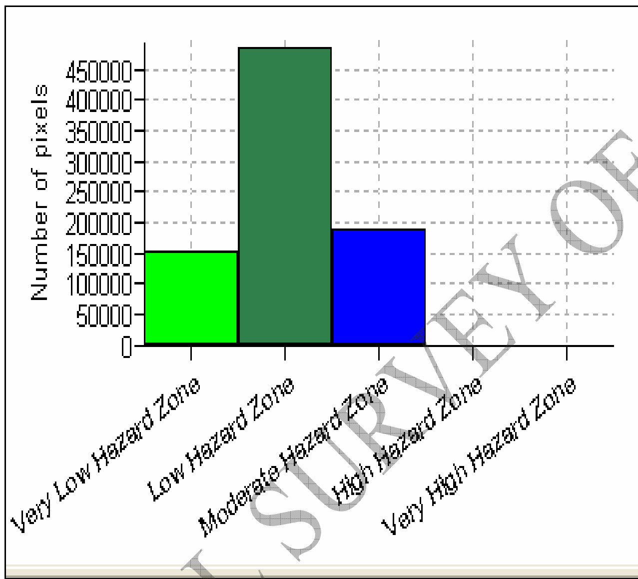

Fig11. Distribution of Landslide hazard zones

The characteristics of different zones have been described below (also see Table below):

Very Low Hazard zone: Very low hazard zone covers an area of 11 sq. km i.e., about 18 % of the total study area. This includes flat agricultural lands in the valleys and the low lying areas with very low relative relief.

Low Hazard zone: Around 59 % of the total area lies in Low Hazard Zone covering 35 sq. km area. It covers major part of the study area.

Moderate Hazard zone: About 23% of the area (14 sq. km) lies in Moderate Hazard Zone. The moderately hazard zone lies along the national highway and state highway. It is mostly restricted to NW and SW part of the investigated area.

High Hazard zone and Very High Hazard Zone: These zones are not present in this area.

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Area covered by different susceptibility classes in the study area.

Type of Hazard zones	**Area covered (in sq. km)**	**% of total area**
Very Low Hazard Zone(VLHZ)	10.98	18.31
Low Hazard Zone(LHZ)	35.30	58.84
Moderate Hazard Zone(MHZ)	13.70	22.84
High Hazard Zone(HHZ)	0	0
Very High Hazard Zone(VHHZ)	0	0

4.2 Section between Sakleshpur-Subrahmanya, Hassan and Dakshina Kannada districts, Karnataka

4.2.1 Thematic maps

Facet map

In this study facets are represented by grid of uniform size, obtained by integrating slope and aspect maps (Plate-11 and 12). The direction component of a facet is obtained from the aspect map, which is a derivative of DEM. In this section the number of facets is more or less uniformly distributed in seven classes. Maximum (39%) number of facets is southerly facing (Fig. 12).

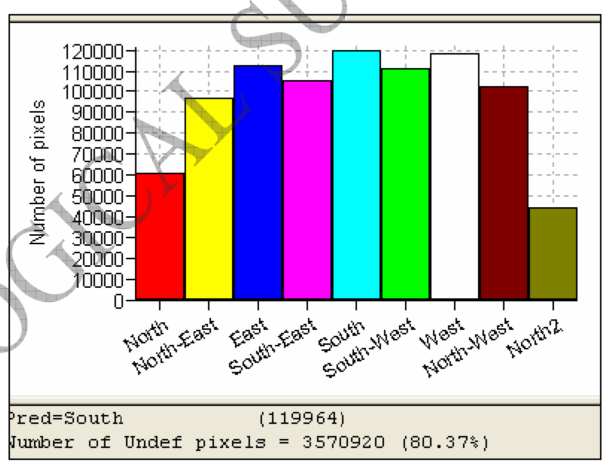

Fig12. Distribution of slope direction between Sakleshpur-Subrahmanya.

Slope morphometry map

The slope map of the area was created from the DEM and was reclassified as per modified BIS code. The maximum (89%) portion of the study area has a very gentle slope with general slope angle <15º (Fig. 13, Plate-10)

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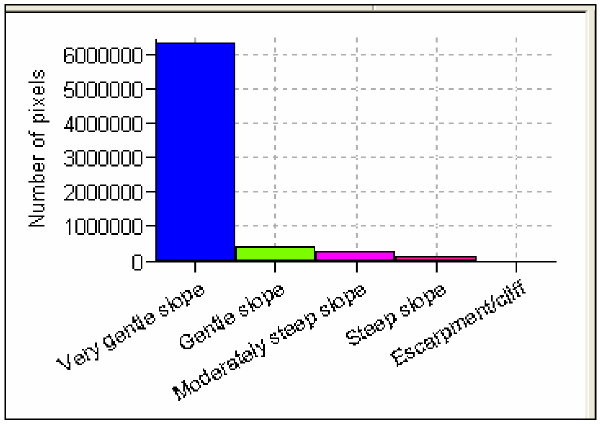

Fig 13. Distribution of slope type between Sakleshpur-Subrahmanya.

Land use map

The different landuse type in this area are the agricultural land/populated flat land, major communication route involving extensive slope cutting and moderately populated slope/village road. Thickly populated slope modified by large scale excavation are not considered here as the study area is restricted to 1 km buffer around the road. The Agricultural land/populated flat land are mainly restricted to the valleys and the modified stream banks. The roads into the coffee and tea estates have been also included in moderately populated slope/village roads class. The major communication route involving extensive slope cutting includes the major NH and state highways and the railroad. The category classed as "major communication routes involving extensive slope cutting" has been given the maximum rating (Plate-13).

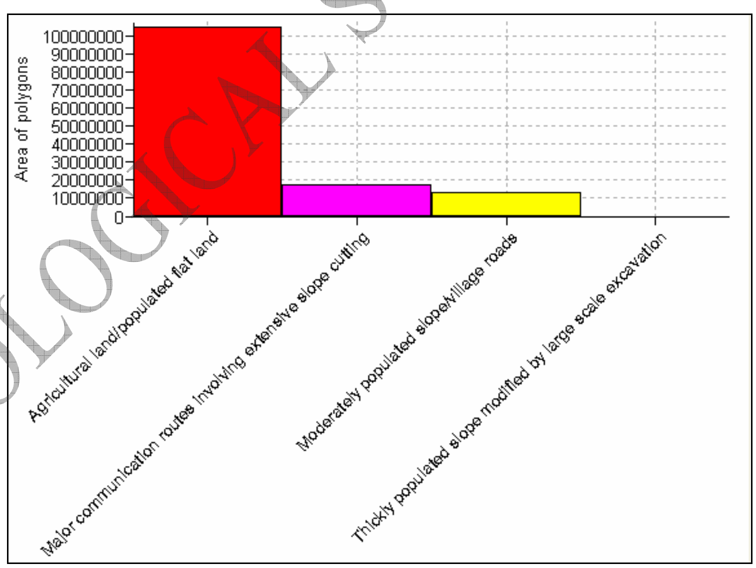

Fig 14. Distribution of different landuse types in the study area.

Land cover map

Dense scrub, Open scrub, Cardamom plantation, Coffee plantation, Open jungle, Eucalyptus plantation and fairly dense mixed jungle are the main land cover in this study section. These land covers were grouped into different classes as suggested by modified BIS guidelines. The coffee and cardamom plantation were grouped as thickly vegetated forest area, while the eucalyptus plantation

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into moderately vegetated area. The thickly vegetated forest area and the sparsely vegetated area cover most part of the study area (Plate-14).

Average annual rainfall

The area receives an average annual rainfall of more than 2000 mm. The rainfall data has been collected from the rain gauge stations in Sakleshpur and Maranhalli. As per the BIS rating the whole area has been kept in high category with a rating of 0.6. Fig. 15 and Fig. 16 show the monthly distribution of rainfall in different years as measured in these rain gauges.

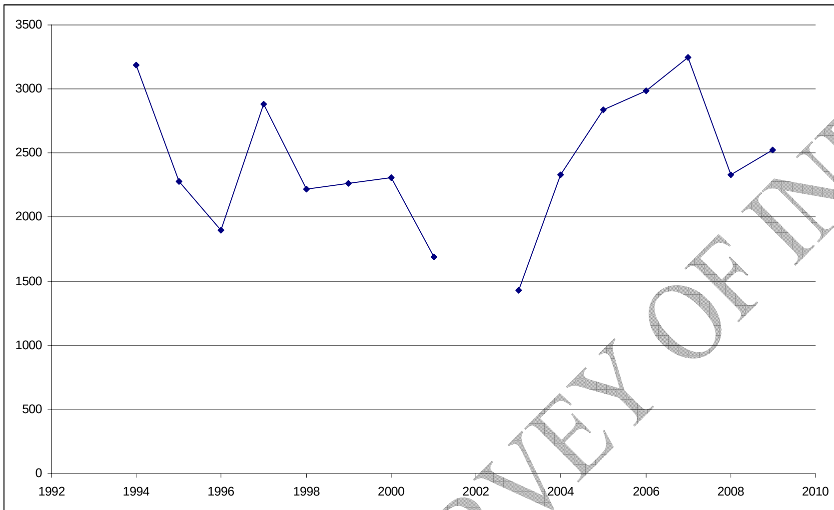

Fig 15. Distribution of rainfall in Sakleshpur area between 1994 and 2009. The annual rainfall is 2427 mm.

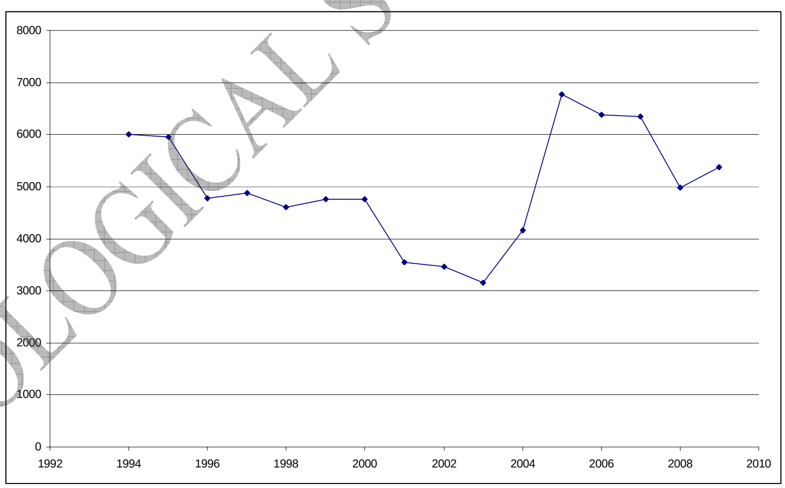

Fig 16. Distribution of rainfall in Maranhalli area between 1994 and 2009. The annual rainfall is 4993 mm.

4.2.2 Landslide hazard susceptibility map for Sakleshpur-Subrahmanya section

All the thematic maps after being assigned LHEF ratings for different factors as per the modified GSI code. Total Estimated Hazard value (TEHD value) was calculated by adding ratings of individual causative factors per facet in GIS. The TEHD values were regrouped to classify the investigated area as 1) very low, 2) low and 3) moderate hazard zones. Palate-8 shows the obtained Landslide Hazard zonation map and Fig 17 shows the statistics.

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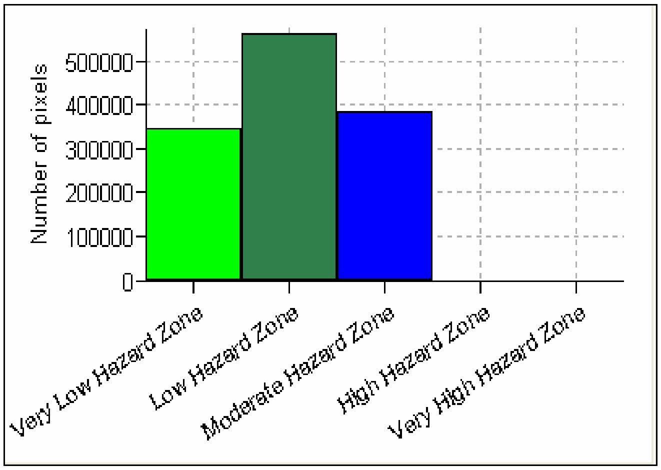

Fig 17. Distribution of landslide hazard zones.

The characteristics of different zones have been described below:

Very Low Hazard zone: Very low hazard zone covers an area of 16.15 sq. km, which is about 27 % of the total study area. This area is distributed all over and is mainly includes the flat agricultural lands in the valleys and the low lying areas having very low relative relief.

Low Hazard zone: Around 43 % of the total area lies in Low Hazard Zone covering 26.03 sq. km area.

Moderate Hazard zone: About 30% of the area lies in Moderate Hazard Zone covering an area of 17.82 sq. km .The Moderately hazard zone lies along the national highway and state highway.

High Hazard zone and Very High Hazard Zone: These zones are not present in this area.

Area covered by different susceptibility classes in the study area.

Type of Hazard zones	Area covered (in sq. km)	% of total area
Very Low Hazard Zone(VLHZ)	16.15	26.92
Low Hazard Zone(LHZ)	26.03	43.39
Moderate Hazard Zone(MHZ)	17.82	29.70
High Hazard Zone(HHZ)	0	0
Very High Hazard Zone(VHHZ)	0	0

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5. CONCLUSIONS AND RECOMMENDATIONS

The landslide hazards, in general cannot be completely prevented, however, the intensity and severity of their impacts can be minimized if the problem is recognized before the development activity. The above study was carried out to bring out the susceptibility of the slopes to failure in two corridor section. Section -1 is from Charmudi to Kotigehara and Kotigehara to Kalasa, Dakshina Kannada and Chikmagalur districts of Karnataka and section-2 includes Shiradi ghat section from Sakleshpur to Gundia (Uppinangadi taluk) along with Sakleshpur –Subrahmanya road and railway sections, Hassan and Dakshina Kannada districts of Karnataka.

A total area of 120 L. km and 240 sq. km (60 L. km & 120 sq. km in each section) were covered and 152 landslide incidences were studied in two sections (Annexure 1). During investigation it is observed that majority of the slides are debris slides occurred due to cutting of the natural slope for making road. The vertical cut slopes have failed due to heavy rain in the ghat section during monsoon. The maximum portion of the study area has a very gentle slope with general slope angle $<15^{o}$. The lithology of the area is granite, biotite gneiss, meta basalt and granulite.

The DEM was generated using contour interpolation and slope and aspect maps were generated from DEM using ILWIS 3.3 software. The other layers include lithology, structure, hydrogeology, slope morphometry, land use, land cover and landslide Incidences. These thematic maps were utilized to generate a landslide susceptibility map. The thematic layers prepared were on the basis of the BIS code modified by GSI. The analysis of data and creation of the model was carried out in ILWIS 3.3. Accordingly three zones were identified in each sections as per the total estimates hazard value viz:

- In section-1: Very low hazard zone covers an area of 10.98 sq. km covering 18 % of the total study area. Around 59 % of the total area lies in Low Hazard Zone covering 35.30 sq. km area. It also lies in majority part of the investigated area. About 23% of the area lies in Moderate Hazard Zone covering an area of 13.70 sq. km. The Moderately hazard zone lies along the national highway and state highway. It is mostly restricted to NW and SW part of the investigated area. High Hazard zone and Very High Hazard Zone are not present in the investigated area.
- In Section-2: Very low hazard zone covers an area of 16.15 sq. km covering 27 % of the total area investigated. Around 43 % of the total area lies in Low Hazard Zone covering 26.03 sq. km area. It also lies in majority part of the investigated area scattered. About 30% of the area lies in Moderate Hazard Zone covering an area of 17.82 sq. km. The Moderately hazard zone lies along the national highway and state highway. High Hazard zone and Very High Hazard Zone are not present in the study area.

Spatial prediction of landslide potential slopes through landslide hazard zonation input is an important tool for disaster management. The different methods have their own merits and demerits. Since the landslide contributing factors vary from region to region, uniform rating criteria can not be applied to different geo-environmental condition. The scheme of classifying factors responsible for landslides in Western ghats should be worked out prior to taking up other landslide zonation projects in these areas.

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Based on the present study the following recommendations are made and should be taken up by the town planners prior to start any development activities.

1. Proper drainage should be maintained. The water from the hill may be diverted in the following ways in order to minimize the slide,
   - making contour drainage at the top of the slopes,
   - the catch water drains in the sections,
   - inserting horizontal perforated pipes in to the slopes which will act as weep holes in the vertical slopes thus reducing the pore pressure by draining out the excess water. This is to be given at suitable interval as per the site condition.
2. Vertical cut slopes should be avoided in future as it does not give stability in such terrain.
3. Retaining structures like retaining wall, stone pitching and gabions are recommended as per the site condition.
4. Geometrical modification of the slope by grading and benching is recommended.

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REFERENCES

Bruce Foote, R. 1900 Geological notes on traverses through Mysore State. Mem. Mys.Geol. Dept. Vol.XIV, Pt. II, PP61-707.

Chappell, B.W., White, A.J.R., (1974) Two contrasting granite types. Pacific. Geol. vol. 8, 173-174.

Maruthi, K.V., Pradhan, U.K., Mishra A.K.,(2010) A report on landslide inventory along NH & SH of ghat roads in Chikmagalur, Coorg and Shimoga districts, Karnataka, Unpublished Progress Report for the FS 2008-09,GSI

Pradhan, U.K., Mishra A.K.,(2010) A report on landslide inventory along NH & SH of ghat roads in Karnataka, Unpublished Progress Report for the FS 2007-08,GSI

Tom, N. G., Prasad, A. V. K.(2010) Specialized thematic mapping of the peninsular gneissic complex along E-W corridor from Hirisave to Mangalore in Hassan and Dakshina Kannada districts, Karnataka, Unpublished Progress Report for the FS 2007-09,GSI

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<u>SYNOPSIS OF WORK DONE</u>

1.	Title of the report	**A REPORT ON THE LANDSLIDE HAZARD ZONATION ON MACRO SCALE OF CHARMUDI GHAT SECTION FROM CHARMUDI TO KOTIGEHARA,KOTIGEHARA TO KALASA, SAKLESHPUR TO UPPINANGADI, DAKSHIN KANNADA AND CHIKMAGALUR DISTRICTS, KARNATAKA**
2.	Item No.	**Code No.: LHZ/SR/KG/2008/044**
3	Field Season	2008-2009 & 2009-2010
4	Date of commencement	1.10.2008
5	Date of completion	30.09.2010
6	Officers Associated with investigation and No. of days spent in the field	A.K. MISHRA GEOLOGIST(Sr) U.K.PRADHAN GEOLOGIST K.V.MARUTHI GEOLOGIST(Sr)
7	Quantum of work done (i) LHZ (1: 25000 scale)	 120 L Km (240 Sq km)
8	Analysis carried out 1) AAS-MIBK for Au 2) ICP-AES	 NA
9	Elements analysed	NA
	Expenditure (1) POL (2) Wages (3) Misc.	 27,215/- 10,082/- 16,514/-
	Other information if any	
1 2 3	Signature of the officer	Sd/- Sd/- Sd/- A.K. MISHRA GEOLOGIST(Sr) U.K.PRADHAN GEOLOGIST K.V.MARUTHI GEOLOGIST(Sr)

GEOLOGICAL SURVEY OF INDIA

LOCALITY INDEX

Section 1: Charmudi-Kotigehara-Kalasa section

Locality	Latitude	Longitude	T. S. No.
Donigal R.S.	12^{0}54′28"	74^{0}45′00"	48P/13/NW
Charmadi	13^{0}03′11.32"	75^{0}25′31.0"3	48O/8/SE
Anta	13^{0} 03′15.32"	75^{0}25′17.16"	48O/8/SE
Marankai	13^{0}03′34.02"	75^{0}25′24.64"	48O/8/SE
Gondulugadde	13^{0}04′24.91"	75^{0}27′36.03"	48O/8/SE
Somanakadu	13^{0}05′44.01"	75^{0}29′08.11"	48O/8/SE
Bidaratale	13^{0}06′27.59"	75^{0}28′40.07"	48O/8/SE
Jenu Kallu	13^{0}05′59.31"	75^{0}28′58.34"	48O/8/SE
Ukkada	13^{0}08′59.07"	75^{0}30′19.04"	48O/12/NW
Darbarpet	13^{0}09′12.51"	75^{0}30′19.04"	48O/12/NW
Ajjikodgi	13^{0}08′25.30"	75^{0}00′36.07"	48O/12/NW
Channahodlu	13^{0}08′00.21"	75^{0}30′46.00"	48O/12/NW
Kalasa	13^{0}13′59.37"	75^{0}21′32.98"	48O/8/NW
Handihadle	13^{0}12′44.47"	75^{0}21′53.93"	48O/8/NW
Kotigehara	13^{0}07′12.23"	75^{0}31′33.57"	48O/12/SW
Devangulu	13^{0}07′26.14"	75^{0}31′17.53"	48O/12/SW
Attigere	13^{0}07′25.46"	75^{0}31′42.92"	48O/12/SW
Javali	13^{0}09′50.3"	75^{0}29′10.85"	48O/8/NE
Sunkasale	13^{0}09′23.0"	75^{0}26′51.87"	48O/8/NE
Aramanetalaguru	13^{0}10′25.17"	75^{0}25′59.57"	48O/8/NE
Hirebail	13^{0}11′49.00"	75^{0}24′44.03"	7548O/8/NE
Marasanige	13^{0}11′48.15"	75^{0}23′25.65"	48O/8/NE
Mavinkere	13^{0}12′06.22"	75^{0}22′51.93"	48O/8/NE
Gangankudige	13^{0}12′48.80"	75^{0}22′50.92"	48O/8/NE
Kelaguru	13^{0}09′54.25"	75^{0}27′35.23"	48O/8/NE

GEOLOGICAL SURVEY OF INDIA

Section 2: Sakleshpur-Subrahmanya section

Locality	Latitude	Longitude	T. S. No.
Kyanhalli	$12^0$53′18″	$75^0$45′00"	48P/9/NE
Donigal	$12^0$54′28"	$74^0$45′00"	48P/9/NE
Maranhalli	$12^0$52′30"	$75^0$43′05"	48P/9/NE
Alvailli	$12^0$51′00"	$75^0$43′13"	48P/9/SE
Kemphole	$12^0$50′00"	$75^0$39′17”	48P/9/SE
Yedekumari	$12^0$49′13"	$75^0$40′00"	48P/9/SE
Shiradi gadi	$12^0$49′39"	$75^0$36′48"	48P/9/SW
Gundia	$12^0$49′39"	$75^0$34′18"	48P/9/SW
Kirnadka	$12^0$47′48.8"	$75^0$31′43.4"	48P/9/SW
Kalaparru	$12^0$50′28.1"	$75^0$31′7.5"	48P/9/SW
Manjoli male	$12^0$48′26.3"	$75^0$21′52.5"	48P/5/SE
Nellyady	$12^0$50′9.8"	$75^0$24′30"	48P/5/SE
Golithottu	$12^0$50′27.5"	$75^0$21′52.5"	48P/5/SW
Nirkatte	$12^0$51′15"	$75^0$19′21"	48P/5/SW
Uppinangadi	$12^0$49′55"	$75^0$15′32"	48P/5/SW
Perne	$12^0$49′18"	$75^0$11′58"	48P/1/SE
Nerlakatte	$12^0$48′45"	$75^0$07′51"	48P/1/SE
Mani	$12^0$50′10"	$75^0$07′09"	48P/1/SW
Kalladka	$12^0$50′43"	$75^0$04′43"	48P/1/SW
Vittalkodi	$12^0$50′43"	$75^0$29′00"	48P/1/SW
Kanchinadka padavu	$12^0$50′21"	$75^0$00′43"	48P/1/SW
Nirpade	$12^0$51′24"	$75^0$06′15"	48L/1/SW
Benjana padavu	$12^0$54′00"	$74^0$59′39"	48L/13/NE
Kodamannu	$12^0$53′13"	$74^0$58′45"	48L/13/NE
Abettu	$12^0$54′45"	$74^0$57′09"	48L/13/NE
Bondantila	$12^0$54′00"	$74^0$56′15"	48L/13/NE
Nirmarge	$12^0$53′00"	$74^0$54′38"	48L/13/NE
Melai padavu	$12^0$52′45"	$74^0$55′23"	48L/13/NE
Shaktinagar	$12^0$53′39.6"	$74^0$52′49"	48L/13/NW
Koppal	$12^0$52′09.6"	$74^0$52′26"	48L/13/NW
Kodikal	$12^0$52′45"	$74^0$55′23"	48L/13/NW
Donigal R.S.	$12^0$54′28"	$74^0$45′00"	48P/13/NW

GEOLOGICAL SURVEY OF INDIA

Annexure-1

Year wise monthly rain fall (in mm) at Kotigehara station. (Charmudi-Kotigehara-Kalasa section)

Year/Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual rainfall
1988	0.0	12.2	0.0	132.2	41.6	802.6	1658.8	821.1	953.8	137.4	5.2	16.4	**4581.3**
1989	0.0	0.0	0.6	38.2	37.4	868.6	1584.8	564.0	243.6	149.4	0.0	0.0	**3486.6**
1990	0.0	0.0	0.0	2.8	310.4	803.7	1396.2	1189.6	218.6	283.6	72.2	0.0	**4277.1**
1991	0.0	0.0	1.4	77.6	117.0	1193.2	1674.6	645.8	127.8	142.5	70.4	0.0	**4050.3**
1992	0.0	0.0	0.0	25.4	53.2	1032.0	1454.2	1046.6	558.4	232.8	371.2	0.0	**4773.8**
1993	0.0	0.0	0.0	1.0	19.6	1049.6	1184.9	833.8	196.8	292.8	18.6	0.0	**3597.1**
1994	0.0	0.0	0.0	144.6	58.2	1781.2	2617.6	666.6	339.6	271.0	20.8	0.0	**5899.6**
1995	0.0	0.0	0.0	51.0	146.2	484.0	2121.6	665.6	457.6	100.6	71.4	0.0	**4098.0**
1996	0.0	0.0	0.0	47.6	21.2	1141.4	1081.2	470.6	310.2	159.6	6.6	0.0	**3238.4**
1997	0.0	0.0	6.4	19.0	49.2	660.6	1830.5	1125.9	191.6	289.6	145.8	66.6	**4385.2**
1998	0.0	0.0	0.0	10.2	56.2	803.4	1254.4	714.4	617.6	453.6	65.2	0.0	**3975.0**
1999	0.0	0.0	0.0	20.0	400.2	722.5	1444.4	556.2	110.6	362.7	0.0	0.0	**3616.6**
2000	0.0	0.0	0.0	62.4	99.8	821.0	1214.6	834.8	287.3	176.2	0.0	3.0	**3499.1**
2001	0.0	0.0	0.0	253.4	89.7	630.2	631.6	532.2	198.0	86.0	112.0	0.0	**2533.1**
2002	0.0	27.2	0.0	55.0	59.8	635.6	308.5	1203.8	206.6	341.6	0.0	0.0	**2838.1**
2003	0.0	0.0	13.6	62.0	6.6	735.2	853.4	488.7	163.0	115.9	0.0	0.0	**2438.4**
2004	0.0	0.0	7.4	21.2	506.3	1367.3	365.2	843.6	201.0	79.4	13.6	0.0	**3405.0**
2005	0.0	0.0	0.0	90.2	36.8	868.8	1333.6	985.7	500.0	211.3	12.4	0.0	**4038.8**
2006	0.0	0.0	0.0	0.0	582.2	1324.9	1745.7	869.8	812.4	106.0	166.4	0.0	**5607.4**
2007	0.0	0.0	0.0	13.6	76.3	1651.4	1848.4	1479.1	957.0	183.8	19.9	0.0	**6229.5**
2008	0.0	64.2	225.6	9.0	101.5	1096.5	819.7	1192.4	541.6	242.2	0.0	0.0	**4292.7**

Average annual rainfall= 4041.0mm

GEOLOGICAL SURVEY OF INDIA

Annexure-2

Year wise monthly rain fall (in mm) at Kalasa station.
(Charmudi-Kotigehara-Kalasa section)

Year/Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual rainfall
1988	0.0	5.8	0.0	87.4	47.2	362.8	1068.8	655.4	264.7	82.7	0.0	14.0	**2588.8**
1989	0.0	0.0	36.0	26.2	15.2	836.2	1251.7	630.8	138.4	122.2	26.2	0.0	**3082.9**
1990	9.4	0.0	2.4	12.8	307.2	793.9	928.0	1040.7	132.0	353.0	30.6	0.0	**3610.0**
1991	0.0	0.0	0.0	103.6	187.8	762.2	1376.3	600.2	108.4	228.2	32.2	0.0	**3398.9**
1992	0.0	0.0	0.0	56.6	34.4	975.4	956.4	872.2	318.5	109.6	326.2	0.0	**3649.3**
1993	0.0	0.0	36.2	98.6	68.4	465.0	968.6	643.2	90.4	398.8	0.0	0.0	**2769.2**
1994	0.0	0.0	22.7	168.4	76.0	1076.4	1798.6	556.0	235.2	346.0	0.0	0.0	**4279.3**
1995	0.0	0.0	0.0	109.8	92.8	268.4	1185.8	501.0	497.4	102.2	0.0	0.0	**2757.4**
1996	0.0	0.0	0.0	77.8	32.8	772.6	909.3	494.9	192.8	125.6	0.0	0.0	**2605.8**
1997	0.0	0.0	40.4	0.0	0.0	728.8	1421.8	1071.3	0.0	95.8	84.8	41.8	**3484.7**
1998	0.0	0.0	39.0	23.4	63.6	533.4	1206.8	451.1	396.0	230.9	35.0	0.0	**2979.2**
1999	0.0	14.8	0.0	47.4	277.8	568.0	1281.9	409.6	108.6	479.4	4.0	8.2	**3199.7**
2000	0.0	0.0	0.0	41.4	92.6	717.6	949.8	724.8	279.2	105.6	15.2	4.4	**2930.6**
2001	0.0	0.0	0.0	166.2	70.2	806.4	745.2	401.2	209.4	144.4	37.4	0.0	**2580.4**
2002	0.0	124.4	0.0	79.9	68.1	354.5	359.9	743.4	92.4	410.0	0.0	0.0	**2232.6**
2003	0.0	0.0	33.0	60.4	20.0	589.2	648.1	413.2	77.2	219.7	5.2	0.0	**2066.0**
2004	0.0	0.0	9.0	94.0	301.2	951.4	425.5	684.0	118.2	105.2	46.8	0.0	**2735.3**
2005	0.0	0.0	0.0	238.4	37.8	575.4	1351.6	825.2	277.6	346.8	26.1	0.0	**3678.9**
2006	0.0	0.0	9.2	15.4	345.0	691.3	1423.3	826.0	299.6	40.9	122.5	0.0	**3773.2**
2007	0.0	0.0	0.0	52.7	69.8	986.0	1530.4	975.2	489.6	225.6	20.2	0.0	**4349.5**
2008	0.0	37.4	300.8	46.7	59.2	613.6	704.4	969.4	288.4	171.6	0.0	0.0	**3191.5**

Average annual rainfall= 3140.2mm

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Annexure-3

Year wise monthly rain fall (in mm) at Javali station (Charmudi-Kotigehara-Kalasa section)

Year/Month	January	Feburary	March	April	May	June	July	August	September	October	November	December	Annual rainfall
1988	0.0	17.0	5.2	133.0	62.8	641.2	924.4	522.0	321.2	42.0	0.0	0.0	**2668.8**
1989	0.0	0.0	17.0	19.0	29.0	544.3	1014.9	411.3	100.2	195.6	42.4	0.0	**2373.7**
1990	13.4	0.0	0.0	4.0	170.8	352.2	473.5	742.5	125.9	372.0	66.8	0.0	**2321.1**
1991	0.0	0.0	25.7	133.6	129.1	748.2	1170.4	536.4	93.5	160.1	43.6	0.0	**3040.6**
1992	0.0	0.0	0.0	87.1	46.3	796.2	810.1	726.2	329.8	175.6	401.0	0.0	**3372.3**
1993	0.0	0.0	0.0	74.9	97.0	563.8	822.0	630.4	109.3	455.6	0.0	0.0	**2753.0**
1994	0.0	0.0	22.0	216.0	97.0	979.7	1399.0	394.0	188.0	387.0	38.0	0.0	**3720.7**
1995	0.0	0.0	0.0	55.0	21.4	326.4	1853.0	442.0	285.0	99.0	0.0	0.0	**3081.8**
1996	0.0	0.0	0.0	81.0	11.2	528.0	519.3	398.6	299.0	105.4	10.0	0.0	**1952.5**
1997	0.0	0.0	21.0	32.0	63.0	498.5	1019.8	820.3	24.7	222.0	117.9	170.8	**2990.0**
1998	0.0	0.0	4.0	40.0	78.0	588.0	872.0	472.0	581.0	445.4	116.0	13.0	**3209.4**
1999	0.0	0.0	0.0	13.0	380.0	488.0	1282.0	315.0	138.0	468.0	15.0	0.0	**3099.0**
2000	3.0	0.0	0.0	60.0	177.0	641.0	806.0	667.0	280.0	227.0	2.0	6.0	**2869.0**
2001	0.0	0.0	0.0	160.0	149.0	629.0	744.0	485.0	198.0	109.0	66.0	0.0	**2540.0**
2002	0.0	51.0	0.0	103.0	55.0	336.0	248.0	603.6	116.0	582.0	0.0	0.0	**2094.6**
2003	0.0	0.0	14.0	84.3	11.2	738.4	586.8	376.0	108.9	175.9	3.0	0.0	**2098.5**
2004	0.0	0.0	6.0	47.0	404.1	927.8	412.2	869.3	234.4	74.5	22.0	0.0	**2997.3**
2005	0.0	0.0	0.0	118.2	115.2	594.9	1101.9	717.8	295.1	238.7	11.0	0.0	**3192.8**
2006	0.0	0.0	0.0	39.2	303.9	845.5	946.6	563.7	452.7	101.0	111.0	0.0	**3363.6**
2007	0.0	0.0	0.0	88.4	42.8	828.6	1019.2	1014.4	616.8	165.2	40.0	0.0	**3815.4**
2008	0.0	44.0	246.6	28.0	60.0	603.9	624.2	770.9	361.8	134.0	0.0	0.0	**2873.4**

Average annual rainfall= 4255.77mm

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Annexure-4

SAKLESHPUR - SUBRAHMANYA SECTION

Annual Rainfall for Sakleshpur rain gauge station ($12^0 50'00"$-$75^0 40'00"$) from 1994 to 2009

Year	Annual rainfall(in mm)
1994	3183.9
1995	2278.2
1996	1899.9
1997	2880.4
1998	2218.4
1999	2264.2
2000	2306
2001	1690.6
2002	n.a.
2003	1427.7
2004	2333.6
2005	2840.3
2006	2983.4
2007	3247.4
2008	2327.4

Average annual rainfall=2426.867

Annual Rainfall for Maranhalli rain gauge station ($12^0 52'14"$-$75^0 42'34"$) from 1994 to 2009

Year	Annual rainfall(in mm)
1994	5998.3
1995	5956.4
1996	4772.3
1997	4880.2
1998	4599.5
1999	4761
2000	4750.7
2001	3545
2002	3459.4
2003	3154.8
2004	4168.9
2005	6763.8
2006	6383.8
2007	6344.3
2008	4979.0
2009	5371.5

Average annual rainfall= 4993.056

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Slide No	Slide No	Location	Toposheet no	Latitude			Longitude			ELEVATION (M)	Taluk	District	State	Landmarks	Date of occurrence	Time of occurrence	Dimension of slide			Base length (Toe length)
				degree	Min	Sec	Deg	Min	Sec								Length (in m)	Width (in m)	Depth(in m)	

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Type of slide	History	Overburden		Material involved	Depth of weathering	Volume of material(cu m)
		Type	depth			

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whether road cutting	Structures affected	Run out Distance(m)	Up to Location	Casualities	Rainfall	Type of Bedrock	Local geology	Regional geology	Structure				Cutslope height	Type of failure surface	Slope morphometry				Repose angle
									Joint orientation	spacing	opening	filling			Slope pre failure	Slope post failure	Slide Direction	General slope gradient	

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Failure angle	horizontal extent	vertical interval

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